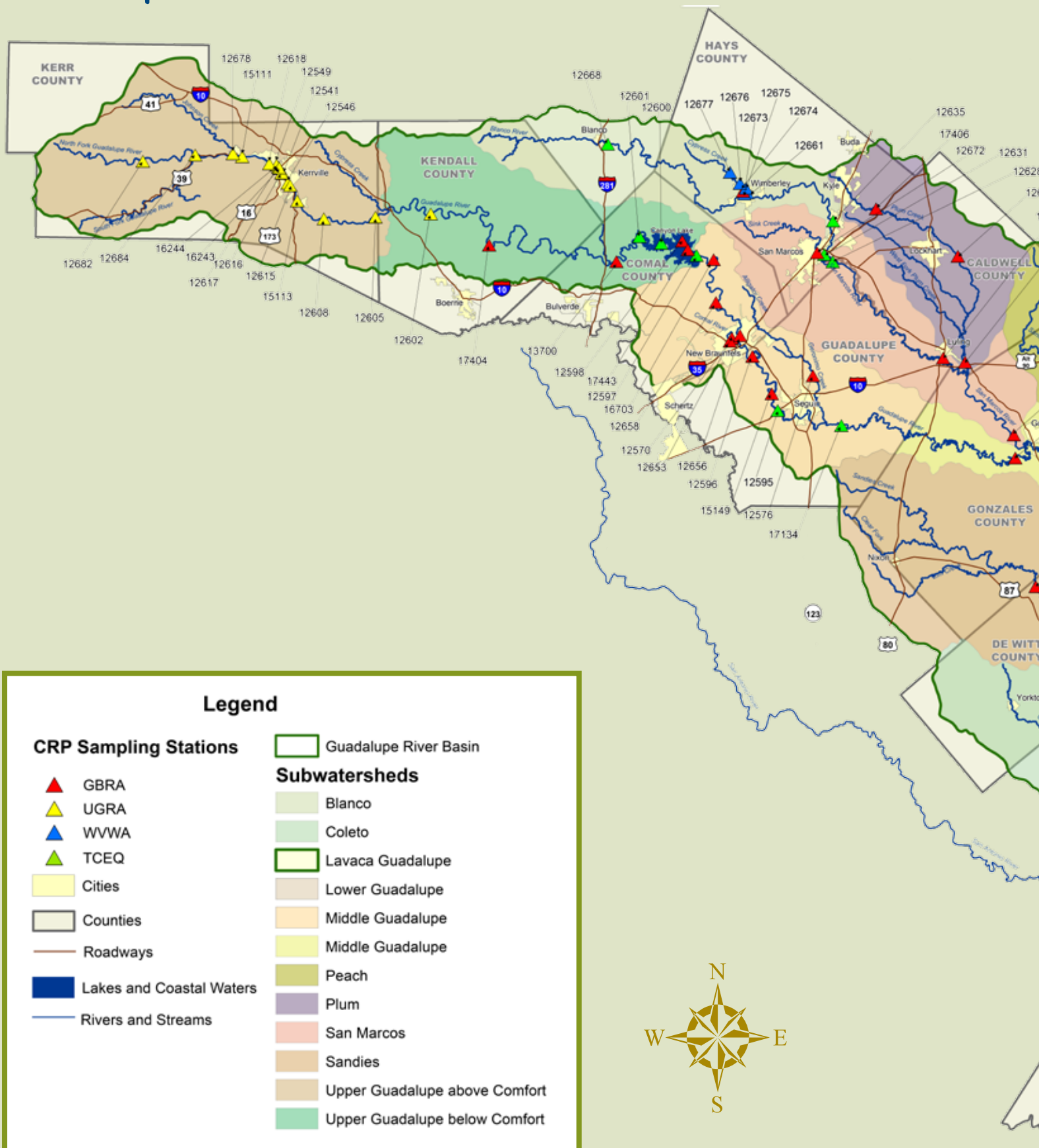
2013
Clean Rivers Program Basin Summary Report

Guadalupe River and Lavaca-Guadalupe Coastal Basins

Guadalupe River Basin



Legend

CRP Sampling Stations

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The Basin Summary report is designed to provide a comprehensive review of water quality data and related information for the Guadalupe River and Lavaca Coastal Basin. The report serves to develop a greater understanding of water quality conditions in the river basin. It also serves to enhance the ability to make decisions regarding water quality issues. The report is compiled every five years. In addition to the water quality data review, the report contains highlights on activities in the Guadalupe River Basin and Lavaca Coastal Basin under the Clean Rivers Program (CRP) and opportunities for the public to have input into the program. The CRP is managed by the Texas Commission on Environmental Quality and funded through the consolidated water quality fees, which include but not limited to fees assessed to wastewater and water rights permit holders. The Guadalupe-Blanco River Authority (GBRA), together with the Upper Guadalupe River Authority (UGRA), carry out the water quality management efforts in these basins under contract with the Texas Commission on Environmental Quality (TCEQ).

Executive Summary

The 2013 Basin Summary Report for the Guadalupe River Basin and Lavaca-Guadalupe Coastal Basin summarizes the monitoring and watershed protection activities, and water quality conditions of the watersheds in the respective basins. Historical data was reviewed for possible trends that would indicate degrading or improving conditions.

Basin Description

The Guadalupe River Basin varies from the steep, limestone Hill Country that is prone to flash flooding, to the flat, rolling terrain of the lower basin. As a result of the turbulent flows of the upper watershed streams, the substrates are primarily composed of bedrock and large gravel and the streams are shallow and swift. The lower basin substrates are silty, and the streams carry logs and debris from upstream which often collect in log jams at the lower end of the river. The middle portion of the river basin is made up of water bodies that are referred to as lakes but are really run-of-river impoundments. Four years out of five respond like rivers with short residence times, rather than true lakes or reservoirs with long residence times and stratification. The Guadalupe River Basin has two primary reservoirs, Canyon Reservoir and Coleto Creek Reservoir. Canyon Reservoir will stratify in most years, with one "turnover" that occurs in the fall. Coleto Creek Reservoir is used for cooling water for a power plant which creates excellent habitat for aquatic vegetation and fish. The tributaries of the middle and lower Guadalupe River have sandy substrates.

The Guadalupe River Basin is home to several endangered species. The Texas Wild Rice and the fountain darter are found in the Comal and San Marcos Springs and Rivers along with other species unique to springs and underground caves. Water quality, quantity and consistency of spring flow are critical to their habitat. The whooping crane that winters in the Aransas National Wildlife Refuge, along San Antonio Bay, is making a comeback. Freshwater inflows, or the lack of inflows due to diversions of water upstream, impact the habitat and biology of this species that is considered the poster child for protection of endangered species. The Senate Bill 3 stakeholder process has recommended instream flows for the Guadalupe River and inflows into the bays and estuaries in the lower basin. TCEQ considered these recommendations when setting the environmental flow requirements for the river.

The land use of the basin includes: Hill Country ranches, primarily used for hunting; farms and ranches; raising row crops; cattle, goats and poultry; and urbanized areas around the growing cities of Kerrville, Boerne, New Braunfels, Seguin, San Marcos, Lockhart, Luling, Gonzales, Cuero, Victoria, and Port Lavaca. The highest population growth is occurring along the major thoroughfares, US 281, IH 35 and SH 130, located in the central portion of the basin. Most of the industrial facilities are located in the lower basin, near the Victoria Barge Canal and ports along the coast. Recreation is an important "industry" in the upper basin and reservoirs, utilizing the clear water

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Photo by Alvin Schuerg



Photos by Janet Thome

and flows for swimming, tubing, canoeing, kayaking, and fishing. Numerous summer camps can also be found along the banks of the upper Guadalupe River. Utilization of the surface water for cooling occurs at power plants in Victoria and Goliad counties.

Watershed Concerns

The watershed segment summaries found in this report include discussions on stakeholders concerns. Those concerns may vary somewhat from watershed to watershed, but most have common issues. Stakeholders are concerned about the impact of human activities on water quality, and how those activities will influence both the recreational, and aesthetic value of the watershed. The human activities range from recreational pressure, to waste discharges and disposal, or lack thereof, to urban development. Recreational activities produce trash that, if not disposed of properly, floats downstream and becomes a nuisance. The wastewater discharges that exist throughout the river basin range in level of treatment, and in permitted volume. The permits are issued to municipalities for domestic waste treatment, to industries for their waste streams, and to power plants that use surface water for cooling. More and more new permits are being issued with nutrient limitations. Wastewater reuse is beneficial because it turns treated wastewater into a resource. This helps conserve water resources, but an unintended consequence of reuse is the reduction in return flows to the river, which can be a factor in water quality and quantity of the river, bay, and estuary. Improperly installed, poorly maintained, or failing septic tanks can be a source of bacteria, and nutrient pollution in the watershed. Additionally, control of illegal dumping at stream crossings is a high priority to stakeholders.

Impacts from urban development are concerns up and down the basin. The impervious cover associated with new houses and roads increases rainfall runoff. This runoff can be a source of "nonpoint source pollution" (pollution not associated with a permitted discharge pipe). Pollutants which soils can readily capture and biodegrade instead wash over cement and pavement, and flow directly into surface waters. Additionally, impervious cover reduces groundwater recharge and in turn, reduces the base flow of the streams.

In Kerr County, stakeholders are concerned about dense stands of ashe juniper and its propensity to intercept rainwater and prevent it from reaching the soil surface. This reduces groundwater recharge, which is critical to the base flow of the river in Kerr County. In Goliad County, the stakeholders are concerned about impacts from oil and gas production, and most recently, the in-situ mining for uranium.

The Eagle Ford Shale underlies much of south Texas, including DeWitt and Gonzales counties, which are located in the heart of the Guadalupe River Basin. The Eagle Ford Shale is a hydrocarbon-producing formation capable of producing both gas and oil. Hydraulic fracturing is a process to stimulate wells, and recover natural gas and oil from unconventional reservoirs of shale gas, and coal beds. Landowners in these counties are concerned with possible impacts of hydraulic fracturing on groundwater, and potential surface water pollution form runoff, or spills.

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Monitoring Water Quality

Most sampling locations have been routinely monitored for quite a number of years, and provide an excellent historical perspective of water quality. Only consistently collected, long term data was used for the trend analysis presented in this document. Monitoring entities include the TCEQ, the GBRA, the UGRA, the WVWA and the USGS The Hays County Development Services Department initiated a monitoring program within their jurisdiction in 2012. Because of economic reasons, funding for the Hays County program has been diverted to other projects. Their monitoring program will be discontinued until funding can be restored.

Trends in Water Quality

Water quality in most locations does not appear to be degrading. Most historical data confirmed the impairments or concerns that were listed in the 2012 Texas Water Quality Inventory. The concentration of total suspended solids, turbidity and *E. coli* bacteria continue to be of concern at most locations throughout the basin. The increase in concentration of these parameters closely correlates with high flows as a result of rainfall runoff. When the opposite conditions occur, like the droughts of 2009-2011, water quality is also impacted; base flow can become higher in dissolved solids, and effluent-dominated streams may have higher concentrations of nutrients.

The Upper Guadalupe River in Kerr County remains listed as impaired for bacteria in a small section in Kerrville. In 2011, the Upper Guadalupe River Authority partnered with the City of Kerrville, Kerr County, and the Texas Department of Transportation to implement the Bacteria Reduction Plan for the Upper Guadalupe River. The plan includes strategies to address the primary sources of bacteria pollution that have been identified in this section of the Guadalupe River, including birds nesting on bridges, large flocks of domestic waterfowl congregating in the lakes, septic systems, and pollution from general urban runoff. Other segments in the Upper Guadalupe River basin are also impaired for bacteria, and there is a concern for depressed dissolved oxygen, and habitat.

Canyon Reservoir remains listed as impaired due to a fish consumption advisory for mercury in fish tissue of the striped bass and long-nosed gar.

There is a concern for ammonia-nitrogen in Plum Creek, at a station downstream of Kyle, Buda, and other small wastewater treatment plants. The magnitude of the concentrations added to the concern. Sources of the ammonia nitrogen could be the wastewater effluent that dominates the flow at this location, but septic tanks and fertilizer can also be sources. Plum Creek is listed with an impairment for bacteria, and thus does not support its contact recreational use. Plum creek also has concerns for nitrate and total phosphorus.

Peach, Sandies and Elm Creeks are in various stages of total maximum daily load (TMDL) development. The Peach Creek TMDL has been completed, but no implementation plan has been initiated. The TMDL found that the impairment was most likely coming from non-point sources, such as failing septic tanks, livestock, and wildlife. Sandies and Elm Creeks have completed the majority of the data collection, but models have not been developed that would establish the sources of the impairments or the recommended total maximum daily loads. Stakeholders in these watersheds are concerned that the contact recreation standard is inappropriate for this stream because of the low potential for exposure to bacteria by swimmers immersed in water in these small tributaries. TCEQ has developed a process to assess the applicability of the recreational standards on these small creeks. A Recreational Use Attainability Assessment (RUAA) can be performed to determine which contact recreational use category (primary contact, secondary contact 1, secondary contact 2, or noncontact recreation) is appropriate for the water body and how it is used. The use category determines the appropriate assessment criteria. Evidence of primary recreation on these water bodies (i.e., swimming) exists. No RUAAs are planned for Elm, Sandies or Peach Creeks.

Overall, the quality of the Guadalupe River and its tributaries is good. The involvement of stakeholders and the ongoing water quality protection efforts in the basin indicate the extensive commitment to maintaining the health of the Guadalupe basin.

Objectives and Goals of the Clean Rivers Program

The Texas Legislature passed the Clean Rivers Act in 1991, which requires water quality assessments for each river basin in Texas. In accordance with the Act, the TCEQ administers the Clean Rivers Program, in partnership with river authorities, municipal water authorities, councils of governments, and other regional entities. The goal of the program is to maintain and improve water quality within each river basin through these partnerships.

The TCEQ, GBRA and UGRA gather data from the Guadalupe River, its sub-watersheds and coastal basins in a watershed management approach, in order to identify and evaluate water quality issues, establish priorities for corrective action, work to implement those actions, and adapt to changing priorities. Examination of long-term data allows comparison between current and historical water quality data, and statistical analysis can indicate any trends in improvement or deterioration of water quality parameters.

Coordination and Cooperation with Other Entities in the Basin

GBRA and UGRA coordinate with other entities interested in monitoring in the Guadalupe River Basin. Those entities include the TCEQ, United States Geologic Survey (USGS), Texas Parks and Wildlife Department (TPWD), Texas State Soil and Water Conservation Board (TSSWCB), the Wimberley Valley Watershed Association (WVWA) and Texas Stream Team. Annually, all cooperators monitoring in the basin meet to coordinate their activities. This coordination minimizes duplication, focuses monitoring and resources where needed, and helps prevent voids in coverage across the basin.

Another important partner in the river basin is the WVWA. The WVWA determined that managing water resources is of paramount importance for the continued health and welfare of the local citizens and economy. WVWA funds the Blanco River – Cypress Creek Water Quality Monitoring Program. The purpose of their program is to protect the water resources in the Wimberley area. The objectives of the monitoring program are to detect and describe spatial and temporal changes, determine impacts of point and nonpoint sources, and assess compliance with established water quality standards for Cypress Creek and the Blanco River. The monitoring program is done under the Guadalupe River Basin Clean Rivers Program Quality Assurance Project Plan (QAPP). By following the strict quality control guidelines spelled out in the QAPP, the data can be contributed to the TCEQ Surface Water Quality Database for use in stream assessments.

The Guadalupe River Basin Clean Rivers Program supports Texas Stream Team monitoring groups in the basin. GBRA provides the Stream Team Citizen Monitors with supplies, replacement chemicals, monitoring training, and quality assurance support. Currently there are monitoring groups on the Guadalupe River near Seguin, the Cyprus Creek in Wimberley, the Geronimo Creek near Seguin, Lake Placid near Seguin, the San Marcos River, the Blanco River and its tributaries, Canyon Reservoir, and Plum Creek and its tributaries.

CRP also provides quality-assured data for use in watershed planning efforts in the river basin. The TCEQ uses water quality data collected by the CRP to assess surface waters to determine if they are meeting the standards for their designated uses. Four watershed protection plans are in various stages of development in the Guadalupe River Basin.

The Plum Creek Watershed Protection Plan (PCWPP) was accepted by the U. S. Environmental Protection Agency in 2008. The PCWPP was the result of a stakeholder driven process, and provides the foundation for ecological restoration of Plum Creek, and its tributaries. Plum Creek is located in Hays and Caldwell counties in one of the most rapidly growing areas in the state. Based on routine water quality sampling, TCEQ listed portions of Plum Creek for high *E. coli* bacteria in 2004. The elevated bacteria concentrations indicated that the creek no longer supported the designated use for contact recreation. Additional segments of the creek were identified as having

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Butterfly photos by John Snyder

high nutrient concentrations. The Plum Creek Watershed Partnership developed a watershed protection plan. Based on the pollutant sources in the watershed, the plan listed both the management measures, as well as the timeline that will help meet the goal of restoring the water quality of the stream. GBRA continues to monitor three routine stations on the main stem as a part of the Clean Rivers Program. The data generated for these stations can be used to assess the success of the implementation of the management measures identified in the plan.

The Geronimo and Alligator Creeks Watershed Partnership was successful in having a watershed protection plan accepted by the EPA in 2012. Like the Plum Creek plan, the Geronimo and Alligator Creek Watershed Protection Plan can be used to restore the environmental health of the creeks. Geronimo Creek and its tributary, Alligator Creek, are located in Comal and Guadalupe Counties, in an area, like many in our basin, that is transitioning from a rural to an urban landscape. The Watershed Protection Plan outlines a series of implementation measures that will reduce nonpoint source pollutant loading from urban storm water sources, such as pet waste, and from wildlife and non-domestic animals, such as feral hogs. The plan recommends the development of water quality management plans on the agricultural operations in the watershed. GBRA continues to monitor monthly at the CRP station that originally identified the bacterial impairment of the stream and collects data to assess the effectiveness of implementation measures.

Two other watershed protection plans are being developed in the Guadalupe River Basin. The Meadows Center for Water and the Environment at Texas State University is facilitating stakeholder development of the Cypress Creek Watershed Protection Plan. The goal of the plan is to protect and preserve the water quality of Cypress Creek that flows through the City of Wimberley for present and future generations. Routine monitoring conducted by the WVWA under the CRP revealed a concern for depressed dissolved oxygen and impacted habitat for macro-invertebrates and fish communities. The Meadows Center facilitates the project and a Clean Water Act Section 319(h) grant from the TCEQ, through the EPA Region VI finances the project.

The Upper San Marcos River is included on the 2012 List of Impaired Water Bodies (303(d) List) due to elevated concentrations of total dissolved solids (TDS). There are significant interactions between the San Marcos River and the Edwards Aquifer, and both are experiencing pressures related to development, and land use changes. This project presents the opportunity to explore ways to manage impacts to surface and groundwater resources through a voluntary, stakeholder driven watershed protection plan for the upper San Marcos River watershed. The WPP will address the listed impairment for TDS. The plan will also be proactive in that it will address *E.coli*, nutrients, sediment, items identified by stakeholders in future growth scenarios (Meadows Center for Water and the Environment -Upper San Marcos Watershed Initiative, 2013). The CRP station located on the San Marcos River at IH 35, in the City of San Marcos, provided the data for the TCEQ stream assessment process. Total dissolved solids were not analyzed directly, rather, the assessment calculates the TDS by multiplying the specific conductance by a factor of 0.65. GBRA is collecting TDS at this station monthly in hopes that when sufficient TDS data is collected the stream can be reassessed for exceedence of the stream standard.

Photo by Elizabeth Aguilar

Photo by LaMarriol Smith

Photo by Janet Thome

Overview of the Guadalupe River Basin

The Guadalupe River Basin is located in south Central Texas, with the headwaters in southwestern Kerr County. The river is 432 miles long and flows southeastward through a drainage area of 6,061 square miles. The Balcones Escarpment divides the basin into two distinct regions. The northern region consists of the Edwards Plateau of the Great Plains Province. Limestone-walled valleys divide the rough area with rolling hills. The southern region is referred to as the Gulf Coastal Plains area, and consists of gently sloping prairie. The basin's principle tributaries are the North and South Fork, Johnson Creek, the Comal River, the Blanco River, the San Marcos River, Geronimo Creek, Plum Creek, Peach Creek, Sandies Creek, and Coleto Creek. The springs that feed the Comal and San Marcos Rivers have an average monthly discharge of 302 cubic feet per second and 187 cubic feet per second, respectively. The Comal River is more subject to drought conditions and has stopped flowing during the severe drought of the 1950's. The San Marcos River is much more environmentally stable.

The geology of the area consists primarily of sedimentary material that was deposited during the latter Mesozoic and Cenozoic Eras. The principle geologic structures in the basin are the Balcones and Luling fault zones. The Balcones Fault Zone consists of a series of semi-parallel faults, about 14.9 miles, extending from Hays County southwestward to Bexar County. The Luling Fault Zone extends from Caldwell County to Medina County and is 9.9 to 19.8 miles southeast of the Balcones Fault Zone. The displacement varies from less than three feet to a combined displacement of over 1500 feet. Edwards limestone covers the Edwards Plateau.

The Guadalupe River Basin and Lavaca-Guadalupe Coastal Basin are located within four ecoregions. The delineation of ecoregions is based on geographic conditions that cause or reflect differences in ecosystem patterns. These conditions include geology, physiography, vegetation, climate, soils, land use, wildlife and hydrology. The basin lies within the Edwards Plateau (Ecoregion 30), the Texas Blackland Prairie (Ecoregion 32), East Central Texas Plains (Ecoregion 33) and the Western Gulf Coastal Plains (Ecoregion 34). In the technical section of this report, specific information on the land use, climate, soil, and key factors that impact water quality are described on the sub-watersheds of the basin.

Spring-fed, perennial streams characterize the Edwards Plateau Ecoregion, and it is predominantly rangeland. The Texas Blackland Prairie Ecoregion has timber along the stream, including oak, pecan, cedar elm and mesquite. In its native state, it was largely a grassy plain, but most of the area has been cultivated and only small areas of meadowland remain. Subtropical dryland vegetation made up of small trees, shrubs, cacti, weeds, and grasses characterize the East Central Texas Plains Ecoregion. Principal plants include mesquite, live oak, post oak, blackbrush acacia, and huisache. Long-continued grazing contributes to the dense cover of brush. The gulf coast and marshes of the Western Gulf Coastal Plains are divided into two subunits: marsh and salt grasses at the tidewater and bluestems and tall grasses more inland. Oaks, elms

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and other hardwoods grow along the streams. The area is abundant with fertile farmland.

The climate of the region is mild and normal temperatures seldom fall below 32°F in the winter. The basin averages 32 inches of rainfall per year. However, in 2011, the state, as a whole, received about 11 inches of rain, about 16 inches less than normal. The rainfall amounts vary with season, with the minimum occurring in the winter, and the maximum in the late spring and early fall. The cool season begins in November, and extends through March. According to the USGS Water-Data Report for 2011, the annual average runoff in the northern part of the river basin is 164,700 acre-feet per year, 1,362,000 acre-feet per year in the middle portion, and 1,420,000 acre-feet in the lower basin. These discharge volumes represent the annual amount of water reaching the stream, in the form of runoff, at the cities of Comfort, Gonzales, and Victoria, respectively.

The region is subject to wide swings in weather and rainfall patterns. The northern part of the basin is known for flash floods, with the lower portion under the threat of tropical storms and hurricanes from mid-June through the end of October. The region has experienced several prolonged droughts, including that of 2011. According to Texas climatologists, the ongoing dry spell covering most of 2011 is the worst single-year drought since Texas rainfall data started being recorded in 1895. That is a significant occurrence. The annual average runoff in 2011 at Comfort was 36,230 acre-feet, less than 22% of the annual average runoff in the water years of 1939 through 2011. The annual average runoff in 2011 at the gages in Gonzales and Victoria were 29% of the annual average runoff recorded at those locations.

Photo by Tammy Beutnagel

However, the 2011 drought is not unprecedented in every way. Much longer droughts have occurred in the past. The Texas "drought of record," or its worst extended drought, is considered to be the 1950s drought in which the state suffered drought conditions for 10 years from the late 1940s to the late 1950s. Tree ring studies have shown even worse and more extended droughts have occurred historically. Some water resource managers predict that, if 2013 is a repeat of recent years, a new "drought of record" could be established.

The mainstream impoundments located in the river basin include Nimitz Lake, Flat Rock Lake, Canyon Reservoir, Lakes Dunlap, McQueeney, Placid, Meadow, Gonzales and Wood, and Coleto Creek Reservoir. Canyon Reservoir, built in the 1960s, is the largest impoundment in the river basin and has 8,230 surface acres. It is a multipurpose reservoir designed to serve flood control and water supply functions. It is also used for recreation. Nimitz Lake, Flat Rock Lake and Lakes Dunlap, McQueeney, Placid, Meadow, Gonzales and Wood are run-of-river impoundments. The physical characteristics of the run-of-river impoundments are given in Table 1.

As populations in the basin grow, the potential for associated anthropogenic impacts increase. Along with urbanization comes increases in impervious cover, larger

Table 1. Physical characteristics of run-of-river impoundments in the Guadaupe River Basin.

Impoundment	Volume (acre-ft)	Surface Area (acres)	Mean Depth (feet)	Elevation (feet msl)	Median Flow (cfs)	Median Residence Time (days)
Nimitz Lake	840	105	8.0	1621	91	4.65
Flat Rock Lake	793	104	7.6	1564	91	4.39
Lake Dunlap	5,900	410	14.4	575.2	583	5.10
Lake McQueeney	5,050	400	12.6	528.7	583	4.37
Lake Placid	2,624	248	10.6	497.5	583	2.27
Meadow Lake	1,460	144	10.1	457.6	583	1.3
Lake Gonzales	4,620	495	9.4	332	583	3.3
Lake Wood	4,000	488	8.2	290.9	583	3.46

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volumes of wastewater discharged to the stream, and greater demands on water supplies, reducing the base flow of the river. The 2010 estimated county population was 673,944, with the heaviest concentrations in Victoria, Comal, Hays, Kendall and Guadalupe Counties. The fastest growing counties in the region are located in the Guadalupe River Basin: Hays, Guadalupe, Kendall and Caldwell Counties. These counties are experiencing explosive growth as the populations of the cities of San Antonio and Austin spill over to the communities in the river basin. Additionally, other significant changes occurred in the watershed that caused the population and the landscape to change.

The oil and gas exploration in DeWitt and Gonzales Counties caused the population and construction activities to rise in these counties. According to the UTSA Center for Community and Business Research, the increased revenue from the Eagle Ford Shale will lead to the creation of approximately 117,000 full-time jobs by 2021. State Highway 130, the tollway that gives traffic an alternative to Interstate Highway 35, connecting Austin and San Antonio, is predicted to see a large amount of commercial and residential growth over the next ten years.

The Eagle Ford Shale, located in DeWitt and Gonzales counties, has become one of the richest oil and gas deposits in Texas because of the exploration technology called hydraulic fracturing or "fracking." Fracking is the process to stimulate wells and recover natural gas and oil by creating fractures that extend from a well bore into formations and allow the product to travel more easily. Agriculture, in the form of crops and livestock production, was the primary industry in the basin, with the manufacture of steel, gravel, plastics and chemicals contributing to the economy of the basin, as well. Oil and gas production can be found in all counties, but especially in the mid-Basin. See pg. 99 for a map of the Eagle Ford Schale Play.

Photos by Elizabeth Aguilar

Summary of Water Quality Characteristics

The groundwater that makes up baseflow highly influences the water quality of the Guadalupe River. The largest contribution to the baseflow is the Edwards Aquifer, with additional volume from the Cow Creek, Trinity, Leona, Carrizo, and Gulf Coast Aquifers. Each aquifer has unique water quality, discharge points and volume. The headwaters of the Guadalupe are located in Kerr County, and originate from springs in the North and South Forks. The discharge of the Edwards Aquifer at the Comal Springs and San Marcos Springs form two small, crystal clear lakes. Landa Lake and Spring Lake, respectively, support aquatic vegetation and wildlife, including the fountain darter and Texas Wild Rice, two endangered species. Springs that come from the Leona formation, which is high in nitrate-nitrogen, are thought to be, in part, the source of the nutrient concern and dissolved solids in Plum and Geronimo Creek.

The Guadalupe River flows through Kerr and Kendall counties and into Canyon Reservoir, the largest reservoir in the basin, located in Comal County. Canyon Reservoir impounds water for water supply, flood control, and recreation. The water exits the reservoir through a bottom penstock and is used for hydroelectric generation. A more complete description of the releases from the reservoir is given in the technical section. In most years, the lake stratifies in the late summer months and, after the first strong cold front of the winter, usually in October, the lake will experience a lake "turnover". During times of lake stratification, the bottom release from the reservoir is low in temperature and dissolved oxygen. The water is aerated as it leaves either the hydroelectric plant or penstock. The cold water conditions of Canyon Reservoir's bottom release have been utilized by TPWD and Trout Unlimited for a put and take trout sport fishery.

Downstream of Canyon Reservoir, the Guadalupe River flows over bedrock substrate and through swift water runs. The river is shallow, with few pools until it nears the City of New Braunfels, where it confluences with the Comal River and enters the first of six hydroelectric impoundments. The flow through the impoundments is diverted through turbines to generate hydroelectric power. A description of the operation of the hydroelectric lakes is given in the technical section. These impoundments are nutrient-rich, with nitrogen and phosphorus contributions from wastewater discharges, and organic sediments. The impoundments exhibit the water quality conditions of a flowing stream in years of high flow. In years of medium to high flows, the impoundments have low chlorophyll concentrations and no stratification. In years of low flow conditions, the impoundments provide the residence time needed for the assimilation of nutrients that promote higher chlorophyll production. Also during periods of low flow, the impoundments exhibit weak temporal stratification. Historically, these impoundments have been subject to infestations of non-native aquatic vegetation, and algal blooms.

From Kerr County to Refugio County, the Guadalupe River receives treated wastewater discharges. The cities of Kerrville, Boerne, Buda, New Braunfels, Kyle, San Marcos, Lockhart, Luling, Seguin, Gonzales, Cuero, and Victoria, along with other small wastewater treatment plants, discharge treated wastewater, most of which provide up to secondary treatment. Secondary wastewater treatment uses biological or chemical processes to remove 80-90% of the suspended matter and oxygen demanding materials. In several locations the Guadalupe River or one of its tributaries is used for cooling water. In the upper part of the watershed, a power plant diverts flow from the Guadalupe River to mix with treated wastewater, and use as cooling water. This is a zero discharge facility, and no water is returned to the stream. A power plant diverts a portion of the flow of the Guadalupe River north of the City of Victoria, and returns it to the stream. The Coleto Creek Reservoir also serves as cooling water for the power plant located in Goliad County. The return water from these two locations is warmer than the receiving water. Coleto Creek Reservoir was designed to hold the water long enough to dissipate the heat. The warm water conditions are conducive for the growth of aquatic vegetation. The volume and temperature of the release from the power plant near Victoria is regulated by a discharge permit that is protective of the receiving stream.

At the lower end of the basin, the Guadalupe River confluences with the San Antonio River. The Guadalupe River Diversion Canal and Fabridam are located below the confluence with the San Antonio River. The fabridam is made up of two large inflatable bags that are used to prevent salt water intrusion from the bay during times of low river flows. The canal system diverts fresh water for irrigation and municipal water supply.

Water Quality Monitoring

The Guadalupe-Blanco River Authority and the Upper Guadalupe River Authority have been monitoring under the Clean Rivers Program since 1996. Prior to the partnership with TCEQ through the CRP, both entities had routine monitoring programs. Other entities contributing data to the historical database include the Wimberley Valley Watershed Association, the Texas Commission on Environmental Quality's Surface Water Quality Monitoring and Total Maximum Daily Load divisions, and USGS.

Table 2 is the summary of water quality sampling currently being performed in the basin. The sections in this report are divided by sub-watershed or segment and will discuss the historical trends observed in the data review, and factors that may be impacting water quality within each sub-watershed.

The Texas State Soil and Water Conservation Board is funding water quality monitoring programs on Plum Creek, and Geronimo and Alligator Creeks in support of the implementation of the watershed protection plans developed on these creeks. The plans were developed using data collected by the Clean Rivers Program and the TCEQ's Surface Water Quality Monitoring Program and, in the case of the Geronimo Creek plan, with additional monitoring done in advance of the plan development. Using the existing monitoring of the three stations on Plum Creek and one station on the Geronimo Creek by TCEQ and GBRA's CRP as match, TSSWCB has funded additional monitoring in these watersheds with Clean Water Act Section 319(h) funds. GBRA, under an EPA-approved QAPP, is performing routine and targeted stream monitoring, and monitoring of springs and storm water within the watersheds. GBRA will submit the data to the TCEQ for inclusion in the biennial assessments.

These monitoring programs are executed under QAPPs. A QAPP is used to plan, organize and define the quality assurance process for the program. Quality assurance is the integrated system of management activities that ensures that data generated is of the type and quality needed for its uses. Those uses include planning, assessment and water quality management. Elements of the program that are controlled by the QAPP include measurement performance specifications, appropriate methods, field and laboratory quality control, data management, and data verification and validation. Additionally, oversight of the laboratory quality system and process of corrective actions are described in the QAPP. The current QAPP is available for review on the GBRA CRP webpage.

Photos by Janet Thome

Table 2. Summary of water quality sampling in the Guadalupe River Basin. DO = dissolved oxygen.

FY 2013 (September 2012 through August 2013)

Sampling Entity	Field	Conventional	Bacteria	Biological and Habitat	24 Hr DO	Metals in Water	Metals in Sediment	Organics in Water	Organics in Sediment
GBRA	18 stations monthly; 8 stations quarterly	18 stations monthly; 8 stations quarterly; 1 station monthly TDS and conductivity	18 stations monthly; 8 stations quarterly	2 stations 2X per year	2 stations 2X per year	1 station 2X per year; 1 station annually	1 station annually	2 stations annually	4 stations annually
UGRA (Kerr Co)	11 stations quarterly; 9 stations - monthly	11 stations quarterly	11 stations quarterly; 9 stations monthly						
TCEQ	10 stations quarterly	10 stations quarterly	10 stations quarterly			2 stations 2X per year	1 station 2X per year	1 station 2X per year	1 station 2X per year
WVWA	5 stations 8 X per year	5 stations 8 X per year	5 stations 8 X per year		1 station annually				
TSSWCB-Plum Creek	5 stations monthly; 40 stations Targeted for wet and dry weather quarterly; 3 stations quarterly for storm water; 7 wastewater effluents monthly; 3 springs quarterly	5 stations monthly; 40 stations targeted for wet and dry weather quarterly; 3 stations quarterly for storm water; 7 wastewater effluents monthly; 3 springs quarterly	5 stations monthly; 40 stations targeted for wet and dry weather quarterly; 3 stations quarterly for storm water; 7 wastewater effluents monthly; 3 springs quarterly		8 stations monthly during index period				
TSSWCB Geronimo Creek	7 stations monthly; 14 stations targeted for wet and dry weather quarterly; 3 springs quarterly	7 stations monthly; 14 stations targeted for wet and dry weather quarterly; 3 springs quarterly	7 stations monthly; 14 stations targeted for wet and dry weather quarterly; 3 springs quarterly		8 stations monthly during index period				

Description of the Water Quality Assessment Process

In compliance with sections 305(b) and 303(d) of the federal Clean Water Act, the TCEQ evaluates water bodies in the state and identifies those that do not meet the uses and criteria defined in the Texas Surface Water Quality Standards. EPA has established guidance that directs TCEQ to document and submit the assessment results to EPA biennially, in even numbered years. The 2012 Texas Integrated Report for Clean Water Act Sections 305(b) and 303(d) summarizes the condition of the state's surface waters, including concerns for public health, fitness for use by aquatic species and other wildlife, and specific pollutants and their possible sources (TCEQ, 2013). It describes the status of water quality in all surface water bodies in the state that were evaluated for the assessment period. The data used in the assessment comes from various sources, including the Guadalupe River Basin CRP partners, TCEQ's Surface Water Quality Monitoring program, and other contributors. Given the regulatory implications associated with the use of the water quality data, the data used in the assessment process must have been collected using consistent and scientifically rigorous sampling and laboratory methods. Data collected under an accepted quality assurance project plan that describes the integrated system of management activities that ensures that data generated is of the type and quality needed for its uses is assessed. Data that are not collected under a TCEQ-approved quality assurance plan, if submitted, must be accompanied by documentation of quality assurance for evaluation by TCEQ water quality staff. Data without appropriate quality assurance documentation is considered as anecdotal evidence to support or refute assessment results, but is not to be used in statistical evaluations. On July 1, 2008 requirements regarding laboratory accreditation went into effect. Data analyzed after that date must comply with the National Environmental Laboratory Accreditation Conference (NELAC) standard to be used to generate the Integrated Report (See 30 TAC, Chapter 25). Both the GBRA and UGRA laboratories are accredited by the Texas Environmental Laboratory Accreditation Program administered by the TCEQ.

The quality of the water described in the assessment report is a snapshot of conditions during the specific time period considered in the assessment. The 2012 assessment covers the period of record from Dec. 1, 2003 to Nov. 30, 2010. Assessors have the option of including more recently collected data than Dec. 1, 2010, if available. The TCEQ develops the assessment methodology through a stakeholder process. River authorities and CRP partners are invited to participate in the development and review of the assessment guidance.

Photo by Janet Thome

Photo by John Snyder

Water quality standards are comprised of two parts, designated uses, and the associated criteria for stream conditions necessary to support that use. The uses of a water body include aquatic life use, providing a suitable environment for fish and other aquatic organisms; and contact recreation use, providing water that is safe for swimming and other recreational activities. The criteria for each use may be described numerically or expressed in terms of desirable conditions.

Continued on next page

Uses and criteria are assigned to a segment. A segment is a water body or a portion of a water body with a specific location, defined dimensions, and designated or presumed uses. If the criterion of a segment are not met, then the segment is designated as impaired. If nonattainment of the criterion is imminent, then the segment is designated with a concern. If there is insufficient data to determine if the standard is attained, but what data is available points to a concern, the segment is noted with a concern in the Texas Water Quality Inventory. Also, a screening level concern may be assigned if no numeric criteria is assigned.

After assessments are completed, water bodies are designated as impaired if the stream exceeds the numeric stream standard or as a concern if the conditions exceed the screening levels established by the assessment team. Overall, the quality of the Guadalupe River Basin is good. According to the 2012 Texas Integrated Report for Clean Water Act Sections 305(b) and 303(d), 11 water bodies are impaired (Table 3). Five water bodies have concerns for nutrient concentrations or depressed dissolved oxygen.

Table 3. 2012 Texas Water Quality Inventory and 303(d) List (Guadalupe River Basin) (assessed using data collected in 12/1/2003 through 11/30/2010)

Segment Number	Water Body	Impairment	Concern
1801	Guadalupe River Tidal		Depressed Dissolved Oxygen; Nitrate-Nitrogen
1802	Guadalupe River below the San Antonio River		Nitrate-Nitrogen
1803	**Guadalupe River below the San Marcos River**		**Bacteria**
1803A	Elm Creek	Depressed Dissolved Oxygen	
1803B	Sandies Creek	Depressed Dissolved Oxygen; Impaired Macrobenthic and Fish Communities; Bacteria	Impaired Habitat
1803C	Peach Creek	Depressed Dissolved Oxygen; Bacteria;	Chlorophyll *a*
1804A	Geronimo Creek	Bacteria	Nitrate-Nitrogen
1805	Canyon Lake	Mercury in Edible Fish Tissue	
1806	Guadalupe River above Canyon Reservoir	Bacteria	**Impaired Habitat**
1806D	Quinlan Creek	Bacteria	
1806E	Town Creek	Bacteria	**Depressed Dissolved Oxygen**
1810	Plum Creek	Bacteria	Depressed Dissolved Oxygen; **Impaired Habitat**; Nitrate-Nitrogen; Orthophosphorus; Total Phosphorus
1811A	Dry Comal Creek	Bacteria	
1813	Upper Blanco River	**Depressed Dissolved Oxygen**	
1814	Upper San Marcos River	Total Dissolved Solids	
1815	Cypress Creek		Depressed Dissolved Oxygen; **Impaired Habitat; Impaired Fish and Macrobenthic Communities**

Bold text indicates additions as of 2012 assessment.

Index of Biotic Integrity

Run - Guadalupe River at Split Rock Dam

Glide - Geronimo Creek

Riffle - Guadalupe River at Split Rock Dam

Pool - Guadalupe River at Split Rock Dam

Photos by Lee Gudgell

The index of biotic integrity (IBI) has been developed in order to assess the health of a biological system, like a stream, river or lake. Assessments are done at selected stream locations, collecting data on fish and invertebrate populations and the condition of the stream and riparian habitat. Data is then put into metrics that result in a score that describes the quality of the stream to support aquatic life. The IBI consists of these metrics, or criteria, that reflect nekton species (aquatic organisms that live in the water column and swim independent of the current, such as fish) richness and composition, number and abundance of indicator invertebrate species, trophic organization and function, reproductive behavior, and the types and availability of habitat. Each metric is scored based on a range of conditions. The score for each element of the biotic index will fall into one of four ranges: limited, intermediate, high and exceptional. Together the combined indices will determine if the stream is meeting its designated uses for aquatic life support. Biological and habitat assessment must be conducted during the critical period that runs from July 1 to September 30.

Stations on the stream are selected to represent conditions of the entire water body. The "reach" of the stream that is assessed should have a variety of habitats such as a run, a pool, glide and a riffle, and should not be impacted by a tributary or discharge within the reach. During a biological assessment, measurements are taken to assess the availability and types of habitat at each station. Measurements include stream width and depth, bank slope, stream type, instream cover, substrate type, percent erosion, and the natural buffer and vegetation along the stream bank. The metrics used to assess habitat quality compare the availability of different types of habitat, bank and substrate stability and changes, and impacts of flow.

To assess the benthic quality of a stream, benthic organisms (aquatic organisms that live on the river or lake substrate) are collected using a kick net sampling method. In this method, an area of substrate is disturbed for five minutes with a net positioned downstream to capture the organisms that are carried to the net by the current. Field staff cut portions of snags, or submerged woody debris exposed to the current, and collect the invertebrates in a sieve. Field staff separate invertebrates by type of feeding method (gatherers, predators, or collectors), and by tolerant and intolerant species. The number of invertebrate species, along with the ratio of the different invertebrate types found at each station, are put into the benthic metrics to determine the benthic index.

To assess a stream's ability to support fish, depending on the applicability of the method to the location, fish are collected using seining and electro-shocking methods. Fish that are collected during the assessment are separated by species categories, method of feeding, natives and non-natives, and those with diseases and anomalies.

Since the 2008 Basin Summary Report, GBRA and UGRA have performed biological assessments at the stations listed in Table 4. Table 4 summarizes the results of those assessments, and possible reasons for why the station is not be meeting its designated uses for supporting of aquatic life. Over the last four years, the Guadalupe River Basin has experienced two prolonged periods of extreme drought, broken by periods of flash flooding. These extreme weather conditions are the most likely causes of the difference between the current aquatic life designation and the measured IBI score at these stations. Limited funding, drought conditions, flood conditions, and other causes have led to a reduction in frequency and the number of available locations for biological assessments.

Table 4. Biological Assessments (assessed using data collected in 2008 through 2011)

Sampling Station (Segment No.)	Sampling Date	Current Aquatic Life Use Designation	Measured Aquatic Use Designation			Meeting Designaged Use?	Known or Potential Causes of Nonsupport
			Nekton (No. of Species Found)	Benthos (No. of Species or Subclass Found)	Habitat		
Guadalupe River at Split Rock (1806)	9/23/2008	Exceptional	High (17)	High (21)	High	No	Severe drought conditions bracketed by periodic pulses of high flow may wash away biological habitat
	9/2/2009	Exceptional	High (14)	High (19)	High	No	Severe drought conditions bracketed by periodic pulses of high flow may wash away biological habitat
	8/10/2010	Exceptional	Exceptional (18)	Exceptional (24)	High	Yes	
	7/28/2011	Exceptional	Exceptional (22)	Exceptional (17)	High	Yes	
Guadalupe River at Riverview Park (1806)	9/22/2008	Exceptional	Exceptional (16)	High (17)	High	Yes	
	9/1/2009	Exceptional	High (15)	High (23)	High	No	Severe drought conditions bracketed by periodic pulses of high flow may wash away biological habitat
	8/17/2010	Exceptional	High (16)	Exceptional (19)	High	Yes	
Dry Comal Creek (1811A)	7/15/2008	High	High (13)	High (16)	High	Yes	
	8/24/2009	High	High (10)	Intermediate (15)	High	No	Severe drought conditions throughout the index period
Peach Creek (1803C)	7/21/2008	High	High (11)	High (19)	High	Yes	
	8/21/2009	High	Intermediate (8)	High (18)	Intermediate	No	Insufficient biological habitat due to impacts of periodic high flow pulses on sandy substrate; extreme low flows due to extended drought
Cypress Creek (1815)	7/18/2008	Exceptional	High (13)	High (16)	High	No	Insufficient biological habitat due to impacts of periodic high flow pulses on bedrock substrate
	9/2009	Exceptional				No	Stream dried up due to drought
	8/20/2010	Exceptional	High (16)	High (15)	Intermediate	No	Insufficient biological habitat due to impacts of periodic high flow pulses on bedrock substrate
	7/14/2011	Exceptional	Intermediate (11)	Limited (0)	Intermediate	No	Insufficient biological habitat due to impacts of periodic high flow pulses on bedrock substrate

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Table 4. Biological Assessments (assessed using data collected in 2008 through 2011) (cont.)

Sampling Station (Segment No.)	Sampling Date	Current Aquatic Life Use Designation	Measured Aquatic Use Designation			Meeting Designaged Use?	Known or Potential Causes of Nonsupport
			Nekton (No. of Species Found)	Benthos (No. of Species or Subclass Found)	Habitat		
Plum Creek at Plum Creek Road (1810)	9/30/2008	High	High (10)	High (19)	High	Yes	
	8/23/2010	High	High (11)	Intermediate (18)	High	Yes	
Plum Creek at CR 202 (1810)	8/8/2008	High	High (11)	Intermediate (15)	Intermediate	No	Insufficient biological habitat due to impacts of periodic high flow pulses on clay substrate; downstream of four major wastewater discharges; frequent illegal dumping at road crossings upstream
	8/27/2009	High	Intermediate (14)	Intermediate (20)	Intermediate	No	Insufficient biological habitat due to impacts of periodic high flow pulses on clay substrate; downstream of four major wastewater discharges; frequent illegal dumping at road crossings upstream
	8/24/2010	High	Intermediate (8)	Intermediate (15)	Intermediate	No	Insufficient biological habitat due to impacts of periodic high flow pulses on clay substrate; downstream of four major wastewater discharges; frequent illegal dumping at road crossings upstream
	7/13/2011	High	High (10)	Intermediate (25)	Intermediate	No	Insufficient biological habitat due to impacts of periodic high flow pulses on clay substrate; downstream of four major wastewater discharges; frequent illegal dumping at road crossings upstream
Geronimo Creek (1804A)	8/16/2010	High	High (12)	Exceptional (23)	High	Yes	
	7/25/2011	High	High (15)	High (25)	High	Yes	

Public Partnerships

Guadalupe-Blanco River Authority

The GBRA sustains a number of communication mechanisms to support the CRP in the Guadalupe Basin, striving to maintain active communication with the public to pursue the goals of public involvement and education in water quality issues. GBRA develops opportunities for direct public participation to ensure that community concerns are addressed. These include producing quarterly *GBRA River Run* magazines, updating the GBRA website, issuing press releases about water topics, and presenting to the public.

Guadalupe River Basin Steering Committee

A major communication vehicle for the CRP is the Basin Steering Committee. Composed of community leaders and interested citizens from throughout the basin, this group meets annually to review activities, and advise the program on priorities for monitoring and special studies. The Steering Committee membership includes; representation from municipalities, counties, industries, homeowner organizations, Texas State Soil and Water Conservation Board, Texas Parks and Wildlife Department, Texas Department of Agriculture, Railroad Commission of Texas, League of Women Voters, chambers of commerce, and local/regional environmental organizations. Steering Committee meetings are open to the public. The committee reviews and approves achievable basin water quality objectives, defines priorities, considers available technologies, considers economic impacts, guides work plans, and guides resource allocation. Notice of the Steering Committee meetings is made available by mail and on the meeting page of the GBRA website (www.gbra.org).

Special Sub-committees for Local Water Quality Issues

In addition to the Basin Steering Committee for the CRP, the GBRA has established the Hydroelectric Lake Citizens Advisory Committee, and the Coleto Creek Reservoir Advisory Committee. Yearly, these groups can learn, question, and provide input on activities that control nuisance, non-native aquatic vegetation, and lake operations and safety. The committees have representatives from homeowners associations, potable water systems, bass clubs, boating sales companies, industries, as well as the Texas Parks and Wildlife Department, and Texas Department of Agriculture. These committees also receive invitations to the CRP Steering Committee meetings.

Regional Lab

The Regional Laboratory located at the General Offices of GBRA in Seguin provides technical assistance and support to GBRA's operations, municipalities, water districts, industries, engineering firms, and other organizations as they comply with federal, state, and local regulatory requirements that protect water quality. The Regional Laboratory has received its accreditation from the Texas Environmental Laboratory Accreditation Program. The Regional Laboratory is equipped to perform physical, chemical, and biological analyses of water from natural streams, potable water and wastewater treatment plants, groundwater wells and treatment residuals. The Regional Laboratory serves as a contract laboratory for the CRP. In addition to its broad water quality planning initiatives, and participation in environmental and water quality monitoring programs within the river basin, the laboratory also sponsors and trains Texas Stream Team. The lab also conducts presentations for schools, civic and other organizations on water quality, environmental issues, Texas Stream Team, and other water-related subjects. The laboratory maintains strong working relationships with federal, state, and local government agencies responsible for water quality, as well as corporations and individuals capable of affecting water quality.

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Public Education Efforts

GBRA's award-winning fourth-grade program, Journey through the Guadalupe River Basin, maintains a strong presence in schools throughout the river basin. This TEKS-correlated program takes an interdisciplinary approach to the subject of water, placing an emphasis on watersheds and water quality, specific to the Guadalupe River Basin. In addition, the curriculum touches on the water cycle, water uses in the basin, population growth, and water conservation. GBRA offers teacher trainings for this program.

