The Challenge of Balancing Water Supply and Demand in the Paso del Norte

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ABSTRACT

The Paso del Norte, a region that includes the ‘sister’ cities of El Paso, Texas and Ciudad Juárez, Chihuahua, is faced with a complex set of water supply problems that embody the range of water issues found elsewhere along the U.S.-Mexico border. Among the circumstances in the Paso del Norte that are generally applicable to the entire U.S.-Mexico border region are the following:

- Water is scarce, and competition for water resources is intensifying.
- Per capita water use is higher on the U.S. side of the border than the Mexican side.
- Agricultural water use is relatively constant; increased water demand is being driven by urban growth.
- Upstream surface water irrigation acts to reduce downstream flow and degrade downstream water quality by concentrating dissolved minerals.
- Intensive human use of water resources has impoverished natural ecosystems.
- The quality of existing water resource infrastructure, financial capability, and technical capability is greater on the U.S. side than the Mexican side.

Urban populations are increasing on both sides of the border, but more so in Cd. Juárez where industrial expansion has acted as a magnet for in-migration and spurred rapid population growth. Because in-migrants tend to be relatively young, the intrinsic rate of growth of Cd. Juárez is higher than that of Mexico as a whole, suggesting that, even absent further in-migration pressures, the city’s population will continue to grow rapidly. Population growth will increase the demand for water.

Both El Paso and Cd. Juárez are heavily dependent on ground water. Underlying the two cities is the Hueco Bolson, an extensive aquifer, but one that receives limited recharge. Ground water extraction from this aquifer by both cities has caused a dramatic decline in the water table and the fresh water fraction of the aquifer is being depleted. El Paso has developed well fields in a different aquifer, the Mesilla Bolson – but the preponderance of this second aquifer is in New Mexico, not Texas, thus restricting El Paso’s access to this source of water. By contrast, Cd. Juárez remains totally reliant on the Hueco Bolson. The portion of the Hueco Bolson underlying Cd. Juárez is relatively ‘pinched-out.’ The useful life of Mexico’s portion of the Hueco Bolson is limited, though officials on opposite sides of the border differ in their projections of the volume of fresh water remaining. The asymmetry of information regarding shared aquifer systems constrains joint management of the region’s ground water resources. Currently, both El Paso and Cd. Juárez are investigating the feasibility of importing ground water from outlying areas,
but legal and political restrictions impede El Paso, and Cd. Juárez has neither technical
documentation of the extent of ground water resources available, nor the financial capability of
aggressively pursing this option.

Due to diminished supplies of ground water, both El Paso and Cd. Juárez are seeking greater
access to replenishable surface water, but the use of surface water is constrained by a complex
set of water laws, allocation systems, international treaties and interstate compacts. Consequently, while the conversion of surface water from agricultural to municipal/industrial
use is beginning, the process is somewhat tortuous, and progress has been slow.

Underlying the fresh water portion of the region’s aquifers is a substantial, though poorly
documented amount of brackish water. Desalination technologies have matured over the last
several decades, but exploiting this water resource will be expensive. The disposal of concentrate
from desalination poses a challenge given the region’s inland location. Nonetheless, both El
Paso and Cd. Juárez are currently investigating this option.

The challenge of securing adequate water supplies requires both ‘supply-side’ and demand
management strategies. Water reuse systems and aggressive demand management strategies have
been implemented in El Paso, and per capita water use has reduced by more than 25 percent
over the last two decades – yet El Pasoans, on average, continue to use considerably more water
than their Juarenze counterparts. Further reductions in per capita water use will be necessary,
though challenging. Because per capita water consumption is already considerably lower in Cd.
Juárez than in El Paso, water conservation campaigns and other demand management strategies
are likely to be less effective in reducing water needs in Cd. Juárez.

The report concludes with a brief analysis of future scenarios and challenges regarding
binational planning the El Paso-Cd. Juárez region.
INTRODUCTION

The United States-Mexico border extends from the Pacific Ocean to the Gulf of Mexico, a distance of more than 3,100 km. More-or-less at the midpoint of the U.S.-Mexico border, at the juxtaposition of the U.S. states of New Mexico and Texas and Mexican state of Chihuahua, is a region known as the Paso del Norte. Flowing through the region is the Río Grande, which is known as the Río Bravo in Mexico. Today, the river that flows through the Paso del Norte is neither grande (large) nor bravo (wild). Instead, its flow is regulated by a series of upstream dams, it is confined within a straightjacket of levees, and its flow is significantly reduced by the time it leaves the region.

The Paso del Norte consists of a mix of agricultural and urban development surrounding a segment of the Río Grande/Río Bravo that extends from Elephant Butte Dam in southern New Mexico to Fort Quitman in far west Texas on the international border. Within this region are located the ‘sister’ cities of El Paso, Texas and Cd. Juárez, Chihuahua. West of El Paso and Cd. Juárez, the international boundary is a land boundary delineated by 276 permanent monuments; to the east, the border is defined by the meandering course of the Río Grande/Río Bravo as it makes its way to the Gulf of Mexico.

Systems of allocation of water resources throughout this region were developed in the early 20th Century based on the irrigation needs of what was then a predominantly rural area. Today, the character of the region is different. Economic opportunities made possible by cross-border commerce have fostered the growth of an urban population. Currently, over two million people reside within the Paso del Norte. Cities in the region have traditionally relied on ground water, but the region’s aquifers receive limited recharge and the principal aquifer serving El Paso and Cd. Juárez is being depleted. Surface water from the Río Grande/Río Bravo represents an alternative and replenishable source of drinking water, but the vast majority of the river’s water is devoted to agricultural use.

Paradoxically, the Paso del Norte is continuing to experience rapid population growth despite its diminishing water resources. Institutional fragmentation in this binational, tri-state region impedes cooperative water resource management, and the unequal distribution of water resources is resulting in growing disparities and conflict. Furthermore, jurisdictional conflicts are tending to obscure the implications of an unsustainable mining of the region’s ground water resources, and thereby forestall difficult choices.

The range of water-related issues in the Paso del Norte covers the gamut of water problems found elsewhere along the international border. In addition to diminishing supplies of ground water, issues include: difficulties regarding the conversion of surface water from agricultural to municipal and industrial use; legal disputes over water rights; impaired surface water quality; water scarcity and drought susceptibility due to climatic conditions; impacts on surface water flows due to the ground water pumping; and impoverished natural ecosystems attributable to intensive water use. Of particular concern are issues that underscore the disparities between the United States and Mexico. Differences are evident in: water resource infrastructure for both municipalities and irrigators; asymmetries in financial capabilities; dissimilar information regarding the region’s aquifers; and legal and institutional differences which, in the instance of the Paso del Norte, include not only differences between the U.S. and Mexico, but also between Texas and New Mexico.

It is not accurate to characterize the immediate water supply situation facing communities in the Paso del Norte as a crisis. The supplies of water that are being depleted are the high quality ground water sources; other, lower value water is available, though treating it to meet drinking water standards will be expensive. In that sense, communities in the Paso del Norte are not
running out of water so much as they are running out of ‘cheap’ water. But, that is only the immediate, short-range problem. From a mid-range perspective, the region is faced with the dilemma of a potential reallocation of water among its jurisdictions and users. Thus far, this highly political issue has tended to promote parochial attitudes. But, technological fixes and political solutions cannot manufacture new water in this arid region. The long-range reality facing the Paso del Norte is one of recognizing that the finite supplies of replenishable water constitute a limit to population growth in the region.

The complex water challenges of the Paso del Norte are, in many aspects, extreme relative to other regions of the border. In a broader context, however, the challenges facing the Paso del Norte are a microcosm of the water problems faced by communities throughout the U.S.-Mexico border region. When scarce water resources must be shared, particularly in times of shortage, competition for, and conflicts over, water are inevitable. More importantly, economic pressures and differences between the two countries complicate a rational approach to sustainable development.

**HISTORICAL DEVELOPMENT**

The morphology of the Río Grande/Río Bravo 500 years ago was very different from what is visible today. Historically, the river had a shallow, meandering, shifting channel with a sandy bottom, and it was prone to periodic flooding during which time it would become a raging river, (Stotz 2000). The shifting river formed braided channels giving rise to a dynamic mosaic of habitat types including sedges and marsh grasses, and bosques of willow, cottonwood and mesquite, (Dick-Peddie 1993).

Archeological evidence indicates that the river valley in the Paso del Norte was inhabited in the late Pleistocene/early Holocene between 10,000-6,000 B.C. The first evidence of village settlements and horticultural activity date from 900 B.C., but year-round occupation of sites appears to have shifted to more dispersed, hunting and gathering lifestyles circa 1375 A.D., possibly in response to an extended period of drought, (Peterson et al. 1992).

In 1598, Spanish explorer Don Juan de Oñate led a colonizing expedition of approximately 600 persons north from the frontier settlement of Santa Bárbara in southern Chihuahua. Oñate arrived in the Paso del Norte in May of that year, and gave the region its name – El Paso del Río del Norte, the Ford of the River of the North. The passage blazed by Juan de Oñate would subsequently become part of the Camino Real, the principal trade route that extended from Mexico City in the south to Santa Fe and the Spanish territories in the north.

When the Spanish explored the upper Río Grande/Río Bravo basin, they encountered permanent settlements of Pueblo Indians that were using river water to irrigate crops along the riverbanks. The Native Americans had developed systems for sharing water at a local level. During the subsequent period of Spanish colonization, the Spanish introduced water rights management as practiced in Spain. The system was supposed to leave Pueblo irrigated lands intact while Spanish land grants developed on nearby lands. Since the Pueblo Indians often had the best land, encroachment gradually took place over time. A hybrid system of water allocation evolved based on Spanish law and water needs of land grant owners. The Spanish system incorporated some elements of the prior appropriation doctrine but gave highest priority to municipal water uses. Under the Spanish system, irrigation rights were reduced as needed to meet the demands of settled villages. Water rights of Native Americans were often incorporated into the evolving system. Only in a few cases do Native American rights remain intact to this day, (Clark 1987).
Permanent settlement in the Paso del Norte did not begin until the latter half of the 17th century when a mission church was constructed in what today is Cd. Juárez. Development north of the river only began in the early 19th century when a hacienda was built at a site that today is occupied by downtown El Paso.

Population growth in the Paso del Norte was slow during the 18th and 19th centuries, as the area was mostly a stopover for travelers. Irrigated agriculture was practiced in the river floodplain, but the vagaries of the river flow and annual surges of flood waters limited development. Initially, diversion structures were primitive and temporary, as permanent fixtures risked diverting flood water into the fields, (Horgan 1954). Nonetheless, agricultural development expanded throughout the El Paso and the Mesilla valleys, the latter being predominantly in Doña Ana County, New Mexico.

