I'M FOR THE Hill Country

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The Upper Guadalupe River: Stewarding a Hill Country Icon

Prepared for
The Guadalupe River Association

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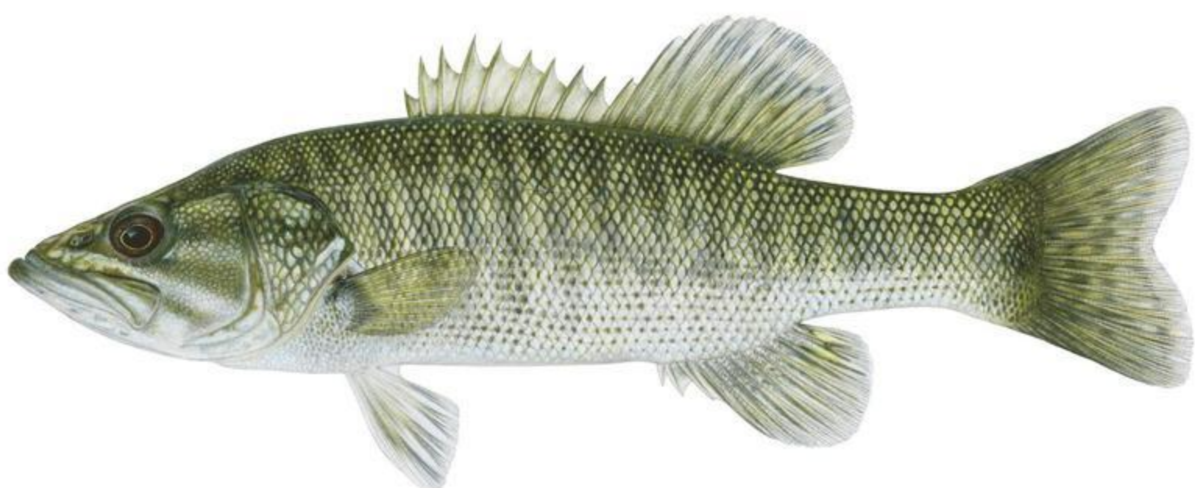
Summary

The Upper Guadalupe River is one of the iconic rivers of the Texas Hill Country, originating from an aquifer underlying the eastern Edwards Plateau, and cutting canyons for 187 miles through rolling limestone hills. Before eventually reaching the confines of Canyon Dam in central Comal County the Upper Guadalupe drains nearly 1,427 square miles of seven counties. For millennia, the river has provided dependable quantities of clean water for fish, game, and humans.

This report summarizes research and stewardship efforts in the Upper Guadalupe River basin. Understanding the river's unique characteristics, the diverse land uses that take place within the basin, and the wide variety of stakeholders interested in its long-term sustainability will inform future efforts to protect its economic and ecologic vitality. There are a variety of organizations, agencies, business, and individuals invested in the future health and protection of the Upper Guadalupe River. Coordinating efforts between these groups will ensure efficiency, enhance community outreach and education efforts, and improve our overall understanding of the river.

This report first summarizes some of the physical, geological, hydrological, ecological, historical, cultural, and demographic characteristics of the Upper Guadalupe basin and its stakeholders. It is sourced from a variety of programmatic reports and scientific journal articles that have been written about the river and the wider Edwards Plateau region. The review goes on to list research needs, challenges to the health of the river, and opportunities for collaboration. Existing and ongoing efforts are then summarized with a list of organizations and agencies that are actively working within the basin.



Guadalupe Bass (Micropterus treculii) Illustration by Joe Tomelleri

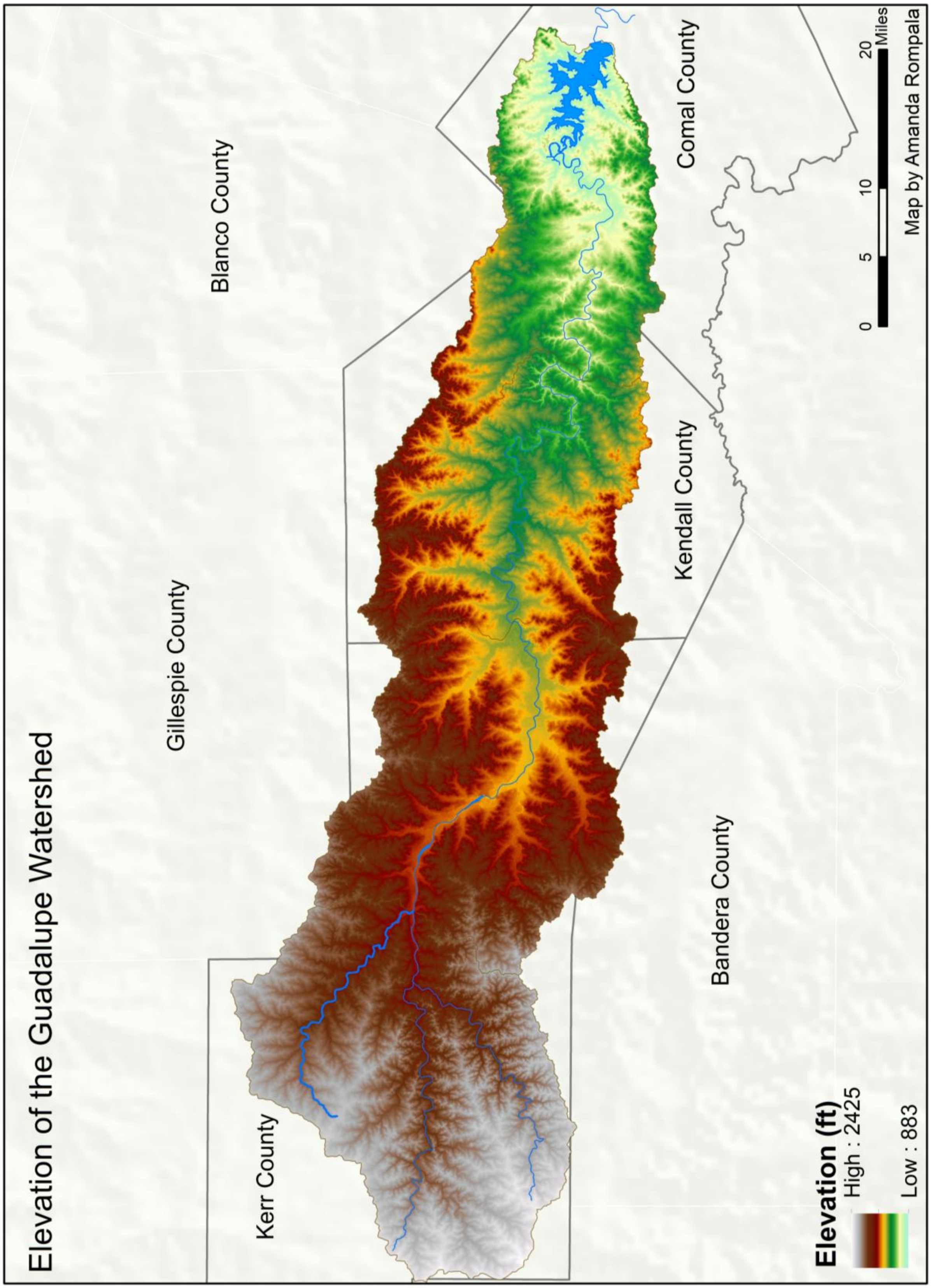


Figure 1: Topographic Map of the Upper Guadalupe River

Table of Contents

Introduction

The Texas Hill Country's iconic Upper Guadalupe River flows from its headwaters to Canyon Lake providing economic benefits through enhanced property values, sport fishing, recreation opportunities, and municipal, agricultural, and wildlife water supplies. Those benefits are dependent on reliable river flow and high-quality water.

The Guadalupe River is considered by many to be Texas's most scenic waterway. The tourism industry values the Guadalupe for its cool blue waters and natural settings; cities along its course use its clean water supplies, and fish and wildlife depend on its reliable flow. As the Guadalupe wanders through mostly rural sections of the Hill Country, it provides excellent habitat for wildlife and humans alike.

Understanding the river is crucial to protecting its ability to provide a high-quality habitat and this report is meant to identify and inform urban and rural stakeholders of its capabilities, limitations, and requirements for a sustainable future.

Currently along this stretch of river, scientific data gathering including base-flow, gain/loss measurements, peak flow, and water quality are valuable, yet insufficient to tell the full story of recharge features, springs, threats to water quantity, sources of water quality degradation and priority conservation areas. The Guadalupe River Association has recognized a need to identify basic hydrologic data gaps, and to expand opportunities for constructive collaboration on the Upper Guadalupe River basin as defined from its uppermost reaches to Canyon Lake.

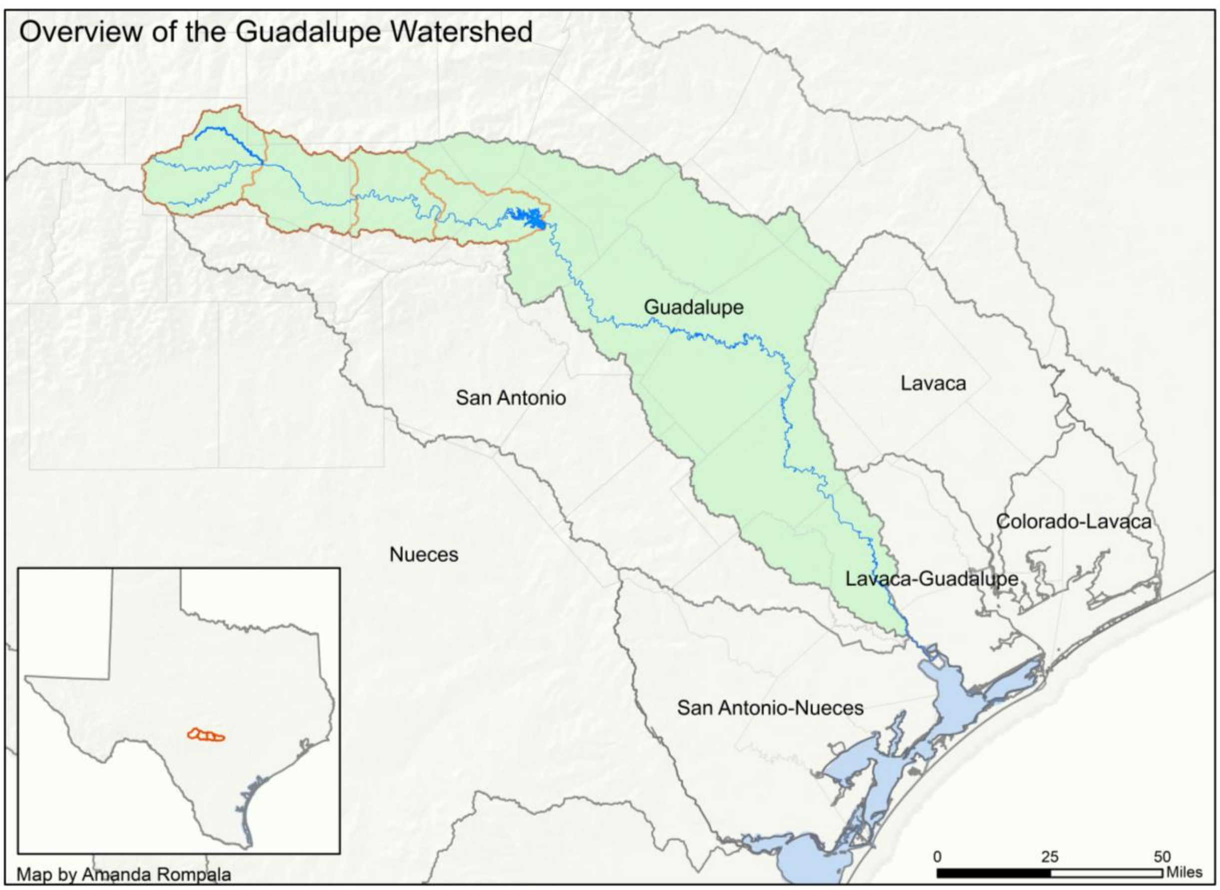


Figure 2: Overview of Guadalupe basin from headwaters to bay

Natural and Cultural History

The name Guadalupe, or Nuestra Señora de Guadalupe, was applied to the river in 1689 when the stream was named by Alonso De León. The artifacts that have been found in the Guadalupe River valley, suggest that the area has supported human habitation for several thousand years. The peoples encountered by early explorers belonged to the indigenous Tonkawa, Waco, Lipan Apache, and Karankawa tribes. These early inhabitants were gradually displaced by settlers from Mexico, Europe, and the United States (Smyrl 2017).

Early written accounts of the Upper Guadalupe River basin come from the 17th century when Spanish explorers were just beginning to enter the area. For the most part, those explorers chose to stay out of the Hill Country region because of heavy “brushwood” found at the edges of the hills in what is now Comal County, and to avoid conflicts with resident Native Americans (Weniger 1984).

By the early-19th century, scouts and German settlers were making their way deeper into the Guadalupe River basin establishing permanent settlements and towns. These early pioneers sent accounts of thick cedar (Ashe Juniper) and oak forested valleys in the uplands of the basin. Jean Louis Berlandier described what he saw in the Guadalupe basin near present day Hunt in 1828: “The forests are very heavy. There is an abundance of cedar and various oaks scattered about in groupings...we went out... to survey the cedar forest to the east...” (Nelle, 2012).

“Pre-1860 eyewitness accounts provide compelling evidence that the Hill Country of Texas was not predominantly open grassland prior to European settlement as is widely believed. The Hill Country did contain areas of open grassland, but these were in combination with large areas of savanna, shrubland, woodland and forest. The landscape was complex and diverse, not uniform or homogeneous. The arrangement of different soils and topography, mixed with the pruning effects of fire, resulted in what can only be called a dynamic mosaic of many vegetation types. There is ample evidence from history that the mosaic of the Hill Country was predominantly wooded” (Nelle, 2012).

Geography

The Upper Guadalupe River flows through three counties and its basin covers an area of approximately 1,427 square miles (913,280 acres) of the Texas Hill Country. It flows in a roughly easterly direction beginning in far-western Kerr County, through Kendall County and into Comal County. The basin’s maximum elevation is 2,424 feet above sea level (MSL), and the lowest is 822 feet MSL giving it a relief of 1,602 feet over its 187 river-mile length. The north-western side of the drainage basin is approximately 2 miles west of the point where Kerr, Kimble, and Gillespie Counties meet. The far western extent of the basin meets the western boundary of Kerr County at the Real County line.

The basin occupies the majority of Kerr and Kendall Counties with the exception of the far northern and southern portions of those counties, and most of the northwestern portion of Comal County. Additionally, the basin covers approximately 33 square miles of the southwest corner of Gillespie County, a smaller portion of northern Bandera County, and about three square miles of the southernmost point of Blanco County (USGS 1982).

Figure 3a: Headwaters to Comfort administered by the Upper Guadalupe River Authority (GBRA 2017)

For administrative and water quality testing purposes, the Upper Guadalupe River basin is divided into eastern and western halves. The western half begins at the Real-Kerr County line as a series of springs and seeps, and terminates at the downstream edge of Comfort Texas [Figure 3a]. The Guadalupe's North and South Fork tributaries join at Hunt to form the main channel of the Guadalupe and are then joined at Ingram by the north-south oriented Johnson Creek. Low water crossings and low dams create a series of pools from Hunt, and Mountain Home through the downstream portion of Kerrville before the river begins to run free again. The eastern half begins east of Comfort with a boundary at Canyon Dam [Figure 3b].

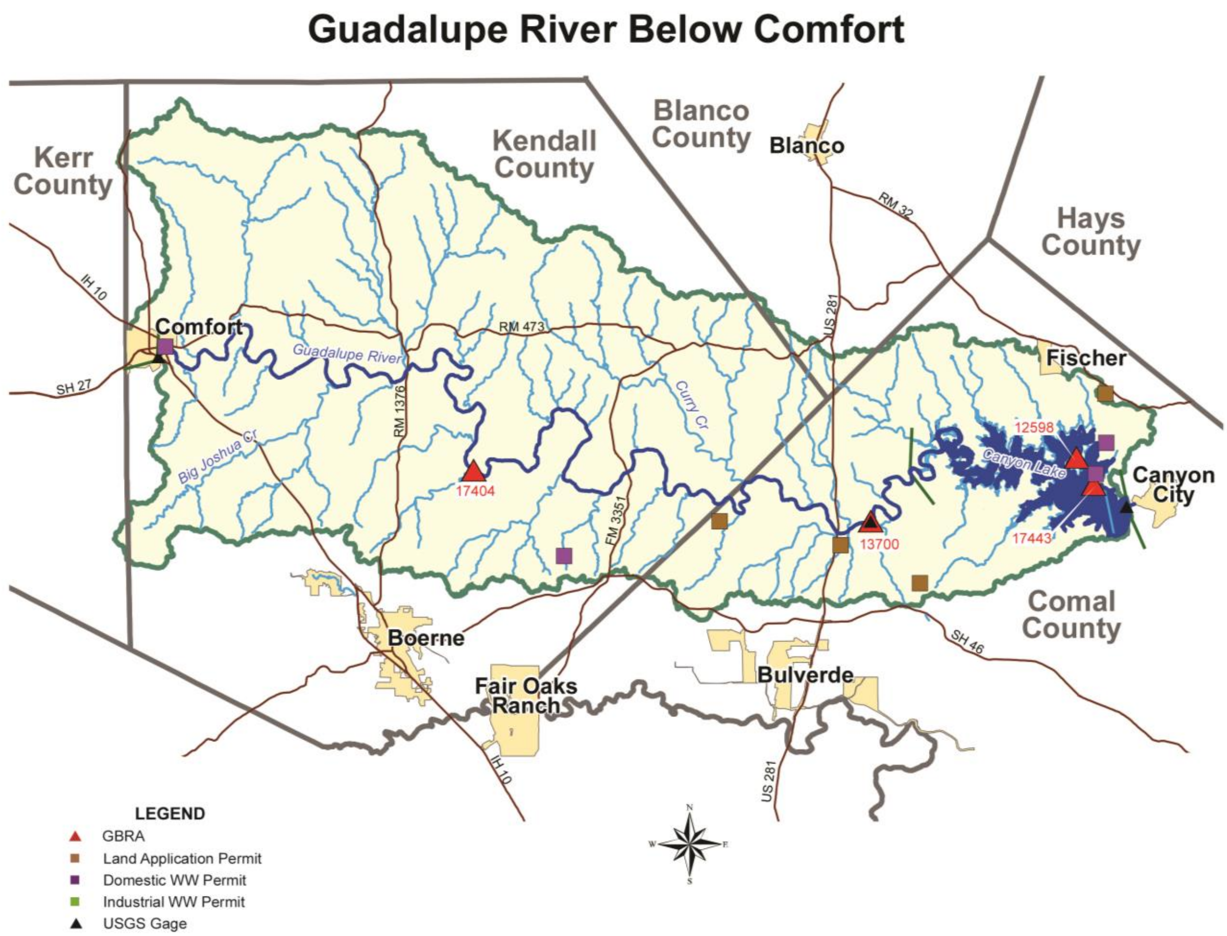


Figure 3b: Comfort to Canyon Dam administered by the Guadalupe Blanco River Authority (GBRA 2017)

Geology, Topography, and Hydrology

"Best known as the Hill Country, the Edwards Plateau is more than scenic hills west of IH-35. Wholly contained within the Texas borders, at a crossroads of arid grasslands, woodlands, and brushlands, its habitats are supported by unique geohydrology. Geology and hydrology are two of the greatest influences in this region on wildlife and fish distribution, rarity, and endemism." (TPWD 2012)

The underlying geology of the Edwards Plateau region is essential to informing our understanding of how the Upper Guadalupe basin functions. Geology determines the creation of soil, the resulting character and structure of plant life, the rate and nature of erosion, ground water recharge processes, and many other characteristics of the drainage basin (Lopes and Oliver 2008).

The Upper Guadalupe River basin sits atop both major [Figure 5] and minor [Figure 6] underground aquifers. Major aquifers are defined by the Texas Water Development Board as those that supply a large quantity of water in large areas of the state (Ashworth and Hopkins 1995). The major aquifers include the cretaceous strata forming the Edwards, Lower Trinity, Middle Trinity, and Upper Trinity and supply all of the groundwater to the river basin [Figure 4] (USGS 2017).

The horizontally layered limestone beds that underlie the central Texas Hill Country were formed in the Lower Cretaceous period (65-145 million years ago) when much of Texas was intermittently covered by shallow inland seas. The limestone beds and canyon-lands that define the physical geography of the region were created through gradual dissolution and erosion [Figure 4] (Stricklin and others 1971).

These limestone bedding layers are of varying degrees of permeability and constitute the many strata of two major aquifers. The younger Edwards Aquifer sits on top of the older Trinity Aquifer. Though there is some leakage between the two through faulting, they are generally separated by impermeable layers of rock (Barker et. al. 1994).

Below the Cretaceous layer lie older Paleozoic strata, which were fractured during tectonic activity 200 million years ago. In some areas, particularly in the higher western elevations of the basin, the Cretaceous layers have been dissected by erosion and solution to reveal the more highly fractured and irregular Paleozoic rock (Lopes and Oliver 2008). Paleozoic sandstone aquifers within the basin include from oldest to youngest, the Hickory and the Ellenburger-San Saba and currently supply no known water wells (USGS 2017).