Waters to the Sea, Guadalupe River is a new multi-media middle school program that GBRA will introduce during 2013-14 school year. Education staff developed this new program with the Center for Global Environmental Education (Hamline University, St. Paul, Minnesota). This new interactive learning program highlights relationships between human activities and water resources within the Guadalupe River watershed, from the river's headwaters to San Antonio Bay. The program addresses Texas science and social studies education standards through numerous short videos, animations, simulations, and multimedia interactives that draw from the region's rich history. Modules focus on themes ranging from traditional Native American uses of natural resources, to the importance of water for agriculture, to the impacts of urban growth on surface water runoff, to the importance of wetlands at the bay. GBRA expects the program's completion in summer 2013, and teacher trainings will begin immediately.

Education staff makes a concerted effort in both the Plum Creek and Geronimo Creek watersheds. Water quality education and monitoring are introduced to fourth and fifth grade students in these target watersheds. GBRA Environmental Education Administrator Cinde Thomas-Jimenez led efforts in nine public schools in the Plum Creek watershed for the sixth consecutive school year in 2011-2012. Working side by side with teachers and students, Jimenez spent two weeks in classrooms presenting information using a tabletop watershed model to discuss watersheds, nonpoint source pollution, and the Plum Creek project directly with the students. All needed supplies were donated to the schools including water monitoring test kits, watershed map posters and student workbooks. A total of 1,000 students and 32 teachers conducted two rounds of water quality testing. Using the Texas Stream Team methods as a model for their monitoring, students tested water from Plum Creek for the following parameters: temperature, dissolved oxygen, pH, turbidity, nitrates, and phosphates. *E. coli* bacteria was also an option. The results of the student monitoring indicate a slight decrease in dissolved oxygen, and increases in phosphates and nitrates as the creek moves from the urban area in the northern portion of the watershed to the more rural southern area. This effort will continue in 11 Plum Creek schools during 2012-2013. In spring of 2011, this same model was introduced in Geronimo Creek schools at both the elementary and secondary levels.

Upper Guadalupe River Authority

As the lead water resource planning agency for the Upper Guadalupe River Basin, UGRA partners with municipal and county governments, communities, civic groups, and citizens to preserve and protect the water quality in all Kerr County surface water bodies.

As an active partner in the Texas Clean Rivers Program, UGRA performs routine, quarterly sampling at ten stations in Kerr County. In 2008, UGRA launched the County Wide Goal Based Monitoring Program to increase the number of stations that are monitored routinely in the Upper Guadalupe River so that water quality concerns can be addressed proactively. The program concentrates on the main tributaries to the Guadalupe River, and monitors the same parameters as the Clean Rivers Program.

UGRA's Summer Swimability Program provides information on current water quality conditions for local citizens. Samples for *E. coli* bacteria analysis are taken at 21 stations on a weekly basis from Memorial Day to Labor Day. The results are compared to state standards for contact recreation, and are posted on the UGRA website.

UGRA provides opportunities for citizen stewardship and community involvement in protecting the water resources of Kerr County. A popular activity is the UGRA Volunteer Summer Study. Interested members of the community who collect samples for E. coli bacteria analysis support the program each summer. The information collected by the volunteers provides important data and helps identify areas in need of further investigation while including the community in water quality monitoring.

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Photo by Travis Linscomb

Central to these varied water monitoring programs is the nationally accredited UGRA Environmental Laboratory, a full service laboratory serving the entire Hill Country. The Laboratory's analytical services include bacteriological, chemical, and biological testing of drinking water, wastewater, and surface water. The Laboratory is accredited according to the National Environmental Laboratory Accreditation Program and is one of the largest microbiological laboratories in the region.

Preservation and Conservation Efforts

UGRA is committed to the elimination of trash from the river, and actively solicits and promotes community involvement in its Trash-Free Initiative. UGRA arranges for and funds routine clean ups at fifteen low water crossings across the county. Over 15,000 pounds of trash was removed from these low water crossings in 2012.

Another cornerstone of the Trash-Free Initiative is UGRA's Annual River Clean Up, a county wide event to promote awareness of the importance of the Guadalupe River to the community and its proper stewardship. In 2012, more than 11,000 pounds of garbage was collected by 270 participants, working along the river from above Hunt, all the way to Center Point.

UGRA partners with other local entities for hazardous material spill containment and clean up. Absorbent hazmat socks and pillows are provided to area fire departments and the environmental health department to aid them in their efforts to contain and clean up oil and gas spills in and near the Guadalupe River.

Through a grant from TCEQ, UGRA was able to facilitate the installation of seven pet waste stations in Flat Rock Park along the Guadalupe River in Kerrville. An effectiveness monitoring program was also initiated and in 2012 over 1,100 pounds of pet waste was collected as a result of these stations.

UGRA promotes landowner practices that have the potential to enhance groundwater and surface water resources. Studies have indicated that brush control, primarily ashe juniper removal, can help increase Edwards Plateau Aquifer recharge, enhance springflow, and improve range and pasture land productivity. Financial assistance is available for eligible landowners to aid their brush management efforts.

UGRA recently launched a rebate program promoting water conservation and watershed stewardship through rainwater harvesting. The Rainwater Catchment System Rebate Program is available to residents with a Kerr County address and reimburses eligible applicants up to $50; contact UGRA for more information.

Public Education to Raise Awareness

Part of UGRA's mission is to actively facilitate the understanding of water issues and engage the community in maintaining and promoting the health and enjoyment of the Upper Guadalupe River Basin.

UGRA has an active education program designed to give Kerr County residents a better understanding of the Upper Guadalupe River and its watershed. UGRA staff prepares presentations for area schools, clubs, organizations, and summer camps to teach about water quality, conservation, the water cycle, and the importance of the Guadalupe River to the community. UGRA publishes a monthly column in the local newspapers about water quality and the aquatic environment, and has an active public awareness campaign to keep the community informed on water issues. The Major Rivers water education program is distributed to 4th and 5th grade teachers in Kerr County to aid their lessons on the water cycle, conservation, and Texas water resources through a joint effort by UGRA and Headwaters Groundwater Conservation District.

Above all, UGRA is a resource and advocate for the community on water quality, surface water, and the Guadalupe River. Please contact UGRA with comments, questions or concerns at (830) 896-5445 or visit www.ugra.org.

Water Quality Parameters

Field Parameters are water quality constituents that can be obtained on-site and generally include: dissolved oxygen, conductivity, pH, temperature, stream flow (not in reservoirs), and secchi disc depth.

Dissolved Oxygen (DO) indicates the amount of oxygen available in the stream to support aquatic life. DO can be reduced by the decomposition of organic matter.

Conductivity is a measure of the water body's ability to conduct electricity and indicates the approximate levels of dissolved salts, such as chloride, sulfate and sodium. Elevated concentrations of dissolved salts can impact water as a drinking water source and aquatic habitat.

pH is a measure of the hydrogen ion concentration in an aqueous solution. It is a measure of the acidity or basic property of the water. Chemical and biological processes can be affected by the pH. The pH can be influenced by dissolved constituents, such as carbon dioxide and by point and nonpoint source contributions to the stream.

Temperature of the water affects the ability of the water to hold dissolved oxygen. It also has an impact on the biological functions of aquatic organisms.

Stream Flow is an important parameter affecting water quality. Low flow conditions common in the warm summer months create critical conditions for aquatic organisms. Under these conditions, the stream has a lower assimilative capacity for waste inputs from point and nonpoint sources.

Secchi Disc transparency is a measure of the depth to which light is transmitted through the water column, and thus the depth at which aquatic plants can grow.

Conventional Parameters are typical water quality constituents that require laboratory analysis and generally include: nutrients, chlorophyll *a*, total suspended solids, turbidity, hardness, chloride, and sulfate.

Nutrients include the various forms of nitrogen and phosphorus. Elevated nutrient concentrations may result in excessive aquatic plant growth and can make a water body unfit for its intended use(s).

Chlorophyll *a* is a plant pigment whose concentration is an indicator of the amount of algal biomass and growth in the water.

Turbidity is a measure of water clarity or light transmitting properties. Increases in turbidity are caused by suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, plankton, and other microscopic organisms.

Total Suspended Solids indicate the amount of particulate matter suspended in the water column.

Hardness is a composite measure of certain ions in water, primarily calcium and magnesium. The hardness of the water is critical due to its effect on the toxicity of certain metals. Typically, higher hardness concentrations in the receiving stream can result in reduced toxicity of heavy metals.

Chloride and Sulfate are major inorganic anions in water and wastewater. Numeric stream standards for chloride and sulfate have been set on all of the classified stream segments in the basin. Both of these inorganic constituents can impact the designated uses, and can come from point and nonpoint sources, such as wastewater discharges, oil field activities, and abandoned flowing wells from groundwater with elevated concentrations of dissolved solids.

Other Parameters

Bacteria, specifically *E. coli*, is used as an indicator of the possible presence of disease-causing organisms. *E. coli* concentrations are reported as Most Probable Number per 100 milliliters (MPN/100mL). MPN/100mL is directly relatable to the units used in the contact recreation standard (126 colonies per 100mL).

Biological and Habitat assessments include collection of fish community data, benthic macroinvertebrate (insects) data, and measurement of physical habitat parameters. This information is used to determine whether the stream adequately supports a diverse and desirable biological community. The physical, chemical, and biological data are used together to provide an integrated assessment of aquatic life support.

24-Hour DO studies perform measurements of DO in frequent intervals (e.g., one hour) in a 24-hour period. The average and minimum concentrations in the 24-hour period are compared to corresponding criteria. This type of monitoring takes into account the diurnal variation of DO and avoids the bias in samples taken only at certain times of the day.

Metals in Water, such as mercury or lead, typically exist in low concentrations, but can be toxic to aquatic life or human health when certain levels are exceeded. To obtain accurate data at low concentrations, the GBRA uses special clean methods that minimize the chance for sample contamination and provide high quality data.

Organics and Metals in Sediment could be a source of toxicants for the overlying water, though currently there are no numeric sediment standards.

Organics in Water, such as pesticides or fuels, can be toxic to aquatic life or human health when certain levels are exceeded.

Overview of the Technical Summary



Photos by Travis Linscomb

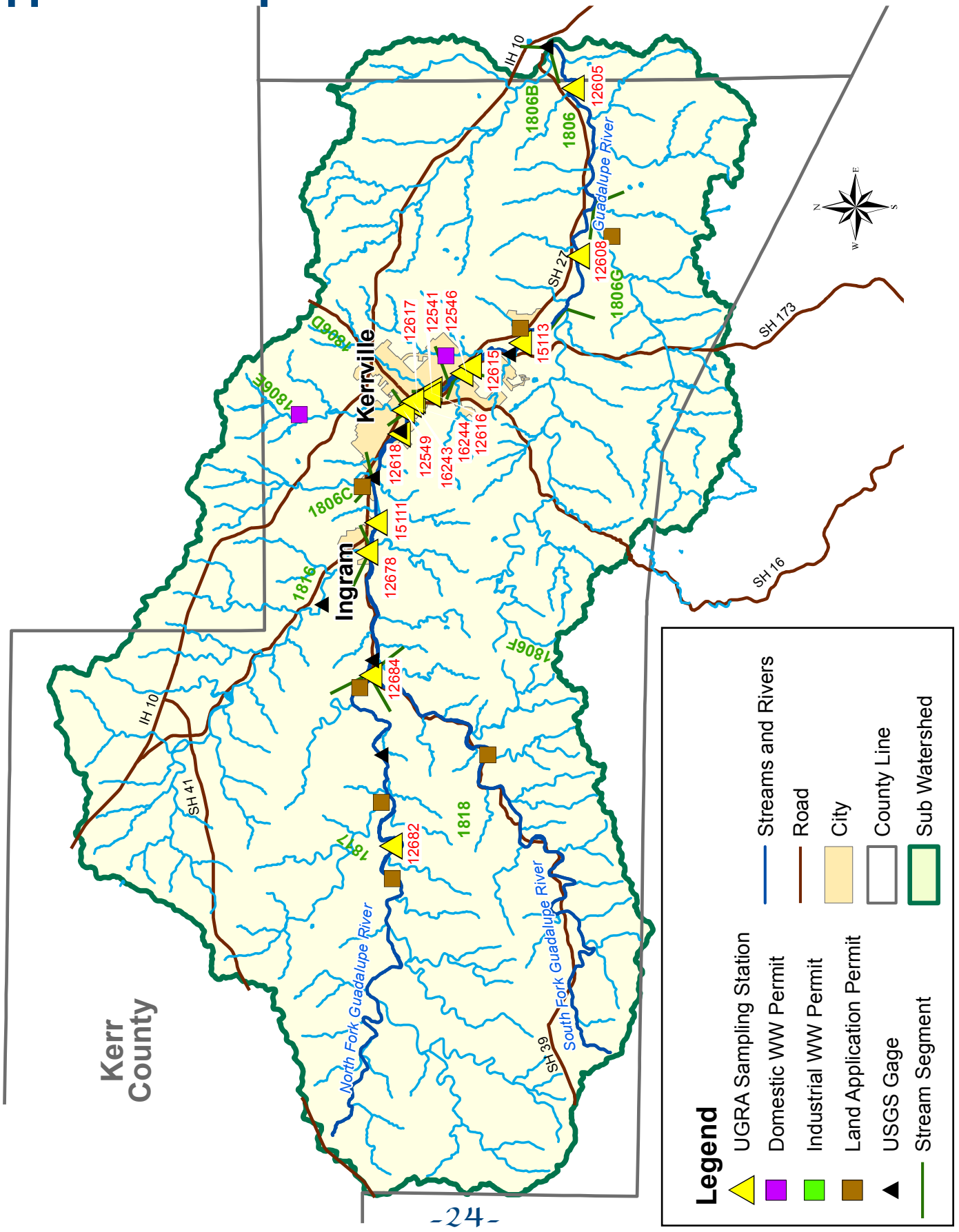
The technical summary section provides a review of the water quality conditions in the Guadalupe River Basin. Also included in this section is a discussion of the latest biennial assessment of the surface water quality done by TCEQ. In an evaluation of the water quality data, stations and parameters for which the data met sample number and sampling duration criteria were examined statistically to identify and verify trends. Also considered in the evaluation of the data were land uses, soils and vegetation, and point source discharges. The factors at play in each sub-watershed are considered in order to identify and prioritize concerns or impairments and their most probable causes, recommend future monitoring activities, implementation of control or remediation actions, public outreach, or other appropriate measures. The origin of the data and the analytic procedures used to evaluate the data are explained in the section, *Description of Water Quality Assessment Process*. The **Watershed Summaries** section provides an overview of existing data, a discussion on the water quality concerns identified during the screening process and an assessment of the trends seen in the water quality data.

The screening and assessment of water quality conditions in this Basin Summary Report is organized by watershed, segment and station. A watershed is the total area that drains to a particular point in a stream. The Guadalupe River basin is broken into 12 watersheds for this report. For assessment and trend analysis, the watersheds were broken down further into sub-watersheds and then further by segment. Segments are contiguous reaches that exhibit similar physical, chemical or biological characteristics and which an uniform set of standards applies. Most segments have one monitoring location. But in those cases where there are multiple sampling locations, the data sets were combined to observe differences within the segment, and/or to strengthen the analyses by increasing the number of data points used in the assessment. If two or more stations within one segment were statistically different for any water quality data type, the data was not combined for more than a comparison between stations and the difference was noted.

For evaluation of trends over time, water quality data available from the TCEQ's Surface Water Quality Monitoring Information System was divided by station and then by parameter. For a given station and parameter the number of data points used in the initial trend analyses was at least 20 points over the historical period, with at least three measurements per year, in five or more years. The data sets that met the data criteria were compared over time to observe any trends. If a trend was observed the data was further evaluated using statistical tools. Linear regressions were performed to confirm the significance of the trend. Additionally, a graph and narrative were created to explain any significant trends.

When looking for potential changes in water quality conditions, water quality parameters are compared over time. The statistical comparisons and graphs of these comparisons can show if there are overall upward or downward trends at a location or in a segment. The graphed data can be represented with or without a line that connects the data points. The line may make it easier to see seasonal patterns in the water quality data. It should be recognized that if the data points are connected by a line in time comparisons, the line between the points does not represent the true conditions of the stream between the times that the data was actually collected.

Upper Guadalupe River Watershed above Comfort



Upper Guadalupe River Watershed above Comfort

River Segments, Descriptions and Concerns

Drainage Area: 850 square miles

Streams and Rivers: North Fork and South Fork of the Guadalupe River, Johnson Creek, Quinlan Creek, Camp Meeting Creek, Town Creek, Cypress Creek, Goat Creek, Turtle Creek, Verde Creek, Bear Creek

Aquifer: Trinity, Edwards Plateau

River Segments: 1816, 1817, 1818, 1806A-G

Cities: Center Point, Ingram, Kerrville, Comfort, Hunt

Counties: Kerr, Gillespie, Bandera, Kendall

EcoRegion: Edwards Plateau

Vegetation Cover: Evergreen Forest 46.9%, Grass/Herbaceous 14.4%, Shrublands 28.8%

Climate: Average annual rainfall 30 inches, Average annual temperature January 32°, July 94°

Land Uses: ranching, farming, tourism, light manufacturing

Water Body Uses: aquatic life, contact recreation, general use, fish consumption, and public water supply

Soils: Dark and loamy over limestone; to the south and east soils are variable with light colored brown to red soils in some areas and dark loamy or loamy soils over clay subsoils elsewhere

Permitted Wastewater Treatment Facilities: Domestic 2, Land Application 6, Industrial 0

Segment 1816 (Johnson Creek) This spring-fed 21 mile segment consisting of Johnson Creek to its confluence with the Guadalupe River in Kerr County has good water quality. Intermittent in stages, the stream crosses an area characterized by steep slopes. The generally shallow, stony soils support grasses and open stands of live oak and ashe juniper.

Segment 1817 (North Fork Guadalupe River) The spring-fed 29 mile North Fork of the Guadalupe River is a perennial stream with exceptional aquatic life designation. River flow is swift but shallow. Typical vegetation are baldcypress, live oak and ashe juniper trees.

Segment 1818 (South Fork Guadalupe River) The spring-fed 27 mile South Fork of the headwaters of the Guadalupe River is clear, with moderately flowing water and has excellent water quality. It is a narrow and shallow scenic river with baldcypress-lined banks.

Segment 1806 (Guadalupe River above Canyon Lake) The Guadalupe River from the city of Comfort in Kendall County to the confluence with the North and South Forks of the Guadalupe River in Kerr County is scenic with crystal clear water between baldcypress-lined banks. The shallow riffle areas, punctuated with deep pools create an exceptional aquatic life ecosystem.

Upper Guadalupe River Watershed above Comfort

River Segments, Descriptions and Concerns

Upper Guadalupe River Watershed above Comfort

The Upper Guadalupe River watershed above Comfort, Texas drains an area of 850 square miles. The majority of this drainage area is contained within Kerr County, although a small portion of the watershed includes areas in Gillespie, Bandera, and Kendall counties. Major streams and rivers within this drainage area include the North and South Fork of the Guadalupe River, Johnson Creek, Indian Creek, Quinlan Creek, Camp Meeting Creek, Town Creek, Third Creek, Cypress Creek, Goat Creek, Turtle Creek, Verde Creek, and Bear Creek. Cities include Hunt, Ingram, Kerrville, Center Point, and Comfort (Kerr and Kendall County).

Soils are generally dark and loamy over limestone, but are more variable in the southern and eastern portions of the watershed. Vegetation cover is primarily herbaceous and dominated by ashe juniper with portions of shrub lands and grass or herbaceous land cover. Average annual rainfall is 30 inches and average temperature is 32ºF in January and 94ºF in July.

Land use is in the Upper Guadalupe watershed is defined by ranching, farming, tourism, and light manufacturing. Water bodies are used for aquatic life, contact recreation, fish consumption, and as public water supplies. There are two domestic permitted wastewater treatment facilities (only one is currently in operation) and six land application facilities in the watershed. The City of Kerrville is permitted to release treated effluent into Third Creek from their wastewater treatment facility. Average annual discharge from this facility in 2012 was 1.42 million gallons per day (MGD) into Third Creek and 0.69 MGD of reclaimed water was sold, primarily for irrigation. Quality limits for this facility are a daily average of 5 milligrams per liter (mg/L) carbonaceous biochemical oxygen demand, 5 mg/L total suspended solids, 1-2 mg/L ammonia nitrogen (flow dependent), 0.5-1 mg/L total phosphorus (flow dependent), and 126 colonies *E. coli* per 100 mL.

Photo by Travis Linscomb

Stakeholder Concerns

Stakeholder concerns in this portion of the Guadalupe River basin are focused on preserving the nearly pristine water quality of the area and conserving the water resource of the Guadalupe River. In addition, many are concerned about the predominance of ashe juniper in the landscape.

Ashe juniper (cedar) is very efficient at intercepting rain, and can capture over ½ inch of rain before it reaches the soil. In a normal year, most rain events produce ½ inch or less of rain. Therefore, rain falling over an area of dense cedar cannot be captured or stored by the watershed. Through brush management, ashe juniper can be replaced with other native vegetation that will help enhance and maintain aquifer recharge and spring flow. Approximately 90% of all flow in the Guadalupe River in Kerr County is attributed to spring flow. Therefore, actions that enhance spring flow are crucial to conserving this precious water resource.

Portions of the Guadalupe River in Kerrville have experienced high *E. coli* bacteria levels in recent years. Many stakeholders are concerned that bacteria contamination will affect the recreational use of their favorite swimming holes, and that the levels indicate degrading water quality. The Bacteria Reduction Plan has been initiated to address this concern.

Additional stakeholder concerns include riparian area management particularly in urban areas and the expansion of *Arundo donax*, an exotic invasive riparian plant. Water conservation is also a high priority for stakeholders. The use of natural, drought

tolerant plants in landscaping and rainwater harvesting are gaining popularity throughout the watershed. In fact, the Upper Guadalupe River Authority (UGRA) offers a rebate on rainwater catchment system equipment.

Water Quality Monitoring

The designated river segments in the Upper Guadalupe River watershed above Comfort listed under the state of Texas Water Quality Management Plan are Segment 1816 (Johnson Creek), Segment 1817 (North Fork Guadalupe River), Segment 1818 (South Fork Guadalupe River), and Segment 1806 (Guadalupe River above Canyon Lake). River Segment 1806 can be further divided into segments 1806A thru 1806G to describe specific streams that contribute flows directly to Segment 1806.

The Guadalupe-Blanco River Authority (GBRA), together with the Upper Guadalupe River Authority (UGRA), carry out the water quality management efforts in this basin under contract with the Texas Commission on Environmental Quality (TCEQ). Ten stations in Kerr County are monitored on a quarterly basis as part of the Clean Rivers Program (CRP). During each sampling event, the following parameters are monitored: pH, dissolved oxygen, conductivity, temperature, flow, total suspended solids, volatile suspended solids, turbidity, sulfate, chloride, nitrate, total kjeldahl nitrogen, total phosphorus, chlorophyll *a*, and *E. coli*. In addition to these routine parameters, sampling is also conducted to assess the biological community. In the past, the biological assessment could not have been conducted annually because of unfavorable conditions due to the flash flood flow regime of the Hill Country and persistent high flow at the sample stations during some years. In general, the water quality of the Upper Guadalupe River watershed is highly impacted by flow because this area frequently experiences times of extremely high and low flow.

Segment 1806, the Guadalupe River above Canyon Lake, was first identified in 2002 by the TCEQ as not supporting designated uses due to elevated *E. coli* bacteria concentrations. The bacteria impairment is concentrated in a small portion of the Guadalupe River in Kerrville. Since 2002, UGRA has worked with TCEQ to address the bacteria impairment, and is currently putting bacteria reduction strategies in place through the Bacteria Reduction Plan.

In 2010, Town Creek and Quinlan Creek, both tributaries to the Guadalupe River in Kerrville, were identified as not meeting the contact recreation criteria due to elevated *E. coli* bacteria concentrations. There is also a concern for depressed dissolved oxygen levels on Town Creek. Both of these creeks have extremely low flow throughout the year, and are reduced to non-flowing pools during the summer months.

These water quality concerns, as well as the continued urbanization of areas adjoining the Guadalupe River in Kerr County, have made it a priority for UGRA to conduct extensive water quality monitoring in addition to the quarterly monitoring that is conducted for the Clean Rivers Program. The cornerstone of UGRA's water quality monitoring program is the County-Wide Goal based monitoring plan that was developed in 2008. The plan will track changes and identify water quality concerns in the primary tributaries that feed the Guadalupe River as well as provide more frequent monitoring of stations along the main stem. In addition, UGRA measures *E. coli* bacteria levels at 21 popular swimming holes on a weekly basis throughout the summer, monitors nine stations on a monthly basis in support of the Bacteria Reduction Plan, and investigates concerns for water quality. In all, over 40 stations are monitored on a routine basis and in 2012 over 2,400 tests were conducted on water bodies in Kerr County.

Guadalupe River above Canyon Lake, Segment 1806

Segment 1806, ***Guadalupe River above Canyon Lake***, extends from a point (1.7 miles) downstream of Rebecca Creek Road in Comal County to the confluence of the North Fork Guadalupe River and the South Fork Guadalupe River in Kerr County. The segment is approximately 103 miles long. The segment is broken into eight assessment units, however only the following are within the Upper Guadalupe River watershed above Comfort: from confluence with Big Joshua Creek to Flat Rock Dam in Kerrville (1806_02), from Flat Rock Dam in Kerrville to 1 mile upstream (1806_03), from 1 mile upstream Flat Rock Dam to confluence with Camp Meeting Creek (1806_04), from confluence with Camp Meeting Creek to 2 miles upstream (1806_5), from RR 394 one mile downstream (1806_06), and the upper 10 miles of Segment (1806_07). There are five USGS gauging stations located in Segment 1806. Median annual

Upper Guadalupe River Watershed above Comfort

River Segments, Descriptions and Concerns

flow of the Guadalupe River at Hunt is 67 cubic feet per second (cfs) and median annual flow of the Guadalupe River at Comfort is 186 cfs.

The following information covers the portion of Segment 1806 above Comfort. For the discussion on the portion of the segment that is below the City of Comfort refer to the watershed summary entitled "Guadalupe River Below Comfort" that follows this section in the *Basin Summary Report*.

The assessment units contain six stations which have been monitored by UGRA quarterly since 1998 as part of the CRP. Guadalupe River at Hermann Sons Road (station no. 12605), Guadalupe River at Center Point Lake (station no. 12608), Guadalupe River at G Street (station no. 12616), and Guadalupe River at Kerrville-Schreiner Park (station no. 12615) also contain historical data dating back to the mid 1970s and early 1980s. Guadalupe River at Split Rock Road (station no. 15113) and the Guadalupe River at Riverview Road (station no. 15111) have been monitored since the beginning of the CRP only. Several additional stations in this segment were monitored during the summer from 2002 through 2007 for *E. coli* and turbidity only. These stations are Guadalupe River at IH 10 in Comfort (station no. 12603), Guadalupe River at Louise Hays Park dam (station no. 16243), Guadalupe River at SH 16 (station no. 12617), Guadalupe River at Louise Hays Park footbridge (station no. 16244), Guadalupe River at UGRA Lake (station no. 12618), Guadalupe River at Bear Creek Road (station no. 12619), Guadalupe River at Ingram Dam (station no. 12620), and Guadalupe River at Kelly Creek Road (station no. 16241).

The 2012 Texas Water Quality Inventory lists two impairments and two concerns in Segment 1806. Assessment units 1806_6, and 1806_8 are impaired for bacteria geometric mean value exceeding state standard for contact recreation. The TCEQ first identified the impairment to the contact recreation use of Segment 1806 in the 2002 Texas Water Quality Inventory and 303(d) List. Due to this concern, a Total Maximum Daily Load (TMDL) study was conducted on the impaired portion of Segment 1806 that flows through the City of Kerrville. The impaired reach is defined as the Guadalupe River from its confluence with Town Creak downstream to Flat Rock Lake. The TMDL was adopted by the TCEQ on July 25, 2007 and accepted by the Environmental Protection Agency (EPA) on September 25, 2007. This TMDL, titled *One Total Maximum Daily Load for Bacteria in the Guadalupe River Above Canyon Lake*, is now a part of the state's *Water Quality Management Plan*.

After the completion of the TMDL, UGRA received a grant from TCEQ to develop an implementation plan at the local level that outlines strategies aimed at reducing bacteria levels in the impaired reach of the Guadalupe River. This Implementation Plan for One Total Maximum Daily Load for Bacteria in Guadalupe River Above Canyon Lake was adopted by TCEQ in August 2011. During that same year, UGRA was selected to receive additional grant funding from TCEQ to put the bacteria reduction strategies in place with the assistance of the City of Kerrville, TXDOT, and Kerr County. This project is called the Bacteria Reduction Plan. The strategies in the plan will address the primary sources of bacteria pollution that have been identified in the section of the Guadalupe River in Kerrville. Sources identified are birds nesting on bridges, large flocks of domestic waterfowl congregating in lakes, septic systems, and pollution from general urban runoff. The ultimate goal of the project is to reduce the bacteria levels in the Guadalupe River to a concentration that does not represent a health risk to swimmers and will allow this segment to be removed from the impaired water body list.

In the 2012 Water Quality Inventory, assessment units 1806_2, and 1806_7 were identified as having concerns for impaired habitat based on annual biological assessments conducted at one station in each assessment unit. Due to the small number of samples included and the drought conditions that were persistent during the assessment period, more data is needed to determine if this trend is consistent.

Despite bacteria concerns, overall water quality in Segment 1806 is very good and all assessment units in the segment maintain an exceptional aquatic life use designation. The Guadalupe River at Riverview Road (station no. 15111) is sampled quarterly by UGRA staff as part of the CRP. This station is located between the cities of Ingram and Kerrville. A review of the data available for the Guadalupe River at Riverview Road indicates a water body with slightly elevated values for nearly all parameters when compared to the upstream North Fork and South

Fork stations. However, the slight elevations still are not sufficient to lower the water quality below a good rating for this section of the river. **Specific conductivity** ranges from 407 micromhos per centimeter (umhos/cm) to 511umhos/cm with the bulk of values within the 400umhos/cm to 500 umhos/cm range. The trends are very consistent year to year. **Dissolved oxygen** ranges from 5.8 milligrams per liter (mg/L) to 11.6 mg/L with only one value out of 41 readings below the assessment criteria of 6.0 mg/L. No dissolved oxygen impacts were seen. **Nitrate nitrogen** values ranged from 0.05 mg/L to 1.04 mg/L. **Total phosphorus** ranged from 0.006 mg/L to 0.07 mg/L with the bulk of values being less than 0.02 mg/L. **Chlorides** ranged from 10 mg/L to 22.2 mg/L. The relatively clean nature of this body of water can be seen by the lack of dissolved salts. **Sulfates** ranged from 7.6 mg/L-16.3 mg/L. There was little variation exhibited annually or from year to year. The geometric mean for *E. coli* at this station is 26 MPN/100mL of water.

The land use in this area of the Guadalupe River may be affected by urbanization from the City of Ingram. However, there does not seem to be any obvious degradation of water quality occurring at this time. The more obvious change in water quality at this station is the significant reduction in stream flow over time as a result of drought conditions beginning around 2008 (Figure 1). Ambient pH concentrations in this portion of the Guadalupe River are significantly increasing over time (Figure 2). One explanation for this upward trend could be an increase in photosynthetic activity that comes with a reduction in flow and longer residence times. As algae and aquatic plants take up carbon dioxide in the photosynthetic process the pH concentrations rise.

Figure 1.

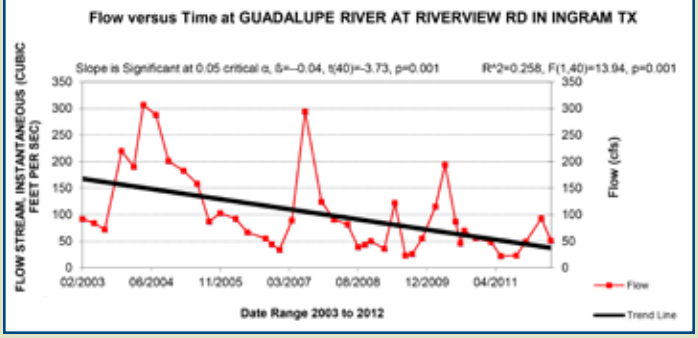
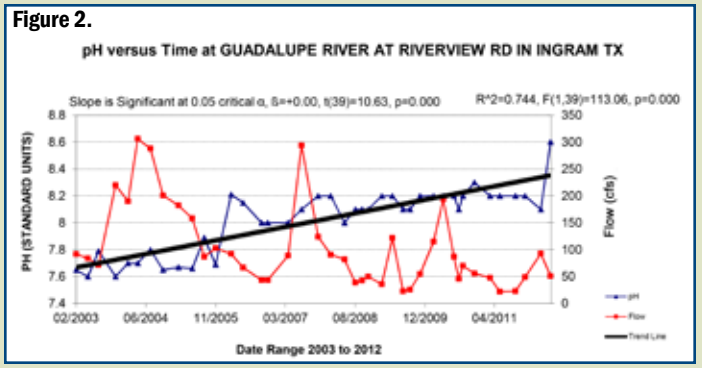


Figure 2.



The Guadalupe River at Split Rock Road (station no. 15113) is sampled quarterly by UGRA staff as part of the CRP and serves as a reference of Guadalupe River conditions downstream of the City of Kerrville. This station is located between the cities of Kerrville and Center Point. A review of the data available indicates some effects on water quality by the increased urbanization in this section of the river. However, the available data indicate that the water quality is still very good. **Specific conductivity** ranges from 412 umhos/cm to 552 umhos/cm with the bulk of values within the 400 umhos/cm to 500 umhos/cm range. The trends are very consistent year to year. **Dissolved oxygen** concentrations ranged from 5.5 mg/L to 14.2 mg/L. Only three measurements out of 43 measurements were below the 6.0 mg/L water quality standard. **Nitrate-nitrogen** values ranged from 0.05 mg/L to 1.4 mg/L. **Total phosphorus** ranged from 0.01 mg/L to 0.08 mg/L with the bulk of values being less than 0.025 mg/L. **Chlorides** ranged from 17.6 mg/L to 31.5 mg/L. **Sulfates** ranged from 10.8 mg/L to 23.8 mg/L with not much variation exhibited annually or from year to year. The geometric mean for ***E. coli*** at the station at Split Rock Road was 19 MPN/100mL. The low levels of *E. coli* at this station are surprising since this station is downstream of the impacted section of the Guadalupe River that flows through Kerrville, but the river appears to recover from any urbanization effects by this point. The land use just upstream of this section of the Guadalupe River is fairly dense residential and commercial urban development on both sides of the river.

Tributaries to Segment 1806

Two of the tributaries to Segment 1806 have been identified as either having an impairment or concern for water quality. The 2012 Texas Water Quality Inventory,

classifies Segment 1806D **Quinlan Creek** as impaired for bacteria geometric mean value exceeding state standard for contact recreation. Quinlan Creek is an unclassified water body in the City of Kerrville with very intermittent flow. The majority of the bacteria samples considered in the Water Quality Inventory were collected during times of extreme low flow or from a stagnant pool. Segment 1806E **Town Creek** was also classified by the 2012 Texas Water Quality Inventory as impaired for the bacteria geometric mean value exceeding the state standard for contact recreation. A concern for depressed dissolved oxygen was also identified. Town Creek is an unclassified water body in the City of Kerrville with very intermittent flow and very low flow during the assessment period.

A review of the data from the Quinlan Creek (station no. 12541) shows a stream that is severely impacted by ***E. coli.*** This segment has a geometric mean of 310 MPN/100 mL, which is more than twice the stream standard of 126 colonies/100 mL. The *E. coli* concentrations at this station have ranged from 10 MPN/100mL to 30,000 MPN/100mL. The Bacteria Reduction Plan efforts on this creek appear to be making a difference as there is a significant decline in *E. coli* over time from 2005 to 2012 (Figure 3).

The green horizontal line on the graph represents the geometric mean contact recreation standard of 126 colonies of *E. coli* per 100 mL of water.

Segment 1806A, Camp Meeting Creek, is an unclassified water body ranging from the confluence of Flat Rock Lake in southeastern Kerrville to the upstream perennial portion of the stream west of Kerrville. The segment contains two assessment units: the lower nine miles of the Segment (1806A_02) and the upper nine miles of the Segment (1806A_03). UGRA has been monitoring Camp Meeting Creek (station 12546) quarterly since 1998 as part of the CRP. This station is located in the most downstream assessment unit of the segment. This location is also a historical station and has data from 1976 to 1997. The Camp Meeting Creek segment is approximately 2.7 miles long and median flow at station no.12546 is 1.4 cfs. Overall water quality at station no.12546 is fair and the segment only maintains a limited aquatic life use designation.

A review of data available for station no. 12546 indicates that water quality in this stream is degrading. The median concentration for ***dissolved oxygen*** is 7.1 mg/L, ranging from a minimum of 2.5 mg/L to a maximum of 13.0 mg/L. On several occasions during the period of 2003 to 2012, the dissolved oxygen values have dropped below the stream standard for dissolved oxygen.

Camp Meeting Creek travels through a densely populated area occupied by single family residences, a golf course, and mobile home parks. Numerous bridges also cross the creek creating opportunities for nonpoint source pollutants to enter the creek as runoff. Many residents in the upper section of Camp Meeting Creek rely on private septic systems. In 2004, the City of Kerrville and UGRA partnered to address potential water quality concerns and initiated municipal sewer collection for some homes in this area, although there are still many more homes on septic systems. Since the end of 2003 the geometric mean for *E. coli* is 91 MPN/100mL and the dissolved oxygen concentration has dropped below the state standard of 4.0 mg/L at this station fifteen times (Figures 4 and 5). Due to the low and intermittent flow of this segment, it is difficult to identify the exact source of *E. coli* and low dissolved oxygen concentrations, but it is likely due to

Figure 3.

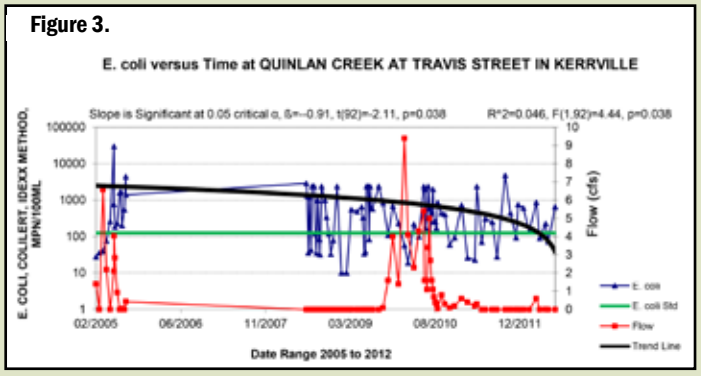


Figure 4.

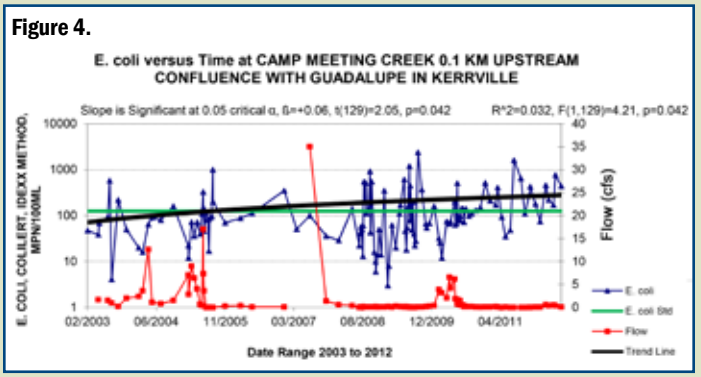
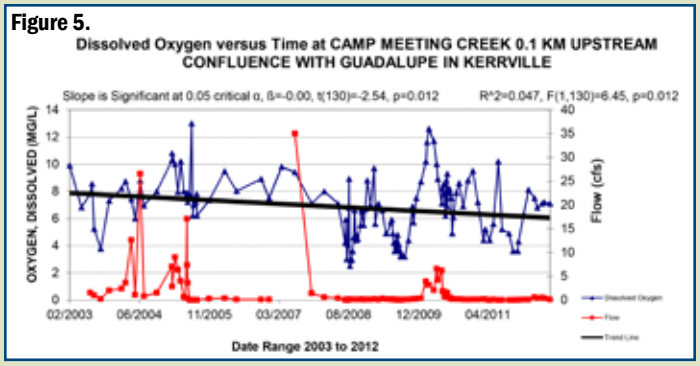


Figure 5.



persistent drought.

Johnson Creek, Segment 1816

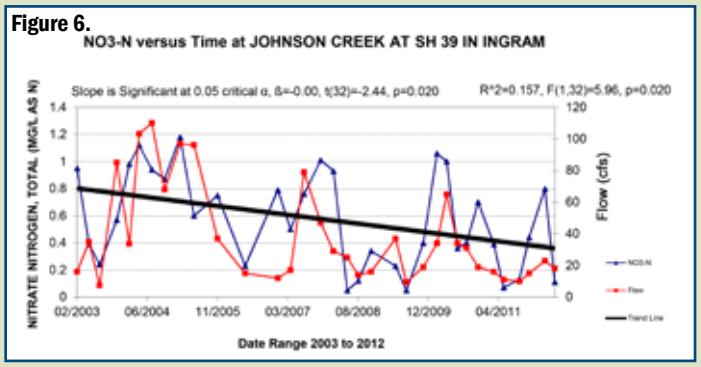
Segment 1816, **Johnson Creek**, extends from the confluence with the Guadalupe River in Kerr County to a point 1.2 km (0.7 miles) upstream of the most upstream crossing of SH 41 in Kerr County. This segment consists of one assessment unit and one monitoring station. UGRA has been monitoring Johnson Creek at SH 39 (station 12678) quarterly since 1998 as part of the CRP. Data was analyzed from 2003 through 2012 for possible trends in water quality conditions. The Johnson Creek segment is spring-fed and approximately 21 miles long. Average **flow** at station no. 12678 over the period of data was 41 cfs. A USGS gauging station is located in this segment approximately 3.5 miles upstream from station no. 12678. Due to severe drought four out of the last five years, the analysis of the instantaneous flow at this station is showing a statistically significant downward trend.

The 2012 Texas Water Quality Inventory has no impairments or concerns listed for Segment 1816. The water quality at station no. 12678 is consistently good and the segment maintains an exceptional aquatic life use designation. The median concentration for **dissolved oxygen** is 8.0 mg/L, ranging from a minimum of 5.8 mg/L to a maximum of 11.4 mg/L. At no time during the period of record analyzed did the dissolved oxygen drop below the state standard (4 mg/L). The **specific conductance** ranged from 360 umhos/cm to 600 umhos/cm, with a median conductivity of 466 umhos/cm.

Water quality is very consistent from year to year. **Nitrate nitrogen** values ranged from 0.05 mg/L to 1.2 mg/L. The data shows a downward trend in nitrate concentrations over time as well as a correlation between increases in flow with corresponding increases in nitrate nitrogen (Figure 6).

Total phosphorus ranged from 0.003 mg/L to 0.12 mg/L.

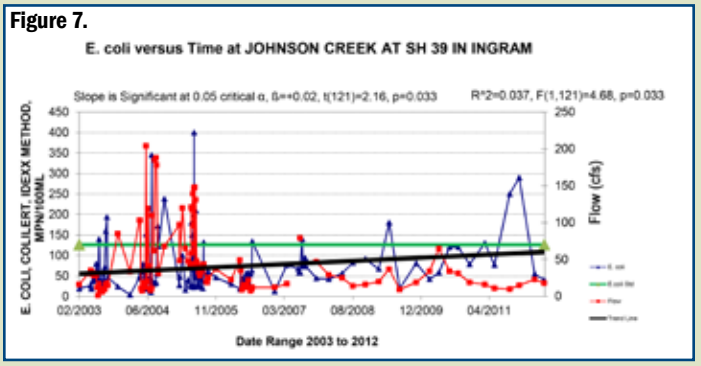
Figure 6.



The detection limit for the total phosphorus analysis changed in 2006 from 0.002 mg/L to 0.05 mg/L due to a change in method. **Chloride** ranged from 13 mg/L to 32.1 mg/L with a median value of 23.9 mg/L. **Sulfate** ranged from 9 mg/L to 27 mg/L with a median of 12.6 mg/L. There was little variation exhibited annually or from year to year.

The land use in the Johnson Creek watershed is rural with very low density residential development and some camps upstream of Ingram. The scenery and recreational opportunities attract many people to Segment 1816. In fact, station no. 12678 is a very popular swimming hole for local residents. The stream standard for contact recreation is a geometric mean of 126 colonies/100mL. The geometric mean for *E. coli* at station no. 12678 from 2003 to 2012 is 53 MPN/100mL. Figure 7 shows that the concentration of *E. coli* is trending upwards.

Figure 7.



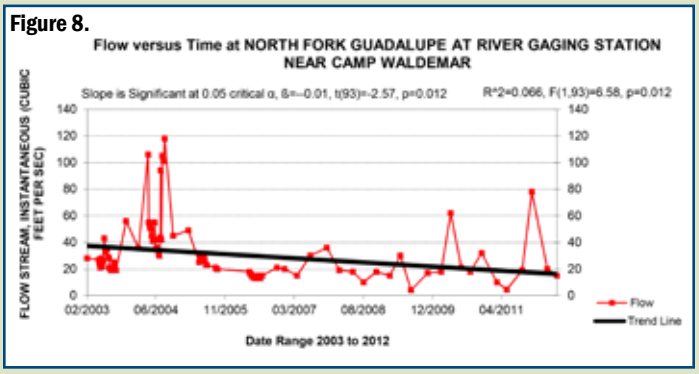
Upper Guadalupe River Watershed above Comfort

River Segments, Descriptions and Concerns

North Fork Guadalupe River, Segment 1817

Segment 1817, **North Fork Guadalupe River**, extends from the confluence with the Guadalupe River in Kerr County to a point 18.2 km (11.3 miles) upstream of Boneyard Draw in Kerr County. This segment consists of one assessment unit and three monitoring stations. UGRA has been monitoring the North Fork Guadalupe near Camp Waldemar (station 12682) station quarterly since 1998 as part of the CRP. Two additional stations in this segment were monitored during the summer from 2002 - 2007 for *E. coli* and turbidity only. These stations are North Fork Guadalupe River at FM 1340 (station no. 12681) and North Fork Guadalupe River at Rock Bottom Road (station 16245). The North Fork Guadalupe River segment is spring-fed and approximately 29 miles long. Average **flow** at station 12682 is 30.8 cfs. A USGS gauging station is located in this segment approximately 0.5 miles downstream from station no. 12682. Due to severe drought four out of the last five years, the analysis of the instantaneous flow at this station shows a statistically significant downward trend (Figure 8).

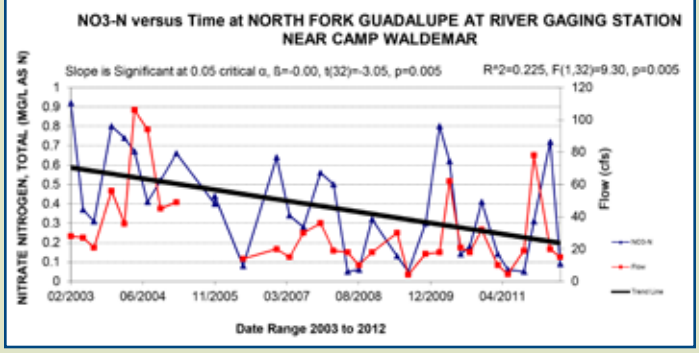
Figure 8.



The 2012 Texas Water Quality Inventory lists no impairments for Segment 1817. Overall water quality at station 12682 is very good and the segment maintains an exceptional aquatic life use designation. The median concentration for **dissolved oxygen** is 7.4 mg/L, ranging from a minimum of 5.0 mg/L to a maximum of 10.8 mg/L. At no time during the period of 2003 to 2012 did the dissolved oxygen drop below the state standard (4 mg/L). The **specific conductance** ranged from 333 umhos/cm to 524 umhos/cm, with a median conductivity of 392 umhos/cm.

A review of the data available for the North Fork of the Guadalupe at this location indicates that consistently good water quality is maintained in this section of the river. Recent **nitrate nitrogen** data ranged from <0.05 mg/L to 0.92 mg/L with a median concentration of 0.36 mg/L. Figure 9 shows a downward trend in the nitrate nitrogen concentration over time at the North Fork monitoring station. **Total phosphorus** was below current detection limit for the analysis method. **Chloride** ranged from 6.1 mg/L to 12 mg/L with a median concentration of 10 mg/L. Again, this reinforces the relatively clean nature of this body of water. **Sulfate** ranged from 4.7mg/L to 13 mg/L with a median concentration of 6.1 mg/L.

Figure 9.



Land use upstream in the North Fork Guadalupe River is rural with very low density residential development. Many Hill Country summer camps are located in Segment 1817 due to the beautiful scenery and numerous recreational opportunities. The stream standard for contact recreation is a geometric mean of 126 colonies/100mL of *E. coli*. The geometric mean at station 12682 from 2003 to 2012 is 32 MPN/100mL.

South Fork Guadalupe River, Segment 1818

Segment 1818, **South Fork Guadalupe River,** extends from the confluence with the Guadalupe River in Kerr County to a point 4.8 km (3.0 miles) upstream of FM 187 in Kerr County. This segment consists of five assessment units and each assessment unit contains one monitoring station. UGRA has been monitoring the South Fork Guadalupe River adjacent to Hunt Lions Park (station no. 12684) quarterly since 1998 as part of the CRP. This station is located in the most downstream assessment unit of the

segment. The four additional stations in this segment were monitored during the summer from 2002 - 2007 for *E. coli* and turbidity only. These stations are South Fork Guadalupe adjacent to Camp Arrowhead (station no. 12685), South Fork Guadalupe River at Seago Rd (station no.16246), South Fork Guadalupe adjacent to Camp Mystic (station no. 12686), South Fork Guadalupe adjacent to Lynxhaven Lodge at SH 39 (station no. 12688). The South Fork Guadalupe River segment is spring-fed and approximately 27 miles long. Average **flow** from 2003 to 2012 at station no. 12684 is 24.6 cfs.

The 2012 Texas Water Quality Inventory lists no impairments or concerns in Segment 1818. Water quality at station no. 12684 is very good and the segment maintains an exceptional aquatic life use designation. The median concentration for **dissolved oxygen** is 7.7 mg/L, ranging from a minimum of 4.8 mg/L to a maximum of 10.8 mg/L. At no time during the period of record did the dissolved oxygen drop below the state standard for dissolved oxygen (4 mg/L). The **specific conductance** ranged from 367 umhos/cm to 481 umhos/cm, with a median conductivity of 417 umhos/cm.

