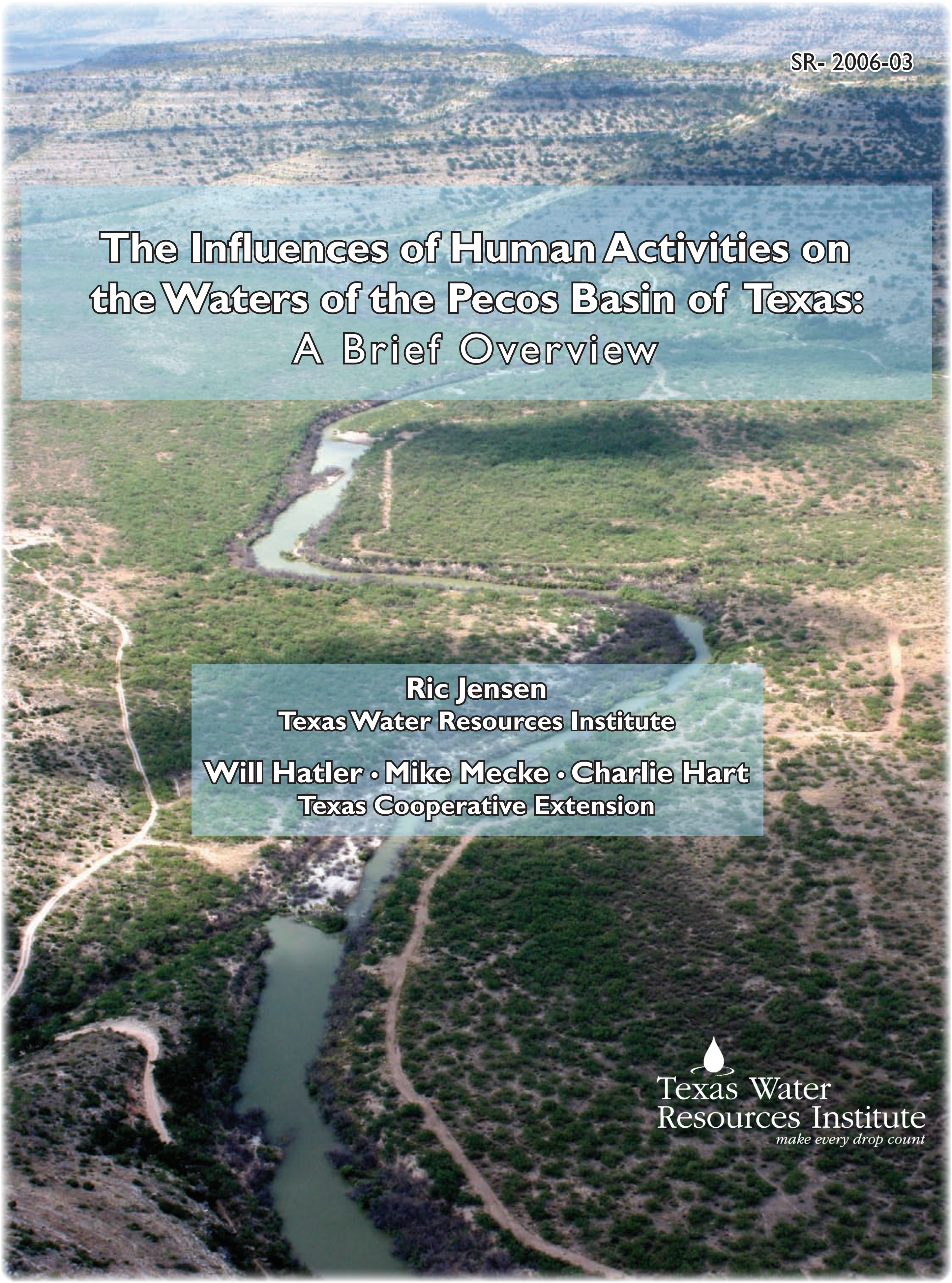

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The Influences of Human Activities on the Waters of the Pecos Basin of Texas: A Brief Overview

Ric Jensen
Texas Water Resources Institute

Will Hatler • Mike Mecke • Charlie Hart
Texas Cooperative Extension

Texas Water Resources Institute
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Introduction

The Pecos River in Texas is challenged by natural conditions and human influences, including a lack of water and elevated levels of salinity. The Pecos River has provided West Texas and Southeastern New Mexico an invaluable source of water for thousands of years allowing plants, animals, and humans to survive the harsh environment. The Trans-Pecos region generally marks the southwestern boundary of the Great Plains and the northeastern fringe of the Chihuahuan Desert. The Pecos River flows 926 miles through Texas and New Mexico draining a 38,000-square mile watershed (Huser, 2000; Graves, 2002; Horgan, 1984). The river flows approximately 418 miles through Texas and is the United States' largest tributary to the Rio Grande.

According to the 2006 Far West Texas Regional Water Plan (LBG-Guyton, 2006), the Pecos River contributes roughly 11% of the flows in the Rio Grande entering Lake Amistad. Salinity from natural sources enters the river at many points, compromising water quality (Miyamoto et al., 2005; Miyamoto, 1996; Miyamoto, 1995). The Pecos River is estimated to contribute roughly 30% of the annual salt loadings to Lake Amistad (LBG-Guyton, 2006).

Lower Pecos River near Pandale

The Pecos River has been profoundly affected over time by the way humans use the river. Native Americans relied on the waters of the Pecos River as a source of fresh water even though some sections of the river were salty and foul-tasting. The river and occasional springs were the only sources of fresh water in the region. Spanish explorers and frontier cattlemen also used the Pecos River as a source of drinking water for humans, horses and cattle.

Although it is difficult to know the condition of the Pecos River of Texas as it existed before American settlement, some early accounts suggest that the river ranged from 65 to 100 feet wide and 7 to 10 feet deep with a fast current (Huser, 2000; Hall 2002). Now the river is rarely, if ever, that wide or deep under normal flow conditions. Dams and pumping water for irrigation have significantly altered the natural flow of the river.

In a turn-of-the-century report submitted to the Governor of Texas (Hollingsworth, 1892), conditions in the Pecos River were described in a way that reflects the natural resources dilemma still facing the region:

> The want of rain in seasonable time is no doubt the principal reason that millions of acres of fertile soil are not utilized at all…Cattle, sheep, and horses…not only suffer, but in many localities frequently die for want of water and grass…We have to meet the questions, can anything be done to utilize the public lands of Trans-Pecos Texas and what can or must be done?...We have to consider that millions of acres of land with fertile soil are nearly valueless, if no provisions for irrigation are made.

By the late 1800s, American settlers began to develop the region for irrigation believing that the waters of the Pecos could support widespread agricultural production (Baggett, 1942; Bogener, 2003; Hayter, 1986). Throughout the Pecos Basin, many irrigation companies were created to attract settlers hoping to make a living by growing irrigated crops. Optimistic developers promoted irrigation projects with such grandiose names as Imperial and Royalty. Sadly, in many instances these attempts to create irrigated oases died quickly due to droughts and occasional floods.

The creation of Red Bluff Dam in the 1930s seemingly had the potential to harness the Pecos River and provide a steady water supply for the people of West Texas. The reservoir has succeeded in storing water for irrigation, but has been plagued by managerial and water quality challenges (Hall, 2002). The Pecos River Compact was enacted between Texas and New Mexico after Red Bluff was built to ensure that Texas would receive a fair proportion of Pecos River waters each year based on the amount of rainfall runoff that occurred in New Mexico. In 1987, the U.S. Supreme Court ruled that from 1950 to 1983 New Mexico's water deliveries to Texas were 340,100 acre-feet (AF) less than the amount of water required under the compact. More recently, New Mexico water deliveries have increased to meet the demands of the Compact and more water is being released from Red Bluff Reservoir. New Mexico currently maintains a surplus of water stored in the reservoir.

The Pecos Basin of Texas is afflicted with major natural resources challenges. First, non-native saltcedar trees, introduced to the region to stabilize stream banks, now proliferate throughout the banks of the Pecos River. Saltcedars consume sizeable amounts of water, choke out native vegetation in riparian areas and increase salt loadings by drawing salts from below ground and depositing them on the surface in leaf litter (Belzer & Hart, 2006; Hart et al., 2005). Second, salts enter the river from natural deposits dissolved in rocks near Malaga Bend in southern New Mexico and between Grandfalls and Girvin, thus reducing the river's quality (Boghici et al., 1999; LBG-Guyton, 2003). Finally, the flows of the Pecos River are often not sufficient to support large-scale irrigation attempted in the past and present (Hall, 2002; Hill, 1965).

To find solutions to these challenges, the Pecos Basin Assessment Program was established in 2005 to develop innovative strategies to manage water resources in the region (Figure 1). The project, led by Texas Cooperative Extension in Fort Stockton, is developing a watershed protection plan for the Pecos Basin of Texas (Hart et al., 2005). Program activities involve identifying sources of salinity, modeling the flow of the river, and determining the extent to which clearing saltcedar might increase flows in the region.

Study Area

In Texas and New Mexico, the Pecos River follows a course of more than 900 river miles and its drainage basin covers an area of more than 38,000 square miles. The Pecos Basin of Texas includes the Pecos River watershed and is bound by the Rio Grande Basin on the south and west. The Pecos Basin of New Mexico lies to the north while the Colorado River of Texas and the Hill Country lay to the east. The elevation shifts from about 9,000 feet above sea level in the mountainous western edge of the watershed to 2,700 feet above sea level at Red Bluff Reservoir to 1,050 feet above sea level at the mouth of the Pecos at the International Amistad Reservoir.

