THE SAN MARCOS RIVER, A COMMUNITY RIVER:

THREATS, IMPACTS, AND STRATEGIES

HONORS THESIS

Presented to the Honors Committee of
Texas State University-San Marcos
in Partial Fulfillment
of the Requirements

for Graduation in the Honors College

by

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San Marcos, Texas
December 2014

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Acknowledgments

This had to be the most intimidating and daunting task of my undergraduate career. However, now that I am at the end of it looking back writing this undergraduate thesis was completely worth all the struggles, hard work, and time. I learned a lot while endeavoring to complete this project. I gained a lot of confidence and experience that I hope to carry over into my graduate career next semester as I take on working on a graduate thesis.

The completion of this project could not have been possible without my advisor, Dr. Lopes, thank you for your commitment, patience, and guidance. Dr. Le Duc, my second reader, was a tremendous help as well. I would also like to give a big thanks to Cindy Zinkgraf for giving me an upper hand in networking for all my interviews. I would also like to thank all my interviewees for participating and all the wonderful feedback you gave me, I could not have completed this task without your wonderful input.

A big thanks to the Honors College Texas State University—San Marcos for giving me the opportunity to complete such a feat and for all the wonderful classes over the past couple of years. The Honors College has really allowed me to become a well-rounded citizen, the courses being unique, diverse, and allowing self-expression in every facet of the classroom. As for Texas State University as a whole thank you for all the knowledge, experiences, and education for the past four and a half years. These have been the best years of my life.

I have to give thanks to all my wonderful friends for being the background support as well for they were the ones who dealt with me as I struggled and pushed forward through this entire project. To my beautiful family especially my mother Claudia

Nava, my father Albert Nava, my two siblings Zachary Sanchez and Ryan Nava, and my grandmother “Mamo”, you all have been my greatest inspiration and motivation. I would not be where I am without you nor could I have completed this without your love and support.

Finally, the last person I would like to thank is my father Antonio Sanchez who passed away thirteen years ago…Thank you for believing in me. Your memory has been with me in every moment and experience driving me to do better and to be better. I love you.

I am indebted to everyone especially God, who helped me throughout this entire process no matter how small or big the help was. I could not have completed without their help.

Chapter I

Introduction

Human beings today are faced with a plethora of environmental issues. Loss of biodiversity, increased air and water pollution, at the same time there is a growing demand for natural resources and global climate change are just a few examples of the environmental issues that we face. There are a variety of human activities that contribute to the cause of habitat loss (Czech et al. 2000), local extinction rates, frequent elimination of the large numbers of native species, and overall degradation of the natural environment (Vale and Vale 1976; Luniak 1994; Kowarik 1995; Marzluff 2001). However, urban development has been found to be one of the strongest forces.

Over 80% of the world's population is exposed to high levels of threat to water security (Vorosmarty et. al. 2010; Malmqvist and Rundle 2002). In the next 25 years this threat is expected to spread even as larger human population rises from 2 billion to 8 billion people (United Nations 1998; Malmqvist and Rundle 2002). River systems have been the center for human settlement resulting in water exploitation, human consumption, irrigation, electricity generation, and waste disposal. Rivers are intricate systems, with their services and goods making them the most impacted ecosystems on the planet.

The human pressure on natural systems especially the delicate freshwater ecosystems has to have a strong negative ecological effect at local and regional scales that will spread to the global scale. Many of these effects will be irreversible and many species will become extinct because of habitat destruction within the system and competition from introduced species (Malmqvist and Rundle 2002). Currently 1.8 billion people currently live under a high degree of water stress with estimated population increases by 2025 this stress will escalate and as a result the pressure on water resources will increase (Vorosmarty et al. 2000; Malmqvist and Rundle 2002).

The force of urban development poses a threat to the state of ecosystems by its growing geographical extent (Benfield et al. 1999). As urban development extends itself species of the area will have added threats from agriculture, recreation, roads, and many other human impacts (McKinney 2004). The comparison of undisturbed landscape ecosystems to human dominated landscape ecosystems has been a useful indicator of the detrimental state urbanization is taking on river systems (Meyer and Turner 1994; Allan 2004). Rivers are the main source of renewable water supply for humans and freshwater ecosystems (Vorosmarty et al 2010). It has been found that river ecosystems are strongly influenced by their surroundings at multiple levels (Allan et al. 1997, Fausch et al. 2002, Schlosser 1991, Townsend et al. 2003). The landscape rivers flow through play a great influential role on their state or the state of their ecosystems (Hynes 1975, Vannote et al. 1980).

The San Marcos River is a prime example of a river ecosystem that is strongly influenced by its surrounding landscape. It has a unique ecosystem with unique characteristics that have attracted many people and animals over the years providing various essential resources, allowing a thriving healthy life. In recent time the area has experienced increasing urbanization and development. As Allan (2004) pointed out in his study, river and stream ecosystems are strongly affected by human actions across spatial scales, it is important to realize that anthropogenic forces have strong affects on their surroundings. In order to maintain the health of the river, sustainable and conservative strategies must be implemented in order to cope with and prevent the potential impacts caused by the growth and development of San Marcos. This issue is especially important now that the city of San Marcos' growth rate has reached an all time high deeming it 'The Fastest Growing City in the Nation' as cited in an article 'Growing Pains in America's Fastest Growing City of San Marcos' (Heinrich, 2013).

With this alarming projection coupled with evidence showing that the extent of change in river health can be anticipated from the relationship between future population growth and development (Baker et al. 2004), it is important to study and observe the effects and potential impacts of urbanization on the San Marcos River and its fragile natural environment. This study will:

- Identify the past and present connection between the community and San Marcos River.
- Address potential threats and impacts that the river faces.
- Introduce Community based strategies to cope with these threats and their potential impacts.

The overall purpose of the study is to understand the significant connection between the river and the community of San Marcos. From this understanding this study will address the strategies and greater community and engagement efforts needed to cope with these threats and potential impact, to decrease the effect of urbanization and conserve the San Marcos River for future generations to come.

Chapter II

Historical Relationship of the San Marcos River and Community

Few people realize as they travel Interstate 35 between San Antonio and Waco that the reason the road is following a particular path is because it is following an ancient path, a trail of springs. San Marcos is one of the oldest inhabited areas in North America. The springs have seen Mastodons die on its banks and Native tribes of North America rise and fall (some believing they were born of the springs themselves). It has seen Spanish explorers seeking the fountain of youth and modern man build dams, roads and bridges. It has been a very old witness to the birth of the current city of San Marcos Texas and the growth of Texas State University.

About 12,000 years ago a clan of Native Americans, the earliest culture of the Paleo-Indians, had traveled for weeks exhausted, hot, and hungry. However, the air became suddenly cooler and a faint scent of water touched their noses. As they walked futher it grew stronger until they happened upon a clear broad shallow pool with water gushing from the surface as high as a grown man. All around them was an abundance of vegetation and animals to consume. They had found a resource that provided an abundance of food and water. Native Americans were the first people to make a

connection with the San Marcos River. 12,000 years later their Clovis points (Figure 1) have been found at the bottom of Spring Lake, a reminder of their existence and discovery of the San Marcos Springs (Bourgeois et al 1996).

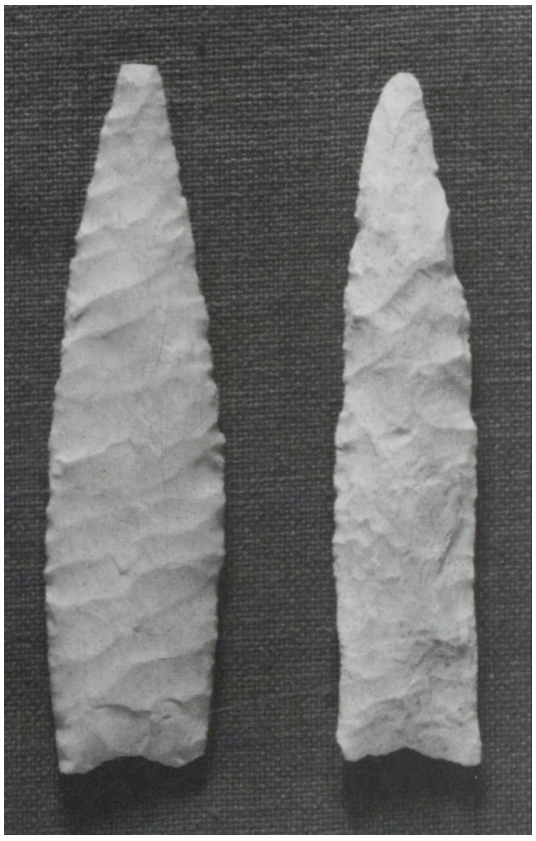


Figure 1. Clovis points found at the bottom of the river.

Most of the Native Americans that came, during the Paleo-Indian period (11,500-8800 B.P.), were nomadic bands of twenty-five to fifty people that moved frequently with their food supply (Willey 1966). With sophisticated spears they preyed on the mega fauna of that time such as herds of mammoths, bison, and mastodons. However, toward the end of this period they started to hunt animals such as turtles, badgers, raccoons, mice, and large herbivores such as deer (Collins 1995; Oksanen and Leezer 2005). Their presence at the

San Marcos Springs was not a permanent one, since they moved with their food source. For the Native Americans life was more fragile, there were huge predatory animals such as huge lions and Dire wolves that were very aggressive. Life for these people was hard, dangerous, and short.

Following the Paleo-Indian period in the early archaic (8800-6000 B.P.), there was a distinct climate change that resulted in higher temperatures and a drought that lasted for about 2,000 years. The larger animals like the bison, mammoths, and mastodons that the Indians had depended on went extinct and caused a shift in their diet towards deer, fish, rodents, rabbits, and plants (Story 1985, Weir 1976; Oksanen and Leezer 2005).

In the middle archaic period (6000-400 B.P.) as cited by Collins (1995), the drought and limited food supply continued, creating further change for the people, animals, and environment. The people were more dependent on plants for nourishment during this time. With the bison gone, the Native Americans developed a growing depedence on resource rich environments fed by natural springs arising along the Balcones Escarpment fault zone. This greatly influenced the Native Americans migration into central Texas (Okasen and Leezer 2005). This migration is reflected by an increase in the number of camp sites with burned rock middens left across central Texas (Weir 1976).

In the late archaic period between 4000-1250 B.P. as cited by Collin (1995), the Natives began their technological advancements of weapons (Yelacic and Lohse 2010). The drought and warmer climate conditions improved during this time and the bison returned (Oksanen and Leezer 2005).

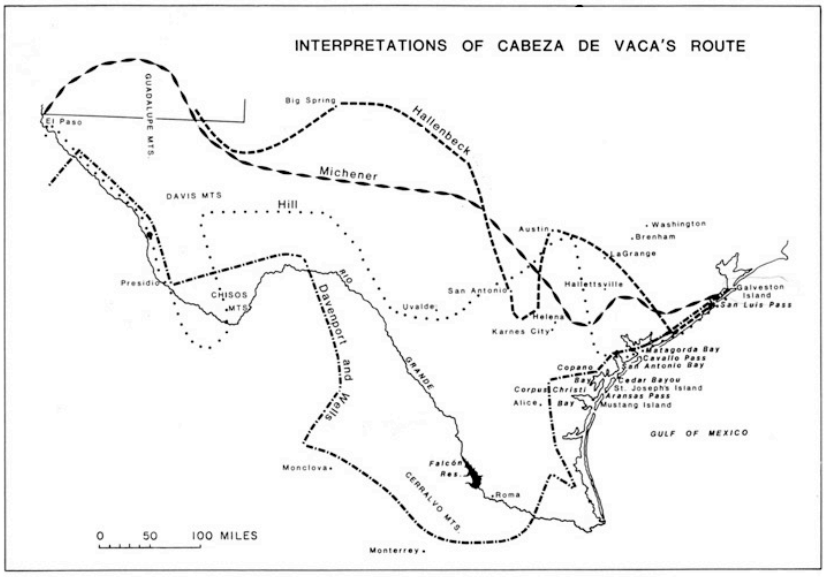
The late Pre-historic era 1250-260 B.P. (Collins 1995; Oksanen and Leezer 2005; Yelacic and Lohse 2010) is marked by the utilizaiton of the bow and arrow and the making of ceramics (Story 1985; Yelacic and Lohse 2010: 7). The making of ceramics was a pivotal move forward for them. They could gather more efficiently and cook with the pots and it was especially revolutionary for gathering water (Kimmel 2006).

For these aformentioned time periods the change that the San Marcos River experienced due to human activity was slow, taking place over many generations. It was in the 1500s that Europeans arrived and became a stronger influence of change in the region (Oksanen and Leezer 2005). The Indians of the springs were no longer nomadic but had established villages and traded. The river supplied them with many goods and services providing the opportunity to settle. Among their villages and trade they told of stories of men on "huge canoes with white cloudy wings". They wore shiny clothes that seemed invincible to their arrows and rode atop wild beasts and brought death. This marked a new chapter for the San Marcos River (Kimmel 2006).

The Spanish famous for their expeditions and conquest of the new world can even included the San Marcos in their writings. In 1528 the Spaniard Cabeza de Vaca shipwrecked near Galveston, Texas (Figure 2) (Covey 1961; Kimmel 2006; Oksanen and Leezer 2005:6; Yelacic and Lohse 2010). He and his men wandered and traded through much of South Texas before making their way back to Mexico City in 1536 leaving death in their wake. In their travels through South Texas half of the native population perished

of stomach illness, which was brought by Cabeza de Vaca, changing the relative stability of the past 12,000 years at an unprecedented rate (Figure 3).

Figure 2. 1528 Spaniard Cabeza de Vaca shipwrecked near Galveston, Texas



Four interpretations of Cabeza de Vaca's route across Texas and Mexico.

Figure 3. The Four Interpretations of Cabeza de Vaca's routes across Texas and Mexico.

