Semiannual Water Quality Report for the Bosque River Watershed

Monitoring Period: July 1, 2013 – June 30, 2020

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This report in part fulfills TIAER's legislative obligations to report water quality in the Bosque River once every six months to the TCEQ. Under TIAER's funding through the State of Texas, TIAER coordinates collection and reporting of data to conform with TCEQ protocols and coordinates monitoring effort with TCEQ and other agencies through participation in coordinated monitoring meetings with the Brazos River Authority and other agencies and entities, as appropriate. Monitoring by TIAER within the Bosque River watershed for the past several years has been integrated with TCEQ projects either through the TMDL or NPS programs, and all monitoring data herein have been collected under TCEQ approved Quality Assurance Project Plans with data submitted and uploaded into the TCEQ Surface Water Quality Monitoring Information System.

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For more information about this document or any other TIAER documents, please contact TIAER via our website at http://tiaer.tarleton.edu/.

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Abstract

The intent of this report is to provide the Texas Commission on Environmental Quality (TCEQ) with a semiannual update on water quality data collected by the Texas Institute for Applied Environmental Research (TIAER) in the Bosque River watershed. The current report covers water quality samples collected from July 1, 2013 through June 30, 2020 for sites active during the last six months of the reporting period focusing on current monitoring sites within the North Bosque River watershed.

With this report, routine grab sample data representing stations on the North Bosque River and its major tributaries are compared to TCEQ water quality criteria or screening levels for dissolved oxygen (DO), water temperature, pH, total dissolved solids (TDS), *Escherichia coli* (*E. coli*), nutrients, and chlorophyll-α (CHLA). While screening levels are not intended for use in evaluating biased flow samples, storm sample data are compared to screening levels for nutrients to give a relative indication of how water quality is impacted during these elevated events.

Water quality criteria for pH, water temperature, DO, TDS, and bacteria serve to protect designated uses associated with classified Segments 1226 (North Bosque River) and 1255 (Upper North Bosque River). Screening levels for nutrients and CHLA were based on general TCEQ assessment guidelines for freshwater streams. Basic statistics (mean, median, standard deviation, minimum, maximum, and number of observations) are also provided for each constituent (excluding TDS) by site and sampling type. Values for TDS were calculated from specific conductance (conductivity), and basic statistics are presented for conductivity.

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Chapter 1

Introduction

The Bosque River watershed encompasses about 4,300 square kilometers (1,660 square miles) in north central Texas, all draining into Lake Waco. Lake Waco provides flood control for the area and supplies drinking water to about 150,000 people. Major tributaries within the Bosque River watershed include the North Bosque River, Hog Creek, Middle Bosque River, and South Bosque River, of which the North Bosque River basin comprises about 74 percent of the total drainage area.

For the North Bosque River watershed, the classified segments are 1226, North Bosque River, and 1255, Upper North Bosque River (Figure 1). Segment 1226 includes the North Bosque River from Lake Waco, up to a point immediately above the confluence of Indian Creek. Segment 1255 includes the North Bosque River from Indian Creek to the confluence of the North Fork and South Fork above Stephenville. Segment 1246 includes the Middle and South Bosque Rivers located in McLennan County, as well as a small portion of the Middle Bosque Rivers located in Coryell County up to the confluence of Cave Creek. Segment 1246 has been the focus of past monitoring by TIAER (e.g., McFarland and Millican, 2012) but is not currently part of TIAER's monitoring network.

The designated uses for Segments 1226 and 1255 along the North Bosque River are quite similar, although differences are indicated for aquatic life and domestic water supply (Tables 1 and 2). Because the aquatic life use levels vary, the associated DO criteria for these segments also varies (Table 2).

Table 1. Designated uses for TCEQ classified segments.

Source: TCEQ (2010).

Segment	Aquatic Life	Primary Contact Recreation	Domestic Water Supply
1226	X	X	X
1255	X	x	

Table 2. Aquatic life uses and DO criteria for TCEQ classified stream segments.

Source: 307 TAC §307.10(1) and TCEQ (2015).

Segment	Segment Name	Aquatic Life[a]	24-hr DO Mean (mg/L)	DO Minimum (mg/L)
1226	North Bosque River	H	5	3
1255	Upper North Bosque River	I	4	3

a. Aquatic life uses are high (H), intermediate (I), limited (L), and minimal (M).

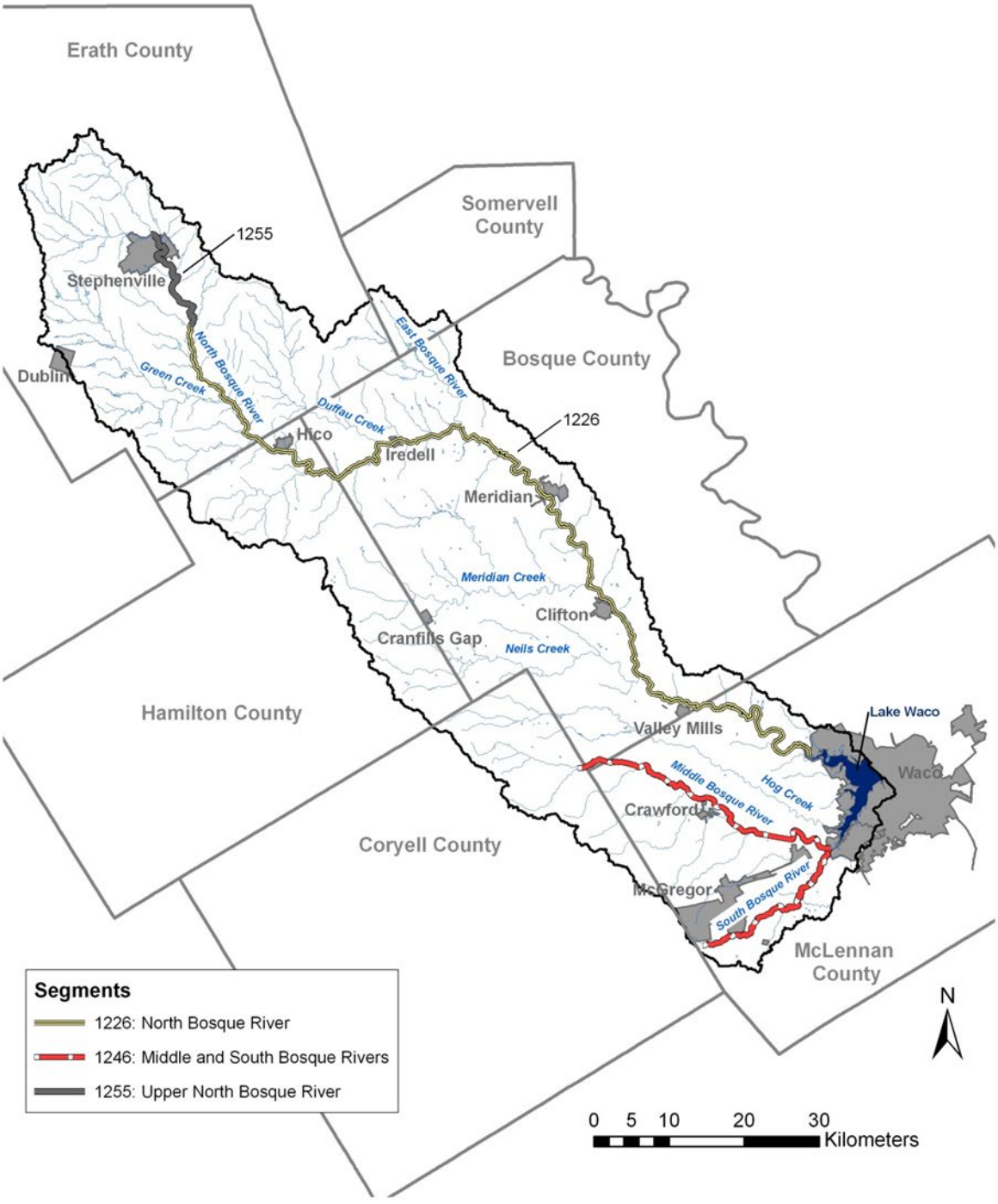

Figure 1. TCEQ classified stream segments in the Bosque River watershed.

Statewide attention since the 1990s has focused on the Bosque River watershed largely due to the prominence of the dairy industry in the northern portion. The headwaters of the North Bosque River are located in Erath County, and for many years prior to 2011, Erath County was the number one milk producing county in Texas. Starting in 2011, Castro or Palmer County has often edged out Erath County for the number one spot for milk production with Moore and Hartley Counties also at times also exceeding that of Erath County (e.g., USDA-AMS, 2017). The 1996 State of Texas Water Quality Inventory indicated that nonpoint source loadings associated with elevated nutrient and fecal coliform levels were the most serious threat to meeting designated uses within Segments 1226 and 1255 (TNRCC, 1996). Elevated nitrogen levels were also indicated in 1996 as a concern within Segment 1246, the Middle Bosque-South Bosque River. In 1998, Segments 1226 and 1255 were included in the Clean Water Act Section 303(d) list for Texas as impaired water bodies under narrative water quality criteria related to nutrients and aquatic plant growth with concentrated animal feeding operations identified as the major nonpoint source of nutrients (TNRCC & TSSWCB, 1999). Nutrients have been the focus of TIAER monitoring efforts due to the role of nutrients in promoting excessive growth algae as indicated by elevated chlorophyll-a levels throughout Segments 1226 and 1255 (TNRCC, 1999).

In February 2001, the Texas Commission on Environmental Quality (TCEQ) adopted a total maximum daily load (TMDL) for soluble reactive phosphorus in Segments 1226 and 1255 that was approved by EPA in December 2001. This TMDL requires about a 50 percent reduction in loading and concentration of soluble reactive phosphorus, depending on the location along the river (TNRCC, 2001). Phosphorus was identified as the nutrient limiting algal growth in the North Bosque River, and, thus, a reduction in soluble reactive phosphorus should reduce algal abundance in the North Bosque River.

The 2020 Texas Water Quality Inventory evaluates water bodies based on assessment units (AUs) describing specific areas within each segment (TCEQ, 2020). Four AUs are defined for Segment 1226 and two AUs for Segments 1255 as follows:

- 1226_01 Portion of North Bosque River from confluence with Lake Waco in McLennan County upstream to confluence with Neils Creek in Bosque County
- 1226_02 Portion of North Bosque River from confluence with Neils Creek upstream to confluence with Meridian Creek in Bosque County
- 1226_03 Portion of North Bosque River from confluence with Meridian Creek upstream to confluence with Duffau Cree in Bosque County
- 1226_04 Portion of North Bosque River from confluence with Duffau Creek in Bosque County upstream to a point immediately upstream of Indian Creek confluence (end of segment) in Erath County
- 1255_01 Portion of North Bosque River from confluence with Indian Creek upstream to confluence with Dry Branch in Erath County
- 1255_02 Portion of North Bosque River from confluence with Dry Branch upstream to confluence with North/South Forks North Bosque River in Erath County

The 2020 Texas Water Quality Inventory uses the seven-year assessment period December 1, 2011 through November 30, 2018 (TCEQ, 2020). The three more upstream AUs in Segment 1226 and both AUs in Segment 1255 are noted as impaired due to excessive algal growth as category 4a, indicating that a TMDL has already been completed and approved by EPA (Table 3). Additional impairments for

Segment 1255 include elevated bacteria in both AUs and depressed dissolved oxygen (DO) in 1255_02. The depressed DO impairment is listed as category 5c, indicating that additional data and information need to be collected before a TMDL is scheduled. The bacteria impairment is categorized as 5b, indicating that a review of water quality standards for this water body will be conducted before a TMDL is scheduled. Concerns were indicated within Segments 1226 and 1255 for chlorophyll-a and nutrients in some AUs. Within Segment 1226, there was also concern noted regarding impairment of the microbenthic community.