Urban development in El Paso accelerated with the completion of the Southern Pacific railroad line in 1881, and between 1880 and 1890, the population in El Paso County quadrupled. The city of El Paso became the county seat and quickly emerged as the dominant city in the region. Despite urban growth, however, the region continued to be largely rural in character. By the turn of the century, the combined population of El Paso County and the Juárez Municipio was less than 35,000, 75 percent of which lived north of the border.

In the 19th century, both El Paso and Cd. Juárez depended on surface water for their drinking water supply, though El Pasans also imported water from Deming, New Mexico, this water being hauled in barrels. In 1892, growth pressures prompted the first water well in El Paso, a 14m deep hand-dug well that tapped into the river alluvium, (Rittmann 2003). Approximately ten years later, the city drilled its second well in the upper mesa; this second well was drilled into an aquifer known as the Hueco Bolson. Thus, a pattern began to be established whereby cities in the Paso del Norte became reliant on ground water, while agriculture relied on the surface waters of the Rio Grande/Río Bravo.

Until the modern era, primitive technology limited the amount of river water that could be diverted, and irrigation use had only a nominal impact on stream flow. Irrigation demands on the river have increased greatly in the last 150 years, causing a substantial diminution in the surface flow. By the end of the 19th century, ever greater amounts of water were being diverted for irrigation throughout the watershed, particularly in the San Luis Valley of Colorado, some 600 km to the north, (Clark 1987). As a consequence, water shortages in the Paso del Norte became ever more common, and the Mexican government protested to the United States. An international treaty and an interstate compact would follow, presumably imposing a permanent settlement on the allocation of the river’s water. These negotiated water allocation settlements were reflective of the irrigation needs of what was predominantly a rural area.

Today, the character of the region is changing. Economic opportunities made possible by cross-border commerce are fostering rapid urban population growth – a kind of growth not anticipated when the interstate compacts and international treaties were negotiated. The ‘sister’ cities of El Paso and Cd. Juárez are turning to the Río Grande/Río Bravo to meet their water needs, and pressures are building to transfer water from agricultural to urban uses.

**Population Growth in the Paso del Norte**

Recent population growth and expectations of continued growth are incongruent with the rapid depletion of the region’s ground water. Figure 1 shows population growth in the Paso del Norte over the last century. Over the last 50 years, El Paso County has had an average annual growth rate of 2.5 percent, during which time it more than tripled in size, increasing from fewer than 200,000 in 1950 to a population of approaching 680,000 in 2000. During that same
timeframe, the Juárez Municipio experienced an average annual growth rate of 4.6 percent, and mushroomed from 122,000 to a population of over 1.2 million, nearly a 10-fold increase. Recent growth trends are especially imbalanced. El Paso continues to increase in population, but it has exhibited a declining rate of growth over the last 30 years whereas the population of Cd. Juárez has continued to increase at nearly four percent annually, and today it is almost twice the size of El Paso. Of particular note is the growth that has occurred over the last 20 years. During this time, the combined populations of El Paso and Juárez have added over 850,000 inhabitants, representing almost a doubling of population. This two-decade span coincides with a relatively ‘wet’ period during which irrigators enjoyed full water allocations from the Rio Grande/Río Bravo, and therefore were less reliant on supplemental pumped ground water.

![Figure 1. Historic Population Growth in the Paso del Norte](image)

Sources: U.S. Census Bureau; INEGI

Although fertility rates are higher in Mexico than the United States, the principal factor of the population growth of Cd. Juárez has not been natural increase; the rapid population growth has been driven by in-migration. Over the last twenty years, Cd. Juárez has experienced an expansion of industries that have lured migrants into the border region. The border industrialization program of the 1960s promoted increased manufacturing employment along the border, and implementation of the North American Free Trade Agreement (NAFTA) in 1994 further accelerated this trend. The term “maquiladora” has come to be used to refer to an industry established under a special Mexican industrial program that allows, under a special customs allowance, mostly non-Mexican operations to establish manufacturing plants in Mexico, which are then allowed to import duty-free raw materials, equipment machinery and replacement parts, (Solunet Info-Mex Inc. 2002). Between 1980 and 2000, the number of maquiladoras in Cd. Juárez more than doubled, and the number of persons employed at maquiladoras increased six-fold, (see Table 1). The economic slowdown in U.S. over the eighteen months has caused massive layoffs of maquiladora workers, and this may have, at least temporarily, lessened in-migration pressure.
Table 1. Maquiladora Employment in Cd. Juárez

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Plants</th>
<th>Number of Employees</th>
<th>Employees Lost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>121</td>
<td>42,412</td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td>248</td>
<td>120,854</td>
<td></td>
</tr>
<tr>
<td>1995</td>
<td>249</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td>1999</td>
<td>–</td>
<td>222,866</td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>312</td>
<td>255,740</td>
<td>- 46,493</td>
</tr>
<tr>
<td>2001</td>
<td>303</td>
<td>209,247</td>
<td></td>
</tr>
</tbody>
</table>

Source: Plan Municipal de Desarrollo Urbano, Diagnostico Integral, IMIP, 2002

Migrants are apt to be relatively young adults seeking improved economic opportunity. As a consequence, positive migration promotes continued population growth by increasing the percentage of persons in the family formation stage-of-life. Thus, the intrinsic rate of growth of a population increases as a consequence of positive net migration, (Namboodiri 1996). Even if migration pressures were to cease, Cd. Juárez is positioned to continue to grow rapidly. By contrast, the 2000 U.S. Census showed that El Paso, although still increasing in population, was experiencing a net out-migration of young adults, most likely lured by better economic opportunities elsewhere. The age cohort of persons between 18 and 34 years of age declined by 11,810 in El Paso during the period from 1990 and 2000, (Ramírez-Cadena 2001). These countervailing trends suggest that the future will see a widening gap in population size between El Paso and Cd. Juárez.

Demographic projections of future populations necessarily rely on a number of assumptions. If migration could be disregarded, future population could be reliably predicted based on knowledge of the existing population’s age distribution coupled with forecast changes in rates of fertility and mortality. But, population projections must also take into account future in- and out-migration, and commonly these variables are simply extrapolated from past trends. Given its water supply problems, the past may not be protocol in the Paso del Norte. The projected combined populations of the Juárez Municipio, Chihuahua, El Paso County, Texas and Doña Ana County, New Mexico, as developed by various local agencies, are shown on Figure 2.

Figure 2. Projected Population Growth in the Paso del Norte
Source: U.S. Census Bureau; INEGI; TWDB; IMIP; City of Las Cruces)
**WATER SUPPLY FOR THE PASO DEL NORTE**

The Paso del Norte depends on both ground water resources and surface waters from the Rio Grande/Río Bravo. Overall, adequate water would appear to be available to satisfy the needs of a growing population. Access to water, however, is constrained by jurisdictional boundaries, systems of allocation, and radically different water laws and institutional frameworks, none of which are amenable to change. These factors complicate water planning in the Paso del Norte. Figures 3 and 4 are maps depicting the water resources of the Paso del Norte.

![Figure 3: The Paso del Norte](image1)

*Figure 3: The Paso del Norte (From Creel et al. 2002)*

![Figure 4: Ground Water Resources in the Paso del Norte](image2)

*Figure 4: Ground Water Resources in the Paso del Norte*
Hueco Bolson: Underlying the cities of El Paso and Cd. Juárez is the Hueco Bolson, which is in the southern portion of a rift basin that extends for approximately 320 km in a north-south direction and has a width of 64 km at the broadest point. The northern portion of this rift basin, known as the Tularosa Basin, lies in southern New Mexico, and is separated from the Hueco Bolson by a minor topographic divide near the New Mexico-Texas boundary. Fresh ground water, defined as water with total dissolved solids (TDS) less than 1,000 mg/l, is found within the Hueco Bolson in an irregularly shaped wedge that borders the Franklin Mountains and the Organ Mountains of southern New Mexico. The fresh water overlays brackish water and, over a geologic time span, it is thought to have remained fresh due to mountain-front recharge. The zone of fresh water extends southward beyond the Franklin Mountains into the area beneath El Paso and Cd. Juárez, (TWDB, and WRRI 1997).

The Hueco Bolson began to be used for drinking water purposes during the first decade of the 20th Century. It has been heavily exploited for municipal and industrial purposes, and ground water withdrawals vastly exceed natural recharge. As a consequence, the water table has been drawn down, and a number of wells in the central portions of both El Paso and Cd. Juárez have had to be taken out of service due to the intrusion of brackish water. In 1979, the Texas Department of Water Resources published a report on ground water availability which projected that the Texas portion of the Hueco Bolson would be virtually exhausted of all economically-retrievable fresh water by the year 2030, (Muller and Price 1979). To forestall such an outcome, El Paso Water Utilities (EPWU), the quasi-independent municipal entity that provides water and wastewater services for the city of El Paso and some outlying Texas communities, has sought to develop alternative sources of water supply and lessen water demand. Nonetheless, the Hueco Bolson continues to provide a significant portion of El Paso’s water supply. Currently, EPWU has 69 operational and 13 blendable production wells in the Hueco Bolson that have a total capacity of 0.55 Mm³/day. During the year 2000, the Utility extracted 73.28 Mm³ of water from the Hueco Bolson, this representing approximately 47.1 percent of the total water demand in El Paso that year, (EPWU 2002).

The Junta Municipal de Aguas y Saneamiento (JMAS), the agency charged with providing water and wastewater services to Cd. Juárez, relies solely on the Hueco Bolson for the city’s drinking water supply. As of 1999, JMAS had 131 wells in production with depths varying from 200 to 400 m. Ground water withdrawals increased from 145.5 Mm³ in 1998, to approximately 150 Mm³ in 1999. Aquifer depletion is evidenced by the production rate changes in the JMAS’s primary well field, which declined from 55 l/s in 1977 to 41.8 l/s in 1998, (Lemus 1999). To place the issue of aquifer depletion in a different context, Lemus estimated that 3,008 Mm³ of ground water has been withdrawn from the Juárez portion of the Hueco Bolson since the inception of pumping in 1926. Estimates of the amount of natural recharge to the aquifer vary from 7 Mm³ to 35 Mm³ annually; using the ‘high end’ estimate of recharge, this represents a net reduction in ground water of approximately 488 Mm³ from pumping by Cd. Juárez alone, and most of this ground water ‘mining’ has occurred during the past two decades.