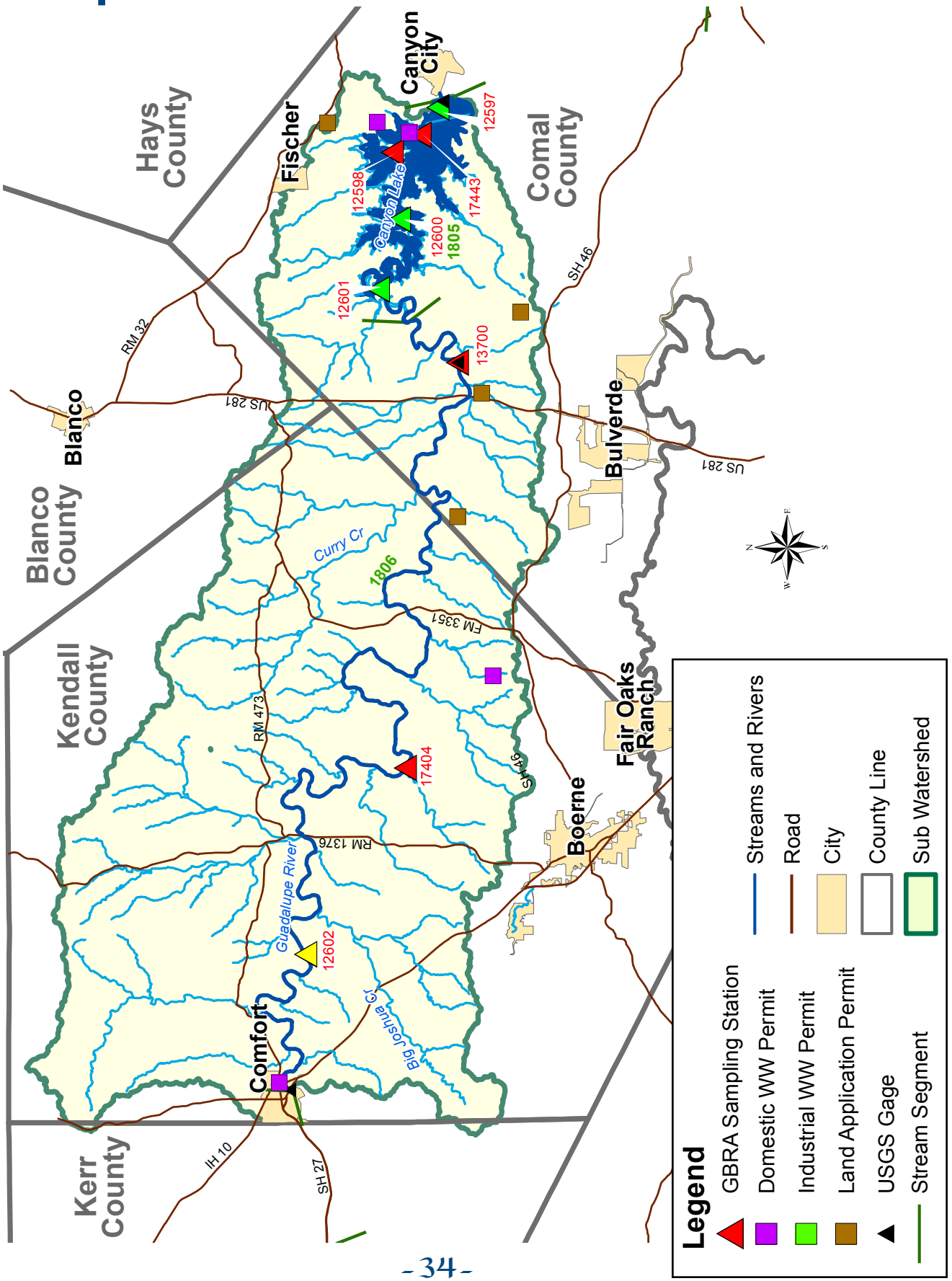
A review of the data available for the South Fork Guadalupe River station indicates consistently good water quality is maintained in this section of the Guadalupe River. **Nitrate nitrogen** values ranged from <0.05 mg/L to 0.74 mg/L with a median concentration of 0.17 mg/L. **Total phosphorus** was consistently less than the detection limit of the analytical method. **Chloride** ranged from 7 mg/L to 36 mg/L with a median concentration of 9.8 mg/L. **Sulfate** ranged from 5 mg/L to 15.3 mg/L with a median concentration of 7.7 mg/L. There was little variation exhibited annually or from year to year.

The land use in the South Fork Guadalupe River watershed is rural with very low density residential development. Much like the North Fork Guadalupe River, Segment 1818 is home to numerous Hill Country summer camps promoting various recreational activities. The stream standard for contact recreation is a geometric mean of 126 colonies/100mL of ***E. coli***. The geometric mean at station no. 12684 from 2003 to 2012 was 16 MPN/100mL.

Photo courtesy of Texas Parks and Wildlife Department

Upper Guadalupe River above Comfort Issues and Concerns			
Water Quality Issue	**Affected Area**	**Possible Influences/Concerns**	**Possible Actions Taken/to be Taken**
Bacteria	Upper Guadalupe River	Pet waste; nesting by birds under bridge crossings; urban storm water	TMDL adopted; Implementation Plan underway - installation of pet waste stations; outreach and education; street sweeping; river clean ups; installation of bird deterrents at bridge crossings
Bacteria	Town Creek, Quinlan Creek	Dry to low flow conditions	Recreational Use Attainability Assessment
Depressed Dissolved Oxygen	Town Creek	Dry to low flow conditions	Review of water quality standards

Guadalupe River Watershed below Comfort



Guadalupe River Watershed below Comfort

River Segments, Descriptions and Concerns

Segment 1806: (Guadalupe River above Canyon Lake): From a point (1.7 miles) downstream of Rebecca Creek Road in Comal County to the City of Comfort in Kendall County.

Segment 1805: (Canyon Lake): From Canyon Dam in Comal County to a point (1.7 miles) downstream of Rebecca Creek Road in Comal County, including Canyon Reservoir. Canyon Reservoir is a flood control and water supply reservoir, impounding the Guadalupe River with a conservation pool elevation of 909 feet mean sea level (msl).

Drainage Area: 596 square miles

Streams and Rivers: Guadalupe River from Comfort to Canyon Lake, Joshua Creek, Flat Rock Creek, Rebecca Creek, Block Creek, West Sister Creek

Lake: Canyon Lake

Aquifer: Trinity, Edwards Plateau

River Segments: 1805, 1806

Cities: Comfort, Kendalia, Bergheim, Bulverde, Canyon City, Spring Branch, Startzville

Counties: Kerr, Comal, Kendall, Blanco

EcoRegion: Edwards Plateau

Vegetation Cover: Evergreen Forest 43.6%, Shrublands 11.0%, Grass/Herbaceous 31.3%

Climate: Average annual rainfall 32 inches, Average annual temperature January 38°, July 95°

Land Uses: urban, unincorporated suburban sprawl, cattle, goat and sheep production, light and heavy industry, and recreational

Water Body Uses: aquatic life, contact recreation, general use, fish consumption, and public water supply

Soils: Dark and loamy over limestone to loam with clay subsoils

Permitted Wastewater Treatment Facilities: Domestic 4, Land Application 4, Industrial 0

Photo by courtesy of US Army Corps of Engineers

Guadalupe River Watershed below Comfort

River Segments, Descriptions and Concerns

Guadalupe River above Canyon Lake

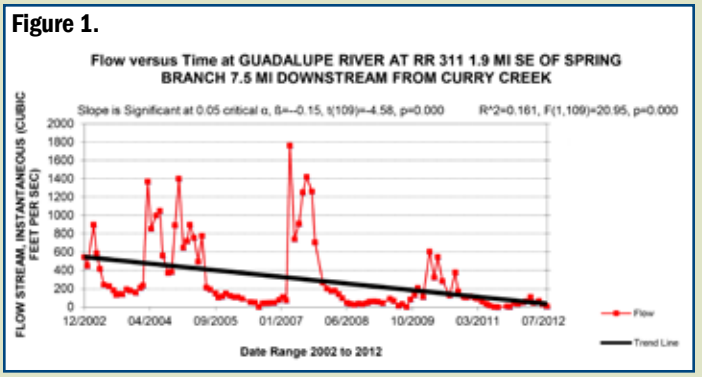
Segment 1806, the ***Guadalupe River above Canyon Lake***, extends from the lake in Comal County, through Kendall County, to the confluence with the North and South forks of the Guadalupe River in Kerr County. For ease in discussing the historical data and understanding the contributing watershed, the segment is separated into two parts in this report. The lower subsegment, which begins below the City of Comfort is separated into three assessment units: the lower 25 miles in Comal County; from the lower 25 miles to the confluence with Big Joshua Creek in Kendall County; and, from the confluence with Big Joshua Creek to the monitoring station near the City of Comfort. (Refer to the Upper Guadalupe River above Comfort for discussion on the water quality of the upper portion of Segment 1806.)

Several entities have been monitoring the lower portion of Segment 1806 since the 1990s. GBRA has two monitoring stations within the lower subsegment, the Guadalupe River at FM 311 in Spring Branch (station no. 13700), which has been monitored monthly since 1996 and the Guadalupe River at FM 474 (station no. 17404), in Kendall County, which has been a quarterly monitoring location since October 2001. Each of the monitoring stations is located in the two lower assessment units. TCEQ has a routine station in the upper assessment unit, located at the Guadalupe River at Waring (station no. 12602) that they have been monitoring quarterly since 1999. In the fall of 2012, the Upper Guadalupe River Authority took over the quarterly monitoring at that station.

The average instantaneous **flow** at the Spring Branch station during the data record used for this trends analysis was 295 cubic feet per second (cfs) and 162 cfs at the FM 474 station. At Waring, the median flow was 359 cfs. The area has suffered under drought conditions for four out of the last five years. The flow in the river was recorded as zero, referred to as "dry with pools", on August 3, 2011. To illustrate the prolonged period of low flows, the flow at the Spring Branch station in the last five years (2008 – 2012) was 106 cfs, 36% of the average flow over the entire 10 year period. Figure 1 shows the decline in flow over time at the Spring Branch station on the Guadalupe River.

The Kendall County Water Control and Improvement District operates the wastewater treatment plant for the

Figure 1.



City of Comfort. The plant is the only wastewater discharge to this portion of Segment 1806, and is located at the most upstream part of the subsegment. The permitted discharge is for 0.35 million gallons per day, with high quality effluent standards of 5 milligrams per liter (mg/L) biochemical oxygen demand, 5 mg/L total suspended solids, 2 mg/L ammonia-nitrogen and 1 mg/L total phosphorus. The plant has been operating under a 210 authorization for beneficial reuse of the effluent on a nearby golf course since 2002.

The 2012 Texas Water Quality Inventory lists the middle assessment unit as impaired for bacteria because the geometric mean for ***E. coli*** at the FM 474 station was 150 MPN/100 mL. The stream standard for contact recreation is a geometric mean of 126 colonies/100 mL. A review of the data set from 2003 through 2012, shows a reduction in the geometric mean at this station to 123 MPN/100 mL. The area has been under significant drought four out of the last five years. One positive aspect of drought, if there is one, is the lack of runoff that would be a source of nonpoint source bacterial loading into the stream. The stream standard exceedence is isolated to the middle assessment unit. Further downstream, the geometric mean for *E. coli* at the Spring Branch station was 61 MPN/100 mL. The TCEQ station, located at Waring, upstream of the FM474 station, had a geometric mean for *E. coli* of 42 MPN/100 mL.

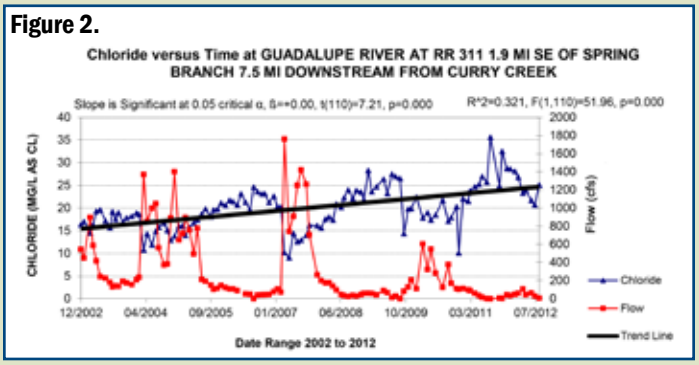
The median concentrations for **dissolved oxygen**, beginning at the downstream station at Spring Branch and moving upstream to the Comfort station are 9.4 mg/L, 9.4 mg/L and 8.9 mg/L, respectively, ranging from a minimum of 5.2 mg/L at the Spring Branch station to a maximum of 14.9 mg/L at the Spring Branch station. At

Continued on next page

no time in the period of record did the dissolved oxygen drop below the standard for the minimum dissolved oxygen concentration (4.0 mg/L). The **temperature** varied between 5.3°C to 32.7°C, with median temperatures of 21.8 °C, 20.6°C and 22.3°C at the three monitoring locations, from downstream to upstream. The **specific conductance** ranged between 277 umhos/cm to 990 umhos/cm, with median conductivities of 516 umhos/cm, 537 umhos/cm and 526 umhos/cm, respectively. The median **pH** of the three monitoring stations, from downstream to upstream, were 8.1, 7.9 and 8.1 respectively, ranging from 7.5 to 8.6 standard pH units, never falling outside the stream standard range of 6.5 to 9.0 standard units.

The median concentrations for **chloride** and **sulfate**, from downstream to upstream, were 19.8 mg/L, 20.4 mg/L and 23 mg/L and 23.6 mg/L, 23.8 mg/L and 23 mg/L respectively. At no time did the concentration of these dissolved constituents exceed the stream standard of 50 mg/L. A slight upward trend was seen in the chloride concentration at the Spring Branch station (Figure 2).

Figure 2.



Nutrients (Total Kjeldahl Nitrogen (TKN), nitrate nitrogen, ammonia nitrogen and total phosphorus) were analyzed at the three main stream stations. The median concentrations for **nitrate nitrogen** ranged from 0.28 mg/L to 0.58 mg/L, with the highest median being seen at the upstream station at Waring. The nitrate nitrogen concentration never exceeded the screening criteria of 1.95 mg/L. The median **ammonia nitrogen** concentration at all three stations was below the detection limit of 0.1 mg/L. The concentration of ammonia nitrogen measured at the main stem stations exceeded the screening concentration of 0.33 mg/L one time (0.35 mg/L). This event occurred at the station at FM474 during the lowest flow recorded in the data period (7.6 cfs). The detection levels for total phosphorus changed from 0.05 mg/L to 0.02 mg/L in FY 2012. The median **total phosphorus** concentrations were at or below the limit of quantification for the method at the FM474 station. **TKN** was added to the suite of nutrients being monitored at the stations within this segment in 2007. The maximum concentration of 0.95 mg/L occurred at the Spring Branch station when station went dry with standing pools, at the height of the drought of 2011.

The substrate in the main stem transitions from a gravel to bedrock substrate. The water is clear and shallow in the majority of locations along the segment, with very few pools. The **suspended solids** ranged from less than 1 mg/L to 236 mg/L, with median concentrations ranging from 4.3 mg/L to 5.5 mg/L at the main stem stations.

The median **chlorophyll *a*** concentration is less than detection and there was never a measured value above the screening concentration of 14.1 micrograms per liter.

Canyon Reservoir

Canyon Reservoir, also known as Canyon Lake, Segment 1805, is located in Comal County, north of the City of New Braunfels. The multipurpose reservoir, built by the US Army Corp of Engineers (COE) and the Guadalupe-Blanco River Authority (GBRA) and impounded in the mid-1960's, is designed to serve flood control and water supply functions. It is also used for recreation. Canyon Lake has 8,230 surface acres and over 80 miles of shoreline, seven public parks, two military recreational areas and two marinas. The lake is divided up into four assessment units: the cove around Jacob's Creek Park, the north end of Crane's Mill Park to the south end of Canyon Park, the upper end of the segment and the lower end of the reservoir near the dam. The lake has designated uses of contact recreation, exceptional aquatic life use, domestic water supply and aquifer protection.

The reservoir is monomictic, stratifying in the summer and having one turnover per year, usually with the first strong cold front in the fall. The reservoir can be divided into three zones, moving down the reservoir, toward the dam. Those zones include the riverine zone, the transitional zone and the lacustrine zone. The **riverine zone** does not routinely stratify because it is flow-dominated, keeping the waters in this zone mixed. The conditions are often turbid because it

is in this zone that sediments carried by stormwater from upstream enter the reservoir. The **transitional zone** is the zone where the river reacts with the reservoir. As the flow from the river slows and spreads, the sediment carried by the river begins to drop out and settles to the bottom. Studies done on the Canyon Reservoir have found that in years of high runoff and sediment loading, the reservoir's anoxic zone can develop in this zone where the decay of the organic deposition depletes the oxygen. The lacustrine zone is located near the dam. The **lacustrine zone** is clear and deep. It is in this area that thermal stratification occurs as well as the development of an anoxic layer. In years of low incoming flow the lake will strongly stratify with "layers" called the epilimnion at the surface and the hypolimnion at the bottom, separated by a thermocline (area of rapid thermal change). In years with heavy spring rains and incoming flows, the lake will be more weakly stratified because of high volume coming into the reservoir, coupled with the bottom releases that are used to evacuate the flood pool. In times where the reservoir is strongly stratified the thermocline is strong enough to keep the waters of the epilimnion and hypolimnion from mixing, creating distinctly different density and oxygen differences through the water column.

The reservoir operates as two parts. The lower portion from elevation 800 to 908 mean sea level (msl) is operated by GBRA for conservation storage. GBRA was granted the original water right for 50,000 acre-feet of water per year to be made available for customers through water purchase contracts. GBRA releases water from the conservation pool as it is called for by downstream customers.

The upper portion of Canyon Reservoir from 909-948 msl, is referred to as the "flood pool" and is controlled by the COE. This part of the reservoir captures floodwaters that are usually released at rates sufficient to empty the flood pool without contributing to downstream flooding.

The land use in the watershed is made up of residential and business development, resorts, parks and recreational facilities, and ranches with unimproved brush, used for cattle and hunting. Comal County has been experiencing a high level of growth and a large portion of that growth is occurring in the Canyon Lake watershed. The watershed contains a relatively small amount of urbanized area. The town of Sattler and the City of Bulverde are in the watershed, both of which are not currently served by a domestic wastewater treatment facility. There is one small package plant that serves a strip center in Bulverde but that facility only serves the businesses in the center.

The COE has one development regulation that affects the area immediately around the reservoir. There can be no on-site septic systems or major buildings with plumbing or electricity built within the 948 mean sea level elevation. Any other construction must be reviewed and approved by the COE.

There are two wastewater treatment plants that discharge directly to the reservoir. The Canyon Park Estates Wastewater Treatment Facility is operated by

GBRA and is permitted to treat 260,000 gallons per day. The facility must treat the domestic wastewater to high quality standards of 5 milligrams per liter (mg/L) of biochemical oxygen demand, 5 mg/L total suspended solids, 2 mg/L ammonia nitrogen and 1 mg/l total phosphorus. The facility discharges to a cove on the north side of the lake. The other wastewater treatment plant that discharges to the lake is operated by the US Department of Army and serves a small recreational facility available to military personnel. The plant is permitted to discharge 12,500 gallons per day. The remaining area around the reservoir is served by septic tanks, with Comal County being the designated representative for enforcement of septic tank rules.

All four assessment units were listed on the 2012 Texas Water Quality Inventory as impaired due to mercury in fish tissue. The listing came as a result of a fish consumption advisory issued by the Texas Department of State Health Services (DSHS) in 2006. In 2003, a tier one fish tissue survey was conducted by TCEQ, DSHS and Texas Parks and Wildlife Department. A follow-up tier two survey was conducted in 2005. In the follow-up survey 30 fish were collected and analyzed for heavy metals. The species of fish collected in the survey included striped bass, long-nosed gar, largemouth bass, blue catfish, flathead catfish and white bass. The action level for mercury in fish tissue is 0.7 mg/kg. The two species identified in the advisory were striped bass and long-nosed gar. These two species contained a mean mercury concentration of 1.149 mg/kg and 0.772 mg/kg respectively. These species are high-end predators that are long-lived and voracious eaters. The mercury bioaccumulated in their tissue as methylmercury, the organometallic form, which is the most toxic form. Because there are only two domestic wastewater discharges to the reservoir, the most likely mechanism for mercury to enter the reservoir is by atmospheric deposition. Possible sources of mercury in the area of the reservoir include emissions from coal-fired power plants and cement plants. Other sources include naturally-occurring sources, volcanoes and industrial emissions. There are 18 other water bodies in Texas that have fish consumption advisories due to mercury. Most are found in East Texas and the Panhandle. These water bodies have low pH, high dissolved organic material or are shallow wetlands, making it very unusual for Canyon Reservoir to be included on that list. Canyon Lake has hard water and very low dissolved organic content.

TCEQ has developed standards for nutrients in reservoirs. Nutrient enrichment from nitrogen and phosphorus can cause excessive growth of macrophytes, algal blooms in the open waters as well as attached to the substrate and floating in mats. The Texas Water Quality Standards have numeric nutrient criteria for chlorophyll *a* in Texas reservoirs. Canyon Reservoir is listed in the Appendix F (Chapter 301.10) of the Texas Water Quality Standards that lists site-specific nutrient criteria for reservoirs and lakes in Texas. The table lists the chlorophyll concentration for each water body. Criteria formulations were based on selected sampling stations that represent the deep pool near the dam for each reservoir, represent average conditions with an allowance for statistical variability, and are calculated as the upper confidence interval of the median with the assumption that a sample size of 10 is used. Based on these assumptions, the nutrient criteria for Canyon Reservoir is 5.0 microgram per liter (ug/L) chlorophyll. When the calculated chlorophyll criterion is below 5.0 ug/L, then the criterion is set at the minimum default criterion of 5.0 ug/L. The calculated value for Canyon Reservoir is 4.11 ug/L.

In order to review the historical data and look for trends that would indicate changes in water quality, the data was separated into two areas in the reservoir, the main pool stations and stations located in coves. The main pool stations and the associated depth profiles were reviewed individually and in comparison with other pool monitoring stations.

Main Pool - Canyon Reservoir

TCEQ has three monitoring stations located in the reservoir, one in the upper portion of the reservoir, located at Cranes Mill Park (station no. 12601), one in the mid-reservoir at Potter's Creek Park (station no. 12600) and one at the dam (station no. 12597). TCEQ Surface Water Quality Monitoring teams collected water quality data from these two stations from two to four times per year. The data set evaluated for trends cover 2002 through 2012. The TCEQ data sets were used in the trend analysis because of the availability of the most recent data.

Guadalupe River Watershed below Comfort

River Segments, Descriptions and Concerns

Photo by Alvin Schuerg

Photo by Janet Thome

Canyon Reservoir at Crane's Mill Park

The Crane's Mill Park station is located in the upper assessment unit and in the riverine zone of the reservoir. The average depth at the upstream location at Crane's Mill Park was 8.6 meters. The reservoir depth fluctuates the most at this location, as the flow from the river upstream varies between wet and dry years. The change in **temperature** from surface to bottom averaged 7.0°C, ranging from median temperature at the surface of 21.4°C to and a median temperature at the bottom of 16.3°C. There was no thermal stratification at this location. The **conductivity** changed an average of 43 umhos/cm at the surface to bottom profiles. In normal to wet years the conductivity is lower at the surface than at the bottom. The surface conductivities at this station ranged from a median of 396 umhos/cm at the surface to a median conductivity at the bottom of 433 umhos/cm.

The difference in **dissolved oxygen** between the surface to bottom averaged 1.75 mg/L. The median surface dissolved oxygen at the Crane's Mill Park station was 8.3 mg/L and a median bottom dissolved oxygen of 6.6 mg/L. The oxygen was depleted to less than 5.0 mg/L from surface to bottom 56 times during the 10 year data set. The difference in **pH** from surface to bottom at this reservoir location averaged a change of 0.4 pH units. No surface or profile sample fell outside the pH standard range of 6.5 to 9.0.

Nutrients, dissolved constituents, suspended solids and chlorophyll *a* were analyzed in the surface samples only. **Nitrate nitrogen** had a median concentration of 0.06 mg/L, ranging from the limit of quantification (LOQ) to 0.63 mg/L. The concentrations measured at the station exceeded the reservoir screening concentration of 0.37 mg/L four times or 12.5 % of the time. **Ammonia nitrogen** had a median concentration of 0.05 mg/L, ranging from the LOQ to 0.08 mg/L, never exceeding the reservoir screening concentration of 0.11 mg/L. The **total phosphorus** concentrations ranged from the LOQ to 0.06 mg/L, with a median concentration of less than method detection.

Chloride and **sulfate** had median concentrations of 16 mg/L and 21.5 mg/L, respectively and ranged from 11 mg/L to 19 mg/L chloride and 18 mg/L to 25 mg/L sulfate, both well below the stream standard of 50 mg/L for each. The **total suspended solids** had a median concentration of 4 mg/L, ranging from 4 mg/L to 8 mg/L, the highest recorded concentrations occurring with high inflows into the reservoir. The high solids content is typical of the riverine zone of the reservoir. All **chlorophyll *a*** concentrations were less than 10 ug/L, the LOQ used by the TCEQ laboratory until May of 2006. At this point, the LOQ for the method was changed to 3 ug/L. Although many of the subsequent data points were found above the new LOQ, all data was well below the screening concentration of 26.7 ug/L for the assessment unit.

TCEQ also collected mercury in water and mercury in sediment at this reservoir location. There were only four data points in each data set. All **mercury in water** data was found below the LOQ of 0.001 ug/L and all **mercury in sediment** was found below the LOQ of 0.045 mg/kg. The analysis for metals in sediment is important in a reservoir, especially in those like Canyon Reservoir, because metals

will be released from the sediment when the hypolimnion becomes anoxic. The metal oxides that are bound in the sediment then become a source of oxygen for bacteria. The metal ions released diffuse into the water column and can be dispersed throughout the volume of the reservoir as the lake turns over in the fall. As the metals enter the water column, the ions can combine with the available oxygen and become oxides again, be diluted by the large volume in the reservoir, and/or possibly bioaccumulate in the food chain. This source of heavy metals could be an explanation for the mercury in fish tissue impairment in Canyon Reservoir.

The low flows associated with the extraordinary drought conditions from 2008 to 2012 in the Guadalupe River basin have driven several trends in Canyon Reservoir. In general, nutrient levels such as TKN are significantly declining (Figure 3), while dissolved salts such as chloride are significantly increasing over time (Figure 4).

Figure 3.

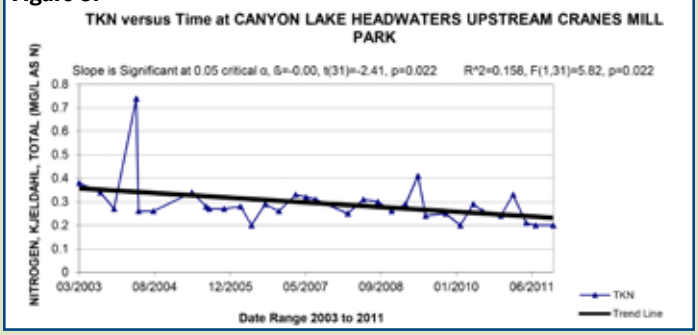
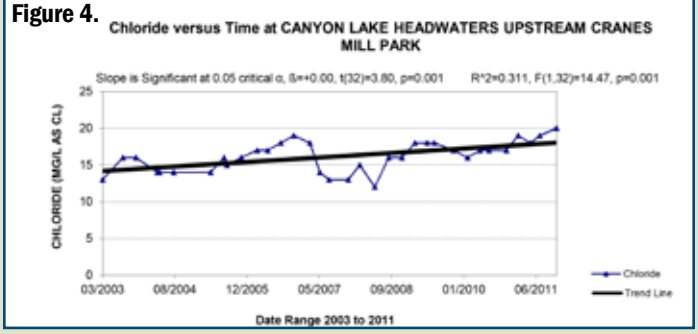


Figure 4.



Canyon Reservoir at Potter's Creek Park

Moving into the transition zone of the reservoir, the TCEQ samples a station at Potter's Creek Park that has an average depth of the sampling events of 15.2 meters. The station weakly stratified in the summer months and was uniform in **dissolved oxygen** and **temperature** in the fall and winter samples. The change in dissolved oxygen in the fall and winter months averaged 1.2 mg/L, with the largest difference of 4.1 mg/L seen in August of 2005. In comparison, the spring and summer months averaged 1.8 mg/L change from surface to bottom profiles. None of the 33 sampling events found less than 1.0 mg/L at the bottom.

As was the case at the Crane's Mill station, the Potter's Creek station profiles had lower **conductivities** at the surface than at the bottom. In all of the 33 profiles taken at the Potter's Creek station, only three were the inverse. The average difference between the surface and bottom profile samples was 51 umhos/cm. The pH change averaged 0.5 pH units from surface to bottom and no individual sample in the profiles exceeded the 6.0 to 9.5 pH standard.

Nutrients, dissolved constituents, suspended solids and chlorophyll *a* were analyzed in the surface samples only. **Nitrate nitrogen** had a median concentration of 0.06 mg/L, ranging from the LOQ to 1.01mg/L. The concentrations measured at the station exceeded the reservoir screening concentration of 0.37 mg/L 5 times or, less than 15.6% of the time. **Ammonia nitrogen** had a median concentration of less than the LOQ, ranging from the LOQ to 0.18 mg/L, exceeding the reservoir screening concentration of 0.11 mg/L only one time. The **total phosphorus** concentration ranged from the LOQ to 0.08 mg/L, with a median concentration at the LOQ.

Chloride and **sulfate** had median concentrations of 16 mg/L and 22 mg/L, respectively and ranged from 12 mg/L to 19 mg/L chloride and 18 mg/L to 25 mg/L sulfate, both well below the stream standard of 50 mg/L for each. The **total suspended solids** had a median concentration of 6.0 mg/L, ranging from 4.0 mg/L to 123 mg/L. The high concentrations associated with high inflows into the reservoir seen in the riverine zone on the reservoir are not seen at the Potter's Creek station, in the transition zone. The **chlorophyll *a*** concentrations were less than 10 ug/L, the LOQ used by the TCEQ laboratory, and well below the screening concentration of 26.7 ug/L for the assessment unit.

TCEQ also collected **mercury in water** and **mercury in sediment** at this reservoir location. There were only four data points in each data set. All mercury in water data was found below the LOQ of 0.001 ug/L and all mercury in sediment was found below the LOQ of 0.045 mg/kg.

The low flows associated with the extraordinary drought conditions from 2008 to 2012 in the Guadalupe River basin have driven several trends in Canyon Reservoir. Total phosphorus may show a significant decline (Figure 5) but it can be attributed to a change in the LOQ from 0.06 mg/L to 0.02 mg/L (as indicated by the red line), while dissolved salts such as sulfate are significantly increasing over time (Figure 6).

Figure 5.

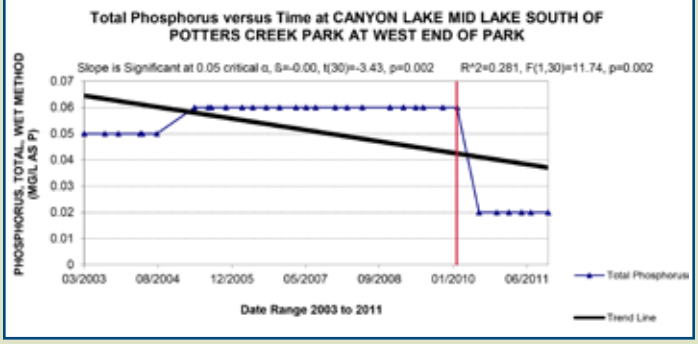
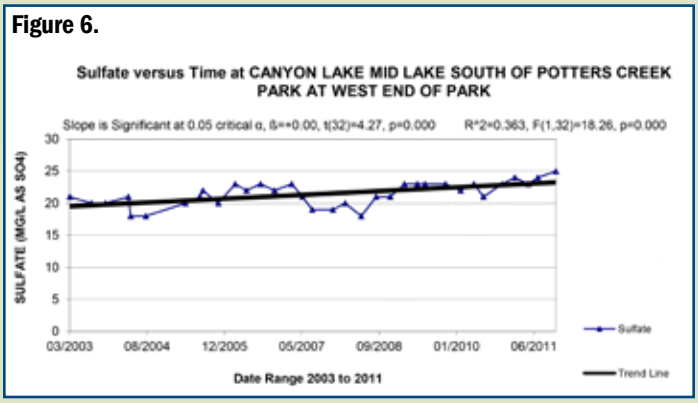


Figure 6.



Canyon Reservoir at the Dam

The TCEQ has been monitoring the location at the dam, in the lacustrine zone, since the summer of 2001. The average depth at the dam was 27.4 meters. The reservoir depth fluctuates as the volume varies between wet and dry years. The change in **temperature** from surface to bottom averaged 7.0°C, ranging from median temperature at the surface of 21.°C to and a median temperature at the bottom of 14.0°C. Thermal stratification occurred in the summer months in most years. As seen at the upstream stations, the **conductivity** gained an average of 28 umhos/cm from surface to bottom profiles. The surface conductivities at this station ranged from a median of 383 umhos/cm at the surface to a median conductivity of 411 umhos/cm at the bottom.

The difference in **dissolved oxygen** between the surface to bottom averaged 3.5 mg/L. The median surface dissolved oxygen at the dam was 8.4 mg/L and a median bottom dissolved oxygen of 1.0 mg/L. The oxygen was depleted to less than 1.0 mg/L from surface to bottom 14 times during the period of record at this station (out of 40 sampling events), with the most recent being in October of 2011.

The difference in **pH** from surface to bottom at both reservoir locations averaged a change of 0.5 pH units. The median surface pH was 8.3 and the median pH at the bottom was 7.8. No surface or profile sample fell outside the pH standard range of 6.5 to 9.0.

Nutrients, dissolved constituents, suspended solids and chlorophyll *a*, were analyzed in the surface samples only. **Nitrate nitrogen** had a median concentration of 0.08 mg/L, ranging from LOQ to 0.32 mg/L. No concentrations measured at the station exceeded the reservoir screening concentration of 0.37 mg/L. **Ammonia nitrogen** had a median concentration at the LOQ, never exceeding the reservoir screening concentration of 0.11 mg/L. The median concentration for **total phosphorus** was also at the LOQ.

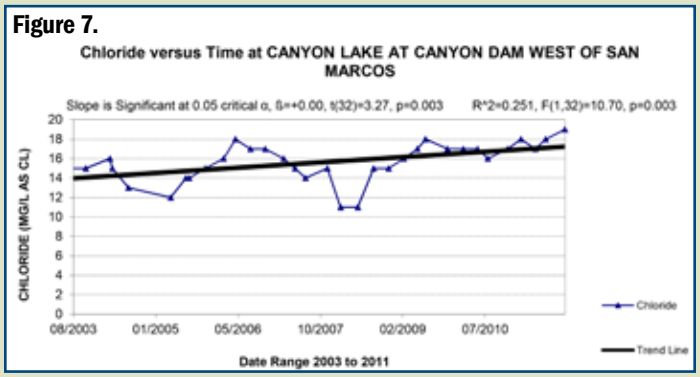
Chloride and **sulfate** had median concentrations of 16 mg/L and 21 mg/L, respectively and ranged from 11 mg/L to 19 mg/L chloride and 16 mg/L to 25 mg/L sulfate, both below the stream standard of 50 mg/L for each. The **total suspended solids** always had concentrations less than the LOQ of 4 mg/L. The **chlorophyll *a*** concentrations were less than 10 ug/L, the LOQ used by the TCEQ laboratory until May 2006, when the LOQ was changed to 3 ug/L. All values were well below the screening concentration of 26.7 ug/L for the assessment unit.

TCEQ also collected **mercury in water** and mercury in sediment at this reservoir location. There were only four data points in each data set. All mercury in water data was found below the LOQ of 0.001 ug/L and all **mercury in sediment** was found below the LOQ of 0.045 mg/kg.

The historical data for the main pool of the reservoir was reviewed for trends over time that may be indicative of a degradation in water quality. The low flows associated with the extraordinary drought conditions from 2008 to 2012

in the Guadalupe River basin have driven several trends in the main pool of Canyon Reservoir. In general, nutrient levels are significantly declining, while dissolved salts such as chlorides are significantly increasing over time (Figure 7).

Figure 7.



Cove Stations – Canyon Reservoir

GBRA has two monitoring locations in coves on Canyon Reservoir. The station located near the Canyon Lake Marina (station no. 12598) was established in 1987 as part of the GBRA historical monitoring program aimed at looking at water quality for contact recreation. The parameter list was expanded in 1996 when GBRA joined the Clean Rivers Program. The TCEQ has also monitored at this location and their data is part of this review. GBRA monitors this station monthly and samples are collected from the first third of a meter.

The other GBRA monitoring station was established in 2001 at the request of the Comal County Judge. He and the Commissioner's Court were concerned about the wastewater discharge to the cove and wanted a monitoring station closer to the discharge. The station near the Jacob's Creek Park is approximately two miles from the discharge. The station is monitored quarterly.

Both coves are relatively shallow as compared to the main pool of the reservoir. The sample stations are located in the assessment unit that refers to the coves around Jacob's Creek Park. There were no concerns noted for this assessment unit other than the mercury in fish tissue impairment previously mentioned.

Looking at the water quality at the Jacob's Creek Park station, the median **temperature** is 21.6°C, ranging from 11.8°C to 30.7°C. The median **specific conductance** was 400 umhos/cm, ranging from 328 umhos/cm to 461 umhos/cm. The **dissolved oxygen** ranged from 6.8 mg/L to 12.5 mg/l, with a median concentration of 9.7 mg/L and never exceeded the screening concentration of 6.0 mg/L. The **pH** of the water at the Jacob's Creek Park station ranged from 7.8 pH units to 8.4 pH units, with a median pH of 8.2.

Nitrates, ammonia and total phosphorus were analyzed at the Jacob's Creek Park station. The median concentration for **nitrate nitrogen** was 0.08 mg/L, ranging from the LOQ

Photo by Connie Rothe

to 0.39 mg/L, exceeding the screening concentration for this assessment unit two times. The ammonia nitrogen was always measured above the screening concentration of 0.11 mg/L 7 times and the median concentration was at the LOQ of 0.1 mg/L. The median concentration for total phosphorous was below detection.

Chlorophyll *a* concentrations were very low and never approached the screening concentration of 26.7 micrograms per liter (ug/L). The median concentration was 1.3 ug/L, and the highest concentration measured in the historical data set was 10.8 ug/L. ***E. coli*** concentrations are also very low, with the highest concentration measured being 61 MPN/100 mL. The geometric mean for the station was 3 MPN/100 mL.

The historical data for this cove of the reservoir was reviewed for trends over time that may be indicative of a degradation in water quality. The low flows associated with extraordinary drought conditions from 2008 to 2012 in the Guadalupe River basin have also driven several significant trends in the Jacob's Creek Park cove of the reservoir. Currently, dissolved oxygen levels are significantly declining (Figure 8), while pH levels are significantly increasing over time (Figure 9). Ammonia nitrogen levels are significantly increasing as well, but this trend may be partially caused by the rise in the analysis LOQ from 0.02 mg/L to 0.10 mg/L in September 2007.

The GBRA station in the cove near the Canyon Lake Marina has an extensive historical data set. The median **temperature** is 24.2°C, ranging from 10.9° to 32.0°C. The median **specific conductance** was 398 umhos/cm, ranging from 325 umhos/cm to 526 umhos/cm. The **dissolved oxygen** ranged from 6.1 to 12.8 mg/L, with a median concentration of 9.0 mg/L and never exceeded the screening concentration of 6.0 mg/L. The pH of the water at the Marina station ranged from 7.5 to 8.5 pH units, with a median pH of 8.2.

Nitrates, ammonia and total phosphorus were analyzed at the GBRA Marina station. The median concentration for **nitrate nitrogen** was 0.08 mg/L, ranging from the LOQ to 1.22 mg/L, exceeding the screening concentration of 0.37 mg/L for this assessment unit 5 out of 126 measurements (4.0%). The median concentration for **ammonia nitrogen** was 0.1 mg/L and ranged from the LOQ to 0.30 mg/L. Ammonia nitrogen appears to be significantly increasing over time (Figure 10). The increase in ammonia nitrogen levels may be partially caused by low flow conditions from 2008 to 2012 and also by a change in the LOQ from 0.02 mg/L to 0.10 mg/L in late 2007.

Chlorophyll *a* concentrations were very low and never exceeded the screening concentration of 26.7 ug/L. The median concentration was 1.6 ug/L. The highest concentration measured in the historical data set was 7.5 ug/L.

Figure 9.

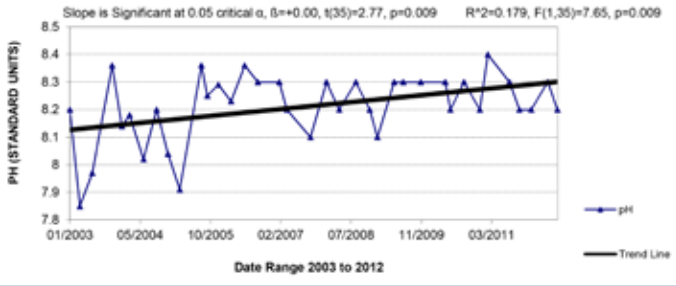


Figure 8.

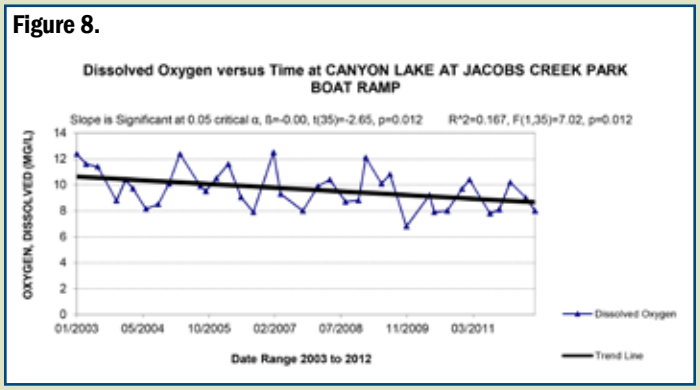
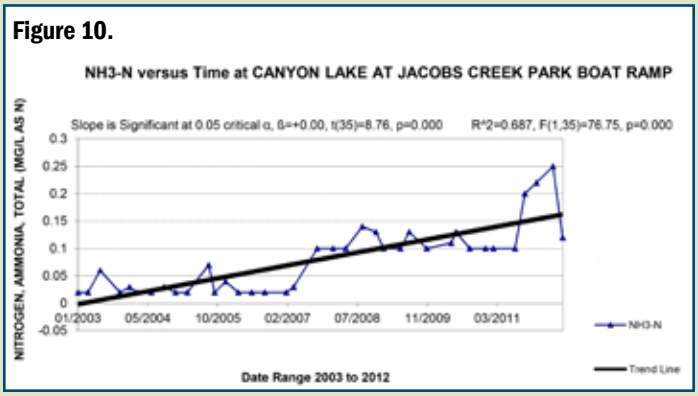


Figure 10.



The geometric mean for ***E. coli*** at the GBRA Canyon Lake Marina station was 5 MPN/100 mL.

The historical data was reviewed for trends over time that may be indicative of degradation in water quality at the Canyon Park Marine location. The majority of the trends discovered appeared to be driven primarily by the low flows and associated extraordinary drought conditions present from 2008 to 2012. The pH at this station appears to be slightly increasing (Figure 11). The nutrient concentrations such as TKN are decreasing (Figure 12), while dissolved salts continue to increase (Figure 13).

Figure 11.

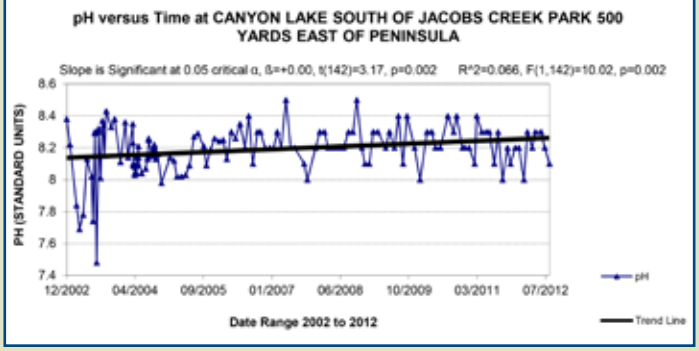


Figure 12.

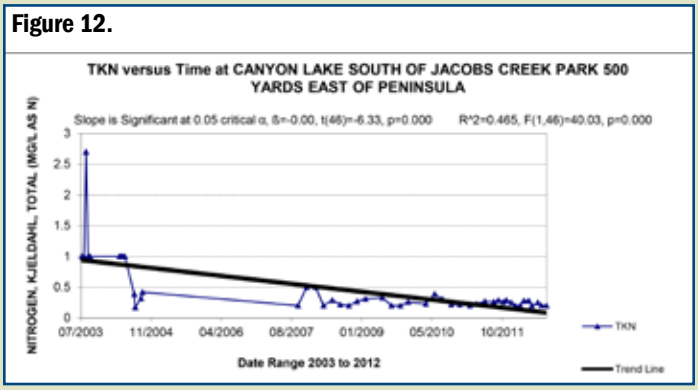
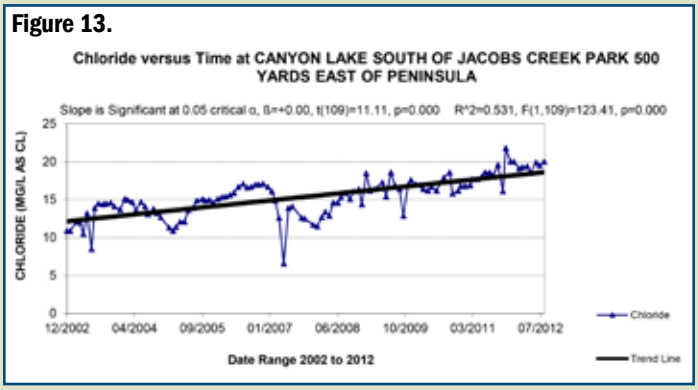
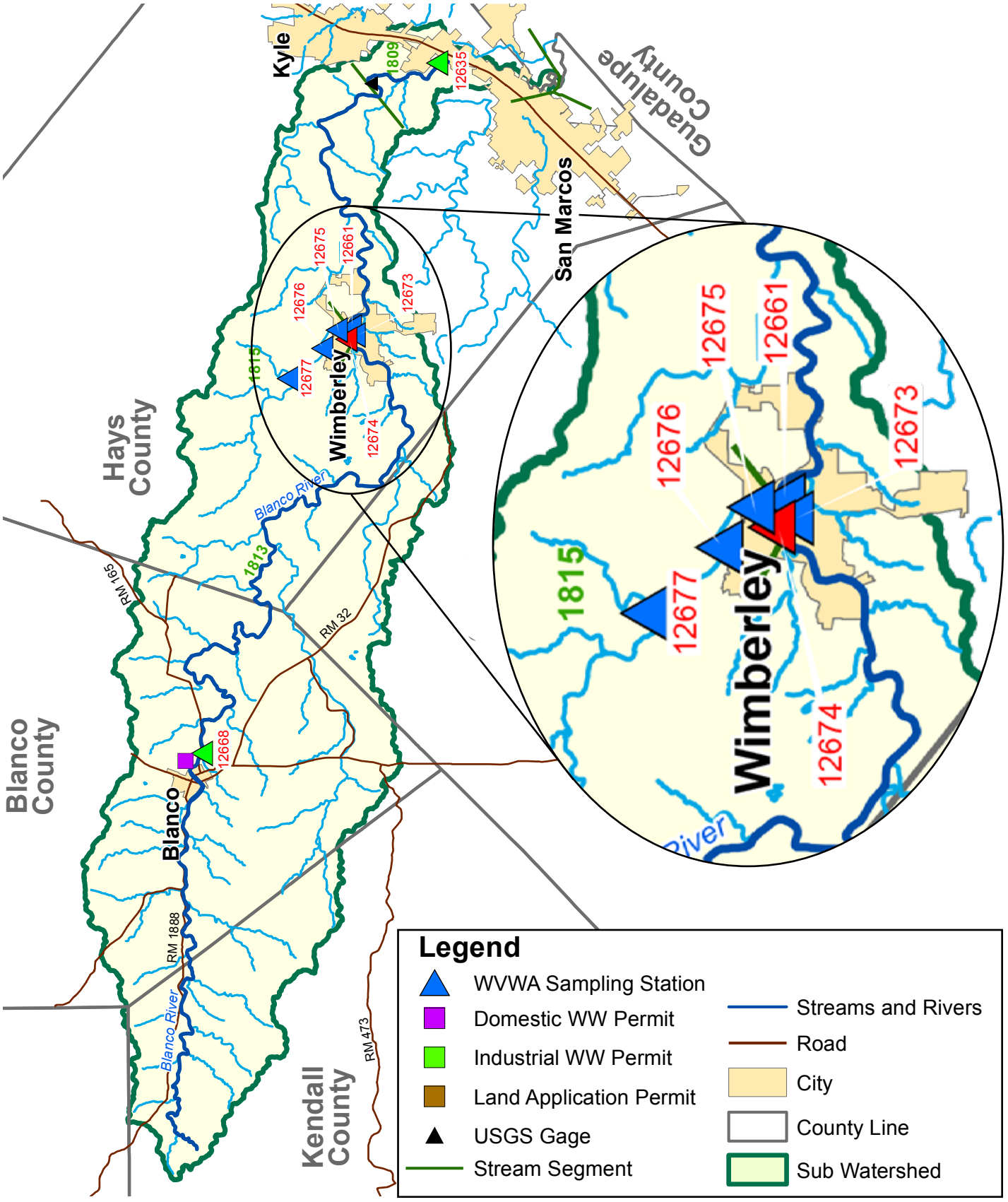


Figure 13.



Guadalupe River below Comfort Issues and Concerns			
Water Quality Issue	**Affected Area**	**Possible Influences/Concerns**	**Possible Actions Taken/to be Taken**
Mercury in Fish Tissue	Canyon Reservoir	Air deposition (volcanoes, coal-fired plants, cement plants)	TMDL; EPA's 5M Strategy (identify air and multi-media sources, adoption of statewide reduction goals, coordination across states); watershed protection plan

Blanco River Watershed



Blanco River Watershed

River Segments, Descriptions and Concerns

Segment 1813 (Upper Blanco River): Flowing 71 miles from northern Kendall County until Lime Kiln Road in Hays County, the upper Blanco is a spring-fed stream. Cypress Creek joins the river in the Village of Wimberley. The steep-sloped, intermittent, meandering stream is lined with baldcypress, oak and ashe juniper.

Segment 1815 (Cypress Creek): The spring-fed creek flows 14 miles into the Village of Wimberley where it merges with the Blanco River in Hays County. A picturesque creek, lined with baldcypress trees, with good water quality.

