Area Study: Parts of the Trans-Pecos, Texas

Evaluation of Selected Natural Resources in Parts of Loving, Pecos, Reeves, Ward, and Winkler Counties, Texas

Pecos River near Girvin, Texas

TEXAS PARKS & WILDLIFE

RESOURCE PROTECTION DIVISION:
WATER RESOURCES TEAM

EVALUATION OF SELECTED NATURAL RESOURCES IN PARTS OF LOVING, PECOS, REEVES, WARD, AND WINKLER COUNTIES, TEXAS

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EXECUTIVE SUMMARY

This report is an evaluation of selected natural resources of parts of the Trans-Pecos natural region of West Texas that includes all of Loving, Reeves, Ward, and Winkler Counties and a small portion of northwestern Pecos County. This report is in response to Senate Bill 1(75th Texas Legislature, 1997) which placed priority on the completion of pending Priority Groundwater Management Area (PGMA) studies mandated by House Bill 2 (69th Texas Legislature, 1985).

The study area has a semi-arid climate characterized by low rainfall and high evaporation rates. Water quality deterioration in parts of the study area has resulted from petroleum extraction activities, irrigation practices, and, for surface waters, erosion caused by overgrazing.

The economy of the area is dominated by the agricultural and petroleum industries, but tourism is also important. The two regional state parks, Balmorhea and Monahan Sandhills, 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.

The native fish fauna of the Pecos River has been negatively impacted by decreased base flow, natural and man-induced salinity increases, and pollution from agriculture and oil fields. More recently, the introduction of sheepshead minnows and toxic blooms of golden algae threatens native fishes. The refugium at Balmorhea State Park is the last stand for the Comanche Springs pupfish and supports other rare species. It is also the site of a restored desert wetland (cienega). If San Solomon Springs go the way of Tunas, Leon, and Comanche Springs, all of which dried up due to overdraft of groundwater, the agricultural and tourism economy of the area, as well as the endangered fishes, will be threatened.

The native cottonwoods, willows, and grasses that once made up the valuable riparian habitats that lined the Pecos River have been largely replaced by mesquite and the introduced saltcedar and Bermuda grass. The high water requirement of saltcedar makes it an undesirable plant for this area. 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 the river banks from erosion. Also, in order to maintain good riparian habitats, grazing pressures must be carefully managed.

Evaluation of Selected Natural Resources in Parts of Loving, Pecos, Reeves, Ward, and Winkler Counties, Texas

INTRODUCTION

Purpose

The Texas Natural Resource Conservation Commission (TNRCC), working with the Texas Water Development Board (TWDB) and the Texas Parks and Wildlife Department (TPWD), is charged with identifying priority groundwater management areas (PGMAs) – areas in the State that are experiencing, or are expected to experience in the future, critical groundwater problems. The purpose of the PGMA program is to assist local and regional interests in addressing groundwater management issues; including the quantity and quality of surface water and groundwater, contamination, and land subsidence.

Senate Bill 1 (75th Texas Legislature, 1997) placed priority on the completion of pending PGMA studies that were called for by House Bill 2 (69th Legislature) in 1985. The TNRCC and TWDB identified all or parts of Loving, Pecos, Reeves, Ward, and Winkler Counties for continued monitoring. The Trans-Pecos Study Area was not designated as a critical area for a PGMA study in 1990, but the TWDB and TNRCC were to continue monitoring groundwater levels and local groundwater management initiatives. A groundwater study was initiated in 1990 with the TNRCC requesting a groundwater resource and availability study from the TWDB. The TWDB completed the report *Evaluation of Ground-water Resources in Parts of Loving, Pecos, Reeves, Ward, and Winkler Counties, Texas* (TWDB Report No. 317, Ashworth) in January of 1990.

Location and Extent

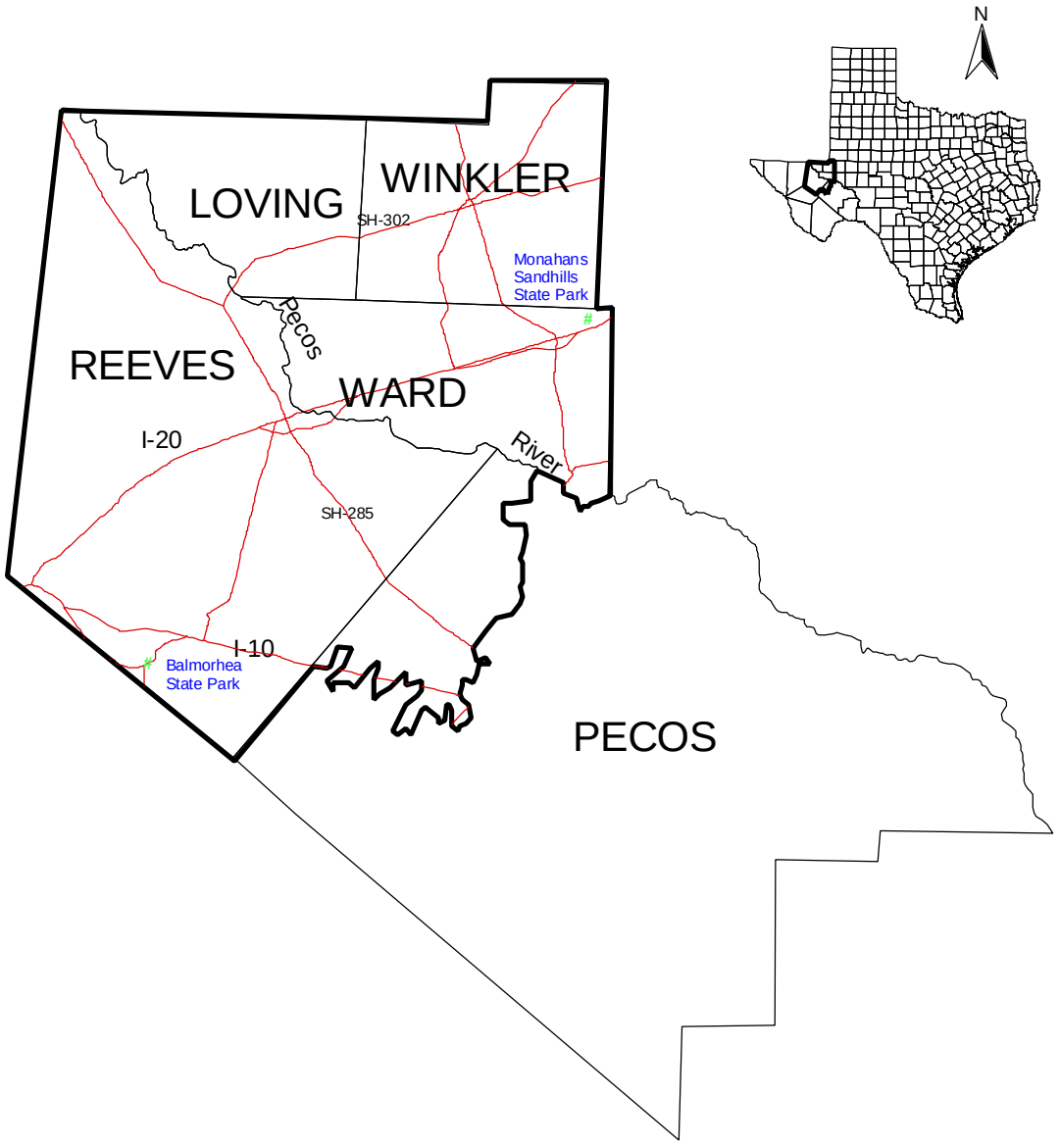
The study area is located in the northern part of the Trans-Pecos region of West Texas, which is in the Great Plains physiographic province, and falls within the Rio Grande basin. The boundary of the area is defined by the areal extent of the Cenezoic Pecos Alluvium Aquifer in parts of Loving, Pecos, Reeves, Ward, and Winkler Counties (Fig. 1) and includes the population centers of Kermit, Monahans, Pecos, and several smaller communities. The study area covers approximately 5,500 square miles.

Geography and Ecology

The study area is located within the Trans-Pecos Natural Region (LBJ School of Public Affairs 1978; Fig. 2). The Trans-Pecos region is in the northern portion of the Chihuahuan Desert, occupying the extreme western part of the state eastward to the Pecos River, and including the Stockton Plateau and the Sand Hills near the southeast corner of New Mexico.

Most of the study area is in the Desert Scrub sub-region, which typifies the Trans Pecos Region. The flora of the region is dominated by desert scrub such as creosotebush and tarbush, desert grasslands, and pinyon-oak-juniper woodland. The composition of many desert plant communities