Mesilla Bolson / Conejos Médanos: Beginning in 1951, in response to then drought conditions, El Paso Water Utilities developed a well field in the Mesilla Bolson. The Mesilla Bolson is an extensive aquifer, but the vast majority of it lies in southern New Mexico and northern Chihuahua, (see Figure 4). A small portion of the Mesilla Bolson is in Texas, located in the northwesternmost portion of El Paso County, near the unincorporated community of
Canutillo. Hence, EPWU’s well field is locally referred to as the “Canutillo Well Field.” Currently, EPWU’s Canutillo Well Field consists of nineteen production wells, drilled to three different formations at varying depths, with a total capacity of 0.16 Mm$^3$/day. In the year 2000, the Mesilla Bolson supplied EPWU with a total of 30.44 Mm$^3$, representing approximately 19.6 percent of El Paso’s water supply, (EPWU 2002). In the 1980s, EPWU sought to gain access to the New Mexico portion of the Mesilla Bolson, but this effort was blocked by legal action, (see El Paso v. Reynolds, 597 Fed.Sup. 694, 1984). The decade-long period of acrimonious litigation between El Paso and the state of New Mexico ended in 1991 with a settlement agreement that established a basis for cooperative planning activities, but neither enabled nor totally precluded future cross-state transfer of ground water.

While only a small portion of the Mesilla Bolson is in Texas, this aquifer does extend into Mexico, where it is known as the Conejos Médanos. It lies west of the Sierra de Juárez, whereas the developed area of Cd. Juárez lies east of these low mountains. Limited public information is available regarding the lateral extent, saturated thickness or water quality of the Conejos Médanos, but the little information that is available suggests that it may be mildly brackish. Currently, JMAS obtains all of its water from ground water and relies solely on the Hueco Bolson, but investigations have begun regarding the feasibility of using the Conejos Médanos as a supplemental source of water. Under this scenario, water would be extracted from the Conejos Médanos, and then delivered to the developed area of Cd. Juárez via a transmission line, most likely looping south of the Sierra de Juárez.

**Ground Water Production Costs:** The cost of developing and maintaining well fields is a consideration in water supply. Ground water production costs have exhibited a marked increase over the last three decades. This increase is shown in Figure 5 titled, “Ground Water Production Costs for EPWU.” Ground water production costs, adjusted for inflation, increased from less than five cents per m$^3$ in 1971 to approximately 10 cents per m$^3$ in 1995. The primary factors influencing ground water production costs are pumping costs and well replacement. Another factor is the increasing salinity of ground water. Both Texas and Mexico limit salinity for public drinking water supplies to 1,000 mg/l of total dissolved solids (TDS), (Secretaría de Salud, E.U.M. 1999). EPWU and the JMAS each have been forced to remove approximately 25 wells from production because the TDS concentrations reached the 1,000 mg/l level, thus limiting the useful life of the well and the time over which initial costs can be amortized. The JMAS laboratory reported that, as of 1999, 12% of its ground water wells tested exceeded TDS limit of 1,000 mg/l, with the maximum reported exceedance being 1,600 mg/l, (PDNWTF 2001).

![Figure 5. Ground Water Production Costs for EPWU](image-url)
**Rio Grande/Río Bravo:** The Rio Grande/Río Bravo provides a replenishable source of water to the Paso del Norte. It rises in the San Juan Mountains of southern Colorado, with its headwaters lying at an altitude of over 4,000 m. Initially, the river flows easterly to the San Luis Valley in southern Colorado, then turns south and continues in a southerly alignment, bisecting the state of New Mexico. Snowmelt from the higher elevations provides the major source of water for this river. Evapotranspiration losses from intensive upstream irrigation use and evaporation from reservoir surfaces act to diminish the river’s flow and degrade its quality as it makes its way to the Paso del Norte. The flow of the Rio Grande/Río Bravo is controlled by a series of upstream dams, the largest and first to be built of which is Elephant Butte Dam, completed in 1916 by the U.S. Bureau of Reclamation. Releases of water from the dam are based primarily on the needs of downstream irrigators. A graph of Rio Grande/Río Bravo flows from 1888 through 1998 is shown in Figure 6. The graph includes surface flows from both before and after the construction of Elephant Butte Dam. Note the lessened variability in flow following the completion of the dam.

![Graph of Rio Grande/Río Bravo Annual Flows](source)

Figure 6. Rio Grande/Río Bravo Annual Flows between Stream Gauges at Elephant Butte, Caballo, & El Paso
(Source: Landis 2001)

Surface water in the Paso del Norte is allocated by a series of legal instruments. Internationally, water is shared between the two countries by the Mexican Water Treaty of 1906. This treaty commits the United States to annually deliver 74 Mm$^3$ of water to Mexico, (U.S. Dept. of State 1944). Together with its sister treaty, the Mexican Water Treaty of 1944, the two treaties allocate virtually all of the water resources of the Rio Grande/Río Bravo between the two countries from El Paso to the Gulf of Mexico. It is noteworthy that Mexico’s 74 Mm$^3$ share of the Rio Grande/Río Bravo represents only about 10 percent of the total surface water available in the Paso del Norte during ‘normal’ flow years. The reasoning behind this low allocation, at the time the Treaty was negotiated, had to do with the amount of farmland then in production in the Juárez valley, and the fact that Mexico did not financially participate in the construction of Elephant Butte Dam. Today, this small allocation limits options for providing surface water to meet the municipal water needs of Cd. Juárez.
On an interstate basis, water from the Rio Grande/Río Bravo is managed by the Rio Grande Compact that apportions the river’s flow between the states of Colorado, New Mexico and Texas. On a local level, irrigation water is managed by the region’s three irrigation districts: in New Mexico, by the Elephant Butte Irrigation District; in Texas, by El Paso County Improvement District No. 1 (EPCWID); and in Mexico, by Distrito de Riego 009, a sub-unit of the Comisión Nacional de Agua, (CNA). The overwhelming majority of surface water is used for irrigation purposes in the Paso del Norte.

Currently, EPWU is the only municipal utility that uses surface water for a portion of its drinking water supply. EPWU’s first surface water treatment plant was built in El Paso in 1943. Initially it had a capacity for treating 0.7 m$^3$s$^{-1}$. It was expanded in 1967, boosting its capacity to 1.75 m$^3$s$^{-1}$. A second surface water treatment plant, with a capacity of another 1.75 m$^3$s$^{-1}$ was developed, and is currently being further expanded. EPWU receives surface water via the irrigation canals of the EPCWID. In 2000, EPWU diverted and treated a total of 51.7 Mm$^3$ of surface water for drinking water supply purposes, this representing the remaining 33.3 percent of its supply that year, (EPWU 2002).

Cd. Juárez, as noted previously, currently relies on the Hueco Bolson as its sole source of drinking water supply. Discussions are underway regarding the development of a surface water treatment plant, but a number of factors impede implementation of this action. Recall that Mexico is only allocated 74 Mm$^3$ of surface water annually. Even if all this water were to be used for municipal and industrial purposes, this quantity would meet only half of the current water demand of Cd. Juárez. Further constraining this option, laterally-extensive well fields serve a relatively decentralized water distribution system in Cd. Juárez, whereas economies of scale will dictate that a surface water treatment plant feed a more centralized system. This will require upgrading portions of the distribution infrastructure of Cd. Juárez.

**Surface Water Production Costs:** While the region’s fresh ground water is high quality, biologically inactive, and requires only chlorination before its use, surface water requires expensive treatment before it can be used for drinking water purposes. An example of surface water treatment costs, adjusted for inflation, is provided in Figure 7 titled, “Cost of Rio Grande/Río Bravo Surface Water Production based on EPWU Canal Street Plant.” Note the large year-to-year variations in cost. This is due to relatively fixed operational costs but variable inflow volume. In low-flow years, this drives up the per unit production costs. During the period of record, the costs of surface water treatment were almost always higher than ground water treatment, often markedly so. Surface water treatment costs are likely to climb higher still due to escalating costs of surface water acquisition.

A problem common to both cities is that surface water releases are currently timed for delivery from late February through early October, based on the irrigation season. Consequently, EPWU is only able to operate its surface water treatment plants at full capacity for about eight months of the year and, should JMAS opt to develop a surface water treatment plant, it will be faced with the same problem. During the non-irrigation season, releases from the upstream reservoirs cease, and the resulting surface water flow is both too low and markedly poorer in quality in terms of TDS. Water quality improves again once water is released for the resumption of irrigation. The high TDS water during the non-irrigation season is a result of return flows from upstream irrigators. The improvement in water quality when irrigation resumes in the spring is due primarily to the dilution of return flows by copious quantities of lower-TDS reservoir water, and, to a lesser extent, due to a reduction of brackish baseflow as a result of high river stage, (IBWC, et al. 1998).
Article II of the 1906 Mexican Water Treaty specifies a delivery schedule for the 74 Mm$^3$ of water the U.S. is to supply to Mexico annually, (U.S. Dept. of State 1906). The schedule provides for deliveries from February through November. Over the last 40 years, by mutual agreement, the timing of deliveries has been altered to better meet the needs of irrigators on both sides of the border. In 2002, an order from Washington D.C. directed the IBWC to strictly adhere to the delivery schedule specified in the Treaty, (Herrera 2002). Such a change is advantageous to neither party. Water deliveries extending into November do not meet the needs of irrigators, and the U.S. must absorb the ‘carriage losses’ in making such late season deliveries. Some water professionals speculate that the interests of the Paso del Norte are being subordinated to the ongoing controversy over Mexico’s under-deliveries of water from the Río Conchos, some 320 km downstream.

Despite the higher costs and limited times of operation of surface water treatment plants, El Paso and Cd. Juárez have few other water supply options and both utilities are planning to use the Rio Grande/Río Bravo to meet their future water needs. This poses a different problem: surface waters are fully appropriated for use in irrigation. If cities in the Paso del Norte are to transition to greater reliance on the surface waters of the Rio Grande/Río Bravo, water must be converted from agricultural to municipal and industrial use. EPWU’s cost of acquiring Rio Grande surface water rights from EPCWID has been contentious at times and will inevitably lead to higher municipal water rates. The cost of acquiring surface water during the 1990s was $15 per acre-foot, ($12.16 per 1,000 m$^3$), the same as that of irrigators with water rights. The recent agreement, signed between the EPWU and EPCWID in 2001, raised the cost for additional water to more than $200 per acre-foot, ($160 per 1,000 m$^3$), (USBR 2001).

