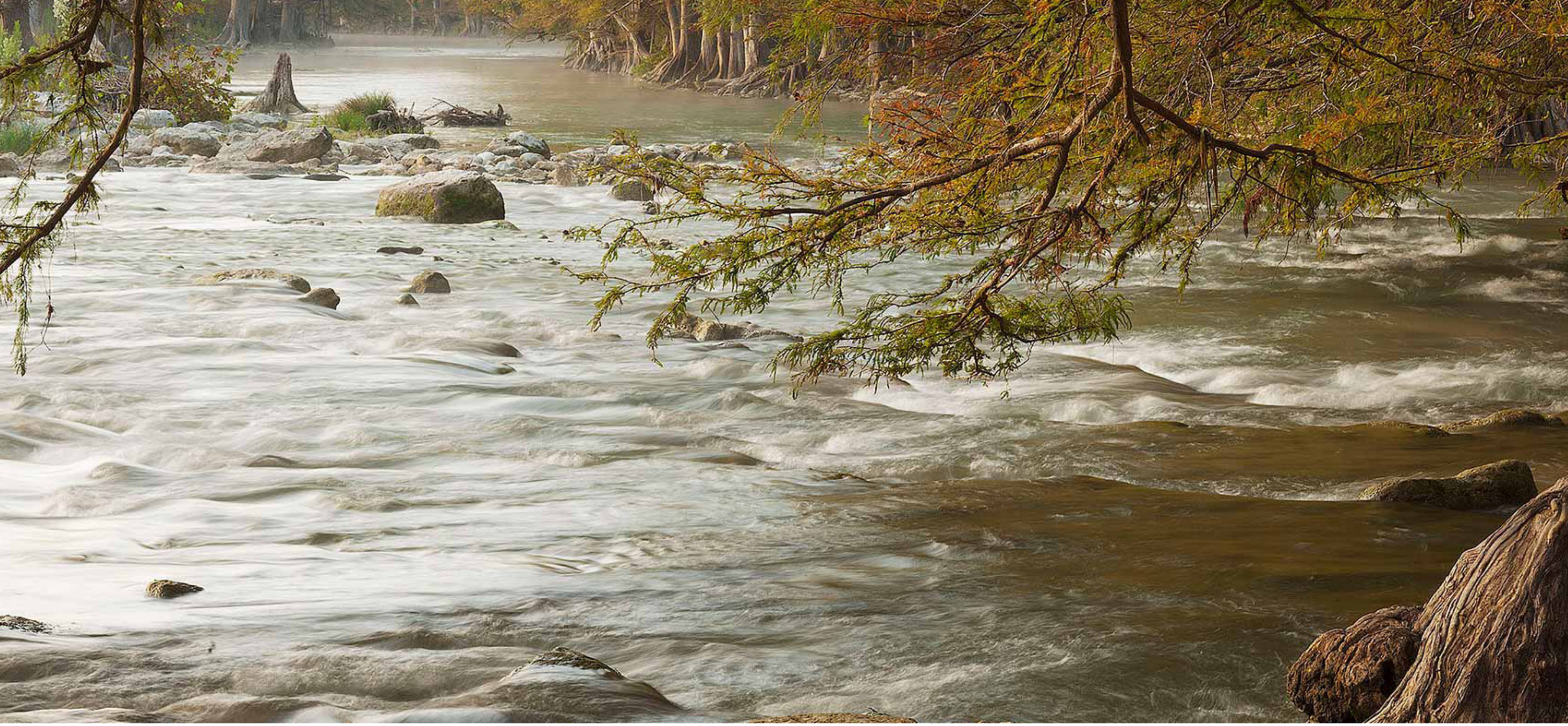

GUADALUPE RIVER BASIN STRATEGIC CONSERVATION PLAN

Produced for the Meadows Center for Water and the Environment
with support from the Texas Parks and Wildlife Department and the Cynthia and George Mitchell Foundation
by Siglo Group
Fall 2019

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THE MEADOWS CENTER FOR WATER AND THE ENVIRONMENT
TEXAS STATE UNIVERSITY

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The mission of the Meadows Center for Water and the Environment is inspiring research, innovation and leadership that ensures clean, abundant water for the environment and all humanity.

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Siglo Group uses the power of geographic information to help clients integrate land use with natural systems. Siglo specializes in conservation planning, regional analysis, site assessment, cartography, and spatial analysis. Their work has contributed to land being set aside in perpetuity for conservation, policies, and projects that work towards more sustainable land use, good development, and a greater understanding of the attributes and value of land.

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The Texas-based Cynthia and George Mitchell Foundation is a grantmaking foundation that seeks innovative, sustainable solutions for human and environmental problems. The foundation works as an engine of change in both policy and practice in Texas, supporting high-impact projects and practices at the nexus of environmental protection, social equity, and economic vibrancy.

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PROJECT GOALS

1. Provide an overview of the Guadalupe Basin, its relevant history, land use changes, and significant natural resources to inform conservation efforts and support thoughtful decision making.

2. Utilize advanced data analysis methods to identify areas of highest conservation value within the Guadalupe Basin.

3. Identify conservation opportunities that help protect the water supply and natural resources of communities and wildlife within the Guadalupe Basin.

4. Recommend paths forward that support the protection and efficient use of water, cultural, and ecological resources.

5. Provide information that facilitates implementation, fundraising, and education, as well as on the ground conservation and restoration activities that are the outcome of the next phase of the project.

Photo courtesy Texas Parks and Wildlife Department © 2006

SUMMARY

The Guadalupe River Basin provides ecological value and natural resources to over 600,000 and growing basin residents. Ecologically, it is home to numerous endemic species, along with Guadalupe bass and freshwater mussels. Furthermore, it empties into the San Antonio Bay, where one of the most endangered bird species in the world—the Whooping Crane—breeds every winter. The basin also provides ecosystem services that are vital to human communities. Surface and groundwater provide drinking water, while open, unpaved spaces have the demonstrated ability to mitigate flood damage. Numerous cultural resources are provided by the basin, including farming, ranching, hunting, birdwatching, fishing, and recreation. However, rapid growth around several highway corridors threatens to substantially degrade the Guadalupe Basin, limiting the river's ability to provide these services.

By analyzing the distribution of these valuable natural resources, the Guadalupe River Basin Strategic Conservation Plan is intended to assist the Meadows Center for Water and the Environment and its conservation partners in taking a strategic, proactive approach. The goal of this work is to safeguard resources in the region by identifying the most advantageous lands for protection. This project assessed over 3 million acres of land in the Guadalupe Basin using a geographic procedural model. Model inputs included variables associated with water, cultural, and ecological resources. These inputs were used to identify and rank potential conservation areas (Figure 1). Those areas with the highest rank reflected the confluence of multiple, high-value conservation resources, and therefore, are prime areas to effectively and efficiently apply conservation dollars. The top 10% of these prioritized lands (approx. 380,000 acres) include habitat for Guadalupe Bass, freshwater mussels, flood mitigation lands, lands adjacent to existing open space, ranchlands, areas threatened by development, and riparian corridors, as well as numerous other conservation resources (Figure 2). Specific highlights of the areas identified as top priority for conservation include:

- Approximately 350,000 acres of Native Fish Conservation Areas;
- A complex of 40,000 acres at the headwaters of the Guadalupe River;
- 30,515 acres in the Edwards Aquifer Recharge Zone surrounding San Marcos and New Braunfels;
- 31,273 acres of lands within the Western Gulf Coastal Plains.

The identification of these top priority areas addresses a critical planning gap for conservation. Planning gaps are areas for which conservationists require additional data-based research regarding where to effectively and efficiently apply their resources. Research results are then utilized for inter- and intra-jurisdictional decision making. By conducting this evaluation of multiple resources across the landscape and the impact of land use trends on them, this report supports conservationists in the Guadalupe Basin in closing this planning gap. Once the decision-making process is complete, conservationists will address the implementation gap, which is the space between knowing what needs to be done and determining how to do it. This stage of conservation planning involves identifying mechanisms for completing the work, potential partners, and methods to facilitate conversation between partners. In addressing the planning and implementation gaps, conservationists can utilize a proven framework for moving projects from conceptualization to implementation. This analysis can serve as a catalyst for that work to begin.

This analysis has multiple strategic advantages. First, the breadth of conservation resources represented by any prioritized area allows for a variety of distinct conservation-focused groups to partner in land conservation initiatives. Furthermore, by conserving any top priority area, conservation practitioners are positioned to meet their own objectives along with numerous other ecological goals. Finally, top priority areas represent an efficient pathway to apply limited conservation resources in order to achieve high-impact results. By focusing conservation efforts on the lands prioritized here, the Meadows Center and its partners will be well-equipped to support the conservation of valuable land throughout the Guadalupe River Basin. In doing so, the Meadows Center will support the basin's continued health and ensure that vital natural resources are available for future generations.

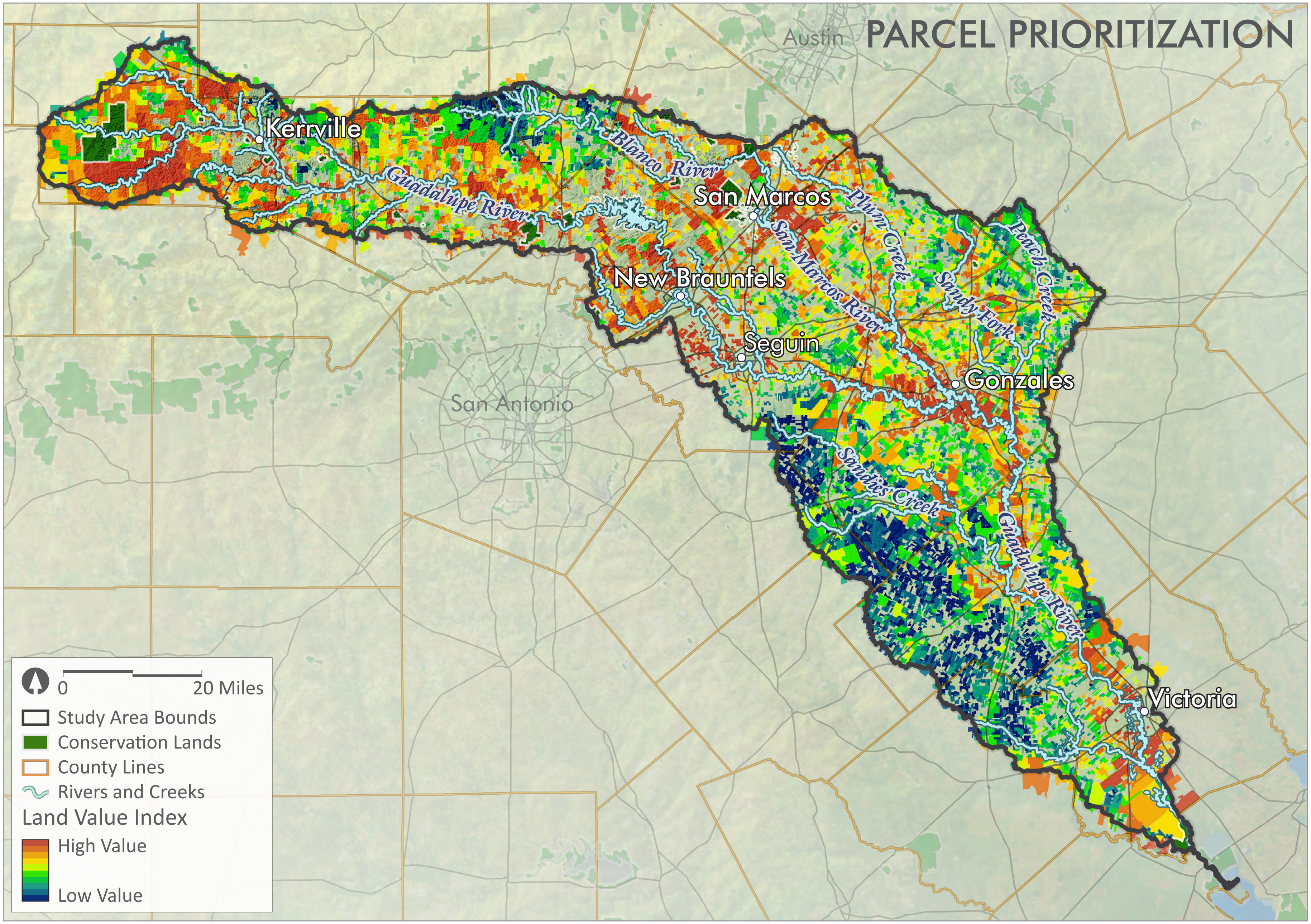


Figure 1. Parcel prioritization based on the average Land Value Index of each parcel in the Preferred Conservation Scenario.

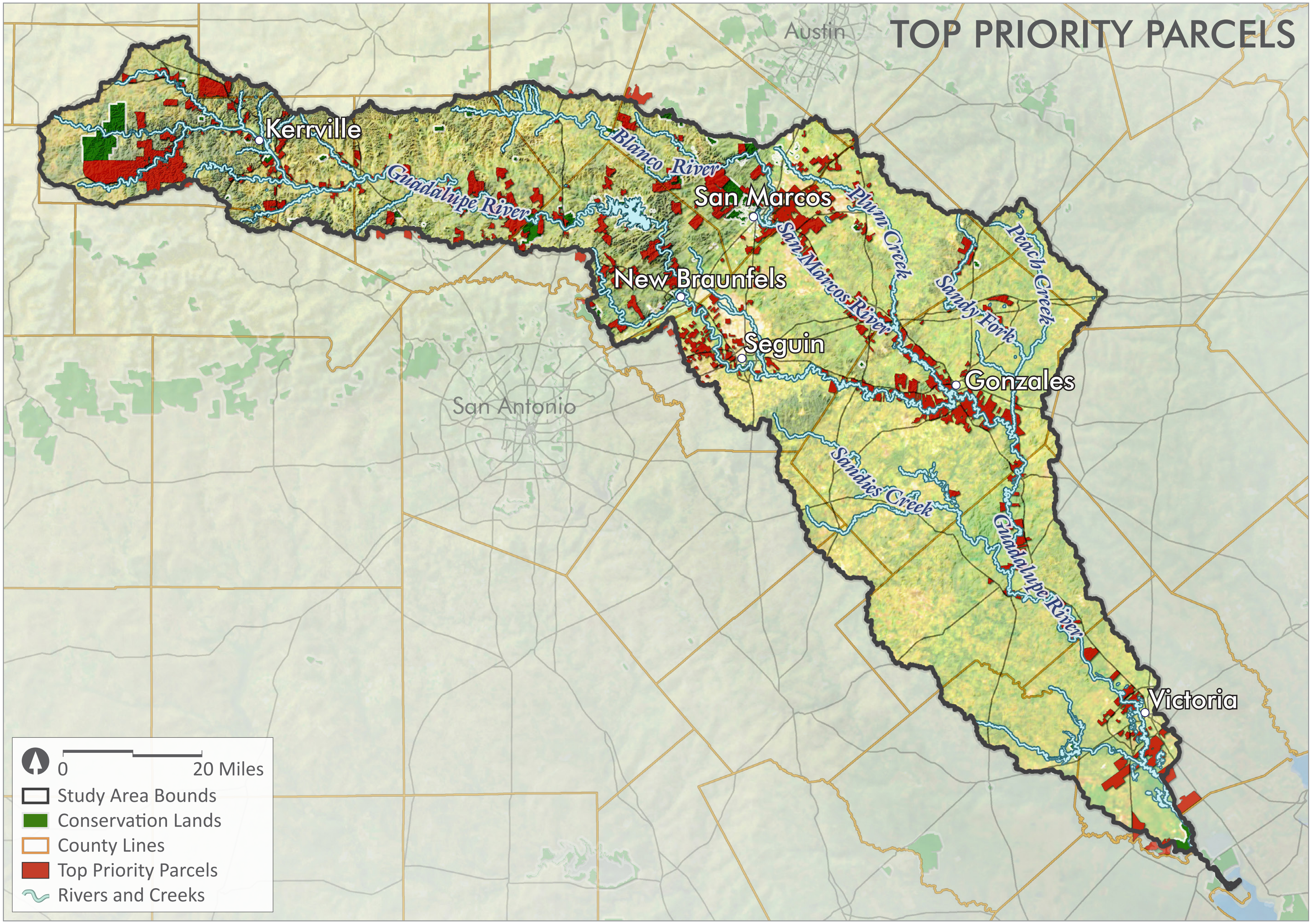


Figure 2. Top priority parcels are the parcels with the highest average Land Value Index together totaling 10% of the study area.


Photo courtesy of the Meadows Center

INTRODUCTION

A well-functioning environment provides the numerous services upon which community health is built. The Guadalupe River and its surrounding basin provide fresh water, flood control, species habitat, recreational opportunities, and natural beauty.[1] Currently, the Guadalupe River is a healthy body of water, capable of providing these services. However, ongoing growth around the I-35, I-10, and 281 highway corridors threatens to decrease the basin's ability to provide these vital services. Furthermore, the Texas Water Development Board (TWDB) predicts that the steady growth of cities within the Guadalupe Basin will increase water demand by 33% over the next 50 years.[2] It is imperative that residents respond to this information and adjust course by planning and implementing systems that utilize conservation to enhance health and livability. This will require a concerted and persistent strategy. The Guadalupe River Basin Strategic Conservation Plan addresses this need by delivering a data-based analysis of regional lands and identifying areas that are of the utmost importance for conservation.

Prioritizing and conserving key areas of land has precedence. Studies and historical accounts have demonstrated that the conservation of water, ecological, and cultural resources serves as a cost-effective way to meet a wide variety of societal needs. As far back as the 1800s, emerging cities across the U.S. made substantial investments to protect the lands adjacent to their water supply sources. As a result of these historic investments, basins in the Catskills, Sierras, Cascades, and their foothills continue to provide safe drinking water for millions of Americans to this day.[3] This same process is currently occurring throughout the country and even in our own backyard. The City of San Antonio's Edwards Aquifer Protection Program[4] is a prime example of water-focused conservation in Texas and has led to more than 200,000 acres being permanently conserved to date. Much of this acreage was identified through a geographic procedural model[5] similar to the one utilized in this study.

