2017 BASIN SUMMARY REPORT

A Summary of Water Quality Activities
in the Colorado River Basin (2012-2016)

This report, which summarizes water quality activities in the Colorado River basin between January 2012 and December 2016, was prepared by the Lower Colorado River Authority (LCRA) and Upper Colorado River Authority (UCRA) with contributions from the City of Austin. The report was financed through grants from the Texas Commission on Environmental Quality (TCEQ).

TABLE OF CONTENTS

I. Introduction

Texas Clean Rivers Program Goals and Objectives....3
Colorado River Basin Characteristics....4
Water Quality Overview....6

II. Public Involvement

Water Quality Advisory Committee Activity....10
Permit Application Review and Response....10
Volunteer Monitoring....11
Environmental Outreach....12
UCRA Public Involvement....12

III. Water Quality Analysis

Technical discussion....13
Trend Analysis....13
Water Quality Standards....14
Restoring Impaired Water Bodies....16

IV. Watershed Summaries

Upper Colorado River Watershed....19
Concho River Watershed....33
Pecan Bayou Watershed....53
Lake Buchanan Watershed....61
Lake LBJ Watershed....71
Lake Travis Watershed....79
Austin Watershed....87
Lower Colorado River Watershed (Austin to Columbus)....97
Coastal Watershed....111

V. Conclusions and Recommendations

Conclusions....114
Summary of Water Quality Conditions....114
Recommendations....115

VI. Appendices

Appendix A: Water Quality Constituents....116
Appendix B: Trend Analysis Methodology....119

LIST OF ACRONYMS

ALU	aquatic life use
BMP	best management practices
CFU	colony forming units
COA	City of Austin
CRP	Clean Rivers Program
CRWN	Colorado River Watch Network
EPA	United States Environmental Protection Agency
LCRA	Lower Colorado River Authority
mg/L	milligrams per liter (parts per million)
RRC	Texas Railroad Commission
SWQMIS	Surface Water Quality Monitoring Information System
TCEQ	Texas Commission on Environmental Quality
TDS	total dissolved solids
TPWD	Texas Parks and Wildlife Department
TSS	total suspended solids
TMDL	total maximum daily load
TSSWCB	Texas State Soil and Water Conservation Board
TSWQS	Texas Surface Water Quality Standards
UCRA	Upper Colorado River Authority
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WWTP	wastewater treatment plant

I. INTRODUCTION

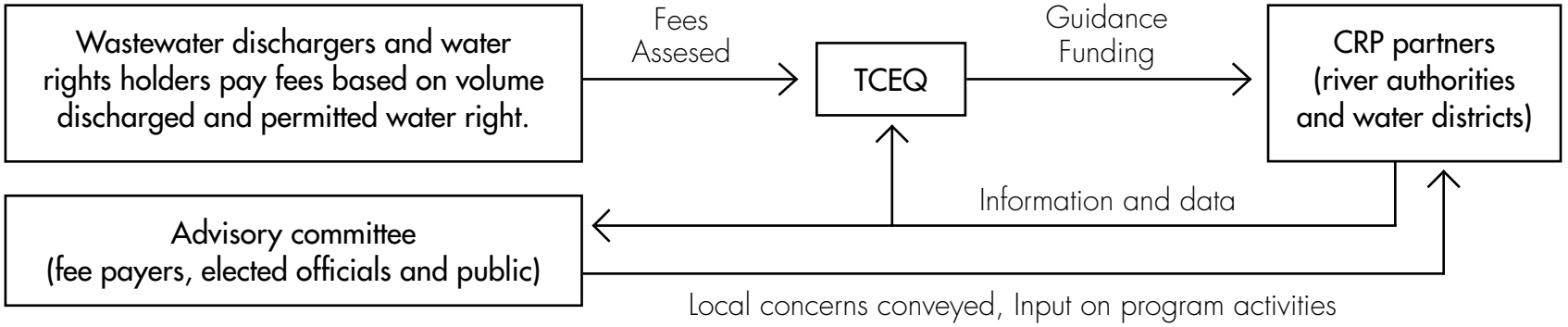
Texas Clean Rivers Program Goals and Objectives

With the passage of Senate Bill 818 in 1991, the Clean Rivers Program (CRP) established a statewide coalition of water monitoring agencies to collect data and disseminate water quality information on a regional level. Today, CRP partners and the TCEQ collect data from 1,900 water monitoring stations throughout the state. The data are used for many purposes, including developing the Texas Surface Water Quality Standards (TSWQS), determining if water bodies meet TSWQS, modeling trends, providing baseline data for water quality protection projects and helping to establish wastewater permit limits.

The program is administered by the TCEQ and funded by fees paid by municipal and industrial dischargers and water rights holders such as LCRA. Advisory committees provide input on local water quality concerns and help guide CRP activities (Figure 1). This system of statewide funding and local resource management encourages locally driven watershed protection efforts.

Lake Buchanan in drought

Figure 1. CRP Funding and Public Input



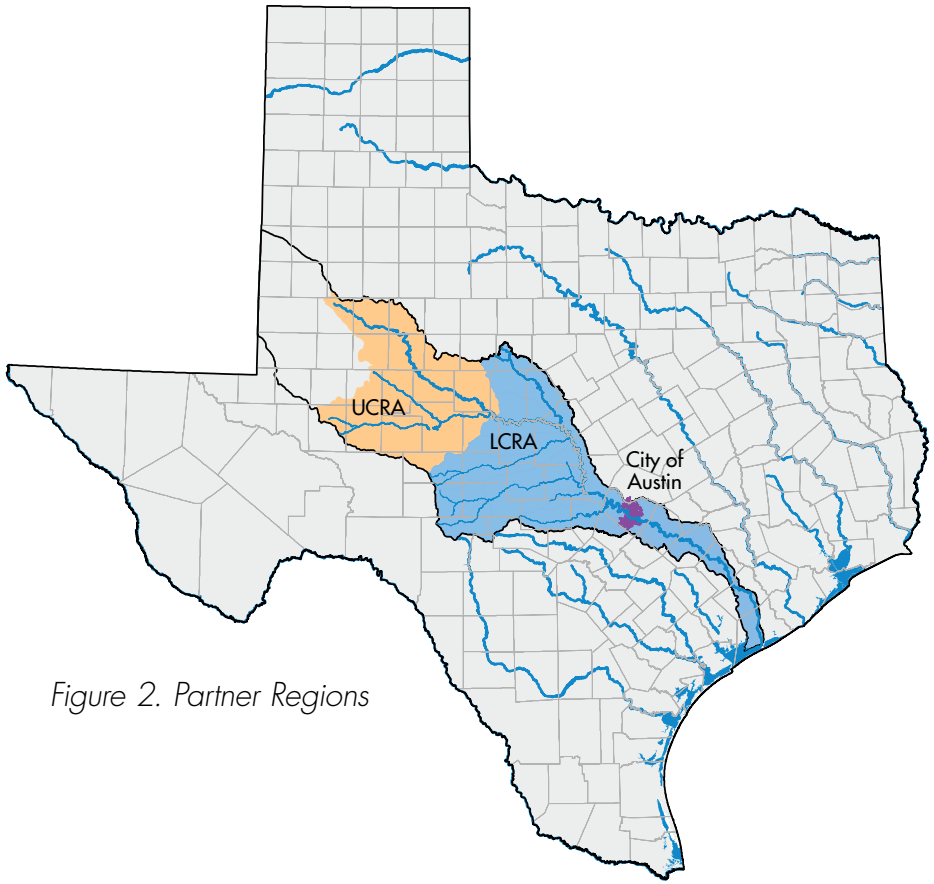


Figure 2. Partner Regions

Long-term objectives for CRP are to:

- Provide quality-assured data to the TCEQ for use in water quality decision-making.
- Identify and evaluate water quality issues.
- Promote cooperative watershed planning.
- Document water quality improvements.
- Recommend management strategies.
- Inform and engage stakeholders.
- Maintain efficient use of public funds.

The TCEQ allocated approximately $420,000 per year to the Colorado River basin between 2012 and 2016. During this time, CRP partners LCRA and UCRA monitored water quality and coordinated outreach efforts in their jurisdictions (Figure 2), often providing their own funding or matching grants to leverage resources. Additionally, the City of Austin contributed water quality data and in-kind services to help meet program objectives.

Colorado River Basin Characteristics

The Colorado River begins in the West Texas Plains and flows southeast more than 600 miles before emptying into Matagorda Bay. A wide range of topography, geology, soils, climate and human influences shape the river. The 40,000-square-mile river basin is divided into nine watersheds (Figure 3). Topography is extremely varied with elevation changes from nearly 3,000 feet in the upper watershed to sea level near the coastal watershed.

Watershed	Approximate Area (in Square Miles)
Upper Basin	6,000
Concho River	6,700
Pecan Bayou	2,200
Lake Buchanan	5,650
Lake LBJ	5,000
Lake Travis	1,830
Austin	250
Lower Basin	3,520
Coastal Watershed	240

Table 1. Watersheds in the Colorado River Basin

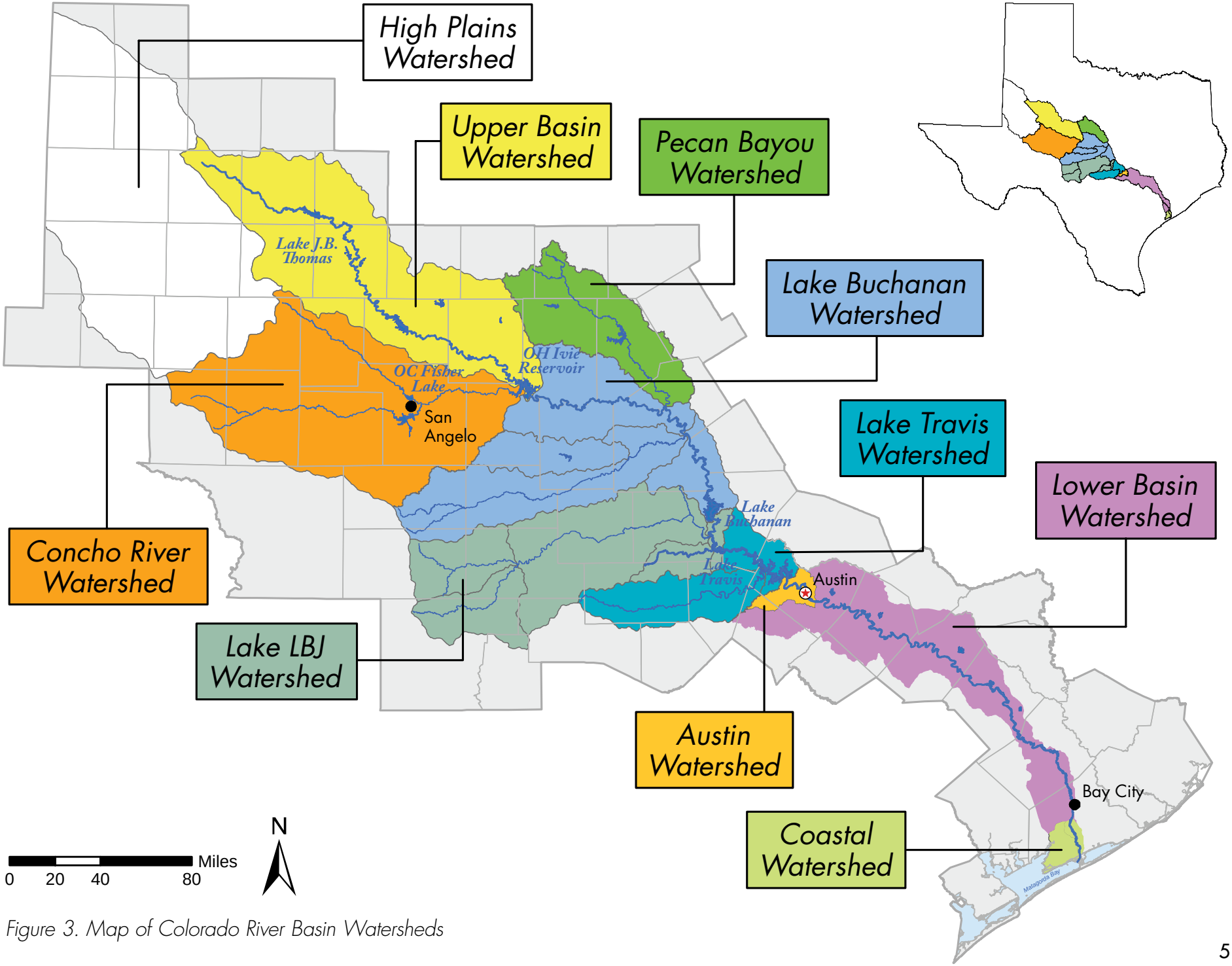


Figure 3. Map of Colorado River Basin Watersheds

Water Quality Overview

As with all surface water, the Colorado River is directly influenced by geology, soils, climate, vegetation and land uses. These physical factors make up unique geographic areas, or ecoregions. The Colorado River flows through eight ecoregions (Figure 4).

The upper Colorado and Concho river basins correspond with the Central Great Plains ecoregion, where soils typically have elevated levels of minerals and salts, and streams contain high levels of chloride and sulfate. Streams in the Central Great Plains tend to be turbid. A long-term drought in the upper basin has concentrated chloride and sulfate levels in reservoirs, making some of them comparable to brackish water in Matagorda Bay.

Chloride and sulfate levels in the northern Concho River west of San Angelo and nitrogen levels in the Concho River east of San Angelo are typically high. Conversely, the southern Concho River is influenced by major springs south of San Angelo, and it contains some of the best water quality in the basin.

In the middle portion of the basin, the Central Texas Plateau ecoregion corresponds with the Pedernales, Llano and San Saba river basins. Dominated by limestone and granite bedrock, the steep terrain of the Edwards Plateau gives rise to clear, fast-flowing, perennial streams. The principal tributaries – the San Saba, Llano and Pedernales rivers – play an important part in diluting the salinity and suspended sediment from upstream flows. The pH level is typically higher in this region due to limestone deposits in the Hill Country. This region includes the Texas Hill Country and the Highland Lakes: Buchanan, Inks, LBJ, Marble Falls, Travis and Austin.

Downstream of Austin, the Colorado River flows through the East Central Texas Plains and Blackland Prairies ecoregions to Columbus where the Western Gulf Coastal Plain defines flat topography and coastal marshes. Below Austin, the limestone canyons of the Hill Country give way to deep clay soils. Water in this region tends to be turbid, with higher amounts of total suspended solids (TSS). Treated wastewater that is discharged into the river affects flow and water quality downstream of Austin.

Chloride rings in the upper Colorado River.
Photo: Margie Crisp

Llano River in Llano County

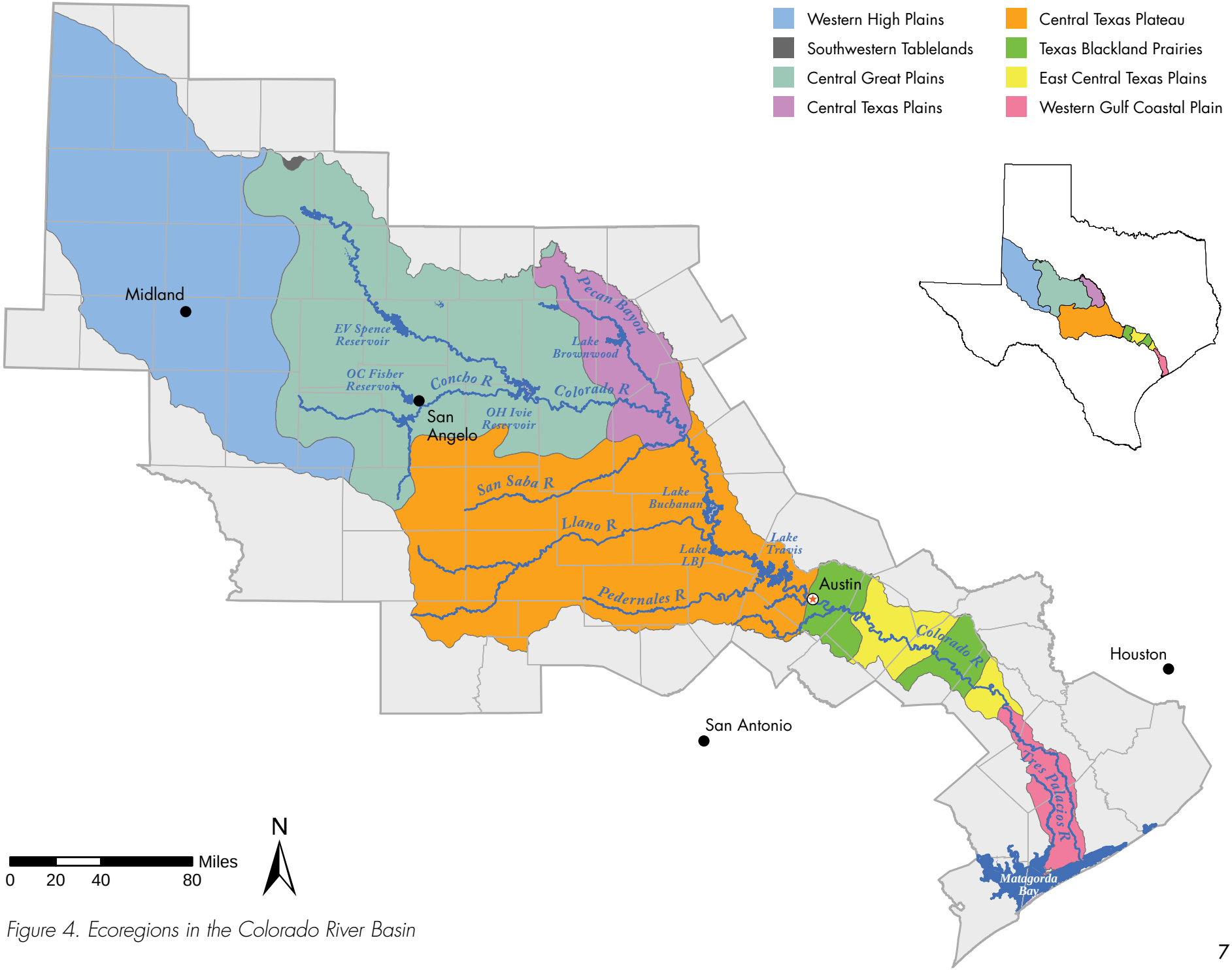


Figure 4. Ecoregions in the Colorado River Basin

Drought and Water Quality

State Climatologist John Nielson-Gammon reported that the most recent drought began in the early 2000s, and during 2012 and 2013, Texas received 68 percent of its normal precipitation. The decade-long drought conditions in the upper basin left many streams dry and reservoirs at fractions of their capacities.

In the middle basin, where flows have historically been higher because of springs and more frequent rain, lakes were reduced to levels not seen since the drought of the 1950s. From 2012 to 2015, inflows to the Highland Lakes were reduced to some of the lowest levels ever recorded. Gauged inflows were about 10 percent of the historical average.

In January 2013, reservoir levels in the upper basin were a small fraction of their capacities. The levels of the Highland Lakes were comparatively better, but still extremely low (Table 2).

By October 2015, consistent and sometimes heavy rain fell across the region, lifting drought conditions in most of the basin. From October 2015 until November 2016 steady rains replenished base flows in streams and filled the Highland Lakes. Likewise, reservoir levels in the upper basin increased (Table 2).

Figure 5. According to the U.S Drought Monitor, all of Texas was in some stage of drought in January 2012. Most of the Colorado River basin experienced extreme to exceptional drought conditions from 2012 through 2015.

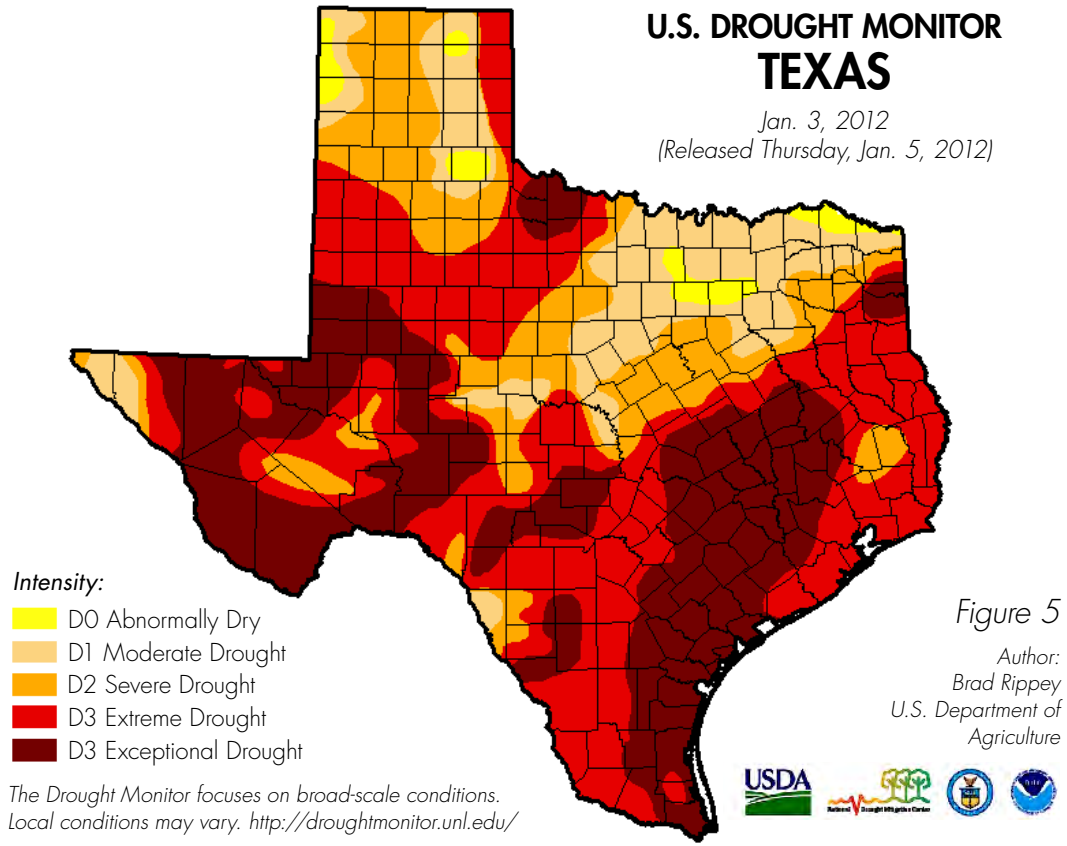


Figure 5

Author:
Brad Rippey
U.S. Department of Agriculture

Lake Travis in drought

Reservoir	Watershed	Percent Full (%) on Jan. 14, 2013	Percent Full (%) on Nov. 14, 2016
Lake J.B. Thomas	Upper Colorado River	0.6	66
E.V. Spence Reservoir	Upper Colorado River	5.5	12
O.C. Fisher Reservoir	Concho River	0.8	15
Twin Buttes Reservoir	Concho River	2.5	9.9
Lake Nasworthy (Feb. 14, 2013)	Concho River	78	84
O.H. Ivie Reservoir	Upper Colorado River	23	23
Lake Brownwood	Pecan Bayou	56	100
Lake Buchanan	Lower Colorado River	42	100
Lake Travis	Lower Colorado River	39	100

Table 2. Percent Full Values for Reservoirs in the Colorado River Basin *Sources: Texas Water Development Board and City of San Angelo*

Lake Travis in drought

Persistent drought conditions impact water quality directly. Reduced flows can increase water temperatures and dissolved solids and decrease dissolved oxygen levels, which negatively impact aquatic life. Water quality is also impacted by intense flood events such as those that occurred in the Colorado River basin in late 2015 and in 2016. Stormwater runoff typically increases bacteria levels and suspended solids before subsiding to sustain stream flows and dilute dissolved solids.

II. PUBLIC INVOLVEMENT

Public participation always has been a key component of the Clean Rivers Program. From 2012 to 2016, CRP partners continued to engage stakeholders through water quality advisory committee meetings and by supporting education/outreach and volunteer monitoring.

Water Quality Advisory Committee Activity

Advisory committees provide insight into local water quality issues and help prioritize water quality improvement projects and monitoring. Members include representatives from city and county government, industrial and agricultural interests, state agencies, environmental organizations and the public. Eighteen advisory committee meetings were held from 2012 to 2016 in Austin, Bay City, Brady, Columbus, Goldthwaite, Lockhart, San Angelo, San Saba and Wharton. Topics included monitoring activities, drought, wildfire, wastewater discharge permits, aquatic vegetation, invasive species and harmful algal blooms. Meeting minutes are posted on the LCRA Clean Rivers website at http://www.lcra.org/water/quality/texas-clean-rivers-program/Pages/public-outreach.aspx.

Permit Application Review and Response

Wastewater discharges in Texas generally require a specific level of treatment to remove harmful pathogens and pollutants. LCRA monitors discharge permit applications that may impact water quality and makes recommendations to minimize the effects of pollutants from regulated discharges and waste disposal facilities.

Through the Application Review and Response Process (ARRP), LCRA reviews permits issued under the authority of the TCEQ, the United States Environmental Protection Agency (EPA), the Texas Railroad Commission (RRC), the Texas Parks and Wildlife Department (TPWD), the United States Army Corps of Engineers, and cities and counties throughout the region. ARRP staff has been instrumental in securing more protective requirements for a multitude of permits through formal and informal actions that include recommendations, collaboration, mediation and contested case hearings.

Water Quality Advisory Committee members meet in Goldthwaite / 2015

Volunteer Monitoring

The Colorado River Watch Network (CRWN) began in 1988 when a handful of Austin citizens began sampling local creeks. Today, CRWN volunteers include citizens, teachers, students, scouts and groups such as the Austin Youth River Watch. On average, 85 volunteers sample for dissolved oxygen, pH, specific conductivity, nitrates and temperature at 100 stations annually. Many also test for *E. coli* bacteria. Between 2012 and 2016, volunteers contributed 8,783 hours to monitor 104 stations in the lower basin.

Since 2011, 14 CRWN volunteers have monitored the Highland Lakes for invasive zebra mussels. The zebra mussel watchers continue to provide early detection of this species, which threatens aquatic ecosystems and water utilities. Zebra mussels have been in the northeastern United States since the 1980s and in Texas since 2008. They have not been found in the Colorado River basin, but are in the Brazos River basin just to the north.

River cleanup on Red Arroyo / 2014

Volunteer Phil Wyde installs a zebra mussel sampler on Inks Lake

Environmental Outreach

CRP partners are dedicated to educating children and adults about water quality issues in their watersheds. Numerous outreach events were held throughout the basin between 2012 and 2016.

UCRA Public Involvement

UCRA reached over 16,000 people through its Water Education Center and community outreach programs from 2012 to 2016. Even though the Water Education Center was forced to close due to a lack of funding in 2015, UCRA continues to support environmental outreach in San Angelo and the surrounding areas.

Outreach efforts included contributions to local festivals, summer camps, teacher training and curricula development. They also collaborated with other local environmental groups to sponsor river cleanups. As a partner with the San Angelo Museum of Fine Arts, UCRA participated in Camp Odyssey and the Art of Nature Camp, which provide educational opportunities for over 200 students each year. UCRA also partnered with the museum to develop Eco Fair, an annual event that celebrates the Concho River. Now called River Fest, the event has since been adopted by the City of San Angelo, and it attracts an estimated 10,000 people each year. Additionally, the UCRA helped develop Aqua Squad, a youth group that serves as local water ambassadors by making presentations at local events.

In 2012, the UCRA developed and taught an environmental science curriculum for the local middle schools. Since then, teachers have adopted the lessons and incorporated them into the environmental science curriculum. UCRA also created a Water Stewardship program for two local elementary schools in 2012. The short-term project reached 100 people and was completed in 2014.

In 2013, UCRA, Texas Disposal Systems, the City of San Angelo and several local businesses began an annual river cleanup effort on the Red Arroyo. About 200 people have volunteered for the event, which is held each spring to celebrate World Water and Earth Day.

Art of Nature Camp / 2013

Testing water in Sulphur Springs Draw / 2014

III. WATER QUALITY ANALYSIS

The watershed summaries in this section are based on chemical and biological data collected from 200 stations in the Colorado River basin. Water samples were collected by the TCEQ, UCRA, the City of Austin and LCRA. Samples were collected and analyzed according to a TCEQ-approved Quality Assurance Project Plan.

Two methods of analyses were used: trend analysis and a review of how water quality compares to TSWQS using the 2014 Texas Integrated Report for Clean Water Act sections 305(b) and 303(d).

To discuss the complex issues surrounding water quality monitoring and assessment, we must first establish a common vocabulary. This technical discussion is an overview of water quality terms and processes. A list of water quality parameters, their sources and impacts can be found in Appendix A.

TECHNICAL DISCUSSION

Classified Segments

Classified segments are streams, rivers, bays, estuaries and reservoirs that serve as the geographic unit for assigning TSWQS and applying water quality management strategies. Classified water bodies have segment-specific water quality standards assigned by the TCEQ and described in TSWQS. They are identified by four-digit codes. The first two digits correspond to the river basin in which they are located, and the last two digits distinguish a specific area within the basin. For example, Segment 1428 is in basin 14 (the Colorado River basin) and 28 represents the river between Longhorn Dam in Austin and Utley.

Unclassified Water bodies

Unclassified segments are small, often intermittent water bodies for which specific water quality standards are not typically assigned. Unclassified waters are assessed based on their flow status and the criteria for the classified segment into which they flow. However, the TCEQ has assigned site-specific standards to unclassified streams in some cases. The same naming convention applies with the addition of a letter to denote the associated segment. For example, 1428C is Gilleland Creek – a tributary of the Colorado River downstream of Longhorn Dam.

Trend Analysis

Trends analyses were performed using data collected over a 10-year period from 2006 through 2015. Data met the following criteria unless otherwise noted in the watershed summary:

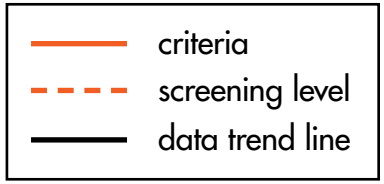
1. At least 20 data points were collected within the 10-year period of record.
2. Data points were fairly evenly distributed over most of the 10-year period of record.

Trends were examined for the following water quality parameters:

1. temperature
2. pH
3. chlorophyll *a*
4. *E. coli* (freshwater)
5. Enterococci (saltwater)
6. nitrate+nitrite nitrogen
7. total Kjeldahl nitrogen (TKN)
8. ammonia nitrogen
9. total phosphorus
10. total suspended solids (TSS)
11. total dissolved solids (TDS)
12. sulfate
13. chloride
14. dissolved oxygen deficit
    (a measure of the theoretical amount of oxygen water can hold vs. the actual amount measured based on water temperature)
15. Secchi depth (a measure of water transparency) in reservoirs only

Lake Marble Falls

Bacteria data was log transformed to make the data easier to view and analyze. When applicable, graphs in this report display criteria (solid red line) designated in the TSWQS or screening levels (dashed red line) based on historical data (legend to right). The statistical methodology for determining trends is listed in Appendix B.



Water Quality Standards

As the state regulatory agency, the TCEQ establishes TSWQS for all surface water in Texas. The standards are made up of two components: designated uses and criteria. Designated uses are purposes for which water is used. They include general use, aquatic life use (ALU) and contact recreation use. Criteria are numeric or narrative limits used to compare water quality data or conditions. The designated uses and their associated criteria are:

General use - Temperature, pH, chloride, sulfate and TDS criteria are used to gauge support for general use. In the Colorado River basin, pH criterion is a range between 6.5 and 9.0 standard units as outlined in the TSWQS. Criteria for chloride, sulfate and TDS varies by segment.

Aquatic life use - There are five levels of aquatic life use: exceptional, high, intermediate, limited and minimal. Aquatic life use is assessed using dissolved oxygen, and fish and benthic macroinvertebrate (aquatic bugs) community evaluation. Results from intensive field surveys are used to calculate aquatic life use.

As a general rule, perennial streams are presumed to support a high aquatic life use. Water bodies that have designations other than high will be identified in each watershed summary section.

Contact recreation - This use refers to how well a water body can safely support activities that involve physical contact such as swimming. The standard for contact recreation is a measure of bacteria levels. In freshwater, the indicator is Escherichia coli bacteria (*E. coli*), though fecal coliform bacteria have historically been used. Enterococci bacteria are the indicators in coastal water bodies. Criteria for fecal coliform, *E. coli* and Enterococci are 200, 126 and 35 colony forming units (CFU), respectively. Because of the high salt content of many West Texas waters, the TCEQ also uses *Enterococcus* as the bacteriological indicator in select inland water bodies. This is the case in Segment 1412 in the upper basin where the criteria is 33 CFU.

Assessment of Water Quality Data

Every two years, the TCEQ compares all available quality-assured data to the TSWQS (or to screening levels when no standards have been established) and publishes the results in the Texas Integrated Report for Clean Water Act, sections 305(b) and 303(d). The report defines each water body as one of the following:

1. **Meets or supports status** - At least 10 data points were available to assess, and the water body meets TSWQS or supports the water body's designated use(s).
2. **Concern status** - a) sufficient data to perform a full assessment were not collected, but the limited data indicate standards are not met, or b) standards have not yet been established, as is the case with nutrients. If standards have not been established, the data are compared to screening levels.
3. **Impaired status** - Sufficient amount of data are available and the water body does not meet state standards. The TCEQ publishes impaired water bodies in the Texas Integrated Report for Clean Water Act, Section 303(d) List.

Water bodies may or may not support their designated uses based on a comparison of monitoring data to the water body's standards. In the simplest terms, if monitoring data indicate that a water body fully supports its uses, then the water body meets TSWQS and water quality is considered good. If water quality data indicate a concern status based on the aforementioned definition, then resources are allocated to collect more data and verify the concern. If monitoring data indicate that the water body does not support any of its designated uses, then it is said to be impaired and may have poor water quality. Impaired water bodies are placed on the TCEQ 303(d) List of the Integrated Report and are sometimes referred to as "listed." The 303(d) List refers to the section of the Clean Water Act that requires states to identify impaired water bodies. Impaired water bodies in the Colorado River basin are identified in the segment summary tables contained in Section IV of this report.

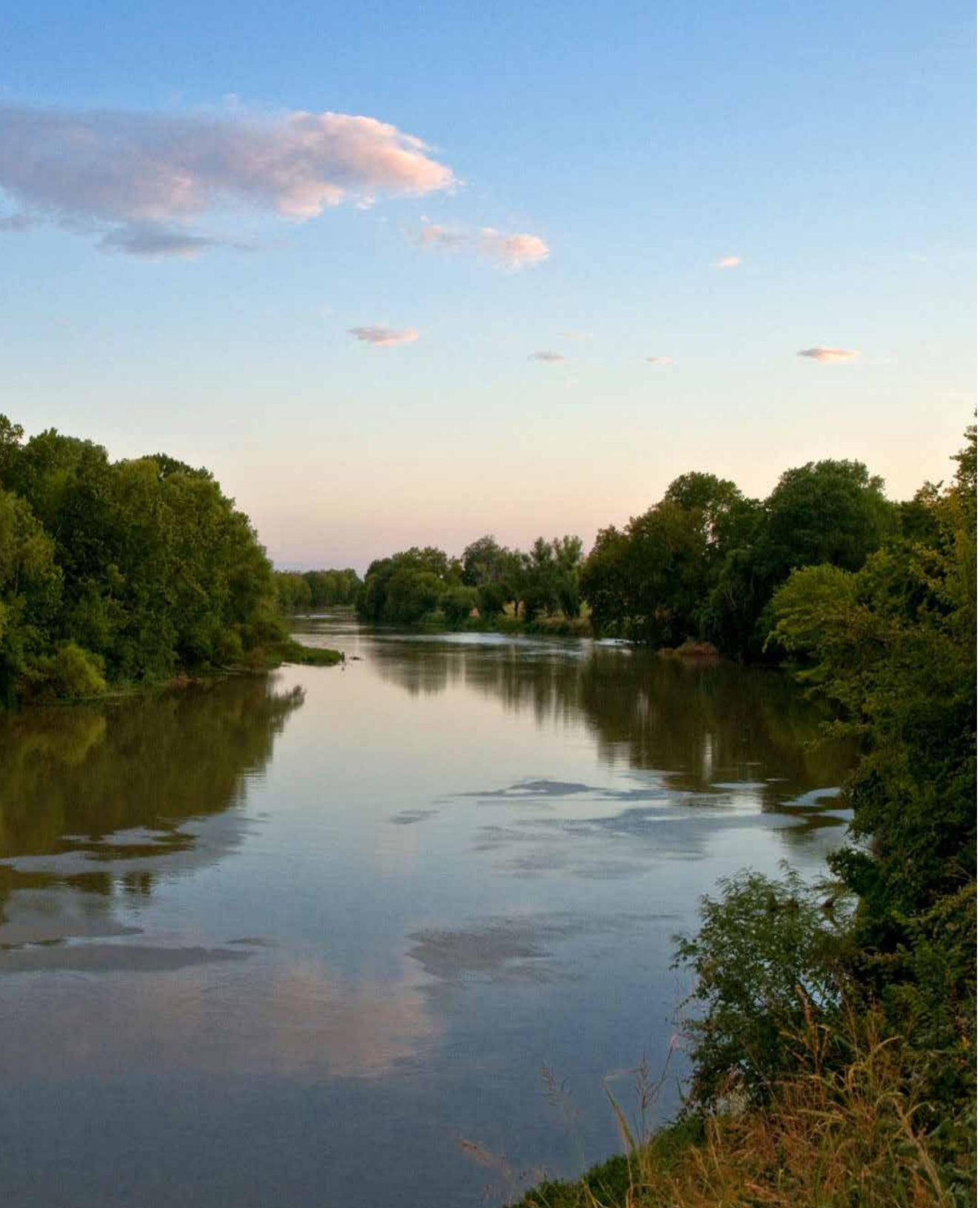
Sunrise over the Colorado River

Restoring Impaired Water Bodies

The first step to restoring impaired waters is to determine the cause(s) of the impairment. This usually involves a special study that may include a historical water quality data review, targeted monitoring or a detailed watershed analysis. After the cause of the impairment is identified, one of the following is usually put into place to address the impairment:

- **Total Maximum Daily Load (TMDL)** - a scientific model used to determine the amount or "load" of a pollutant that a water body can receive yet still support its designated uses. After the load is allocated among all potential sources, an Implementation Plan outlines strategies to reduce pollutants. Implementation Plans are enforced through regulatory compliance.
- **Watershed Protection Plan (WPP)** - A stakeholder-driven process to address causes of the identified impairments and develop strategies to reduce pollutant loads. Compliance with WPP strategies is voluntary rather than regulatory.
- **Use Attainability Analysis (UAA)** - Whereas TMDL and WPP strategies are designed to improve water quality by limiting pollutants, a UAA can help determine if the level of use originally assigned to the water body is appropriate. For example, in the late 1980s most rivers and streams were assigned a high aquatic life use. Since then, routinely collected data have shown that some water bodies do not meet a high aquatic life use; not because of pollution, but because natural conditions prevented high aquatic life use from being attained. The TCEQ has performed UAAs to establish a more appropriate level of aquatic life use in the TSWQS.
- **Recreational Use Attainability Analysis (RUAA)** - Similar to a UAA, it confirms the level of recreational use that takes place in a stream. UAAs and RUAAs can result in a revision to TSWQS.

The Pedernales River supports a high aquatic life use based on biological data collected during monitoring events upstream of Fredericksburg.

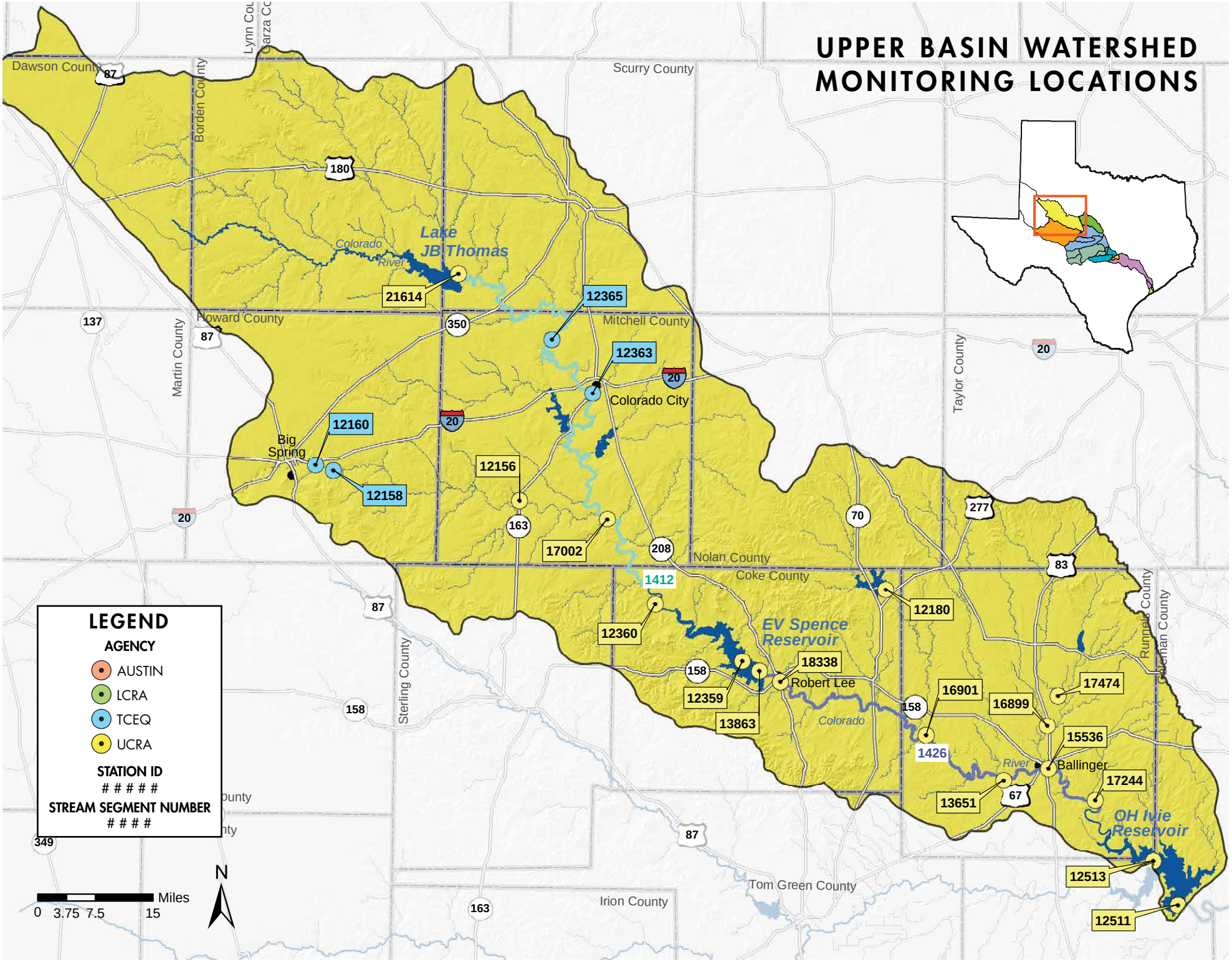


IV. WATERSHED SUMMARIES

The watershed summaries on the following pages provide detailed information about the status of water quality in each of thenine watersheds in the basin. The watersheds, listed from west to east, are:

- Upper Colorado River Watershed
- Concho River Watershed
- Pecan Bayou Watershed
- Lake Buchanan Watershed
- Lake LBJ Watershed
- Lake Travis Watershed
- Austin Watershed
- Lower Colorado River Watershed
- Coastal Watershed

Each summary includes watershed maps accompanied by a description of each watershed. Watershed summaries are further broken down into segment discussions, and they include information from the TCEQ's 2014 Water Quality Inventory and from a 10-year trend analysis based on data collected from 2006 to 2015. A good understanding of the technical process previously discussed will help the reader interpret data presented in the watershed summaries.


UPPER BASIN WATERSHED MONITORING LOCATIONS
Dawson County
Borden County
Scurry County
Howard County
Martin County
Mitchell County
Taylor County
Nolan County
Coke County
Sterling County
Runnels County
Coleman County
Tom Green County
Irion County
Lake JB Thomas
Colorado River
EV Spence Reservoir
OH Ivie Reservoir
Colorado City
Big Spring
Robert Lee
Ballinger
21614
12365
12363
12160
12158
12156
163
17002
208
1412
12360
12359
13863
158
18338
12180
16901
16899
17474
15536
1426
17244
13651
67
12513
12511
LEGEND
AGENCY
AUSTIN
LCRA
TCEQ
UCRA
STATION ID
# # # # #
STREAM SEGMENT NUMBER
# # # #
N
Miles
0 3.75 7.5 15

UPPER COLORADO RIVER WATERSHED

There were 21 stations monitored in 10 segments of the Upper Colorado River watershed from 2012 to 2016.

Segment 1411 – E.V. Spence Reservoir
Segment 1412 – Colorado River below Lake J.B. Thomas
Segment 1412B – Beals Creek (unclassified tributary of the Colorado River)
Segment 1413 – Lake J.B. Thomas
Segment 1426 – Colorado River below E.V. Spence Reservoir
Segment 1426A – Oak Creek Reservoir
Segment 1426B – Elm Creek (unclassified tributary of the Colorado River)
Segment 1426C – Bluff Creek (unclassified tributary of Elm Creek)
Segment 1426D – Coyote Creek (unclassified tributary of Elm Creek)
Segment 1433 – O.H. Ivie Reservoir

Watershed Characteristics

The Upper Colorado River Watershed covers approximately 12,000 square miles. It is situated mostly in the Rolling Plains and High Plains ecoregions of Texas. Semiarid climatic conditions exist over most of the watershed. Annual average precipitation ranges from less than 14 inches in its western portion to approximately 21 inches in its eastern portion. Many of the tributaries and drainage features of the watershed are either ephemeral or intermittent.

The majority of the watershed's soils consist of sand and clay, which contribute to turbidity. A major portion of the watershed is used for agriculture. Farming is common, though irrigation is often necessary in the High Plains. Much of the watershed is used for rangeland to graze livestock and for commercial wildlife operations.

O.H. Ivie Reservoir

SEGMENT SUMMARIES

Segment 1411 – E.V. Spence Reservoir

E.V. Spence Reservoir is an impoundment on the Colorado River near the community of Robert Lee. It drains about 4,000 square miles and has a surface area of 15,893 acres when full. The reservoir was almost completely dry from 2012 to 2015 until much-needed rains added 70,000 acre feet of water.

Based on the 2014 Integrated Report, the reservoir does not support general uses due to high chloride, TDS and sulfate levels. Drought and low lake levels are the cause of elevated salt constituents in the reservoir, and while recent data indicate TDS, chloride and sulfate levels have been reduced with increasing lake levels, salts still remain high.

