BLANCO AND UPPER SAN MARCOS WATERSHED STRATEGIC CONSERVATION PRIORITIZATION

The Meadows Center for Water and the Environment, Texas State University
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Cover Image. The San Marcos River, Downtown San Marcos. Courtesy of San Marcos Watershed Intiative, http://smwatershedinitiative.org

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PROJECT GOALS

1. **Use the best data and analysis methods available to inform good decision making and the efficient use of resources associated with conservation projects in the Blanco and Upper San Marcos Watersheds with a focus on water resources.**

2. **Conduct an overall characterization of land use and natural resources in the Watersheds to inform conservation efforts.**

3. **Create an informative, compelling tool that identifies areas of highest conservation value in the watersheds to support and catalyze action by stakeholders, decision makers, and conservation practitioners.**

Figure 1. Jacab's Well springs at the headwaters of Cypress Creek, a tributary of the Blanco River. Picture courtesy of Carl Griffin.

SUMMARY

Growth is occurring at unprecedented rates in Central Texas. This is especially true in the Blanco and Upper San Marcos Watersheds in Hays County and the City of San Marcos. San Marcos was the fastest growing city in the nation in its size class from 2000 to 2014, and Hays County was the fastest growing county in the state from 2010 to 2015 (Ura & McCullough 2015, Ura & Flannery 2016, Solomon 2014). This growth is driven by numerous industries, an affordable cost of living, Texas State University growth, favorable climate, and the aesthetic beauty of the Hill Country.

Rapid development that does not respond to the unique, important natural resources of the area will have implications for generations to come. Particularly at risk are the water resources communities depend on for water supply, safety, recreation, and natural beauty. Growth in inappropriate areas or without best practices and its associated expansion of infrastructure, groundwater pumping, and impervious cover can result in negative impacts to spring flows, decreases in water quality, and increases in the impacts of flood events. Conservation of key lands and natural resources within the watersheds through conservation easements, fee simple purchase, and stewardship efforts will support sustained economic vitality, quality of life, and access to indispensable natural resources.

Throughout the country, conservation initiatives dedicated to the protection of water, ecological, and cultural resources are playing a key role in reducing losses of ecological functionality and quality of natural resources. This is occurring through public and private organizations. Programs have a range of interaction with lands from full ownership to cost sharing on stewardship projects. In Texas, conservation easements have become a powerful tool bringing together willing landowners and conservation organizations. Over the past four decades these partnerships have resulted in over 1 million acres being put into conservation easements in the state. The conservation easement allows the land owner to maintain ownership and continue traditional agricultural practices while preserving open space and the vital ecological resources our state depends on such as flood control and clean water. Conservation easements are complemented by the acquisition and purchase of key conservation lands that allow for recreation, interactions with nature, and/or the protection of critical resources.

Landowner stewardship programs are another important conservation tool that compliment and work in tandem with conservation easements and fee simple purchases. Stewardship programs focus on numerous activities including: low impact development, green infrastructure, rain water catchment, riparian restoration, brush management, and erosion control. In addition, landowners can obtain the same tax valuation for wildlife management as they can for agricultural production through the 1-d-1 wildlife use tax valuation. These programs and tax benefits allow for a spectrum of opportunities working with conservation easements and fee simple properties to protect and enhance natural resources within the Watersheds.

The Blanco and Upper San Marcos Watersheds Strategic Conservation Prioritization identifies areas for conservation. The study area, as seen in Figure 2, is defined by the Blanco and Upper San Marcos Watersheds, as well as the San Marcos Water Quality Protection Plan Boundary.

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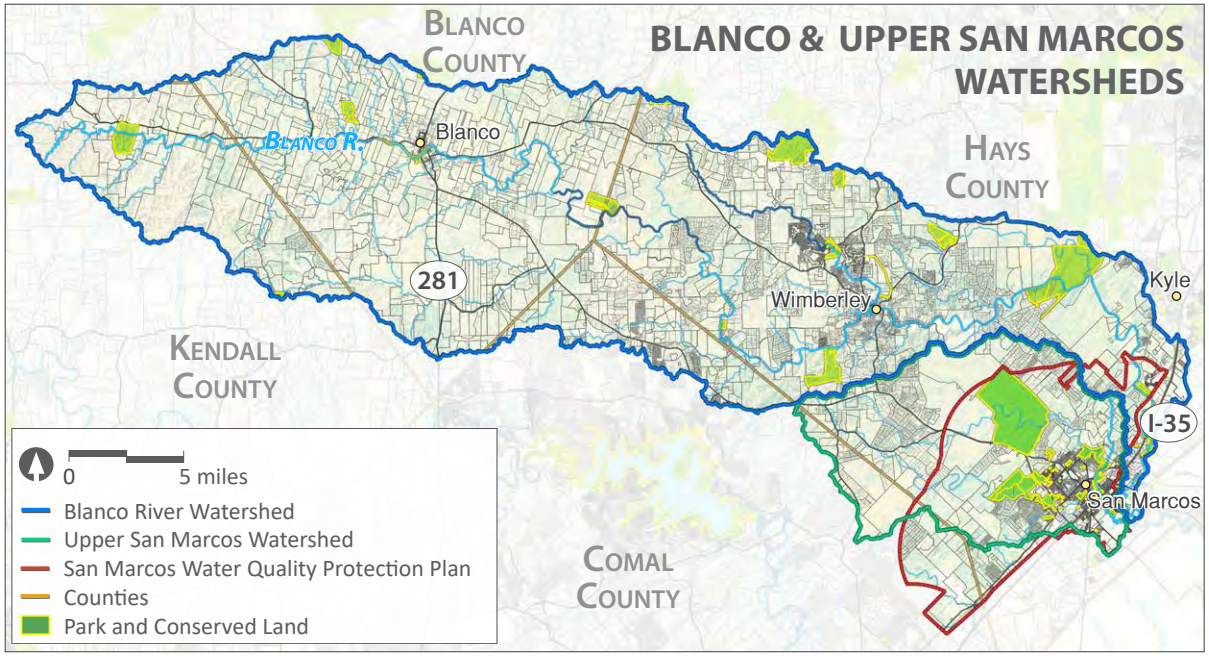


Figure 2. Study Area including the Blanco and Upper San Marcos Watersheds along with the San Marcos Water Quality Protection Plan Boundary, parcels, conservation lands, major roads, and county lines.

The prioritization uses a geographic information system (GIS) framework using a repeatable, procedural model. Within the model, the geographic distribution of conservation resources and their significance are used to determine conservation priorities throughout the Watersheds. The conservation planning process and results were evaluated by the project team and professional representatives working on water and conservation issues in the area. The actions required to bring these priorities into conservation will take considerable effort and resources by numerous organizations and individuals in the coming years. That said, all areas prioritized here are suitable for immediate conservation action. The process is time sensitive. Some priority areas will be negatively impacted by ongoing development, rises in property costs, and degradation of natural resources.

The prioritization results identify those areas most in need of conservation as seen in Figure 3. These results are based on 20 conservation resources, nine associated with water resources, six associated with cultural resources, and five associated with ecological resources. Collectively 46,227 acres, or 12.9% of the study area, are determined to be of high conservation value. Within this total, 3,539 acres are in existing conservation lands and 32,583 acres are in areas available for conservation. It is important to note the remaining 10,105 acres are in developed areas or 100 to 20 acres parcels, neither of which meet the criteria for conservation consideration. These priority areas contain the greatest co-occurrence of conservation resources and their protection will provide the greatest acre-for-acre impact. As additional conservation lands are acquired or preserved, new data becomes available, or priorities shift, the model can be revised to address new conditions.

Within the high priority areas, water resources are strongly represented. This is expected because of the high value given to them in the prioritization process, the number of co-occurring water resources within the model, and the importance put on resources that protect spring flow, water quality, and flood mitigation.

Four clusters of priorities that can serve as focus areas for conservation action are worth pointing out here:

- The ring around the San Marcos core associated with karst features, Spring Lake, riparian areas, Edwards Aquifer recharge, and trails buffer;
- Fern Bank Springs area associated with Edwards Aquifer recharge, opportunity area, spring buffers, water quality buffers, and golden cheeked warbler habitat;
- Cypress Creek area associated with Trinity Aquifer recharge, spring buffers, golden cheeked warbler habitat, and karst features;
- The area around Pleasant Valley Springs area also associated with Trinity Aquifer recharge, spring buffers, Golden-cheeke Wabler habitat, and karst features.

With finite resources available, it is critical to evaluate the allocation of conservation dollars. Conservation action is needed in the Upper San Marcos and Blanco Watersheds where land use change has rapidly increased to meet the needs of record growth in San Marcos, Buda, Wimberley, and Hays County. This project provides a path forward for philanthropists, municipalities, river authorities, water supply entities, and organizations to efficiently and effectively invest in conservation. This investment will result in the conservation of vital resources that have long supported the region's prosperity and growth. Protecting these lands provides direct and tangible economic benefits, facilitates a healthier and more active community, reduces water resource costs associated with water supply development, water treatment, floodplain mitigation, as well as protects human life and property from catastrophic events.

