THE RÍO CONCHOS:

A PRELIMINARY OVERVIEW

Prepared by: **Mary E. Kelly, Director**

JANUARY 2001

TEXAS CENTER FOR POLICY STUDIES

44 East Avenue, Suite 306 • Austin Texas 78701
512.474.0811 phone • 512.474.7846 fax
tcps@texascenter.org • www.texascenter.org

TABLE OF CONTENTS

The Río Conchos Basin: High Sierra to Desert Valley 4

Water Availability: Reservoirs, Aquifers and Drought 7

Water Quality 11

A Changing Economic Base 12

Current and Future Demand for Water 15

Will Any Water be Left for the Environment? 20

Legal and Institutional Framework for Water Management in Mexico 21

Transboundary Implications 23

Next Steps 26

Bibliography 27

Credits and Acknowledgements

This report was prepared by Mary E. Kelly, the director of the Texas Center for Policy Studies, with assistance from TCPS staff, including Cyrus Reed and Alicia Isaac-cura. Design and layout was provided by Marla Camp, Impact Productions, Austin, Texas.

The Texas Center for Policy Studies is grateful for the support of the C.S. Mott Foundation and the William and Flora Hewlett Foundation, which made research and preparation of this report possible. The views expressed herein, however, are solely those of the author.

Cover photo: Karen Chapman

Where the river [Río Bravo] reappeared, it was brought back to life by the never-failing, full and clear green water of the Río Conchos out of México.

Paul Horgan, Great River: The Río Grande in North American History

The Río Conchos basin is one of the most important river systems in all of northern Mexico. From its headwaters high in the Sierra Madre Occidental, to its banks bordered by large irrigation districts in the central plains of Chihuahua, to its confluence with the Río Bravo (Río Grande) just above Big Bend National Park, the Conchos is an essential ribbon of life in an arid desert climate.

For centuries, flow from the Conchos has replenished the Río Bravo, ultimately reaching the Gulf of Mexico. Early Native Americans lived and migrated along the river. In the 17th century Spanish explorers followed the Conchos north to the junction with the Río Bravo before moving into the lands that eventually became New Mexico and Texas.

Today, the Río Conchos supplies burgeoning municipal, industrial and agricultural water needs in Chihuahua. Once the waters from the Conchos join the Río Bravo, they are used to meet the same type of water demands in Texas and the more eastern Mexico border states of Coahuila, Nuevo Leon and Tamaulipas.

The very aspects that make the Conchos so vital—a large transboundary river in an arid region facing high growth—also present vexing water management challenges. Yet, for all its importance to both Mexico and Texas, much remains to be understood about this large basin. As Paul Horgan has written of the Río Bravo itself, "the river had to be discovered over and over again."

The very aspects that make the Conchos so vital—a large transboundary river in an arid region facing high growth—also present vexing water management challenges.

The impetus for better understanding of the Conchos basin is growing every day. A prolonged drought in northeastern Mexico has reduced stream flows and reservoir storage levels and forced more reliance on already over-taxed groundwater aquifers in the basin. Mexico now finds itself "owing" a large amount of water to the U.S. under the 1944 water treaty that governs the binational allocation of the Río Bravo and its tributaries. Texas farmers' claims that Mexico has violated the treaty have garnered the attention of diplomats in Washington, D.C. and Mexico City.

At the same time, there is increased pressure on the Conchos. Agricultural irrigation accounts for 90% of water use in the basin. Population growth and industrialization, both of which are linked to the integration of the U.S. and Mexican economies and to NAFTA, are resulting in increased municipal and industrial water demand, and those

Agricultural irrigation accounts for 90% of water use in the basin.

demands are expected to escalate over the next few decades. But concern about preserving environmental values in the Conchos basin is also growing. One example is the efforts of indigenous Tarahumara ejidos located in the Sierra Madre to stop forestry practices that are damaging the Conchos headwater streams. Another example is the World Wildlife Fund's Chihuahua Desert Ecoregion Project and its emphasis on the unique freshwater aquatic ecosystems supported by instream and spring flows.

Government agencies have also recently begun to sharpen their focus on the challenges facing the Conchos. They are starting to gather and make available more information on how much water is in the streams and aquifers of the basin, how it is currently used and how water demand patterns may change in the future.[1] Water users in the Lower Río Bravo region of Texas are beginning to more directly acknowledge their dependence on flows from the Conchos and to consider this factor in long-term water management planning. Despite this progress, however, there are still large gaps in understanding the Conchos basin and in planning for more sustainable management of its water resources.

This brief overview paper examines what type of information is now available about the Conchos and identifies gaps in information. It also explores the relevant legal and institutional framework for water resources management. This preliminary overview is a prelude to a more detailed assessment of the Conchos basin that will be conducted by the Texas Center for Policy Studies, in partnership with Mexican organizations, beginning in 2001.

THE RIO CONCHOS BASIN: HIGH SIERRA TO DESERT VALLEY

The Conchos basin covers about 64,000 km^2 (26,400 square miles). It accounts for roughly 14 % of the total area of the Río Bravo basin. The two sub-basins contributing most of the Río Conchos flow are both born high in the pine and oak forests of the Sierra Madre Occidental. The Río Florido's headwaters are found on the Sierra's highest peak—Mohinora—located in the state of Durango, which lies on Chihuahua's southern border. Before it reaches the Conchos, the Florido flows into the Presa San Gabriel, a reservoir that provides water for the Río Florido irrigation district in southern Chihuahua. Further downstream, the Florido, joined by the Río Parral, reaches the smaller Pico de Aguila

1 In fact, much of the information in this paper comes from the Program Hidraulico de Gran Vision, Estado de Chihuahua (1996-2000) (Water Plan for the State of Chihuahua). This plan, which was recently made public, was developed in 1997 by Mexico's National Water Commission (Comisión Nacional de Aguas or CNA) in 1997.

reservoir, which is used for irrigation in the Camargo-Jimenez area.

To the northwest, in the Sierra Tarahumara near the town of San Juanito, lie the headwaters of the Río Sisoguichi (this branch is often itself referred to as the Río Conchos headwaters). From an elevation of about 2200m (7200 ft) in an area with about 600 mm/yr (23.6 in/yr) average rainfall, the river drops out of the Sierra into a high mesa region. After being joined by the Nonoava and Balleza rivers and other tributaries, it