With a wider lens, Native Fish Conservation Areas (NFCAs) represent a mechanism to prioritize conservation lands throughout Texas and the country. This ecologically-focused conservation work targets fish species of interest and creates a mechanism to move conservation from a reactive to a proactive process, allowing for more efficient use of financial resources over the long-term. This work can then be implemented through on-the-ground conservation actions, as determined through a stakeholder process.

For cultural resources, success has already been demonstrated by federal and state farm and ranchland protection programs. Through partnerships with private landowners, these programs have allowed for the protection of open lands while allowing the landowner to continue farming and ranching, thus meeting a broader societal need.

Action-oriented conservation initiatives such as these must strike a balance between the protection of natural resources and economic opportunity if they are to be successful. This project aims to assist the Meadows Center for Water and the Environment and watershed conservation partners by taking a strategic, proactive approach to conserving resources in the Guadalupe Basin. The Guadalupe River Basin Strategic Conservation Plan is intended to serve as a guide to future conservation efforts in the region. It provides a site description, historical context, known and potential site values, data analysis, and geographic modeling results. These methods are flexible and allow for repeat evaluations, enabling results to be revised as new information comes to light or as conservation opportunities and priorities change. This information is intended for use by stakeholders, decision makers, and conservation practitioners at the local, regional, and state levels. Its intended outcome is to assist stewards in applying their limited resources to the preservation of areas with the richest conservation value and to catalyze grassroots efforts.

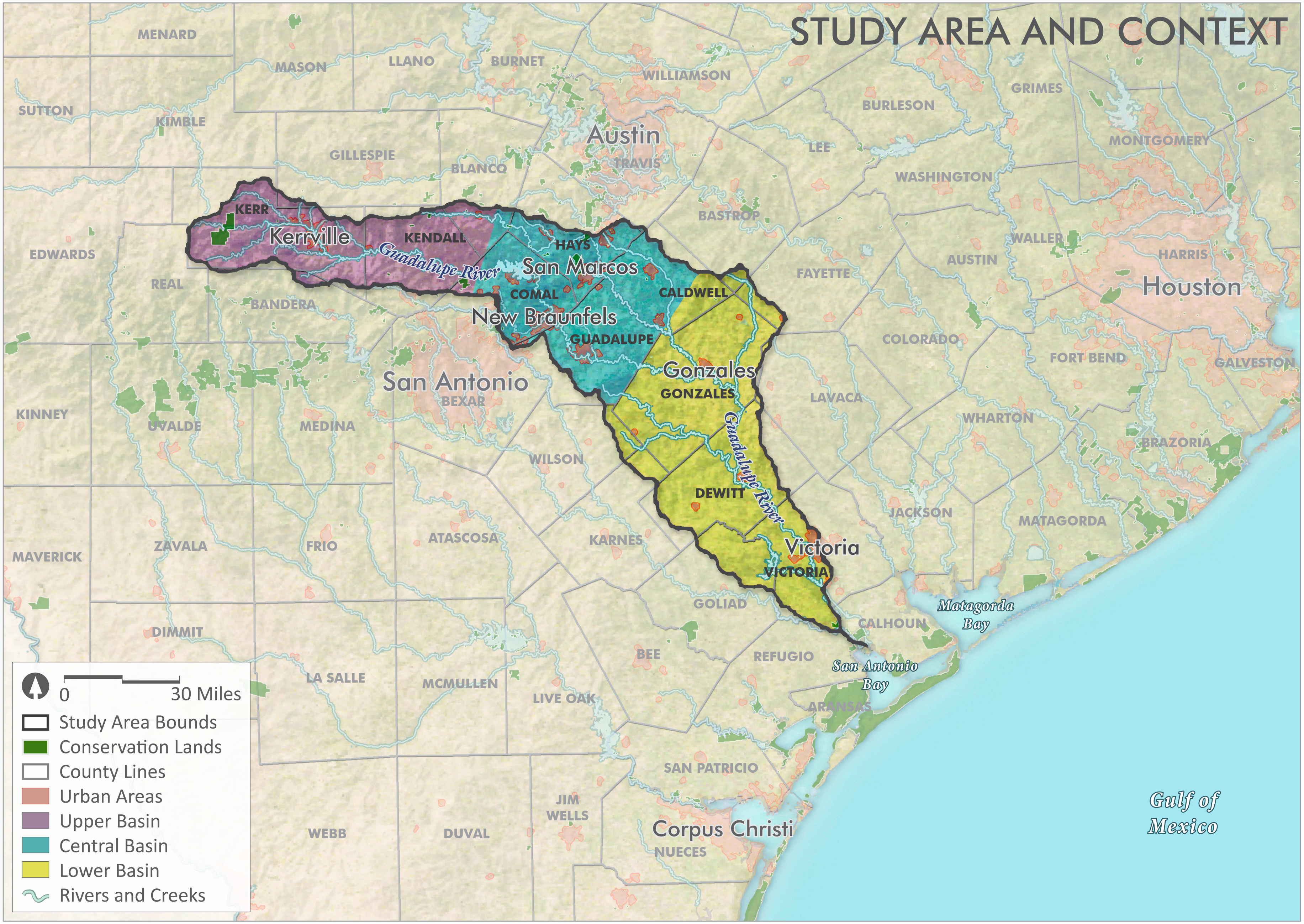


Figure 3. Context map of the study area.

GUADALUPE BASIN STUDY AREA

The study area extends from the Hill Country to the coast and is defined by the flow of water into and through the Guadalupe River Basin. The northwest boundary of the study area begins at the headwaters of the Guadalupe River, west of Kerrville. It extends east to the cities of San Marcos and New Braunfels and south toward the cities of Seguin, Gonzales, and Victoria, ending at the Gulf of Mexico. The major tributaries of the Guadalupe River are the San Marcos, Blanco, and Comal rivers. Major creeks include Johnson, Geronimo, Plum, Peach, Sandies, and Coleto creeks. Counties with significant area within the basin include Kerr, Kendall, Comal, Hays, Caldwell, Guadalupe, Gonzales, DeWitt, Victoria, and Calhoun (Figure 3).

EXISTING CONSERVATION LANDS

Currently, the study area has 54,034 acres identified as park or conserved lands—accounting for approximately 1.4% of the study area. These lands include open spaces for recreation, preserves, state parks, and privately conserved areas. Major owners of conserved land, based on acreage, include the Texas Parks and Wildlife Department (TPWD), Texas State University System, Bat Conservation International, City of San Marcos, City of Kerrville, Kendall County, Guadalupe-Blanco River Authority, and the City of Seguin. Additionally, conservation easements are held on privately owned lands by the Nature Conservancy, the Natural Resource Conservation Service (NRCS), the Guadalupe-Blanco River Trust, the Texas Land Conservancy, and the Hill Country Conservancy.

Of the many conservation methods available, conservation easements have become a powerful tool for bringing together willing landowners and conservation organizations. Over the past four decades, these partnerships have resulted in over one million acres being put into conservation in Texas. In the Guadalupe Basin, conservation easements make up approximately half of all conserved land. Conservation easements allow the landowner to maintain ownership and, in many cases, continue traditional agricultural practices, while preserving open space and the vital natural services our state depends on such as flood control, wildlife habitat, and clean drinking water. These conservation easements are complemented by the acquisition of key conservation lands by private conservation organizations or by public agencies. In many cases, these preserves and parks allow for recreation and interactions with nature along with the protection of critical resources. Numerous city and state parks are scattered throughout the study area, providing open space for residents as well as habitat for flora and fauna.

Future conservation work can be guided by understanding the current state on conservation in various regions and counties within the study area. The county with the most conserved land in the basin is Kerr, with a total of 19,370 acres. Of the counties that fall primarily within the basin, the one with the least conserved land in the basin is DeWitt, with 157 acres. Wilson, Lavaca, Fayette, Bastrop, Gillespie, Bandera, Travis, and Karnes Counties fall partially within the basin, but have no conserved land within the basin. By combining conservation easements with fee simple purchases and landowner engagement, stewards have the potential to form an interconnected network of open spaces that help mitigate the effects of rapid suburban development and contribute invaluable ecosystem services to their surrounding communities.

Upper Basin

There are 27,057 acres of conserved land in the Upper Basin, which includes 13 conservation easements that protect 13,826 acres. Land trusts working in the Upper Basin include Texas Land Conservancy, The Nature Conservancy, Cibolo Conservancy, Guadalupe-Blanco River Trust, Green Spaces Alliance of South Texas, and Hill County Land Trust.

Stowers Ranch, located in Kerr County, is the largest conservation easement in the basin (10,620 acres). The property includes 1.5 miles of

Guadalupe riverfront, springs, as well as habitat for rare Black-capped Vireos, Golden-cheeked Warblers, and Guadalupe Bass. The conservation easement was donated in 2007 by G. A. Stowers' descendants to The Nature Conservancy.[6]

Adjacent to Stowers Ranch is the 6,500-acre Kerr Wildlife Management Area established by TPWD in 1950. This area is used to research, develop, and manage wildlife habitats. TPWD uses information from this area to advise resource managers, landowners, and other interested groups or individuals on best practices for wildlife habitat management.

Located in Kendall and Comal counties, the Guadalupe River State Park is the largest contiguous state park in the study area, with 1,940 acres of land in conservation. It lies adjacent to Honey Creek State Natural Area, which increases the combined conserved area to 4,200 acres. Guadalupe River State Park was purchased from private owners in 1975 and serves as habitat for diverse wildlife including raccoons, white-tailed deer, golden-cheeked warblers, and many migratory birds.

Central Basin

There are 20,229 acres of conservation land in the Central Basin, which includes 15 easements protecting over 6,000 acres. Land trusts active in the Central Basin include Texas Land Conservancy, The Nature Conservancy, Hill County Land Trust, Hill Country Conservancy, the Guadalupe-Blanco River Trust, and the Wimberley Valley Watershed Association.

The largest conservation easement is 2,239 acres in Hays County. It is within the Edwards Aquifer Recharge Zone and protects riparian areas along the shores of the Blanco River. The second largest easement is 1,401 acres in Comal County. This property protects valuable riparian areas along the Guadalupe River and large areas designated as prime farmland soils.

Freeman Ranch, managed by the Texas State University system, is comprised of over 3,000 acres. The land is intended for farm, ranch, game management, educational, and experimental purposes, and is home to the Texas State Forensic Anthropology Research Facility, an experimental and teaching farm devoted to sustainable practices. The academic use of this property has resulted in nearly 60 academic publications.[7]

The Kerr Wildlife Management Area provides habitat for numerous birds, including the Golden-cheeked Warbler. Photo by Bettina Arrigoni (License: https://creativecommons.org/licenses/by/2.0/legalcode)

Spring Lake Preserve is another noteworthy green space in the region—not necessarily due to its size (it's 251 acres), but due to its proximity to Spring Lake, the headwaters of the San Marcos River.[8] This preserve is also visited by endangered Golden-cheeked Warblers, which nest in the Ashe juniper and oak found on site. In an effort to protect these rare birds, some trails in the vicinity are closed every spring.[8] Several archeological digs have taken place around this site, which has greatly increased the public's interest in the history of San Marcos and has yielded artifacts dating back 13,500 years.[9]

Overall there is not a great deal of conserved land in the Central Basin when compared to counties both north and south of the Guadalupe Basin, where major conservation efforts have already led to the protection of hundreds of thousands of acres within the Edwards Aquifer Recharge Zone. Since 1992, Travis, Bexar, Hays, and Kendall Counties have each passed ballot measures dedicating money to conservation, however, Comal County has not. Over $300 million of the bond funds approved by San Antonio voters have already gone toward protecting lands in Edwards Aquifer Contributing and Recharge Zones in Bexar, Medina, Uvalde, Bandera, and Real Counties.[10] By bringing additional lands into conservation, aquifer protection can be greatly enhanced in the Central Basin.

Lower Basin

There are 6,748 acres of conservation land in the Lower Basin, which includes 3 easements that protect 4,249 acres. The region has two active land trust—Pines and Prairies Land Trust and Guadalupe-Blanco River Trust. Additionally, publicly owned properties account for 716 acres and include Palmetto State Park and Coleto Creek Park.

Palmetto State Park, opened in 1936 by TPWD, conserves 246 acres of Post Oak Savannah in Gonzales County. The park features numerous riparian areas surrounding water bodies including the San Marcos River, which runs through the park, and Oxbow Lake. Flora and fauna include dwarf palmetto, red buckeye, and over 240 species of birds.[11]

Coleto Creek Park are owned by the Guadalupe-Blanco River Authority and account for approximately 470 acres of conserved lands in the Lower Basin. The park contains a reservoir which, at normal pool elevation, contains 3,100 surface acres of water and is bordered by 61 miles of shoreline. Common activities at the park include fishing and hiking.[12]

ECOLOGY

Ecoregions

The Guadalupe River travels through multiple ecoregions between its headwaters and the Gulf of Mexico (Figure 4). Along this path, elevation, soil type, soil depth, and rainfall vary widely. Annual precipitation averages about 30 inches west of Kerrville and exceeds 40 inches near the mouth of the river. The Balcones Escarpment divides the Guadalupe Basin into the Edwards Plateau to the west and the prairies and plains to the east. Portions of the basin in the Edwards Plateau have elevations exceeding 2,400 feet. Thin soils, often less than 10 inches deep, support a complex of savannah plant communities dominated by oak and juniper. Adjacent and east of the escarpment is the Blackland Prairie with deep, fertile,

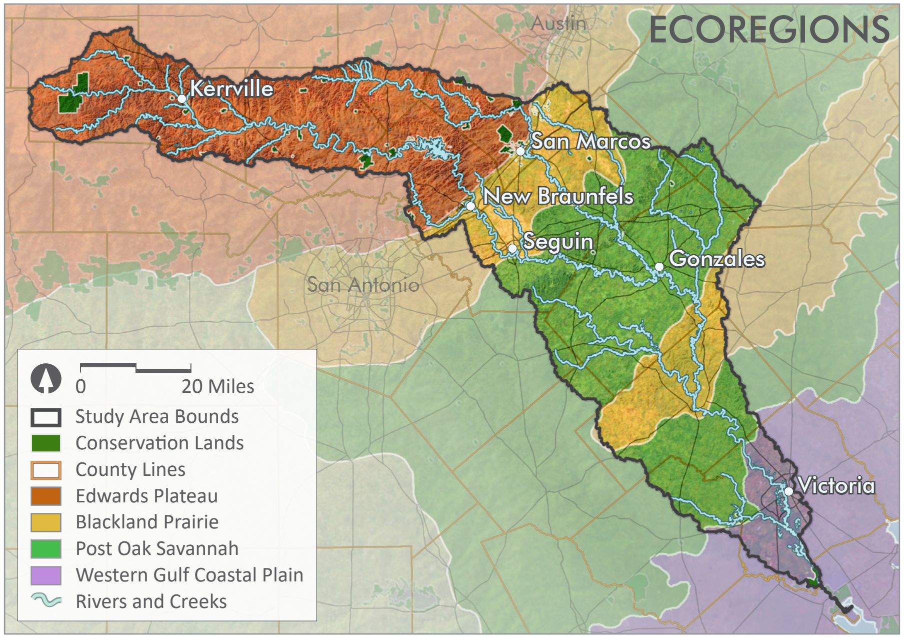


Figure 4. Ecoregions in the Guadalupe Basin. Mapped based on EPA Level III Ecoregions.

dark alkaline clay soil that historically supported an expansive tall grass prairie that included big bluestem, little bluestem, and Indiangrass. Farther east is the Post Oak Savannah, which is characterized by rolling, light colored, slightly acidic, sandy soils that support mottes of post oaks and savannahs of bunch grasses. The river then flows into the Western Gulf Coastal Plain where the river estuary turns to marsh.

Flora and Wildlife

The Guadalupe Basin contains many plant and animal species that are uniquely adapted to its varied ecoregions. These species, along with other generalist species, work together to form an integrated web of biodiversity that sustains the living systems of the basin. Many of these species are captured as conservation resources and were used in the conservation planning process.

Biodiversity in the Upper Basin

The Edwards Plateau, the iconic ecoregion of the Texas Hill Country, covers the entire Upper Basin and is home to more than 100 of Texas' threatened plant species. Protected valleys shelter isolated populations of Texas madrone, Texas smoke tree, witch hazel, and big-tooth maples; while river corridors are lined with bald cypress, pecan, hackberry, and sycamore. This region is host to some of the most spectacular wildflower blooms in the state, featuring bluebonnets, Indian paintbrush, gaillardia, and golden wave to name a few. The Upper Basin is also home to the Golden-cheeked Warbler, which builds its nests from old-growth Ashe juniper trees.

> **The eastern edge of the Edwards Plateau is filled with abundant springs and supports a large number of rare plant and animal species.**

Along the banks of the Hill Country's rivers, riparian forests flourish and provide oases for swimming and play. These forests include tree species such as cedar elm, bur oak, sycamore, and bald cypress; while drier upland areas more commonly support Ashe juniper, Texas persimmon, and mountain laurel. In the rocky ravines of the basin, canyon forests dominate and are characterized by Ashe juniper, Texas oak, Texas ash, and cedar elm.[13] Because of the multitude of species that are endemic to the Hill Country, many of which thrive around the seeps and springs that originate here, healthy riparian habitat in the Hill Country is uniquely important.