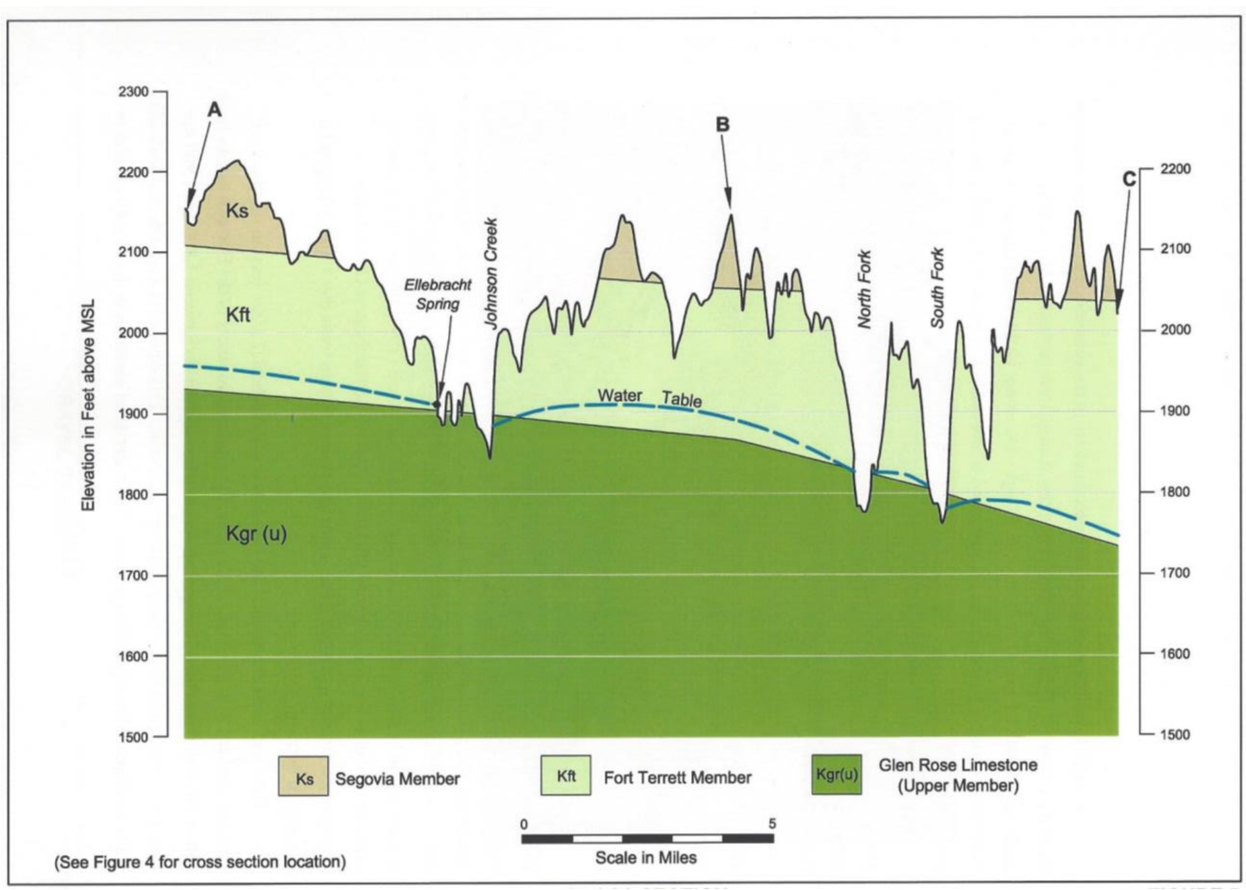


Figure 4: Bisect of Edwards and Trinity Strata (Ashworth 2005)

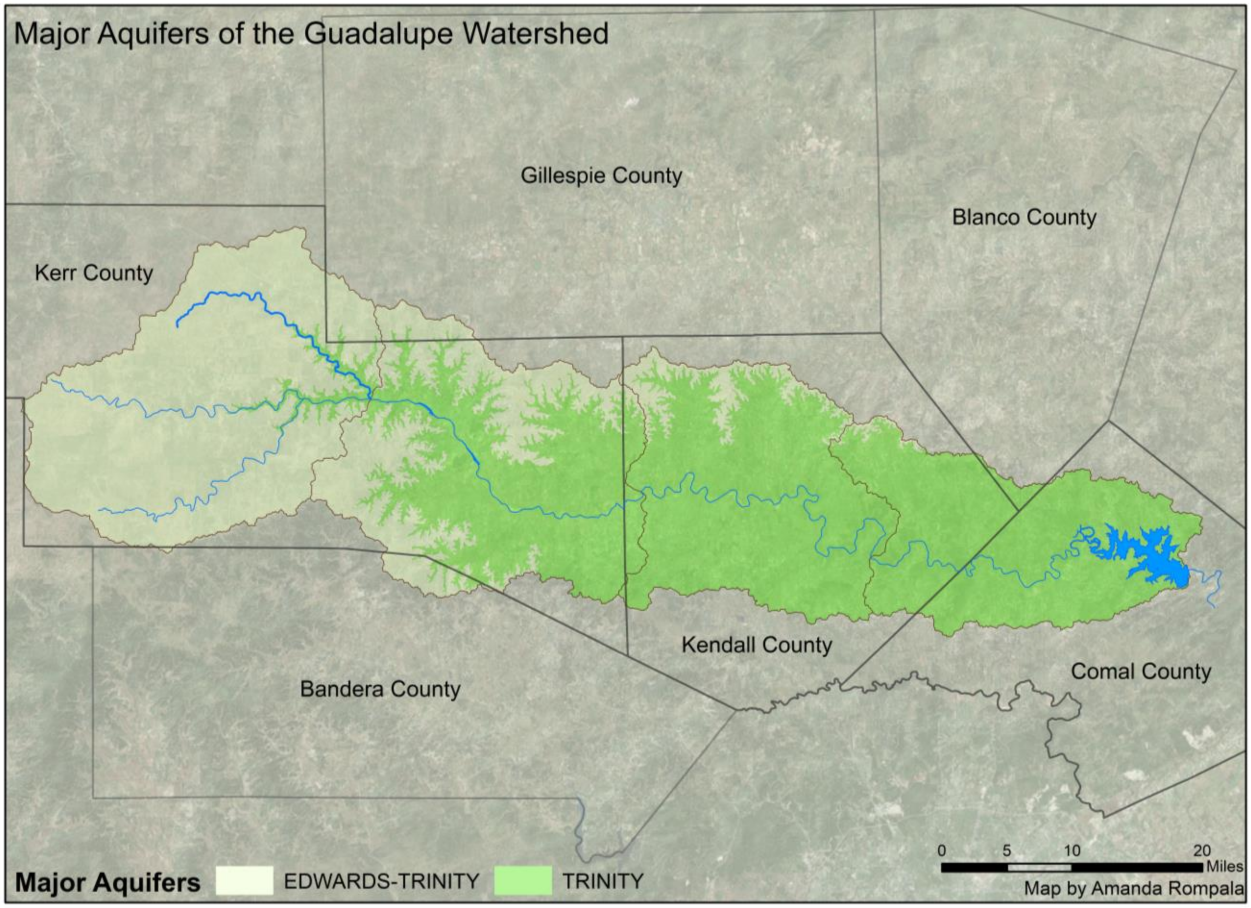


Figure 5: Major Aquifers of the Upper Guadalupe Basin

The Edwards Plateau erodes into the valleys of the Texas Hill Country. The topography is hilly with elevations from 600 feet MSL to more than 2,500 feet MSL and is commonly incised by streams. Soils are mostly shallow, underlain by limestone, cemented alluvials, or caliche. Typical land use is grazing ranchland, open woodland (Anderson, 1970).

The soil profile of the canyon-lands that is not dominated by limestone outcrop generally consists of thin clay layers on steep slopes in the uplands, more developed soils in the bottom-lands, and rock, gravel, and sand in river and stream beds. (Wilson 2008)

Soil composition and steep slopes in concert with periodic heavy rainfall [Table 1] are conducive to flash-flood events. The records indicate regular disastrous events in the basin. Flash flooding is a threat in all sectors of the Hill Country and heavy losses of life and property are frequent enough to warrant extreme caution during high volume rain events especially in the spring and fall months.

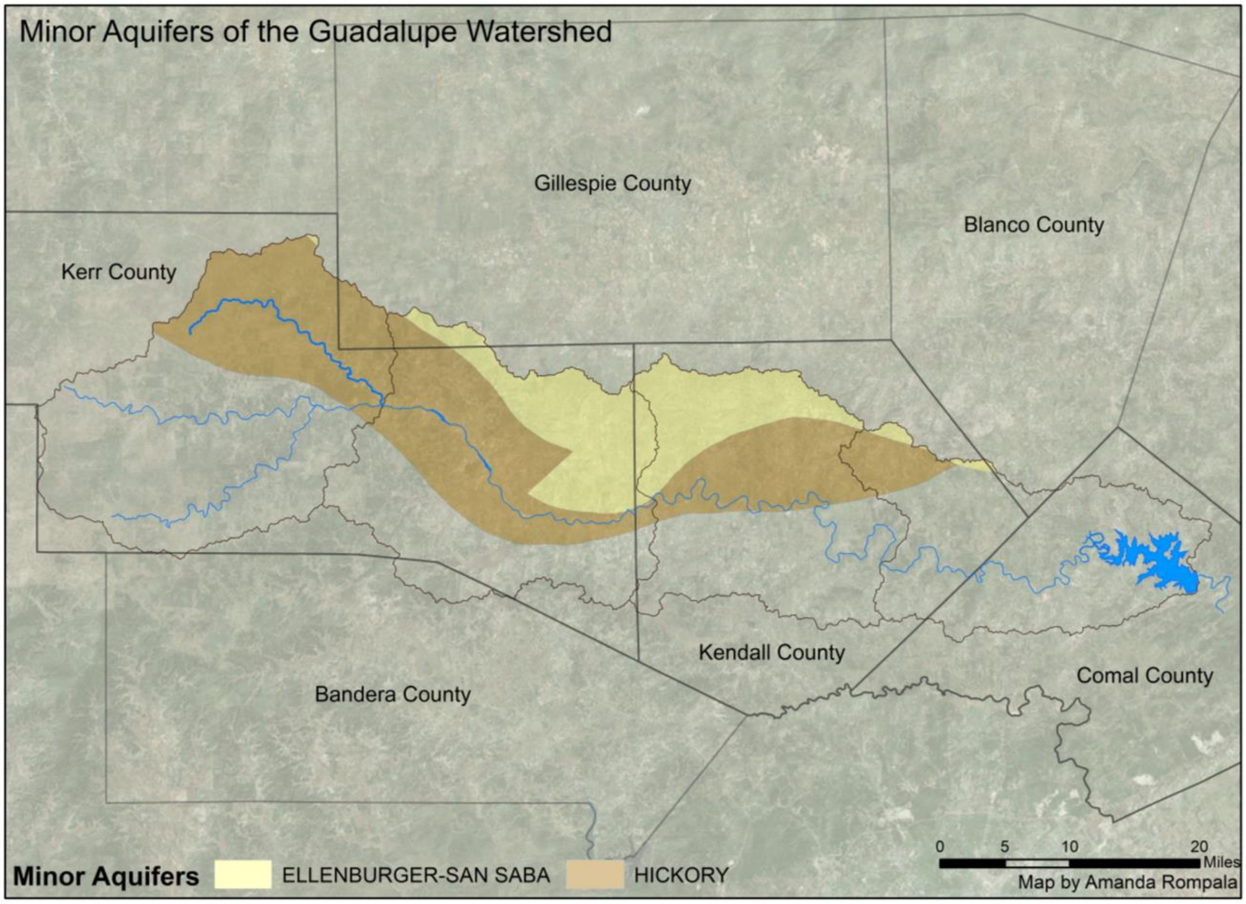


Figure 6: Minor Aquifers of the Upper Guadalupe Basin

Table 1: Historic Daily Maximum Precipitation by County (USGS 2016)

Kerrville Municipal Airport, Kerr County	
August 2, 1978	15.2 in.
May 29, 2016	10.02 in.
June 23, 1965	8.25 in.
July 23, 1909	8.2 in.
July 17, 1987	8.2 in
Boerne Stage Field, Kendall County	
October 2, 1913	9.04 in.
June 22, 1997	8.93 in.
September 10, 1952	7.41 in.
May 24, 2015	7.33 in.
August 17, 2007	7.33 in.
Spring Branch, Comal County	
October 17-18, 1998	33 in.
March 11, 2007	12.7 in.
October 31, 2013	11.75 in.
June 9, 2010	11.3 in.

Climate

The climate of the Upper Guadalupe River basin is subtropical, with hot and dry summers. The basin's mean annual temperature is 65 degrees Fahrenheit, the average summertime highs are in the upper 90s and wintertime highs are in the low 60s (CH2M Hill 1992). The region is prone to drought, with major rainfall events clustered in the spring and fall. An in-depth analysis of precipitation patterns conducted by the Meadows Center for Water and the Environment[1] revealed that precipitation falls in the Hill Country at an extremely localized spatial scale – meaning that areas within relatively close proximity can see very different rainfall totals (Lopes and Oliver 2008). Annual rainfall averages range from 27-inches in the western highlands, to 36-inches in the eastern basin [Figure 7] (NRCS 2010). The evaporation rate is almost twice the rainfall totals in the basin (Wilson 2008)

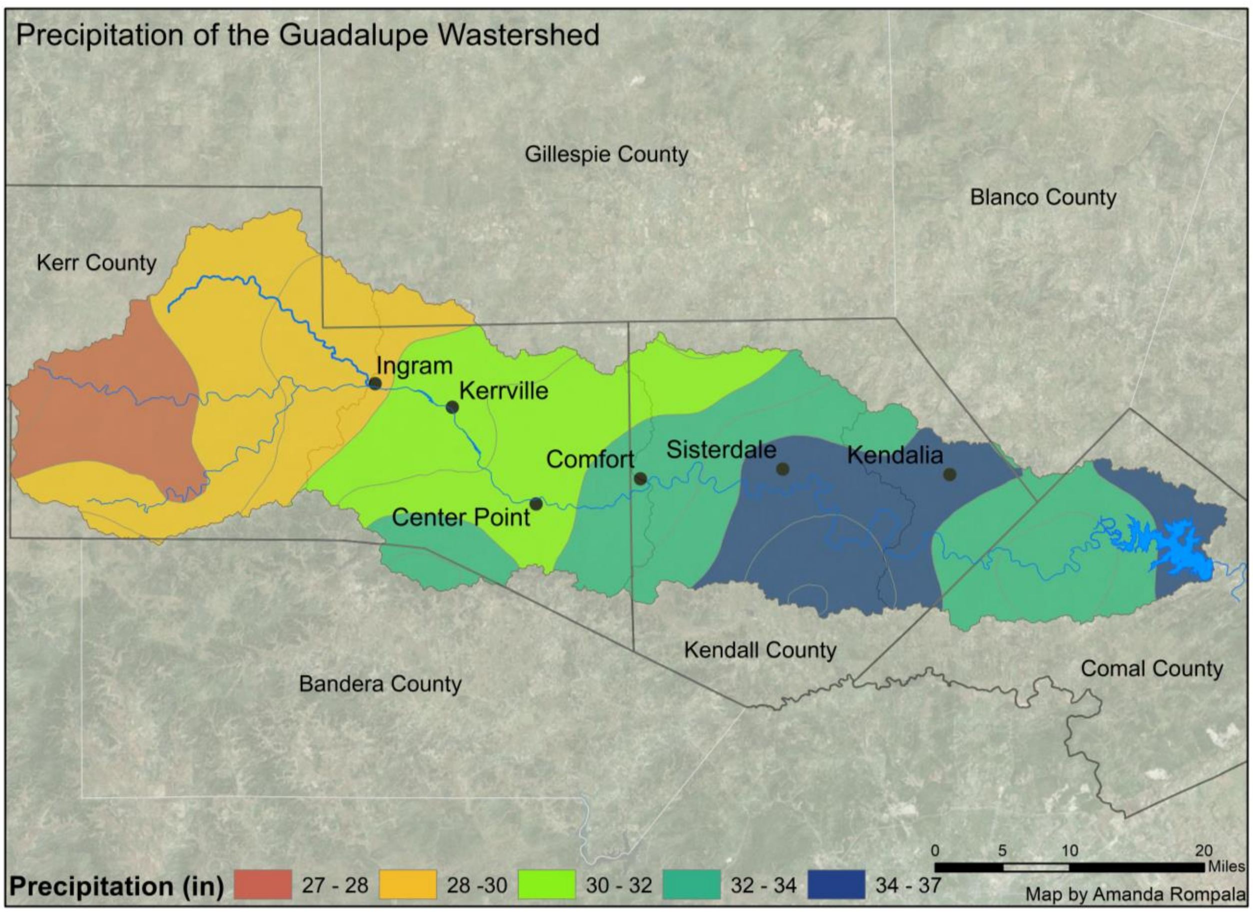


Figure 7: Average Annual Rainfall Totals in the Upper Guadalupe Basin

[1] Formerly called the Rivers Systems Institute.

Water Resources

Water Quality

The Texas Commission on Environmental Quality (TCEQ) along with the US Environmental Protection Agency (EPA) are charged with assessing and protecting the water quality of our rivers. They have designated the Upper Guadalupe with the HUC (Hydrologic Unit Code) number 12100201 (EPA 2017).

Within that designated reach, there are 40 discrete testing stations that measure a variety of water quality characteristics from a list that includes biological, habitat, metal, microbiological, contaminants, not assigned, nutrient, other, and physical factors. These measurements are variously conducted on monthly, quarterly, summer weekly, and yearly schedules (EPA 2017).

States are required by Section 303(d) of the federal Clean Water Act and Texas Law to identify water body segments that exceed applicable healthy water quality standards and develop Total Maximum Daily Load (TMDL) parameters to maintain their designated uses (EPA 2017).

Watershed Quality Assessment Reports for four sites in Canyon Lake, Quinlan Creek tributary, and Town Creek tributary [Figure 8] listing impairment include TMDLs and contaminant listings that are unsafe for recreation, aquatic biota, or drinking water resources (EPA 2017).

All segments of Canyon Lake have been designated as impaired due to elevated mercury levels in fish tissue[2], and need TMDL development and implementation. For striped bass and longnose gar, adults and children 12 and older are advised to eat no more than two 8-ounce servings per month. Children under 12 should eat no more than two 4-ounce servings per month (TPWD 2017).

Beginning in 2014, assessment indicated that two tributaries to Segment 1806, Town Creek (segment 1806E) and Quinlan Creek (segment 1806D), sometimes have bacteria concentrations that are too high for safe human contact. The areas of concern were confined to two small assessment areas within the city of Kerrville: (1) one mile upstream of Flat Rock Dam to a confluence with Camp Meeting Creek, and (2) from RR 394 to one mile downstream. (TCEQ 2017)

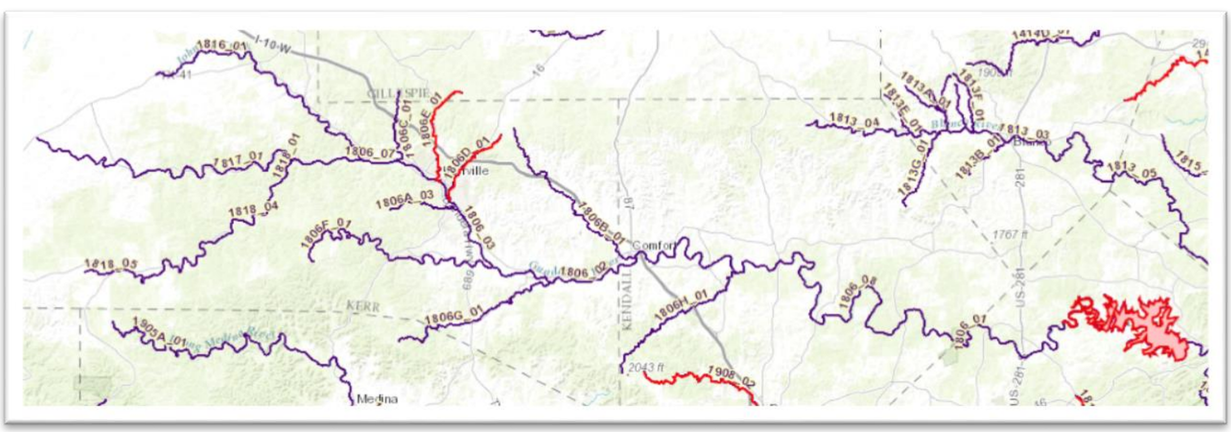


Figure 8: Impaired Stream segments and Reservoirs (TCEQ 2017)

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[2] Emissions fall-out from up-wind coal-fired power plants are the leading single cause of mercury contamination in fish in the Texas, according to a 2006 TCEQ study. EPA standards, set to begin in 2016, should require coal power plants to install scrubbers or shut down (TCEQ 2006).

Additionally, the Guadalupe-Blanco River Authority (GBRA) partners with the TCEQ to administer the *Clean Rivers Program* (CRP) for the Guadalupe River and Lavaca-Guadalupe Coastal Basins. The Texas CRP is managed by the TCEQ and is funded entirely by fees assessed to wastewater discharge and water rights permit holders. GBRA, along with the Upper Guadalupe River Authority (UGRA), carries out this water quality management effort at 21 sites on a quarterly basis with weekly testing in the summer (GBRA 2017).

Chemical and biological indicators in streams show that stream-quality degradation tends to be associated with urban land to a greater degree than with range or agricultural land. With a few exceptions in 2000, pesticides and volatile organic compounds (VOCs) were either not detected or detected at concentrations below levels of concern for human health or aquatic life in most monitored stream segments. Discharges from wastewater treatment plants had the greatest effect on nutrient concentrations of any identified source in the study unit (Bush 2000).

Most utilities realize the value of their waste water and either sell it as irrigate, or beneficially reuse it. Nonetheless, there are at least six direct discharge effluent permits on the Upper Guadalupe. The TCEQ permits for these treatment facilities have water quality requirements relating to total suspended solids, ammonia-nitrogen, dissolved oxygen levels, and CBOD[3]. The TCEQ does not require complete scrubbing of pollutants such as algae inducing nutrients or "contaminants of emerging concern" such as pharmaceuticals, fragrances, plastic components, surfactants, fire retardants, hormones, pesticides, or inorganic chemicals such as metals, which are used in large quantities for a range of purposes by modern society (USGS 2017).

Water Quantity

There are 51 documented springs in the Upper Guadalupe branches upstream of Ingram [Figure 9]. In most cases, the spring location contains numerous springs rather than a single outlet (Ashworth 2005). The springs that feed the river and its tributaries emerge from the Edwards-Trinity Aquifer complex at the river's headwaters in western Kerr County, and from the Trinity Aquifer downstream. These heterogeneous karst limestone aquifers are slowly recharged by rainfall on the Edwards Plateau and in the Hill Country, and flow down-dip in a roughly south-eastern direction through honeycombed limestone formations to emerge in seeps and springs along the river and its tributaries. These aquifer systems produce high quality rock-filtered well water upon which many residents in the basin rely for their needs.

Thus, base flow in the Upper Guadalupe River is not from rainfall, but from the many springs that occur within the main stem and tributaries [Figure 10]. These springs represent outflow from the underlying groundwater system, and act as a direct link between groundwater to surface water.

The river gains water from these aquifers along its path, but there are also places along the river route where the river loses water to the aquifer through fault lines and other recharge features – especially in drought conditions when the aquifers are declining and surface flow volume is low. In these conditions, water may change from surface flow to underflow to aquifer flow many times as it makes its way from headwaters to the southeastern edge of the Edwards Escarpment at the Interstate-35 corridor (Ashworth 2005).

[3] CBOD stands for carbonaceous biochemical oxygen demand, and is considered to be an indication of wastewater pollutants.

A good example of this phenomenon is *The Cave Without a Name* in Kendall County. A working hypothesis is that its main cavern chambers were formed by an ancient pirated segment of the river as a connection between the close points of an Upper Guadalupe oxbow north of the City of Boerne (Venni 1994). Today, the surface sourced spring-shed creates a flowing subterranean "groundwater" stream that issues forth as "surface water"[4] to create the tributary known as Spring Creek (Tobin 2012).

The U.S. Geological Survey (USGS) maintains nine Discharge (flow rates and stage) Monitor Stations along the Upper Guadalupe and one at Canyon Dam. Near instantaneous detailed flow rate and stage information may be accessed by station at the USGS National Water Information System: Web Interface website. https://waterdata.usgs.gov/nwis

The USGS has 10 flow gauges on the Upper Guadalupe River. The longest regularly maintained gauge is USGS #08167000, on the North Fork above Hunt. Data has regularly been collected there since 1935. USGS gauge #08167000 near Comfort is also a long-running monitoring site with data from 1941 (USGS 2017).

Historic data from a flow gauge located outside of Comfort[5] shows that the highest recorded flow on the Guadalupe River was 240,000 cubic feet per second (cfs) on August 2, 1978. The median flow at Spring Branch is ~150 cfs (GBRA 2017).

Rainfall events create runoff into the river and account for seasonable variability, but year-round base-flow is made up entirely of spring-flow. Groundwater enters the river from headwater springs originating from the Edwards and Trinity Aquifers [Figures 9, 10]. Other seeps and springs along its tributaries are the primary sources for the increase in flow downstream (Ashworth 2005). Decreases in base flow are generally the result of evaporation, municipal, and irrigation withdrawals. Aquifer management is thus a critical step in the overall protection of both the groundwater and surface water resources in the basin.