Figure 1. Location of the Study Area



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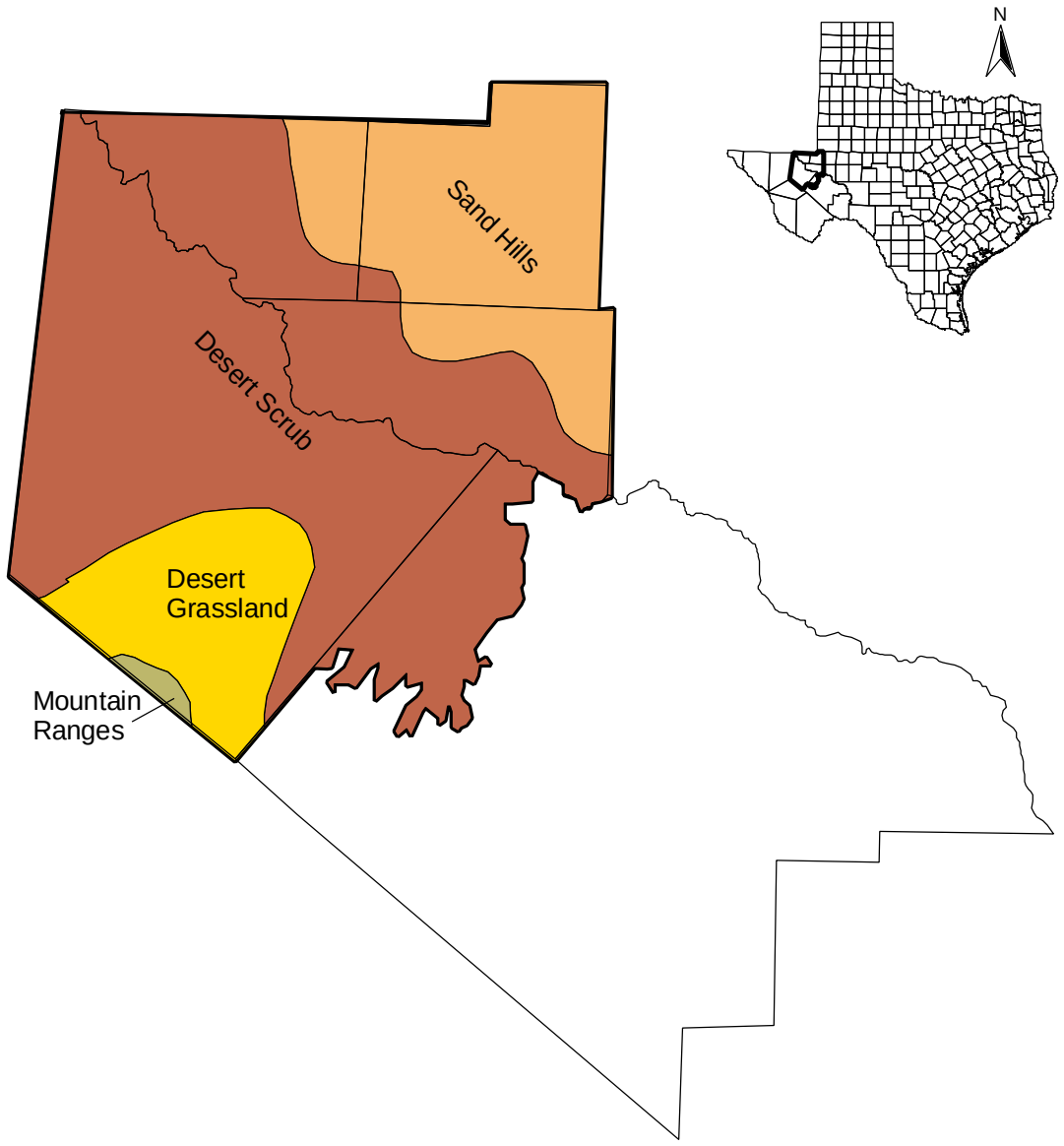
Produced by the TPWD Water Resources Team, July 1998. No claims are made to the accuracy of the data or the suitability of the data for a particular use.

Sources:
TPWD GIS lab archives data 1998.

Projections:
Texas Statewide Projection
(Lambert Conformal Conic)

Figure 2. Natural Subregions of the Study Area



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TEXAS PARKS & WILDLIFE

Produced by the TPWD Water Resources Team, July 1998. No claims are made to the accuracy of the data or the suitability of the data for a particular use.

Sources:
Preserving Texas' Natural Heritage. LBJ School of Public Affairs Policy Research Project, Report 31, 1978.

Projections:
Texas Statewide Projection

has been drastically altered in the last 75 years (LBJ School of Public Affairs. 1978).

The topography of the region is uplands that gently slope toward the Pecos River. The river terraces are mantled by fine- to medium-textured gypsiferous soils that historically were extensively cultivated (White 1971 in TWDB Report No. 317, Ashworth).

Among the major physiographic features of the study area are (1) the flood plain of the Pecos River; (2) the Cenozoic Pecos Alluvium Aquifer; (3) the Sandhills in northeastern Ward and eastern Winkler Counties; (4) and the Davis Mountains to the south (Figs. 1 & 2).

A wide range in temperature, low rainfall, and a high rate of evaporation, as recorded by the National Weather Service, characterizes the semi-arid climate in the region. Average annual rainfall ranges from 9.1 inches in the north-northwest to about 13.9 inches in the east-southeast. Mean monthly low temperatures for January range from about 27° F in the north-northwest to 30° F in the south-southeast and the mean monthly high for July is 97° F and 100° F respectively (Dallas Morning News 1997).

Demographics

The 1990 census estimated the population of the study area, including all of rural Pecos County, to be 42,529 (Table 1; TWDB 1998). People are not distributed uniformly throughout the region. The largest city within the study area is Pecos, with a population of just under 11,900, in Reeves County. The projection for growth in the study area for year 2050, including all of rural Pecos County, is a population of 53,362 (TWDB 1998).

Table 1. Population Projection for the Study Area (TWDB 1998)

Year Þ Locality ß	***1990***	***2000***	***2010***	***2020***	***2030***	***2040***	***2050***
Loving	107	105	98	84	74	62	49
Reeves	15,852	17,580	19,356	20,812	21,541	22,127	22,546
Pecos*	4,829	5,267	5,783	6,126	6,210	6,246	6,062
Ward	13,115	13,969	14,822	15,206	14,956	14,508	13,885
Winkler	8,626	9,282	10,042	10,599	10,764	10,875	10,820

*Not all of the rural population of Pecos County is within the study area.

Economy and Land Use

The economy of the area consists primarily of farming, ranching, petroleum production, and the attendant service infrastructure. Service businesses include agribusiness and tourism (Dallas Morning News 1997).

Agricultural production includes cotton, alfalfa, pecans, hay, and some vegetables. The study area includes an estimated 71,000 acres of irrigated land (Dallas Morning News 1997). Livestock production includes beef cattle, swine, and horses.

Acknowledgements

The authors wish to thank the numerous individuals who provided in providing information on the selected natural resources in the study area. Additional thanks are given to those individuals whose comments and proofreading allowed us to put this report out. We appreciate and acknowledge the help and expertise of Jackie Poole, David Bradsby, David Riskind, Peggy Horner, Gordon Linam, John Maresh, Andy Price, Dorinda Scott, Gena Janssen, Joan Glass, and Jason Singhurst.

SELECTED NATURAL RESOURCES*

TPWD Regional Facilities

Within the study area, the TPWD operates two state parks (Fig. 1), Balmorhea State Park (SP) and Monahans Sandhills SP. The former requires water to operate and provide recreational opportunities to the public, as well as to maintain a refugium harboring endangered fish species and other unique fauna and flora.

Balmorhea SP is located on 45.9 acres in the foothills of the Davis Mountains, southwest of Balmorhea in Reeves County. The park's main attraction is a large (77,053 sq.ft) artesian spring pool that is open to the public. The pool is fed by San Solomon Springs and has a capacity of more than 3 ½ million gallons. The San Solomon Springs also fill a cienega (desert wetland) and the canals of a refugium; home to endangered species of fish, assorted invertebrates, and turtles.

Monahans Sandhills SP consists of 3,840 acres of sand dunes, some up to 70 feet high, in Ward and Winkler Counties. The park is a small portion of a dune field that extends about 200 miles from south of Monahans westward and north into New Mexico. Most of these dunes are stabilized by vegetation, but the park is one area where the dunes are still active. Fresh water occurs at shallow depths within the dune field and sometimes stands in shallow ponds in low areas between dunes.

Estimates of the economic importance of these parks to Reeves and Ward Counties are shown in Table 2. The economic impact parameter measures the infusion of "new money" into the local economy by out-of-county visitors to the parks. It is a better measure of economic importance than "economic surge" which also includes expenditures by local visitors. More detailed breakdowns of the data summarized in Table 2 are found in Appendix A.

Table 2. Summary of Estimated Economic Importance (Impact and Surge) of TPWD facilities in Reeves and Ward Counties (Crompton et al. 1998)

County	Total Visitors	Total Expenditures ($)	Total Sales ($)	Total personal Income ($)	Total Employment (persons)
Reeves					
Impact	155,657	893,085	1,494,409	422,897	39.5
Surge	155,657	895,911	1,499,149	424,236	39.6
Ward					
Impact	77,569	362,173	687,644	188,288	16.4
Surge	77,569	463,112	879,062	240,696	20.9

* The fauna and flora described in this report represents those species that are riparian, semi-aquatic, and aquatic, unless otherwise noted.

Vegetation and Soil

The natural regions of Texas were delineated largely on the basis of soil type and major vegetation types (McMahan et al. 1984). The study area soils consist of limestone and igneous rock outcrops of mountains and hills and mostly shallow, loamy soils; some deep soils with loamy surface layers; and clayey subsoil (Godfrey et al. 1973). The Pecos River terraces are also mantled by fine-to medium-textured gypsiferous soils that were historically cultivated.

The vegetation type map of Figure 3 shows the Creosotebush-Tarbush Shrub type as dominant in Reeves and Pecos counties. Associated plants include range ratany, cholla, four-wing saltbush, sotol, mesquite, whitethorn acacia, catclaw, lechuguilla, chino grama, gyp grama, alkali sacaton, false nightshade, false jimmyweed, and jimmyweed (McMahan et al. 1984).

The Mesquite-Lotebush Shrub type is principally found in Loving, Winkler, and Ward counties within the study area. The associated plants include yucca, skunkbush sumac, juniper, tasajillo, cane bluestem, silver bluestem, little bluestem, Texas grama, sideoats grama, hairy grama, red grama, tobosa, buffalograss, Texas wintergrass, purple three-awn, Engelmann daisy, broom snakeweed, and bitterweed (McMahan et al. 1984).

Other non-dominant vegetation types include Creosotebush-Mesquite Shrub, Havard Shin Oak Brush, and Four-wing Saltbush-Creosotebush Shrub (McMahan et al. 1984).

Cultivated crops are found mostly in Reeves and Pecos Counties. As seen in Figure 3, crops cover a relatively small portion of the study area.

Riparian and aquatic vegetation of Balmorhea SP and along the Pecos River are typical vegetation present in the study area at creeks, rivers, and wetlands (Tables 3 and 4). The puzzle sunflower *(Helianthus paradoxus)*, a spring-dependent plant species, is reported to be present in the study area, and will soon be listed by the federal government as an endangered species.

Table 3. Selected* Plants of Balmorhea State Park (Wildlife Diversity Program 1998)

Scientific Name	Common Name
BIGNONIACEAE	**CATALPA FAMILY**
Chilopsis linearis	Desert willow
CYPERACEAE	**SEDGE FAMILY**
Cyperus odoratus	Rusty flatsedge
Eleocharis montevidensis	Sand spikerush
Scirpus acutus	Hardstem bulrush
S. americanus	Olney's bulrush
S. robustus	Alkali bulrush
JUGLANDACEAE	**WALNUT FAMILY**
Juglans microcarpa	River walnut
JUNCACEAE	**RUSH FAMILY**
Juncus sp.	Rush
POACEAE	**GRASS FAMILY**
Phragmites australis	Common reed
Sporobolus airoides	Alkali sacaton
PONTEDERIACEAE	**PICKEREL WEED FAMILY**
Heteranthera liebmannii	Liebmann's mud-plantain
PRIMULACEAE	**PRIMROSE FAMILY**
Samolus cuneatus	Limerock brookweed
SALICACEAE	**WILLOW FAMILY**
Populus fremontii	Freemont's cottonwood
TAMARICEAE	**TAMARISK FAMILY**
Tamarix ramosissima	Saltcedar
TYPHACEAE	**CATTAIL FAMILY**
Typha latifolia	Broad-leaf cattail
ULMACEAE	**ELM FAMILY**
Celtis reticulata	Netleaf hackberry
C. pallida	Spiny hackberry

Table 3 is based on reports and observations by Texas Parks and Wildlife Department staff biologists. See Appendix B for a complete checklist of vascular plants in Balmorhea State Park.