Segment 1809 (Lower Blanco River): This 15-mile lower stretch of the Blanco River from Lime Kiln Road until the confluence with the San Marcos River varies from a rapid moving stream as it crosses the Balcones Fault Zone to a shallow, slow moving stream, lined with scrub oaks as it enters the Blackland Prairies.

Drainage Area: 440 square miles

Streams and Rivers: Guadalupe River, Lower Blanco River, Upper Blanco River, Cypress Creek, Meier Creek, and Sycamore Creek

Aquifers: Edwards-Trinity, Trinity

River Segments: 1813, 1815, 1809

Cities: Blanco, Fischer, Wimberley, Kyle, San Marcos

Counties: Kendall, Comal, Blanco and Hays

EcoRegions: Edwards Plateau, Texas Blackland Prairies

Vegetation Cover: Evergreen Forest 42.9%, Shrublands 11.0%, Grass/Herbaceous 32.2%, Deciduous Forest 7.7%

Climate: Average annual rainfall 31 inches, Average annual temperature January 34°, July 94°

Land Uses: urban, agricultural crops (wheat, hay, oats, peaches and pecans), sheep, cattle, goats and turkey productions; light manufacturing and recreation

Water Body Uses: aquatic life, contact recreation, general use, fish consumption use, and public water supply use

Soils: Varies from thin limestone to black, waxy, chocolate, and grey loam, calcareous, stony, and clay loams

Permitted Wastewater Treatment Facilities: Domestic 1, Land Application 0, Industrial 0

Photo by Lee Gudgell

Blanco River Watershed

River Segments, Descriptions and Concerns

Blanco River Watershed - Upper Blanco River

The **Blanco River** is divided into two classified stream segments. Segment 1813, the **upper Blanco River**, extends for 71 miles from Lime Kiln Road in Hays County, through Blanco County, to the spring-fed headwaters in northern Kendall County. The lower segment is described later in this section. Segment 1813 consists of 355 square miles of drainage basin that is separated into five assessment units. Assessment unit 1813_01 evaluates the 14.2 mile lower section of the segment, between Lime Kiln Road and Hays CR 314. Unit 1813_02 assesses the 3.5 mile section below the City of Wimberley, between Hays CR 314 and Hays CR 1492. Unit 1813_03 evaluates the 6.5 mile section, below the City of Blanco, between Blanco CR 406 and Highway 281 in Blanco County. Unit 1813_04 assesses the 17.3 mile section between Highway 281 and the headwaters of the segment. Unit 1813_05 assesses the 29.5 mile section between Hays CR 1492 and Blanco CR 406. This segment also receives the Cypress Creek tributary below the City of Wimberley. Cypress Creek has been designated as a separate segment, Segment 1815, and is discussed in a later section of this document. Segment 1809, the lower Blanco River, is described in the following section. GBRA has routinely monitored one station in Segment 1813 (station no.12668), monthly, since October of 1996. The GBRA monitoring station is located at FM 165, ½ mile east of the city and 2 miles below the City of Blanco wastewater treatment plant discharge. The Wimberley Valley Watershed Association (WVWA) recognized the need for more assessment data in this segment of the Blanco River and partnered with the GBRA to initiate routine monitoring of three stations (station no. 12660, Station no. 12661, and station no. 12663) on the Blanco River, in February of 2003. The data collected by the WVWA, is quality-assured by the GBRA and submitted to the TCEQ under the GBRA QAPP. The WVWA station no. 12660 is a historical station originally monitored by TCEQ and located 3.1 miles downstream of the Cypress Creek confluence at the Fulton Ranch Road crossing. The WVWA station no. 12661 was initially sampled by the USGS in May of 1990 and is located 0.4 miles downstream of the Cypress Creek confluence, just below the Ranch Road 12 crossing. WVWA station no. 12663 is a new station, located 1.2 miles upstream of the Cypress Creek confluence, at CR 1492, in the upper end of assessment unit 1813_02. Hays County attempted to establish a monitoring program, taking over the monitoring of station no. 12660 and station no. 12663 monthly. Their program lost its funding in 2013, causing them to discontinue monitoring until the funding can be restored.

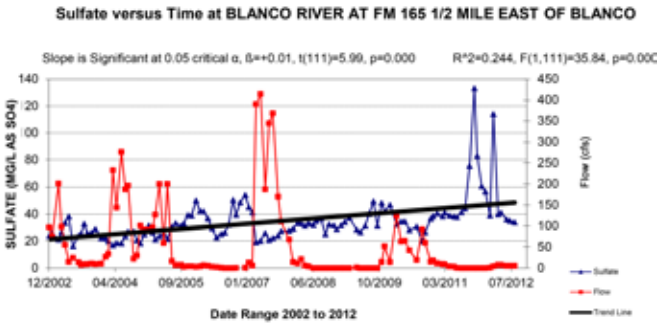
Segment 1813 is a spring-fed stream, on the Edwards Plateau. The majority of the segment exhibits limestone substrate with occasional gravel, silt, or clay strata. The limestone is known to contain gypsum deposits, which can contribute to high sulfate concentrations in groundwater. The stream has historically displayed exceptional water quality and usually exhibits extremely clear water. Generally, most water quality concerns in this segment of the Blanco River are linked to changes in stream flow. Upper portions of the river have been known to go dry during prolonged periods of drought and the banks and substrate of the entire segment exhibit significant scouring during extended wet periods. The 2012 Texas Water Quality Inventory lists a concern for dissolved oxygen for aquatic life use in assessment unit 1813_05, and has persisted since 2006. The concern is most likely due to low base flow conditions that are common in that portion of the segment. The increasing population in this area has raised concerns about strains on the available water supply and increased stream erosion potential. As the population in this area continues to climb, so does the importance of maintaining the water quality of available surface water.

Currently, there are two domestic wastewater treatment plant discharges permitted in the upper Blanco River. Both discharges occur just outside of the City of Blanco, in assessment unit 1813_03. The City of Blanco municipal plant is situated ½ mile east of central Blanco and discharges the majority of its effluent into irrigation ponds for fields of coastal bermuda. This plant is permitted to discharge excess effluent into the Blanco River at an average rate of 0.90 million gallons per day. The permitted discharge to the Blanco River rarely occurs, except during periods when the coastal bermuda irrigation fields are being harvested. The municipal effluent must meet water quality standards of 30 milligrams per liter (mg/L) biochemical oxygen demand, 30 mg/L total suspended solids, 1.0 mg/L

chlorine residual, and a pH between 6.0 and 9.0. The City of Blanco Water Treatment plant is permitted for an average discharge of 0.050 million gallons per day, in the form of backwash water and settling sludge supernatant. The water treatment plant discharge is permitted to have a total suspended solids level of 20 mg/L and a pH of between 6.0 and 9.0 standard units.

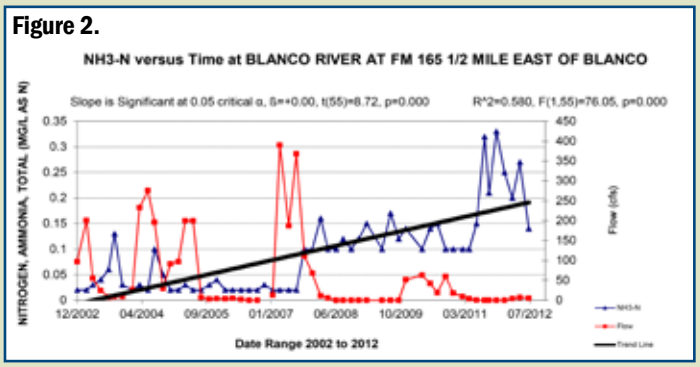
Over the period of record, the **sulfate** concentration at the Blanco River at FM 165, station no. 12668 had a median value of 31.9 mg/L with a maximum value of 133 mg/L and a minimum value of 16.1 mg/L. **Sulfates** at this station exceeded the stream screening criteria of 50 mg/L fourteen times over the period of record, as seen in Figure 1. The sulfate concentration at this station appears to be exhibiting a significant downward trend with time. A significant portion of the variance in sulfate at this station appears to be explained by stream flow. Over the period of record there appears to be an inverse relationship between sulfate concentration and flow.

Figure 1.



Nitrate nitrogen, ammonia nitrogen, total phosphorus, and chlorophyll *a* were also analyzed at this monitoring location. The median **nitrate nitrigen** concentration was 0.12 mg/L, with a maximum value of 1.17 mg/L and a minimum value of <0.01 mg/L. None of the samples exceeded the nitrate nitrogen screening criteria of 1.95 mg/L. The median **ammonia nitrogen** concentration of the GBRA monitoring location at FM 165 ranged from the Limit of Quantification (LOQ) to 0.33 mg/L. There appears to be an upward trend in ammonia concentration that can be attributed to the change in the LOQ from 0.02 mg/L to 0.1 mg/L and the prolonged period of low flows caused by the drought in 2008-09 and 2011 (Figure 2).

Figure 2.



The median **total phosphorus** concentration was below the LOQ for the method and when total phosphorus was detected in a sample it did not exceed the screening concentration of 0.69 mg/L. The median **chlorophyll *a*** concentration was below the LOQ and there was never a measured value above the screening concentration of 14.1 microgram per liter.

Nitrate nitrogen, ammonia nitrogen total phosphorus, and chlorophyll *a* were analyzed at the WVWA stations on Blanco River. The median **nitrate nitrogen** concentration ranged between 0.19 mg/L and 0.22 mg/L. None of the samples exceeded the nitrate nitrogen screening criteria of 1.95 mg/L. The **ammonia nitroge**n concentrations of the WVWA monitoring locations showed the same upward trends tied to flow. The median **total phosphorus** concentration was below the LOQ for the method and when total phosphorus was detected in a sample it did not exceed the screening concentration of 0.69 mg/L.

Segment 1813 provides clear, spring water for contact recreational opportunities. The low base flows in the river often prevent canoeing and tubing, but many dammed pools exist in the segment, which attract campers and swimmers. The stream standard for contact recreation is a geometric mean of 126 colonies per 100 milliliters. The geometric mean for ***E. coli*** at the GBRA FM165 station (station no. 12668) is 24 MPN/100 mL. The geometric mean for *E. coli* at the WVWA CR1492 station (station no.12663) is 93 MPN/100 mL.

Photo by Lee Gudgell

Blanco River Watershed

River Segments, Descriptions and Concerns

The geometric mean for *E. coli* at the WVWA RR12 (station no. 12661) is 62 MPN/100 mL. The geometric mean for *E. coli* at the WVWA CR173 station (station no.12660) is 41 MPN/100 mL. The geometric means for *E. coli* in the monitoring stations of this segment appear to be lowest in the upper reaches of the segment, highest before the Cypress Creek confluence in the City of Wimberley and begin declining after the confluence, as the water leaves the city.

The land use in the segment consists of increasingly urbanized areas above or near the City of Blanco and the City of Wimberley. In the long stretches above and below these two cities farm and ranch land is prevalent. Many family farms are being sold and subdivided, and this area is expected to continue to increase its residential land use over the next few years. The impervious cover that is created by residential land use and subdivisions, i.e. streets, rooftops and parking lots, can be a source of nonpoint source pollution. The impervious cover forces water that could be captured by the soil to runoff directly into the creeks and streams. This runoff can increase erosion and suspended sediment loading in the water bodies as well as carry other organic pollutants. The median **total suspended solids** (TSS) value at the Blanco River at FM165 monitoring station is 3.4 mg/L. The WVWA monitoring stations exhibited median TSS values of 1.7 mg/L with a maximum value of 43.3 mg/L at the CR1492 station, 1.7 mg/L with a maximum value of 40.2 mg/L at the RR12 station and 1.6 mg/L with a maximum value of 49.7 mg/L at the CR173 station. The highest TSS values occurred during high flow events.

The historical data from the two monitoring stations was reviewed for trends, comparing constituents over time and flow regimes. Statistically significant trends that were noted, either positive or negative, were not indicative of degrading water quality conditions.

Cypress Creek

Segment 1815, the **Cypress Creek**, extends from the confluence of the Cypress Creek and the Blanco River in the City of Wimberley, to the Jacob's Well, its headwaters, north of the City. The entire segment lies within Hays County. GBRA monitors the Cypress Creek at Ranch Road 12 ("RR 12"; station no. 12674) quarterly. TCEQ monitored the RR 12 station quarterly from 1991 until GBRA assumed the quarterly monitoring in 1998. The stations in the WVWA monitoring project include the Cypress Creek at Jacob's Well, the headwaters of the Cypress Creek; the Cypress Creek at Ranch Road 12, one mile north of the City of Wimberley; and the Cypress Creek at the confluence with the Blanco River. They added a new station, the Cypress Creek near the Blue Hole recreational area in late 2005.

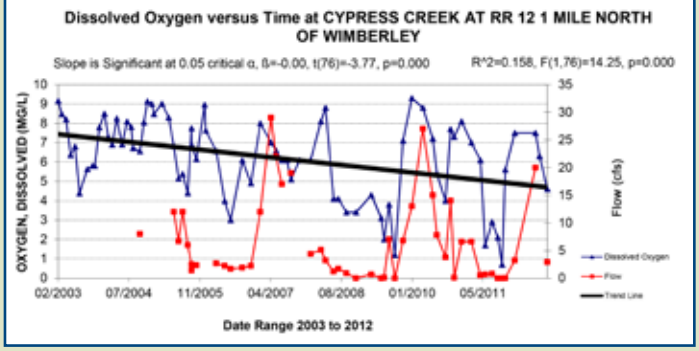
Stakeholders in the Cypress Creek watershed have raised three issues that they feel are impacting water quality. The issues include the small, overloaded septic tanks used by the businesses along the creek in Wimberley which could be contributing bacteria to the stream. Another issue is the increased urbanization of previously unused areas which can bring in a variety of pollutants such as nutrients and suspended solids that can decrease oxygen in the stream, especially during periods of low flow. Finally, the stakeholders are concerned by the increasing demand on the groundwater resources in the area which reduces the flows from Jacob's well which in turn reduces the oxygen in the stream as well as the water becomes more stagnant during times of low flow. These concerns are not unfounded as the limited data set on Cypress Creek (dissolved oxygen, *E. coli* and nutrients) shows later in this section.

There is one wastewater plant in the watershed of the Cypress Creek. The Blue Hole wastewater plant is permitted to the City of Wimberley. The facility disposes of the treated waste by subsurface irrigation at a volume not to exceed 15,000 gallons per day and at a rate that does not exceed 0.16 gallons per square foot. The permit allows for surface irrigation when the plant is expanded to 50,000 gallons per day. There is no permitted discharge to the waters of the Cypress Creek in either phase of operation. The Blue Hole plant has only one customer, a 122 -bed rehabilitation facility.

The 2012 Texas Water Quality Inventory lists Cypress Creek with a concern for depressed dissolved oxygen. Out of 320 measurements, 108 fell below the screening criteria of 6.0 milligrams per liter (mg/L). The station located at Jacob's Well which is the headwaters of the creek has a median **dissolved oxygen** concentration of 5.9 mg/L, ranging from 3.8 mg/L to 9.8 mg/L. The water leaving the well, as expected for ground water, is low in dissolved oxygen.

The WVWA station that is on RR12, approximately 1 mile upstream of the City of Wimberley, has a median dissolved oxygen concentration of 6.6 mg/L, ranging from 0.7 mg/L to 9.3 mg/L. As the water in the creek travels downstream through the watershed it is aerated and the median concentration for dissolved oxygen goes up. The median concentration for dissolved oxygen at the GBRA RR12, in the City of Wimberley, is 8.8 mg/L, ranging from 1.4 to 11.7 mg/L. The median concentrations of dissolved oxygen rise as the creek flows downstream. However, the WVWA monitoring station at RR12 shows a significant decline in dissolved oxygen concentration over the past 10 years (Figure 3).

Figure 3.



A fourth monitoring station is located on the Cypress Creek just upstream of the Blanco River confluence. This station has a median dissolved oxygen level of 8.0 mg/L with a range from 1.7 mg/L to 10.9 mg/L. This station has values slightly lower than the RR12 station in Wimberley, but this is most likely a result of the larger data set available at this station.

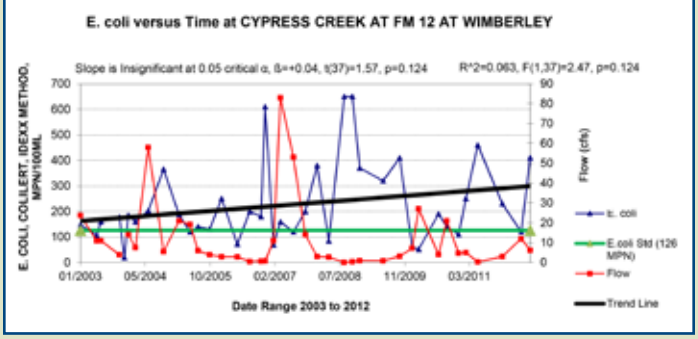
The new monitoring station located near the Blue Hole recreational facility on Cypress Creek has a median dissolved oxygen concentration of 5.3 mg/L, ranging from 1.5 mg/L and 9.2 mg/L, but it has a much smaller data set than the other two monitoring stations located downstream of Jacob's Well. This station was added by the WVWA in late 2005 after the park was purchased by the City of Wimberley. Jacob's Well is very important to the residents in the area, with historical, sentimental and ecological significance and warrants continued monitoring.

Considering all of the monitoring locations on the segment, the **temperature** varied between 8.4°C to 32.4°C, with a median temperature of 20.8°C. The ***specific conductance*** ranged between 369 umhos/cm and 916 umhos/cm, with a median conductivity of 557 umhos/cm. The median **pH** of all stations was 7.6, ranging from a low pH of 6.3 at the Jacob's Well station, to high pH of 8.3 at the GBRA RR12 location. The median concentrations for **chloride** and **sulfate** at the GBRA RR12 location were 14.2 mg/L and 17.3 mg/L respectively. At no time did the concentration of these dissolved constituents exceed the stream standard of 50 milligrams per liter.

Nitrate nitrogen, ammonia nitrogen and total phosphorus, were analyzed at all of the monitoring locations on the segment. The median concentrations of **nitrate nitrogen** for all the locations were 0.18 mg/L and ranged from 0.02 mg/L to 1.73 mg/L. At no time did the nitrate nitrogen concentration exceed the screening criteria of 1.95 milligrams per liter at any monitoring location. The median **ammonia nitrogen** concentration was 0.10 mg/L at all monitoring locations. The median **total phosphorus** concentration was below the LOQ for the method and when total phosphorus was detected in a sample, it did not exceed the screening concentration of 0.69 milligrams per liter.

Segment 1815 is a slow meandering stream with a bedrock substrate. The contact recreation stream standard, using ***E. coli***, is a geometric mean of 126 colonies per 100 milliliters. The geometric mean for *E. coli* at the GBRA RR12 station is 178 MPN/100 mL, which exceeds the stream standard. Often, *E. coli* concentrations increase with rises in flow due to storm water runoff. At the GBRA RR12 station, there are periods where *E. coli* numbers are high without corresponding influences from flow (Figure 4). A possible explanation for this phenomenon could be

Figure 4.



that the contributions of *E. coli* from failing septic tanks in the City of Wimberley are more easily detected when the base flow is not sufficient enough to dilute the bacteria. This theory is reinforced by the distribution of *E. coli* concentrations throughout the watershed. The most upstream monitoring station at Jacob's Well (station no. 12677) has a geometric mean of 8 MPN/100 mL with an average flow of 6.4 cfs. The next monitoring station downstream at RR12 (station no. 12676) has a geometric mean *E. coli* concentration of 94 MPN/100 mL with an average flow of 6.5 cfs. The Blue Hole monitoring station (station no. 12675) has a geometric mean of 70 MPN/100 mL with an average flow of 7.4 cfs. The GBRA RR12 monitoring station (station no. 12674) in downtown Wimberley exceeds the stream standard with a geometric mean of 178 MPN/100 mL and an average flow of 12.0 cfs. The *E. coli* concentrations remain above the stream standard at the most downstream station near the confluence with the Blanco River (station no. 12673) with a geometric mean of 146 MPN/100 mL and an average flow of 13.8 cfs. These *E. coli* values illustrate a stream that has very low *E. coli* at the headwaters and increases in concentration when it reaches an urbanized area, followed by a slight decline as it moves to a less densely populated portion of the watershed (Figure 5). There is also a significant decreasing trend in *E. coli* over time at the Jacob's Well and Blue Hole monitoring stations, which may be the result of decreasing flows in this segment (Figures 6 & 7).

The **suspended solids** ranged from 1 milligrams per liter (mg/L) to 35 mg/L, with a median of 1.3 mg/L. The median **chlorophyll *a*** concentration was below the LOQ and there was never a measured value above the screening concentration of 14.1 microgram per liter.

Figure 5.

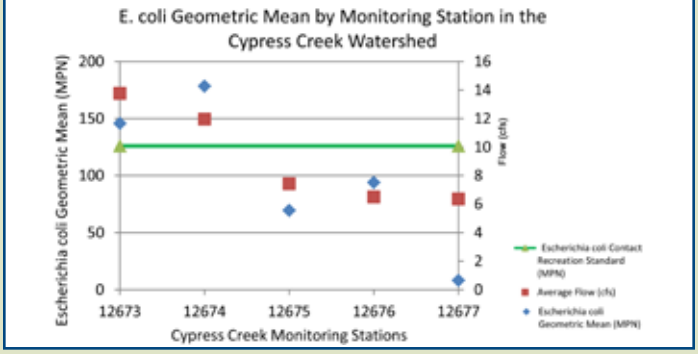


Figure 6.

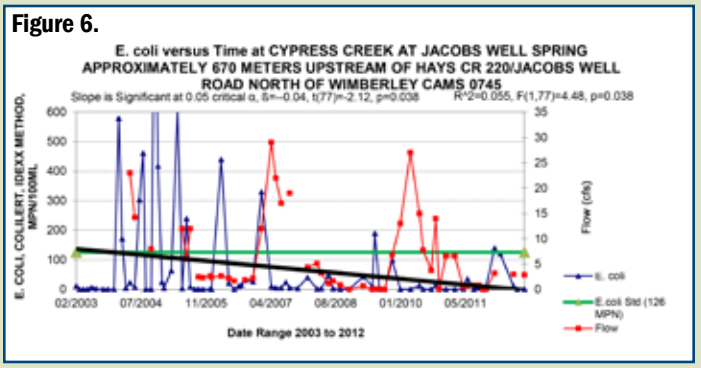
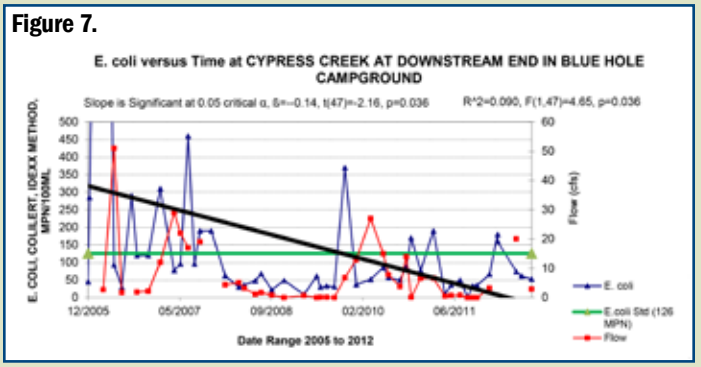


Figure 7.



Blanco River Watershed - Lower Blanco River

Segment 1809, the **lower Blanco River**, extends from the confluence of the Blanco and San Marcos Rivers, just outside the City of San Marcos, upstream to the Lime Kiln Road crossing in Hays County. The segment is 15 miles long and is separated into two assessment units. Assessment unit 1809_01 consists of the segment from the confluence with the San Marcos River to seven miles upstream. Assessment unit 1809_02 consists of the upper eight miles of the segment from seven miles upstream of the San Marcos River confluence, to Lime Kiln Road. The upper Blanco River, Segment 1813, includes the area upstream of Lime Kiln Road and is described in the preceding section. TCEQ has been monitoring the Blanco River at Hays CR 295/Old Martindale Road, east of San Marcos (station no. 12631) quarterly since May of 1994. The TCEQ monitoring station is located in the lower half of the segment, in assessment unit 1809_01. TCEQ monitors this station four times per year. A statistical review of the data in this segment was performed on data collected between 2003 and 2012.

The 85 square mile drainage area of the lower Blanco River is primarily located on the Edwards Plateau, but enters the Blackland Prairies on the eastern edge of Hays County. This segment consists of limestone substrate with occasional stony and clay loams. The changes in elevation as the river crosses the Balcones fault increase the streamflow, but there are also several slow moving stretches throughout the segment. The water is primarily used for aquatic life, contact recreation and fish consumption. The land in the basin is used for farming, ranching, recreation, light manufacturing and urban development. The urban development of this segment is increasing at a rapid pace due to the river's location in the middle of the IH 35 corridor and its close proximity to the growing cities of San Marcos and Kyle. The rapidly increasing population in this area raises concerns about the increasing amount of impervious cover and subsequent potential for non-point source pollution.

The lower Blanco River has no major tributaries to contribute to flow and sediment loading of the stream. High flow events are almost exclusively associated with flow contributions from Segment 1813 or runoff from dry creeks within the segment. The median instantaneous flow of the CR 295 monitoring station, in Segment 1809, was 30 cubic feet per second (cfs). However, the stream experiences wide swings in flow, from 0 cfs to 1270 cfs, throughout the period of record, going dry or having no measureable flow from July 2008 through September 2009.

Due to the bedrock substrate of the lower Blanco River, **total suspended solid (TSS)** values are relatively low in this segment of the river. The median TSS value for the CR 295 station is 4.0 mg/L, with a maximum value of 83 mg/L during a high flow event. The stream standard for contact recreation is a geometric mean ***E. coli*** concentration of 126 colonies/100mL. The CR 295 monitoring location has a geometric mean of 34 MPN/100 mL.

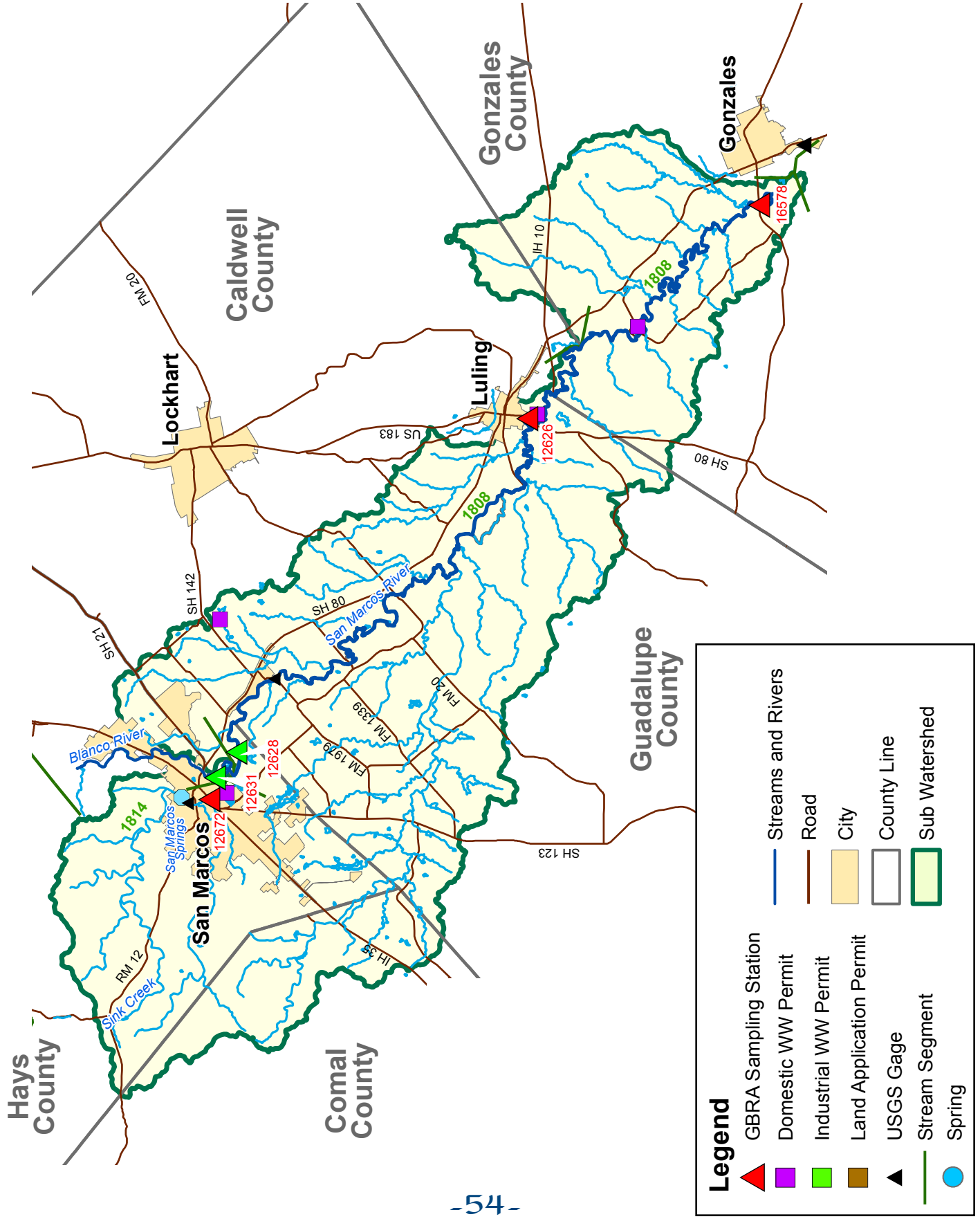
There are no permitted dischargers in Segment 1809 of the Blanco River. The 2012 Texas Water Quality Inventory Report has no impairments or concerns listed for Segment 1809. The TCEQ CR 295 monitoring station had median concentrations of **conductivity, chloride** and **sulfate** of 487 umhos/cm, 17.0 mg/L and 32.0 mg/L respectively. The TCEQ station never exceeded the stream standard for chlorides or sulfates of 50 mg/L. The median concentration for **dissolved oxygen** is 7.7 mg/L, ranging from a minimum of 5.0 mg/L to a maximum of 11.1 mg/L at the TCEQ station at CR 295. The median **pH** value at this station was 7.8 and ranged from a low of 7.10 to a high of 8.30, never falling outside the stream standard range of 6.5 to 9 standard pH units.

Nitrate nitrogen, ammonia nitrogen and total phosphorus, were analyzed at the TCEQ CR 295 location. Over the period of record, the median concentration of **nitrate nitrogen** was 0.22 mg/L, ranging from 0.04 mg/L to 1.75 mg/L never falling outside of the screening concentration of 1.95 mg/L. The median concentration for **ammonia nitrogen** was below the LOQ for the method and the maximum ammonia nitrogen value recorded at this station was 0.08 mg/L, well below the screening concentration of 0.33 mg/L. Median **total phosphorus** concentration at the TCEQ CR 295 station was below the LOQ for the method and had a maximum value of 0.07 mg/L, which was well below the screening concentration of 0.69 mg/L. The data from this monitoring station indicates that the quality of the water at this monitoring station is of excellent quality.

A trend analysis of all the data available in Segment 1809 showed no significant changes over time.

Blanco River Issues and Concerns			
Water Quality Issue	**Affected Area**	**Possible Influences/Concerns**	**Possible Actions Taken/to be Taken**
Urban and Suburban Growth	Upper Blanco River	Impervious cover; urban storm water	
Depressed Dissolved Oxygen	Cypress Creek	Urban storm water	Watershed Protection Plan under development
Impaired Aquatic Habitat and Communities	Cypress Creek	Reductions in flow; periods of dry conditions	Reassess stream use designation to intermittent stream, although many stakeholders are not in favor of the change in designation
Urban and Suburban Growth	Lower Blanco River	Construction and urban storm water	City of San Marcos, Texas State University and Hays County are developing storm water pollution prevention plans

San Marcos River Watershed



San Marcos River Watershed

River Segments, Descriptions and Concerns

Segment 1814 (Upper San Marcos River): Beginning at the San Marcos Springs that are fed by the Edwards Aquifer in Hays County, the five mile stretch of river continues through to the confluence with the Blanco River east of San Marcos. The headwaters of the San Marcos River are clear flowing and a constant temperature year long.

Segment 1808 (Lower San Marcos River): From the confluence of the San Marcos River with the Blanco River continuing about 75 miles until the point of confluence with the Guadalupe River outside the City of Gonzales. Includes the confluence with Plum Creek. The lower San Marcos River is a lazy, smooth flowing river during normal flow.

Drainage Area: 522 square miles

Streams and Rivers: Lower San Marcos River, Upper San Marcos River, Sink Creek, York Creek, Purgatory Creek, Sessom Creek

Aquifers: Edwards-Balcones Fault Zone, Carrizo-Wilcox

River Segments: 1814, 1808

Cities: San Marcos, Maxwell, Martindale, Fentress, Prairie Lea, Luling, Ottine, Gonzales

Counties: Hays, Guadalupe, Caldwell, Gonzales

EcoRegions: Edwards Plateau, Post Oak Savannah, Texas Blackland Prairies

Vegetation Cover: Pasture/Hay 27.0%, Evergreen Forest 12.8%, Shrublands 12.2%, Grass/Herbaceous 16.3%, Deciduous Forest 19.0%, Row Crops 8.6%

Climate: Average annual rainfall 33 inches
Average annual temperature January 40°, July 96°

Land Uses: Urban, industry, agricultural crops (corn, sorghum, hay, cotton, wheat, pecans), cattle and hog production, poultry production, oil production, and recreation

Water Body Uses: aquatic life, contact recreation, general use, fish consumption, and public water supply

Soils: Varies from thin limestone to black, waxy, chocolate, and grey loam

Permitted Wastewater Treatment Facilities: Domestic 4, Land Application 0, Industrial 0

Photo by Glenn Longley

San Marcos River Watershed

River Segments, Descriptions and Concerns

San Marcos River Watershed - Upper San Marcos River

The **San Marcos River** is divided into two classified stream segments. Segment 1814, the **upper San Marcos River**, extends from the confluence of the San Marcos and Blanco Rivers, just outside the City of San Marcos, to the headwaters of the river in and around Spring Lake within the city. The segment is 4.5 miles long and is separated into four assessment units: the lower 1.5 miles; from that point to IH 35; from IH 35 to Spring Lake; and, the remaining portion of the segment to the headwaters. The lower San Marcos, Segment 1808, is described in the following section. GBRA has been monitoring the San Marcos River at IH 35 (station no. 12672) quarterly since 1998. The GBRA station is located in the upper half of the segment, above the discharge of the city's wastewater treatment plant but below the city's downtown and business district. TCEQ has one historical station less than one mile downstream of the GBRA station that has data from 1991 to 1997. TCEQ monitored this station two to four times per year. There are other TCEQ stations in this segment but with very limited data sets. Beginning in 2012, TCEQ assumed the quarterly monitoring at the IH 35 station but GBRA continues to go to the station monthly to collect samples for total dissolved solids and conductivity.

The City of San Marcos operates a wastewater treatment plant that discharges to the upper San Marcos River (Segment 1814). The facility is permitted to discharge 9.0 million gallons per day, with permit limitations of 5 milligram per liter (mg/L) carbonaceous biochemical oxygen demand, 5 mg/L total suspended solids, 2 mg/L ammonia nitrogen and 1 mg/L total phosphorus. The facility also has a permit limit for bacteria. In addition to the City of San Marcos's Wastewater Treatment Plant, there is one other wastewater discharge to the segment. The Texas Parks and Wildlife Department's A.E. Wood Fish Hatchery is complying with a concentrated aquatic animal production general permit. The General Permit (TXG130005) requires measuring and reporting flow once daily; daily maximum total suspended solids of 90 mg/L monitored once per month; dissolved oxygen of 5.0 mg/L monitored once per week; carbonaceous oxygen demand of 250 pounds per day maximum reported once per month and an ammonia daily maximum of 2.0 mg/L.

The San Marcos River is home to the Texas Wild Rice and fountain darter, both endangered species. The constant temperature and consistent flow make the conditions conducive to these unique species as well as other native and non-native, aquatic flora and fauna. The Texas Wild Rice was in danger of being eliminated by an invasive plant called Cryptocoryne, also known as water trumpet. Water trumpet is a fast-growing rooted aquatic plant. Not only did it pose a threat to the Texas Wild Rice, it was replacing the habitat that the fountain darter relies on. Several years ago, the US Fish and Wildlife Service, along with area volunteers, meticulously removed the plant

Photo by Elizabeth Aguilar

Stock Photo

Photo by LaMarriol Smith

Photo by Janet Thome

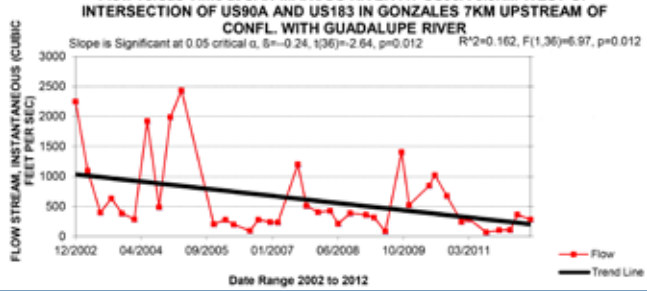
by hand. The plant is no longer out-competing the Wild Rice. In fact it is close to being removed entirely. The area where it was removed is checked a few times per year. It is quite a success story.

However, there are still quite a number of other exotic invasive plants introduced to the San Marcos River, like elephant ears, water hyacinth and alligator weed, that grow along the banks in San Marcos, and in the stream. There are very large colonies of alligator weed found upstream and downstream of Martindale, and hyacinth and elephant ears are found all the way to the coast. Volunteers from the San Marcos River Foundation have had great success after eight years of hyacinth removal from Spring Lake at Aquarena. They are now seeing open water on the slough, where there was once 100% coverage of the water by the floating hyacinth.

The cryptocoryne is an example of the damage that can come from introduction of non-native species, in this case, most likely introduced by people disposing of the contents of their aquariums. Other species that are associated with the improper disposal of aquarium populations include loriicarids (algae eaters), hydrilla and the giant ram's horn snail.

The stream segment is heavily influenced by springs from the Edwards Aquifer, located in the hills above the city and in Spring Lake. The springs discharge a median **flow** of 169 cubic feet per second. The flow from these springs keeps the temperature in the upper San Marcos River stable, at a median **temperature** of 22.8°C, ranging from 19.2°C to 25.2°C. The small range of temperature change shows how stable the temperature of the upper San Marcos River is. However, Figure 1 shows that there has been a downward trend in flow over the last 10 years.

Figure 1.



The 2012 Texas Water Quality Inventory lists Segment 1814 as impaired for **dissolved solids** (TDS). The TDS concentration used in the assessments were estimates based on the conductivity measured at the station. TDS is estimated by multiplying the conductivity by a factor of 0.65. The mean TDS estimated by this method is 402 mg/L at the IH35 monitoring location, exceeding the stream standard of 400 mg/L established for this river segment. GBRA has collected both TDS and conductivity at this station for two years. The average concentration of TDS measured since GBRA began collecting samples (22 samples) for this parameter is 337 mg/L, which is below the stream standard.

The median concentration for **dissolved oxygen** is 10.4 mg/L, ranging from a minimum of 8.1 mg/L to a maximum of 13.0 mg/L. At no time in the period of record did the dissolved oxygen drop below the minimum dissolved oxygen standard (4.0 mg/L). The **specific conductance** ranged between 579 micromhos per centimeter (umhos/cm), and 833 umhos/cm with a median conductivity of 625 umhos/cm. The median **pH** was 7.7, ranging from 7.4 to 7.9 standard units, never falling outside the stream standard range of 6.5 to 9 standard pH units. The median concentrations for **chloride** and **sulfate** were 19.1 mg/L and 26.9 mg/L respectively. At no time did the concentration of these dissolved constituents exceed the stream standard of 50 mg/L.

Nutrients, nitrate nitrogen, ammonia nitrogen and total phosphorus, were analyzed at the GBRA. The median concentration for **nitrate nitrogen** was 1.18 mg/L, ranging from 0.29 mg/L to 1.69 mg/L. Statistical analysis of the data collected over the last 10 years shows a rising trend in nitrate nitrogen over time as seen in Figure 2.

The median **ammonia nitrogen** concentration was 0.05 mg/L, ranging from less than the Limit of Quantification (LOQ of 0.02 mg/L to 0.51 mg/L; exceeding the screening concentration of 0.33 mg/L one time. The median **total phosphorus** concentration was below the LOQ for the

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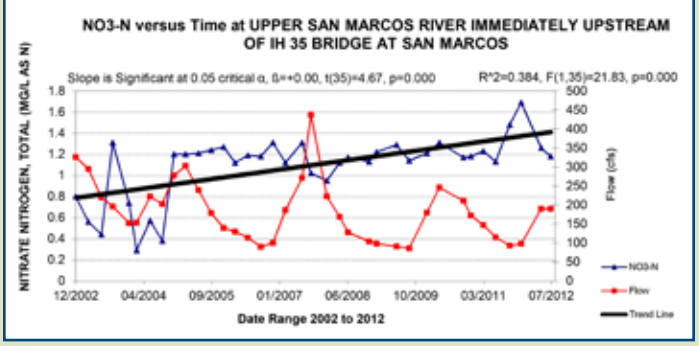
Figure 2.



method and when total phosphorus was detected in a sample it did not exceed the screening concentration of 0.69 mg/L. The median **chlorophyll *a*** concentration was less than the LOQ and there was never a measured value above the screening concentration of 14.1 microgram per liter.

Segment 1814 is known for its contact recreational opportunities. The clear, cool spring water attracts recreationists. Flows from the springs create excellent conditions for snorkeling, tubing and canoeing. The San Marcos River is home to the Texas Water Safari, one of the world's largest canoe races. The race attracts over 200 canoeing teams each June. The stream standard for contact recreation is a geometric mean of 126 colonies per 100 milliliters. The geometric mean for ***E. coli*** at the GBRA IH 35 station is 51 MPN/100mL.

The **suspended solids** ranged from less than method detection (1.0 mg/L) to 6.3 mg/L, with a median of 2.8 mg/L. The sediment at the GBRA monitoring location in this segment was analyzed for organics analysis three times over the period of record, specifically looking for the constituents associated with urban environments, such as total petroleum hydrocarbons (TPHs). No TPHs were detected in any sample.

The historical data from the monitoring station was reviewed for trends, comparing constituents over time and flow regimes. Any statistically significant trends not yet noted in this section, either positive or negative, were not indicative of degrading water quality conditions.

San Marcos River Watershed - Lower San Marcos River

Segment 1808, the **lower San Marcos River**, extends from the confluence of the San Marcos and Guadalupe Rivers, just outside the City of Gonzales, upstream to the confluence with the lower Blanco River near the City of San Marcos in Hays County. The segment is 75 miles long and is separated into four assessment units: the lower 18 miles; from the confluence with Mile Creek to the confluence with Plum Creek; from the confluence with Plum Creek to the Guadalupe County Road 239; and, the remaining portion of the segment to the confluence with the Blanco River. GBRA has been monitoring the San Marcos River at Luling (station no. 12626) monthly since 1987 and at the San Marcos at SH 90A (station no. 16578) quarterly since 1999. The GBRA Luling station is located in the upper half of the segment, in the third assessment unit. The GBRA 90A station is in the most downstream assessment unit, just upstream of the confluence with the Guadalupe River. TCEQ has one historical station located just downstream of the confluence with the Blanco River in Hays County (station no. 12628).

The City of San Marcos operates a wastewater treatment plant that discharges to the upper San Marcos River (Segment 1814). The facility is permitted to discharge 9.0 million gallons per day, with permit limitations of 5 mg/L carbonaceous biochemical oxygen demand, 5 mg/L total suspended solids, 2 mg/L ammonia nitrogen and 1 mg/l total phosphorus. The facility also has a permit limit for bacteria. In addition to the City of San Marcos's Wastewater Treatment Plant (WWTP) located in the upper segment, there is one other wastewater discharge to the segment. The City of Luling's south plant discharges to the San Marcos River and is permitted to discharge up to 500,000 gallons per day. The facility is permitted to discharge total suspended solids of 20 milligrams per liter (mg/L), 20 mg/L carbonaceous biochemical oxygen demand, and ammonia-nitrogen of 2.0 mg/L.

The lower San Marcos River has two major tributaries that contribute flow and loading to the stream, the Blanco River and Plum Creek. The lower segment does not have the endangered species that are found in the upper segment. The median instantaneous **flow** of the uppermost station in Segment 1808 was 272 cubic feet per second (cfs) which is made up of the combined flow of the San Marcos River and the Blanco River. As evidence of the severe drought that has plagued the area for 4 of the last 5 years, Figure 3 shows the decline in average instantaneous flow at

the TCEQ station. The same trend persists downstream at the station at the end of the San Marcos River (Hwy 90A) as seen in Figure 4.

There are very little contributions of flow downstream of the Blanco River to Luling so the concentrations of dissolved constituents remain relatively unchanged. The median concentrations for **conductivity**, **chloride** and **sulfate** are 596 umhos/cm, 20 mg/L and 26 mg/L respectively at the TCEQ station just downstream of the Blanco River. The GBRA Luling station had median concentrations of conductivity, chloride and sulfate of 551 umhos/cm, 25.2 mg/L and 30.8 mg/L respectively.

Plum Creek enters the lower San Marcos River just downstream of the City of Luling. The median instantaneous flow at the GBRA station at SH 90A was 608 cfs. Plum Creek's impacts on the water quality of the San Marcos River can be seen in the rise in dissolved constituents. The GBRA station at SH 90A had median concentrations of 611 umhos/cm conductivity, 39.6 mg/L chloride, and 35.5 mg/L sulfate. At the GBRA SH 90A station downstream of the confluence with Plum Creek, the stream standard for chlorides of 50 mg/L was exceeded 15% of the time, ranging from 11.6 to 115 mg/L which is lower by 5% as compared to the trend analyses done in 2008. The stream exceeded the standard for sulfate which is also 50 mg/L twice in the period of record. Plum Creek contributes nutrients and bacteria to the San Marcos River as well. A more detailed discussion of the water quality of the Plum Creek can be found in the section on that creek.

The 2012 Texas Water Quality Inventory has no impairments or concerns listed for Segment 1808. The median concentration for **dissolved oxygen** is 9.2 mg/L, ranging from a minimum of 7.4 mg/L to a maximum of 12.1 mg/L at the TCEQ station below the confluence with the Blanco River. At the GBRA Luling station, the median concentration for dissolved oxygen was slightly lower at 8.5 mg/L, ranging from a minimum of 5.2 mg/L to a maximum of 14.5 mg/L. Statistical analyses of the dissolved oxygen collected over the last 10 years (2003 – 2012) shows a slight downward trend in dissolved oxygen at the Luling station (Figure 5).

The median concentration for dissolved oxygen was 8.5 mg/L, ranging from a minimum of 5.6 mg/L to a maximum of 11.3 mg/L at the GBRA 90A station. At no time in the data sets of all three monitoring locations did the dissolved oxygen drop below the minimum dissolved oxygen standard (3.0 mg/L). The median **pH** values at the three stations were 7.9, 7.9 and 8.0, upstream to downstream, and ranged from a low of 7.3 to a high of 8.6.

The moderating effect of the San Marcos Springs on water temperature in the upper segment is lost as the stream flows downstream through the watershed. The median **temperature** of the TCEQ station on the San Marcos River, downstream of the Blanco River was 22.8°C,

Figure 3.

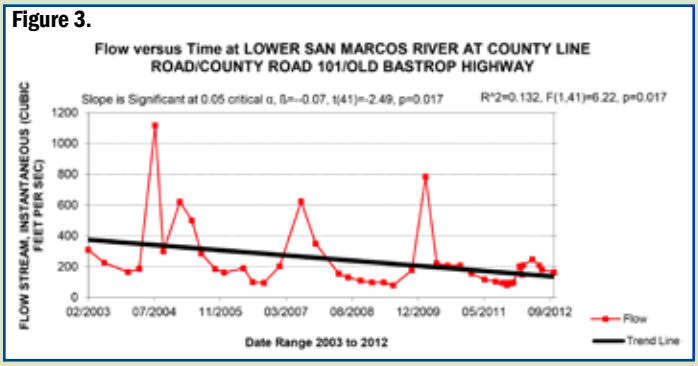


Figure 4.

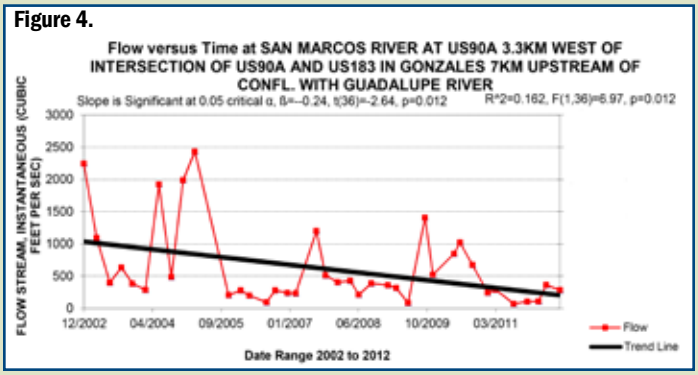
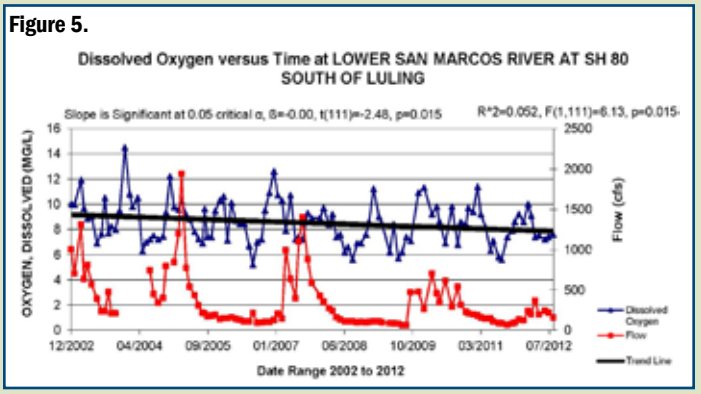


Figure 5.

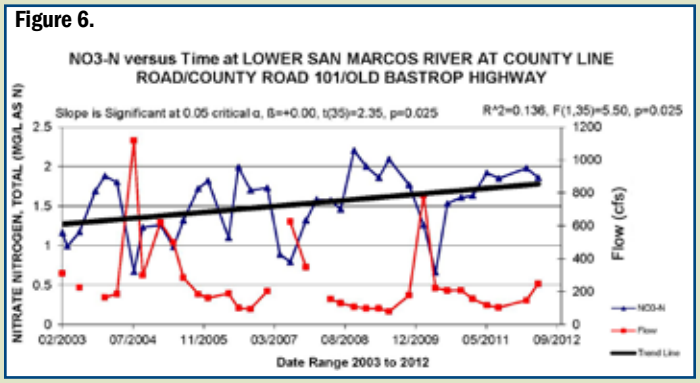


ranging from 13.3°C to 26.4°C. The median temperature at the GBRA Luling station was 24°C, ranging from 10.3°C to 31.2°C, and the median temperature at the GBRA 90A station was 23.3°C, ranging from 11.7°C to 30.7°C.

