Cypress Creek Flow Study: Blanco and Travis Counties, Texas

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The Meadows Center for Water and the Environment
Texas State University

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Mr. Wierman was the lead researcher for the project.

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© Zak Zeinert - sun rising behind the Pedernales River in the Texas Hill Country

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Figure 1. Towering Bald Cypress tree along Cypress Creek

EXECUTIVE SUMMARY

Cypress Creek, a natural jewel and significant tributary of the Pedernales River, is at a cross-roads as rapid growth in the Austin region spreads west into the Hill Country and extended droughts and potential climate change reduce rainfall, recharge, and springflow, negatively affecting the creek's flow patterns and health. Land fragmentation within the larger Pedernales watershed is already evident, altering the habitat and land management activities. What will the future hold for this remarkable Hill Country stream?

Many opportunities exist to better understand our creeks and rivers and how they interact with the local aquifers. Improved understanding can lead to new development practices and land management strategies that can change the way we use water while sustaining the economic vitality of the region. The challenge is illustrating the potential water crisis, its cost, and efficient management and conservation measures that are recognized and accepted by the Hill Country's residents and visitors.

The Meadows Center for Water and the Environment's "How Much Water is in the Pedernales?" Research (2015-2017) series focused on the surface and groundwater resources of the Pedernales River and the threats to its continued sustainability by examining water quality and flows across the watershed to help us better define the primary water sources and potential management and conservation activities to protect and enhance the river flow and quality. A gain-loss study of the Pedernales River determined how the river may have changed from similar studies conducted in 1956 and 1963. Further studies targeting tributaries, such as Cypress Creek, are essential in a more in-depth understanding of the health of the watershed, as they provide an estimated sixty percent of the flow in the Pedernales.

While the cities in the Pedernales watershed are not growing at the pace of Austin or San Antonio, their steady growth combined with the increased partitioning of large tracts into smaller ranches, expanding tourism, and thriving agricultural industry, are expected to increase the water demands by about thirty percent over the next fifty years. The regional Groundwater Management Area (GMA) 9, has established a Desired Future Condition (DFC) for some of the underlying aquifers, but not all. The DFC for the Trinity Aquifer is 35 feet of drawdown over 50 years, but the Ellenburger –San Saba Aquifer has been designated as non-relevant and does not have a DFC. This decline in aquifer levels will have a significant negative impact on springflow, the main stem of the Pedernales and its tributaries, such as Cypress Creek, underscoring the need for the continuance or implementation of new measures to sustain flow in the Pedernales River basin.

INTRODUCTION

The Texas Hill Country is a unique place known for its stunning spring fed creeks, limestone bluffs, soaring cypress trees, and expansive scenic views. Over the past several years, the Meadows Center for Water and the Environment has been working to answer the question – How much water is in the Hill Country? Although this seems like a straightforward question that merits a straightforward answer, the reality is that the largely hidden and unknown complexities of Hill Country hydrogeology make it challenging to answer.

Building upon the "How Much Water is in the Pedernales?" research, The Meadows Center teamed up with the Colorado River Land Trust to direct this question towards Cypress Creek, a significant tributary that joins the Pedernales River before it meets Lake Travis. The Cypress Creek watershed is currently made up of mostly ranchlands with steady spring flows and good water quality. Gaining a greater understanding of these types of natural systems and the interconnectedness between surface and groundwater allows for informed water planning, wise water policy and the health of Hill Country springs, streams, and rivers in the future.

BACKGROUND

Over the years, various aspects of the Pedernales watershed have been studied by several entities dating as far back as the 1950s. The Hill Country Alliance's "The State of the Pedernales: Threats, Opportunities and Research Needs" (2015), provides an overview of the main characteristics of the watershed and summarizes the findings of previous studies, and further research needs. A gain-loss study conducted by the United States Geological Survey (USGS) in 1962 confirmed that the Pedernales River is a gaining stream, meaning as one moves downstream from the headwaters, the flow rate increases due to springs, seeps, and inflows from the tributaries.

Historic and more recent changes in land use activities can affect the flow in the Pedernales River and its tributaries, aquifer storage, and the groundwater-surface water interaction. Due to these land use changes combined with a large number of wells now pumping from the basin's aquifers, it is important to know how land use change, groundwater pumpage, and the increase in demands affect the river and tributary flows today and into the future.

Figure 2. Monument commemorating the Fuchs Mill at Cypress Mill

In 2015, the Meadows Center focused its efforts on an improved understanding of the intricacies of the Pedernales watershed and its underlying hydrogeology. By refining a gain-loss study with groundwater information using current hydrology, we were able to better identify threatened or critical river segments to guide management efforts to protect and enhance recharge, maintain flows, and sustain the current exceptional surface water quality.

A water inventory event nicknamed a "Hydro-Blitz" occurred over a two-day period in early August 2015 as numerous teams fanned out across the watershed. Observations were made at 931 river and tributary sites to document the existence of flows in the river and tributaries during a summer dry spell to establish the groundwork for a future gain-loss study. If water was found, a later sampling effort in mid-August collected field parameters and water samples for a detailed water quality analysis. Flowing water was observed along Stribling Creek, Wallace Branch, and North Cypress Creek within the Cypress Creek basin, with the exception of the Cleveland Branch. Cypress Creek itself had ample flow and large stands of Cypress trees were observed along the river corridor.

Following the Hydro-Blitz, the Meadows Center and partners conducted a base flow study of the Pedernales River in 2016. The study started near the headwaters springs near Harper and concluded at Hamilton Pool Road at Hammett's Crossing. Due to the high lake levels in Lake Travis (approximately 14 feet higher in 2016 versus 1962), water was backed up in the river to just north of Hamilton Pool Road and the study could not proceed to the confluence of Cypress Creek as in the 1962 study. Thirty-one main channel sites, nine tributary sites and one spring were measured in 2016. Qualitative flow observations were made at an additional 36 tributary sites.

The outcome of the Hydro-blitz and the base flow study confirmed the previous gain-loss studies' findings that over 20 major tributaries, including Cypress Creek, play a vital role in sustaining and adding to the Pedernales River flows, resulting in the realization that a future gain-loss study should extend into key tributaries to pinpoint priority water management areas and appropriate strategies. This benefits the landowner community and agricultural practices and preserves the ecology to ensure Cypress Creek remains a treasured fixture of the Texas Hill Country.

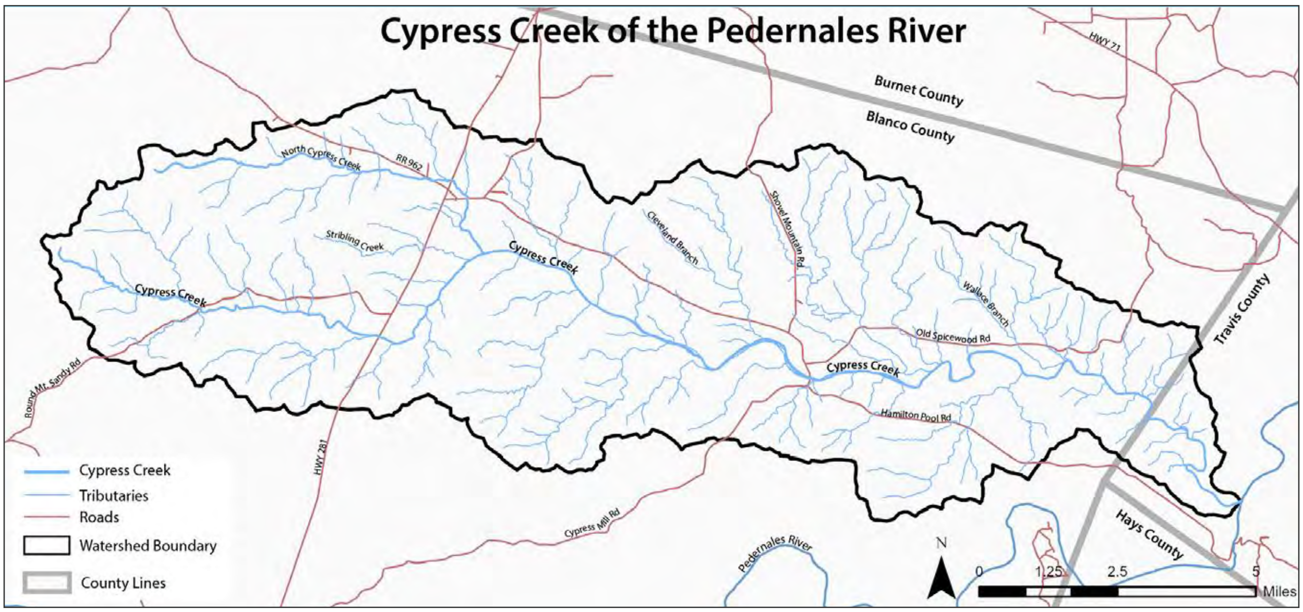

Figure 3. Cypress Creek of the Pedernales River

PURPOSE

Multiple aquifers contribute to base flow in Cypress Creek but there is a lack of research and awareness about the contributing and recharge zones within Cypress Creek. A gain-loss study performed by the Meadows Center allows for a better understanding of Cypress Creek's flow moving downstream, and to identify the locations of gaining and losing reaches where surface water recharges the underlying aquifers. The results of this research will contribute valuable insight towards strategic conservation prioritization.

In the first phase of this study, the Meadows Center sought to understand both where water is normally located within Cypress Creek, and to determine where flows within the watershed are primarily spring-fed. By gathering these data and synthesizing them with geology and land use/land cover data within the watershed, we conducted a gain-loss study that explains the surface-groundwater interactions. Based on recent studies, field work, data collection and evaluations, input from stakeholders across the watershed, and river health, this report establishes baseline data and focuses on the highest priority and regionally appropriate actions that will improve and sustain water resources.

WATERSHED SUMMARY

Figure 4. Study area within the larger Pedernales Watershed (Wierman et al., 2017)

Gaining and losing reaches are generally attributable to the underlying geology, though groundwater pumpage may be influencing Cypress Creek base flow. The study also offers a baseline for future studies looking at how increased groundwater pumpage and weather patterns impact the base flow of the creek. Analysis of several water chemistry parameters indicate where water chemistry is primarily influenced by geology and land cover. These findings allow for a narrowed focus on future conservation priorities in the watershed.

Cypress Creek, a major tributary of the Pedernales River, is situated in the northeast portion of the Pedernales watershed in Blanco County and spans 81.60 square miles. US Highway 281 crosses the western portion of the Cypress Creek watershed in a northeast-southwest orientation, and RM 962 traverses much of the watershed in a northwest-southeast orientation. Cypress Creek flows eastward towards its confluence with the Pedernales shortly before flowing into Lake Travis just west of Austin, Texas. Lake Travis is a reservoir on the Colorado River formed by Mansfield Dam and serves as the primary drinking water source for the City of Austin and surrounding areas.

SCOPE OF STUDY

The study consisted of several primary efforts: a literature review, GIS data collection and mapping, water quality sampling and laboratory analysis, base flow study and preliminary data analysis and interpretation. The study area included Cypress Creek from the headwaters west of Highway 281 to the confluence with the Pedernales River just above Hammett's Crossing where the river enters backwaters of Lake Travis.

GIS DATA COLLECTION, MAPPING AND DATABASE

GIS is a versatile tool that can be used for a variety of functions, including mapping physical and hydrological features of a certain area, housing and centralizing multiple forms of environmental data, and performing spatial and data analysis using various tools offered within the program. The study used the ESRI suite of GIS products, specifically ArcGIS Pro. Land cover data was collected and analyzed for patterns using National Land Cover Database (NLCD) raster files, along with shapefiles of watershed and subwatershed boundaries, tributaries and flowlines from the National Hydrological Database (NHD). A composite geologic map of the watershed created from The Bureau of Economic Geology, University of Texas at Austin geologic quadrangle maps was added for analysis of geology. Groundwater quality data was extracted from the Texas Water Development Board online database and sorted by aquifer in addition to the water quality samples collected and analyzed by Meadows Center staff and partner laboratories.

WATER CHEMISTRY MAPPING AND ANALYSIS

Chemical analysis of surface water and groundwater is used to evaluate water quality, examine human impacts, and understand water pathways of groundwater to the surface and vice versa. Major ion chemistry is a standard tool used to decipher hydrogeochemical patterns as well as impacts of human activity (Dunne and Leopold 1978). Spatial patterns in water chemistry were evaluated as related to both man-made and natural sources by utilizing spatial analysis in ArcGIS. The field data points provide spatial locations for the water samples. Surface water samples were collected by Meadow's team and analyzed for naturally occurring cations and anions by the Edwards Aquifer Research Data Center (EARDC) Laboratory at Texas State University. Historic water quality monitoring results from Texas Commission for Environmental Quality (TCEQ), Lower Colorado River Authority (LCRA), and Colorado River Watch Network (CRWN) were also evaluated.

DISCHARGE MEASUREMENTS

To determine losing and gain reaches of the creek, two synoptic discharge measurement events were performed. Based on available landowner access, measurements were made at semi-regular intervals along the length of the creek with "live" water.

LAND COVER ANALYSIS

Land cover, particularly developed land use containing impervious cover, septic systems, sewage treatment, and nonpoint source pollution plays a role in determining water quality, and both storm and base flow. GIS files of basin land cover data from 2001 and 2016 were obtained from the National Land Cover Database (NLCD) provided by the Multi-Resolution Land Characteristics (MRLC) Consortium (MRLC 2011). Although the data sets contained a detailed breakdown of many land cover types, many similar land uses were combined for the purpose of this

Figure 5. Meadows Center staff measuring flow with the Sontek FlowTracker sonde

report and consolidated into six categories. As stated in the Regional Water Quality Plan (2005), "various published and unpublished reports and in unpublished data compilations, the City of Austin has indicated that physical and biological degradation of streams begins to occur at between five and eighteen percent (5-18 percent) impervious cover."

STUDY RESULTS

LAND COVER

Land cover, particularly developed land use, can play a role in determining water quality, and both storm flow and base flow. Increased impervious cover, septic systems, organized sewage treatment, and non-point source pollution can impact water quality. GIS files of basin land cover data from 2001 and 2016 were obtained from the National Land Cover Database (NLCD) provided by the Multi-Resolution Land Characteristics (MRLC) Consortium (MRLC 2016). NLCD is updated every five years. Figures 6 and 7 indicate 2001 and 2016 land cover of the Cypress Creek watershed.

The land cover data sets from 2001 and 2016 were compared in order to determine land cover changes over the fifteen-year period. Although the data sets contained a detailed breakdown of many land cover types, many similar land uses were combined for the purpose of this report and consolidated into five categories to analyze land use changes. The watershed was primarily deciduous forest, evergreen forest, shrub/scrub and grasslands in 2001. Less than 1 percent of the watershed was developed. Table 1 includes a listing of land cover types with a detailed description of each type contained in Appendix A.