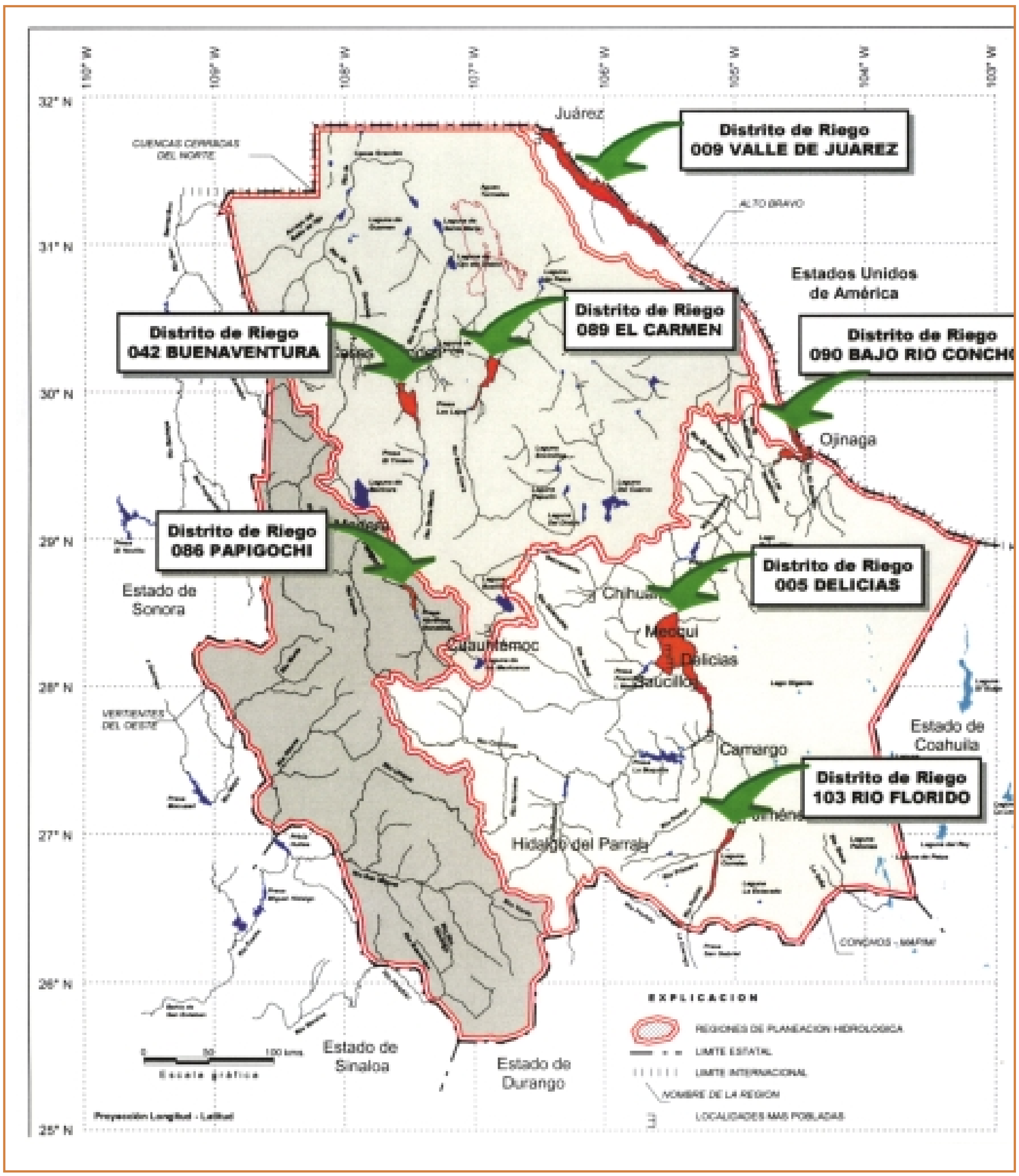


FIGURE 1. CHIHUAHUA HYDROLOGICAL AREAS, INCLUDING RIO CONCHOS BASIN

(Source: CNA, Programa Hidraulico)

flows into La Boquilla reservoir (also known as Lake Toronto). Begun during the Mexican revolution of 1910, La Boquilla is Chihuahua's largest reservoir. In tandem with the Colina impoundment about 6 km downstream, it is used to generate hydropower and meet irrigation demands.

Near Chihuahua's largest irrigation district, named for the nearby city of Delicias, this sub-basin joins with the Florido waters to form the mainstem of the Río Conchos. Here, in addition to using water to grow maize, alfalfa and winter wheat, farmers flood-irrigate pecan orchards. A little further downstream, the San Pedro river enters from the west, where its upstream flows have been stored in the Francisco Madero reservoir. Completed in 1949, this reservoir is used for sediment control and to supply irrigation water in the San Pedro sub-basin.

After the Conchos turns north toward the U.S. border, it is joined by the smaller Río Chuvíscar. The Chuvíscar, which originates at about 2300 m (7500 ft) in The Serrania de Mesa Montosa, supplies part of the City of Chihuahua's municipal water needs, as well as irrigation water in the Aldama area. There is one relatively small water supply and flood control reservoir on the Chuvíscar, called Presa Chihuahua.

The river continues its northerly flow through an increasingly arid desert valley, ultimately flowing into the Luis L. León reservoir. This is the last major reservoir upstream of the Conchos' confluence with the Río Bravo, and its waters are used for irrigation of pasture, alfalfa and cotton crops, primarily in the Bajo Río Conchos irrigation district. Fed by a number of smaller, intermittent tributaries, the Conchos finally reaches the Río Bravo near Ojinaga, just upstream of Big Bend Park on the U.S. side of the border.

A number of important aquifers are found in the Conchos basin. Groundwater from these formations is used to supply municipal, irri-

TABLE 1. MAJOR CITIES IN THE RIO CONCHOS BASIN

LOCALITY	1995 POPULATION	2000 POPULATION	ESTIMATED 2020 POPULATION	% CHANGE (2000-2020)
Chihuahua	609,059	677,852	957,347	41
Hidalgo de Parral	95,913	103,285	136,048	32
Delicias	93,447	99,137	124,996	26
Camargo	37,572	39,189	47,881	22
Jiménez	30,992	32,966	42,121	28
Meoqui	25,066	27,288	34,838	28
Ojinaga	18,063	18,342	20,353	11
Saucillo	15,454	15,679	17,917	14

Source: CNA, Programa Hidraulico.

gation and industrial water needs, but is also the source of spring flow and base stream flow in some areas. Major aquifers include those found near Hidalgo-Parral, Camargo-Jimenez, Delicias and Cd. Chihuahua.

Mexico's National Water Commission (Comisión Nacional de Aguas or CNA) has concluded that there are few, if any, options for building new reservoirs in the Conchos basin.

WATER AVAILABILITY: RESERVOIRS, AQUIFERS AND DROUGHT

Water resources development in the Conchos basin has been concentrated along two lines:

- development of large reservoirs, primarily to provide a reliable supply of water for irrigation, but also for flood and sediment control; and
- development of extensive well fields to pump groundwater for municipal and industrial needs and for irrigation.

In addition to the major reservoirs shown in Table 2, there are several small dams on various tributaries. These are designed primarily to meet localized municipal and agricultural needs.

Mexico's National Water Commission (Comisión Nacional de Aguas or CNA) has concluded that there are few, if any, options for building new reservoirs in the Conchos basin. There has, however, apparently been discussion of increasing the height of the dam at La Boquilla to increase the storage capacity of that reservoir.

In the last few years the amount of water entering the Conchos reservoirs has been severely reduced by the effects of a persistent drought, and the reservoirs have reached some of the lowest levels since the

TABLE 2. MAJOR RESERVOIRS IN THE RIO CONCHOS BASIN

RIVER	RESERVOIR	YEAR COMPLETED	STORAGE CAPACITY MM³ (MAF)	USES
Florido	San Gabriel	1981	255 (0.21)	Irrigation
Florido	Pico de Aguila	1993	50 (0.045)	Irrigation
Conchos	La Boquilla	1916	2903 (2.34)	Irrigation, hydroelectricity
Conchos	La Colina	1927	24 (0.195)	Irrigation, hydroelectricity
San Pedro	F. Madero	1949	348 (0.28)	Irrigation, sediment control
Chuvíscar	Chihuahua	1960	26 (0.021)	Municipal, irrigation, flood control
Conchos	Luis L. León	1968	337 (0.29)	Irrigation, flood control

Source: CNA, Programa Hidraulico; Mm³ = million cubic meters; MAF = million acre feet. Storage capacity in some reservoirs has been reduced by sedimentation.

dams were constructed. For example, the average annual amount of water entering the La Boquilla reservoir in the period 1935-1992 was 1,272 million cubic meters (Mm^3) (1.043 million acre feet-MAF); during the drought period of 1993 to 1999, it was 853 Mm^3 (0.699 MAF).

The drought was particularly hard on many indigenous communities in the high Sierras, affecting their maize and bean harvests severely. Also, as discussed below, the drought had major adverse effects on ranching and dryland farming throughout the basin.

Even irrigated agriculture has not been immune to the drought. Some researchers, such as Diana Liverman at the University of Arizona, have noted that construction of large reservoirs in arid regions can actually increase long-term social vulnerability to drought because the reservoirs allow a level of irrigation and population that might not otherwise be possible. Mirroring these predictions, recent data from CNA show that irrigation in the major Conchos irrigation districts was reduced during the 1994 to 1999 drought period.

TABLE 3. EFFECT OF DROUGHT ON IRRIGATION DISTRICTS IN THE CONCHOS BASIN

Irrigation District	Average Annual Historical Use Mm^3 (MAF)	Average Annual Use 1994-1999 Mm^3 (MAF)	% of Average Historical Use
Río Florido (103)	94 (0.077)	80 (0.066)	85
Delicias (005)	1,137 (0.932)	663 (0.54)	58
Bajo Río Conchos (090)	102 (0.084)	89 (0.073)	87

Source: CNA, 2000, Anexo 38. Note 1: According to CNA figures, the Delicias district used only 135 Mm^3 in 1995 and 317 Mm^3 in 1996. Note 2: It is not clear whether these figures include supplemental groundwater pumping, especially in the Delicias district, which has historically relied on both groundwater and surface water.

