UPDATED EVALUATION FOR THE TRANS-PECOS PRIORITY GROUNDWATER MANAGEMENT STUDY AREA

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Priority Groundwater Management Area File Report

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EXECUTIVE SUMMARY ✯✯✯

In 1990, the Texas Water Commission [Texas Commission on Environmental Quality (TCEQ) predecessor agency] determined the Cenozoic Pecos Alluvium aquifer area did not meet the criteria to be designated as a "critical area," but requested the area to be reinvestigated at a later date when more data became available. This report summarizes and evaluates data and information that has been developed in the Trans-Pecos study area over the past dozen years to determine if the area is experiencing or is expected to experience, within the next 25-year period, critical groundwater problems. For the purposes of this report, the Trans-Pecos PGMA Study Area includes Loving, Reeves, Ward, and Winkler counties.

This update study was originally initiated in December 1998 by the Executive Director of TCEQ. Specific area-evaluation update reports were prepared by the Executive Administrator of the Texas Water Development Board and the Executive Director of the Texas Parks and Wildlife Department. Water stakeholder input was solicited by TCEQ questionnaires in May 1999. Twenty study-area stakeholders generally responded that there were no major groundwater declines in the Trans-Pecos study area, that groundwater quality problems were mostly found in localized groundwater-level decline areas or areas associated with the naturally occurring salts, and that the water supply corporations and improvement districts exercise some limitations on water usage based on availability. The responding surface water districts noted that they have developed and implement water conservation plans. Due primarily to major statutory changes to the water planning provisions of state law, the completion of the report was purposely delayed until the regional and state water plans had been developed and adopted, and the planning data could be considered. This report relies primarily on the data and supporting information used to develop conclusions and recommendations in the 2001 Region F and 2002 State Water Plans.

Study area water supplies include the Cenozoic Pecos Alluvium, Dockum, and Edwards-Trinity Plateau aquifers; surface water from Red Bluff Reservoir, the Pecos River, Balmorhea Lake, and stock tanks; and, wastewater reuse. In 2000, groundwater sources accounted for over 80 percent of water usage in the area, and provided about 85,813 acre-feet (af) of water for in- and out-of-area uses. Groundwater supplies from the Cenozoic Pecos Alluvium aquifer accounted for 89 percent of this source type, and the Dockum and Edwards-Trinity Plateau aquifers accounted for about 9 and 2 percent of this source type, respectively. Red Bluff Reservoir and releases to the Pecos River supplied 14,451 af of water in 2000 for irrigation purposes. Another 308 af of surface water from other local sources, and 1,889 af of direct reuse supplies were also used in 2000. In 2000, irrigation accounted for about 80 percent of water use followed by municipal and rural domestic uses at 13 percent; power, less than 5 percent; and in decreasing order, mining, manufacturing, and livestock at less than 2, 1, and 1 percent, respectively. The regional and state water plans project that between the years 2000 and 2030, total population within the study area will increase by approximately 14 percent (from 40,936 inhabitants in 2000 to 47,339 inhabitants in 2030). However, the total projected water demand from the four-county study area is not expected to change significantly over the next 30-year period. The total projected demand for 2000 was 146,548 af and the total projected demand for 2030 is 146,032 af, a difference of only 516 af, or less than one percentage point over the 30-year time frame.

Decreased streamflow, natural and man-induced salinity increases, and pollution from oil fields and agriculture have adversely affected the fish population in the study area. The drying up of springs in the study area has been attributed to a lowering of the water table caused by groundwater withdrawal for irrigation purposes. The native cottonwoods, black willow, and grasses that once dominated the riparian corridor along the Pecos River have been taken over by saltcedar, mesquite brush and woods, and Bermuda grass. The water supply problems identified in this report are localized and are not study-area wide problems. The problems identified include naturally occurring and man-induced poor-quality groundwater zones, lack of firm alternative supplies for some irrigation and livestock use, water-level

declines and water-quality degradation in some areas of continued irrigation overdraft and municipal pumpage, potential groundwater impacts from new well field development and demands from outside the area, potential cross-formation water-quality impacts from localized areas of subsidence, and mining of groundwater from aquifer storage to meet future demands. Public health risk due to natural and man-induced contamination, inadequate groundwater supply, lack of supply enhancement such as aquifer recharge, and lack of groundwater protection programs were the major water concerns noted by study area respondents.

The available data indicates that water is of sufficient quality in the study area to meet intended and projected uses. Based on criteria adopted by the Region F Water Planning Group, surface and groundwater supplies are sufficient to meet the present needs, and are projected to be sufficient to meet all future needs to 2030 except for some irrigated agriculture and livestock shortfalls. Therefore, the water supply and water quality issues identified in the report are not presently critical problems, and are not anticipated to be critical problems during the next 25-year planning horizon. Primarily for these reasons, the report concludes and recommends that this study area should not be designated as a priority groundwater management area at this time.

The report evaluates water management entities within the area, and recommends groundwater management strategies to monitor, evaluate, and understand the aquifers and to establish protection programs to minimize drawdown of water levels and maintain existing spring flows to facilitate protection of natural resources. Cooperation and continuation of the Pecos River Ecosystem Project, and facilitation of this and longer-term brush maintenance and control programs are identified as primary groundwater management strategies to help conserve natural resources in the study area. Facilitating administrative programs to help agricultural producers secure conservation grant or loan monies for conversion to more efficient irrigation systems is another groundwater management strategy identified to conserve the natural resources of the study area.

The report evaluates the feasibility and practicability for groundwater management by a groundwater conservation district (GCD), and concludes that groundwater management would be beneficial for the study area. The report concludes that a GCD could benefit the study area by implementing aquifer and area-specific strategies for: water quantity and quality research, monitoring, data collection, and assessment; comprehensive water well inventory, registration, and permitting; and weather enhancement and aquifer recharge. Strategies to encourage conservation of fresh groundwater and the use of poorer-quality groundwater, to educate school children and the public about the finite water resources and of actions that can be taken to conserve the resources, and to protect fresh-water zones by administering an abandoned well location and plugging program would also benefit the citizens of the area. Even though most of the respondents considered significant groundwater problems likely in the next 25-year time frame, only two respondents from the four-county study area favored the creation of GCDs in the area.

Because the available data does not justify PGMA designation for the study area at this time, the report suggests that the local leadership and citizens must determine if they desire to manage groundwater resources. If their answer is yes, these landowners, on their own initiative, will need to consider the different methods available to create a groundwater conservation district. They must also consider several different GCD creation options and the implications for each. The report concludes that either the creation of a multi-county GCD consisting of all four counties in the study area, or the addition of the four-county study area to the existing Middle Pecos Groundwater Conservation District would be the most feasible, economical, and practical options to achieve groundwater management for the Cenozoic Pecos Alluvium aquifer.

INTRODUCTION ☆☆☆

To enable effective management of the state's groundwater resources in areas where critical groundwater problems exist or may exist in the future, the Legislature has authorized the Texas Commission on Environmental Quality (TCEQ), with assistance from other agencies, to study, identify, and delineate priority groundwater management areas (PGMAs), and to initiate the creation of groundwater conservation districts (GCDs) within those areas, if necessary. State law directs the TCEQ to complete PGMA studies and designation for the state's major and minor aquifers by September 1, 2005.

In 1990 and 1991, the Texas Water Commission (TCEQ predecessor agency) completed 14 "critical area" studies (now PGMA studies) in various parts of the state to determine if these areas were experiencing critical water problems, or were expected to experience such problems in the next two decades. The Commission determined that four of these study areas had or were expected to have critical groundwater problems and designated them as such, and that five of the study areas did not have and were not expected to have critical groundwater problems and no further evaluation or action was needed.

The Commission determined that the other five study areas did not meet the criteria to be designated as having critical groundwater problems; however, the Commission requested that these five areas be reinvestigated at a later date when more data became available. The Trans-Pecos area overlying the Cenozoic Pecos Alluvial aquifer in Loving, Pecos, Reeves, Ward, and Winkler counties was one of these five study areas. Appendix 1 includes a reproduction of the technical summary for the Trans-Pecos 1990 study and recommendations.

Purpose and Scope

This report summarizes and evaluates data and information that has been developed in the Trans-Pecos area over the past dozen years to determine if the area is experiencing or is expected to experience, within the next 25-year period, critical groundwater problems. By statutory definition, these critical groundwater problems can include shortages of surface water or groundwater, land subsidence resulting from groundwater withdrawal, and contamination of groundwater supplies.

Further, since the end-purpose of PGMA designation is to ensure that GCDs are created in areas of the state with critical groundwater problems, PGMA evaluation is not necessary for areas that are presently within the jurisdiction of an existing GCD. The existing GCDs are authorized to adopt policies, plans, and rules that can address critical groundwater problems. Pecos County has been excluded from this update study for these reasons.

Methodology and Acknowledgments

This report evaluates the reasons and supporting information for or against designating the four-county Trans-Pecos study area as a PGMA. Based on this evaluation, the report provides conclusions and recommendations regarding PGMA designation, conservation of natural resources, and creation of GCDs and management of groundwater resources in the area.

This report relies primarily on the data and supporting information that was used to develop conclusions and recommendations in the *Region F Regional Water Plan* (Freese et al., 2001) and in the 2002 State Water Plan (TWDB, 2002). Much of the data used to support the regional and state water plans and this report is the result of other significant Texas Water Development Board (TWDB) efforts (Ashworth, 1990; Ashworth and Hopkins, 1995; Boghici, 1998; Boghici, Coker and Guevara, 1999; Jones, 2001 and 2004; Mace, Mullican and Angle, 2001; and TWDB, 1997 and 2001). Special thanks are given to

Sanjeev Kalaswad, Craig Caldwell, and Rima Petrossian for their assistance in various aspects of data compilation and interpretation (TWDB, 2003). Furthermore, this report considers natural resource issues identified in the *Region F Regional Water Plan* and by the Texas Parks and Wildlife Department (El-Hage and Moulton, 1998).

Location, Climate, and Topography

The Trans-Pecos study area is located in west Texas and covers approximately 5,000 square miles. For this evaluation, the study area includes all of Loving, Reeves, Ward and Winkler counties (Figure 1). Pecos County has been removed from the study area as originally delineated in 1990 because local actions have been accomplished to create and confirm creation of a groundwater conservation district.

The climate of the study area is arid and is characterized by low precipitation, high evaporation rates, and large variations in daily temperature. Much of the rainfall in the region occurs between May and September, and the amount of rainfall received in the area is strongly related to elevation. For example, the average rainfall rate ranges from 9.5 inches per year at Toyah (elevation 2,916 feet MSL) to 13.3 inches per year at Balmorhea (elevation 3,205 feet MSL). Pan-evaporation data collected at Balmorhea between 1940 and 1990 indicate evaporation rates of up to 115.7 inches per year (Boghici, 1998).

The study area is located in the Great Plains physiographic province of west Texas. The area is relatively flat and elevations range from approximately 3,000 feet above mean sea level (msl) in the north to 3,500 feet msl in the south. Regional topographic slope primarily is northward. The southeast-flowing Pecos River which bisects the study area, and its tributaries, drain the study area. Except for a very small part of northeastern Winkler County, the four-county study area is located in the upper portion of the Rio Grande River Basin.

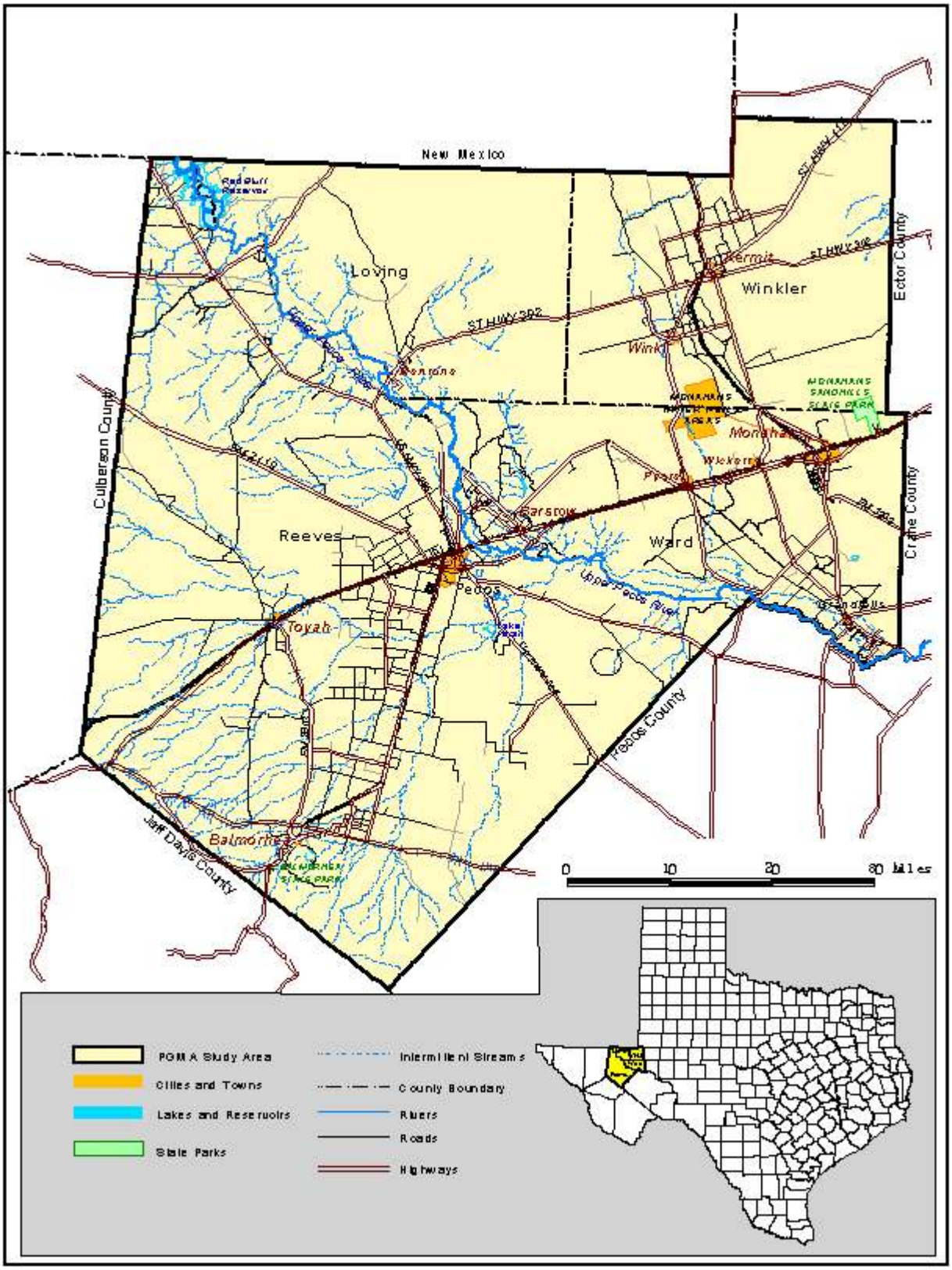
The study area is relatively sparsely populated. In 2000, the total population in the area was approximately 40,936 (TWDB, 2003). Loving County had the lowest population in the study area with 105 inhabitants, and Reeves County the highest with approximately 17,580 inhabitants. Kermit (pop. 7,348), Pecos (pop. 13,389) and Monahans (pop. 8,392) are some of the large towns in the study area, and Barstow, Pyote, Toyah, Wickett and Wink are some of the small towns (Figure 1).

Geology and Groundwater Resources

The study area is underlain by sedimentary rocks ranging in age from Paleozoic to Recent. Surficial sediments consist of Quaternary windblown sand deposits north and east of the Pecos River, and alluvium south and west of the Pecos River (Geologic Atlas of Texas, 1976). Underlying the Quaternary sediments is a thick sequence of Cenozoic alluvial deposits that accumulated in the northwest-southeast trending Pecos trough and in the Monument Draw. Rocks underlying the Cenozoic alluvium consist of Cretaceous limestone and sandstone, Triassic shale and sandstone, and Permian limestone, dolomite, halite and sandstone (Ashworth, 1990).

Structurally, the study area lies within the Permian Basin of west Texas which consists of the Delaware Basin in the west and the Midland Basin on the east (outside of the study area). The two basins are separated by the north-south trending Central Basin platform; a structural high that is present in the eastern part of the study area. A large barrier reef complex known as the Capitan Reef Complex is present along the eastern edge of the Delaware Basin at depths of approximately 2,000 feet below the ground surface.

Figure 1. Trans-Pecos PGMA Study Area Location Map



Several major and minor aquifers (as defined by the TWDB, Ashworth and Hopkins, 1995) are present in the study area. The major aquifers include the Cenozoic Pecos Alluvium aquifer and the Edwards-Trinity (Plateau) aquifer and the minor aquifers include the Capitan Reef Complex aquifer, the Rustler aquifer and the Dockum aquifer. The most important of these aquifers is the Cenozoic Pecos Alluvium aquifer (Figure 2). It is also the shallowest aquifer in the study area and is a principal source of water for irrigation in Reeves and northwest Pecos counties, and for industrial and public use elsewhere. The aquifer is formed in the 1,500-foot-thick unconsolidated to partially consolidated sand, silt, gravel, clay and caliche deposits that occupy the western Pecos trough and the eastern Monument Draw trough (Figure 3). Groundwater in the Cenozoic Pecos Alluvium aquifer generally occurs under semiconfined or unconfined conditions, although local confining clay beds may create localized artesian conditions (Ashworth, 1990).

Depth to groundwater in the Pecos River valley generally is between 10 to 20 feet below the ground surface (bgs). The water table, however, deepens to approximately 50 feet away from the river valley in Winkler, Loving and Ward counties and could be as deep as 300 feet bgs in parts of the irrigation districts of Pecos and Reeves counties. Perched aquifers have also been encountered in the area south of the city of Pecos (Ogilbee et al., 1962 in Boghici, 1999).

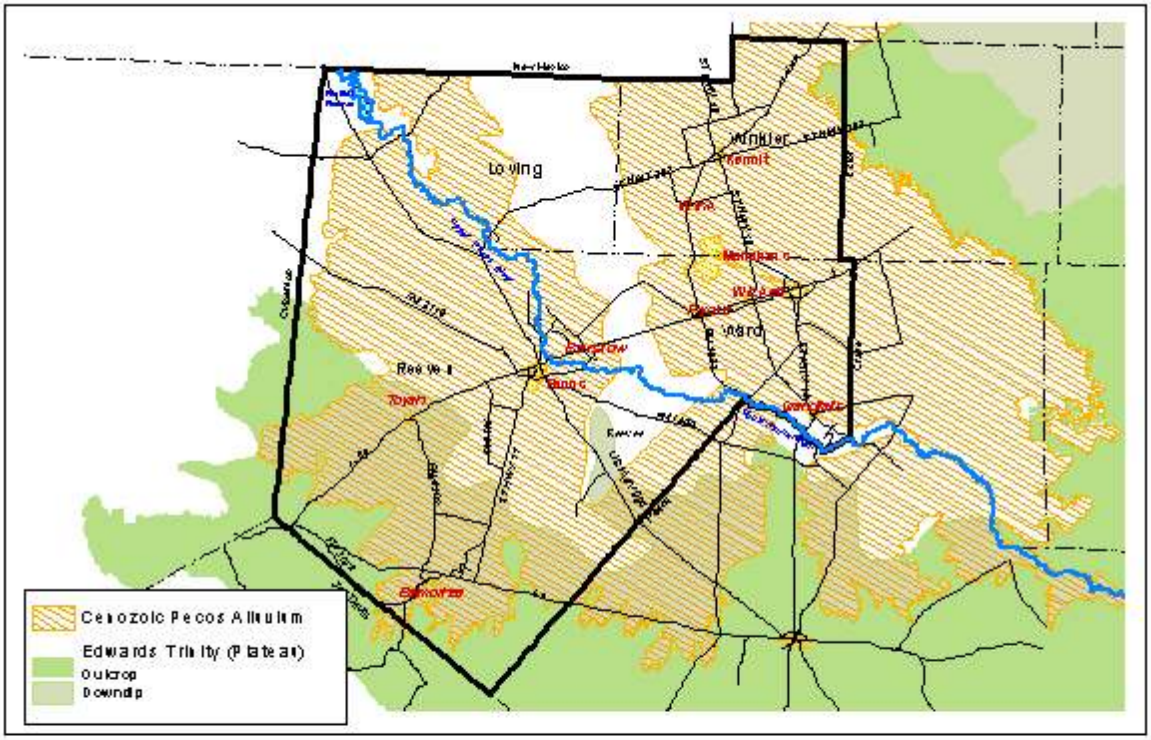
Natural recharge to the Cenozoic Pecos Alluvium aquifer occurs by infiltration of precipitation, seepage from ephemeral stream channels, and lateral subsurface flow from adjacent aquifers. Artificial recharge of the aquifer occurs by seepage from irrigation canals and infiltration of irrigation water on fields (Ashworth, 1990). The total annual effective recharge for the Cenozoic Pecos Alluvium aquifer in the study area is estimated to be 67,800 acre-feet and was determined by the United States Geological Survey (USGS) in 1918 by conducting a seepage study along the Pecos River. For the study, the USGS assumed that the amount of water entering the aquifer as recharge was equal to the amount discharging naturally. In addition to pre-development baseflow, seepage of irrigation-water into the aquifer is accounted for as a part of the total annual effective recharge (Ashworth, 1990).

The Triassic-aged Dockum Formation underlies the Cenozoic Pecos Alluvium in the eastern half of the study area. The principal water-bearing stratum in the Dockum aquifer (Figure 2), the Santa Rosa Sandstone, serves as a source of groundwater in Winkler, Ward, eastern Loving, and eastern Reeves counties where the aquifer is relatively near the surface. The Dockum is the primary aquifer utilized in Winkler County. The City of Kermit relies exclusively on supplies from the Dockum aquifer and the cities of Pecos and Monahans rely in part on supplies from the aquifer. The Dockum aquifer is also used for rural domestic and livestock supplies in Reeves and Winkler counties, irrigation supplies in Ward and Winkler counties, and mining supplies in Winkler County. The thickness of the Santa Rosa usually varies from 100 to 300 feet, with a maximum thickness of about 520 feet in the Monument Trough. In some parts of the study area, the Dockum aquifer is hydraulically connected to the Cenozoic Pecos Alluvium aquifer, and is called the Allurosa aquifer (Ashworth, 1990; Freese et al., 2001).

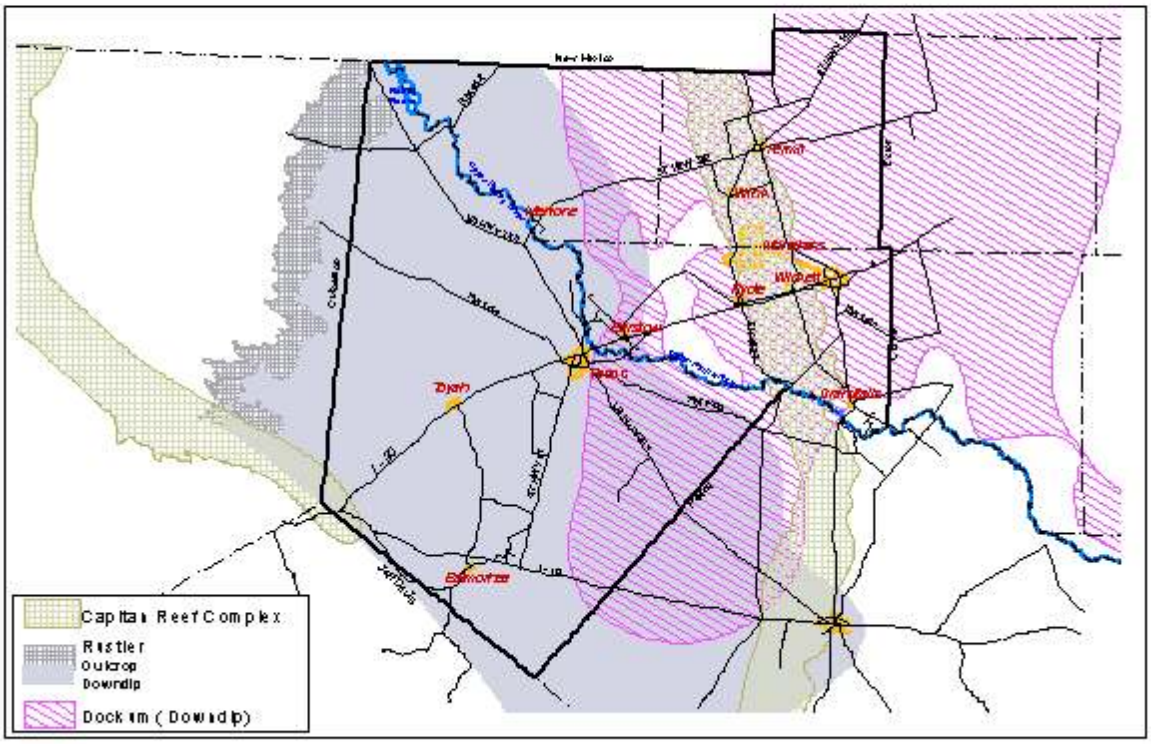
In portions of south-central Reeves and northern Pecos counties, the Cretaceous-aged Edwards-Trinity Plateau aquifer underlies and is in hydraulic connection with the Cenozoic Pecos Alluvium aquifer (Figure 2). This aquifer yields small to moderate quantities of fresh to moderately saline groundwater that is used for rural domestic and livestock supplies.

More detailed discussions and illustrations regarding study area stratigraphy, structure, and hydrogeology can be found in Ashworth, 1990; Boghici,1998; Boghici et al., 1999; and Jones, 2001 and 2004.

