APPENDIX A: WATERSHED CHARACTERISTICS

The Upper San Marcos Watershed and River

I. Watershed

The Upper San Marcos watershed is 94.6 mi^2 (60,605 acres) and is divided into four main contributing subbasins: Sink Creek (48.26 mi^2/30,906 acres), Sessom Creek (0.63 mi^2/402 acres), Purgatory Creek (36.96 mi^2/23,698 acres), and Willow Creek (5.90 mi^2/3,778 acres). Much of the watershed is in the Edwards Aquifer Recharge Zone and the eastern portion of the watershed encompasses much of the City of San Marcos and Texas State University (Figure 1).

II. Spring Lake and the San Marcos River

Artesian spring water from the Edwards Aquifer emerges through 200 spring openings forming Spring Lake and the headwaters of the San Marcos River. This spring system is the second most productive in the state and it is the primary source of flows to the San Marcos River.

Spring Lake is a horseshoe-shaped water body with two main regions: the Spring Arm to the north and the Slough Arm to the south. Most of the hydrological inputs to Spring Lake occur from spring openings in the Spring Arm, meaning that most of the flow in the river is comprised of groundwater. Sink Creek discharges into the Slough Arm of the lake and is the lake's only significant surface water tributary (Nowlin and Schwartz, 2012).

The San Marcos River is divided into upper and lower segments. The Upper San Marcos River (Segment 1814) is 4.5 miles long, extending from its headwaters at the San Marcos Springs to its confluence with the Blanco River. The land area within the watershed has an average elevation of 574 ft. (9318.96 m) above sea level (TPWD, 1974). The upper portion of the river receives periodic inputs of rainwater from four major tributaries before joining the Blanco River's flow and meeting the Guadalupe River in Gonzales, Texas. These combined rivers flow into the San Antonio Bay in the Gulf of Mexico (Figure 2).

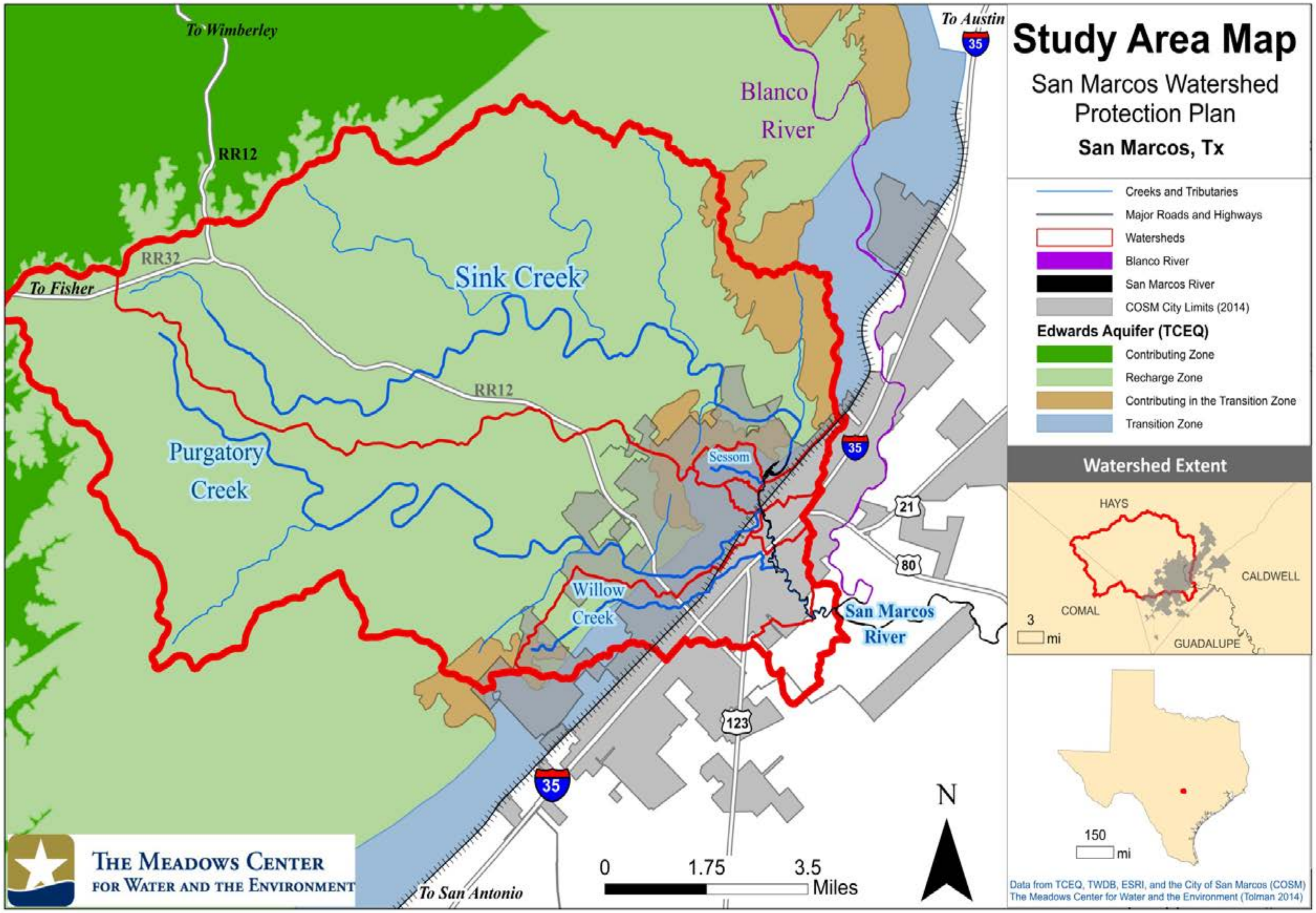

Figure 1. Upper San Marcos River and tributaries (COSM and MCWE, 2013)

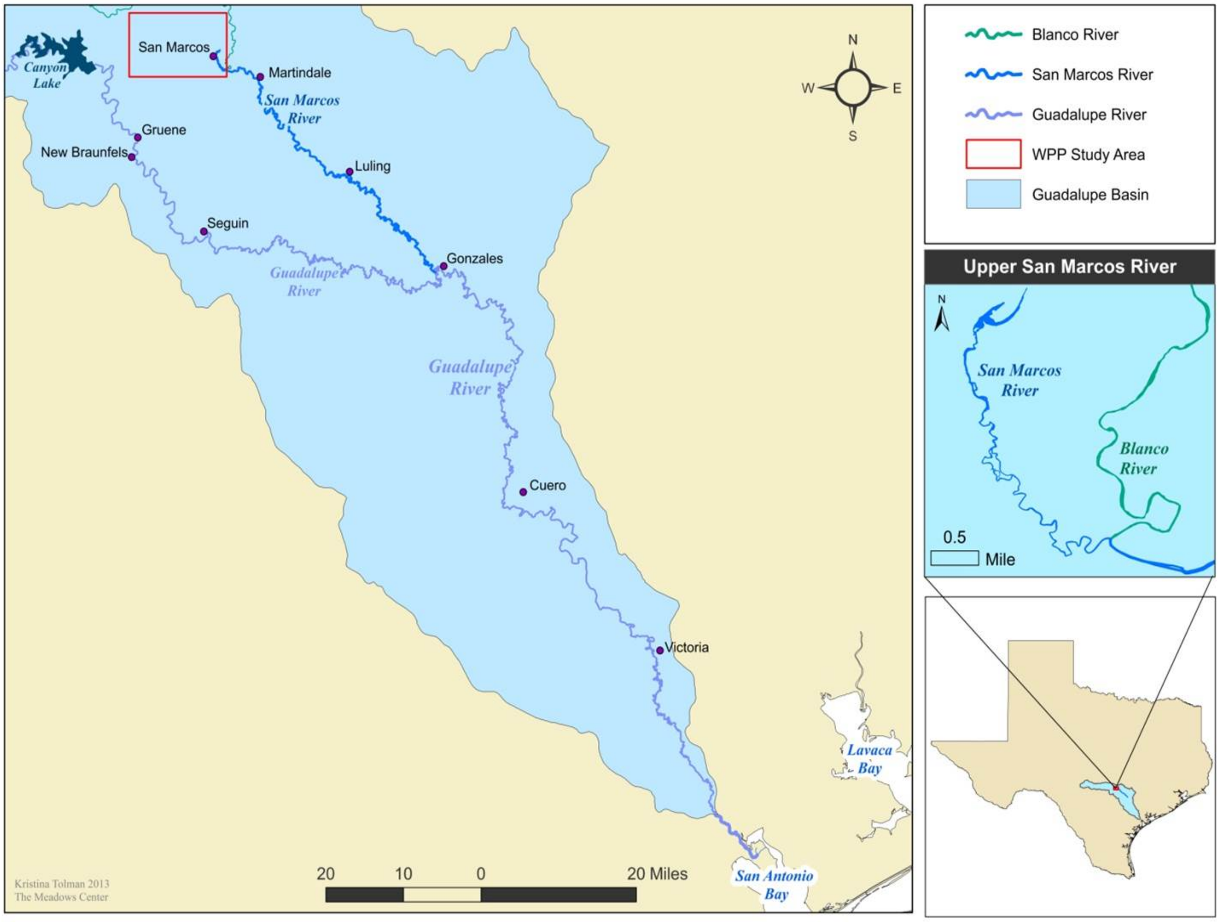

Figure 2. Upper San Marcos River Segment within the Guadalupe River Basin

III. Watershed Topography, Soils and Karst Features

The Upper San Marcos watershed is located along the edge of the Balcones Escarpment, resulting in varied elevation. Moving eastward through the watershed, the topography slopes downward, reaching the lowest elevations at the San Marcos River, the ultimate destination for runoff from all of the subbasins.