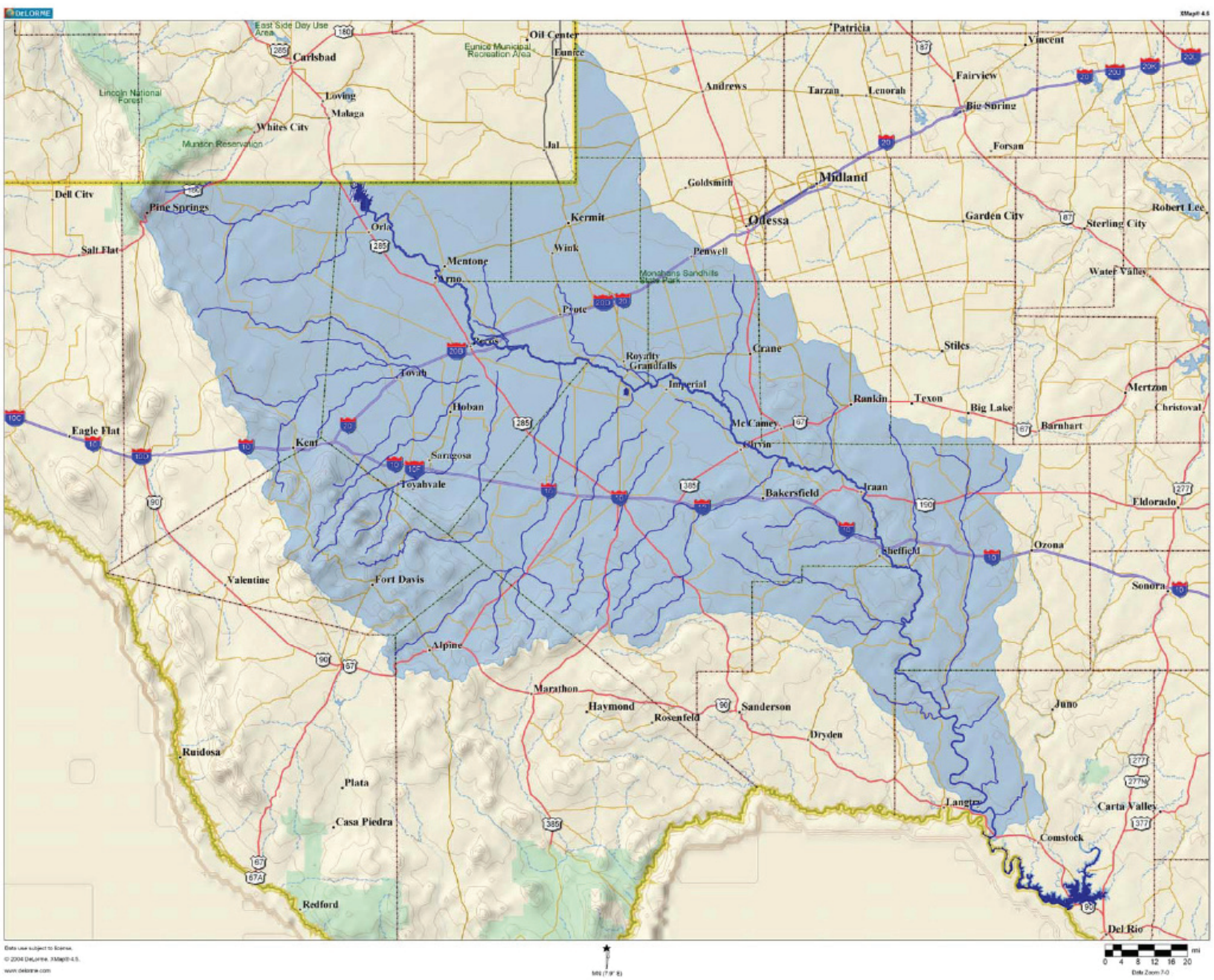

Figure 1. Area studied by the Pecos River Assessment Project.

Average rainfall in the Pecos Basin of Texas ranges from 18 to 20 inches per year in the Davis Mountains to only 9 inches annually at Pecos. Because much of the basin lies in the Chihuahuan Desert, annual potential evapotranspiration greatly exceeds precipitation in most years. At Fort Davis, Texas, the average rainfall is 17 inches annually while the average potential evapotranspiration is 72 inches per year; a 55 inch deficit.

Droughts are common in the region and have caused widespread devastation. Droughts have occurred in 1863, 1864, 1888-1889, 1907, 1909-1910, 1916-1917-18, 1922, 1923-24, 1925, 1933-34, 1948, 1951-1956, 1964-1965, 1994-1995 and 1998-2003 (Nielsen-Gammon, 2006; Horgan, 1984; Horgan, 1984; Huser, 2000). The drought of 1888-1889 is known as "The Big Die-Off" and killed large numbers of cattle.

Lower Pecos River near Sheffield

Severe flash floods also plague the region. Major storm events that caused significant flooding occurred in 1904, 1909, 1941, 1954, 1965, 1974, 1978 and 2004. The 1904 flood caused the Pecos to swell and reach a mile in width at some points; the 1954 flood occurred when Hurricane Alice stalled over the region and caused the river to crest at 86 feet. This cresting flooded the lower Pecos River near Independence Creek, and washed out a bridge near Langtry that was built 50 feet above the river bed.

In 1965, a major flood at Sanderson sent a 15-foot high wall of water through the town, washed away entire city blocks and killed 26 people (Scogin, 1995). The 1978 flood set a high water mark of 38.14 feet for the Pecos River near Langtry; 20 feet is considered "Major Flood Stage" (AHPS 2007).

Charlena Chandler’s family has lived on the lower reach of the Pecos River near its confluence with Independence Creek since the 1930s. During that time, they have endured droughts, floods and other natural calamities while operating a fishing camp, a resort, small farms, a ranch and deer leases. One of Charlena’s most vivid memories includes dealing with the flooding caused by Hurricane Alice in 1954, which washed out a highway bridge near Eagle Pass and flooded low lying sections of the town of Ciudad Acuna.

Several river and stream segments, as well as springs, within the Pecos Basin of Texas have been classified as ecologically significant by Texas Parks and Wildlife Department (TPWD). Segments are considered ecologically significant if they meet at least one of the following criteria: they contain outstanding biodiversity and habitat value, perform important hydrologic functions, include ecologically important riparian areas, exhibit high water quality, and/or are home to threatened and endangered species (El-Hage & Moulton, 1998; El-Hage & Moulton, 2001; Linam & Kleinsasser, 1996). Surface waters designated as ecologically significant include segments of the Pecos River, Independence Creek, Live Oak Creek, Salt Creek, Toyah Creek and Little Aguja Creek. TPWD has also recognized Diamond Y Springs (Pecos County), East Sandia Springs, Giffin Springs and San Solomon Springs (all in Reeves County) as ecologically significant.

According to Gunnar Brune’s comprehensive description of the springs of Texas (2002), the Pecos Basin originally contained more than 50 flowing springs. Some of these springs stopped flowing during the “drought of record” that lasted in Texas throughout most of the 1950s. According to local experts (Karges, personal communication, 2006), as few as eight springs may still flow in Reeves and Loving counties. Some of the springs in the Pecos Basin includes:

- Kokernot Spring (Brewster County)
- Live Oak Springs and Cedar Springs (Crockett County)
- Rustler Springs (Culberson County)
- Madera Springs, Phantom Lake Springs and Seven Springs (Jeff Davis County)
- Comanche Springs, Diamond Y Springs, Leon Springs, Pedro Ureta Springs, Santa Rosa Springs and San Pedro Springs (Pecos County)
- Giffin Springs, Sandia Springs, San Solomon Springs (Reeves County)
- Red Bluff Springs (Loving County)
- Caroline Springs, Cedar Springs, Geddes Springs, King Springs, Myers Springs and Vanderbeek Springs (Terrell County)

TPWD staff (Norris, personal communication, 2006) recently analyzed a database of historically documented springs in Texas developed by the U.S. Geological Survey (Heitmuller, 2004). The TPWD analysis suggests that 53 springs existed in the Pecos River Basin, but the number of these springs that still flow today is not well-known.

These springs flow or flowed from shallow groundwater tables located in the Pecos River Basin. Extensive pumping from substantial groundwater resources including the Cenozoic Pecos Alluvium and the Dockum, Capitan Reef, Rustler, Igneous, and Edwards-Trinity Plateau aquifers (Mills, 2005; Mace, Mulligan, & Angle, 2001; Boghici et al., 1999) is one factor that may have led to the decline in flowing springs. Mills (2005) documented an accumulated groundwater use of 85,813 AF in 2000 and suggests that groundwater inflows to the Pecos River between Red Bluff and Girvin averaged 30,000 AF per year before large-scale irrigation projects were developed. 2006 data from the TWDB reports that the depth-to-groundwater in Pecos and Reeves counties averages 125 feet and ranges from 12 to 1,492 feet. The greatest depth-to-groundwater occurs in Pecos and Reeves counties where cones of depression have developed as a consequence of groundwater pumping for agriculture and other purposes.

Water Quality

Lower Pecos River near Pandale

The Pecos Basin has also been severely challenged by water quality issues, including high levels of salinity (Miyamoto, 1995; El-Hage & Moulton, 1998), heavy metals and pesticides (Schmitt et al., 2004). Some of the largest sources of saline water occur in the Malaga Bend region of southern New Mexico and between Grandfalls and Girvin, Texas (Boghici et al., 1999; LBG-Guyton, 2003; Miyamoto et al., 2005; Miyamoto, 1996; Miyamoto, 1995). To prevent inflows of saline water, individuals have sought to mine, recover and market salts at Malaga Bend that would normally flow into the main stem of the Pecos River. However, to date these efforts have not been economically successful (Mills, 2005). The main source of heavy metal pollution is thought to be the oil industry, while pesticides are present due to agriculture; the extent of these effects is not fully understood at this point.

