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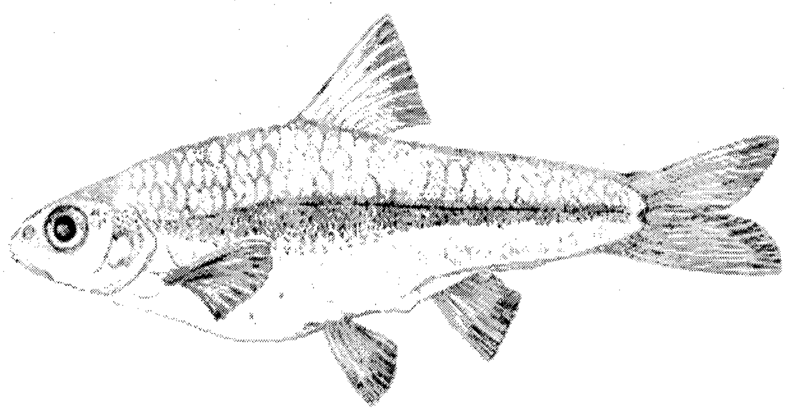

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GARY P. GARRETT AND NATHAN L. ALLAN

Contemporary Water Supply in West Texas as an Example for the Northern Chihuahuan Desert

Kevin Urbanczyk

Abstract

Water supply in the northern Chihuahuan Desert region occurs as both surface water and groundwater sources. The Rio Grande basin is the most significant of the surface water sources. This basin includes both the Río Conchos and the Pecos River systems. The Rio Grande Compact, the 1944 Treaty with Mexico regarding deliveries from the Río Conchos to the Rio Grande, and the Pecos River Program, governs water use in the basin. Groundwater resources in west Texas include several distinct aquifers. The Texas Water Development Board has categorized these aquifers as Major or Minor, based upon their size, geographic location, and geologic structure. Population growth predictions suggest large increases in the west Texas region, mostly in the El Paso area. These increases will place a significant strain on the available water supplies, and further use of both surface and groundwater sources will place a strain on the water available for wildlife. Within Texas, the Far West Texas Water Planning Group suggests several strategies for dealing with both the predicted population increase, and the decrease in available water due to drought and overuse of certain aquifers. These strategies include conversion of surface water appropriations from agricultural to municipal use, desalination, and interbasin transfer. Of these, the desalination and interbasin transfer of groundwater could significantly impact the ability of the groundwater to sustain wildlife populations.

Introduction

The northern Chihuahuan Desert encompasses parts of northern Mexico and the southwestern United States. As in all populated arid regions, water supply in this area is an essential issue for human habitation of the region. Complex legislation exists to control water use and, particularly in regions with expanding populations, overconsumption of water resources not only degrades the quality of life for humans, but significantly alters the natural ecosystems of this sensitive desert region.

This paper summarizes water supply in this arid region. Water "supply" is intimately associated with water "demand". This supply and demand concept is complex, and involves not only municipal water use, but also agricultural and industrial use. State, interstate and international government legislation is required to attempt to manage the use of this precious resource. Therefore, a summary of water supply necessarily requires the inclusion of both a discussion of demand and of legislation governing water use. Water supplies in the northern Chihuahuan Desert occur as both surface and as groundwater. These two distinct sources of water occur in different areas, and are legislated in manners that also are quite different.

Figure 1 includes the Rio Grande drainage basin and major political boundaries. The Rio Grande drainage basin begins in southern Colorado, flows through New Mexico, enters Texas near El Paso, and continues to the Gulf of Mexico where it forms the boundary between the United States and Mexico. Significant tributaries to the Rio Grande in the northern Chihuahuan Desert region include the Río Conchos (confluence located at Presidio, Texas and Ojinaga, Mexico), and the Pecos River (confluence near Langtry, Texas).