Legal constraints in gaining access to surface water may be less onerous for Cd. Juárez. While the U.S. Constitution is silent on the subject of water, Article 27 of the Mexican Constitution, as adopted in 1917, addresses the subject in rather considerable detail and declares virtually all water to be public, (Bath 1977). As a result, water law is markedly different on opposing sides of the border. This has significant implications regarding the conversion of water from agricultural to municipal and industrial use. On the U.S. side, property owners possess ‘water rights,’ giving the owners assured use of surface water. Water rights are generally regarded as appurtenant to and inseverable from the land. Such rights can be ‘perfected’ through an adjudication process. In Mexico, water rights, per se, have no meaning. Instead, the federal government, acting through the Comisión Nacional de Agua (CNA), grants ‘concessions’ for the
use of surface water. Consequently, the issue of converting water to municipal and industrial use is a political, rather than legal issue. To address the political concern, JMAS is investigating the feasibility of using surface water to supplement its drinking water supply, then ‘repaying’ Distrito de Riego 009 with treated wastewater. Basically, water from the Rio Grande/Río Bravo would first be treated and distributed to meet municipal and industrial needs, and then wastewater (the source of which includes both surface and ground water) would be collected, treated and used by Distrito de Riego 009 for irrigation.

The ability of the Rio Grande/Río Bravo to be used as a source of municipal and industrial water during an ‘average’ flow year is not in doubt as long as the water can be transferred away from agricultural use. Figure 8 titled, “Rio Grande Diversions from Elephant Butte to El Paso,” shows the annual diversions from the Rio Grande to the various water users below Elephant Butte Dam between 1950 and 1996. The reader should examine this figure closely and observe that nearly all of the water is allocated to agriculture uses. The very bottom line on the graph shows the quantity of water used by EPWU. Table 2 titled, “Summary of Rio Grande Project Water Statistics,” provides a partial summary of the data shown in the Figure. The table does not show water deliverables to EPWU, as EPWU receives its water from EPCWID. In 2000, EPWU received approximately 51.8 Mm$^3$ of Rio Grande/Río Bravo water via EPCWID. EPCWID receives 444 Mm$^3$ of water in a year of full supply, (meaning years when the Elephant Butte Reservoir has an ample amount of water in storage), but, in this example, only 268 Mm$^3$ when Elephant Butte has 606 Mm$^3$ available for release. This table and the accompanying Figure suggest that, provided an agreement can be reached that facilitates conversion of water from agricultural irrigation to municipal and industrial use, El Paso has access to large quantities of water during average years from EPCWID. The JMAS options are more limited due to Mexico’s lesser allocation of Rio Grande/Río Bravo water.

![Figure 8. Río Grande Diversions from Elephant Butte to El Paso](image)

Figure 8. Río Grande Diversions from Elephant Butte to El Paso
Table 2. Summary of Rio Grande Project Water Statistics (Source: USBR 1980)

<table>
<thead>
<tr>
<th>ITEM</th>
<th>EPCWID</th>
<th>EBID</th>
<th>MEXICO</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land with water rights *</td>
<td>27,927 ha</td>
<td>36,681 ha</td>
<td>8,029 ha</td>
<td>72,637 ha</td>
</tr>
<tr>
<td>Percent of total</td>
<td>38.5%</td>
<td>50.5%</td>
<td>11%</td>
<td>100%</td>
</tr>
<tr>
<td>Delivered at head gates when 606 Mm$^3$ are available for release</td>
<td>268 Mm$^3$</td>
<td>352 Mm$^3$</td>
<td>41 Mm$^3$</td>
<td>606 Mm$^3$</td>
</tr>
<tr>
<td>Delivered at head gates in years of full supply</td>
<td>444 Mm$^3$</td>
<td>586 Mm$^3$</td>
<td>74 Mm$^3$</td>
<td>1,104 Mm$^3$</td>
</tr>
</tbody>
</table>

* Note: Lands in Mexico do not have 'water rights' in the sense understood in the U.S. Rather, property owners are granted water use 'concessions' by the Comisión Nacional de Agua (CNA).

While the reservoirs act to lessen the variability in the Paso del Norte region’s surface water supply, prolonged drought years present a problem that is not easily solved. The drought of record in the Paso del Norte occurred during the 1950s. The past two decades, particularly the period from 1981 to 1993, was an unusually ‘wet’ period, and water rights holder in the Paso del Norte have enjoyed full allocations. Snowfall in the Colorado Rockies over the past three years has been meager, and inflows into the Elephant Butte reservoir in 2002 were less than 10 percent of average, (USBR 2002). Reservoirs are commonly operated for both water conservation purposes and flood control, this dual use meaning that a certain volume, or pool, of each reservoir is designated for water conservation and a separate pool for flood control. The combined conservation capacity of the Elephant Butte and Caballo reservoirs is 2,776 Mm$^3$; by of mid-September, 2002, the two reservoirs only impounded 340 Mm$^3$, and Elephant Butte Reservoir was reduced to less than 11 percent of its capacity, (USBR 2002). 1992 will almost certainly be the last year of a full allocation until such time as the current drought cycle ends.

Flows in the Rio Grande at El Paso during drought periods and average flow years are shown in Figures 9 and 10, titled “Average Flow Years at El Paso 1900-2000” and “Drought Flow Years at El Paso - 1955, 1956 & 1964” respectively. These figures indicate that flow at El Paso is reduced from nearly 1,200 cfs (34 m$^3$ s$^{-1}$) to less than 200 cfs (6 m$^3$ s$^{-1}$) during drought periods, meaning that both agricultural and municipal and industrial users must rely on ground water during these low-flow periods. Thus, the longer-term issue becomes one of allocation of ground water resources between different users during critical drought periods, an issue made more complicated by the decreasing availability and increasing salinity of the region’s ground water.

The Río Grande/Río Bravo is a highly regulated river with many reservoirs in both Colorado and New Mexico upstream of the Paso del Norte. These reservoirs are largely operated to meet the requirements of the Río Grande Compact, the legal agreement that allocates water between the states of Colorado, New Mexico and Texas. Most of the water originates in the San Juan and Sangre de Cristo mountains in southern Colorado and northern New Mexico. Historically, irrigation was widely practiced in the area between Albuquerque and El Paso long before it began to develop in San Luis Valley of Colorado. The principle of ‘prior appropriation’ was applied in the Río Grande Compact, thus ensuring a surface water supply to the Paso del Norte.
The distribution of surface water flows in the Rio Grande Basin are shown in Figures 11 and 12, titled “Average Flows for the Rio Grande” and “Average Low Flows for the Rio Grande,” respectively. These figures show the mean monthly flow for selected years that are representative of average and low-flow periods at gauging stations at: Lobatos, Colorado; Albuquerque, New Mexico; below Elephant Butte Dam; and at El Paso near its border with New Mexico. Figure 11, titled “Average Flows for the Rio Grande,” shows that flows in the Rio Grande/Río Bravo decrease as water is diverted for agricultural and municipal and industrial uses. Figure 12, titled “Average Low Flows for the Rio Grande,” shows the impact of the Compact and how Elephant Butte Reservoir is used to implement the terms of the Compact. The figure shows low monthly flows at the Lobatos, Colorado and Albuquerque, New Mexico gauges, but then a sudden increase at Elephant Butte Reservoir where water, held in storage from previous years, is released to meet Compact obligations. Water reaching the El Paso gauge diminishes between the two points due to utilization by the Elephant Butte Irrigation District in New Mexico as provided by the Compact.
Figure 11. Average Flows for the Rio Grande

Figure 12. Average Low Flows for the Rio Grande
Brackish Ground Water Resources: Underlying the fresh water portion of the Paso del Norte region’s aquifers are considerable, though poorly documented, quantities of brackish water. The mineral content of the region’s brackish ground water varies from 1,200 to 3,000 mg/l. Recall that 1,000 mg/l is the legal upper limit for TDS for municipal water in both Texas and throughout Mexico. Thus brackish water cannot be used without desalination.

Permeate, the low TDS product water from desalination, can be blended with high TDS well water from the same aquifer, which was previously unusable because of its high salinity, to achieve a finished TDS concentration of less than 1,000 mg/l. Blending these two waters enhances the yield of usable water. Membrane desalination technologies have advanced and the cost of desalination is becoming more economic. Desalination, however, generates saline concentrate, the disposal of which poses a challenge for in-land locations. While membrane desalination costs less than 13 cents per m$^3$ for large facilities, disposal of the resulting concentrate that contains the salts from the product water can easily triple this cost for landlocked municipalities like El Paso and Cd. Juárez.

Thus far, two small utilities in El Paso County have employed reverse osmosis treatment to exploit the region’s brackish ground water resources. Although none of the larger utilities in the region are currently employing desalination treatment, recently EPWU and Fort Bliss, a U.S. Army facility in the El Paso area, entered into an agreement to develop a large-scale, 1.23 m$^3$s$^{-1}$ membrane desalination treatment plant to supplement their water supplies. The JMAS is also investigating desalination options.

Outlying Ground Water Resources: Both EPWU and the JMAS are seeking access to ground water resources in their outlying areas as a means of supplementing local supplies. In the mid-1990s, EPWU acquired two large ranches, the Antelope Valley Ranch and the Wild Horse Valley Ranch, located in west Texas approximately 180 km east of El Paso, to secure access to the potentially significant quantities of underlying ground water. A private investment company proposed a similar ground water importation scheme for property in the vicinity of Dell City, Texas, a small community located approximately 120 km east of El Paso. On April 13, 2002, the El Paso Times reported that EPWU had taken an option on 10,000 ha of property in the Dell City area to secure the underlying water rights, (Williams 2002). While preliminary feasibility analyses have been performed regarding the importation of water from these sources, EPWU contends that importation options represent only a contingency to assure future water supply for El Paso. Residents of the small nearby west Texas communities expressed vehement opposition to this proposal, and the issue of potential future ground water importation became a major stumbling block in the final adoption of the Far West Texas Water Plan, a component of a regional planning approach that the Texas Legislature had mandated as part of an update of the overall water plan being prepared by the Texas Water Development Board. The ultimate wording of the regional water plan strategy included a statement to the effect that, prior to effectuating any ground water transfers, further hydrological studies of the affected aquifers would be needed to fully address potential impacts of such ground water exportation, (RGCOG 2001).

The JMAS of Cd. Juárez is also considering importation of ground water from outlying areas. In addition to investigating the option of utilizing ground water from the nearby Conejos Médanos, the JMAS has proposed using the ground water from Bismark Mine, located approximately 120 km west of Cd. Juárez in northern Chihuahua, as a source of additional drinking water supplies, (JMAS 2001). Unfortunately, no feasibility studies have been performed regarding this option, and the amount and quality of ground water available at the Bismark Mine is largely unknown. Financial limitations hamper the JMAS from fully evaluating this option.
Wastewater Reuse: Treated wastewater is a potential means of supplementing municipal water supplies. In the early 1980s, EPWU’s constructed a wastewater treatment plant that employs tertiary water treatment and annually re-injects as much as 3.6 Mm$^3$ of treated wastewater into the Hueco Bolson, (EPWU 2002). More recently, EPWU has instituted an aggressive water reuse program using special distribution lines from its wastewater treatment plants to provide water for irrigating parks and school playing fields, and EPWU is marketing this reclaimed water for non-potable industrial uses. The JMAS’s initial foray into wastewater reuse has been to provide treated wastewater for use in irrigating the large Chamizal Park. More extensive reuse of treated wastewater by JMAS will be limited by the poor quality of treated effluent, as JMAS’s two recently completed wastewater treatment plants only provide primary treatment.