Figure 2. Major and Minor Aquifers, Trans-Pecos PGMA Study Area

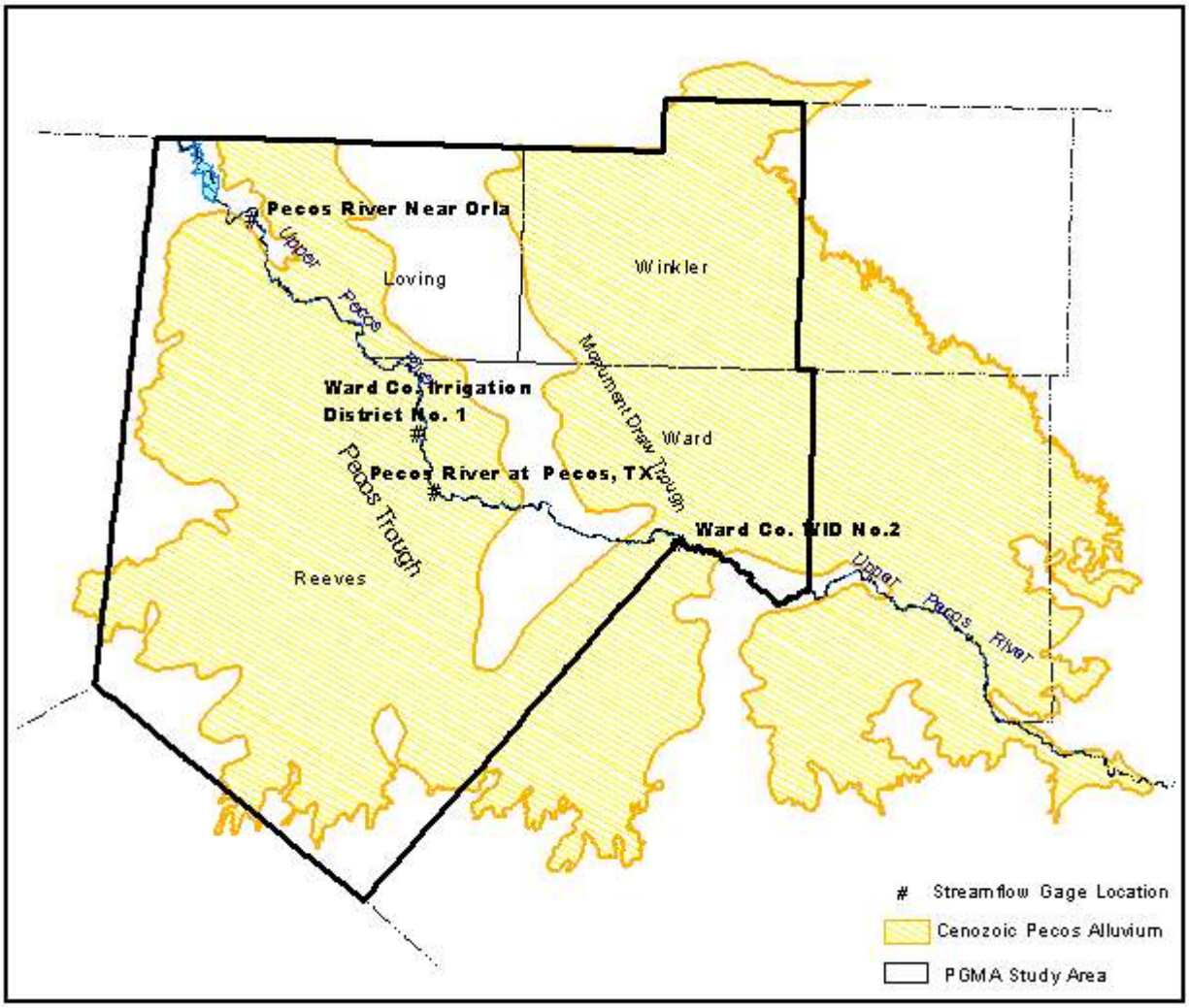


Major Aquifers



Minor Aquifers

Figure 3. Cenozoic Pecos Alluvium Aquifer Basins and Select Pecos River Gauging Stations



Pecos River

The Pecos River enters Texas from New Mexico and flows across the study area from the northwest to the southeast (Figure 3). Prior to the development of large-scale irrigation, studies of base-flow-gain indicated that groundwater inflow to the river between Red Bluff Reservoir near the New Mexico-Texas state line and Girvin, Texas (Figure 3), averaged 30,000 acre-feet or more per year (Ashworth, 1990). However, increased irrigation pumpage in the 1950's and 1960's, resulted in declining groundwater levels, and caused the groundwater flow to reverse direction and flow away from the river. Pecos River water, which is applied to crops, can reach the aquifer in areas with a shallow water table, consequently impacting groundwater quality. Conversely, aquifer pumping in areas adjacent to the river can cause the river to recharge the aquifer, thus changing the chemical characteristics of the groundwater (Boghici, 1999).

Flow of the Pecos River at Orla (Figure 3) shows large seasonal variations and is controlled by releases from the Red Bluff Reservoir (Boghici, 1999) located in Reeves County immediately south of the Texas-New Mexico state line. Pecos River flow and specific conductance measurements recorded by the USGS at Orla (Reeves County) between 1989 and 1997 suggest an inverse relationship between flow and specific conductance: specific conductance decreases when flow is high and vice versa (Boghici, 1999). (Specific conductance related to the concentration of dissolved solids is typically used as a general indicator of water quality.) This is a direct result of dilution by large quantities of fresh water released from the Red Bluff Reservoir.

Seven irrigation districts throughout Loving, Pecos, Ward and Reeves counties obtain water from the Pecos River to irrigate croplands. The Pecos River Compact provides for the division and apportionment of the use of the Pecos River and promotes interstate comity and facilitates for the construction of works for the more efficient use of water and for the protection of life and property from floods.

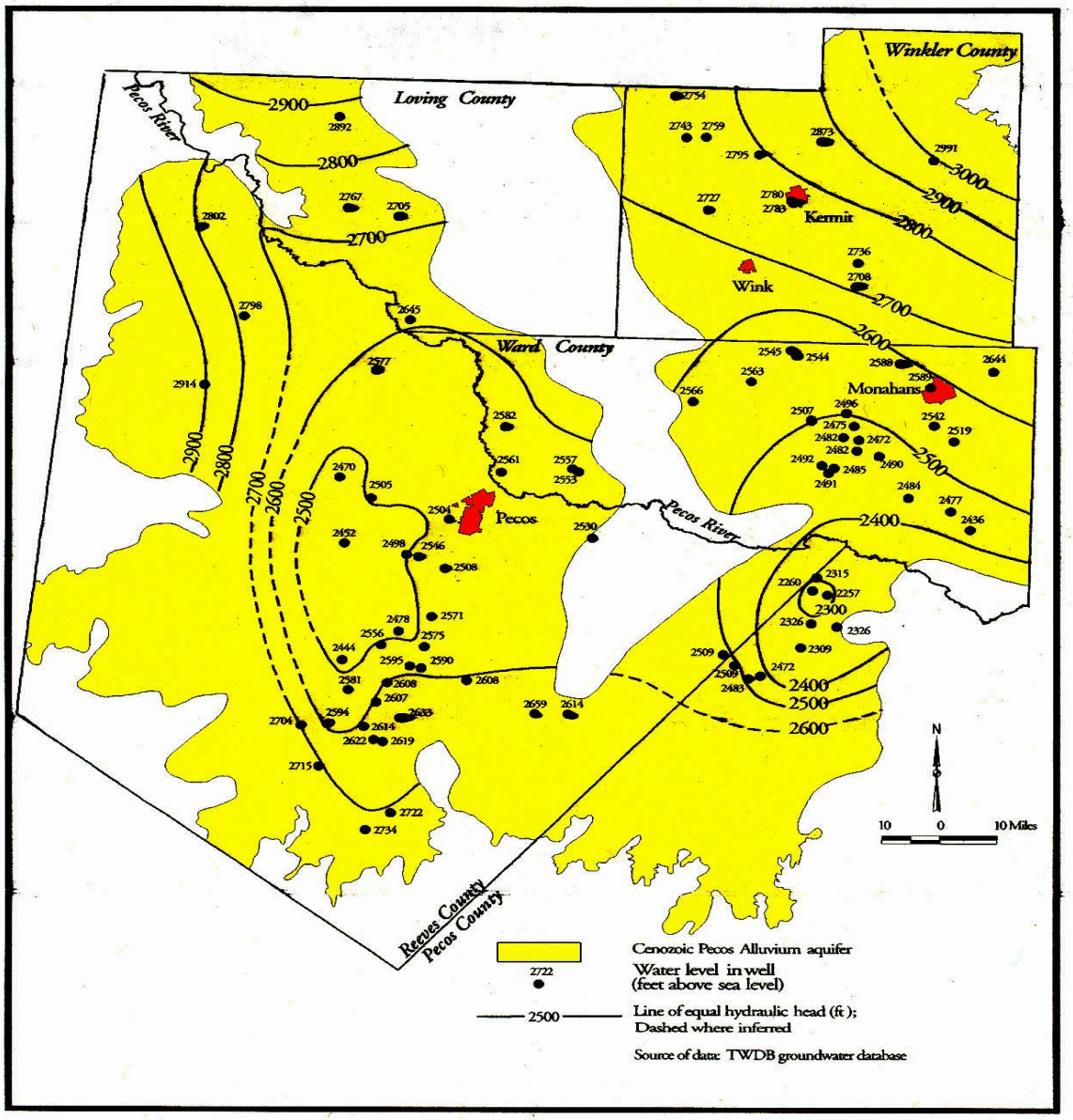
Groundwater-Surface Water Relationships

The potentiometric map constructed from water level data gathered in 1997/1998 (Figure 4) shows baseflow and losing stream conditions on different segments of the Pecos River. In the segment between the gauging station at Orla and the Ward-Loving County line, groundwater contour lines are almost perpendicular to the river channel which suggests that groundwater is discharging to the river (baseflow conditions). In Ward and Pecos counties, pumping from wells located along the river has resulted in reversal of the hydraulic gradient between the river and the aquifer and caused the river to recharge the aquifer (losing stream conditions).

Studies conducted by Grozier (1967) along the Pecos River suggest that the river was losing up to 4.17 cubic feet per second (ft^3/sec) per mile between the gauging station at Orla and Ward County Irrigation District No. 1 irrigation canal. The river was losing 2.12 ft^3/sec per mile in the segment between the city of Pecos gauging station and Ward County Improvement District No. 2 diversion dam. These amounts represent losses due to both evapotranspiration and seepage from the canal. More recent seepage studies in the study area have not been conducted (Boghici, 1999).

Figure 4. Potetiometric Surface Map, 1998

(Boghici et al., 1999)



BACKGROUND ☆☆☆

On April 23, 2003, the TCEQ requested TWDB to provide summarized information from the state and regional water plans for the Trans-Pecos study area. The TWDB, on June 16, 2003, provided population, water use and demand, water supply and availability, and water management strategy information for Loving, Pecos, Reeves, Ward, and Winkler counties from the 2002 water planning cycle (TWDB, 2003).

This section includes descriptions of the local and state agency actions that have affected data acquisition and groundwater management in the Trans-Pecos study area since the Commission's 1990 decision regarding the area. The purpose of the section is to describe data collection efforts, statutory changes regarding priority groundwater management areas and water planning, interim agency studies and activities, and creation of groundwater conservation districts leading up to the writing of this report.

Data Collection

As part of its ongoing water monitoring program, the TWDB continued to collect groundwater elevation and groundwater quality data in the Trans-Pecos area. Water levels in 87 wells were measured between January 1997 and February 1998 to allow for potentiometric surface mapping. Many other wells have also been measured by the TWDB and its cooperators numerous times over the past decade. These measurements allow for the development of well hydrographs and yield information about water-level trends over the past decade. Also, as part of its ambient water quality monitoring program, the TWDB has collected water quality samples from the study area in 1995 and 1999-2000 (TGPC, 1996 and 2001).

Statutory Changes - Senate Bill 1

In 1997, the Texas Legislature made significant changes to the laws governing groundwater management and water planning. Senate Bill 1 (SB 1), the omnibus water bill passed by the 75th Legislature, renamed "critical areas" as PGMAs, significantly amended the PGMA process, and placed a renewed emphasis on the PGMA program. SB 1 also directed the TWDB to coordinate a regional water planning process and to develop a state water plan that incorporates regional water plans, resolves interregional conflicts, provides additional analyses, and makes policy recommendations.

SB 1 extended the PGMA planning horizon from 20 to 25 years, formally included the involvement of area water stakeholders and the Texas Parks and Wildlife Department in the PGMA study process, and directed the Texas Cooperative Extension Service to develop and implement a water education program. In addition, SB 1 changed the PGMA designation process from an agency rulemaking procedure to a TCEQ order and mandated that previously initiated PGMA studies be completed. Two pending studies were completed by TCEQ in 1998. Of these two study areas, one was determined not to be a PGMA and one area was designated as a PGMA. Also during this implementation period, the TCEQ's Executive Director requested updated studies from the TWDB and new studies from the TPWD for the five study areas that required further evaluation, and distributed water-issue questionnaires to statutorily-identified stakeholders in two of the five areas.

SB 1 established a new approach to water management and planning in Texas by creating a long-range, bottom-up, continuous water supply planning process in which regional water planning groups (RWPGs) are responsible for assessing the needs for water in their regions during drought-of-record conditions and developing conservation, management, and mitigation plans to meet those needs. The TWDB established 16 regional water planning areas covering the entire state, and a RWPG for each of theses areas. Each regional water planning area, through its RWPG, is responsible for obtaining local input and developing a regional water plan. Once adopted, the regional water would then be updated on a five-year cycle. The

Trans-Pecos study area was included in the 32-county Region F RWPG covering most of the Edwards-Trinity Plateau area of the state (Figure 5).

SB 1 also charged the TWDB with guiding the development of a statewide water resources data collection and dissemination network to insure that water data is effectively and efficiently collected, maintained, and made available for all users. To accomplish this, the TWDB initiated the statewide Texas Water Information Network. The primary objective of this network is to identify potential program cooperators presently involved in data collection and dissemination activities throughout Texas and build and maintain partnerships with the cooperators for the data network (TNRCC and TWDB, 2001).

Study Update Actions

At an April 1998 annual TCEQ/TWDB meeting, the agency executives recognized that the groundwater needs and availability information developed in the regional water planning process would be a valuable asset for the PGMA program assessments. At this meeting, the agency executives prioritized initiation of completing update studies as a Fiscal Year 1999 work effort. Subsequently in December 1998, TCEQ's Executive Director requested updated water planning information for the Trans-Pecos study area from the Executive Administrator of the TWDB, and natural resource information from the Executive Director of the TPWD. The TWDB update study was provided by the Executive Administrator on December 4, 1998 (Boghici, 1998) and the TPWD study was provided by the Executive Director on December 31, 1998 (El-Hage and Moulton, 1998). Results of these two studies are discussed in detail in subsequent sections of this report.

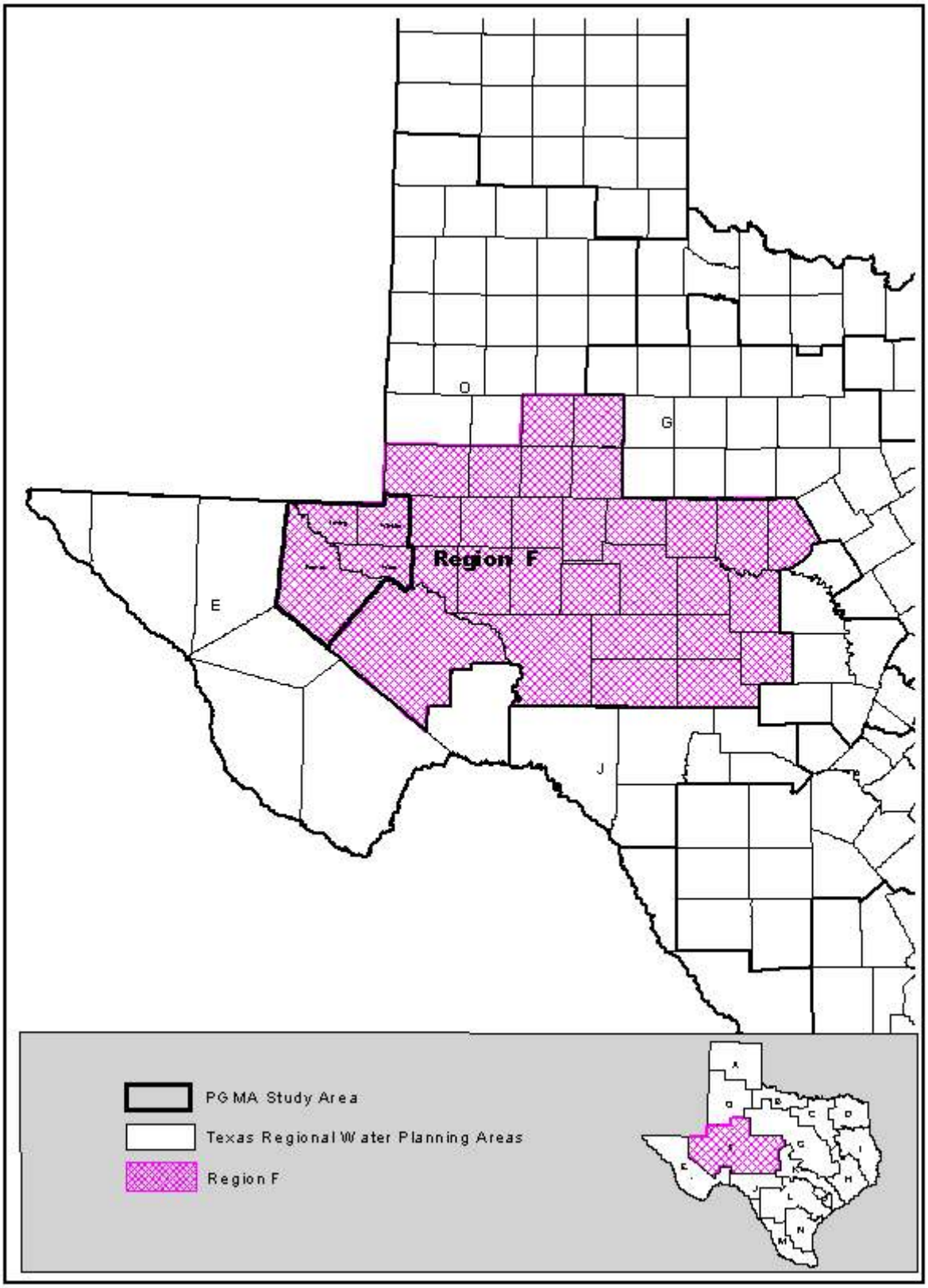
Groundwater Availability Models

In 1999, the 76th Legislature approved TWDB funding for the Groundwater Availability Modeling (GAM) program. The purpose of GAM is to provide reliable and timely information on groundwater availability to the citizens of Texas to ensure adequate supplies or recognize inadequate supplies over a 50-year planning period. Numerical groundwater flow models of the major aquifers in Texas will be used to make this assessment. The expectation is that GAM will: 1) include substantial stakeholder input; 2) result in standardized, thoroughly-documented, and publicly available numerical groundwater flow models and support data; and 3) provide predictions of groundwater availability through 2050 based on current projections of groundwater usage and future demands during normal and drought-of-record conditions. The Cenozoic Pecos Alluvium aquifer has been modeled by the TWDB as part of the GAM for the Edwards-Trinity Plateau aquifer. A final report for the Edwards-Trinity Plateau GAM was completed in September 2004 (Anaya and Jones, 2004). In late 2004, the TWDB was also considering the development of a specific Cenozoic Pecos Alluvium aquifer GAM at a future date.

Regional Water Plans

The first RWPG task was to review and adopt population growth and water demand projections, using the TWDB's extensive population growth and demand estimates. All 16 RWPGs submitted requests for revisions to population and water demand projections for some of the water users within their region, and the TWDB formally approved the requests for revisions that met the criteria established for this process. Water demand was calculated for all cities with a population of 500 or greater and aggregated by county for water user groups, such as manufacturing. A water user group could be a small, rural community or all of the manufacturers in a county. Each RWPG was responsible for identifying all water user groups in the regional planning area.

Figure 5. Region F Regional Water Planning Area



The next RWPG step was to determine what water supplies were available during a drought-of-record. Planning for a drought-of-record was required by SB 1 and is important because it helps communities prepare for drought, which will likely continue to occur in Texas. The RWPGs used groundwater and surface water availability data developed for the 1997 Consensus State Water Plan (TWDB, 1997). In some cases, the RWPGs undertook new studies to update existing TWDB data. After collecting this information, the RWPGs analyzed it to determine when and where there was a surplus or a need for additional water supplies for each identified water user group.

If current supplies did not meet demand, the RWPGs recommended specific water management strategies to meet near-term (less than 30 years) needs and either strategies or options to meet long-term (30-50 years) needs. The RWPGs also determined the social and economic impact of not meeting those needs. If it was not feasible to meet a need, the regions noted and explained the conditions that led to their inability to meet the need. The RWPGs considered a variety of issues when they determined the feasibility of water management strategies, such as conservation, reuse of wastewater, and development of new supplies. They also evaluated the cost, reliability, and environmental factors of selected strategies, their affect on other water resources, and the potential impact to agricultural and natural resources.

All 16 of the regional water plans were formally adopted and submitted to the TWDB prior to the statutory deadline of January 5, 2001 (TWDB, 2001). Significant water data and analysis regarding the study area is included in the *Region F Regional Water Plan* (Freese et al., 2001). The next round of regional water plans must be completed before January 5, 2006. The water plan demand projections for the second round of regional planning were approved by the TWDB in February 2004; however, for consistency this report relies solely on the data from Freese et al., 2001.

State Water Plan

The 2002 State Water Plan was the culmination of a three-year effort by local, regional, and state representatives. Clearly, the most significant difference in this planning effort as compared with previous efforts was the broad level of public involvement that occurred throughout the process. Nearly 900 public meetings and hearings, along with technical assistance and support from the state's natural resource agencies, demonstrate the broad commitment of Texas to plan for adequate water supplies to meet future needs. During the month of October 2001, 26 public meetings were held by the TWDB in 16 cities to ensure that as many individuals and organizations as possible would have an opportunity to provide comments on the draft 2002 State Water Plan. In addition, video conferences were held in 10 cities to receive comments on the draft 2002 State Water Plan. Finally, in November 2001, two public hearings were held in Austin. Throughout this effort, more than 600 individuals provided comments on the draft 2002 State Water Plan.

The 2002 State Water Plan provides for detailed water management for the next 50 years, identifies all water user groups in the state including cities having populations of 500 or more, and aggregates demands by county for all water use sectors. It also records the projected water demand for each water user group over the 50-year planning period, indicates whether the water user group has a need for additional water in the future, and provides water management strategies to meet the projected need. The 2002 State Water Plan, developed with unprecedented extensive and intensive public involvement and decision making, is based principally on local and regional needs and solutions for meeting future water demand. The 2002 State Water Plan was adopted unanimously by the TWDB on December 12, 2001 (TWDB, 2002). The State Water Plan will be due for readoption in 2007, after completion of the second round of regional planning has been completed.

Statutory Charge - Senate Bill 2

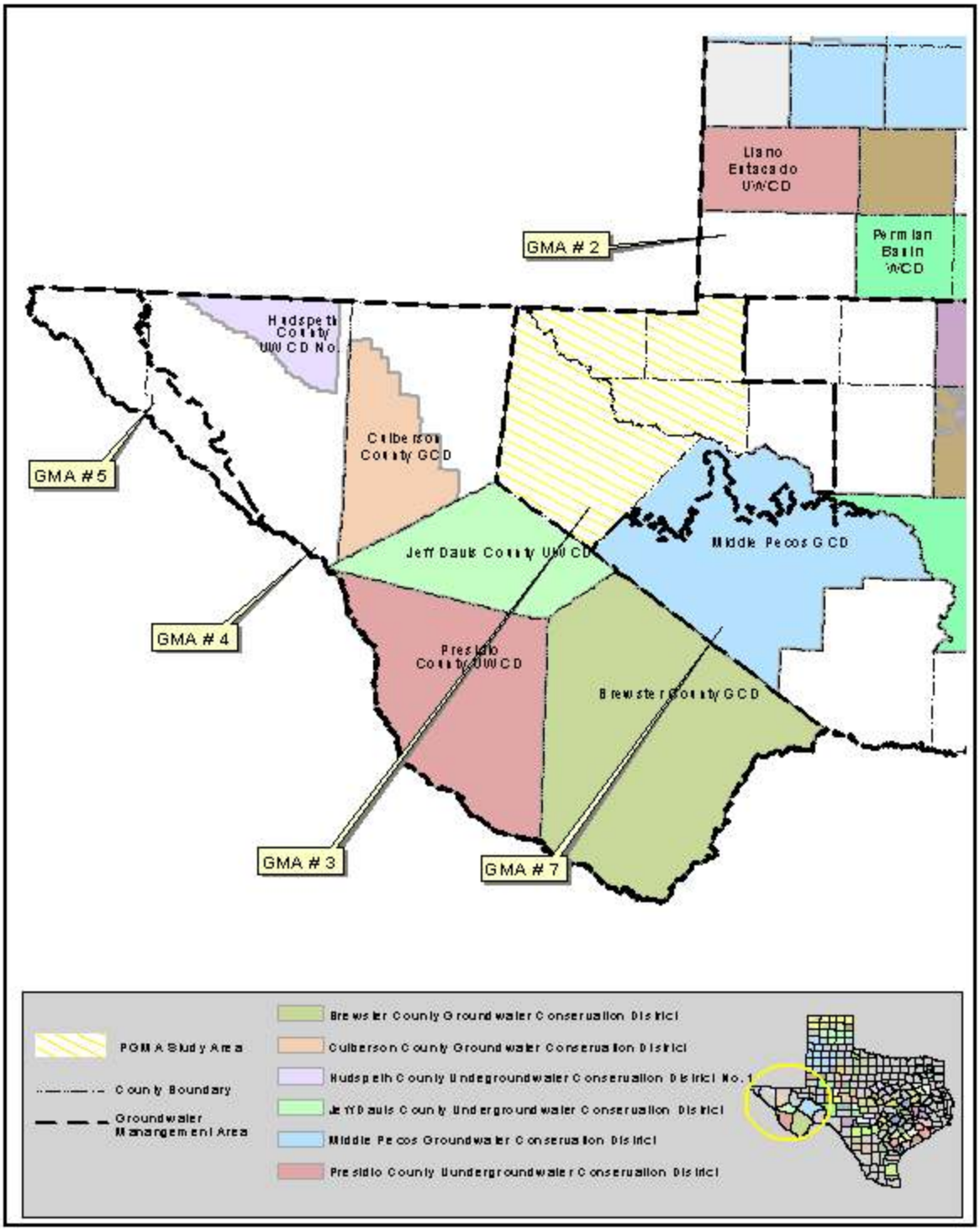
Senate Bill 2, passed by the 77th Legislature in 2001 (Chapter 966), was an omnibus water bill relating to the development and management of the water resources of the state. SB 2 set a September 1, 2005 deadline for the TCEQ to complete the initial designation of PGMAs across all major and minor aquifers of the state for all areas that meet the criteria for that designation. Other statutory changes by SB 2 streamlined the PGMA designation process and the process for the creation of GCDs in designated PGMAs. The streamlined PGMA designation process incorporates considerations for district creation in addition to the determination of critical groundwater problems in a PGMA designation hearing. The law now requires specific GCD recommendations be considered in a TCEQ's PGMA evidentiary hearing and PGMA designation order. SB 2 also provided the TCEQ greater flexibility to make legislative recommendations if GCD creation in a designated PGMA would not be appropriate for, or capable of, protection of groundwater resources.

Creation of Groundwater Conservation Districts

The number of groundwater conservation districts in the state has more than doubled since 1990. During the original Trans-Pecos PGMA study, the only GCD present west of the Pecos River was the Hudspeth County Underground Water Conservation District No. 1, and no GCDs were present in the five-county study area (Loving, Pecos, Reeves, Ward, and Winkler counties). Over the past dozen years, new GCDs have been established in west Texas in a portion of Culberson County and in all of Brewster, Jeff Davis, and Presidio counties (Figure 6).

In Pecos County, the Middle Pecos Groundwater Conservation District was created on a temporary basis by Chapter 1331, Acts of the 76th Legislature, Regular Session, 1999 (SB 1911). In 2001, the 77th Legislature ratified the creation of the Middle Pecos GCD (Chapter 1229, Acts of the 77th Legislature, Regular Session, 2001; House Bill 1258). The residents of Pecos County confirmed creation of the Middle Pecos GCD by election on November 5, 2002 by a vote of 1,597 for to 1,363 against, authorized the collection of an ad valorem tax not to exceed $0.025 per $100 assessed valuation to finance district operations and maintenance, and elected the initial board of directors for the district. The Middle Pecos GCD is authorized to adopt policies, plans, and rules that can address groundwater management within Pecos County; therefore, further PGMA evaluation for Pecos County will not be undertaken in this report. The Middle Pecos GCD's management plan was certified by the Executive Administrator of the TWDB for on August 18, 2004.