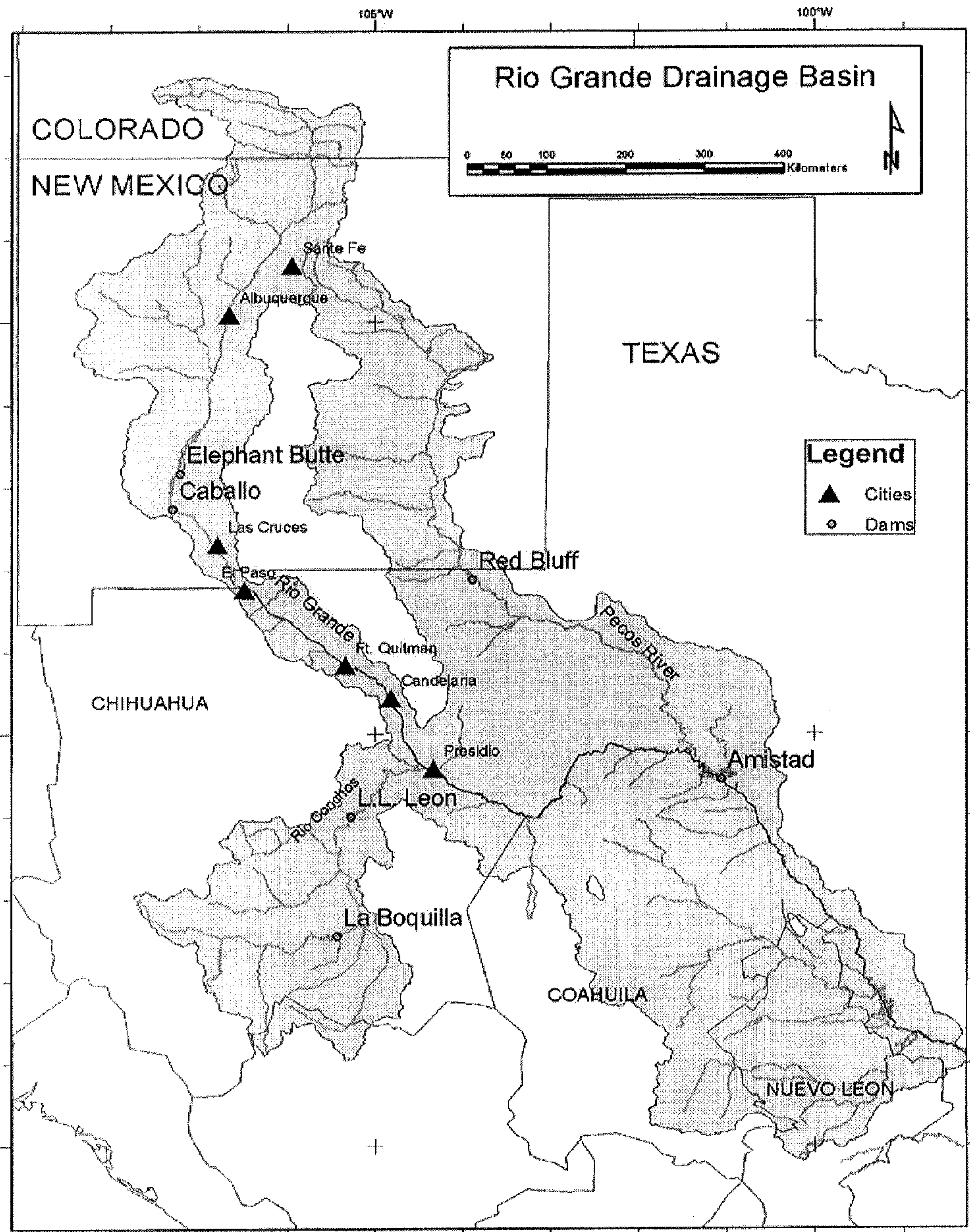


Figure 1. Rio Grande drainage basin with selected cities and dams. Basin boundaries and drainage patterns are from Texas Natural Resources Conservation Commission, and are available at http://www.riogrande.org/programs/gis/gisdata.htm (10/22/01).

Much of the content of this paper utilizes data available for the state of Texas. These data were produced in association with the development of the 1997 State Water Plan, and the development of the draft version of the 2002 State Water Plan. The data represent the most complete compilation of water resources information for any section of the Chihuahuan Desert. Discussions of areas outside of Texas are included where appropriate and available.

WATER LAW

Water laws in Texas are similar to those in most other western states, but may differ from laws in Mexico. In Texas, water is classified as to where it physically occurs: percolating groundwater, underground streams, diffuse surface water, and streamflow (Wurbs et al., 1994). Of these, percolating groundwater and stream flow are the two significant water sources present in the northern Chihuahuan Desert. Groundwater has been historically governed by the "Right (or Rule) of Capture" doctrine. According to this doctrine, a landowner has the right to use or sell all of the water that can be captured from beneath a property (Wurbs et al., 1994). Stream flow is governed by the "Prior Appropriation" doctrine. Surface water (in Texas) is publicly owned, and permits must be obtained to use surface water. The permitting, which is controlled by agencies such as the Texas Commission on Environmental Quality (TCEQ, formerly Texas Natural Resource Conservation Commission, TNRCC), is generally based upon who received the rights first ("first come, first serve"). Diffuse surface water is water such as return flow from an irrigated property. It is the property of the landowner until it reaches a watercourse. Underground streams are present in the northern Chihuahuan Desert. These feed water sources such as San Salomon springs in the Balmorhea area (Sharp et al., this volume).

SURFACE WATER RESOURCES

The Rio Grande basin encompasses approximately 180,000 square miles (466,000 square kilometers, Figure 1). It is best considered as two separate basins – an upper basin that ends at Presidio, Texas, and a lower basin that extends from there to the Gulf of Mexico. Additionally, the Pecos River and the Río Conchos can be considered part of the lower basin. Most of the flow in the upper basin is due to precipitation in southern Colorado and northern New Mexico (Wilson, 2000). This flow is impounded in a series of reservoirs. These include Elephant Butte (constructed in 1916; 2.11 million acre-feet (MAF) capacity) and Caballo (1938; 0.331 MAF) in southern New Mexico (Figure 1). As an example of evaporation rates, Elephant Butte and Caballo account for 85% of the 0.34 MAF/year that evaporate off of New Mexican Rio Grande reservoirs (Wilson, 2000). Dams in the Chihuahuan Desert region of the lower basin include La Boquilla (1916; 2.34 MAF) and Luis L. Leon (1968; 0.29 MAF) on the Río Conchos (Mexico), and Red Bluff (1921; 0.31 MAF) on the Pecos River (Texas).