Temperatures of the main springs in Kerr County and the smaller springs throughout the basin are close to 69° F. at all times of the year, but a variation of several degrees is possible. Spring temperature fluctuations downstream in the Guadalupe and tributaries are significant, i.e., four miles downstream from Kerrville, where the river was heavily coated with winter ice, twenty-two fish species were collected on August 6, 1951 (Hubbs 1953).

The average yearly flow of the Upper Guadalupe River at Kerrville is 78,921 acre feet (seven million gallons per day or 109 cfs). It is fully appropriated to water rights holders, and it is doubtful that the TCEQ will issue any new water rights in the future (Wilson 2008). As of mid-2017, there were just under 200 active permits for surface water withdrawals from the Upper Guadalupe River in Kerr and Kendall Counties[3], totaling about 24,450 acre-feet of water[6] . The oldest is in Kerr County and was issued in

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[4] Of note, the Court of Civil Appeals of Texas has confirmed in *Pecos County Water Control and Imp. Dist. V. Williams (1954)* that one may drill a well that captures every ounce of any subterranean river under the groundwater *Rule of Capture* without permit, regardless of its obvious negative effect on surface water flow and harm to downstream rights holders.

[5] The drainage area to the gauge site is 839 square miles. This data comes from USGS gauge #008167000.

[3] Comal County has almost 500,000 acre-feet of surface water permits and was excluded from this list due to the inability to separate the eastern and western permits.

[6] One acre-foot of water is enough to cover one acre of land with one foot of water, or 325,851 gallons.

[5] The oldest surface water permit in the state has a priority date of 1731 and lives in Bexar County.

1887, the oldest in Kendall County is dated to 1912; the oldest in Comal was secured in 1914 [5](TCEQ 2017).

Municipalities use the majority of the water resource within the basin, closely followed by rural domestic use. Kerrville is by far the largest municipal user and uses an annualized average of approximately 3.6 million gallons per day (mgd) of combined surface and groundwater. The utility has a safe operating production cap of 9.7-mgd. Kerrville maintains the first aquifer storage and recovery facility in the state, which at the time of this writing has about 850 million gallons of net storage in the Trinity Aquifer, and a reclaimed water facility for irrigation use sales (City of Kerrville 2017) – See appendix for historical status.

The City of Kerrville relied on the lower Trinity as a source of water from the 1920s to the early 1980s, and water-level declines of as much as 250 feet were observed during that time. In 1981, a surface-water treatment plant was brought on-line, and ground-water production was reduced dramatically. This resulted in water levels in the Kerrville area rebounding as much as 200 feet between 1982 and 1990. Since 1990, however, many wells are again showing significant water-level declines as ground-water use has again increased. (Ashworth 2001)

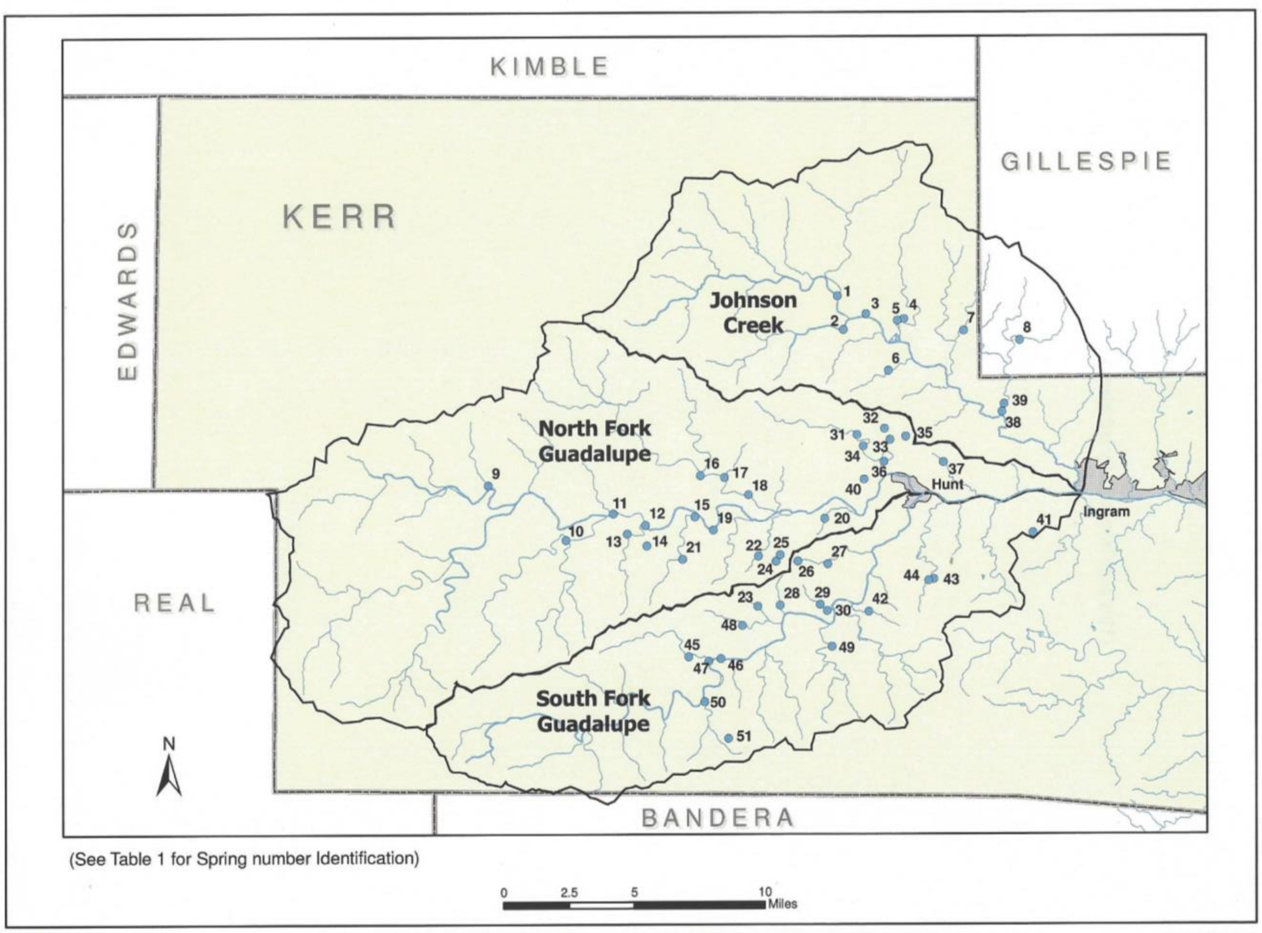


Figure 9: Springs in the Upper Guadalupe Headwaters (Ashworth 2005)

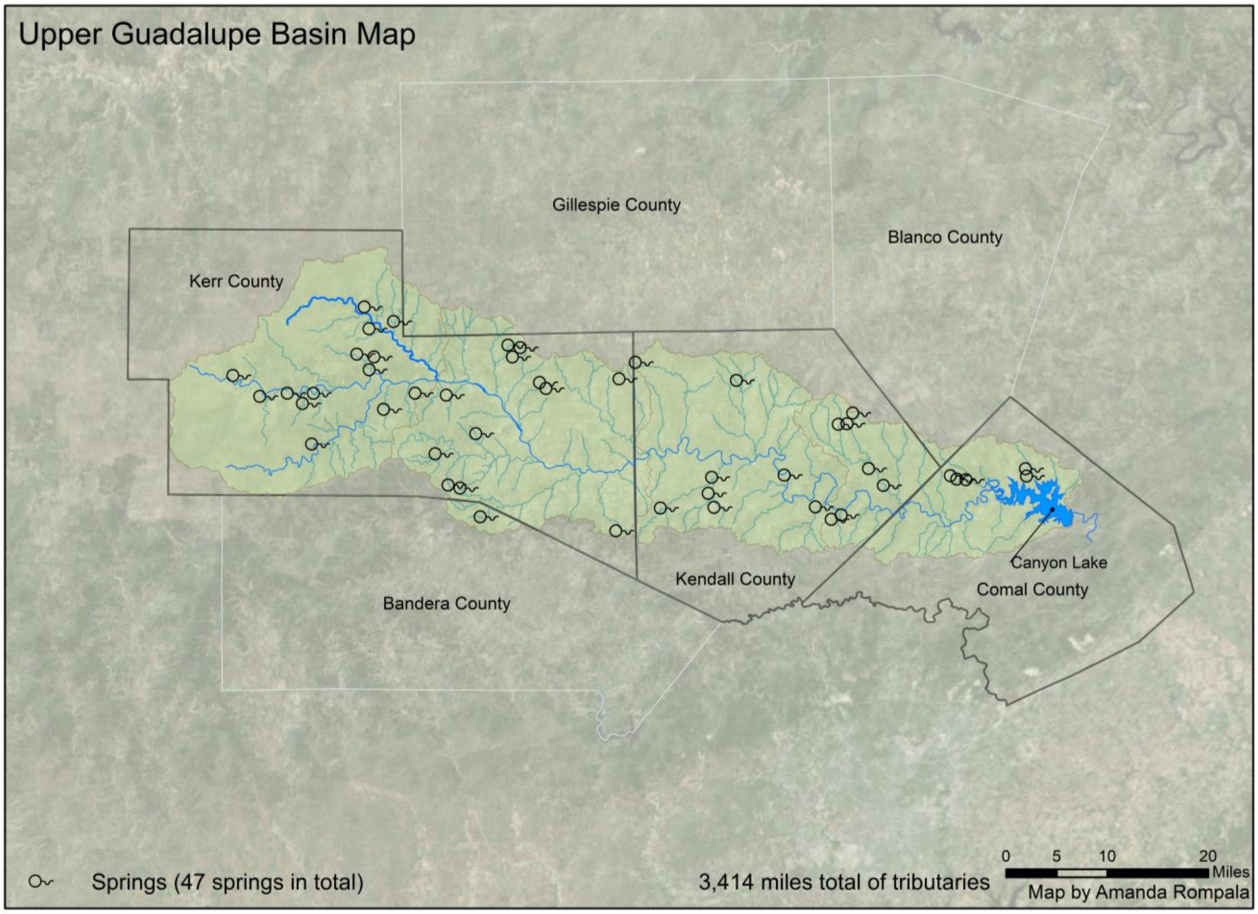


Figure 10: Springs in the Upper Guadalupe basin

Kerrville maintains a capped 6,051 acre-feet per year of junior surface water rights on the river and 4,160 acre-feet in annual groundwater permits; as the population grows more pressure will be put on its alternative supply strategies. In addition, local pumping rights and in-stream flows in the basin are appropriated to downstream users, and priority calls have been made to curtail Kerrville's junior standing water right in the past -- and will be curtailed in the future (Wilson 2008).

Groundwater withdrawals through wells alter the natural fluctuations of the aquifer recharge and discharge conditions—but much remains unknown on exactly how those interactions function. The Texas Water Development Board maintains the *Water Data for Texas* database which records the water level records for hundreds of water wells in Kerr, Kendall, and Comal Counties [Figure 11] (TWDB 2017).

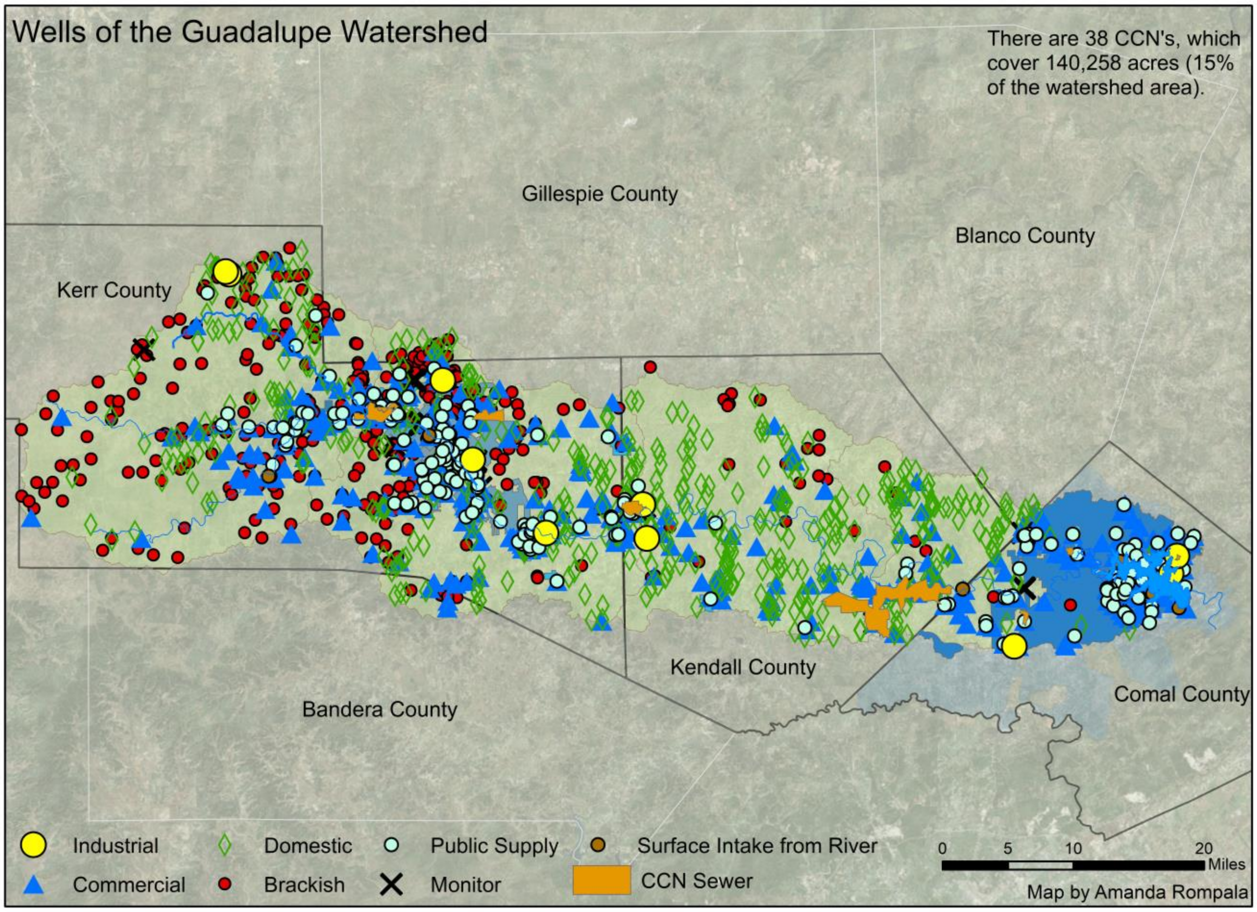


Figure 11: Water Well, Utility Intake, and CCN Locations within the Upper Guadalupe Basin

Water Resource Management

A variety of agencies and organizations each play a role in managing ground and surface waters within the basin. The Upper Guadalupe River basin includes portions of five groundwater conservation districts that generally follow county lines for Kerr, Gillespie, Kendall, Blanco, and Comal Counties. The

Headwaters (Kerr County) Groundwater Conservation District (GCD), the Cow Creek (Kendall County) GCD, the Comal Trinity GCD, the Blanco-Pedernales Groundwater Conservation District and the Bandera County River Authority and Groundwater Conservation District have jurisdiction based on county line boundaries

By statute, wells used solely for domestic or livestock purposes on tracts that are more than 10 acres and that are capable of producing no more than 10,000 to 25,000 gallons of water per day (depending on enabling statue) are exempt from permitting by groundwater districts. Thus, many of the wells within the basin are exempt from permitting (State of Texas 2017).

Because groundwater conservation districts (GCD) in this region follow county lines rather than drainage basin or aquifer lines, the State Legislature set up a process by which groundwater districts could work together to conduct joint planning to maintain shared aquifers. Groundwater Management Areas (GMA) were authorized and formed to allow GCDs to manage whole aquifers based on natural boundaries. For regional planning and management purposes, the Upper Guadalupe basin falls entirely within GMA 9. GMAs are tasked with establishing Desired Future Conditions (DFCs) for the aquifers every five years. The DFC establishes the parameters (usually water table depth rather than spring-flow rates) within which the aquifer will be managed over the next 50 years.

In 2015, GMA 9 adopted desired future conditions that would allow for a region-wide water-level decline of an additional 30 feet through year 2070, as averaged over the entire management area. This could have serious implications for spring flow and river recharge in the region. The Texas Water Development Board takes those drawdown numbers and creates a volumetric quantity of withdrawable water in acre-feet called the Modeled Available Groundwater (MAG). [Table 2]

Table 2

Modeled Available Groundwater (MAG) By County and Aquifer		
County	**Aquifer**	**2020 MAG**
Kerr	Trinity	14,129
Kendall	Edwards Group of the Edwards-Trinity (Plateau)	130
	Trinity	6,028
	Ellenburger-San Saba	64
	Hickory	128
Comal	Trinity	6,906
Total:		**27,385**
	MAG volumes in acre-feet TWDB 2017	

The DFC planning process provides an excellent opportunity for groundwater districts and the general public to voice their concerns and ensure the sustainable management of their groundwater resources (TWDB 2017).

In addition to the GMA planning process, there are also Regional Water Planning Groups (RWPGs) that guide the formation of a statewide water plan every 5 years. This regional water planning process was initiated in 1997, and there are 16 RWPGs across the state. The Kerr County section of the basin falls within the Plateau RWPG (Region J), and Kendall and Comal Counties fall into the South Central Texas RWPG (Region L). The RWPGs last cycle of planning work has informed the most recent 2017 State Water Plan.

RWPGs are tasked with assessing current and future water uses, and compiling future water requirements based on population projections (TWDB 2017). [Table 3]

Table 3

Projected Population and Water Demand in Kerr, Kendall, and Comal Counties						
	Annual Water Demand in Acre-Feet (325,853 gallons)					
	2020	**2030**	**2040**	**2050**	**2060**	**2070**
Kerr County Population	52,644	55,407	57,044	58,665	59,830	60,725
Municipal	7,230	7,341	7,362	7,455	7,569	7,670
Irrigation	842	816	790	765	741	719
Livestock	890	890	890	890	890	890
Mining	76	80	100	102	111	120
Manufacturing	25	27	29	30	32	34
Total	**9,063**	**9,154**	**9,171**	**9,242**	**9,343**	**9,433**
Existing Supplies	10,149	10,149	10,149	10,149	10,149	10,149
Kendall County Population	42,185	52,213	62,807	73,308	84,028	94,549
Municipal	6,766	8,335	10,014	11,679	13,460	15,216
Irrigation	375	367	359	352	346	339
Livestock	395	395	395	395	395	395
Mining	0	0	0	0	0	0
Manufacturing	0	0	0	0	0	0
Total	**7,536**	**9,097**	**10,768**	**12,426**	**14,201**	**15,950**
Existing Supplies	13,577	13,796	13,978	14,115	14,234	14,331
Comal County Population *	140,825	178,399	216,562	255,092	293,362	330,099
Municipal	4,810	30,597	36,568	42,704	48,918	54,917
Irrigation	429	390	351	312	275	252
Livestock	258	258	258	258	258	258
Mining	8,600	9,996	11,340	12,513	13,982	15,628
Manufacturing	8,563	9,314	10,045	10,672	11,553	12,507
Total	**42,660**	**50,555**	**58,562**	**66,459**	**74,986**	**83,562**
Existing Supplies	41,807	43,550	45,235	46,693	48,391	50,200

Numbers in RED indicate projected shortages.
* Note: Most of the population is not in the Upper Guadalupe basin
Municipal use is total commercial and residential.

2017 State Water Plan Texas Water Development Board

Species and Ecology

Aquatic life is abundant in the Upper Guadalupe River, especially in spring-fed areas. Minor tributaries contain the same submerged aquatic plants in spring-fed areas. Aquatic flora and fauna are detailed by category and location in the Upper Guadalupe basin in Hubbs' 1953 *The Fishes of the Upper Guadalupe River, Texas* (Hubbs et. al. 1953).

The Upper Guadalupe River have been recommended for designation as an Ecologically Significant Stream Segment [Figure 12] by the Texas Parks and Wildlife Department from the confluence of the Comal River in Comal County upstream to the Kendall/Kerr County line, with the exception of Canyon Lake Reservoir (TPWD 2017). Criteria for significance includes: hydrologic function in the Edwards Aquifer Recharge Zone, riparian conservation area at Guadalupe River State Park, high water quality/exceptional aquatic life/high aesthetic value and Overall use (Texas Natural Resource Conservation Commission 1995). Those TPWD recommendations will require and act by the Texas Legislature in order to become official.

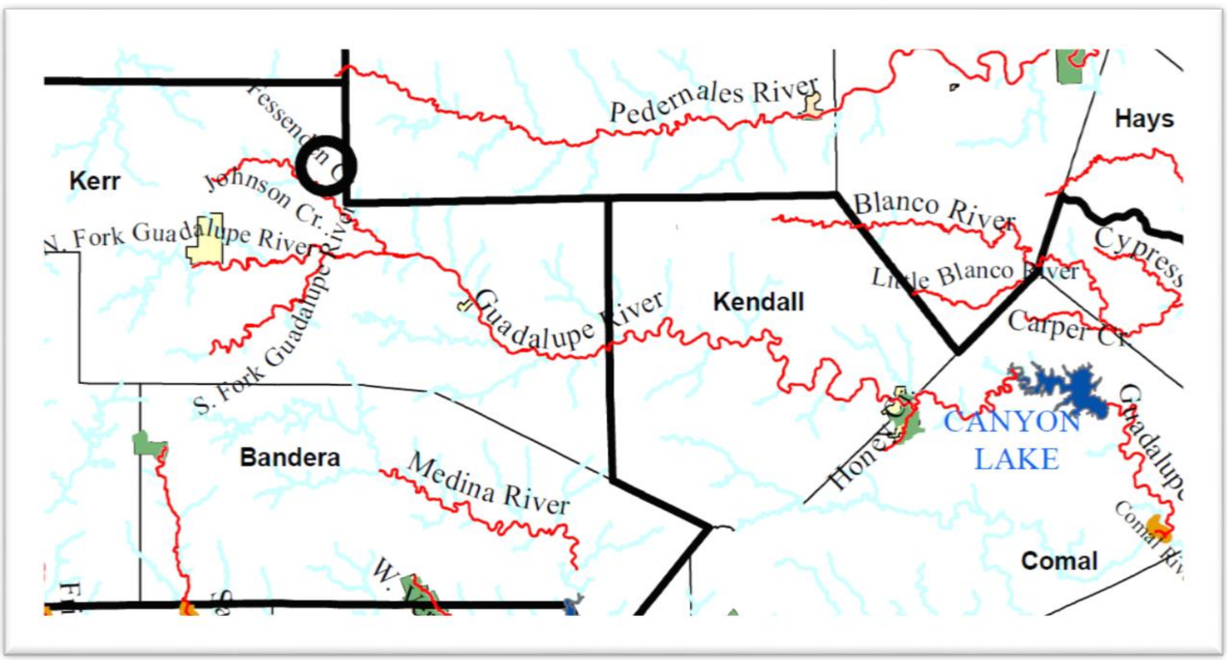


Figure 12: TPWD Recommended Ecologically Significant Streams in red. (TPWD 2012)

Biology:

In the early 1840s the area was open country with scattered trees. Grass was waist high, and there was an abundance of turf and bunchgrass. As a result of the livestock industry, overstocking depleted the fragile rangeland. Undesirable forbs, grasses, and brush, especially cedar, overran the rangeland. Pervasively plowing soil that was too steep, too shallow, or too close to streambanks created increased runoff on the overused rangeland and caused poor croplands to erode (USDA 1982).