* The fauna and flora described in this report represents those species that are riparian, semi-aquatic, and aquatic, unless otherwise noted.

Table 4. Rare Plant Species of the Study Area* (Poole and Carr 1997)

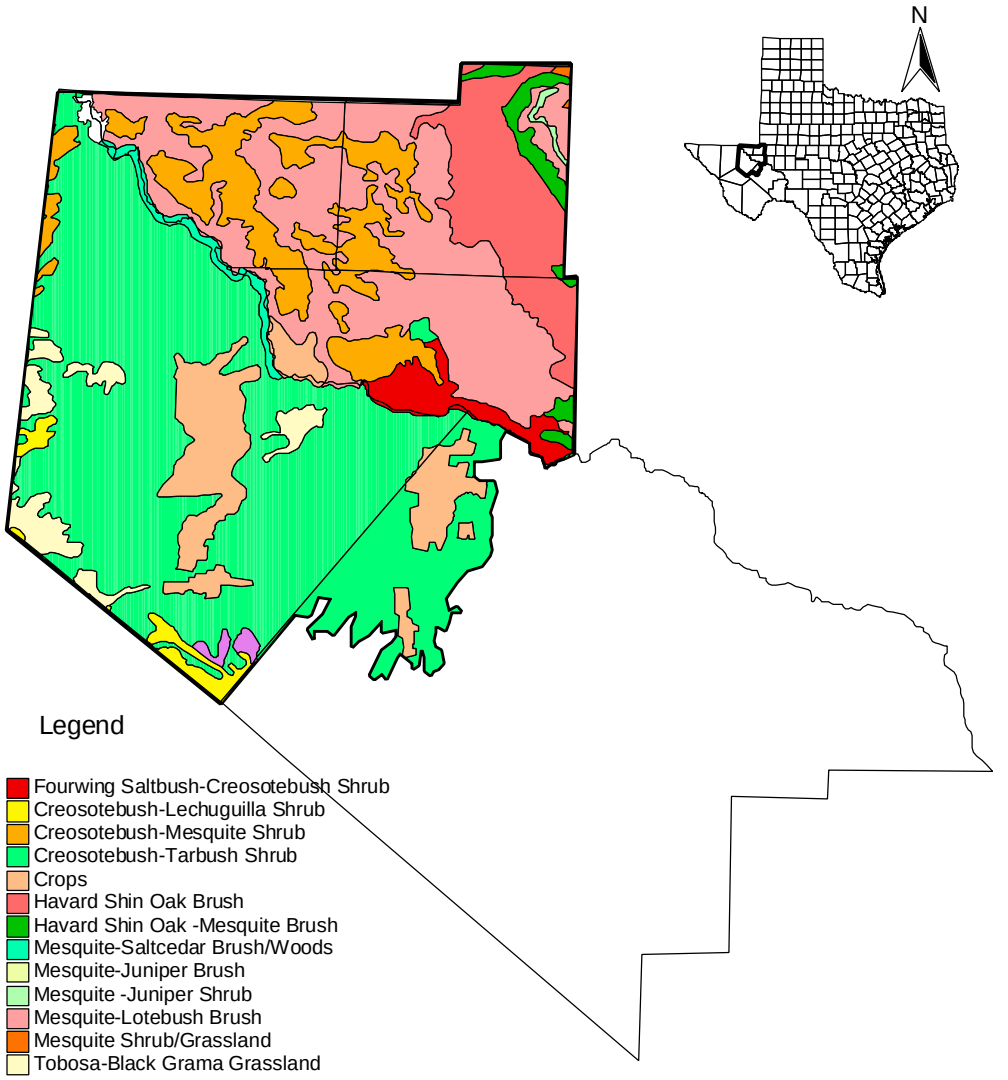
Scientific Name	Common Name	County
Acleisanthes wrightii	Wright's trumpets	Reeves, Pecos
Amsonia tharpii	Tharp's blue-star	Pecos
Astragalus gypsodes	Gyp locoweed	Reeves
Cereus greggii var. greggii	Desert night-blooming cereus	Pecos
Chamaesyce albicolumnaria	White column cactus	Pecos
Chamaesyce jejuna	Dwarf broomspurge	Pecos
Coryphantha albicolumnaria	White column cactus	Pecos
Coryphantha dasyacantha var. dasyacantha	Dense cory cactus	Pecos
Coryphantha hesteri	Hester's cory cactus	Pecos
Cyperus onerosus	Dune flatsedge	Winkler, Ward
Echinocereus viridiflorus var. correllii	Correll's green pitaya	Pecos
Eriogonum nealleyi	Irion county wild-buckwheat	Pecos
Eriogonum suffruticosum	Bushy wild-buckwheat	Pecos
Helianthus neglectus	Neglected sunflower	Loving, Ward, Winkler
Helianthus paradoxus	Puzzle sunflower	Reeves, Pecos
Justicia wrightii	Wright's water-willow	Pecos
Perityle bisetosa var. bisetosa	Two-bristle rock-daisy	Pecos
Perityle cinerea	Grayleaf rock-daisy	Reeves, Pecos
Proboscidea sabulosa	Dune unicorn-plant	Loving, Ward, Winkler
Suaeda duripes	Hardtoe seepweed	Reeves, Pecos

*Species appearing in Table 4 do not all share the same probability of occurrence within a county. The plants in this table are the most globally-rare taxa that occur naturally in the study area.

General Description of the Pecos River

The Pecos River originates in the Sangre de Cristo Mountains of northern New Mexico and flows 1320 km southeast to the Rio Grande (Fig. 4). It traverses the study area from northwest to southeast. Naturally occurring brine springs and dissolution of subsurface Permian salts in the middle reach of the river (between Fort Sumner and Roswell, New Mexico) contribute to increases in salinity as do low rainfall, high evaporation rates, and a paucity of contributing freshwater tributaries (Davis 1987 in Linam and Kleinsasser 1996). Prior to the development of large-scale irrigation, base flow gain studies indicated that groundwater inflow to the river between Red Bluff Reservoir near the New Mexico-Texas state line and Girvin, Texas, averaged 30,000 acre-feet or more per year (Grover et al. 1922; and U.S.National Resources Planning Board, 1942 in TWDB Report No. 317, Ashworth).

Figure 3. The Vegetation Types of the Study Area



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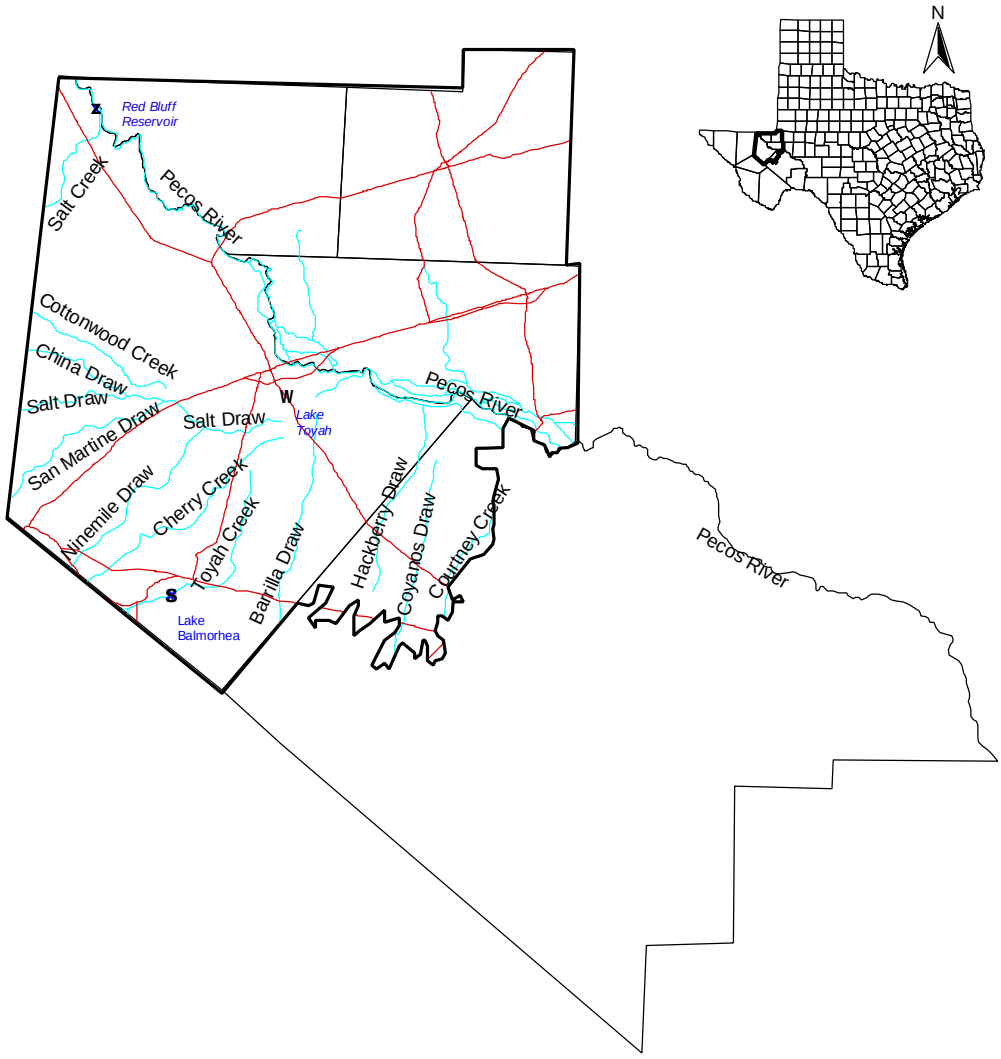
Produced by the TPWD Water Resources Team, October 1998. No claims are made to the accuracy of the data or the suitability of the data for a particular use.