Nitrate nitrogen, ammonia nitrogen and total phosphorus, were analyzed at the GBRA and TCEQ locations. At the TCEQ station in the upper part of the segment, the median concentrations for **nitrate nitrogen** was 1.61 mg/L, ranging from 0.66 mg/L to 2.2 mg/L, falling outside of the screening concentration of 1.95 mg/L three times. Moving downstream to the GBRA Luling station, the median concentration was 1.03 mg/L, ranging from 0.08 mg/L to 1.84 mg/L. In the lower portion of the segment, median concentrations for nitrate nitrogen was 0.9 mg/L, ranging from 0.38 mg/L to 1.58 mg/L. There is an upward trend in nitrate concentration over the last 10 years at the TCEQ station at Old Bastrop Road as seen in Figure 6. The flow from the Blanco River has dropped due to the severe drought. This flow had slightly diluted the nitrates contributed from the San Marcos Springs.

The median **ammonia nitrogen** concentration, at both GBRA stations, was 0.1 mg/L, ranging from the LOQ to 0.28 mg/L; never exceeding the screening concentration of 0.33 mg/L. The LOQ used for analyses was raised from 0.02 mg/L to 0.1 mg/L in 2010 which accounts for any upward trend in ammonia concentrations. Median **total phosphorus** concentrations were 0.06 mg/L, 0.05 mg/L and 0.08 mg/L, from upstream to downstream respectively, and ranged from below the LOQ for the method to 0.83 mg/L. Concentration of total phosphorus exceeded the screening concentration of 0.69 mg/L one time at the SH 90A station which can be attributed to the flood flows at that time.

Figure 6.



Segment 1808 is known for its contact recreational opportunities. Flows in the river create excellent conditions for snorkeling, tubing and canoeing. The San Marcos River is home to the Texas Water Safari, one of the world's largest canoe races, attracting over 200 canoeing teams each June. Additionally, it was in this segment that the Texas Parks and Wildlife Department opened their first Paddling Trail. The Luling Paddling Trail begins at the river crossing at SH 90 west of Luling and ends at the Zedler Mill in the city. The stream standard for contact recreation is a geometric mean of 126 colonies/100 mL. Over the last ten years, the geometric mean for ***E. coli*** is 107 MPN/100 mL at the TCEQ station at Old Bastrop Road, 72 MPN/100 mL at the station at Luling and 73 MPN/100 mL at SH 90A.

A review of the data for **suspended solids** at each location shows no significant trend over time. Looking at the segment as a whole, the median concentration of

Photo by Janet Thome

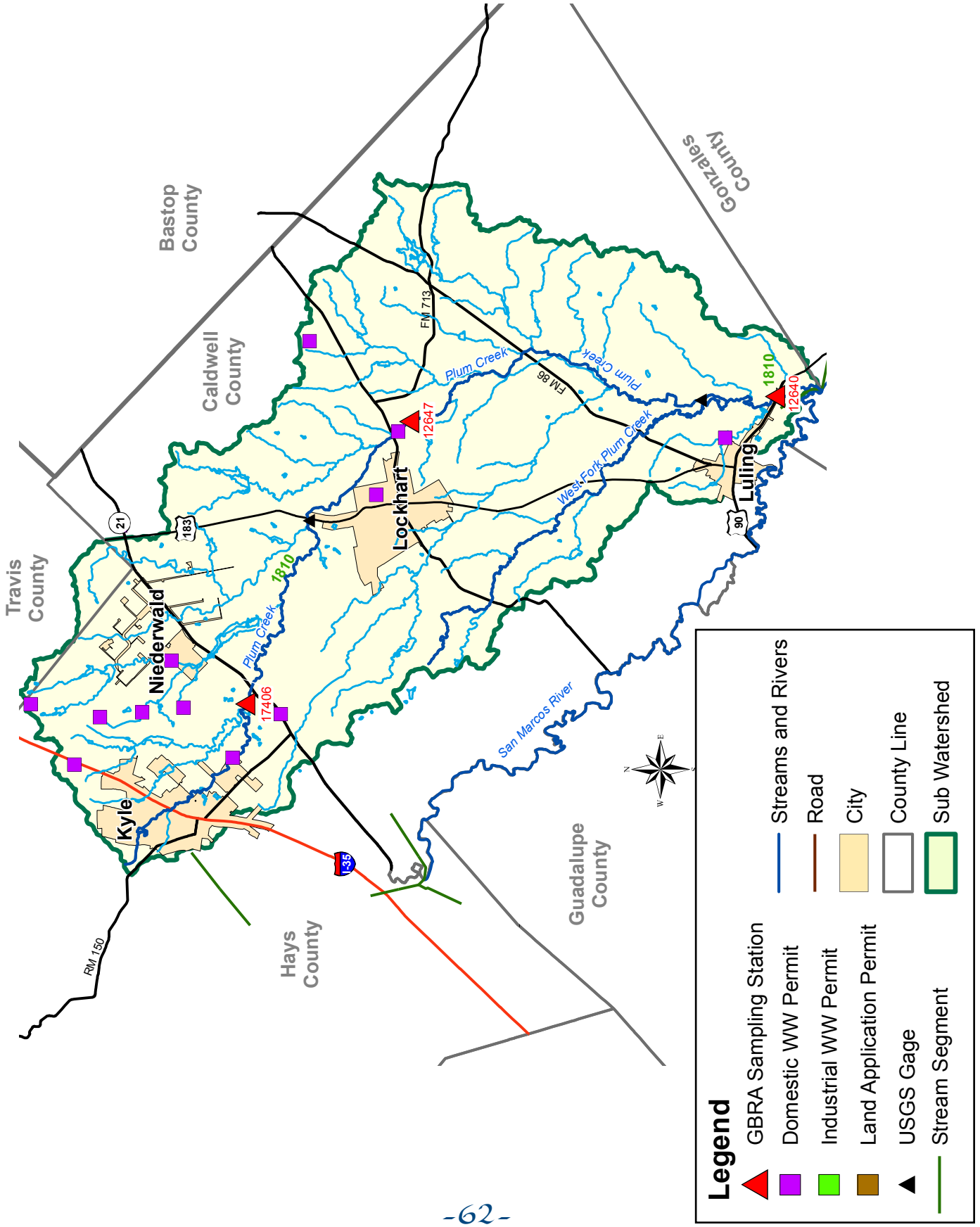
suspended solids increases as you move downstream, beginning at 7 mg/L at the uppermost station, going to 16 mg/L at the GBRA Luling station and then to 28.7 mg/L at the downstream station at SH 90A. The land use in the watershed that drains to the segment consists of mostly large farms and ranch land. These family farms are being sold and subdivided, so the region will likely begin to see more roof tops in the watershed than cattle, and those cattle in much more concentrated areas. With urban sprawl comes more impervious cover, more runoff and more pollutant loading.

The median **chlorophyll *a*** concentration is less than the LOQ and there was never a measured value above the screening concentration of 14.1 microgram per liter.

Photo by Earl Nottingham, TPWD

San Marcos River Issues and Concerns			
Water Quality Issue	**Affected Area**	**Possible Influences/Concerns**	**Possible Actions Taken/to be Taken**
Reduction in Spring Flow	Upper San Marcos River	Impacts to habitat for endangered species	Minimization and mitigation measures recommended in the Habitat Conservation Plan developed as a result of the Edwards Aquifer Recovery Implementation Program
Exceedence of Total Dissolved Solids Water Quality Standard	Upper San Marcos River		Watershed protection plan underway; GBRA collecting TDS data to confirm impairment

Plum Creek Watershed



Plum Creek Watershed

River Segments, Descriptions and Concerns

Segment 1810 (Plum Creek): Plum Creek begins in northeastern Hays County at about FM 2770 and continues 52 miles to the confluence with the San Marcos River south of Luling in Caldwell County. Plum Creek is typically a shallow, slow moving stream flowing through gently rolling hills lined with agricultural fields and scrub oak trees.

Drainage Area: 397 square miles

Streams and Rivers: San Marcos River, Plum Creek, Clear Fork Creek

Aquifers: Edwards-Balcones Fault Zone, Carrizo Wilcox

River Segments: 1810

Cities: Kyle, Buda, Uhland, Luling, Neiderwald, Lockhart

Counties: Hays, Travis, Caldwell

EcoRegions: Texas Blackland Prairies, Post Oak Savannah

Vegetation Cover: Deciduous Forest 23.6%, Pasture/Hay 22.9%, Shrublands 11.4%, Grass/Herbaceous 22.4%, Row Crops 14.4%

Climate: Average annual rainfall 33 inches, Average annual temperature January 40°, July 95°

Land Uses: Industry, urban, oil and gas production, cattle, hog and poultry productions, agriculture, crops (sorghum, hay, cotton, wheat and corn)

Water Body Uses: Aquatic life, contact recreation, general use and fish consumption

Soils: Black, waxy soil to sandy soil, limestone to black waxy chocolate and grey loam

Permitted Wastewater Treatment Facilities: Domestic 12, Land Application 0, Industrial 0

Photo by Lee Gudgell

Plum Creek Watershed

River Segments, Descriptions and Concerns

Plum Creek Watershed

Plum Creek, Segment 1810, has its headwaters in Hays County near the City of Kyle. The creek travels through Hays and Caldwell Counties and confluences with the San Marcos River near the City of Luling. The stream has been assessed by TCEQ and is listed on the 2012 Texas Water Quality Inventory as impaired for bacteria, with concerns for nutrients, including nitrate nitrogen, ammonia nitrogen, orthophosphate and total phosphorus. Additionally, it is listed with a concern for dissolved oxygen at the minimum grab concentration of 3.0 milligram per liter (mg/L) and impaired habitats. This segment was listed as impaired in 2004 for exceedences of *E. coli* bacteria. The creek still appears on the list of impaired water bodies but as a category 4b waterbody. This designation means that there are activities being implemented in the watershed that "are reasonably expected" to result in the attainment of the water quality standards.

Plum Creek was selected by the Texas State Soil and Water Conservation Board (TSSWCB) for a voluntary effort to improve water quality. The Plum Creek Watershed Partnership, made up of local stakeholders, was formed to guide the process and address the bacteria and nutrient concerns. The Partnership developed the **Plum Creek Watershed Protection Plan** (PCWPP) to serve as guidance for restoring and protecting local water quality. The Partnership spent a significant amount of time identifying potential sources of the bacteria and nutrient loads. Those sources included pet waste from urban areas, failing septic systems, wastewater treatment plants, livestock, feral hogs, and other agricultural activities. In 2008 the PCWPP was accepted by the US EPA. The efforts of the Partnership moved to voluntary implementation of the best management practices recommended in the plan.

Led by a steering committee, the Partnership worked with citizens, businesses, public officials and state and federal agencies in the watershed to develop a plan that recommended implementation practices that could restore the health of Plum Creek. The PC WPP recognized that success in improving and protecting water resources depends on the people who live and work in the watershed. After first determining the potential sources and locations of the pollutant loads, the Partnership determined to what degree bacteria and nutrient concentrations should be reduced to meet the water quality standards.

To better determine the sources of pollutant loads and related implementation recommendations, the Partnership divided Plum Creek into three regions. The Uhland region is the upper portion of the watershed and contains the City of Kyle and parts of the City of Buda. This region has dense urban development and the stream is effluent-dominated. The middle watershed is referred to as the Lockhart region and is a mix of land uses including urban development in the City of Lockhart and along the SH 130 corridor, and agricultural operations including both cropland and livestock. The lower portion of the watershed is referred to as the Luling area. This portion of the creek receives flow from two tributaries, Clear Fork and West Fork. The creek confluences with the San Marcos River near the City of Luling. These creeks flow primarily through rural areas that support livestock, farming and pastureland. Bacteria reductions needed to restore water quality to stream standards range from a 15% reduction in the Lockhart area to a 65% reduction in the Uhland portion. Nitrate nitrogen would need to be reduced by 43% in the Uhland portion to 80% in the Lockhart portion. Phosphorus loading would need to be reduced by 27% in the Uhland reach to 49% in the Lockhart portion.

In addition to identification of potential sources and load reductions, the WPP recommends management measures that, if implemented, would go a long way in reducing those pollutant loads. Topical work groups looked at key land uses, activities and related pollutant sources. Those areas include agricultural sources, urban sources and wastewater, including septic systems. Management measures that could reduce bacteria and nutrient loading from urban sources include management of pet waste by collection stations and pet waste ordinances, as well as urban storm water assessments and conveyance modifications. Management measures that could reduce the loading from agricultural-related activities include planning and financial assistance to farmers and ranchers for development of

management plans that reduce bacteria and nutrient losses, including grassed waterways, nutrient management and conservation easements. The plan also suggested outreach and education activities and feral hog controls.

The efforts of the Partnership are focused now on voluntary implementation of the best management practices recommended in the plan. Since 2008 significant changes have taken place in the Plum Creek watershed. The region has endured the most severe drought since the 1950's, resulting in all but those areas immediately below the springs or effluent discharges running dry. In addition, large areas of the watershed have been transformed by the construction of State Highway 130. New commercial and residential development has exploded along the highway as well as along the IH 35 corridor between Austin and San Antonio.

Acknowledging and understanding the changing land use and activities in the watershed are key to adaptive management. Combined with continued intensive water quality monitoring of the watershed, necessary adjustments can be made in response to these changes that will enable continued progress toward the water quality goals established in the plan (TSSWCB, 2012). The TSSWCB has funded water quality monitoring to support the data being collected by the Clean Rivers Program in order to assess implementation practices that have been or will be implemented as a result of the Plum Creek Watershed Protection Plan.

The stream is broken into three assessment units: from the confluence with the San Marcos River to 2.5 miles upstream of the confluence with Clear Fork Plum Creek; from that point to 0.5 mile upstream of the crossing with SH 21; and, from that point to the upper end of the segment.

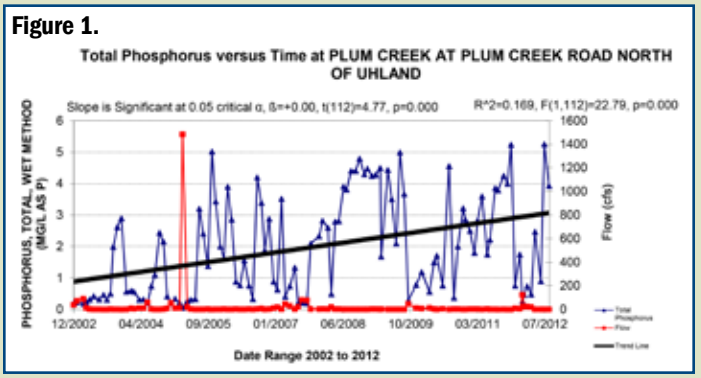
The Upper Plum Creek Watershed

The stream begins in an area of rapid development along the IH 35 corridor, between the cities of Kyle and Buda. The stream is made up of flow from several tributaries such as Andrews Branch, Porters Creek and Bunton's Branch. These streams receive wastewater discharges from the City of Kyle's wastewater plant (WWTP), the City of Buda's wastewater plant and several smaller plants that serve new subdivisions just beginning to develop. In the upper portion of the watershed, there are eight wastewater plants that are constructed and currently discharge to tributaries of Plum Creek. The largest facility of which is the City of Kyle's WWTP at 4.5 million gallons per day (MGD). Most of these facilities are permitted with future phases that when all the plants reach their final capacity will be permitted for over 10 MGD. The permit limits for the majority of the facilities in the upper portion of the watershed are 5 mg/L biochemical oxygen demand; 10 mg/L total suspended solids and 2 mg/L ammonia-nitrogen. The effluents of the WWTP serving of Buda, Sunfield and Shadow Creek have limits for total phosphorus of 0.8 mg/L, 1.0 mg/L and 1.0 mg/L respectively. These facilities all utilize chlorine for disinfection.

In addition to urban areas, this portion of the watershed includes agricultural land and areas that have been known to have old, failing or inappropriately built septic tanks, according to the Hays County Environmental Health Office. In addition to these sources of nonpoint source loading of bacteria, pet waste is considered a source of *E. coli* as well.

GBRA maintains a routine monitoring location in the upper assessment unit located at the crossing of the creek at Plum Creek Road near the community of Uhland. Uhland is not served by a municipal wastewater system at this time. A review of the historical data from the Plum Creek at Plum Creek Road station (station no. 17406) shows trends of diminishing water quality. The most prominent water quality concerns are for nutrient and bacteria concentrations. The increased nutrient levels in the creek are due in large part because the stream is effluent-dominated. Additional wastewater effluent and nutrient loading has been added to the creek in recent years as the Kyle and Buda WWTPs have increased in capacity. Figure 1 shows the increasing trend in total phosphorus concentrations over time.

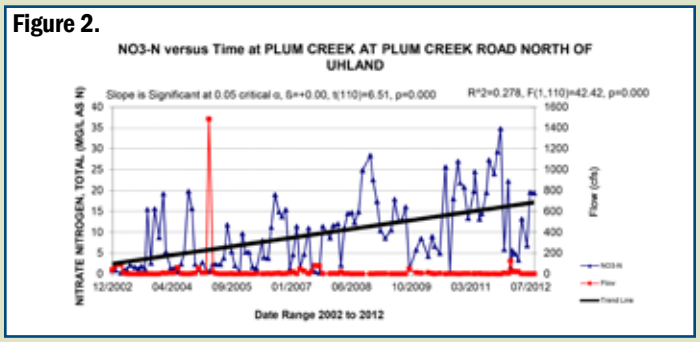
Figure 1.



The median concentration of **total phosphorus** was 1.73 mg/L, ranging from 0.05 mg/L to 5.26 mg/L. For 67.5% of the monitoring events from 2003 to 2012 the data for total phosphorus was above the screening concentration of 0.69 mg/L.

Nitrate nitrogen also shows an increasing trend over time (Figure 2). The median concentration for nitrate nitrogen was 8.24 mg/L, ranging from 0.22 mg/L to 34.8 mg/L, exceeding the screening concentration of 1.95 mg/L 75.9% of the time. Spikes in nitrate concentrations appear to be linked to low flow periods when the stream is effluent-dominated. Total phosphorus and nitrate nitrogen are of concern because of the potential for promoting nuisance algal blooms that can deplete oxygen in the stream, especially in the early morning hours, degrading the habitat for fish and aquatic invertebrates.

Figure 2.



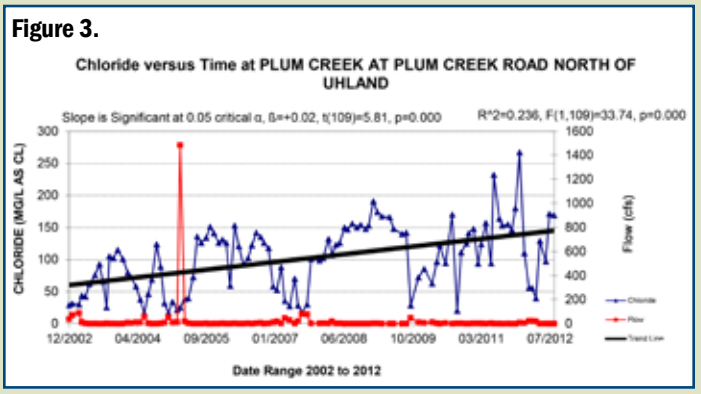
Ammonia nitrogen exceeded the screening concentration 14.8% of the time but of more concern was the magnitude of the exceedences. Three of the 12 sampling events that exceeded the 0.33 mg/L screening concentration for ammonia nitrogen were greater than 10 mg/L. Ammonia nitrogen is a concern because of its toxicity to fish. Because of the effluent dominance of the stream, the most logical source of these nutrients is wastewater discharge but other sources of nutrients should be considered such as runoff carrying fertilizers from agricultural fields and lawns and organic wastes from animals such as livestock, pets and wildlife.

This portion of the stream is impaired by fecal bacteria, including ***E. coli***. The geometric mean of the *E. coli* concentrations was 282 MPN/100 mL, which exceeds the stream standard for contact recreation of 126 colonies/100 mL. The concern for the exceedence of the stream standard for contact recreation has become increasingly elevated as the areas surrounding this portion of Plum Creek have become increasingly urbanized, with more chance for interaction between the creek and people living in the watershed.

The **temperature** ranged from 6.0°C to 28.4°C at the Plum Creek Road station, with a median temperature of 21.4°C. The **pH** ranged from 7.0 to 8.2, with a median value of 7.8. The median ***dissolved oxygen*** concentration was 7.3 mg/L, ranging from 2.2 mg/L to 14.1 mg/L. The stream standard for dissolved oxygen for this segment is 5.0 mg/L and the minimum dissolved oxygen standard is 3.0 mg/L. The stream was at or below 5.0 mg/L eight times out of 118 sampling events and below 3.0 mg/L four times.

Total suspended solids (TSS) have ranged between 0.8 mg/L and 177 mg/L with a median value of 21.1 mg/L between 2003 and 2012. TSS can consist of suspended materials including algal cells, organic material and sediment brought in by rainfall runoff from fields and construction stations. The median ***conductivity*** during this period was 1065 micromhos per (umhos/cm) ranging from 330 umhos/cm to 1600 umhos/cm. Conductivity levels along with dissolved salts are significantly increasing over time (Figure 3). The increase in dissolved solids during low flows can be attributed to contributions from groundwater sources that have elevated dissolved solids or from wastewater effluent.

Figure 3.



The Middle Plum Creek Watershed

The water quality of the middle portion of Segment 1810, is represented by the data collected by the GBRA at the monthly monitoring site at CR 202 (station no. 12657), southeast of the City of Lockhart. The middle portion of the creek flows through agricultural cropland, pastureland and the urbanized areas in and around the City of Lockhart. There is some ground water recharge by the stream near

Hwy 183 north of Lockhart. Additionally, it is near this area that oil and gas production begins to become a dominant land use.

The City of Lockhart, as well as Caldwell County, are primed for growth over the next few years as construction of the SH 130 tollway and its spur, SH 45, bring traffic into the area. The Texas Department of Transportation has constructed a mitigation wetland near the creek and Hwy 183. The area includes walking and bike trails, kiosks and birding trails. The area is strictly to mitigate lost wetlands during construction of SH 130. Water quality was not considered in the design though it will capture flood

Photo by Debbie Magin

waters that would normally inundate Plum Creek, and slow water down as it travels through weirs. There is no way to pump water from Plum Creek to supplement the wetlands in times of drought. The site took a big hit during the droughts of 2009 and 2011.

The creek receives wastewater effluent discharged from the City of Lockhart's two WWTPs, whose combined permitted volume is 2.6 MGD. Neither plant have effluent limits for phosphorus but do have an effluent limit for ammonia nitrogen of 3.0 mg/L. The effluents must meet a carbonaceous biochemical oxygen demand of 10 mg/L and total suspended solids of 15 mg/L. The Lockhart Larremore facility, located in the city, uses chlorine to disinfect the effluent. The Lockhart FM 20 facility, located outside the city and upstream of the GBRA monitoring location at CR 202, uses ultraviolet light to disinfect the effluent and must analyze the effluent for fecal coliform bacteria daily.

The median **flow** at the GBRA station at CR 202 (3.9 cubic feet per second or cfs) is approximately two times the flow at the upstream Plum Creek at Plum Creek Road station (2.2 cfs) that is monitored by GBRA. Even though there is loss of flow to recharge upstream of Lockhart, the additional flow from groundwater springs and the two wastewater treatment plants that are located in and near the city are sufficient and consistent enough to double the flow at this monitoring station. These springs, according to local citizens, are not known to go dry, even in driest periods. The springs are thought to originate from the Leona formation that is known for elevated nitrate nitrogen.

The median **conductivity** at the Plum Creek at CR 202 station is 921 umhos/cm, ranging from 223 umhos/cm to 1140 umhos/cm, which are slightly lower levels than are seen upstream. The median **dissolved oxygen** concentration was 7.7 mg/L, ranging from 4.4 mg/L to 13.6 mg/L. The median **temperature** at the TCEQ station was 22.9°C, ranging from 8.1°C to 28.8°C. The median **pH** was 7.9, ranging from 7.4 to 8.4, not falling outside the range of the pH stream standard. The highest recorded temperature and lowest recorded flow at this station occurred in July of 2009 during a period of drought conditions and extremely low flows.

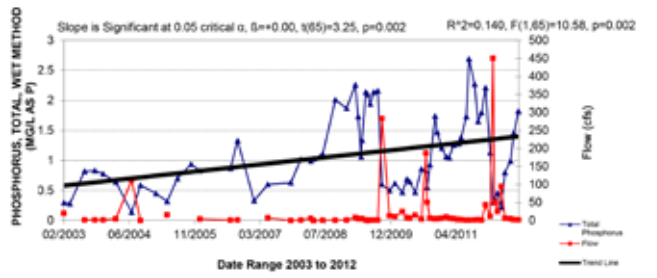
The median concentration for **total suspended solids** was 13.8 mg/L, ranging from 1 mg/L to 414 mg/L. Comparing the TSS to flow data at this station suggests that the TSS increases with high flows which are often associated with storm events. The inorganic constituents, **chloride** and **sulfate**, had median concentrations of 89.4 mg/L and 78.6 mg/L respectively, never exceeding the stream standard for these constituents of 350 mg/L and 150 mg/L.

Nitrate nitrogen, ammonia nitrogen, and total phosphorus were measured at the TCEQ station at CR202. The **nitrate nitrogen** median concentration was 5.8 mg/L, ranging from 0.65 mg/L to 51.6 mg/L and exceeding the stream stream screening criteria of 1.95 mg/L 63 out of 67 measurements (94.0%). The maximum value (51.6 mg/L) was collected by the TCEQ regional office in October of 2008 during a period of extremely low stream flow. Sources of the nitrates at this location are most likely the springs that originate from the Leona formation as well as wastewater effluent. **Ammonia** nitrogen ranged

from the Limit of Quantification (LOQ) to 0.1 mg/L, with a median concentration that was less than the LOQ. The concentrations that were measured exceeded the stream screening criteria of 0.33 mg/L a total of two times.

Figure 4 shows that **total phosphorus** concentrations are increasing over time at this monitoring station. Sources of total phosphorus include wastewater effluent, storm water that carries in fertilizers and organic material and failing septic tanks.

Figure 4.



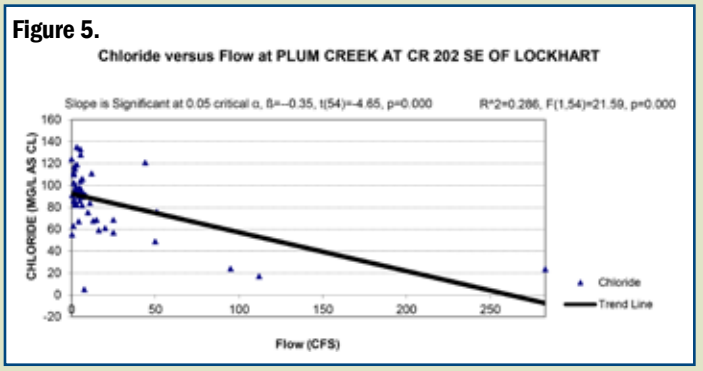
Confirming the bacterial impairment identified in the 2008 Texas Water Quality Inventory, the geometric mean for ***E.coli*** at the CR202 station was 227 MPN/100mL, exceeding the contact recreation standard for *E. coli* of 126 colonies/100mL. No sampling events measured **chlorophyll *a*** greater than the LOQ used by the laboratory.

The Lower Plum Creek Watershed

Land use in the lower Plum Creek watershed is primarily agricultural crop and pastureland and forests with a heavy concentration of oil and gas production activities. The only urbanized area is the City of Luling where the creek confluences with the San Marcos River. GBRA has had a monthly monitoring station in this portion of the watershed located at CR 135 since 1998. TCEQ has monitored this station and their data was included in the historical review. The 2012 Texas Water Quality Inventory listed the lowest assessment unit of the Plum Creek as impaired for bacteria, with a concern for nitrate nitrogen.

The base flow in the lower portion of the watershed is impacted by saline groundwater. As the stream flow is increased with storm water and runoff, the concentration of dissolved salts goes down. For example, Figure 5 shows the inverse relationship of chloride and flow, with a decreasing

Figure 5.



trend over time. Another source of dissolved solids occurs when there are spills or leaks associated with oil field activities.

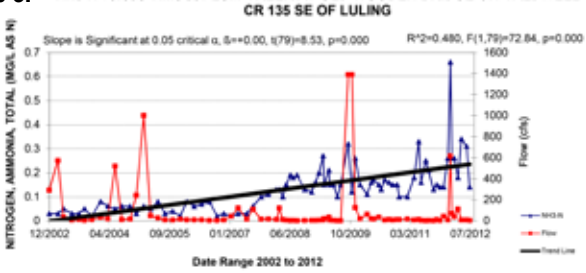
Median flow (11 cfs) in the lower portion of the creek is nearly three times the flow at the TCEQ station in the middle Plum Creek (3.9 cfs), due to the contribution of flow from the West Fork and Clear Fork tributaries that confluence with the Plum Creek in the lower portion of the watershed.

The median **temperature** at the GBRA CR135 station is 22.0°C, ranging from 6.2°C to 29.3°C. The **conductivity** ranged from 239 umhos/cm to 2660 umhos/cm, with a median conductivity of 1244 umhos/cm, 10% higher than the lower two monitoring stations. The **pH** ranged from 7.0 to 8.3, with a median pH of 7.9. The ***dissolved oxygen*** ranged from 3.4 mg/L to 14.6 mg/L, with a median concentration of 7.4 mg/L. The dissolved oxygen fell below the stream standard of 5.0 mg/L 14 times out of 117 measurements from 2003 to 2012. The stream had sustained oxygen levels below 5.0 mg/L during much of the dry summers of 2008 and 2009.

Total suspended solids ranged from 2 mg/L to 527 mg/L, with a median concentration of 21.3 mg/L. The highest concentrations of solids are associated with high flows, following storm events as the runoff carries in sediments. **Chloride** and **sulfate** concentrations were higher at this station than the other two monitoring stations. The median chloride concentration was 155 mg/L, ranging from 124 mg/L to 495 mg/L, exceeding the stream standard of 350 mg/L for chloride 3 times. Sulfate ranged from 14.9 mg/L to 163 mg/L, with a median concentration of 83.5 mg/L, exceeding the stream standard for sulfate of 150 mg/L one time.

Nitrate nitrogen, ammonia nitrogen and total phosphorus were analyzed at the GBRA station in the lower Plum Creek. The median concentration for **nitrate nitrogen** was 1.40 mg/L, ranging from 0.05 mg/L to 7.52 mg/L, and exceeding the screening concentration of 1.95 mg/L 37 times out of 112 measurements, or 33% of the time. The **ammonia nitrogen** concentration ranged from the LOQ to 0.66 mg/L, with a median concentration of 0.13 mg/L, only exceeding the screening concentration of 0.33 mg/L one time. Looking at the concentration of ammonia nitrogen over time, we see a significant drop in concentration in 2001. Ammonia nitrogen appears to be significantly increasing with time (Figure 6). This is possibly due to reduction in flow due to drought conditions, which are causing the stream to be more heavily influenced by wastewater and groundwater.

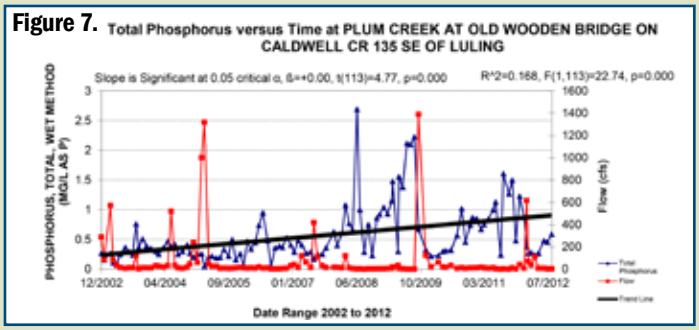
Figure 6. NH3-N versus Time at PLUM CREEK AT OLD WOODEN BRIDGE ON CALDWELL CR 135 SE OF LULING



Total phosphorus concentrations showed a significant increasing trend over time (Figure 7). The median concentration of total phosphorus was 0.39 mg/L, ranging from 0.05 mg/L to 2.69 mg/L. Ten of the 133 measurements were higher than the screening concentration of 0.69 mg/L, or 7.5% of the time. A possible explanation for the trend could be the increased frequency of analysis in the later years of the historical record.

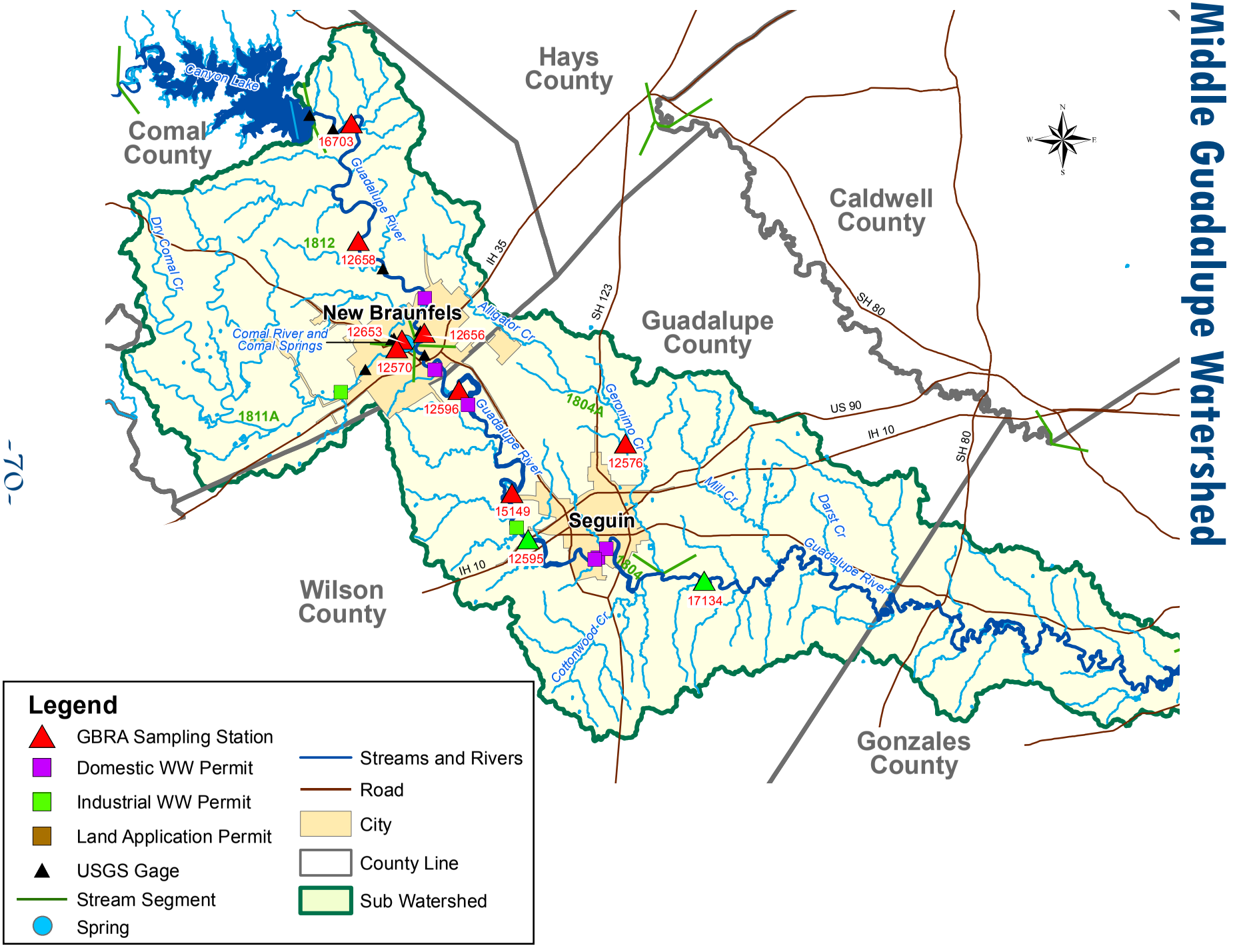
From 2003 to 2010 the geometric mean for ***E. coli*** at the Plum Creek at CR 135 was 180 MPN/100mL. As expected there is a rise in *E. coli* concentrations as storm flows bring in more sediment and associated bacteria.

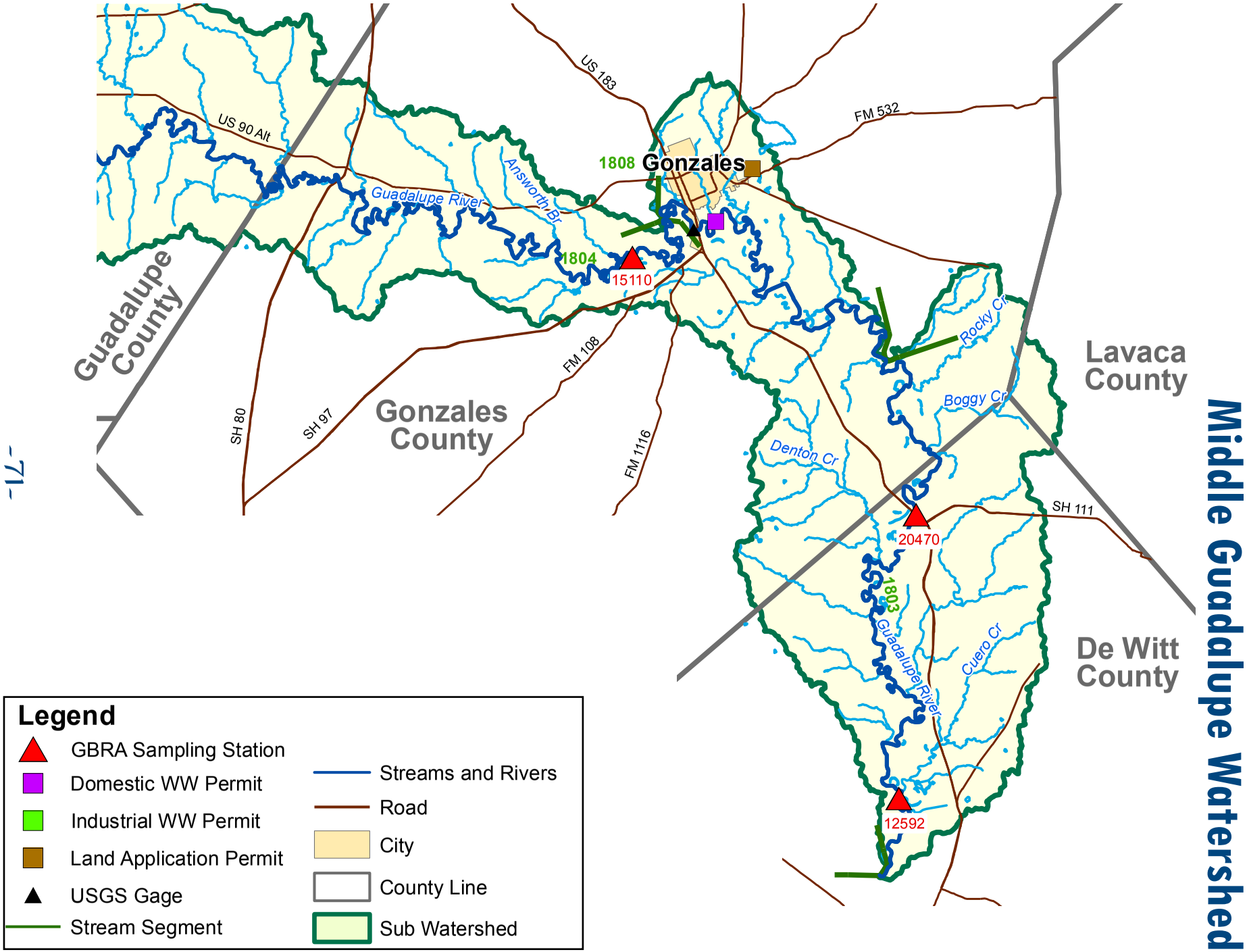
Figure 7. Total Phosphorus versus Time at PLUM CREEK AT OLD WOODEN BRIDGE ON CALDWELL CR 135 SE OF LULING



The stakeholders that have attended the annual meetings for the Clean Rivers Program Steering Committee as well as those that have commented at other Plum Creek watershed meetings are concerned about several issues. The issues include the impacts from wastewater effluents, the potential for contamination and spills from unattended oil and gas production facilities, excessive illegal trash dumping in the creek and poorly functioning or failing septic tanks. Two major wastewater plant upsets occurred at the City of Kyle's WWTP near the headwaters of the stream during this assessment period. TCEQ has been working with the city to ensure that such events do not happen again. The Plum Creek Watershed Partnership completed the development of a watershed protection plan that was adopted by the US EPA as a means to repair the water quality impairments in the Plum Creek watershed. As part of the plan, the members recommended that a compact be entered into by governmental entities and interested parties in the watershed, promoting regionalization of wastewater facilities rather than package plants, the utilization of wastewater for reuse and the increased level of wastewater treatment that includes reduction of nutrient concentrations.

Plum Creek Issues and Concerns			
Water Quality Issue	**Affected Area**	**Possible Influences/Concerns**	**Possible Actions Taken/to be Taken**
Bacteria	Plum Creek	Urban storm water; pet waste; failing septic systems; poorly treated wastewater; livestock and agricultural runoff; feral hogs; wildlife	Implementation of the watershed protection plan adopted in 2008
Nutrients	Plum Creek	Wastewater effluent; urban runoff; pet waste; failing septic systems; livestock and agricultural runoff; Feral hogs; wildlife	
Impaired Habitat	Plum Creek	Illegal dumping	


Middle Guadalupe Watershed
Canyon Lake
Comal County
Hays County
Caldwell County
Guadalupe County
Wilson County
Gonzales County
16703
Guadalupe River
Dry Comal Cr
1812
12658
IH 35
New Braunfels
Comal River and Comal Springs
12653
12656
12570
Alligator Cr
SH 123
SH 80
1811A
12596
1804A
Geronimo Cr
12576
US 90
IH 10
Mill Cr
Darst Cr
15149
Seguin
12595
1804
17134
Cottonwood Cr
Legend
GBRA Sampling Station
Domestic WW Permit
Industrial WW Permit
Land Application Permit
USGS Gage
Stream Segment
Spring
Streams and Rivers
Road
City
County Line
Sub Watershed


Middle Guadalupe Watershed
Guadalupe County
Gonzales County
Lavaca County
De Witt County
US 90 Alt
US 183
FM 532
SH 80
SH 97
FM 108
FM 1116
SH 111
Guadalupe River
Answorth Br
Rocky Cr
Boggy Cr
Denton Cr
Cuero Cr
1808 Gonzales
1804
15110
20470
1803
12592
Legend
GBRA Sampling Station
Domestic WW Permit
Industrial WW Permit
Land Application Permit
USGS Gage
Stream Segment
Streams and Rivers
Road
City
County Line
Sub Watershed

Middle Guadalupe River Watershed

River Segments, Descriptions and Concerns

Segment 1812 (Guadalupe River below Canyon Reservoir): The Guadalupe River flows from Canyon Dam to the confluence with the Comal River, is considered one of the finest white-water stretches in the state. Rapids are attributed to the change in elevation as the river cuts through the Balcones Fault Zone. The river is scenic, with limestone bluffs, bald cypress, pecan and elm trees. Trout Unlimited and Texas Parks and Wildlife Department take advantage of cold-water releases from the bottom of Canyon Dam to sponsor the stocking of rainbow trout in the tailrace.

Segment 1811 (Comal River): The 2½-mile-long Comal River, spring-fed from the Edwards Aquifer through Comal Springs, has no water quality concerns, but has developed large stands of aquatic macrophytes. The clean, clear, fast moving water is a constant temperature all year, and supports a number of endangered species as well as intensive recreational uses. Dry Comal Creek is also included in this segment.

Photo by LaMarriol Smith

Drainage Area: 939 square miles

Lakes, Streams and Rivers: Lake Dunlap, Lake McQueeney, Lake Placid, Guadalupe River below Canyon Dam, Dry Comal Creek, Blieders Creek, Comal River, Geronimo Creek

Aquifers: Edwards Trinity, Edwards Balcones Fault Zone, Carrizo Wilcox

River Segments: 1811, 1811A, 1812

Cities: Sattler, New Braunfels, Schertz Seguin, Geronimo, Kingsbury

Counties: Comal, Guadalupe, Gonzales

EcoRegions: Texas Blackland Prairies, Post Oak Savannah

Vegetation Cover: Pasture/Hay 25.5%, Grass/Herbaceous 15.1%, Evergreen Forest 18.0%, Shrublands 12.0%, Deciduous Forest 15.5%; Row Crops 8.1%

Climate: Average annual rainfall 29 inches, Average annual temperature January 35°, July 95°

Land Uses: urban, light manufacturing, heavy manufacturing, farming, cattle ranching, poultry, petroleum production, and gravel mining

Water Body Uses: aquatic life, contact recreation, fish consumption, general, public water supply, hydroelectricity, agricultural and industrial

Soils: Dark, calcareous clay, sandy loam, loam with clay subsoils, dark red sandstone, light tan and gray sandstone

Permitted Wastewater Treatment Facilities: Domestic 8, Land Application 7, Industrial 2

Middle Guadalupe River Watershed

River Segments, Descriptions and Concerns

Drainage Area: 939 square miles

Lakes, Streams and Rivers: Lake Gonzales (H-4), Lake Wood, Guadalupe River from confluence with the San Marcos River, Geronimo Creek

Aquifers: Carrizo Wilcox

River Segments: 1804, 1804A, 1803

Cities: Gonzales

Counties: Guadalupe, Gonzales, Lavaca, DeWitt

EcoRegions: Texas Blackland Prairies, Post Oak Savannah

Vegetation Cover: Pasture/Hay 25.5%, Grass/Herbaceous 15.1%, Evergreen Forest 18.0%, Shrublands 12.0%, Deciduous Forest 15.5%, Row Crops 8.1%

Climate: Average annual rainfall 29 inches, Average annual temperature January 35°, July 95°

Land Uses: urban, light manufacturing, heavy manufacturing, farming, cattle ranching, poultry, petroleum production, and gravel mining

Water Body Uses: aquatic life, contact recreation, fish consumption, general, public water supply, hydroelectricity, agricultural and industrial

Soils: Dark, calcareous clay, sandy loam, loam with clay subsoils, dark red sandstone, light tan and gray sandstone

Permitted Wastewater Treatment Facilities: Domestic 7, Land Application 1, Industrial 2

Segment 1804 (Guadalupe River below Comal River): This stretch of the Guadalupe River between the confluence with the Comal River in New Braunfels to the confluence of the San Marcos River in Gonzales is a beautiful flowing river. Seven GBRA hydroelectric facilities utilize the elevation changes, creating small lakes that are widely used for recreation in Guadalupe County. Lake elevations are managed by GBRA. From New Braunfels to below Seguin, the banks of the hydroelectric lakes are lined with private residences, primarily on septic tanks.

Segment 1804A (Geronimo Creek): Geronimo Creek and its tributary, Alligator Creek, are located in Comal and Guadalupe Counties, almost entirely within the extra-territorial jurisdictions of the cities of New Braunfels and Seguin. The almost 70-square mile watershed has its headwaters in southeastern Comal County. Alligator Creek is intermittent with pools. Geronimo Creek's flow is sustained by two major springs, the Timmermann Spring and an unnamed spring, coming from the Leona Aquifer and the alluvium. The creek flows through the Blackland Prairies Ecoregion. Land use in the watershed is transitioning from predominantly agriculture to urban development.

Segment 1803 (Guadalupe River below San Marcos River): From the point of the confluence of the San Marcos River, the Guadalupe becomes a much larger, slower moving stream as it flows toward the coast. Elevation changes are minimal. (See next section: Lower Guadalupe River Watershed for detailed description.)

Middle Guadalupe River Watershed

River Segments, Descriptions and Concerns

Guadalupe River Below Comal River

Segment 1804, the **Guadalupe River below the Comal River,** extends from the confluence of the Guadalupe and Comal Rivers, in New Braunfels, 103 miles downstream to the confluence with the San Marcos River. The segment is separated into four assessment units. Assessment unit 1804_01 consists of the lower 25 miles of the segment from the confluence with the San Marcos River to approximately eight miles downstream of the FM 1117 crossing in Gonzales County. Assessment unit 1804_02 consists of the area approximately eight miles upstream of the FM 1117 crossing to 58 miles upstream at Lake McQueeney Dam. Assessment unit 1804_03 consists of the seven mile portion of the river upstream of Lake McQueeney Dam. Assessment unit 1804_04 consists of the upper 13 miles of the segment from seven miles upstream of Lake McQueeney Dam to the confluence with the Comal River in Comal County. The entire segment spans three Texas counties: Comal County, Guadalupe County and Gonzales County. GBRA has monitored the Guadalupe River at AC's Place, on the north bank of Lake Dunlap (station no.12596), monthly since 1987. GBRA has monitored the Guadalupe River at Hot Shot's on the Southeast bank of Lake McQueeney (station no. 15149), monthly since 1987. GBRA has monitored the Guadalupe River, below the H-5 Dam, before the San Marcos River confluence (station no.15110), monthly since 1996. TCEQ has monitored the Guadalupe River at IH10 (station no. 12595) on a quarterly basis since 1998. TCEQ has also monitored the Guadalupe River at FM 1117 (station no. 17134) on a quarterly basis since 1999. The 2012 Texas Water Quality Inventory Report has no impairments or concerns listed for Segment 1804.

Photo by Janet Thome

The upper portion of Segment 1804 is heavily influenced by the Comal River. The Comal River maintains a fairly consistent annual stream flow from its springs, which often makes up a majority of the water entering the segment, especially during times of dry weather or drought. The upper portion of the segment often exhibits many of the water quality properties of the Comal River. As the water moves downstream it is impounded by a series of six dams, which are operated by the GBRA to generate hydroelectric power. The river must initially pass through the Dunlap Dam, which impounds Lake Dunlap; followed by the McQueeney Dam, which impounds Lake McQueeney; TP4 Dam, which impounds Lake Placid; Nolte Dam, which impounds Meadow Lake; H-4 Dam, which impounds Lake Gonzales; and the H-5 Dam, which impounds Lake Wood. The water impounded in these series of hydroelectric lakes does not take on many of the properties of a reservoir and maintains the attributes of a flowing stream segment, due to the shallow depths and lower retention time of the water in these structures. The river must support at 528 cubic feet per second (cfs) discharge at the Lake Dunlap power plant in order for the power plants to generate power. When a discharge of this volume cannot be supported, the water is allowed to pass directly through the turbines of the plant without the generation of power. The flow from the Guadalupe River is diverted through a water canal above the Dunlap Dam to the hydroelectric turbines. It is from this canal that a pipeline takes raw water to the City of San Marcos Water Treatment Plant. Two additional tributaries contribute to the base flow near the City of Seguin, the Walnut Branch and the Geronimo Creek. The Geronimo Creek tributary of Segment 1804 is dominated by spring flow and is discussed in a later section as Segment 1804A.