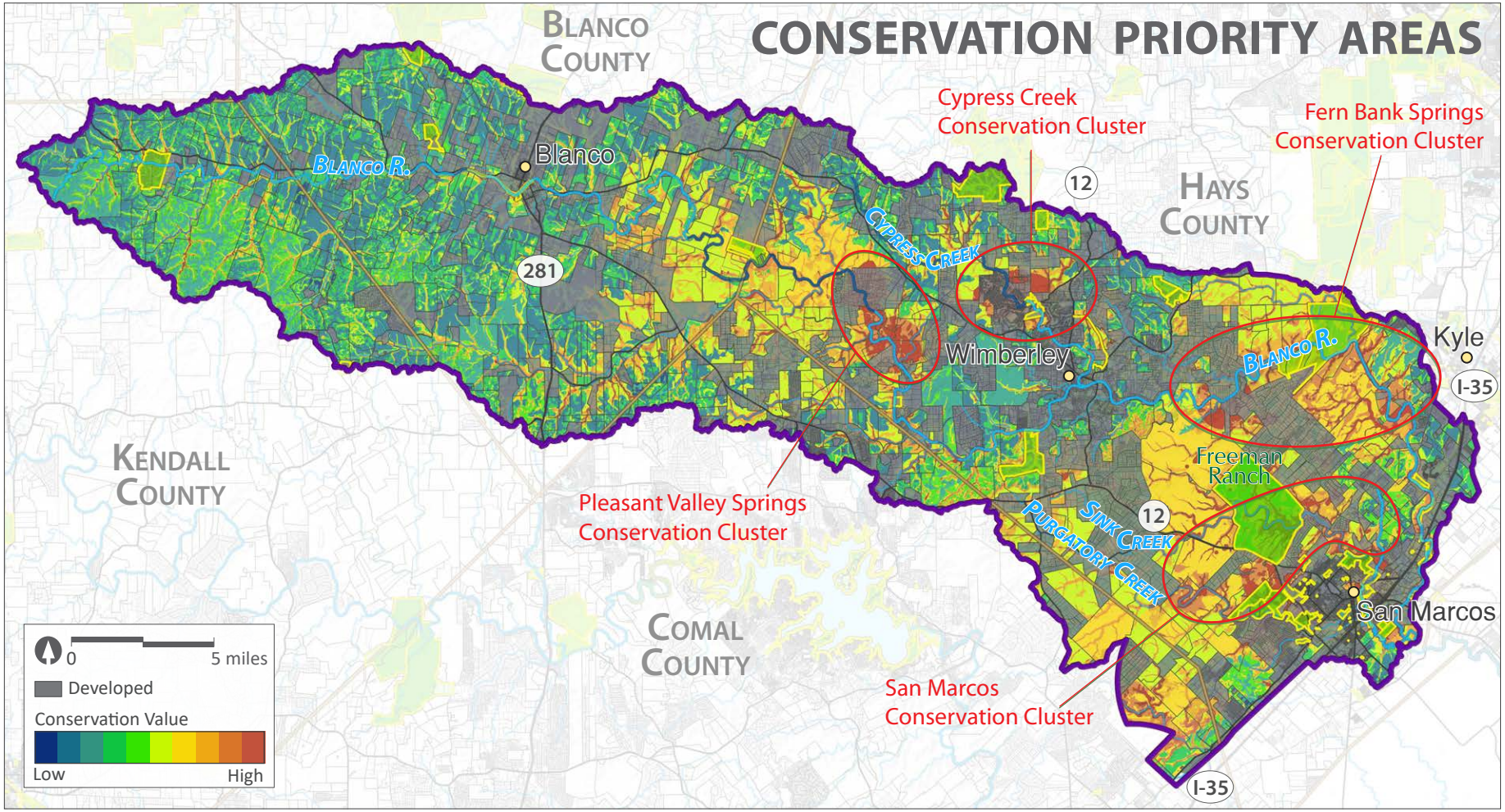


Figure 3. Conservation priority areas including nodes of conservation priorities at Cypress Creek, Fern Bank Springs, Pleasant Valley Springs and around San Marcos can serve as focal points for conservation action

Figure 4. The Blanco River near Wimberley. Picture courtesy of www.islandtradervacations.info

INTRODUCTION

The population of Central Texas is growing rapidly and sprawling into rural areas. Here and throughout the country, studies are showing that long-term economic security is dependent on accessibility to basic natural resources like clean water and flood control, as well as preserving agricultural production and maintaining quality of life by providing recreational opportunities and natural beauty. This project recognizes the need to balance growth with the conservation of resources vital to continued prosperity by prioritizing lands for conservation based on water, cultural, and ecological resources.

Studies have shown that the conservation of natural systems is a cost-effective way to meet many societal needs. A global assessment of the value of all ecological functions found that the output of intact environments through water supply, water quality, raw materials, and numerous other factors is worth 33 trillion dollars per year and financially unfeasible to replace (Costanza et al. 1997). At the local level, municipalities are coming to the same conclusion. Cities such as San Antonio are conserving land to protect their water supply, which results in significant sustained financial savings on water treatment (Appleton 2002; ESA 2000). To date San Antonio and its partners have worked with local landowners to protect over 200,000 acres of land important for water supply and water quality at a fraction of the cost of finding and treating new water supplies (Siglo Group 2017).

To maximize the use of limited conservation resources, a team of planners, engineers, hydrologists, and geospatial analysts developed a land conservation prioritization process for the study area. It allows the Meadows Center for Water and the Environment at Texas State University, along with its partners, to take a strategic, proactive approach to conserving resources in the Watersheds. The results were reviewed by organizations and entities responsible for conservation work in the area including: San Marcos River Foundation, Hill Country Conservancy, The Nature Conservancy, Sierra Club, Greater Edwards Aquifer Alliance, Wimberley Valley Watershed Alliance, Hill Country Alliance, and the Edwards Aquifer Habitat Conservation Plan.

This project follows best practices being utilized in the region to protect natural resources and applies them to the Blanco and Upper San Marcos Watersheds. Conservation priorities were determined through a procedural model in a geographic framework that allows for repeat evaluations as new information comes to light, additional lands are put into conservation, or conservation priorities change. The model follows the methodology developed by the San Antonio Edwards Aquifer Protection Plan to determine conservation areas that protect water resources over the Edwards Aquifer (Siglo Group 2014). This systematic approach avoids the pitfalls of reactive, piecemeal conservation efforts that do not always contain or protect the most significant conservation resources in a region (Margules 1989, Pressey et al. 1993).

The results of this project can help guide the protection of priority conservation lands throughout the study area that are threatened by rapid development. Philanthropists, conservation organizations, municipalities, and agencies can use this information to direct conservation efforts for fee simple purchase, conservation easement acquisitions, and stewardship programs that help sustain quality of life, protect water supplies, and mitigate flood damage in the area. This project is only one component of the effort needed to make conservation transactions and actions a reality. Other critical components include identifying conservation funding mechanisms, finding and forming relationships with willing landowners, evaluating particular properties, and the detailed work of land transactions.

Figure 5. Blanco Narrows in the portion of the Blanco River known as the Dry Blanco. Picture courtesy of texasriverbum.com

STUDY AREA

The study area is defined by the flow of water in the Blanco and Upper San Marcos Watersheds, as well as all areas in the Upper San Marcos Water Quality Protection Plan (SMWI 2016). The area includes portions of Hays, Blanco, Kendall, and Comal Counties. It includes portions of San Marcos, Kyle, Wimberley, Woodcreek, and Blanco city limits and extra territorial jurisdictions (Figure 2). The total study area is 358,240 acres, with 279,076 acres in the Blanco watershed, 60,703 acres in the San Marcos watershed, and the remaining 18,461 acres in the southern San Marcos extra territorial jurisdiction (ETJ). The area is known for its springs, clear running rivers and creeks, and Hill Country topography.

Growing Population

San Marcos is the largest population center in the study area with a 2010 population of 44,894 that grew by 31% to 58,892 people in 2014. During this period, it was the fastest growing city of its size in the country (Ura & Flannery 2016). Hays County grew from a population of 158,275 in 2010 to a population of 194,739 in 2015. This increase of 23% in five years made Hays County the fastest growing county in Texas during that time period (Ura & Flannery 2016).

Currently within the study area 60,436 acres have been developed (16.9% of the study area). For this study, developed areas are parcels under 20 acres, as well as portions of larger parcels characterized as urban or suburban development in the 2011 National Land Cover Dataset or the TPWD Ecological Systems Classification. Much of this development and population is expanding from the cities into the surrounding open space, aquifer recharge zones, and areas traditionally used for ranching and agricultural production. In addition, areas just outside of the study area including San Antonio, Austin, New Braunfels, and Dripping Springs are experiencing substantial growth.

By 2050, Texas Water Development Board (2016) projects the Hays County population will reach 474,801, a 143% increase over the 2015 population. San Marcos is projected to have a population of 120,648 by 2050, a 104% increase over 2014 numbers (TWDB 2016). If current land development practices continue, these projections translate into dramatic changes in land use. In rural parts of the study area, this means substantial reductions in ranching, agricultural, and natural lands. In urban areas adjacent to sensitive environmental features this means continued degradation, such as the areas around Texas State University, where the combined desire for additional housing for university students and residents is driving further development of Sink Creek and the watersheds that feed Spring Lake.