After Cabeza de Vaca, the region was not visited for another 100 years (Oksanen and Leezer 2005). It was not until the late 1600s and 1700s with the arrival of Alonso de Leon's expedition and establishment of the El Camino Real that the Spanish came through central Texas with plans of establishing Spanish missions and forts (Oksanen and Leezer 2005; Yelacic and Lohse 2010). It was the Spanish who first recorded the native groups that camped near San Marcos Springs. Later groups such as the Tonkawa from Oklahoma and Lipan Apache, and the Comanche from the Plains would replace the former groups through warfare, disease, and settlement at missions (Dunn 1911; Campbell and Campbell 1985; Newcombe 1961, 1963; Oksanen and Leezer 2005; Yelacic and Lohse 2010).

It was around A.D. 1755 that the San Xavier mission and presidio were established on the banks of the San Marcos River (Oksanen and Leezer 2005; Bourgeois et al 1996). At this time, the Europeans while exploring and trying to colonize the river saw much conflict between the Tonkawa, Apache, Comanche, and the Spaniards, as they all grappled for the unique safe haven of the San Marcos Springs making settlement difficult (Dobie 1932; Oksanen and Leezer 2005; Kimmel 2006).

The many people who stopped at the springs were not just hunters, raiders, or colonizers but were also traders. The natives were interested in the Spanish for three reasons. Their livestock and possessions were easy prey. Second, the Spanish in Texas gave gifts to maintain the support of cooperative tribes. Third, the Spanish were potential powerful allies against enemy tribes (Kimmel 2006; Bourgeois et al 1996). This created constant

shifting promises of allegiance between the Spanish and the various tribes. For a brief period in 1808 San Marcos de Neve, the first Spanish settlement was established. However, it was quickly abandoned in 1812 due to the constant hostilities of raids among the local tribes (Kimmel 2006; Bourgeois et al 1996; Oksanen and Leezer 2005; Yelacic and Lohse 2010). The 1840 battle of Plum Creek would mark the last Comanche effort to raid the settlers of central Texas and the beginning of the collapse of Indian cultural groups in the area (Bourgeois et al 1996).

In 1836 the Texas Revolution was won and a republic established. For the first time white people began to settle the land including the San Marcos River (Yelacic and Lohse 2010). In the late 1840's Post San Marcos was established at the San Marcos Springs and a road was built from San Marcos to Austin (Stoval et al 1986). The fort was actually only occupied from October 1840 to March 1841. However its location, at the junction of the old road to Bastrop and the new road to Austin, was perfect for a town to serve travelers. In 1845 the first Anglo settlers came to the present San Marcos and surrounding area, which would later become Hays County.

In June 1846, German geologist Dr. Ferdinand Roemer stopped by the San Marcos River, as he traveled from Austin to New Braunfels. At the time he didn't see the area's potential as a suitable place for settlement. Instead he observed:

"Unfortunately the broad fertile bottom of the San Marcos River will never be suitable for agriculture since it is subject to inundation. While riding through it we noticed with

astonishment dry cane and limbs hanging fifteen to twenty feet high above the ground from the trees, which the spring floods had left there(Kimmel, 2006 Pg 52-53)."

On his second visit to San Marcos a month later, he found a company of mounted rangers stationed there and several families with large wagons that had come to establish a new settlement. His previous outlook on the San Marcos area as a potential settlement changed:

"In fact, a more advantageous and pleasant place for a settlement could not be imagined than this parklike little praire, surrounded on one side by the forest fringing the San Marcos and on the other by the steep hills, the beginning of the higher hill country (Kimmel, 2006 Pg 54)."

In 1847, the first post office was opened and by 1848 stage coaches were going from San Antonio, through San Marcos to Austin. The town became a shipping terminal for agricultural products headed to the coast. The Moons, Merrimans, Lindseys, Sessoms, and Burelsons were among the first families to settle (Figure 4) (Stoval et al 1986; Hoffman 2003). Moon was a farmer and blacksmith from Alabama, Merriam a doctor from Connecticut, and Mike Sessom a blacksmith from Tennessee (Hoffman 2003). General Burelson was the first to take advantage and exploit the resource of the San Marcos River. In 1849, he built a dam just below the springs at the head of the San Marcos River (Figure 5). This transformed the headwater springs from its natural state as a spring-fed marsh with geysers to a deeper clear water lake. In 1958 J. de Cordova would describe this feature as:

"The water power afforded by the Saint Mark's River is not only extensive but susceptible of application with little trouble or expense, and is destined to perform far more important service than it is doing now, -- the driving of a single saw and grist mill (Stoval et al 1986 Pg 71)."

How almost prophetic J. de Cordova's words would be as San Marcos began to grow.

Figure 4. Burleson's Homestead when he first settled

Figure 5. The San Marcos River in its natural state.

It was the “headwaters” of this newly created deep clear water lake that would become of great importance. The headwaters were about 8 to 12 feet and provided power before internal combustion engines and electricity were created. The utilization of springs of the San Marcos River had become an essential power source (Figure 6). In 1851 it became official that San Marcos was the county seat of Hays County, 640 acres were obtained and the town was laid out (Bourgeois et. al 1996; Stoval et. al 1986).

Figure 6. View of the San Marcos River at the Power House in 1921. The power plant was located at Burleson's dam, where the Salt grass Steakhouse is today.

The area at this time was a subsistence oriented and rural agricultural society. Corn was the main crop planted and cattle raising the chief economic activity (Stoval et. al 1986). At this time Burelson’s dam utilized a water fall to turn waterwheels to power a gritsmill, sawmill, cotton gin, and cotton press contributing to the growth of the city. In 1884 the springs’ flow gave power for the ice factory and electric generating plant on the east side

of the river providing ice and electricity for the city. The San Marcos River had become a workhorse and force in the development of the San Marcos settlement.

In 1893, San Marcos was selected by the U.S. government to host the first fish hatchery west of the Mississippi River (Bourgeois et al 1996). The ponds and office were placed on the west bank of the river as seen in Figure 7. Today however they serve as an aesthetic feature for Texas State University.

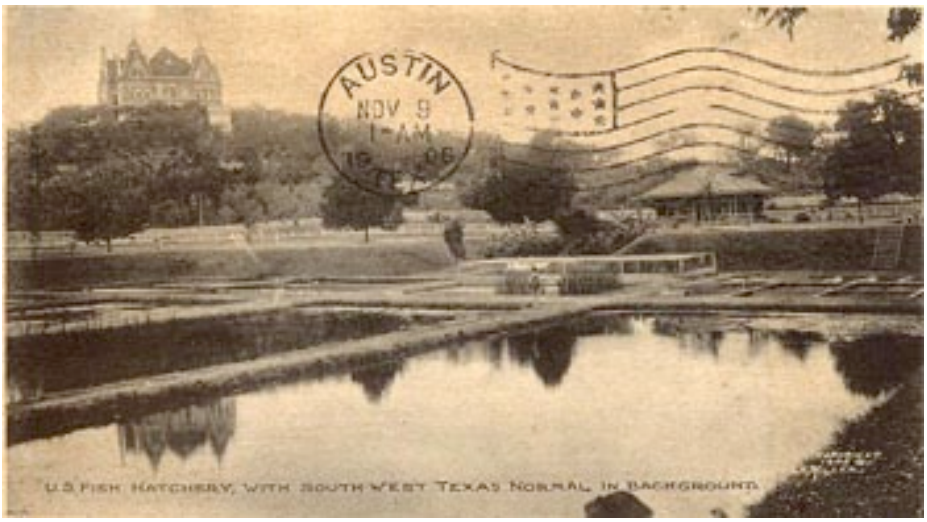


Figure 7. Ponds and Office of the first Fish Hatchery in San Marcos

In 1895 attitudes toward the river began to change and a law was passed by the twenty fourth Texas Legislature to take these changes into accordance: An Act to Encourage Irrigation and to Provide for the Acquisition of the Right to Use of Water, and for the Construction and Maintenance of Canals, Ditches, Flumes, Dams, Reservoirs, and Wells for Irrigation and for Mining and Milling and the Construction of Water Works for Cities and Towns and Stock Raising. This law required a description and map of all water

diversions from the river. In the Hays County Irrigation Records there were a total of six dams or other diversions in the first one and three-fourths miles of the San Marcos River. The people of San Marcos at this time were taking serious advantage of the water resource and putting it to work expanding the growth of its city.

A lot of water was pumped out of the lake for use in irrigation of a variety of vegetables and fruit along with agricultural stock raising. The San Marcos Water Company owned by Eugene and Ed J.L. Green, pumped large amounts of water from the river to support the growing city of San Marcos (Stoval et. al 1986). However, by 1927 the river's flow would be insufficient for the demands of electricity and diesel engines were installed to accommodate the increasing energy demand of the growing city (Kimmel, 2006).

In 1899 establishment of what is now known as Texas State University was approved by state officials and community leaders giving it the name Southwest Texas State Normal School on Chautaugua Hill just west of the river (Bourgeois et al 1996) (Figure 8) . It opened its doors in 1903 with great effort from both city and state.

By 1918 the school gained enough academic success to promote it to college status. In 1922 the school became Southwest Texas State Teachers College. In 1940 the school was expanded to include twenty five classrooms, dormitories, administration building, and recreational facilities at Sewell Park and Rio Vista (Figure 9) (Bourgeois et al 1996).

Like today many students flocked to the river. In 1917 J.A. Clayton the general yardman at the college used a mud scraper and mule teams on each side of the channel to develop

a swimming pool for the growing student body. This pool, which was once scraped out is now concrete based. It is still enjoyed by the students of today (Figure 10).

Figure 8. Southwest Texas State Normal School on Chautaqua Hill

Figure 9. Rio Vista Park still exists at the corner of Cheatham Street and CM Allen Parkway. On its 14 acres it offers a city swimming pool, tennis and basketball courts, picnic facilities, and a pavilion.

Figure 10. One of the pools previously made by J.A. Clayton connecting Sewell Park to Rio Vista.

In 1897 A.B Rogers, an entrepreneur, came to the city of San Marcos and would leave a signigicant mark on the San Marcos River. It began when he establish a truck garden beside the San Marcos River and then later converted it into Rogers park, which is the current site of Rio Vista (Figure 9 and 10). However, his lasting mark came March 12, 1926 when he purchased 125 acres of land from the San Marcos' utilities company which included the head of the river (Weber 2009). He decided that this would become a place of entertainment.

Figure 11. The Headwaters of the San Marcos River and its natural growth

A huge motor boat was built to clear growth out of the headwaters of the river and eventually that part of the river and its banks were made into a bathing pool and beach with walkways for pedestrians (Figure 11).

In April 22, 1929 the Spring Lake Park Hotel (Figure 12) overlooking the headwaters of the San Marcos River was opened (Weber 2009; Kimmel 2006). The opening of the hotel was celebrated with a plethora of events such as a gala, a golf tournament, a band concert, dinner, and a rooftop dance. The early years of the depression did not suit the hotel's business well. Dances continued to be held on the rooftop until the guests fell witness to an argument and murder. Following this incident Rogers leased the hotel for other uses.

Figure 12. Spring Lake Park Hotel built by A. B. Rogers.

The 1930's and World War II were a quiet and slow period for the river. Gary Field a training site for the Army Air Corps navigators was hosted in San Marcos (Bourgeois et al 1996). The river however was declared off limits because the city's old waste water treatment plant had caused a great amount of pollution in the water.

After WWII in May 1946, the San Marcos River began to jump back to life with the community. A.B. Rogers's son Paul Rogers built a fishing pier on the river and began to envision a way of giving visitors new ways of enoying and connecting to the river. A.B. Rogers would come to transform the San Marcos River into a tourist attraction nobody had ever dreamed of.

In 1949 Paul Rogers bought the land from his parents and founded Aquarena Springs, which became a popular tourist attraction and resort. In 1950 Paul Roger influenced by glass boats seen on Catalina Island, California, built his own glass bottom boats and announced to the people that they could enjoy a boat ride that would provide a new perspective of Spring Lake (Weber 2009; Kimmel 2006). The glass bottom boat rides were a big attraciton, allowing people to peer through the depths of Spring Lake's clear water, see the springs and the varied life beneath it (Weber 2009).

In October 1950 in the depths of Spring Lake became the site of to the World's only underwater submarine theatre (Weber 2009; Kimmel 2006). It took 50 tons of steel and 20 tons of concrete and much disruption and alteration of the rivers natural state to complete the structure (Figure 13).

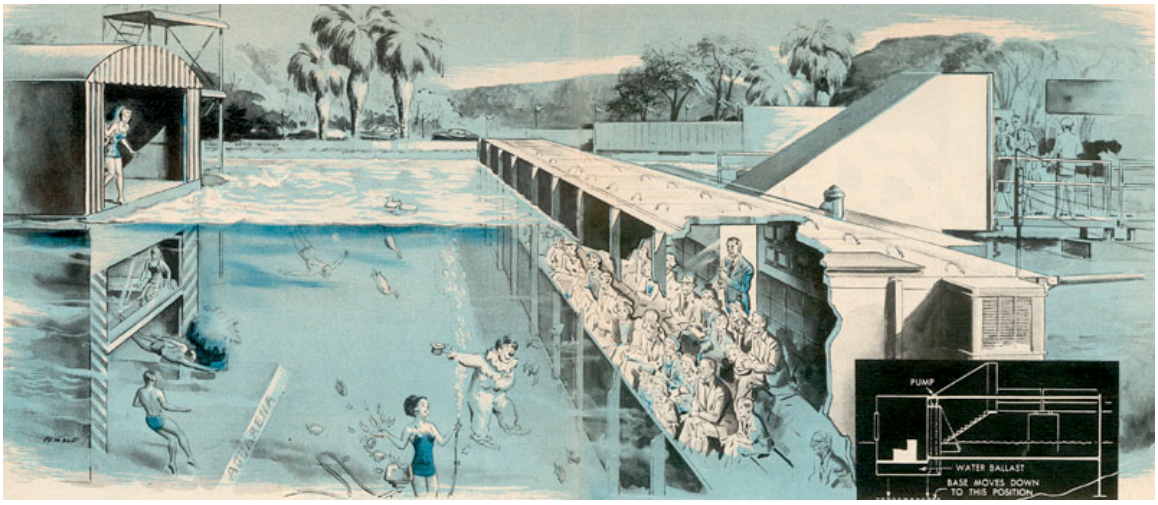


Figure 13. Aquarena's Underwater Submarine

Aquarena Springs brought considerable entertainment along with some educational awareness of the river (Figure 14 and 15). Hour long programs with swimming

mermaids, a variety of underwater routines, trained California sea lions, and even Ralph the famous swimming pig, could be enjoyed (Figure 16-19).