TMDLs for total dissolved solids and sulfate in the E. V. Spence Reservoir were approved by EPA in 2003. Implementation continues to use point-source controls, modification of reservoir operations, water quality enhancement diversions, and oil well plugging as means for controlling salt loading. The Integrated Report also identified concerns for high levels of chlorophyll *a* and biology (fish kills). Golden algae blooms occur infrequently in the reservoir, and they are responsible for periodic fish kills.

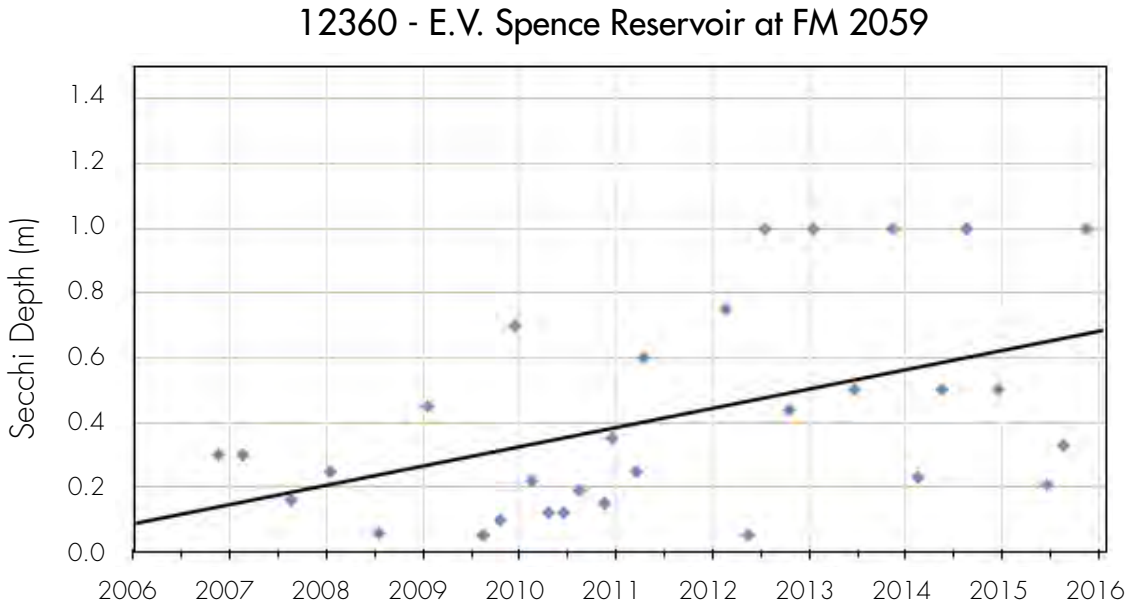


Figure 6. Transparency Trend / Segment 1411

Water transparency showed an increasing trend over time. This is likely due in part to a decreased amount of suspended solids and nutrients coming into the lake during the drought when there was little to no runoff (Figure 6).

M - Meets water quality standard
C - Concern for water quality standard
I - Impaired for water quality standard

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12359	M	C	M	M	M	I	M	C
12360	M	C	M	M	M	I	M	C
13863	M	C	M	M	M	I	M	C

Table 3. Summary of the 2014 Integrated Report / Segment 1411

Segment 1412 – Colorado River below J.B. Thomas Reservoir

This segment of the Colorado River begins below the J.B. Thomas Reservoir Dam in Scurry County and ends about 99 miles downstream near the river's confluence with Little Silver Creek in Coke County. The watershed consists mainly of agricultural land. Colorado City is located in the middle of the segment along I-20.

Monitoring data collected and analyzed for the 2014 Integrated Report indicate that the segment does not support recreational use and illustrates concerns for dissolved oxygen and chlorophyll. Potential sources of bacteria include urban runoff, failing wastewater lines and inadequate septic systems. A portion of the area upstream of the monitoring site consists of farms and rangeland, and runoff from these operations and wildlife in the area also represent a potential source of bacteria. Depressed dissolved oxygen concentrations likely are associated with low flow during drought conditions.

In 2016, Texas A&M AgriLife Extension Service began work on a recreational use attainability analysis (RUAA) in Segment 1412. Work is ongoing, and a draft report is expected to be completed in August 2017.

A superfund site, the former Col-Tex Refinery, is located near the middle of Segment 1412. The site is still listed on the state's Superfund Registry and post-remediation monitoring of organic chemicals at the site is ongoing. However, contamination from this site is not considered a likely source of the impairment or concerns.

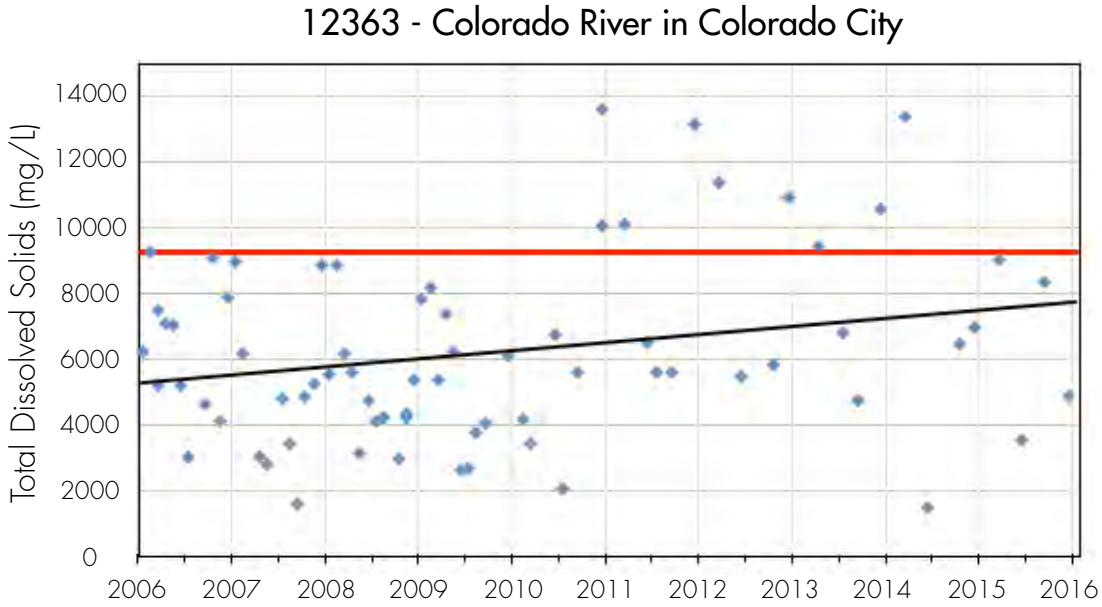


Figure 7. Total Dissolved Solids Trend / Segment 1412

Total dissolved solids increased at Station 12363 (Figure 7). The trend is likely due to natural sources or oil field activity in the region.

M - Meets water quality standard
C - Concern for water quality standard
I - Impaired for water quality standard

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12363	C	-	I	M	M	M	M	C
12365	M	-	M	M	M	M	M	C
17002	M	-	M	M	M	M	M	M

Table 4. Summary of 2014 Integrated Report / Segment 1412

Segment 1412B – Beals Creek

Beals Creek begins just upstream of Big Spring and ends about 60 miles downstream at its confluence with the Colorado River. The watershed drains an area of approximately 2,000 square miles and consists mainly of agricultural land. Oil and gas production activities occur in the segment.

Beals Creek is impaired due to high bacteria levels and has concerns for nutrients and chlorophyll. The impairment was first documented in 2010. Subsequent monitoring shows bacteria levels remain high. The City of Big Spring and the CRMWD are permitted to discharge treated effluent into Beals Creek, but they are not likely sources of bacteria. Stormwater from Big Spring, failing septic systems and wildlife are more likely sources of bacteria in this stretch of the creek. In 2016, Texas A&M AgriLife Extension Service began work on an RUAA in Beals Creek. Work is ongoing, and a draft report is expected to be completed in August 2017.

Nutrient and chlorophyll concerns are likely attributable to nonpoint sources and the wastewater discharge from Big Spring's direct potable reuse plant upstream of the monitoring sites sites (for more information visit Colorado River Municipal Water District's webpage at crmwd.org).

M - Meets water quality standard
C - Concern for water quality standard
I - Impaired for water quality standard

Beals Creek, a tributary of the Colorado River in the upper basin

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12156	M	-	C	M	M	M	M	C
12158	M	-	M	M	M	M	M	M
12160	M	-	I	M	M	M	C	C

Table 5. Summary of the 2014 Integrated Report / Segment 1412B

Segment 1413 – Lake J.B. Thomas

Lake J.B. Thomas is an impoundment on the Colorado River in Scurry County. The lake has a surface area of 7,708 acres with a conservation storage capacity of 204,604 acre-feet. Historically, the lake has maintained only a fraction of its storage capacity. The watershed contains oil and gas deposits that have been in production since the 1930s. Seeps resulting from oil and gas production activities, including abandoned or inadequately plugged wells, have been identified in the watershed. These seeps typically produce high-saline water and contaminate surface water.

Data from the 2014 Integrated Report indicates that the lake does not meet its general use due to high levels of salts. Chloride, TDS and sulfate levels exceeded the state criteria. A combination of factors are responsible for the impairment: regional soils with high salt content and extremely low lake levels caused by the drought. More recent data indicate an improvement in water quality as 2015 storm events increased water storage from 2,000 acre-feet to over 150,000 acre-feet. Water data collected in 2016 also indicate lower salt levels.

M - Meets water quality standard
I - Impaired for water quality standard

Lake J.B. Thomas

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12367	M	-	M	M	M	M	M	M
21614	M	-	M	M	M	I	M	M

Table 6. Summary of the 2014 Integrated Report / Segment 1413

Segment 1426 – Colorado River below E.V. Spence Reservoir

This segment of the Colorado River begins at the E.V. Spence Reservoir dam and continues about 72 miles downstream to just above O.H. Ivie Reservoir in Runnels County. This stretch of river flows through ranches and farms and the cities of Robert Lee and Ballinger. Oil and gas production occurs throughout the segment. The watershed is overrun with salt cedar (Tamarix sp.), a highly competitive non-native tree that increases salt content of surface soils and consumes large amounts of water through evapotranspiration.

Monitoring data indicate that the segment does not support its general use due to elevated levels of TDS and chloride. Likely sources of salts are geological formations and seeps from abandoned oil wells in the region. The segment also has concerns for bacteria and chlorophyll *a*. The Texas Parks and Wildlife Department also attributed fish kills in the lower part of the segment to golden algae blooms.

A TMDL for chloride and TDS was completed and approved by the EPA in 2007. Implementation, which includes salt cedar removal and oil-well plugging, is ongoing. In 2014 the TMDL I-Plan was revised and updated. In 2016, the UCRA was awarded a grant to investigate potential sources of high-salinity seeps into the Colorado River near site 18338. Investigation is ongoing.

Trend analyses indicated that salts are decreasing at Station 17244 (Figures 8-10). The decreasing trend is likely a result of the TMDL and other water quality improvement measures in the watershed along with recent rains and increased base flows.

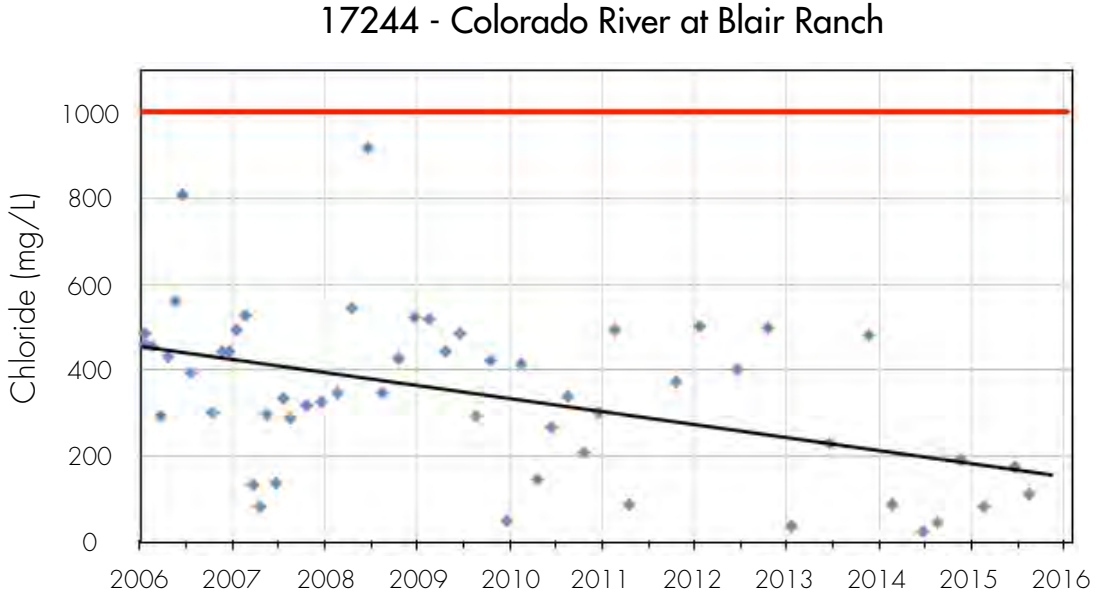


Figure 8. Chloride Trend / Segment 1426

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
13651	M	-	M	M	M	M	M	M
16901	M	-	C	M	M	I	M	C
17244	M	-	C	M	M	I	M	C
18338	M	-	M	M	M	I	M	C

Table 7. Summary of the 2014 Integrated Report / Segment 1426

M - Meets water quality standard
C - Concern for water quality standard
I - Impaired for water quality standard

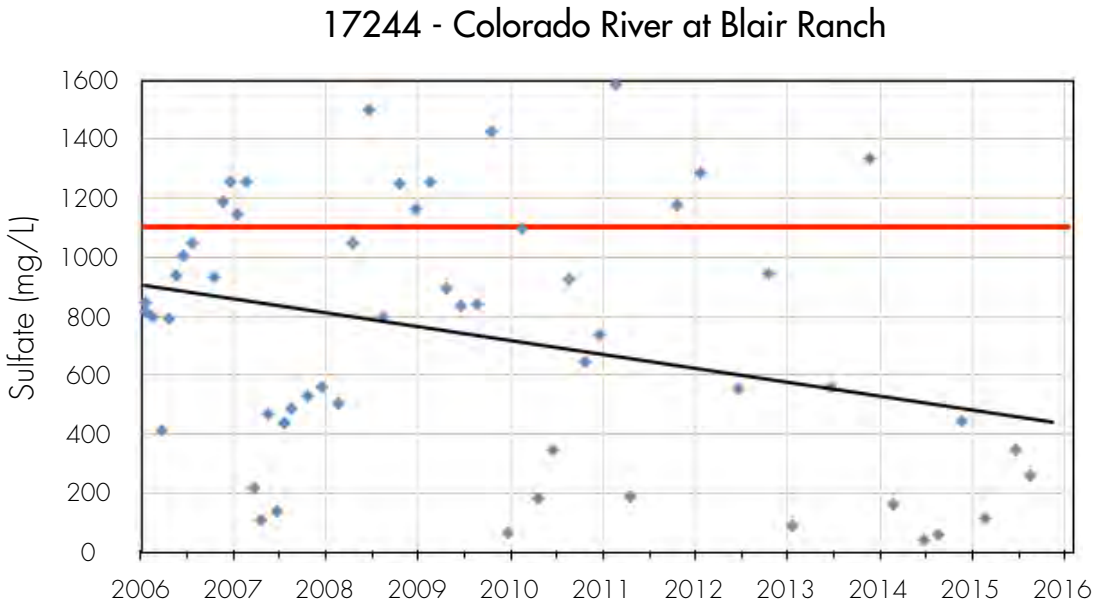


Figure 9. Sulfate Trend / Segment 1426

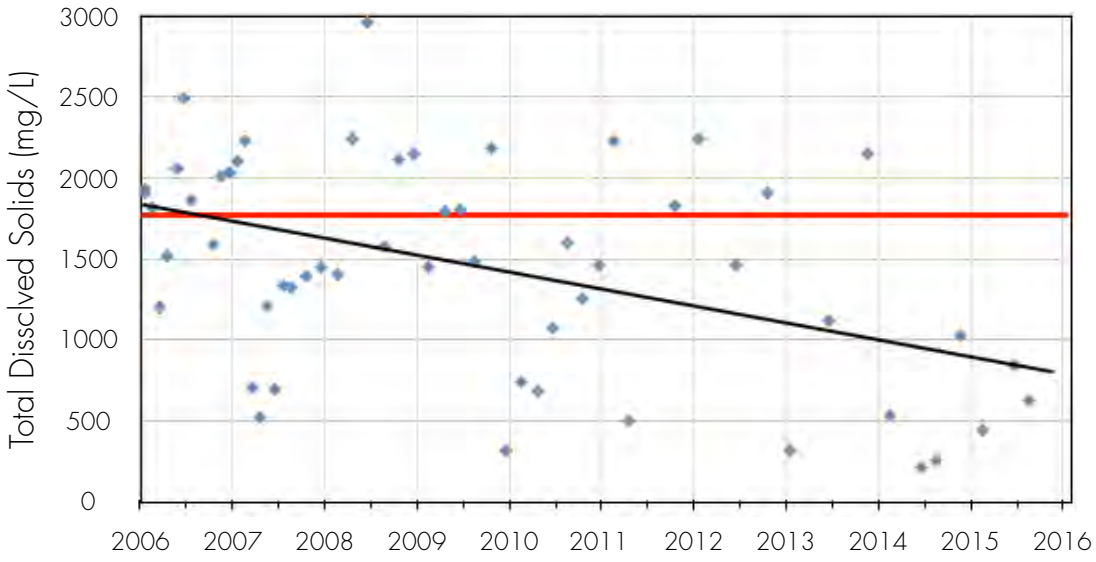
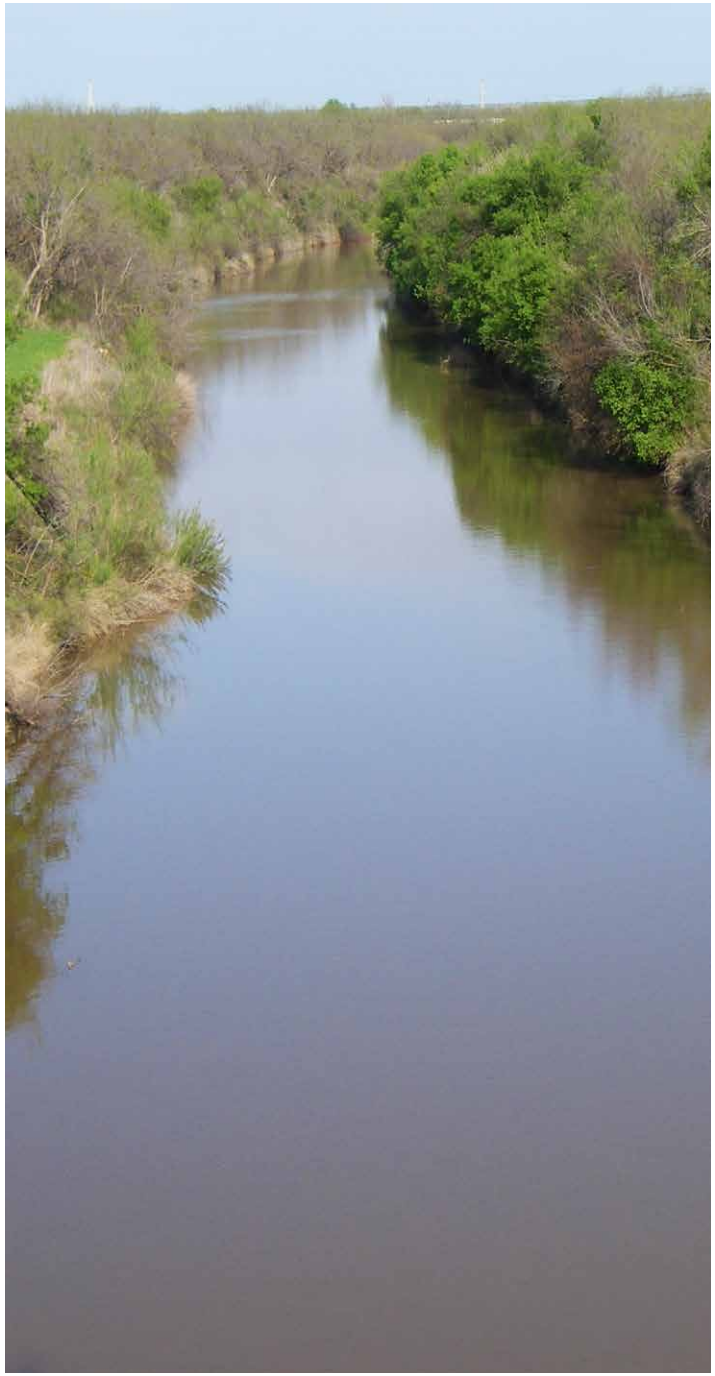


Figure 10. Total Dissolved Solids Trend / Segment 1426



Colorado River below E.V. Spence Reservoir

Segment 1426A – Oak Creek Reservoir

Oak Creek Reservoir is located on Oak Creek in Coke County, 8 miles north of Bronte. The watershed is about 238 square miles with a surface area of 2,375 acres. The cities of Sweetwater, Bronte and Robert Lee use the reservoir as a public water supply. The 2014 Integrated Report indicates that the water quality fully supports all its uses.

Trend analysis indicates that chloride levels are decreasing over time. This may be attributed to an increase in freshwater from sporadic rains.

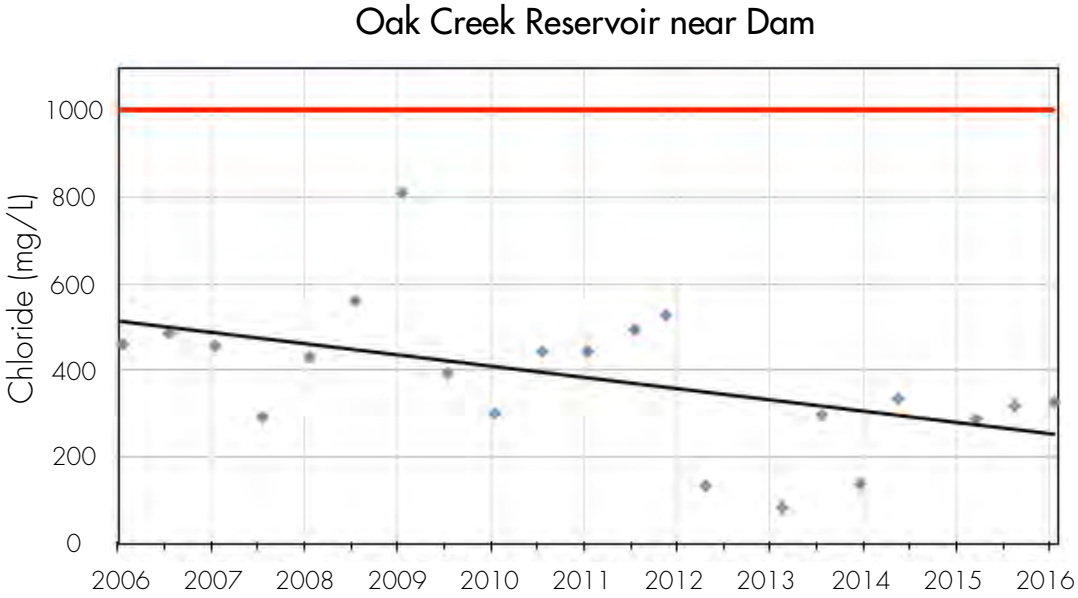
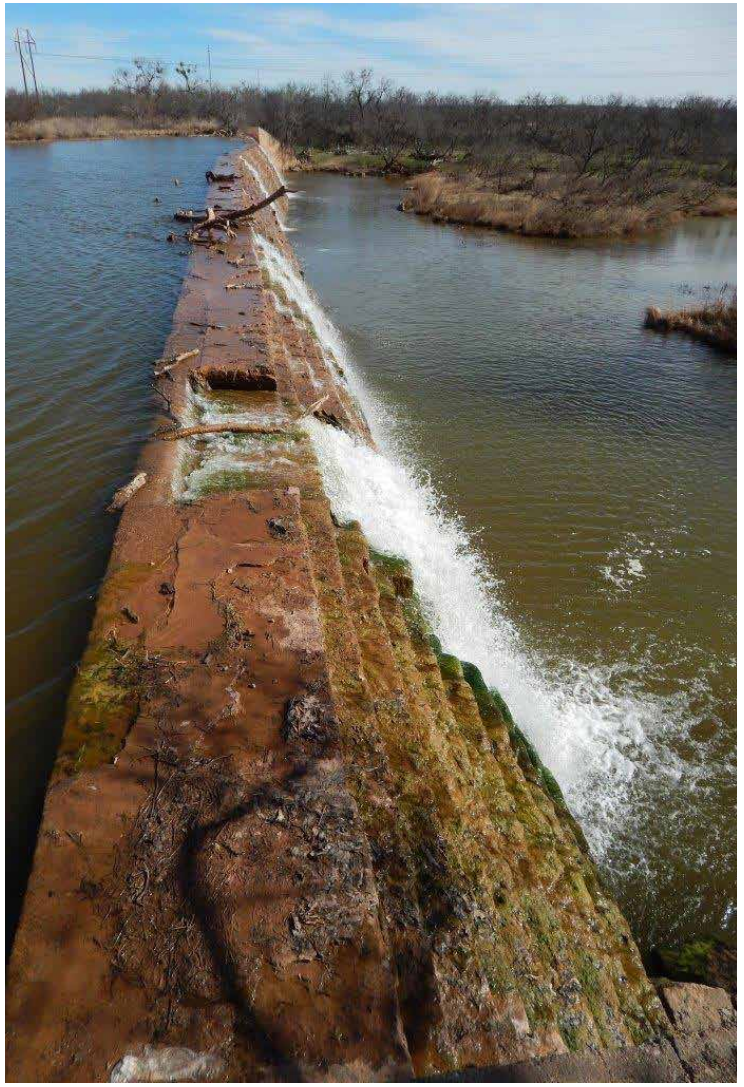


Figure 11. Chloride Trend / Oak Creek Reservoir



Elm Creek at Ballinger Park

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12180	M	-	M	M	M	M	M	M

M - Meets water quality standard

Table 8. Summary of the 2014 Integrated Report / Segment 1426A

Segment 1426B

Elm Creek is a tributary of the Colorado River. The creek is 15 miles long. The confluence with the Colorado River is located in Ballinger. The watershed is rural. Land is predominantly used for agriculture and water quality is typically good. The 2014 Integrated Report indicates all uses are supported, though a concern has been identified for elevated levels of chlorophyll *a*.

Chloride and TDS are decreasing at Station 15536 in Ballinger (Figures 12 and 13). Similar to other segments in the upper Colorado River basin, these decreasing trends are likely due to rainfall and freshwater inflow to the stream.

Colorado River at Blair Ranch, upstream of O.H. Ivie Reservoir

15536 - Elm Creek in Ballinger

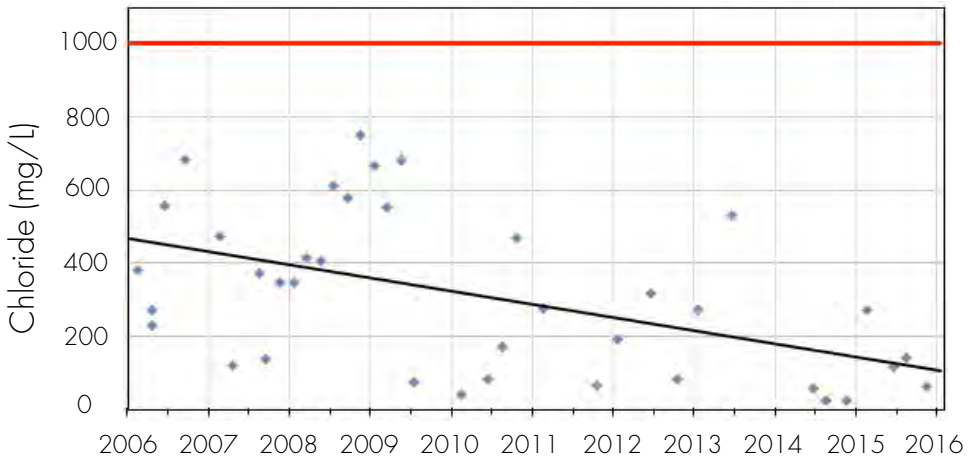


Figure 12. Chloride Trend / Elm Creek

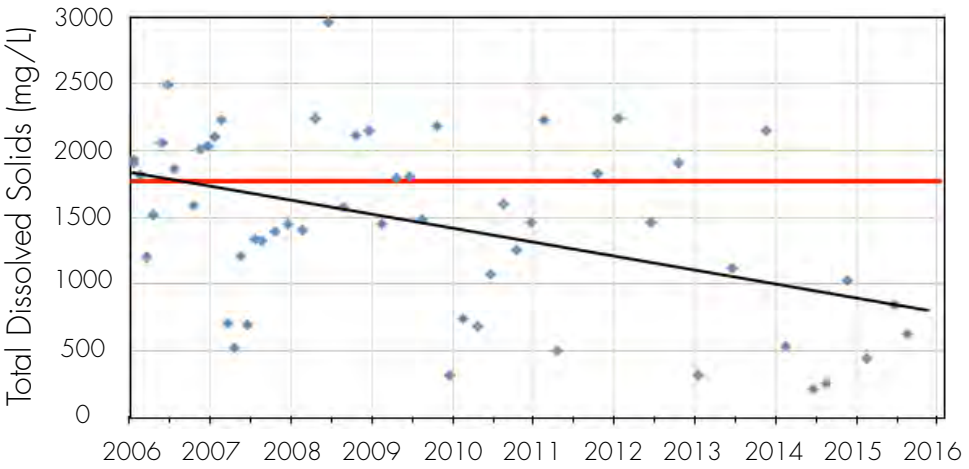


Figure 13. Total Dissolved Solids / Elm Creek

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
15536	M	-	M	M	M	M	M	C

M - Meets water quality standard
C - Concern for water quality standard

Table 9. Summary of the 2014 Integrated Report / Segment 1426B

Segment 1426C – Bluff Creek

Bluff Creek is a tributary of Elm Creek and is located mostly in Runnels County. It begins at the confluence and continues upstream into southern Taylor County and ends in the Callahan Divide. Bulger Creek, Salt Branch and Mill Creek are the significant tributaries of Bluff Creek. Almost all of the land use in Bluff Creek's watershed is farmland.

The 2014 Integrated Report data indicate that this segment fully supports its uses except for a concern for nitrates, which could potentially be due to runoff from agricultural operations in the watershed and/or the infiltration of shallow groundwater. Groundwater in Runnels County typically is high in nitrates.

Figure 14 presents one statistically significant trend analysis performed on the 2014 Integrated Report data. It shows a declining trend in chloride. The cause of this improving trend in chloride is unknown, but may be attributable to increased flows.

Figure 14. Chloride Trend / Segment 1426C

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
17474	M	-	M	M	M	M	C	M

Table 10. Summary of the 2014 Integrated Report / Segment 1426C

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
16899	M	-	M	M	M	M	C	M

Table 11. Summary of the 2014 Integrated Report / Segment 1426D

M - Meets water quality standard
C - Concern for water quality standard

Segment 1426D – Coyote Creek

Coyote Creek is a tributary of Elm Creek located mostly in Runnels County. The description of the segment is from the confluence with Elm Creek upstream to the confluence of Big Coyote Creek and Little Coyote Creek. The drainage area includes both of these upstream tributaries. Land use in the watershed is almost exclusively farmland.

The 2014 Integrated Report data indicates that the segment is fully supporting its uses except for a concern for nitrates. The nitrates are likely attributable to runoff from fertilized farmland and/or the infiltration of shallow groundwater. Groundwater in Runnels County typically is high in nitrates.

Figures 15-17 present three statistically significant trend analyses. The analyses of chloride and TDS levels show significantly decreasing trends, while the pH values exhibit a flat trend. The reason for the improvements in chloride and TDS are unknown. However, both graphs show higher values during the period of drought from 2012 through 2014. Therefore, the improvements may be associated with increased flows.

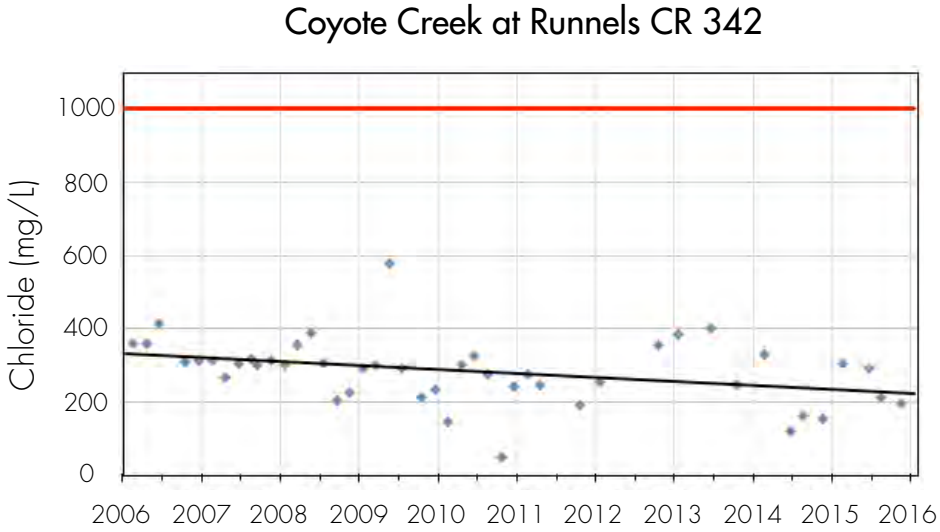


Figure 15. Chloride Trend / Segment 1426D

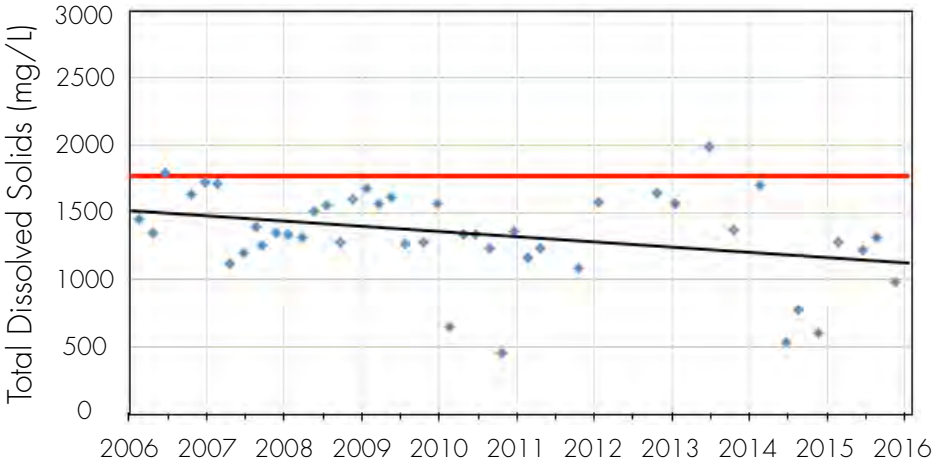


Figure 16. Total Dissolved Solids / Segment 1426D

Figure 17. pH Trends / Segment 1426D

Segment 1433 – O.H. Ivie Reservoir

O.H. Ivie Reservoir is an impoundment of the Colorado River and Concho River. It is located in Coleman, Concho and Runnels counties. The contributing area is approximately 1,820 square miles. When full, the reservoir holds 554,335 acre-feet of water. During the severe drought in the region through 2014, the reservoir was only been able to keep up with reductions from pumping and evaporation. However, after rains from 2015 to present, the contents of the reservoir have begun to climb, and currently stand at approximately 137,000 acre-feet, which is almost 25 percent of conservation storage capacity.

UCRA has applied to the TSSWCB Water Supply Enhancement Program for cost-share funding to treat salt cedar and willow baccharis within the O.H. Ivie Reservoir basin.

The 2014 Integrated Report data indicate that water in O.H. Ivie Reservoir is fully supporting of all designated uses except for a concern for nitrate on the Concho River arm of the reservoir.

Two statistically significant trend analyses were detected. Secchi depth, a measure of water transparency, shows a declining trend. This may be attributable to the low-water content levels associated with the drought. However, Secchi depths have been improving since the end of 2014, which coincides with the drought-ending rains and the beginning of significant stormwater inflows to the reservoir. Ammonia trended lower from 2006 to 2013, but the reason is unknown. Ammonia is not a current parameter of the CRP at O.H. Ivie Reservoir.

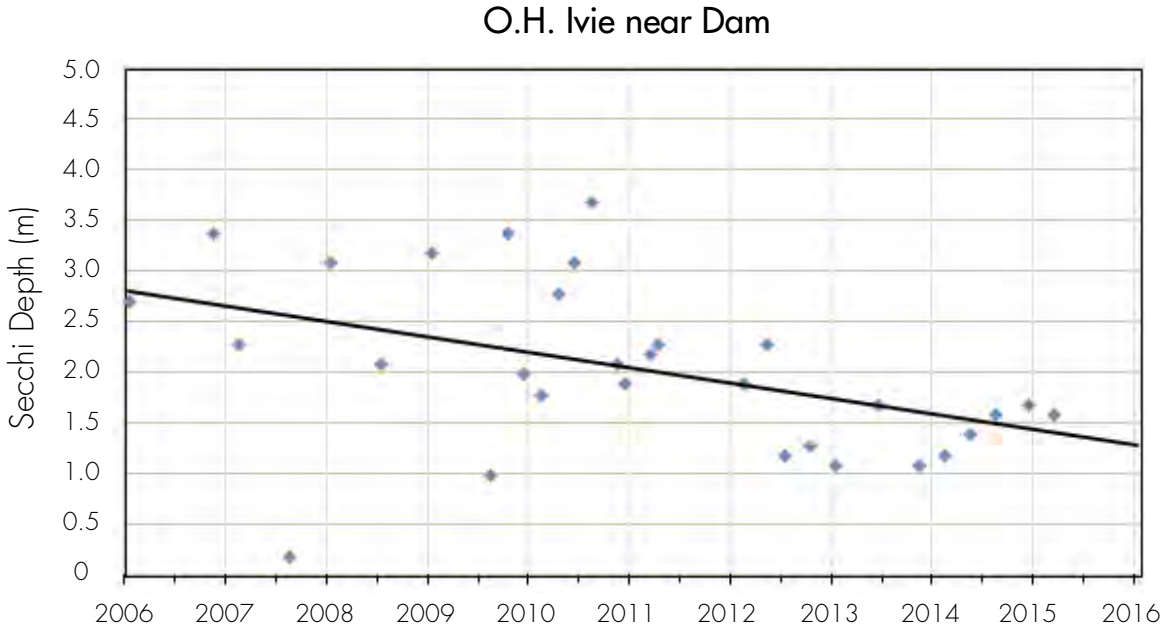


Figure 18. Secchi Depth Trend / Segment 1433

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12511	M	-	M	M	M	M	M	M
12512	M	-	M	M	M	M	C	M
12513	M	-	M	M	M	M	M	M

Table 12. Summary of the 2014 Integrated Report / Segment 1412B

M - Meets water quality standard
C - Concern for water quality standard

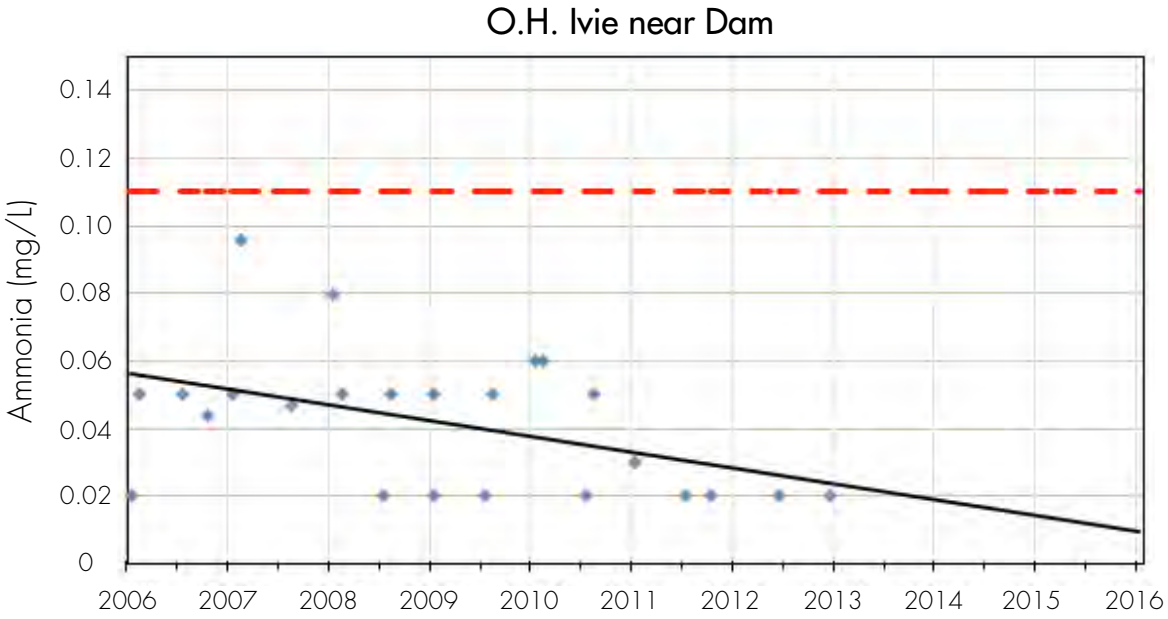
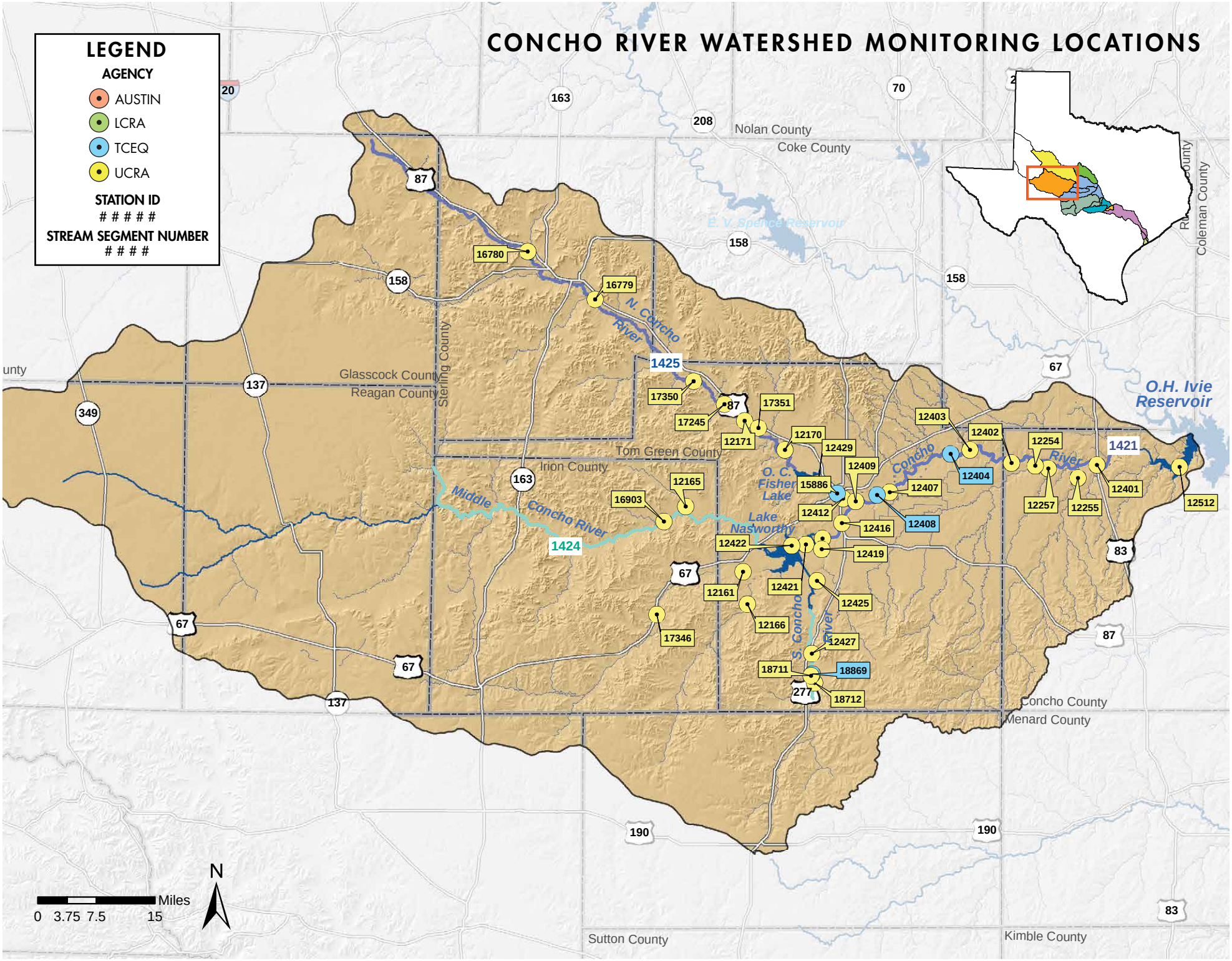


Figure 19. Ammonia Trend / Segment 1433

Future Challenges for the Upper Colorado River Watershed

- Lack of sufficient rainfall and low flows are prevalent throughout the upper watershed, and most likely always will be the most significant factor driving water quality challenges in the upper Colorado River.
- Golden algae blooms will likely remain a significant challenge in the watershed. UCRA will monitor and document fish kills and continue to cooperate with TPWD in an effort to combat the problem.

O.H. Ivie Reservoir


CONCHO RIVER WATERSHED MONITORING LOCATIONS
LEGEND
AGENCY
AUSTIN
LCRA
TCEQ
UCRA
STATION ID
# # # # #
STREAM SEGMENT NUMBER
# # # #
Nolan County
Coke County
Coleman County
Glasscock County
Reagan County
Sterling County
Tom Green County
Irion County
Concho County
Menard County
Sutton County
Kimble County
E. V. Spence Reservoir
O.H. Ivie Reservoir
O. C. Fisher Lake
Lake Nasworthy
N. Concho River
Middle Concho River
S. Concho River
Concho River
1425
1424
1421
16780
16779
17350
17245
17351
12171
12170
12429
12403
12402
12404
12254
12257
12255
12401
12512
12409
15886
12407
12408
12412
12416
12422
12419
16903
12165
12161
12166
17346
12421
12425
12427
18711
18869
18712
277
158
87
163
208
70
67
137
349
20
83
190
Miles
0 3.75 7.5 15
N

CONCHO RIVER WATERSHED

There were 29 stations monitored in 13 designated river segments of the Concho River watershed from 2012 to 2016.