Each hydroelectric impoundment has its own unique structure and associated water quality characteristics. Historical data has shown that four out of five years these run-of-river impoundments function as rivers with short residence times. In those years with low flows in the Guadalupe River, longer water residence times in the

impoundment will create more "reservoir-like" conditions. The impoundments will weakly stratify in the deep portions. Additionally, the longer residence times allow for nutrient uptake by algae and aquatic plants, promoting blooms and nuisance aquatic infestations.

These impoundments are subject to localized flooding and extended periods of high releases from Canyon Reservoir needed to evacuate the flood pool. Runoff carries insediment and the prolonged high flows keep sediment suspended. An example of the effect of flow on suspended sediments can be seen in Figure 1 that shows the relationship between flow and turbidity over time. This figure also shows the decreasing trend in turbidity due to reduction in flow during drought conditions. The total suspended solids measured at all five of the monitoring stations on the middle Guadalupe River increase with high flows, and at times when the flows are sufficient enough to keep the solids in suspension. In addition to adding organic oxygen-demanding material, suspended solids create turbid conditions that shade out the sunlight and can have the potential bringing in and maintaining elevated bacteria concentrations. From 2003 to 2012 the flows on the middle Guadalupe have been significantly decreasing (Figure 2) due to sustained drought conditions as seen at the FM 1117 monitoring station. The reductions in flow also affect other water quality parameters such as pH which is significantly rising throughout this portion of the Guadalupe River. As more photosynthesis occurs in slower moving river systems, carbonic acid is removed from the water column, which increases pH levels (Figure 3).

Figure 1.

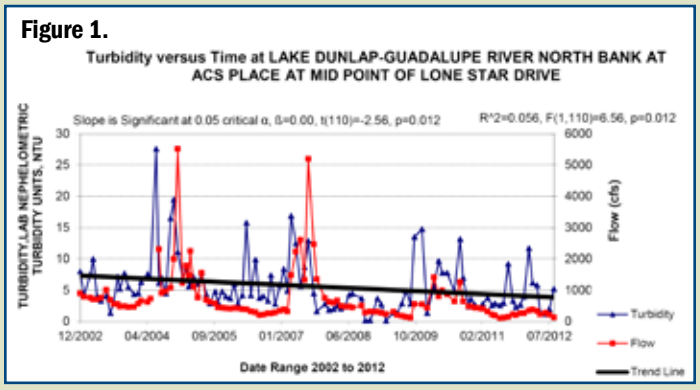


Figure 2.

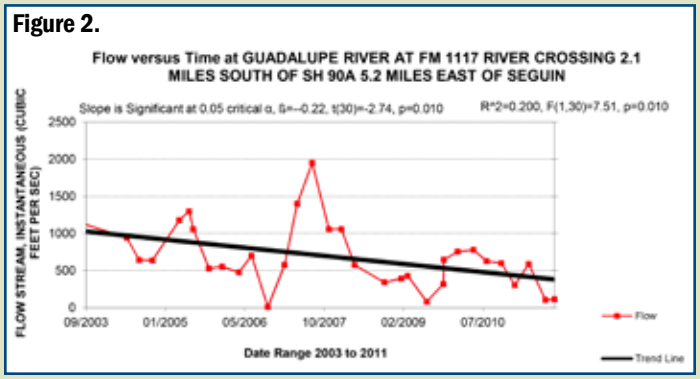
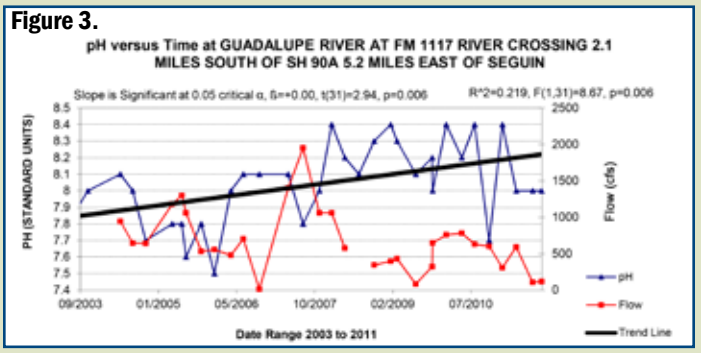


Figure 3.



Lake Dunlap, the most upstream run-of river impoundment, begins at the City of New Braunfels and it's banks are almost completely lined with residences. The impoundment is narrow and shallow. It has a plunge point midway down the reservoir. Here, in years of low flow, inflow that is cooler because of the temperature of the springs and bottom release of the upstream reservoir, will dip down and flow along the bottom of the impoundment, creating a warm strata of water along the surface. It is at this plunge point that the impoundment will begin to weakly stratify. In years of normal to high river flows, inflows are sufficient enough to keep the water mixed and prevent this stratification from occurring.

Reviewing the data over the last 10 years at the GBRA station on Lake Dunlap, the ***dissolved oxygen*** concentrations ranged from 6.3 milligrams per liter (mg/L) to 15.3 mg/L, with a median concentration of 9.8 mg/L and not falling below the dissolved oxygen requirement of 5.0 mg/L. The ***temperature*** at the surface ranged from 14.6°C to 30.6°C, with a median temperature of 22.5°C. The **pH** never fell outside of the standard range of 6.5 to 9.0 units. The ***specific conductance*** is showing a very slight rise over time, with a median concentration of 541 micromhos per centimeter (umhos/cm), ranging from 431 umhos/cm to 705 umhos/cm. Lower conductivities occur with elevated flows due to localized rainfall.

Middle Guadalupe River Watershed

River Segments, Descriptions and Concerns

The **total suspended solids** ranged from 1.0 mg/L to 28.7 mg/L, with a median concentration of 5.2 mg/L. **Chloride** and **sulfate** concentrations did not exceed the stream standard of 50 mg/L through historical period of data, ranging from 9.6 mg/L to 41.3 mg/L chloride (median = 17.9 mg/L) and 15.2 mg/L to 30.1 mg/L sulfate (median = 25.1 mg/L).

Nitrate nitrogen, ammonia nitrogen and total phosphorus was measured at the GBRA location on Lake Dunlap. The Edwards Aquifer contributed to the nitrate concentrations by way of the springs in the Comal River, along with wastewater treatment plants in the City of New Braunfels. The median concentration for **nitrate nitrogen** was 1.22 mg/L, ranging from 0.24 mg/L to 2.04 mg/L, exceeding the screening concentration of 1.95 mg/L 1 out of 113 monitoring events. The **ammonia nitrogen** concentrations ranged from the Limit of Quantification (LOQ) to 0.32 mg/L, never exceeding the screening criteria of 0.33 mg/L. The median concentration for **total phosphorus** was 0.05 mg/L, ranging from less than the LOQ to 0.4 mg/L and never exceeded the screening concentration of 0.69 mg/L.

Chlorophyll *a* concentrations exceeded the screening criteria of 14.1 micrograms per liter (ug/L) three times. These exceedences occurred when the flow in the impoundment was extremely low.

Lake McQueeney has the largest open water area of all of the hydroelectric impoundments. Its banks, like Lake Dunlap, are lined with private residences with large yards. Along this open area is the area referred to as Treasure Island, a residential subdivision with greater than 80 high-end homes. Because of the high water table on the island, the effectiveness of the septic tanks that serve the residences here is highly suspect. Failing septic tanks or septic tanks that drain to the lake rather than a drain field can be sources of bacteria and nutrients. GBRA's sampling location is directly across the open area of the impoundment from Treasure Island. The location has seen spikes in chlorophyll *a* associated with low flow conditions. Low flow conditions create longer residence times, allowing for uptake of nutrients and blooms to occur. As previously mentioned the flows in the middle Guadalupe are declining over time. Sources of the nutrients for the algae are both point and non-point sources, such as the upstream wastewater discharges, septic tanks that have direct connection with the surface water and excess fertilizers used by residences along the banks and carried in by runoff. The median concentration for **chlorophyll *a*** over the period of record was 3.5 ug/L and concentrations ranged from 1 ug/L to 31.7 ug/L.

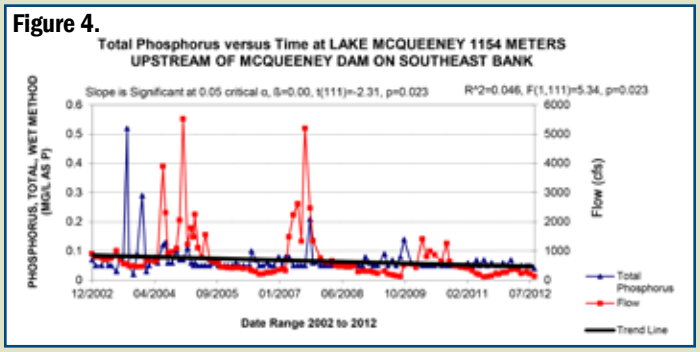
Photo by Willi Carville

Reviewing the other historical data on Lake McQueeney at the GBRA monitoring location, the **temperature** ranged from 12.2°C to 33.0°C, with a median temperature of 23.4°C. The **pH** ranged from 7.4 to 8.3 pH units, not falling outside the standard range of 6.5 to 9.0. The **conductivity** ranged from 267 umhos/cm to 598 umhos/cm, with a median conductivity of 525 umhos/cm. The median **dissolved oxygen** concentration was 9.1 mg/L, ranging from 4.9 mg/L to 12.9 mg/L, only falling below the stream standard of 5.0 mg/L one time.

Nitrate nitrogen, ammonia nitrogen and total phosphorus were measured at the GBRA location. **Nitrate nitrogen** ranged from 0.13 mg/L to 1.82 mg/L, with a median concentration of 0.87 mg/L. The **ammonia nitrogen** concentrations ranged from less than the LOQ to 0.25 mg/L, with a median concentration of 0.06 mg/L. The **total phosphorus** concentrations ranged from less than the LOQ to 0.52 mg/L, never exceeding the screening concentration of 0.69 mg/L. The historical data shows a slight downward trend in total phosphorus concentrations over time (Figure 4).

Median **chloride** and **sulfate** concentrations were 18.2 mg/L and 25.0 mg/L, never exceeding the stream standard concentration of 50 mg/L. **Total suspended solids** ranged from 1.0 mg/L to 43.7 mg/L, with a median concentration of 9.0 mg/L.

Figure 4.



The geometric mean of ***E. coli*** was 25 MPN/100 mL ranging from 1 MPN/100 mL to 2400 MPN/100mL. The violations of the stream standard in these pooled portions of the middle Guadalupe are often associated with visible migratory waterfowl activity on Lake Dunlap and McQueeney.

Lake Placid and **Meadow Lake** are shallow and narrow. Both these impoundments and the riverine portion that connects the two, referred to as Lake Seguin, are susceptible to impacts by urbanization. They received non-point source pollution from runoff from homes and streets. As seen in other urbanized areas, impervious cover created by streets, parking lots and roof tops, allow the pollutants that might be captured and bio-degraded by soils, to instead readily wash over cement and pavement, directly into the surface water bodies.

The TCEQ maintains a monitoring location on Lake Placid at IH 10, downstream of the Commercial Metals steel mill. The list of parameters includes field, nutrient, and inorganics. The temperature, pH, dissolved oxygen and conductivity median concentrations and ranges were comparable to the monitoring locations that GBRA maintains in Lakes Dunlap and McQueeney. The similarity applies to the ammonia nitrogen, nitrate nitrogen, total phosphorus, chloride and sulfate between these impoundments. At this location there were no sampling events that exceeded the screening concentrations or stream standards for these parameters. The median concentration for **total suspended solids** was higher (13 mg/L) at the TCEQ station as compared to the upper impoundments (5.2 mg/L and 9.0 mg/L) , but the range was similar to Lake McQueeney. The median chlorophyll *a* concentration was less than the LOQ.

Lake Placid showed the most difference from the upstream impoundment stations in the ***E. coli*** concentrations. The monitoring station in Lake McQueeney had a geometric mean of 25 MPN/100 mL over the historical period, and Lake Dunlap had a geometric mean of 51 MPN/100 mL over the same period. The TCEQ Lake Placid station had a geometric mean of 113 MPN/100 mL, which comes close to exceeding the contact recreation standard of 126 colonies/100 mL. Looking for explanations for the differences, one must consider that there were only 30 sampling events on Lake Placid as compared to 111 monitoring events for *E. coli* on Lakes Dunlap and McQueeney. Also, the station on Lake Placid is located on the upstream side of a bridge that not only shades the station, but has a population of birds that roost above the monitoring location. For many years, the Citizens United for Lake Placid has monitored the lake as part of the Texas Stream Team. Recently the organization funded a water quality monitoring data station that collects dissolved oxygen. The DO data is reported along with turbidity, E. coli, alkalinity, pH, and temperature on the Springs Hill Water Supply Corporation website.

Lake Gonzales and **Lake Wood** are very long and narrow. Lake Gonzales has very limited residential development along its banks. Lake Wood has some development but it, like Lake Gonzales, flows through agricultural lands, dominated by row crops and pastureland. Lake Wood has been severely impacted by sediment loading. The sediment that is picked up by flood waters from upstream has been deposited in the area directly in front of the dam that impounds the lake, reducing the depth at this location to less than four feet.

TCEQ maintains a quarterly monitoring station in the riverine portion above Lake Gonzales and downstream of the City of Seguin, next to the USGS flow gage. The station located at FM 1117 has a parameter list that includes the

same parameters that GBRA monitors at their locations. Comparing the TCEQ station that is downstream of the city and its wastewater treatment plants, we see no significant changes in water quality. The median concentrations for pH, dissolved oxygen, conductivity and temperature are comparable to the other upstream stations and none fall outside of the stream standards. The total suspended solids, chloride and sulfate are comparable as well.

Nitrate nitrogen had a median concentration of 1.36 mg/L, ranging between 0.5 mg/L to 2.13 mg/L, slightly higher than the upstream locations. Two of the data points were higher than the screening concentration for nitrates of 1.95 mg/L (5.7%). **Ammonia nitrogen** had a median concentration of less than the LOQ and never exceeded the screening concentration of 0.33 mg/L. The median concentration for **total phosphorus** was slightly higher at the FM 1117 location (0.11 mg/L) as compared to the median concentrations upstream (0.08 mg/L, 0.06 mg/L, <0.06 mg/L moving from upstream to downstream). The geometric mean for the ***E. coli*** concentrations was 26 MPN/100 mL.

GBRA's last monitoring station in this segment, the Guadalupe River downstream of the H-5 dam, is downstream of Lake Wood. Flow at this location is impacted by hydroelectric generation. Although the station is not located in an impoundment it can be compared to the upstream locations because those stations are similar in flow and exhibit riverine characteristics the majority of the time. The median concentrations for pH, dissolved oxygen, conductivity and temperature are comparable to the upstream stations, and none fall outside of the stream standards. The total suspended solids, chloride and sulfate are comparable as well. As shown in Figure 5, overall stream flows on the middle Guadalupe River are declining and this may be driving many of the water quality measurements in this area. There is a significant negative correlation of chloride with flow, and the same is seen with conductivity and sulfates, indicating that as flows increase the background concentration of chloride and other dissolved constituents, are diluted (Figure 6). Figure 7 shows that the **dissolved oxygen** levels in the river also appear to be declining and this may also be attributed to reductions in stream flow due to drought conditions.

Nitrate nitrogen had a median concentration of 0.84 mg/L, ranging between 0.05 mg/L to 1.83 mg/L, slightly lower than the locations in Lake Dunlap and Lake Placid, and more comparable to the Lake McQueeney station. None of the data points were higher than the screening concentration for nitrates of 1.95 mg/L. **Ammonia nitrogen** had a median concentration of 0.08 mg/L never exceeding the screening concentration of 0.33 mg/L. The median concentration for **total phosphorus** was 0.08 mg/L and comparable to the FM 1117 location (0.08 mg/L).

The geometric mean for *E. coli* was 33 MPN/100 mL. The median concentration for **chlorophyll *a*** was 3.3 ug/L, exceeding the screening concentration of 14.1 ug/L two times.

Figure 5.

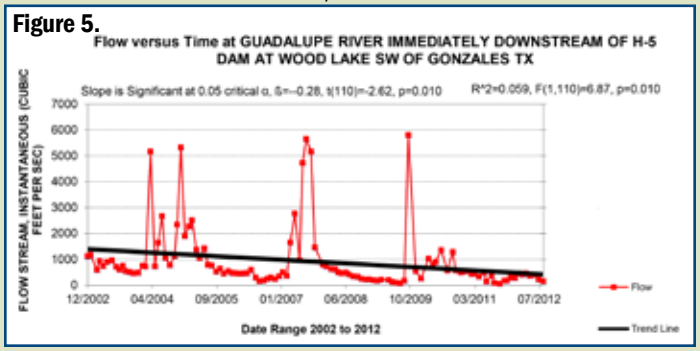


Figure 6.

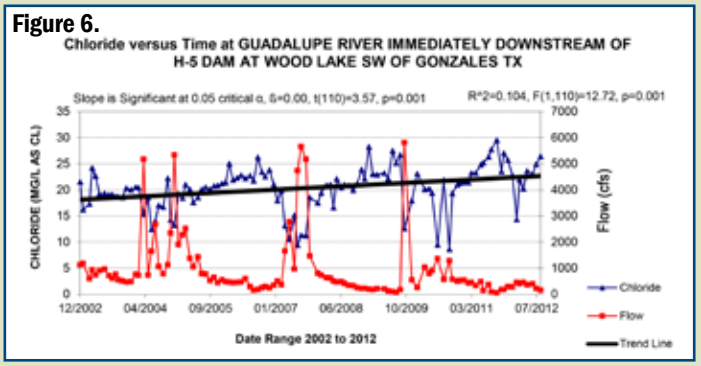
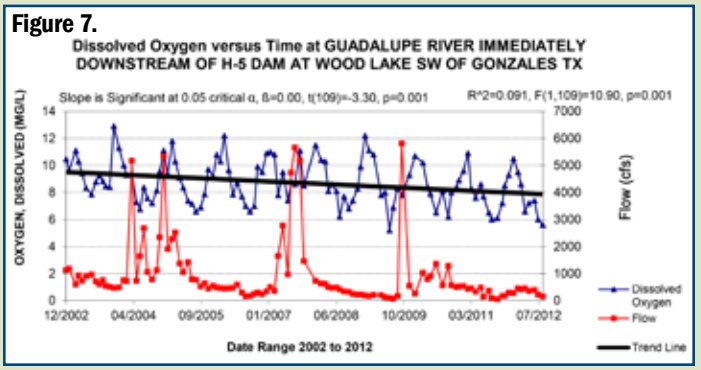


Figure 7.



Stakeholder issues in this portion of the Guadalupe River basin include concerns of the impacts of trash that comes in from upstream and the impacts of nutrient loading from the New Braunfels wastewater discharges. The river downstream of Canyon Reservoir and the Comal River are highly recreated. The residents that live along the hydro lakes downstream see the impacts of the recreational pressure in the form of trash and vegetation as this material floats down and collects along bulkheads and piers. Aquatic vegetation is broken off and floats downstream as people are tubing or canoeing in areas of submerged plants

such as hygrophilla and vallisneria (eelgrass). The plant mass collects in low flow areas and when a large mass builds up it breaks free and floats further downstream, eventually arriving in Lake Dunlap in amounts that impede boat traffic and swimming and creating aesthetically unappealing conditions. The ordinance adopted by the City of New Braunfels that established a ban on disposable containers was in place over the 2012 recreational season and there has been a noticable decrease in the amount of trash that floats down to the hydroelectric lake downstream of the city. The ordinance imposes a $500 fine on any disposable food or beverage container used on the Comal River or the portions of the Guadalupe River that flows through the city. The goal of the ordinance is to reduce the amount of trash and litter deposited in the rivers each tourist season.

There are seven domestic wastewater discharge permits and one industrial wastewater discharge permit issued in Segment 1804. The City of New Braunfels has two wastewater facilities that combine to discharge to Lake Dunlap. The Kuehler plants combined have a permitted discharge volume of 7.3 million gallons per day (MGD), with quality limits of 10 mg/L biochemical oxygen demand and 15 mg/L total suspended solids. The residents along Lakes Dunlap and McQueeney have raised concerns that these facilities impact the water quality of the impoundments by discharging nutrients that promote the growth of algae and aquatic macrophytes. Considering the history of infestations of aquatic vegetation at these hydroelectric impoundments, it is a valid concern.

Other large permitted discharges are from the City of Seguin. One plant is permitted to discharge up to an annual daily average of 4.9 MGD of treated domestic wastewater to the Guadalupe River. The second WWTP is permitted to discharge up to an annual daily discharge rate of 2.13 MGD of treated domestic wastewater into the Geronimo Creek, 190 feet upstream of the confluence with the Guadalupe River. Both Seguin wastewater treatment plants must meet a seven day average biochemical oxygen demand of 20 mg/L and a seven day average total suspended solids level of 20 mg/L. The Walnut Branch plant has an ammonia limitation of 3 mg/L. The effluent water must contain a chlorine residual of at least 1.0 mg/L of chlorine residual for at least 20 minutes of detention time and must then be dechlorinated to a value of less than 0.1 mg/L. The effluent water must also maintain a pH between 6.0 and 9.0 standard unit and a minimum dissolved oxygen level of 2.0 mg/L. Additionally, no floating solids, foam or oils must be visible in the discharge.

A concern of residents along Lake Placid just upstream of the City of Seguin is the discharges and nonpoint source pollution associated with the steel mill that is located on

the east banks of the impoundments. In the 1980s the steel mill was linked to contamination of nearby wells with chromium. Since that time, the facility has implemented a progressive environmental program on site that includes reuse of process water and extensive treatment of stormwater before it leaves the facility grounds. Also, TCEQ has a monitoring location downstream of the facility previously discussed in this section.

Segment 1804 of the Guadalupe River has had a number of problems with invasive plant species. The aquatic species include blooms of filamentous algae, waterhyacinth, hydrilla and water lettuce. It is because of the infestation of the upper lakes by hydrilla in the mid-90s that the residents along Lakes Dunlap, McQueeney and Placid organized into homeowner associations. These groups are very active, expanding their areas of concern outside of aquatic vegetation to include water safety, quality and quantity issues. It is members of these groups that make up a large part of the active membership of the Guadalupe River Basin Clean Rivers Program Stakeholders Committee.

The upper lakes are not alone in their battle with aquatic weed infestations. The waterhyacinth, *Eichhornia crassipes*, has dominated the impoundments at Lake Gonzales and Lake Wood. This invasive plant covers the surface of the lakes, which prevents mixing and oxygen exchange, and shades out sunlight, reducing native plant habitat. This plant also impedes recreational activities such as swimming and canoeing, while generally reducing the aesthetic quality of the lakes. In order to combat this nuisance, in 2008, the GBRA and the Texas Park and Wildlife Department implemented a treatment program that included mechanical shredding and chemical treatment. The shredding process was followed by a chemical treatment with 2, 4-D in Lake Gonzales and glyphosphate in the Lake Wood area. Treatment of aquatic vegetation is not new to this portion of the river basin. In the 1990's, infestations of hydrilla, *Hydrilla verticillata*, in Lake McQueeney and Lake Dunlap were treated by introducing sterile, triploid grass carp, into these lakes as a biological control, as well as chemical treatments with aquatic herbicides. The water hyacinth problems on both lakes appear to have recurred in subsequent years following the treatment event in 2008.

Geronimo Creek, 1804A, is a tributary of the Guadalupe River near Seguin. The current Clean Rivers Program monitoring station on the Geronimo Creek is located at Haberle Road, which is approximately 3.6 miles downstream of SH 123, in the town of Geronimo, and 5.1 miles downstream of the headwater springs. This location receives year round flows from several springs and also experiences significant runoff from the upper Geronimo Creek and Alligator Creek watersheds. The median **flow** at the Haberle Road location from 2003 to 2012 is 9 cfs and ranged from 2.4 cfs to 94 cfs. The stream flow at this station has significantly decreased over the past 10 years (Figure 8), possibly due to the droughts that have plagued central Texas since 2008. The **pH** data from the 108 samples collected at the Haberle Road monitoring station from 2003 to 2012 showed a median value of 7.8, with values ranging from 7.5 to 8.0. The temperature, specific conductance and dissolved oxygen levels of the Geronimo Creek were all highly variable. The **temperature** fell between 11.6°C and 28.9°C with a median temperature of 22.4°C. **Specific conductance** ranged from 395 umhos/cm to 1100 umhos/cm with a median value of 844 umhos/cm. **Dissolved oxygen** ranged from 6.6 mg/L to 13.0 mg/L with a median of 8.9 mg/L.

Figure 8.

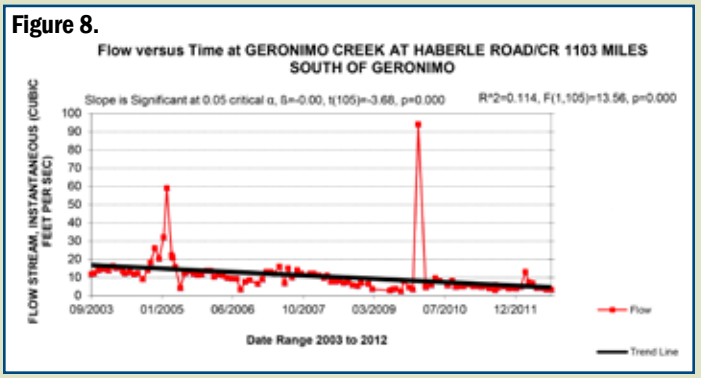
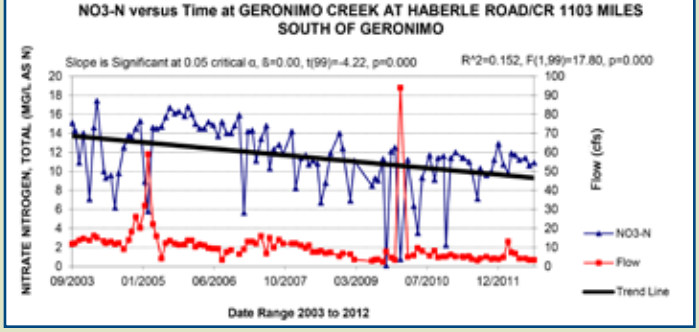


Photo by Lee Gudgell

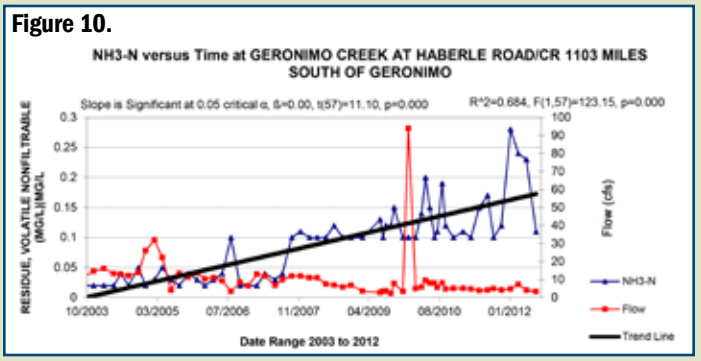
The **nitrate nitrogen** concentrations for Geronimo Creek have significantly declined over the past 10 years (Figure 9). In the 101 data points collected, nitrates ranged from 0.1 to 17.4 mg/L with a median of 11.6 mg/L. Most of the low nitrate values occurred during high flow events that diluted the influence of groundwater on the Creek. Nitrate nitrogen is listed as a concern on the state 303(d) list because the average value is greater than the 1.95 mg/L. The median concentration for nitrates is greater than the Maximum Contaminent Limit (MCL) of 10.0 mg/L for drinking water. The maximum concentration measured is nearly twice the MCL. There is a significant amount of groundwater influence on Geronimo Creek and many drinking water wells in this watershed are known to share nitrate values similar to or even higher than the creek itself. The radical deviation of the nitrate concentrations in Geronimo Creek from similar streams in the Guadalupe basin present an interesting question about the source of this contamination. The GBRA and USGS will be conducting a nitrogen isotope study beginning in 2014 will attempt to determine the source of nitrates in the Leona formation.

Figure 9.



While nitrate nitrogen appears to be decreasing over time, **ammonia nitrogen** levels appear to be significantly increasing (Figure 10). Declining stream flows may be driving the increases in ammonia as this agriculturally driven watershed sees greater influence from leaking septic tanks or ammonia based fertilizers. In contrast to ammonia nitrogen, **total phosphorus** levels are significantly declining over time. The median total phosphorus concentration is 0.05 mg/L ranging from less than the LOQ to 0.66 mg/L.

Figure 10.



Chloride and **sulfate** levels have remained relatively stable in the watershed with median values of 39.1 mg/L and 65.4 mg/L, respectively. The chloride concentration ranged from 12.5 mg/L to 48.9 mg/L and the sulfate concentrations ranged from 24 mg/L to 85 mg/L. The stream concentration of these dissolved salts did not appear to be significantly correlated with changes in stream flow.

The Geronimo Creek was listed in the state 303(d) list for exceeding the state contact recreation limit for ***E. coli*** of 126 colonies/100 mL. The geometric mean for *E. coli* collected from 2003 to 2012 is 154 MPN/100 mL of water. The Geronimo Creek is currently designated by the state in category 5c, which means that the stream does not meet state water quality standards. The designated contact recreation use for the stream is being threatened by the *E. coli* pollutant.

The Texas State Soil and Water Conservation Board selected the Geronimo Creek for development of a watershed protection plan (WPP). The Geronimo and

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Alligator Creek Partnership was formed to guide the WPP development process. Led by a steering committee made up of citizens, businesses, public officials and state and federal agencies, the partnership is working to restore the health of Geronimo and Alligator Creeks. The WPP states "The Partnership recognizes that success in improving and protecting water resources depends on the people who live and work in the watershed." The WPP was accepted by US EPA in the fall of 2012. After first determining the potential sources and locations of the pollutant loads, the Partnership determined to what degree bacteria and nitrate-nitrogen concentrations should be reduced to meet the water quality standards. Bacteria concentrations require a 26% reduction and nitrate nitrogen needs to be reduced by 85%. The WPP also recommends management measures that if implemented would go a long way in reducing those pollutant loads.

Topical work groups look at three key areas and the related pollutant sources and loading. Those areas include agricultural sources, urban sources and wastewater, including septic systems. Management measures that could reduce bacteria and nutrient loading from urban sources include management of pet waste by collection stations and pet waste ordinances, as well as urban storm water assessments and conveyance modifications. Management measures that could reduce the loading from agricultural-related activities include planning and financial assistance to farmers and ranchers for development of management plans that reduce bacteria and nutrient losses. Best management practices (BMPs) that could be implemented include grassed waterways, nutrient management and conservation easements. The plan also suggested outreach and eduction activities and landowner information for feral hog control.

Photo by Janet Thome

Comal River and Dry Comal Creek Watersheds

Segment 1811, the **Comal River,** extends from the confluence of the Guadalupe River to its headwater springs coming from the Edwards Aquifer, located in and near Landa Lake. The entire segment lies within the city of New Braunfels. GBRA maintains a monitoring location in the Comal River at Hinman Island (station no.12653) and has been monitoring at this station monthly since late 1994. A major tributary to the Comal River is the **Dry Comal Creek**. GBRA has maintained a monitoring station located on the Dry Comal Creek very near its confluence with the Comal River in New Braunfels since 1996. TCEQ and the US Geological Survey have monitored the Comal River as well but GBRA assumed consistent monitoring of the Comal River when it joined the Clean Rivers Program in 1996.

The Comal River is the shortest river in the State of Texas. It is home to the fountain darter, a federally-listed endangered species. The river is spring-fed, making it a consistent temperature and clarity. Landa Park and its spring-fed pool are located at the headwaters. Landa Lake, located in the park, is the home of ducks, native fish and a healthy stand of rooted, aquatic plants. A concern of stakeholders is the introduction of non-native species such as hygrophila (aquatic plant), ram's horn snail, and loriicarids (aquarium algae eaters) that without natural predators can out-compete the native species and upset

the ecological balance in the river. A source of the non-native species is improper disposal of aquarium populations by local residents.

The Comal River is heavily recreated, especially in times when the flow from Canyon Reservoir is reduced due to drought, making the flow in the Guadalupe River too low for tubing and rafting. With increased recreation pressure comes increased stress and pollution loading (trash) on the Comal River. The public responded to these concerns by passing a city ordinance that makes it unlawful to carry or possess a cooler with a capacity of greater than 16 quarts on or in the public waters of the Comal River. All coolers must be secured by a zipper, Velcro snap, mechanical latch or bungee cord to prevent the loss of contents if the cooler should flip. Also it is unlawful to carry or possess food or beverages in "disposable containers," defined as receptacles designed to be used once and thrown away. Examples of these types of containers include metal and aluminum cans, glass containers, Styrofoam cups and containers, cardboard containers, paper sacks, boxes and plastic containers and utensils.

The land use in the watershed of the river proper is entirely urban. Residential property with manicured lawns and impervious cover associated with urban land uses, including roads, roof tops and parking lots can be sources of pollutant loading to the river. Pollutants that might be captured and bio-degraded by soils are instead readily washed over the cement and pavement and directly into the surface water.

The Dry Comal Creek is a small creek with a mean instantaneous flow of 4 cubic feet per second that flows through a large watershed that is currently more rural than urban. As in other areas in the Austin-San Antonio IH 35 corridor, there are new subdivisions being planned in the watershed that will, over time, reverse the dominance of land use from rural to urban. There are sand and gravel operations in the watershed. There are no wastewater or industrial plants that discharge to either the Comal River or Dry Comal Creek.

Another contributing subwatershed to the Comal River is Blieders Creek. The creek is intermittent and the watershed is mostly undeveloped agricultural lands, located north of the Comal River. The creek enters the Comal River above the headwater springs located in Landa Park. A large development project is planned in this subwatershed. A 5,000-home community development is scheduled to begin construction in 2013. The master-planned development project will include a university campus, a resort hotel, and 480 acres of parks. The Veramendi development is being built on the 2,400 acre Word-Borcher Ranch and will also have waterfront property along the Guadalupe River near New Braunfels. This project will vastly alter the current rural aspects of the subwatershed. The project will include a second dam on Blieders Creek, designed to reduce runoff by 1000 cubic feet per second, and help alleviate flooding in Landa Park.

Photo by Janet Thome

The 2012 Texas Water Quality Inventory listed the Dry Comal Creek as impaired for elevated bacteria concentration. No source was identified or suggested. The Comal River was not listed with any impairments or concerns. The data set from 09/01/2002 through 08/31/2012 was used to evaluate the monitoring station on the Comal River as well as the Dry Comal Creek for historical trends. Based on the available historical data on the Comal River (station no. 12653), the **temperature** varied between 14.0°C to 28.0°C, with a median temperature of 23.6°C. TCEQ has adopted new temperature criteria for portions of the Comal River. The criteria has been lowered from 26.7°C to 25.6 °C in the portion of the Comal River that extends from Landa Lake Park Dam immediately upstream of Landa Park Drive upstream to Klingemann Street in New Braunfels, excluding the western channel at Spring Island, the eastern channel

at Pecan Island and the Bleiders Creek arm of Landa Lake, upstream of the springs in the upper spring run reach (TCEQ, 2010). The lower criterion is to protect the sensitive habitat of the fountain darter found in the Comal Springs. The EPA has not accepted the adopted temperature criteria.

The **specific conductance** ranged between 359 umhos/cm and 684 umhos/cm, with a median conductivity of 561 umhos/cm. The median **pH** of the station was 7.6, ranging from 6.9 to 8.3. The median concentrations for **chloride** and **sulfate** in the Comal River were 17.2 mg/L and 24.8 mg/L respectively. All data points for chloride were lower than the stream standard of 50 mg/L except for one point (92.2 mg/L) that appears to be a one-time occurrence. Only three data points for sulfate concentration fell outside of the stream standard of 50 mg/L.

However, in the historical data set for the Dry Comal Creek (station no. 12570), the water quality has exceeded the stream standard for sulfate102 times. The Dry Comal Creek is not a classified stream segment, so it is assessed using the stream standards of the Comal River. More than half of the samples analyzed for sulfate exceeded the stream standard of 50 mg/L. Figure 11 shows a statistically significant downward trend in the sulfate concentration over time in the Dry Comal Creek, beginning in 2002. There is not a statistically significant correlation between sulfate and flow at this station, suggesting that the sulfate is associated with base flows and not rainfall runoff. The sources of base flow at the Dry Comal Creek monitoring station are springs located mainly in the city, with no known contributions from point source discharges. The majority of the upper watershed is dry for the majority of any given year.

Nitrate nitrogen, ammonia nitrogen and total phosphorus were analyzed at the monitoring locations on both water bodies. The source of the Comal River is the Edwards Aquifer which has historically exhibited elevated **nitrate nitrogen**. The median concentration for the locations on the Comal River ranged from 0.02 mg/L to 2.70 mg/L. Looking at the historical data set for the Comal River, the nitrate nitrogen concentration exceeded the screening criteria of 1.95 mg/L 25 times out of 257 analyses (9.73%). Figure 12 shows the consistent input of nitrogen from the springs coming from the Edwards Aquifer. The exception was during the period of high flows that contributed flow to the stream as well as recharge to the Edwards Aquifer possibly diluting the naturally-occurring nitrate nitrogen in the base flow (Figure 13).

The source of the Dry Comal Creek is primarily ground water and rainfall runoff off of pasture and farmland. The median concentration for nitrate nitrogen in the Dry Comal Creek is lower than the Comal River, ranging from 0.15 mg/L to 1.90 mg/L, and during the period of record, did not exceed the screening concentration. The median

Figure 11.

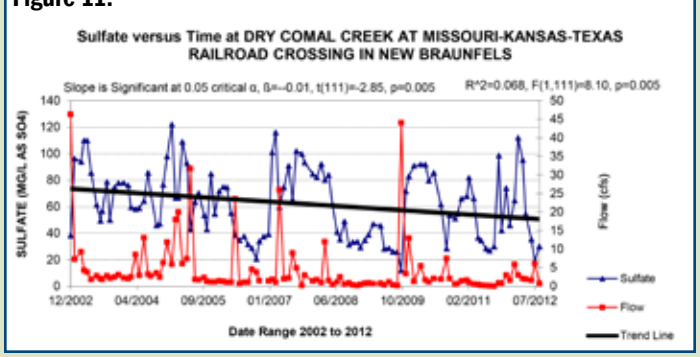


Figure 12.

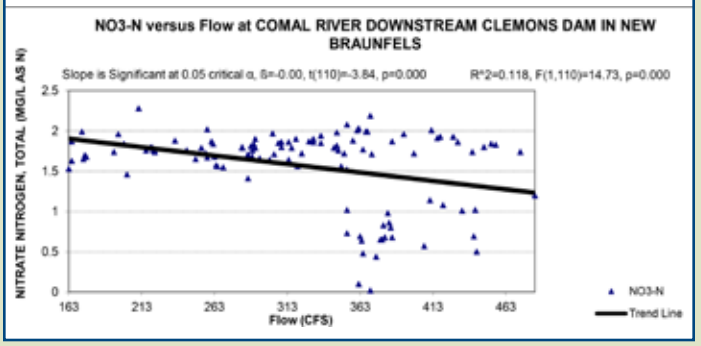
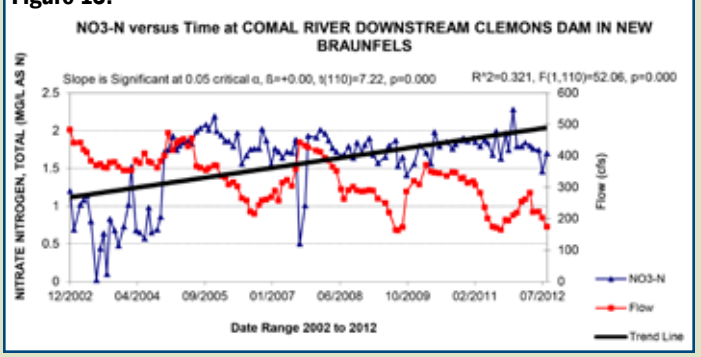


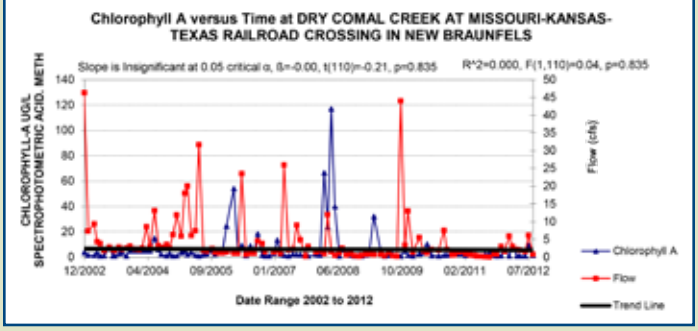
Figure 13.



ammonia nitrogen concentration for the Comal River was 0.03 mg/L and 0.095 mg/L for the Dry Comal Creek. The median total phosphorus concentration was 0.044 mg/L for the Comal River and 0.05 mg/L for the Dry Comal Creek. When total phosphorus was detected in a sample from either water body it did not exceed the screening concentration of 0.69 mg/L.

The nitrate nitrogen concentrations in the Dry Comal Creek appeared to be decreasing in previous assessments, but with the contribution of additional monitoring data over the last five years, this trend is no longer statistically significant. The previously perceived nitrate nitrogen declines were originally attributed to several spikes in the chlorophyll *a* concentration in the Dry Comal Creek (Figure 14), which could explain the decrease in nitrate concentration as the nutrients are taken up by algae and macrophytes. The median chlorophyll *a* concentration on the Comal River is less than the LOQ and there was never a measured value above the screening concentration of 14.1 micrograms per liter (ug/L). Whereas, the median concentration for chlorophyll *a* on the Dry Comal Creek is 2.3 ug/L and exceeded the screening concentration ten times over the period of record.

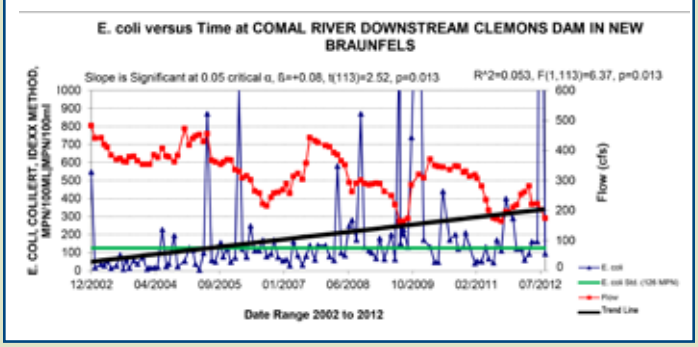
Figure 14.



An explanation for the upward trend in the concentration of chlorophyll *a* in the Dry Comal Creek may be the predominant low flow conditions that have defined the creek since 2005. Low flow conditions give the stream more time to assimilate the nutrients, resulting in an increase in algal and macrophyte growth. 2005 and 2006 had prolonged dry periods. Regardless of meteorological conditions, reduction in recharge due to impervious cover in the Dry Comal Creek watershed will continue to result in a corresponding reduction in base flow with more frequent and prolonged low flow conditions, making low base flow the norm rather than the exception.

The Comal River is a slow, meandering stream with a silt substrate that supports large stands of rooted aquatic macrophytes. The stream standard for contact recreation for ***E. coli*** is a geometric mean of 126 colonies/100 mL. The geometric mean for *E. coli* at the Comal River at Hinman Island station is 58 MPN/100 mL. There is a upward trend in the *E. coli* concentration seen in the data, over the period of record (Figure 15). However, the significant upward trend in *E. coli* becomes more pronounced beginning in the summer of 2005. The stream was assessed during the 2012 water quality inventory. The geometric mean was 105 MPN/100 mL. If this trend does not change the Comal River will likely be listed on the state 303(d) list of impaired water bodies for exceeding the *E. coli* geometric mean standard. Additionally, there is no statistically significant positive or negative correlation with flow in the historical data set.

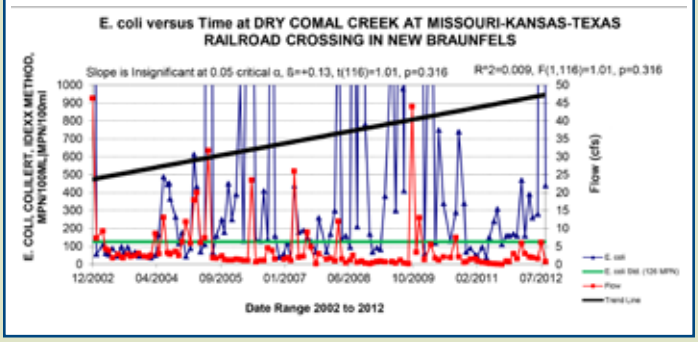
Figure 15.



The Dry Comal Creek exhibits typical concentrations of *E. coli* bacteria for a stream that receives the majority of its flow from a rural watershed with agricultural bacterial loading. The geometric mean for *E. coli* is 154 MPN/100 mL in the data set that begins in 1996, exceeding the stream standard of 126 colonies/100 mL (Figure 16). A positive correlation with flow can be seen in the historical data set, which would suggest that elevated *E. coli* numbers may be partially due to non-point source runoff.

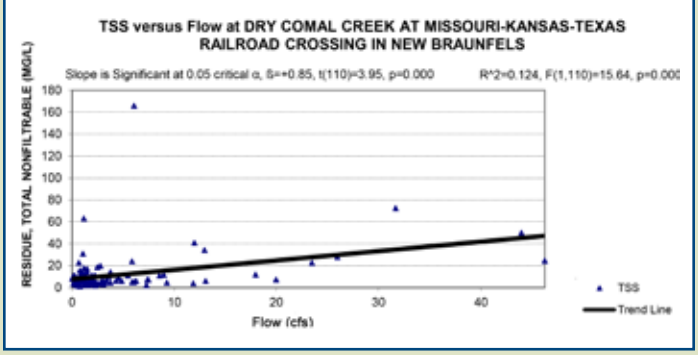
The **total dissolved solids** in the Comal River ranged from 233 mg/L to 444 mg/L, with a median of 364 mg/L, and ranged from 144 mg/L to 725 mg/L, with a median of 439 mg/L for the Dry Comal Creek. The mean concentration of total dissolved solids in the Dry Comal Creek is slightly

Figure 16.



greater than the 400 mg/L assessment criteria for the Comal River. Total dissolved solids are small particles such as salts, sugars and metals dissolved in the water, which are not necessarily associated with non-point source pollution. In contrast, the **total suspended solids** in the water column are larger pieces of organic matter that are often associated with runoff and elevated bacteria levels. In the Comal River total suspended solid values ranged from 1 mg/L to 20 mg/L with a median value of 1.8 mg/L. In the Dry Comal Creek total suspended solid values ranged from 0.6 mg/L to 111 mg/L with a median value of 6.2 mg/L. In the Dry Comal Creek, the total suspended solid concentrations increase with additional flow as expected. However, possibly due to the smaller size of the watershed the correlation between flow and total suspended solids in the Comal River is not statistically significant. Non-point source pollution in the form of rainfall runoff carries in suspended solids and associated bacteria along with oxygen-depleting organic material. Storm events in the Dry Comal Creek watershed have been shown to carry in high levels of bacteria and suspended material (Figure17).

Figure 17.



The Edwards Aquifer Recovery Implementation Program (EARIP) has been completed. Legislation passed in 2007 codified the EARIP into state law and required that the EARIP prepare a USFW-approved Habitat Conservation Plan (HCP) for managing the Edwards Aquifer. The EARIP was a multi-stakeholder initiative that developed an HCP that will balance water use and development with the recovery of federally-listed endangered or threatened species. The EARIP used a long-term, multidisciplinary approach to policy formation, scientific research, habitat restoration and education to come up with a plan that included recommendations regarding withdrawal adjustments during critical periods to protect the federally-listed endangered species. The stakeholders that met regularly for over four years included representatives of state and regional water agencies, municipalities, industries, agriculture, environmental interest groups, and the public at large. The US Fish and Wildlife Service approved the HCP as of January 1, 2013. According to the HCP, the plan "is intended to support the issuance of an Incidental Take Permit which would allow the "incidental take" of threatened or endangered species resulting from the otherwise lawful activities involving regulating and pumping of groundwater from the Edwards Aquifer within the boundaries of the EAA for beneficial use for irrigation, industrial, municipal and domestic and livestock uses, and the use of the Comal and San Marcos spring and river systems for recreational and other activities." The HCP includes measures that, if implemented, will minimize and mitigate to the "maximum extent practicable" the incidental take and not reduce the

likelihood of survival and recovery of the endangered species found within the Edwards Aquifer and the Comal and San Marcos Springs. These measures stand to positively impact the water quality and habitat found in the Comal River.

Additionally, after the 2010 census, the City of New Braunfels was designated as a Phase II Municipal Separate Storm Sewer System and is required to develop a storm water pollution prevention plan (SWPPP). The city is currently in the process of developing the SWPPP that will include minimum control measures to reduce the pollutants carried into waterways in storm water. These efforts will positively impact the water quality of the streams in the city's jurisdiction.