The Pecos Basin was once covered by the shallow Permian Sea. When the sea receded, significant amounts of evaporated gypsum, halites and related salts were left in soils and rock formations. Today, these formations contribute large amounts of salt to the Pecos River.

Research by Miyamoto et al. (2005) suggests that salinity levels in the Pecos River average more than 6,000 mg/l at the Texas-New Mexico state line and often exceed 12,000 mg/l near Girvin. High salt loads are associated with the flushing of geological salt deposits during high flow events. Miyamoto reports that the Pecos River contributed 5 million tons of salt at its confluence with the Rio Grande after large storms in 1941 and 1942. A Texas Commission on Environmental Quality (TCEQ) study investigated five sites on the Pecos River from Orla (downstream of Red Bluff Dam) to a site in Val Verde County. The study described the river's increases in salinity from Red Bluff to Girvin. However, south of Girvin the water quality improves as the river receives freshwater inflow from groundwater and surface water sources. According to the 2006 Far West Regional Water Plan (LBG-Guyton, 2006), freshwater flows from Independence Creek at its confluence with the lower Pecos River increase flows in the river by 42% and reduce total suspended solids concentrations by 50%.

Data from Miyamoto, Yuan & Anand (1996) show that the salinity loads from the Pecos River account for about 29.5% of the salts entering Lake Amistad while only contributing 11% of the flow. Salinity levels in the lake have steadily increased and have exceeded the maximum values allowed for drinking water (1,000 mg/l) twice. Miyamoto suggests that reducing salt loads in the Pecos River may be a viable strategy to keep salinity levels below the drinking water standard.

Early settlers also noticed a high salt content in the waters of the Pecos. Some portions of the river were sometimes referred to as the "dirty river" or "pig river" (Rio Puerco) or the "salty river" (Rio Salado) (Daggett, 1985; Dearen, 2000; Williams, 1982). Spanish explorers and early cattlemen noted the skulls of cattle, bison and horses at Horsehead Crossing that did not safely cross the river or died when they drank river water with high salinity levels. Many of the first American settlers noted that alkali ponds adjacent to the Pecos River would often kill cattle that drank from these waters.

Tiny Earp, a rancher in the Pecos River Basin since WWII, recalls that one could learn about the sites with good and poor quality water based on the extent to which wildlife would visit those sites. "If animals came to one spring over and over, you could guess the water was pretty good."

Charlena Chandler also recalls how she believes the water quality in Independence Creek was consistently better and clearer than the waters of the main stem of the lower Pecos River. "One of the consistent problems," she said, "is there is always less water in the Pecos than we need."

Tom Nance of Barstow, the former general manager of Ward County Irrigation District Number 1, said his father and uncle farmed in the region in the 1950s. “I can remember when Barstow was the county seat in the 1940s—it was the biggest and most prosperous town in the county and was home to 5,000 residents. I grew cantaloupes and people were delighted and amazed at how sweet they were, but now, because of increased salinity in the Pecos River water, you can only grow them once every five years.”

River Biology and Ecology

Plant and animal life in the river and on its adjacent banks has changed significantly since American settlement began. An early account given in 1849 by Lieutenant S.G. French of the U.S. Corps of Topographical Engineers described the condition of the Pecos River of Texas this way (cited in Campbell, 1958):

> It is a narrow deep stream, its waters turbid and bitter, and… [it carries] more impurities than any other river of the south. The only inhabitants of its waters are catfish.

In 1950s, the Texas Fish and Game Commission (Campbell, 1958) surveyed the aquatic biology at 28 stations on the Pecos River in Texas from Red Bluff Dam to a site near Langtry. Results showed that the gizzard shad and white bass were frequently found in the upper reaches of the Pecos while blue catfish and channel catfish were most common in the middle and lower reaches of the river.

In 1996, TPWD (Linam & Kleinsasser, 1996) and TCEQ (Larson, 1996) assessed fish and aquatic life in the Pecos River and its tributaries. TPWD gathered data on fish species and water quality at 16 sites on the Pecos River from Red Bluff Reservoir to Amistad Reservoir and found 26 of the more than 40 historic fish species present in the river. The most common species collected included red shiner, hybrid pupfish, rainwater killifish, western mosquitofish, Mexican tetra and inland silverside. TPWDs study concluded that the volume of flow in the river, salinity from natural and man-made sources and contaminants from oil production and agricultural activities influence the aquatic biology of the river.

Hoagstrom (2003) examined changes in the composition of fish and other aquatic species over time along the reaches of the Pecos River from Orla to Sheffield and downstream to the confluence of the Pecos River with the Rio Grande. Hoagstrom reports that, since the arrival of American settlers in the 1850s, the diversity and populations of native fish species at these sites has declined by more than 50%, while the number of non-native fish species that prefer saline waters has increased significantly. Factors that have influenced water quality, flows and fish populations in the Pecos

River include diminished springflows, the spread of toxic Golden algae blooms, the introduction of non-native fish species and the deterioration and fragmentation of riparian habitats.

Several investigations have examined aquatic biology present in the Lower Pecos River of Texas near its confluence with Independence Creek. Larson (1996) studied possible correlations between water quality trends and populations of benthic insects. Results show that water quality in the

Pecos River prior to 1918 (photo courtesy Red Bluff Water and Power Control District)

main stem of the Pecos River improved significantly downstream of the river's junction with Independence Creek. In 2005, Texas State University (Bonner et al., 2005) researchers found that the number of fish species in the Lower Pecos River had declined slightly since the 1950s, possibly due to such human influences as reduction in flows and land use practices that degrade water quality.

Several state and federal listed threatened or endangered fish species live in the Pecos River Basin. The Pecos pupfish is listed by the state as a threatened species. The Comanche Springs pupfish and the Leon Springs pupfish are listed by the federal and state government as endangered species. These species were adversely affected by the introduction of the sheepshead minnow, which has extensively hybridized with the Leon Springs and Pecos pupfish (Hubbs et al., 1991; Hubbs et al., 1992). The Rio Grande darter and the Proserpine shiner are listed as a threatened species by the state (El-Hage & Moulton, 2001). Federal and state agencies are now working with university researchers and landowners to improve conditions in the Pecos River to support healthy populations of fish and other aquatic life.

In her account of the Lower Pecos Basin, resident Charlena Chandler notes that in the early 1900s the waters of Independence Springs were "clear as crystal" and supported large numbers of bass, darters and catfish, as well as such aquatic vegetation as watercress and ferns. Those conditions still exist today. Studies by the University of Texas at Austin suggest that 27 species of fish including bass, darters, gar, eels, carp and suckers can be found in the Lower Pecos River near Independence Creek (Hubbs, 1991). That research shows that Caroline Springs discharges roughly 5,000 gallons per minute into Independence Creek.

Currently, the Texas Nature Conservancy (2006) owns and manages the Independence Creek Preserve and the Diamond Y Spring Preserve on the Lower Pecos to conserve critical habitat. Independence Creek, the largest source of water flowing into the Lower Pecos River, almost doubles the flow of the Pecos River at its confluence and dilutes the concentration of salinity in the river's main stem (Brown Engineering Company, 2003; Larson, 1996). The Diamond Y Springs site includes a large spring pool and many peripheral springs, creeks and marshes. The Diamond Y site features a rare desert spring habitat that supports two rare, federally endangered fish species—the Leon Springs pupfish and the Pecos gambusia—as well as several rare aquatic invertebrates. The Nature Conservancy efforts include restoring and improving pastures, initiating sustainable grazing management strategies, removing saltcedar to increase surface water flows, improving fish and wildlife habitat and developing environmental education projects for future implementation.

Since the 1980s, several toxic golden algae blooms have occurred in the Pecos Basin of Texas. Along the reach of the Pecos River between Iraan and Amistad Reservoir, breakouts of golden algae killed more than 110,000 fish in 1985 and roughly 500,000 fish in 1986. In 1988, more than 1.5 million fish were killed by a golden algae bloom that stretched from southeast New Mexico to Imperial (James and De La Cruz, 1989). Rhodes and Hubbs (1992) report that a 1986 toxic golden algae bloom killed more than 99% of the fish in the Pecos River between Iraan and Amistad Reservoir. They suggest that golden algae have led to occasional fish kills along the Pecos since the 1960s and may result from a combination of natural conditions and human activities.

Native American and Early Hispanic Settlement in the Region

Archaeological evidence shows that humans have lived in the Pecos Basin for thousands of years. Artifacts found at the Arenosa Shelter near the confluence of the Pecos River and the Rio Grande and the Bonfire Shelter near Langtry suggest that humans lived in the region as long as 9,600 years ago (Horgan, 1984; Handbook of Texas, 2006.).

Native Americans who lived in the lower Pecos Basin include members of the Jumano, Pecos, Comanche, Apache, Pawnee, Kickapoo, Kiowa and Shawnee tribes. When the Spanish explorer Antonio de Espejo traveled through what is now Pecos County in 1583, he found that Native

Americans near San Solomon Springs were using irrigation to grow beans and other crops. Throughout the 1800s, Hispanics raised grains and vegetables near the town of Brogado in Pecos County, which they sold at the U.S. Army Post at Fort Davis (Williams, 1982). Several Native American tribes cultivated lands between Presidio del Norte and the Horsehead Crossing of the Pecos in the 1850s (Huser, 2000).