Biodiversity in the Central Basin

The Central Basin includes the transitional zone between the Edwards Plateau and the Blackland Prairie. The eastern edge of the Edwards Plateau is filled with abundant springs and supports a large number of rare plant and animal species. Some of these areas, like the massive upwelling of springs at the headwaters of the Comal and San Marcos Rivers, contain unique plant and wildlife communities that have co-evolved in these particular habitats. There are eight known species listed as endangered or threatened by the U.S. Fish & Wildlife Service and Texas Parks & Wildlife Department that live in the San Marcos region of the Edwards Aquifer, Spring Lake, and the upper four miles of the San Marcos River.[14] These species include the Comal Spring Dryopid Beetle, Peck's Cave Amphipod, San Marcos Gambusia, Comal Springs Riffle Beetle, Fountain Darter, San Marcos Salamander, Texas Blind Salamander, and Texas Wild Rice.[14] As suggested in many of their names, all of these species are endemic to Central Texas. The Fountain Darter fish and Comal Riffle Beetle, for example, are found only in the Comal and San Marcos Rivers. In the San Marcos River, another rare Texas endemic, Texas Wild Rice, provides habitat for the Fountain Darter. Both the Fountain Darter and Texas Wild Rice are on the federal list of endangered species.[15,16]

The Central Basin also includes a strip of Blackland Prairie running along the eastern edge of the I-35 corridor. It's estimated that a healthy Blackland Prairie supports over 500 species of plants and animals with complex interdependencies.[17] These deep, fertile soils, characteristic of the Blackland Prairie, made it a prime location for agriculture, drawing homesteaders from across the US to farm its soils. However, with over 99% of Blackland Prairie being converted to development or agriculture, this ecosystem is at risk of disappearing completely.[18]

Biodiversity in the Lower Basin

The Guadalupe River flows south through the Lower Basin before emptying into the San Antonio Bay and Gulf of Mexico. Along its way, it passes through the Post Oak Savannah, Blackland Prairie, and Western Gulf Coastal Plains ecoregions. The Post Oak Savannah is characterized by patches of oak woodland interspersed amongst grasslands. Post, bur, blackjack, chinkapin, and southern red oaks are common in this ecoregion, where wild turkeys feed on their acorns.[19] In the southernmost portion of the Lower Basin, the coastal plains have notably more annual precipitation than other ecoregions of the Guadalupe Basin. The Western Gulf Coastal Plains ecoregion supports a wide variety of vegetation—ranging from red chokecherry to Texas madrone—and animal species such as muskrat, mink, gulls, terns, and pelicans.[20]

As the Guadalupe River leaves the Western Gulf Coastal Plains, it empties into the San Antonio Bay, and subsequently, the Gulf of Mexico. Freshwater inflow to this bay is critically important because this aquatic habitat, at the far eastern end of the Guadalupe Basin, supports a crab population upon which one of the most endangered bird species in the world, the whooping crane, feeds. These majestic cranes winter in the Aransas National Wildlife Refuge in the San Antonio Bay. As of 1941, there were only 15 remaining in the world.[21] However, over many decades, the wild whooping crane population has increased due to a concerted breeding effort aided by both human intervention and legislation. The State of Texas continues to monitor both water flow and estuary health in order to maintain this vital habitat.[22]

The Guadalupe bass. Photo courtesy The Meadows Center © 2018, Jennifer Idol.

Biodiversity in the Guadalupe River

The Guadalupe Bass

Within the greater context of conserving and protecting habitat for wildlife species throughout the region, this project emphasizes protecting suitable habitat for Guadalupe bass (*Micropterus treculii*) as a focal species for conservation. The Guadalupe bass is an endemic fish species found only in streams of the Edwards Plateau ecoregion.

As an apex predator, they serve a vital ecological role in regulating prey populations and ensuring population genetic health by removing weak individuals.[23,24] Species that the Guadalupe Bass preys upon include Ephemeroptera, Megaloptera, crayfish, and other fish.[25,26] Among these species, Ephemeroptera (mayflies), Megaloptera (lacewings), and crayfish are particularly well-known for their ecological contributions, which range from improving water quality to recycling nutrients to serving as important food sources for numerous other species.[27–29] Ephemeroptera and Megaloptera are also frequently used as indicator species for stream health. By regulating these species, Guadalupe bass increase the resiliency of the ecosystems in which they are found. Many gaps in knowledge remain regarding the full breadth of the ecological contributions made by Guadalupe bass and much more is yet to be discovered.

Culturally, Guadalupe bass are important due to their position as the state fish of Texas and as a TPWD Species of Greatest Conservation Need. Further, almost half of all anglers, contributing to the estimated $71 million/year in value associated with recreational angling in Central Texas, target this species.

Between 1970 and 2000, studies revealed that this species was extirpated from portions of its native range due to stream habitat alteration and hybridization with the non-native, introduced smallmouth bass.[30] However, over the past two decades, TPWD has made a concerted effort to restore the Guadalupe bass by stocking nearly one million individuals of this species in the Guadalupe River Basin and restoring its original habitat. Due to these efforts, the Guadalupe bass has returned to parts of its native range, but the fate of the Guadalupe bass is still tenuous.

Today, the TPWD continues this work through the implementation of a 10-year conservation plan for the species.[30] This plan offers a well-defined framework for planning and measurement, with a major goal of restoring native Guadalupe bass populations. The Guadalupe River Basin is a primary management unit in the plan, which is used by TPWD to guide investments in Guadalupe bass restoration through programs such as the Landowner Incentive Program, Texas Farm and Ranch Lands Conservation Program, and the River Access and Conservation Areas Program.

Native Fish Conservation Areas

Another initiative that benefits both the Guadalupe Bass and other species of concern are Native Fish Conservation Areas (NFCAs), a TPWD initiative. NFCAs are habitats (terrestrial or aquatic) that adequately support: (1) the maintenance of processes that create habitat complexity; (2) the protection of all life stages of the priority species; (3) the long-term persistence of these species; and (4) a framework for sustainable management over time.[31] Individual NFCA units are composed of high value stream segments that have similar species composition. These NFCA units can serve as the building blocks of a cohesive conservation action program for sets of native fish species' 'strongholds.' Together, they facilitate proactive conservation action by providing a spatial- and assemblage-based framework for communication and coordination.[31]

Freshwater Mussels

The Guadalupe River is home to a number of freshwater mussel species, some of which are threatened—including the Guadalupe orb, Guadalupe fatmucket, and false spike. Not only are mussels the most globally threatened freshwater organism, but they also perform invaluable services in their aquatic habitats.[32] Mussels are considered "ecosystem engineers" because they modify their aquatic habitat by filtering water, making it more suitable for themselves and others. They feed on organic material in the water, thus building their body and shell and excreting nutrients that are available for other plants and animals. Even after a mussel dies, its shell continues to act as a substrate for algae and insect larvae and as food for fish, birds, and racoons.[33] Major threats to freshwater mussels include habitat destruction, habitat fragmentation, invasive species, and drought.[32]

WATER IN THE BASIN

In a 2019 study titled, How Much Water is in the Guadalupe?,[34] the Meadows Center identified that consumptive development, improper management, and incomplete knowledge were key threats to the Guadalupe Basin's continued prosperity. These water uses alter the hydrology of the Basin, and have the potential to degrade drinking water supplies, spring flows, and environmental flows. In addition, increases in impervious cover and land development in flood-prone areas escalate flood potential, as well as the severity of flooding.

In years to come, the water supply's quality and quantity will be a primary limiting factor for development and long-term economic prosperity in Central Texas. Furthermore, demand on water, for drinking as well as for other uses, is predicted to increase as the population increases. If kept in good health and managed responsibly, the Guadalupe Basin's surface and ground waters can serve as sustainable, complementary water sources. To achieve this end, new policies and site monitoring should acknowledge the impacts of ground water pumping,[35] impermeable surface expansion,[36] and increased water nitrification and sedimentation.[37,38]

Springs

Springs from the Edwards Aquifer are a significant contributor to the Guadalupe River's flow and include Comal Springs, San Marcos Springs, Hueco Springs, Pleasant Valley Springs, and Jacob's Well. These and other springs contribute to the continuous flows of the Guadalupe, Comal, Blanco, and San Marcos Rivers, which rarely, if ever, run dry. The Guadalupe-Blanco River Authority reported in 2019 that the two largest springs—the Comal and San Marcos—discharge 205,607 and 127,418 acre-feet of water per year, respectively, into the Guadalupe River, accounting for about 25% of the Guadalupe's total flow.[39] However, during periods of drought, this balance shifts. In a 1996 drought, the springs accounted for 70% of the river flow that reached Victoria.[40] The Guadalupe River itself discharges 1.53 million acre-feet of water per year, as measured by the Victoria gauge.

Drinking Water Supplies

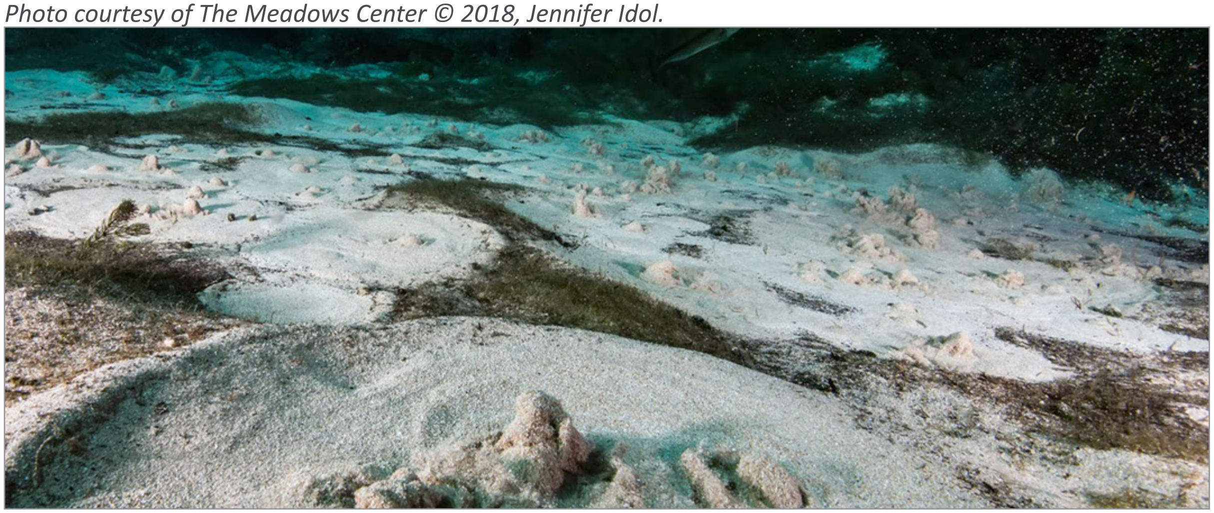
Water flowing through the basin is incredibly important as the drinking water supply for the basin's 633,000 plus residents.[41] Fast-growing urban areas—such as Kyle, San Marcos, and New Braunfels—place pressure on their water resources by allocating water rights permits and drawing surface water for drinking from Lake Dunlap, an impoundment on the Guadalupe River. These same cities also supplement surface water with aquifer groundwater.[42–44] In San Marcos, the standard city water supply is a mixture of 80% surface water and 20% groundwater. When a dam failed in May 2019 and drained Lake Dunlap, San Marcos and Kyle relied entirely on groundwater from the Edwards and Trinity Aquifers.[45] Due to the availability of a clean, alternate water source and redundancy planning, these towns were able to sustain themselves on aquifer water for multiple days. The dam failure and the subsequent municipal response highlights how resiliency can be enhanced by waterwise resource planning and the availability of multiple healthy water sources.

Due to the availability of a clean, alternate water source and redundancy planning, these towns were able to sustain themselves on aquifer water for multiple days.

Environmental Flows

Extracting water from river systems can have numerous negative impacts on wildlife by decreasing the water flow needed to sustain various ecosystems, known as environmental flow. An example of this can be seen along the Gulf Coast. In spite of the restrictions that Central Basin cities enacted during drought conditions, advocates for Whooping Crane protection continually assert that there is insufficient flow to keep the estuary where the cranes winter healthy.[46] Additionally, two species of clam (Genus: *Rangia*) live in the Guadalupe River's estuary system.[47] These clams prefer soft sediment and are non-selective filter feeders. Low freshwater inflow has been shown to decrease sediment deposition, which can result in sediment compaction and erosion.[47] This can have negative effects on the clams' ability to feed. In healthy systems, these clams remove particulate from the water, which greatly improves the water clarity and

San Marcos Springs is one of the Edwards Aquifer springs that contribute greatly to the Guadalupe River's flow. Photo courtesy of The Meadows Center © 2018, Jennifer Idol.



impacts which aquatic flora and fauna can flourish. The clams' presence has been shown to have a significant impact on phytoplankton populations in the Guadalupe Bay and could be effective in ameliorating the negative impacts of eutrophication, a common side-effect of water pollution.[47] Additional monitoring and study are needed for determining precise inflow and outflow rates of the Guadalupe River and ensuring the stability of its ecological health.[34]

Flooding

The Guadalupe Basin intersects a part of Central Texas known as Flash Flood Alley. In this region, the river and its tributaries flow through lands characterized by heavy rainfall events, steep slopes, thin soils, and sparse vegetation, which results in an increased susceptibility to severe flooding. Except for Canyon Dam, the impoundments along the Guadalupe River, many built in the 1920's and 1930's, were not designed for flood control. Major flooding events have occurred in 1869, 1998, 2002, 2004, and 2015, with water levels reaching between 26 to 42 feet above flood stage.[48,49] Flooding in urban areas is costly and upstream development, with its associated impervious cover, exacerbates the likelihood of floods downstream and increases pollution flowing into waterways when flooding occurs.

These ecosystem benefits directly translate to reduced water treatment costs, minimized peak flows during rain events, reduced sedimentation in impoundments, and stabilized waterways.

Conservation and land stewardship on public and private lands have the demonstrated ability to mitigate flood damage by increasing water retention in soil and reducing infrastructure within the floodplain. The outcome of stewardship practices on conservation lands includes stabilized soils, which results in increased infiltration and reduced runoff. These ecosystem benefits directly translate to reduced water treatment costs, minimized peak flows during rain events, reduced sedimentation in impoundments, and stabilized waterways.[50]

Effects of Climate Change

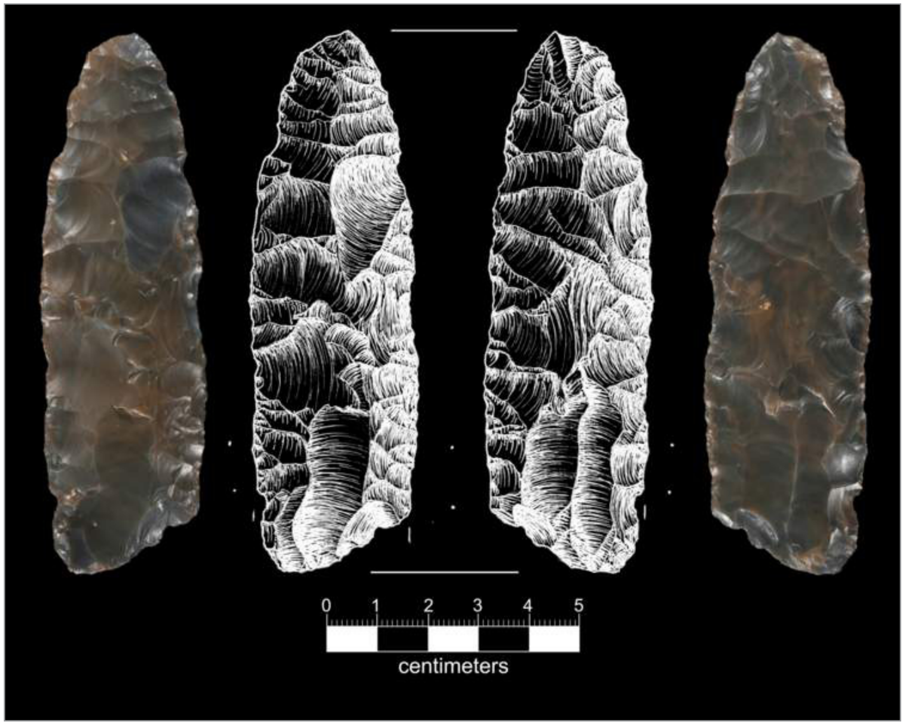
There is a broad scientific consensus that climate change will result in hotter, drier conditions throughout Texas.[51,52] These hotter, drier conditions will likely be punctuated by more extreme rainfall events.[53] Research on the Guadalupe River has projected that river flow will be marked by increased periods of drought and intense, high river flow events.[51] This increased variability in river flow will have important implications for the availability of freshwater and the health of the Guadalupe Basin's ecosystems. Additional research on the Edwards Aquifer has concluded that an increase in temperature would cause an increase in water demand for irrigation and municipal use, but would also increase evaporation, thus lowering runoff and Edwards Aquifer recharge. These projections estimate a 21-33% recharge reduction in drought years and a 24-49% recharge reduction during wet years. Additionally, the Comal springflows are estimated to decrease by 10-16% in 2030 and 20-24% by 2090. This projected reduction in springflow would put the endangered species in the spring emergence areas in great peril. To protect these species and maintain springflow, researchers estimated that pumping should be reduced by 9-20% annually.[54] With the state population of Texas projected to double by 2060 and water demand estimated to increase by 27%,[41,53] it is imperative that government officials, land managers, and stewards alike take these projections into account and spearhead initiatives to conserve the precious water resources of the Guadalupe Basin.

Tens of thousands of Paleo-Indian artifacts have been discovered in Spring Lake, the spring-fed headwaters of the San Marcos River, indicating human activity up to 13,500 years ago.

HISTORY & LAND USE

Relevant Site History

To put the Guadalupe Basin's growth in perspective, the settlement history is presented in chronological order with a final section addressing the impact of the I-35 highway corridor. This historical overview will illustrate why these subregions face differing rates of



A Clovis projectile discovered in Spring Lake. Photo courtesy of The Meadows Center.

growth and how the Guadalupe Basin's settlement history has impacted land use and development patterns.

Indigenous Peoples

The Guadalupe Basin and all of Texas have an extensive history of human settlement. Native peoples lived in Texas for at least 11,000 years before the arrival of Spanish explorers in the 1500s.[55] American Indian tribes such as the Karankawa, Caddo, Apache, Comanche, Wichita, Coahuiltecan, Neches, and Tonkawa are all recorded as living in Texas.[55] In the Central Guadalupe Basin in particular, natural springs have long attracted people to the area. Tens of thousands of Paleo-Indian artifacts have been discovered in Spring Lake, the spring-fed headwaters of the San Marcos River, indicating human activity up to 13,500 years ago.[9,56]

Settlement in the Lower Basin

In the mid-1800's, settlers poured into the Lower Guadalupe Basin, concentrating around the cities of Victoria (on the banks of the Guadalupe, 40 miles inland from the river's mouth) and Indianola (just 30 miles southeast of the basin's southernmost point). Victoria's proximity to several cities—San Antonio, Austin, Houston, and Corpus Christi—and a major port in Indianola made it a commercial hub and regional trade center. Many of the German immigrants who arrived in the US through Indianola's port traveled north and eventually settled in coastal prairies throughout the basin, using wagons to transport farm products back to the port.