Source: TPWD GIS lab archives. The vegetation represents a general summary of previously produced larger scale maps. Delineation of the vegetation occurs only where the actual vegetation exhibited adequate resolution for definition.

Figure 4. Surface Water Resources in the Study Area



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Sources:
Texas Natural Resources Information System,
Texas Water Developement Board,
TPWD GIS lab archives data 1998.

Projections:
Texas Statewide Projection

Increased irrigation pumpage in the 1950s and 1960s resulted in declining water levels, which caused the groundwater to reverse direction and flow away from the river. In 1965, Grozier et al. (1966) measured a streamflow loss of approximately 2,480 acre-feet of water in the Red Bluff to Girvin segment (TWDB Report No. 317, Ashworth).

Springs

The distribution and size, as of 1980, of springs and seeps in the area are given by county in Table 5 (Brune 1981). Flowing springs emphasize the fact that ground and surface water are related. Most springs emanate from the top of the groundwater reservoir, so changes in water table elevation generally have immediate impact upon spring discharge rates.

Table 5. Distribution and Estimated Size (in 1980) of Springs and Seeps in the Study Area (Brune 1981)

County	Large	Moderately large	Medium	Small	Very small	Seep	Former
Loving	0	0	0	1	0	0	2
Pecos	0	0	0	0	0	0	0
Reeves	1	1	1	3	0	0	15
Ward	0	0	0	0	0	0	4
Winkler	0	0	0	0	0	1	2

The numbers above are a reflection of either a spring or a group of springs.
Codes:
Large = 280 to 2,800 cfs
Moderately large = 28 to 280 cfs
Medium = 2.8 to 28 cfs
Former = no flow or inundated
Small = 0.28 to 2.8 cfs
Very Small = 0.028 to 0.28 cfs
Seep = less than 0.028 cfs

As Table 1 shows, Loving County is the most sparsely populated county in the study area, with only 107 residents in 1990, and a TWDB projection of 49 residents for 2050. Brune (1981) cites a lack of good water for this projected population decline, but that was not always the case. Archeological finds such as projectile points, metates, and manos found near Mentone suggest that springs of pure, fresh water once existed. Also, historical records, from the late 1500s, show the Pecos River was very deep and “formidable” to cross, with steep banks (Brune 1981).

According to Brune (1981): irrigation wells, mostly in Reeves County, greatly lowered the water table, causing springs to cease flowing. The hydrology of the Pecos River in this reach changed. Where it formerly was fed by springs, now it must feed the groundwater reservoir. And since the river water is quite salty, the groundwater is also now becoming salty. The same is true for the areas in Ward and Reeves Counties bordering the Pecos River.

The only known springs that are still flowing in Loving County are Allison Spring (inundated) and Red Bluff Springs. The latter 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. These springs of moderately saline water sustain killifish, brine shrimp, turtles, salt cedars and rushes (Brune 1981).

Of the 21 springs or spring groups in Reeves County (Table 5), six are still flowing (Brune 1981). Major springs including Giffin, Sandia, and San Solomon, are still used for irrigation, recreation (Balmorhea SP), and as a public water supply (Cities of Balmorhea and Toyah).

Most of the springs formerly supported marshes within which grew cattails, sedges, rushes or tules, sacaton grasses, common reed, and saltgrass. Cottonwood and willow trees often surrounded the marshes. Today most of this vegetation has disappeared with the springs, along with the animal life that thrived on them (Brune 1981).

San Solomon Springs support several rare and endangered species of small fish. These include the pupfish that were found only 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 (Brune 1981). Other springs, such as Sandia Springs also supports rare plants such as the puzzle sunflower mentioned earlier in the text.

The implementation of a PGMA in this region could prevent the lowering of groundwater tables to the point where more springs dry up. In general, a flowing spring emphasizes the fact that ground and surface water supplies are related.

Groundwater

The Cenozoic Pecos Alluvium Aquifer, located in the upper part of the Pecos River Valley of west Texas, provides water to portions of Loving, Pecos, Reeves, Ward, and Winkler Counties. The aquifer is the principal source of water for irrigation in Reeves and northwestern Pecos counties and for industrial power generation, and public supply elsewhere. Water is exported from Ward County to the City of Odessa by the Colorado River Municipal Water District (CRMWD). The Edwards-Trinity (Plateau) Aquifer is another major aquifer that extends from the Hill Country of Central Texas to the Trans-Pecos region of West Texas (TWDB 1997).

Three minor aquifers underlie the study area. These are: the Dockum, Rustler, and Capitan Reef Complex aquifers. The hydrogeology, water quality, water availability, and resource management of all of the aquifers that underlie the study area are covered in detail in the PGMA report 317 prepared by TWDB in 1990 and updated in 1998.

Wetlands

The native cottonwoods, black willow, and grasses that once dominated the riparian corridor along the Pecos River have been, long ago, taken over by saltcedar and mesquite brush and woods, and Bermuda grass. Saltcedar was introduced early in the century in an effort to stabilize the eroding banks of the river. The erosion was brought on by poor land

management such as overgrazing and inappropriate farming practices. This riparian vegetation, although not natural or ideal, does help stabilize the river banks and provide some useable habitat for migrating birds and some resident animals. Unfortunately, saltcedar uses large amounts of water and may, in some areas, have contributed to declines in ground and surface water. Also, saltcedar tends to form monocultures, or at best plant assemblages of reduced diversity over large areas and this leads to an overall decline in biological diversity.

The sand dunes of Monahans Sandhills SP would seem an unlikely place to encounter wetlands. Nevertheless, there are actually numerous ephemeral and some permanent fresh water ponds inside and outside the state park. These ponds and fringing wetlands are found in interdunal depressions. These ponds exist because a perched water table is underlain by impermeable caliche layers. The interdunal ponds are dynamic and change location as active dunes migrate. The fringing wetland plants of the more permanent ponds include willows, bulrushes, cattails, flatsedges, rushes, spikerushes, and others. Dune flatsedge *(Cyperus onerosus)* is a rare plant, endemic to this region, also associated with these unusual wetlands.

At Balmorhea SP, there is a restored desert wetland, cienega, associated with San Solomon Springs. This wetland supports many wetlands plants (Table 3), associated wetland wildlife (Tables 8, 9, 10, and 11), and fishes (Table7), as well as tourists and irrigated agriculture.

Fishes

The Pecos River between Red Bluff Reservoir and Girvin, Texas has a characteristic fish fauna (Table 6). Streamflow, natural salinity as well as that induced by man's activities, and agricultural and oil field pollution are the major factors that have affected the Pecos River fish fauna (Campbell 1959; Davis 1987 in Linam and Kleinsasser 1996). More recent factors include the introduction of non-native fish and toxic blooms of the yellow alga *Prymnesium parvum* (Linam and Kleinsasser 1996).

Historically, the Pecos River drainage supported 51 species of native fish and one introduced, inland silverside (*Menidia beryllina*) (Smith and Miller 1986 in Linam and Kleinsasser 1996). Of the 51 species, 8 are restricted to the New Mexico reach of the river and 3 other species occur in drainages outside the mainstem: Leon Springs pupfish (*Cyprinodon bovinu*s), Comanche Springs pupfish (*Cyprinodon elegans*), and Pecos gambusia (*Gambusia nobilis*) (Hubbs et al. 1991 in Linam and Kleinsasser 1996). Species that have been extirpated from the main river include American eel (*Anguilla rostrata*) and Rio Grande silvery minnow (*Hybognathus amarus*) (Hubbs et al. 1991 in Linam and Kliensasser 1996). Bluntnose shiner (*Notropis simus*) and Pecos pupfish (*Cyprinodon pecosensis*) have been extirpated from the Texas reach of the river, but still exist in New Mexico (U.S. Fish and Wildlife Service 1992; Hubbs et al. 1991; Echelle et al. 1987 in Linam and Kleinsasser 1996). In addition, the Pecos pupfish may occur in Salt Creek in northern Reeves County (Bauer et al. 1996).

Table 6. Summary of Recent and Historic Field Collections of Fish Species from the Pecos River Drainage Between Red Bluff Reservoir and Girvin, Texas (Linam and Kleinsasser 1996)

Scientific Name	Common Name
Anguilla rostrata (extirpated)	American eel
Astyanax mexicana	Mexican tetra
Cichlasoma cyanoguttatum	Rio Grande cichlid
Cyprinella lutrensis	Red shiner
Cyprinella proserpina	Proserpine shiner
Cyprinodon bovinus	Leon Springs pupfish
Cyprinodon elegans	Comanche Springs pupfish
Cyprinodon pecosensis	Pecos pupfish
Cyprinodon sp.	Pupfish hybrid
Cyprinodon variegatus (introduced)	Sheepshead minnow
Cyprinus carpio	Common carp
Dorosoma cepedianum	Gizzard shad
Fundulus grandis (introduced)	Gulf killifish
Fundulus zebrinus	Plains killifish
Gambusia affinis	Western mosquitofish
Gambusia geiseri (introduced)	Largespring gambusia
Gambusia nobilis	Pecos gambusia
Hybognathus amarus (extirpated)	Rio Grande silvery minnow
Lucania parva	Rainwater killifish
Menidia beryllina (introduced)	Inland silverside
Notropis simus (extirpated)	Bluntnose shiner

Salt tolerant species are the most abundant fishes in the Red Bluff to Girvin reach of the river. Red shiner and western mosquito fish were the most abundant species. A Pecos pupfish x sheepshead minnow hybrid also occurs in this reach (Linam and Kleinsasser 1996). Past records indicate that salinity increases from the headwaters to Girvin, and then decreases downstream (Davis 1987 in Linam and Kleinsasser 1996). Fish species abundance and distribution appear to be determined by water quality factors, primarily salinity, which has increased over time (Davis 1987 Linam and Kleinsasser 1996). This trend is likely to continue. Small to large overdrafts of groundwater have been documented in Reeves and Pecos Counties (due primarily to withdrawals for irrigation purposes), where groundwater levels have fallen as much as 492 feet (Texas Department of Water Resources 1984; Brune 1981 in Linam and Kleinsasser 1996).