Theobald (2005), in association with the U.S. Forest Service, looked at projected land development changes for the study area and throughout the southeast United States. According to his projections, considerable urban and suburban development around San Mar-

Table 1. Conservation Acreage by Study Area and Watershed

Area	Private Conservation Acres	Public Conservation Acres	Total Conservation Acres	Total Acres
Study Area	6,967	6,934	13,901	358,240
Blanco River Watershed	6,658	590	7,248	279,074
Upper San Marcos River Watershed	4	6,340	6,344	60,703
Sink Creek Sub-Watershed	0	4,536	4,536	29,154

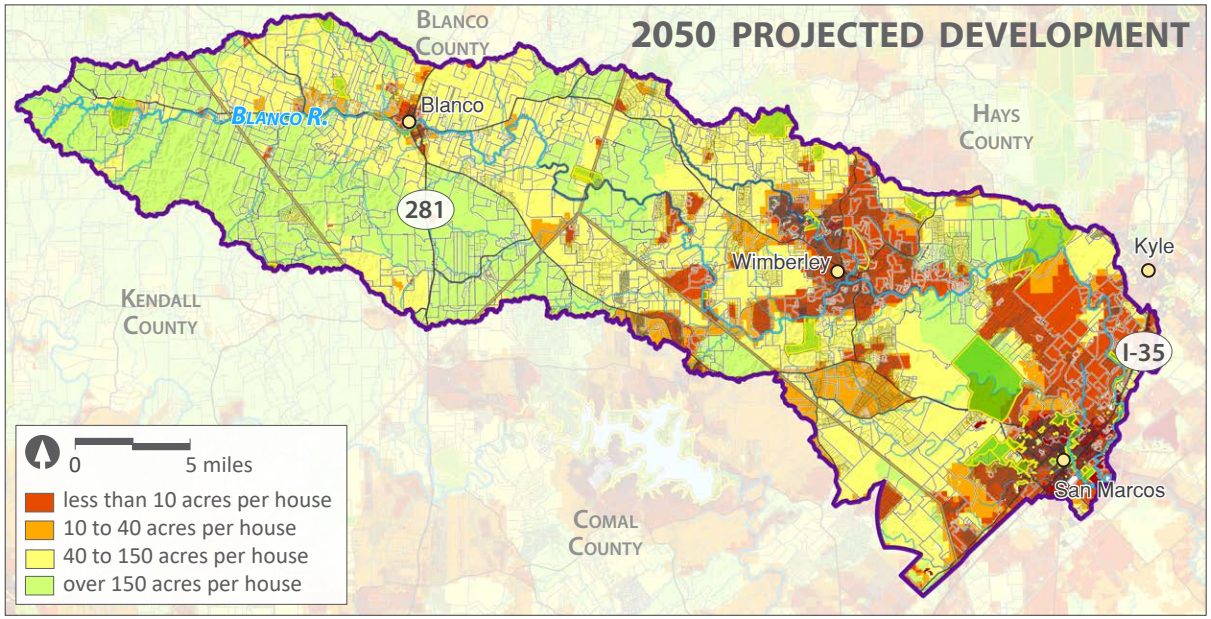


Figure 6. Projected 2050 development based on Theobald (2005). Areas in red are more intense development with areas in green having less human impact.

cos, Kyle, and Wimberley will form an almost continuous blanket of low density development (Figure 6). This projected development will continue to increase the network of impervious cover associated with roadways, infrastructure, and community services, and inevitably degrade water resources in the study area. Risks to spring flows arise from increases in local and regional groundwater usage, as well as changes in surface hydrology that affect the amount and quality of water entering recharge features. Risks to water quality include increased nutrient, sediment, and bacteria levels in waters running off developed areas. The expansion of impervious cover associated with development also increases the likelihood of more extreme, and more destructive flood events.

Conservation Lands

The study area has 13,901 acres of lands in conservation/parkland—3.9% of the study area. Conservation lands include the 4,262 acre Freeman Ranch, 66 public parcels totaling 2,689 acres, and 22 parcels in private conservation totaling 6,967 acres. The Blanco River Watershed contains 7,248 acres of conservation lands, with 6,658 acres in private conservation and 590 acres in public conservation. In the Upper San Marcos River Watershed 6,344 acres are in conservation, with Freeman Ranch making up the vast majority of the acreage, along with 2,082 acres in public conservation, and an additional 4 acres in private conservation. Sink Creek is of particular interest within the San Marcos River Watershed because it flows into Spring Lake, has a history of flooding issues, recharges the Edwards Aquifer, and is facing substantial development pressure due to the explosive growth of San Marcos. The Sink Creek watershed is 29,154 acres of which 4,536 acres are in conservation and/or park lands—4,258 acres are the Freeman Ranch (Figure 3).

Freeman Ranch is owned by the Freeman Foundation and is under a long-term lease to Texas State University which currently manages the ranch for conservation purposes. The family and the foundation have a long tradition of stewardship on the ranch, however research for this report was unable to find any permanent conservation arrangement in place once the lease expires. This property is figuratively and literally at the center of conservation efforts in the Upper San Marcos watershed. A plan for the permanent conservation of the property, or at least significant parts of the property, is a critical step in the long-term protection of the Sink Creek Watershed and the entire study area.

Flooding in the Basin

Flooding in urban areas is costly and can be catastrophic. It often results from developing in low lying areas or upstream development that exacerbates flooding downstream. Con-

servation lands and stewardship activities have played roles in numerous places in reducing the potential of floods and their impact by maintaining native vegetation that absorb rainfall and stabilize waterways, allowing for water retention in healthy soil, and informing the location of development outside areas where it impacts sensitive environmental features or could be susceptible to flooding.

Flooding on the San Marcos River is common, as the watershed is in the heart of "Flash Flood Alley", an area known for some of the most intense rainfall events in the United States and characterized by steep slopes, thin soils, and sparse ground cover leading to rapid runoff and the potential for devastating and deadly flooding. The City of San Marcos experienced a massive flood in 1970 that took the lives of four children, inundated nearly 2,000 acres of the city, required the rescue of hundreds of residents, flooded 405 buildings, and caused more than 400 million dollars in damage.

In response to this and many previous floods, the City of San Marcos partnered with the federal Soil Conservation Service to create the Upper San Marcos River Watershed Reclamation and Flood Control District. This organization funded and oversaw the construction of five flood control dams on Sink and Purgatory Creeks from 1981 to 1991 at a cost of roughly 12 million dollars. These dams range in height from 50 to 100 feet, contain a combined storage of 18,924 acre-feet (6.2 billion gallons), and reduced the 100-year flood peak flow rate at Interstate 35 by 80 percent from about 104,000 cubic feet per second (cfs) to nearly 22,000 cfs. These are the most important flood control features that protect the City of San Marcos and provided significant flood reduction benefits in the floods of 1998, 2013, and 2015. For more information regarding flooding and potential regulatory and land conservation measures that can help reduce flood damages, please see the report titled "Upper San Marcos River, Flooding and Land Conservation, January 2017" (Hegemier 2017).

Figure 7. Flood damage on the Blanco River near Wimberley. Picture courtesy of media.victoriaadvocate.com

Flooding on the Blanco River is also common, as the Watershed has characteristics similar to the San Marcos River. Devastating and deadly floods occurred in 2015, and the ongoing Guadalupe Blanco River Authority-Army Corps of Engineers Floodplain Mapping project is developing potential flood reduction project options for future consideration. The City of San Marcos is also currently evaluating multiple flood reduction projects along the Blanco River within the City's jurisdiction. The planning process is scheduled for completion in 2017.

Figure 8. Spring Lake, headwaters of the San Marcos River, Picture courtesy of the Meadows Center

METHODS

This project determines conservation priorities for the Blanco and Upper San Marcos Watersheds using a geographic procedural model. The model proactively determines priority conservation areas within the Watersheds to more efficiently and effectively use conservation dollars in fee simple and conservation easement transactions. Model inputs include variables associated with water, culture, and ecology while also taking into account the threat of development in the coming years. The major steps of the process are outlined in Figure 9. They included collecting and evaluating available and usable data, determining the overall approach, creating preliminary results, refining approach and results based on stakeholder feedback, and creating the final process, results and documentation.

The geographic procedural model used here follows the work of the San Antonio Edwards Aquifer Protection Program (Siglo Group 2014), with alterations to fit the needs of the study area and the interests of the stakeholders. The San Antonio model determines conservation priorities in the Edwards Aquifer Contributing and Recharge Zone associated with protecting water quality and the drinking water supply for San Antonio. The program has led to over 200,000 acres (including partner organizations) being permanently conserved to date. Recently, voters renewed the program with an additional 90 million dollars allocated for conservation easements and fee simple acquisitions in the coming years.