The International Boundary and Water Commission (IBWC) has operated a series of gages in the Rio Grande basin since 1880 for some locations. Figure 2 shows the annual runoff past a series of these gages (IBWC; data from http://www.ibwc.state.gov/wad/rio_grande.htm). Several features are apparent upon observation of these data. First, there exists a general decline in discharge from Elephant Butte down river to Caballo, then to El Paso, and finally to Ft. Quitman. There have been periods of no flow in the Rio Grande at and below Ft. Quitman, particularly during and after the drought of the 1950s. Second, the buffering effect of the installation of Elephant Butte dam on the discharge at El Paso is evident. Note the oscillation (higher high flows and lower low flows) evident in the early 1900s, which disappears after the construction of Elephant Butte Dam in 1916. Third, significant, yet declining, flow is provided by the Río Conchos near Presidio. Below the confluence of the two rivers, the Río Conchos provided 83% of the total downstream flow during the period 1961 to 1999, but only 55% during the period 1992 to 1999 (Brock et al., 2001). This demonstrates a considerable decline in the amount of water added to the main channel via the Río Conchos, a symptom of both Mexican water use and long-term drought. Fourth, from the mid-1990s on, the flow in both the Río Conchos and the Rio Grande has diminished to protracted low levels not seen since the drought of the 1950s. For a complete overview of the hydrology of the Rio Grande, see Schmidt, et al. (this volume).

Legislative action that governs appropriation of Rio Grande waters in the Chihuahuan Desert region begins with the 1902 (extended in 1905 to include western Texas) Reclamation Act (Littlefield, 2000). This act authorized the construction of Elephant Butte Dam and reservoir. Waters stored in the reservoir would be diverted to users through a system referred to as the Rio Grande Project. This 1905 law was the first interstate allocation of any river mandated by Congress. In 1906, an agreement was made between the U.S. and Mexico, which required that 60,000 acre-feet (AF) of water be allocated to Mexico