Segment 1421 – Concho River
Segment 1421A – Dry Hollow Creek
Segment 1421B – Kickapoo Creek
Segment 1421C – Lipan Creek
Segment 1422 – Lake Nasworthy
Segment 1423 – Twin Buttes Reservoir
Segment 1423A – Spring Creek
Segment 1423B – Dove Creek
Segment 1424 – Middle and South Concho Rivers
Segment 1424A – West Rocky Creek
Segment 1424B – Cold Creek
Segment 1425 – O.C. Fisher Lake
Segment 1425A – North Concho River

Watershed Characteristics

With an area of approximately 6,700 square miles, the Concho River watershed is the largest in the Colorado River basin. It is situated at the convergence of the High Plains, the Rolling Plains and Edwards Plateau ecoregions. Semiarid conditions exist over most of the watershed with annual average precipitation ranging from less than 14 inches in its western portion, to 21 inches in the eastern portion. Many of the tributaries are ephemeral or intermittent.

The principal rivers in the watershed are the North Concho, Middle Concho and South Concho, which all join to form the Concho River. The rivers are impounded several times near San Angelo. The confluence of the Middle Concho River and South Concho River is located at Lake Nasworthy west of San Angelo. The South Concho River continues below Lake Nasworthy to its confluence with the North Concho River above Bell Street Dam in east San Angelo to form the Concho River. The Concho River flows, although sometimes sparsely, through pastures and irrigated fields to O.H. Ivie Reservoir about 60 miles downstream of San Angelo.

The Middle and South Concho rivers are impounded in the north and south pools of Twin Buttes Reservoir, respectively. The pools, which are connected by an equalization channel, serve as the municipal water supply for San Angelo. From Twin Buttes Reservoir, water is released or pumped into Lake Nasworthy, situated immediately downstream. Downstream of Lake Nasworthy, the Concho River converges with sporadically released water from O.C. Fisher Lake on the North Concho River.

The North Concho River, Middle Concho River and Concho River valleys are characterized by broad floodplains that contain fluvial deposits of gravel, sand and clay and form shallow alluvial aquifers. The South Concho River, including Spring Creek and Dove Creek, are characterized by much narrower and steeper valleys. These waterways are primarily fed by springs from the northern edge of the Edwards-Trinity Aquifer.

SEGMENT SUMMARIES

Segment 1421 – Concho River

Segment 1421 includes the Concho River downstream of the O.C. Fisher Dam and the Lake Nasworthy Dam. Below San Angelo, the segment extends downstream approximately 45 river miles to Paint Rock in an area known as Lipan Flats. The area is comprised of rich farmland and sits atop the Lipan Aquifer, known for groundwater with high nitrogen concentrations.

A previous concern for benthic macroinvertebrate habitat was removed in the 2012 Integrated Report because AU_1421_08 was deemed unsupportive for high aquatic life use by TCEQ personnel. A small fish kill also occurred near station 12403 but the cause was deemed to be overspray of herbicide by the adjacent landowner. The level of impact was minimal.

The 2014 Integrated Report data indicate that the upper reaches of the segment in San Angelo are non-supportive for bacteria and dissolved oxygen with concerns for chlorophyll *a*. The dissolved oxygen deficiency is attributable to low flows through the many impoundments from the O.C. Fisher Dam to the Bell Street Dam. These impoundments act as a series of stormwater detention ponds even though they were not constructed for that purpose. The chlorophyll *a* concern is likely caused by decomposition of organic matter and nutrient loadings. The bacteria impoundment is likely caused from avian sources.

From 2014-2015 the UCRA conducted a screening bacterial source tracking project funded by the EPA's Urban Waters Small Grants program. Genetic testing of samples resulted in the identification of humans and birds as likely sources. This prompted the City of San Angelo to conduct testing on its sewer line that crosses the river in the vicinity. The test results eliminated the sewer line as a source. From the data, it is likely that the human bacteria source came from transient inhabitants along the river in this area. It also is likely that the main source of bacteria causing the impairment is attributable to abundant birds that roost under bridges and in trees along the bank.

M - Meets water quality standard
C - Concern for water quality standard
I - Impaired for water quality standard

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12401	M	-	M	M	M	M	C	C
12402	M	-	M	M	M	M	C	M
12403	M	-	M	M	M	M	C	C
12407	C	-	M	M	M	M	M	M
12409	M	-	M	M	M	M	M	C
12412	I	-	I	M	M	M	M	C
12416	M	-	M	M	M	M	M	M
15886	I	-	I	M	M	M	M	C

Table 13. Summary of the 2014 Integrated Report / Segment 1426

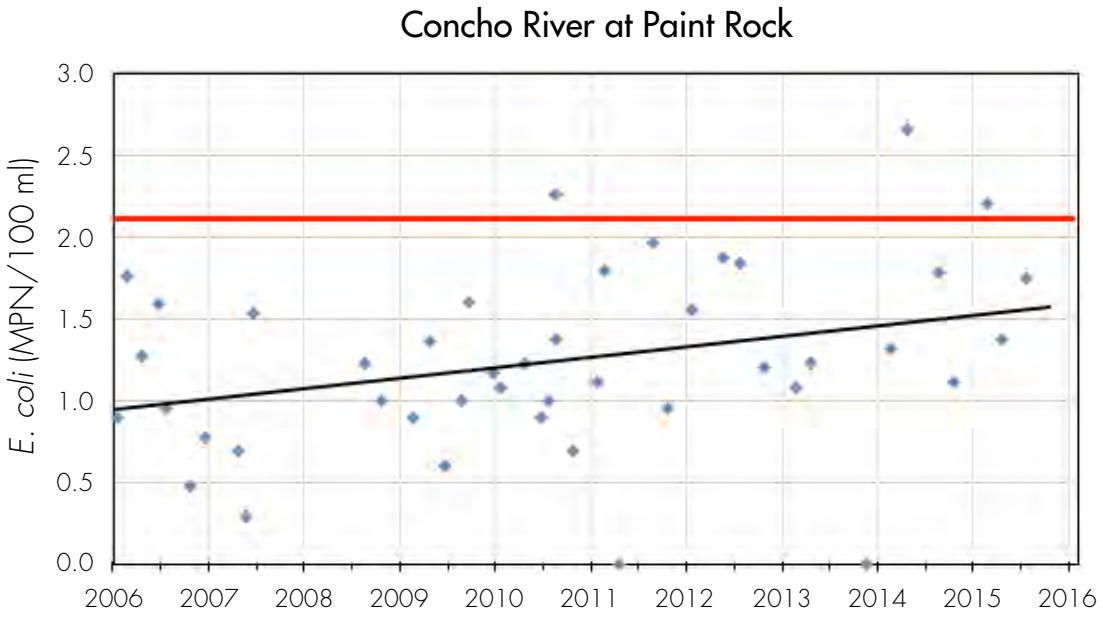


Figure 20. E. coli Trend / Segment 1421

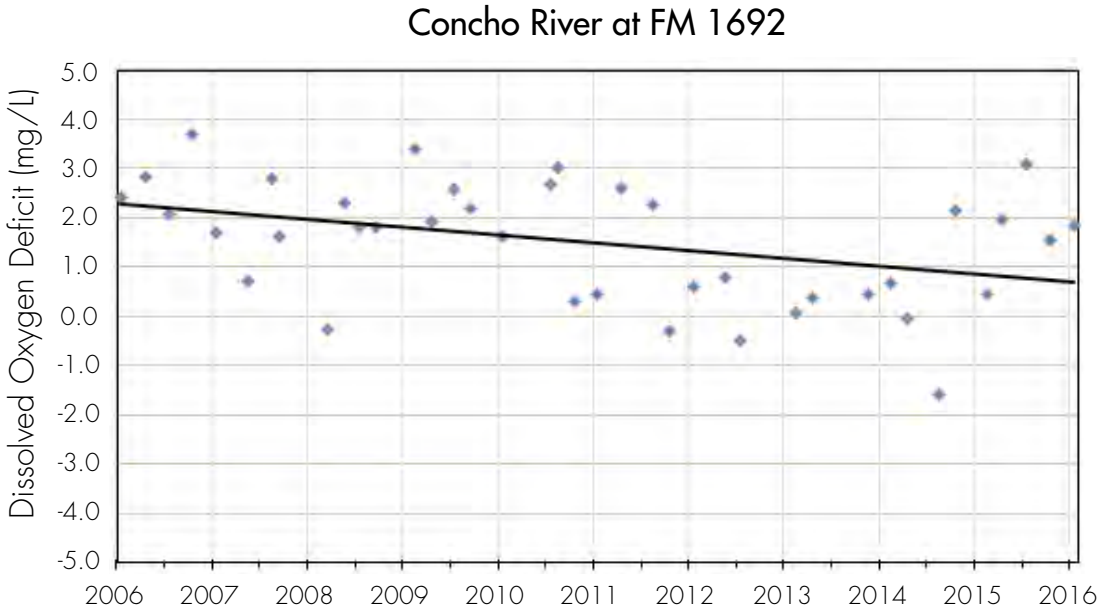


Figure 21. Dissolved Oxygen Trend / Segment 1421

Concerns for nutrients and chlorophyll *a* in the lower reaches of the segment are likely attributable to naturally occurring sources and possibly agricultural practices on the Lipan Flats.

Several statistically significant trends were identified for this segment.

The cause(s) for the increasing *E. coli* trend is unknown. Livestock, wildlife and human sources are all possibilities (Figure 20).

The improving trend in dissolved oxygen deficit is likely attributable to the Concho River Watermaster program and increased base flows (Figure 21).

The increasing chlorophyll *a* trend is likely attributable to fertilizer runoff from a large 12-field baseball complex located adjacent to this segment (Figure 22).

The declining Secchi depth trend coincides with the beginning and continuation of increased releases from Lake Nasworthy, and likely is the cause for the decline (Figure 23).

The declining trend in *E. coli* is attributable to the stabilization of approximately 8,000 feet of river bank completed in 2013 and the dredging of a stretch of river (Figure 24).

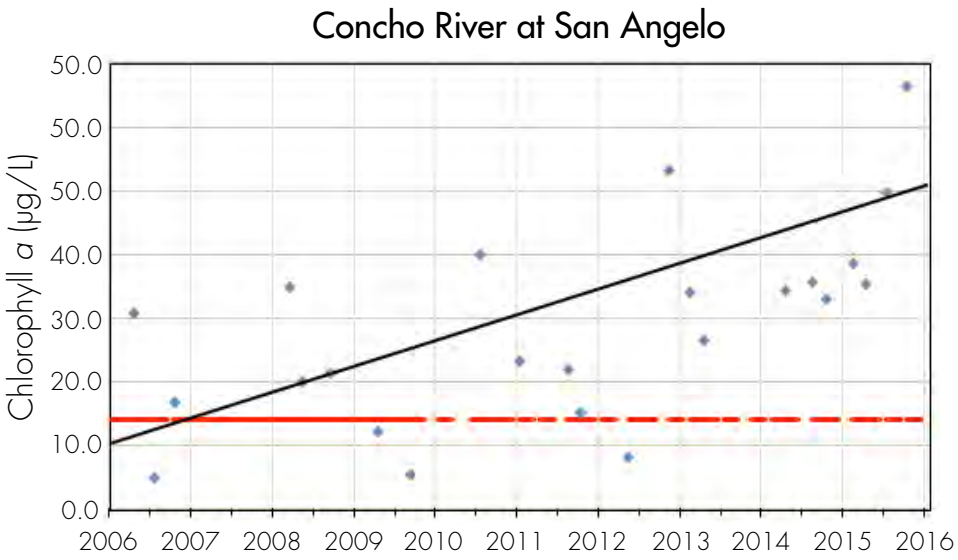


Figure 22. Chlorophyll a Trend / Segment 1421

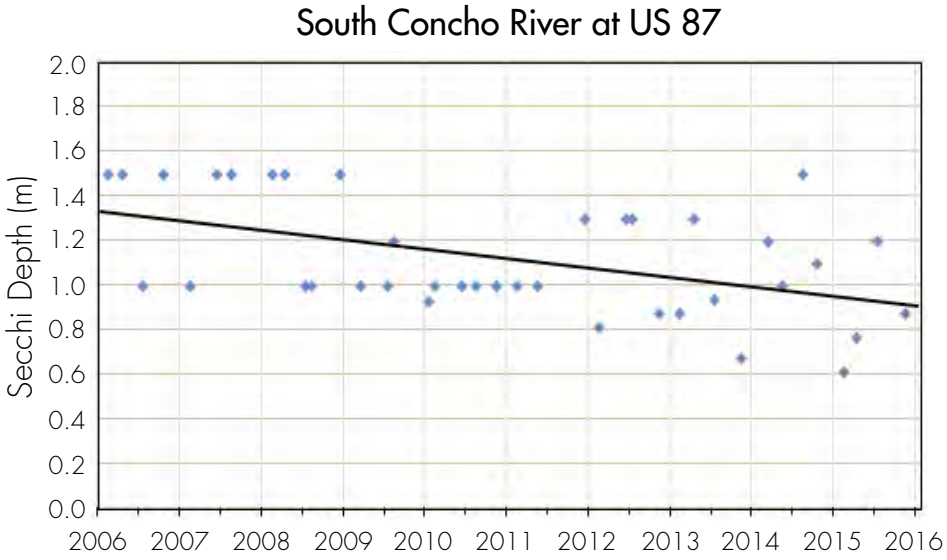


Figure 23. Secchi Depth Trend / Segment 1421

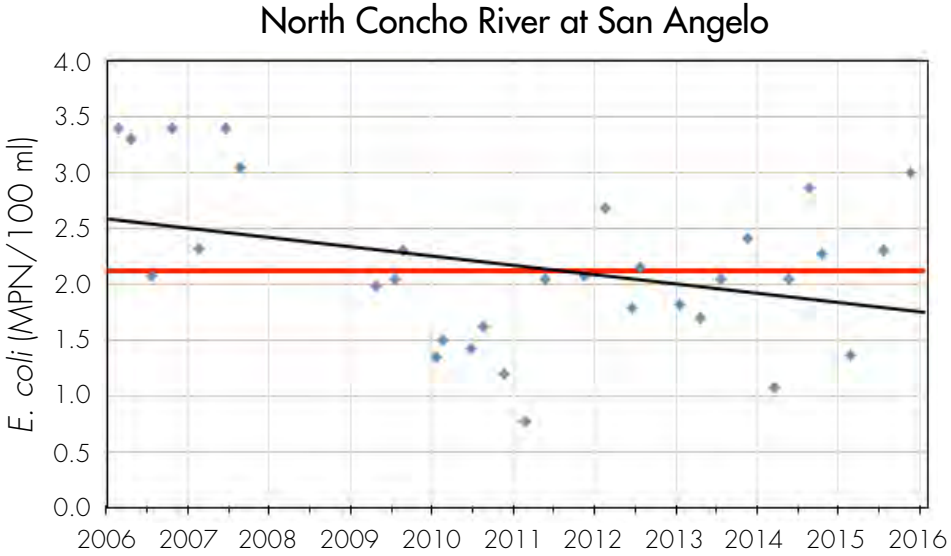


Figure 24. E. coli Trend / Segment 1421

Concho River

North Concho River at San Angelo

Segment 1421A – Dry Hollow Creek

Dry Hollow Creek is a tributary of the Concho River. Its drainage basin is approximately 45 square miles. It has no major tributaries. When the aquifer is recharged, Dry Hollow Creek flows from springs and seeps that dewater the Leona Formation, which is the upper alluvial portion of the Lipan Aquifer. Chandler Lake, located on Dry Hollow near its confluence with the Concho River, is a privately owned lake with about 33 surface acres when full.

Dry Hollow Creek fully supports all parameters except a screening level concern for nitrates. The water of the Lipan Aquifer is high in nitrates. The source is unknown, but some attribute the high levels to historic agricultural practices and some studies characterize it as naturally occurring.

Two statistically significant trend analyses were performed on Dry Hollow Creek. The Secchi depth is improving and TDS is decreasing. These results are likely due to increased water flow and depth.

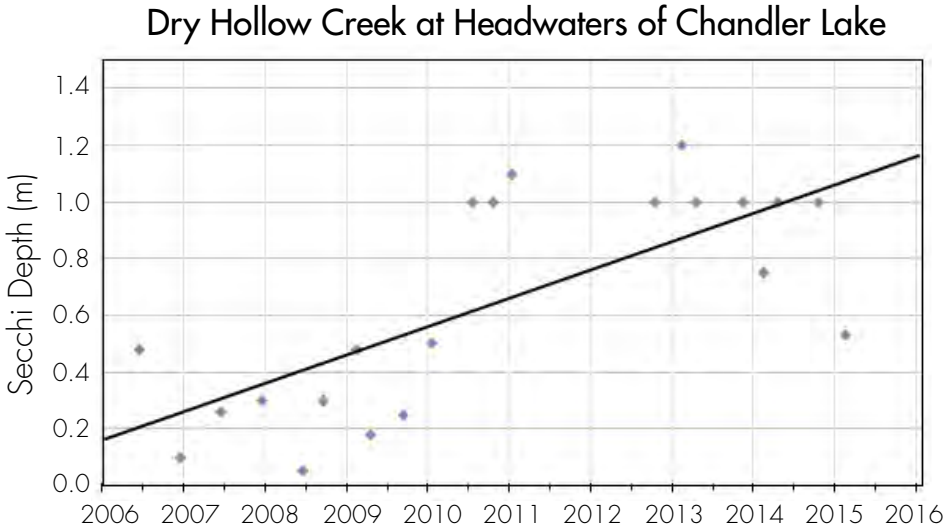


Figure 25. Secchi Depth Trend / Segment 1421A

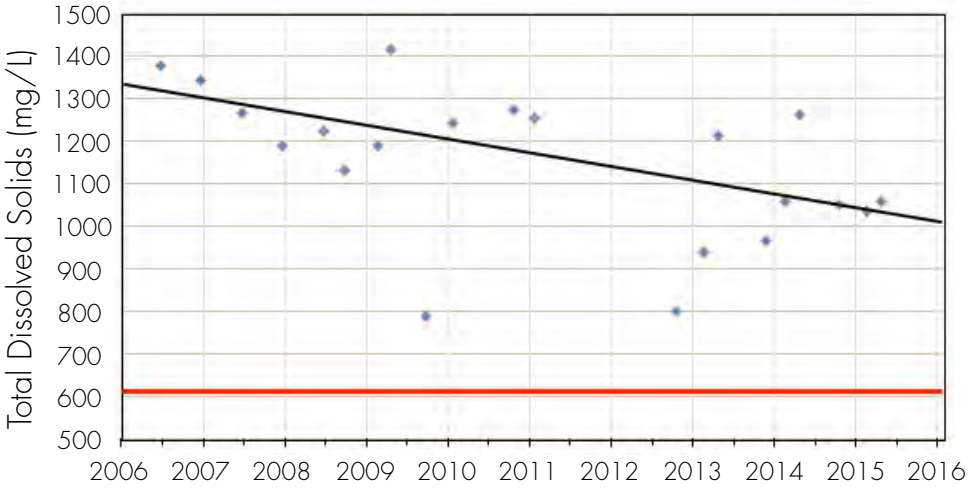


Figure 26. Total Dissolved Trend / Segment 1421A

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12257	M	-	M	M	M	M	C	M

Table 14. Summary of the 2014 Integrated Report / Segment 1421A

M - Meets water quality standard
C - Concern for water quality standard

Segment 1421B – Kickapoo Creek

Kickapoo Creek is a major tributary of the Concho River. Its confluence is located 2.7 miles west of the U.S. Highway 83 bridge in Paint Rock. The drainage area of the creek is over 200 square miles. Numerous springs exist on the creek and it dewaters the Leona Formation of the Lipan Aquifer. The 2014 Integrated Report data indicate that Kickapoo Creek fully supports all assessment parameters. No trend analyses were performed.

M - Meets water quality standard

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12255	M	-	M	M	M	M	M	M

Table 15. Summary of the 2014 Integrated Report / Segment 1421B

Segment 1421C – Lipan Creek

Lipan Creek also is a major tributary to the Concho River. Its confluence is located approximately 2 river miles upstream from the Dry Hollow Creek confluence. Its drainage area is approximately 200 square miles. It is located toward the up-dip edge of the Lipan Aquifer and therefore does not have as many springs and seeps as the more easterly tributaries that are on the down-dip of the groundwater gradient. Monitoring data from the 2014 Integrated Report indicates that Lipan Creek has concerns for nitrates and chlorophyll *a*. Nitrate levels can likely be attributed to influence of groundwater from the Lipan Aquifer, which is known to have high levels of nitrates. Monitoring is ongoing.

M - Meets water quality standard
C - Concern for water quality standard

Lipan Creek

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12254	M	-	M	M	M	M	C	C

Table 16. Summary of the 2014 Integrated Report / Segment 1421C

Segment 1422 – Lake Nasworthy

Lake Nasworthy is an impoundment on the South Concho River, just below Twin Buttes Reservoir. Water released from Twin Buttes Reservoir is the primary source of water for Lake Nasworthy, which holds approximately 14,000 acre-feet of water at full conservation storage.

The 2014 Integrated Report data indicates that Lake Nasworthy fully supports all designated uses. Lake Nasworthy has increasingly good water quality. Sulfate, chloride and TDS have decreased, and while pH has increased, it is well within the acceptable range. The decrease in salts is likely a result of the quality of pass-through water from Twin Buttes Reservoir.

Five statistically significant trend analyses were performed at three different stations in the segment. Each analysis is concisely addressed following each chart.

The trend analyses performed on Lake Nasworthy data indicate an increasing trend in total nitrogen. However, the chart also shows that since the end of 2014, total nitrogen levels have been declining. This coincides with drought-ending rains in 2015 (Figure 27).

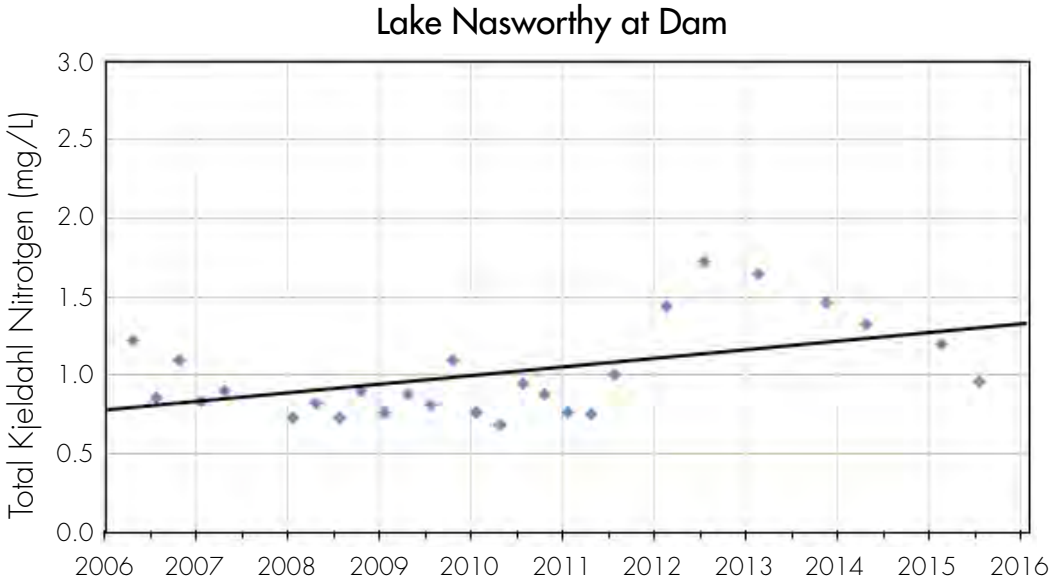


Figure 27. Total Kjeldahl Nitrogen Trend / Segment 1422

The dissolved oxygen deficit trend indicates improving dissolved oxygen levels. This is likely attributable to water being passed through the lake to satisfy downstream release obligations (Figure 28).

The total phosphorus shows a slightly increasing trend, but levels remain below the assessment screening criteria. The source of the phosphorus is unknown; however, it could potentially be due to improperly maintained septic systems in the contributing watershed (Figure 29).

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12418	M	M	M	M	M	M	M	M
12419	M	M	M	M	M	M	M	M
12421	M	M	M	M	M	M	M	M

M - Meets water quality standard

Table 17. Summary of the 2014 Integrated Report / Segment 1422

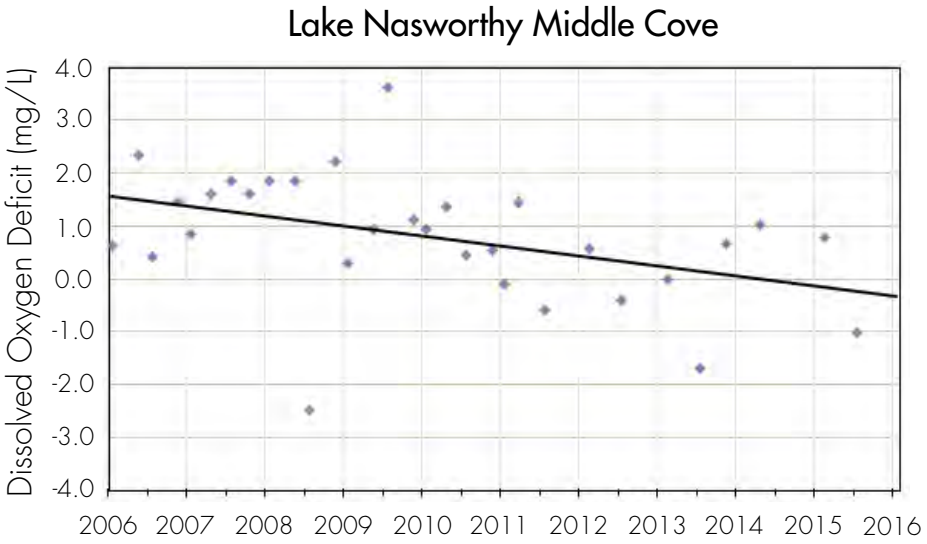


Figure 28. Dissolved Oxygen Deficit Trend / Segment 1422

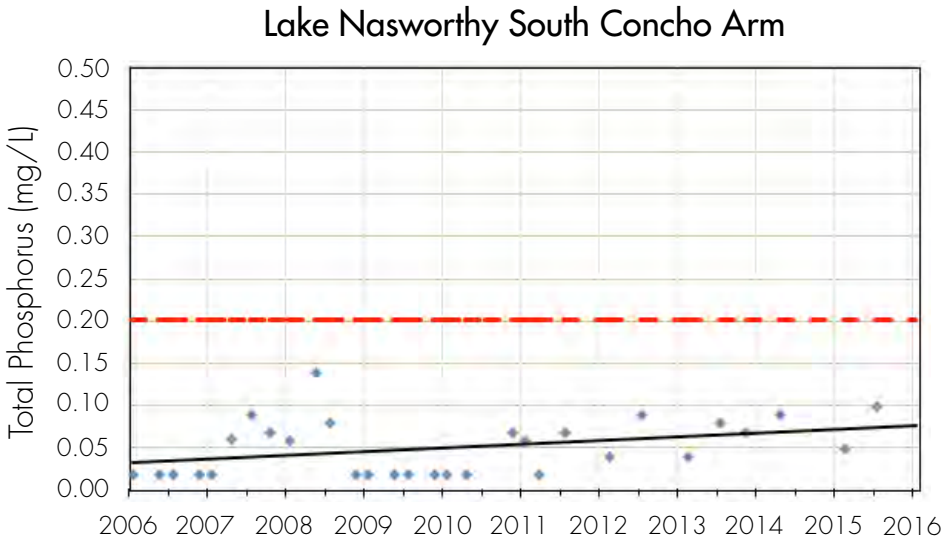


Figure 29. Total Phosphorus Trend / Segment 1422

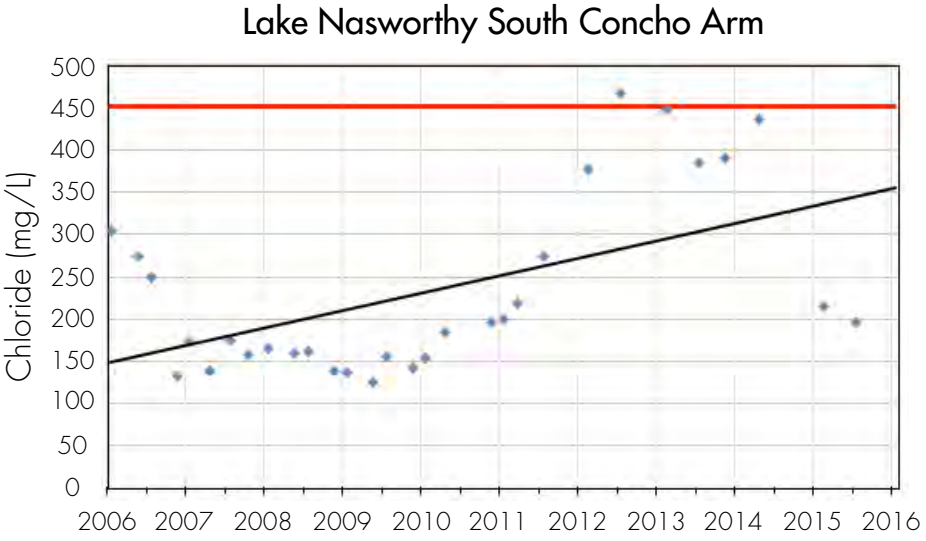


Figure 30. Chloride Trend / Segment 1422

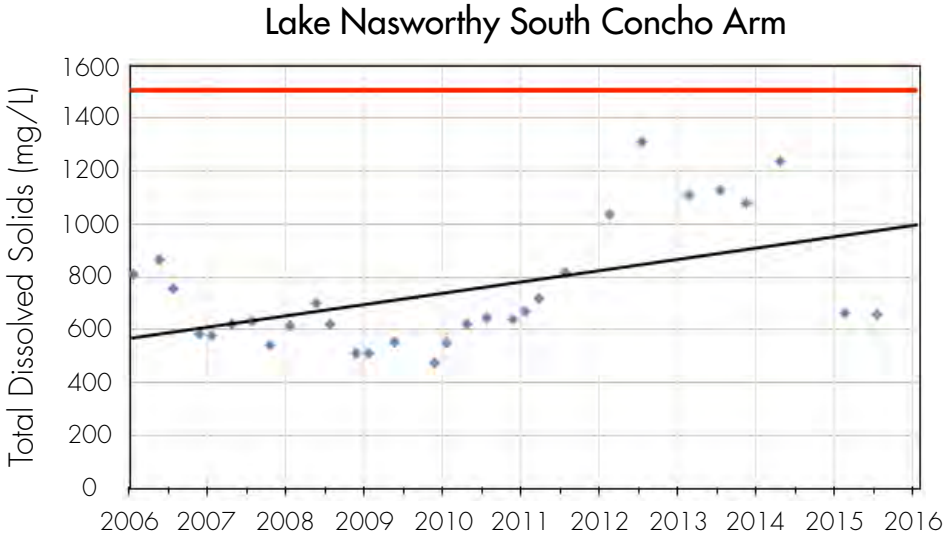


Figure 31. Total Dissolved Solids Trend / Segment 1422

The chloride is trending up; however, the results appear to be skewed by outliers measured during the drought that have since come back down to typical levels (Figure 30). The total dissolved solids are trending up; however, the results appear to be skewed by outliers measured during the drought that have since come back down to typical levels (Figure 31).

Segment 1423 – Twin Buttes Reservoir

Twin Buttes Reservoir is an impoundment on the South Concho and Middle Concho rivers, including Spring and Dove creeks. It impounds water from a drainage area of approximately 3,868 square miles, of which approximately 1,055 square miles is noncontributing. The reservoir has a conservation storage capacity of 186,000 acre-feet and a flood storage capacity of 640,000 acre-feet. Water in the lake is used by the City of San Angelo as a public supply. The reservoir consists of a north pool located on the Middle Concho River and the South Pool is located on the South Concho River.

The 2014 Integrated Report data indicate that Twin Buttes Reservoir fully supports all uses.

Statistically significant trend analyses were performed at two sites; one on the North Pool and one on the South Pool. Sulfate is trending down in the North Pool for unknown reasons. Dissolved oxygen deficit is trending down in the South Pool, and this improving trend is likely attributable to increased base flows from the South Concho River, which typically has excellent water quality.

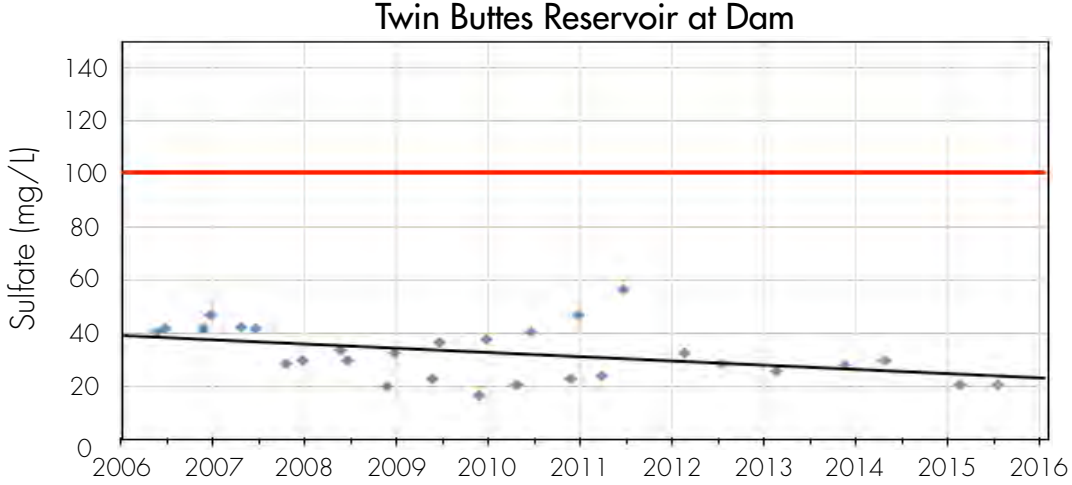


Figure 32. Sulfate Trend / Segment 1423

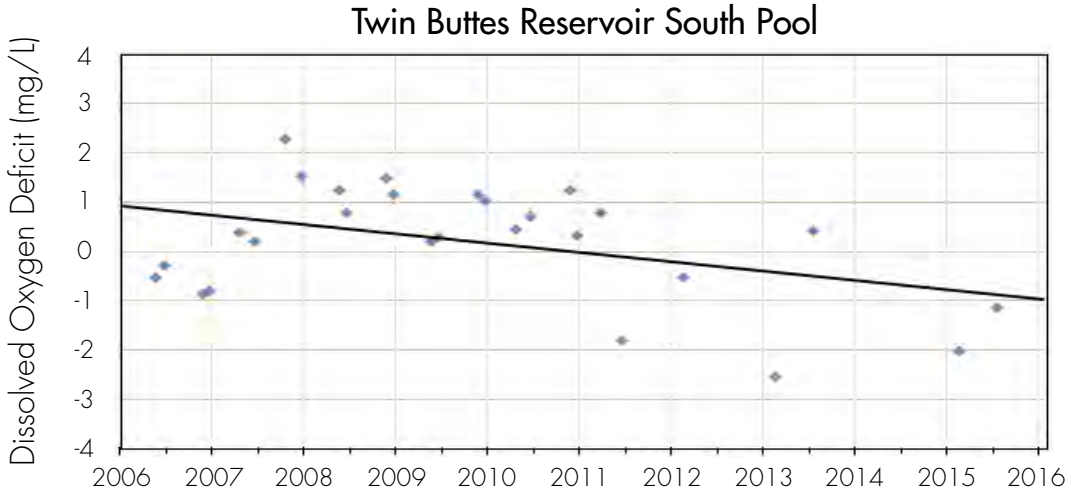


Figure 33. Dissolved Oxygen Deficit Trend / Segment 1423

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12422	M	-	M	M	M	M	M	M
12425	M	-	M	M	M	M	M	M

M - Meets water quality standard

Table 18. Summary of the 2014 Integrated Report / Segment 1423

Segments 1423A – Spring Creek

Spring Creek, a tributary of Twin Buttes Reservoir, is a rural stream with perennial flows. As the name implies, the stream is spring-fed and contains some of the best water quality in the Concho River basin. The creek is about 40 miles long and Dove Creek is its major tributary. The confluence of the two is located near the Twin Buttes North Pool. Its headwaters begin in the Edwards Trinity-Plateau Aquifer.

Twin Buttes Reservoir

The 2014 Integrated Report indicates that Spring Creek fully supports all designated uses. Seven statistically significant trend analyses were performed at two different stations in the segment. Each trend analysis is concisely addressed following each chart.

Sulfate levels are increasing. The highest numbers were obtained during the drought and the levels started to drop coincidental with drought-ending rains. A potential source might be oil and gas production activities (Figure 34). The total dissolved solids show an increasing trend. The highest levels were measured during the drought, and have decreased with the drought-ending rains (Figure 35). The source of the increasing trend of *E. coli* levels is most likely an established population of domestic ducks that live adjacent to the sampling station (Figure 36). The dissolved oxygen increasing trend is attributable to increased spring flows (Figure 37).

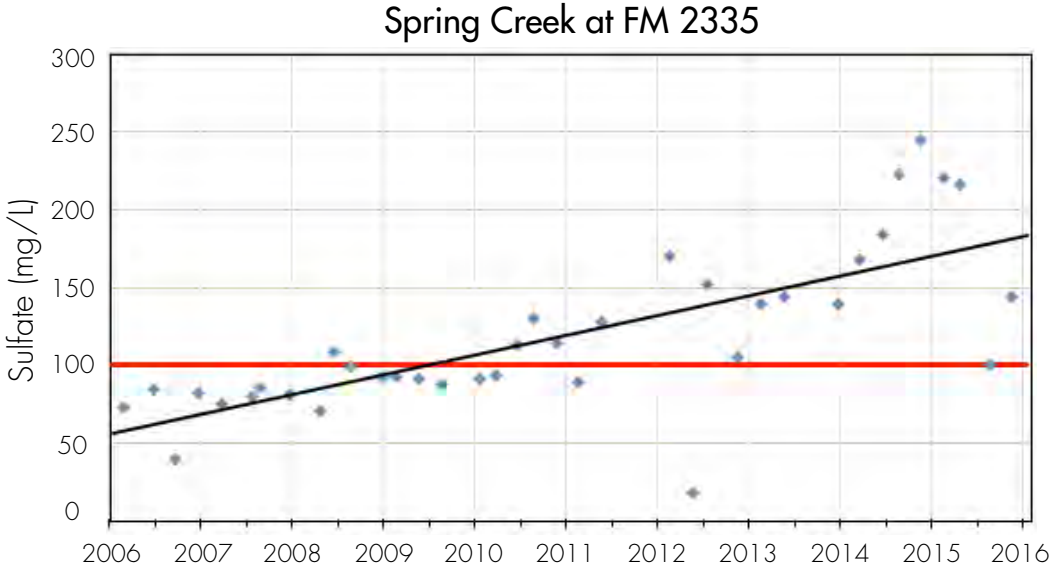


Figure 34. Sulfate Trend / Segment 1423A

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12161	M	-	M	M	M	M	M	M
17346	M	-	M	M	M	M	M	M

M - Meets water quality standard

Table 19. Summary of the 2014 Integrated Report / Segment 1423A

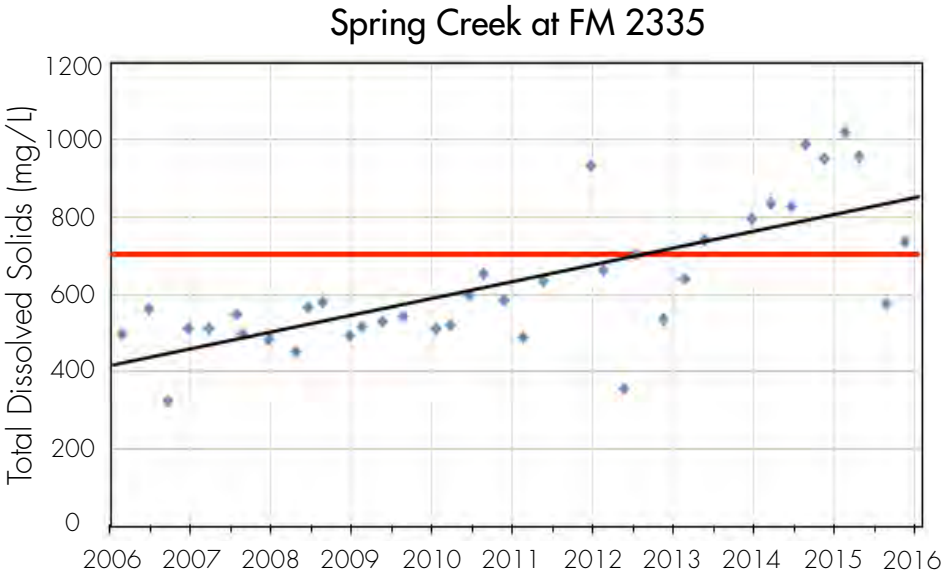


Figure 35. Total Dissolved Solids Trend / Segment 1423A

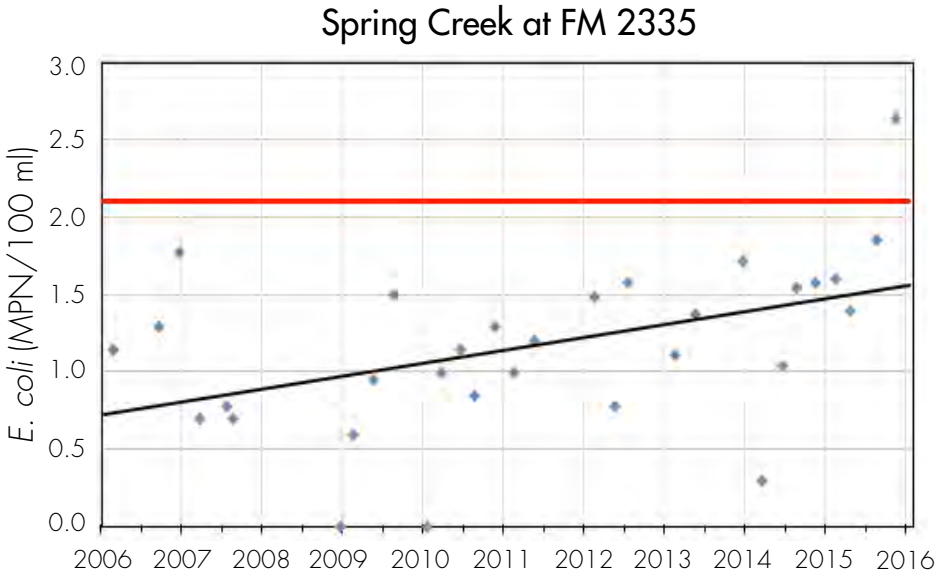


Figure 36. E. coli Trend / Segment 1423A

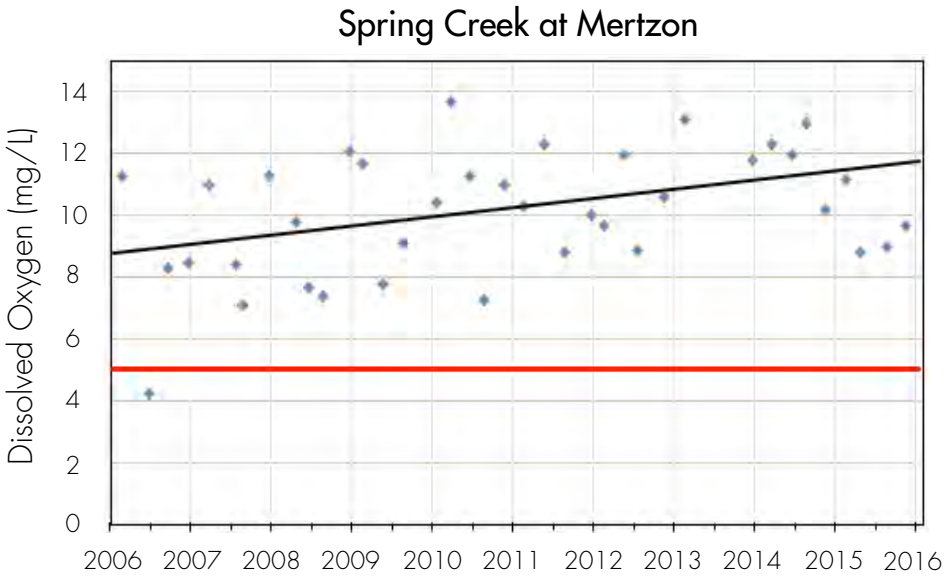


Figure 37. Dissolved Oxygen Trend / Segment 1423A

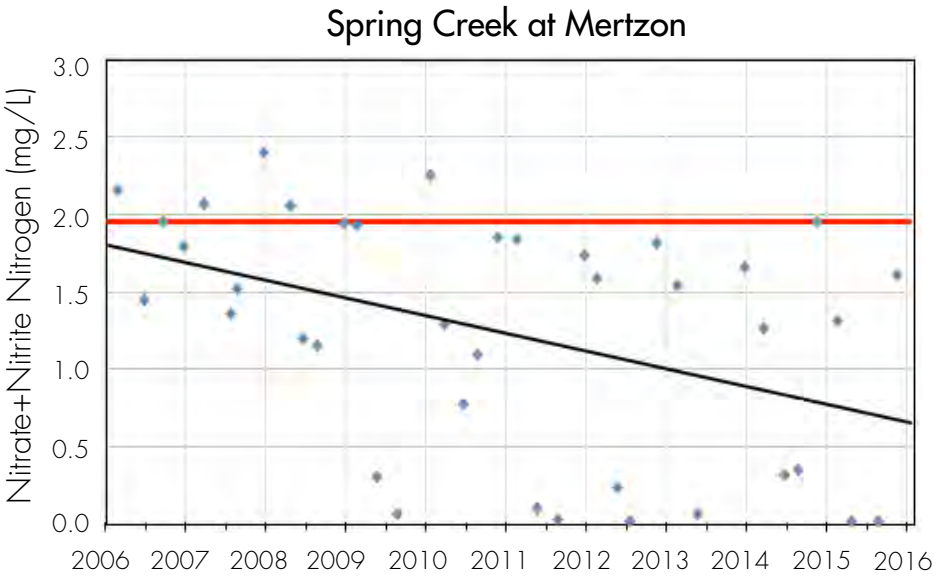


Figure 38. Nitrate+Nitrite Nitrogen Trend / Segment 1423A

The downward trending nitrogen levels include a wide range of numbers. The cause of the swings or the source of the nitrogen is unknown. It may be related to seasonality because the spring and summer quarters exhibit lower levels than the last and first quarter measurements. This was the case beginning in 2009 and continuing throughout the rest of the reporting period (Figure 38).