The first Europeans who traveled through the Pecos Basin region include the Spanish explorers Álvar Núñez Cabeza de Vaca (1530), Francisco Vázquez de Coronado (1540), Fray Augustín Rodriguez (1580) and Antonio de Espejo (1583). De Vaca was so impressed with the size and flow of the Pecos he referred to it as the "great river." Coronado recorded seeing agricultural irrigation systems near the present location of the town of Pecos. In 1684, Juan Domínguez de Mendoza led an expedition that traveled from Mexico City throughout the Pecos Basin (*Handbook of Texas*, 2006; Dearen, 2000; Hughes, 1978).

American Exploration of the Pecos Valley of Texas

Beginning in the mid-1800s, American settlement began in the region. When they arrived, many American settlers brought cattle with them and their herds often drank from numerous flowing springs as well as the Pecos River. During the late 1860s, the Goodnight and Loving trails were used to drive large herds of cattle from West Central Texas through the Pecos Valley to points north and west. The lack of drinkable water constituted one of the most serious obstacles on the way. Further compounding matters, alkali ponds adjacent to the Pecos River would often kill cattle that drank from them as they prepared to cross the river at Horsehead Crossing. Despite these problems, settlers established vast cattle ranches on each side of the Pecos River in the 1870s and 1880s (Daggett 1985; Dearen, 2000; Eagleton, 1971; Hayter, 1986; Newman & Dale, 1993; Williams, 1982).

In 1849, landowners first drilled water wells near Van Horn in Culberson County that were recognized as some of the few dependable sources of water in West Texas. John Coffee Hays led an expedition through what now is Crockett County to find and chart waterholes to support stagecoaches traveling from El Paso to San Antonio. In 1852, T.W. Chandler (Casey, 1972) surveyed the area along the Rio Grande from Presidio del Norte to the mouth of the Pecos River. In 1853, an Army surveying party led by John Pope searched in vain for an artesian water source in Culberson County (Dearen, 2000; Williams 1982) and later successfully drilled groundwater wells in Loving County near the stateline in 1857 (Dunn, 1948).

In 1849, a U.S. Army reconnaissance party headed by William Whiting reached Comanche Springs and described the spring's clear waters and aquatic habitat (Kaiser, 2005). In 1859, the U.S. Army sent an expedition equipped with 24 camels to explore the area near Independence Creek and find dependable water resources.

Alan Zeman has spent most of his adult life living in the Pecos River watershed, and the history of his family is intertwined with the river for more than a century. Zeman works for the Pecos Irrigation District. His grandfather moved to the region from East Texas in the 1890s, ironically, to avoid the drought. “Strangely, it was raining here in the Pecos Basin at that time but there was a drought in East Texas,” Zeman said. “My grandfather was grazing cattle so he moved here.”

Early Attempts to Develop Irrigation in the Pecos Basin of Texas

Historically, the majority of early efforts to develop irrigation in the Pecos Basin were focused on flowing streams and the river, shallow alluvial aquifers and sites with plentiful groundwater supplies. In the late 1800s and early 1900s, irrigation and land development companies would acquire the title to large tracts along rivers and streams with the hope of selling water and land to settlers. There were many instances in which development companies sold land for high prices within proposed irrigation developments, even though it was unlikely that enough water could be supplied to support irrigation.

According to the information Zeman gleaned from his grandfather and other ancestors, some of the first attempts at irrigation began in Pecos and Loving counties in the 1870s near the towns of Balmorhea and Porterville. In 1914, canal companies were formed in Pecos and Loving counties, while the first irrigation districts were incorporated in the 1930s. Irrigation water use and irrigated acreage peaked in the 1930s. “Our family has water rights for irrigation that go back to the 1880s,” he said.

In a 1914 report by the U.S. Reclamation Service, P.M. Fogg expressed the concerns of settlers who had purchased lands they mistakenly thought would be irrigated:

> Failure to furnish water in an amount necessary for crops does not render the promoting companies liable for damages, provided that such water as may be available is distributed pro rata to the land holders…There has been no restraint upon the promotion of irrigation tracts and the settler has little recourse in the event of dissatisfaction.

In a 1961 report by the Pecos River Commission, Lingle & Linford (page 81) describe the problem this way:

> In Texas, it was the practice for the irrigation-development companies to acquire title to large tracts along rivers whose currents they intended to divert and subsequently, to sell land and water both to settlers. In the early years, the State exercised almost no control over apportionment of water and, inevitably, there were many instances in which development companies sold at high prices lands within irrigation projects which could not be supplied with water.

In 1913 the Texas Legislature passed a bill that declared that the State of Texas had the right to grant water rights to unappropriated surface waters. In practical terms, the 1913 statute made it much more difficult for irrigation and land development companies to offer the hope of supplying lands with irrigation unless they had procured the rights to that water.

In the 1870s, attempts were made to irrigate large amounts of land throughout the Pecos Basin of Texas (Hill, 1965) as shown in Table 1. The acreage listed reflects the total land area that could potentially be irrigated if these projects had been fully developed. In reality, most of the projects irrigated much less land than listed here and/or existed for only a few years before being abandoned. Hill's data suggests that the amount of land actually irrigated ranged from 37,493 acres in 1924 to 14,794 acres in 1934 (Table 2).

Table 1. Early Irrigation Projects in the Pecos Basin

Irrigation Project	*County*	*Year Started*	*Potential maximum acreage*
Imperial	Pecos	1887	25,000
Barstow & West Valley	Ward, Reeves	1889	27,000
Grand Falls	Ward	1890	32,000
Big Valley	Ward	1906	16,000
Arno	Reeves	1908	15,000
Porterville	Loving	1908	6,000
Farmers' Independent	Reeves	1908	10,000
Biggs	Ward	1908	12,000
Zimmerman	Pecos	1909	26,000
Victor	Crane	1914	4,000
Total Acreage			173,000

Source: Hill,1965.

In the 1890s, companies constructed railroad lines as part of efforts to irrigate and develop lands throughout the Pecos Basin (Bogener, 2003; Dearen, 2000). The Pecos River Railroad Company built a line from Pecos City to the New Mexico state line in 1890 that operated until the 1980s. One goal of the railroad was to establish human settlement by encouraging irrigation throughout the region. In Ward County, the Texas & Pacific Railroad promoted settlement near Barstow, Grandfalls and Royalty and brought settlers to the region. When railroads expanded into Pecos County in 1911, the Fort Stockton Irrigation Lands Company encouraged settlers and prospectors by selling farmland that could be irrigated in 10-acre plots.

In 1912, *the Fort Stockton Pioneer* described the prospects of widespread irrigation this way (Daggett, 1985):

> We know of a number of our prosperous irrigated land citizens who are now planning and arranging to commence building in the near future. It will not be long until our irrigated territory will look… beautiful, for the alfalfa fields, orchards and the vineyards are more delightful to behold than city lawns.

Some of the crops grown in the Pecos Basin of Texas throughout the early 1900s included cantaloupes, alfalfa, vegetables, grapes, orchard crops and strawberries (Newman & Dale, 1993).

Irrigation Development along Tributaries of the Pecos River

One of the first irrigation developments along tributaries of the Pecos River began in 1854 near Balmorhea. Artesian springs including Phantom Lake Spring, San Solomon Spring and Griffin Spring supported irrigation in Reeves County. In the early 1860s, farmers began to use several other springs in the county (including Comanche Springs, San Pedro Springs, Leon Springs, and Santa Rosa Springs) to support agricultural irrigation. The combined flow of these four major springs at this time was estimated to be as much as 50,000 acre-feet annually (Lingle & Linford, 1961).

Irrigation Ditch near Pecos, Texas

In 1868, Peter Gallagher purchased lands along Comanche Creek where Comanche Springs is located and supplied irrigation water for alfalfa and other forage crops to support the cattle industry. That land became the site of Fort Stockton. Cesario and Bernardo Torres (along with other investors) started the first irrigation project near Fort Stockton in 1869 by tapping the waters of Comanche Springs (Baggett, 1942). They constructed a small diversion dam, ditches and canals that would later be used by the Torres Irrigation Company upon its establishment.

In 1875, the Texas Legislature passed an act encouraging the construction of canals and ditches for irrigation and navigation. This led to the establishment of several irrigation and canal companies in 1875 in Ward and Pecos counties, including the Torres Irrigation and Manufacturing Company, the Comanche Creek Irrigation Company, the Fengall Irrigation Company, the Garza Irrigation Company and the Toyah Creek Irrigation Company. A lawsuit was filed in 1875 to resolve concerns that irrigation from San Solomon Springs might decrease the amount of water flowing in the Pecos River (Williams, 1982).

In 1908, a project sought to develop irrigated farming at Upland in Upton County (Eagleton, 1971) but eventually proved unsuccessful. Many of the settlers who tried irrigated agriculture left the county in 1912 after encountering problems with poor soils and droughts.

Irrigation well near Pecos, Texas

The Fort Stockton Irrigation Company proposed to irrigate 50,000 acres in 1909 (Williams, 1982) and the Toyah Valley Irrigation Company in Reeves County was organized by consolidating several small canal systems (Hughes, 1978; Dearen, 2000; Williams, 1982). In 1914, the company was reorganized as the Reeves County Irrigation District No. 1 and made plans to irrigate 10,600 acres. Ultimately, only 7,520 acres were irrigated. Farmers in the district shifted from growing alfalfa (which has a high water demand) to cotton, grains and grain sorghum, which consume lesser amounts of water. In 1917, the district reorganized becoming the Reeves County Water Improvement District No. 1 and constructed a dam across Toyah Creek to support irrigation.

Irrigation Development along the Main Stem of the Pecos River

Efforts to divert the main stem of the Pecos River for irrigation began in the 1870s. The Torres Irrigation Company began using the waters of the Pecos River to support irrigation in Pecos County. It watered 480 acres that produced 12,000 bushels of corn in that year (Williams, 1975).