As discussed in more detail below, Texas farmers are alleging that under the 1944 Treaty governing binational allocation of the Río Bravo and its tributaries, Mexico should have been using the reservoir system on the Conchos to release more water to the Río Bravo, even during the drought period. Mexico disagrees with this position and points out that the Treaty does not prevent it from operating the reservoirs to first meet water demands within the basin.

The reduced flows from the Conchos have also hurt Mexican irrigation districts in the Lower Río Bravo, however. For example, during 1994-1999, Irrigation District 025 in Tamaulipas, which is supplied by the Río Bravo, used only about 65% of its historical average. Thus, decisions made about Conchos releases affect not only U.S. irrigation but also affect downstream Mexican irrigation, particularly in Tamaulipas. These difficult decisions are essentially made, at least initially, by CNA.

The development of large well fields has resulted in the over-exploitation of several important aquifers in the Conchos basin, as shown in Figure 2.

According to CNA, only about one quarter of Chihuahua's 60 principal aquifers have been studied in much detail, and even these studies generally lack sufficient detail on current pumping or recharge rates.

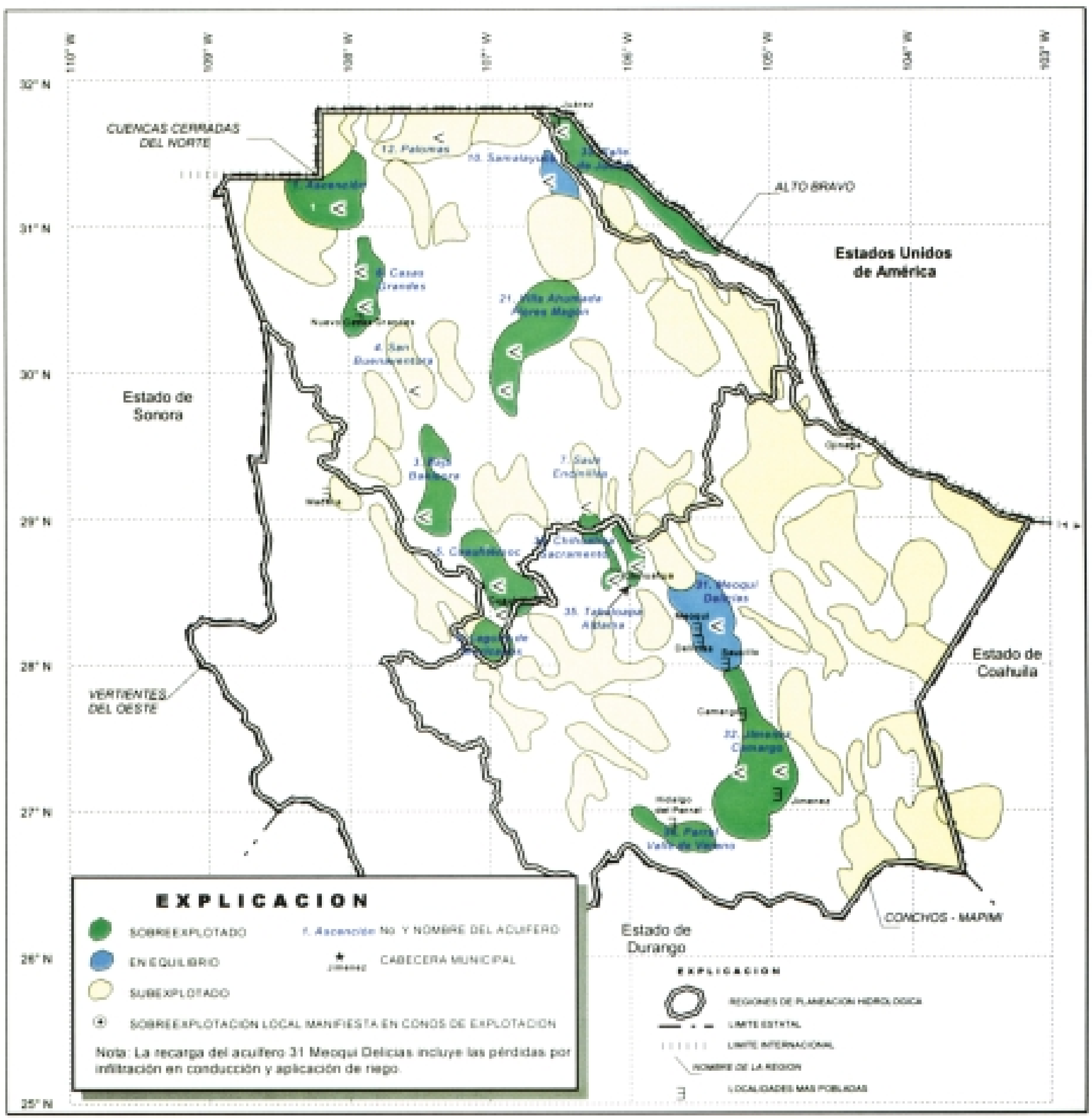


FIGURE 2. OVER-EXPLOITED AQUIFERS
(Source: CNA, Programa Hidraulico)

Only about one quarter of Chihuahua's 60 principal aquifers have been studied in much detail, and even these studies generally lack sufficient detail on current pumping or recharge rates.

Many of the studies looked at the aquifer at one point in time—most before 1986—and there has been little follow-up since then. Most piezometric (water level) measurements were suspended in 1990. Only about 1% of the groundwater wells have meters, undercutting the reliability of pumping estimates.

Using the limited available data, however, CNA has identified several aquifers that are considered "over-exploited" (annual pumping exceeds annual recharge). These aquifers are shown in Table 4. In the Chihuahua-Sacramento, Parral Valle de Verano and Tabaloapa-Aldama aquifers, pumping for industrial and municipal uses is "on the same order of magnitude" as pumping for agricultural uses, according to CNA. In the Jiménez-Camargo aquifer, pumping for agricultural use dominates.

The federal government has issued decrees designed to limit pumping in these aquifers, declaring them "zonas de veda" or "prohibition zones". Some of these decrees were adopted in the 1950s and 1960s. CNA reports, however, that the specific norms and regulations setting pumping limits in these zones have not yet been adopted.

Pumping from the groundwater aquifers may also have reduced spring flow, though CNA notes that there is a general lack of information about groundwater/surface water interaction in Chihuahua.

Aquifer recharge can also be reduced by persistent drought such as the one plaguing Chihuahua for the last several years. Moreover, groundwater pumping may increase during drought as water users attempt to make up for reduced surface water supplies. As noted by CNA, however, the detailed aquifer studies necessary to estimate the effect of drought on aquifer levels in the Conchos basin are lacking.

TABLE 4. MAJOR OVER-EXPLOITED AQUIFERS IN THE CONCHOS BASIN

AQUIFER	TOTAL ANNUAL PUMPING Mm^3 (MAF)	TOTAL ANNUAL RECHARGE Mm^3 (MAF)	% OVER-EXPLOITATION (pumping in excess of recharge)
Chihuahua-Sacramento	125 (0.102)	55 (0.045)	127
Jiménez -Camargo	580 (0.475)	440 (0.361)	88
Parral-Valle de Verano	32 (0.026)	26 (0.021)	21
Tabaloapa-Aldama	66 (0.054)	55 (0.045)	19

Source: CNA, Programa Hidraulico.

WATER QUALITY

Maintaining good water quality is especially important in water-scarce regions like Chihuahua. Unfortunately, comprehensive data on the quality of surface water and groundwater in the Conchos basin are lacking. For example, there is only one water quality monitoring station on the entire Río Florido, located just above the confluence with the Conchos. There are only four water quality monitoring stations on the mainstem of the Conchos itself. Nevertheless, there are signs of serious water quality degradation in some areas of the basin.