The Blanco and the Upper San Marcos model includes the input of conservation resources, standardization between data layers, evaluation of priorities through a weighted sum, and the aggregation of results to the parcel level. The procedural model was designed to incorporate numerous variables in determining conservation priorities associated with the protection of water, cultural, and ecological resources. The project team evaluated numerous data layers and determined those in Table 3 to be most appropriate to determine conservation priorities at this time. Data were evaluated for use based on their importance for conservation, the reliability of their source, their comprehensiveness throughout the study area, their resolution, and their temporal accuracy. Because of the importance of water resources for the area and stakeholders, the prioritization placed an emphasis on water resources that will reduce flooding, protect spring flow, and enhance

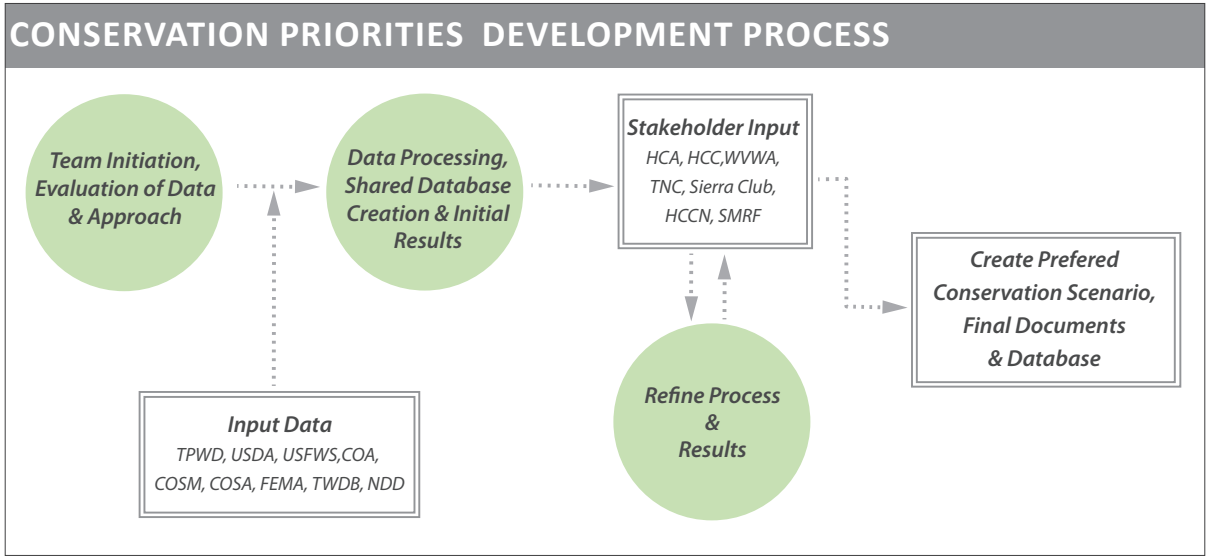


Figure 9. General steps associated with the process for determining conservation priorities in the Blanco and Upper San Marcos Watersheds.

water quality. Individual conservation resource examples can be seen in Figures 11 a,b,c,d and more information about these resources can be found in the Table 3.

The conservation resources and their associated values were used in the model to determine priority areas. After the initial model run, the model was executed iteratively to include new conservation resources, incorporate stakeholder input, and better understand the effects of particular resources on the resulting conservation priorities.

The output of a model run is a conservation value for each 30-meter by 30-meter area in the study area. The highest ranked areas are considered the priorities. These high priority areas together are termed a conservation scenario. The numerous model runs were used to understand how altering the values of conservation resources altered the resulting conservation scenario. Evaluation of multiple conservation scenarios resulted in the creation of the preferred conservation scenario described in greater detail in the Findings Section. The prioritized areas can be aggregated to the parcel level to give a value per parcel. The preferred scenario was determined by its ability to include numerous conservation resources considered important by the stakeholders and its general ability to define conservation priorities through numerous parts of the landscape.

Table 2. Conservation resources used in the prioritization processed divided into water (blue), cultural (orange), and ecological (green) resources.

Conservation Resource	Acres	% of Area	Value
Trinity Aquifer Recharge	57,020	15.9	High
Edwards Aquifer Recharge	81,608	22.8	High
Karst Areas	7,684	2.1	Very High
Minor Spring Buffers	362	0.1	Moderate
Major Spring Buffers (4 Spring Areas)	7,911	2.2	Very High
Wetlands	2,320	0.6	Moderate
100-year Floodplain	20,087	5.6	High
Public Water Supply Well Buffers	5,296	1.5	Low
Water Quality Buffers	61,741	17.2	High
Prime Farmland Soils	59,083	16.5	High
Scenic Vistas	21,819	6.1	Moderate
Trail and Proposed Trail Buffers	15,931	4.4	Moderate
Adjancency to Existing Open Space	19,701	5.5	Moderate to High
Parcel Size	236,222	65.9	Low to High
Opportunity Areas	86,238	24.1	Moderate to High
High Propability Golden Cheeked Warbler Habitat	54,850	15.3	High
Steep Slopes	38,364	10.7	Moderate to Very High
Cagles Map Turtles	315	0.1	Very High
Texas Pimpleback Mussels	4	0.0	Very High
Riparian and Floodplain Vegetation	23,419	6.5	High

Conservation Resources

The study area contains a mosaic of water, cultural, and ecological resources that define the character of the landscape and sustain the communities within the watershed. The conservation resources being used in the model are shown in Table 2 with further information in Table 3. A description of some of those resources with a focus on the water resources critical to the study area, is described below.

Water resources being used in the evaluation encompass those associated with spring flows, water quality, and flooding. The following variables are incorporated into the model: aquifer recharge zones, buffers around springs, karstic areas, floodplain, water quality buffers, wetlands, and buffers around public water supply wells. Two primary aquifer systems, the Trinity and Edwards, supply water in western portions of the study area, and are the primary supply for the towns of Wimberley and Woodcreek. The Edwards and Trinity are connected through faulting. The resulting hydrologic linkage becomes more evident in low rainfall periods, as water migrates through the system. The Trinity Aquifer is the source aquifer for Jacobs Well Spring and Pleasant Valley Springs. The Edwards

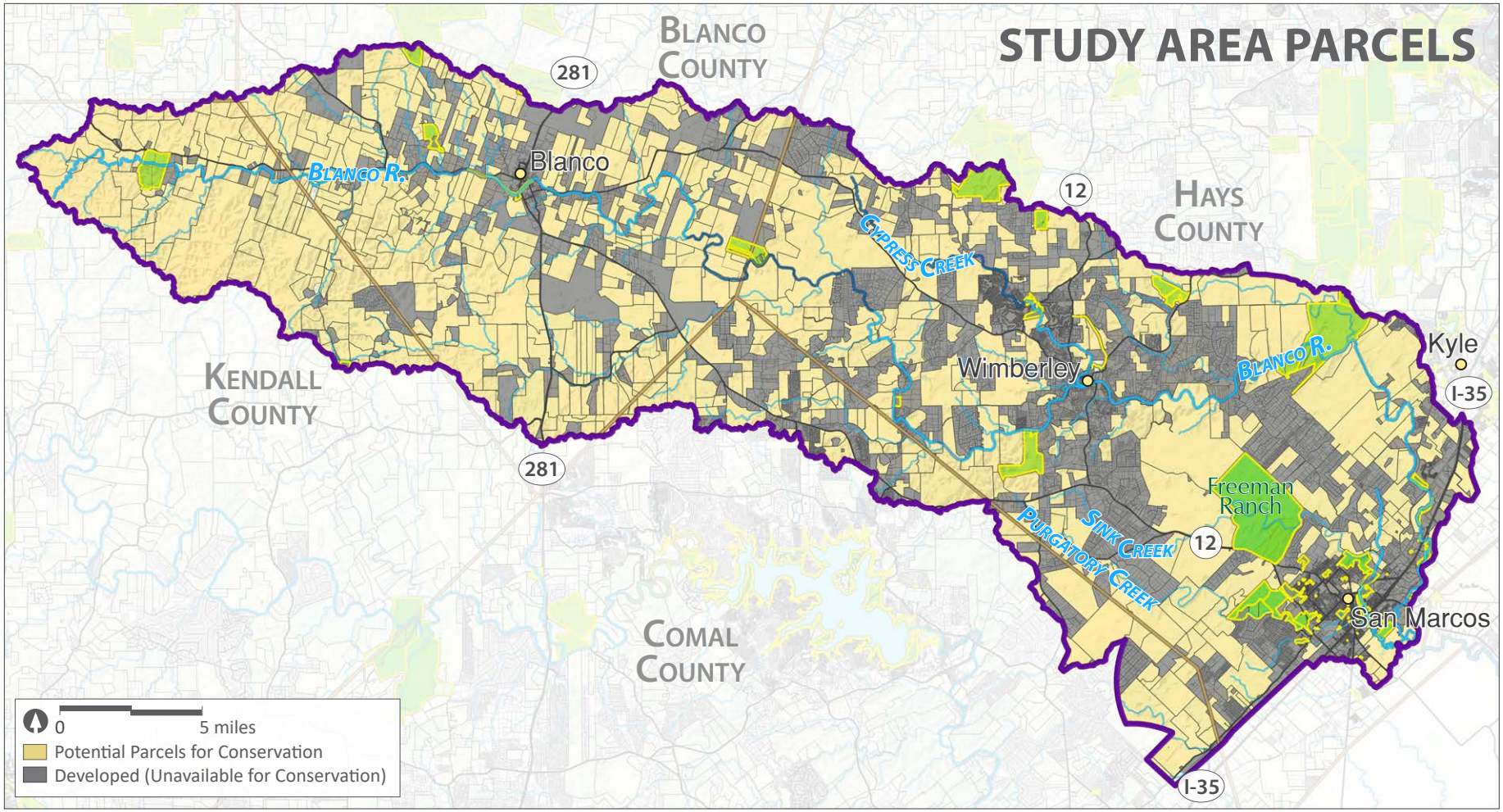


Figure 10. Potential parcels for conservation along with areas not available for conservation due to development and parcelization.