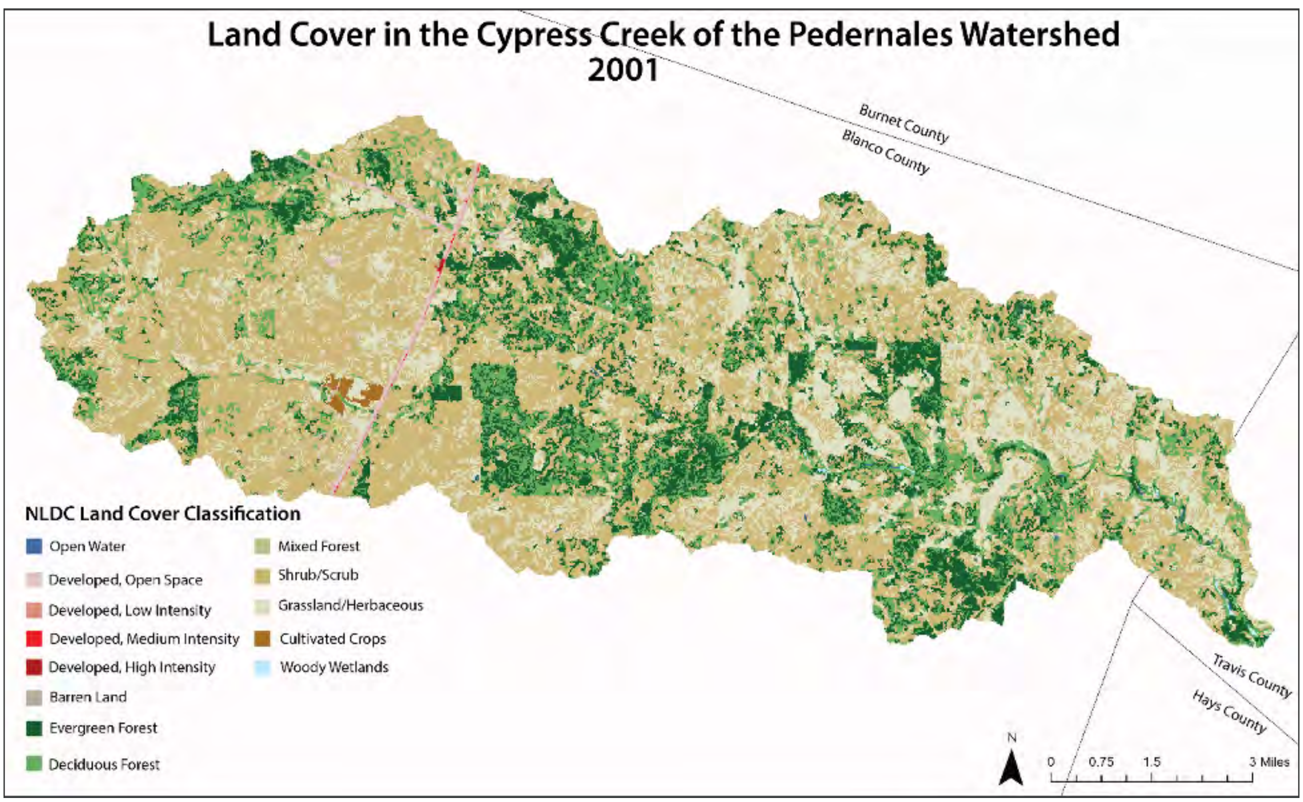

Figure 6. NLCD Land Cover – 2001

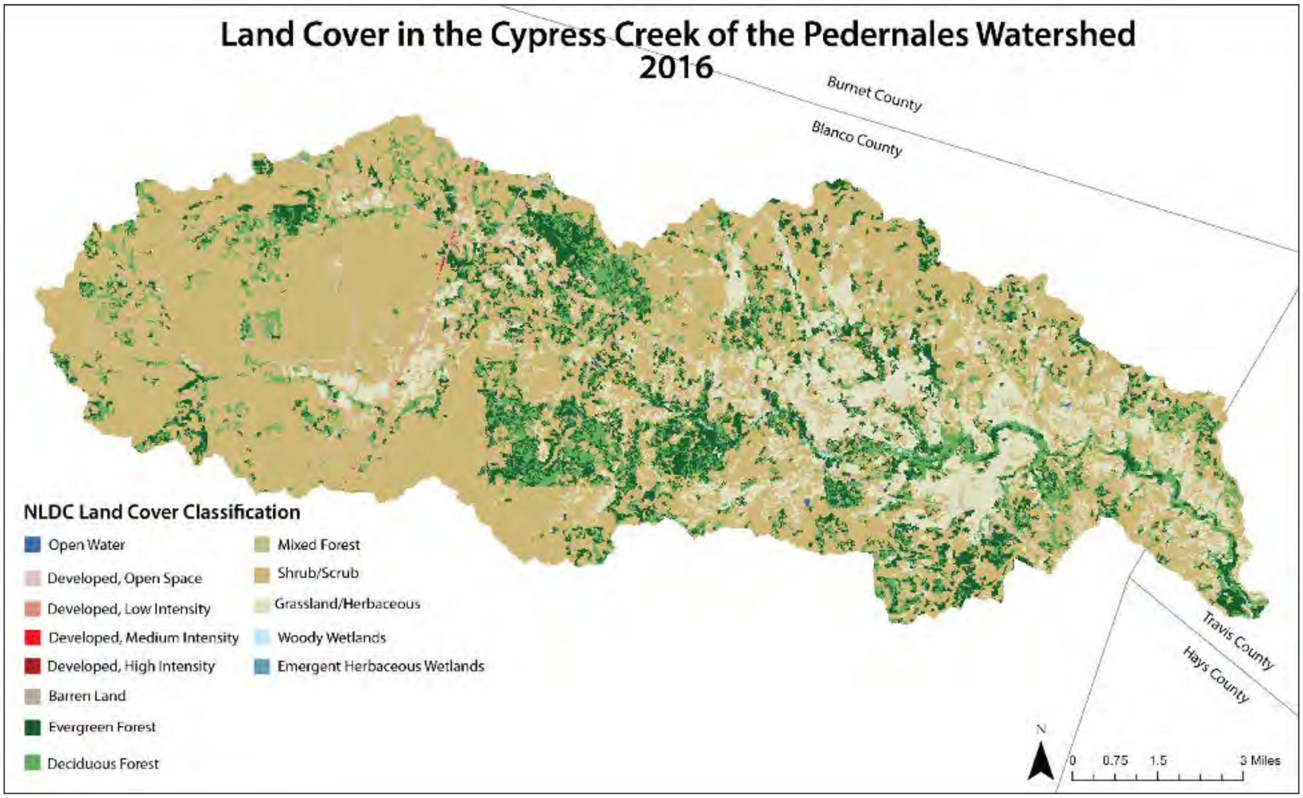

Figure 7. NLCD Land Cover – 2016

Table 1. Change in Land Cover 2001 – 2016

Land Cover Type	2001 Land Cover (acres)	2016 Land Cover (acres)	Change in Land Cover (acres)
Open Water	27.2	32.4	5.2
Developed, Open Space	396.9	522.2	125.3
Developed, Low Intensity	62.7	67.9	5.2
Developed, Med. Intensity	10.4	10.4	0.0
Developed, High Intensity	7.3	3.7	-3.7
Barren Land	0.0	36.6	36.6
Decid. Forest	6893.3	5170.0	-1723.3
Evergreen Forest	7379.0	6057.8	-1321.2
Mixed Forest	0.0	6.8	6.8
Shrub/Scrub	26267.7	32691.0	6423.3
Grassland/Herbaceous	11018.8	7572.2	-3446.7
Cultivated Crops	130.6	0.0	-130.6
Woody Wetlands	40.2	57.4	17.2
Emergent Herbaceous Wetlands	0.0	5.2	5.2

While the four major land cover types still dominate the watershed in 2016, there was a significant decline in deciduous forest, evergreen forest and grasslands, totaling approximately 6,500 acres (12 percent of the watershed). Anecdotal information indicates this decline could possibly be attributed to on the intentional removal of Ashe Juniper trees and other non-native species within the watershed in recent decades. Shrub and scrub areas increased by 6,423 acres, or 12 percent of the watershed (Figure 8). Based on Figures 6 and 7, the change from Grassland to Shrubs appears most pronounced in the western area of the watershed, west of Hwy 281 and north of the creek in the eastern areas of the watershed.

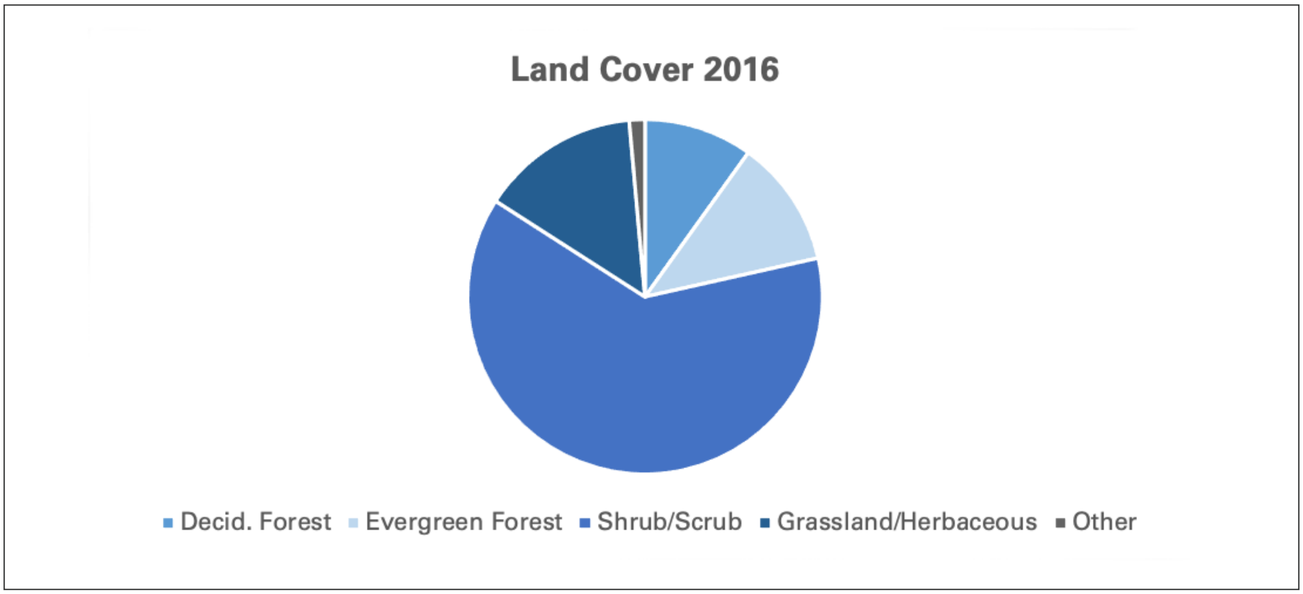

Figure 8. Land Cover - 2016

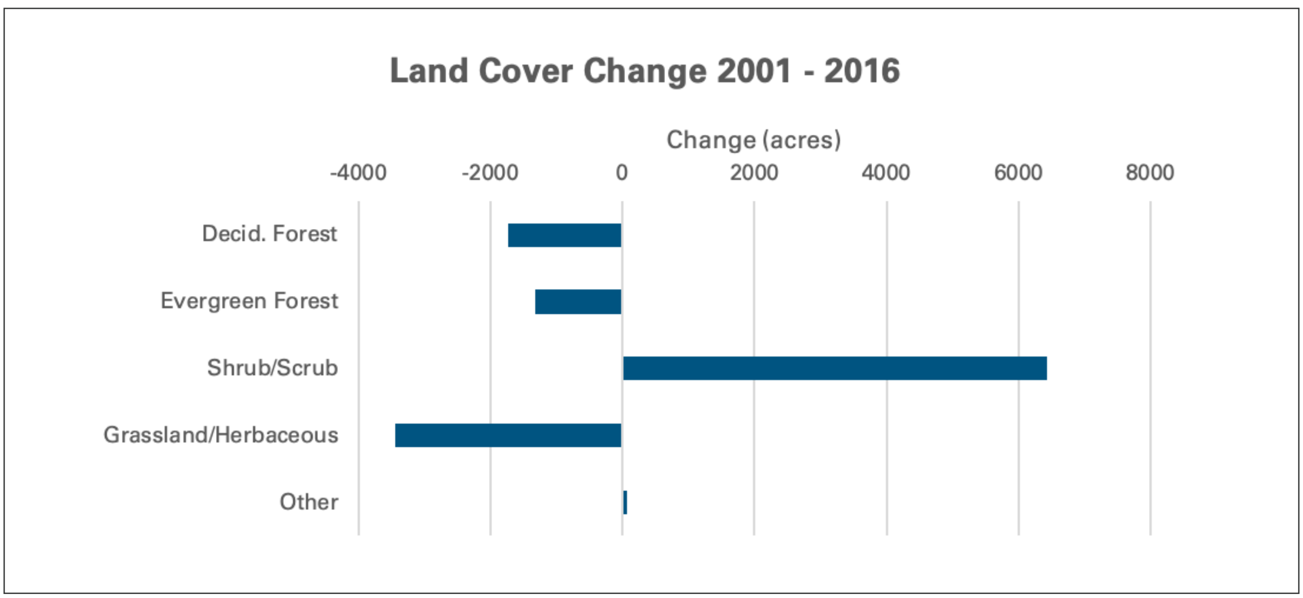

Figure 9. Land Cover Change 2001 – 2016

GEOLOGY OF THE CYPRESS CREEK WATERSHED

Geologically and hydrogeologically, the watershed can be best described in three sections: western, central, and eastern. The surficial rocks of the Cypress Creek watershed range in age between the Upper Cambrian and Quaternary ages. The eastern and western ends of the watershed are dominated by Cretaceous carbonates, with the central area of the watershed dominated by Paleozoic carbonates (Figure 10).

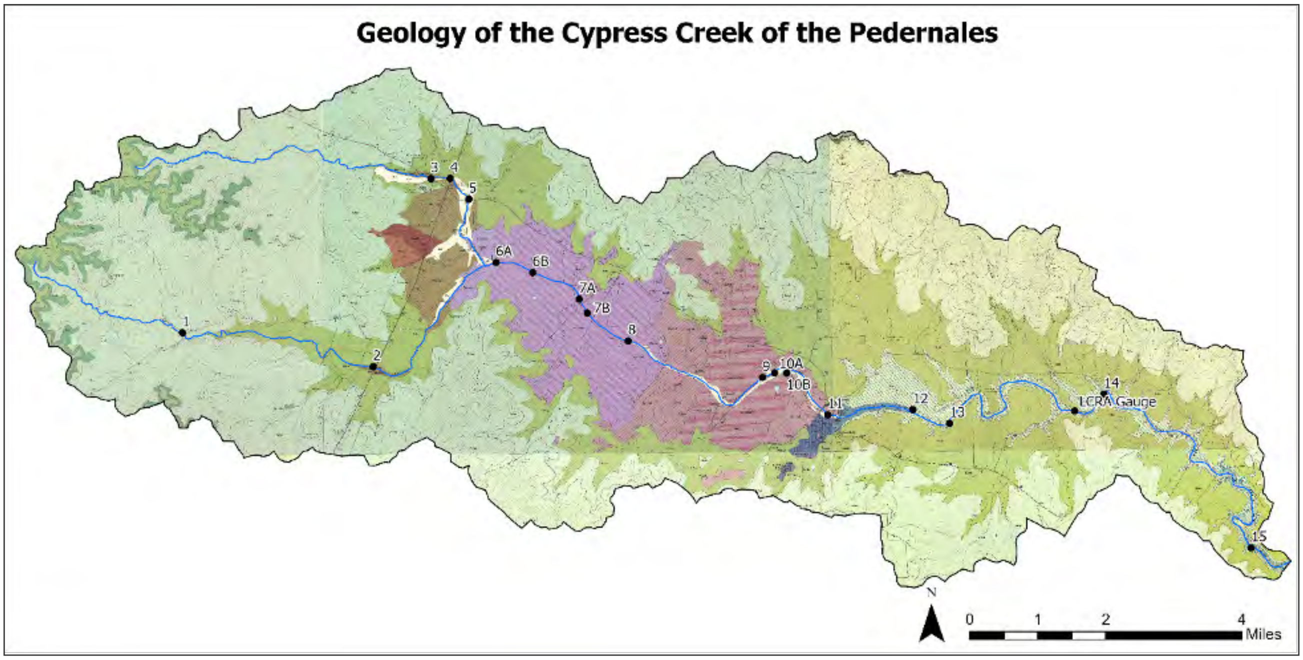

Figure 10. Geologic Map of the Cypress Creek Watershed with Sampling Locations

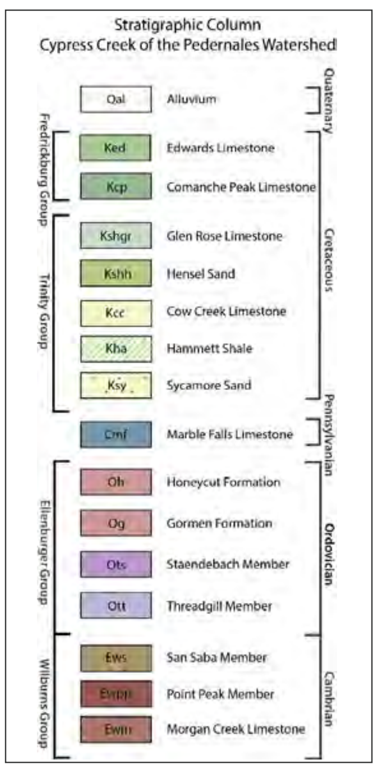

Figure 11. Geologic Legend of the Cypress Creek Watershed

General Structural History

The structural history of the region can be described as follows:

> *The structural grain of the Central Texas Hill Country follows the Paleozoic tectonic template defined by the Llano (Massif) Uplift and the Ouachita Orogenic Belt. Late Paleozoic tectonic plate movement to the northwest resulted in the thrusting of a thick basinal facies, sedimentary prism against the Llano Uplift…. Llano, Precambrian and Cambrian igneous and metamorphic rocks, and surrounding Paleozoic foreland facies were uplifted at the end of the Paleozoic… With the opening of the Gulf of Mexico, the peneplained Paleozoic surface (flat, eroded surface) tilted to the southeast and was flooded by early Cretaceous onlapping sediments (Wierman, 2010).*

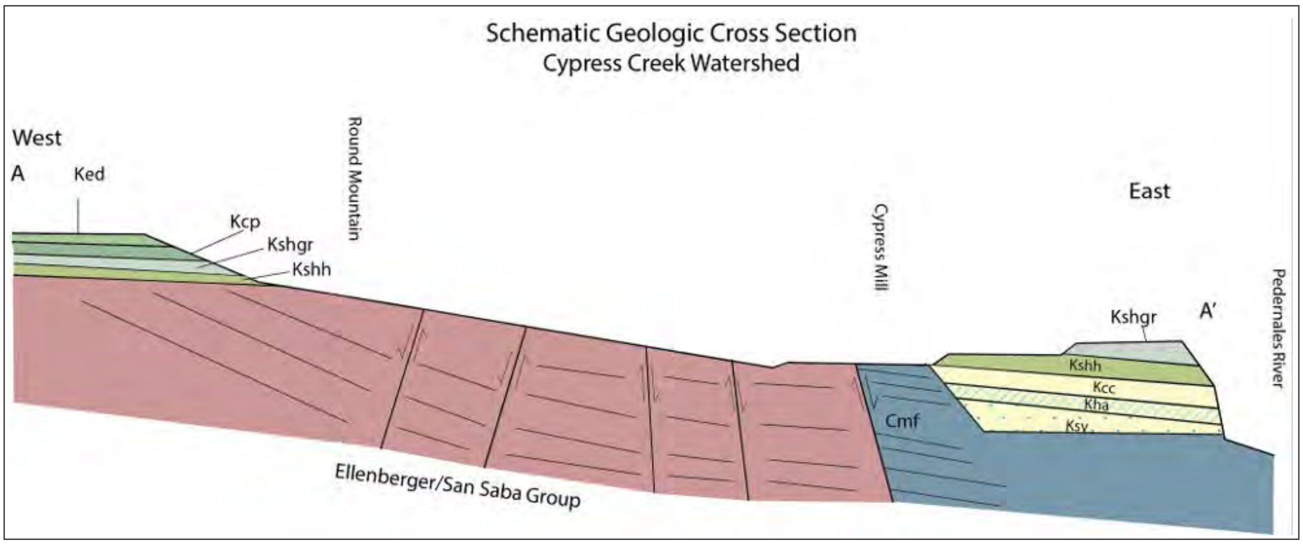

Figure 12. Schematic Geologic Cross Section Cypress Creek Watershed

Western Section

The surficial geology western portion of the watershed, generally west of Hwy 281 (Figure 13), consists of Cretaceous carbonates, primarily of Upper Glen Rose (Kshgr). In the bed of the creek, the Glen Rose (Kshgr) has been eroded to expose the underlying Hensel Sand (Kshh). In the far western edges of the watershed, Comanche Peak and Edwards the higher elevations. The beds have a slight regional dip to the east and south. Both Cypress Creek (marked as South Cypress on the sign along Hwy 281) and North Cypress Creek originate in the western area. During the course of this study, North Cypress Creek was dry as observed at Hwy 281. This is likely the normal condition of North Cypress in the western area, being an ephemeral stream. During early 2020, there was very low flow in Cypress Creek observed at the bridge at Hwy 281 (Site 2, Figure 13), but not enough to measure. Later in 2020 as warmer, drier weather prevailed, there was no observable flow. A review of the Texas Water Development Board (TWDB) groundwater database indicates most wells are completed in and draw water from the Upper Glen Rose (Kshgr) or Hensel Sand (Kshh) with a few Hickory wells in the northern part of the area.

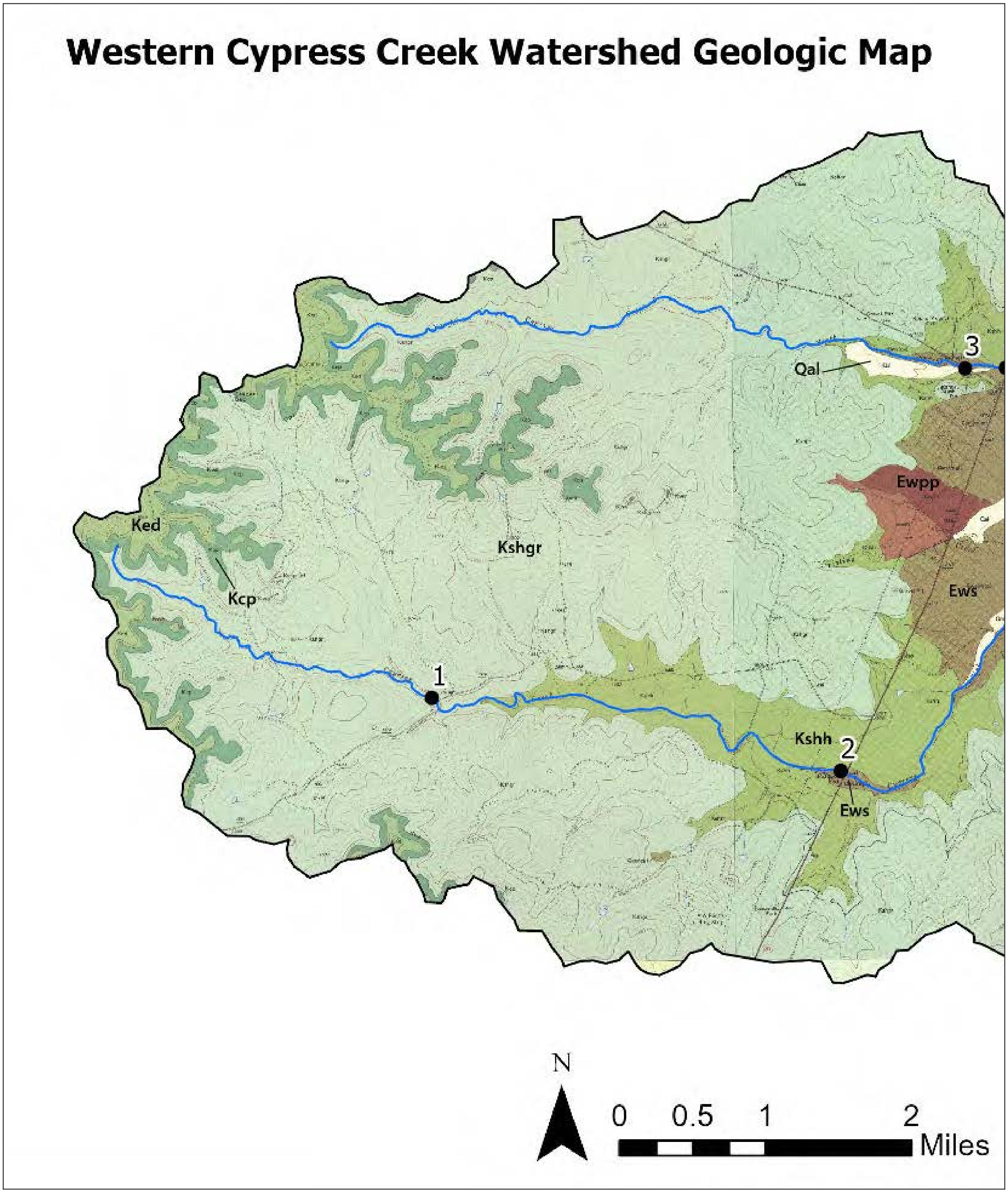

Figure 13. Western Cypress Creek Watershed with sampling locations (Barnes, 1978a and Barnes, 1978b)

Central Section

The central section of Cypress Creek is the most geologically diverse. The section starts just west of Round Mountain and ends to the south of Cypress Mill (Figure 14). Surficial geology ranges from Upper Cambrian age and Quaternary. The Cambrian rocks consist of the Morgan Creek (Ewm), Point Peak (Ewpp), and San Saba Members (Ews) of the Wilberns Group. The Hickory Member of the Wilberns Group underlies Morgan Creek (Ewm) but does not crop out in the watershed. These rocks are primarily limestone and dolomites with some siltstones. The oldest rocks present crop out in Round Mountain and south along Hwy 281. The San Saba (Ews) crops out in the bed of Cypress Creek at the bridge at Hwy 281. The Hickory is a source of groundwater to some wells, particularly north and west of Round Mountain.

Members of the Ordovician Ellenburger Group form a large, broad valley stretching southeast from Round Mountain. Much of the area is out crop with sparse vegetation. From upstream to downstream, the Ellenburger Members include the Threadgill (Ott), Staendebach (Ots), Gorman (Og) and Honeycut (Oh) members. Groundwater production from wells can be variable. There are several northeast/southwest trending mapped faults in the Staendebach (Ots) near Site 7. There is a major spring complex along the creek coincident with these faults. The contact between the Staendebach (Ots) and Gorman (Og) is mapped as a similar northeast/southwest trending fault. Faulting becomes somewhat more complex near the Cypress Mill. Based on several field measurements, these strata generally dip to the south and east at 3-10 degrees. There are a series of cross cutting faults in the Honeycut (Oh). Two of the mapped faults run parallel to the creek or under the creek bed, influencing the direction of the creek. Several major springs originate in this area.

Just downstream of this area and upstream of the Hwy 962 low water crossing, there is an outcrop of younger Pennsylvanian-age Marble Falls Limestone (Cmf) which has been down faulted against the Honeycut (Oh). The outcrop of Marble Falls (Cmf) extends in the creek bed approximately a mile downstream from the low water crossing.

The upland areas of the central section are generally underlain by Cretaceous Age Hensel Sand (Kshh) and Upper Glen Rose (Kshgr). A named tributary, Cleveland Branch, originates in the Upper Glen Rose (Kshgr) and Ellenburger north of Hwy 962 and flows into Cypress Creek near Site 10. Low flows were observed on several occasions but were too low to measure.

Quaternary alluvial deposits (Qal) can be found in the stream beds of both Cypress and North Cypress Creeks in the vicinity of Hwy 281 and extend to the confluence of the two branches. The alluvium (Qal) in North Cypress Creek can seasonally contain shallow groundwater and discharge it to the creek. The alluvial reach of North Cypress Creek downstream of the Hwy 281 (Site 5) was observed to flow during much of 2020 but was not flowing during the synoptic gauging events. Estimates of flow were in the 1 to 5 gpm range.

There is little to no alluvium (Qal) from the confluence downstream to Site 8. The first occurrence of cypress trees along the creek coincides with the presence of the alluvial material. Alluvium (Qal) is present from Site 8 to the outcrop of Marble Falls Limestone (Cmf) just downstream of Cypress Mill. The alluvium (Qal) consists of sand sized material up to large cobbles. The alluvium (Qal) had several influences on this study. Given the course nature of the material, it is likely that underflow occurs which would not be measured in the main channel. Secondly, alluvial material has created a braided creek network in many locations. While the braided channels give the creek much of its unique character, they make flow gauging challenging.

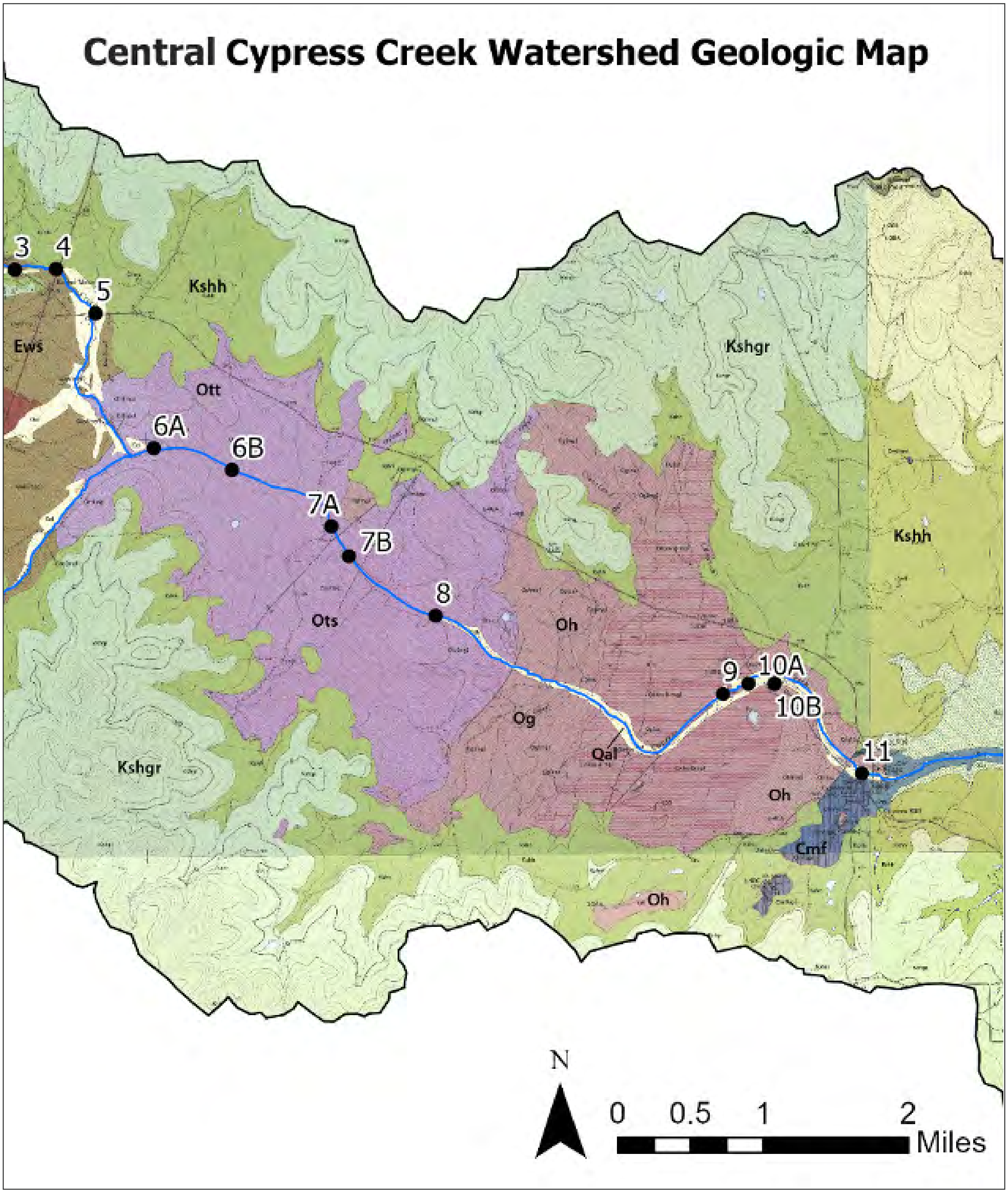

Figure 14. Central Cypress Creek Watershed with sampling locations (Barnes, 1978b; Barnes, 1982a; Barnes, 1982b; and Barnes 1982c)

Eastern Section

The eastern section is dominated by the Trinity Group of the Cretaceous Age. From oldest to youngest are the Sycamore Sand (Ksy), Hammett Shale (Kha), Cow Creek Limestone (Kcc), Hensel Sand (Kshh), and the Lower and Upper Glen Rose (Kshgr) formations. The Sycamore Sand (Ksy), Hammett Shale (Kha), Cow Creek Limestone (Kcc) are often referred to as the Travis Peak Group in the literature. The basal section of the Sycamore (Ksy) is a conglomerate consisting of sand to boulder-sized material. It is often exposed in the incised bottom of the creek valley and becomes more prevalent closer to the confluence of the Pedernales River. It is exposed near Site 14, somewhat further upstream than previously mapped by Barnes (1982) (Figure 15).