For example, according to CNA:

> *Chihuahua's most important river, the Conchos, has been converted into the biggest collection system for contaminated agricultural and municipal waste-water. The aquifers most used to supply potable water demand are threatened by municipal contamination, industrial discharges and agricultural activities.*

CNA recognizes that a principal problem is lack of data—on ambient water quality and on sources of contamination such as pesticides, fertilizers, industrial discharges and agricultural return flows. Another issue is lack of municipal wastewater treatment: of the major cities in the Conchos basin, only Chihuahua and (very recently) Ojinaga have treatment plants, and most of the rural communities lack even basic sewage collection and disinfection facilities.

WATER QUALITY MONITORING

The one monitoring station on the Río Florido shows that part of the river to be "contaminated to severely contaminated." It is not suitable for domestic or recreational use and cannot be used for irrigation of food crops. Available data indicate the most serious problem is fecal coliform contamination from municipal waste discharges, primarily from Cd. Jiménez and Cd. Camargo. The Florido is also contaminated with high levels of oil and grease from a chemical plant in Camargo, by discharges from a fertilizer plant and by agricultural return flows from the Río Florido Irrigation District. According to CNA, the Florido is an intermittent river that sometimes has all of its flow made up of industrial and municipal wastewater discharges.

Source: CNA, Programa Hidraulico.

CNA reports that nutrient pollution, primarily from fertilizer use, is a problem in the Conchos, especially downstream of the Delicias irrigation district. Over-fertilization, combined with irrigation, has led to soil salination problems, with 10% of the Delicias district and 20% of the Bajo Río Conchos district considered unusable.

High arsenic levels in groundwater is a problem in parts of the Meoquí-Jiménez aquifers, with some wells exceeding permissible levels for arsenic in drinking water. CNA indicates that this water is mixed with other water to reduce the arsenic concentrations to "non-toxic" levels. Some wells in the Tabaloaja-Aldama and Jiménez-Camargo aquifers have shown the presence of heavy metals.

A CHANGING ECONOMIC BASE

The economic base of an area often determines how much water is used, where it used and what is left in the streams and aquifers. The economy of the Conchos basin, like that of much of the rest of Chihuahua, has been linked closely to agriculture, mining and forestry activities, but that is changing. The manufacturing, construction, transportation and services industries have all had substantial positive growth rates in the state during in the 1990s, while agriculture and mining have had negative growth rates.

Agriculture is still important throughout the Conchos basin, however, especially in those areas with large irrigation districts (Hidalgo de Parral, Camargo-Jiménez, Delicias and the lower Río Conchos). The irrigation districts in the Conchos basin produce a variety of crops, including maize, winter wheat, alfalfa, cottons, pecans and various vegetables and fruits. (Table 5). Irrigated crops are also produced in "Unidades de Riego" (Irrigation Units), many of which rely largely on groundwater.

According to CNA, the irrigation districts account for about 43% of the total irrigated acreage in the Conchos basin, with the rest in Unidades de Riego. This is greater than the statewide average, where districts

TABLE 5. IRRIGATED AGRICULTURE IN THE CONCHOS BASIN

Irrigation District	Principal Crops
Río Florido (103)	Maize, winter wheat, alfalfa, pecans, oats
Delicias (005)	Maize, alfalfa, pecans, peanuts, sorghum, soybeans, chiles, winter wheat
Bajo Río Conchos (090)	Pasture, cotton, alfalfa, maize, nuts, melons, winter wheat

Source: CNA, Programa Hidraulico and Kelly & Contreras, 1998.

TABLE 6. TRENDS IN ACRES PLANTED IN IRRIGATION DISTRICTS IN THE CONCHOS BASIN (1988-1995+)

DISTRICT	88-89	89-90	90-91	91-92	92-93	93-94	94-95*
Río Florido							
Total hectares planted	6041	7211	8132	7269	6901	8331	2118
Total Water used Mm^3	141.5	136	150	130	167	151	36.2
Ha alfalfa	1224	1439	1503	1072	1047	963	505
Ha pecans	178	209	171	246	413	421	324
Ha maize++	2255	2212	3180	4456	3644#	4767	798#
Delicias**							
Total Hectares planted	89,005	83,370	96,355	82,904	82,508	79,796	11,187
Total Water used Mm^3	1451	1307	1265	1437	1724	1390	134
Ha alfalfa	10,701	11,914	12,059	12,556	12,323	11,486	6,439
Ha pecans	3872	4057	4057	3651	4054	4111	537
Ha maize++	7491	7302	9980	15766	23851	19531	724
Bajo Río Conchos							
Total Hectares planted	6762	6802	5410	3306	4374	4444	5513
Total Water used Mm^3	95.7	100	118	80	142	109	145
Ha alfalfa	356	875	569	410	511	768	1092
Ha maize++	374	440	412	578	407	379	111
Ha cotton	1207	1360	2017	234	10	443	1160

Source: CNA, Programa Hidraulico
+ Data past 1995 not readily available.
** Districts greatly reduced area planted in 1994-1995 cycle due to drought.*
*** Down from about 120,000 to 129,000 hectares planted in 1985 to 1987 period.*
++ Two crop cycles.
 # No crop planted in second cycle.

account for about 32% of irrigated acreage. The irrigation districts in the Conchos basin account for about 57% of the irrigation water use. Table 6 shows acreage planted and water used in the three major districts in the Conchos basin.

Nevertheless, several factors have recently combined to hurt the agricultural sector. These include the 1994 devaluation of the Mexican peso and the consequent credit squeeze faced by most farmers; competition from U.S. products; inefficient production methods; and the persistent drought that has affected Chihuahua for the last several years. Dryland farming and livestock raising have been hit much harder than irrigated agriculture by these factors, but the drought has also resulted in less acreage being irrigated and less production.

For example, the data in Table 6 show some general trends of expanding irrigation in the early 90s, especially for alfalfa and maize in

The presence of industry is also attracting thousands of new residents to the cities with the promise of jobs, putting great pressure on municipal water and wastewater systems.

the Delicias district and pecans in the Río Florido district, but irrigated acreage dropped sharply as the drought took hold in 1994 and 1995.[2] In the Bajo Río Conchos, however, the irrigated acreage of cotton and alfalfa actually increased during the 1993-1995 cycles.

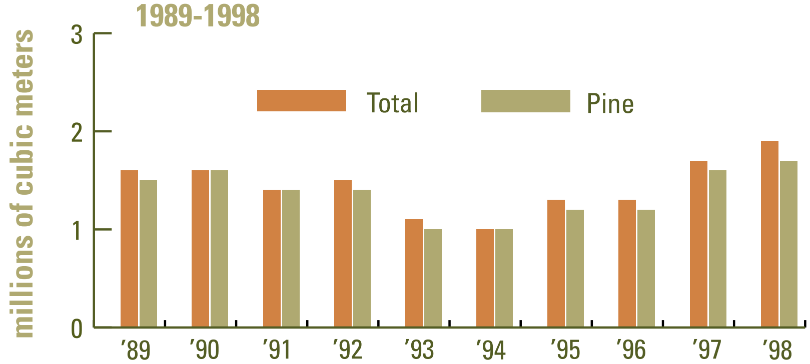
Livestock raising, primarily on natural pasture, was estimated to take place on 13.6 million hectares (36.6 million acres) in Chihuahua in 1995, or about 56% of Chihuahua's total land area. The drought, however, has resulted in a substantial reduction in Chihuahua's cattle herds over the last few years.

Mining, too, has declined in relative economic importance in recent years, though it still takes place in various areas of the Conchos basin, including the municipalities of Parral, Santa Bárbara, San Francisco del Oro and Aquiles Serdan (25 km east of Cd. Chihuahua).

Forest production declined in the mid-1990s, due largely to the peso crisis, weak domestic demand for wood and wood products and inefficient forestry production methods. Since 1995, however, forest harvesting and production of paper and other wood products in Chihuahua has increased (Figure 3). There is concern among indigenous leaders and support groups, such as the Comisión de Solidaridad y Defensa de Derechos Humanos, A.C. and the Sierra Madre Alliance, that increased unsustainable forestry harvesting in the Sierra Tarahumara could increase sediment erosion and adversely affect water flows and water quality in some Conchos headwater streams.

