PLATEAU REGION WATER PLAN

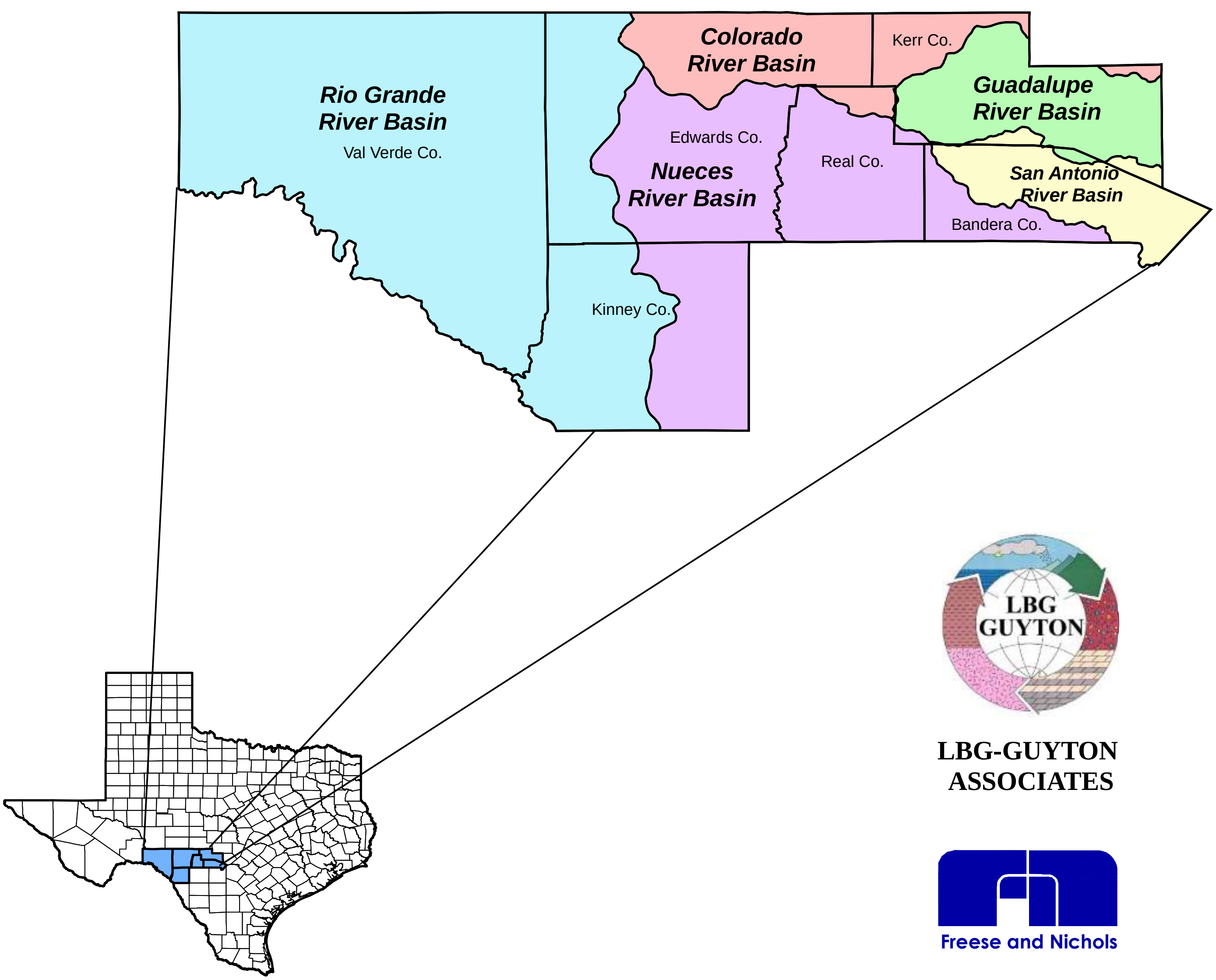
JANUARY 2011

Prepared by

Plateau Water Planning Group

Prepared for

Texas Water Development Board



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Freese and Nichols

EXECUTIVE SUMMARY

PLATEAU REGION

Located along the southern boundary of the Texas Edwards Plateau, the Plateau Water Planning Region (originally designated as Region J) stretches from the Central Texas Hill Country westward to the Rio Grande and consists of Bandera, Edwards, Kerr, Kinney, Real and Val Verde Counties. The regional economy is based primarily on tourism, hunting, ranching, agribusiness, government and military activities. The beauty of the Hill Country, the solitude of the forested canyons and plateau grasslands, and the gateway to Mexico all support a major tourist and recreational trade. The natural resources of the Region include both terrestrial and aquatic habitats that boast some of the best scenic drives, beautiful vistas, river rafting, and hunting and fishing in Texas. Natural resources also include the great diversity of plant and animal wildlife that inhabit these environments.

In January of 2006, the second round of regional water planning was concluded with the adoption of the *2006 Plateau Region Water Plan*. It is understood that this plan is not a static plan but rather is intended to be revised as conditions change. For this reason, the current 2011 Plan put forth in this document is not a new plan, but rather an evolutionary modification of the preceding plan. Only those parts of the original plan that require updating, and there are many, have been revised.

The purpose of the *Plateau Region Water Plan* is to provide a document that water planners and water users can reference for long- and short-term water management recommendations. Equally important, this Plan serves as an educational tool to enlighten all citizens as to the importance of properly managing and conserving the delicate water resources of this pristine Region.

POPULATION AND WATER DEMAND

The U.S. Census Bureau performed a census count in 2000, which provides the base year for future population projections. Although the Plateau Water Planning Group (PWPG) accepts the 2000 census count, members express concern that the census does not recognize the significant seasonal population increase that occurs in these counties as the area draws large numbers of hunters and recreational visitors, as well as absentee land owners who maintain vacation, retirement, and hunting cabins. Therefore, an emphasis is made in this planning document, especially for the rural counties, to recognize a need for more water than is justified simply from the population-derived water-demand estimates.

The Plateau Region covers 9,252 square miles and contains a projected year-2010 population of 135,723. The mostly rural nature of this Region is reflected in its population density of 14.7 (in 2010) people per square mile, which is significantly less than the State average of 72 people per square mile. Approximately 46 percent of the total population of the area is located in the two largest cities, Del Rio and Kerrville. In the year 2010, Del Rio, including the population of Laughlin Air Force Base, is projected to have 39,249 residents and Kerrville with 23,044. The projected year-2010 population of other major communities in the Region are: Bandera (1,056); Rocksprings (1,380); Brackettville and Fort Clark Springs (3,257); and Camp Wood (826). These population estimates do not include a significant transient (tourist, hunting, recreation, etc.) population that has a resulting significant impact on overall water supply demand in the Region.

Total population of the six counties is expected to increase by 52 percent from the projected year-2010 census count of 135,723 to 205,910 by 2060. The greatest percentage increase in population is projected to occur in Bandera County, which is expected to grow from a projected year-2010 population of 26,373 to 60,346 by the year 2060, an increase of 129 percent. This growth is primarily influenced by the rapid expansion in the San Antonio metroplex. However, future escalation of fuel cost and cost of living could slow this growth rate. Population in the rural counties of Edwards, Kinney and Real is expected to remain relatively constant over the 50-year planning period, however the transient population will likely increase.

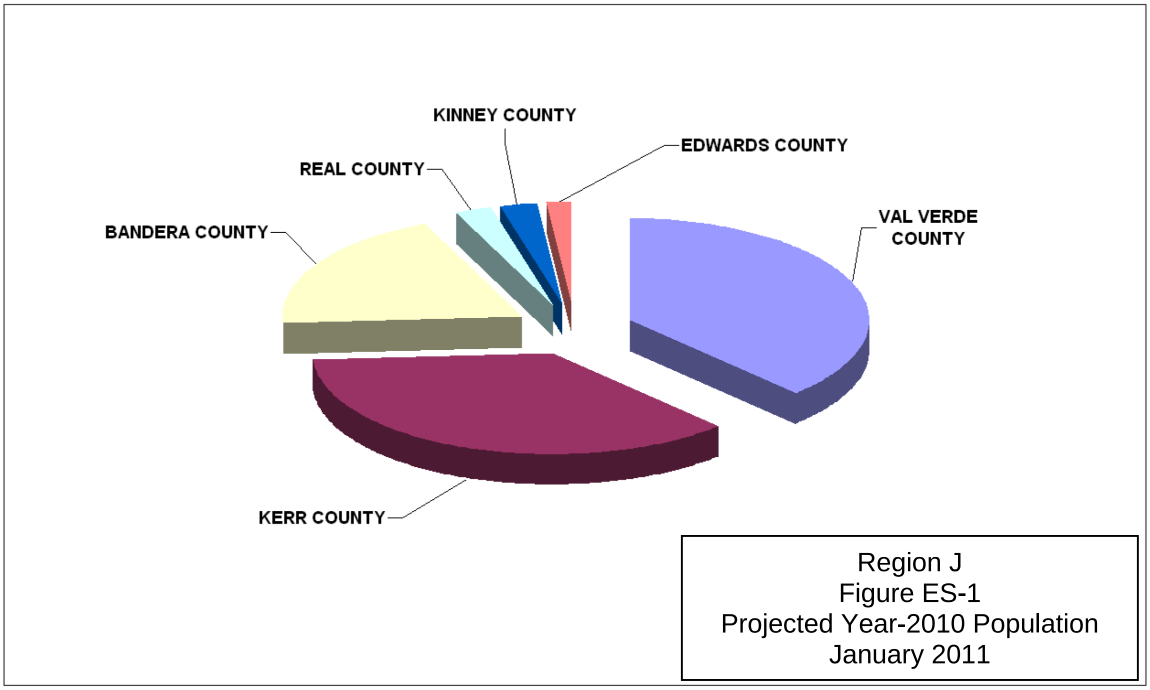

FIGURE ES-1. PROJECTED YEAR-2010 POPULATION

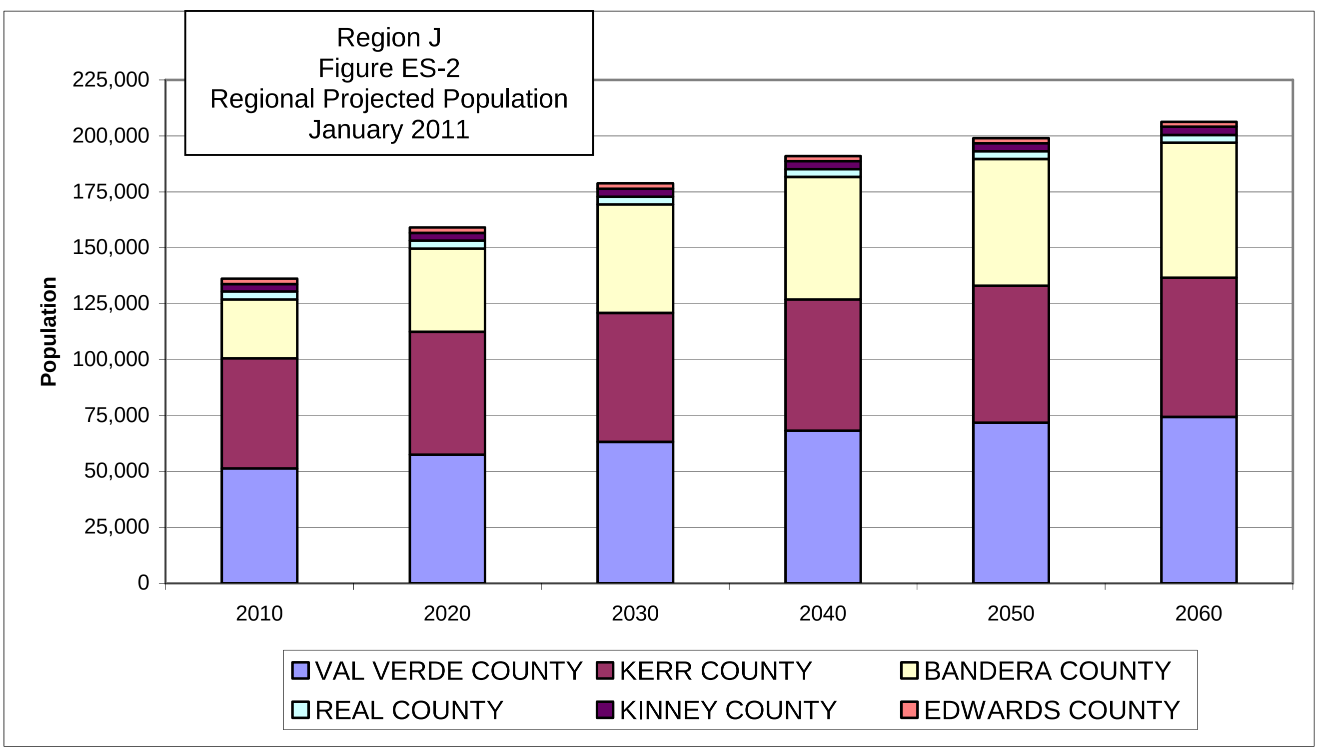

FIGURE ES-2. REGIONAL POPULATION PROJECTION

Total projected water consumptive use in the Plateau Region in the year 2010 is 51,928 acre-feet. The largest category of projected demand is municipal (29,320 acre-feet), followed by irrigation (19,423 acre-feet), livestock (2,752 acre-feet), mining (403 acre-feet), and manufacturing (30 acre-feet). Municipal and irrigation combined represent 94 percent of all water used in the Region. The forecasted total demand for water needed in the Region will increase from the year 2010 by 13 percent or a total of 58,643 acre-feet per year by the year 2060.

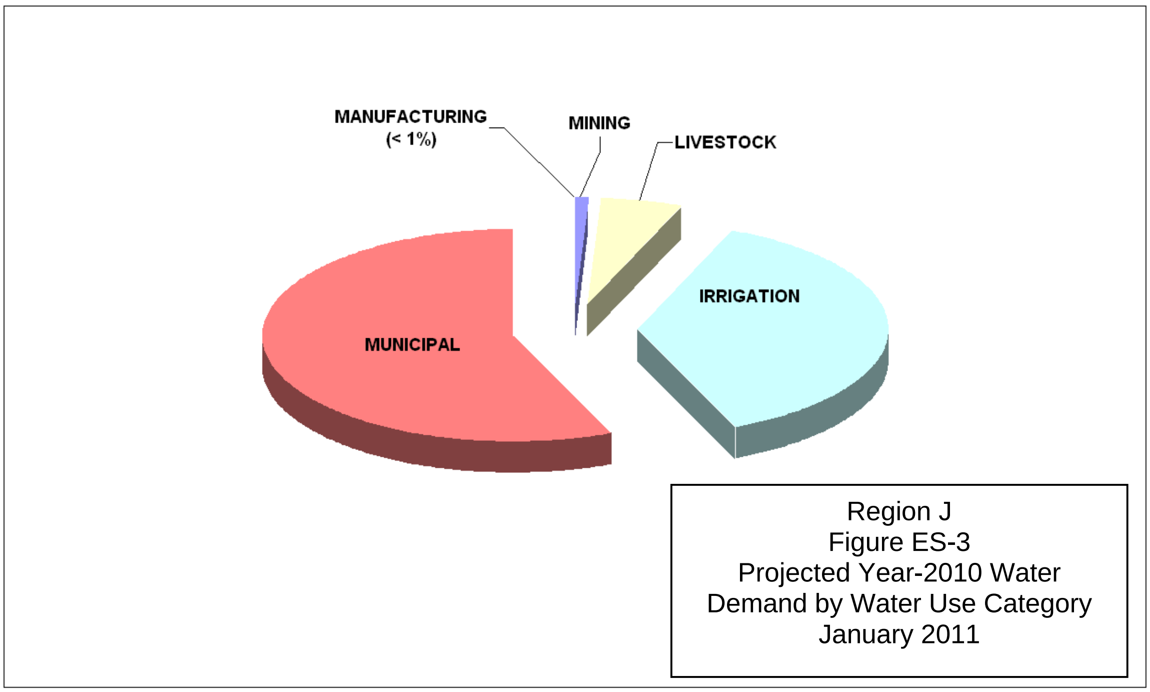

FIGURE ES-3. PROJECTED YEAR-2010 WATER DEMAND BY WATER USE CATEGORY

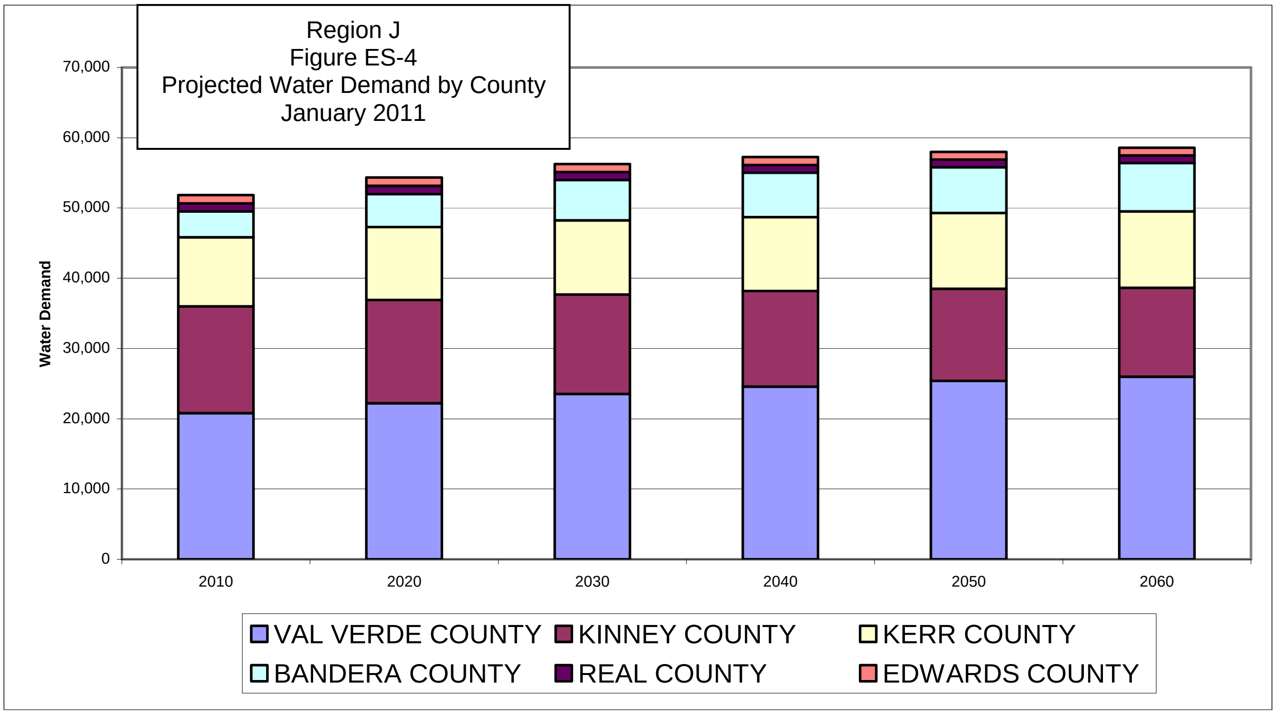

FIGURE ES-4. PROJECTED WATER DEMAND BY COUNTY

The largest center of municipal demand is Del Rio in Val Verde County, where 14,909 acre-feet of water is projected to have been used in 2010 to supply all areas of residential, commercial and military consumption. Fifty-seven percent of the Region's total municipal water use occurs in Val Verde County, and 25 percent in Kerr County. The use of water for manufacturing purposes only occurs in Kerr County.

The City of Del Rio is the only entity in the Plateau Region that is designated as a wholesale water provider. In addition to its own use, the City provides water to Laughlin Air Force Base and subdivisions outside of the City. The Upper Guadalupe River Authority (UGRA) anticipates becoming a wholesale water provider in coming years with the intent to provide conjunctive water-supply sources to meet the needs of Kerr County citizens that will not be served by the City of Kerrville.

Municipal water demand in the Plateau Region is projected to increase from a year-2010 level of 29,320 acre-feet to 39,632 acre-feet by the year 2060. Because municipal water demand is directly related to population, Val Verde County has the highest demand in the Region.

Bandera County, with the greatest projected percentage population increase, will likewise see the greatest percentage municipal water demand increase over the 50-year period, 113 percent.

Most irrigation that occurs in the Plateau Region is for the watering of pastures and hay fields. Because of the typically rocky and uneven terrain throughout much of the Region, irrigation of commercial row crops is minimal. Kinney County has the highest irrigation water use (70 percent of the Region's total) and is the only county in which irrigation use is greater than municipal use. On a regional basis, water used for irrigation is projected to decline slightly over the 50-year planning horizon, from the year-2010 level of 19,423 acre-feet to 15,837 acre-feet by 2060. However, as any irrigator can attest, climate, water availability, and the market play key roles in how much water is actually applied on a year-by-year basis.

Environmental and recreational water use in the Plateau Region is recognized as being an important consideration as it relates to the natural community in which the residents of this Region share and appreciate. In addition, for rural counties, tourism activities centered around the natural resources offer perhaps the best hope for modest economic growth to areas that have seen a long decline in traditional economic activities such as agriculture.

WATER SUPPLY RESOURCES

Water supply sources in the Plateau Region include groundwater from six aquifers and surface water within five river basins. Reuse of existing supplies is also considered a water supply source. Water supply availability under drought-of-record conditions is considered in the planning process to insure that water demands can be met under the worst of circumstances. In the consideration of available water supply sources, this plan fully recognizes and protects existing water rights, water contracts, and option agreements.

Within the Plateau Region, the TWDB recognizes three major aquifers [the Trinity, the Edwards-Trinity (Plateau), and the Edwards (Balcones Fault Zone)]. For this plan, the Austin Chalk Aquifer in Kinney County, and the Frio and Nueces River Alluvium Aquifers in Edwards and Real Counties are also identified as groundwater sources. Groundwater conservation districts in Bandera, Kerr, Kinney, Real and Edwards Counties provide for local management control of the groundwater resources in their respective districts. Over much of the Region, water levels generally fluctuate with seasonal precipitation and are highly susceptible to declines during drought conditions. Discharge from the aquifers occurs naturally through springs and seeps, and artificially by pumping from wells. Some discharge also occurs through leakage from one unit to another and through natural down-gradient subsurface flow out of the Region.

Base flow to the many rivers and streams that flow through the Plateau Region is principally generated from the numerous springs that issue from rock formations that form the major aquifers. It is thus recognized that sustaining flow in these important rivers and streams is highly dependent on maintaining an appropriate water level in the aquifer systems that feed the supporting springs. With the sustainability of local water supplies and the economic welfare of the Region in mind, the PWPG thus defines groundwater availability as a maximum level of aquifer withdrawal that results in an acceptable level of long-term aquifer impact such that the base flow in rivers and streams is not significantly affected beyond a level that would be anticipated due to naturally occurring conditions. The PWPG also acknowledges that groundwater conservation districts have regulatory authority over permitted withdrawals. Where available, TWDB groundwater availability models (GAMs) were used to assist in the availability analysis process.

The counties that comprise the Plateau Region contain the headwaters of the Guadalupe, San Antonio, Medina, Sabinal, Frio, Nueces, and West Nueces rivers; and tributaries to the Colorado River and Rio Grande such as the Pecos, Devils, and South Llano rivers. Flow in these rivers and streams is critical to the Plateau Region in that it provides municipal drinking water, supplies irrigation and livestock needs, maintains environmental habitats, and supports a thriving ecological and recreational tourist economy. Water users downstream of the Plateau Region (Regions K, L, and M) likewise have a stake in maintaining and protecting river flows.

Although rather limited during severe drought conditions, surface-water supplies in the Region are important. The Cities of Kerrville and Del Rio currently use surface water from the Guadalupe River and from San Felipe Springs, respectively. Camp Wood in Real County is supplied from Old Faithful Spring located on a tributary to the Nueces River. For surface-water supplies, drought-of-record conditions relate to the quantity of water available to meet existing permits from the Rio Grande, Nueces, Colorado, Guadalupe, and San Antonio rivers and their tributaries as estimated by Run 3 of the TCEQ Water Availability Models (WAMs).

Water recycling, or reuse, is reusing treated wastewater for beneficial purposes such as agricultural and landscape irrigation or industrial processes. The Cities of Kerrville and Camp Wood have active water reuse programs.

The PWPG recognizes the important ecological water supply function that all springs perform in the Region. Springs create and maintain base flow to rivers, contribute to the esthetic and recreational value of land, and are significant sources of water for wild game and aquatic species. Water issuing from springs forms wetlands that attract migratory birds and other fowl that inhabit the Region throughout the year. The spring wetlands host numerous terrestrial and aquatic species, some of which are recognized as threatened and endangered.

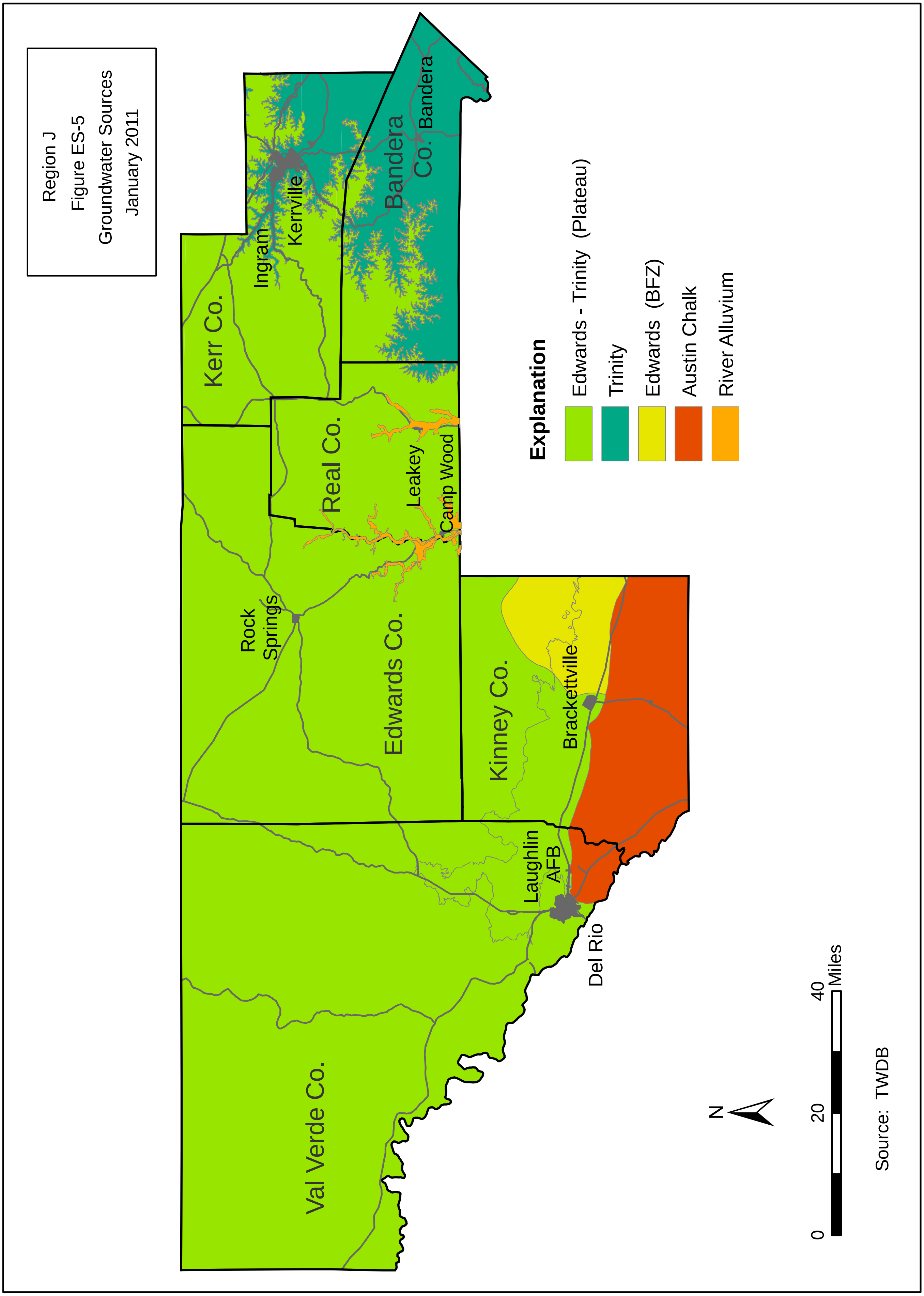

FIGURE ES-5. GROUNDWATER SOURCES

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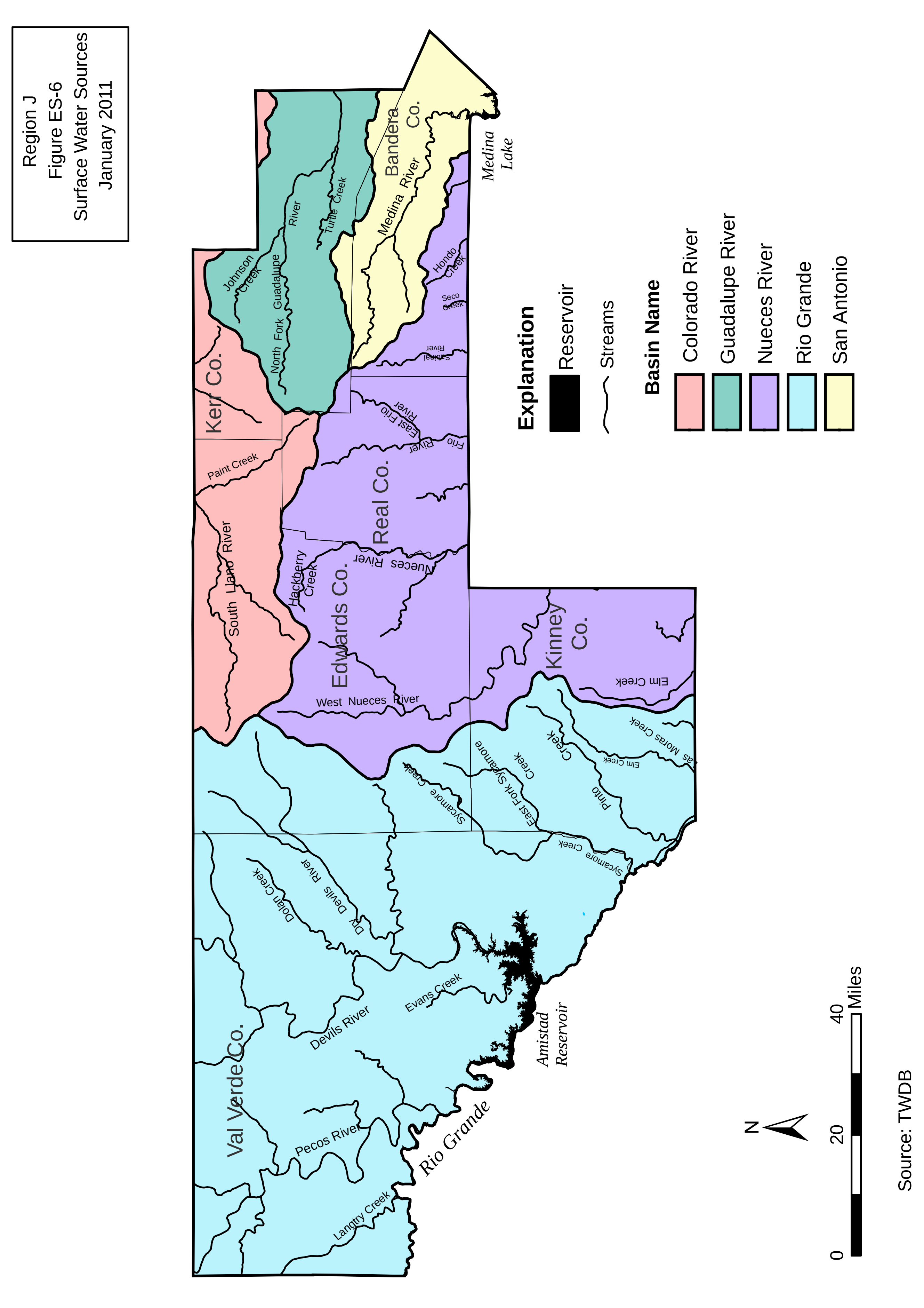

FIGURE ES-6. SURFACE WATER SOURCES

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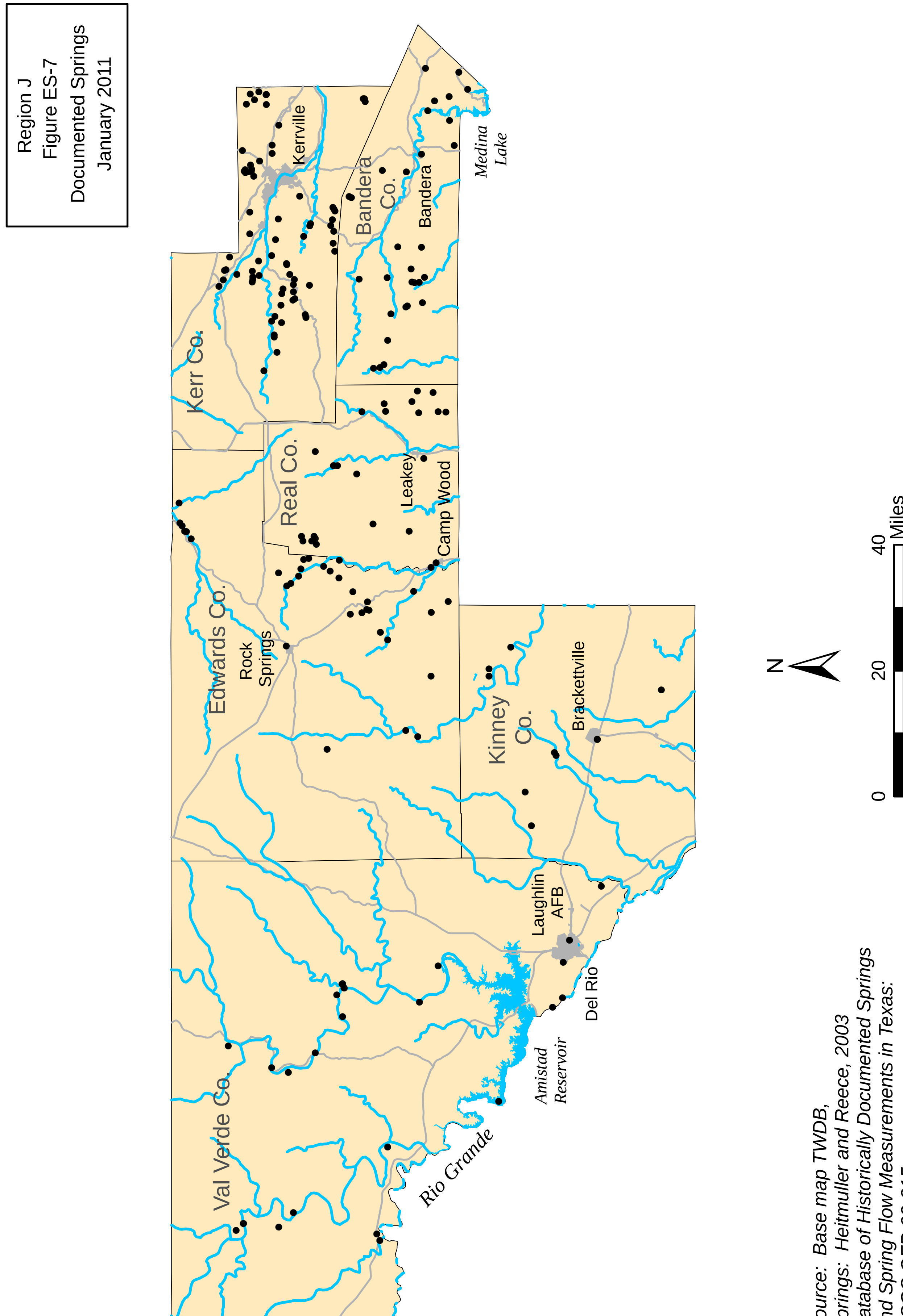
The PWPG has identified three "Major Springs" that are important for their municipal water supply contribution. The fourth largest spring system in Texas, San Felipe Springs, discharges to San Felipe Creek east of Del Rio and provides municipal drinking water for the City, as well as irrigation use downstream. Las Moras Springs in Kinney County is of historical significance for its importance as a supply source on early travel routes and military fortifications. Today, Las Moras Springs supports the Fort Clark Springs community and is hydrologically associated with the same aquifer system that serves Fort Clark Springs MUD and the City of Brackettville. The third major spring is Old Faithful in Real County, which is the drinking-water supply for the City of Camp Wood. Although only three springs are identified as "Major Springs", the PWPG recognizes that all springs in the Region are important and are deserving of natural resource protection.



Source: Base map TWDB,
Springs: Heitmuller and Reece, 2003
Database of Historically Documented Springs
and Spring Flow Measurements in Texas:
USGS OFR 02-315

FIGURE ES-7. LOCATION OF DOCUMENTED SPRINGS

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WATER MANAGEMENT STRATEGIES

A major component of this Plan is to identify municipalities and water-use categories that may, in times of severe drought, be unable to meet expected water-supply needs based on today's ability to access, treat, and distribute the supply. Recommended alternatives, or strategies, to meet anticipated drought-induced shortages are presented for consideration. It should be acknowledged that the PWPG has no authority to mandate that any recommended strategy be implemented, and that it is the individual entity's initiative to act on needed changes.

Table ES-1 below lists the projected water supply shortages for the Cities of Kerrville and Camp Wood under drought-of-record conditions based on no new infrastructure development. Water management strategies are recommended in this Plan that if implemented may assist in meeting these supply shortages. Although water supply deficits are not projected, strategies, including conservation activities, are also developed for the Communities of Bandera, Barksdale, Brackettville, Leakey, and for the Upper Guadalupe River Authority. All recommended strategies are listed in Table ES-2. Total capital cost to implement the recommended strategies is $54,792,390.

TABLE ES-1. WATER SUPPLY SHORTAGES DURING DROUGHT-OF-RECORD CONDITIONS

(Acre-Feet/Year)

WATER USER GROUP	S2010	S2020	S2030	S2040	S2050	S2060
KERR COUNTY						
Kerrville	-1,322	-1,706	-1,878	-1,897	-2,112	-2,222
REAL COUNTY						
Camp Wood	-172	-172	-166	-160	-163	-167

TABLE ES-2. RECOMMENDED WATER MANGEMENT STRATEGIES

Entity	Strategy
City of Bandera	Surface water acquisition, treatment and ASR
	Conservation: Public information
Community of Barksdale (Edwards County Other)	Additional groundwater wells
	Replace pressure tank
	Conservation: Public information
City of Kerrville	Purchase water from UGRA
	Increased water treatment and ASR capacity
	Conservation: System water audit and water loss audit
	Conservation: Public information
Upper Guadalupe River Authority (Kerr County Other)	Surface water acquisition, treatment and ASR
	Surface water storage
	Conservation: Brush management
	Conservation: Public information
City of Brackettville	Conservation: System water audit and water loss audit
City of Leakey (Real County Other)	Additional groundwater wells
	Conservation: System water audit and water loss audit
City of Camp Wood	Groundwater wells
	Conservation: Public information

A goal of this Plan is to provide for the health, safety, and welfare of the human community, with as little detrimental effect to the environment as possible. Recreation activities involve human interaction with the outdoor environment and are often directly dependent on water resources. It is recognized that the maintenance of the regional environmental community's water supply needs serves to enhance the lives of citizens of the Plateau Region as well as the tens of thousands of annual visitors to this Region.

The implementation of water management strategies recommended in Chapter 4 of this Regional Plan is not expected to have any impact on native water quality. In particular, primary and secondary safe drinking water standards, which are the key parameters of water quality identified by the PWPG as important to the use of the water resource, are not compromised by the implementation of the strategies. Also, no recommended strategies involve moving water from a rural location for use in an urban area.

WATER QUALITY

Water quality plays an important role in determining the suitability of water supplies to meet current and future water needs. Primary and secondary safe drinking water standards are the key parameters of water quality identified by the PWPG as important to the use of water resources and are used for comparisons of water quality data. The reservoirs within the Plateau Region - Amistad Reservoir and Medina Lake - are some of the clearest (most transparent) water bodies in the State of Texas. Amistad Reservoir is the third clearest water body in Texas and Medina Lake is the fifth clearest.

Groundwater resources in the Plateau Region are generally potable, although between five and ten percent of the groundwater is brackish. Groundwater quality problems are generally related to naturally high concentrations of total dissolved solids (TDS) or to the occurrence of elevated concentrations of individual dissolved constituents. High concentrations of TDS are primarily the result of the lack of sufficient recharge and restricted circulation. Together, these retard the flushing action of fresh water moving through the aquifers.

Water quality is generally good throughout the Plateau Region; however, a few specific water quality issues are of concern.

- Increase in urban runoff generally comes with an increase in impervious cover in populated areas. Urbanization also causes increased pollutant loads, including sediment, chemicals from motor vehicles, pesticides/herbicides/fertilizers from gardens and lawns, viruses/bacteria/ nutrients from human and animal wastes including septic systems, heavy metals from a variety of sources, and higher temperatures of the runoff.
- Increasing population has also manifested itself in the fragmentation of larger properties. With the advent of fragmentation comes the proliferation of new wells being drilled to serve individual properties. Each new well thus becomes another potential conduit for surface contamination to reach the underlying aquifer system.

- Vehicular traffic in streambeds disrupts streamflow, damages plants and animals living in these areas, damages channels and erodes banks, and decreases water quality by increasing the turbidity of the water in these rivers and streams.
- The constituent of most concern is nitrate, which was found above the primary maximum contaminant level in a number of water-sample analyses from the Edwards (BFZ) Aquifer and the Austin Chalk Aquifer in Kinney County. Historically, the primary contribution to poor groundwater quality occurs in wells that do not have adequately cemented casing.
- Poorer groundwater quality in the Region is generally from two sources, evaporite beds in the Glen Rose limestone and from surface contamination, both of which can be prevented by proper well construction. Also of concern are above normal levels of radioactivity that have been detected in sand sequences of the Glen Rose and Hensell Formations.

WATER CONSERVATION AND DROUGHT CONTINGENCY

Water conservation and drought contingency planning are two of the most important components of water supply management. Recognizing their potential contribution, setting realistic goals, and aggressively enforcing their implementation may significantly extend the time when new supplies and associated infrastructure are needed. Water conservation are those practices, techniques, programs, and technologies that will protect water resources, reduce the consumption of water, reduce the loss or waste of water, improve the efficiency in the use of water, or increase the recycling or reuse of water so that a water supply is made available for future or alternative uses.

Although residents of the Plateau Region are generally accustomed to highly variable climatic conditions, the relatively low rainfall and the accompanying high levels of evaporation underscore the necessity of developing plans that respond to potential disruptions in the supply of groundwater and surface water caused by drought conditions.

Drought contingency plans provide a structured response that is intended to minimize the damaging effects caused by water shortage conditions. A common feature of drought contingency plans is a structure that allows increasingly stringent drought response measures to be implemented in successive stages as water supply or water demand conditions intensify. This measured or gradual approach allows for timely and appropriate action as a water shortage develops. The onset and termination of each implementation stage should be defined by specific “triggering” criteria. Triggering criteria are intended to ensure that timely action is taken in response to a developing situation and that the response is appropriate to the level of severity of the situation.

PROTECTION OF WATER, AGRICULTURAL AND NATURAL RESOURCES

The long-term protection of the Plateau Region's water resources, agricultural resources, and natural resources is an important component of this 2011 update of the *Plateau Region Water Plan*. Long-term water resources protection occurs in the conservative methodology of estimating water supply availability, evaluation of water management strategies for potential threats to water resources, the recommendation of water conservation strategies, and regional recommendations pertaining to water conservation and drought management practices. When enacted, the conservation practices will diminish water demand, the drought management practices will extend supplies over stress periods, and land management practices (land stewardship) will potentially increase aquifer recharge and stream base flow conditions.

Agricultural resources are protected in this Plan. There is no current movement of water from agricultural areas in the Region for use in urban areas; and there are no recommended strategies in this Plan that involve moving water from rural locations. Also, non-agricultural strategies include an analysis of potential impact to agricultural interests.

The protection of natural resources as intended in this Plan is closely linked with the protection of water resources as discussed above. The methodology adopted to assess groundwater source availability is based on not significantly impacting spring flows that contribute to base flows in area rivers. Thus, the intention to protect surface flows is directly related to those natural resources that are dependent on surface water sources for their existence.

Environmental impacts were evaluated in the consideration of strategies to meet water-supply deficits. Of prime consideration was whether a strategy potentially could diminish the quantity of water currently existing in the natural environment and if a strategy could impact water quality to a level that would be detrimental to animals and plants that naturally inhabit the area under consideration. Although no specific "ecologically unique river and stream segments" are recommended in this Plan, the PWPG is very explicit in acknowledging the importance of all springs and stream segments for their significance as wildlife habitat.

RECOMMENDATIONS

Water-supply resources intended to meet the future needs of all water-use categories in the Plateau Region are recognized to be limited in comparison to resources available in many other parts of the State. A conscientious effort to maintain an awareness of existing conditions and anticipate future water needs is recognized by the PWPG as being the foundation of continued regional water planning. In support of this belief, the PWPG is providing specific recommendations in this plan that address:

- Participation of State Agencies Involved with the Planning Process
- Conservation Management of State-Owned Lands
- Brush Management Practices
- Recharge Structures
- Rainwater Harvesting as an Alternative Sources of Water
- Training for New Regional Water Planning Group Members
- Irrigation Surveys
- Transient Population Impact on Water Demand
- Peak-Use Management
- Groundwater Availability Analysis
- Better Methodologies for Estimating Population and Water Demand
- Educational Programs by the State to Assist Regional Water Planning Groups
- Conservation and Drought Planning
- Management of the Aquifer in Western Kerr County
- Local Groundwater Management
- Aquifer Recharge with Harvested Rainwater
- Land Stewardship
- Regional Planning Coordination
- Needed Studies and Data

The PWPG encourages the continued public process of developing region-based water plans. Copies of the *2011 Plateau Region Water Plan* are accessible in county courthouses, public libraries, and through the PWPG website at http://www.ugra.org/waterdevelopment.html. The Plan is also accessible through the Texas Water Development Board web site: http://www.twdb.state.tx.us/.

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CHAPTER 1

PLATEAU REGION DESCRIPTION

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1.1 INTRODUCTION

Located along the southern boundary of the Texas Edwards Plateau, the six-county Plateau Water Planning Region stretches from the Central Texas Hill Country westward to the Rio Grande. Apache and Comanche Indians populated the Region in its early history. Under land grants issued by Mexico and later by the Republic of Texas, German immigrants colonized the area. These first immigrants and those to follow settled small towns along many of the spring-fed streams that crossed the area and from these way stations spread out to establish farms and ranches throughout the Region. Even today, the area retains much of its original cowboy frontier and German heritage. Chapter 1 that follows is a broad introduction to this Region and the water supply challenges it faces. The Region's economic health and quality of life concerns, including the aquatic environment and recreational opportunities, are dependent on a sustainable water supply that is equitably managed.

In January of 2006, the second round of regional water planning was concluded with the adoption of the *2006 Plateau Region Water Plan*. It is understood that this Plan is not a static plan but rather is intended to be revised as conditions change. For this reason, the current 2011 Plan put forth in this document is not a new plan, but rather an evolutionary modification of the preceding plans. Only those parts of the previous plan that required updating, and there were many, have been revised.

The first half of the current planning period (January 2006 to January 2011) was involved with the completion of the following three interim projects designated by the Plateau Water Planning Group (PWPG) to evaluate specific water supply availability and management issues.

- Water Rights Analysis and ASR Feasibility in Kerr County

  (Results used to characterize Strategies J-6, J-7 and J-10 in Chapter 4)

- ASR Feasibility in Bandera County

  (Results used to characterize Strategy J-1 in Chapter 4)

- Groundwater Data Acquisition in Edwards, Kinney and Val Verde Counties, Texas

  (Results used in Chapter 3 groundwater characterization)

Summaries and conclusions of the projects are provided as Appendices 1A, 1B and 1C; and the full reports can be accessed on the Upper Guadalupe River Authority website at http://www.ugra.org/waterdevelopment.html. Information gained from these projects is also incorporated in specific water-supply management strategies discussed in Chapter 4.

The purpose of the *2011 Plateau Region Water Plan* is to provide a document that water planners and users can reference for long- and short-term water management recommendations. Equally important, this Plan serves as an educational tool to enlighten all citizens as to the importance of properly managing and conserving the delicate water resources of this pristine Region. Chapter 1 presents a broad overview of the Region and of many of the key issues that must be addressed as part of any attempt to develop a comprehensive water management plan that is acceptable to those who reside here.

1.1.1 Planning Process

The *2011 Plateau Region Water Plan* follows an identical format as the plans prepared by the other 15 water planning regions in the State as mandated by the Texas Legislature and overseen by the Texas Water Development Board (TWDB). The Plan provides an evaluation of current and future water demands for all water-use categories, and evaluates water supplies available during drought-of-record conditions to meet those demands. Where future water demands exceed available supplies, management strategies are considered to meet the potential water shortages. Because our understanding of current and future water demand and supply sources are constantly changing, it is intended for this Plan to be revised every five years or sooner if deemed necessary. There are no known conflicts between this Plan and plans prepared for other regions.

Water supply availability under drought-of-record conditions is considered in the planning process to insure that water demands can be met under the worst of circumstances. For surface water supplies, drought-of-record conditions relate to the quantity of water available to meet existing permits from the Rio Grande, Nueces, Colorado, Guadalupe, and San Antonio rivers and their tributaries as estimated by Run 3 of the Texas Commission on Environmental Quality (TCEQ) - Water Availability Models (WAM). This Plan has no impact on navigation on these surface-water courses.

The availability of groundwater during drought-of-record conditions is based on an annual quantity of water that can be withdrawn from each aquifer that results in an acceptable level of water-level decline over the 50-year planning period. Where available, TWDB groundwater availability models (GAM) were used to assist in this process. Chapter 3 contains a detailed analysis of water supply availability in the Region.

Since the completion of the 2006 Plan, a number of advances in water planning have been made available. Groundwater and surface water availability models (GAMs and WAMs) have continued to be developed or improved as resource tools for use in evaluating water-supply source availability. These computer simulation models were used in the current planning process and provided a more realistic analysis of possible water supply source conditions. Results from the use of these models are reported in Chapter 3.

Also new to this planning period was the availability, through Texas Parks & Wildlife Department, of environmental data on the more prominent watercourses in the Region. This data was useful in the assessment and consideration of environmental flow needs, springs, and ecologically significant stream segments. The Plan also acknowledges the City of Kerrville's 2004 Comprehensive Water Management Plan, which documents the City's conjunctive-use policy for both surface water and groundwater.

This *2011 Plateau Region Water Plan* fully recognizes and protects existing water rights, water contracts, and option agreements. The PWPG strongly encouraged all entities to participate in the planning process so that their specific concerns could be recognized and addressed. The PWPG also encouraged the participation of groundwater conservation districts and recognized their management plans and rules. District management plans were specifically respected when establishing groundwater availability estimates.

Water quality is recognized as an important component in this 50-year water plan. Water supplies can be diminished or made more costly to prepare for distribution if water quality is compromised. To insure that this Plan fully considers water quality, the Federal Clean Water Act and the State Clean Rivers Program were reviewed and considered when developing water-supply availability estimates (Chapter 3), water deficit strategies (Chapter 4), water quality impacts (Chapter 5), and recommendations (Chapter 8).

In the year 2000, the U.S. Census Bureau performed a census count, which provides the base year for future population projections in the Region. Although the PWPG accepts the 2000 census count, members express concern that the census does not recognize the significant seasonal population increase that occurs in these counties as the area draws large numbers of hunters and recreational visitors, as well as absentee land owners who maintain vacation, retirement, and hunting homes and cabins. Therefore, an emphasis is being made in this planning document, especially in the rural counties, to recognize a need for more water than is justified simply from the population-derived water demand quantities.

1.1.2 Groundwater Management Areas

In recent sessions, the Texas Legislature has redefined the manner in which groundwater is to be managed (http://www.twdb.state.tx.us/GwRD/GMA/gmahome.htm). Senate Bill 2 of the 77th Texas Legislature (2001) authorized:

- The TWDB to designate *groundwater management areas* that would include all major and minor aquifers of the State.
- Required groundwater conservation districts to share groundwater plans with other districts in the *groundwater management area*.
- Allowed a groundwater conservation district to call for joint planning among districts in a *groundwater management area*.

The objective was to delineate areas considered suitable for management of groundwater resources. A *groundwater management area* (GMA) should ideally coincide with the boundaries of a groundwater reservoir (aquifer) or a subdivision of a groundwater reservoir, but it may also be defined by other factors, including the boundaries of political subdivisions. In December 2002, the TWDB designated 16 GMAs covering the entire State (http://www.twdb.state.tx.us/mapping/index.asp).

In 2005, the Legislature once again changed the direction of groundwater management. The new requirements, codified in Texas Water Code Chapter 36.108, required joint planning in management areas among groundwater conservation districts. The new requirements direct that,

"Not later than September 1, 2010, and every five years thereafter, the districts shall consider groundwater availability models and other data or information for the management area and shall establish desired future conditions for the relevant aquifers within the management area."

Desired future conditions are a description of aquifers at some time in the future. This description is a precursor to developing a volumetric number called *managed available groundwater*. The TWDB is responsible for providing each groundwater conservation district and regional water planning group, located wholly or partly in the management area, with *managed available groundwater*. Once the *managed available groundwater* is determined, the districts begin issuing groundwater withdrawal permits to support the *desired future condition* of the aquifer up to the total amount of *managed available groundwater*. These permits express *desired future conditions* by only allowing withdrawals that will support the conditions established by the *groundwater management area*. Future regional water plans must also incorporate the *managed available groundwater* for each aquifer within their regions.

The counties of the Plateau Region are included in three *groundwater management areas* (GMAs):

- GMA 7 includes Edwards, Kinney (partial), Real and Val Verde
- GMA 9 includes Bandera and Kerr
- GMA 10 includes Kinney (partial)

As of October 1, 2009, *desired future conditions* have not been adopted for any aquifers in these GMAs. It is anticipated that the *2016 Plateau Region Water Plan* will include a significant revision to all groundwater source availability estimates based on *managed availability groundwater* volumes generated from the *groundwater management area process*.

1.1.3 Definitions

The following definitions are included to provide the reader with a reference source for selected technical terms found in this report.

Acre-Feet – A quantity of water equal to 325,851 gallons – or the volume of water required to cover one acre of land to a depth of one foot.

Alluvial / Alluvium – A geologic unit composed of sediment deposited by a stream or river.

Aquifer - One or more formations that contain sufficient saturated permeable material to conduct groundwater and to yield economically significant quantities of water to wells and springs.

Drought-of-Record - A drought period with the greatest hydrologic/ agricultural/public water-supply impact recorded in a region.

Firm Yield - That amount of water that a reservoir could have produced annually if it had been in place during the worst drought of record. In performing this simulation, naturalized streamflows will be modified as appropriate to account for the full exercise of upstream senior water rights is assumed as well as the passage of sufficient water to satisfy all downstream senior water rights valued at their full authorized amounts and conditions as well as the passage of flows needed to meet all applicable permit conditions relating to instream and freshwater inflow requirements.

Geologic Formation - The basic geologic unit in the classification of rocks, consisting of a body of rock generally characterized by some degree of compositional homogeneity and by a prevailingly but not necessarily tabular shape over its areal extent.

Recharge - The addition of water into an underground reservoir or aquifer by natural or artificial means.

Reuse - The process of recapturing water following its initial use and making it available for additional uses. The process generally requires a level of treatment appropriate for its next intended use.

Riparian – An ecological/hydrological area situated on the bank of a body of water, especially of a watercourse such as a river.

Sustainability - An amount of water that can be produced over a planning period to meet specified demands that results in an acceptable level of impact to the source.

Water Demand - The total volume of water required to meet the needs of a water-use category. This quantity may exceed actual usage.

Water Supply Availability – The volume of water capable of being withdrawn or diverted from specific sources of supply that results in an acceptable impact on the water source and its primary users. It is generally desirable that this volume be "sustainable" (see definition above).

1.2 REGIONAL GEOGRAPHIC SETTING

1.2.1 Plateau Region

The Plateau Region encompasses six counties in the west-central part of the State of Texas, stretching from the headwaters of the Guadalupe and San Antonio rivers in the Central Texas Hill Country westward to Del Rio and the Rio Grande international border (Figure 1-1). With a total area of 9,252 square miles (mi^2), the Plateau Region represents 3.5 percent of the total area of the state and includes the counties of Bandera (792mi^2), Edwards (2,120mi^2), Kerr (1,106mi^2), Kinney (1,364mi^2), Real (700mi^2), and Val Verde (3,171mi^2).

1.2.2 Physiography

The Plateau Region lies primarily along the southern edge of the Edwards Plateau and is bounded on the east by the Central Texas Hill Country and on the west by the Rio Grande international border. The Balcones escarpment generally forms the southern boundary of the Plateau Region. The escarpment is a steep topographic feature that traces the path of a major fault system that formed more than 10 million years ago. The escarpment separates the more resistant rocks of the Edwards Plateau to the north from softer and more easily erodible rocks to the south. Erosion by streams has cut steep canyons into the thick limestone beds of the Edwards Plateau.

Its rolling prairies and the large number of spring-fed perennially flowing streams characterize the Region. The uplands are fairly level, but the landscape of the stream valleys is very hilly with steep canyons that provide rapid drainage. Upland soils are dark alkaline clays and clay loams; the river valley soils are gravelly and light colored. Some cultivation takes place in the deep, dark-gray or brown loams and clays of the river bottoms and to a greater extent over the broad flat farming belt of Kinney County. The major soil-management concerns are brush control, low fertility and excess lime.

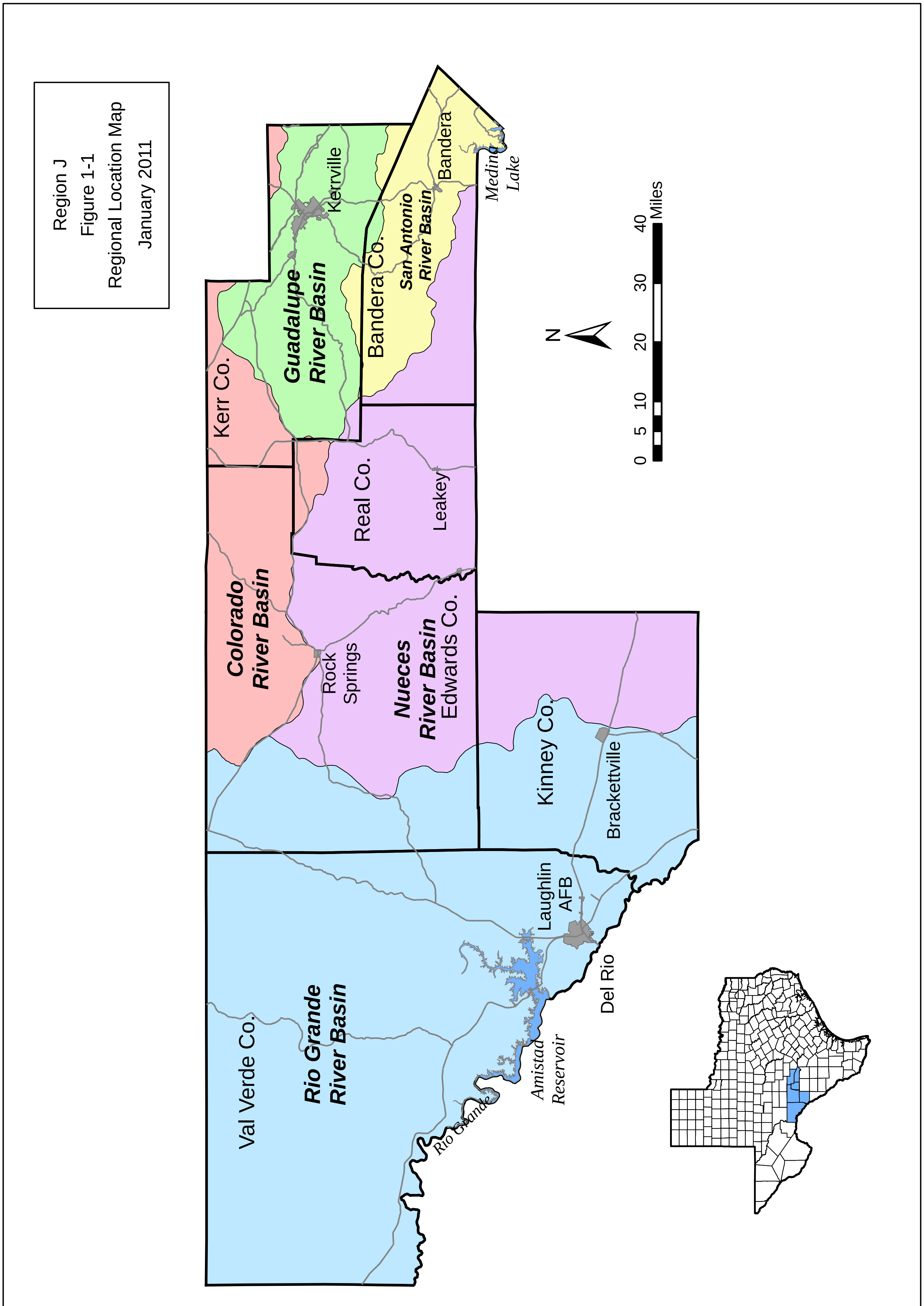

FIGURE 1-1. LOCATION OF THE PLATEAU REGION

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1.2.3 Population and Regional Economy

The projected year-2010 population in the Plateau Region is 135,723 (Figure 1-2). The population density of the Region is 14.7 people per square mile, which is much less than the state average of 72 people per square mile. Current and projected future population of the Region is discussed in detail in Chapter 2.

Approximately 46 percent of the total population of the Region is located in the two largest cities, Del Rio and Kerrville. In the year 2010, Del Rio, including the population of Laughlin Air Force Base, is projected to have 39,249 residents and Kerrville with 23,044. The projected year-2010 population of other major communities in the Region are: Bandera (1,056); Rocksprings (1,380); Brackettville and Fort Clark Springs (3,257); and Camp Wood (826). These population estimates do not include a significant transient (tourist, hunting, recreation, etc.) population that has a resulting significant impact on overall water supply demand in the Region.

The regional economy is based primarily on tourism, hunting, ranching agribusiness and government. The beauty of the Hill Country, the solitude of the forested canyons and plateau grasslands, and the gateway to Mexico all support a major tourist trade. Agribusiness is predominantly associated with the raising of sheep, goats, beef cattle and exotic game throughout the Region. Apple orchards in Bandera County, oil and gas production and mohair production in Edwards and Real Counties, medical services and manufacturing in Kerr County, irrigated cotton, hay and wheat in Kinney County, and a military base and trade with Mexico in Val Verde County all contribute largely to the Region's overall economy.

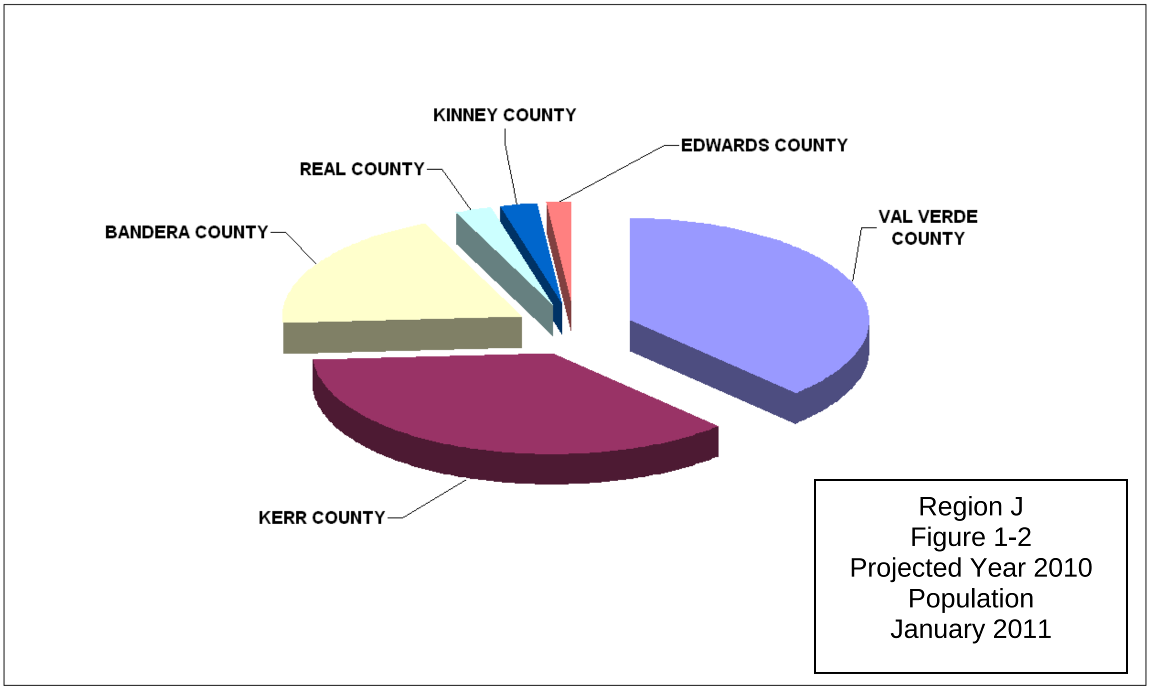

Figure 1-2. Projected Year-2010 Population

1.2.4 Land Use

Land use in the six-county Region is divided into seven categories (Figure 1-3):

- Urban (or developed)
- Agricultural (cultivated)
- Range
- Forest
- Water
- Wetlands
- Barren

Urban lands are the location of cities and towns that make up less than one percent of the Region's total land area. Agricultural lands are identified as areas that support the cultivation of crops. These lands, which potentially involve extensive irrigation, also occupy less than one percent of the Region. Together, urban and agricultural lands comprise the two most significant areas of water consumption in the Plateau Region.

Rangeland is defined as all areas that are either associated with or are suitable for livestock production. Although this is the largest category of land use in areal extent in the Region, rangeland accounts for one of the smallest sources of water demand. Forestland is limited to areas where topography and climate support the growth of native trees. Areas designated as either water or wetlands are associated with the rivers and their tributaries. Barren lands are defined as undeveloped areas with little potential for use as agricultural land, rangeland or forestland.

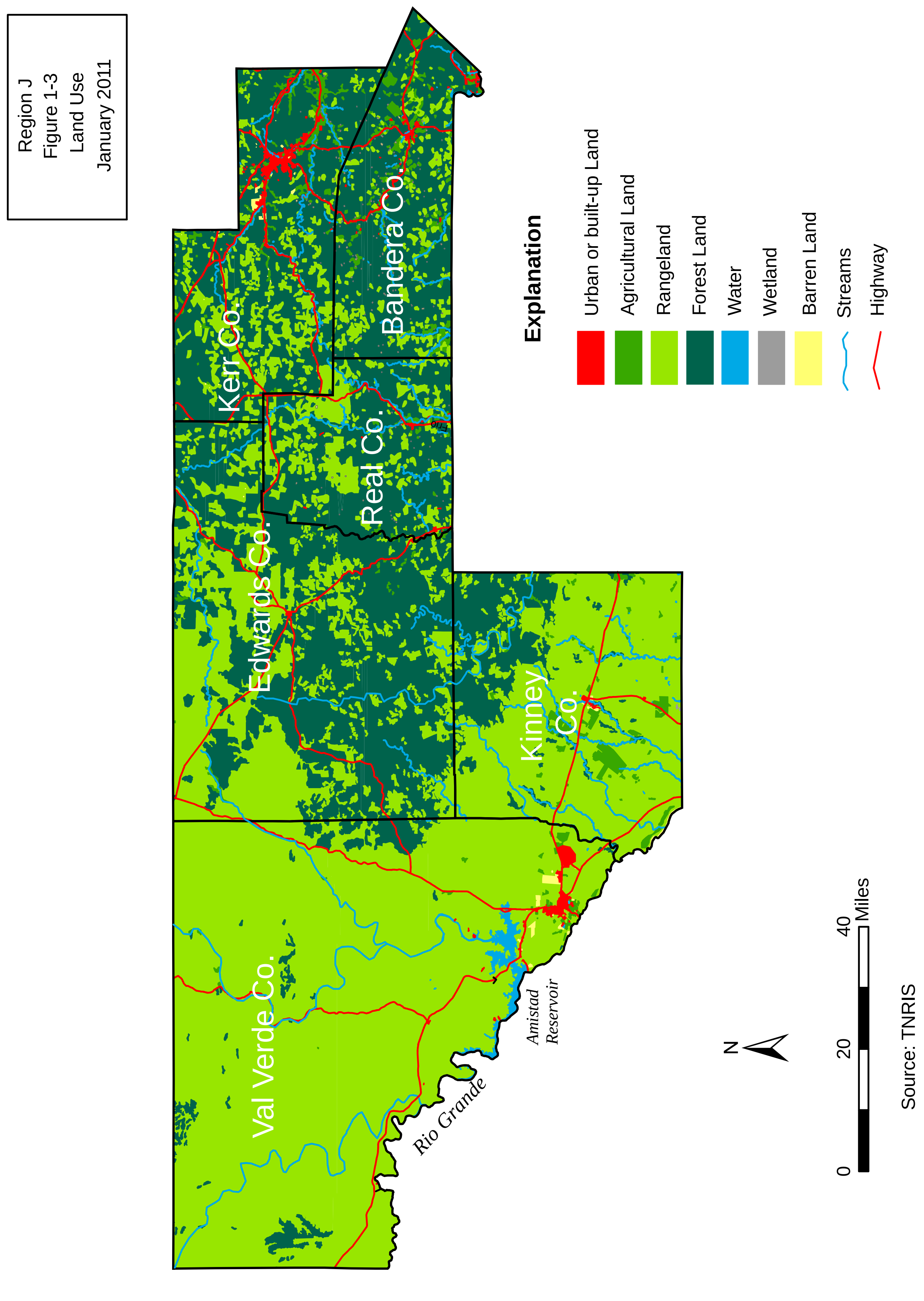

FIGURE 1-3. LAND USE

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1.2.5 Climate

The climate of the Plateau Region is semi-arid to arid as precipitation decreases westward across the Region. The average for the Edwards Plateau is 25 inches. Figure 1-4 illustrates the variability with respect to the six counties of the Region. Precipitation decreases from approximately 32 inches in the easternmost reaches of Bandera and Real Counties to less than 20 inches in western Val Verde County (National Weather Service). Net lake evaporation (Figure 1-5) increases from 38 inches in Bandera and Real Counties to about 60 inches in western Val Verde County (TWDB). Net lake evaporation is the difference between total evaporation from a lake and total precipitation. Figure 1-6 illustrates average monthly rainfall recorded at selected stations.

Long periods of below-normal rainfall may have severe impacts on groundwater recharge, spring flow, and stream flow. The effects of low rainfall over long periods of time are most readily reflected in the form of decreased spring flow and stream flow. Under these conditions, the lack of rainfall leads to reduced recharge to aquifers and to lower water levels in wells. As water levels fall in aquifers in drought-stricken areas, the volume of water discharging from San Felipe Springs, for example, may decrease to levels that are insufficient to supply the full needs of the City of Del Rio with enough drinking water to meet all municipal, industrial and manufacturing demands. Landowners who are dependent on spring-fed stream flow may also find insufficient volumes of surface water needed to support irrigation or other farming and ranching activities. The direct linkage between precipitation and water levels in aquifers of the Plateau Region is indicated by hydrograph records of wells that show rapid increases in water levels as a response to local rainstorms.

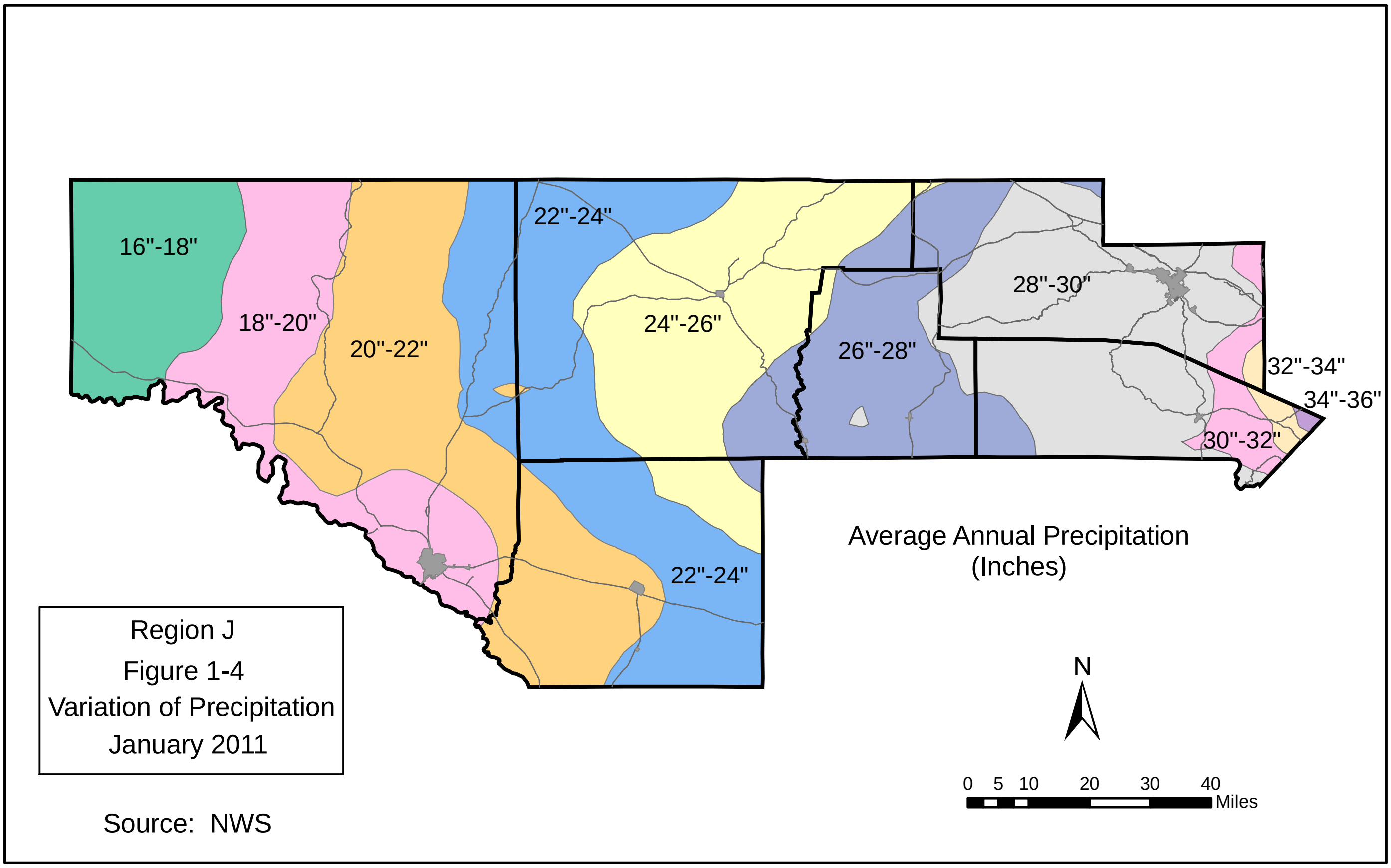

FIGURE 1-4. VARIATION OF PRECIPITATION, 1961-1990

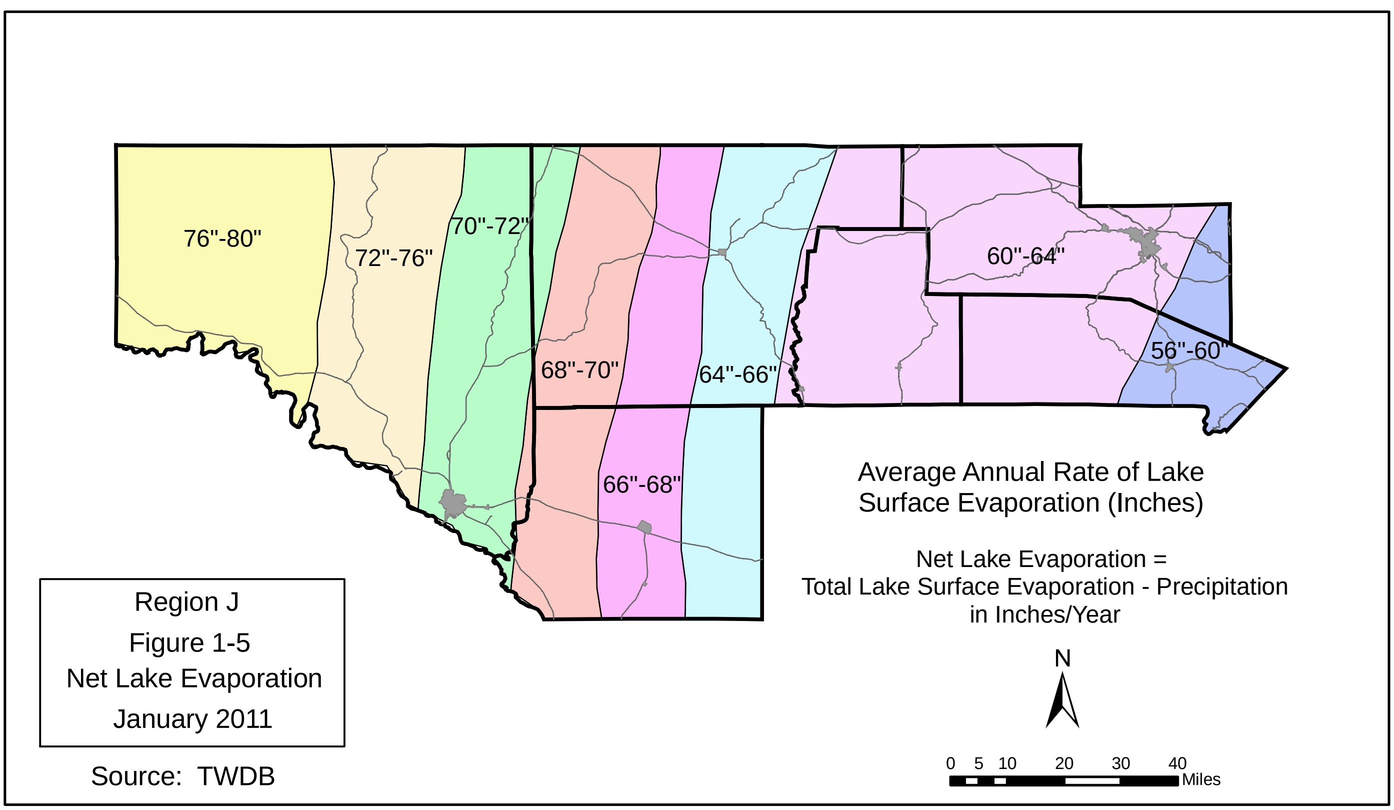

FIGURE 1-5. NET LAKE SURFACE EVAPORATION, 1940-1978

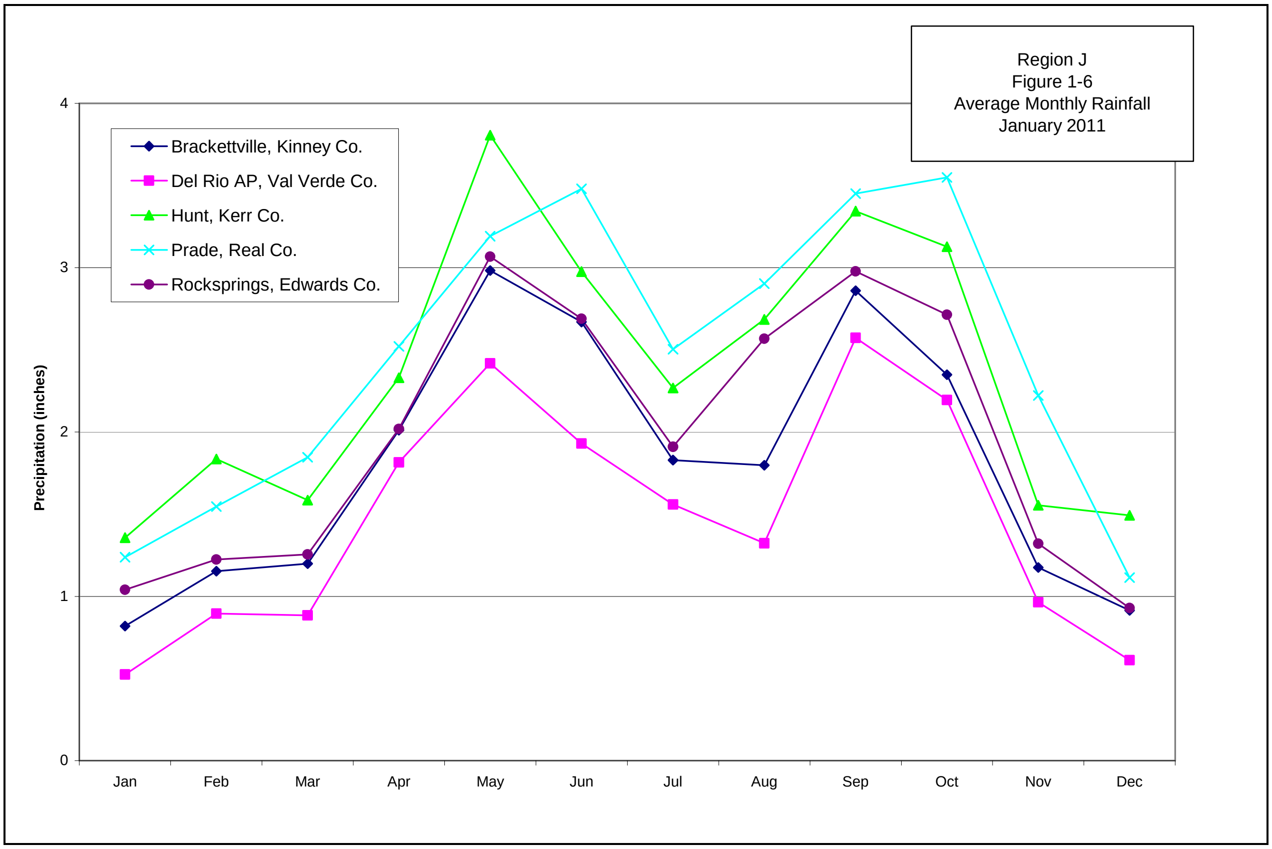

Figure 1-6. Average Monthly Rainfall for Selected Stations

1.2.6 Drought

Drought conditions are assumed in the planning process to insure that adequate infrastructure and planning is in place under severe water shortage conditions. Drought is generally defined as a period of abnormally dry weather of sufficient length to cause a serious hydrologic imbalance, which may be observed in any of the following conditions:

- Lower precipitation in key watersheds
- Extended periods of high temperature
- Higher levels of evapotranspiration
- Reduced runoff
- Stressed plants and grasses
- Reduced stream flow and spring flow
- Lower reservoir and groundwater levels
- Increased regional water demand

Drought can also be defined in the following operational definitions:

Meteorological drought is a shortfall of precipitation, usually over a period of months or years, compared with the expected supply.

Agricultural drought is defined as that condition when rainfall and soil moisture are insufficient to support the healthy growth of crops and to prevent extreme crop stress. It may also be defined as a deficiency in the amount of precipitation required for the support of livestock and other farming or ranching operations.

Hydrologic drought is a long-term condition of abnormally dry weather that ultimately leads to the depletion of surface-water and groundwater supplies; the drying up of lakes and reservoirs; and the reduction or cessation of spring flow or stream flow. The tables developed in this report are based on the concept of hydrologic drought.

Although agricultural drought and hydrologic drought are consequences of meteorological drought, the occurrence of meteorological drought does not guarantee that either one or both of the others will develop.

1.2.7 Native Vegetation and Ecology

A biotic province is a considerable and continuous geographic area that is characterized by the occurrence of one or more ecologic associations that differ, at least in proportional area covered, from the associations of adjacent provinces. In general, biotic provinces are characterized by peculiarities of vegetation type, ecological climax, flora, fauna, climate, physiography and soil. Most of the Plateau Region has been classified as belonging to the "Balconian" Biotic Province, but small portions of Val Verde and Kinney Counties also lie within the "Tamaulipan" and "Chihuahuan" Biotic Provinces (Figure 1-7).

In the 1800s, the area was predominantly savannas of tall native grasses with occasional stands of Live Oak and Spanish Oak. Largely because of the suppression of prairie fires in the last century, most of the area has become blanketed by Ashe Juniper (commonly referred to as "cedar"), which once was primarily found within steep canyon lands. Another infestation of tree species found in the area is that of Mesquite. Infestation of trees may reduce the quantity and quality of water from watersheds, as well as reduce the diversity of plant species beneath the trees' canopies.

Cypress trees line the banks of many of the rivers and are known to reduce flows in the streams during their active season. Other species of trees that are generally found are Post Oak, Elm, Hackberry, Cottonwood, Sycamore and Willow. Native grass species include Little and Big Bluestem, Indian Grass, Sideoat Grama and Texas Winter Grass. Some of the introduced species of grass include Coastal Bermuda, Plains Lovegrass, Klein Grass and King Ranch Bluestem. In the western portion of the Region, a varying growth of prickly pear, other cactus species, sage, and other brushy species predominate.

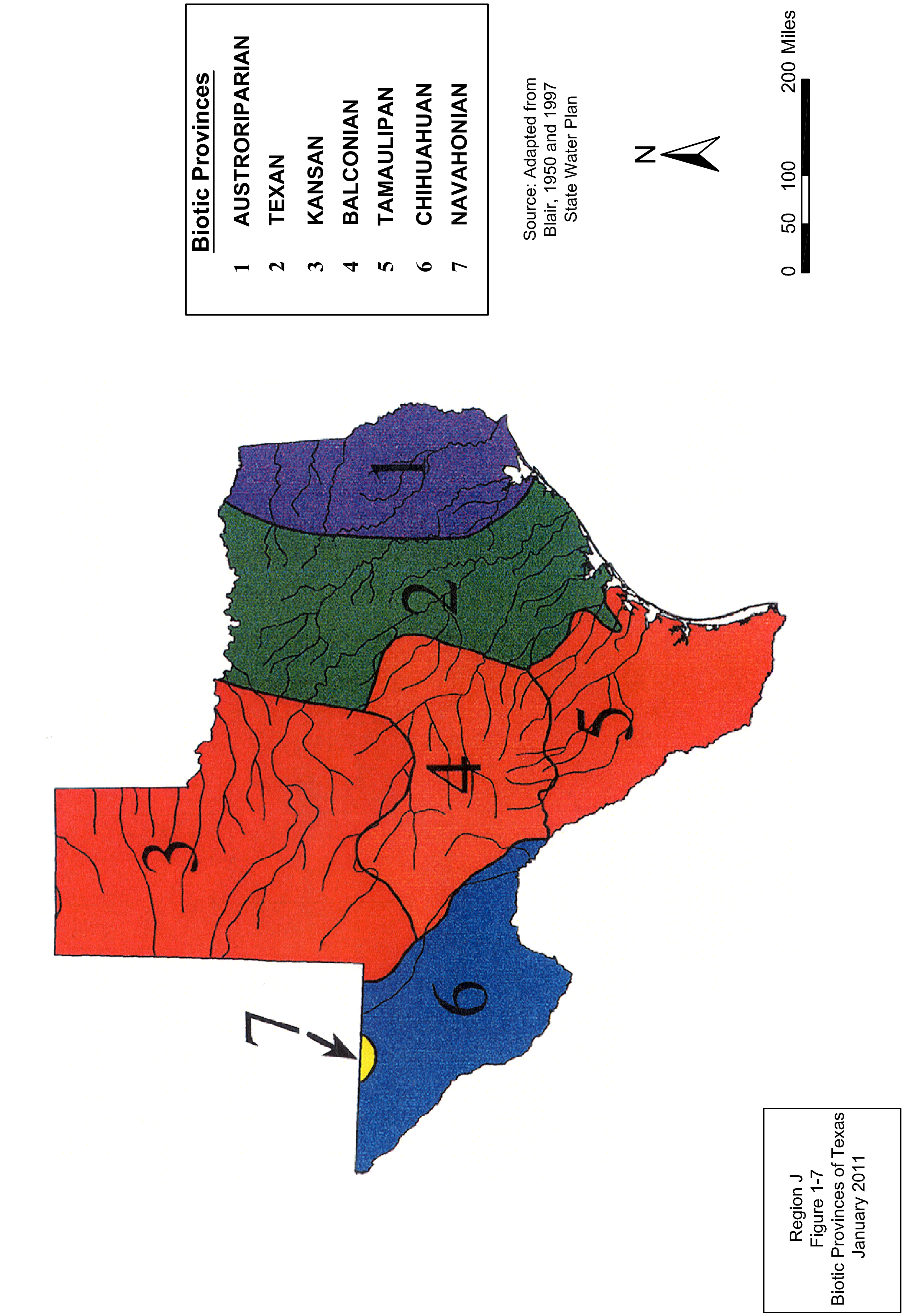

FIGURE 1-7. BIOTIC PROVINCES OF TEXAS

1.2.8 Agricultural and Natural Resources

Agricultural resources in the Region include beef cattle, sheep, goat, and exotic game animals. Apple and pecan orchards, along with hay, are grown in the eastern part of the Region. Kinney County, with its extensive irrigated lands in the western half of the county, account for twice the amount of water used for irrigation as the rest of the Region combined.

The natural resources of the Region include both terrestrial and aquatic habitats that boast some of the best scenic drives and vistas, river rafting, and hunting and fishing in Texas. Natural resources also include the great diversity of plant and animal wildlife that inhabit these environments. Texas Parks and Wildlife Department maintains a comprehensive source of information on State and Federally listed rare, threatened, and endangered plants and animals (http://www.tpwd.state.tx.us/huntwild/wild/species/endang/index.phtml).