Fate arrived in the form of a hurricane in 1875 and nearly destroyed Indianola, which was just a few feet above sea level. After an additional hurricane in 1886 and a fire in 1887, the town was completely abandoned, and the focal point for population growth moved away from the Lower Guadalupe Basin to the Houston-Galveston area (127 miles east). Farming and ranching in the Lower Basin continued, but the loss of a nearby port meant products needed to travel a greater distance. To this day, the population of the Lower Basin is still growing slowly and, in some areas, even declining. The town of Gonzales, for example, lies adjacent to the Guadalupe River and had 7,152 residents in 1980. By 2018, the census reported a population increase of only 500 people.[57] In contrast to the rapid population expansion in the Hill Country and along the I-35 corridor, the Lower Basin does not face comparable development pressure.

Settlement in the Upper Basin

The Upper Basin sits within the Texas Hill Country. As European homesteaders displaced indigenous peoples, newcomers found themselves in isolated communities, like the woodsmen of Appalachia. This rugged lifestyle made for a hardscrabble life, but also offered amazing natural features and wide-open spaces. Prior to the political career of Lyndon B. Johnson, the residents of the Hill Country were captivated by its beauty, but struggled with the poor farming soils and lack of basic services.[58] Johnson spent his childhood in the area, and as he gained political power, he vowed to improve living conditions of the region. As a congressman, Johnson advocated fiercely for a Rural Electrification Loan from the federal government by relaxing its population density requirements. He also

The Upper and Central Basins contain three counties with the highest growth rate in Texas: Comal, Kendall, and Hays.

convinced Hill Country residents to establish their own power cooperatives.

His success transformed the region and catapulted him to the national stage and eventually the presidency. Years later, he still considered the electrification of the Hill Country to be one of his greatest achievements.[58] This work marked a major change in the accessibility of the Hill Country, and the availability of power attracted many wealthy city-dwellers who would transform the landscape. Many of these newcomers created their own private refuges, which increased the region's recognition and established it as a popular tourism hub. Even today, tourists from the US and abroad arrive year-round to experience the beauty of the Hill Country.[59]

Settlement in the Central Basin

The land between Austin and San Antonio, across which the Guadalupe River and its tributaries flow, was sparsely settled until the 1840s, when the counties of the Central basin were established. The land was fertile—existing in the transition zone between the deep soils of the Blackland Prairie and the thin, rocky soil of the Edwards Plateau. However, in contrast to the early farms of the Lower Guadalupe Basin, the only way to export produce was by driving ox carts to the Indianola port nearly 150 miles away. Farms that existed in Hays County produced vegetables and cotton for the surrounding area, and cattle ranches dotted the landscape. In the 1880's the first railroad was built in the county. It, along with additional roads, stimulated additional settlement that resulted in the population of Hays Country growing from 2,000 in 1860 to 14,000 in 1900.[60] Further growth was slow. For the next 60 years, the population never exceeded 20,000. In 1962, Interstate Highway 35 (I-35) was built and changed everything.

The Guadalupe Basin Today

A Growing Population

I-35 is the major north-south transportation corridor within the study area and connects two commutable urban areas—San Antonio and Austin—with over 900,000 inhabitants each.[60] This interstate is a vital link for trade between the U.S. and Mexico, and an estimated 125,000 cars travel north or south daily in the section that passes between San Marcos and New Braunfels.[61] Accessibility in the region increased dramatically after its construction in 1962 and the population of surrounding counties increased rapidly. Highway 281 and I-10 facilitate additional travel through the region and open the door to further development in the north and west corners of the study area. As San Antonio continues to expand along 281 and I-10, with I-35 and Highway 46 providing access, development west of New Braunfels will continue to expand.

The Upper and Central Basins contain three counties with the highest growth rate in Texas: Comal, Kendall, and Hays. Comal County surpassed both Hays and Kendall Counties in 2018, becoming the second fastest-growing county in the country.[62] Comal County runs along the I-35 corridor and New Braunfels, the largest population center in the Guadalupe Basin with 84,612 residents in 2018,[57] has significantly contributed to its growth. Kendall County has shown similar population growth—growing almost 37% since 2010. This growth has resulted in Kendall County being ranked seventh among U.S. counties for population growth, with its largest increase occurring between 2010 and 2018.[57,63] Hays County has over 10 times the population it had in 1960 (estimated at 222,621 in 2018). Between 2010 and 2018 alone, the population of Hays County rose by over 40%, growing from 158,275 to 222,621.[57] This is due in large part to population growth in cities along I-35 such as San Marcos (population 63,509) and Kyle (population 46,874).[57]

If this development continues without thoughtful ecological planning, the characteristics of the Guadalupe Basin—quiet and beautiful landscapes, abundant clean water, and native wildlife—may disappear forever.

In contrast to the rapidly growing counties of the Upper and Central Basin, the fastest-growing counties in the Lower Basin—Gonzales and Victoria—have 5% and 6% growth rates respectively from 2010 to 2018.[57] Although the Lower Basin is experiencing slower population growth, the City of Victoria is still the second largest population center in the basin, with 67,015 residents in 2018.[57]

Central Texas' explosive growth was predicted in a 2005 study that analyzed projected land development changes throughout the southeast U.S. It concluded that development in the I-35 corridor would result in a contiguous blanket of low-density development along its margins.[64] Continued change is also corroborated by predictions made by the TWDB. As part of their planning process, they estimate that population growth in the Guadalupe Basin will more than double in the next 50 years.[41]

Agricultural Production

While agriculture was a major component of what historically brought settlers to the basin, it now plays a reduced, yet still significant, role in the basin. The 10 counties with large areas within the Guadalupe Basin have 3.9 million acres under agricultural production, which generates $839 million worth of farm products.[56] Of this total, $700 million is from livestock and $139 million is from crop sales.[56] Of the $700 million in livestock sales, $400 million comes from poultry farming in the Lower Basin county of Gonzales.[56] When additional cattle sales are factored in, Gonzales County accounts for more than half of all agricultural production in the basin.

Land Use Trends

Current land use conversion in the Guadalupe Basin commonly occurs near population hubs, follows traffic arteries, and encroaches into the open space surrounding urban areas, including aquifer recharge zones and areas traditionally used for ranching and agriculture.[56] If this development continues without thoughtful ecological planning, the characteristics of the Guadalupe Basin—quiet and beautiful landscapes, abundant clean water, and native wildlife may disappear forever.

Changes associated with population increases are occurring most rapidly in the Upper and Central Basin, as compared to the Lower Basin. In the process, large ranches are being fragmented into smaller parcels. Fragmentation is an indicator of increasing population growth and development, with the affiliated infrastructure impacting local water quality and supplies, reducing habitat, and exacerbating flood damage. Highways and pipelines—known as linear developments—are known to negatively impact watershed quality and function,[57–61] fragment habitat,[62,63] damage streams through crossings, disrupt natural drainage systems,[59,64] escalate soil erosion,[65] increase noise pollution,[66,67] and introduce invasive species.[68]

Between 1997 and 2012, counties throughout the basin saw increased fragmentation as larger ranches were broken up into smaller units. The combined area of larger ranches (those over 100 acres) went from 2.9 million acres in 1997 to 2.6 million acres by 2012—a 10% decrease. During the same period, the number of smaller farms and ranches (due to the fragmentation of bigger ranches) increased in total acreage from 181,470 acres in 1997 to 216,582 acres in 2012—a 19% increase.[69] Often these large ranches are sold as families reclaim landlocked wealth near urban centers. These sold lands are then divided—some as small farms and others as future residential development lands.[55]

In the Lower Basin, fracking is a major current driver of land use change. In 2008, the first successful fracking site of the Eagle Ford Shale—one of the richest oil and gas deposits in the US—was established in Cuero, TX.[1,70] This multimillion dollar industry made the City of Cuero, which lies between Gonzales and Victoria, a major hub of oil and gas extraction.[70] Since then, numerous other fracking sites have popped up throughout the Lower Basin counties of DeWitt and Gonzales. The widespread presence of fracking in the Guadalupe Basin has important implications for water health, as this practice requires approximately two million gallons of freshwater each time fracking triggers the flow of oil or gas into a well.[70,71] This may disrupt other commercial uses of water—for industries such as farming and ranching—while impacting the flow and supply of surface water and underground drinking water sources.[1,70] Land use changes such as these impair local natural resources. This prioritization highlights key areas to invest resources and to help sustain the health of the watershed as a whole.

Photo courtesy The Meadows Center © Scott Bauer

METHODS

This project determines conservation priorities for the Guadalupe Basin using a geographic procedural model (Figure 5). The procedure follows methodologies used by the San Antonio Edwards Aquifer Protection Program to determine water resource conservation areas over the Edwards Aquifer recharge and contributing zones west of San Antonio.[5] In addition, the method has been used to prioritize lands for conservation in the Blanco, Upper San Marcos, and Pedernales Watersheds, as well as lands in the Katy Prairie.[81–83] Model inputs include variables associated with water, culture, and ecology. These inputs were used to identify and rank potential conservation areas. Areas with the highest rank reflect the confluence of multiple high-value conservation resources and represent prime areas to effectively and efficiently apply conservation dollars.

Stakeholder engagement was managed through a collaboration with the Meadows Center for Water and the Environment, Texas Parks and Wildlife Department (TPWD), and Siglo Group. The Meadows Center led the effort by inviting key stakeholders, organizing logistics, and moderating discussions for a webinar and an in-person meeting in New Braunfels. TPWD presented information that provided context for the project and explained how the process could fit into state-wide conservation planning and NFCAs. The Meadows Center presented information on water flow within the basin, including areas where flow rates significantly fluctuate. Siglo Group led the discussion regarding conservation planning, the study area, the need for conservation, potential data for use in the assessment, associated conservation resources, and the potential outcomes of the prioritization. Siglo Group also facilitated discussions to determine relative values of potential conservation resources and solicited new potential resources to incorporate into the process from stakeholders.

Numerous stakeholders and professionals provided feedback and data for this process. They helped determine which conservation

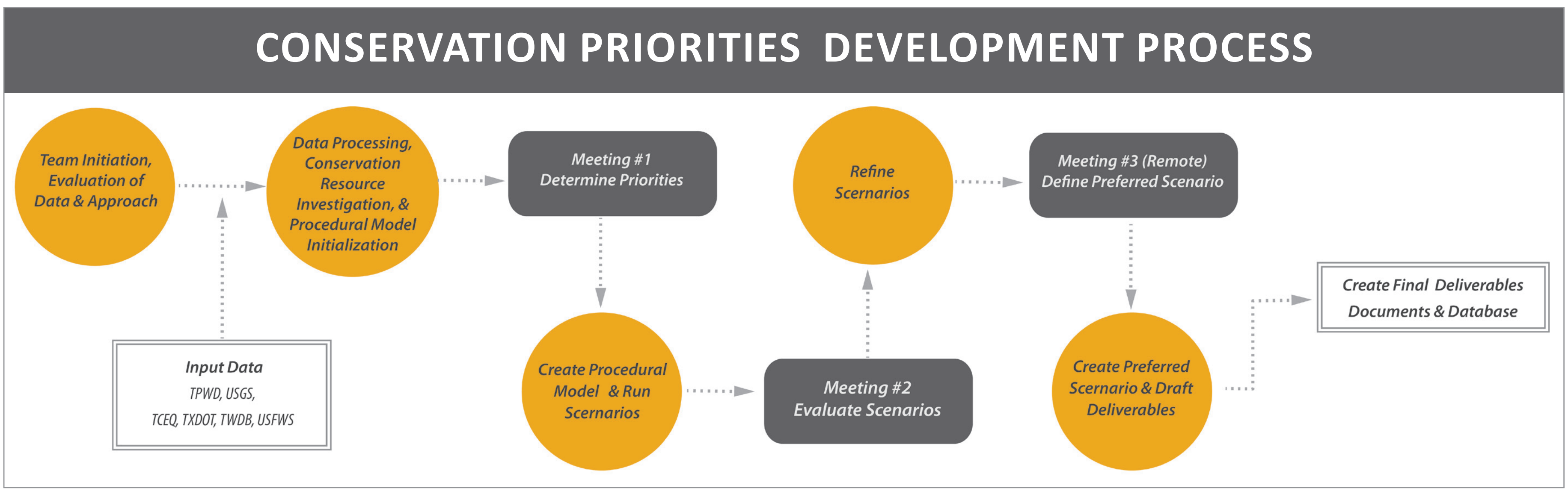


Figure 5. Conservation Priorities Development Process.

resources would be assessed and the relative importance of each resource in the procedural model. Stakeholders included experts and representatives from TPWD, U.S. Fish and Wildlife Service, Texas State University, Southwest Research Institute, Guadalupe-Blanco River Authority, Texas Wildlife Association, City of San Antonio, City of New Braunfels, City of Kyle, Comal County, Comal County Conservation Alliance, Plum Creek Conservation, San Marcos River Foundation, Hill Country Alliance, San Antonio Bay Partnership, Comal-Trinity Groundwater Conservation District, Audubon Texas, and Upper Guadalupe River Authority.

The geographic procedural model used for this study builds upon Siglo Group's previous conservation prioritization projects.[5,81,82] The methodology has been adapted to fit the ecology of the Guadalupe Basin study area and the interests of its stakeholders. In line with these past studies, the Guadalupe model includes the input of conservation resources, the evaluation of priorities through a weighted sum, the display of results at 100-foot resolution, and the averaging of those results within parcels. To evaluate data layers for feasibility of use, data was considered based on its relative importance for conservation, reliability of the source, comprehensiveness throughout the study area, resolution, and temporal accuracy.

The analysis involved running multiple distinct prioritization scenarios, while incorporating stakeholder feedback to refine the effects of individual resources and their relative values (Figure 6). Each time the model was run, it generated a study-wide map, or conservation scenario, consisting of a Land Value Index (LVI) for each 100-foot by 100-foot area, which was then averaged by parcel (Figure 7). These repeated runs also provided a sensitivity analysis of the results, ensuring that no one variable overly

STEPS IN RUNNING THE GEOGRAPHIC PROCEDURAL MODEL

1. **Evaluate and adjust the existing conservation lands file if new lands are conserved or new information is revealed about existing conservation lands;**
2. **Adjust any of the processes as needed;**
3. **Add or delete conservation resources as needed;**
4. **Adjust the values/weights of conservation resources as needed;**
5. **Run model;**
6. **Evaluate Prioritization Results (conservation scenarios);**
7. **Repeat as needed (final result: the Preferred Conservation Scenario).**

Figure 6. Seven key steps form the basis of the conservation modeling process.

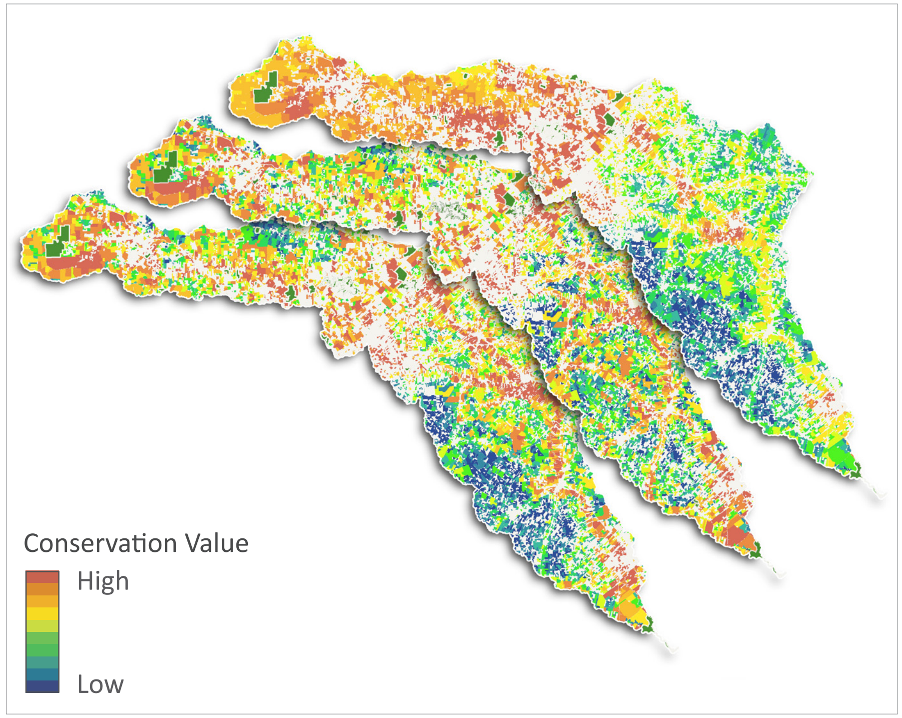


Figure 7. A comparison of several conservation scenario iterations.

impacted the findings. Through this process, conservation resource values were adjusted to create additional scenarios, and to eventually generate the Preferred Conservation Scenario, discussed in the Findings section. Parcels with the highest average LVI were considered to be priorities. The Preferred Conservation Scenario represented the best balance of important conservation resources within the study area.

CONSERVATION RESOURCES

This model utilized data for conservation resources that were considered highly influential in the Guadalupe Basin. For the purposes of the model, these resources were subdivided into three categories: water, cultural, and ecological. Conservation resources and their values can be found in Table 1, while Table 2 provides a justification and source for each resource. Basin-wide distributions of selected conservation resources are shown in Figures 8-13.

Water Resources

Water resources used in the model include: Major Spring Buffers, Aquifer Recharge Areas, Karst Areas, Public Water Supply Surface Intakes, Riparian Areas, and 303D Impaired Waterway Buffers.

Major Spring Buffers represent the vital lands surrounding springs, where freshwater emerges from the earth. These areas support a wide array of flora and fauna, some of which only exist in the unique conditions immediately surrounding springs. Springs are also important hydrologically, draining into rivers and contributing substantially to base flows throughout the basin. Furthermore, they are culturally important outdoor spaces where people gather, swim, and recreate.