In 1877, the Pecos River Irrigation Company was incorporated to take water from the Pecos River to develop irrigation on 320 acres (Bogener, 2003; Daggett, 1985; Dearen, 2000; Williams, 1982; Bogener, 1993).

By 1914, at least 10 projects (discussed below) stretching from Arno (near the Texas-New Mexico border) to Girvin, about 150 river miles downstream, (Lingle & Linford, 1961) had been initiated or completed. On paper, these 10 projects included more than 173,000 acres of irrigable land; less than 30,000 acres were actually cultivated.

Center Pivot Irrigation near Pecos, Texas

The Imperial or Buenavista Project—In 1876, Francis Rooney led efforts to construct the first dam on the Pecos River at a site 28 miles below the town of Pecos. In 1914, the project supplied water to 8,000 acres; this number decreased to 5,000 acres in 1939. In 1922, the project was reorganized and managed by the Pecos County Water Improvement District No. 2.

The Arno Project—This northern-most irrigation project developed along the Pecos River about 28 miles north of Pecos City, began in the 1890s and featured a 15-mile canal to supply water to irrigate about 15,000 acres. By 1914 about 100 acres remained under cultivation.

The Porterville Project—In 1908, the Porterville project was organized from the Loving Canal and Irrigation Company to irrigate up to 6,000 acres in Loving County. Water was pumped from the river 20 miles north of Pecos beginning in 1910. 600 acres were irrigated in 1914; the project is now included in the Loving County Water Improvement District No. 1. The earlier Loving Canal and Irrigation Company (Williams, 1982; Dunn, 1948) began in 1893 but was destroyed by a flood in 1894.

The Farmers Independent Project—The Farmers Independent Project was organized in 1907 in Reeves County 17 miles northwest of the town of Pecos. The project consisted of more than 10,000 acres in 1909. The Farmers project merged with the western portion of the Barstow Project in 1934 to create the Reeves County Water Improvement District No. 2. The district supplied irrigation to 2,522 acres in 1934.

The Biggs or Cedarvale Project—The Biggs or Cedarvale Project, organized in 1906 and included 15,000 acres, diverted water from the Pecos River at a site nine miles north of Pecos. However, the plan failed in 1909 when the flow in the Pecos River proved insufficient to support all of the irrigation dams built in the area. By 1914, farmers learned that the Pecos River was too salty to support most irrigated agriculture and cultivated only 1,400 acres (Dunn, 1948; Dearen, 2000).

The Barstow Project—The Barstow Project was organized in 1888 to divert water from the Pecos River at a site nine miles north of Pecos, Texas. Original plans were to irrigate 24,000 acres in Ward County and 3,400 acres in Reeves County. The project irrigated more than 8,000 acres in 1904, including vineyards at Barstow that produced award-winning grapes recognized at the 1904 St. Louis World's Fair. This project included the Pioneer Canal Company in Pecos City, which hoped to supply irrigation to more than 12,780 acres in Reeves and Ward counties. The project was reorganized as the Ward County Irrigation County District No. 1 in 1913.

The Big Valley Project—The Big Valley Project, which diverted water from the Pecos River at a site 14 miles east of the town of Pecos, was constructed in 1906 and originally was designed to irrigate 16,000 acres. However, by 1908 only 600 acres were irrigated and that number dropped to only 160 acres in 1914. The Big Valley Project united with the Grandfalls Project in 1917 when the Ward County Improvement District No. 2 was created.

The Grandfalls Project—Beginning in the late 1880s, settlers began to migrate to Grandfalls to develop farms irrigated by the Pecos River. By 1887, irrigation systems near Grandfalls supported more than 4,000 acres of cropland. The Grandfalls Project, organized in 1890, diverted the Pecos River waters at a site 25 miles east of the town of Pecos. Original plans proposed to irrigate more than 32,000 acres in Ward County. By 1914, the project irrigated roughly 7,000 acres. In 1939, the Grandfalls and Big Valley projects were merged to form the Ward County Improvement District No. 2 and supported irrigation on 5,500 acres.

The Zimmerman Project—In 1909, the Zimmerman Irrigation Company began to construct the Zimmerman Dam in Pecos County about 50 miles east of Fort Stockton (Hall, 2002). The company completed the dam in 1922 and the dam was touted as one of the longest earthen dams in the world at the time. The project was designed to serve up to 26,000 acres; several thousand acres of farmland were sold for prices of up to $100 per acre. In 1931, the project was reorganized as the Pecos County Water Improvement District No. 3. The area supported 3,900 irrigated acres in 1924 and 2,500 acres in 1939. In 1941, a large flood breached Zimmerman Dam when the river crested at 20.49 ft; 12.48 ft above flood stage. After the flood, irrigation to the Zimmerman project was supplied through the Imperial Project, which was managed by Pecos County Water Improvement Districts No. 2 and 3.

The Victor Pumping Project—In 1914, the Victor Pumping Project was developed to divert the Pecos River at a site 60 miles south of Pecos, Texas in Crane County. The project was designed to irrigate 4,000 acres but it was abandoned after several years of operation.

Trends in Irrigated Acreage in the Pecos Basin of Texas

Information compiled by the U.S. Bureau of Reclamation suggests that irrigated acreage in the region between 1914 and 1938 ranged from as little as 14,794 acres in 1934 to as much as 37,493 acres in 1924 (Table 2).

Table 2. Pecos Basin Irrigated Acreage

Year	Irrigated Acreage
1914	27,960
1922	28,896
1924	37,493
1932	18,541
1934	14,794
1936	15,398
1937	21,971
1938	25,417

U. S. Bureau of Reclamation, 1965

The Texas Board of Water Engineers published a report titled *Irrigation in Texas in 1958* that presents data on irrigated acreage from 1939 through 1959 (Texas Board of Water Engineers, 1961). According to the report, irrigated acreage in the Pecos Basin totaled nearly 65,000 acres in 1939, jumped to more than 93,000 acres in 1949, and totaled more than 242,000 acres in 1959 (Table 3). Much of the increase in the 1949 and 1959 data can be associated with the expansion of groundwater pumping in the region.

Since the 1950s, the Texas Water Development Board (TWDB) has regularly published updates about the amount of irrigated agricultural acreage and the amount of water applied for agricultural irrigation. TWDB reports that irrigated acreage rose to 233,578 acres in 1958 and peaked at nearly 260,000 acres in 1964 as result of widespread groundwater pumping. Irrigated acreage then declined throughout the 1970s and 1980s reaching a low of 69,499 acres in 1989 (Table 3). The reduction in acreage since the 1970s occurred because it became more expensive to pump groundwater from greater depths and because less water was flowing in the Pecos River. Currently, irrigated acreage is making a small comeback in the region with data from 2000 showing 73,101 acres in the Pecos Basin.

Table 3. Irrigated Acreage in the Pecos Basin of Texas

County	1939	1949	1958	1964	1969	1974	1979	1984	1989	1994	2000
Brewster	1,113	259	234	220	0	148	248	233	120	116	145
Crane	0	0	0	0	0	0	0	115	12	12	0
Crockett	0	701	805	1,320	1,718	908	909	450	341	345	118
Culberson	0	1,885	9,905	10,480	8,974	8,429	21,105	9,819	9,013	2,806	5,620
Loving	0	387	700	273	68	51	40	0	42	583	358
Pecos	23,346		117,413	119,313	55,043	51,795	27,291	31,232	25,296	24,369	27,083
Reeves	18,067		96,000	118,200	82,035	78,170	36,502	27,061	19,509	27,526	24,063
Terrell	347	734	111	207	277	106	194	166	264	196	96
Upton	0	0	550	2,810	5,676	6,486	14,002	12,067	10,906	13,573	9,843
Val Verde	2,968	2,105	2,200	1,300	1,575	1095	870	1022	792	835	953
Ward	18,655		5,660	5,447	6,496	5,536	1,788	284	3,204	2,651	4,892
Totals	64,496		233,578	259,570	161,862	152,724	102,949	82,449	69,499	73,012	73,171

Surveys of Irrigation in Texas. 2001. Technical Report 347, published by the TWDB

Data from the TWDB also reveals how groundwater and surface water have been used for agricultural irrigation since the 1950s. For example, groundwater pumping for irrigation totaled more than 684,972 acre-feet (AF) in 1958, peaked at 777,785 AF in 1964, and has declined ever since (Table 4).

Table 4. Acre-feet of Groundwater Use for Irrigation in the Pecos Basin of Texas

County	1958	1964	1969	1974	1979	1984	1989	1994	2000
Brewster	0	50	0	130	311	427	238	327	430
Crane	0	0	0	0	0	90	7	22	0
Crockett	1,839	3,197	3,167	2,090	1,305	338	412	419	160
Culberson	29,176	24,512	31,861	28,935	46,885	20,051	14,145	5,583	24,765
Loving	0	0	0	0	0	0	0	0	0
Pecos	313,900	339,397	187,157	171,240	90,147	90,022	65,932	70,946	72,412
Reeves	335,168	402,017	310,092	286,856	105,103	63,226	61,345	93,579	63,228
Terrell	0	0	1,050	257	489	242	389	494	0
Upton	698	3,594	5,438	9,015	17,493	15,235	14,394	18,483	12,471
Val Verde	2,369	2,174	2,155	401	220	736	386	363	270
Ward	1,822	2,844	2,918	2,136	577	357	295	529	2,805
Totals	***684,972***	***777,785***	***543,838***	***501,060***	***262,530***	***190,724***	***157,543***	***190,745***	***176,541***

Surveys of Irrigation in Texas. 2001. Technical Report 347, published by the TWDB

In contrast, irrigation from the Pecos River and other surface waters has largely been confined to Reeves, Ward and Val Verde Counties. The volume of surface water used for irrigation is only a small percentage of overall agricultural water use in the region (Table 5). Data from 2000 suggest that the volume of surface water used for irrigation is now increasing; additional flows from New Mexico are allowing more water to be stored at Red Bluff Reservoir and could be the cause of this increase.