Understandably, both local residents and tourists make use of these resources in their enjoyment of numerous public parks, dude ranches, resorts, recreational vehicle parks, and camping facilities. The following protected sites located within the Plateau Region depend upon adequate water to supply both environmental and recreational needs:

- Lost Maples State Natural area
- Hill Country State Natural Area
- Devils River State Natural Area
- Seminole Canyon State Historic Park
- Dolan Falls Ranch Preserve (Nature Conservancy)
- Devils Sinkhole State Natural Area
- Kickapoo Cavern State Park
- Kerrville-Schreiner Park
- Heart of the Hills Fisheries Science Center
- Amistad Natural Recreational Area

Both agricultural and natural resources water-supply needs are directly influenced by the quantity and quality of water available primarily in rivers and tributaries that flow through the Region and to a lesser extent on impounded lakes, ponds and tanks. With the exception of the Rio Grande, much of the drainage basins for the headwater of local rivers lie within Plateau Region counties. Springflow emanating from bedrock aquifers (particularly the Edwards-Trinity Plateau Aquifer) create the base flow of these streams. As such, these headwater areas are particularly susceptible to drought conditions as the water table naturally drops and springflow diminishes.

Agricultural activities in the Region that rely on surface water are designed to accommodate the intermittent nature of the supply. In most cases, this means that agricultural water supply needs will be supplemented by groundwater sources, or that irrigation activities will cease until river supplies are replenished. Both plant and animal species endemic to this Region have developed a tolerance for the intermittent nature of surface water availability; however, significantly long drought conditions can have a sever effect on these species. Riparian water needs for birding habitat is particularly critical. Of recognized importance to the water planning process is the concern of the effect that future development of water supplies might have on the diversity of species in the Region. Water-supply deficit strategies developed in Chapter 4 of this plan include an evaluation of each strategy's effect on agricultural and environmental concerns.

1.3 REGIONAL WATER DEMAND

1.3.1 Major Demand Categories

Total estimated year-2010 water consumptive use in the Plateau Region is 51,928 acre-feet. The largest category of demand is municipal (29,320 acre-feet), followed by irrigation (19,423 acre-feet), livestock (2,752 acre-feet), mining (403 acre-feet), and manufacturing (30 acre-feet). Municipal and irrigation combined represent 94 percent of all water use in the Region (Figure 1-8). Current and projected water demand for all water-use types are discussed in detail in Chapter 2.

1.3.2 Municipal

Municipal demand consists of both residential and commercial water uses. Commercial water consumption includes business establishments, public offices, and institutions, but does not include industrial water use. Residential and commercial uses are categorized together because they are similar types of uses, i.e.: they both use water primarily for drinking, cleaning, sanitation, air conditioning, and landscape watering.

The largest center of municipal demand is Del Rio in Val Verde County, where 16,822 acre-feet of water was estimated to have been used in 2010 to support all areas of residential, commercial, public and military consumption. Fifty-seven percent of regional municipal water is used in Val Verde County, and 25 percent is used in Kerr County.

1.3.3 Wholesale Water Provider

The City of Del Rio is the only entity in the Plateau Region that is designated as a wholesale water provider. In addition to its own use, the city provides water to Laughlin Air Force Base and subdivisions outside of the city. The city also provides water and wastewater services to two colonias, Cienegas Terrace and Val Verde Park Estates.

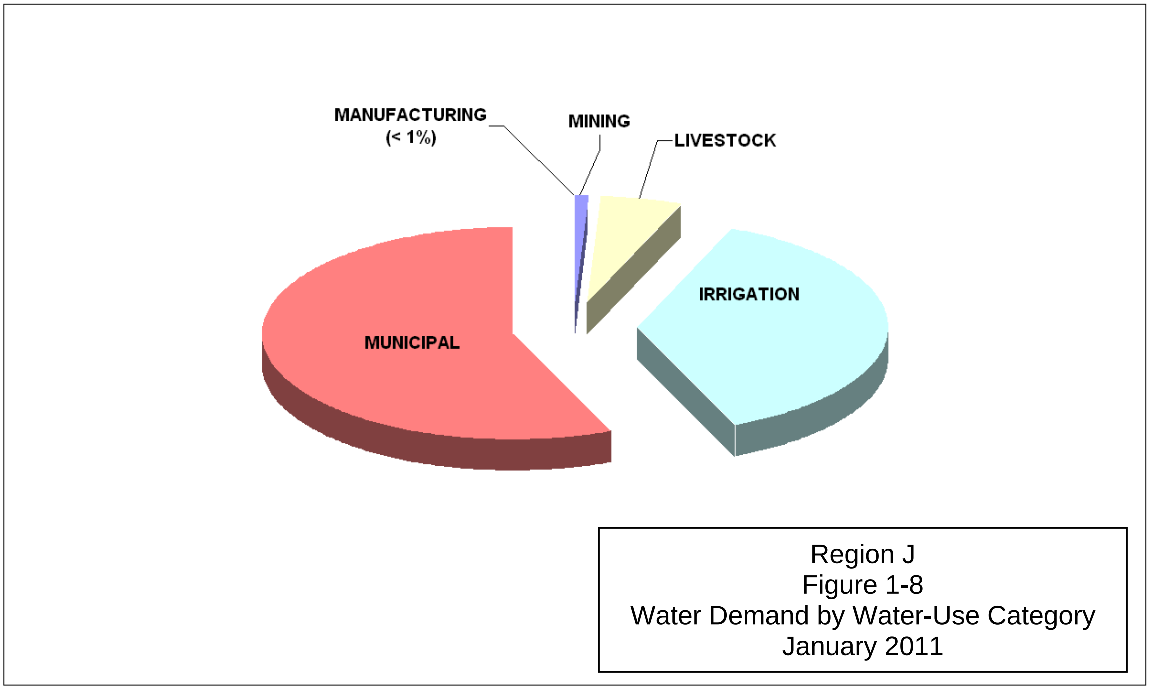

Figure 1-8. Projected Year-2010 Water Demand by Water-Use Category

1.3.4 Agriculture and Ranching

Agriculture and ranching water demand consists of all water used by the agricultural industry to support the cultivation of crops and the watering of livestock and wildlife. Where groundwater is the source of irrigation water, the TWDB defines irrigation use as "on farm demand." Where surface water is the source of irrigation water, the TWDB defines irrigation use as both "on farm" demand and "diversion loss." Diversion loss, also referred to as conveyance loss, is the amount of water lost during the delivery of surface water from the point of diversion on the river or stream to the point of use on the farm. Surface water is typically conveyed by an open canal system, which exposes the water supply to possible loss from seepage, breaks, evaporation, and uptake by riparian vegetation.

In the year 2010, irrigation represents the second greatest water use in the Region (19,423 acre-feet) with Kinney County accounting for 70 percent. Livestock use in the Region amounted to 2,752 acre-feet.

1.3.5 Manufacturing and Mining

Manufacturing (and industrial) demand consists of all water used in the production of goods for domestic and foreign markets. Some processes require direct consumption of water as part of the manufacturing process. Others require very little water consumption, but may require large volumes of water for cooling or cleaning purposes. In some manner or another, water is passed through the manufacturing facility and used either as a component of the product or as a transporter of waste heat and materials. Within the Plateau Region, manufacturing is only accounted for in Kerr County.

Mining demand consists of all water used in the production and processing of nonfuel (e.g., sulfur, clay, gypsum, lime, salt, stone and aggregate) and fuel (e.g., oil, gas, and coal) natural resources by the mining industry. In all instances, water is required in the mining of minerals either for processing, leaching to extract certain ores, controlling dust at the plant site, or for reclamation. This also includes the production of crude petroleum and natural gas. With the exception of Edwards County, most of the water used in the mining industry in the Plateau Region is related to the extraction of gravel and road-base material, with Kerr and Val Verde Counties recording the greatest use.

1.3.6 Environmental and Recreational Water Needs

Environmental and recreational water use in the Plateau Region is recognized as being an important consideration as it relates to the natural community in which the residents of this Region share and appreciate. In addition, for rural counties, tourism activities based on natural resources offer perhaps the best hope for modest economic growth to areas that have seen a long decline in traditional economic activities such as agriculture.

A goal of this Plan is to provide for the health, safety, and welfare of the human community, with as little detrimental effect to the environment as possible. To accomplish this goal, the evaluation of strategies to meet future water needs (Chapter 4) includes a distinct consideration of the impact that each implemented strategy might have on the environment.

Recreation activities involving human interaction with the outdoor environment are often directly dependent on water resources. It is recognized that the maintenance of the regional environmental community's water supply needs serves to enhance the lives of citizens of the Plateau Region as well as the tens of thousands of annual visitors to this Region. Environmental and recreational water needs are further discussed throughout the Plan and especially in Chapters 2, 3, 4 and 8.

1.4 WATER SUPPLY SOURCES

Water supply sources in the Plateau Region include groundwater primarily from six aquifers and surface water from five river basins. Reuse of existing supplies is also considered a water supply source. A more detailed description of these sources and estimates of their supply availability are provided in Chapter 3.

1.4.1 Groundwater

Within the Plateau Region, the TWDB recognizes three major aquifers [the Trinity, the Edwards-Trinity (Plateau), and the Edwards (Balcones Fault Zone)] (Figure 1-9). For this Plan, the Austin Chalk Aquifer in Kinney County and the Frio and Nueces River Alluvium Aquifers in Real and Edwards Counties have also been identified as groundwater sources. Groundwater conservation districts in Bandera, Kerr, Kinney, Real and Edwards Counties provide for local management control of their groundwater resources.

1.4.1.1 Trinity Aquifer

The Trinity Aquifer occurs in its entirety in a band from the Red River in North Texas to the Hill Country of south central Texas and provides water in all or parts of 55 counties. Trinity Group formations also occur as far west as the Panhandle and Trans-Pecos regions where they are included as part of the Edwards-Trinity (High Plains) and Edwards-Trinity (Plateau) Aquifers. The Trinity Aquifer is composed of marine sediments (primarily limestone) deposited during the Cretaceous Period. The Trinity Group in the Plateau Region includes the Glen Rose and underlying Travis Peak formations. The Glen Rose consists of up to approximately 1,000 feet of limestone with interbedded shale, marl and occasional anhydrite (gypsum). The Travis Peak contains sands, clays and limestones and is subdivided into water-bearing members of the Hensell, Cow Creek, Sligo and Hosston.

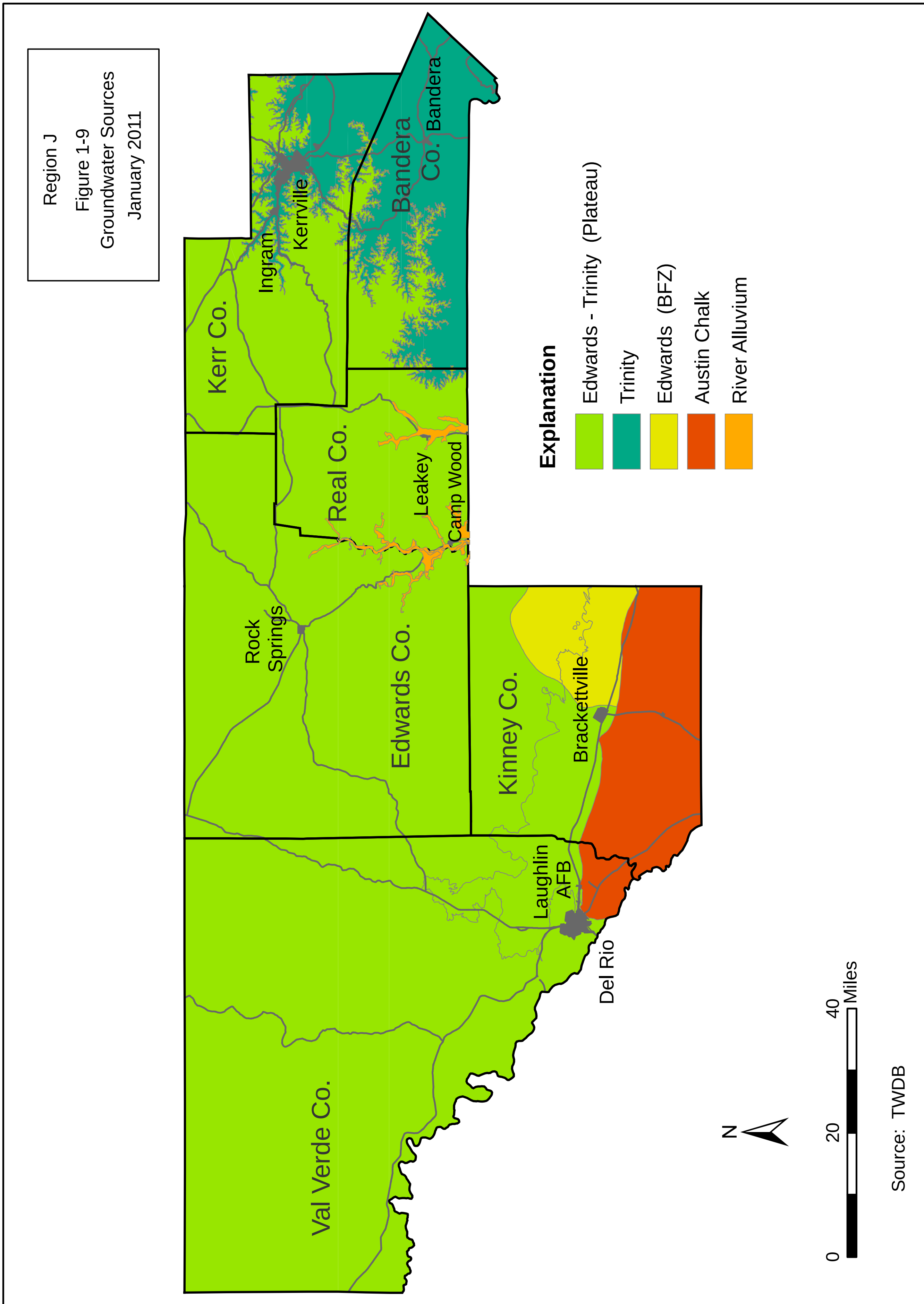

FIGURE 1-9. GROUNDWATER SOURCES

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1.4.1.2 Edwards-Trinity (Plateau) Aquifer

Rock formations of the Edwards-Trinity (Plateau) Aquifer form the Edwards Plateau east of the Pecos River, and in its entirety provide water to all or parts of 38 counties. The aquifer extends from the Hill Country of Central Texas to the Trans-Pecos region of West Texas. The aquifer consists of saturated sediments of lower Cretaceous age Trinity Group formations and overlying limestones and dolomites of the Edwards Group. The Glen Rose limestone is the primary unit in the Trinity in the southern part of the Plateau. Springs issuing from the aquifer form the headwaters of several eastward and southerly flowing rivers. Some of the largest springs of the area are located in Val Verde County, such as San Felipe Springs near Del Rio.

1.4.1.3 Edwards (BFZ) Aquifer

The Edwards (Balcones Fault Zone)(BFZ) Aquifer in its entirety covers approximately 4,350 mi^2 in parts of 11 counties. It forms a narrow belt extending from a groundwater divide in Kinney County through the San Antonio area northeastward to the Leon River in Bell County. Within the Region, water in the aquifer generally moves from the recharge zone toward natural discharge points such as Las Moras Springs near Brackettville or southeasterly toward San Antonio.

1.4.1.4 Austin Chalk Aquifer

The Austin Chalk Aquifer occurs in the southern half of Kinney County and in the southernmost extent of Val Verde County. Most Austin Chalk wells discharge only enough water for domestic or livestock use; however, primarily in the area along Las Moras Creek, a few wells are large enough to support irrigation.

1.4.1.5 Nueces River Alluvium Aquifer

The Nueces River Alluvium occurs along the boundary between Edwards and Real Counties. Extending over an area of approximately 24,450 acres, the alluvial aquifer contains approximately 3,574 acre-feet of annually available water (see Appendix 3B). The Community of Barksdale, subdivisions, and other rural domestic homes derive their water supply from this aquifer.

1.4.1.6 Frio River Alluvium Aquifer

The Frio River Alluvium in central Real County extends over an area of approximately 9,530 acres and contains approximately 2,145 acre-feet of annually available water (see Appendix 3B). Water supplies for the Community of Leakey, several subdivisions, and other rural domestic homes are derived from this small aquifer.

1.4.1.7 Other Aquifers

Located along many of the streams and rivers throughout most of the Region are shallow alluvial floodplain deposits mostly composed of gravels and sands eroded from surrounding limestone hills. Wells completed in these deposits supply small to moderate quantities of water mostly for domestic and livestock purposes.

Also within the Region, the State has identified other minor aquifers only in Kerr County. These are the downdip extensions of the Ellenburger-San Saba and the Hickory. According to TWDB records none of their inventoried wells penetrate either aquifer.

1.4.2 Surface Water

The Plateau Region is unique within all planning regions in that it straddles five river basins rather than generally following a single river basin or a large part of a single river basin (Figure 1-10). From west to east, these basins include the Rio Grande, Nueces, Colorado, Guadalupe, and San Antonio. The headwaters of rivers that form the Nueces, Guadalupe, and San Antonio river basins originate within this Region; and the headwaters of the South Llano River, a major tributary to the Colorado River, also occur here.

1.4.2.1 Rio Grande Basin

The Rio Grande, or Rio Bravo as it is known in Mexico, forms the border between the United States and Mexico. International treaties governing the ownership and distribution of water in the Rio Grande are discussed in Chapter 3. The 3.4 million acre-foot International Amistad Reservoir is located on the Rio Grande in Val Verde County. Within the Plateau Region, the Pecos and Devils Rivers in Val Verde County are the primary tributaries to the Rio Grande. Numerous springs, including San Felipe, Goodenough, and Las Moras Springs issue from the Edwards Aquifer and flow into tributaries of the Rio Grande. The Rio Grande does not provide water for municipal use in the Plateau Region and only provides limited amounts for irrigation use, primarily from San Felipe Creek.

1.4.2.2 Nueces River Basin

The main stem of the Nueces River forms a portion of the border between Edwards and Real Counties. Tributaries of the Nueces River located in the Plateau Region include the Sabinal River and Hondo Creek in Bandera County, the West Nueces River in Edwards and Kinney Counties, and the Frio, East Frio, Dry Frio Rivers in Real County and other minor tributaries.

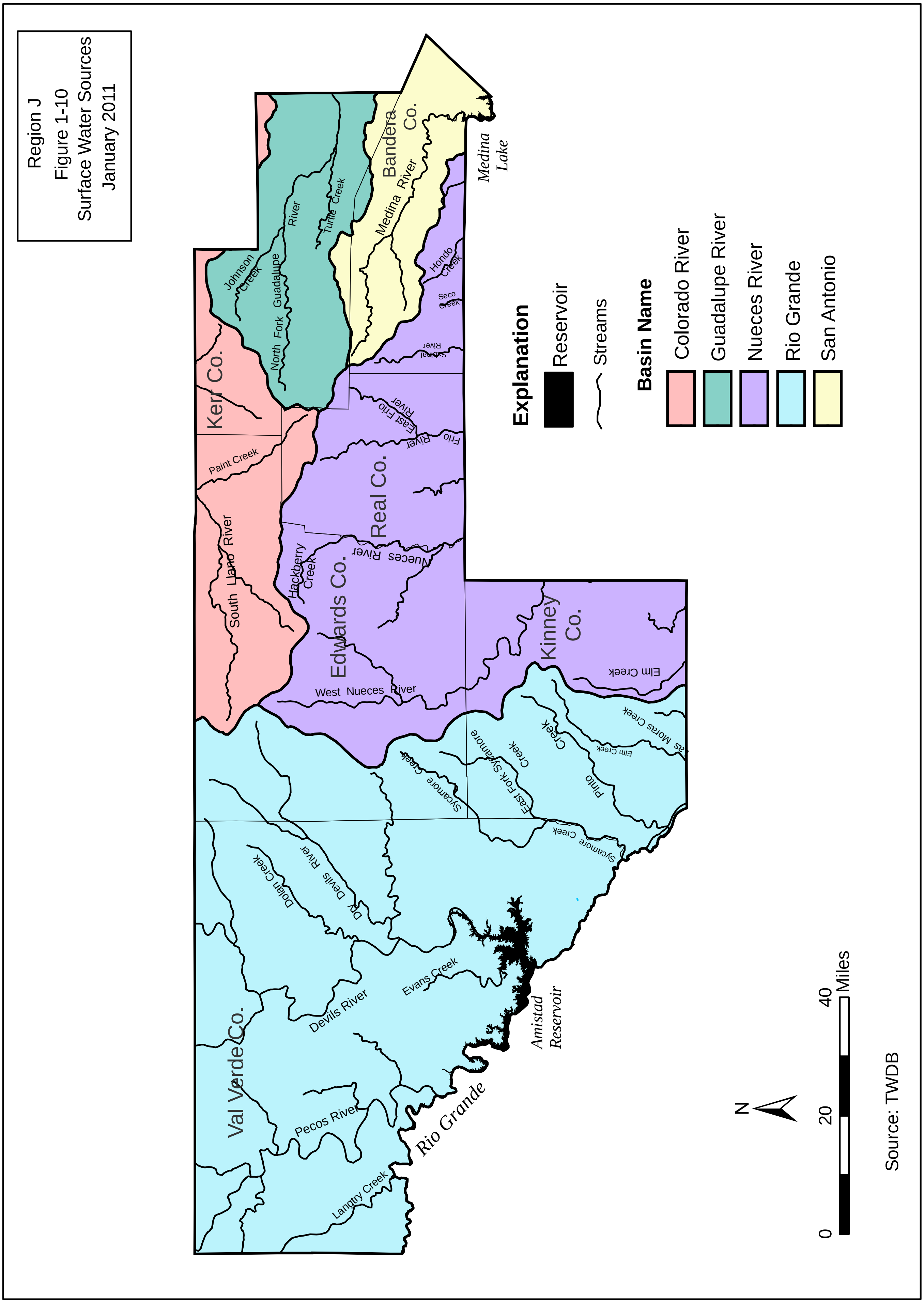

FIGURE 1-10. SURFACE WATER SOURCES

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1.4.2.3 Colorado River Basin

The City of Rocksprings in Edwards County straddles the drainage divide between the Nueces River Basin and the Colorado River Basin. The portion of Edwards County north of Rocksprings, small northern portions of Real County and the northwestern part of Kerr County drain to the Llano River watershed in the Colorado River Basin. The South Llano River, part of the headwaters of the Llano/Colorado, begins in Edwards County.

1.4.2.4 Guadalupe River Basin

The majority of Kerr County lies in the Guadalupe River Basin. The Guadalupe is not only an important water supply source for Kerrville and other communities in Kerr County, but is also a major tourist attraction for the area. Although Kerrville and the Upper Guadalupe River Authority own water rights, much of the flow of the Guadalupe is permitted for downstream use.

1.4.2.5 San Antonio River Basin

Most of Bandera County is split between the Nueces and San Antonio River Basins. The Medina River flows through Bandera County and drains to the San Antonio River. Medina Lake straddles the boundary between Bandera, Medina and Bexar Counties. This reservoir has a volume of 254,843 acre-feet and serves as a major irrigation source for land downstream in Medina County. The firm yield of Medina Lake and its associated Diversion Lake is zero. Bandera County has contracted for 5,000 acre-feet and Bexar Metropolitan Water District has contracted for 6,000 acre-feet. The Bexar-Medina-Atascosa Counties Water Control and Improvement District #1 has a permit to sell 20,000 acre-feet of water diverted from Medina Lake.

1.4.3 Springs and Wildlife Habitat

Springs have played an important role in the development of the Plateau Region. They were important sources of water for Native American Indians, as indicated by the artifacts and petroglyphs found in the vicinity of many of the springs. These springs were also principal sources of water for early settlers and ranchers. Although springs are often recognized by a given name, in reality, most springs are a complex of numerous openings through which groundwater flows to the surface. Additional discussion pertaining to springs and their function in the relationship between groundwater and surface water is contained in Chapter 3.

The PWPG has identified three "Major Springs" that are important for their municipal water supply (Figure 1-11). The fourth largest spring in Texas, San Felipe Springs, discharges to San Felipe Creek east of Del Rio and provides municipal drinking water for Del Rio, as well as irrigation use downstream. Las Moras Springs in Kinney County is of historical significance for its importance as a supply source on early travel routes and military fortifications. Today, Las Moras Springs supports the Fort Clark community and is hydrologically associated with the same aquifer system that serves Fort Clark MUD and the City of Brackettville. The third major spring is Old Faithful in Real County, which is the drinking-water supply source for the City of Camp Wood. Although only three springs are identified as "Major Springs", the PWPG recognizes that all springs in the Region are important and are deserving of natural resource protection.

The PWPG also recognizes the important ecological water supply function that all springs perform in the Region. Springs create and maintain base flow to rivers, contribute to the esthetic and recreational value of land, and are significant sources of water for wild game and aquatic species. Water issuing from springs forms wetlands that attract migratory birds and other fowl that inhabit the Region throughout the year. The spring wetlands host numerous terrestrial and aquatic species, some of which are listed as threatened or endangered.

Two supplemental study reports were prepared during the previous planning period for the PWPG that address springs. The first report (Ashworth and Stein, 2005) considers the location and geohydrology of springs in Kinney and Val Verde Counties, and the second report (Ashworth, 2005) relates springflow in western Kerr County to base flow in the three branches of the upper Guadalupe River.

1.4.4 Reuse

Water recycling, or reuse, is reusing treated wastewater for beneficial purposes such as agricultural and landscape irrigation or industrial processes. The Cities of Kerrville and Camp Wood have active water reuse programs that are described in Chapter 3.

1.4.5 Water Quality Issues

Water quality is generally good throughout the Plateau Region; however, a few specific water quality issues should be mentioned. A more detailed discussion on these issues can be found in Chapter 5.

Increasing population impacts water quality in many ways, one of which is the increase in urban runoff that comes with the increase in impervious cover in populated areas. Impervious cover concentrates runoff into storm sewers and drains, which then discharges into streams, increasing the flow, which also increases the erosional power of the water. In addition, urbanization also causes increased pollutant loads, including sediment, oil/grease/toxic chemicals from motor vehicles, pesticides/herbicides/fertilizers from gardens and lawns, viruses/bacteria/ nutrients from human and animal wastes including septic systems, heavy metals from a variety of sources, and higher temperatures of the runoff.

Increasing population has also manifested itself in the fragmentation of larger properties. With the advent of fragmentation comes the proliferation of new wells being drilled to serve the individual properties. Each new well thus becomes another potential conduit for surface contamination to reach the underlying aquifer system.

From a regional perspective, groundwater quality is relatively good. However, the constituent of most concern is nitrate, which is found above the primary maximum contaminant level in a number of water-sample analyses from the Edwards (BFZ) Aquifer and the Austin Chalk Aquifer in Kinney County.

Historically, the primary contribution to poor groundwater quality occurs in wells that do not have adequately cemented casing. Improperly completed wells allow poorer quality water to migrate into zones containing good quality water. Poorer groundwater quality in the Region is generally from two different sources, evaporite beds in the Glen Rose formation and from surface contamination, both of which can be prevented by proper well construction. Also of concern are above normal levels of radioactivity that have been detected in sand sequences of the Glen Rose and Hensell formations in some areas.

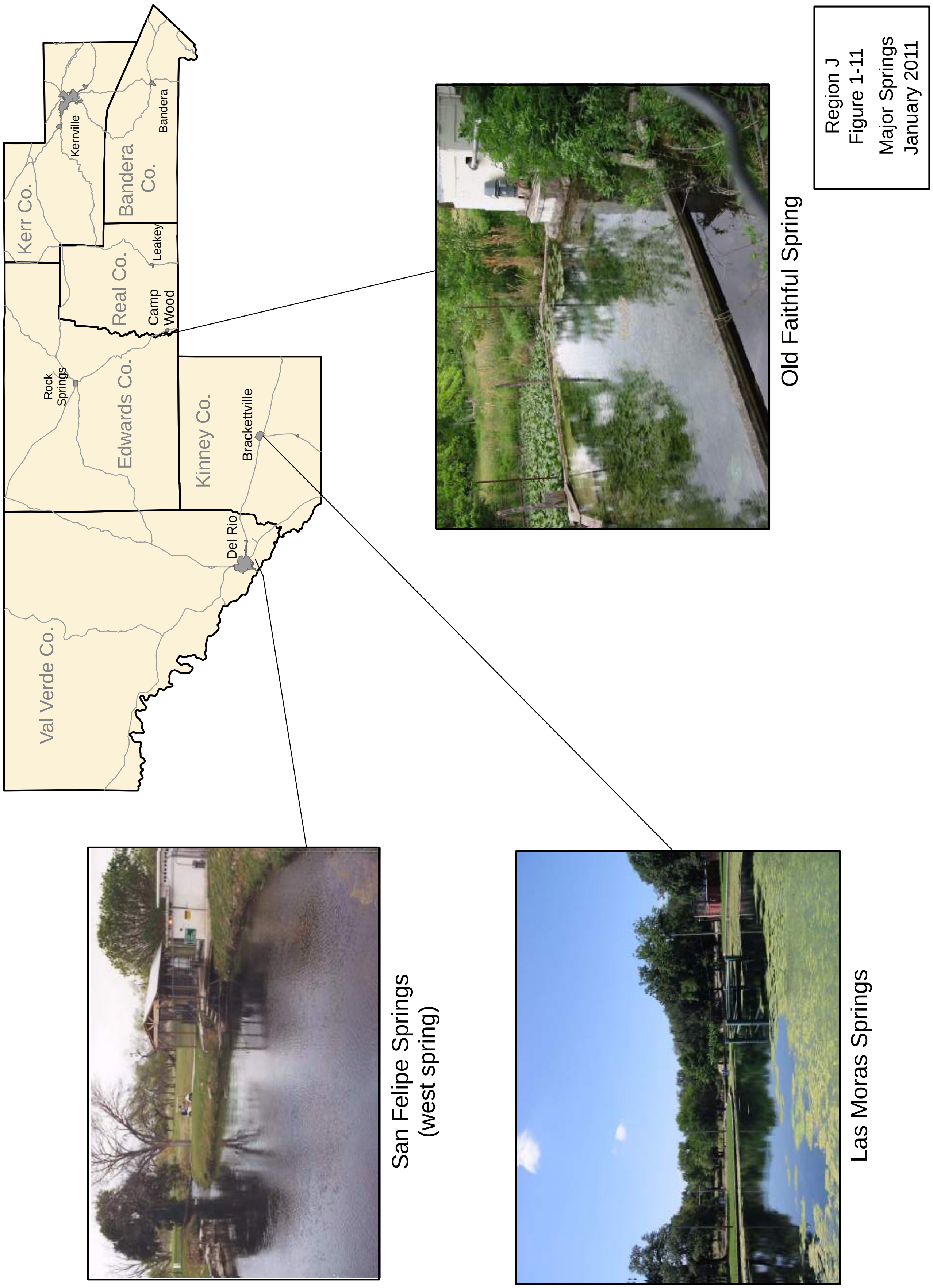

FIGURE 1-11. MAJOR SPRINGS

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1.5 WATER MANAGEMENT PLANNING

1.5.1 State Water Plan

The TWDB adopted *Water for Texas - 2007* in January 2007 as the official water plan for Texas. The Texas Water Code directs the TWDB to update this comprehensive water plan, which is used as a guide for the management of the State's water resources. This State Plan was the result of a consensus planning process that is directed by the TWDB and included efforts by the Texas Commission on Environmental Quality (TCEQ), the Texas Parks and Wildlife Department (TPWD), and the Texas Department of Agriculture (TDA). This plan is the direct result of local input from 16 regional water-planning areas as authorized under Senate Bill 1 of the 77th Legislative Session. Key points mentioned in the State Plan for the Plateau Region include strategies to develop 14,869 acre-feet of additional water supply by the year 2060 at a total capital cost of $14,371,600.

1.5.2 Water Management Plans

The Plateau Region often experiences periods of limited rainfall, especially compared with more humid areas in the eastern part of the state. Although residents of the region are generally accustomed to these conditions, the low rainfall and accompanying high evaporation underscore the necessity of developing plans to manage resources responsibly and to respond to potential disruptions in the supply of groundwater and surface water caused by drought conditions. The following entities have developed water management and drought contingency plans:

- City of Del Rio;
- City of Brackettville;
- City of Kerrville;
- Fort Clark Municipal Utility District;
- Headwaters Groundwater Conservation District;
- City of Bandera;

- Real-Edwards Conservation and Reclamation District;
- City of Leakey; and
- City of Camp Wood.

1.5.3 Groundwater Conservation Districts

The Texas Legislature has established a process for local management of groundwater resources through groundwater conservation districts, which are charged with managing groundwater by providing for the conservation, preservation, protection, recharging and prevention of waste of groundwater within their jurisdictions. An elected or appointed board governs these districts and establishes rules, programs and activities specifically designed to address local problems and opportunities. Texas Water Code §36.0015 states, in part, *"Groundwater Conservation Districts created as provided by this chapter are the state's preferred method of groundwater management."* Four districts are currently in operation within the Plateau Region (Figure 1-12), their management goals are discussed in further detail in Chapter 6.

- Bandera County River Authority and Groundwater District
- Headwaters Groundwater Conservation District
- Real-Edwards Conservation and Reclamation District
- Kinney County Groundwater Conservation District

1.5.4 Water-Supply Source Vulnerability/Security

Following the events of September 11th, Congress passed the Bio-Terrorism Preparedness and Response Act. Drinking water utilities serving more than 3,300 people were required and have completed vulnerability preparedness assessments and response plans for their water, wastewater, and stormwater facilities. The U.S. Environmental Protection Agency (EPA) funded the development of three voluntary guidance documents, which provide practical advice on improving security in new and existing facilities of all sizes. The documents include:

- Interim Voluntary Security Guidance for Water Utilities

  www.awwa.org
- *Interim Voluntary Security Guidance for Wastewater/Stormwater Utilities*

  www.wef.org
- *Interim Voluntary Guidelines for Designing an Online Contaminant Monitoring System*

  www.asce.org

1.5.5 Hill Country Priority Groundwater Management Area

A portion of the Plateau Region (Bandera and Kerr Counties) is included in the initial Hill Country Priority Groundwater Management Area. The Priority Groundwater Management Area (PGMA) process is initiated by the TCEQ, who designates a PGMA when an area is experiencing critical groundwater problems, or is expected to do so within 25 years. These problems include shortages of surface water or groundwater, land subsidence resulting from groundwater withdrawal, or contamination of groundwater supplies. Once an area is designated a PGMA, landowners have two years to create a Groundwater Conservation District (GCD). Otherwise, the TCEQ is required to create a GCD or to recommend that the area be added to an existing district. The TWDB works with the TCEQ to produce a legislative report every two years on the status of PGMAs in the state. The PGMA process is completely independent of the current Groundwater Management Area (GMA) process and each process has different goals. The goal of the PGMA process is to establish GCDs in these designated areas so that there will be a regulating entity to address the identified groundwater issues. PGMAs are still relevant as long as there remain portions within these designated areas without GCDs. The Plateau Region's portion of the Hill Country PGMA (Bandera & Kerr Counties) has GCDs established now; however, the Comal County portion of the Hill Country PGMA (located in Region L) still does not have a GCD and therefore, this PGMA is currently active and relevant. A statewide map of the declared PGMA areas is available at: http://www.tceq.state.tx.us/assets/public/permitting/watersupply/groundwater/maps/pgma_areas.pdf.

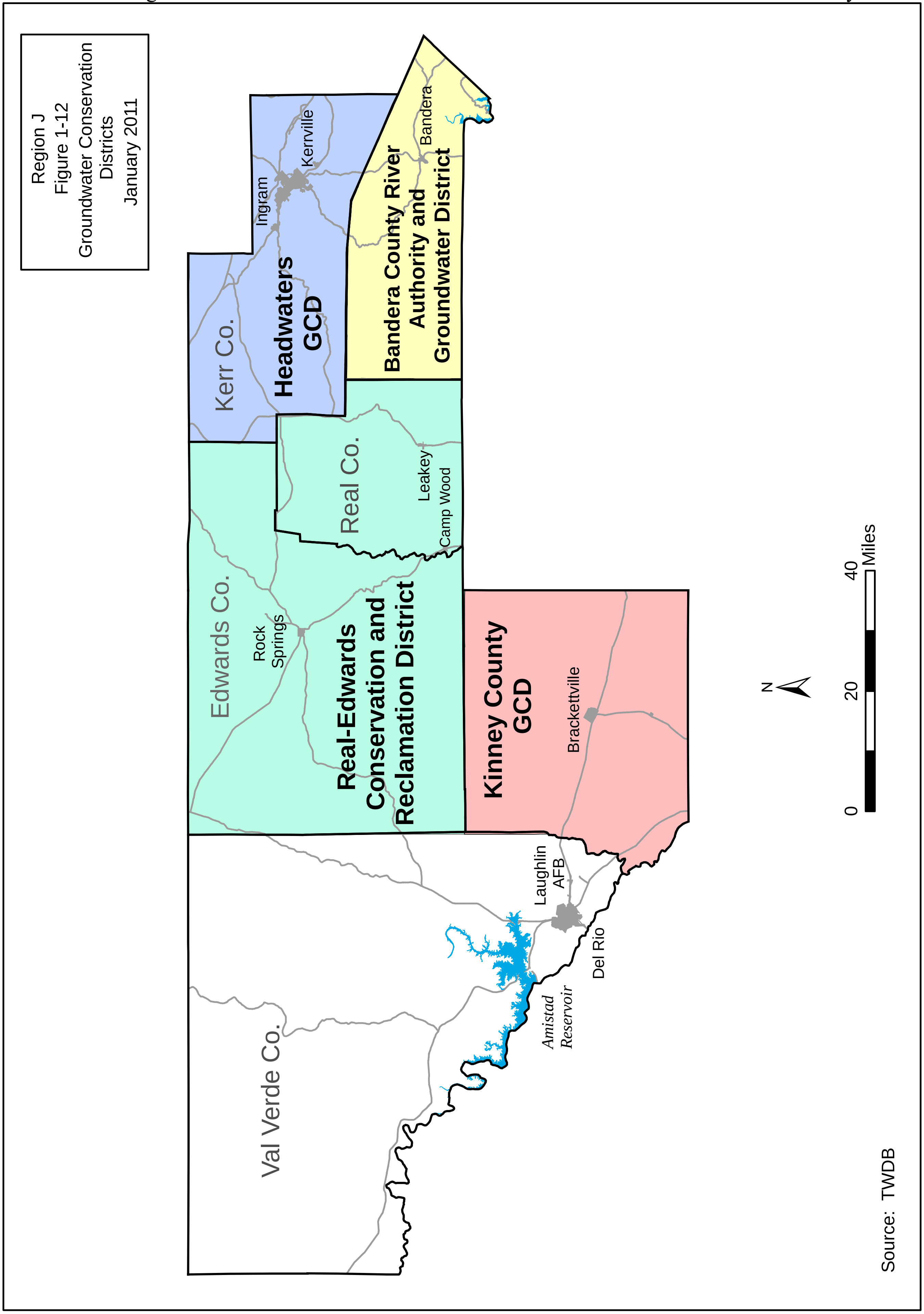

FIGURE 1-12. GROUNDWATER CONSERVATION DISTRICTS

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1.6 COLONIAS

Colonias represent a special, and growing, subset of municipal demand in the Region, and a challenge to water suppliers. Most colonias are subdivisions in unincorporated areas located along the United States/Mexico international border and typically consist of small land parcels sold to citizens of low-income. These subdivisions often lack basic services such as potable water, sewage disposal and treatment, paved roads, and proper drainage. Public health problems are often associated with these colonias.

The Economically Distressed Area Program (EDAP) was created by the Texas Legislature in 1989 and is administered by the TWDB. The intent of the program is to provide local governments with financial assistance for bringing water and wastewater services to the colonias. An economically distressed area is defined as one in which water supply or wastewater systems are not adequate to meet minimal state standards, financial resources are inadequate to provide services to meet those needs, and there was an established residential subdivision on or prior to June 1, 2005. Affected counties are counties adjacent to the Texas/Mexico border, or that have per capita income 25 percent below the state median and unemployment rates 25 percent above the state average for the most recent three consecutive years for which statistics are available. Additional information pertaining to eligibility and requirements for this program are available on the TWDB web site: http://www.twdb.state.tx.us/assistance/financial/fin_infrastructure/edapfund.asp.

EDAP projects in the Plateau Region are located in Kerr, Kinney and Val Verde Counties. Data pertaining to all EDAP projects in the State can be accessed through the TWDB web site: http://www.twdb.state.tx.us/publications/reports/Colonias/status.pdf. The following three projects and one planning grant have been completed as of December 31, 2008:

City of Spofford – Kinney County
New water service for 66 colonia residents
$400,000
Completed 9-22-1998

City of Del Rio (Cienegas Terrace) – Val Verde County
Water and wastewater service for 1,412 colonia residents
$3,510,000
Completed 10-16-1996

City of Del Rio (Val Verde Park Estates) – Val Verde County
Water and wastewater service for an estimated 2,747 colonia residents
$11,480,000
Completed 8-21-2002

Kerr County
Planning grant to provide first time wastewater services to the Community of Center Point and Eastern Kerr County
$175,800

1.7 STATE AND FEDERAL AGENCIES

1.7.1 Texas Water Development Board (TWDB)

The TWDB is the state agency charged with statewide water planning and administration of low-cost financial programs for the planning, design and construction of water supply, wastewater treatment, flood control and agricultural water conservation projects. The TWDB, especially the Water Resources Planning Division, is at the center of the legislatively mandated regional water planning effort. The agency has been given the responsibility of directing the process in order to ensure consistency and to guarantee that all regions of the state submit plans in a timely manner.

1.7.2 Texas Commission on Environmental Quality (TCEQ)

The TCEQ strives to protect the state's natural resources, consistent with a policy of sustainable economic development. TCEQ's goal is clean air, clean water, and the safe management of waste, with an emphasis on pollution prevention. The TCEQ is the major state agency with regulatory authority over state waters in Texas and administers water rights of the Lower Rio Grande through the office of the Watermaster. The TCEQ is also responsible for ensuring that all public drinking water systems are in compliance with the strict requirements of the State of Texas. TCEQ is involved with the TWDB in developing a state consensus water plan. Prior to permit approval, TCEQ is required to determine if projects are consistent with regional water plans.

1.7.3 Texas Parks and Wildlife Department (TPWD)

The TPWD provides outdoor recreational opportunities by managing and protecting wildlife and wildlife habitat and acquiring and managing parklands and historic areas. The agency currently has six internal divisions: Wildlife, Coastal Fisheries, Inland Fisheries, Law Enforcement, State Parks, Infrastructure, TPWD is involved with the TWDB in developing a state consensus water plan. Specifically, the agency looks to see that statewide environmental water needs are included. A TPWD staff person is a non-voting member of the Plateau Water Planning Group and provides essential environmental expertise to the planning process.

1.7.4 Texas Department of Agriculture (TDA)

The TDA was established by the Texas Legislature in 1907. The TDA has marketing and regulatory responsibilities and administers more than 50 separate laws. The current duties of the Department include: (1) promoting agricultural products locally, national, and internationally (2) assisting in the development of the agribusiness in Texas; (3) regulating the sale, use and disposal of pesticides and herbicides; (4) controlling destructive plant pests and diseases; and (5) ensuring the accuracy of all weighing or measuring devices used in commercial transactions. The Department also collects and reports statistics on all activities related to the agricultural industry in Texas. A TDA staff person is a non-voting member of the Plateau Water Planning Group and provides essential agricultural expertise to the planning process.

1.7.5 Texas State Soil and Water Conservation Board (TSSWCB)

The TSSWCB is charged with the overall responsibility for administering and coordinating the state’s soil and water conservation program with the state’s soil and water conservation districts. The agency is responsible for planning, implementing, and managing programs and practices for abating agricultural and sivicultural nonpoint source pollution. Currently, the agricultural/sivicultural nonpoint source management program includes: problem assessment, management program development and implementation, monitoring, education, and coordination.

1.7.6 International Boundary and Water Commission (IBWC) and Comisión Internacional de Límites y Aquas (CILA)

The IBWC and CILA provide binational solutions to issues that arise during the application of United States - Mexico treaties regarding boundary demarcation, national ownership of waters, sanitation, water quality, and flood control in the border region; the treaties are discussed in Chapter 3.

1.7.7 United States Geological Survey (USGS)

The USGS serves the Nation by providing reliable scientific information to (1) describe and understand the Earth; (2) minimize loss of life and property from natural disasters; (3) manage water, biological, energy, and mineral resources; and (4) enhance and protect quality of life.

The USGS's Water Resources Division has played a major role in the understanding of the groundwater resources of Texas. Scientists with the USGS have conducted regional studies of water availability and water quality. Many of these studies have been conducted in conjunction with the TWDB. These studies have provided much of the data for more recent investigations conducted by graduate students and faculty members of the geology departments of many Texas universities.

1.7.8 United States Environmental Protection Agency (EPA)

The mission of the EPA is to protect human health and the environment. Programs of the EPA are designed (1) to promote national efforts to reduce environmental risk, based on the best available scientific information; (2) ensure that federal laws protecting human health and the environment are enforced fairly and effectively; (3) guarantee that all parts of society have access to accurate information sufficient to manage human health and environmental risks; and (4) guarantee that environmental protection contributes to making communities and ecosystems diverse, sustainable, and economically productive.

1.7.9 United States Fish and Wildlife Department (USFWS)

The USFWS enforces federal wildlife laws, manages migratory bird populations, restores nationally significant fisheries, conserves and restores vital wildlife habitat, protects and recovers endangered species, and helps other governments with conservation efforts. It also administers a federal aid program that distributes money for fish and wildlife restoration, hunter education, and related projects across the country. The USFWS has provided comments that are pertinent to wildlife water needs to draft planning documents.

APPENDIX 1A

Water Rights Analysis and ASR Feasibility

in Kerr County

Water Rights Analysis and ASR Feasibility in Kerr County

Executive Summary

As the population of Kerr County continues to increase, the availability of water to meet the growing demand and the infrastructure to deliver the water continues to be of local concern. Although the Guadalupe River traverses the County, local entities have limited permitted access to surface water supplies. While Kerrville is able to use both surface water and groundwater, other municipal water suppliers rely entirely on groundwater sources. The purpose of this study was to assess the feasibility of two water management strategies proposed in the 2006 Plateau Region Water Plan to address potential future water shortages for the City of Kerrville and the rural population of Kerr County as potentially serviced by the Upper Guadalupe River Authority (UGRA).

The Guadalupe River Basin has 358 water right permits, of which 191 are located above Canyon Lake. The best water rights to supplement Kerr County water supplies are those located above Canyon Lake. An analysis of potentially available water rights was performed in which reliability, location, and valuation were considered. Also evaluated were the impact of moving diversion points upstream and the potential use of wastewater effluent.

The feasibility of constructing an aquifer storage and recovery (ASR) facility to provide additional water supplies for the eastern part of Kerr County was evaluated. The evaluation assumed a facility site near the Community of Center Point, a water supply source based on UGRA water rights, additional water rights that could be leased or purchased, and injection and storage of treated water underground in the Lower Trinity Aquifer.

For this analysis a surface water diversion of 3,029 acre-feet per year is assumed. This diversion is composed of the existing UGRA water right (2,000 acre-feet per year) and additional rights leased or purchased (1,029 acre-feet per year). A direct distribution from the treatment facility of 1,124 acre-feet per year (1.5 MGD) would be made and a maximum consideration of 1,905 acre-feet per year (2.5 MGD) would be injected and recovered. The cost of purchasing additional water rights for 1,029 acre-feet per year is $974,100 (2008 dollars).

The facility for treating water from the Guadalupe River near Center Point is assumed to have an approximate capacity of 4 MGD. Cost estimates assume a low-pressure membrane treatment process for particle removal (microfiltration) and a second stage treatment with high-pressure membranes (nanofiltration) for softening 50% of the flow. A 16 MG terminal reservoir is recommended to buffer high turbidity peaks from the Guadalupe River.

The estimated capital cost for this plant is $13,725,000 (2008 dollars), which includes the raw water pump station, terminal storage reservoir, residuals handling facilities, high service pump station, clearwell, engineering and contingencies. The annual cost of operation and maintenance is $194,000. The cost to construct and equip a single Lower Trinity well capable of both injection and withdrawals is approximately $403,000. Modeling results suggest that at least two wells will be needed. The overall capital cost is $15,505,100, which includes purchase of 11 water rights, a 4 MGD treatment plant and 2 wells. The unit cost of this strategy is $1,217 per acre-foot.

A Lower Trinity Aquifer groundwater simulation model constructed by LBG-Guyton Associates for the Bandera County River Authority and Groundwater District and supported by the Headwaters Groundwater Conservation District was used to assess the ASR potential in eastern Kerr County. Based on the conceptual understanding and assimilated data, a one-layer MODFLOW groundwater flow model was developed. The model was calibrated to pre-development conditions and the transient conditions from 1950 through 2005.

The model evaluation indicates that a total injection of 2.54 MGD in two wells is overly aggressive from a hydrogeologic perspective because the Lower Trinity water level (pressure) in the nearby wells would be above ground surface. Alternative simulation scenarios suggest that, under the given assumptions, around 0.6 MGD would be the most feasible injection rate at which pressurized water levels near the injection wells would not rise above the land surface. However, increased well spacing or additional wells could potentially allow for an increased injection rate.

APPENDIX 1B

ASR Feasibility in Bandera County

ASR Feasibility in Bandera County

Executive Summary

The City of Bandera and many other residents of Bandera County rely on the Lower Trinity Aquifer for municipal, domestic, and irrigation water-supply needs, and the demand from the Lower Trinity is projected to increase as the population increases. Because the water level in the Lower Trinity has declined about 350 feet in City of Bandera wells since pumping started in the 1950s, there is concern that continued withdrawals from the aquifer may negatively impact the aquifer's ability to meet the long-term water supply needs of the area. The purpose of this project is to investigate the feasibility of constructing and operating an aquifer storage and recovery (ASR) facility using treated surface water from the Medina River and stored in the Lower Trinity Aquifer.

The Trinity is the most important water-bearing unit in Bandera County and is collectively referred to as the Trinity Group Aquifer. Based on their hydrologic relationships, the water-bearing rocks of the Trinity Group are organized into Upper, Middle and Lower aquifer units. The Lower Trinity Aquifer, the most important aquifer for municipal use, is comprised of the Sligo Limestone and underlying Hosston Sand.

Bandera County currently has an agreement with the Bexar-Medina-Atascosa Water Control and Improvement District #1 (BMAWCID#1) for purchase of up to 5,000 acre-feet per year of water from the Medina River. The reliability of the River diversion was calculated with a version of the Water Availability Model of the Guadalupe-San Antonio Basin dated March 2008 provided by the Texas Commission on Environmental Quality (TCEQ). The average diversion over the historical hydrologic period 1934-1989 is 3,680 acre-feet per year. Based on this assessment, a water diversion and treatment facility size of 6.7 mgd is recommended for a supply of 3,100 acre-feet per year, with an ASR injection and recovery rate of 1.0 mgd.

At the request of the Bandera County River Authority and Groundwater District (BCRAGD), LBG-Guyton conducted a modeling study of the Lower Trinity in Bandera and surrounding counties (LBG-Guyton Associates, 2009). Based on the conceptual understanding and assimilated data, a one-layer MODFLOW groundwater flow model was

developed. The model was calibrated to pre-development and transient conditions from 1950 through 2005.

The Lower Trinity Aquifer model was used to evaluate ASR impacts on the aquifer system based on varying scenarios of injection rate, injection location, and annual withdrawals from the aquifer. At the higher end, an injection rate of 2.54 mgd was found to be overly excessive from a hydrogeologic perspective regardless of the level of projected water demand. If only the City of Bandera municipal wells are considered as the point of injection, the model suggests that 0.5 mgd would be the most appropriate rate of injection. Additional scenarios considered a reduced rate of injection at the City of Bandera municipal wells and an increased rate in southeast Bandera County, where new subdivisions under full buildout would increase the need for additional water supplies. Based on this scenario, the modeling results suggest a total injection of around 1.0 mgd is reasonable.

The estimated infrastructure cost for the completion of an ASR facility was prepared. The estimated capital costs for a 6.7 mgd capacity source-water treatment facility is $17,973,000 (2008 dollars) and the annual cost of operation and maintenance is $540,000, which results in a treatment unit cost of $595 per acre-foot. The cost to construct and equip a single Lower Trinity well capable of both injection and withdrawals is approximately $454,000. The total capital cost is $ 18,881,000 and the total overall unit cost of the ASR strategy is $659 per acre-foot.

APPENDIX 1C

Groundwater Data Acquisition in Edwards, Kinney and Val Verde Counties, Texas

Groundwater Data Acquisition in Edwards, Kinney and Val Verde Counties, Texas

Executive Summary

The purpose of this project is to assist in the further characterization of the Edwards and associated aquifers in Kinney, Val Verde and southern Edwards Counties by acquiring additional hydrologic data that was not available during the development of the Edwards-Trinity Plateau Groundwater Availability Model (GAM) (September 2004) and the most recent revision of the Edwards Balcones Fault Zone (BFZ) aquifer model. It is anticipated that this additional hydrologic data will improve the existing models or provide sufficient data for the construction of a new model that will produce a more useful groundwater supply management tool. To accomplish this mission, data acquisition is organized into four general tasks: (1) review of existing aquifer evaluations, field studies and new well data; (2) performance of dye tracer tests to analyze groundwater flow direction and speed; (3) measurement of water levels in wells during two seasonal periods; and (4) review of recent water quality sampling projects.

International Boundary and Water Commission (IBWC) reports document the extent of aquifer water-level rise, change in flow direction, and increase in spring flow as a result of the construction and subsequent filling of the Amistad reservoir on the Rio Grande. Spring flow hydrographs of major springs illustrate change in flow volume over time. Numerous new wells have been drilled in Edwards, Kinney, and Val Verde Counties since 2004 and are documented in Appendix A. Recent aquifer reports provide new aquifer characterization of the study area.

Three dye tracer tests were conducted for this project, one in the Pinto Valley of Kinney County and two in the vicinity of Del Rio in Val Verde County. The dye tracer tests entailed introducing dye into the aquifer at designated locations and monitoring its rate and direction of travel over time. After more than two months of monitoring, dye was detected in

a number of sites. This type of information is beneficial when assessing contamination issues, water supply availability, and other groundwater related evaluations.

Two synoptic water-level measurement events were conducted during February and September 2008. Wells selected for this project included those that are annually measured by the Texas Water Development Board (TWDB) and the Real-Edwards Conservation and Reclamation District (CRD). Additional wells were selected with the assistance of the Kinney County Groundwater Conservation District (GCD) and the Real-Edwards CRD. TWDB staff also participated in the project by measuring water levels in wells on the Texas Nature Conservancy's Devils River Preserve and in other wells in Val Verde County. The results of these synoptic water-level measurements are provided in figures and tables. Water levels were generally higher during the February measurement; however, a few wells had the opposite trend. Water-level maps provided in other recent studies are also included in this report.

Chemical analyses of water samples collected between January 2004 and August 2007 are available on the TWDB groundwater database. A map detailing well locations that were sampled within this timeframe and their corresponding total dissolved solids concentrations (TDS) are included in this report. Also, recent isotope studies are summarized.

CHAPTER 2

POPULATION AND WATER DEMAND

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2.1 INTRODUCTION

Planning for the wise use of the existing water resources in the Plateau Region requires a reasonable estimation of current and future water needs for all water-use categories. The TWDB Regional Planning Guidelines specify in Section 357.5 (d) that in developing regional water plans, the Regional Water Planning Groups shall use for population and water-demand projections one of the following:

- *State population and water demand projections contained in the state water plan or adopted by the TWDB after consultation with the Texas Commission on Environmental Quality, Texas Department of Agriculture, Texas Parks and Wildlife Department, and regional water planning groups in preparation for revision of the state water plan; or*
- *Population or water demand projection revisions that have been adopted by the TWDB, after coordination with Texas Commission on Environmental Quality, Texas Department of Agriculture, Texas Parks and Wildlife Department, and regional water planning groups when the requesting regional water planning group demonstrates that the population and water demand projections developed pursuant to paragraph (1) of this subsection no longer represent a reasonable projection of anticipated conditions based on changed conditions and availability of new information.*

Regional population and water demand data was initially provided to the planning groups at the beginning of the planning period. This information incorporated data from the State Data Center and from the U.S. Census Bureau's 2000 census count. In accordance with the second criteria above, the Plateau Water Planning Group (PWPG) requested and was given approval to revise specific population and water demand data for use in the *2011 Plateau Region Water Plan*. Thus, the population and water demand projections shown in this chapter are derived from a combination of TWDB data and approved revisions.

2.2 POPULATION AND WATER DEMAND PROJECTION REVISIONS

The PWPG provided draft population and water demand summary tables to municipalities, water providers, county judges, and non-municipal water use representatives, and solicited all entities within the Region to submit desired changes to the projections. After thoughtful consideration, the PWPG chose not to modify the draft population estimates. However, the PWPG did voice reservations with the way that these population numbers are used to calculate county rural water demand projections as further expressed in the last paragraph of Section 2.3.1 below. Requested revisions in draft water-demand projections fell into only one category, mining in Edwards County, which was subsequently granted by the TWDB.

2.3 POPULATION

2.3.1 Population Projection Methodology

Starting with the 2000 census year count, TWDB staff used a cohort-component procedure to calculate population projections. Separate cohorts (age, sex, race, and ethnic groups) and components of cohort change (fertility rates, survival rates, and migration rates) are used to estimate county populations. The projected county population is then allocated to each city containing 500 or more people on the basis of each city's historic share of the county population. In some cases, the water user group (WUG) is a utility. In these cases, the population reported for the utility represents the population served by that utility. The rural "county other" population is calculated as the difference between the total projected population of cities and major utilities, and the total projected county population. Population is thus projected from the 2000 base year by decade to the year 2060.

The PWPG expresses concern that the population projections do not recognize the impact to the municipal and rural population and its related water demand that occurs as the result of seasonal vacationers, hunters, and absentee land-owner homes, especially in the rural counties. The PWPG recommends that for future regional water plans, that a region be allowed to adjust the total regional population rather than having to adjust individual county populations to achieve a non-changeable total population.

2.3.2 Year-2000 and Projected Population

In the year 2000, the U.S. Census Bureau performed a census count, which provides the base year for future population projections in the Region. Although the PWPG accepts the 2000 census count, members again expressed concern that the census does not recognize the significant seasonal population increase that occurs in these counties as the area draws large numbers of hunters and recreational visitors, as well as absentee land owners who maintain vacation, retirement, and hunting cabins. Laughlin Air Force Base in Val Verde County is also anticipating an increase in military population in the near future. Therefore, an emphasis is being made in this planning document, especially for the rural counties, to recognize a need for more water than is justified simply from the population-derived water demand quantities.

The approved projections may also underestimate population and subsequent water demand in Kerr County by more than just undercounting hunters, absentee landowners and tourists. The cohort-component model used to project population growth does not adequately account for expected business and market factors that can influence population growth. Several Kerr County organizations are actively pursuing market development and business growth in order to maintain a consistent double-digit growth rate not reflected in the long-term population forecast. Similar underestimations may also occur elsewhere in the Region.

Population projections by decade for communities, water utilities, and county rural areas in the Plateau Region are listed in Table 2-1. The projected year-2010 population for the entire Region is 135,723 of which 74 percent reside in Kerr and Val Verde Counties (Figure 2-1). Del Rio (including Laughlin AFB), with a year-2010 projected population of 39,249, is the largest community in the Region. The Regional population is projected to increase by 52 percent to 205,910 by the year 2060, which is an increase of 70,187 citizens (Figure 2-2).

The greatest percentage increase in population is projected to occur in Bandera County, which is expected to grow from a projected year-2010 population of 26,373 to 60,346 by the year 2060, an increase of 129 percent. This rapid growth is primarily influenced by the rapid expansion in the San Antonio metroplex. However, future escalation of fuel cost and cost of living could slow this growth rate. Population in the rural counties of Edwards, Kinney and Real is expected to remain relatively constant over the 50-year planning period, however the transient population is expected to increase.

Table 2-1. Plateau Region Population Projection

COUNTY	WATER USER GROUP	2010	2020	2030	2040	2050	2060
BANDERA	Bandera	1,056	1,179	1,307	1,411	1,499	1,586
	County-Other	25,317	36,086	47,270	53,418	55,143	58,760
	BANDERA TOTAL	**26,373**	**37,265**	**48,577**	**54,829**	**56,642**	**60,346**
EDWARDS	Rocksprings	1,380	1,439	1,405	1,362	1,346	1,290
	County-Other	942	982	959	929	918	880
	EDWARDS TOTAL	**2,322**	**2,421**	**2,364**	**2,291**	**2,264**	**2,170**
KERR	Kerrville	23,044	25,681	26,934	27,544	28,926	29,545
	Ingram	1,963	2,188	2,295	2,219	2,081	1,963
	County-Other	24,243	27,017	28,336	28,899	30,197	30,744
	KERR TOTAL	**49,250**	**54,886**	**57,565**	**58,662**	**61,204**	**62,252**
KINNEY	Brackettville	1,893	1,914	1,933	1,952	1,965	1,968
	Fort Clark Springs	1,364	1,433	1,499	1,563	1,609	1,619
	County-Other	146	115	97	86	79	75
	KINNEY TOTAL	**3,403**	**3,462**	**3,529**	**3,601**	**3,653**	**3,662**
REAL	Camp Wood	826	839	821	807	828	845
	County-Other	2,237	2,272	2,221	2,186	2,242	2,287
	REAL TOTAL	**3,063**	**3,111**	**3,042**	**2,993**	**3,070**	**3,132**
VAL VERDE	Del Rio	37,024	40,050	42,869	45,270	47,024	48,289
	Laughlin AFB	2,225	2,225	2,225	2,225	2,225	2,225
	County-Other	12,063	15,225	18,171	20,680	22,512	23,834
	VAL VERDE TOTAL	**51,312**	**57,500**	**63,265**	**68,175**	**71,761**	**74,348**
	REGION TOTAL	**135,723**	**158,645**	**178,342**	**190,551**	**198,594**	**205,910**

Note: The PWPG expresses concern that the population projections do not recognize the impact to the municipal and rural population and its related water demand that occurs as the result of seasonal vacationers, hunters, and absentee land-owner homes, especially in the rural counties. The PWPG recommends that for future regional water plans, that a region be allowed to adjust the total regional population rather than having to adjust individual county populations to achieve a non-changeable total population.

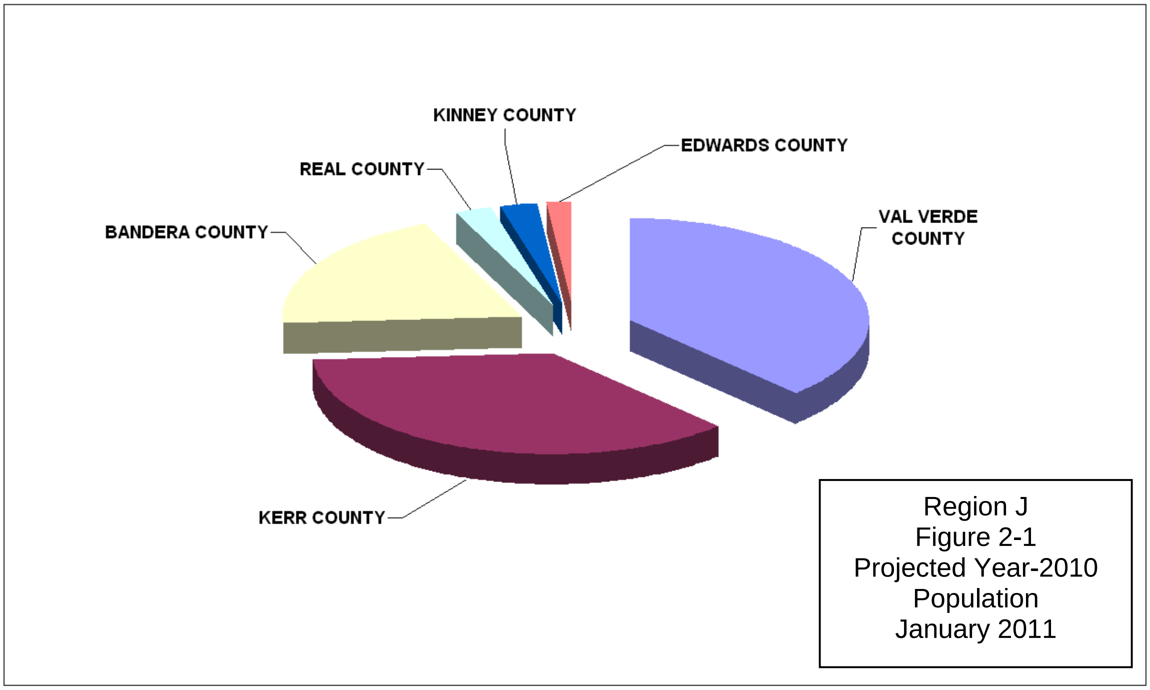


Figure 2-1. Projected Year-2010 Population

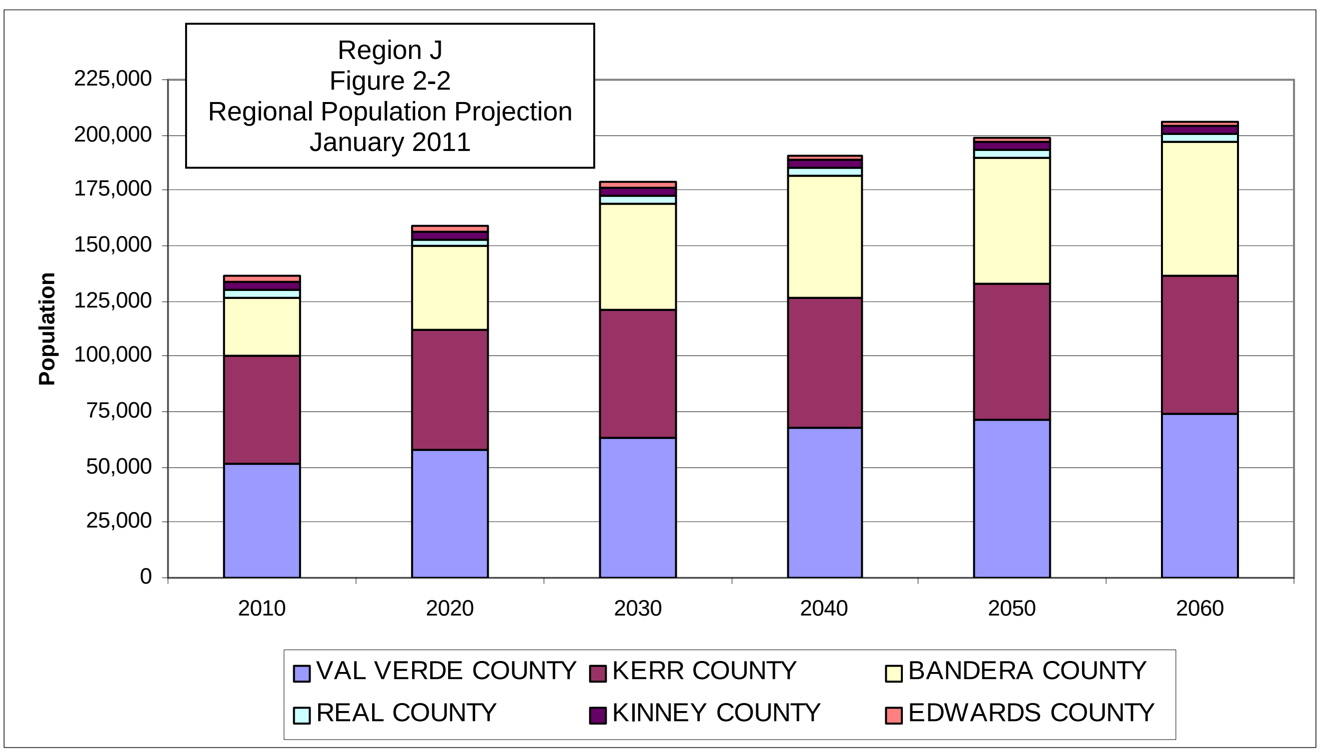


Figure 2-2. Regional Population Projection

2.4 WATER DEMAND

A major component of water planning is the establishment of accurate water demand estimates for all water-use categories. Water demands in this Plan represent annual drought-of-record conditions and not a peak demand condition within a single year. Categories of water use include (1) municipal, (2) rural domestic (county-other), (3) manufacturing, (4) irrigation, (5) livestock, and (6) mining. There is no recognized water use in the Plateau Region for “steam-electric power generation”. Table 2-2 lists the current and future projected Regional water demand by county and water-use category. Water demand is further distributed by county and river basin in Appendix 2A. The municipal category includes cities and retail public utilities. The percent distribution of water demand in the Region by the five water-use categories is shown in Figure 2-3. Water demand is reported in “acre-feet”; one acre-foot is equivalent to a quantity of water one foot deep occupying one acre, or 325, 851 gallons. Other water use categories that are not quantified in this Plan include environmental and recreational needs, and are addressed in section 2.5.

Figures 2-4 and 2-5 show projected water demand by county in acre-feet per year. From the year 2010 to 2060 the total water demand in the Region is projected to increase from 51,928 acre-feet to 58,643 acre-feet. Water demand methodologies and trends for each of the five water-use categories are provided in the following subsections.

The potential role of conservation is an important factor in projecting future water supply requirements. Water demands listed in this Plan included demand adjustments based on expected conservation practices. In this Plan, conservation is only included in the municipal projections as a measure of expected savings based on requirements of the State plumbing code. All other conservation practices are discussed in terms of water supply strategies in Chapter 4 and as a component of drought management plans in Chapter 6.

The following sections present an overview of water supply needs for each of the designated water-use categories and includes methods and assumptions used in the State's consensus water planning process. This information has been taken from the 2002 State Water Plan (Water For Texas - 2002) and Exhibit B - Guidelines for Regional Water Plan Development. The 2002 State Water Plan can be found on the Texas Water Development Board's web page, http://www.twdb.state.tx.us.

As stated previously in Section 2.3.2, the PWPG is concerned that the population and subsequent water demand projections throughout the Region may be understated due to the large number of temporary residents in the Region including hunters, tourists and absentee landowners. In addition to these factors, water demand may be understated in Kerr County (as well as elsewhere in the Region) because the cohort-component model does not reflect market and business factors that are expected to increase water demand in the county, especially in the municipal and manufacturing use category.

Table 2-2. Plateau Region Water Demand Projections

(Acre-Feet/Year)

COUNTY	WATER USER GROUP	2010	2020	2030	2040	2050	2060
BANDERA	Bandera	259	284	312	332	351	371
	County-Other	2,609	3,638	4,659	5,206	5,374	5,726
	Manufacturing	0	0	0	0	0	0
	Irrigation	464	464	464	464	464	464
	Mining	24	24	24	24	24	24
	Livestock	315	315	315	315	315	315
	BANDERA TOTAL	**3,671**	**4,725**	**5,774**	**6,341**	**6,528**	**6,900**
EDWARDS	Rocksprings	272	279	268	256	250	240
	County-Other	173	177	169	163	158	152
	Manufacturing	0	0	0	0	0	0
	Irrigation	153	147	141	135	129	123
	Mining	89	89	89	89	89	89
	Livestock	562	562	562	562	562	562
	EDWARDS TOTAL	**1,249**	**1,254**	**1,229**	**1,205**	**1,188**	**1,166**
KERR	Ingram	220	238	242	229	212	200
	Kerrville	4,362	4,746	4,918	4,937	5,152	5,262
	County-Other	2,727	2,947	2,999	2,996	3,098	3,155
	Manufacturing	30	33	36	39	41	44
	Irrigation	1,821	1,761	1,706	1,652	1,599	1,548
	Mining	167	165	164	163	162	161
	Livestock	487	487	487	487	487	487
	KERR TOTAL	**9,814**	**10,377**	**10,552**	**10,503**	**10,751**	**10,857**
KINNEY	Brackettville	583	583	582	582	581	582
	Fort Clark Springs	626	653	678	704	723	727
	County-Other	67	52	44	39	35	34
	Manufacturing	0	0	0	0	0	0
	Irrigation	13,507	12,928	12,373	11,843	11,337	10,853
	Mining	0	0	0	0	0	0
	Livestock	445	445	445	445	445	445
	KINNEY TOTAL	**15,228**	**14,661**	**14,122**	**13,613**	**13,121**	**12,641**
REAL	Camp Wood	172	172	166	160	163	167
	County-Other	428	427	411	396	405	413
	Manufacturing	0	0	0	0	0	0
	Irrigation	392	377	361	346	330	314
	Mining	5	5	5	5	5	5
	Livestock	176	176	176	176	176	176
	REAL TOTAL	**1,173**	**1,157**	**1,119**	**1,083**	**1,079**	**1,075**
VAL VERDE	Del Rio	12,898	13,817	14,646	15,314	15,855	16,281
	Laughlin AFB	1,303	1,296	1,289	1,281	1,276	1,276
	County-Other	2,621	3,274	3,888	4,378	4,766	5,046
	Manufacturing	0	0	0	0	0	0
	Irrigation	3,086	2,968	2,852	2,743	2,636	2,535
	Mining	118	111	107	104	101	99
	Livestock	767	767	767	767	767	767
	VAL VERDE TOTAL	**20,793**	**22,233**	**23,549**	**24,587**	**25,401**	**26,004**
	REGION TOTAL	**51,928**	**54,407**	**56,345**	**57,332**	**58,068**	**58,643**

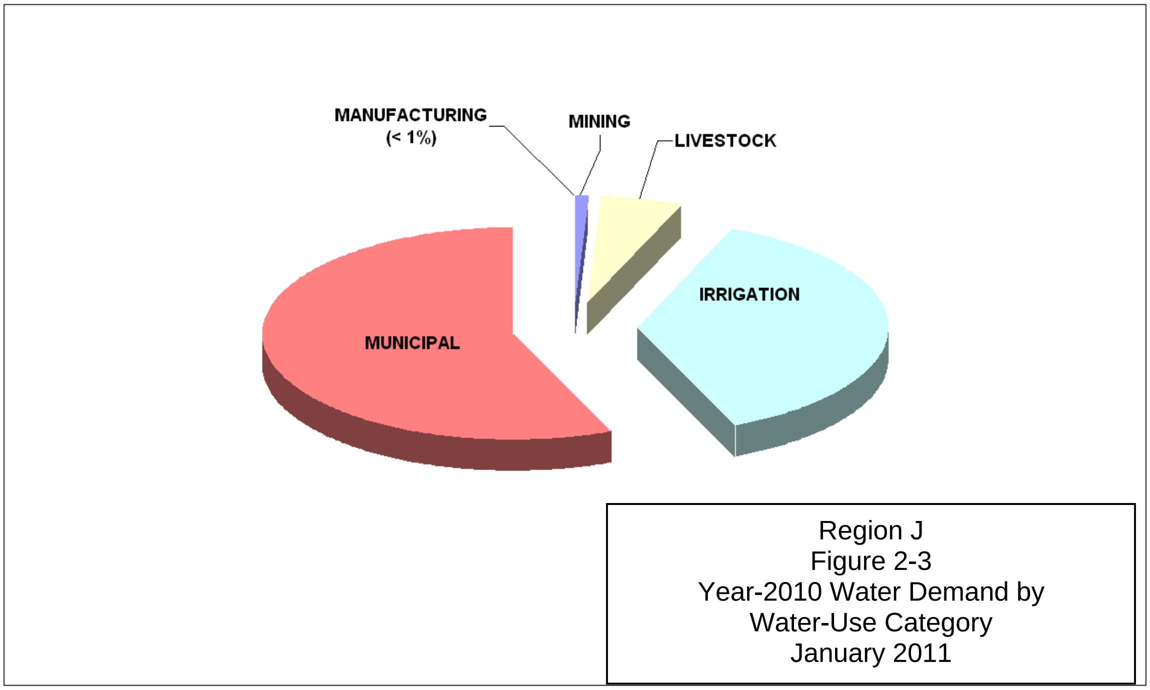


Figure 2-3. Year-2010 Water Demand By Water-Use Category

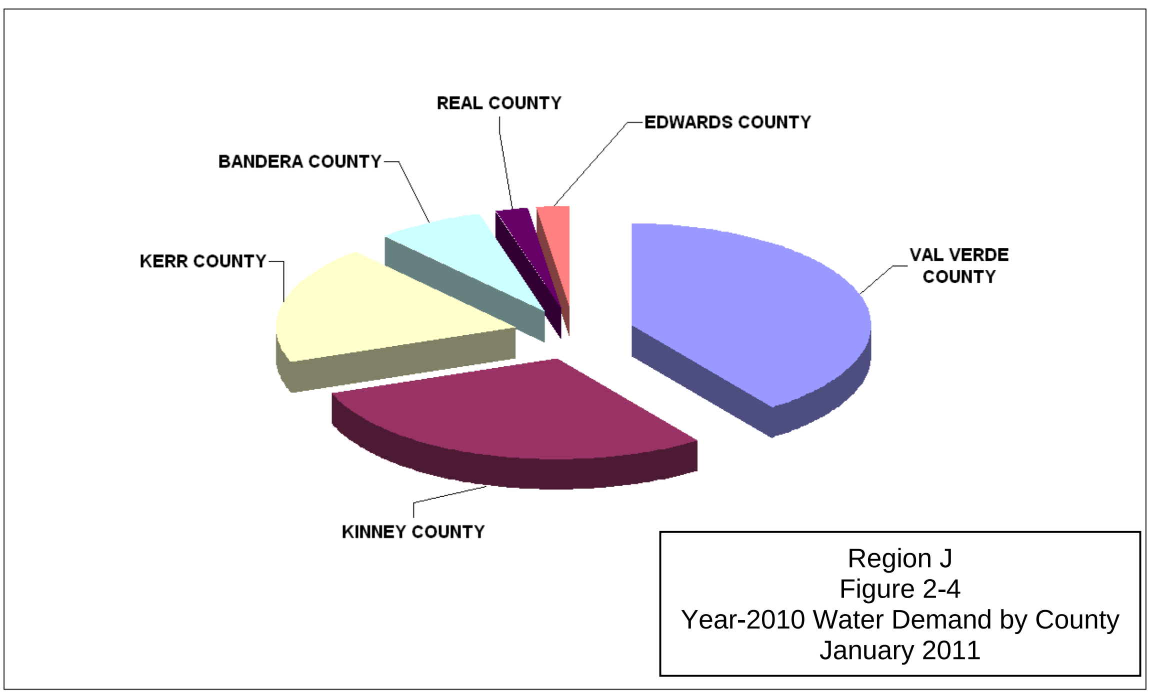


Figure 2-4. Year-2010 Water Demand By County

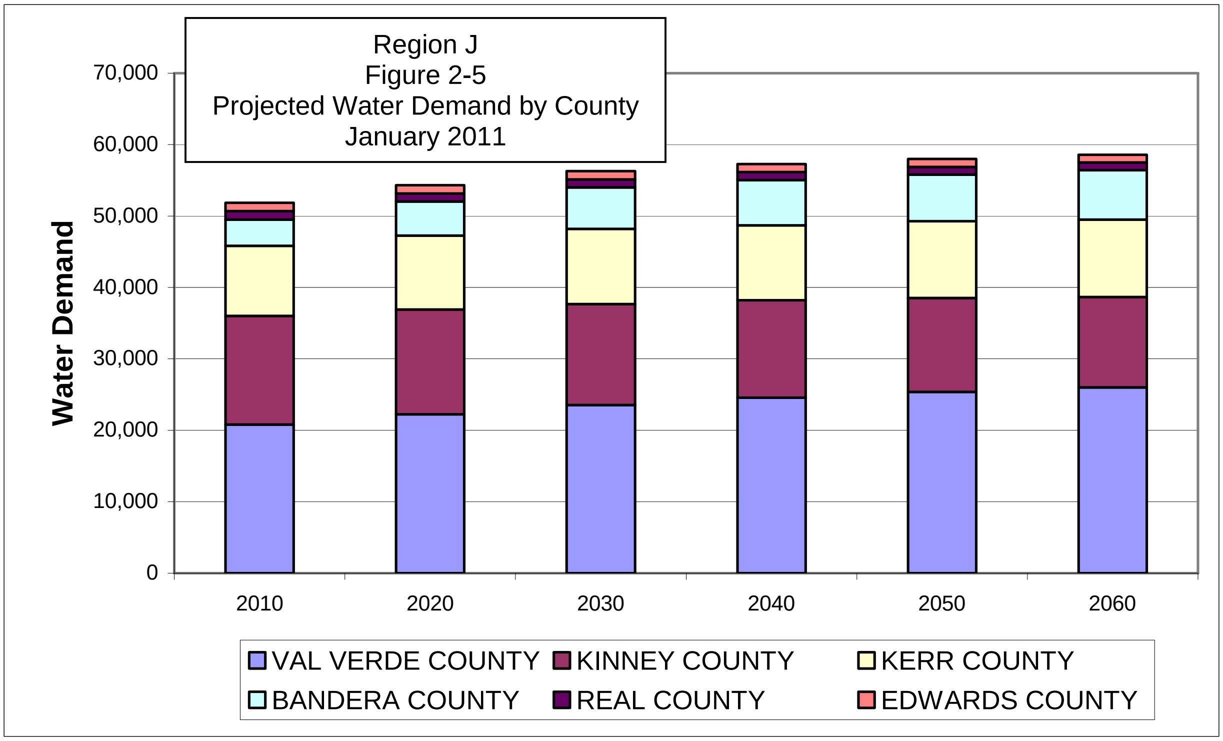


Figure 2-5. Projected Water Demand By County

2.4.1 Municipal and County Other

The quantity of water used for municipal and rural domestic (County-Other) purposes is heavily dependent on population growth, climatic conditions, and water-conservation measures. For planning purposes, municipal water use comprises both residential and commercial. Commercial water use includes business establishments, public offices, and institutions. Residential and commercial uses are categorized together because they are similar types of uses: i.e., they both use water primarily for drinking, cleaning, sanitation, air conditioning, and landscape watering. Also included in this category is water supplied to golf courses from municipal supply sources. Water use within a city that is not included in the quantification of municipal demand is that used in manufacturing and industrial processes.

Projected municipal water demand is based on the year-2000 per-capita water use, which is calculated with year-2000 population counts divided into reported water use for the same year. Per-capita water use in communities with significant non-residential water demands, such as commercial customers will appear abnormally high. The year-2000 per-capita water use is reduced slightly over time to simulate expected conservation savings due to State-mandated plumbing code implementation. The conservation adjusted per-capita water use is then applied to each of the decade population estimates to produce the projected water demand for each entity.

Municipal (and County-Other) water demand in the Plateau Region is projected to increase from a year-2010 level of 29,320 acre-feet to 39,632 acre-feet by the year 2060. Because municipal water demand is directly related to population, Val Verde County has the highest demand in the Region. Water demand in Val Verde County may increase even beyond the current projection if the Laughlin Air Force Base expansion occurs as expected. Bandera County, with the greatest projected percentage population increase, will likewise see the greatest percentage municipal water demand increase over the 50-year period, 113 percent.

Municipal Water Demand Projection (acre-feet/year)

County	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Bandera	2,868	3,922	4,971	5,538	5,725	6,097
Edwards	445	456	437	419	408	392
Kerr	7,309	7,931	8,159	8,162	8,462	8,617
Kinney	1,276	1,288	1,304	1,325	1,339	1,343
Real	600	599	577	556	568	580
Val Verde	16,822	18,387	19,823	20,973	21,897	22,603
Total	**29,320**	**32,583**	**35,271**	**36,973**	**38,399**	**39,632**

Wholesale Water Provider

A wholesale water provider is any person or entity that has contracts to sell more than 1,000 acre-feet of water wholesale in any one year during the five years immediately preceding the adoption of the last regional water plan. The City of Del Rio is the only entity in the Plateau Region to meet this criterion. In addition to its own use, the city provides water to Laughlin Air Force Base and subdivisions outside of the city. Del Rio also provides water and wastewater services to two colonias, Cienegas Terrace and Val Verde Park Estates.

The Upper Guadalupe River Authority (UGRA) anticipates becoming a wholesale water provider in coming years with the intent to provide conjunctive water-supply sources to meet the needs of Kerr County citizens that will not be served by the City of Kerrville.

City of Del Rio Wholesale Water Demand by Recipient (acre-feet/year)

County	Basin	Water User Group	2010	2020	2030	2040	2050	2060
Val Verde	Rio Grande	City of Del Rio	12,898	13,817	14,646	15,314	15,855	16,281
		Laughlin AFB	1,238	1,231	1,225	1,217	1,212	1,212
		County Other	708	884	1,050	1,182	1,287	1,362

2.4.2 Manufacturing

Manufacturing and industrial water use is quantified separately from municipal use even though the demand centers may be located within a city limits. Future manufacturing and industrial water use is largely dependent on technological changes in the production process, on improvements in water-efficient technology, and on the economic climate of the marketplace. Technological changes in production affect how water is used in the production process, while improvements in water-efficient technology affect how much water is used in the production process. As older production facilities and accompanying production processes are modernized or retooled, the new production processes are anticipated to be more resource efficient. In the Plateau Region, the use of water for manufacturing purposes is only recognized in Kerr County.

Manufacturing Water Demand Projection (acre-feet/year)

County	2010	2020	2030	2040	2050	2060
Bandera	0	0	0	0	0	0
Edwards	0	0	0	0	0	0
Kerr	30	33	36	39	41	44
Kinney	0	0	0	0	0	0
Real	0	0	0	0	0	0
Val Verde	0	0	0	0	0	0
Total	**30**	**33**	**36**	**39**	**41**	**44**

2.4.3 Irrigation

A comprehensive irrigation survey was performed for the TWDB in 2000 that provided up-to-date crop and irrigation data. The acreage planted for each crop under irrigation, along with the water application rate for each crop, was estimated by the Natural Resource Conservation Service (NRCS) and computed to give total irrigation use for each county. Irrigation water demand includes estimates of surface water lost in the process of transportation to the field. In lieu of the above process, irrigation districts could provide more accurate estimates based on actual measured diversions or pumping withdrawals. Future irrigation use is then projected from this 2000 base year at a rate established for the same county irrigation projection in the previous regional water plan.

Statewide, irrigation water demands are expected to decline over time. More efficient canal delivery systems have improved water-use efficiencies of surface water irrigation. More efficient on-farm irrigation systems have also improved the efficiency of groundwater irrigation. Other factors that have contributed to decreased irrigation demands are declining groundwater supplies and the voluntary transfer of water rights historically used for irrigation to municipal uses.

Kinney County has the highest irrigation water use in the region (70 percent) and is the only county in which irrigation use is greater than municipal use. Elsewhere in the Region, most irrigation that occurs is for the watering of pastures and hay fields. Because of the typically rocky and uneven terrain throughout much of the Region, irrigation of commercial row crops is minimal. On a regional basis, water used for irrigation is projected to decline slightly over the 50-year planning horizon, from the year-2010 level of 19,423 acre-feet to 15,837 acre-feet by 2060. However, as any irrigator can attest, climate, water availability, and the market play key roles in how much water is actually applied on a year-by-year basis.

The PWPG is concerned about the accuracy of the irrigation surveys and believes that there is significantly more irrigation water use than is documented. For example, numerous small irrigated exotic and wildlife feed plots are likely not identified. Also, groundwater used to irrigate golf courses, if not provided by municipalities, may not be accounted for in the irrigation survey estimates. These withdrawals may have a significant impact on local supplies.

Irrigation Water Demand Projection (acre-feet/year)

County	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Bandera	464	464	464	464	464	464
Edwards	153	147	141	135	129	123
Kerr	1,821	1,761	1,706	1,652	1,599	1,548
Kinney	13,507	12,928	12,373	11,843	11,337	10,853
Real	392	377	361	346	330	314
Val Verde	3,086	2,968	2,852	2,743	2,636	2,535
Total	**19,423**	**18,645**	**17,897**	**17,183**	**16,495**	**15,837**

2.4.4 Livestock

Texas is the nation's leading livestock producer, accounting for approximately 11 percent of the total United States production. Although livestock production is an important component of the Texas economy, the industry consumes a relatively small amount of water.

Estimating livestock water consumption is a straightforward procedure that consists of estimating water consumption for a livestock unit and the total number of livestock. Texas A&M University Cooperative Extension Service provides information on water-use rates, estimated in gallons per day per head, for each type of livestock: cattle, poultry, sheep and lambs, hogs and pigs, horses, and goats. The Texas Agricultural Statistics service provides current and historical numbers of livestock by livestock type and county. Water-use rates are then multiplied by the number of livestock for each livestock type for each county.

For water-supply planning purposes, livestock water use is held constant throughout the 50-year planning period. However, reality dictates that during prolonged drought periods, when poor range conditions exist and/or during unfriendly market conditions, livestock herds are generally reduced thus resulting in significantly less water demand. Val Verde County has the greatest livestock water use in the region.

In recent years, an expanding use of groundwater in the Region has been to fill and maintain artificial lakes that primarily are intended to add aesthetic value to the property. Although not quantified, the amount of water pumped from local aquifers for this purpose is likely significant and is not reflected in the water demand estimates provided in this chapter. To manage the volume of groundwater used for this purpose, the Headwaters Groundwater Conservation District in Kerr County permits a maximum production of one acre-foot (325,851 gallons) per year.

Exotic game ranching has become commonplace throughout the state, and is quite evident in the Plateau Region counties. Bandera and Kerr Counties have the largest population of exotic game in the State (Texas A&M exotics on the Range). The total numbers of exotic game likely may equal or even exceed domestic livestock. Yet the livestock water demand projections reported in this plan may not fully reflect this water use.

High game fences that come with the exotic game industry often block the ability of both native and exotic game to access surface water, thus requiring more wells and groundwater use. Groundwater is also often used to irrigate small acreage feed plots for these animals. Future water plans will need to attempt to quantity this specific use and include it in the overall total projected water needs in the State.

Appendix 2B presents the results of a Water Use by Livestock and Game Animals in the Plateau Regional Water Planning Area analysis. In the report, the amount of water used by various exotic game species is estimated. However, the report states that there is insufficient data on the number of animals in the Region to make an estimate of total use. Estimates made by the Real-Edwards Conservation and Reclamation District find that approximately 602 and 233 acre-feet per year in Edwards and Real Counties is consumed by exotic game animals.