Riparian forests include tree species such as cedar elm, bur oak, sycamore, and bald cypress, while upland areas more commonly support Ashe juniper, Texas persimmon and mountain laurel. Native grasses including little bluestem, indiangrass, and sideoats grama mix with non-native King Ranch bluestem. The basin also includes rocky canyon forests with Ashe juniper, Texas oak, Texas ash, and cedar elm (TNC 2007).

Two of the most widely known avian species in the Edwards Plateau are the endangered Black-capped vireo and Golden-cheeked warbler, both of which can be found in the Upper Guadalupe basin. These species rely on the presence of old growth Ashe juniper (cedar) breaks for nesting habitat and cover, which has implications for proposed widespread removal of brush. Public agencies including the Texas Parks & Wildlife Department (TPWD), Natural Resources Conservation Service (NRCS), and Texas A&M AgriLife Extension advocate avoiding brush control in areas that could include endangered species habitat.

The NAS (Nonindigenous Aquatic Species) division of the USGS maintains an extensive though not complete aquatic species listing of exotic, exotic hybrid, and native transplants. Kerr County lists 13, Kendall County lists eight, and Comal County lists 33 non-indigenous species on the USGS website (USGS 2017).

In the Texas Conservation Action Plan, the TPWD created a list of Priority Habitats for conservation action throughout the state of Texas. Within the Edwards Plateau ecoregion, riverine and riparian ecosystems including the Upper Guadalupe River are listed as conservation priorities (TPWD 2012).

Threatened and Endangered Species:

There are a number of threatened and endangered species in the Upper Guadalupe basin. TPWD has cataloged threatened or endangered species/unique communities at Honey Creek including the Guadalupe bass, Cagle's map turtle, Honey Creek Cave salamander, and Texas salamander (TPWD 2000). Additionally, the Upper Guadalupe River hosts one of only four known remaining populations of endemic Texas fatmucket freshwater mussel and endemic golden orb freshwater mussel (Howells, 1997; Howells, 1998).

Land Use

In 1856, Kerr County was formally organized as a carve-out of Bexar County. It was named for Major James Kerr, an early settler on the Guadalupe River. Early settlers in the area, established a shingle-making camp, harvesting the mature cypress trees along the banks of the Guadalupe River. As hand-cutting shingles became obsolete, hydro powered sawmills replaced this laborious method. The first mill also served as a grist mill, and was located on Verde Creek, near Center Point.

As German immigrants and Anglo pioneers settled the area, they cleared the fertile bottom lands and planted grains, corn, and cotton. The upland cattle, goat, and sheep tenders eventually out produced the farms and became the county's chief economic resource. (USDA 1978)

The basin’s economy is tied to agricultural interests including livestock, hunting, and irrigated agriculture [Table 4]. It is evolving towards recreation, and retirement, and as the City of San Antonio continues to grow, that lifestyle will be affected by new commuters along Interstate-10 (CH2M Hill 1992).

Table 4: 1997-2013 Land Use Trends (Texas A&M IRNR 2017)

1997- 2012 Land Use Acres by Land Use Group								
	Cropland		**Grazing Land**		**Wildlife Management**		**Other**	
Kerr County	5,092	-8%	414,643	-12%	81,346	458%	502	-56%
Kendall County	13,946	-6%	293,998	-15%	45,490	0%	323	37%
Comal County	15,550	-33%	201,644	-21%	25,974	1728%	445	259%
Statewide	25,203,278	-8%	105,036,897	-2%	3,306,557	3500%	927,875	-19%

Changes to Agricultural Land Acreage and Value				
	Ranches < 100 acres: 68% Increase		**Land Value: 321% Increase / acre**	
	1997	2012	1997	2012
Kerr County	356	459	$1,476	$5,929
Kendall County	376	769	$1,647	$8,324
Comal County	401	679	$2,418	$8,629

TPWD has undertaken an intensive ecological systems classification project for the entire state of Texas. Phase 1 of the project included classification of the Edwards Plateau, which includes the Upper Guadalupe basin. TPWD's classification shows that almost 43,000 acres of the basin - about 4.5% of the total area – is considered to be riparian. Slightly more than 33,000 acres, or about 3.5%, are considered to be floodplain. TPWD's classification shows that just over 0.33% of the drainage basin is urban.

Farmland

Farming is difficult in the stony uplands of the basin, but there is some dedicated row and grass farming in the bottoms and where good soil has accumulated. About 3,500 acres – less than ½ of 1% -- of land in the basin are put into regular crop rotation.

Rangeland

The TPWD classifies the vast majority of lands in the Upper Guadalupe basin (more than 91%) as pasture or rangeland. Ranching continues to be an important economic activity in the basin, as does hunting - though there is no accurate data on acreage relating to hunting leases. Monitoring the impacts of grazing on ecosystem health is important, particularly during times of drought when overgrazing can dramatically reduce biodiversity of plant species and leave exposed soil vulnerable to erosion (TPWD 2017).

Conserved Lands

The Upper Guadalupe basin includes a number of parks and protected areas that are preserved in varying degrees of natural state. Parks makeup roughly 3,700 acres and constitutes roughly 0.5% of the total land area of the basin. These parks provide public access points to some of the recreational activities the basin has to offer: hiking, bird watching, mountain biking, swimming, kayaking, tubing, trail riding and simply enjoying the diverse flora and fauna of the region. Private lands can be conserved through conservation easements and deed restrictions, preserving open spaces in perpetuity. The total sum of publicly conserved lands is 15,548 acres - roughly 1.7% of the drainage basin (TPWD 2017).

Demographics

The upper Guadalupe River basin is largely undeveloped and rural with the river passing through several municipalities along its path. The highest elevation developments of any density are vacation homes built along the river's edge in the unincorporated Village of Hunt, west of Ingram [Table 5].

Table 5: Population Facts (USGS 2017)

2017	Population	Density/sq.mi.	Median Age	% of Basin in Co.	% of Co. in Basin
Kerr County	50,149	45.5	47.9	70	54
Kendall County	37,361	56.4	43.6	67	31
Comal County	48,468	146.9	47.3	29	11
Note: the major population Centers of Kendall and Comal Co.s are outside of the basin boundaries					
Texas Average density of persons per square mile is ~98.1					

Trends

As more people move to the Texas Hill Country, landholding sizes will shift [Table 6]. Historic, large-scale ranching and farming operations are beginning to mix with smaller recreational ranches and home sites. Land fragmentation and changing ownership patterns have the potential to drastically impact wildlife movement and habitat health. In Kerr, Kendall, and Comal Counties the number of acres in small farms increased dramatically between 1997 and 2012. Collectively, they saw a 68% increase in tracts of 100 acres or smaller in that 15-year period (Texas A&M IRNR 2017). This proliferation of small parcels generally indicates growth in the number of landowners who do not make a living off their land. This can provide needed rest from grazing and farming pressures, and have implications on the spread of brush species.

In the same 15-year period mentioned above, land values rose by 321% [Table 7]. This explosive growth in land prices puts pressure on traditional farming and ranching operations (Texas Land Trends 2017). Higher land values result in smaller parcels and greater fragmentation. Owners of these properties are more likely to own their land as a hobby, and are less likely to have a goal of making a living from the land. Subdividing can put stress on water resources, lead to additional septic systems and potential for contamination of ground and surface water, and can also lead to increased brush cover unless actively managed.

Table 6: 1997-2012 Population Trends (Texas A&M IRNR 2017)

Population Trends						
	1997	**2002**	**2007**	**2012**	**Change**	
Kerr County	42,874	44,752	47,504	47,491	4,617	**11%**
Kendall County	20,386	25,633	31,816	38,117	17,731	**87%**
Comal County	71,043	84,226	106,080	131,409	60,366	**85%**
Statewide	19,439,337	21,779,893	23,904,380	26,403,743	6,964,406	**36%**

Table 7: 1997-2012 Property Value Trends (Texas A&M IRNR 2017)

1997- 2012 Property Market Value per Acre						
	1997	**2002**	**2007**	**2012**	**Change**	
Kerr County	$714	$1,078	$2,535	$2,917	$2,203	**309%**
Kendall County	$1,583	$2,402	$5,080	$5,544	$3,961	**250%**
Comal County	$1,623	$2,564	$6,899	$7,533	$5,910	**364%**
Statewide	$501	$677	$1,195	$1,573	$1,072	**214%**

Brush Control

The density of Ashe juniper has increased in Central Texas over the past 200 years. Ashe juniper now covers 6.7 million acres of the Edwards Plateau (Owens et al. 2006). The scale-like leaf structure and large leaf area of juniper trees are well designed for capturing and storing rainwater. Many see the removal of Ashe juniper as a way to increase the amount of rainwater that enters the ground and surface water systems.

One analysis of Ashe juniper's impacts on the ability of rainwater to reach the ground in the Texas Hill Country found that very small amounts of rainwater (<2.5mm) were entirely captured in the canopy and evaporated into the atmosphere. The study, which involved rainfall and rainwater interception measurements across 10 sites for 5 years, found that roughly 60% of the rainfall reached the soil beneath the trees, while 40% was intercepted either in the trees' canopy or leaf litter (Owens et al. 2006). Lighter storms with lower precipitation totals were more likely to result in interception, while heavier rainfall events saw upwards of 80% of rain reaching the soil beneath the trees.

While selective brush control may be one way to increase overall water yield in a system, it is important to remember that Ashe juniper play an important ecological role in the Texas Hill Country and is native to the Edwards Plateau ecoregion. Some research indicates that upland brush management will only benefit areas that receive at least 18 inches of rain per year (Ball and Taylor 2003). In arid areas where soils are extremely dry, rainfall that reaches the ground is often evaporated before plants can use it or it can recharge the aquifer. Brush management is often costly and when done improperly can increase erosion, decrease natural habitat for wildlife, and have long-term negative impacts on the land (Ball and

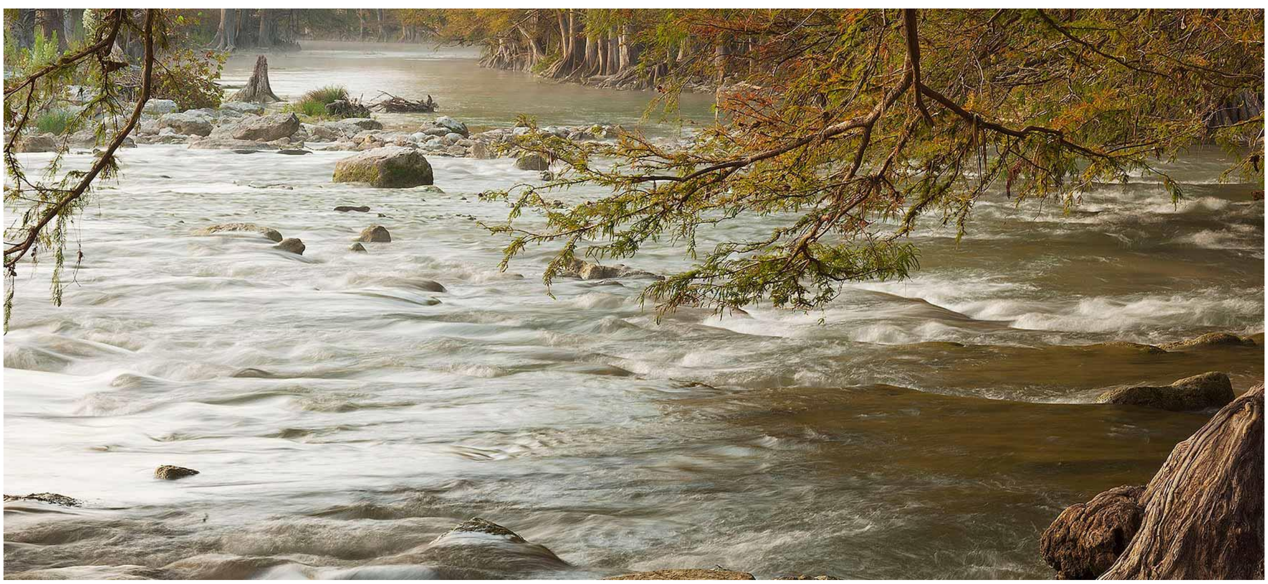
Taylor 2003). Changes in water yield as a result of brush control are intimately connected to soil typology and health, as well as the underlying geology. Brush control, when done properly, can be used to improve habitat diversity and resilience.

Conserved Lands, Parks, And Public Access

One measure of public engagement with the river is the amount of publically conserved land along the river and its tributaries. The public purposes of conserved land range from increased parkland, to research facilities, to the protection of water supplies. There are approximately 15,550 acres of conserved land in the Upper Guadalupe basin of which about 3,750 acres are public parks.

Texas Parks and Wildlife Department:

Guadalupe River State Park is located along the boundary of Comal and Kendall counties. The Guadalupe River bisects the park.



Guadalupe River State Park (TPWD 2017)

Nichol's Landing Paddling Trail. This 9.9-mile reach of the Guadalupe River in Comal County is lined with an abundance of mature trees and a spectacular mix of limestone cliffs and shelves. Paddlers will enjoy a 3-6 hour ride on a variety of rapids between gentle stretches (TPWD 2017).

The Heart of the Hills Fisheries Science Center is located on Highway 27 in Kerr County, Texas, approximately two miles south of the town of Mountain Home. The facility receives water from Stockman's Springs (also called Ellebracht Springs). Water temperatures range from 60º to 75ºF year-round, which allows investigations of both cold-water and warm-water fishes. The property covers 55.8 acres and includes 25 research ponds, laboratories, offices, and storage buildings[7].

The Kerr Wildlife Management Area is owned and operated by the TPWD. This area was selected as a land base for the Edwards Plateau ecological area to develop and manage wildlife habitats and populations of indigenous wildlife species, provide a site where research of wildlife populations and habitat can be conducted under controlled conditions, and to provide public hunting and appreciative use of wildlife in a manner compatible with the resource. The Area's primary mission is to function as a wildlife management, research, and demonstration site for trained personnel to conduct wildlife related studies and provide resultant information to resource managers, landowners, and other interested groups or individuals to acquaint them with proven practices in wildlife habitat management.

The Kerr Wildlife Management Area is located at the headwaters of the North Fork of the Guadalupe River. The Area contains 6,493 acres that are representative of the Edwards Plateau habitat type of Texas. The Area was purchased by the State of Texas (Game, Fish and Oyster Commission) in 1950 from the Presbyterian MO Ranch Assembly.

Kerr County:

Flat Rock Park 3705 Highway 27, Kerrville, TX

Hunt-Ingram area. There are numerous low-water crossings that provide river access and recreation opportunities along SH-39 and Co. Rd. 1340

- **Schumacher Crossing** State Hwy 39 a little east of Hunt
- **Ingram Dam** near the intersection of State Hwy 39 and 27
- **Lions Park** TX 39 at Point Theatre Rd S.

City of Kerrville http://www.kerrvilletx.gov/index.aspx?nid=1271

- **Cypress Park** 1601 Junction Hwy, Kerrville, TX
- **Guadalupe Park** 700 Guadalupe St S, Kerrville, TX
- **Lowry Park** 209 Guadalupe St, Kerrville, TX
- **Tranquility Island** 202 Thompson Dr., Kerrville, TX
- **Louise Hays Park** 202 Thompson Dr., Kerrville, TX
- **Lehmann-Monroe Park** 200 Park Ln E, Kerrville, TX
- **Kerrville-Schreiner Park (nee Kerrville State Park)** 517.2-acres. 2385 Bandera Hwy, Kerrville, TX

[7] Heart of the Hills Fisheries Science Center has its origins in Stockman's Springs. These life-giving waters once supplied the Indians of the Archaic period (400-3,000 years ago) and possibly provided for Cabeza de Vaca and his men as they passed through the area in 1534. Later the springs offered respite to weary travelers on the Chihuahua Road from Mexico to Indianola.

In 1925, the State of Texas obtained water rights to Stockman's Springs and, thanks to the donation of 36.4 acres of land by C.R. and Maud Eddins, opened Heart of the Hills Fish Hatchery. In 1929, 19.4 additional acres were purchased from the Schreiner family, and in 1935, the Works Project Administration built the present-day concrete canal system. The facility remained a fish hatchery for more than four decades. In 1969, with the support of the Federal Aid in Sport Fish Restoration Act, the HOH Fisheries Science Center was established.

Kendall County:

Kreutzberg Canyon Natural Area has 117 acres and 1,700 feet of Guadalupe River frontage for access to river recreation. 143 Mark Twain Drive - Boerne, Texas 78006**.**

James Kiehl River Bend Park is a serene 25-acre natural area with grassland, woodland, and riparian habitats. 1,634 feet of Guadalupe River frontage provides access to the river for fishing, paddling, swimming, and relaxing. 118 River Bend Road, Comfort, TX 78013.

Joshua Springs Park and Preserve. Ring Mountain rises above this 365-acre park and natural area on the banks of Little Joshua and Allen Creeks south of Comfort. 716 FM 289 - Comfort, Texas 78013.

Comal County:

Nichols Crossing County Park Spring Branch. Additionally, there are a number of low water crossings that act as river access points between Comfort and Canyon Lake.

The Built Environment

The Upper Guadalupe basin is largely rural with no large reservoirs along its reach (save Canyon Dam at its end), and sees little infrastructure interference aside from the incidental small town and road crossings [Figure 12]. In order of flow, the Village of Hunt, Mountain Home, Ingram, Kerrville, Center Point, Comfort, and Spring Branch are the only towns along the way.

Bridges

There are multiple bridges and low water crossings especially in the upper basin. Interstate-10 crosses at Comfort, US Highway 281 crosses near Spring Branch, and several State Highways and county roads cross the river [Figure 13].

Utility Easement Crossings

There is a relatively low number of utility easements on the Upper Guadalupe River. They include several natural gas pipeline and high-voltage power line crossings [Figure 14].

Rail Crossings

All that remains of an abandoned rail line that ran from San Antonio through Comfort to Fredericksburg or Kerrville is a sturdy bridge over the Guadalupe River between Comfort and Waring[8].

[8] The *San Antonio & Aransas Pass* railroad reached Comfort and Kerrville via Boerne and Waring in 1887. The railroad was originally planned to cross the Hill Country and terminate in San Angelo. For a variety of financial and geographic reasons, the line never did pass beyond Kerrville or Fredericksburg. In 1914 The *San Antonio, Fredericksburg & Northern* joined the main *S.A. & A.P*. line just before it came into Comfort. The new line failed financially and in 1917 it was reorganized as the *Fredericksburg & Northern*. *F & N* service lasted until 1942, at which point Comfort once again became the terminus. "In 1959, Comfort also became the depot for nearby Center Point when its depot was closed. This was the last year for passenger service on the line. The railroad abandoned

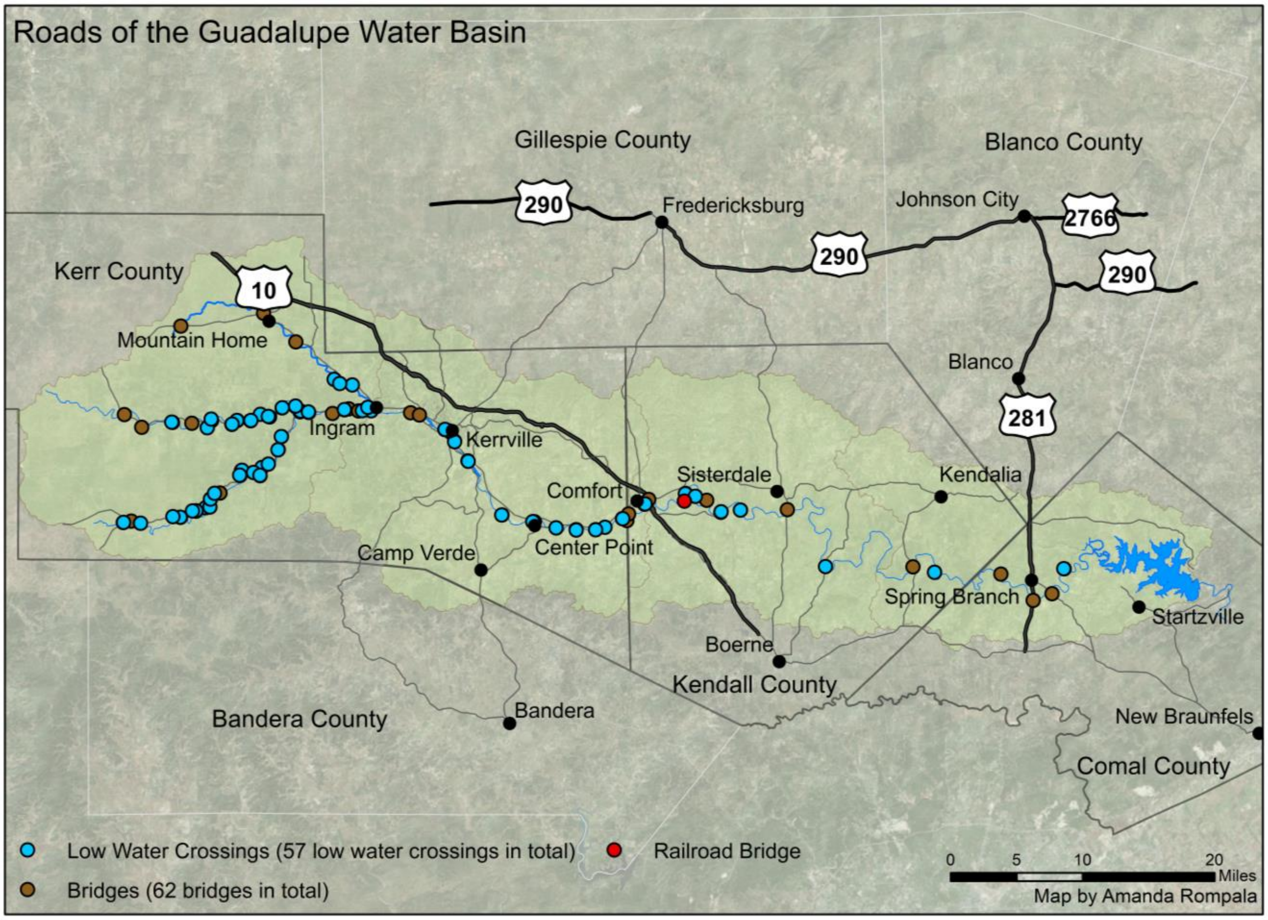


Figure 13: Major Roads, Bridges, and Low Water Crossings

Canyon Dam

United States Army Corps of Engineers in cooperation with the GBRA completed Canyon Dam in 1964 for flood control, regional water supply, and in the 1980s hydro-electric generation. The 224-foot-high dam is 974 feet above sea level (MSL) and has a conservation pool height set at 909 MSL with an emergency spillway height of 943 MSL. At full conservation height capacity, the reservoir holds 123,449,303,052 gallons of water, and has a surface area of 8230 acres[9].

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the line beyond that point on February 4, 1971. Comfort claimed the now abandoned right of way within the eastern part of town and converted it into HWY 473, under IH-10, towards Sisterdale. The line west of the depot is sometimes visible and there are still various remnants of rail infrastructure and equipment along the abandoned lines to Fredericksburg and Kerrville. (Hemphill 2011).

[9] The July 2002 flood brought 34 inches of rain in one week to the upper basin causing the reservoir to overflow its emergency spillway for the first time. At its peak spill rate, 67,000 cfs over-poured the spillway. Normal discharge from the dam is 350 cfs, with a maximum discharge rate is 5,000 cfs. Water poured over the spillway for six weeks and released one and one-half the lake's total storage amount (~246 billion gallons of water) (GBRA 2017).