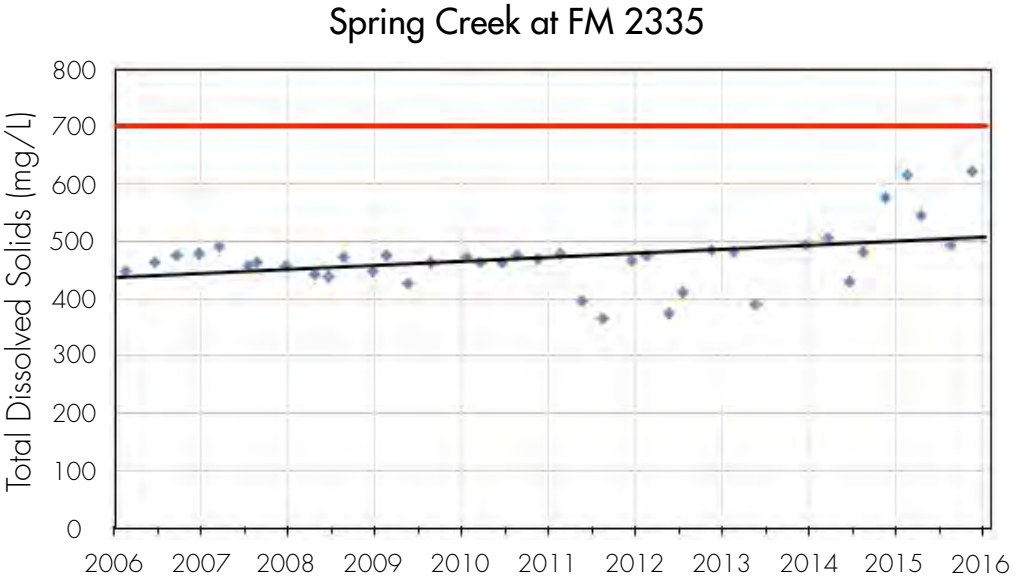
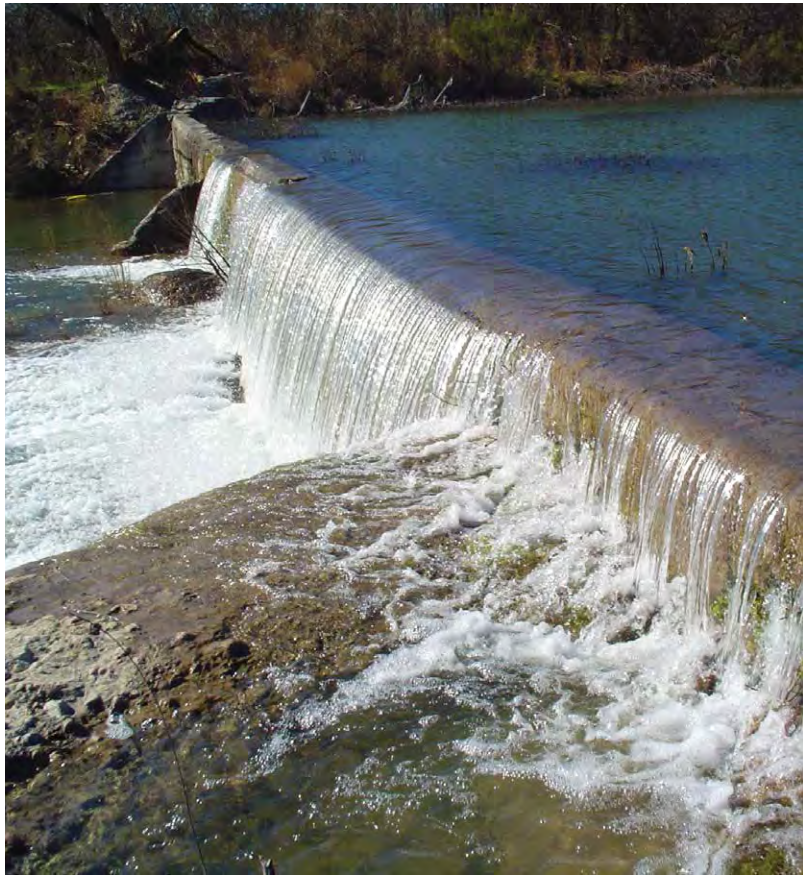


Figure 39. Total Dissolved Solids Trend / Segment 1423A

Total dissolved solids are trending slightly upward. The reason is unknown, but is likely related to groundwater influences (Figure 39).



Spring Creek

Segment 1423B – Dove Creek

Dove Creek is a tributary of Spring Creek, and like Spring Creek it is fed primarily by springs. It is approximately 18 miles long, and the water quality is typically pristine. The creek's headwater spring issues forth from the Edwards-Trinity Plateau Aquifer. The confluence of Dove Creek with Spring Creek is in the Twin Buttes Reservoir Basin.

The 2014 Integrated Report data indicated that Dove Creek is fully supportive of its designated uses. No statistically significant trend analyses were performed.

M - Meets water quality standard

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12166	M	-	M	M	M	M	M	M

Table 20. Summary of the 2014 Integrated Report / Segment 1423B

Segment 1424 – Middle and South Concho Rivers

Segment 1424 consists of the Middle Concho and South Concho rivers. Although the Middle and South Concho rivers are included in the same segment, the two rivers have very different characteristics. The South Concho River is a perennial spring-fed stream created by several large springs that form its headwaters. The Middle Concho River flows intermittently, and it has been dry during most of the reporting period. The South Concho River generally has better water quality. The watersheds surrounding both streams historically have been used almost entirely for agriculture, consisting primarily of rangeland and farmland. Most of the farmland is located in the northwestern portion of the watershed.

The 2014 Integrated Report data indicate that the Middle Concho and South Concho rivers are fully supporting of their designated uses. The only concern is for nitrates. The mean exceedance value that generated the concern is 2.12 mg/L with an exceedance criteria of 1.95 mg/L. The exceedance is less than 20 percent of the criteria, and the source of the nitrates is unknown. Monitoring is ongoing.

Four statistically significant trend analyses were performed. The dissolved oxygen deficit increasing trend shows improvement. The declining pH trend is within the standards, but the reason for the decreasing trend is unknown. The nitrate+nitrite nitrogen trend is decreasing, and well below the standard, which is in contrast to the nitrate screening level concern. Sulfate at Anson Spring is nearly 0 and the trend line is flat. Anson Spring and other unnamed springs in the immediate area produce the best quality water in the Concho River basin.

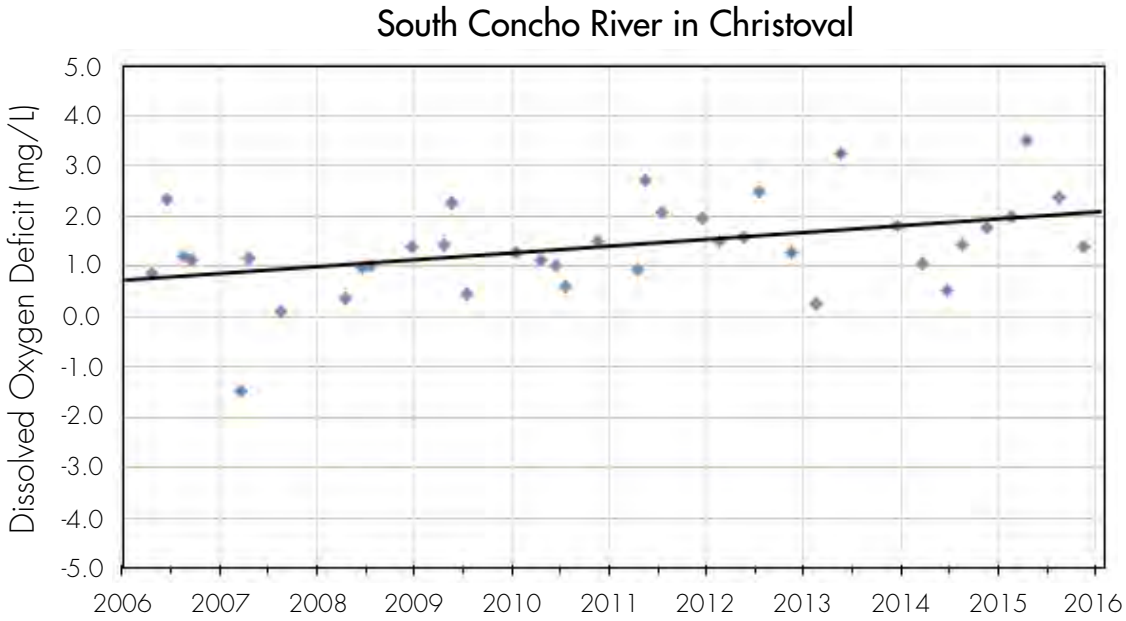


Figure 40. Dissolved Oxygen Deficit Trend / Segment 1424

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12427	M	M	M	M	M	M	C	M
16903	M	M	M	M	M	M	M	M
18712	M	M	M	M	M	M	M	M

Table 21. Summary of the 2014 Integrated Report / Segment 1424

M - Meets water quality standard
C - Concern for water quality standard

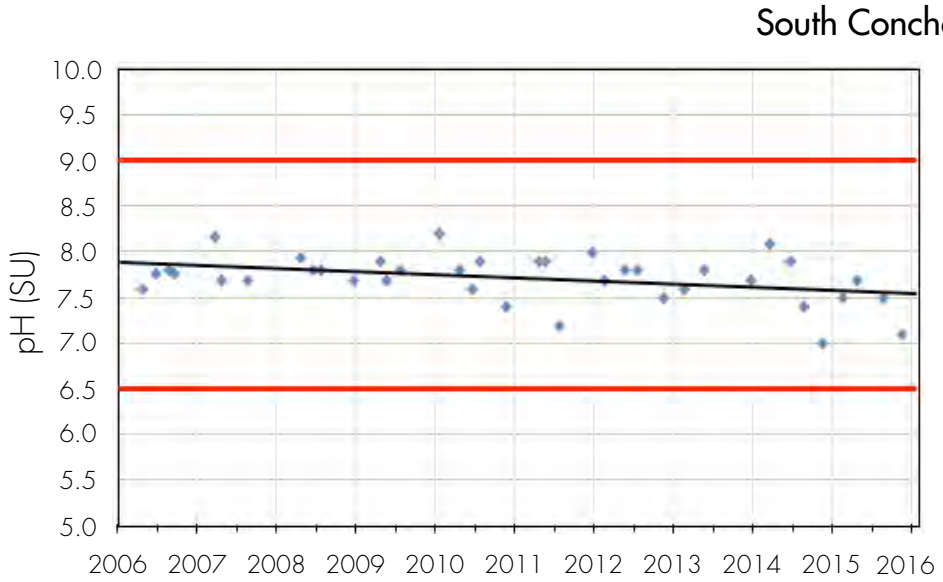


Figure 41. pH Trend / Segment 1424

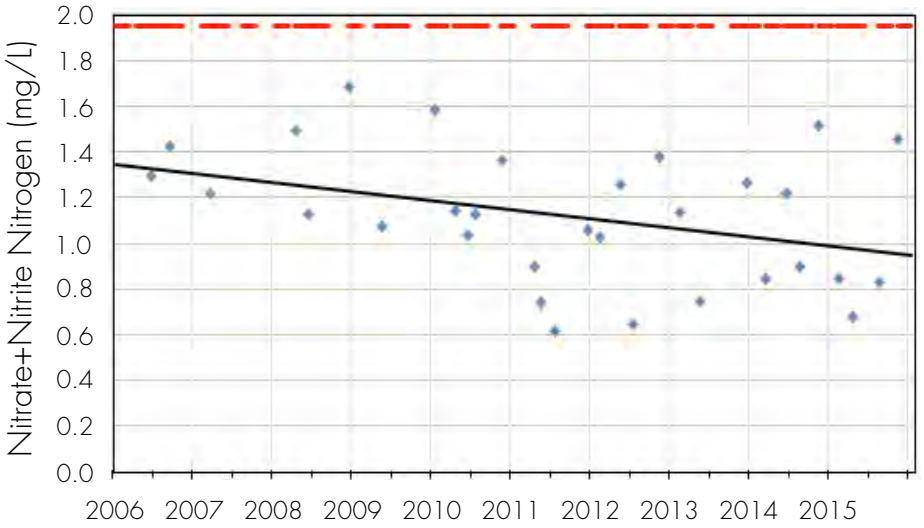


Figure 42. Nitrate+Nitrite Nitrogen Trend / Segment 1424

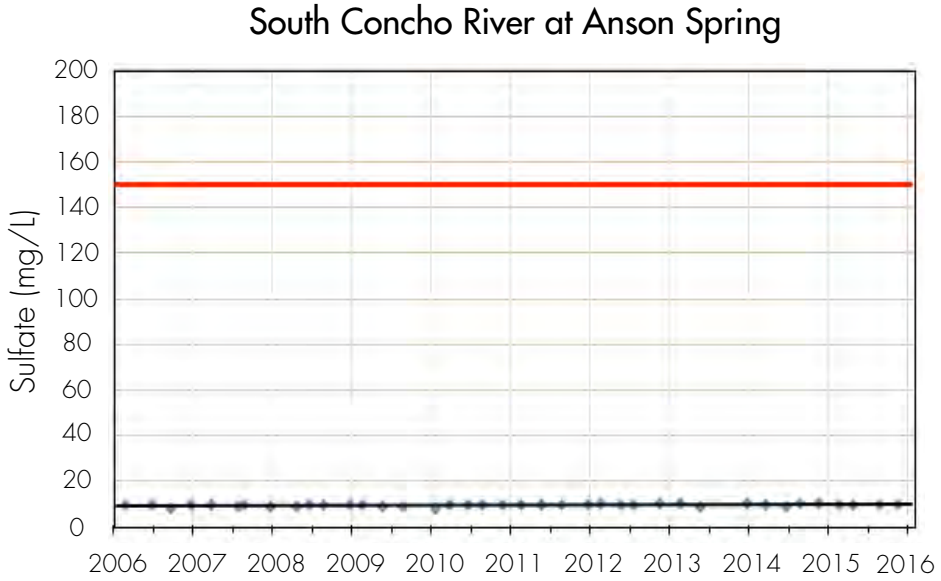


Figure 43. Sulfate Trend / Segment 1424

South Concho River

Segment 1424A – West Rocky Creek

West Rocky Creek is a tributary of the Middle Concho River. Its confluence with the Middle Concho is at a point approximately 9.5 miles upstream of where the Middle Concho crosses U.S. Highway 67 near the North Pool of Twin Buttes Reservoir. Dog Creek and Dry Rocky Creek are the major tributaries of West Rocky Creek. The creek's sample site is located where it crosses RM 853, which is about 1 mile upstream of its confluence with the Middle Concho River.

The 2014 Integrated Report data indicate that West Rocky Creek's designated uses are fully supported with the exception of dissolved oxygen. Six analytical results out of 22 used for the assessment were exceedances. However, five of the six were collected prior to 2009, and since then all results have met water quality standards.

Dissolved oxygen deficit and dissolved oxygen showed significant trends (Figures 44 and 45). The analyses indicate that while dissolved oxygen is improving, dissolved oxygen deficit is trending down. The reason for these trends is unknown

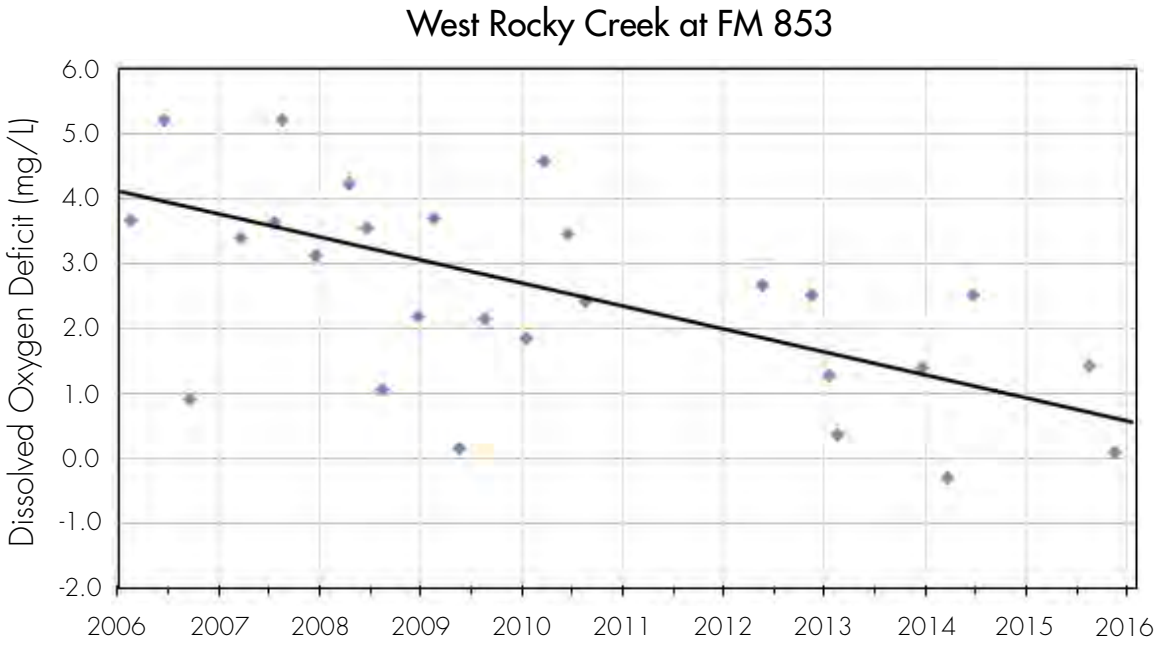


Figure 44. Dissolved Oxygen Deficit Trend / Segment 1424

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12165	C	-	M	M	M	M	M	M

M - Meets water quality standard
C - Concern for water quality standard

Table 22. Summary of the 2014 Integrated Report / Segment 1424A

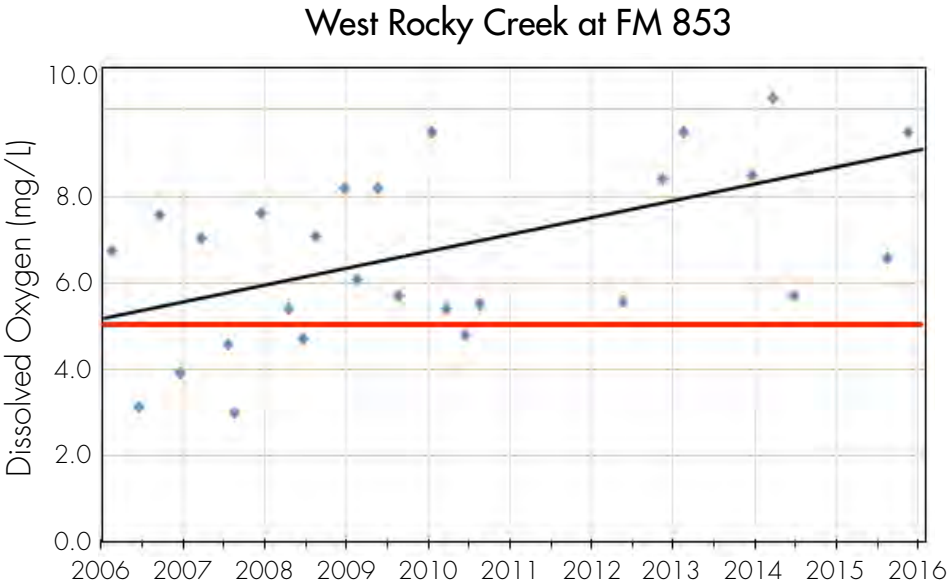


Figure 45. Dissolved Oxygen Trend / Segment 1424A

Segment 1421

Segment 1424B – Cold Creek

Cold Creek is a tributary of the South Concho River. It is fed by Cold Creek spring, which, like the South Concho River, rises out of the northern extremity of the Edwards-Trinity Plateau Aquifer. The spring is located less than 1 mile from the headwater springs of the South Concho River. Cold Creek is less than 1 mile in total length from its headwaters to where it joins the South Conch River.

Based on the 2014 Integrated Report data, Cold Creek's designated uses are fully supported, although there is a concern for nitrates. This is most likely attributable to a small pool situated between the headwaters and the sample site that is frequented by waterfowl. Other wildlife and livestock also are
potential contributors.

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
18711	M	-	M	M	M	M	C	M

M - Meets water quality standard
C - Concern for water quality standard

Table 23. Summary of the 2014 Integrated Report / Segment 1424B

Segment 1425 – O.C. Fisher Lake

O.C. Fisher Lake is an impoundment on the North Concho River west of San Angelo. The lake has a total storage capacity of 395,717 acre-feet and a drainage area of about 1,488 square miles (1,383 contributing). Its conservation storage capacity is 119,445 acre-feet. The contributing watershed of O.C. Fisher Lake consists mainly of rangeland with relatively few acres dedicated to irrigate and some dry-land farming operations. Owing to lingering drought conditions during the early part of the reporting period, the lake intermittently held small to no amounts of water. The drought-ending rains that began in 2015 have helped the lake level to rise. The lake currently contains over 18,000 acre-feet.

Although the 2014 Integrated Report data indicate the lake is impaired for chloride and total dissolved solids, and it has concerns for total phosphorus, chlorophyll *a* and dissolved oxygen, these assessments are related to the low levels of water that existed when samples were collected during the drought. Recent sample analyses show significant improvement in all parameters.

M - Meets water quality standard
C - Concern for water quality standard
I - Impaired for water quality standard

O.C. Fisher Lake during drought in May 2011

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12429	C	-	M	M	M	I	C	C

Table 24. Summary of the 2014 Integrated Report / Segment 1425

Segment 1425A – North Concho River

This segment consists of the North Concho River from O.C. Fisher Lake near San Angelo in Tom Green County upstream to the Glasscock/ Howard County line. The watershed is primarily used for agriculture and wildlife operations. A small percentage of the watershed's acreage is dedicated to farming operations. The North Concho River is intermittent and about 104 miles long.

Water quality data assessments from the 2014 Integrated Report indicate concern levels for bacteria, chlorophyll *a* and dissolved oxygen. The cause of the bacteria concern is unknown. However, station 16779 where the concern was assessed is at a road crossing at which the river typically does not flow or only flows minimally. The dissolved oxygen concern was measured at station 16780, which is a small impoundment that rarely flows over the dam. It is the farthest upstream station on the North Concho River. None of the dissolved oxygen exceedances that resulted in the concern assessment occurred in the reporting period, and attribution of the causes of the four exceedances is unknown. The chlorophyll *a* concerns are likely attributable to low flows.

Two statistically significant analyses were performed. Total dissolved solids (Figure 46) and Secchi depth (Figure 47). Figure 47 shows lower measured values near the end of the reporting period and a declining trend that indicates that TDS in the upstream portion of the segment is improving. The Secchi depth declining trend measured at station 16780 is deceiving and attributable to the shallowness of the pool not affording an accurate measurement. Often, the measurement is recorded with a greater-than symbol preceding the value.

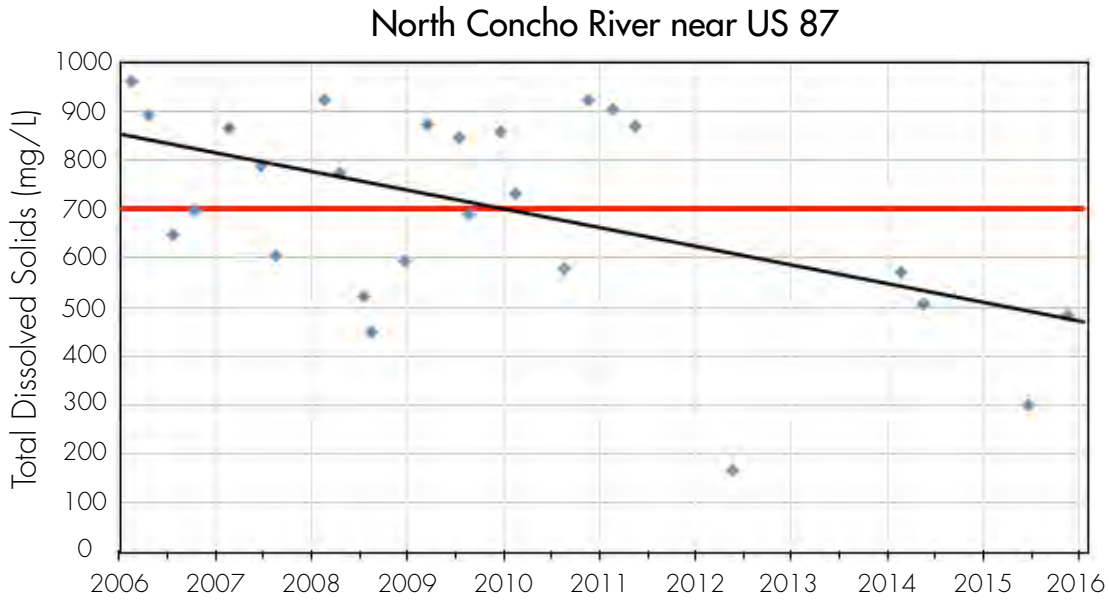


Figure 46. Dissolved Solids Trend / Segment 1425A

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12171	M	M	M	M	M	M	M	C
16779	M	M	C	M	M	M	M	M
16780	C	M	M	M	M	M	M	M
17350	M	M	M	M	M	M	M	C

Table 25. Summary of the 2014 Integrated Report / Segment 1425A

M - Meets water quality standard
C - Concern for water quality standard

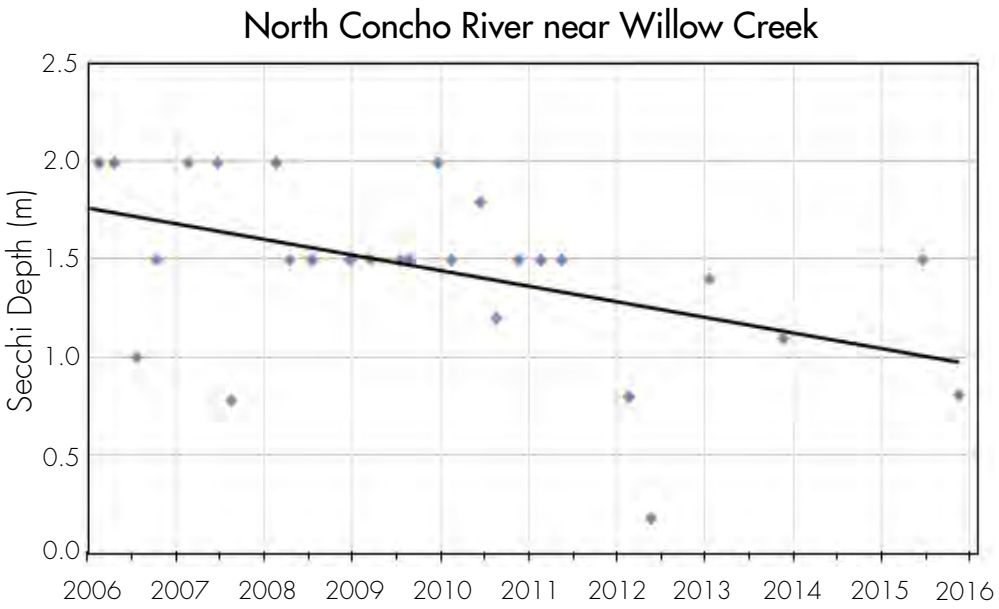
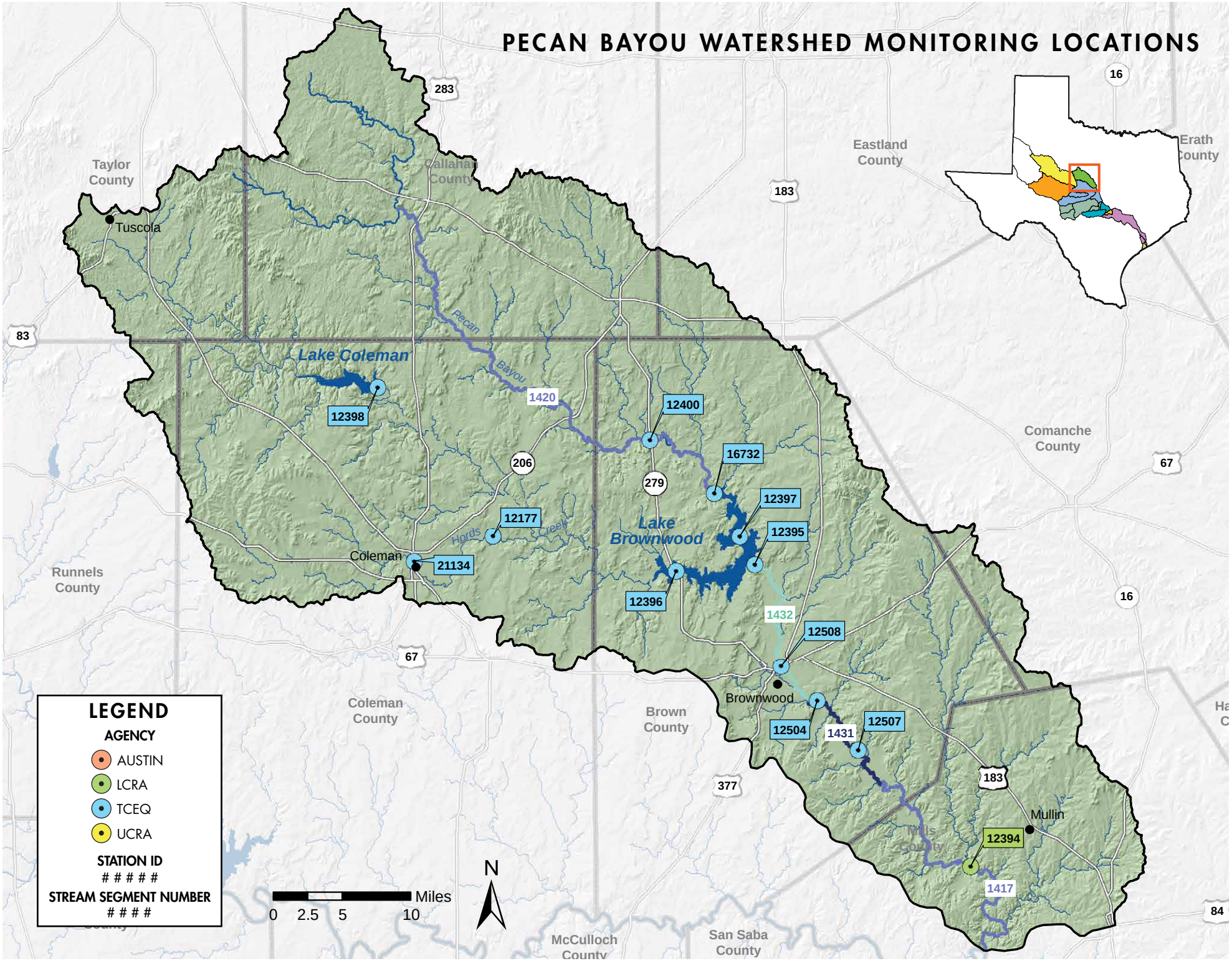


Figure 47. Secchi Depth Trend / Segment 1425A

Future Challenges for the Concho River Watershed

- Lack of precipitation and low flows continue to impact water quality in the Concho River basin.
- Bacteria levels in urban areas are problematic. During the reporting period, through the EPA Urban Waters Small Grants Program, UCRA performed a bacteria source tracking study in the downtown urban portion of the Concho River. The results indicated that avian sources are the most likely causes. However, additional research followed by remediation actions still need to be implemented.
- Golden algae will remain a significant challenge. UCRA will monitor and document fish kills, and will continue to cooperate with TPWD to combat the problem.

Creek overflow neear Segment 1421


PECAN BAYOU WATERSHED MONITORING LOCATIONS
Taylor County
Callahan County
Eastland County
Erath County
Comanche County
Runnels County
Coleman County
Brown County
Mills County
McCulloch County
San Saba County
Tuscola
Coleman
Brownwood
Mullin
Lake Coleman
Lake Brownwood
Pecan Bayou
Hords Creek
283
183
16
83
67
206
279
377
84
1420
1432
1431
1417
12398
12400
16732
12397
12395
12396
12177
21134
12508
12504
12507
12394
LEGEND
AGENCY
AUSTIN
LCRA
TCEQ
UCRA
STATION ID
# # # # #
STREAM SEGMENT NUMBER
# # # #
0 2.5 5 10 Miles
N

PECAN BAYOU WATERSHED

Nineteen stations in the Pecan Bayou watershed were monitored from 2006 to 2016.

Segment 1417 – Lower Pecan Bayou
Segment 1418 – Lake Brownwood
Segment 1418A – Hords Creek
Segment 1419 – Lake Coleman
Segment 1420 – Pecan Bayou above Lake Brownwood
Segment 1431 – Mid-Pecan Bayou
Segment 1432 – Upper Pecan Bayou

Watershed Characteristics

The Pecan Bayou headwaters are southeast of Abilene. The stream flows to the southeast and into the Colorado River in Mills County above Lake Buchanan. Flat terrain and sluggish flow make the bayou more akin to an East Texas stream than other Colorado River tributaries. The 2,200-square-mile watershed is part of the fertile Central Oklahoma-Texas Plains Ecoregion.

Several small tributaries provide intermittent flows to the bayou. Jim Ned Creek, a major tributary, forms Lake Coleman and merges with Pecan Bayou to form Lake Brownwood, near the City of Brownwood.

Routine water sampling in the watershed indicates that several segments have elevated nutrient and chlorophyll *a* levels. Lake Brownwood has elevated levels of manganese and Pecan Bayou below Brownwood is impaired due to high levels of bacteria.

Lake Brownwood near Goat Island

SEGMENT SUMMARIES

Segment 1417 – Lower Pecan Bayou

The most downstream segment of Pecan Bayou is undeveloped and includes mostly pasture land. This segment supports its designated uses according to the 2014 Integrated Report, but chlorophyll is a concern. High chlorophyll levels are likely from nutrient-rich waters in the upper watershed.

Trend analyses of data collected at FM 504 (Station 12394) indicate total dissolved solids have decreased. Drought began to impact this area in 2008, during which TDS levels increased; however, since the drought subsided, the base flow in the stream increased and TDS resumed a downward trend.

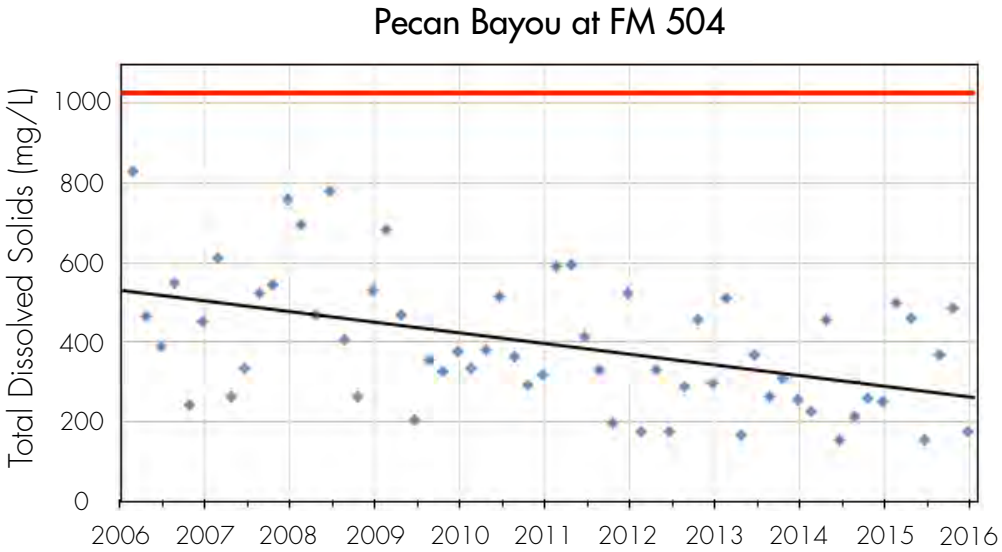
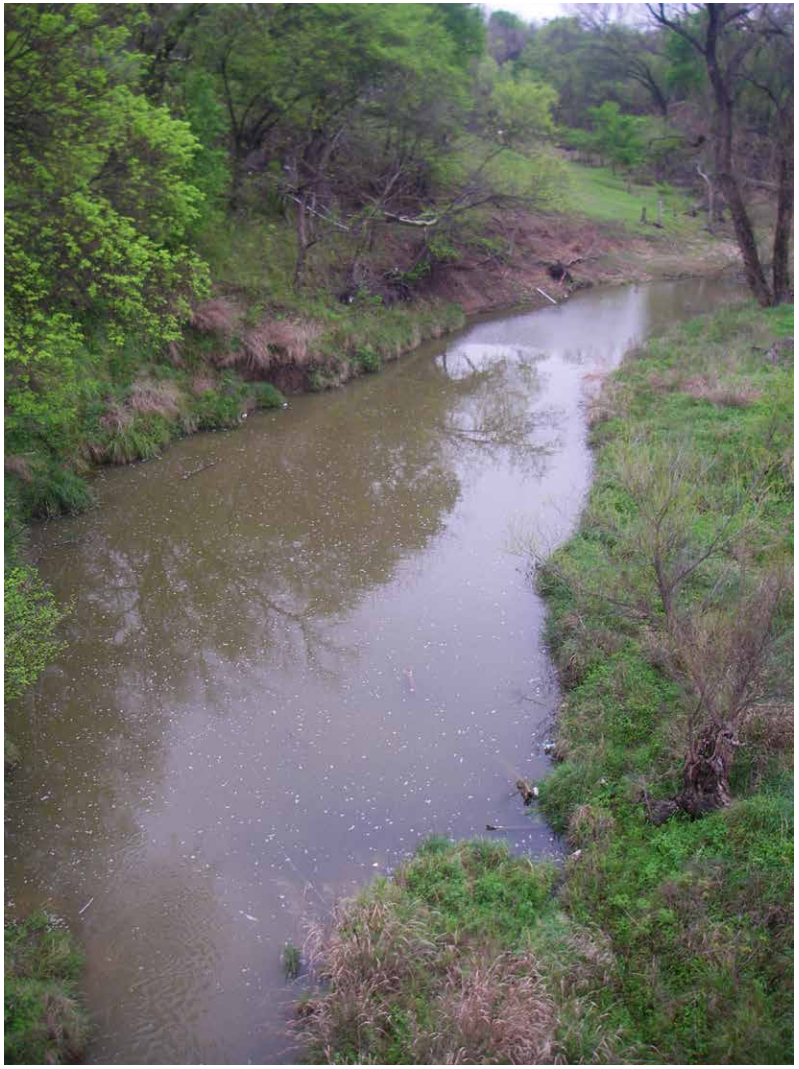


Figure 48. Dissolved Solids Trend / Lower Pecan Bayou



Pecan Bayou at Highway 67 in Brownwood

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12394	M	-	M	M	M	M	M	C

M - Meets water quality standard
C - Concern for water quality standard

Table 26. Summary of the 2014 Integrated Report / Segment 1417

Segment 1418 – Lake Brownwood

Lake Brownwood is an impoundment of Pecan Bayou and Jim Ned Creek. The reservoir has a surface area of approximately 7,300 acres at its conservation pool elevation. It was built in the early 1930s as a municipal and agricultural water supply for the region.

While Lake Brownwood supports its designated uses, in 2008, TCEQ identified a concern for aquatic life due to high levels of manganese found in sediment. The TCEQ regional office in Abilene monitored again for the heavy metal in 2013 and 2014, and results indicate that levels remain high. The source of manganese in Lake Brownwood is challenging to verify; however, it is a naturally occurring element that has been found in high concentrations in pockets throughout Texas.

Trend analysis revealed a decrease in chloride (Figure 49) in Lake Brownwood. The trend, which was evident at two monitoring stations, is indicative of increased lake levels from rainfall in the area as the drought ended.

Pecan Bayou above Lake Brownwood

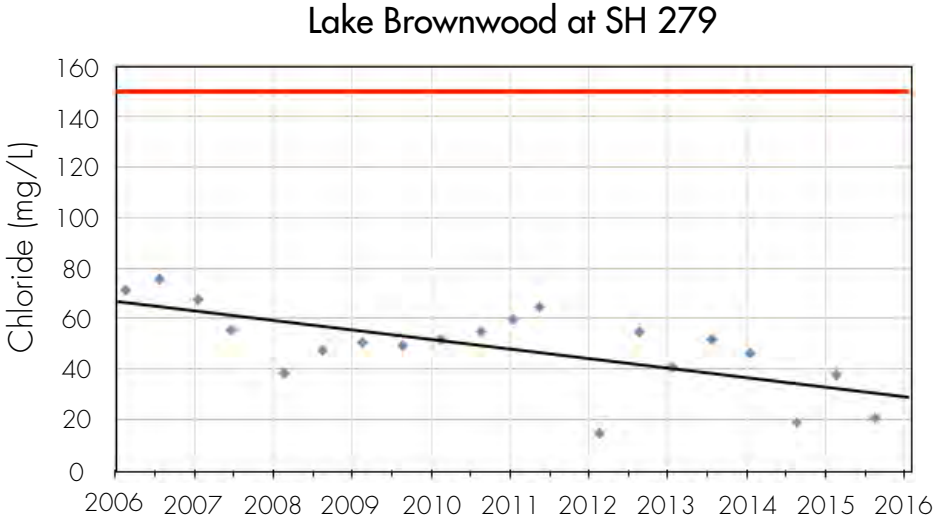


Figure 49. Chloride Trend / Lake Brownwood

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12171	M	-	C	M	M	M	M	M
16779	M	-	M	M	M	M	M	M
16780	M	-	M	M	M	M	M	M

M - Meets water quality standard
C - Concern for water quality standard

Table 27. Summary of the 2014 Integrated Report / Segment 1418

Segment 1418A – Hords Creek

Hords Creek is a tributary of Jim Ned Creek. It is about 30 miles long and flows from the headwaters at Hords Creek Reservoir to the confluence with Jim Ned Creek. The Hords Creek watershed is rural, and land is used primarily for agriculture production. Much of the riparian vegetation along the creek has been removed. Routine monitoring by the TCEQ near Coleman (population 5,100) shows the lake supports its designated uses. There were no significant trends found in Hords Creek.

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12177	M	M	M	M	M	M	M	M
21134	M	M	M	M	M	M	M	M

Table 28. Summary of the 2014 Integrated Report / Hords Creek

Segment 1419 – Lake Coleman

Lake Coleman is an impoundment on Jim Ned Creek in Coleman County. The lake, which was impounded in 1966, has a surface area of approximately 2,000 acres at its normal pool elevation. Routine monitoring shows the lake supports its designated uses. Trend analysis showed a rise in total dissolved solids concentration and a decrease in Secchi depth from 2006 to 2016 (Figure 50). Prolonged drought and lack of inflows are the most likely causes.

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12398	M	-	M	M	M	M	M	M

Table 29. Summary of the 2014 Integrated Report / Segment 1419

Segment 1420 – Lower Pecan Bayou

Pecan Bayou above Lake Brownwood is approximately 51 miles long. The uppermost portion begins as little more than a trickle. In its upper reaches, the stream is narrow and much of the riparian corridor is intact. As it flows southeast, the stream picks up flow from two tributaries – Little Pecan Bayou and Turkey Creek. Below State Highway 283, the riparian corridor is less intact and row crops are more prominent. The 2014 Integrated Report shows the lake supports its designated uses with a concern status for elevated levels of chlorophyll *a*. There were no significant trends in Segment 1420.

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12400	M	-	M	M	M	M	M	C

Table 30. Summary of the 2014 Integrated Report / Segment 1420

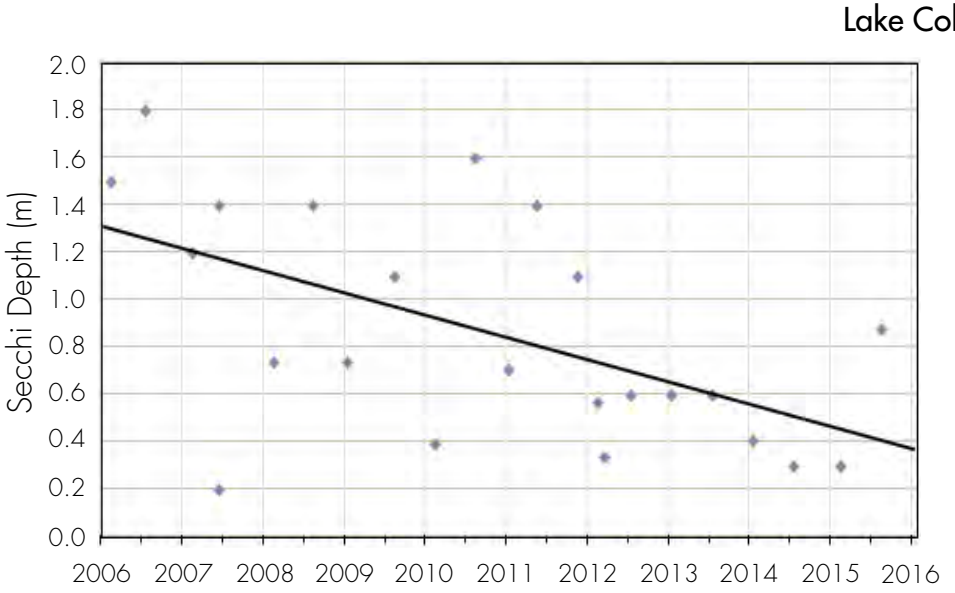


Figure 50. Transparency Trend / Lake Coleman

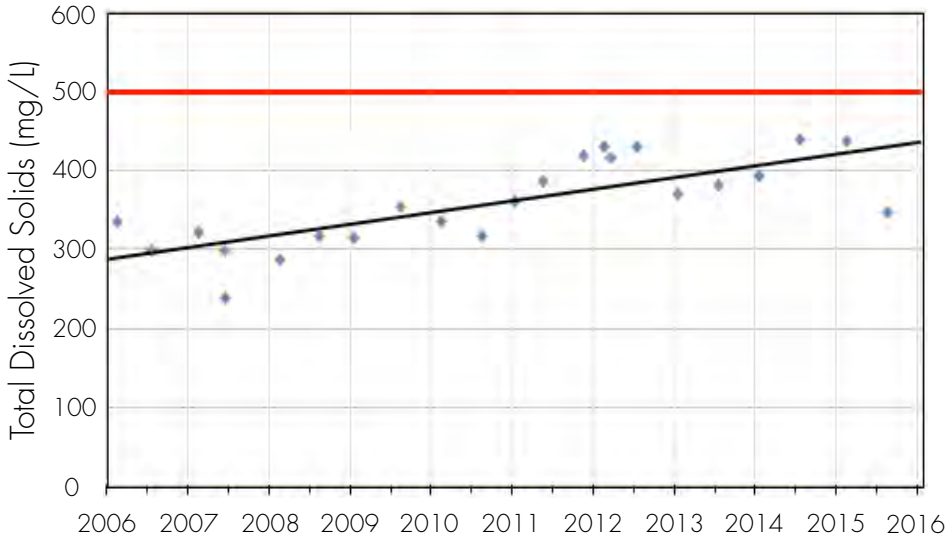


Figure 51. Total Dissolved Solids Trend / Lake Coleman

Segment 1431– Mid-Pecan Bayou

Mid-Pecan Bayou is approximately 13 miles long. Brownwood is located at the headwaters of the segment. Immediately downstream of the city, the surrounding watershed is primarily used for hay production and row crops. There is a concentrated animal feeding operation in the upper end of the segment, and the City of Brownwood's wastewater treatment plant discharges into Willis Creek about 1.5 miles upstream of the monitoring station.