Aquifer is a significant source of water along the I-35 corridor and is the source aquifer for San Marcos springs (Wierman, et al, 2010). Both the Edwards and the Trinity Aquifer recharge areas are included as conservation resources.

In addition to the connection between aquifers, studies have shown significant interaction between surface water and groundwater in the watersheds (Smith, et al, 2014, Hunt, et al, 2017). Most of the base flow of surface water in Cypress Creek originates from Jacobs Well.

The Blanco River has several gaining and losing reaches. From its headwaters in Kendall County, the river gains water until it enters the Trinity Aquifer recharge zone, near the Blanco/ Hays County boundary. Through the recharge zone, the river typically loses water to the aquifer and

CONSERVATION RESOURCE EXAMPLES

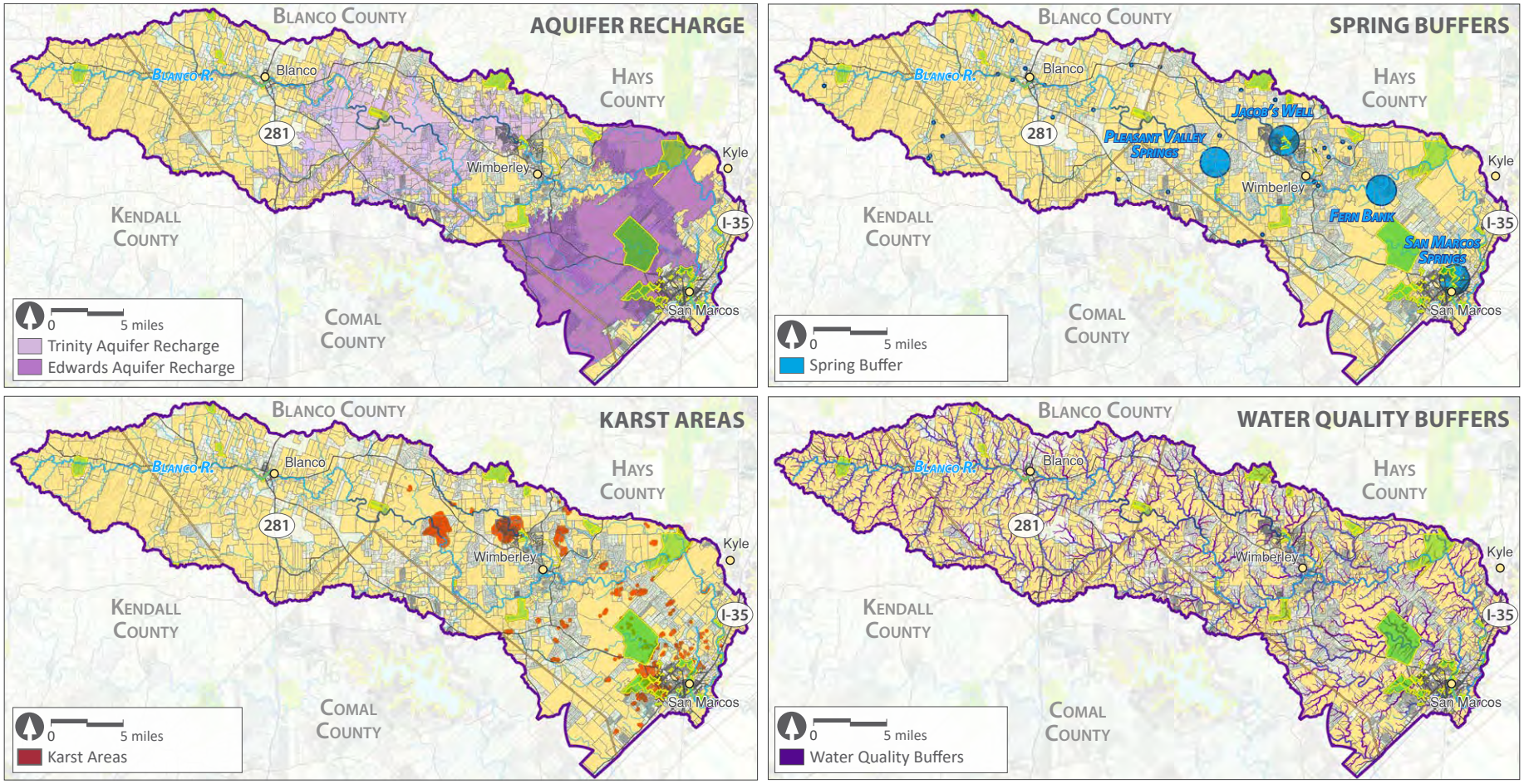


Figure 11a. (Top Left) Aquifer Recharge Zones (TCEQ 2016); Figure 11b. (Top Right) Major and Minor Spring Buffers (Heitmuller & Williams 2006); Figure 11c. (Bottom Left) Karst Areas (Hays County HCP & Weirman 2010); Figure 11d. (Bottom Right) Water Quality Buffers (BSEAA 2013)

is often dry. Many of these loss areas are associated with karst features. These karstic areas are included as a conservation resource because of their importance for recharge and the impact the areas around them can have on the quality and quantity of water entering the aquifer.

There are a series of springs upstream from Wimberley, including Pleasant Valley Springs and Jacob's Well, which feed the river. Flow continues downstream across the Balcones Fault Zone where the river loses most of its flow into the Edwards Aquifer. Dye tracing studies have shown some of the water lost to the aquifer discharges from San Marcos Springs and the Barton Springs segmant of the Edwards Aquifer to the north, particularly during drought. Buffers around springs are included as conservation resources because of the ecological and cultural significance of springs with the four major springs—San Marcos, Fern Ridge, Pleasant Valley, and Jacob's Well—receiving larger buffers. These buffers are areas important to the springs for quality and quantity of flow.

Beyond aquifers and springs, the areas around waterways and water bodies are considered significant for water infiltration, filtration, flood control, habitat, sustained flows, erosion control, and bank stability. To represent these as conservation resources, the 100-year floodplain as well as quality buffers based on the Regional Water Quality Protection Plan are included as conservation resources (BSEACD 2013).

STEPS IN RUNNING THE MODEL

1. *Evaluate and adjust the existing conservation lands file if new lands are conserved, developed, 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 results;*
7. *Repeat as needed.*

Figure 12. Steps in Running the Priority Model

Cultural resources include elements associated with agriculture, scenic views, proximity to existing open space, potential of development, and recreation trail corridors. Agriculture is an important economic and cultural land use in the study area. To incorporate areas significant for long-term agricultural production the NRCS (2016) prime farmland soils are included as a conservation resource. These are soils important for agriculture throughout the watershed.

Scenic views are part of what makes the Hill Country the Hill Country. Data from a scenic views study from Texas State University (TXS 2010) are incorporated as a conservation resource to represent those areas that have high visibility within the landscape.

Development and land transformations occur in patterns radiating out from municipalities and highways. Projections by Theobald (2005) and the Texas Water Development Board (2016), suggest that this process will accelerate in the study area over the coming decades. To capture

this trend in the model these corridors were hilighted as opportunity areas. These opportunity areas were defined as land in need of conservation within municipal ETJs or within 1 mile of I-35 and highway 281.

Recreation trails have been a significant driver of conservation in the greater San Marcos area. Spearheading this movement, the San Marcos Greenbelt Alliance and others have called for implementation of the loop and check vision articulate in the San Marcos Proposed Greenways Plan (2017). To accommodate this future green infrastructure, areas within a ¼ mile of existing and proposed trails are included as a conservation resource.

Building onto existing conservation lands is an efficient and effective way to increase overall conservation lands. It creates more robust habitat, greater connectivity, reduces management costs, and provides for greater recreational opportunities. To that end, adjacency is used as a conservation resource by prioritizing areas that are within 1,200 feet of existing conservation lands.

The size of parcels is another important consideration in conservation planning, effectiveness of transactions, habitat conservation, natural area management, and water resource impacts. Parcels available for conservation are defined as those greater than 100 acres or greater than 20 acres and within a ½ mile of a perennial waterway, 1 mile of a major spring, 350' of a spring, sink, or karst, or in an area defined as karstic. Collectively this included 439 parcels between 20 and 100 acres, and 605 parcels over 100 acres. Parcels greater than 100 acres are preferentially prioritized in the model with those from 100 to 640 acres receiving more preference, and those over 1,280 acres receiving the highest preference.

Ecological resources for this study include species of concern, specific vegetation types, and areas with substantial topographic relief. Species of concern are a cornerstone of the Edwards Aquifer Habitat and the Hays County Habitat Conservation Plans. Species of concern in the study area include Texas wild rice, San Marcos salamander, Blanco River Springs salamander, Texas Blind salamander, Comal Springs riffle beetle, and the Texas Pimpleback fresh water mussel, golden-cheeked warbler, and black capped vireo (TPWD 2016, Edwards Aquifer Habitat Conservation Plan 2012, Hays County Habitat Conservation Plan 2010). The Golden Cheeked Warbler, Texas pimpleback mussels, and Cagle's map turtle are incorporated as representative conservation resources, because of the extent of their habitats and availability of data. Based on Aurora (2016), golden-cheeked warble habitat that was considered of high potential quality in at least two of three habitat models used—models a, c, and l—is included as a conservation resource. The known habitat for both the pimpleback and Cagle's map turtle, identified in the TXNDD database (2016), are relatively small areas but considered important by some stakeholders as conservation resources.