Figure 14. Depicts some of the advertisements for the Park

Figure 15. A.B. Rogers and Associates

ıre 17. (Right) The Ad ıs of nermaid programs at the park

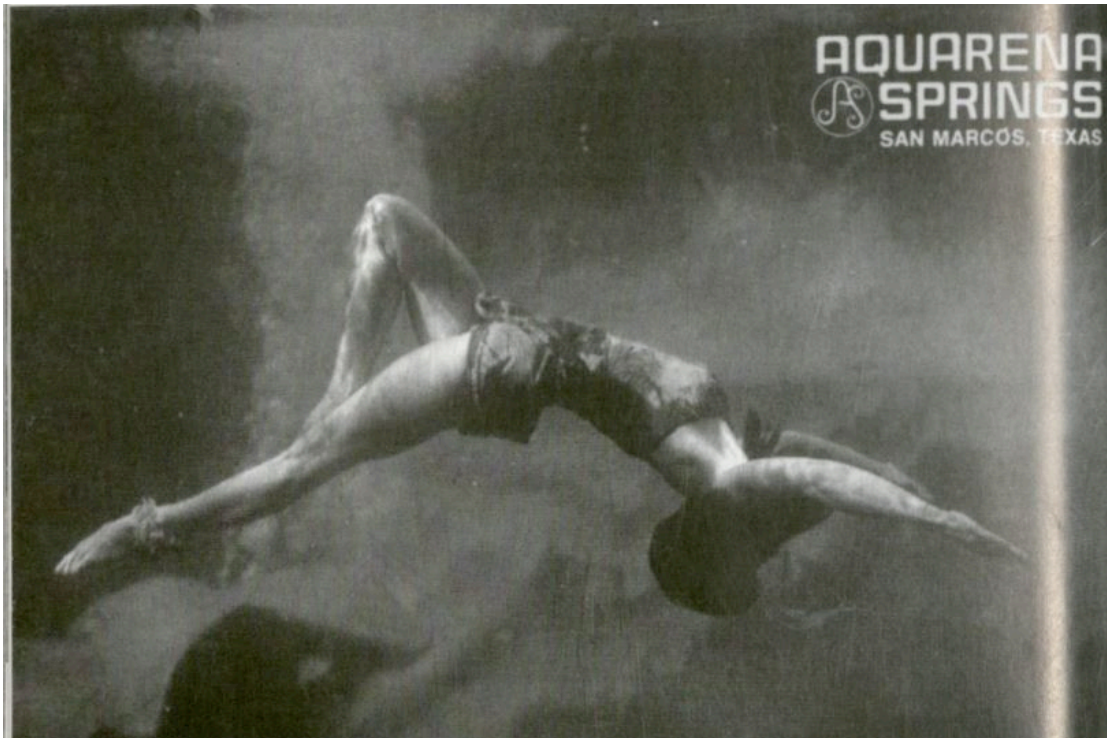
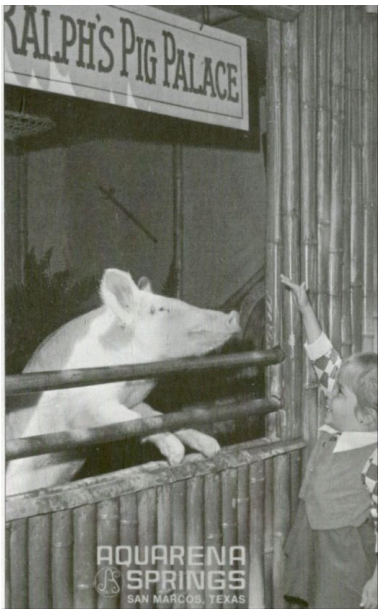


Figure 18. One of the many young ladies who performed many water acts.

Figure 19. Two young aquamaids performing a water skit

Raulph was a national celebrity appearing on a CBS program in 1967, but most of all he was loved and treasured by the people of San Marcos. Aquarena was a treasure for the people of San Marcos where they could visit the attractions and enjoy the grounds and river for very little money (Figure 20 and 21).



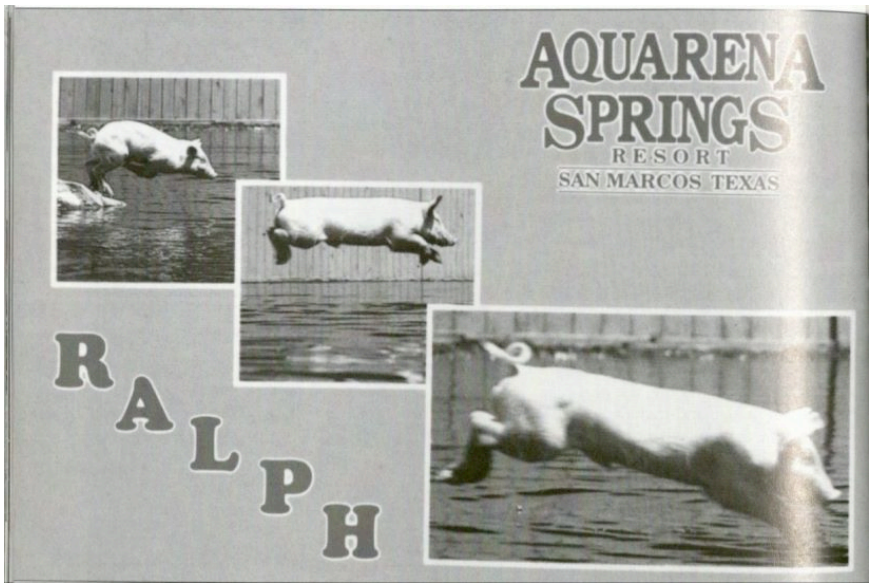


Figure 20 & 21. Ralph the swimming pig was a famous and beloved attraction to the people of San Marcos.

Aquarena was even a source of romance. In 1954 it was the site of the wedding between clown Bob Smith and former Aquamaid Mary Beth Sanger. They exhanged their vows in the underwater submarine theatre arena (Figure 22 and 23).

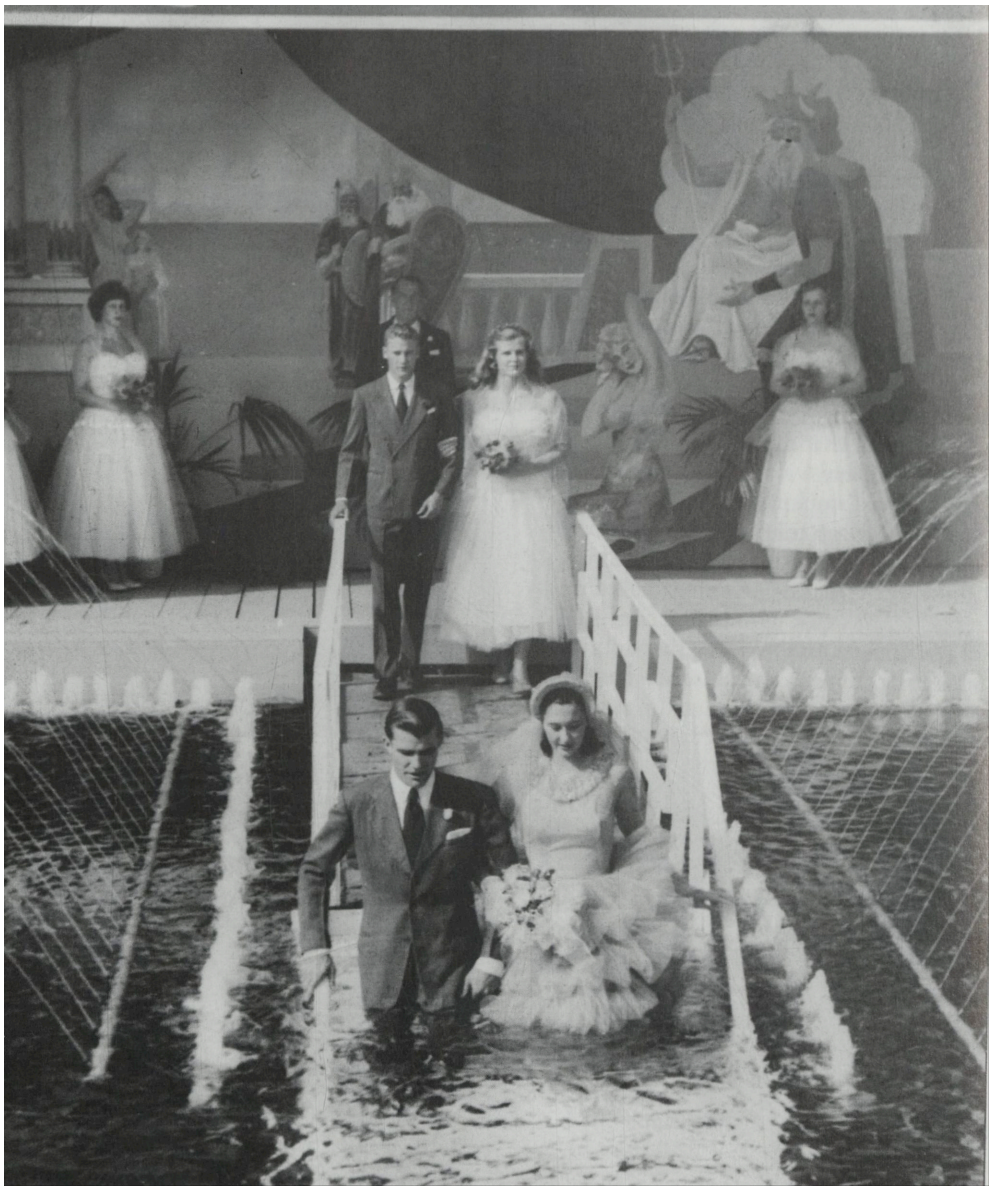


Figure 22. Bob Smith and former Aquamaid Mary Beth Sanger walking down their watery isle.

Figure 23. Former Aquarena Clown Bob Smith and Aquamaid Mary Beth Sanger exchange their watery vows.

In 1960 just 10 years after the opening of the theme park, a water curtain 80 feet long with periodic streams of water shooting 30 feet into the air was added as a feature to the theme park (Figure 24). Tropical gardens and an aviary behind the hotel were new additions as well (Figure 25) along with walking trails in the natural landscape that people could enjoy (Figure 26) (Weber 2009; Kimmel 2006).

In 1963 a Sky ride was added suspended 110 feet above the river giving people a bird-eye view of the entire park (Figure 27-30). Then the Gyro Tower a sky spiral was added and opened in 1979 giving the people atop the towers a spectacular view of the city of San Marcos, the Balcones Fault, Devil's Backbone, the San Marcos and Blanco Rivers, and praires to the east (Figure 31) (Doni Weber 2009).

The theme park caused many changes and lots of growth. Buildings were put up to provide a restaurant, souvenir shop, and administration offices to cope with the expanding theme park. There was a constant demand for new attractions so new features were constantly added throughout the theme parks existence.

Figure 24. The water curtain of 80 feet long and with periodic streams of water shooting 30 feet into the air feature for the opening of the park.

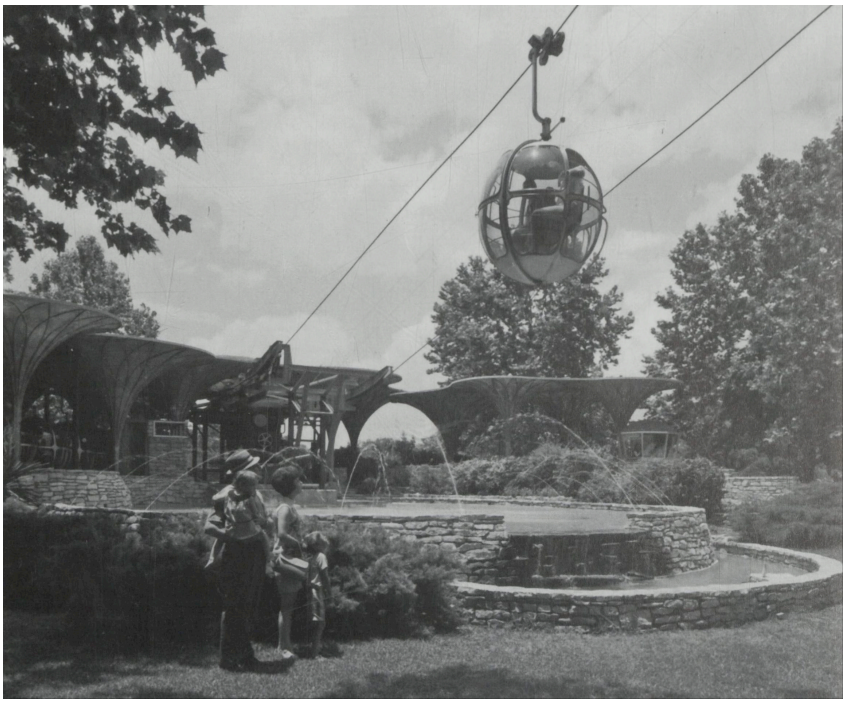


Figure 25. A family enjoying one of the gardens and a view of a couple as they enjoy the Sky ride.

Figure 26. One of the trails offered at the park for individuals to enjoy.