Overlying the Sycamore Sand (Ksy) is the Hammett Shale (Kha). The shale (Kha) can be 30 to 40 feet in thickness and acts as an aquitard between the Sycamore (Ksy) and overlying Cow Creek Limestone (Kcc). Outcrops of Sycamore Sand (Ksy), Hammett Shale (Kha), and Cow Creek Limestone (Kcc) are generally confined to the down cut creek and tributary valleys. The Hensel Sand (Kshh) overlies the Cow Creek Limestone (Kcc) and crops out over much of the eastern section of the watershed. The Upper and Lower Glen Rose (Kshgr) outcrop along the upland edges of the eastern section. Regionally, the Hammett Shale (Kha), Cow Creek Limestone (Kcc) and Lower Glen Rose (Kshgr) pinch out in the vicinity of Cypress Mill and are not present further to the west (Broun, 2020).

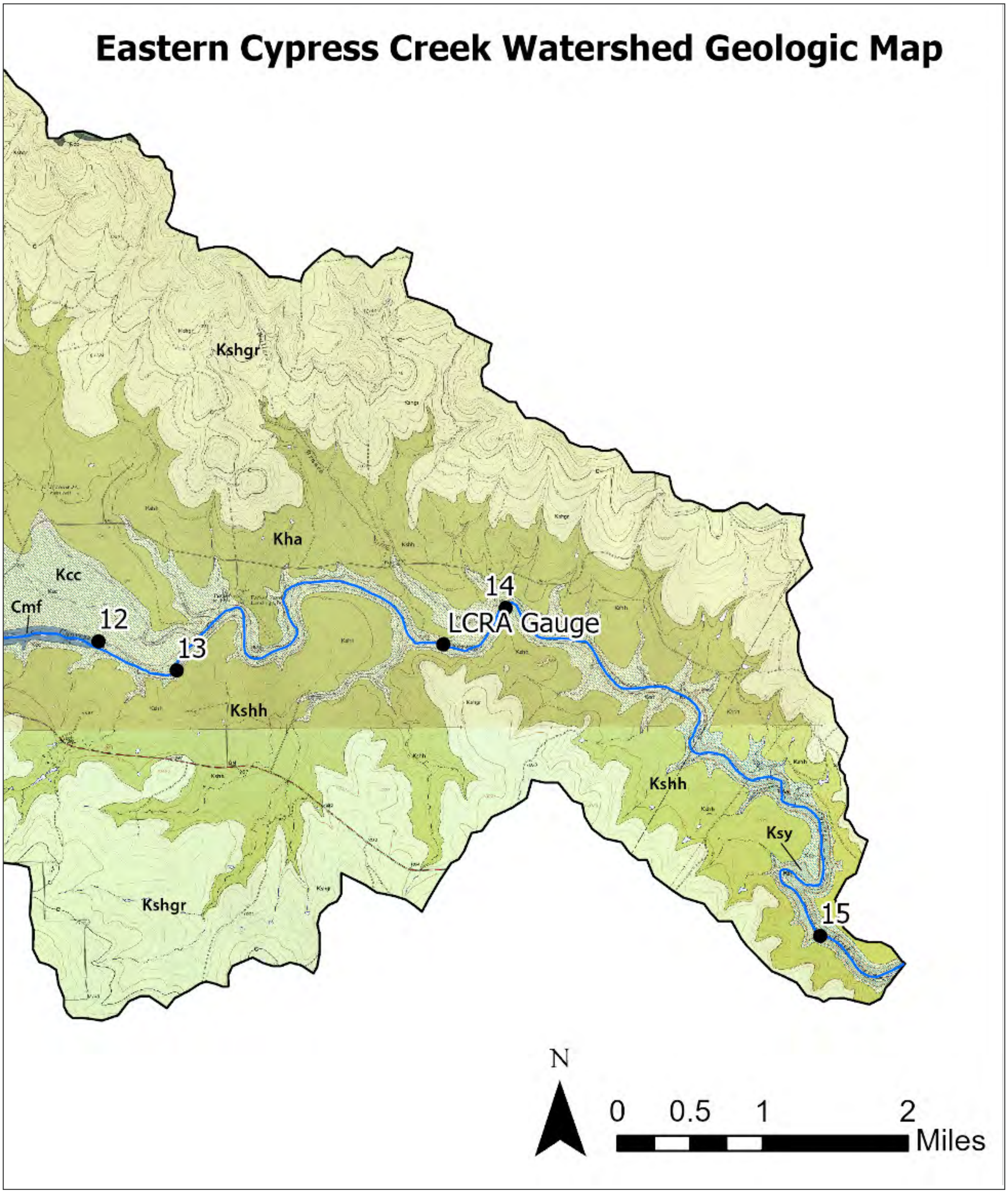

Figure 15. Eastern Cypress Creek Watershed with sampling locations (Barnes, 1982a and Barnes, 1982c)

Figure 16. Conglomerate Facies at the top of the Sycamore Sand near Site 14

GROUNDWATER RESOURCES

Hydrogeology

There are two main aquifers of interest in the study area in terms of surface water/groundwater interactions: the Ellenburger-San Saba and the Trinity aquifers. The following descriptions are summarized by Anaya, et al., 2016.

Ellenburger-San Saba

The Ellenburger-San Saba aquifer is designated as a minor aquifer in Texas. The aquifer surrounds the Llano Uplift in Central Texas. It crops out in the central section of the Cypress Creek watershed and covers approximately six percent of the surface (Wierman, 2017). Water occurs in fractures, solution cavities, and along faults and groundwater yields to wells varies. Numerous springs originate from the aquifer and support stream baseflow.

Based on a review of TWDB well reports and monitoring results measured by BPGCD, water levels in the Ellenburger are relatively shallow. Figure 17 represents water level monitoring results from an Ellenburger well located along Hwy 281 near Round Mountain. Over a ten-year period of record, water levels fluctuated between 2 and 25 feet bgs.

Recharge to the aquifer is primarily from precipitation and runoff from upland areas. The area of Ellenburger outcrop in the Central Section of the watershed was modeled as a major recharge zone in the TWDB numerical modeling report for the minor aquifers of the Llano Uplift (Shi, et al., 2016). An average of 3.06 inches per year (2.3 to 3.6 inches per year) of recharge was simulated in the model. Estimates of baseflow to surface water in Blanco County from the Ellenburger – San Saba are an annual average of 2 cubic feet per second (cfs) with a median baseflow of 0.5 cfs (Anaya, 2016).

Trinity Aquifer

The Trinity Aquifer is a major aquifer in Texas and covers approximately 78 percent of the watershed (Wierman, 2017). In the study area, the Trinity aquifer can be divided into three units: Upper, Middle, and Lower Trinity aquifers. The Upper Trinity is present over a large portion of the watershed and consists of the Upper Glen Rose (Kshgr) Formation. The Middle Trinity Aquifer consists of the Lower Glen Rose (Kshgr), Hensel Sand (Kshh), and Cow Creek Formations (Kcc). Beneath the Cow Creek (Kcc) lies the Hammett Shale (Kha) which acts as an aquitard between the Middle and Lower Trinity. The Lower Trinity is comprised of the Sycamore (Ksy)

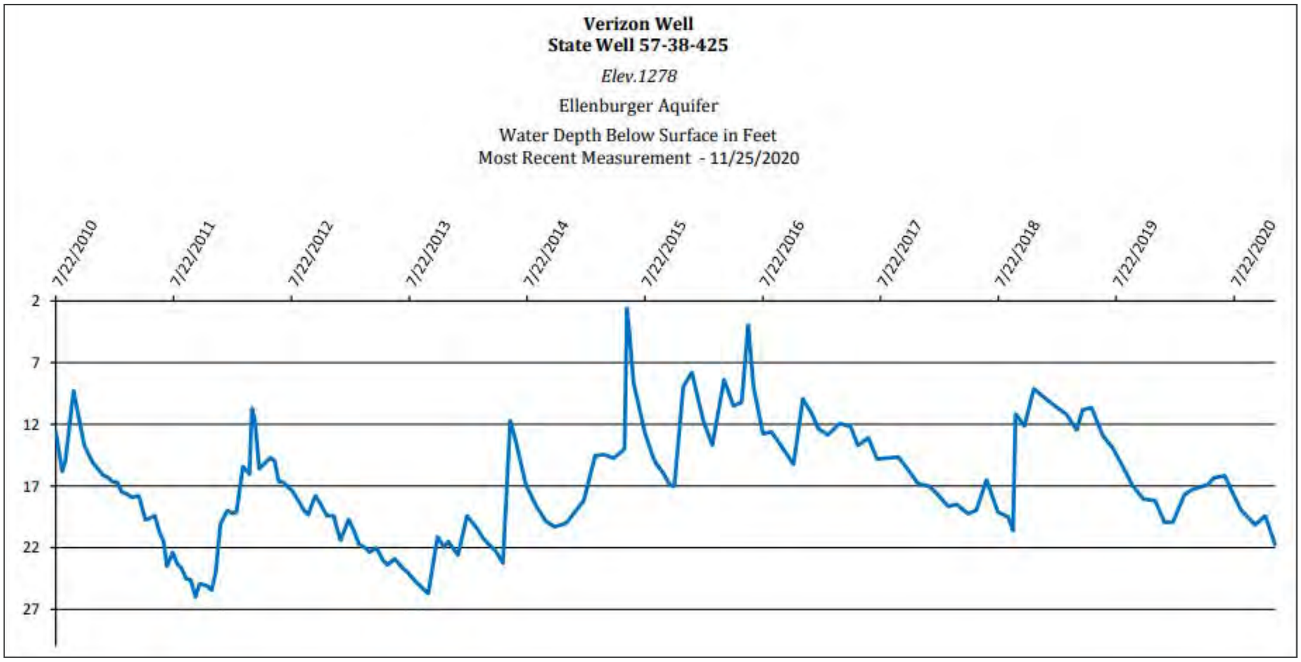

Figure 17. Verizon Well Water Level Monitoring Results (Source: BPGCD, 2020)

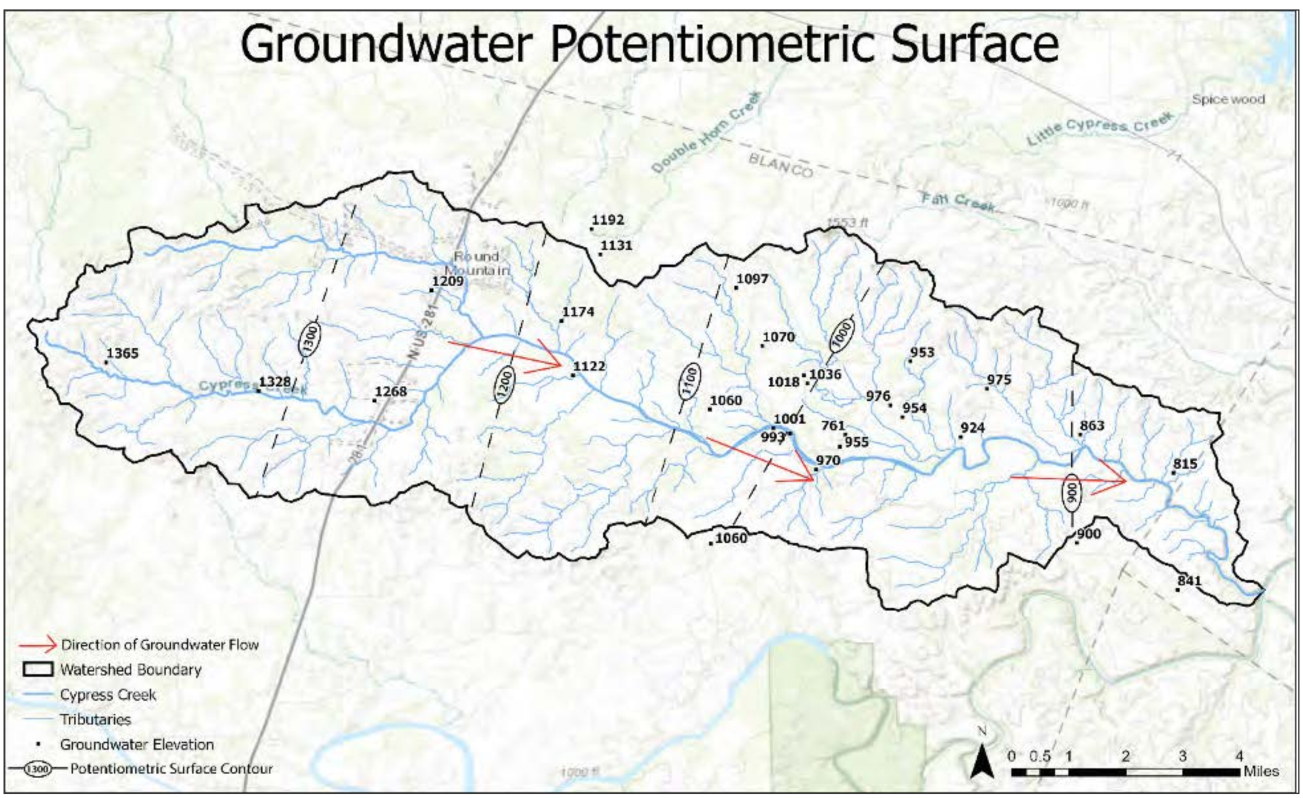

Figure 18. Groundwater Potentiometric Surface Map

Formation. The Upper Trinity is used for domestic use, primarily in the western section of the watershed. The Hensel (Kshh) and Cow Creek (Kcc) (where present) are also used for domestic and livestock wells in the western section, as is the Sycamore (Ksy). Recharge occurs primarily from precipitation and runoff from areas of higher elevations. Estimates of baseflow to surface water in Blanco County for the combined Trinity are an annual average of 57.6 cfs with a median annual baseflow of 14.9 cfs (Anaya, 2016).