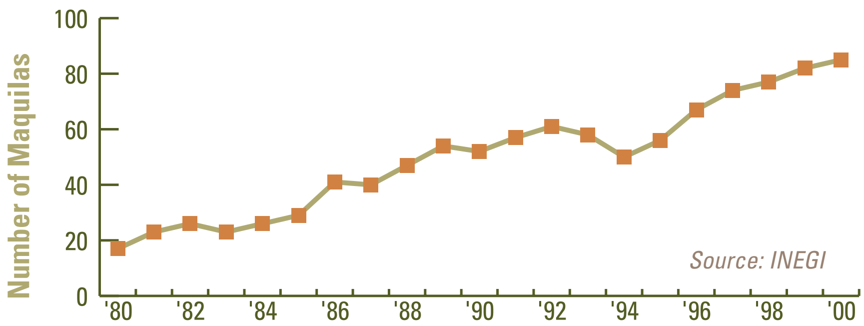
Industrial production, particularly in the automotive and assembly (maquiladora) sectors has become an increasingly important part of Chihuahua's economy. In the Conchos basin, industrial production is concentrated in Cd. Chihuahua, Camargo-Jiménez and Ojinaga. Figure 4 shows that the number of maquiladoras in Cd. Chihuahua increased

FIGURE 3. CHIHUAHUA'S ANNUAL FORESTRY PRODUCTION 1989-1998



2 Pecan irrigation in the Delicias district reached a peak of about 10,000 hectares in the 1986-1988 period.

FIGURE 4. NUMBER OF MAQUILADORA FACILITIES IN CHHUAHUA CITY 1980-2000



Water use efficiency in the three major irrigation districts in the Conchos basin is only about 40%, but per capita municipal use in the Conchos basin is only about 1/2 what it averages in Texas.

from about 18 in 1981 to about 85 in 2000, with a consequent increase in employment from about 4,000 to 50,000. The presence of industry is also attracting thousands of new residents to the cities with the promise of jobs, putting great pressure on municipal water and wastewater systems.

Service industries and the transportation industry are also increasing in relative importance in Chihuahua as a whole and in the Conchos basin. In the Sierra Madre, there are efforts to promote tourism on a larger scale, an initiative which could require more water to be made available for hotels and related services.

CURRENT AND FUTURE DEMAND FOR WATER

Irrigation is by far the dominant water use in the Conchos basin, accounting for over 90% of water withdrawls (Table 7).

Inefficient irrigation systems contribute substantially to high water use in the agricultural sector. CNA estimates that water use efficiency in the three major irrigation districts in the Conchos basin is only about 40 %. This efficiency is estimated by two methods. One compares the water required by the crop to the water applied; the other examines estimated water losses in the irrigation distribution system, based on the state of the irrigation infrastructure. The two methods generally result in similar estimates of irrigation efficiency.

The Río Florido irrigation district relies on surface water from Presas San Gabriel and Pico de Aguila; the Delicias district relies on surface water from Presas La Boquilla and Francisco Madero, as well as groundwater from over 350 deep wells[3]; and the Bajo Río Conchos district uses surface water from the Presa Luis L. Leon and associated smaller holding reservoirs. The remainder of irrigation water use is in the Unidades

3 Groundwater accounts for about 20% of total irrigation water use in the Delicias district.

de Riego, most of which rely more heavily on groundwater (Table 8).

Municipal water use is also significant in the Conchos basin, even though per capita water consumption is much less than in the average U.S. community. CNA estimates domestic water use rates in the Conchos basin (based on 1995 data) at about 260 to 300 liters per capi-

DATA RELIABILITY

The data in Table 7 provide a reasonable overall picture of relative water use in the Conchos basin. Nevertheless, these are only water use estimates since many wells and even some municipal water distribution systems are not metered. CNA does not have sufficient resources to verify the accuracy of all estimated water use. The CNA reports the amounts of water as "consumptive" and "non-consumptive" use.

TABLE 7. ESTIMATED TOTAL WATER WITHDRAWLS BY USE IN CONCHOS BASIN (1995)

USE CATEGORY	WITHDRAWLS/USE+ Mm^3 (MAF)	% TOTAL
Domestic	199.9 (0.164)	6.4
Industrial	24.8 (0.02)	< 1
Commercial	11.0 (0.09)	< 0.5
Agriculture	2,887.5 (2.37)	92.7
Livestock	25.6 (0.021)	< 1
Electric Energy	12.5 (0.01)	< 0.5
Mining	4.0 (0.003)	< 0.5
Tourism	0.9 (0.0007)	< 0.1
Total consumptive uses	**3116.2 (2.55)**	
Hyrdroelectric generation	741.7 (0.61)	
Aquaculture	9.5 (0.008)	
Total non-consumptive uses		

Source: CNA, Programa Hidraulico. +Includes groundwater and surface water. The data is reported as water use by CNA, though return flows may not be reflected for either domestic, agricultural or other uses.

TABLE 8. ESTIMATES OF GROUNDWATER AND SURFACE WATER WITHDRAWLS IN MAJOR "UNIDADES DE RIEGO" IN THE CONCHOS BASIN

AREA	GROUNDWATER WITHDRAWLS Mm^3 (MAF)	SURFACE WATER WITHDRAWLS Mm^3 (MAF)	TOTAL WITHDRAWLS Mm^3 (MAF)	% GROUNDWATER
Chihuahua	231.8 (0.19)	44.2 (0.036)	276 (0.23)	84
Río Conchos	11.6 (0.095)	32.6 (0.027)	44.1 (0.036)	26
Parral	26.5 (0.022)	93.7 (0.077)	120.2 (0.099)	22
Delicias	266.7 (0.22)	45.3 (0.037)	312 (0.256)	85
Río Florido	343 (0.28)	53.6 (0.044)	397 (0.325)	86

Source: CNA, Programa Hidraulico.

TABLE 9. WATER LOSS AND METERING IN MAJOR MUNICIPALITIES IN THE CONCHOS BASIN

Municipality	% Loss	% Metering
Chihuahua	29	76
Hidalgo de Parral	5*	11
Delicias	40	31
Camargo	31	69

Source: CNA, Programa Hidraulico.
** CNA notes that this information is unreliable, especially because of the low level of metering.*

TABLE 10. ESTIMATED WATER USE RATES BY INDUSTRY SECTOR IN THE CONCHOS BASIN (1995)

Sector	Estimated Use (liters/sec)	Estimated Use (million gallons per day)
Wood products	394.3	9
Non-metallic minerals	200.7	4.6
Food & Beverage	114.3	2.6
Chemical	32.0	0.7
Paper & Cellulose	25.6	0.6
Maquiladora	12.8	0.3
Textil	9.2	0.2

Source: CNA, Programa Hidraulico.

ta per day (about 70 to 80 gallons per capita per day). By contrast, average daily per capita water use in Texas is about 606 liters (160 gallons). Thus, per capita municipal use in the Conchos basin is only about one half of what it averages in Texas.

These lower consumption rates include water losses in the municipal distribution systems. Available data indicate these losses are reaching 40% in some cities in the basin, according to CNA (Table 9).

Most of the municipal water supply in the Conchos basin comes from groundwater, with the exception of Cd. Chihuahua, which obtains about 8% of its supply from the Presas Chihuahua and El Rejón.

Including water for steam electric plants, industrial water use still accounts for only about 1 percent of the total water use in the Conchos basin, according to CNA estimates. With the exception of the Cd. Camargo area, these industrial demands are generally supplied with

MUNICIPAL WATER DEMAND IN CHIHUAHUA

The state's second largeat city, Cd. Chihuahua, relies on grounsdwater for about 92% of its needs, using deep wells in the three primary aquifers. The Chihuahua-Sacramento aquifer, which constitutes about 65% of current supply – is already over-exploited, however. In addition to aggressive water conservation measures, CNA's plan for meeting Chihuahua's municipal needs includes reducing pumping from this aquifer and pumping more from the Aldama-San Diego Aquifer. It is also seeking to reduce agricultural use of groundwater from these aquifers through conservation.