Livestock Water Demand Projection (acre-feet/year)

County	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Bandera	315	315	315	315	315	315
Edwards	562	562	562	562	562	562
Kerr	487	487	487	487	487	487
Kinney	445	445	445	445	445	445
Real	176	176	176	176	176	176
Val Verde	767	767	767	767	767	767
Total	**2,752**	**2,752**	**2,752**	**2,752**	**2,752**	**2,752**

2.4.5 Mining

Although the Texas mineral industry is foremost in the production of crude petroleum and natural gas in the United States, it also produces a wide variety of important nonfuel minerals. In all instances, water is required in the mining of these minerals either for processing, leaching to extract certain ores, controlling dust at the plant site, or for reclamation. For each category of mineral products, the requirements for mining water are determined as a function of production. Estimates of future production are calculated by analyzing both recent data, and state and national production trends. A water-use coefficient, computed from data collected by the TWDB's Water Use Survey, which reports the quantity of water used in the production of each increment of output, was applied to estimate mineral production levels. A rate of water consumption derived from U.S. Bureau of Mines data was then applied to the total water use for each mineral industry.

Although the oil and gas industry is relatively minor compared to other parts of the state, in recent years increased oil and gas exploration activity has occurred in the Plateau Region. Railroad Commission of Texas files list 263 wells drilled in Edwards County from 1999 through 2008. As a result, increased water demand is projected for the mining category in Edwards County. Increases in Kerr and Real Counties were not considered to be of sufficient magnitude to warrant projection changes.

Mining Water Demand Projection (acre-feet/year)

County	2010	2020	2030	2040	2050	2060
Bandera	24	24	24	24	24	24
Edwards	89	89	89	89	89	89
Kerr	167	165	164	163	162	161
Kinney	0	0	0	0	0	0
Real	5	5	5	5	5	5
Val Verde	118	111	107	104	101	99
Total	403	394	389	385	381	378

2.5 ENVIRONMENTAL AND RECREATIONAL WATER NEEDS

Environmental and recreational water use in the Plateau Region is not quantified but is recognized as being an important consideration as it relates to the natural community in which the residents of this region share and appreciate. In Chapter 1, environmental and recreational resources are identified and described. In this section, the water resources needed to maintain these functions are discussed. Water-supply sources that serve environmental needs are characterized in Chapter 3 and potential water-supply strategy consequences on the environment are analyzed in Chapter 4.

All living organisms require water. The amount and quality of water required to maintain a viable population, whether it be plant or animal, is highly variable. While some individuals are capable of migrating long distances in search of water (birds, larger mammals, etc.), others are stationary (plants, fishes, etc.) and must rely on existing supplies.

Natural and environmental resources are often overlooked when considering the consequences of prolonged drought conditions. As water supplies diminish during drought periods, the balance between both human and environmental water requirements becomes increasingly competitive. A goal of this plan is to provide for the health, safety, and welfare of the human community, with as little detrimental effect to the environment as possible. To accomplish this goal, the evaluation of strategies to meet future water needs includes a distinct consideration of the impact that each implemented strategy might have on the environment.

As discussed in Section 2.4.4 (Livestock), an expanding use of groundwater in the Region has been to fill and maintain artificial lakes. Although this use may exert stress on the local aquifer system, the resulting impoundments do provide aesthetic value to the property and a water source for wildlife.

Recreational activities that involve human interaction with the outdoors environment are often directly dependent on water resources such as fishing, swimming and boating; while a healthy environment enhances many others, such as hunting, hiking, and bird watching. Thus, it is recognized that the maintenance of the regional environmental community's water-supply needs serves to enhance the lives of citizens of the Plateau Region as well as the multitude of annul visitors to this region.

In Chapter 4, each water management strategy contains an environmental impact assessment. A review of these strategies reveals that while some strategies may contain variable levels of negative impact, other strategies may likely have a positive effect. Negative environmental impacts are generally associated with the lowering of aquifer water levels due to increased groundwater withdrawals and its potential to cause a reduction or cessation of spring flow. Also of concern is that lowered water levels could deplete supplies in shallow livestock wells, which are often the only available source of water for some wildlife. The positive environmental aspect of the strategies is that during severe drought conditions when normal wildlife water supplies may naturally diminish, new supply sources might be developed such that wildlife could benefit.

APPENDIX 2A

REGIONAL WATER DEMAND PROJECTIONS

BY COUNTY AND RIVER BASIN

Regional Water Demand Projections By County And River Basin (Acre-Feet*/Year)

County	Water User Group	Basin	2010	2020	2030	2040	2050	2060
Bandera	Bandera	San Antonio	259	284	312	332	351	371
	County Other	Guadalupe	1	2	2	3	3	3
		San Antonio	2,425	3,381	4,330	4,817	4,932	5,232
		Nueces	183	255	327	386	439	491
	Mining	San Antonio	24	24	24	24	24	24
	Irrigation	San Antonio	283	283	283	283	283	283
		Nueces	181	181	181	181	181	181
	Livestock	Guadalupe	6	6	6	6	6	6
		San Antonio	218	218	218	218	218	218
		Nueces	91	91	91	91	91	91
	Bandera County Total		**3,671**	**4,725**	**5,774**	**6,341**	**6,528**	**6,900**
Edwards	Rocksprings	Colorado	174	179	172	164	160	154
		Nueces	98	100	96	92	90	86
	County Other	Colorado	35	36	34	33	32	31
		Nueces	118	121	116	111	108	104
		Rio Grande	20	20	19	19	18	17
	Mining	Colorado	89	89	89	89	89	89
	Irrigation	Colorado	43	41	39	38	36	34
		Nueces	87	84	81	77	74	71
		Rio Grande	23	22	21	20	19	18
	Livestock	Colorado	175	175	175	175	175	175
		Nueces	230	230	230	230	230	230
		Rio Grande	157	157	157	157	157	157
	Edwards County Total		**1,249**	**1,254**	**1,229**	**1,205**	**1,188**	**1,166**

County	Water User Group	Basin	2010	2020	2030	2040	2050	2060
Kerr	Ingram	Guadalupe	220	238	242	229	212	200
	Kerrville	Guadalupe	4,362	4,746	4,918	4,937	5,152	5,262
	County Other	Colorado	58	62	63	60	56	52
		Guadalupe	2,651	2,866	2,917	2,918	3,025	3,087
		San Antonio	18	19	19	18	17	16
	Manufacturing	Guadalupe	30	33	36	39	41	44
	Mining	Colorado	13	12	12	12	12	12
		Guadalupe	154	153	152	151	150	149
	Irrigation	Guadalupe	1,821	1,761	1,706	1,652	1,599	1,548
	Livestock	Colorado	125	125	125	125	125	125
		Guadalupe	324	324	324	324	324	324
		San Antonio	34	34	34	34	34	34
		Nueces	4	4	4	4	4	4
	Kerr County Total		**9,814**	**10,377**	**10,552**	**10,503**	**10,751**	**10,857**
Kinney	Brackettville	Rio Grande	583	583	582	582	581	582
	Fort Clark Springs	Rio Grande	626	653	678	704	723	727
	County Other	Nueces	35	21	13	8	4	3
		Rio Grande	32	31	31	31	31	31
	Irrigation	Nueces	338	323	310	296	284	271
		Rio Grande	13,169	12,605	12,063	11,547	11,053	10,582
	Livestock	Nueces	187	187	187	187	187	187
		Rio Grande	258	258	258	258	258	258
	Kinney County Total		**15,228**	**14,661**	**14,122**	**13,613**	**13,121**	**12,641**
Real	Camp Wood	Nueces	172	172	166	160	163	167
	County Other	Colorado	11	11	11	10	11	11
		Nueces	417	416	400	386	394	402
	Mining	Colorado	5	5	5	5	5	5
	Irrigation	Nueces	392	377	361	346	330	314
	Livestock	Nueces	148	148	148	148	148	148
		Colorado	28	28	28	28	28	28
	Real County Total		**1,173**	**1,157**	**1,119**	**1,083**	**1,079**	**1,075**

County	Water User Group	Basin	2010	2020	2030	2040	2050	2060
Val Verde	Del Rio	Rio Grande	12,898	13,817	14,646	15,314	15,855	16,281
	Laughlin AFB	Rio Grande	1,303	1,296	1,289	1,281	1,276	1,276
	County Other	Rio Grande	2,621	3,274	3,888	4,378	4,766	5,046
	Mining	Rio Grande	118	111	107	104	101	99
	Irrigation	Rio Grande	3,086	2,968	2,852	2,743	2,636	2,535
	Livestock	Rio Grande	767	767	767	767	767	767
	Val Verde County Total		**20,793**	**22,233**	**23,549**	**24,587**	**25,401**	**26,004**

*One acre-foot is equal to 325,851 gallons.

APPENDIX 2B

WATER USE BY LIVESTOCK AND GAME ANIMALS IN THE PLATEAU REGIONAL WATER PLANNING AREA

Water Use by Livestock and Game Animals in the Plateau Regional Water Planning Area

Jeremy Rice & Jon Albright – Freese and Nichols

April 28, 2010

Introduction

Hunting is a large part of the economy in the Plateau Region. In some cases hunting has replaced traditional livestock as the primary source of income for ranches. In addition to native species, some ranches have imported exotic game animals for their hunting clients. These exotic species are usually confined by high fencing. The high fencing limits access by both the native and non-native animals to natural sources of water, creating greater reliance on pumped groundwater to support these species. In addition, some of these exotic game animals, most notably axis deer, have escaped and established large free-roaming populations throughout the area. Feral hogs, which have originated either as escaped domestic hogs or European wild hogs imported for hunting, have large populations in the region as well.

The Plateau Regional Water Planning group is concerned that the water use for game species is not included in the regional plan. These species are similar to livestock in that they provide considerable economic benefit to the region. Ranchers develop groundwater supplies to provide water for confined exotic species as well as to attract native species. Preliminary estimates of water use by exotic animals show that these animals use about the same amount of water as more conventional livestock species.

This memorandum describes:

- Methods used by the Texas Water Development Board (TWDB) to determine water use and projected demands for traditional livestock
- Trends in water use for traditional livestock
- Available data on the population and water use by game species in the Plateau Region

Changes to the livestock demand projections for the region are not recommended at this time. However, the Plateau Regional Water Planning Group may wish to consider revisions in the next round of regional water planning. More complete data on animal populations in each county will be needed to develop these projections.

Historical and Projected Livestock Water Use in the Plateau Region

Table 1 shows the historical and projected use for livestock in the Plateau Region from the Texas Water Development Board (TWDB). The projected water demands are equal to the year 2000 historical use and remain the same throughout the planning period. Livestock water use was about 6 percent of the total historical water use in the Plateau Region in 2007. (At this time, 2007 is the last year of complete historical water use available for the Plateau Region.)

Table 1
Historical and Projected Livestock Use in the Plateau Region from the Texas Water Development Board
(Values in Acre-Feet per Year)

Historical							
Year	Bandera County	Edwards County	Kerr County	Kinney County	Real County	Val Verde County	Region Total
1974	427	1,311	1,012	780	329	1,223	5,082
1980	376	1,011	535	618	267	1,053	3,860
1984	319	510	442	482	227	471	2,451
1985	284	513	407	468	210	495	2,377
1986	265	443	306	567	226	545	2,352
1987	283	486	337	632	225	596	2,559
1988	331	552	390	680	235	687	2,875
1989	327	549	384	620	234	678	2,792
1990	325	552	382	624	232	691	2,806
1991	333	600	399	648	244	749	2,973
1992	333	615	526	675	174	663	2,986
1993	312	595	488	592	139	676	2,802
1994	361	603	492	553	182	592	2,783
1995	362	596	473	536	180	565	2,712
1996	294	426	432	465	128	534	2,279
1997	275	424	448	391	144	465	2,147
1998	288	473	428	346	143	599	2,277
1999	346	568	501	404	156	733	2,708
2000	315	562	487	445	176	767	2,752
2001	314	520	450	419	158	773	2,634
2002	278	460	415	387	160	687	2,387
2003	241	446	415	285	141	590	2,118
2004	253	439	414	309	136	533	2,084
2005	263	463	369	331	160	516	2,102
2006	263	391	385	298	127	497	1,961
2007	279	312	385	272	143	437	1,828

Projected							
Year	Bandera County	Edwards County	Kerr County	Kinney County	Real County	Val Verde County	Region Total
2000	315	562	487	445	176	767	2,752
2010	315	562	487	445	176	767	2,752
2020	315	562	487	445	176	767	2,752
2030	315	562	487	445	176	767	2,752
2040	315	562	487	445	176	767	2,752
2050	315	562	487	445	176	767	2,752
2060	315	562	487	445	176	767	2,752

TWDB calculates historical livestock water use by multiplying the number of livestock animal units by the estimated water needs for each type of animal. The Natural Resources Conservation Service *National Range and Pasture Handbook* defines an animal unit as "one mature cow of approximately 1,000 pounds and a calf up to weaning, usually 6 months of age, or their equivalent." Animal units can be used to estimate the amount of water or feed needed in livestock operations. One animal unit can represent many individual animals. For example, 1,000 hens is one animal unit.

Table 2 shows the historical animal units from 2003 to 2007, as provided by TWDB. TWDB obtains the number of animal units from the United States Department of Agriculture (USDA). Cattle, sheep, goats and horses are the dominant types of livestock in the Plateau Region. Table 3 shows the water use factors used by TWDB to develop historical water use data.

Trends in Livestock Water Use

Figure 1 compares the historical to projected livestock water use for the region. There is a significant decline in water use between 1974 and 1984, and a slight downward trend since 1984. The estimated year 2007 livestock water use is about 37 percent of the 1974 water use and about 66 percent of the projected livestock water used for planning. This trend is probably the result of the reduction of traditional ranching as a source of income in the region.

Exotic Game Animal Water Use

Numerous exotic game species have been introduced into the Plateau Region. These species were primarily introduced for hunting, which has become a significant source of income in the region. Many of these species are confined in high fenced areas. These animals are essentially equivalent to other types of livestock kept on ranches for commercial purposes. Some of these species have escaped confined operations and have become established throughout the region. Species such as axis deer can out-compete native deer for food. As a result there are now large free-roaming populations of axis deer in addition to the confined populations.

Because many of these species are kept in confined areas, access to natural sources of water may be limited. As a result, groundwater is used as a water source for the commercial herds. Other ranches that are not confined may supplement natural water sources with groundwater to attract game species and improve hunting. The Plateau Regional Water Planning Group believes that, because hunting is a major commercial activity in the area, water use by game species should be considered in regional water planning.

Although not considered a game species, feral hogs have also established significant populations in the region. These hogs originated as domestic hogs or imported European wild hogs. Because there are so many of these animals, water use by feral hogs is significant as well.

Table 2
Historical Livestock Animal Units in the Plateau Region Years 2003 to 2007

Year	County	Cattle	Hogs	Sheep	Goats	Broilers	Horses	*County Total*
2003	Bandera	11,000	0	8,100	11,000	0	2,465	*32,565*
	Edwards	16,000	438	37,000	67,000	0	3,797	*124,235*
	Kerr	20,000	0	13,000	21,000	0	2,828	*56,828*
	Kinney	11,000	0	23,000	22,000	249	2,491	*58,740*
	Real	7,000	0	4,200	10,000	0	534	*21,734*
	Val Verde	15,000	0	108,000	42,000	0	5,396	*170,396*
	Category Total	*80,000*	*438*	*193,300*	*173,000*	*249*	*17,511*	*464,498*
2004	Bandera	12,000	0	5,500	11,000	0	2,465	*30,965*
	Edwards	16,000	0	35,000	73,000	0	3,797	*127,797*
	Kerr	20,000	0	12,000	21,000	0	2,828	*55,828*
	Kinney	13,000	0	18,000	21,000	257	2,491	*54,748*
	Real	7,000	0	2,100	9,000	0	534	*18,634*
	Val Verde	14,000	0	90,000	41,000	0	5,396	*150,396*
	Category Total	*82,000*	*0*	*162,600*	*176,000*	*257*	*17,511*	*438,368*
2005	Bandera	12,000	0	5,000	11,000	0	3,252	*31,252*
	Edwards	17,000	0	36,000	77,000	0	4,022	*134,022*
	Kerr	18,000	0	12,000	22,000	0	2,054	*54,054*
	Kinney	15,000	0	17,000	24,000	0	2,054	*58,054*
	Real	7,000	0	2,300	8,000	3	2,396	*19,699*
	Val Verde	11,000	0	91,000	43,000	0	7,702	*152,702*
	Category Total	*80,000*	*0*	*163,300*	*185,000*	*3*	*21,480*	*449,783*
2006	Bandera	12,000	0	4,900	12,000	0	3,252	*32,152*
	Edwards	13,000	0	34,000	75,000	0	4,022	*126,022*
	Kerr	19,000	0	12,000	21,000	0	2,054	*54,054*
	Kinney	13,000	0	17,000	24,000	0	2,054	*56,054*
	Real	5,000	0	2,500	8,500	3	2,396	*18,399*
	Val Verde	10,000	0	89,000	46,000	0	7,702	*152,702*
	Category Total	*72,000*	*0*	*159,400*	*186,500*	*3*	*21,480*	*439,383*
2007	*Bandera*	*13,000*	*0*	*4,600*	*11,000*	*0*	*3,252*	*31,852*
	Edwards	9,000	0	30,000	70,000	0	4,022	*113,022*
	Kerr	19,000	0	12,000	20,000	0	2,054	*53,054*
	Kinney	12,000	0	13,000	24,000	0	2,054	*51,054*
	Real	6,000	0	2,200	8,500	14	2,396	*19,110*
	Val Verde	7,000	0	85,000	45,000	0	7,702	*144,702*
	Category Total	66,000	0	146,800	178,500	14	21,480	*412,794*

* Data are from the Texas Water Development Board

Table 3
TWDB Livestock Water Use Factors

Livestock Type	**Water Needs** (gallons per animal unit)
Dairy Cattle	75
Fed Cattle	15
Other Cattle	15
Hogs & Pigs	11
Sheep	2
Goats	0.5
Hens (thousand)*	90
Broilers (thousand)*	15
Horses	12

* For poultry 1 animal unit equals 1,000 birds

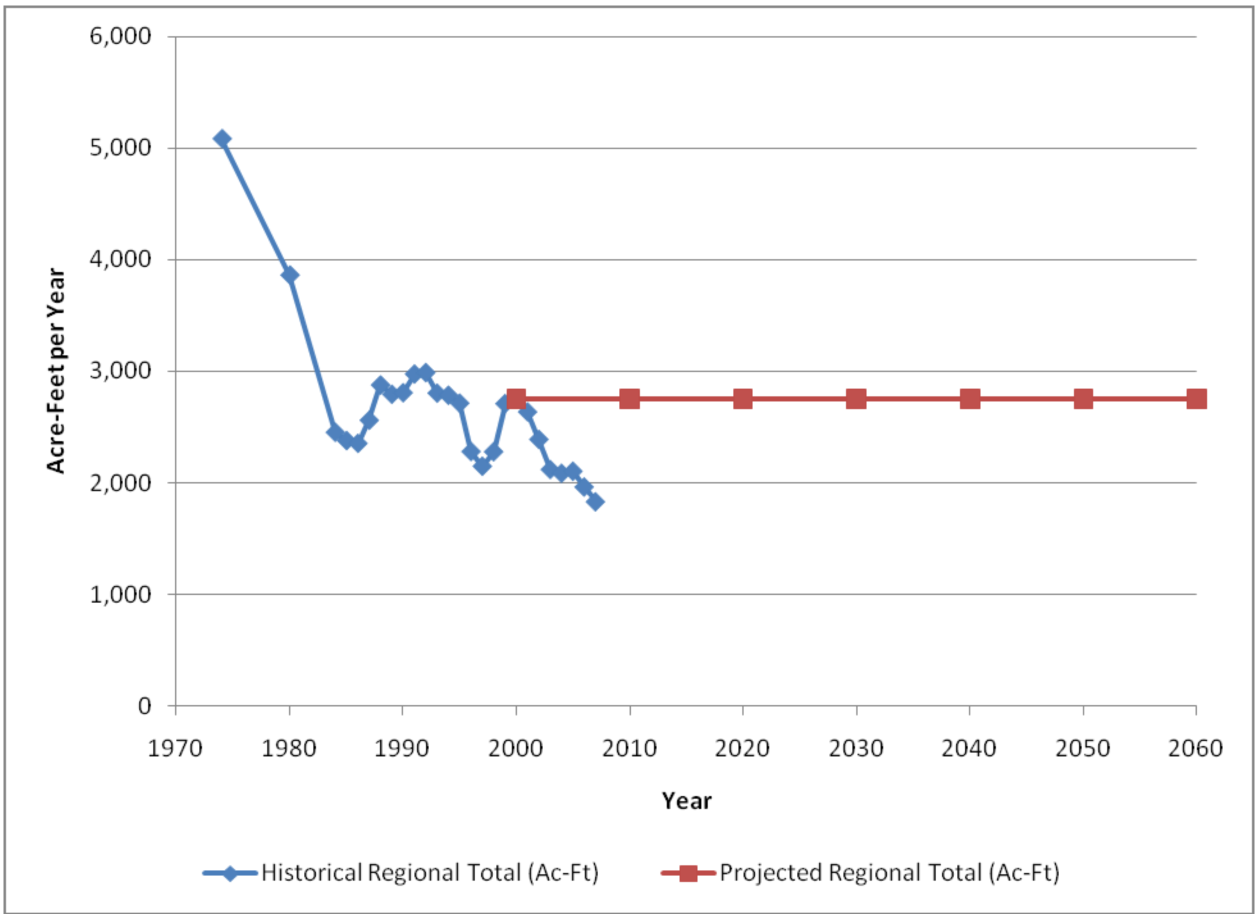


Figure 1
Historical and Projected Livestock Water Use for the Plateau Region

A four-step methodology was developed to determine the water used by game species and feral hogs:

1. Select dominant species
2. Determine water use per animal
3. Estimate population
4. Multiply population by water use per animal.

In the mid 1990s two surveys were conducted on the populations of exotic game animals in Texas. In 1995 the Texas Parks and Wildlife Department (TPWD) conducted a statewide census of exotic big game animals. TPWD reported these data for each county. The second survey was conducted in 1996 by the Texas Agricultural Statistics Service and the Exotic Wildlife Association. In this survey the state was divided into four regions. Figure 2 shows that the Plateau Regional Planning Area falls in Region 3 in this survey. Since Region 3 is a large area it is difficult to apply the results to the Plateau Region. FNI was unable to locate more recent surveys of exotic game species.

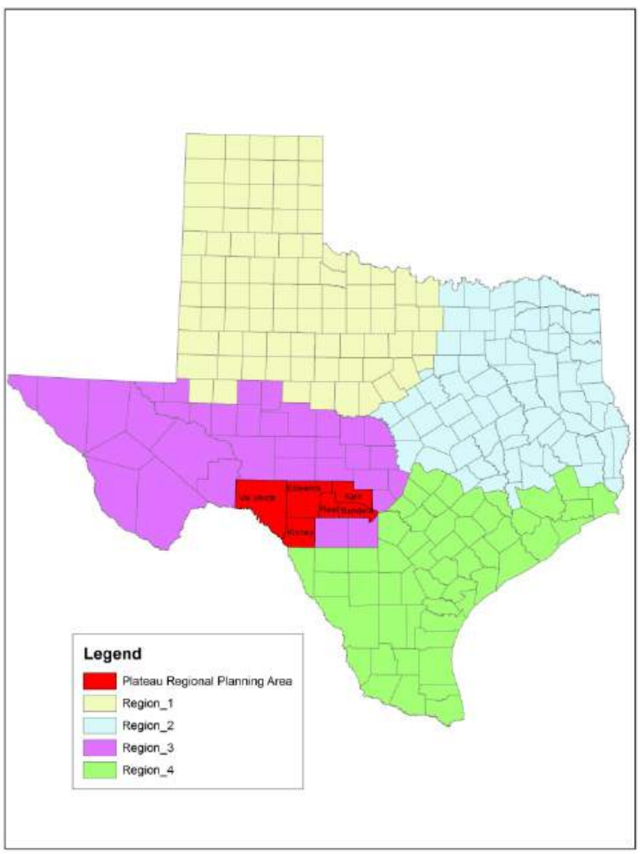
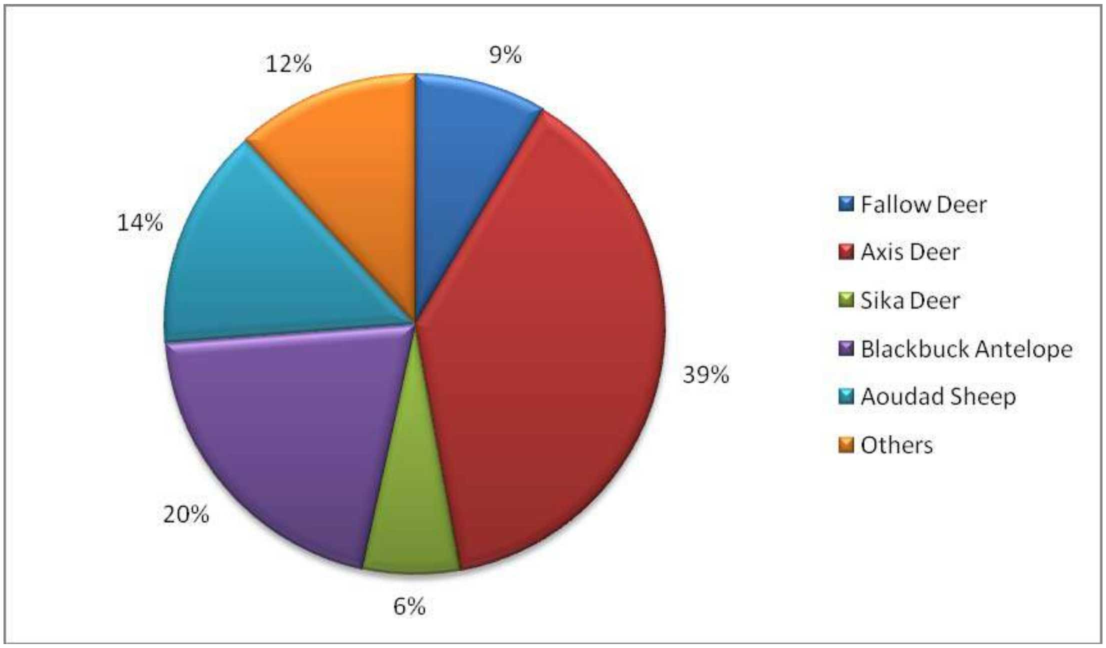


Figure 2
Texas Agricultural Statistics Service and the Exotic Wildlife Associations Survey Regions

According to the 1995 TPWD survey, the dominant species in the Plateau Region were axis deer, aoudad sheep, blackbuck antelope, fallow deer, and sika deer. Figure 3 shows the percentage of these animals compared to the overall population of exotic game species in the Plateau Region.



Data are from the 1995 TPWD Statewide Census of Exotic Big Game Animals.

Figure 3
Percentage of Exotic Game Species in the Plateau Region from 1995 TPWD Survey

Data on water use by these exotic game animals are not readily available. According to Dr. Fred Bryant of Texas A&M – Kingsville and Dr. Urs Kreuter of Texas A&M - College Station, water use by exotic game is proportional to the weight of the animal. Dr. Bryant recommends using 0.005 gal/day/lb and Dr. Kreuter recommends using 0.008 gal/day/lb. These water use factors can be multiplied by the average weight of exotic species to estimate gallons per animal per day. Average weights for exotic species were determined from the *Mammals of Texas Online Edition*. Table 4 shows the estimated average weight and water needs for exotic game using both factors.

Table 4
Exotic Game Average Adult Weight and Range of Estimated Water Needs

Species	Average Adult Weight (lbs)	Estimated Water Needs (gallons per animal per day)	
		@ 0.005 gal/day/animal	@ 0.008 gal/day/animal
Fallow Deer	132	0.7	1.1
Axis Deer	173	0.9	1.4
Sika Deer	175	0.9	1.4
Blackbuck Antelope	72	0.4	0.6
Aoudad Sheep	231	1.2	1.8

The only comprehensive sources of exotic species population data are the two surveys conducted in the mid 1990s. TPWD and other agencies no longer collect data on exotic game species, so more recent data are not readily available. Mr. Ray Aguirre, a TPWD biologist in Kerr County, estimates that there are 8,000-10,000 axis deer in Kerr County and 6,000 axis deer in Bandera and Real Counties. Ryan Schmidt, a TPWD biologist in Edwards County, estimates that in Edwards County there is one white tail deer for every 11 to 15 acres, one axis deer for every 20 acres, and 1 feral hog for every 10 acres. Lee Sweeten of the Real Edwards Conservation and Reclamation District (RECRD) provided both population and water use estimates for game species and feral hogs in Edwards and Real Counties (Tables 5 and 6). Mr. Sweeten estimates 602 acre-feet of water use by exotics in Edwards County and 233 acre-feet in Real County. The projected demands for traditional livestock in these counties are 562 and 176 acre-feet per year, respectively. These estimates show that including exotic species could more than double livestock water use projections in these counties.

Table 5
RECRD Exotic Species Estimates for Edwards County

Edwards County	Estimated Number	Gallons per Day	Gallons per Year	Acre Feet per Year
White Tail	106,899	106,899	39,045,004	120
Axis	67,840	138,723	50,668,559	156
Feral Hog	135,680	281,282	102,738,093	315
Black Buck	4,500	3,681	1,344,390	4
Elk	500	4,499	1,643,143	5
Other	1,500	1,840	672,195	2
Totals	*316,919*	*536,924*	*196,111,384*	*602*

Table 6
RECRD Exotic Species Estimates for Real County

Real County	Estimated Number	Gallons per Day	Gallons per Year	Acre Feet per Year
White Tail	44,800	44,800	16,363,200	50
Axis	29,867	61,073	22,306,913	68
Feral Hog	44,800	92,876	33,922,955	104
Black Buck	2,500	2,045	746,883	2
Elk	500	4,499	1,643,143	5
Other	2,000	2,454	896,260	3
Totals	*124,467*	*207,746*	*75,879,354*	*233*

Conclusions

- The water use projections for traditional livestock may be higher than the actual livestock needs in the region. The Plateau Region may wish to monitor livestock population data to see if the downward trend in livestock populations continues.
- Water use by game species can be estimated using techniques similar to those employed by TWDB in estimating traditional livestock water use. However, at this time there are insufficient data on the number of animals in the region to make these estimates. Additional information on exotic game populations will be required if the Plateau Region wishes to include this water use in regional planning.

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CHAPTER 3

REGIONAL WATER SUPPLY SOURCES

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3.1 INTRODUCTION

From the semi-arid Hill Country to the arid Rio Grande Basin, both groundwater and surface water are critical resources for the livelihood of the citizens of the Plateau Region and the environment in which they reside. Chapter 3 explores the current and future availability of all water supply resources in the Region including surface water, groundwater and reuse. The water demand and supply availability analysis developed in Chapters 2 and 3, respectively, form the basis for identifying in Chapter 4 the areas within the Plateau Region that potentially could experience supply shortages in future years. Water quality considerations pertaining to the identified water-supply sources are discussed in Chapter 5.

The City of Kerrville currently uses surface water from the Guadalupe River in conjunction with their groundwater supply. Kerrville also injects excess treated surface water into the Trinity Aquifer through an aquifer storage and recovery (ASR) system. The City of Del Rio obtains their water from San Felipe Springs, which issues from the Edwards limestone. The spring water is treated to surface water standards in a new microfiltration plant prior to distribution. Camp Wood in Real County is supplied from Old Faithful Springs on a tributary of the Nueces River. All other communities in the Region are totally dependent on groundwater sources for their supplies.

Water supplies available to meet the demands reported in Chapter 2 are shown in Tables 3-1, 3-2 and 3-3. Table 3-1 lists groundwater and surface water availability by county and river basin. Water source availability analyses are discussed in more detail in Section 3.2 (groundwater) and Section 3.3 (surface water). Table 3-2 lists water supplies available to cities and general water use categories based on the current infrastructure ability of each to obtain water supplies. Likewise, Table 3-3 lists water supplies available to the one wholesale water provider in the Region, the City of Del Rio. These abilities primarily include existing infrastructure, water-rights limitations, and groundwater conservation district permit limitations. All water supplies based upon contracts are assumed to be renewed. Appendix 3A lists all authorized surface water rights in the Region.

Table 3-1. Water Source Availability
(Acre-Feet/Year)

COUNTY	AQUIFER / RIVER	RIVER BASIN	SOURCE AVAILABILITY (All Decades)
Bandera	Edwards-Trinity (Plateau)	Guadalupe	860
	Edwards-Trinity (Plateau)	San Antonio	11,250
	Edwards-Trinity (Plateau)	Nueces	5,200
	Trinity	Nueces	5,969
	Trinity	San Antonio	12,589
	Livestock Local Supply	San Antonio	72
	Upper Guadalupe River	Guadalupe	3
	Medina River	San Antonio	0
	Medina Lake/Reservoir	San Antonio	0
	Sabinal River	Nueces	7
	Hondo Creek	Nueces	20
	County Total		**35,970**
Edwards	Edwards-Trinity (Plateau)	Colorado	2,610
	Edwards-Trinity (Plateau)	Nueces	3,480
	Edwards-Trinity (Plateau)	Rio Grande	2,609
	Nueces River Alluvium	Nueces	1,787
	Livestock Local Supply	Colorado	61
	Livestock Local Supply	Nueces	62
	Nueces River	Nueces	138
	West Nueces River	Nueces	5
	South Llano River	Colorado	43
	County Total		**10,795**
Kerr	Edwards-Trinity (Plateau)	Colorado	4,250
	Edwards-Trinity (Plateau)	Guadalupe	11,500
	Edwards-Trinity (Plateau)	San Antonio	330
	Edwards-Trinity (Plateau)	Nueces	330
	Trinity	Guadalupe	15,492
	Trinity	San Antonio	1,832
	Livestock Local Supply	Colorado	20
	Livestock Local Supply	Guadalupe	73
	Livestock Local Supply	San Antonio	12
	Upper Guadalupe River	Guadalupe	1,221
	County Total		**35,060**

Kinney	Edwards-Trinity (Plateau)	Nueces	1,432
	Edwards-Trinity (Plateau)	Rio Grande	21,000
	Edwards (BFZ)	Nueces	6,925
	Edwards (BFZ)	Rio Grande	1,800
	Austin Chalk	Rio Grande	4,928
	Livestock Local Supply	Nueces	45
	Livestock Local Supply	Rio Grande	90
	Mud Creek	Rio Grande	120
	Pinto Creek	Rio Grande	95
	Los Moras Creek	Rio Grande	669
	Elm Creek	Rio Grande	43
	Rio Grande	Rio Grande	176
	County Total		**37,323**
Real	Edwards-Trinity (Plateau)	Colorado	200
	Edwards-Trinity (Plateau)	Nueces	5,537
	Trinity	Nueces	380
	Frio River Alluvium	Nueces	2,145
	Nueces River Alluvium	Nueces	1,787
	Livestock Local Supply	Nueces	25
	Livestock Local Supply	Colorado	24
	Old Faithful Springs	Nueces	0
	Nueces River	Nueces	648
	Frio River	Nueces	1,514
	County Total		**12,260**
Val Verde	Edwards-Trinity (Plateau)	Rio Grande	49,607
	Livestock Local Supply	Rio Grande	153
	Rio Grande	Rio Grande	125
	Cienagas Creek	Rio Grande	794
	San Felipe Creek	Rio Grande	13,016
	County Total		**63,695**

One acre-foot is equal to 325,851 gallons.

Table 3-2. Water User Group Water Supply Capacity[(a)]

(Based on Current Infrastructure and Regulatory Caps)
(Acre-Feet/Year)

County	Water User Group	Source Basin	Specific Source Name	Water Supply Capacity (All Decades)
Bandera	Bandera	San Antonio	Trinity	1,210
	County Other	Guadalupe	Edwards-Trinity (Plateau)	31
		San Antonio	Edwards-Trinity (Plateau)	803
			Trinity	9,870
			Medina River	0
		Nueces	Edwards-Trinity (Plateau)	115
			Trinity	689
			Sabinal River	2
	Mining	San Antonio	Trinity	24
	Irrigation	San Antonio	Trinity	283
			Medina River	0
		Nueces	Trinity	156
			Hondo Creek	20
			Sabinal River	5
	Livestock	Guadalupe	Edwards-Trinity (Plateau)	6
		San Antonio	Trinity	158
			Edwards-Trinity (Plateau)	32
			Local Supply	72
		Nueces	Trinity	80
			Edwards-Trinity (Plateau)	15

Edwards	Rocksprings	Colorado	Edwards-Trinity (Plateau)	322
		Nueces	Edwards-Trinity (Plateau)	180
	County Other	Colorado	Edwards-Trinity (Plateau)	121
		Nueces	Edwards-Trinity (Plateau)	411
			Other Aquifer (Nueces Alluvium)	34
		Rio Grande	Edwards-Trinity (Plateau)	72
	Mining	Colorado	Edwards-Trinity (Plateau)	89
	Irrigation	Colorado	Edwards-Trinity (Plateau)	53
			South Llano River	43
		Nueces	Edwards-Trinity (Plateau)	54
			Nueces River	138
			West Nueces River	5
		Rio Grande	Edwards-Trinity (Plateau)	53
	Livestock	Colorado	Edwards-Trinity (Plateau)	164
			Local Supply	61
		Nueces	Edwards-Trinity (Plateau)	168
			Local Supply	62
		Rio Grande	Edwards-Trinity (Plateau)	164

Kerr[b]	Kerrville	Guadalupe	Trinity	2,890[c]
			Upper Guadalupe River (+ASR)	150
	Ingram	Guadalupe	Trinity	585
	County Other	Colorado	Edwards-Trinity (Plateau)	251
		Guadalupe	Edwards-Trinity (Plateau)	5,547
			Trinity	6,504
			Upper Guadalupe River	15
		San Antonio	Edwards-Trinity (Plateau)	125
			Trinity	627
	Manufacturing	Guadalupe	Trinity	12
			Edwards-Trinity (Plateau)	30
			Upper Guadalupe River	9
	Mining	Colorado	Edwards-Trinity (Plateau)	13
		Guadalupe	Trinity	159
			Edwards-Trinity (Plateau)	4
			Upper Guadalupe River	89
	Irrigation	Guadalupe	Trinity	863
			Upper Guadalupe River	958
	Livestock	Colorado	Edwards-Trinity (Plateau)	105
			Local Supply	20
		Guadalupe	Trinity	122
			Edwards-Trinity (Plateau)	160
			Local Supply	73
		San Antonio	Edwards-Trinity (Plateau)	22
			Local Supply	12
		Nueces	Edwards-Trinity (Plateau)	12

Kinney	Brackettville	Rio Grande	Edwards (BFZ)	645
			Los Mora Creek	2
	Fort Clark Springs	Rio Grande	Edwards (BFZ)	1,120
	County Other	Nueces	Edwards (BFZ)	41
			Edwards-Trinity (Plateau)	7
		Rio Grande	Edwards-Trinity (Plateau)	24
			Austin Chalk	64
	Irrigation[d]	Nueces	Edwards (BFZ)	4,382
			Edwards-Trinity (Plateau)	0
		Rio Grande	Edwards-Trinity (Plateau)	20,813
			Austin Chalk	3,872
			Mud Creek	120
			Pinto Creek	95
			Los Mora Creek	665
			Elm Creek	43
			Rio Grande	176
	Livestock	Nueces	Edwards (BFZ)	130
			Edwards-Trinity (Plateau)	159
			Local Supply	45
		Rio Grande	Edwards-Trinity (Plateau)	159
			Austin Chalk	92
			Local Supply	90
Real	Camp Wood	Nueces	Old Faithful Springs	0
	County Other	Colorado	Edwards-Trinity (Plateau)	34
		Nueces	Edwards-Trinity (Plateau)	491
			Other Aquifer (Frio Alluvium)	997
			Nueces River	0
	Mining	Colorado	Edwards-Trinity (Plateau)	6
	Irrigation	Nueces	Edwards-Trinity (Plateau)	349
			Nueces River	648
			Frio River	1,514
	Livestock	Nueces	Edwards-Trinity (Plateau)	180
			Local Supply	25
		Colorado	Edwards-Trinity (Plateau)	15
			Local Supply	24

Val Verde	Del Rio	Rio Grande	San Felipe Springs	7,461
			Edwards-Trinity (Plateau)	9,116
	Laughlin AFB	Rio Grande	Edwards-Trinity (Plateau) (Purchase from Del Rio)	2,178
			Edwards-Trinity (Plateau)	121
	County Other	Rio Grande	Edwards-Trinity (Plateau) (Supplied by Del Rio)	1,631
			Edwards-Trinity (Plateau)	4,413
	Mining	Rio Grande	Edwards-Trinity (Plateau)	156
	Irrigation	Rio Grande	Edwards-Trinity (Plateau)	363
			Cienegas Creek	794
			San Felipe Springs	5,555
			Rio Grande	125
	Livestock	Rio Grande	Edwards-Trinity (Plateau)	614
			Local Supply	153

Remarks:

(a) Water supply capacity is the volume of water apportioned to a Water User Group (WUG) from each current existing, connected, and accessible water source, during drought-of-record conditions, taking into consideration all constraints that limit the supply amount.

(b) Kerr County - Headwaters Groundwater Conservation District has pumping limitations on Trinity aquifer wells.

(c) Kerrville groundwater capacity is based on GCD cap. Actual Kerrville infrastructure capacity is 6,625 ac-ft per year.

(d) Kinney County irrigation based on Kinney County Groundwater Conservation District year-2005 permitted allocation as of 4-23-05. However, current District rules are not based on these volumes.

Table 3-3. Del Rio Wholesale Water Supply Capacity

(Acre-Feet/Year)

Wholesale Water Provider	County	Basin	Receiving Entity	Supply Source	All Decades
Del Rio	Val Verde	Rio Grande	City of Del Rio	San Felipe Springs	7,461
				Edwards-Trinity (Plateau)	9,116
			Laughlin AFB	Edwards-Trinity (Plateau)	2,178
			County Other	Edwards-Trinity (Plateau)	1,631
			Total Supply		**20,386**

3.2 GROUNDWATER RESOURCES

The principal aquifers in the Plateau Region are the Trinity, Edwards-Trinity (Plateau), Edwards (Balcones Fault Zone), Austin Chalk, and Frio and Nueces River Alluviums (Figure 3-1). Aquifer descriptions provided in this chapter are relatively limited; more detailed hydrogeologic characterization of the aquifers may be obtained from reports published by the TWDB, USGS, UTBEG, and other agencies and universities. The water quality of aquifers is relatively good and a detailed discussion on water-quality characteristics and issues is provided in Chapter 5.

A study was conducted during this planning period to identify and quantify viable groundwater sources in shallow alluvial aquifers that parallel many of the major streams in the Region. As a result of the study, substantial volumes were estimated for the Frio and Nueces River Alluvium Aquifers in Real and Edwards Counties, and the Nueces River Alluvium Aquifer is added as a supply source in this Plan. The study report is provided in Appendix 3B of this chapter.

Another study (Groundwater Data Acquisition in Edwards, Kinney and Val Verde Counties, Texas) was performed to assist in the further characterization of the Edwards and associated aquifers in the western part of the Plateau Region. The project included four general tasks: (1) review of existing aquifer evaluations, field studies and new well data; (2) performance of dye tracer tests to analyze groundwater flow direction and speed; (3) measurement of water levels in wells during two seasonal periods; and (4) review of recent water quality sampling projects. A summary of the project is provided in Appendix 1C of Chapter 1 of this Plan.

Over much of the Region, water levels generally fluctuate with seasonal precipitation and are highly susceptible to declines during drought conditions. Discharge from the aquifers occurs naturally through springs and artificially by pumping from wells. Some discharge also occurs through leakage from one water-bearing unit to another and through natural down-gradient flow out of the Region.

3.2.1 Trinity Aquifer

Located mostly in the Hill Country counties of Bandera and Kerr, the Trinity Aquifer system is composed of deposits of sand, clay and limestone of the Glen Rose and Travis Peak formations of the Lower Cretaceous Trinity Group. The water-bearing units include, in descending order, the Glen Rose Limestone, Hensell Sand, Cow Creek Limestone, Sligo Limestone and Hosston Sand. The Glen Rose formation is divided informally into upper and lower members. Based on their hydrologic relationships, the water-bearing rocks of the Trinity Group, collectively referred to as the Trinity Aquifer system, are organized into the following aquifer units.

Aquifer	Formations
Upper Trinity	Upper Glen Rose Limestone
Middle Trinity	Lower Member of the Glen Rose Limestone, Hensell Sand and Cow Creek Limestone
Lower Trinity	Sligo Limestone and Hosston Sand

Because of fractures, faults and other hydrogeologic factors, the upper, middle and lower Trinity Aquifer units often are in hydraulic communication with one another and collectively should be considered a leaky-aquifer system.

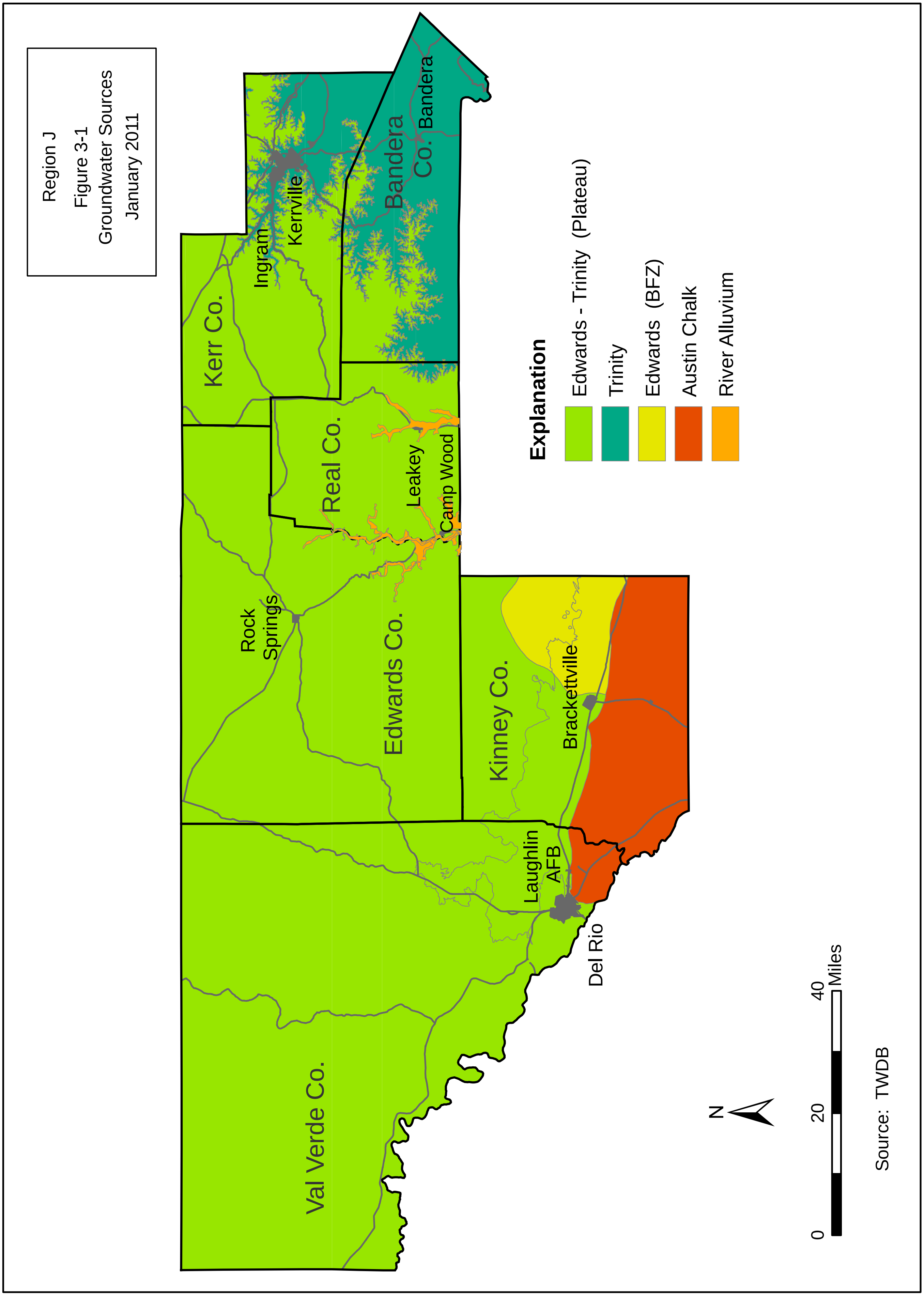


FIGURE 3-1. GROUNDWATER SOURCES

LBG-GUYTON ASSOCIATES

<u>Upper and Middle Trinity Aquifer</u>

The upper member of the Glen Rose, when weathered on the land surface, creates the distinctive "stair-step" topography found throughout the hilly train of the Hill Country. The upper Glen Rose, which forms the Upper Trinity Aquifer, often contains water with relatively high concentrations of sulfate. Total dissolved solids (TDS) often exceed 1,000 milligrams per liter (mg/l), especially in wells that penetrate “gyp” (evaporite) beds. Water in evaporite beds has a tendency to be high in sulfate and generally should be sealed off in a well. Upper Trinity wells are generally shallow and are mostly used for domestic and livestock purposes.

The Middle Trinity aquifer, consisting of lower Glen Rose, Hensell, and Cow Creek formations, generally contains TDS of less than 1,000 mg/l. In the Hill Country region, the primary contribution to poor water-quality occurs in wells that do not adequately case off water from evaporite beds in the upper part of the Glen Rose (Upper Trinity Aquifer). Water levels in Upper and Middle Trinity wells fluctuate with seasonal precipitation and are highly susceptible to declines during drought conditions.

<u>Lower Trinity Aquifer in Bandera and Kerr Counties</u>

Separating the Middle and Lower Trinity is the Hammett Shale (sometimes referred to as the Pine Island Shale). The approximately 60-foot thick formation acts as a confining bed, or barrier to cross-formational flow in most areas, and thus divides the producing sections of the Middle and Lower Trinity Aquifer units.

The Lower Trinity Aquifer is composed of sandy limestones, sand, clay and shale of the Sligo and Hosston. The Lower Trinity thins toward the northeast and is completely missing or coalesces with upper Trinity units near the Llano Uplift. The Lower Trinity is principally used to provide water supplies for the Cities of Bandera and Kerrville and for a few private water-supply companies and resorts.

Yields from wells completed into the Lower Trinity are generally unpredictable and vary greatly. The greater depth and difficulty of sealing off the Hammett Shale make completing wells into the Lower Trinity more difficult. However, in some areas, the Lower Trinity has higher yields and better water quality than shallower aquifers. Recharge to the Lower Trinity in Bandera and Kerr Counties likely occurs primarily by lateral underflow from the north and west. The overlying Hammett Shale mostly prevents vertical movement of water downward except possibly in highly fractured or faulted areas.

3.2.2 Edwards-Trinity (Plateau) Aquifer

The Edwards-Trinity (Plateau) Aquifer consists of lower Cretaceous age saturated limestones and dolomites of the Edwards Group and underlying sediments of the Trinity Group where they occur underlying the Edwards Plateau. The upper Edwards portion of the aquifer system is generally more porous and permeable than the underlying Trinity, and where exposed at the land surface, the Edwards-Trinity (Glen Rose) interface gives rise to numerous springs that form the headwaters of several eastward and southerly flowing rivers.

In Kinney and Val Verde Counties, the Edwards aquifer consists of the Devils River Limestone or the Salmon Peak, McKnight and West Nueces Limestones. Aquifer thickness is as much as 1,000 feet. All known water wells produce water from the Salmon Peak and McKnight formations. San Felipe Springs in Val Verde County issues from the Edwards and is the primary municipal supply source for Del Rio.

Recharge to the aquifer occurs primarily by the downward percolation of surface water from streams draining off the Edwards Plateau to the north and west and by direct infiltration of precipitation on the outcrop. Some water enters the region in the aquifer as underflow from counties up gradient (generally north).

The Glen Rose Limestone is the primary unit in the Trinity in the southern part of the Plateau. The aquifer generally exists under water-table conditions; however, where the Glen Rose is fully saturated and a zone of low permeability occurs near the base of the overlying Edwards, artesian conditions exist.

Reported well yields commonly range from less than 50 gallons per minute (gpm) where saturated thickness is thin to more than 1,000 gpm where large-capacity wells are completed in jointed and cavernous limestone. There is little pumpage from the aquifer over most of its extent, and water levels have generally fluctuated only with seasonal precipitation. In some instances, water levels have declined as a result of increased pumpage. Del Rio, Brackettville, Fort Clark, and Rocksprings have municipal wells that produce from this aquifer.

3.2.3 Edwards (BFZ) Aquifer

In the Plateau Region, the Edwards-Balcones Fault Zone (BFZ) Aquifer occurs only in eastern Kinney County at its westernmost extent. The Edwards portion of the Edwards-Trinity (Plateau) Aquifer and the Edwards of the Edwards (BFZ) Aquifer are the same geologic formation and their boundary is arbitrarily established by the TWDB. There is no significant hydrologic boundary between the outcrops of these two aquifer systems, thus groundwater in the Edwards-Trinity freely moves downgradient into the Edwards (BFZ).

The Edwards (BFZ) Aquifer exists under water-table conditions in the outcrop and under artesian conditions where it is confined below the overlying Del Rio Clay in its downdip extent. Water in the aquifer generally moves from the recharge zone toward natural discharge points such as Las Moras Springs at Brackettville. Additional water is lost from the Kinney County area as underflow that leaves the County to the east into Uvalde County (Region L). Very little pumping has occurred from this aquifer in Kinney County, and therefore water levels have remained relatively constant with only minor changes over time.

3.2.4 Austin Chalk Aquifer

The Austin Chalk is located in the southern half of Kinney County and the southernmost part of Val Verde County. Many wells located south of Highway 90 obtain part or all of their water from the Austin Chalk. A veneer of gravel deposits covers much of the southwest portion of Kinney County; some wells penetrate both these gravels and the underlying Austin Chalk. Source of water in the Austin Chalk is from precipitation recharge and stream loss over the outcrop areas and probably from Edwards Aquifer underflow through faults located up gradient.

A wide range of production rates exists for wells completed in the Austin Chalk. The best production from the aquifer occurs in areas that have been fractured or contain a number of solution openings. Most wells only discharge enough water for domestic or livestock use, but a few wells are large enough for irrigation purposes. The largest reported yield for an Austin Chalk well in Kinney County is 2,000 gpm (Bennett and Sayre, 1962). Most of the more productive wells completed in the Austin Chalk are located along Las Moras Creek. Much less production is apparent in the Nueces River Basin in the eastern part of the county.

3.2.5 Frio River Alluvium Aquifer

The Frio River Alluvium in central Real County extends over an area of approximately 9,530 acres (see Appendix 3B). Recharge to the aquifer is from stream loss and direct infiltration of precipitation. Water supplies for the City of Leakey and other rural domestic homes are derived from this small aquifer. Because of the limited extent of this aquifer and its shallow water table, the aquifer system is readily susceptible to diminished supplies during drought conditions and potentially from over pumping. Also due to its shallow nature, the aquifer is susceptible to contamination from surface sources.

3.2.6 Nueces River Alluvium Aquifer

The Nueces River Alluvium between Edwards and Real Counties extends over an area of approximately 24,450 acres (see Appendix 3B). Recharge to the aquifer is from stream loss and direct infiltration of precipitation. Water supplies for the Community of Barksdale and rural domestic homes are derived from this small aquifer. As with the Frio Alluvium, the Nueces River Alluvium Aquifer is readily susceptible to diminished supplies during drought conditions and potentially from over pumping, and to contamination from surface sources.

3.2.7 Other Aquifers

Located along many of the streams and rivers are shallow alluvial floodplains composed of sediments ranging from clay and silt to sand, gravel, cobbles and boulders. Wells completed in these deposits supply small to moderate quantities of water mostly for domestic and livestock purposes. The alluvium is often in direct hydraulic connection with the rivers and streams that meander through them. However, because these wells are relatively shallow, many are prone to going dry during drought conditions.

In addition, the TWDB has identified the downdip extents of the Ellenburger-San Saba and the Hickory Aquifers in northeast Kerr County. Because no known wells have penetrated these aquifers in Kerr County, very little is known about their water-bearing characteristics. These aquifers are only mentioned as possible resources but are not included in the supply analysis for this Plan.

3.2.8 Groundwater Availability

Base flow to the many rivers and streams that flow through the Plateau Region is principally generated from the numerous springs that issue from rock formations that form the major aquifers in the Region. It is thus recognized that sustaining flow in these important rivers and streams is highly dependent on maintaining an appropriate water level in the aquifer systems that feed the supporting springs. With the sustainability of local water supplies and the economic welfare of the Region in mind, the Plateau Water Planning Group (PWPG) thus defines groundwater availability as **a maximum level of aquifer withdrawal that results in an acceptable level of long-term aquifer impact such that the base flow in rivers and streams is not significantly affected beyond a level that would be anticipated due to naturally occurring conditions**. The PWPG also acknowledges that groundwater conservation districts have regulatory authority over permitted withdrawals.

The PWPG acknowledges that the definition of "groundwater availability" as contained in this Plan is an interim definition pending completion of the Groundwater Management Area (GMA) "desired future condition" process by those GMAs setting the conditions for the various portions of aquifers lying within the Plateau Region. (See Section 1.1.2 in Chapter 1 for a more complete explanation of the GMA process.)

There has been no promulgation of water availability requirements for the designated Hill Country Priority Groundwater Management Area by County Commissioner's Courts. The more current Groundwater Management Area process has generally replaced this responsibility.

The concepts of groundwater availability and aquifer sustainability as it relates to the regional water planning process have resulted in significant confusion. The PWPG believes that the best interests of the area are served by maintaining an acceptable level of aquifer sustainability. In so defining groundwater availability, the planning group is establishing a policy decision to protect the long-term water supply and related economic needs of the Plateau Region. However, the planning group also acknowledges that additional water does occur in storage within the aquifers and that a portion of that water is capable of being retrieved for desired uses.

For groundwater availability, the TWDB planning guidelines (Exhibit C) require that regional planning groups "Calculate the largest annual amount of water that can be pumped from a given aquifer without violating the most restrictive physical or regulatory or policy conditions limiting withdrawals, under drought-of-record conditions. Regulatory conditions refer specifically to any limitations on pumping withdrawals imposed by groundwater conservation districts through their rules and permitting programs." This guideline requires that planning groups make a policy decision as to the interpretation of the term "most restrictive" as it relates to long-term groundwater availability.

The counties that comprise the Plateau Region contain the headwaters of the Guadalupe, San Antonio, Medina, Sabinal, Frio, Nueces, and West Nueces Rivers; and tributaries to the Colorado River and Rio Grande such as the Pecos, Devils, and South Llano Rivers. Flow in these rivers and streams is critical to the Plateau Region in that it provides municipal drinking water, supplies irrigation and livestock needs, maintains environmental habitat, and supports a thriving ecological and recreational tourist economy. Water users downstream of the Plateau Region (Regions K, L, and M) likewise have a stake in maintaining and protecting river flows that originate in the Plateau Region.

TWDB Chapter 357 Regional Water Planning Guidelines states that "Once GAM (Groundwater Availability Model) information is accessible for an area within a region, the Planning Group shall incorporate this information in its next planning cycle unless better site-specific information is developed." Following review of available data, the PWPG concludes that in general two completed GAMs incorporate the most currently available information for the Edwards-Trinity (Plateau) and Hill Country Trinity Aquifers, and that the GAMs are an appropriate tool for analyzing groundwater availability in the Plateau Region. Where better site-specific information is available, appropriate alterations have been considered. The aquifer simulation models were thus run by increasing pumping withdrawals at set intervals until reasonably acceptable levels of impact to surface water drains were observed. It should be noted that this means of defining groundwater availability is not directly linked to recharge, but rather to pumping withdrawals that result in acceptable levels of impact.

Some aquifer areas within the Region were not incorporated into GAMs. In those areas, a reduced percentage of recharge (two percent or less of total precipitation) was used to estimate aquifer availability. The areas for aquifer recharge in the Plateau Region were determined by using geographic information system (GIS) coverages, which allowed calculation of specific areas. The volumes were then calculated based on a percent of annual recharge for each aquifer by river basin and county.

The accuracy by which groundwater availability can be estimated is also a function of the amount of data that is available to characterize each aquifer. The lack of such data has been a continuing problem in the planning process. In recognition of this limitation, the TWDB has provided funding for data acquisition and dye-tracer studies, and the purchase and installation of continuous water-level monitoring equipment in six wells. The continuation of groundwater data acquisition, hydrologic characterization, and groundwater modeling are critical to the development of meaningful aquifer availability analysis in this Region.

3.2.9 Public Supply Use of Groundwater

All communities in the Plateau Region rely partially or completely on groundwater supply sources. Even the spring sources used by Del Rio and Camp Wood originate from aquifers. The higher concentration of wells in Kerr and Bandera Counties related to population growth may present water supply availability problems in the future. Public supply wells serving communities in Edwards, Kinney, Real and Val Verde Counties are not anticipated to have long-term declines due to the relatively smaller quantities of water that are needed to serve these communities. Also, no long-term water-quality deterioration has been detected in groundwater supplies for these communities. Long-term viability of the aquifers serving these other communities appears to be acceptable. However, new wells should be located outside the local areas of pumping influence of the existing wells. Although no evidence of contamination from surface sources have been detected in public-supply groundwater sources in the Plateau Region, a wellhead protection program should be considered by all communities. Kerrville South, which appeared as a municipal water user entity in the 2006 Plateau Region Water Plan, has been purchased by Aqua Texas and is now included in the County Other group category.

City of Bandera

The City of Bandera is dependent on wells completed into the Lower Trinity Aquifer and must compete for this water with numerous private wells in the county. Long-term viability of the Trinity Aquifer as a supply source for Bandera and outlying areas will require implementation of management policies aimed at establishing withdrawals based on the sustainable yield of the aquifer. Sustainable yield of the Lower Trinity has not been established due to lack of available hydrologic data; additional studies based on evaluation of continuous water-level trends is needed.

City of Bandera Well No. 69-24-202 shows a consistent decline from the 1950s through the 1990s, with a total of approximately 400 feet of water level decline. Most of the water withdrawn by Bandera public supply wells is produced from the Lower Trinity which receives very little vertical recharge and an undetermined amount of lateral underflow from the north and west of the well fields. Because of the continuous water-level decline in these well fields, the City should monitor levels to anticipate production reductions.

City of Kerrville

The City of Kerrville is dependent on conjunctive use of surface water from the Guadalupe River and groundwater from Lower Trinity Aquifer wells. Kerrville Wells No. 4 and No. 11 experienced declines of as much as 200 feet through the early to mid-1980s. Between the early to mid-1980s and the early 1990s, water levels in these two wells increased by as much as 200 feet in response to the decreased pumpage by the City when surface water sources were brought on-line. Since 1998, water levels have remained relatively constant.

The only long-term water-quality degradation trend observed in Kerrville public-supply wells is noted in the increase in sodium, chloride and total dissolved solids in the City's Travis Well No. 14 during the late 1960s to mid-1970s. The well showed steady increases in sodium (18 to 72 mg/l), chloride (55 to 200 mg/l), and total dissolved solids (417 to 624 mg/l) between 1968 and 1976. This corresponded with the time period that large drawdowns in water levels were occurring in the Kerrville area. Today, the City mixes water from Well No. 14 with water from all other sources to maintain acceptable overall quality.

The City of Kerrville operates an aquifer storage and recovery (ASR) operation where treated surface water is injected into the Lower Trinity Aquifer to maintain aquifer pressure and provide a source for peak demand periods.

Specific strategies to meet Kerrville's future water needs are addressed in Chapter 4. If additional wells are needed for increasing supply needs, the City should consider locating new wells outside the local area of pumping influence. The City should also cooperate with efforts of the local groundwater conservation districts to establish aquifer management policies.

<u>City of Ingram</u>

Ingram Water Supply Inc. provides water to the City of Ingram from wells completed in the Middle and Lower Trinity Aquifers. The supply source appears to be sufficient to meet future needs. However, these wells are completed in the same aquifer as many other wells in the area and thus may be somewhat impacted in the future.

<u>City of Rocksprings</u>

The City of Rocksprings obtains its water supply from wells completed in the Edwards Limestone of the Edwards-Trinity (Plateau) Aquifer. This rural community has little competition for groundwater and, thus, its supply is considered dependable.

<u>City of Brackettville and Fort Clark Springs MUD</u>

Water wells completed in the Edwards portion of the Edwards-Trinity (Plateau) Aquifer produce water used for municipal supply in these two adjacent communities. Las Moras Springs, an identified major spring, also exists at the same location of the Fort Clark Springs wells. Under existing conditions, there appears to be sufficient supply to meet futures needs. The Kinney County Groundwater Conservation District is currently evaluating potential impacts that might result from increased future pumping within the District.

<u>City of Camp Wood</u>

Camp Wood located in southwestern Real County derives its water supply from Old Faithful Springs. The spring has reportedly always flowed. However, with increasing population and the drilling of additional wells in the area, the spring may experience decreasing flow during drought periods in the future.

<u>City of Leakey</u>

The City of Leakey obtains its water supply from four shallow wells ranging in depth from 34 to 42 feet in the Frio River Alluvium Aquifer. An additional well has recently been constructed and an application for an operation permit is being filed with the Real-Edwards Conservation and Reclamation District. The City must compete for groundwater from this small aquifer with numerous private domestic wells.

City of Del Rio

The City of Del Rio is supplied with water from San Felipe Springs, which issue from the Edwards portion of the Edwards-Trinity (Plateau) Aquifer. The water is collected through pumps set in the springs, treated with microfiltration and chlorine and then distributed to the City and to Laughlin Air Force Base.

The average discharge of San Felipe Springs since Lake Amistad was filled is about 110 cubic feet per second or about 80,000 acre-ft/yr. During recent droughts, the spring discharge has fallen below 50 cfs or, extrapolated over one year, about 36,000 acre-feet. Recent droughts as compared to the 1950s drought would be appropriate to use as a drought-condition gage because the filling of Amistad Lake has generally increased the springflow after the late 1960s. A minimum flow has not been determined for the threatened species living down stream of the springs and a study is needed to determine the actual amount that would have to be subtracted from the total spring flow to meet these environmental needs.

3.2.10 Agricultural Use of Groundwater

Because of the arid conditions and lack of well-developed soils over much of the Region, irrigated agricultural activities are generally limited in most of the counties. Low well yields common throughout much of the Region also limit the development of large-scale irrigation. Water quality, however, is not generally a limiting factor for irrigation in the Region. Kinney County has the greatest amount of agricultural use of water. The acreage of land irrigated by groundwater in the year 2000 in each county as reported in TWDB Report 347 is, from most to least, Kinney, 4,865 acres; Bandera, 173 acres; Val Verde, 145 acres; Kerr, 57 acres; Edwards, 40 acres; and Real, 15 acres. The PWPG is concerned about the accuracy of the irrigation surveys and believes that there is significantly more irrigation water use than is documented. For example, the Headwaters Groundwater Conservation

District in Kerr County documents approximately 700 acres being irrigated just with groundwater.

A review of historical and current data suggests that there has been no long-term change in regional water levels or water quality as a result of agricultural pumping. Local water-level declines occur during the irrigation season but generally recover during the off-season. Although irrigation conservation efficiencies could be improved, currently used equipment and practices are not resulting in depletion of the aquifers. At the current rate of agricultural use, groundwater of sufficient quantity in the Edwards-Trinity (Plateau), Edwards (BFZ), and Austin Chalk Aquifers should remain available for future agricultural use. However, the competition for Trinity Aquifer water between municipal and agricultural needs in Bandera and Kerr Counties is increasing. The Bandera County River Authority and Groundwater District and the Headwaters Groundwater Conservation District are both actively involved in managing the use of groundwater in these counties.

3.2.11 Brackish Groundwater Desalination Sources

As observed in Figure 5-1 in Chapter 5, most groundwater in the Plateau Region contains total dissolved-solids (TDS) concentrations of less than 1,000 mg/l and thus meets drinking water standards. Groundwater of slightly lesser quality (1,000 to 3,000 mg/l) may occur in the Trinity Aquifer, specifically in eastern Bandera and Kerr Counties. Elevated levels of calcium-sulfate resulting from the dissolution of evaporate beds in the upper Glen Rose is the primary source of higher TDS groundwater in these two counties. Productivity from this aquifer source makes desalination a marginal option at this time. Thus, no desalination strategies are recommended in this current Plan. However, the option under appropriate circumstances should remain as a consideration.

3.3 SURFACE WATER SUPPLIES

The Plateau Region is unique within all planning regions in that it straddles several different river basins rather than generally following a single river basin or a large part of a single river basin (Figure 3-2). From west to east, these basins include the Rio Grande, Nueces, Colorado, San Antonio, and Guadalupe. The headwaters of three of these river basins (Nueces, San Antonio, and Guadalupe), as well as major tributaries of the Rio Grande and Colorado River, originate in this Region.

Available surface water supplies under drought-of-record conditions depend on two components: water that is physically present (usually substantially reduced during a drought-of-record since by definition it is the most severe) and the authorized amount per existing water right adjudications. The Texas Commission on Environmental Quality (TCEQ) Water Availability Models (WAMs) perform a simulation of availability and diversion for all water rights in a river basin based on naturalized flows over a specified hydrologic period. These models generally follow an appropriation of water in priority date order, but appropriation order from upstream to downstream may be simulated. The TCEQ WAMs of the five river basins were used to determine surface water availability during a drought-of-record. The simulations used to determine water availability assume that all water rights in each basin are allowed to divert the full authorized amount when water is available, following appropriation in priority date order. They also assume that no return flows are present. These assumptions are known as the “Run 3” scenario. Area-capacity of major reservoirs was adjusted to reflect sedimentation conditions for 2000 and 2060. Drought-of-record supply source amounts by county and river basin are provided in Table 3-1. Authorized surface water rights are listed in Appendix 3A.

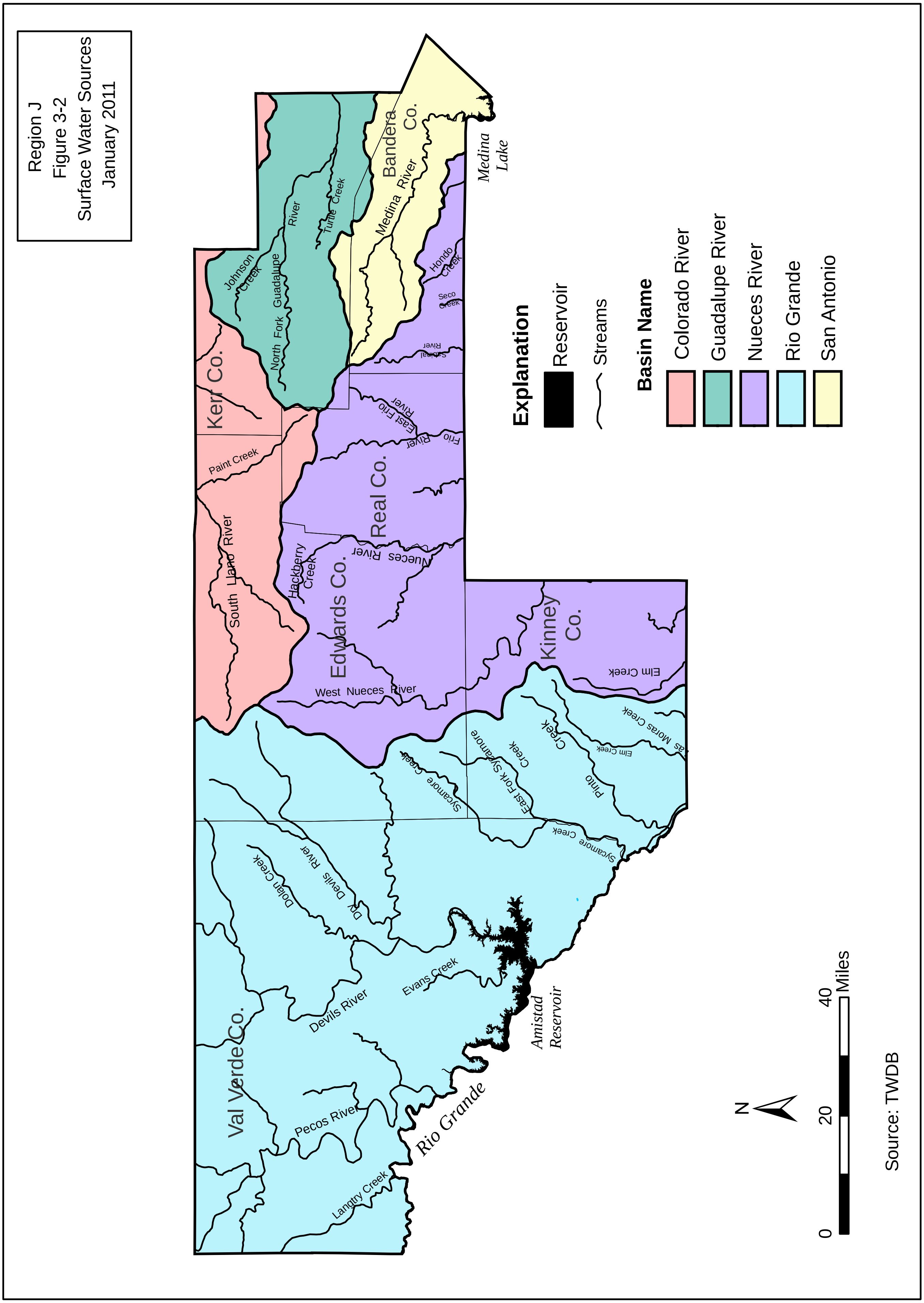


FIGURE 3-2. SURFACE WATER SOURCES

LBG-GUYTON ASSOCIATES

The term "run-of-the-river" is used to distinguish water rights with diversion points directly on a watercourse from water rights with diversion points on a reservoir. Generally, run-of-the-river water rights, also referred to as "direct diversions”, are less dependable than water rights on reservoirs because of the lack of storage. However, run-of-the-river diversions are often very convenient, especially for irrigators and small entities, because a diversion point on a watercourse can be located extremely close to the location where the water will actually be consumed, thereby negating the need to pipe the water over long distances.

Diversions under a drought-of-record are extracted from results of a WAM simulation for each basin. For purposes of this Plan, a drought-of-record supply for run-of-the-river diversions is categorized by use (municipal, irrigation, industrial and other) and by county. Supply amounts on river segments have always been difficult to assess due to the lack of storage to catch excess flows. In this Plan, the reliable supply for run-of-the-river diversions is expressed as the minimum annual diversion for each category during the hydrologic period considered in the water availability models.

Drought-of-record supply amounts for reservoirs are on a firm-yield basis. To understand firm yield, one must understand the concept of "mass balance" - the simple but true principle of physics that mass can neither be created nor be destroyed (i.e., what goes in has to come out). In practical terms as applied to a reservoir, the water going in (inflows from drainage areas of tributaries feeding the reservoir site) equals the water going out (evaporation off the lake surface plus water spilled over the dam plus any water allowed to pass through the dam to satisfy senior water rights downstream plus the demand placed on the reservoir plus other factors which may exist). Engineers and hydrologists simulate the operation of a reservoir under various demands placed on the reservoir, iterating the simulation to find a demand that the reservoir can supply consistently throughout a repeat of the historical hydrologic regime. Demand is termed the "firm yield" of the reservoir if for every year of the historical hydrologic regime (even during a drought-of-record) the reservoir can supply the demand placed on it.

Canyon Reservoir and the Medina/Diversion system are key water supply reservoirs for the Plateau Region's future water needs. Although neither reservoir currently serves a water need within the Region, both reservoirs will likely do so in the future.

Although recreational use of streams and lakes serves an important function in the Plateau Region, its use has no impact on reservoir yields, as these uses are non-consumptive. However, in some instances, recreational use may harm the water quality of a water supply (e.g., fuel byproducts from boat engines).

3.3.1 Rio Grande Basin (Including the Pecos and Devils River)

The Rio Grande, or Rio Bravo as it is known in Mexico, forms the border between the United States and Mexico. International treaties govern the ownership and distribution of the water in this river. Under The 1906 Treaty, the United States is obligated to deliver 60,000 acre-feet annually from the Rio Grande to Mexico, except in the cases of severe drought or serious accident to the irrigation system in the United States. The 1944 Treaty addresses the waters in the international segment of the Rio Grande from Fort Quitman, Texas to the Gulf of Mexico. The United States receives 1/3 of the flow from six tributaries (Rio Conchos, San Diego, San Rodrigo, Escondido, Salado Rivers, and Las Vacas Arroyo), provided that the running average over a five-year period cannot be less than 350,000 acre-ft/yr.

While the International Boundary and Water Commission is responsible for implementing the allocation of water on the U.S. side, the Watermaster office of TCEQ administers the allocation of Texas' share of the international waters. The two reservoirs located in the middle of the lower Rio Grande, the Amistad and Falcon, store the water regulated by the Watermaster. The Watermaster oversees Texas' share of water in the Rio Grande and its Texas tributaries from Fort Quitman to Amistad Dam, excluding drainage basins of the Pecos River and Devils River.

The Pecos River forms a portion of the boundary between Terrell County in the Far West Texas Region and Crockett County in Region F before reaching Langtry in Val Verde County in the Plateau Region. The Devils River originates in Sutton County and proceeds generally southward through Val Verde County before reaching Amistad International Reservoir. There are no surface-water rights on the Pecos and Devils Rivers within the Plateau Region.

Flow of the Pecos River within the Plateau Region is inconsistent, with livestock and wildlife watering apparently being the only use made of whatever water that may remain in the River. Independence Creek, a large spring-fed creek in northern Terrell County west of Val Verde County, is the most important of the few remaining freshwater tributaries to the lower Pecos River. Independence Creek's contribution increases the Pecos River water volume by 42 percent at the confluence and reduces the total suspended solids by 50 percent, thus improving both water quantity and quality (Nature Conservancy of Texas descriptive flier).

Flows of the Devils River are gaged at the Pafford Crossing near Comstock in Val Verde County. This gage (USGS 08449400) began recording in 1978 and was discontinued in 1985. Therefore, it does not record flows for the 1950s. However, from 1978 through 1985 the flows are consistently between approximately 100 and 300 cfs, with rare spikes ranging from 4,000 cfs up to 50,000 cfs. These spikes result from unusually intense but short rainfall events. In absence of data for the 1950s drought period, and considering the generally low and undependable flows within the Devils River, a realistic estimate of the drought-of-record amount of supply from the Devils River within the Plateau Region is zero.

3.3.2 Amistad International Reservoir on the Rio Grande

The Amistad International Reservoir is located on the border between the United States and Mexico near the City of Del Rio, was constructed jointly by the two nations. It was completed in 1968 with a maximum capacity of 5,250,000 acre-feet, 3,505,000 acre-feet of which are used for water conservation. The water is distributed among downstream users of Mexico and the United States. However, Amistad is not a source of supply for the Plateau Region, as the City of Del Rio and downstream irrigators in Val Verde County obtain their supply primarily from San Felipe Springs and Creek. Thus the constraints on Amistad

Reservoir as a source of water supply for the Plateau Region are the existing water rights held by water rights holders and enforced by the Rio Grande Watermaster.

Goodenough Spring is inundated by Lake Amistad and was at one time considered the third largest spring in Texas. The spring, which discharges from the Edwards-Trinity (Plateau) Aquifer, still provides a significant flow contribution to the Rio Grande.

3.3.3 The Nueces River Basin

The upper Nueces River Basin lies in Edwards, Real, Bandera, and Kinney Counties, with the main stem Nueces forming a portion of the border between Real County and Edwards County. Headwater tributaries of the Nueces River located in the Plateau Region include the Sabinal River and Hondo Creek in Bandera County, the West Nueces River in Edwards and Kinney Counties, and the Frio, East Frio, and Dry Frio Rivers in Real County. Although undocumented, there appears to be a significant amount of underflow occurring through gravel beds that line long stretches of the river bottom.

Total authorized diversions by water rights on the Nueces River within the Plateau Region are 11,419 acre-ft/yr. Most of this amount (10,116 acre-ft/yr or 88 percent) is for irrigation use. Diversions for municipal use total 1,259 acre-ft/yr. The City of Camp Wood holds the largest municipal right for 1,000 acre-ft/yr. Small water rights for other uses have a total authorized diversion of 44 acre-ft/yr.

The drought-of-record for the Nueces River Basin appears to have occurred not in the 1950s, but in 1996. USGS gages on the Sabinal River, Hondo Creek and West Nueces River seem to substantiate this assertion; flows at these gages during 1996 were significantly reduced from expected historical flows. The locations of gages USGS 08198500 (Sabinal River at Sabinal in eastern Uvalde County) and USGS 08200700 (Hondo Creek at King Waterhole near Hondo in central Medina County) are outside the Plateau Region, but the gages themselves measure flows from drainage areas lying within counties of the Plateau Region. The location of USGS gage 08190500 on the West Nueces River is near Brackettville in Kinney County.

An internal TWDB memorandum dated May 26, 1998 cites the Sabinal and Hondo gages as having experienced streamflows in calendar years 1994 through 1996 significantly reduced from expected historical flows, and cites the West Nueces gage as having experienced streamflow in calendar years 1994 and 1995 significantly reduced from expected historical flows. The memorandum defines "significantly reduced" as showing a 40 percent or more difference between the historical and the recent year nonexceedance probabilities. (It should be noted that for all three of these gages 1997 flows were higher than the 1994 through 1996 flows.)

Flows for the main stem Nueces River are gaged at USGS 08192000 near Uvalde in Uvalde County. These gaged flows for a period of record of 1939 through 1997 indicate a low annual flow of 3.63 cfs (approximately 2,650 acre-ft/yr), occurring in 1956. Flows for the Frio River are gaged at USGS 08195000 at Concan in Uvalde County. These gaged flows for a period of record of 1930 through 1997 indicate a low annual flow of 8.8 cfs (approximately 6,424 acre-ft/yr), occurring in 1956. For these areas, the 1950s drought was evidently the drought-of-record.

The TCEQ Water Availability Model for the Nueces River Basin was used to evaluate surface water supplies. The model includes data through the year 1996, and therefore addresses the drought-of-record occurring in 1996 for the localized areas on the Sabinal River and Hondo Creek.

3.3.4 Colorado River Basin

The headwaters of the South Llano River, a tributary of the Colorado River, lie in Edwards County. There are three water rights on the South Llano River and Paint Creek within the Plateau Region for irrigation use. The combined authorized amount of these rights is 180 acre-ft/yr.

The TCEQ Colorado River Basin WAM was used to evaluate the supply for these rights. This model covers the period 1940-1998. Hydrologic data for these streams suggest that the drought-of-record occurred during the 1950s. The minimum annual diversion for the three rights is 43 acre-ft/yr.

3.3.5 San Antonio River Basin

Headwaters of the San Antonio River lie in Bandera County. Most water right authorizations from the San Antonio Basin are run-of-the-river diversions for irrigation use. Run-of-the-river diversions exclude authorizations on Medina Lake. Eight authorized water rights on the Medina River main stem total 236 acre-ft/yr. Of these eight water right holders on the River, six use the water for irrigation. The sum of these six irrigation rights totals 227 acre-ft/yr. Of the remaining two water right holders, one is for 9 acre-feet of water per year used by an individual for municipal purposes, and the other is for a non-consumptive recreation reservoir owned by the City of Bandera. This recreation-only reservoir is for non-consumptive use only.

Since the Guadalupe-San Antonio WAM covers the period 1934-1989, it is appropriate to consider if the drought of 1996 exceeded the severity of the drought of the mid 1950s. USGS gage 08178880 on the Medina River at Bandera just downstream of State Highway 173 gives a lowest annual streamflow amount at 33.7 cubic feet per second (cfs) (approximately 24,600 acre-ft/yr) in 1996. However, this gage did not begin recording until 1982, and therefore records from the 1950s drought are missing and cannot be compared directly to the low flows of 1996. Data for the 1950s at the Bandera gage as extracted from the Guadalupe-San Antonio River Basin WAM gives an annual naturalized flow of 10,500 acre-feet in 1956. Regulated flows would be even lower once upstream diversions and impoundments are accounted for. Therefore, based on estimates of the Guadalupe-San Antonio Basins WAM, the drought of the 1950s represents the drought-of-record conditions for the San Antonio Basin in the Plateau Region.

3.3.6 Medina Lake on the Medina River

Medina Lake was constructed in 1911 to provide irrigation water for farmers to the southwest of San Antonio. Although commonly referred to as Medina Lake, the lake is actually a system consisting of Medina Lake and Diversion Lake. Impounded in 1913, Diversion Lake is approximately 4 miles downstream of Medina Lake.

Diversions from the dual-lake system are authorized only from Diversion Lake, as per the water right held by Bexar-Medina-Atascosa Water Control and Improvement District #1 (BMAWCID#1). BMAWCID#1's Adjudication Certificate No. 19-2130C authorizes the District to divert up to 65,830 acre-ft/yr of water for irrigation, municipal and industrial use, up to 750 acre-ft/yr specifically for domestic and livestock purposes, and up to 170 acre-ft/yr specifically for municipal use.

BMAWCID#1 has signed contracts to supply several irrigators and a development corporation with water. In January 2000, BMAWCID#1 signed a contract with Bexar Metropolitan Water Authority indicating that BMAWCID#1 will sell 20,000 acre-ft/yr to the Authority for municipal use.

Bandera County currently has a Water Supply Agreement with BMAWCID#1 for purchase of up to 5,000 acre-ft/yr; however, this agreement is not currently associated with the infrastructure necessary to carry out the purchase and subsequent distribution of the water. Strategy J-1 discussed in Chapter 4 describes the potential use of this source.

Loss of impounded water from Medina Lake to the Trinity Aquifer and Diversion Lake to the Edwards Aquifer reduces the firm yield of the system. This loss has long been known to be substantial. Quantification of water recharging the aquifers has been elusive, as different estimates of recharge have resulted in different firm-yield estimates for the system. In 1957, a Bureau of Reclamation study estimated the firm annual yield of the Medina Lake/Diversion Lake system to be 27,500 acre-ft/yr if the lake system were operated under an agricultural (irrigation) demand only scenario, but it estimated 29,700 acre-ft/yr as the firm yield for municipal and industrial demand. Due to effects of seepage around the dam and of recharge to the underlying aquifers, Espey Huston estimated a firm yield of zero for Medina Lake in 1994, based on the relationship they found between the Lake stage and recharge. HDR Engineering modified the Espey Huston stage-recharge curves for its Trans-Texas report and cited 8,770 acre-ft/yr as the firm yield. According to personal communication, HDR assumed diversions would be from Medina Lake rather than from Diversion Lake and that all irrigation use would be curtailed. This assumption does not comply with existing conditions as regards to water right authorizations.

The latest USGS report, "Assessment of Hydrogeology, Hydrologic Budget, and Water Chemistry of the Medina Lake Area, Medina and Bandera Counties, Texas," maintains that earlier methods of estimating recharge (Lowry, Espey Huston curves as modified by HDR for the Trans-Texas report) overestimate recharge. Overestimation of recharge would result in an underestimation of firm yield; however, the USGS report did not include a firm-yield estimate for the reservoir system.

The TCEQ Guadalupe-San Antonio River Basins WAM incorporates the HDR Trans-Texas method of estimating recharge and probably provides the best overall data (water rights, inflows determined by water rights) available at this time. The model was used to determine a firm yield of the Medina/Diversion system of zero acre-ft/yr.

3.3.7 Guadalupe River Basin

Within the Plateau Region, the Guadalupe River Basin occurs almost exclusively within Kerr County. The Basin drains approximately 510 square miles at Kerrville, and approximately 839 square miles at Comfort near the eastern county line. The River originates almost entirely within western Kerr County as three branches (Johnson Creek, North Fork, and South Fork) merge west of Kerrville to form the main river course. Spring flow contribution to the headwaters of the Guadalupe River is discussed in a report prepared for the PWPG (Ashworth, 2005).

The total amount of authorized water rights for the Guadalupe River within the Plateau Region is 21,020 acre-ft/yr. Municipal use accounts for the highest authorization at 8,076 acre-ft/yr. Holders of these water rights include the City of Kerrville, the Upper Guadalupe River Authority (UGRA), and independent persons.

The City of Kerrville and the UGRA own the largest municipal water rights. Certificate of Adjudication 1996 and Permit 3505 are held solely by Kerrville. UGRA and Kerrville hold Permit 5394 jointly. Authorized diversions from the Guadalupe River associated with these water rights are taken from an 840-acre on-channel reservoir located in the City of Kerrville and are pumped from the reservoir to Kerrville's water treatment plant. A summary of the pertinent information for their water rights is shown in Table 3-4.

Texas Parks and Wildlife Department owns a continuous flow-through water right for 5,780 acre-ft/yr used for the Heart of the Hills Fisheries Science Center, consumptive use is approximately 400 acre-ft/yr. Industrial use permits are authorized for 17 acre-ft/yr and irrigation rights for 6,904 acre-ft/yr. The remaining water-rights holders use their water for mining, hydroelectric power, and recreation. One individual holds a water right (35,125 acre-ft/yr) for hydroelectric use; however, this right has not been exercised. Kerr County holds the rights for three non-consumptive recreation-use reservoirs in and near Kerrville.

Table 3-4. Municipal Water Rights for Kerrville And UGRA

Water Rights Permit	Authorized Diversion (ac-ft/yr)	Permit Holder	Priority Date	Storage (ac-ft)	Restrictions
1996 (amended 4/10/98)	150 (mun) 75 (irr)	Kerrville	April 4, 1914		
3505	3,603	Kerrville	May 23, 1977	840	Max diversion rate = 9.7 cfs Divert only when reservoir is above 1,608 ft msl
5394 (amended 4/10/98)	2,169	Kerrville (Kerrville Municipal use)	January 6, 1992	Utilizes the storage authorized for Permit 3505	Max combined diversion rate for water rights #3505 and #5394 = 15.5 cfs. Minimum instream flow requirements vary from 30 to 50 cfs during year.
	2,000	UGRA (County Municipal use)			

Note: Permit 1996 authorizes a total diversion of 225 acre-ft/yr, of which 150 acre-ft/yr is designated for municipal use and 75 acre-ft/yr for irrigation purposes.

