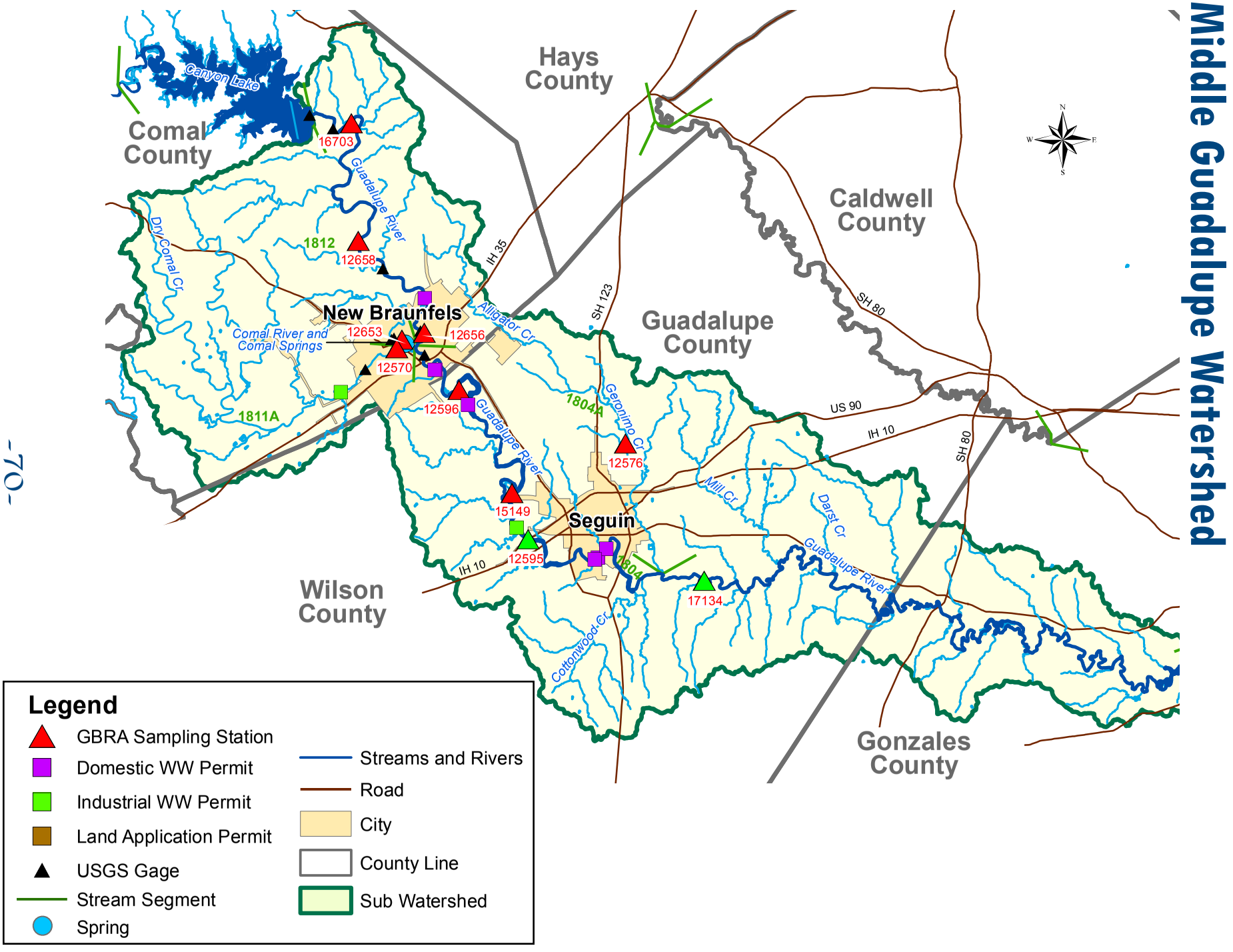