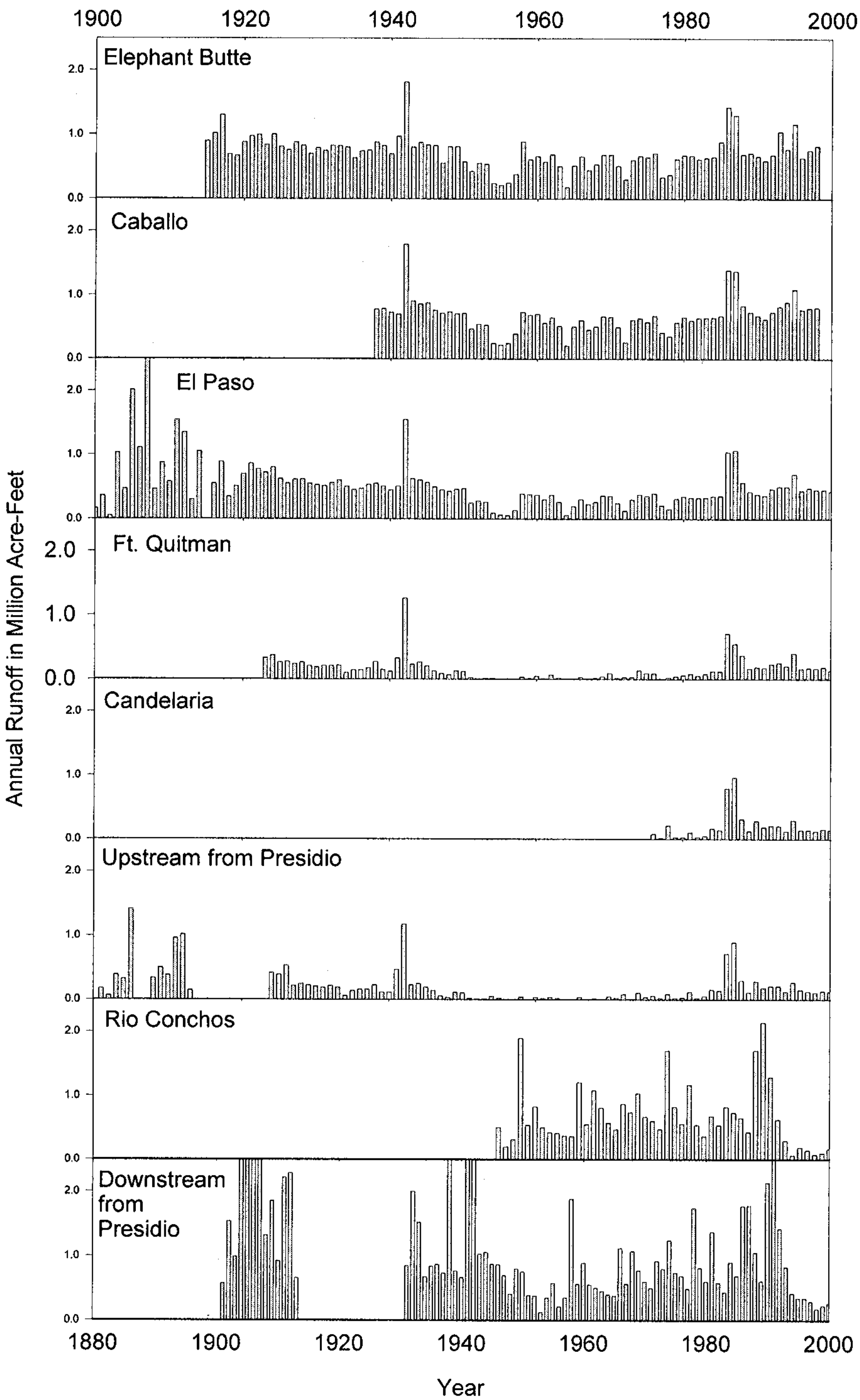


Figure 2. Annual runoff for selected sites along the Rio Grande in the northern Chihuahuan desert region (IBWC, 2002). The y-axis is fixed with a range of 0 to 2.5 MAF to aid in visual comparison between graphs. Note that for certain years the El Paso and downstream from Presidio graphs exceeded this value.

annually at a location upstream from Ciudad Juarez (Equitable distribution of waters of the Rio Grande Convention between the United States and Mexico, available at: http://www.ibwc.state.gov/FORAFFAI/1906_convention.HTM). Elephant Butte Dam was constructed in 1916, primarily for irrigation and flood control. Part of the appropriations from this project included enough water to irrigate 88,000 acres (35,600 ha) in New Mexico, and 67,000 acres (27,000 ha) in western Texas.

Appropriation of water between Colorado, New Mexico, and Texas is governed by the Rio Grande Compact of 1939 (Rio Grande Compact, reprinted in NMWRRI, 2000). This compact defines the obligations of Colorado and New Mexico to deliver water ultimately to the Elephant Butte reservoir (from there to be distributed via the Rio Grande Project). The Rio Grande Compact requires minimum discharges be maintained at a series of gauging stations along the course of the upper Rio Grande. A complex set of equations was established to determine the amount of flow to be delivered from Colorado to New Mexico, and on to Elephant Butte. Total available water was therefore variable as discharge varied, but guaranteed flow to both New Mexico and Texas. Approximately 2.5 MAF of water are available for use within the Rio Grande Compact states annually. Most of this water is used to irrigate nearly 1,000,000 acres (405,000 ha) in the upper Rio Grande basin. Approximately 600,000 acres (243,000 ha) are in the San Luis valley of Colorado; additional irrigated acreage is located in the "middle" Rio Grande valley in New Mexico. Approximately 300,000 AF/year are used in the "middle" Rio Grande valley (Wilson, 2000), while 60 to 80% of flow at the Otowi gage (near Santa Fe) must be bypassed to Elephant Butte Reservoir due to Compact restrictions. Downstream from Elephant Butte, the Rio Grande Project (agricultural irrigation) and the delivery to Mexico (1906 Treaty) consume most (or all) of the remaining flow. Only in wet years is there any expected (or actual) flow downstream from Ft. Quitman. In fact, the average flow at Ft. Quitman is 140,000 AF/year, only 5% of the total water supply in the upper Rio Grande basin. The river is completely appropriated. New Mexico is currently in compliance with the Rio Grande Compact with regards to the delivery of water to Texas. It had accrued a total of 529,000 AF deficit to Texas after an all-time low of 19,000 AF stored in Elephant Butte in 1951 (Mutz, 2000). This deficit was erased by 1972, and New Mexico has been in compliance with the Rio Grande compact since then.

There continues to be diminished flow in the Rio Grande channel downstream from Ft. Quitman until the confluence with the Río Conchos (Figure 2). At this point, the Rio Grande once again becomes a perennial stream, with most of the water provided by the Río Conchos. Figure 2 demonstrates the impact the Río Conchos has on the main Rio Grande channel. Note the significantly different character of the annual runoff curve seen in the Rio Grande downstream from the Río Conchos confluence when compared to the Rio Grande upstream from Presidio. Also apparent on this Figure is the diminished flow provided by the Río Conchos since the mid 1990s. Appropriation of the Río Conchos, and delivery of water to Texas, is governed by the 1944 Treaty between Mexico and the United States (Treaty Between the United States of America and Mexico, available at http://www.ibwc.state.gov/FORAFFAI/treaties.HTM). In summary, Mexico is entitled to two thirds of the flow reaching the main channel of the Rio Grande through a series of rivers and streams, the largest of which is the Río Conchos. This is subject to the U.S. right to an average of 350,000 AF/year in cycles of five consecutive years. According to this agreement, Mexico is currently in a deficit situation (Kelly, 2001). As of October 1997, Mexico owed the U.S. 1.024 MAF, a figure that is twice the deficit incurred by Mexico during the drought of the 1950s. An additional 0.48 MAF deficit has been added as of early 2000 (Brock et al., 2001). According to the 1944 Treaty, Mexico is obligated to repay the water debt by October 2002. There does exist some question about this, though, because a provision exists in the treaty to alter the deliveries during "extraordinary drought". The exact definition of "extraordinary drought" is not made, and the drought of the mid-1990s might qualify.

