Water resources management in Mexico

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Water resources management is a significant challenge for Mexico. Furthermore, water management is imposing a heavy cost to the economy. The arid northwest and central regions contain 77% of Mexico's population and generate 87% of the gross domestic product (GDP).[1] By contrast, the poorer southern regions have abundant water resources ;however, surface and groundwater are overexploited and polluted thus leading to an insufficient water availability to support economic development and environmental sustainability. The country has in place a system of water resources management that includes both central (federal) and decentralized (basin and local) institutions.

Water resources management in Mexico	
Withdrawals by sector 2008	Domestic: 14% Agriculture: 76.8% Industry: 9.3%
Surface water produced internally	361 km3 (87 cu mi)
Groundwater recharge	139 km3 (33 cu mi)
Overlap shared by surface water and groundwater	91 km3 (22 cu mi)
External renewable water resources	48.22 10^9 m3 per capita
Renewable water resources per capita	3,606 m3 (127,300 cu ft)
Wetland designated as Ramsar sites	53,178.57 km2 (13,140,710 acres)
Hydropower generation	22%

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Water management history and recent developments

Mexico has a long and well-established tradition on water resources management (WRM) which started approximately in the 1930s when the country began investing heavily in water storage facilities and groundwater development to expand irrigation and supply water to the rapidly increasing population.

The 1934 Código Agrario, promulgated during the Cárdenas administration (1934–1940), granted the federal government powers to define the "public interest" to which water could be harnessed. By virtue of such legislation, between the 1930s and 1970s, the rural community and ejido sector were subject to direct federal control over water.[2] Private landowners, on the other hand, enjoyed the benefits of federally subsidized irrigation infrastructure and guaranteed market prices. Over time, large landowners became highly capitalized, while small land owners, by the 1970s, were suffering from the effects of water monopolies.[3]

In the 1970s, the Mexican government entered into a tripartite agreement with the World Bank and the United Nations Development Program to prepare the 1975 National Water Plan (NWP), which identified the need to enact a New Water Law (NWL) and a National Water Authority (ANA) as well as decentralize responsibilities and promote water user participation in operational and maintenance (O&M). The NWP spurred a significant institutional development and infrastructural achievements: (i) the federal government transfer responsibilities for water supply and sanitation to municipalities and states in 1983, (ii) the Mexican Institute of Water Technology was established in 1986, (iii) the National Commission on Water (CONAGUA (http://www.cna.gob.mx/Default.aspx)) was established in 1988, and (iv) in 1989, the first Basin Council was created in Lerma Chapala, incorporating water users from multiple sectors.

During the 1990s, there was a rapid groundwater development and aquifer pumping for combined agricultural, urban, and industrial demand. Also the federal government decentralized responsibility for large irrigation infrastructure to autonomous agencies (irrigation districts).

In 1992, Mexico adopted the Ley de Aguas Nacionales (LAN), which contained specific provisions for the role of the CONAGUA, the structure and functioning of river basin councils, public participation in water management, etc. In 1993 the Cutzamala system, one of the largest pumping schemes in the world, was completed. The Cutzamala system pumps 19 cubic meters per second (670 cu ft/s) of water into the Mexico City metropolitan area.

In 1997 the first technical groundwater committee was created to manage an overexploited aquifer in the state of Guanajuato.

With the 2004 Revision of the National Water Law, the thirteen decentralized CNA regions would become basin organizations serving as the technical arm of more broad-based basin councils that incorporate civil society interests including the private sector and citizens' groups.[3]

Water resource base

Surface and ground water resources

Watersheds of Mexico. Basins in green drain to the Pacific, in brown to the Gulf of Mexico, and in yellow to the Caribbean Sea. Grey indicates interior basins that do not drain to the sea.

Mexico's internal renewable water resources per capita is 4,016 cubic metres (141,800 cu ft), which is below the average in the Central American and the Caribbean region, 6,645 cubic metres (234,700 cu ft).

A volume of 396 cubic kilometres (95 cu mi) of water per year flows through Mexico's rivers, including imports from other countries and excluding exports. A total of 65% of this surface runoff occurs in seven rivers: Grijalva, Usumacinta, Papaloapan, Coatzacoalcos, Balsas, Panuco, Santiago and Tonala, whose total watershed area represents 22% of the country's total land area. The Balsas and Santiago rivers empty on the Pacific Ocean, while the other five empty into the Gulf of Mexico.[4]

The historical mean annual precipitation (1941–2004) is 773 mm (30.4 in), with 77% of all precipitation accruing between June and October.[5] A little over 70% of rainwater in Mexico is lost through evapotranspiration and returns to the atmosphere. The rest runs off rivers and streams or infiltrates into the subsoil and recharges groundwater.[6]

Mexico shares three watersheds (Colorado, Bravo and Tijuana) with the United States, four with Guatemala (Grijalva, Usumacintam Suchiate, Coatan, and Candelaria) and one with Belize and Guatemala (Rio Hondo). The waters are shared with the U.S. in accordance with the stipulations included in the Treaty on the Utilization of the Waters of the Colorado, Tijuana and Rio Grande Rivers, signed in 1944.

