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Paper

Growth with no water? The challenges of urban water management in Mexican arid regions vis-à-vis economic growth and climate change

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In the years after World War II, American tourists used to cross the border into Mexico expecting a landscape of dusty towns where they could buy tequila, exotic food, and handcrafts. But with the emergence of manufacturing plants, called maquiladoras, and the North American Free Trade Agreement (NAFTA), exchanges between both sides of the border increased considerably; northern Mexico now resembles U.S. border cities like San Diego and El Paso, with modern factories, hotels, fast-food restaurants, and shopping malls. Northern Mexico, especially the cities that border the U.S., has become an increasingly important economic zone that is often used to exemplify the impacts of free trade and foreign investment in Latin America (Marston et al. 2002). The border region includes major cities with populations of more than one million people, such as Tijuana and Ciudad Juárez (Fig. 21.1). The region also is home to irrigated agricultural valleys, such as the Mexicali and the Lower Río Grande along the border or, farther south, the Yaqui and Mayo in Sonora, that produce a large percentage of Mexico's domestic and export crops. Also, the border towns of Nogales, Nuevo Laredo, and Reynosa became important commercial and industrial centers due to the industrial push brought about by the maquiladora plants during the last three decades of the 20th century. In addition, the state capital cities of Mexicali, Hermosillo, Chihuahua, and Saltillo, each with a population of more than half a million

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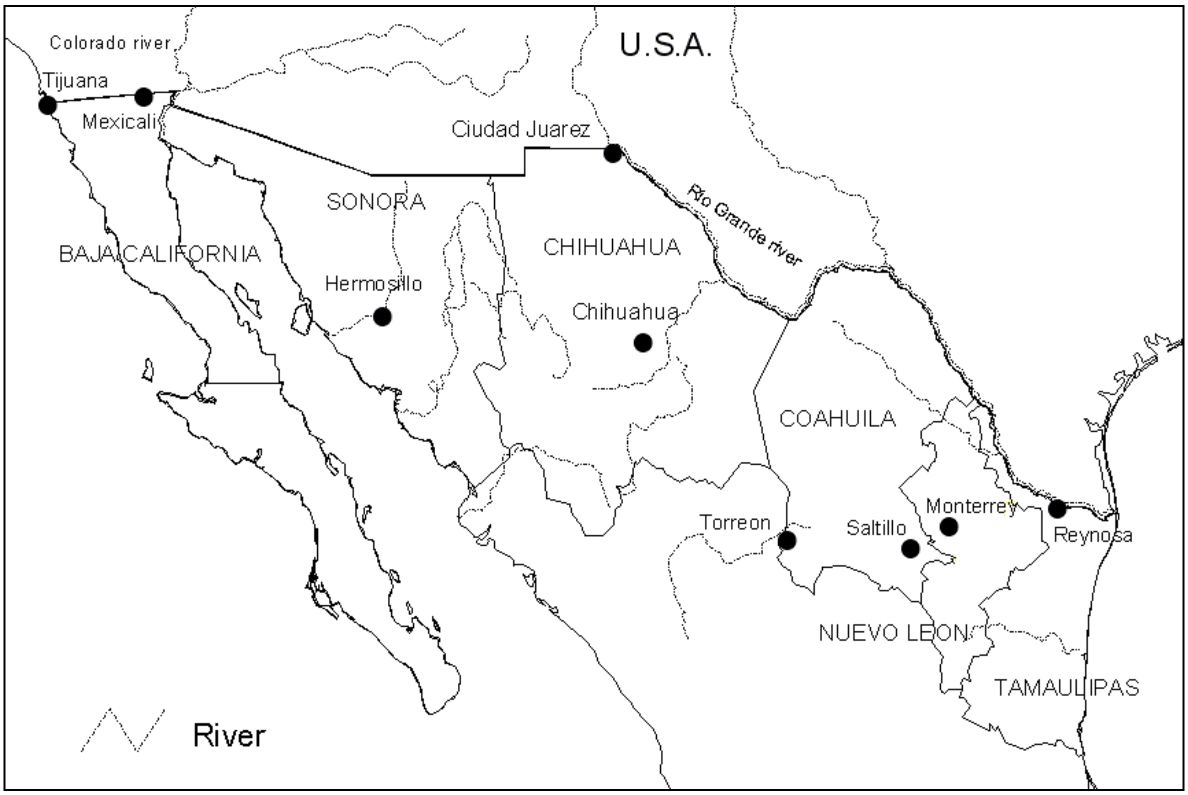
people, and Monterrey, home to around 3.5 million residents, have become centers for business, services, universities, and technology even though they are located much farther from the border.

Figure 1 Mexico's north borderlands



The problem posed by this rapid growth and development is that these cities are located in the fragile environment of the Sonoran and Chihuahuan deserts, where annual rainfall is low, summers are hot, and water is scarce.