All water has value in arid regions. Obviously, throughout the length of the Rio Grande/Río Bravo, irrigation return flows and wastewater discharges into the river are put to beneficial use downstream. Over time, wastewater discharges from municipalities have represented a supplement to streamflow because most cities’ water supplies are drawn from ground water. As cities throughout the length of the Rio Grande/Río Bravo transition to conjunction water use of both surface and ground water, the net effect will be a reduction in streamflow. And, just as cities are recognizing the potential value of their treated wastewater, downstream irrigators are becoming concerned with the potential consequences of reduced wastewater discharge and they are seeking to protect this source of water. Recent tri-party contracts between EPWU and EPCWID, whereby EPWU is able to purchase additional surface water, also obligate EPWU to discharge part of its wastewater into EPCWID’s irrigation canals, thus reducing the amount of treated effluent available for its urban water reuse program, (USBR 2001). The JMAS may be faced with a similar challenge, as some industries have expressed interest in using its treated wastewater, and this will reduce the amount of such water JMAS can provide to downstream Distrito de Riego 009 irrigators.

**IMPACTS OF WATER USE**

The human appropriation of water resources has repercussions on both physical and natural systems. Water management must always be cognizant of the impacts of water use.

**Water Quality Impacts:** Discussion of water quantity is incomplete unless it is coupled with a discussion of water quality. The water quality parameter of greatest interest is salinity as represented by TDS. Snowmelt runoff from the Rio Grande/Río Bravo headwaters in the mountains of Colorado is nearly free of dissolved minerals. By the time the water reaches Elephant Butte Reservoir, the TDS has reached approximately 300 mg/l. A TDS concentration of 300 mg/l contains a solids mass of 0.4 tons per acre foot (1.46 kg/m$^3$) of water. This value can be contrasted with values seen in Figures 13 and 14, respectively titled “Total Annual Salt Load at El Paso, 1933-1994” and “El Paso Annual Mean Salt Load in Tons per Acre-Foot, 1933-1994.” The total salt load graph shows a distinct decrease in total salts at El Paso from approximately 1950 onward. Large increases in the use of ground water occurred about this time and continue to the present. Since ground water pumped for irrigation generally has a higher TDS than surface water from the Rio Grande/Río Bravo, the salt load would be expected to have increased. The cause of this anomaly is unknown at this time. Figure 14, showing the tons of salt per acre-foot of water, indicates this trend with salt load averaging about one ton per acre-foot (3.6 kg/m$^3$) of water. This represents an increase of 250 percent between Elephant
Butte Reservoir and El Paso. This salt load significantly impacts both agricultural and municipal and industrial uses, as agricultural productivity is impaired and the value of the water for municipal and industrial uses decreases with increasing salt concentrations.

Figure 13. Total Annual Salt Load at El Paso, 1933-1994

Figure 14. El Paso Annual Mean Salt Load in Tons per Acre-Foot, 1933-1994

Figure 15, titled “Flow vs. Total Salts at El Paso, 1933-1994,” shows the variability of salt load with total annual flow. The linear relationship indicates a relatively constant salt load for similar total annual flows measured in acre-feet. Figure 15, titled “Total Cumulative Salt at El Paso, 1933-1994,” shows the sum of salts at El Paso when totaled for each successive year. A straight-line relationship with a constant slope would indicate that the salt load has remained constant over time. There is some variability, however, and a change in slope can be seen in about 1950.
Ecosystem Concerns: In July of 1998, President Clinton, by Executive Order 13061, designated the Texas portion of the Rio Grande/Río Bravo as an “American Heritage River.” Such designation was to be based, in part, on “characteristics of the natural, economic, agricultural, scenic, historic, cultural, or recreational resources of the river that render it distinctive or unique,” (Clinton 1998). For such designation to be given to the reach of the river in the El Paso-Cd. Juárez region reflects support for efforts to restore the river, rather than a statement of the river’s current condition.

Elephant Butte Dam, completed in 1916, is located in Sierra County, New Mexico, approximately 160 km upstream of El Paso. The dam provides flood protection, and the storage and controlled release of impounded waters from both Elephant Butte Reservoir and Caballo Reservoir (completed by the U.S. Bureau of Reclamation in 1938 and located immediately downstream of Elephant Butte) facilitated the agricultural development of the river floodplain.

The managed release of water for irrigation purposes has consequences for both the rate of flow and the quality of the water. The flow rate, measured at a gauging station upstream of El Paso, during the peak of the irrigation season in July, averages more than 34 m$^3$/s; in January, flows at this same station are reduced to 8.5 m$^3$/s, and represent primarily return flows from
irrigated lands upstream of the cities but downstream of the reservoirs, (Turner, Quezada, and Troncoso 1998). Water quality in this reach of the river varies with the flow rate in an exponential manner: total dissolved solids (TDS) range from less than 500 mg/l for flows greater than 40 m$^3$/s, to over 1,000 mg/l for flows less than 10 m$^3$/s, (Bahr, Keyes, Jr., and Kenny 1998). The seasonal fluctuation in flow and water quality not only limits the time periods during which surface water treatment plants can operate; it stresses aquatic life. Today, the river supports only a fraction of the number of species once present.

The Rio Grande/Río Bravo channel in the Paso del Norte has been considerably altered. In the mid-1930s, two projects, the Rio Grande Rectification Project along the international border and the Rio Grande Canalization Project in southern New Mexico, eliminated the river’s meanders and forever altered the riparian habitat throughout approximately 200 km of the river valleys of Doña Ana County, New Mexico and the reach between the Texas counties of El Paso and Hudspeth and the Chihuahuan municipios of Juárez, Guadalupe and Praxedis G. Guerrero.

In the mid-1960s, the Chamizal Settlement (a resolution to a 100-year old boundary dispute between the two countries) resulted in the relocation of the river channel between the central, most densely settled portions of both El Paso and Cd. Juárez. The new realigned segment of the river now flows through a five km long concrete-lined trapezoidal channel. Immediately upstream of this reach of the river, the American Dam and International Dam divert surface flows into the principal irrigation canals serving El Paso and Juárez respectively. The river below is depleted of water – so much so that EPWU sought to commission a study to have the Rio Grande/Río Bravo from the International Dam diversion to below the Utilities’ Haskell Street Wastewater Treatment Plant classified as ‘intermittent,’ meaning that it has a flow of less than 0.003 m$^3$/s at least once every two years, (TAC 2002). The Utilities’ interest in this classification is understandable since, by so doing, it will have to meet less stringent discharge standards for its wastewater treatment plant. Yet, such designation for an ‘American Heritage River’ is ironic.

Downstream of the two cities, irrigated farmland makes extensive use of the available water. By the time the Rio Grande/Río Bravo passes the Fort Quitman gauging station in eastern Hudspeth County, the river’s flow is substantially depleted and its quality is significantly impaired. This marks the beginning of a reach of the Rio Grande/Río Bravo that is commonly referred to as the “Forgotten River.” From this point, the main stem of the river does not have any significant stream inflow until it is joined by the Río Conchos, some 320 km downstream. Water quality in this lower reach commonly exceeds 2,000 mg/l. Unable to transport sediment, the low flow-rates cause aggregation of the river channel. The lack of disruptive flood waters and the poor quality of the water have accelerated the spread of invasive Saltcedar (Tamarix sp.), further impoverishing the habitat.

An example of the continued impact of competition for water resources is the Rio Bosque Wetlands Park, located in the southeast portion of El Paso County. The park, approximately 150 hectares in size, lies adjacent to the Rio Grande/Río Bravo and, in fact, prior to the river rectification project, the site was part of one of the river’s meanders. Cut-off by the rectification project, the site was left undeveloped and remained federal property until, 40 years later, when title was conveyed to the city of El Paso to enable the development of a park. No development ensued until, in the late 1990s, the International Boundary and Water Commission (IBWC) approached the city with the concept of developing a wetlands park, as the IBWC was obligated to ‘mitigate’ other wetlands being disrupted by a canal extension project, (Watts, Sproul, and Hamlyn 2002). It was anticipated that water would be provided to the park from an adjoining EPWU wastewater treatment plant. Unfortunately, the wastewater plant’s effluent is allocated to EPGWID, and generally, the wetlands park only receives water during the non-irrigation season. The lack of water during the spring and summer months all but precludes the reestablishment of
native riparian plant species. In the future, water supplied to the park may be further reduced as EPWU’s water reuse program is expanded.

**Ground Water/Surface Water Interaction:** Historically, water laws have treated surface water and ground water as though they were distinct. In rare instances, surface water flows are separate from underlying ground water by virtue of intervening aquicludes, defined as extreme low-permeability soil stratum that will not transmit ground water. More commonly, ground water and surface water ‘communicate.’ Examples of the interrelationship of ground water and surface water in the Paso del Norte include a noticeable lowering of the water table in the central portion of El Paso and Cd. Juárez following the concrete-lining of a reach of the Rio Grande/Río Bravo described previously (the surface water no longer able to recharge ground water), and diminished surface flows in vicinity of EPWU’s Canutillo well field due to a lowering of the water table, (Walton and Ohlmacher 2000).

Water laws are evolving to account for the interaction of ground water and surface water. New Mexico water law expressly acknowledges ground water/surface water interaction, and further applies the principle of ‘prior appropriation’ to both surface water and ground water. Texas water law applicable to ground water is based on the ‘right of capture.’ This allows a landowner the unfettered right to pump ground water from their property without regard to the impact on neighboring ground water users nor being held accountable for the impact on hydraulically-connected surface waters. This somewhat antiquated system may cause problems in the future. Although Texas water law does not acknowledge the interaction of ground and surface water, recently negotiated agreements between EPWU and EPCWID have taken this factor into account, (USBR 2001). Mexico, by virtue of public control of both surface and ground water, is positioned to be able to manage the interaction of ground water and surface water.