Freshwater springs throughout the basin have gone dry in recent years, but especially hard hit has been the upper basin, which is now nearly destitute of springs. Because of this, the Pecos River is now much smaller than it once was in the upper reach (Brune 1981). Groundwater no longer contributes freshwater flow to the Upper Pecos River, but has receded. Now, saline river water influences the quality of the groundwater which in the past had provided freshwater input to the river (Brune 1981). The operation of Red Bluff Reservoir will also likely continue impacting the river water quality. Except during floods, the flow of the Pecos River for a considerable distance downstream from the reservoir

consists principally of releases and some seepage from the reservoir. As a result, total dissolved solids in this reach vary between 2,700 and 15,000 mg/L and exceed 7,500 mg/L 50 percent of the time (Texas Department of Water Resources 1984). Oil and gas production are major activities in every Texas county bordering the Pecos River (Kingston 1991), and will continue to be a potential source of pollution, as will agriculture.

Cotton is the major crop produced in the Pecos River watershed, with the majority of the production concentrated in Reeves and Pecos Counties (Texas Agric. Statistics Serv. 1998). Production of cotton typically includes application of arsenic based defoliants prior to harvesting. These, as well as other agriculture chemicals used in the production of crops, are potential pollution sources. Livestock production is also a major activity in certain areas of the watershed and can affect the water quality in a number of ways through feedlot waste runoff and by decreases in groundwater recharge through overgrazing and soil compaction (Davis 1987). Stocking of introduced species will continue to present inherent risks to the native fish fauna. Non-native species often impact native species resulting in decreased numbers or their extirpation. An example is the introduction of sheepshead minnow (*Cyprinodon variegatus*) to the river and its hybridization with the Pecos pupfish (Echelle et al. 1987 in Linam and Kleinsasser 1996).

Lastly, toxic algae blooms may continue to be a recurring problem. Little is known on the conditions that promote a bloom of *P. parvum*, but more than 2 million fish have already succumbed to its toxin (James and De La Cruz 1989 in Linam and Kleinsasser 1996). Only one fish kill has been documented since 1988; however, this may only be due to above average annual rainfall (Anderson et al. 1991; Anderson et al. 1990 in Linam and Kleinsasser 1996). Toxin production, toxin toxicity, and the species' growth are linked to salinity and nutrient concentration (Holdway et al. 1978 in Linam and Kleinsasser 1996). In addition, stressful conditions appear to decrease other algae forms and enhance toxic algae blooms and toxin toxicity levels (Shilo 1981 in Linam and Kleinsasser 1996).

San Solomon Springs in the refugium in Balmorhea SP is another place where some native fish species can be found. The refugium was constructed in 1975 to provide suitable, lasting habitat for the endangered Comanche Springs pupfish and the Pecos gambusia. These two species also occur in Toyah Creek from the headwaters to the FM 2448 crossing (Bauer et al. 1991). One can also observe in the refugium Mexican tetra, channel catfish, largespring gambusia, roundnose minnow, and green sunfish (Hubbs 1993; Table 7).

Table 7. Fishes of the Refugium at Balmorhea State Park (Hubbs 1993)

Scientific Name	Common Name
Cyprinodon elegans	Comanche Springs pupfish
Gambusia nobilis	Pecos gambusia
Astyanax mexicanus	Mexican tetra
Ictalurus punctatus	Channel catfish
Gambusia geiseri	Largespring gambusia
Dionda episcopa	Roundnose minnow
Lepomis cyanellus	Green sunfish

As indicated by its common name, the Comanche Springs Pupfish once occurred in Comanche Springs at Fort Stockton. Tunas, Leon, and Comanche Springs have all gone dry due to overdraft of groundwater. The sole remaining populations of the pupfish inhabit the springs and irrigation canals of the Balmorhea area (Hubbs 1993). Reduction of flow at San Solomon and other springs in the Balmorhea area threatens not only the endangered fishes but also the agricultural and tourist economy in the area.

Birds and Waterfowl

Many species of migrating birds, wintering shorebirds, and neotropical songbirds (Table 8) 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, and San Solomon Springs, as well as the water holes/depressions in the sandhills of Ward and Winkler Counties. The trees and shrubs that grow along the river, streams and lakes, the riparian habitat, are of special importance to nesting songbirds and raptors, such as the southwest willow flycatcher and the zone-tailed hawk.

Lake Balmorhea is located about 2 miles east of the town of Balmorhea. It is a spring-fed lake and one of the largest bodies of water in the Trans-Pecos. As a result, large numbers of birds congregate there. The lake is used to store water for irrigation and its level fluctuates seasonally. In dry years, it can be almost dry by mid-summer, while it may overflow in wet years into several overflow ponds. One of the ponds is located on the west side of the lake at the base of an earthen dike. This pond is part of an extensive marsh and offers good birding opportunities. The southern edge of the lake is excellent for shorebirds in dry years when water levels are low. The east end of the lake is where the dam is located. It is the deepest and is preferred by loons and western grebes in fall and winter. Below the dam is an area of sedges, reeds, and saltcedar. Overall, the lake attracts large numbers of waterbirds, especially in winter (Lockwood 1992).

Table 8. Selected Birds and Waterfowl of the Study Area (Wildlife Diversity Program (TXBCD) 1998; Lockwood 1992)

Scientific Name	Common Name	Season	Fed/ State Status
Actitis macularia	Spotted sandpiper	W	
Agelaius phoeniceus	Red-winged blackbird	YR	
Aechnophorus occidentalis	Western grebe	W, M	
Aix sponsa	Wood duck	W	
Anas acuta	Northern pintail	W	
Anas americana	American wigeon	W	
Anas clypeata	Northern shoveler	W	
Anas crecca	Green-winged teal	W	
Anas cyanoptera	Cinnamon teal	YR	
Anas discors	Blue-winged teal	B	
Anas platyrhynchos	Mallard	YR	
Anas strepera	Gadwall	W	
Anser albifrons	Greater white-fronted goose	W	
Anthus rubescens	American pipit	W	
Ardea alba	Great egret	W	
Ardea herodias	Great blue heron	YR	
Aythya affinis	Lesser scaup	W	
Aythya americana	Redhead	W	
Aythya collaris	Ring-necked duck	W	
Aythya valisineria	Canvasback	W	
Botaurus lentiginosus	American bittern	W, R	
Branta canadensis	Canada goose	W	
Bucephala albeola	Bufflehead	W	
Bucephala clangula	Common goldeneye	W, R	
Buteo albonotatus	Zone-tailed hawk	B, R	
Butorides virescens	Green heron	YR	
Calidris minutilla	Least sandpiper	B, M	
Ceryle alcyon	Belted kingfisher	W, M	
Charadrius alexandrinus	Snowy plover	B, M	
Charadrius semipalmatus	Semipalmated plover	M, B	
Charadrius vociferus	Killdeer	YR	
Chen caerulescens	Snow goose	W	
Cistothorus palustris	Marsh wren	M, W	
Colaptes auratus	Northern flicker	M, Y	
Contopus sordidulus	Western wood-pewee	M	
Dendrocygna bicolor	Fulvous whistling-duck	B	
Egretta caerulea	Little blue heron	M, R	

Continued

Egretta thula	Snowy egret	M	
Empidonax traillii	Willow flycatcher	M, R	
Empidonax traillii exteimus	Southwestern willow flycatcher	M, R	LE, E
Fullica americana	American coot	YR	
Gallinula chloropus	Common moorhen	M,W	
Gallinago gallinago	Common Snipe	W, M	
Geothlypis trichas	Common yellowthroat	M,W,R	
Icteria virens	Yellow-breasted chat	B, R	
Ixobrychus exilis	Least bittern	B	
Larus delawarensis	Ring-billed gull	YR	
Limnodromus scolopaceus	Long-billed dowitcher	W, M	
Lophodytes cucullatus	Hooded merganser	W,M,R	
Melospiza georgiana	Swamp sparrow	W	
Mergus merganser	Common merganser	W, M	
Oxyura jamaicensis	Ruddy duck	W, M	
Pandion haliaetus	Osprey	M, W	
Pelecanus erythrorhynchos	American white pelican	M, W	
Phainopepla nitens	Phainopepla	YR	
Phalacrocorax auritus	Double-crested comorant	W, M	
Phalacrocorax brasilianus	Neotropic cormorant	W, M	
Plegadis chihi	White-faced ibis	B, M	T
Pluvialis squatarola	Black-bellied plover	M	
Podiceps auritus	Horned grebe	W, M	
Podiceps nigricollis	Eared grebe	W, M	
Podilymbus podiceps	Pied-billed grebe	W, M	
Porzana carolina	Sora	W	
Recurvirostra americana	American avocet	M	
Riparia riparia	Bank swallow	M, W	
Sayornis nigricans	Black phoebe	M, W	
Sayornis phoebe	Eastern phoebe	W	
Spizella passerina	Chipping sparrow	M, W	
Stelgidopteryx serripennis	Northern rough-winged swallow	M, W	
Tachycineta bicolor	Tree swallow	M	
Tringa flavipes	Lesser yellowlegs	M, B	
Tringa melanoleuca	Greater yellowlegs	M, B	
Xanthocephalus xanthocephalus	Yellow-headed blackbird	M	

LE - Federally Listed Endangered
E - State Endangered
T - State Threatened

YR - Year Round
W – Wintering
B - Breeding Season (Spring & Summer)

M - Migrant
R - Rare

Reptiles, Mammals, and Amphibians

There are 1,100 vertebrate species in Texas, 60 of which are found nowhere else in the world (Texas Audubon Society 1997). There are at least 37 species of reptiles (Table 9), mammals (Table 10), and amphibians (Table 11), that are either aquatic, semi-aquatic, or in some way wetland-dependent, present in the study area.

The bats listed in Table 10 feed regularly over rivers and riparian habitats. The listed frogs, salamanders, turtles, and muskrat are aquatic animals. Most toads require aquatic habitats in order to reproduce. The red-spotted toad is found in desert streams and pools (Stebbins 1985). The Western harvest mouse prefers grassy areas, especially in the vicinity of water . In the study area, it is found mostly in meadows, marshes, and weed-covered banks of irrigation ditches, while the white-footed mouse prefers creek and river bottoms (Davis and Schmidly 1994). In the study area, most of the snakes and lizards listed in Table 9 are restricted to riparian habitats adjacent to the Pecos River, springs, ponds, and wetlands.

The following tables are based on the Texas Biological and Conservation Data System (TXBCD) inventory, and input from Texas Parks and Wildlife staff scientists.