Segment 1431 was first placed on the 2006 303(d) List for not supporting contact recreation due to elevated levels of *E. coli*. High bacteria counts were found in subsequent assessments. Based on the 2014 Integrated Report, the geometric mean for *E. coli* was 191 CFU, exceeding the criterion of 126. The 2014 Integrated Report also identified high levels of chlorophyll *a*. Total phosphorus and nitrate also were identified as concerns in the 2014 report.

M - Meets water quality standard
C - Concern for water quality standard
I - Impaired for water quality standard

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12504	M	-	I	M	M	M	C	C
12507	M	-	I	M	M	M	C	C

Table 31. Summary of the 2014 Integrated Report / Segment 1431

Segment 1431 – Mid-Pecan Bayou (cont.)

Trend analyses verified the concern for nutrients. Nitrate (Figure 52) and phosphorus (Figure 53) increased significantly, which resulted in a decreasing trend in Secchi depth.

Potential sources of bacteria and nutrients include the City of Brownwood's discharge, urban stormwater runoff, and the concentrated animal feeding operation, wildlife or a combination of these. A Recreational Use Attainability Analysis was started in August 2010 to determine if contact recreation occurred in the segment. Texas A&M University's AgriLife Extension Service and Texas Institute for Applied Environmental Research completed the study in January 2012 –funded by a grant from the Texas Soil and Water Conservation Board and EPA. Based on the results of the study, TCEQ recommended the stream retain its primary contact recreation use and the corresponding geometric mean criteria of 126 CFU/100 mL for the entire stream segment.

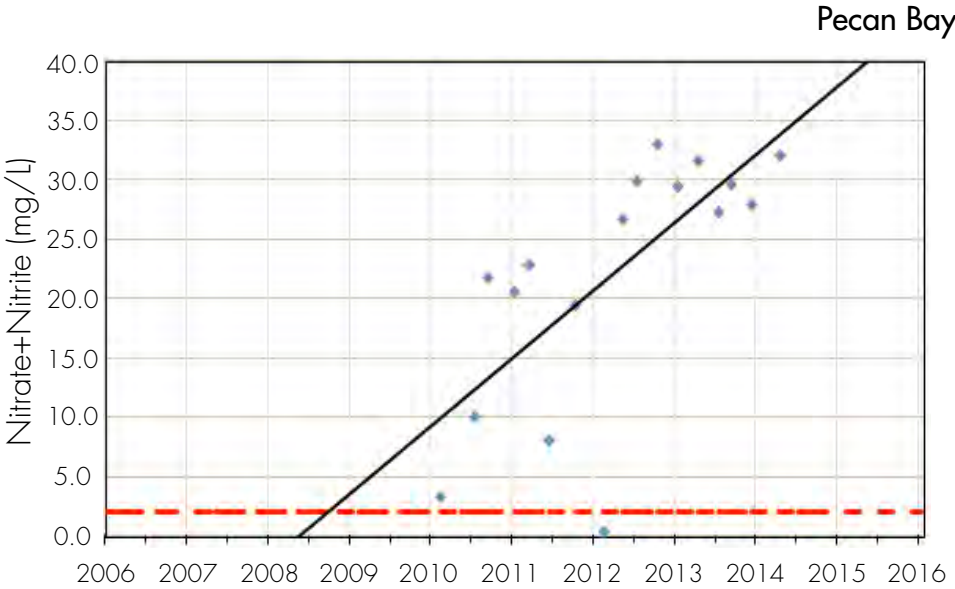


Figure 52. Nitrogen Trend / Mid-Pecan Bayou

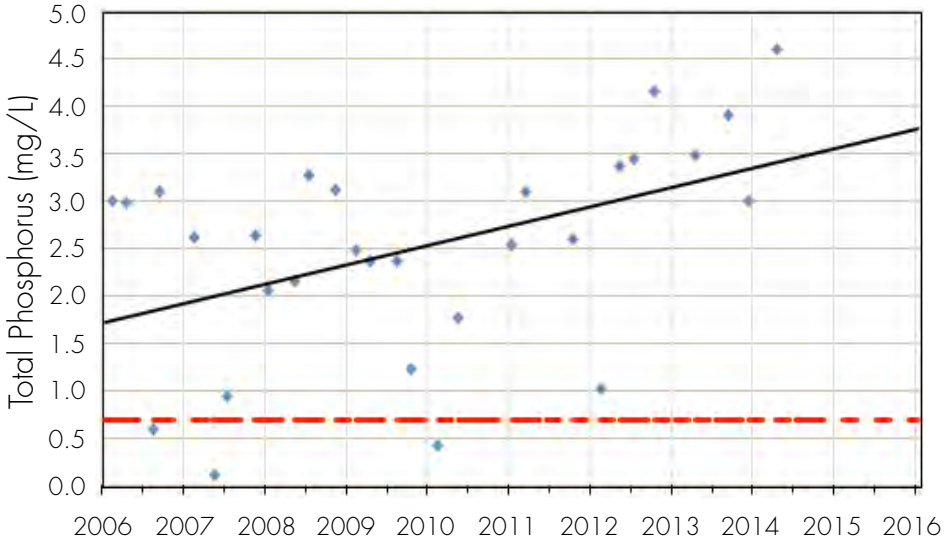


Figure 53. Phosphorus Trend / Mid-Pecan Bayou

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12504	M	-	I	M	M	M	C	C
12507	M	-	I	M	M	M	C	C

M - Meets water quality standard
C - Concern for water quality standard
I - Impaired for water quality standard

Table 32. Summary of the 2014 Integrated Report / Segment 1431

Aquatic Life

The level of aquatic life use support has not been established for Segment 1431. In 2010, the TCEQ and LCRA began collecting biological data that would help establish an appropriate aquatic life use designation. Data collection continued through 2012, and currently is under review by TCEQ. An update is expected in the next revision of the Texas Surface Water Quality Standards.

Segment 1432 – Upper Pecan Bayou

Upper Pecan Bayou is not, as its name implies, the uppermost segment in the watershed. The name is a relic of old segment descriptions assigned by TCEQ and its predecessor agencies in the early days of delineating Texas streams. The segment, which is downstream of Lake Brownwood, is approximately 15 miles long. The 2014 Integrated Report placed Upper Pecan Bayou on the 303(d) List for not supporting contact recreation due to high levels of *E. coli*. Potential sources of the bacteria include livestock, wildlife and urban runoff from Brownwood and nearby Earl during rain events. Monitoring data indicate the lake has elevated levels of chlorophyll *a* and low dissolved oxygen. There were no significant trends in Upper Pecan Bayou.

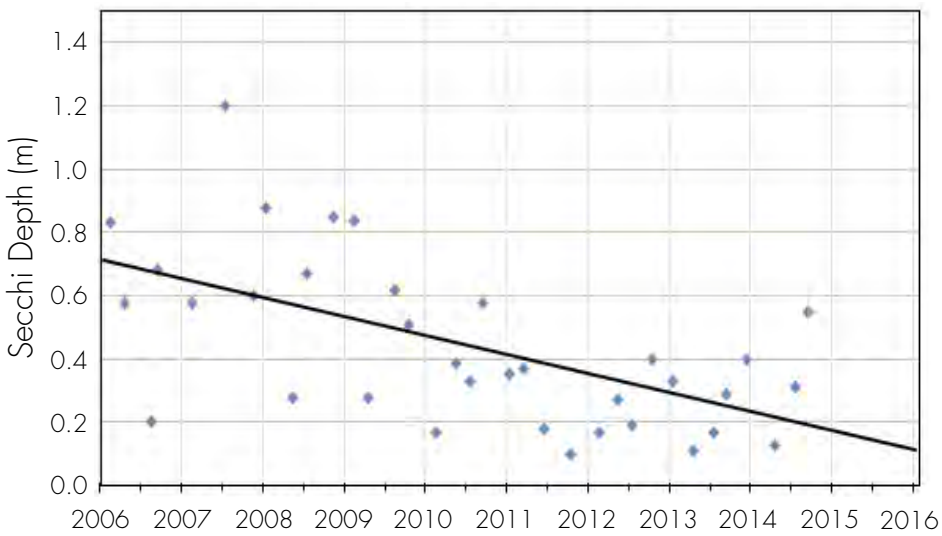


Figure 54. Transparency Trend / Mid-Pecan Bayou

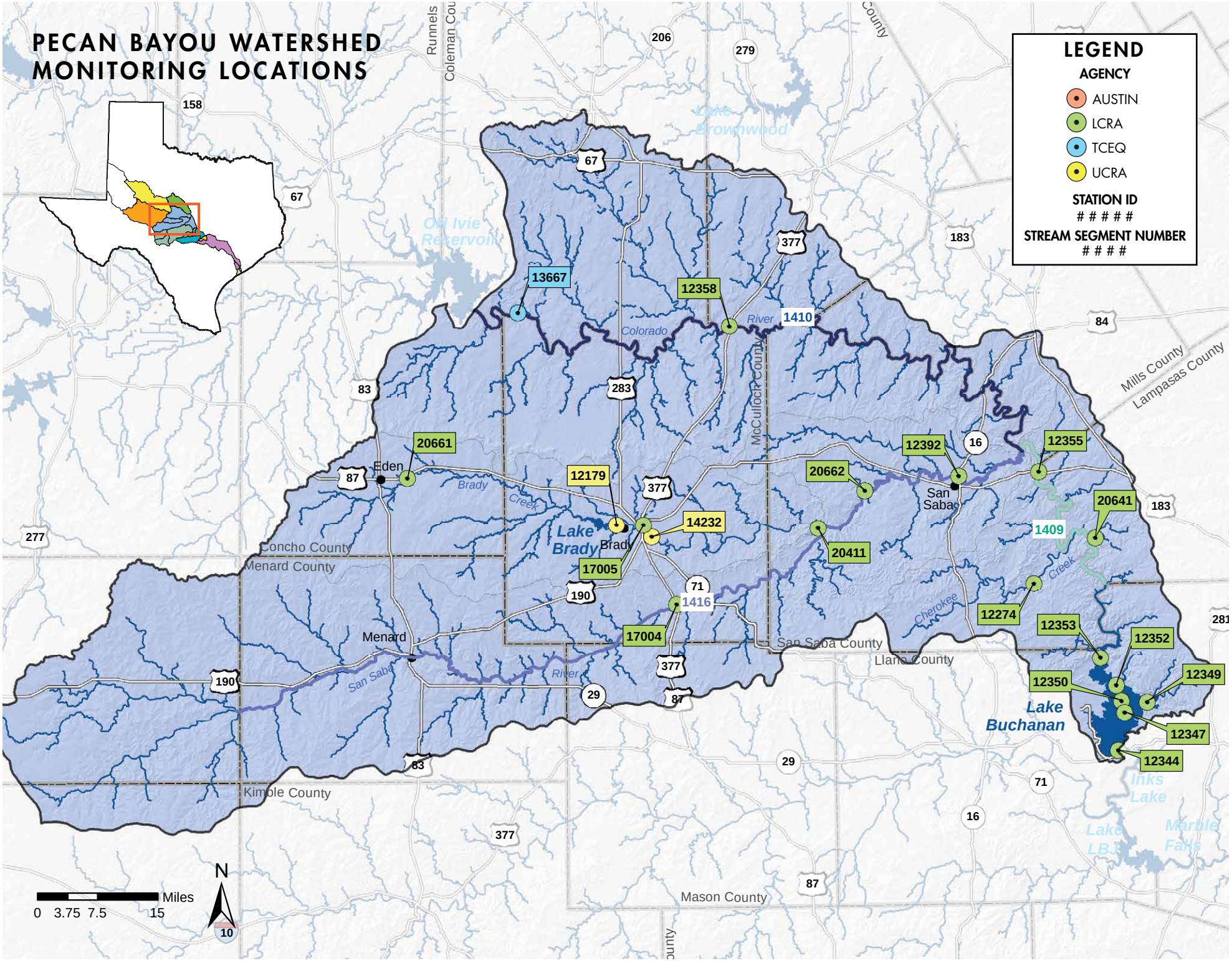
	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12508	C	-	I	M	M	M	M	C

Table 33. Summary of the 2014 Integrated Report / Segment 1432

M - Meets water quality standard
C - Concern for water quality standard
I - Impaired for water quality standard

Future Challenges for the Concho River Watershed

- Assignment of an aquatic life use designation for Segment 1431.
- Implementation of the Segment 1431 RUAA.


PECAN BAYOU WATERSHED
MONITORING LOCATIONS
LEGEND
AGENCY
AUSTIN
LCRA
TCEQ
UCRA
STATION ID
# # # # #
STREAM SEGMENT NUMBER
# # # #
13667
12358
1410
20661
12179
14232
17005
1416
17004
20662
12392
12355
20641
1409
20411
12274
12353
12352
12349
12350
12347
12344
Eden
Brady
Brady Creek
Lake Brady
Menard
San Saba River
Colorado River
Cherokee Creek
San Saba
Lake Buchanan
Lake Brownwood
Oak Ivie Reservoir
Inks Lake
Lake LBJ
Marble Falls
Concho County
Menard County
Kimble County
Mason County
San Saba County
Llano County
McCulloch County
Mills County
Lampasas County
Runnels County
Coleman County
Miles
0 3.75 7.5 15
N

LAKE BUCHANAN WATERSHED

Sixteen stations in the Lake Buchanan watershed were monitored from 2006 to 2016.

Segment 1408 – Lake Buchanan
Segment 1409 – Colorado River above Lake Buchanan
Segment 1410 – Colorado River below O.H. Ivie Reservoir
Segment 1416 – San Saba River
Segment 1416A and 1416B – Brady Creek, an unclassified tributary of the San Saba River

Watershed Characteristics

The Lake Buchanan watershed covers 5,650 square miles. It is situated mostly in the Central Great Plains and the Central Texas (Edwards) Plateau, with each ecoregion contributing slightly different characteristics to water quality. The Central Great Plains in the uppermost portion of the watershed historically has received about 20 inches of rain annually. Drought has decreased the amount of rainfall, and most of the streams in the region have flowed intermittently. Soils consist of sand and clays, which contribute to turbidity. In contrast, the Edwards Plateau, in the lower parts of the watershed, contains a sparse network of historically perennial streams that flow over granite and limestone substrates. Streams in this region are relatively clear, but many were dry until 2016 due to drought conditions.

Lake Buchanan and Buchanan Dam

SEGMENT SUMMARIES

Segment 1408 – Lake Buchanan

Lake Buchanan is an impoundment of the Colorado River in Burnet and Llano counties. With 22,335 surface acres, Buchanan is the largest of the Highland Lakes. Designated uses are fully supported with the exception of a concern for chlorophyll *a* levels in the uppermost portion of the lake. Data collected from Station 12353 had a mean of 54.5, almost double the screening level of 26.7. High chlorophyll *a* values are likely a result of reduced inflow and pooling at the upper end of the reservoir. Between August 2011 and August 2015, the station was not monitored because dry conditions made it inaccessible.

Data collected from four stations on the lake show increasing trends for chloride, sulfate and TDS. All trends were similar and remain well within TSWQS. Only Station 12344 is shown (Figure 55-57). The trend is a result of drought conditions from increased dissolved solids as the lake levels fell.

M - Meets water quality standard
C - Concern for water quality standard

Lake Buchanan

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12344	M	-	M	M	M	M	M	M
12347	M	-	M	M	M	M	M	M
12349	M	-	M	M	M	M	M	M
12350	M	-	M	M	M	M	M	M
12352	M	-	M	M	M	M	M	M
12353	M	-	M	M	M	M	M	C

Table 34. Summary of the 2014 Integrated Report / Segment 1408

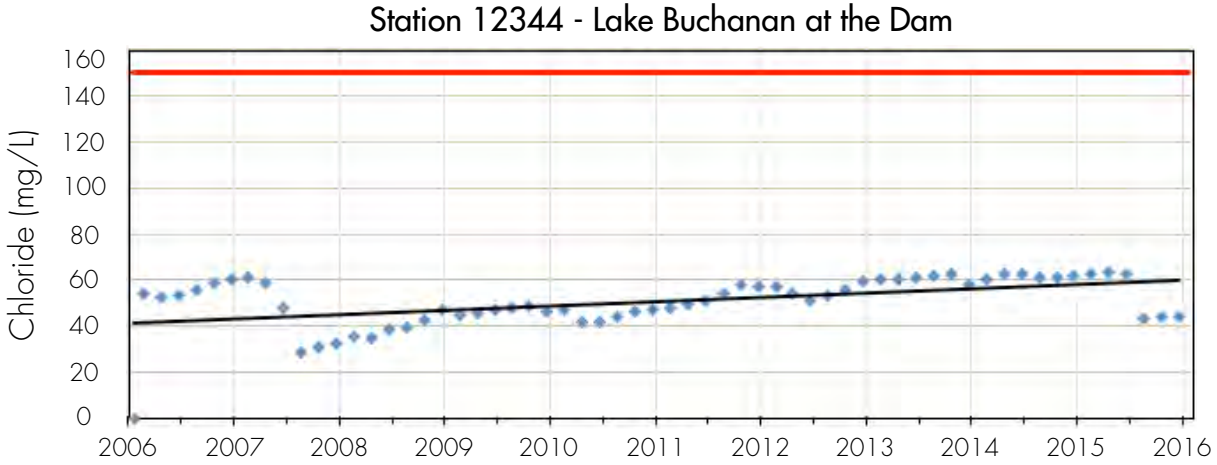


Figure 55. Chloride Trend / Lake Buchanan

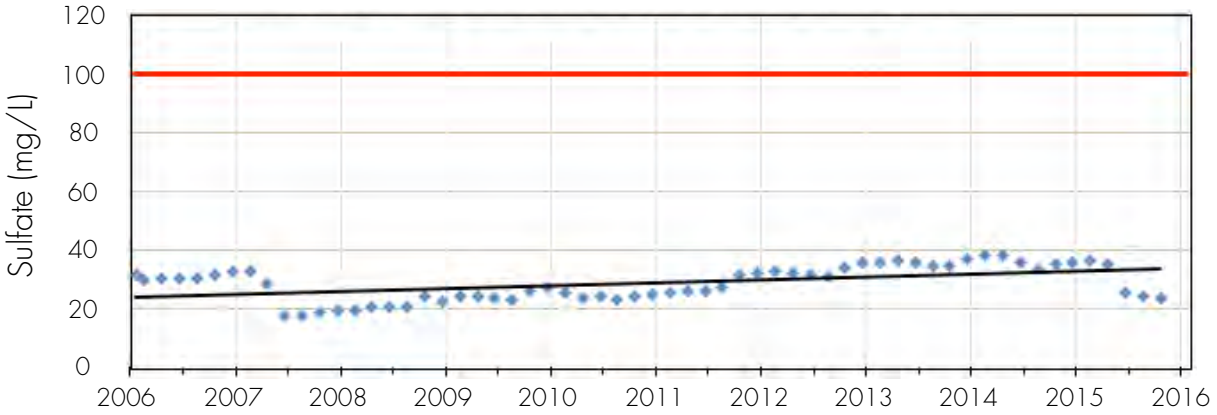


Figure 56. Sulfate Trend / Lake Buchanan

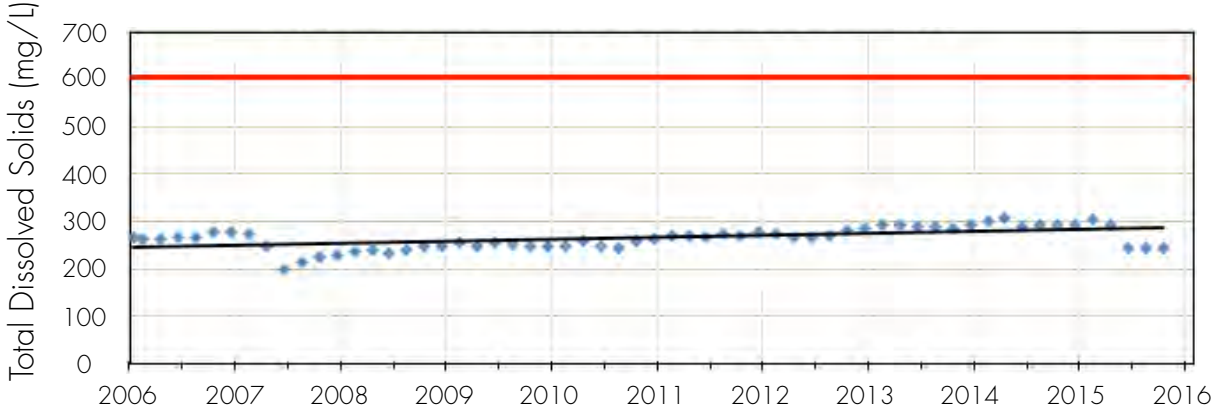
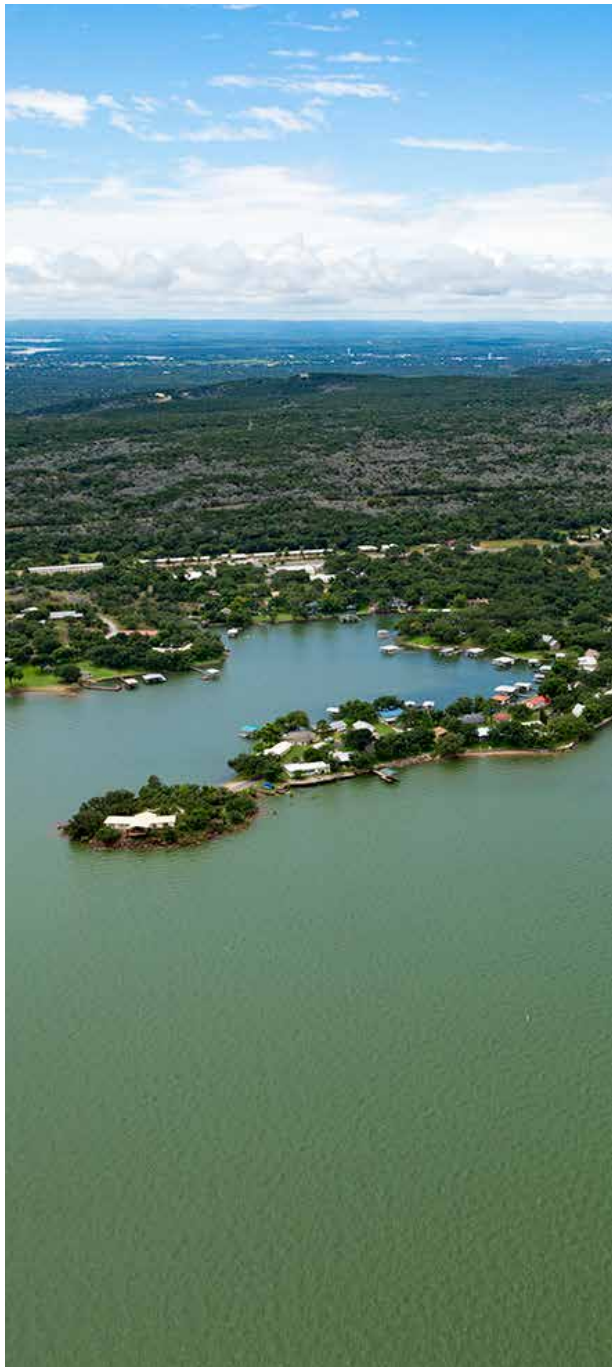


Figure 57. Total Dissolved Solids Trend / Lake Buchanan



Lake Buchanan

Segment 1409 – Colorado River Above Lake Buchanan

The Colorado River above Lake Buchanan is located between Lake Buchanan and the confluence of the San Saba and Colorado rivers in San Saba County. The segment is approximately 37 miles long. The upper reaches consist of pastures and irrigated cropland. Historically, chloride and TDS were diluted as the San Saba River and smaller perennial streams supplied freshwater into the Colorado River. During the drought, these historically perennial streams went dry, resulting in intermittent pools in the main stem of the Colorado River in Segment 1409. Despite the dry conditions, this stretch of the river met all designated uses, and there were no significant trends in the segment.

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12355	M	-	M	M	M	M	M	M
20641	M	M	M	M	M	M	M	M

M - Meets water quality standard

Table 35. Summary of the 2014 Integrated Report / Segment 1409

Colorado River upstream of Lake Buchanan during drought

Colorado River at the same site after drought

LCRA performed aquatic life monitoring in Segment 1409 upstream of Colorado Bend State Park. Samples of fish and benthic macroinvertebrates and habitat assessments were performed twice per year from 2010 to 2013.

Segment	Samples Collected	Station	Mean Benthic Macroinvertebrate Score	Mean Fish Score	Mean Habitat Score
12355	8	20641	High	High	High

Table 36. Summary of Routine Biological Monitoring / Segment 1409

Segment 1410 – Colorado River Below O.H. Ivie Reservoir

Colorado River below O.H. Ivie Reservoir is located between the confluence of the Colorado and San Saba rivers and the O.H. Ivie Reservoir Dam. The segment is approximately 138 miles long. Water is released from O.H. Ivie Reservoir and flows through farmland and ranches. Some of the water in this stretch of river is used for crop irrigation. The segment is monitored in two locations: Station 12358 at State Highway 377 and Station 13667 at FM 503.

Based on the 2014 Integrated Report, Segment 1410 fully supports its designated uses with the exception of a concern for high levels of chlorophyll *a*. The mean was reported at 45.5, three times the screening level of 14.1. High chlorophyll *a* values may be a result of stagnant water during persistent drought conditions. No statistically significant trends were detected from Station 12358. *E. coli* levels at Station 13667 decreased over time and remained well below the surface water quality standard.

M - Meets water quality standard
C - Concern for water quality standard

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12358	M	-	M	M	M	M	M	M
13667	M	-	M	M	M	M	M	C

Table 37. Summary of the 2014 Integrated Report / Segment 1410

LCRA biologists sample the Colorado River near Colorado Bend State Park.

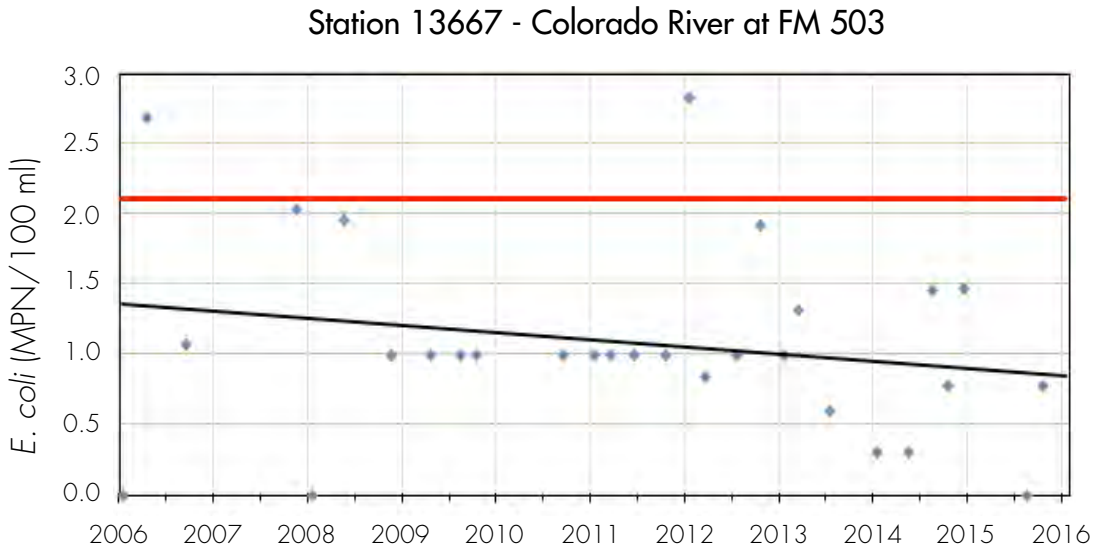


Figure 58. E. coli Trend / Segment 1410

Segment 1416 – San Saba River

The San Saba River begins in Schleicher County where the north and middle prongs of the San Saba River converge. It flows approximately 168 miles downstream to the confluence with the Colorado River in San Saba County. The San Saba River watershed is predominantly rural. Near its headwaters, flow is sparse and the landscape is natural, dotted with a few ranch houses among the oaks and mesquites along the river. As the river flows past the city of Menard, the landscape changes to irrigated hayfields and row crops. Downstream of Menard, the river winds through unimproved pastures and pecan orchards before reaching the city of San Saba and, ultimately, the Colorado River.

The San Saba River fully supports its general and aquatic life uses, according to TCEQ's 2014 Integrated Report. It does not support contact recreation based on *E. coli* data collected near the city of San Saba. The segment was first placed on the 303(d) List in 2008. Data collected since the original listing indicate that the water body continues to be impaired.

Sources of the impairment are unknown. There are no permitted discharges immediately upstream of the monitoring station. Potential causes include stormwater runoff from San Saba and agricultural and wildlife nonpoint sources. The bacteria impairment could most appropriately be addressed by a Watershed Protection Plan; however, local stakeholder interest has not been supportive of this approach to-date.

M - Meets water quality standard
I - Impaired for water quality standard

San Saba River at San Saba Nature Park

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12392	M	-	I	M	M	M	M	M
17004	M	-	M	M	M	M	M	M
20662	M	M	M	M	M	M	M	M

Table 38. Summary of the 2014 Integrated Report / Segment 1416

Segment	Samples Collected	Station	Mean Benthic Macroinvertebrate Score	Mean Fish Score	Mean Habitat Score
1416	8	20662	Exceptional	Exceptional	High

Table 39. Summary of Routine Biological Monitoring / San Saba River

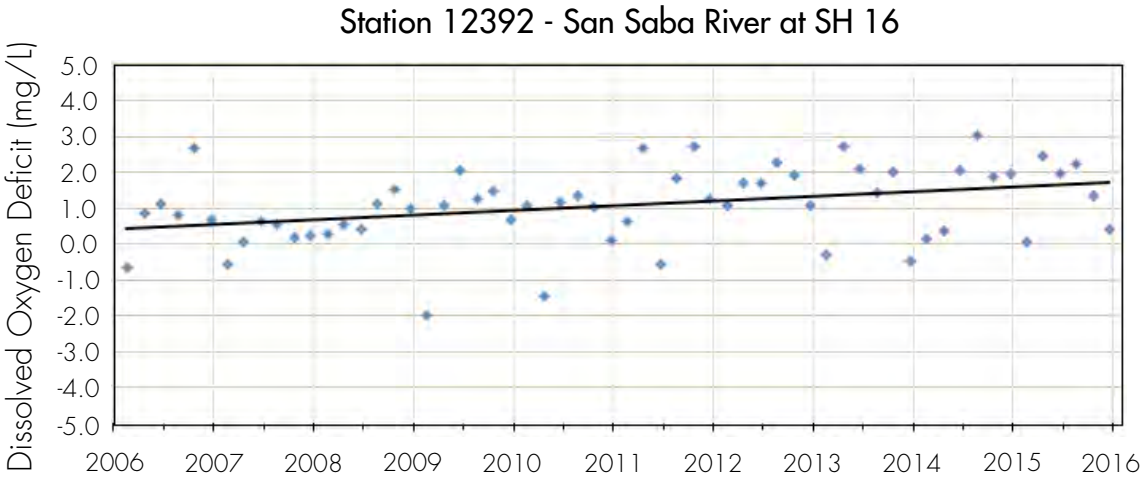


Figure 59. Dissolved Oxygen Deficit Trend / San Saba River

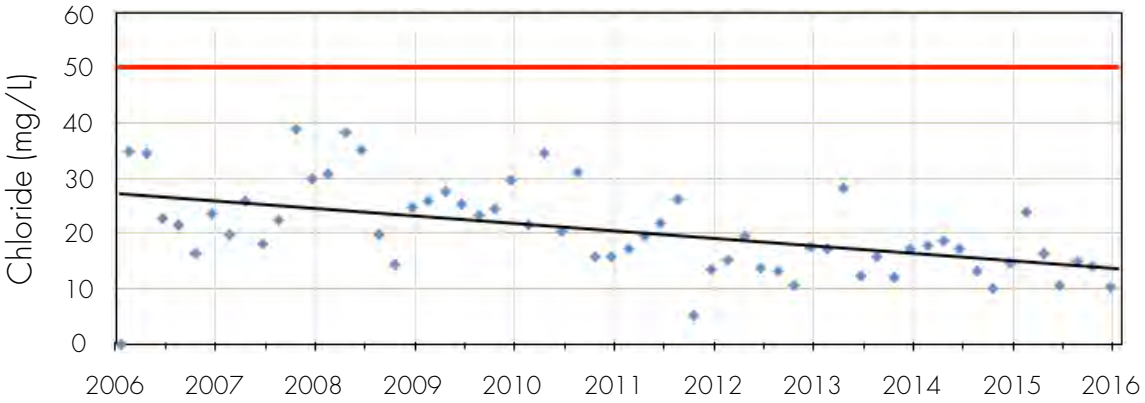


Figure 60. Chloride Trend / San Saba River

LCRA performed aquatic life monitoring in Segment 1416 upstream of San Saba. Samples of fish and benthic macroinvertebrates and habitat assessments were collected twice per year from 2010 to 2013.

Data from Station 12392 showed an increasing trend for dissolved oxygen deficit (Figure 59) and a decreasing trend for chloride (Figure 60). The oxygen deficit can be explained by reduced flows during the drought. The cause of the decrease in chloride is unknown and curious because chlorides would be expected to increase with decreasing flows.

LCRA biologists capture, identify, and count fish before releasing them back into the San Saba River.

Segments 1416A and 1416B – Brady Creek

The Brady Creek watershed encompasses about 784 square miles. It is primarily rural with much of the upper portion used for agriculture. Brady Creek is 90 miles long. The TCEQ has divided the stream into three unclassified water bodies for assessment purposes. Segment 1416A is between the confluence with the San Saba River and the Brady Creek Reservoir Dam. This reach is spring-fed with perennial flows. Segment 1416B is Brady Creek Reservoir, a 2,000-acre reservoir used for water supply and recreation. Segment 1416C is Brady Creek upstream of Brady Reservoir. This section of the creek has little riparian vegetation, and flows are intermittent. Brady Creek is routinely monitored in Segment 1416A at Station 14232 and Segment 1416B (Brady Creek Reservoir) at Station 12179.

Brady Creek fully supports its general and contact recreation uses, according to TCEQ's 2014 Integrated Report. Aquatic life use is not supported. It was first placed on the 2004 303(d) List based on low levels of dissolved oxygen collected from Station 17005, an abandoned monitoring station in Brady. The 2004 listing, which was based on grab samples, was confirmed through 24-hour monitoring, and the creek remains on the 2014 303(d) List. The 2014 Integrated Report also identified concerns for elevated levels of chlorophyll *a*, total phosphorus and nitrate.

M - Meets water quality standard
C - Concern for water quality standard
I - Impaired for water quality standard

Brady Creek near the confluence with the San Saba River

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
14232	M	-	M	M	M	M	C	C
12179	I	-	M	M	M	M	M	C

Table 40. Summary of the 2014 Integrated Report / Segment 1416

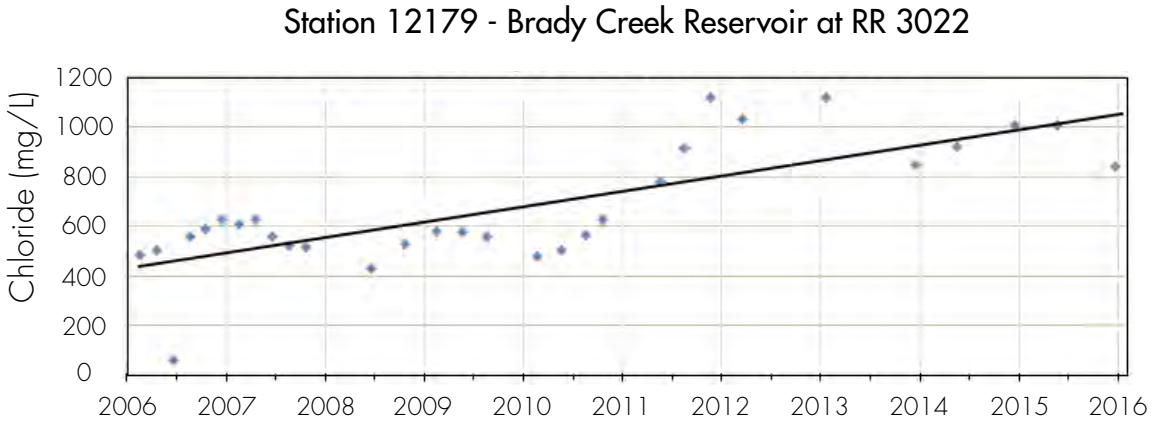


Figure 61. Chloride Trend / Brady Creek

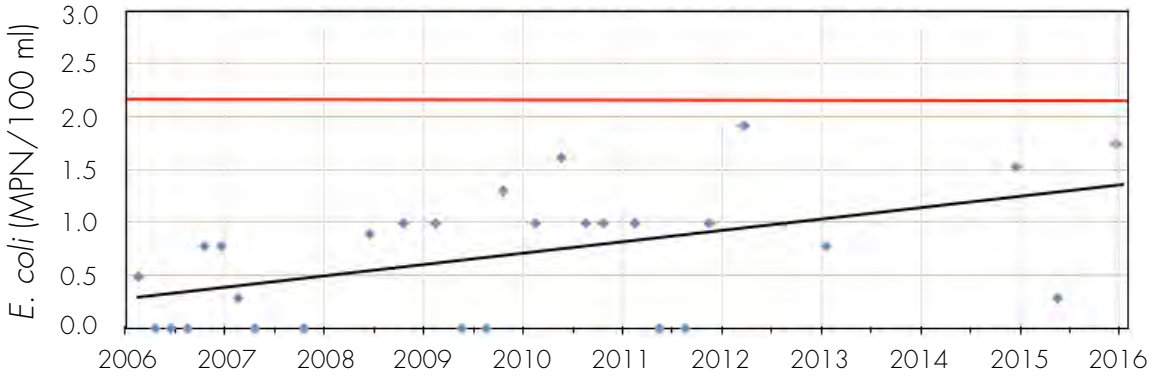


Figure 62. E. coli Trend / Brady Creek

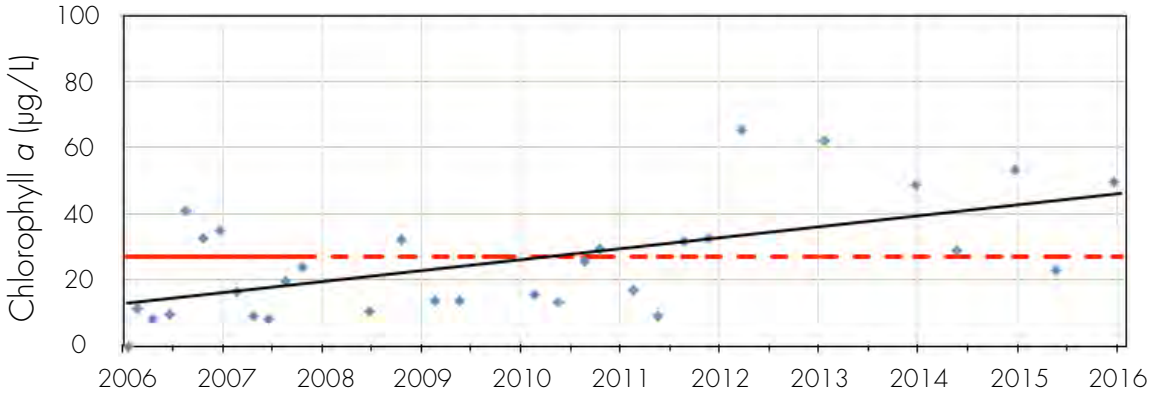


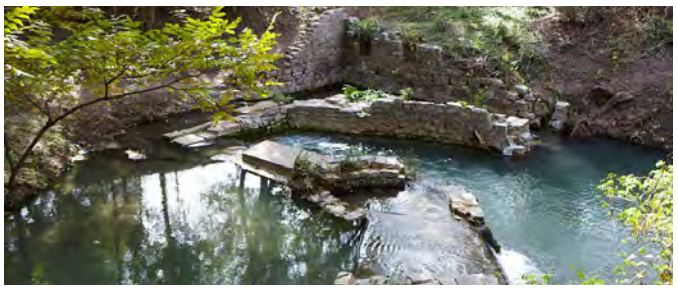
Figure 63. Chlorophyll a Trend / Brady Creek

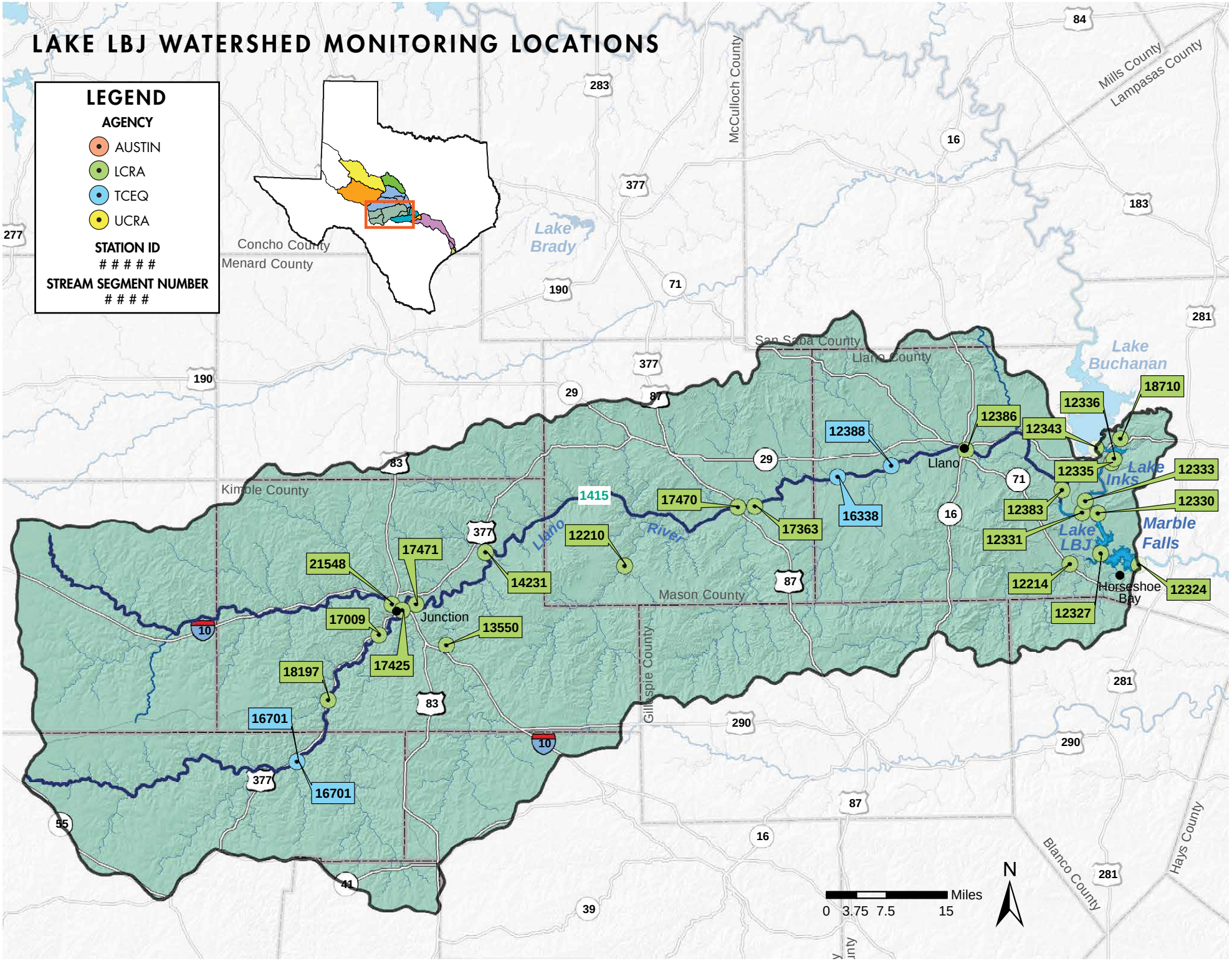
In 2010, UCRA received a Clean Water Act 319(h) grant from the TCEQ to develop the Brady Creek Watershed Protection Plan (WPP). The stakeholder-driven initiative identified stormwater runoff from the City of Brady as a source of the impairment. The WPP was submitted to the TCEQ in September 2014, resubmitted with corrections in August 2015, and approved by the EPA in August 2016. The UCRA is seeking funding to begin the first phase of programming identified in the plan.

Trend analysis showed a statistically significant increase in chloride, *E. coli* and chlorophyll *a* concentrations in Brady Creek Reservoir (Figures 61 - 63). The cause of the chloride and chlorophyll *a* increases is likely the prolonged drought conditions and low reservoir levels. The cause of the increasing bacteria is unknown.

Future Challenges for the Lake Buchanan Watershed

- San Saba River bacteria impairment.
- Elevated nutrient and chlorophyll *a* levels in segments 1408, 1410, 1416A and 1416B.
- Implementation of the Brady Creek WPP.




LAKE LBJ WATERSHED MONITORING LOCATIONS
LEGEND
AGENCY
AUSTIN
LCRA
TCEQ
UCRA
STATION ID
# # # # #
STREAM SEGMENT NUMBER
# # # #
Concho County
Menard County
McCulloch County
Mills County
Lampasas County
Lake Brady
San Saba County
Llano County
Lake Buchanan
Lake Inks
Lake LBJ
Marble Falls
Horseshoe Bay
Llano
Kimble County
Mason County
Gillespie County
Junction
Blanco County
Hays County
1415
Llano River
18710
12336
12386
12343
12388
12335
12333
12383
12330
12331
12214
12324
12327
17470
17363
16338
12210
17471
21548
14231
17009
13550
17425
18197
16701
16701
N
Miles
0 3.75 7.5 15

LAKE LBJ WATERSHED

Twenty four stations in the Lake LBJ watershed were monitored from 2006 to 2015.

Segment 1406 – Lake LBJ
Segment 1407 – Inks Lake
Segment 1407A – Clear Creek
Segment 1415 – Llano River

Watershed Characteristics

The Lake LBJ watershed begins where the Colorado River is released from Buchanan Dam in Burnet and Llano counties. Immediately below Buchanan Dam, the river flows into the headwaters of Inks Lake, a pass-through reservoir with little detention time. Below Inks Dam, the river flows about 10 miles to the community of Kingsland, where it merges with the Llano River before flowing into Lake LBJ.

The 5,000-square-mile watershed is entirely within the Edwards Plateau. Steep hills with rock and limestone substrate create clear, cool, fast-flowing streams like the Llano and James rivers. Perennial streams in the watershed are spring-fed and typically more alkaline because of the limestone geology. Severe drought during the reporting period dramatically decreased stream flows in the watershed.