During winter months when there is surplus surface water supply, a portion of the treated water is injected into the Lower Trinity Aquifer for subsequent use during the typically dry summer months. This aquifer storage and recovery (ASR) program has been in full operation since 1998.

Both the City of Kerrville and the UGRA have within their authorizations (Permits Nos. 5394B and 5394A respectively) a Special Condition addressing the seasonal distribution of allowed diversions. The Special Condition stipulates that during the months of October through May, the permitees may divert only when the flow of the Guadalupe River exceeds 40 cfs, and during the months of June through September, the permitees are authorized to divert only when the flow of the Guadalupe River exceeds 30 cfs. Another Special Condition common to both permitees is that, when inflows to Canyon Reservoir are less than 50 cfs, each permitee is to restrict diversions to allow a flow of at least 50 cfs to pass through. Yet another Special Condition imposed on both permitees is that diversions may be made only when the level of UGRA Lake is above 1,608 feet above mean sea level.

Pursuant to a Memorandum of Understanding (MOU) between the Guadalupe-Blanco River Authority (GBRA) and the Commissioner's Court of Kerr County, the South Central Texas Water Planning Group (Region L) recognizes a potential commitment of approximately 2,000 ac-ft/yr from the firm yield of Canyon Reservoir for the calendar years 2021 through 2050. GBRA's hydrology studies indicate that a commitment of about 2,000 acre-ft/yr would be necessary to allow permits for 6,000 ac-ft/yr to be issued by TCEQ for diversions in Kerr County.

Data from the Corps of Engineers show a computed inflow into Lake Canyon of 132,900 acre-ft/yr in 1996. The Guadalupe-San Antonio WAM estimates naturalized flows to be 27,800 acre-ft in 1956. The USGS gage 08167000 on the Guadalupe River at Comfort gives a lowest annual streamflow amount of 14.5 cfs (approximately 10,585 acre-ft/yr) occurring in 1956. This gage has been recording since 1939. Interestingly, statistics for the gage include the fact that, for water years 1939 through 1997, the mean annual runoff was 157,800 acre-feet or approximately 216 cfs, and that 90 percent of these flows exceeded 25 cfs. This puts the 1956 occurrence of 14.5 cfs within the 0 to 10 percent nonexceedance category. In calendar year 1996, the annual mean was 151 cfs and the median was 85 cfs. The mean and median for 1997 exceeded the 1996 values. These facts seem to substantiate that the drought-of-record for Kerr County occurred in 1956, not in 1996, as consistent with most other areas of the State.

3.3.8 Canyon Reservoir

The construction of Canyon Reservoir was completed and impoundment commenced in June 1964. This reservoir controls approximately 1,425 square miles of drainage area and serves to impound water for various uses (mostly appropriated to the GBRA for use primarily in the South Central Texas Region). Canyon is also an Army Corps of Engineers (COE) Reservoir and as such operates under the Army COE Operations Manual as occasionally modified by request of GBRA (and agreed to by county judges of the downstream counties). Canyon Reservoir is also subject to the Federal Emergency Management Agency's (FEMA) requirements as to daily releases. The Army COE and FEMA operations and release requirements are incorporated into the updated TCEQ WAM for the Guadalupe-San Antonio River Basin. GBRA’s TCEQ permit currently authorizes an average annual diversion from Canyon Reservoir of 90,000 ac-ft/yr. The firm yield of Canyon Reservoir used in the Region L Plan ranges from 88,232 ac-ft/yr to 87,484 ac-ft/yr in years 2000 and 2060 respectively.

3.3.9 San Felipe Springs

The City of Del Rio has a water right authorizing it to divert 11,416 acre-ft/yr from San Felipe Springs for municipal use. San Felipe Manufacturing and Irrigation Company has a water right authorizing it to divert 4,962 acre-ft/yr for irrigation use and 50 acre-ft/yr for industrial use. No data exists for flows during the drought of the 1950s. The only available records are from USGS gage 08452800 maintained by the IBWC at San Felipe Springs that covers the period of February 1961 to present. The minimum annual amount during this time period was 36,580 acre-ft/yr (occurring in 1963).

3.3.10 Old Faithful Springs

Issuing from the upper Glen Rose Limestone portion of the Edwards-Trinity (Plateau) Aquifer and shallow creek alluvium, Old Faithful Springs is the sole-source water supply for the City of Camp Wood. The Springs has been a dependable source and was reported to have continuously flowed during the 1950s drought. There is current concern that the increase in the number of wells being drilled in the area may lower the local water table and thus negatively impact spring flow.

3.3.11 Surface Water Rights

The right to use water from streams and lakes is permitted through the State of Texas. Current permit holders in the Region are listed in Appendix 3A. The following permits are due to expire during the 50-year planning period:

- WR #5401 - a non-consumptive recreational use, on Turtle Creek in Kerr County (Guadalupe Basin), expires 12/31/2012
- WR #5097 - a consumptive irrigation use for 120 acre-ft/yr, on West Prong of Medina River in Bandera County (San Antonio Basin), expires 02/02/2016
- WR #3853 - a non-consumptive recreational use, on Spires Creek in Bandera County (San Antonio Basin), expires 04/12/2018

Major downstream water rights include those in Region L supplied by the Guadalupe-Blanco River Authority out of Canyon Lake and by the Bexar-Medina-Atascosa WCID#1 out of the Medina/Diversion system. The firm yields of Canyon and Medina limit the amount of water available for appropriation in both the Plateau Region and Region L. Major downstream water rights in Region M (i.e., cities and irrigators on the Rio Grande downstream from Amistad Reservoir) do not limit the amount of water available for appropriation in the Plateau Region because currently the Plateau Region does not depend on the Falcon-Amistad system. TCEQ's Lower Rio Grande Watermaster allocates water rights on the Rio Grande according to the supply in the Amistad Reservoir and in accordance with the 1944 International Treaty with Mexico.

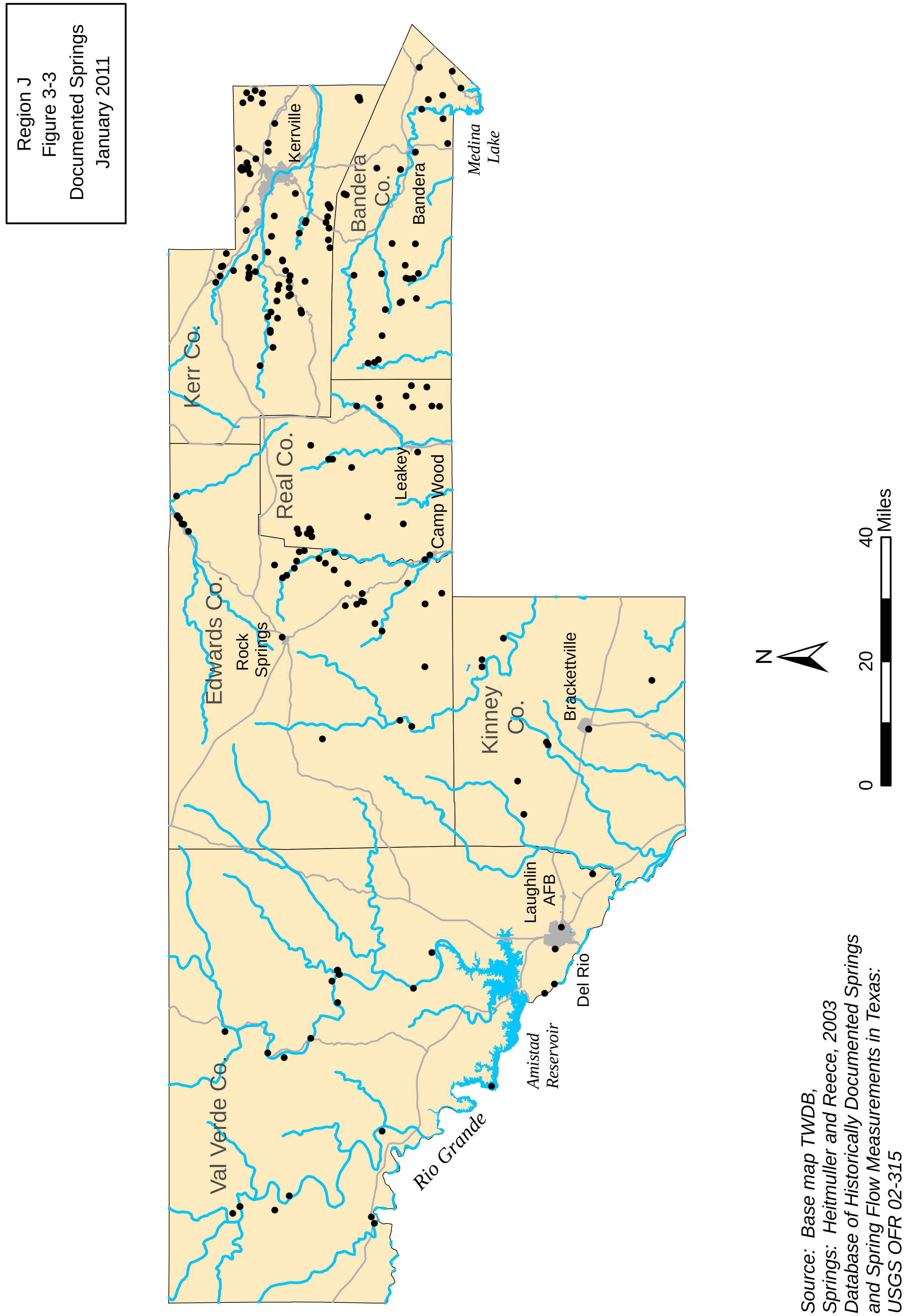
3.4 GROUNDWATER/SURFACE WATER RELATIONSHIP

In the natural environment, water is constantly in transition between the land surface and underground aquifers. Under certain conditions, stream losses percolate downward to underlying aquifers as recharge; while in other cases, aquifers give up water to the land surface in the form of springs and seeps.

Most of the Plateau Region occurs at higher elevations that constitute the headwaters of the numerous streams and tributaries that frequent this Region. At these elevations, significant quantities of water exit the aquifer systems through springs and form the base flow of the surface streams (Figure 3-3). Downstream, only a portion of that water may renter the underground system. For this reason, these streams are generally gaining throughout much of their extent within the Plateau Region. Spring flows are also environmentally important in that they are the primary source of water for wildlife in the area. These discharges from springs are thus the primary source of continuous flow to the rivers downstream and, therefore, their protection is warranted.

Some of the largest springs in the Region, such as San Felipe Springs (Val Verde County) and Las Moras Springs (Kinney County), issue from the Edwards limestone. However, numerous other springs issue from either the Edwards or Glen Rose limestones. Many of the springs, such as Fessenden Spring (Kerr County), issue near the contact between the Edwards and the upper Glen Rose limestones. Smaller springs are more prevalent where they issue from the Glen Rose, particularly in Bandera and Kerr Counties.

Most springs located in the headwaters of rivers that traverse the eastern part of the Region issue from the contact between the Edwards limestone and underlying upper Glen Rose limestone. Most well production in this area is from deeper aquifers and, therefore, little impact to spring flow from the pumping is anticipated. However, as new development expands to the west, care should be given to potential water level declines that could diminish spring flow and base flow to the rivers.



Source: Base map TWDB,
Springs: Heitmuller and Reece, 2003
Database of Historically Documented Springs
and Spring Flow Measurements in Texas:
USGS OFR 02-315

FIGURE 3-3. LOCATION OF DOCUMENTED SPRINGS

LBG-GUYTON ASSOCIATES

Springs located in the western part of the Region issue primarily from the Edwards limestone. Because of limited pumping of groundwater from wells in the Del Rio area, San Felipe Springs has not had to compete for source water. A significant increase in groundwater pumpage immediate updip and to the east of the springs may lower the water table sufficiently to affect flow from the springs. Because much of the recharge areas for the contributing zones of these western springs occur in remote areas, very little information is available concerning the relationship between the springs and the underlying aquifers.

Gain/loss studies are needed to identify stream segments that are critical to aquifer recharge and spring discharge. The studies can be used to identify where recharge structures would be most efficient and where most river base-flow gain occurs. Specific candidate areas occur over the plateau area that is underlain by Edwards limestone, especially in the upper tributaries of all the rivers. Gain/loss studies of tributaries in the vicinity of Del Rio would be beneficial in understanding the recharge areas that contribute to San Felipe Springs.

Two supplemental study reports were prepared for the Plateau Region Water Plan that address springs. The first report (Ashworth and Stein, 2005) considers the location and geohydrology of springs in Kinney and Val Verde Counties, and the second report (Ashworth, 2005) relates springflow in western Kerr County to base flow in the three branches of the upper Guadalupe River.

3.5 WATER REUSE

While recycling is a term generally applied to aluminum cans, glass bottles, and newspapers, water can be recycled as well. Water recycling is reusing treated wastewater for beneficial purposes such as agricultural and landscape irrigation, industrial processes, toilet flushing, and replenishing a groundwater aquifer (referred to as groundwater recharge or ASR for aquifer storage and recovery). Water is sometimes recycled and reused onsite; for example, when an industrial facility recycles water used for cooling processes. A common type of recycled water is water that has been reclaimed from municipal wastewater, or sewage. The term "water recycling" is generally used synonymously with water reclamation and water reuse.

In Kerrville, wastewater is treated to strict government standards. In fact, Kerrville treats its wastewater to the strictest set of standards in the State of Texas. Because of the high level of treatment, Kerrville's wastewater nearly meets drinking water standards. Treated wastewater is pumped through a dedicated pipeline for reuse as irrigation water for the Scott Schreiner Municipal Golf Course, the Hill Country Youth Soccer Fields, and the golf course at Comanche Trace Ranch & Golf Club. Additional treated water is sold by the truckload for construction projects. The remaining wastewater is released into Third Creek, which flows into Flatrock Lake on the Guadalupe River. That water is then available for use downstream of Kerrville. Future expansion of Kerrville’s reuse project is anticipated to yield approximately 1 million gallons per day. The current thinking within city leadership is that potable reuse is a better use for that water than irrigation.

The City of Camp Wood also has a water reuse program. Treated wastewater is used to irrigate hay fields in the near vicinity of town.

APPENDIX 3A

AUTHORIZED SURFACE WATER RIGHTS

APPENDIX 3A. AUTHORIZED SURFACE WATER RIGHTS AS EXTRACTED FROM TCEQ'S ACTIVE WATER RIGHTS MASTER FILE

Water Right Number	Type	County	River Order Permit	Name	Stream	Use	Amount in Ac-Ft/Yr	Acreage	Res Cap in Ac-Ft	Remarks
2027-000	6	Bandera	7720000000	ROBERT L PARKER SR ET AL	VERDE CRK	IRRG	8	3		
2028-000	6	Bandera	7750000000	HOWARD E BUTT	PALMER CRK	OTHER			30	
2103-000	6	Bandera	5903000000	O S PETTY	HONEY CRK	IRRG	96	38		
2104-000	6	Bandera	5902000000	CLARENCE E LAUTZENHEISER ET UX	N PRONG MEDINA RIVER	IRRG	20.24	23.85		AMEND 9/29/88, 8/22/89
2105-000	6	Bandera	5901500000	STEVEN L PRICHARD TRUSTEE	MICKLE	IRRG	5.44	8.16	5	
2105-000	6	Bandera	5901500000	NEAL INCORPORATED	MICKLE	IRRG	7.32	10.99	5	
2106-000	6	Bandera	5901450000	BREWINGTON LAKE RANCH ASSN	BREWINGTON CRK	REC	190		190	
2107-000	6	Bandera	5901100000	JOEL HELD, TRUSTEE/JJJ RANCH	N PRONG MEDINA RIVER	IRRG	19	25		OUT OF A 1666.5 ACRE TRACT
2108-000	6	Bandera	5900100000	BEN & KAY MAYBERRY FAM PART	ROCKY CRK	IRRG	19.82	14.41		ALSO KERR CO
2108-000	6	Bandera	5900100000	WALTER A WILLOUGHBY	ROCKY CRK	IRRG	24.18	17.59		ALSO KERR CO
2109-000	6	Bandera	5897200000	NEVIN MARR	N PRONG MEDINA RIVER	IRRG	2	10		AMEND 1-21-83 INCREASE ACRES
2110-000	6	Bandera	5897000000	DONALD F & MARTHA M MEAD	N PRONG MEDINA RIVER	IRRG	21	12		
2111-000	6	Bandera	5896000000	TEXAS PETROLEUM CO. TR EST	COLLINS CRK	IRRG	4	2	16	
2112-000	6	Bandera	5894500000	MRS MARY WINKENHOWER	ELAM CRK	IRRG	27	27		JOINTLY OWNS 27 AF TO IRR 27 ACRES
2113-000	6	Bandera	5894000000	SUSAN CRAWFORD TRACY	W PRONG MEDINA RIVER	IRRG	35	45		OUT OF A 156 ACRE TRACT
2114-000	6	Bandera	5892000000	PHIL A GROTHUES ET UX	UNNAMED TRIB	IRRG	5.705	20.715		
2114-000	6	Bandera	5892000000	INMANN T DABNEY JR ET UX	UNNAMED TRIB	IRRG	6.542	23.756		
2114-000	6	Bandera	5892000000	RICHARD E WILSON	UNNAMED TRIB	IRRG	3.753	13.629		
2115-000	6	Bandera	5891500000	DAVID R SCHMIDT MD ET AL	BAUERLEIN CRK	IRRG	15	16		
2116-000	6	Bandera	5891000000	PAUL LAVON GARRISON	W PRONG MEDINA RIVER	IRRG	36	36		
2116-000	6	Bandera	5891000000	GEORGE C. YAX	W PRONG MEDINA RIVER	IRRG	15	15	162	
2117-000	6	Bandera	5889000000	G. MILTON JOHNSON, ET UX	MEDINA RIVER	IRRG	7	7		OUT OF A 175.5 ACRE TRACT
2118-000	6	Bandera	5888870000	DAVID J BRASK	UNNAMED TRIB	IRRG	16	16		
2119-000	6	Bandera	5888090000	RAYMOND HICKS	MEDINA RIVER	IRRG	3	8		
2120-000	6	Bandera	5888051000	BANDERA ELECTRIC COOP INC	MEDINA RIVER	IRRG	2	4		7/8/82 ADD DIV PT
2121-000	6	Bandera	5888087000	ANN DARTHULA MAULDIN	INDIAN CRK	IRRG	31.03	8.27		
2121-000	6	Bandera	5888087000	TOLBERT S WILKINSON ET UX	INDIAN CRK	IRRG	69.47	18.53		AMEND 7/30/90

Water Right Number	Type	County	River Order Permit	Name	Stream	Use	Amount in Ac-Ft/Yr	Acreage	Res Cap in Ac-Ft	Remarks
2121-000	6	Bandera	5888087000	JOHN W DINSE ET UX	INDIAN CRK	IRRG	49.5	13.2		
2122-000	6	Bandera	5887330000	DON HICKS	MEDINA RIVER	MUNI	9			
2123-000	6	Bandera	5887150000	DON F TOBIN	MEDINA RIVER	IRRG	152	61		OUT OF A 452 ACRE TRACT
2124-000	6	Bandera	5887130000	EVANGELINE RATCLIFFE WILSON	SAN JULIAN CRK	IRRG	3	5		
2125-000	6	Bandera	5887129000	PETER K SHAVER ET UX	SAN JULIAN CRK	IRRG	18	30		
2126-000	6	Bandera	5887105000	STANLEY D ROSENBERG ET UX	MEDINA RIVER	IRRG	47	36		
2127-000	6	Bandera	5887100000	JERRY B PARKER ET AL	MEDINA RIVER	IRRG	16	8		
2128-000	6	Bandera	5887050000	JOE H BERRY	SADDLE CRK	IRRG	14	12	3	
2129-000	6	Bandera	5887000000	JOE H BERRY	PRIVILEGE CRK	IRRG	40	33	110	
2135-000	6	Bandera	5660000000	KITTIE NELSON FERGUSON	SAN GERONIMO CRK	IRRG	5	5	28	
3176-000	6	Bandera	2851020000	TEXAS PARKS & WILDLIFE DEPT	CAN CRK	MUNI	7			
3176-000	6	Bandera	2851020000	TEXAS PARKS & WILDLIFE DEPT	CAN CRK	IRRG		3		
3177-000	6	Bandera	2850500000	BETTY F LEIGHTON	SABINAL RIVER	MUNI	4			
3178-000	6	Bandera	2850000000	KING & JEWEL FISHER	SABINAL RIVER	IRRG	40	56	2	AMENDED 6/21/96
3179-000	6	Bandera	2825000000	JOHN K HARRELL	SABINAL RIVER	IRRG	28.196	95.257		
3179-000	6	Bandera	2825000000	BARBARA JEAN GROTH ET VIR	SABINAL RIVER	IRRG	8.804	29.743		
3184-000	6	Bandera	2675000000	ENRIQUE S PALOMO ET UX	SPRING CRK	IRRG	10	5	42	
3185-000	6	Bandera	2651700000	W H THOMPSON JR	WILLIAMS CRK	IRRG	15	5	2	CURRENT OWNER UNKNOWN, 5/98
3186-000	6	Bandera	2651500000	DOROTHY BAIRD MATTIZA	WILLIAMS CRK	IRRG	128	88	73	
3187-000	6	Bandera	2651000000	CHESTER N POSEY ET UX	WILLIAMS CRK	IRRG	23	21	15	
3188-000	6	Bandera	2650000000	W J SCHMIDT	HONDO CRK	IRRG	24	47	16	
3693-000	1	Bandera	5887260000	GERALD H PERSYN	UNNAMED TRIB BANDERA CRK	REC			11	
3824-000	1	Bandera	5887295000	CITY OF BANDERA	MEDINA RIVER	REC			22	
3825-000	1	Bandera	7718000000	ROBERT L PARKER SR ET AL	VERDE CRK	REC			277	
3853-000	1	Bandera	5888230000	ROCK CLIFF RESERVOIR LAND ASSN	SPIRES CRK	REC			925.4	AMENDED 2/17/98: IMPOUNDMENT AND EXP
3909-000	1	Bandera	5888150000	MAUDEEN M MARKS	MONTAGUE HOLLOW	REC			500	DOMESTIC, LIVESTOCK & REC
3944-000	1	Bandera	5887120000	CONOCO INCORPORATED	UNNAMED TRIB MEDINA RIVER	REC			180	2 DAMS
3949-000	1	Bandera	5886550000	CASTLE LAND & LIVESTOCK CO INC	BEAR CRK	REC	33		33	DOM & LIVESTOCK - SC

Water Right Number	Type	County	River Order Permit	Name	Stream	Use	Amount in Ac-Ft/Yr	Acreage	Res Cap in Ac-Ft	Remarks
4	1	Bandera	5887125000	HILL COUNTRY MANAGEMENT CORP	SAN JULIAN	REC			3	ALSO DOM & LIVESTOCK
5097-000	1	Bandera	5890300000	DON CODY ET UX	W PRONG MEDINA RIVER	IRRG	120	72		EXP 2/2/2016 BY CONTRACT 1610;AMEND 9/94
5186-000	1	Bandera	2824000000	HILL COUNTRY SPRING WATER TX	SPRING	MUNI	161			BOTTLED WATER, .049 RES
5204-000	1	Bandera	2840000000	ROGER E. CANTER ET UX	SABINAL RIVER	IRRG	60	20		
5305-000	1	Bandera	2621000000	UTOPIA SPRING WATER INC	W SECO CRK	MUNI	72			
5339-000	1	Bandera	5888089000	YMCA/GREATER HOUSTON AREA	INDIAN CRK	REC			30	
5342-000	1	Bandera	5890200000	RENE H GRACIDA	W PRONG MEDIA	REC			7	
5475-000	1	Bandera	2850600000	GALLERIA HOLDING, LTD	JERNIGAN CRK	IRRG	26	18	63	2 RESERVOIRS
5575-000	1	Bandera	2850900000	ALBERT R GAGE ET UX	MARLER CRK	IRRG	12	6		SC: FLOW RESTRICTIONS
1527-000	6	Edwards	1750010000	ADDISON LEE PFLUGER	HUFFMAN SPRING	IRRG	32	20	1	
1528-000	6	Edwards	1735000000	RUTH MCLEAN BOWERS	PAINT CREEK	IRRG	60	54	58	CO 134, 2 RES
2451-000	6	Edwards	1750000000	ADDISON LEE PFLUGER ET AL	S LLANO RIVER	IRRG	88	74	7	AMEND 5/9/83
3017-000	6	Edwards	9520000000	RAY H EUBANK	RUTH DRAW	IRRG	50	50		AMEND 7/3/84
3023-000	6	Edwards	9195000000	DONALD P TARPEY	NUECES RIVER	IRRG	108	27		
3024-000	6	Edwards	9170000000	DOUGLAS B & MARGARET MARSHALL	NUECES RIVER	IRRG	65	43		
3038-000	6	Edwards	8900000000	ROYCE I REID ESTATE	PULLIAM CRK	IRRG	48	20		
3039-000	6	Edwards	8800000000	OLGA H. CLOUDT, ET AL	PULLIAM CRK	IRRG	75	50	8	
3039-000	6	Edwards	8800000000	OLGA H. CLOUDT, ET AL	PULLIAM CRK	IRRG	30	20		
3040-000	6	Edwards	8790000000	J R WILLIAMS ET AL	PULLIAM CRK	IRRG	34	17		
3041-000	6	Edwards	8780000000	JOSEPH C WILLIAMS	PULLIAM CRK	IRRG	60	44		1/2 INTEREST IN 60 AF FOR IRR OF 44 AC
3042-000	6	Edwards	8779000000	J R WILLIAMS ET AL	PULLIAM CRK	IRRG	22	13		
3043-000	6	Edwards	8760000000	JOY JERNIGAN OWENS	PULLIAM CRK	IRRG	32	16		
3044-000	6	Edwards	8700010000	SUSAN PETTY ARNIM ET AL	CEDAR CRK	IRRG	6	12		
3044-000	6	Edwards	8700010000	SUSAN PETTY ARNIM ET AL	CEDAR CRK	IRRG	20			
3044-000	6	Edwards	8700010000	SUSAN PETTY ARNIM ET AL	CEDAR CRK	IRRG	4	20		
3046-000	6	Edwards	8460500000	NORMA JEAN EASLEY	PULLIAM CRK	IRRG	30	59		
3047-000	6	Edwards	8400000000	BRUCE I HENDRICKSON ET UX	CLEAR CRK	IRRG	6	6	11	
3048-000	6	Edwards	8340000000	L A MALACHEK ET AL	PULLIAM CRK	IRRG	27	14		

Water Right Number	Type	County	River Order Permit	Name	Stream	Use	Amount in Ac-Ft/Yr	Acreage	Res Cap in Ac-Ft	Remarks
3049-000	6	Edwards	7630010000	EDWARDS CO INVEST. PARTNER	PULLIAM CRK	IRRG	250	400		
3049-000	6	Edwards	7630010000	BRUCE I HENDRICKSON ET UX	PULLIAM CRK	IRRG	350	150		
3070-000	6	Edwards	7041600000	E B CARRUTH, JR, TRUST	W NUECES RIVER	IRRG	200	184		
3070-000	6	Edwards	7041600000	E B CARRUTH, JR, TRUST	W NUECES RIVER	REC			19	
3957-000	1	Edwards	8550000000	S A WILLIAMS	CEDAR CRK	IRRG	40	40		AMEND 1/13/87
4006-000	1	Edwards	8790100000	BAY-HOUSTON TOWING CO	PULLIAM	IRRG	150	75		
4278-000	1	Edwards	8920000000	BERRYMAN INVESTMENTS INC	PULLIAM CRK	IRRG	4.34	7.38		OWNS DAM & RESERVOIR
4278-000	1	Edwards	8920000000	SAM P WORDEN ET UX	PULLIAM CRK	IRRG	5.66	9.62		
1930-000	6	Kerr	9570000000	HERSHEL REID ET UX	FLAT ROCK CRK	IRRG	69	66	35	
1932-000	6	Kerr	9560000000	PRESBYTERIAN MO-RANCH ASSEMBLY	N FRK GUADALUPE RIVER	MUNI	60			AMEND 6/7/94
1932-000	6	Kerr	9560000000	PRESBYTERIAN MO-RANCH ASSEMBLY	N FRK GUADALUPE RIVER	IRRG	14	7		AMEND 6/7/94
1932-000	6	Kerr	9560000000	PRESBYTERIAN MO-RANCH ASSEMBLY	N FRK GUADALUPE RIVER	REC	25		20	AMEND 6/7/94
1934-000	6	Kerr	9527000000	CHARLES K HICKEY JR ET AL	DRY CRK	IRRG	0.45	0.68		
1934-000	6	Kerr	9527000000	KATHY JAN FREEMAN	DRY CRK	IRRG	1.55	2.32		
1935-000	6	Kerr	9525100000	CHARLES K HICKEY JR ET AL	N FRK GUADALUPE RIVER	IRRG	8	8		
1936-000	6	Kerr	9523000000	WILLIAM H ARLITT JR ET UX	N FRK GUADALUPE RIVER	IRRG	17	6	5	
1936-000	6	Kerr	9523000000	WILLIAM H ARLITT JR ET UX	INDIAN CRK	IRRG	134	48		
1937-000	6	Kerr	9515200000	BOY SCOUTS- ALAMO AREA	BEAR CRK	REC			10	
1938-000	6	Kerr	9515000000	LOUIS H STUMBERG	N FRK GUADALUPE RIVER	IRRG	2	4		
1938-000	6	Kerr	9515000000	LOUIS H STUMBERG	N FRK GUADALUPE RIVER	IRRG	15	22		
1939-000	6	Kerr	9512000000	LOUIS H STRUMBERG	GRAPE CRK	IRRG	3	6	6	
1940-000	6	Kerr	9511000000	B E QUINN III ET AL	N FRK GUADALUPE RIVER	IRRG	32	16	10	
1941-000	6	Kerr	8154502000	DELMAR SPIER AGENT	TURTLE CRK	IRRG	6	9	5	
1943-000	6	Kerr	9505000000	J CONRAD PYLE, ET AL	N FRK GUADALUPE RIVER	MUNI	14			
1945-000	6	Kerr	9485010000	JOHN P HILL	N FRK GUADALUPE RIVER	IRRG	25	20		
1946-000	6	Kerr	9485000000	JOHN P HILL ADMINISTRATOR	N FRK GUADALUPE RIVER	IRRG	11	9		
1947-000	6	Kerr	9480000000	GUAD VALLEY LOT OWNERS ASSN	N FRK GUADALUPE RIVER	IRRG	6	10		AMEND 3/6/91
1947-000	6	Kerr	9480000000	GUAD VALLEY LOT OWNERS ASSN	N FRK GUADALUPE RIVER	MUNI	3			

Water Right Number	Type	County	River Order Permit	Name	Stream	Use	Amount in Ac-Ft/Yr	Acreage	Res Cap in Ac-Ft	Remarks
1948-000	6	Kerr	9489000000	JOHN H DUNCAN	BRUSHY CRK	IRRG	7	7		
1949-000	6	Kerr	9488000000	WILLIAM O CARTER, TRUSTEE	HONEY CRK	IRRG	6	2		OUT OF A 80 ACRE TRACT
1949-000	6	Kerr	9488000000	WILLIAM O CARTER, TRUSTEE	HONEY CRK	IRRG	27	9		
1950-000	6	Kerr	9487000000	JOHN H DUNCAN	HONEY CRK	IRRG	6	20	13	ALSO USE 7
1953-000	6	Kerr	9476000000	LAURA B LEWIS ET VIR	N FRK GUADALUPE RIVER	IRRG	40	24		
1956-000	6	Kerr	9897000000	RIVER INN ASSOC OF UNIT OWNERS	S FRK GUADALUPE RIVER	REC			50	
1956-000	6	Kerr	9897000000	RIVER INN ASSOC OF UNIT OWNERS	S FRK GUADALUPE RIVER	MUNI	10			AMEND 4/19/84, 1/4/85
1957-000	6	Kerr	9880000000	BILLIE R VALICEK	S FRK GUADALUPE RIVER	REC			10	
1958-000	6	Kerr	9780000000	T J MOORE ESTATE	CYPRESS CRK	IRRG	20	10	100	
1961-000	6	Kerr	9670000000	LAVERNE CRIDER MOORE ET VIR	S FRK GUADALUPE RIVER	MUNI	3			
1961-000	6	Kerr	9670000000	LAVERNE CRIDER MOORE ET VIR	S FRK GUADALUPE RIVER	IRRG	1	3		
1963-000	6	Kerr	9620000000	LAWRENCE L GRAHAM ET AL	S FRK GUADALUPE RIVER	IRRG	2	12	21	AMEND 9/10/85
1963-000	6	Kerr	9620000000	LAWRENCE L GRAHAM ET AL	S FRK GUADALUPE RIVER	REC			16	AMENDS 5/26/83 CHG PUR USE & ADD RES
1964-000	6	Kerr	9400000000	VIRGINIA MOORE JOHNSTON	TEGENER	IRRG	10	10	12	
1967-000	6	Kerr	9305000000	SARAH HICKS BUSS	UNNAMED TRIB GUADALUPE RIVER	REC	20			ALSO USE 1, AMEND 3/19/91
1968-000	6	Kerr	9261000000	LOUIS DOMINGUES	GUADALUPE RIVER	IRRG	10	20		
1969-000	6	Kerr	9260000000	TOMMIE SMITH BLACKBURN	GUADALUPE RIVER	INDU	15		15	USE 2: MILLING
1969-000	6	Kerr	9260000000	TOMMIE SMITH BLACKBURN	KELLY CRK	IRRG	49	80		USE 3 - DIVERTING FROM KELLY CREEK
1969-000	6	Kerr	9260000000	TOMMIE SMITH BLACKBURN	GUADALUPE RIVER	IRRG	59			USE 3 - DIVERTING FROM GUADALUPE RIVER
1969-000	6	Kerr	9260000000	TOMMIE SMITH BLACKBURN	GUADALUPE RIVER	HYDRO				USE 5; NONCONSUMPTIVE
1970-000	6	Kerr	9220000000	CARL HAWKINS	GUADALUPE RIVER	MUNI	10			
1970-000	6	Kerr	9220000000	CARL HAWKINS	GUADALUPE RIVER	IRRG	32	25		
1971-000	6	Kerr	9140000000	COUNTY OF KERR	GUADALUPE RIVER	REC			450	
1972-000	6	Kerr	9110000000	WESLEY ELLEBRACHT	WELSH BR	IRRG	0.8	0.8		
1972-000	6	Kerr	9110000000	WELCH CREEK PARTNERS LTD	WELSH BR	IRRG	5.15	5.15		
1972-000	6	Kerr	9110000000	ARANSAS BAY COMPANY	WELSH BR	IRRG	0.05	0.05		
1973-000	6	Kerr	9100000000	SHELTON RANCHES INC	SMITHS BR	IRRG	10	10	6	
1974-000	6	Kerr	9050000000	SHELTON RANCHES INC	SMITHS BR	IRRG	70	35	15	ALSO JOHNSON CREEK

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1975-000	6	Kerr	9025000000	TEXAS PARKS & WILDLIFE DEPT	FESSENDEN BR	INDU	400			FISH HATCHERY & GAME PRESERVE
1975-000	6	Kerr	9025000000	TEXAS PARKS & WILDLIFE DEPT	FESSENDEN BR	INDU	5780		72	2 IMP & A POND; USES 3, 1 & 7; EXP 2012
1976-000	6	Kerr	8950000000	F P ZOCH III TRUST & ZEE RANCH	FESSENDEN BR	IRRG	29	14		
1976-000	6	Kerr	8950000000	F P ZOCH III TRUST & ZEE RANCH	FESSENDEN BR	REC			184	
1977-000	6	Kerr	8839000000	TEXAS CATHOLIC BOYS' HOME	JOHNSON CRK	IRRG	23	23	23	
1978-000	6	Kerr	8815000000	A J RUST	JOHNSON CRK	IRRG	33	65		
1979-000	6	Kerr	8808000000	KEITH S MEADOW	BYAS CRK	IRRG	18	6		
1980-000	6	Kerr	8805000000	A L MOORE	JOHNSON CRK	IRRG	12	6		
1981-000	6	Kerr	8800000000	JACK D CLARK JR ET AL	JOHNSON CRK	IRRG	32	16		
1981-000	6	Kerr	8800000000	JACK D CLARK JR ET AL	JOHNSON CRK	IRRG	143	76		OUT OF A 111.9 ACRE TRACT
1982-000	6	Kerr	8775000000	LOLA DEAN SMITH	JOHNSON CRK	IRRG	133	50	12	
1983-000	6	Kerr	8770000000	N V MAMIMAR	JOHNSON CRK	IRRG	32	17		JOINTLY OWN 32 & 67 AF TO IRR 17 & 35 AC
1983-000	6	Kerr	8770000000	N V MAMIMAR	JOHNSON CRK	IRRG	67	35		JOINTLY OWN 32 & 67 AF TO IRR 17 & 35 AC
1983-000	6	Kerr	8770000000	DAVID J COPELAND ET UX	JOHNSON CRK	IRRG				JOINTLY OWN 32 & 67 AF TO IRR 17 & 35 AC
1983-000	6	Kerr	8770000000	DAVID J COPELAND ET UX	JOHNSON CRK	IRRG				JOINTLY OWN 32 & 67 AF TO IRR 17 & 35 AC
1984-000	6	Kerr	8750000000	MICHAEL E & GAIL SEARS	JOHNSON CRK	IRRG	1	2		
1985-000	6	Kerr	8746000000	ROBERT B O'CONNOR JR ET UX	JOHNSON CRK	IRRG	80	31		
1987-000	6	Kerr	8744000000	REGINALD E WARREN JR	JOHNSON CRK	IRRG	90	30		
1988-000	6	Kerr	8720000000	JIMMIE L QUERNER SR ESTATE	FALL BR	IRRG	128	64		ALSO GILLESPIE CO
1990-000	6	Kerr	8650000000	DOROTHY L JENKINS ET AL	JOHNSON CRK	IRRG	3	1		
1991-000	6	Kerr	8615001000	LAZY HILLS GUEST RANCH INC	HENDERSON BR	IRRG	21	28		
1992-000	6	Kerr	8600000000	MARK A RYLANDER ET AL	JOHNSON CRK	IRRG	23	15		
1993-000	6	Kerr	8550000000	ROY LITTLEFIELD	JOHNSON CRK	IRRG	50	50	4	
1994-000	6	Kerr	8500000000	M H & MARY FRANCES MONTGOMERY	GUADALUPE RIVER	IRRG	5	4		
1995-000	6	Kerr	8451000000	HENRY GRIFFIN CONSTRUCTION CO	GOAT CRK	IRRG	11	11	6	
1996-000	6	Kerr	8287000000	KERRVILLE, CITY OF	GUADALUPE RIVER	MUNI	150			AMEND 3/19/91, 4/10/98: DIV PT #4.SC.
1996-000	6	Kerr	8287000000	KERRVILLE, CITY OF	GUADALUPE RIVER	IRRG	75	44	75	AMEND 3/19/91, 4/10/98: DIV PT #4.SC.

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1997-000	6	Kerr	8310000000	DARRELL G LOCHTE ET AL	GUADALUPE RIVER	MINE	143			
1997-000	6	Kerr	8310000000	DARRELL G LOCHTE ET AL	GUADALUPE RIVER	INDU	2			
1998-000	6	Kerr	8295000000	C W SUNDAY	TOWN CRK	IRRG	22.3	22.3	10	
1998-000	6	Kerr	8295000000	JOSE A LOPEZ ET UX	TOWN CRK	IRRG	4.18	4.18		
1999-000	6	Kerr	8297000000	KERRVILLE STATE HOSPITAL	UNNAMED TRIB GUADALUPE RIVER	REC	44		44	
2000-000	6	Kerr	8260010000	RIVERHILL COUNTRY CLUB INC	GUADALUPE RIVER	IRRG	350	160	70	8/31/87
2001-000	6	Kerr	8255000000	CARL D. MEEK	GUADALUPE RIVER	IRRG	295	194		AMEND 4/9/92,5/12/95.DIFF PRIORITY DATES
2002-000	6	Kerr	8230000000	COMANCHE TRACE RANCH & GOLF CL	GUADALUPE RIVER	IRRG	136	99		
2003-000	6	Kerr	8250000000	WHEATCRAFT, INC.	GUADALUPE RIVER	IRRG	42	21		
2003-000	6	Kerr	8250000000	SHELTON RANCH CORPORATION	GUADALUPE RIVER	MINE	10			
2004-000	6	Kerr	8200000000	COUNTY OF KERR	GUADALUPE RIVER	REC			720	ALSO USE 8
2005-000	6	Kerr	8185500000	HARRIET BOCKHOFF ESTATE	GUADALUPE RIVER	IRRG	59	98		
2006-000	6	Kerr	8174000000	FARM CREDIT BANK OF TEXAS	GUADALUPE RIVER	IRRG	179.06	512.55		AMEND 2/3/88,6/18/90. MAX COMB. CFS:4.0
2006-000	6	Kerr	8174000000	FARM CREDIT BANK OF TEXAS	GUADALUPE RIVER	IRRG	83.94			AMEND 2/3/88, 6/18/90
2006-000	6	Kerr	8174000000	1967 SHELTON TRUSTS PART ET AL	GUADALUPE RIVER	IRRG	106.9	78.55		AMEND 2/3/88, 6/18/90
2006-000	6	Kerr	8174000000	1967 SHELTON TRUSTS PART ET AL	GUADALUPE RIVER	IRRG	50.1			AMEND 2/3/88, 6/18/90
2006-000	6	Kerr	8174000000	KENNETH W WHITEWOOD ET UX	GUADALUPE RIVER	IRRG	34.04			AMEND 2/3/88, 6/18/90, 11/22/96
2006-000	6	Kerr	8174000000	KENNETH W WHITEWOOD ET UX	GUADALUPE RIVER	IRRG	15.96			AMEND 2/3/88, 6/18/90, 11/22/96
2006-000	6	Kerr	8174000000	KENNETH W WHITEWOOD ET UX	GUADALUPE RIVER	IRRG	100	76		AMEND 2/3/88, 6/18/90, 11/22/96
2007-000	6	Kerr	8160000000	RAY ELLISON JR	SPRING CRK	IRRG	31	31	50	
2008-000	6	Kerr	8156160000	LUTHERAN CAMP CHRYSALIS	TURTLE CRK	MUNI	11		12	
2009-000	6	Kerr	8155750000	FRANCIS C & WILLADEAN BOLEN	BUSHWACK CRK	IRRG	5	5	5	
2010-000	6	Kerr	8155700000	G ROBERT SWANTNER JR ET UX	BUSHWACK CRK	IRRG	7	5	5	OUT OF 68.8 ACRE TRACT
2011-000	6	Kerr	8155000000	H J GRUY	TURTLE CRK	IRRG	80	50	10	
2012-000	6	Kerr	8154501000	SANDRA BLAIR	TURTLE CRK	IRRG	1	1	5	
2013-000	6	Kerr	8154500000	FELIX R & LILLIAN STEILER REAL	WEST CRK	IRRG	11	12		
2014-000	6	Kerr	8152000000	LEAH MARTHA STEPHENS	TURTLE CRK	IRRG	6.36	5.63		
2014-000	6	Kerr	8152000000	BENNO OOSTERMAN ET UX	TURTLE CRK	IRRG	6.36	5.63		

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2014-000	6	Kerr	8152000000	JOHN M LEBOLT TRUSTEE	TURTLE CRK	IRRG	9.02	7.98		
2015-000	6	Kerr	8151000000	JAMES E NUGENT	GUADALUPE RIVER	IRRG	27	21		
2016-000	6	Kerr	8150500000	DORIS J HODGES	GUADALUPE RIVER	IRRG	8	8		
2017-000	6	Kerr	8050000000	COUNTY OF KERR	GUADALUPE RIVER	REC			87	ALSO USE 8
2018-000	6	Kerr	8049000000	LEE ANTHONY MOSTY	GUADALUPE RIVER	IRRG	154	94		
2020-000	6	Kerr	7970000000	ROBERT LEE MOSTY	GUADALUPE RIVER	IRRG	60	30		
2021-000	6	Kerr	7940000000	RAYMOND F MOSTY ET AL	GUADALUPE RIVER	IRRG	103	45	5	
2022-000	6	Kerr	7950000000	ROBERT LEE MOSTY	GUADALUPE RIVER	IRRG	17	119	20	
2023-000	6	Kerr	7935000000	ROY A GREEN	GUADALUPE RIVER	IRRG	7	3		
2024-000	6	Kerr	7924990000	CARL E RHODES	GUADALUPE RIVER	IRRG	114	125		
2025-000	6	Kerr	7925000000	HARRY J WRAY	GUADALUPE RIVER	IRRG	155	80		JOINTLY OWNS 155 AF TO IRR 80 ACRES
2025-000	6	Kerr	7925000000	DAVID B WRAY	GUADALUPE RIVER	IRRG				JOINTLY OWNS 155 AF TO IRR 80 ACRES
2025-000	6	Kerr	7925000000	BYNO SALSMAN ET UX	GUADALUPE RIVER	IRRG				JOINTLY OWNS 155 AF TO IRR 80 ACRES
2026-000	6	Kerr	7920000000	ELGIN JUNG	GUADALUPE RIVER	IRRG	3.309	2.118		
2026-000	6	Kerr	7920000000	ZANE H ROBINSON ET UX	GUADALUPE RIVER	IRRG	53.945	34.52		
2026-000	6	Kerr	7920000000	RONNIE W SCHLOTTMAN ET UX	GUADALUPE RIVER	IRRG	17.83	11.41		
2026-000	6	Kerr	7920000000	KENNETH W WHITEWOOD ET UX	GUADALUPE RIVER	IRRG	149.916	44.72		AMENDED 11/22/96
2029-000	6	Kerr	7710000000	ROLAND WALTERS	PRISON CANYON	IRRG	25	200	420	& CO 010, 10/5/82 ADD DIV PT
2030-000	6	Kerr	7704000000	JAMES S ERNST	UNNAMED TRIB VERDE CRK	IRRG	247		120	
2030-000	6	Kerr	7704000000	PETE R SMITH	UNNAMED TRIB VERDE CRK	IRRG	19			
2031-000	6	Kerr	7701000000	JOSEPH PAUL MILLER ET UX	GUADALUPE RIVER	IRRG	115	80		AMEND 11/4/85
2032-000	6	Kerr	7700700000	DAVID M LEIBOWITZ ET UX	GUADALUPE RIVER	IRRG	10	6		
2033-000	6	Kerr	7699900000	JAVIER G REYES ET UX	GUADALUPE RIVER	IRRG	90	90		
2034-000	6	Kerr	7699500000	CHESTER P HEINEN ET AL	GUADALUPE RIVER	IRRG	2	6		
2037-000	6	Kerr	7652500000	GENE ARTHUR ALLERKAMP	CYPRESS CRK	IRRG	5	6.33		
2037-000	6	Kerr	7652500000	JANICE CHARLOTTE BULLARD	CYPRESS CRK	IRRG	5	6.34		
2037-000	6	Kerr	7652500000	ROMAN LUNA ET UX	CYPRESS CRK	IRRG	10	12.67		
2037-000	6	Kerr	7652500000	CURTIS BERNARD ALLERKAMP	CYPRESS CRK	IRRG	5	6.33		
2037-000	6	Kerr	7652500000	WERNER WAYNE ALLERKAMP	CYPRESS CRK	IRRG	5	6.33		

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2038-000	6	Kerr	7652000000	HARRY E REEH	CYPRESS CRK	IRRG	15	15		
2039-000	6	Kerr	7650500000	FRED SAUR	CYPRESS CRK	IRRG	7	7		
2040-000	6	Kerr	7650000000	A C & DOROTHY PFEIFFER	CYPRESS CRK	IRRG	10	5		
2041-000	6	Kerr	7645000000	THOMAS L BRUNDAGE ET AL	CYPRESS CRK	IRRG	134	57		AMEND 2/1/85
2042-000	6	Kerr	7644800000	E J & VIRGINIA DOWER	CYPRESS CRK	IRRG	209	125		
2043-000	6	Kerr	7644600000	MARY LEE EDWARDS	CYPRESS CRK	IRRG	19.57	14.68		
2043-000	6	Kerr	7644600000	EDGAR SEIDENSTICKER ET UX	CYPRESS CRK	IRRG	16.85	12.63		
2043-000	6	Kerr	7644600000	L J MANNERING ET UX	CYPRESS CRK	IRRG	3.58	2.69		
2437-000	6	Kerr	9550000000	CHLOE CULLUM KEARNEY ET AL	N FRK GUADALUPE RIVER	REC			100	D&L. RESERVOIR JOINTLY OWNED BY SEVERAL.
2437-000	6	Kerr	9550000000	DAN W BACON ET UX	N FRK GUADALUPE RIVER	REC				D&L. RESERVOIR JOINTLY OWNED BY SEVERAL.
2438-000	6	Kerr	9528000000	LUTZ ISSLIEB ET AL	N FRK GUADALUPE RIVER	IRRG	30	18	30	
2439-000	6	Kerr	9510000000	DALE B AND MARSHA G ELMORE	N FRK GUADALUPE RIVER	IRRG	8	8	20	AMEND 10/29/90
2440-000	6	Kerr	9507000000	L F SCHERER	N FRK GUADALUPE RIVER	IRRG	1	1		
2441-000	6	Kerr	9490000000	SILAS B RAGSDALE	N FRK GUADALUPE RIVER	IRRG	21	105		
2442-000	6	Kerr	9486000000	LUTHER GRAHAM	HONEY CRK	IRRG	28	14	17	
2443-000	6	Kerr	9476500000	JOHN H DUNCAN	HONEY CRK	IRRG	40	20	25	
2444-000	6	Kerr	9980000000	BRUCE F. HARRISON	S FRK GUADALUPE RIVER	IRRG	6	3	10	
2444-000	6	Kerr	9980000000	BRUCE F. HARRISON	S FRK GUADALUPE RIVER	REC			17	
2445-000	6	Kerr	9680000000	CAMP MYSTIC INC	CYPRESS CRK	IRRG	12	15		
2445-000	6	Kerr	9680000000	CAMP MYSTIC INC	CYPRESS CRK	MUNI	14		20	
2446-000	6	Kerr	9675000000	BOB/KAT INC	S FRK GUADALUPE RIVER	IRRG	10	10		
2446-000	6	Kerr	9675000000	BOB/KAT INC	S FRK GUADALUPE RIVER	MUNI	10			
2447-000	6	Kerr	9625000000	CAMP LA JUNTA INC	S FRK GUADALUPE RIVER	IRRG	26	15	30	
2447-000	6	Kerr	9625000000	CAMP LA JUNTA INC	S FRK GUADALUPE RIVER	MUNI	14			& RECREATION
2448-000	6	Kerr	9350000000	ALICE CYNTHIA SIMKINS	TEGENER CRK	IRRG	6	5		
2449-000	6	Kerr	9310000000	BILLIE ZUBER ET AL	GUADALUPE RIVER	IRRG	17	25.5		AMEND 9/24/93:ADD ACREAGE.JUNIOR PRIORTY
2450-000	6	Kerr	7999000000	ROBERT L MOSTY ET AL	GUADALUPE RIVER	IRRG	158	117		
3769-000	1	Kerr	8300010000	CITY OF KERRVILLE	GUADALUPE RIVER	MUNI	3603		840	

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3769-000	1	Kerr	8300010000	CITY OF KERRVILLE	GUADALUPE RIVER	IRRG		192		USING 2450 AF WASTEWATER FROM SEWAGE.SC
3846-000	1	Kerr	7715000000	T & R PROPERTIES	PALMER CRK	REC	322		322	
3896-000	1	Kerr	8276000000	KENNETH W & MARCIA C MULFORD	RATTLESNAKE	MUNI			13	3 TRACTS 34.55 AC, ALSO REC
3904-000	1	Kerr	8275500000	CITY OF KERRVILLE	QUINLAN CRK	IRRG	80	56	10	& REC-2 RES-146-AC TR-EXPIRES 20 YEARS
4007-000	1	Kerr	7703100000	PECAN VALLEY RANCH OWNERS ASSO	ELM CRK	REC			157	ALSO DOMESTIC & LIVESTOCK
4034-000	1	Kerr	9040000000	SHELTON RANCHES INC	JOHNSON CRK	REC			122	2 RES, SEE FILE, & ADJ 1974
4223-000	1	Kerr	9105000000	SHELTON RANCHES INC	JOHNSON CRK	IRRG	20	14	39	
4298-000	1	Kerr	8294800000	ALISON B MENCAROW LIVING TRUST	TOWN CRK	IRRG	12	18		AMEND 12/10/91
4486-000	1	Kerr	7644900000	JAY & HILDA POTH	CYPRESS CRK	IRRG	70	35		RATE SEE 18-2041
5060-000	1	Kerr	8710000000	HORACE COFER ASSOCIATES, INC	FALL BR CRK	IRRG	10	12		
5122-000	1	Kerr	8150800000	JAMES C STORM	GUADALUPE RIVER	IRRG	75	50	8	
5208-000	1	Kerr	7701500000	JAMES F HAYES & MARY K HAYES	VERDE CRK	IRRG	40	40		
5315-000	1	Kerr	8294000000	DANA G KIRK TRUSTEE	E TOWN CRK	OTHER				PRIVATE WATER
5322-000	1	Kerr	8705000000	E RAND SOUTHARD ET UX	FALL BR	REC				
5331-000	1	Kerr	9660000000	KATHLEEN B FLOURNOY, ET AL	S FRK GUADALUPE RIVER	MUNI	15		30	& RECREATION
5331-000	1	Kerr	9660000000	KATHLEEN B FLOURNOY, ET AL	S FRK GUADALUPE RIVER	IRRG	96	30		
5348-000	1	Kerr	9526000000	BRYON DONZIS	N FRK GUADALUPE RIVER	IRRG	5	4		
5352-000	1	Kerr	9650000000	BONITA OWNERS ASSOC INC	S FRK GUADALUPE RIVER	IRRG	2	2		
5394-000	1	Kerr	8300010000	UPPER GUADALUPE RIVER AUTH	GUADALUPE RIVER	MUNI	1661			FIRM YIELD BASIS. AMENDED 4/10/98. SCS.
5394-000	1	Kerr	8300010000	UPPER GUADALUPE RIVER AUTH	GUADALUPE RIVER	MUNI	339			FIRM YIELD BASIS. AMENDED 4/10/98. SCS.
5394-000	1	Kerr	8300010000	CITY OF KERRVILLE	GUADALUPE RIVER	MUNI	761			FIRM YIELD BASIS. AMENDED 4/10/98. SCS.
5394-000	1	Kerr	8300010000	CITY OF KERRVILLE	GUADALUPE RIVER	MUNI	339			RUN OF RIVER BASIS. AMENDED 4/10/98.SCS
5394-000	1	Kerr	8300010000	CITY OF KERRVILLE	GUADALUPE RIVER	MUNI	1069			RUN OF RIVER BASIS. AMENDED 4/10/98.SCS
5401-000	1	Kerr	8156130000	H E BUTT GROCERY CO	TURTLE CRK	REC			16	EXP 12/31/2012
5402-000	1	Kerr	8155300000	TURTLE CREEK INDUSTRIES INC	TURTLE CRK	REC				
5444-000	1	Kerr	8490000000	EUGENE D ELLIS ET UX	GUADALUPE RIVER	IRRG	10	25.5		

Water Right Number	Type	County	River Order Permit	Name	Stream	Use	Amount in Ac-Ft/Yr	Acreage	Res Cap in Ac-Ft	Remarks
5479-000	1	Kerr	7701250000	CITY SOUTH MANAGEMENT CORP	GUADALUPE RIVER	IRRG	566	283		AMENDED 3/13/98
5495-000	1	Kerr	9800000000	LOIS & JOSEPH WESSENDORF ET AL	S FRK GUADALUPE RIVER	REC			9	
5521-000	1	Kerr	8300050000	DON D WILSON	GUADALUPE LAKE	IRRG	30	30		GUADALUPE RIVER
5531-000	1	Kerr	8185700000	LEE ROY COSPER ET UX	GUADALUPE RIVER	IRRG	80	40		
5536-000	1	Kerr	7701350000	ROBERT H & CHARLOTTE JENNINGS	GUADALUPE RIVER	IRRG	400	200		
5541-000	1	Kerr	9476150000	BASHARDT LTD	N FRK GUADALUPE RIVER	IRRG	14	15		
2671-000	6	Kinney	4950000000	MAVERICK CO WCID 1	RIO GRANDE	IRRG	134900	45000		& CO 162, AMEND 8/22/86,9/22/88,10/30/98
2671-000	6	Kinney	4950000000	MAVERICK CO WCID 1	RIO GRANDE	MUNI	2049			AMEND 8/22/86,9/22/88,10/30/98
2671-000	6	Kinney	4950000000	MAVERICK CO WCID 1	RIO GRANDE	REC	196			AMEND 8/22/86,9/22/88,10/30/98
2671-000	6	Kinney	4950000000	MAVERICK CO WCID 1	RIO GRANDE	HYDRO	1085966			AMEND 8/22/86,9/22/88,10/30/98
2673-000	6	Kinney	4950000000	LENDELL MARTIN ET UX	MUD CRK	IRRG	52	35	16	
2674-000	6	Kinney	4950000000	CLYDE M BRADLEY	MUD CRK	IRRG	20	15		RATE SEE 23-2673
2675-000	6	Kinney	4950000000	SHERWOOD GAINES TRUSTEE	MUD CRK	IRRG	60	30		RATE SEE 23-2673
2676-000	6	Kinney	4950000000	JEWEL FOREMAN ROBINSON	PINTO CRK	IRRG	252	126		
2677-000	6	Kinney	4950000000	MARLIN E BRAUCHLE	PINTO CRK	IRRG	21	14		
2678-000	6	Kinney	4950000000	JOHNNY E RUTHERFORD	PINTO CRK	IRRG	135	90		
2679-000	6	Kinney	4950000000	CITY OF BRACKETTVILLE	LAS MORAS SPRING	MUNI	3			
2680-000	6	Kinney	4950000000	ELISE AULGUR HUNTSMAN ET AL	LAS MORAS CRK	IRRG	15	15		JOINT OWNER OF 15 AF TO IRR 15 ACRES
2680-000	6	Kinney	4950000000	ANN A LEGG & ERNESTINE A LOPEZ	LAS MORAS CRK	IRRG				JOINT OWNER OF 15 AF TO IRR 15 ACRES
2681-000	6	Kinney	4950000000	EARL H NOBLES	LAS MORAS CRK	IRRG	10	10		
2682-000	6	Kinney	4950000000	BERNARD C MEISCHEN ET AL	LAS MORAS CRK	IRRG	25	25		
2682-000	6	Kinney	4950000000	CHARLES W GAEBLER ET AL	LAS MORAS CRK	IRRG	75	75		+50 AF FROM 7 RES FOR STOCK RAISING
2683-000	6	Kinney	4950000000	ANDREW P MALINOVSKY JR	LAS MORAS CRK	IRRG	60	30		
2684-000	6	Kinney	4950000000	BEN S JONES	ELM CRK	IRRG	47	26	6	
2685-000	6	Kinney	4950000000	EARL A KELLEY	ELM CRK	IRRG	53	35	15	
2686-000	6	Kinney	4950000000	ROBERT H MEISCHEN, ET AL	LAS MORAS CRK	IRRG	300	300		
2686-000	6	Kinney	4950000000	ROBERT H MEISCHEN, ET AL	LAS MORAS CRK	MUNI	50			4 RESERVOIRS
2687-000	6	Kinney	4950000000	CELIA R DE PLAZA, ET AL	LAS MORAS CRK	IRRG	110	55		
2913-000	6	Kinney	4950000000	MOODY RANCHES INC	RIO GRANDE	IRRG	5500	3000	17	

Water Right Number	Type	County	River Order Permit	Name	Stream	Use	Amount in Ac-Ft/Yr	Acreage	Res Cap in Ac-Ft	Remarks
2913-000	6	Kinney	4950000000	MOODY RANCHES INC	RIO GRANDE	IRRG	500	250		
3071-000	6	Kinney	7023010000	LLOYD L DAVIS	W NUECES RIVER	OTHER			25	IMPOUNDMENT
4365-000	1	Kinney	7028000000	ROBERT L MOODY JR	SPRING BR	REC	10		42	4 RES
4389-000	1	Kinney	4950000000	FORT CLARK SPRINGS ASSOC INC	LAS MORAS CRK	REC				
4517-000	1	Kinney	4950000000	FORT CLARK SPRINGS ASSOC INC	LAS MORAS CRK	REC			3	
1610-000	9	Medina	5700000000	L KEN EVANS	MEDINA RIVER	IRRG	20			LAKE MEDINA, EXP 2016
3016-000	6	Real	9615000000	JOHN H WATTS III ET UX	E PRONG NUECES RIVER	IRRG	4	2		SC. TWO PRIORITY DATES. AMEND 7/10/98
3016-000	6	Real	9615000000	JOHN H WATTS III ET UX	E PRONG NUECES RIVER	IRRG	54	27		SC. TWO PRIORITY DATES. AMEND 7/10/98
3018-000	6	Real	9450000000	LEWIS CLECKLER ET UX	SPRING CRK	IRRG	22.7	12.1		BULLHEAD HOLLOW
3018-000	6	Real	9450000000	EL CAMINO GIRL SCOUT COUNCIL	SPRING CRK	IRRG	7.3	3.9		BULLHEAD HOLLOW
3019-000	6	Real	9410000000	SARAH M DAVIS	BULLHEAD CRK	IRRG	80	40		
3019-000	6	Real	9410000000	SARAH M DAVIS	BULLHEAD CRK	IRRG		13		
3020-000	6	Real	9320000000	H C MCCARTY JR ET UX	BULLHEAD CRK	IRRG	34.736	17.368		
3020-000	6	Real	9320000000	F WALTER CONRAD JR ET UX	BULLHEAD CRK	IRRG	85.264	42.632		
3021-000	6	Real	9198500000	DSD, INC	BULLHEAD CRK	IRRG	418	210		
3022-000	6	Real	9190000000	MARVIN L BERRY	UNNAMED TRIB NUECES RIVER	IRRG	259	300	14	TRIB OF NUECES RIVER
3022-000	6	Real	9190000000	MARVIN L BERRY	UNNAMED TRIB NUECES RIVER	IRRG	485			
3025-000	6	Real	9150000000	WILLIAM C & WANDA LEA LANE	DRY CRK	IRRG	40	20	1	
3026-000	6	Real	9075000000	JOHN A DANIEL ET UX	DRY CRK	IRRG	16	8	90	
3027-000	6	Real	9050000000	J F ALSOP	DRY CRK	IRRG	20	10		
3028-000	6	Real	9040000000	CLARENCE W HARRISON ET UX	DRY CRK	IRRG	15.43	7.72	43	
3028-000	6	Real	9040000000	CLARENCE W HARRISON ET UX	DRY CRK	REC			4	
3028-000	6	Real	9040000000	W THOMAS TAYLOR ET UX	DRY CRK	IRRG	4.36	2.18		
3029-000	6	Real	9008000000	HENRY D ENGELKING	NUECES RIVER	IRRG	43	52		
3034-000	6	Real	9004000000	HERBERT C JEFFRIES ET UX	NUECES RIVER	IRRG		2		SEE ADJ 3030
3036-000	6	Real	9000000000	SALVADOR ORTIZ ET AL	NUECES RIVER	IRRG	125	50		
3037-000	6	Real	8950000000	DAVID WELDON TINDLE	NUECES RIVER	IRRG	25	25		
3050-000	6	Real	8000000000	W A MALEY	E CAMP WOOD CRK	IRRG	28	14		

Water Right Number	Type	County	River Order Permit	Name	Stream	Use	Amount in Ac-Ft/Yr	Acreage	Res Cap in Ac-Ft	Remarks
3051-000	6	Real	7980000000	ROBERT J LLOYD ET UX	E CAMP WOOD CRK	IRRG	1.42	1.42		
3051-000	6	Real	7980000000	WANNA LOU LLOYD	E CAMP WOOD CRK	IRRG	4.08	4.08		
3052-000	6	Real	7970000000	BARRY BLANKS MCHALEK ET UX	E CAMP WOOD CRK	IRRG	5	5		SEE ADJ 3051
3053-000	6	Real	7960000000	BARRY BLANKS MCHALEK ET UX	E CAMP WOOD CRK	IRRG	1	1		SEE ADJ 3051
3054-000	6	Real	7950000000	JOHN CHAMBERS ET AL	E CAMP WOOD CRK	IRRG	10	10		SEE ADJ 3051
3055-000	6	Real	7900000000	WILLIAM C & PATRICIA K SUTTON	E CAMP WOOD CRK	IRRG	105	130	2	
3056-000	6	Real	7810000000	ROY GIBBENS	E CAMP WOOD CRK	IRRG	18	9	4	
3056-000	6	Real	7810000000	ROY GIBBENS	E CAMP WOOD CRK	IRRG	2			
3057-000	6	Real	7800000000	MAGELEE V SWIFT	E CAMP WOOD CRK	IRRG	21	16	8	SEE ADJ 3056
3057-000	6	Real	7800000000	MAGELEE V SWIFT	E CAMP WOOD CRK	IRRG	10	4	4	
3058-000	6	Real	7740000000	DOROTHY MERRITT ANDERSON	NUECES RIVER	IRRG	8	8		
3059-000	6	Real	7730000000	F L JR & CHARLOTTE HATLEY	NUECES RIVER	IRRG	11	7		
3060-000	6	Real	7631000000	E E GILDART	NUECES RIVER	IRRG	42	21		
3060-000	6	Real	7631000000	E E GILDART	NUECES RIVER	IRRG	54	26		
3060-000	6	Real	7631000000	E E GILDART	NUECES RIVER	IRRG	35	46		
3061-000	6	Real	7630000000	E E GILDART	NUECES RIVER	IRRG	31	31		
3062-000	6	Real	7550000000	JOANNE FRIEND	NUECES RIVER	IRRG	46	46		
3145-000	6	Real	3900000000	GEORGE S HAWN INTERESTS ET AL	S P/L P W FRIO RIVER	REC			27	
3145-000	6	Real	3900000000	GEORGE S HAWN INTERESTS ET AL	S P/L P W FRIO RIVER	REC			68	
3145-000	6	Real	3900000000	GEORGE S HAWN INTERESTS ET AL	S P/L P W FRIO RIVER	IRRG	156	78		
3146-000	6	Real	3850000000	JAMES W HALE ET AL	W FRIO RIVER	REC			16	
3147-000	6	Real	3810000000	DIAMOND J RANCH INC	W FRIO RIVER	IRRG	165	55		
3148-000	6	Real	3750000000	H. E. BUTT FOUNDATION	E FRIO RIVER	REC	3.5		10	
3148-000	6	Real	3750000000	H. E. BUTT FOUNDATION	E FRIO RIVER	IRRG	6.5	2		UPPER SINGING HILLS RESERVOIR
3148-000	6	Real	3750000000	H. E. BUTT FOUNDATION	E FRIO RIVER	REC	11		11	UNNAMED DOWNSTREAM RESERVOIR (D-0340)
3148-000	6	Real	3750000000	H. E. BUTT FOUNDATION	E FRIO RIVER	IRRG	34.8	12.9		UNNAMED RESERVOIR (D-0340)
3148-000	6	Real	3750000000	H. E. BUTT FOUNDATION	E FRIO RIVER	IRRG	6.7	2.5		UNNAMED RESERVOIR (D-0340)

Water Right Number	Type	County	River Order Permit	Name	Stream	Use	Amount in Ac-Ft/Yr	Acreage	Res Cap in Ac-Ft	Remarks
3148-000	6	Real	3750000000	H. E. BUTT FOUNDATION	E FRIO RIVER	REC	25.08		25.08	LINNET'S WINGS DAM (D-0220);AMEND 3/91
3148-000	6	Real	3750000000	H. E. BUTT FOUNDATION	E FRIO RIVER	IRRG	3.2	1.2		LINNET'S WINGS DAM (D-0220)
3148-000	6	Real	3750000000	H. E. BUTT FOUNDATION	E FRIO RIVER	REC	34		68.7	LAITY LODGE DAM (D-0240);AF/WATERFALL
3148-000	6	Real	3750000000	H. E. BUTT FOUNDATION	E FRIO RIVER	IRRG	4	2		LAITY LODGE DAM (D-0240)
3148-000	6	Real	3750000000	H. E. BUTT FOUNDATION	E FRIO RIVER	REC	5.51		5.51	LOWER SINGING HILLS DAM (D-0280)
3148-000	6	Real	3750000000	H. E. BUTT FOUNDATION	E FRIO RIVER	IRRG	4.1	1.5		LOWER SINGING HILLS DAM (D-0280)
3148-000	6	Real	3750000000	H. E. BUTT FOUNDATION	E FRIO RIVER	REC	2.64		2.64	SILVER CREEK DAM (D-0300)
3148-000	6	Real	3750000000	H. E. BUTT FOUNDATION	E FRIO RIVER	REC	0.24		0.24	LOWER SILVER CREEK DAM (D-0320)
3148-000	6	Real	3750000000	H. E. BUTT FOUNDATION	E FRIO RIVER	REC	17.86		17.86	ECHO VALLEY DAM (D-0360)
3149-000	6	Real	3660000000	ORA L ROGERS ESTATE	E FRIO RIVER	IRRG	30	28		
3150-000	6	Real	3655000000	R F BINDOCK	E FRIO RIVER	IRRG	3	11		
3151-000	6	Real	3620000000	KATHERINE MAXINE MORELAND	E FRIO RIVER	IRRG	67	30		
3152-000	6	Real	3600000000	DAN AULD, JR	E FRIO RIVER	IRRG	324	162		
3153-000	6	Real	3490000000	JOHN J BURDITT, ET AL	UNNAMED TRIB E FRIO RIVER	IRRG	15	50		
3153-000	6	Real	3490000000	JOHN J BURDITT, ET AL	UNNAMED TRIB E FRIO RIVER	IRRG	23			
3154-000	6	Real	3430000000	JAMES TREES	YOUNGBLOOD SPRING	IRRG	2	6		
3155-000	6	Real	3420000000	LOTTIE N WRIGHT	FRIO RIVER	IRRG	164	43		
3156-000	6	Real	3400000000	H P COOPER ET AL	FRIO RIVER	IRRG	20	22		
3156-000	6	Real	3400000000	H P COOPER ET AL	FRIO RIVER	IRRG	2			
3157-000	6	Real	3350000000	E F BAYOUTH, MD PENSION PLAN	FRIO RIVER	IRRG	250	125		AMEND 1/9/85. CURRENT OWNER UNKNOWN 5/98
3158-000	6	Real	3375000000	LOMBARDY IRRIGATION CO	FRIO RIVER	IRRG	1600	800	6	ALSO COUNTY 232
3159-000	6	Real	3294000000	SAM G HARRISON	FRIO RIVER	IRRG	140	70		
3160-000	6	Real	3290000000	GRACIA BASSETT HABY	FRIO RIVER	IRRG	60	100		JOINTLY OWNS 60 AF TO IRR 100 ACRES
3160-000	6	Real	3290000000	THEODORE R REED TRUSTEE	FRIO RIVER	IRRG				JOINTLY OWNS 60 AF TO IRR 100 ACRES
3161-000	6	Real	3289500000	R L HUBBARD	DRY FRIO CRK	IRRG	17	21		
3162-000	6	Real	3287500000	CARL A. DETERING, JR., ET AL	UNNAMED TRIB BUFFALO CRK	IRRG	5	25	15	

Water Right Number	Type	County	River Order Permit	Name	Stream	Use	Amount in Ac-Ft/Yr	Acreage	Res Cap in Ac-Ft	Remarks
3180-000	6	Real	2799000000	LANA J STORMONT	UNNAMED TRIB W SABINAL RIVER	IRRG	5	10		
3878-000	1	Real	3645000000	C B SLABAUGH	CYPRESS CRK	IRRG	40	30		68-AC TR, SC, AMEND 11/12/84
3978-000	1	Real	9421000000	N M FITZGERALD JR ESTATE	FLYNN CRK	IRRG	187	63		156.95-AC TR, SC
4008-000	1	Real	9172500000	DOUGLAS B & MARGARET MARSHALL	NUECES RIVER	IRRG	400	200		AMEND 12/15/81 INCR AC-FT, ACRES, CFS
4094-000	1	Real	3905500000	GEORGE S HAWN INTERESTS ET AL	W FRIO RIVER	IRRG	56	28	9	OUT OF 1118 ACRES
4169-000	1	Real	7910000000	ROARING SPRINGS RANCH INC	CAMP WOOD CRK	IRRG	15	10	41	6 RES & REC
4169-000	1	Real	7910000000	ROARING SPRINGS RANCH INC	CAMP WOOD CRK	MUNI	15			
4405-000	1	Real	7760000000	CITY OF CAMP WOOD	UNNAMED TRIB NUECES RIVER	MUNI	1000			
4405-000	1	Real	7760000000	CITY OF CAMP WOOD	UNNAMED TRIB NUECES RIVER	IRRG	83	16		
4413-000	1	Real	8240000000	WILLIAM C SUTTON ET UX	CAMP WOOD CRK	REC			2	
5009-000	1	Real	3830000000	JACKSON L BABB ET AL	W FRIO RIVER	IRRG	60	30		
2653-000	6	Val Verde	4950000000	PHIL B FOSTER	CIENEGAS CRK &/OR THE RIO GRANDE	IRRG	122.25	61.13		AMEND 10/15/91
2653-000	6	Val Verde	4950000000	DAVID B TERK ET AL	CIENEGAS CRK	IRRG	27.75	13.87		AMEND 10/15/91
2654-000	6	Val Verde	4950000000	THURMAN W OWENS	CIENEGAS CRK	IRRG	26	13		RATE SEE 23-2653
2655-000	6	Val Verde	4950000000	JOSE C OVIEDO ET UX	CIENEGAS CRK	IRRG	28	14		RATE SEE 23-2653
2656-000	6	Val Verde	4950000000	RANDOLPH J N & SHARON M ABBEY	CIENEGAS CRK	IRRG	68	43		RATE SEE 23-2653
2657-000	6	Val Verde	4950000000	RONALD J PERSYN ET UX	CIENEGAS CRK	IRRG	150	75		RATE SEE 23-2653
2657-000	6	Val Verde	4950000000	RONALD J. PERSYN, ET UX	CIENEGAS CRK	IRRG	150	68		SEE 23-2653 RATE; AMEND 10/89
2657-000	6	Val Verde	4950000000	RONALD J. PERSYN, ET UX	CIENEGAS CRK	IRRG		89		AMEND 8/2/94
2659-000	6	Val Verde	4950000000	JOHN F QUALIA	CIENEGAS CRK	IRRG	112	56		FOR RATE SEE 23-2653
2660-000	6	Val Verde	4950000000	JOSE A CORTINAS ET AL	CIENEGAS CRK	IRRG	16	5		
2660-000	6	Val Verde	4950000000	LJB ENTERPRISES	CIENEGAS CRK	IRRG	296	99		
2661-000	6	Val Verde	4950000000	BARBARA GULICK RATHKE, ET AL	CIENEGAS CRK	IRRG	120	40	10	
2662-000	6	Val Verde	4950000000	CAPITOL AGGREGATES INC	CIENEGAS CRK	MINE	166	17		AMEND 11/2/87

Water Right Number	Type	County	River Order Permit	Name	Stream	Use	Amount in Ac-Ft/Yr	Acreage	Res Cap in Ac-Ft	Remarks
2663-000	6	Val Verde	4950000000	ALFREDO GUTIERREZ JR	CIENEGAS CRK	IRRG	24	8		
2664-000	6	Val Verde	4950000000	SAN FELIPE A MFG & I COMPANY	SAN FELIPE CRK	IRRG	4950	1700		AMEND 12/16/88, 10/31/94
2664-000	6	Val Verde	4950000000	SAN FELIPE A MFG & I COMPANY	SAN FELIPE CRK	IRRG	6		6	IMPOUNDMENT #1
2664-000	6	Val Verde	4950000000	SAN FELIPE A MFG & I COMPANY	SAN FELIPE CRK	IRRG	6		6	IMPOUNDMENT #2
2664-000	6	Val Verde	4950000000	SAN FELIPE A MFG & I COMPANY	SAN FELIPE CRK	INDU	50			AMENDMENT EXP 12/31/96
2665-000	6	Val Verde	4950000000	JOSE OVIEDO JR ET UX	SAN FELIPE CRK	IRRG	60	40		AMENDED 9/13/96
2666-000	6	Val Verde	4950000000	PETRA ABREGO MUNOZ	SAN FELIPE CRK	IRRG	23.56	7.85		
2669-000	6	Val Verde	4950000000	RODOLFO MOTA	SAN FELIPE CRK	IRRG	6	2		
2670-000	6	Val Verde	4950000000	VICTOR D BOLNER	SAN FELIPE CRK	IRRG	6	3		
2672-000	6	Val Verde	4950000000	CITY OF DEL RIO	SAN FELIPE CRK	MUNI	4416			
2672-000	6	Val Verde	4950000000	CITY OF DEL RIO	SAN FELIPE CRK	MUNI	7000			
2811-000	6	Val Verde	4950000000	RIO BRAVO INC	CIENEGAS CRK &/OR THE RIO GRANDE	IRRG	51.08	997.97	47	& REC/DOM, AMEND 1/84,6/91
2811-000	6	Val Verde	4950000000	DAVID B TERK	CIENEGAS CRK	IRRG	114.64	95.38		
2912-000	6	Val Verde	4950000000	MOODY RANCHES INC	SAN FELIPE CRK	IRRG	800	400	10	
3880-000	1	Val Verde	4950000000	SOUTH TEXAS ELECTRIC CO-OP INC	RIO GRANDE	HYDRO	1500000			AMEND 12/14/87. POWER POOL WITH MEDINA.
3880-000	1	Val Verde	4950000000	MEDINA ELECTRIC CO-OP INC	RIO GRANDE	HYDRO				AMEND 12/14/87. POWER POOL WITH S.TX.EL.
5506-000	1	Val Verde	4950000000	DEL RIO, CITY OF	SAN FELIPE CRK	REC			0.19	WATER PARK LANDING POOL

APPENDIX 3B

OCCURRENCE OF SIGNIFICANT RIVER ALLUVIUM AQUIFERS IN THE PLATEAU REGION

Occurrence of Significant River Alluvium Aquifers in the Plateau Region

Prepared for:

Plateau Region Water Planning Group
and
Texas Water Development Board

January 2010

LBG-Guyton Associates

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1.0 Occurrence of River Alluvium in the Plateau Region

1.1 Introduction

The Plateau Region contains five river basins, four of which represent the headwaters of these rivers or their tributaries. Variable widths and thicknesses of floodplain deposits, or alluvium, are characteristic of these stream courses. Figure 1 illustrates the extent of all river alluvium in the Plateau Region. The Plateau Region Water Planning Group recognizes that river alluvium aquifers have not been adequately documented in the Plateau Regional Water Plan. The previous Plan published in 2006 recognized only the Frio River Alluvium Aquifer in Real County and estimated its water supply availability as a factor of recharge over a limited portion of the alluvial outcrop area.

This current study evaluates all river alluviums throughout the Region except in Val Verde County. River alluviums that were found to contain a viable aquifer were further analyzed to estimate reasonable and quantifiable annual water supply availability. Availability volumes that are considered relevant by the residing groundwater conservation district will be provided in the appropriate Chapter 3 tables of the 2011 Plateau Region Water Plan.

1.2 Origin and Hydrologic Characteristics

Precipitation runoff moves rapidly down gradient from the highlands of the Edwards Plateau. As the surface water gravity flows to the east and south, the various riverbeds continuously erode deeper into the Edwards limestone formations creating along the way spectacular canyons and relatively narrow floodplains. Once the streambed has incised through the Edwards and exposed the underlying Trinity - Glen Rose Limestone, the gradient of the river lessens. With a slower rate of flow, the active riverbed may meander from side to side, thus creating an ever-widening floodplain relative to the upstream canyons. Periods of intense rainfall often cause the rivers to overspill their banks with sediment-laden floodwaters that continuously contribute to the thickness of the developing floodplain. These floodplain deposits ranging in size from silt to gravel are collectively referred to as river alluvium.

Water in the form of rainfall, surface runoff from adjacent highlands, and occasional flood overflows percolate downward into the alluvial sediments where it generally moves slowly through the floodplain system, eventually draining to the river where it contributes to the base flow of the river. This captured groundwater may accumulate in sufficient volumes to be considered a viable aquifer capable of supplying water to wells. However, due to the relatively thin nature of the water-bearing thickness, alluvial aquifers generally produce only low to moderate yields to wells.

1.3 Methodology

The evaluation of river alluviums entailed two phases, the consideration of the existence of groundwater in all river alluviums and the quantification of groundwater availability in those river alluviums that were considered to contain a viable aquifer. The potential for the existence of groundwater in sufficient quantities to allow flow to wells was evaluated based on the compilation and evaluation of recorded well data from: 1) wells listed in the TWDB groundwater database and retrieval through the Board's WIID system; 2) drillers logs also retrievable from the TWDB WIID system; and 3) well data housed with local groundwater conservation districts. All identified wells located within a mile of the river channels were placed on surface geologic maps (GAT sheets). The wells were then evaluated based on location in reference to a floodplain area, on well depth, and on driller's lithologic descriptions. The number of wells considered to be producing from alluvial aquifers in each river basin are listed in Table 1. Driller’s lithologic log descriptions were also used to compute the average depth to the base of alluvial sediments.

Table 1. Alluvial Wells Used for Analysis per Basin

Basin	Well Count
Guadalupe	7
Medina	0
Sabinal	2
South Llano	0
West Nueces	4
Nueces	29
Frio	55 with locations
	158 RECRD database

In addition, managers of the Bandera County River Authority and Groundwater District, the Headwaters Groundwater Conservation District, and the Real-Edwards Conservation and Reclamation District were interviewed in regard to their knowledge of existing wells completed in the alluvial systems within their respective districts. Based on the above evaluation, only the Guadalupe, Nueces, and Frio River Alluviums were considered to contain viable aquifers.

Phase Two provided the quantification of annual groundwater availability from the three alluvial aquifers. The quantification process required certain assumptions. Due to the potential variable nature of these assumptions, other researchers could reach different conclusions. Two basic assessments are made for each aquifer, water in storage and recharge.

Water in storage within the aquifer is based on area of significant alluvial outcrop times the average saturated thickness times a specific yield of 15 percent. The area of significant alluvial outcrop is arbitrarily set at 70 percent of the total area of alluvial outcrop for the Guadalupe and Nueces Alluviums and 90 percent for the Frio Alluvium. Average saturated thickness is the average depth to the base of the lowest gravel layer in the alluvium minus the average depth to groundwater.

To test the assumption that only a portion (70-90 percent) of the total outcrop area contains sufficient volumes of water such that leakage to the river occurs, gain-loss study data were reviewed to determine stretches of the Frio River that appear to be receiving inflow from the adjacent alluvium. As can be seen in Figure 8, the data illustrates that the river is losing flow to the underlying bedrock in the upper two branches above Leakey where the alluvium coverage is narrow. From the confluence of the two upper branches downstream to the southern county line, the data shows that the river is gaining as groundwater in the alluvium and bedrock springs discharge to the river course.

Recharge is computed as total area of alluvial outcrop times the average annual rainfall times a recharge factor of 0.04 percent. Average annual rainfall in the Guadalupe, Nueces, and Frio basins is 29, 25 and 27 inches respectively.

The final computation of total (annual) groundwater availability is calculated as annual average recharge plus a portion of water in storage. To avoid over estimating availability, an assumption is made that only one-tenth of the volume of water in storage is available to be depleted in any one year. It is further assumed that any storage depletion would be replenished by recharge in years when rainfall was above average. Summaries of these computations are provided for the three alluvial aquifers in Tables 2, 3 and 4.

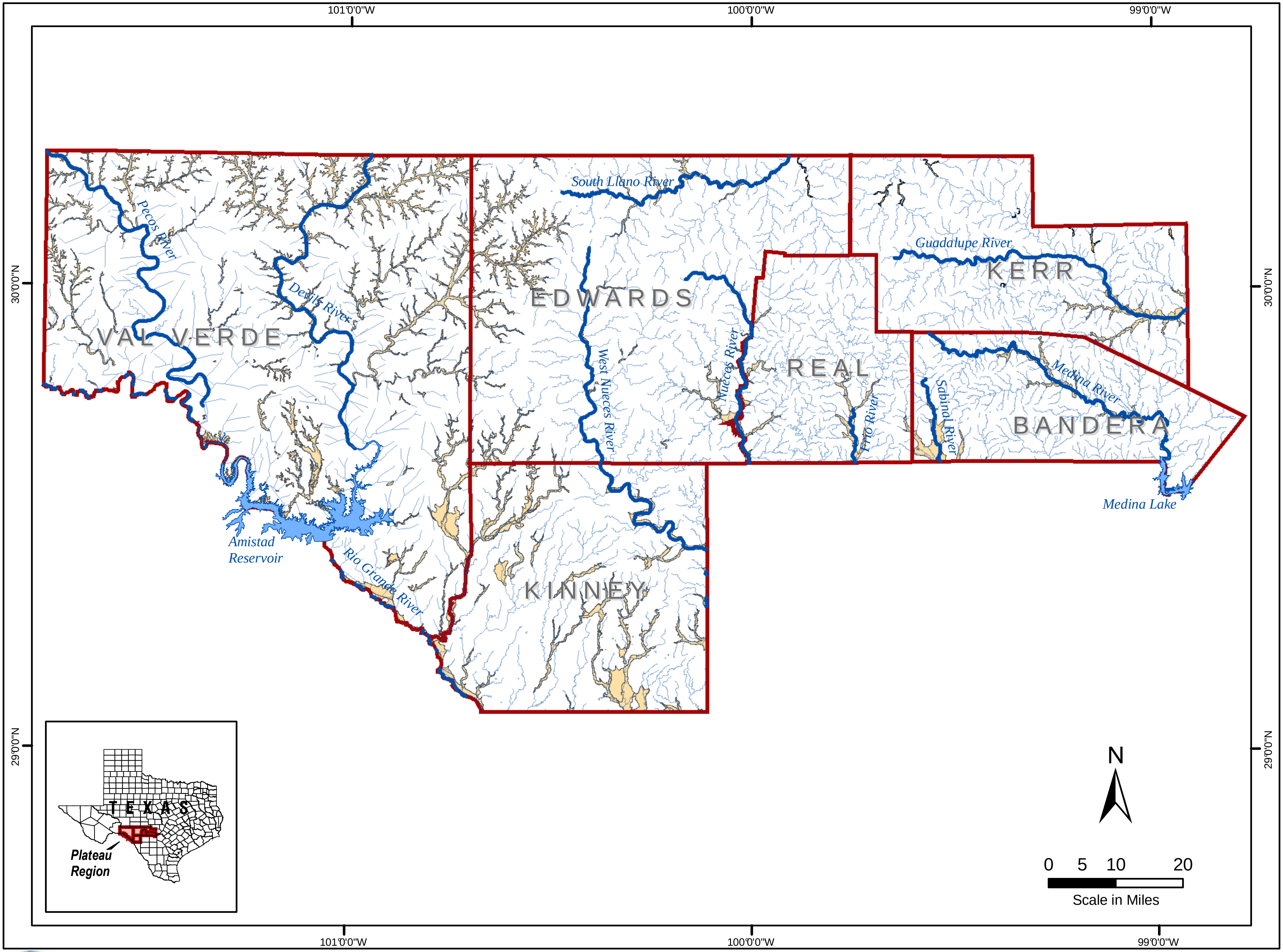

FIGURE 1
EXTENT OF ALL RIVER ALLUVIUM IN THE PLATEAU REGION

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2.0 River Basins

2.1 Guadalupe River Alluvium

Seven alluvial wells identified in the Guadalupe River Alluvium are shown on Figure 2. Note that these locations do not coincide with irrigation pivots that are visible along the river from SH 27 downstream from Kerrville; these pivots utilize surface water taken directly from the Guadalupe River. Many alluvial wells in Kerr County are not registered with Headwaters Groundwater Conservation District, therefore there are likely to be numerous unrecognized additional wells. Due to the minimal number of wells on file that are available to characterize the formation, only a limited analysis was performed on the main alluvial segment from Kerrville downstream to the county line. After consultation with the Headwaters Groundwater Conservation District, the groundwater availability estimated from this analysis is not included in the Plateau Region Water Plan Chapter 3 listing of water-supply sources.

Table 2. Guadalupe River Alluvium Aquifer

Parameter	Estimated Value
Total Area of Alluvium Outcrop	8,928 ac
Area of Significant Alluvium Outcrop *(70%)*	6,250 ac
Average Depth to Base of Alluvium	30 ft
Average Depth to Water	20 ft
Average Saturated Thickness	10 ft
Saturated Volume of Alluvium *(Significant Area x Saturated Thickness)*	62,500 ac-ft
Volume of Water in Storage *(Sat. Vol. of Alluv. x Specific Yield [15%])*	9,375 ac-ft
Average Annual Recharge *(Total Outcrop Area x 29 in/yr x .04)*	857 ac-ft/yr
Total Groundwater Availability *(Recharge + 0.1 Vol. Water in Storage)*	1,795 ac-ft/yr

2.2 Medina and Sabinal River Alluviums

No alluvial wells are listed in the TWDB groundwater database in the Medina River Alluvium, and only two wells are identified in the upper reaches of the Sabinal River basin are shown on Figure 3. Due to the minimal number of alluvial wells identified in these basins and after consultation with the Bandera County River Authority and Groundwater District, no further analyses of groundwater availability from these particular alluviums were considered necessary.

2.3 South Llano River Alluvium

As no alluvial wells are listed in the TWDB groundwater database in the South Llano River Alluvium (Figure 4) and the indication that the existing alluvium is very thin, no further analyses of groundwater availability from this particular alluvium was considered necessary.

2.4 West Nueces River Alluvium

Only four alluvial wells identified in the West Nueces River Alluvium are shown on Figure 5. Due to the minimal number of alluvial wells identified in this basin and the indication that the existing alluvium is very thin, no further analysis of groundwater availability from this alluvium was considered necessary.