In addition, climate projections call for warmer and stormier conditions. Thus, this region faces the challenge of maintaining the pace of economic growth and development with ever diminishing water and the prospect of tougher and longer droughts in the near future. In an abstract way, the region faces the problem of how to urbanize, industrialize, and develop a region where water is scarce and contested while ensuring the region's sustainability. From an economic point of view, it is a problem of fixed and diminishing water supply and growing demand. From a sociological standpoint it might be seen as a matter of conflict and tension centered on a critical resource. Environmental concerns also exist regarding economic growth and development in the desert and the sustainability not only of cities, but also of sensitive natural habitats with their rich flora and varied fauna. In addition, the region faces the geopolitical complication of being the political divide between the most powerful country and a developing nation where security, illegal drug trafficking, human smuggling, and international diplomacy are everyday issues. The questions are: Can we have growth and development in the desert? What alternatives are being considered? Which constraints and hurdles are being addressed?

GROWTH AND WATER

The northern borderlands of Mexico include six states: Baja California, Sonora, Chihuahua, Coahuila, Nuevo Leon, and Tamaulipas. Socio-economic and environmental factors converge to make water management a key issue for the development of this arid and semi-arid region. While this area was grossly underpopulated up to the 1950s, the total population of the region has grown from 7.9 million in 1970 (a few years after the start of the maquildora programs) to 19 million in 2008, with an average annual growth of 2.3% (Table 21.1). Projections suggest that the population of the six Border States will grow at an annual average rate of 1.1% within the next two decades—almost twice the estimated rate of the rest of Mexico (Conapo 2008).

Table 1 Estimated country and state population for 2008, 2020, and 2030

	2008	*2020*	*2030*	*Annual growth*
Mexico	106,682,518	115,762,289	120,928,075	0.6%
Baja California	3,079,363	4,152,585	5,074,986	2.3%
Coahuila	2,601,884	2,884,127	3,054,774	0.7%
Chihuahua	3,359,934	3,673,626	3,838,176	0.6%
Nuevo Leon	4,393,095	4,995,659	5,398,387	0.9%
Sonora	2,487,608	2,716,953	2,841,311	0.6%
Tamaulipas	3,154,947	3,565,224	3,824,091	0.9%
North borderlands	*19,076,831*	*21,988,174*	*24,031,725*	*1.1%*

Source: Conapo 2008

Table 2 Estimated population in cities with a population greater than 100,000

	2008	*2020*	*2030*	*Annual growth*
Mexico	53,152,848	59,922,990	65,480,763	1.0%
Baja California	2,376,332	3,397,442	4,164,884	2.6%
Coahuila	1,729,662	1,970,286	2,248,647	1.2%
Chihuahua	2,475,554	2,656,183	2,888,111	0.7%
Nuevo Leon	3,598,717	4,038,820	4,472,779	1.0%
Sonora	1,521,528	1,750,017	1,906,268	1.0%

Tamaulipas	2,168,196	2,694,182	2,980,810	1.5%
North borderlands	*13,869,989*	*16,506,930*	*18,661,499*	*1.4%*

Source: Conapo 2008

Meanwhile, the population of the cities in these states will grow at a rate of 1.4% (Table 21.2). Thus, the population growth is not evenly distributed, as it tends to be concentrated in cities and is basically urban; the larger the city, the higher the growth rate. Currently, Tijuana, Ciudad Juarez, and Monterey each already have a population of more than one million people. Mexicali, Saltillo, Torreón, Chihuahua, Hermosillo, and Reynosa each have more than 500,000 residents. Thus, the population of the northern states is not only growing at a faster pace than the population in the rest of the country, but it is also agglomerating into the largest cities and with no local planning (Garza 2003).

Industry jobs are triggering this growth. Border states are now among the most industrialized in Mexico. The gross domestic product (GDP) of the region grew at an annual rate of 4.2% from 1993 to 2004, while that of the rest of the country trailed at 2.4%. Drawn to the region, American companies established maquiladoras across the border, taking advantage of cheap labor and tax incentives from the Mexican government through an industrialization plan for the region that started in 1965. In 1980, the maquiladora industry employed about 105,000 people. NAFTA was signed in 1994, and the number of jobs in the maquiladora industry increased to 572,000 a year later. A little more than one million people were employed in the industry by 2000 (Turner 2006). A characteristic of this labor force, however, is that it tends to be young, female, low-skilled, and low-paid. For this reason, maquiladora jobs tend to be only a temporary option, highly mobile, and characterized by high rates of turnover (Kopinak 1996).

Rapid growth in the region has also had an impact on the patterns of urban settlement and the type of housing available. Border urban growth tends to be irregular, unplanned, and disorderly, as it expands by means of shantytowns and squatter settlements made by people who build their houses with recycled materials in empty plots they do not legally own (Alegría and Ordoñez 2005). Beyond the tourist districts visited by American visitors, the landscape of Mexican border cities includes vibrant commercial zones; a varied mix of residential neighborhoods, ranging from elite districts to the newly founded squatter settlements on the urban fringe; the old industrial districts; and the new industrial quarters of maquiladora parks (Arreola and Curtis 1993).