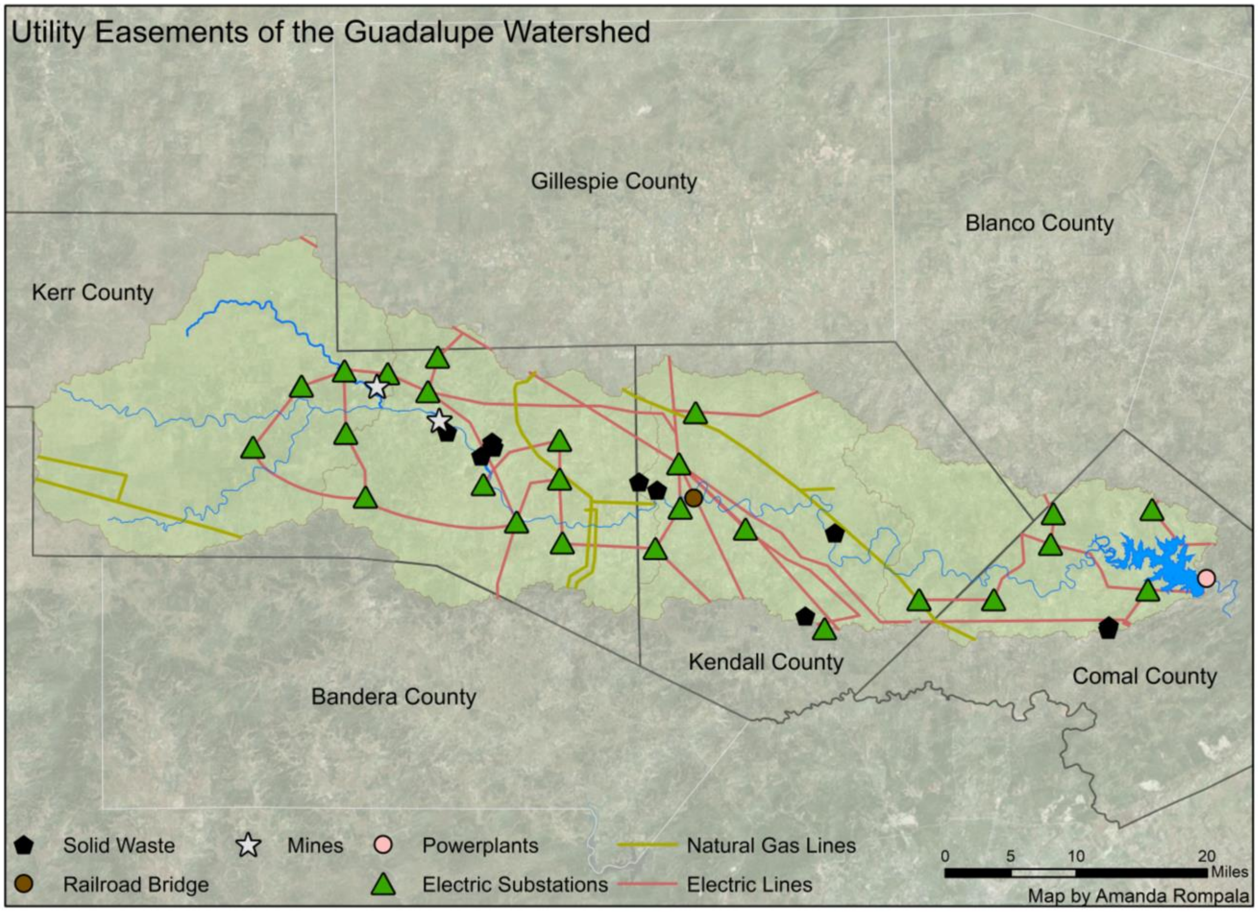


Figure 14: Utility easements, electric substations, mines, solid waste dumps, and power plants

Research Needs

Monitoring the long-term health of the Upper Guadalupe basin will require robust baseline documentation with which to compare future changes. While some important information has already been collected, opportunities remain for enhancing our existing understanding of the basin, its hydrology, flora and fauna, and how human development in the basin may be shaping the future health of the entire system.

Hydrological Data

Regional water planners rely on TCEQ certified Water Availability Models (WAMs) to inform the *State Water Plan*'s projections of demand. The WAMs currently being used are over 20-years old and are out of date. They need to be updated as soon as possible to make realistic decisions about the future of the basin.

Though data exist, basic precipitation/flow regime relationship studies for the upper basin are lacking. Aggregation of readily available USGS certified data would be useful to determine aquifer recharge trends, spring-flow and base-flow relationships, climatic trends, flood severity projections, among other rudimentary but significant relationship studies.

The more complex hydrologic conditions that govern the Upper Guadalupe are still not completely understood. Connectivity exists between surface water and underlying groundwater resources, but a more thorough account of hydrological changes over the course of the river are needed. A central catalog of recharge features, seeps and springs, and a more complete understanding of how the basin is connected to its contributory aquifers in the Edwards Plateau region are needed to fully understand the basin.

The most recent, though partial, gain-loss study of the Upper Guadalupe by the TWDB and the USGS studied specific reaches of the river and several tributaries (Slade et.al. 2002). An expansion of that study, as well as the incorporation of existing monitor well information and spring-flow records will advance the understanding of how the basin collects, retains and sheds water.

The Meadows Center for Water and the Environment plans to undertake a basin-level study to understand the hydrological forces at work in the basin. The U.S. Geologic Service (USGS) has expressed interest in re-creating portions of the 2002 study in order to create data for comparison on how the drainage basin has changed relative to the 2011 drought.

Tributary Health

An undetermined portion of the main stem flow of the Upper Guadalupe comes from its tributaries. More data is needed on the health and volumetrics of these systems. There has been no basin-wide effort to study the ecological health of the ephemeral and perennial streams that feed the river's main stem. Invasive species, erosion, and declines in water quality that happen on the tributaries of the Upper Guadalupe will ultimately impact downstream river health. By targeting these areas for conservation and stewardship the health of the wider system can be maintained.

Groundwater Resources and Spring Flow

Gunnar Brune's 1975 *Major and Historic Springs of Texas* identifies a series of springs in the Upper Guadalupe basin and remains the definitive -though incomplete- reference manual. Many of the springs that Brune identified and measured are currently inaccessible, and further study is needed to update their historical flow patterns (Brune 1975).

A number of ground-water resource investigations have been conducted in the region. Stricklin and others (1971) authored one of the first major reports explaining how the Trinity was originally deposited. Ashworth (1983) and Bluntzer (1992) conducted regional investigations on Hill Country aquifers.

In preparing the Regional Aquifer-System Analysis (RASA) for the Edwards-Trinity aquifer system, the U. S. Geological Survey produced several papers that included the lower Trinity aquifer. Local reports include investigations on groundwater resources of Kerr County (Reeves, 1969), and the Kerrville area (Guyton, 1973). CH2M Hill prepared several reports (1988, 1989 and 1992) on aquifer storage and recovery (ASR) investigations in the Kerrville area. (Ashworth 2001)

Groundwater withdrawals throughout the basin will impact the aquifers' ability to sustain spring flow into the future. Only by establishing Desired Future Conditions (DFCs) that recognize and protect future spring flow can we ensure the river's connection with its underground aquifers. Generally speaking, there is a lack of data on the number of springs, the quantity of water entering the system through springs, and baseline water quality of water originating from springs.

Ecological Data

In addition to the hydrological data needed to form a robust baseline picture of the health of the basin, having a picture of the health and resilience of the river's plant and animal communities is critical to prioritize conservation and stewardship efforts.

Invasive Species Mapping

In order to establish a strategic plan for controlling the spread of invasive plant species, we must first understand their existing range within the drainage basin. *Dreissena polymorpha* (Zebra mussel) is one species which has just been identified the basin (TPWD 2017). Mapping the extent of invasive plant and animal species throughout the basin should be a priority.

Land Management Challenges: Information Sharing

The majority of landowners are interested in seeing the overall health and resilience of their land improve during their tenure as the steward of that property. At the same time, the land management challenges faced by landowners in the Hill Country are incredibly site-specific – no two ranches are the same, and the goals and priorities of each landowner will inform the methods and tools that are most effective for their property. There is a need for increased information sharing, monitoring and research into the land management tools most commonly used in the Hill Country. Programs that include public funding or reimbursement for stewardship should include resources to track the successes and failures of those activities. We need a better understanding of the impacts of drought on these ecosystems and the tools available to recover plant communities after fire, drought or overgrazing. Our state and federal agencies should be keenly curious in seeking empirical and anecdotal evidence to support their efforts.

Ecosystem Services Analysis

The Guadalupe River provides numerous environmental resources that directly benefit the economic health of the area. These benefits can be quantified in terms of market products, non-market services and added value. An analysis of the economic contributions of the Upper Guadalupe in terms of water quality, water supply, farm products, wildlife habitat, increased property values, carbon storage and sequestration, and revenues generated from tourism and recreation would be useful in making the case for the river's long term conservation and protection.

Threats to Basin Health

The primary threats to the health of Upper Guadalupe Basin ecosystems are residential and commercial development, overabundant wild ungulates, exotic plants and aquatic wildlife, ecologically incompatible land and livestock management, and unsustainable groundwater and surface water withdrawal.

Annual average flow trends incorporating the full extent of USGS discharge records indicate decreasing flows in the upper basin and increasing flows in the Comfort to Spring Branch reach. The increased flows may be the result of a series of major flooding events in the 1980s, 1990s, and 2000s that impacted river-flow more notably in the lower reaches of the upper basin. More sophisticated statistical analyses are needed to help bring flow regime characteristics and their causes into sharper focus. [Tables 8, 9]

Trend lines of USGS flow gauge data indicate a 30-year decline in mean annualized flow volumes. This 30-year dataset begins with the very wet 1987 and includes the drought years of 2011-2014 [Table 8].

TPWD has identified numerous threats to ecosystem health in its 2012 *Texas Conservation Action Plan*. The extensive list of threats identified by TPWD range from land fragmentation and infrastructure construction to fire suppression and a lack of planning regulations in unincorporated areas. Understanding the nature of these myriad threats and filling the gaps in our baseline understanding of the river's health will be critical to prioritizing efforts in the future (TPWD 2012).

Drought

Drought is an undeniable and unavoidable reality that periodically affects the basin. Statistics show that a dry year is more likely to be followed by another dry year than by a wet year (2006 Earl). That is to say, droughts are more persistent than wet periods as illustrated by the U.S. National Oceanic and Atmospheric Administration's Paleo-Climatology Program using precipitation data reconstructed from tree ring studies. [Figure 16]

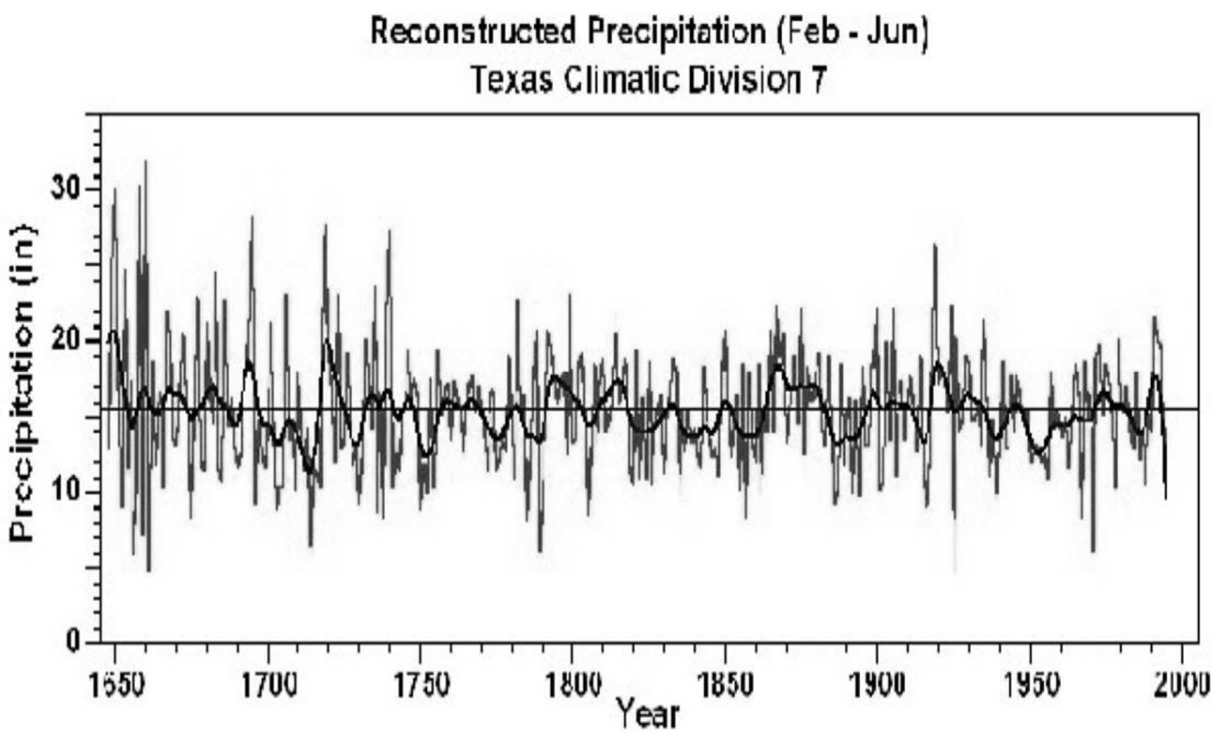
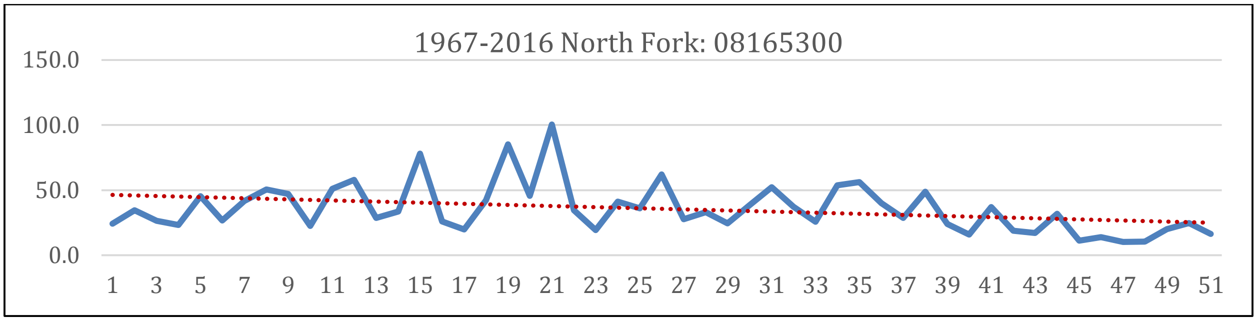
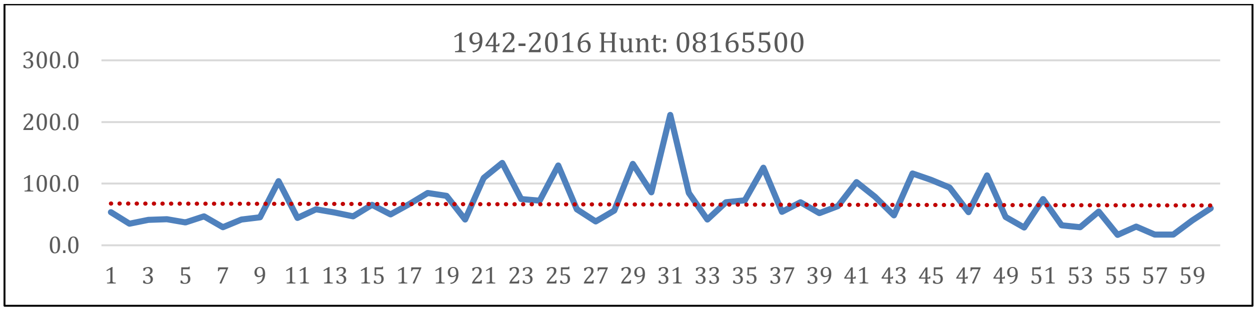
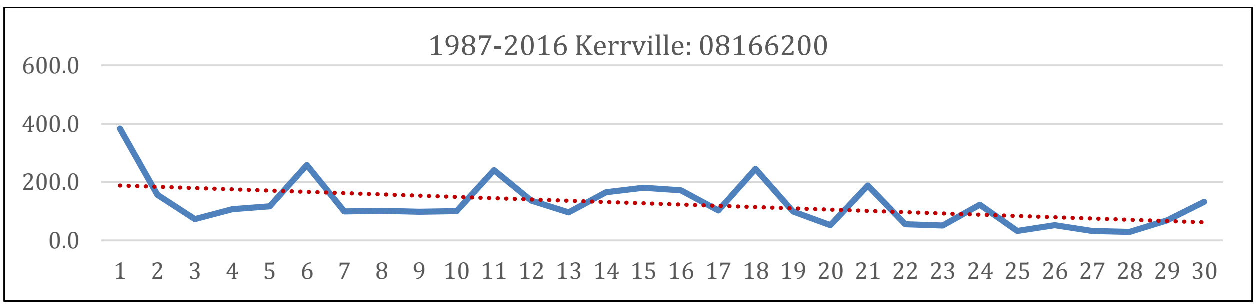


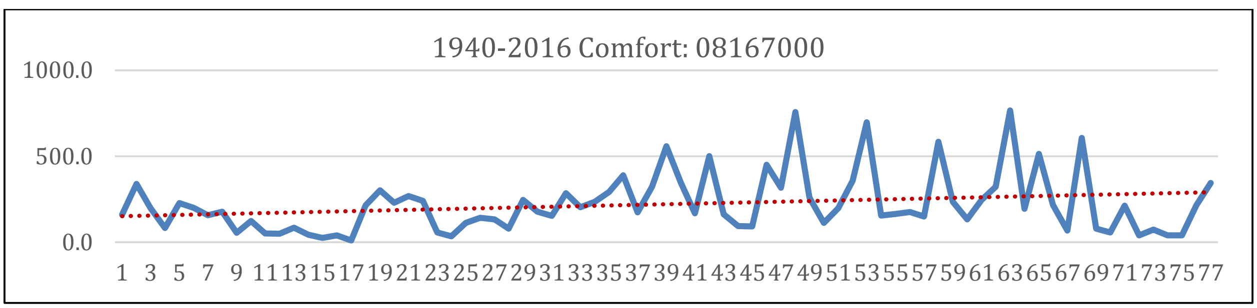
Figure 16 (2006 NOAA)

Table 8: Annual Average Flow CFS (Ft³/Second) – Total Historical Dataset Trends (USGS 2017)









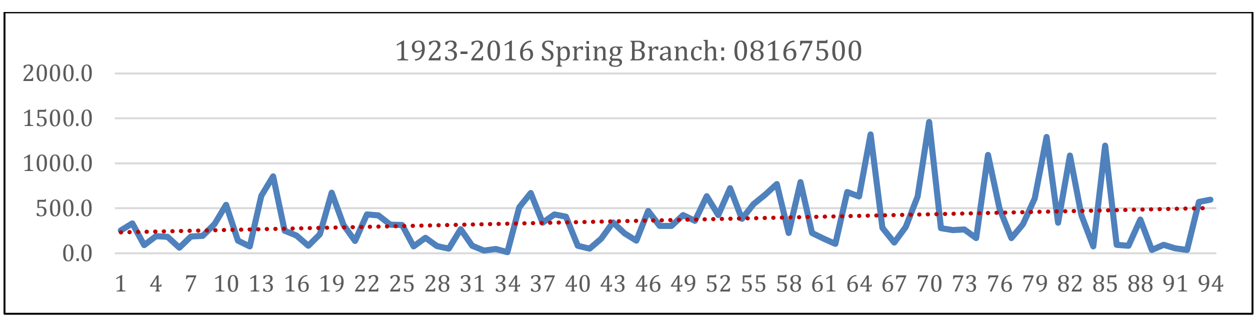
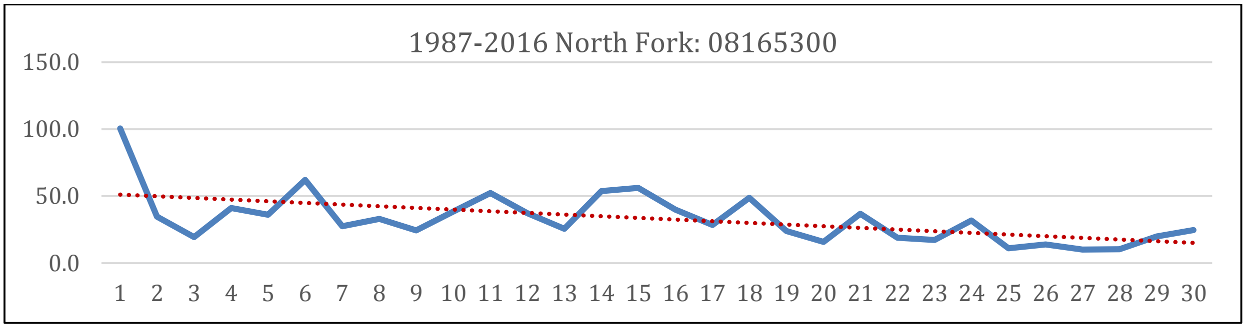
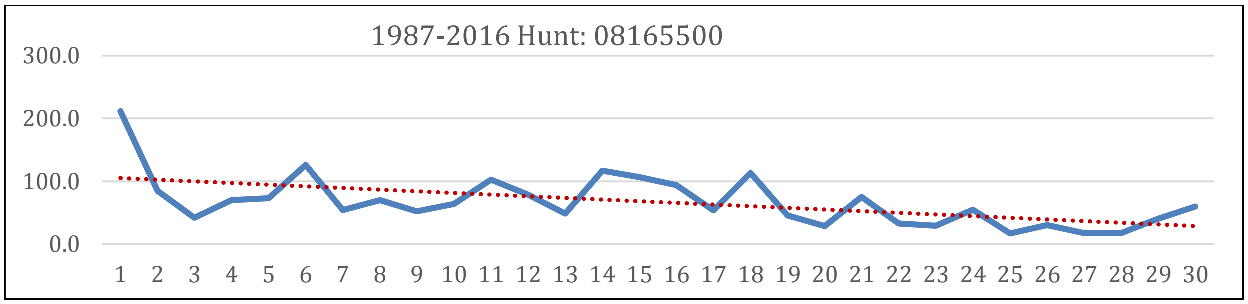
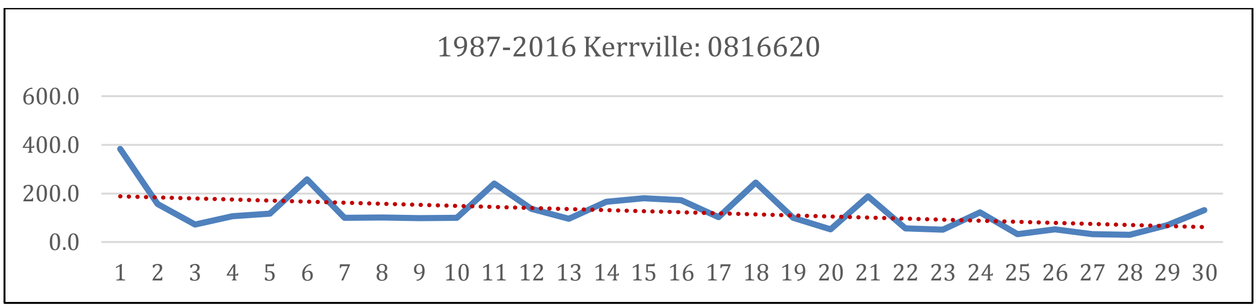
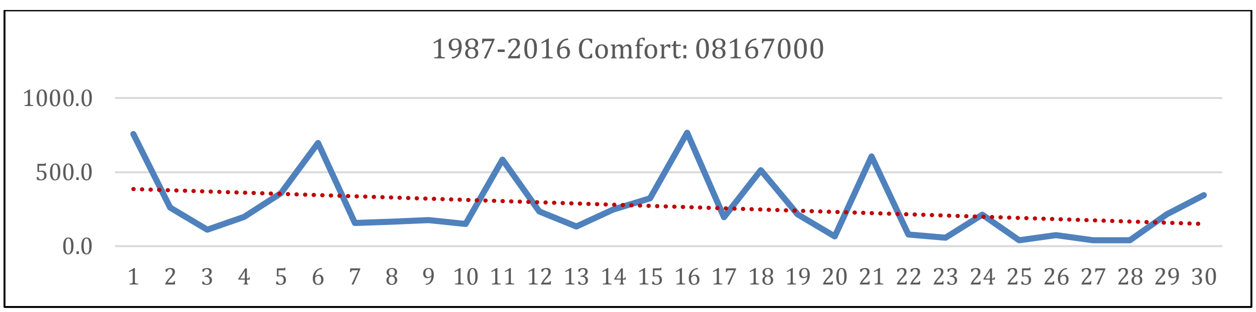


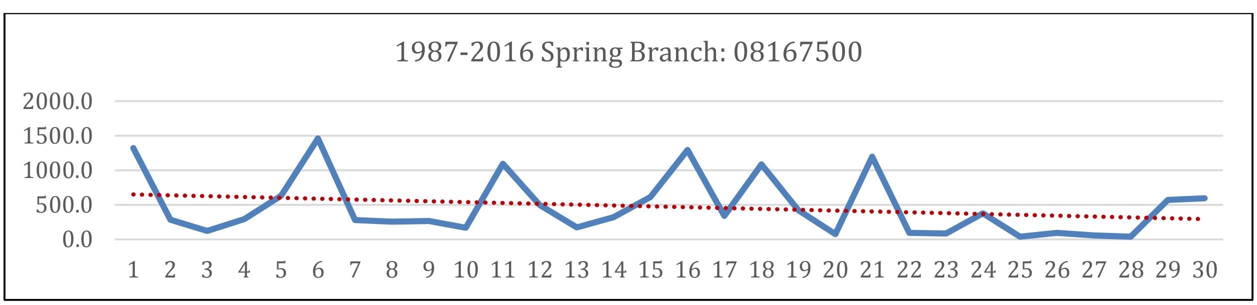
Table 9: Annual Average Flow CFS (Ft³/Second) -- 30 Year Trends 1987-2016 (USGS 2017)











Population Growth and Development

Population growth models for the three counties that contain the bulk of the Upper Guadalupe basin, Kerr, Kendall, and Comal Counties, show significant growth over the next 50 years. As the US-281 and Interstate-10 corridors of San Antonio become more densely populated, the Comal and Kendall portions of the basin will see increased demands on the groundwater supply in the basin that could impact the flow of the Upper Guadalupe.