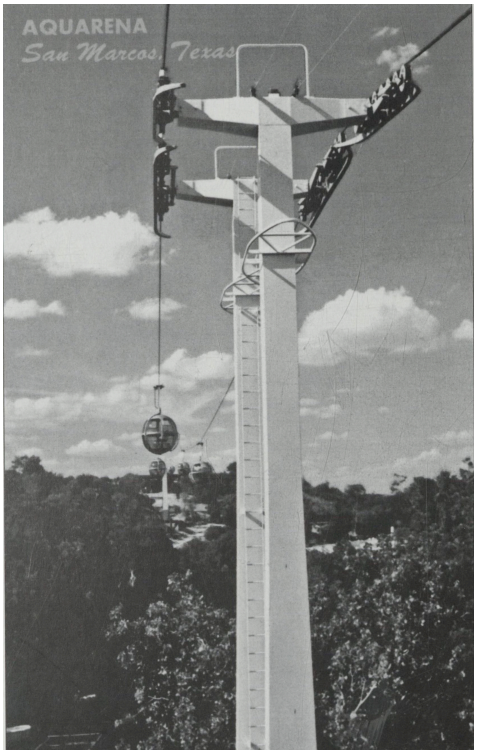


Figure 27. Sky Ride at Aquarena Springs Theme Park

Figure 28. The Sky ride that reached 110 feet above the river giving them a bird-eye view of the entire park.

Figure 29. A family climbing into the Sky ride to enjoy the bird-eye view.

Figure 30. One of the advertisements for the new Swiss Sky ride

Figure. 31. Gyro Tower a sky spiral was added and opened in 1979

In 1965 Paul Rogers died, leaving his family in control of the theme park and his estate. In 1976 because of electrical refrigerators the Southland Ice Company stopped manufacturing ice and in 1977 the ice factory was sold back to Aquarena Springs. Five years later it was converted into a restaurant becoming an added attraction to the theme park. It was not until 1985 that the river finally saw some glimmer of hope returning to its earlier more natured state. In that year John Baugh purchased Aquarena from the Rogers family (Weber 2009). Over time Ralph the swimming pig and the various aspects and

attractions of the theme park became irrelevant and inappropriate. Finally people were starting to see the river as a unique and important resource. It had become hard to find beautiful clear water in Texas.

The San Marcos River has indeed gathered a plethora of experiences. It first encountered people 12,000 year BP when the first Native Americans happening upon the springs. The European and Spanish settlers tried to settle the area. Up to this point the river had experience slow and subtle change. It was a short time from 1864 when the first Anglo settlement in San Marcos was established, to the start of Roger's exploitation of the river as a business of entertainment in 1911 to 1985. The river in 121 years had changed drastically compared to the 12,000 years prior. Then John Baugh's purchase of the land would begin a changing era for the river. All the pruning and disruption of the river would begin to cease. In 1994 Texas State University bought Aquarena for 7 million dollars and endeavored to find a meaningful purpose that retained and appreciated the uniqueness of the San Marcos River (Weber 2009).

A 10-year transformation from theme park to educational nature center began to take place. The glass bottom boat tours would become the only remainders of Roger's original Aquarena Theme Park legacy. The glass bottom boat tours are utilized for educational means. They provide information on the headwaters ecosystem, its endangered species, archaeology, and the Edward's aquifer. In 1997 the Texas Parks and Wildlife teamed up with the University and converted the theme park into the Texas Rivers Center. In 2006 renovations were completed to convert the hotel into the Meadows River Center and

interpretive center. The buildings on the east short of the lake were removed and the river restored to its natural state.

The Meadow's Center is an institution committed to "studying, preserving, and interpreting the remarkable aquatic system that surrounds it as it extends that attention and concern to freshwater systems across the state, the nation and the world (Weber 2009)." Relating the importance of aquifers, river and aquatic systems is a main focus and mission for the center.

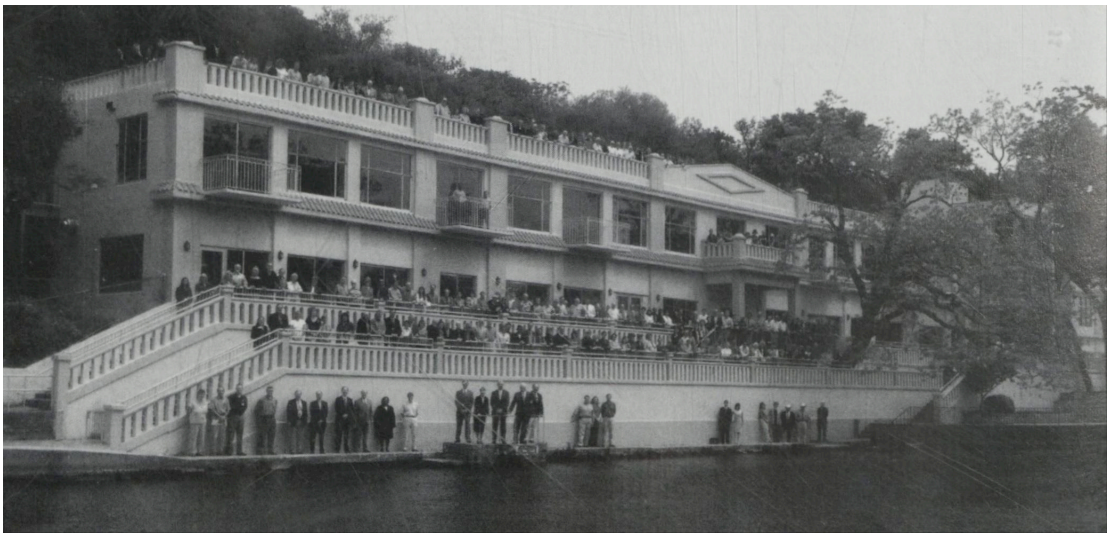


Figure 32. The newly renovated Meadow's Center

Finally by 2014, almost every single trace of the old Aquarena theme park had been removed from the river. The Sky Ride and Sky Spiral infrastructure were dismantled, the Submarine Theater was pulled from the Lake, and the old gift shop, restaurant, and outbuildings establish by Rogers were demolished. Instead in its place native prairie vegetation and grasses were planted, giving a visitor the belief that Aquarena Springs them park had never existed.

Chapter III

Threats to the River

3.1 Urban Development

In a study by the United Nations (1995) net increase of the human population up until 2025 is set to occur in urban areas of developing countries. In that time as much as 60% of the world population (about 5 billion) will live in cities (Young et al. 1994; Bernhardt & Palmer 2007). The majority of these cities are situated on rivers (Malmqvist & Rundle 2002). Climate change alone is said to increase the demand/supply ratio of water by <5% for the globe as a whole. However, increase of population (and urbanization) for water demand increased the ratio by 50% and 60% in combination with climate change (Malmqvist & Rundle 2002; Vorosmarty et al 2000).

Over 130,000 km of streams and rivers in the United States are impaired by urbanization (USEPA 2000; Paul & Meyer 2001). It is estimated that the pressure on running water ecosystems by 2025 will stem from human enterprise (a result of the predicted increase in the human population). Concurrent increases in urban development, industry, agricultural activities and water abstraction, recreation, and international commerce will be sources of great disturbance affecting river systems (Malmqvist and Rundle 2002; Lake et al 2000). The main types of destruction that effect lotic systems (river systems) are as follows: ecosystem destruction, physical habitat alteration; water chemistry alteration; and direct

species additions or removals, which stem from several types of proximate causes (Malmqvist and Rundle 2002). These destructions coincide with those of Lake et al (2000) in which they found that "All forms of anthropogenic disturbance—changes in land use, biogeochemical processes, or biotic addition or loss—not only damage the biota (plant and animal life) of freshwater sediments but also disrupt the linkages between above-sediment and sediment-dwelling biota". These losses are usually in correlation to an increase in domestic and agricultural demand for water and the physical components of the ecosystems themselves during urban or agricultural development (Meyer & Wallace 2001).

As of now 80% of the United States is or is in the process of becoming urbanized (Wang et. al 2011). Wheeler (2005) defines urbanization as development in a watershed; such as building construction that changes land use typical of rural areas to uses more typical of residential and industrial areas. Urbanization has been found to convert naturally vegetated or agricultural lands to an urban environment that increases storm water runoff to streams. This increases the frequency and severity of flooding, accelerated channel erosion, and altered stream channel forms and bed composition (Klein, 1979; Wang et. al 2011; Lake et al 2000). Increased runoff and reduced infiltration, in the stream watershed lowers the stream base flows, alters water temperature regimes and energy inputs, and increases loadings of nutrients and toxic substances (Lake et al 2000; Wang et al, 2011). All these impacts lead to significant changes in aquatic biological communities (Allan, 2004; Wang et al 2011).

Urban areas are growing at a fast pace to meet the growing housing demands, population growth, and industrial growth (Wang 2011). A stream's physical habitat and chemical environment are intimately connected and products of its watershed. The landscape which a river system flows through shapes and directs the condition of the river itself. This intimate contact with its surrounding catchments and terrestrial ecosystems makes the river susceptible to any activity within its catchment. This susceptibility allows the potential to cause environmental change and any pollutant entering the river to exert its effects for a large distance downstream and among the various ecosystems within it (Malmqvist and Rundle 2002). So as a watershed urbanizes, changes occur in the stream habitat, water chemistry, and ultimately biota.

Ecosystem Destruction and Physical Habitat Alteration

Urbanization has a variety of factors that destroy the ecosystems within a river system. The urban landscape is characterized by rooftops, asphalt, compacted soils, and other impervious surfaces (Wheeler et al 2005). Impervious surfaces do not allow fluids to pass through or soak into the ground. These surfaces are the agents that drive precipitation and route it to storm sewers, gutters, and the stream itself. Over all, these impervious surfaces alter the natural delivery of water to the stream, thus altering, stream flow regimes and causing an increase in peak flow volume from storm runoff (rain water) events (Wheeler et al 2005). This flow regulation prevents the natural flood regime from occurring, which during seasonal flooding allows vital exchange between aquatic sediments and the adjacent terrestrial above sediment habitats (Lake et al 2000). This in turn stimulates the

distribution and growth of riparian vegetation and biodiversity. The growth of imperviousness areas is also responsible for not just increasing runoff but decreasing groundwater recharge and increasing pollution in water sources (Hugo & Ordenes 2004). The result is a reduction of base flow discharge in urban streams (Paul & Meyer 2001). Also causing a variety of changes to the physical features of a stream (Lake et al 2000; Malmqvist & Rundle 2002). It increases the amount of water flow back into the stream increasing the channel capacity by eroding the banks. This creates the characteristic wider and deeper channel that identifies an urban stream (Wheeler et al 2005). This increase in erosion as well as runoff from urban construction increases the deposition amount of fine sediment that can devastate and destroy the biota of the river system (Wheeler et al 2005; Paul & Meyer 2001).

Another detriment of urbanization on river ecosystems is the loss of riparian vegetation as areas near the stream are cleared (Lake et al 2000; Malmqvist and Rundle 2002; Paul and Meyer 2001). Riparian vegetation is found on lands that occur along watercourses and water bodies. They are distinctly different from surrounding vegetation's because of unique soil and habitats that are strongly influenced by the presence of water. In the western United States riparian areas comprise less than 1% percent of the land area, but they are among the most productive and valuable natural resources. However, 1% presence doesn't do justice to the critical role they play in the ecological integrity of freshwater ecosystems (Lake et al 2000). A disturbance in riparian vegetation can lead to a decrease in the biota of a stream, which may lead to an alteration of aquatic production.

These areas absorb and filter out metals, fine sediment, and nutrients from overland runoff (Lake et al 2000; Wheeler et al 2005; Paul & Meyer 2001) and serve as a buffer to the physical and chemical effects of urbanization. This special vegetation creates stability along the stream banks and reduces erosion, while helping to moderate urban stream temperatures (Wheeler et al 2005; Bernhardt & Palmer 2007; Paul & Meyer 2001). The moderation of stream temperature is very important for it determines the distribution and abundance of the animal and plant life of the river. Riparian vegetation does this by sheltering the stream from warming by absorbing or reflecting sunlight before it reaches the water (Wheeler et al 2005).

Wang (2012) found that channel width and substrate size had a strong correlation with the presence of riparian vegetation and the alteration of stream hydrology from urban land use. The removal of riparian vegetation, wider channels, and substrate size was an indicator of stream physical habitat alteration and ecosystem destruction. A correlation between intact riparian vegetation on urban stream macro invertebrate taxa richness was found in Moore & Palmer's (2005; Bernhardt & Palmer 2007) study. Though it only comprises 1% of land area the presence of riparian vegetation can be conclusively beneficial for the health of all freshwater systems. Since the settlement of the San Marcos area in 1845 anthropogenic forces and urbanization have been the sources for various modifications such as bank stabilization, dams, and landowner maintenance activities in waterways and on adjacent tracts of land. These changes have significantly

altered the natural configuration and drainage of the San Marcos River system (Figure 33).