Table 9. Selected Reptiles of the Study Area (Wildlife Diversity Program (TXBCD) 1998)

Scientific Name	**Common Name**	**County**
Chelydra serpentina	Snapping turtle	Pecos, Reeves
Cnemidophorus inornatus	Little striped whiptail	Pecos, Loving, Reeves
Diadophis punctatus	Ringneck snake	Pecos
Elaphe guttata	Corn snake	Pecos, Reeves
Eumeces obsoletus	Great plains skink	Reeves
Kinosternon flavescens	Yellow mud turtle	Loving, Pecos, Reeves, Ward
Nerodia erythrogaster	Plainbelly water snake	Pecos, Reeves
Nerodia rhombifer	Diamondback water snake	Pecos
Pseudemys gorzugi	River cooter	Loving, Reeves
Sistrurus catenatus	Massasauga	Pecos, Reeves, Ward
Tantilla nigriceps	Plains blackhead snake	Reeves
Tantilla hobartsmithi	Southwestern blackhead Snake	Pecos, Reeves
Thamnophis cyrtopsis	Blackneck garter snake	Pecos, Reeves
Thamnophis marcianus	Checkered garter snake	Loving, Pecos, Reeves
Trionyx spinifera	Spiny softshell	Loving

Table 10. Selected Mammals of the Study Area (Wildlife Diversity Program (TXBCD) 1998; Davis and Schmidly 1994)

Scientific name	Common name	County
Antrozous pallidus	Pallid bat	Pecos, Reeves
Didelphis virginiana	Virginia opossum	All study area
Ondatra zibethicus ripensis	Pecos river muskrat	Pecos, Reeves
Perognathus flavus	Silky pocket mouse	Pecos, Reeves
Peromyscus leucopus	White-footed mouse	Pecos, Reeves, Winkler
Reithrodontomys fulvescens	Fulvous harvest mouse	All study area
Reithrodontomys megalotis	Western harvest mouse	Pecos, Reeves, Winkler

Table 11. Selected Amphibians of the Study Area (Wildlife Diversity Program (TXBCD) 1998)

Scientific Name	Common Name	County
Acris crepitans	Northern cricket frog	Pecos, Reeves, Ward
Ambystoma tigrinum	Tiger salamander	All study area
Bufo cognatus	Great plains toad	Reeves
Bufo debilis	Green toad	Pecos, Reeves, Winkler
Bufo punctatus	Red-spotted toad	Pecos, Reeves
Bufo speciosus	Texas toad	Pecos, Loving, Ward
Bufo woodhousei	Woodhouse toad	Pecos, Ward, Winkler
Eleutherodactylus augusti	Barking frog	Reeves, Ward
Gastrophryne olivacea	Great plains narrow- mouth toad	Pecos, Reeves
Hyla arenicolor	Canyon tree frog	Reeves
Rana berlandieri	Rio Grande leopard frog	Pecos, Reeves, Ward, Winkler
Rana blairi	Plains leopard frog	Winkler
Scaphiopus couchii	Couch's spadefoot	All study area
Spea bombifrons	Plains spadefoot	Pecos, Ward, Winkler
Spea multiplicata	New Mexico spadefoot	Pecos, Reeves

Conclusion

Stresses on the different ecosystems come not just from the number of people but also from their location, and in the nature and scale of their activities. The 1990 human population of the study area was less than 42,600 and is expected to increase by slightly more than 10,000 by the year 2050.

Some of the selected natural resources covered in the report face an uncertain future, a future that depends on the quality and quantity of the water resources, both surface and ground, within the study area.

Mitigating the negative impacts of past and current land-use practices, such as grazing, agriculture, oil and gas extraction, and urbanization, will improve the chances of natural resources recovery. In addition, fundamental changes in natural resources management strategies and valuation are needed to protect the biological systems and natural resources in the study area.

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APPENDIX A

Estimated Economic Importance of Balmorhea and Monahans Sandhills State Parks

MONAHANS SANDHILLS STATE PARK

ECONOMIC IMPACT

AVERAGE PARTY SIZE:

Day Visitors = 3.57
Overnight Visitors = 2.57

AVERAGE DISTANCE TRAVELED TO SITE:

Day Visitors = 145.6 miles
Overnight Visitors = 161.3 miles

ACTUAL 1997 VISITATION (Fiscal Year)**:**

Day Visitors = 77,569
Overnight Visitors = 4,900

PERCENT OF OUT-OF-COUNTY VISITORS:

Day Visitors = 77.09
Overnight Visitors = 96.50

PER PERSON PER DAY EXPENDITURES

Sector	**Day Visitors**			**Overnight Visitors***			**Visitor**
	Adjacent	Enroute	Total	Adjacent	Enroute	Total	**Average**
Transportation	$1.89	$1.99	$3.88	$1.39	$2.07	$3.46	**$3.67**
Food	2.12	1.42	3.54	2.71	2.46	5.17	**4.36**
Lodging	0.92	1.30	2.22	0.41	0.14	0.54	**1.38**
Other	0.69	0.35	1.04	0.92	0.23	1.15	**1.10**
Total	**5.63**	**5.06**	**10.69**	**5.42**	**4.90**	**10.32**	**10.50**

ESTIMATED ANNUAL ECONOMIC IMPACT ON SALES

Sector	**Day Visitors**			**Overnight Visitors***			**Visitor**
	Expenditures	Direct Impact	Total Impact	Expenditures	Direct Impact	Total Impact	**Total**
Transportation	$113,253	$113,253	$188,203	$6,589	$6,589	$10,949	**$199,152**
Food	127,005	127,005	254,035	12,793	12,793	25,589	**279,624**
Lodging	55,008	55,008	107,547	1,919	1,919	3,752	**111,299**
Other	41,256	41,256	88,264	4,350	4,350	9,306	**97,570**
Total	**336,522**	**336,522**	**638,048**	**25,651**	**25,651**	**49,596**	**687,644**

ESTIMATED ANNUAL ECONOMIC IMPACT ON PERSONAL INCOME

Sector	**Day Visitors**			**Overnight Visitors***			**Visitor**
	Expenditures	Direct Impact	Total Impact	Expenditures	Direct Impact	Total Impact	**Total**
Transportation	$113,253	$38,370	$57,226	$6,589	$2,232	$3,329	**$60,556**
Food	127,005	34,520	66,462	12,793	3,477	6,695	**73,156**
Lodging	55,008	12,426	25,480	1,919	434	889	**26,369**
Other	41,256	13,784	25,517	4,350	1,453	2,690	**28,207**
Total	**336,522**	**99,100**	**174,685**	**25,651**	**7,596**	**13,603**	**188,288**

ESTIMATED ANNUAL ECONOMIC IMPACT ON EMPLOYMENT

Sector	**Day Visitors**			**Overnight Visitors***			**Visitor**
	Expenditures	Direct Impact	Total Impact	Expenditures	Direct Impact	Total Impact	**Total**
Transportation	$113,253	2.57	3.79	$6,589	0.15	0.22	**4.01**
Food	127,005	4.35	6.43	12,793	0.44	0.65	**7.08**
Lodging	55,008	1.51	2.35	1,919	0.05	0.08	**2.43**
Other	41,256	1.80	2.59	4,350	0.19	0.27	**2.86**
Total	**336,522**	**10.23**	**15.16**	**25,651**	**0.83**	**1.22**	**16.38**

* Average PPPD Expenditure data for Texas State Parks were used.

MONAHANS SANDHILLS STATE PARK

ECONOMIC SURGE

AVERAGE PARTY SIZE:

Day Visitors = 3.57
Overnight Visitors = 2.57

AVERAGE DISTANCE TRAVELED TO SITE:

Day Visitors = 145.6 miles
Overnight Visitors = 161.3 miles

ACTUAL 1997 VISITATION (Fiscal Year)**:**

Day Visitors = 77,569
Overnight Visitors = 4,900

PERCENT OF OUT-OF-COUNTY VISITORS:

Day Visitors = 77.09
Overnight Visitors = 96.50

PER PERSON PER DAY EXPENDITURES

Sector	**Day Visitors**			**Overnight Visitors***			**Visitor**
	Adjacent	Enroute	Total	Adjacent	Enroute	Total	**Average**
Transportation	$1.89	$1.99	$3.88	$1.39	$2.07	$3.46	**$3.67**
Food	2.12	1.42	3.54	2.71	2.46	5.17	**4.36**
Lodging	0.92	1.30	2.22	0.41	0.14	0.54	**1.38**
Other	0.69	0.35	1.04	0.92	0.23	1.15	**1.10**
Total	**5.63**	**5.06**	**10.69**	**5.42**	**4.90**	**10.32**	**10.50**

ESTIMATED ANNUAL ECONOMIC SURGE ON SALES (Including Local Visitors)

Sector	**Day Visitors**			**Overnight Visitors***			**Visitor**
	Expenditures	Direct Impact	Total Impact	Expenditures	Direct Impact	Total Impact	**Total**
Transportation	$146,909	$146,909	$244,134	$6,828	$6,828	$11,346	**$255,480**
Food	164,748	164,748	329,530	13,257	13,257	26,518	**356,047**
Lodging	71,356	71,356	139,508	1,989	1,989	3,888	**143,396**
Other	53,517	53,517	114,494	4,508	4,508	9,643	**124,138**
Total	**436,531**	**436,531**	**827,667**	**26,581**	**26,581**	**51,395**	**879,062**

ESTIMATED ANNUAL ECONOMIC SURGE ON PERSONAL INCOME (Including Local Visitors)

Sector	**Day Visitors**			**Overnight Visitors***			**Visitor**
	Expenditures	Direct Impact	Total Impact	Expenditures	Direct Impact	Total Impact	**Total**
Transportation	$146,909	$49,773	$74,233	$6,828	$2,313	$3,450	**$77,683**
Food	164,748	44,779	86,213	13,257	3,603	6,938	**93,151**
Lodging	71,356	16,119	33,052	1,989	449	921	**33,973**
Other	53,517	17,880	33,100	4,508	1,506	2,788	**35,888**
Total	**436,531**	**128,551**	**226,599**	**26,581**	**7,872**	**14,097**	**240,695**

ESTIMATED ANNUAL ECONOMIC SURGE ON EMPLOYMENT (Including Local Visitors)

Sector	**Day Visitors**			**Overnight Visitors***			**Visitor**
	Expenditures	Direct Impact	Total Impact	Expenditures	Direct Impact	Total Impact	**Total**
Transportation	$146,909	3.33	4.92	$6,828	0.15	0.23	**5.14**
Food	164,748	5.65	8.35	13,257	0.45	0.67	**9.02**
Lodging	71,356	1.95	3.05	1,989	0.05	0.08	**3.13**
Other	53,517	2.34	3.35	4,508	0.20	0.28	**3.64**
Total	**436,531**	**13.27**	**19.66**	**26,581**	**0.86**	**1.27**	**20.93**

* Average PPPD Expenditure data for Texas State Parks were used.