Another water source in the western Texas region is the Pecos River. In its western Texas reach, flow in the Pecos River is controlled by releases from the Red Bluff Reservoir. The delivery of water from New Mexico is the primary control on storage in the Red Bluff Reservoir. The Pecos River Program (NMSEO, 1998) allocates Pecos River water between New Mexico and Texas. In 1988, the U.S. Supreme Court determined that New Mexico had underdelivered an average of 10,000 AF/year during the period 1950 to 1983. New Mexico agreed to pay $14 million to Texas to eliminate this deficit. Today, average daily discharges along the Pecos River downstream from Red Bluff Reservoir vary from 4 to 15 cubic-feet per second (0.1 to 0.4 cubic-meters per second) (FWTRWPG, 2001).

GROUNDWATER RESOURCES

Groundwater is another major source of water for the northern Chihuahuan Desert region. Groundwater is inherently more difficult to study than surface water, particularly for estimating total resources. Aquifers are recharged by precipitation that infiltrates into the ground, by losing streams, by inflow from adjacent aquifers, and by irrigation return flow. Aquifer types in the general northern Chihuahuan Desert region include bolson type aquifers, alluvial aquifers, limestone aquifers, and igneous aquifers (Mace et al., 2001). The following discussion focuses primarily on the western Texas aquifers with information pertaining to the development of the 2002 State Water Plan for Texas. This plan will supersede the existing 1997 plan. The 2002 plan is the first to be adopted since the passage of Senate Bill 1, which has allowed for more public participation in the production of regional water plans. The portion of Texas that includes the northern Chihuahuan Desert is located in Region E of the 2002 State Water Plan (Figure 3). This region includes the counties of El Paso, Hudspeth, Culberson, Presidio, Jeff Davis, Brewster, and Terrell. Associated with the water planning and the preparation of the 2002 State Water Plan has been research and data gathering by the Texas Water Development Board (TWDB). These data are used in the following summary of the most detailed assessment of water resources in the northern Chihuahuan Desert.

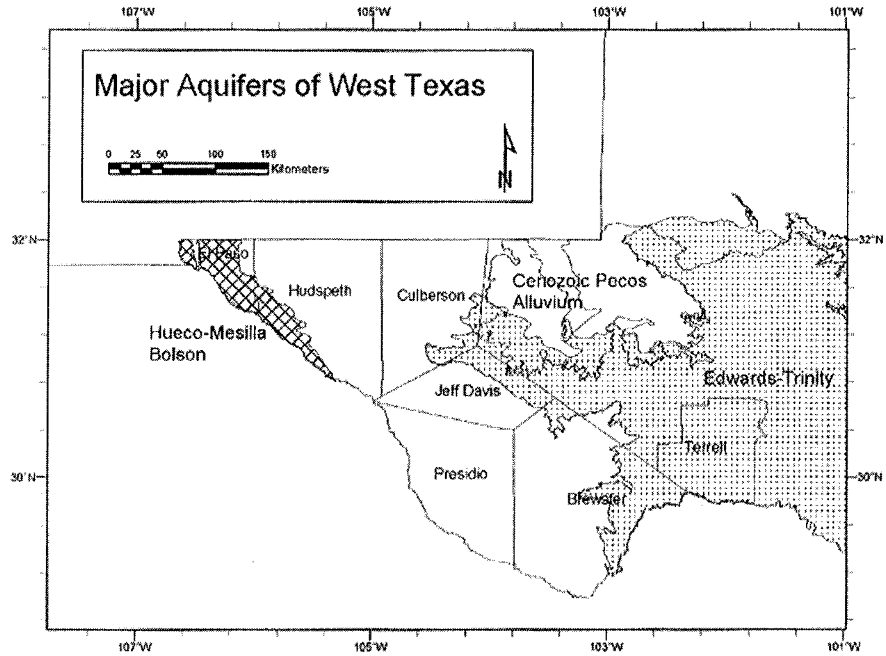
AQUIFER DETAILS

The TWDB has formally designated several aquifers in western Texas (TWDB, 1997; Figure 3). Note that in Figure 3, several of these aquifers overlap because the Figure includes both surface and subsurface spatial locations for the aquifers. These include the Hueco-Mesilla Bolson, Cenozoic Pecos Alluvium, and Edwards-Trinity (major aquifers), and the Bone-Spring Victorio Peak, Capitan Reef Complex, West Texas Bolsons, Igneous, Rustler, and Marathon (minor aquifers) (Mace et al., 2001). The Hueco-Mesilla Bolson and West Texas Bolson aquifers are located in sedimentary deposits associated with Basin and Range type extensional tectonics typical of the southwestern United States. This type of geologic activity produces linear mountain ranges separated by linear basins, which fill with sedimentary deposits as the mountain ranges rise over time. These linear basins are typically fertile sources of groundwater with recharge of water occurring primarily at the margins of the basins. Like other groundwater sources in this arid area, these aquifers are not recharged at rapid rates. The TWDB data compilation (TWDB, 1997) includes an estimate of "sustainable" water supply based upon precipitation and recharge rates for selected aquifers, and also includes an estimate of total useable (non-saline) water in storage for each of the aquifers. These figures for the Hueco-Mesilla Bolson aquifer are 0.024 MAF/year recharge, and 9 MAF storage, and 0.024 MAF/year recharge and 7 MAF storage in the West Texas Bolson aquifers. Recharge rates of 1% are estimated for the west Texas Bolson aquifers.