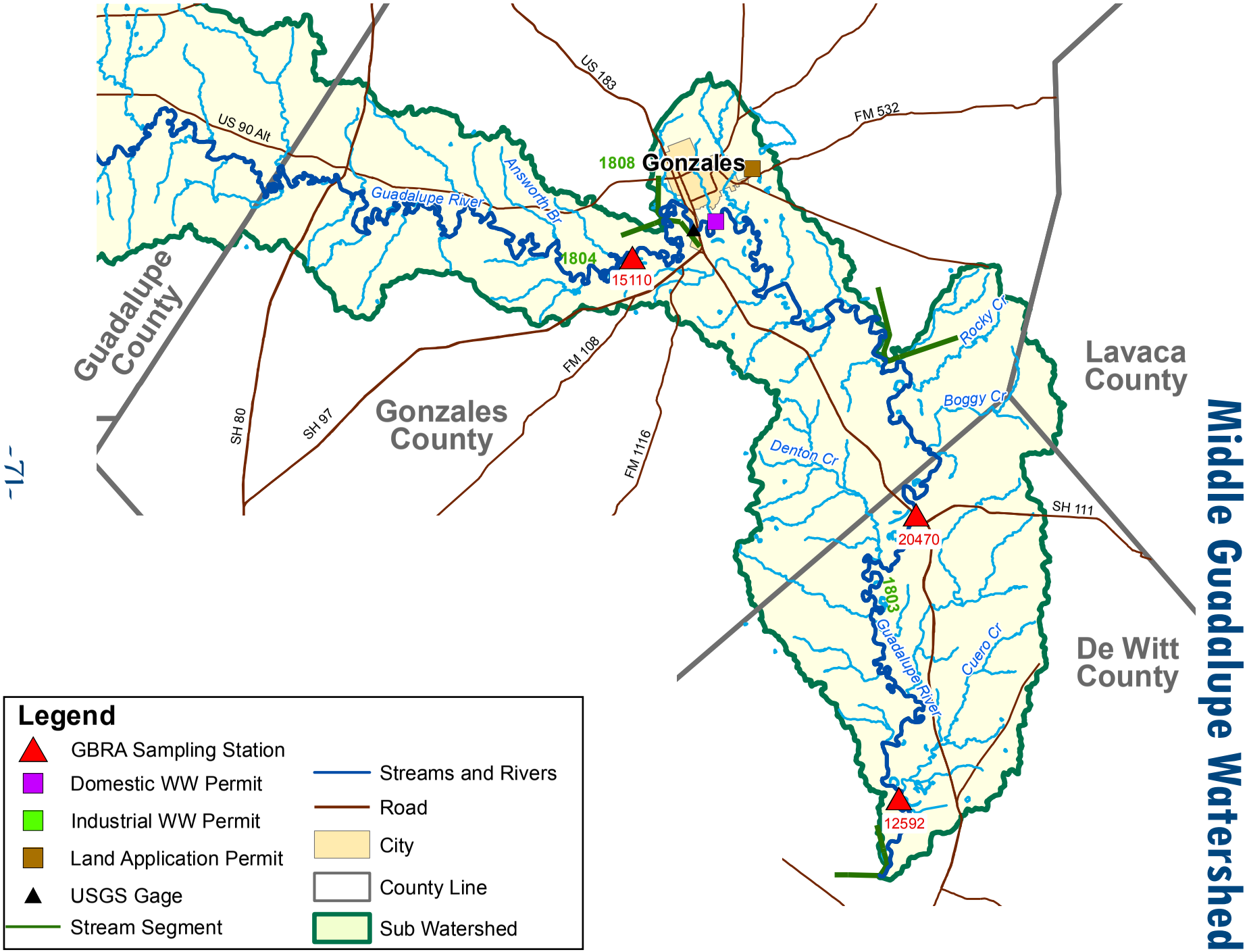