Aquifer Recharge Areas replenish aquifers, renewing the freshwater sources that municipalities use for drinking, residential, and industrial uses. Two major aquifer systems contribute to the Guadalupe River—the Trinity and the Edwards. The river is fed by springs from the Edwards Aquifer and to a lesser extent, the Trinity Aquifer. Therefore, maintaining healthy water levels in these aquifers, especially the Edwards, is essential for maintaining sufficient water flow in the river. The Edwards Aquifer is the primary source of drinking water for San Antonio and is expected to become a source of drinking water for several rapidly growing population centers in the basin, making protection of land in the recharge zone, and thereby protection of the water flowing into the aquifer, even more critical.

Table 1. The value of each conservation resource in the preferred conservation scenario of the prioritization model.

	Conservation Resources	Weighting
Water	Major Spring Buffers	High
	Aquifer Recharge Areas	High
	Karst Areas	Moderate
	Public Water Supply Surface Intakes	Moderate
	Riparian Corridors	High
	303D Impaired Waterway Buffers	Low
Cultural	Parcel Size	High
	Proximity to Conserved Land	Moderate
	Development Corridors	Moderate
	Prime Farmland Soils	Moderate
Ecological	Native Fish Conservation Areas	High
	Guadalupe Bass Fish Priority Areas	High
	Mussel Priority Areas	Moderate
	Terrestrial Fauna Ecological Index	High

Karst Areas—defined as limestone landforms characterized by sinks, ravines, and underground streams—are dynamic systems with rapid water conveyance and a limited ability to filter pollutants.[84] These characteristics have a unique and significant impact on water flow and quality, as water moves through the ground and into groundwater sources below.

Public Water Supply Surface Intakes are areas where water quality is of particular importance, because drinking water for communities is

Table 2. The purpose, criteria, and source for each of the conservation resources used in the study.

	Conservation Resources	Purpose and Criteria	Source
Water	Major Spring Buffers	Buffers were placed around major springs to promote the conservation of groundwater and maintain spring flows. Mapping Criteria: 1 mile radius around major springs.	Wierman, D. A., Broun, A. S., Hunt, B. B., 2010, Hydrogeologic Atlas of the Hill Country Trinity Aquifer, Blanco, Hays, and Travis Counties, Central Texas. Hays-Trinity Groundwater Conservation District. Water-Quality Data for Selected Springs in Texas by Ecoregion. 2006; U.S. Geological Survey
Water	Aquifer Recharge Areas	Considered significant for human water supplies and numerous endangered species. Preservation of these lands helps protects the water quality and quantity recharge of connected aquifers and springs. Recharge zones for Edwards, Trinity, and Edwards-Trinity aquifers received different values based on their contribution to the Guadalupe River. Mapping Criteria: Recharge zones for the Edwards (highest value), Trinity (high value), and Edwards-Trinity (moderate value).	Major Aquifers, downloaded 2019 from Texas Water Development Board: http://www.twdb.texas.gov/mapping/gisdata.asp
Water	Karst Areas	High probability recharge/karst features. Preservation of these lands helps protects the water quality and quantity recharge of connected aquifers and springs. Mapping Criteria: Defined for this study as the areas mapped as Lower Glenrose or Edwards limestone.	Barnes, V.E. 1981. Geologic Atlas of Texas. The University of Texas at Austin, Bureau of Economic Geology, Austin, Texas. USGS. 2016. Geologic Atlas of Texas (GAT). Downloaded from https://tnris.org/data-catalog/entry/geologic-database-of-texas/.
Water	Public Water Supply Surface Intakes	Intake areas for public water supply are especially important for water quality. Conservation of this immediate area should be a conservation priority, preventing encroachment of development, point and non-point source pollution. Mapping Criteria: sub-basin 12-digit HUCs upstream of Public Water Supply Surface Intakes.	TCEQ GIS Data downloaded 2017, https://www.tceq.texas.gov/gis/download-tceq-gis-data/#water
Water	Riparian Corridors	Riparian plant communities offer important water quality benefits, high-quality habitat and forage. Mapping Criteria: Areas defined as riparian or floodplain in the Texas Ecological Mapping Systems, FEMA 100-year Flood Zones, and 100-ft buffers around streams flow lines from TCEQ.	FEMA 100-year Flood Zones Viewed and downloaded 2019: https://msc.fema.gov/portal/advanceSearch. Texas Ecological Mapping Systems: TPWD and Missouri Resource Assessment Partnership. 2014. Texas Ecological Mapping Systems of Texas. Viewed and Downloaded 2016: http://tpwd.texas.gov/landwater/land /programs/landscape-ecology/ems/. TCEQ flowlines downloaded 2017, https://www.tceq.texas.gov/gis/download-tceq-gis-data/
Water	303D Impaired Waterway Buffers	Stream segments designated by the TCEQ as 303(d), are water bodies which do not meet designated water quality standards for listed pollutants. In the model these segments were given a 300-foot buffer which serves as a filter to improve water quality, and the accessory benefits of providing habitat and flood mitigation.	TCEQ Impaired Waterways 2014, downloaded 2017, https://www.tceq.texas.gov/gis/download-tceq-gis-data/
Cultural	Parcel Size	Larger sized parcels create valuable contiguous habitat that is required by many species. Over 1,280 acres were given a very high value, 640- 1,280 acres were valued high, 320- 640 acres were valued moderate, and 100-320 acres were given a low value.	County appraisal district shapefiles and tax rolls
Cultural	Proximity to Conserved Land	Incorporated to create larger nodes of conservation that are more effective in protecting resources, supplying environmental services, and creating corridors of open space. Mapping criteria: 400-ft and 1,200-ft buffers around conserved land.	Conservation Lands inventory, Texas Land Trust Council.
Cultural	Development Corridors	Defining areas that will be impacted in coming decades by continued urban and suburban land use. Mapping Criteria: Urbanized areas and 1 mile around major road corridors.	Major roads and urbanized areas, downloaded 2019 from Texas Department of Transportation, http://gis-txdot.opendata.arcgis.com/.
Cultural	Prime Farmland Soils	Prime farmland soils play a crucial role in a robust agricultural system and are an indicator of areas more likely to qualify for state and federal protection programs. Mapping Criteria: Areas considered significant for agricultural production as defined as prime agricultural soil by NRCS	Natural Resource Conservation Service. 2016. Prime Farmland Soils. SSURGO- NRCS-USDA. Downloaded 2016: https://tnris.org/data-catalog/entry/soils/
Ecological	Native Fish Conservation Areas	Native fish habitat or native fish conservation areas (NFCAs) are significant for the health and conservation of endemic fish populations. NFCAs used in the model include the basins of the Llano and Pedernales Rivers, and portions of the Upper and lower Colorado River.	NFCAs based upon findings of Williams et Al. 2011 and Labay and Hendrickson 2014. More information can be found at http://nativefishconservation.org
Ecological	Guadalupe Bass Fish Priority Areas	Included to target distribution areas of Guadalupe Bass. Guadalupe Bass Fish Priority Areas scores from Labay and Hendrickson 2014 were scaled from 0 to 100 to be used in the model.	Fish Priority Areas based upon findings of Williams et Al. 2011 and Labay and Hendrickson 2014. More information can be found at http://nativefishconservation.org
Ecological	Mussel Priority Areas	Prioritize protection of populations of Guadalupe orb, Guadalupe fatmucket, and false spike freshwater mussels. Mussels are ecologically important, filtering water providing food for other animals. Mapping criteria: 600-ft and 1200-ft buffers around current distributions of Guadalupe orb, Guadalupe fatmucket, or false spike. The 600-ft buffer was given a higher score than the 1200-ft buffer.	Based on communication with Gary Pandolfi, US Fish and Wildlife Service.
Ecological	Terrestrial Fauna Ecological Index	Prioritize habitat protection for species of concern. These species are either Species of Greatest Conservation Need or Species of Economic Importance as defined by Texas Parks and Wildlife Department. Mapping criteria: The Terrestrial Fauna Ecological Index aggregates the scores for potential habitat for focal species as defined by Texas Parks and Wild-life Department. The index was scaled from 1 to 100 for use in this model.	German, Carl D., Amie Treuer-Kuehn, and Laura Chapa. 2013-2019. Texas Ecological Indices, in preparation. Texas Parks & Wildlife Department, Austin, Texas.

drawn from them. For this model, the HUC-12 watersheds upstream of Public Water Supply Surface Intakes were used as inputs.

Riparian Corridors were incorporated into the model to protect water quality, water quantity, flood damage mitigation, critical habitat, and foraging grounds for both aquatic and terrestrial species. To account for this, the TPWD Ecological Systems Classification[85] was used to define riparian and floodplain areas. These areas were combined with FEMA 100-year Flood Zones and 100-foot buffers around all streams to capture areas where riparian vegetation and floodplains could be restored.

303D Impaired Waterway Buffers, are the areas around waterways that, as classified by the Clean Water Act Section 303(d), exceed federal limits for total maximum daily loads for nutrients, pollutants, or bacteria. A 300-foot buffer around these stream segments represent areas where additional conversion of land from natural habitat would likely further impair water quality. Conservation and associated land

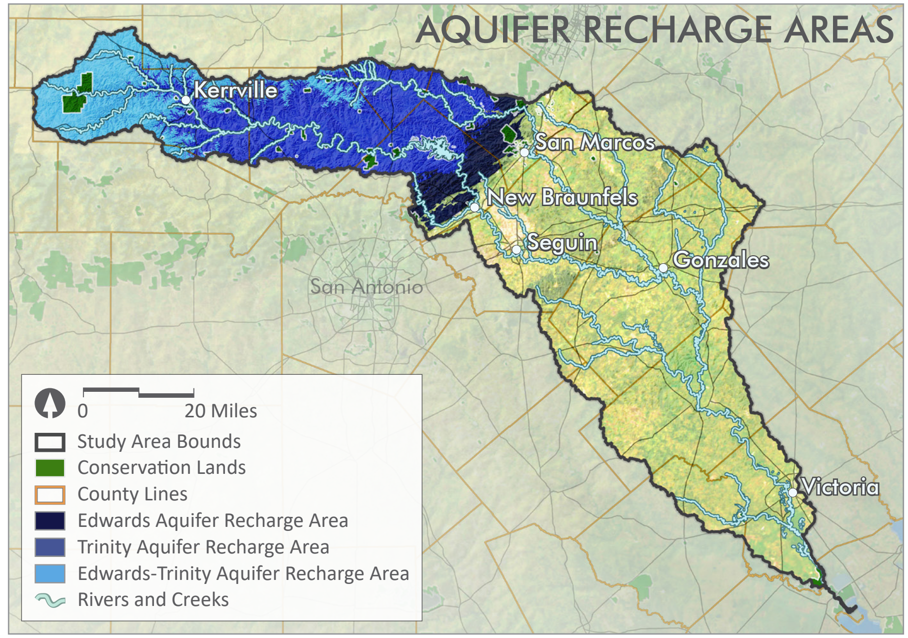
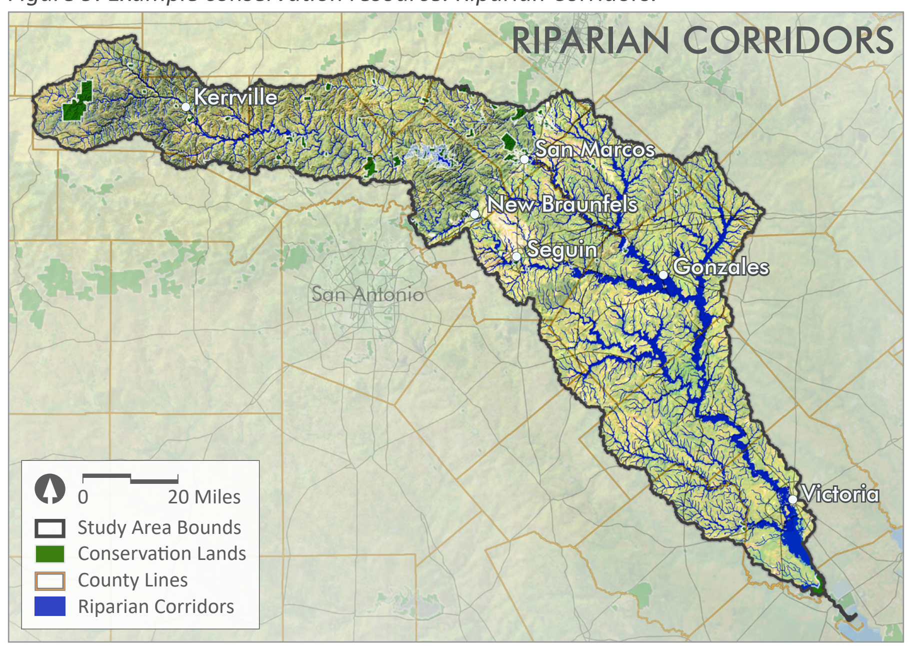


Figure 8. Example conservation resource: Aquifer Recharge Areas.

Healthy riparian corridors are essential for healthy waterways. Photo courtesy of the Meadows Center.

Figure 9. Example conservation resource: Riparian Corridors.



management improvements in these buffer areas could help improve water quality.

Cultural Resources

The cultural resources used in the procedural model include Parcel Size, Proximity to Conserved Land, Development Corridors, and Prime Farmland Soils.

Parcel Size represents how land is divided for ownership. These dividing lines have implications for infrastructure, use, and management. Larger parcels are easier to acquire than several smaller ones, have a proportionally larger effect on hydrology; and can support robust habitat for more species, thereby making land management more efficient.[78] Prioritizing larger parcels underscores the importance of reducing fragmentation (a common side effect of ownership transfer), while allowing landowners and their families to continue living and working on the land.[65] Parcel Size was grouped into 4 classes, with larger parcels assigned higher value as a conservation resource.

Proximity to Conserved Land is a gateway to enhanced open spaces throughout the basin. Expanding existing conservation lands by managing adjacent properties is one of the most efficient and effective ways to increase the impact of conservation lands. Not only does proximity create connections between protected areas across the landscape, it also creates more robust habitat, offers additional wildlife migration routes, reduces management costs, and can provide for greater recreational opportunities. This priority is established by increasing the value of those areas that lie within 1,200 feet of existing conservation lands in the model, with an even higher priority assigned to lands within 400 feet.

Development Corridors represent foci of land use change, as projected development increases over the coming decades. Therefore, this model prioritizes areas with a high probability of development. In the basin, land use change and fragmentation are expected to follow existing patterns, in which subdivisions and intense land use radiates out from municipalities and existing road corridors. Recognizing

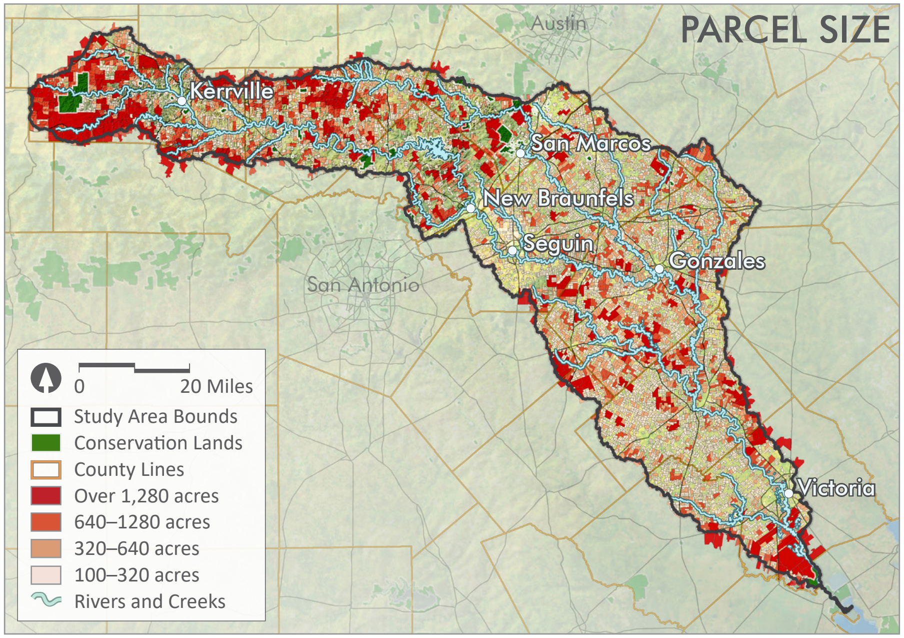
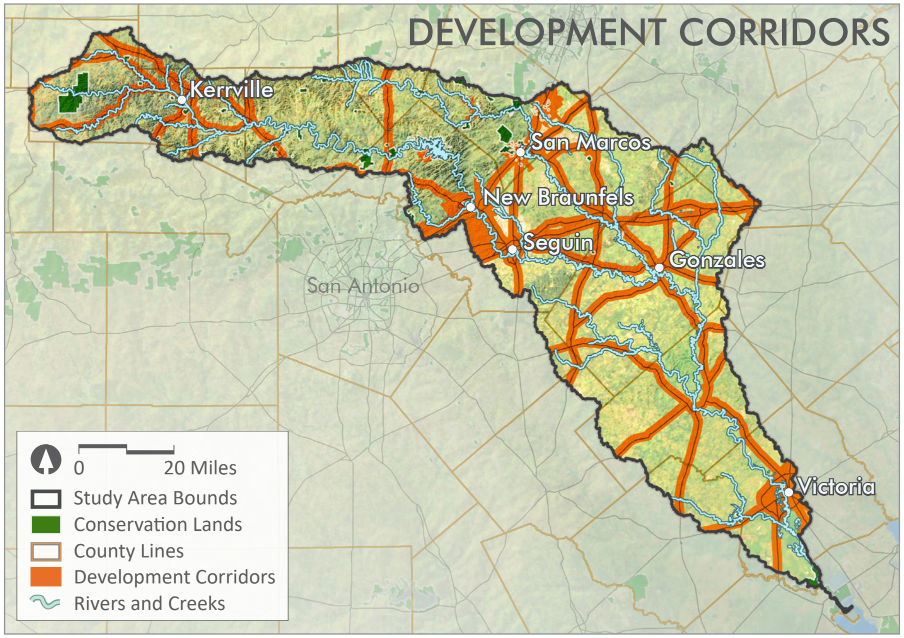


Figure 10. Example conservation resource: Parcel Size.