Table 3. Summary of TCEQ assessment of use impairments and concerns for 2020.
Source: 2020 Texas Water Quality Inventory (TCEQ, 2020)

	Segment 1226 – North Bosque River	Segment 1255 – Upper North Bosque River
Assessment	Not Supporting: General use – nutrient enrichment	Not Supporting: Primary Contact Recreation us – bacteria; Aquatic life use – dissolved oxygen; General use – nutrient enrichment.
Description of Impairment	Excessive algal growth (AUs 02, 03 & 04)	*E. coli* exceeding single sample and geometric criteria (AUs 01 & 02), depressed dissolved oxygen (AU 02), and excessive algal growth (AUs 01 & 02)
Concerns	Elevated chlorophyll-α (AUs 02, 03 & 04) and orthophosphorus (AU 04), depressed dissolved oxygen (AU 02) and impaired microbenthic community (AU 04)	Elevated nitrate (AU 01), orthophosphorus (AUs 01 & 02), total phosphorus (AU 01), and chlorophyll-α (AUs 01 & 02)

The intent of this report is to provide the TCEQ with a semiannual update on water quality data collected by the Texas Institute for Applied Environmental Research (TIAER) in the Bosque River watershed. The current report covers water quality samples collected between July 1, 2013 and December 31, 2019. A seven-year period of data was selected to resemble the length of time outlined in assessment methodology (TCEQ, 2020).

This report includes only sampling stations monitored by TIAER that were active during the last six months of the seven-year period. In this report, TIAER grab and storm event water quality data collected from sites on mainstem or major tributaries of the North Bosque River were compared to TCEQ water quality criteria for classified segments (TCEQ, 2010) and TCEQ nutrient and chlorophyll-α screening levels (TCEQ, 2020). Basic statistics (mean, median, standard deviation, minimum, maximum, and number of observations) were also calculated for each constituent by site and sampling type.

Chapter 2

Current Water Quality Monitoring in the Bosque River Watershed

Seven sampling sites are currently monitored by TIAER within the Bosque River watershed (Figure 2). All sampling sites are labeled using a five-character alphanumeric code. The first two letters specify the tributary or river (e.g., BO or North Bosque River) on which the site is located, while the last three digits indicate the relative location of the site. Lower numeric values indicate sites nearer the headwaters, while larger numeric values indicate sites further downstream. Corresponding TCEQ Station IDs are provided in Table 4 along with the general location and monitoring histories of each site.

Table 4. Sampling history of monitoring sites in the Bosque River watershed

Site	TCEQ ID	Watershed and General Location[a]	Sample Type[b]	Date of First Grab Sample	Date of First Automatic Storm Sample
Category 1: Sites on major tributaries on the North Bosque River					
GC100	13486	Green Creek 1.8 km upstream of confluence with North Bosque River	C	06-Jan-93	01-Sep-92
Category 2: Sites on the North Bosque River					
BO020	17226	North Bosque River at FM 8 above Stephenville	C	26-May-94	06-Feb-97
BO040	11963	North Bosque River at Erath CR 454 below Stephenville	C	04-Apr-91	25-Aug-93
BO070	11961	North Bosque River at US 281 near Hico	C	04-Apr-91	08-May-91
BO083	18003	North Bosque River at CR 2371	G	06-Nov-02	Not applicable
BO090	11956	North Bosque River at FM 219 at Clifton	C	26-Sep-95	04-Nov-95
BO095	11954	North Bosque River at CR 3310 off SH6 west of Valley Mills	C	02-May-01	03-Sep-01

a. SH = State Highway, FM = Farm-to-Market, CR = County Road, and US = United States Highway.
b. G = grab sampling site and C = ombined grab and storm sampling site.

General land-use descriptions are based on National Land Cover Database (NLCD) 2016 (USGS, 2019) supplemented with information summarized by TIAER on animal waste application fields (WAFs) within the watershed (Table 5). This land use information has been updated in comparison to many previous semiannual reports in which general land-use information had been based on data from Narasimhan et al. (2005). As with the land cover developed by Narasimhan et al. (2005), the category of grassland/herbaceous for the NLCD 2011 data base was considered part of pasture for the watershed area representing Hico and above. Below Hico, the land-use category of grassland/herbaceous defined by the NLCD 2011 was divided evenly between categories of pasture and wood/range.

Figure 2. TIAER sampling sites within the Bosque River watershed.

Table 5. Estimated land use and drainage area above sampling sites

Site	Wood & Range (%)	Pasture & Cropland (%)	Animal Waste App Fields[a] (%)	Historical Animal Waste Appl. Fields[b] (%)	Urban (%)	Other (%)	Total Area (Hectacres)
GC100	30.3	38	4	5	5	0.7	25,200
BO020	34	41	4	15	6	0.9	21,700
BO040	32	41	4	14	9	0.9	25,700
BO070	38	45	3	7	6	0.8	93,100
BO083	57	28	3	5	5	0.7	178,000
BO090	57	31	2	3	4	0.6	253,000
BO095	59	32	2	3	4	0.6	297,000

a. Animal waste application fields represent estimates from milking operations and non-milking operations as of August 2019 based on a review of permit information.
b. Historical fields are previously permitted fields that are no longer permitted for animal waste application. Area represented as historical fields is as of August 2019.

Information on animal WAFs was compiled by TIAER from review of TCEQ permit information for permitted facilities. For smaller nonpermitted operations or animal feeding operations (AFOs), dairy inspection and milk production records were used to identify the location of these operations. For nonpermitted facilities, the size of WAFs was estimated based on a maximum herd size of 199 head, and these fields were then located on land contiguous with the location of the AFO. Active WAFs are those that were permitted or associated with active AFOs as August 2019. Historical WAFs were defined as those previously permitted for WAF or fields associated with AFOs that are no longer active.

The updated information on WAFs includes milking operations and non-milking operations, although milking operations represent over 80 percent of the concentrated animal feeding operations (CAFOs) and animal feeding operations (AFOs) in the watershed. A biogas production facility that received dairy waste was active in the watershed roughly between late 2007 and 2010, and its WAFs are included in the historical WAFs.

Drainage areas above sampling sites were delineated using 30-meter digital elevation models created from United States Geological Survey 1:24,000 topographic maps (Table 5). Drainage areas for sampling sites were calculated using the AVSWAT 2000 extension in ArcView. The drainage area values presented in Table 5 may differ from those reports prior to January 2002 due to changes in the GIS system and the calculation method used to determine these areas.

Data were analyzed in this report only for sampling stations that were monitored for water quality during the last six months of the seven-year reporting period. Previous editions of the Semiannual Report contain data summaries for many sites that are no longer active in TIAER's monitoring program. For example, monitoring at sites along the Middle and South Bosque Rivers and Hog Creek was discontinued in December 2010, so previous reports, such as Adams and McFarland (2011) should be referenced for analyses of data for these locations. Monitoring at microwatershed locations representing smaller creeks or tributaries within the North Bosque River watershed was discontinued in June 2014, but can be referenced in reports, such as McFarland and Adams (2015).

Sites on Major Tributaries to the North Bosque River

Sampling site GC100 is located on Green Creek and represents the only sampling site currently monitored on a major tributary to the North Bosque River. GC100 was monitored through the collection of manual grab samples on a biweekly basis. Storm sampling has occurred at GC100 since September 1992, although the amount of storm monitoring has varied per year depending on weather conditions and available funding.

Improved pasture dominates the land area above GC100, and over 8 percent of the drainage area above GC100 is associated with either active or historical WAFs.

Green Creek

Site GC100 Site GC100 is an automated sampling site on Green Creek, located about 1.8 kilometers (1.1 miles) upstream of the confluence with the North Bosque River off of CR 266 near Clairette, Texas. Land use within the GC100 watershed is closely divided between wood/range and improved pasture.

Sites on the North Bosque River

Sampling on the North Bosque River was conducted routinely during the reporting period at six sites, with the most upstream at BO020 above Stephenville and the most downstream at BO095 near Valley Mills (Figure 2). Routine grab samples were collected at all six North Bosque River sites, while storm event samples were collected at all but BO083. A storm monitoring station has not been implemented at BO083 due to access issues to the creek at this location.

Land use/land cover above these six North Bosque River sites general decreases from upstream to downstream sites in the percent permanent pasture, WAFs, and cropland, and increases in the percent wood and range (Table 5). About 5 percent of the drainage area above BO095 is associated with active or historical WAFs, almost all of which occur in the upper portion of the North Bosque River watershed above site BO070 (see Figure 3).