2.5 Nueces River Alluvium

Twenty-nine alluvial wells identified in the Nueces River Alluvium are shown on Figure 6. The Real-Edwards Conservation and Reclamation District is scheduled to collect additional well data for this aquifer system in the near future. As a result of a significantly larger outcrop area, the availability volume calculated for the Nueces Alluvium is greater than the volume reported for the Frio Alluvium. However, due to thinner average saturated thickness, average well yields may be less in the Nueces Alluvium. The Community of Barksdale pumps groundwater from this aquifer for public supply use. Analysis of potential groundwater availability in the Nueces River Alluvium is as follows:

Table 3. Nueces River Alluvium Aquifer

Parameter	Estimated Value
Total Area of Alluvium Outcrop	24,450 ac
Area of Significant Alluvium Outcrop *(70%)*	17,115 ac
Range in Depth to Base of Alluvium	17-35 ft
Average Depth to Base of Alluvium	25 ft
Range in Depth to Water	10-35 ft
Average Depth to Water	19 ft
Average Saturated Thickness	6 ft
Saturated Volume of Alluvium *(Significant Area x Saturated Thickness)*	102,690 ac-ft
Volume of Water in Storage *(Sat. Vol. of Alluv. x Specific Yield [15%])*	15,404 ac-ft
Average Annual Recharge *(Total Outcrop Area x 25 in/yr x .04)*	2,034 ac-ft/yr
Total Groundwater Availability *(Recharge + 0.1 Vol. Water in Storage)*	3,574 ac-ft/yr

2.6 Frio River Alluvium

The 32 alluvial wells identified in the Frio River Alluvium are shown on Figure 7. The Real-Edwards Conservation and Reclamation District has a total of 158 wells listed as being completed in the Frio River Alluvium; however, only 55 of these wells have location coordinates for display on Figure 7, some of which are duplicates of TWDB database wells. Of the 158 wells, 144 wells have sufficient well log data to calculate a saturated thickness (10 feet average) and average well yield of 31 GPM. The district feels that there may be several hundred additional undocumented wells in the Frio Alluvium. The City of Leakey, along with several other small public water supply corporations, pumps groundwater from this aquifer for public supply use. Analysis of potential groundwater availability in the Frio River Alluvium is as follows:

Table 4. Frio River Alluvium Aquifer

Parameter	Estimated Value
Total Area of Alluvium Outcrop	9,530 ac
Area of Significant Alluvium Outcrop *(90%)*	8,577 ac
Range in Depth to Base of Alluvium	15-42 ft
Average Depth to Base Alluvium*	32 ft
Range in Depth to Water	5-35 ft
Average Depth to Water*	22 ft
Average Saturated Thickness*	10 ft
Saturated Volume of Alluvium *(Significant Area x Saturated Thickness)*	85,770 ac-ft
Volume of Water in Storage *(Sat. Vol. of Alluv. x Specific Yield [15%])*	12,866 ac-ft
Average Annual Recharge *(Total Outcrop Area x 27 in/yr x .04)*	858 ac-ft/yr
Total Groundwater Availability *(Recharge + 0.1 Vol. Water in Storage)*	2,145 ac-ft/yr
** Averages based on data from 144 wells in RECRD database.*	

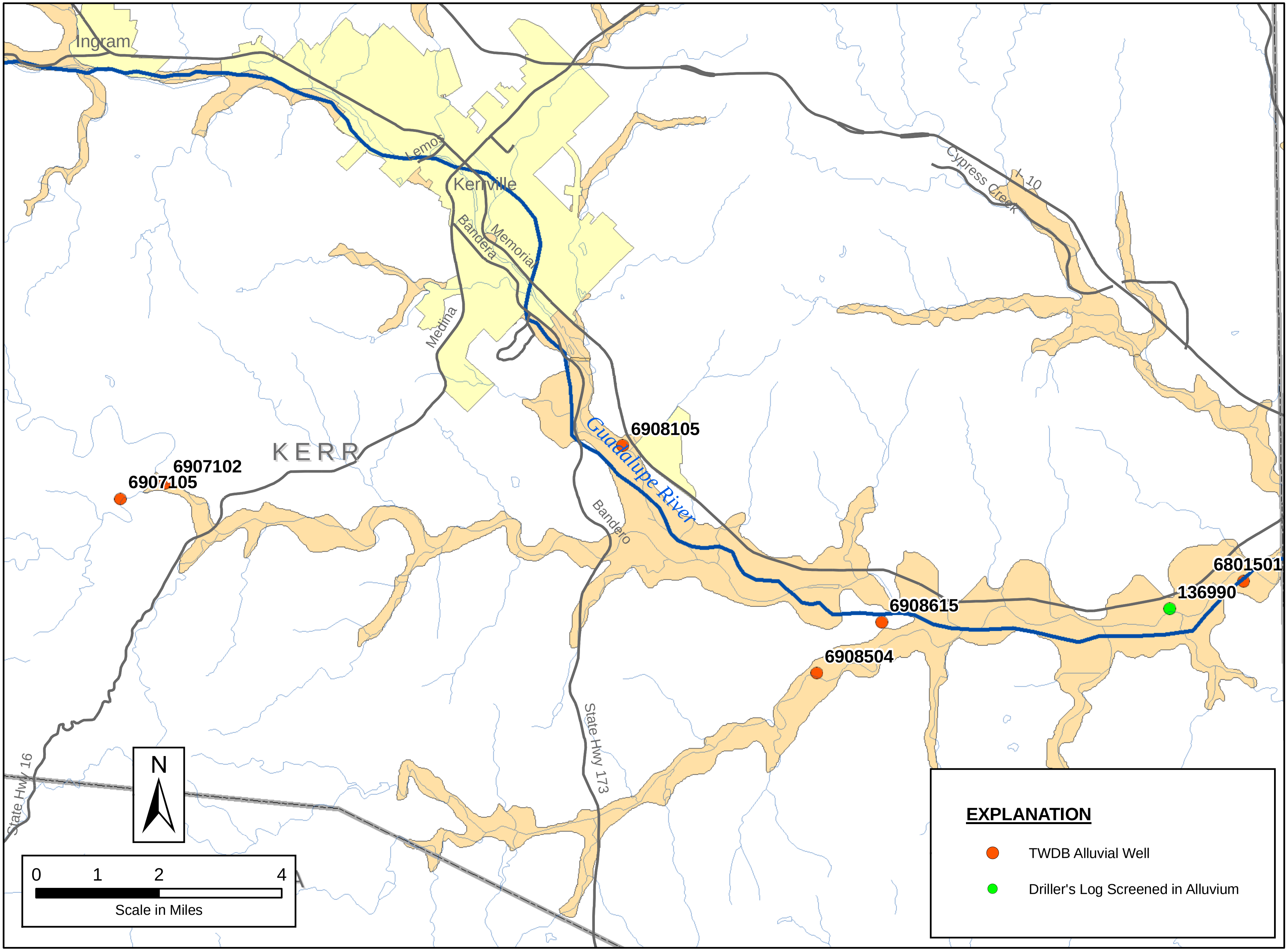

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FIGURE 2
RIVER ALLUVIUM IN THE GUADALUPE RIVER
EASTERN KERR COUNTY, TEXAS

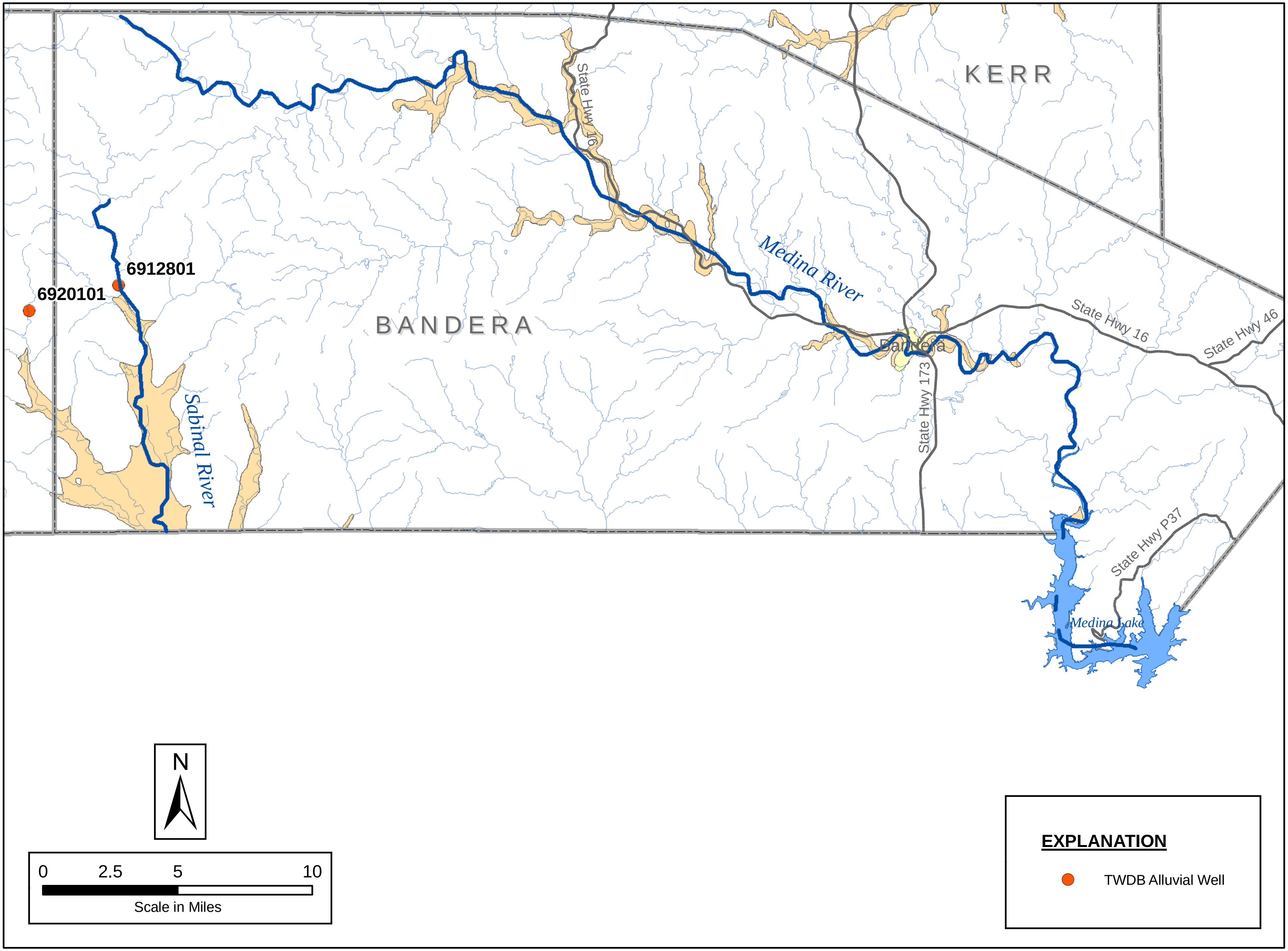

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FIGURE 3
RIVER ALLUVIUM IN THE MEDINA AND SABINAL RIVERS
BANDERA COUNTY, TEXAS

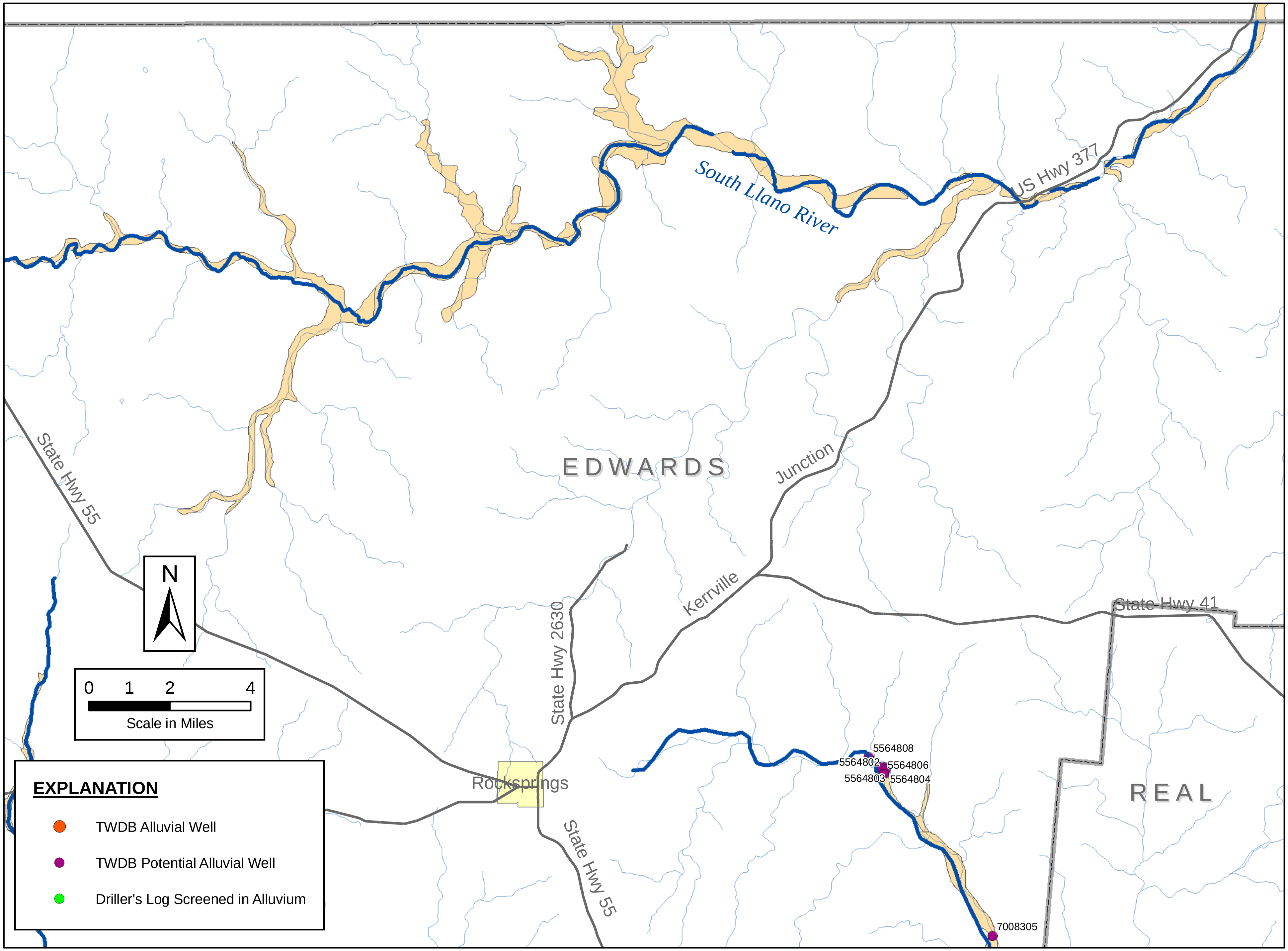

FIGURE 4
RIVER ALLUVIUM IN THE SOUTH LLANO RIVER
EDWARDS COUNTY, TEXAS

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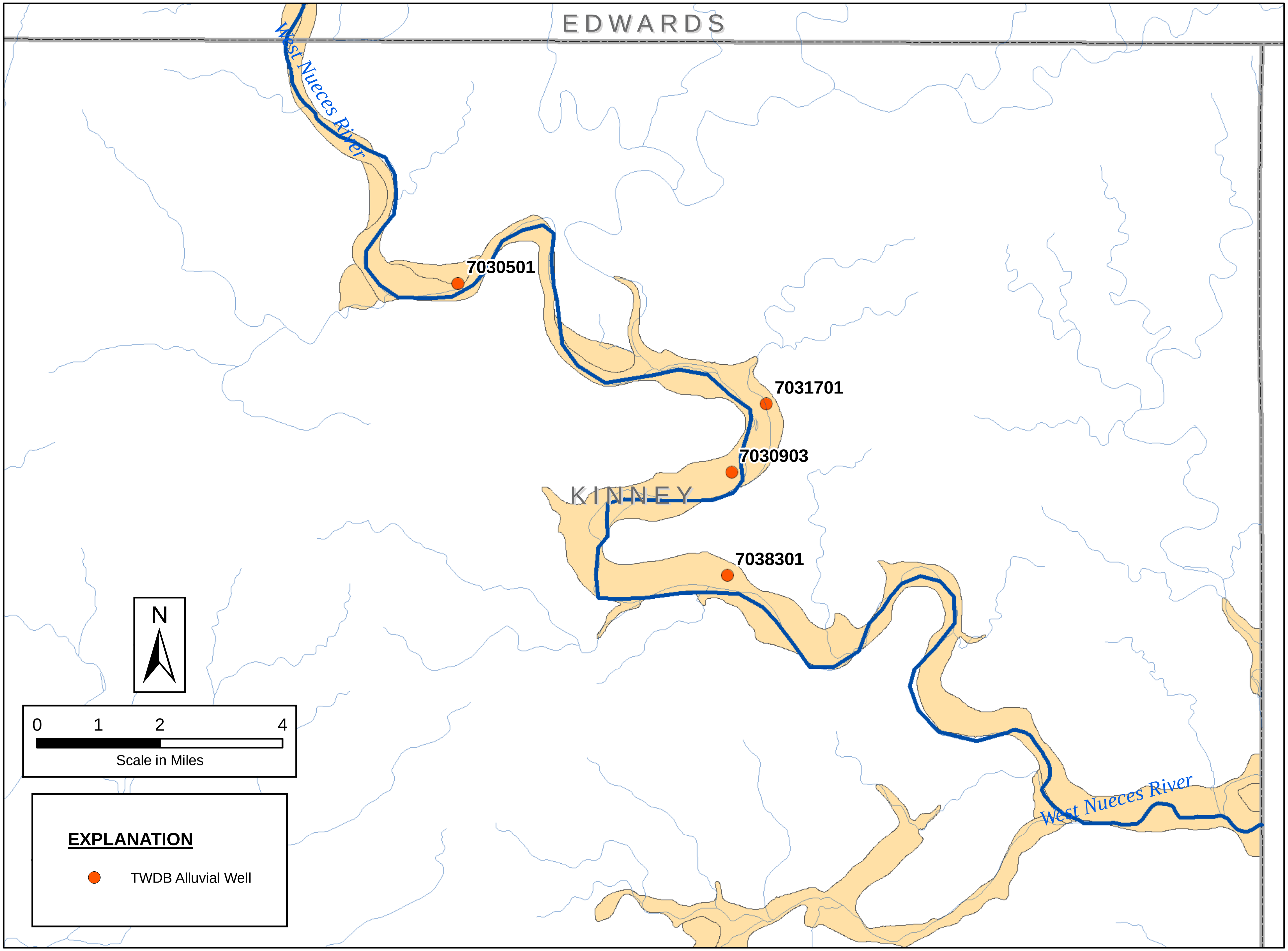

FIGURE 5
RIVER ALLUVIUM IN THE WEST NUECES RIVER
NORTHEASTERN KINNEY COUNTY, TEXAS

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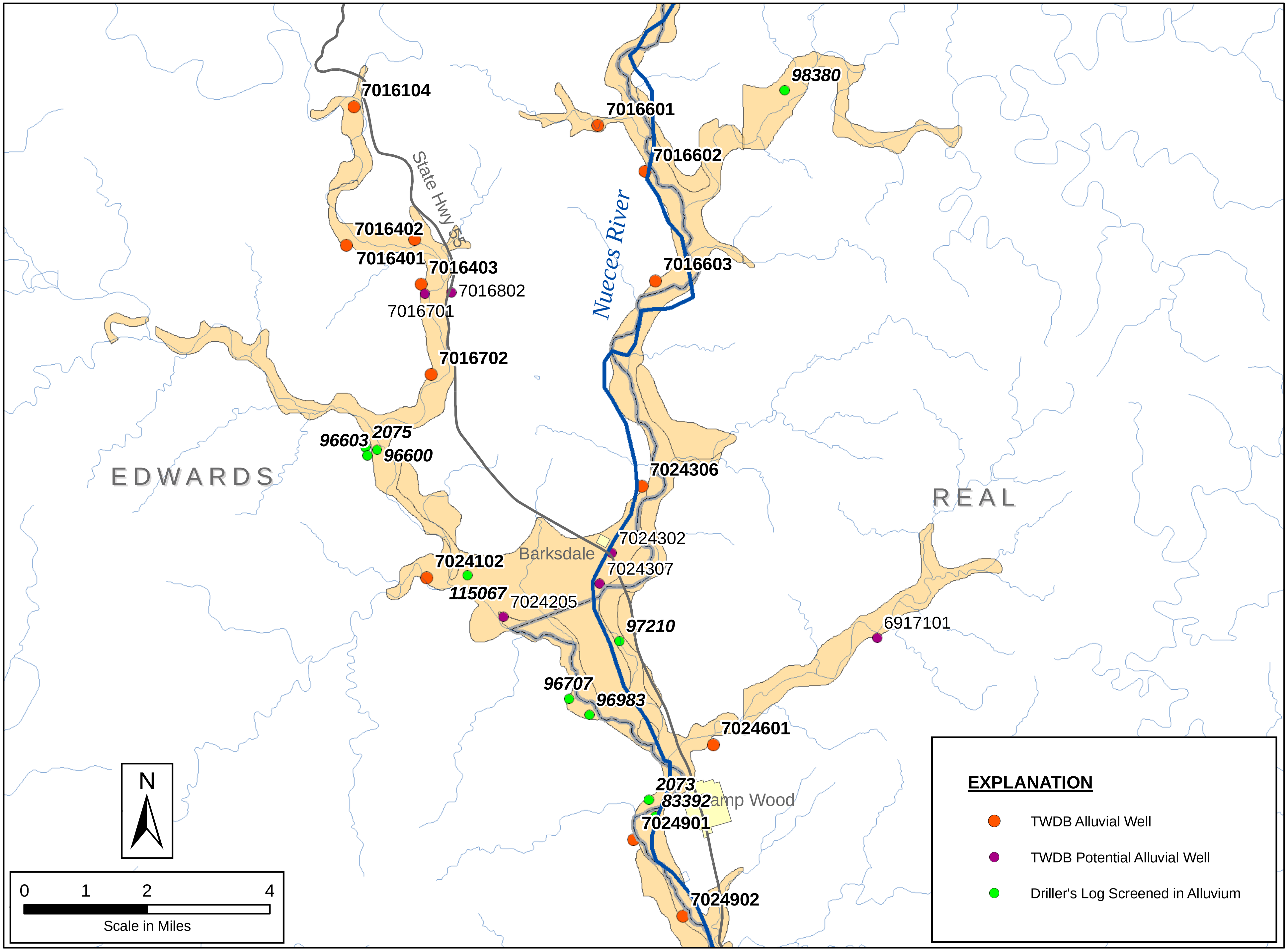

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FIGURE 6
RIVER ALLUVIUM IN THE NUECES RIVER
EDWARDS AND REAL COUNTIES, TEXAS

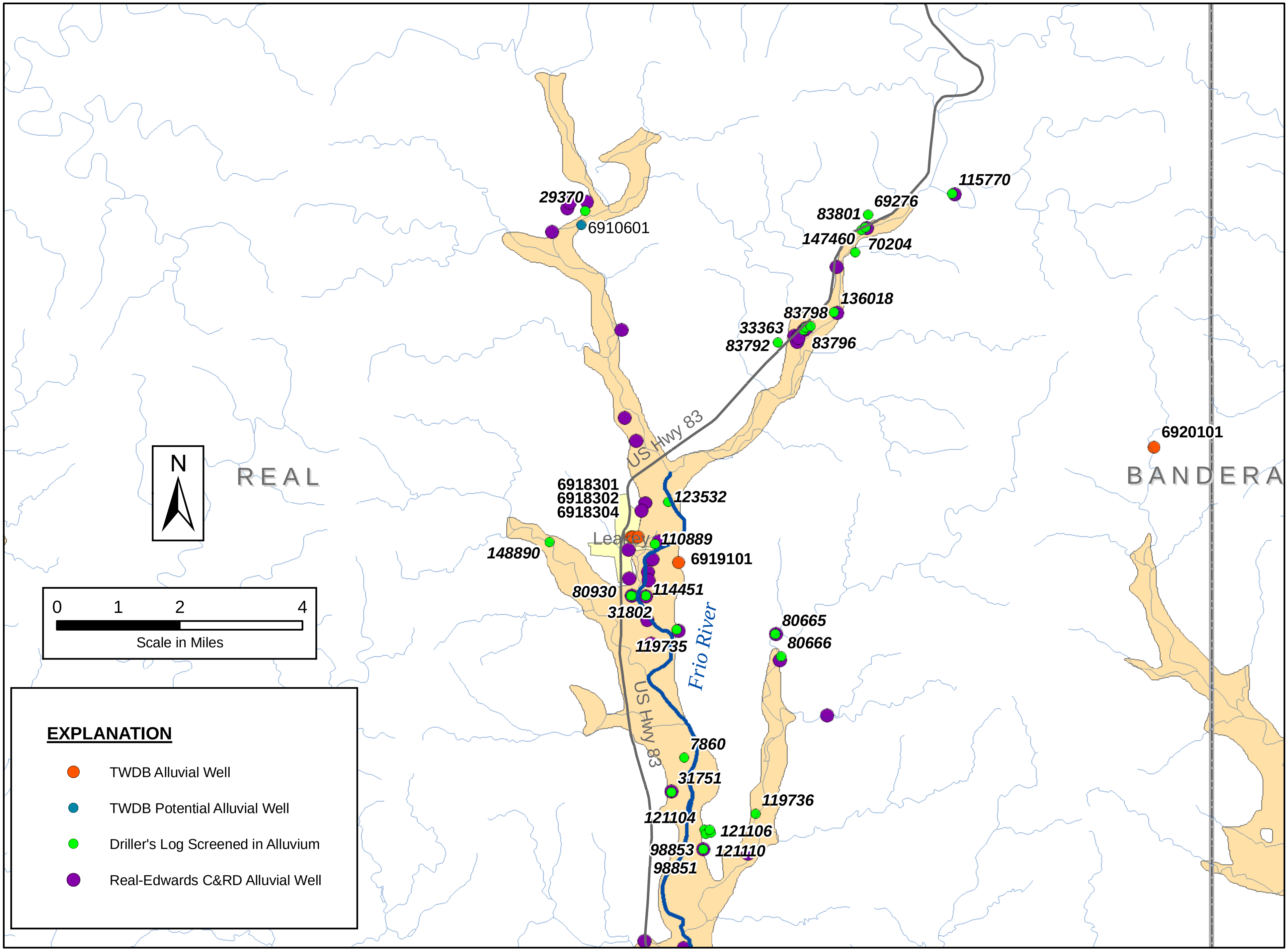

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FIGURE 7
RIVER ALLUVIUM IN THE FRIO RIVER
REAL COUNTY, TEXAS

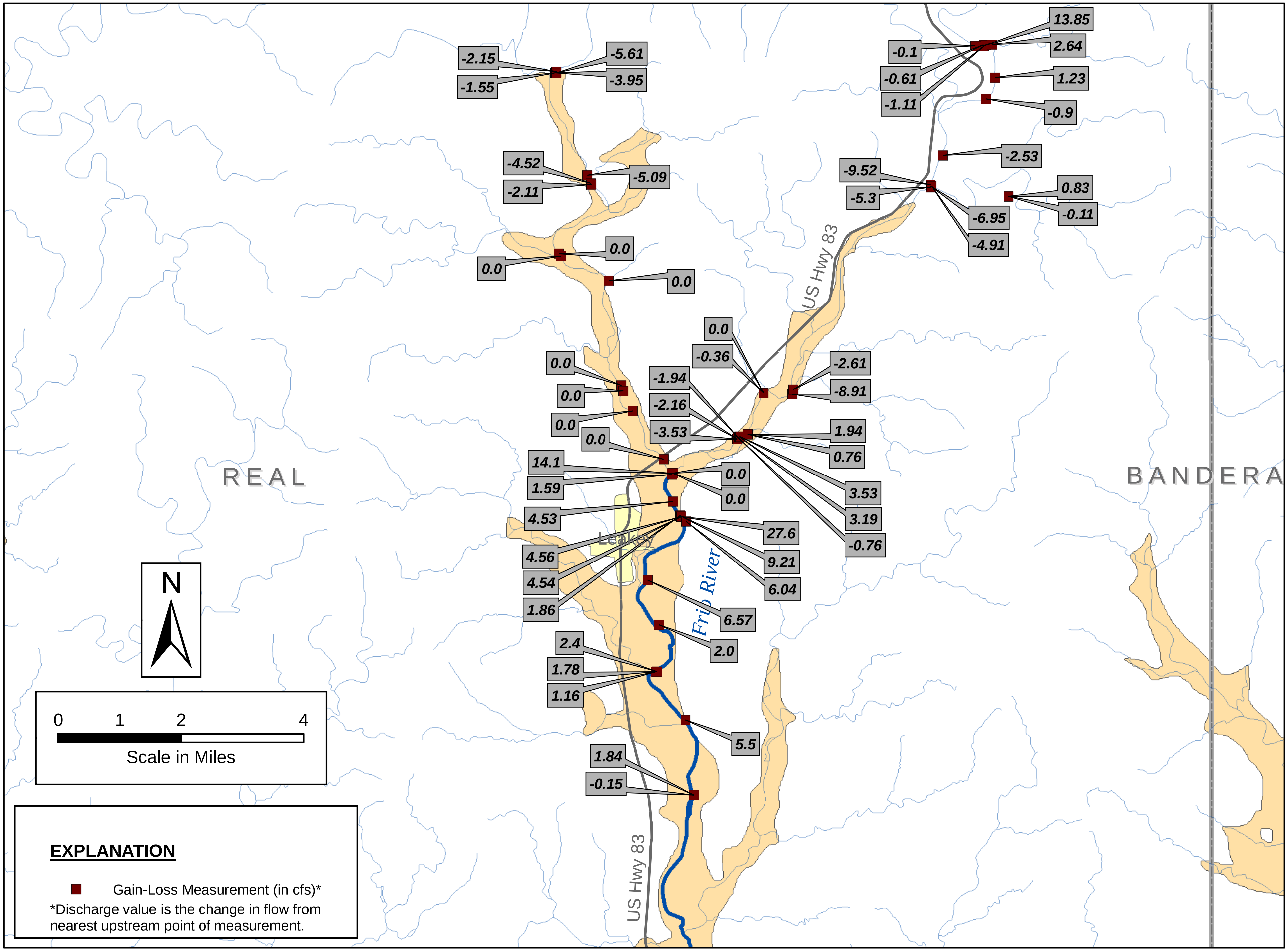

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FIGURE 8
GAIN-LOSS DATA IN THE FRIO RIVER
REAL COUNTY, TEXAS

CHAPTER 4

WATER MANAGEMENT STRATEGIES

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4.1 INTRODUCTION

Chapter 4 contains a comparison of projected water demands for each water-use category from Chapter 2 with water supplies available to meet those demands from Chapter 3. Water supply strategy recommendations are then made for those water users that have projected water supply deficits based on the comparison between demand and supply. In addition, strategies are also developed for specific entities that although they are not projected to have future shortages, they do have anticipated water-supply projects that deserve to be recognized in the Regional Plan.

In the development of the water management strategies, existing water rights, water contracts, and option agreements (including those associated with Amistad International Reservoir) are recognized and fully protected. A socioeconomic impact of unmet water needs analysis prepared by the Texas Water Development Board is provided in Appendix 4A.

In determining water management strategies, it is important to note that population centers and subsequent municipal and manufacturing water demands are not evenly distributed. In fact, municipal and manufacturing demands are often concentrated in high-density nodes creating large water supply demands in relatively small geographic areas. The supply and demand estimates for Kerr County in Table 4-1 may be misleading because the numbers were calculated assuming even demand distribution, when in fact, growth is likely to occur in concentrated nodes. Though Kerr County as a whole may have enough groundwater supply to meet projected demands for the various user groups, groundwater may not be available where needed. Concentrated growth will necessitate additional management strategies to supplement the limited groundwater supply in the small geographic areas.

The Texas Legislature has established a statute (Texas Water Code 11.139) by which non-municipal surface-water rights may temporarily be interrupted to make water available for public-supply needs during times of emergencies. The intent of the statute is to reduce the health and safety impact to communities that have run short of water because of unexpected circumstances. The statute was specifically enacted as an emergency process to bring relief to several communities that had been affected by drought conditions that had severely diminished their water-supply sources. The PWPG considered the potential for emergency transfer of surface water for communities in the region and chose not to recommend this strategy for this planning period.

4.2 WATER SUPPLY AND DEMAND COMPARISON

Table 4-1 compares available supplies for each water user (Table 3-2) with their corresponding future projected demands (Table 2-2). Water supply deficits are thus identified where the demand exceeds the supply. Supply deficits are identified for the City of Kerrville and the City of Camp Wood. Table 4-2 provides a similar comparison for the City of Del Rio as the Region's only wholesale water provider.

TABLE 4-1. WATER SUPPLY CAPACITY AND WATER DEMAND COMPARISON BY RIVER BASIN (Acre-Feet/Year)
(Shaded areas designate shortages)

County/ Water Use Category	Source Basin	Supply/ Demand	2010	2020	2030	2040	2050	2060
Bandera County								
Bandera	San Antonio	S	1,210	1,210	1,210	1,210	1,210	1,210
		D	259	284	312	332	351	371
			951	**926**	**898**	**878**	**859**	**839**
County Other	Guadalupe	S	31	31	31	31	31	31
		D	1	2	2	3	3	3
			30	**29**	**29**	**28**	**28**	**28**
	San Antonio	S	10,673	10,673	10,673	10,673	10,673	10,673
		D	2,425	3,381	4,330	4,817	4,932	5,232
			8,248	**7,292**	**6,343**	**5,856**	**5,741**	**5,441**
	Nueces	S	806	806	806	806	806	806
		D	183	255	327	386	439	491
			623	**551**	**479**	**420**	**367**	**315**
Mining	San Antonio	S	24	24	24	24	24	24
		D	24	24	24	24	24	24
			0	**0**	**0**	**0**	**0**	**0**
Irrigation	San Antonio	S	283	283	283	283	283	283
		D	283	283	283	283	283	283
			0	**0**	**0**	**0**	**0**	**0**
	Nueces	S	181	181	181	181	181	181
		D	181	181	181	181	181	181
			0	**0**	**0**	**0**	**0**	**0**
Livestock	Guadalupe	S	6	6	6	6	6	6
		D	6	6	6	6	6	6
			0	**0**	**0**	**0**	**0**	**0**
	San Antonio	S	262	262	262	262	262	262
		D	218	218	218	218	218	218
			44	**44**	**44**	**44**	**44**	**44**
	Nueces	S	95	95	95	95	95	95
		D	91	91	91	91	91	91
			4	**4**	**4**	**4**	**4**	**4**

County/ Water Use Category	Source Basin	Supply/ Demand	2010	2020	2030	2040	2050	2060
Edwards County								
Rocksprings	Colorado	S	322	322	322	322	322	322
		D	174	179	172	164	160	154
			148	**143**	**150**	**158**	**162**	**168**
	Nueces	S	180	180	180	180	180	180
		D	98	100	96	92	90	86
			82	**80**	**84**	**88**	**90**	**94**
County Other	Colorado	S	121	121	121	121	121	121
		D	35	36	34	33	32	31
			86	**85**	**87**	**88**	**89**	**90**
	Nueces	S	445	445	445	445	445	445
		D	118	121	116	111	108	104
			327	**324**	**329**	**334**	**337**	**341**
	Rio Grande	S	72	72	72	72	72	72
		D	20	20	19	19	18	17
			52	**52**	**53**	**53**	**54**	**55**
Mining	Colorado	S	89	89	89	89	89	89
		D	89	89	89	89	89	89
			0	**0**	**0**	**0**	**0**	**0**
Irrigation	Colorado	S	96	96	96	96	96	96
		D	43	41	39	38	36	34
			53	**55**	**57**	**58**	**60**	**62**
	Nueces	S	197	197	197	197	197	197
		D	87	84	81	77	74	71
			110	**113**	**116**	**120**	**123**	**126**
	Rio Grande	S	53	53	53	53	53	53
		D	23	22	21	20	19	18
			30	**31**	**32**	**33**	**34**	**35**
Livestock	Colorado	S	225	225	225	225	225	225
		D	175	175	175	175	175	175
			50	**50**	**50**	**50**	**50**	**50**
	Nueces	S	230	230	230	230	230	230
		D	230	230	230	230	230	230
			0	**0**	**0**	**0**	**0**	**0**
	Rio Grande	S	164	164	164	164	164	164
		D	157	157	157	157	157	157
			7	**7**	**7**	**7**	**7**	**7**

County/ Water Use Category	Source Basin	Supply/ Demand	2010	2020	2030	2040	2050	2060
Kerr County								
Kerrville	Guadalupe	S	3,040	3,040	3,040	3,040	3,040	3,040
		D	4,362	4,746	4,918	4,937	5,152	5,262
			-1,322	**-1,706**	**-1,878**	**-1,897**	**-2,112**	**-2,222**
Ingram	Guadalupe	S	585	585	585	585	585	585
		D	220	238	242	229	212	200
			365	**347**	**343**	**356**	**373**	**385**
County Other	Colorado	S	251	251	251	251	251	251
		D	58	62	63	60	56	52
			193	**189**	**188**	**191**	**195**	**199**
	Guadalupe	S	12,066	12,066	12,066	12,066	12,066	12,066
		D	2,651	2,866	2,917	2,918	3,025	3,087
			9,415	**9,200**	**9,149**	**9,148**	**9,041**	**8,979**
	San Antonio	S	752	752	752	752	752	752
		D	18	19	19	18	17	16
			734	**733**	**733**	**734**	**735**	**736**
Manufacturing	Guadalupe	S	51	51	51	51	51	51
		D	30	33	36	39	41	44
			21	**18**	**15**	**12**	**10**	**7**
Mining	Colorado	S	13	13	13	13	13	13
		D	13	12	12	12	12	12
			0	**1**	**1**	**1**	**1**	**1**
	Guadalupe	S	252	252	252	252	252	252
		D	154	153	152	151	150	149
			98	**99**	**100**	**101**	**102**	**103**
Irrigation	Guadalupe	S	1,821	1,821	1,821	1,821	1,821	1,821
		D	1,821	1,761	1,706	1,652	1,599	1,548
			0	**60**	**115**	**169**	**222**	**273**
Livestock	Colorado	S	125	125	125	125	125	125
		D	125	125	125	125	125	125
			0	**0**	**0**	**0**	**0**	**0**
	Guadalupe	S	355	355	355	355	355	355
		D	324	324	324	324	324	324
			31	**31**	**31**	**31**	**31**	**31**
	San Antonio	S	34	34	34	34	34	34
		D	34	34	34	34	34	34
			0	**0**	**0**	**0**	**0**	**0**
	Nueces	S	12	12	12	12	12	12
		D	4	4	4	4	4	4
			8	**8**	**8**	**8**	**8**	**8**

County/ Water Use Category	Source Basin	Supply/ Demand	2010	2020	2030	2040	2050	2060

Kinney County

County/ Water Use Category	Source Basin	Supply/ Demand	2010	2020	2030	2040	2050	2060
Brackettville	Rio Grande	S	647	647	647	647	647	647
		D	583	583	582	582	581	582
			64	**64**	**65**	**65**	**66**	**65**
Fort Clark Springs	Rio Grande	S	1,120	1,120	1,120	1,120	1,120	1,120
		D	626	653	678	704	723	727
			494	**467**	**442**	**416**	**397**	**393**
County Other	Nueces	S	48	48	48	48	48	48
		D	35	21	13	8	4	3
			13	**27**	**35**	**40**	**44**	**45**
	Rio Grande	S	88	88	88	88	88	88
		D	32	31	31	31	31	31
			56	**57**	**57**	**57**	**57**	**57**
Irrigation	Nueces	S	4,382	4,382	4,382	4,382	4,382	4,382
		D	338	323	310	296	284	271
			4,044	**4,059**	**4,072**	**4,086**	**4,098**	**4,111**
	Rio Grande	S	25,784	25,784	25,784	25,784	25,784	25,784
		D	13,169	12,605	12,063	11,547	11,053	10,582
			12,615	**13,179**	**13,721**	**14,237**	**14,731**	**15,202**
Livestock	Nueces	S	334	334	334	334	334	334
		D	187	187	187	187	187	187
			147	**147**	**147**	**147**	**147**	**147**
	Rio Grande	S	341	341	341	341	341	341
		D	258	258	258	258	258	258
			83	**83**	**83**	**83**	**83**	**83**

Real County

County/ Water Use Category	Source Basin	Supply/ Demand	2010	2020	2030	2040	2050	2060
Camp Wood	Nueces	S	0	0	0	0	0	0
		D	172	172	166	160	163	167
			-172	**-172**	**-166**	**-160**	**-163**	**-167**
County Other	Colorado	S	34	34	34	34	34	34
		D	11	11	11	10	11	11
			23	**23**	**23**	**24**	**23**	**23**
	Nueces	S	1,488	1,488	1,488	1,488	1,488	1,488
		D	417	416	400	386	394	402
			1,071	**1,072**	**1,088**	**1,102**	**1,094**	**1,086**
Mining	Colorado	S	6	6	6	6	6	6
		D	5	5	5	5	5	5
			1	**1**	**1**	**1**	**1**	**1**
Irrigation	Nueces	S	2,511	2,511	2,511	2,511	2,511	2,511
		D	392	377	361	346	330	314
			2,119	**2,134**	**2,150**	**2,165**	**2,181**	**2,197**
Livestock	Nueces	S	205	205	205	205	205	205
		D	148	148	148	148	148	148
			57	**57**	**57**	**57**	**57**	**57**
	Colorado	S	39	39	39	39	39	39
		D	28	28	28	28	28	28
			11	**11**	**11**	**11**	**11**	**11**

County/ Water Use Category	Source Basin	Supply/ Demand	2010	2020	2030	2040	2050	2060
Val Verde County								
Del Rio	Rio Grande	S	16,577	16,577	16,577	16,577	16,577	16,577
		D	12,898	13,817	14,646	15,314	15,855	16,281
			3,679	**2,760**	**1,931**	**1,263**	**722**	**296**
Laughlin AFB	Rio Grande	S	2,299	2,299	2,299	2,299	2,299	2,299
		D	1,303	1,296	1,289	1,281	1,276	1,276
			996	**1,003**	**1,010**	**1,018**	**1,023**	**1,023**
County Other	Rio Grande	S	6,044	6,044	6,044	6,044	6,044	6,044
		D	2,621	3,274	3,888	4,378	4,766	5,046
			3,423	**2,770**	**2,156**	**1,666**	**1,278**	**998**
Mining	Rio Grande	S	156	156	156	156	156	156
		D	118	111	107	104	101	99
			38	**45**	**49**	**52**	**55**	**57**
Irrigation	Rio Grande	S	6,837	6,837	6,837	6,837	6,837	6,837
		D	3,086	2,968	2,852	2,743	2,636	2,535
			3,751	**3,869**	**3,985**	**4,094**	**4,201**	**4,302**
Livestock	Rio Grande	S	767	767	767	767	767	767
		D	767	767	767	767	767	767
			0	**0**	**0**	**0**	**0**	**0**

Table 4-2. Del Rio Wholesale Water Supply Capacity and Water Demand Comparison

(Acre-Feet/Year)

Wholesale Water Provider	County	Basin	Receiving Entity	Supply / Demand	2010	2020	2030	2040	2050	2060
Del Rio	Val Verde	Rio Grande	City of Del Rio	Supply	16,577	16,577	16,577	16,577	16,577	16,577
			Laughlin AFB		2,178	2,178	2,178	2,178	2,178	2,178
			County Other		1,631	1,631	1,631	1,631	1,631	1,631
			Total Supply		**20,386**	**20,386**	**20,386**	**20,386**	**20,386**	**20,386**
			City of Del Rio	Demand	12,898	13,817	14,646	15,314	15,855	16,281
			Laughlin AFB		1,238	1,231	1,225	1,217	1,212	1,212
			County Other		708	884	1,050	1,182	1,287	1,362
			Total Demand		**14,844**	**15,932**	**16,921**	**17,713**	**18,354**	**18,855**
			Supply Surplus		**5,542**	**4,454**	**3,465**	**2,673**	**2,032**	**1,531**

4.3 STRATEGY EVALUATION PROCESS

A specific process was used in the selection and evaluation of water management strategies and is summarized in the flow chart illustrated in Figure 4-1. The process started with a consideration of potentially feasible strategies to meet the needs of each entity or category with a supply deficit and for other entities as desired. From this list, the PWPG selected specific strategies for further feasibility and impact analysis. Impacted entities were notified of the strategy recommendation process and asked to review and comment on suggested strategies. After considering the analysis, the PWPG selected all the evaluated strategies for inclusion in the Regional Plan.

The strategy evaluation procedure was designed to provide a side-by-side comparison such that all strategies could be assessed based on the same following considerations.

- Strategy description
- Time intended to implement
- Quantity of water supply generated
- Water quality considerations
- Reliability of the water source
- Cost (Table 4-4).
- Environmental issues (Table 4-5)
- Impacts to other water resources
- Impacts to agricultural resources
- Threats to natural resources
- Required interbasin transfers
- Social and economic impacts
- Impacts on water rights, contracts, and option agreements

Table 4-3 provides a comparative listing of potentially feasible strategies that the PWPG recommends in total for inclusion in this 2011 Plan. No "alternative" strategies are recommended by the PWPG. Table 4-4 provides a more in-depth accounting of the strategy costs. A summary of the environmental assessments of each strategy is shown in Table 4-5. No strategy in this Plan results in an interbasin transfer of water.

Cost evaluations for all strategies (Table 4-4) include capital cost, debt service, and annual operating and maintenance (O&M) expenses. Capital costs are estimated based on

September 2008 US dollars. The length of debt service is 20 years unless otherwise stated. An annual unit cost is also calculated based on the O&M cost per acre-foot of water supplied.

Although Table 4-1 does not forecast a supply deficit for the Kerr County Other category, the PWPG is concerned that future population growth in the unincorporated areas of the county could result in supply problems. Strategies that incorporate the Upper Guadalupe River Authority's intent to be a wholesale water provider are included in this plan to meet this potential need. In addition, other entities that are not projected to have shortages, but are included with strategies in this plan include the City of Bandera, the Community of Barksdale, the City of Brackettville, and the City of Leakey. Municipal strategies are discussed for each entity in the following sections.

Water planning requires an accurate assessment of the amount of water that is currently being consumed. Reported municipal use generally includes a variable amount of water that does not reach the intended consumer due to water leaks in the distribution lines, unauthorized consumption, storage tank overflows, and other wasteful factors. For some communities, attending to these issues can be a proactive conservation strategy that may result in significant water savings. To address the lack of information on water loss, the 78th Texas Legislature passed House Bill 3338, which required retail public utilities that provide potable water to perform and file with the TWDB a water audit computing the utility's most recent annual system water loss every five years. A summary of the first audit, An Analysis of Water Loss as Reported by Public Water Suppliers – 2007 (http://www.twdb.state.tx.us/RWPG/rpgm_rpts/0600010612_WaterLossinTexas.pdf) was provided to the PWPG for consideration in developing water supply management strategies. The PWPG acknowledges the value of this important planning tool, but identified apparent errors in some of the data. The report does offer the recognition that "as utilities refine their water audits, reducing balancing adjustments and improving real loss estimates, it is expected that water loss data reported from the next round of water audits will be more useful for planning purposes than the current water loss data. Based on this concern, the PWPG chose to not use the supplied data for this current Plan, but looks forward to the next improved water loss audit survey.

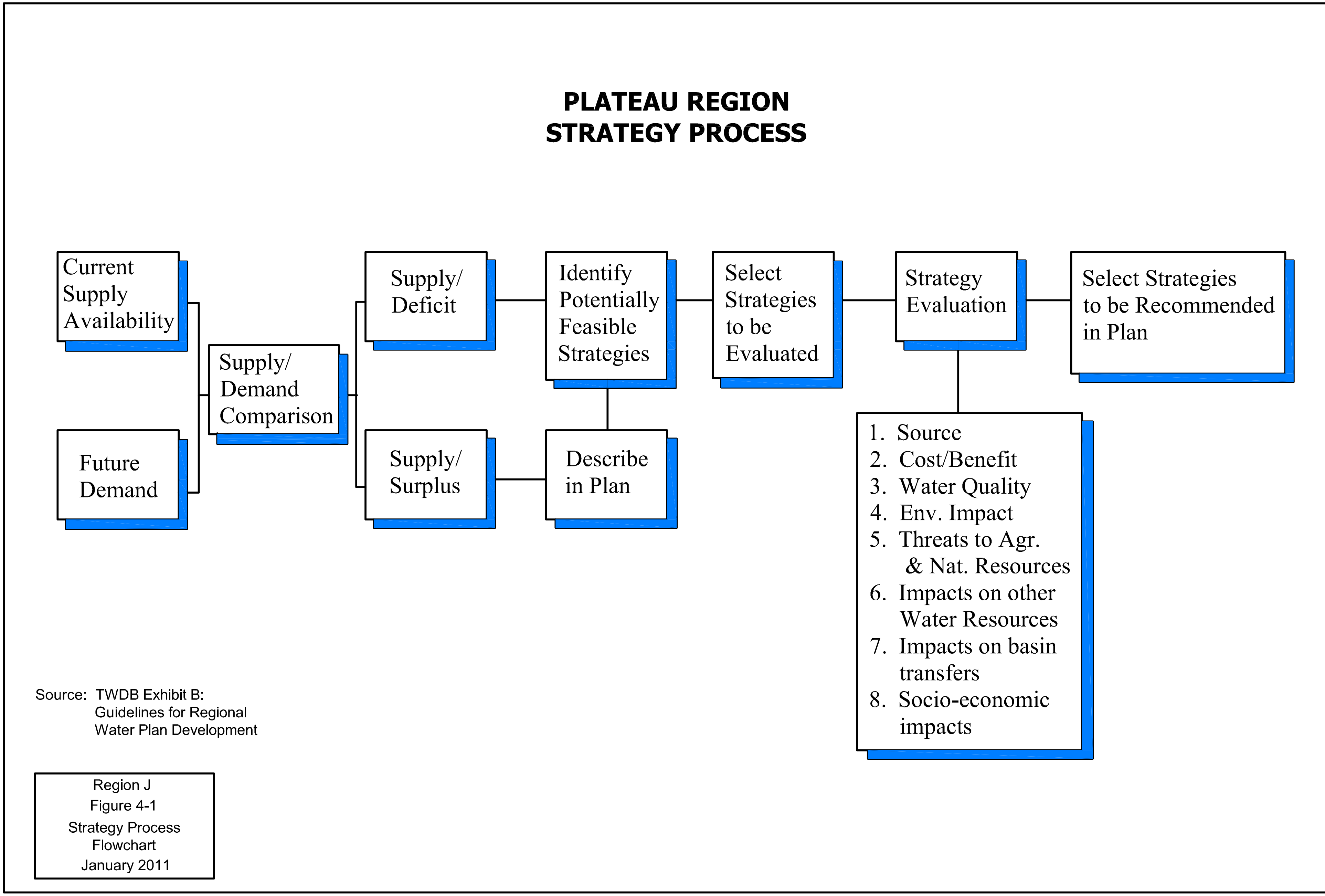

FIGURE 4-1. STRATEGY PROCESS FLOW CHART

LBG-GUYTON ASSOCIATES

TABLE 4-3. SUMMARY OF RECOMMENDED WATER MANAGEMENT STRATEGY EVALUATIONS

Water User Group	County Used	Basin	Strategy	Strategy ID	Strategy Supply (Acre-Feet/Year)						Source	Total Capital Cost (Table 4-4)	Quality [a]	Reliability [b]	Recreation [c]	Environmental Factors (Table 4-5)	Strategy Impacts [d]		
					2010	2020	2030	2040	2050	2060							Water Resources (1-5)	Agricultural Resources (1-5)	Natural Resources (1-5)
*City of Bandera	Bandera	San Antonio	Surface water acquisition, treatment and ASR	J-1		500	500	1,000	1,000	1,500	Medina River	$19,654,900	2	2	2	2	3	2	2
			Conservation: Public information	J-2	3	3	3	3	4	4	Conservation	$0	NA	NA	2	2	1	2	2
*Community of Barksdale (Edwards County Other)	Edwards	Nueces	Additional groundwater wells	J-3	17	17	17	17	17	17	Nueces River Alluvium Aquifer	$50,600	1	2	2	2	3	2	2
			Replace pressure tank	J-4	0	0	0	0	0	0	Nueces River Alluvium Aquifer	$7,000	NA	NA	2	2	2	2	2
			Conservation: Public information	J-5	2	2	2	2	2	2	Conservation	$0	NA	NA	2	2	1	2	2
City of Kerrville	Kerr	Guadalupe	Purchase water from UGRA [e]	J-6			3,840	3,840	3,840	5,450	Guadalupe River	$0	2	2	2	2	2	2	2
			Increased water treatment and ASR capacity	J-7	2,240	2,240	2,240	2,240	2,240	2,240	Guadalupe River	$6,650,000	2	2	2	2	2	2	2
			Conservation: System water audit and water loss audit	J-8	436	475	492	494	515	526	Conservation	$0	NA	NA	2	2	1	2	2
			Conservation: Public information	J-9	44	47	49	49	52	53	Conservation	$0	NA	NA	2	2	1	2	2
*Upper Guadalupe River Authority (Kerr County Other)	Kerr	Guadalupe	Surface water acquisition, treatment and ASR	J-10		1,124	1,124	1,124	1,124	1,124	Guadalupe River	$17,005,100	2	2	2	2	2	2	2
			Surface water storage [e]	J-11		1,121	1,121	1,121	1,121	1,121	Guadalupe River	$7,050,000	2	2	2	2	1	2	2
			Conservation: Brush management	J-12	10,500	10,500	10,500	10,500	10,500	10,500	Conservation	$3,937,790	NA	NA	2	1	1	1	1
			Conservation: Public information	J-13	14	15	15	15	16	16	Conservation	$0	NA	NA	2	2	1	2	2
*City of Brackettville	Kinney	Rio Grande	Conservation: System water audit and water loss audit	J-14	58	58	58	58	58	58	Conservation	$0	NA	NA	2	2	1	2	2
*City of Leakey (Real County Other)	Real	Nueces	Additional groundwater wells	J-15	205	205	205	205	205	205	Trinity Aquifer	$189,750	1 or 2	1 or 2	2	2	3	2	2
			Conservation: System water audit and water loss audit	J-16	20	20	20	20	20	20	Conservation	$0	NA	NA	2	2	1	2	2
City of Camp Wood	Real	Nueces	Groundwater wells	J-17	172	172	172	172	172	172	Edwards-Trinity (Plateau) Aquifer	$247,250	1 or 2	1 or 2	2	2	3	2	2
			Conservation: Public information	J-18	2	2	2	2	2	2	Conservation	$0	NA	NA	2	2	1	2	2

*Table 4-1 does not forecast a supply deficit for City of Bandera, Community of Barksdale, UGRA, City of Brackettville, and the City of Leakey.

[a] Quality range: 1= Meets safe drinking-water standards; 2=Must be treated or mixed to meet safe drinking-water standards.

[b] Reliability range: 1=Sustainable; 2=Interruptible during droughts; 3=Non-sustainable.

[c] Recreation: 1=Provides additional recreational opurtunities; 2=Has no impact on recreation; 3=Reduces existing recreational opurtunities.

[d] Strategy impact range: 1=positive; 2=no new; 3=minimal negative; 4=moderate negative; 5=significant negative.

[e] Strategy is not intended to meet a need during a drought-of-record condition as identified in Table 4-1.

Supply derived from Public Information conservation strategy is one percent of WUG demand.
Supply derived from Water Loss Audit conservation strategy is ten percent of WUG demand.
Capital Costs are estimated based on September 2008 US dollars.

TABLE 4-4. SUMMARY OF RECOMMENDED WATER MANAGEMENT STRATEGY COST

Water User Group		Strategy ID	Total Capital Cost	O&M Cost/Year						Cost per Acre-Foot/Year					
				2010	2020	2030	2040	2050	2060	2010	2020	2030	2040	2050	2060
City of Bandera	Surface water acquisition, treatment and ASR	J-1	$19,654,900		$1,039,375	$1,039,375	$1,449,875	$592,875	$1,003,375		$2,079	$2,079	$1,450	$593	$669
	Conservation: Public information	J-2	$0	$422	$472	$523	$564	$600	$634	$141	$157	$174	$188	$150	$159
Community of Barksdale (Edwards County Other)	Additional groundwater wells	J-3	$50,600	$600	$600	$600	$600	$600	$600	$35	$35	$35	$35	$35	$35
	Replace pressure tank	J-4	$7,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Conservation: Public information	J-5	$0	$377	$393	$384	$372	$367	$352	$189	$197	$192	$186	$184	$176
City of Kerrville	Purchase water from UGRA	J-6	$0			$3,840,000	$3,840,000	$3,840,000	$5,450,000			$1,000	$1,000	$1,000	$1,000
	Increased water treatment and ASR capacity	J-7	$6,650,000	$815,441	$815,441	$815,441	$337,000	$337,000	$337,000	$364	$364	$364	$150	$150	$150
	Conservation: System water audit and water loss audit	J-8	$0	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000	$46	$42	$41	$40	$39	$38
	Conservation: Public information	J-9	$0	$9,218	$10,272	$10,774	$11,018	$11,570	$11,818	$210	$219	$220	$225	$223	$223
Upper Guadalupe River Authority (Kerr County Other)	Surface water acquisition, treatment and ASR	J-10	$17,005,100		$1,592,000	$1,592,000	$1,592,000	$357,000	$357,000		$1,416	$1,416	$1,416	$318	$318
	Surface water storage	J-11	$7,050,000		$651,000	$651,000	$651,000	$651,000	$651,000		$581	$581	$581	$581	$581
	Conservation: Brush management	J-12	$3,937,790	$15,000	$150,000	$150,000	$150,000	$150,000	$150,000	$14	$14	$14	$14	$14	$14
	Conservation: Public information	J-13	$0	$4,849	$5,403	$5,667	$5,780	$6,039	$6,148	$346	$360	$379	$385	$377	$384
City of Brackettville	Conservation: System water audit and water loss audit	J-14	$0	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$17	$17	$17	$17	$17	$17
City of Leakey (Real County Other)	Additional groundwater wells	J-15	$189,750	$900	$900	$900	$900	$900	$900	$4	$4	$4	$4	$4	$4
	Conservation: System water audit and water loss audit	J-16	$0	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$50	$50	$50	$50	$50	$50
City of Camp Wood	Groundwater wells	J-17	$247,250	$1,200	$1,200	$1,200	$1,200	$1,200	$1,200	$7	$7	$7	$7	$7	$7
	Conservation: Public information	J-18	$0	$330	$336	$328	$323	$331	$338	$165	$168	$164	$162	$166	$169

Where applicable, capital costs include: construction, engineering, and easement, environmental, interest during construction, and purchased water.

Engineering, contingency, construction management, financial and leagal costs are estimated at 30 percent of construction costs for pipelines and 35 percent for pump stations and treatment facilities.

Permitting and mitigation for transmission and treatment projects are estimated at 1 percent of total construction costs.

Surface water treatment costs are estimated at $0.35 per 1,000 gallons for a conventional plant.

Annual costs include operations and maintenance, power cost, and debt service at 6% over 20 years.

Capital costs are estimated based on September 2008 US dollars.

TABLE 4-5. SUMMARY OF RECOMMENDED WATER MANAGEMENT STRATEGY ENVIRONMENTAL ASSESSMENTS

Water User Group	Strategy ID	* Total Acres Impacted	Wetland Acres Impacted	**Total Number of Rare, Threatened & Endangered Species in County (species impacted is undetermined)	Environmental Impact Factors ***						Comments
					Envir. Water Needs	Habitat	Cultural Resources	Envir. Water Quality	Bays & Estuaries	Overall Envir. Impact	
					(1-5)	(1-5)	(1-5)	(1-5)		(1-5)	
City of Bandera	J-1	5	0	22	2	2	2	2	NA	2	Will decrease dependence on new groundwater.
	J-2	NA	NA		2	2	2	2		2	Intended to reduce water use.
Community of Barksdale (Edwards County Other)	J-3	1	0	21	2	2	2	2		2	Caution will be necessary to not over exploit the local aquifer supply.
	J-4	1	0		2	2	2	2		2	Allows for more efficient use of existing supplies.
	J-5	NA	NA		2	2	2	2		2	Intended to reduce water use.
City of Kerrville	J-6	NA	NA	22	2	2	2	2		2	Will likely observe current low-flow restrictions.
	J-7	7	0		2	2	2	2		2	Will decrease dependence on new groundwater.
	J-8	NA	NA		2	2	2	2		2	Intended to reduce water use.
	J-9	NA	NA		2	2	2	2		2	Intended to reduce water use.
Upper Guadalupe River Authority (Kerr County Other)	J-10	10	0	22	2	2	2	2		2	Will decrease dependence on new groundwater.
	J-11	Unk	0		2	2	2	2		2	Provides additional supplies from surplus high-flows of the river.
	J-12	15,000	Unk		1	1	1	1		1	Significantly improves historical condition of the natural habitat.
	J-13	NA	NA		2	2	2	2		2	Intended to reduce water use.
City of Brackettville	J-14	NA	NA	22	2	2	2	2		2	Intended to reduce water use.
City of Leakey (Real County Other)	J-15	2	0	21	2	2	2	2		2	Avoids overdevelpment of Frio River Alluvium Aquifer.
	J-16	NA	NA		2	2	2	2		2	Intended to reduce water use.
City of Camp Wood	J-17	5	0	21	2	2	2	2		2	No new impact assumes wells are drilled away from Old Faithful Spring.
	J-18	NA	NA		2	2	2	2		2	Intended to reduce water use.

* Total Acres Impacted:
- A - Temporary excavation for pipelines and ditches
- B - Temporary local land disturbance while drilling and repairing water wells
- C - Disturbance of cultivated land

** Texas Parks & Wildlife Department's Natural Diversity Database of rare, threatened, and endangered species.

*** Strategy impact range: 1=positive; 2=no new; 3=minimal negative; 4=moderate negative; 5=significant negative

4.4 City of Bandera

The City of Bandera and many other residents of Bandera County rely on the Lower Trinity Aquifer for municipal, domestic, livestock, and irrigation water-supply needs, and the demand from the Lower Trinity is projected to increase as the population increases. Because the water level in the Lower Trinity has declined about 350 feet in City of Bandera wells since pumping started in the 1950s, there is concern that continued withdrawals from the aquifer may negatively impact the aquifer's ability to meet the long-term water supply needs of the area.

4.4.1 Strategy J-1 (Surface water acquisition, treatment and ASR)

The City of Bandera and the Bandera County River Authority and Groundwater District are studying the feasibility of constructing a water treatment facility to treat surface water from the Medina River. As much of the treated water as is needed will go directly into customer distribution, with the excess being injected into existing public supply wells for future retrieval (ASR). A May 2009 study report titled ASR Feasibility in Bandera County (http://www.ugra.org/pdfs/Bandera_ReportMay09.pdf) was prepared for the Plateau Region Water Planning Group (see Appendix 1B), which provides additional detail on this strategy.

Bandera County currently has a Water Supply Agreement with Bandera-Medina-Atascosa WCID#1 (BMAWCID#1) for the option of up to 5,000 acre-ft/yr. The BMAWCID#1 owns Certificate of Adjudication CA-19-2130, which authorizes the District to divert up to 65,830 acre-ft/yr for irrigation, municipal and industrial uses, up to 750 acre-ft/yr specifically for domestic and livestock purposes, and up to 170 acre-ft/yr specifically for municipal use.

Under CA-19-2130, BMAWCID#1 is authorized to divert water from Medina Lake and Diversion Dam. However, it is anticipated that the surface water purchased by Bandera County for local use and the potential ASR project will be diverted in the vicinity of the City of Bandera, upstream of Medina Lake. As a result, an amendment of the existing water right owned by BMAWCID#1 will be required and the upstream diversion point would likely be subject to additional bypass requirements. A minimum bypass equal to the 7Q2 was assumed to evaluate the reliability of this diversion. The 7Q2 is defined as the minimum average 7-day flow that has a return period of 2 years. The published 7Q2 for the Medina River at Bandera is 20 cfs (Chapter 307 - Texas Surface Water Quality Standards, TCEQ).

The reliability of the River diversion was calculated with a Run 3 version of the Water Availability Model of the Guadalupe-San Antonio Basin dated March 2008 provided by the TCEQ. Assumptions of the Run 3 version include adherence to strict prior appropriation, maximum use and storage, no return flows, and a hydrologic simulation period of 1934-1989. The version as received from the TCEQ includes updates for Lake Medina/ Diversion Lake and the addition of channel loss factors to all main stem water rights in the Guadalupe and San Antonio River Basins. The results are summarized as follows:

- The average diversion over the historical hydrologic period 1934-1989 is 3,680 acre-ft/yr.
- The full diversion of 5,000 acre-feet is possible for 32 percent of the years (about 1 every 3 years).
- Seventy percent of the full diversion (3,500 acre-feet) is possible for 66 percent of the years (about 2 every 3 years).
- There is one year with no diversion.

An initial facility will provide 500 acre-ft/yr of treated water. As much as is needed will go directly into customer distribution, with the excess being injected into existing public supply wells. In 2040 the facility will increase capacity to 1,000 acre-ft/yr, and in 2060 the capacity increases to 1,500 acre-ft/yr.

Water supply generated from this strategy will provide an additional source of supply that will hopefully allow the City to decrease its sole dependence on the Trinity Aquifer. Treated Medina River water is injected into the aquifer during non-drought conditions when surface water is plentiful and is retrieved at a later time as a supply source during drought-of-record conditions when surface water is scarce.

4.4.2 Strategy J-2 (Conservation: Public information)

The City of Bandera is encouraged to emphasize conservation through public information programs. A total of 1 percent reduction in demand is anticipated, which would result in a water savings of 3 acre-feet in 2010 and increasing to 4 acre-feet by 2060.

Public information programs, even though they may not be directly related to any equipment or operational change, can result in both short- and long-term water savings. Behavioral changes by customers will only occur if a reasonable yet compelling cause can be presented with sufficient frequency to be recognized and absorbed by the customers. There are many resources that can be consulted to provide insight into implementing effective information programs. Like any marketing or public information program, to be effective, water conservation public information should be planned out and implemented in a consistent and continual manner. A more detailed description of conservation best management practices that might be encouraged is available in TWDB Report 362, Water Conservation Best Management Practices Guide.

4.5 Community of Barksdale

The Barksdale Water Supply Corporation is a Not for Profit 501 C Corporation that serves the small Community of Barksdale. Currently the system has two small (40 gpm each) alluvial wells that pump water into the systems pressure tank and is then distributed to 83 active connections in the system. Due to the small number of connections and relatively low water rates, the income of the system is not adequate to set aside funding for capital improvements. Therefore, over the years the infrastructure of the water supply corporation has deteriorated and the system is in need of repair and upgrade. The system is currently at peak output and the projected increase demands from new subdivisions in the area will require extensive upgrades to the water supply system including an additional well (Strategy J-3) and a new larger capacity pressure tank (Strategy J-4). In full build-out, the subdivision will add an additional 28 connections or a 34 percent increase in capacity.

4.5.1 Strategy J-3 (Additional groundwater wells)

While wells in the Nueces River Alluvium Aquifer have been adequate to date, there was some concern during the recent (2009) drought that the system would not sustain the current pumping demands much less the projected increased demands. It is an almost certainty that the system will need to add at least one additional well that can maintain minimum production of 50 gpm for at least 5 hours per day or approximately 16.8 acre-ft/yr.

Sufficient groundwater is available from the Nueces River Alluvium Aquifer without causing excessive water-level declines; however, it is recommended that the new well be placed a sufficient distance from other municipal wells in the system to prevent overlapping cones-of-pumping influence. Temporary water shortages may occur during drought periods, which may require the lowering of pumps or deepening of wells.

As mentioned, the current wells have met the demand thus far. However, in a severe drought, alluvial aquifers are the first to go dry. Under such prolonged conditions, it may become necessary to complete a well or wells in the Trinity Aquifer well below the alluvium.

The chemical quality of groundwater in the Trinity Aquifer in this area is generally poor and will likely require treatment (RO) to make it palatable for human use.

4.5.2 Strategy J-4 (Replace pressure tank)

One 900-gallon pressure tank is needed to replace the existing smaller old pressure storage tank. Currently the system has two pressure tanks. However, one of these has had numerous repairs and still will not maintain continual pressure. The proposed 900 gallon pressure tank will increase the capacity of the system, reduce the cost of operation, and will be able to meet projected increase in capacity through 2060.

4.5.3 Strategy J-5 (Conservation: Public information)

The community should also look towards conservation measures through public information. Public information programs, even though they may not be directly related to any equipment or operational change, can result in both short- and long-term water savings. Behavioral changes by customers will only occur if a reasonable yet compelling cause can be presented with sufficient frequency to be recognized and absorbed by the customers. There are many resources that can be consulted to provide insight into implementing effective information programs. Like any marketing or public information program, to be effective, water conservation public information should be planned out and implemented in a consistent and continual manner. A more detailed description of conservation best management practices is available in <u>TWDB Report 362, Water Conservation Best Management Practices Guide</u>.

4.6 City of Kerrville

The City of Kerrville has developed a conjunctive-use policy for both surface water and groundwater, and passed a comprehensive Water Management Plan in early 2004. The policy specifies that: (1) surface water will be used to the maximum extent that it is available, (2) groundwater will be a supplemental source of supply, and (3) water consumption will be reduced through conservation.

The TCEQ Guadalupe River WAM Run 3 drought-of-record analysis yields 150 acre-ft/yr of surface water as reliable for the City of Kerrville. For planning purposes, the City proposes to use this estimate of available surface water, even though the estimate is significantly less than the permitted amount based on availability during a drought-of-record. Kerrville will develop additional surface and groundwater supplies, storage options or modifications to the existing permits, and expansion of the aquifer storage and recovery (ASR) system if it can be shown that there are periods when the City will not be able to use the permitted water from the Guadalupe River.

The City of Kerrville has been operating an ASR system for the past several years. In this system, a portion of treated Guadalupe River surface water is injected into the Lower Trinity Aquifer during months of water surplus and recovered from the aquifer for subsequent use during dry summer months. Currently, the ASR has two wells that serve for both injection and recovery. The capacity of the storage in the ASR is virtually unlimited, but the rates of injection and recovery are limited to 1 million gallons per day (mgd) in each of the two wells. A third well with equal capacity is in the construction stages. As of June 2010, the total storage in the ASR was 644 million gallons (1,976 acre-feet).

The analysis of current availability from surface water diversions for the City of Kerrville includes the storage and back up supply provided by the ASR system. This analysis considers the availability from surface water diversion under existing water rights with the Guadalupe WAM, storage in the on-channel reservoir in the Guadalupe River, injections into the ASR during periods of surplus, and recovery during periods when surface water is not sufficient to meet municipal demands. The maximum reliable supply during a drought-of-record (similar to the historical drought during the period 1949-1956) depends on the ASR storage as shown below.

Storage needed in the ASR system for different levels of reliable supply

Maximum reliable supply for Kerrville (Acre-ft/yr)	**Storage in ASR at the beginning of the drought-of-record (Acre-Feet)**
135	1,000
150	**1,230**
245	2,000
350	3,000
450	4,000
550	5,000

Assuming that a drought-of-record starts immediately, the maximum reliable supply for the City of Kerrville is 150 acre-ft/yr using the volume stored in the aquifer as of June 2010. Permit 1996 would provide an additional 150 acre-feet for municipal use for a total of 300 acre-ft/yr. However, the ASR storage does not recover quickly, and if there are multiple drought years, the ASR may not have enough storage for a reliable supply to cover the entire drought period. Therefore, a reliable surface water supply of 150 acre-ft/yr for the City of Kerrville is recommended.

Based on current groundwater availability estimates, the firm yield of the Lower Trinity Aquifer is estimated at 4,250 acre-ft/yr in the Kerrville area. The City of Kerrville uses a figure of 3mgd, or 3,360 acre-ft/yr as an available groundwater supply during a drought year. The City continues to rely on the Lower Trinity Aquifer as a dependable source of water. Through the City's conjunctive use policy, groundwater is reserved for meeting peak demand in a normal year and base demand in a drought year. For planning purposes, the estimates of available groundwater are 5mgd (5,600 acre-ft/yr) for peak demand and 3mgd (3,360 acre-ft/yr) for average demand.

The City has identified the possibility of modifying its own existing water permits. Currently the City's ability to divert under its existing permits is dependent on whether more senior water right holders exercise their rights, and is also affected by the City's Special Conditions written into its permits. If the City had more reliability from the Guadalupe River, and more latitude in its ability to divert during certain months of the year, the City could more fully utilize its ASR facility.

The City of Kerrville's water treatment capacity also limits its utilization of its ASR facility. The City needs excess treatment capacity to treat and store 4mgd during periods of higher streamflow; the current ASR system is limited to 2mgd. During the winter of 2010-2011 the City plans to bring the third ASR well online elevating its storage and retrieval capacity to 3mgd. The City has included the necessary project to increase the ASR system to 4mgd in the ten-year capital improvement program.

Kerrville passed a comprehensive water management plan in 2004 (updated in 2010). This plan focuses on water conservation and efficient management of local water resources. The plan outlines water conservation activities and provides guidance for the various stages of emergency water conservation measures and enforcement.

The availability of water will become a factor limiting the growth of both Kerrville and Kerr County. Water management strategies that the City can consider as possible future sources of supply include:

- Contracting with UGRA for additional water supply to be delivered to Kerr County (Strategy J-6).
- Increasing water treatment capacity in conjunction with increasing ASR capacity. This includes evaluating the possibility of treating wastewater to drinking water standards and storing it in ASR. (Strategy J-7)
- Municipal conservation savings (Strategies J-8 and J-9).

4.6.1 Strategy J-6 (Purchase water from UGRA)

The City of Kerrville could purchase or acquire under contract a portion of UGRA's surface water right. The City would use the additional water to supplement its existing water permits on the Guadalupe River and/or wholesale finished water to UGRA. Presumably the purchase or acquirement of water from UGRA will involve a contractual agreement between the two entities allowing the City to divert more water from the Guadalupe River than it is authorized under its current permits. This strategy could also provide water to areas served by UGRA or stored in their network.

The City's objective in obtaining more water from the Guadalupe River is to have more reliability from the River flows and more latitude in its ability to divert during certain months of the year. This would allow the City to more fully utilize its ASR facility. Up to 3,840 acre-ft/yr is needed by the year 2030 and an additional 1,610 acre-ft/yr (5,450 acre-ft/yr) in 2060 for a total of 116,810 acre-feet over the 30-year period. An estimated purchase price of $1,000 per acre-foot is assumed for this planning process; however the City will negotiate an actual price when and if this strategy is implemented in the future.

The reliability is dependent on the amount of water physically present within the Guadalupe River. UGRA and the City both take from the same source (Guadalupe River). The term "regulated stream flow" is generally synonymous with water that is physically present within a water body. It is noted that the upper Guadalupe River's minimum regulated stream flow (flow during drought-of-record), as determined by TCEQ's WAM Run 3, is 6,867 acre-ft/yr. However, the sum of authorized water rights is 12,128 acre-ft/yr. This means that during a drought-of-record, the water present in the Upper Guadalupe River is only half the amount of water authorized for diversion. Thus, this strategy could be of some assistance if needed in the early stages of a drought-of-record, but could not be used to meet needs in an extended drought period. However, Kerrville's future needs can be met by implementing Strategies J-7, J-8 and J-9.

The existing water permits of both UGRA and the City contain Special Conditions that allow diversions only when flows of the Guadalupe are above a minimum level. These restrictions help protect instream flows and the aquatic environment, in addition to serving as key water supply indicators. Any water purchase contract will likely have to contain the same or similar stream flow restrictions because TCEQ and TPWD are interested in maintaining minimum flows regardless of where the water is purchased.

The source of the water is Guadalupe River water through a purchase contract with UGRA, or a subordination and purchase contract with GBRA. All water purchase contracts must be approved by TCEQ, just as new or amended water rights must be approved by TCEQ. This means that - although TCEQ staff will not conduct a full hydrologic study for a contract - the agency will likely investigate any implications of the proposed contract on the Special Conditions outlined within the City's existing water permit. See "Environmental Issues" above. Bookkeeping within the TCEQ master water rights database would simply show the City's new diversions as a contract keyed to the water right of whichever entity provides the water.

4.6.2 Strategy J-7 (Increased water treatment and ASR capacity)

The City of Kerrville is planning on expanding its existing water treatment plant from its current capacity of 5.5mgd to 7mgd, and the ASR pumping and storage capacity of 2mgd to 4mgd. By the end of 2010 the ASR capacities will be increased to 3 mgd for a total of 3,360acre-ft/yr of possible storage. Upon the completion of the fourth ASR well the City will have the storage capability of 4,480 acre-ft/yr. These projects are listed in the City's Capital Improvement Project List.

The City is also evaluating the possibility of treating wastewater to drinking water standards and storing it in the ASR system. Wastewater is one of the most reliable sources of water during a drought and thus must be considered as a possible water supply. If it were decided to proceed with this project the City would need an additional 2-3mgd of ASR capacity.

The City's current water treatment capacity limits its utilization of its ASR facility. The City has identified the need for an additional 2mgd of treatment capacity to take care of peak use, take advantage of periods when higher streamflows occur in the Guadalupe River, and thus fully utilize its ASR. The increased storage capacity provided by the expanded ASR operation will make available water supplies more reliable. However, during drought-of-record conditions, water available from the upper Guadalupe River may be limited or nonexistent. Treated Guadalupe River water is injected into the aquifer during non-drought conditions when surface water is plentiful and is retrieved at a later time as a supply source during drought-of-record conditions when surface water is scarce.

4.6.3 Strategy J-8 (Conservation: System water audit and water loss audit)

System water audits and water loss programs are effective methods of accounting for all water usage by a utility within its service area. The structured approach of a water audit allows a utility to reliably track water uses and provide the information to address unnecessary water and revenue losses. The resulting information from a water audit will be valuable in setting performance indicators and in setting goals and priorities for cost-effectively reducing water losses. By adopting this best management practice, a utility will be implementing a more frequent implementation of water auditing and loss reduction techniques than required by HB 3338. A more detailed description of this best management practice is available in TWDB Report 362, Water Conservation Best Management Practices Guide, and in the TWDB Water Loss Manual. The reliability of this water savings is contingent on the aggressive implementation of this BMP and the public's willingness to do their part. The community should also look towards conservation measures thru public information and thru progressive water rate increases.

Currently the City of Kerrville is replacing old inaccurate water meters with new remote read meters. With the increase in accuracy, the City is planning to reduce unaccounted for water and getting an accurate look at water consumption.

The City's next project will be a four-year water leak detection survey. This project will identify leaky pipes in one of four quadrants of the city. Discovered leaks will be quantified and repaired accordingly.

4.6.4 Strategy J-9 (Conservation: Public information)

Public information programs, even though they may not be directly related to any equipment or operational change, can result in both short- and long-term water savings. Behavioral changes by customers will only occur if a reasonable yet compelling cause can be presented with sufficient frequency to be recognized and absorbed by the customers. There are many resources that can be consulted to provide insight into implementing effective information programs. Like any marketing or public information program, to be effective, water conservation public information should be planned out and implemented in a consistent and continual manner. A more detailed description of conservation best management practices is available in TWDB Report 362, Water Conservation Best Management Practices Guide.

A total of 1 percent reduction in demand is anticipated, which would result in a water savings of 44 acre-feet in 2010 and increasing to 53 acre-feet by 2060. The reliability of this water savings is contingent on the aggressive implementation of this BMP and the public’s willingness to do their part.

4.7 Upper Guadalupe River Authority (UGRA)

The mission of the Upper Guadalupe River Authority is to conserve and reclaim surface water through the preservation and distribution of the water resources for future growth in order to maintain and enhance the quality of life for all Kerr County citizens. UGRA's commitment to water conservation is reflected in its Fiscal Year 2009 budget which contains $23,400 for watershed programs, $30,000 for water research, $20,000 for water development and over $100,000 for various water quantity and water quality monitoring programs. Projects or activities UGRA may consider pursuing include, but are not limited to, are:

- Surface water acquisition, treatment and ASR in portions of Kerr County (Strategy J-10).
- Flood flow capture, storage, and utilization (Strategy J-11).
- Water enhancement through brush management and recharge facilitation (Strategy J-12).
- Seeking a subordination agreement with GBRA regarding Canyon Lake diversion rights.
- Groundwater recharge.
- Potentially amending UGRA's Permit 5394A so water use authorized under the permit may be used by the City of Kerrville.
- Providing public information on conservation practices (Strategy J-13).

4.7.1 Strategy J-10 (Surface water acquisition, treatment and ASR)

One of UGRA's major objectives is to provide for conjunctive use of surface water and groundwater in high-density growth areas within a portion of Kerr County outside of the area serviced by the City of Kerrville. UGRA, utilizing an EDAP grant from the TWDB, is developing a facility plan for a wholesale surface water supply in Center Point and Eastern Kerr County. Completion of the facility plan is expected in May 2010.

Strategy J-10 includes obtaining additional water rights to the Guadalupe River, construction of a treatment facility in the vicinity of the Town of Center Point in the eastern part of Kerr County, the direct distribution of needed treated supplies, and the construction of water wells in the vicinity of the treatment plant for injection and recovery (ASR) of excess treated water. Additional raw supplies generated from Strategy J-11 will also be available for treatment at the facility.

UGRA provided match funding to TWDB funding for a special interim study (see Appendix 1A) that is included in this 2011 Plan; specifically, UGRA matched funding for evaluating ASR and water rights purchasing methodology *(TWDB Contract No. 0704830695: Alternative Water Supply Analysis for Kerr and Bandera Counties)*. A May 2009 study report titled Water Rights Analysis and ASR Feasibility in Kerr County (http://www.ugra.org/pdfs/Kerr Report May09.pdf) was prepared for the Plateau Region Water Planning Group, which provides additional detail on the feasibility of this strategy.

ASR is being considered as a necessary component of the Center Point and Eastern Kerr County water supply project. The system is intended to provide a means of storing excess Guadalupe River supplies for use during drought or reduced surface water flows. For strategy analysis a facility capable of treating, distributing and injecting into an ASR 1,124 acre-ft/yr is considered. The objective in obtaining more water from the Guadalupe River is to have more reliability from the Guadalupe River flows and more latitude in the ability to divert during certain months of the year, thus allowing UGRA to more fully utilize a future ASR facility. Surface water supplies will be firmed up with groundwater. Treated Guadalupe River water is injected into the aquifer during non-drought conditions when surface water is plentiful and is retrieved at a later time as a supply source during drought-of-record conditions when surface water is scarce.

UGRA desires to obtain a greater portion of the water that is available in the Guadalupe River. One way to accomplish this is to buy existing water rights on the Guadalupe River or its tributaries. A water rights methodology developed in the special interim study may be used by UGRA as a guide in purchasing or leasing water rights.

The existing water permits of UGRA contain Special Conditions that restrict diversions only when flows of the Guadalupe are above a minimum level. These restrictions help protect instream flows and the aquatic environment, in addition to serving as key water supply indicators. Any water purchase contract will likely have to contain the same or similar stream flow restrictions because TCEQ and TPWD are interested in maintaining minimum flows regardless of where the water is purchased.

All water purchase contracts must be approved by TCEQ, just as new or amended water rights must be approved by TCEQ. This means that - although TCEQ staff will not conduct a full hydrologic study for a contract - the agency will likely investigate any implications of the proposed contract on the Special Conditions outlined within the City’s existing water permit. Bookkeeping within the TCEQ master water rights database would simply show UGRA's new diversions as a contract keyed to the water right of whichever entity provides the water.

4.7.2 Strategy J-11 (Surface water storage)

Strategy J-11 provides for the securing of one or more off-channel ground storage facilities. The facility will be lined with impervious material to prevent subsurface seepage loss. Guadalupe River water will be captured during excessive flow episodes. Following a period of time to allow for settling of sediment, the captured water will be diverted for treatment to drinking water quality to a facility presented in Strategy J-10. Water supply generated from this strategy will be combined with water supplies generated in Strategy J-10 for public distribution. Because water is only generated by this strategy during high river flow episodes, this strategy is not considered sustainable during drought periods. Although UGRA is not projected to have future water supply shortages, the water that is captured can be added to the ASR supply and later retrieved for use in serving unexpected peak demands and drought-of-record needs.

4.7.3 Strategy J-12 (Brush management)

UGRA has implemented a water enhancement cost share program targeting the removal of brush and is currently in the process of applying for a federal grant to continue their goal of effective land management practices. Priority agricultural water enhancement activities to be applied will focus on brush clearing (primarily Ashe Juniper and Mesquite) and construction of water and sediment control basins. In UGRA's water enhancement cost share program, UGRA is matching a percentage of eligible landowners cost in removing brush. Eligible landowners include those who have an approved NRCS or Kerr County SWCD contract. Additionally, UGRA is soliciting brush removal funds through the NRCS AWEP grant program. NRCS is requested to provide 70 percent of project costs ($2,756,453) through AWEP for the five-year project timeframe.

The location of the project will be within the drainage basins of the three forks of the upper Guadalupe River in Kerr County including Johnson Creek, North Fork Guadalupe, and South Fork Guadalupe. Strategy J-12 supports the current water enhancement cost share program and this grant request to be partially funded by UGRA.

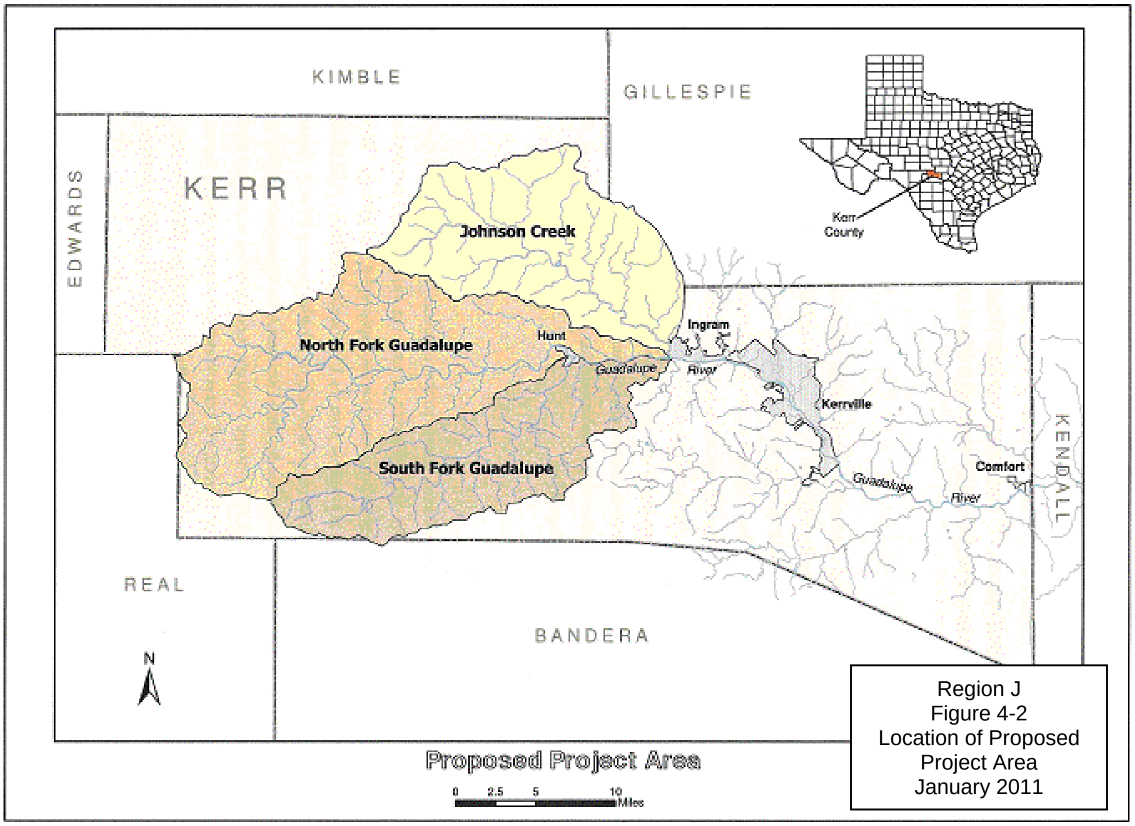

FIGURE 4-2. LOCATION OF PROPOSED PROJECT AREA

In November 2008, UGRA and the Kerr County Soil and Water Conservation District executed a Memorandum of Understanding (MOU) in which the two entities agreed to work cooperatively in seeking funding and in the administration for brush removal on the upper Guadalupe River watershed that will benefit the landowners and all downstream water users.

Additionally, in March 2008, a MOU was executed with the City of Kerrville, City of Ingram, Kerr County Commissioners' Court, and the Headwaters Groundwater Conservation District in which the parties agreed to cooperate in good faith for purposes of facilitating range and land management practices that will improve and maintain surface water and groundwater quality and/or availability. UGRA agreed to prepare and distribute a Range and Watershed Improvement Plan that will identify best management practices to improve surface water quality and availability.

Studies performed at the Kerr Wildlife Management Area (Kerr WMA) demonstrate that about 35 percent of precipitation that falls on Ashe Juniper is intercepted by the canopy and another five percent is intercepted by the litter. Modeling in the study indicated that the pattern of storms at the Kerr WMA resulted in an average interception loss of 0.82 acre-feet per acre of cedar break. Kerr WMA staff have stated that they could measure an increase of 45,000 to 55,000 gallons of available water per acre per inch of rainfall on the Kerr WMA after brush removal.

Base flow in the North Fork and South Fork of the Guadalupe River and Johnson Creek is derived from many springs that occur within the branch tributaries. These springs represent outflow from the underlying Edwards Plateau Aquifer and thus provide the direct link that connects groundwater to surface water. The Edwards Plateau Aquifer is a karst aquifer and recharges directly from precipitation falling on it. Removal of brush that uses available water or intercepts available water increases recharge to the aquifer. The increase in recharge provides for more springflow, which ultimately increases the base flow of the Guadalupe River.