Figure 6. Groundwater Conservation Districts and Groundwater Management Areas in West Texas



PUBLIC PARTICIPATION ☆☆☆

To understand local perspective relating to water resource issues for the purposes of this report, the TCEQ has relied on three sources: comments received in response to a specific 1999 questionnaire, stakeholder comments received regarding the June 2004 draft of this report, and local input required for and developed into the *Region F Regional Water Plan* (Freese et al., 2001).

Questionnaires & Comments

In July 1999, TCEQ staff mailed questionnaires regarding water issues to county and municipal officials, water districts or other entities that supply public drinking water, and other identified interested persons in the Trans-Pecos area (including stakeholders in Pecos County). This questionnaire was also sent to the Region F Water Planning Group, the Pecos River Compact Commission, and to other identified local, regional, state, or federal entities such as the Trans-Pecos Cotton Association, Pecos-Reeves County Farm Bureau, Texas Water Conservation Association, Texas Rural Water Association, and Pecos Valley Rural Conservation District. In total, 52 questionnaires were sent to identified water stakeholders. Twenty of the stakeholders provided responses to the TCEQ via the questionnaires. None of the respondents were from Loving County; three were from Pecos County; one was from Reeves County; six were from Ward County; three were from Winkler County; and seven were from regional, state or federal entities outside of the area.

The 1999 questionnaire focused on groundwater and surface water quantity and quality, water conservation, and potential solutions for perceived water problems, if any. Respondents reported that there were no major groundwater declines in the Trans-Pecos study area; the average groundwater decline since 1990 was reported to be between five to ten inches. According to the respondents, these conditions are mostly associated with long-term groundwater pumpage effects and are localized. A respondent noted that groundwater pumpage had contributed to a 10 - 20 inch water-level decline in one of the municipal and industrial water use areas in Ward County over the last ten years. One respondent noted that regional drought conditions in west Texas over the last 11 years may have an effect on long-term water level declines because groundwater usage has exceeded recharge rates. One respondent also noted that some areas have experienced water-level increases, even when the areas were experiencing drought conditions. One respondent noted that in areas of Winker, Loving, and Pecos counties, the water-level decline was smaller than areas in Ward or Reeves counties.

Respondents commented that groundwater quality problems are mostly found in areas where there is a groundwater level decline or associated with the naturally occurring salts. Water-level declines in Ward County lead to an increase in total dissolved solids (TDS) according to one of the respondents. Other respondents noted that fluoride concentrations in the City of Pecos are slightly above the drinking water standard and that surface water in the study area has high salt concentrations.

Conjunctive use of surface and groundwater is not used in all counties of the study area. At places, respondents reported that there was no surface water or the surface water was contaminated with naturally occurring salts. Some respondents noted that oil field contamination and poor surface water quality degrades and limits this source for conjunctive use. High demand for conjunctive use of surface and groundwater was reported in the study area during the summer.

Six respondents noted that they did not use any kind of water conservation plan, and four respondents answered unknown regarding water conservation plans. Most of the respondents noted that major water supply corporations and water improvement districts exercise some limitations on water usage based on

availability. The responding surface water districts noted that they have developed and implemented water conservation plans in their districts.

Some respondents noted cases of groundwater contamination caused by gasoline and industrial pollutants and from improper construction of wells. One respondent commented that older oil wells and injection wells that go through the fresh water-bearing zones were concerns in Ward and Winkler counties. More than half of the respondents noted that most of the wells were capped in the study area.

Most of the respondents considered critical groundwater problems likely in the next 25-year time frame. Public health risk due to natural and human contamination, inadequate groundwater supply, lack of supply enhancement such as aquifer recharge, and lack of groundwater protection programs were the major water concerns of the respondents. However, only four respondents from the study area favored the creation of GCDs in the area; two in Pecos County, and one each in Reeves and Ward counties. Two respondents from Ward County opposed the creation of GCDs, and seven respondents (one from Pecos County and three each from Ward and Winkler counties) were undecided about GCD creations or did not respond to this specific question.

TCEQ solicited additional stakeholder input by making a draft study area update report available for public inspection and comment. Notice of the draft report's availability and request for comment was mailed on June 28, 2004 to 90 study-area stakeholders. Copies of the draft report were sent to county judges and county clerks, the Regional F Water Planning Group, and adjacent groundwater conservation districts. In addition, the draft report was made available on the TCEQ website and stakeholders were provided an opportunity to request copies.

Four study-area stakeholders provided comments. Three stakeholders found the report to be informative and useful, and did not offer any objections or suggestions. The fourth stakeholder provided some irrigated agriculture information for Winkler County and requested clarifications be made to and regarding Table 6, Comparison of Water Demand, Supply, and Availability.

Regional Water Plan Development

The Region F Water Planning Group is composed of voting and non-voting members who represent the general public, counties, municipalities, industry, agriculture, environmental, small business, electric generating utility, river authorities, water districts, and water utilities. The Region F Water Planning Group made special efforts to contact municipalities, water districts, and rural water supply corporations and others in the region and obtain their input in the planning process. Questionnaires were sent to county judges, selected cities, rural water supply corporations, regional water suppliers, groundwater conservation districts, steam electric power providers, and industries. The questionnaires sought information on population and water use projections, drought planning, water quality issues, and other water supply issues. The questionnaires were also handed out at public meetings. The response rate for all questionnaire recipients was 37 percent, excluding the 54 responses from the public meeting questionnaires.

Initially, the Region F Water Planning Group held two public meetings in July 1998 to discuss the planning process and the scope of work for the region. Presentations were made on the planning process and input was solicited from participants. Between February 1999 and June 2000, the Region F Water Planning Group held a series of five workshops and two public meetings focusing on groundwater and surface water issues in the planning process. At these workshops and public meetings presentations were made on the status of the plan and issues relating to ground or surface water users. Opportunities were given for members of the public to provide input on these issues or any other aspects of the plan. Media

outreach during development of the Region F plan included using a number of communications vehicles (e.g., public meeting notices, press releases, media advisories) to keep the media, and hence the public, informed of the progress and activities of the Region F Water Planning Group.

In July 2000, copies of the draft *Initially Prepared Region F Water Plan* were mailed to the Region F county courthouses and libraries for public review. Copies of the draft plan were also posted on the Region F website, and additional hard copies were made available to interested parties. Notices of the upcoming public meetings were sent to the Secretary of State, county clerks, county judges, regional legislators, groundwater and irrigation districts, and regional newspapers along with a description of how to obtain copies of the draft plan for review. On September 5 and 6, 2000, the Region F Water Planning Group held public meetings in San Angelo and Odessa to present the draft *Initially Prepared Region F Water Plan* and seek public input. Oral comments were received following the presentation and written comments were accepted through September 11, 2000. Where appropriate, modifications to the plan were made and incorporated into the adopted *Regional Water Plan*.

Implementation issues identified for the *Region F Regional Water Plan* include: 1) financial issues associated with paying for the proposed capital improvements, 2) identification of the governing authorities for general regional strategies such as brush control, recharge enhancement and weather modification, 3) cooperation between entities to implement regional strategies, 4) public acceptance of selected strategies, and 5) public participation in the water conservation measures that are factored into the plan.

In order to make the adopted *Region F Regional Water Plan* more accessible to the public, it was made available on the Freese and Nichols web page. Freese and Nichols, the Colorado River Municipal Water District and the TWDB each maintained web sites with information on the Region F planning process as planning efforts proceeded. (Freese et al., 2001)

NATURAL RESOURCES ✯✯✯

As requested by the TCEQ, an evaluation of selected natural resources in the study area was conducted by the Texas Parks and Wildlife Department (TPWD) in 1998. Most information presented in this section was obtained from TPWD's 1998 report prepared by El-Hage and Moulton. The remaining information has been obtained from the *Region F Regional Water Plan* (Freese et al., 2001) or other sources as noted.

Texas Parks and Wildlife Department Regional Facilities

The TPWD operates two state parks in the study area: Balmorhea State Park and Monahans Sandhills State Park (Figure 1). Balmorhea State Park in Reeves County has a large artesian spring pool that is open to the public. The pool is fed by the San Solomon Springs which also fills a cienega (desert wetland) and the canals of a refugium which is home to endangered species of fish, assorted invertebrates and turtles. Monahans Sandhills State Park which consists of 3,840 acres of sand dunes (some up to 70 feet high) in Ward and Winkler counties is a small portion of a dune field that extends about 200 miles from south of Monahans westward and northward into New Mexico. Freshwater occurs at shallow depths within the dune field and sometimes stands in shallow ponds in low areas between dunes. El-Hage and Moulton (1998) note that the two regional state parks have $611,186 economic impact on personal incomes of the residents of Reeves and Ward counties and provide about 56 full-time equivalent jobs for the county residents.

Springs

At present, nine springs are flowing in the study area: six in Reeves County, two in Loving County, and one, a very small seep, in Winkler County. El-Hage and Mouton (1989) report that the only known springs still flowing in Loving County are Red Bluff Springs. These springs issue in the upper end of Red Bluff Reservoir and up the Pecos River to Amerada Falls, approximately one mile north of the New Mexico State line. The springs contain moderately saline water which sustain killfish, brine shrimp, turtles, saltcedars and rushes. In addition, the *Region F Regional Water Plan* (Freese et al., 2001) reports that Allison Spring also continues to flow in Loving County.

Of the 21 springs or spring groups in Reeves County, six are still flowing. These include Giffin, Sandia and San Solomon springs which are still used for irrigation, recreation (Balmorhea State Park) and for public water supplies in the cities of Balmorhea and Toyah. The San Solomon Springs support several rare and endangered species of small fish including the pupfish. The pupfish were once found in Comanche and Leon springs, in Pecos County, before the springs were pumped dry. San Solomon Springs also harbor the endangered Pecos gambusia (a small crustacean) and two kinds of aquatic snails. Other springs, such as Sandia Springs, support rare plants such as the puzzle sunflower which is soon to be listed by the federal government as an endangered species.

Brune (1981) identified some 27 springs in the four-county area that have dried up, 19 of which were in Reeves County. In the past, most of the springs in the study area supported marshes containing cattails, sedges, rushes or tules, sacaton grasses, common reed and saltgrass. Cottonwood and willow trees often grew around the marshes. Today, most of this vegetation and the wildlife that thrived in them has disappeared along with the springs. The drying up of the springs in the study area has been attributed to a lowering of the water table caused by groundwater withdrawal for irrigation purposes (Brune, 1981). El-Hage and Moulton (1998) are of the opinion that the creation of a PGMA in the study area would reduce further lowering of the water table and prevent more springs from drying up.

Wetlands

The native cottonwoods, black willow and grasses that once dominated the riparian corridor along the Pecos River have been taken over by saltcedar, mesquite brush and woods, and Bermuda grass. Saltcedar was introduced early in the century to stabilize the eroding banks of the river resulting from poor land management practices such as overgrazing and inappropriate farming practices. Although saltcedar helps to stabilize the river banks and provides some usable habitat for migrating birds and resident animals, it uses large amounts of water and may, in some cases, have contributed to declines in groundwater levels and scarcity of surface water. El-Hage and Moulton (1998) conclude that control or elimination of this introduced species would be good for wildlife and the rivers only if native species replace the saltcedar, mesquite, and Bermuda grass to provide habitat and protect river banks from erosion. El-Hage and Moulton are also of the opinion that in order to maintain good riparian habitats, grazing pressures must be carefully managed.

Ephemeral and some permanent freshwater ponds occur in interdunal depressions at Monahans Sandhills State Park. These ponds exist because a perched water table is formed below the ground surface by underlying impermeable caliche layers. The interdunal ponds are dynamic and migrate as the active dunes migrate. Wetland plants found at the more permanent ponds include willows, bulrushes, cattails, flatsedges, rushes, spikerushes and the rare dune flatsedge.

At Balmorhea State Park, a restored desert wetland (a cienega) associated with the San Solomon Springs is present. This wetland supports several wetland plants, associated wetland wildlife as well as tourists and irrigated agriculture.

Fishes and Stream Segments with Significant Natural Resources

The Pecos River between Red Bluff Reservoir and Girvin, Texas, has a characteristic fish fauna. Decreased streamflow, natural and man-induced salinity increases and pollution from oil fields and agriculture have adversely affected the fish population in the study area. More recently, native fishes have been threatened by the introduction of the sheepshead minnows and toxic blooms of golden algae which produce toxins detrimental to fish.

As discussed above, San Solomon Springs in the refugium in Balmorhea State Park is another place were some native fish species are found. El-Hage and Moulton (1998) report that the sole remaining populations of the Comanche Spring pupfish inhabit the springs and irrigation canals of the Balmorhea area and conclude that reduction of flow at San Soloman and other springs in the Balmorhea area threatens not only endangered fishes, but also the agriculture and tourist economies in the area.

The Texas Water Code requires the State Water Plan to identify river and stream segments of unique ecological value. Among the criteria for identifying a stream segment as one with unique ecological value are its biological and hydrologic functions. In addition, segments with riparian conservation areas, or high water quality, exceptional aquatic life, or high aesthetic quality may be identified as having unique ecological value. Stream or river segments where water development projects would have significant detrimental effects on state or federally listed threatened or endangered species may also be considered ecologically unique (Freese et al., 2001).

Using these criteria, the TPWD has developed a draft list of Texas streams and rivers satisfying at least one of the criteria defined by state law for ecologically unique river and stream segments. The following five significant stream segments are identified by the TPWD and in the *Region F Regional Water Plan*:

- East Sandia Springs (Reeves County).
  - Endangered/Threatened: Pecos gambusia; Puzzle sunflower
- Giffen Springs (Reeves County).
  - Endangered/Threatened: Comanche Springs pupfish, Pecos gambusia
- Salt Creek – From the confluence with the Pecos River in Reeves County upstream to the Reeves/Culberson County line.
  - Endangered/Threatened: Pecos pupfish
- San Solomon Springs (Reeves County).
  - Resource Conservation Area: Balmorhea State Park
  - Endangered/Threatened: Comanche Springs pupfish, Pecos gambusia
- Toyah Creek – From the confluence with the Pecos River in Reeves County upstream to FM 1450 in Reeves County.
  - Endangered/Threatened: Comanche Springs pupfish

Other Creatures

Many species of migrating birds, wintering shorebirds, and neotropical songbirds stopover in the study area. They feed and rest along the banks of the Pecos River and other water bodies such as Red Bluff Reservoir, Lake Toyah, Lake Balmorhea, San Salomon Springs, and the water holes and depressions in the sandhills of Ward and Winkler counties. In addition, there are at least 37 species of reptiles, mammals, and amphibians, that are either aquatic, semi-aquatic, or in some way wet-land dependent present in the study area. Riparian habitat is of special importance to nesting songbirds and raptors like the southwest willow flycatcher and the zone-tailed hawk, and mammals such as the pallid bat, Pecos river muskrat, and the white-footed mouse. Frogs, salamanders, and turtles are aquatic animals, and most toads require aquatic habitats in order to survive. Most of the snakes and lizards in the study area are restricted to riparian habitat adjacent to the Pecos River, springs, ponds, and wetlands. Detailed information and tables relating to birds and waterfowl, reptiles, mammals, and amphibians of the study area are provided in El-Hage and Moulton, 1998.

In the *Region F Regional Water Plan*, Table 1-17 lists "species of special concern" identified by TPWD in the Region F counties. Species of special concern include those listed or proposed to be listed as threatened or endangered at the federal level. Also included are species listed as threatened or endangered at the state level. Species of special concern also include those considered by the TPWD as rare, having limited range within the state. The TPWD maintains a list of species of special concern in the Texas Biological and Conservation Data System (Freese et al., 2001).

Agriculture and Farmland

Based on 1997 U.S. Department of Agriculture County Census Data as reported in the *Region F Regional Water Plan* (Table 1-18; Freese et al., 2001), the study area includes approximately 2,216,643 acres in 314 farms. The data does not provide the total number of acres of crop land in the four counties, but does reflect that there are 19,984 acres of irrigated crop land in Reeves and Ward counties and no irrigated crop land in Loving County. Similar data for Winkler County was not provided, but one Winkler County stakeholder reported there was presently 1,800+ irrigated acres in vegetable production in the county. The market value of agriculture products (crops and livestock), for the study area in 1997 was almost $46,600,000.

In addition, the *Region F Regional Water Plan* reports shrimp farming as a relatively new business in west Texas. Presently, 150 acres of ponds are located in Pecos and Ward counties with plans to expand at a rate of 12 to 15 percent per year. Estimated water usage is 3,300 acre-feet per year of salt water from

the Cenezoic Pecos Alluvium aquifer. Because the water used in this industry has a TDS range of 3,000 to 20,000 parts per million, it is not in direct competition with most other uses.

Mineral Resources

Oil and natural gas fields are significant natural resources throughout the Region F Water Planning Area including the study area. Data available on the Texas Railroad Commission internet homepage (TRC, 2003) indicates that as of February 2003, over 10,000 oil wells and 1,200 gas wells have been drilled in the four-county area (numbers do not include plugged or abandoned wells). The data indicate that these mineral resources are most prolific in Ward (4,544 oil wells, 347 gas wells) and Winkler (3,575 oil wells, 545 gas wells) counties. The data also indicates that total gas well gas production in 2001 topped 138 million cubic feet (55 million cubic feet from Ward County alone), and that crude oil production topped 11.5 million barrels (with about 5.4 million and 4.2 million barrels from Ward and Winkler counties respectively). The *Region F Regional Water Plan* notes the following (Freese et al., 2001):

> "In some cases, improperly abandoned oil and gas wells have served as a conduit for brines originating deep within the earth to contaminate the shallower water supply aquifers. Also, prior to 1977 it was a common practice to dispose of the brines associated with oil and gas production in open, unlined pits. In many cases, these disposal pits have not been remediated and remain as sources of salt contamination. Currently, the practice is to use these brines to repressure hydrocarbon-producing formations or dispose of the brines using deep well injection. This practice leads to the possibility of leaks into water supply aquifers. In other aquifers, excessive pumping may cause naturally occurring poor quality water to migrate into fresh water zones."

Water Related Threats to Natural Resources

The development of reservoirs and invasion by non-native brush species have altered natural stream flow conditions in the study area. Spring flows have diminished and many springs have dried up because of groundwater development or the spread of high water-use plant species such as mesquite and saltcedar. These activities have reduced reliable flows for many tributaries. Reservoir development also changes natural hydrology, diminishing flood flows and capturing low flows. It is unlikely that future changes to flow conditions will be as dramatic as those that have already occurred. Furthermore, if additional reservoirs are developed in the future, they will be required to make low flow releases to maintain downstream flow conditions, which was not often required in the past (Freese et al., 2001).

WATER USE, DEMAND, SUPPLY AND AVAILABILITY ✯✯✯

Evaluations of historic water usage, population and water demand projections, current water supplies, and total water availability are provided in this section. The evaluated data come predominantly from the 2002 State Water Plan, *Water For Texas - 2002* (TWDB, 2002). Data from *Region F Regional Water Plan* (Freese et al, 2001) has also been utilized. If not discussed here, the methodologies for development of the evaluated data may be referenced in the state and regional water plans.

Water Usage

In 1995, approximately 139,400 acre-feet (af) of water extracted from the study area was used to meet the needs of the four-county study area and surrounding regions. Bodhici et al. reported in 1999 that this amount of water was a 30 percent increase compared to the amount used in1985, and was caused by a big surge in irrigation operations in Reeves County. Area-wide estimated water use for 2000 is shown in Table 1. In 2000, TWDB water use data indicate that 113,732 af of water, a decrease of 18 percent from 1995 usage estimates, was used in the study area and for export to the City of Odessa. In a similar but inverse manner, decreases in groundwater production for irrigation in Reeves County accounted for a large percentage of this difference as well.

Table 1. Estimated Water Use, 2000, Trans-Pecos PGMA Study Area

USE TYPE	LOVING COUNTY		REEVES COUNTY		WARD COUNTY		WINKLER COUNTY	
	GW	SW	GW	SW	GW	SW	GW	SW
MUNICIPAL AND COUNTY OTHER	11	0	3,414	315	8,778	0	2,268	0
MANUFACTURING	0	0	644	0	6	0	0	0
POWER	0	0	0	0	5,360	0	0	0
IRRIGATION	0	358	63,228	10,811	2,962	11,001	2,002	0
MINING	3	0	203	0	147	0	1,104	0
LIVESTOCK	32	8	796	42	111	6	142	7
2000 USE	**46**	**366**	**68,258**	**11,168**	**17,364**	**11,007**	**5,516**	**7**
PREVIOUS TRANS-PECOS PGMA STUDY AREA WATER USE BY SOURCE								
1985 USE	23	4	64,106	13,347	18,572	1	5,416	24
1990 USE	24	68	39,733	16,543	14,287	10,950	3,088	4
1995 USE	31	384	110,952	2,093	14,444	7,629	3,979	5

Notes: **Water quantity in acre-feet**; GW - groundwater; SW - surface water.
Municipal and County Other Use Type for Ward County includes water quantity exported from Ward County to City of Odessa, Ector County, for municipal purposes.

Adapted from Bodhici et al., 1999 and TWDB, 2003.

Water needs throughout the study area continue to be met primarily with groundwater from the Cenozoic Pecos Alluvium aquifer; however, increased quantities of surface water are being utilized. In 1995, groundwater accounted for 94 percent of all water used in the study area, and was up from 91 percent in 1985. The remainder was water released from the Red Bluff Reservoir and surface water from Balmorhea Lake (Boghici et al., 1999). In 2000, groundwater accounted for 80 percent (91,184 af), and surface water accounted for 20 percent (22,548 af) of water used in the study area. This represents an increase of 45 percent for surface-water use over this five-year period.

More water is used for irrigation in the study area than for any other purpose. In 2000, irrigation accounted for 90,362 af (80 percent) of the total amount of water used, down from 115,291 af (83 percent) in 1995, and up from 63,588 af (75 percent) in 1990. Of the amount of water used for irrigation purposes in 2000, 68,192 af (75 percent) was supplied by groundwater sources and 22,170 af (25 percent) was supplied from surface water sources. Eighty-two percent of the water used in 2000 for irrigation (74,039 af) was used in Reeves County.

Municipal and County Other (primarily rural domestic) use accounted for 14,786 af, or slightly more than 13 percent of the total water used in 2000. Ninety-eight percent of this water was groundwater. As a comparison, water used for these purposes in 1990 was 14,003 af (or 10 percent of the total water used), with groundwater constituting 98 percent of this amount. These use numbers include water use from the study area that is exported to the City of Odessa.

Water for power generation accounted for 5,360 af of water use in Ward County in 2000, representing less than five percent of the total water use in the study area. Groundwater was used to supply 1,457 af of water for mining purposes (less than two percent of total water use) and 650 af of water for manufacturing purposes (less than one percent of total water use) in 2000. Use of surface and groundwater sources for the watering of livestock accounted for 1,137 af of use (less than one percent of total water use) in 2000; 95 percent groundwater (1,081 af) and 5 percent surface water (56 af).

Population and Water Demand Projections

TCEQ staff note that the 2000 population projection used by the Region F Water Planning Group (36,589 residents in the study area) is almost 15 percent higher than the 2000 U.S. Census Bureau population data (31,289 residents), and that the 2000 projected water demand estimates are some 22 percent greater than the TWDB water use estimates for the same year (146,564 af compared to 113,732 af). To err conservatively and allow for projection consistency, this report uses the population and water demand projections developed for the regional and state water plans.

Based on U.S. Census Bureau data, the total population of the four-county study area in 2000 was 31,289. Of this, the population of the larger cities (Pecos, Monahans, and Kermit) was 23,036 and that of rural areas, 8,253. Overall, the total population of the study area decreased by around seven percent (2,990 people) between 1980 and 1990, and another 15 percent (5,533 people) between 1990 and 2000.

The regional and state water plans project that between the years 2000 and 2030, total population within the study area will increase by approximately 14 percent (from 40,936 inhabitants in 2000 to 47,339 inhabitants in 2030). During that time period, the population of small cities is projected to decrease by about 11 percent (336 people), while the county-other and larger city populations are projected to increase by about 21 percent, or 1,858 people for county-other population, and about 14 percent, or 4,907 people for larger cities. Population projection data are shown in Table 2.

Table 2. Projected Population, Trans-Pecos PGMA Study Area

LOVING

WUG[1]	COUNTY	BASIN	YR1996	YR2000	YR2010	YR2020	YR2030	YR2040	YR2050
MENTONE	LOVING	RIO GRANDE	51	51	45	35	29	24	20
COUNTY-OTHER	LOVING	RIO GRANDE	46	54	53	49	45	38	29
			97	**105**	**98**	**84**	**74**	**62**	**49**

REEVES

WUG	COUNTY	BASIN	YR1996	YR2000	YR2010	YR2020	YR2030	YR2040	YR2050
BALMORHEA	REEVES	RIO GRANDE	824	832	830	812	778	729	670
PECOS	REEVES	RIO GRANDE	11,634	13,389	14,746	15,857	16,415	16,867	17,331
TOYAH	REEVES	RIO GRANDE	115	118	117	114	110	103	95
COUNTY-OTHER	REEVES	RIO GRANDE	2,736	3,241	3,663	4,029	4,238	4,428	4,450
			15,309	**17,580**	**19,356**	**20,812**	**21,541**	**22,127**	**22,546**

WARD

WUG	COUNTY	BASIN	YR1996	YR2000	YR2010	YR2020	YR2030	YR2040	YR2050
BARSTOW	WARD	RIO GRANDE	560	501	470	431	402	391	382
GRANDFALLS	WARD	RIO GRANDE	619	612	602	581	560	563	571
MONAHANS	WARD	RIO GRANDE	7,851	8,392	8,847	9,054	8,857	8,548	8,250
THORNTONVILLE	WARD	RIO GRANDE	756	749	745	727	694	649	611
WICKETT	WARD	RIO GRANDE	543	490	459	423	414	405	397
COUNTY-OTHER	WARD	RIO GRANDE	2,557	3,225	3,699	3,990	4,029	3,952	3,674
			12,886	**13,969**	**14,822**	**15,206**	**14,956**	**14,508**	**13,885**

WINKLER

WUG	COUNTY	BASIN	YR1996	YR2000	YR2010	YR2020	YR2030	YR2040	YR2050
KERMIT	WINKLER	RIO GRANDE	6,534	7,348	7,952	8,393	8,523	8,611	8,700
WINK	WINKLER	RIO GRANDE	1,150	1,303	1,430	1,517	1,544	1,567	1,590
COUNTY-OTHER	WINKLER	COLORADO	5	6	6	6	6	6	5
COUNTY-OTHER	WINKLER	RIO GRANDE	608	625	654	683	691	691	525
			8,297	**9,282**	**10,042**	**10,599**	**10,764**	**10,875**	**10,820**

Note: Water User Group (WUG) population data from 2002 State Water Plan. Adapted from TWDB, 2003).

The City of Odessa in Ector County obtains a portion of its water supply from the Cenozoic Pecos Alluvium aquifer from a well field located in Ward County. The water is exported from Ward County to the City of Odessa by the Colorado River Municipal Utility District. Select population data for the City of Odessa is as follows:

YR1980	YR1985	YR1990	YR1996	YR2000	YR2030
90,127	101,165	89,504	93,580	100,144	139,866

Between 1980 and 1985, the population of the City of Odessa increased over 12 percent (11,038 people), and between 1985 and 1990, the population decreased by over 11 percent (11,661 people). From 1990 and 1996, the population of the City of Odessa increased by slightly more than four percent (4,076 people). The regional water planning data project the population of the City of Odessa will increase by over 39 percent (39,722 people) between 2000 and 2030.