**WATER DEMAND IN THE PASO DEL NORTE**

**Basic Principles:** Water demand, for any given geographic area, is the aggregate of all categories of human water use, including irrigation water for agriculture, livestock use, electrical power cooling, manufacturing and industrial use, domestic use, and other urban uses. To the extent that native riparian environment is valued, this element may be incorporated in minimum instreamflow requirements, but generally it is not recognized as a source of water demand. Water use, however, need not imply water consumption. Consumptive water use, in the most complete sense of the term, involves a change in the state of water, namely the conversion of H₂O from either a solid (ice) or liquid, to that of a gas (water vapor), for once vaporized, water is lost to the atmosphere. The dominant water ‘sinks,’ or absolute loss of water from a region are evaporation from reservoir surfaces and evapotranspiration – this term including both the loss of water from soil by evaporation and by transpiration from the leaves of plants. In the first instance, evaporation from surface reservoirs, the amount of loss is not trivial.

When Elephant Butte Dam was built, it impounded a reservoir over 65 km in length that was touted as being one of the largest man-made lakes in the world. Pan evaporation data for this location averages almost three meters annually (NMSU 1995). The reservoir’s vast surface area results in a significant evaporative loss of water. While evaporation is a factor of a number of variables, such as temperature, humidity, solar gain, wind speed and reservoir pool size, annual evaporative loss from Elephant Butte and Caballo reservoirs generally approximates seven percent of the average volume in storage, (Landis 2002).
Water contamination, whether from natural sources (such as minerals dissolved in ground water), or human sources (such as pesticides and high levels of nutrients from agricultural runoff, pathogens from human waste, or heavy metals and anthropogenic chemicals urban runoff), limits the range of potential uses of water. Technologies exist that can ‘treat’ water to remove contaminants, but the level of treatment, and cost thereof, vary depending on the intended subsequent use of the treated water.

**Agricultural Water Demand:** The adopted *Far West Texas Region Water Plan* noted that, although irrigated land represents less than one percent of the total land in its seven county planning area, this category is the largest source of water demand, (RGCOG 2001). The generalization that irrigation is the dominant user of water is relevant to the Paso del Norte, defined here as including Doña Ana and El Paso counties and the Juárez Municipio, as collectively, these three jurisdictions form a geographically comprehensive area with regard to the region’s water resources. As part of study of comparative approaches to water planning, undertaken by a voluntary organization known as the Paso del Norte Water Task Force, data was compiled on water use from all sources (ground water and surface water) within the region. Figure 17 shows total water use during 1999 in the Paso del Norte. Irrigation accounted for more than three-quarters of the total 1,500 Mm³ of water that was used that year, (PDNWTF 2001). The summation of water used by the three irrigation districts exceeds the amount of water diverted from the river primarily due to reuse of water, in the form of irrigation return flows, by downstream irrigators.

![Figure 17: Paso del Norte Water Use in 1999](source: PDNWTF 2001)

Of special note is the quantity of water, some 197.4 Mm³, used by Distrito de Riego. This far exceeds the 74 Mm³ of ‘Treaty water’ provided under the 1906 Mexican Water Treaty, because irrigators in the Juárez valley supplement their irrigation allotment with water from other sources. For example, in 1998, only 38 percent of the water used by Distrito de Riego irrigators was surface water, (i.e. ‘Treaty water’ from the Rio Grande/Río Bravo), while another 38 percent was wastewater from Cd. Juárez, and the remaining 24 percent was pumped ground water,
Thus, in large measure due to the limited surface water allocation México receives, agriculture in the Juárez valley is also a significant user of the region’s ground water.

Whereas agricultural water use is constrained based on the amount of arable land and the historic allocation system as codified in water rights, municipal growth is relatively unconstrained, and thus the increasing demand for water in the Paso del Norte is driven by urban water use. If cities in the Paso del Norte are to transition from dependence on ground water to conjunctive use of both surface and ground water, surface water will have to be ‘converted’ from agricultural to municipal and industrial use. The combined effects of agricultural displacement by urban expansion and EPWU’s increased use of surface water, would be expected to have resulted in a decline in the land area devoted to irrigated agriculture in the region. Experience indicates otherwise. According to data compiled by the Texas A&M University’s Agricultural Research and Extension Center in El Paso, and for Distrito de Riego 009 by the Department of Rural Development in Mexico, from 1979 through 1999, the amount of cropped land area in the Paso del Norte remained relatively stable. Ironically, only cropped land area in Doña Ana County, the jurisdiction with the smallest urban population, noticeably declined, though only by about 6 percent, (PDNWTF 2001).

A different issue concerns the type of crops that are being grown. Over the past several decades, traditional row crops grown in the region such as cotton, alfalfa and chilies have been displaced by groves of pecan trees. Pecan trees require more irrigation water than many of the crops they replaced, but, more importantly, unlike an annual crop, pecans represent a multi-year commitment. This creates for a somewhat inflexible demand for irrigation water. This inflexibility is reflected in the recently negotiated tri-party agreement, whereby EPWU obtains water from EPCWID, which contains provisions that place EPWU in a position analogous to a ‘junior water rights holder,’ (USBR 2001). During years of low-flow, less surface water will be available to EPWU. Recall that the past two decades have been relatively ‘wet’ years; during drought conditions, cities will be almost totally reliant on ground water.

Municipal and Industrial Water Demand: Municipal and industrial water use sums all categories of urban water use. Normalizing the total quantity of water used by the population served allows the water use characteristics of different cities to be compared. El Paso and Cd. Juárez are markedly dissimilar in their rates of water use. In 1999, EPWU customers used an average of 617 liters/person/day; customers of the JMAS used an average of 321 liters/person/day, (PDNWTF 2001).

The recently adopted Far West Texas Region Water Plan broke down water demand by: municipal; irrigation; manufacturing and industrial; electric power cooling; livestock; and mining. Both population and demand for water were projected in 10-year intervals to the year 2050. By the end of the 50-year planning horizon, total water demand in El Paso County, from all sources of water, was projected to be 522.03 Mm$^3$, of which 64 percent was municipal and industrial water use. Irrigation water use was expected to decline by approximately 20 percent, based on expected agriculture-to-municipal and industrial use conversions. The plan notes that EPWU contends that the conversion rate will be “significantly greater” than reflected in the plan, (RGCOG 2001).

JMAS also developed a master plan incorporating projections of population, future water demand, and needed infrastructure improvements. Indicative of a difference in perspective, whereas the Far West Texas Region Water Plan has a 50-year planning horizon, the Ciudad Juárez Plan Maestro para el Mejoramiento de los Servicios de Agua Potable, Alcantarillado y Saneamiento, (Cd. Juárez Master Plan for the Improvement of Potable Water Services, Water Storage, and
Wastewater Treatment), only has a 20-year planning horizon. Similarly, public agencies in México generally do not project population growth more than 20 years into the future. Among the analytical elements of the JMAS plan was a projection of the sources of water demand, as shown on Table 3. Consistent with the JMAS water billing system, household water use was broken down into four separate income categories. Non-domestic water demand was projected based on a ratio per household. Neither a significant increase in income level nor a significant change in per capita use is implied by this analysis. This suggests a relatively low aggregate water demand, markedly lower in Cd. Juárez than in its ‘sister’ city El Paso. The lack of any significant projected change in income levels has implications regarding the community’s expectations for its future.

<table>
<thead>
<tr>
<th>Use</th>
<th>Allocation l/person/day</th>
<th>Allocation l/hshld./mo.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-income</td>
<td>270</td>
<td></td>
</tr>
<tr>
<td>Moderate-income</td>
<td>339</td>
<td></td>
</tr>
<tr>
<td>Middle-income</td>
<td>386</td>
<td></td>
</tr>
<tr>
<td>Upper Middle-income</td>
<td>521</td>
<td></td>
</tr>
<tr>
<td>Commercial</td>
<td></td>
<td>88.06</td>
</tr>
<tr>
<td>Industrial</td>
<td></td>
<td>802.06</td>
</tr>
<tr>
<td>Public</td>
<td></td>
<td>402.30</td>
</tr>
</tbody>
</table>

Table 3. JMAS Projected Sources of Water Demand
Source: Elaborado para el Plan Maestro, 1999

**Balancing Supply and Demand**

Water scarcity is an issue of increasing concern for both El Paso and Cd. Juárez. Scarcity, however, is a relative term. Scarcity of water, at least in the near term, means scarcity of ‘cheap water.’ It is the supply of inexpensive ground water is being rapidly depleted. Future urban water demand must be met by converting Rio Grande/Río Bravo surface water from agricultural to municipal and industrial use, or by desalinating brackish ground water supplies, or by importing water from outside the region. All of these options are very expensive compared to pumping and distributing high quality ground water.

Supply and demand can be balanced by increasing the former or reducing the latter. ‘Demand management’ is a term that refers to a holistic approach that integrates water conservation with water resource planning, and it includes evaluating the determinants of water demand, the impact of water pricing structures and financing alternatives, and the effectiveness of water conservation programs, (Bauman, Boland, and Hanemann 1998). Numerous efforts and programs are underway in the Paso del Norte to effect a reduction in per capita demand for water.

**Reducing Demand:** Logically, it would seem that the most effective means of reducing water demand would be to increase the price of water. in fact, many empirical studies have demonstrated that consumers do respond to increasing water prices by reducing their consumption (Boland et al. 1984). Some recent research, however, argues that price increases alone have limited effect, and instead researchers advocate that a suite of coordinated, non-price
conservation programs can be more effective at reducing demand than simple water rate hikes. Rate increases themselves were found to be most effective when implemented through graduated rate structures and coupled with public education programs. Summertime outdoor domestic irrigation was found to be the most responsive, though a price elasticity of 0.2, (the percentage decrease in water use in response to a given percentage increase in cost), was the most that could be expected, (Michelsen, McGuckin, and Stumpf 1998). Given the relatively low-incomes of Paso del Norte residents, using large rate increases to reduce water use is unlikely to find political favor.

The approach to educating the public regarding the importance of water conservation differs north and south of the border. On the U.S. side, the focus is on developing a greater awareness of water usage, educating the public regarding means of conserving water (e.g. using water efficient appliances and fixtures, and landscaping with drought-tolerant plant species), and trying to instill an environmental ethic. In Mexico, much of the focus is on changing a basic attitude regarding water, often expressed as changing the “culture” of water. Part of this stems from Article 27 of the Mexican Constitution, described earlier, that declared all the country’s water resources to be public. Taken literally, if all water is public, some individuals contend that they should not have to pay for what is already theirs. In practice, water supply systems in Mexico have been heavily subsidized, and users are accustomed to paying very little for their water. An attitudinal change is needed to gain public acceptance for higher water rates, metering individual users, charging based on use, and accepting different levels of charges as are embodied in graduated rate structures.