The majority of the drainage basin falls in unincorporated areas, and counties in Texas have little authority to direct development in any organized way. Incremental land fragmentation for development may result in the loss or degradation of wildlife habitat. Development of rural lands and the associated increases in impervious surfaces will likely result in increased sediment loading to the tributaries of the Upper Guadalupe and the river itself. More study of the nature of this growth is needed to understand the potential implications for the health of the river. The demographic changes associated with this growth could have implications for the stewardship of the land.

Increasing Groundwater Demand

With the predicted population growth within the drainage basin, demands for groundwater will rise. Improving our understanding of the complex workings of the aquifer system will inform responsible groundwater management. Determining the environmental and societal base flow needs for the river will also help to ensure that aquatic and terrestrial ecosystems are protected. As groundwater resources are increasingly accessed for a growing population, challenges could arise when springs stop flowing and the connection between the groundwater and the river becomes more intermittent.

Pollutants

The US Environmental Protection Agency (EPA) has noted a series of threats to the Upper basin. Elevated levels of mercury are found in fish stocks due to soot fallout from upwind coal fired electrical generating plants. Potential sources of emerging contaminants from wastewater discharge at both permitted (National Pollutant Discharge Elimination System (NPDES)) and non-permitted sites, and sedimentation, herbicide and fertilizer contamination due to agricultural and improper brush/range management runoff has been detected and threaten water quality within the Guadalupe River (TSC 2017 DRAFT).

Invasive Plant Species

While some baseline climate and water quality data exist for the river, little is known about the ecological health of the system. The encroachment of invasive species such as giant cane (*Arundo donax*) and elephant ear (*Colocasia esculenta*) could impact the river's natural hydrology and crowd out native plants. Non-native grasses are also perceived to be problematic in the area. Bermudagrass, a common feature in pastures with deep soils and urban areas, as well as King Ranch bluestem are thought to be very common in the Upper Guadalupe. Other invasive species including chinaberry (*Melia azedarachl*), Japanese privet (*Ligustrum japonicum*) and Christ's thorn (*Paliurus spina-christi*) have been identified within the basin and could pose additional challenges.

Invasive & Overabundant Animal Species

In addition, overabundant wild ungulates, including feral hogs, white-tailed deer, axis deer, and blackbuck antelope have profound impacts on riparian areas. The recommended density of white tail in the Hill Country is one deer per 10-12 acres. In some areas of the Hill Country those rates are closer to one deer per every 3.5 acres (Armstrong and Young 2002). While TPWD suggest white-tailed populations are healthiest at 1 per 10-12 acres, rates of exotic ungulates, livestock and other grazers should be considered when determining the carrying capacity of the habitat.

More information is needed regarding the river's aquatic species. Additionally, the habitat preferences and life history traits of a number of aquatic species need to be studied in order to understand how changes in the basin are impacting populations and their ability to survive.

Basin Resources

Perhaps the greatest opportunities for protecting the long-term health of the basin lie in the organizations, agencies, businesses, and individuals working for sustainable land management and conservation. By collaborating and sharing resources across groups we can achieve improved outreach and education results. The following is not an exhaustive list, but a brief summary of some of those organizations that are active in the Upper Guadalupe basin.

State Agencies:

Texas Parks and Wildlife Department (TPWD)

TPWD operates in several modes in the Upper Guadalupe basin including the maintenance and operation of state parks and the protection, preservation, stewardship, and restoration of rangeland and wildlife. The TPWD has extensive knowledge, expertise and resources to offer in the Basin. Technical guidance is available from wildlife biologists assigned to each county. TPWD staffers commonly assist with game counts, wildlife and land management strategies and in providing assistance in writing wildlife management plan applications. TPWD staffers are also hard at work on restoration initiatives and in conducting research. Among other improvement programs, the Landowner Incentive Program (LIP) provides funding for sustainable land management practices.

Texas State Soil and Water Conservation Board (TSSWCB)

The Texas State Soil and Water Conservation Board (TSSWCB) is the state agency that administers Texas' soil and water conservation law and coordinates conservation and nonpoint source water pollution abatement programs throughout the State. The TSSWCB offers technical assistance to the State's 216 soil and water conservation districts (SWCDs). The TSSWCB is the lead state agency for the planning, management, and abatement of agricultural and silvicultural (forestry) nonpoint source water pollution, and administers the Water Supply Enhancement Program. The TSSWCB maintains regional offices in strategic locations in the State to help carry out the agency's responsibilities.

The TSSWCB partnered with USGS to create a model for the effectiveness of a brush control program in the Upper Guadalupe Basin with the goal of increasing flow to Canyon Lake. In 2012 the program's name was changed from Brush Control Program to Water Supply Enhancement Program (USGS 2012).

On November 17, 2016, the State Board allocated $700,360 in FY2017 cost-share incentive funds to several ongoing Water Supply Enhancement Program (WSEP) projects that were initiated in 2016: Among them was the a WSEP Project on 952 acres to serve Nimitz and Canyon Lakes on the Upper Guadalupe River projecting a yield of 37,242,000 gallons of water (TSSWCB 2017).

The TSSWCB also runs the Water Quality Management Plan Program, designed to assist large farm or ranch owners to manage their property in a way that protects water quality. They also work with TCEQ to implement Watershed Protection Plans.

Texas Commission on Environmental Quality (TCEQ)

The TCEQ is the state's regulatory agency responsible for establishing surface water quality standards in Texas. In addition, TCEQ holds the public permits for surface water withdrawals from the Guadalupe, and wastewater and stormwater discharge. TCEQ periodically updates its surface water quality standards. Public involvement in this process is an important component to those updates, and engagement by local stakeholders will be important in the future.

Texas Water Development Board (TWDB)

The TWDB is the state's water science and data repository, and its water infrastructure financing agency. TWDB proctors all regional planning, produces the *Texas State Water Plan,* and administers state funded grants and loans for water-oriented projects.

The Meadows Center for Water and the Environment

The Meadows Center is based in Texas State University at San Marcos Springs. The purpose of the Meadows Center is scientific research, education, stewardship, and leadership in the states waterways from headwaters to bay. It has generated important data and research in the Pedernales and Blanco basins and will do so in the Guadalupe River basin in the future.

Texas State University Departments of Geography, and Biology

Texas State University has facilities and research based programs geared toward river and karst systems. It has a robust presence in the basin, and should be capable of producing some portion of the research needed in the upper basin as master's thesis and dissertation projects.

The Edwards Aquifer Research & Data Center (EARDC)

The EARDC was established in 1979 with special funding for Texas State University to provide a public service in the study, understanding and use of the very fragile natural resource, the Edwards Aquifer.

The Edwards Aquifer Authority (EAA)

The EAA is a state agency dedicated to the management and scientific research of the Edwards Aquifer. The authority regularly conducts hydrologic studies in the upper basin to more fully understand the connections of groundwater and surface water.

County and Local:

Upper Guadalupe River Authority (UGRA)

The Upper Guadalupe River Authority was created as a conservation and reclamation district by the Texas Legislatures in 1939. The mission of the Upper Guadalupe River Authority is to conserve and reclaim surface water through the preservation and distribution of the water resources for future growth in order to maintain and enhance the quality of life for all Kerr County citizens, and as such has a vested interest in the environmental sustainability and resilience of the Guadalupe River and its tributaries.

The UGRA runs a water quality testing lab, performs regular water quality testing, and provides scientific data collection and research on the upper reaches of the river. The UGRA also has care and custody of the Guadalupe Basin Natural Resources Center. One of the purposes of the Center is to provide the community with a place to meet, especially with respect to the development and protection of the natural resources.

Guadalupe-Blanco River Authority (GBRA)

Established by the Texas Legislature, GBRA was first created in 1933 as a water conservation and reclamation district. "The Mission of the of the GBRA is to protect, conserve, reclaim and steward the resources of the District, and provide leadership in regional cooperation in order to enhance quality of life for those we serve." GBRA provides stewardship for the water resources in its ten-county statutory district, which begins near the headwaters of the Guadalupe and Blanco Rivers, ends at San Antonio Bay, and includes Kendall, Comal, Hays, Caldwell, Guadalupe, Gonzales, DeWitt, Victoria, Calhoun and Refugio counties. Planning and resource development efforts are carefully coordinated within the broader consideration of regional and statewide water needs in order to fulfill GBRA's primary responsibilities of developing, conserving and protecting the water resources of the Guadalupe River Basin.

Guadalupe-Blanco River Trust

The Guadalupe-Blanco River Trust is a 501(c)(3) nonprofit land trust organization that was developed to conserve land in the Guadalupe River basin for its natural, recreational, scenic, historic and productive value. It was founded in 2001 by the Guadalupe-Blanco River Authority

Groundwater Conservation Districts

The Upper Guadalupe River basin includes portions of six groundwater conservation districts (GCDs) that generally follow county lines for Kerr, Gillespie, Kendall, Blanco, and Comal Counties. The basin is primarily in three of those. These districts are responsible for managing the majority of the area's groundwater, and will be critical in ensuring that groundwater is used in a sustainable way. The GCDs also have requirements for public outreach and education, and have been good partners for those efforts.

The Headwaters GCD (Kerr County)
The Cow Creek GCD (Kendall County)
The Comal Trinity GCD (Comal County)

Soil and Water Conservation Districts (Kerr, Kendall, and Comal)

These agencies serve as a source of ecologically and conservation oriented information and resources at the county level. Kendall County Soil and Water Conservation District, for example, provides cost-share assistance and other financial incentives for the construction or adoption of projects that conserve soil and protect water quality. The Districts assist landowners in preparing conservation plans, developing prescribed burning plans, and planning for pond construction and erosion control. Local Soil and Water Conservation Districts also have access to the statewide resources offered by the Texas State Soil and Water Conservation Board (TSSWCB).

US Department of Agriculture (USDA) and Natural Resources Conservation Service (NRCS)

Though federally created and funded, these agencies work at the local level to provide a variety of riparian conservation and range management services including technical assistance and cost-share services across the Hill Country.

Texas A&M AgriLife Extension Service

Offices are funded and operated by the Texas A&M University. Various AgriLife specialists provide a wide range of public services and information related to farming, ranching, gardening and land management. AgriLife hosts a variety of educational events for landowners throughout the year and staff are available to make site-specific stewardship recommendations.

The Texas Clean Rivers Program (CRP)

The goal of CRP is to maintain and improve the quality of water within each river basin in Texas through an ongoing partnership involving TCEQ, local entities (UGRA and GBRA), and citizens. The program aims to identify and evaluate water quality issues by looking at the entire drainage basin.

The Upper Guadalupe River Authority (UGRA) carries out the CRP water quality management efforts in the upper Guadalupe River basin under contract to TCEQ. These efforts include water quality monitoring, assessment, and public outreach activities at eleven sites from Hunt to Waring in Kerr and Kendall Counties. The Guadalupe Blanco River Authority (GBRA) conducts similar efforts at ten sites in Kendall and Comal Counties.

Schreiner University

Schreiner University in Kerrville is an independent liberal arts college affiliated with the Presbyterian Church (USA) and dedicated to educating its students holistically. It has educational and research opportunities in aquatic and riparian sciences.

Alamo Area Council of Governments (AACOG)

AACOG was established in 1967 under Chapter 391 of the Local Government Code as a voluntary association of local governments and organizations that serves its members through planning, information, and coordination activities. AACOG serves all counties in the basin. The mission of the Alamo Area Council of Governments is to enhance the quality of life of all residents of the Alamo Region in partnership with elected and appointed officials, funders, community partners and beneficiaries.

Municipalities:

Hunt - unincorporated
Mountain Home – unincorporated
Ingram - 230 Hwy. 39. Ingram, TX 78025
Kerrville - 701 Main Street. Kerrville, TX 78028
Center Point - unincorporated
Comfort - unincorporated
Waring - unincorporated
Spring Branch - 9850 FM 311. Spring Branch, Tx.

County Offices:

Kerr County - 700 Main Street. Kerrville, Texas 78028
Kendall County - 201 E. San Antonio Ave. Boerne, TX 78006
Comal County - 205 North Seguin Ave. New Braunfels, Texas 78130

Non-Government Organizations:

Hill Country Alliance (HCA)

HCA is a regional non-profit whose mission is "to bring together an ever-expanding alliance of groups throughout a multi-county region of Central Texas with the long-term objective of preserving open spaces, water supply, water quality, and the unique character of the Texas Hill Country."

HCA includes resources and expertise working in all Hill Country river basins, and acts as convener for Hill Country-related groups. HCA hosts educational events, creates educational materials, facilitates discussion, research and stewardship of our Hill Country natural and cultural resources.

Greater Edwards Aquifer Alliance

The Greater Edwards Aquifer Alliance (GEAA) is a 501(c)(3) nonprofit organization that promotes effective broad-based advocacy for protection and preservation of the Edwards Aquifer, its springs, basins, and the Texas Hill Country that sustains it. The Edwards Aquifer is the source of the largest springs in Texas and the sole source of drinking water for more than 1.5 million Central Texas residents.

Texas Master Naturalist Program

The Master Naturalist Program is a statewide volunteer program coordinated by TPWD and AgriLife Extension. They have a strong presence in the Texas Hill Country and within the Upper Guadalupe basin. Volunteers working with the Master Naturalist program provide education, outreach and service for the beneficial management of natural resources.

The Nature Conservancy (TNC)

The Nature Conservancy works across the Lone Star State to conserve the lands and waters on which all life depends. To date TNC has protected more than 878,000 acres in Texas and has more than 100 conservation easements in place with private landowners. Thousands of those acres are in the Texas Hill Country, where much of the original savanna has been lost to urbanization and invasive species.

Unique to the Upper Guadalupe:

Cibolo Conservancy

The Cibolo Conservancy, based in Boerne, was formed in 1998 as a sister organization of the Cibolo Nature Center, a community educational center founded ten years earlier. Its focus is the preservation and conservation of the cultural and natural resources of the Cibolo Creek Basin and surrounding areas in the Texas Hill Country. The Cibolo Conservancy now holds conservation easements on over 20 square miles of the Hill Country.

Green Spaces Alliance of South Texas (GSA)

Green Spaces Alliance of South Texas (formerly Bexar Land Trust) was founded in 1998 and focuses on land conservation in the Southern Edwards Aquifer region and the San Antonio and Nueces River basins. Its mission is to sustain the natural environment and enhance urban spaces through land conservation, community engagement, and education. In San Antonio, they foster community gardens and a youth nature photography program. GSA's landowner relationships emphasize available options to achieve long-term goals for ecologically healthy properties and for the management of natural resources, with an eye toward preserving family heritage, and potential economic benefits of the land. GSA is part of a team that has negotiated conservation easements through the City of San Antonio's Edwards Aquifer Protection Program, with the goal of protecting critical acreage over the Edwards Aquifer Recharge Zone.

Guadalupe River Association (GRA)

The Guadalupe River Association was formed in 1971 for the purpose of the preservation of the scenic and natural state and ecology of the Guadalupe River, and for the purpose of educating the public in the protection and conservation of the fish, game and other wildlife, as well as the grasslands and forests in, around and along the Guadalupe River.

Hill Country Land Trust (HCLT)

The HCLT is a regional land trust that is connected to local leaders and landowners in the Upper Guadalupe basin. Formed in 1998, HCLT has the mission of conserving and protecting the agricultural lands, wildlife habitat, and watersheds of the Texas Hill Country for present and future generations. HCLT is responsible for the monitoring and enforcement of 17 easements in the Texas Hill Country, totaling 4,850 acres.

Riverside Nature Center

The five-acre Riverside Nature Center Association (RNC) was organized in 1989 just upstream of downtown at 150 Francisco Lemos St, at the confluence of the Guadalupe River and Town Creek. Over the past 25 years RNC members and volunteers have replaced the non-natives by planting HC native plants (100+ species of trees and shrubs, 200+ wildflowers, plus cacti, grasses and even ferns). The RNC provides educational programs that provide a unique opportunity to foster awareness of plants, animals, ecology and natural resources of Kerr County.

Native Plant Society of Texas

The Kerrville chapter of the Native Plant Society recognizes that Texans value native plants, habitats, and healthy ecosystems as essential to the well-being of all living things and to our quality of life. The Society serves to see that Texas native habitats are managed as critically beneficial natural assets, and that Texas residential and commercial developments employ sustainable designs that preserve and promote native habitats.

Harper Wildlife Management Association

Wildlife Management Associations are groups of private citizens that have joined together to manage their land for the benefit of wildlife. They are recognized and supported by the TPWD and hold regular meetings. The Harper Wildlife Management Association is listed as active in Kerr County.

Railroad bridge at Waring   (Barclay Gibson)

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Historical USGS Flow Rate Data Appendix

For ease of interpretation, low flows are marked in **RED** and represent monthly average values of less than 1/3 of the overall average flowrate. High flows are marked in **BLUE** and represent monthly average values of over twice the recorded annual highest value of record. Absolutes are rendered in **BOLD.**

North Fork of the Guadalupe River

YEAR	North Fork USGS Gauge 08165300: Monthly Discharge Mean in ft^3/s (Calculation Period: 1967-08-01 -> 2017-01-31)											Annual	YEAR
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean	
1967								12.8	17.3	31.5	35.6	23.6	24.2	**1967**
1968	112.8	41.8	33.4	37	32.4	25.2	28.2	20.4	22.5	20.5	19.4	20.5	34.5	**1968**
1969	19.3	18.8	17.3	19.6	15	11.7	11.1	12.6	16	79.2	45.2	51.4	26.4	**1969**
1970	32.5	28.7	37.8	27.5	23.7	22.7	18.4	16.8	17.7	17.3	18	16.9	23.2	**1970**
1971	16	15.2	13.6	13.6	11.8	10.7	11	302.5	28.7	60.5	32.4	28	45.3	**1971**
1972	24.6	21.3	18.7	16.1	64.1	25.1	22.3	33.7	26.7	23.1	22.3	22.8	26.7	**1972**
1973	22.5	21.9	21.5	20.7	16.9	16.1	23.9	25.7	19	240.4	40.1	31.9	41.7	**1973**
1974	26.7	21.7	19.6	18.1	54.1	18.8	19.9	98.6	126.8	107.6	54.4	41	50.6	**1974**
1975	37.2	43.3	35.1	31.6	117	78.1	51.6	40.1	35.3	32.9	32	29.9	47.0	**1975**
1976	24.1	23.8	23.5	23.9	20.9	16.5	24.4	20.2	20.8	22.4	24.9	24.4	22.5	**1976**
1977	23.7	21.1	18.3	351.1	45.3	30.8	23.2	20.4	19.2	19	20.6	21	51.1	**1977**
1978	20.1	20.2	18.8	18.4	15.1	17.6	11.2	451.6	43.1	27.4	27.5	24.2	57.9	**1978**
1979	23.8	24.8	30.3	31	27.8	59.4	29.8	27.2	24.4	22.1	21.8	22.4	28.7	**1979**
1980	22.2	20.1	19	18.2	18.5	14.2	11.9	13.3	171.6	41.7	26.6	25.2	33.5	**1980**
1981	23.3	23.6	27.9	158.2	42.5	278.4	59.9	41.9	34.8	160.8	46.6	38.4	78.0	**1981**
1982	34.8	30.9	27.5	25.9	37.5	27	21.8	19.6	19.8	20	23.4	23.8	26.0	**1982**
1983	23	27.4	24.4	21.2	23.6	23.1	20.1	15.3	13.8	12.5	14.8	18.5	19.8	**1983**
1984	16.4	13.3	13.9	13.9	12.9	11.9	11	10.6	10.8	56	37.9	296.2	42.1	**1984**
1985	59.8	57.9	36.7	29.8	130.3	33.7	29.2	22.4	22.7	**529**	41	31.1	85.3	**1985**
1986	26.4	23.2	19.5	20.5	22.4	24.4	20.7	21.3	198.4	70.9	43.3	55.9	45.6	**1986**
1987	48.9	45.8	42.6	36.2	37.7	239.2	465.3	75.2	67.8	50.1	49.3	47.6	**100.5**	**1987**
1988	38	33.3	32.6	33.7	43.3	30	79.1	27.5	26.1	25.4	23.4	23	34.6	**1988**
1989	24.5	28.1	27.2	24.1	21.9	14.6	12.9	12.5	12.5	18.9	19.5	16.2	19.4	**1989**
1990	15.2	20.1	18.9	15.7	149.4	19.7	29.1	129.6	28.2	23.1	24.8	20.1	41.2	**1990**
1991	21.6	21.9	17.5	16.4	16.9	13.6	11.1	11	56	34.5	24.7	187.6	36.1	**1991**
1992	67	108.4	144	73.8	58	48.1	44.8	40.4	35.6	33.9	47.2	44.1	62.1	**1992**
1993	40.8	33.8	29.8	28.7	33.5	29.9	22.7	19	22.2	20.6	24.1	26.8	27.7	**1993**
1994	25.2	20.8	21.2	19.7	149.1	32.2	22.4	20.7	18.6	19.5	22.7	24.1	33.0	**1994**
1995	24.8	24.2	24.4	23.4	23.9	27.1	22.5	19.8	25.1	29.4	25.4	22.4	24.4	**1995**
1996	20.6	20.9	17.7	15.9	13.9	17.5	13.1	13	26.8	208.5	52.1	41	38.4	**1996**
1997	35.4	59	57.9	52.9	47.1	130.7	61.1	43.5	38.5	34.7	33.6	33.3	52.3	**1997**
1998	34.7	33.3	35.3	29.7	25.2	23.3	17.7	125.9	32.3	32.7	31	25.7	37.2	**1998**
1999	23.5	19.7	23.5	24.7	22.5	44.7	35.8	22.9	20.8	23.9	22.9	23.1	25.7	**1999**
2000	21.5	23.6	18.4	16.9	21.3	24.1	17.2	13.2	12.8	252.1	167.5	56.5	53.8	**2000**
2001	45.2	43.2	45.6	36.4	27.8	25.3	21.8	21	34.8	25.3	289.5	59.1	56.3	**2001**
2002	44.3	38.1	34.4	33.1	31.4	27.9	93.1	34.1	31.4	41.2	35.8	34.5	39.9	**2002**
2003	29.7	28.9	29.4	29.8	25.6	27.1	20.9	18.2	19.5	63.6	26.4	23.6	28.6	**2003**
2004	23.5	22.3	30.6	181.4	49.8	54.6	52.2	40.4	34.6	31.5	35	30	48.8	**2004**
2005	28.3	31.2	31.3	27.8	25.2	22.1	21.7	21.6	19.8	19.8	20.3	19.9	24.1	**2005**
2006	19.1	19.3	18	16.2	15.4	13.7	13.9	13.4	14.2	17.1	15.4	15.9	16.0	**2006**
2007	16.3	16.9	23.5	19.8	70.3	33.2	62	54.4	44.8	37	33.5	31.2	36.9	**2007**
2008	26.7	25.9	23.1	19.7	19.6	14.7	13.6	16.3	14.4	13.5	18.2	21.3	18.9	**2008**
2009	17.7	18.2	25	19.6	18.9	13.2	13	16.1	18.2	15.8	16.2	14.6	17.2	**2009**
2010	17.2	33.7	22.3	118.8	37.9	22.4	19.8	14.9	23.8	18	26.3	27.7	31.9	**2010**
2011	18.5	16.5	12.3	10.6	14.8	11.7	6.79	6.59	9.63	8.51	**4.56**	12.6	11.1	**2011**
2012	11.3	6.65	18.8	11.4	40.2	12.2	14.5	9.36	11.9	9.75	7.44	13	13.9	**2012**
2013	14.2	8.91	10.7	7.9	12.2	12.2	9.77	5.58	8.43	11	7.98	13.6	**10.2**	**2013**
2014	11	10	10.9	8.69	15.3	11.7	8.93	5.25	6.51	8.98	14.9	12.8	10.4	**2014**
2015	14.4	8.08	12.4	7.5	51.7	32.1	21	14.4	9.65	16.7	29.9	21.5	19.9	**2015**
2016	16.3	12.3	16.8	15	32.5	78.5	22	25.2	21.8	19.4	17.6	19.8	24.8	**2016**
2017	16.4		Low values in red are less than **15 CFS** and High Values in blue are greater than **201 CFS**										16.4	**2017**
Mean of monthly Discharge	**28**	**27**	**27**	**38**	**38**	**38**	**35**	**42**	**33**	**55**	**36**	**36**	Overall Mean **36.1**	