Cd. Chihuahua also faces challenges in expanding its municipal potable water infrastructure to meet existing and future demands.

Source: CNA, Programa Hidraulico.

MUNICIPAL WATER DEMAND IN HIDALGO DE PARRAL

The Valle de Verano aquifer supplies Hidalgo de Parral, neighboring municipalities and local industrial and agricultural operations. The aquifer supplies about 70% of the Hidalgo de Parral's current municipal use. Pumping from this aquifer now exceeds recharge by about 2.5 Mm^3/year (0.002 MAF/yr), according to CNA estimates. The government proposes that pumping from this aquifer be reduced, with supply being replaced by groundwater from the Alto Rio Florido aquifer, transported to Hidalgo de Parral via 30 km aqueduct.

Source: CNA, Programa Hidraulico.

TABLE 11. PROJECTED WATER DEMAND IN MAJOR MUNICIPALITIES IN THE CONCHOS BASIN

(Assuming reduction to 25% loss in water distribution systems and water conservation in those cities with currently higher per capita consumption rates)

MUNICIPALITY	DEMAND MM^3		
	1995	2000	2020
Chihuahua	95.7	100.7	119.0
Hidalgo de Parral	11.4	11.8	14.2
Delicias	19.2	19.5	17.3
Camargo	7.3	7.3	6.6
Jiménez	6.1	6.2	5.3
Meoqui	4.2	4.3	4.4
Ojinaga	9.0	8.4	4.8
Saucillo	2.3	2.2	1.9

Source: CNA, Programa Hidraulico.

groundwater—either through a municipal water system or through independent wells.

Due to substantial increase in population projected for the Conchos basin, municipal water use is expected to increase over the next few decades if aggressive water conservation measures are not put in place. Population in the basin is projected to increase from about 1.32 million in 2000 to about 1.77 million in 2020 and 2.44 million in 2050, with continued concentration of people in urban centers. Table 11 shows CNA's projected water use for major municipalities in the basin, assuming a general reduction to 25% in losses from municipal distribution systems and conservation in those cities that currently have higher per capita water consumption rates. With these assumptions, CNA predicts that municipal use will decrease by 2020, relative to current levels, even with a population increase. If these changes are not realized, however, overall municipal use in the Conchos basin would steadily increase. In Cd. Chihuahua, for example, 2020 water demand would reach about 170 Mm^3 (0.14 MAF), versus 119 Mm^3 (0.098 MAF) with the conservation and distribution loss reduction assumptions.

CNA projects that industrial water use in Chihuahua as a whole is likely to increase at about 3% annually over the next few decades.[4] Even

4 Industrial water use in Chihuahua actually declined by over 15% between 1989 and 1994. CNA attributes this decline to closure of various mines due to fluctuations in mineral prices and to the closing of the Pondercel cellulose plant in 1994. The Pondercel plant, which accounts for about 50% of water use in Chihuahua's pulp and paper sector, has since re-opened. This plant is located just outside the Conchos basin.

if this increase were to occur, industrial water use would still not represent a major portion of overall water demand in the basin. Nevertheless, industrial use could be significant in some local areas, especially if a large water user wants to pump from an already overexploited aquifer.

CNA predicts that agricultural production will grow by about 3% per year in Chihuahua, though it states that the availability of water could be a major impediment to growth in irrigated agriculture. Whether this projection accurately reflects the effects of tighter credit and competition from U.S. agricultural imports (particularly from Canada and the U.S. under NAFTA) on agricultural production in Chihuahua remains to be seen. In any case, CNA acknowledges that there is a dire need for conservation in agricultural irrigation practices through improvements in water delivery, measurement of water use and irrigation techniques.

The federal government developed estimates in 1997 of the resources it will need to make the necessary municipal and agricultural conservation investments, to better monitor flows and operate reservoirs and to better monitor water quality. The total investment needs projected for the state of Chihuahua between 1997 and 2000 was about $ 500 million, or about $ 170 million per year. This level of investment would be equivalent to about 80% of the state's total budget in 1996.

Projected agricultural conservation investment needs in the major irrigation districts in the Conchos basin over the 1997-200 time period total about $ 90 million (Table 12). In addition, CNA estimates a similar level of investment is needed to improve water use efficiency in the basin's Unidades de Riego. At press time, no information was readily available as to whether these investments were, in fact, made during the 1997-2000 time period.

Substantial investment is also needed to improve municipal water and wastewater infrastructure (including metering, wastewater treatment plant construction and expanded coverage of water and wastewater sys-

Projected agricultural conservation investment needs in the major irrigation districts in the Conchos basin over the 1997-2000 time period total about $ 90 million.

TABLE 12. PROJECTED AGRICULTURAL WATER CONSERVATION INVESTMENTS REQUIRED FOR MAJOR IRRIGATION DISTRICTS IN THE CONCHOS BASIN (1997-2000; 1997 U.S. $)

DISTRICT	CONSERVATION INVESTMENT PROJECTED (1997-2000) (IN 1997 U.S. $)
Río Florido	$ 3,500,000
Delicias	$ 78,849,600
Bajo Río Conchos	$ 8,086,900
Total	**$ 90,436,500**

Source: CNA, Programa Hidraulico.

Sufficient stream and spring flow could be an important factor in attracting visitors and outdoor recreation enthusiasts to various areas of the basin—and these visitors could, in turn, be an important source of revenue for local economies.

tems). For example, CNA projected investment needs for Cd. Chihuahua (in 1997 $) range from $ 26.9 million in the 1998-2000 time period to $ 45.7 million in the 2001-2005 period, totaling $ 187.6 million over the 1998-2020 timeframe.

Where will these funds come from? CNA identifies federal sources of funding such as various government infrastructure programs (some of which are largely funded by loans from the World Bank) and credit from Mexican national development banks, including BANOBRAS and BANRURAL. It also projects that some funds will come from Chihuahua state government programs and from the U.S./Mexico binational border development bank, NADBank. There is plenty of competition for these limited funds, both within Mexico and along the border, however. It remains to be seen what level of priority will be given to the investment needs in Chihuahua and in the Conchos basin in particular.

WILL ANY WATER BE LEFT FOR THE ENVIRONMENT?

The water resources of the Conchos basin will be subjected to increasing pressure over the coming decades as population grows, industrial activity increases and irrigated agriculture continues. CNA's plan for meeting future water needs in the basin sensibly relies on water conservation, in both the municipal and agricultural sectors. This is appropriate because: (1) agricultural use accounts for over 90% of the total water withdrawls and, thus, savings in this sector will be significant and (2) there are substantial inefficiencies (i.e. water being wasted) in both the agricultural and municipal sectors.

In addition, as CNA's plan recognizes, there are likely to be opportunities for inter-sectoral reallocation of water rights. The opportunities are likely to include shifting agricultural water use to municipal use in some areas of the basin. Developing adequate policies to ensure that such transfers do not adversely affect the viability of the rural communities from which the water is transferred will be a central challenge for federal and state authorities.

What is not clear from CNA's plan, however, is whether environmental water needs will be recognized and protected. That is, what plans will be put in place to protect spring flow and instream flows, especially in ecologically-important areas of the basin?

The CNA's plan does devote some attention to these questions. It recognizes the importance of adequate instream flows and good water quality for maintaining aquatic habitat. However, of the 13 principal fresh water fish native to the streams and springs of the Conchos basin, 1 is threatened, 4 are endangered and the status of 4 species is unknown. Only three species of carp and one of trout seem to be maintaining healthy populations.

The plan also contains some very rough estimates of required instream flows, using what CNA terms the "Montana" method developed by the U.S. Fish and Wildlife Service. This method estimates instream flow requirements by season as a percentage of median flows. The plan does not attempt, however, to analyze whether those flows are currently available or will be available if water use increases in the future. In addition, CNA's plan does not contain any specific analysis of what has happened to instream flow rates or spring flows in particular areas of the basin.

Thus, with the current state of available information, it is difficult to draw any conclusions about environmental water needs in the Conchos basin or about whether there will be water to meet those needs. It should be noted that this is more than a purely environmental issue. Sufficient stream and spring flow could be an important factor in attracting visitors and outdoor recreation enthusiasts to various areas of the basin—and these visitors could, in turn, be an important source of revenue for local economies.