The topography, especially in the western portion of the watershed is hilly, with karstic terrain. These karst features serve as recharge areas for the Edwards, Edwards-Trinity, and Trinity Aquifers. The Blackland Prairies that dominate much of the watershed are characterized by a lower layer of white chalky limestone, shale, and marlstone covered by dark alkaline clay soil interspersed with sandy loam. (TPWD, 2015; NPAT, 2015). These soils are composed of approximately 50 different soil units, which range greatly in their properties and coverage (Batte, 1984). Detailed information about the watershed's soils and geology can be found in the Watershed Characterization document included in Supporting Documents on the SMWI website.

IV. Climate and Rainfall

The headwaters of the Upper San Marcos River flow from karstic limestone rock openings in the Edwards Aquifer and are dammed, creating Spring Lake. The lake varies in depth and has a substrate of silt and sand, with occasional rock outcrops. Once in the main stem of the river below the dam, the river morphology consists of gravel, sand and cobble substrates. The Upper stream segment from Rio Vista Dam to Spring Lake Dam has primarily sand and small gravel substrates. Below Rio Vista Dam the mesohabitats primarily consist of runs with sand, small gravel, silt, and clay (Saunders, 2001). The implementation of flood control structures, mainly dams, has affected both the flow of the river and deposition of sediments, causing major siltation problems throughout the river and several of its tributaries.

The climate in the central Texas region can be categorized as semi-arid. This region is prone to drought, but Central Texas is also prone to severe flooding caused by intense periods of rainfall. Data show a great deal of inter-annual and decadal variability in climatic conditions, which can affect water resources and subsequent ground water discharge from the Edwards Aquifer (Cox et al., 2009).

From 1946 to 2011, the mean annual total precipitation was 37.2 inches (0.945 m) and the mean annual air temperature was 68.5 °F (20.3°C) at the City of San Marcos Weather Station [National Oceanic and Atmospheric Administration Station ID TX417983, 29.8832°, -97.9494°]. However, temperatures vary greatly between seasons, with long periods of hot, dry weather in the summer. Rainfall totals tend to be higher in spring and fall. Mean monthly precipitation and temperature are shown in Figure 3.

Annual gross lake surface evaporation in this region is estimated to be 60-65 inches or 1.524-1.651 meters (TWDB, 2007).

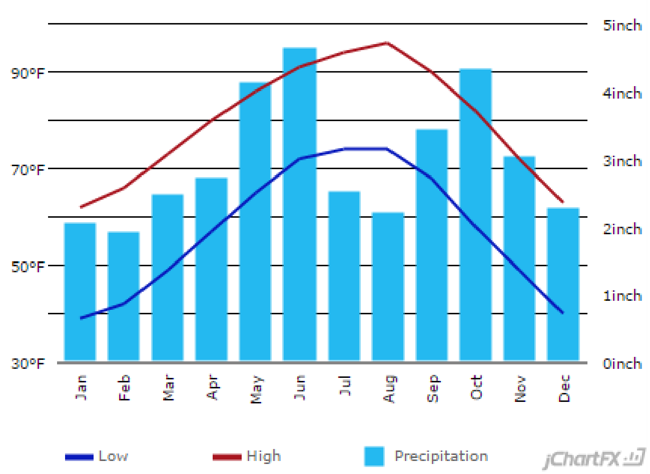

Figure 3. San Marcos mean temperature and rainfall, 1981-2010 (US Climate Data, 2014)

Figure 4 illustrates average annual precipitation in inches from 1980-2010 throughout Willow Springs, Purgatory, Sessom, and Sink Creek sub-basins. The average annual rainfall of 36 in (0.914 m) is nearly 10% higher in the far northwestern portion of the basin, compared with 33 in (0.838 m) in the eastern portion of the watershed, primarily Sessom and Willow Creek sub-basins.

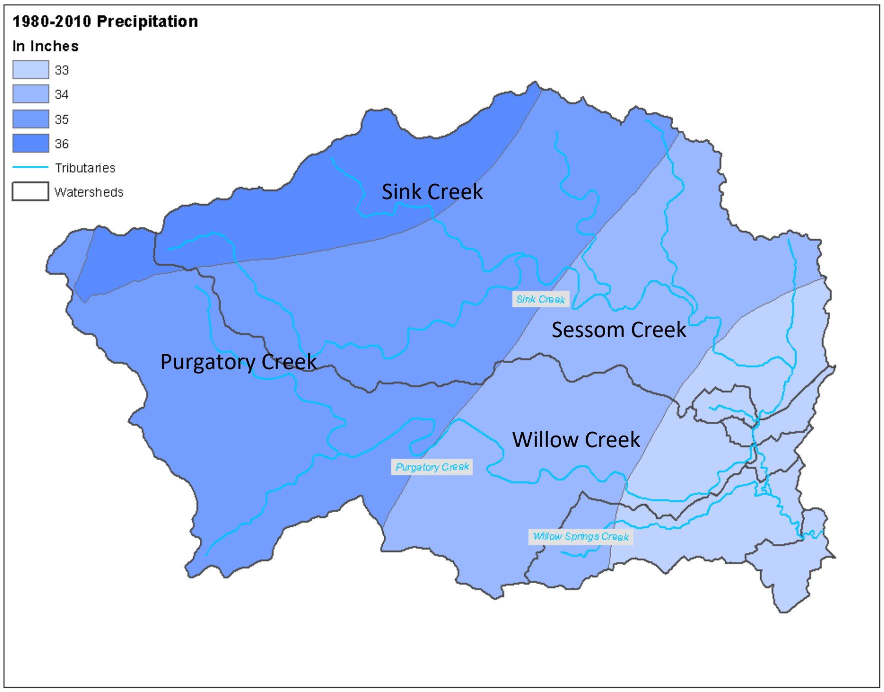

Figure 4. Average annual precipitation by sub-basin from 1980 - 2010 (TNRIS/NCDC 2013, NOAA/EAA NEXRAD data, 2014)

Watershed Ecology

I. Ecoregions

The watershed is located upon and along the margins of the Edwards Plateau and Blackland Prairie regions of the Texas Hill Country. The western portion of the watershed falls into the Edwards Plateau region, with landscapes characteristically referred to as the Texas Hill Country. Hills and steep canyons with shallow soils underlain by limestone bedrock are common. The Balcones Escarpment separates this ecoregion from the Blackland Prairie ecoregion which has milder topography and is characterized by thicker, heavier, productive soils. Vegetation within the watershed is characteristic of much of the Texas Hill Country, composed primarily of perennial and annual grasses and is dominated by oak, hackberry, pecan, elm, and other trees.

II. Wildlife, Aquatic Life, Endangered Species

Due to the relatively large spring water influence, Spring Lake and the upper river reaches are characterized by clear water and abundant and productive macrophytes (aquatic plants). The lake and the upper river also exhibit nearly constant seasonal flows and water temperatures 71.6 ^{o}F (22^{o}C). This relative environmental constancy has led to a high number of endemic species in the headwaters.

The river is home to 56 fish species, including 44 native species, and 8 wildlife species listed by US Fish and Wildlife Service as endangered (Saunders et al. 2001). Endangered species include the San Marcos salamander (*Eurycea nana*), Texas blind salamander (*Typhlomolge rathburni*), Texas wild rice (*Zizania texana*), the fountain darter (*Etheostoma fonticola*), the San Marcos Gambusia (*Gambusia georgei*), the Comal Springs riffle beetle (*Heterelmis comalensis*), the Dryopid Beetle (*Stygoparnus comalensis*), and the Peck's Cave Amphipod (*Stygobromus pecki*). All of these species are present in the headwaters and the Edwards Aquifer immediately below Spring Lake. The Guadalupe roundnose minnow (*Dionda nigrotaeniata*) and the bigclaw river shrimp (*Macrobrachium carcinus*) also occur in the headwaters and have been identified by the Texas Comprehensive Wildlife Conservation Strategy as species of "high priority" for conservation.

These species are sensitive to pollution and rely on the suitable flows and constant temperatures, as well as high water quality for survival (Bonner et al., 1998; Trolley-Jordan and Power, 2007). Of the threatened and endangered species, the fountain darter and Texas wild rice have both been used as focus organisms in restoration and mitigation actions in the Edwards Aquifer Recovery Implementation Plan and HCP.

Watershed Hydrology

I. Source Waters

Edwards Aquifer

The Edwards Aquifer is a confined aquifer, composed primarily of porous or karst limestone, 300-700 feet thick. There are honeycomb-like formations that form underground conduits and store water. Groundwater within the aquifer typically moves from areas of higher southwestern elevations toward lower discharge areas in the northeast, as shown in Figure 5 . During normal conditions, flow is guided by barrier faults that block the continuity of connected and permeable limestone strata, creating a pathway or pipeline for groundwater (Eckhardt, 2016). More detailed information regarding the geology and stratigraphy of the Edwards Aquifer is provided in the Watershed Characterization document included in Supporting Documents on the SMWI website.