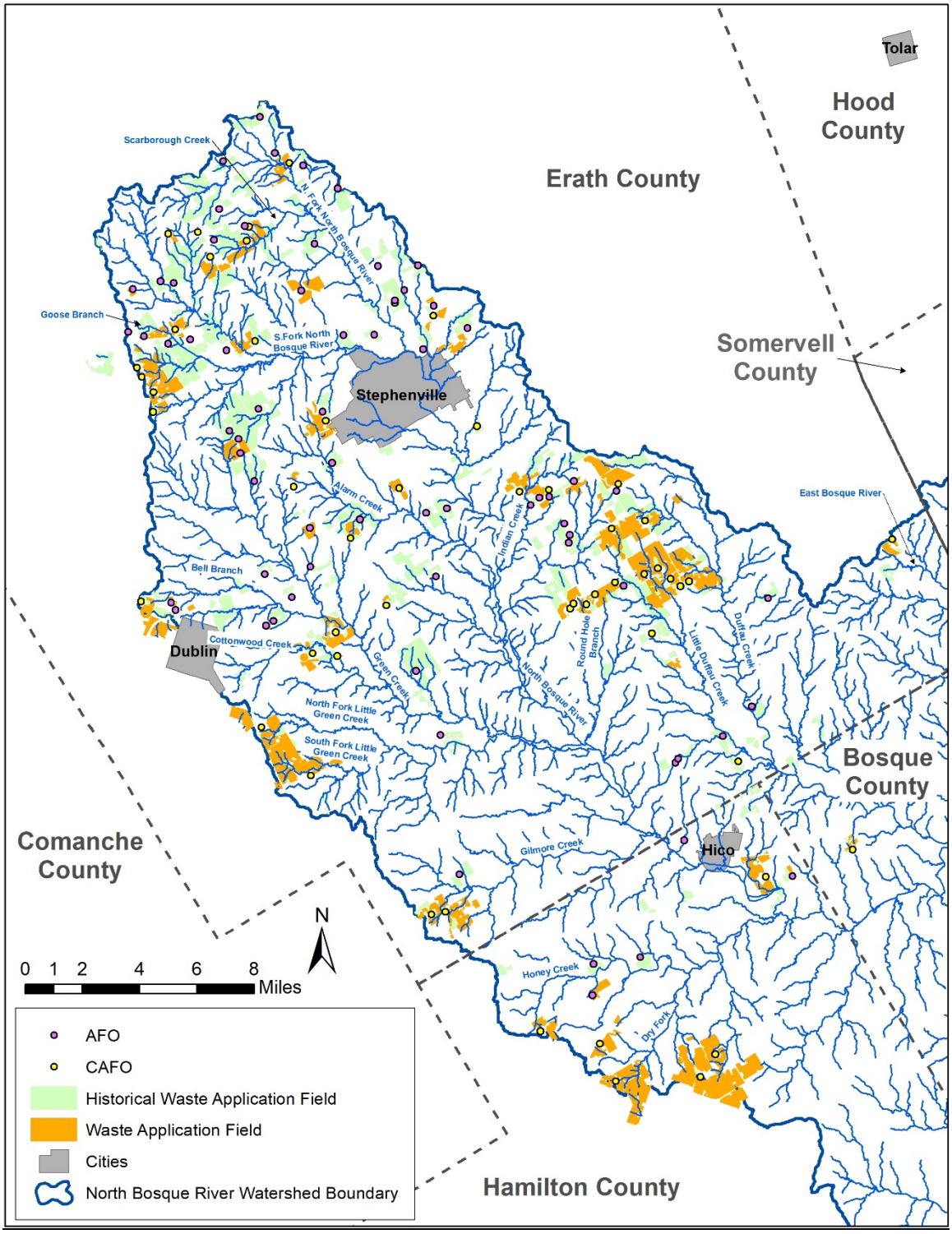

Figure 3. Map of CAFOs, AFOs, and associated WAFs (active and historical) within the North Bosque River watershed representing conditions as of fall 2019.

Six cities are located along the North Bosque River. These cities, listed upstream to downstream with population estimates, are Stephenville (22,065), Hico (1,462), Iredell (340), Meridian (1,511), Clifton (3,562), and Valley Mills (1,292). Population estimates are for January 1, 2019 provided by the Texas State Data Center (2019).

North Bosque River above Stephenville

Site BO020 Site BO020 is an automated sampling site located on the North Bosque River, at the crossing of FM 8, on the northeast boundary of Stephenville. BO020 is located just below the confluence of the North and South Forks of the North Bosque River. The drainage are for BO020 is primarily rural, but does contain a small portion of the City of Stephenville. Just upstream of BO020, the South and North Forks of the North Bosque River converge to form the North Bosque River. Older reports include data for stations along the South and North Forks of the North Bosque River as well as several upstream tributary stations.

North Bosque River below Stephenville

Site BO040 Site BO040 is an automated sampling site located on the North Bosque River, approximately 0.4 river kilometers (0.25 river miles) downstream of the Stephenville wastewater treatment plant (WWTP), at the crossing of CR 454, and about 8 river kilometers (5 river miles) below site BO020. Site BO040 is the only North Bosque River site located directly below a municipal WWTP discharge. Although the WWTP is a dominant influence on the water quality at BO040 during low flow conditions, the drainage area includes stormwater runoff from the City of Stephenville and from many of the rural land areas above and around Stephenville. Tributaries entering the river between sites BO020 and BO040 for which historical data are available include Methodist Branch and Dry Branch.

North Bosque River at Hico

Site BO070 Site BO070, an automated sampler site, is located near U.S. Geological Survey (USGS) station 08094800, on the North Bosque River, at the crossing of U.S. Highway 281 in Hico, Texas. The drainage area for this site is often referred to as the upper North Bosque River watershed in TIAER reports that focus on monitoring within the upper third of the watershed (e.g., McFarland and Hauck, 1995; 1997a). Site BO070 is located about 1.6 river kilometers (1 river mile) upstream of the WWTP discharge for the City of Hico. Several small tributaries enter the river upstream between BO040 and below BO070 including Indian Creek and Sims Creek to the east and Alarm Creek, Green Creek, Spring Creek and Gilmore Creek to the west, on which some previous monitoring has occurred. Site GC100 on Green Creek is the only tributary station currently monitored.

North Bosque River at CR 2371

Site BO083 Site BO083 is a grab sampling site located on the North Bosque River, at Bosque CR 2371, about 10 kilometers east of the City of Iredell. The East Bosque River enters the North Bosque River about two miles upstream of BO083. Initial water quality samples were collected at BO083 as part

of a Periphyton study starting in November 2002. Water quality samples were not routinely collected at BO083 until March 31, 2003. Tributaries flowing in between BO070 and BO083 with historical data collected by TIAER include Honey Creek, Duffau Creek, Little Duffau Creek, and Walker Branch.

North Bosque River near Clifton

Site BO090 Site BO090 is an automated sampler site located near USGS station 08095000 on the North Bosque River, near the crossing of FM Road 219, about 0.8 km (0.5 miles) northeast of Clifton, Texas. Site BO090 is located upstream of the City of Clifton WWTP discharge. Meridian Creek enters the river between sites BO083 and BO090. TIAER has collected limited water quality data for Meridian Creek as historical data.

North Bosque River above Valley Mills

Site BO095 Site BO095 is located on the North Bosque River at CR 3310, off SH 6, west of Valley Mills, in Bosque County and is about three river miles upstream of USGS station 08095200 on the North Bosque River. Grab sampling was initiated at BO095 in May 2001. Site BO095 was installed as an automated sampling in July 2001 to replace site BO100 (TCEQ 11953), which was removed as a sampling site location due to problems with stream bank stability. BO095 is located approximately 16 river kilometers (10 river miles) downstream of BO090. Neils Creek enters the river between sites BO090 and BO095.

Chapter 3

Collection and Analysis Methods

The TIAER monitoring program includes routine and storm event sampling at sites throughout the Bosque River watershed. Particular emphasis is given to analyzing waterborne nutrient constituents due to their potential impact on eutrophication.

Quality Assurance Procedures

Monitoring data collected by TIAER in the North Bosque River watershed during the reporting period was conducted under the following projects with the most recent revisions of Quality Assurance Project Plans (QAPPs) noted:

- The *Lake Waco-Bosque River Initiative* funded by the U.S. Department of Agriculture (e.g., TIAER, 2005a) and approved by TCEQ.
- The *North Bosque River Watershed Water Quality Assessment* CWA Section 319(h) project funded through the TCEQ (e.g., TIAER, 2009).
- The CWA Section 319(h) project *Monitoring Effectiveness of Nonpoint Source Nutrient Management in the North Bosque River Watershed* funding through TSSWCB (e.g., TIAER, 2013a).
- The *North Bosque River Watershed Monitoring Project* funded through the TCEQ (e.g., TIAER, 2010).
- The CWA Section 319(h) project *Evaluating Effectiveness of Implementation Activities within the North Bosque River Watershed* funding through the TCEQ (e.g., TIAER, 2013b).
- The CWA Section 319(h) project *Evaluating Effectiveness of Total Maximum Daily Load (TMDL) Activities within the North Bosque River Watershed* funding through the TCEQ (e.g., TIAER, 2016).
- The TCEQ project Evaluating Effectiveness of Total Maximum Daily Load (TMDL) Implementation Plan (I-Plan) Activities within the North Bosque River Watershed funded in through the TMDL program (e.g., TIAER, 2017).

General Collection Procedures for Grab Samples

Collection of routine grab samples consisted of a single representative sample. Grab samples were taken near the surface at depths of 0.3 m (1 ft) or less depending on total water depth, as recommended in TCEQ surface water quality monitoring procedures (TCEQ, 2003; 2008; 2012b). When grab samples were collected, water temperature, DO, pH, and specific conductance (conductivity) were measured in situ with a Hydrolab or YSI (multiprobe) field sampling instrument. Because stream sites within the Bosque River watershed are generally shallow and unlikely to stratify, multiprobe readings were taken only at the surface depth corresponding to routine grab samples.

Routine sampling at stream sites occurred on a biweekly schedule throughout most of the reporting period, although some parameters are analyzed at different monitoring frequencies. For example, bacteria is generally only analyzed monthly. Grab samples were not collected when a stream site was dry or when water at a site was pooled and not flowing. Appendix A indicates presence or absence of flow during each

routine sampling period at each site. The percentage of routine sampling events at which flow was present at each stream site during the reporting period is shown on the last row of each table in Appendix A. In Appendices B and C, basic statistics are presented for grab and storm samples. Basic statistics for grab samples include routine grab as well as any additional grab samples collected for projects during the reporting period.

General Collection Procedures for Storm Samples

Each automated stormwater sampling site consists of an ISCO 4230 or 3230 bubbler-type flow meter and an ISCO 3700 or 6712 sampler. Both are enclosed in a sheet metal shelter. The ISCO flow meters operate by measuring the pressure required to force an air bubble through a 3 millimeter (0.125 inch) polypropylene tube, or bubbler line, and record this pressure as the water level. The ISCO flow meters are programmed to record water level or stage and initiate sample retrieval by the ISCO 3700 samplers. Electrical power is provided by marine deep-cycle batteries, with recharge provided by solar cells.

The ISCO flow meters initiate preset sampling programs for the ISCO samplers when threshold water levels are exceeded. Each flow meter is programmed to record water level at 5-minute intervals and typically actuate the sampler when a designated stream rise, generally 8 centimeters (3 inches) above the bubble datum, is registered. The actuation level was selected by trial-and-error as the lowest level that would actuate for rainfall-runoff events and avoid undesired actuation from nonrainfall event causes such as waves. For some projects, higher activation levels may be implemented based on project objectives.

Of note, prior to the spring of 2008, an attempt was made to monitor all storm events through the watershed. In 2008 with a decrease in funding, objectives for monitoring within the North Bosque River watershed were changed to monitor only selected events rather than all events. This modified monitoring frequency for storm events impacted sites along the mainstem of the North Bosque River and major tributary site GC100 starting in May 2008. Most storm events in 2008 and 2009 were monitored despite a reduction in storm monitoring resources. In 2010 no storm sampling occurred between January and August 2010 at most mainstem sites along the North Bosque River and major tributary site Green Creek due to funding constraints. Some limited storm monitoring occurred between January and May 2010 at sites BO070 and BO095. Starting in September 2010, storm sampling was reinitiated at all storm sites along the mainstem of the North Bosque River and at GC100 under new project funding, although still with the caveat of monitoring only selected, rather than all, events. Monitoring through 2021 continues to include only select storm events.

Once activated for a selected event, samplers were programmed to retrieve one-liter sequential samples. The typical sampling sequence for the major tributary and mainstem sites was:

- An initial sample
- One sample taken at a one-hour interval
- One sample taken at a two-hour interval
- One sample taken at a three-hour interval
- All remaining samples taken at four-hour intervals

Most storm samples were composited on a daily basis using a flow-weighted strategy to decrease the overall number of storm samples submitted for laboratory analysis.