Guadalupe River near Hunt

YEAR	Hunt USGS Gauge 816550: Monthly mean in ft^3/s (Calculation Period: 1941-10-01 -> 2017-01-31)												Annual Mean	YEAR
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
1941										63.2	53.6	48.6	55.1	1941
1942	44.3	43	39.5	78.1	103.2	51.8	38.6	38.8	45.5	71.4	49.7	43.1	53.9	1942
1943	40	38	40.5	37	34.7	59.2	30	22.5	28	29.3	29.3	32.5	35.1	1943
1944	38	38.1	43.6	34.3	62.2	54.5	30.4	36.6	45.2	35.7	35.3	41.9	41.3	1944
1945	66.7	51.9	49.9	59.3	37.6	33.9	29.2	22.6	21.5	52.6	37	46	42.4	1945
1946	39.1	35.6	32.6	33	49.8	31	23.9	15.5	26.5	54.8	60.2	39.8	36.8	1946
1947	66.8	55.2	49.7	57.2	56.1	64	49.1	38.1	29.9	29.6	33.1	36.8	47.1	1947
1948	32.6	36.4	36.2	38.1	33.6	23.2	33.6	18.9	24.6	22.9	25.9	26.1	29.3	1948
1949	27.6	32.8	63.5	47.5	48.6	47.1	29.5	45.9	34.7				41.9	1949
1965				48.5	83.5	82	34.2	27.3	28.8	33.4	34	35.3	45.2	1965
1966	31.1	30.4	28.8	74.4	60.7	30.8	37.6	656.9	139.6	67.9	50.9	41.8	104.2	1966
1967	40.3	38.3	33.6	32.5	25.7	17.1	53.9	18.3	39.9	98.4	78	56.9	44.4	1967
1968	151.3	47.1	70	81.2	69.2	50.7	50.1	30.5	39.3	34.8	38	40.2	58.5	1968
1969	36.9	35.5	35.3	49.1	38.7	27.7	23.3	24.4	36.8	157.7	79.1	95.7	53.4	1969
1970	67.5	61.6	81.6	57.5	51.5	42	33.5	27	35.1	33.6	37.5	37.1	47.1	1970
1971	35.5	36	32.7	34.2	27.5	19.7	19.4	338.2	51.2	84.9	59.4	51.7	65.9	1971
1972	45	40.1	35	31.2	117.2	42.8	31.1	84.7	49.4	41.8	42.2	40	50.0	1972
1973	41.2	43.1	42.7	39.5	32.4	36.6	63.8	45.7	37.5	296.5	68.7	55.4	66.9	1973
1974	51.4	47.6	46	39.6	165.6	37.8	30.7	116.8	168.6	124.1	113.6	79	85.1	1974
1975	74	104.7	75.1	59	173.1	124	81.2	57.3	53.1	53.7	56	52.2	80.3	1975
1976	42.5	40.7	39.8	47.2	37	26.8	66.4	36.3	39.3	39.1	43.5	42.5	41.8	1976
1977	42.2	37.6	36.2	569.9	268.2	67.9	47.3	38.9	41.2	56.5	53.1	51.8	109.2	1977
1978	45.2	45.5	42.1	41.5	29.7	41.4	20.1	**992.5**	133.3	75.1	75.7	60.7	133.6	1978
1979	57	67.1	111.1	88	61.5	168	70.2	62.7	57.1	52.7	50.4	53.4	74.9	1979
1980	53.9	48.3	45.6	42	52.8	31.5	24.2	27.5	311.8	109.7	61	62	72.5	1980
1981	56	48.6	73.3	242.5	100.7	367.5	117.7	81.1	67.5	237.9	88.2	75	129.7	1981
1982	69.5	67.5	62.2	53	140.3	56.4	47.3	39.3	36.1	35.9	47.3	47.1	58.5	1982
1983	45.2	58	57.9	38.6	36.1	37.4	25.8	30.5	29	33.5	37.8	36.6	38.9	1983
1984	37.2	38.4	35	28.6	21.1	17	14.9	14.6	17.1	77.9	49.2	322.4	56.1	1984
1985	132.2	114.3	82.1	59.6	194.1	60.4	52.5	35.3	37.9	676.9	79.9	61.2	132.2	1985
1986	53.2	56.7	40.9	40.1	57.9	57.1	37.5	35.9	265.8	177.4	89.2	116.6	85.7	1986
1987	106	91.9	99.6	82.2	97.9	550.7	956.2	155.9	132.6	94.4	89	85.5	**211.8**	1987
1988	82.2	76.9	70.3	62.6	87.1	63.9	291.3	62.5	52.4	53.5	56.8	59.9	85.0	1988
1989	60.6	68.8	54.9	51.4	41.6	31	26.6	24.9	22.9	36.7	44.5	38.7	41.9	1989
1990	36.3	47.6	45.6	42	191	34.7	46.3	176.6	46	57.3	61.4	53.4	69.9	1990
1991	57.8	57.7	43.7	51.8	47.9	37.2	34.8	34.5	92.8	71.9	54.8	289.8	72.9	1991
1992	143.3	212.7	257	152.6	128.6	143.5	96.8	72.1	63.4	53.2	95.6	94.2	126.1	1992
1993	78	78.1	73.6	67	51.8	44	41.6	33.1	40	38	49.5	52.6	53.9	1993
1994	42.8	46.4	50.8	45.9	285.8	68.8	43.5	38.7	48.3	49.9	61.4	56.9	69.9	1994
1995	58.4	52.9	75.8	52	51.3	53.9	38.1	33	69	53.7	47.9	39	52.1	1995
1996	38.2	38.6	40	37.7	34	29.6	21.3	21.4	62	310.5	69.4	61.9	63.7	1996
1997	44.4	140.4	101.1	102.6	90.2	320.5	116.5	71.7	60.5	62.4	60.7	60.7	102.6	1997
1998	76.1	68.8	91.1	60.5	44	37.9	28.3	258	67.3	61.4	84.2	67.5	78.8	1998
1999	54.7	46.4	50.8	49.4	51.1	91.1	52.6	38.6	35.8	35.6	36.2	41.9	48.7	1999
2000	42.5	39.9	35.5	37.7	44.9	42.2	23.8	19.5	21.7	580.5	414.1	98.2	116.7	2000
2001	82	80.4	88.7	74.5	65.2	46.3	35.7	35.1	73.5	53.5	538.1	103.9	106.4	2001
2002	81.2	65	61	53.7	49.6	41.8	407.3	64	63	94.9	77.2	66.9	93.8	2002
2003	56.8	56.9	55	46.9	40.3	53.9	43	34.7	42.8	114.4	54.6	46.5	53.8	2003
2004	47	45.1	70.4	395.7	67.4	288.6	107.7	76.1	64.3	60	71.5	64.6	113.2	2004
2005	58.4	64.9	63.6	58.9	53.7	41.8	34.1	36.6	30.9	31.6	33	40.4	45.7	2005
2006	39.4	34.7	33.6	29.5	26.5	20.2	19.6	18.9	29	31.3	29.6	31	28.6	2006
2007	32	27.5	43.8	39.6	144.7	62.4	121	135.5	128	66	53.2	48.8	75.2	2007
2008	49.6	47.3	42.2	38.5	34	22.5	23.7	25.5	25.1	25.9	27.6	29.7	32.6	2008
2009	34	32.5	39.4	29.8	27.7	15.3	13.6	19.2	32.7	35.8	34.8	38.1	29.4	2009
2010	42.2	76.6	48.7	266.7	41.3	25.5	27.7	19.8	30.2	25.1	26.1	24.8	54.6	2010
2011	25.9	21.9	21.1	17.7	14.5	10.1	8.83	8.23	10.9	15.5	19.8	29.9	**17.0**	2011
2012	28	24.9	60.5	27.7	81.4	24.5	19.5	16.3	19.7	19.4	19.1	21.5	30.2	2012
2013	25.5	20.5	18.8	18	19.2	15.1	11.8	10.1	13.7	17.9	18.3	20.9	17.5	2013
2014	20.8	19.9	18.7	16	45.6	20.9	10.4	**6.75**	9.06	11.3	13	16.4	17.4	2014
2015	20.4	18.9	19.2	34.2	101.3	68.9	26.4	21	17.2	31.7	75.3	48.6	40.3	2015
2016	42.7	30.4	42.7	39.3	129.4	148.3	48.7	47.3	49	36.6	42	61.1	59.8	2016
2017	51.8		Low values in red are less than **20 CFS** and High Values in blue are greater than **422 CFS**										51.8	2017
Mean of monthly Discharge	**54**	**54**	**56**	**71**	**74**	**71**	**67**	**78**	**57**	**86**	**67**	**60**	Overall Mean **66.3**	

Guadalupe River at Kerrville

YEAR	Kerrville USGS Gauge 08166200: Monthly mean in ft^3/s (Calculation Period: 1986-06-01 -> 2017-01-31)												Annual Mean	YEAR
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
1986						152.6	65.5	44.9	256.1	252.4	179.6	212.4	166.2	**1986**
1987	197	178.7	187.6	148.6	246.5	1,089	**1,572**	281.5	221.6	163.6	156.8	156.2	**383.3**	**1987**
1988	137.9	89.6	99.7	96.2	218.4	121.8	572.8	171	113.4	98.1	85	78.9	156.9	**1988**
1989	98.7	101.5	117.5	101.5	80.9	53.2	37.3	39.2	38.5	64.8	77.7	64.1	72.9	**1989**
1990	59.1	71.1	81.9	74.6	303.6	58.2	91	221.4	91.6	78.2	80.5	72.3	107.0	**1990**
1991	87.7	104.5	72.4	66.6	69.8	56	40.3	36.4	129.1	91.8	87.2	571.5	117.8	**1991**
1992	282	555.3	546.5	329.2	286.2	255.4	167.2	147.6	112.3	104.4	160.3	155.3	258.5	**1992**
1993	143.7	137.9	135.7	135.2	117.6	92.6	55.8	53.5	100.7	74.1	74.1	77	99.8	**1993**
1994	83.5	75.9	101.5	81.8	312.8	97.3	55.5	51.7	77.7	71.9	100.6	109.2	101.6	**1994**
1995	111	84.8	129.7	101.9	138.9	151.8	79.4	37.3	115.9	88.5	81.1	67.4	99.0	**1995**
1996	56.6	59.4	68.6	68.2	55.6	40.1	27.3	34.1	118.1	441.6	122	115	100.6	**1996**
1997	91.7	332.5	270.5	253.3	251.7	786.3	270.9	166.6	115.9	114.2	114.7	121.5	240.8	**1997**
1998	164.5	145.9	226.9	131.4	93.5	80.7	48.8	244	103	121.5	154	134.8	137.4	**1998**
1999	120.9	108	117.4	104.5	123.3	165.9	100.3	62.8	57.7	59.7	63.7	68.1	96.0	**1999**
2000	66.6	68.6	57.1	46.9	66.8	72	35.5	30	34.9	676.4	648.3	187.6	165.9	**2000**
2001	170.5	171.2	189	152.6	126.9	79.1	59.3	66.8	142.8	95.8	718.3	198.8	180.9	**2001**
2002	144.2	118.3	107	104	85.2	64.7	748.4	120.3	110.8	181.5	150.4	134.5	172.4	**2002**
2003	113.5	117.6	115	94.1	72.9	105.4	82.3	65.3	83	210.5	97.4	80.9	103.2	**2003**
2004	92.5	91.5	140.4	623.5	159.4	899.7	260.1	169.1	133.6	115.3	142	115.9	245.3	**2004**
2005	109.8	143.5	165.9	127.6	120.6	93.2	77.9	78.9	70.7	66.6	70.5	73.1	99.9	**2005**
2006	69	68	68	45.9	62.8	40.4	35.8	24.1	44.9	58.8	49.1	59.7	52.2	**2006**
2007	65.1	51	127.8	81.4	444	221.6	287.6	377.3	254.4	140.8	114.4	98.9	188.7	**2007**
2008	87	82.2	74.9	67.7	60.2	35.2	37.4	47.7	40	45.1	45.4	50.9	56.1	**2008**
2009	54.1	37.9	66.7	54.1	51.1	29.2	21.6	28.6	76.4	67	66.6	61	51.2	**2009**
2010	71	175.9	99.2	478.3	155.3	80.9	91.8	40.9	99.8	56.9	61	61.9	122.7	**2010**
2011	62.7	54.6	37.2	39.4	31.8	15	11.2	12.1	14	25.4	39.1	51	32.8	**2011**
2012	46.6	49.7	147.5	46	146.3	32	26.1	13.7	28	30.9	28.1	32.8	52.3	**2012**
2013	54.6	32.1	31.6	42.2	37.7	25.6	15.5	**7.37**	29.2	47.6	33.8	35.4	32.7	**2013**
2014	28.2	26.8	24	22.7	84	37.5	17.3	7.41	19.3	25.4	33.1	29.9	**29.6**	**2014**
2015	40.3	30.8	36.3	59.7	222.2	118	59.3	22.7	16.7	46.3	80.5	101.3	69.5	**2015**
2016	90.6	68.4	101.3	80.9	403.9	292.8	69.1	132.8	101.1	70.2	73.7	101.6	132.2	**2016**
2017	91.3		Low values in red are less than **40 CFS** and High Values in blue are greater than **766 CFS**										91.3	**2017**
Mean of monthly Discharge	**100**	**114**	**125**	**129**	**154**	**176**	**165**	**92**	**95**	**122**	**129**	**112**	Overall Mean **126.1**	

For ease of interpretation, low flows are marked in **RED** and represent monthly average values of less than 1/3 of the overall average flowrate. High flows are marked in **BLUE** and represent monthly average values of over twice the recorded <u>annual</u> highest value of record. Absolutes are rendered in **BOLD.**

Guadalupe River at Comfort 1939-1979

YEAR	Comfort USGS Gauge 08167000: Monthly mean in ft^3/s (Calculation Period: 1939-05-01 -> 2017-01-31)												Annual Mean	YEAR
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
1939					76	17.5	144.5	49.3	30.4	129.6	52.1	50	68.7	**1939**
1940	51.5	80.6	94.7	307.9	241.1	186.7	139.2	82.2	45.3	93.4	173.3	448.7	162.1	**1940**
1941	141.4	559.9	427.8	801	783.8	259.2	165.8	115.3	212.5	313.2	150.7	133.7	338.7	**1941**
1942	122.3	111.6	93.4	465.8	638.1	172.4	95.6	70.4	94.7	254.9	142.6	125.9	199.0	**1942**
1943	105.9	94.4	101.4	110.4	82.5	208	58.9	28.8	46.7	51.9	50.3	65.3	83.7	**1943**
1944	88.3	109.4	186.6	116.6	**1,114**	367.3	96.2	102.9	126	138	91.1	194.6	227.6	**1944**
1945	317.4	302.8	411.3	365	156.3	101	83.3	41.1	158.1	189.6	91	198.4	201.3	**1945**
1946	122.3	138	137.5	126.8	223.4	130.5	45.7	24.6	68	268.9	428	188.8	158.5	**1946**
1947	401.4	267.9	215.1	235.8	201	410.1	115	67.6	44.1	42.8	60.5	68.9	177.5	**1947**
1948	63.3	85	75.8	82.8	67.3	56.5	67.8	23.9	32	40.7	36.9	42.9	56.2	**1948**
1949	55.8	346.7	175.6	201.2	135.7	118	54.4	123.5	98.2	60.9	53.3	61.6	123.7	**1949**
1950	69.3	77.8	60	87.3	92.3	58.3	29	17.2	30.5	27.2	32.5	35.8	51.4	**1950**
1951	36.8	42.2	69	49.7	191.7	118.6	15.2	6.16	10.9	13	27.5	29.7	50.9	**1951**
1952	29.5	30.9	38.2	83.6	131.6	110.1	25	3.2	382.2	41	38.4	119.1	86.1	**1952**
1953	91.2	57.3	56	41.6	19.7	2.33	9.1	13.1	111	59.4	40.5	36.4	44.8	**1953**
1954	38	32.7	22.7	62.5	63.5	9.66	2.12	**0**	**0**	39.7	28	20	26.6	**1954**
1955	39	43	23.1	13.2	113.4	12.9	141.7	25.6	20.5	16.1	17.1	24.6	40.9	**1955**
1956	21.5	27.1	16.6	15.5	14.9	0.097	**0**	14.6	5.9	**0**	3.63	10.5	**10.9**	**1956**
1957	16.8	24.4	92.8	603.3	345.4	226	23.3	4.28	51.7	721.6	266	207.7	215.3	**1957**
1958	335.4	553.3	552	253.7	255.7	352.6	119.1	67.4	517.9	181.5	242.8	199.5	302.6	**1958**
1959	165.1	146.8	110	190.5	131.5	402.8	149.4	75.5	55.7	**1,094**	124	115.4	230.1	**1959**
1960	143.4	220.3	158.8	138.6	96.6	44.2	105.9	611.6	131	727	362.8	485.7	268.8	**1960**
1961	404.9	758.1	424.4	244.1	152.6	236.6	163.7	123.9	94.1	90.8	103.1	99	241.3	**1961**
1962	92.3	84.8	75.4	94.6	85.5	65.3	22.8	10.4	15.6	49.2	42.4	53.2	57.6	**1962**
1963	51.6	49.4	45.2	41.8	37.4	21.7	6.3	2.66	22.8	37.5	69.7	46.3	36.0	**1963**
1964	45.4	81.6	134.8	78	44.1	13.3	0.403	79.4	574.5	141.7	84.5	72.9	112.6	**1964**
1965	68.5	207.7	129.1	107.9	488.6	354.3	71.3	35.5	40.8	63.8	59.7	84.7	142.7	**1965**
1966	73.4	78.5	71.1	171.6	156.2	61.9	44.5	470.1	207.1	104.3	83.5	75.6	133.2	**1966**
1967	75.2	63.6	51.8	48.4	29.7	10.6	49.8	16.1	117.1	213.6	169.2	102.8	79.0	**1967**
1968	811.5	350.7	352.5	354	338.8	201	144.5	70.3	72.3	70.2	87.7	98.4	246.0	**1968**
1969	78.2	89.1	82.2	131.2	77.4	35.6	13.7	50.6	97	964.7	246	282.8	179.0	**1969**
1970	203	203.9	342.1	219.5	264.2	164.5	86.4	55.2	75.2	85.6	76.4	76.1	154.3	**1970**
1971	70.1	65.5	58.9	57.9	45.8	29.8	24.5	1,741	180.5	592.7	322.8	239.8	285.8	**1971**
1972	189	157.7	126.5	112.1	762.1	237.1	136.7	250	140.1	111.3	118.6	104.7	203.8	**1972**
1973	113.2	154.3	179.5	166	122.7	167.3	408.7	212.2	143.3	724.1	259.2	188.5	236.6	**1973**
1974	171.2	144.1	134.4	105.4	663.9	122.7	64.8	475.5	437.9	372.7	518.3	297.5	292.4	**1974**
1975	300.9	811.8	379.5	314.1	1,122	646.5	320.2	193.6	159.6	156.9	138.7	137.1	390.1	**1975**
1976	125.9	110.7	103.1	183.6	153.5	139.8	352.8	130.5	194.6	173.3	188.4	227.2	173.6	**1976**
1977	235.9	219.4	181.3	**1,598**	663.4	285.8	154.7	97.2	78.7	113.5	126.6	118	322.7	**1977**
1978	104.9	112.5	91.1	87	69.9	160.3	41.9	4,782	574.7	250.6	237.8	200.7	559.5	**1978**
1979	239.9	374.6	550.2	594	384	938	311.6	241.4	149.5	112.1	127.7	131.7	346.2	**1979**