Figure 11. Example conservation resource: Development Corridors.



this trend and the ability of conservation to shape land use in these areas, opportunity zones for potential conservation were defined as land within urban areas or within one mile of major highways.

Prime Farmland Soils are significant to the future of productive agriculture throughout the country.[86] As development increases and a growing populations' demand for food rises, these fertile soils will become even more important. Additionally, ranching is a prominent cultural cornerstone within the basin and the establishment of wineries represents a growing industry. Prime farmland soils offer immense cultural and economic value, while also providing the open space that many wildlife species consider home.

Ecological resources

Ecological resources include Native Fish Conservation Areas, Guadalupe Bass Fish Priority Areas, Mussel Priority Areas, and the Terrestrial Fauna Ecological Index.

Native Fish Conservation Areas (NFCAs) are the product of a systematic, multi-species method of assessment and prioritization. By providing a geographic framework for conservation action that balances the habitat needs of many species of concern, NFCAs make impactful fish conservation easier to achieve.[31] Species included in the assessment include the Guadalupe Bass (*Micropterus treculii*) and the following threatened or endangered fish: Alligator Gar (*Atractosteus spatula*); American Eel (*Anguilla rostrata*); Pallid Shiner (*Hybopsis amnis*); Ironcolor Shiner (*Notropis chalybaeus*); Burrhead Chub (*Macrhybopsis marconis*); Guadalupe Roundnose Minnow (*Dionda flavipinnis*); Headwater Catfish (*Ictalurus lupus*); Widemouth Blindcat (*Satan eurystomus*); Toothless Blindcat (*Trogloglanis pattersoni*); San Marcos Gambusia (*Gambusia georgei*); Fountain Darter (*Etheostoma fonticola*); Guadalupe Darter (*Percina apristis*); and River Darter (*Percina shumardi*).

Guadalupe Bass Fish Priority Areas are given particular attention in this model due to their unique cultural, ecological, and economic importance. The dataset for this work was based on a spatial distribution model that included climatic, hydrologic, and

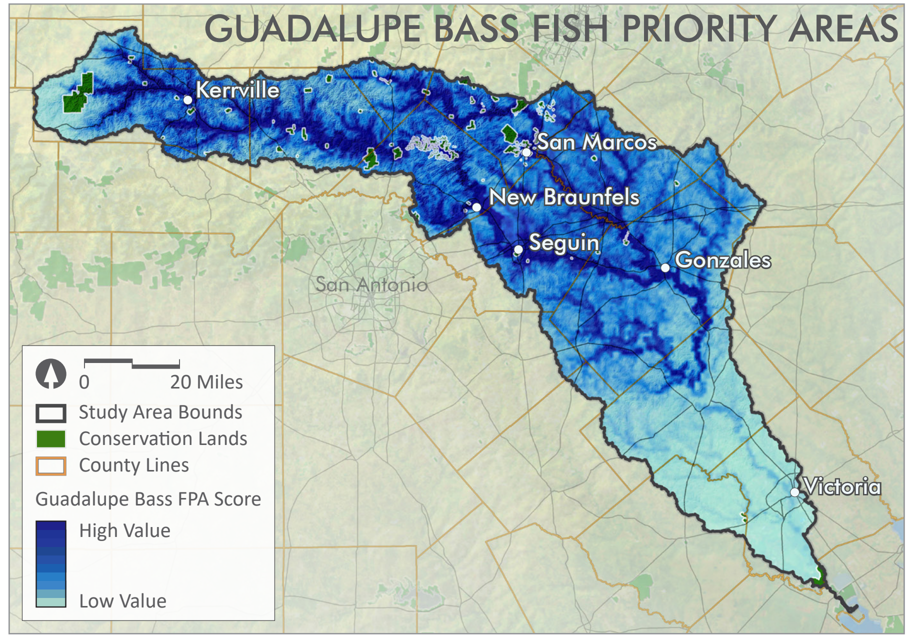
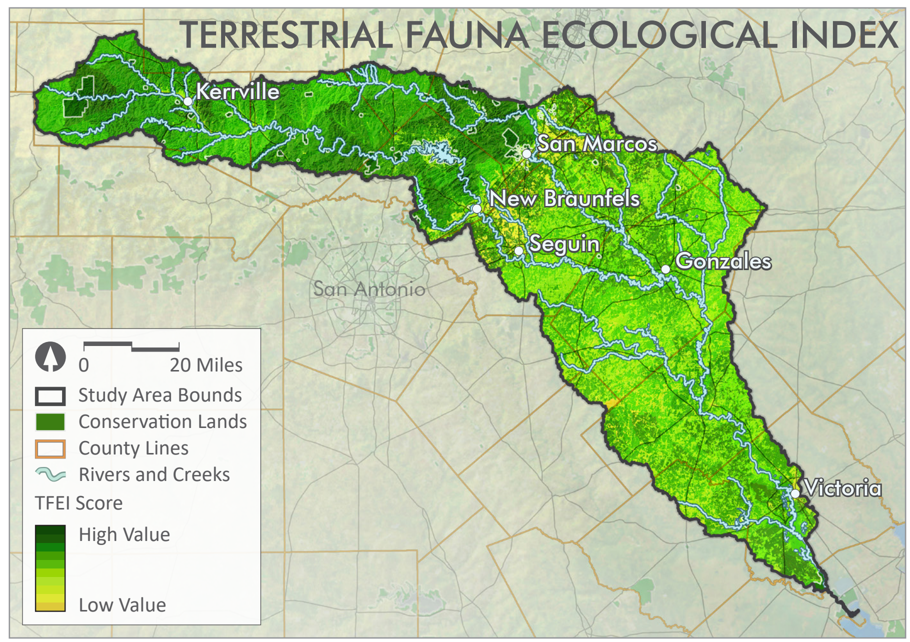


Figure 12. Example conservation resource: Guadalupe Bass Fish Priority Areas.

Figure 13. Example conservation resource: Terrestrial Fauna Ecological Index.



topographic variables to identify high probability distribution areas for this species.[87] The predictions were then constrained based on historical accounts of the presence/absence of Guadalupe bass in particular watersheds.

Mussel Priority Areas are buffers around sections of river with known populations of three priority mussel species: false spike (*Fusconaia mitchelli*), Guadalupe orb (*Cyclonaias necki*), and Guadalupe fatmucket (*Lampsilis bergmanni*). Both the species included and their locations were based on personal communication with Fish and Wildlife Service staff. These priority areas were included because of the vital ecological role mussels play in streams and rivers. As filter feeders, mussels help keep water clear and provide an important food source for other animals. Populations of many Texas freshwater mussels are declining due to: decreased stream flow; sedimentation; contamination; lack of native fish hosts for the mussels' larval stage; and introduction of invasive species such as the zebra mussel.[88]

The Terrestrial Fauna Ecological Index was created by the TPWD, who assessed and assigned a score for various habitat areas based on the range and known habitat preferences of focal wildlife species in each of the four ecoregions. The Edwards Plateau includes 21 focal species, Blackland Prairie includes 25 focal species, Post Oak Savannah includes 27 focal species, and Coastal Prairie includes 45 focal species. For a full list of focal species in the

Table 3. Focal Species in the Guadalupe Basin used in the Terrestrial Fauna Ecological Index.

Scientific Name	Common Name	Edwards Plateau	Western Gulf Coastal Plain	Post Oak Savannah	Blackland Prairie
Aimophila botterii	Botteri's Sparrow		X		
Aimophila ruficeps	Rufous-crowned Sparrow	X			
Ammodramus leconteii	LeContesSparrow			X	X
Ammodramus maritimus	Seaside Sparrow		X		
Ammodramus savannarum	Grasshopper Sparrow				X
Anas acuta	Northern Pintail		X		
Anas fulvigula	Mottled Duck		X		
Anaxyrus houstonensis	Houston toad			X	X
Anthus spragueii	Sprague's Pipit		X		X
Antrostomus carolinensis	Chuck's-will's-widow	X			
Arethaea phantasma	Rio Grande Thread-legged katydid		X		
Automeris louisiana	Louisiana eyed silkmoth		X		
Aythya americana	Readhead		X		
Bombus pensylvanicus	American Bee			X	X
Buteo lineatus	Red shouldered hawk			X	X
Buteo plagiatus	Gray Hawk		X		
Calcarius pictus	Smiths Longspur				X
Cemophora coccinea lineri	Texas Scarlet Snake		X		
Cenophengus pallidus	Glowworm beetle		X		
Charadrius melodus	Piping Plover		X		
Charadrius wilsonia	Wilson's Plover		X		
Colinus virginianus	Northern Bobwhite	X	X	X	X
Conepatus mesoleucus	Hog-nosed Skunk	X			
Cotalpa conclamara	Goldsmith Beetle			X	X
Cotinis boylei	Scarab beetle		X	X	X
Crotalus horridus	Timber Rattlesnake			X	X
Cynomys ludovicianus	Black-tailed Prairie Dog	X			
Cyrtonyx montezumae	Montezuma Quail	X			
Danaus plexippus	Monarch		X		
Dendroica chrysoparia	Golden-cheeked Warbler	X			
Drymarchon melanurus erebennus	Texas Indigo Snake	X			
Dryocopus pileatus	Pileated Woodpecker			X	
Egretta caerulea	Little Blue Heron			X	X
Euglandina texasiana	Glossy wolfsnail		X		
Falco femoralis	Aplomado Falcon		X		
Falco peregrinus	Peregrine Falcon		X		
Geomys personatus	Barrier Island Pocket Gopher		x		
Geomys texensis texensis	Llano pocket gopher	X			
Glaucidium brasilianum	Ferruginous Pygmy-Owl		X		
Graptemys caglei	CaglesMapTurtle			X	X
Grus americana	Whooping Crane		X		
Heterodon nasicus	Western hognosed snake	X	X		
Holbrookia lacerata	Spot tail earless lizard	X			

Table 3 continued. Focal Species in the Guadalupe Basin used in the Terrestrial Fauna Ecological Index.

Scientific Name	Common Name	Edwards Plateau	Western Gulf Coastal Plain	Post Oak Savannah	Blackland Prairie
Holbrookia propinqua propinqua	Northern keeled earless lizard		X	X	
Icterus graduacauda	Audubon's Oriole		X		
Lanius ludovicianus	Loggerhead Shrike		X	X	X
Leopardus pardalis	Ocelot		X		
Lepidochelys kempii	Kemp's Ridly Sea Turtle		X		
Leptodeira septentrionalis septentrionalis	northern cat-eyed snake		X		
Lithobates areolatus (Rana areolata)	Crawfish frog		X	X	X
Litoria infrafrenata	White Lipped Frog		X		
Lutra canadensis	River Otter	X	X		
Macrochelys temminckii	Alligator Snapping Turtle			X	
Malaclemys terrapin	Diamondback Terrapin		X		
Meleagris gallopavo	Wild Turkey		X		
Notophthalmus meridionalis	black-spotted Newt		X		
Numenius americanus	Long-billed Curlew		X		
Ortalis vetula	Chachalaca		X		
Parkesia motacilla	Louisiana Waterthrush			X	
Passerina ciris	Painted Bunting			X	X
Phrynosoma cornutum	Texas horned lizard	X			X
Piranga rubra	Summer Tanager	X		X	X
Pogonomyrmex comanche	Comanche harvester ant			X	X
Protonotaria citrea	Prothonotary Warbler		X	X	
Puma conconlor	Mountain Lion	X			
Rallus elegans	King Rail		X		
Rynchops niger	Black Skimmer		X		
Setophaga dominica	Yellow Throated Warbler	X			
Siren Intermedia	Lesser Siren		X		
Somatochlora magarita	Texas Emerald			X	X
Spilogale putorius	Eastern Spotted Skunk	X	X		
Spiza americana	Dickcissel			X	X
Spizella pusilla	Field Sparrow			X	X
Sturnella magna	Eastern Meadowlark			X	X
Sylvilagus aquaticus	Swamp Rabbit		X		
Taxidea taxus	American Badger		X		
Terrapene ornata	Ornate box turtle	X			
Thamnophis sirtalis annectens	Texas Garter Snake	X		X	X
Tympanuchus cupido attwateri	Greater Prairie-Chicken		X		
Tyrannus forficatus	Scissor-tailed Flycatcher			X	X
Ursus americanus	Black Bear			X	
Vireo atricapilla	Black-capped Vireo	X			
Vireo bellii	Bell's Vireo	X			

Guadalupe Basin, see Table 3.

Photo courtesy of the Meadows Center

FINDINGS

The following section presents the results of the prioritization process and looks at how particular conservation resources are represented in the Preferred Conservation Scenario (Figure 1). These findings are based on current conditions, available data, current best analysis practices, existing conservation lands, and stakeholder input.

Within the Preferred Conservation Scenario, water resources contributed approximately 37% of the value in the model, while cultural and ecological resources each contributed approximately 32% and 31% of the value respectively. The resulting scenario identifies 380,630 acres as top priority conservation areas—approximately 10% of the 3,800,697-acre study area (Figure 2). The Guadalupe Basin study area includes 2,674,263 acres (70%) that are available for conservation, and 1,126,434 acres (30%) that did not meet the criteria for conservation consideration because they were either in developed areas, under 100 acres in size, or already conserved. The top priority areas are characterized by the occurrence of multiple conservation resources in the same location. These areas represent strategic opportunities, where time and money can be put to maximum effect.

Table 4 lists the value of each conservation resource in the model, the total acreage of each resource within the study area, and the percentage of each resource found within the top priority areas. Water resources contained in the top priority areas ranged from 12% to 32% of total resource acreage in the basin. Of these, Public Water Supply Surface Intakes had the highest level of representation, though this is likely a result of its co-occurrence with other conservation resources, as it had only a moderate value in the model. Aquifer Recharge Areas, Karst Areas, and Riparian Corridors had lower levels of representation, though this is largely due to the total amount of these resources within the study area.

Cultural resources ranged from 12% to 33% representation in the Preferred Conservation Scenario. The top priority areas captured 16% of Development Corridors and 12% of Prime Farmland Soils. The largest Parcel Size classification was over 1,280 acres. Of the 231 parcels of that size, 76 were identified as top priority (33%). Additionally, of the 41,488 acres in the buffers created to represent adjacency to conserved land in the study area, 9,342 acres were identified as top priority (23%).

Table 4. Summary of the conservation resources represented within the top priority areas along with the total amount of each resource within the study area.

	Conservation Resources	Total Amount of Resource in Study Area	Amount of Resource in Top priority areas (% of total)
Total	Total Acreage		380,630
	Number of Parcels		876
	Average parcel size (acres)		435
Water	Major Spring Buffers (acres)	8,402	2,209 (26%)
	Aquifer Recharge Areas (acres)	934,782	112,622 (12%)
	Karst Areas (acres)	382,052	64,253 (17%)
	Public Water Supply Surface Intakes (acres)	414,842	131,987 (32%)
	Riparian Corridors (acres)	787,486	137,427 (17%)
	303D Impaired Waterway Buffers (acres)	15,025	3,258 (22%)
Cultural	Number of Parcels Over 1,280 acres	231	76 (33%)
	Proximity to Conserved Land Buffer (acres)	41,488	9,342 (23%)
	Development Corridors (acres)	1,106,671	178,156 (16%)
	Prime Farmland Soils (acres)	1,133,323	130,512 (12%)
Ecological	Native Fish Conservation Areas (acres)	2,975,987	369,655 (12%)
	Guadalupe Bass Fish Priority Areas (acres)	8,274	3,936 (48%)
	Mussel Priority Areas (acres)	119,259	44,065 (37%)
	High Terrestrial Fauna Ecological Index (acres)	389,621	64,249 (16%)

Top priority areas included 48% of areas with high scores for Guadalupe Bass Fish Priority Areas. Photo courtesy The Meadows Center © 2018, Jennifer Idol.

Overall, ecological resources, ranging from 12 to 48%, were most strongly represented in the Preferred Conservation Scenario (Table 4). Top priority areas captured 48% of the areas with a high score for Guadalupe Bass Fish Priority Areas and 37% of Mussel Priority Areas. Lower percentages of the areas with high Terrestrial Fauna Ecological Index scores (16%) and NFCAs (12%) are captured in the top priority areas. For NFCAs, this is due to the extremely large area covered by the resource within the study area (nearly 3 million acres).

Differing patterns of conservation priorities are evident across the basin due to the varied distribution of conservation resources. Below, we investigate the Upper, Central, and Lower Basins individually to further explore the pattern of high value conservation lands in each area.

UPPER BASIN

The Upper Basin includes 116,859 acres of top priority areas (Figure 14). These areas are relatively dispersed, as compared to those in the Central and Lower Basins. This is due in large part to resources such as the Aquifer Recharge Areas, Karst Areas, and NFCAs that cover large swaths of the region. There is still some concentration of priority areas along the Guadalupe River. These areas include Mussel Priority Areas, Guadalupe Bass Fish Priority Areas, Riparian Corridors, and 303D Impaired Waterway Buffers. Many of these areas also fall within the Development Corridor.

Away from the Guadalupe River, many of the top priority areas are large with moderate or high Terrestrial Fauna Ecological Index scores.

Proximity to Conserved Land contributes to the conservation value of some of the top priority areas. There is a cluster of top priority areas around Honey Creek State Natural Area and Guadalupe River State Park (in Comal County), with high conservation value due to their Proximity to Conserved Lands, very high Terrestrial Fauna Ecological Index scores, Riparian Corridors, Guadalupe Bass Fish Priority Areas, and Mussel Priority Areas.

At the headwaters of the basin, a complex of top priority conservation areas covers over 41,000 acres adjacent to over 16,000 acres of existing conservation lands in Kerr County. These areas offer the opportunity to build upon existing conserved land, expanding wildlife habitat and protecting the vital headwaters of the Guadalupe River. Notably, this cluster contains priority areas for the Guadalupe bass and relatively high Terrestrial Fauna Ecological Index scores. Much of this land also occurs within the Development Corridor.