BALMORHEA STATE RECREATION AREA

ECONOMIC IMPACT

AVERAGE PARTY SIZE:

Day Visitors = 2.65
Overnight Visitors = 2.54

AVERAGE DISTANCE TRAVELED TO SITE:

Day Visitors = 164.8 miles
Overnight Visitors = 289.1 miles

ACTUAL 1997 VISITATION (Fiscal Year)**:**

Day Visitors = 132,496
Overnight Visitors = 23,161

PERCENT OF OUT-OF-COUNTY VISITORS:

Day Visitors = 100.0
Overnight Visitors = 98.00

PER PERSON PER DAY EXPENDITURES

Sector	**Day Visitors***			**Overnight Visitors***			**Visitor**
	Adjacent	Enroute	Total	Adjacent	Enroute	Total	**Average**
Transportation	$1.68	$1.88	$3.56	$1.69	$2.07	$3.76	**$3.66**
Food	2.69	1.47	4.17	3.15	2.45	5.60	**4.88**
Lodging	0.31	0.15	0.46	0.27	0.07	0.34	**0.40**
Other	1.01	0.15	1.16	0.99	0.15	1.14	**1.15**
Total	**5.70**	**3.65**	**9.35**	**6.10**	**4.73**	**10.84**	**10.09**

ESTIMATED ANNUAL ECONOMIC IMPACT ON SALES

Sector	**Day Visitors***			**Overnight Visitors***			**Visitor**
	Expenditures	Direct Impact	Total Impact	Expenditures	Direct Impact	Total Impact	**Total**
Transportation	$222,258	$222,258	$333,276	$38,382	$38,382	$57,554	**$390,830**
Food	356,689	356,689	620,317	71,544	71,544	124,422	**744,740**
Lodging	41,225	41,225	71,019	6,141	6,141	10,579	**81,598**
Other	134,430	134,430	237,619	22,415	22,415	39,621	**277,240**
Total	**754,603**	**754,603**	**1,262,232**	**138,482**	**138,482**	**232,176**	**1,494,408**

ESTIMATED ANNUAL ECONOMIC IMPACT ON PERSONAL INCOME

Sector	**Day Visitors***			**Overnight Visitors***			**Visitor**
	Expenditures	Direct Impact	Total Impact	Expenditures	Direct Impact	Total Impact	**Total**
Transportation	$222,258	$71,189	$98,683	$38,382	$12,294	$17,042	**$115,724**
Food	356,689	104,046	168,714	71,544	20,869	33,840	**202,554**
Lodging	41,225	9,420	16,589	6,141	1,403	2,471	**19,060**
Other	134,430	47,696	73,332	22,415	7,953	12,227	**85,559**
Total	**754,603**	**232,351**	**357,317**	**138,482**	**42,519**	**65,580**	**422,898**

ESTIMATED ANNUAL ECONOMIC IMPACT ON EMPLOYMENT

Sector	**Day Visitors***			**Overnight Visitors***			**Visitor**
	Expenditures	Direct Impact	Total Impact	Expenditures	Direct Impact	Total Impact	**Total**
Transportation	$222,258	5.39	7.54	$38,382	0.93	1.30	**8.85**
Food	356,689	11.66	16.68	71,544	2.34	3.35	**20.03**
Lodging	41,225	1.11	1.69	6,141	0.17	0.25	**1.95**
Other	134,430	5.38	7.40	22,415	0.90	1.23	**8.63**
Total	**754,603**	**23.55**	**33.32**	**138,482**	**4.33**	**6.13**	**39.45**

* Average PPPD expenditure data for Texas State Recreation Areas were used.

BALMORHEA STATE RECREATION AREA

ECONOMIC SURGE

AVERAGE PARTY SIZE:

Day Visitors = 2.65
Overnight Visitors = 2.54

AVERAGE DISTANCE TRAVELED TO SITE:

Day Visitors = 164.8 miles
Overnight Visitors = 289.1 miles

ACTUAL 1997 VISITATION (Fiscal Year)**:**

Day Visitors = 132,496
Overnight Visitors = 23,161

PERCENT OF OUT-OF-COUNTY VISITORS:

Day Visitors = 100.0
Overnight Visitors = 98.00

PER PERSON PER DAY EXPENDITURES

Sector	**Day Visitors***			**Overnight Visitors***			**Visitor**
	Adjacent	Enroute	Total	Adjacent	Enroute	Total	**Average**
Transportation	$1.68	$1.88	$3.56	$1.69	$2.07	$3.76	**$3.66**
Food	2.69	1.47	4.17	3.15	2.45	5.60	**4.88**
Lodging	0.31	0.15	0.46	0.27	0.07	0.34	**0.40**
Other	1.01	0.15	1.16	0.99	0.15	1.14	**1.15**
Total	**5.70**	**3.65**	**9.35**	**6.10**	**4.73**	**10.84**	**10.09**

ESTIMATED ANNUAL ECONOMIC SURGE ON SALES (Including Local Visitors)

Sector	**Day Visitors***			**Overnight Visitors***			**Visitor**
	Expenditures	Direct Impact	Total Impact	Expenditures	Direct Impact	Total Impact	**Total**
Transportation	$222,258	$222,258	$333,276	$39,165	$39,165	$58,728	**$392,005**
Food	356,689	356,689	620,317	73,004	73,004	126,961	**747,279**
Lodging	41,225	41,225	71,019	6,266	6,266	10,795	**81,814**
Other	134,430	134,430	237,619	22,873	22,873	40,429	**278,049**
Total	**754,603**	**754,603**	**1,262,232**	**141,308**	**141,308**	**236,914**	**1,499,146**

ESTIMATED ANNUAL ECONOMIC SURGE ON PERSONAL INCOME (Including Local Visitors)

Sector	**Day Visitors***			**Overnight Visitors***			**Visitor**
	Expenditures	Direct Impact	Total Impact	Expenditures	Direct Impact	Total Impact	**Total**
Transportation	$222,258	$71,189	$98,683	$39,165	$12,545	$17,389	**$116,072**
Food	356,689	104,046	168,714	73,004	21,295	34,531	**203,245**
Lodging	41,225	9,420	16,589	6,266	1,432	2,522	**19,111**
Other	134,430	47,696	73,332	22,873	8,115	12,477	**85,809**
Total	**754,603**	**232,351**	**357,317**	**141,308**	**43,387**	**66,919**	**424,236**

ESTIMATED ANNUAL ECONOMIC SURGE ON EMPLOYMENT (Including Local Visitors)

Sector	**Day Visitors***			**Overnight Visitors***			**Visitor**
	Expenditures	Direct Impact	Total Impact	Expenditures	Direct Impact	Total Impact	**Total**
Transportation	$222,258	5.39	7.54	$39,165	0.95	1.33	**8.87**
Food	356,689	11.66	16.68	73,004	2.39	3.41	**20.10**
Lodging	41,225	1.11	1.69	6,266	0.17	0.26	**1.95**
Other	134,430	5.38	7.40	22,873	0.92	1.26	**8.65**
Total	**754,603**	**23.55**	**33.32**	**141,308**	**4.42**	**6.26**	**39.58**

* Average PPPD expenditure data for Texas State Recreation Areas were used.

APPENDIX B

CHECKLIST OF VASCULAR PLANTS - BALMORHEA STATE PARK

APPENDIX B
CHECKLIST OF VASCULAR PLANTS - BALMORHEA STATE PARK

This checklist is based on the following in addition to subsequent reports by Texas Parks and Wildlife Department staff biologists:
Texas Natural Heritage Program. 1989. Balmorhea State Park, Reeves County, Texas. *Preliminary Checklist of Vascular Plants. Report prepared for Texas Parks and Wildlife Department. Copy on file at Region 1 office, Fort Davis, Texas.*

LEGEND:
N = non-native species occurring in natural communities
L = used in landscaping; not naturally-occurring

ACANTHACEAE (ACANTHUS FAMILY)
Anisacanthus linearis - Dwarf anisacanthus (L)
Dyschoriste linearis - Narrowleaf dyschoriste
Siphonoglossa pilosella - Hairy tubetongue

AMARANTHEIACEAE (AMARANTH FAMILY)
Alternanthera caracasana - Matt chaff flower
Amaranthus palmeri - Palmer amaranth

AMARYLLIDACEAE (AMARYLLIS FAMILY)
Agave havardiana - Havard agave
Zephranthes longiflora - Copper zephyrlily

ANACARDIACEAE (SUMAC FAMILY)
Rhus microphylla - Littleleaf sumac
Rhus virens - Evergreen sumac

APOCYNACEAE (DOGBANE FAMILY)
Nerium oleander - Common oleander (L)

ASCLEPIADACEAE (MILKWEED FAMILY)
Asclepias subverticillata - Horsetail milkweed

ASTERACEAE (SUNFLOWER FAMILY)
Artemesia ludoviciana - Louisiana sagebrush
Aster subulatus - Hierba del marrano
Berlandiera lyrata - Lyreleaf greeneyes
Brickellia laciniata - Splitleaf bricklebush

Calyptocarpus vialis - Prostrate lawnflower
Chrysothamnus nauseosus - Rabbitbrush
Cirsium texanum - Southern thistle
C. *undulatum* - Wavyleaf thistle
Conyza canadensis - Horsetail conyza
C. *coulteri* - Coulter conyza
Engelmannia pinnatifida - Engelmann daisy
Erigeron modestus - Plain's fleabane
Gaillardia suavis - Suavis indianblanket
Gnaphalium chilense - Cottonbatting
Grindelia squarrosa var. nuda - Curlycup gumweed
Gutierrezia microcephala - Broom snakeweed
Helenium amarum - Yellow bitterweed
Helianthus annuus - Common sunflower
H. ciliaris - Blueweed
Hymenoxys odorata - Western bitterweed
Isocoma wrightii - Jimmyweed
Lactuca ludoviciana - Louisiana lettuce
Liatris punctata - Dotted gayfeather
Lygodesmia texana - Texas skeleton plant
Machaeranthera gracilis
M. pinnatifida - Pinnatifid machaeranthera
M. scabrella
M. tanacetifolia - Tahoka daisy
Parthenium confertum - False ragweed
P. incanum - Mariola
Perezia wrightii - Pink perezia
Pluchea odorata - Purple marsh-fleabane
Ratibida columnaris - Mexican hat
Senecio flaccidus - Threadleaf groundsel
Simsia calva - Awnless bush sunflower
Sonchus oleraceus - Sowthistle
Taraxacum officinale - Common dandelion (N)
Thamophylla acerosa - Prickleaf dogweed
Thelesperma megapotamicum - Rayless greenthread
Verbesina encelioides - Cowpen daisy
Viguiera longifolia - Longleaf goldeneye
Xanthium strumarium - Cocklebur
X. spinosum - Spiny cocklebur (N)