Riparian vegetation, vegetation around streams and waterways, is critical for healthy aquatic ecosystems, water quality and sustained stream flow. To account for this in the model, the Texas Parks and Wildlife Department Ecological Systems Classification (2014) is used to define riparian and floodplain vegetation as a conservation resource.

Steep slopes are also included as an ecological resource in the model. Steep slopes are less practical for development, have higher likelihood of erosion, and can serve as safe harbor for species that are extirpated from more accessible parts of the landscape. The national elevation dataset, 30m resolution, was used to determine slope. Areas that had greater than 15% slope were incorporated as a conservation resource, and slopes greater than 60% were weighted more heavily.

Table 3. Conservation Resource Information: Purpose, Use, and Criteria, along with Sources.

Water Resources	Purpose, Use and Criteria	Source
Karst Areas	Prioritize protection of sensitive mapped caves and karst features, serves as both water quality buffer and habitat conservation. Mapping Criteria: 350 foot radius around mapped caves and karsts as well as generalized polygons of karstic areas.	Loomis Partners, Inc., Smith, Robertson, Elliott, Glen, Klein, & Bell, LLP, Zara Environmental, LLC, J. Lessard, Texas Perspectives, LLC, Capitol Market Research. 2010. Hays Country Regional Habitat Conservation Plan. Viewed 2016: http://www.hayscountyhcp.com/docs/FINAL _Hays_ County_HCP_20100621.pdf, Zara Environmental, LLC. 2016. Personal Correspondence, Weirman, D.A. (2016) Personal Correspondence
Major Spring Buffers (4 Spring Areas)	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
Trinity Aquifer Recharge	High probability recharge/karst features. Preservation of these lands helps protect the water quality and quantity recharge of connected aquifers and springs. Mapping Criteria: Defined for this study as the area where the Lower Glen Rose is exposed at the surface.	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). Viewed and downloaded: https://tnris.org/data-catalog/entry/geologic-database-of-texas/
Edwards Aquifer Recharge	High probability recharge/karst features. Preservation of these lands helps protect the water quality and quantity recharge of connected aquifers and springs. Mapping Criteria: Defined for this study in the Texas Administrative Code 30 TAC 213.	Texas Commission on Environmental Quality. 2016. Edwards Aquifer Regulatory Boundary (TSMS Version). Viewed and downloaded 2016: https://www.tceq.texas.gov/gis/download-tceq-gis-data/
100-year Floodplain	Identified as areas of high flooding potential critical for maintenance of water quality, erosion control, and bank stability, and riparian vegetation. Mapping Criteria: FEMA-100 year flood plain (note: for some parts of the study area this is currently being updated)	Meadows Center for Water and the Environment. 2016. Data delivery. From: Sansom A., Y. Xia, M. Clary, L. Parchman, M. Blount, and E. Warren. 2010. Geography & Water: Blanco Watershed Characterizing and Modeling Project, CFDA# 66-202. 2010. River Systems Institute. Texas State University.
Water Quality Buffers	These are critical for water filtration, erosion control, and bank stability. Mapping Criteria: Buffers based on National Hydrography Dataset Plus flow accumulation to define catchment areas in the following size classes with associated buffers: 32 to 120 acres buffer 100' from center line; 120 to 300 acres buffer 150' from center line; 300 to 640 acres buffer 200' from center line; greater than 640 acres; buffer 300' from center line.	Barton Springs Edwards Aquifer Conservation District. 2013. An Overview of the Regional Water Quality Protection Plan. Viewed 2016: http://bseacd.org/uploads/01_NextWave_Update-2013-04-26.pdf, National Hydrography Dataset Plus. 2006. Environmental Protection Agency. Viewed and downloaded 2009: https://www.epa.gov/waterdata/nhdplus-national-hydrography-dataset-plus.
Minor Spring Buffers	Buffers were placed around springs to promote the conservation of groundwater and maintain spring flows. Mapping Criteria: 350ft Buffers were placed around known springs.	Heitmuller, Franklin T. and Iona P. Williams. Compilation of Historical Water-Quality Data for Selected Springs in Texas, by Ecoregion. 2006; U.S. Geological Survey and Texas Parks & Wildlife Department. Data requested and provided 2012.
Wetlands	Improve water quality by filtering nutrients and sediments, and provide valuable habitat. Mapping Criteria: Wetland soils as identified and classified by the National Wetlands Inventory	U.S. Fish and Wildlife Service. 2016. Texas: National Wetland Inventory. Viewed 2016: https://www.fws.gov/wetlands/data/State-Downloads.html
Public Water Supply Well Buffers	Buffers help maintain and improve public water supply critical to long term community health and development. Mapping Criteria: 1000 foot radius around municipal wells	Texas Center on Environmental Quality. 2016. Public Water System Wells & Surface Water Intakes. Viewed 2016: https://www.tceq.texas.gov/gis/download-tceq-gis-data/.
Cultural Resources	**Purpose, Use and Criteria**	**Source**
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	Natural Resource Conservation Systems. 2016. Prime Farmland Soils. SSURGO- NRCS-USDA. Viewed and downloaded 2016: https://tnris.org/data-catalog/entry/soils/
Adjacency to Existing Open Space	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: Parcels adjacent to conservation lands	Texas Parks and Wildlife Department Land and Water Resources Conservation Program Open lands database, http://tpwd.texas.gov/gis/; Texas Parks & Wildlife Department. Conservation lands inventory, http://tpwd.texas.gov/gis/; Texas Land Trust Council
Opportunity Areas	Defining areas that will be impacted in coming decades by continued urban and suburban land use. Mapping Criteria: Extra territorial jurisdictions and 1 mile around major road corridors (I-35 & 281).	Major roads and extra territorial jurisdictions; Viewed and downloaded 2016: City of Austin, ftp://ftp.ci.austin.tx.us/GIS-Data/Regional/coa_gis.html; City of San Marcos, http://www.ci.san-marcos.tx.us/index.aspx?page=281; and Texas Department of Transportation, http://gis-txdot.opendata.arcgis.com/.
Scenic Vistas	Define areas Important for preserving the Hill Country aesthetic. Mapping Criteria: Area that can be see by 20 or more locations in the landscape determined through a viewshed analysis.	Texas State University and National Environmental Resource Data Solutions. 2010. Analysis of Potential Scenic Sites for the Hill Country Conservancy and Hill Country Alliance. Viewed and downloaded 2016: http://sites.geo.txstate.edu/g4427/F10/NERDS/index_files/Page392.htm.
Trail and Proposed Trail Buffers	Trail alignments and potential trail alignments were based on the City of San Marcos Proposed Greenways Plan as well as existing trails throughout the study area. Mapping Criteria: 1200' buffers around existing and proposed trail alignments.	City of San Marcos. 2016. Map Library. City Limits and ETJ. Viewed and downloaded 2016: http://www.ci.san-marcos.tx.us/index.aspx?page=281. City of Austin. 2016. Jurisdiction Boundaries. GIS/Maps Download. Viewed and downloaded 2016: ftp://ftp.ci.austin.tx.us/GIS-Data/Regional/coa_gis.html
Parcel Size	Larger sized parcels create valuable contiguous habitat that is required by many species. Mapping Criteria: Parcels of 100 acres in all areas; 20 acres or large within 1/2 mile of perennial waterway or within 350ft of springs, sinks, and karst features; Case-by-case basis for anything smaller than 20 acres, taking into consideration adjacency to existing open space, underrepresented areas, and parcel size.	Blanco (2016), Comal (2015), Hays (2016), and Kendall (2013) county appraisal districts shapefiles and tax roll.
Ecological Resources	**Purpose, Use and Criteria**	**Source**
Cagles Map Turtles	Prioritize protection habitat protection for endangered Cagles Map Turtles. Mapping Criteria: Areas defined as Cagles map turtle habitat.	Texas Parks and Wildlife. 2016. Texas Natural Diversity Database (NDD). Data requested and received in 2016.
Texas Pimpleback Mussels	Prioritize protection habitat protection for endangered Texas Pimpleback Mussels. Mapping Criteria: Areas defined as Texas pimpleback habitat.	Texas Parks and Wildlife. 2016. Texas Natural Diversity Database (NDD). Data requested and received in 2016.
Golden Cheeked Warbler Habitat	Prioritize protection high probability habitat for endangered Golden Cheeked Warbler. Mapping Criteria: Areas with attributes likely to be high quality habitat based on at least two of the three habitat models used—models l, a, and c.	Aurora, A. 2014. Personal Correspondence and Data Delivery.
Riparian and Floodplain Vegetation	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.	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/
Steep Slopes	Serve as surrogates for areas with endemic species and areas more susceptible to erosion and increased stormwater velocities. Mapping Criteria: Slopes 15 to 60% and Slopes over 60%.	U.S. Geological Survey. National Elevation Dataset, 30 Meter. Viewed and Downloaded 2016: https://nationalmap.gov/elevation.html

Figure 13. The Blanco River near Wimberley. Picture courtesy of sstatic1.squarespace.com

FINDINGS

The following section presents the results of the prioritization process, looks at how particular conservation resources are represented in the preferred scenario, provides a description of some areas of particularly high value, and suggests how these findings are applicable to conservation action. These findings are based on current conditions, available data, current best analysis practices, existing conservation lands, and stakeholder input.