EPWU has instituted a broad range of programs designed to reduce per capita consumption. Among the elements of EPWU’s strategy have been changes in the local plumbing code to require more water-efficient fixtures, implementing a graduated block rate structure, enacting an ordinance that limits the time-of-day during which residents can engage in outdoor irrigation, incentive programs to encourage xeriscaping and to encourage replacement of older, less efficient plumbing fixtures, and an aggressive public education campaign to raise public awareness of the need to conserve water. EPWU’s approach to reducing per capita consumption appears to have had its intended impact. Figure 18 shows a comparison in changes in per capita water consumption by EPWU customers and JMAS customers over a 28-year time period. Note the reduction in water demand by EPWU customers since the advent of an aggressive demand management program in the early 1980s. The price of water cannot have been a significant factor in this change. In fact, a recent survey, conducted by NUS Consulting Group, found EPWU to have the fourth lowest water costs among 51 water systems across the U.S that were surveyed, (Kolenc 2001). Buoyed by its success in attaining previously established water conservation goals, the managing Board of EPWU recently adopted a goal of further reducing per capita demand to 530 liter/day.

The JMAS has also developed programs to reduce water demand in Cd. Juárez. Like EPWU, the JMAS promotes water conservation through various public education efforts and in partnership with a non-governmental organization known as Aqua XXI. Some of the challenges faced by the JMAS are, by American standards, very basic. The JMAS has worked to meter water consumption, but many service connections remain un-metered. As of 1999, only 59 percent of registered users (representing 92 percent of total accounts) had water meters, and only two-thirds of those meters were regarded as functioning properly and read on a regular basis, (JMAS 2001). The relatively unchanged per capita water demand by JMAS customers, as shown in Figure 18, may not indicate a lack of effectiveness in the JMAS water conservation programs. Given that the average Juarenzes uses less than 60 percent as much water as the average El Pasoan, dramatic reductions in water use should not be expected.
The two cities have taken different approaches in developing graduated rate structures as a means of discouraging excessive water use. One of the issues involved in developing a rate structure is to ensure that the poorest citizenry are able to afford sufficient water for their basic needs. That poses a challenge given that the number of individuals sharing a domicile (and therefore on a single account) vary from single-person households to large families. EPWU addressed this concern by tying excess volume charges to a percentage of the average winter consumption (for which the months of December, January and February are used), as outdoor irrigation use is minimal during the wintertime. JMAS uses a different approach. JMAS assesses water use fees based on a combination of usage and account location, the latter based on an assessment of the character, (and likely household income), of the neighborhood. For billing purposes, JMAS divides Cd. Juárez into a series of zones, and assigns each zone into one of four categories based on the assumed average household income level. Table 4 provides a summary of the number of connections based on the household economic income level categorization as of 1999. Note the relationship of average household consumption and economic level. Given that family size tends to reduce with rising income, this suggests a strong correlation between per capita water use and income level.

### Table 4. Water Consumption of JMAS Household Accounts, 1999
(Source: Lemus 1999)

<table>
<thead>
<tr>
<th>Household Economic Level</th>
<th>No. of connections (Dec. 1999)</th>
<th>Annual Volume (m³)</th>
<th>Average Consumption (m³/household/month)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-income</td>
<td>80,275</td>
<td>28,308,600</td>
<td>30.15</td>
</tr>
<tr>
<td>Moderate-income</td>
<td>96,726</td>
<td>36,007,559</td>
<td>31.76</td>
</tr>
<tr>
<td>Middle-income</td>
<td>35,352</td>
<td>14,851,458</td>
<td>35.07</td>
</tr>
<tr>
<td>Upper middle-income</td>
<td>19,660</td>
<td>8,205,669</td>
<td>34.88</td>
</tr>
<tr>
<td>Total</td>
<td>232,013</td>
<td>87,373,286</td>
<td>31.38</td>
</tr>
<tr>
<td>Weighted Average</td>
<td></td>
<td></td>
<td>31.38</td>
</tr>
<tr>
<td>Arithmetic Average</td>
<td></td>
<td></td>
<td>32.97</td>
</tr>
</tbody>
</table>
While household income and water use appear to be correlated, the rate of water consumption for families reliant on hauled water is dramatically lower than for households served by public water systems. The Paso del Norte provides a dramatic illustration of this phenomenon. In Cd. Juárez, outlying areas beyond the limits of the JMAS water lines are served by water haulers, known as pipas, that provide between 760 and 1,900 liters of water per week to homes within which typically reside four or five individuals. Using the midpoint of this range, and assuming a four-person household, this represents an average domestic water use of approximately 50 liters per person per day.

A similar situation exists across the border in El Paso County. Developments at the margins of the city of El Paso sometimes lack water, or wastewater, or both. Such developments are the legacy of the laissez-faire attitude embodied in the relatively weak land development laws of Texas that allowed unscrupulous developers to sell building lots in marginally-improved subdivisions, often by contract-for-deed, to low-income purchasers. Perhaps because many of the purchasers of these lots were recent émigrés from Mexico, the resulting developments came to be known as colonias. Water service to homes in colonias is often provided by delivery trucks, registered by the Texas Commission on Environmental Quality, that refill 9.5 m³ capacity individual storage tanks on a monthly basis, (Graham 2002). Assuming a four-person household, this translates into approximately 80 liters per person per day. By contrast, documented water use by low-income households in Cd. Juárez that connected to public water lines, averages 250 liters per person per day, (Lemus 1999). Inevitably, as water lines are extended to unserved areas, water use will increase.

**Increasing Supply:** Reducing per capita water consumption, though important, will not address the Paso del Norte region’s fundamental problem of an increasing population and diminishing water resources. New sources of water will have to be developed to increase the water supply. The approaches of the two cities to this challenge differ.

EPWU, as part of its 1992 management plan, adopted a five-part strategy to cope with the region’s water supply problems, (Boyle Engineering Corp. 1992). The first component of EPWU’s strategy is demand management (i.e. water conservation). The remaining four components are as follows:

- Promote water reuse, in the form of use of treated wastewater for non-potable uses.
- Increase the use of Rio Grande/Río Bravo surface waters, possibly coupled with an aquifer storage and recovery (ASR) option during years of high surface flow.
- Desalinate brackish ground water.
- Increase withdrawals from the Mesilla Bolson.

EPWU has aggressively pursued this approach, and has also sought access to ground water resources elsewhere in the west Texas area. The last option listed in the strategy, namely that of increasing withdrawals from the Mesilla Bolson, implies a potential future attempt to gain access to ground water from New Mexico.

The JMAS, with the financial support of the Border Environment Cooperation Commission (BECC), developed a water master plan that was released in the year 2000. Long-range water planning requires taking inventory of existing facilities, evaluating the current water demand characteristics, projecting future population and water demand, and identifying sources of water and the cost and timing of needed infrastructure improvements. Figure 19, taken from the *Ciudad Juárez Plan Maestro para el Mejoramiento de los Servicios de Agua Potable, Alcantarillado y*
Saneamiento (Cd. Juárez Master Plan for the Improvement of Potable Water Services, Water Storage, and Wastewater Treatment), shows a graph of expected water demand matched with planned water supply.

Figure 19 suggests that the JMAS can increase its water supply sufficient to meet future water demand, albeit without any surplus capacity as a contingency supply. The sources of this supply, however, may be questionable. Figure 20 reproduces the same bar graph of water supply, but identifies the proposed sources of water.

Figure 19. Projected Water Demand and Supply for Cd. Juárez
(Source: JMAS Plan Maestro 2001)

Figure 20. Sources of Water Supply for Cd. Juárez
(Source: JMAS Plan Maestro 2001)
In concept, the JMAS proposes to meet rising demand by tapping into ever more distant sources of water, but the plan presupposes that each water source, as developed, can be relied on to produce a sustainable quantity of water. The plan projects that, by the year 2020, more than half of the water needs of Cd. Juárez will be supplied by sources other than the Hueco Bolson. Particularly disturbing, however, is the assumption that withdrawals from the Hueco Bolson can be increased to a level of 6.0 m$^3$/s, and sustained thereafter, though the twenty-year planning horizon. That assumption may be incorrect.

In February, 2000, shortly after the JMAS Master Plan was completed, the *El Paso Times* published a story that stated that, based on the current and projected rates of withdrawal, the fresh water portion of the Hueco Bolson underlying Cd. Juárez would be virtually depleted of fresh water by the year 2005, (Simonson 2000). The story was based on statements made by EPWU officials, and the story was given added credibility by virtue of recent ground water modeling of the Hueco Bolson that EPWU had undertaken with the U.S. Geological Survey. Officials from the JMAS, though they declined to give statements to the press, dispute this projection and assert that a vertical assessment of water quality of the Mexican portion of the Hueco Bolson is lacking. It well may be true that the full extent of the Hueco Bolson is not known, but, absent better information, it seems imprudent to base long-range planning on the assumption that a constant supply of water will be available from this source.

The other proposed sources of water supply lack sufficient information for water management planning purposes. This will be a constraint on implementing the plan’s recommendations because, before funding is committed to implement the plan’s recommendations, additional information is needed about the quality of ground water and the extent of supply available. Thus far, the JMAS has lacked sufficient financial resources to undertake this next step.

The magnitude of investment required to implement the recommendations of the Master Plan is considerable. Table 5 provides a summary of the costs of different plan element recommendations.
Table 5. Estimated Costs of the Cd. Juárez Master Water Plan Recommendations
(Source: JMAS Plan Maestro 1999;)
(Note: Assumes a currency exchange rate of one U.S. dollar per 9.7 Mexican pesos)

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
<th>Total Investment Required</th>
<th>Millions of Pesos</th>
<th>Mlls. of Dlls.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>DRINKING WATER SYSTEM</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Development of infrastructure (well fields, transmission lines, etc.) to provide new water sources to meet future water demand of Cd. Juárez.</td>
<td>4,160.35</td>
<td>428.90</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Rehabilitation &amp; enhancement of the water distribution system</td>
<td>2,181.38</td>
<td>224.88</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>WASTEWATER COLLECTION SYSTEM</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Investments to the wastewater collection system</td>
<td>1,358.78</td>
<td>140.08</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>WASTEWATER TREATMENT SYSTEM</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Investments to the wastewater treatment system</td>
<td>380.8</td>
<td>39.26</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>REUSE OF TREATED WATER</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Investments for water reuse systems</td>
<td>104.66</td>
<td>10.79</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>OTHER STUDIES &amp; PROGRAMS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Studies to determine necessary enhancements of the administrative &amp; technical capacity of JMAS</td>
<td>53.86</td>
<td>5.55</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Studies of potential new sources of potable water supply for Cd. Juárez</td>
<td>21.84</td>
<td>2.25</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Actions and programs by JMAS to promote water conservation.</td>
<td>76.54</td>
<td>7.89</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>TOTAL</strong></td>
<td></td>
<td>8,338.21</td>
<td>859.61</td>
</tr>
</tbody>
</table>

**ALTERNATIVE STRATEGIES**

Projected water shortages have forced utilities in the Paso del Norte to adopt more sophisticated planning and demand management strategies, and to be more creative in identifying alternative sources of water supply. Other approaches, not currently under consideration, may be needed in the future, but the impacts of such alternatives must be evaluated.