Groundwater accounts for 64% of the volume for public water supply, 33% of all water used for agriculture and livestock, and 24% of water utilized by self-supplied industry. There are 653 groundwater aquifers in Mexico. CONAGUA estimates the total amount of groundwater recharge to be around 77 cubic kilometres (18 cu mi) per year, 36.4% of which, (around 28 km^3 or 6.7 cu mi per year) are actually used. This average rate does not fully represent the situation of the arid region, where a negative balance is threatening the sustainable use of groundwater resources.

Groundwater is a key water supplier for several users in the arid region or in some cities where groundwater is most of the time the sole water resource available. About 71% of the groundwater is used for agriculture, 20% for water urban supply and 3% for domestic and animal use.[7]

Storage capacity and infrastructure

Mexico counts with 4,000 dams and other hydraulic infrastructure with a storage capacity of 180 cubic kilometres (43 cu mi), which account for 44% of the annual flow. In the arid regions, dams are mostly used for irrigation. In the humid areas, dams are mostly used for electricity generation. Dams are also considered a means for flood protection in Mexico. Approximately 63 dams have a storage capacity of over 100,000,000 cubic metres (81,000 acre·ft), and account for 95% of Mexico's storage capacity.[6] The largest reservoirs are La Angostura (20,217 km^2), Nezahualcóyotl (14,0298 km^2), Chicoasén (11,883 km^2), and Infiernillo (11,860 km^2).[8]

Mexico has approximately 70 lakes with a storage capacity of 14 km^3 (3.4 cu mi). The largest lake, the Chapala Lake, has a storage capacity of 8,126 cubic hectometres (1.950 cu mi).

Main lakes and storage capacity					
Lake	River basin area		Storage capacity		Federal Entity
	km²	sq mi	hm³	acre feet	
Chapala	1,116	431	8,126	6,588,000	Jalisco and Michoacan
Cuitzeo	306	118	920	750,000	Michoacan
Patzcuaro	97	37	550	450,000	Michoacan
Yuriria	80	31	188	152,000	Guanajuato
Catemaco	75	29	454	368,000	Veracruz
Tequesquitengo	8	3.1	16	13,000	Morelos
Nabor Carrillo	10	3.9	12	9,700	Mexico

Source: CONAGUA

Water quality

According to the Water Quality Index, 96% of Mexico's surface water bodies have different levels of pollution. OECD estimates the economic cost of water pollution in Mexico at US$6 billion per year. The problem is most serious in the Valle de Mexico region where 100% of the water bodies have different levels of contamination, 18% of which are highly polluted. Low water quality is due to untreated discharge of industrial effluents and municipal wastewater into rivers and lakes, solid waste deposits along river banks, uncontrolled seepage from unsanitary landfills, and non-point pollution mainly from agricultural production.[9]

CONAGUA has also detected infiltration of untreated municipal wastewater in 8 aquifers, iron and manganese in 2, arsenic in 1 aquifer of the Lagunera region. In overexploited aquifers, contamination tends to worsen over time as the groundwater reservoir is depleted. This is the case of the Lagunera region, where concentration of 0.09 to 0.59 mg/L of arsenic found in the drinking water, are above of the permissible level of 0.05 mg/L. In addition, information regarding water quality, available by the Public Water Rights and Registry, is scarce and often unreliable.[9]

Water resources management by sector

Water withdrawal per sector in 2005							
Withdrawal	Freshwater		Groundwater		Total		%
	hm³	acre feet	hm³	acre feet	hm³	acre feet	
Agriculture (a)	39,545.0	32,059,700	19,176.0	15,546,200	58,721.3	47,606,100	76.8
Domestic	3,879.0	3,144,800	6,824.5	5,532,700	10,703.5	8,677,500	14.0
Industrial (d)	5,347.2	4,335,000	1,736.4	1,407,700	7,083.6	5,742,800	9.3
Total	48,771.5	39,539,700	27,736.9	22,486,700	76,508.4	62,026,400	100
Source: CONAGUA (a) Including livestock and aquaculture (b) Including hydropower							