Middle Guadalupe Watershed
Canyon Lake
Comal County
Hays County
Caldwell County
Guadalupe County
Wilson County
Gonzales County
16703
Guadalupe River
Dry Comal Cr
1812
12658
IH 35
New Braunfels
Comal River and Comal Springs
12653
12656
12570
Alligator Cr
SH 123
SH 80
1811A
12596
1804A
Geronimo Cr
12576
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.

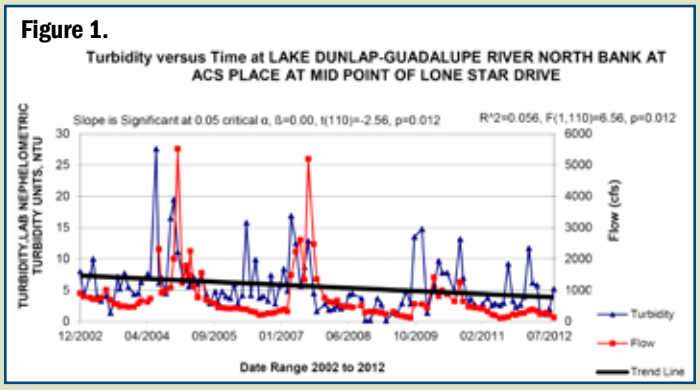


Figure 2.

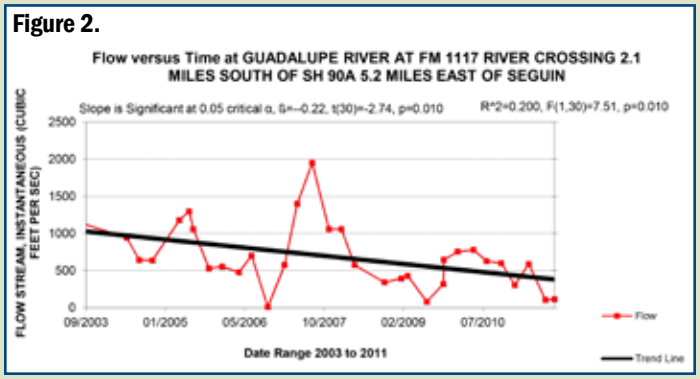
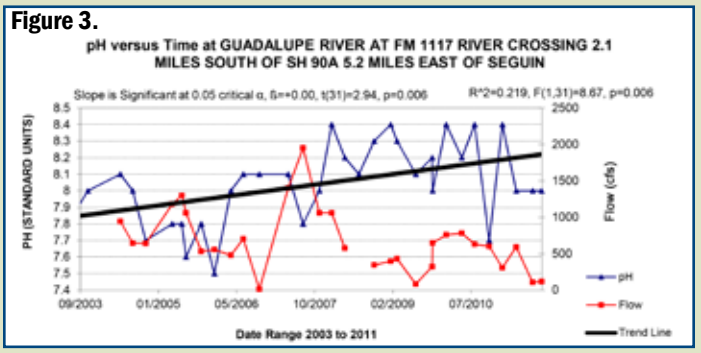


Figure 3.



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.

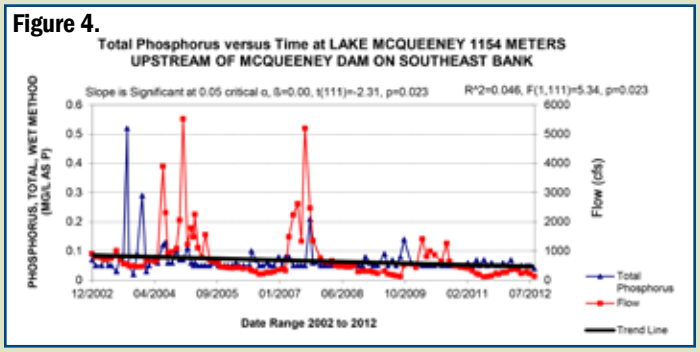
Photo by Willi Carville

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.