Much of Kerr County is infested with Ashe Juniper. The number of acres needing treatment exceeds available funding. Additionally, some large landowners with Ashe Juniper infestations will not meet the eligibility requirements under this program. To that end, a practical approach at identifying and clearing a set number of acres per year is envisioned. If 3,000 acres are cleared per year for five years the total acres cleared will be 15,000 non-contiguous acres. Clearing 15,000 acres will yield approximately 10,500 acre-feet of water per year (based on results from Kerr WMA; Thurow, T.L. and J.W. Hester. 1997. How an Increase or Reduction in Juniper Cover Alters Rangeland Hydrology. Ecology and Management Symposium 1997, Texas A&M University) or about 3,423,000,000 gallons of water per year and can potentially increase the base flow of the river by about 14.4 cubic feet per second. The reliability of this water savings is contingent on the aggressive implementation of the project and the producers' (land owners') willingness to participate.

UGRA has partnered with the Kerr County SWCD. UGRA, under the current water enhancement program and the anticipated AWEP program, will provide matching funds. Landowners will be qualified under NRCS and/or Kerr County SWCD contract guidelines. Additionally, NRCS and/or the Kerr County SWCD will provide the task certification and payment approval.

The AWEP project would be funded by NRCS (70%), UGRA (10%), and Producers (20%) as shown in the table below. UGRA's cost (10% of total cost) is $393,779. A portion of the funding may be used to construct water and sediment control basins and other water enhancement strategies which will decrease the total amount of acres cleared, but will still contribute to the goal of increasing water availability. Cooperating landowners are responsible for the continued maintenance of cleared land beyond the 5-year project horizon. At $100 per acre per decade, the estimated cost for continued maintenance of the cleared 15,000 acres is $150,000 per year.

Year	NRCS (70%)	UGRA (10%)	Producers (20%)
2010	$451,500	$64,500	$129,000
2011	$496,650	$70,950	$141,900
2012	$546,315	$78,045	$156,090
2013	$600,947	$85,850	$171,699
2014	$661,041	$94,434	$188,869
Total	**$2,756,453**	**$393,779**	**$787,558**
Project Total	**$3,937,790**		

4.7.4 Strategy J-13 (Conservation: Public information)

Once a month, UGRA publishes a column in the local newspapers, "Currents," in which various issues are discussed and explained such as water quality issues and best management practices for protecting water quantity and quality. UGRA is currently developing an educational video on water enhancement strategies for the Upper Guadalupe River Watershed to be used to help agricultural producers better understand water enhancement and range management strategies.

Public information programs such as these, even though they may not be directly related to any equipment or operational change, can result in both short- and long-term water savings. Behavioral changes by customers will only occur if a reasonable yet compelling cause can be presented with sufficient frequency to be recognized and absorbed by the customers. There are many resources that can be consulted to provide insight into implementing effective information programs. Like any marketing or public information program, to be effective, water conservation public information should be planned out and implemented in a consistent and continual manner. A more detailed description of conservation best management practices is available in TWDB Report 362, Water Conservation Best Management Practices Guide.

4.8 City of Brackettville

4.8.1 Strategy J-14 (Conservation: System water audit and water loss audit)

System water audits and water loss programs are effective methods of accounting for all water usage by a utility within its service area. The structured approach of a water audit allows a utility to reliably track water uses and provide the information to address unnecessary water and revenue losses. The resulting information from a water audit will be valuable in setting performance indicators and in setting goals and priorities for cost-effectively reducing water losses. By adopting this best management practice, a utility will be implementing a more frequent implementation of water auditing and loss reduction techniques than required by HB 3338. A more detailed description of this best management practice is available in TWDB Report 362, Water Conservation Best Management Practices Guide, and in the TWDB Water Loss Manual. The reliability of this water savings is contingent on the aggressive implementation of this BMP and the public's willingness to do their part. A potential water savings of 58 acre-ft/yr is estimated for this strategy.

4.9 City of Leakey

4.9.1 Strategy J-15 (Additional groundwater wells)

Currently the City of Leakey has a total of 5 Frio River Alluvium Aquifer wells. During the recent drought, it appeared that the water level would drop to the point where one or more of these wells would no longer be viable. In consideration of this, the Real Edwards Conservation and Reclamation District passed an emergency rule that would allow for the immediate permitting of an additional well or other potential water source for the City of Leakey. In addition, the City of Leakey is looking at a solid waste disposal system and it is anticipated that such a system will require additional water. Since current supply is from an alluvial aquifer and during a drought this supply may not be capable of sustaining demand, the City of Leakey should consider one or more wells located in the Edwards-Trinity (Plateau) Aquifer. The potential of constructing wells capable of producing at an adequate rate is good, although exploratory drilling and testing will likely be needed before this strategy can be relied upon as a dependable source. A minimum of two wells capable of producing 80 to 1,000 gpm each will be needed to supply an anticipated 205 acre-ft/yr.

Chemical quality of the water from wells should be acceptable providing the wells are properly constructed. The Trinity portion of the aquifer can have gypsum beds in the Glen Rose that may cause elevated sulfates and total dissolved solids. If these are present, these gypsum intervals in the limestone should be cased and cement off in the well. Not currently included in this strategy is the potential need for an RO plant to treat Trinity water to drinking water standards if necessary.

4.9.2 Strategy J-16 (Conservation: System water audit and water loss audit)

System water audits and water loss programs are effective methods of accounting for all water usage by a utility within its service area. The structured approach of a water audit allows a utility to reliably track water uses and provide the information to address unnecessary water and revenue losses. The resulting information from a water audit will be valuable in setting performance indicators and in setting goals and priorities for cost-effectively reducing water losses. By adopting this best management practice, a utility will be implementing a more frequent implementation of water auditing and loss reduction techniques than required by HB 3338. A more detailed description of this best management practice is available in TWDB Report 362, Water Conservation Best Management Practices Guide, and in the TWDB Water Loss Manual. The reliability of this water savings is contingent on the aggressive implementation of this BMP and the public's willingness to do their part. The community should also look towards conservation measures thru public information and thru progressive water rate increases. A potential water savings of 20 acre-ft/yr is estimated for this strategy.

4.10 City of Camp Wood

The City of Camp Wood derives all of its municipal water from Old Faithful Spring (also known as Krueger Spring or Camp Wood Spring) that issues from alluvial gravel overlying the Glen Rose Limestone of the Edwards-Trinity (Plateau) Aquifer. Discharge from the spring is occasionally insufficient to meet all current needs, and the City is considering developing an alternate source of supply. Other significant problems in the past with the spring have been the occurrence of Giardia (in late 1988) and intermittent high turbidity.

Camp Wood water demand is projected to be as high as 172 acre-ft/yr within the next 50 years. The TCEQ Nueces River WAM results indicate that there is no reliable water available from the spring during a repeat of the drought-of-record. However, Old Faithful did not cease to flow during the drought of the 1950s.

4.10.1 Strategy J-17 (Groundwater wells)

During a drought, the City could rely on water wells completed into the Edwards-Trinity (Plateau) Aquifer to supplement the spring. The potential of constructing wells capable of producing at this desired rate is good, although exploratory drilling and testing will likely be needed before this strategy can be relied upon as a dependable source. A minimum of two wells capable of producing 50 to 70 gpm each will be needed to supply the anticipated 172 acre-ft/yr at an estimated total capital cost of $247,250.

Sufficient groundwater is likely available from the Edwards-Trinity (Plateau) Aquifer, however, local water-level declines could be expected as a result of pumping new wells. Because the source of Old Faithful Spring is at least partially from the Trinity aquifer, some spring flow reduction may occur as a result of pumping wells. Accordingly, any new wells should be located as far from Old Faithful Spring as possible. Chemical quality of the water from wells should be acceptable providing the wells are properly constructed. The Trinity portion of the aquifer can have gypsum beds in the Glen Rose that may cause elevated sulfates and total dissolved solids. If these are present, these gypsum intervals in the limestone should be cased and cement off in the well.

4.10.2 Strategy J-18 (Conservation: Public information)

In addition to the strategy of constructing new groundwater wells, Camp Wood may benefit from conservation measures including a system and water loss audit and providing local citizens with water-saving conservation tips. Public information programs, even though they may not be directly related to any equipment or operational change, can result in both short- and long-term water savings. Behavioral changes by customers will only occur if a reasonable yet compelling cause can be presented with sufficient frequency to be recognized and absorbed by the customers. There are many resources that can be consulted to provide insight into implementing effective information programs. Like any marketing or public information program, to be effective, water conservation public information should be planned out and implemented in a consistent and continual manner. A more detailed description of conservation best management practices is available in TWDB Report 362, Water Conservation Best Management Practices Guide. A potential water savings of 2 acre-ft/yr is estimated for this strategy.

4.11 OTHER WATER MANAGEMENT ISSUES

4.11.1 Brush Management and Land Stewardship

Selective Brush Management, as a tool to improve watershed yields and water quality, is a strategy of great interest in the Plateau Region, as well as in surrounding planning regions. Funding and direction is needed to expedite multi-disciplinary research to develop methodologies of defining watersheds of greatest potential for increasing water yields. Teams of geologists, hydrologists, ecologists, wildlife biologists, economists and rangeland scientists working with GIS and various types of aerial photography would have the highest probability of developing tools to identify and quantify the best yielding watersheds for treatment. These studies would estimate the cost-benefit ratios of this management practice including cost of initial brush management; ecological benefits; grazing benefits; reseeding costs, if necessary; and other range management practices as needed to restore brush-infested rangelands while preserving or enhancing wildlife and esthetic values. The end product would quantify both the short-term and long-term costs and benefits per acre-foot of water to such a regional program. Downstream and aquifer users in urban areas would possibly be major beneficiaries and as such should be part of the final equation and possibly part of the funding mechanism. Studies should be of a realistic, large-scale size in order to more accurately correlate with full-scale watershed treatments.

Currently, Texas Parks & Wildlife Department (TPWD) has a program specifically directed at utilizing best management practices for landowners involving brush management in areas possibly containing endangered species. As has been proven on the Kerr Wildlife Management Area (TPWD) with long-term studies, selective brush management coupled with good rangeland management can benefit endangered species and ranchers as well. It is highly likely that watershed values will fit into the same package to provide a win-win situation for all. The voluntary partnership of landowners and TPWD is important to this program, just as it was under the NRCS' Great Plains Program. However, as major parts of targeted watersheds must be treated in order to provide the desired hydrological benefits, it is likely that a high percentage of watershed landowners must opt-in to the program before it could be accepted by the State for treatment and management contracts.

The PWPG further endorses the overall concept of voluntary land stewardship. Land stewardship recognizes that the relationship between the land's condition and the quality and quantity of water available to all Texans is inextricably linked. In fact, good land stewardship encompasses a myriad of activities far beyond brush control.

4.11.2 Desalination Potential

The Trinity Aquifer in eastern Bandera and Kerr Counties is identified in Chapter 3 Section 3.2.10 as being the most likely brackish groundwater source that might be desalinated to produce drinking water of acceptable quality. However, low productivity from this aquifer source makes desalination an economically marginal option at this time. Thus no desalination strategies are recommended in this current Plan. However, the option should remain as a consideration under appropriate circumstances.

4.11.3 Export of Groundwater

The PWPG considered the issue of groundwater export. No projects entailing groundwater export from the Plateau Region to markets outside the Region have reached a contractual stage to warrant bringing them before the Group for consideration. However, there are two projects in Kinney County that are currently being marketed. Although these two projects are not included in this Plan as inter-regional management strategies, the PWPG did begin the process of considering potential aquifer impacts.

The TWDB provided funding to the PWPG to evaluate the potential effects that pumping might have on springs and subsequent base flow to rivers and streams. The study included a survey and characterization of 73 springs in Kinney and Val Verde Counties. Several pumping scenarios were run using the TWDB Edwards-Trinity (Plateau) Aquifer groundwater availability model (GAM). The aquifer simulation model was run by increasing pumping withdrawals at set intervals until reasonably acceptable levels of impact to surface water drains (non-specified springs) were observed. For regional planning purposes, this exercise resulted in a maximum pumping level from the Edwards-Trinity (Plateau) Aquifer in Kinney County of 22,432 acre-ft/yr. However, it is important to recognize that this amount of pumping is assumed to be evenly spaced over the extent of the aquifer. Concentrating pumping in smaller areas could increase the impact potential on springs in the immediate vicinity. Also, these model runs assumed average rainfall/recharge conditions. Less then normal recharge would intensify the pumping impact. The Kinney County Groundwater Conservation District does not currently (as of Jan 1,2010) limit pumping withdrawals by rule in the county.

4.11.4 Regional Facility Planning

Utilizing a TWDB EDAP grant, the Upper Guadalupe River Authority (UGRA) and the Kerr County Commissioners' Court are evaluating ways in which water supply and wastewater treatment can be made available from regional facilities that will service the Community of Center Point and much of the unincorporated portion of eastern Kerr County. A surface water treatment facility will provide drinking water to customers currently served by several privately owned water systems. The construction of a new wastewater collection system will provide first-time service to many citizens and may potentially include a gravity interceptor to connect the system to the Kendall County WCID#1 wastewater treatment plant downstream in the town of Comfort.

Another example of regional cooperation can be seen in a March 2008 MOU executed with the UGRA, City of Kerrville, City of Ingram, Kerr County Commissioners' Court, and the Headwaters Groundwater Conservation District in which the parties agreed to cooperate in good faith for purposes of facilitating range and land management practices that will improve and maintain surface water and groundwater quality and/or availability.

APPENDIX 4A

Socioeconomic Impact of Unmet Water Needs Analysis

April 30, 2010

Mr. Jonathan Letz
Chairman, Plateau Regional Water Planning Group
c/o Kerr County
700 Main St., Suite 101
Kerrville, Texas 78028

Re: Socioeconomic Impact Analysis of Not Meeting Water Needs for the 2011 Plateau (Region J) Regional Water Plan

Dear Chairman Letz:

We have received your request for technical assistance to complete the socioeconomic impact analysis of not meeting water needs. In response, enclosed is a report that describes our methodology and presents the results. Section 1 provides an overview of the methodology, and Section 2 presents results for each water user group with needs.

If you have any questions or comments, please feel free to contact me at (512) 463-7928 or by email at stuart.norvell@twdb.state.tx.us.

Sincerely,

Stuart Norvell
Manager, Water Planning Research and Analysis
Water Resources Planning Division

SN/ao

Enclosure

c: Angela Kennedy, Texas Water Development Board

Socioeconomic Impacts of Projected Water Shortages for the Plateau (Region J) Regional Water Planning Area

Prepared in Support of the 2011 Plateau Regional Water Plan

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April 2010

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Introduction

Water shortages during drought would likely curtail or eliminate economic activity in business and industries reliant on water. For example, without water farmers cannot irrigate; refineries cannot produce gasoline, and paper mills cannot make paper. Unreliable water supplies would not only have an immediate and real impact on existing businesses and industry, but they could also adversely affect economic development in Texas. From a social perspective, water supply reliability is critical as well. Shortages would disrupt activity in homes, schools and government and could adversely affect public health and safety. For all of the above reasons, it is important to analyze and understand how restricted water supplies during drought could affect communities throughout the state.

Administrative rules require that regional water planning groups evaluate the impacts of not meeting water needs as part of the regional water planning process, and rules direct TWDB staff to provide technical assistance: "*The executive administrator shall provide available technical assistance to the regional water planning groups, upon request, on water supply and demand analysis, including methods to evaluate the social and economic impacts of not meeting needs*" [(§357.7 (4)(A)]. Staff of the TWDB's Water Resources Planning Division designed and conducted this report in support of the Plateau Regional Water Planning Group (Region J).

This document summarizes the results of our analysis and discusses the methodology used to generate the results. Section 1 outlines the overall methodology and discusses approaches and assumptions specific to each water use category (i.e., irrigation, livestock, mining, steam-electric, municipal and manufacturing). Section 2 presents the results for each category where shortages are reported at the regional planning area level and river basin level. Results for individual water user groups are not presented, but are available upon request.

1. Methodology

Section 1 provides a general overview of how economic and social impacts were measured. In addition, it summarizes important clarifications, assumptions and limitations of the study.

1.1 Economic Impacts of Water Shortages

1.1.1 General Approach

Economic analysis as it relates to water resources planning generally falls into two broad areas. Supply side analysis focuses on costs and alternatives of developing new water supplies or implementing programs that provide additional water from current supplies. Demand side analysis concentrates on impacts or benefits of providing water to people, businesses and the environment. Analysis in this report focuses strictly on demand side impacts. When analyzing the economic impacts of water shortages as defined in Texas water planning, three potential scenarios are possible:

1) Scenario 1 involves situations where there are physical shortages of raw surface or groundwater due to drought of record conditions. For example, City A relies on a reservoir with average conservation storage of 500 acre-feet per year and a firm yield of 100 acre feet. In 2010, the city uses about 50 acre-feet per year, but by 2030 their demands are expected to increase to 200 acre-feet. Thus, in 2030 the reservoir would not have enough water to meet the city's demands, and people would experience a shortage of 100 acre-feet assuming drought of record conditions.

Under normal or average climatic conditions, the reservoir would likely be able to provide reliable water supplies well beyond 2030.

2) Scenario 2 is a situation where despite drought of record conditions, water supply sources can meet existing use requirements; however, limitations in water infrastructure would preclude future water user groups from accessing these water supplies. For example, City B relies on a river that can provide 500 acre-feet per year during drought of record conditions and other constraints as dictated by planning assumptions. In 2010, the city is expected to use an estimated 100 acre-feet per year and by 2060 it would require no more than 400 acre-feet. But the intake and pipeline that currently transfers water from the river to the city's treatment plant has a capacity of only 200 acre-feet of water per year. Thus, the city's water supplies are adequate even under the most restrictive planning assumptions, but their conveyance system is too small. This implies that at some point – perhaps around 2030 - infrastructure limitations would constrain future population growth and any associated economic activity or impacts.

3) Scenario 3 involves water user groups that rely primarily on aquifers that are being depleted. In this scenario, projected and in some cases existing demands may be unsustainable as groundwater levels decline. Areas that rely on the Ogallala aquifer are a good example. In some communities in the region, irrigated agriculture forms a major base of the regional economy. With less irrigation water from the Ogallala, population and economic activity in the region could decline significantly assuming there are no offsetting developments.

Assessing the social and economic effects of each of the above scenarios requires various levels and methods of analysis and would generate substantially different results for a number of reasons; the most important of which has to do with the time frame of each scenario. Scenario 1 falls into the general category of static analysis. This means that models would measure impacts for a small interval of time such as a drought. Scenarios 2 and 3, on the other hand imply a dynamic analysis meaning that models are concerned with changes over a much longer time period.

Since administrative rules specify that planning analysis be evaluated under drought of record conditions (a static and random event), socioeconomic impact analysis developed by the TWDB for the state water plan is based on assumptions of Scenario 1. Estimated impacts under scenario 1 are point estimates for years in which needs are reported (2010, 2020, 2030, 2040, 2050 and 2060). They are independent and distinct "what if" scenarios for a particular year and shortages are assumed to be temporary events resulting from drought of record conditions. Estimated impacts measure what would happen if water user groups experience water shortages for a period of one year.

The TWDB recognize that dynamic models may be more appropriate for some water user groups; however, combining approaches on a statewide basis poses several problems. For one, it would require a complex array of analyses and models, and might require developing supply and demand forecasts under "normal" climatic conditions as opposed to drought of record conditions. Equally important is the notion that combining the approaches would produce inconsistent results across regions resulting in a so-called "apples to oranges" comparison.

A variety tools are available to estimate economic impacts, but by far, the most widely used today are input-output models (IO models) combined with social accounting matrices (SAMs). Referred to as IO/SAM models, these tools formed the basis for estimating economic impacts for agriculture (irrigation and livestock water uses) and industry (manufacturing, mining, steam-electric and commercial business activity for municipal water uses).

Since the planning horizon extends through 2060, economic variables in the baseline are adjusted in accordance with projected changes in demographic and economic activity. Growth rates for municipal water use sectors (i.e., commercial, residential and institutional) are based on TWDB population forecasts. Future values for manufacturing, agriculture, and mining and steam-electric activity are based on the same underlying economic forecasts used to estimate future water use for each category.

The following steps outline the overall process.

Step 1: *Generate IO/SAM Models and Develop Economic Baseline*

IO/SAM models were estimated using propriety software known as IMPLAN PRO™ (Impact for Planning Analysis). IMPLAN is a modeling system originally developed by the U.S. Forestry Service in the late 1970s. Today, the Minnesota IMPLAN Group (MIG Inc.) owns the copyright and distributes data and software. It is probably the most widely used economic impact model in existence. IMPLAN comes with databases containing the most recently available economic data from a variety of sources.[1] Using IMPLAN software and data, transaction tables conceptually similar to the one discussed previously were estimated for each county in the region and for the region as a whole. Each transaction table contains 528 economic sectors and allows one to estimate a variety of economic statistics including:

- **total sales** - total production measured by sales revenues;
- **intermediate sales** - sales to other businesses and industries within a given region;
- **final sales** – sales to end users in a region and exports out of a region;
- **employment** - number of full and part-time jobs (annual average) required by a given industry including self-employment;
- **regional income** - total payroll costs (wages and salaries plus benefits) paid by industries, corporate income, rental income and interest payments; and
- **business taxes** - sales, excise, fees, licenses and other taxes paid during normal operation of an industry (does not include income taxes).

TWDB analysts developed an economic baseline containing each of the above variables using year 2000 data. Since the planning horizon extends through 2060, economic variables in the baseline were allowed to change in accordance with projected changes in demographic and economic activity. Growth rates for municipal water use sectors (i.e., commercial, residential and institutional) are based on TWDB population forecasts. Projections for manufacturing, agriculture, and mining and steam-electric activity are based on the same underlying economic forecasts used to estimate future water use for each category. Monetary impacts in future years are reported in constant year 2006 dollars.

It is important to stress that employment, income and business taxes are the most useful variables when comparing the relative contribution of an economic sector to a regional economy. Total sales as reported in IO/SAM models are less desirable and can be misleading because they include sales to other industries in the region for use in the production of other goods. For example, if a mill buys grain from local farmers and uses it to produce feed, sales of both the processed feed and raw corn are counted as "output" in an IO model. Thus, total sales double-count or overstate the true economic value of goods

[1]The IMPLAN database consists of national level technology matrices based on benchmark input-output accounts generated by the U.S. Bureau of Economic Analysis and estimates of final demand, final payments, industry output and employment for various economic sectors. IMPLAN regional data (i.e. states, a counties or groups of counties within a state) are divided into two basic categories: 1) data on an industry basis including value-added, output and employment, and 2) data on a commodity basis including final demands and institutional sales. State-level data are balanced to national totals using a matrix ratio allocation system and county data are balanced to state totals.

and services produced in an economy. They are not consistent with commonly used measures of output such as Gross National Product (GNP), which counts only final sales.

Another important distinction relates to terminology. Throughout this report, the term *sector* refers to economic subdivisions used in the IMPLAN database and resultant input-output models (528 individual sectors based on Standard Industrial Classification Codes). In contrast, the phrase *water use category* refers to water user groups employed in state and regional water planning including irrigation, livestock, mining, municipal, manufacturing and steam electric. Each IMPLAN sector was assigned to a specific water use category.

Step 2: *Estimate Direct and Indirect Economic Impacts of Water Needs*

Direct impacts are reductions in output by sectors experiencing water shortages. For example, without adequate cooling and process water a refinery would have to curtail or cease operation, car washes may close, or farmers may not be able to irrigate and sales revenues fall. Indirect impacts involve changes in inter-industry transactions as supplying industries respond to decreased demands for their services, and how seemingly non-related businesses are affected by decreased incomes and spending due to direct impacts. For example, if a farmer ceases operations due to a lack of irrigation water, they would likely reduce expenditures on supplies such as fertilizer, labor and equipment, and businesses that provide these goods would suffer as well.

Direct impacts accrue to immediate businesses and industries that rely on water and without water industrial processes could suffer. However, output responses may vary depending upon the severity of shortages. A small shortage relative to total water use would likely have a minimal impact, but large shortages could be critical. For example, farmers facing small shortages might fallow marginally productive acreage to save water for more valuable crops. Livestock producers might employ emergency culling strategies, or they may consider hauling water by truck to fill stock tanks. In the case of manufacturing, a good example occurred in the summer of 1999 when Toyota Motor Manufacturing experienced water shortages at a facility near Georgetown, Kentucky.[2] As water levels in the Kentucky River fell to historic lows due to drought, plant managers sought ways to curtail water use such as reducing rinse operations to a bare minimum and recycling water by funneling it from paint shops to boilers. They even considered trucking in water at a cost of 10 times what they were paying. Fortunately, rains at the end of the summer restored river levels, and Toyota managed to implement cutbacks without affecting production, but it was a close call. If rains had not replenished the river, shortages could have severely reduced output.[3]

To account for uncertainty regarding the relative magnitude of impacts to farm and business operations, the following analysis employs the concept of elasticity. Elasticity is a number that shows how a change in one variable will affect another. In this case, it measures the relationship between a percentage reduction in water availability and a percentage reduction in output. For example, an elasticity of 1.0 indicates that a 1.0 percent reduction in water availability would result in a 1.0 percent reduction in economic output. An elasticity of 0.50 would indicate that for every 1.0 percent of unavailable water, output is reduced by 0.50 percent and so on. Output elasticities used in this study are:[4]

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[2] Royal, W. "*High And Dry - Industrial Centers Face Water Shortages.*" in Industry Week, Sept, 2000.

[3] The efforts described above are not planned programmatic or long-term operational changes. They are emergency measures that individuals might pursue to alleviate what they consider a temporary condition. Thus, they are not characteristic of long-term management strategies designed to ensure more dependable water supplies such as capital investments in conservation technology or development of new water supplies.

[4] Elasticities are based on one of the few empirical studies that analyze potential relationships between economic output and water shortages in the United States. The study, conducted in California, showed that a significant number of industries would suffer reduced output during water shortages. Using a survey based approach researchers posed two scenarios to different industries. In

- if water needs are 0 to 5 percent of total water demand, no corresponding reduction in output is assumed;
- if water needs are 5 to 30 percent of total water demand, for each additional one percent of water need that is not met, there is a corresponding 0.50 percent reduction in output;
- if water needs are 30 to 50 percent of total water demand, for each additional one percent of water need that is not met, there is a corresponding 0.75 percent reduction in output; and
- if water needs are greater than 50 percent of total water demand, for each additional one percent of water need that is not met, there is a corresponding 1.0 percent (i.e., a proportional reduction).

In some cases, elasticities are adjusted depending upon conditions specific to a given water user group.

Once output responses to water shortages were estimated, direct impacts to total sales, employment, regional income and business taxes were derived using regional level economic multipliers estimating using IO/SAM models. The formula for a given IMPLAN sector is:

$$D_{i,t} = Q_{i,t} * S_{i,t} * E_Q * RFD_i * DM_{i(Q, L, I, T)}$$

where:

$D_{i,t}$ = direct economic impact to sector *i* in period *t*

$Q_{i,t}$ = total sales for sector *i* in period *t* in an affected county

$RFD_{i,}$ = ratio of final demand to total sales for sector *i* for a given region

$S_{i,t}$ = water shortage as percentage of total water use in period *t*

E_Q = elasticity of output and water use

$DM_{i(L, I, T)}$ = direct output multiplier coefficients for labor (L), income (I) and taxes (T) for sector *i*.

Secondary impacts were derived using the same formula used to estimate direct impacts; however, indirect multiplier coefficients are used. Methods and assumptions specific to each water use sector are discussed in Sections 1.1.2 through 1.1.4.

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the first scenario, they asked how a 15 percent cutback in water supply lasting one year would affect operations. In the second scenario, they asked how a 30 percent reduction lasting one year would affect plant operations. In the case of a 15 percent shortage, reported output elasticities ranged from 0.00 to 0.76 with an average value of 0.25. For a 30 percent shortage, elasticities ranged from 0.00 to 1.39 with average of 0.47. For further information, see, California Urban Water Agencies, "*Cost of Industrial Water Shortages,*" Spectrum Economics, Inc. November, 1991.

General Assumptions and Clarification of the Methodology

As with any attempt to measure and quantify human activities at a societal level, assumptions are necessary and every model has limitations. Assumptions are needed to maintain a level of generality and simplicity such that models can be applied on several geographic levels and across different economic sectors. In terms of the general approach used here several clarifications and cautions are warranted:

1. Shortages as reported by regional planning groups are the starting point for socioeconomic analyses.

2. Estimated impacts are point estimates for years in which needs are reported (i.e., 2010, 2020, 2030, 2040, 2050 and 2060).They are independent and distinct "what if" scenarios for each particular year and water shortages are assumed to be temporary events resulting from severe drought conditions combined with infrastructure limitations. In other words, growth occurs and future shocks are imposed on an economy at 10-year intervals and resultant impacts are measured. Given, that reported figures are not cumulative in nature, it is inappropriate to sum impacts over the entire planning horizon. Doing so, would imply that the analysis predicts that drought of record conditions will occur every ten years in the future, which is not the case. Similarly, authors of this report recognize that in many communities needs are driven by population growth, and in the future total population will exceed the amount of water available due to infrastructure limitations, regardless of whether or not there is a drought. This implies that infrastructure limitations would constrain economic growth. However, since needs as defined by planning rules are based upon water supply and demand under the assumption of drought of record conditions, it improper to conduct economic analysis that focuses on growth related impacts over the planning horizon. Figures generated from such an analysis would presume a 50-year drought of record, which is unrealistic. Estimating lost economic activity related to constraints on population and commercial growth due to lack of water would require developing water supply and demand forecasts under "normal" or "most likely" future climatic conditions.

3. While useful for planning purposes, this study is not a benefit-cost analysis. Benefit cost analysis is a tool widely used to evaluate the economic feasibility of specific policies or projects as opposed to estimating economic impacts of unmet water needs. Nevertheless, one could include some impacts measured in this study as part of a benefit cost study if done so properly. Since this is not a benefit cost analysis, future impacts are not weighted differently. In other words, estimates are not discounted. If used as a measure of economic benefits, one should incorporate a measure of uncertainty into the analysis. In this type of analysis, a typical method of discounting future values is to assign probabilities of the drought of record recurring again in a given year, and weight monetary impacts accordingly. This analysis assumes a probability of one.

4. IO multipliers measure the strength of backward linkages to supporting industries (i.e., those who sell inputs to an affected sector). However, multipliers say nothing about forward linkages consisting of businesses that purchase goods from an affected sector for further processing. For example, ranchers in many areas sell most of their animals to local meat packers who process animals into a form that consumers ultimately see in grocery stores and restaurants. Multipliers do not capture forward linkages to meat packers, and since meat packers sell livestock purchased from ranchers as "final sales," multipliers for the ranching sector do fully account for all losses to a region's economy. Thus, as mentioned previously, in some cases closely linked sectors were moved from one water use category to another.

5. Cautions regarding interpretations of direct and secondary impacts are warranted. IO/SAM multipliers are based on "fixed-proportion production functions," which basically means that input use - including labor - moves in lockstep fashion with changes in levels of output. In a

scenario where output (i.e., sales) declines, losses in the immediate sector or supporting sectors could be much less than predicted by an IO/SAM model for several reasons. For one, businesses will likely expect to continue operating so they might maintain spending on inputs for future use; or they may be under contractual obligations to purchase inputs for an extended period regardless of external conditions. Also, employers may not lay-off workers given that experienced labor is sometimes scarce and skilled personnel may not be readily available when water shortages subside. Lastly people who lose jobs might find other employment in the region. As a result, direct losses for employment and secondary losses in sales and employment should be considered an upper bound. Similarly, since projected population losses are based on reduced employment in the region, they should be considered an upper bound as well.

6. IO models are static. Models and resultant multipliers are based upon the structure of the U.S. and regional economies in 2006. In contrast, water shortages are projected to occur well into the future. Thus, the analysis assumes that the general structure of the economy remains the same over the planning horizon, and the farther out into the future we go, this assumption becomes less reliable.

7. Impacts are annual estimates. If one were to assume that conditions persisted for more than one year, figures should be adjusted to reflect the extended duration. The drought of record in most regions of Texas lasted several years.

8. Monetary figures are reported in constant year 2006 dollars.

1.1.2 Impacts to Agriculture

Irrigated Crop Production

The first step in estimating impacts to irrigation required calculating gross sales for IMPLAN crop sectors. Default IMPLAN data do not distinguish irrigated production from dry-land production. Once gross sales were known other statistics such as employment and income were derived using IMPLAN direct multiplier coefficients. Gross sales for a given crop are based on two data sources:

1) county-level statistics collected and maintained by the TWDB and the USDA Farm Services Agency (FSA) including the number of irrigated acres by crop type and water application per acre, and

2) regional-level data published by the Texas Agricultural Statistics Service (TASS) including prices received for crops (marketing year averages), crop yields and crop acreages.

Crop categories used by the TWDB differ from those used in IMPLAN datasets. To maintain consistency, sales and other statistics are reported using IMPLAN crop classifications. Table 1 shows the TWDB crops included in corresponding IMPLAN sectors, and Table 2 summarizes acreage and estimated annual water use for each crop classification (five-year average from 2003-2007). Table 3 displays average (2003-2007) gross revenues per acre for IMPLAN crop categories.

Table 1: Crop Classifications Used in TWDB Water Use Survey and Corresponding IMPLAN Crop Sectors	
IMPLAN Category	**TWDB Category**
Oilseeds	Soybeans and other oil crops
Grains	Grain sorghum, corn, wheat and other grain crops
Vegetable and melons	Vegetables and potatoes
Tree nuts	Pecans
Fruits	Citrus, vineyard and other orchard
Cotton	Cotton
Sugarcane and sugar beets	Sugarcane and sugar beets
All other crops	Forage crops, peanuts, alfalfa, hay and pasture, rice and all other crops

Table 2: Summary of Irrigated Crop Acreage and Water Demand for the Plateau Regional Water Planning Area (average 2003-2007)

Sector	Acres (1000s)	Distribution of Acres	Water Use (1000s of AF)	Distribution of Water Use
Grains	1.48	26%	1.67	18%
Tree nuts	0.34	6%	0.76	8%
Fruits	0.04	1%	0.09	1%
Cotton	0.58	10%	0.82	9%
All other crops	3.28	57%	5.83	64%
Total	1.48	26%	1.67	18%

Source: Water demand figures are a five year average (2003-2007) of the TWDB's annual Irrigation Water Use Estimates. Statistics for irrigated crop acreage are based upon annual survey data collected by the TWDB and the Farm Service Agency. Values do not include acreage or water use for the TWDB categories classified by the Farm Services Agency as "failed acres," "golf course" or "waste water."

Table 3: Average Gross Sales Revenues per Acre for Irrigated Crops for the Plateau Regional Water Planning Area (2003-2007)

IMPLAN Sector	Gross revenues per acre	Crops Included in estimates
Oilseeds	NA	Based on five-year (2003-2007) average weighted by acreage for "irrigated soybeans" and "irrigated other oil crops."
Grains	$162	Based on five-year (2003-2007) average weighted by acreage for "irrigated grain sorghum," "irrigated corn", "irrigated wheat" and "irrigated 'other' grain crops."
Vegetable and melons	NA	Based on five-year (2003-2007) average weighted by acreage for "irrigated shallow and deep root vegetables," "irrigated Irish potatoes" and "irrigated melons."
Tree nuts	$3,468	Based on five-year (2003-2007) average weighted by acreage for "irrigated pecans."
Fruits	$3,155	Based on five-year (2003-2007) average weighted by acreage for "irrigated citrus," "irrigated vineyards" and "irrigated 'other' orchard."
Cotton	$517	Based on five-year (2003-2007) average weighted by acreage for "irrigated cotton."
All "other" crops	$303	Irrigated figure is based on five-year (2003-2007) average weighted by acreage for "irrigated 'forage' crops", "irrigated peanuts", "irrigated alfalfa", "irrigated 'hay' and pasture" and "irrigated 'all other' crops."

*Figures are rounded. Source: Based on data from the Texas Agricultural Statistics Service, Texas Water Development Board, and Texas A&M University.

An important consideration when estimating impacts to irrigation was determining which crops are affected by water shortages. One approach is the so-called rationing model, which assumes that farmers respond to water supply cutbacks by fallowing the lowest value crops in the region first and the highest valued crops last until the amount of water saved equals the shortage.[5] For example, if farmer A grows vegetables (higher value) and farmer B grows wheat (lower value) and they both face a proportionate cutback in irrigation water, then farmer B will sell water to farmer A. Farmer B will fallow her irrigated acreage before farmer A fallows anything. Of course, this assumes that farmers can and do transfer enough water to allow this to happen. A different approach involves constructing farm-level profit maximization models that conform to widely-accepted economic theory that farmers make decisions based on marginal net returns. Such models have good predictive capability, but data requirements and complexity are high. Given that a detailed analysis for each region would require a substantial amount of farm-level data and analysis, the following investigation assumes that projected shortages are distributed equally across predominant crops in the region. Predominant in this case are crops that comprise at least one percent of total acreage in the region.

The following steps outline the overall process used to estimate direct impacts to irrigated agriculture:

1. *Distribute shortages across predominant crop types in the region.* Again, unmet water needs were distributed equally across crop sectors that constitute one percent or more of irrigated acreage.

2. *Estimate associated reductions in output for affected crop sectors.* Output reductions are based on elasticities discussed previously and on estimated values per acre for different crops. Values per acre stem from the same data used to estimate output for the year 2006 baseline. Using multipliers, we then generate estimates of forgone income, jobs, and tax revenues based on reductions in gross sales and final demand.

Livestock

The approach used for the livestock sector is basically the same as that used for crop production. As is the case with crops, livestock categorizations used by the TWDB differ from those used in IMPLAN datasets, and TWDB groupings were assigned to a given IMPLAN sector (Table 4). Then we:

1) *Distribute projected water needs equally among predominant livestock sectors and estimate lost output*: As is the case with irrigation, shortages are assumed to affect all livestock sectors equally; however, the category of "other" is not included given its small size. If water needs were small relative to total demands, we assume that producers would haul in water by truck to fill stock tanks. The cost per acre-foot ($24,000) is based on rates charged by various water haulers in Texas, and assumes that the average truck load is 6,500 gallons at a hauling distance of 60 miles.

3) *Estimate reduced output in forward processors for livestock sectors.* Reductions in output for livestock sectors are assumed to have a proportional impact on forward processors in the region such as meat packers. In other words, if the cows were gone, meat-packing plants or fluid milk manufacturers) would likely have little to process. This is not an unreasonable premise. Since the

[5] The rationing model was initially proposed by researchers at the University of California at Berkeley, and was then modified for use in a study conducted by the U.S. Environmental Protection Agency that evaluated how proposed water supply cutbacks recommended to protect water quality in the Bay/Delta complex in California would affect farmers in the Central Valley. See, Zilberman, D., Howitt, R. and Sunding, D. "*Economic Impacts of Water Quality Regulations in the San Francisco Bay and Delta.*" Western Consortium for Public Health. May 1993.

1950s, there has been a major trend towards specialized cattle feedlots, which in turn has decentralized cattle purchasing from livestock terminal markets to direct sales between producers and slaughterhouses. Today, the meat packing industry often operates large processing facilities near high concentrations of feedlots to increase capacity utilization.[6] As a result, packers are heavily dependent upon nearby feedlots. For example, a recent study by the USDA shows that on average meat packers obtain 64 percent of cattle from within 75 miles of their plant, 82 percent from within 150 miles and 92 percent from within 250 miles.[7]

Table 4: Description of Livestock Sectors

IMPLAN Category	TWDB Category
Cattle ranching and farming	Cattle, cow calf, feedlots and dairies
Poultry and egg production	Poultry production.
Other livestock	Livestock other than cattle and poultry (i.e., horses, goats, sheep, hogs)
Milk manufacturing	Fluid milk manufacturing, cheese manufacturing, ice cream manufacturing etc.
Meat packing	Meat processing present in the region from slaughter to final processing

1.1.3 Impacts to Municipal Water User Groups

Disaggregation of Municipal Water Demands

Estimating the economic impacts for the municipal water user groups is complicated for a number of reasons. For one, municipal use comprises a range of consumers including commercial businesses, institutions such as schools and government and households. However, reported water needs are not distributed among different municipal water users. In other words, how much of a municipal need is commercial and how much is residential (domestic)?

The amount of commercial water use as a percentage of total municipal demand was estimated based on "GED" coefficients (gallons per employee per day) published in secondary sources.[8] For example, if year 2006 baseline data for a given economic sector (e.g., amusement and recreation services) shows employment at 30 jobs and the GED coefficient is 200, then average daily water use by that sector is (30 x

[6] Ferreira, W.N. *"Analysis of the Meat Processing Industry in the United States."* Clemson University Extension Economics Report ER211, January 2003.

[7] Ward, C.E. *"Summary of Results from USDA's Meatpacking Concentration Study."* Oklahoma Cooperative Extension Service, OSU Extension Facts WF-562.

[8] Sources for GED coefficients include: Gleick, P.H., Haasz, D., Henges-Jeck, C., Srinivasan, V., Wolff, G. Cushing, K.K., and Mann, A. "*Waste Not, Want Not: The Potential for Urban Water Conservation in California.*" Pacific Institute. November 2003. U.S. Bureau of the Census. 1982 Census of Manufacturers: Water Use in Manufacturing. USGPO, Washington D.C. See also: "*U.S. Army Engineer Institute for Water Resources, IWR Report 88-R-6.,*" Fort Belvoir, VA. See also, Joseph, E. S., 1982, "*Municipal and Industrial Water Demands of the Western United States.*" Journal of the Water Resources Planning and Management Division, Proceedings of the American Society of Civil Engineers, v. 108, no. WR2, p. 204-216. See also, Baumann, D. D., Boland, J. J., and Sims, J. H., 1981, "*Evaluation of Water Conservation for Municipal and Industrial Water Supply.*" U.S. Army Corps of Engineers, Institute for Water Resources, Contract no. 82-C1.

200 = 6,000 gallons) or 6.7 acre-feet per year. Water not attributed to commercial use is considered domestic, which includes single and multi-family residential consumption, institutional uses and all use designated as "county-other." Based on our analysis, commercial water use is about 5 to 35 percent of municipal demand. Less populated rural counties occupy the lower end of the spectrum, while larger metropolitan counties are at the higher end.

After determining the distribution of domestic versus commercial water use, we developed methods for estimating impacts to the two groups.

Domestic Water Uses

Input output models are not well suited for measuring impacts of shortages for domestic water uses, which make up the majority of the municipal water use category. To estimate impacts associated with domestic water uses, municipal water demand and needs are subdivided into residential, and commercial and institutional use. Shortages associated with residential water uses are valued by estimating proxy demand functions for different water user groups allowing us to estimate the marginal value of water, which would vary depending upon the level of water shortages. The more severe the water shortage, the more costly it becomes. For instance, a 2 acre-foot shortage for a group of households that use 10 acre-feet per year would not be as severe as a shortage that amounted to 8 acre-feet. In the case of a 2 acre-foot shortage, households would probably have to eliminate some or all outdoor water use, which could have implicit and explicit economic costs including losses to the horticultural and landscaping industry. In the case of an 8 acre-foot shortage, people would have to forgo all outdoor water use and most indoor water consumption. Economic impacts would be much higher in the latter case because people, and would be forced to find emergency alternatives assuming alternatives were available.

To estimate the value of domestic water uses, TWDB staff developed marginal loss functions based on constant elasticity demand curves. This is a standard and well-established method used by economists to value resources such as water that have an explicit monetary cost.

A constant price elasticity of demand is estimated using a standard equation:

$$w = kc^{(-\varepsilon)}$$

where:

- w is equal to average monthly residential water use for a given water user group measured in thousands of gallons;
- k is a constant intercept;
- c is the average cost of water per 1,000 gallons; and
- ε is the price elasticity of demand.

Price elasticities (-0.30 for indoor water use and -0.50 for outdoor use) are based on a study by Bell et al.[9] that surveyed 1,400 water utilities in Texas that serve at least 1,000 people to estimate demand elasticity for several variables including price, income, weather etc. Costs of water and average use per month per household are based on data from the Texas Municipal League's annual water and

[9] Bell, D.R. and Griffin, R.C. "*Community Water Demand in Texas as a Century is Turned.*" Research contract report prepared for the Texas Water Development Board. May 2006.

wastewater rate surveys - specifically average monthly household expenditures on water and wastewater in different communities across the state. After examining variance in costs and usage, three different categories of water user groups based on population (population less than 5,000, cities with populations ranging from 5,000 to 99,999 and cities with populations exceeding 100,000) were selected to serve as proxy values for municipal water groups that meet the criteria (Table 5).[10]

Table 5: Water Use and Costs Parameters Used to Estimate Water Demand Functions (average monthly costs per acre-foot for delivered water and average monthly use per household)

Community population	Water	Wastewater	Total monthly cost	Avg. monthly use (gallons)
Less than or equal to 5,000	$1,335	$1,228	$2,563	6,204
5,000 to 100,000	$718	$1,162	$1,880	7,950
Great than or equal to 100,000	$1,047	$457	$1,504	8,409

Source: Based on annual water and wastewater rate surveys published by the Texas Municipal League.

As an example, Table 6 shows the economic impact per acre-foot of domestic water needs for municipal water user groups with population exceeding 100,000 people. There are several important assumptions incorporated in the calculations:

1) Reported values are net of the variable costs of treatment and distribution such as expenses for chemicals and electricity since using less water involves some savings to consumers and utilities alike; and for outdoor uses we do not include any value for wastewater.

2) Outdoor and "non-essential" water uses would be eliminated before indoor water consumption was affected, which is logical because most water utilities in Texas have drought contingency plans that generally specify curtailment or elimination of outdoor water use during droughts.[11] Determining how much water is used for outdoor purposes is based on several secondary sources. The first is a major study sponsored by the American Water Works Association, which surveyed cities in states including Colorado, Oregon, Washington, California, Florida and Arizona. On average across all cities surveyed 58 percent of single family residential water use was for outdoor activities. In cities with climates comparable to large metropolitan areas of Texas, the average was 40 percent.[12] Earlier findings of the U.S. Water Resources Council showed a national

[10] Ideally, one would want to estimate demand functions for each individual utility in the state. However, this would require an enormous amount of time and resources. For planning purposes, we believe the values generated from aggregate data are more than sufficient.

[11] In Texas, state law requires retail and wholesale water providers to prepare and submit plans to the Texas Commission on Environmental Quality (TCEQ). Plans must specify demand management measures for use during drought including curtailment of "non-essential water uses." Non-essential uses include, but are not limited to, landscape irrigation and water for swimming pools or fountains. For further information see the Texas Environmental Quality Code §288.20.

[12] See, Mayer, P.W., DeOreo, W.B., Opitz, E.M., Kiefer, J.C., Davis, W., Dziegielewski, D., Nelson, J.O. "*Residential End Uses of Water.*" Research sponsored by the American Water Works Association and completed by Aquacraft, Inc. and Planning and Management Consultants, Ltd. (PMCL@CDM).

average of 33 percent. Similarly, the United States Environmental Protection Agency (USEPA) estimated that landscape watering accounts for 32 percent of total residential and commercial water use on annual basis.[13] A study conducted for the California Urban Water Agencies (CUWA) calculated average annual values ranging from 25 to 35 percent.[14] Unfortunately, there does not appear to be any comprehensive research that has estimated non-agricultural outdoor water use in Texas. As an approximation, an average annual value of 30 percent based on the above references was selected to serve as a rough estimate in this study.

3) As shortages approach 100 percent values become immense and theoretically infinite at 100 percent because at that point death would result, and willingness to pay for water is immeasurable. Thus, as shortages approach 80 percent of monthly consumption, we assume that households and non-water intensive commercial businesses (those that use water only for drinking and sanitation would have water delivered by tanker truck or commercial water delivery companies. Based on reports from water companies throughout the state, we estimate that the cost of trucking in water is around $21,000 to $27,000 per acre-feet assuming a hauling distance of between 20 to 60 miles. This is not an unreasonable assumption. The practice was widespread during the 1950s drought and recently during droughts in this decade. For example, in 2000 at the heels of three consecutive drought years Electra - a small town in North Texas - was down to its last 45 days worth of reservoir water when rain replenished the lake, and the city was able to refurbish old wells to provide supplemental groundwater. At the time, residents were forced to limit water use to 1,000 gallons per person per month - less than half of what most people use - and many were having water delivered to their homes by private contractors.[15] In 2003 citizens of Ballinger, Texas, were also faced with a dwindling water supply due to prolonged drought. After three years of drought, Lake Ballinger, which supplies water to more than 4,300 residents in Ballinger and to 600 residents in nearby Rowena, was almost dry. Each day, people lined up to get water from a well in nearby City Park. Trucks hauling trailers outfitted with large plastic and metal tanks hauled water to and from City Park to Ballinger.[16]

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[13] U.S. Environmental Protection Agency. *"Cleaner Water through Conservation."* USEPA Report no. 841-B-95-002. April, 1995.

[14] Planning and Management Consultants, Ltd. *"Evaluating Urban Water Conservation Programs: A Procedures Manual."* Prepared for the California Urban Water Agencies. February 1992.

[15] Zewe, C. *"Tap Threatens to Run Dry in Texas Town."* July 11, 2000. CNN Cable News Network.

[16] Associated Press, *"Ballinger Scrambles to Finish Pipeline before Lake Dries Up."* May 19, 2003.

Table 6: Economic Losses Associated with Domestic Water Shortages in Communities with Populations Exceeding 100,000						
Water shortages as a percentage of total monthly household demands	No. of gallons remaining per household per day	No of gallons remaining per person per day	Economic loss (per acre-foot)		Economic loss (per gallon)	
1%	278	93	$748		$0.00005	
5%	266	89	$812		$0.0002	
10%	252	84	$900		$0.0005	
15%	238	79	$999		$0.0008	
20%	224	75	$1,110		$0.0012	
25%	210	70	$1,235		$0.0015	
30%[a]	196	65	$1,699		$0.0020	
35%	182	61	$3,825		$0.0085	
40%	168	56	$4,181		$0.0096	
45%	154	51	$4,603		$0.011	
50%	140	47	$5,109		$0.012	
55%	126	42	$5,727		$0.014	
60%	112	37	$6,500		$0.017	
65%	98	33	$7,493		$0.02	
70%	84	28	$8,818		$0.02	
75%	70	23	$10,672		$0.03	
80%	56	19	$13,454		$0.04	
85%	42	14	$18,091		$0.05	
90%	28	9	$27,363	($24,000)[b]	$0.08	($0.07)[b]
95%	14	5	$55,182	($24,000)	$0.17	($0.07)
99%	3	0.9	$277,728	($24,000)	$0.85	($0.07)
99.9%	1	0.5	$2,781,377	($24,000)	$8.53	($0.07)
100%	0	0	Infinite	($24,000)	Infinite	($0.07)

[a] The first 30 percent of needs are assumed to be restrictions of outdoor water use; when needs reach 30 percent of total demands all outdoor water uses would be restricted. Needs greater than 30 percent include indoor use.

[b] As shortages approach 100 percent the value approaches infinity assuming there are not alternatives available; however, we assume that communities would begin to have water delivered by tanker truck at an estimated cost of $24,000 per acre-foot when shortages breached 85 percent.

Commercial Businesses

Effects of water shortages on commercial sectors were estimated in a fashion similar to other business sectors meaning that water shortages would affect the ability of these businesses to operate. This is particularly true for "water intensive" commercial sectors that are need large amounts of water (in addition to potable and sanitary water) to provide their services. These include:

- car-washes,
- laundry and cleaning facilities,
- sports and recreation clubs and facilities including race tracks,
- amusement and recreation services,
- hospitals and medical facilities,
- hotels and lodging places, and
- eating and drinking establishments.

A key assumption is that commercial operations would not be affected until water shortages were at least 50 percent of total municipal demand. In other words, we assume that residential water consumers would reduce water use including all non-essential uses before businesses were affected.

An example will illustrate the breakdown of municipal water needs and the overall approach to estimating impacts of municipal needs. Assume City A experiences an unexpected shortage of 50 acre-feet per year when their demands are 200 acre-feet per year. Thus, shortages are only 25 percent of total municipal use and residents of City A could eliminate needs by restricting landscape irrigation. City B, on the other hand, has a deficit of 150 acre-feet in 2020 and a projected demand of 200 acre-feet. Thus, total shortages are 75 percent of total demand. Emergency outdoor and some indoor conservation measures could eliminate 50 acre-feet of projected needs, yet 50 acre-feet would still remain. To eliminate" the remaining 50 acre-feet water intensive commercial businesses would have to curtail operations or shut down completely.

Three other areas were considered when analyzing municipal water shortages: 1) lost revenues to water utilities, 2) losses to the horticultural and landscaping industries stemming for reduction in water available for landscape irrigation, and 3) lost revenues and related economic impacts associated with reduced water related recreation.

Water Utility Revenues

Estimating lost water utility revenues was straightforward. We relied on annual data from the "*Water and Wastewater Rate Survey*" published annually by the Texas Municipal League to calculate an average value per acre-foot for water and sewer. For water revenues, average retail water and sewer rates multiplied by total water needs served as a proxy. For lost wastewater, total unmet needs were adjusted for return flow factor of 0.60 and multiplied by average sewer rates for the region. Needs reported as "county-other" were excluded under the presumption that these consist primarily of self-supplied water uses. In addition, 15 percent of water demand and needs are considered non-billed or "unaccountable" water that comprises things such as leakages and water for municipal government functions (e.g., fire departments). Lost tax receipts are based on current rates for the "miscellaneous gross receipts tax, "which the state collects from utilities located in most incorporated cities or towns in Texas. We do not include lost water utility revenues when aggregating impacts of municipal water shortages to regional and state levels to prevent double counting.

Horticultural and Landscaping Industry

The horticultural and landscaping industry, also referred to as the "green Industry," consists of businesses that produce, distribute and provide services associated with ornamental plants, landscape and garden supplies and equipment. Horticultural industries often face big losses during drought. For example, the recent drought in the Southeast affecting the Carolinas and Georgia horticultural and landscaping businesses had a harsh year. Plant sales were down, plant mortality increased, and watering costs increased. Many businesses were forced to close locations, lay off employees, and even file for bankruptcy. University of Georgia economists put statewide losses for the industry at around $3.2 billion during the 3-year drought that ended in 2008.[17] Municipal restrictions on outdoor watering play a significant role. During drought, water restrictions coupled with persistent heat has a psychological effect on homeowners that reduces demands for landscaping products and services. Simply put, people were afraid to spend any money on new plants and landscaping.

In Texas, there do not appear to be readily available studies that analyze the economic effects of water shortages on the industry. However, authors of this report believe negative impacts do and would result in restricting landscape irrigation to municipal water consumers. The difficulty in measuring them is two-fold. First, as noted above, data and research for these types of impacts that focus on Texas are limited; and second, economic data provided by IMPLAN do not disaggregate different sectors of the green industry to a level that would allow for meaningful and defensible analysis.[18]

Recreational Impacts

Recreational businesses often suffer when water levels and flows in rivers, springs and reservoirs fall significantly during drought. During droughts, many boat docks and lake beaches are forced to close, leading to big losses for lakeside business owners and local communities. Communities adjacent to popular river and stream destinations such as Comal Springs and the Guadalupe River also see their business plummet when springs and rivers dry up. Although there are many examples of businesses that have suffered due to drought, dollar figures for drought-related losses to the recreation and tourism industry are not readily available, and very difficult to measure without extensive local surveys. Thus, while they are important, economic impacts are not measured in this study.

Table 7 summarizes impacts of municipal water shortages at differing levels of magnitude, and shows the ranges of economic costs or losses per acre-foot of shortage for each level.

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[17] Williams, D. *"Georgia landscapers eye rebound from Southeast drought."* Atlanta Business Chronicle, Friday, June 19, 2009

[18] Economic impact analyses prepared by the TWDB for 2006 regional water plans did include estimates for the horticultural industry. However, year 2000 and prior IMPLAN data were disaggregated to a finer level. In the current dataset (2006), the sector previously listed as "Landscaping and Horticultural Services" (IMPLAN Sector 27) is aggregated into "Services to Buildings and Dwellings" (IMPLAN Sector 458).

Table 7: Impacts of Municipal Water Shortages at Different Magnitudes of Shortages		
Water shortages as percent of total municipal demands	Impacts	Economic costs per acre-foot*
0-30%	✓ Lost water utility revenues ✓ Restricted landscape irrigation and non-essential water uses	$730 - $2,040
30-50%	✓ Lost water utility revenues ✓ Elimination of landscape irrigation and non-essential water uses ✓ Rationing of indoor use	$2040 - $10,970
>50%	✓ Lost water utility revenues ✓ Elimination of landscape irrigation and non-essential water uses ✓ Rationing of indoor use ✓ Restriction or elimination of commercial water use ✓ Importing water by tanker truck	$10,970 - varies
*Figures are rounded		

1.1.4 Industrial Water User Groups

Manufacturing

Impacts to manufacturing were estimated by distributing water shortages among industrial sectors at the county level. For example, if a planning group estimates that during a drought of record water supplies in County A would only meet 50 percent of total annual demands for manufactures in the county, we reduced output for each sector by 50 percent. Since projected manufacturing demands are based on TWDB Water Uses Survey data for each county, we only include IMPLAN sectors represented in the TWBD survey database. Some sectors in IMPLAN databases are not part of the TWDB database given that they use relatively small amounts of water - primarily for on-site sanitation and potable purposes. To maintain consistency between IMPLAN and TWDB databases, Standard Industrial Classification (SIC) codes both databases were cross referenced in county with shortages. Non-matches were excluded when calculating direct impacts.

Mining

The process of mining is very similar to that of manufacturing. We assume that within a given county, shortages would apply equally to relevant mining sectors, and IMPLAN sectors are cross referenced with TWDB data to ensure consistency.

In Texas, oil and gas extraction and sand and gravel (aggregates) operations are the primary mining industries that rely on large volumes of water. For sand and gravel, estimated output reductions are straightforward; however, oil and gas is more complicated for a number of reasons. IMPLAN does not necessarily report the physical extraction of minerals by geographic local, but rather the sales revenues reported by a particular corporation.

For example, at the state level revenues for IMPLAN sector 19 (oil and gas extraction) and sector 27 (drilling oil and gas wells) totals $257 billion. Of this, nearly $85 billion is attributed to Harris County. However, only a very small fraction (less than one percent) of actual production takes place in the county. To measure actual potential losses in well head capacity due to water shortages, we relied on county level production data from the Texas Railroad Commission (TRC) and average well-head market prices for crude and gas to estimate lost revenues in a given county. After which, we used to IMPLAN ratios to estimate resultant losses in income and employment.

Other considerations with respect to mining include:

1) Petroleum and gas extraction industry only uses water in significant amounts for secondary recovery. Known in the industry as enhanced or water flood extraction, secondary recovery involves pumping water down injection wells to increase underground pressure thereby pushing oil or gas into other wells. IMPLAN output numbers do not distinguish between secondary and non-secondary recovery. To account for the discrepancy, county-level TRC data that show the proportion of barrels produced using secondary methods were used to adjust IMPLAN data to reflect only the portion of sales attributed to secondary recovery.

2) A substantial portion of output from mining operations goes directly to businesses that are classified as manufacturing in our schema. Thus, multipliers measuring backward linkages for a given manufacturer might include impacts to a supplying mining operation. Care was taken not to double count in such situations if both a mining operation and a manufacturer were reported as having water shortages.

Steam-electric

At minimum without adequate cooling water, power plants cannot safely operate. As water availability falls below projected demands, water levels in lakes and rivers that provide cooling water would also decline. Low water levels could affect raw water intakes and outfalls at electrical generating units in several ways. For one, power plants are regulated by thermal emission guidelines that specify the maximum amount of heat that can go back into a river or lake via discharged cooling water. Low water levels could result in permit compliance issues due to reduced dilution and dispersion of heat and subsequent impacts on aquatic biota near outfalls.[19] However, the primary concern would be a loss of head (i.e., pressure) over intake structures that would decrease flows through intake tunnels. This would affect safety related pumps, increase operating costs and/or result in sustained shut-downs. Assuming plants did shutdown, they would not be able to generate electricity.

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[19] Section 316 (b) of the Clean Water Act requires that thermal wastewater discharges do not harm fish and other wildlife.

Among all water use categories steam-electric is unique and cautions are needed when applying methods used in this study. Measured changes to an economy using input-output models stem directly from changes in sales revenues. In the case of water shortages, one assumes that businesses will suffer lost output if process water is in short supply. For power generation facilities this is true as well. However, the electric services sector in IMPLAN represents a corporate entity that may own and operate several electrical generating units in a given region. If one unit became inoperable due to water shortages, plants in other areas or generation facilities that do not rely heavily on water such as gas powered turbines might be able to compensate for lost generating capacity. Utilities could also offset lost production via purchases on the spot market.[20] Thus, depending upon the severity of the shortages and conditions at a given electrical generating unit, energy supplies for local and regional communities could be maintained. But in general, without enough cooling water, utilities would have to throttle back plant operations, forcing them to buy or generate more costly power to meet customer demands.

Measuring impacts end users of electricity is not part of this study as it would require extensive local and regional level analysis of energy production and demand. To maintain consistency with other water user groups, impacts of steam-electric water shortages are measured in terms of lost revenues (and hence income) and jobs associated with shutting down electrical generating units.

1.2 Social Impacts of Water Shortages

As the name implies, the effects of water shortages can be social or economic. Distinctions between the two are both semantic and analytical in nature – more so analytic in the sense that social impacts are harder to quantify. Nevertheless, social effects associated with drought and water shortages are closely tied to economic impacts. For example, they might include:

- demographic effects such as changes in population,
- disruptions in institutional settings including activity in schools and government,
- conflicts between water users such as farmers and urban consumers,
- health-related low-flow problems (e.g., cross-connection contamination, diminished sewage flows, increased pollutant concentrations),
- mental and physical stress (e.g., anxiety, depression, domestic violence),
- public safety issues from forest and range fires and reduced fire fighting capability,
- increased disease caused by wildlife concentrations,
- loss of aesthetic and property values, and
- reduced recreational opportunities.[21]

[20] Today, most utilities participate in large interstate "power pools" and can buy or sell electricity "on the grid" from other utilities or power marketers. Thus, assuming power was available to buy, and assuming that no contractual or physical limitations were in place such as transmission constraints; utilities could offset lost power that resulted from waters shortages with purchases via the power grid.

[21] Based on information from the website of the National Drought Mitigation Center at the University of Nebraska Lincoln. Available online at: http://www.drought.unl.edu/risk/impacts.htm. See also, Vanclay, F. "*Social Impact Assessment.*" in Petts, J. (ed) International Handbook of Environmental Impact Assessment. 1999.

Social impacts measured in this study focus strictly on demographic effects including changes in population and school enrollment. Methods are based on demographic projection models developed by the Texas State Data Center and used by the TWDB for state and regional water planning. Basically, the social impact model uses results from the economic component of the study and assesses how changes in labor demand would affect migration patterns in a region. Declines in labor demand as measured using adjusted IMPLAN data are assumed to affect net economic migration in a given regional water planning area. Employment losses are adjusted to reflect the notion that some people would not relocate but would seek employment in the region and/or public assistance and wait for conditions to improve. Changes in school enrollment are simply the proportion of lost population between the ages of 5 and 17.

2. Results

Section 2 presents the results of the analysis. Included are regional level economic data for each water use category, and estimated economic impacts of water shortages for water user groups with reported deficits. According to the 2011*Plateau Regional Water Plan*, during severe drought irrigation and municipal water user groups would experience water shortages in the absence of new water management strategies.

2.1 Overview of Regional Economy

The Plateau regional economy generates nearly $3.0 billion in gross state product for Texas (nearly $2.8 billion worth of income and $211 million in business taxes). The region also provides 55,275 jobs for our state (Table 8). Manufacturing, tourism, mining and agriculture are the primary base economic industries in Region J.[22] Municipal sectors, which include businesses that rely on tourism, generate nearly $2.4 billion per year.

Table 8: The Plateau Regional Economy by Water User Group ($millions)

Water use category	Total sales	Intermediate sales	Final sales	Jobs	Income	Business taxes
Irrigation	$2.93	$0.93	$1.99	50	$1.73	$0.06
Livestock	$162.16	$88.64	$73.52	2,780	$15.01	$2.03
Manufacturing	$1,151.36	$168.03	$983.33	6,610	$349.07	$6.21
Mining	$52.19	$44.22	$7.96	95	$28.82	$3.13
Steam-electric	$41.34	$11.63	$29.71	130	$28.71	$4.90
Municipal	$3,831.52	$809.64	$3,021.89	45,611	$2,427.64	$195.23
Regional total	$5,241.50	$1,123.09	$4,118.40	55,275	$2,850.98	$211.56

Based on data from the Texas Water Development Board, and year 2006 data from the Minnesota IMPLAN Group, Inc.

[22] Base industries are those that supply markets outside of the region. These industries are crucial to the local economy and are called the economic base of a region. Appendix A shows how IMPLAN's 529 sectors were allocated to water use category, and shows economic data for each sector.

2.2 Impacts of Agricultural Water Shortages

According to the 2011 *Plateau Regional Water Plan*, during severe drought farmers in Bandera and Kerr counties of would experiences shortages of irrigation water. In 2010, deficits range from 10 to 25 percent of annual demands. In total, farmers would be short 571 acre-feet in 2010 and 298 acre-feet in 2060 resulting in estimated losses in gross state product (income plus taxes) of roughly $60,000 per year (Table 9).

Table 9: Economic Impacts of Water Shortages for Irrigation Water User Groups ($millions)

Decade	Lost income from reduced crop production [a]	Lost state and local tax revenues from reduced crop production	Lost jobs from reduced crop production
		Bandera County	
2010	$0.0438	$0.0018	2
2020	$0.0438	$0.0018	2
2030	$0.0438	$0.0018	2
2040	$0.0438	$0.0018	2
2050	$0.0438	$0.0018	2
2060	$0.0438	$0.0018	2
		Kerr County	
2010	$0.0207	$0.0008	0
2020	$0.0180	$0.0007	0
2030	$0.0310	$0.0011	0
2040	$0.0261	$0.0010	0
2050	$0.0213	$0.0008	0
2060	$0.0167	$0.0006	0

[a] Changes to income and business taxes are collectively equivalent to a decrease in gross state product, which is analogous to Gross Domestic Product measured at the state rather than national level.

2.3 Impacts of Municipal Water Shortages

Water shortages are projected to occur in Camp Wood and Kerrville. Deficits range from 30 to 100 percent of total annual water use. The costs of domestic water shortages for the region total roughly $6 million in 2010 and 16 million in 2060 (Table 10). In Camp Wood shortages would effectively halt the operation of some commercial businesses resulting in lost income valued at nearly $2 million in each decade.

Table 10: Economic Impacts of Water Shortages for Municipal Water User Groups ($millions)					
Decade	Monetary value of domestic water shortages	Lost income from reduced commercial business activity	Lost state and local taxes from reduced commercial business activity	Lost jobs from reduced commercial business activity	Lost water utility revenues
Kerrville					
2010	$2.69	$0.00	$0.00	0	$0.26
2020	$9.01	$0.00	$0.00	0	$0.34
2030	$10.84	$0.00	$0.00	0	$0.38
2040	$10.95	$0.00	$0.00	0	$0.38
2050	$12.19	$0.00	$0.00	0	$0.42
2060	$12.82	$0.00	$0.00	0	$0.45
Camp Wood					
2010	$3.47	$1.84	$0.25	61	$0.03
2020	$6.36	$1.84	$0.25	61	$0.03
2030	$6.14	$1.78	$0.24	59	$0.03
2040	$5.91	$1.71	$0.23	57	$0.03
2050	$3.29	$1.74	$0.24	58	$0.03
2060	$3.37	$1.79	$0.24	59	$0.03
Regional Total					
2010	$5.61	$1.84	$0.25	61	$0.29
2020	$15.37	$1.84	$0.25	61	$0.37
2030	$16.97	$1.78	$0.24	59	$0.41
2040	$16.86	$1.71	$0.23	57	$0.41
2050	$15.48	$1.74	$0.24	58	$0.45
2060	$16.19	$1.79	$0.24	59	$0.48

2.7 Social Impacts of Water Shortages

As discussed previously, estimated social impacts focus on potential population loss and declines in school enrollment. In 2010 estimated population losses total 80 people with a corresponding reduction in school enrollment of 20 students (Table 14).

Table 11: Social Impacts of Water Shortages (2010-2060)

Year	Population Losses	Declines in School Enrollment
2010	80	20
2020	80	20
2030	80	20
2040	80	20
2050	80	20
2060	80	20

2.8 Distribution of Impacts by Major River Basin

Table 15 displays economic and social impacts by major river basin. Impacts were allocated based on distribution of water shortages by river basin. For instance, if 50 percent of water shortages in River Basin A and 50 percent occur in River Basin B then impacts were split equally among the two basins.

Table 12: Distribution of Socioeconomic Impacts by Major River Basin ($millions)						
Major River Basin	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
		Colorado				
Income*	$1.22	$5.22	$6.59	$6.52	$7.29	$6.33
Business Taxes	$0.04	$0.07	$0.08	$0.08	$0.10	$0.08
Jobs	9	18	20	19	23	20
Population	11	23	27	23	28	27
Declines in School Enrollment	3	6	7	7	8	7
		Guadalupe				
Income	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Business Taxes	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Jobs	0	0	0	0	0	0
Population	0	0	0	0	0	0
Declines in School Enrollment	0	0	0	0	0	0
		Nueces				
Income	$7.29	$13.05	$13.19	$13.04	$10.93	$12.67
Business Taxes	$0.22	$0.18	$0.16	$0.16	$0.14	$0.16
Jobs	53	44	40	38	35	40
Population	69	57	53	47	42	53
Declines in School Enrollment	17	14	13	13	12	13
		Rio Grande				
Income	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Business Taxes	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Jobs	0	0	0	0	0	0
Population	0	0	0	0	0	0
Declines in School Enrollment	0	0	0	0	0	0
		San Antonio				
Income	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Business Taxes	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Jobs	0	0	0	0	0	0
Population	0	0	0	0	0	0
Declines in School Enrollment	0	0	0	0	0	0

* Includes the estimated value of domestic water shortages, which is treated as an income effect when aggregating results across different water user groups.

Appendix: Economic Data for Individual IMPLAN Sectors for the Plateau Regional Water Planning Area

Economic Data for Agricultural Water User Groups ($millions)

Water Use Category	IMPLAN Sector	IMPLAN Code	Total Sales	Intermediate Sales	Final Sales	Jobs	Income	Business Taxes
Irrigation	Grain Farming	2	$0.24	$0.00	$0.24	11	$0.23	$0.01
Irrigation	Tree Nut Farming	4	$1.19	$0.00	$1.19	17	$0.84	$0.03
Irrigation	Fruit Farming	5	$1.30	$0.10	$1.19	28	$0.73	$0.03
Irrigation	Cotton Farming	8	$0.30	$0.00	$0.30	6	$0.07	$0.00
Irrigation	All "Other" Crop Farming	10	$1.00	$0.92	$0.08	11	$0.48	$0.02
Livestock	Animal- except poultry- slaughtering	67	$71.33	$19.07	$52.25	189	$6.79	$0.38
Livestock	Cattle ranching and farming	11	$47.74	$33.10	$14.64	819	$3.77	$1.01
Livestock	Animal production- except cattle and poultry	13	$41.98	$35.59	$6.39	1,768	$4.08	$0.65
Livestock	Poultry and egg production	12	$1.11	$0.87	$0.24	5	$0.37	$0.00
	Total Agriculture		$166.19	$89.65	$76.52	2,854	$17.36	$2.12

Based on year 2006 data from the Minnesota IMPLAN Group, Inc.

Economic Data for Mining and Steam-electric Water User Groups ($millions)

Water Use Category	IMPLAN Sector	IMPLAN Code	Total Sales	Intermediate Sales	Final Sales	Jobs	Income	Business Taxes
Mining	Oil and gas extraction	19	$46.70	$43.37	$3.33	60	$26.77	$2.93
Mining	Gold- silver- and other metal ore mining	23	$1.27	$0.71	$0.56	5	$0.43	$0.04
Mining	Sand- gravel- clay- and refractory mining	25	$0.89	$0.09	$0.79	4	$0.52	$0.03
Mining	Support activities for other mining	29	$3.33	$0.05	$3.28	26	$1.10	$0.13
	Total Mining		$52.19	$44.22	$7.96	$95.00	$28.82	$3.13
Steam-electric	Power generation and supply	30	$41.34	$11.63	$29.71	127	$28.71	$4.90

Based on year 2006 data from the Minnesota IMPLAN Group, Inc.

Economic Data for Manufacturing Water User Groups ($millions)								
Water Use Category	IMPLAN Sector	IMPLAN Code	Total Sales	Intermediate Sales	Final Sales	Jobs	Income	Business Taxes
Manufacturing	Aircraft manufacturing	351	$226.46	$11.52	$214.94	466	$32.27	$0.68
Manufacturing	New residential one unit structures	33	$163.43	$0.00	$163.43	1,184	$47.67	$0.75
Manufacturing	Commercial and institutional buildings	38	$87.37	$0.00	$87.37	1,033	$40.65	$0.51
Manufacturing	Motor and generator manufacturing	334	$69.71	$6.62	$63.09	270	$20.90	$0.45
Manufacturing	Plastics plumbing fixtures and all other plastics	177	$61.97	$44.90	$17.08	349	$20.27	$0.35
Manufacturing	Foam product manufacturing	178	$52.44	$39.93	$12.51	227	$13.04	$0.26
Manufacturing	All other electronic component manufacturing	312	$40.30	$23.09	$17.20	149	$16.84	$0.39
Manufacturing	Other rubber product manufacturing	181	$40.05	$1.04	$39.01	208	$12.49	$0.22
Manufacturing	Other new construction	41	$37.81	$0.00	$37.81	472	$18.88	$0.15
Manufacturing	Jewelry and silverware manufacturing	380	$36.60	$0.74	$35.86	179	$8.12	$0.14
Manufacturing	Ready-mix concrete manufacturing	192	$35.72	$0.17	$35.54	151	$8.81	$0.22
Manufacturing	Motor vehicle parts manufacturing	350	$25.76	$2.07	$23.69	74	$5.33	$0.08
Manufacturing	Air and gas compressor manufacturing	289	$25.54	$0.26	$25.28	63	$7.47	$0.14
Manufacturing	Sanitary paper product manufacturing	134	$24.51	$0.21	$24.30	3	$17.92	$0.07
Manufacturing	New residential additions and alterations-all	35	$22.77	$0.00	$22.77	141	$7.51	$0.11
Manufacturing	Doll- toy- and game manufacturing	382	$21.10	$0.42	$20.67	96	$5.32	$0.10
Manufacturing	Highway- street- bridge- and tunnel construct	39	$18.72	$0.00	$18.72	201	$8.70	$0.11
Manufacturing	Wood kitchen cabinet and countertop manufacturing	362	$18.65	$14.52	$4.12	156	$7.86	$0.13
Manufacturing	New multifamily housing structures- all	34	$17.15	$0.00	$17.15	172	$7.39	$0.04
Manufacturing	Other basic organic chemical manufacturing	151	$16.41	$3.06	$13.35	16	$1.40	$0.06
Manufacturing	Water, and sewer and pipeline construction	40	$13.87	$0.00	$13.87	131	$5.58	$0.08
Manufacturing	Hunting and trapping	17	$9.83	$0.80	$9.02	54	$3.20	$0.57
Manufacturing	Commercial printing	37	$6.80	$0.00	$6.80	90	$3.35	$0.04
Manufacturing	Motor vehicle body manufacturing	139	$6.65	$3.31	$3.35	116	$4.39	$0.05
Manufacturing	Agriculture and forestry support activities	346	$6.40	$0.37	$6.03	23	$0.98	$0.02
Manufacturing	Plastics material and resin manufacturing	18	$6.24	$3.55	$2.69	260	$4.06	$0.05
Manufacturing	All other manufacturing	Various	$53.00	$11.20	$41.80	325	$16.19	$0.35
	Total Manufacturing		$1,151.36	$168.03	$983.33	6,612	$349.07	$6.21
Based on year 2006 data from the Minnesota IMPLAN Group, Inc.								

Economic Data for Municipal Water User Groups ($millions)									
Water Use Category	IMPLAN Sector	IMPLAN Code	Total Sales	Intermediate Sales	Final Sales	Jobs	Income	Business Taxes
Municipal	Real estate	$228.82	$90.58	$138.24	1,268	$132.38	$28.21	$228.82
Municipal	Wholesale trade	$117.81	$56.40	$61.41	827	$62.05	$17.40	$117.81
Municipal	Monetary authorities and depository credit in	$116.47	$38.36	$78.11	567	$81.79	$1.49	$116.47
Municipal	Waste management and remediation services	$53.03	$29.81	$23.22	327	$24.93	$1.99	$53.03
Municipal	Scenic and sightseeing transportation and sup	$78.31	$29.38	$48.93	583	$53.31	$8.89	$78.31
Municipal	Services to buildings and dwellings	$38.41	$28.34	$10.07	765	$17.84	$0.68	$38.41
Municipal	Accounting and bookkeeping services	$29.81	$24.21	$5.60	335	$14.87	$0.12	$29.81
Municipal	Telecommunications	$69.95	$24.03	$45.93	183	$29.56	$4.95	$69.95
Municipal	Other State and local government enterprises	$72.67	$23.66	$49.01	372	$24.25	$0.01	$72.67
Municipal	Hotels and motels- including casino hotels	$44.96	$23.16	$21.80	784	$24.02	$4.12	$44.96
Municipal	Truck transportation	$42.17	$22.83	$19.33	363	$17.47	$0.40	$42.17
Municipal	Legal services	$33.01	$20.95	$12.06	363	$19.65	$0.62	$33.01
Municipal	Insurance agencies- brokerages- and related	$35.69	$20.94	$14.75	416	$30.27	$0.20	$35.69
Municipal	Postal service	$29.53	$20.11	$9.43	441	$23.55	$0.00	$29.53
Municipal	Maintenance and repair of nonresidential buil	$28.93	$19.17	$9.76	265	$10.02	$0.19	$28.93
Municipal	Rail transportation	$38.63	$18.68	$19.95	107	$23.75	$0.75	$38.63
Municipal	Food services and drinking places	$138.65	$17.71	$120.95	2,907	$56.63	$6.62	$138.65
Municipal	Couriers and messengers	$18.36	$16.69	$1.67	395	$10.19	$0.24	$18.36
Municipal	Civic- social- professional and similar organ	$38.86	$13.65	$25.20	1,416	$14.44	$0.09	$38.86
Municipal	Management consulting services	$17.64	$13.58	$4.06	119	$9.58	$0.07	$17.64
Municipal	Advertising and related services	$14.06	$13.10	$0.95	122	$5.30	$0.09	$14.06
Municipal	Architectural and engineering services	$20.60	$12.98	$7.61	184	$10.47	$0.09	$20.60
Municipal	Securities- commodity contracts- investments	$18.42	$12.23	$6.19	155	$6.56	$0.19	$18.42
Municipal	General and consumer goods rental except vide	$29.68	$10.07	$19.61	536	$16.49	$0.38	$29.68
Municipal	All other municipal sectors	$2,477.06	$209.01	$2,268.05	31,811	$1,708.31	$117.46	$2,477.06
Municipal	Total municipal	$3,831.52	$809.64	$3,021.89	45,611	$2,427.64	$195.23	$3,831.52

Based on year 2006 data from the Minnesota IMPLAN Group, Inc.

CHAPTER 5

WATER QUALITY IMPACTS AND

IMPACTS OF MOVING WATER

FROM AGRICULTURAL AREAS

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5.1 INTRODUCTION

Water quality plays an important role in determining the availability of water supplies to meet current and future water needs in the Plateau Region. This chapter describes the general water quality of the surface water and groundwater sources in the Region, discusses specific water quality issues, and considers potential water management strategy impacts on water quality. In consideration of impacts on water quality, the Plateau Water Planning Group identified primary and secondary safe drinking-water standards as being the significant factor that determines the usefulness of the various water resources in the Region (Table 5-1).

A groundwater quality database comprised of water quality analyses from the TWDB groundwater database was established for the four primary aquifers in the Region. Tables 5-2 through 5-5 provide information pertaining to the number of mineral constituent analyses available and the percent of these analyses that depict concentration levels above safe drinking water standards.

While there appears to be a sufficient number of evenly distributed sample locations (Figure 5-1) for making regional quality assumptions, many of the sample dates are relatively old and thus less reliable as current indicators. It is recommended that these older analyses be replaced by re-sampling the same wells or, if not practical, new wells in the same general area. Groundwater conservations districts should take the lead in this task within their respective areas. A water quality survey of sampled wells in the Frio River Alluvium Aquifer in Real County, concentrating on nitrates, would be beneficial in assessing impacts of urbanization in the general area of the City of Leakey.

5.2 WATER QUALITY STANDARDS

Screening levels for public drinking water supplies are used for comparisons of water quality data in the Region. Drinking water standards are classified as primary and secondary and are listed in terms of maximum contaminant levels (MCLs) as defined in the Texas Administrative Code (30 TAC, Chapter 290, Subchapter F). U.S. Environmental Protection Agency (EPA) MCLs for certain secondary constituents are more stringent than the State standards.

Primary MCLs are legally enforceable standards that apply to public drinking water supplies in order to protect human health from contaminants in drinking water. Secondary standards are non-enforceable guidelines based on aesthetic effects that these constituents may cause (taste, color, odor, etc.). In addition to primary MCLs and secondary standards, two constituents, lead and copper, have specified action levels. These action levels apply to community and non-transient non-community water systems, and to new water systems when notified by the Texas Commission on Environmental Quality (TCEQ) Executive Director. A summary of the public drinking water supply parameters used to evaluate water quality is provided in Table 5-1. Certain constituents on the State list are not included on the table because there is a significant lack of analyses containing these elements in the public databases that were used.

On October 31, 2001, EPA announced that the new arsenic MCL for drinking water would be 10 parts per billion (ppb) with a compliance date of January 23, 2006. Until recently, the MCL for arsenic allowed under the Safe Drinking Water Act was 50 ppb. Because of this impending new standard, a screening level of 10 ppb is used for the evaluation in this chapter.

Table 5-1. Selected Public Drinking Water Supply Parameters

Constituent	Maximum Contaminant Level (mg/L unless otherwise noted)	Type of Standard
Nitrate-N	10	Primary
Fluoride	4	Primary
Barium	2	Primary
Alpha	15 pc/L	Primary
Cadmium	0.005	Primary
Chromium	0.1	Primary
Selenium	0.05	Primary
Arsenic	0.01	Primary
Lead	0.015	Action Level
Copper	1.3	Action Level
TDS	1000	Secondary
Chloride	300	Secondary
Sulfate	300	Secondary
pH	6.5 – 8.5	Secondary
Fluoride	2	Secondary
Iron	0.3	Secondary
Manganese	0.05	Secondary
Copper	1	Secondary

Primary drinking water standard from 30 TAC Chapter 290 Subchapter F, Rule 290.106

Action Level for Copper and Lead from 30 TAC Chapter 290 Subchapter F, Rule 290.117

Secondary drinking water standard from 30 TAC Chapter 290 Subchapter F, Rule 290.118

5.3 GROUNDWATER QUALITY

All groundwater contains minerals carried in solution and their concentration is rarely uniform throughout the extent of an aquifer. The degree and type of mineralization of groundwater determines its suitability for municipal, industrial, irrigation and other uses. Groundwater resources in the Plateau Region are generally potable, although Region wide between five and ten percent of the groundwater is brackish. Groundwater quality issues in the Region are generally related to naturally high concentrations of total dissolved solids (TDS) or to the occurrence of elevated concentrations of individual dissolved constituents.

High concentrations of TDS are primarily the result of the lack of sufficient recharge and restricted circulation. Together, these retard the flushing action of fresh water moving through the aquifers.

The quality of groundwater in the aquifers was evaluated to help determine the suitability of the groundwater sources for use and potential impacts on recommended water management strategies. Water-quality data was compiled from the TWDB groundwater database and the TCEQ public water-supply well database.

TDS is commonly used to generally define water quality. TDS refers to the sum of the concentrations of all the dissolved ions in water, which are chiefly composed of sodium, calcium, magnesium, potassium, chloride, sulfate, and bicarbonate ions. The TWDB has defined gross aquifer water quality in terms of TDS concentrations expressed in milligrams per liter (mg/l), and has classified water into four broad categories:

- fresh (less than 1,000 mg/l); *(Note: 500 mgl is Secondary Standard)*
- slightly saline (1,000 - 3,000 mg/l);
- moderately saline (3,000 - 10,000 mg/l); and
- saline (10,000 - 35,000 mg/l).

Because of its usefulness as an indicator of general groundwater quality, TDS serves as a primary parameter of interest for this evaluation. Figure 5-1 shows the water quality, in terms of TDS, for groundwater from the three primary aquifers in the Plateau Region area; the Edwards-Trinity (Plateau), the Trinity, and the Edwards (BFZ) Aquifers. This figure indicates that a majority of groundwater in the Plateau Region is fresh, with limited occurrences of slightly to moderately saline groundwater occurring in the Trinity Aquifer in Bandera County, and in the Edwards-Trinity (Plateau) Aquifer in Val Verde and Real Counties in particular. It should be noted that wells in much of the extent of the Edwards-Trinity (Plateau) Aquifer produce from the shallower Edwards Formation, and there is probably brackish groundwater occurring in the underlying Trinity portions of this aquifer in much of the Region. However, there is no data from which to base an evaluation of this part of the Trinity Formation due to the lack of wells producing from this lower zone.

Most of the parameters in groundwater samples from the Plateau Region were found below the applicable water quality standard. Three constituents that were found above the applicable standard in a significant number of wells are fluoride, sulfate and iron. More than one-third of the samples from the Trinity Aquifer and between ten and fifteen percent of samples from the Edwards-Trinity (Plateau) Aquifer have concentrations of these parameters above the secondary standard. Figures 5-2 and 5-3 show the distribution of fluoride and iron in the Plateau Region, respectively. As shown in these figures, a larger percentage of groundwater in Kerr and Bandera Counties, where the Trinity Aquifer is heavily used, have concentrations of these two analytes above the drinking water standard. More detail on the presence of these analytes in each aquifer is given in the sections below.