Ironically, this region, with such important economic development and high population growth, is also the most arid region in Mexico and North America. The average precipitation throughout the six states ranges from 202 to 463 mm a year (Conagua 2007a); the area next to the Colorado River has an average annual precipitation of only 50 mm (García 2003). The climate of the Río Grande states, on the eastern part of the border area, is warm, windy, and predominantly sunny. Although rain and humidity increase closer to the Gulf of Mexico, the area is also characterized as tropical and subtropical desert (Eaton and Anderson 1987). In contrast, the south and southeastern regions of Mexico (which are also the most underdeveloped) receive precipitation totaling 1,171 to 2,300 mm a year. The north borderlands are a drought-prone region that has faced significant and prolonged shortages in precipitation. The last drought started in the mid 1990s and ended in the mid 2000s (Esquivel 2002), and the region is expected to face a stronger and longer drought by the 2030s (Lenart 2007).

The climatic outlook is not very promising either. Borrowing from studies of the U.S. Southwest, which has the same climate system as northern Mexico, global warming and its associated climate changes are likely to affect this region in a number of ways: warmer temperatures and more heat waves; more droughts yet more floods; reduced snow cover; increased strain on water resources; and an earlier spring with larger wildfires (Lenart 2007). The Intergovernmental Panel on Climate Change (IPCC) estimates an increase of 3 to 4 °C in average annual temperatures in this region during this century (IPCC 2007).

The region is home to some important water resources that likely will be affected by climate change (Table 21.3). Mexico and the U.S. share parts of two major river basins: the Colorado River and the Rio Grande. Irrigation districts and cities located on both sides of the border have access to these rivers and have to share the water. Because population and economic activities have increased considerably, a great amount of stress is being put on the basin waters. To date, the amount of water drawn ranges from 72% to 86% of available water; an extraction of more than 40% is considered a constraining factor to development (Conagua 2006) (Table 21.4).

Table 3 Water sources by city

Tijuana:	Surface impoundment on the Tijuana River, augmented through an aqueduct from the Colorado River
Mexicali:	Sources connected to the Colorado River
Hermosillo:	Abelardo L. Rodriguez dam and groundwater from La Victoria and La Sauceda wells
Ciudad Juárez:	Groundwater (despite being next to the Rio Grande)
Monterrey:	La Boca and El Cuchillo dams on the San Juan River, and the Cerro Prieto Reservoir
Reynosa:	Surface water from the Rio Grande, treated by two water treatment plants

Source: U.S. Environmental Protection Agency 2001; Aranda et al. 1998; Salinas 2003

Table 4 Water extraction by use (2006)

Region	*Agricultural*	*Municipal (1)*	*Industrial (2)*	*Thermoelectrical use*	*Extraction Total hm3*[3]
North borderlands	83.9%	12.7%	1.8%	1.6%	19521.8
National	76.8%	13.9%	3.8%	5.4%	77322.2

(1) Includes industries and services supplied by municipal water networks.

(2) Self supplied industry, thermoelectrical plants excluded.

(hm3): cubic hectometers 1hm3 = 1 000 000 m3.

Source: Conagua 2007; *Estadísticas del Agua en México*

Most of the binational water is used in agriculture, while most cities along the border resort to pumping underground water to satisfy the needs of residential and industrial users. For instance, Ciudad Juarez, despite its proximity to the Rio Grande, uses groundwater. However, most groundwater in the north borderlands of Mexico is already over utilized. According to official data, 41 aquifers are over-exploited throughout the border states (Conagua 2007a). One reason for this is that the estimations of the water pumped are generally based on the declarations of agricultural producers themselves who, in order to protect their own interests, tend to underreport the volume actually pumped. In addition, pollution is plaguing an increasing amount of groundwater, and saltwater intrusion has occurred in 14 aquifers (Table 21.5). Thus, demographic, environmental, and social factors as well as the climatic outlook increase the hydraulic stress of the region.

Table 5 Characteristics of aquifers in northern Mexican states

Hydraulic	*Num. aquifers*	*Overexploited*	*With saltwater*	*Withdrawal*	*Average*

[3] Cubic hectometer.

Region			intrusion	hm^3	recharge hm^3
Baja California	87	8	9	1,512	1,411
Noroeste	63	17	5	2,730	2,754
Río Bravo	96	16	0	4,123	5,218
Total	246	41	14	8,366	9,384

Source: Comisión Nacional del Agua 2004; *Estadísticas del Agua en México*

FACING THE WATER CHALLENGE

In order to cope with the challenge posed by growth and water scarcity, urban water utilities in the northern borderlands made remarkable efforts during the 1990s to build the necessary infrastructure and have improved their efficiency and quality of service. Nevertheless, additional improvements are required. These include four main measures: (1) making water available for everybody; (2) increasing the efficiency of water management and reducing the loss of water; (3) treating and reusing wastewater in such a way as to minimize contamination; and, (4) finding additional sources of water for the cities if the goal of satisfying increasing growing demand is not met.

Service Coverage

The first challenge is service coverage—making water available to cover everyone's main needs, regardless of income or social condition. It is an equity challenge in a poverty-stricken country. In north Mexico, an estimated 4.7% of the population in 2001 lacked water service to their homes, and 19.2% were not connected to the wastewater network (Saade 2005) (Table 21.6).