Three example conservation scenarios are shown in Figure 14. These conservation scenarios were used by stakeholders to consider the impact of different resources in the model. Conservation resource values were then adjusted iteratively to create additional scenarios and eventually the preferred conservation scenario (Figure 15). Within the preferred scenario water resources contributed approximately half the value in the model with cultural and ecological resources each contributing approximately a quarter of the value. The preferred scenario includes 46,227 acres as high priority conservation areas —12.9% of the study area. This total includes 3,539 acres of existing conservation lands, 32,583 acres available for conservation, and 10,105 acres which did not meet the criteria for conservation consideration because it was in developed areas or a parcel between 20 and 100 acres. The high 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 2 lists the conservation resources, their value in the model, the total acres of each resource found within priority areas, and the percentage of each resource occurring inside priority areas. Because of the high value placed on water resources in the model, they are well represented in the preferred scenario with percent representation ranging from 25 to 89%. Karst areas had the highest representation, followed by major spring buffers, and wetlands. Cultural resources ranged from 5 to 23%. Prime farmland soils had the highest level of representation—a result of it occurring with other conservation resources and the high value it was given in the model. Scenic vistas had the lowest level of representation—a result of it having a moderate value in the model, and it often occurring without other conservation resources. Ecological resources ranged from 31 to 100% representation. The Texas pimpleback mussel and Cagle's map turtle habitat was essentially 100% included in the preferred scenario. This was a result of their very high value in the model as well as their co-occurrence with water resources. Other ecological resources had moderate to high values in the model. Nodes of conservation priorities are evident in

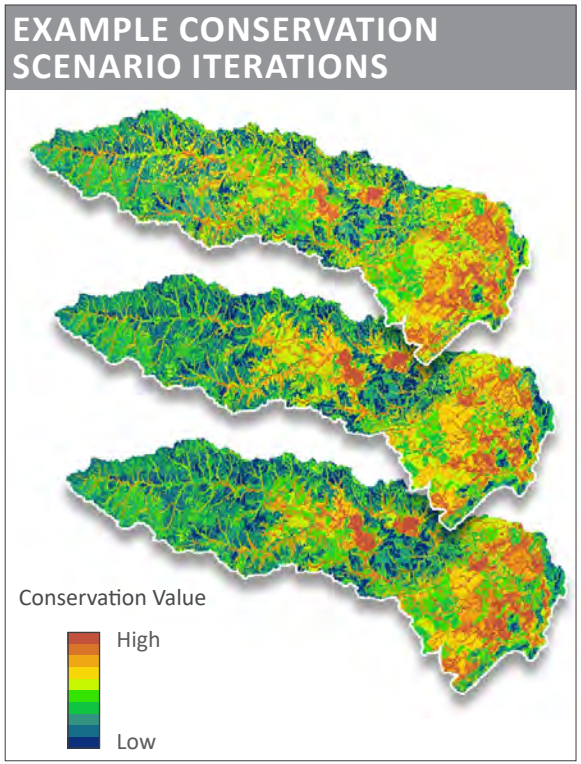
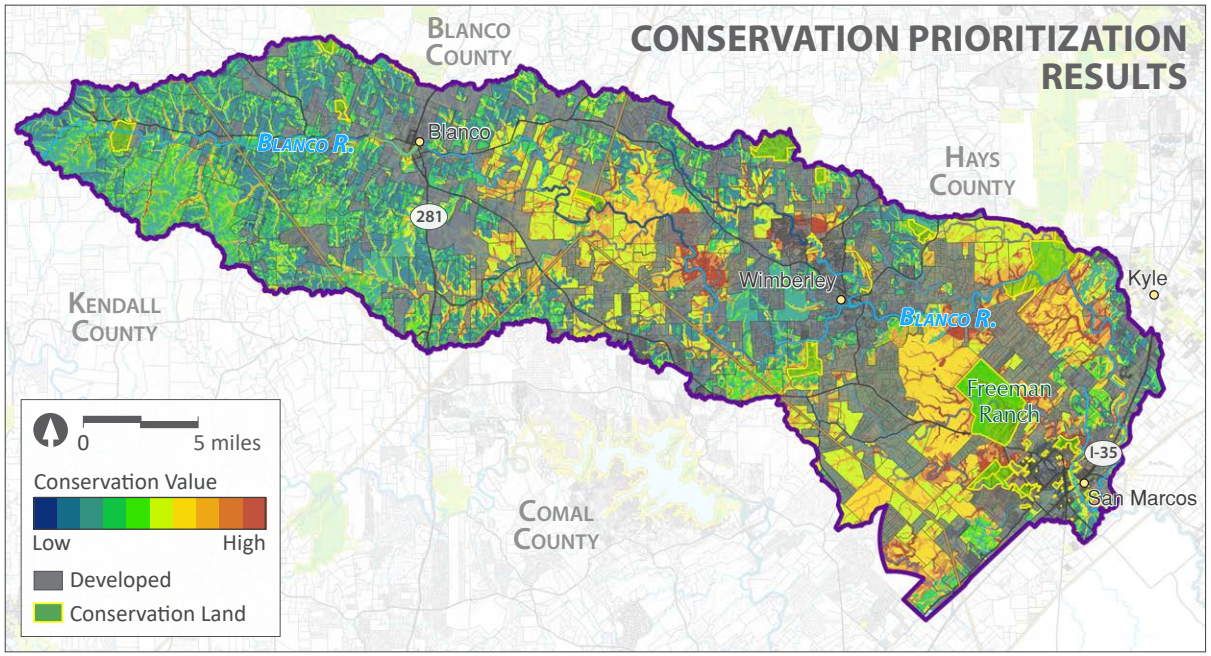


Figure 14. Example Conservation Scenario Iterations



Conservation Resource	Value	Acres in Study Area	% in Priority Area
Karst Areas	Very High	6,833	88.9
Major Spring Buffers (4 Spring Areas)	Very High	5,943	75.1
Trinity Aquifer Recharge	High	14,338	25.1
Edwards Aquifer Recharge	High	22,095	27.1
100-year Floodplain	High	13,869	69.0
Water Quality Buffers	High	27,094	43.9
Springs Buffers	Moderate	184	50.9
Wetlands	Moderate	1,676	72.2
Public Water Supply Well Buffers	Low	1,578	29.8
Prime Farmland Soils	High	13,766	23.3
Adjancency to Existing Open Space	Moderate to High	6,774	34.4
Opportunity Areas	Moderate to High	20,045	23.2
Scenic Vistas	Moderate	1,063	4.9
Trail and Proposed Trail Buffers	Moderate	8,166	51.3
Parcel Size	Low to High	29,912	12.7
Cagles Map Turtles	Very High	310	98.2
Texas Pimpleback Mussels	Very High	4	100.0
High Propability Golden Cheeked Warbler Habitat	High	17,282	31.5
Riparian and Floodplain Vegetation	High	13,602	58.1
Steep Slopes	Moderate to Very High	6,143	16.0

Figure 15. (Above) Conservation Priority Areas; Table 4: (Below) Preferred Conservation Scenario Results including water (blue), cultural (yellow), and ecological (green) resources.

some areas as a result of the co-occurrence of numerous conservation resources (Figure 16). These clusters should serve as focal points of priority conservation action. Four distinct clusters worth mentioning here include:

- The ring around the San Marcos core where karst features, the springs, riparian areas, recharge zone, and the trail buffer combine to form an almost continuous loop around the city.
- Fern Bank Springs has a cluster of conservation priorities as a result of the recharge zone, opportunity area, spring buffers, water quality buffers, and golden cheeked warbler habitat.
- The Cypress Creek area has clusters of conservation priorities as a result of the Trinity Aquifer recharge, spring buffers, golden cheeked warbler habitat, and karst features.
- The Pleasant Valley Springs area, much like Cypress Creek, has clusters associated with the Trinity Aquifer recharge, spring buffers, golden cheeked warbler habitat, and karst areas.

The areas prioritized here are appropriate for immediate conservation actions that can include fee simple purchase, conservation easement acquisition, or land stewardship activities that protect, maintain, and enhance the conservation resources within the watersheds.