Drinking water and sanitation

In 1998, domestic consumption accounted for 17% of surface water withdrawals in Mexico. During the past decade, the Mexican **water supply** and **sanitation** sector made major strides in service coverage. In urban areas almost 100% of the population is estimated to have access to improved water supply and 91% to adequate sanitation. In rural areas, the respective shares are 87% for water and 41% for sanitation.[10] Coverage levels are particularly low in the southern regions. (See also Water supply and sanitation in Mexico)

Irrigation and drainage

In 1998, agriculture accounted for 78% of surface water withdrawals in Mexico. A total of 62,000 km² (15.3 million acre) count with irrigation infrastructure (22.9% of the total cultivated area), 55,000 km² (13.6 million acres) of which are actually irrigated. In 1997, 58,000 km² (14.3 million acres) use surface irrigation, 3,000 km² use sprinkler irrigation and 1,000 km² localized irrigation. Ineffective irrigation has generated salinization and drainage problems in 3,841.63 square kilometers (949,290 acres) of a total irrigated area of 62,560 square kilometers (15,460,000 acres).[6] (See also Irrigation in Mexico)

Hydropower

The electricity sector in Mexico relies heavily on thermal sources (74% of total installed capacity), followed by hydropower generation (22%). The largest hydro plant in Mexico is the 2,300 MW Manuel Moreno Torres in Chicoasén, Chiapas. This is the world's fourth most productive hydroelectric plant.[11] (See also Electricity sector in Mexico)

Aquatic ecosystems

There are approximately 70 lakes in Mexico, covering a total area of 3,700 square kilometers (910,000 acres). Some of these lakes, especially in the Eastern side, have a volcanic origin and count with numerous endemic species. Lake Chapala, the largest Mexican lake, is considered a hydrological priority region for biodiversity conservation due to its 39 local species, 19 of which are endemic. The Lake Catemaco, located in Veracruz, has 12 native species 9 of which are endemic.[12]

Wetlands in Mexico are dynamic, complex and productive ecosystems. Six major wetland are registered in the RAMSAR Convention on Wetlands: Lagartos River (Yucatan Peninsula), Cuatrocienagas (Coahuila), La Encrucijada (Chiapas), Marsh Nayarit and Sinaloa, Centla Swamp (Tabasco), and the Colorado River (Baja California).

Cenotes, sinkholes on the Yucatan peninsula that are filled with groundwater, host a number of unique species from bacteria, algae and protozoa (i.e. copepoda, cladocera and rotifera) to vertebrates (i.e.lepisosteus).[12] Cenotes are the main water source for many ancient and contemporary Maya people, as there are no rivers and very few lakes on the peninsula.

A *Lepisosteus*, one of the endemic species of Mexico

Legal and institutional framework

Legal framework

The main law governing water resources management in Mexico is the National Water Law of 1992 (Ley de Aguas Nacionales -LAN), revised on April 29, 2004.[13]

According to the LAN key functions in the sector are the responsibility of the federal government, through the National Water Commission (CNA or CONAGUA). The LAN made possible to implement a regulatory framework that seeks to encourage greater efficiency and a more accurate perception of the social, economic, and environmental value of water resources. Therefore, waters users operate within a framework of rights and obligations that are clearly defined in three basic instruments:

- Titles of concession or allocation, which establish the right to withdraw, use or enjoy in usufruct a specific volume of water
- Permits for wastewater discharges. This instrument establishes the concession under which permittees must dispose of resulting wastewater
- Enrollment in the Public Registry of the Water Rights (Registro Publico de Derechos de Agua – REDPA) of both titles of concession or allocation and permits for discharging wastewater, which affords the rights granted to water users greater certainty and assistance form a legal standpoint.

The 2004 amended National Water Law (NWL) aims to restructure CONAGUA key functions through the transfer of responsibilities from the central level to subnational entities: the basin agencies (Organismos de Cuenca – BA) and Basin Councils (Consejos de Cuenca – BC). BA and BCs are expected to play an increasing role in the sector limiting CONAGUA's role to the administration of the NWL, the conduct of national water policy, and planning, supervision, support and regulatory activities.

The NWL also introduced a Water Financing System (Sistema Finaciero del Agua – SFA). CONAGUA will create together with the Ministry of Finance appropriate instruments to determine funding sources, spending guidelines, cost recovery, settling of accounts and management indicators.

Institutional framework

Three groups of institutions have been assigned with the main responsibilities for WRM: (i) the National Water Commission (Comision Nacional del Agua –CONAGUA), at the federal level; (ii) Water Commissions (Comisiones Estatales del Agua – CEAs), at the State level; and (iii) basin authorities and basin councils.