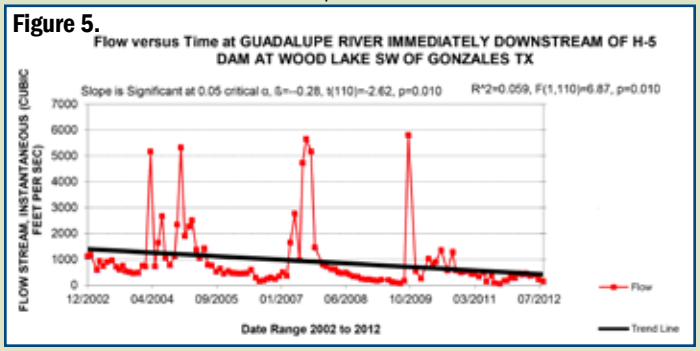


Figure 6.

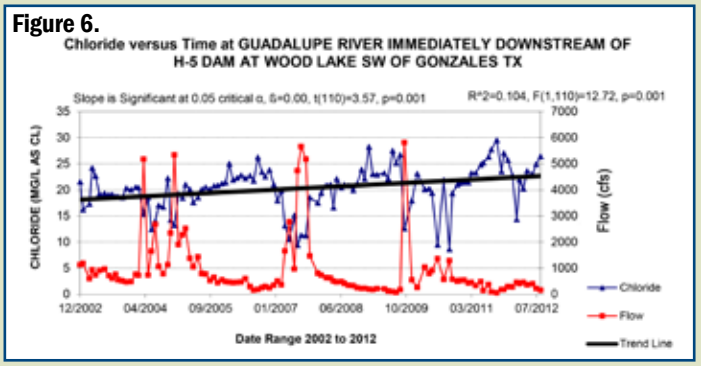
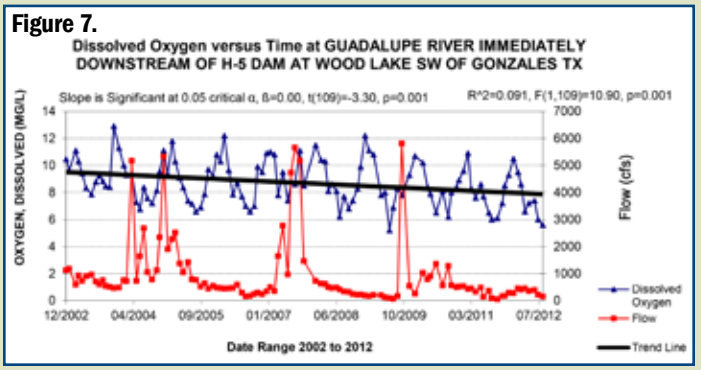


Figure 7.



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.

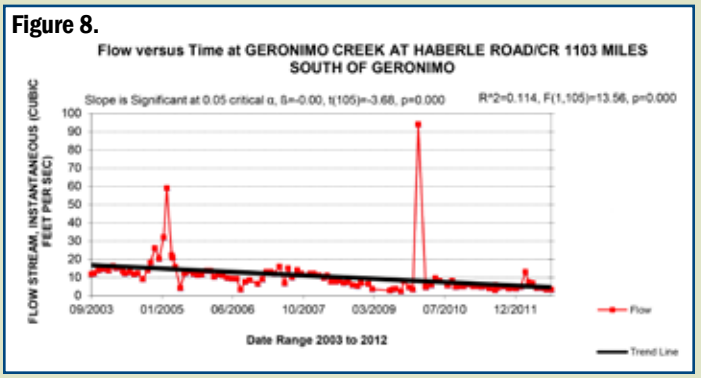
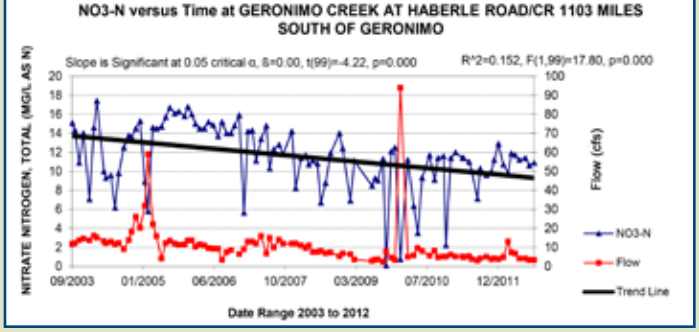