Annual recharge rates for the aquifer over 80 years average 692,000 acre feet, but as Figure 6 shows, this recharge is highly variable and can differ dramatically over time. Rainfall, the primary source of recharge, also varies annually. Note that 2014 had the second lowest total annual recharge (107,000 af). While it appears that total annual recharge may be trending upward, it is more likely that increased pumping has created more space in the aquifer for water to be replaced or recharged (Eckhardt, 2016).

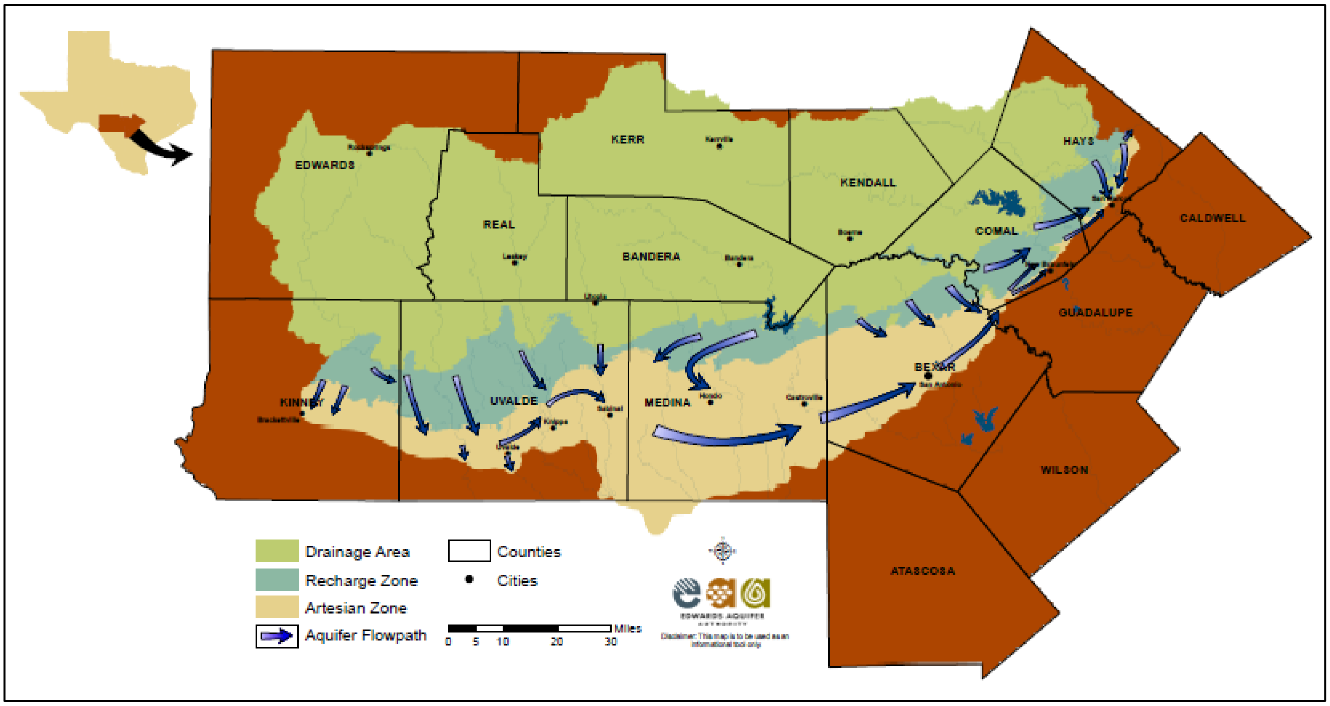

Figure 5. General Edwards Aquifer flow path (EAA)

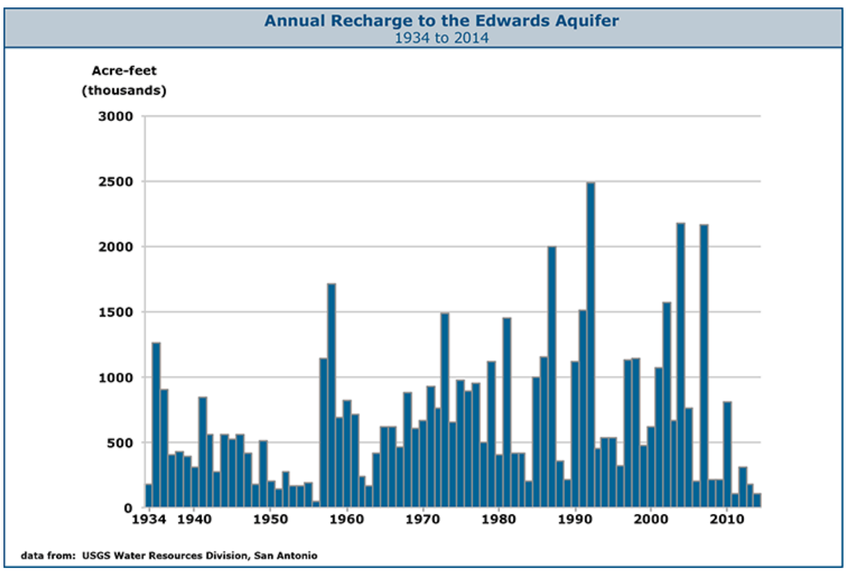

Figure 6. Annual recharge to the Edwards Aquifer (USGS, Eckhardt)

An estimated 25-55 million acre-feet of water is stored in the aquifer (Maclay, 1981; Ogden, 1986). However, much of this water is not easily available for use and springs can stop flowing even when the aquifer is relatively full (Eckhardt, 2016). Groundwater expert Gregg Eckhardt notes that some of the water in the aquifer is needed to maintain regional ecosystems and economies:

> "In order to maintain at least minimal natural springflows for the sake of endangered species, recreational economies, downstream ecosystems, and

downstream economies, then the large amount of water below the level of the springs is essentially unavailable to us."

Figure 7 depicts yearly discharge volumes from the Edwards Aquifer by type of use. A significant portion of groundwater or source water is attributed to spring flows, which comprise the majority of the flows of the Upper San Marcos River. These source waters are used for human and environmental purposes. In recent years, likely attributable to urbanization, livestock/domestic and irrigation uses have been replaced with industrial uses.

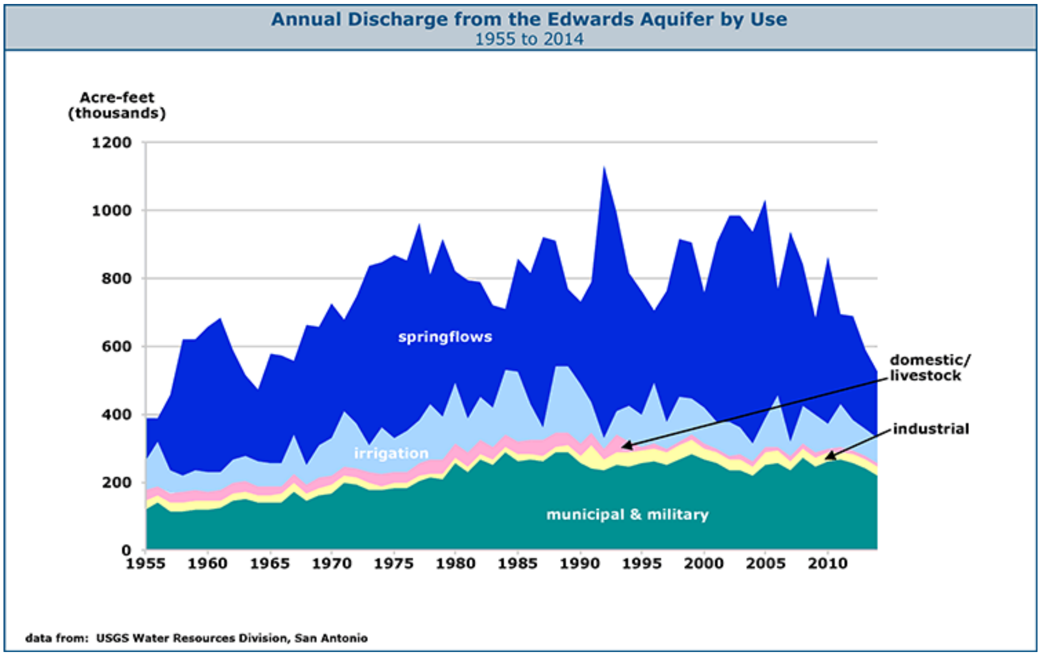

Figure 7. Annual discharge from the Edwards Aquifer by type of use (USGS, Eckhardt)

Spring Lake and San Marcos Springs

Spring Lake and San Marcos Springs are located along the transition/artesian zone of the Edwards Aquifer as shown in Figure 5. The perennial discharge from the artesian springs into Spring Lake are a result of confined flow within the aquifer. This discharge is comprised mainly of source waters from regional recharge and flow paths, even when rainfall contributes additional local recharge via nearby streams, creeks, and recharge features (USGS, 2012). This indicates that flow and water quality are dependent on recharge occurring outside the watershed. However, precipitation in the watershed can greatly impact both spring and surface flows. Rainfall in the watershed can vary greatly in frequency, duration, and intensity, which can have an impact on discharge (Figure 8).