The Edwards-Trinity aquifer extends only partly into the Chihuahuan Desert region. This large aquifer system is located in Cretaceous limestone. It extends eastward into central Texas where it is connected to the Ogallala and the Edwards aquifers. It has approximately 145 MAF in storage, with an effective recharge rate of 0.776 MAF/yr.

The Cenozoic Pecos Alluvium aquifer is located in alluvial deposits of the Pecos River. This aquifer has an estimated recharge rate of 0.071 MAF/year, and 9.5 MAF in storage (available non-saline water). More than 200 feet (61 m) of water level declines have occurred in this aquifer in Reeves and Pecos counties. Groundwater that once contributed base flow to the Pecos River now flows in the subsurface to areas with heavy withdrawals.

The Bone Spring-Victorio Peak aquifer is located in joints, fractures, and cavities in Permian limestone beds. Recharge estimates are 0.09 MAF/year (annual recharge and irrigation return flow), and no total storage estimates are available. The Capitan Reef Complex aquifer is also located in Permian limestone, including the Capitan reef and reef talus. These limestone beds are commonly very porous (vuggy) and in extreme conditions may be cavernous (Carlsbad Caverns are located in this type of rock). Recharge estimates are 0.012 MAF/year, and total storage is estimated to be 0.385 MAF.



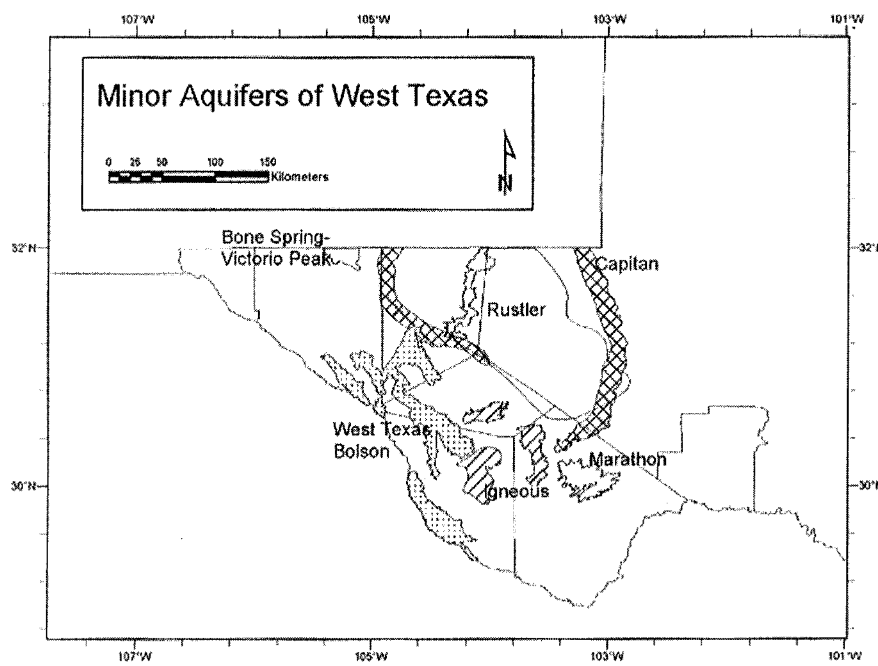


Figure 3. Major and minor aquifers of western Texas (TWDB, 2001b). The Region E counties are labeled in the top map.

The Igneous aquifers are located in Brewster, Presidio, and Jeff Davis counties. These aquifers are located in Tertiary (approximately 30 to 40 million years old) volcanic and volcaniclastic deposits, and associated recent alluvial sediments. They have estimated recharge rates of 0.014 MAF/year. The TWDB estimates total recharge rates in the aquifer system to be 2.5% of precipitation.

The Marathon aquifer is located in Paleozoic marine sediments. This aquifer has an estimated recharge of 0.018 MAF/year, and a recharge rate of 2.5% of total precipitation.

The Rustler aquifer exists in up to 500 feet (152 m) of basinal limestone, dolomite, and evaporites representing the demise (drying up) of the Permian reef basin. The evaporite beds formed as the inland bay was cut-off from seawater circulation with the open ocean. Estimated recharge rates are 0.004 MAF/year. Water in this aquifer is not suitable for human consumption due to the high total dissolved solids (up to 6,000 mg/L).