Under Mexico's system it appears that all users may have their allocations reduced during times of shortage.

LEGAL AND INSTITUTIONAL FRAMEWORK FOR WATER MANAGEMENT IN MEXICO

Article 27 of the Mexican constitution establishes the legal framework for water resources management in Mexico. It essentially provides the federal government with ownership of and jurisdiction over almost all surface water and groundwater. The federal government issues permits for water use, pursuant to the 1992 federal water law.[5] The "permits" include concessions to private interests and assignments to governmental entities, such as municipal water supply systems. These permits can be in force for anywhere from 5 to 50 years, with extensions available. No permit is required for domestic uses that do not involve construction of a water distribution system.

In theory, permit issuance is contingent on water being available. However, in many areas the hydrological and current water use data needed to determine water availability may not exist or may be insufficient or unreliable.

Mexico has not developed what is known in the U.S. as a "prior appropriation" system for allocating water in times of shortage. Under the prior appropriation doctrine, "senior" water rights (i.e. the oldest water rights) can be fully satisfied before junior water right holders in the same basin get their water. Thus, under Mexico's system it appears that all users may have their allocations reduced during times of shortage. The 1992 water law gives the federal government broad discretion

5 Water use authorizations issued prior to the 1992 law remain in effect if they are registered in the Public Water Rights Registry established by the 1992 act.

Responsibility for operation of the three major districts in the Conchos basin has been transferred to the respective user associations.

to impose water use restrictions and allocations in areas of shortages or periods of drought. Significantly, use restrictions can also be imposed to "protect or restore" an ecosystem, as well as to prevent over-exploitation of aquifers, preserve potable water sources and prevent contamination.

Mexico's water rights registry is still somewhat incomplete and inconsistent, but it has been greatly improved over the last several years with funding from a World Bank loan. Developing an accurate and complete water rights registry will be important to the success of future water management efforts (including the potential for a water rights market) in the Conchos basin, and in Mexico as a whole. In Chihuahua, CNA reports that it has registered about 3,850 water rights (122 for surface water use and 3,753 for groundwater use). According to CNA, this accounts for about 27% of the water use systems, but about 77% of the annual volume of water used in the state. In the Conchos/Río Bravo basins, CNA reports that the registry has about 27% of the known water supply projects included, but the registry's reported volume of water "extracted" is 25% greater than the extraction estimated from other sources of data.

The federal government imposes a fee for development and use of surface and subsurface water, with certain important exceptions. In 1996, the fee varied with the location of the use and the time of year, but generally ranged from about $ 1 per thousand cubic meters for use in aquaculture, recreation centers or generation of hydroelectricity to $50 to $ 100 per thousand cubic meter for potable water. The government does not charge a fee for extraction and use of water for personal domestic use, for domestic use in small towns and villages, or for agricultural use in irrigation districts or unidades de riego (with the exception of "agro-industrial use").

Due in part to the lack of water metering, municipal water systems generally charge a fixed monthly fee for water and sewer service for domestic users, though some also have a volume-based fee for industrial users. In the Conchos basin in 1996, municipal water systems were charging domestic users between 15 and 100 pesos per month (about $ 2.00 to $ 12.50 at 1996 peso conversion rates). Industrial users were being charged between 1.6 and 4.4 pesos per cubic meter (about $ 0.20 to $ 0.55) depending on the amount used, with a higher price per cubic meter for higher use rates.

The federal government's dominant role in water resources management is lodged in CNA, which is now part of Mexico's environmental agency, SEMARNAT (Secretaria de Medio Ambiente y Recursos Naturales). There is a division of CNA that deals with water in the northern border states, and a part of that division is devoted to oversight of water issues in Chihuahua. Recently, CNA has begun to work more cooperatively with state governments, including that of Chihuahua, involving the states more closely in planning and decision-making.

TABLE 13. 1995-1996 BUDGETS FOR IRRIGATION DISTRICTS IN THE RIO CONCHOS BASIN

DISTRICT	1995-1996 BUDGETS (000S $)			% FEDERAL
	USER ASSN.	FEDERAL	TOTAL	
Río Florido	1,117	504	1,681	29
Delicias	9,916	1,468	11,384	12
Bajo Río Conchos	2,415	482	2,898	16

Source: CNA, Programa Hidraulico.

At the state level, there is a "Junta Central de Agua y Saneamiento" (Central Directorate of Water and Sewer) that is primarily responsible for the state's role in water issues. Larger municipalities have their own water and sewer departments and there are also "Juntas Rurales de Agua Potable," rural water supply directorates.

Irrigation districts are generally established by presidential decree. In recent years, the federal government has moved to delegate responsibility for operation of the districts to "user associations". The user associations hold title to the water rights and are to implement a system of fees to help pay for the operation and maintenance of the water delivery structure. The ultimate objective is to have the districts be financially and operationally self-sufficient.

Responsibility for operation of the three major districts in the Conchos basin has been transferred to the respective user associations. As shown in Table 13, however, the districts still receive substantial federal funding.

The 1992 water law contains a procedure for establishing "Consejos de Cuenca", or basin management councils. The purpose of the basin council is to improve inter-governmental coordination in water resources management and to improve cooperation among the governmental entities, water users and other interests, including the public. A Consejo de Cuenca for the Río Bravo basin in Mexico, including the Río Conchos, was established in 1994, but there has been almost no progress in getting the Consejo off the ground.

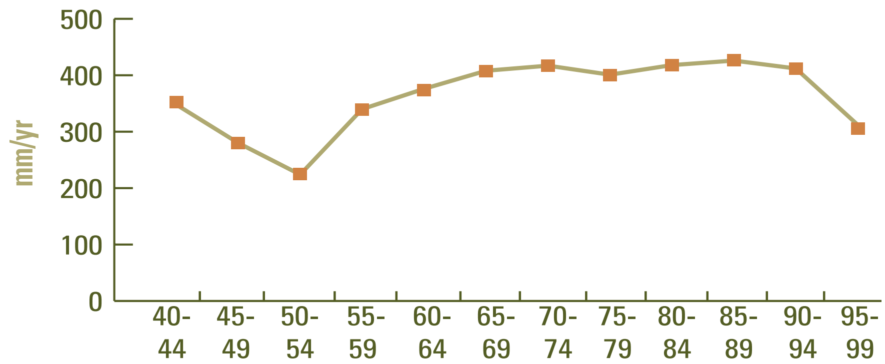
TRANSBOUNDARY IMPLICATIONS

The persistent drought in Chihuahua has led to significantly less water from the Conchos reaching the mainstem of the Río Bravo (Figure 5). In fact, flows have been reduced to the point where Mexico is now in a "deficit" situation with respect to the 1944 U.S./Mexico water treaty that governs allocation of the Río Bravo/Río Grande.

In the five-year cycle ending on October 2, 1997, Mexico owed the U.S. about 1,240 Mm^3 (1.024 million acre feet).

By February 2000, Mexico had accumulated an additional 480 Mm^3 (0.40 MAF) deficit in the current five-year cycle.

FIGURE 5. AVERAGE ANNUAL RAINFALL IN THE CONCHOS BASIN



The 1944 Treaty provides that one-third (1/3) of the flow reaching the main channel of the Río Bravo from the Rios Conchos, San Diego, San Rodrigo, Escondido and Salado and the Las Vacas Arroyo is allocated to the United States, provided that this third shall not be less, as an average amount in cycles of five consecutive years, than 431 Mm^3/year (350,000 acre-feet per year). The vast majority of this water comes from the Conchos basin, as flow in the other tributaries is minimal during much of the year.