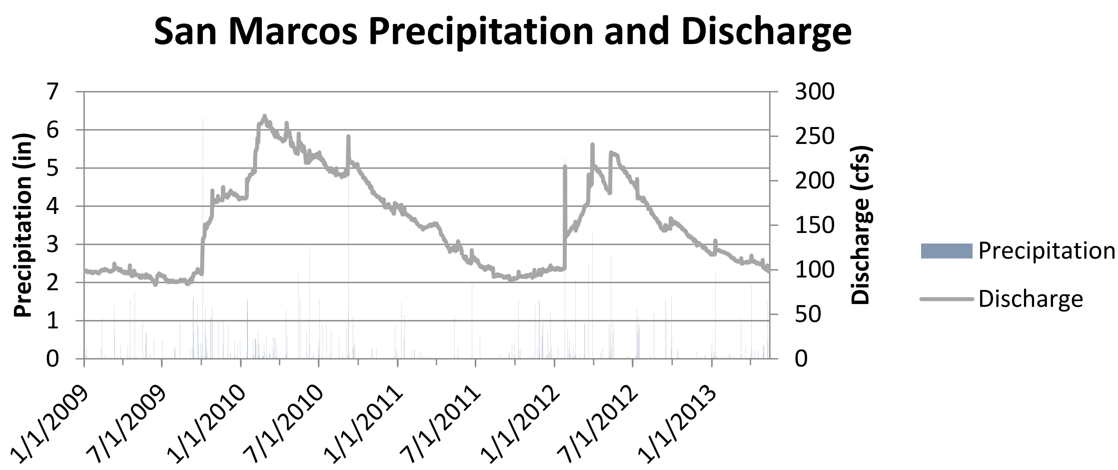

Figure 8. Discharge and precipitation data for the San Marcos River between January 2009 and May 2013 (NCDC 2013, USGS 2013)

Due to the complex nature of the flows within the aquifer, the precise origin and age of waters emerging from the various spring openings in Spring Lake is not well understood; however, there is information on the general flow paths of water emerging from the springs. The recharge and transition zones lie on and follow the large Balcones Fault Zone, which is a complex series of roughly parallel faults forming a zone between the deep artesian zone and the shallower recharge zone. See the Watershed Characterization document included in Supporting Documents on the SMWI website for more information.

A recent study found that drought, coupled with typical pumping levels, results in water bypassing the underground barrier faults that block the continuity of connected and permeable limestone strata in the aquifer. Consequently, in major drought conditions, the San Antonio and Barton Springs segments are no longer hydrologically separated, potentially allowing flow to bypass San Marcos Springs and flow instead toward Barton Springs (GBRA, 2010).

II. Surface waters

Watershed Tributaries

As depicted in Figure 1, the Upper San Marcos watershed can be divided into hydrologic units or sub-basins corresponding with the four major tributaries that feed the main stem of the San Marcos River: Sink, Purgatory, Willow, and Sessom Creeks. For the purposes of accurately modeling pollution and flows, the watershed was further broken down into even smaller drainage units within the four sub-basins, and four additional sub-basins/drainage areas were added: City Park, Downtown, Below Purgatory Creek, and Below Willow Creek, shown in Figure 9.

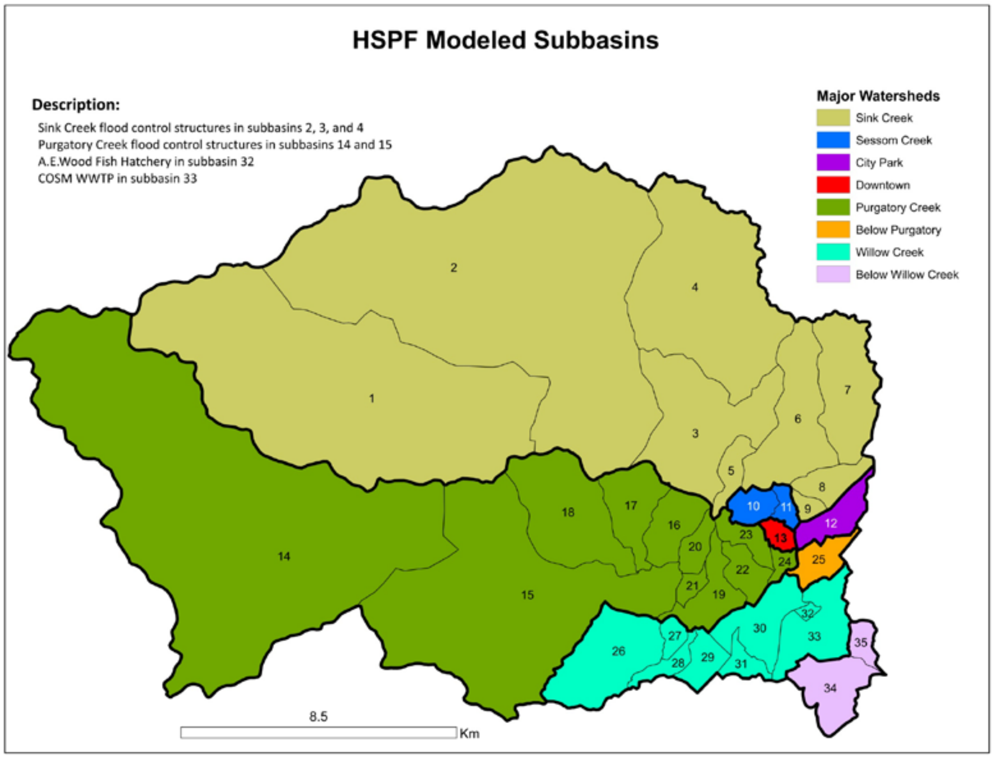

Figure 9. Watershed subbasins used for modeling

Surface Water Flows

The San Marcos River flows from the second largest spring system in Texas, and due to their location within the potentiometric zone of the Edwards Aquifer, the San Marcos springs has maintained the most consistent spring flow recorded in Texas. Although consistent, spring flow is still susceptible to fluctuations from severe drought or extreme rainfall, as shown in Figure 10. Since 2008, the lowest recorded discharge, 82 cfs, occurred in the summer of 2009. Record discharges likely occurred during the May and October floods of 2015, however, no discharge was recorded during the peak flows of these floods because the USGS gage was rendered inoperable.

The river's four major tributaries are intermittent and contribute minimal flow except during and after storm events. Sink Creek is mostly intermittent with small pockets of springs located near Spring Road and Bert Brown road. It enters the San Marcos River near the golf course at Spring Lake, providing water to the Slough Arm section of the lake. In wet years, the springs provide very minimal inflows. Due to its large size, Sink Creek is very responsive to surface water runoff during rain events and is prone to flooding. Purgatory Creek is the 2nd largest tributary and has a history of flooding during large rain events. Similar to Sink Creek, this tributary is intermittent and only flows during significant rain events.

Willow Creek is also an intermittent tributary with some scattered springs along the main stem. The average springflow is unknown but it is estimated to not exceed 3-5 cfs. The lower reaches of Willow Creek are highly urbanized and collect surface water runoff from impervious surfaces. Sessom Creek is the smallest subwatershed and tributary, yet contains several springs that produce flow even during the driest years. The combined base springflow generally does not exceed 10 cfs. However, the watershed is highly urbanized making it susceptible to stormwater runoff.

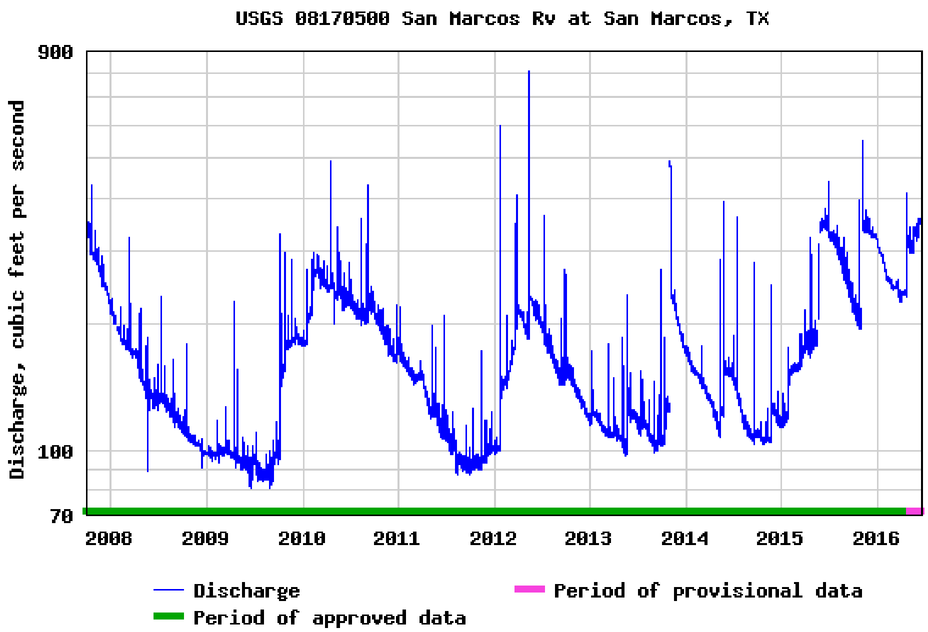

Figure 10. San Marcos River discharge measured at the USGS gage #8170500 in Sewell Park (2008-2016)

Flooding

Central Texas, a part of "Flash Flood Alley," commonly experiences intense rainfall events that can result in the accumulation of tremendous volumes of water in a short period of time. Stormflow or runoff from these intense events, coupled with steep slopes, poorly vegetated hillsides, and impervious cover lead to flash floods. Increasing urbanization, especially impervious cover and improperly placed development, add to the severity of flooding by increasing the rate and flow of runoff across the landscape and eroding stream channels. The City of San Marcos' 2007 Flood Protection Plan points out that previously nuisance scale flooding has increased as the City has grown (COSM, 2007). The City and surrounding areas have been impacted by at least 6 major flood events since 1998, resulting in loss of life and extensive damage to property and infrastructure. Further, storm water and flooding increase erosion and carry pollutants across the watershed and downstream. Figure 11 shows floodwaters from the San Marcos River during the October 30, 2015 flood.