Photo by Lee Gudgell

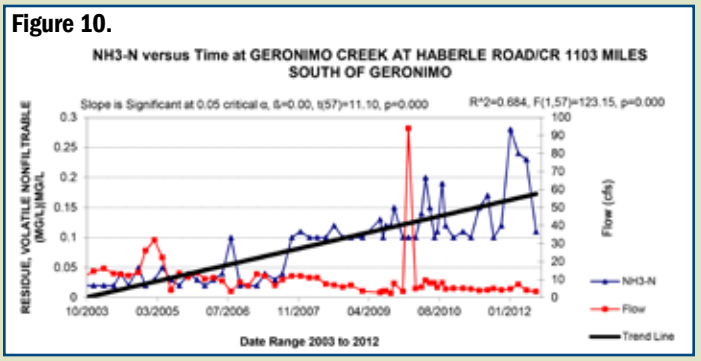
The **nitrate nitrogen** concentrations for Geronimo Creek have significantly declined over the past 10 years (Figure 9). In the 101 data points collected, nitrates ranged from 0.1 to 17.4 mg/L with a median of 11.6 mg/L. Most of the low nitrate values occurred during high flow events that diluted the 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

Middle Guadalupe River Watershed

River Segments, Descriptions and Concerns

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.

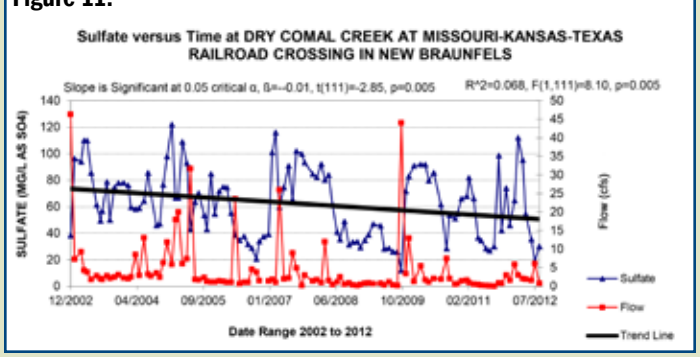


Figure 12.

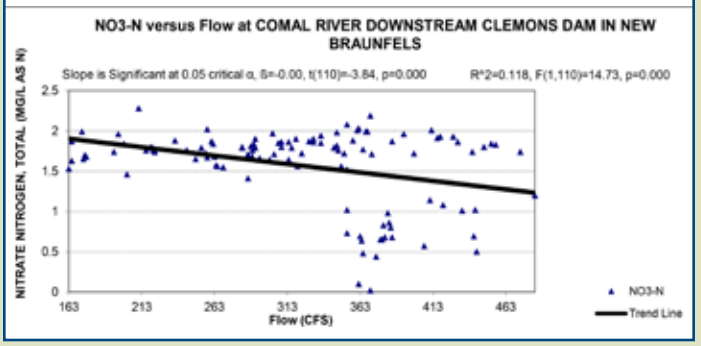
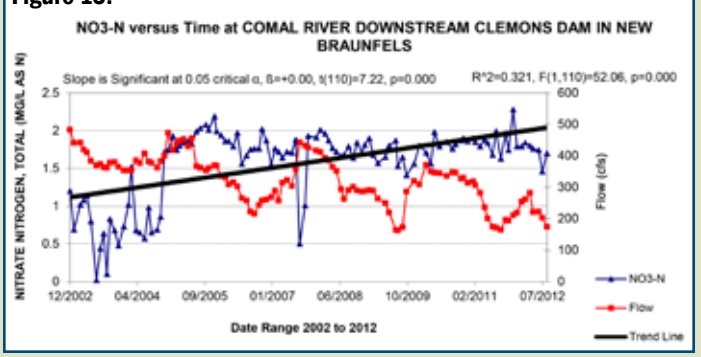