Figure 19. Water quality sampling at Cypress Creek springs.

Groundwater Flow

General groundwater flow directions were determined using historical data from the TWDB groundwater database, which contains water level data from existing wells spanning the last several decades. The BPGCD monitors several wells in the watershed, but the arial distribution is not sufficient to determine watershed wide groundwater flow directions. Available water level data of wells within the watershed was used to develop a potentiometric surface map (Figure 18). Groundwater flows generally to the east-southeast, trending with the general regional dip of the local geology. In the Ellenburger, as groundwater flows downgradient, the regional dip tends to direct water deeper in the aquifer, creating confined conditions. These data represent water levels taken over time, not during a synoptic event. Even though the data spans decades, it does portray general groundwater flow directions in the watershed.

FLOW DISCHARGE MEASUREMENTS

Occurrence of Flow

There are several major springs observed in this study that originate from the Ellenburger and Marble Falls aquifers, with lesser springs originating from the Trinity formations. A complex of springs near Site 7 originates from the Ellenburger. A second cluster of springs is present near Site 10, and a third set of springs is present near Site 12. The springs appear to correlate with several mapped faults in this area. The faults are likely providing a pathway for deeper confined groundwater to emerge at the surface as spring flow. The springs at Sites 7 and 10 were sampled for basic water quality by the Works Project Administration at the University of Texas under the direction of the United States Geological Survey. These data are reported in Barnes and Cumley (1942). Flowing wells and springs were noted at the same locations in Follett, C.R. (1973).

In the Trinity formations of the eastern section of the watershed, downward movement of recharge likely encounters impervious rock units, such as the Hammett Shale (Kha), which creates small gravity springs that discharge in the incised creek valleys. Access to this area was limited and no springs were observed in the eastern watershed area. There are likely intermittent springs that originate from the Trinity Aquifer and flow during wet weather periods in the western area.

Historic Flow in Cypress Creek

The Lower Colorado River Authority (LCRA) maintains a surface water flow gauging station (LCRA Gauge 12258) in Cypress Creek. The gauge measures precipitation, stream stage, and discharge. The data from the gauge is available in real time on the LCRA's Hydromet website (hydromet.lcra.org). The gauge is located upstream of Site 14 (Figure 15). LCRA has indicated the data should be considered provisional at this time.

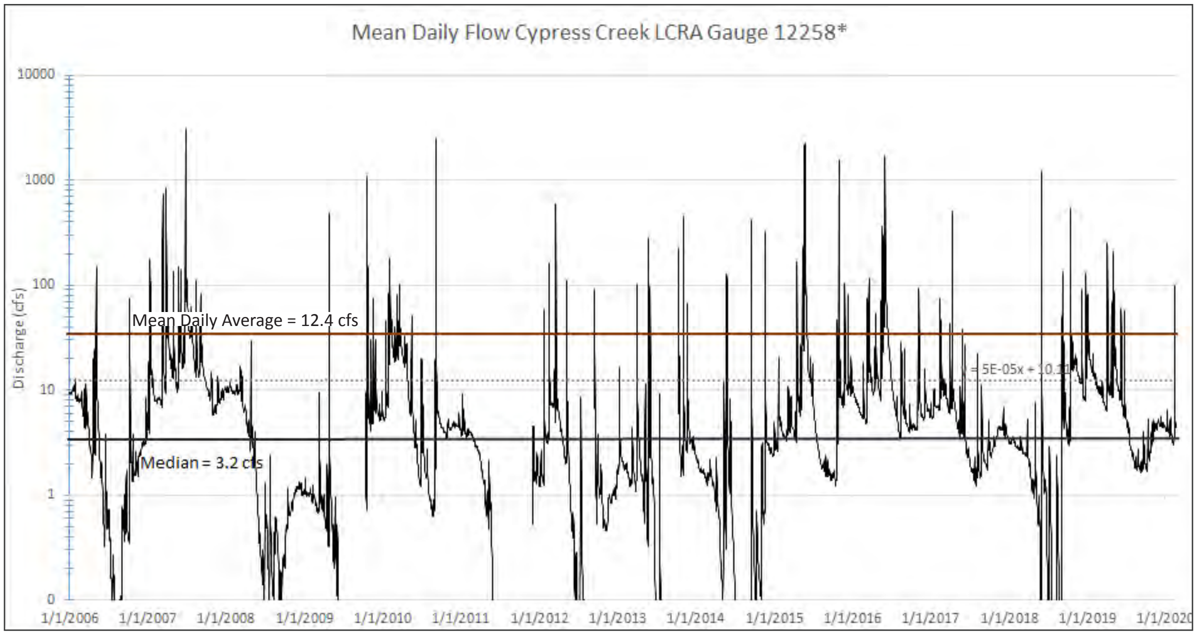

Figure 20. Mean daily flow at LCRA Gauge 12258 **Note: Per LCRA, data is to be considered provisional.*

The mean daily discharge for the period of record is 12.4 cfs with a median discharge of 3.2 cfs. The linear trend of the discharge data is flat, indicating little change in overall discharge from 2006 – 2019. As evident from the figure, the creek responds quickly to precipitation events, resulting in short term spikes in discharge. Several creek side landowners indicated that the creek recedes quickly as well. Flow percentiles from the discharge data were calculated (Figure 21). Using the average discharge measured at the LCRA gauge over the period of record, Cypress Creek has contributed a minimum of 9,000+ acre-feet, over 2.9 billion gallons, annually of water to the Pedernales River over the period of record of the gauge. This estimation is likely low as the creek does gain additional flow downstream of the gauge before entering the Pedernales River.

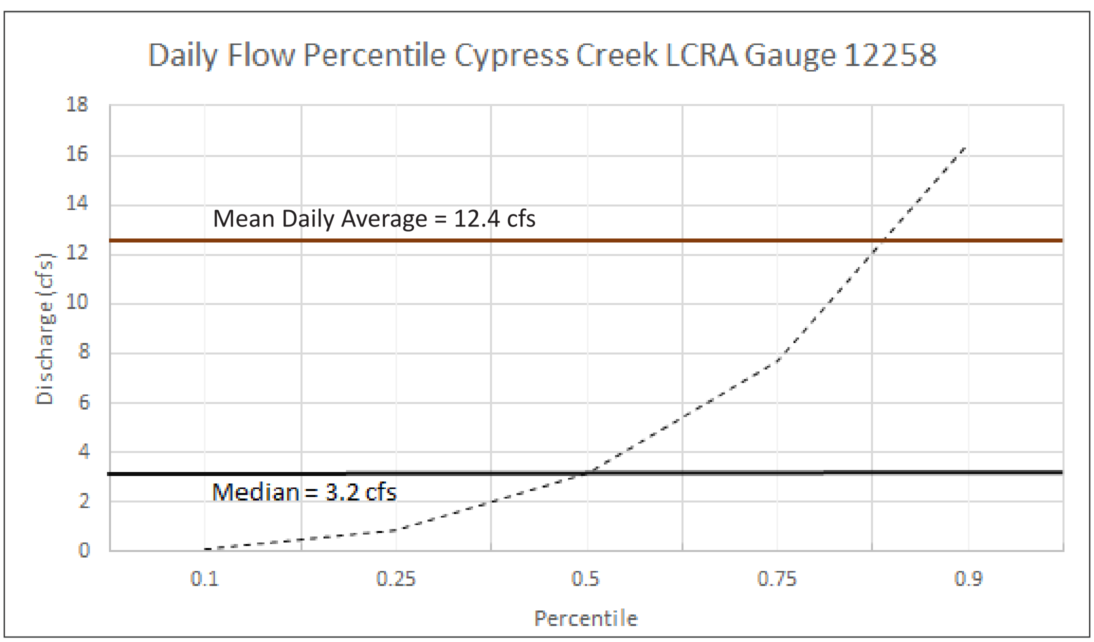

Figure 21. Daily flow percentile LCRA gauge 12258

Synoptic Surface Water Gauging Events Results

Synoptic surface water gauging events took place on July 23-24, 2020 and December 17, 2020 to measure base flow in Cypress Creek. Base flow is key to maintaining flow in the stream to maintain its ecologic health and value to local landowners. The results from the events are included on Table 2 and shown on Figures 24 and 25. Flow measurements were made using a FlowTracker (FT2) handheld Acoustic Doppler Velocimeter® generally following USGS protocols. River miles from the confluence of Cypress Creek and the Pedernales River were determined using GIS techniques. Due to low flows during the synoptic gauging events, discharge values are expressed as gallons per minute (gpm) as opposed to cfs (1 cfs= approximately 449 gpm).

Baseflow has many definitions, including the following:

> *"Baseflow is the sustained flow of water in a river including contributions from both interflow and groundwater discharge, independent of dry or wet weather conditions" (Groundwater Dictionary, 2019).*
>
> *"Baseflow is the portion of streamflow that comes from "the sum of deep subsurface flow and delayed shallow subsurface flow" (www.definitions.net).*

The USGS defines baseflow as groundwater discharge (Barlow, 2015).

The key to understanding base flow is to understand interactions with the aquifers that contribute to base flow. Aquifer health is key to creek health. Storm flow from precipitation events can be important to creek health, but they have a short duration in nature. Storm flow was not evaluated in this study. Losses from evapotranspiration were not accounted for and were believed to be minimal.

Table 2. Surface Water Flow Measurements (gpm)

Site ID	River Mile	9/23-24/2020	12/17/2020
1	19.22	0	0
2	16.38	0	Water Present, No Flow
3	15.74	0	0
4	15.43	0	0
5	15.01	0	0
6A	14.01	4.5	23.8
6B	13.46	Flowing, Not Measured	Flowing, Not Measured
7A	12.68	202.0	Not measured
7B	12.47	356.3	Not measured
8	11.73	673.2	501.5
9	9.73	369.8	206.5
10A	9.54	264.3	259.5
10B	9.36	605.9	345.7
11	8.51	659.7	423.0
12	7.26	740.5	657.3
13	6.71	843.7	592.7
14	4.47	893.1	552.3
15	0.71	1068.1	722.9

Figure 22. Water Quality Sampling and Discharge Gauging at Site 15

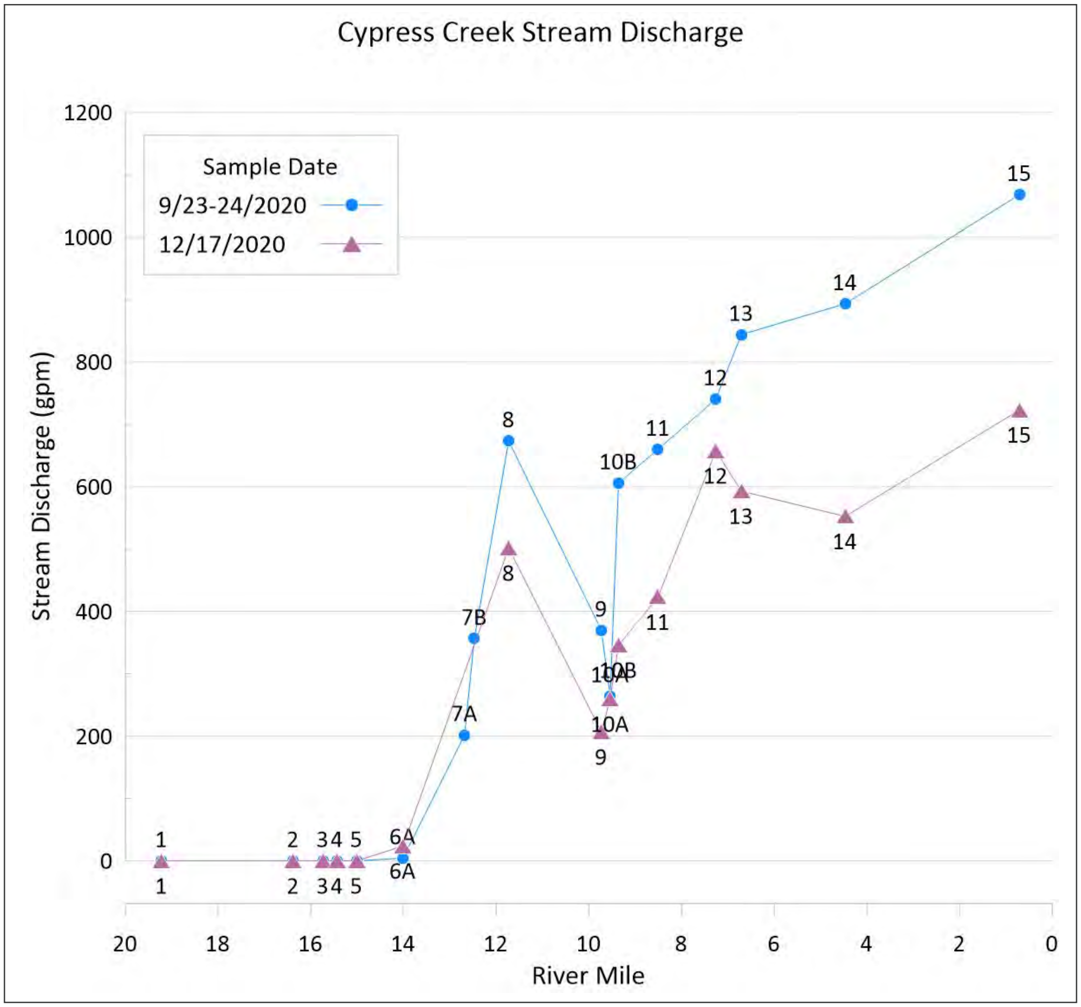

Figure 23. Cypress Creek Stream Discharge

During the July event (Figure 24), no flow was observed at Sites 1-5 in the western part of the watershed, though minimal flow had been observed at Sites 2 and 5 several months earlier. The minimal flow observed at Site 5 originates from direct recharge from precipitation into the alluvial deposits in that area. The creek is a gaining stream between Sites 6A and 8, with springs originating in the Ellenburger Group near Sites 7A and 7B significantly contributing to the flow. There are likely other similar springs in this reach on properties not accessible during this study.

There was a loss in flow between Sites 8 and 10A in the Ellenburger Group. The loss accounted for approximately fifty percent of the flow measured at Site 8. There are several mapped faults crossing the creek along this reach that may influence the losses. The study team was not able to access this reach of the river.

Site 10A had the first occurrence of significant deposits of alluvium in the stream channel. Underflow moving through the alluvium diverted from the main channel, which may account for some of the loss of flow. There was a significant gain between Sites 10A and 10B due to the presence of major Ellenburger springs. Some of the gain may be groundwater resurfacing from the upstream losing reach. Flow gradually increased in the eastern watershed area across the Marble Falls and Trinity Formations to the confluence.

The same general gain/loss pattern was observed during the December (Figure 25) synoptic event except a small loss of less than ten percent was noted between Sites 12 and 14. The loss between Sites 8 and 9 was approximately sixty percent of flow.

Cypress Creek Water Quality

Waters of similar quality can be inferred to originate from the same source. Comparing aquifer water quality to surface water quality may provide insight into the surface water/groundwater interactions. Several data sets were evaluated in this study.