Table 5. Acre-feet of Surface Water Used for Irrigation in the Pecos Basin of Texas

County	1958	1964	1969	1974	1979	1984	1989	1994	2000
Brewster	588	665	0	249	316	0	0	0	191
Crane	0	0	0	0	0	0	0	0	0
Crockett	0	0	0	0	0	0	0	0	0
Culberson	0	0	0	0	0	0	0	0	0
Loving	700	273	68	51	40	0	42	583	358
Pecos	0	0	0	0	0	0	7,530	1,160	1,824
Reeves	33,400	12,200	333	317	613	0	3,527	300	10,811
Terrell	501	1,035	200	0	76	0	0	0	80
Upton	0	0	0	0	0	0	0	0	0
Val Verde	0	0	187	1,344	1,130	1,612	1,612	1,279	1,258
Ward	0	0	627	317	333	0	13,705	10,781	10,597
Totals	***35,189***	***14,173***	***1,415***	***2,278***	***2,508***	***1,612***	***26,416***	***14,103***	***25,119***

Surveys of Irrigation in Texas. 2001. Technical Report 347, published by the TWDB

Total water use for agricultural irrigation in the region peaked in 1964 at 835,412 AF and declined to a low of 193,163 AF in 1989. The most recent data show that agricultural water use totaled 202,221 AF in 2000 (Table 6). Increasing and decreasing trends in water use correspond with increasing and decreasing trends in total acres of irrigated agriculture in all reported periods except for the change between 1994 and 2000.

Table 6. Total AF of Water Used for Irrigation in the Pecos Basin of Texas

County	1958	1964	1969	1974	1979	1984	1989	1994	2000
Brewster	588	715	0	379	627	427	238	327	621
Crane	0	0	0	0	0	90	7	22	0
Crockett	1,964	3,197	3,167	2,090	1,305	338	412	419	160
Culberson	29,176	24,512	31,861	28,935	46,885	20,051	14,145	5,583	24,765
Loving	700	273	68	51	40	0	42	583	358
Pecos	345,266	367,455	201,748	184,669	94,463	90,022	73,462	72,106	74,236
Reeves	368,568	414,217	334,392	319,785	127,470	89,689	74,076	101,723	74,039
Terrell	501	1,035	1,250	257	565	242	389	494	80
Upton	698	3,594	5,438	9,015	17,493	15,235	14,394	18,483	12,471
Val Verde	2,369	2,174	2,342	1,745	1,350	2,348	1,998	1,642	1,528
Ward	14,739	18,240	23,806	22,975	7,549	357	14,000	11,310	13,963
Totals	***764,569***	***835,412***	***604,072***	***569,901***	***297,747***	***218,799***	***193,163***	***212,692***	***202,221***

Surveys of Irrigation in Texas. 2001. Technical Report 347, published by the TWDB

How Water Management at Red Bluff Reservoir Affects the Pecos River

The construction of Red Bluff Dam and Reservoir fostered the development of water improvement districts and agricultural irrigation throughout the Pecos Basin of Texas. The dam is located on the Pecos River in Reeves and Loving counties, roughly 45 miles north of Pecos, Texas.

Some of the earliest discussions of building Red Bluff Dam go back to 1905 (Bogener, 2003; Hall, 2002). In 1916, the Pecos Valley of Texas Water Users Association (which consisted of the Porterville, Farmers Independent, Cedarvale/Imperial, Barstow, Big Valley-Grandfalls, Imperial and Zimmerman projects) filed a petition with the U.S. Secretary of the Interior to request that a dam be constructed. In 1917, the Red Bluff Water Improvement District (which was formed by the seven irrigation projects mentioned above) developed plans to use the proposed dam to irrigate farmlands from Red Bluff to the town of Grandfalls.

The Public Works Administration and these seven Texas irrigation districts financed the construction of Red Bluff Dam. Work to build the dam began in 1934 and it was completed in 1936. Red Bluff drains an area of 20,720 square miles and the reservoir has a storage capacity of more than 307,000 acre-feet (AF). In 1948, Texas and New Mexico signed the Pecos Interstate Compact to jointly manage the river and ensure that Texas receives its fair share of water.

Red Bluff Reservoir provides water for irrigation throughout the region. Releases of water are made at the request of the seven downstream irrigation districts. Each irrigation district has its own diversion and distribution system; however, not all waters released from Red Bluff actually flow to farmers. In a technical report developed for the TWDB, Boghici et al. (1999) suggested that water losses in the channels of the Pecos River downstream of Red Bluff can be as high as 45%.

In 1962, the U.S. Bureau of Reclamation surveyed agricultural lands downstream from Red Bluff to determine how much acreage might support crop production. Results suggested that 42,750 of the 47,350 acres in Loving, Reeves, Ward and Pecos counties served by the Red Bluff Power Control District were "physically suitable" for irrigation (Hill, 1965). As defined in this report, even lands with high levels of soil salinity were classified as being physically suitable for irrigation if they could be leached with proper water management and drainage. Lands were classified as not being physically suitable for irrigation if they had restricted internal drainage.

Data from Miyamoto, Yuan & Anand (2006) and Miyamoto (1996) show that the salinity loads from Red Bluff Dam may be adversely affecting the water quality in Amistad Reservoir. Miyamoto suggests that controlling the salinity level at Malaga Bend and in Red Bluff Reservoir may be a viable strategy to protect and improve water quality in Amistad Reservoir.

In 1958, Public Law 85-33 was authorized funding the “Malaga Bend Salinity Alleviation Project.” Five years later, in 1963, the United States Geological Survey (USGS) and the Pecos River Compact Commission initiated the project. The project pumped saline groundwater from the Rustler Formation and other saline aquifers in the Malaga Bend region into evaporation ponds. The idea behind the project was to reduce the volume and flow rate of high salinity groundwater entering the Pecos River in the area.

Havens and Wilkins (1979) describe results of a USGS research project that was conducted from 1963 through 1968. This specific project evaluated the effects of pumping and disposing of saline groundwater from Malaga Bend to reduce salt loadings to the Pecos River. During this period, more than 3,878 acre-feet of saline groundwater were pumped from Malaga Bend and salinity loads to the Pecos River decreased from roughly 250 tons per day to as little as 75 tons per day. However, as the project progressed some of the brine that had been trapped leaked from the evaporation basins back into the river effectively raising salinity loadings to roughly 200 tons per day (Kunkler, 1980). The USGS concluded that “Pumping the brine aquifer appears to be an effective method of reducing brine inflow to the river…If brine inflow to the river is to be reduced on a long-term basis…a suitable disposal site must be found.”

The initial phase of the project operated through 1976 when it was suspended. A similar project was initiated in 2002 and saline groundwater was once again pumped to evaporation ponds beginning in 2003; however, pumping was halted once again when the effort was determined to be economically unfeasible. The hope was that brines captured from groundwater formations could be evaporated in shallow basins with the hope of recovering salts that can be sold, thus making the project more economically viable.

Initially, the goal of the project was to reduce salt loadings by more than 367 tons per day (a 25% reduction compared to current levels). Data suggest this water quality goal was met 86% of the time in 2004 (D’Antonio, 2006).

According to the Pecos River Compact Commission (Thrasher, 2004), this program “is the single most important project which could enhance the quality of water in the Pecos River entering Texas and subsequently the Rio Grande.”

Each year, Red Bluff Dam releases water to support agricultural irrigation. The amount of water released from Red Bluff is shown in Table 7. Water was not released from Red Bluff during several years: 1962-67; 1978; 1984; and 2002-2003.

Table 7. Water Releases from Red Bluff Dam (Acre-feet)

Year	AF Released	Year	AF Released
1959	24,008	1985	33,645
1960	32,548	1986	33,588
1961	49,189	1987	107,468
1968	68,577	1988	53,099
1969	32,851	1989	84,673
1970	53,747	1990	45,338
1971	33,962	1991	27,286
1972	24,700	1992	38,479
1973	43,301	1993	78,027
1974	23,830	1994	51,315
1975	61,108	1995	43,038
1976	41,600	1996	44,556
1977	39,600	1997	53,025
1979	48,000	1998	59,594
1980	34,500	1999	33,064
1981	32,800	2000	56,186
1982	22,077	2001	44,843
1983	19,100	2004	38,303

Source: Red Bluff Water and Power District

Don Howell came to the Pecos Basin in 1927 to work in the oil and gas exploration industry and has lived in Grandfalls since that time. He was living in the region when the Zimmerman Dam washed out in a 1942 flood and has urged that the dam be rebuilt to restore the region's water supply. Howell estimates that a rebuilt Zimmerman Dam could salvage and store more than 26,000 AF of water annually by impounding surface water in the Pecos and by capturing alluvial groundwater flows to promote aquifer recharge. He has made presentations to county commissioners and water planning groups in the region and has raised funds that may pay for needed environmental and archaeological studies.

"We need the Zimmerman Dam to stop the flow of groundwater and make the river fresh again," he said. "Now, without the dam, if any rainfall occurs it flows in the river all the way to Amistad Reservoir. If we could slow the flow of groundwater, we could develop recreation along the river and it would be a boon to the economy."