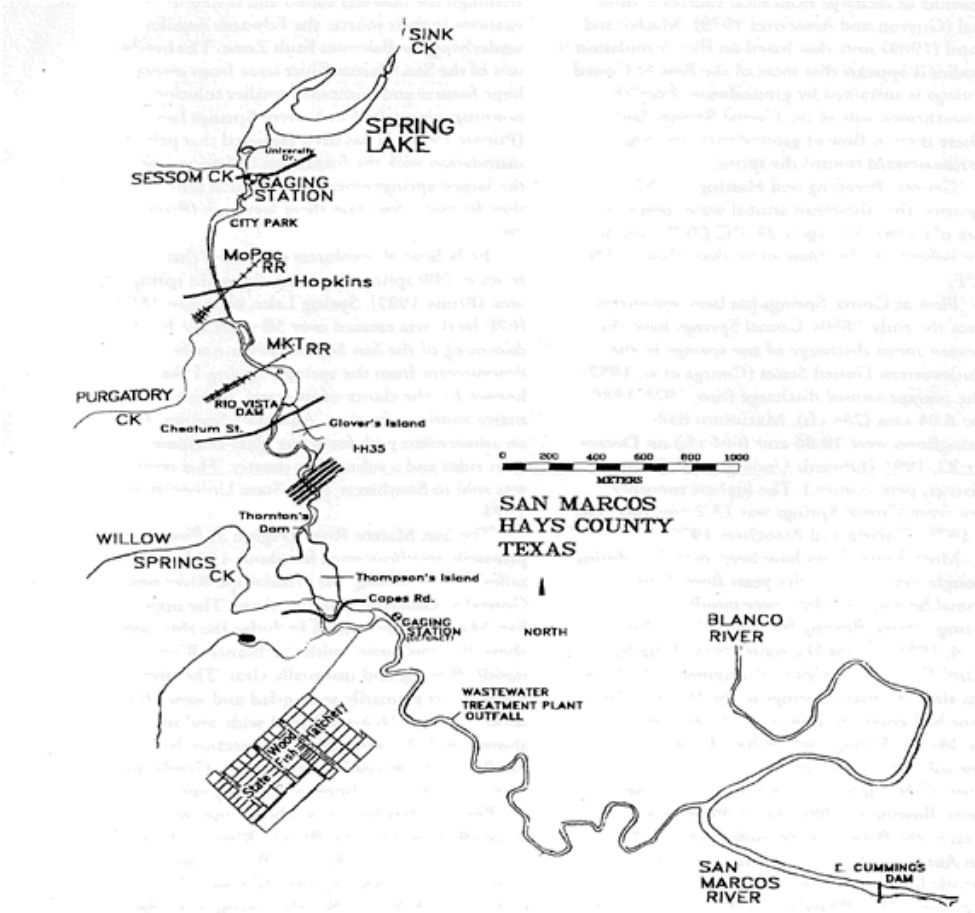


Figure 33. San Marcos Aquatic Ecosystem

Surrounding development and urbanization have also played a role in indirect impacts toward this system. There are a series of five-flood retardation structures built by the Soil Conservation Service on tributary creeks feeding into the San Marcos River to decrease the severity of flooding. Flooding usually flushes silt and other soft materials from the bottom of the river however these structures affect flushing flows and silt accumulation. These structures may not be adequate to maintain natural habitats. In fact a gravel bar has

accumulated below the confluence of Sessom Creek due to construction in the watershed. Flooding not only controls silt removal, as found in the previous studies above but can maintain habitats for some species by periodically removing riparian vegetation from parts of the banks creating openings in shoreline and redistributing the vegetation. Species composition, distribution, and density of aquatic vegetation are very important for many of the endangered listed species. These factors influence the quality and quantity of available habitat that is important to biodiversity. Cutting and removing vegetation from Spring Lake can harm or kill San Marcos salamanders and fountain darters and has posed a serious threat to the San Marcos salamanders since the algal mats provide a food source and protection from predators. The cutting of aquatic vegetation has also led to the threaten endangerment of Texas wild rice. This cutting of vegetation shades and entangles Texas wild rice resulting in lodging of inflorescences. Vegetation cutting also threatens other species of concern by direct damage or lowering habitat quality. In fact the San Marcos River has a constant 22^{o}C temperature which riparian vegetation helps to regulate and maintain. Recreational activities on the San Marcos River such as kayaking, tubing, fishing, snorkeling, scuba diving, and glass - bottom boat tours also have a direct or indirect impact on the ecosystems and their species. Texas wild-rice plants or its inflorescence may be physically damaged by water activity preventing plants from successfully producing seeds. It can also lead to further habitat alteration with bottom disturbance and vegetation control. Other habitat alterations may

be caused by compaction, erosion, litter, pollution, and runoff from parking areas and support facilities.

Community member thoughts on this have been expressed through personal interviews. Six of ten community members interviewed for this study agreed that land conversion has decreased the availability of permeable ground which is how the aquifer is recharged. The water from the aquifer is what gives flow to the springs which are the head of the San Marcos River allowing for its continuous flow. Interviewees also addressed that development in the recharge zone is destroying native plants (riparian vegetation) that is essential for filtering of water and habitat make-up of the river which poses a threat for the 7 endangered species residing in the various parts of the basin. Another concern they raised was recreational use of the river. Interviewees 1-6 stated that they saw recreation such as rafters and tubers as a threat to habitat degradation from direct contact with aquatic organisms. These activities also degrade the river shoreline (decreasing bank stability), leave hundreds of thousands of pounds of garbage, and increase sediment in the water.

Water Chemistry Alteration

Rivers and streams receive 84% of urban runoff (Wheeler et al 2005). This runoff contains chemical pollutants such as petroleum, metals, and nutrients from the urban landscape. These are all considered nonpoint source pollution (NPS). Unlike pollution from industrial and sewage treatment plants this comes from many natural and human activities. These chemical pollutants are often stored in stream sediments. Oil and grease

enter urban runoff by deliberate dumping, automobile engine emissions, and chemical spills. The majority of oil and grease contribution to runoff comes from automobile drippings and can be found in accumulations of deposits by parked vehicles in parking lots (Hoffman et al 1982; Wheeler et al 2005; Paul & Meyer 2001). Other contributions of automotive to runoff are sources of metals like zinc from tire wear and motor oil, platinum from catalytic converter emissions, and lead from motor oil (Wheeler et al 2005; Bernhardt & Palmer 2007). Lead from brick and painted surfaces, zinc from corrosion of metals from roofing, and painted wood also contribute to the various chemicals in urban runoff. Various chemicals from fertilizers and agricultural chemicals like pesticides and PCBs contribute to urban runoff as well (Malmqvist & Rundle 2002; Bernhardt & Palmer 2007; Paul & Meyer 2001). Urban use of pesticides actually accounts for more than 136,000 kg, which is two thirds of U.S. pesticide use for homes, commercial/industrial buildings, and lawn and golf courses (Paul & Meyer 2001). In a study by Meyer (et al 2005) a comparison of un-urbanized streams to urbanized streams showed that urbanized streams had elevated inputs of nutrients and a reduction of removal of these nutrients. The urbanized streams were found to have less riparian zones and high impervious surfaces in the landscape. The amount of high impervious surfaces in the landscape accounts for elevated inputs of nutrients and the low amount of riparian zones shows their importance in filtration of these pollutants. These introductions of pollutants and nutrients usually are not present alone when in runoff but in a mixture with

other dangerous chemicals. Many forms of these pollutions actually have more than one effect (Malmqvist & Rundle 2002; Lake et al 2000).

Wastewater effluent is not an uncommon contributor of runoff as well. During storms it's not uncommon for storm water and untreated sewage to be combined and diverted to streams and rivers (Paul & Meyer 2001). Ultimately these pollutions degrade and devastate the aquatic biota (plant and animal) life of the river (Paul & Meyer 2001). Various factors are having an effect on the water quality of the San Marcos River. There have been various times where dangerous levels of fecal coliform have been reached in the river. Just recently August 27th 15,000 gallons of raw sewage was poured into the San Marcos River as contractors were preparing a construction site on River Road for the forthcoming Woodlands of San Marcos. Development breached one of two wastewater force mains that connect a major lift station at the apartment property's edge to the city's nearby wastewater treatment plant (Mishap spills 15,000 gallons of raw sewage into the river, The Mercury Staff August 2014). Another incident occurred in 2010 when Texas State University had a chemical spill into the river (approximately 446 gallons of sulfuric acid (San Marcos Daily Record 10/31/2010). The impervious cover (impenetrable surfaces like roads, parking lots, rooftops etc.) increase the collection of nonpoint source pollution and its runoff into the river.

The destruction of the aquatic biota is not the only threat feared from this runoff but the pollution of the freshwater itself, because it is the main source of drinking water. One of the major threats that the San Marcos River faces is declines in water quality to the five

endangered species of the San Marcos River, the fountain darter in San Marcos, San Marcos gambusia, San Marcos Salamander, Texas Blind Salamander, and Texas Wild Rice (Figure 34). Anthropogenic factors can lead to the distribution of chemical constituents such as dissolved ions, trace elements, pH, nutrients, dissolved oxygen, and organic contaminants (compounds of petrochemical or pesticide origins). The pH measures how acidic or alkaline a river is with levels lower than 7.0 being more acidic and those higher being more alkaline. A healthy range for most aquatic organisms is 6.5-8.0 SU. The pH affects many chemical and biological processes in the water. Spills from railroad tank cars, tractor trailers, or other motor vehicles crossing the San Marcos River on railroad bridges, the interstate highway, or other road crossing have been contributing factors to the decline in water quality. Another contributor has been underground storage tank leaks which have been a significant source of groundwater contamination in the state of Texas (TWC 1989). Reduction in water levels in the Edward's Aquifer also decreases water quality.

Endangered Species of the San Marcos River
Fountain darter *(Etheostoma fonticola)*
San Marcos gambusia *(Gambusia georgei)*
San Marcos salamander *(Eurycea nana)*
Texas blind Salamander *(Eurycea rathbuni)*
Texas wild-rice *(Zizania texana)*

Figure 34. Table of the five main endangered species of the San Marcos River

Interviewees concerns were very high for water quality and quantity of the river. All ten interviewees stated that non-point source pollution is an increasing threat as landscape around the river and in the San Marcos watershed become more urbanized and if poor land use practices are allowed to continue. Nonpoint source pollution and sedimentation from urbanization directly threatens water quality. "You have non-point sources like pesticides, herbicides, personal products, birth control, medications, and caffeine that is going into sewage streams and ending up in the aquifer and river", interviewee 2 voiced. Runoff from parking lot and leaking cars releases hydrocarbons and other compounds that flow into the river. Increased solid waste production as well as sewer breaks especially during storm runoff will have detrimental effects. Interviewee 2 stated, "There have been sewer breaks especially during storm runoff and it this gets into the aquifer and from there we cannot treat it there, it will take years to flush out. The next time we see that water is when it flows out of the springs at the headwaters of the San Marcos River." These impacts will inevitably lead to "deteriorated water quality, which in turn affects habitat quality for various organisms", as stated by interviewee 5.

Direct species additions or removals

Approximately 42% of endangered species are at risk primarily due to invasive species (National Wildlife Federation). With humankind's capabilities of mobility increased by technological advancement there has been a transfer of a diverse range of organisms from their natural habitat into newer habitats where they are thriving and driving out the native species.

Many of these introductions have occurred unintentionally, brought in accidently alongside intended specie, ballast water of ships, or as escapees (Malmqvist and Rundle 2002). These exotic species tend to thrive in their new environments due to lack of their natural predators and controls. They also grow and reproduce quickly and spread aggressively, with potential to cause harm. In this way they quickly take over an area. Native wildlife often does not have defenses against the invader or they cannot compete with a species that has no predators. Direct threats by an exotic invasive specie that native species experience are being preyed upon, out-competed for nutrients and other resources, causing or carrying diseases harmful to the native species of the river, and prevention of reproduction or killing of young. Indirect threats are changing of the food web, decreasing biodiversity, and altering ecosystem conditions by disruptions of food webs and ecological processes (Wilcove et al 1998). This together causes a dramatic and cascading effect that may lead to the extinction of native species both plant and animal (Lake et al 2000).

Introduction of alien species has posed a threat to the San Marcos River system. Elephant ears and giant rams horn snails are two nonnative species that pose a threat to other native species of the river. Aquatic plants in many areas of the river have been grazed to the bottom by giant rams horn snails and elephant ears have taken up much of the area displacing native species such as the Wild Texas Rice.

Furthermore, this displacement has reduced cover for species such as the fountain darter and gambusia. It has made the habitat unsuitable for many of the species created

competition for needed resources (food, habitat, breeding grounds) or preyed upon. Nutria another introduced mammal that is native to South America has been a common invader of the San Marcos River. They feed on a variety of aquatic vegetation but have been observed to feed on the Texas Wild Rice leading to significant damage to the stands of the vegetation. Tilapia a nonnative species of fish that has become more abundant than any native family of sunfish reducing resources that would be readily available to sunfish, and help them to have increased numbers.

Introduction of nonnative species, alteration of plant and animal communities can have a drastic effect on endemic species and the river ecosystem as a whole. With an increase of habitat modification through anthropogenic forces and nonnative species there is a real threat to the many endangered species of plants and animals to the river. These native plants and animals are vital to the overall function of the river system.

All interviewees expressed concerns with how water quality change and habitat alteration could be detrimental to the San Marcos River system. Interviewee 6 even stated, "A usual factor causing impact, a legacy, is the invasive species left over from the aquarium industry use of the river". Introduction of new invasive species continues to alter the habitat as they replace natives in their conquest to exist and thrive. If this occurrence keeps on then the natural habitat will be changed and ecosystems will degrade.

3.2 Climate Change/ Global Warming

"Global climate change is predicted to be a major cause of change across all ecosystems, and there are particular concerns about impacts on freshwater systems due to the coupling of direct impacts on both hydrology and ecology" (Muir et al 2012). These systems are

specifically vulnerable to climate change because they are isolated and physically fragmented within a large terrestrial landscape as well as heavily exploited by humans for the provisions of goods and services (Woodward et al 2010). Many stream organisms have precise thermal and hydrological tolerances. Climate models predict that all regions in the United States will be warmer in the future and trends in precipitation more varied geographically (Leavesley et al. 1997; Schindler 1997; Malmqvist and Rundle 2002). Increases in CO_2 and temperatures are some of the consequences of climate change on freshwater ecosystems. Changes in precipitation regimes, snowmelt events, runoff patterns, evapotranspiration, droughts and floods, groundwater resources, and loss of water quality are among some of the alterations that climate change induces upon freshwater ecosystems. The CO_2 and temperature changes will increase the frequency and spatial extent of terrestrial disturbances (drought, wildfire, debris flows, biological invasions, and insect outbreaks) that will change terrestrial ecosystem structure (Davis et al 2013).

Anthropogenic release of CO_2 has increased greatly since the industrial age began, because fossil fuels became the main energy source (Dale 1997). Another factor that has contributed to the release of CO_2 is the alteration and manipulation of landscapes that has led to the altering and distribution of ecosystems and their associated fluxes of energy within those landscapes. Human activities also influence the greenhouse effect by releasing greenhouse gases and through changes in CO_2 fluxes. Manipulations of the land during increased urbanization causes change in the atmospheric flux of CO_2. About 61% of the anthropogenic greenhouse forcing can be attributed to CO_2 increases. Clearing of

vegetation and land also induces carbon losses from the soil and vegetation. In the United States, habitat for cool and cold-water species throughout their existing range is predicted to be reduced by approximately 50% by warming resulting from a doubling CO_2 concentrations, with losses greater for species with the smallest distributions (Eaton & Scheller 1996; Malmqvist and Rundle 2002).