Table 6 Coverage, average water supply, and water loss (2007)

City	*Population*	*Population with no water service*	*Water supply liters/person/ day*	*Water loss*
Mexicali	698,357	1%	330	14%
Tijuana	1,315,773	6%	222	19%
Saltillo	583,604	4%	181	67%
Torreón	544,875	2%	340	52%
Chihuahua	716,781	6%	440	47%
Monterrey	3,459,121	1%	276	30%
Hermosillo	671,909	3%	345	38%
Reynosa	490,531	7%	316	36%

Source: Conagua 2007; *Situación del Subsector de Agua Potable, Alcantarillado y Saneamiento*

These proportions usually correspond to the poorest strata of the population and affect women, children, and rural populations the most. Although these figures are lower than the national average, the challenge still exists and demands attention. The most dramatic case is Tijuana, where 24% of the population has no access to wastewater services. The challenge is to provide both piped water and wastewater services to every household. Meeting this challenge, however, competes with the fight against poverty and unemployment, which are the main problems in Mexico, and with efforts to improve urban planning and social policies at the local level. The provision of water and wastewater services for everybody in northern Mexico is therefore the shared responsibility of the federal, local, and city governments and relies on the effectiveness of the programs that deal with these issues.

Reducing Water Loss

Increasing efficiency in water utilities—the second measure—is essential to water management in northern Mexico. A large proportion of water that is introduced into the system does not reach registered customers; it is lost due to old water pipe networks that lack maintenance and to leaks and clandestine taps (see Table 21.6). Therefore, reducing water loss means having additional water available for users without having to supply more water to the system. Efficient water management is a first priority for urban water utilities.

Four published indicators exist to measure the efficiency of Mexican water utilities: water loss (physical efficiency), water liters supplied per person (customer efficiency), proportion of free-rider customers (commercial efficiency), and the ratio of employees per water connections (administrative efficiency). The proportion of water loss or physical efficiency is perhaps the most important for this analysis and corresponds to the percentage of water introduced to the network that actually reaches customers. The loss of water in northern Mexican cities ranges from 14% in Mexicali, which reflects very good management given the difficulty in achieving lower proportions, to a 67% water loss in Saltillo—that is, two-thirds of the water introduced into the network is lost and only 33% reaches customers. Because Saltillo has a water supply shortage, this is an indication of poor performance of water management, and it is also a potential source of additional water for future needs.

The number of water liters per person per day relates to the efficiency of water used by customers (see Table 21.6). This indicator varies from 181 L per person per day in Saltillo to 440 L per person per day in Chihuahua. The reduction in the amount of water used by customers might also provide additional amounts of water for future growth. The target number in Mexico is around the level of consumption reported by Saltillo. A matter of debate, however, is whether it is acceptable to ration Mexico's water service—reduce it to a certain number of hours per day, as is done in Saltillo—or whether it should be provided 24 hours a day, 365 days a year. The standard in northern Mexican cities is still to provide the service around the clock every day of the year. Only in exceptional cases have cities established rationing, usually as a temporary measure, to cope with water shortages. In these cases, customers usually install water tanks on the roofs of their houses to have a back-up water supply.

The proportion of free riders—the number of customers who fail to pay for the services—reflects the financial management of water utilities and the behavior of customers. Commercial efficiency is the proportion of water bills actually paid by customers. The fact that many cities do not report this indicator highlights significant shortfalls in this regard. Among the cities that report the proportion of free riders is Chihuahua, where approximately 89% of the bills are paid and, on the other extreme, the city of Reynosa, which reports that only 64% of its customers pay. The proportion of unpaid bills points either to potential resources to finance service improvements or mismanagement of the customers' cadastres. In any, case, this is an issue that should be addressed for the sake of the service and its financial sustainability.

The number of utility employees per every thousand water connections is a sign of administrative efficiency—whether the utility has just enough personnel or whether it is overstaffed. In this regard, Saltillo, which is managed by a public-private partnership, has the greatest administrative efficiency, reporting 2.2 workers for every 1,000 connections (Table 21.7). Conversely, Reynosa reports having 6.9 employees for every 1,000 customers—three times the personnel of Saltillo, making it the least administratively efficient of the four cities sampled.

Finally, global efficiency is obtained by multiplying the physical efficiency by the commercial efficiency. Hermosillo has the most globally efficient water utility, reporting 49%.[4] The city with the least efficient water utility of the four sampled is Reynosa, at 41%. (Conagua 2007b). These efficiency levels clearly are still very low.

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[4] We have information to estimate this indicator for only four cities and all of them fall in the range of 41%–49%.