SOCIAL IMPACTS AND SUPPLY VS. DEMAND PREDICTIONS

The population of Texas is expected to double in the next 50 years, from 21 million in 2000, to 40 million in 2050 (TWDB, 2001a). The Region E population is expected to increase from 800,000 to 1,587,097. The project population for El Paso county alone is 1,536,423, a 99% increase over the year 2000 census. By the year 2050, 38 percent of Texas' population will need to reduce demand or develop addition resources to meet projected demands during drought conditions (TWDB, 2001a). Agriculture, which is currently the largest water user in the state, will be surpassed by the combination of municipal and manufacturing demand. Impacts of this on western Texas include decreased irrigation due to depletion of groundwater resources and increase of groundwater use by urban centers such as El Paso. The TWDB recommends that the state Legislature establish protection of rural-community access to local water resources. They also recommend the use of groundwater models to evaluate the long-term sustainable levels of groundwater aquifers. Water demand in Texas is projected to increase from the current 17 MAF per year to 20 MAF in the year 2050. Region E demand is expected to increase from 0.509 to 0.586 MAF/year. Municipal demand is expected to increase by 67%, while irrigation demand is expected to decrease 12%. This decline will be due to more efficient irrigation systems and canal delivery systems, declining groundwater supplies, and the transfer of groundwater rights to municipal use as population increases. Current per capita water use throughout the state is 181 gallons/person/day (gpd), with a range of 275 gpd in Richardson and a low of 120 in Killeen (El Paso ranks near the bottom, using 144 gpd). Conservation efforts are expected to reduce the average per capita use to 159 gpd by 2050.

Total water supply projections (surface and ground, from existing sources) indicate an expected decrease of 18%, from 17.8 MAF/year in 2000 to 14.5 MAF/year in 2050 (TWDB, 2001b). Total groundwater *availability* is estimated by the Regional Planning groups to be 14.9 MAF/year. Total groundwater supplies (water accessible with existing infrastructure) are estimated to be 8.8 MAF/year in 2000, and are projected to decline 18% by 2050. Note that these "supply" estimates include the water available with existing infrastructure, and differ from the recharge and total storage estimates listed in the aquifer descriptions above. Statewide, groundwater constituted 50% of the total water supply in 2000 and is projected to provide the same in 2050. In Region E, groundwater constituted 79% of the total water supply in 2000, and is projected to supply 88% by the year 2050. These estimates again pertain to existing sources, and are skewed by the anticipated depletion of the usable portion of the Hueco-Mesilla bolson aquifer by the year 2030. The depletion of this major aquifer will create a critical need to find other sources to meet the projected growing demands for water. El Paso will clearly be unable to meet water demands by 2030 considering the existing supply. The Region E planning group recommends the following strategies to increase supply: 1) obtain additional surface water from conservation savings in irrigation; 2) purchase irrigation rights; 3) reuse; 4) desalinate; 5) purchase and use groundwater from outside of El Paso County. The impacts of groundwater transfers from rural counties will become a critical issue.

RELATED INFORMATION FROM NORTHERN MEXICO

Only about one quarter of 60 aquifers in Chihuahua have been studied in any detail (Kelly, 2001), and most water level measurements were suspended in 1990. The Mexican National Water Commission (Comision Nacional de Aguas (CNA)) has identified several over-exploited aquifers which are listed in Table 1. Currently, only 1% of the wells have any type of metering (CNA, 1997).

Table 1. Major over-exploited aquifers in the Río Conchos basin (data from CNA, 1997).

Aquifer	Total Annual Pumping (MAF)	Total Annual Recharge (MAF)	% Over-Exploitation
Chihuahua-Sacremento	0.102	0.045	127%
Jimenez-Camargo	0.475	0.361	88%
Parral-Valle de Verano	0.026	0.021	21%
Tabaloapa-Aldama	0.054	0.045	19%

LONG-TERM PROGNOSIS

The long-term prognosis for the west Texas and northern Chihuahuan Desert region is difficult to determine. The projected population growth and anticipated depletion of groundwater reservoirs are critical water resource issues that need careful attention. Anthropogenic manipulation of surface and groundwater sources has and will further impact the ability of the water sources to sustain wildlife populations. This issue is compounded by the fact that we are in a significant drought. It is clear that we are using several of the groundwater sources at levels that are not sustainable. This has led policy makers to develop strategies to try to increase future municipal water supply. Some strategies proposed in west Texas, such as converting irrigation appropriations to municipal supply or increasing the amount of "reused" water, will not likely diminish the amount of available surface water for support of wildlife. However, desalination and interbasin transfer of groundwater could impact local surface water resources. Sharp et al. (this volume) suggest that there are prolonged groundwater flow paths from locations such as the Wild Horse basin aquifer near Van Horn that likely feed spring systems such as San Salomon at Balmorhea. The export of water from the Wild Horse basin aquifer could, therefore, impact flow rates from these springs. Detailed studies such as these should be done to evaluate the impact of interbasin transfers of groundwater.