Temperature is probably the most important environmental variable for aquatic organisms where even the smallest alterations to water temperatures can have cascading effects (Malmqvist & Rundle 2002; Woodward et al 2010). With increased temperature more changes in freshwater include physico-chemical changes, hydro morphological changes, and biological changes. Physico-chemical changes include increased water temperatures that may cause earlier onset and longer periods of thermal stratification. This can lead to the modification of dissolved oxygen and CO_2. More sediment bound nutrients are prone to be released into the water column as well as contaminants as temperature increases. This in turn can lead to cyanobacterial blooms that can alter the photic environment and the whole ecological system at various organizational levels (Woodward et al. 2010). Hydromorphological changes attribute to the changes in precipitation amounts and timings. This could potentially lead to extreme floods and droughts. A change in floods and droughts can further lead to alterations in surface and ground water flows, which can lead to change in habitat structure for aquatic biota. Biological changes from climate change alters productivity, phenology, trophic structure, species composition, and the potential of invasive and non-invasive species. Other effects

may include the abundance, distribution, and size of the biota. Temperature controls metabolic rates, food requirements, and developmental processes of aquatic biota (Naiman and Turner 2000; Wrona et al. 2006).

Climate change is changing the composition, diversity, and functioning of many freshwater ecosystems (Woodward et al. 2010); Dossena et al. 2012). Most of these freshwater ecosystems operate at a narrow and optimum balance. Their aquatic biota thrives at certain temperatures. They are linked together both plant and animal in a food web with complex trophic levels that are directly affected by the other. With the issue of climate change the trajectories of community change will not be random but certain taxa especially those higher in the food web will be the first to be affected and more vulnerable to extinction (Woodward et al. 2010).

In a study by Dossena et al. (2012) the effects of a 4°C rise in temperature on the size structure and taxonomic composition of benthic communities in aquatic mesocosms (an experimental water enclosure designed to provide a limited body of water with close to natural conditions), and the rates of detrital decomposition were assessed. In this study they found that there was no effect on biodiversity but community size structure was altered in two ways. In the spring warmer systems had steeper size spectra driven by declines in total community biomass and the proportion of large organisms. Autumn warmer systems had shallower size spectra driven by elevated total community biomass and a greater proportion of large organisms. Decomposition rates were also found to have mirrored the community level shifts seen in the previous. In the end this study

demonstrated that the 4°C rise that is expected at the end of the century will have the potential to change the structure and functioning of aquatic ecosystems. It will also have the potential to disrupt the intimate linkages between these levels of ecological organization.

In a case study in the Middle Rio Grande, a rapidly growing area that holds more than half of the state's population water balance needs, Jackson et al (2001) looked at annual variability, measurement uncertainty, and conflicting water demands for the region. Water management has changed the floodplain ecosystem completely. Riparian zones are limited by the levees of these water systems. Invasions of exotic species have also completely changed the riparian forest composition. There have been major changes in hydrology, the riparian ecology, and groundwater pumping. The major sources of water depletion have been found to be urban uses, irrigation, plant transpiration, open-water evaporation, and aquifer recharge. This study is a direct reflection for other arid and semiarid regions that are experiencing increased urban growth and water conflicts between human needs and those of native ecosystems (Christensen et al. 1996; Jackson et al. 2001).

Anthropogenic global warming is an obvious dangerous threat to many physical and biological systems. Shifting in precipitation with increasing dryness at low altitudes (the U.S. Southwest and northern Mexico) is proving to be a threat to dry landscape ecosystems and freshwater ecosystems that are directly connected and influenced by the landscape they flow through. With increasing temperature and less precipitation the

dryness of the 1930s Dust Bowl is expected to return to the American Southwest by midcentury (Kerr 2007). This will lead people to extract more water from the Edward's Aquifer. The Edward's Aquifer already supplies much of central Texas with drinking water and now exceeds annual recharge rates (Jackson et al. 2001). The aquifer depends on precipitation for refilling and is susceptible to changes in quantity and quality of recharge water. With an increase in water use, which is predicted, the aquifer will be more susceptible to drought and contamination. Depletion of this ground water source will permanently alter and reduce the aquifer storage. Furthermore, changes in surface and ground water will change the biogeochemistry of streams (Jackson et al. 2001). With increasing human growth and anthropogenic warming water consumption will places a great pressure on freshwater resources and their intricate ecosystems.

Again these prior studies about potential impacts of climate change on river systems are relevant to the San Marcos River. The San Marcos River is a small isolated river system making it highly delicate to change. The river has always had a specific temperature of 22˚C that all aquatic biota function and thrive at. If these levels rise above this with climate change many organisms will be affected. This potential thermal change could have detrimental effects. For instance, the amount of oxygen dissolved in water will decrease as the water becomes warmer and has a reduce annual flow due to decreased spring flow. Dissolved oxygen is an important requirement for fish, invertebrates, plants, and aerobic bacteria for respiration in a river system. Temperature as mentioned before is an important control for metabolic rates, food requirements, and the developmental

processes of aquatic biota. Any diversion from its constant 22˚C water can cause the health of these organisms to decline.

The primary threat of climate change to the five endangered species of the San Marcos River and their ecosystems is the loss of spring flows. These spring flows happen to not only support the entire San Marcos river ecosystem but are tied to water usage from the entire Edward's Aquifer (Fig 35). Use of groundwater from this region decreases flow of water from the springs. As populations rise the demand for water will increase and with it the amount of water pumped from the aquifer. In this period of drought and the expected projection of its continued existence, water levels will fall below the water table level making it more susceptible to pollution. This will also have an extended effect leaving less water for the spring flow which is essential for productivity, phenology, trophic structure, species composition, and allow invasive species to have stronger effects on native species. The overall biogeochemistry of the river will be changed as well as the biodiversity of all living organisms within the system.

One of the interviewees stated "The primary threats to the San Marcos are first, the declining flow of the San Marcos Springs, primarily due to drought but exacerbated by increasing pumping from the Aquifer." Another interviewee also stated in parallel with interviewee 1, "The River is mostly spring fed and as the drought continues and people irresponsibly draw down the aquifer, the level of the river decrease (which also happens to concentrate pollution)." Climate change poses a serious threat to the amount of spring flows as well as to the temperature gradient that the river and its organisms function at.

Most interviewees expressed that decreased spring flow is a serious threat that the river faces. Interviewee 7 stated, "The primary threat to the San Marcos is first the declining flow of the San Marcos Springs, primarily due to drought but exacerbated by increasing pumping from the aquifer." All interviewees voiced that increasing population will increase demand for water and put a greater pressure on the Edward's aquifer which will in turn affect the San Marcos River's spring flow. Interviewee 4 also expressed that, "As the drought continues and the people irresponsibly draw down the aquifer, the level of the river decreases which happens to increase pollution." Further, interviewee 4 expressed concern on decreased spring flow by stating, "All of the aquatic plants and animals in the river depend upon a regular flow of water, and have adapted over hundreds of years to this environment. A reduction of stream flow affects the habitats for all the river inhabitants."

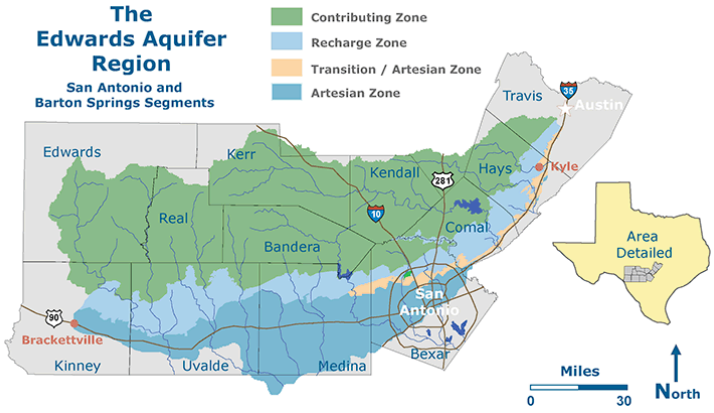


Figure 35. The Edwards Aquifer Region

Chapter IV

Strategies to Cope with Potential Threats

Despite the ubiquity of water on earth only a small portion of it is available as freshwater. Renewability of freshwater withdrawals or sustainability is a key issue and will continue to be so in the future with growing populations, urbanization of landscapes, and climate change. The scarcity of water is not just a fear that threatens humanity but ecosystems and diversity. These ecosystems and biodiversity are things humanity depends on as well. For instance, nature provides ecological services that are inseparable from a healthy human habitat. When ecosystems experience degradation they begin to lose their diversity and surrounding organisms including us begin to see deteriorating health (Brown and Grant 2005).

There are various potential threats that the San Marcos River faces. Some of the threats and their consequences have not yet taken hold but will soon if action is not implemented. From previous studies in other river systems experiencing the impacts of growing urbanization and climate change, it can be concluded that it is a matter of time before the adverse effects taken hold upon those systems will be replicated in the San Marcos River. However, these studies give the San Marcos River an upper hand in

preventing the degradation that these rivers have experienced and an opportunity to keep its healthy state. That is why now it is more important than ever to apply strategies to cope with these potential impacts. It is an easier task to prevent an impact than to reverse its effects as many river systems have degraded past rescue and others are still struggling to maintain their existence.

The issue of preserving the San Marcos River from the potential threats and impacts in the previous chapters has not solely been the worry of public officials or researchers, but has invoked concern among the community of San Marcos. Interviewees have had various thoughts on what needs to be done in order to preserve and protect the river. They have found that these three areas are vital to producing the strategies that the river needs most to prevent the many threats that growing urbanization and climate change will have on it in the near future. From my interviews with community members it can be concluded that there are three areas that should be the focus of attention in order to develop strategies to cope with potential adversities to the San Marcos River. These are: 1) comprehensive water quality protection, 2) regulated development and growth, and 3) education of residents and students. These strategies are briefly described in the following.

4.1 Comprehensive Water Quality Protection

Comprehensive water quality protection must continue and should increase due to the growing implications of population's growth and climate change that will challenge San Marcos. The Meadows Center for Water and the Environment has partnered with TCEQ

to collect data in order to develop a watershed protection plan for the San Marcos River. Furthermore, the data will be used to develop and implement watershed protection plans. The involvement of the community in getting the data will help create further connection between the community and the river. For example, the data collected by schools in the area could be analyzed and discussed in the classrooms. Comprehensive water quality protection reports could be sent out once a month to the community to keep them in the loop and aware of the river. It is important that the local government keep in communication with the locals of San Marcos in order to prepare communities and get them to actually implement adaption efforts towards preservation of the river.

Two of the ten interviewees expressed that utilization of the Upper San Marcos Watershed Protection Plan and the Habitat Conservation Plan should be taken into account. The San Marcos Watershed Initiative (SMWI) is a three-year process of researching and gathering information with the end goal of implementing a community and federally approved Watershed Protection Plan (WPP) for the upper San Marcos River. It explores way to manage impacts to surface water resources. There are nine elements of this plan as follows (Draft Upper San Marcos Watershed Characterization Report, 2014):

A. Identify causes and sources of pollution that need to be controlled to achieve load reductions described in (B)

B. Estimate load reductions expected from management strategies

C. Description of management strategies

D. Estimate of technical and financial assistance needed to implement the plan

E. Information and education component used to enhance public understanding of the plan

F. Schedule for implementation of management strategies

G. Description of interim, management milestones for determining whether management strategies are being implemented

H. Set of criteria that can be used to determine whether load reductions in (B) are being achieved

I. Water quality monitoring component to evaluate effectiveness of implementation measured against the information described in (H) (Bass, 2013).

The watershed protection plan will prove vital implementation strategies to protect the San Marcos River. Other interviewees also expressed the need for serious water enforcement. All interviewees expressed that people should be held accountable for their uses of water. How they use their water should observed and if there is violation of water use they should be warned and if water abuse is continued they should be fined. People need to understand the severity of water conservation and preservation.

4.2 Regulated Development and Growth

The second area of attention is the regulated growth and development of the city of San Marcos. The San Marcos River Planning and Development Services needs to make environmental conscious decisions when determining which direction to take the expansion of the city of San Marcos. Growth should be encouraged to stay centered in the

downtown area of San Marcos in areas that are identified as buildable. These buildable areas should be identified as areas that are not environmentally sensitive areas like Sessom Creek. The growth of the city should be conscious of the aquifer recharge zone, building too close to the river, and the watershed area that drains into Spring Lake. In the past many apartments have been built along North LBJ and it was found that the bacteria load was significant enough to show up on water quality studies done of the Spring Lake watershed (Heinrich, 2013). The increase of development of the city to accommodate a growing population is inevitable and it is sure to increase conflicts about environmental issues affecting the river. However, sustainable building and development plans that are conscious of environmentally sensitive areas will be the key balance to allowing growth and protecting of the city and the beautiful river of San Marcos.

Most communities members expressed that future development needs to be more strict than the minimal standards they are at now. Interviewee 3 expressed some ideas for greener development, "There are both structural and non-structural actions that could be implemented to address at least some of these threats. A major structural activity would be construction of detention ponds to collect and hold storm water runoff. The introduction of impervious parking lot and street surfaces would help storm water drain into the soil, rather than along the impervious street surfaces directly into the river. The planting of buffer strips or green belts along the river would work to slow down storm water runoff, thereby removing some of the polluting materials carried in it. Cleaning the streets on a regular basis would remove solid wastes that would otherwise flow into the river." All interviewees expressed in different word but conceptually that "development

and growth needs to be regulated in a way that ensures that it is smart, green, and sustainable" (interviewee 4).