Table 7 Coverage and management efficiency in northern Mexico cities

City	*Water Supply coverage*	*Wastewater service coverage*	*Employees/ 1,000 customers*	*Physical efficiency %*	*Commercial efficiency %*	*Global efficiency %*
Mexicali	99	93	n.a.	86	n.a	n.a.
Tijuana	94	78	3.9	81	n.a	n.a.
Saltillo	96	93	2.2	n.a.	n.a.	n.a.
Torreón	98	96	3.8	48	87	42
Chihuahua	94	89	4.3	53	89	47
Ciudad Juárez	n.a.	88	3.3	n.a.	n.a.	n.a.
Monterrey	99	98	3.7	70	n.a.	n.a.
Hermosillo	97	94	4.1	62	80	49
Reynosa	93	89	6.9	64	64	41

Source: Conagua 2007; *Situación del Subsector de Agua Potable, Alcantarillado y Saneamiento.*

Although these statistics are not outstanding, they mean an improvement with respect to the performance observed during the 1990s. Also, these figures exceed the national averages of 44% physical efficiency and 69% commercial efficiency (Conagua 2005). Thus, while the average global efficiency at the national level is 30%, the sample of statistics available for borderland cities shows levels that exceed 40%. Hence, perhaps because of the water scarcity and a more industrialized economy, north borderland water utilities show a greater efficiency than those in the central and southern regions of Mexico. However, there is still significant room to improve water management efficiency.

Wastewater

The third goal is to increase the proportion of wastewater treatment, recycling, and reuse. Nuevo Leon, the state with the best figures in water treatment at the turn of the 21st century, treats 100% of its wastewater, which is then reused for crop production (Table 21.8). Baja California follows with 83%. Of the other four states, only Sonora is below the national average; it treats less than one-third of its wastewater. Although the proportion of wastewater treated in the region is greater than the national average, a significant volume is still polluting rivers instead of being used to irrigate parks and gardens or for other public uses. If water becomes scarcer and more valuable, wastewater treatment will become an important source of additional water for desert cities.

Table 8 Wastewater treatment (liters/second)

	Generated	*Collected*	*Treated*	*%*
Baja California	6,058	5,349	4,442	83.0%
Chihuahua	12,320	11,001	6,242	56.7%

Coahuila	7,020	6,416	2,753	42.9%
Nuevo León	9,650	9,178	11,102	100.0%
Sonora	9,929	8,450	2,581	30.5%
Tamaulipas	8,715	7,155	3,444	48.1%
Mexico	*242,099*	*205,838*	*74,388*	*36.1%*

Source: Conagua 2007; *Situación del Subsector de Agua Potable, Alcantarillado y Saneamiento.*

Finding Additional Sources of Water

The fourth challenge is to increase the supply of water for cities. Many city authorities traditionally consider the first option for meeting demand, focusing only on the supply side of water management while ignoring the management of water demand. Usually this translates to the transfer of water from other basins and the construction of aqueducts to bring additional water to the city. For instance, the technological solution for the provision of water in Tijuana and Monterrey was the construction of aqueducts and canals for inter-basin water transfers (see Table 21.8). Tijuana relies on an aqueduct built in the 1970s that brings water from the Colorado River delta and feeds most of the city's water needs. Since the mid-1990s, Monterrey has pumped water from the El Cuchillo dam, located in the neighboring state of Tamaulipas, thus solving its own serious supply problems. The aqueducts and canals were made possible by expropriations and, in the case of Monterrey, faced great opposition from Tamaulipas. There is a growing awareness of the problems this solution presents: it disrupts the water cycle, discriminates against users downriver, and most of all, does not fit well into the approach of integral and sustainable water management (Carabias and Landa 2005).

Other alternatives that have been considered to increase water supply are the transfer of water rights from agriculture to urban use and the desalination of sea water. The latter has already been applied in Baja California, where a desalination plant was built in 1970 (Correa 2007). Attempts were made at the turn of the century to install a desalination plant in Hermosillo, but those efforts were blocked (Pineda-Pablos 2007). The other alternative, water transfers from agriculture, face a number of legal hurdles as well as opposition from the crop-exporting farmers of the region. The Mexican Law of National Waters of 1992 did not anticipate the transfers from agriculture into urban use, and these transfers were only made by presidential order and usually among much opposition and conflict. The law was modified in 2004 to introduce, among many other measures, "title transmission" (Diario Oficial de la Federación 2004). Now, with the democratization of the country and the diminished powers of the president, these transfers have to go through difficult negotiations and are still subject to authorization by water authorities. With this new legal base and the support of national and state water authorities, Hermosillo signed a deal in 2005 with local farmers to acquire agriculture water rights. This acquisition has provided a new source of water for the city and has helped meet the peak urban demand in the summertime without resorting to rationing. This operation taps a new water supply source for the city in the future, but new negotiations and costly deals are necessary to make water transfers from agriculture available for cities.

LIMITATIONS OF THE INSTITUTIONAL FRAMEWORK

Despite having made significant improvements, north borderland cities have not fully applied alternatives to meet the urban demand for water because they face obstacles embedded in the current institutional arrangement that might prevent their implementation. Institutions constrain and orient human behavior and activities. The aim of an institution is to reduce uncertainty by establishing procedures and structures for human interaction. The concept of an institution is reduced to formal rules and laws, and comprises "rules-in-use" (Ostrom et al. 1993; Ostrom 2007). Therefore, in order to analyze the situation and outlook of water management in arid and semi-arid northern Mexico, it is necessary to review some existing rules and incentives for administering this resource. Three major institutional constraints prevent water utilities from implementing long-term planning and achieving self-sustainability: (1) the high turnover of urban water managers and the failure of long-term planning, (2) the criteria used to design and approve water rates, and (3) limitations for the enforcement of sanctions for free riders.