Measurement of Physical and Chemical Constituents

A variety of physical and chemical parameters were measured to evaluate water quality within the North Bosque River (Table 6). These parameters focus on nutrients, but also included laboratory measurements of bacteria, chlorophyll-α (CHLA), and total suspended solids (TSS). Field constituents measured in situ with a multiprobe included water temperature, DO, specific conductance, and pH. While not directly measured, total dissolved solids (TDS) was estimated by multiplying specific conductance by 0.65 for water quality evaluations. Field constituents were measured only when routine grab samples were collected.

Table 6. Descriptions, abbreviations, and units of water quality constituents

Constituent	Abbreviation	Units	Description
Ammonia-nitrogen, dissolved	NH_3-N	mg/L	Inorganic form of nitrogen that is readily soluble and available for plant uptake. Elevated levels are toxic to many fish species.
Chlorophyll-α	CHLA	µg/L	Indicator of algae and phytoplankton biomass.
Specific conductance	Conductivity	µS/cm	Measure of the ability of water to carry an electric current and is used as an indicator of the salt content of the water.
Dissolved oxygen	DO	mg/L	Indicator of the amount of oxygen available in the water for biological activity and chemical reactions.
Escherichia coli	*E. coli*	MPN/100 mL	Indicator of public health hazards from infectious microorganisms.
Nitrite-plus-nitrate nitrogen, dissolved	NO_2-N+ NO_3-N	mg/L	Inorganic forms of nitrogen. NO_2-N is general a transitory phase in the nitrification of NH_3 to NO_3. NO_3-N is readily soluble and available for plant uptake. NO_3-N is considered the end product in the conversion of N from the ammonia form to nitrite then to nitrate under aerobic conditions.
Orthophosphate-phosphorus, dissolved	PO_4-P	mg/L	Inorganic form of phosphorus that is readily soluble and available for plant uptake. Soluble reactive phosphorus (SRP) is another name for this constituent.
pH	pH	Standard units	Measures the hydrogen ion activity in a water sample.
Total Kjeldahl nitrogen	TKN	mg/L	Organic and ammonia forms of nitrogen are included in TKN.
Total phosphorus	Total-P	mg/L	Represents both organic and inorganic form of phosphorus.
Total dissolved solids	TDS	mg/L	A measure of the amount of material dissolved in water mostly inorganic salts. TDS is associated with water hardness and may be measured gravimetrically or via electric conductivity.
Total suspended solids	TSS	mg/L	Measures the solid materials, i.e., clay, silts, sand, and organic matter suspended in water.
Water temperature	Water temp.	°C	Indicator of temperature condition for aquatic life.

All storm and routine samples were generally analyzed for ammonia-nitrogen (NH_3-N), nitrite-nitrogen plus nitrate-nitrogen (NO_2-N+NO_3-N), total Kjeldahl nitrogen (TKN), orthophosphate-phosphorus (PO_4-P), total phosphorus (total-P), and total suspended solids (TSS). Chlorophyll- α was also included with

routine monitoring samples but not storm samples. Bacteria monitoring by TIAER has generally occurred on a monthly basis as part of routine monitoring.

Reporting limits for the data presented are based on ambient water reporting limits (AWRLs) set by TCEQ (TCEQ, 2012a) or project specific reporting limits or limits of quantitation (LOQs). In most cases, the AWRL and LOQ are the same, unless the project requires a lower LOQ. TIAER continues to evaluate method detection limits (MDLs) as part of good laboratory practice, but also makes sure that appropriate analytical limits of quantitation are met for projects and that results are reported to project sponsors according to their specifications. For reference, the range of TCEQ AWRLs and project LOQs for the reporting period are presented in Table 7. As a data management procedure, TIAER uses half the reporting limit as the value for concentrations measured below the reporting limit in statistical evaluations.

Table 7. Analysis methods and method detection limits for water quality constituents

Constituent	Method	Range of TCEQ AWRLs or Project LOQs[a]
Field Measurements[b]		
Conductivity	EPA[c] 120.1	Not applicable
Dissolved oxygen	EPA 360.1	Not applicable
pH	EPA 150.1	Not applicable
Water temperature	EPA 170.1	Not applicable
Laboratory Measurements		
Ammonia-nitrogen (dissolved)	EPA 350.1 or SM[d] 4500-NH3 G	0.02 – 0.1 mg/L
Chlorophyll-a	SM 10200-H	3.0 – 5.0 µg/L
Sulfate	EPA 300.0 or SM426C	5 – 10 mg/L
Escherichia coli	IDEXX Colilert[c]	1 colonies/100 mL
Nitrite-nitrogen+nitrate-nitrogen (dissolved)	EPA 353.2 or SM 4500-NO3 F	0.04 – 0.05 mg/L
Total Kjeldahl nitrogen	EPA 351.2 or SM 4500-NH3 G	0.20 mg/L
Orthophosphate-phosphorus (dissolved)	EPA 365.2 or SM 4500P-E	0.005 mg/L[f]
Total phosphorus	EPA 365.4	0.06 mg/L
Total suspended solids	EPA 160.2 or SM 2540 D	4 mg/L

a. Source: *Appendix D, Surface Water Quality Monitoring Procedures Manual, Volume 1* (TCEQ, 2003; 2008; 2012b) and listing of *Ambient Water Quality Reporting Limits (AWRLs) for Texas Surface Water Quality Monitoring Programs* (TCEQ, 2012a). If the project LOQ is lower than the program AWRL, then the project LOQ is presented.
b. All field activities follow guidelines as outlined in the applicable version of TCEQ's *Surface Water Quality Monitoring Procedures Manual* (e.g., TCEQ 2003; 2008; 2012b).
c. EPA refers to *Methods for Chemical Analysis of Water and Wastes* (EPA, 1983).
d. SM refers to the *Standard Methods for the Examination of Water and Wastewater*, 18th Edition (APHA, 1992) or most recent online edition.
e. Results from IDEXX method are generally report MPN/100 mL whereas plating technique results are reported as colonies/100 mL. In this report, data for all *E. coli* results are presented in units of MPN/100 mL for consistency. For assessment purposes by TCEQ, MPN/100 mL and colonies/100 mL for *E. coli* are considered equivalent.
f. For PO_4-P the AWRL is 0.04 mg/L, but for the Bosque River a reporting limit of 0.005 mg/L has been established for TCEQ projects due to the TMDLs for soluble reactive phosphorus for Segments 1226 and 1255.

Chapter 4

Data Analysis Methods

Outliers

Values for each constituent were screened to detect questionable data points. Questionable data were then tracked through the chain of custody sheets and field data sheets and laboratory notebooks, as necessary, to ascertain whether these points represented transcription errors in the database. If a transcription error was found, the error was corrected prior to statistical analysis of the data.

Censored Data

Left censored data (values measured below the report limit, MDL or LOQ) for laboratory constituents were entered as one-half the reporting limit, as recommended by Gilliom and Helsel (1986) and Ward *et al.* (1988). Reporting limits for these variables are listed in Table 7 of the previous chapter. The number of samples with values measured below the reporting limit is presented for each constituent by site in Appendices B and C.

Methods for Assessment of Surface Water Quality

Numeric water quality criteria are designated for parameters, such as water temperature, pH, *E. coli*, TDS, and DO, on a segment-by-segment basis in relation to specific uses (Table 8). Criteria for water temperature, pH, and TDS are considered to protect the general use of a water body, while *E. coli* criteria are used to assess support of specific recreational use categories (i.e., primary contact recreation, secondary contact recreation 1, secondary contact recreation 2, and noncontact recreation). Dissolved oxygen criteria are generally associated with assessing the aquatic life use of a given segment.

Support of the general use of a water body also includes assessing nutrient concentrations and algal abundance as indicators of water quality problems associated with nutrient enrichment. Screening levels, rather than criteria, are set for nutrients and CHLA by TCEQ to help identify concerns and causes of nonsupport of narrative criteria for nutrient enrichment. Screening levels for nutrients and CHLA, unless specified in the Texas Surface Water Quality Standards, are statistically derived from long-term surface water quality monitoring data (TCEQ, 2015). These screening levels represent the 85 percentile for each parameter for a given water body type (i.e., freshwater streams, tidal streams, reservoirs, and estuaries) generally for a 10-year period (TCEQ, 2015). These screening levels are updated periodically by TCEQ, and the most recent screening levels are shown for nutrients and CHLA for freshwater streams in Table 9.

Table 8. Water quality criteria for Segments 1226 and 1255 of the North Bosque River.

Source: TCEQ (2015)

Water Quality Parameter	Use Assessed	Segment 1226	Segment 1255
24-hour mean DO (mg/L)	Aquatic Life	5.0	4.0
Springtime mean DO (mg/L)	Aquatic Life	5.5	5.0
Absolute minimum DO (mg/L	Aquatic Life	3.0	3.0
Springtime absolute minimum DO (mg/L)	Aquatic Life	4.5	4.0
E. coli (MPN/100 mL), long-term geometric average	Primary Contact Recreation	126	126
pH (standard units)	General	6.5 – 9.0	6.5 – 9.0
TDS (mg/L), long-term average	General	540	1000
Water temperature °C	General	32.8	32.8

Table 9. Screening levels for streams in Texas.

Water Quality Parameter	Screening Level for Freshwater Streams (TCEQ, 2015)
CHLA (µg/L)	14.1
NH_3-N (mg/L)	0.33
NO_2-N+NO_3-N (mg/L)	1.95
PO_4-P (mg/L)	0.37
Total-P (mg/L)	0.69

Assessments for aquatic life, recreation, and general uses normally are conducted by comparing individual or average constituent concentrations to the criterion or screening level. For the Bosque monitoring data, individual values were compared to segment specific criteria for DO, pH, and water temperature and screening levels for nutrients and CHLA (Tables 8 and 9). Averages over the seven-year period were compared to criteria for TDS, while the long-term geometric mean was compared for *E. coli*. Mean values for TDS were calculated by multiplying the mean conductivity by 0.65. Assessments were made following the *2014 Guidance for Assessing and Reporting Surface Water Quality in Texas* (TCEQ, 2015) with additional information provided from the Texas Surface Water Quality Standards (TCEQ, 2010) but with some modifications noted below.

Assessments were conducted by site for major tributary and mainstem sites to allow for the evaluation of water quality at specific sites within the Bosque watershed. This differs from the reporting of surface water quality for Texas conducted by TCEQ in which all data for sites within a segment or assessment unit are generally combined for assessment purposes. Criteria and screening levels for mainstem segments were applied to major tributary sites, unless specifically indicated. Although assessments are designed for routine grab samples, which are generally representative of baseflow conditions, storm samples were also separately assessed to give a better indication of nonpoint source contributions.

A 10 sample minimum (20 for bacteria) is needed for assessment purposes, although fewer than 10 samples (4-9) can be used to identify nonsupport or concerns of use attainment parameters (TCEQ, 2015). If fewer than 10 samples (4-9) were collected but values indicate compelling evidence of a potential water quality problem, a concern for near non-attainment but supporting the designated use can be identified.

Likewise, a concern for near non-attainment but supporting the designated use can be identified if the number of exceedances from 10 or more samples are insufficient for designation of nonsupport but indicate evidence of a potential water quality problem. Near non-attainment is defined in the binomial tables developed by TCEQ (2015). In general, assessment of no concern for criteria requires the fewest exceedances per sample size, concern for near non-attainment but supporting of criteria requires the second fewest, and nonsupport of criteria requires the highest number of exceedances. Assessments were not made if fewer than four samples were available.