Figure 11. San Marcos River and flooded areas, October 30, 2015 (photo courtesy of Kristina Tolman)

Water Quality

I. Water Quality Criteria and Standards

Surface water quality standards and screening levels for the Upper San Marcos River are set by TCEQ. Designated uses in the segment are Contact Recreation, Exceptional Aquatic Life Use, and Aquifer Protection (Table 1). Standards and screening levels are provided in Table 2.

Table 1. TCEQ Upper San Marcos River use designations

USES*	Seg #	Segment Name	Recreation	Aquatic Life	AP
	1814	Upper San Marcos River	Primary contact recreation	Exceptional aquatic life designation	AP - Aquifer regulated activities: any construction/post-construction activity occurring on the contributing zone of the Edwards Aquifer that has the potential for contributing pollution to surface streams that enter the Edwards Aquifer recharge zone (§213)**. The aquifer protection use applies to the contributing, recharge and transition zones of the Edwards Aquifer.

* As per Texas Administrative Code, Title 30, Part 1, Chapter 307, Rule §307.7, Site-Specific Uses and Criteria (https://texreg.sos.state.tx.us/public/readtac$ext.TacPage?sl=R&app=9&p_dir=&p_rloc=&p_tloc=&p_ploc=&pg=1&p_tac=&ti=30&pt=1&ch=307&rl=7)

** As per Texas Administrative Code, Title 30, Part 1, Chapter 213, Edwards Aquifer (https://texreg.sos.state.tx.us/public/readtac$ext.ViewTAC?tac_view=4&ti=30&pt=1&ch=213)

Table 2. TCEQ Upper San Marcos River water quality criteria

	mg/L								CFU/100ml
Parameter	Chloride	Sulfate	TDS	DO	TSS	Nitrate-Nitrogen	Phosphorus	Oil and Grease	*E. coli*
Standard/ Screening level	50	50	400	6.0	2.0*	1.95	0.69	N/A	126

II. Integrated Report (305(b), 303(d) List)

Segment 1814 has previously been included in the 303d list of impaired waterbodies due to elevated TDS (Table 3). TDS was not directly measured, but was reported at 406.09 mg/L, based on the application of a standard correction factor of 0.65 times measured conductivity. This measurement was slightly above the stream standard of 400 mg/L. The Upper San Marcos River is not currently listed as impaired.

Table 3. Upper San Marcos River Segments included in 303(d) listing (TCEQ, 2012)

Assessment Units (Segment ID)	Segment Name	Description	Parameters	Category/First Year Listed
1814_01- Lower 1.5 mi of segment **1814_02- From sub-segment 01 to IH 35 E frontage rd.** **1814_03- From IH 35 E frontage rd. to Spring Lake Dam** **1814_04- Remainder of segment**	Upper San Marcos River	From a point 1.0 km (0.6 mi) upstream of the confluence of the Blanco River in Hays County to a point 0.7 km (0.4 mi) upstream of Loop 82 in San Marcos in Hays County	TDS	5c/2010

III. Total Dissolved Solids

TDS is described in the Texas Surface Water Quality Standards – Chapter 307 as: "The amount of material (inorganic salts and small amounts of organic material) dissolved in water and commonly expressed as a concentration in terms of milligrams per liter." Sources of TDS in freshwater include calcium, chlorides, nitrogen, phosphorus, iron, sulfur, and other ions. When dissolved into their ionic form, these solids will pass through a filter with pores of around two microns (0.002 cm) in size (USEPA, n.d. [a]). Background TDS levels for a specific area depends mainly on the solubility of rocks and soils the water contacts. For instance, water that flows through limestone and gypsum dissolves calcium, carbonate, and sulfate, resulting in high levels of TDS. Fluctuations in TDS could also indicate human-caused pollution. Discharges into a water body can change the conductivity depending on the effluent characteristics. A failing sewage system, for example, could raise the conductivity because of the presence of chloride, phosphate, and nitrogen (Texas Stream Team Water Quality Monitoring Manual: 2012).

High TDS concentrations can pose a threat to aquatic life in a freshwater environment by affecting the osmotic balance in aquatic organisms' cells (USEPA, n.d. [a]). Fish and macro-invertebrates can become dehydrated in water bodies with high TDS as water is released from their cells into the environment via osmosis. Elevated TDS concentrations in drinking water do not pose a direct health hazard, however, the hardness and saltiness of drinking water associated with TDS can give the water an unpleasant taste. The USEPA does not regulate TDS concentrations under the National Primary Drinking Water Regulations because TDS in drinking water is not considered to a risk to human health. However, TDS is listed under the Secondary Drinking Water Regulations, which are established as non-mandatory guidelines for managing drinking water aesthetics such as taste, color, and odor. The USEPA's secondary drinking water standard for TDS is 500 mg/L (USEPA, n.d. [a]).

Comparison of TDS and Conductivity Data

SMWI stakeholders addressed concerns and provided input regarding TDS in the Upper San Marcos River, namely that the derivation of the TDS values by converting specific conductivity may provide an inaccurate assessment of Upper San Marcos River water quality. The calcium and carbonate ions from this aquifer may naturally elevate the level of TDS in the water, and if so, the stakeholders would like to investigate if the current standard and conversion are appropriate for this particular water body. WPP activities will include an analysis of TDS constituents to determine the chemical composition. This will provide detailed information about the origins of the dissolved solids and if they are naturally occurring.

GBRA and the Meadows Center collected TDS and conductivity measurements to confirm the impairment and recommend a site-specific conversion factor that can be used to more accurately estimate the TDS in this segment of the river (GBRA, 2012). Direct TDS measured in a laboratory and conductivity measurements taken in the field were compared at six sites along the Upper San Marcos River. Figure 12 shows the variation between these methods. TDS measurements were taken at each site and measured in the laboratory, using a standard protocol (Standard Method2540C). Results for all six sites are well below the recommended 400 mg/L (blue bars). A conductivity meter (Standard Method 2510, nemi.gov/methods/method_summary/5702/) was used to collect conductivity at each of the six sites and each reading was at least 600 umhos/cm (dark red bars). The conductivity measurements were then converted to TDS using the standard conversion factor of 0.65, and the resulting TDS measurement for each site is higher than direct TDS measurement and is much closer to the 400 mg/L maximum (green bars). Higher TDS conversion results may have skewed the historical average of collected data towards maximum of 400 mg/L, leading to the listing of an impairment. The relationship between conductivity and TDS in the Upper San Marcos river appears to be closer to 0.55. It is suggested that the factor to convert conductivity to TDS should be studied further, and pending study results, data monitoring protocols should be altered accordingly.

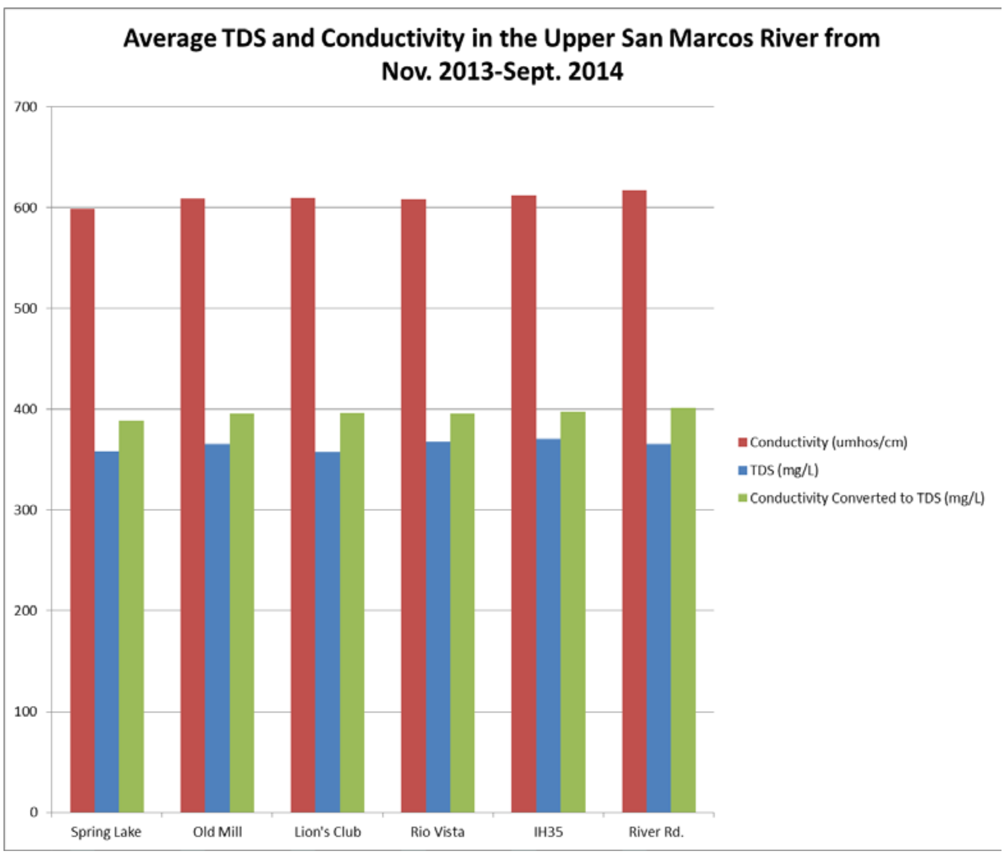

Figure 12. Comparison of average TDS and conductivity from data collected in 2013-2014