Water supply services in Mexico were transferred from the federal government to state and municipal governments in the 1980s, and the appointment of water managers has been linked to the politics of local governments ever since (Pineda-Pablos 2008). Because there is no re-election in Mexico and municipal governments change every three years, water managers are removed at least every time a new government administration takes office, if not more frequently (Table 21.9). In Sonora, for example, water managers remain in office for an average of 26 months (Pineda-Pablos 2008). In addition, the selection of people for these positions is based on political and electoral criteria rather than on technical competence.

Table 9 Water managers turnover

City	*Number of managers 1990-2006*	*Average years in office*
Tijuana	5	3.2
Saltillo	5	3.2
Chihuahua	7	2.3
Monterrey	8	2
Hermosillo	10	1.6

Source: Data collected directly by the authors

Due to these high turnover rates, neither continuity in the management of urban water resources nor effective planning exists. Nevertheless, the principle of no re-election is considered a remarkable outcome of the Mexican Revolution and a protection against dictatorial governments or caciques (local overlords).[5] The elimination of this principle must be reconsidered because it has perverse effects on municipal planning and administration. The expectation is that, as free and competitive elections provide a means for penalizing bad governments, the no re-election rule will be eliminated in the future.

Among the likely solutions for this lack of management continuity are the introduction of a merit-based civil service in the water sector and the establishment of regulatory boards. Some efforts have been made in the state water laws to introduce permanence and incentives for a civil service career in water management, but they are weak and insufficient. Governors and water authorities are reluctant to renounce their vested appointed powers. Thus, more citizen pressure is required to attain the necessary legal reforms and their due enforcement to really establish a career and civil service in the sector.

Another likely solution is the creation of state technical regulatory boards that might participate in the appointment of utility managers, help build institutional capacities, and generally oversee and assess the operation of water services. Although this idea has been around for some time, it also faces the same problem as civil service: it implies a diminishing power of governors and authorities. Therefore, it depends on further political and citizen development.

So far, the only solution devised and put into practice to overcome the lack of continuity in the

[5] The Mexican Revolution started in 1910 with the purpose of overthrowing Porfirio Díaz, who had been in power for more than 30 years. When the revolution succeeded, a new constitution was written in 1917 prohibiting the re-election not only of the president, but of any authority at any level in the country, to prevent power perpetuation.

management of urban water utilities is to promote the participation of the private sector in the operation of urban water services (Diario Oficial 1992; Conagua 1989, 1990). Responding to this call, the private sector has increased its participation, mainly in the construction and operation of wastewater treatment plants and aqueducts (Conagua 2003). Nevertheless, in the operation of water services, private participation has been rather low. Only four cities (out of more than 130 cities with more than 50,000 inhabitants) have contracted with private management. Among the few cases of private participation are the cities of Aguascalientes, Cancún, and, in part, Mexico City, which introduced private participation in 1994 and 1995. In 2001, Saltillo entered into a joint venture with Aguas de Barcelona to manage the water utility.

The primary reasons for this overall lack of participation are the higher stakes in service quality stipulated in operation contracts, the inexperience of local companies, the greater financial risks posed by free-riding customers, and the political overtones posed by the operation and management of water utilities (Conagua 1990; Saade 2005). A characteristic of private participation in Mexico is that contracts have been assigned only to large construction corporations, such as ICA (Ingenieros Civiles Asociados) or Tribasa (Triturados Basálticos), in conjunction with multinational companies like Aguas de Barcelona or Lyonnaise des Eaux. These corporations take great care in the billing and collection of water user payments without investing significantly in improving infrastructure or customer service. On the other hand, community associations or small-sized local firms have not been invited and have not had the same opportunity to participate in water investment ventures. Thus, the most widely used strategy for the management of urban water in Mexico is that of public management provided by the local government. For this reason, it is necessary to institute procedures that encourage administration and planning that are not limited by the short life spans of local governments.

Another rule or procedure of the institutional framework that causes adverse effects on water management is the criteria used to approve the water rates. The federal government allowed water utilities to approve their own water rates according to their financial needs, thus avoiding the interference of political bodies such as the state congresses or municipal councils, which often care more about the electoral impact of raising water rates (Conagua 1989). In this regard, during the 1990s, 23 states passed legal reforms to grant utilities the authority to set their own water rates

(Alcántara Palma 1996). However, in response to several lawsuits, the Supreme Court decided in 2001 that rates must be passed by the state congresses. As a result, the approval of water rates has been given back to the state congresses, where the criteria for the design and approval of rates are becoming more political than technical. The revision and increase of water rates has become a subject debated among congress members of different parties with an eye to obtaining electoral gains, so the rates are not increased or they fall short of the level required for the sustainable operation of the service and the total recovery of costs. Therefore, the court's decision is counter to the financial health of water utilities and inhibits their development.