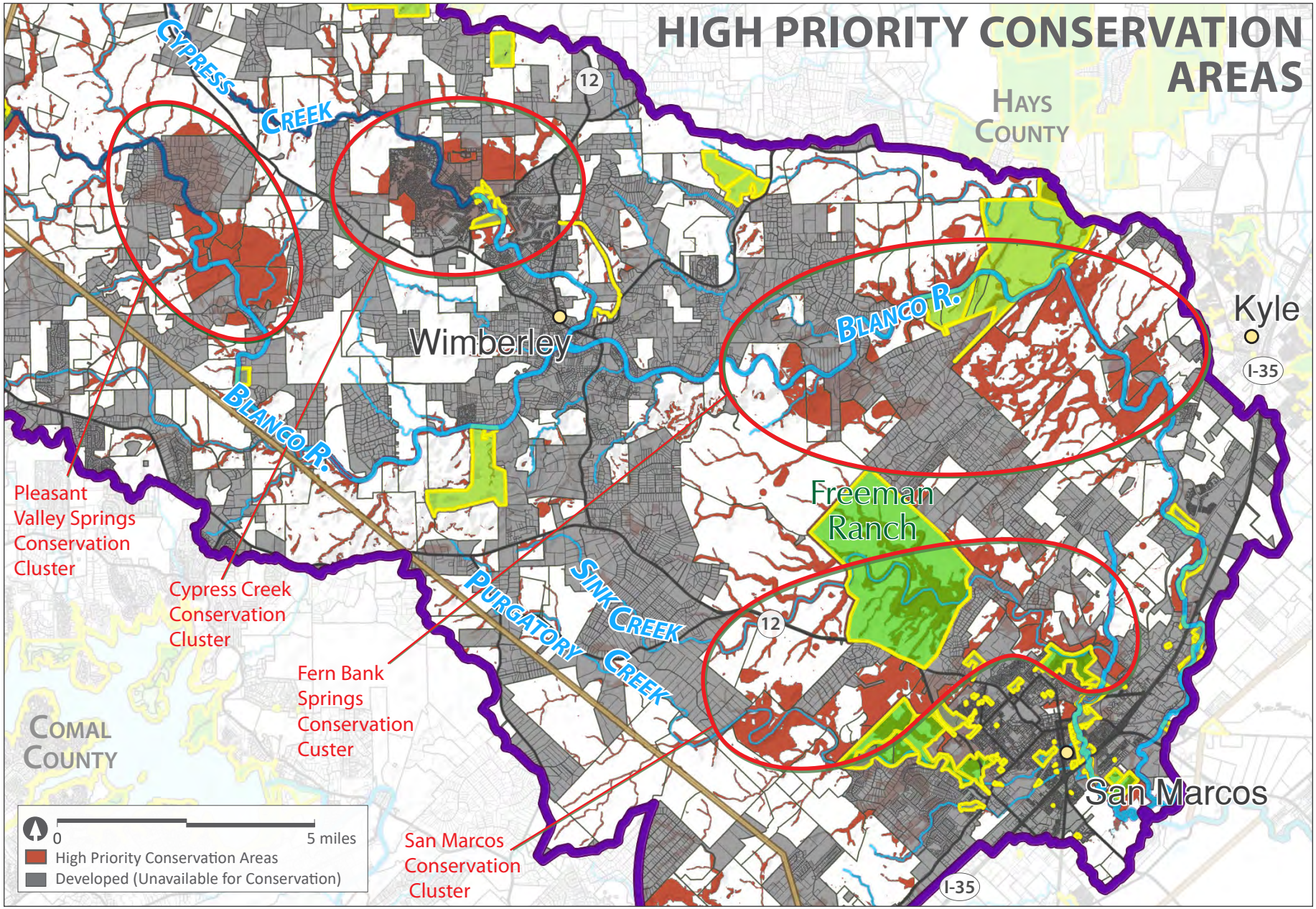


Figure 16. High Priority Conservation Areas

Figure 17. The Blanco River Valley Ranch. Picture courtesy of texaslandman.com

DISCUSSION & CONCLUSION

The Blanco and San Marcos Watersheds are at a pivotal moment. New growth is driving substantial land use change and significant additional growth is expected in the coming decades. The critical water, cultural, and ecological resources that are helping to drive this prosperity are under threat due to land transformation. Vital resources and ecosystem services are being lost including flood protection, quality drinking water, soil stability, agricultural production, natural beauty, and protection of unique flora and fauna. Through strategic actions there is still time to maintain and enhance these conservation resources through conservation easements, fee simple purchases, and land stewardship activities. These strategies are being used throughout Texas to protecting water supplies, aquifer recharge, important landscapes, heritage ranches, and important recreational areas. Action is needed now in the study area to respond to the rapid and ongoing population growth of San Marcos, Buda, Kyle, Wimberley, and surrounding municipalities.

The project evaluated 358,240 acres and prioritizes 46,227 acres, 12.9% of the study area as conservation priorities. Proponents of conservation can use this information to galvanize support and direct action as they find funding, identify willing landowners, and work out the details of specific land transactions. This work will have the highest likelihood of success by aligning and combining the efforts of municipalities, state and federal agencies, philanthropic conservation buyers, advocacy groups, and land trusts.

To facilitate conservation action, the prioritization results can be aggregated to parcels. In Figure 18 an example of aggregation to parcels can be seen based on the mean value of conservation values in a parcel. Much like the priorities described above there is an evident pattern of clustering circling San Marcos, around Fern Bank and Pleasant Valley Springs, and up into the Cypress Creek watershed. In addition to being able to compare parcels based on the prioritization results, this data allows practitioners to look at any area in the Watersheds and

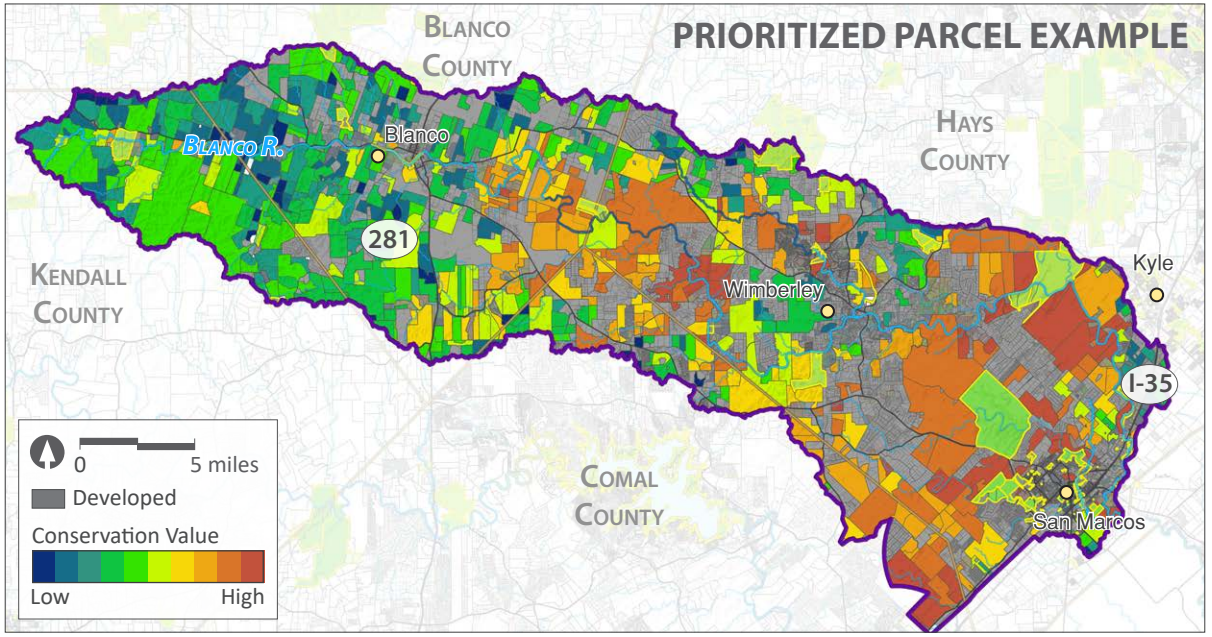


Figure 18. Example of parcel prioritization based on mean value of all conservation values occurring in a parcel.

understand what conservation resources occur there.

These findings should be coupled with those of other studies such as the Upper San Marcos River Flooding and Land Conservation Technical Report (Hegemier 2017) to provide the most robust conservation program. Suggestions from that study, which are supported by these findings include promoting sound management practices on conservation lands, and encouraging city and county policies that incorporate conservation and stream buffers in land development requirements.

San Antonio's success provides another important model of how to take the next steps toward conservation action. The office of the San Antonio Edwards Aquifer Protection Program is willing to be a resource for conservation efforts in the Blanco and San Marcos River Watersheds (Ellis 2016). They realize that regional growth patterns are impacting the same water resources they are protecting. In addition, it is imperative that conservation actions and conservation planning are integrated into future transportation, land use, water quality, and watershed planning in the study area.

This prioritization suggests a number of starting points for conservation action. The Freeman Ranch is, and should continue to be, the cornerstone of conservation in the Upper San Marcos watershed. Understanding the long-term status of the property is a key step in moving forward. Additionally, the City of San Marcos has vested interested in pushing conservation forward in the large tracts that are upstream of spring lake that are in environmentally sensitive areas. This makes priority properties immediately around the area between Freeman Ranch and Purgatory Creek, as well as the priority properties connecting Freeman Ranch to the Spring Lake Preserve in the Sink Creek Watershed critical first conservation actions. Hays County can utilize this resource to address the needs of the Hays County Habitat Conservation Plan and Edwards Aquifer Habitat Conservation Plan while conserving important resources in the Watersheds through future bond dollars and working in partnership with both landowners and philanthropic conservation buyers. The county and philanthropic buyers can focus on the high priority areas around Fern Bank, Pleasant Valley Springs, and Jacob's Well. Interested private landowners can look to the landowner group started in the Pedernales River watershed that has been successful in bringing numerous landowners together from different backgrounds with the common interest of conserving the integrity of natural resources and being good land stewards.

The results of this project can be used to support the efficient and effective protection of water, spring flow, working agricultural lands, and rural aesthetics while reducing the impacts of future flooding events. Conservation of a substantial part of the priorities highlighted here will take a major effort of time and resources by numerous organizations and individuals. The result of that action will be a network of conserved properties that maintain ecosystem services vital for all communities in these Watersheds to prosper and grow.

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