Assessments of support and concern for individual values were made based on the binomial method for categorizing exceedances using tables and figures included in the 2014 Guidance for Assessing and Reporting Surface Water Quality in Texas (TCEQ, 2015). The binomial method takes into account sample size as well as probability of making both Types I and II decision errors. Type 1 decision errors are inappropriate indications of concern or lack of full support for a water body when it actually has no concerns and is fully supporting of criteria. Type II decision errors are inappropriate indications of no concern or full support when the water body actually has concerns or is not fully supporting criteria. For conventional parameters and bacteria, the desired Type I error rate for identifying impairments and concern noted by TCEQ is less than 20 percent and the desired Type II error rate is above 40 percent. The binomial tables developed in the TCEQ guidance indicate the number of exceedances needed for a given sample size to best meet these desired Type I and II error rates (TCEQ, 2015). For constituents with screening levels but without numeric criteria (CHLA, NH_3-N, NO_2-N+NO_3-N, PO_4-P, and total-P), concerns were assessed using Figure B-4 in *2014 Guidance for Assessing and Reporting Surface Water Quality in Texas* (TCEQ, 2015).

Because aquatic life uses differ some by segment (Table 2), DO criteria for these segments differ slightly (Table 8). Additionally, to protect fish spawning periods during that portion of the first half of the year when temperatures are 17.2°C (63.0°F) to 22.8°C (73.0°F) in classified water bodies, springtime criteria for mean and absolute minimum DO are included as part of the TCEQ assessment (TCEQ, 2010) but are not evaluated in this report.

All DO and pH measurements used in this report represent instantaneous measurements taken during the daytime near the water surface. In reservoirs and slow, deep streams that are likely to stratify, measurements of DO and pH should be made based on profile measurements within the mixed surface layer for assessment purposes (TCEQ, 2015). Stream sites within the Bosque River watershed are generally shallow at baseflow and relatively fast moving when deeper, and, thus, not likely to stratify.

Even if waters do not stratify, a complete assessment for DO criteria requires intensive 24-hour measurements, which are not part of TIAER's routine monitoring program. Although support of the 24-hour DO criteria cannot be evaluated using instantaneous DO measurements, concerns can be identified by comparing individual observations to the 24-hour mean and minimum (TCEQ, 2015).

Support of the pH and water temperature criteria was assessed by determining the number of individual readings that exceeded the criteria for a given sample size (TCEQ, 2012). Support of the absolute minimum DO criterion was assessed by comparing the number of exceedances of instantaneous DO data for a given sample size to binomial method-graphic tables developed by TCEQ (Figure B-1 *in 2014 Guidance for Assessing and Reporting Surface Water Quality Data in Texas*; TCEQ 2015) Concerns with

respect to DO were also assessed using instantaneous DO data compared to Figure B-2 in *2014 Guidance for Assessing and Reporting Surface Water Quality Data in Texas* (TCEQ, 2015).

To assess whether a water body is fully supporting bacteria criterion for primary contact recreation, the geometric mean of samples is compared to the associated criterion (Table 8). If the geometric mean for *E. coli* indicates nonsupport, the water body is assessed as not supporting the use of primary contact recreation (TCEQ, 2015). Support of bacteria criterion was assessed by comparing the seven-year geometric mean for *E. coli* to the long-term geometric average criterion.

Basic statistics (mean, median, standard deviation, minimum, maximum, and number of observations) for grab and storm event samples were also calculated to provide general information on the water quality at each site (see Appendices B and C). Of note grab samples include routine grabs (biweekly or monthly) as well as any additional special project samples and are not necessarily representative of baseflow conditions. Storm samples are primarily flow-composited samples representing biased or elevated flows.

Chapter 5

Water Quality Assessment Results

Basic statistics for each site are presented in Appendix B for major tributary site GC100 and Appendix C for mainstem sites. Statistics include mean, median, standard deviation, minimum value, maximum value, number of values, and number of values measured below the reporting limit for all analytes at each sampling site. Because TDS was estimated from conductivity and not measured, it is excluded from the appendices. In addition, the long-term geometric average for *E. coli* is presented for sites on the North Bosque River and its major tributaries.

Assessments compare TCEQ criteria and screening levels to values for both routine and storm samples collected at major tributary and mainstem sites. While TCEQ criteria and screening levels are established for comparison with routine sampling data, the comparison to storm samples is included because nonpoint source or storm driven runoff is considered a primary source of water quality impairment to the North Bosque River.

For assessments requiring the comparison of individual samples to criteria or screening levels, the number of samples analyzed and the percentage of those samples in exceedance of criteria or screening levels are shown. The binomial method for assessing support or concern, based on figures in *2014 Guidance for Assessing and Reporting Surface Water Quality in Texas* (TCEQ, 2015), was used to determine the level of support or concern for constituents at each site.

Sites on Major Tributaries to the North Bosque River

Data from GC100 represents a major tributary to the North Bosque River were compared to criteria and screening levels to evaluate levels of support and concern with respect to designated uses (Table 10).

The DO criterion applied was based on the aquatic life use designation of the water body (TCEQ, 2010). Greens Creek has a limited aquatic life use (TCEQ, 2015). The 24-hour DO mean criterion is 3.0 mg/L and the absolute minimum DO criterion is 2.0 mg/L for site GC100. A comparison of DO concentrations from individual grab samples to the 24-hr mean and minimum DO criteria indicated no concern for the aquatic life use for this major tributary site (Table 10).

No measurements of pH were outside the range of 6.5 and 9.0 standard units nor were any water temperature measurement greater than 32.8°C (Table 10). Excessive algae was indicated as a concern at GC100 based on CHLA measurements with routine grab samples, while nutrient concerns were indicated at GC100 for NH_3-N and total-P only with storm samples.

Table 10. Percent of North Bosque tributary samples exceeding criteria or screening levels collected between July 1, 2013 and June 30, 2020.

Shaded values indicate concern or lack of support of criteria based on the binomial method (TCEQ, 2015)

Site	Sample Type[a]	DO < 3 mg/L[b]	DO Abs Min < 2 mg/L[c]	pH < 6.5 or >9.0	Water Temp > 32.8 °C	CHLA > 14.1 µg/L	NO_2-N +NO_3-N > 1.95 mg/L	NH_3-N > 0.33 mg/L	PO_4-P > 0.37 mg/L	Total-P > 0.69 mg/L
GC100	R	0%	0%	0%	0%	28%	0%	1%	1%	0%
	n	93	93	93	93	93	91	91	93	93
	S						2%	21%	4%	21%
	n						52	52	52	52

a. R=routine grab sample, but may also include some special project samples; S=storm sample; n=number of samples.
b. The 24-hr DO mean criterion is 3 mg/L for site GC100.
c. The absolute minimum Do criterion is 2 mg/L for GC100.

To evaluate support of primary contact recreation, the geometric mean of *E. coli* was compared to the criterion of 126 MPN/100 mL (Table 11). Support for primary contact recreation was indicated at site GC100 based on the long-term geometric mean of *E. coli* (Table 11).

Table 11. Geometric mean *E. coli* and mean TDS concentrations for routine grab samples at major tributary site GC100.

Shaded values are above criterion.

Site	Geometric Mean *E. coli* (MPN/100mL)	Number of Obs.	Mean TDS (mg/L)	Number of Obs.
Criterion	126		500	
GC100	125	43	401	93

Average TDS concentrations for GC100 were below the associated segment criterion. Site GC100 is associated with Segment 1226, which has a TDS criterion of 500 mg/L.

Sites on the North Bosque River

In the assessment summary for the mainstem of the North Bosque River, sites are presented in upstream to downstream order beginning with BO020, the most upstream site, and ending with BO095, the most downstream site (Table 12). Routine and storm samples were collected at all sites on the North Bosque River but BO083. At site BO083 only routine grab samples were collected due to access issues limiting the installation of an automated sampler for storm monitoring.

Table 12. Percent of North Bosque River samples exceeding criteria or screening levels collected between July 1, 2013 and June 30, 2020.

Shaded values indicate concern or lack of support of criteria based on the binomial method (TCEQ, 2015)

Site	Sample Type[a]	DO < 4 or 5 mg/L[b]	DO Abs Min < 3 mg/L	pH < 6.5 or >9.0	Water Temp > 32.8 °C	CHLA > 14.1 µg/L	NO_2-N +NO_3-N > 1.95 mg/L	NH_3-N > 0.33 mg/L	PO_4-P > 0.37 mg/L	Total-P > 0.69 mg/L
BO020	R	20%	13%	0%	0%	61%	11%	2%	18%	8%
	N	127	127	127	127	127	124	125	127	127
	S						0%	10%	41%	36%
	N						107	107	107	107
BO040	R	3%	1%	0%	0%	37%	88%	9%	55%	23%
	N	183	183	183	183	183	126	181	185	183
	S						29%	13%	38%	32%
	N						107	107	107	106
BO070	R	2%	0%	0%	1%	37%	0%	1%	1%	1%
	N	171	171	171	171	171	169	169	171	171
	S						4%	0%	3%	17%
	N						135	135	135	135
BO083	R	0%	0%	0%	0%	37%	0%	0%	0%	0%
	N	150	150	150	150	150	148	148	148	150
BO090	R	0%	0%	0%	0%	26%	0%	0%	0%	0%
	N	175	175	175	175	174	173	173	175	175
	S						0%	0%	0%	16%
	N						122	122	122	122
BO095	R	0%	0%	0%	0%	22%	0%	0%	0%	0%
	N	177	177	177	177	175	175	175	177	177
	S						0%	0%	0%	10%
	N						120	120	119	119

a. R = routine grab sample, but may also include some special project samples; S = storm sample; n = number of samples.
b. The 24-hr DO mean criterion is 4 mg/L for sites BO020 and BO040 and 5 mg/L for sites BO070, BO083, BO090, and BO095.

The DO criterion varies along the North Bosque River based on changes in the aquatic life use. The 24-hour mean criterion is 4.0 mg/L for Segment 1255 (sites BO020 and BO040) for support of an intermediate aquatic life use and 5.0 mg/L for Segment 1226 (the remainder of the North Bosque River sites) for support of a high aquatic life use. The absolute minimum criterion is 3.0 mg/L for both segments.

All DO comparisons represent individual measurements taken in conjunction with grab samples compared to the 24-hr mean and absolute minimum criteria. Concern for the 24-hour DO mean criterion and nonsupport of the absolute minimum criterion were indicated at site BO020. The remaining five sites on the North Bosque River were fully supporting with respect to the minimum DO criterion and had no concerns in comparison to the 24-hour mean DO criterion.

Only one measurement of water temperature was greater than 32.8°C and all pH measurements were within the designated range of 6.5 to 9.0 standard units, indicating a preliminary assessment of full

support for these general use criteria. The one instance when water temperature was recorded to be greater than 32.8°C occurred at BO070 on July 23, 2013, when a temperature of 33.4°C was measured.