In addition to the constraints imposed on pricing policy, payment is not enforced in most states. Most utilities issue bills, but almost half of the users in some cities do not pay them on time or stop paying without facing penalties. The basis for this lack of enforcement is an interpretation of Article 121 of the Ley General de Salud (General Health Law), which establishes that water providers will not be able to withhold the supply of water and sewage services of inhabited buildings except in cases determined by the general applicable laws (Diario Oficial 1984). Most utilities do not cut off the service because of this rule. In some cases, the sewage outlet is only restricted as a substitute for a sanction, or the water quantity provided is reduced. This situation has created commercial efficiency problems because a large number of users have refrained from paying the service, damaging the financial sustainability of water utilities.

RATIONALITY IN WATER MANAGEMENT

The cities of Mexico's north borderlands face the challenge of providing water to an ever increasing population that demands greater levels of consumption with limited resources. This challenge will only grow if projections of more severe drought play out in the future. These cities have to increase their efficiency and their levels of wastewater treatment and resort to the transfer of water rights from the agricultural sector to the urban and industrial sectors. To a lesser extent, the cities of Baja California and Sonora, located near the coast, can also resort to sea water desalination in order to satisfy demand.

The task of revising and adjusting the institutional framework must be accomplished to remove obstacles and to correct behaviors that are or can be harmful and may affect the performance of water management. The frequent turnover of managers in Mexican water utilities is directly tied to the periodic change of local governments; the life span of these administrations—and therefore the time directors of water utilities remain in office—is three years at most due to a no re-election principle. In order to strengthen the technical capacity of water utilities, it is necessary to institute new forms of management that allow more effective planning for this sector and more consistent decision making. Without this institutional change, medium and long-term urban development planning cannot occur, and water management will remain stuck in the vicious cycle of lack of resources, low management capacity, and cheap low-quality services. In addition, the most important change perhaps is in the financial realm and has to do with achieving self-sufficiency of water services.

The price of water is the key mechanism to introduce rationality into water management; however, the Supreme Court has determined that the state congresses are to determine or approve the rates instead of water utilities themselves. As a result, water prices do not tend to promote the total recovery of costs and self-sufficiency; it is therefore necessary to find mechanisms that compensate for the political and electoral criteria of congress members and emphasize the requirements of self-sufficiency and sustainability of water utilities.

Users must pay for the service if the price mechanism is to work as a rationalizing element that encourages water conservation. Nevertheless, water providers in Mexico cannot discontinue the service to residential users who do not pay on time due to an interpretation of the General Health Law. As a result, between one-third and one-half of the users do not pay their water bills on time.

In order to strengthen and encourage sustainability and efficiency in water management in Mexico, it will be necessary to debate and revise the current institutional framework and General Health Law so the northern Mexico borderlands can meet water demands in the future.

REFERENCES

Alcántara Palma, V. 1996. Marco legal actual de los servicios de agua potable, alcantarillado y saneamiento a nivel local. Una visión de conjunto. *Federalismo y Desarrollo*, no. 54.

Alegría, T., and G. Ordoñez. 2005. *Legalizando la ciudad. Asentamientos informales y procesos de regularización en Tijuana*. Tijuana: El Colegio de la Frontera Norte.

Aranda, R., R. Zamarripa, L. Rojas, J. Navarro, and J. Návar. 1998. Ordenamiento hidrológico de la cuenca del río San Juan. In: G.J. Gottfried, C.B. Edminster, and C. Madelyn (compilers), *Cross Border Waters: Fragile Treasures for the 21st Century*. *Ninth US/Mexico Border States Conference on Recreation, Parks and Wildlife*. Tucson: USDA.

Arreola, D., and J. Curtis. 1993. *The Mexican Border Cities. Landscape Anatomy and Place Personality*. Tucson: The Arizona University Press.

Carabias, J., and R. Landa. 2005. *Agua, medio ambiente y sociedad: Hacia la gestión integral de los recursos hídricos en México*. Mexico, D.F.: Universidad Nacional Autónoma de México, El Colegio de México y Fundación Gonzalo Río Arronte.

Conagua (Comisión Nacional del Agua). 1989. *Lineamientos para el Programa Nacional de Agua Potable y Alcantarillado*. Mexico, D.F.

Conagua. 1990. Programa Nacional de Agua Potable y Alcantarillado 1990–1994. *Federalismo y Desarrollo*, no. 19: 11–21.

Conagua. 2003. *Participación Privada en los Servicios de Agua y Saneamiento. Conceptos Básicos y Experiencias.* 2ª Versión actualizada. Mexico, D.F.

Conagua. 2005. *Situación del Subsector de Agua Potable, Alcantarillado y Saneamiento*. México, D.F.: Subdirección General de Infraestructura Hidráulica Urbana.