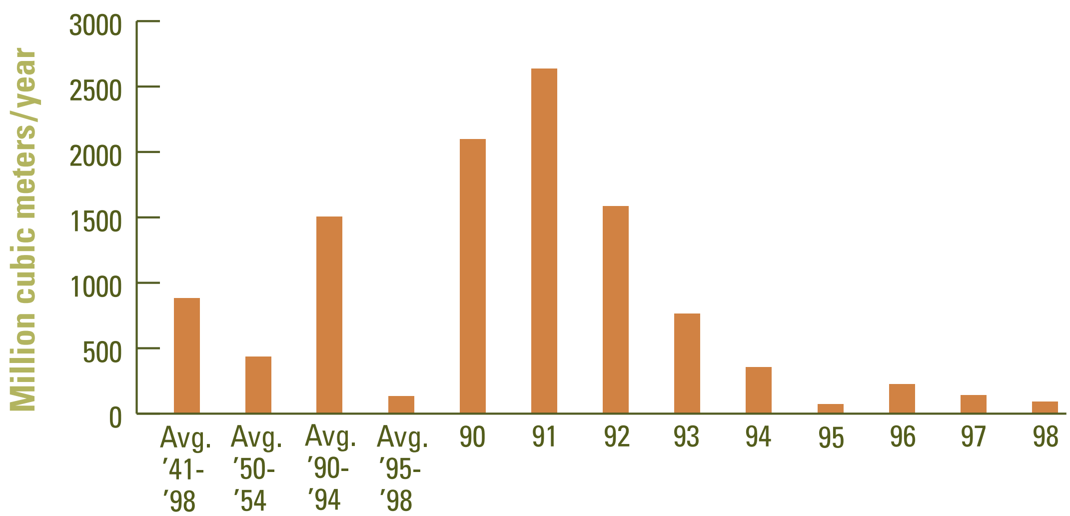
In the five-year cycle ending on October 2, 1997, Mexico owed the U.S. about 1,240 Mm^3 (1.024 million acre feet). This is more than double the deficit incurred by Mexico during the drought of the 1950s, which is the only other time Mexico has failed to meet the minimum flow requirements during a five-year cycle. By February 2000, Mexico had accumulated an additional 480 Mm^3 (0.40 MAF) deficit in the current five-year cycle.

According to Article 4 of the Treaty, total flow from these Mexican tributaries can average less than 350,000 acre-feet/year over a five-year cycle without Mexico being in “violation” of the treaty if there is a situation of “extraordinary drought”. The treaty requires that Mexico make up the deficit in the subsequent five-year cycle.

Unfortunately, the Treaty does not provide further definition of the term “extraordinary” drought. This lack of certainty is now at the heart of a raging controversy, as U.S. farmers in the Lower Rio Grande are alleging that the drought in Chihuahua was not so severe as to justify Mexico’s withholding of flows in the Conchos basin. Based on a report by the consulting firm R.J. Brandes and Associates, the farmers essentially claim that the Conchos basin received about 80 percent of its normal rainfall during the 1993 to 1997 period and that because flow in the Mexican tributaries did not cease “entirely” there was no “extraordinary drought”.[6] They further claim that, under the treaty, Mexico should

6 The Brandes report places annual average rainfall in the Conchos basin at 47% of normal in 1994 and 69% of normal in 1995, with three others years (1993, 1996 and 1997) experiencing normal or near normal rainfall levels.

FIGURE 6. FLOW OF RÍO CONCHOSE INTO RÍO BRAVO



have released water stored in reservoirs in the Conchos basin to meet the 350,000 acre-feet/year requirement.

Mexico has responded that the lower levels of rainfall, particularly in the Conchos basin, do constitute an extraordinary drought, though it did not dispute the Brandes report calculation of an average 80% of normal rainfall during 1993-1997. Nevertheless, as shown in Figure 6, only during the late 1940s and early 1950s was average annual rainfall in the Conchos basin less than during the 1995-1999 period. Mexico further argues that it is entitled, under the treaty, to withhold enough water in reservoir storage to meet water demands in the Conchos basin before water is released to the Río Bravo to satisfy treaty requirements, as long as it pays back the water "owed" in the subsequent five-year cycle. It also states that the storage capacity of the reservoirs on the Conchos is less than assumed by the U.S. since there has been significant sedimentation in some of those reservoirs.

The dispute has reached the level of the respective state departments in Mexico and U.S. The International Boundary and Water Commission (IBWC), a binational agency set up under the Treaty to administer the water allocation between U.S. and Mexico, has been meeting with government agencies and water users in both countries in an attempt to resolve the disputes. Since February 2000, through a combination of releases from the Conchos and transfer of Mexico-owned water in the Amistad/Falcon reservoir system to U.S. ownership, Mexico has reduced its deficit for the 1992-1997 cycle to about 841 Mm^3 (0.69 MAF). Under the treaty, this entire deficit must be repaid by the time the current five-year cycle ends on October 2, 2002.

The current controversy over the interpretation and implementation of the 1944 Treaty indicates the need for the two countries to better define the term "extraordinary drought" and, possibly, to clarify other provisions of the treaty.

The situation has also affected water resources planning in the Lower Rio Grande Valley in Texas.[7] Here, the local planning committee has essentially assumed that it will receive no more than the minimum 350,000 acre-feet per year from the Conchos and other tributaries in developing its long-range water supply strategies. This is about the level of flow received from Mexican tributaries during the "drought of record" that occurred in the 1950s. Under this assumption, some projected agricultural irrigation needs cannot be supplied. It should also be noted that such reduced flows from the Conchos—on a regular basis—could make it more difficult to secure instream flows for the Río Bravo, both above and below the Amistad/Falcon reservoir system.

NEXT STEPS

This report has provided only a preliminary picture of water resources management in the Conchos basin. In the coming year, the Texas Center for Policy Studies will be conducting additional research into existing water use patterns, water demand projections, legal and institutional aspects of water rights management and preservation of spring and stream flows in the basin.

In partnership with various Mexican non-governmental organizations, we will consult with experts, water user groups, government officials and others in an attempt to gather more detailed information on these and other topics. We will also be examining whether the necessary changes and investments identified in CNA's 1997 Programa Hidraulico have been made, whether those strategies are working and whether there are any barriers that might have prevented their full implementation.

Our objective is to produce, by September 2001, a more detailed assessment that can be used in both countries to highlight and improve understanding of the importance of the Conchos basin to both Mexico and the U.S.

We look forward to receiving comments on this preliminary report and we encourage readers to contact us with any questions or perspectives on water resources management in the Conchos basin. Comments and questions can be sent to Mary E. Kelly, Executive Director, Texas Center for Policy Studies, 44 East Ave. # 306, Austin, Texas 78701, mek@texascenter.org.

7 A 1997 law required various regions of the state to prepare long-term water management plans, delineating how the region will meet water demand for the next 20 to 50 years. The Valley's plan relies primarily on aggressive municipal and agricultural water conservation, inter-sectoral re-allocation of water rights from agricultural to municipal use, and increased water re-use.

BIBLIOGRAPHY

Comisión Nacional del Agua (1997), Programa Hidraulico de Gran Vision, Estado de Chihuahua (1996-2020) (available at www.sequia.edu.mx/plan-hidra/)

Comisión Nacional del Agua (2000), Comentario al Documento Estadounidense "Análisis preliminary del Déficit Mexicano de las Aguas del Río Bravo, bajo el Tratado de 1944

R.J. Brandes Company (2000), Preliminary Analysis of Mexico's Rio Grande Water Deficit Under the 1944 Treaty

Secretaria de Desarollo Rural, Estado de Chihuahua (2000), Chihuahua: Otro Año de Sequía (available at www.chihuahua.gob.mx/cies/Informacion /Integral/medio%20Ambiente.htm)

Steve Lee & Brendan Case, "Parched Battle: Rio Grande Valley drought sparks friction on both sides of the border", Dallas Morning News, March 26, 2000.

Isaac Levi, "Mexico's worst drought is ruining cattle ranchers", Corpus Christi Caller Times, May 30, 1999.

International Boundary and Water Commission, "IBWC Credits Additional Water to the United States", July 25, 2000 (available at www.ibwc.state.gov/ PAO/CURPRESS/5yrJulya.htm).

Diana Liverman, "Vulnerability and Adaptation to Drought in Mexico" in Natural Resources Journal, 39:1, pp. 99-116.

Mary Kelly and Salvador Contreras (1998), Water Use and Water Management Policy in the Chihuahuan Desert Ecoregion, prepared for the World Wildlife Fund's Chihuahuan Desert Ecoregion Project Conference in El Paso, Texas (available from the Texas Center for Policy Studies).