4.3 Education of Residents and Students

The next important point that attended to is educating the residents and students of the San Marcos area. Very few people understand their connection to the San Marcos River. As a person living here for decades or just entering the scene as a freshman Texas State University student the time allotted by their presence is of no importance. The great fact is that they have become automatically entangled in the complex ecosystem of the San Marcos River. It is this knowledge that will help the community understands that every life style choice we make has ecological consequences. All interviewees expressed agreement that educating the people is a valuable strategy in attempting to protect the San Marcos River. As interviewee 4 stated, "People do not protect what they don't know or understand."

This knowledge needs to be integrated into the young through elementary schools, to the University students, and even the adults of the community. Interviewee 3 recommended, "A strong education campaign conducted concurrently on a city-wide basis, along with education of students at all levels (including college) would help people better understand how their actions can have environmental impacts about which they may not be aware. All of these actions individually and collectively would help cope with these impacts. Whether they could be best done by city leaders, environmental activities, citizens, etc., would also be a topic of discussion." The content of these courses should include the

history of the San Marcos River, its ecosystems, diverse organisms, and the threats it faces. They should also include ways of decreasing and preventing negative contributions to pollution, degradation, and unnecessary water use of the San Marcos River. Residents can protect the river by cleaning up pet waste in their yards, fixing automobile leaks, and leaving buffers of grass on the watershed that drains into Spring Lake (Heinrich, 2013; Mary Van Zant research specialist at Texas State's Meadows Center for Water and Environment). These courses should extend to the adult portion of the community through seminars and adult community centers. These courses should promote awareness as well as a connection of environmental stewardship towards the river. There is a difference between seeing the destruction of the environment and actually feeling its devastated effects. The community must build a connection and a relationship with the river so that pro-active action can be carried out successfully with community support.

The actions of the community will be the most important despite government involvement. These actions will need to be carried out at the individual level in order for change to occur. This can only work if everyone cooperates and participates. It is not a given effort by some but by all.

Many people of the community of San Marcos are already aware and fighting for the rights of the San Marcos River and to protect it. For instance, the residents of Sessom Creek Neighborhood Association stopped the City Council from approving a Sessom complex to be built. This fight lasted for a period of two years with the continual bringing up of serious obstacles such as suspended solids in the river, building in a floodplain, and

building within a hundred feet of tributaries to the San Marcos River. Many people were conscious that anything done on Sessom Creek would pour straight to the start of the San Marcos River in the heart of town posing a threat to the many endangered species of the river and its water quality. It is community involvement that will be the key in addressing the potential threats to the river.

Chapter V

Conclusion

"Many of the wars of the 20th century were about oil, but wars of the 21st century will be over water unless we change the way we manage water". - Ismail Serageldin, former chairman of the World Commission for Water in the 21st Century

The main theme of this study resonates with the various anthropogenic forces that are taking a toll on the river systems today, specifically urbanization and climate change. Only about 2.5% of all Earth's water is freshwater and only a bit more of that 1.2% being surface water. The rest is locked up in ice or in the ground. Freshwater is the basic essential for life and rivers are where humans get the majority of their water from. With rivers making up as little as 1.49% of fresh water resources it is essential to understand how the detrimental effects like urbanization and climate change are having on these essential ecosystems and the quality of the freshwater they provide. This study has observed the impacts that urbanization and climate change have had on other river systems in the world and has applied them to the San Marcos River.

Currently the city of San Marcos has been named "The fastest growing city in the Nation". This is an alarming notation seeing as San Marcos is home to a unique river system. Through literature review and interviews with 10 members of the San Marcos

community, this study explored potential threats to the San Marcos River associated with climate change and urbanization.

Increasing modifications in the watershed landscape associated with urbanization creates changes in the stream's physical habitat and chemical environment. As a river flows through a landscape it adopts the qualities of that landscape and any changes or additions from it. The two are in intimate contact making the river susceptible to any effects brought on by the landscape. Headwater streams are exceptionally susceptible to their surrounding catchments. They are smaller in size and liable to urban development disturbances that surround them (Kollaus et al 2014). These headwater streams in turn not only hold a valuable water source for people but diverse and distinct aquatic communities that contain rare and endemic taxa (Kollaus et al 2014). The fountain darter, San Marcos gambusia, San Marcos Salamander, Texas Blind Salamander, and Texas Wild-Rice are some of the species unique to the San Marcos River and currently considered endangered. The growth of San Marcos has been spiking at such alarming rates and with higher growth projected. The population of Hays County in 2012 was estimated to be about 169,000 people (SMWI 2014). About 50,000 of these people were found to live in the city of San Marcos. Based on U.S. Census data, the population of San Marcos increased from 34,733 in 2000 to 44,894 in 2010, a 29.3% increase in just 10 years (USCB, 2014). For this same time the population of Hays County increased from 97,589 to 157,107, a 61% increase. It is projected that the population of the county will continue to increase significantly. This added population is predicted to increase approximately 400% in the

next 50 years, to a population of 493,320 (SMWI, 2014). Furthermore, the entire Edward Aquifer region will increase 63% to nearly 1.3 million people (The Meadows Center for Water and Environment, 2012). This will definitely put pressure on water resources in the Edward Aquifer and therefore output to the San Marcos Springs. Moreover, development in the upper San Marcos watershed is expected to continue and increase. There will be an increase in enhanced urban development (The Meadows Center for Water and the Environment, 2012).

This will lead to future impacts on the San Marcos River such as continued modifications in hydrology and stream morphology. Furthermore, with increased development there will be an expansion of impervious surfaces and an increase in run-off with more nutrients and contaminants into the river. This new growth will also increase pressure on water resources to accommodate the growing mass of people and development. In turn this will increase groundwater pumping, decrease aquifer recharge, and lower base flows at the headwaters. All this in turn can elevate stream temperatures and increase the concentration of pollutants degrading the water quality, the aquatic biota, and the ecosystem itself. If this is not prevented there may be irreversible consequences and endangered species may become loss forever.

Climate change is the second factor taking a toll on the San Marcos River as it has over other river systems across the world. The consequences have been seen in those rivers to increase anthropogenic release of CO_2 and cause the streams to have lower oxygen levels, which is damaging to the plants and animals living within the San Marcos River. The San

Marcos River functions at a constant 22^{o}C temperature and this is likely to change in the future as climate change worsens and will have damaging and changing effects on the habitat structure and on the aquatic biota themselves. These anthropogenic factors causing climate change are going to worsen as populations increase in the San Marcos area.

It is important that strategies be implemented to prevent further destruction of the San Marcos River as seen in other river systems. The three main areas that need to concentrate on are Comprehensive water quality protection, regulated development and growth, and education of residents and students. The continued comprehensive research and protection of water quality is vital to sustaining ecosystem health. Regulated development and growth will insure the protection of the San Marcos River and all the organisms within it. Education of students and residents will be a key factor in making sure that all this occurs and is carried out successfully. To prevent and cope with future impacts everyone must take an active role of action.

The quality of life experience within the city is tied to the quality of the clear flowing waters that originate in Spring Lake (SMWI Draft, 2014). The recharge zone and contributing upper watershed portions of the river basin are key hydrological factors that give continuing superior water quality and quantity that generate invaluable ecosystem services by the San Marcos River (SMWI Draft, 2014). These services contribute a net worth of about $12.9 million to the local economy annually. The San Marcos River ecosystem provides surface and ground water storage and flow. It also provides

infiltration within the ecosystem to deliver quality water (filtering out pathogens, nutrients, salinity, and sediment). It provides water for municipal, agriculture, commercial, industrial, and thermoelectric power generation uses. It can be used for a variety of recreational, educational and tourism uses, bringing money into the economy. It also supplies fish and other freshwater products. The San Marcos River ecosystem provides water and nutrients to support vital estuaries and other habitats. It has a plethora of other essential services that if were to be recreated by man would cost millions of dollars but is provided "freely".

As the city of San Marcos continues to grow rapidly, the number of people using these ecosystem services will grow as well. The river provides so many services and provides essential resources to the people of San Marcos as well as the various life forms within the river. It is less expensive to take measures to protect the river than to restore a damaged river. As interviewee 8 stated, "We are looking at Austin for help and at what they've had to implement from their growth and to protect their water resource. They have had to buy back land with development on it, tear it down and restore it back to its natural state to provide more area for infiltration during rainfall. We are realizing that it's less expensive to prevent the state at which Austin is at and to start taking preventive measures protecting the San Marcos River and surrounding area."

William Ashworth once said, "Children of a culture born in a water-rich environment, we have never really learned how important water is to us. We understand it, but we do not respect it." Many of the river systems of the world's health have been compromised due

to the negative effects of urbanization and climate change. In Baker et al. (2004) study, a negative relationship between future population growth, development, and river health was identified. The goal of this study was to observe the significant connection between the river and community of San Marcos. Humans have had a long relationship with the river in this area. It is one of the oldest inhabited areas in the nation. The river has provided an enhanced quality of life and now the city built around it is growing at an alarming rate that threatens the health of its water quality and ecosystem. Members of the community have shown concern and ideas for strategies to be implemented in order to mitigate the effects of urbanization, climate change, and preservation of the San Marcos River for generations to come. The people of San Marcos have always depended upon the river for a variety of reasons whether it be recreation, solace, or the beautiful clean water it provides.

As Leonardo DiCaprio said in his statement at the United Nations, “We only get one planet. Humankind must become accountable on a massive scale for the wanton destruction of our collective home. Protecting our future planet depends on the conscious evolution of our species… The time to answer humankind’s greatest challenge is now." This applies to the protection of our river systems. This challenge begins at the local level of protecting systems such as the San Marcos River. It is time that the community becomes aware of potential consequences urbanization and climate change will have on the river, and implement ways to mitigate these consequences. We must become children

of understanding, appreciation, and stewards of the San Marcos River and its environment.

Chapter VI

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Chapter VII

Appendix A

(Figures Cited)

Chapter 2

Figure 1. Bourgeois, Eugene, and Teja. 1996. *San Marcos: A Guide to a Historic Texas Town*. San Marcos, TX: Dept. of History, Southwest Texas State U, Print.

Figure 2. Witliff Collections. Cabeza de Vaca Image Gallery.

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Figure 32. Weber, Doni. Aquarena Springs. Charleston, SC: Arcadia Pub., 2009. Print.

Chapter 3

Figure 33. *San Marcos and Comal Springs and Associated Aquatic Ecosystems (revised) Recovery Plan (short Title: San Marcos/Comal (revised) Recovery Plan) for San Marcos Gambusia (Gambusia Georgei), Fountain Darter (Etheostoma Fonticola), San Marcos Salamander (Eurycea Nana), Texas Wild-rice (Zizania Texana), Texas Blind Salamander (Typhlomolge Rathbuni)*. Austin, TX: Service, *1996. Print.*

Figure 34. Table made by author: Brittney L. Sanchez from San Marcos and Comal Springs and Associated Aquatic Ecosystems (revised) Recovery Plan (short Title: San Marcos/Comal (revised) Recovery Plan) for San Marcos Gambusia (Gambusia Georgei), Fountain Darter (Etheostoma Fonticola), San Marcos Salamander (Eurycea Nana), Texas Wild-rice (Zizania Texana), Texas Blind Salamander (Typhlomolge Rathbuni). Austin, TX: Service, 1996. Print.

Figure 35. "The Edwards Aquifer Website." *The Edwards Aquifer Website*

Chapter VIII

Appendix B

(Community Members Interviewed)

Questions Asked:

1. What are the threats that you believe the San Marcos River faces? And what are the potential impacts to come from these threats?
2. Do you believe that the fast urbanization, now deeming San Marcos the fastest growing city in the Nation poses a threat?
3. What are some strategies you believe will help cope with the potential threats and impacts?

Interviewee 1

1. What are threats that you believe the San Marcos River faces? And what are the potential impacts to come from these threats?

The major threat is a reduction of Spring flow, which feeds the river. All of the aquatic plants and animals in the river depend upon a regular flow of water, and have adapted over hundreds of years to this environment. A reduction of stream flow affects the habitats for all of the river inhabitants. First of all I don't believe urbanization or development is a threat, so much as it is conscious of the environment it is adapting to. What I perceived as a threat is a complete disregard for creating urbanization and development within the context of what we clearly know to be an environmentally sacred river. Anyone can look into the history of urbanization where a natural resource was present before and is now either nonexistent or so polluted that it is no longer considered a value to that area.

2. Do you believe that the fast urbanization, now deeming San_Marcos the fastest growing city in the Nation poses a threat?

Absolutely. The more our area is urbanized the more that will demand water. With a few sources of sustainable water, an aquifer, which feeds our river, can only be replenished at a rate which is a combination of our average yearly rainfall and the availability of permeable ground which is how our rock for is recharged.

3. What are some strategies you believe will help cope with these potential impacts?

I think educating people with very clear scientific presentations on the relationship between their actions and long term environmental impact can have a positive effect. Where education does not reach people who would not listen, we must strive to create and enforce what we know personally will preserve the river for many generations to enjoy.

Interviewee 2

1. What are threats that you believe the San Marcos River faces? And what are the potential impacts to come from these threats?

Water quality and quantity are the biggest threats and Urbanization and expanding out to the recharge zone. It has happened in other communities up and down the IH 35 quarter. Many people in the city pretend that they don't know whats happening but we have seen this before. Changes in hydrology, sewer main breaks that leak into the river etc. Also with the quantity of water we can't keep growing like this with the drought we are in. We need to start limiting growth and getting serious about water conservation. Also during storm events flooding in the sewer lines causes leakage. Updating structures is the main solution and this will continue to happen if we continue to build on the recharge zone. Contamination loads such as pesticides, herbicides, and personal products like birth control, medications, and caffeine go up in the river due to urban runoff but goes back to normal in our river. However, if it ends up in the ground it goes into the aquifer and takes years to flush out. The next time you see this water is when it comes out at the spring headwaters affecting everything down stream.

2. Do you believe that the fast urbanization, now deeming San Marcos the fastest growing city in the Nation poses a threat?

As said before urbanization is a big threat as we continue expanding out into the recharge zone. The growth and demand for water during a drought such as this will place a great pressure on water resources.