A concern regarding algal abundance was indicated for CHLA at all six mainstem sites, while concerns regarding excessive nutrients were indicated at sites BO020, BO040, BO070, and BO090. At BO020, storm samples indicated concerns for PO_4-P and total P, while routine samples only indicated concern for PO_4-P. At BO040, routine and storm samples indicated concern for NO_2-N+NO_3-N, PO_4-P, and total-P. In addition, NH_3-N reached levels of concern at BO040 during storm monitoring. Concern for total-P concentrations at sites BO070 and BO090 were noted only during storm events, not with routine monitoring.

To evaluate support of primary contact recreation, the geometric mean of *E. coli* was compared to the criterion of 126 MPN/100 mL (Table 13). Nonsupport for primary contact recreation was indicated at the two most upstream sites, BO020 and BO040, based on the long-term geometric mean of *E. coli*. At sites further downstream, no concern was noted for primary contact recreation based on bacteria concentrations.

Table 13. Geometric mean *E. coli* and mean TDS for routine grab samples at mainstem sites.

Shaded values are above criteria.

Site or Segment	Geometric Mean *E. coli* (MPN/100mL)	Number of Obs.	Mean TDS (mg/L)	Number of Obs.
Segment 1255				
Criteria	126		1000	
BO020	204	58	647	127
BO040	137	84	683	183
Segment 1226				
Criteria	126		540	
BO070	82	79	428	171
BO083	48	67	349	150
BO090	39	81	298	175
BO095	70	82	307	177

Mean conductivity for each site was multiplied by 0.65 to estimate TDS. Mean TDS concentrations were then compared to the appropriate criterion (540 mg/L for Segment 1226 and 1000 mg/L for Segment 1255) on a site-by-site basis to assess general use. All sites had mean TDS concentrations below the segment specific criterion for general use.

Chapter 6

Summary and Conclusions

This report presents a synthesis of water quality data for TIAER sampling sites that were active within the Bosque River watershed between July 2013 and June 2020. Data presented covers a seven year period, July 1, 2013 and June 30, 2020 for six mainstem and one major tributary sites. Most grab samples were collected on a routine biweekly schedule and analyzed for DO, pH, water temperature, CHLA, TSS, and nutrients. *E. coli* was generally analyzed on a monthly basis. Values for mean TDS were not directly measured but calculated from the seven-year mean of conductivity multiplied by 0.65. Basic statistics for eight monitoring sites are presented separately for storm and routine grab data in Appendices B and C.

Based on TCEQ assessment methodology (TCEQ, 2015), water quality data from these seven sites within the Bosque River watershed were compared to state numeric criteria and screening levels. Numeric criteria are the part of the state water quality standards that protect designated uses, while numeric screening levels for nutrients and CHLA are used to identify areas of concern with regard to nutrient enrichment compared to other water bodies within the state. Levels of support and concern can be identified for parameters with numeric criteria; concerns can be identified for parameters with screening levels.

Assessments in most cases employed the binomial method for determining levels of support or concern (TCEQ, 2015). The Binomial method incorporates sample size and probability rates for making Type I and II decision errors in determining the number of exceedances that can occur before impairment or concern is indicated.

Numeric criteria for DO, pH, water temperature, and *E. coli* were based on designated uses for Segment 1226, North Bosque River and Segment 1255, Upper North Bosque River (TCEQ, 2010). Screening levels used to evaluate CHLA and nutrients were from the *2014 Guidance for Assessing and Reporting Surface Water Quality in Texas* (TCEQ, 2015). Numeric criteria for TDS used to evaluate general use were from Appendix A of the Texas Surface Water Quality Standards (TCEQ, 2010).

Measurements for DO represented instantaneous measurements taken during daylight hours rather than summary data from intensive 24-hour evaluations. To fully assess the DO criteria for aquatic life use, intensive 24-hour measurements are required, which are not part of TIAER's routine monitoring program.

A summary of the water quality findings for the six mainstem sites and two major tributaries evaluated for the North Bosque River follows:

- DO, pH, and water temperature supported designated uses throughout the North Bosque River watersheds, except at site BO020 (Table 14). Of the eight sites evaluated, nonsupport of the minimum DO criterion and concern for the 24-hr mean DO criterion were indicated only at site BO020. Full support for pH and temperature criteria were indicated at all eight sites.
- For routine grab samples, two mainstem station (BO020 and BO040) indicated nonsupport of the use of primary contact recreation with regard to *E. coli* concentrations based on the geometric

mean compared to the criterion (Table 14). Both stations indicating nonsupport of primary contact recreation were located in the upper portion of the North Bosque River watershed.

- Regarding general use criteria for TDS, a preliminary assessment of routine grab samples indicated full support at all eight sites evaluated.

Table 14. Sampling sites indicating nonsupport or concern for numeric criteria for routine samples collected between July 1, 2013 and June 30, 2020

Constituent	Site	% Samples Exceeding Criterion	# Samples Evaluated	Geometric Mean E. coli (MPN/100mL)[a]	Assessment
DO minimum	BO020	13%	127	Not applicable	Not supporting
DO mean	BO020	20%	127	Not applicable	Concern
E. coli	BO020	Not applicable	58	204	Not supporting
E. coli	BO040	Not applicable	84	137	Not supporting

a. The long-term geometric mean criterion of 126 MPN/100 mL *E. coli* was exceeded.

- Concerns for CHLA occurred at seven of the eight sites evaluated indicating general use concerns for excessive algae (Table 15).
- Of the seven sites assessed, concerns regarding excessive nutrients were indicated in routine samples at only two sites in the upper portion of the North Bosque watershed (Table 15). During storm events, nutrient concerns were indicated at five of the eight monitoring stations.

Of note, criteria and screening levels were not intended to be strictly applied to storm or biased flow sampling, but rather routine, ambient sampling. Comparisons of storm data to criteria and screening levels are presented as a relative comparison to routine grab data.

Table 15. Sampling sites indicating concern for screening levels for samples collected between July 1, 2013 and June 30, 2020.

Routine grab sample concerns are indicated by R, and storm sample concerns are indicated by S.

Site	CHLA	NO_2-N +NO_3-N	NH_3-N	PO_4-P	Total-P
GC100	R	–	S	–	S
BO020	R	–	–	R, S	S
BO040	R	R, S	–	R, S	R, S
BO070	R	–	–	–	S
BO083	R	–	–	–	–
BO090	R	–	–	–	–
BO095	R	–	–	–	–

More detailed reports on trends in water quality within the Bosque River watershed are available from TIAER or may be accessed from TIAER's website at www.tarleton.edu/tiaer/.

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Appendix A

Grab Sampling History

These tables indicate the routine sampling history for site GC100 and the presence or absence of flow during each biweekly or monthly sampling event. The last row of each table for stream sites presents the percentage of sampling events for which flow was present and grab samples were collected.

Table A-1. Biweekly grab sampling history at major tributary sites along the North Bosque River.

Year	Month	Day	GC100
2013	Jul	8	D
		22	D
	Aug	5-6	D
		19	D
	Sep	3	D
		16	D
	Oct	1	D
		14, 16	D
		29	D
	Nov	11	D
		25	D
	Dec	11	D
		16-18	D
2014	Jan	9	D
		21	D
	Feb	3	D
		18	D
	Mar	5	D
		17	D
	Apr	1	D
		15	D
		28-29	D
	May	12	D
		27-28	D
	Jun	10	D
		24	D
	Jul	7	D
		21	D
	Aug	4	D
		18	D
	Sep	2	D
		15	D
		29	D
	Oct	13	D
		28	D
	Nov	10	D
		24	D
	Dec	8	D
		22	D
2015	Jan	6	D
		20	D

Year	Month	Day	GC100
	Feb	3	D
		18	D
	Mar	3	D
		17	D
		30	D
	Apr	13	D
		29	X
	May	13	X
		26	X
	Jun	8	X
		23	X
	Jul	7	X
		21	X
	Aug	4	X
		18	D
	Sep	1	D
		15	D
		29	D
	Oct	12	D
		27	D
	Nov	9	X
		23	X
	Dec	7	X
		21	X
2016	Jan	4	X
		19	X
	Feb	1	X
		15	X
	Mar	1	X
		15	X
		28	X
	Apr	12	X
		26	X
	May	10	X
		24	X
	Jun	7	X
		21	X
	Jul	7	X
		18	X
	Aug	1	X
		15	X
	Sep	1	X
		15	X
		27	X
	Oct	10	X
		24	X
	Nov	8	X
		22	X
	Dec	5	X
		19	X
2017	Jan	3	X
		17	X
		31	X
	Feb	13	X
		28	X

Year	Month	Day	GC100
	Mar	14	X
		27	X
	Apr	10	X
		24	X
	May	9	X
		23	X
	Jun	5	X
		19	X
	Jul	5	X
		17	X
		31	X
	Aug	14	X
		29	X
	Sep	12	D
		26	D
	Oct	9	D
		24	D
	Nov	7	D
		21	D
	Dec	5	D
		20	D
2018	Jan	4	D
		18	D
		29	D
	Feb	14	D
		27	X
	Mar	12	X
		27	X
	Apr	9	X
		23	X
	May	9	X
		22	X
	Jun	4	D
		18	D
	Jul	2	D
		16	D
		31	D
	Aug	14	D
		28	D
	Sep	11	D
		25	D
	Oct	8	D
		23	X
	Nov	5	X
		19	X
	Dec	3	X
		17	X
2019	Jan	3	X
		14	X
		28	X
	Feb	13	X
		25	X
	Mar	12	X
		25	X
	Apr	8	X

Year	Month	Day	GC100
		22	X
	May	6	X
		20	X
	Jun	3	X
		18	X
	Jul	1	X
		17	X
		30	X
	Aug	13	X
		27	X
	Sep	10	D
		24	D
	Oct	8	D
		21	D
	Nov	4	D
		18	D
	Dec	3	D
		16	D
2020	Jan	2	D
		13	D
		27	D
	Feb	11	D
		26	D
	Mar	9	X
		23	X
	Apr	6	X
		20	X
	May	4	X
		18	X
	Jun	1	X
		15	D
		29	D
Percentage of events at which flow was present[c]			51%

a. X indicates a grab sample was collected.
b. D indicates no flow (pooled) or dry conditions during which grab samples were not collected.
c. The percentage is based on total visits (182) to a site during the full seven-year period. The percentages are adjusted according to the number of times a site was monitored.

Table A-2. Biweekly grab sampling history at main stem sites along the North Bosque River.