Projected water demand data, by county and category for the study area are presented in Table 3. The Water User Groups (WUGs) have been identified by the Region F Water Planning Group. The WUG projected water demand data include municipal demands for cities and towns, rural water supply demands for county-other uses, agricultural demands for irrigation and livestock, and other water demands for manufacturing, mining, and steam electric power generation. Projections for the City of Odessa in Ector County are listed under the Ward County portion of the table, and reflect only the amount of water the city will require from its well field inside Ward County.

Development of the demand projection data is detailed in *Region F Regional Water Plan* (Freese et al., 2001). The total projected water demand from the four-county study area is not expected to change significantly over the next 30-year period. The total projected demand for 2000 is 146,548 af and the total projected demand for 2030 is 146,032 af, a difference of only 516 af, or less than one percentage point over the 30-year time frame.

Irrigated agriculture represents the largest demand for water in the study area. Water for irrigation accounts for 81 percent of the total water demand in 2000 and only decreases slightly to 80 percent of the total water demand in 2030. The demand projections for irrigation decline three percent between 2000 and 2030, from 119,186 af to 116,102 af. The Region F Water Planning Group (Freese et al., 2001) notes that the irrigation projections are for dry-year conditions to represent the maximum demand that could be expected, and that during most of the planning period, irrigation demand will probably be less than predicted.

Demand for municipal supplies from 2000 to 2030 are projected to account for a fairly consistent 10 percent of total water demand in the study area. Water for municipalities is the second largest demand category in the study area. Water demand for the larger cities (Pecos, Monahans, Kermit, and for export to Odessa) is projected to increase three percent between 2000 and 2030 (from 13,440 af to 13,823 af); however, demand for the small towns is projected to decrease 12 percent during this same period (from 1,246 af to 1,095 af). Demand for rural domestic water supplies, identified under the WUG name "County-Other," are projected to increase 11 percent over the 30-year planning horizon, and, like the smaller towns, will continue to account for about one percent of total water demand in the study area.

Steam electric power generation is the third largest demand for water in the study area even though this demand is located solely in Ward County. Steam electric water demand is expected to increase 37 percent between 2000 and 2030, from 5,500 af to 8,712 af. Demand for steam electric power generation

in Ward County makes up four percent of the study area total water demand in 2000, but will increase to six percent of the total water demand by 2030.

Mining demand includes water used in both the production of minerals and the production of oil and gas. Oil field flooding is the primary water use that is associated with the production of oil and gas. In 2000, mining demand was the fourth highest category in the study area and accounted for two percent of the total water demand in the area (2,853 af). This demand is projected to decrease by 31 percent (down to 1,783 af) by 2030, at which time it would account for only one percent of the total demand in the area. The majority of use and projected water demand for mining is located in Winkler County.

In 2000, livestock watering accounted for about two percent of total groundwater use in the study area (2,804 af). This demand is projected to remain the same for the next 30-year period, and will continue to account for two percent of study area water demand in 2030.

Demand for manufacturing, water used by industries to produce merchandise or wares, is projected to increase 23 percent in the study area between 2000 and 2030 (from 24 af to 31 af). However, this demand accounts for significantly less than one percent of the total water demand in the study area.

Table 3. Total Water Demand Projections, Trans-Pecos PGMA Study Area

LOVING COUNTY

WUG NAME	CATEGORY	WUG BASIN	YR1996	YR2000	YR2010	YR2020	YR2030	YR2040	YR2050
MENTONE	MUN	RIO GRANDE	6	7	5	4	3	3	2
COUNTY-OTHER	MUN	RIO GRANDE	6	6	6	5	4	4	3
IRRIGATION	IRR	RIO GRANDE	583	582	580	578	576	574	572
LIVESTOCK	STK	RIO GRANDE	54	65	65	65	65	65	65
MINING	MIN	RIO GRANDE	3	3	2	3	3	3	3
			652	**663**	**658**	**655**	**651**	**649**	**645**

REEVES COUNTY

WUG NAME	CATEGORY	WUG BASIN	YR1996	YR2000	YR2010	YR2020	YR2030	YR2040	YR2050
BALMORHEA	MUN	RIO GRANDE	166	97	90	83	76	68	62
PECOS	MUN	RIO GRANDE	2,362	3,030	3,155	3,233	3,291	3,325	3,397
TOYAH	MUN	RIO GRANDE	109	102	102	102	102	102	102
COUNTY-OTHER	MUN	RIO GRANDE	357	773	817	844	867	882	868
IRRIGATION	IRR	RIO GRANDE	100,306	105,831	104,942	104,053	103,164	102,274	101,385
LIVESTOCK	STK	RIO GRANDE	2,103	2,254	2,254	2,254	2,254	2,254	2,254
MANUFACTURING	MFG	RIO GRANDE	1,391	12	13	13	13	14	15
MINING	MIN	RIO GRANDE	213	175	136	116	113	112	115
			107,007	**112,274**	**111,509**	**110,698**	**109,880**	**109,031**	**108,198**

WARD COUNTY

WUG NAME	CATEGORY	WUG BASIN	YR1996	YR2000	YR2010	YR2020	YR2030	YR2040	YR2050
BARSTOW	MUN	RIO GRANDE	289	103	92	80	72	69	67
GRANDFALLS	MUN	RIO GRANDE	194	216	204	187	179	177	179
MONAHANS	MUN	RIO GRANDE	2,642	2,839	2,874	2,819	2,728	2,585	2,495
THORNTONVILLE	MUN	RIO GRANDE	172	164	155	143	134	122	114
WICKETT	MUN	RIO GRANDE	142	218	197	174	168	163	159
COUNTY-OTHER	MUN	RIO GRANDE	509	568	632	673	667	639	597
IRRIGATION	IRR	RIO GRANDE	8,808	11,273	11,136	10,999	10,862	10,725	10,588
LIVESTOCK	STK	RIO GRANDE	94	293	293	293	293	293	293
MANUFACTURING	MFG	RIO GRANDE	5	4	4	5	6	6	7
MINING	MIN	RIO GRANDE	160	635	495	318	231	190	194
STEAM ELECTRIC	PWR	RIO GRANDE	5,749	5,500	6,050	7,260	8,712	10,454	12,545
ODESSA, ECTOR CO.	*MUN*	*RIO GRANDE*	*5,275*	*5,184*	*5,249*	*5,082*	*5,312*	*5,081*	*5,162*
			24,039	**26,997**	**27,381**	**28,003**	**29,364**	**30,504**	**32,400**

WINKLER COUNTY

WUG NAME	CATEGORY	WUG BASIN	YR1996	YR2000	YR2010	YR2020	YR2030	YR2040	YR2050
KERMIT	MUN	RIO GRANDE	1,839	2,387	2,467	2,491	2,492	2,489	2,505
WINK	MUN	RIO GRANDE	334	339	354	360	361	360	363
COUNTY-OTHER	MUN	COLORADO	1	1	1	1	1	1	1
COUNTY-OTHER	MUN	RIO GRANDE	108	147	146	145	143	141	110
IRRIGATION	IRR	RIO GRANDE	0	1,500	1,500	1,500	1,500	1,500	1,500
LIVESTOCK	STK	COLORADO	1	2	2	2	2	2	2
LIVESTOCK	STK	RIO GRANDE	76	190	190	190	190	190	190
MANUFACTURING	MFG	RIO GRANDE	0	8	10	11	12	14	17
MINING	MIN	RIO GRANDE	1,437	2,040	1,779	1,605	1,436	1,360	1,398
			3,796	**6,614**	**6,449**	**6,305**	**6,137**	**6,057**	**6,086**

Notes: **All water demand projections in acre-feet.**
City of Odessa projected water demands from Ward County calculated from percentage of total supply for the city and projected total water demands for the city.

Adapted from TWDB, 2003.

Water Supply

The regional water plan describes current supplies to water user groups based on existing conditions and limitations. All supplies that are presently available to a water user group are identified and quantified. Restraining limitations for surface water supplies may include water rights, contracts, or reservoir yields, and limitations for groundwater supplies may be based on developed well fields and aquifer availabilities. The water supply in the four-county study includes groundwater, surface water from Red Bluff Reservoir, Balmorhea Lake and stock tanks, and wastewater reuse. The total quantity of water suppled in the study area is estimated to be 102,453 acre-feet (af) in 2000, and is not projected to fluctuate by more than one percent between 2000 and 2030. In the study area, groundwater supplies account for, and are projected to continue accounting for almost 84 percent of water usage. Current and projected water supply data by county, water user group, and year for the study area are tabulated in Appendix 2.

In 2000, groundwater supplied an estimated 80,613 acre-feet (af) in the study area. An additional 5,200 af of groundwater was exported from Ward County to the City of Odessa in Ector County. The Cenozoic Pecos Alluvium aquifer is the primary groundwater source, supplying an estimated 76,103 af in 2000 for all uses in the study area, including the export supply for the City of Odessa. Of this 2000 quantity, irrigation use in Reeves County accounted for 56,868 af, or about 75 percent of this supply. Water supply from the Cenozoic Pecos Alluvium aquifer is projected to fluctuate from a high of 70,925 af in 2010, decreasing to 70,748 af in 2020, and back up to 70,762 af by 2030. The Dockum aquifer supplies water in Reeves and Ward counties and is the primary groundwater source in Winkler County. In 2000, the Dockum aquifer supplied 8,534 af of water in the study area, 70 percent of which was supplied for Winkler County uses. Water supply from the Dockum aquifer is projected to increase by about four percent, up to 8,869 af, in 2030. The Edwards-Trinity Plateau aquifer and other, undifferentiated aquifers supplied 1,176 af of water in Reeves County in 2000. This groundwater supply is projected to remain the same through 2030.

Red Bluff Reservoir and releases to the Pecos River supplied 14,451 af of water in 2000 for irrigation in Loving, Reeves, and Ward counties. In 2000, Balmorhea Lake and other surface sources supplied 288 af of water in Reeves County for municipal, rural, and livestock uses; and 12 and 8 af for livestock uses in Ward and Winkler counties respectively. Reuse of surface water for municipal and irrigation purposes is exercised in Reeves and Ward counties. In Reeves County, 689 af of direct reuse is used for irrigation, and in Ward County, 1,200 af of direct reuse is used by the City of Monahans. These surface water and reuse supplies are projected to remain the same through 2030.

Groundwater Availability

In the *Region F Regional Water Plan* (Freese et al., 2001), groundwater availability is based on an assessment of historic water-use practices in the region. For each aquifer, the Region F Water Planning Group used calculations to estimate the quantity of water held in storage, the potential for recharge to the aquifer, and an assessment of the practicality of withdrawing water from the aquifer. The resulting availability was further quantified based on ranges of water quality of less than 1,000 milligrams per liter (mg/l) and 1,000 to 3,000 mg/l total dissolved solids (TDS). The Region F Water Planning Group considered water with TDS concentrations greater than 3,000 mg/l unusable for water supply.

For the *Region F Regional Water Plan*, the available supply from an aquifer was defined as the annual effective recharge to the aquifer plus a portion of water taken from aquifer storage. Based on location and historic aquifer usage, the Region F Planning Area was divided into three groundwater availability categories as follows: 1) areas limited to annual effective recharge only, 2) areas limited to annual

effective recharge plus an annual amount equal to 75 percent of the retrievable storage over 100 years, and 3) areas limited to annual effective recharge plus an annual amount equal to 75 percent of the retrievable storage over 50 years. The four counties in the study area were included in category 3 (recharge plus 75 percent of storage over 50 years). The water planning group noted that for counties with high storage use, the assumptions do not imply that 75 percent of the retrievable groundwater supply will be gone in 50 years, but that the actual quantities of water available on an annual basis would be dependant on previous use. The demands used in the regional water plan analysis were drought-year demands, and that in most years, the demands should be less than predicted thereby reducing the amount of aquifer mining (see Section 3.1, Figure 3-1, and Tables 3-1 through 3-6 in Freese et al., 2001).

Table 4 summaries groundwater availability data from the *Region F Regional Water Plan.* The data indicate that 238,271 acre-feet per year of groundwater with a TDS concentration less than 3,000 mg/l is available in the four-county study area. Of this quantity, 95,332 acre-feet per year (40 percent) is from annual recharge and 142,939 acre-feet per year (60 percent) is from aquifer storage. The Cenozoic Pecos Alluvium aquifer accounts for 58 percent of the available groundwater supply. The Edwards-Trinity Plateau aquifer in Reeves and Winkler counties accounts for 35 percent, and the Dockum aquifer, primarily in Winkler County, accounts for seven percent of the available groundwater supply.

Table 4. Annual Groundwater Availability, Trans-Pecos PGMA Study Area

SOURCE	COUNTY	ANNUAL RECHARGE	ANNUAL SUPPLY FROM STORAGE	ANNUAL AVAILABILITY
CENOZOIC PECOS ALLUVIUM AQUIFER	LOVING	4,320	3,906	8,226
	REEVES	37,800	20,421	58,221
	WARD	7,000	11,304	18,304
	WINKLER	5,000	48,267	53,267
	SUBTOTAL	54,120	83,898	138,018
EDWARDS-TRINITY PLATEAU AQUIFER	REEVES	41,112	41,936	83,048
	WINKLER	0	94	94
	SUBTOTAL	41,112	42,030	83,142
DOCKUM AQUIFER	LOVING	0	860	860
	REEVES	0	3,065	3,065
	WARD	0	2,340	2,340
	WINKLER	0	10,746	10,746
	SUBTOTAL	0	17,011	17,011
OTHER AQUIFER	REEVES	100	0	100
TOTAL		95,332	142,939	238,271

All values are acre-feet per year. Adapted from Freese et al., 2001.

Surface Water Availability

Bodhici et al. (1999) reported that an estimated 34,000 acre feet of water from Red Bluff Reservoir would be available for release each year into the Pecos River through the year 2030. Bodhici also noted that channel losses in excess of 45 percent have been calculated along the river, thus adjusting the amount of surface water available to downstream users down to approximately 18,700 acre-feet per year. In 2001, the Region F Water Planning Group determined that there was insufficient data to perform a meaningful operational study of Red Bluff Reservoir, noted that inflows to the reservoir were controlled by the Pecos River Compact between Texas and New Mexico, and noted that the provisions of the compact had been subject to extensive litigation. The planning group recommended that the *Region F Regional Water Plan* use the average allocation from the reservoir between 1950 and 1987, that being 32,000 acre-feet per year (Freese et al., 2001). Accounting for the 45 percent channel losses along the river, approximately 17,600 acre-feet per year could be available for downstream users. Freese et al. also reported a firm supply from Red Bluff Reservoir of 16,000 acre-feet per year (Table 3-13, 2001). The more conservative estimate of 16,000 acre-feet per year will be used for further purposes of discussion in this report.

In addition to Red Bluff Reservoir, other local surface water sources of 308 acre-feet per year are available in the study area (288 af/year in Reeves County, 12 af/year in Ward County, and 8 af/year in Winkler County). Further, reuse of surface water effluent is practiced in Reeves and Ward counties. Reuse makes an additional 1,889 acre-feet per year available in the two counties (689 af/year in Reeves and 1,200 af/year in Winkler).

For further purposes of this evaluation, the total annual availability of surface water is estimated to be 18,197 acre-feet as shown in Table 5.

Table 5. Annual Surface Water Availability, Trans-Pecos PGMA Study Area

RED BLUFF RESERVOIR	OTHER SURFACE WATER	REUSE	TOTAL ANNUAL AVAILABILITY
16,000	308	1,889	18,197

All values are acre-feet per year.

GROUNDWATER AND WATER SUPPLY CONCERNS ✯✯✯

This section summarizes data and information to evaluate whether the four-county study area is experiencing or is expected to experience, within the next 25-year period, critical groundwater problems. Discussions in this section regard groundwater level declines that may be indicative of aquifer-overdrafting, water quality conditions that may limit usability, instances of surface collapse and subsidence, and water supply concerns. This discussion relies primarily upon previous work by Ashworth (1990), Baumgardner et al. (1982), Boghici et al. (1999), Jones (2001 and 2004) and the *Region F Regional Water Plan* (Freese et al., 2001).

Groundwater Level Declines - Cenozoic Pecos Alluvium Aquifer

Before the 1940s, water levels in the study area did not vary much and any fluctuations were attributed to recharge input to the aquifer system. After 1940, extensive pumpage for irrigation purposes greatly increased groundwater withdrawal rates and led to large water-level declines in the area. After World War II, water-level declines in excess of 200 feet occurred in the irrigation areas of south-central Reeves County, but have moderated since the mid 1970s due to a decrease in irrigation pumpage. From the mid 1970s to late 1980s, continued groundwater declines were observed only along a narrow area of land between the cities of Pecos and Balmorhea. North-central Ward and south-central Winkler counties have experienced historic water-level declines of lesser magnitude. Elsewhere in the study area, water levels have not changed significantly (Ashworth, 1990).

In 1989, depth to the water table ranged from less than 50 feet around the periphery of the aquifer to approximately 300 feet in parts of the irrigated areas of Reeves and Pecos counties. Water levels in the irrigation areas of Reeves County generally exhibit a seasonal fluctuation. Measurements made in 31 wells in early fall of 1988 during the pumping season, and again in the winter, showed an average water-level change of approximately six feet (Ashworth, 1990).

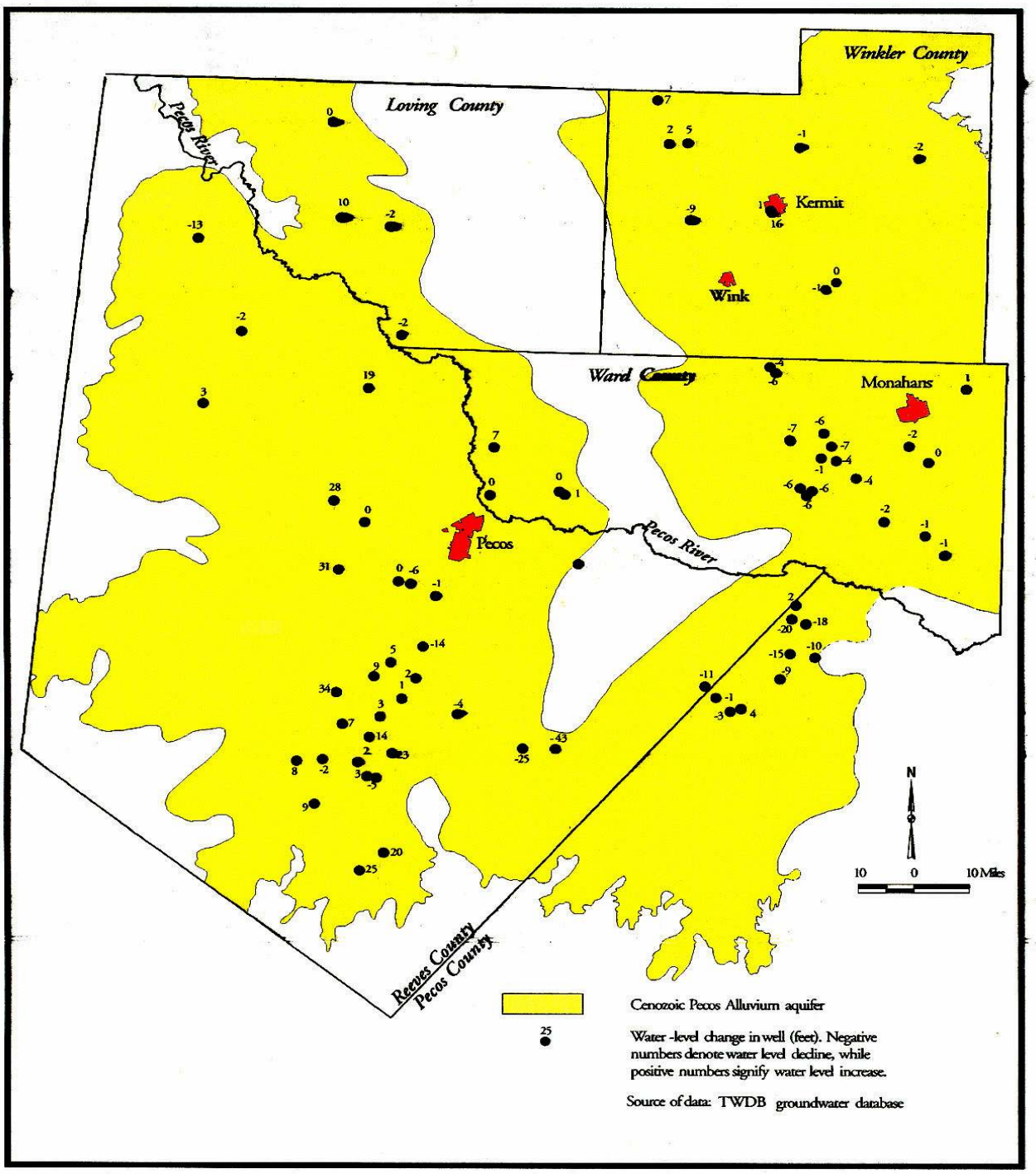
Boghici's 1998 potentiometric map (Figure 4), prepared from water levels measured in 87 wells between January 1997 and February 1998, showed an eastward groundwater flow in the western portion of the study area and a generally southward flow in the northern portion of the area. The 1998 potentiometric map also showed two centers of depression in water levels in the study area: one located southwest of the City of Pecos in the irrigated areas of Reeves County and, the other located south of the City of Monahans in the Coyanosa irrigation area of Pecos and Reeves counties. Hydraulic gradients range from 0.003 in areas with no groundwater development (such as in parts of Winkler and Loving counties) to 0.007 under the irrigated areas of Pecos and Reeves counties. To a lesser extent, some groundwater flow is being diverted toward the public supply and industrial pumping centers southwest of Monahans in Ward County (Figure 2 in Boghici et al., 1999).

Between 1989 and 1998, water levels in many wells located west of the City of Pecos rose by 30 feet and declined by as much as 40 feet in wells located south and southeast of the City of Pecos -- along the Reeves-Pecos county line (Boghici et al., 1999). Water levels in Loving and northeastern Winkler counties were nearly unchanged or had risen slightly (up to 10 feet) during the 1989-1998 time period; continuing a long-term trend of increasing storage because of a reduction in groundwater mining. In Ward County, water levels had declined by an average of five feet southwest of Monahans (Figure 7).

Jones (2004) also reports that 2003 water levels in the aquifer indicate slight recovery in parts of Reeves County that were previously heavily impacted by irrigation pumping. However, in the vicinity of northern Pecos and central Ward counties, declining water levels are evident in the aquifer due to ongoing pumping related to public supply and industrial uses.

Figure 7. Approximate Water-Level Change from 1989 - 1998

(Boghici et al., 1999)



The final report for the TWDB's groundwater availability model (GAM) for the Edwards-Trinity (Plateau) and Cenozoic Pecos Alluvium aquifer systems (Anaya and Jones, 2004) was not completed until after the draft of this report was distributed for stakeholder review and comments. TCEQ has not done a full analysis of input data and assumptions for this GAM. The GAM and final report are not considered in this report's critical groundwater problem determinations. However, TCEQ has reviewed the predictive modeling information in the GAM report. The predictive model runs that are discussed in Anaya and Jones (2004) consider the water demands and recommended water management strategies from the adopted regional water plans. The accuracy and applicability of the model decreases when moving from regional- to local-scale issues because of the information limitations used in model construction and the model cell size that determines spacial resolution. Because of this scale of application, the illustrations of the predictive model runs through 2030 are not sufficient to indicate problematic declines in water levels or decreases in saturated thickness in the Cenozoic Pecos Alluvium aquifer. Anaya and Jones recommend that calibration of the Cenozoic Pecos Alluvium aquifer can be improved by creation of a separate GAM, and model results could be improved by using a smaller grid interval than the one used for the Edwards-Trinity (Plateau) and Cenozoic Pecos Alluvium aquifer systems GAM.

Groundwater Quality Conditions

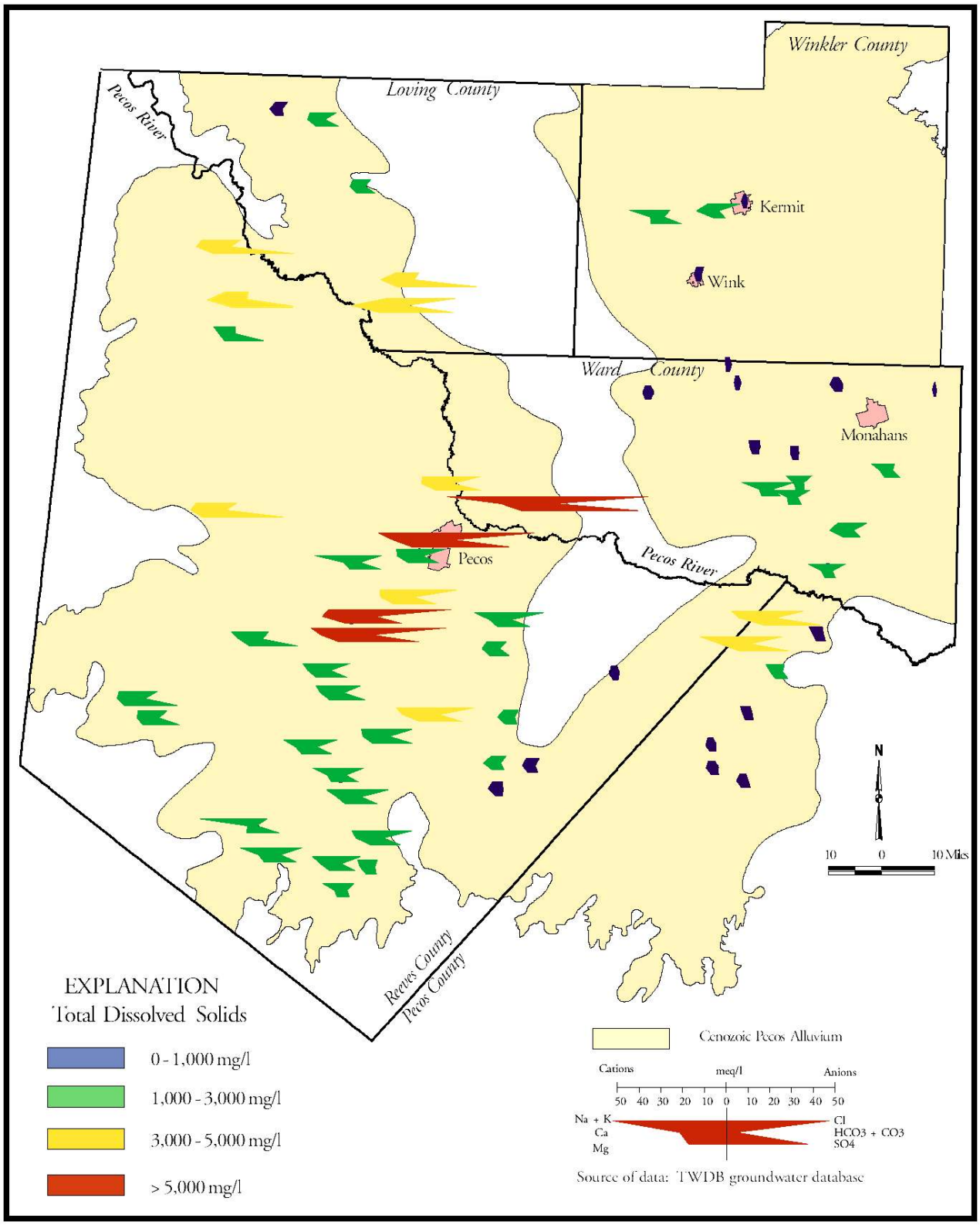
The chemical quality of groundwater in the Cenozoic Pecos Alluvium aquifer is highly variable and changes naturally with location and depth. Water quality in the aquifer is influenced by: 1) presence of evaporite beds in the northern and western part of the Pecos trough which increases the concentration of sulfate in the water, 2) recharge of highly mineralized water by irrigation return flow in south-central Reeves County and the Coyanosa area, 3) concentration by evapotranspiration of shallow mineralized water in the alluvium of the Pecos River valley, 4) saline-water encroachment in areas of heavy pumpage, and 5) local contamination by oil field brine, primarily in Winkler and Loving counties (Ashworth, 1990).