Irrigation in the Pecos Basin of Texas after the Completion of Red Bluff Dam

Since the 1940s, the U.S. Bureau of Reclamation has worked to rebuild and improve the irrigation infrastructure at Balmorhea. The Bureau's work has supported the irrigation of more than 8,700 acres in the region (Bogener, 1993). In 1943, more than 2,170 acres near the town of Pecos were irrigated with groundwater (Hughes, 1978). In the 1950s, plans were underway to develop up to 35,000 acres of irrigated cropland near Coyanosa in Pecos County but these plans collapsed.

Until the 1950s, more than 3,500 acres near Fort Stockton were irrigated with groundwater from Leon Springs (Hughes, 1978; Williams, 1982). During the drought of the 1950s, the flow of Comanche Springs decreased significantly and an investigation revealed that irrigation wells drilled into the aquifer lowered the water level and caused Comanche Springs to go dry. After negotiations failed, the Pecos County Water Control and Improvement District (WCID) No. 1 sued Clayton Williams and other landowners to regulate groundwater pumping to maintain normal flows at Comanche Springs. In 1954, the Texas Court of Civil Appeals ruled that groundwater contributing to the flow of Comanche Springs belonged to Clayton Williams while it was under his land. The court rejected all legal claims of the Pecos County WCID. It said that the district's rights to these waters only begin after groundwaters are discharged to a spring—not while they are still in a groundwater formation (Kaiser, 2005). As a result, the court said that Williams could beneficially use as much groundwater as he wished, regardless of the impact on springs and receiving waters.

Alan Zeman, who works for the Pecos Irrigation District, notes that most of the irrigation has left the region. A large part of the problem is that low volumes of water were stored in Red Bluff Reservoir for many years when New Mexico was not releasing the amount of water required by interstate compacts. Now that New Mexico has begun to again make the required diversions, irrigators are finding it difficult to invest the amount of money needed to restart wells, pumps and irrigation infrastructure.

Conflicts Between Texas and New Mexico Management over the Pecos River

To understand the flows of the Pecos River in Texas, it is helpful to understand how the river is managed in New Mexico and the legal struggle between that state and Texas over water rights (Hall, 2002; Johnson et al., 2003). Early disputes between Texas and New Mexico often erupted over how much water in the river belonged to which state.

One of the earliest disputes took place when the West Texas Reclamation Association and other interests in Texas threatened to sue if New Mexico built a third dam on its reach of the Pecos River in 1914. The first Pecos River Compact was proposed in 1924 and was approved by Texas, but vetoed by the governor of New Mexico. This compact would have limited New Mexico to using the Pecos River to irrigate 76,000 acres between Santa Rosa and the Texas-New Mexico state line and guaranteed Texas enough water to irrigate 40,000 acres and would have given Texas the right to build a reservoir at Red Bluff. In the early 1930s, seven West Texas irrigation districts agreed to sell bonds to fund and build Red Bluff Dam despite the 1924 Pecos River Compact's disapproval; the dam was completed in 1936.

Participants in a Pecos Basin Assessment Program Stakeholder Meeting

In 1948, Texas and New Mexico signed the Pecos Interstate Compact to jointly manage the river and its waters. In basic terms, the Compact outlines a formula that determines the volume of Pecos River water that New Mexico must deliver to the Texas-New Mexico state line at Red Bluff Reservoir. The compact ensures that Texas should receive a fair proportion of Pecos River waters each year, based on the amount of rainfall and runoff that have occurred.

Texas and New Mexico often disagreed about the volume of Pecos River water that Texas should receive each year. Texas contended that New Mexico did not consistently deliver the amount of water promised under the compact for many years. In 1987, the U.S. Supreme Court ruled that from 1950 to 1983 New Mexico water deliveries to Texas were 340,100 AF less than the amount of water required under the Compact. The court ordered New Mexico to repay this deficit over a 10-year period and to begin to deliver the volume of water required by the compact each year. In addition, the court required New Mexico to pay Texas nearly $14 million to offset financial hardships resulting from insufficient deliveries of Pecos River water, most of which went to the seven irrigation districts that developed Red Bluff Dam. The settlement also decreed that the U.S. Supreme Court would appoint a river master to ensure the terms of the settlement continued to be met. New Mexico was also ordered to always deliver the amount of water prescribed by the compact to Texas (Hall, 2002; Johnson et al., 2003). New Mexico has met its Compact obligations since that time and has retired 18,000 acres of previously irrigated cropland near the towns of Carlsbad and Roswell.

J.W. Thrasher of Monahans was appointed to serve as the Texas representative on the Pecos River Compact Commission in 1999. His brother-in-law, R.B. McGowan, was also a Commissioner and led the efforts to bring the lawsuit against New Mexico to ensure that sufficient water deliveries were made to Texas to comply with the Compact. "One of the problems with the settlement is that the irrigation districts in Texas make their money selling water," he said. "By the time the settlement had been reached, there was not a large demand for irrigation water because adequate deliveries had not been made for several years. I think additional deliveries of water from New Mexico will help out if we can build up enough water in Red Bluff Reservoir to assure there will be enough water for farming for many years. The question now is, Will there still be enough farmers still in business once Red Bluff begins to fill on a regular basis?"

Tom Nance, former general manager of Ward County Irrigation District Number 1, described how irrigation in this part of Ward County has been sporadic since the 1950s, in large part because Texas residents could not count on receiving a consistent volume of water deliveries from New Mexico. As a result, he says it's been hard for people to continue farming, since they are dependent on irrigation to make successful crops.

Pecos River, October 1961, before saltcedar control (photo courtesy of Red Bluff Water and Power Control District)

However, he hopes that farming can come back in the region once New Mexico meets its water obligations and once Red Bluff can again provide consistent water deliveries. "I hope the farmers will do more to increase their water use efficiency, improve canals and make improvements to their fields. Our idea is to use the increased water Texas receives from New Mexico, and the water saved by clearing saltcedar, to convince farmers we can sustain irrigation in the Pecos Basin."

Removing Saltcedar to Increase Flows of the Pecos River

Control of saltcedar included aerial spraying with herbicides

One alternative that can potentially increase the flows of water in the Pecos River Basin is to clear excessive populations of saltcedar and other nuisance brush species that infest much of the zone along the river. TCEQ (Mills, 2005) and other sources (Belzer & Hart, 2006; Hart et al., 2005; El-Hage & Moulton, 1998) suggest that saltcedar and mesquite have replaced much of the native vegetation in the Pecos Basin of Texas, which is thought to have originally consisted of cottonwoods, black willow and grasses. Belzer & Hart (2006) state that saltcedar was introduced to the United States as an ornamental plant in the early 1800s. In the early 1900s, government agencies and private landowners began planting saltcedar to control stream bank erosion on the Pecos River in Texas and New Mexico. Since that time saltcedar has proliferated and its population has grown out of control, especially in riparian areas near river banks, creeks and arroyos, in irrigation ditches and canals, and at sites with shallow groundwater.

Saltcedar typically grows in areas where its roots can tap shallow alluvial aquifers, usually near rivers. Saltcedar water use often approaches the volume of water lost to potential evapotranspiration; this can be as much as 50 to 60 inches in the basin. Texas Agricultural Experiment Station (TAES) scientists suggest mature saltcedar trees can consume more than 50 inches of rain annually. If saltcedar were replaced with shallow-rooted perennial grasses, substantial water savings could be realized. One acre of saltcedar-infested land typically uses 48 acre-inches of water annually while an acre of grasses might be expected to use only 12 acre-inches of water annually. Experiment Station studies suggest that a dense, mature stand of saltcedar growing in a shallow groundwater table will consume about 3 to 4 acre-feet of water per year, but 1 to 2 acre-feet of water may be salvaged per year for each acre of saltcedar treated (Hart et al., 2005).

Water salvage from saltcedar control is highly dependent on the environment it grows in, depth to the water table, salinity of the water, characteristics of saltcedar stands and the type of vegetation that will replace saltcedar once it is cleared. Belzer & Hart (2005) describe how saltcedar now infests an area stretching along 271 miles of the Pecos River downstream of Red Bluff Dam. In these regions, saltcedar has spread over an area ranging from 25 feet to 500 feet away from the river banks. Saltcedar also degrades water quality by bringing salts to the surface through the plant. These salts are then excreted through plant leaves that drop to the ground as the plant becomes dormant. As a result, only extremely salt-tolerant plants can survive in areas beneath the canopy of saltcedars.

The "Pecos Basin Water Salvage Project" is a U. S. Bureau of Reclamation-funded project that employed mechanical treatments to control the growth of saltcedar throughout a region from Santa Rosa, New Mexico to Girvin, Texas. The Environmental Impact Statement developed for the project in 1979 suggests that as many as 200,000 acres in this region were afflicted with saltcedar. Of this total, saltcedar infested roughly 78,000 acres at riparian sites near the banks of the river where the depth-to-groundwater was less than 10 feet. Sites in Texas where saltcedar infestations were especially significant include riparian areas near Toyah Creek, Tornillo Draw, and Salt Draw as well as gypsum soils in areas near Pecos, Imperial, Fort Stockton, and Girvin.

The project was authorized through Public Law 88-594, which was passed in September 1964. The purpose of PL-88-594 was to enhance the water supply for municipal, industrial, irrigation and recreation uses, to increase flood protection and to provide habitat for fish and wildlife. Over the life of the project, more than 53,950 acres of saltcedar-infested lands were selectively cleared. Another 24,050 saltcedar-infested acres (mainly sites in riparian areas near the river) were left untreated in order to provide habitat for wildlife.