Guadalupe River at Comfort 1980-2017

1980	133.9	124.2	110.4	106.7	131.1	61.4	29	30.1	521	400.5	181.9	186.3	168.0	**1980**
1981	157.8	147.9	565.2	726.6	386.7	1,452	443.4	226.9	220.9	1,117	332.8	245.8	501.9	**1981**
1982	199.5	182.7	174.7	139.9	384.5	329.8	109.1	80.8	72.5	72.7	107.6	113.5	163.9	**1982**
1983	102.5	132.6	159.1	93.8	95.4	137.8	73.6	52	52.7	70	77.3	80.5	93.9	**1983**
1984	85.5	65.1	61.3	45.5	40.5	30.5	14.1	14.3	13.5	136.1	105.2	501.7	92.8	**1984**
1985	361.7	332	362.2	265	649	186.9	156.6	65.1	94.2	2,417	269.7	244.2	450.3	**1985**
1986	199	308.1	131.8	124.3	242.5	400.6	142.8	74.5	429.3	587.1	447.3	724.3	317.6	**1986**
1987	572.4	434.6	512.8	373.2	793.1	2,820	1,974	465.9	378.8	263.1	260.1	247.2	757.9	**1987**
1988	219.3	196.8	180.6	141.7	250.4	167	**1,111**	282.1	178.7	148.4	125.4	120.8	260.2	**1988**
1989	169.1	207	186.1	174	149.5	76.2	43.5	44.2	46.9	70.2	97.8	84.2	112.4	**1989**
1990	74.8	93.2	122.8	143.4	884.6	106.4	142.8	301.3	140.7	128.2	129	112.9	198.3	**1990**
1991	141.3	158.9	124.4	126.5	143.3	120.4	79.7	59.4	294.1	158.6	190.9	2,700	358.1	**1991**
1992	987.4	**1,728**	**1,559**	937.5	809.5	764.8	417.7	275	208.9	179.8	263.7	241.5	697.7	**1992**
1993	226.7	245.7	248.1	239.4	199	160.4	102.8	62.8	77.1	97.2	107.8	110.6	156.5	**1993**
1994	116.4	140	175.1	136.2	481.7	163.5	80.8	64.3	111.5	104.4	163.9	244.9	165.2	**1994**
1995	228.9	158.5	220.2	187.1	228.6	284.5	154.5	76.6	164.6	124.3	166.7	128.6	176.9	**1995**
1996	113.3	99	92.3	81.6	58.4	48.6	23.7	27.8	138.4	714.7	216.1	195.5	150.8	**1996**
1997	155.7	565.4	520.6	784.4	589.8	2,651	676.7	306.1	209	217.1	177.5	166.4	585.0	**1997**
1998	235.3	251	508.5	253.6	152.8	115.2	62.8	308.1	127.4	239.1	326	251.2	235.9	**1998**
1999	192.4	159.1	189	164.8	177.2	218.4	149.3	71	61.6	69	75.8	81.5	134.1	**1999**
2000	78.6	84.6	67.8	55.8	75.8	90.5	33.6	22.7	31.3	820	**1,277**	325.5	246.9	**2000**
2001	379.2	422.5	482.3	340.3	257.8	119.4	66.2	65.9	188.8	139.9	**1,111**	297.2	322.5	**2001**
2002	204.1	171.1	141.9	139.2	108.8	374.3	**5,809**	410.9	318.8	573.1	551.2	394.1	**766.4**	**2002**
2003	278.8	315.3	331.4	209.8	113.3	203.8	161.3	101.7	125.8	277.5	122.7	105.5	195.6	**2003**
2004	152.6	136.9	252.7	1,303	409.4	**1,226**	646.1	345.4	246.9	420.5	630.8	397.7	514.0	**2004**
2005	311.5	409.7	482.2	302.5	259.5	203.9	109.8	106.4	106.7	96	105.6	103.1	216.4	**2005**
2006	96.5	93.8	102.8	78.3	95.8	41	33.2	24.7	59	69	49.7	69.2	67.8	**2006**
2007	90.1	70.6	604.8	362.8	1,159	679.9	**1,052**	**1,637**	845.9	362.6	228.7	188.2	606.8	**2007**
2008	160.8	139.9	137	114.8	96.6	44.1	34.7	46.6	42.2	48.1	44.7	54	80.3	**2008**
2009	48.7	40	62.4	56.9	53.8	26.8	20	22.2	73.3	80.3	108.3	99.9	57.7	**2009**
2010	134.1	430.1	234.9	698.5	289.2	161.6	146	58.4	159.1	85.2	81.8	82.8	213.5	**2010**
2011	90.5	81.6	61.1	44.9	33.8	14.2	8.64	8.18	10.6	26.6	43.3	61.4	40.4	**2011**
2012	64	72.2	232.9	62.3	207	42.1	34.8	28.7	35.9	34.8	36.8	45.6	74.8	**2012**
2013	72.7	49.5	46	51.8	49.6	33.3	12	2.93	25.9	43	50.8	45.4	40.2	**2013**
2014	41.8	35.2	34.6	26.3	136	49.1	29.6	10.2	18.7	26.3	44.1	38	40.8	**2014**
2015	47.8	40.5	49.8	103.9	**1,368**	399.7	147.3	58.7	35.1	57.2	124.5	157.4	215.8	**2015**
2016	146.4	117.9	162.2	235.9	**1,617**	846	180.3	179.1	147.9	114.7	153.5	233.5	344.5	**2016**
2017	209.5		Low values in red are less than **75 CFS** and High Values in blue are greater than **1742 CFS**										209.5	**2017**
Mean of monthly Discharge	**169**	**207**	**212**	**240**	**308**	**283**	**239**	**213**	**150**	**250**	**182**	**192**	Overall Mean **220.4**	

For ease of interpretation, low flows are marked in **RED** and represent monthly average values of less than 1/3 of the overall average flowrate. High flows are marked in **BLUE** and represent monthly average values of over twice the recorded annual highest value of record. Absolutes are rendered in **BOLD.**

Guadalupe River near Spring Branch 1922-1969

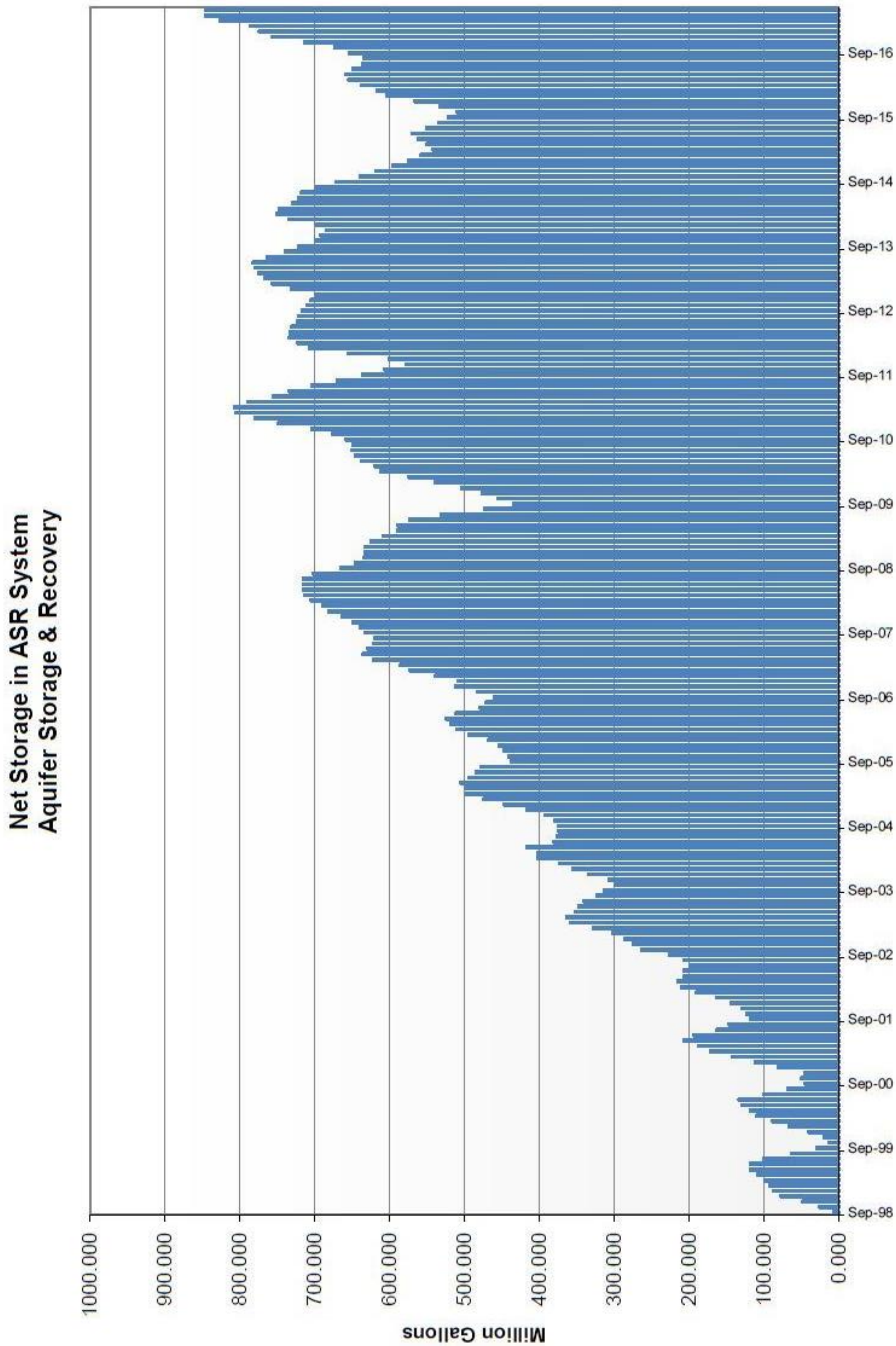
YEAR	Spring Branch USGS Gauge 08167500: Monthly Discharge Mean in ft^3/s (Calculation Period: 1922-06-01 -> 2017-03-31)												Annual Mean	YEAR
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
1922						81	69.1	44.9	34.8	42.3	60.6	52.2	55.0	1922
1923	52.2	78.8	86.7	291.8	133.2	46	22.9	10.2	842.2	102.4	532.8	829.4	252.4	1923
1924	417.3	450.3	639.6	565.1	798.2	484.5	167.9	79.1	117.8	78	87.1	95.4	331.7	1924
1925	88.9	80.3	69.3	58.9	72.9	32.9	21.4	30	45	296.1	189.2	81.8	88.9	1925
1926	89.1	73.5	146.6	722.6	394.1	162	227.8	86.8	53.1	67.7	108.9	131.9	188.7	1926
1927	93.5	300.9	418.7	362.1	192.9	404.4	104.6	46.8	50.2	105.5	57.9	69.4	183.9	1927
1928	73	91	142.5	59.5	70	121.5	27.1	19.5	31	39.9	36.7	42.6	62.9	1928
1929	45.2	46.4	56.8	84.7	1,088	239.6	443.4	52	43.1	33	48.1	70.8	187.6	1929
1930	57.9	63.9	55.3	45.4	411.9	399.2	69.7	19.9	19.5	870.5	173.4	151	194.8	1930
1931	299.1	553.6	471.8	700.3	918.8	274.1	255.7	128.3	65.6	57.7	83.1	102.6	325.9	1931
1932	157.8	162	345.5	234.2	254.6	104.5	3,744	205.4	631.2	259.7	175.9	204.5	539.9	1932
1933	352.2	233.8	231.1	185.4	231.6	121.4	65.3	51	54.7	48.9	53.1	61.1	140.8	1933
1934	114.9	88.5	122.7	228	98.7	36	77.6	22.5	25.7	17.7	31.3	41.1	75.4	1934
1935	40.7	84.4	49.9	55.8	932.6	3,997	424.5	162.5	983.2	336.8	236.9	351.1	638.0	1935
1936	259.5	201.1	198.3	149.3	710.8	945.9	1,214	214.5	4,055	1,131	661.7	530.8	856.0	1936
1937	453.6	374.3	400.2	285	181.8	621.5	142.9	70.6	79.1	93	87.9	227.2	251.4	1937
1938	490	314.6	229.4	411.2	371.2	165.3	90.2	51.5	61.3	47.4	54.5	56.1	195.2	1938
1939	100.7	74.1	67.5	66.3	74.3	22.2	151.1	54.2	23.7	228.7	64.9	66.2	82.8	1939
1940	66.3	97.8	147.8	371.6	265.1	330.4	173.9	82.8	48.9	69.1	216.3	646.1	209.7	1940
1941	232.4	1,274	1,039	1,504	1,820	585.5	378.4	180.8	268.9	410.6	220.4	183	674.8	1941
1942	153.5	142.5	123.8	652.5	835.1	238.1	142.2	106.2	379.3	479.5	283.1	232.9	314.1	1942
1943	207.3	164.3	160.8	184.2	126.7	293.9	140	47.7	91.1	71.1	63.2	89.1	136.6	1943
1944	147.5	244.1	499.5	293.2	1,662	636.7	189.3	286.9	312.8	255.9	175.5	482.4	432.2	1944
1945	732.6	761.1	959.7	725.7	304.5	187.3	150.5	94.6	245.2	328.7	156.2	384.5	419.2	1945
1946	238.1	309.1	310.8	243.3	487.4	233.9	89.1	54.3	232.5	389.3	758	446.8	316.1	1946
1947	964.3	605.2	432.1	414.7	344.5	444.4	169.7	93.3	58.6	55.2	76.2	91.2	312.5	1947
1948	83.9	95.8	88.6	89.2	74.7	166.5	89.4	35	39.2	56.9	44.4	52.4	76.3	1948
1949	69	377.3	214.6	402	299.6	170.4	78.7	128.1	112	77.6	70.4	78.9	173.2	1949
1950	85.9	106.7	80.4	112.6	183.2	106.3	81.3	31.1	42.5	32.6	36	48.2	78.9	1950
1951	47.9	53.6	82.4	66	181.7	119.2	13.3	**0.906**	**0.907**	5.91	21	36.2	52.4	1951
1952	32.1	31.3	40.3	109.9	331	153.5	36	7.08	2,119	75.6	78.5	187.1	266.8	1952
1953	163.2	107.3	109	83.3	45.1	10.4	15.7	15.9	247.4	85.7	61.4	61.1	83.8	1953
1954	60.2	46.7	36.6	25.7	118.3	12.3	0.539	0.255	0.287	27.3	19.6	19.2	30.6	1954
1955	39.5	75.4	29	16.1	137.5	38.8	138.2	37.8	15.4	14.2	13.6	23.3	48.2	1955
1956	24.5	29.3	16.8	6.11	19.3	**0**	**0**	5.65	6.85	6.77	11.1	6.48	**11.1**	1956
1957	10.9	35.1	262.5	1,478	740.9	617.7	66.6	26.1	273.8	1,391	740.7	482.5	510.5	1957
1958	757.5	1,099	1,076	518.1	1,699	677.1	264.9	115.2	675.8	376.7	486.4	303	670.7	1958
1959	230.9	228.8	177.4	308.3	220.1	619.5	247.3	120	83.6	1,397	205.8	213.9	337.7	1959
1960	274.8	342.5	278.1	249.7	154.7	81.7	140.1	787	183.2	1,312	576.1	797.6	431.5	1960
1961	688.6	1,470	716.8	411.5	250.3	463.7	261.5	154.7	118.2	106.5	122.8	114	406.6	1961
1962	105.3	106.7	95.8	121.1	96.3	152.6	34.9	12	47.8	76.6	68.6	82.1	83.3	1962
1963	67.1	62.6	60.1	109.9	49.2	26.5	10.7	3.24	8.75	54.8	96.4	64.4	51.1	1963
1964	59.8	148.7	273.5	119.4	61.9	50.6	3.86	80.6	690	197.7	160.7	108.4	162.9	1964
1965	98.9	419.2	217	368	1,365	733.9	166	79.9	102.8	183.2	115.2	258.3	342.3	1965
1966	171.2	177.5	168.3	360	339.3	152.6	85.1	531.9	306.9	156	114.4	103.2	222.2	1966
1967	90.8	93.8	80.6	66.7	48	16.9	41	21.9	394	280.8	327.3	209.4	139.3	1967
1968	1,683	714.3	644.2	662.5	714.4	384.2	238.3	117.4	130.8	105.6	110.1	136.2	470.1	1968
1969	111.4	136.6	134.7	254.5	295.7	190.9	63.7	111.9	168.8	1,265	346.7	549.7	302.5	1969

Guadalupe River near Spring Branch 1970-2017

1970	371.4	372.8	708.7	414.5	644.3	407.5	169.5	92.4	115.3	125.5	106.3	106.7	302.9	**1970**
1971	99.3	91.2	88.4	76.7	62.6	25.4	20.6	1,975	467.8	1,048	633.3	509.3	424.8	**1971**
1972	329.3	267.5	208.1	218.1	1,457	492.7	219.9	334.7	195.2	195.8	235.1	182.5	361.3	**1972**
1973	220.7	334.6	381.4	378	279.9	504	2,019	539.8	433.4	1,508	627	366.4	632.7	**1973**
1974	289.4	237.5	217.6	173.1	793.9	191.5	89.4	692.6	630.4	325.5	938.5	505.7	423.8	**1974**
1975	577.3	1,869	685.4	540	1,819	1,254	721.7	344.7	264.2	236.8	184.4	169.7	722.2	**1975**
1976	156.3	143.4	129.7	667.8	518.3	362.2	747.9	268.3	269.6	368.2	430.5	499	380.1	**1976**
1977	477	480.5	349.4	2,417	1,164	558.2	255.1	142.1	117.2	217.1	204.8	158.9	545.1	**1977**
1978	137.4	143.6	119.5	109.2	81.4	197.9	34.6	4,980	941.4	356.5	359.2	348.4	650.8	**1978**
1979	682.4	934.1	1,448	1,486	948.7	1,933	682.3	380.3	222.6	161.1	166.3	178.8	768.6	**1979**
1980	171	154.8	155.5	148.5	263.2	122.4	46.3	40.1	534.4	601.6	213.9	248.7	225.0	**1980**
1981	197.8	186.2	819.8	955.5	455.6	3,112	796.7	324.5	280.8	1,584	453.8	328.5	791.3	**1981**
1982	261.2	220.8	208.4	189.3	769.4	387.7	136.2	91.3	107.7	82.7	112.3	133.3	225.0	**1982**
1983	112.5	154.7	231.3	143.7	252.8	375.5	145.3	78.6	61.1	131.9	149.6	111	162.3	**1983**
1984	118.3	94	84.5	58	43.9	36.9	8.93	20.1	12.3	226.4	149.9	416.1	105.8	**1984**
1985	1,241	630.4	764.5	498.2	551.7	1,280	429.7	137.1	172.4	1,366	497.3	610.6	681.6	**1985**
1986	382.5	509.5	285.3	222.1	385.9	746.7	253.8	126.8	733	1,345	850.6	1,708	629.1	**1986**
1987	1,151	767.9	956.1	589.3	1,305	6,329	2,626	687.6	515.2	317.8	314.6	299.4	1321.6	**1987**
1988	268.7	236.1	221.6	179.5	273.9	195.1	1,079	328.8	194.1	156	134.4	130.8	283.2	**1988**
1989	174.9	221.7	194	177.3	172.1	95.4	50.3	39.2	45.1	61.6	97.6	96.7	118.8	**1989**
1990	85	99.7	182.9	272.9	1,237	162.3	357.6	402.3	194.4	174.2	185	151.6	292.1	**1990**
1991	217.7	355.4	231.5	266.7	368.2	237.7	137.1	83.3	339.2	174.5	222.8	4,927	630.1	**1991**
1992	1,903	4,164	3,306	1,593	2,216	1,774	817.8	467.1	299.9	216.1	395.4	376.2	**1460.7**	**1992**
1993	434.7	485.2	457.5	419.3	335.8	290.6	195.3	93	135.5	245.4	133.5	125.6	279.3	**1993**
1994	135.2	182.1	290.1	200	822.6	271.5	122	83.3	136.7	229.9	243.9	354.5	256.0	**1994**
1995	376.6	242.2	321.5	283.9	426.3	478.3	235.6	105	199.6	148.1	213.7	152.2	265.3	**1995**
1996	131.7	113.1	102.4	94.8	60.1	46.1	20.8	33.6	211.4	718.1	245.5	237.4	167.9	**1996**
1997	184.8	660.3	740.3	1,560	1,195	6,107	1,231	465.7	253.6	258.7	223.3	235.1	1092.9	**1997**
1998	300.7	505.8	1,352	585.5	258.6	171.7	80.4	317.6	161	1,073	735	422.9	497.0	**1998**
1999	280.4	215.2	219.1	195.6	202.9	301.8	221.9	89.7	69	73	82.4	89.1	170.0	**1999**
2000	87.8	98.8	87.3	71.3	88.9	109.4	28.9	13.1	20.5	669	2,053	519.3	320.6	**2000**
2001	651.5	810.5	893.4	617.2	450	191.9	98.9	135.2	563	426.3	1,749	729.4	609.7	**2001**
2002	432.3	310.4	237.7	208.6	144.1	208.2	**10,530**	760.9	483.7	780.2	787.6	644.5	1294.0	**2002**
2003	518.4	653.2	665.3	401.7	248	344.1	268.2	144.1	184.7	308.3	169.2	145.1	337.5	**2003**
2004	189.4	210.4	367.5	1,963	846.6	2,006	1,313	600.1	394	1,077	2,993	1,060	1085.0	**2004**
2005	586.8	717	1,241	692.5	527.6	347.9	187.3	259.8	135.8	117.6	122.7	127.3	421.9	**2005**
2006	110.3	104.1	113	78.4	169.3	55.7	41.1	17.2	49.7	55.7	51.5	68.5	76.2	**2006**
2007	154.7	98.2	1,425	790	1,799	1,092	2,847	3,495	1,431	623.7	332.8	259.6	1195.7	**2007**
2008	216	169.3	164.7	134	110	46.3	38.7	55.5	38.7	43	46.4	57.6	93.4	**2008**
2009	64.9	43.6	98.3	62	54	26	4.81	11	74.4	224.7	183	159.2	83.8	**2009**
2010	288.8	1,007	438.9	843.9	530	258	240.1	83.2	435.1	149.1	117.5	109.6	375.1	**2010**
2011	120.2	100	71.2	52.5	33.7	7.18	0.818	**0**	**0.001**	7.91	22.6	45.5	38.5	**2011**
2012	79.3	86.9	287.5	96.5	316	70.7	37.4	6.87	39.4	45.1	34.4	40	95.0	**2012**
2013	87.7	48.9	44	53.2	133.5	63.4	16.1	0.772	14	102	61.3	46.6	56.0	**2013**
2014	43.6	38.4	31.2	19.2	141.9	61.8	12.3	0.394	5.51	15.4	53.9	35.1	38.2	**2014**
2015	88.1	63.1	70.9	187.4	3,468	1,177	410.2	130.5	68.3	482.1	312.2	372.1	569.2	**2015**
2016	293.7	201.2	282.3	501.9	2,296	1,811	429	350.6	264.1	190	201.1	309.8	594.2	**2016**
2017	343	472.8	464.6	Low values in red are less than **120 CFS** and High Values in blue are greater than **3020 CFS**									426.8	**2017**
Mean of monthly Discharge	**281**	**349**	**366**	**391**	**542**	**552**	**435**	**258**	**286**	**339**	**288**	**301**	**Overall Mean 365.7**	

For ease of interpretation, low flows are marked in **RED** and represent monthly average values of less than 1/3 of the overall average flowrate. High flows are marked in **BLUE** and represent monthly average values of over twice the recorded annual highest value of record. Absolutes are rendered in **BOLD.**

City of Kerrville Aquifer Storage and Recovery Net Storage Status: September 1996-2016



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