Groundwater and Stormwater Contributions to TDS

The San Marcos system has shown an inverse relationship between peak discharge from rain events and TDS, which indicates that rainfall runoff is low in TDS and spring water has higher concentrations of TDS. Figure 13 shows specific conductance data for a site monitored in the Slough Arm of Spring Lake. Discharge at the USGS San Marcos River site is also shown. Note that specific conductance changes are dominated by daily and storm events. Additionally, there is a general increase in specific conductivity during the summer months. This is likely from evaporative effects, which would result in increased concentrations of TDS (reduced total available water). Storm responses are characterized by significant decreases in conductance. Sudden spikes in discharge are related to runoff associated with storm events, while longer term increases in discharge are attributed to increases in groundwater discharge resulting from increased recharge in the Edwards Aquifer after single storm events or periods of rain (Nowlin and Schwartz, 2012).

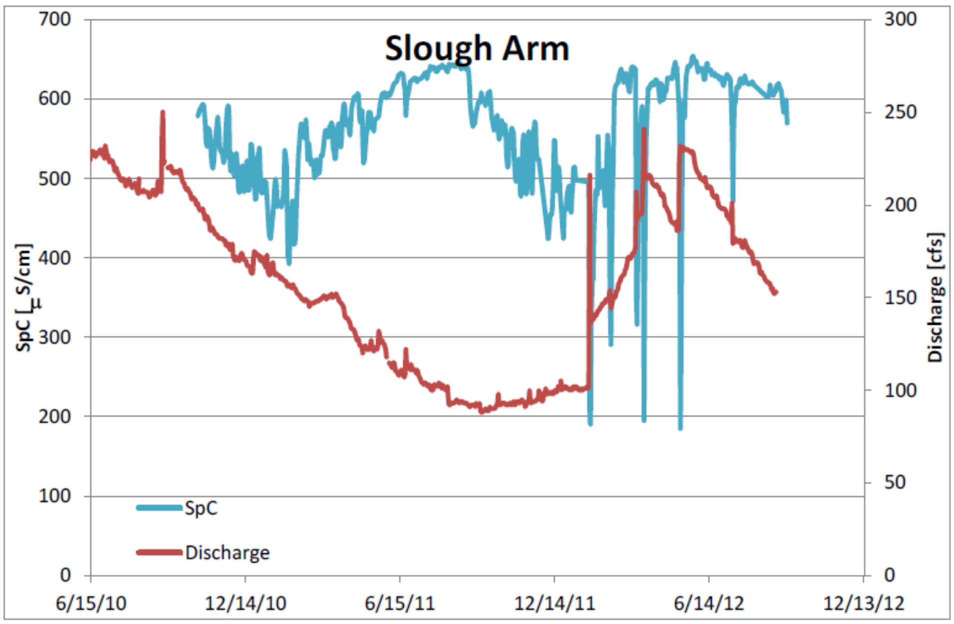

Figure 13. TDS (Specific conductance converted [SpC]) and discharge from 2010 - 2012 in the Slough Arm of Spring Lake

IV. Permitted Point Sources

Point source pollution is from a discrete, discernable source, such as effluent from a water treatment plant or concentrated animal feeding operation (USEPA, n.d. [b]). Discharge from a point source is permitted by TCEQ and is subject to standards set by section 502 (14) of the federal Clean Water Act. Each permit varies depending on the source; however, the permit holder must routinely monitor the amount and quality of their outflow. There are two point sources along the Upper San Marcos River (Figure 14): the San Marcos WWTP and the A.E. Wood State Fish Hatchery. These point sources are respectively located in Subbasins 32 and 33 downstream of Thompson's Island, and discharge into the main stem of the river between IH-35 and the confluence with the Blanco River, in the Willow Springs Creek subbasin (GBRA, 2012).

Wastewater Treatment Plant

The San Marcos WWTP adheres to strict water quality regulations and has been rated superior by the State of Texas. The wastewater treatment plant is owned by the City of San Marcos and operated by CH2MHill. Odor control improvements were completed in 2006, which reduced the odors emitted from the raw sewage by 99%. The treatment plant routinely monitors the effluent to ensure compliance of the permit effluent limits (Table 4).

Table 4. TCEQ WWTP permitted effluent limits

Parameter	Maximum	Monitored
Discharge	9.0 MGD	Daily
TSS	5.0 mg/L	Daily
DO	5.0 mg/L	Daily
Carbonaceous Biochemical Oxygen Demand (CBOD)	5.0 mg/L	Daily
Ammonia nitrogen (NH3-N)	2.0 mg/L	Daily
TP	1.0 mg/L	Daily

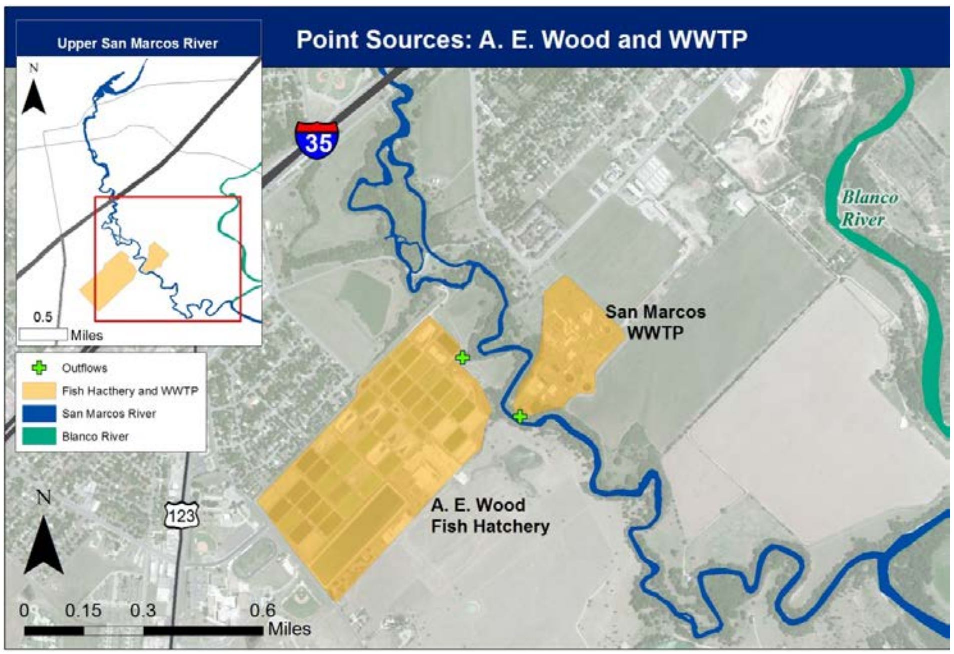

Figure 14. Point sources: A. E. Wood Fish Hatchery and San Marcos Waste Water Treatment Plant

A.E. Wood Fish Hatchery

The Texas Parks and Wildlife Fish Hatchery currently operates under a general concentrated aquatic animal production permit, TXG130005, granted by TCEQ. This permit requires a daily flow measurement, TSS monitoring once per month, DO monitoring once per week, and carbonaceous oxygen demand and ammonia level monitoring once per month. The effluent limits are listed in Table 5.

Parameter	Maximum	Monitored

Discharge	9 MGD	Daily
Total Suspended Solids (TSS)	90 mg/L	Once per Month
Dissolved Oxygen (DO)	5.0 mg/L	Once per Week
Carbonaceous Biochemical Oxygen Demand (CBOD)	250 lbs/day	Once per Month
Ammonia (NH3)	2.0 mg/L	Once per Month

Table 5. TCEQ A.E. Wood Fish Hatchery permitted effluent limits

The Meadows Center for Water and the Environment obtained discharge data for both point sources from January 1, 2009 to May 30, 2013. The WWTP daily records include measurements of discharge, TSS, ammonia, *E. coli*, biochemical oxygen demand, nitrate, turbidity, DO, and total phosphorous. Data for the A. E. Wood Fish Hatchery includes average monthly estimates of discharge and daily amounts of TSS. A point source function was created within HSPF to account for and calibrate the amount and type of inflow from these sources.

Demographics

I. Population Growth

According to 2010 census data, the population of Hays County was approximately 160,000, with nearly one third of that population residing in the City of San Marcos. The population of Hays County increased by 61% between 2000 and 2010 (USCB, 2014). During this same time interval, San Marcos grew from 34,700 persons in 2000 to nearly 45,000, a 29% increase in 10 years. These unprecedented growth rates in the Upper San Marcos watershed were larger than those for the state of Texas during the same time interval (20.6%) and far larger than growth rates for the United States (9.7%) (USCB, 2014).