The intent of the "Pecos Basin Water Salvage Project" was to continue maintenance and management efforts along 47,200 acres of lands between Lake Sumner, New Mexico and Pecos, Texas that were previously cleared of saltcedar from 1967 to 1971. Nearly 21,000 acres of saltcedar-plagued lands were cleared between the Texas-New Mexico state line and the city of Pecos. Saltcedar was cleared in riparian areas along each bank of the river to create a continuous 30- to 50-foot wide green belt or vegetative buffer strip. Clearing was not carried out at inland sites where the depth-to-groundwater was more than 10 feet. To lessen the risk of erosion, riverbanks were not cleared of saltcedar where the slope was greater than 1.5 to 1.

Some of the mechanical methods used in this project to control saltcedar included plowing, mowing, bulldozing, and chaining. To control regrowth of saltcedar, the program relied on root

Pecos River, March 2005, after saltcedar control

plowing with heavy equipment. Herbicides were used to control saltcedar in the vicinity of Red Bluff Dam and along a 40-mile stretch from Orla to the city of Pecos.

Since 1995, Bureau of Reclamation-funded efforts to mechanically treat saltcedar-infested acreage are no longer being conducted in Texas although the project is still active in New Mexico (USBOR, 1979).

Several state and federal agencies are working to eradicate saltcedar throughout the Pecos Basin of Texas with the intent of increasing water yields (Hart et al., 2005). The Experiment Station and Texas Cooperative Extension have undertaken several research and Extension programs to evaluate the extent to which saltcedar removal may increase flows of water and water yields, including many studies now underway.

Methods evaluated to manage saltcedar include aerial spraying with herbicides, mechanical removal and using biological controls that prey on these plants (Belzer & Hart, 2006). From 1999 through 2005, aerial spraying programs led by Extension treated more than 13,497 acres of saltcedar-plagued acreage along the Pecos River of Texas.

Studies are now being conducted to ascertain how clearing saltcedar may benefit the hydrology of the region (Hart et al., 2005). Extension is now analyzing satellite images to determine how herbicide applications and other control methods are affecting the density of saltcedar populations along the Pecos River near Mentone (Nagihara & Hart, *In Press*). Researchers with Texas A&M University and Extension are also investigating the extent to which clearing saltcedar may boost the

Irrigation diversion dam on the Pecos River near Coyanosa, Texas

flows of surface water and groundwater in the main channel of the Pecos River and its tributaries (Hart et al., 2005). The goal is to quantify the hydrologic impacts that clearing saltcedar might have on the region and to identify the best methods to most effectively control and manage saltcedar; (i.e., the use of biological, mechanical and chemical methods).

Tiny Earp and his wife moved to the Pecos River Basin shortly after World War II. His father fenced their property so they could graze sheep on the grasslands in the area. During most of the time Earp has lived in the region, he has worked at ranching. His major concern is to improve the riparian areas along the river to improve conditions for cattle.

"We'll need a lot of money to clear all the saltcedar that needs to be removed, and I'm not sure if the landowners can afford it," he said. "But if clearing saltcedar caused the water level in the river to rise, it might have the effect of increasing groundwater flows along the banks and that might improve water quality."

Earp believes saltcedar management efforts should extend as far as two miles beyond the banks of the river. Earp's passion is ensuring that brush clearing will improve rangeland conditions for ranchers. He feels the most good could come from clearing saltcedar north of the town of Imperial.

Solutions to the Pecos River Water Challenge

The problems and challenges facing the Pecos River Basin of Texas are well-known. There simply is not enough water; the water that is present is often salty or of poor quality, and significant volumes of water are lost due to evaporation and percolation in reservoirs and the stream channel. These three primary problems are often exacerbated by other problems and human activities. Many of these problems can be effectively addressed, but economics prevents action from being done.

For many years, solutions have been identified that may help resolve some of the water resources challenges facing the Pecos Basin of Texas. Some of these strategies center on efforts to clear saltcedar and potentially increase flows of fresh water; reduce salt loading from saltcedar die-off; prevent natural and man-made contaminants from entering the river; improve irrigation efficiency; and develop improved water management systems. These efforts have not been carried out on an extended basis in most cases. Treatment and continued monitoring are critical to ensuring that management efforts are not done in vain.

Ultimately, the initiative and vision to improve the Pecos River must come from the people who live and work throughout the region. Coordination and cooperation among interested parties is vital to the success of a project that addresses water quality and quantity issues basin-wide. The Pecos Basin Assessment Program is working with stakeholders throughout the region to develop a coordinated water protection plan for the Pecos Basin region focused on solving these complex issues.

County Highlights

Brewster County

- Brewster County was explored in 1852 when M.T.W. Chandler led a party from Presidio Del Norte through the "Big Bend" to the mouth of the Pecos River in what is now Big Bend National Park and Big Bend Ranch State Park.
- Most of the county drains into the Rio Grande, but the northern part of the county drains toward the Pecos River.
- Ranching and mining were major industries in the county in the late 1800s and early 1900s; ranching is still practiced widely today.
- Although there has never been substantial irrigation in Brewster County, the concept of dryland farming was widely promoted in the region in the early 1900s. In 1909, the West Texas Dry Farm Congress met in Alpine.

Crane County

- The Victor Pumping Project was developed in 1914 to develop agricultural irrigation but the project was unsuccessful and lasted only a few years.
- The county has never experienced significant irrigated crop production, although attempts at farming were made during the 1920s.

Crockett County

- In Ozona, a high-volume water well was developed in 1891, one of many factors that led to Ozona being named the county seat.

Culberson County

- A general shortage of water has always limited irrigated agriculture in this county.
- Due to the scarcity of water and other factors, until 1949 Culberson County was the only county in Texas to never produce a bale of cotton.
- Cotton production in the county peaked at 6,215 acres in 1959. However, since that time the amount of land devoted to cotton production has declined significantly, in large part due to the lack of sustainable water resources.

Jeff Davis County

- Prehistoric people camped at Phantom Springs and Phantom Lake and likely used the springs for irrigation.
- Madera Springs was founded in the 1920s as a resort, but was forced to close in the 1950s when the springs dried up.

Pecos River at Reeves County Line

Loving County

- In 1893, the Loving Canal and Irrigation Company was organized in Mentone, with the goal of constructing an irrigation canal from the town of Pecos to farm land throughout Loving County. The project was soon abandoned.
- In 1908, developers began an irrigation project near Porterville that would take water from the Pecos River and irrigate 10,000 acres. The project was unsuccessful because flows in the river were not adequate to support irrigation and because water in the river was too saline to grow crops.
- Because the water in the Pecos River is too salty for human consumption, groundwater had to be hauled in from other regions for many years.

Pecos County

- Several springs (including Comanche, San Pedro and Leon) are present in the county and were once an important source of water for the county. The flow of Comanche Springs and other spring systems diminished or ceased due to groundwater pumping for irrigation.
- American settlement began in the 1860s. Some of the earliest locations people settled were near rivers.
- From 1911 to 1913, a railroad line was constructed and irrigation projects along the Pecos River were developed.

- At the time it was completed in 1922, Zimmerman Dam was thought to be one of the longest earthen dams in the world built to support agricultural irrigation. Between 1922 and 1941, Zimmerman Dam supported significant irrigated agricultural production. A large flood in 1941 washed out the dam and agricultural production has never fully recovered.

Reeves County

- Irrigation began in the late 1890s. Early sources of irrigation water included springs as well as small reservoirs that stored surface water.
- Significant irrigation from San Solomon Springs still occurs near the town of Balmorhea as part of a project developed by the U.S. Bureau of Reclamation.
- Land promotion and speculation was widespread in the 1910s and 1920s. The Toyah Irrigation Company developed more than 17,000 acres of irrigated farmland in 1910-11.
- The county is the center of the region that produces world-famous Pecos cantaloupes. A cantaloupe growers association was formed in 1917. The unique soils, water quality and climate of the region give the cantaloupes a distinctive and pleasant taste.
- During the Great Depression, several farmers left the region and the amount of irrigated and dryland cropland declined sharply.

Terrell County

- Although the Pecos River and the Rio Grande cross through the county, the steep and rocky terrain and widespread shallow soils make it difficult to access these waters for irrigation and other agricultural uses.
- A number of springs in the county provide water for livestock.
- Less than 1% of the land in the county is considered prime farmland.

Upton County

- The first water well in the county was drilled in 1881. Water was found at a depth of 30 feet.
- In 1908, irrigation for agricultural crop production was established at Upland. Many of the settlers who tried irrigated agriculture left the county in 1912 after having encountered problems with poor soils and droughts.
- In 1929, because of water challenges facing the town of McCamey, water had to be freighted in from Alpine (100 miles away) and sold for $1 per barrel. Later, conditions improved when groundwater was imported from the Trinity Sands Formation, located 17 miles away.

Val Verde County

- As the Lower Pecos River flows by northeastern Terrell County and into western Val Verde County, it gains considerable flows from springs and streams. This has the beneficial effect of increasing the volume of flow in the river, thus lowering salinity levels.
- The Pecos High Bridge spans the Pecos River northwest of Del Rio in Val Verde County.

Ward County

- By 1904, Barstow became a farming center, accommodating several orchards and vineyards.
- In 1904, the collapse of an earthen dam in New Mexico caused widespread flooding and damaged vineyards and grape production in Ward County. By 1918, few vineyards remained in the county.
- Serious droughts plagued farmers in the county in 1907 and 1910.
- In 1924, more than 27,493 acres in the county were irrigated. However, irrigated acreage declined to 14,794 acres by 1934.

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EPA United States Environmental Protection Agency

Soil Water TSSWCB Texas State Soil and Water Conservation Board

THE TEXAS CLEAN RIVERS PROGRAM

Texas Cooperative EXTENSION The Texas A&M University System

Texas Agricultural Experiment Station THE TEXAS A&M UNIVERSITY SYSTEM

Texas Water Resources Institute

make every drop count