Colorado River Watch Network (CRWN)

The CRWN is a program of citizen scientists that monitor water quality at a fixed location for field indicator parameters such as pH, specific conductivity, nitrates, dissolved oxygen, water temperature, fecal colonies, and visual observations. Sites are typically monitored on a monthly basis. Cypress Creek has been monitored on a nearly continuous basis since 2009 through the CRWN. The CRWN monitoring site is located at Site 15 (Figure 25) near the confluence of the Pedernales River. This downstream location should be representative of the entire stream. Some key data from this data set are shown on Figures 27 - 29 and discussed below.

Texas Commission for Environmental Quality (TCEQ) Sampling Data

TCEQ has monitored Cypress Creek several times a year for a series of chemical indicator parameters since 1998. The sampling point is located at the low water crossing at Cypress Mill (Hwy 962) and is, therefore, only representative of upstream water quality. Some key data from this data set are shown on Figures 30-32 and discussed below.

These two long-term data sets can be used to assess potential changes in water quality within the watershed over time. Samples can represent storm flow or base flow depending on when the water samples were obtained.

TWDB Groundwater Database

The TWDB database (TWDB, 2020) contains water quality data from springs and water wells in the Cypress Creek Watershed dating back to the late 1930s. Wells are sampled by the TWDB or others on a hit or miss basis. There are typically one or two data points for a given location. These data are useful in general to characterize aquifer water quality, but not particularly useful for determining long term trends at a given location.

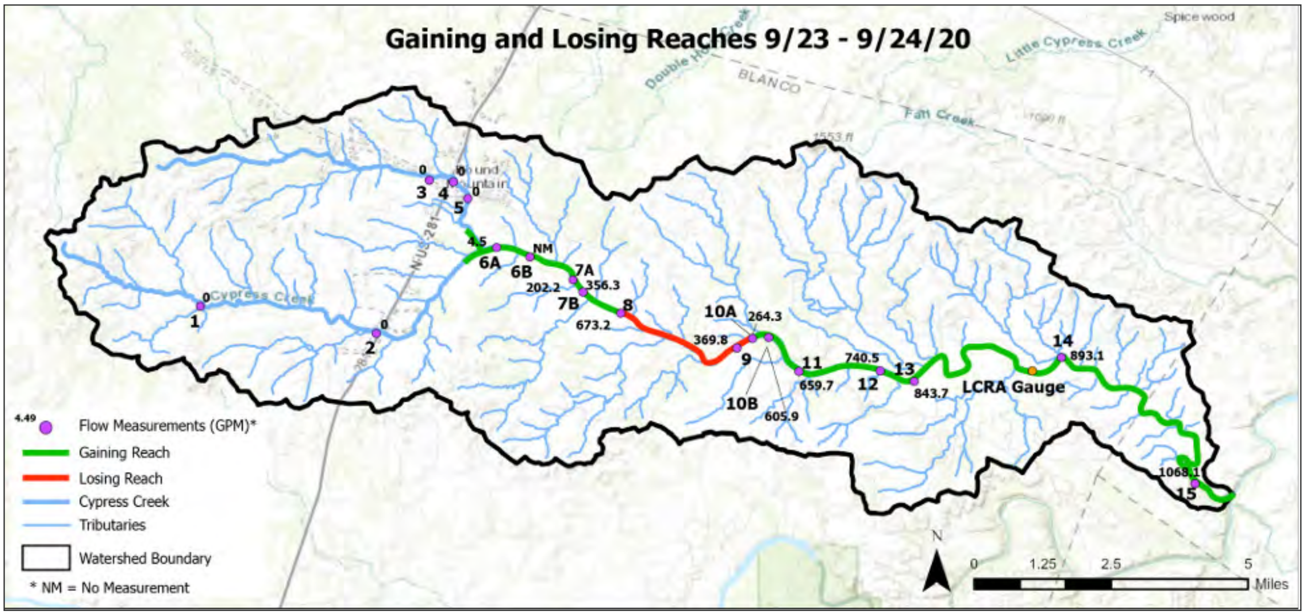

Figure 24. Surface Water Flow Measurements 9/23-24/2010

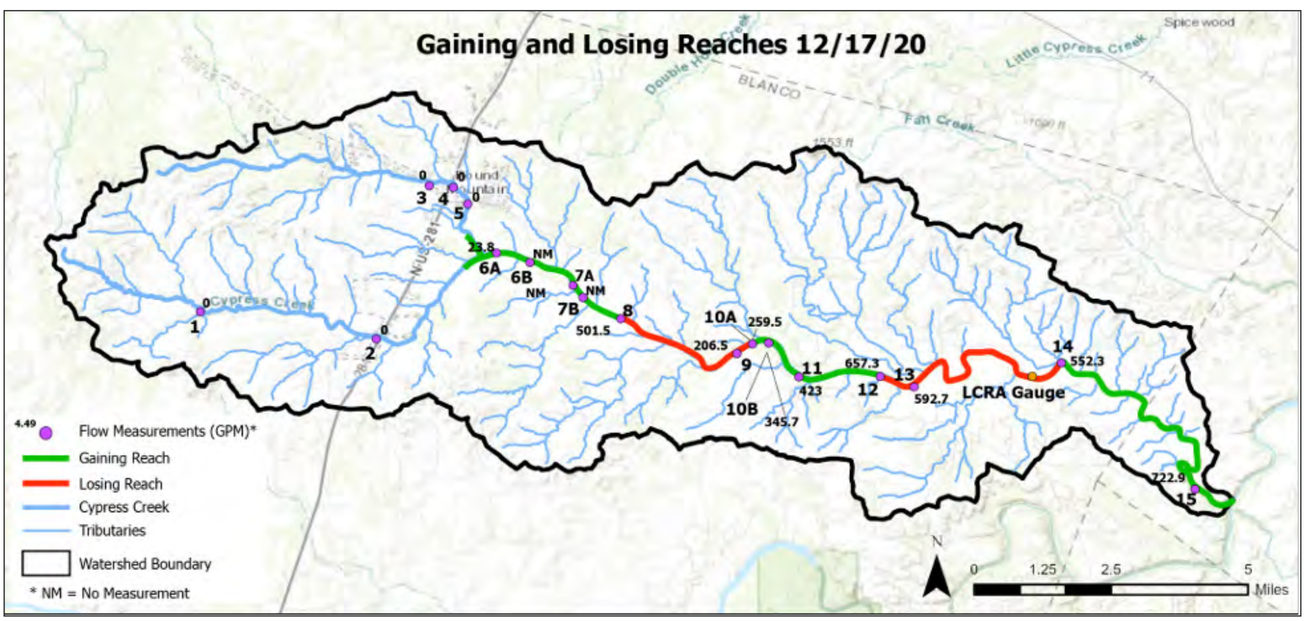

Figure 25. Surface Water Flow Measurements 12/17/2020

Figure 26. CRWN Water Quality Monitoring Site

MCWE Synoptic Water Quality Data

As part of this study, the Meadows Center collected water samples at each of the flow gauging stations in September 2020. These samples represent a synoptic snapshot in time of base flow conditions. A series of common, naturally occurring anions and cations were analyzed by the Edwards Aquifer Research Data Center (EARDC) Laboratory at Texas State University. Anions were analyzed using the Environmental Protection Agency (EPA) Method 300.1A and cations were analyzed using Standards Methods 2320B. These data along with laboratory QA/QC data are included in Appendix B and summarized below. Several spring samples were also collected on July 29th, 2020 and analyzed through the ongoing TWDB water monitoring program (https://www.twdb.texas.gov/groundwater/index.asp). Parameters included isotopes useful for age dating water: Carbon-14 and tritium.

CRWN Water Quality Results

Figures 27-29, below, are representative of the CRWN water quality data set from 2009 to present. Figure 27 represents specific conductivity, which is a measurement of water ability to conduct electrical current. Conductivity has been in the 350 to 600 umhos/cm range, typical of fresh water. The long-term trend is generally flat, indicating no significant change over the period of record.

Figure 28 is a combined graph of dissolved oxygen and temperature. Dissolved oxygen, an indicator of the creek's ability to support aquatic life, varies seasonally due to temperature changes, but has maintained an unchanging long-term trend. Dissolved oxygen and temperature have an inverse relationship as colder water can hold more dissolved oxygen. Dissolved oxygen has remained fairly consistent in the 4.5 to 8.5 mg/l range which is typical for natural Hill Country creeks.

Fecal coliform bacteria are a group of bacteria that are passed through the fecal excrement of humans, livestock, and wildlife. Figure 29 represents monthly fecal coliform testing results. Levels are typically less than 100 colonies. The elevated levels are likely from samples obtained during or after larger precipitation events where wildlife and livestock excrement is washed into the creek. Overall, the levels are relatively constant with no long-term trends.

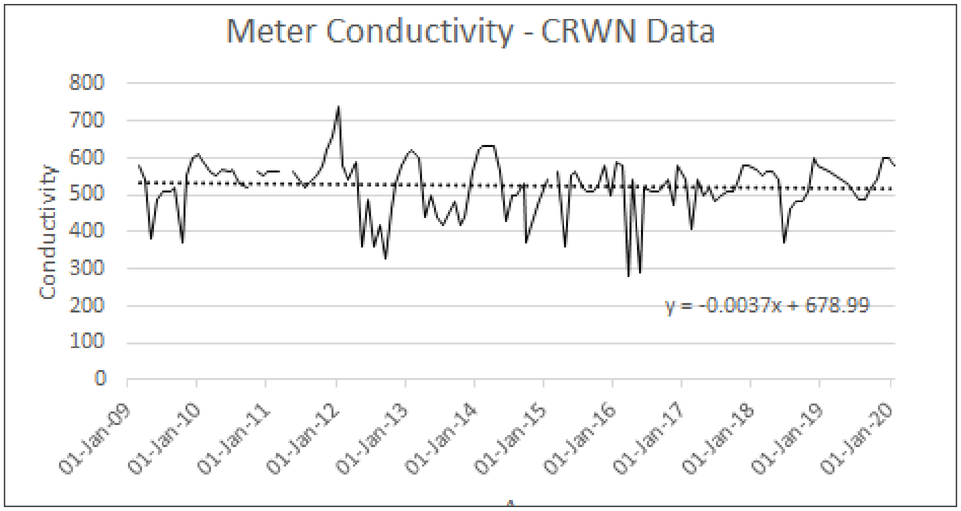

Figure 27. Meter Conductivity - CRWN Data

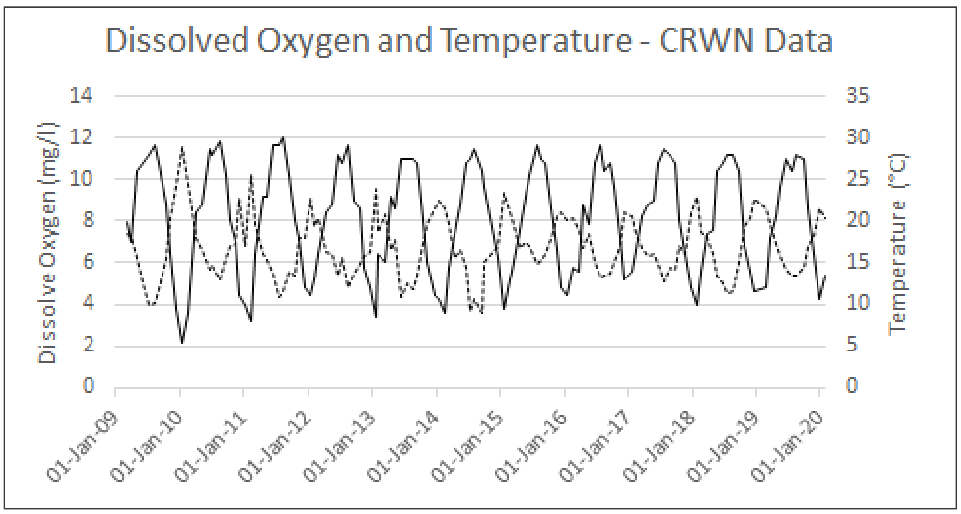

Figure 28. Dissolved Oxygen and Temperature - CRWN Data

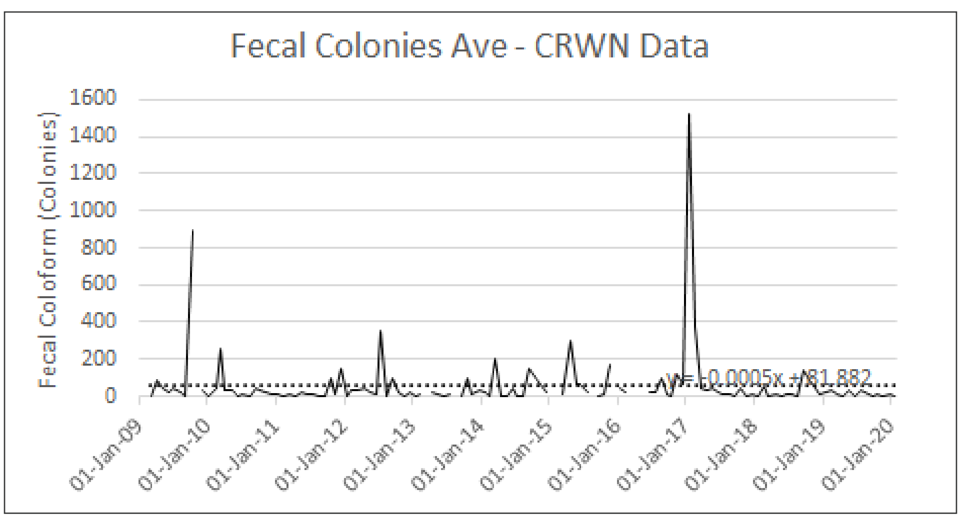

Figure 29. Fecal Coliform - CRWN

TCEQ Sampling

As stated earlier, CRWN chemical analyses are field measurements whereas TCEQ sampling analyses are for additional cations and anions analyzed in a certified laboratory. The limitation on the TCEQ data is that it only reflects water quality upstream of Cypress Mill. Two common anions found in surface water and groundwater in Central Texas are chloride and sulfate. Both parameters are naturally occurring but can also be from anthropogenic sources. Figures 30 and 31 illustrate the trends in chloride and sulfate from 2009 through 2019. Average values for chloride and sulfate are 15.3 mg/l and 17.9 mg/l, respectively. Both parameters are slightly declining since 1998.

Nutrient testing for total phosphorous and nitrite nitrogen compounds are also routinely analyzed by the TCEQ. A lack of nutrients is an indicator of good stream health as algae depends on nutrients to grow. During the period of record of TCEQ sampling, total phosphorous has been below laboratory detection limits. Total nitrogen compounds have also consistently been very low.

E. coli (Figure 32) are mostly harmless bacteria that live in the intestines of people and animals and contribute to intestinal health. These differ somewhat from fecal coliform that is found in fecal matter of warm-blooded animals. At the Cypress Mill road site, there is an increasing trend of E. coli concentrations. The longer-term trend may be somewhat skewed from several elevated events in the 2013-2015 time period.