By 2014, the populations in Hays County and San Marcos respectively, are estimated to have grown by 24,000 (17%) and 14,000 (31%) (USCB, 2016; You and Potter, 2016). Population growth projections for the next several decades forecast continued and increasing rates of growth in the region and the watershed. The population of Hays County is expected increase by approximately 400% over the next 50 years. Figure 15 shows an expected doubling of county and city population by 2050. Further, the population of the entire Edwards Aquifer region is expected to increase by 63%. Given this tremendous growth, land use demands within the Upper San Marcos River watershed will be greatly increased, and will likely be coupled with changes in impervious cover, stormwater patterns, and nonpoint source and point source pollution. Demands will also rise for Edwards Aquifer water resources (MCWE, 2012).

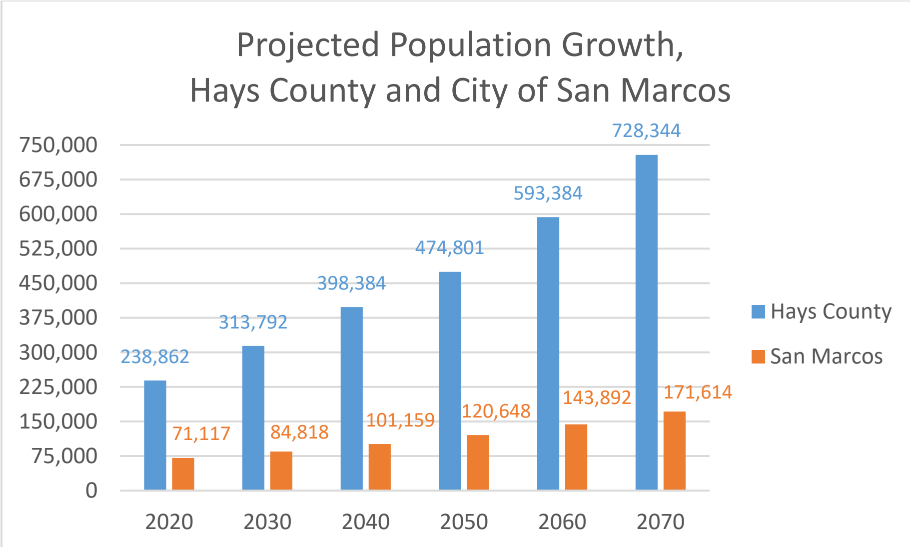

Figure 15. Projected population growth for primary county and city within the Upper San Marcos watershed (TWDB, 2016)

II. Watershed Demographics

Hays County has a reported 66% of total population above the age of 16 with 17.5% of county residents living below the poverty level. The mean owner-occupied housing rate between 2010 and 2014 was 65%, with approximately 59,400 households (USCB, 2016). Not surprising for a university town, 60% of San Marcos' population is above the age of 16 and more than 37% live below the poverty level, accounting for much of the total County population living below the poverty level. The mean owner-occupied housing rate between 2010 and 2014 was 27%, with just under 19,000 households (USCB, 2016). It is anticipated that as the population rises in the watershed and surrounding areas, the percentage of younger residents, poverty rates, and number of households will rise (You and Potter, 2016).

Watershed Land Use, Land Cover

I. Current Land Use and Land Cover

Land use in much of the watershed is dominated by rangeland and undeveloped land, with dense urbanization occurring in the southeastern portion of the watershed and some significant current and planned residential development in the far western portion of the watershed (Figure 16). The primary land use in the urbanized area in the eastern watershed (City of San Marcos) is residential, but there is also some commercial development and a small portion of industrial land uses in the southern section of the city. Development is spreading westward along established transportation routes.

Land cover in the watershed is primarily forest and grassland. In the southeastern portion of the watershed, there are dense transportation routes, buildings, parking lots, and driveways associated with urban development in the City of San Marcos (Figure 17). These types of impervious cover can intensify and exacerbate the contributions of nonpoint source pollution. Figure 18 shows that urban land uses/land cover have the highest contribution of impervious cover and are located primarily in the southeastern portion of the watershed.

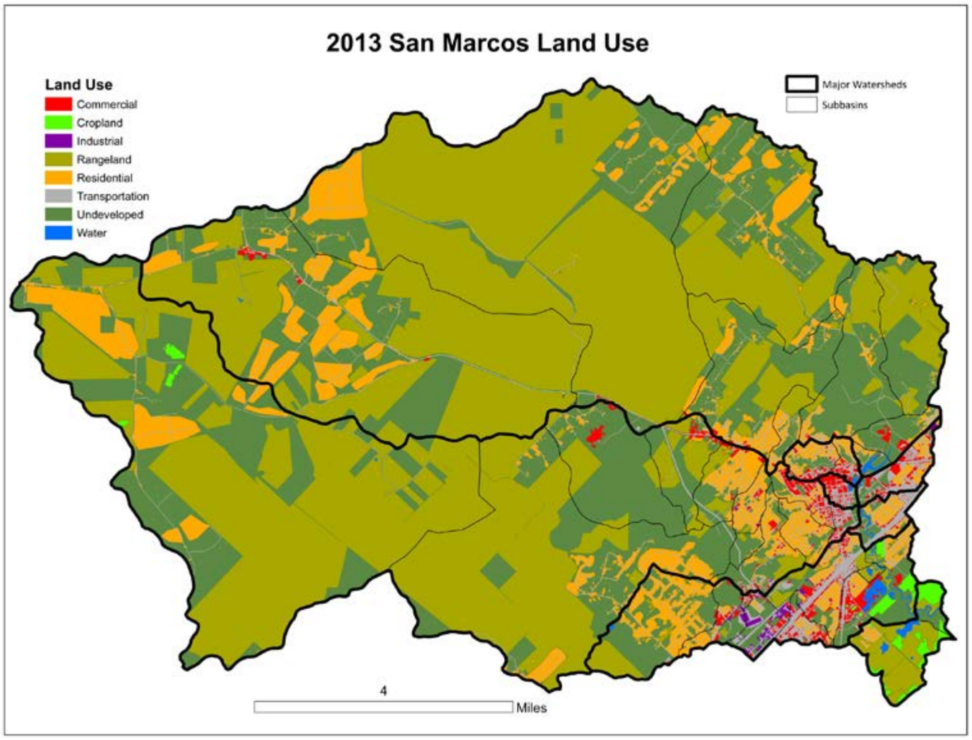

Figure 16. Existing/current watershed land use (TPWD 2009, COSM 2013 data)

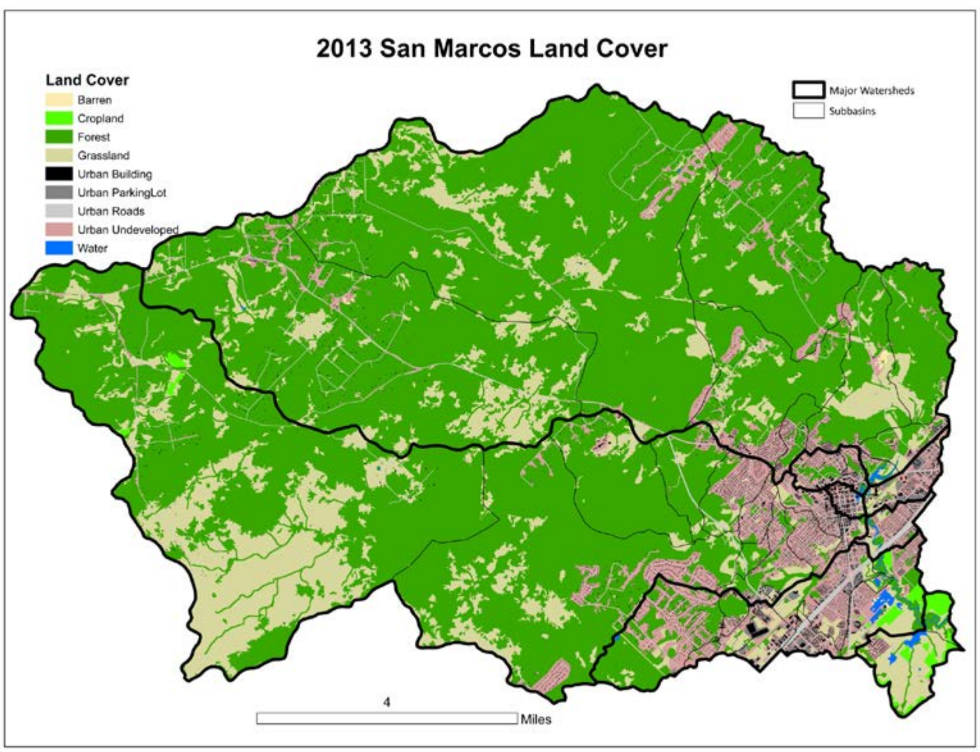

Figure 17. Existing/current watershed land cover (TPWD 2009, COSM 2013 data)