Horseshoe Bay on Lake LBJ

SEGMENT SUMMARIES

Segment 1406 – Lake LBJ

Lake LBJ is impounded where the Colorado and Llano rivers converge in Burnet and Llano counties. The 6,256-acre reservoir was completed in 1950 to supply hydroelectric power to the area. Granite Shoals, Sunrise Beach, Horseshoe Bay and Kingsland are growing communities that surround the lake. Development around the lake has the potential to impact water quality through increased impervious cover. The Highland Lakes Watershed Ordinance and the On-Site Sewage Facility Ordinance, which are administered by LCRA, help reduce the impact of development on water quality.

Water quality in the lake remains good. The 2014 Integrated Report identified a concern for low dissolved oxygen levels at the dam. However, this is a function of lake mixing – a natural phenomenon that can periodically cause dissolved oxygen levels to drop as deep, cold, oxygen-depleted water rises and mixes into the water column.

Lake LBJ

Data collected from two stations in Lake LBJ indicate an increasing trend for total Kjeldahl nitrogen (TKN) and a decreasing trend for total suspended solids (TSS) (Figures 64 and 65). Both likely were caused indirectly by the drought and significantly reduced inflows.

M - Meets water quality standard
C - Concern for water quality standard

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12324	C	-	M	M	M	M	M	M
12327	M	-	M	M	M	M	M	M
12330	M	-	M	M	M	M	M	M
12331	M	-	M	M	M	M	M	M
12333	M	-	M	M	M	M	M	M

Table 41. Summary of the 2014 Integrated Report / Segment 1406

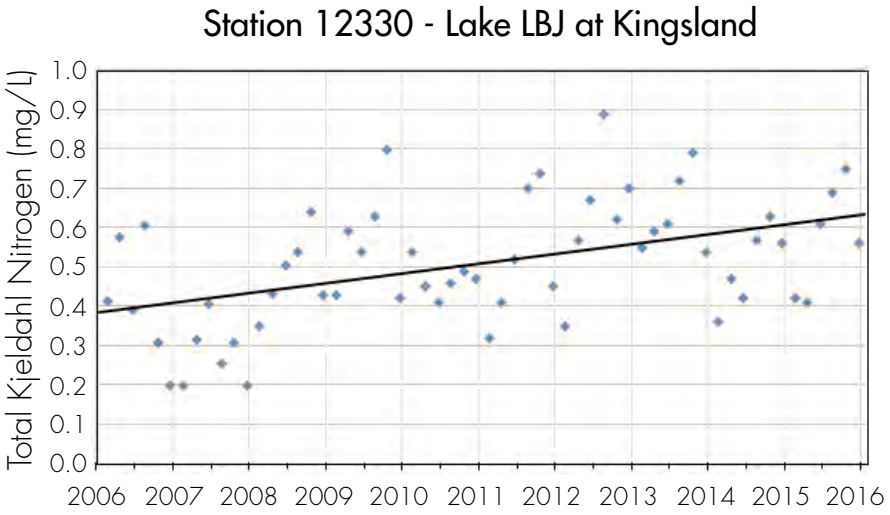


Figure 64. TKN Trend / Lake LBJ

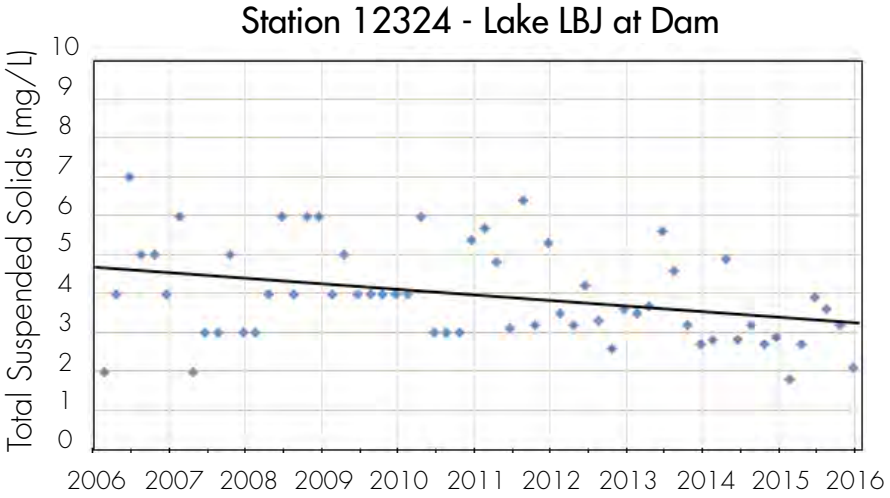


Figure 65. Total Suspended Solids Trend / Lake LBJ

Highland Lakes Watershed Ordinance

Stormwater runoff carries pollution – pesticides, soil, nutrients, toxics and other residues from everyday human activities. LCRA actively manages stormwater runoff around the Highland Lakes through the Highland Lakes Watershed Ordinance. Through a permitting process, the ordinance requires developers and other permittees to stabilize land and minimize sediment migration. Water quality is protected by limiting stormwater runoff, creating buffer zones and installing erosion and sediment controls. New quarries and mines also are covered under the HLWO and must implement measures similar to other development.

During the five-year period from 2012 to 2016, LCRA issued 175 development permits, two dredge and fill permits, one quarry/mine permit and 10 utility permits under the HLWO. HLWO Program staff performed 4,362 construction inspections of permit sites and 1,738 construction inspections of smaller non-permit (dredge and fill projects of less than 500 feet in length and less than 500 cubic yards). These inspections involve verifying the proper installation and maintenance of temporary erosion and sediment controls, ensuring compliance with creek buffer zones, ensuring proper construction of engineered water quality management facilities, and ensuring that construction sites are stabilized upon project completion.

In 2013, LCRA initiated a stakeholder process to update the Highland Lakes Watershed Ordinance which resulted in the third amendment to the rrdinance (effective Feb. 19, 2014) and also increased permit and inspection fees to cover costs of administering the program that had not been changed since the original ordinance adoption in 1990. In 2016, LCRA created an online permitting management software system to improve customer service and enable applicants to apply for permits, track permit review status and obtain inspection results online.

On-Site Sewage Facility Ordinance

Septic systems are an integral part of rural America. They can be an efficient way to remove household waste and protect the environment when properly designed and maintained. The TCEQ delegated authority to LCRA in September 1971 to regulate the installation and operation of on-site sewage facilities around the upper Highland Lakes. Regulating over 21,000 systems in a four-county area ensures the best available technology is used to treat septic wastes so pollutants such as phosphorus and nitrogen don't leach into the Highland Lakes.

Segment 1407 – Inks Lake

Inks Lake is a 777-acre impoundment on the Colorado River just downstream of Buchanan Dam. Monitoring data indicate the lake supports its designated uses, but concerns for low dissolved oxygen and manganese in sediment have been identified by the TCEQ. Releases of water from the bottom of Lake Buchanan are the cause of low dissolved oxygen. The source of manganese in sediments is not known but, like Lake Brownwood, natural sources are suspected.

Chloride, sulfate and TDS increased slightly. Only the chloride trend is shown (Figure 68). All trends were similar and remain well within TSWQS. The trend is a result of drought conditions when there was a reduction to the inflows into the lake.

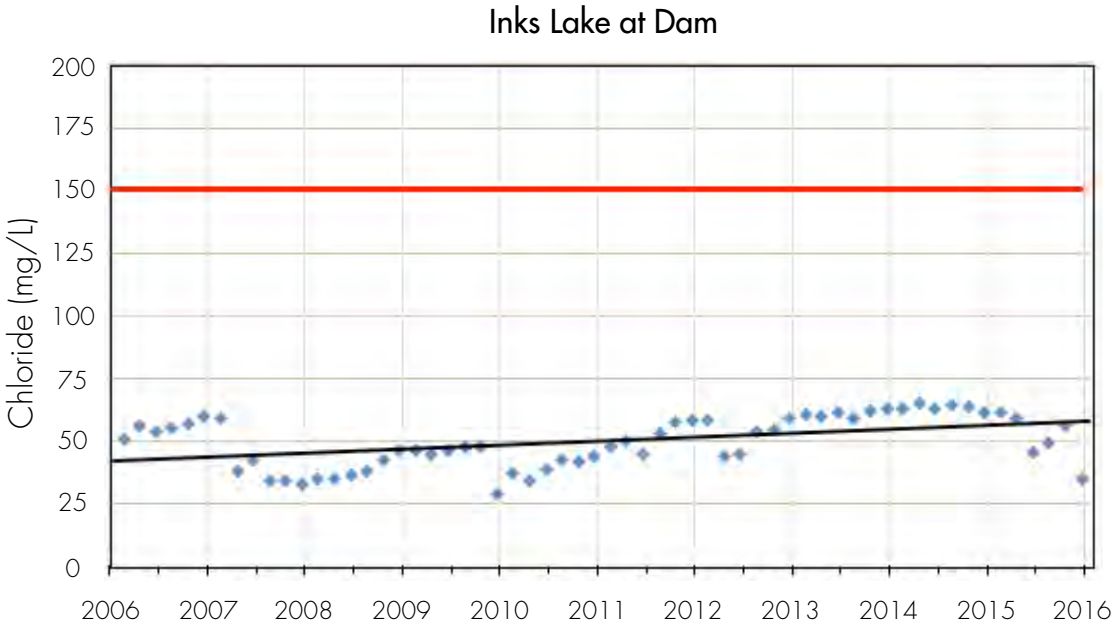
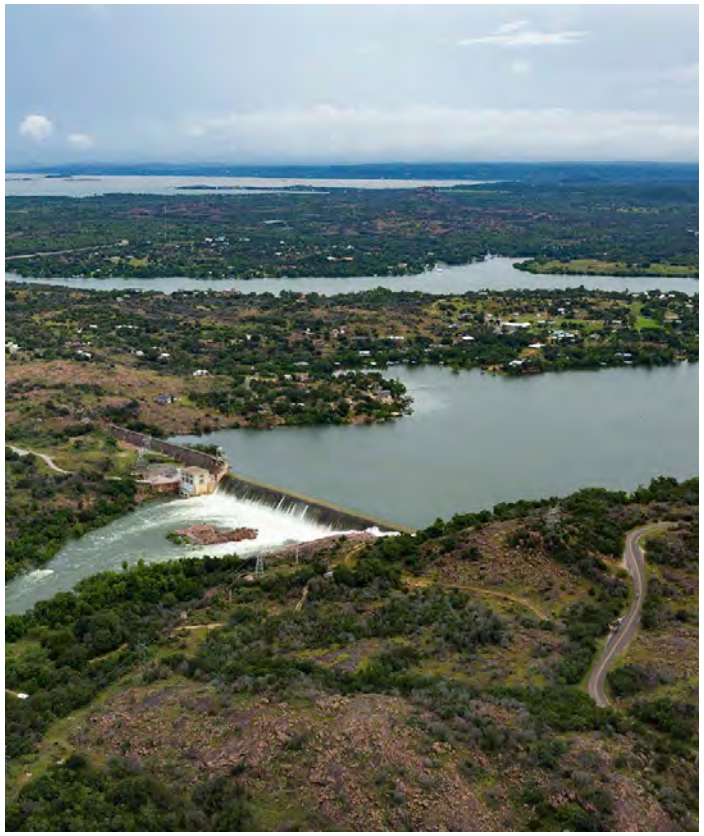


Figure 66. Chloride Trend / Inks Lake



Inks Lake at Inks Dam

M - Meets water quality standard
C - Concern for water quality standard

	Aquatic Life			Recreation	General				
Station ID	Dissolved Oxygen	Biology	Metals	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12358	C	-	C	M	M	M	M	M	M

Table 42. Summary of the 2014 Integrated Report / Segment 1407

Segment 1407A – Clear Creek

Clear Creek is an intermittent tributary of Inks Lake. The creek is about 4.5 miles long, and its watershed is comprised mostly of ranchland. However, a 23-acre tailings pile – a remnant of an abandoned graphite mine – is located on the banks of the creek, and it is the source of pH, TDS, sulfate and aluminum impairments. Stormwater runoff from the pile results in acid mine drainage.

Mining operations began in 1915. The property has had several owners, and currently it is owned by Greensmiths Inc., which purchased the facility in 2000 and began using reclaimed tailings materials to landscape golf courses. Greensmiths has engineered best management practices (BMPs) to prevent runoff and improve water quality in Clear Creek. Monitoring by the TCEQ and LCRA is ongoing to determine if BMPs have effectively contained stormwater to prevent contaminated runoff. There were not enough data to perform a trend analysis on Clear Creek because the creek is often dry.

M - Meets water quality standard
I - Impaired for water quality standard

	Aquatic Life			Recreation	General				
Station ID	Dissolved Oxygen	Biology	Metals	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
18710	M	-	I	M	M	I	I	M	M

Table 43. Summary of the 2014 Integrated Report / Clear Creek

Measuring water quality at Clear Creek

Salts remain after drought

Segment 1415 – Llano River

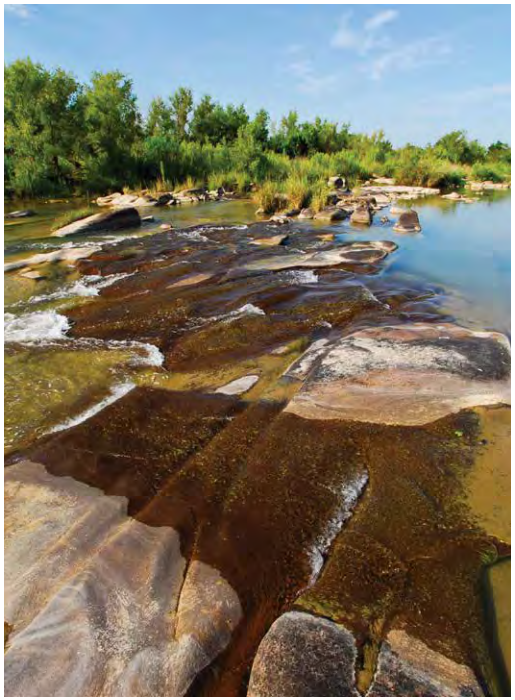
The Llano River begins in Junction where the North Llano and South Llano rivers converge. The river, including the north and south forks, is approximately 231 miles long. Both streams are spring-fed from the Edwards-Trinity Aquifer, and they continued to flow during the drought.

Below Junction, the Llano River flows east to the town of Llano. This area, known as the Llano Uplift, contains granite and limestone outcrops that produce clear, fast-flowing streams. Below the town of Llano, the river flows into the Colorado River and the headwaters of Lake LBJ.

The Llano River watershed remains largely rural. Soils and geology in the watershed lend themselves to ranching more than farming. There are fewer irrigated fields compared to the surrounding watersheds. Monitoring data collected between 2006 and 2016 indicate the river supports its designated uses. Station 14231 showed a decreasing trend for sulfate. E.coli at the same site is trending upward and is near the 126 CFU criteria. The causes of the trends are unknown.

Segment	Samples Collected	Station	Mean Benthic Macroinvertebrate Score	Mean Fish Score	Mean Habitat Score
12355	8	20641	High	High	High

Table 45. Summary of Routine Biological Monitoring / Llano River



Llano River

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12383	M	-	M	M	M	M	M	M
12386	M	-	M	M	M	M	M	M
12388	M	-	M	M	M	M	M	M
14231	M	-	M	M	M	M	M	M
16701	M	-	M	M	M	M	M	M
17425	M	-	M	M	M	M	M	M
17470	M	-	M	M	M	M	M	M
17471	M	-	M	M	M	M	M	M
18197	M	-	M	M	M	M	M	M
21548	M	-	M	M	M	M	M	M

M - Meets water quality standard Table 44. Summary of the 2014 Integrated Report / Llano River

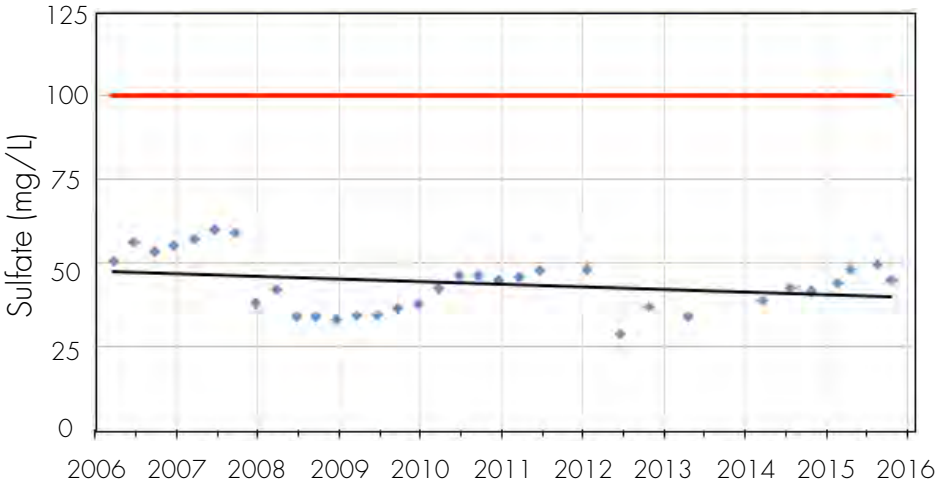


Figure 67. Sulfate Trend / Llano River

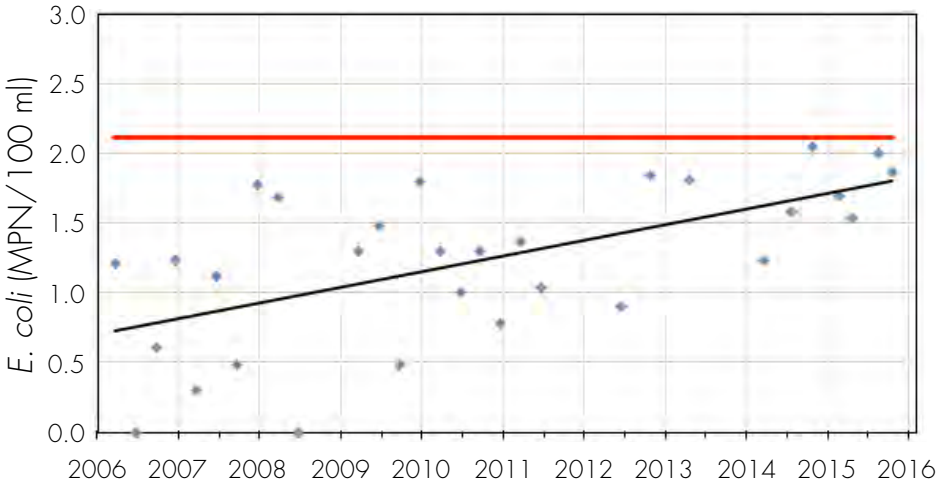


Figure 68. E. coli Trend / Llano River

Llano River Watershed Protection Plan

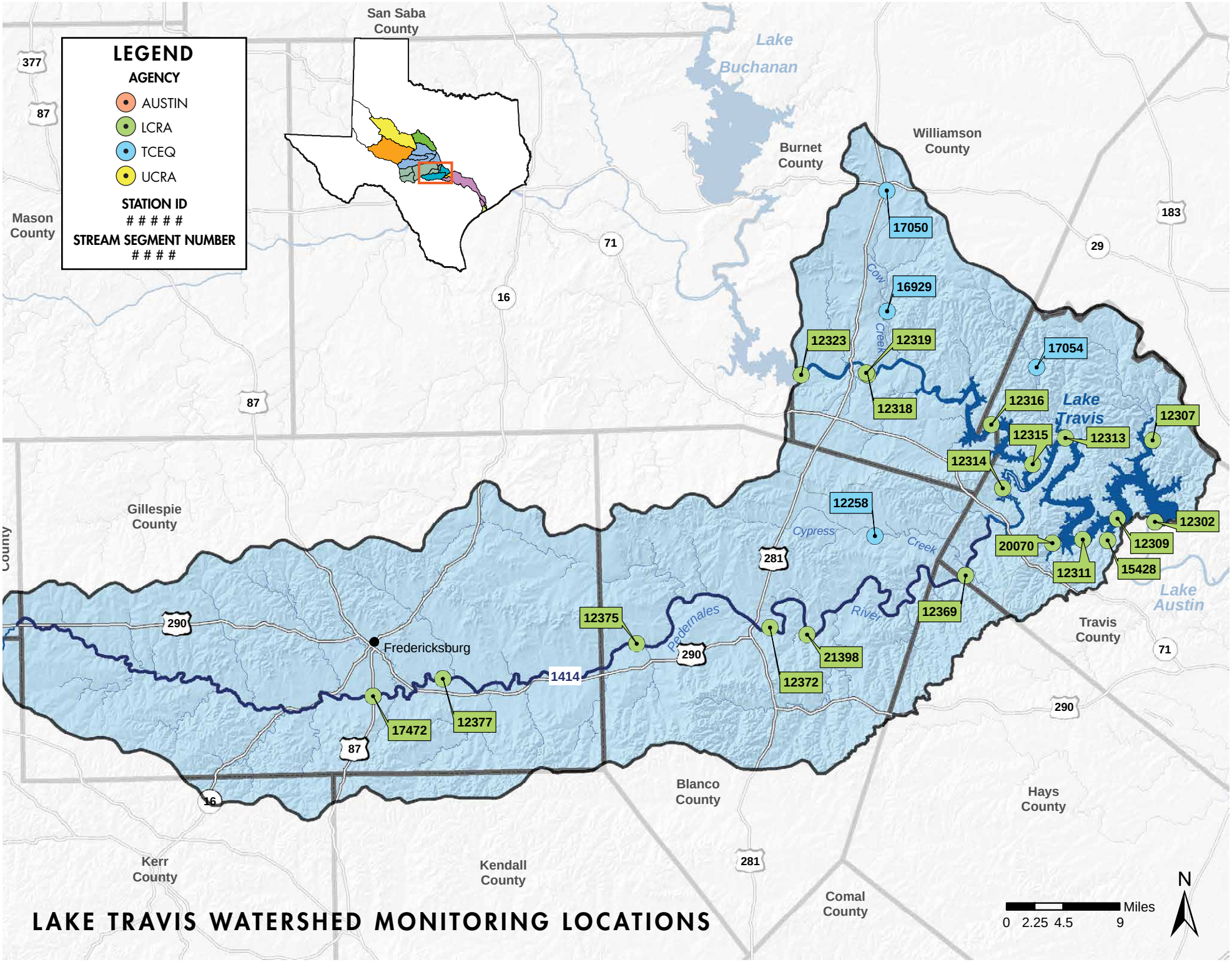
In 2011, the Texas State Soil and Water Conservation Board (TSSWCB) and TPWD began work on the Upper Llano River Watershed Protection Plan. Guided by EPA's Healthy Watersheds Initiative, the two agencies worked with the Llano River Watershed Alliance and other stakeholders to characterize historical and current water quality conditions. The project developed models to help educate the public about water quality in the watersheds.

Stakeholders identified loss of spring flow, spread of invasive species and potential for declines in water quality and stream flows as their primary concerns. The resulting plan outlines strategies for implementing water quality management plans, wildlife habitat management, feral hog management and septic system education and outreach. The plan was approved by the EPA in 2016, and the group is working to secure funding to implement the strategies. The plan can be viewed at http://www.llanoriver.org/watershed-protection-plan.

Future Challenges for the Lake LBJ Watershed

- Continued development, an increase in impervious cover and the potential for increase in nonpoint-source pollution.
- Implementation of the Llano River WPP.

LCRA and TCEQ biologists seine for fish in the Llano River



LAKE TRAVIS WATERSHED MONITORING LOCATIONS

LAKE TRAVIS WATERSHED

Twenty stations in the Lake Travis Watershed were monitored from 2006 to 2016.

Segment 1404 – Lake Travis
Segment 1405 – Lake Marble Falls
Segment 1414 – Pedernales River
Segment 1414B – Cypress Creek

Watershed Characteristics

Located in the Texas Hill Country, the Lake Travis watershed, including the Pedernales River and lakes Travis and Marble Falls, is approximately 1,830 square miles. The watershed lies within the Edwards Plateau, a region distinguished by rocky terrain and clear perennial streams. Growth and development have dramatically changed the landscape in the region over the past 20 years.

Lack of rainfall since 2008 lowered Lake Travis to levels not seen since the drought of record during the 1950s. Inflows to the Highland Lakes in 2013 were the second lowest on record; 2011 and 2008 were first and third, respectively. Lake Travis and other Central Texas lakes began to fill as a result of floods and increased rainfall in the region late in 2015 and into 2016.

Lake Travis

SEGMENT SUMMARIES

Segment 1404 – Lake Travis

Mansfield Dam impounds Lake Travis on the Colorado and Pedernales rivers in western Travis County. The reservoir, which is about 18,929 surface acres, originally was designed to contain floodwaters. It is one of the clearest reservoirs in Texas and is a popular recreation destination.

Monitoring data from stations near Lakeway indicate a concern for low dissolved oxygen. First noted in the TCEQ 2010 Integrated Report, it is likely a result of lake mixing – a natural phenomenon that can cause dissolved oxygen levels to temporarily drop as cold, oxygen-depleted water rises from the bottom and mixes into the water column.

Trend analysis on Lake Travis showed an increase in salts in five of the nine water monitoring stations on Lake Travis. Chloride, sulfate or TDS concentrations trended higher at stations 20070, 12313, 15428, 12307 and 12302. The trend is a function of low lake levels during the drought as demonstrated by the decreasing values after significant rains raised lake levels in 2015 at Station 15428 (Figure 69). Values for each of the salt parameters remain well below the criteria at all stations.

M - Meets water quality standard
C - Concern for water quality standard

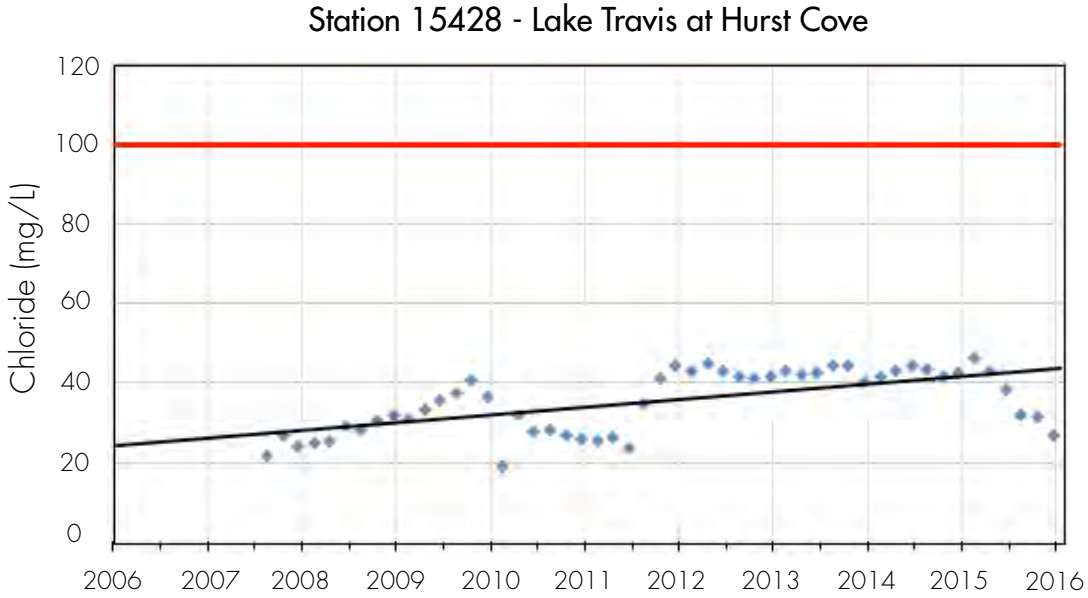


Figure 69. Chloride Trend / Lake Travis

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12302	M	-	M	M	M	M	M	M
12307	M	-	M	M	M	M	M	M
12309	C	-	M	M	M	M	M	M
12311	M	-	M	M	M	M	M	M
12313	M	-	M	M	M	M	M	M
12315	C	-	M	M	M	M	M	M
12316	M	-	M	M	M	M	M	M
15428	M	-	M	M	M	M	M	M
20070	C	-	M	M	M	M	M	M

Table 46. Summary of the 2014 Integrated Report / Llano River

Mansfield Dam at Lake Travis / 2016

Colorado River Environmental Models

Ongoing LCRA initiatives to protect the lake include the Highland Lakes Watershed Ordinance and the Colorado River Environmental Models (CREMS). The watershed ordinance (see LBJ Watershed Summary) manages nonpoint-source pollution around the lake, and CREMS is a modeling tool used to determine how various development scenarios impact water quality.

Stricter management of water supply and river flows, increasing pollution loads brought about by a growing population, and greater regulatory pressures all require sophisticated management and analysis of water data. CREMS is a system of integrated computer-based models and data sets developed to help LCRA manage the Highland Lakes and the lower Colorado River system. CREMS serves as part of a decision support system that facilitates decision-making for analyzing the water quality impacts of discharge permits, nutrient loading, stream and reservoir standards, water supply planning, implications or growth and development, and nonpoint-source pollution issues.

LCRA has used model outputs to help the cities of Burnet and Fredericksburg develop more protective discharge limits for their wastewater treatment plant and provided invaluable information that helped manage water supplies during the drought. LCRA will continue to develop the models as lake conditions change, and work with the Highland Lakes communities to develop reasonable treatment options that protect water quality. For more information on CREMS, visit lcra.org/water/quality/water-quality-permit-review-program/pages/water-quality-models.aspx.

Segment 1405 – Lake Marble Falls

Max Starcke Dam forms Lake Marble Falls on the Colorado River near the town of Marble Falls. With a surface area of 545 acres, it is the smallest reservoir in the chain of Highland Lakes.

All water quality standards were attained and no statistically significant trends were found for Lake Marble Falls.

M - Meets water quality standard

Lake Marble Falls

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12319	M	-	M	M	M	M	M	M

Table 47. Summary of the 2014 Integrated Report / Segment 1405

Segment 1414 – Pedernales River

The headwaters of the Pedernales River are located near Harper in Kimble County. The river flows east through Fredericksburg, Stonewall and Johnson City before reaching the mouth of Lake Travis. It is approximately 125 miles long. In the upper reaches, it is intermittent. Occasional, intense thunderstorms over the watershed create heavy rainfall that dramatically increases flow in the river. These surges of water typically transport large amounts of silt and organic debris downstream and into Lake Travis.

M - Meets water quality standard

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12369	M	-	M	M	M	M	M	M
12372	M	-	M	M	M	M	M	M
12375	M	-	M	M	M	M	M	M
12377	M	-	M	M	M	M	M	M
17472	M	-	M	M	M	M	M	M
21398	M	-	M	M	M	M	M	M

Table 48. Summary of the 2014 Integrated Report / Pedernales River

Segment 1414 – Pedernales River (cont.)

Monitoring data collected from stations near Harper, Fredericksburg and Johnson City show the river meets all applicable water quality standards.

Trend analysis indicated a decrease in chloride (Figure 70), sulfate and TDS on the Pedernales River near Hammett's Crossing.

Monitoring data showed increasing bacteria levels at stations 17472 and 12375 (Figures 71 and 72). The cause of the trend is unknown, but the trend line indicates both stations are approaching the state criteria of 126 MPN. The trend may be drought-related.

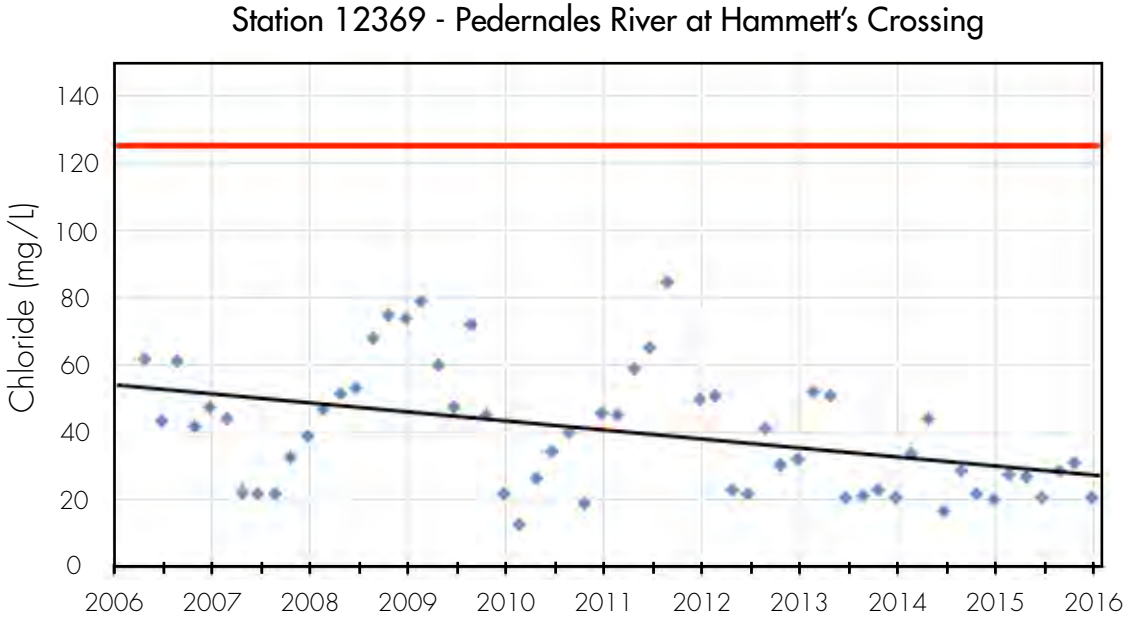
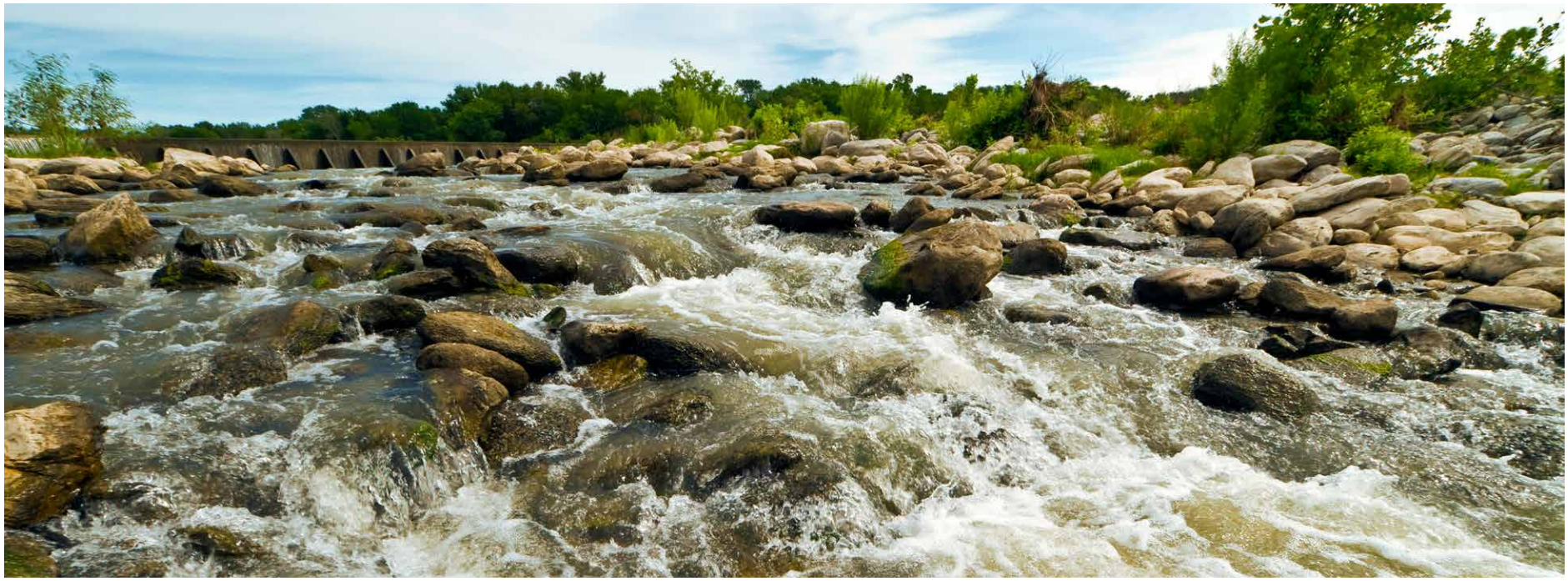


Figure 70. Chloride Trend / Pedernales River



Pedernales River in Blanco County

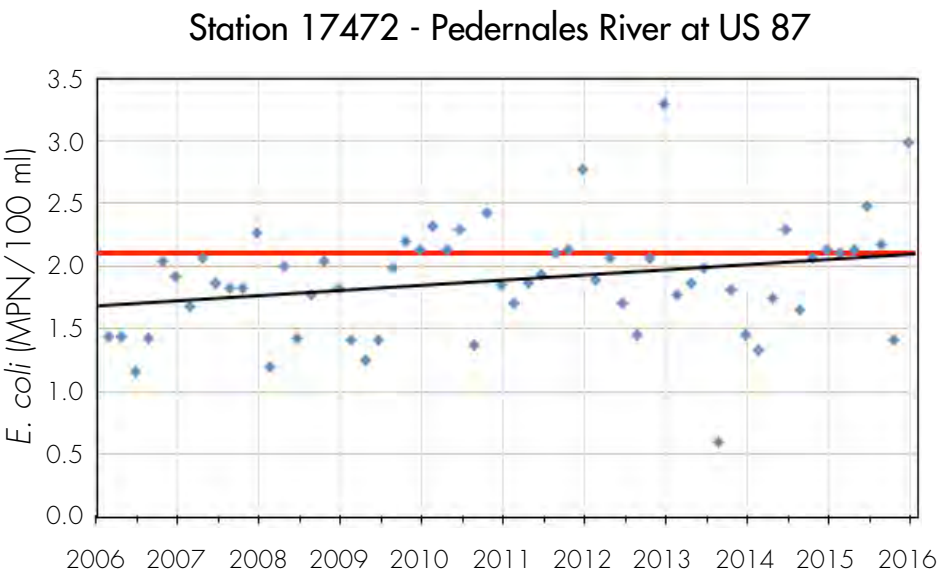


Figure 71. E. coli Trend / Pedernales River

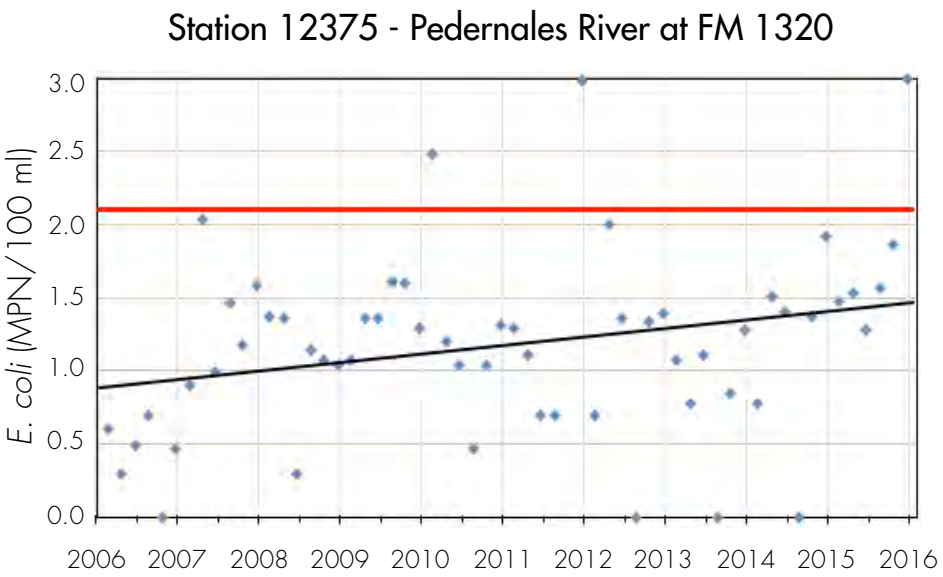


Figure 72. E. coli Trend / Pedernales River

Segment 1414B – Cypress Creek

Cypress Creek is a tributary of the Pedernales River near the confluence with Lake Travis. The stream is about 23 miles long, and historically has flowed year-round due to springs in the area. Intermittent flows have been recorded since the start of the drought in 2008. Water quality samples collected by the TCEQ from Station 12258 show the river meets all applicable water quality standards.

Bacteria levels have increased over time in Cypress Creek. Wildlife or livestock may be sources, but the reduced flow during the drought is a likely cause of the increasing trend. While the bacteria levels have not triggered an impairment, they are close to the state criteria, and they will exceed water quality standards if the trend continues over the next few years. TDS in Cypress Creek also increased. Despite the increase, TDS remains well below the criteria.

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12258	M	-	M	M	M	M	M	M

M - Meets water quality standard

Table 47. Summary of the 2014 Integrated Report / Cypress Creek

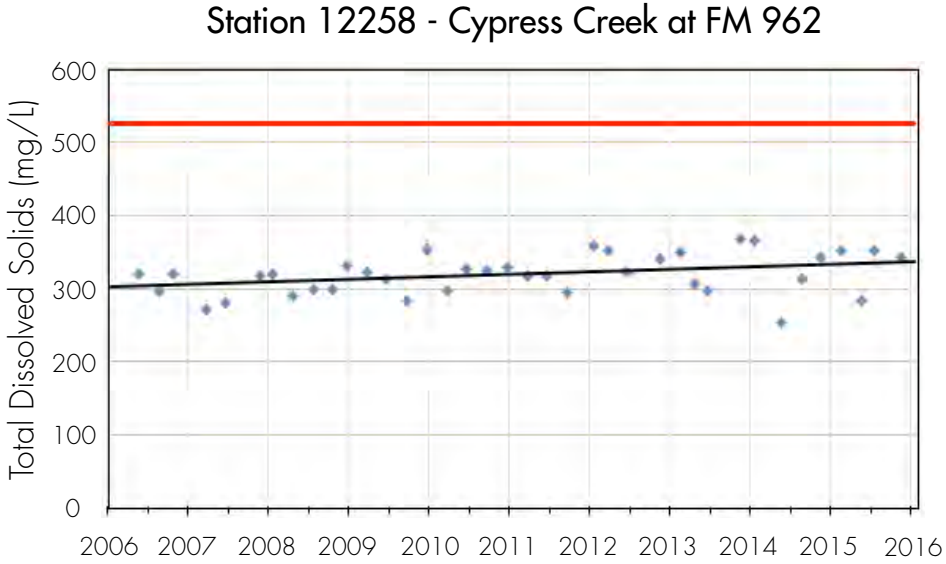


Figure 73. Total Dissolved Solids Trend / Cypress Creek

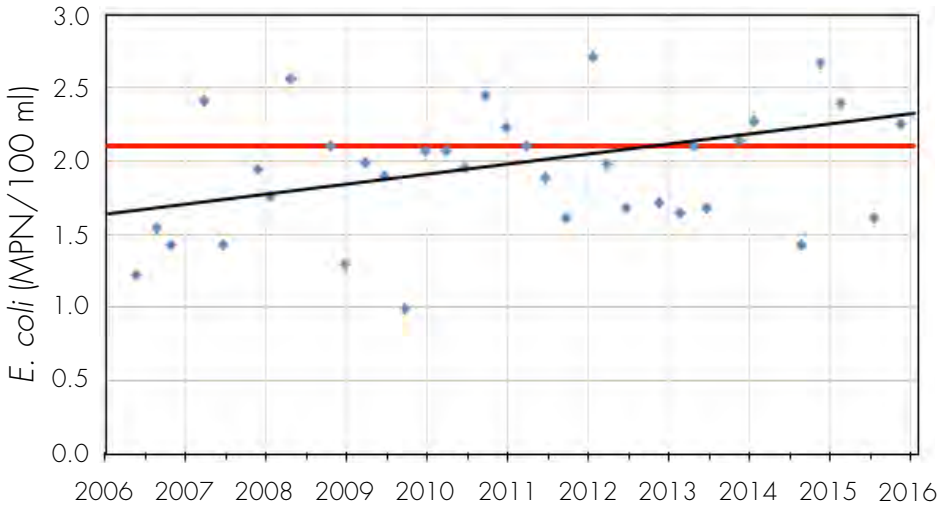
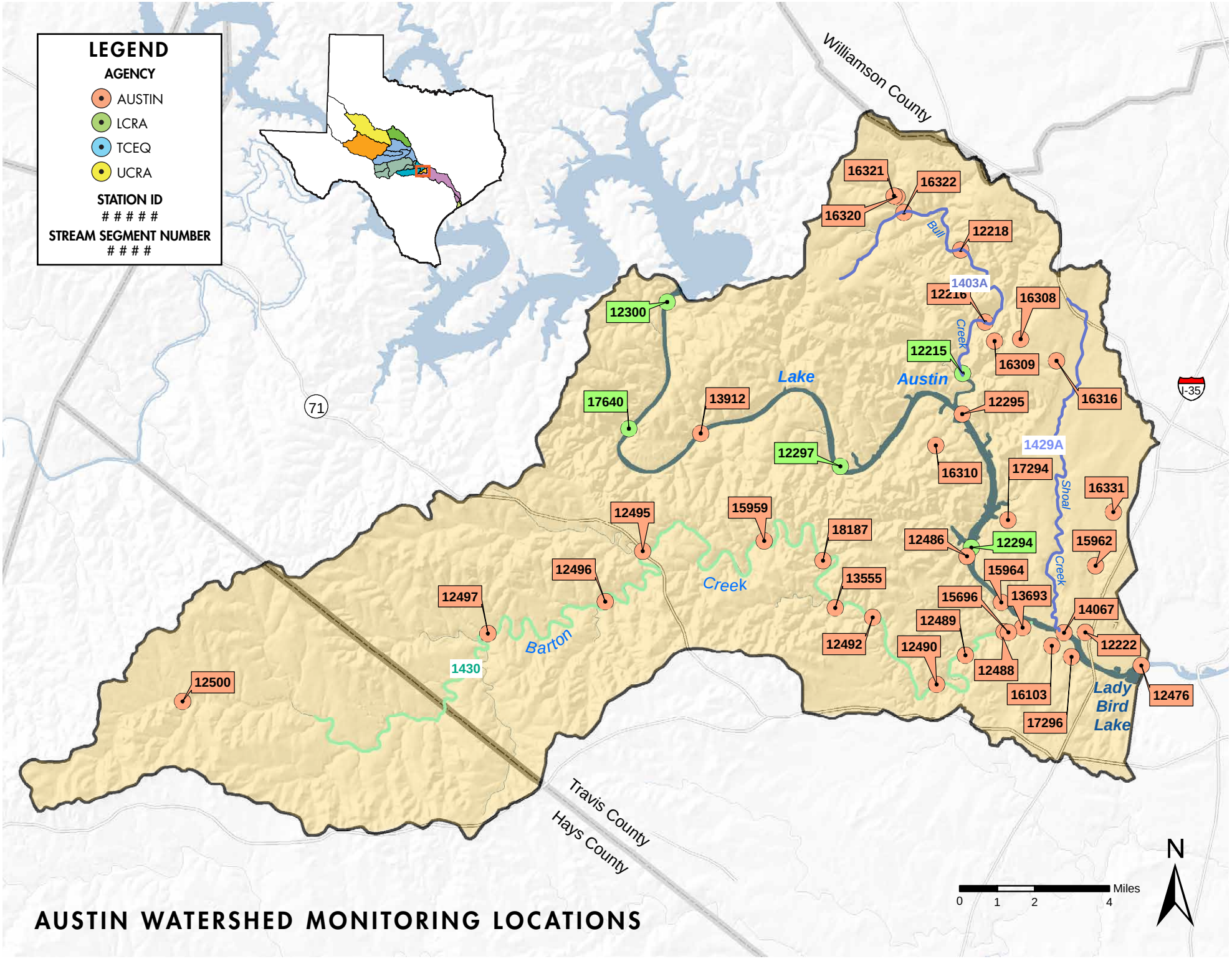


Figure 74. E. coli Trend / Cypress Creek

Cottonwood Hollows on Lake Travis

Future Challenges for the Lake Travis Watershed

- The continued surge in development around Lake Travis has the potential to increase runoff and nonpoint source pollution from impervious surfaces.
- Continued investigation of Increasing bacteria trend on the Pedernales River and Cypress Creek.