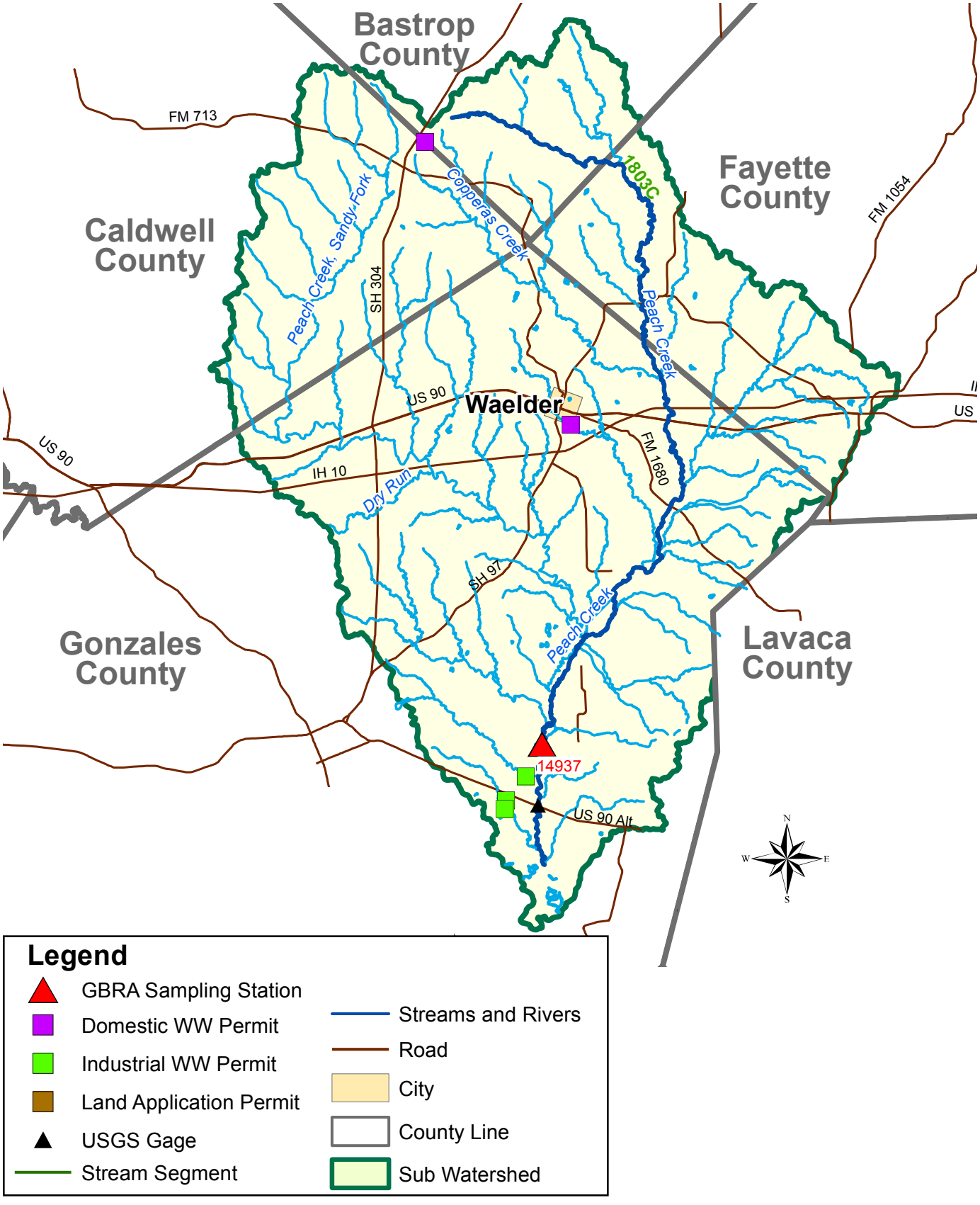
Comal Springs Dryopid Beetle
(*Stygoparmus comalensis*)

Comal Springs Riffle Beetle
(*Heterelmis comalensis*)

Fountain Darter
(*Etheostoma fonticola*)

Middle Guadalupe River Issues and Concerns			
Water Quality Issue	**Affected Area**	**Possible Influences/Concerns**	**Possible Actions Taken/to be Taken**
Trash and Litter	Guadalupe River below Canyon	Recreational impacts	City of New Braunfels has enacted a Can Ban ordinance, requiring the use of reusable containers for drinks and food to reduce the amount of containers and trash that is lost in the river
Bacteria	Dry Comal River	Urban storm water; livestock and agricultural runoff; wildlife	Watershed protection plan; monitoring in the watershed
Introduction of invasive, non-native species (hygrophila, loricariids, rams horn snail)	Comal River	Aquariums	Education on dangers of disposing of aquarium species that are non-native and lack natural predators
Bacteria	Geronimo Creek	Urban runoff; pet waste; septic systems; livestock; wildlife and feral hogs	Implementation of watershed protection plan accepted in 2012
Nitrate-Nitrogen	Geronimo Creek	Urban runoff; pet waste; septic systems; livestock; wildlife and feral hogs	Implementation of watershed protection plan accepted in 2012

Peach Creek Watershed



Peach Creek Watershed

River Segments, Descriptions and Concerns

Segment 1803C (Peach Creek, unclassified water body): A small system, Peach Creek flows east and south through gently rolling hills for 64 miles from Bastrop and Fayette counties northeast of Waelder into the Guadalupe River in eastern Gonzales County.

Drainage Area: 480 square miles

Streams and Rivers: Guadalupe River, Peach Creek, Copperas Creek

Aquifers: Carrizo-Wilcox

River Segments: 1803C

Cities: Waelder, Flatonia

Counties: Caldwell, Bastrop, Fayette, Gonzales

EcoRegions: Texas Blackland Prairies, Post Oak Savannah

Vegetation Cover: Shrublands 13.9%, Grass/Herbaceous 23.4%, Deciduous Forest 34.1%, Pasture/Hay 21.1%

Climate: Average annual rainfall 31 inches, Average annual temperature January 39°, July 94°

Land Uses: Recreation, extensive cattle and poultry productions, light industry and agricultural crops

Water Body Uses: Aquatic life, contact recreation, and fish consumption

Soils: Dark red sandstone and tan and grey sandstone

Permitted Wastewater Treatment Facilities: Domestic 2, Land Application 0, Industrial 3

Photo by Janet Thome

Peach Creek Watershed

River Segments, Descriptions and Concerns

Peach Creek Watershed

Peach Creek, a tributary of Segment 1803, the Guadalupe River below the San Marcos River, extends from its confluence with the Guadalupe River in Gonzales County, northward, with portions of the watershed in Fayette, Bastrop and Caldwell counties. The segment is separated into three assessment units: the lower 25 miles; the portion that extends from FM 1680 in Gonzales County to the confluence with Elm Creek in Fayette County; and, the remainder of the water body. GBRA has been monitoring Peach Creek (station no. 14937) monthly since 1996. The GBRA station is located in the lower assessment unit. Peach Creek was listed as impaired for bacteria in 2000. A **Total Maximum Daily Load Study** (TMDL) performed by TCEQ confirmed the impairment in the lower two assessment units and found that the upper assessment unit is not impaired for bacteria. The TMDL developed in 2008 modeled the watershed to determine the amount of load reduction that would be necessary to bring the stream back into compliance with stream standards but has not been adopted. After looking into the operation of the wastewater plants discharging to the creek, it was determined that the sources of bacterial loading are most likely from nonpoint sources, such as failing septic tanks, livestock and wildlife. The study determined that a 47 to 100 percent reduction in non-point source bacterial loading is necessary to bring Peach Creek into compliance with stream standards. However, TCEQ recognizes the potential for bacterial contributions from these wastewater facilities so there are waste load allocations assigned to the wastewater plants that require that they maintain adequate disinfection. To assure that there is a reduction of bacteria in the waste, the cities have bacterial monitoring requirements in their permits. There are five point sources that have permits to discharge treated water to the segment, two of which could potentially contribute to the bacterial impairment. The cities of Waelder and Flatonia operate wastewater plants that are facultative lagoon systems that do not include chemical disinfection. TCEQ believes that the lagoon process holds the wastewater with sufficient time for reduction in bacteria by solar radiation and other natural processes. Both cities currently have satisfactory permit compliance histories with TCEQ.

Photo by Janet Thome

The proposed Total Maximum Daily Load for Bacteria in Peach Creek report can be accessed at http://www.tceq.state.tx.us/implementation/water/tmdl/34-peachcreekbacteria.html. The Texas State Soil and Water Conservation Board, along with the Gonzales County Soil and Water Conservation District, have funds available to provide technical and financial assistance to landowners and ag producers for the development of water quality management plans (WQMPs). The WQMPs are written specifically for each landowner's property and uses, with the goal to reduce the bacterial loading to Peach Creek. The funding includes cost sharing for water quality management practices that give livestock alternatives to watering directly in the creek or work to retain storm water off pastureland. These practices include fencing, stock ponds, troughs and water wells, as well as brush management, riparian herbaceous cover and forest buffers.



Photos by Janet Thome

The GBRA routine monitoring station at CR 353 exhibits wide swings in water quality. The median concentration for **dissolved oxygen** is 6.7 milligrams per liter (mg/L), ranging from a minimum of 2.1 mg/L to a maximum of 13.5 mg/L. During the period of record the dissolved oxygen dropped below the standard for the minimum dissolved oxygen concentration (4.0 mg/L) 4 times. This segment is currently listed on the state 303(d) list for depressed dissolved oxygen. The **temperature** varied between 5.4°C to 28.8°C, with a median temperature of 22.4°C. The **specific conductance** ranged between 146 micromhos per centimeter (umhos/cm) and 1420 umhos/cm, with a median conductivity of 628 micromhos per centimeter. The median **pH** of the station was 7.8, ranging from 6.8 to 8.4 standard pH units, never falling outside the stream standard range of 6.5 to 9.0 standard units.

The median concentration for **chloride** was 53.8 mg/L, ranging from 5.68 mg/L to 170 mg/L, falling outside the stream standard of 100 mg/L used for assessment 19 times out of 112 data measurements. Peach Creek exhibited a wide range in **sulfate** concentrations, ranging between 7.62 mg/L and 327 mg/L, with a median concentration of 32 mg/L. The sulfate concentrations fell outside the stream standard of 50 mg/L 45 times out of 112 measurements. There is a slight downward trend in sulfate concentrations over time as seen in Figure 1. The same wide range in concentrations is seen with **total hardness**, which has a median 70.4 mg/L and ranges between 20.5 mg/L and 424 mg/L from 2002 to 2012. Total hardness concentrations on the Peach Creek have also experienced a significant downward trend over the last 10 years as seen in Figure 2. As seen in Figure 3, the ionic constituents, represented by conductivity, are negatively

Figure 1.

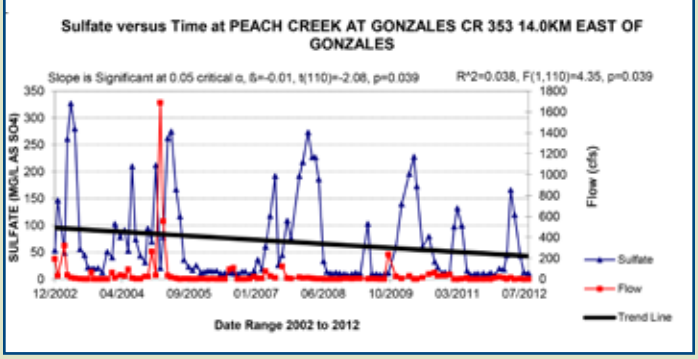
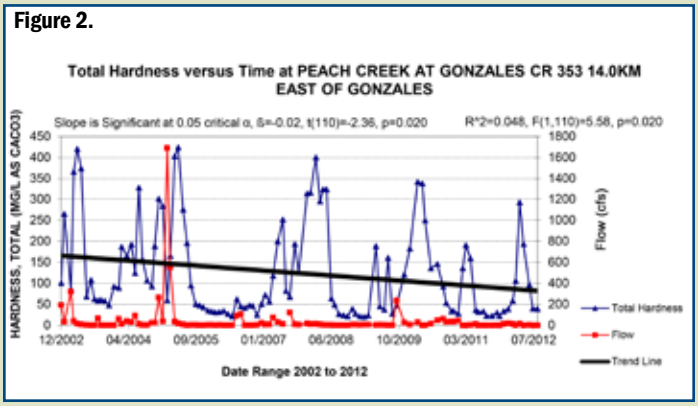


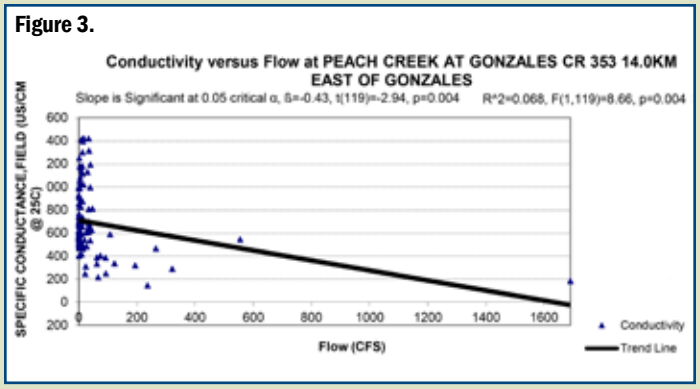
Figure 2.



Peach Creek Watershed

River Segments, Descriptions and Concerns

Figure 3.



correlated with flow. The constituents that make up the majority of the dissolved solids also correlate with each other, meaning that when the hardness and chloride are elevated, the sulfate follows the same pattern. Two of the other three permitted dischargers in the watershed are from clay mining operations and may be linked to the wide swings in the dissolved constituents. These discharges are intermittent and while within the permitted allowances could explain the wide swings in concentrations.

Most locations in the Guadalupe River basin have relatively high hardness concentrations with one exception, Peach Creek. The toxicity of certain **metals** is dependent on the hardness of the stream. The metals toxicity criteria that are hardness-dependent are cadmium, chromium, copper, nickel, lead and zinc. The hardness concentration at the 15th percentile is 31.62 mg/L in Peach Creek as compared to an average a little over 200 mg/L in other parts of the basin. It is at this percentile that the toxicity criteria for Peach Creek are calculated. The acute and chronic toxicity criteria are considerably lower for Peach Creek than at other locations in the river basin. Also, the highest concentrations of aluminum, arsenic, chromium, nickel and zinc in the basin are found at the CR 353 station. Currently, Peach Creek does not exceed the standards for acute and chronic toxicity but the concentrations that have been found do warrant continued monitoring.

Nitrate nitrogen, ammonia nitrogen and total phosphorus, were analyzed at the GBRA monitoring location on Peach Creek. Over the period of record, the median concentration of **nitrate nitrogen** was 0.12 mg/L, ranging from less than the Limit of Quantification (LOQ) to 1.32 mg/L. At no time did the nitrate nitrogen concentration exceed the screening criteria of 1.95 mg/L. The median **ammonia nitrogen** concentration was 0.1 mg/L, ranging from 0.02 mg/L to 0.44 mg/L which was a one-time occurrence in the data. Four sampling events showed the concentration of ammonia nitrogen over the screening concentration of 0.33 mg/L. The median **total phosphorus** concentration was 0.24 mg/L, and ranged from less than the LOQ for the method to 0.69 mg/L.

Peach Creek is a slow, meandering stream with pools. Median **flow** at the GBRA station at FM 353 is 4.3 cubic feet per second (cfs), ranging from 0.00 cfs to 1,690 cfs.

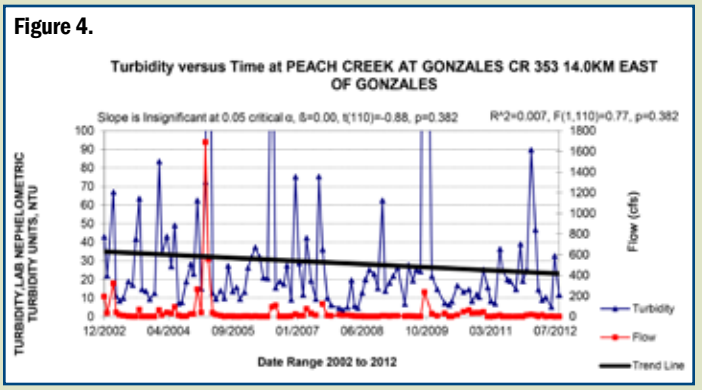
Photos by Janet Thome

Over the period of record the stream stopped flowing about 2.5% of the time. The approximate depth at the sampling location is 2.5 to 3.0 feet, many stream reaches in the upper portion are known to go dry. The pools are typically 2 to 5 feet in depth.

Because there is evidence of primary contact recreation at the monitoring location (station no. 14937), Peach Creek was assessed using the water quality standard for primary contact recreation. The stream standard for contact recreation is a geometric mean of 126 colonies per 100 milliliters. The geometric mean for E. *coli* bacteria at CR 353 is 214 MPN/100 mL.

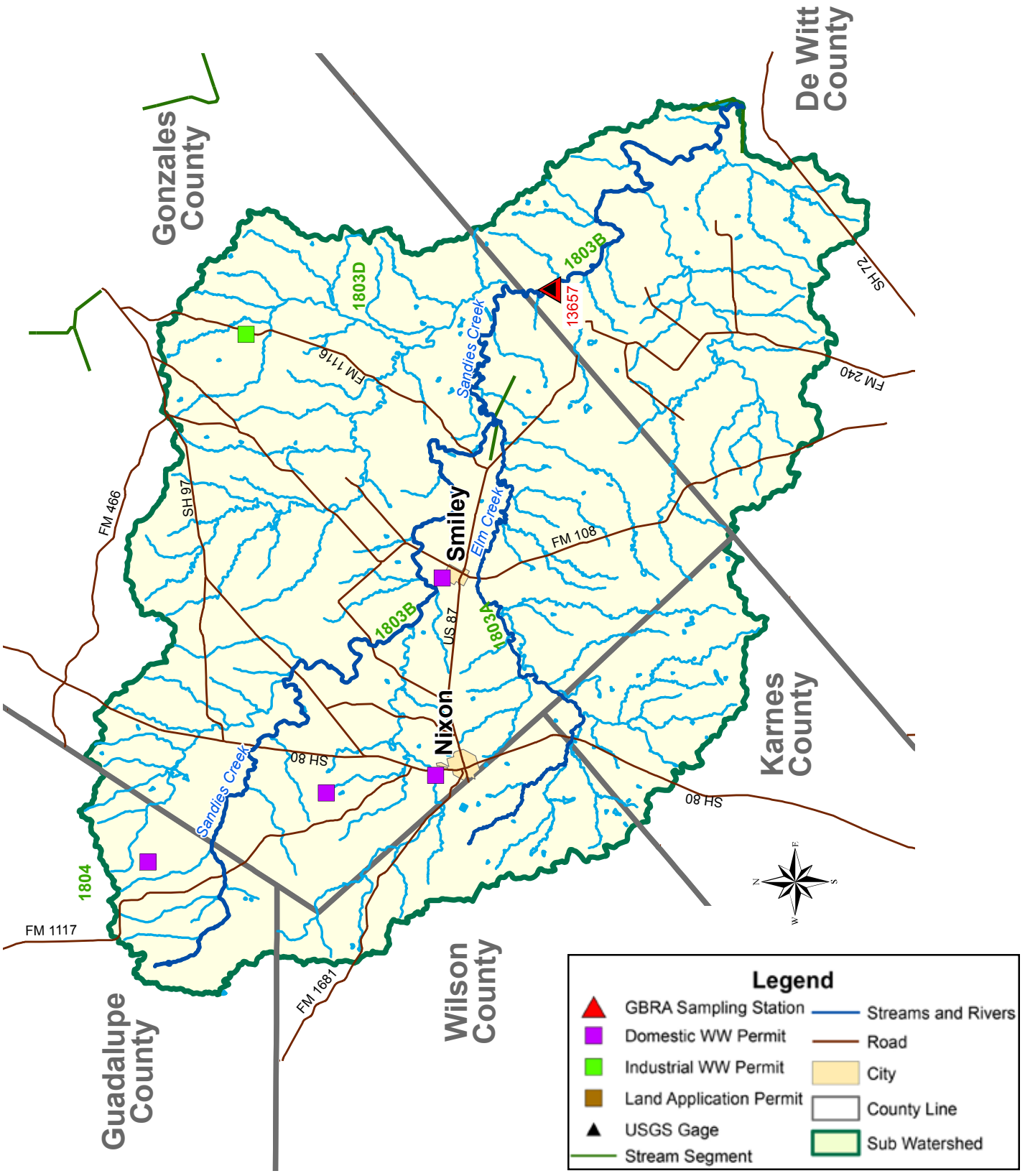
The substrate at the GBRA monitoring location on Peach Creek ranges from sandy to small cobble. The water is **turbid** (median = 19.0 nephlometric turbidity units) and can have a slight brown tint from tannins that leach from decaying plant material. The **suspended solids** ranged from <1 mg/L to 394 mg/L, with a median of 8.3 mg/L. The median **chlorophyll *a*** concentration is 1.3 micrograms per liter (ug/L) and ranged from less than the LOQ to 9.8 ug/L. There were no monitoring events that were above the screening concentration of 14.1 ug/L. Reviewing the data to look for links between turbidity and flow, a significant correlation was found. However, the period of time illustrated in Figure 4 shows that turbidity can stay elevated with no corresponding peaks in flow. The data was reviewed and there were no elevated chlorophyll *a* values associated with algal blooms during these periods. One possible link to the turbidity could be the extreme flood events prior to each period of sustained turbidity shown on the graph. The inundation of the banks causes loss of grasses along the shoreline that would provide stabilization and prevent or minimize erosion and loss of sediment.

Figure 4.



Peach Creek Issues and Concerns			
Water Quality Issue	**Affected Area**	**Possible Influences/Concerns**	**Possible Actions Taken/to be Taken**
Bacteria	Peach Creek	WWTF facultative lagoons; urban runoff; pet waste; septic systems; livestock; wildlife and feral hogs	Implementation of the proposed Total Maximum Daily Load; 24-hr Dissolved Oxygen measurements
Chlorophyll *a*			
Depressed Dissolved Oxygen			
Aluminum			

Sandies Creek Watershed



Sandies Creek Watershed

River Segments, Descriptions and Concerns

Segment 1803A (Elm Creek, unclassified water body): Elm Creek flows 24.3 miles before it confluences with Sandies Creek, east of Smiley in Gonzales County.

Segment 1803B (Sandies Creek, unclassified water body): Sandies Creek is a 65 mile long stream originating in Guadalupe County northwest of Nixon to the confluence of the Guadalupe River west of Cuero in DeWitt County.

Drainage Area: 711 square miles

Streams and Rivers: Guadalupe River, Elm Creek, Sandies Creek, Five Mile Creek, Salty Creek, Clear Creek, and O'Neil Creek

Aquifers: Carrizo-Wilcox, Gulf Coast

River Segments: 1803A, 1803B

Cities: Smiley, Nixon

Counties: Guadalupe, Karnes, Wilson, Gonzales, DeWitt

EcoRegions: Texas Blackland Prairies, Post Oak Savannah

Vegetation Cover: Pasture/Hay 24.9%, Deciduous Forest 19.6%, Row Crops 3.4%, Grass/Herbaceous 24.3%, Evergreen Forest 5.3%, Shrublands 21.1%

Climate: Average annual rainfall 31 inches, Average annual temperature January 39°, July 94°

Land Uses: Light manufacturing, extensive cattle production and poultry production, agricultural crops (hay, sorghum, etc.)

Water Body Uses: Aquatic life, contact recreation and fish consumption

Soils: Dark red sandstone, light tan and gray sandstone

Permitted Wastewater Treatment Facilities: Domestic 4, Land Application 0, Industrial 1

Photo by Elizabeth Aguilar

Sandies Creek Watershed

River Segments, Descriptions and Concerns

Sandies Creek Watershed

Sandies Creek, Segment 1803B, extends approximately 65 miles, from its confluence with the Guadalupe River in DeWitt County, near the City of Cuero, upstream, through Gonzales County, to its headwaters in Guadalupe County. The creek flows through a watershed that is made up of hardwoods, pines, mesquites and a variety of grasses. **Elm Creek**, Segment 1803A, is a tributary of Sandies Creek that flows from its headwaters in Wilson County through Gonzales County to converge with Sandies Creek, downstream of the City of Smiley. Elm Creek is approximately 24 miles long, in a watershed that is rural, and characterized by flat to rolling terrain, dominated by hardwoods, pines, mesquite and a variety of grasses. Both creeks are unclassified stream segments that were assessed as one assessment unit each, using the stream standards for the main stem Guadalupe River that receives their combined flow. GBRA has historical monitoring stations on Sandies Creek since 1996. The current station, monitored since 2000, is located at Westhoff (station no. 13657). The original station, located at FM 1116, was moved to the Westhoff station in order to more accurately record flow by using the USGS gaging station nearby. Also, there were safety considerations that made the Westhoff station a better long term station. GBRA does not maintain a routine station on Elm Creek. There was not enough long term data on Elm Creek to look for trends in water quality. Other stations on Sandies and Elm Creeks have been monitored for short periods of time for special studies, one of which was to determine the impacts of poultry operations if any on watersheds. The study collected monthly data from each creek from November 1997 to August 1998. It was because of this limited study that the creeks were suspected of being impaired. Other data collected in the watershed were for the TCEQ total maximum daily load study started in 2002.

The land use is primarily agricultural with row crops and poultry and livestock production. There are two wastewater treatment plants in the watershed, one for the City of Nixon and one for the City of Smiley. Both plants are permitted to discharge to small tributaries of Sandies Creek. The City of Nixon facility is permitted to discharge up to 0.45 million gallons per day, with quality limits of 10 milligrams per liter (mg/L) carbonaceous biochemical oxygen demand, 15 mg/L total suspended solids and 3 mg/L ammonia nitrogen. The facility uses chlorine to disinfect the effluent. The City of Smiley treats its wastewater in a lagoon system and is

authorized to use their effluent to irrigate a hay field in lieu of discharge. Beginning in 2010, the Sandies and Elm Creek watersheds have seen a significant growth in oil and natural gas extraction through hydrological fracturing technology in the Eagle Ford Shale deposits.

Sandies and Elm Creeks were both listed on the 2006 Texas Water Quality Inventory as impaired for depressed dissolved oxygen and for exceedence of the bacteria standard for contact recreation. Currently, a total maximum daily load (TMDL) study is being conducted by the TCEQ. Data was collected on the two tributaries in 2002 and 2004. TCEQ is analyzing the data to develop TMDLs for dissolved oxygen and for bacteria. The goal of the TMDL study is to determine the amount of a pollutant that a body of water can receive and still support its designated uses. The allowable load is then allocated among the potential sources of pollution within the watershed. Potential sources of pollutants include point sources such as wastewater discharges, and nonpoint sources, including agricultural land use activities, wildlife and septic tanks.

In Sandies and Elm Creeks, low dissolved oxygen levels indicate that existing conditions are not optimal for aquatic life support. To meet the aquatic life support standards, the creek must have better than a 5.0 mg/L median ***dissolved oxygen*** concentration. Also, the creek should not fall below 3.0 mg/L more than 25% of the time. Reviewing the historical data at the GBRA station at Westhoff on Sandies Creek, the median dissolved oxygen was 6.4 mg/L, ranging from 0.8 mg/L to 13.5 mg/L. The stream dropped below 3.0 mg/L 12 times out of 127 measurements, or 9.4%. As seen in Figure 1, there is a wide range of measured dissolved oxygen concentrations over the period of record. The variation in dissolved oxygen can be due to several factors, including time of day when photosynthesis adds oxygen during the sunlit hours, time of year when the colder water can hold more saturated dissolved oxygen, or early morning hours when dissolved oxygen drops due to respiration of algal cells overnight. Additionally, if the sediment load of the stream increases due to runoff, decomposition and bacterial respiration can cause a drop in the dissolved oxygen concentration. All of these factors are possible in Sandies Creek.

The ***temperature*** in Sandies Creek ranged from 8.5°C to 31.0°C, with a median temperature of 23.2°C. The median **pH** was 7.9, ranging from 6.71 to 8.9, and never fell outside of range of the stream standards of 6.5 to 9.0. The ***conductivity*** and dissolved constituents of Sandies Creek are also highly variable, as seen in Figure 2.

The stream is high in dissolved solids in comparison to the lower Guadalupe River. The median dissolved solids in Sandies Creek, based on conductivity, are approximately 976 mg/L, as compared to near 350 mg/L in the lower Guadalupe River. In Figure 3, increases in flow see Oelevated at low flows, indicating that the base flow is high in dissolved salts.

Figure 1.

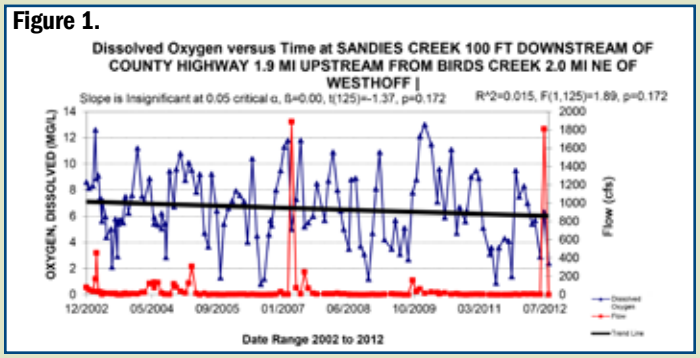


Figure 2.

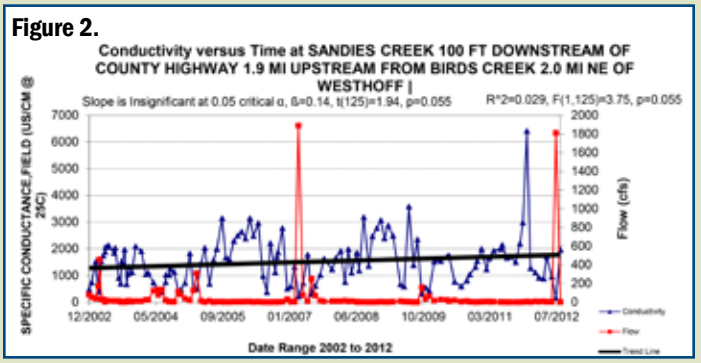
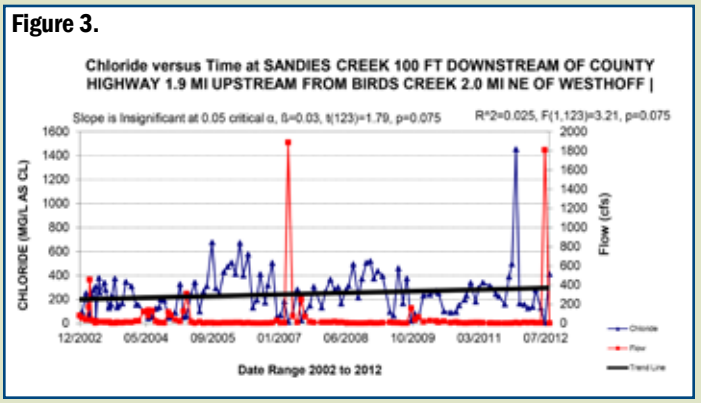


Figure 3.



Sandies Creek Watershed

River Segments, Descriptions and Concerns

Continuous water quality monitoring at Sandies Creek station.

Photos by Lee Gudgell

Chloride and **sulfate** concentrations ranged from 4.65 mg/L to 1455 mg/L and 3.48 mg/L to 206 mg/L, respectively, with median concentrations of 233 mg/L and 45.3 mg/L. The median concentration of **total suspended solids** was 31.9 mg/L, ranging from 8.0 mg/L to 766 mg/L.

Chlorophyll *a* concentrations have spiked in Sandies Creek and those spikes are associated with low flow periods. The median concentration is 4.5 micrograms per liter (ug/L), ranging from 0.25 ug/L to 125 ug/L. Twenty-three of the 126 sampling events had chlorophyll *a* concentrations that exceeded the screening concentration of 14.1 ug/L.

Nitrogen and phosphorus were analyzed at the GBRA Sandies Creek location. **Ammonia nitrogen** concentrations exceeded the screening concentration of 0.33 mg/L six times during the period of record and had a median concentration of 0.10 mg/L, ranging from the Limit of Quantification (LOQ) to 1.0 mg/L. The median concentration for **nitrate nitrogen**, combining all methods was 0.24 mg/L, ranging from 0.02 mg/L to 1.05 mg/L, never exceeding the screening concentration of 1.95 mg/L. The median concentration of **total phosphorus** was 0.41 mg/L, ranging from the LOQ to 1.59 mg/L, exceeding the screening concentration of 0.69 mg/L 15 times out of 124 measurements (12.1%). There was no correlation with rises in flow to explain the spikes in phosphorus concentration so the most likely source of the phosphorus is wastewater effluent, although, of the median flow in the creek of 9.9 cubic feet per second, the contribution of wastewater is less than 0.5 cubic feet per second on a daily basis. Total phosphorus levels and TKN levels are significantly increasing over time (Figures 4 & 5).

E. coli was analyzed and the bacterial impairment noted in the assessment was confirmed over the period of time that GBRA has monitored at the Westhoff location. The geometric mean for *E. coli*, is 200 MPN/100 mL, exceeding the stream standard for contact recreation of 126 colonies/100 mL.

Figure 4.

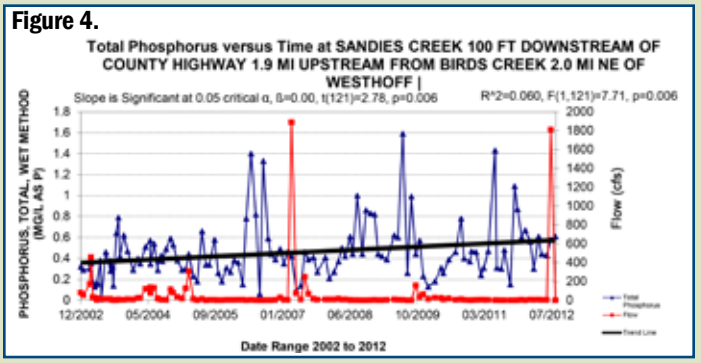
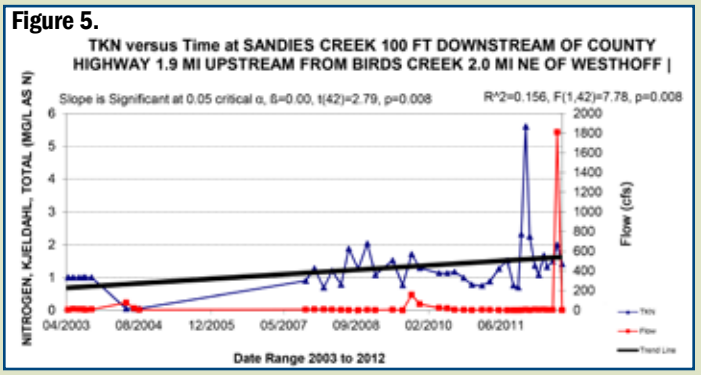


Figure 5.



It should be noted that the conditions in Sandies Creek and the lack of public access for contact recreation reduce the potential of human exposure to bacteria during contact recreation. The watershed is a major development area for oil and natural gas from the Eagle Ford Shale through hydrological fracturing techniques. Some stakeholders have expressed concerns about the impact these extraction activities have on ground and surface water in the watershed. Figure 6 show the increase in drilling activity from 2008 through April 2013. Figure 7 shows a map of the Eagle Ford Shale Play that underlies much of south central Texas with the wells permitted and completed through May 2013.

Figure 6.

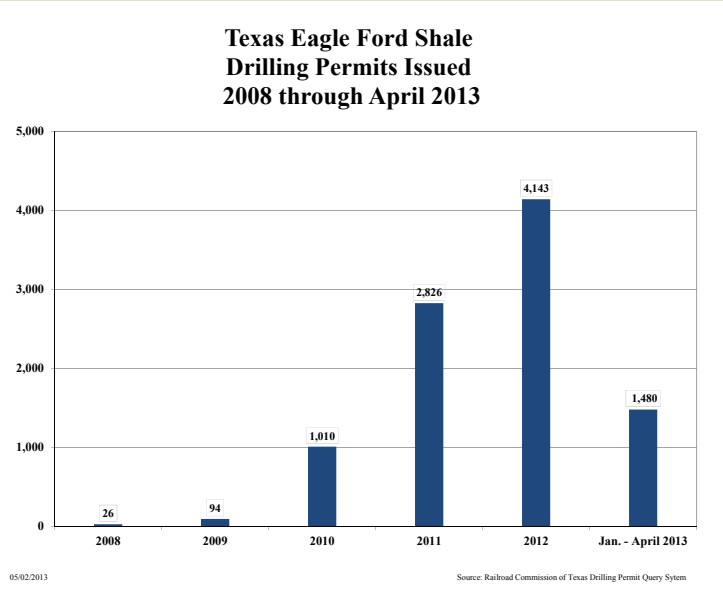
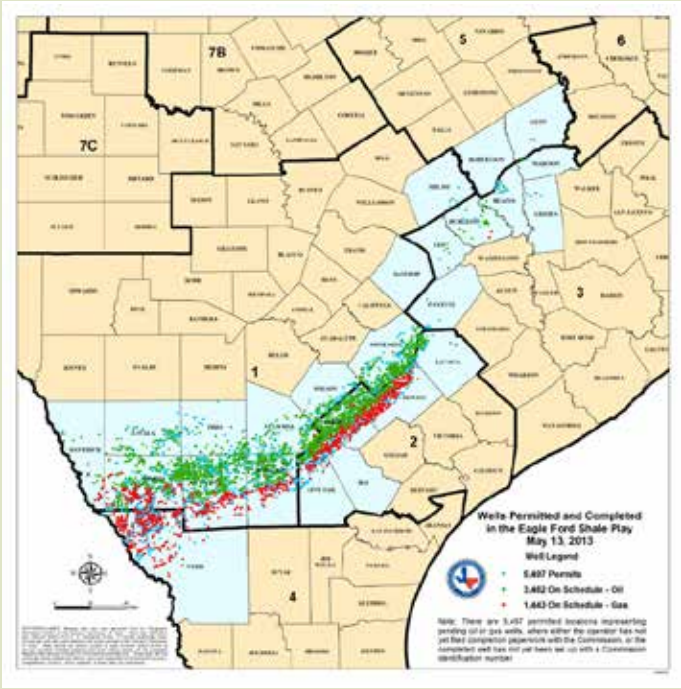
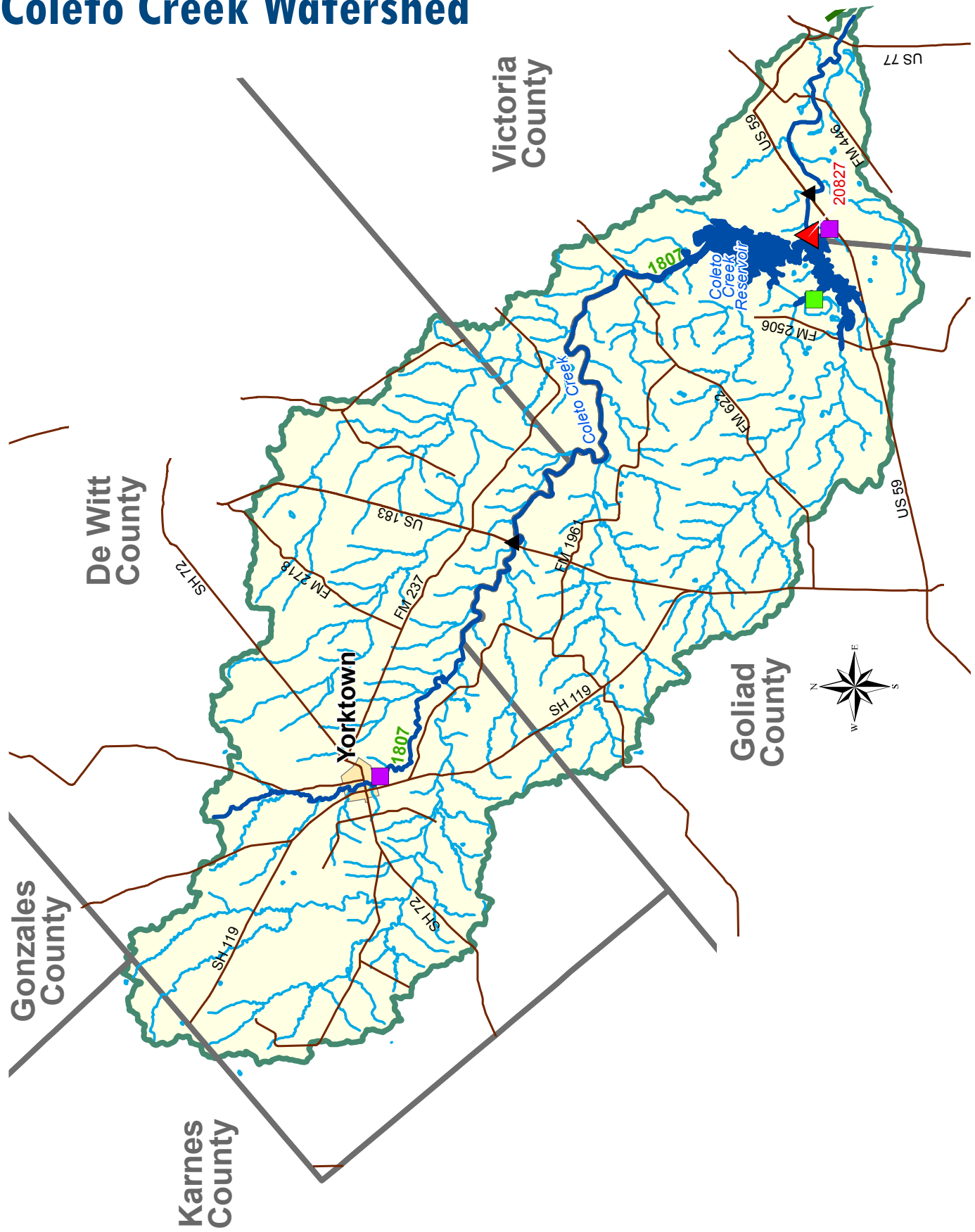


Figure 7.



Sandies Creek Issues and Concerns			
Water Quality Issue	**Affected Area**	**Possible Influences/Concerns**	**Possible Actions Taken/to be Taken**
Bacteria	Sandies Creek	Septic systems; livestock; wildlife and feral hogs	Review of water quality standards; completion of a total maximum daily load or watershed protection plan; bacterial source tracking
Impaired Biological Habitat and Communities		Illegal dumping	
Depressed Dissolved Oxygen	Elm Creek	Septic systems; livestock; wildlife and feral hogs	Review of water quality standards; completion of a total maximum daily load or watershed protection plan; bacterial source tracking

Coleto Creek Watershed



Coleto Creek Watershed

River Segments, Descriptions and Concerns

Segment 1807 (Coleto Creek): Coleto Creek extends 27 miles beginning in DeWitt County, through Goliad and Victoria Counties, including the 3,100-acre Coleto Creek Reservoir to the confluence with the Guadalupe River in Victoria County. Because of the size of Coleto's drainage basin, this normally slow moving creek can become a fast, flowing river during a typical South Texas rainstorm. Much of the creek bottom is made up of sand with typical vegetation ranging from mesquite and huisache to large live oaks and anaque trees. Because of its rural setting and limited development you can still find a wide range of Texas wildlife along its shores ranging from turkey and deer, to red fox and bobcats. With the completion of the Coleto Creek Reservoir, it now supports over 100 different species of birds with the most noted being the Southern Bald Eagle, Osprey, and Roseate Spoonbills.

Drainage Area: 558 square miles

Streams and Rivers: Guadalupe River, Coleto Creek, Perdido Creek, Twelve Mile Creek, Thomas Creek

Aquifer: Gulf Coast

River Segments: 1807

Cities: Yorktown

Counties: DeWitt, Goliad, Victoria

EcoRegions: Texas Blackland Prairies, Gulf Coastal Plains

Vegetation Cover: Pasture/Hay 15.3%, Shrublands 9.7%, Grass/Herbaceous 33.2%, Deciduous Forest 18.7%, Row Crops 5.0%

Climate: Average annual rainfall 30 inches, Average annual temperature January 41°, July 95°

Land Uses: Agricultural crops (sorghum, rice, cotton and corn), beef, hogs and poultry productions and oil and gas production

Water Body Uses: Aquatic life, contact recreation, fish consumption, public water supply and power plant cooling

Soils: Sandy, sandy loam and clay loam

Permitted Wastewater Treatment Facilities: Domestic 2, Land Application 0, Industrial 1

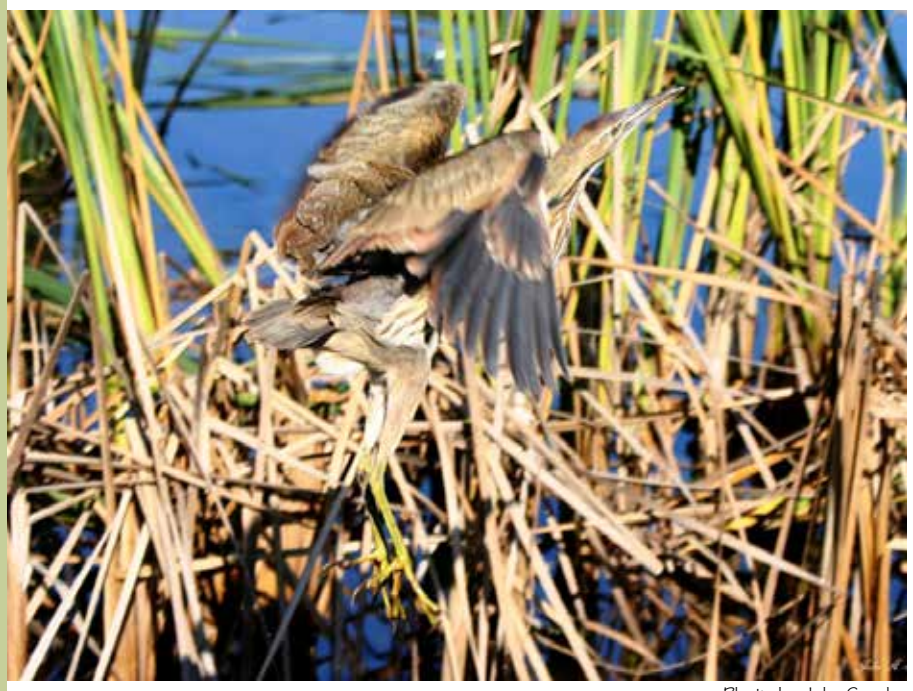


Photo by John Snyder

Coleto Creek Watershed

River Segments, Descriptions and Concerns

Coleto Creek and Reservoir

The ***Coleto Creek***, Segment 1807, flows through DeWitt, Goliad and Victoria counties. The land uses in the watershed include farming and ranching, oil and gas production and recently, in-situ uranium mining. The only urbanized area is the small community of Yorktown located in DeWitt County in the upper watershed. The segment is divided into two assessment units: from the confluence with the Guadalupe River to the Coleto Creek Reservoir Dam; and, the remaining portion of the segment. The upper part of the segment includes Coleto Creek Reservoir. The segment summary will be separated into two sections, the reservoir and the creek.

Coleto Creek Reservoir

Coleto Creek Reservoir began impounding water in 1980, and is primarily used as a cooling pond for the coal-fired Coleto Creek power plant located in Goliad County. The power plant discharges 360,000 gallons per minute of water per year to the reservoir. The temperature of the discharge cannot exceed 108°F. In addition to cooling capacity, the 3,100 surface acre reservoir is used for recreation, including swimming, boating, skiing and fishing. The reservoir is one of the best fishing sites in the Guadalupe River Basin because of the warm water and excellent fish habitat. The reservoir has 61 miles of shoreline, with a sandy substrate and an average depth of eleven feet (2.5 meters).

The reservoir is fed by four major creeks, Coleto Creek, Perdido Creek, Turkey Creek and Sulphur Creek. The reservoir is maintained at a constant level. In times of drought, water can be pumped from the Guadalupe River to maintain lake levels, under a water right permit held by the power company. As evidence to the severity of the recent drought, the power plant's water right was used on July 14, 2011. Pumping of water from the Guadalupe River continued through February 2013 in order to maintain a volume sufficient to maintain the temperature required in their discharge permit.

The warm water in the reservoir creates ideal conditions for the growth of several species of aquatic vegetation, including non-native stands of Eurasian milfoil, waterhyacinth and the dominant species, hydrilla. These aquatic plants provide excellent fish habitat but have been known to grow to excessive amounts that can restrict cooling water flow and public access in several areas of the reservoir. GBRA has a program to maintain the appropriate level of vegetation by controlling the plants with biological, chemical and mechanical means. The park staff has established a lake stakeholder group that is consulted each year that a vegetation management treatment program is needed. The stakeholder group includes TPWD, fishermen, members of local landowner associations and representatives of the recreation industry.

GBRA moved its historical monitoring station which was located at the park on the Coleto Creek Reservoir (station no. 12623) to a station located at the dam in September 2010. TCEQ had maintained two monitoring locations in the reservoir but discontinued monitoring on Coleto Creek Reservoir when GBRA moved their monitoring station to the dam. The monitoring station at the dam was established in order to collect enough data to establish a water quality standard for nutrients in reservoirs, as represented by chlorophyll *a*. Additionally, quarterly depth profiles are performed at the station.

Nutrient enrichment from nitrogen and phosphorus can cause excessive growth of macrophytes, algal blooms in the open waters as well as attached to the substrate and floating in mats. The Texas Water Quality Standards have numerical nutrient criteria for reservoirs, as represented by chlorophyll *a*. Coleto Creek is not listed on the Appendix F (Chapter 301.10) of the Texas Water Quality Standards that lists site-specific nutrient criteria for reservoirs and lakes in Texas. Criteria formulations were based on selected sampling stations that represent the deep pool near the dam for each reservoir, represent average conditions with an allowance for statistical variability, and are calculated as the upper confidence interval of the mean with the assumption that a sample size of 10 is used. Based on these criteria, a nutrient standard cannot be calculated on Coleto Creek Reservoir because the data set collected at the sampling station at the dam is not large enough.

The original GBRA station on the reservoir would have a sufficient amount of data but the station is not located in the main pool. The GBRA station is located at the boat ramp in a cove, very near a swimming station on the reservoir. The station was originally established to assess the water quality for contact recreation. The median **chlorophyll *a*** concentration at the GBRA dam station on the reservoir is 2.6 micrograms per liter (ug/L), with no data points exceeding the screening criteria of 14.4 ug/L. The data set for chlorophyll *a* on Coleto Creek at the dam location is very limited with only 23 data points. A factor that may play into the development of nutrient criteria for Coleto Creek Reservoir will be if the reservoir will be designated as "impacted" due to the warm water discharge from the power plant that utilizes the water body for cooling purpose. There are no other domestic or industrial discharges to the reservoir or upstream tributaries.

The depth at the dam location is approximately 11 meters. Reviewing the limited data set that GBRA has collected at the station at the dam, the lake begins to stratify at the dam during the spring and summer months. The **temperature** change through the depth profile was 6.9°C and 4.4°C from surface to bottom respectively by season. The **conductivity** changed, on average, less than 23.5 micromhos per centimeter (umhos/cm) from surface to bottom.

The **dissolved oxygen** measured at the bottom went to less than one milligram per liter at the dam consistently during the warmer months. In the limited historical data set, there were no surface measurements that dropped below the stream standard of 4.0 mg/L.

The difference in **pH** from surface to bottom at both reservoir locations averaged a change of 0.98 pH units. No surface or profile sample fell outside the pH standard range of 6.5 to 9.0.

GBRA collected nutrients and dissolved constituents at the surface at the location monitored at the dam. The data set was too small to do trend analyses.