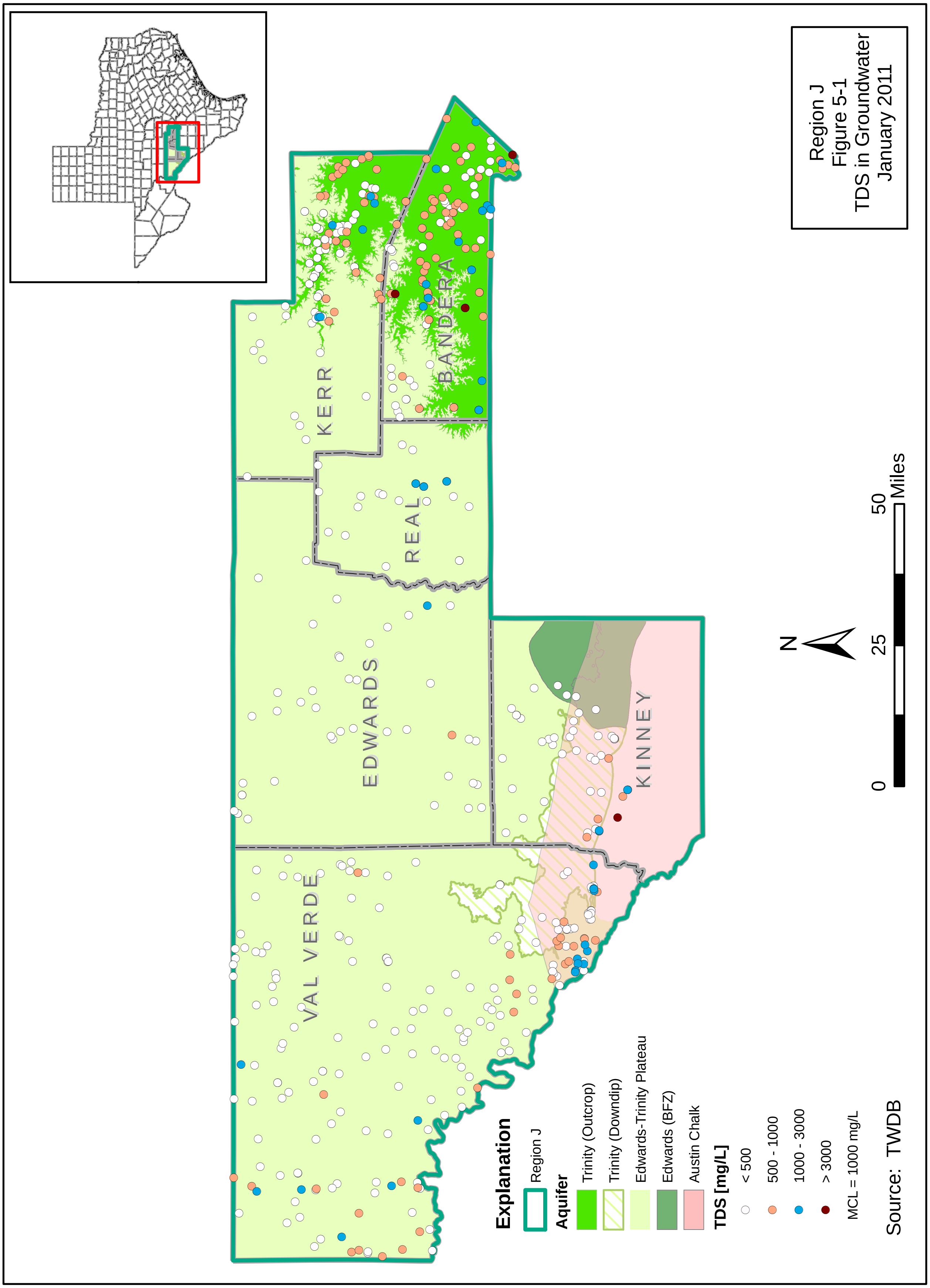

FIGURE 5-1. TOTAL DISSOLVED SOLIDS IN GROUNDWATER IN THE PLATEAU REGION

LBG-GUYTON ASSOCIATES

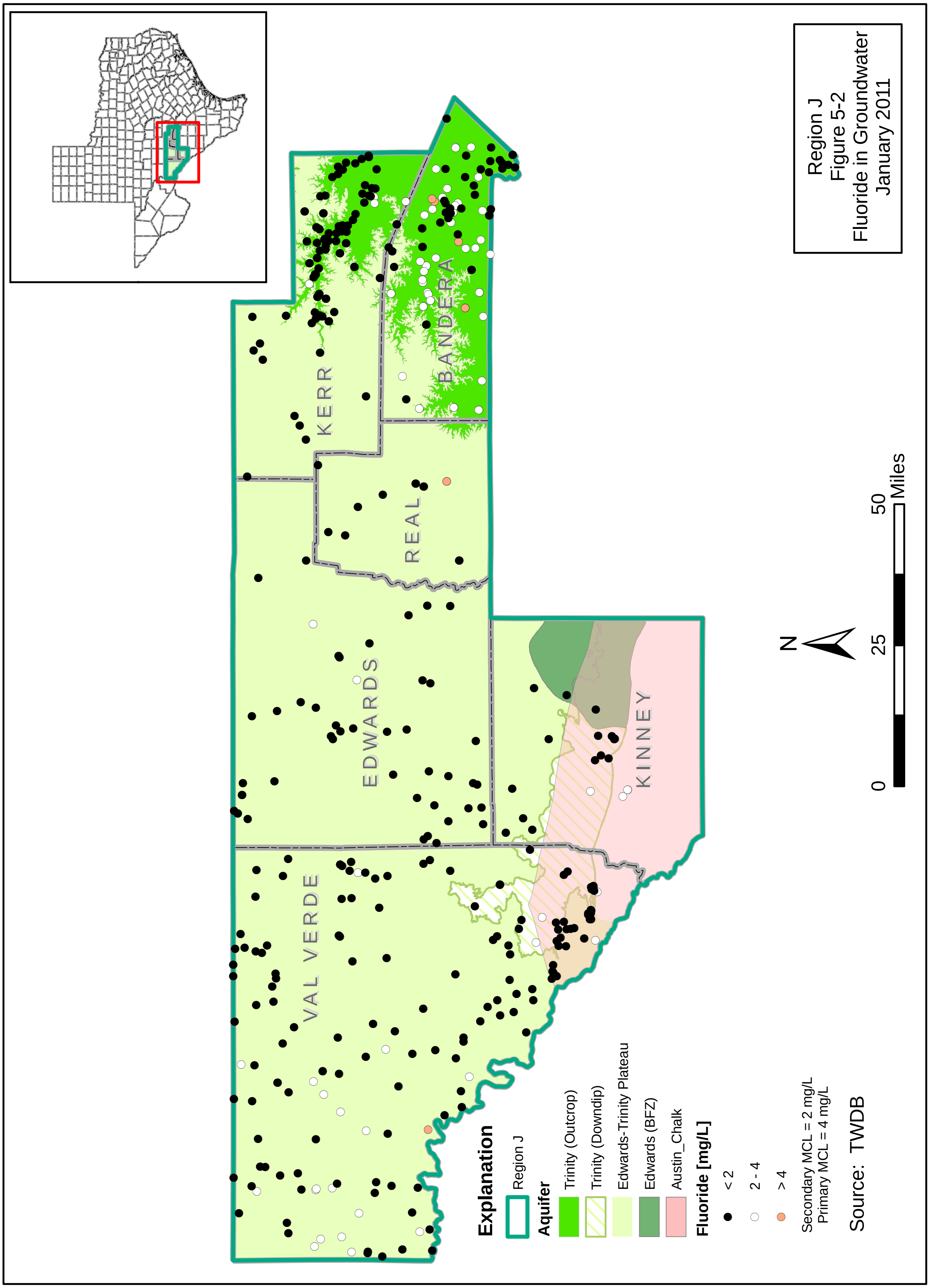

FIGURE 5-2. FLUORIDE IN GROUNDWATER IN THE PLATEAU REGION

LBG-GUYTON ASSOCIATES

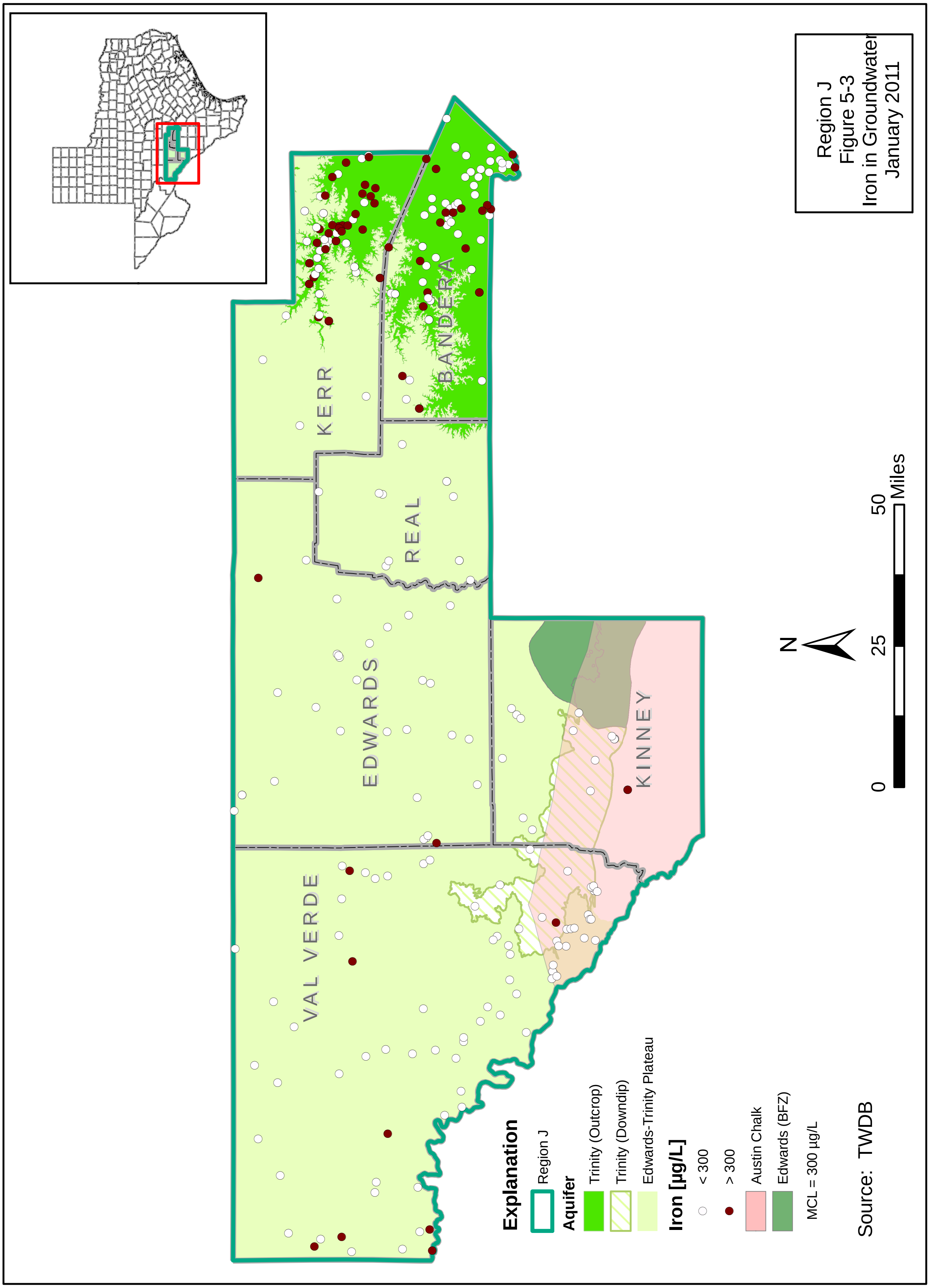

FIGURE 5-3. IRON IN GROUNDWATER IN THE PLATEAU REGION

LBG-GUYTON ASSOCIATES

5.3.1 Edwards-Trinity (Plateau) Aquifer

Usable quality water (containing less than 3,000 mg/l dissolved solids) in the Edwards-Trinity (Plateau) Aquifer occurs to depths of up to about 3,000 feet. The water is typically hard and may vary widely in concentrations of dissolved solids consisting mostly of calcium and bicarbonate. The salinity of the groundwater in the Trinity portion of the aquifer tends to increase toward the southwest. Water quality from primarily the Edwards portion of the aquifer is acceptable for most municipal and industrial purposes; however, excess concentrations of certain constituents in many places exceed drinking-water standards for municipal supplies. In most instances, excess levels of constituents are naturally occurring.

Up to 439 results were included in the analysis of groundwater quality in the Edwards-Trinity (Plateau) Aquifer. The occurrence of selected drinking water parameters for the Edwards-Trinity (Plateau) compared to screening levels is shown in Table 5-2. As indicated in this table, water in the Edwards-Trinity (Plateau) Aquifer contains only a few occurrences of constituents above primary MCLs, including alpha radiation (3.5% of the results), fluoride (1.1%), and nitrate (0.9%). Of the parameters with secondary drinking water standards, all but copper were detected above the screening level in some of the results, including TDS (8.2%), sulfate (9.6%), chloride (1.1%), fluoride (13.1%), iron (13.2%), manganese (1.4%), and pH (1.4%).

Table 5-2. Occurrence and Levels of Selected Public Drinking Water Supply Parameters in the Edwards-Trinity (Plateau) Aquifer

	Number of Results	Screening Level (mg/L unless otherwise noted)	Type of Standard	Percent of Results Exceeding Screening Level
Nitrate-N	425	10	Primary	0.9%
Fluoride	343	4	Primary	1.1%
Barium	136	2	Primary	0%
Alpha	85	15 pc/L	Primary	3.5%
Cadmium	102	0.005	Primary	0%
Chromium	108	0.1	Primary	0%
Selenium	113	0.05	Primary	0%
Arsenic	136	0.01	Primary	0%
Lead	132	0.015	Action Level	0%
Copper	137	1.3	Action Level	0%
TDS	439	1000	Secondary	8.2%
Chloride	438	300	Secondary	1.1%
Sulfate	439	300	Secondary	9.6%
pH	368	6.5 – 8.5	Secondary	1.4%
Fluoride	343	2	Secondary	13.1%
Iron	174	0.3	Secondary	13.2%
Manganese	145	0.05	Secondary	1.4%
Copper	137	1	Secondary	0%

5.3.2 Trinity Aquifer

The Upper and Middle Trinity Aquifer units are divisible based on differences in water quality. The upper member of the Glen Rose Limestone, which forms the Upper Trinity Aquifer unit, contains water with relatively high concentrations of sulfate. TDS often exceeds 1,000 mg/l, as compared to the generally fresher Middle Trinity Aquifer. Middle Trinity Aquifer water quality is generally acceptable for most municipal and industrial purposes; however, certain constituents, such as sulfate and fluoride, exceed drinking-water standards for municipal supplies in many places. In most instances, excess levels of constituents are naturally occurring.

The water chemistry in the Lower Trinity is generally suitable for most uses in Bandera and Kerr Counties, the only areas where this portion of the aquifer is used. However, the dissolved solids can occasionally be found at concentrations above 1,000 mg/l.

Up to 162 results were included in the analysis of groundwater quality in the Trinity Aquifer. The occurrence of selected drinking water parameters compared to screening levels is shown in Table 5-3. As indicated in this table, water in the Trinity Aquifer contains only a few occurrences of constituents above primary MCLs, including chromium (1.6% of the results), fluoride (4.9%), and nitrate (0.6%). Of the parameters with secondary drinking water standards, all except chloride and copper were detected above the screening level in some of the results, including TDS (14.2%), sulfate (20.4%), fluoride (34.3%), iron (38.1%), manganese (6.5%), and pH (1.9%).

Table 5-3. Occurrence and Levels of Selected Public Drinking Water Supply Parameters in the Trinity Aquifer

	Number Of Results	Screening Level (Mg/L Unless Otherwise Noted)	Type Of Standard	Percent Of Results Exceeding Screening Level
Nitrate-N	425	10	Primary	0.6%
Fluoride	343	4	Primary	4.9%
Barium	136	2	Primary	0%
Alpha	85	15 Pc/L	Primary	0%
Cadmium	102	0.005	Primary	0%
Chromium	108	0.1	Primary	1.6%
Selenium	113	0.05	Primary	0%
Arsenic	136	0.01	Primary	0%
Lead	132	0.015	Action Level	0%
Copper	137	1.3	Action Level	0%
TDS	439	1000	Secondary	14.2%
Chloride	438	300	Secondary	0%
Sulfate	439	300	Secondary	20.4%
Ph	368	6.5 – 8.5	Secondary	1.9%
Fluoride	343	2	Secondary	34.3%
Iron	174	0.3	Secondary	38.1%
Manganese	145	0.05	Secondary	6.5%
Copper	137	1	Secondary	0%

5.3.3 Edwards (BFZ) Aquifer

The chemical quality of water in the Edwards (BFZ) Aquifer is typically fresh, although hard, with dissolved-solids concentrations averaging less than 500 mg/l. The downdip interface between fresh and slightly-saline water represents the extent of water containing less than 1,000 mg/l. Within a short distance downgradient of this "bad water line" the groundwater becomes increasingly mineralized.

Up to 23 results were included in the analysis of groundwater quality in the Edwards (BFZ) Aquifer in Kinney County, the only county in the Region where this aquifer occurs. The occurrence of selected drinking water parameters for the aquifer compared to screening levels is shown in Table 5-4.

As indicated in Table 5-4, the only primary standard constituent that was detected above the screening level in the Edwards (BFZ) Aquifer is nitrate, with more than one-quarter of the results being above the screening level. Of the parameters with secondary drinking water standards, only TDS (4.3%), sulfate (8.6%), and fluoride (13%) were detected above the screening level.

Table 5-4. Occurrence and Levels of Selected Public Drinking Water Supply Parameters in the Edwards (BFZ) Aquifer

	Number of Results	Screening Level (mg/L unless otherwise noted)	Type of Standard	Percent of Results Exceeding Screening Level
Nitrate-N	23	10	Primary	26.1%
Fluoride	5	4	Primary	0%
Barium	7	2	Primary	0%
Alpha	6	15 pc/L	Primary	0%
Cadmium	6	0.005	Primary	0%
Chromium	6	0.1	Primary	0%
Selenium	6	0.05	Primary	0%
Arsenic	7	0.01	Primary	0%
Lead	7	0.015	Action Level	0%
Copper	6	1.3	Action Level	0%
TDS	23	1000	Secondary	4.3%
Chloride	23	300	Secondary	0%
Sulfate	23	300	Secondary	8.6%
pH	13	6.5 – 8.5	Secondary	0%
Fluoride	5	2	Secondary	13%
Iron	16	0.3	Secondary	0%
Manganese	11	0.05	Secondary	0%
Copper	6	1	Secondary	0%

5.3.4 Austin Chalk Aquifer

Up to 29 results were included in the analysis of groundwater quality in the Austin Chalk Aquifer in Kinney County, the only county in the Plateau Region where this aquifer occurs. The occurrence of selected drinking water parameters for the aquifer compared to screening levels is shown in Table 5-5.

As indicated in Table 5-5, the only primary constituent that was detected above the screening level in the Austin Chalk Aquifer is nitrate, with more than one-fifth of the results being above the screening level. Of the parameters with secondary drinking water standards, only TDS (4.5%), sulfate (3.4%), and chloride (3.4%) were detected above the screening level.

Table 5-5. Occurrence and Levels of Selected Public Drinking Water Supply Parameters in the Austin Chalk Aquifer

	Number of Results	Screening Level (mg/L unless otherwise noted)	Type of Standard	Percent of Results Exceeding Screening Level
Nitrate-N	29	10	Primary	20.7%
Fluoride	17	4	Primary	0%
Barium	3	2	Primary	0%
Alpha	3	15 pc/L	Primary	0%
Cadmium	3	0.005	Primary	0%
Chromium	3	0.1	Primary	0%
Selenium	3	0.05	Primary	0%
Arsenic	3	0.01	Primary	0%
Lead	3	0.015	Action Level	0%
Copper	3	1.3	Action Level	0%
TDS	22	1000	Secondary	4.5%
Chloride	29	300	Secondary	3.4%
Sulfate	29	300	Secondary	3.4%
pH	6	6.5 – 8.5	Secondary	0%
Fluoride	17	2	Secondary	0%
Iron	3	0.3	Secondary	0%
Manganese	3	0.05	Secondary	0%
Copper	3	1	Secondary	0%

5.4 SURFACE WATER QUALITY

Reservoirs within the Plateau Region - Amistad Reservoir, Medina Lake and Medina Diversion Lake - are some of the clearest (most transparent) water bodies in the State of Texas. Amistad Reservoir is the third clearest, Medina Lake is the fifth clearest, and Medina Diversion Lake is the ninth clearest water body in the State (TNRCC, 1996, Table 41, p. 171). TNRCC (now TCEQ) compared chlorophyll values for 104 Texas reservoirs from the 1994 and 1996 reporting cycles. Of these, reservoirs that showed the most improvement in nutrient status, as evidenced by decreases in algal biomass, included Medina Lake (TNRCC, 1996, p. 177). However, the State also identified the levels of diazanon in Medina Lake as exceeding both the chronic and acute criteria for protection of aquatic life (TNRCC, 1996, Table 52, p. 217). These criteria are defined in terms of toxic substances in ambient water.

The state has also defined criteria in terms of toxic substances found in fish tissue harvested from water bodies. In the Plateau Region, the water-quality segment of concern for toxic substances found in fish tissue is the Rio Grande above Amistad Reservoir; selenium is the toxin identified (TNRCC, 1996, Table 55, p. 222).

The State's Clean Water Program administers federal Clean Water Act directives through TCEQ's Water Quality Inventories. TCEQ is the responsible agency for identifying water-quality problems within the Water Quality Inventory. However, the Inventory does not identify sources of water-quality problems; in most cases, the problems are "non-point source" pollutants. TCEQ, EPA and other agencies have discussed and researched methodologies by which non-point source pollution could be modeled, but thus far modeling efforts have been less than satisfactory. Detailed excerpts from the Water Quality Inventory were included in the Chapter 3 Appendices in the first (2001) Plateau Regional Water Plan; these excerpts address potential water-quality threats to river systems in the Plateau Region, including Medina Lake, citing no known water quality problems (i.e., Plateau rivers are clear of the parameters which the agency monitors).

5.5 CURRENT WATER QUALITY ISSUES

Water-quality problems sometimes pose potential threats to natural resources and the ecological environments therein. Fecal coliform bacteria, in addition to posing a potential public health threat, tend to upset the microbiological balance of a water system. Generally the presence of fecal coliform bacteria also indicates the presence of other pathogens. Watercourses where high levels of nutrients have been identified have the potential to experience algal blooms, which may consume too much of the available dissolved oxygen in the water leaving less oxygen for fish. High levels of dissolved minerals such as sodium in water used to irrigate crops can harm or kill the crops.

In terms of agricultural activity, pesticide and fertilizer application poses a potential threat to underlying groundwater supplies. The propensity for pesticides and fertilizers to leach past the root zone depends on which chemicals are chosen and on the soil's leaching potential. The U.S. Natural Resource Conservation Service has developed a Soil-Pesticide Interaction Screening Procedure, which evaluates the potential for pesticide loss from a field (and thus into groundwater). According to the methodology utilized in the procedure, very little of the Plateau Region has soils in the "High Soil Leaching Class".

Water quality is generally good throughout the Plateau Region; however, a few specific water quality issues should be mentioned, including the impact of urban runoff on surface water and groundwater quality, the impact of vehicular traffic in riverbeds on surface water, and general water quality problems, including the presence of nitrate in the Edwards (BFZ) and Austin Chalk Aquifers.

5.5.1 Urban Runoff

Increasing population impacts water quality in many ways, one of which is the increase in urban runoff that comes with the increase in impervious cover in populated areas. Within the Plateau Region, urban runoff can impact both surface water and groundwater in a variety of ways. First is the increase in runoff. Impervious cover concentrates runoff into storm sewers and drains, which then discharges into streams, increasing the flow, which also increases the erosional power of the water. Groundwater can also be impacted due to this increase in runoff, including a decrease in the infiltration of precipitation into the ground due to impervious cover, thus impacting recharge to the aquifers.

In addition to the problem with increase in runoff, urbanization also causes increased pollutant loads, including sediment, oil/grease/toxic chemicals from motor vehicles, pesticides/herbicides/fertilizers from gardens and lawns, viruses/bacteria/ nutrients from human and animal wastes including septic systems, heavy metals from a variety of sources, and higher temperatures of the runoff. All of these can have significant adverse impacts on the water quality in both surface waters and groundwater, as all of the contaminants that are increased in surface waters through runoff from impervious cover can be introduced into groundwater via the infiltration of the runoff. This is especially true in the more karstic aquifers that are present in the Region, which are characteristically rapidly recharged through sinkholes and other conduits into the subsurface.

5.5.2 UGRA Application for Funding to Reduce E. coli Pollution

The Upper Guadalupe River Authority (UGRA) is developing a grant to fund the reduction of E. coli pollution in the Guadalupe River within the urban area of Kerrville. An earlier study identified a 3.5-mile segment of the river between Town Creek and Flat Rock Lake that has high levels of pollution. Portions of this stretch are often closed to public contact due to elevated E. coli levels during times of drought and low water. The proposed solution includes reducing bird feeding at public parks, installing bird deterrent devises on bridges to reduce bird nesting, managing waterfowl population in the river, reducing and inspecting sewer systems near the river, installing pet waste stations at the public parks, education programs for local livestock owners, and reducing pollution from storm runoff.

5.5.3 Turbidity in San Felipe Springs

Occasionally after rainstorms, water discharging from San Felipe Springs becomes turbid. This turbidity caused some concern with regulating agencies about the potential for microbial contamination and the reliability of the City of Del Rio's chlorine treatment of the spring water. As a result, a microfiltration plant was constructed to treat all spring water that is supplied to the City. This plant was completed and brought on-line in 2002, and has the capacity to treat 16 million gallons of water per day.

5.5.4 Well Construction

The primary contribution to poor groundwater quality occurs in wells that do not have adequately cemented casing, thus allowing poorer quality water or contamination to commingle with good quality water within an aquifer. Poorer water quality in the Region is generally the result of two well-completion problems. First, if a well is not properly sealed, poor quality water in part of an aquifer can migrate upward or downward in the well and mix with fresher zones. This is often the case when "gyp" water in the upper Glen Rose formation is not adequately cemented off from better water lower in the aquifer.

A second possible means of contamination is from surface sources of bacteria and high nitrates from grazing animals or leachate from septic systems. Fecal coliform bacteria can pose a potential public health threat and can also indicate the presence of other pathogens. High nitrate levels in consumed water can cause a disease known as methemoglobinemia especially in small children. This problem is generally the result of wells that are not adequately cased and cemented at the land surface of a well.

The best consideration for addressing groundwater quality problems is to have all wells properly completed with adequate amounts of cemented surface casing, especially in areas that have a high density of closely spaced wells. Closely spaced wells increase the potential that a poorly constructed well can impact numerous surrounding wells.

Groundwater conservation districts play a key role in establishing and enforcing well construction policies for the purpose of maintaining desired water quality. These districts generally follow Water Well Drillers standards established by the Texas Department of Licensing and Regulation.

5.5.5 Radioactivity

Above normal levels of radioactivity have been detected in sand sequences of the Glen Rose and Hensell formations in a few areas of their extent. The origin of the radioactivity is the product of eroded granitic rocks from the Llano uplift region to the north.

5.5.6 Salt Water Disposal Wells and Oil Field Operations

The oil and gas drilling industry is not a major activity within the Plateau Region; however, active and abandoned wells do exist in the area. Most of the Region is characterized by karst terrain which is highly susceptible to surface contamination. It is highly advisable for ongoing oilfield activities and future drilling operations to be particularly cognizant of preventing unwarranted releases on the land surface that might percolate downward to the underlying aquifer. Unlined and lined surface pits should be properly maintained to prevent contamination leakage to underlying aquifers, and the land surface should be properly restored when operations are completed. Likewise, salt-water disposal wells and injection wells used to enhance the recovery of shallow oil in operation in Edwards County must be maintained and monitored to prevent leakage into freshwater formations.

5.5.7 Water Quality Impacts on Potential Strategies

Water quality has the potential to significantly impact water management strategies. Based on currently observed water quality characteristics of surface water and groundwater sources, few impacts are expected to occur due to water quality issues. Of the primary groundwater sources in the Region, most have acceptable water quality, with only a few parameters of potential concern.

The constituent of most concern in groundwater is nitrate, which was found above the primary maximum contaminant level in more than one-quarter of the results from the Edwards (BFZ) Aquifer, and about one-fifth of the results from the Austin Chalk Aquifer, both of which are only present in Kinney County. Nitrate contamination of groundwater supplies is a fairly common problem in many parts of the State, and is most commonly the result of contamination from septic tanks and/or contamination due to farming activities, in particular resulting from the application of fertilizer or from animal waste. Because farming is relatively uncommon in much of the Region, most of the nitrate contamination is presumed to be due to contamination from septic tanks to shallow wells. Due to the nature of nitrate contamination, it should be evaluated on a site-specific basis.

Another potential contaminant to both surface water and groundwater relates to agricultural activity and the use of pesticides. The propensity for pesticides to leach past the root zone depends on which pesticide is chosen and on the soil's leaching potential. The best preventative for agricultural activities is to minimize usage and not over apply many of the common agricultural chemicals.

Water quality degradation can also pose threats to natural resources and ecological environments. Watercourses where high levels of nutrients have been identified have the potential to experience algal blooms, which may consume too much of the available dissolved oxygen in the water, leaving less oxygen for fish. High levels of dissolved minerals such as sodium in water used to irrigate crops can harm or kill the crops.

5.6 WATER QUALITY IMPACTS OF IMPLEMENTING WATER MANAGEMENT STRATEGIES

The implementation of water management strategies recommended in Chapter 4 of this Plan is not expected to have any impact on native water quality. In particular, primary and secondary safe drinking water standards, which are the key parameters of water quality identified by the Plateau Water Planning Group as important to the use of the water resource, are not compromised by the implementation of the strategies.

5.7 IMPACTS OF MOVING WATER FROM AGRICULTURAL AREAS

There is no current movement of water from agricultural areas in the Region for use in urban areas; and there are no recommended strategies in this Plan that involve moving water from rural locations.

CHAPTER 6

WATER CONSERVATION AND

DROUGHT CONTINGENCY

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6.1 INTRODUCTION

Water conservation and drought contingency planning are two of the most important components of water supply management. Recognizing their impact, setting realistic goals, and aggressively enforcing their implementation may significantly extend the time when new supplies and associated infrastructure are needed. This chapter explores conservation opportunities and provides a road map for integrating both conservation and drought contingency planning into long-range water supply management goals.

6.2 WATER CONSERVATION

Water conservation are those practices, techniques, programs, and technologies that will protect water resources, reduce the consumption of water, reduce the loss or waste of water, improve the efficiency in the use of water, or increase the recycling or reuse of water so that a water supply is made available for future or alternative uses. Water conservation management strategies recommended in Chapter 4 include water loss audits to reduce distribution losses, public education to bring awareness of wasteful practices, and brush management.

The Texas Water Development Board and the Texas State Soil and Water Conservation Board jointly conducted a study of ways to improve or expand water conservation efforts in Texas. The results of that study are available in a joint 2006 report titled "An Assessment of Water Conservation in Texas, Prepared for the 80th Texas Legislature" (http://www.twdb.state.tx.us/publications/reports/TWDBTSSWCB_80th.pdf) and contains the following:

- An assessment of both agricultural and municipal water conservation issues;
- Information on existing conservation efforts by the TWDB and the TSSWCB;
- Information on existing conservation efforts by municipalities receiving funding from the TWDB, as specified in water conservation plans submitted by the municipalities as part of their applications for assistance;
- A discussion of future conservation needs;
- An analysis of programmatic approaches and funding for additional conservation efforts;
- An assessment of existing statutory authority and whether changes are needed to more effectively promote and fund conservation projects; and
- An assessment of the TWDB's agricultural water conservation program.

The implementation of water conservation programs that are cost effective, meet state mandates, and result in permanent real reductions in water use will be a challenge for the citizens of the Plateau Region. Smaller communities that lack financial and technical resources will be particularly challenged and will look to the State for assistance.

Because portions of the Region are particularly susceptible to water-supply shortages during periods of drought conditions, these areas are especially encouraged to develop conservation oriented management plans. Likewise, water-user entities within these areas should become actively involved in the regional water planning activities associated with this plan.

The PWPG considers all groundwater sources recognized in this Plan as being critical to the future health and economic welfare of the Plateau Region. Because of the reliance on groundwater to meet current and future water needs, the PWPG recommends that local groundwater conservation districts be formed throughout the entire Region to administer sound, reasonable, and scientifically-based management objectives; and that these districts play a major role in the regional water planning process.

It is generally recognized that brush infestations are the symptom of deeper ecological disturbances such as fire control, drought, grazing mismanagement, wildlife overpopulations and other causes. Selective Brush Management, as a tool to improve watershed yields and water quality, is a conservation management strategy of great interest in the Plateau Region, as well as in surrounding planning regions. The State should draft legislation based upon the best available science and input from all stakeholders to provide a cost-share funding program to landowners in the targeted watersheds for the Selective Brush Management BMP and required other practices.

The PWPG joins with the Rio Grande Region (M) and the Far West Texas Region (E) in encouraging funding for projects aimed at the eradication and long-term suppression of salt cedar and other nuisance phreatophytes in the Rio Grande watershed.

6.2.1 Water Conservation Considerations

6.2.1.1 Water-Saving Plumbing Fixture Program

The Texas Legislature created the Water-Savings Plumbing Fixture Program on January 1, 1992 to promote water conservation. Manufacturers of plumbing fixtures sold in Texas must comply with the Environmental Performance Standards for Plumbing Fixtures, which requires all plumbing fixtures such as showerheads, toilets and faucets sold in Texas to conform with specific water use efficiency standards.

Because more water is used in the bathroom than any other place in the home, water-efficient plumbing fixtures play an integral role in reducing water consumption, wastewater production, and consumers' water bills. It is estimated that switching to water-efficient fixtures can save the average household between $50 and $100 per year on water and sewer bills. Many hotels and office buildings find that water-efficient fixtures can save 20 percent on water and wastewater costs.

6.2.1.2 Water Conservation Best Management Practices

The 78th Texas Legislature under Senate Bill 1094 created the Texas Water Conservation Implementation Task Force and charged the group with reviewing, evaluating, and recommending optimum levels of water use efficiency and conservation for the state. TWDB Report 362, Water Conservation Best Management Practices Guide was prepared in partial fulfillment of this charge. The Guide is organized into three sections, for municipal, industrial, and agricultural water user groups with a total of 55 Best Management Practices (BMPs). Each BMP has several elements that describe the efficiency measures, implementation techniques, schedule of implementation, scope, water savings estimating procedures, cost effectiveness considerations, and references to assist end-users in implementation. This document can be accessed at the following TWDB web site: http://www.twdb.state.tx.us/assistance/conservation/TaskForceDocs/WCITFBMPGuide.pdf.

6.2.1.3 Water Conservation Education

Public education may be one of the most productive actions that can result in the greatest amount of water savings. Most citizens are willing to actively do their part to conserve water once the need is communicated and the means by which to accomplish the most benefit is explained. Numerous state, county, and academic agencies provide educational material and demonstrations. Groundwater conservation districts also provide water conservation activities. The TWDB provides a significant amount of information and services pertaining to water conservation that can be accessed at http://www.twdb.state.tx.us/assistance/conservation/consindex.asp. Likewise, Water Conservation Tips were developed by the TCEQ's Clean Texas 2000. TPWD also offers programs geared toward the appreciation and conservation of the state's outdoor natural resources.

Education of our youth may be one of the best ways to spread the word about water conservation. The TWDB provides an excellent educational program for 4th and 5th grade elementary school levels. Information pertaining to this program can be accessed at http://www.twdb.state.tx.us/assistance/conservation/conservationpublications/majorrivers.asp

The groundwater conservation districts in the Plateau Region have water conservation management goals that include:

- Publishing conservation articles in local newspapers;
- Providing conservation presentations and demonstrations at county shows;
- Conducting school programs relating to conservation issues; and
- Working with river authorities top promote the clean rivers program.

6.2.2 Watershed Best Management Practices

6.2.2.1 Brush Management

A potential means of increasing water supply is to reduce the amount of water consumed by shrubs and trees on rangelands. The density and coverage of shrubs has increased dramatically during the past century as former grasslands have now converted to shrublands or closed-canopy woodlands. A total loss of herbaceous vegetation cover will increase water yields in the form of surface runoff; however, this process will accelerate erosion, degrade water quality, and damage aquatic ecosystems. A more desirable way of increasing water yield is to manage vegetation to decrease evapotranspiration, which will generally increase the amount of water that percolates below the root zone into groundwater and eventually back into streams. Researchers* believe it is appropriate to broaden the issue from solely focusing on "brush control for increasing water yield" to "best management practices for watershed health and sustainability".

** Wilcox, B.P., Dugas, W.A., Owens, M.K., Ueckert, D.N., and Hart, C.R., 2005, Shrub Control and Water Yield on Texas Rangelands, Current State of Knowledge: Texas Agricultural Experiment Station Research Report 05-1.*

6.2.2.2 Rainwater Harvesting

The following discussion on Rainwater Harvesting is taken from the Texas Water Development Board's The Texas Manual on Rainwater Harvesting, 3rd Edition. This manual can be accessed from TWDB's website: http://www.twdb.state.tx.us/publications.

Rainwater is valued for its purity and softness. It has a nearly neutral pH, and is free from disinfection by-products, salts, minerals, and other natural man-made contaminants. Plants thrive under irrigation with stored rainwater. Appliances last longer when free from the corrosive or scale effects of hard water. Users with potable systems prefer the superior taste and cleansing properties of rainwater. Rainwater harvesting, in its essence, is the collection, conveyance, and storage of rainwater.

Rainwater harvesting systems can be as simple as a rain barrel for garden irrigation at the end of a downspout, or as complex as a domestic potable system or a multiple end-use system at a large corporate campus.

Advantages and benefits of rainwater harvesting are numerous (Krishna, 2003):

- The water is free; the only cost is for collection and use.
- The end use of harvested water is located close to the source, eliminating the need for complex and costly distribution systems.
- Rainwater provides a water source when groundwater is unacceptable or unavailable, or it can augment limited groundwater supplies.
- The zero hardness of rainwater helps prevent scale on appliances, extending their use; rainwater eliminates the need for a water softener and the salts added during the softening process.

- Rainwater is sodium-free, important for persons on low-sodium diets.
- Rainwater is superior for landscape irrigation.
- Rainwater harvesting reduces flow to stormwater drains and also reduces non-point source pollution.
- Rainwater harvesting helps utilities reduce the summer demand peak and delay expansion of existing water treatment plants.
- Rainwater harvesting reduces consumers' utility bills.

From a financial perspective, the installation and maintenance costs of a rainwater harvesting system for potable water cannot compete with water supplied by a central utility, but is often cost-competitive with installation of a well in rural settings.

The State of Texas also offers financial incentives for rainwater harvesting systems. Senate Bill 2 of the 77th Legislature exempts rainwater-harvesting equipment from sales tax, and allows local governments to exempt rainwater harvesting systems from ad valorem (property) taxes.

6.2.2.3 Landscape Maintenance

A significant amount of water is used each year in the maintenance of residential and non-residential landscapes. Landscape irrigation conservation practices are an effective method of accounting for and reducing outdoor water usage while maintaining healthy landscapes and avoiding runoff. Water wise landscape programs should follow the seven principals of xeriscape:

- Planning and design
- Soil analysis and improvement
- Appropriate plant selection
- Practical turf area
- Efficient irrigation

- Use of mulch
- Appropriate maintenance

Additional detail on this subject is available in TWDB Report 362 Water Conservation Best Management Practices Guide.

6.2.3 Model Water Conservation Plan

Water Conservation Plan forms are available from TCEQ in MSWord and PDF formats. The forms for the following entity types listed below are available at http://www.tceq.state.tx.us/permitting/water_supply/water_rights/conserve.html. You can receive a print copy of a form by calling 512/239-4691 or by email to wras@tceq.state.tx.us.

Municipal Use - Utility Profile and Water Conservation Plan Requirements for Municipal Water Use by Public water Suppliers (TCEQ-10218)

Wholesale Public Water Suppliers - Profile and Water Conservation Plan Requirements for Wholesale Public Water Suppliers (TCEQ-20162)

Industrial/Mining Use - Industrial/Mining Water Conservation Plan (TCEQ-10213)

Agricultural Uses –
Agriculture Water Conservation Plan-Non-Irrigation (TCEQ-10541)
System Inventory and Water Conservation Plan for Individually-Operated Irrigation System (TCEQ-10238)
System Inventory and Water Conservation Plan for Agricultural Water Suppliers

Providing Water to More Than One User (TCEQ-10244)

6.2.4 Municipal Water Conservation Plans

Texas Water Code §11.1271 requires water conservation plans for all municipal and industrial water users with surface water rights of 1,000 acre-feet per year or more and irrigation water users with surface water rights of 10,000 acre-feet per year or more. Water conservation plan summaries for the cities of Kerrville and Del Rio, which meet these criteria, are provided in the following sections. The Upper Guadalupe River Authority, which also has water rights that meet the criteria, is not currently providing water and therefore has not developed a conservation plan under the above TWC requirement. However, UGRA does have a Water Conservation/Drought Management Plan, which was adopted in 1993. Water conservation plans are also required for all other water users applying for a State water right, and may also be required for entities seeking State funding for water supply projects.

6.2.4.1 City of Kerrville Water Conservation Plan

The City of Kerrville adopted a new Water Management Plan on Jan. 27, 2004 (updated in 2010). This Plan includes, for the first time, year-round water conservation measures that limit irrigation watering to the hours of 6 p.m. to 10:00 a.m. and bans water runoff in streets and gutters. The year-round measures also include: banning the waste of water; banning the use of water from fire hydrants and blow-offs other than for their intended purpose and/or maintenance; requirement for customers to repair leaks within 24 hours of receiving notice of the leak; providing educational information to the public on water use and water conservation; adopting and enforcing plumbing codes to ensure the use of water conservation devices in new construction; universal metering; encouraging water conservation landscaping; increased effort in leak detection and repair; continued evaluation of methods of reuse and recycling of wastewater; and water saving measures for the service industry.

6.2.4.2 City of Del Rio Water Conservation Plan

The City of Del Rio adopted a new Water Conservation Plan and Drought Contingency and Water Emergency Plan on May 12, 2009. The Plan provides for the following measures.

- Establishes a conservation goal of 176 gpd per person, a 20% reduction from the 2007 rate;
- Requires the testing and installation of meters on all connections;

- Develops a more detailed management plan to more accurately account for otherwise unaccounted for water;
- Coordinates Plan with the Plateau Water Planning Group; expands educational programs;
- Considers potential to modify current rate structure to actively discourage increased water use;
- Ensures that any new wholesale contracts or contract extensions will require wholesale customers to develop and implement water conservation plans consistent with this Plan.

The City's Drought Contingency and Water Emergency Plan is intended to establish criteria to identify when water supplies may be threatened and the actions that should be taken to ensure these potential threats are minimized.

6.2.5 Regional Water Loss Audit

Reported municipal use generally includes a variable amount of water that does not reach the intended consumer due to water leaks in the distribution lines, unauthorized consumption, storage tank overflows, and other wasteful factors. For some communities, attending to these issues can be a proactive conservation strategy that may result in significant water savings. To address the lack of information on water loss, the 78th Texas Legislature passed House Bill 3338, which required retail public utilities that provide potable water to perform and file with the TWDB a water audit computing the utility's most recent annual system water loss every five years. A summary of the first audit, An Analysis of Water Loss as Reported by Public Water Suppliers – 2007 (http://www.twdb.state.tx.us/RWPG/rpgm_rpts/0600010612_WaterLossinTexas.pdf) was provided to the Plateau Water Planning Group (PWPG) for consideration in developing water supply management strategies. The report lists utilities in Region J (Plateau), along with Region I, as having the highest non-revenue water percentage and the highest reported average unbilled authorized water use of the 16 regions in the state. The PWPG acknowledges the value of this important planning tool, but identified apparent errors in some of the data. The report does offer the recognition that "as utilities refine their water audits, reducing balancing adjustments and improving real loss estimates, it is expected that water loss data reported from the next round of water audits will be more useful for planning purposes than the current water loss data. Based on this concern, the PWPG chose to not use the supplied data for this current Plan, but looks forward to the next improved water loss audit survey.

6.3 DROUGHT CONTINGENCY

6.3.1 Drought Contingency Planning

Drought is a frequent and inevitable factor in the climate of Texas, and therefore it is vital to plan for the effect that droughts will have on the use, allocation and conservation of water in the state. In 2009, the Texas Water Development Board published Drought Management in the Texas Regional and State Water Planning Process (http://www.twdb.state.tx.us/RWPG/rpgm_rpts/0804830819_DroughtMgmt.pdf), which examines the potential benefits and drawbacks of including drought management as a regional water management strategy.

The climate of the Plateau Region is intermediate to the more humid climates of regions to the northeast and east and drier climates of regions to the northwest and west. The combination of high temperatures, high potential evapotranspiration and intermediate rainfall totals combine to produce a semi-arid climate with drought conditions during all or parts of some years (Bomar, 1995).

Although residents of the Region are generally accustomed to the highly variable climatic conditions typical for the Region, the relatively low rainfall and the accompanying high levels of evaporation underscore the necessity of developing plans that respond to potential disruptions in the supply of groundwater and surface water caused by drought conditions.

Because of the range of conditions that affected the more than 4,000 water utilities throughout the State in 1997, the Texas Legislature directed the TCEQ to adopt rules establishing common drought plan requirements for water suppliers. As a result, the TCEQ requires all wholesale public water suppliers, retail public water suppliers serving 3,300 connections or more, and irrigation districts to submit drought contingency plans. For all retail public water suppliers serving less than 3,300 connections, the drought contingency plans must be prepared and adopted no later than May 1, 2005, and shall be available for inspection upon request.

Droughts typically develop slowly over a period of months or even years and can have a major impact on the region. Water shortages may also occur over briefer periods as a result of water production and distribution facility failures. Drought contingency plans provide a structured response that is intended to minimize the damaging effects caused by the water shortage conditions. A common feature of drought contingency plans is a structure that allows increasingly stringent drought response measures to be implemented in successive stages as water supply or water demand worsens. This measured or gradual approach allows for timely and appropriate action as a water shortage develops. The onset and termination of each implementation stage should be defined by specific “triggering” criteria. Triggering criteria are intended to ensure that timely action is taken in response to a developing situation and that the response is appropriate to the level of severity of the situation.

Each water-supply entity is responsible for establishing its own drought or emergency contingency plan that includes appropriate triggering criteria. Water-supply management and drought contingency plans have been prepared by the cities of Bandera, Brackettville, Del Rio, and Kerrville, by the Fort Clark MUD, and by the Headwaters GCD.

6.3.2 Drought Triggers

Drought response triggers should be specific to each water supplier and should be based on an assessment of the water user’s vulnerability. In some cases it may be more appropriate to establish triggers based on a supply source volumetric indicator such as a lake surface elevation or an aquifer static water level. Similarly, triggers might be based on supply levels remaining in an elevated or ground storage tank within the water distribution system; this is not a recommended approach, as the warning of supply depletion would be only three to four days. Triggers based on demand levels can also be effective, if the demands are very closely and frequently monitored. Whichever method is employed, trigger criteria should be defined on well-established relationships between the benchmark and historical experience. If historical observations have not been made then common sense must prevail until such time that more specific data can be presented.

6.3.2.1 Surface Water Triggers

Surface water sources are among the first reliable indicators of the onset of hydrologic drought, as defined in Section 1.2.6. Diminished spring discharge and stream flow, for example, can be monitored daily by city, county, and state agencies, and also by landowners. Of particular interest, however, are the levels to which spring discharge and stream flow must be reduced before the onset of drought is declared and appropriate response measures are initiated in the region. Cities that rely exclusively on spring flow for municipal water are particularly vulnerable to drought-induced reductions in discharge, especially if alternative sources of supply have not been developed to make up potential shortfalls created by lower discharge. As an operating definition of hydrologic drought, it is recommended that reductions of spring discharge between 25 percent and 33 percent (compared with average discharge and flow) be considered effective hydrologic drought triggers in the Plateau Region.

The major water right holder on the lake, Bexar-Medina-Atascosa WCID 1, administers the Medina/Diversion lake system operation. Operations are constrained by a Special Condition of BMAWCID1’s water right that specifies that emergency firefighting vehicles should have access to impounded water, and further constrained by a Memorandum of Understanding between BMAWCID1, Bandera County, Bandera County River Authority and Groundwater District, and Bexar Metropolitan Water District dated March 19, 1997. The MOU specifies that BMA will restrict diversions for municipal purposes when the level of Medina Lake is at or below 1,035 feet (which level is to be measured based upon the datum plane for the Medina Dam identified as being located at the 1,084 feet amsl level). The 1,035-ft level can very well be considered a drought trigger, although the term is not explicitly applied within the MOU.

6.3.2.2 Groundwater Triggers

Groundwater triggers that indicate the onset of drought are not as easily identified as factors related to surface-water systems. This is attributable to (1) the rapid response of stream discharge and reservoir storage to short-term changes in climatic conditions within a region and within adjoining areas where surface drainage originates, and (2) the typically slower response of groundwater systems to recharge processes. Although climatic conditions over a period of one or two years might have a significant impact on the availability of surface water, aquifers of the same area might not show comparable levels of response for much longer periods of time, depending on the location and size of recharge areas in a basin, the distribution of precipitation over recharge areas, the amount of recharge, and the extent to which aquifers are developed and exploited by major users of groundwater. It is recognized, however, that karstic formations may produce rapid recharge rates in aquifers such as the Edwards-Trinity (Plateau).

With the exception of the Trinity Aquifer of Bandera and Kerr Counties, all other aquifers in the rural counties are unlikely to experience significant water-level declines, based on comparisons between projected water demand, aquifer recharge and storage. In these areas, water levels are expected to remain constant or relatively constant over the 50-year planning period. Observation wells in major recharge areas and in areas adjacent to municipal well fields in the rural counties might provide a sufficient number of points to monitor water levels, provided that water-level measurements are made on a regular basis for long periods of time. Water levels below specified elevations for a pre-determined period of time might be interpreted to be reasonable groundwater indicators of drought conditions in any basin.

Basins that do not receive sufficient recharge to offset natural discharge and pumpage may be depleted of groundwater (e.g., mined). This is especially the case with the Trinity Aquifer of Bandera and Kerr Counties. The rate and extent of groundwater mining in any area are related to the timeframe and the extent to which withdrawals exceed recharge. In such basins, water levels may fall over long periods of time, eventually reaching a point at which the cost of lifting water to the surface becomes uneconomical. Thus, water levels in such areas may not be a satisfactory drought trigger. Instead, communities might consider the rate at which water levels decline in response to increased demand as a sufficient indicator of drought.

Because of the above described problems with using water levels as drought-condition indicators, most municipal water-supply entities in the Plateau Region that rely on groundwater generally establish drought-condition triggers based on levels of demand that exceed a percentage of the systems production capacity. Table 6-1 provides a list of groundwater dependent entities, their supply source, their type of trigger, and their associated responses.

Water levels in observation wells in and adjacent to municipal well fields, especially where wells are completed in aquifers that respond relatively quickly to recharge events, may be established as drought triggers for municipalities in the future providing a sufficient number of measurements are made annually to establish a historical record. Water levels below specified elevations for a pre-determined period of time might be interpreted to be reasonable groundwater indicators of drought conditions. Until such historical water-level trends are established, municipalities will likely continue to depend on demand as a percentage of production capacity as their primary drought trigger.

Water-use categories in the Region other than municipal that are dependent on groundwater as their primary or only source of supply must rely on a number of factors to identify drought conditions. In most cases, atmospheric condition (days without measurable rainfall) is the most obvious factor. Various drought indices (Palmer, Standard Precipitation, and Keetch-Byram) are available from State and local sources. Groundwater conservation districts, agricultural agencies, as well as individuals can access these indices for use in determining local drought conditions and appropriate responses.

Table 6-2 provides a selection of wells with a history of measurements and a proposed drought trigger level. Five of the nine wells are equipped with continuously recording devises. In time, all wells on this list should be similarly equipped. Other wells on this list are measured on an annual basis by TWDB staff, which does not allow for observation of seasonal fluctuation or response to recharge events. Wells selected for drought contingency triggers should be re-evaluated for appropriateness during the next planning period, and where possible, should be selected or positioned so that local pumping does not influence the water level.

Groundwater conservation districts are generally responsible for monitoring conditions within their boundaries and making appropriate public notification. Outside of existing districts, the TWDB should assume responsibility of public notification of drought conditions based on their water-level monitoring network. County Commissioners are expected to designate trigger levels and establish responses. In Val Verde County, the City of Del Rio is responsible for designating trigger levels and establishing responses. Appropriate drought responses are also the responsibility of and at the discretion of private well owners.

Table 6-1. Suggested or Mandated Drought Triggers for Groundwater Dependent Entities

Water-Supply Entity	Water Supply Source	Drought Trigger	Trigger Response
City of Bandera	Trinity	Multi-stage drop in water levels in the Dallas Street Municipal Well.	Multi-stage limitation on water use.
Town of Rocksprings	Edwards-Trinity (Plateau)	Water level drops 20 feet below summertime average.	Multi-stage limitation on water use.
City of Kerrville	Upper Guadalupe River Trinity	Drought triggers based on flows in the Guadalupe River and relationship between supply and demand.	Multi-stage limitation on water use.
Community of Ingram	Trinity	Water level drops 20 feet below summertime average.	Multi-stage limitation on water use.
Town of Brackettville	Edwards (BFZ)	Multi-stage drop in water levels in city well.	Multi-stage limitation on water use.
Fort Clark Municipal Water District	Edwards (BFZ)	Multi-stage drop in water levels in municipal well.	Multi-stage limitation on water use.
Town of Camp Wood	Spring flow from Edwards-Trinity (Plateau)	Spring flow diminishes by 20% of average summertime level.	Multi-stage limitation on water use.
Town of Leakey	Frio River Alluvium	Water level drops 20 feet below summertime average.	Multi-stage limitation on water use.
City of Del Rio	San Felipe Springs Edwards-Trinity (Plateau)	Water level in Bedell Street Storage Reservoir is less than a designated depth; and designated decline in San Felipe Spring flow.	Multi-stage limitation on water use.

Table 6-2. Suggested Groundwater Level Trigger Wells in Each Aquifer Source

Aquifer	County	Well ID	Lat. / Long.	Avg. Depth to Water
Trinity	Bandera	Purple Sage Well	29.44651 / 99.01831	215
Trinity	Kerr	56-63-916	30.00741 / 99.09592	295
Edwards-Trinity	Edwards	55-63-803	30.01833 / 100.20778	415
Edwards-Trinity	Kerr	56-53-304	30.22028 / 99.40667	181
Edwards-Trinity	Kinney	Ring Well	29.23243 / 100.28408	40
Edwards-Trinity	Val Verde	Old Y Well	29.26241 / 100.54578	105
Edwards (BFZ)	Kinney	70-38-902	29.41333 / 100.26194	187
Austin Chalk	Kinney	70-45-404	29.31222 / 100.46806	Unknown
Frio River Alluvium	Real	69-18-302	29.72583 / 99.76000	25

* Wells selected for drought triggers should be re-evaluated for appropriateness during each planning period.
** Local groundwater conservation districts will continue to refine this monitoring network.

6.3.3 Model Drought Contingency Plans

The TCEQ has prepared model drought contingency plans for wholesale and retail public water suppliers, water supply corporations, and investor owned utilities that meet the TCEQ's minimum requirements. The forms for the entity types listed below are available at http://www.tceq.state.tx.us/permitting/water_supply/water_rights/contingency.html. Printed copies of the model plan are also available by calling 512/239-4691, or by e-mail to wras@tceq.state.tx.us.

- Handbook for Drought Contingency Planning for Retail Public Water Suppliers.
- Handbook for Drought Contingency Planning for Wholesale Public Water Suppliers.
- Handbook for Drought Contingency Planning for Irrigation Districts.
- Model Drought Contingency Plan for the Investor Owned Utility.
- Model Drought Contingency Plan for the Water Supply Corporation.

The model drought contingency plans for the above categories incorporate the following guidelines:

- Specific, quantified targets for water use reductions
- Drought response stages
- Triggers to begin and end each stage
- Supply management measures
- Demand management measures
- Descriptions of drought indicators
- Notification procedures
- Enforcement procedures
- Procedures for granting exceptions
- Public input to the plan
- Ongoing public education
- Adoption of plan
- Coordination with regional water planning group

6.4 GROUNDWATER CONSERVATION DISTRICTS

The Texas Legislature has established a process for local management of groundwater resources through Groundwater Conservation Districts. The districts are charged with managing groundwater by providing for the conservation, preservation, protection, recharging and prevention of waste of groundwater within their jurisdictions. An elected board governs these districts and establishes rules, programs and activities specifically designed to address local problems and opportunities. Texas Water Code §36.0015 states, in part, "Groundwater Conservation Districts created as provided by this chapter are the state's preferred method of groundwater management." Four districts are currently in operation within the planning region.

- Bandera County River Authority and Groundwater District
- Headwaters Groundwater Conservation District (Kerr County)
- Kinney County Groundwater Conservation District
- Real-Edwards Conservation and Reclamation District

In recent sessions, the Texas Legislature has redefined the manner in which groundwater is to be managed by establishing a process referred to as Groundwater Management Areas (http://www.twdb.state.tx.us/GwRD/GMA/gmahome.htm). This new process is summarized in Chapter 1, Section 1.1.2. The Real-Edwards and a portion of Kinney districts are in GMA 7. The Bandera and Kerr (Headwaters) districts are in GMA 9, and a portion of the Kinney district is in GMA 10. As of the preparation of this Plan, *desired future conditions* have not been adopted for any aquifers in these GMAs.

6.4.1 Bandera County River Authority and Groundwater District

The Bandera County River Authority and Groundwater District (http://www.banderacounty.org/services/BCRAGD.htm) was originally the Bandera County River Authority, created by the Texas legislature in 1971, and the Springhills Water Management District, created by the legislature in 1989. The authority of the Bandera

County River Authority was incorporated into the Springhills Water Management District, and in 2003 the TCEQ authorized changing the District's name to Bandera County River Authority and Groundwater District. The District includes all of Bandera County within its jurisdiction and includes the following applicable goals in its 2004 management plan:

- Manage groundwater in order to provide the most efficient use of groundwater resources
- Control and prevent the waste of groundwater
- Address conjunctive surface water management issues
- Address drought conditions
- Address conservation
- Address water quality

6.4.2 Headwaters Groundwater Conservation District

The Headwaters Groundwater Conservation District (http://www.hgcd.org/) was created by the Texas legislature in 1991 (HB 1463) and includes all of Kerr County within its jurisdiction. The purpose of the District is to provide for the conservation, preservation, protection, recharging and prevention of waste of groundwater reservoirs or their subdivisions within the defined boundaries of the District. The District's management plan was revised in 2008 and contains the following management goals:

- Provide for the most efficient use of groundwater
- Control and prevent waste of groundwater
- Address conjunctive surface water management issues
- Address natural resources issues
- Address drought conditions

- Address conservation
- Address rainwater harvesting
- Address in a quantitative manner the desired future conditions of the groundwater resources

6.4.3 Kinney County Groundwater Conservation District

The Kinney County Groundwater Conservation District was created by the legislature in 2001 (HB 3243), and was confirmed by the voters of Kinney County in 2002. The District includes all of Kinney County within its jurisdiction. The District adopted a management plan in 2003. The District was created to develop, promote, and implement water conservation and management strategies to conserve, preserve, protect groundwater supplies within the District, protect and enhance recharge, prevent waste and pollution, and to promote the efficient use of groundwater within the District. The following goals are included in the District's 2008 management plan:

- Provide the most efficient and sustainable use of groundwater
- Control and prevent waste of groundwater
- Address conjunctive surface water management issues
- Address drought conditions
- Address conservation, recharge enhancement, rainwater harvesting, precipitation enhancement and brush control
- Address natural resource issues
- Participate in the development of desired future conditions of aquifers

6.4.4 Real-Edwards Conservation and Reclamation District

The Real-Edwards Conservation and Reclamation District (http://www.recrd.org/) was formed by the Texas legislature in 1959 (HB 447) and includes all of Real and Edwards Counties within its jurisdiction. The District was created to provide for the conservation, preservation, protection, recharge and prevention of waste of the underground water reservoirs located under the District. The District strives to bring about conservation, preservation and the efficient, beneficial and wise use of water for the benefit of the citizens and the economy of the District through monitoring and protecting the quantity and quality of the groundwater. The District also strives to maintain groundwater ownership and rights of the landowners.

District activities include regulating groundwater withdrawals by means of spacing and production limits, using the Texas Water Development Board's observation network to monitor changing storage conditions of groundwater supplies within the District, undertaking, as necessary, and cooperating with investigations of the groundwater resources within the District and making the results of investigations available to the public upon adoption by the Board, and potentially requiring reduction of groundwater withdrawals to amounts which will not cause harm to the aquifer. The following goals are included in the District's 2009 management plan:

- Providing the most efficient use of groundwater
- Management strategies to protect and enhance the quantity and quality of usable groundwater by controlling and preventing contamination and waste
- Management strategies under drought conditions
- Promote water conservation
- Implementation of public relations and public awareness programs
- Address brush and invasive plant control
- Address rainwater harvesting
- Participate in the development of desired future conditions of aquifers
- Address natural resource issues
- Address conjunctive surface water management issues

CHAPTER 7

PLAN CONSISTENCY

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7.1 INTRODUCTION

The long-term protection of the Plateau Region's water resources, agricultural resources, and natural resources is an important component of this 2011 update to the Plateau Region Water Plan. Specific guidance is provided to insure that the Plan reaches this goal. 31 TAC 357.14 (C) defines this requirement by the following consistency rules:

a) 31 TAC §358.3 relating to guidelines for state water planning,

b) 31 TAC §357.5 relating to guidelines for the development of Regional Water Plans,

c) 31 TAC §357.7 relating to Regional Water Plan development,

d) 31 TAC §357.8 relating to ecologically unique river and stream segments, and

e) 31 TAC §357.9 relating to unique sites for reservoir construction.

Chapter 7 identifies those considerations that provide for the long-term protection of water resources, agricultural resources, and natural resources that are important to the Plateau Region; and describes how those resources are protected through the regional water planning process.

7.2 PROTECTION OF WATER RESOURCES

Water resources in the Plateau Region as described in Chapter 3 include groundwater in six principal aquifers and surface water occurring in tributaries, mainstream branches, and lakes within five river basins. The numerous springs, which represent a transition point between groundwater and surface water, are also recognized in this Plan for their major importance.

The first step in achieving long-term water resources protection is in the process of estimating each source’s availability. Surface water estimates are developed through a water availability model process (WAM) and are based on the quantity of water available in each river basin to meet existing water rights during a drought-of-record.

Groundwater availability estimates are set at a conservative level that is estimated to not have significant impacts to spring flows. Where available, groundwater availability models (GAMs) are used as a tool to estimate this impact threshold. Establishing conservative levels of water source availability thus results in less potential of over exploiting the supply.

The next step in establishing the long-term protection of water resources occurs in the water management strategies developed in Chapter 4 to meet potential water supply shortages. Each strategy is evaluated for potential threats to water resources in terms of source depletion, quality degradation, and impact to environmental habitat.

Water conservation strategies are also recommended for each entity with a supply deficit. Conservation reduces the impact on water supplies by reducing the actual water demand for the supply. Table 4-3 in Chapter 4 provides an overview of these impact evaluations.

Chapters 6 and 8 contain information and recommendations pertaining to water conservation and drought management practices. When enacted, conservation practices will diminish water demand, drought management practices will extend supplies over the stress period, and land management practices will potentially increase aquifer recharge and stream base flow conditions.

7.3 PROTECTION OF AGRICULTURAL RESOURCES

Although irrigated agriculture is not as prevalent in the Plateau Region as in other areas of the State, agricultural use does represent 41 percent of total water use in the Region. Only municipal and domestic water consumption combined is greater. Many of the communities in the Region depend on various forms of agricultural industry for a significant portion of their economy. It is thus important to the economic health and way of life in these communities to protect water resources that are dedicated to agriculture. The analysis of strategy impacts on agriculture is provided in Table 4-3 in Chapter 4.

7.4 PROTECTION OF NATURAL RESOURCES

The Plateau Water Planning Group has adopted a strong stance toward the protection of natural resources. Natural resources are defined in Chapter 1 as including terrestrial and aquatic habitats that support a diverse environmental community as well as provide recreational and economic opportunities. Appendix 8B (Texas Parks and Wildlife Recommended Ecologically Significant River and Stream Segments) provides information on species and aquatic habitat.

The protection of natural resources as impacted by this Regional Water Plan is closely linked with the protection of water resources as discussed in Section 7.2 above. The methodology adopted to assess groundwater source availability estimates is based on not significantly impacting spring flows that contribute to base flows in area rivers (Chapter 3, Section 3.2.8). Thus, the intention to protect surface flows is directly related to those natural resources that are dependent on surface water sources for their existence.

Environmental impacts were evaluated in the consideration of strategies to meet water-supply deficits. Table 4-5 in Chapter 4 provides an environmental impact analysis of strategies listed in this Plan. Of prime consideration was whether a strategy potentially could diminish the quantity of water currently existing in the natural environment and if a strategy could impact water quality to a level that would be detrimental to animals and plants that naturally inhabit the area under consideration.

Although no specific ecologically unique river and stream segments are recommended in this plan, the PWPG is very explicit in acknowledging the importance of all springs and stream segments for their significance as wildlife habitat. Several recommendations in Chapter 8 are related to the protection of natural resources.

- Section 8.2.2 Conservation Management of State-Owned Lands
- Section 8.2.3 Brush Management Practices
- Section 8.2.14 Management of the Edwards-Trinity Aquifer in Kerr County
- Section 8.3.5 Groundwater / Surface Water Relationship
- Section 8.3.8 Salt Cedar Eradication
- Section 8.3.9 Upper Guadalupe River Basin / Spring Flow Analysis
- Section 8.4 Policy Issues - Environmental

CHAPTER 8

RECOMMENDATIONS

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8.1 INTRODUCTION

The regional water planning process offers an opportunity to make recommendations pertaining to the development and management of the groundwater and surface water resources of the State of Texas. This chapter contains specific suggestions and decisions made by the Plateau Water Planning Group (PWPG). Regional water planning is a relatively new process for the State of Texas. Because of the complex nature of this undertaking, many ideas and approaches to the problems of water-resource management are either refined or changed significantly as all participants in the planning process learn more about the Region’s water resources and about what is required to produce a plan that will benefit all areas of the Region. The PWPG supports the continuation of the regional planning process and recommends certain modifications intended to strengthen its effectiveness.

The following recommendations by the PWPG are derived from careful consideration of many issues covered during the course of the planning exercise including needed legislative actions, state funding and assistance, water supply management planning, and needed studies and data. Issues concerning ecologically unique river and stream segments and sites for the construction of reservoirs are covered. The recommendations in the following sections are designed to present new and/or modified approaches to key technical, administrative, institutional, and policy matters that will help to streamline the planning process, and to offer guidance to future planners with regard to specific issues of concern within the Region.

8.2 RECOMMENDATIONS

8.2.1 Require Participation of State Agencies Involved with the Planning Process

Representatives of State agencies involved in the regional planning process could effectively derail a regional plan at the end of the planning period - without attending as much as one meeting. The PWPG recommends that nonvoting members of State agencies be required to attend and provide input at every planning group meeting. If an agency's nonvoting representative does not contribute or fails to attend meetings, then that agency should not be permitted to object to or alter contents of a planning group's adopted plan. It should be noted that TWDB and TPWD staff were very active (and much appreciated) in the Plateau Region planning process.

8.2.2 Conservation Management of State-Owned Lands

All state-owned land should be managed in ways that enhance water conservation. State agencies need to take the lead in water conservation and it should start on state-owned properties. Unless State agencies set good conservation examples for the public, any public program encouraging such conservation will likely be perceived as "do as I say, not as I do", something that never plays well. Considering that approximately 95 percent of Texas land is privately owned, the State needs to be convincing when making recommendations to the public if it hopes to be successful.

8.2.3 Brush Management Practices

Selective brush management, as a tool to improve watershed yields and water quality, is a strategy of great interest in the Plateau Region, as well as in surrounding planning regions. The legislature should dedicate funds to expedite funding of multi-disciplinary research to develop methodology of defining watersheds of greatest potential for increasing water yields. Teams of geologists, hydrologists, ecologists, wildlife biologists, economists and rangeland scientists working with GIS and various types of aerial photography would have the highest probability of developing tools to identify and quantify the best yielding watersheds for treatment. These studies would estimate the cost-benefit ratios of this management practice including cost of initial brush management; ecological benefits; grazing benefits; reseeding costs, if necessary; and other range management practices as needed to restore brush-infested rangelands while preserving or enhancing wildlife and esthetic values. The end product would quantify both the short-term and long-term costs and benefits per acre-foot of water to such a regional program. Downstream and aquifer users in urban areas would possibly be major beneficiaries and as such should be part of the final equation and possibly part of the funding mechanism. Studies should be of a realistic, large-scale size in order to more accurately correlate with full-scale watershed treatments.

The State should draft legislation based upon the best available science and input from all stakeholders to provide a cost-share funding program to landowners in the targeted watersheds for selective brush management and required other practices. It is generally recognized that brush infestations are the symptom of deeper ecological disturbances such as fire control, drought, grazing mismanagement, wildlife overpopulations and other causes. As such, the cost-share program should involve a long-range contract between the State and the landowner for at least ten (10) years of post-treatment management with required brush re-invasion treatments. A successful model program exists with the Natural Resources Conservation Service, USDA's (NRCS) Great Plains Conservation Program and many Texas landowners are familiar with it. To accurately assess the benefits, treated watersheds will require thorough monitoring of groundwater, springs and surface waters by the US Geological Survey (USGS) or other agencies.

Currently, Texas Parks & Wildlife Department (TPWD) has a program specifically developed for landowners involving brush management in areas possibly containing endangered species. As has been proven on the Kerr Wildlife Management Area (TPWD) with long-term studies, selective brush management coupled with good rangeland management can benefit endangered species and ranchers as well. It is highly likely that watershed values will fit into the same package to provide a win-win situation for all. The voluntary partnership of landowners and TPWD is important to this program, just as it was under the NRCS' Great Plains Program. However, as major parts of targeted watersheds must be treated in order to provide the desired hydrological benefits, it is likely that a high percentage of watershed landowners must opt-in to the program before it could be accepted by the State for treatment and management contracts.

8.2.4 Recharge Structures

Recharge structures are a relatively low cost method of enhancing aquifer recharge if sited to provide adequate streambed water percolation based upon the best available science. Recharge structures such as small dams, gabions, or terraces can provide multiple benefits under ideal conditions as has been proven along the Edwards Aquifer Recharge Zone. This interest in recharge structures should be encouraged, funding provided, and perhaps some streamlining of any required permitting procedures as possible and as advised. Programs and funding should be available to identify appropriate locations for recharge structures and technical assistance provided for construction and maintenance.

8.2.5 Rainwater Harvesting as an Alternative Sources of Water

Rainwater harvesting programs should be supported by the State. Rainwater harvesting is one way to meet rural or urban domestic water demands, as well as use for limited irrigation, such as vineyards, orchards or small farms under drip irrigation. Livestock and wildlife can also be provided supplemental water by rainwater harvesting. This should be widely encouraged by funded education programs and cost-share funding to individual homeowners, farmers, businesses, public entities and ranchers.

8.2.6 Training for New Regional Water Planning Group Members

The TWDB is encouraged to continue providing training opportunities for new planning group members. Planning group members provide better input to the planning process when they fully understand the requirements, schedules, and the multitude of internal components of the regional plan.

8.2.7 Irrigation Surveys

Irrigation application is the largest use of water in the State, yet its quantification is probably the least accurate. Irrigation use is only being accurately determined in areas where groundwater conservation districts are requiring the installation of irrigation well flow meters and where irrigation districts record surface water diversions. Elsewhere, planning group members directly involved in the agricultural industry have viewed irrigation surveys with skepticism in many counties. Nursery farms, greenhouse operations, wildlife and exotic animal food plots, and non-municipal golf courses are just a few of the irrigation activities that are often overlooked in the surveys. The TWDB is encouraged to develop a more confident means of estimating actual irrigation use.

8.2.8 Transient Population Impact on Water Demand

Municipal water use reports capture the total amount of water produced and distributed by the city. In concept, this volume includes water consumed by both permanent and transient populations within the community. However, the counties of the Plateau Region have a high transient influx of vacationers and hunters that frequent the more remote areas and are not likely included in the water demand estimates. Likewise, there are a high percentage of second-home owners in the rural counties that is also not accounted. Officials in the most rural counties in the Region estimate that as much as 70 percent of landowners are not permanent residents. This transient water demand likely has a significant impact on water demand estimates used by the planning group. The PWPG encourages the TWDB to consider this water-use category and develop a method for estimating its impact.

8.2.9 Peak-Use Management

Drought management plans need to be developed based on peak use demand instead of annual production capabilities. The current Plan is based on drought-of-record conditions on an annual basis. While this is a good starting point in the planning process, it would be beneficial to also plan based on peak demand during a year. For example, current planning does not address water needs during the peak use period of summer months. During the summer, in many areas of the State, severe water problems may exist that are not apparent based on an annual water management plan. This results in a plan that may indicate that water supply needs are satisfied for a region, when in reality such needs may not be satisfied throughout the year. This presents a significant problem in the current planning process.

8.2.10 Groundwater Availability Analysis

In the past, the method for estimating groundwater availability was not standardized statewide, which resulted in aquifer availability estimates made for the same aquifer in adjoining regions being non-comparable. This problem has been significantly improved with the advent of groundwater availability models (GAMs).

While GAMs have improved regional analysis of aquifers, it is recognized that they are only as accurate at simulating actual groundwater flow as the quantity and quality of data that is used to construct the models. Much of the Plateau Region occurs along the outer margins of modeled areas where data is limited and model simulation accuracy is uncertain. Though the PWPG encourages the continued development and improvement of GAMs, caution must be used in using the models as a stand-alone tool. Model results should be used in concert with other available tools. Models are simply a series of algorithms and should not be used to model results for purposes beyond their level of sophistication. As with any mathematical model, data is key in producing accurate results. The PWPG encourages TWDB funding for data development to be used in the GAM process.

8.2.11 Development of Better Methodologies for Estimating Population and Water Demand

The revision of population and demand estimates should be discussed by regional water planning groups and put before the public for several months, and then be presented to the planning groups for consideration and adoption. This will allow more time for water users within the region to hear about the planning effort and to have input to the revisions of population, water demand, and water supply.

Modification of demand numbers should be allowed further into the planning process. Demand errors may not be discovered until the supply-demand analysis is performed. Some entities or water-use categories may have been overlooked early in the process and their demands need to be added later for the supply-demand analyses to match.

8.2.12 Educational Programs by the State to Assist Regional Water Planning Groups

There is a need for the development of educational programs by State agencies to assist Regional Water Planning Groups in educating both the public and private sectors. Examples of the educational programs include the following:

- Encourage development and construction of recharge structures
- Encourage rainfall harvesting to supplement or replace aquifer pumping
- Educate and encourage municipalities to manage water systems to maximize their preparedness for drought conditions
- Encourage the public to conserve water through low-flow appliances and fixtures, low-water landscaping and elimination of waste

8.2.13 Conservation and Drought Planning

Because portions of the Plateau Region are particularly susceptible to water-supply shortages during periods of drought conditions, these areas are especially encouraged to develop conservation oriented management plans. Likewise, water-user entities within these areas should become actively involved in the regional water planning activities associated with this plan.

8.2.14 Management of the Aquifer in Western Kerr County

Numerous springs in western Kerr County generate the base flow in the three branches of the upper Guadalupe River. The maintenance of this base flow is thus dependent on long-term preservation of the springs. It is therefore reasonable that the Headwaters Groundwater Conservation District should consider management rules for the Edwards-Trinity (Plateau) Aquifer in Kerr County that sustains flow to these important springs.

8.2.15 Local Groundwater Management

The PWPG considers all groundwater sources recognized in this Plan as being critical to the future health and economic welfare of the Plateau Region. Because of the reliance on groundwater to meet current and future water needs, the PWPG recommends that local groundwater conservation districts be formed throughout the entire Region to administer sound, reasonable, and scientifically-based management objectives.

8.2.16 Aquifer Recharge with Harvested Rainwater

To promote rainwater harvesting by reducing the cost of above ground storage, rainwater could be injected into some domestic water wells. The injection of rainwater would reduce aquifer depletion, and in some cases, provide recharge of the aquifer. In the Hill Country Priority Groundwater Management Area with an average rainfall of 28 to 32 inches per year, the amount of water captured annually from an average residential roof would exceed the amount of water used annually by the average household.

Injection of rainwater into a domestic well must be regulated on a local level for the protection of the aquifer. At the present, TCEQ rules would require modification to delegate the registration and inspection of injection systems to the local groundwater districts for local control. After a complete evaluation and study of the local or domestic ASR process, it should be found that the aquifer would benefit by gaining water of a better quality than is generally found in the aquifer.

8.2.17 Land Stewardship

The interaction between soil, water and vegetation in the floodplains and along streambeds constitutes riparian function, which buffers and slows floodwaters, filters sediment, improves natural infiltration and recharge of alluvial aquifers, and enhances water quality. The PWPG encourages riparian landowners to learn and implement land stewardship practices that support healthy riparian function.

8.2.18 Regional Planning Coordination

The two regional planning processes developed by the Legislature (Regional Water Planning and Groundwater Management Areas) have in some cases resulted in conflicting methodologies of reaching long-term planning goals. The PWPG encourages better communication between the stakeholders at earlier stages of both processes in the future. The PWPG also encourages the Legislature to examine ways in which both planning processes can better interact for the good of all citizens and economies in the impacted regions.

8.3 NEEDED STUDIES AND DATA

The State should fund or conduct specific studies that will shed more information on specific water-resource issues. The questions unanswered by current sources of information are critical to future PWPG decisions. The following are recommendations pertaining to specific studies and data acquisition that the PWPG believes would provide significant insight into specific planning issues in the Region.

8.3.1 Edwards-Trinity (Plateau) Aquifer

All six counties in the Plateau Region are partially or fully underlain by the Edwards-Trinity (Plateau) Aquifer. Even though a groundwater availability model (GAM) has been constructed for this aquifer, there remain many hydrological questions about the aquifer. Specific counties are embroiled in controversy pertaining to groundwater supply availability. At issue is the disagreement about the total amount of water in the county that is available on an annual basis to meet all of the counties projected water demands now and into the future, and the amount of groundwater in excess of that amount that might be available for other purposes other than in-county use. All concerned agree that sound science is needed to assess this quantification.

A basic, unbiased, scientific study that encompasses the hydrologic characterization of the Edwards-Trinity (Plateau) Aquifer and adjacent associated aquifers (Edwards-BFZ and Austin Chalk) and the inter-formational flow between them, their contribution to surface water flows, and the historical withdrawals from the aquifers is needed in order for the local groundwater management entities and the PWPG to make sound management decisions and recommendations.

8.3.2 Trinity Aquifer

The Trinity Aquifer is the principal source of water supply in Bandera and Kerr Counties, and is of vital importance during drought conditions when minimal flows occur in the Guadalupe and Medina Rivers. A reliable system of observation wells in the Trinity aquifer is presently being put in place and managed by the local groundwater conservation districts. The districts would benefit from technical assistance from TWDB staff in gathering and interpreting water level and other appropriate data on the local aquifer system. The PWPG also encourages the further revision of the Hill Country Trinity Aquifer GAM and particularly the inclusion of the lower Trinity Aquifer layer.

The Plateau (J), Lower Colorado (K), and South Central Texas (L) Regions share the Trinity Aquifer and should jointly evaluate and determine in what context the Trinity GAM should be used in current and future planning efforts.

8.3.3 Unpermitted Withdrawals of Riparian Water

A significant amount of unpermitted riparian water is withdrawn from rivers and their tributaries in the Region. Unpermitted pumping is particularly escalated during drought periods when increased withdrawals occur for irrigation of lawns. This water use is unaccounted for in the Water Availability Models that are developed for these waterways. State water agencies should devise a survey method to establish a reasonable estimate of these diversions.

8.3.4 Emphasis on Basic TWDB Water Evaluation Studies

In the past, the TWDB has provided significant knowledge concerning the groundwater resources in the State in the form of basic data and reports. The Board's current emphasis on groundwater modeling with its intended use as a water management planning tool, is recognized as an important advancement in providing planning tools. However, the Board should not abandon its important basic data gathering and evaluation responsibility. The Board should emphasize more realistic and useful groundwater studies that include the extensive field data collection necessary for such studies. TWDB staff effort and funding should go to these more realistic and focused studies.

8.3.5 Groundwater / Surface Water Relationship

The PWPG defines groundwater availability as a maximum level of aquifer withdrawal that results in an acceptable level of long-term aquifer impact such that the base flow in rivers and streams is not significantly affected beyond a level that would be anticipated due to naturally occurring conditions. This water supply policy definition can best be achieved when the relationship between groundwater and surface water is fully understood. The PWPG encourages the State (TWDB) to embrace this concept and focus water availability studies on this topic.

8.3.6 Impact of Transient Water Demand in Rural Counties

The concern pertaining to transient population water demand in rural counties was expressed in Section 8.2.8. A study is needed to quantify this impact that is not based solely on the resident population but rather considers the total count of individuals within the respective area.

8.3.7 Underestimated Water Demand of Exotic Animals

The PWPG investigated the water use generated by the expanding exotic animal industry within the Region (see Appendix 2B) and expects to build on this information to generate more accurate water demand estimates in future regional plans. The PWPG encourages the TWDB and other agencies to continue funding for this endeavor in the Plateau Region and throughout the state.

8.3.8 Salt Cedar Eradication

The PWPG continues to encourage funding for projects aimed at the eradication and long-term suppression of salt cedar and other nuisance phreatophytes in the Rio Grande and Pecos watershed.

8.3.9 Upper Guadalupe River Basin Groundwater / Springflow Analysis

Surface water base flow in the three branches of the upper Guadalupe River in western Kerr County is derived almost exclusively from groundwater discharge through springs. Both the PWPG and members of Groundwater Management Area 9 recognize the need to manage groundwater use in this area where critical surface water/groundwater interaction occurs. However, developing management decisions is impaired by the lack of current understanding of how groundwater level elevations relate to spring flow rates. Only one monitoring well is in place that provides continuous water level readings, and no attempt has thus far been made to relate this recent data to spring flows. A study is needed to evaluate this critical interaction so that future management decisions can be based on a more substantial level of scientific knowledge.

8.4 POLICY ISSUES

During the 2006 regional planning development period, the TWDB provided regional planning groups with water issue discussion topics divided into the following categories:

- Agricultural and Rural Water
- Conservation
- Data
- Environmental
- Groundwater
- Innovative Strategies
- Providing and Financing Water/WW Services
- Surface Water
- Other Issues

The PWPG reviewed and discussed the topics during several meetings, and culminated the discussions by prioritizing the issue topics in each category (Appendix 8A). The priority order displayed in the survey provides a view of those issues that are of greatest concern in the Plateau Region. A common theme throughout the policy issue survey is the interest in water-use and land-use management that protects each of the five river basins in the Region.

8.5 CONSIDERATION OF ECOLOGICALLY UNIQUE RIVER AND STREAM SEGMENTS

Under regional planning guidelines, each planning region may recommend specific river or stream segments to be considered by the legislature for designation as ecologically unique. The legislative designation of a river or stream segment would only mean that the State could not finance the construction of a reservoir that would impact the segment. The intent is to provide a means of protecting the segments from activities that may threaten their environmental integrity.

Texas Parks and Wildlife Department (TPWD) provided a list of stream segments that were identified as meeting ecologically unique criteria. This list and map can be viewed in Appendix 8B. For each segment, TPWD lists qualities of each segment that support the stream's candidacy. These qualities may include but are not limited to biological function, hydrological function, location with respect to conservation areas, water quality, the presence of state- or federally-listed threatened or endangered species, and the critical habitat for such species.

The Plateau Region contains some of the most ecologically pristine areas in the State. The preservation of this natural environment is an important component of the Region's economy, which is closely tied to these natural resources. The PWPG recognizes the uniqueness of this Region and has followed a policy throughout this planning period of always considering the impact that their decisions have on the area's ecological resources. However, because the subsequent ramifications of designation are not fully understood, the PWPG has chosen to refrain from recommending specific segments for designation as "ecologically unique" at this time. The PWPG strongly maintains that all river and stream segments in the Plateau Region are vitally important and their flows constitute a major consideration in adoption of this plan.

8.6 CONSIDERATION OF UNIQUE SITES FOR RESERVOIR CONSTRUCTION

Regional water planning guidelines (§357.9) instruct that planning groups may recommend sites of unique value for construction of reservoirs by including descriptions of the sites, reasons for the unique designation, and expected beneficiaries of the water supply to be developed at the site. The following criteria shall be used to determine if a site is unique for reservoir construction:

(1) site-specific reservoir development is recommended as a specific water management strategy or in an alternative long-term scenario in an adopted plan; or

(2) the location, hydrologic, geologic, topographic, water availability, water quality, environmental, cultural, and current development characteristics, or other pertinent factors make the site uniquely suited for:

- (a) reservoir development to provide water supply for the current planning period; or
- (b) where it might reasonably be needed to meet needs beyond the 50-year planning period.

Following consideration of the above criteria the PWPG makes no recommendation of unique sites for reservoir construction.

APPENDIX 8A

Plateau Region Policy Issues Survey

APPENDIX 8A. PLATEAU REGION POLICY ISSUES SURVEY

A.	Agricultural and Rural Water
1	Quantification of impacts to rural Texans of water transfers (e.g. effects on income, employment, population)
2	Protecting agricultural and rural water supplies, considering economic constraints and competing uses
3	Impacts on water supply and quality resulting from conversion of agricultural lands to urban lands
4	Improved water use information for irrigation and livestock watering categories
5	Effects of Safe Drinking Water Act on Small Water supply systems
6	Conservation of agricultural water for additional agricultural use, urban uses or for environmental purposes (i.e. how to treat this “new” water)
7	Incentives for individual projects, including stock tanks
8	Use of playa lakes for recharge, considering impacts and constraints

B.	Conservation
1	Relationship between drought contingency planning and regional water planning
2	Per capita water use analysis considering commercial and institutional use, income, hosting stock characteristics, and geographical location
3	Retail customer water pricing
4	Quantifying conserved water
5	Incentives (e.g. landscaping and plumbing rebates)

C.	Data
1	Consistent analytical techniques
2	Data for rural areas
3	Compatibility of data from different sources
4	Linkages of databases
5	Trends in data collection and availability
6	Access to data, including security constraints

D.	**Environmental**
1	Springflow protection
2	Instream flows
3	Watershed planning/source water protection
4	Regional or statewide environmental mitigation system
5	Environmental criteria to measure and maintain a sound ecological environment
6	Integrating water quality and water supply considerations
7	Environmental water permits
8	Sustainable growth, including impacts of growth
9	Invasive species
10	Bays and estuaries
11	Unique stream segments
12	Wildlife resources, including threatened and endangered species
13	Texas Water Trust

E.	**Groundwater**
1	Sustainability and groundwater management
2	Linking groundwater and surface water models (see also surface water)
3	Coordination between Groundwater Conservation Districts and Regional Water Planning Groups
4	Groundwater export and potential equity issues (e.g. use of export fees)
5	Conjunctive use of groundwater and surface water (see also surface water)
6	Rule of capture
7	Standardized methods/policy for determining groundwater availability
8	Improving groundwater availability data
9	Water marketing (e.g. water rights leases, sales, transfers)
10	Impacts of Texas Water Code of 36.121, “Limitation on Rulemaking Power of Districts Over Wells in Certain Counties”
11	Clarifying state roles and district roles
12	Adequate financial resources for districts
13	Variability of “historical water use” definition
14	Storm water runoff for groundwater recharge purpose (see also surface water)
15	Abandoned oil and gas wells, including waters supply and quality impacts

F.	Innovative Strategies
1	Brush management, including potential impacts on water supply and wildlife
2	Desalination of seawater and brackish water
3	Reuse (including basin-specific assessment of reuse potential and impacts)
4	Planning beyond the current fifty-year time horizon
5	Groundwater banking
6	Weather modification
7	Climate change

G.	Providing and Financing Water/WW Services
1	State participation
2	Incentives for planning implementation
3	Potential funding sources for water supply
4	Public-private partnerships
5	Ranking proposals as a component of financial assistance
6	Regionalized water supply

H.	Surface Water
1	Water marketing (e.g. water right leases, sales, transfers)
2	Cumulative effects on water availability of exempt water storage facilities (e.g. stock ponds)
3	Linking groundwater and surface water models (see also groundwater)
4	Conjunctive use of groundwater and surface water (see also groundwater)
5	Interbasin Transfer (IBTs)
6	Assessment of the current water resource regulatory system to meet water management needs of the 21^{st} century
7	Competing demands on reservoir operation (e.g. B&E flows, recreation, municipal supply, aesthetics, etc.)
8	Reservoir storage reallocation (e.g. from flood storage to water supply storage)
9	Subordination agreements (including basin-specific assessment of subordination agreements)
10	System operation of water facilities (e.g. coordination of multiple reservoirs)
11	International treaty compliance
12	Watermaster program (e.g. expansion, funding, enforcement)

I.	**Other Issues**
1	Education
2	Consistency between regional water planning and rules for drinking water systems regarding minimum requirements for water supply
3	Security of supply from potential disruptions
4	Public involvement
5	Inter-regional cooperation / Inter-regional water sharing
6	Heritage / tourism / recreation / cultural resources

APPENDIX 8B

Texas Parks and Wildlife Department

Suggested Ecologically Significant

River and Stream Segments

Texas Parks and Wildlife

Suggested Ecologically Significant River and Stream Segments

Devils River - From a point 0.4 mile downstream of the confluence of Little Satan Creek in Val Verde County upstream to the Val Verde/Sutton County line (within TNRCC classified stream segment 2309).

Biological function - National Wild and Scenic Rivers System nominee for outstandingly remarkable fish and wildlife values (NPS, 1995)

Riparian conservation area - Devils River State Natural Area

High water quality/exceptional aquatic life/high aesthetic value - ecoregion stream (Bayer et al., 1992); highwater quality and exceptional aquatic life use (TNRCC, 1996); exceptional aesthetic value (NPS, 1995)

Threatened or endangered species/unique communities - Devils River minnow (Fed.E/St.T), Conchos pupfish (SOC/St.T) (Hubbs et al., 1991); proserpine shiner (SOC/St.T), Rio Grande darter (SOC/St.T) (Bayer et al., 1992; Hubbs et al., 1992); largest known population of Texas snowbells (Fed.E.St.E) (J. Poole, 1999, pers. comm.)

Fessenden Branch - From the confluence with Johnson Creek upstream to Fessenden Springs.

Hydrologic function - valuable hydrologic function relating to groundwater discharge (Brune, 1975)

Frio River - From the Real/Uvalde County line upstream to the confluence of the West Frio River and the East Frio River in Real County (within TNRCC classified stream segment 2113).

Biological function - Texas Natural Rivers System nominee for outstandingly remarkable wildlife values (NPS, 1995)

Hydrologic function - valuable hydrologic function relating to groundwater discharge and recharge of the Edwards Aquifer (Brune, 1981)

High water quality/exceptional aquatic life/high aesthetic value - high water quality and exceptional aquatic life use (TNRCC, 1996); exceptional aesthetic value (NPS, 1995)

Guadalupe River - From the Kerr/Kendall County line upstream to the confluence of the North Fork Guadalupe River and the South Fork Guadalupe River in Kerr County (within TNRCC classified stream segment 1806).

Hydrologic function - valuable hydrologic function relating to groundwater recharge and discharge of the Edwards Aquifer (Brune, 1975)

Riparian conservation area - Kerrville State Park

High water quality/exceptional aquatic life/high aesthetic value - exceptional aquatic life use (TNRCC, 1996); rated #2 Scenic river in Texas (NPS, 1995)

Threatened or endangered species/unique communities - one of only four known remaining populations of endemic Texas fatmucket freshwater mussel; one of only four known remaining populations of endemic golden orb freshwater mussel (Howells, 1997; Howells, 1998)

Johnson Creek - From the confluence with the Guadalupe River in Kerr County to a point 0.7 mile upstream of the most upstream crossing of SH 41 in Kerr County (TNRCC classified stream segment 1816).

High water quality/exceptional aquatic life/high aesthetic value - high water quality and exceptional aquatic life use (TNRCC, 1996)

Las Moras Creek - From the Kinney/Maverick County line upstream to its headwaters four miles north of Brackettville in Kinney County.

Hydrologic function - valuable hydrologic function relating to groundwater discharge of the Edwards Aquifer (Brune, 1975)

High water quality/exceptional aquatic life/high aesthetic value - high water quality, diverse benthic macroinvertebrate community (Bayer et al., 1992)

Threatened or endangered species/unique communities - proserpine shiner (SOC/St.T) (Hubbs et al., 1991)

Medina River - From a point immediately upstream of the confluence of Red Bluff Creek in Bandera County to the confluence of the North Prong Medina River and the West Prong Medina River in Bandera County (TNRCC classified stream segment 1905).

Biological function - Texas Natural Rivers System nominee (NPS, 1995)

High water quality/exceptional aquatic life/high aesthetic value - ecoregion stream (Bayer et al., 1992); exceptional aquatic life use (TNRCC, 1996)

Mud Creek - From the confluence with Sycamore Creek in Kinney County upstream to its headwaters located about six miles northeast of Amanda in Kinney County.

High water quality/exceptional aquatic life/high aesthetic value - ecoregion stream; high water quality, diverse benthic macroinvertebrate community (Bayer et al., 1992)

North Fork Guadalupe River - From the confluence with the Guadalupe River in Kerr County to a point 11.3 miles upstream of Boneyard Draw in Kerr County (TNRCC classified stream segment 1817).