AUSTIN WATERSHED MONITORING LOCATIONS

AUSTIN WATERSHED

Segment 1403 – Lake Austin
Segment 1403A – Bull Creek
Segment 1403J – Spicewood Tributary to Shoal Creek
Segment 1403K – Taylor Slough South
Segment 1429 – Lady Bird Lake
Segment 1429C – Waller Creek
Segment 1430 – Barton Creek

Watershed Characteristics

The Austin metropolitan watershed encompasses about 250 square miles on the eastern edge of the Central Texas or Edwards Plateau. The Edwards Aquifer intermittently surfaces in the watershed to form springs, clear streams and groundwater recharge features. Lake Austin and Lady Bird Lake are narrow and shallow in comparison to the Highland Lakes. Rather than lakes, they resemble large rivers that cut through Austin and create a natural boundary that bisects and defines the city. Once a sleepy college town, Austin has grown into an urban center with a population of more than 750,000, making it the most densely urbanized watershed in the Colorado River basin. Monitoring by the City of Austin indicates some urban creeks have elevated bacteria levels. The upper end of Lake Austin periodically contains low levels of dissolved oxygen.

Loop 360 overlook and Pennybacker Bridge over Lake Austin

SEGMENT SUMMARIES

Segment 1403 – Lake Austin

Lake Austin is impounded by Tom Miller Dam on the Colorado River in Austin. Lake Austin is a narrow and shallow lake that, by size and fluvial properties, is more akin to a river than the upstream Highland Lakes. Water moves through the lake relatively quickly in a typical year, retained only a few hours in the 20 miles between Mansfield Dam and Tom Miller Dam. Land around the lake is developed with little natural riparian corridor. The lake, which is approximately 1,830 surface acres, is used extensively for recreation.

Historical data indicate frequent low dissolved oxygen levels near the headwaters of the lake near Mansfield Dam and high levels of manganese in sediment near Tom Miller Dam. The low dissloved oxygen levels were caused by hypolimnetic releases of oxygen-depleted water from Mansfield Dam. In an effort to increase dissolved oxygen, LCRA installed an aerator in Mansfield Dam to oxygenate the water in the upper end of Lake Austin. Twenty-four-hour monitoring performed in 2012 and 2013 showed improved dissolved oxygen levels, and noted a high aquatic life use designation. The impairment status will be removed in the 2016 Integrated Report.

The source of manganese is unknown, though manganese is a common element also present in the sediment of other reservoirs in the Colorado River basin.

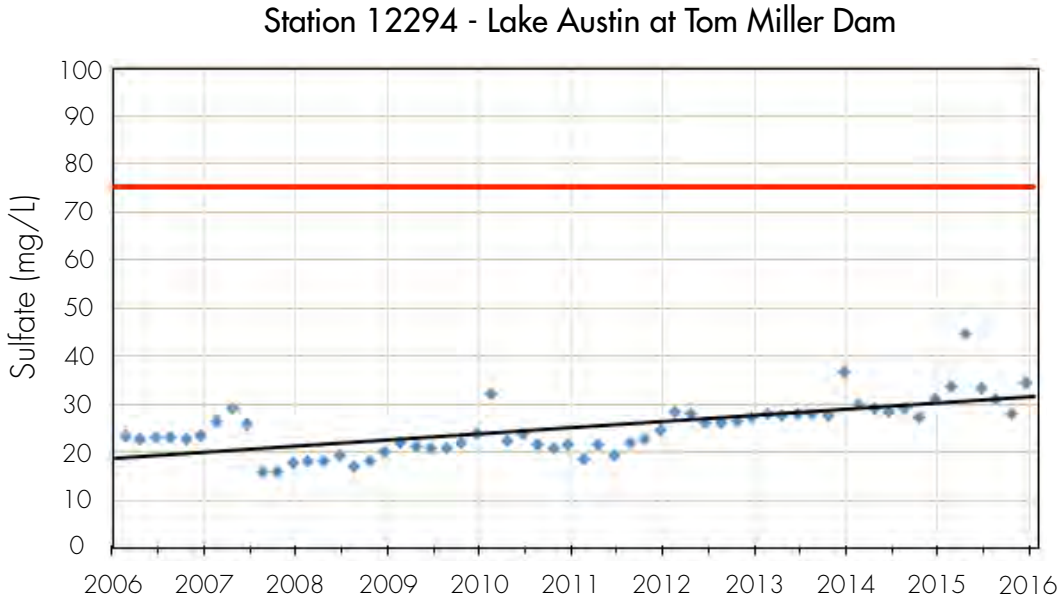


Figure 75. Sulfate Trend / Tom Miller Dam at Lake Austin

M - Meets water quality standard
C - Concern for water quality standard
I - Impaired for water quality standard

	Aquatic Life				Recreation	General				
Station ID	Dissolved Oxygen	Biology	Metals	Organics	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12294	M	-	C	M	M	M	M	M	M	M
12297	M	-	M	M	M	M	M	M	M	M
17640	M	-	M	M	M	M	M	M	M	M
12300	I	-	M	M	M	M	M	M	M	M

Table 48. Summary of the 2014 Integrated Report / Lake Austin

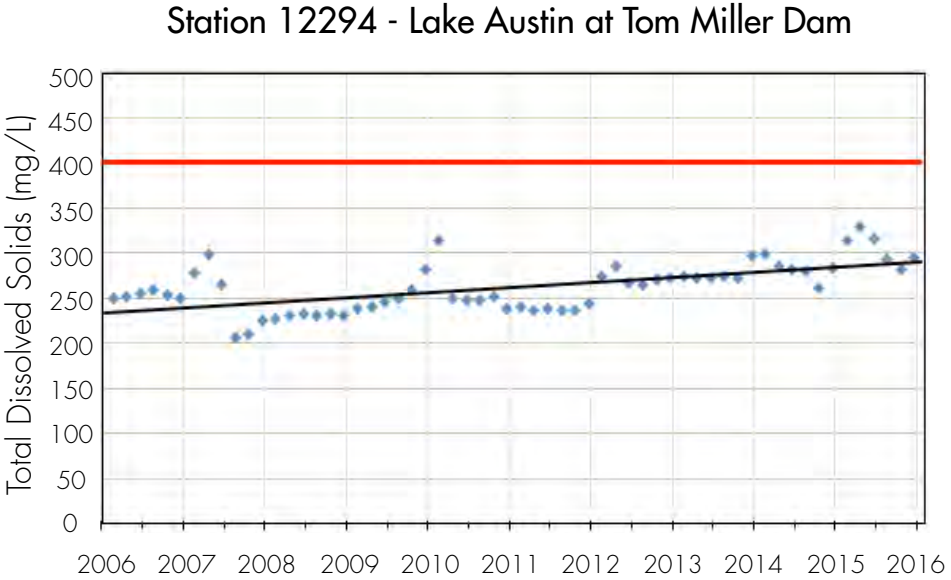


Figure 76. Total Dissolved Solids Trend / Tom Miller Dam

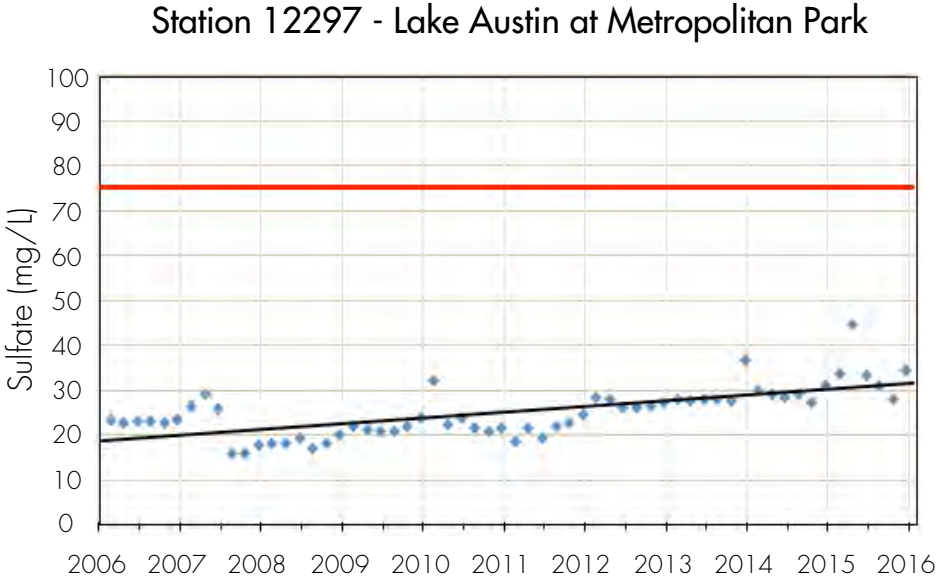


Figure 77. Sulfate Trend / Metropolitan Park

Tom Miller Dam at Lake Austin

Salt constituents increased over time at two stations on Lake Austin. Sulfate and TDS increased at Station 12294 near Tom Miller Dam and sulfate, TDS and chloride increased at Station 12297 at Metropolitan Park. These increases are typical during drought conditions as water quantity decreases from evaporation and salts remain in the reservoir. In this case, the increase in salts is due to saltier water from upstream passing through the lake.

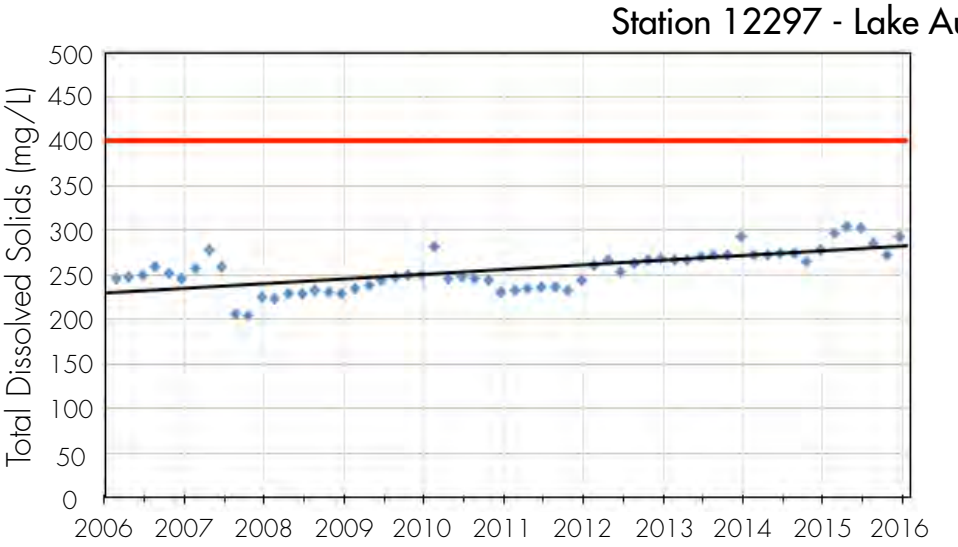


Figure 78. Total Dissolved Solids Trend / Metropolitan Park

Figure 79. Chloride Trend / Metropolitan Park

Segment 1403A – Bull Creek

Bull Creek is a perennial, spring-fed tributary of Lake Austin. About 40 percent of the watershed is developed, and the remaining 60 percent remains in a natural state protected from further development by the City of Austin. Springs in the upper watershed provide base flows, but the groundwater typically contains very little dissolved oxygen (DO). Consequently, the stream does not meet aquatic life use standards due to low levels of DO at Station 12218. The City of Austin initiated a multi-year study in 2013 to collect additional diel DO data to better evaluate the temporal and spatial extent of low DO in Bull Creek. Initial results have shown strong groundwater connections with low DO in the upper reaches of the creek. In addition, TCEQ has performed aquatic life monitoring in this segment. The data show some improvement in dissolved oxygen levels and aquatic life suitability, but the stream will remain on the 303(d) List for the 2016 Integrated Report.

M - Meets water quality standard
I - Impaired for water quality standard

	Aquatic Life				Recreation	General				
Station ID	Dissolved Oxygen	Biology	Metals	Organics	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12216	M	-	M	M	M	M	M	M	M	M
12218	I	-	M	M	M	M	M	M	M	M
16322	M	-	M	M	M	M	M	M	M	M
16320	M	-	M	M	M	M	M	M	M	M
16321	M	-	M	M	M	M	M	M	M	M

Table 49. Summary of the 2014 Integrated Report / Bull Creek

Segment 1403J – Spicewood Tributary to Shoal Creek

The small tributary to Shoal Creek, known as Spicewood Springs tributary, is located in the upper portion of the Shoal Creek watershed, which lies on the north side of Lady Bird Lake in Austin. It begins near the west side of the MoPac Expressway in North Austin, where Spicewood Springs discharge. The shallow, spring-fed stream is only about a half-mile long, but it is important habitat for a very small population of threatened Jollyville Plateau salamanders (*Eurycea nana*).

Water samples collected near the springs indicate elevated levels of bacteria and nitrate. In 2012, the TCEQ initiated a bacteria TMDL for several Austin streams, including Spicewood Tributary of Shoal Creek. TCEQ contracted with The University of Texas Center for Public Policy Dispute Resolution to facilitate public input and develop a TMDL Implementation Plan in partnership with the City of Austin Watershed Protection Department and other stakeholders. Strategies proposed by the stakeholder group included riparian zone restoration, wastewater infrastructure maintenance, domestic pet waste education, resident outreach and stormwater treatment. In January 2015, TCEQ commissioners adopted the TMDL and I-Plan for Spicewood Tributary. Implementation by the various stakeholders is ongoing. More information is available at www.tceq.texas.gov/waterquality/tmdl/101-austinbacteria.

M - Meets water quality standard
C - Concern for water quality standard
I - Impaired for water quality standard

	Aquatic Life				Recreation	General				
Station ID	Dissolved Oxygen	Biology	Metals	Organics	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
16316	M	-	M	M	I	M	M	M	C	M

Table 50. Summary of the 2014 Integrated Report / Segment 1403J

Bull Creek near the headwaters

Headwater spring of Shoal Creek Tributary

Segment 1403K – Taylor Slough South

The Taylor Slough watershed is located on the north side of Lake Austin. The headwaters of the stream begin about a mile upstream of its confluence with Lake Austin. The watershed is a dense urban landscape composed mostly of single-family residences. Sewer mains cross the creek at several locations in the watershed. Water quality data collected from Reed Park in the downstream portion of the stream indicate elevated levels of bacteria and nitrate.

The watershed is highly urbanized. Potential sources of bacteria include urban runoff and pet waste from Reed Park, where water quality samples are collected. Given the elevated nutrient concentrations found during monitoring, wastewater lines located near the creek likely contribute to the impairment. At the request of the City of Austin, the TCEQ initiated a TMDL for bacteria in in 2012. TCEQ contracted with The University of Texas Center for Public Policy Dispute Resolution to facilitate public input and develop a TMDL Implementation Plan in partnership with the City of Austin and other stakeholders. Strategies proposed by the stakeholder group included riparian zone restoration, wastewater infrastructure maintenance, domestic pet waste education and waste stations, resident outreach and stormwater treatment. In January 2015, TCEQ commissioners adopted the TMDL and I-Plan for Taylor Slough. Implementation by the various stakeholders is ongoing. More information is available at www.tceq.texas.gov/waterquality/tmdl/101-austinbacteria.

Taylor Slough in Reed Park

M - Meets water quality standard
I - Impaired for water quality standard

	Aquatic Life				Recreation	General				
Station ID	Dissolved Oxygen	Biology	Metals	Organics	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
17294	M	-	M	M	I	M	M	M	M	M

Table 51. Summary of the 2014 Integrated Report / Taylor Slough

Segment 1429 – Lady Bird Lake

Lady Bird Lake is formed by Longhorn Dam in Austin. The lake extends upstream approximately 5 miles to Tom Miller Dam, and it has a surface area of approximately 500 acres. Known as a pass-through lake, water moves quickly from the headwaters below Tom Miller Dam toward Longhorn Dam on the east side of Interstate 35 in Austin. Monitoring data collected from several stations on the lake indicate applicable water quality standards are met, though a concern was identified for elevated levels of organic pollutants in sediment. There were no significant trends detected for Lady Bird Lake.

M - Meets water quality standard
C - Concern for water quality standard

	Aquatic Life				Recreation	General				
Station ID	Dissolved Oxygen	Biology	Metals	Organics	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12476	M	-	M	M	M	M	M	M	M	M
12486	M	-	M	M	M	M	M	M	M	M
14067	M	-	M	C	M	M	M	M	M	M

Table 52. Summary of the 2014 Integrated Report / Lady Bird Lake

Lady Bird Lake in Austin

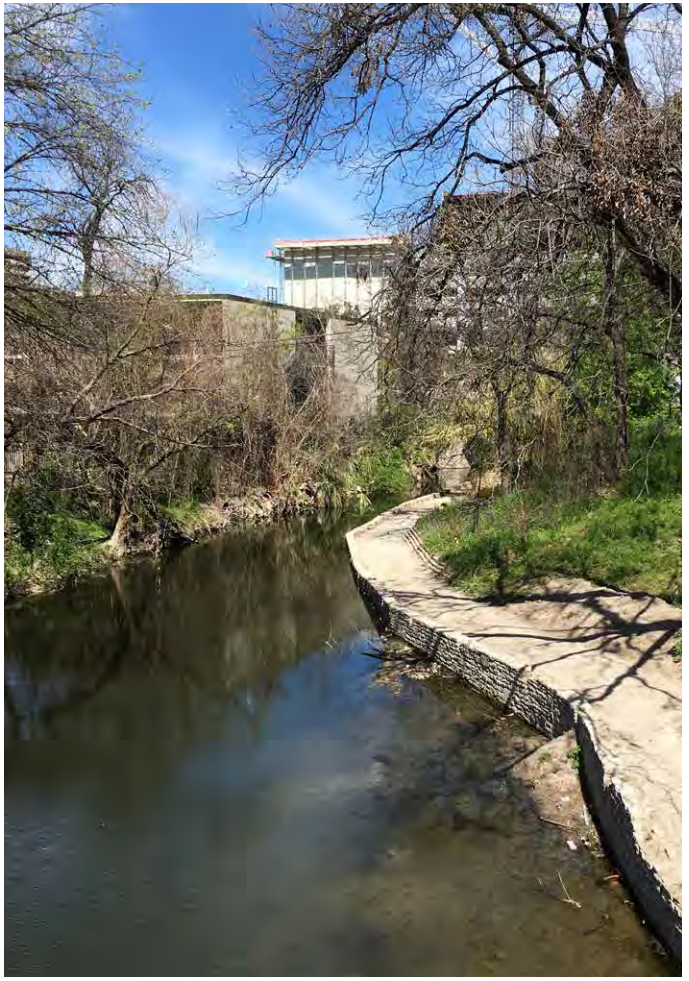
Segment 1429C – Waller Creek

The Waller Creek watershed is located on the north side of Lady Bird Lake in downtown Austin. The headwaters begin in North Austin and the stream flows about 5 miles to its confluence with Lady Bird Lake. Waller Creek is heavily urbanized. Riparian buffers are lacking, and the creek is frequently reduced to concrete-lined channels where stormwater outlets drain runoff from downtown Austin. The creek is frequently used by transient populations as a bathroom.

Monitoring data collected from several stations on the creek showed elevated levels of bacteria and toxins in sediment. Concern levels for aquatic life also were found due to low levels of dissolved oxygen and sediment toxicity. Potential sources of bacteria include pet and human waste, leaking wastewater infrastructure and urban runoff.

In 2012, the TCEQ initiated a bacteria TMDL for several Austin streams, including Waller Creek. The TCEQ contracted with The University of Texas Center for Public Policy Dispute Resolution to facilitate public input and develop a TMDL Implementation Plan in partnership with the City of Austin and other stakeholders. Strategies proposed by the stakeholder group included riparian zone restoration, wastewater infrastructure maintenance, domestic pet waste education and waste stations, resident outreach and stormwater treatment. In January 2015, TCEQ commissioners adopted the TMDL for Waller Creek.

Construction of the Waller Creek Tunnel, a major channelization project, began in 2011. The project was completed in 2015, and it now circulates water from Lady Bird Lake down Waller Creek during non-storm conditions.



Waller Creek at Waterloo Park

M - Meets water quality standard
C - Concern for water quality standard
I - Impaired for water quality standard

	Aquatic Life				Recreation	General				
Station ID	Dissolved Oxygen	Biology	Metals	Organics	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12222	M	-	M	M	M	M	M	M	M	M
15962	M	-	C	C	I	M	M	M	M	M
16331	M	-	M	M	I	M	M	M	M	M

Table 53. Summary of the 2014 Integrated Report / Waller Creek

Segment 1430 – Barton Creek

Barton Creek is the largest tributary to Lady Bird Lake. The headwaters are located near Dripping Springs. The creek flows intermittently about 38 miles to its confluence with the lake. Eight square miles of the watershed are in the Edwards Aquifer Recharge Zone where water travels into caves and sinkholes, recharging the aquifer. Groundwater resurfaces near Barton Springs Pool in Austin.

While Barton Creek met applicable Surface Water Quality Standards, monitoring data indicate concern levels for dissolved oxygen and for toxicity in sediment at Barton Springs. The source of low dissolved oxygen is groundwater at the springs, and only during low flow periods. The toxicity concern is based on historic polycyclic aromatic hydrocarbons concentrations in sediment that was collected by the City of Austin. Follow up studies by the City of Austin, USGS and TCEQ connected these high concentrations to coal-tar based pavement sealants. A water-quality control structure was built below the most likely source of these pollutants, and a citywide ban on the sale and use of these products in 2006 has resulted in reduced loads and concentrations in receiving water bodies throughout Austin, as documented in a 2014 study by USGS, and a 2017 study by the City of Austin. The Texas Department of Health performed a human health risk assessment of Barton Springs, and concluded that Barton Springs water quality is safe for human swimming (https://www.tceq.texas.gov/toxicology/barton/).

M - Meets water quality standard

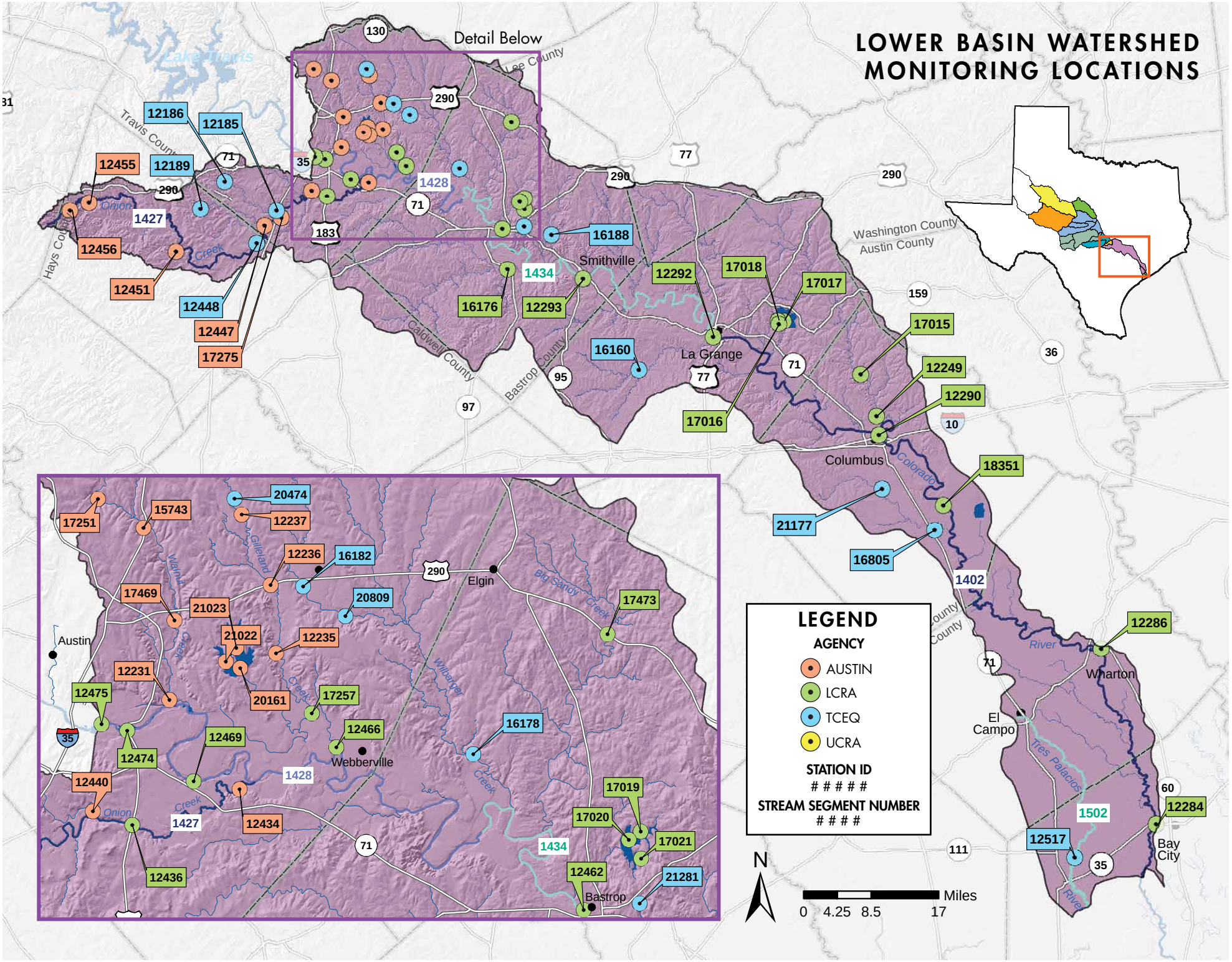
	Aquatic Life				Recreation	General				
Station ID	Dissolved Oxygen	Biology	Metals	Organics	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12488	M	-	M	M	M	M	M	M	M	M
12495	M	-	M	M	M	M	M	M	M	M
12497	M	-	M	M	M	M	M	M	M	M
13555	M	-	M	M	M	M	M	M	M	M
15959	M	-	M	M	M	M	M	M	M	M

Table 54. Summary of the 2014 Integrated Report / Barton Creek

Future Challenges for the Austin Watershed

- Implementation of bacteria TMDLs.
- Re-evaluation by City of Austin Watershed Protection Department of the water quality in Waller Creek since the completion of the Waller Tunnel.
- In Barton and Onion creeks, wastewater disposal outside of COA jurisdiction is accomplished by individual on-site facilities or via centralized land application under the TCEQ Texas Land Application Permit program. While not specifically prohibited by rule, wastewater discharge to the Barton Springs Contributing Zone has not yet occurred.

Barton Creek Greenbelt


LOWER BASIN WATERSHED MONITORING LOCATIONS
Detail Below
Lake Travis
Travis County
Hays County
Lee County
Washington County
Austin County
Caldwell County
Bastrop County
Smithville
La Grange
Columbus
Elgin
Austin
Webberville
Bastrop
Wharton
El Campo
Bay City
Onion Creek
Gilleland Creek
Walnut Creek
Big Sandy Creek
Wilbarger Creek
Colorado River
Tres Palacios River
1427
1428
1434
1402
1502
12186
12185
12455
12189
12456
12451
12448
12447
17275
16188
16176
12293
12292
17018
17017
17015
12249
12290
16160
17016
18351
21177
16805
12286
12284
12517
20474
12237
15743
17251
12236
16182
17469
21023
20809
21022
12235
12231
12475
20161
17257
12466
12469
12474
12440
12434
12436
16178
17473
17019
17020
17021
12462
21281
LEGEND
AGENCY
AUSTIN
LCRA
TCEQ
UCRA
STATION ID
# # # # #
STREAM SEGMENT NUMBER
# # # #
N
0 4.25 8.5 17
Miles

LOWER COLORADO RIVER WATERSHED

Segment 1402 – Colorado River Below La Grange
Segment 1402C – Buckners Creek
Segment 1427 – Onion Creek
Segment 1427A – Slaughter Creek
Segment 1428 – Colorado River Between Austin and Utley
Segment 1428B – Walnut Creek
Segment 1428C – Gilleland Creek
Segment 1434 – Colorado River Between Utley and La Grange
Segment 1502 – Tres Palacios Creek (Nontidal)

Watershed Characteristics

The lower Colorado River watershed begins just below Lady Bird Lake's Longhorn Dam in Austin where it then flows for approximately 264 river miles until it reaches the tidally influenced region of the river near the coast. The watershed encompasses an area of about 3,560 square miles. Water typically flows more slowly here than in the river above Austin because of the relatively low relief. The watershed slices through a variety of Texas ecoregions starting in the Blackland Prairies east of Austin, traveling into the Post Oak Savannah and ending in the Gulf Coast Prairies. The annual average precipitation ranges from 34 inches near Austin to 46 inches at the southern edge of the watershed. From November to February, when water is not being released for downstream irrigation, treated effluent from WWTPs can make up the majority of the flow in the Colorado River. Elevated nutrients and bacteria can be problematic in the watershed.

Rice is an important crop and an economic driver in the downstream region of the watershed. LCRA typically releases water from the Highland Lakes from March to October to supply rice farmers with irrigation water. Because of drought conditions in the basin, releases for irrigation were drastically reduced from 2012 to 2015.

Sunrise over the lower Colorado River

SEGMENT SUMMARIES

Segment 1427 – Onion Creek

The headwaters of Onion Creek are located in Blanco County. The creek flows intermittently about 78 miles to the east to its confluence with the Colorado River in Travis County. The stream interacts with groundwater as it flows over and into limestone fissures in the Edwards Aquifer recharge zone southwest of Austin. High sulfate levels in the upper part of the watershed resulted in the creek not supporting general uses in 2014. There were no statistically significant trends in Onion Creek.

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12434	M	-	M	M	M	M	M	M
12436	M	-	M	M	M	M	M	M
12440	M	-	M	M	M	M	M	M
12447	M	-	M	M	M	M	M	M
12448	M	-	M	M	M	M	M	M
12451	M	-	M	M	M	I	M	M
12456	M	-	M	M	M	I	M	M
17275	M	-	M	M	M	M	M	M

Table 55. Summary of the 2014 Integrated Report / Segment 1427

Segment 1427A – Slaughter Creek

Located in southern Travis County, the Slaughter Creek watershed is approximately 31 square miles. While the watershed is urban, the riparian area surrounding the creek remains largely intact. The lower watershed consists primarily of densely clustered housing subdivisions and the upper watershed is less developed. From the headwaters near State Highway 290, the stream flows to the east about 17 miles to its confluence with Onion Creek. A 6-mile section of the creek near the MoPac Expressway lies over the Edwards Aquifer recharge zone and this midreach portion of the creek does not maintain base flow under normal conditions. Monitoring data indicate an impairment for aquatic life and a concern due to low levels of dissolved oxygen.

There are no permitted wastewater discharges into Slaughter Creek, but wastewater lines and septic systems are located throughout the watershed. Urban stormwater runoff could be a source of organics and cause oxygen depletion. A Use Attainability Analysis (UAA) was conducted by the TCEQ in 2004. The findings were inconclusive due to drought conditions and accurate Aquatic Life Use (ALU) designations were not determined. In 2016, the TCEQ proposed new ALU standards for the upper portion of the stream, designating it as an intermediate ALU.

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12434	C	I	M	M	M	M	M	M
12436	C	I	M	M	M	M	M	M

Table 56. Summary of the 2014 Integrated Report / Slaughter Creek

Segment 1428 – Colorado River Between Austin and Utley

The Colorado River below Lady Bird Lake is approximately 41 miles long. It begins at Longhorn Dam and ends near the river's intersection with FM 969 northwest of Bastrop. The upper end of the segment is urbanized while the lower end is mostly rural but with a growing amount of development. The two City of Austin WWTPs with major discharges to the Colorado River (South Austin Regional and Walnut Creek) have a total permitted capacity of 150 million gallons per day of treated effluent. Between October and March, if LCRA is not releasing water to all of the downstream irrigators, treated effluent can make up the majority of the flow in this section of river.

According to the 2014 Integrated Report, the lower end of the segment at Webberville has concerns for both biology and nutrients. There also is concern for nutrients in the stretch of the river near FM 973. The source of nutrients likely is a cumulative effect of wastewater discharges. Nitrogen levels typically are higher in the winter when flows are low.

A trend analysis showed an increase in the amount of sulfate (Figure 80) and chloride (Figure 81), as well as total dissolved solids (Figure 82).

The Colorado River below Austin is impacted by water releases for irrigation from LCRA and from City of Austin wastewater discharges.

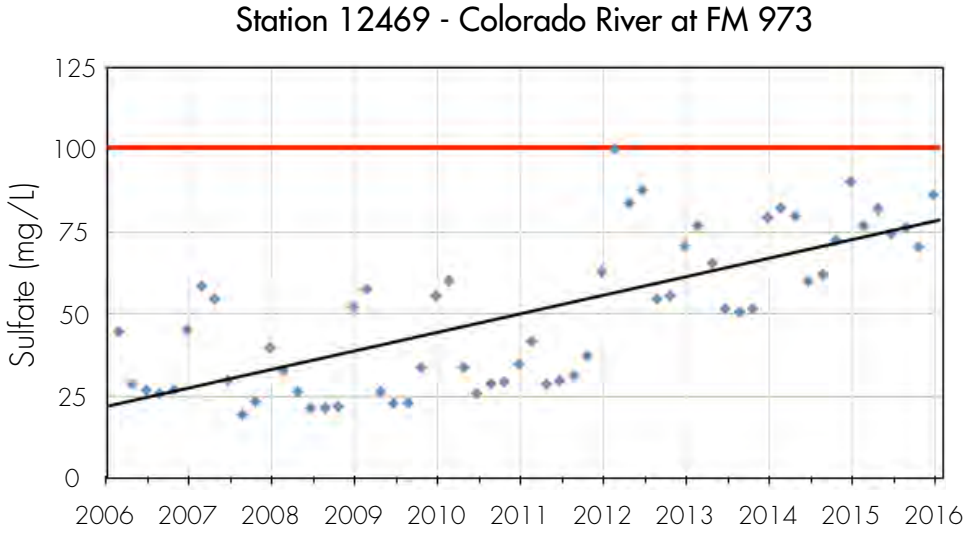


Figure 80. Sulfate Trend / Segment 1428

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12466	M	C	M	M	M	M	C	M
12469	M	-	M	M	M	M	C	M
12474	M	-	M	M	M	M	M	M

M - Meets water quality standard
C - Concern for water quality standard
I - Impaired for water quality standard

Table 57. Summary of the 2014 Integrated Report / Segment 1428

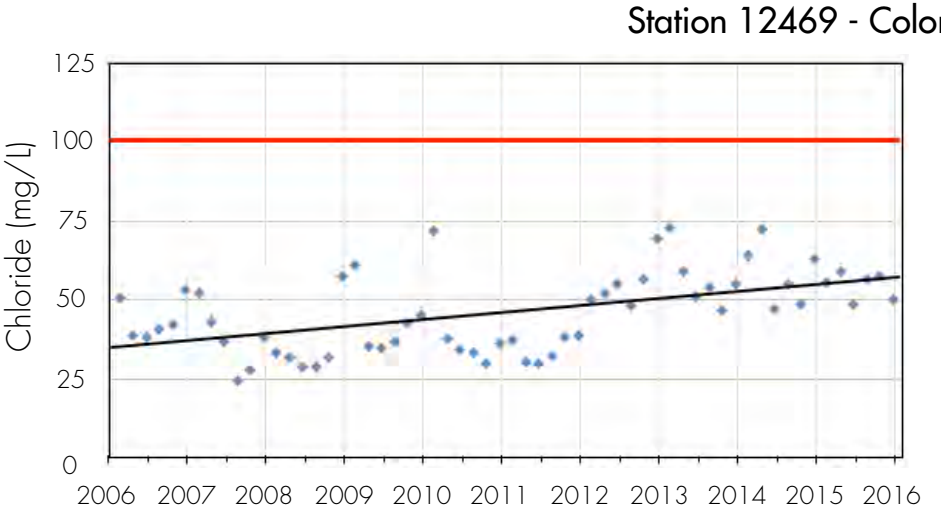


Figure 81. Chloride Trend / Segment 1428

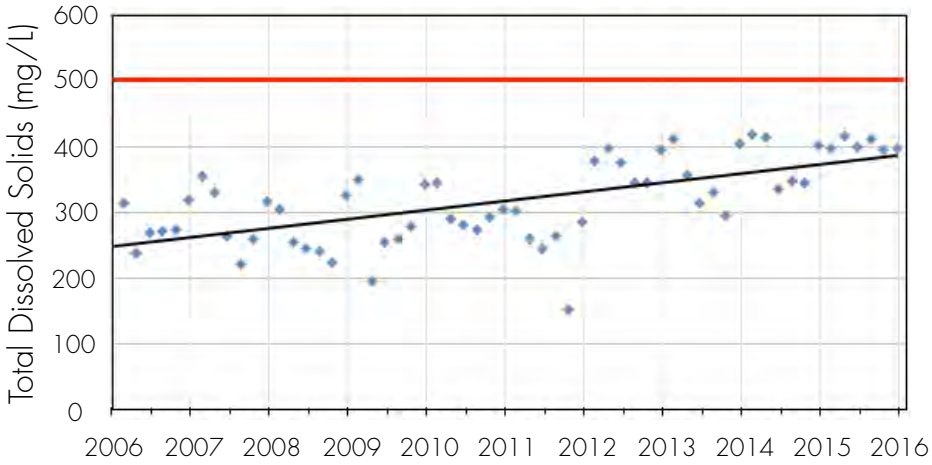


Figure 82. Total Dissolved Solids Trend / Segment 1428

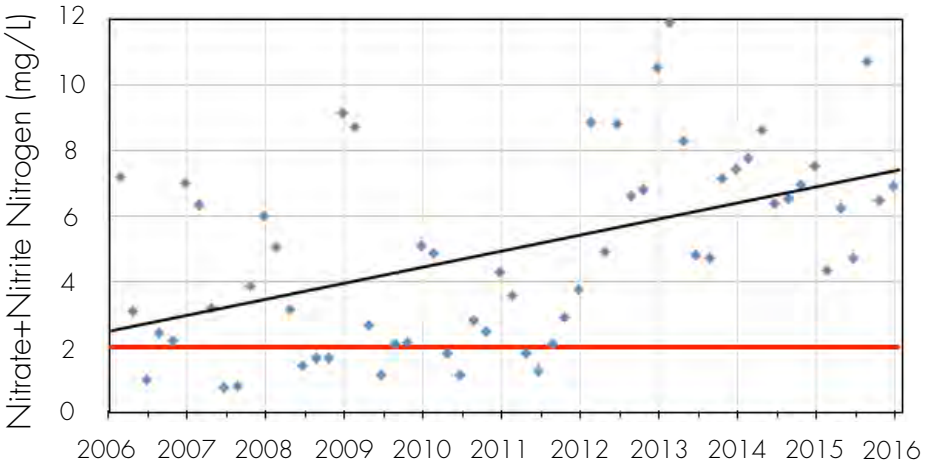


Figure 83. Nitrogen Trend / Segment 1428

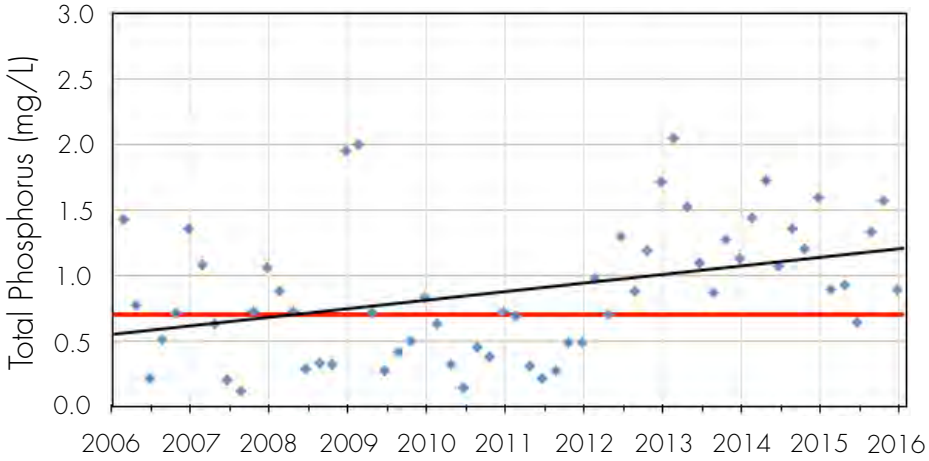


Figure 84. Total Phosphorus Trend / Segment 1428

Nutrient trends have continued to increase over the assessment period timeframe, with both nitrogen and total phosphorus rising above concern levels in the farthest downstream station at Webberville (Figures 83 and 84). These trends can be attributed to the drought when significantly less water was being released from the Highland Lakes into the river below Austin, often resulting in treated effluent from City of Austin dominating the flow. Values remained high in 2015 and 2016 after the drought-ending rains occurred likely because sampling occurred during low flow times.

Segment 1428B – Walnut Creek

Walnut Creek begins in northeast Austin and ends about 20 miles downstream where it flows into the Colorado River just below Longhorn Dam. The watershed is approximately 44 square miles and primarily urban, comprised mostly of residential housing and commercial uses. Walnut Creek was first listed on the 303(d) List in 2006, when three of the five assessment units (AUs) had elevated levels of bacteria. Subsequent assessments found bacteria numbers have decreased, and data reviewed for the 2014 Integrated Report showed only the uppermost AU as impaired (Table 57). The primary sources of bacteria loading in this creek are from various nonpoint sources, including urban runoff and leaking wastewater lines. A TMDL and Implementation Plan have been developed for Walnut Creek (in conjunction with three other Austin waterways) and were approved by the TCEQ in January of 2015. Details of this plan can be found at tceq.texas.gov/waterquality/tmdl/101-austinbacteria.

The 2014 Integrated Report also identified concerns for aquatic life in two Walnut Creek AUs based on habitat and benthic macroinvertebrate community data. There is an increasing trend for nitrogen in the creek shown in Figure 85.

M - Meets water quality standard
C - Concern for water quality standard
I - Impaired for water quality standard

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12231	M	-	M	M	M	M	M	M
12232	M	-	C	M	M	M	M	M
15743	M	C	M	M	M	M	C	M
17521	M	-	I	M	M	M	M	M
17469	M	C	M	M	M	M	M	M

Table 58. Summary of the 2014 Integrated Report / Segment 1428B

Walnut Creek

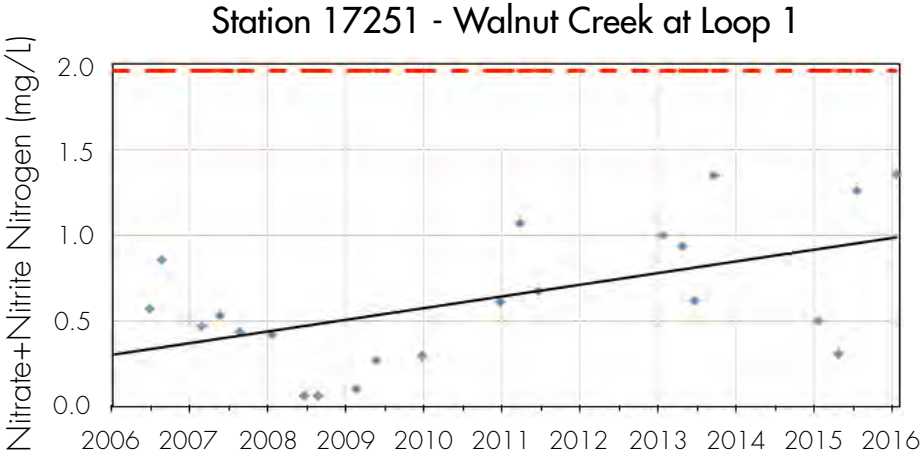


Figure 85. Nitrogen Trend / Walnut Creek

Segment 1428C – Gilleland Creek

Gilleland Creek begins near Pflugerville and ends approximately 31 miles downstream where it flows into the Colorado River downstream of Austin. In 2000, based on data collected near the confluence with the Colorado River, the creek was given an impaired status due to bacteria levels. Elevated nitrate levels have been found at the same station.

Flow in the creek is predominantly from treated wastewater. Through a contract with the TCEQ, LCRA developed the Gilleland Creek TMDL. The TMDL was adopted by TCEQ commissioners in August 2007 and by EPA in April 2009. An Implementation Plan (I-Plan) – including waste load allocations, stormwater prevention, education and other controls – was approved by TCEQ commissioners in February 2011. Bacteria levels have not significantly declined since the I-Plan was put in place; however, implementation is ongoing, and stakeholders currently are evaluating and revising the original I-Plan to identify additional strategies for addressing the impairment. More information can be found at tceq.texas.gov/aterquality/tmdl/nav/69-gillelandcreekbacteria/69-gillelandcreekbacteria-iplan-revision.