Concentrations of dissolved-solids in groundwater samples obtained from the Cenozoic Pecos Alluvium aquifer ranged from less than 300 milligrams per liter (mg/l) to more than 5,000 mg/l. Sulfate and chloride were found to be the most prominent constituents. The Monument Draw trough contains fresh water (less than 1,000 mg/l), with higher concentrations of dissolved solids in the following areas: 1) Winkler County in an area west of Kermit and north of Wink; 2) Ward County in an area from northwest to southeast of Pyote, an area south of Monahans, and an area north and east of Grandfalls; and, 3) Pecos County in an area consisting of the Coyanosa farming region and extending west to the Pecos River. Groundwater in the Pecos trough generally is poor, ranging from slightly to moderately saline over much of the region. Ashworth (1990) reported groundwater containing dissolved solids in excess of 5,000 mg/l in extreme western Ward County and in the central part of Reeves County south and west of the city of Pecos. Jones (2004) reports the most saline groundwater in the aquifer occurs in shallow wells less than 300 feet deep, and that at greater depths, groundwater salinity is generally uniform.

In 1995, the TWDB collected groundwater samples from 89 wells within the study area and analyzed for major and minor ions, trace elements and radionuclides. Using this data, the TWDB prepared the regional Stiff-diagram map, presented here as Figure 8, to show the general quality of the Cenozoic Pecos Alluvium aquifer. Boghici et al. (1999) reported that the majority of samples collected from wells in Reeves, Loving and western Ward counties contained total dissolved solids (TDS) in concentrations greater than 1,000 mg/l. Most TDS concentrations ranged from 1,000 to 3,000 mg/l. Several samples had TDS concentrations greater than 9,000 mg/l. Groundwater in Winkler, eastern Ward and northwest Pecos counties generally has TDS concentrations less than 1,000 mg/l and appears to be of better quality than in the rest of the study area. In southern Ward County, the groundwater samples had TDS concentrations of

Figure 8. Stiff Diagrams for Selected Groundwater Samples

(Boghici et al., 1999)



1,000 to 3,000 mg/l. Several groundwater samples collected from northwest Pecos County had TDS concentrations in the 4,000 mg/l range.

In 1995, the concentration of at least one analyte in 21 samples was above its maximum contaminant level (MCL) established by the USEPA's National Primary and Secondary Drinking Water regulations. The concentrations of iron in seven samples, manganese in eight samples, selenium in one sample and cadmium in two samples were also found to be above their respective MCLs. Two samples collected from Reeves County had lead concentrations higher than the 1994 USEPA action level and ten samples collected from the same county exhibited gross alpha activities above the USEPA-established MCL. The beta activity in one sample from Reeves County exceeded the MCL of 50 picocuries per liter (Boghici et al., 1999). The alpha- and beta-emitting substances in natural waters are mainly the isotopes of radium and radon (Hem, 1985 in Boghici et al., 1999). These elements are commonly found in volcanic rocks and such rocks are present in southern Reeves County.

The dominant ions detected in groundwater samples from the study area were sulfate and chloride. In 1995, 41 samples collected in the study area exceeded EPA's secondary standards for the constituents sulfate and chloride. Eighty-five groundwater samples collected in 1995 were analyzed for nitrate. Six samples had nitrate concentrations (calculated as NO_3) exceeding the MCL of 44.3 mg/l for nitrate (as NO_3). Five of these samples were collected from near the city of Pecos in Reeves County. The source of nitrate in this area could be the ammonia in the fertilizers that are being applied to irrigated crops. Fifty-two groundwater samples from the study area had a high- to very-high salinity hazard for irrigated croplands and approximately half of these samples exhibiting a medium- to very-high risk for sodium hazard (Boghici et al., 1999).

From a comparison of TDS data collected from twenty wells during 1988/89 and 1995, Boghici et al. (1999) determined that TDS concentrations in 15 samples had not changed much during this time interval. In the remaining samples, TDS concentrations had fluctuated by more than 100 mg/l. The largest increases had occurred in the southeastern portion of the study area in Pecos and Ward counties, and the greatest decrease in northwest Pecos County. However, with few exceptions, the concentrations of selected ions had not changed significantly over time. The concentration of TDS in the aquifer is the primary limiting factor for groundwater use in the study area.

Based on the chemical constituents detected in the water samples, Boghici et al. (1999) identified three general types of groundwater in the study area:

(1) a Na-Ca-Cl-SO_4 type in moderately saline (>3,000 mg/l) wells throughout Loving and Reeves counties and along the Pecos River,

(2) a Na-Cl type observed in several slightly saline (1,000 to 3,000 mg/l) samples in Winkler and Ward counties, and

(3) a Ca-HCO_3 type with a minor SO_4 component, observed in several fresh water (<1,000 mg/l) wells in Winkler, Ward and Pecos counties.

Groundwater quality in the Cenozoic Pecos Alluvium aquifer is dependent on both natural and anthropogenic factors. For example, dissolution of naturally occurring gypsum ($CaSO_4 \cdot 2H_2O$), halite (NaCl) and calcite ($CaCO_3$) contributes to the three types of water described above. Evaporite beds are common in the northern and western parts of the study area and likely contribute to the high SO_4 and Cl concentrations detected in groundwater samples. The Ca-HCO_3 signature observed in type 3 water occurs in parts of the aquifer that overly the Dockum aquifer, a potential source of saline water. The low TDS

water in parts of Pecos and Reeves counties is a product of infiltration through non-reactive quartz sands that occur north and east of the Pecos River.

Recent and historical data suggest that salinization of groundwater in the Cenozoic Pecos Alluvium aquifer is of primary concern in the study area. Decreasing salinity with depth can be attributed partially to evaporation in areas where the water table is shallow. The ion concentrations in types (1) and (2) waters most likely are being increased by input of highly saline irrigation return flow, such as in the Toyah Basin area of Reeves County. Elevated nitrate levels south of the City of Pecos are probably the result of application of fertilizers to cropland in the area.

Fluid exchange between the saline waters of the Pecos River and the aquifer is yet another mechanism by which groundwater in the aquifer becomes more saline. This interaction between river and aquifer is further increased by groundwater withdrawals from wells located near the river, as for example in the Coyanosa area. Groundwater withdrawal alters the hydraulic gradient of the water table and causes saline river water to enter the aquifer, thereby accelerating its degradation. Wells with TDS concentrations higher than 3,000 mg/l are a common occurrence along the Pecos River throughout the study area.

Heavy pumpage may increase groundwater salinity by drawing in poorer-quality groundwater that occurs at depth. Jones (2004) notes increasing salinity observed in three wells in central Ward County that have experienced long-term water-level declines because of municipal pumpage. In this case, declining hydraulic heads in the Cenozoic Pecos Alluvium aquifer with respect to the hydraulic heads in the underlying, poorer-quality aquifers, seem to indicate that increased cross-formational flow has resulted in a detrimental impact to water quality from the increased influx of saline groundwater. Jones notes that this process may also be a contributing factor to elevated salinity in the historic water-level decline area of central Reeves County.

In Winkler County, groundwater quality degradation most likely is the result of the dumping of an estimated 800,000 acre-feet of oil-field brines into unlined pits prior to 1969. The effects of this dumping are evident even today: some wells in the area still produce 1,000 to 3,000 mg/l TDS groundwater (Boghici et al., 1999).

Based on the limited data available to date, it appears that the groundwater quality of the Cenozoic Pecos Alluvium aquifer did not changed much in the 1989 to 1995 time period (Figure 9 in Boghici et al., 1999). With few exceptions, the TDS concentrations detected in groundwater samples collected in 1995 had not changed by more than 10 percent from concentrations detected during the 1989 sampling event. However, the increases in major ion concentrations appear to be primarily associated with areas of active irrigation and municipal pumpage in central Reeves and central Ward counties, respectively. Additional data and analyses would be required to determine if this observation would be typical for the entire extent of the aquifer.

The Texas Groundwater Protection Committee's *Joint Groundwater Monitoring and Contamination Report - 2001* (TGPC, 2002) reports 72 groundwater contamination cases in the study area. These cases have predominantly been documented through regulatory requirements for compliance monitoring or through investigations in response to groundwater contamination complaints. Sixty of the cases are related to activities under the jurisdiction of the Texas Commission on Environmental Quality and include:

- 56 leaking petroleum storage tank cases (34 in Pecos, 13 in Monahans, 6 in Kermit, and 1 each in Balmorhea, Wickett, and Grandfalls);

- 1 pesticide related case (DDT, Dieldrin and Methyl Parathion in Reeves County);
- 2 industry related cases (volatile organic compounds and Varsol solvent in Monahans);
- 1 case of unknown source (Trichloroethene in Kermit).

The remaining 12 cases (seven in Ward County, three in Winkler County, and one each in Loving and Reeves counties) are related to oilfield activities under the jurisdiction of the Railroad Commission of Texas (RCT). Contaminants at these sites are identified as hydrocarbon condensate (five cases); benzene, toluene, ethylbenzene, and xylene (three cases); phase separated hydrocarbons (two cases); and dense phase hydrocarbons and crude oil (one case each). Statewide, groundwater contamination cases under the jurisdiction of the RCT account for less than three percent of the total groundwater cases documented in 2001 (TGPC, 2002); however, in the study area, these cases account for over 16 percent of the documented cases.

Surface Collapse and Subsidence

Six sinkholes have formed in hydrocarbon producing areas of West Texas and New Mexico since 1969. The most recent sinkhole, Wink Sink 2, formed on May 21, 2002 between the cities of Wink and Kermit in Winkler County and is about 750 to 1,000 feet in diameter. This sinkhole is located about one mile south-southwest of "The Wink Sink," the 300-feet diameter sinkhole that developed on June 3, 1980. These recent sinkholes are likely associated with a group of ancient natural dissolution and collapse features that include Carlsbad Caverns and the Clayton Basin in Eddy County, New Mexico, and the San Samone Swale and San Samone Sink in Lea County, New Mexico.

Structurally, most of the study area is within the Delaware Basin except for the eastern parts of Winkler and Ward counties that overlie the Central Basin Platform. Baumgardner et al. (1982) note that evaporites have been dissolving in the Delaware Basin for millions of years and the formation of the Wink Sink is an example of surface collapse and subsidence caused by salt dissolution. A probable precursor of the sinkhole was a solution cavity that migrated upward by successive roof failures, thereby producing a collapse chimney filled with brecciated rock. Dissolution of salt in the Permian Salado Formation is inferred to have produced the solution cavity. Fracture or cavernous permeability occurs above, within, and below the Salado Formation, as indicated by the loss of circulation of drilling fluid in wells drilled near the Winkler County sinkholes.

The two sinkholes in Winkler County and the other natural dissolution and collapse features occur in a bow-shaped trend across West Texas and New Mexico. This trend is coextensive with the subsurface occurrence of the Permian Capitan Reef Complex on the northeast margin of the Delaware Basin. The coincidence of the sinkholes and surface subsidence features with the trend suggests that the reef has facilitated dissolution of overlying and adjacent salt in two ways. Differential compaction of sediments overlying the reef or faults parallel to the reef may have fractured the evaporite section, providing conduits for downward groundwater movement. Also, water under artesian pressure in the reef may have moved upward into salt beds. Hydraulic head of water from the Capitan Reef is higher than the elevation of the Salado Formation but lower than the head in the near-surface Triassic Santa Rosa Formation (Dockum aquifer).

Water from the Capitan Reef is undersaturated with respect to sodium chloride. A brine-density-flow cycle may be operating whereby relatively fresh water moves upward under artesian pressure and dissolves salt and the denser brine moves downward under gravity flow in the same fracture system. However, the downward flow of water from aquifers such as the Dockum or Quaternary sediments above

the salt is a more likely possible explanation for dissolution. The 1982 composition of water in the Wink Sink resembled that of water in nearby wells producing from the Quaternary alluvium and from the Dockum aquifer (Baumgardner et al., 1982).

Oil field activities may also contribute to sinkhole formation by exacerbating natural salt dissolution and removal, through reservoir compaction and subsurface piping, or through a combination of these. At least three sinkholes are spatially associated with the location of drilled boreholes along the Capitan Reef trend. Plugged water supply wells were located within the circumference of two recent sinkholes, Wink Sink 2 and the Jal Sink in Lea County, New Mexico, and a plugged oil production well was located within the circumference of the Wink Sink. About 3,000 feet east of Wink Sink 2, a plugged water supply well is located within an area that has subsided approximately 21 feet and is surrounded by a concentric ring of ground fractures. This area appears to be at a high risk for complete surface collapse in the future.

The wellbores within these localized areas have most likely acted as conduits to allow undersaturated Capitan Reef water to dissolve Salado Formation salt and create an unstable cavern. In addition, corrosion of casing in a borehole or failure of cement plugs could facilitate vertical movement of groundwater and allow undersaturated water to dissolve Salado Formation salt. The surface disposal of approximately 11 billion barrels of undersaturated produced waters in surface pits may have also contributed to subsidence through removal (piping) of unconsolidated sands in the shallow subsurface. This process may be particularly effective when working in conjunction with subsidence as a result of salt dissolution or reservoir compaction.

All of these mechanisms may interact in complicated ways to facilitate the subsurface removal of material. At this time, not enough scientific data is available to positively determine how these processes may have acted alone or in combination to form the Winkler County sinkholes.

Collapse of the land surface at a sinkhole will destroy man-made structures within and near its perimeter, including both surface and subsurface infrastructure. Surface fissures and faults with displacement of up to 10 feet typically encircle sinkholes and can extend in concentric bands out to a radius of two- to three-times the diameter of the sinkhole. Sinkhole collapse or faulting can sever buried utilities such as high-pressure pipelines. Hundreds of miles of pipeline transect West Texas transporting crude oil and product, high-pressure flammable gases (methane), dense volatile liquids (ethane, propane, and mixtures of natural gas liquids), as well as poisonous gases (hydrogen sulfide). In the limited areas where sinkholes actually occur, failure of such pipelines would have immediate consequences for public health and safety. If localized sinkhole formation is preceded by a history of gentle, imperceptible subsidence, then failure of buried utilities might go undetected until leaks or other problems are manifested at the surface.

Sinkholes also pose a significant threat to the environment. A sinkhole is the surface expression of a cavernous void that overlies a near vertical pipe of collapse breccia. The breccia pipe typically comprises a jumble of small to very large unsorted materials that represent a highly permeable conduit for the cross-formation migration of subsurface fluids. The association of sinkholes in West Texas with oil and gas fields allows the possibility that subsurface brine, oil, and gas could migrate to the shallow subsurface or surface. Such migration would result in pollution of underground sources of drinking water and surface waters.

Potential infrastructure impacts and threats to the environment are valid concerns in the limited areas where sinkholes occur. However, little site-specific, scientific data exist to distinguish among the processes that may have contributed to the development of the Winkler County sinkholes, and sufficient data has not been developed to determine if the sinkholes are causing negative impacts to usable quality groundwater supplies in the immediate area.

Water Supply and Strategies to Address Identified Needs

Table 6 summarizes and compares projected water demand, current water supply, and water availability in the four-county study area (Freese et al., 2001). The last column in Table 6 identifies unmet water needs for year 2030 that are not addressed by Region F Water Planning Group recommended water management strategies. The following discussion regarding water supply concerns and identified strategies for each county, and regional strategies in general are summarized from Freese et al., 2001, and TWDB, 2003.

Reeves County

The primary sources of irrigation supply in Reeves County are Red Bluff Reservoir and the Cenozoic Pecos Alluvium aquifer. Water supply from Red Bluff Reservoir depends upon water deliveries from New Mexico governed by the Pecos River Compact and the supply in some years may be curtailed or even eliminated. There are also significant losses in delivery of water from Red Bluff Reservoir to Reeves County. It is likely that this supply will be limited under drought-of-record conditions. In 1997 there was 99,428 acre-feet of irrigation use from the Cenozoic Pecos Alluvium. The estimated annual supply is 56,870 acre-feet. The estimated irrigation needs for Reeves County are 39,164 acre-feet in 2000 decreasing to 36,497 in 2030. No readily available water supplies were identified in the Region F Regional Water Plan (Freese et at., 2001) that could be developed to fully meet all irrigation needs. The Region F Water Planning Group recommended that improved irrigation practices be implemented to maximize benefit of existing supplies. In addition, the Region F Water Planning Group identified precipitation enhancement, brush control programs, and wastewater reuse as potential sources that may be utilized to reduce the unmet irrigation needs. Freese et al. (2001) report that the types of crops presently grown in the region are typically water efficient varieties and that the primary advanced water conservation strategy identified for Region F is irrigation equipment efficiency improvements. The Region F Regional Water Plan provides a detailed analysis of potential irrigation efficiency improvements and that by aggressively utilizing these improvements the unmet irrigation need for Reeves County for 2030 would be reduced to 29,241 acre-feet. Freese et al. anticipate that by 2030, 8,755 irrigated acres will be required to shift to non-irrigation crop production or other uses.

Rural water users in Reeves County (under category of County-Other) may experience small shortages beginning in 2010, and increasing through the planning period. County-Other is currently supplied through sales from the cities of Balmorhea and Pecos, and groundwater from the Cenozoic Pecos Alluvium and Edwards-Trinity (Plateau) aquifers. The Region F Water Planning Group recommends that the identified rural needs can be met through increased sales from the two cities, that no additional infrastructure is needed, and that there is adequate supply from the cities to meet the need.

The main source of water for mining and livestock purposes in Reeves County is the Cenozoic Pecos Alluvium aquifer and there is competition for this limited source with irrigation and municipal user groups. Using the allocation scheme adopted by the Region F Water Planning Group, there is no supply available from this source for mining purposes. Potential mining needs in Reeves County are 175 acre-feet in the year 2000 and 115 acre-feet in the year 2050. The Region F Water Planning Group recommends that using non-potable water from the Cenozoic Pecos Alluvium aquifer will meet the mining demand need. The Region F Water Planning Group did not identify any water management strategies to meet livestock needs of eight acre-feet above projected supplies from the Cenozoic Pecos Alluvium aquifer and other sources through the year 2030.

Table 6. Comparison of Water Demand, Supply, Availability and Identified Needs, Trans-Pecos PGMA Study Area

COUNTY & YEAR	PROJECTED DEMAND	CURRENT SUPPLY			AVAILABILITY				2030 UNMET NEED TYPES
		GW	SW	TOTAL	GW RECHARGE	GW STORAGE	SW	TOTAL	
LOVING									
2000	663	81	324	405	4,320	4,766	324	9,410	IRRIGATION
2010	658	79	324	403					
2020	655	78	324	402					
2030	651	77	324	401					
REEVES									
2000	112,274	62,977	10,087	73,064	79,012	65,422	10,087	154,521	IRRIGATION, LIVESTOCK
2010	111,509	63,252	10,087	73,339					
2020	110,698	63,307	10,087	73,394					
2030	109,880	63,307	10,087	73,394					
WARD									
2000	26,997	10,949	6,221	17,170	7,000	13,644	6,221	26,865	IRRIGATION, LIVESTOCK
2010	27,381	10,956	6,221	17,177					
2020	28,003	10,773	6,221	16,994					
2030	29,364	10,786	6,221	17,007					
WINKLER									
2000	6,614	6,606	8	6,614	5,000	59,107	8	64,115	LIVESTOCK
2010	6,449	6,603	8	6,611					
2020	6,305	6,634	8	6,642					
2030	6,137	6,639	8	6,645					

Notes: **Water demand and supply in acre-feet, availability in acre-feet per year**; GW - groundwater; SW - surface water.
For comparison purposes, surface water supply and availability assumed to be the same.

Loving, Ward and Winkler Counties

Irrigation supply in Loving County comes from Red Bluff Reservoir and water supply from this reservoir depends upon hydrologic conditions in New Mexico and the provisions of the Pecos River Compact. Water supply in some years may be curtailed or, in some cases, eliminated. There are also significant losses in delivery of water from Red Bluff to downstream users. It is likely that this supply will be limited under drought-of-record conditions. However, the Region F Water Planning Group did not identify any water management strategies to meet these shortages during drought-of-record conditions.

The primary source of irrigation supply in Ward County is Red Bluff Reservoir, with lesser supplies produced from the Cenozoic Pecos Alluvium and Dockum aquifers. As above, it is likely that supply from Red Bluff Reservoir will be limited under drought-of-record conditions. Irrigation in Ward County has an estimated need of 5,430 acre-feet in the year 2000 and 4,806 acre-feet in 2030. The Region F Water Planning Group recommended that improved irrigation practices be implemented to maximize benefit of existing supplies. Utilizing the irrigation efficiency improvements referenced above, the unmet irrigation need for Ward County for year 2030 would be reduced to 4,963 acre-feet. Freese et al. anticipate that by 2030, 518 irrigated acres in Ward County will be required to shift to non-irrigation crop production or other uses.

Texas Utilities (TXU) operates a steam-electric plant in Ward County that uses water from the Cenozoic Pecos Alluvium aquifer. There is competition for this limited supply between municipal, mining and steam-electric user groups that may limit expansion of this facility. The need for steam electric water in Ward County is projected to be 6,782 acre-feet by 2050. The Region F Water Planning Group recommends that this demand be met with groundwater supplies from Winkler County, which has sufficient water supplies to meet the needs of the county. Freese et al. (2001) estimate that approximately ten new wells and a 30-inch transmission line will be needed to meet the need, and that the well field should be within ten miles of the power plant. Freese et al. note that there should be minimal impacts to water resources in Winkler County since there is available supply in the aquifer.

In addition, the Colorado River Municipal Water District (CRMWD) is pursuing additional water resources to improve the quantity and quality of their water supplies. One strategy CRMWD is considering is the development of a Cenozoic Pecos Alluvium aquifer well field in Winkler County, and CRMWD's preliminary studies indicate this potential well field could produce 6,000 acre feet of water per year. If developed, this water would be pumped about 45 miles directly to the City of Odessa.

In recent years the primary source of water for mining purposes in Ward County has been the Cenozoic Pecos Alluvium aquifer. There is competition for this limited source among municipal, steam-electric and mining user groups. Using the allocation scheme adopted by the Region F Water Planning Group, there are no supplies from this source remaining for mining purposes. Potential needs are 635 acre-feet in the year 2000 and 194 acre-feet in the year 2050. Again, the Region F Water Planning Group recommends using non-potable water from the Cenozoic Pecos Alluvium aquifer to meet the mining demand need.

For Ward and Winkler counties, the Region F Water Planning Group did not identify any water management strategies to address unmet livestock needs through the year 2030. The main source of livestock water in the two counties is the Cenozoic Pecos Alluvium aquifer, and shortfalls of water for this use are projected through 2030 to be six acre-feet in Ward County, and three acre-feet in Winkler County.

Other Generally Recommended Strategies

The *Region F Regional Water Plan* (Freese et al., 2001) identified several water management strategies that may be implemented to reduce or offset unmet needs. These general strategies include making full use of available treated effluent, precipitation enhancement, brush control programs, and recharge enhancement. Advanced water conservation technology has been factored into the regional and state water plan water demand projections (Table 3). For municipal use, assumed reduction in per capita use is the result of implementation of the State Water-Efficiency Plumbing Act, water conservation programs promoted by state and federal regulations, and the increasing cost of water. The manufacturing projections assume that manufacturing use per unit of output will be reduced over time due to improvements in technology and other water conservation efforts, and irrigation use is expected to decrease approximately one percentage point per decade based on more efficient irrigation systems. If the expected conservation is not achieved, then the water needs identified in the plans may be greater than projected.

Water reuse is the intentional use of treated wastewater effluent for a beneficial purpose that takes the place of potable or raw water that would otherwise be used. Common uses for wastewater effluent include irrigation, fire protection, and cooling-tower circulation. Reuse of wastewater can provide a drought resistant source, increases with economic and population growth, and provides an alternative source when high-quality water is not required. In the study area there are 12 publicly-owned facilities and industrial wastewater treatment facilities that generate wastewater effluent (five in Reeves Co., five in Ward Co., and two in Winkler Co.). Nine of the 12 facilities presently reuse effluent for agricultural or city landscape irrigation. The other three facilities manage effluent through evaporation or percolation. Since 75 percent of the study-area facilities presently utilize wastewater reuse, the remaining wastewater effluent from the other three facilities could provide only a very limited alternative supply in the study area.

Weather modification is defined as an attempt to increase the efficiency of a cloud to yield more water as precipitation. Hail suppression and rainfall enhancement are common forms of weather modification. Two weather modification programs are ongoing in the Region F Water Planning Area; CRMWD has a permit to operate in a 14-county area along the Colorado River, and the West Texas Weather Modification Association (WTWMA) by the City of San Angelo and seven groundwater conservation districts has a permit to operate in an eight-county area on the Edwards-Trinity Plateau. Research has suggested increases of 15 percent or more of rainfall in areas participating in weather modification, however, local experience has shown increases of 27 percent. Other methods of measuring the effects of rainfall enhancement have shown other positive benefits such as increased dryland farm production. Continuation, enhancement, or expansion of these programs could increase surface runoff to reservoirs, reduce irrigation demands, and increase recharge to aquifers.

Brush control was identified as a preferred management strategy to increase groundwater recharge and stream flows. The Region F Water Planning Group estimated that one acre-foot of water is lost annually for every ten acres of brush. Research for the Pecos River Ecosystem Project indicates that invasive saltcedar trees along the Pecos River may use as much as 7.7 acre-feet of water per acre per year. After three years of herbicide treatment along 120 miles of the river, Texas Cooperative Extension (TCE) range specialists estimate that about 3,500 acres of saltcedar have been cleared. TCE estimates indicate that saltcedar control has salvaged more than 36,000 acre-feet of water in the Pecos River. As more saltcedar is controlled, TCE reports up to 6,300 acres by June 2003, potential water savings are estimated to increase to 48,000 acre-feet. Using helicopters, satellite guidance and other technology to minimize drift, the TCE applies the slow-acting herbicide annually in September, and, by the following spring, more than 90 percent of the saltcedar trees die of root kill. To date, the entire spray project encompasses

nearly one-third of the river's length in Texas plus the Red Bluff Reservoir area and portions of some Pecos River tributaries. The initial phase of the treatment is targeted for a 2004 finish, with a second phase starting in 2006 - 2007 dedicated to pretreatment debris removal. Because saltcedar pumps salts from the ground, through the plant, and deposits them in the soil, saltcedar treatment also helps control salinity in the river (http://agnews.tamu.edu/dailynews/stories/RNEC/Feb2503a.htm, July 20, 2003). Administration of the Pecos River Ecosystem Project is discussed in further detail in the next section of this report.