Careful attention must be given to compliance with respect to legislation and treaties governing deliveries of surface water between states and countries. It is important that we recognize how the effects of the current drought impacts Mexico's ability to deliver water via the Río Conchos. That deficit is definitely not the only surface water supply problem in west Texas. The over appropriation of the Rio Grande is at fault, also. There are no easy solutions to any of our water resource issues.

CONCLUSION

The information presented in this paper is representative of the water supply issues in the arid northern Chihuahuan Desert. Surface water resources are very limited, and are appropriated to the point of severe damage to natural ecosystems such as the Rio Grande. Many argue that we can adhere to legislation such as the Rio Grande Compact without the ecological destruction that currently occurs, and will likely occur in the future (Harris, 2000). As population increases in this region, there will be a continuous shift to more dependence on groundwater rather than surface water to meet the growing demand. A necessary consideration will be the sustainable limits to groundwater withdrawals that will not completely mine these limited resources and will allow for the presence of both humans and wildlife.

LITERATURE CITED

Brock, L., Kelly, M.E., and Chapman, K. 2001. Legal and institutional framework for restoring instream flows in the Rio Grande: Fort Quitman to Amistad. Texas Center for Policy Studies, document presented to the World Wildlife Fund, http://www.texascenter.org/publications/instreamflow.pdf (10/22/01).

CNA (Comision Nacional del Agua). 1997. Programa hydraulico de gran vision, Estado de Chihuahua (1996-2020). Comision Nacional del Agua, http://www.sequia.edu.mx/plan-hidra/ (10/22/01).

FWTRWPG (Far West Texas Regional Water Planning Group). 2001. Executive Summary, Region E Far West Texas Regional Water Plan. http://www.twdb.state.tx.us/assistance/rwpg/main-docs/regional-plans-index.htm (10/22/01).

Harris, S. 2000. Opportunities and constraints for environmental enhancement and recreation along the Rio Grande. The Rio Grande Compact: It's the Law. Proceedings of the 44th Annual New Mexico Water Conference, New Mexico Water Resources Research Institute, WRRI Report #312, December 2-3, 1999, Santa Fe, New Mexico, 5 pp.

IBWC (International Boundary and Water Commission). 2002. Historical Rio Grande flow conditions. http://www.ibwc.state.gov/wad /histflo1.htm (05/10/02).

Kelly, M. E. 2001. The Río Conchos: A preliminary overview. Texas Center for Policy Studies, Austin, Texas, 27 pp.

Littlefield, D.R. 2000. The history of the Rio Grande Compact of 1938. The Rio Grande Compact: It's the Law. Proceedings of the 44th Annual New Mexico Water Conference, New Mexico Water Resources Research Institute, WRRI Report #312, December 2-3, 1999, Santa Fe, New Mexico, 8 pp.

Mace, R. E., W. F. Mullican III, and E. S. Angle (editors). 2001. Aquifers of West Texas. Report 356. Texas Water Development Board, Austin, Texas, 272 pp.

Mutz, P. 2000. Post Compact delivery of water by New Mexico. The Rio Grande Compact: It's the Law. Proceedings of the 44th Annual New Mexico Water Conference, New Mexico Water Resources Research Institute, WRRI Report #312, December 2-3, 1999, Santa Fe, New Mexico, 4 pp. http://wrri.nmsu.edu/publish/watcon/proc/proc44/contents.html (10/22/01).

NMSEO (New Mexico State Engineers Office). 1998. Office of the State Engineer, Interstate Stream Commission, 1997-1998 Annual Report, http://www.seo.state.nm.us/publications/97-98-annual-report/index.htm (10/22/01).

NMWRRI (New Mexico Water Resources Research Institute). 2000. Reprint of the Rio Grande Compact The Rio Grande Compact: It's the Law. Proceedings of the 44th Annual New Mexico Water Conference, New Mexico Water Resources Research Institute, WRRI Report #312, December 2-3, 1999, Santa Fe, New Mexico, 12 pp.

TWDB (Texas Water Development Board). 1997. Water for Texas: A consensus based update to the State Water Plan; Volume II Technical Planning Appendix, Texas Water Development Board, Document # GP-6-2 .

TWDB (Texas Water Development Board). 2001a. Draft, State Water Plan, Water for Texas 2002, draft version available for public comment at http://www.twdb.state.tx.us (10/22/01).

TWDB (Texas Water Development Board). 2001b. Major and minor aquifers of Texas, http://www.twdb.state.tx.us/gis_data /aquifers/ (05/10/02).

Wilson, L. 2000. Surface water hydrology of the Rio Grande Basin. The Rio Grande Compact: It's the Law. Proceedings of the 44th Annual New Mexico Water Conference, New Mexico Water Resources Research Institute, WRRI Report #312, December 2-3, 1999, Santa Fe, New Mexico, 12 pp.

Wurbs, R.A., Sanchez-Torres, G., and Dunn, D.D. 1994. Reservoir/river system reliability considering water rights and water quality. Technical Report No. 165, Texas Water Resources Institute, Austin, Texas.

Address of author:

KEVIN URBANCZYK

Department of Earth and Physical Sciences
Sul Ross State University
Alpine, TX 79832
e-mail address: kevinu@sulross.edu