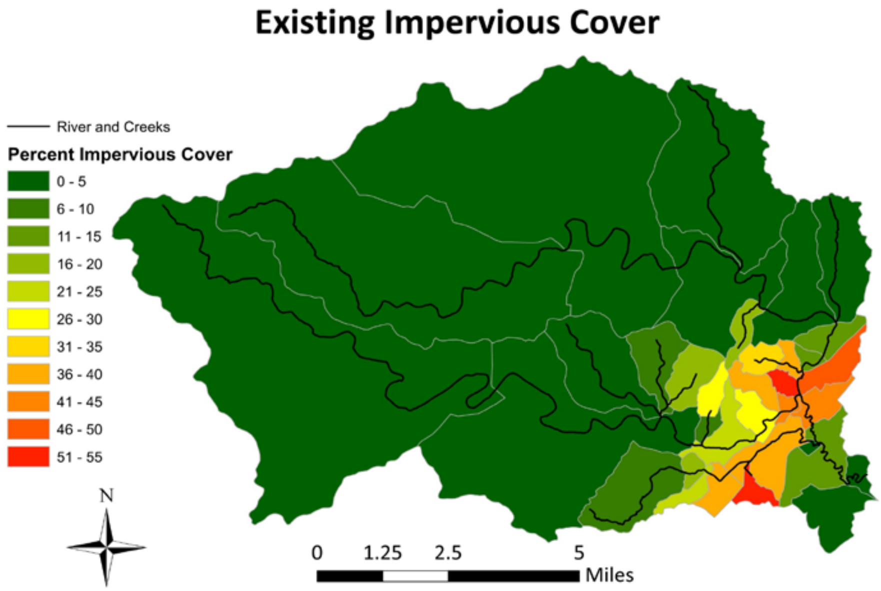

Figure 18. Modeled current/existing impervious cover *CITE DATA*

II. Future Land Use and Land Cover

Development in the Upper San Marcos watershed is expected to increase, converting from traditionally low-impact land uses to more intense urban developments (Nowlin and Scwartz, 2012). Predicted future land cover and land use was developed to allow modeling and estimation of future pollutant loads in the watershed. This future growth scenario is a combination of the City of San Marcos preferred development scenario and the development trend scenario for the year 2035. The preferred scenario was developed in 2013, during a Comprehensive Master Planning process at the City of San Marcos. The trend scenario is derived from current growth projected out if it were to continue on its established trajectory (currently platted/permitted lands that have not yet been developed).

Land use and land cover associated with this combined expected future development are shown in Figure 19 and Figure 21. Residential and commercial land uses are predicted to increase by a combined 5% between 2013 and 2035. Small decreases are also predicted in crop land, undeveloped land and rangeland (Figure 20). These land use and land cover changes will be coupled with increases in impervious cover.

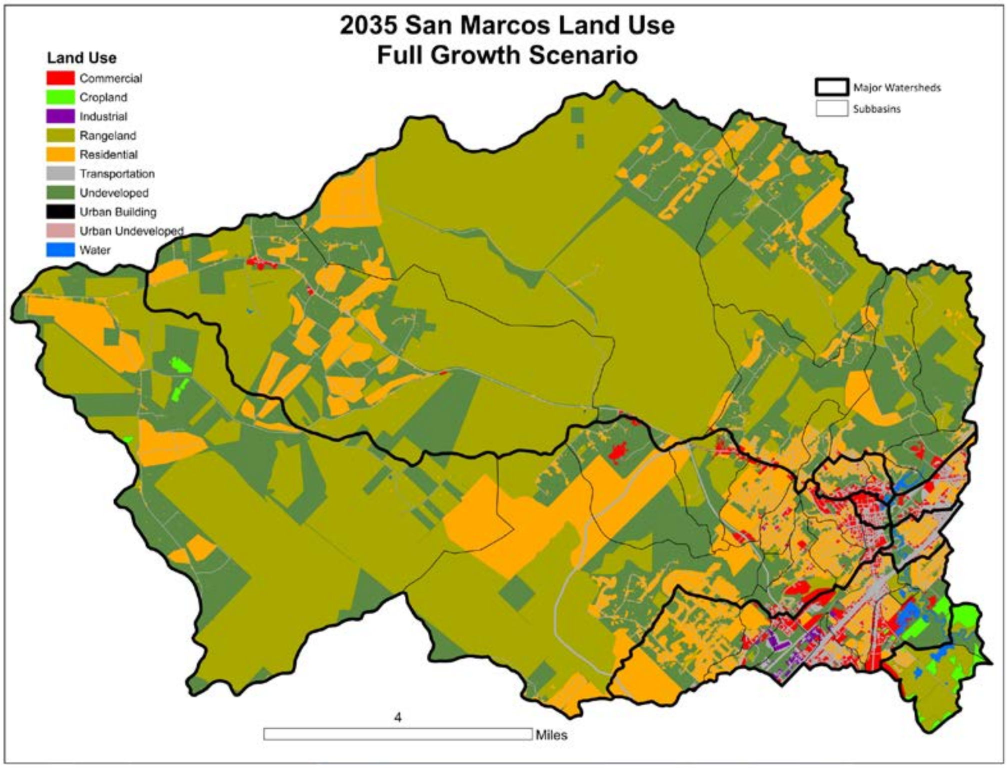

Figure 19. Future watershed land use using City of San Marcos preferred development scenario and the development trend scenario

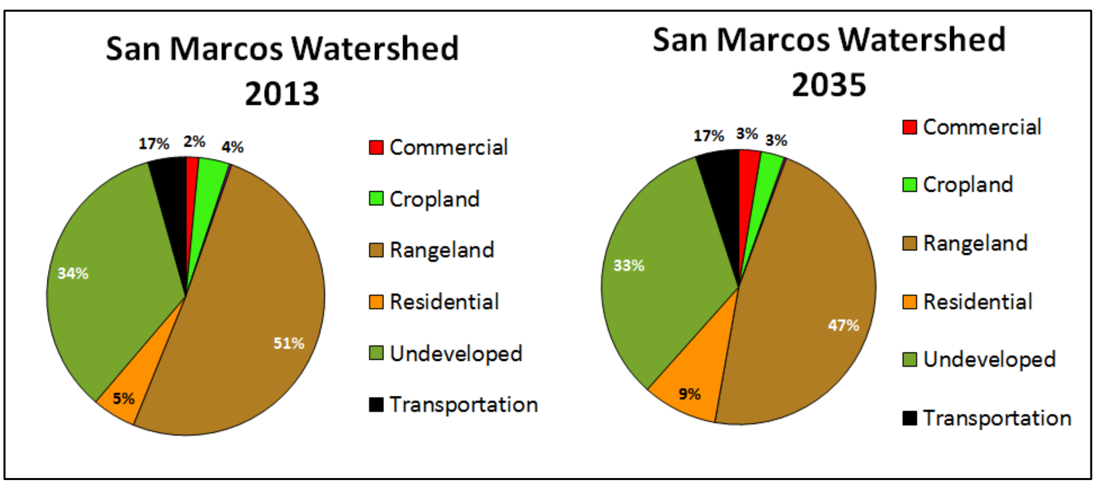

Figure 20. Percentages of land use in existing (2013) and full (2035) development scenarios

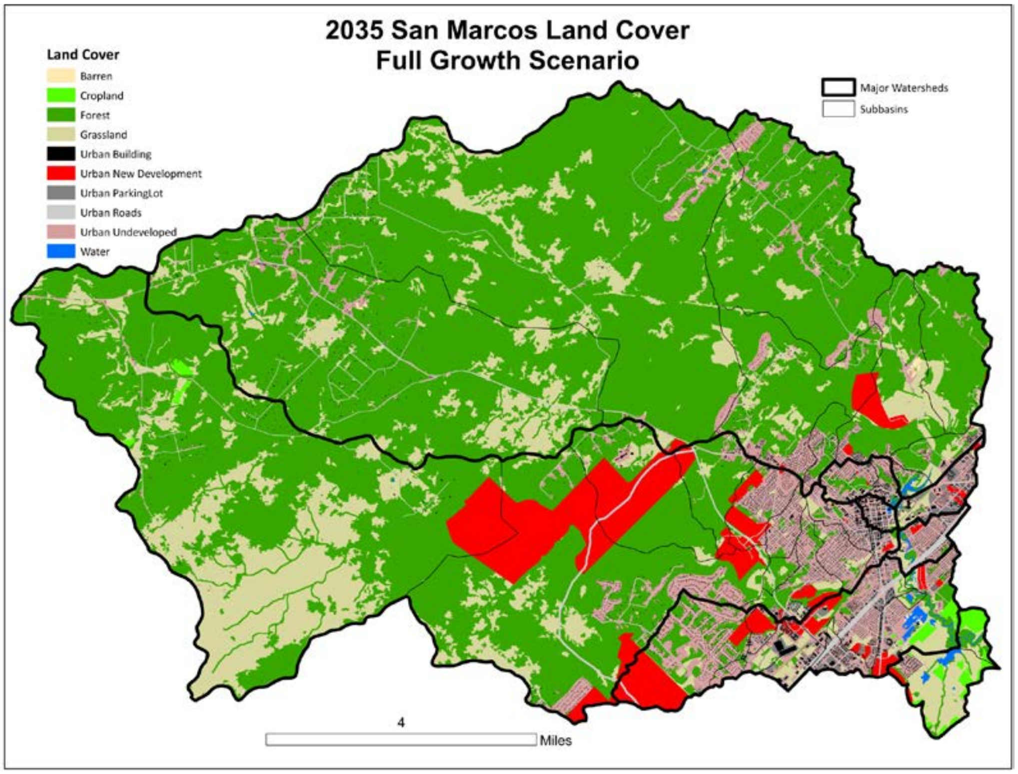

Figure 21. Future watershed land cover using City of San Marcos preferred development scenario and the development trend scenario