Recharge enhancement is the process whereby surface water is purposefully directed to areas where permeable soils or fractured rock allow rapid infiltration of the water into the subsurface to increase localized groundwater recharge. Recharge enhancement includes any man-made structures to impede or hold surface water to increase the probability of aquifer recharge. The Region F Water Planning Group utilized a layered GIS approach considering the most likely recharge parameters to give an initial indication of areas that may be suitable for recharge enhancement projects. Through this effort, large areas of Loving, Reeves, Ward and Winkler counties were identified as having a high to moderate potential for recharge sites (Figure 5-8, Freese et al., 2001). Topography, drainages, soil properties, and the extent and hydraulic characteristics of aquifer outcrops on a local scale would need to be evaluated to determine final site selection. Consideration should also be given to potential reduction of surface water runoff and how that may affect existing reservoirs. Freese et al. opined that the applicability of aquifer storage and recovery (ASR), the practice of placing surface water into an aquifer from which it can later be recovered, in Region F is generally limited by the lack of excessive seasonal surface-water supplies that could be applied to a groundwater storage facility.

In addition, the *Region F Regional Water Plan* noted that removing salts from groundwater and surface water has the potential to improve existing supplies and make new supplies available. There are two basic approaches to removal of salt. One is to control the amount of salt entering the water resource (chloride control projects) and the second is to remove salts before use (desalination). Upriver from the study area in New Mexico, the U.S. Bureau of Reclamation implemented a chloride control project in the 1960s at Malaga Spring. The saline spring from the Rustler aquifer was diverted into a small earth depression where 120,000 gallons of water were deposited each year for about five years. However, the project was abandoned because there was no market for the salt concentrate. At present, the Red Bluff Power Water Control District is working with the states of New Mexico and Texas, the Pecos River Compact Commission, and a private company to start pumping the spring again. The Pecos River Compact Commission noted that resuming the Malaga operation would reduce the river's salinity by 300 tons per day, but farmers in Texas could lose as much as 600 acre-feet of water per year because of the project. The Red Bluff Power Water Control District would benefit from the project because water quality of the Pecos River inflowing into the reservoir would be enhanced, and because a portion of the revenue generated by the sale of the removed salt would go to the District.

Information about brackish groundwater was not readily available during the 2001 regional water planning cycle. Since then, a LBG Guyton report (2003) on the subject notes that the Cenozoic Pecos Alluvium aquifer contains significant volumes of brackish groundwater, especially in the Pecos trough. Previous estimates have put the brackish groundwater reserves in the aquifer at tens of millions of acre-feet. Where available, the productivity of brackish sections of the aquifer should be good and wells should be relatively easy to install and fairly productive. The use of this readily available brackish water supply is a strategy to address unmet needs, especially unmet needs for mining purposes. It is anticipated the Region F Water Planning Group will reevaluate this source of additional water supply, and other desalination opportunities, during the 2006 planning cycle.

Lastly, the Railroad Commission of Texas (RCT) has regulatory authority over activities that may have contributed to the formation of the Winkler County sinkholes. Present RCT regulatory actions regarding this issue are discussed in the next chapter. However, longer-term RCT strategies are presented here.

The RCT convened a sinkhole workshop in Midland, Texas on April 28, 2004 that was attended by about 70 people including oil and gas company officials, research scientists and hydrologists, members of state and local government, and landowners. The purpose of the workshop was to discuss problems associated with sinkholes; to stress the need for a common, integrated solution; and, to discuss ideas for methods to better understand the processes that are forming the sinkholes in order to reduce risk to public health and safety and the environment (TRC, 2004). Cost-effective preventative measures can be implemented when it is known how sinkholes form. Therefore, a specialized research program is needed to clearly identify natural and man-induced processes that contribute to sinkhole formation, and to identify processes to arrest or impede sinkhole development where possible.

Several different methods or programs could be used to identify active processes and help RCT insure activities under its jurisdiction do not contribute to the sinkhole-forming process. Regional, satellite-based remote-sensing methods and regional digital elevation modeling may serve as an early warning detecting system to identify precursor subsidence patterns that precede imminent sinkhole development. New seismic techniques also have the sensitivity to detect shallow subsurface features such as caverns that could develop into sinkholes. Magnetotelluric or gravimetric methods might be able to image subsurface voids. A shallow boring program around actual sinks and subsiding areas might help identify pertinent subsurface conditions such as void geometry, orientation, bulking factor, and fracture distribution. At this time, the RCT has not evaluated how it will promote subsidence monitoring over subregional areas, and the necessary funds to evaluate the problem are not presently available. However, state and local leadership, The University of Texas at Austin Bureau of Economic Geology, and The University of Texas Permian Basin Center for Energy and Economic Diversification have indicated willingness to partner with the RCT to try to find solutions to surface collapse and sinkhole threats (TRC, 2004).

EXISTING WATER PLANNING, REGULATORY AND MANAGEMENT ENTITIES ☆☆☆

In evaluating the need for groundwater management, it is important to examine the efficiency of existing institutions in managing, planning, and regulating groundwater use. If existing entities can effectively develop and implement groundwater management and protection strategies, new entities may neither be necessary nor desirable. However, if such entities do not exist, or if an existing entity does not implement its programs consistently, or does not have sufficient authority, then alternatives may need to be considered.

Several major groups of entities can be considered in the evaluation of groundwater management. These include government entities, authorities and planning groups, water suppliers and water users. Entities that may be involved with groundwater regulatory or management activities include local municipalities; counties; state and federal government; regional planning authorities and commissions; regional surface water and groundwater management authorities; regional, municipal, and private water suppliers; and major agricultural, industrial and commercial water users.

Federal and Interstate Programs

The U.S. Environmental Protection Agency (USEPA), U.S. Department of Agriculture (USDA), and U.S. Nuclear Regulatory Commission are federal agencies responsible for enforcing numerous federal laws for protecting groundwater resources. Generally, these agencies have delegated the administration of federal regulatory programs to individual states, or occasionally to local authorities. For example, the USEPA which has authority over the federal Resource Conservation and Recovery Act; the Comprehensive Environmental Response, Compensation and Liability Act; the Clean Water Act; the Safe Drinking Water Act; and the Federal Insecticide, Fungicide and Rodenticide Act has delegated administration of these programs in Texas to the TCEQ.

The USDA administers numerous programs at the local level to protect and conserve water resources. The USDA Farm Service Agency's Conservation Reserve Program (CRP) undertakes to reduce soil erosion and sedimentation in streams and lakes, improve water quality, establish wildlife habitats, and enhance wetland resources. The CRP encourages farmers to convert highly erodible cropland or other environmentally sensitive areas to vegetative cover such as native grasses. The USDA Natural Resource Conservation Service (NRCS) provides technical assistance to landowners, communities, and local governments in planning and implementing conservation programs. The USDA/NRCS's national Farm*A*Syst and Home*A*Syst programs promote voluntary assessments to prevent pollution. Step-by-step worksheets allow individuals to apply site-specific management practices to their property.

The NRCS Environmental Quality Incentives Program (EQIP) provides cost share and/or incentive payments to farmers and ranchers for applying conservation practices on their land. The program is designed to address both locally identified resource concerns and state priorities. The EQIP is a voluntary conservation program that supports production agriculture and environmental quality as compatible goals. Through EQIP, farmers may receive financial and technical help with structural and management conservation practices on agricultural land. EQIP may pay up to 75 percent of the costs of eligible conservation practices. Incentive payments may be made to encourage a farmer to adopt land management practices, such as nutrient management, manure management, integrated pest management, and wildlife habitat management.

The Pecos River Compact Commission (PRCC) is authorized by Chapter 42 of the Texas Water Code. The Pecos River Compact was ratified by the legislature in Chapter 30, Acts of the 51st Legislature, Regular Session, 1949. The compact was signed by representatives of Texas, New Mexico, and the

United States on December 3, 1948. The compact allocates the waters of the Pecos River between the two states and establishes an interstate Pecos River Commission to administer the compact. The PRCC protects Texas' rights and interests under the compact and works to implement programs to increase the quantity, improve the quality, and improve the economic development of the water available to Texas.

Developing and communicating saltcedar control methods to conserve water is among the objectives of the Rio Grande Basin Initiative (RGBI) which is administered in Texas by the Texas Water Resources Institute (TWRI). The RGBI is funded through the USDA Cooperative State Research, Education, and Extension Service. A joint effort of the Texas A&M University System Agricultural Program and the New Mexico State University College of Agriculture and Home Economics, the RGBI is focused on research and Extension activities to facilitate efficient irrigation for water conservation. Texas Cooperative Extension (TCE) research specialist and county agents also work on the Pecos River Ecosystem Project. This project was organized in 1997 to address ways to control saltcedar along the Pecos River. The group is composed of state and federal agencies, irrigation districts and water systems in the region, and is administered by the Upper Pecos Soil and Water Conservation District. Funding for the project has been provided by area water and irrigation districts and a $1 million grant from the Texas Department of Agriculture.

State Water Planning and Regulatory Programs

State agencies do not have authority to manage or regulate groundwater resources. The roles of state agencies in addressing the problems and concerns identified in the study area are limited to water quality protection primarily through the regulation of waste management, water resource planning and project funding, and facilitation of groundwater management activities through the creation and limited oversight of groundwater conservation districts.

Water planning efforts at the state level are the responsibility of the TWDB which prepares a statewide water plan using information provided by regional stakeholders and other state water agencies. The TWDB has established 16 regional water planning areas covering the entire state, and a regional water planning group (RWPG) in each of these areas. Each regional water planning area, through its RWPG, is responsible for obtaining local input and developing a regional water plan. The study area is in the 32-county Region F Water Planning Area. The *Region F Regional Water Plan* (Freese et al., 2001) was adopted and submitted to the TWDB prior to January 5, 2001, and incorporated into the 2002 State Water Plan, adopted by the TWDB on December 12, 2001 (TWDB, 2002).

In addition to its water planning responsibilities, the TWDB collects and analyzes data to support its planning functions, and administers water development funds under state and federal programs. Water development funds generally are available as low interest loans and some as grants to local and regional governments for water supply and wastewater planning, feasibility, and infrastructure development. TWDB financial assistance may be provided only to water supply projects that meet needs in a manner that is consistent with an approved regional water plan. In addition, the TCEQ cannot issue a water right for municipal purposes unless it is consistent with an approved regional water plan.

Other state agencies such as the TPWD, TCEQ, Railroad Commission of Texas, Texas Department of Health, Texas Department of Agriculture, Texas Department of Licencing and Regulation, and the Texas State Soil and Water Conservation Board have management or regulatory responsibilities for activities related to environmental protection (TGPC, 2001). TPWD is the state agency with primary responsibility for protecting the state's fish and wildlife resources. The TCEQ is the state's primary environmental regulatory agency. TCEQ administers the supervision program for public drinking water systems and has primary responsibility for public water system aspects of the federal Safe Drinking Water Act. Among its

other regulatory authorities are surface water rights permitting; creation and supervision of water districts; industrial, municipal and hazardous waste management; and water quality protection. State law, however, does not provide the TCEQ or any other state agency the authority to manage or control groundwater pumpage and use.

The Railroad Commission of Texas (RCT) has regulatory authority over activities that may have contributed to the formation of the Winkler County sinkholes described in the preceding chapter. Stated RCT goals regarding this local issue include: 1) insuring that activities under RCT jurisdiction do not contribute to natural conditions or processes that cause salt dissolution and sinkhole formation; 2) understanding sinkhole-forming processes to better design preventive regulatory procedures; and 3) minimizing impact of sinkholes on public health and safety, the environment, and infrastructure through a proactive monitoring of surface conditions. The RCT has identified areas of Winkler, Ward, and Pecos counties as susceptible for the development of sinkholes and started a process to identify wells and processes that constitute the greatest risk of contributing to salt dissolution problems. RCT now requires mechanical integrity testing of all water supply wells in this three-county area. If the water supply wells cannot demonstrate mechanical integrity, further testing is required to evaluate if salt dissolution has occurred and, if it has, its extent and the threat of surface subsidence. In addition, more stringent plugging requirements are being implemented in this area to insure the Salado Formation salt and the Capitan Reef are isolated when wells are plugged and abandoned (TRC, 2004).

Regional Institutions

Besides the Region F Water Planning Group, other regional planning and water supply authorities to be considered in evaluating groundwater management activity include some water districts, river authorities, and surface water management authorities. There are six active water districts within the study area: Loving County Water Improvement District No. 1, Reeves County Water Improvement Districts Nos. 1 and 2, Ward County Irrigation District No. 1, and Ward County Improvement Districts Nos. 2 and 3. These water districts manage surface water drainage, flood control, irrigation, and wholesale untreated supplies. All of these districts except Reeves County Water Improvement District No. 1 are members of the Red Bluff Power Water Control District which oversees surface water use in the Loving-Pecos-Reeves-Ward county area and works to provide equitable distribution of the water supplies from Red Bluff Reservoir.

The Upper Pecos Soil and Water Conservation District (SWCD) No. 213 was organized in 1943 and includes all of Loving, Winkler, and Ward counties and parts of Reeves and Pecos counties. SWCD programs and plans inventory the land and water resources, describe physical and socio-economic conditions bearing on the land and its use, and identify conservation problems. Each local SWCD develops a long-range program and plan of work and an annual plan of operations which guides the district in solving its conservation problems. These district programs and plans of work are updated regularly to recognize and evaluate changes in agriculture, economy and natural resources. With appropriate education, landowners recognize the desirability of implementing suitable management practices to conserve natural resources. Farmers and ranchers desiring to use a conservation program on their land receive assistance from their local district. The landowner's interest and the district's commitment of assistance is formalized by both parties signing a cooperative agreement to implement conservation best management practices. A conservation plan, which may include or be classified as a water quality management plan for each individual farm or ranch, is then developed. The Upper Pecos SWCD No. 213 includes approximately 1,600 landowners or operators with about 3,175,000 acres of land. The District has assisted 403 cooperators and approved conservation plans for 1,637,000 acres of land (http://www.tsswcb.state.tx.us/swcd/factsheets/213.pdf; August 13, 2003).

The Colorado River Municipal Water District (CRMWD) was authorized by the 51st Texas Legislature in 1949 for the purpose of providing water to the cities of Odessa, Big Spring, and Snyder. The CRMWD also has contracts to provide specified quantities of water to the cities of Midland, San Angelo, Stanton, Robert Lee, Grandfalls, Pyote, and Abilene. The CRMWD owns and operates Lake J. B. Thomas, the E. V. Spence Reservoir, and the O. H. Ivie Reservoir. Additionally, CRMWD operates five well fields for water supply. Three of these fields were developed by the member cities prior to 1949 and the fourth field, located in Martin County, begin delivering water in 1952. The fifth field, located in Ward County southwest of Monahans, can supply up to 28 million gallons of water per day. The District primarily uses these well fields to supplement surface water deliveries during the summer months. The CRMWD also operates a "diverted water" supply system. The primary function of this system is to prevent the highly mineralized low flow of the Colorado River and Beals Creek (a tributary to the Colorado River) from reaching the Spence Reservoir. The system delivers this highly mineralized water to oil companies for use in oil field secondary recovery operations.

The study area is part of the 16-county Permian Basin Regional Planning Commission (PBRPC). The PBRPC was founded for purposes of solving area-wide problems through promoting intergovernmental cooperation and coordination, conducting comprehensive regional planning, and providing a forum for the study and resolution of area-wide problems. Through this regional council, individual governments may combine their resources and talents to meet challenges beyond their individual capabilities. Such councils of government (COGs) are political subdivisions of the state and are basically planning and funding distribution agencies with no independent regulatory authority. Among numerous other responsibilities, COGs may make recommendations concerning recreational sites, public utilities, and water supplies. State law mandates that COGs have primary responsibility for the development of regional municipal solid waste plans. Regional solid waste plans must conform with the state plans and are adopted by TCEQ rule.

Local Government and Water Purveyors

Counties and municipalities typically carry out public health programs such as disposal of municipal solid waste; production, distribution, and protection of public drinking water supplies; and treatment and discharge of municipal wastewater. Local government can also accomplish other activities such as regulating underground storage tanks, implementing wellhead and source water protection programs, inspecting and regulating septic tanks, and public-health administration. Texas Water Code, Section 26.177 describes some of the duties of cities in the area of water pollution control and authorizes cities to adopt and implement water pollution abatement plans.

Local water suppliers include municipalities, water supply corporations (WSC), water supply districts, and water improvement and irrigation districts. Wholesale and retail water suppliers are required to prepare and adopt drought contingency plans under TCEQ rules (Title 30, Texas Administrative Code, Chapter 288). These plans are to be implemented during times of water shortage or drought and usually address a variety of measures to reduce peak demands and to extend existing water supplies or identify alternative water supplies.

The TCEQ's public water system database lists 21 active public water supply systems in the study area. Some of the water purveyors in the study area include the cities of Balmorhea, Toyah, Pecos, Barstow, Grandfalls, Monahans, Pyote, Wickett, Kermit, and Wink; Balmorhea Lake Water System; Madera Valley Water Supply Corporation (WSC); Southwest Sandhills WSC; and the Texas Parks and Wildlife Department's Balmorhea and Monahans Sandhills State Parks. Six of the public water supply systems including the cities of Pecos, Barstow, Grandfalls, and Kermit, and the Madera Valley and Southwest

Sandhills WSCs have TCEQ-certificated service areas within the study area. The location of public water supply wells are shown on Figure 9.

The Local Government Code, §§212.0101 and 232.0032 provide permissive groundwater availability certification authority to all municipal and county platting authorities in the state. Under this statute, a municipal platting authority or county commissioners court may require a person submitting a plat for the subdivision of a tract of land for which the intended source of water supply is groundwater under that land to demonstrate that adequate groundwater is available for the proposed subdivision. If groundwater availability certification is required by the local platting authority under the Local Government Code, the plat applicant must evaluate groundwater resources and prepare the availability certification pursuant to TCEQ rules. The rules establish the appropriate form and content of a groundwater availability certification and have been adopted as Title 30, Texas Administrative Code, Chapter 230.

Municipalities have authorities for the protection of public health but are not directly authorized to manage or regulate groundwater withdrawals. Municipalities and other water suppliers can indirectly limit groundwater withdrawals by implementing and enforcing water conservation programs and securing and developing alternative supplies. Municipal and county groundwater availability authority under the Local Government Code can be an effective groundwater management tool in areas undergoing significant growth and development. However, this management tool is limited because it only addresses platted areas that are being subdivided and does not allow for aquifer-wide or regional considerations.

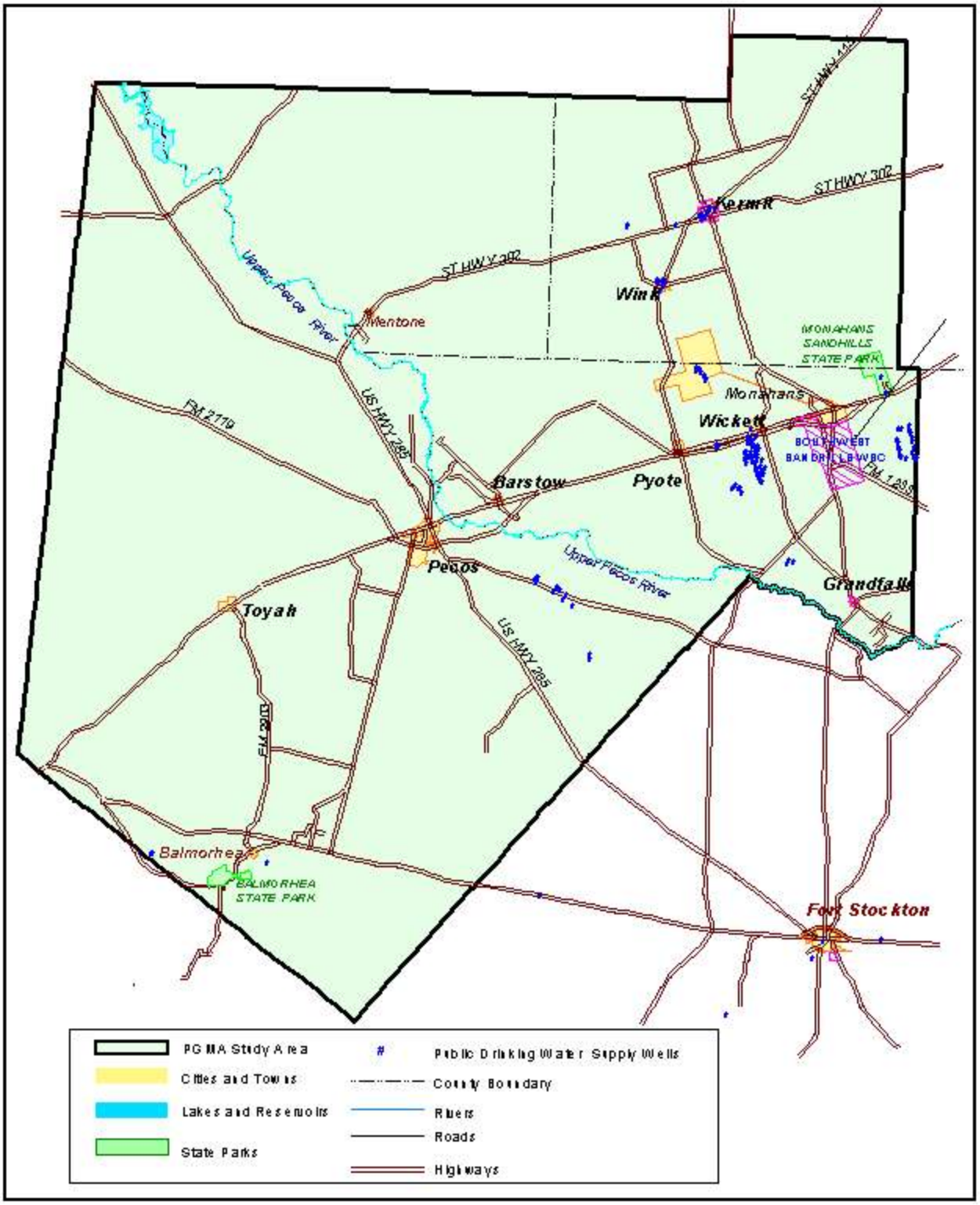
Groundwater Conservation Districts

Groundwater conservation districts (GCDs) are statutorily charged and authorized to manage groundwater resources by providing for the conservation, preservation, protection, recharging, and prevention of waste of the groundwater resources within their jurisdictions. In addition to groundwater management planning as outlined below, GCDs manage groundwater resources by adopting necessary rules to implement management plans; requiring permits for drilling, equipping, or completing wells that produce more than 25,000 gallons per day or for alterations to well size or well pumps; and requiring records to be kept of the drilling, equipping, and completion of water wells, as well as on the production and use of groundwater resources.

State law has prioritized the importance of a groundwater conservation district's management plan to guide district operations and activities. Texas Water Code, Chapter 36 outlines the general contents of a GCD's locally developed and adopted management plan and requires coordination to develop the plan with surface water entities on a regional basis. Chapter 36 also requires that a groundwater district's TWDB certified management plan must be submitted to and considered by a regional water planning group in development of the region's water plan.

Groundwater conservation districts are authorized to manage groundwater resources by adopting rules and permit requirements for the spacing of water wells, regulating the production of wells, and for transferring groundwater out of the district. These districts may also undertake projects to recharge aquifers; survey, monitor, evaluate, and research groundwater quantity and quality; and protect groundwater quality by adopting well construction standards more stringent than state standards and requiring the closure of abandoned water wells. No other such entities are authorized with these broad powers to manage groundwater resources. No GCDs have been established in the four-county study area.

Figure 9. Public Water Supply Wells, Trans-Pecos PGMA Study Area



Under Texas Water Code, Chapter 36, groundwater conservation districts must file district creation confirmation election results and register their board of directors with the TCEQ. Groundwater conservation district management plans are also subject to a certain level of state agency oversight. Chapter 36 requires that GCD management plans (and subsequent amendments to the plans) be submitted to the TWDB for administrative certification and outlines procedures for the TWDB's certification of the plans. The TWDB management plan certification rules are contained in Title 31, Texas Administrative Code, Chapter 356.

Groundwater conservation district implementation of management plans is also subject to review by the State Auditor's Office (SAO) under the direction of the Legislative Audit Committee. The SAO is authorized to conduct a review of district activity and performance under its certified management plan one year after the plan has been certified by the TWDB. Subsequent SAO district management plans audits may be conducted every seventh year thereafter. The SAO reports it findings to the Legislative Audit Committee and to the TCEQ.

The TCEQ is required to initiate certain enforcement actions (outlined in Subchapter I, Chapter 36, Texas Water Code) if a GCD fails to submit a management plan to the TWDB or fails to receive certification of its management plan from the TWDB. The TCEQ is also required to initiate enforcement action if the SAO reports that a district is not actively engaged in achieving the objectives of its management plan or if the district is not operational. The TCEQ district management plan noncompliance review rules are adopted in Title 30, Texas Administrative Code, §293.22.

ADMINISTRATIVE FEASIBILITY OF GROUNDWATER MANAGEMENT ✯✯✯

The feasibility of managing groundwater resources within the study area is presented within this section. Groundwater management approaches that can be utilized by groundwater conservation districts are evaluated. Area-specific groundwater management strategies, economic and financial considerations, and available district-creation options are discussed below. At present, no groundwater conservation districts exist in the four-county study area.

Groundwater Management Approaches

Various mechanisms are available for protecting groundwater resources in an area. They range from imposing restrictions on groundwater withdrawals to developing alternate supplies, to conjunctively using both surface water and groundwater. Regulating groundwater withdrawal can prolong the life of an aquifer and increase land value by assuring a reliable supply of water for future use and economic development.

Local or regional groundwater conservation districts (GCDs) are the state's preferred method of managing groundwater resources, and are the only entities in Texas explicitly granted the power to regulate groundwater withdrawals. These districts are charged with managing groundwater by conserving, preserving, protecting, recharging, and preventing wastage of the groundwater resources within their jurisdiction. The GCD approaches or techniques for managing groundwater include:

- water resource planning;
- groundwater resource assessment and research;
- monitoring of water levels, water quality and land subsidence;
- well inventory, registration, permitting and closure;
- limiting withdrawals through well spacing or setback requirements;
- well pumpage or use limitations; and
- use of engineered structures or injection wells to enhance natural recharge or artificially recharge groundwater aquifers.

Through groundwater monitoring (both quantity and quality) and assessment functions, a GCD can quantify groundwater resources, study and investigate aquifer characteristics, and identify groundwater problems that need to be addressed. Planning functions outline appropriate management objectives and goals for the district to preserve and protect groundwater resources and GCD rules are adopted to achieve the management planning objectives and goals.

Groundwater conservation districts are required to establish water well permitting and registration programs and through these programs, can quantify aquifer impacts from pumpage. An efficient water well inventory, permitting, and registration program allows a GCD to establish an overall understanding of groundwater use and production within the district. This water well and water use data provides the scientific bases for a GCD to development aquifer-specific permit requirements that protect well owners. Permits must be obtained from the district to drill, equip or complete wells, or to substantially alter the size of wells or well pumps. Certain types of water wells are exempted from GCD permitting. These exempted wells generally include wells incapable of producing 25,000 gallons per day on tracts of land larger than 10 acres and wells supplying water for exploration, production, and other activities permitted by the Railroad Commission of Texas. Wells exempted from regulation by a district must, however, be completed and maintained in accordance with the district's rules regarding prevention of waste and pollution of the groundwater, and must be registered with the district before being installed.

Groundwater conservation districts may also adopt rules to regulate the spacing and production of water wells. Spacing regulations are generally adopted by a district to minimize drawdown of water levels (both water table and artesian pressure), control subsidence, prevent waste, and prevent interference from other nearby wells. Spacing and production regulations are commonly based on minimum distances from other wells or property lines, a maximum number of wells in a specified area of land (e.g., ¼-section, ½-section, or full-section), or a maximum allowable production per a given unit of land (e.g., 5 gallons per minute per acre or 1 acre-foot of production per year per acre of land).