CENTRAL BASIN

The Central Basin includes 136,358 acres of top priority area (Figure 15). This includes 31,275 acres in the Edwards Aquifer Recharge Zone, which is split between 18,121 acres in Comal County and 13,154 acres in Hays County. To the east of the Edwards Aquifer Recharge Zone, top priority areas are primarily small and clustered within the Riparian and Development Corridor, particularly between New Braunfels and Seguin and between San Marcos and Luling. These areas coincide with Public Water Supply Surface Intakes, areas with high Terrestrial Fauna Ecological Index scores, Prime Farmland Soils, and, to a lesser extent, Guadalupe Bass Fish Priority Areas. Of fish-related resources, Guadalupe Bass Fish Priority Areas are noticeably underrepresented, while almost the entire Central Basin contains NFCAs. Due to the abundance of NFCAs in the study area, this conservation resource does not help distinguish between areas in this

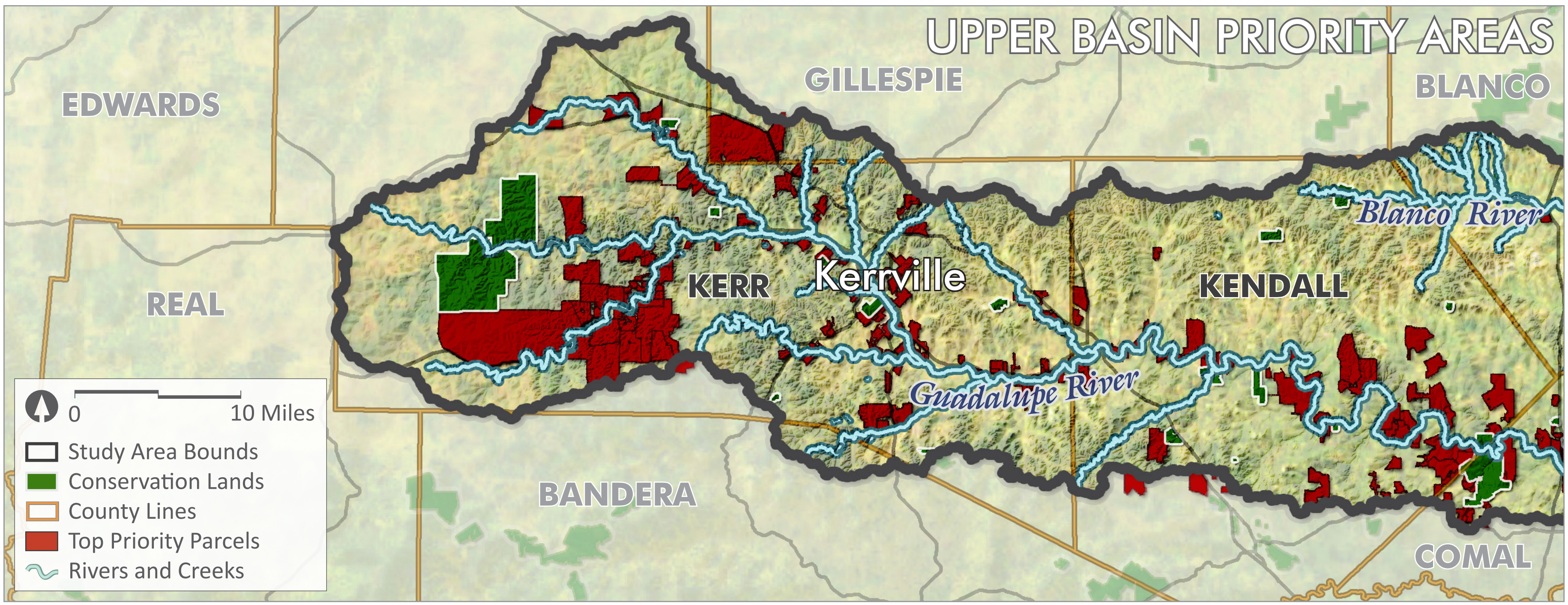


Figure 14. Top priority areas in the Upper Basin totaling 116,859 acres.

region. It does, however, add to their overall conservation value.

Another resource, Proximity to Conserved Land, also contributes to the conservation value of the top priority areas adjacent to them. Both Freeman Ranch and Halifax Ranch in San Marcos abut several top priority parcels. Another notable finding is that of the 25,116 acres of top priority areas in San Marcos, nearly 60% (14,100 acres) of these lands contain Prime Farmland Soils.

The Development Corridor that runs between San Marcos and Luling closely follows the San Marcos River and includes Riparian Corridors, Mussel Priority Areas, and Guadalupe Bass Fish Priority Areas. Several top priority areas in and around San Marcos fall within the Major Springs Buffers zone, some of which is already conserved, like Spring Lake Natural Area. A cluster of prioritized land just north of New Braunfels also contains a Major Spring Buffer, and several large properties in the western portion of the Central Basin contain vital water resources such as Aquifer Recharge Areas and Karst Areas.

LOWER BASIN

In the Lower Basin, 127,413 acres of top priority areas were identified (Figure 16). This includes 40,564 acres within the Western Gulf Coastal Plains ecoregion. Top priority areas follow the Guadalupe and San Marcos Rivers, with dense clusters surrounding the cities of Gonzales and Victoria. These urban areas have especially high concentrations of top priority areas for several reasons. First, these areas lie

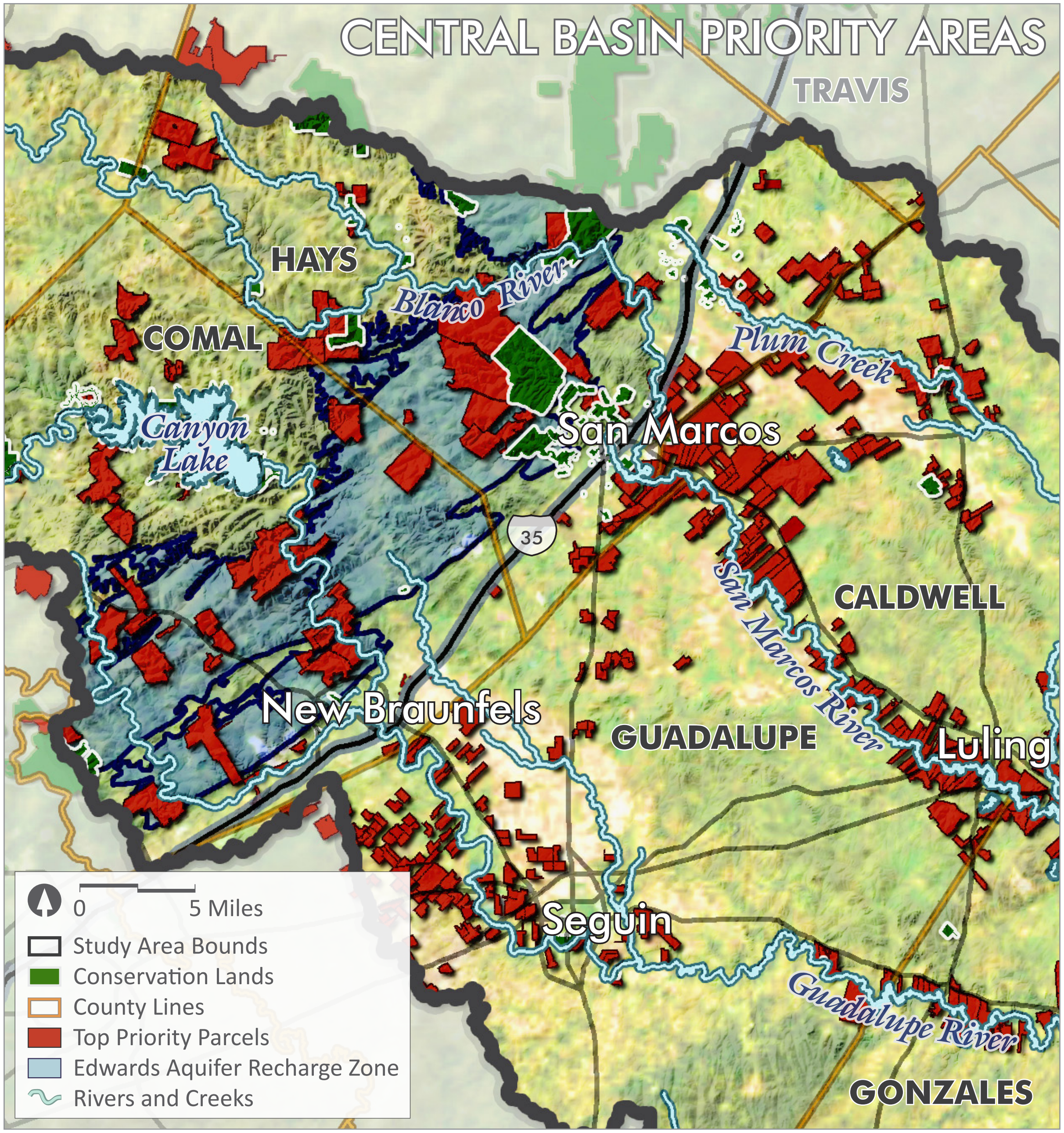


Figure 15. Top priority areas in the Central Basin totaling 136,358 acres.

largely within the Development Corridor (which closely follows rivers) and second, the Riparian Corridor along stretches of river close to both cities are more expansive than along other, more rural, stretches. This proximity to the river also results in high scores for NFCAs, Mussel Priority Areas, and Guadalupe Bass Fish Priority Areas, which all contribute to the high conservation value of these areas.

Apart from the strong impact the river has on prioritized lands, the areas around Gonzales and Victoria contain abundant Prime Farmland Soils and the Victoria area has many properties with large Parcel Size. Additionally, some of the areas around Victoria also have very high scores for the Terrestrial Fauna Ecological Index.

Notably, there are few top priority areas situated away from rivers in this part of the basin. This is largely due to the majority of lands southwest of the Guadalupe River being made up of very small parcels, which were not included in the model. Of those areas that were large enough to be included, most were in the smallest size class for the Parcel Size conservation resource.

Welder Flats at San Antonio Bay in the Lower Basin. Photo courtesy of the Meadows Center.

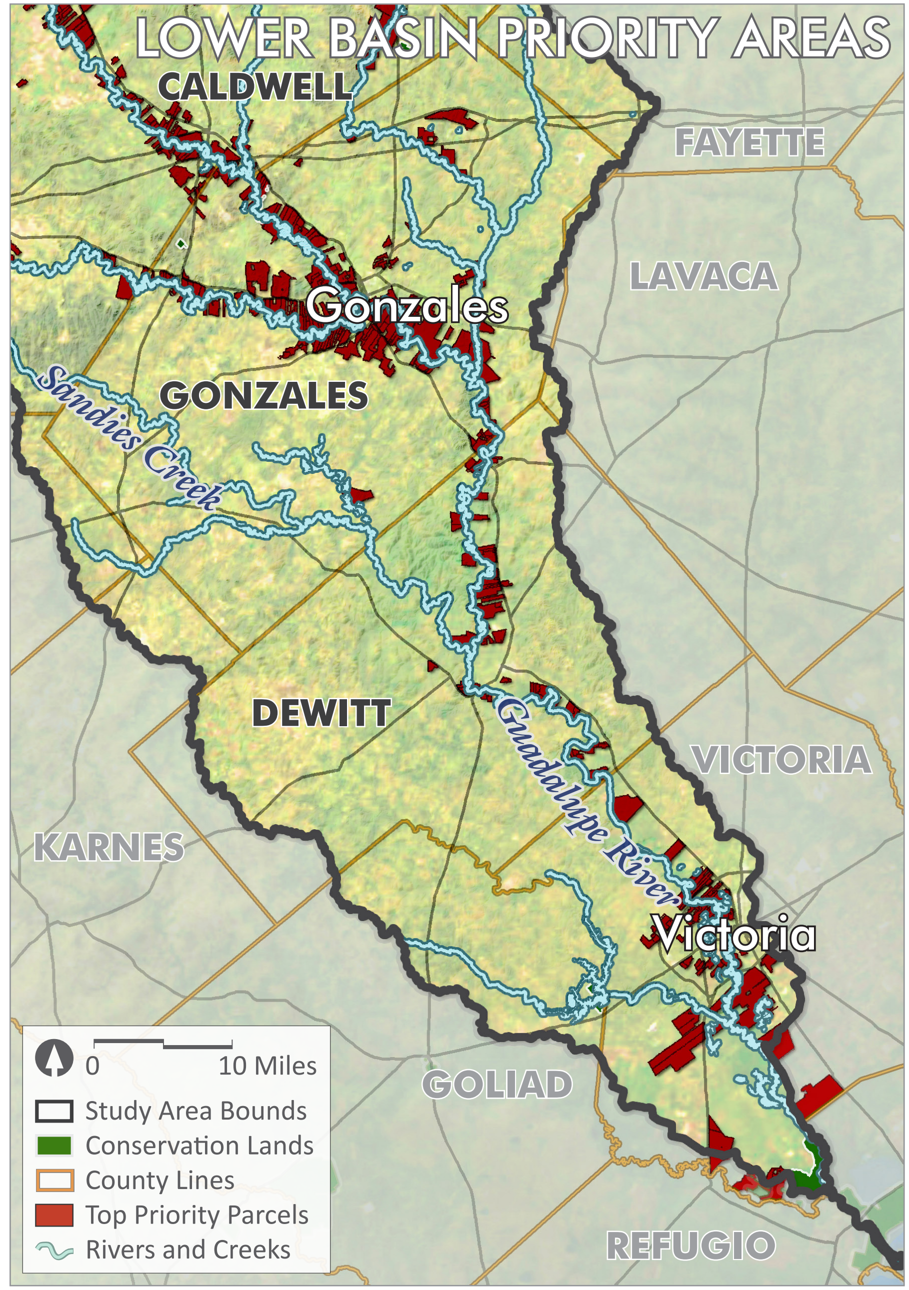


Figure 16. Top priority areas in the Lower Basin totallng 127,413 acres.


Photo by Chris Oswalt

DISCUSSION & CONCLUSIONS

In the coming decades, the Guadalupe Basin will experience significant land use transformation. This imminent development will take many forms, much of which will be detrimental to the area's water, cultural, and ecological resources. It is therefore imperative that residents take action to safeguard the basin's ecosystems and natural features, which are vital to its continued health and prosperity. These features affect the region's beauty and culture, while providing raw materials for industry, high-quality drinking water, flood damage mitigation, soil stabilization, and agricultural land.[1] By utilizing the prioritizations in this document, stewards can expediently conserve these vital resources by protecting lands with the richest conservation value. Additionally, by overlaying top priority areas with known history, current activity, and future development projections, potential opportunities and partnerships can be discovered.

If the goal is to maintain a healthy region, the I-35 corridor is critical. Areas in this corridor are under high risk of development, but there is also significant potential for collaborative work to conserve resources. Of particular importance is access to clean and abundant water. Two of the ten major water intakes in the Guadalupe Basin lie along the I-35 corridor. These intakes provide water for the populous cities of San Marcos and New Braunfels. By protecting these surface waters, stewards can help ensure a healthy water supply for years to come. In addition, the recharge zone for the Edwards Aquifer, arguably the basin's most important aquifer, is located just west of the I-35 corridor. Protecting even a percentage of the 30,515 acres of top priority areas in the recharge zone in Comal and Hays Counties will safeguard this groundwater source and support waterwise resource planning.

This work is vital because there is not a great deal of conserved land in the Central Basin as compared to counties both north and south of the Guadalupe Basin, where hundreds of thousands of acres within the Edwards Aquifer Recharge Zone have already been conserved. Conservation efforts in Comal County should, therefore, be increased to enhance the substantial work already occurring in Uvalde, Medina, Bexar, Hays, and Travis Counties. These counties have received substantial funding to protect their recharge zone acreage, so expanding this work will not only bring new lands into conservation but will also protect the investment already made in other counties. Potential conservation efforts in Comal County could be further enhanced through the use of a green infrastructure framework, where rural and urban interests can be combined to realize the multifaceted value of open space, not only for recreation but for enhanced ecosystem services as well.

Potential conservation efforts in Comal County could be further enhanced through the use of a green infrastructure framework, where rural and urban interests can be combined to realize the multifaceted value of open space, not only for recreation but for enhanced ecosystem services as well.

In addition to protecting water, conservation should also include terrestrial resources. Flooding is of great concern in the Central Basin, with the Memorial Day floods of 2015 costing more than $34 million in San Marcos and Wimberley.[89] By stabilizing soils and protecting open space, municipalities can reap the benefits of increased water infiltration, better filtered runoff, reduced water treatment costs, and reduced peak flows during rain events.[50] Conserving prime agricultural farmland in areas of fast population growth can be a great way to achieve this. The health of these lands is not only imperative for agricultural productivity (which will become increasingly important as population-driven food demand intensifies), but can also help mitigate flooding by allowing water from impermeable surfaces to soak into the ground. For example, of the 25,116 acres of top priority area in San Marcos, nearly 60% (14,100 acres) contain prime agricultural farmland. By aligning this data with the City of San Marcos' established goal of conserving environmentally sensitive areas in its ETJ and within its city limits, stewards can take advantage of an opportunity to leverage distinct conservation interests to satisfy multiple conservation goals.

Likewise, the presence of top priority areas near existing conservation lands in the Upper Basin presents a unique opportunity to expand existing conservation lands and protect ecological resources. Stewarding larger areas is important, because it maintains valuable contiguous habitat while reducing management costs. This is beneficial for many wildlife species, as some require larger spaces for breeding, hunting, and territorial behavior. Expanding refuges in the Hill Country ecoregion of the Upper Basin could protect an even broader array of endemic species than are already conserved. One noteworthy example highlighted by this analysis is an opportunity to add over 40,000 contiguous acres of conservation space to two already sizable conservation blocks in the Upper Basin. These areas would create a far larger complex of conservation lands, further safeguarding the headwaters of the Guadalupe River and delivering compounding positive ecological effects throughout the basin.

These areas would create a far larger complex of conservation lands, further safeguarding the headwaters of the Guadalupe River and delivering compounding positive ecological effects throughout the basin.