Year	Month	Day	BO020	BO040	BO070	BO083	BO090	BO095
2013	Jul	8	D	X	D	D	D	X
		22	X	X	X	X	X	X
	Aug	5	D	X	D	D	X	X
		19	D	X	D	D	D	D
	Sep	3	D	X	D	D	D	D
		16	D	X	D	D	D	D
	Oct	1	D	X	X	D	X	X
		14	X	X	X	D	X	X
		29	D	X	X	X	X	X
	Nov	11	D	X	X	D	X	X
		25	X	X	X	D	X	X
	Dec	11	X	X	X	D	X	X
		18	X	X	X	X	X	X
2014	Jan	9	X	X	X	X	X	X
		21	D	X	X	X	X	X
	Feb	3	D	X	X	X	X	X
		18	D	X	X	X	X	X
	Mar	5	D	X	X	X	X	X
		17	D	X	X	X	X	X
	Apr	1	D	X	X	X	X	X
		15	X	X	X	X	X	X
		29	D	X	X	X	X	X
	May	12	D	X	X	D	X	X
		27	X	X	X	X	X	X
	Jun	10	X	X	X	X	X	X
		24	X	X	X	X	X	X
	Jul	7	D	X	X	D	X	X
		21	D	X	X	X	X	X
	Aug	4	D	X	D	D	X	X
		18	D	X	D	D	X	X
	Sep	2	D	X	D	D	X	D
		15	D	X	D	D	D	D
		29	D	X	D	D	D	D
	Oct	13	X	X	X	D	X	X
		28	D	X	X	D	X	X
	Nov	10	D	X	X	D	X	X
		24	X	X	X	D	X	X
	Dec	8	D	X	X	D	X	X
		22	D	X	X	D	X	X
2015	Jan	6	X	X	X	X	X	X
		20	D	X	X	X	X	X
	Feb	3	X	X	X	X	X	X
		18	D	X	X	X	X	X
	Mar	3	X	X	X	X	X	X
		17	X	X	X	X	X	X
		30	X	X	X	X	X	X
	Apr	13	X	X	X	X	X	X
		29	X	X	X	X	X	X
	May	13	X	X	X	X	X	X
		26	X	X	X	X	X	X
	Jun	8	X	X	X	X	X	X
		23	X	X	X	X	X	X

Year	Month	Day	BO020	BO040	BO070	BO083	BO090	BO095
	Jul	7	X	X	X	X	X	X
		21	X	X	X	X	X	X
	Aug	4	X	X	X	X	X	X
		18	X	X	X	X	X	X
	Sep	1	D	X	X	X	X	X
		15	D	X	X	X	X	X
		29	D	X	X	X	X	X
	Oct	12	D	X	X	D	X	X
		27	D	X	X	X	X	X
	Nov	9	X	X	X	X	X	X
		23	X	X	X	X	X	X
	Dec	7	X	X	X	X	X	X
		21	X	X	X	X	X	X
2016	Jan	4	X	X	X	X	X	X
		19	X	X	X	X	X	X
	Feb	1	X	X	X	X	X	X
		15	X	X	X	X	X	X
	Mar	1	X	X	X	X	X	X
		15	X	X	X	X	X	X
		28	X	X	X	X	X	X
	Apr	12	X	X	X	X	X	X
		26	X	X	X	X	X	X
	May	10	X	X	X	X	X	X
		24	X	X	X	X	X	X
	Jun	7	X	X	X	X	X	X
		21	X	X	X	X	X	X
	Jul	7	X	X	X	X	X	X
		18	X	X	X	X	X	X
	Aug	1	X	X	X	X	X	X
		15	D	X	X	X	X	X
	Sep	1	D	X	X	X	X	X
		15	X	X	X	X	X	X
		27	X	X	X	X	X	X
	Oct	10	X	X	X	X	X	X
		24	D	X	X	X	X	X
	Nov	8	X	X	X	X	X	X
		22	X	X	X	X	X	X
	Dec	5	X	X	X	X	X	X
		19	X	X	X	X	X	X
2017	Jan	3	X	X	X	X	X	X
		17	X	X	X	X	X	X
		31	X	X	X	X	X	X
	Feb	13	X	X	X	X	X	X
		28	X	X	X	X	X	X
	Mar	14	X	X	X	X	X	X
		27	X	X	X	X	X	X
	Apr	10	X	X	X	X	X	X
		24	X	X	X	X	X	X
	May	9	X	X	X	X	X	X
		23	X	X	X	X	X	X
	Jun	5	X	X	X	X	X	X
		19	X	X	X	X	X	X
	Jul	5	X	X	X	X	X	X
		17	X	X	X	X	X	X

Year	Month	Day	BO020	BO040	BO070	BO083	BO090	BO095
		31	X	X	X	X	X	X
	Aug	14	X	X	X	X	X	X
		29	X	X	X	X	X	X
	Sep	12	D	X	X	X	X	X
		26	D	X	X	D	X	X
	Oct	9	D	X	X	X	X	X
		24	D	X	X	X	X	X
	Nov	7	D	X	X	D	X	X
		21	D	X	X	X	X	X
	Dec	5	D	X	X	X	X	X
		20	X	X	X	X	X	X
2018	Jan	4	X	X	X	X	X	X
		18	X	X	X	X	X	X
		29	X	X	X	X	X	X
	Feb	14	X	X	X	X	X	X
		27	X	X	X	X	X	X
	Mar	12	X	X	X	X	X	X
		27	X	X	X	X	X	X
	Apr	9	X	X	X	X	X	X
		23	X	X	X	X	X	X
	May	9	X	X	X	X	X	X
		22	X	X	X	X	X	X
	Jun	4	D	X	X	X	X	X
		18	D	X	X	D	X	X
	Jul	2	D	X	X	D	X	X
		16	D	X	X	D	X	X
		31	D	X	D	D	X	X
	Aug	14	X	X	X	D	X	X
		28	D	X	D	D	X	X
	Sep	11	X	X	X	X	X	X
		25	X	X	X	X	X	X
	Oct	8	D	X	X	X	X	X
		23	X	X	X	X	X	X
	Nov	5	X	X	X	X	X	X
		19	X	X	X	X	X	X
	Dec	3	X	X	X	X	X	X
		17	X	X	X	X	X	X
2019	Jan	3	X	X	X	X	X	X
		14	X	X	X	X	X	X
		28	X	X	X	X	X	X
	Feb	13	X	X	X	X	X	X
		25	X	X	X	X	X	X
	Mar	12	X	X	X	X	X	X
		25	X	X	X	X	X	X
	Apr	8	X	X	X	X	X	X
		22	X	X	X	X	X	X
	May	6	X	X	X	X	X	X
		20	X	X	X	X	X	X
	Jun	3	X	X	X	X	X	X
		18	X	X	X	X	X	X

Year	Month	Day	BO020	BO040	BO070	BO083	BO090	BO095
	Jul	1	X	X	X	X	X	X
		17	X	X	X	X	X	X
		30	X	X	X	X	X	X
	Aug	13	X	X	X	X	X	X
		27	X	X	X	X	X	X
	Sep	10	D	X	X	X	X	X
		24	D	X	X	X	X	X
	Oct	8	D	X	X	X	X	X
		21	D	X	X	X	X	X
	Nov	4	X	X	X	X	X	X
		18	X	X	X	X	X	X
	Dec	3	X	X	X	X	X	X
		16	X	X	X	X	X	X
2020	Jan	2	X	X	X	X	X	X
		13	X	X	X	X	X	X
		27	X	X	X	X	X	X
	Feb	11	X	X	X	X	X	X
		26	X	X	X	X	X	X
	Mar	9	X	X	X	X	X	X
		23	X	X	X	X	X	X
	Apr	6	X	X	X	X	X	X
		20	X	X	X	X	X	X
	May	4	X	X	X	X	X	X
		18	X	X	X	X	X	X
	Jun	1	X	X	X	X	X	X
		15	D	X	X	X	X	X
		29	X	X	X	X	X	X
Percentage of events at which flow was present[c]			69%	100%	93%	83%	97%	97%

a. X indicates a grab sample was collected.
b. D indicates no flow or dry conditions during which grab samples were not collected.
c. The percentage is based on total number of biweekly visits (182) to each site over the full seven-year period. The percentages are adjusted according to the length of time the site was monitored.

Appendix B

Major Tributary Site to the North Bosque River

This table list basic statistics and automatic storm event samples for major tributary site GC100 to the North Bosque River. Grab samples represent routine biweekly sampling plus a few samples for special projects. The mean for bacteria provides both the arithmetic mean and the seven-year geometric mean. Reporting limits (RLs as MDLs or AWRLs) are not established for field parameters DO, pH, conductivity, and water temperature. Therefore, the number of samples below the reporting limit for those parameters is NA (not applicable).

Table B-1. Preliminary water quality analysis for major tributary site GC100

Site	Type	Constituent	Mean	Median	Std Dev	Min	Max	N	Number Below RL
GC100	Grab	CHLA (µg/L)	11.5	7.6	12.7	1.5	85.8	93	13
GC100	Grab	Conductivity (µS/cm)	617	638	137	226	885	93	NA
GC100	Grab	DO (mg/L)	8.3	7.9	1.8	4.5	13.7	93	NA
GC100	Grab	*E. coli* (MPN/100 mL)	1611/125	96	8800	3.1	57900	43	0
GC100	Grab	NH_3-N (mg/L)	0.072	0.030	0.087	0.030	0.761	91	50
GC100	Grab	NO_2-N+NO_3-N (mg/L)	0.348	0.065	0.440	0.025	1.750	91	43
GC100	Grab	pH (standard units)	8.0	8.0	0.2	7.6	8.4	93	NA
GC100	Grab	PO_4-P (mg/L)	0.056	0.009	0.098	0.003	0.406	93	34
GC100	Grab	TKN (mg/L)	0.62	0.48	0.54	0.10	2.68	93	25
GC100	Grab	Total-P (mg/L)	0.13	0.09	0.13	0.03	0.63	93	26
GC100	Grab	TSS (mg/L)	15	7	66	2	642	93	26
GC100	Grab	Water temp. (°C)	19.2	19.5	6.8	4.6	29.9	93	NA
GC100	Storm	NH_3-N (mg/L)	0.201	0.107	0.267	0.030	1.520	52	18
GC100	Storm	NO_2-N+NO_3-N (mg/L)	0.338	0.264	0.372	0.025	2.460	52	8
GC100	Storm	PO_4-P (mg/L)	0.193	0.172	0.184	0.009	1.180	52	0
GC100	Storm	TKN (mg/L)	2.12	2.00	1.40	0.24	6.42	52	0
GC100	Storm	Total-P (mg/L)	0.51	0.46	0.35	0.03	1.73	52	1
GC100	Storm	TSS (mg/L)	291	137	329	7	1250	51	0

a. Arithmetic mean/geometric mean

Appendix C

North Bosque River Sites

These tables list basic statistics for routine grab samples and automatic storm event samples for sites on the North Bosque River collected between July 1, 2013 and June 30, 2020. Grab samples represent routine biweekly sampling plus some sampling for special projects. The mean for *E. coli* provides the arithmetic mean and the seven-year geometric mean. Reporting limits (RLs as MDLs or AWRLs) are not established for field parameters DO, pH, conductivity, and water temperature. Therefore, the number of samples below the reporting limit for those parameters is NA (not applicable).