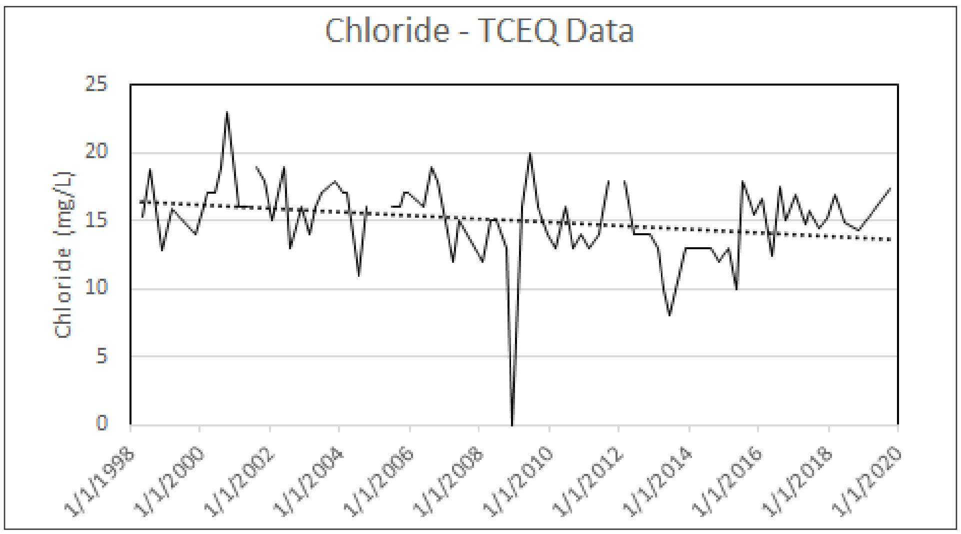

Figure 30. Chloride Concentrations – TCEQ

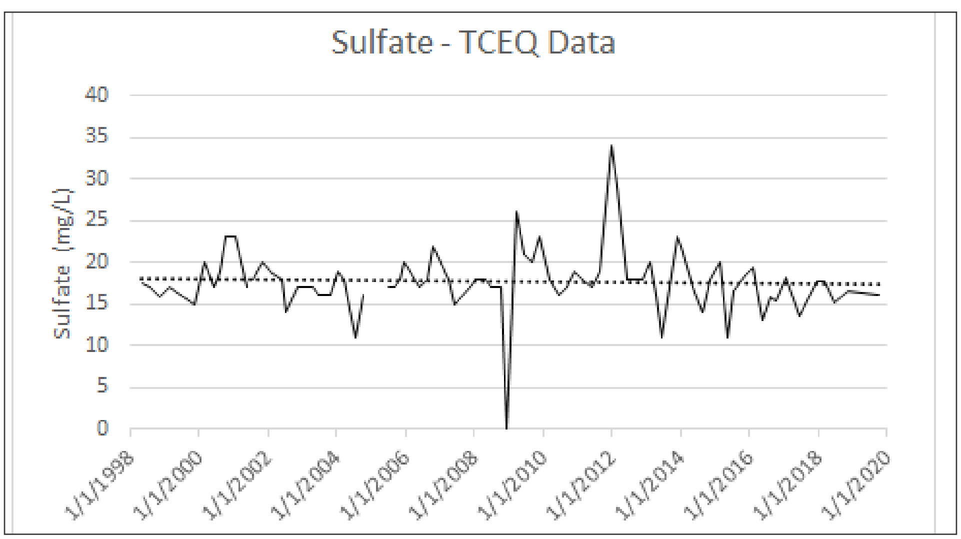

Figure 31. Sulfate Concentrations – TCEQ

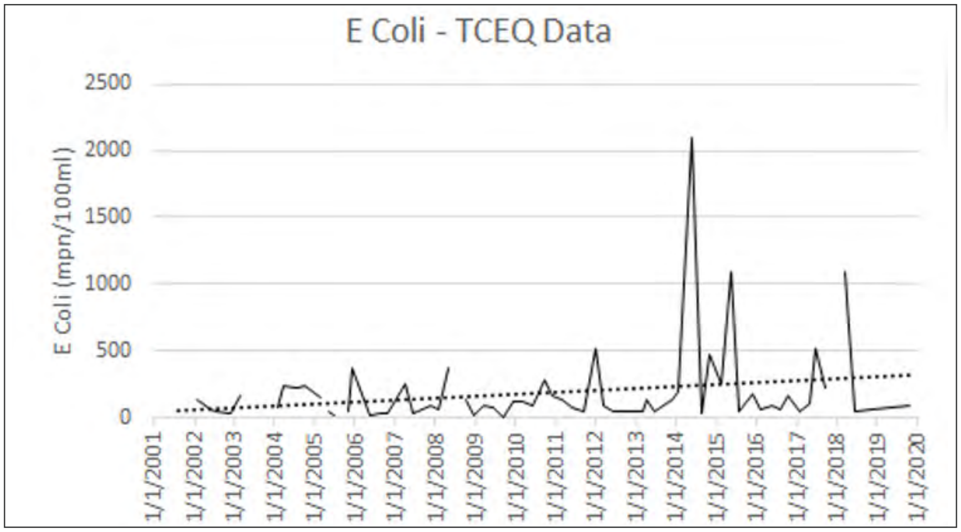

Figure 32. E. coli Concentrations - TCEQ

TWDB Well Water Monitoring Results

A summary of historical water quality data from the TWDB groundwater database is shown on the piper plot, Figure 34. The water quality results are summarized on the Piper Plot, Figure 35. Piper plots (also known as trilinear diagrams) are used to visualize the abundance of common, natural ions in water. The plot comprises a ternary diagram showing cations (lower left), a ternary diagram representing anions (lower right) and a rhombic plot in middle.

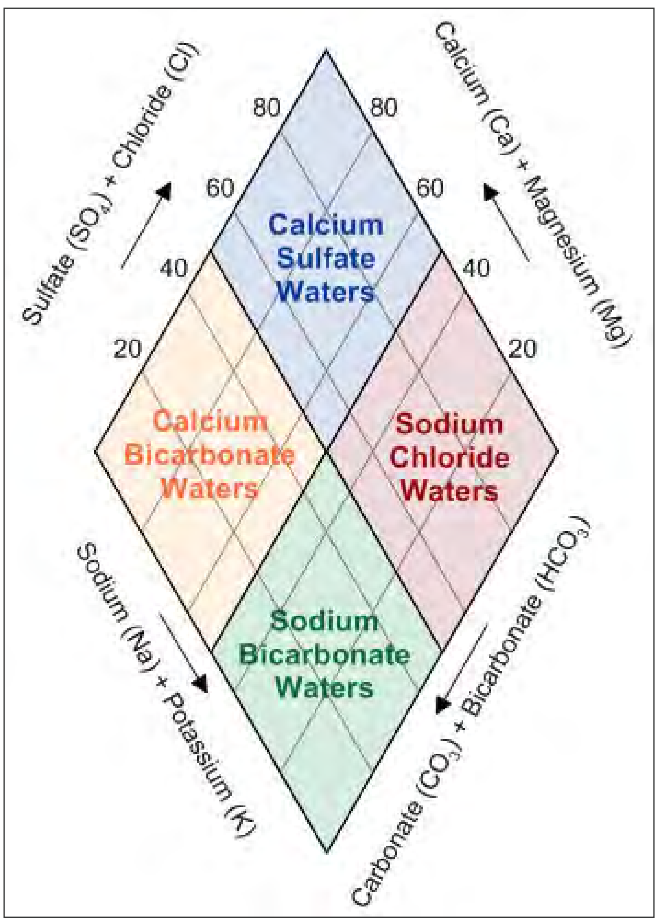

Figure 33. Piper Plot Sample

Samples in the top quadrant are calcium sulfate waters, which are typical of gypsum ground water and mining drainage. Samples in the left quadrant are calcium bicarbonate waters, which are typical of shallow fresh ground water. Samples in the right quadrant are sodium chloride waters, which are typical of marine and deep ancient ground water. Samples in the bottom quadrant are sodium bicarbonate waters, which are typical of deep ground water influenced by ion exchange (Golden Software, 2020).

The data are plotted by aquifer group. The Cretaceous Trinity group and Paleozoic Ellenburger group plot in a similar fashion. Both aquifers are primarily carbonate rocks with high calcium carbonate. The Hickory Sandstone wells are lower in calcium carbonate and higher in sodium and magnesium. All the aquifers have low sulfate. These samples would be considered calcium bicarbonate water. The Hickory samples would be characterized as calcium chloride or sodium bicarbonate waters.

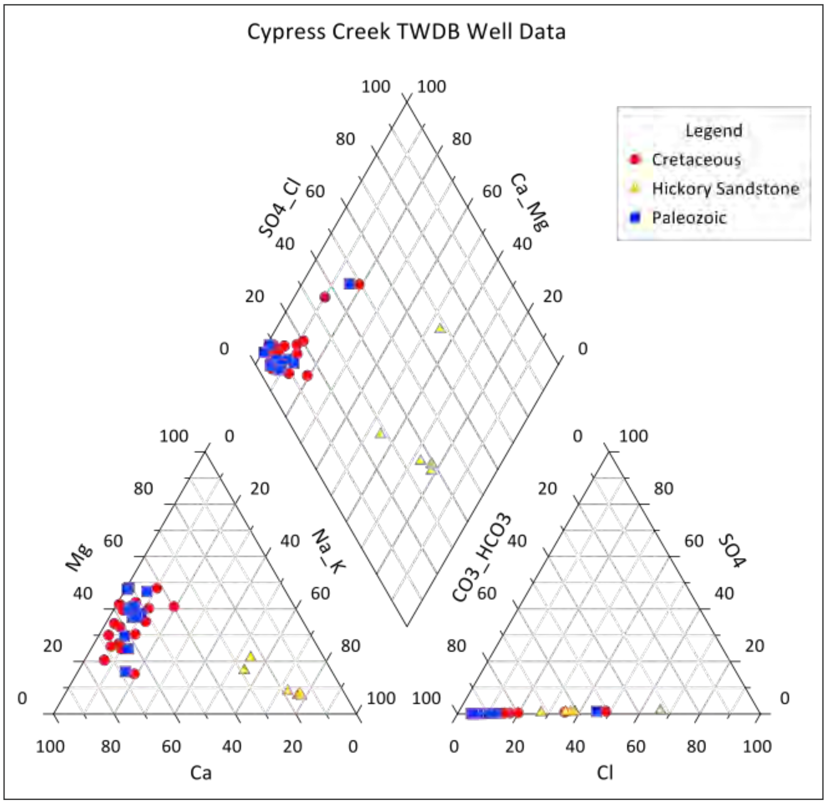

Figure 34. Piper Plot of TWDB Water Quality Data

Meadows Center Water Quality Results

The results are sorted by surface water samples and spring samples on Figure 35. Both surface water and spring water closely resemble each other, indicating the springs are likely the source of creek water. These data also closely resemble the aquifer data from the Ellenburger and Trinity Aquifers. The water quality of the Hickory is distinctly different, indicating the Hickory is not a source of spring flow in this area.

Carbon-14 dating, also called radiocarbon dating, is a method developed in the 1940s to determine the age of organic material. The half-life of Carbon-14 is 5,730 years. Any sample containing a Carbon-14 fraction of 1 is very young water with Carbon-14 reflecting atmospheric level. All the waters sampled indicated Carbon-14 fraction near one, showing the water is very young. The range of Carbon-14 fraction was 0.9426 to 0.9864 with apparent ranging from 110 to 480 years Before Present. The young age indicates the aquifer recharge area is near and there has been little residency time in the subsurface.

Tritium was detected in the three springs, Table 3. Tritium is a naturally occurring radioactive isotope of hydrogen, which decays as a beta emitter. It is produced in small quantities in the upper atmosphere where it is incorporated into water molecules and is, therefore, present in rainwater and surface recharge to aquifer systems. With a half-life of 12.3 years, tritium can be used to trace and date ground water. The amount of tritium in the atmosphere was greatly increased as a result of nuclear weapons testing causing recharge waters to be "tagged" with excess tritium beginning in about 1954. Given the short half-life of tritium, the presence of tritium indicates relatively young water. Samples collected indicate values between 1.14 Tritium Units (TU) and 1.44 TU, indicative of young water For comparison, 2017 sample of rainwater (TWDB Sample# 58-49-324) collected in southwest Austin indicated a tritium value of 2.65 TU.

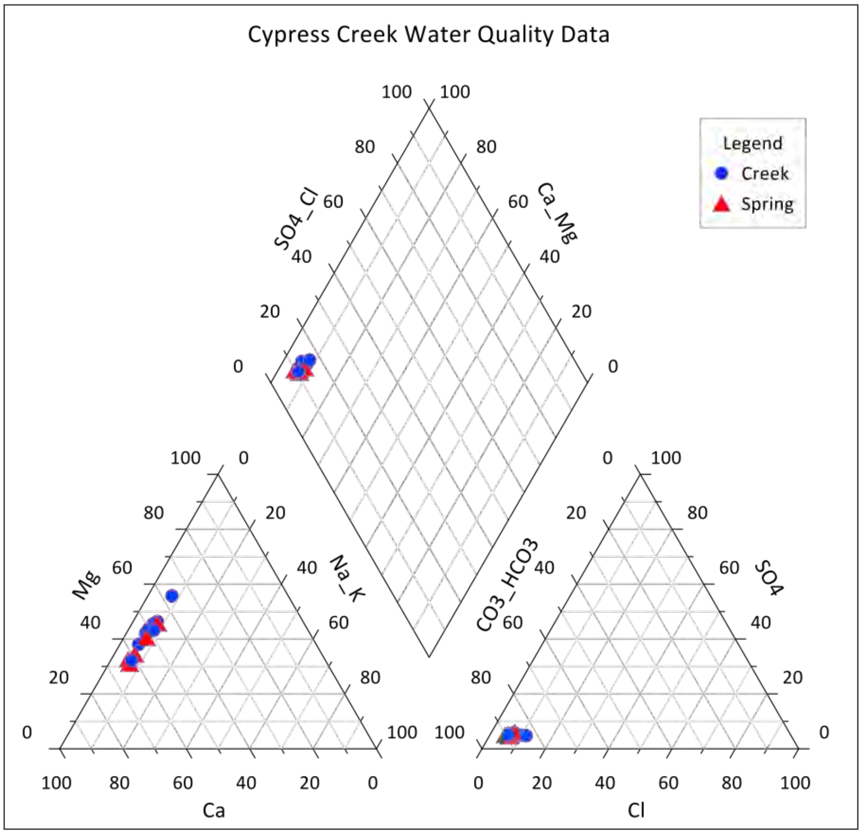

Figure 35. Piper Plot of Meadows Center Water Quality Data.

Table 3. Carbon 14 and Tritium Sampling Results (* units – 0/00)

Spring Sampling Location	TWDB SWR#	Carbon-14 Fraction Modern	Carbon-14 Apparent Age	Tritium in Water (Tritium Units)
Near Site 7B	5738804	0.9426	480 y-BP	1.14
Near Site 7A	5738806	0.9569	350 y-BP	1.44
Near Site 10B	5738902	0.9864	110 y-BP	1.26

Note: y-BP = years before present

SUMMARY OF RESULTS

The results of this study indicate that based on available data Cypress Creek has not been significantly degraded and is in very good condition. Its condition today is the result of little development in the watershed and the good land stewardship of the landowners. There have been changes to land cover (large conversion of grassland and forest to shrub/scrub growth) but there does not appear to impact the volume of flow or water quality based on the data sets reviewed in this study.

Hydrogeologically, the watershed can be described by three distinct areas. The western area, west of Highway 281is dominated by the Cretaceous Trinity Group strata. Both Cypress and north Cypress Creeks originate in this area. Both creeks are ephemeral, or wet weather.

The geology of central watershed area consists of Paleozoic strata, primarily the Ellenburger Group, in the center of the watershed and Cretaceous Trinity rocks on the upland flanks. Major permanent springs originate in Ellenburger and possibly the Marble Falls near Cypress Mill. There is a large losing reach in the center of the central area with roughly half of the upstream flow lost during the two synoptic events. Losses could be greater during drier times. Flow resumes due downstream of the losing reach, including several permanent springs. It is not clear how the losing reach and downstream springs are related.