Groundwater conservation district management activities can include protecting water quality by regulating water well construction and ensuring proper well closure and actively identifying and closing abandoned wells. Districts may also implement activities such as recharge enhancement projects or use-efficiency services to enhance natural recharge, decrease groundwater usage, and increase groundwater supplies. Other important GCD management programs include water conservation and public education efforts and providing conservation assistance through loan and grant programs.

Other types of regional, county, or local governments do not have the statutory authority to regulate groundwater production. However, municipalities and water purveyors can indirectly limit groundwater withdrawals by implementing and enforcing water conservation measures. Municipalities, water supply districts, and river authorities play key roles in the development of alternative supplies such as surface water reservoirs or reuse systems that can reduce dependence on groundwater supplies. Public water suppliers are required to prepare drought contingency plans and to implement the plans during times of water shortages and drought. These drought contingency plans generally call for mandatory water conservation and address options for alternate supplies during times of shortage.

The Region F Water Planning Group's policy is to support the creation of local groundwater conservation districts because these districts more clearly define and protect the rights of landowners, treat groundwater as a property right, and foster good stewardship of groundwater resources. This water planning group has also noted that monitoring groundwater levels on a regular basis provides critical data that is necessary to manage the water supply for municipal, industrial, and irrigation demands, and that historic water levels combined with water demand or pumping data allows groundwater managers to establish drought response or other management triggers and actions. Further, this planning group notes that groundwater in a few areas of Region F, including parts of the study area, is being mined. In these areas, pumpage exceeds recharge and water is removed from aquifer storage. Water levels are expected to be lowered each year when this occurs. In these areas, Region F suggest that the managing entity of the water resource needs to consider the long-term impact on availability and to establish the maximum allowable drop in water level per year (Freese et al., 2001). Presently, there are no groundwater management entities that are authorized or sufficiently empowered to address the needed management activities identified by the Region F Water Planning Group.

Identified Groundwater Management Strategies

The water supply problems identified in the study area include naturally occurring poor-quality groundwater zones, lack of firm alternative supplies for irrigation and livestock use, water-level declines and water-quality impacts in some areas of continued irrigation overdraft and municipal pumpage, potential groundwater impacts from new well field development and demands from outside the area, potential cross-formation water-quality impacts from localized areas of subsidence, and mining of groundwater from aquifer storage to meet future demands. Opportunities for the study area include participating in regional water planning and cooperation with local water supply, conservation and education entities. The following management strategies are recommended for the area to address identified problems and issues:

- quantify groundwater availability and quality, understand aquifer characteristics, and identify groundwater problems that should be addressed (both quantity and quality) through aquifer- and area-specific research, monitoring, data collection, and assessment programs;

- quantify aquifer impacts from pumpage and establish an overall understanding of groundwater use through a comprehensive water well inventory, registration, and permitting program;

- quantify aquifer and other contributing characteristics sufficiently to evaluate the feasibility and practicability for weather enhancement and aquifer recharge projects;

- cooperate in ongoing brush-control programs and facilitate longer-term brush maintenance and control programs;

- establish programs that encourage conservation of fresh groundwater and the use of poorer-quality groundwater when feasible and practicable and facilitate such transitions;

- evaluate and understand aquifers sufficiently to establish spacing regulations to minimize drawdown of water levels and to prevent interference from neighboring wells;

- establish administrative programs and contacts to assist agriculture producers secure conservation grant or loan monies for conversion to more efficient irrigation systems;

- cooperate and work with the Railroad Commission of Texas to inventory wells, boreholes, or other man-made structures that could potentially contribute to dissolution of subsurface salt formations;

- establish a monitoring program to track ambient groundwater quality and trends in areas proximal to localized surface collapse or other subsidence features;

- establish school and public educational programs to increase awareness of the finite water resources and actions that can be taken to conserve the resources;

- protect water quality by encouraging water well construction to be protective of fresh-water zones and by administering a program to locate and plug abandoned water wells; and,

- actively participate in the regional water planning process, groundwater availability model refinements, and regional groundwater management and protection programs with other west Texas groundwater conservation districts and entities.

Economic Considerations and Impacts

Obtaining alternative sources of water for an area is often cost prohibitive because either new or additional surface water rights must be acquired or infrastructure constructed to deliver surface water or groundwater from outside sources. The economic impacts of managing groundwater resources through a groundwater conservation district are both positive and negative. For example, managing an area's groundwater resources can increase the value of land in the area by extending the economic life of the aquifer(s), limiting the possible encroachment of salt-water, and reducing other water quality impacts. Indeed, one of the greatest benefits of a GCD is the district's proactive approach through its assessment and monitoring, planning, permitting, and other conservation programs to equitably extend groundwater supplies for future use and economic development. GCDs also benefit the area by developing and

implementing regulations for adequate well spacing, water well construction, pollution prevention through the plugging of abandoned wells, and also by providing public education outreach programs.

While a district may provide many benefits to those living within its boundaries, there is a cost for the groundwater management programs and activities that are provided. To finance its operations, a GCD must generate revenue which is generally done either through property taxes collected from all residents within the district or from well production fees collected from major water users. Collection of tax to operate a district places an additional financial burden on all property owners within the district, and the collection of well production fees adds a financial burden to the users of water with permitted wells. The scale of cost for residents is dependent upon many factors including the size and total tax base of the district or the quantity of water that is subject to production fees, and the scale and scope of the programs undertaken by the district. Additionally, because a GCD is a political subdivision, it is an additional layer of local government that may not be welcomed by all residents.

Financing Groundwater Management Activities

Groundwater conservation districts are required to operate from an annual budget with spending limited to budgeted items. Present budgets for existing, operational GCDs range from slightly over $100,000 for some single-county districts with limited permitting and monitoring programs to over several million dollars for special-law type, multi-county districts with specific statutory groundwater management responsibilities such as restricting production to protect spring-flow or to cease subsidence caused by groundwater withdrawal. Present budgets for highly-active GCDs that include three- to four-counties range from about $150,000 to about $425,000 (GCDs, 2003).

Under Texas Water Code, Chapter 36, a GCD may levy an ad valorem tax at a rate not to exceed 50 cents per $100 assessed valuation to pay for maintenance and operating expenses. In fact, most GCDs have lower ad valorem tax caps established either by their enabling legislation or by voters. Existing groundwater conservation districts currently have tax rates ranging from $0.004 to $0.0775 per $100 assessed valuation (or, $4.00 to $77.50 annual tax paid on property valued at $100,000) (TAGD, 2003). Single-county districts generally tend to have higher tax rates than multi-county districts which typically have tax rates averaging around $0.01 per $100 assessed valuation.

The total appraised value for county taxation in each of the four counties in the study area is as follows: Loving - $205,457,620, Reeves - $477,592,370, Ward - $1,008,106,323, and Winkler - $630,658,131 (Texas Association of Counties, 2003). For the four-county study area, the total appraised value is approximately $2,321,814,424. Assuming a GCD was created that covered all four counties, a tax rate of $0.01 (one cent) per $100 value would generate approximately $232,200 annually. If four single-county GCDs were created, and each assessed a tax at the same rate ($0.01 per $100), the following approximate revenue would be generated for each: Loving - $20,500, Reeves - $47,800, Ward - $100,800, and Winkler - $63,100.

Groundwater conservation districts may also generate revenue through the assessment and collection of well production fees on permitted wells. Unless otherwise addressed by a district's enabling legislation, the production fees are capped by state law at $1 per acre-foot/year for agricultural use, and $10 per acre-foot/year for other uses. Based on year 2000 supply data provided in Appendix 2, and assuming that county-other, livestock, and mining uses would be exempt from potential regulation and fees, about 59,192 acre-feet of water was produced for irrigation and about 20,434 acre-feet of water was produced for other purposes (municipal, manufacturing, steam electric) in the four-county study area. Making the same assumption that a GCD was created that included all four counties, and utilizing the maximum statutory well production fee rates ($1 per acre-foot/year for agricultural use and $10 per acre-foot/year

for other uses), it is estimated that about $263,500 of revenue could be generated through this method of financing district operation and maintenance.

To a lesser extent, GCDs may also recover costs by assessing fees for administrative services such as processing permit or groundwater transport applications, performing water quality analysis, providing services outside of the district, and capping or plugging abandoned wells. These fees must not unreasonably exceed the cost of providing these services. GCDs can also impose export fees (see below) and apply for and receive grants, loans and donations from governmental agencies, individuals, companies or corporations for specific conservation projects or research.

In addition, GCDs can issue and sell tax bonds for capital improvements such as building dams, draining lakes and depressions, installing pumps and equipment, and providing facilities for the recharge of aquifers. Such tax bonds are subject to voter authorization, TCEQ review, and the State Attorney General's approval. The taxing rate is not capped for the repayment of bond indebtedness.

GCDs may impose an export fee on water transferred out of the district. Unless specified in the legislation creating the district, the export fee is based on the district's existing tax or production fee rates or is negotiated with the transporter. GCDs are allowed to charge a 50 percent export surcharge in addition to the production fee charged for in-district use.

Conversely, a few groundwater conservation districts have been created without the authority to impose ad valorem taxes or water use fees. These districts have generally been funded by county government and are limited, by the amount of funding received, in the scope of programs they can implement.

Management Options

Water management and management planning can be carried out at various scales of oversight and authority. On a state-wide scale, no federal or state entity has authority to regulate groundwater withdrawal or use. However, state-level water planning responsibilities and groundwater conservation district management plan oversight responsibilities are well defined, as previously discussed. Assessment and planning by the regional water planning groups can identify groundwater problem areas and appropriate management options for use by regional and local entities, but these planning entities are not authorized to manage and regulate groundwater resources or implement water conservation programs. County and municipal authorities can require plat applicants to evaluate and demonstrate that site-specific groundwater resources are available and sufficient for new subdivisions, and cities, utilities, and water suppliers can implement programs to discourage groundwater waste and seek alternative supplies. However, none of these local entities are directly authorized to manage groundwater pumpage.

Several groundwater management options are available for the study area. In one scenario, local leadership, landowners, and citizens can opt not to take any action. If an area does not have any demonstrated or anticipated groundwater problems or issues, this may be an appropriate choice. If this is not the case, however, this choice would not offer any resource protection to landowners and would allow existing or anticipated groundwater problems to persist or worsen.

A groundwater conservation district created within the study area would have the necessary authority to address groundwater issues and accomplish groundwater management objectives identified in the preceding text. Such a district would have the best available regulatory authority to manage and protect groundwater resources in the area. A GCD could benefit the study area by implementing groundwater management strategies as authorized under Texas Water Code, Chapter 36. The study area could benefit from monitoring, assessment, planning, and permitting programs as well as water well spacing, and

water-quality protection rules for the Cenozoic Pecos Alluvium aquifer. Due to the highly variable groundwater chemistry in the aquifer, district well construction standards that are more stringent than the state standards may be more protective of the aquifer. The protection of groundwater quality is of great importance because alternative sources are not readily available. A long-term controlled brush management program could potentially enhance both groundwater quantity and quality.

One provision in Texas Water Code, Chapter 36 specifically exempts from groundwater district regulation wells and water produced in counties with a population of 14,000 or less if the water is used solely to supply a municipality that has a population of 121,000 or less and the rights to the water are owned by a political subdivision that is not a municipality, or by a municipality that has a population of 100,000 or less. If the circumstances of this provision apply, a groundwater conservation district may not regulate or prohibit a political subdivision or municipality from transporting produced water inside or outside of the district's boundaries.

With a 2000 population of 13,969, it appears this provision may apply to potential groundwater district regulation of the Colorado River Municipal Water District wells in Ward County that are used as a supply to the City of Odessa. The population of Ward County is projected to surpass the statutory threshold of 14,000 before the year 2010 and it is not clear what authority any future groundwater district in the county may have regarding these type wells after that time.

Without authority to regulate large capacity wells that fall within this exemption, a groundwater district governed solely by Chapter 36 would be limited in its ability to implement rules to prevent or mitigate well interference and aquifer overdrafting from wells meeting the exemption criteria. However, some groundwater conservation districts created and governed by special law have specific language in their legislation providing that §36.121 does not apply. In these districts, these types of wells and groundwater pumpage could be regulated.

If groundwater management is desired, the local leadership and concerned citizens must consider several methods for the creation of a groundwater conservation district. Most GCDs are created by special Acts of the Texas Legislature. In other general law procedures, statute allows landowners to petition the TCEQ for the creation of a GCD, or allows landowners to petition another district to have property be added into that district. Lastly, if an area is designated as a PGMA, landowners are provided a two-year period to accomplish one of the above district creation actions. If they do not, TCEQ is required to create a GCD or recommend the area be added to an existing GCD. (Methods of, and procedures for GCD creation are discussed in significant detail in TCE, 2002a and 2002b.)

District size must also be considered. Historically, single-county groundwater conservation districts have been the predominant choice of Texas citizens. However, multi-county GCDs covering larger portions of aquifers have increased in popularity over the past half-dozen years. Such districts can exercise consistent regulation and effective conservation and management planning on a larger or even aquifer-wide scale. Generally, multiple single-county GCDs or a few multi-county GCDs are created within the same groundwater management area and each district operates under its own rules and regulations to manage the groundwater resource. However, because these GCDs share common groundwater resources, it is imperative that their efforts to manage the resource be coordinated.

Under Texas Water Code, §36.108, GCDs within a common groundwater management area are required to share their certified groundwater management plans with the other districts that are present within the management area. The GCDs are encouraged (under §36.108) to conduct joint public meetings to review management plans and plan-accomplishments for the management area. The districts are further advised under §36.108 to consider the goals and effectiveness of each management plan and each management

plan's impact on planning throughout the management area. Through these cooperative efforts, local GCDs can effectively provide coordinated regional management of a shared groundwater resource. The four-county study area, Crane County, and parts of northern Pecos County are included in Groundwater Management Area 3 for the Cenozoic Pecos Alluvium Aquifer as designated by the TWDB in November 2002 (Figure 6).

Multi-County Groundwater Conservation District

Besides considering the different groundwater conservation district creation methods, citizens must also consider several different GCD creation options and the implication for each. The most economical option would be a multi-county GCD consisting of all four counties in the study area. Because of the broader tax base that this option provides, sufficient revenue could be generated to finance district operation and maintenance at a very low tax rate. As discussed above, a tax rate of $0.01 (one cent) per $100 assessed valuation would generate about $232,200 annually; a two-cent tax rate would generate about $464,400. These revenue estimates are in line with existing GCDs of the same size, and tax rates of one or two cents per $100 would be considered low to finance groundwater management activity through a GCD.

Alternatively, a four-county GCD could finance operations and maintenance through the assessment of well production fees and it is estimated (see above) that about $263,500 could be generated annually at the maximum fee rates authorized by Texas Water Code, Chapter 36. Although Chapter 36 authorizes GCDs to generate revenue through the levy of taxes and the assessment of well production fees, TCEQ is unaware of any districts that do both simultaneously. Frequently, the authority for special-law created GCDs requires the generation of revenue through either taxes or fees, but not both.

Furthermore, since the four-county GCD creation option would include the greatest areal extent of the Cenozoic Pecos Alluvium aquifer, a single GCD management program for the aquifer would also represent the most optimal groundwater management option. The only areas outside of Groundwater Management Area 3 for the Cenozoic Pecos Alluvium aquifer would be Crane County and parts of northern Pecos County.

Single-County Groundwater Conservation Districts

Citizens could also consider a combination of district configurations ranging from single-county GCDs to two bi-county GCDs to a single-county and tri-county GCD. The generation of revenue to finance meaningful groundwater management programs would be the limiting factor for the consideration of these GCD creation options. If sufficient revenue – estimated here at a minimum of about $150,000 – cannot be generated through either the levy of taxes or the assessment of well production fees, then the proposed GCD creation option would not be viable to address groundwater management. None of the counties alone would be able to generate sufficient revenue to operate a GCD through the assessment of well production fees. For example, at the maximum rate authorized by state law, only about $89,000 could be generated annually in Reeves County, and the other three counties would be significantly less.

Also, as the total tax base becomes smaller, the tax rate needed to generate sufficient revenue for GCD operation increases. For example, Loving County would require a tax rate of over $0.07 (seven cents) per $100 valuation to generate $150,000 per year; and Reeves, Ward, and Winkler counties would require tax rates of $0.03, about $0.015 and about $0.024 per $100, respectively, to generate the same amount. However, even though these tax rates would represent a larger economic impact on property owners, they are consistent with existing rates presently levied by existing GCDs.

Having two, three, or even four GCDs would require a like number of individual groundwater management programs. These options provide for the most local control because each director represents a smaller area. However, these options would also require that largely duplicative administrative and management programs be implemented. For example, each GCD would be required to:

- establish and maintain an office;
- establish procedures to address open meetings and open records and records retention;
- annually address financial budgeting and auditing requirements;
- develop and adopt a management plan;
- develop and adopt administrative, well permitting and other regulatory rules; and,
- meet and uphold other statutory requirement relating to policies and district operation.

The creation of single-county districts in the study area is feasible. Nevertheless, citizens should understand that better economic and administrative options do exist. The only apparent trade-off would be the conception that the most-localized form of groundwater management was being forfeited if something other than single-county GCDs were created. However, the creation of GCDs by special law, and Texas Water Code, Chapter 36, allow sufficient flexibility to assure that the number and representation by district directors alleviate this misconception. Under either method, district directors must be accountable to, and responsive to the electorate.

Addition to Existing Groundwater Conservation District

Alternatively, the study area could opt to join an existing groundwater conservation district through the petition and annexation procedures outlined in Texas Water Code, Chapter 36, Subchapter J. Under such circumstances, and assuming that a petition to add territory is accepted by the receiving district, landowners in the study area would agree to assume the financial obligations of the district they would join and be provided equitable representation on the receiving district's board of directors. The advantage of joining an existing district include accessibility to the district's established regulations, programs, and infrastructure, and an increased tax base which may be less burdensome on the taxpayers in the study area.

Presently, the only GCDs (Figure 6) that landowners in the study area could join are the Middle Pecos Groundwater Conservation District or the Jeff Davis County Underground Water Conservation District (UWCD). The residents of Pecos County confirmed creation of the Middle Pecos GCD by election on November 5, 2002 by a vote of 1,597 for to 1,363 against, authorized the collection of an ad valorem tax at a rate not to exceed $0.025 per $100 assessed valuation to finance district operations and maintenance, and elected the initial board of 11 directors for the District. At present, the Middle Pecos GCD is levying an operation and maintenance tax at a rate of $0.0115 per $100 valuation, and working to develop and adopt the District's management plan and rules. With the total tax base of Pecos County being about $1,826,736,515 (Texas Association of Counties, 2003), it is estimated that the present tax revenue available for the Middle Pecos GCD is around $210,000 per year at their present rate.

If the Middle Pecos GCD was agreeable to an inclusion-petition from the four counties in the study area, the resultant five-county GCD would have the benefit of an even larger tax base, would include a larger areal extent of the Cenozoic Pecos Alluvium aquifer, and would be able to develop uniform management programs for the area aquifers. However, the District's enabling legislation, Chapter 1229, Acts of the 77th Legislature, Regular Session, 2001, would need to be amended to allow flexibility for board member representation.

The Jeff Davis County UWCD was created by Chapter 641, Acts of the 73rd Legislature, 1993, and confirmed by the residents of Jeff Davis County on November 2, 1993. This District does not have statutory authority to levy ad valorem taxes and is primarily funded by appropriations from the county commissioners court and administrative fees. The District's 2004 budget was about $28,500, and the District plans to start assessing well production fees in 2005 that would generate about $25,000 per year. The District's five board members are appointed by the commissioners court of Jeff Davis County.

Only a very minor amount of Cenozoic Pecos Alluvium aquifer outcrop extends into Jeff Davis County; therefore, the county is included in Management Area 4 for the West Texas Bolsons, Igneous, Bone-Spring-Victorio Peak, Marathon, and part of the Capitan Reef aquifers. The Jeff Davis County UWCD is presently working with two other GCDs in Management Area 4 to coordinate management plans and rules. Primarily because of the aquifer and groundwater management differences, it would be less practicable to attempt to add the study area to the Jeff Davis County UWCD.

Under any of the groundwater conservation district creation scenarios outlined above, it will be imperative for a district to understand the water supply options and strategies that have been identified in the *Region F Regional Water Plan* (Freese et al., 2001) and the groundwater data that is built into the State Water Plan (TWDB, 2002) and TWDB's pending groundwater availability model. This data and these water supply strategies will serve as guides for water planning in the study area, and in the region for the next 50 years. Further, a district should also intimately understand and recognize the drought contingency plans of the wholesale and retail water suppliers in the area and the water demands of areas that are proposed for platting. Through monitoring programs, assessment, research, and cooperation, a district in the study area should be able to institute successful groundwater management programs for the Cenozoic Pecos Alluvium and other aquifers and provide better information and input about the groundwater resources for consideration in future updates to the regional and state water plans.

SUMMARY AND CONCLUSIONS ☆☆☆

Texas Water Code, Section 35.007, requires that a TCEQ Priority Groundwater Management Area (PGMA) report: 1) examine the reasons and supporting information for or against designating the study area as a PGMA; 2) recommend the delineation of boundaries if PGMA designation is proposed; 3) provide recommendations regarding groundwater conservation district creation in the study area; 4) recommend actions necessary to conserve natural resources within the study area; and 5) evaluate information or studies submitted by the study area stakeholders.

The Texas Water Code requires the report to identify present critical groundwater problems, or those expected to occur within a 25-year planning horizon. Critical groundwater problems which warrant PGMA designation include shortages of surface water or groundwater, land subsidence resulting from groundwater withdrawal, and contamination of groundwater supplies. This report evaluates the authorities and management practices of existing groundwater management entities within the study area and makes recommendations on appropriate strategies necessary to conserve and protect groundwater resources in the area.

TCEQ staff have considered data and information provided by the TWDB, TPWD, stakeholders in the study area, the *Region F Regional Water Plan*, and from independent research to support the following conclusions and recommendations regarding the Trans-Pecos PGMA Study Area.

Water Use and Supply

The water supplies in the four-county study area include groundwater, surface water from Red Bluff Reservoir (Pecos River), Balmorhea Lake and stock tanks, and wastewater reuse. More water is used for irrigation in the study area than for any other purpose. In 2000, irrigation accounted for 80 percent of the total amount of water used, down from 83 percent in 1995, and up from 75 percent in 1990. Of the amount of water used for irrigation purposes in 2000, 75 percent was supplied by groundwater sources and 25 percent was supplied from surface water sources. Municipal and County Other (primarily rural domestic) use accounted for slightly more than 13 percent of the total water used in 2000, and 98 percent of this water was groundwater. As a comparison, water used for these purposes in 1990 accounted for 10 percent of the total water used. These use numbers include water that is exported from the study area to the City of Odessa. Water for power generation in 2000 represented less than 5 percent of the total water use in the study area. Groundwater was used to supply water for mining and manufacturing purposes, and in 2000 represented less than 2 percent and 1 percent of total water use in the study area, respectively. Use of surface and groundwater sources for the watering of livestock accounted for less than 1 percent of total water use in 2000.

The total quantity of water supplied in the study area is estimated to be 102,453 acre-feet (af) in 2000, and is not projected to fluctuate by more than one percent between 2000 and 2030. In the study area, groundwater supplies account for, and are projected to continue accounting for over 80 percent of water usage. In 2000, groundwater supplied an estimated 80,613 af in the study area. An additional 5,200 af of groundwater was exported from Ward County to the City of Odessa in Ector County. The Cenozoic Pecos Alluvium aquifer is the most accessible and prolific groundwater source in the study area, supplying an estimated 76,103 af in 2000 for all uses including the export supply for the City of Odessa. Of this 2000 quantity, irrigation use in Reeves County accounted for 56,868 af, or about 75 percent of this supply. Water use from the Cenozoic Pecos Alluvium aquifer is projected to fluctuate from a high of 70,925 af in 2010, decreasing to 70,748 af in 2020, and back up to 70,762 af by 2030.

The Triassic aged Dockum aquifer underlies the Cenozoic Pecos Alluvium aquifer in the eastern half of the study area and supplies water in Reeves, Ward, and Winkler counties. In 2000, the Dockum aquifer supplied 8,534 af of water in the study area, 70 percent of which was supplied for Winkler County uses. Water use from the Dockum aquifer is projected to increase by about 4 percent, up to 8,869 af, by 2030. The Cretaceous aged Edwards-Trinity Plateau aquifer underlies and is in hydraulic connection with the Cenozoic Pecos Alluvium aquifer. The Edwards-Trinity Plateau aquifer and other undifferentiated aquifers supplied 1,176 af of water in Reeves County in 2000 for rural domestic and livestock uses. This groundwater supply is projected to remain consistent through 2030.

The Pecos River enters Texas from New Mexico and flows across the study area from the northwest to the southeast. Seven irrigation districts throughout Loving, Pecos, Ward and Reeves counties obtain water from the Pecos River to irrigate croplands. Red Bluff Reservoir and releases to the Pecos River supplied 14,451 af of water in 2000 for irrigation in Loving, Reeves, and Ward counties. In 2000, other surface sources supplied 288 af of water in Reeves County for municipal, rural, and livestock uses; and 12 and 8 af for livestock uses in Ward and Winkler counties, respectively. Reuse of surface water for municipal and irrigation purposes is exercised in Reeves and Ward counties. In Reeves County, 689 af of direct reuse is used for irrigation, and in Ward County, 1,200 af of direct reuse is used by the City of Monahans. These surface water and reuse supplies are projected to remain the same through 2030.

Groundwater Supply Concerns

Continued groundwater-level declines in the Cenozoic Pecos Alluvium aquifer were documented in parts of the study area between 1988 - 1998. The continued declines are due to irrigation overdraft in the heavily farmed areas of Reeves County southwest of the City of Pecos and municipal pumpage in central Ward County. Generally, the other parts of the study area have stationary or rising water levels because groundwater withdrawals have been reduced to levels less than the effective rate of recharge. The final report for the TWDB's groundwater availability model (GAM) for the Edwards-Trinity (Plateau) and Cenozoic Pecos Alluvium aquifer systems was not completed until after the draft of this report was distributed for stakeholder review and comments. For this reason and because of apparent scale of application limitations, the GAM and GAM final report are not considered in critical groundwater problem determinations for this update evaluation.

The chemical quality of groundwater in the Cenozoic Pecos Alluvium aquifer is highly variable and changes naturally with location and depth. Water quality in the aquifer is influenced by: 1) presence of evaporite beds in the northern and western part of the Pecos trough which increases the concentration of sulfate in the water, 2) recharge of highly mineralized water by irrigation return flow in south-central Reeves County and the Coyanosa area, 3) concentration by evapotranspiration of shallow mineralized water in the alluvium of the Pecos River valley, 4) saline-water encroachment in areas of heavy pumpage, and 5) local contamination by oil field brine, primarily in Winkler and Loving counties (Ashworth, 1990). Based on the available data, it appears that the groundwater quality of the Cenozoic Pecos Alluvium aquifer has not changed much since 1989.

Two salt dissolution sinkholes in Winkler County are spatially associated with the location of drilled boreholes that penetrated the Permian-aged Capitan Reef Complex. A plugged oil-field water supply well was located within the circumference of the Wink Sink 2, and a plugged oil production well was located within the circumference of the first Wink Sink. However, little site-specific data is available to determine the processes that may have contributed to the development of the sinkholes, and sufficient data has not been developed to determine if the sinkholes are causing negative impacts to usable quality groundwater supplies in the immediate area.