Zinnia acerosa - Spiny leaf zinnia
Z. grandiflora - Plains zinnia

BERBERIDACEAE (BARBERRY FAMILY)
Mahonia trifoliolata – Agarito

BIGNONIACEAE (CATALPA FAMILY)
Chilopsis linearis - Desert willow
Tecoma stans var. angustata - Trumpetflower (L)

BRASSICACEAE (MUSTARD FAMILY)
Lesquerella fendleri - Fendler's bladderpod
Lepidium virginicum - Virginia peppergrass

CACTACEAE (CACTUS FAMILY)
Echinocereus viridifIorus var. cylindricus - Green pitaya
Mammillaria meiacantha - Pincushion cactus
Opuntia imbricata - Walkingstick cactus
O. leptocaulis - Tasajillo
O. engelmannii - Engelmann prickly pear
O. phaeacantha - Brown-spine prickly pear
Peniocereus greggii - Night blooming cereus

CAPRIFOLIACEAE (HONEYSUCKLE FAMILY)
Lonicera albiflora - White honeysuckle (L)

CHENOPODIACEAE (GOOSEFOOT FAMILY)
Atriplex argentea - Argentea saltbush
A. canescens - Fourwing saltbush
A. semibaccata - Australian Saltbush (N)
Bassia hyssopifolia - Smotherweed (N)
Chenopodium album - Lambsquarters (N)
Kochia scoparia - Mexican fireweed (N)
Salsola kali - Russian thistle (N)

COMMELINACEAE (SPIDERWORT FAMILY)
Commelina dianthifolia - Birdbill dayflower

CONVOLVULACEAE (MORNING-GLORY FAMILY)
Convolvulus equitans - Bindweed
Cuscuta sp. - Love-vine

CUCURBITACEAE (GOURD FAMILY)
Cucurbita foetidissima - Stinking gourd

CUPRESSACEAE (CYPRESS FAMILY)
Cupressus arizonica - Arizona cypress (L)
Juniper sp. - Ornamental juniper (L)

CYPERACEAE (SEDGE FAMILY)
Cyperus odoratus – Umbrella sedge
Eleocharis montevidensis - Sand spikerush
Scirpus acutus - Hardstem bulrush
S. americanusi - Olney bulrush
S. maritimus - Alkali bulrush

EPHEDRACEAE (EPHEDRA FAMILY)
Ephedra trifurca - Longleaf teabush

EUPHORBIACEAE (SPURGE FAMILY)
Croton pottsii - Leatherweed croton
Chamaesyce albomarginata - Whitemargin euphorbia
Chamaesyce sp.

FABACEAE (LEGUME FAMILY)
Acacia constricta - Mescat acacia
A. greggii - Catclaw acacia
A. neovernicosa - Viscid acacia
Calliandra humilis - Dwarf calliandra
Hoffmanseggia glauca - Indian rushpea
Melilotus indicus - Annual yellow sweetclover (N)
M. offiicinalis - Yellow sweetclover (N)
Medicago sativa - Alfalfa (N)
Mimosa aculeaticarpa var. biuncifera - Catclaw mimosa
Parkinsonia aculeata - Retama (L)
Prosopis glandulosa - Honey mesquite
Rhynchosia texana - Texas snoutbean

FAGACEAE (OAK FAMILY)
Quercus fusiformis - Plateau live oak (L)

FOUQUIERIACEAE (OCOTILLO FAMILY)
Fouquieria splendens - Ocotillo (L)

GENTIANACEAE (GENTIAN FAMILY)
Eustoma exaltatum (Tall prairie gentian)

GERANIACEAE (GERANIUM FAMILY)
Erodium cicutarium - Alfilaria (N)

JUGLANDACEAE (WALNUT FAMILY)
Juglans microcarpa - Little walnut

JUNCACEAE (RUSH FAMILY)
Juncus sp.

LAMIACEAE (MINT FAMILY)
Marrubium vulgare - Horehound (N)
Salvia greggii - Autumn sage (L)
S. *regla* - Mountain sage (L)

LILIACEAE (LILY FAMILY)
Asparagus officinalis - Garden asparagus (N)
Nolina texana - Sacahuista
Yucca elata - Soaptree yucca
Y. *treculeana* - Spanish dagger

LOASACEAE (STICKLEAF FAMILY)
Cevallia sinuata - Stinging cevallia

LOGANIACEAE (LOGANIA FAMILY)
Buddleja scordioides - Escobilla butterfly bush
B. marrubiifolia - Wooly butterfly bush (L)

MALVACEAE (MALLOW FAMILY)
Malvella leprosa - Alkali sida
Rhynchosida physocalyx - Spearleaf sida
Sphaeralcea angustifolia – Narrowleaf globemallow
S. *coccinea* - Scarlet globemallow
Wissadula holosericea - Velvet leaf (L)

MORACEAE (MULBERRY FAMILY)
Morus sp. - Mulberry (L)

NYCTAGINACEAE (FOUR O'CLOCK FAMILY)
Acleisanthes longiflora - Angel trumpets
Boerhaavia coccinea - Scarlet spiderling
B. gracillima - Slimstalk spiderling
Mirabilis pseudoaggregata

OLEACEAE (OLIVE FAMILY)
Fraxinus velutina - Velvet ash (L)
Menodora longiflora - Showy menodora

ONAGRACEAE (EVENING PRIMROSE FAMILY)
Gaura coccinea - Scarlet gaura
G. sufulta - Wild honeysuckle
G. *villosa* - Woolly gaura
Oenothera brachycarpa - Shortpod eveningprimrose
O. hookeri - Hooker eveningprimrose (L)

OXALIDACEAE (WOOD SORREL FAMILY)
Oxalis dillenii - Common sourclover

PAPAVERACEAE (POPPY FAMILY)
Argemone squarrosa - Desert pricklypoppy

PLATANACEAE (PLANE-TREE FAMILY)
Platanus occidentalis - Sycamore (L)

POACEAE (GRASS FAMILY)
AIlolepis texana (L)
Aristida ternipes - Spidergrass
Bothriochloa barbindois var. barbindois - Cane bluestem
B. ischaemum - King Ranch bluestem (N)
Bouteloua aristoides - Needle grama
B. barbata - Sixweeks grama
B. breviseta - Gyp grama
B. chondrosioides - Sprucetop grama
B. curtipendula - Sideoats grama
B. trtftda - Red grama
Buchloe dactyloides - Buffalograss
Cenchrus incertus - Sandburgrass
Chloris crinita - False rhodesgrass
C. *virgata* - Showy chloris

POACEAE (GRASS FAMILY) - Continued
Cynodon dactylon - Bermudagrass (L,N)
Digitaria californica - Arizona cottontop
Echinochloa crusgalli - Barnyardgrass (N)
Eragrostis lehmanniana - Lehmann lovegrass (N)
Erioneuron pilosum - Fluffgrass
Hilaria mutica - Tobosagrass
Leptochloa dubia - Green sprangletop
Lycurus phleoides - Wolftail
Panicum hallii - Hall panicurn
P. obtusum - Vine mesquite
Pappophorum vaginatum - Whiplash pappusgrass
Phragmites australis - Common reed
Setaria leucopila - Plains bristlegrass
Sorgum halepense - Johnsongrass (N)
Sporobolus airoides - Alkali sacaton
S. wrightii - Giant sacaton
Tridens albescens - White tridens

POLYGONACEAE (SMARTWEED FAMILY)
Eriogonum abertianum - Abert wildbuckwheat
Rumex crispus - Yellow dock
R. hymenosepalus – Canaigre

PONTEDERIACEAE (PICKERELWEED FAMILY)
Heteranthera liebmannii - Water stargrass

PORTULACACEAE (PORTULACA FAMILY)
Portulaca oleracea - Common purslane
P. pilosa - Chisme
Talinum angustissimum - Yellow flameflower

PRIMULACEAE (PRIMROSE FAMILY)
Samolus cuneatus - Lime brookweed

RANUNCULACEAE (BUTTERCUP FAMILY)
Clematis drummondii - Old man's beard
Aquilegia sp. - Columbine (L)

RHAMNACEAE (BUCKTHORN FAMILY)
Ziziphus obtusifolia – Lotebush

ROSACEAE (ROSE FAMILY)
Crataetus tracyi - Tracy hawthorne (L)
Fallugia paradoxa - Apache plume

RUBIACEAE (MADDER FAMILY)
Cephalanthus occidentalis - Common buttonbush (L)

SALICACEAE (WILLOW FAMILY)
Populus fremontii subsp. *mesetae* - Freemont cottonwood

SCROPHULARIACEAE (FIGWORT FAMILY)
Leucophyllum frutescens - Ceniza (L)
L. candidum - Boquillas silverleaf (L)
Penstemon havardii - Havard penstemon (L)

SOLANACEAE (TOMATO FAMILY)
Solanum elaeagnifolium - Silverleaf nightshade
Lycium torreyi - Torrey wolfberry
Physalis hedaerafolia - Heartleaf groundcherry

TAMARICACEAE (TAMARISK FAMILLY)
Tamarix sp. - Salt-cedar (N)

TYPHACEAE (CATTAIL FAMILY)
Typha latifolia. - Common cattail

ULMACEAE (ELM FAMILY)
Celtis reticulata - Netleaf hackberry
C. *pallida* - Spiny hackberry

VERBENACEAE (VERVAIN FAMILY)
Aloysia gratissima - Whitebrush
Glandularia wrightii - Wright verbena

VITACEAE (GRAPE FAMILY)
Cissus incisa - *Ivy* treevine

ZYGOPHYLLACEAE (CALTROP FAMILY)
Larrea tridentata - Creosotebush
Tribulus terrestris - Goathead (N)