*Reallocation through Water Markets*: Given that ample water for municipal and industrial use is available on a regional basis provided less water is devoted to agriculture, the future may see the development of broader water markets whereby water rights holders lease their water allotment to municipalities. This is already in place in the form of the conversion of EPCWID water from agricultural to municipal and industrial use. Not under consideration is a cross-jurisdictional water market, such as New Mexico surface water being sold for use in Texas. This
approach, though controversial, could be a means by which EPWU could gain access to additional water supplies. By contrast, water law in Mexico precludes individual ownership of water, therefore open water markets cannot develop within México. Water law in Mexico, however, does allow for the transfers of water concessions, so a type of water market may emerge. Unfortunately, because Mexican communities have considerably less financial resources than do their American counterparts, an international market for water could hurt, rather than help their situation. Even applied only within the region’s separate jurisdictions, the consequences of unregulated water marketing may have undesirable consequences, particularly for natural ecosystems.

**Direct Reuse of Treated Wastewater:** Currently in the Paso del Norte, most municipal wastewater is treated and then released, either into the Rio Grande/Río Bravo, or into the canals of the various irrigation districts. Exceptions to this generalization are the re-injection of tertiary-treated wastewater into the Hueco Bolson by EPWU, and the water reuse programs that make treated wastewater available for non-potable purposes. No wastewater, however, is treated and directly reused for drinking water purposes. Direct reuse is referred to as a ‘pipe-to-pipe’ system, though it is sometimes disparagingly labeled ‘toilet-to-tap’ by the public. Technologies are available that are capable of treating effluent so that it meets the drinking water standards, but thus far, no U.S. municipality has opted for a pipe-to-pipe system. Rather, water reuse systems avoid direct connections between sewage treatment plants and public water supply systems by discharging treated effluent into a natural surface water body so that it blends with surface water before it is diverted for municipal water supply, or by means of artificial recharge of groundwater to enable soil-aquifer treatment and blending with native groundwater before being pumped out and used for drinking water.

During the first “Water Summit” that Congressman Silvestre Reyes convened in the spring of 2001, Dr. Douglas Rittman proposed that EPWU, which has side-by-side surface water and wastewater treatment plants, blend treated effluent with surface water and treat this mixture for use as drinking water, (Rittmann 2001). Unfortunately, even if this idea could win political favor, it is not possible under the terms of EPWU’s current contractual obligations to release treated effluent into EPCWID’s irrigation system.

**Growth Management:** The term growth management refers to assessing costs to new development based on the added financial burden such development imposes on an existing community, including indirect impacts. An example of this approach was proposed by means of a guest editorial written by the General Manager of EPWU and published in the *El Paso Times* on March 31, 2002. This editorial advocated the use of impact fees to offset EPWU’s costs of upgrading its utility infrastructure. Local builders expressed opposition to the proposal, and the city of El Paso has not acted on this recommendation.

Cd. Juárez currently assesses a fee from all new development, though the fees collected are insufficient to meet the city’s considerable infrastructure needs. Since in-migration is fundamentally a factor of the expansion of so-called ‘base industries,’ JMAS might adopt a strategy of targeting new *maquiladoras* and other new industries with an impact fee that is expressly tied to the capital costs of developing new sources of water. Such an approach, however, may not be politically feasible. Despite recent efforts to decentralize governmental decision-making, the federal government still has considerable influence on local financing, and it is unlikely that all additional revenues collected from higher impact fees would be retained for local use. Nor, if this kind of strategy were adopted, would it be appropriate solely in border
communities, because water problems in México are not unique to the border region. For example, water supply problems in Chihuahua, the capital of the state of Chihuahua, have resulted in frequent service interruptions. On both sides of the border, because one of the effects of impact fees is to slow development, compromise will be needed to balance infrastructure financing needs with economic development aspirations.

Using growth management as a means of restricting growth is contrary to current programs that seek to promote economic development. Yet, from a long-term perspective, this may be necessary. For example, while current water supply problems in the Paso del Norte could be significantly remedied by the conversion of surface water from agricultural to municipal and industrial use, that strategy has limits. Dr. Anthony Tarquin wrote a paper that was published in 1998 wherein he argued that the upper limit of the population carrying capacity of the region should be based solely on replenishable water supplies. From this perspective, replenishable water, in the form of average annual inflow of surface water and the estimated annual aquifer recharge, is analogous to income; ground water that has accumulated over geologic time is analogous to stored capital. Translating the amount of replenishable water into population requires that assumptions be made regarding the average per capita water use – essentially choices regarding the types of land use and lifestyles. Figure 21, recreated from Tarquin’s paper, shows three extreme scenarios: a 50 percent reduction in the region’s agricultural water use with the saved water used for municipal and industrial purposes; an abandonment of all agriculture in the region with all replenishable water devoted to municipal and industrial use; and a final alternative wherein all agriculture is abandoned and 50 percent of all water is reclaimed and reused. The horizontal access on this graph represents alternative per capita water use rates. (Recall that the current per capita water use in Cd. Juárez is approximately 321 l/day.) Disquietingly, regardless which set of assumptions are used, the resulting ‘carrying capacities’ from this analysis are less than population projected to live in the region in the near future.

![Figure 21. Paso del Norte Population Carrying Capacity](image)
(Adapted from Tarquin 1998)
REGIONAL COOPERATION

Given the Paso del Norte region’s rapidly diminishing water resources, water issues in the Paso del Norte can only become more prominent. The ‘null alternative,’ is unacceptable, as inaction will only forestall the selection and implementation of actions to address the region’s problems, and major water supply projects require considerable lead times to implement. Because many aspects of the economies of El Paso and Cd. Juárez are tightly coupled, consequences of water supply problems will have repercussions for both cities.

The severity of water problems in the Paso del Norte has forced greater interaction among the many entities charged with aspects of water management in the region. Sometimes, this is a negative process, as evidenced by the plethora of lawsuits regarding water resources. Other times, it is positive. Examples of such positive interaction include: special state legislation designating EPWU as the sole water planning entity for El Paso County; the formation of a New Mexico-Texas Water Commission, (this, an outgrowth of a settlement agreement ending a protracted series of lawsuits), which provides a forum for bi-state dispute resolution and which led to the development of the Las Cruces-El Paso Sustainable Water Project; the seven-county Far West Texas Water Planning Group, created in response to Texas state legislation that incorporated a ‘bottom-up’ approach to state water planning; the formation of the Lower Rio Grande Water Users Association (initially created to help counteract El Paso’s efforts at gaining access to New Mexico water), which today is coordinating water planning in Doña Ana County; and the recent BECC-funded Tri-Region Water Planning initiative that is exploring the potential of water supply projects of mutual benefit to El Paso and Cd. Juárez. Voluntary organizations are also active, examples of which are: Aqua XXI, a non-governmental organization working to promote more dialogue regarding water issues in Cd. Juárez; the Paso del Norte Water Task Force that is promoting regional water planning; and the Paso del Norte Watershed Council, focusing on environmental issues along the Rio Grande/Río Bravo.

Despite efforts at promoting regional water planning, numerous factors continue to impede cooperation, among which are: existing, inflexible water allocation systems; different legal systems; different economic pressures and financial abilities; centralized versus decentralized decision-making structures; cultural differences that influence water use; differences in perspective (long-term future versus immediate needs); and, a lack of complete information regarding the region’s water resources, particularly in Mexico.

Some factors favor regional water management planning, among which are: the growing economic interdependence of El Paso and Cd. Juárez; physically, water resources are shared; drought, when it occurs, will affect all jurisdictions; combining resources can help attract more outside financial assistance; and, a growing sense of a shared destiny should work to prevent extreme hardships from being borne by some of the region’s population as this will, to greater or lesser degrees, impair the quality-of-life of everyone in the region.

Water planning and management in the Paso del Norte could evolve in at least three different directions:

• Dialogue and cooperation could dissipate as water shortages become more severe. Under this scenario, parochialism could lead to a reticence to share information, legal maneuvering could further drain financial resources, and opportunities for combining resources could be lost.

• The current situation of guarded dialogue and willingness to consider projects and programs of mutual benefit could continue, interspersed with conflict and dissention. The effectiveness of the current approach will only be demonstrated if, despite differences, significant, mutually beneficial cross-jurisdiction projects and programs are implemented.
Greater trust could develop and lead to a willingness to pursue a regional approach to water management. Common systems of pricing and regional growth management could help reconcile the region's development with its resource base, and enable entities to pursue sustainable, region-based quality-of-life initiatives rather than have to focus on near-term crises.

Not included as a scenario is the development a regional water management authority. Any such entity would only be effective if empowered to take decisive action, including having a regulatory function. Issues of sovereignty preclude this possibility. The region's best hope is that continued dialogue will foster a sense of a shared destiny, and that this will promote willingness to cooperate to achieve a mutually-beneficial future.

**AFTERWORD**

In 1987, the United Nations-created World Commission on Environment and Development, published a landmark report titled *Our Common Future*, a report that is often referred to as the “Brundtland Report,” named after the Commission’s Chairman, Gro Harlem Brundtland. This report gave what has become a commonly-accepted definition sustainable development. The definition is deceptively simple; it reads: “Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” The concept is straightforward; its application, however, is not.

Provided equitable reallocation mechanisms can be devised, sufficient water resources are available in the Paso del Norte to provide the next several generations with drinking water, though the cost of water will almost certainly escalate dramatically. More optimistically, emerging technologies may vastly increase water use efficiency, make possible the treatment of wastewater sufficient for its direct reuse, and make available previously unknown or inaccessible water resources. But, in a long-term context, it may be foolhardy to dismiss the consequences of unsustainable use of natural resources by forever assuming that technology will develop an answer to the problem.

Because resources are finite, development can be sustained; growth, however, cannot. In terms of water resources in the Paso del Norte, extracting ground (whether fresh or brackish, and whether within the immediate region or imported from outside of the region) at a rate exceeding the aquifers’ natural recharge rate, is inherently unsustainable. So doing only postpones the inevitable need to balance supply and demand. Eventually, El Paso and Cd. Juárez will have to match their consumption of water resources with the natural rate of replenishment.
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