Projected Demand, Availability, and Strategies to Meet Needs

Overall, the total population of the study area decreased by around seven percent (2,990 people) between 1980 and 1990, and another 15 percent (5,533 people) between 1990 and 2000. The regional and state water plans project that between the years 2000 and 2030, total population within the study area will increase by approximately 14 percent (from 40,936 inhabitants in 2000 to 47,339 inhabitants in 2030). However, the total projected water demand from the four-county study area is not expected to change significantly over the next 30-year period. The total projected demand for 2000 was 146,548 af and the total projected demand for 2030 is 146,032 af, a difference of only 516 af, or less than one percentage point over the 30-year time frame.

Irrigated agriculture will continue to represent the largest demand (over 80 percent) for water in the future, and this demand is projected to decrease slightly by 2030. Demand for municipal supplies from 2000 to 2030 are projected to account for a fairly consistent 10 percent of total water demand in the study area. Steam electric power generation represents the third largest demand (4 percent) for water in the study area. Steam electric water demand is expected to increase 37 percent (up to 6 percent of total water demand) between 2000 and 2030. In 2000, mining demand was the fourth highest category in the study area and accounted for 2 percent of the total water demand in the area. This demand is projected to decrease by 31 percent by 2030, at which time it would account for only 1 percent of the total demand in the area. In 2000, livestock watering accounted for about 2 percent of total groundwater use in the study area and this demand is projected to remain the same for the next 30-year period. Demand for manufacturing is projected to increase 23 percent in the study area between 2000 and 2030; however, this demand accounts for and will continue to account for significantly less than 1 percent of the total water demand in the study area.

For the *Region F Regional Water Plan*, the groundwater availability for the study area's aquifers was calculated as the annual effective recharge to the aquifer plus an allowed use of 75 percent of water in storage over a 50-year period. The data indicate that 238,271 af per year of groundwater with a TDS concentration less than 3,000 mg/l is available in the four-county study area. Of this quantity, 95,332 af per year (40 percent) is from annual recharge and 142,939 af per year (60 percent) is from aquifer storage. The Cenozoic Pecos Alluvium aquifer accounts for 58 percent of the available groundwater supply. The Edwards-Trinity Plateau aquifer in Reeves and Winkler counties accounts for 35 percent, and the Dockum aquifer, primarily in Winkler County, accounts for 7 percent of the available groundwater supply.

The total annual availability of surface water is estimated to be 18,197 af. The *Region F Regional Water Plan* reports a firm supply from Red Bluff Reservoir of 16,000 af per year. In addition to Red Bluff Reservoir, Balmorhea Lake and other local surface water sources of 308 af per year are available in the study area (288 af/year in Reeves County, 12 af/year in Ward County, and 8 af/year in Winkler County). Further, reuse of surface water effluent is practiced in Reeves and Ward counties. Reuse makes an additional 1,889 af per year available in the two counties: 689 af/year in Reeves and 1,200 af/year in Winkler.

The state and regional water plans have identified alternative water supply strategies to meet all of the identified year 2030 water supply needs in the study area except for some irrigation in Loving, Reeves, and Ward counties, and some livestock in Reeves, Ward, and Winkler counties. The identified water supply strategies generally include increased municipal sales to rural areas, use of non-potable groundwater for mining purposes, and developing and moving additional in-area groundwater supplies for steam-electric generation. The Region F Water Planning Group recommended that improved irrigation practices be implemented to maximize benefit of existing water supplies because no readily

available alternative supplies can be developed to fully meet all estimated irrigation needs for Reeves and Ward counties. The *Region F Regional Water Plan* estimates that by 2030, 8,755 irrigated acres in Reeves County, and 518 irrigated acres in Ward County will be required to shift to non-irrigation crop production or other uses.

Natural Resources Considerations

Reservoir development has changed the natural hydrology in the study area by diminishing flood flows and capturing low flows. The Pecos River between Red Bluff Reservoir and Girvin, Texas, has a characteristic fish fauna. Decreased streamflow, natural and man-induced salinity increases, and pollution from oil fields and agriculture have adversely affected the fish population in the study area. More recently, native fishes have been threatened by the introduction of the sheepshead minnows and toxic blooms of golden algae. At present, nine springs are flowing in the study area. The springs contain moderately saline water which sustain killfish, brine shrimp, turtles, saltcedars and rushes. There are at least 37 species of reptiles, mammals, and amphibians that are either aquatic, semi-aquatic, or in some way wet-land dependent present in the study area.

Natural resources in the area also support agricultural and petroleum production. The study area includes approximately 2,216,643 acres in 314 farms. The data does not provide the total number of acres of crop land in the four counties, but does reflect that there are 19,984 acres of irrigated crop land in Reeves and Ward counties and no irrigated crop land in Loving County (similar data for Winkler County not provided). As of February 2003, over 10,000 oil wells and 1,200 gas wells have been drilled in the four-county area (numbers do not include plugged or abandoned wells).

Brune (1981) identified some 27 springs in the four-county study area that have dried up, 19 of which were in Reeves County. In the past, most of the springs in the study area supported marshes containing cattails, sedges, rushes or tules, sacaton grasses, common reed, and saltgrass. Cottonwood and willow trees often grew around the marshes. Today, most of this vegetation and the wildlife that thrived in them has disappeared along with the springs. The native cottonwoods, black willow, and grasses that once dominated the riparian corridor along the Pecos River have been taken over by saltcedar, mesquite brush and woods, and Bermuda grass.

The spring flows have diminished and many springs have dried up because of groundwater development or the spread of high water-use plant species such as mesquite and saltcedar. El-Hage and Moulton (1998) conclude that control or elimination of this introduced species would be good for wildlife and the rivers only if native species replace the saltcedar, mesquite, and Bermuda grass to provide habitat and protect river banks from erosion. El-Hage and Moulton are also of the opinion that in order to maintain good riparian habitats, grazing pressures must be carefully managed.

Public Participation Evaluation

In July 1999, TCEQ staff mailed questionnaires regarding water issues to county and municipal officials, water districts or other entities that supply public drinking water, and other identified interested persons in the Trans-Pecos area (including stakeholders in Pecos County). In total, 52 questionnaires were sent to identified water stakeholders and 20 of the stakeholders provided responses to the TCEQ.

The respondents reported that there were no major groundwater declines in the Trans-Pecos study area and commented that groundwater quality problems are mostly found in localized groundwater-level decline areas or areas associated with the naturally occurring salts. Respondents noted that conjunctive use of surface and groundwater is not used in all counties of the study area. At places, respondents

reported that there was no surface water or the surface water was contaminated with naturally occurring salts. Some respondents noted that oil field contamination and poor surface water quality degrades and limits this source for conjunctive use. Most of the respondents noted that major water supply corporations and water improvement districts exercise some limitations on water usage based on availability. The responding surface water districts noted that they have developed and implement water conservation plans in their districts.

Most of the respondents considered critical groundwater problems likely in the next 25-year time frame. Public health risk due to natural and human contamination, inadequate groundwater supply, lack of supply enhancement such as aquifer recharge, and lack of groundwater protection programs were the major water concerns of the respondents. However, only two respondents from the four-county study area favored the creation of GCDs in the area, one each from Reeves and Ward counties. Two respondents from Ward County opposed the creation of GCDs, and three respondents from each of Ward and Winkler counties were undecided about GCD creations or did not respond to this specific question.

In June 2004, TCEQ staff solicited additional input by making a draft study area update report available for public inspection and comment and provided mailed notice of this opportunity to 90 study-area water stakeholders. Four study-area stakeholders provided comments with three finding the report to be informative and useful and not offering any suggestions or objections, and the fourth providing some irrigated agriculture information for Winkler County and requesting clarification be made to one table.

Regarding public participation opportunities in the regional water planning process, the Region F Water Planning Group made special efforts to contact municipalities, water districts, and rural water supply corporations and others in the region and obtain their input for the plan. The Region F Water Planning Group conducted two public meetings in July 1998 to discuss the planning process and the scope of work for the region. Between February 1999 and June 2000, the Region F Water Planning Group held a series of five workshops and two public meetings focusing on groundwater and surface water issues in the planning process. In July 2000, copies of the draft *Initially Prepared Region F Water Plan* were mailed to the Region F county courthouses and libraries for public review. On September 5 and 6, 2000, the Region F Water Planning Group held public meetings in San Angelo and Odessa to present the draft *Initially Prepared Region F Water Plan* and seek public input. Oral comments were received following the presentation and written comments were accepted through September 11, 2000. Where appropriate, modifications to the plan were made and incorporated into the adopted *Regional Water Plan*.

RECOMMENDATIONS

The following priority groundwater management area designation, conservation of natural resources, and groundwater conservation district creation recommendations are made for this Trans-Pecos study area of Loving, Reeves, Ward and Winkler counties.

Study Area Designation Recommendation

The water supply problems identified in the study area include naturally occurring and man-induced poor-quality groundwater zones, lack of firm alternative supplies for some irrigation and livestock use, water-level declines and water-quality degradation in some areas of continued irrigation overdraft and municipal pumpage, potential groundwater impacts from new well field development and demands from outside the area, potential cross-formation water quality impacts from localized areas of subsidence, and mining of groundwater from aquifer storage to meet future demands. However, it is concluded and recommended that the Trans-Pecos PGMA study area should not be designated as a priority groundwater management area at this time.

Most of the identified water supply problems are localized and are not study area-wide problems. The available data indicates that water is of sufficient quality in the study area to meet intended and projected uses. Surface and groundwater supplies are sufficient to meet the present needs, and are projected to be sufficient to meet all future needs to 2030 except for some irrigated agriculture and livestock shortfalls. Therefore, the water supply and water quality issues identified in the report are not presently critical problems, and are not anticipated to be critical problems during the next 25-year planning horizon.

New population and water demand projections have been adopted for the second round of the state water-planning cycle, and the second round of regional plans are due in 2006. TCEQ staff support TWDB's interest to develop a specific Cenozoic Pecos Alluvium aquifer groundwater availability model. With a refined GAM tailored specifically to this aquifer, the Region F Regional Water Planning Group and study area stakeholders would be able to consider refined predictive GAM runs that address the newly adopted demand projections and specific Cenozoic Pecos Alluvium aquifer pumpage strategies to meet those demands. This scale and level of evaluation should provide a better and more detailed understanding of water-level trends and impacts to storage (saturated thickness). If this level of evaluation were to indicate significant water-level declines and decreases in saturated thickness because of increased pumpage, then a further reevaluation of this area for critical groundwater problems could be warranted in the future.

Natural Resources Recommendations

Groundwater management strategies to monitor, evaluate, and understand the aquifers sufficiently to establish protection programs to minimize drawdown of water levels and to maintain existing spring flows are recommended to facilitate protection of natural resources in the study area. Cooperation and continuation of the Pecos River Ecosystem Project and facilitation of this and longer-term brush maintenance and control programs are recommended as primary groundwater management strategies to help conserve natural resources in the study area. Facilitating administrative programs to help agricultural producers secure conservation grant or loan monies for conversion to more efficient irrigation systems is another recommended groundwater management strategy to conserve the natural resources of the study area.

Groundwater Conservation District Considerations and Recommendations

It is the policy of the Region F Water Planning Group to support the creation of local groundwater conservation districts (GCDs) because these districts more clearly define and protect the rights of landowners, treat groundwater as a property right, and foster good stewardship of groundwater resources. It is concluded that managing and protecting the groundwater resources within the study area could be accomplished through the establishment of a groundwater conservation district. A GCD could benefit the study area by implementing monitoring, assessment, planning, and permitting programs as well as water well spacing and water-quality protection rules for the Cenozoic Pecos Alluvium aquifer. Due to the highly variable groundwater chemistry in the aquifer, district well construction standards that are more stringent than the state standards may be more protective of the aquifer. The protection of groundwater quality is of great importance because alternative sources are not readily available. A long-term controlled brush management program could potentially enhance both groundwater quantity and quality.

Because the data does not justify PGMA designation for the study area at this time, the local leadership, landowners, and citizens must determine if they desire to manage their groundwater resources. If their answer is yes, the citizens, on their own initiative, would need to consider the different methods available to create a groundwater conservation district. Most GCDs are created by special laws of the Texas Legislature. In other general law procedures, statute allows landowners to petition the TCEQ for the creation of a GCD, or allows landowners to petition another district to be added into that district.

The citizens must also consider several different GCD creation options and the implication for each. The most economical creation option would be a multi-county GCD consisting of all four counties in the study area. Because of the broader tax base that this option provides, sufficient revenue could be generated to finance district operation and maintenance at a very low tax rate. Alternatively, a four-county GCD could finance operations and maintenance through the assessment of well production fees at the maximum fee rates authorized by Texas Water Code, Chapter 36. Furthermore, since the four-county GCD creation option would include the greatest areal extent of the Cenozoic Pecos Alluvium aquifer, a single GCD management program for the aquifer would also represent the most optimal groundwater management option.

Alternatively, and under the second most feasible option, study-area residents could petition to join the Middle Pecos Groundwater Conservation District through the procedures outlined in Texas Water Code, Chapter 36, Subchapter J. If the Middle Pecos GCD was agreeable to an inclusion-petition from the four counties in the study area, the resultant five-county GCD would have the benefit of an even larger tax base, would include a larger areal extent of the Cenozoic Pecos Alluvium aquifer, and would be able to develop uniform management programs for the area aquifers. However, the District's enabling legislation, Chapter 1229, Acts of the 77th Legislature, Regular Session, 2001, would need to be amended to allow flexibility for board member representation.

Citizens could also consider a combination of district configurations ranging from single-county GCDs to two bi-county GCDs to a single-county and tri-county GCD. The generation of revenue to finance meaningful groundwater management programs would be the limiting factor for the consideration of these GCD creation options, because as the total tax base becomes smaller, the tax rate needed to generate sufficient revenue for GCD operation increases. None of the counties alone would be able to generate sufficient revenue to operate a GCD through the assessment of well production fees. In addition, having two, three, or even four GCDs would require a like number of individual groundwater management programs and would necessitate that largely duplicative administrative and management programs be implemented. The creation of single-county districts in the study area is feasible; nevertheless, citizens should understand that better economic and administrative options do exist.

Lastly, only a very minor amount of Cenozoic Pecos Alluvium aquifer outcrop extends into Jeff Davis County and the county is included in different groundwater management area than the study area. Primarily because of the aquifer and groundwater management differences, it would be less practicable for citizens to attempt to have the study area added to the Jeff Davis County Underground Water Conservation District.

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APPENDIX 1.

1990 CRITICAL AREA REPORT SUMMARY FOR TEXAS WATER COMMISSION

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GROUND WATER PROTECTION AND MANAGEMENT STRATEGIES
FOR THE TRANS-PECOS REGION
(A Critical Area Ground Water Study)
Subchapter C, Chapter 52, Texas Water Code

TECHNICAL SUMMARY

The Trans-Pecos Region was identified as a potential critical area and nominated for a detailed study by the Texas Water Commission and the Texas Water Development Board in a joint press release dated January 13, 1987. A study of the Trans-Pecos Region was requested by the Executive Director in a letter to the Executive Administrator dated September 1, 1989. A draft report was received from the Executive Administrator in December 1989. A Critical Area Report has been prepared by Commission staff recommending that the Trans-Pecos Region not be designated as a Critical Area, proposing a ground water management strategy for the study area, and providing information about the area in support of the recommendations.

The proposed critical area covers portions of five counties: Reeves, Winkler, Ward, Pecos, and Loving counties. The study area's boundaries are defined by the areal extent of the Cenozoic Pecos Alluvium aquifer, the main ground water source in the area. The Cenozoic Pecos Alluvium aquifer is underlain by older, less important aquifers: the Capitan Reef Complex (oldest), the Rustler Formation, the Dockum Group, and the Edwards-Trinity (Plateau). The Cenozoic Pecos Alluvium aquifer is characterized by two slump structures, the Monument Draw and Pecos troughs, that exist as separate and distinct ground water systems. The Pecos Trough, primarily in Loving and Reeves counties, supplies ground water mainly for livestock and irrigation. In Ward and Winkler counties, the Monument Draw Trough is a source of ground water for public supply and industrial applications in the study area. Irrigation farmers in the Coyanosa area of northwest Pecos County also rely on the Monument Draw Trough for a reliable source of ground water for their crops.

Ninety percent of the water needs are met with ground water, and the remaining ten percent with surface water. For 1985, about 117,430 acre-feet of ground water and 13,384 acre-feet of surface water were used. Average annual effective recharge to the aquifer is on the order of 70,000 acre-feet.

For the future, the Trans-Pecos Region study area faces a small projected population increase of about 15 percent for the period 1990-2010, and an approximate total water demand increase of about 5 percent for the same period. Mining is the only use that is projected to make a noteworthy increase; the other uses will account for approximately the same amounts for the period 1990-2010. Upon completion of the O.H. Ivie Reservoir, at least 110,000 acre-feet of surface water will be available to reduce Midland/Odessa's reliance on ground water pumped from the study area.

Ground water problems in the study area are primarily concerned with water level declines and water quality deterioration. Water level declines have historically been a large problem in the irrigation areas of the Pecos Trough in Reeves and Pecos counties with declines up to 200 feet reported from the 1940's to 1970's. The 1980's has been a period of recovery for many of the water wells, with rises in water levels documented in the study area due to reductions in ground water pumpage for irrigation use. The

Monument Draw Trough historically has not experienced water level declines of the severity of the Pecos Trough area. Small annual declines of one to two feet a year are, however, common in Ward County, where ground water is pumped for municipal, industrial, and irrigation purposes.

Ground water in the study area, due to a close proximity to natural evaporite formations, has historically been of marginal quality. But due to human activities such as oil and gas exploration and recovery in Loving, Ward, and Winkler counties, and agricultural practices in the main irrigation areas Pecos, Reeves, and Ward counties, the naturally marginal quality of ground water in the study area has further deteriorated.

Throughout the critical area process, citizens of the Trans-Pecos Region have been involved. In September, 1986, two public meetings were held in Odessa and Midland. Public comment was taken, and based upon the results of the two hearings, and other information, the only area that was identified as needing a detailed ground water study in the Midland/Odessa area was the Trans-Pecos Region. Representatives and residents of Sterling, Midland, Andrews, Howard, and other nearby counties expressed views against the need for district creation in their areas.

During October of 1988, and March of 1989, knowledgeable and interested individuals of business, government, agriculture, and private sectors in the Trans-Pecos Region were interviewed. From this group, nine individuals were nominated and approved as members of the Trans-Pecos Critical Area Advisory Committee. The Committee has provided input and comments on the Critical Area Report and concur with its conclusions and recommendations.

Locally implemented ground water management practices and protection activities are recommended for the Trans-Pecos study area to help reduce or minimize water level declines and ground water degradation. Opinions and input received from those interviewed and the advisory committee reflect a consensus that ground water problems in the study area should not be considered critical, and that the designation of the study area as a critical area is not favored. Ground water problems are a concern to many in the study area and local action is favored for developing and implementing ground water management strategies in the area. There is also interest in locally initiated district creation, especially in Ward and Winkler counties.

It is also recommended that the Texas Water Commission not designated the Trans-Pecos Region study area as critical at this time. The progress of local entities toward implementing ground water management strategies should be monitored by the Texas Water Commission over the next five years, and if local efforts are not successful in addressing current ground water problems, consideration should again be given to “critical area” designation.

Prepared by:	John A. Williamson, Geologist Ground Water Conservation Section Texas Water Commission	March 30, 1990
Approved by:	Bill Klempt, Chief Ground Water Conservation Section Texas Water Commission	March 30, 1990

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APPENDIX 2.

Appendix 2. Current and Projected Water Supplies, Trans-Pecos PGMA Study Area

LOVING COUNTY

WUG NAME	BASIN	SOURCE TYPE	SOURCE NAME	YR2000	YR2010	YR2020	YR2030	YR2040	YR2050
MENTONE	23	01	CENOZOIC PECOS ALLUVIUM	6	6	6	6	6	6
COUNTY-OTHER	23	01	CENOZOIC PECOS ALLUVIUM	7	5	4	3	3	2
IRRIGATION	23	00	RED BLUFF LAKE/RESERVOIR	324	324	324	324	324	324
LIVESTOCK	23	01	CENOZOIC PECOS ALLUVIUM	65	65	65	65	65	65
MINING	23	01	CENOZOIC PECOS ALLUVIUM	3	3	3	3	3	3
				405	**403**	**402**	**401**	**401**	**400**

Appendix 2. Current and Projected Water Supplies, Trans-Pecos PGMA Study Area

REEVES COUNTY

WUG NAME	BASIN	SOURCE TYPE	SOURCE NAME	YR2000	YR2010	YR2020	YR2030	YR2040	YR2050
BALMORHEA	23	00	OTHER LOCAL SUPPLY	30	30	30	30	30	30
BALMORHEA	23	01	OTHER AQUIFER	100	100	100	100	100	100
PECOS	23	01	CENOZOIC PECOS ALLUVIUM	1,840	1,840	1,840	1,840	1,840	1,840
PECOS	23	01	DOCKUM AQUIFER	1,270	1,600	1,600	1,600	1,600	1,600
TOYAH	23	00	OTHER LOCAL SUPPLY	102	102	102	102	102	102
COUNTY-OTHER	23	00	OTHER LOCAL SUPPLY	50	50	50	50	50	50
COUNTY-OTHER	23	01	CENOZOIC PECOS ALLUVIUM	280	280	280	280	280	280
COUNTY-OTHER	23	01	CENOZOIC PECOS ALLUVIUM	260	260	260	260	260	260
COUNTY-OTHER	23	01	DOCKUM AQUIFER	130	130	130	130	130	130
COUNTY-OTHER	23	01	EDWARDS-TRINITY-PLATEAU	76	76	76	76	76	76
IRRIGATION	23	00	DIRECT REUSE	689	689	689	689	689	689
IRRIGATION	23	00	RED BLUFF LAKE/RESERVOIR	9,110	9,110	9,110	9,110	9,110	9,110
IRRIGATION	23	01	CENOZOIC PECOS ALLUVIUM	56,868	56,868	56,868	56,868	56,868	56,868
LIVESTOCK	23	00	LIVESTOCK LOCAL SUPPLY	106	106	106	106	106	106
LIVESTOCK	23	01	CENOZOIC PECOS ALLUVIUM	1,060	1,060	1,060	1,060	1,060	1,060
LIVESTOCK	23	01	DOCKUM AQUIFER	80	80	80	80	80	80
LIVESTOCK	23	01	EDWARDS-TRINITY-PLATEAU	900	900	900	900	900	900
LIVESTOCK	23	01	OTHER AQUIFER	100	100	100	100	100	100
MANUFACTURING	23	01	CENOZOIC PECOS ALLUVIUM	13	13	13	13	13	13
MINING	23	01	CENOZOIC PECOS ALLUVIUM	0	0	0	0	0	0
				73,064	**73,394**	**73,394**	**73,394**	**73,394**	**73,394**

Appendix 2. Current and Projected Water Supplies, Trans-Pecos PGMA Study Area

WARD COUNTY

WUG NAME	BASIN	SOURCE TYPE	SOURCE NAME	YR2000	YR2010	YR2020	YR2030	YR2040	YR2050
BARSTOW	23	01	CENOZOIC PECOS ALLUVIUM	103	92	80	72	69	67
GRANDFALLS	23	01	CENOZOIC PECOS ALLUVIUM	216	204	0	0	0	0
MONAHANS	23	00	DIRECT REUSE	1,200	1,200	1,200	1,200	1,200	1,200
MONAHANS	23	01	CENOZOIC PECOS ALLUVIUM	2,139	2,174	2,119	2,028	1,885	1,795
MONAHANS	23	01	DOCKUM AQUIFER	700	700	700	700	700	700
THORNTONVILLE	23	01	CENOZOIC PECOS ALLUVIUM	164	155	143	134	122	114
WICKETT	23	01	CENOZOIC PECOS ALLUVIUM	218	197	174	168	163	159
COUNTY-OTHER	23	01	CENOZOIC PECOS ALLUVIUM	568	632	673	667	639	597
IRRIGATION	23	00	RED BLUFF LAKE/RESERVOIR	5,009	5,009	5,009	5,009	5,009	5,009
IRRIGATION	23	01	CENOZOIC PECOS ALLUVIUM	534	540	624	747	908	1,015
IRRIGATION	23	01	DOCKUM AQUIFER	300	300	300	300	300	300
LIVESTOCK	23	00	LIVESTOCK LOCAL SUPPLY	12	12	12	12	12	12
LIVESTOCK	23	01	CENOZOIC PECOS ALLUVIUM	250	250	250	250	250	250
LIVESTOCK	23	01	DOCKUM AQUIFER	25	25	25	25	25	25
MANUFACTURING	23	01	CENOZOIC PECOS ALLUVIUM	4	4	5	6	6	7
MINING	23	01	CENOZOIC PECOS ALLUVIUM	0	0	0	0	0	0
STEAM ELECTRIC	23	01	CENOZOIC PECOS ALLUVIUM	5,728	5,683	5,680	5,689	5,724	5,763
				17,170	**17,177**	**16,994**	**17,007**	**17,012**	**17,013**

Appendix 2. Current and Projected Water Supplies, Trans-Pecos PGMA Study Area

WINKLER COUNTY

WUG NAME	BASIN	SOURCE TYPE	SOURCE NAME	YR2000	YR2010	YR2020	YR2030	YR2040	YR2050
KERMIT	23	1	DOCKUM AQUIFER	2,387	2,467	2,491	2,492	2,489	2,505
WINK	23	01	CENOZOIC PECOS ALLUVIUM	339	354	360	361	360	363
COUNTY-OTHER	23	01	CENOZOIC PECOS ALLUVIUM	50	50	50	50	50	50
COUNTY-OTHER	14	01	DOCKUM AQUIFER	1	1	1	1	1	1
COUNTY-OTHER	23	01	DOCKUM AQUIFER	100	100	100	100	100	100
IRRIGATION	23	01	DOCKUM AQUIFER	1,500	1,500	1,500	1,500	1,500	1,500
LIVESTOCK	23	00	LIVESTOCK LOCAL SUPPLY	8	8	8	8	8	8
LIVESTOCK	23	01	CENOZOIC PECOS ALLUVIUM	180	180	180	180	180	180
LIVESTOCK	14	01	DOCKUM AQUIFER	1	1	1	1	1	1
MANUFACTURING	23	01	CENOZOIC PECOS ALLUVIUM	8	10	11	12	14	17
MINING	23	01	DOCKUM AQUIFER	2,040	1,940	1,940	1,940	1,940	1,940
				6,614	**6,611**	**6,642**	**6,645**	**6,643**	**6,665**

Appendix 2. Current and Projected Water Supplies, Trans-Pecos PGMA Study Area

CITY OF ODESSA, ECTOR COUNTY

WUG NAME	BASIN	SOURCE TYPE	SOURCE NAME	YR2000	YR2010	YR2020	YR2030	YR2040	YR2050
ODESSA	14	0	COLORADO RIVER MWD SYSTEM	15,567	16,765	18,114	20,320	21,954	24,047
ODESSA	14	1	CENOZOIC PECOS ALLUVIUM	5,200	5,200	5,200	5,200	5,200	5,200
ODESSA	14	1	EDWARDS-TRINITY PLATEAU	432	456	484	510	510	510
ODESSA	14	1	OGALLALA	400	400	400	531	565	607
				21,599	**22,812**	**24,198**	**26,561**	**28,229**	**30,364**

Basin: 14 = Colorado; 23 = Rio Grande
Source Type: 00 = Surface Water; 01 = Groundwater
All supplies are in acre-feet