The eastern area is characterized by the creek incised into the Trinity Group. Based on field measurements, flow roughly doubles across the eastern area. No major springs were observed or found in the literature over the eastern reach though access was limited in this area. The flow increase is likely the result of local recharge discharging from the base of the more permeable strata such as the Cow Creek which is underlain by impermeable Hammett Shale.

Groundwater flow directions are generally to the southeast. southeasterly flow direction tend to flow the regional structure dip of the Paleozoic and Cretaceous aquifers.

Water quality results indicate good water quality, typical of carbonate aquifers. Little or no change was noted over

the period of record of water quality sampling. The waters of the Paleozoic and Cretaceous aquifers and surface water are similar, and very young indicating a similar source. The aquifers and, therefore, the creek are supported by local recharge originating primarily in the watershed.

NEXT STEPS

While a working model of the creek was developed during this study, there are several specific areas that need further study. The possible relationship of the losing reach in the central area of the watershed and downstream springs has not been studied. Access to this reach and targeted flow measurements are needed. If a specific losing feature, such as a swallet, can be identified, a short-term dye tracing study from the losing reach to the springs may be appropriate.

Similarly, additional access to the stream in the downstream in the Trinity Aquifer gain reaches to identify specific springs would shed additional light on how the Trinity interacts with the creek.

Groundwater level monitoring in the watershed should be expanded to include additional wells monitored on a regular basis. The current BPGCD program could be expanded to include additional existing/residential/agricultural wells. The water level monitoring program should be coupled with a routine (annual) water quality sampling program to track potential changes in groundwater quality.

Land cover changes should continue to be tracked as additional data becomes available. The next NLCD data set is due in 2021. These data should be compared to past data sets to assess recent changes in the watershed.

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APPENDIX A: LAND COVER DESCRIPTIONS

Class\ Value		Classification Description
Water		
	11	Open Water- areas of open water, generally with less than 25% cover of vegetation or soil.
	12	Perennial Ice/Snow- areas characterized by a perennial cover of ice and/or snow, generally greater than 25% of total cover.
Developed		
	21	Developed, Open Space- areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.
	22	Developed, Low Intensity- areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20% to 49% percent of total cover. These areas most commonly include single-family housing units.
	23	Developed, Medium Intensity -areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of the total cover. These areas most commonly include single-family housing units.
	24	Developed High Intensity-highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80% to 100% of the total cover.
Barren		
	31	Barren Land (Rock/Sand/Clay) - areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.
Forest		
	41	Deciduous Forest- areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species shed foliage simultaneously in response to seasonal change.
	42	Evergreen Forest- areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species maintain their leaves all year. Canopy is never without green foliage.
	43	Mixed Forest- areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75% of total tree cover.
Shrubland		
	51	Dwarf Scrub- Alaska only areas dominated by shrubs less than 20 centimeters tall with shrub canopy typically greater than 20% of total vegetation. This type is often co-associated with grasses, sedges, herbs, and non-vascular vegetation.
	52	Shrub/Scrub- areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.
Herbaceous		
	71	Grassland/Herbaceous- areas dominated by gramanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.
	72	Sedge/Herbaceous- Alaska only areas dominated by sedges and forbs, generally greater than 80% of total vegetation. This type can occur with significant other grasses or other grass like plants, and includes sedge tundra, and sedge tussock tundra.
	73	Lichens- Alaska only areas dominated by fruticose or foliose lichens generally greater than 80% of total vegetation.
	74	Moss- Alaska only areas dominated by mosses, generally greater than 80% of total vegetation.
Planted/Cultivated		
	81	Pasture/Hay-areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20% of total vegetation.
	82	Cultivated Crops -areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.
Wetlands		
	90	Woody Wetlands- areas where forest or shrubland vegetation accounts for greater than 20% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
	95	Emergent Herbaceous Wetlands- Areas where perennial herbaceous vegetation accounts for greater than 80% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

Courtesy of the Multi-Resolution Land Characteristics Consortium: https://www.mrlc.gov/data/legends/national-land-cover-database-2016-nlcd2016-legend.

APPENDIX B: MCWE WATER QUALITY DATA

Anions

Sample ID	Sample Date	Fluoride mg/L	Chloride mg/L	Nitrite mg/L	Bromide mg/L	Nitrate mg/L	Phosphate mg/L	Sulfate mg/L
#12	9/24/20	3.05	15.27	<1.0	<1.0	1.50	<1.0	14.50
Robinson Spring	9/23/20	3.87	12.69	<1.0	<1.0	4.48	<1.0	17.47
11A	9/24/20	3.42	14.51	<1.0	<1.0	2.06	<1.0	16.01
7A	9/23/20	2.86	17.54	<1.0	<1.0	2.10	<1.0	11.86
#13	9/24/20	2.79	16.06	<1.0	<1.0	2.02	<1.0	14.29
10A	9/23/20	3.21	14.08	<1.0	<1.0	1.93	<1.0	15.67
10B	9/23/20	2.92	14.11	<1.0	<1.0	2.08	<1.0	15.74
6A	9/23/20	1.87	15.86	<1.0	<1.0	1.53	<1.0	17.52
15	9/24/20	2.20	19.60	<1.0	1.06	1.98	<1.0	13.31
8	9/23/20	2.42	14.40	<1.0	<1.0	1.73	<1.0	16.00
7B	9/23/20	3.58	21.96	<1.0	<1.0	3.63	<1.0	17.15
9	9/23/20	2.42	15.44	<1.0	<1.0	1.40	<1.0	16.66
14	9/24/20	3.45	27.69	<1.0	1.08	2.02	<1.0	15.43
Martine Spring	9/24/20	4.07	16.80	<1.0	<1.0	5.43	<1.0	17.58

Cations

Sample ID	Sample Date	Lithium mg/L	Sodium mg/L	Ammonium mg/L	Potassium mg/L	Mangesium mg/L
#12	9/24/20	<0.1	9.14	<0.1	<0.1	31.44
Robinson Spring	9/23/20	<0.1	8.46	<0.1	<0.1	27.46
11A	9/24/20	<0.1	8.83	<0.1	<0.1	32.57
7A	9/23/20	<0.1	9.78	<0.1	<0.1	38.11
#13	9/24/20	<0.1	9.65	<0.1	<0.1	32.36
10A	9/23/20	<0.1	8.60	<0.1	<0.1	31.64
10B	9/23/20	<0.1	8.62	<0.1	<0.1	31.77
6A	9/23/20	<0.1	9.23	<0.1	<0.1	33.16
15	9/24/20	<0.1	9.45	<0.1	<0.1	28.54
8	9/23/20	<0.1	9.02	<0.1	0.62	29.92
7B	9/23/20	<0.1	8.87	<0.1	<0.1	30.33
9	9/23/20	<0.1	8.75	<0.1	2.63	30.67
14	9/24/20	<0.1	11.36	<0.1	<0.1	32.15
Martine Spring	9/24/20	<0.1	10.58	<0.1	<0.1	29.50

TEXAS STATE UNIVERSITY
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Water Analysis Report

Parameter	Results	MDL	Coefficient of Determination (r^2)	Date Analyzed	Analyst	Method
Anions						
Flouride	1.0451	1	99.009	10/6/20	AC	EPA 300.1 A
Chloride	1.0968	1	98.7719	10/6/20	AC	
Nitrite (NO_2-N)*	1.0228	1	99.2318	10/6/20	AC	
Bromide	1.0489	1	99.0241	10/6/20	AC	
Nitrate (NO_3-N)**	1.0904	1	98.9515	10/6/20	AC	
Phosphate (PO_4-P)***	1.0317	1	98.6845	10/6/20	AC	
Sulfate	1.0623	1	99.1444	10/6/20	AC	

	Results (mg/L)	Expected (mg/L)		%Recovery	Acceptable Range
Lab Blank	0	0		0	<20
LCS	5.2859	5		105.718	90-110%
Matrix Spike_1	0.9836	1		98.36	90-110%
Matrix Spike_2	48.1258	50		96.2516	90-110%
Sample Dup_1	15.6725		**Avg.**	15.7066	
Sample Dup_2	15.7407		**%RPD=**	0.4342124	0-20%

Parameter	Results	MDL	Coefficient of Determination (r^2)	Date Analyzed	Analyst	Method
Cations						
Lithium	0.0978	0.1	99.6771	10/6/20	AC	Standard M
Sodium	0.1256	0.1	98.0945	10/6/20	AC	
Ammonium [b]	0.124	0.1	98.7318	10/6/20	AC	
Potassium	0.1754	0.1	99.7547	10/6/20	AC	
Magnesium	0.1135	0.1	99.3833	10/6/20	AC	
Manganese	0.1102	0.1	98.0495	10/6/20	AC	
Calcium	0.1254	0.1	99.6218	10/6/20	AC	
Strontium	0.0968	0.1	99.4179	10/6/20	AC	
Barium	0.09874	0.1	99.783	10/6/20	AC	

[b]Quadratic fit

	Results (mg/L)	Expected (mg/L)		%Recovery	Acceptable Range
Lab Blank	0	0		0	<20
LCS	25.3281	25		101.3124	90-110%
Matrix Spike_1	1.0788	1		107.88	90-110%
Matrix Spike_2	79.0202	80		98.77525	90-110%
Sample Dup_1	32.3612		**Avg.**	31.9994	
Sample Dup_2	31.6376		**%RPD=**	2.2612924	0-20%

APPENDIX C: MAP CREDITS

Figure 2: Cypress Creek of the Pedernales

United States Geological Survey, Texas Department of Transportation, Texas Natural Resources Information System

Figure 3: NLDC Land Cover – 2001

United States Geological Survey, Texas Department of Transportation, USGS National Land Cover Database, 2001.

Figure 4: NLDC Land Cover – 2016

United States Geological Survey, Texas Department of Transportation, USGS National Land Cover Database, 2016.

Figure 5 – Cypress Creek Geology

United States Geological Society, Texas Natural Resources Information System, V. E. Barnes, 1982, Barnes, V.E., 1982, Geology of the Hammetts Crossing Quadrangle, Blanco, Hays, and Travis Counties, Texas: University of Texas at Austin, Bureau of Economic Geology, Geologic Quadrangle Map GQ-0051, scale 1:24,000. Scanned, collars clipped, and georeferenced November 2014 at UT Austin Walter Geology Library by BSEACD intern Chase Svoboda, Barnes, V.E., 1978, Geology of the Howell Mountain quadrangle, Blanco and Llano Counties, Texas: University of Texas at Austin, Bureau of Economic Geology, Geologic Quadrangle Map GQ-0046, scale 1:24,000. Scanned, collars clipped, and georeferenced November 2014 at UT Austin Walter Geology Library by BSEACD intern Chase Svoboda, Barnes, V.E., 1982, Geology of the Pedernales Falls quadrangle, Blanco County, Texas: University of Texas at Austin, Bureau of Economic Geology, Geologic Quadrangle Map GQ-0049, scale 1:24,000 Scanned, collars clipped, and georeferenced November 2014 at UT Austin Walter Geology Library by BSEACD intern Chase Svoboda, Barnes, V.E., 1978, Geologic map of the Round Mountain quadrangle, Blanco, Burnet, and Llano counties. Texas: University of Texas at Austin, Bureau of Economic Geology, Geologic Quadrangle Map GQ-0047, scale 1:24,000. Scanned, collars clipped, and georeferenced November 2014 at UT Austin Walter Geology Library by BSEACD intern Chase Svoboda, V.E. Barnes, 1982, Geology of the Spicewood Quadrangle, Bureau of Economic Geology Scanned, collars clipped, and georeferenced November 2014 at UT Austin Walter Geology Library by BSEACD intern Chase Svoboda.

Figure 8 – Western Cypress Creek Watershed with Sampling Locations

United States Geological Society, Texas Natural Resources Information System, Barnes, V.E., 1978, Geologic map of the Round Mountain quadrangle, Blanco, Burnet, and Llano counties. Texas: University of Texas at Austin, Bureau of Economic Geology, Geologic Quadrangle Map GQ-0047, scale 1:24,000. Scanned, collars clipped, and georeferenced November 2014 at UT Austin Walter Geology Library by BSEACD intern Chase Svoboda, Barnes, V.E., 1978, Geology of the Howell Mountain quadrangle, Blanco and Llano Counties, Texas: University of Texas at Austin, Bureau of Economic Geology, Geologic Quadrangle Map GQ-0046, scale 1:24,000. Scanned, collars clipped, and georeferenced November 2014 at UT Austin Walter Geology Library by BSEACD intern Chase Svoboda

Figure 9 – Central Cypress Creek Watershed with Sampling Locations

United States Geological Society, Texas Natural Resources Information System, V. E. Barnes, 1982, Barnes, V.E., 1982, Geology of the Hammetts Crossing Quadrangle, Blanco, Hays, and Travis Counties, Texas: University of

Texas at Austin, Bureau of Economic Geology, Geologic Quadrangle Map GQ-0051, scale 1:24,000. Scanned, collars clipped, and georeferenced November 2014 at UT Austin Walter Geology Library by BSEACD intern Chase Svoboda, Barnes, V.E., 1982, Geology of the Pedernales Falls quadrangle, Blanco County, Texas: University of Texas at Austin, Bureau of Economic Geology, Geologic Quadrangle Map GQ-0049, scale 1:24,000 Scanned, collars clipped, and georeferenced November 2014 at UT Austin Walter Geology Library by BSEACD intern Chase Svoboda, Barnes, V.E., 1978, Geologic map of the Round Mountain quadrangle, Blanco, Burnet, and Llano counties. Texas: University of Texas at Austin, Bureau of Economic Geology, Geologic Quadrangle Map GQ-0047, scale 1:24,000. Scanned, collars clipped, and georeferenced November 2014 at UT Austin Walter Geology Library by BSEACD intern Chase Svoboda, V.E. Barnes, 1982, Geology of the Spicewood Quadrangle, Bureau of Economic Geology Scanned, collars clipped, and georeferenced November 2014 at UT Austin Walter Geology Library by BSEACD intern Chase Svoboda

Figure 10 – Eastern Cypress Creek Watershed with Sampling Locations

United States Geological Society, Texas Natural Resources Information System, V.E. Barnes, 1982, Geology of the Spicewood Quadrangle, Bureau of Economic Geology Scanned, collars clipped, and georeferenced November 2014 at UT Austin Walter Geology Library by BSEACD intern Chase Svoboda, Barnes, V.E., 1978, Geology of the Howell Mountain quadrangle, Blanco and Llano Counties, Texas: University of Texas at Austin, Bureau of Economic Geology, Geologic Quadrangle Map GQ-0046, scale 1:24,000. Scanned, collars clipped, and georeferenced November 2014 at UT Austin Walter Geology Library by BSEACD intern Chase Svoboda

Figure 12: Groundwater Potentiometric Surface Map

United States Geological Society, Texas Natural Resources Information System, Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri Chain (Hong Kong), © OpenStreetMap contributors, and the GIS User Community

Figure 14: Surface Water Flow Measurements 9/23 – 9/24

United States Geological Society, Texas Natural Resources Information System, Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri Chain (Hong Kong), © OpenStreetMap contributors, and the GIS User Community

Figure 15: Surface Water Flow Measurements 12/17/20

United States Geological Society, Texas Natural Resources Information System, Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri Chain (Hong Kong), © OpenStreetMap contributors, and the GIS User Community


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