Conagua. 2006. La Gestión del Agua en México. Avances y Retos. Mexico, D.F

Conagua. 2007a. *Estadísticas del Agua en México, Edición 2007*. Mexico, D.F.: Subdirección General de Infraestructura Hidráulica Urbana.

Conagua. 2007b. *Situación del Subsector de Agua Potable, Alcantarillado y Saneamiento, Edición 2007*. México, D.F.: Subdirección General de Infraestructura Hidráulica Urbana.

Conapo (Consejo Nacional de Población). 2008. *Proyecciones de la Población de México 2005–2050*. http://www.conapo.gob.mx. Accessed January 15, 2008.

Correa, F. 2007. El impacto Social y Económico de la Desalación de Agua de Mar. In: Nava, C. and G. Hiriart (eds.), *Desalación de agua con energías renovables.* Mexico, D.F.: Instituto de Investigaciones Jurídicas, UNAM, 103–123.

Diario Oficial de la Federación. 1984. *Ley General de Salud*. Mexico, D.F.

Diario Oficial de la Federación. 1992. *Ley de Aguas Nacionales*. Mexico, D.F.

Diario Oficial de la Federación. 2004. *Ley de Aguas Nacionales*. Mexico, D.F.

Eaton, D. E., and J.M Anderson. 1987. *The State of the Rio Grande/Río Bravo: A Study of the Water Resource Issues Along the Texas/Mexico Border*. Tucson: The University of Arizona Press.

Esquivel, E. 2002. Lluvia y sequía en el norte de México. Un análisis de la Precipitación en Chihuahua. *Gaceta Ecológica*. October–December, 065, 24–42. INE.

Fournier, J.M. 2001. *L'eau dans les villes d'Amérique Latine*, Paris: Editions l'Harmattan.

García, E. 2003. Distribución de la Precipitación en la República Mexicana. *Investigaciones Geográficas*. 50: 67–76

Garza, G. 2003. *La urbanización de México en el siglo XX*. México D.F.: El Colegio de México.

Intergovernmental Panel on Climate Change. 2007. *Climate Change 2007: The Physical Science Basis. Summary for Policymakers*. http://ipcc-wg1.ucar.edu/wg1/docs/WG1AR4_SPM_PlenaryApproved.pdf. Accessed April 23, 2008.

Kopinak, K. 1996. *Desert Capitalism. Maquiladoras in North America's Western Industrial Corridor*. Tucson: The University of Arizona Press.

Lenart, M. 2007. *Global Warming in the Southwest. Projections, Observations and Impacts.* Climate Assessment for the Southwest, Institute for the Study of Planet Earth, The University of Arizona. www.ispe.arizona.edu/climas/forecasts/swarticles.html. Accessed April 17, 2008.

Marston, S.A., P.L. Knox, and D.M. Liverman. 2002. *World Regions in Global Context: Peoples, Places, and Environments*. Upper Saddle River: Prentice Hall.

Ostrom, E., L. Schroeder, and S. Wynne. 1993. *Institutional Incentives and Sustainable Development: Infrastructure Policies in Perspective*, Oxford: Westview Press.

Ostrom, E. 2007. Institutional Rational Choice: An assessment of the Institucional Análisis and Development Framework. In: Sabatier, P. (ed.), *Theories of the Policy Process* 2nd Ed., West View Press.

Pineda-Pablos, N. 2007. Construcciones y demoliciones. Participación social y deliberación pública en los proyectos del acueducto de El Novillo y de la planta desaladora de Hermosillo, 1994–2001. Región y Sociedad, vol. 19, número especial, 89–115.

Pineda-Pablos, N. 2008. Nacidos para perder dinero y derrochar agua. El inadecuado marco institucional de los organismos operadores de agua potable en México. In: Soares, D. (ed.), *Gestión del agua. Realidades y perspectivas* (in press).

Saade, L. 2005. *Participación de la Iniciativa Privada en la Provisión de los Servicios de Agua Potable y Saneamiento en México: Retos y Mitos.* Mexico, D.F.: El Colegio de México/Fundación Gonzalo Díaz Arronte/UNAM.

Salinas, G. 2000. *Abastecimiento de Agua Potable a la Ciudad de Hermosillo, Sonora*. Geos, 20(3), 187–200.

Schneier-Madanes, G. 2005. Conflicts and the rise of user's participation in the Buenos Aires Water Supply concession (1993–2003). In: Coutard, O., R. Hanley, and R. Zimmerman., *Sustaining urban networks*, London-New York: Routledge, 151–171.

Schneier-Madanes, G., and B. de Gouvello. (eds.) 2003. *Eaux et réseaux: les défis de la mondialisation*, Paris: Travaux et Mémoires IHEAL/La Documentation Française.

Turner, E. 2006. Influencia de la industria maquiladora y el TLCAN en la demografía y el desarrollo económico de la frontera norte de México. *Análisis Económico* 21(46) 369–396.

U.S. Environmental Protection Agency. 2001. *Status Report on the Water-Wastewater Infrastructure Program for the US-Mexico Borderlands*. http://www.epa.gov/OWM/mab/mexican/usmexrpt. Accessed April 17, 2008.