3. What are some strategies you believe will help cope with these potential impacts?

First, we need to get serious about water conservation and enforcement. This is the first year the city has done anything for enforcement, giving fines and warnings. A lot of this is also going to depend on neighbors account. We should of course educate and give a warning the first time on an offense because most people don't know.

Second, we must educate the people. Most people don't know about this area, and where their water comes from, and how serious this problem is. People are arguing for more water and saying we shouldn't have water restrictions. The city has not done a good job in educating the people.

Thirdly, future development needs to be stricter than the minimal standards. We need to be more conscious of where we develop and build green. Development pressure needs to be taken off the recharge zone and moved to the east side (to prevent the issue of water degradation of the aquifer itself) we can deal with treatment of water issues but we cannot go back and treat what is in the aquifer, the next time we will see this water is when it comes out the springs and by then it will have detrimental effects.

Interviewee 3

1. What are threats that you believe the San Marcos River faces? And what are the potential impacts to come from these threats?

Since human activities within a drainage basin (and sometimes even outside via atmospheric transport) are typically at the core of environmental degradation, the main threats to the San Marcos River would include increased urbanization and development, along with the attendant effects of such urbanization. The latter would include increased tourism utilizing the river causing degradation of water quality, biota and bank stability, as well as land conversion, increased impervious surfaces, increased solid waste production and other polluting activities, and also possible impacts of these activities on aquatic organisms (particularly the 7 endangered species residing in various parts of the basin). I would also add environmental ignorance (or at least lack of awareness) on the part of humans of the consequences of their activities in the river drainage basin. The latter also applies to city and county officials charged with developing policies and institutions for addressing such issues.

All water issues involve quantity and quality and/or habitat degradation. With an increasing population, depending on the specific water source, these threats might include increased water withdrawals to meet human needs (although not without obtaining necessary permits for water withdrawals). They certainly would include increasing pollution of the river, coincident with increasing development and other polluting activities. The habitat degradation would result from direct human contact with aquatic organisms (e.g., Texas wild rice) or activities that might degrade the river shoreline and/or the land areas closest to the river. Although it is not clear how this could easily be achieved, the issue of control of storm water runoff also represents a threat after rainfall events.

2. Do you believe that the fast urbanization, now deeming San Marcos the fastest growing city in the Nation poses a threat?
Yes, for the reasons mentioned above. By the way, I think the fastest growing area in the nation is actually the Round Rock - Austin - San Marcos complex. I might add that it would be difficult to try to slow down this fast urbanization, since how can one get people to NOT move to San Marcos?

3. What are some strategies you believe will help cope with these potential impacts?
There are both structural and non-structural actions that could be implemented to address at least some of these threats. A major structural activity would be construction of

detention ponds to collect and hold stormwater runoff. The introduction of impervious parking lot and street surfaces would help stormwater drain into the soil, rather than along the impervious street surfaces directly into the river. The planting of buffer strips or green belts along the river would work to slow down stormwater runoff, thereby removing some of the polluting materials carried in it. Cleaning the streets on a regular basis would remove solid wastes that would otherwise flow into the river. Educating people to drive less, use less energy at home, reduce their desire for buying new "stuff" all the time, whether it be cell phones, cars, groceries, furniture, etc., and particularly to consider what they 'need' (versus what they 'want') would also reduce our resource (and attendant pollution impacts) on the river. A strong education campaign conducted concurrently on a city-wide basis, along with education of students at all levels (including college) would help people better understand how their actions can have environmental impacts about which they may not be aware. All of these actions individually and collectively would help cope with these impacts. Whether they could be best done by city leaders, environmental activities, citizens, etc., would also be a topic of discussion.

Interviewee 4

1. What are threats that you believe the San Marcos River faces? And what are the potential impacts to come from these threats?

The river faces several threats, primarily related to water quality and quantity**.** Nonpoint source pollution increases as the landscape around the river and in the San Marcos watershed become urbanized and if poor land use practices are allowed to continue. Water quality sampling in the upper portion of the river has shown increased levels of several types of pollution, such as total dissolved solids and bacteria. These are likely to increase every year if no action is taken. Another important issue or potential threat to the river is recreation. Without adequate laws and regulations in place, tubers and people who recreate along the banks leave hundreds of thousands of pounds of garbage, cause increased sediment in the water and harm fish and wildlife habitat. The river is mostly spring fed and as the drought continues and people irresponsibly draw down the aquifer, the level of the river decrease (which also happens to concentrate pollution).

2. What do you believe are the potential impacts to come from these threats?

Impacts include degraded water quality (and potentially high cost of cleaning up the river if preventative measures like the Upper San Marcos Watershed Protection Plan and the Habitat Conservation Plan are not undertaken), degraded and lost habitat for fish and wildlife and a loss of revenue/change in culture – people come to San Marcos, do business and live in San Marcos because of the pristine and beautiful river.

3. What are some strategies you believe will help cope with these potential impacts?

Comprehensive water quality protection efforts are critical. Development and growth needs to be regulated to ensure that it is smart, green and sustainable. Education of residents and students is also important. People don’t protect what they don’t know or understand.

Interviewee 5

1. What are the threats that you believe the San Marcos River faces? And what are the potential impacts to come from these threats?

In my opinion, main threats to the San Marcos River are overuse by recreational users (rafters and tubers) and potentially diminishing inflow water supply from aquifer. I don't know of any strategies that would be effective in ameliorating the threats and also be accepted by local residents and businesses.

2. Do you believe that the fast urbanization, now deeming San Marcos the fastest growing city in the Nation poses a threat?

Urbanization in the form of more people moving and residing here could contribute to excess recreational use. Other urban-related issues such as run-off may not be as big a problem given that the river has a fairly good buffer zone along its length through SM.

3. What are some strategies you believe will help cope with the potential threats and impacts?

Impacts are deteriorated water quality, which in turn affects habitat quality for various aquatic organisms

Interviewee 6

1. What are the threats that you believe the San Marcos River faces? And what are the potential impacts to come from these threats?

Mostly just the usual threats, such as water use, agriculture runoff (nonpoint pollution), urban-associated point source, and some nonpoint urban runoff. However there are two more unusual factors causing impact, one a legacy and the other ongoing. These are the invasive species left over from the aquarium industry use of the river and the ongoing, sometimes intense recreational usage, especially in the upper reaches of the river. I see the recreation as both opportunity for protection and a potential source of minor threat.

2. Do you believe that the fast urbanization, now deeming San Marcos the fastest growing city in the Nation poses a threat?

Despite the growth, the city seems focused on doing what it can to protect the river. If the attitude toward protecting the river was confrontational, I would consider it a much worse problem.

3. What do you believe are the potential impacts to come from these threats?

I am assuming you mean from the city and growth. Just the usual water quality issues, but again the city (and university) seems to understand the importance of protecting river quality. The presence of endangered species in the uppermost reaches probably helps drive home the need for protection.

Interviewee 7

1. What are the threats that you believe the San Marcos River faces? And what are the potential impacts to come from these threats?

There are hundreds, but springflow is probably the most important, since without good springflow, no use in worrying about litter or anything else. We have to have water in the river, for it to be a river. Drought and the possibility that we are in one of those very long droughts, which we know happened historically from tree ring studies, is very worrisome. We are doing many projects to help springflow as part of the HCP or Habitat Conservation Plan for the Edwards Aquifer, but we started these projects in the middle of the drought, so they are not "filled" yet. So we are not fully ready with all our protective strategies, and we are hoping that it will rain this winter. Many climatologists have predicted a wet winter, and we hope they are right. If the aquifer does not rise quite a bit this winter, we will start next spring at a lower level in the aquifer than we had last spring. So next summer could be disastrous for SM and Comal springs.

2. Do you believe that the fast urbanization, now deeming San Marcos the fastest growing city in the Nation poses a threat?

Oh yes, the land above our springs, out Lime Kiln Road, is very vulnerable to development as SM grows. We are working to preserve land there. That is mostly recharge zone and we need it to remain open and vegetated land to help ensure recharge to our springs, when it rains. We don't want to ever see this land urbanized. Urbanization brings hydrocarbons from roads and autos, herbicides and pesticides from lawns, and lots of sewage leaks from pipes put in trenches sawed right into the recharge zone. All this contamination, once trickled into the aquifer with rainfall, cannot be cleaned up. The aquifer is not a big pool of water, it is water in cracks and holes of porous limestone rock. It can't be pumped out and cleaned and pumped back in once contaminated, in order to keep our springs flowing and clean. Also, runoff flows into the river from every spot in town, taking all the litter with it and all the nonpoint source pollution as well.

3.What are some strategies you believe will help cope with these potential impacts?

Buy land and preserve it. Educate people about littering, lawn care, install filters in places where storm drains empty to the river to catch litter, hydrocarbons, sediment from construction projects, and keep after our sewage lines to be sure they are not leaking.

Interviewee 8

1. What are the threats that you believe the San Marcos River faces? And what are the potential impacts to come from these threats?

I believe the San Marcos River faces a host of threats from development, pollution, litter, overuse by humans, drought conditions, non-native species that have been introduced, siltation from construction, and wastewater effluent discharge.
Poorz water quality thus loss of endangered species habitat, increased costs for municipalities to treat water for drinking, lowered recreational potential, negative economic impacts, and aesthetic demise.

2. Do you believe that the fast urbanization, now deeming San Marcos the fastest growing city in the Nation poses a threat?

Yes. Construction sites have had an unfortunate history of doing a poor job of keeping sediment from leaving their sites and entering the river causing unnatural gravel bars, covering wild rice, and causing the water to become murky. The murky water hampers sunlight from reaching plants such as the wild rice causing them damage. Development not only near, but far away, such as parking lots and asphalt rooftops send run-off into ditches and creeks which eventually feed into the river taking with it petroleum products and anti-freeze. Development creates impervious cover which since water rapidly into the river causing flooding to be more common the's damaging plants along it's shoreline that would typically hold soil in place. Development over the recharge zone creates impervious cover that does not allow water to naturally percolate slowly and be filtered moving into the aquifer that feeds the San Marcos Springs. It also brings with it the opportunity for there to be brakes and leaks in waste water lines and human effluent entering the aquifer when septic systems fail or are poorly designed or maintained. Development where there was none before, such as homesites & businesses, change the landscape from a natural organic one, often to one that is laden with pesticides, fertilizers, and various other chemicals. All of these potentially make it either into the aquifer and are discharged in the springs, or find their way into run-off that eventually flows into the river.

3. What are some strategies you believe will help cope with these potential impacts?

Stricter development regulations, education, limitations on pumping from the aquifer, restoration of native plants and animals, and removal of non-native plants and animals. I believe there should be a great demand to increase the efficiency of water systems by working diligently to upgrade water distribution systems before they age to the point of leaking, being vigilant about repairs, encouraging or mandating water restrictions not only in times of drought but at all times. I believe there should be landscaping restrictions and education that native lawns require far less, if any, water to maintain. I believe strongly that building a very dense development is far greater than urban sprawl. You can accommodate many people living, working, eating, and plating in vertical development causing infrastructure to be much more efficient. Although I don't believe all of the apartments in San Marcus are designed well, I disagree with many that are opposed in

general to apartment complexes being built in San Marcos. (I won't get into placement as that is a separate issue) If you took every unit that was in every apartment complex in San Marcos and turned it into a single family household with a lawn, you would have incredible sprawl and a city many times the size it already is. This would bring with it the additional burden of roads, wastewater lines, impervious cover, chemical intensive lawns, increased water usage, and a host of other problems.

Interviewee 9

1. What are the threats that you believe the San Marcos River faces? And what are the potential impacts to come from these threats?

Over pumping of groundwater affecting spring flow, introduction of non-native plants and animals, urban runoff, and irresponsible over recreational use. At present, storm runoff with non-point pollution and physical destruction of habitat due to some peoples irresponsible use of the river (garbage, physical tromping through sensitive vegetation, bank erosion). The direct disturbance of the endangered Texas wild rice by trampling and uprooting can be problematic in localized area with high recreation use (i.e., City Park, Rio Vista).

2. Do you believe that the fast urbanization, now deeming San Marcos the fastest growing city in the Nation poses a threat?

Yes, anytime you start to exceed about 10 percent imperious cover in a watershed, you start seeing impacts to water quality, also as population density increases in San Marcos, the sheer numbers of people using the river increases and can cause physical damage.

3.What are some strategies you believe will help cope with these potential impacts?

Education and outreach, imposition of the existing State Scientific Areas which has been a great success, continued TWR restoration efforts by removal of non-native aquatic vegetation and planting of TWR, and continued riparian system restoration and bank stabilization to reduce fine sediment runoff into the river.

Interviewee 10

1. What are the threats that you believe the San Marcos River faces? And what are the potential impacts to come from these threats?

Changes in land cover and an increase in impervious cover is a threat to the river. With increasing impervious cover more pollutants taken up, there is greater erosion, and steeper banks. Creating exponential problems. Imperviousness disrupts hydrology. It causes flooding, erosion and water pollution It decreases the base flow of streams and increases greater nutrient concentration. Also tearing up of the riparian vegetation is a

problem. This vegetation/the roots hold the bank. Recreation tends to create unstable banks. Another problem the river faces is invasive species which is being addressed with the habitat conservation plan.) There are 8 federally endangered species in the river. The water is constantly clear, clean, flowing at a specific temp and pH and has a unique good water quality and that's how they survive.

2. Do you believe that the fast urbanization, now deeming San Marcos the fastest growing city in the Nation poses a threat?

I believe it could be a problem if we let it get out of our hands. We need to utilize low impact development. If you look at Austin, they are currently spending lots of money. They are buying back land from buildings and returning it to natural state to get back infiltration because of their water resource problem.

3.What are some strategies you believe will help cope with these potential impacts?

Using low impact development by using drainage/hydrology as a design element (keep water where it falls), minimize the quantity and rate of runoff, promote infiltration where appropriate, reduce/minimize/disconnect impervious areas, and use less toxic materials. As for climate change the ways to off set it and offset damage to water quality, urban heat island effect if you put in green infrastructure and break up impervious areas and vegetation buffers then you lower these effects and have less water evaporation and more infiltration.