Coleto Creek

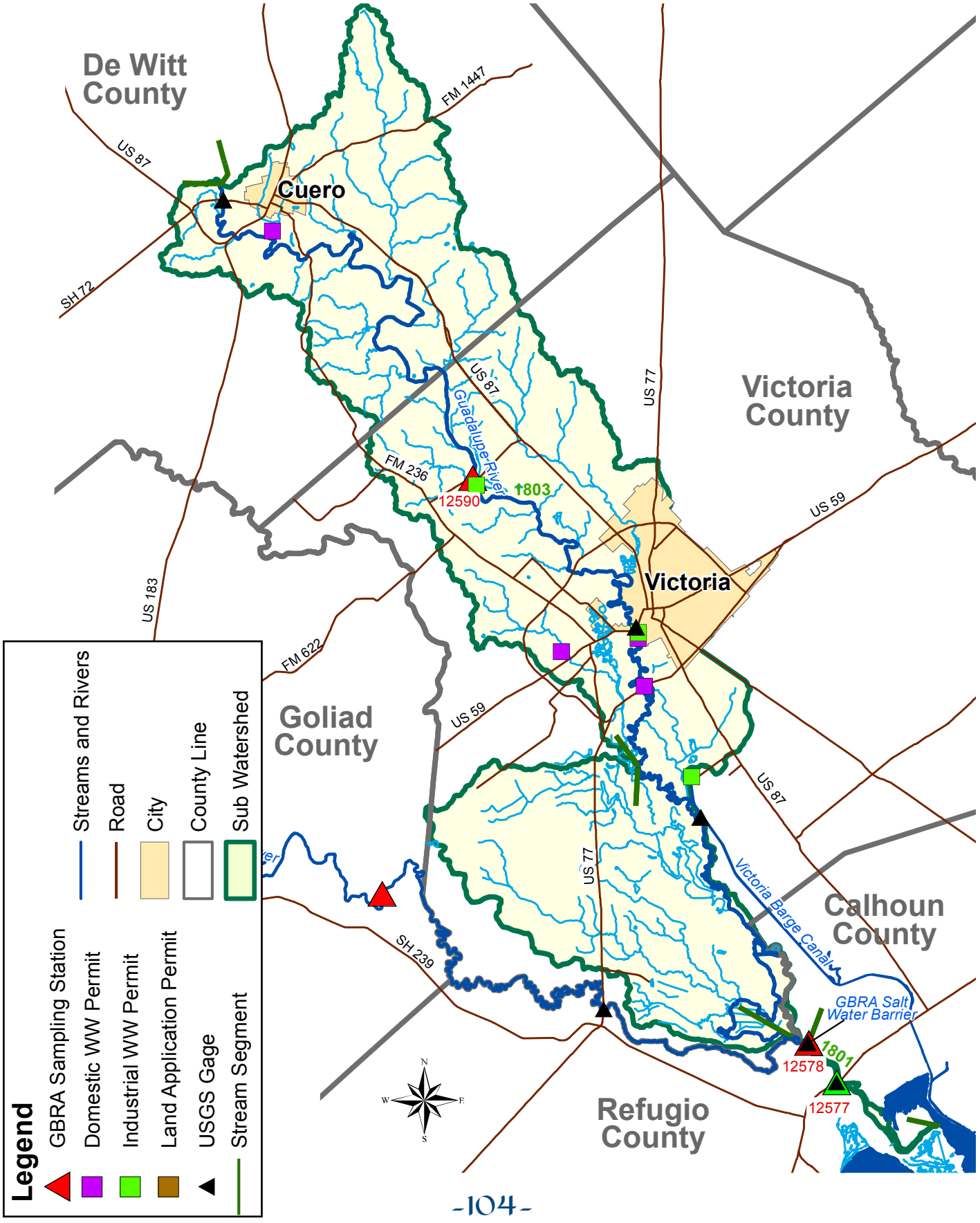
The lower assessment unit is approximately 15 miles in length with a median flow of 5.6 cubic feet per second (cfs). Because very little of the watershed is below the Coleto Creek Reservoir, the flow in the lower assessment unit is dependent on releases from the reservoir. The upper assessment unit has the majority of the watershed for the Coleto Creek and its tributaries. Guadalupe River Basin stakeholders have voiced concerns about the impacts from oil and gas production and most recently, the possible impacts from the exploration and in-situ mining for uranium on the water quality in the Coleto Creek, upstream of the reservoir. In response to this concern GBRA established two stream stations upstream of the reservoir on Coleto Creek at Arnold Road (station no. 18594), Perdido Creek (station no. 18595) and sampled over two years. The data sets for each station are very limited and not appropriate for trends over time analyses but the systematic monitoring does record baseline conditions for comparison in future years. The mining has not been started, as of January 2013. After the mining begins, GBRA will discuss periodic monitoring in these watersheds to assess impacts, if any.

The TCEQ has a stream monitoring (station no. 12622) located downstream of the reservoir that was discontinued in November 2010. The TCEQ station below the reservoir has an extensive data set, from 1991 to 2010, but only data from 2003 through 2010 was evaluated for trends. The median **flow** was 5.5 cfs. The median ***temperature*** was 25.3°C, ranging from 13°C to 33.7°C. The **dissolved oxygen** ranged from 4.8 mg/L to 12.5 mg/L, with a median concentration of 8.29 mg/L.

The median **specific conductance** was 774 umhos/cm, ranging from 274 umhos/cm to 927 umhos/cm. The **chloride** contributes the most to the conductivity, with a median concentration of 119 mg/L but the stream did not exceed the stream standard of 250 mg/L in the historical data set.

Continuing with the evaluation of the historical data at the TCEQ station downstream of the reservoir, the ***E. coli*** geometric mean concentration was 8 MPN/100 mL, well below the stream standard for primary contact recreation. Based on the 2012 Texas Water Quality Inventory, the dissolved nutrient concentrations, ammonia nitrogen, nitrate nitrogen and orthophosphate never exceeded the stream screening concentrations for each respective nutrient. **Total phosphorus** had only one exceedence of the screening criteria of 0.69 mg/L, out of 105 measurements assessed.

Lower Guadalupe River Watershed



Lower Guadalupe River Watershed
River Segments, Descriptions and Concerns

Drainage Area: 488 square miles

Streams and Rivers: Guadalupe River Tidal, Guadalupe River below San Antonio River, Guadalupe River below San Marcos River, Sandies Creek, Elm Creek, Coleto Creek, Spring Creek, McDonald Bayou

Aquifers: Carrizo-Wilcox, Gulf Coast

River Segments: part of 1803, 1802, 1801, 1701

Cities: Cuero, Victoria, Tivoli

Counties: Calhoun, Refugio, Victoria, DeWitt

EcoRegions: Gulf Coastal Plains, East Central Texas Plains

Vegetation Cover: Pasture/Hay 14.8%, Shrublands 21.1%, Row Crops 4.2%, Grass/ Herbaceous 22.6%, Evergreen Forest 5.7%, Wetlands 10.2%, Deciduous Forest 14.8%

Climate: Average annual rainfall 37.4 inches, Average annual temperature January 53°, July 84°

Land Uses: Urban, agricultural crops (cotton, corn, wheat, rice, hay, grain sorghum), cattle and hog productions, industrial (plastics, chemicals, petrochemicals)

Water Body Uses: Aquatic life, contact recreation, general, fish consumption, heavy industrial and public water supply

Soils: Cracking clay subsoil, sandy, sandy and clay loam

Permitted Wastewater Treatment Facilities: Domestic 4, Land Application 0, Industrial 3

Segment 1803 (Guadalupe River below San Marcos River): From the point where the San Marcos River confluences with the Guadalupe River in Gonzales, Segment 1803 becomes a twisting, slow-moving coastal river, lined with pecan bottoms, with no rapids of any consequence. This portion of Segment 1803 begins to the west of the City of Cuero, flowing south to the west of the City of Victoria, to immediately upstream of the confluence with the San Antonio River.

Segment 1802 (Guadalupe River below San Antonio River): This 0.4-mile long stretch between the confluence of the San Antonio and Guadalupe Rivers to the GBRA Salt Water Barrier is a typical slow moving coastal river.

Segment 1801 (Guadalupe River tidal): From the confluence with Guadalupe Bay in Calhoun and Refugio counties to the GBRA Salt Water Barrier (0.4 miles) downstream of the confluence of the San Antonio River in Calhoun and Refugio counties.

Photo by John Snyder

Lower Guadalupe River Watershed

River Segments, Descriptions and Concerns

Lower Guadalupe River

The Lower Guadalupe River is made up of three river segments. Segment 1801, **Guadalupe Tidal**; Segment 1802, **Guadalupe River below the San Antonio River**; and, Segment 1803, the **Guadalupe River below the confluence with the San Marcos River**.

Guadalupe Tidal

Segment 1801, **Guadalupe Tidal**, extends from one-half mile downstream of the GBRA Salt Water Dam to where the river enters Guadalupe Bay in Calhoun County. This eleven-mile stretch is a typical marshy, tidal river. The Salt Water Dam is a set of two inflatable fabridams, used during times of low river flow to prevent salt water intrusion by tides. The TCEQ Region 14 office has monitored at the tidal bridge over the Guadalupe River two to four times per year since 1990. Unfortunately, the data set did not include flow data with each constituent, so it is difficult to correlate extremes in water quality to extremes in flow.

Segment 1801 is made up of one assessment unit. The segment was listed with concerns on the 2012 Texas Water Quality Inventory for depressed dissolved oxygen and nitrate nitrogen. The Inventory cites that the segment exceeded the **dissolved oxygen** grab criteria of 5.0 milligrams per liter (mg/L) 8 times out of the 35 data points assessed. The median concentration for dissolved oxygen was 6.5 mg/L, ranging from 3.9 mg/L to 12.3 mg/L.

Nitrate nitrogen exceeded the screening concentration of 1.10 mg/L 20 out of 25 sampling events. The median concentration was 2.02 mg/L, ranging from 0.06 mg/L to 4.72 mg/L. The exceedence of the nitrate screening criteria is due to the concentration of nitrate nitrogen coming from the San Antonio River. GBRA established a monitoring station on the lower San Antonio River at Fannin in 1987, in part, to help explain impacts of high flows coming from this "tributary" of the Guadalupe River. The GBRA San Antonio River station had a median concentration of 5.42 mg/L over the period of historical monitoring performed by GBRA from 1987 to 2012. The San Antonio River is effluent-dominated with the City of San Antonio and other smaller cities downstream discharging to the stream. Prior to major upgrades to the wastewater plants that serve the City of San Antonio, the stream routinely violated the drinking water standard of 10 mg/L nitrate nitrogen. Since the upgrade of the City of San Antonio's Dos Rios Wastewater plant and the installation of a major water reuse program that diverts a large portion of the city's wastewater effluent to industrial users, concentration of nitrate nitrogen in the San Antonio River has been reduced. However, the San Antonio River routinely discharges into the Guadalupe River with nitrate nitrogen levels above the screening criteria (1.1 mg/L). The nitrate nitrogen concentration upstream, in Segment 1803, ranged from 0.85 mg/L at the Guadalupe River at FM 766 in DeWitt County to 0.7 mg/L at the Hwy 59 Bridge in downstream of Victoria (very limited data set collected by USGS.)

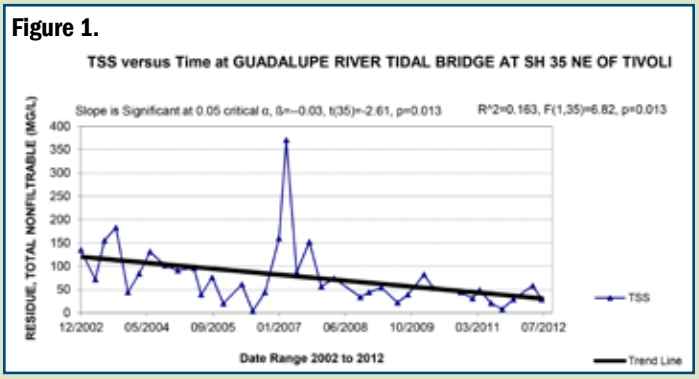
Despite the **total phosphorus** contributions from the San Antonio River, Segment 1801 never exceeded the screening concentration of 0.66 mg/L for total phosphorus in the 2012 Texas Water Quality Inventory. Improvements to the City of San Antonio's Dos Rios Wastewater plant and the installation of a major water reuse program that diverts the majority of the city's wastewater effluent to industrial users is no longer resulting in a significant decline in total phosphorus concentrations. The San Antonio River at Fannin has contributed a median of 0.92 mg/L of phosphorus over the period of record.

The median concentration of the **specific conductance** from 2003 through 2012 was 690 micromhos per centimeter (umhos/cm), ranging from 400 umhos/cm to 3550 umhos/cm. The largest conductance was recorded in Sepember of 2011 during extreme drought conditions. Higher conductivity results at this station during 2011 are most likely due to tidal influences, because the specific conductance contribution from the San Antonio River never exceeded 1690 umhos/cm.

The median **pH** was 7.9, ranging from 7.5 to 8.4. The temperature ranged from 8.9°C to 31.9°C, with a median **temperature** of 26.9°C. The **total suspended solids** ranged from 4 mg/L to 371 mg/L, with a median

concentration of 56 mg/L. TSS was the only parameter to show any significant trend within the last 10 years (Figure 1). **Ammonia nitrogen** did not exceed the screening concentration during the period of record. **Chloride** concentrations ranged from 29 mg/L to 908 mg/L, with a median concentration of 64 mg/L. **Sulfate** concentrations ranged from 25 mg/L to 191 mg/L, with a median concentration of 55 mg/L. Since 2001 this station has been monitored for Enterococcus bacteria. The concentration of Enterococcus only exceeded the stream standard one time.

Figure 1.



An environmental flows analysis as required by Senate Bill 3 was completed in 2012 in order to give the state a better idea of how to manage water rights and allocate adequate freshwater for endemic species habitat. The nationally endangered whooping crane spends the winter near the San Antonio Bay and the long term reduction in fresh water inflows due to upstream demands and wastewater reuse could impact the tidal stretches of the Guadalupe River and may result in a change to the habitat of these species. Log jams on the Guadalupe River tidal segment create impedances that force the rivers and streams in the segment to leave their channels and flow across property.

Guadalupe River Below the San Antonio River

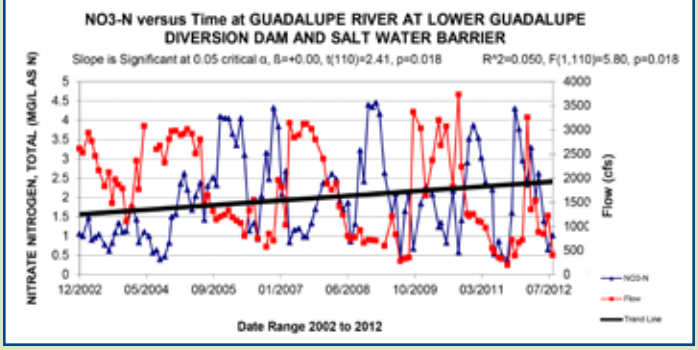
Segment 1802, **Guadalupe River below the San Antonio River**, is a 0.4 mile section of river that extends from the confluence of the Guadalupe River and the San Antonio River in Refugio County to 0.5 mile downstream of the Salt Water Barrier. In this stretch, the Guadalupe River is a slow moving coastal river that is characterized by log jams and fractured flow patterns. Currently, the flow from the San Antonio River is still entering the Guadalupe River through the old river channel, however, the majority of the flow appears to be passing through Elms Bayou, due to the log jams that have built up and created a diversion of the main flow. GBRA, along with other entities in the area, including the Refugio and Calhoun counties, the US Corp of Engineers, and NRCS, have been investigating this area to determine the extent of the changes in these flow patterns.

Segment 1802 is made up of one assessment unit. GBRA has one historical monitoring station in Segment 1802. The "Salt Water Barrier" site (GBRA SWB), station no. 12578, has been sampled monthly since 1987. The flow was recorded as gage height until the year 2000, where mean daily flow or instantaneous flow in cubic feet per second is now being recorded for each sampling event.

The segment was listed with concerns on the 2012 Texas Water Quality Inventory for **nitrate nitrogen**, with 39 out of 79 measurements exceeding the screening concentration of 1.95 mg/L. In the GBRA data set, the median concentration for nitrate nitrogen from 2003 through 2012 was 1.75 mg/L, ranging from 0.40 mg/L to 4.46 mg/L. As described in the summary for Segment 1801, Segment 1802 is also highly influenced by the contributions of the effluent-dominated San Antonio River during low flows. There is a significant increasing trend in nitrate nitrogen at the Guadalupe River at Salt Water Barrier station from 2003 to 2012 (Figure 2).

Figure 3 shows a decreasing trend in **total suspended solids**, similar to the downward trend seen in Segment 1801. The decreasing concentrations of TSS may be associated with an improvement in wastewater treatment in both watersheds over time, but this is most likely due to a

Figure 2.



significant increasing correlation with flow (Figure 4) and a significant decrease in overall flows in this segment during the past 10 years (Figure 5), resulting in less solids contributed from runoff. The median concentration of TSS was 61 mg/L, ranging from 16 to 398 mg/L.

The water quality at the GBRA SWB station was very similar to the TCEQ monitoring location at the Tidal Bridge in Segment 1801, since both are downstream of the San Antonio River, the largest influence to the water quality

Figure 3.

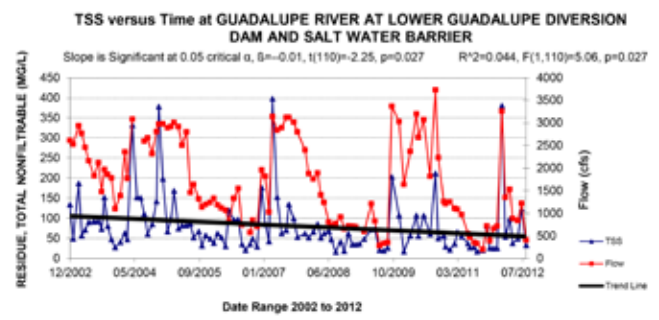


Figure 4.

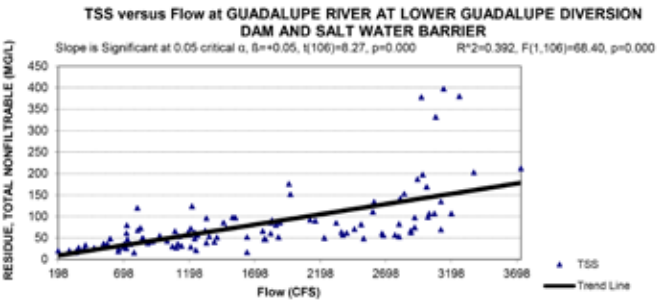
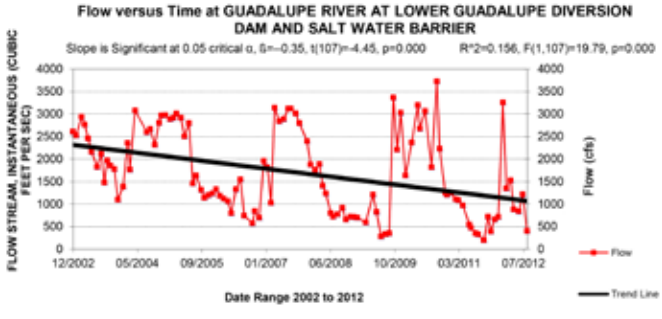


Figure 5.



in this portion of the river. The **temperature** ranged from 9.5°C to 32.2°C, with a median temperature of 24.4°C. The **pH** ranged from 7.5 to 8.9, with a median pH of 7.99. The **total phosphorus** had a median concentration of 0.28 mg/L, ranging from 0.05 mg/L to 0.71 mg/L. The **chloride** and **sulfate** concentrations had median concentrations of 62.3 mg/L and 55.4 mg/L, ranging from 19.1mg/L to 163 mg/L and 17.2 mg/L to 139 mg/L respectively.

The bacterial analysis of Segment 1802 utilized ***E. coli,*** but not enterococcus. The *E. coli* concentrations ranged from 4 MPN/100 ml to 3300 MPN org/100 mL, with higher concentrations correlated with higher flow events and a geometric mean of 80 MPN/100 mL from 2003 to 2012. The **chlorophyll *a*** ranged from less than method detection to 38.3 micrograms per liter (ug/L) exceeding the screening concentration of 14.1 ug/L 19 times out of 135 sampling events. There was no statistical correlation with flow.

No specific stakeholders concerns have been voiced at Clean Rivers Program meetings for Segment 1802 but issues that have been raised over the years include reduction in fresh water flows due to upstream demands and wastewater reuse, impacting the bay and estuary and threatening the habitat of the whooping crane, an endangered species that winters near San Antonio Bay, and log jams that create dams that force the rivers and streams in the segment to leave their channels and flow across property.

Guadalupe River below the confluence with the San Marcos River

The **Guadalupe River below the confluence with the San Marcos River**, Segment 1803, begins in Gonzales County, flowing downstream to the confluence with the San Antonio River in Refugio County. The river flows through Gonzales, DeWitt, Victoria, Refugio and Calhoun counties. This portion of the Guadalupe River is a slow-moving, coastal river with a silty substrate, and lined with pecan bottoms. Because of the change in elevation, the upper reaches of the Guadalupe River located in the hill country are shallow and turbulent. Conversely, the lower Guadalupe River flows through low hills and flat plains, with very little turbulence. Segment 1803 is subject to flooding during which the river often leaves its

Photo by Alvin Schuerg

banks and inundates the riparian areas along the river. While high flows during flooding events scour the inundated areas in the upper segments of the river, the flood waters in the lower basin, spread out over the land that is along the river, deposits silt and carries material such as logs downriver.

Segment 1803 is divided into five assessment units: the lower 25 miles (1803_01); from the confluence with the Coleto Creek 25 miles upstream (1803_02); from the confluence with the Sandies Creek upstream 25 miles (1803_03); from 25 miles upstream of the confluence with Coleto Creek to the confluence with Sandies Creek (1803_4); from 25 miles upstream of the confluence with Sandies Creek to the upper end of the segment (confluence with the San Marcos River) (1803_05).

GBRA has an historical station near Cuero ("FM 766"; station no. 12595) in Segment 1803. GBRA has monitored this station monthly since 1990. The FM 766 station is located in the assessment unit 1803_03, approximately at the halfway point down the segment. Also in Segment 1803, in assessment unit 1803_02, GBRA maintains a quarterly monitoring station upstream of the City of Victoria, near the community of Nursery. The station at Nursery (station no. 12590) has been monitored since late 1999. GBRA discontinued monitoring at a quarterly station on the Guadalupe located near the Invista (formerly I.E. Dupont deNemours, Inc.) in 2006. After reviewing the flow, it was determined that the sampling location was in the mixing zone of the industrial discharge and not representative of the flow and water quality of the segment. The station has not been replaced because of the lack of public access locations in the area. A station was added to the Guadalupe River at US 183 near Hochheim (station no. 20470) in September of 2008. The area downstream of the industrial plant is in large tracts of private land with no public access points. The next closest monitoring station was a station maintained in the early 1990s by the US Geological Survey located downstream of the City of Victoria at Hwy 59.

The land use in the upper portion of Segment 1803 is primarily agricultural, with row crops, pastures, hog, chicken and cattle operations. The cities of Gonzales and Cuero are located in the upper portion, both of which have wastewater plants that discharge into the segment. The City of Gonzales operates a wastewater facility that is permitted to discharge 1.5 million gallons per day (MGD), with limitations of 10 mg/L biochemical oxygen demand, 15 mg/L total suspended solids and utilizes ultraviolet light for disinfection of the effluent. The City of Cuero wastewater treatment plant is designed and permitted to treat 1.5 MGD. The facility has permit limitations of 20 mg/L biochemical oxygen demand and 20 mg/L total suspended solids. The City of Victoria is located further

downstream and is the largest city in the watershed, with a population of greater than 60,000. The city is served by two wastewater treatment plants. The Victoria Willow Street plant is designed and permitted to treat 2.5 MGD. The facility is a combination trickling filter/activated sludge facility, with permit limitations of 20 mg/L biochemical oxygen demand and 20 mg/L total suspended solids. The Victoria Regional plant is designed and permitted to treat 9.6 MGD. Its effluent limitations include 20 mg/L carbonaceous biochemical oxygen demand and 20 mg/L total suspended solids.

In addition to the municipal wastewater systems, there are industrial discharge permits issued in the segment. There are two power plants that serve the City of Victoria and surrounding area that use flow from the Guadalupe River as once-through cooling, discharging warm water back to the mainstem. The power plant located in the City of Victoria must monitor and record the daily maximum flow, temperature and rise in river temperature, along with river stage. The second facility is located upstream of the city and near the community of Nursery. Invista has discharge permits, in addition to injection wells and a wetlands area, that treat and dispose of different waste streams on their plant site.

There are two stations on Segment 1803 with sufficient historical data for trends analyses and review, the GBRA's monthly station near Cuero ("FM 766") and the GBRA station upstream of the City of Victoria near Nursery ("Nursery"). The Nursery station is only monitored quarterly and was established in late 1999. The USGS monitoring location at Hwy 59 downstream of Victoria has a very limited data set from the early to mid-90s. The data can be used for comparison to the upstream locations but not for trend analysis.

The median **flow** that was recorded during the historical monitoring from 2003 to 2012 at the FM 766 station in the upper portion of the segment was 952 cubic feet per second (cfs) and at Nursery, the median flow during sampling was 809 cfs. This difference in flow is not due to a loss in water but mostly due to difference in the size of the data sets. The **temperature** ranged from 9.4°C to 33.4°C, with a median temperature of 24.6 °C at the FM 766 station. The range of temperature measured at the Nursery station was similar, 11.1°C to 31.3°C, with a median temperature of 22.4°C. The median **pH** for the FM766 station was 8.1, and 8.0 at Nursery. Neither stations exceeded the stream standard range of 6.5 to 9.0. The **conductivity** at the FM766 station ranged from 266 umhos/cm to 691 umhos/cm, and ranged from 302 umhos/cm up to 688 umhos/cm, at the Nursery station, with medians of 540 umhos/cm and 569 umhos/cm respectively. Both stations show a significant decline in stream flow over the past 10 years (Figure 6 & Figure 7). The entire watershed was impacted by extreme drought conditions in 2011 and 2012. The pH at both stations appears to be increasing along with the changes in stream flow (Figure 8 & Figure 9).

There is very little change in nutrient concentrations between the two stations. The Nursery station never exceeded the screening concentration for **ammonia nitrogen** of 0.33 mg/L, and the FM 766 only exceeded the screening criteria one time in May of 2012 (0.36 mg/L). Overall ammonia nitrogen levels appear to be increasing at both stations, but this is most likely due to a change in

Figure 6.

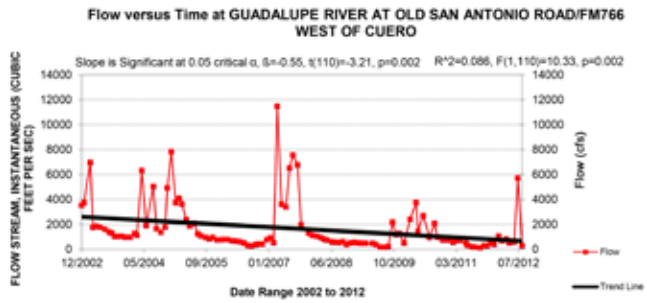
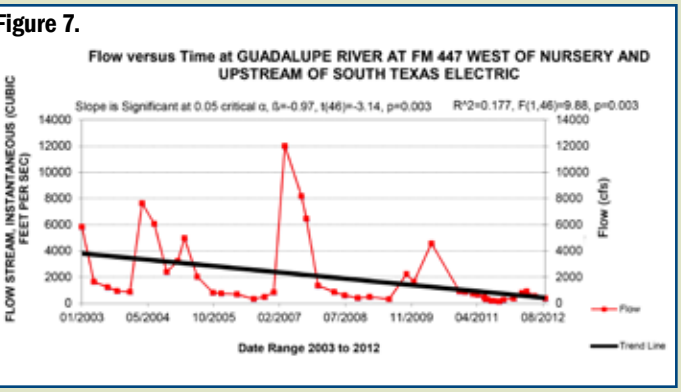


Figure 7.



the Limit of Quantification (LOQ) of the analysis from 0.02 mg/L to 0.10 mg/L in September of 2007. The median concentration for **nitrate nitrogen** was 0.78 mg/L at the FM 766 station and 0.73 mg/L at the Nursery station. Neither station exceeded the nitrate screening criteria of 1.95 mg/L during the assessment period. There is very little correlation of nitrate concentration with flow.

Total phosphorus has a positive correlation with higher flows at the FM 766 station as seen in Figure 10. The source of the total phosphorus is most likely the suspended material that is carried in during high runoff events. To support this likelihood, Figure 10 shows the statistical correlation between Total Phosphorus and flow at the FM 766 station and Figure 11 shows the correlation between TSS and flow at the FM 766 station. The suspended material is made up of sediment and organic material which contains phosphorus, in the form of inorganic phosphates that are added to the fields as fertilizer and organic phosphorus, bound in plant material and soil. The same relationships are seen at the Nursery station as well.

The median total phosphorus is 0.08 mg/L at both the FM 766 and the Nursery monitoring station. The median **total suspended solids** concentration at the FM 766 station was 29.1 mg/L, ranging from 6.0 mg/L to 2010 mg/L. The Nursery station had a median concentration of 35.4 mg/L, ranging from 8.3 mg/L to 948 mg/L.

An increase in stream flow has the opposite effect on dissolved constituents, diluting the natural background concentrations of chloride and sulfate. The median concentrations of **chloride** at the FM 766 station was 28.7 mg/L, ranging from 7.2 mg/L to 45.1 mg/L, and never exceeded the stream standard of 100 mg/L. The median concentration for **sulfate** at the FM 766 station was 31.8 mg/L, ranging from 12.6 mg/L to 45.8 mg/L and never exceeded the stream standard of 50 mg/L. The concentrations for these dissolved constituents were similar at the Nursery station.

The ***E. coli*** geometric mean at the FM766 station was 54 MPN/100 mL. The *E. coli* geometric mean at the Nursery station was slightly higher, at 115 MPN/100 mL.

Figure 8.

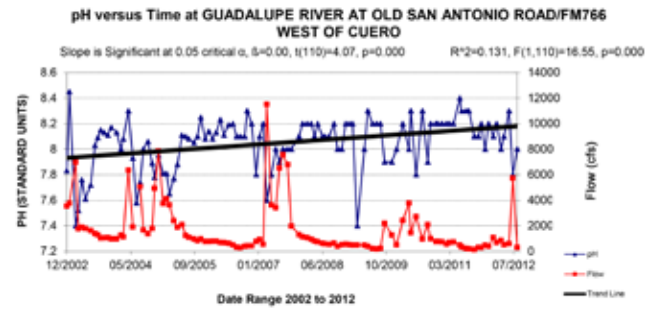


Figure 9.

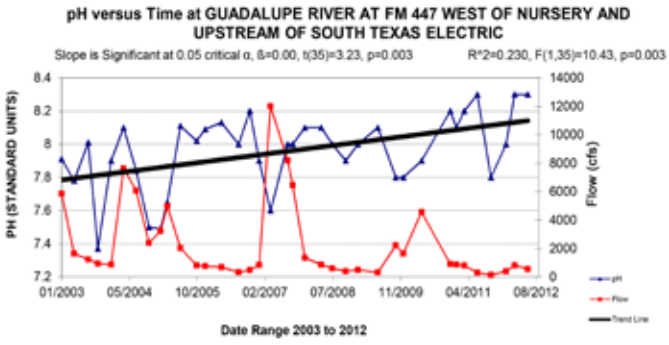


Figure 10.

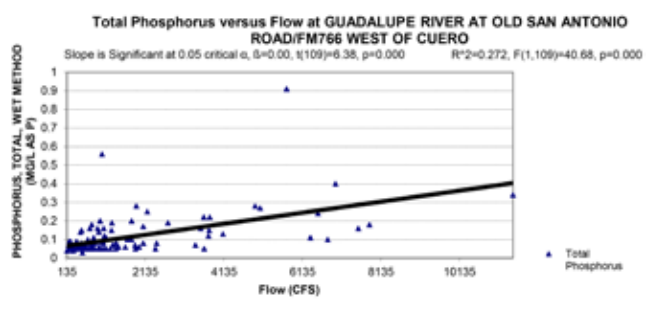
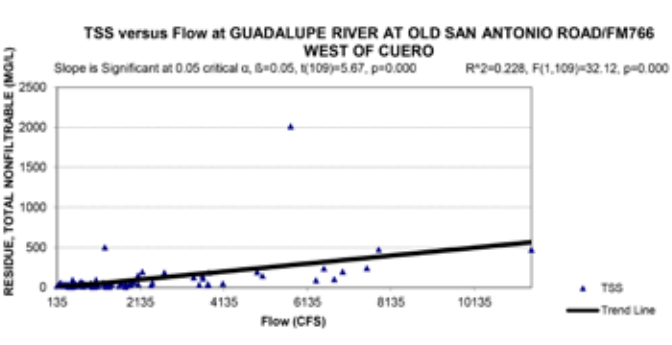


Figure 11.



Lower Guadalupe River Watershed

River Segments, Descriptions and Concerns

The difference between stations is most likely due to the differences in the size of the two data sets and the larger drainage area of the Nursery station and not due to a consistent source of bacteria. Median **chlorophyll *a*** concentrations at the FM 766 and Nursery monitoring stations were 2.9 ug/L and 3.1 ug/L respectively. The ranges differed slightly, with higher concentrations occurring at the FM 766 station. The station exceeded the 14.1 ug/L screening concentration for chlorophyll *a* 3 out of 111 measurements. The Nursery station did not exceed the screening concentration in the period of assessment. As with other constituents monitored the differences between stations are most likely due to the smaller size of the data set.

Stakeholder concerns in this segment include impacts of poultry operations, primarily in the Sandies and Elm Creek watersheds; impacts from bacterial and nutrient contributions from nonpoint source runoff, ranging from small cow/calf operations to confined animal feed lots; potential for spills and leaks from the many chemical pipelines that cross the river; impacts from in-situ uranium mining; long-term drought effects and, impacts of endocrine disrupting chemicals associated with agricultural

operations, such as synthetic growth hormones and antibiotics, as well as those that fall in the group of chemicals referred to as "personal care products", such as lotions, pain relievers and insect repellents. This area of the watershed has also seen the greatest development of oil and natural gas extraction from the Eagle Ford shale deposits in the area through hydraulic fracturing technology. Some stakeholders have expressed concern about potential impacts to ground and surface water due to the development of these resources. Hydraulic fracturing activities on the Eagle Ford shale began in 2010 and more data will need to be collected in order to assess any long term impacts. The bacterial impairments on Sandies and Elm Creeks were being investigated in the total maximum daily load project that finished data collection in 2008. This TMDL was never finalized due to stakeholder concerns about appropriate contact recreational use designation.

The potential for spills and leaks is difficult to address. TCEQ regional offices are responsible for responding to spills, as well as the Texas Parks and Wildlife Department's Spills and Kills Team. Specific to the Guadalupe Basin, GBRA sends letters each year to the fire and emergency management offices of each county, requesting that GBRA be notified if there is spill or leak response required in their county. Our field crew will respond in order to offer assistance in monitoring the stream, to provide historical water quality information as well as gather current information that can be relayed to operations and water users downstream of the spill and to keep the events inventory up to date for future reference. In-situ uranium mining is discussed in the section on the Coleto Creek watershed, Segment 1807.

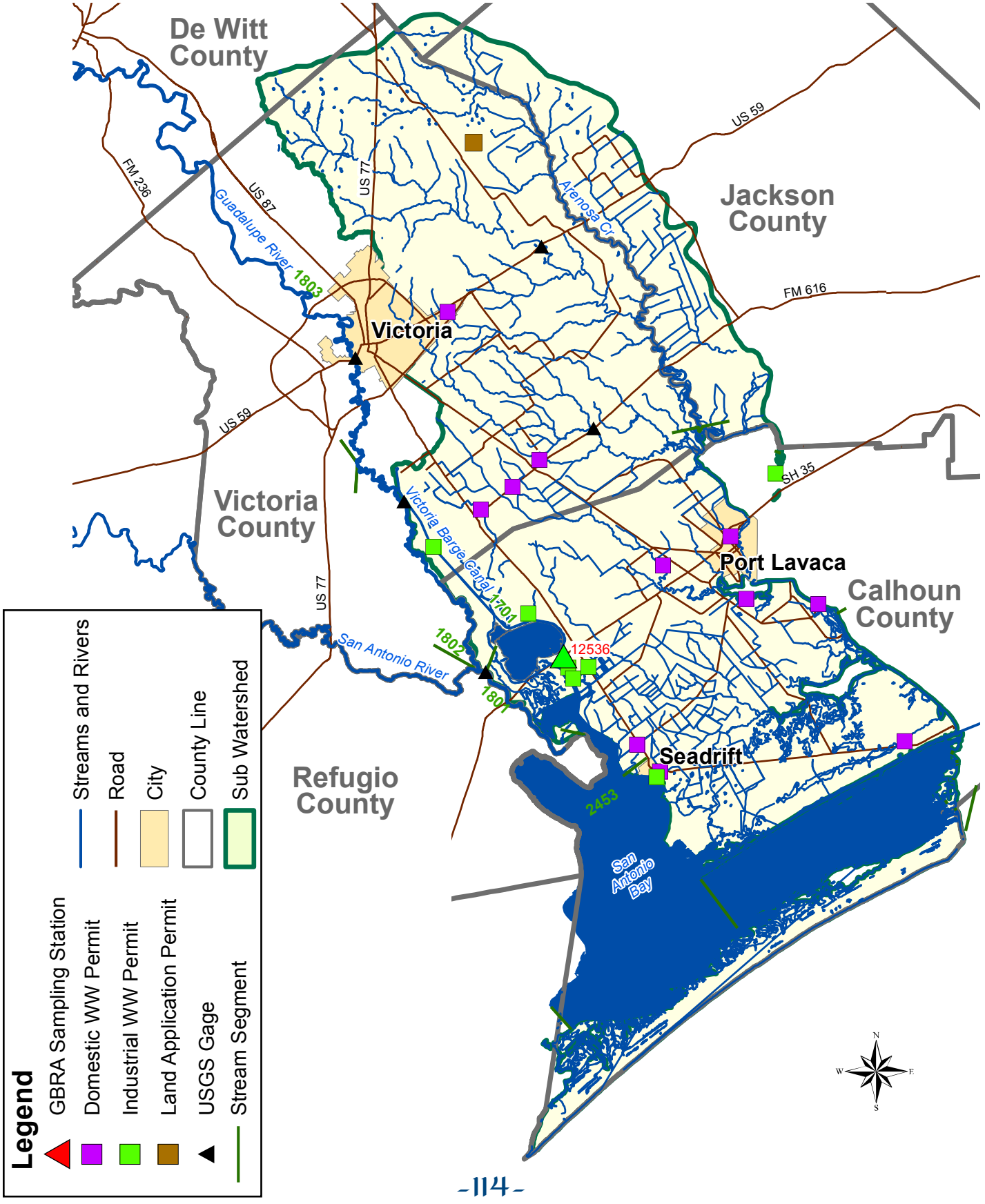
Investigation into the potential for endocrine disrupting chemicals in the watershed is very costly and there are very few laboratories available to analyze for that large suite of compounds. As technology improves, the compounds are more easily detected, but there is little known as to what concentrations in surface water should raise a red flag. In the future, CRP and GBRA will discuss the need for these analyses and whether the funding for those analyses is available.

Photo by Connie Rothe

Lower Guadalupe River Issues and Concerns

Water Quality Issue	Affected Area	Possible Influences/Concerns	Possible Actions Taken/to be Taken
Exceedence of Chlorophyll *a* screening criteria	Victoria Barge Canal	Wastewater discharges	Continued monitoring
Exceedence of nitrate nitrogen screening criteria			

Lavaca-Guadalupe Coastal Basin



Lavaca-Guadalupe Coastal Basin

River Segments, Descriptions and Concerns

Segment 1701 *(Victoria Barge Canal): From the Victoria Turning Basin in Victoria County to the confluence with San Antonio Bay in Calhoun County.*

Drainage Area: 998 square miles

Streams and Rivers: Guadalupe River, Garcitas Creek, Victoria Barge Canal, Marcado Creek, Arenosa Creek

Aquifer: Gulf Coast

River Segments: 1701

Cities: Victoria, Seadrift, Bloomington, Inez, Port O'Connor, Port Lavaca

Counties: Calhoun, Victoria, Jackson

EcoRegion: Gulf Coastal Plains

Vegetation Cover: Pasture/Hay 15.1%, Shrublands 16.9%, Row Crops 21.4%, Grass/ Herbaceous 13.7%, Deciduous Forest 8.4%, Wetlands 17.2%

Climate: Average annual rainfall 42 inches, Average annual temperature January 44°, July 93°

Land Uses: Agriculture row crops (cotton, corn, rice and grain sorghum), urban, recreation, oil and gas production, cattle, hog and poultry production and industry (plastics, chemicals, petrochemicals)

Water Body Uses: Aquatic life, non-contact recreation, fish consumption and industrial cooling

Soils: Clay subsoils, deep black soil, sandy clay, dark clay loam, clay

Permitted Wastewater Treatment Facilities: Domestic 11, Land Application 1, Industrial 7

Photo by Janet Thome

Lavaca-Guadalupe Coastal Basin

Segment 1701, the **Victoria Barge Canal**, extends from the turning basin downstream to the confluence with the San Antonio Bay. The TCEQ Region 14 has one monitoring location in the Barge Canal. The station has been monitored from 2003 to 2012. The regional office crew monitored the station quarterly.

The barge canal is used by industries for both barge traffic and waste discharge. Several industries, such as Union Carbide and BP Chemical, discharge permitted waste to the water body. The water body has been listed with concern for nitrate nitrogen and chlorophyll a concentrations. The designated use is listed as non-recreational. The impairment for aquatic life support because of dissolved oxygen concentrations was lifted after diurnal monitoring collected additional data and showed sufficient dissolved oxygen to support aquatic life use.

Field parameters were collected over the period of record, and through the water column, at depths of 0.3 meter (m) through 5 m. The following table shows the median values for each field parameter by depth, measured over the period of record:

The canal is brackish, uniform in pH, temperature and dissolved oxygen through the water column, some density stratification from surface to bottom.

Conventional parameters were collected at the surface, within 0.3 m. The **total suspended solids** ranged from 4 milligrams per liter (mg/L) to 93 mg/L, with a median concentration of 30 mg/L.

The 2012 Texas Water Quality Inventory listed the barge canal with concerns for chlorophyll *a* and nitrate nitrogen. The **nitrate nitrogen** concentrations ranged between 0.05 mg/L to 1.04 mg/L, with a median concentration of 0.20 mg/L. The screening concentration for nitrate nitrogen in estuarine environments is 0.66 mg/L.

The Victoria Barge Canal exceeded this screening concentration 14 times out of 26 measurements. The **ammonia nitrogen** concentrations ranged from below the Limit of Quantification (LOQ) to 0.30 mg/L, with a median concentration of 0.05 mg/L. The station exceeded the screening criteria 2 times. **Total phosphorus** concentrations ranged from 0.05 to 0.30 mg/L, with a median concentration of 0.17 mg/L. From 2003 to 2012 there is very little change in the phosphorus concentrations and no significant trend is indicating a degrading water quality. **Chlorophyll *a*** concentrations ranged from below the LOQ to 56.1 micrograms per liter. Three measurements fell outside the screening concentration of 14.4 micrograms per liter.

No stakeholders have voiced concerns with the Barge Canal. General concerns for water quality and the impact of barge traffic, chemical pipelines and industrial discharge quality would apply.

Median Values For Each Field Parameter by Depth Measured Over the Period of Record

Depth	Conductivity	pH	Dissolved Oxygen	Temperature	Salinity
0.3 m (surface)	6930	7.8	8.1	27.6	4.0
0.31 - 1.0 m	6230	7.7	8.0	27.5	3.4
1.1 - 2.0 m	6480	6.9	8.0	27.2	3.6
2.1 - 3.0 m	4200	8.0	8.3	25.0	3.5
31.0 - 5.0 m	2570	7.3	8.3	28.0	1.4

Inventory of Events
January - December 2012

Event	Segment	Comments
Ban the Can	1811, 1804	The ordinance adopted by the city of New Braunfels that established a ban on disposable containers was in place over the 2012 recreational season and there has been a noticable difference in the amount of trash that floats down to the hydroelectric lake downstream of the city. The ordinance imposes a $500 fine on any disposable food or beverage container used on the Comal River or the portions of the Guadalupe River that flows through the city.
Habitat Conservation Plan signed by USFW	1811, 1808, 1804	After more than seven years and rigorous negotiations between 26 stakeholders and a dedicated program manager, the U.S. Fish and Wildlife Service has approved the Edwards Aquifer Recovery Implementation Program (EARIP) Habitat Conservation Plan (HCP) and issued an incidental take permit under the Endangered Species Act to protect most users of aquifer water. The EARIP process began in 2006 with an "ad hoc" effort and progressed in 2007 with the passage of Senate Bill 3, Article 12, by the Texas Legislature. The efforts of those 26 stakeholders and another 60 participants resulted in the Edwards Aquifer HCP designed to protect endangered species that depend on spring flow emanating from the Edwards Aquifer springs.
BBASC Work Plan Submitted	All	The Work Plan for Adaptive Mangement from the Guadalupe, San Antonio, Mission and Aransas Rivers and Mission, Copano, Aransas, and San Antonio Bays Basin and Bay Stakeholder Committee (BBASC) was submitted to TCEQ on May 25, 2012. The work plan followed the submittal of an environmental flow analyses and a recommended environmental flow regime for the river basin and bay system completed in 2011. The work plan is a comprehensive list of study efforts and activities that will provide additional information for future environmental flow rule-making as well as expand knowledge on the ecosystems of the rivers and bays within our basin.
Drought Persists	All	Drought conditions across the river basin continue to persist in 2012.
Hydraulic Fracturing in the Eagle Ford Shale in DeWitt and Gonzales Counties	1803	The Eagle Ford Shale in DeWitt and Gonzales Counties continues to be one of the richest oil and gas deposits in the U.S. The exploration technology of hydraulic fracturing is used to recover oil and gas deposits. Concerns about the impacts of these operations continue to be raised. These concerns include potential for contamination of groundwater by fracking fluids and drilling activities, spills, that could enter the surface water resources and demand on the stressed water resources of the area.
Meadows Center for Water and the Environment	All	Texas State University - San Marcos established the Meadows Center for Water and the Environment, formerly the River Systems Institute, as a leadership initiative to coordinate and further university-wide efforts in the field of aquatic resource management. The Meadows Center started out as the International Institute for Sustainable Water Resources in January 2002, and was renamed the River Systems Institute in 2005.

Inventory of Events
January - December 2012

Event	Segment	Comments
Cypress Creek Watershed Protection Plan	1815	Phase II of the Cypress Creek Project is being facilitated by the Meadows Center for Water and the Environment. The main goal for the Cypress Creek Project is to ensure that the long-term integrity and sustainability of the Cypress Creek Watershed is preserved and that water quality standards are maintained for present and future generations.
Upper San Marcos, Sink Lake and Sink Creek Project	1814	The Upper San Marcos River is included on the 2012 Texas Water Quality Inventory and 303(d) list due to elevated concentrations of total dissolved solids (TDS). This project will develop a WPP for the San Marcos River to reduce TDS in the river, and also proactively address concerns related to bacteria, nutrients and sediment in the river and in Spring Lake. The project is being facilitated by the Meadows Center for Water and the Environment.
Texas Instream Flow Program to Begin in 2013	1803, 1804	The Texas Instream Flow program was created in 2001 by the state legislature to study Texas rivers and streams in an effort to determine the amount of water required to maintain a healthy river (sound ecological environment). The study on the Lower Guadalupe River will begin in 2013, and end in December 2016.
GBRA Funds Environmental Flow Study in Mid-Basin	1803	GBRA is funding a study to characterize the flow-habitat and flow-ecological relationships in this reach to provide a means of assessing biological impacts or benefits of various flow regimes relative to the Mid-Basin project. The study is being conducted on the Gonzales reach, the Lower Guadalupe River below confluence with the San Marcos River to near the City of Cuero. The study will be concluded in 2014.
UGRA Bacteria Reduction Plan	1806	In the second year of the grant from TCEQ, the groundwork has been laid for implementing numerous bacteria reduction strategies and UGRA is coordinating with the City of Kerrville, TXDOT, and Kerr County to put those strategies in place. The strategies will address the primary souces of bacteria pollution that have been identified in the Guadalupe River in Kerrville including birds nesting on the SH16 bridge, large flocks of domestic waterfowl congregating on the lakes, septic systems and pollution from general urban runoff. The ultimate goal of the project is to reduce the bacteria levels in the Guadalupe River to a concentration that does not represent a health risk to swimmers and will allow this segment to be removed from the impaired water body list. Construction of the bird deterrents on the SH16 bridge in Kerrville was completed in January 2013.
Kyle WWTP Spill	1810	Aqua-TX reported a spill of at least 100,000 gallons of partially treated sewage containing solids from a final clarifier into Plum Creek from the Kyle WWTP on November 21, 2012. TCEQ and TPWD investigations continue.

Inventory of Events

January - December 2012

Event	Segment	Comments
City of Buda and Hays County Partner to Remove Failing Septic Systems and Treat at City's WWTP	1810	The City of Buda and Hays County have partnered to submit an application for the planning and design of the Hillside Terrace Project through the Texas State Revolving Fund Loan Forgiveness Program. The project will design a collection system and lift station to remove over 260 homes off of failing septic systems and process the wastewater at the City of Buda's WWTP. Due to the economic status of Hillside Terrace residents, the project qualified for 70% loan forgiveness (highest available). This area was identified in the Plum Creek Watershed Protection Plan as a potential source of E. coli bacteria in the creek.
Feral Hog Task Force to form in Caldwell, County	1810	Caldwell County, landowners, SH130 and others have formed a task force to control populations of feral hogs in the county. Feral hogs have established themselves across Texas and pose a variety of challenges, including direct depositon of bacteria; streambank destabilization; agricultural damage; predation of livestock, pets and wildlife; transmission of disease and parasites; and environmental damage to both urban and rural environments.
Geronimo and Alligator Creeks Watershed Protection Plan Accepted by EPA	1804A	The WPP was accepted by EPA on September 13, 2012 as meeting their guidance requirements for watershed protection plans. It is only the third WPP developed for Texas waters that has this designation. Since that time, implementation of the WPP has been underway. All implementation activities are voluntary, and are dependent upon a combination of factors such as stakeholder participation, financial and technical resources, and political will.

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Guadalupe-Blanco River Authority

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