Hydrologic function - valuable hydrologic function relating to groundwater discharge of the Edwards Aquifer (Brune, 1975)

Riparian conservation area - Kerr Wildlife Management Area

High water quality/exceptional aquatic life/high aesthetic value - high water quality and exceptional aquatic life use (TNRCC, 1996)

Nueces River - From the Real/Edwards/Uvalde County line upstream to the confluence of the East Prong Nueces River and Hackberry Creek in Edwards County (within TNRCC classified stream segment 2112).

Biological function - Texas Natural Rivers System nominee for outstandingly remarkable fish and wildlife values, Top 100 Texas Natural Areas list (NPS, 1995)

Hydrologic function - valuable hydrologic function relating to groundwater discharge and recharge of the Edwards Aquifer (Brune, 1981)

High water quality/exceptional aquatic life/high aesthetic value - exceptional aesthetic value (NPS, 1995)

Threatened or endangered species/unique communities - Texas snowbells (Fed.E/St.E) (J. Poole, 1999, pers. comm.)

Pecos River - From a point 0.4 miles downstream of the confluence of Painted Canyon in Val Verde County upstream to the Val Verde/Crockett County line (TNRCC classified stream segment 2310 and part of 2311).

Biological function - Texas Natural Rivers System nominee for outstandingly remarkable fish and wildlife values (NPS, 1995)

High water quality/exceptional aquatic life/high aesthetic value - diverse benthic macroinvertebrate community (Bayer et al., 1992); exceptional aesthetic value (NPS, 1995)

Threatened or endangered species/unique communities - Rio Grande darter (SOC/St.T) (Hubbs et al., 1991); proserpine shiner (SOC/St.T) (Hubbs et al., 1991; Linam and Kleinsasser, 1996)

Pinto Creek - From the confluence with the Rio Grande in Kinney County upstream to its headwaters northeast of Brackettville in Kinney County.

High water quality/exceptional aquatic life/high aesthetic value - ecoregion stream; diverse benthic macroinvertebrate community (Bayer et al., 1992)

Threatened or endangered species/unique communities - proserpine shiner (SOC/St.T) (Hubbs et al., 1991)

Sabinal River - From the Bandera/Uvalde County line upstream to the most upstream crossing of RR 187 in Bandera County (within TNRCC classified stream segment 2111).

Biological function - Texas Natural Rivers System nominee for outstandingly remarkable wildlife values (NPS, 1995).

Hydrologic function - Insufficient information to confirm significance.

Riparian conservation area - Lost Maples State Park (National Natural Landmark)

High water quality/exceptional aquatic life/high aesthetic value - exceptional aesthetic value (NPS, 1995)

Threatened or endangered species/unique communities - genetic refuge for pure strain Guadalupe bass (SOC) (G. Garrett, 2000, pers. comm.)

San Felipe Creek - From the confluence with the Rio Grande in Val Verde County upstream to a point 2.5 miles upstream of US 90 in Val Verde County (TNRCC classified stream segment 2313).

Hydrologic function - valuable hydrologic function relating to groundwater discharge of San Felipe Springs, which contributes to baseflow of Rio Grande River (Brune, 1981)

Riparian conservation area - Insufficient data to merit designation.

Threatened or endangered species/unique communities - proserpine shiner (SOC/St.T), Devils River minnow (Fed.E/St.T), Rio Grande darter (SOC/St.T) (Hubbs et al., 1991)

South Fork Guadalupe River - From the confluence with the Guadalupe River in Kerr County to a point three miles upstream of FM 187 in Kerr County (TNRCC classified stream segment 1818).

Hydrologic function - valuable hydrologic function relating to groundwater discharge of the Edwards Aquifer (Brune, 1975)

High water quality/exceptional aquatic life/high aesthetic value - high water quality and exceptional aquatic life use (TNRCC, 1996)

South Llano River - From the Kimble/Edwards County line upstream to SH 55 in Edwards County (within TNRCC classified stream segment 1415).

High water quality/exceptional aquatic life/high aesthetic value - ecoregion stream; high water quality, diverse benthic macroinvertebrate and fish communities (Bayer et al., 1992; Linam et al., 1999)

Threatened or endangered species/unique communities - only major watershed containing a genetically pure population of Guadalupe bass (SOC) (G. Garrett, 2000, pers. comm.)

Sycamore Creek - From the confluence with the Rio Grande in Val Verde/Kinney County upstream to US 90 on Val Verde/Kinney County line.

High water quality/exceptional aquatic life/high aesthetic value - ecoregion stream; diverse benthic macroinvertebrate community (Bayer et al., 1992 and Davis, 1999)

Threatened or endangered species/unique communities - proserpine shiner (SOC/St.T) (Hubbs et al., 1991); Rio Grande darter (SOC/St.T) (Hubbs et al., 1991; Bayer et al., 1992); Devils River minnow (SOC/St.T) (Hubbs et al., 1991)

West Nueces River - From the Kinney/Uvalde County line upstream to the Kinney/ Edwards County line.

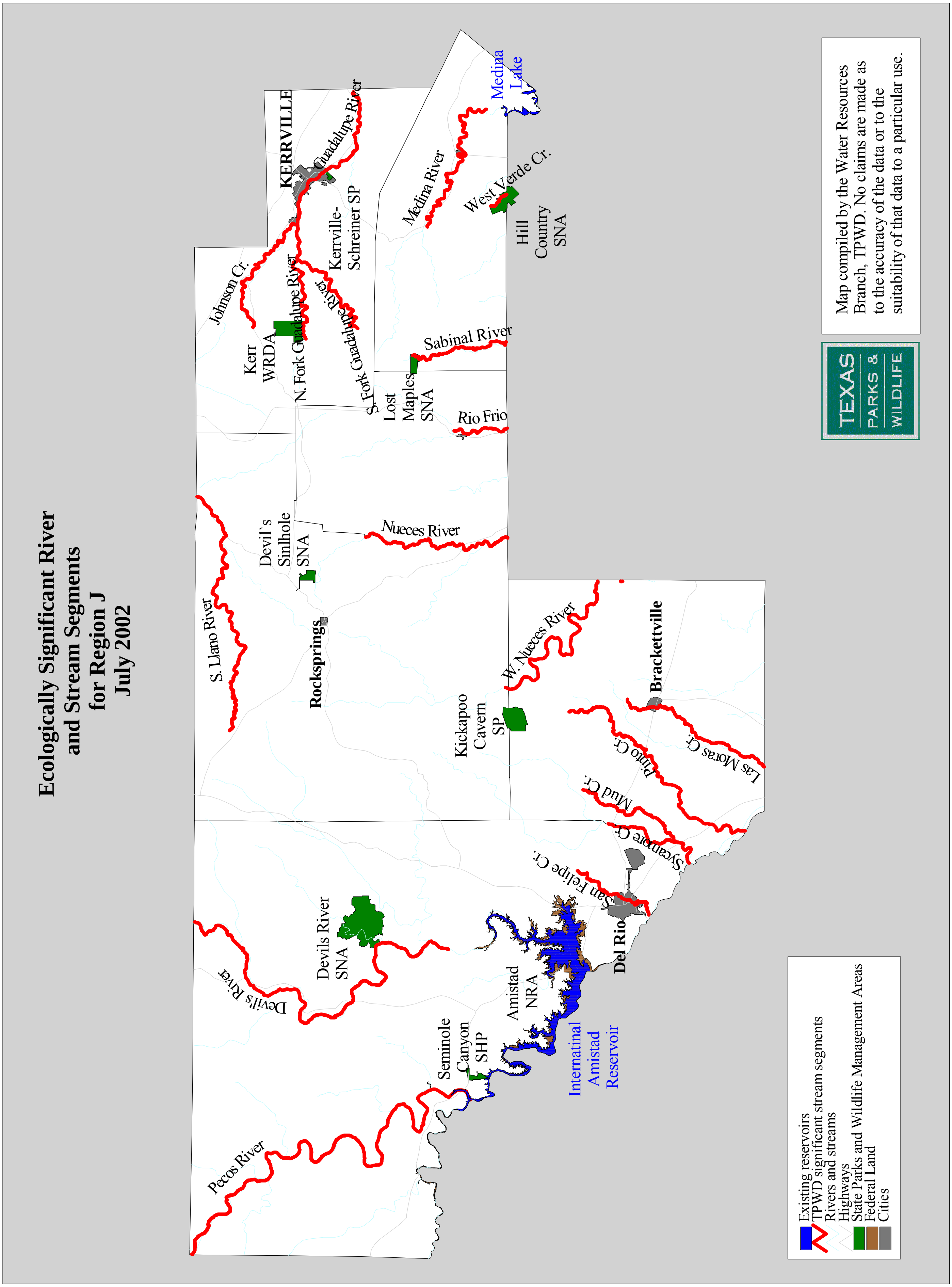
Hydrologic function - valuable hydrologic function relating to groundwater discharge and recharge of the Edwards Aquifer (Brune, 1981)

Threatened or endangered species/unique communities - Texas snowbells (Fed.E/St.E) (J. Poole, 1999, pers. comm.)

West Verde Creek - From the Bandera/Medina County line upstream to its headwaters in Bandera County.

Hydrologic function - valuable hydrologic function relating to groundwater recharge of the Edwards Aquifer (Brune, 1981)

Riparian conservation area - Hill Country State Natural Area


Ecologically Significant River
and Stream Segments
for Region J
July 2002
KERRVILLE
Guadalupe River
Kerrville-
Schreiner SP
Johnson Cr.
Kerr
WRDA
N. Fork Guadalupe River
S. Fork Guadalupe River
Medina
Lake
Medina River
West Verde Cr.
Hill
Country
SNA
Sabinal River
Lost
Maples
SNA
Rio Frio
Nueces River
Devil's
Sinlhole
SNA
S. Llano River
Rocksprings
W. Nueces River
Brackettville
Kickapoo
Cavern
SP
Pinto Cr.
Las Moras Cr.
Mud Cr.
Sycamore Cr.
San Felipe Cr.
Del Rio
Devils River
SNA
Devil's River
Amistad
NRA
International
Amistad
Reservoir
Seminole
Canyon
SHP
Pecos River
Existing reservoirs
TPWD significant stream segments
Rivers and streams
Highways
State Parks and Wildlife Management Areas
Federal Land
Cities
TEXAS
PARKS &
WILDLIFE
Map compiled by the Water Resources Branch, TPWD. No claims are made as to the accuracy of the data or to the suitability of that data to a particular use.

CHAPTER 9

WATER INFRASTRUCTURE FUNDING

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9.1 INTRODUCTION

The Infrastructure Financing Report (IFR) survey presented in this chapter identifies the state financing options proposed by entities in this Plan to meet future infrastructure needs. The IFR also presents the Plateau Water Planning Group’s (PWPG's) consideration of the role that the State should take in financing water supply projects.

Chapter 4 identifies six entities (Bandera, Barksdale, Camp Wood, Kerrville, Leakey and the Upper Guadalupe River Authority) that either have a projected water supply deficit and recommended strategies to meet that need, or they have an identified need for a water supply infrastructure project, which may require state financial assistance. These entities were surveyed to determine their proposed method(s) for financing the estimated capital costs involved in implementing the water supply strategies recommended in the 2011 Plateau Region Water Plan.

Unlike infrastructure financing surveys conducted for previous regional water plans, questions during this planning cycle focused on projected needs for financial assistance from programs administered by the TWDB. The TWDB will aggregate the projected requests for funding from these programs from the 16 water planning regions to provide a picture of estimated long-term infrastructure funding needs to the state legislature.

9.2 TWDB FUNDING PROGRAMS AVAILABLE

The TWDB offers financial assistance for the planning, design and construction of projects identified in regional water plans or the State Water Plan. Programs available include the Water Infrastructure Fund (WIF), the State Participation Fund (SP), and the Economically Distressed Areas Program (EDAP). In order to be eligible to apply for funding from any of these sources, the applicant must be a political subdivision of the state, or in some cases a water supply corporation, and the proposed project must be a recommended water management strategy in the most recent approved regional plan or State Water Plan. In 2007 the 80th Texas Legislature appropriated funding to enable the issuance of $812 million in bonds for water plan projects, an amount estimated to meet water supply needs identified in the 2007 State Water Plan through 2020.

9.2.1 Water Infrastructure Fund (WIF)

The Water Infrastructure Fund (WIF) provides subsidized interest rate loans for planning, design and construction. The WIF-Deferred fund offers the option of deferring all interest and principal payments for up to 10 years for planning, design and permitting costs, while the WIF-Construction fund offers subsidized interest for all construction costs including planning, acquisition, design, and construction.

9.2.2 State Participation Fund (SP)

The State Participation Fund (SP) is geared towards large projects which are regional in scope and meant to capitalize on economies of scale in design and construction, but where the local project sponsors are unable to assume the debt for an optimally sized facility. The TWDB assumes a temporary ownership interest in the project, and the local sponsor repays the cost of the funding through purchase payments on a deferred schedule. The goal of the program is to build a project that will be the right size for future needs, even if that results in the short term in building excess capacity, rather than constructing one or more smaller projects now. On new water supply projects, the TWDB can fund up to 80 percent of the costs provided that the applicant can fund the other 20 percent through an alternate source and that at least 20 percent of the total capacity of the project serves current needs.

9.2.3 Rural and Economically Distressed Areas (EDAP)

Both grants and zero percent interest loans for planning, design and construction costs are offered through these programs, which are available to eligible small, low-income communities. Rural and economically distressed areas that meet population, income and other criteria are eligible to apply for these funds. EDAP funding eligibility also requires adoption of the Texas Model Subdivision Rules by the applicant planning entities.

9.3 THE INFRASTRUCTURE FINANCING SURVEY

The survey instrument is prefaced with an explanation of its purpose in identifying the need for financial assistance programs offered by the State of Texas and administered by the TWDB. The available funding programs (WIF, SP and EDAP) are summarized, and the survey participant is asked to: 1) identify the amounts they might request from each funding source for each identified project or strategy; and 2) the earliest date the funds would be needed, by fund type. Water user groups with multiple strategies to meet future water needs are only surveyed for strategies with a capital cost.

The Cities of Bandera, Barksdale, Camp Wood, Kerrville, Leakey, and the Upper Guadalupe River Authority (UGRA) were presented with surveys provided by the TWDB. The survey along with supporting documentation that summarized the water management strategies included in the Regional Plan for that entity were delivered to the mayor or the city/utility manager and follow-up contacts were made with each entity to encourage response to the survey. The following Table 9-1 presents the actions taken on these surveys.

Table 9-1. Summary of Infrastructure Financing Options Identified in the Surveys

Political Subdivision Name	Strategy ID	Project Name	Total Project Capital Cost	TWDB Funding Type	Capital Cost Financed by Fund	Earliest Year of Need	% TWDB Financed
CITY OF BANDERA	J-1	SURFACE WATER ACQUISITION, TREATMENT AND ASR	$19,654,900	WIF: DEFFERED	$3,930,980	2015	100%
				WIF: CONSTRUCTION	$13,758,430	2017	
				SP: EXCESS CAPACITY	$1,965,490	2020	
				EDAP - RURAL			
				EDAP - DISADVANTAGED			
COMMUNITY OF BARKSDALE	J-3	ADDITIONAL GROUNDWATER WELLS	$50,600	WIF: DEFFERED			100%
				WIF: CONSTRUCTION			
				SP: EXCESS CAPACITY			
				EDAP - RURAL			
				EDAP - DISADVANTAGED	$50,600	Undetermined	
	J-4	REPLACE PRESSURE TANK	$7,000	WIF: DEFFERED			No response
				WIF: CONSTRUCTION			
				SP: EXCESS CAPACITY			
				EDAP - RURAL			
				EDAP - DISADVANTAGED			
CITY OF CAMP WOOD	J-17	GROUNDWATER WELLS	$247,250	WIF: DEFFERED			100%
				WIF: CONSTRUCTION			
				SP: EXCESS CAPACITY			
				EDAP - RURAL			
				EDAP - DISADVANTAGED	$247,250	Undetermined	
CITY OF KERRVILLE	J-7	INCREASED WATER TREATMENT AND ASR CAPACITY	$6,650,000	WIF: DEFFERED			No response
				WIF: CONSTRUCTION			
				SP: EXCESS CAPACITY			
				EDAP - RURAL			
				EDAP - DISADVANTAGED			
CITY OF LEAKEY	J-15	ADDITIONAL GROUNDWATER WELLS	$189,750	WIF: DEFFERED			100%
				WIF: CONSTRUCTION			
				SP: EXCESS CAPACITY			
				EDAP - RURAL			
				EDAP - DISADVANTAGED	$189,750	Undetermined	
UPPER GUADALUPE RIVER AUTHORITY	J-10	SURFACE WATER ACQUISITION, TREATMENT AND ASR	$17,005,100	WIF: DEFFERED			65%
				WIF: CONSTRUCTION			
				SP: EXCESS CAPACITY			
				EDAP - RURAL			
				EDAP - DISADVANTAGED	$11,050,907	Undetermined	
	J-11	SURFACE WATER STORAGE	$7,050,000	WIF: DEFFERED	$1,000,000	Undetermined	28%
				WIF: CONSTRUCTION	$1,000,000	Undetermined	
				SP: EXCESS CAPACITY			
				EDAP - RURAL			
				EDAP - DISADVANTAGED			
	J-12	BRUSH MANAGEMENT	$393,779	WIF: DEFFERED			100%
				WIF: CONSTRUCTION			
				SP: EXCESS CAPACITY			
				EDAP - RURAL	$393,779	Undetermined	
				EDAP - DISADVANTAGED			

9.4 PROPOSED ROLE OF THE STATE IN FINANCING WATER INFRASTRUCTURE PROJECTS

The PWPG acknowledges that the availability and accessibility of adequate funds to finance identified infrastructure needs is essential to the health, welfare, and economic vitality of the Region and the State. To achieve a level of infrastructure stability, the PWPG supports the financing policy recommendations set forth in the *Water for Texas – 2007 State Water Plan*. Specific issues of concern to the PWPG include the following:

- A centralized office should be designated to access information pertaining to all state and federal funding programs. The function of this office would not be to distribute funds, but rather to assist potential recipients in identifying appropriate fund sources. Where appropriate, the office should identify potential sources that can be matched with greatest effect and at least cost to the consumer.
- It is expected that many water sources used to meet future supply needs will be located at ever increasing distances from demand centers. A significant influence on cost to the consumer for these supplies arises in the expense of transportation. The State should continue its efforts to identify the most economical means of moving water from its source to its final destination.
- The State legislature should increase the availability of infrastructure financing funds for water suppliers/users and should assume approximately 80 percent of new infrastructure cost.
- It is obvious that the state and federal agencies cannot bear the total cost of future infrastructure requirements. A major portion of these costs must be assumed locally. Therefore, consumption use fees must increase accordingly. As fees increase, a greater level of conservation is likely to follow. Under no circumstances should utility revenues be obtained through income or property taxes. Also, to prevent negative impact to local economies, utilities should not be burdened with greater percentage of the cost than they currently bear.

Likewise, a sliding scale for consumptive use fees should be established by utilities such that lower-income water consumers will not be costed out of an adequate safe drinking-water supply.

- The State should step up its efforts to assist water utilities in identifying and repairing water distribution leaks. It is recognized that a number of communities in the Plateau Region, and likely throughout the state, experience significant losses through pipeline leaks. Fixing this problem is usually significantly less expensive than developing and treating additional supplies.
- The State should assist water users in improving inefficient water use and development of more conservative practices.
- The PWPG supports the use of "Private Activity Bonds" for generating additional infrastructure financing revenues.
- The PWPG also encourages the State to assist in the establishment of pipeline networks to assist local projects.

CHAPTER 10

PUBLIC PARTICIPATION

AND

PLAN ADOPTION

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10.1 INTRODUCTION

Chapter 10, the final chapter of the Plan, contains an overview of the Plateau Water Planning Group (PWPG) representation, administrative planning process, specific activities that insured that the public was informed and involved in the planning process, and the implementation of the Plan. Chapter 10 appendices contain responses to public and TWDB comments on the Initially Prepared (Draft) Plan, and also a comment letter from TPWD.

10.2 PLATEAU WATER PLANNING GROUP

The TWDB appointed an initial coordinating body or PWPG for the original Region J based on names submitted by the public for consideration. The PWPG then voted to change its name to Plateau and expanded its membership based on the their knowledge of additional persons who could appropriately represent water user groups. State planning provisions mandate that one or more representatives of the following water user groups be seated on each planning group: agriculture, counties, electric generating utilities, environment, industries, municipalities, river authorities, public, small business, water districts, and water utilities. An electric generating utility does not exist within the Plateau Region and is therefore not represented. In addition to the other 10 categories, the PWPG chose to appoint a member to represent the tourism industry because of its prevalence in the Region. Also, to insure adequate geographic representation, the PWPG made sure that at least one member was selected from each of the six counties. Staff persons from both the Texas Parks and Wildlife Department and the Texas Department of Agriculture were also appointed as non-voting members. The PWPG members voluntarily devote considerable amounts of their time to the planning process.

PLATEAU WATER PLANNING GROUP MEMBERS
(Effective January 12, 2010)

Name	**Water-use Category**	**County**
Jonathan Letz, *Chair*	Small Businesses	Kerr
Jerry Simpton, *Vice Chair*	Other	Val Verde
Ronnie Pace, S*ecretary/Treasurer*	Industries	Kerr
William Feathergail Wilson	Other	Bandera
Homer T. Stevens, Jr.	Tourism	Bandera
David Jeffery	Water Districts	Bandera
Perry Bushong	Water Districts	Edwards/Real
Stuart Barron	Municipalities	Kerr
Howard Jackson	Municipalities	Kerr
Ray Buck *(UGRA–Political Entity)*	River Authorities	Kerr
Gene Williams	Water Districts	Kerr
Charlie Wiedenfeld	Water Utilities	Kerr
Zach Davis	Agriculture	Kinney
Tully Shahan	Environment	Kinney
Kent Lowery	Water Districts	Kinney
Lee Sweeten	Counties	Real
Otila Gonzalez	Municipalities	Val Verde
Mitch Lomas	Public	Val Verde
Thomas M. Qualia	Public	Val Verde

10.3 ADMINISTRATIVE PROCESS AND PROJECT MANAGEMENT

The PWPG adopted bylaws and submitted a scope of work and associated budget to the TWDB. With planning funds administered through TWDB, the PWPG then hired consultants to perform the work of preparing the regional plan. Work required completing the plan following well-defined guidelines intended to meet the mandated legislation and to establish a degree of format uniformity between all 16 regional plans. The PWPG operates its administrative function through the Upper Guadalupe River Authority (UGRA); all billing of expenses goes to TWDB through UGRA. All meetings of the PWPG are open to the public and meet Open Meetings Act requirements.

10.4 PLANNING GROUP MEETINGS AND PUBLIC HEARINGS

All meetings of the PWPG, including committee meetings, were open to the public where visitors were afforded the opportunity and encouraged to voice their opinions, concerns, or suggestions. Meeting locations were rotated evenly between all six counties so that all citizens within the Region would have an equal opportunity to attend. In accordance with the State Open Meetings Act, meeting notices were posted with the County Commissioners' Courts of each county.

A public hearing was held in Camp Wood on April 15, 2010 to receive comments on the initially prepared plan. Notice of the Public Hearings was sent to 334 down-river water rights holders as well as to each county commissioner's court and designated libraries. Hard copies of the Initially Prepared Plan were placed in the courthouse and a designated library in each of the Regions' six counties listed below, and an electronic copy of the draft Plan was made available on the Upper Guadalupe River Authority web site http://www.ugra.org/waterdevelopment.html. The public was given a full month prior to the hearing to review the document.

- Bandera County Library
- Butt-Holdsworth Memorial Library (Kerr County)
- Claud H. Gilmer Memorial Library (Edwards County)
- Kinney County Public Library
- Real County Public Library
- Val Verde County Library

Prior to receiving official comments during the public hearing, a question and answer session was held so that the public attendees would have an opportunity to gain a better understanding of how the draft plan was formulated. Nine people representing the public attended the hearing, along with a majority of the planning group members. At the conclusion of the hearing, the public was notified that there would be a 60-day period in which the PWPG would continue to receive written comments. The TWDB also reviewed the Initially Prepared Plan and provided comments. Responses to all comments (including TWDB, public hearing, and written comments) are provided in Appendices 10A - 10C.

10.5 COORDINATION WITH OTHER REGIONS

Coordination with other regions was accomplished through liaisons shared with adjacent regions and through active participation in Chairs Conferences scheduled by the TWDB.

10.6 PLAN IMPLEMENTATION

Following final adoption of the 2011 Plateau Region Water Plan, copies of the Plan were provided to each municipality and county commissioners' court in the Region. An electronic copy of the Plan is also available on the UGRA and TWDB web sites.

APPENDIX 10A

RESPONSES TO PUBLIC COMMENTS

RESPONSES TO PUBLIC COMMENTS

Comments Made by Planning Group Members Intended as Points of Clarification. (No Response Required)

Jerry Simpton: In prior Plateau Plans, and I think in this Plan, there has been a lot of speculation in relation to the effects of Lake Amistad on the springs in Kinney County. We know that that San Felipe Springs (in Val Verde County) receives contribution from the lake. The question is, does the lake effect the springs in Kinney County? We questioned, and a lot of people speculated, that when the lake fills it contributes to extra spring flow in Mud, Pinto and possibly Los Moras Creeks. We had a chance to correlate that this past year. The lake has been full for the last few years and we have been watching the spring flow primarily in Mud Creek in Kinney County, which is the closest to Lake Amistad. The lake filled mostly by large releases in Mexico that contribute to the lake. We did not have similar rainfall that contributed to our aquifers over the last couple of years. So the discussion last summer is, let's watch Mud Creek and see what happens if it continues to be dry. Well, Mud Creek currently is shutting down and it is not flowing. So if we correlate that to the lake, the lake is at full capacity (1,117 feet) and it's been up there until this spring when it dropped back to about 1,115 feet; but for all practical purposes, it's at full stage. If you reason that out, if the lake is full and Mud Creek is shutting down, it's because Mud Creek's drainage area is not producing (recharging) enough to keep it going. Last year we were in a sever drought and the (Mud Creek) watershed did not get any recharge; it's now basically in a shut down mode and the lake is full. So I would think we need to point that out for future people that are trying to make these determinations. I can basically testify that from my observation that there's no contribution from the lake (Amistad) to those springs in Kinney County.

Stuart Barron: The City of Kerrville has some minor corrections in the IPP for Kerrville, just some updates on numbers. When we get closer to the completion date we can actively see what we have stored in ASR at that time, and our most current estimated population. We'll provide the latest and greatest numbers right at the deadline to be included in the Plan, but basically it's going to stay the way it is just maybe some small changes in the numbers.

Lee Sweeten: The last sentence in Strategy J3 for the Community of Barksdale states that the strategy is not needed at this time but will be useful in the future. I suggest that we drop the last sentence so that the text does state that the strategy is currently recommended.

Responses to Oral Comments at Public Hearing April 15, 2010 – Camp Wood, Texas

Tyson Broad: Will written comments submitted by June be included in the Plan and not treated any differently?

Response: *The comment period will remain open for 60 days and the written comments will be treated the same as the oral comments.*

Responses to Written Public Comments

Leroy Kneupper March 8, 2010:

In the Executive Summary page ES-7 the proposed plan prominently, and appropriately, notes the definition of "available groundwater" used in the plan;

> "With the sustainability of local water supplies and the economic welfare of the Region in mind, the PWPG thus defines groundwater availability as a maximum level of aquifer withdrawal that results in an acceptable level of long-term aquifer impact such that the base flow in rivers and streams is not significantly affected beyond a level that would be anticipated due to naturally occurring conditions".

Indirectly this definition effectively specifies "acceptable" levels of the aquifers within Region J, to wit the aquifer levels that maintain base flow in rivers and streams such that said base flow is not "significantly affected." Again indirectly this definition effectively specifies "acceptable" future conditions for the aquifers.

Further the inclusion of this definition in the proposed plan thereby expresses the intent or desire of Region J so far as impact to the aquifers. Thus since Region J desires to maintain the indirectly specified "acceptable" future conditions for the aquifers, this definition becomes a statement of Region J's "desired" future conditions for the aquifers. This indirect statement of "desired" future conditions is entirely analogous to the direct statements of Desired Future Conditions, which have been and are being developed by the various Groundwater Management Areas.

I question first the application of this definition to the derivation of "available" groundwater for the Upper, Middle, and Lower Trinity Aquifers in Bandera and Kerr County. Arguably the definition appropriately specifies, albeit indirectly, a desired future condition for the Edwards-Trinity (Plateau) Aquifer. There maintaining base flow to rivers and streams is a primary consideration. However, for the Trinity aquifers, with the primary utilization of the aquifers being pumping by wells, aquifer levels are of foremost concern. I suggest that "available" groundwater for the Trinity aquifers be defined as "a maximum level of aquifer withdrawal that results in an acceptable level of long-term aquifer impact such that <u>production from wells</u> is not significantly affected beyond a level that would be anticipated due to naturally occurring conditions."

Second, and no matter how "available" groundwater is defined in the plan, I suggest that the plan include a quantified presentation of anticipated aquifer levels for the year 2060. Such presentation will well illustrate what Region J sees as the "acceptable level of long-term aquifer impact," and I believe that such presentation is very important for public information and understanding. As an example of a quantified presentation attached is a map taken from TWDB GAM Run GR08-70.

Thirdly, as noted in the proposed plan, local groundwater conservation districts working within the respective Groundwater Management Areas are in the business of setting Desired Future Conditions of the aquifers in the various GMAs. Since the "available groundwater" definition in the proposed Region J plan effectively specifies, in Region J's view at this time, the desired future conditions of the Region J aquifers, there is built in potential conflict between Region J's view and the decisions made and being made by GMAs. This in particular applies to GMA-9 as GMA-9 sets DFCs for the aquifers in Bandera and Kerr Counties. It has already happened with the conflict between the DFC set by GMA-9 for the Edwards-Trinity (Plateau) Aquifer in Bandera and Kerr Counties and the implicit desired future condition of the Edwards-Trinity (Plateau) Aquifer in those same counties as contained in the 2006 Region J Water Plan. I suggest that words be added to the plan to this effect;

> "The PWPG acknowledges that the definition of "available groundwater" as contained in this plan is an interim definition pending completion of the GMA DFC process by those GMAs

> setting the DFCs for the various portions of the aquifers lying within Region J."

Response: *The first point pertaining to the Trinity Aquifer is reasonable; however, the PWPG desires to retain the current definition for this Plan as the model runs used to generate the availability volumes were based on the current definition's premise. The PWPG acknowledges that the next round of regional planning will culminate in a totally revised set of groundwater availability volumes based on "desired future conditions" of aquifers as generated through the GMA process.*

The second point is also reasonable; however, there is insufficient time to regenerate the water-level maps that were originally used to produce the availability estimates. The GAM models used in the original evaluation have also changed.

The third point is accepted and the suggested wording has been added to Section 3.2.8 in Chapter 3.

Leroy Kneupper March 10, 2010:

Table 3-1 in the Region J IPP 3-1-10 shows a total of 17,310 afy available from the Edwards-Trinity (Plateau) Aquifer for Bandera County. Likewise Table 3-1 shows a total of 16,410 afy available from the ET-P for Kerr County. Both these numbers appear extraordinarily high.

They appear extraordinarily high because;
1. It seems unlikely that pumping at such rates is consistent with the definition of available groundwater being used in the IPP;

> "With the sustainability of local water supplies and the economic welfare of the Region in mind, the PWPG thus defines groundwater availability as a maximum level of aquifer withdrawal that results in an acceptable level of long-term aquifer impact such that the base flow in rivers and streams is not significantly affected beyond a level that would be anticipated due to naturally occurring conditions."

I question whether pumping at such rates would result in an "acceptable level of long-term aquifer impact."

2. As I recall from the last meeting of GMA-9 the properly, that is consistent with the definition above, calculated total groundwater available from the ET-P for Kerr County was noted as about 4,000 afy.

3. The TWDB Water Use Survey (WUS) data indicate 2003 pumping from the ET-P in Bandera County of 95 afy.

4. The TWDB WUS data indicate 2003 pumping from the ET-P in Kerr County of 361 afy.

5. Table Table 3-2 Water User Group Water Supply Capacity of the IPP shows 40 afy as the available supply from the ET-P in Bandera County.

6. Table Table 3-2 Water User Group Water Supply Capacity of the IPP shows 6,269 afy as the available supply from the ET-P in Kerr County.

7. TWDB GAM Run GR08-15 used an estimate of 596 afy for 2008 pumping from the ET-P in Bandera County.

8. TWDB GAM Run GR08-15 used an estimate of 1,036 afy for 2008 pumping from the ET-P in Kerr County.

9. The geographic extent of the ET-P in Bandera County is very limited. I find it hard to imagine that enough wells could be drilled in the ET-P in Bandera County to produce anything like 17,310 afy. Also since the ET-P geographic extent in Kerr County is much larger than in Bandera County, it is unclear how more water could be available in Bandera County than in Kerr County.

Again the availability numbers for the ET-P in Kerr and Bandera Counties appear extraordinarily high. I suggest that Region J review the numbers and confirm or correct as appropriate. I understand that the availability numbers for "edge" counties like Bandera and Kerr have been questioned in the past.

Response: *The PWPG recognizes that the Edwards-Trinity (Plateau) Aquifer availability volumes in Bandera and Kerr Counties appear to be relatively high. However, these volumes were generated from GAM model runs during the previous planning period. The PWPG is recommending (see Chapter 8) that additional studies be funded that will better characterize both the Edwards-Trinity (Plateau) and Trinity Aquifers, and that will improve their corresponding GAM models.*

Leroy Kneupper April 8, 2010a:

In looking at the projected water demands shown in the IPP for Bandera and Kerr Counties I find a gross disparity between IPP projected demand and estimates of actual 2008 pumping as being used by GMA-9 in its considerations to set DFCs. This is illustrated in the table below. The GMA-9 estimates indicate that pumping in excess of the IPP projected 2030 demand has already occurred in Kerr County and has nearly occurred in Bandera County. I suggest that the disparity be acknowledged in the IPP and that, if explainable, the disparity be explained.

Comparison of Estimated 2008 Actual GW Pumping versus Projected Demand in IPP (Acre Feet per Year)			
	Bandera County	**Kerr County**	**GMA-9 GAM Run**
Upper Trinity	270	213	GR08-15
Middle Trinity	4,215	7,513	GR08-70
Lower Trinity	469	5,547	GR09-24
Edwards Group	596	1,036	GR08-15
2008 Total GW	**5,550**	**14,309**	
RWG 2010	3,671	9,814	GW and SW
RWP 2020	4,725	10,377	GW and SW
RWP 2030	5,774	10,552	GW and SW

Response: *Water demand volumes presented in this Plan are developed by the TWDB and their use is mandated by TWDB guidelines. The GMAs are more at liberty to estimate water demand based on other considerations. At this point in the regional planning process, the PWPG is reluctant to debate the merits of the various demand scenarios with the understanding that revised demands will be generated based on new censes data in the next plan.*

Leroy Kneupper April 8, 2010b:

Appendix 1B of the IPP includes a discussion of ASR Feasibility in Bandera County. As noted the feasibility of ASR for Bandera County, in particular for the City of Bandera, relies on "treated surface water from the Medina River" as the source of ASR injection water. However, as noted in Table 3-1 Water Source Availability there is no surface water available from the Medina River or Medina Lake. It would seem that considering the unavailability of surface water from the Medina River that the feasibility of ASR for Bandera County is problematical at best. I suggest that words be added to the IPP to that effect.

Mention is made in Appendix 1B of a purchase agreement between Bandera County and BMAWCID#1 for purchase of up to 5,000 acre-feet per year of water from the Medina River. However, in reviewing the agreement I find that it is not at all a purchase agreement. It is difficult to describe the agreement, but I would call it a sort of option. There is no firm agreement for Bandera County to buy nor for BMAWCID#1 to sell. In particular there is no price of water mentioned and the possible delivery of water by BMAWCID#1 is very qualified and dependent on water availability and prior commitments. I suggest that either the mention of the "purchase agreement" be deleted from the IPP or that words be added to fully describe the agreement's exact terms and conditions.

Response: *Table 3-1 lists supplies available during "drought-of-record" conditions. Strategy J-1 in Chapter 4 and Appendix 1B considers the potential availability of supply during an extended period of time that would include both wet and dry periods. Wording in Strategy J-1 (Section 4.4.1 of Chapter 4) is changed from "purchase" to "option" as suggested.*

Leroy Kneupper April 8, 2010c:

Table 3-1 Water Source Availability does not list "Alluvial Aquifers" as a source of water for Bandera County. However, in looking at the TWDB Water Use Survey data for Bandera County, the data indicate that alluvial aquifers (called "Other" aquifer in the WUS database) have been the source of 200-300 afy for Bandera County in prior years. I suggest that an entry be added to Table 3-1 for "Alluvial Aquifers" in Bandera County. It would seem that "Alluvial Aquifers" have been, and still are, a source of water for Bandera County greater than other, lesser sources that are included as line items in the table.

Response: *A report of the results of a river alluvial aquifer analysis performed during this planning period is added to the Plan as Appendix 3B in Chapter 3. The report states that" no Medina River alluvial wells are listed in the TWDB groundwater database, and only two wells are identified in the upper reaches of the Sabinal River basin". After consultation with the BCRAGD, it was decided not to include the Bandera County alluvial aquifers as* <u>*significant*</u> *sources in the current Plan.*

Leroy Kneupper April 8, 2010d:

In table 3-1 Water Source Availability I suggest that the entries for the Edwards/Trinity in Bandera County and in Kerr County each be split into two entries, one for the Edwards Group of the Edwards/Trinity and one for the Trinity Group of the Edwards/Trinity. As presented the table is very confusing. It is not possible from the table to come up with a total Trinity Group/Trinity Aquifer total for comparison with other documents, which treat the Trinity formation as a entity into and of itself regardless of any overlying formation. It is not possible from the table to come up with a total Edwards Group total for comparison with other documents, which treat the Edwards formation as an entity into and of itself regardless of any underlying formation. Attached is a breakdown for Kerr County provided by Bill Hutchinson, with some embellishment by me, that illustrates what I mean.

Response: *The PWPG agrees that the aquifer availability reporting for the Edwards-Trinity (Plateau) and Trinity Aquifers is confusing. Currently there is insufficient time to revise the reporting configuration as presented in this Plan; however, the PWPG intends to resolve this issue in the next Plan.*

APPENDIX 10B

TEXAS PARKS AND WILDLIFE DEPARTMENT LETTER

June 14, 2010

Mr. Jonathan Letz
Kerr County
700 Main Street, Suite 101
Kerrville, Texas 78028

Re: 2010 Plateau Region J Initially Prepared Plan

Dear Mr. Letz:

Thank you for the opportunity to review and comment on the 2010 Initially Prepared Regional Water Plan (IPP) for Region N. Texas Parks and Wildlife (TPW) acknowledges the time, money and effort required to produce the regional water plan as mandated by Senate Bill 1 of the 75th Legislature. A number of positive steps have been taken since the first planning cycle to advance the issue of environmental protection. For example, the regional water planning groups are required by TAC §357.7(a)(8)(A), to perform a "quantitative reporting of environmental factors including effects on environmental water needs, wildlife habitat, cultural resources, and effect of upstream development on bays, estuaries, and arms of the Gulf of Mexico" when evaluating water management strategies (WMS). Quantification of environmental impacts is a critical step in planning for our state's future water needs while also protecting environmental resources.

TPW staff has reviewed the IPP with a focus on the following questions:

- Does the plan include a quantitative reporting of environmental factors including the effects on environmental water needs, and habitat?
- Does the plan include a description of natural resources and threats to natural resources due to water quantity or quality problems?
- Does the plan discuss how these threats will be addressed?
- Does the plan describe how it is consistent with long-term protection of natural resources?
- Does the plan include water conservation as a water management strategy? Reuse?
- Does the plan recommend any stream segments be nominated as ecologically unique?
- If the plan includes strategies identified in the 2006 regional water plan, does it address concerns raised by TPW at that time?

After a detailed review of the Plateau Region J IPP, it appears there is a limited quantitative reporting of environmental factors, presumably because environmental impacts are considered negligible. Factors considered include total acres impacted, acres of wetlands impacted, rare, threatened, and endangered species, and other environmental factors. While the table includes the number of rare, threatened, and endangered species potentially impacted by each strategy, there is no comprehensive table that lists the individual species. Chapter 1 provides a description of the Plateau Region, including groundwater and surface water as well as other resources. Some sections, for example the description of native vegetation and ecology, are brief, while an adequate description of natural resources is provided. There is also a mention of the TPW Natural Diversity Database.

Environmental and recreational water needs are discussed and a stated goal of the plan is to "provide for the health safety, and welfare and the human community, with as little detrimental effect to the environment as possible." While this section acknowledges the importance of environmental water needs in terms of ecotourism and quality of life, it does not quantify environmental water needs. Various surface water and groundwater sources in the region are described, including springs and wildlife habitat. The PWPG identified 3 "major" springs in the region: Las Moras, San Felipe, and Old Faithful, all of which provide municipal water supply. They also recognize that all springs are important and deserving of protection.

Protection of natural resources, including water resources, is discussed with each water management strategy assessed for potential threats to water resources in terms of source depletion, quality degradation, and impact to environmental habitat. No quantification of environmental impacts is presented for any of the water management strategies. It is recognized that some of the proposed strategies (i.e. off channel storage, additional surface water for subsequent ASR) require site specific studies to truly assess potential impacts.

Conservation is a recommended strategy for many, if not all, communities and a water audit and water loss analysis is recommended for the cities of Kerrville, Brackettville, and Leakey. Additional groundwater wells and a new pressure tank are recommended for the community of Barksdale. The City of Kerrville has various strategies, including the purchase of water from the Upper Guadalupe River Authority (UGRA). No quantity is specified, but they do acknowledge that the Upper Guadalupe River is over-appropriated and that special conditions would need to be put in place to protect instream flows. Other recommended water conservation measures addressed include brush management, rainwater harvesting, landscape maintenance, water conservation plans, best management practices, and education.

Brush management is recommended as a water management strategy for UGRA. In general TPW supports the concept of land stewardship as an approach to water conservation. However, benefits from clearing brush varies based on location, geology, the condition of the land cleared, and the plans for maintenance on the lands initially cleared. The section on brush management and land stewardship discusses TPW recommendations for habitat and the importance of identifying the best land for clearing. The RWPG recommends the legislature should appropriate funds to develop methods of defining watersheds of greatest potential in terms of producing water from brush management and forming a cost-sharing program to act on results. TPW supports such efforts to focus funding for brush management and providing incentives for landowners.

The Plateau Region J IPP recommends reuse of treated wastewater effluent. TPW supports reuse to the extent that it does not jeopardize subsistence flows in rivers and streams. There are active reuse programs in the City of Kerrville and the Community of Camp Wood. Drought contingency plans are also discussed and recognized as important to water supply management.

The Plateau Region J IPP discusses the use of groundwater to fill and maintain artificial lakes. The plan states that "although this use may exert stress on the local aquifer system, resulting impoundments do provide aesthetic value to the property and a water source for wildlife." TPW cautions against the pumping of groundwater to maintain surface water bodies as this practice may rob water from an aquifer system that would otherwise store and slowly release this water in a temporally reliable fashion. Pumping groundwater to maintain surface water bodies may also negatively impact spring flows that contribute to the ecological uniqueness of the Plateau region. Because groundwater is likely to be pumped at its highest intensity during drought (i.e. when aquifer levels are low), the cumulative effect of pumping groundwater to fill ponds may exacerbate the effects of drought and result in further groundwater level declines. Also, the wildlife benefits associated with the artificial habitats formed by filling impoundments with groundwater are limited. Many of these same benefits could be realized with the use of wildlife guzzlers or other forms of supplemental water that do not waste as much water.

The Plateau Region J IPP provides a good overview of the relationship between groundwater and surface water. The IPP acknowledges the importance of more gain-loss streamflow studies. This section also recognizes the importance of springs and states that their "protection is warranted." TPW recommends hydrogeologic research and recharge zone protection as steps towards springflow protection.

Groundwater availability is defined as "a maximum level of aquifer withdrawal that results in an acceptable level of long-term aquifer impact such that the base flow in rivers and streams is not significantly affected beyond a level that would be anticipated due to naturally occurring conditions." TPW supports the planning group's policy decision to protect the long-term water supply and related economic needs of the Plateau Region. TPW also recommends defining the springflows necessary to sustain the ecology of the region long-term when considering future availability of groundwater. Many of the aquatic organisms dependent upon springflows are adapted to perennial habitats. While these organisms survived the drought of the 1950s, it is likely droughts of a lesser extent will have larger impacts than the drought of the 1950s given the large increase in groundwater pumping. In the event these historically perennial habitats were to dry up, irreparable damage could occur to the natural diversity of the region.

It should be noted that the means of defining groundwater availability in the IPP is not directly linked to recharge, but rather to pumping withdrawals that result in acceptable levels of impact. This method of quantifying groundwater availability is significantly different than the method used in the 2001 Plateau Regional Water Plan. The RWPG should acknowledge that significant changes to these numbers could occur as a result of the GMA process.

The Plateau Region J IPP discusses Ecologically Significant Stream Segments but does not recommend nomination of any stream segments as ecologically unique. TPW has identified several stream segments in the region that meet at least one of the criteria for classification as ecologically unique should the regional planning group wish to pursue nomination of an ecologically significant stream in the future.

Lastly, TPW appreciates the acknowledgment of our nonvoting member participation in the Plateau Region water planning process.

Thank you for your consideration of these comments. TPW looks forward to continuing to work with the planning group to develop water supply strategies that not only meet the future water supply needs of the region but also preserve the ecological health of the region's aquatic resources. Please contact Cindy Loeffler at (512) 389-8715 if you have any questions or comments.

Sincerely,

Ross Melinchuk
Deputy Executive Director, Natural Resources

RM:CL:ms

APPENDIX 10C

RESPONSES TO TWDB COMMENTS

TWDB Comments on Initially Prepared 2011 Region J Regional Water Plan

LEVEL 1. Comments and questions must be satisfactorily addressed in order to meet statutory, agency rule, and/or contract requirements.

Executive Summary

1. Page ES-5, paragraph 1: The Del Rio and Laughlin Air Force Base 2010 municipal water demand of 16,822 acft/yr does not match the TWDB approved 2010 water demand projections and those presented in Chapter 2, Table 2-2, page 2-9, combined sum for Del Rio and Laughlin Air Force Base of 14,201 acft/yr (12,898+1,303). Please revise to reflect the TWDB-approved 2010 water demand projection of 14,201 acft/yr.

Response: Paragraph is corrected to read 14,909 acre-feet. This includes the City of Del Rio (12,898), LAFB (1,303), and a local portion of County-Other (708).

2. Page ES-13, paragraph 3: Recommended water management strategies for the Upper Guadalupe River Authority (J-10, J-11, J-12, J-13) and the cities of Bandera (J-1, J-2), Barksdale (J-3, J-4, J-5), Brackettville (J-14), and Leakey (J-15, J-16) are not included in the executive summary of water management strategies. Please include all of the recommended water management strategies in the Executive Summary of the plan. *[Title 31Texas Administrative Code (TAC) §357.10(a)(2)]*

Response: Table ES-2 listing all strategies is included.

Chapter 1

3. Page 1-10, paragraph 2; page ES-2: The 2010 projected population for Rocksprings, page ES-2, of 1,380 does not match the 2010 population projection presented on page 1-10 (1,680). Please revise to reflect the TWDB-approved 2010 population projection of 1,380.

Response: Rocksprings population is corrected to 1,380 in Chapter 1.

4. Page 1-22, paragraph 1; page ES-4: The total 2010 projected water consumptive use volume of 51,928 acft/yr on page ES-4, does not match the 2010 total water demand presented on page 1-22 (51,844 acft/yr). Please revise to reflect the TWDB-approved 2010 water demand projection of 51,928 acft/yr.

Response: Total 2010 water use is corrected to 51,928 in Chapter 1.

5. Page 1-22, paragraph 1; Page ES-4: The 2010 mining water demand of 403 acft/yr on page ES-4 does not match the 2010 mining water demand presented on page 1-22 (319 acft/yr). Please revise to reflect the TWDB-approved 2010 water demand projection of 403 acft/yr.

Response: *2010 mining water use is corrected to 403 in Chapter 1.*

6. Page 1-33, Section 1.4.2.5: Please include the firm yield of Medina Lake/Reservoir.

Response: *Firm yield of zero is added to Section 1.4.2.5.*

7. Page 1-38: Please update sections 1.5.1 and 1.5.2 to revise the apparent out of date information throughout the plan regarding the official state water plan; and other local water plans. *[31 TAC §357.5(c); and Contract Exhibit "A" Tasks 1 2, and 9]*

Response: *Sections 1.5.1 and 1.5.2 are revised.*

Section 1.5.1 - The TWDB adopted Water for Texas - 2007 in January 2007 as the official water plan for Texas. The Texas Water Code directs the TWDB to update this comprehensive water plan, which is used as a guide for the management of the State's water resources. This State Plan was the result of a consensus planning process that is directed by the TWDB and included efforts by the Texas Commission on Environmental Quality (TCEQ), the Texas Parks and Wildlife Department (TPWD), and the Texas Department of Agriculture (TDA). This plan is the direct result of local input from 16 regional water-planning areas as authorized under Senate Bill 1 of the 77th Legislative Session. Key points mentioned in the State Plan for the Plateau Region include strategies to develop 14,869 acre-feet of additional water supply by the year 2060 at a total capital cost of $14,371,600.

Section 1.5.2 - The Plateau Region often experiences periods of limited rainfall, especially compared with more humid areas in the eastern part of the state. Although residents of the region are generally accustomed to these conditions, the low rainfall and accompanying high evaporation underscore the necessity of developing plans to manage resources responsibly and to respond to potential disruptions in the supply of groundwater and surface water caused by drought conditions. The following entities have developed water management and drought contingency plans:

- *City of Del Rio;*
- *City of Brackettville;*
- *City of Kerrville;*
- *Fort Clark Municipal Utility District;*

- *Headwaters Groundwater Conservation District;*
- *City of Bandera;*
- *Real-Edwards Conservation and Reclamation District;*
- *City of Leakey; and*
- *City of Camp Wood.*

Chapter 2

8. Page 2-17; page 8-12 Section 8.3.7: Please present the quantity of unaccounted water use (livestock category) by large numbers of unsurveyed exotic game in the region including contract 'Survey and Report' deliverables. *[Contract Exhibit "A" Task 2.4]*

Response: *The results of the livestock and game animal water use analysis are discussed in Section 2.4.4 and the report is provided in Appendix 2B.*

Appendix 2B presents the results of a Water Use by Livestock and Game Animals in the Plateau Regional Water Planning Area analysis. In the report, the amount of water used by various exotic game species is estimated. However, the report states that there is insufficient data on the number of animals in the Region to make an estimate of total use. Estimates made by the Real-Edwards Conservation and Reclamation District find that approximately 602 and 233 acre-feet per year in Edwards and Real Counties is consumed by exotic game animals.

9. Page 2-18: Please include in the plan the evaluation of recent increases in water use by the petroleum exploration industry (i.e. mining water user category) in Kerr, Edwards, and Real counties. *[Contract Exhibit "A" Task 2.5]*

Response: *Discussion is provided in Section 2.4.5.*

Although the oil and gas industry is relatively minor compared to other parts of the state, in recent years increased oil and gas exploration activity has occurred in the Plateau Region. Railroad Commission of Texas files list 263 wells drilled in Edwards County from 1999 through 2008. As a result, increased water demand is projected for the mining category in Edwards County. Increases in Kerr and Real Counties were not considered to be of sufficient magnitude to warrant projection changes.

<u>Chapter 3</u>

10. Chapters 3, 4, and Section 8.2.15: Please discuss in the plan the promulgation of water availability requirements for the designated Hill Country Priority Groundwater Management Area by a county commissioners court pursuant to Texas Water Code §35.019, if appropriate. *[31 TAC §357.5(k)(1)(G)]*

Response: *Discussion is provided in second and third paragraphs of Section 3.2.8.*

The PWPG acknowledges that the definition of "groundwater availability" as contained in this Plan is an interim definition pending completion of the Groundwater Management Area (GMA) "desired future condition" process by those GMAs setting the conditions for the various portions of aquifers lying within the Plateau Region. (See Section 1.1.2 in Chapter 1 for a more complete explanation of the GMA process.)

There has been no promulgation of water availability requirements for the designated Hill Country Priority Groundwater Management Area by County Commissioner's Courts. The more current Groundwater Management Area process has generally replaced this responsibility.

11. Page 3-1, paragraph 3: Please clarify in the plan whether water supplies based upon contracts were assumed to be renewed. *[31 TAC §357.7(a)(3)(E); Contract Exhibit "C" Section 3.0]*

Response: *Statement is provided in third paragraph of Section 3.1.*

All water supplies based upon contracts are assumed to be renewed.

12. Pages 3-15 and 3-16: Please identify and quantify supply availability from specific shallow alluvial aquifers where a significant number of wells are known to exist in all counties except Val Verde and provide appropriate maps and updated tables as needed. *[Contract Exhibit "A" Task 3.6]*

Response: *The study is mentioned in Section 3.2 and the results are listed in Sections 3.2.5 and 3.2.6. The report is provided as Appendix 3B.*

A study was conducted during this planning period to identify and quantify viable groundwater sources in shallow alluvial aquifers that parallel many of the major streams in the Region. As a result of the study, substantial volumes were estimated for the Frio and Nueces River Alluvium Aquifers in Real and Edwards Counties, and the Nueces River Alluvium Aquifer is added as a supply source in this Plan. The study report is provided in Appendix 3B of this chapter.

Section 3.2.5 - The Frio River Alluvium in central Real County extends over an area of approximately 9,530 acres (see Appendix 3B). Recharge to the aquifer is from stream loss and direct infiltration of precipitation. Water supplies for the City of Leakey and other rural domestic homes are derived from this small aquifer. Because of the limited extent of this aquifer and its shallow water table, the aquifer system is readily susceptible to diminished supplies during drought conditions and potentially from over pumping. Also due to its shallow nature, the aquifer is susceptible to contamination from surface sources.

Section 3.2.6 - The Nueces River Alluvium between Edwards and Real Counties extends over an area of approximately 24,450 acres (see Appendix 3B). Recharge to the aquifer is from stream loss and direct infiltration of precipitation. Water supplies for the Community of Barksdale and rural domestic homes are derived from this small aquifer. As with the Frio Alluvium, the Nueces River Alluvium Aquifer is readily susceptible to diminished supplies during drought conditions and potentially from over pumping, and to contamination from surface sources.

13. Page 3-16: Please update municipal well field discussions for the nine communities in Region J that are dependent on groundwater as shown in the 2006 Regional Water Plan, Chapter 3.2.8. *[Contract Exhibit "A" Task 3.3]*

Response: *Discussion is provided in Section 3.2.9.*

All communities in the Plateau Region rely partially or completely on groundwater supply sources. Even the spring sources used by Del Rio and Camp Wood originate from aquifers. The higher concentration of wells in Kerr and Bandera Counties related to population growth may present water supply availability problems in the future. Public supply wells serving communities in Edwards, Kinney, Real and Val Verde Counties are not anticipated to have long-term declines due to the relatively smaller quantities of water that are needed to serve these communities. Also, no long-term water-quality deterioration has been detected in groundwater supplies for these communities. Long-term viability of the aquifers serving these other communities appears to be acceptable. However, new wells should be located outside the local areas of pumping influence of the existing wells. Although no evidence of contamination from surface sources have been detected in public-supply groundwater sources in the Plateau Region, a wellhead protection program should be considered by all communities.

Additional detail is provided in Section 3.2.9.

14. Page 3-16 through 3-18: Please incorporate results from the Phase 1 Study "Groundwater Data Acquisition in Edwards, Kinney, and Val Verde Counties, Texas" into the plan. *[Contract Exhibit "A"]*

Response: *The study is discussed in Section 3.2 and a summary of the study is provided in Appendix 1C in Chapter 1.*

Another study (Groundwater Data Acquisition in Edwards, Kinney and Val Verde Counties, Texas) was performed to assist in the further characterization of the Edwards and associated aquifers in the western part of the Plateau Region. The project included four general tasks: (1) review of existing aquifer evaluations, field studies and new well data; (2) performance of dye tracer tests to analyze groundwater flow direction and speed; (3) measurement of water levels in wells during two seasonal periods; and (4) review of recent water quality sampling projects. A summary of the project is provided in Appendix 1C of Chapter 1 of this Plan.

Chapter 4

15. Please describe how the plan considered the benefits of regional water supply and/or wastewater facilities or providing regional management of regional facilities. *[31 TAC §357.5(e)(6) and (k)(2)(C)]*

Response: *The Plan discusses the development of a new regional water supplier, UGRA, in Section 4.7.*

The mission of the Upper Guadalupe River Authority is to conserve and reclaim surface water through the preservation and distribution of the water resources for future growth in order to maintain and enhance the quality of life for all Kerr County citizens. UGRA's commitment to water conservation is reflected in its Fiscal Year 2009 budget which contains $23,400 for watershed programs, $30,000 for water research, $20,000 for water development and over $100,000 for various water quantity and water quality monitoring programs. Projects or activities UGRA may consider pursuing include, but are not limited to, are:

- *Surface water acquisition, treatment and ASR in portions of Kerr County (Strategy J-10).*
- *Flood flow capture, storage, and utilization (Strategy J-11).*
- *Water enhancement through brush management and recharge facilitation (Strategy J-12).*
- *Seeking a subordination agreement with GBRA regarding Canyon Lake diversion rights.*
- *Groundwater recharge.*
- *Potentially amending UGRA's Permit 5394A so water use authorized under the permit may be used by the City of Kerrville.*

- *Providing public information on conservation practices (Strategy J-13).*

16. Please include a list of all potentially feasible water management strategies that were evaluated. *[Contract Exhibit "C" Section 11.1]*

Response: Table 4-3 contains all feasible water management strategies evaluated.

17. Please include tables summarizing all recommended water management strategies with associated water supplies presented by decade and capital costs. *[Contract Exhibit "C" Sections 4.3, 11.1]*

Response: Tables 4-3, 4-4 and 4-5 contain all recommended strategies.

18. Please include a table listing alternative strategies, if alternative water management strategies were included. *[Contract Exhibit "C" Sections 4.3, 11.1]*

Response: No "alternative" strategies are recommended.

19. Pages 4-12 and 4-13, Tables 4-3, 4-4: Recommended water management strategies J-4, J-5, J-6, J-8, J-11, J-12, J-14, J-16, and J-18 are missing one or more of the following required water management strategy evaluation criteria: quantified strategy supply volume; capital costs; and/or, annual costs. Please revise Tables 4-3 and 4-4 as appropriate and include only 'recommended' water management strategies in the plan that have been evaluated for supply, impacts, and cost. *[31 TAC §357.7(a)(8)(A)(i]*

Response: All tables are revised.

20. Page 4-1, Table 4-3: Please reconcile the specific water management strategy supply volumes presented for J-6 and J-10 in Table 4-3 with the plan statement on pages 4-22 and 4-27 that "no quantity has been specified thus far" for these strategies. *[31 TAC §357.7(a)(8)(A)(i) and (a)(9); Contract Exhibits "C" and "D"]*

Response: Statements are deleted from strategy discussions.

21. Page 4-13, Table 4-4, footnote: Please revise cost estimate or justify why a 30-year debt service period rather than the TWDB-recommended 20-year debt service period was used for evaluating water management strategies other than reservoirs. *[Contract Exhibit "C" Section 4.1.2]*

Response: Footnote is revised to read 20-year.

22. Page 4-13, Table 4-4: Please confirm whether water management strategy capital costs are in September 2008 dollars. *[Contract Exhibit "C" Section 4.1.2]*

Response: *Notation is made in footnotes of Table 4-4.*

23. Page 4-18: The J-3 water management strategy supply of 16.8 acft/yr does not match Table 4-3, page 4-12, J-3 16,800 acft/yr strategy supply for all decades. Please revise plan as appropriate.

Response: *Table 4-3 is revised to list 17 acre-feet/year.*

24. Page 4-30, second paragraph; table: The project capital cost of $3,937,790 associated with Upper Guadalupe River Authority in the text does not match the project cost to Upper Guadalupe River Authority of $393,799 presented in the unlabeled table on page 4-30. Please revise as appropriate.

Response: *UGRA cost is corrected in the text.*

25. Page 4-30, paragraph 1: Please clarify whether water management strategy J-12 includes a single 15,000-acre area site.

Response: *Sentence is changed to read "15,000 <u>non-contiguous</u> acres".*

26. Page 4-32: The J-15 water management strategy supply of 205 acft/yr does not match the Table 4-3 (page 4-12) J-15 supply volume of 17 acft/yr. Please revise as appropriate.

Response: *J-15 on Table 4-3 is changed to list 205 acre-feet/year. Table 4-4 cost per acre-foot is corrected to $4.*

27. Page 4-34: The J-17 water management strategy supply of 172 acft/yr and cost of $206,000 do not match the Table 4-3 (page 4-12) strategy supply volume (178 acft/yr) or cost ($247,250). Please revise as appropriate throughout plan and, if necessary, in the online planning database.

Response: *J-17 on Table 4-3 is changed to list 172 acre-feet/year. Cost is changed to $247,250 in strategy discussion in Section 4.10.1.*

Chapter 6

28. Please include a summary of information regarding water loss audits specific to Region J. *[TAC 31§ 357.7 (a)(1)(M)]*

Response: *Discussion is added as Section 6.2.5.*

Reported municipal use generally includes a variable amount of water that does not reach the intended consumer due to water leaks in the distribution lines, unauthorized consumption, storage tank overflows, and other wasteful factors. For some communities, attending to these issues can be a proactive conservation strategy that may result in significant water savings. To address the lack of information on water loss, the 78th Texas Legislature passed House Bill 3338, which required retail public utilities that provide potable water to perform and file with the TWDB a water audit computing the utility's most recent annual system water loss every five years. A summary of the first audit, An Analysis of Water Loss as Reported by Public Water Suppliers – 2007 (http://www.twdb.state.tx.us/RWPG/rpgm_rpts/0600010612_WaterLossinTexas.pdf) was provided to the Plateau Water Planning Group (PWPG) for consideration in developing water supply management strategies. The report lists utilities in Region J (Plateau), along with Region I, as having the highest non-revenue water percentage and the highest reported average unbilled authorized water use of the 16 regions in the state. The PWPG acknowledges the value of this important planning tool, but identified apparent errors in some of the data. The report does offer the recognition that "as utilities refine their water audits, reducing balancing adjustments and improving real loss estimates, it is expected that water loss data reported from the next round of water audits will be more useful for planning purposes than the current water loss data. Based on this concern, the PWPG chose to not use the supplied data for this current Plan, but looks forward to the next improved water loss audit survey.

Chapter 7

29. Page 7-2, paragraph 3, line 3: Reference to Table 4-2 in Chapter 4 appears to be incorrect. Please revise as appropriate.

Response: *Table number is corrected to read 4-3.*

30. Page 7-3, paragraph 3, line 5: The reference to the section on groundwater source availability appears to be incorrect. Please revise as appropriate.

Response: *Reference is changed to read Section 3.2.8.*

31. Page 7-4, bullets: The Chapter 8 section references in text appear to be incorrect. Please revise as appropriate.

Response: *Bullets are revised.*

<u>Chapter 8</u>

32. Page 8-13, paragraph 3 and 8-14, paragraph 1: Reference to appendix 8A appears incorrect. Appendix 8B appears to be missing. Please revise as appropriate.

Response: *Reference to Appendix 8A is correct. Appropriately named and numbered appendices are provided.*

33. (Attachment B) Comments on the online planning database (i.e. DB12) are herein being provided in spreadsheet format. These Level 1 comments are based on a direct comparison of the online planning database against the Initially Prepared Regional Water Plan document as submitted. The table only includes numbers that do not reconcile between the plan (left side of spreadsheet) and online database (right side of spreadsheet). An electronic version of this spreadsheet will be provided upon request.

Response: *PWPG consultant is working with TWDB staff to assure accuracy of the DB 12 data set.*

34. (Attachment C) Based on the information provided to date by the regional water planning groups, TWDB has also attached a summary, in spreadsheet format, of apparent unmet water needs that were identified during the review of the online planning database and Initially Prepared Regional Water Plan. *[Additional TWDB comments regarding the general conformance of the online planning database (DB12) format and content to the Guidelines for Regional Water Planning Data Deliverables (Contract Exhibit D) are being provided by TWDB staff under separate cover as 'Exception Reports']*

Response: *PWPG consultant is working with TWDB staff to assure accuracy of the DB 12 data set.*

LEVEL 2. Comments and suggestions that might be considered to clarify or enhance the plan.

General Comments

35. Please consider labeling all tables and figures with unique identification numbers and include data units, where applicable (e.g. page ES-4, page ES-5, Figure 1-6, Figure 1-8, Figure 2-3, Figure 2-4, Figure 2-5, page 2-13 table, page 2-18 table, Table 3-1, Table 3-3)

Response: Changes are made where deemed appropriate.

Chapter 1

36. Page 1-14: Please consider providing references for rainfall estimates in the plan.

Response: References provided for rainfall estimates.

37. Pages 1-23 and 1-24: Please consider indicating where Appendices 1A – 1C are referenced and discussed within the plan.

Response: Discussion is added on pages 1-1 and 1-2.

38. Page 1-29: The Frio alluvium and Nueces alluvium are not state-recognized aquifers. Please provide a technical reference source for the annually available water volumes present for these alluvia.

Response: The alluvial aquifer analysis report is provided as Appendix 3B.

39. Page 1-42, paragraph 2, lines 7 and 9: Please consider updating the definition of an 'economically distressed area' to include the most current criteria: please change "...established residential subdivision on June 1, 1989." to "...established residential subdivision on or prior to June 1, 2005."; please change "...per capita income 25 percent below the state average..." to "...per capita income 25 percent below the state *median*..." *[Contract Exhibit "A" Task 1.4]*

Response: Appropriate changes are made to Section 1.6.

Chapter 3

40. Page 3-8, Table 3-2: Please consider including a 'Water User Group' label for the second to last (irrigation) water user group row.

Response: Label is appropriately placed in Table 3-2.

<u>Chapter 4</u>

41. Page 4-13, Table 4-4 footnotes: Please consider adding a section to the text of Chapter 4 describing in more detail the basis for the estimated costs of water management strategies that are referred to in the footnotes. Estimated costs are to be developed according to Contract Exhibit “C”.

Response: Discussion is added to Section 4.3.

ATTACHMENT B: LEVEL 1 COMMENTS - INITIALLY PREPARED REGIONAL WATER PLAN VS. ONLINE PLANNING DATABASE REVIEW

Shaded values indicate the location of the correct volumes at the time of the IPP review, and these values now appear in the final Plateau Region Water Plan.

Plateau Region (J)	IPP document reference:		*Non-matching numbers*															Remarks
			IPP document number							Online Planning Database (DB12) number								
Item	Page No.		non-decadal number	2010	2020	2030	2040	2050	2060	non-decadal number	2010	2020	2030	2040	2050	2060	
Total capital cost to implement recommended WMSs ($)	ES-12	text	44,198,379							51,248,379							Revised cost is $54,792,390
Edwards Co, Colorado Basin, Irrigation Demands (acft/yr)	2A-1	App. 2A		153	147	141	135	129	123		43	41	39	38	36	34	
Edwards Co, Nueces Basin, Irrigation Demands (acft/yr)	2A-1	App. 2A		0	0	0	0	0	0		87	84	81	77	74	71	
Edwards Co, Rio Grande Basin, Irrigation Demands (acft/yr)	2A-1	App. 2A		0	0	0	0	0	0		23	22	21	20	19	18	
Bandera Co, Nueces Basin, Trinity Aq, Irrigation Supply (acft/yr)	3-4	3-2		156	156	156	156	156	156		118	118	118	118	118	118	
Bandera Co, San Antonio Basin, Trinity Aq, Irrigation Supply (acft/yr)	3-4	3-2		283	283	283	283	283	283		207	207	207	207	207	207	
Bandera Co, Guadalupe Basin, Guadalupe River, Irrigation Supply (acft/yr)	3-4	3-2		3	3	3	3	3	3		NA	NA	NA	NA	NA	NA	Deleted from Plan Tables 3-2 & 4-1.
Bandera Co, San Antonio Basin, Medina R-O-R, Livestock Supply (acft/yr)	3-4	3-2		NA	NA	NA	NA	NA	NA		0	0	0	0	0	0	
Bandera Co, Nueces Basin, Sabinal R-O-R, Livestock Supply (acft/yr)	3-4	3-2		NA	NA	NA	NA	NA	NA		0	0	0	0	0	0	Not listed as a source in Table 3-2. Sources
Edwards Co, Nueces Basin, West Nueces R-O-R, Livestock Supply (acft/yr)	3-5	3-2		NA	NA	NA	NA	NA	NA		0	0	0	0	0	0	are deleted from DB12.
Edwards Co, Colorado Basin, South Llano R-O-R, Livestock Supply (acft/yr)	3-5	3-2		NA	NA	NA	NA	NA	NA		0	0	0	0	0	0	
Kerr Co, Guadalupe Basin, Trinity Aq, Irrigation Supply (acft/yr)	3-6	3-2		863	863	863	863	863	863		406	406	406	406	406	406	
Kerr Co, Guadalupe Basin, Upper Gualdalupe River, Kerrville Supply: Source Name	3-6	3-2		150	150	150	150	150	150								Upper Guadalupe River + ASR
Kinney Co, R-G Basin, County-Other Supply: GW Source Name	3-7	3-2		64	64	64	64	64	64								Other Aquifer - Austin Chalk
Kinney Co, R-G Basin, Irrigation Supply: GW Source Name	3-7	3-2		3,872	3,872	3,872	3,872	3,872	3,872								Other Aquifer - Austin Chalk
Kinney Co, R-G Basin, Livestock Supply: GW Source Name	3-7	3-2		92	92	92	92	92	92								Other Aquifer - Austin Chalk
Kinney Co, Nueces Basin, Other Aquifer, Irrigation Supply (acft/yr)	3-7	3-2		NA	NA	NA	NA	NA	NA		0	0	0	0	0	0	
Kinney Co, Nueces Basin, West Nueces R-O-R, Livestock Supply (acft/yr)	3-7	3-2		NA	NA	NA	NA	NA	NA		0	0	0	0	0	0	Not listed as a source in Table 3-2. Sources
Real Co, Livestock Supply, Nueces Basin, Frio R-O-R (acft/yr)	3-8	3-2		NA	NA	NA	NA	NA	NA		0	0	0	0	0	0	are deleted from DB12.
Real Co, Livestock Supply, Nueces Basin, Nueces R-O-R, (acft/yr)	3-8	3-2		NA	NA	NA	NA	NA	NA		0	0	0	0	0	0	
Val Verde Co, R-G Basin, Edwards-Trinity Aq, Del Rio Supply (acft/yr)	3-8	3-2		9,116	9,116	9,116	9,116	9,116	9,116		12,925	12,925	12,925	12,925	12,925	12,925	
WWP Supply missing breakdown by Water Source: Del Rio, Edwards-Trinity Aq (acft/yr)	3-9	3-3		16,577	16,577	16,577	16,577	16,577	16,577		9,116	9,116	9,116	9,116	9,116	9,116	Revised to 12,925 for every decade in both the Plan and DB12.
WWP Supply missing breakdown by Water Source: Del Rio, San Felipe R-O-R (acft/yr)	3-9	3-3		NA	NA	NA	NA	NA	NA		7,461	7,461	7,461	7,461	7,461	7,461	
Bandera Co, San Antonio Basin, Medina Lake Supply Source Availability (acft/yr)	1-33	text	20,000	20,000	20,000	20,000	20,000	20,000	20,000		NA	NA	NA	NA	NA	NA	This is not a source availability volume.
Bandera Co, San Antonio Basin, Medina Lake Supply Source Availability (acft/yr)	3-2	3-1		0	0	0	0	0	0		NA	NA	NA	NA	NA	NA	
Kinney Co, Nueces Basin, Other Aquifer Availability (acft/yr)	3-3	3-1		NA	NA	NA	NA	NA	NA		0	0	0	0	0	0	Not listed as a source in Table 3-1. Sources is deleted in DB12.
Real Co, Nueces Basin, "Other Aq-Nueces River Alluvium" Availability (& IPP incomplete name)	3-3	3-1		1,787	1,787	1,787	1,787	1,787	1,787		NA	NA	NA	NA	NA	NA	
Val Verde Co, R-G Basin, Devils River Availability (acft/yr)	3-3	3-1		0	0	0	0	0	0		NA	NA	NA	NA	NA	NA	These supply sources are deleted from the
Val Verde Co, R-G Basin, Pecos River Availability (acft/yr)	3-3	3-1		0	0	0	0	0	0		NA	NA	NA	NA	NA	NA	Plan and DB12.
Barksdale (Edwards C-O) WMS J-3 (Additional GW Wells) supply (acft/yr)	4-12	4-3		16,800	16,800	16,800	16,800	16,800	16,800		17	17	17	17	17	17	
Barksdale (Edwards C-O) WMS J-4 (Replace Pressure Tank) supply (acft/yr)	4-12	4-3		NA	NA	NA	NA	NA	NA		0	0	0	0	0	0	
Barksdale (Edwards C-O) WMS J-5 (Conserv.Pub.Info.) supply (acft/yr)	4-12	4-3		NA	NA	NA	NA	NA	NA		2	2	2	2	2	2	
Kerrville WMS J-8 (Conserv.Water Sys & Loss Audits) supply (acft/yr)	4-12	4-3		NA	NA	NA	NA	NA	NA		436	475	492	494	515	526	
Brackettville WMS J-14 (Conserv.Water Sys & Loss Audits) supply (acft/yr)	4-12	4-3		NA	NA	NA	NA	NA	NA		58	58	58	58	58	58	
Leakey (Real C-O) WMS J-16 (Conserv.Water Sys & Loss Audits) supply (acft/yr)	4-12	4-3		NA	NA	NA	NA	NA	NA		20	20	20	20	20	20	
UGRA (Kerr C-O) WMS J-10 (Surface Water Acquisition/Treatment/ASR) supply (acft/yr)	4-12	4-3		1,124	1,124	1,124	1,124	1,124	1,124		0						
UGRA (Kerr C-O) WMS J-13 (Conservation Public Info) supply (acft/yr)	4-12	4-3		27	29	30	30	31	32		14	15	15	15	16	16	
UGRA (Kerr C-O) WMS J-11 (Surface Water Storage) supply (acft/yr)	4-12	4-3		NA	NA	NA	NA	NA	NA		0	1,121	1,121	1,121	1,121	1,121	
UGRA (Kerr C-O) WMS J-11 (Surface Water Storage) Capital Cost ($)	4-12	4-3	NA							7,050,000							
UGRA (Kerr C-O) WMS J-11 (Surface Water Storage) O&M Cost ($)	4-13	4-4		NA	NA	NA	NA	NA	NA		0	651,000	651,000	651,000	651,000	651,000	
Leakey (Real C-O) WMS J-15 strategy supply (acft/yr)	4-32	text	205	205	205	205	205	205	205	17							Table 4-3
Camp Wood WMS J-17 strategy supply (acft/yr)	4-34	text	172	172	172	172	172	172	172	178							Table 4-3
Bandera Co, Nueces Basin, Irrigation Needs (acft/yr)	4-3	4-1		0	0	0	0	0	0		(38)	(38)	(38)	(38)	(38)	(38)	
Bandera Co, San Antonio Basin, Irrigation Needs (acft/yr)	4-3	4-1		0	0	0	0	0	0		(76)	(76)	(76)	(76)	(76)	(76)	
Kerr Co, Guadalupe Basin, Irrigation Needs (acft/yr)	4-5	4-1		0	60	115	169	222	273		(457)	(397)	(342)	(288)	(235)	(184)	This volume represents a surplus.

Plateau Region Water Plan

ERRATA SHEET

(The following revisions are incorporated in this printed copy of the 2011 Plan)

Executive Summary

The second sentence of the third paragraph on page ES-2 is revised as follows:

The greatest percentage increase in population is projected to occur in Bandera County, which is expected to grow from a projected year-2010 population of 26,373 to 60,346 by the year 2060, an increase of ~~229~~ ***129*** *percent.*

The first sentence on page ES-6 is revised as follows:

Bandera County, with the greatest projected percentage population increase, will likewise see the greatest percentage municipal water demand increase over the 50-year period, ~~213~~ 113 percent.

In the last sentence on page ES-13, the total capital cost to implement the recommended strategies is changed from $51,248,379 to $54,792,390.

Chapter 1

The following subsection is added at the end of Section 1.5:

1.5.5 Hill Country Priority Groundwater Management Area

A portion of the Plateau Region (Bandera and Kerr Counties) is included in the initial Hill Country Priority Groundwater Management Area. The Priority Groundwater Management Area (PGMA) process is initiated by the TCEQ, who designates a PGMA when an area is experiencing critical groundwater problems, or is expected to do so within 25 years. These problems include shortages of surface water or groundwater, land subsidence resulting from groundwater withdrawal, or contamination of groundwater supplies. Once an area is designated a PGMA, landowners have two years to create a Groundwater Conservation District (GCD). Otherwise, the TCEQ is required to create a GCD or to recommend that the area be added to an existing district. The TWDB works with the TCEQ to produce a legislative report every two years on the status of PGMAs in the state. The PGMA process is completely independent of the current Groundwater Management Area (GMA) process and each process has different goals. The goal of the PGMA process is to establish GCDs in these designated areas so that there will be a regulating entity to address the identified groundwater issues. PGMAs are still relevant as long as there remain portions within these designated areas without GCDs. The Plateau Region's portion of the Hill Country PGMA (Bandera & Kerr Counties) has GCDs established now; however, the Comal County portion of the Hill Country PGMA (located in Region L) still does not have a GCD and therefore, this PGMA is currently active and relevant. A statewide map of the declared PGMA areas is available at: http://www.tceq.state.tx.us/assets/public/permitting/watersupply/groundwater/maps/pgma_areas.pdf.

Chapter 2

Table 2-1 Population:

Kerrville South WC is deleted from the Table and its population is added to County Other as follows:

Kerr	County Other	24,243	27,017	28,336	28,899	30,197	30,744

Table 2-2 Water Demand:

Kerrville South WC is deleted from the Table and its water demand is added to County Other as follows:

Kerr	County Other	2,727	2,947	2,999	2,996	3,098	3,155

Appendix Table 2A Water Demand Projections:

- Bandera County, Irrigation, Guadalupe Basin line is removed from the Table.
- The following revision is made in the distribution of water demand by basins for Edwards County irrigation:
-

			2010	2020	2030	2040	2050	2060
Edwards County	Irrigation	Colorado	**43**	**44**	**39**	**38**	**36**	**34**
		Nueces	**87**	**84**	**81**	**77**	**74**	**71**
		Rio Grande	**23**	**22**	**21**	**20**	**19**	**18**

- Kerr County, Kerrville South WSC is deleted from the Table and its water demand is added to County-Other, Guadalupe Basin as follows:

			2010	2020	2030	2040	2050	2060
Kerr County	County-Other	Colorado	58	62	63	60	56	52
		Guadalupe	**2,651**	**2,866**	**2,917**	**2,918**	**3,025**	**3,087**
		San Antonio	18	19	19	18	17	16

The first sentence of the fourth paragraph of Section 2.3.2 on page 2-4 is revised as follows:

*The greatest percentage increase in population is projected to occur in Bandera County, which is expected to grow from a projected year-2010 population of 26,373 to 60,346 by the year 2060, an increase of ~~229~~ **129** percent.*

The last sentence of the third paragraph of Section 2.4.1 on page 2-12 is revised as follows:

Bandera County, with the greatest projected percentage population increase, will likewise see the greatest percentage ***municipal*** *water demand increase over the 50-year period, ~~213~~* ***113*** *percent.*

Chapter 3

The following sentence is added at the end of the first paragraph of Section 3.2.9 on page 3-19:

Kerrville South, which appeared as a municipal water user entity in the 2006 Plateau Region Water Plan, has been purchased by Aqua Texas and is now included in the County Other group category.

Table 3-1 Source Availability:

- Val Verde County, Devils River, Rio Grande Basin line is removed from the Table.
- Val Verde County, Pecos River, Rio Grande Basin line is removed from the Table.

Table 3-2 Existing Supplies:

- Bandera County, Irrigation, Guadalupe Basin, Upper Guadalupe River line is removed from the Table.
- "Other Aquifer (Nueces Alluvium)" with a supply of 34 acre-feet/year is added to Edwards County / County Other / Nueces Basin. This change will also be addressed in the TWDB DB12 database.
- In Val Verde County, the source of water shown to be purchased or supplied from Del Rio is from the Edwards-Trinity (Plateau) Aquifer is as follows:

Laughlin AFB	Rio Grande	**Edwards-Trinity (Plateau)** *(Purchased from Del Rio)*	2,178
County Other	Rio Grande	**Edwards-Trinity (Plateau)** (*Supplied from Del Rio*)	1,631

Table 3-3 Wholesale Water Provider Existing Supplies:

A supply source column is added to the table as follows:

City of Del Rio	**San Felipe Springs**	7,461
	Edwards-Trinity (Plateau)	9,116
Laughlin AFB	**Edwards-Trinity (Plateau)**	2,178
County Other	**Edwards-Trinity (Plateau)**	1,631

Chapter 4

Table 4-1 Needs Analysis:

- Bandera County, Irrigation, Guadalupe Basin line is removed from the Table.
- The supply and net difference by decade for Edwards County / County Other / Nueces Basin is revised as follows:

	2010	2020	2030	2040	2050	2060
S	**445**	**445**	**445**	**445**	**445**	**445**
D	118	121	116	111	108	104
	327	**324**	**329**	**334**	**337**	**341**

Table 4-3 List of Recommended Water Management Strategies:

- **Total capital cost for the UGRA / Strategy J-12 is changed from $393,779 to $3,937,790.**
- Strategy supply for the City of Leakey / Strategy J-15 is changed from 17 to 205 ac-ft/yr for all decades.
- Strategy supply for the City of Camp Wood / Strategy J-17 is changed from 178 to 172 ac-ft/yr for all decades.
- The following footnote is added to the table:
  Capital costs are estimated based on September 2008 US dollars.
- Footnote "e" is removed from the end of the strategy name for Strategies J-1, J-7 and J-10.
- Footnote "e" is revised to read "Strategy is not intended to meet a need during a drought-of-record condition as identified in Table 4-1."

Table 4-4 Recommended Water Management Strategy Costs:

- O&M cost for the City of Kerrville / Strategy J-6 is $3,840,000 for decades 2030 through 2050 and $5,450,000 for the 2060 decade.
- Cost per acre-foot/year for the City of Kerrville / Strategy J-6 is $1,000 for decades 2030 through 2060.
- Total capital cost for the UGRA / Strategy J-12 is changed from $393,779 to $3,937,790.
- O&M cost for the UGRA / Strategy J-12 is changed from $0 to $150,000 per year for all decades.
- Cost per acre-foot/year for the UGRA / Strategy J-12 is changed from $0 to $14 for all decades.
- Cost per acre-foot/year for the City of Leakey / Strategy J-15 is changed from $53 to $4 for all decades.
- The fifth footnote is revised from 30 years to 20 years.
- The following footnote is added to the table:
  Capital costs are estimated based on September 2008 US dollars.

The following paragraph is added at the end of subsection 4.4.1 Bandera WMS J-1:

> *Water supply generated from this strategy will provide an additional source of supply that will hopefully allow the City to decrease its sole dependence on the Trinity Aquifer. Treated Medina River water is injected into the aquifer during non-drought conditions when surface water is plentiful and is retrieved at a later time as a supply source during drought-of-record conditions when surface water is scarce.*

The last sentence of the second paragraph of subsection 4.6.1 (UGRA WMS J-6) is revised and additional text is added as follows:

> *Up to 3,840 acre-ft/yr is needed by the year 2030 and an additional 1,610 acre-ft/yr (5,450 acre-ft/yr) in 2060 for a total of 116, 810 acre-feet over the 30-year period. An estimated purchase price of $1,000 per acre-foot is assumed for this planning process; however the City will negotiate an actual price when and if this strategy is implemented in the future.*

The following text is added to the end of the third paragraph of subsection 4.6.1 UGRA WMS J-6:

> *Thus, this strategy could be of some assistance if needed in the early stages of a drought-of-record, but could not be used to meet needs in an extended drought period. However, Kerrville's future needs can be met by implementing Strategies J-7, J-8 and J-9.*

The following text is added to the end of the third paragraph of subsection 4.6.2 Kerrville WMS J-7:

> *Treated Guadalupe River water is injected into the aquifer during non-drought conditions when surface water is plentiful and is retrieved at a later time as a supply source during drought-of-record conditions when surface water is scarce.*

The following text is added to the end of the fourth paragraph of subsection 4.7.1 UGRA WMS J-10:

> *Treated Guadalupe River water is injected into the aquifer during non-drought conditions when surface water is plentiful and is retrieved at a later time as a supply source during drought-of-record conditions when surface water is scarce.*

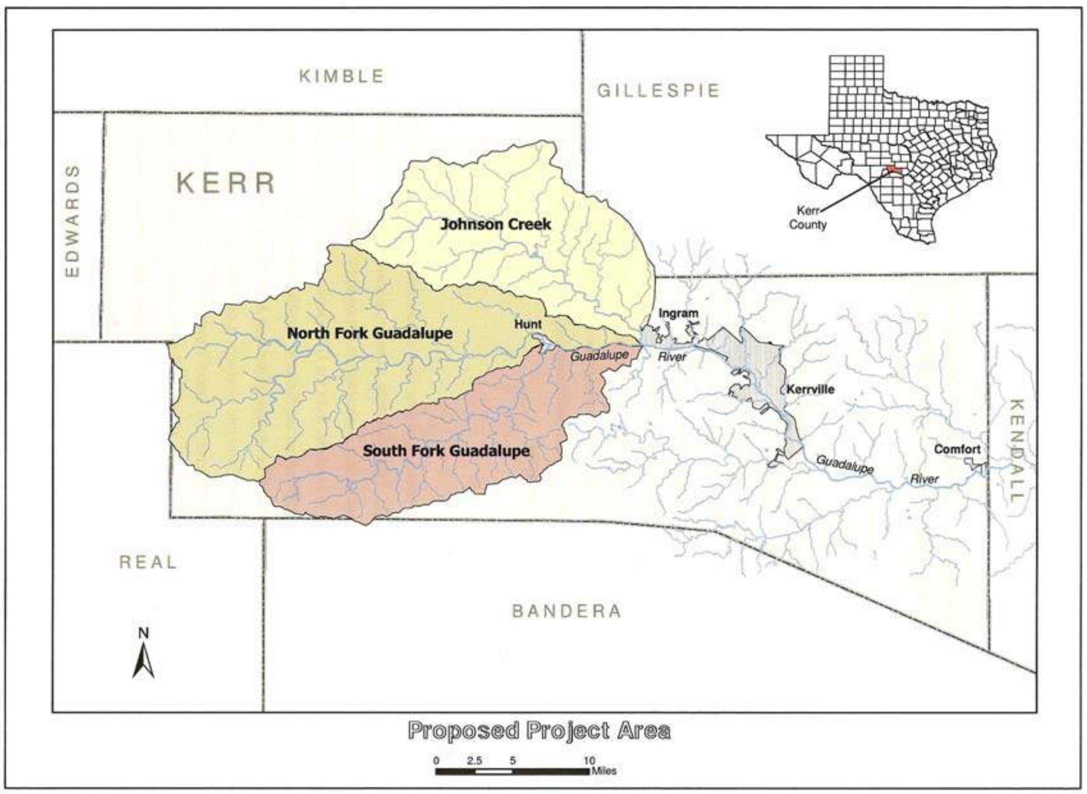
The following text is added at the end of subsection 4.7.2 UGRA WMS J-11:

> *Although UGRA is not projected to have future water supply shortages, the water that is captured can be added to the ASR supply and later retrieved for use in serving unexpected peak demands and drought-of-record needs.*

The following text is added to paragraph seven in subsection 4.7.3 *UGRA WMS J-12:*

Clearing 15,000 acres will yield approximately 10,500 acre-feet of water per year *(based on results from Kerr WMA; Thurow, T.L. and J.W. Hester. 1997. How an Increase or Reduction in Juniper Cover Alters Rangeland Hydrology. Ecology and Management Symposium 1997, Texas A&M University) or about 3,423,000,000 gallons of water per year and can potentially increase the base flow of the river by about 14.4 cubic feet per second*.

The following map is added as Figure 4-2 after the second paragraph in subsection 4.7.3 *UGRA WMS J-12:*



The following text is added to the last paragraph in subsection 4.7.3 *UGRA WMS J-12:*

Cooperating landowners are responsible for the continued maintenance of cleared land beyond the 5-year project horizon. At $100 per acre per decade, the estimated cost for continued maintenance of the cleared 15,000 acres is $150,000 per year.

The following subsection is added at the end of Section 4.11 on page 4-41:

4.11.4 Regional Facility Planning

Utilizing a TWDB EDAP grant, the Upper Guadalupe River Authority (UGRA) and the Kerr County Commissioners' Court are evaluating ways in which water supply and wastewater treatment can be made available from regional facilities that will service the Community of Center Point and much of the unincorporated portion of eastern Kerr County. A surface water treatment facility will provide drinking water to customers currently served by several privately owned water systems. The construction of a new wastewater collection system will provide first-time service to many citizens and may potentially include a gravity interceptor to connect the system to the Kendall County WCID#1 wastewater treatment plant downstream in the town of Comfort.

Another example of regional cooperation can be seen in a March 2008 MOU executed with the UGRA, City of Kerrville, City of Ingram, Kerr County Commissioners' Court, and the Headwaters Groundwater Conservation District in which the parties agreed to cooperate in good faith for purposes of facilitating range and land management practices that will improve and maintain surface water and groundwater quality and/or availability.

Chapter 10

Additional responses to TWDB IPP review comments (Attachment 10C) as they relate to the Plan's coordination with the TWDB DB12 planning database are provided in the form of a spreadsheet.

This Errata Sheet is added to the end of Attachment 10C. These revisions are incorporated in this printed copy of the 2011 Plan.