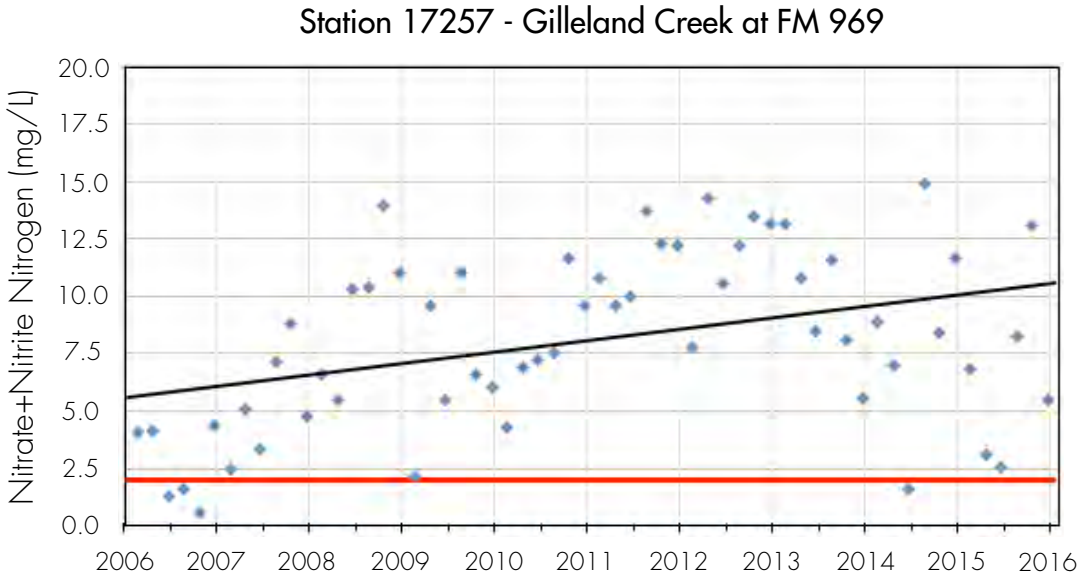


Figure 86. Nitrate Trend / Gilleland Creek

A trend analysis of data from Gilleland Creek showed a significant increasing trend in nitrate concentrations (Figure 86). Nitrate consistently exceeds TCEQ screening criterion. Nitrate levels in the creek have increased with the volume of discharge from WWTPs.

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12231	M	-	C	M	M	M	C	M
12232	M	-	I	M	M	M	C	M
15743	M	-	M	M	M	M	C	M
17521	M	-	C	M	M	M	C	M

Table 59. Summary of the 2014 Integrated Report / Segment 1428C

M - Meets water quality standard
C - Concern for water quality standard
I - Impaired for water quality standard

Segment 1434 – Colorado River Between Utley and La Grange

The Colorado River segment between Utley and La Grange begins at FM 969 near Bastrop and ends at State Highway 71 in La Grange. The segment is approximately 74 miles long. With the exception of Bastrop, Smithville and La Grange, this section of the river flows through mostly farmland. The water is turbid due to sandy loams and clay soils in the East Central Texas Plains ecoregion.

Data from monitoring sites in Bastrop and Smithville show concerns for nutrients (both nitrate and total phosphorus levels), according to the 2014 Integrated Report. A trend analysis indicated an increasing trend in chlorides, sulfates and total dissolved solids in all AUs (Figures 87-89) trends at the Colorado River at Smithville are similar to those in the other AUs). Data from the Colorado River at Bastrop show an increasing trend in nitrate levels and pH (Figures 90 and 91). These trends are largely attributed to the recent drought.

Colorado River in the fall

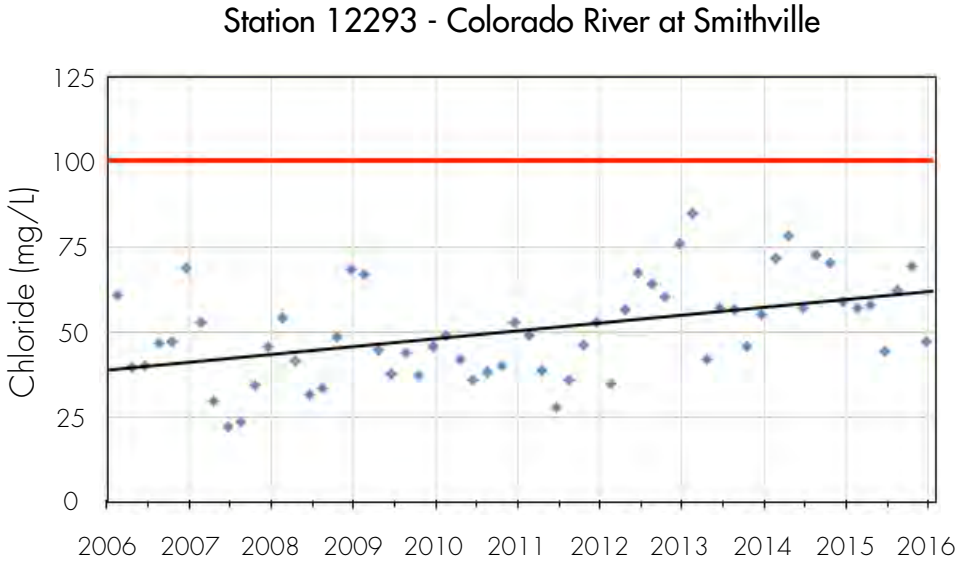


Figure 87. Chloride Trend / Segment 1434

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12462	M	-	M	M	M	M	C	M
12293	M	-	M	M	M	M	M	M

M - Meets water quality standard
C - Concern for water quality standard

Table 60. Summary of the 2014 Integrated Report / Segment 1434

Station 12293 - Colorado River at Smithville

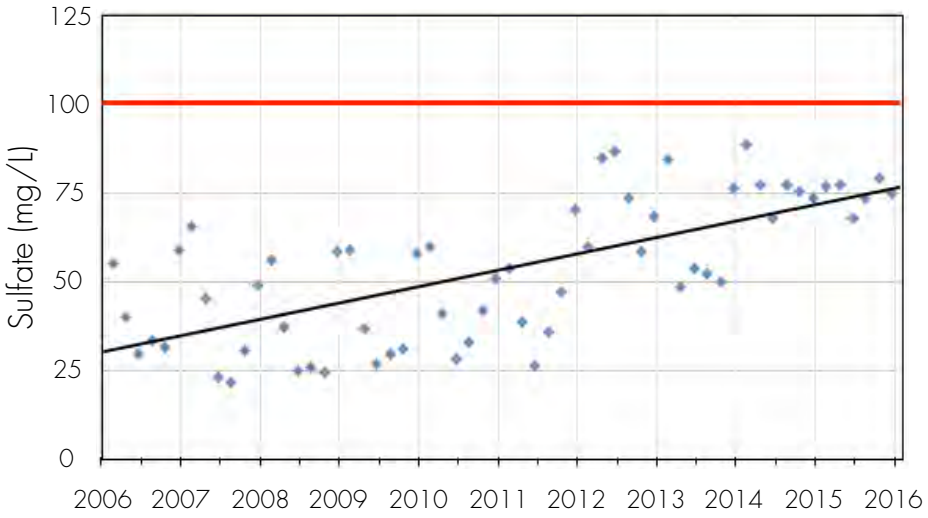


Figure 88. Sulfate Trend / Segment 1434

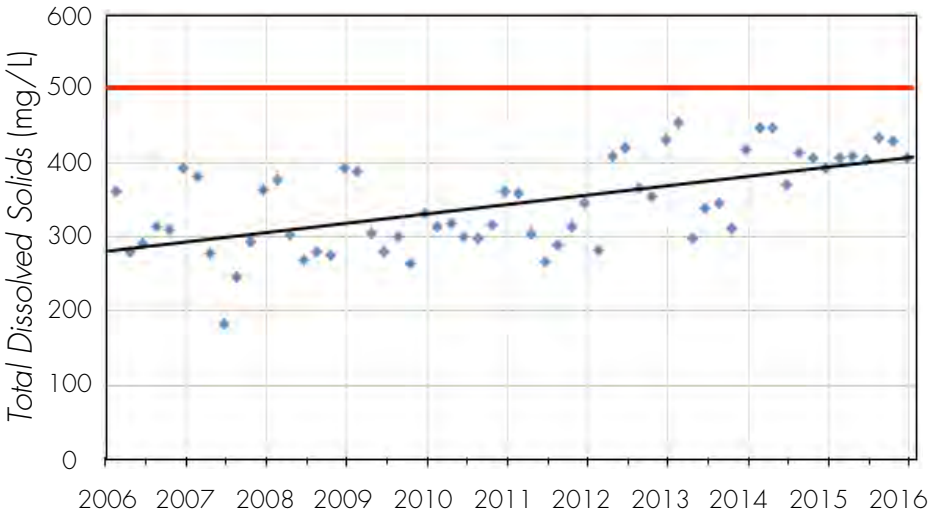


Figure 89. Total Dissolved Solids Trend / Segment 1434

Station 12462 - Colorado River at Bastrop

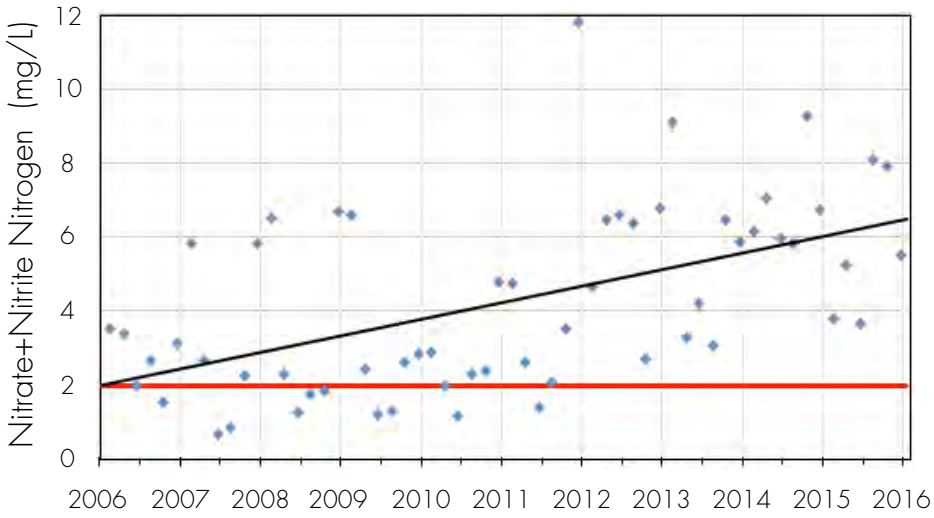


Figure 90. Nitrate Trend / Segment 1434

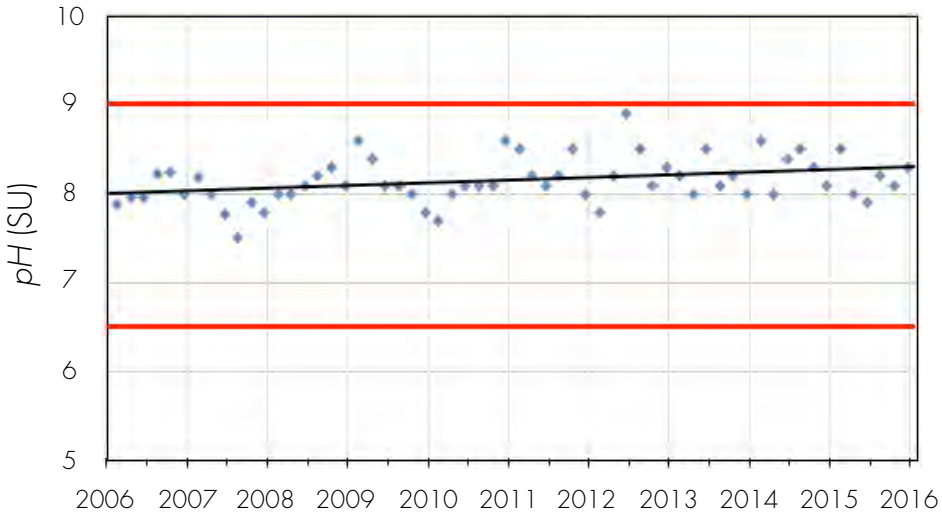


Figure 91. pH Trend / Segment 1434

Segment 1402 – Colorado River Below La Grange

The Colorado River below La Grange begins in the town of La Grange below Business Highway 71 and ends approximately 150 miles downstream near Bay City. The portion of the Colorado River represented by Segment 1402 is a seventh-order stream. This is the lowermost freshwater segment of the Colorado River. Flows are typically higher from mid-October through early March due to irrigation releases. This section of the river is home to a relatively high abundance and diversity of native freshwater mussel species.

Data collected from the Colorado River at Wharton have shown elevated levels of *E. coli* bacteria, leading to a nonsupport rating for contact recreation and placement on the 303(d) List in 2014. The TCEQ assigned the segment to a category 5c, meaning more data should be collected before a water quality project is implemented. The source of the bacteria is currently unknown. Two water quality monitoring sites were added in 2016 to this segment of the river in order to gather more data on the impairment.

The 2014 Integrated Report also identified concerns for nitrate and chlorophyll *a* in this segment.

Rainbow over the lower Colorado River

	Aquatic Life		Recreation	General				
Station ID	Dissolved Oxygen	Biology	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12284	M	-	M	M	M	M	C	C
12286	M	-	I	M	M	M	C	M
18351	M	-	M	M	M	M	M	M
21807	M	-	M	M	M	M	M	M
21808	M	-	M	M	M	M	M	M
21809	M	-	M	M	M	M	M	M

Table 61. Summary of the 2014 Integrated Report / Segment 1402

M - Meets water quality standard
C - Concern for water quality standard
I - Impaired for water quality standard

A trend analysis for data collected from Segment 1402 during the period of record indicates a statistically significant increasing trend for sulfate at four monitoring sites (Colorado River at Bay City, Wharton, Altair and Columbus). Dissolved oxygen deficit shows a decreasing trend in the river at Wharton (Figure 92). Data from the Colorado River at Altair and Columbus show increasing trends for total dissolved solids, and chloride levels are showing an increasing trend from the river in Altair. The drought is the primary cause behind these trends.

Freshwater mussels

The Colorado River watershed is home to approximately 22 species of freshwater mussels. These native mussels burrow into the sediment of rivers and lakes where they fill an important niche in the aquatic ecosystem by filtering water and contributing to both aquatic and terrestrial food chains.

In the past several decades, a variety of factors are believed to have led to a decline in freshwater mussel populations throughout the state. In 2011, the U.S. Fish and Wildlife Service (FWS) was petitioned to consider listing five mussel species known to occur in the Colorado River under the Endangered Species Act. These species are Texas pimpleback, smooth pimpleback, Texas fawnsfoot, Texas fatmucket and false spike. The proposed listing decisions for four of the five species are expected by September 2018, with the remaining candidate mussel species scheduled for a listing decision by September 2020.

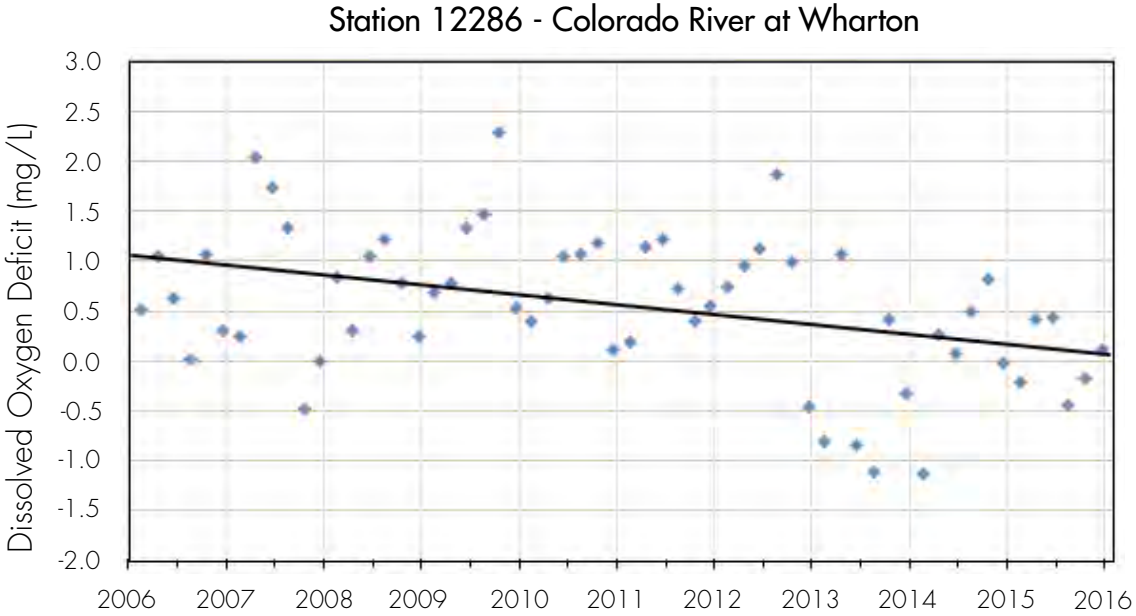


Figure 92. Dissolved Oxygen Deficit Trend / Segment 1402

Colorado River at Wharton

Segment 1402C – Buckners Creek

Located on the south side of the Colorado River near La Grange, the Buckners Creek watershed is about 176 square miles. The stream begins at the headwaters near the community of Rosanky in Bastrop County and ends 26 miles downstream at its confluence with the Colorado River. The Buckners Creek watershed is rural. The majority of the watershed has been cleared, but land along the riparian area surrounding the creek remains intermittently intact, particularly in the upper end of the watershed.

Buckners Creek was monitored by TCEQ Region 11 until 2009, but is currently not being monitored. The creek is designated as a high aquatic life use in TSWQS Appendix D. It was first placed on the 303(d) List in 2010 for not supporting its designated aquatic life use based on the 24-hour dissolved oxygen average and minimum. Potential causes of low dissolved oxygen include decomposition of organic matter coupled with slow flows and inadequate mixing. Buckners Creek is currently designated in Category 5c, meaning more information is needed before a TMDL or other water quality project is implemented. LCRA hopes to acquire funding to conduct a Use Attainability Analysis of the waterway in the near future. The 2014 Integrated Report also identified chlorophyll *a* levels as a concern. There was not enough recent data to perform a trend analysis for Buckners Creek.

Buckners Creek

Segment 1502 – Tres Palacios Creek (Nontidal)

The nontidal portion of Tres Palacios Creek flows from the headwaters near U.S. Highway 59 in Wharton County for approximately 45 miles to the end of the segment, which is below State Highway 35. The upper end of Segment 1502 is narrow with steep banks. A narrow riparian area is maintained as the stream winds through cultivated farmland. Segment 1501, the tidally influenced section of Tres Palacios Creek, is described in the Coastal Watershed section. The entire watershed area of Tres Palacios Creek is approximately 268 square miles and flows directly into the Matagorda Bay system.

There are concerns for depressed dissolved oxygen and chlorophyll *a* levels in the nontidal portion of Tres Palacios Creek.

Statistically significant data trends in this segment for the period of record include an increase in *E. coli* bacteria levels (Figure 93) and total suspended solids (Figure 94).

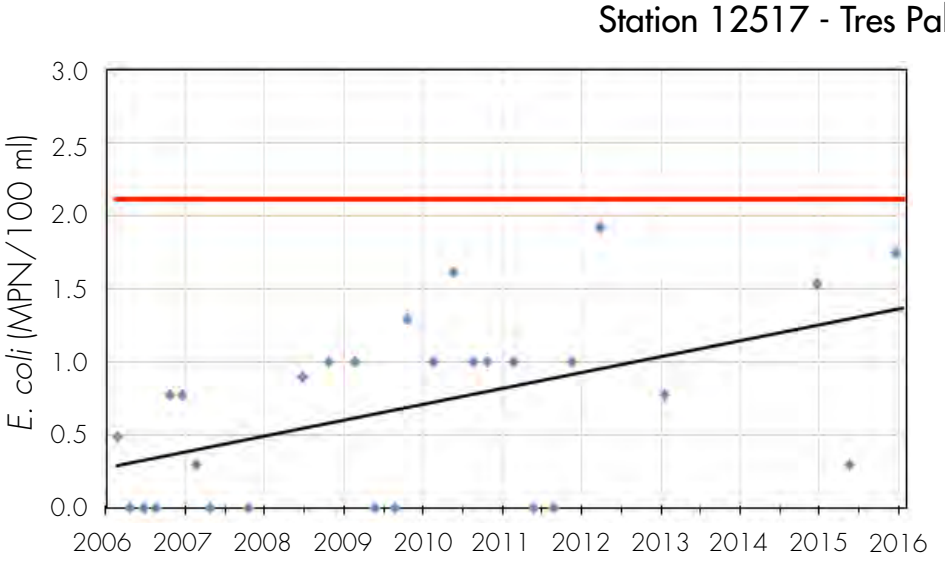


Figure 93. E. coli Trend / Segment 1502

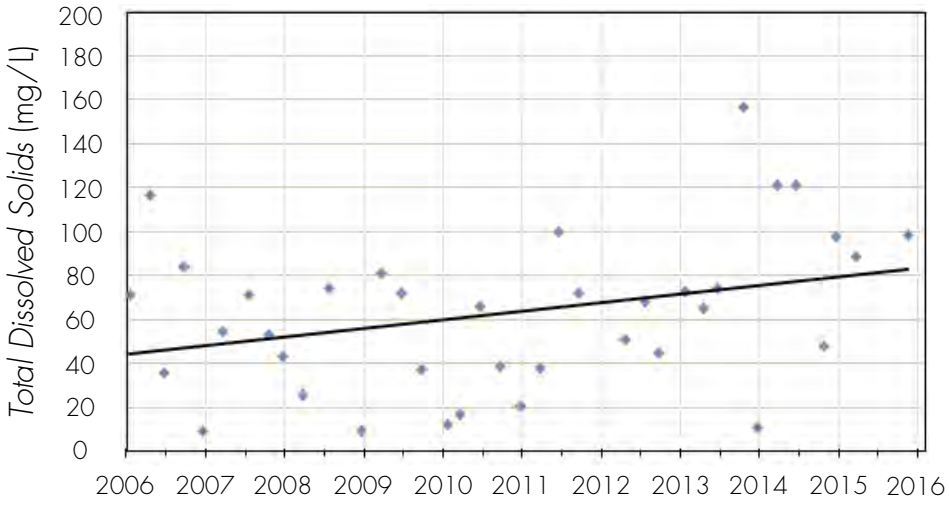


Figure 94. Total Suspended Solids Trend / Segment 1502

M - Meets water quality standard
C - Concern for water quality standard

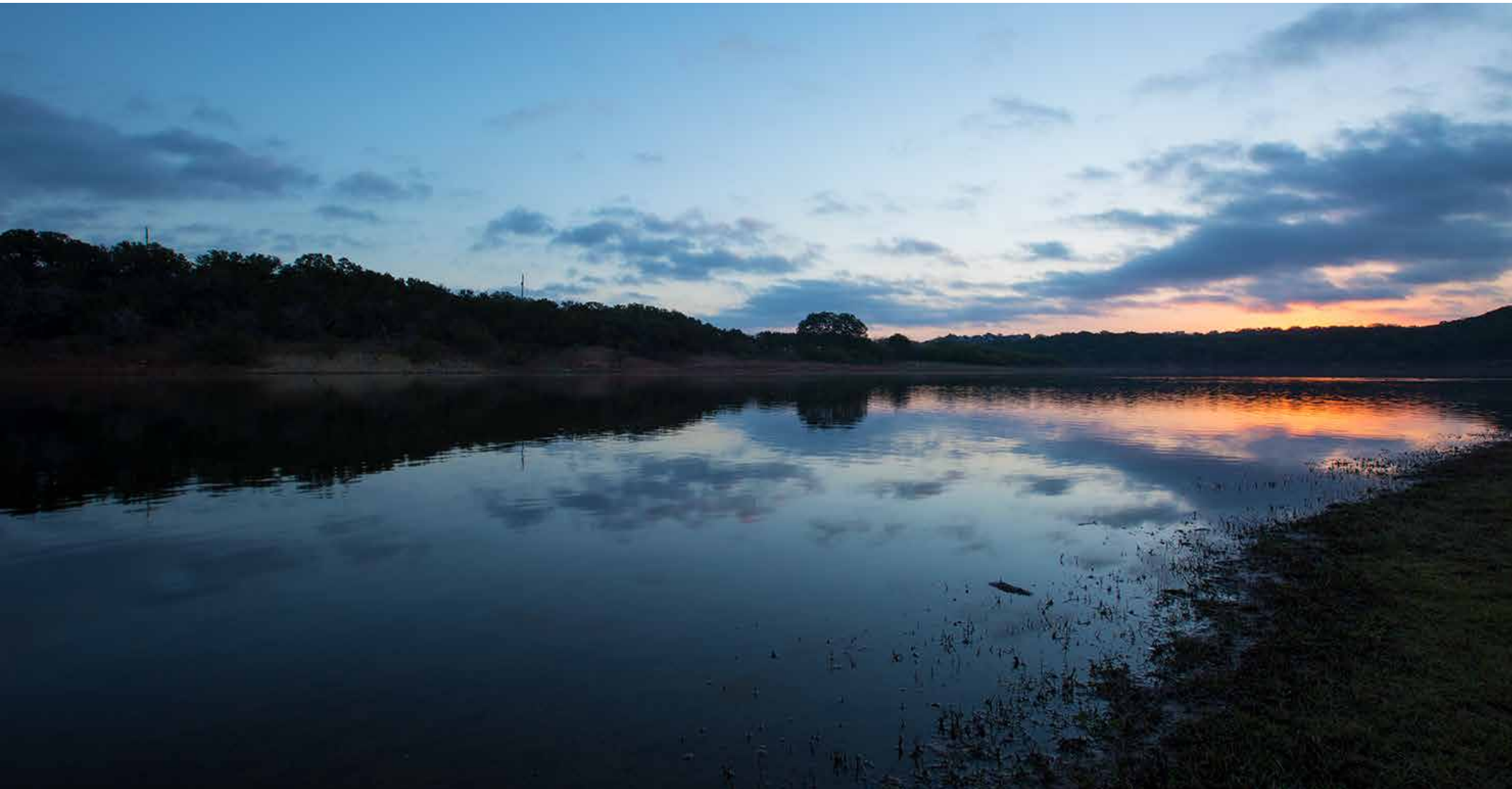
	Aquatic Life				Recreation	General				
Station ID	Dissolved Oxygen	Biology	Metals	Organics	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12517	C	-	M	M	M	M	M	M	M	C

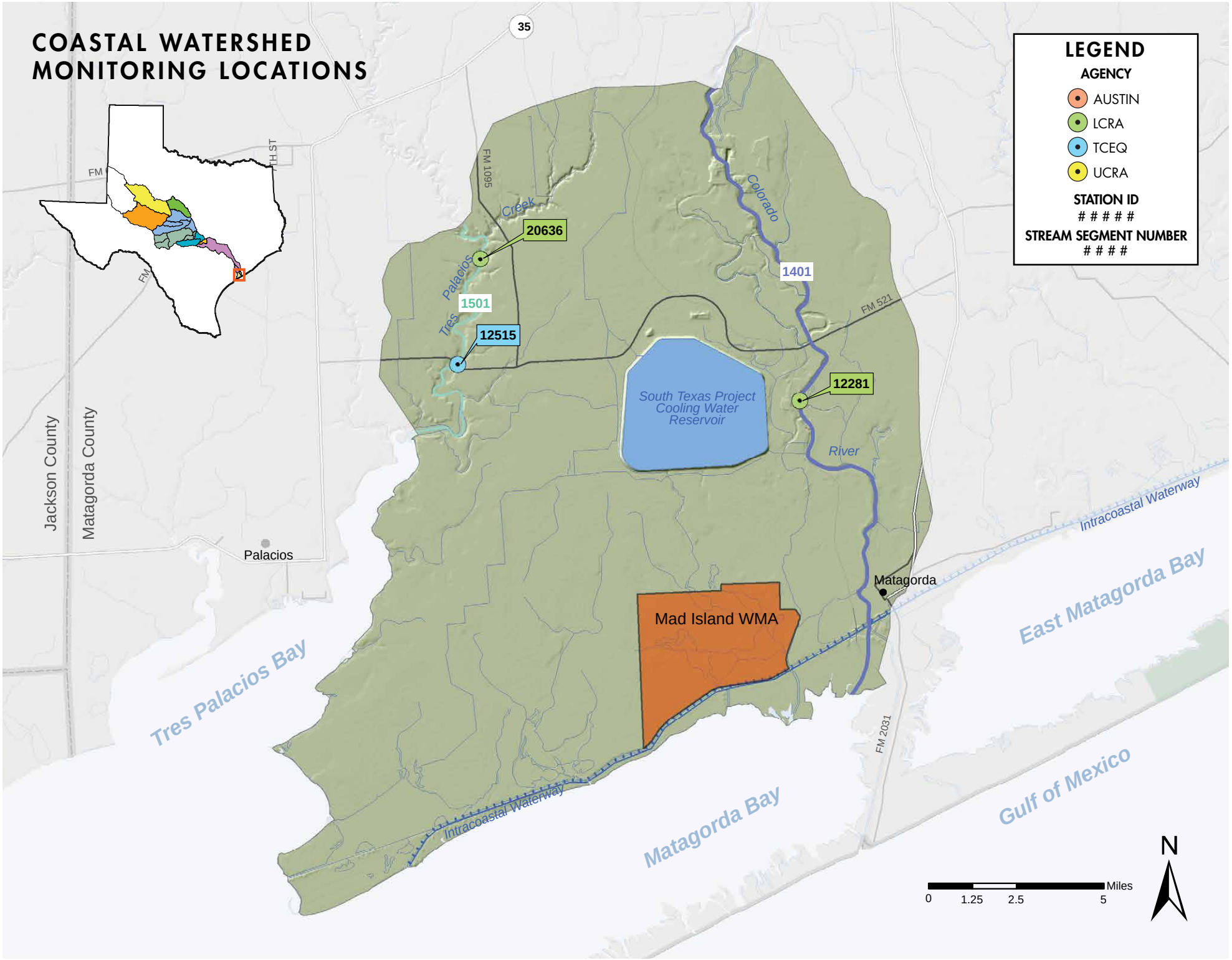
Table 62. Summary of the 2014 Integrated Report / Segment 1502

Future Challenges for the Lower Colorado River watershed

- Continued implementation of the Gilleland Creek TMDL.
- The U.S. Fish and Wildlife Service is in the beginning stages of evaluating several freshwater mussel species that inhabit this lower part of the river, as well as waterways in the middle and upper part of the basin, for listing under the Endangered Species Act. The impact of the potential listing of these mussels on the Colorado River is yet to be determined.
- Collect additional data from two new sites in Segment 1402 to help identify *E. coli* sources.
- Obtain funding for additional water quality monitoring in Buckners Creek.

Lower Colorado River at sunrise




COASTAL WATERSHED
MONITORING LOCATIONS
LEGEND
AGENCY
AUSTIN
LCRA
TCEQ
UCRA
STATION ID
# # # # #
STREAM SEGMENT NUMBER
# # # #
35
FM 1095
Palacios Creek
Tres
20636
1501
12515
Colorado
1401
FM 521
12281
South Texas Project
Cooling Water
Reservoir
River
Jackson County
Matagorda County
Palacios
Matagorda
Intracoastal Waterway
East Matagorda Bay
Mad Island WMA
Tres Palacios Bay
FM 2031
Intracoastal Waterway
Matagorda Bay
Gulf of Mexico
N
0
1.25
2.5
5
Miles

COASTAL WATERSHED

Segment 1401 – Colorado River (Tidal)
Segment 1501 – Tres Palacios River (Tidal)

Watershed Characteristics

The coastal watershed encompasses the tidally influenced portions of the Colorado and Tres Palacios rivers in Matagorda County. The watershed lies within the Western Gulf Coastal Plains ecoregion, a belt of flat prairies along the Gulf of Mexico. It is an area of approximately 198 square miles and typically receives 40 to 54 inches of rain per year. The coastal watershed begins just downstream of State Highway 35 on the Colorado and Tres Palacios rivers and ends at the mouth of each river. In this section, the fresh flows mix with brackish water to create unique ecosystems with diverse populations of both freshwater and saltwater species.

Both of these tidally influenced segments in the Colorado River basin (1401 and 1501) are impaired for contact recreation. One reason for this could be the type of bacteriological indicator used by the TCEQ to assess coastal waters. Prior to 2006, fecal coliform was the primary bacterial indicator in tidal water bodies. In 2006, the TCEQ began to use *Enterococcus* to measure attainment of contact recreation standards. The result was an increase in bacteria listings along the Texas Coast, including these two tidally influenced segments in the coastal basin.

Matagorda Bay sunset

SEGMENT SUMMARIES

Segment 1401 – Colorado River (Tidal)

The tidal portion of the Colorado River begins downstream of Bay City and flows to its convergence with West Matagorda Bay. The watershed surrounding the 27-mile segment is rural and much of it is farmed, with an increasing amount of tourism-based residential development along waterfront areas.

Monitoring data collected about 12 miles upstream of the Gulf Intracoastal Waterway indicate elevated levels of nutrients. Potential sources include failing septic systems, wildlife and agricultural runoff. There were no significant trends in the tidal portion of the Colorado River during the review period.

M - Meets water quality standard
C - Concern for water quality standard

	Aquatic Life				Recreation	General				
Station ID	Dissolved Oxygen	Biology	Metals	Organics	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12281	M	-	M	M	M	M	M	M	C	M

Table 63. Summary of the 2014 Integrated Report / Segment 1401

Segment 1401 of the lower Colorado River

Segment 1501 – Tres Palacios River (Tidal)

Segment 1501 is the tidally influenced portion of the Tres Palacios River. It begins below State Highway 35 and meanders slowly downstream approximately 8 miles until it meets Tres Palacios Bay and the Matagorda Bay system. The surrounding watershed is rural and much of the land along the river is used for farming.

Historical monitoring data collected by the TCEQ in Segment 1501 has shown recurring high levels of indicator bacteria, which ultimately led to the river being added to the 303(d) List in 2014. Beginning in 2015, the Texas Water Resources Institute led an effort with help from stakeholders to develop a Watershed Protection Plan for Tres Palacios Creek. This document is expected to be approved by the U.S. Environmental Protection Agency in the coming months.

There were no statistically significant data trends for this segment during the current review period for this report.

Kayakers on Matagorda Bay

M - Meets water quality standard
C - Concern for water quality standard
I - Impaired for water quality standard

	Aquatic Life				Recreation	General				
Station ID	Dissolved Oxygen	Biology	Metals	Organics	Bacteria	Temperature	pH	Salts	Nutrients	Chlorophyll
12515	I	-	M	M	I	M	M	M	C	M

Table 64. Summary of the 2014 Integrated Report / Segment 1501

IV. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

There have been many accomplishments in the Colorado River basin in the past five years. Clean Rivers Program partners, the City of Austin, UCRA and LCRA have generated huge amounts of publicly available quality assured data. In addition, they have participated and led watershed protection projects such as the Austin Urban Creeks TMDLs, the Brady Creek WPP and San Angelo WPP to improve water quality and lessen the impact of urban development. Outreach efforts have reached hundreds of Colorado River basin residents, providing an essential element in protecting the resource through knowledge and understanding.

Summary of Water Quality Conditions

Drought was a major cause of water quality and quantity problems during the period of record. Low flows and lake levels throughout the basin caused increased levels of dissolved solids, sulfate and chloride. Implementation of the TMDLs on E.V. Spence Reservoir and the Colorado River below E.V. Spence Reservoir continues, but rains that fell in 2016 brought much-needed relief to the region. Recent water quality monitoring data showed lower salt levels and improved water quality.

Golden algae has become a persistent problem in upper basin reservoirs. Fish kills were reported in the upper Colorado River and in J.B. Thomas, E.V. Spence and Brady Creek reservoirs. The TPWD and UCRA continue to collect data to discover more about golden algae in hopes of predicting and preventing future kills.

The Concho River basin also displays elevated TDS levels in dispersed pockets throughout its watershed. UCRA continues to apply for grants to develop nonpoint-source projects on Brady Creek and the Concho River.

Most water bodies in the middle portion of the basin, from Lake Buchanan to Columbus, support their designated uses. The San Saba River and several small creeks in Austin do not support contact recreation because of elevated bacteria levels. In the lower basin, the bacteria levels in the Colorado River at Wharton and the dissolved oxygen impairment on Buckners Creek need further action and investigation.

Recommendations

Clean Rivers partners in the Colorado River basin should continue to monitor and provide quality assured data to the TCEQ for assessment. The partners should seek opportunities to work with state, federal and local agencies to implement water quality improvement projects based on newly acquired data and Water Quality Advisory Committee input.

The following water quality protection efforts have been identified as priorities for the next biennium:

- Continue to coordinate water quality monitoring by LCRA, UCRA, the City of Austin and TCEQ regional offices to ensure geographic coverage and the most efficient use of resources and funds.
- Continue to leverage resources by working with in-kind contributors such as the City of Austin.
- Improve public awareness on water quality issues through outreach and educational programs.
- Continue to work with the TCEQ nonpoint-source program and Texas Railroad Commission to remediate oilfield contamination of surface water in the upper basin.
- Continue to support TPWD and other resource agencies to investigate golden algae blooms in the Colorado River basin.
- Support stakeholder efforts in the Llano River and Brady Creek watersheds to continue implementation of Watershed Protection Plans.
- Work with stakeholders in the San Saba River to evaluate the best way to address the bacteria impairment.
- Acquire funding to complete a UAA for Buckners Creek to make progress on the dissolved oxygen impairment.
- Continue to monitor and assess bacteria levels in the Colorado River at Wharton and work with local stakeholders to determine potential sources of bacteria.
- Remain apprised and assist when needed with the efforts of the Improving Austin Streams TMDL and I-Plan, as well as the Tres Palacios Watershed Protection Plan.
- Continue to work with other stakeholders on revisions to the Gilleland Creek I-Plan.

APPENDIX A

Water Quality Constituents

The following table lists the parameters collected by the CRP partners and their potential impacts to water and possible sources:

Parameter	Impact	Cause/Source
Ammonia	Ammonia is naturally occurring in surface and wastewater, and is produced by the breakdown of compounds containing organic nitrogen. Elevated ammonia levels are a good indicator of organic pollution, and they can adversely affect fish and invertebrate reproductive capacity and reduce the growth of the young.	Ammonia is excreted by animals and produced during the decomposition of plants and animals. It is an ingredient in many fertilizers, and it also is present in sewage, stormwater runoff, certain industrial wastewater and runoff from animal feedlots.
Chloride	Chloride is one of the major inorganic ions in water and wastewater. Chloride is an essential element for maintaining normal physiological functions in all organisms. Elevated chloride concentrations can disrupt osmotic pressure, water balance and acid/base balances in aquatic organisms, which can adversely affect survival, growth and reproduction.	Chloride compounds, often known as salts, can be an indicator of natural or man-made pollution. Natural weathering and leaching of sedimentary rocks, soils and salt deposits can release chloride into the environment. Other sources can be attributed to oil exploration and storage, sewage and industrial discharges, runoff from dumps and landfills, and saltwater intrusion.
Chlorophyll *a*	Chlorophyll *a* refers to increased nutrients in water bodies that create diurnal swings, which can stress aquatic life. In the presence of sunlight and abundant food sources, photosynthesis increases and DO levels rise and pH levels fall. At night, respiration begins and oxygen is consumed, so DO levels fall and pH levels rise.	Chlorophyll *a* is a photosynthetic pigment found in green plants and algae. The concentration of chlorophyll *a* is used to estimate phytoplankton biomass in surface water. Results are expressed in µg/L (micrograms per liter).
Dissolved Oxygen (DO)	Dissolved oxygen (DO) is the amount of oxygen freely available in water. Aquatic life needs oxygen to live. DO is vital to fish and other aquatic life. Acceptable ranges of dissolved oxygen are the most important indicator of a water body's ability to support aquatic life.	Human activity in the riparian zone can affect water temperatures adversely, and excessive or unusual quantities of organic material combined with bacteria and large algae blooms may cause DO levels to fluctuate. In some segments where DO can fluctuate, aquatic life may not have sufficient oxygen to survive.
Escherichia coli (*E. coli*)	*E. coli* is the current indicator bacteria to determine if a freshwater body is suitable for contact recreation. It typically is not harmful, but their presence, expressed in colony-forming units (CFU) per 100 mL of water, is an indicator of fecal matter contamination, which may contain other pathogens.	High numbers of *E. coli* can indicate a potential pollu¬tion problem. Although *E. coli* is used as an indicator, it can be potentially harmful. It is present in warm-bod¬ied animals and may come from poorly maintained or ineffective septic systems, overflow of domestic wastewater plants and runoff from feedlots.

Parameter	Impact	Cause/Source
pH	The pH determines whether a water body is acidic, neutral or basic. The pH of the water can affect the toxicity of many substances. Most aquatic life is adapted to live within a specific pH range. Changes in pH can control toxic effects of other substances that may be in runoff.	Elevated pH can be related to industrial and wastewater discharge, runoff, accidental spills and nonpoint sources. It also can be tied to human activity that increases organic matter and bacteria, and over-abundant algae.
Nitrites	High levels of nitrates and nitrites can produce nitrite toxicity, or brown blood disease, in fish. This disease reduces the ability of blood to transport oxygen throughout the body.	Nutrients are found in effluent released from wastewa-ter treatment plants, fertilizers and agricultural runoff carrying animal waste from farms and ranches.
Nitrates	Nitrate additions to surface water can lead to excessive growth of aquatic plants. High groundwater nitrate levels can cause methemoglobinemia, or blue baby syndrome, in infants. Elevated concentrations can be used as an indicator of human-caused pollution.	Nitrates are used as fertilizers to supply a nitrogen source for plant growth. The presence of nitrates in groundwater occurs from the conversion of nitroge-nous matter into nitrates by bacteria, and represents the process whereby ammonia in wastewater is oxi-dized to nitrite and then to nitrate by bacterial or chemical reactions.
Total Suspended Solids (TSS)	Total suspended solids (TSS) is the measure of the organic and inorganic total suspended solids in water. Increased turbidity can reduce the amount of light to plants, which decreases oxygen production. Additionally, too much sediment can cover habitat, smother benthic organisms and eggs, and even clog fish gills.	TSS can have origins from multiple point and nonpoint sources, but the most common source is soil erosion. A good measure of the upstream land-use conditions can be gauged by how much TSS increases after heavy rain.
Flow	Flow is the velocity of a water body at the time of sampling expressed in cubic feet per second (CFS). Flow combined with other parameters can be a good indicator of water quality.	Changes in flow can be natural or man-made. Natural changes include beavers building dams and the overgrowth of vegetation in times of low flow. Man-made changes include new bridges restricting flow and new construction altering landscapes and runoff.
Total Dissolved Solids (TDS)	Total dissolved solids (TDS) is an important use of the measure of the quality of drinking water. TDS is a quantification of the material dissolved in water, typically the chloride and sulfate anions, which form salt.	Primary sources for TDS are agricultural and stormwater runoff. Other sources include the leaching of soil contamination and point-source water pollution from industrial or sewage treatment plants. Certain naturally occurring TDS arise from weathering and the dissolution of rocks and soils.
Sulfate	Sulfate is usually dissolved into waters from rocks and soils containing gypsum, iron sulfides and other sulfur compounds. Sulfate can affect the taste and odor of drinking water.	Sulfate is present due to the abundance of elemental and organic sulfur. Sulfide minerals and soluble sulfate exist in almost all natural water bodies. Other sources are the burning of sulfur-containing fossil fuels, steel mills and fertilizers.

Parameter	Impact	Cause/Source
Temperature	Temperature refers to the temperature of water when a sample is collected. Colder water typically contains higher amounts of DO. As temperatures fluctuate, there is a direct effect on dissolved oxygen levels.	Natural changes in water temperature occur seasonally. Changes also can be caused by the alteration of the riparian zone, drought or as a result of industrial uses such as electric generation.
Total Organic Carbon (TOC)	Total organic carbon (TOC) is a measure of the amount of suspended or dissolved organic materials in water. It represents an estimation of the strength or potential damage that effluent or runoff can cause in a body of water if the dissolved oxygen was organically removed from the water.	TOC comes from decaying matter, detergents, pesticides, fertilizers, herbicides, industrial chemicals and chlorinated organics.
Conductivity	Conductivity is often used as an indicator of TDS. Conductivity is a measurement of the capacity of water to conduct electrical current. Salts such as chloride and sulfate increase conductivity.	Agricultural and stormwater runoff, outfall from industrial or sewage treatment plants, and weathering and dissolution of certain rocks and soils can impact conductivity.
Turbidity	Turbidity is a measure of water clarity expressed in nephelometric turbidity units (NTUs). Water that is turbid can reduce light penetration and photosynthesis and affect aquatic life.	Sediment from natural processes, construction activity, urbanization and disturbance of streambeds can impact turbidity.
Alkalinity	Alkalinity is a measure of the acid-neutralizing or buffering capacity of water. It indicates the presence of calcium carbonate ions to the buffering system. Alkalinity is a measure of how much acid can be added to a liquid without causing a large change in pH. Alkalinity is important for fish and aquatic life because it protects or buffers against rapid pH changes. Living organisms, especially aquatic life, function best in a pH range of 6.0 to 9.0. Higher alka¬linity levels in surface waters will buffer acid rain and other acid wastes and prevent pH changes that are harmful to aquatic life.	Alkalinity is often related to hardness because the main source of alkalinity is usually the result from dissolved carbonate rock formation.
Chemical Oxygen Demand (COD)	Chemical Oxygen Demand (COD)	COD is an indicator of how much organic load is placed on the oxygen in a water body.

Parameter	Impact	Cause/Source
Orthophosphorus	Orthophosphorus is a soluble form of phosphorus (PO4) that is applied to urban and agricultural land as fertilizers, and it is often found in stormwater runoff. It is considered the limiting factor of plant growth in a water body.	Orthophosphorus is essential to plant life but contributes to an increased trophic level (eutrophication) of water bodies. Phosphorus is commonly known as a man-made pollutant. It is an ingredient found in soaps and detergents, and it also is present in sewage and runoff from animal feedlots.
Total Phosphorus	Total phosphorus is an essential nutrient required for the growth of organisms. It is frequently the nutrient that limits primary productivity and algal growth.	In excessive amounts from wastewater, agricultural drainage, and certain industrial wastes, total phosphorus also contrib¬utes to the eutrophication of lakes and other water bodies. Phosphorus is commonly known as a man-made pollutant.

APPENDIX B

Trend Analysis Methodology

Trend analysis was conducted following procedures outlined by the TCEQ.

Data Source

Trend analysis data was obtained through the Surface Water Quality Monitoring Information System (SWQMIS), the state's database of water quality data.

Data Set Size

For inclusion, data sets must have had at least 20 points within the 10-year period, and those points must have covered at least two-thirds of the time period. If multiple measurements were collected in the same month, the sample set with the most complete data was used. If different analytical methods were used (e.g., chlorophyll *a* – parameter IDs 32211 and 70953), they were consolidated to create sufficiently large data sets.

Censored Data

To avoid creating trends based on changing reporting and detection limits, censored data were converted to a common parameter-based value. These are listed below:

chlorophyll *a*	2 or dropped <
E. coli / Enterococci	1 or dropped <
NO2+NO3	0.02
NH3	0.02
TKN	0.2
total phosphorus	0.02
chloride	dropped < or >
sulfate	dropped < or >
Secchi depth	dropped < or >

Statistical Criteria

Simple linear regression was performed. The following four criteria were required to be met in order to reject Ho:

t-statistic > |2.00|
p-value< 0.10
skewness/standard error of skewness ≈ 2
kurtosis/standard error of kurtosis ≈ 3


THE TEXAS
CLEAN
RIVERS
PROGRAM
LCRA
ENERGY • WATER • COMMUNITY SERVICES
UCRA
Upper Colorado River Authority
"Keeping an Eye on West Texas Waters"