As waters travel 250 miles from those headwaters to the Gulf of Mexico, they are inundated with runoff and pollutants. This, along with stunted population growth and limited economic opportunity make the Lower Basin a uniquely vulnerable region. However, there are several features that can be leveraged to greatly increase its cultural, ecological, and economic resiliency. Near the city of Gonzales, numerous top priority areas contain prime farmland soils, which provides an opportunity to partner with local agricultural groups and farmers to preserve this resource for generations to come. By partnering under a grant program, such as the NRCS Conservation Innovation Grant or the Texas Farm & Ranchland Protection Program, conservation can be better integrated into the management regimes of these farms.

South of Gonzales, there are many top priority areas along the stretch of river that flows from Gonzales through Victoria to the Gulf of Mexico. This includes 40,564 acres of top priority areas in the Western Gulf Coastal Plains ecoregion. Conservation along this stretch of the river is particularly important, as healthy aquatic ecosystems can help filter the high pollution load accumulated throughout the river's path. This work is vitally important, because it will help protect the precarious Whooping Crane breeding grounds along the coast, along with countless other marine species living in the gulf's waters.

These examples represent just a small selection of the numerous ways that this analysis can be used to identify locations for new conservation initiatives in the Guadalupe Basin, thus closing the planning gap. Once specific areas of work are devised, stewards can then address the implementation gap by determining mechanisms needed to move this process forward. This work can be achieved through development of educational and policy-based stewardship programs; the identification of conservation funding mechanisms; cultivation of relationships with willing landowners; and evaluation of particular properties. Furthermore, the NFCA workshop framework has proven to be successful in other basins and has resulted in research, invasive species removal, wildlife habitat improvement, and conservation of substantial acreage that provides ecosystem services.[90]

Conservation easements, fee simple purchases, and landowner engagement can all be leveraged to bring additional lands into conservation. The City of San Antonio's Edwards Aquifer Protection Program[4] is a prime example of Texas conservation via a combination of conservation easements and fee simple acquisitions. There, rural landowners are working with urban communities to conserve the resources upon which they all depend. Through their

The results of active conservation aligned with the priorities identified here will be a landscape composed of working land, clean flowing rivers, and robust habitats that support community success for generations to come.

collaboration, over 200,000 acres of ranch and farmland, critical habitat, and aquifer recharge areas have been protected in perpetuity. Recently, voters renewed the program with an additional $90 million allocated in the coming years.

Additionally, within the Blanco, Upper San Marcos, and Pedernales Watersheds, stakeholders are using conservation prioritizations, like the one presented in this document, to strategically assemble a network of conservation properties. These projects have been used to galvanize discussion between municipalities that do not share borders but do share common interests associated with clean drinking water sources, development, and conservation lands. These successes can be replicated, and conservation efforts greatly expanded, through utilization of additional conservation prioritizations in neighboring watersheds to complement this work.

In the case of the Guadalupe Basin, protecting top priority areas represents a major step to push conservation forward. With the right funding and support, the current interests of landowners in the area can be harnessed to dramatically change the fate of the Guadalupe Basin over the coming decades. Armed with this strategic tool, conservation advocates can focus their efforts to maximize impact as they form partnerships with landowners, municipalities, state and federal agencies, philanthropic conservation buyers, advocacy groups, and land trusts. In doing so, they will bolster the ecosystem services this basin has to offer, including wildlife habitat, spring protection, reduced flood damage, natural beauty, a clean water supply, and productive farmland.[1] The results of active conservation aligned with the priorities identified here will be a landscape composed of working land, clean flowing rivers, and robust habitats that support community success for generations to come.

The Guadalupe River's natural beauty and ecological role are irreplaceable benefits for the residents of the basin. Photo courtesy of the Meadows Center.

SOURCES

1. *Guadalupe-Blanco River Authority & Texas Commission on Environmental Quality. 2013 Clean rivers program basin summary report: Guadalupe River and Lavaca- Guadalupe Coastal Basins. (2013).*
2. *Texas Water Development Board. Complete Water Demand Projections in Texas by River Basin: 2020-2070 water demand projections by planning region with figures for counties, cities, utilities and county-other rural areas. Texas Water Development Board http://www.twdb.texas.gov/waterplanning/data/projections/2022/demandproj.asp (2016).*
3. *Trust for Public Lands. Protecting the source, land conservation and the future of America's drinking water. (2004).*
4. *City of San Antonio. Edwards Aquifer Protection Program (EAPP). City of San Antonio, Parks and Recreation Department https://www.sanantonio.gov/EdwardsAquifer (2019).*
5. *Siglo Group. City of San Antonio spatial model to identifiy high-priority properties for the Edwards Aquifer Protection Program Project Summary. (2014).*
6. *Stowers Ranch Land and Wildlife Management. A Piece of Texas Since 1904. Stowers Ranch Land and Wildlife Management http://www.stowersranch.com/about (2015).*
7. *Texas State University. Freeman Center. Texas State, Office of Research and Sponsored Programs //www.txstate.edu/freemanranch/ (2019).*
8. *Siglo Group. State of the Hill Country. (in process).*
9. *Texas Parks & Wildlife. Palmetto State Park — Texas Parks & Wildlife Department. Texas Parks and Wildlife, Palmetto State Park https://tpwd.texas.gov/state-parks/palmetto (2019).*
10. *Guadalupe-Blanco River Authority. Coleto Creek Park. Guadalupe-Blanco River Authority, Welcome to Coleto Creek Park https://www.gbra.org/coletocreekpark/default.aspx (2019).*
11. *Asher, J., Bertelsen, M. & O'Toole, M. Restoration Design Guidelines for Texas Hill Country Riparian Areas. (2016).*
12. *United States Fish & Wildlife Services. Species Profile for Texas wild-rice(Zizania texana). Enviromental Conservation Online System https://ecos.fws.gov/ecp0/profile/speciesProfile?spcode=Q24A (2019).*
13. *United States Fish & Wildlife Services. Species Profile for Fountain darter(Etheostoma fonticola). Environmental Conservation Online System https://ecos.fws.gov/ecp0/profile/speciesProfile;jsessionid=E6E190182F527BAE81D2627DB33512C4?spcode=E00T (2019).*
14. *Eidson, J and Smeins, F.E. Texas Blackland Prairies. World Wildlife Fund https://www.worldwildlife.org/ecoregions/na0814.*
15. *Smeins, F. E. & Diamond, D. D. Remnant Grasslands of the Fayette Prairie, Texas. The American Midland Naturalist 110, 1–13 (1983).*
16. *TPWD: Plant Guidance by Ecoregions -- Ecoregion 3 – Post Oak Savannah. https://tpwd.texas.gov/huntwild/wild/wildlife_diversity/wildscapes/ecoregions/ecoregion_3.phtml.*
17. *TPWD Kids: Texas Gulf Coast. https://tpwd.texas.gov/kids/about_texas/regions/gulf_coast/big_kids/.*
18. *United States Fish and Wildlife Service. Annual Whooping Crane Survey - Aransas - U.S. Fish and Wildlife Service. Aransas National Wildlife Refuge: Texas https://www.fws.gov/refuge/aransas/science/whooping_crane_surveys.html (2019).*
19. *Texas Commission on Environmental Quality & Guadalupe-Blanco River Authority. 2018 Clean Rivers Program Basin Summary Report: Guadalupe River and Lavaa-Guadalupe Coastal Basins. 132 (2018).*
20. *Thongda, W. et al. Species-diagnostic SNP markers for the black basses (Micropterus spp.): a new tool for black bass conservation and management. Conservation Genet Resour (2019) doi:10.1007/s12686-019-01109-8.*
21. *UCSB ScienceLine. UC Santa Barbara http://scienceline.ucsb.edu/getkey.php?key=4532 (2014).*
22. *Enriquez, E. J., Gelwick, F. P. & Packard, J. M. Reproductive Seasonality, Courtship and Nesting in Guadalupe Bass (Micropterus treculii). amid 176, 173–185 (2016).*
23. *Bonner, T. H. & Bean, P. T. Guadalupe Bass (Micropterus treculii). Environmental Biology of Fishes (2007) doi:10.1007/s10641-008-9351-9.*
24. *Sustaining America's Aquatic Biodiversity - Crayfish Biodiversity and Conservation. https:////www.pubs.ext.vt.edu/content/pubs_ext_vt_edu/en/420/420-524/420-524.html.*

25. *Rivera-Gasperín, S. L., Ardila-Camacho, A. & Contreras-Ramos, A. Bionomics and Ecological Services of Megaloptera Larvae (Dobsonflies, Fishflies, Alderflies). Insects 10, (2019).*

26. *Macadam, C. R. & Stockan, J. A. More than just fish food: ecosystem services provided by freshwater insects. Ecological Entomology 40, 113–123 (2015).*

27. *Birdsong, T. et al. Guadalupe Bass Restoration Initiative 2018 Annual Report. 8 https://tpwd.texas.gov/publications/pwdpubs/media/pwd_rp_t3200_2079.pdf (2019).*

28. *Siglo Group. Rio Grande Fishes Conservation Assessment and Mapping. (2018).*

29. *Obrien, M. & Walton, M. Mussel Loss - Science Nation | National Science Foundation. National Science Foundation, Where Discoveries Begin https://www.nsf.gov/news/special_reports/science_nation/musselloss.jsp (2019).*

30. *Machtinger, E. Native Freshwater Mussels. (2007).*

31. *Wierman, D., Walker, J. & Moreno, J. How much water is in the Guadalupe: A preliminary data analysis and gap analysis. 49 https://gato-docs.its.txstate.edu/jcr:f35ad1af-8de9-4bcd-b472-5ef493f92bd7 (2019).*

32. *Hunt, B. Unsteady Stream Depletion from Ground Water Pumping. Groundwater 37, 98–102 (1999).*

33. *Konrad, C. P. Effects of Urban Development on Floods. 4 https://pubs.usgs.gov/fs/fs07603/ (2003).*

34. *Nassauer, J. I., Allan, J. D., Johengen, T., Kosek, S. E. & Infante, D. Exurban residential subdivision development: Effects on water quality and public perception. Urban Ecosystems 7, 267–281 (2004).*

35. *Dietz, M. E. & Clausen, J. C. Stormwater runoff and export changes with development in a traditional and low impact subdivision. Journal of Environmental Management 87, 560–566 (2008).*

36. *Meadows Center for Water and the Environment. How much water is in the Pedernales? Conservation strategies, management approaches, and action plan. (2015).*

37. *Guadalupe-Blanco River Authority. Guadalupe-Blanco River Authority : Edwards Aquifer and the Guadalupe River. https://www.gbra.org/drought/edwardsaquifer.aspx.*

38. *Texas Water Development Board. 2021 Regional Water Plan - Populations Projections for 2020-2070 for water user groups by region, county, and basin in Texas. http://www2.twdb.texas.gov/ReportServerExt/Pages/ReportViewer.aspx?%2fProjections%2f2022+Reports%2fpop_WUG_Basin&rs:Command=Render (2019).*

39. *San Marcos Water/Wastewater Deparment. Surface Water Treatment Plant. City of San Marcos, TX https://sanmarcostx.gov/facilities/facility/details/Surface-Water-Treatment-Plant-2 (2019).*

40. *Gonzales County Underground Water Conservation District. Management Plan: Gonzales County Underground Water Conservation District. (2014).*

41. *Calhoun County Groundwater Conservation District. Calhoun County Groundwater Conservation District Management Plan. (2017).*

42. *Winter, L. City says not to worry about water sources. San Marcos Record (2019).*

43. *Rocha, A. Drought leaves Guadalupe tubers, business high and dry | San Marcos Mercury | Local News from San Marcos and Hays County, Texas. San Marcos Mercury (2013).*

44. *Environmental Flows Recommendations Report. https://www.tceq.texas.gov/assets/public/permitting/watersupply/water_rights/eflows/20110301guadbbest_transmission.pdf (2011).*

45. *Guadalupe-Blanco River Authority. Interim Flood Preparedness Plan. 30 https://gbra.org/about/contact.aspx (2005).*

46. *United States Geological Survey. Floods in the Guadalupe and San Antonio River Basins in Texas, October 1998. 4 https://pubs.usgs.gov/fs/FS-147-99/#foot%203 (1999).*

47. *Pitt, R., Lantrip, J., Harrison, R., Henry, C. L. & Xue, D. Infiltration through Disturbed Urban Soils and Compost-Amended Soil Effects on Runoff Quality and Quantity. United States Environmental Protection Agency 11 (1999).*

48. *United States Census Bureau. U.S. Census Bureau QuickFacts. https://www.census.gov/quickfacts/fact/table/lockhartcitytexas,seguincitytexas,newbraunfelscitytexas,victoriacitytexas,kerrvillecitytexas,sanmarcoscitytexas/PST045218.*

49. *LBJ Presidential Library. Experience a dramatic story of Texas at the LBJ Library and Museum. LBJ Presidential Library http://www.lbjlibrary.org/press/experience-a-dramatic-story-of-texas-at-the-lbj-library.*

50. *Dizik, A. In Texas Hill Country, a Land Rush for the Rich. Wall Street Journal (2016).*

51. *United States Census Bureau. United States Dicennial Census. https://www.census.gov/prod/www/decennial.html (2019).*

52. *Texas Department of Transportation. I-35 Capital Area Improvement Program (Mobility35): Corridor Implementation Plan SH 45SE to Posey Road Hays County, Texas. 43 (2015).*

53. *Ura, A. & Daniel, A. Census estimates show another year of rapid growth for Texas suburbs. The Texas Tribune (2018).*

54. *O'Hare, P. Kendall County continues to show rapid growth. San Antonio Express-News (2019).*

55. *Theobald, D. M. Landscape Patterns of Exurban Growth in the USA from 1980 to 2020. Ecology and Society 10, (2005).*

56. *Texas A&M Natural Resources Institute, Texas A&M Agriculture Resarch, Texas A&M Agrilife Extension Service & Texas Agricultural Land Trust. Texas Land Trends. Texas Land Trends http://txlandtrends.org/ (2019).*

57. *Fredriksen, R. L. Erosion and sedimentation following road construction and timber harvest on unstable soils in three small western Oregon watersheds /. http://hdl.handle.net/2027/umn.31951d02995063h (1970).*

58. *Hobbs, J. C. & Ledger, J. A. The environmental impact of linear developments; Powr lines and avifauna. in (1986).*

59. *Trombulak, S. C. & Frissell, C. A. Review of Ecological Effects of Roads on Terrestrial and Aquatic Communities. Conservation Biology 14, 18–30 (2000).*

60. *Geneletti, D. Using spatial indicators and value functions to assess ecosystem fragmentation caused by linear infrastructures. International Journal of Applied Earth Observation and Geoinformation 5, 1–15 (2004).*

61. *Cott, P. A. et al. Implications of linear developments on northern fishes. Environmental Reviews 23, 177-(2015).*

62. *Vos, C. C. & Chardon, J. P. Effects of Habitat Fragmentation and Road Density on the Distribution Pattern of the Moor Frog Rana arvalis. Journal of Applied Ecology 35, 44–56 (1998).*

63. *Keller, I. & Largiadèr, C. R. Recent Habitat Fragmentation Caused by Major Roads Leads to Reduction of Gene Flow and Loss of Genetic Variability in Ground Beetles. Proceedings: Biological Sciences 270, 417–423 (2003).*

64. *Jones, J. A., Swanson, F. J., Wemple, B. C. & Snyder, K. U. Effects of Roads on Hydrology, Geomorphology, and Disturbance Patches in Stream Networks. Conservation Biology 14, 76–85 (2000).*

65. *Forman, R. T. T. & Alexander, L. E. Roads and Their Major Ecological Effects. Annual Review of Ecology and Systematics 29, 207-C2 (1998).*

66. *Kight, C. R. & Swaddle, J. P. How and why environmental noise impacts animals: an integrative, mechanistic review. Ecology Letters 14, 1052–1061 (2011).*

67. *Francis, C. D. & Barber, J. R. A framework for understanding noise impacts on wildlife: an urgent conservation priority. Frontiers in Ecology and the Environment 11, 305–313 (2013).*

68. *Christen, D. C. & Matlack, G. R. The habitat and conduit functions of roads in the spread of three invasive plant species. Biol Invasions 11, 453–465 (2009).*

69. *Texas A&M University Institute of Renewable Natural Resources. Texas land trends: Status update and trends of Texas rural working lands. (2014).*

70. *Cuero Bets on Fracking. The Texas Observer https://www.texasobserver.org/cuero-bets-on-fracking/ (2011).*

71. *Central, B. M., Climate. Water Use Rises as Fracking Expands. Scientific American https://www.scientificamerican.com/article/water-use-rises-as-fracking-expands/.*

72. *Siglo Group. Blanco and Upper San Marcos watershed strategic conservation prioritization. (2017).*

73. *Siglo Group. Pedernales watershed strategic conservation prioritization. (2018).*

74. *Siglo Group. Katy Prairie Conservancy Strategic Conservaction Priorities (In Preparation).*

75. *Kalhor, K., Ghasemizadeh, R., Rajic, L. & Alshawabkeh, A. Assessment of groundwater quality and remediation in karst aquifers: A review. Groundwater for Sustainable Development 8, 104–121 (2019).*

76. *Texas Parks and Wildlife Department. By Ecoregion (Vector) — Texas Parks & Wildlife Department. Texas Parks and Wildlife Mapping By Ecoregion https://tpwd.texas.gov/gis/programs/landscape-ecology/by-ecoregion-vector (2014).*

77. *Prime Farmland. USDA Natural Resources Conservation Service https://www.nrcs.usda.gov/wps/portal/nrcs/detail/null/?cid=nrcs143_014052 (2000).*

78. *Hendrickson, D. A. & Labay, B. J. Final Report: Conservation assessment and mapping products for GPLCC priority fish taxa. (2014).*

79. *Texas Parks and Wildlife Department. TPWD: Texas Mussel Watch: Texas Freshwater Mussel Biology. Wildlife Diversity Program https://tpwd.texas.gov/huntwild/wild/wildlife_diversity/texas_nature_trackers/mussel/biology/ (2019).*

80. *Rollins, B. By the Numbers: Sobering new damage assessments of the Memorial Day weekend flood. San Marcos Mercury (2015).*

81. *Native Fish Conservation Network. Native Fish Conservation https://nativefishconservation.org/.*

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