Table C-1. Preliminary water quality analysis for North Bosque River site BO020

Site	Type	Constituent	Mean	Median	Std Dev	Min	Max	N	Number Below RL
BO020	Grab	CHLA (µg/L)	30.1	18.2	30.4	1.5	132	127	11
BO020	Grab	Conductivity (µS/cm)	996	975	635	111	2890	127	NA
BO020	Grab	DO (mg/L)	7.6	7.7	3.1	0.7	15.5	127	NA
BO020	Grab	*E. coli* (MPN/100 mL)	2750/204	185	10775	3	64900	58	0
BO020	Grab	NH_3-N (mg/L)	0.084	0.030	0.159	0.030	1.340	125	78
BO020	Grab	NO_2-N+NO_3-N (mg/L)	0.699	0.310	0.988	0.025	5.690	124	39
BO020	Grab	pH (standard units)	8.0	8.0	0.2	7.4	8.5	127	NA
BO020	Grab	PO_4-P (mg/L)	0.240	0.207	0.201	0.003	1.450	127	1
BO020	Grab	TKN (mg/L)	1.20	1.07	0.72	0.10	3.48	127	5
BO020	Grab	Total-P (mg/L)	0.36	0.31	0.26	0.03	1.75	126	1
BO020	Grab	TSS (mg/L)	18	10	25	2	184	127	17
BO020	Grab	Water temp. (°C)	16.7	17.1	7.0	3.6	28.5	127	NA
BO020	Storm	NH_3-N (mg/L)	0.164	0.102	0.172	0.030	1.290	107	32
BO020	Storm	NO_2-N+NO_3-N (mg/L)	0.358	0.350	0.222	0.025	1.280	107	5
BO020	Storm	PO_4-P (mg/L)	0.332	0.329	0.169	0.011	0.864	107	0
BO020	Storm	TKN (mg/L)	1.87	1.60	1.42	0.29	9.31	107	0
BO020	Storm	Total-P (mg/L)	0.63	0.60	0.40	0.17	2.78	107	0
BO020	Storm	TSS (mg/L)	1644	81	14944	8	154000	106	0

a. Arithmetic mean/geometric mean

Table C-2. Preliminary water quality analysis for North Bosque River site BO040

Site	Type	Constituent	Mean	Median	Std Dev	Min	Max	N	Number Below RL
BO040	Grab	CHLA (µg/L)	16.8	8.3	23.4	1.5	133	183	39
BO040	Grab	Conductivity (µS/cm)	1051	1120	315	184	1860	183	NA
BO040	Grab	DO (mg/L)	8.1	7.9	2.5	2.0	15.4	183	NA
BO040	Grab	*E. coli* (MPN/100 mL)	978/137	115	4951	9.7	43500	84	0
BO040	Grab	NH_3-N (mg/L)	0.158	0.103	0.214	0.030	1.770	181	53
BO040	Grab	NO_2-N+NO_3-N (mg/L)	5.904	5.880	2.893	0.428	12.90	126	0
BO040	Grab	pH (standard units)	8.0	8.0	0.2	7.5	8.9	183	NA
BO040	Grab	PO_4-P (mg/L)	0.441	0.399	0.301	0.003	2.200	183	1
BO040	Grab	TKN (mg/L)	0.98	0.84	0.62	0.10	4.36	182	9
BO040	Grab	Total-P (mg/L)	0.54	0.49	0.30	0.10	2.31	182	0
BO040	Grab	TSS (mg/L)	9	5	11	2	73	182	77
BO040	Grab	Water temp. (°C)	18.6	19.5	6.6	3.8	28.6	183	NA
BO040	Storm	NH_3-N (mg/L)	0.191	0.168	0.121	0.030	0.501	107	12
BO040	Storm	NO_2-N+NO_3-N (mg/L)	1.558	1.320	1.153	0.330	5.880	107	0
BO040	Storm	PO_4-P (mg/L)	0.312	0.321	0.138	0.008	0.677	107	0
BO040	Storm	TKN (mg/L)	1.90	1.76	1.04	0.10	5.55	107	1
BO040	Storm	Total-P (mg/L)	0.58	0.58	0.27	0.17	1.51	106	0
BO040	Storm	TSS (mg/L)	161	71	221	2	1430	106	1

a. Arithmetic mean/geometric mean

Table C-3. Preliminary water quality analysis for North Bosque River site BO070

Site	Type	Constituent	Mean	Median	Std Dev	Min	Max	N	Number Below RL
BO070	Grab	CHLA (µg/L)	17.9	10.3	33.0	1.5	334	171	38
BO070	Grab	Conductivity (µS/cm)	659	688	174	130	978	171	NA
BO070	Grab	DO (mg/L)	9.6	9.4	2.5	3.7	17.3	171	NA
BO070	Grab	*E. coli* (MPN/100 mL)	849/82	67	5810	6.3	51700	79	0
BO070	Grab	NH_3-N (mg/L)	0.095	0.030	0.569	0.030	7.420	169	123
BO070	Grab	NO_2-N+NO_3-N (mg/L)	0.281	0.025	0.389	0.025	1.940	169	91
BO070	Grab	pH (standard units)	8.1	8.1	0.2	7.7	9.0	171	NA
BO070	Grab	PO_4-P (mg/L)	0.065	0.017	0.129	0.003	1.320	171	20
BO070	Grab	TKN (mg/L)	0.62	0.53	0.48	0.10	2.41	170	32
BO070	Grab	Total-P (mg/L)	0.14	0.10	0.13	0.03	0.77	169	26
BO070	Grab	TSS (mg/L)	13	4	36	2	388	170	83
BO070	Grab	Water temp. (°C)	18.5	19.4	7.5	1.8	33.4	171	NA
BO070	Storm	NH_3-N (mg/L)	0.088	0.065	0.071	0.030	0.294	135	66
BO070	Storm	NO_2-N+NO_3-N (mg/L)	0.508	0.390	0.574	0.025	3.950	135	22
BO070	Storm	PO_4-P (mg/L)	0.151	0.123	0.109	0.005	0.404	135	0
BO070	Storm	TKN (mg/L)	1.66	1.37	1.13	0.10	7.70	135	2
BO070	Storm	Total-P (mg/L)	0.44	0.39	0.31	0.07	1.80	135	0
BO070	Storm	TSS (mg/L)	292	144	389	7	2260	130	0

a. Arithmetic mean/geometric mean

Table C-4. Preliminary water quality analysis for North Bosque River site BO083

Site	Type	Constituent	Mean	Median	Std Dev	Min	Max	N	Number Below RL
BO083	Grab	CHLA (µg/L)	16.4	9.6	26.9	1.5	286	150	16
BO083	Grab	Conductivity (µS/cm)	537	554	122	203	776	150	NA
BO083	Grab	DO (mg/L)	8.7	8.6	2.1	5.1	15.9	150	NA
BO083	Grab	*E. coli* (MPN/100 mL)	199/48	52	566	0.5	4040	67	1
BO083	Grab	NH_3-N (mg/L)	0.060	0.030	0.049	0.030	0.253	148	92
BO083	Grab	NO_2-N+NO_3-N (mg/L)	0.163	0.025	0.233	0.025	0.928	148	96
BO083	Grab	pH (standard units)	8.1	8.1	0.2	7.7	8.9	150	NA
BO083	Grab	PO_4-P (mg/L)	0.030	0.003	0.068	0.003	0.362	150	93
BO083	Grab	TKN (mg/L)	0.70	0.60	0.47	0.10	2.38	149	17
BO083	Grab	Total-P (mg/L)	0.11	0.09	0.11	0.03	0.60	149	33
BO083	Grab	TSS (mg/L)	18	11	26	2	182	150	24
BO083	Grab	Water temp. (°C)	18.9	19.4	7.6	3.4	31.9	150	NA

a. Arithmetic mean/geometric mean

Table C-5. Preliminary water quality analysis for North Bosque River site BO090

Site	Type	Constituent	Mean	Median	Std Dev	Min	Max	N	Number Below RL
BO090	Grab	CHLA (µg/L)	12.9	6.6	18.0	1.5	135	174	36
BO090	Grab	Conductivity (µS/cm)	459	460	92	228	740	175	NA
BO090	Grab	DO (mg/L)	8.9	8.8	1.8	5.1	14.3	175	NA
BO090	Grab	*E. coli* (MPN/100 mL)	274/39	39	987	1	7490	81	0
BO090	Grab	NH_3-N (mg/L)	0.057	0.030	0.047	0.030	0.256	173	118
BO090	Grab	NO_2-N+NO_3-N (mg/L)	0.230	0.193	0.186	0.025	0.771	173	46
BO090	Grab	pH (standard units)	8.0	8.0	0.2	7.4	8.6	175	NA
BO090	Grab	PO_4-P (mg/L)	0.018	0.003	0.045	0.003	0.318	175	128
BO090	Grab	TKN (mg/L)	0.54	0.46	0.45	0.10	2.83	174	42
BO090	Grab	Total-P (mg/L)	0.10	0.08	0.09	0.03	0.62	174	48
BO090	Grab	TSS (mg/L)	20	8	59	2	537	174	50
BO090	Grab	Water temp. (°C)	20.0	20.6	7.5	4.2	32.4	175	NA
BO090	Storm	NH_3-N (mg/L)	0.068	0.030	0.061	0.030	0.285	122	74
BO090	Storm	NO_2-N+NO_3-N (mg/L)	0.281	0.281	0.158	0.025	0.670	122	10
BO090	Storm	PO_4-P (mg/L)	0.067	0.029	0.075	0.003	0.263	122	26
BO090	Storm	TKN (mg/L)	1.52	1.03	1.62	0.10	12.90	122	5
BO090	Storm	Total-P (mg/L)	0.37	0.18	0.44	0.03	2.81	122	11
BO090	Storm	TSS (mg/L)	474	112	1528	2	16000	120	4

a. Arithmetic mean/geometric mean

Table C-6. Preliminary water quality analysis for North Bosque River site BO095

Site	Type	Constituent	Mean	Median	Std Dev	Min	Max	N	Number Below RL
BO095	Grab	CHLA (µg/L)	11.8	5.5	23.8	1.5	253	175	50
BO095	Grab	Conductivity (µS/cm)	473	484	87	154	831	177	NA
BO095	Grab	DO (mg/L)	8.9	8.7	1.9	5.1	15.3	177	NA
BO095	Grab	*E. coli* (MPN/100 mL)	261/70	64	817	1	6500	82	0
BO095	Grab	NH_3-N (mg/L)	0.064	0.030	0.048	0.030	0.258	175	97
BO095	Grab	NO_2-N+NO_3-N (mg/L)	0.424	0.393	0.269	0.025	1.340	175	17
BO095	Grab	pH (standard units)	8.1	8.1	0.2	7.7	8.5	177	NA
BO095	Grab	PO_4-P (mg/L)	0.016	0.003	0.040	0.003	0.284	177	120
BO095	Grab	TKN (mg/L)	0.66	0.59	0.48	0.10	2.79	176	31
BO095	Grab	Total-P (mg/L)	0.10	0.08	0.09	0.03	0.58	176	46
BO095	Grab	TSS (mg/L)	21	9	48	2	443	176	50
BO095	Grab	Water temp. (°C)	19.1	19.9	7.4	1.7	30.9	177	NA
BO095	Storm	NH_3-N (mg/L)	0.070	0.030	0.064	0.030	0.291	120	71
BO095	Storm	NO_2-N+NO_3-N (mg/L)	0.322	0.305	0.162	0.025	0.709	120	6
BO095	Storm	PO_4-P (mg/L)	0.060	0.022	0.072	0.003	0.281	119	22
BO095	Storm	TKN (mg/L)	1.49	1.16	1.32	0.10	9.55	120	3
BO095	Storm	Total-P (mg/L)	0.32	0.24	0.31	0.03	2.11	119	9
BO095	Storm	TSS (mg/L)	309	133	442	5	2380	120	0

a. Arithmetic mean/geometric mean