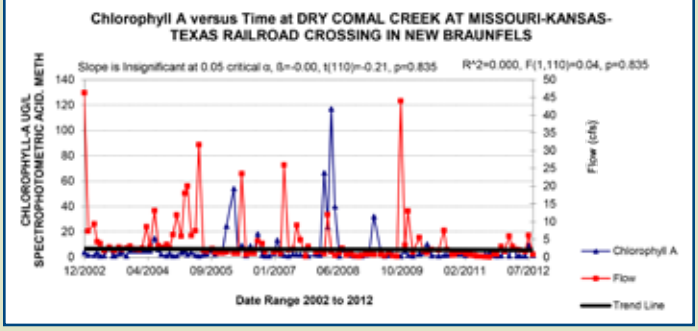
Figure 13.



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.

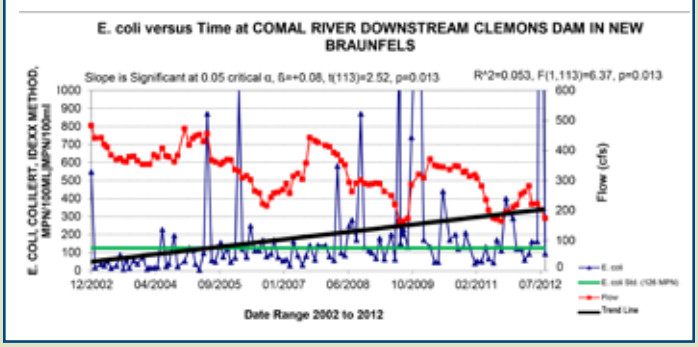
Figure 14.



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.

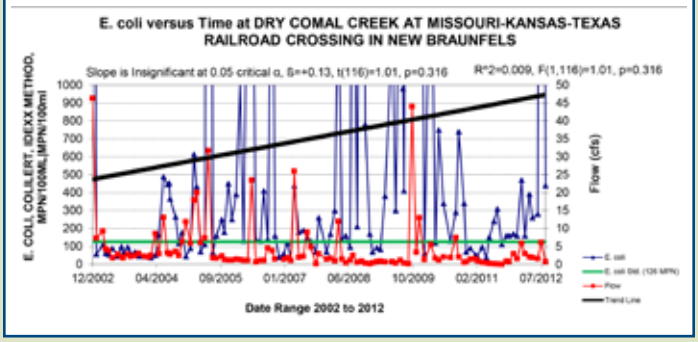
Figure 15.



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.

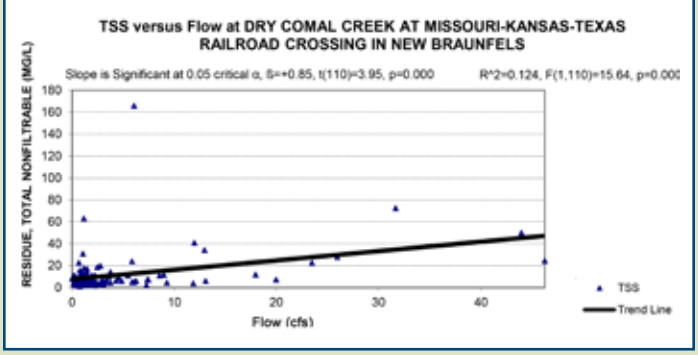
The **total dissolved solids** in the Comal River ranged from 233 mg/L to 444 mg/L, with a median of 364 mg/L, and ranged from 144 mg/L to 725 mg/L, with a median of 439 mg/L for the Dry Comal Creek. The mean concentration of total dissolved solids in the Dry Comal Creek is slightly

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