CONAGUA is the highest institution for water resource management in Mexico, including water policy, water rights, planning, irrigation and drainage development, water supply and sanitation, and emergency and disaster management (with an emphasis on flooding). CONAGUA's mission is to manage and preserve national water resources, with the participation of the society, to reach a sustainable use of the resource.

CONAGUA is formally under the authority of the Ministry of Environment and Natural Resources (Secretaria del Medio Ambiente y Recursos Naturales – SEMARNAT) but it enjoys considerable de facto autonomy. It employs 17,000 professionals, has 13 regional offices and 32 state offices and had an annual budget of US$1.2 billion in 2005. It also directly manages certain key hydraulic facilities such as the Cutzamala Pipeline that supplies a large share of the water used in the Metropolitan Area of Mexico City. CONAGUA also owns and operates most dams in Mexico and operates the country's water monitoring network.[9]

The CEAs are autonomous entities that usually are under the authority of the State Ministry of Public Works. Their attributions are different among states and can include water resources management, irrigation and the provision of water supply and sanitation services.

The recently created Basin Authorities (BAs) will develop from the 13 existing Regional Offices of CONAGUA and are expected to be responsible for formulating regional policy, designing programs to implement such policies, conducting studies to estimate the value of the financial resources generated within their boundaries (water user fees and service fees), recommending specific rates for water user fees and collecting them. Basin Councils (BCs) are expected to guide, together with CONAGUA, BAs work. There are a total of 25 BCs that have been established with the same basin boundaries as the BAs.[9]

Government strategy

The **National Water Plan 2007-2012**, linked to the National Development Plan, aims at ensuring water quality and quantity, recognizing the strategic value of water and promoting sustainable water use and water resources conservation. The Plan has eight objectives, namely: (i) increasing agricultural productivity, (ii) increasing access and quality of water supply and sanitation services, (iii) promoting integrated water resources management at the river basin level, (iv) improving technical, administrative and financial development of the water sector, (v) increase participation of water users and society in general in the management of water resources, (vi) reduce water risks, (vii) evaluate climate change impacts on water resources, and (viii) promote compliance with the National Water Law, especially on administrative matters.

Each objective has a strategy and a set of goals associated. The NWP has a total budget of 227,130 million pesos (about US$21.9 billion), which does not include operational and maintenance costs of hydraulic infrastructure.

Water pricing, cost recovery and subsidies

Mexico lacks a coherent national policy framework for setting and linking water and sanitation tariffs, subsidies and cost-recovery goals. The absence of overarching policies produces a wide variation in the degree of cost recovery and subsidies across regions. Tariffs are set below costs – the most common form of user subsidy in water supply and sanitation.

Water service providers charge industrial and commercial user tariffs that are close to full recovery cost, and cross subsidize residential users. The average tariff across users, US$0.32 per cubic meter ($0.24/cu yd), is half the Latin American and the Caribbean average, US$0.65/m³ ($0.50/cu yd).

The level of collection efficiency in Mexico has been estimated at 72%, far below the levels achieved in developed countries (OECD 95%). Water tariff collections in water supply and sanitation have been estimated at US$1.54 billion in 2002. Billed revenues were estimated at between US$2.14 billion and US$2.9 billion.

Approximately 31% of water customers are not metered and are charged a flat rate, independent of consumption, differentiated by neighborhood.[14]

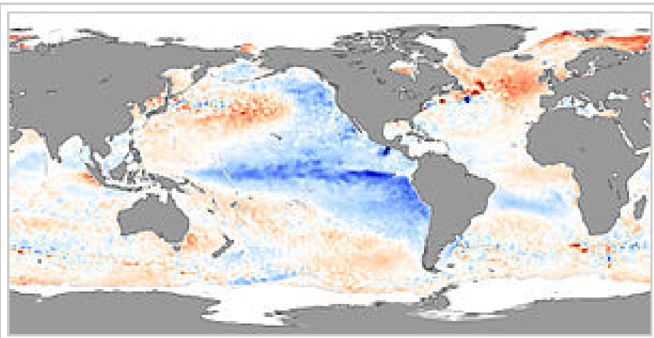
Water-related risks

Hurricane Dean photographed by International Space Station astronauts

Mexico is prone to several weather events including hurricanes on both Pacific and Caribbean coasts. Hurricanes contribute to recharge surface and groundwater reservoirs with increases water supply for cities, irrigation and electricity generation. Hurricanes pose also a threat to service delivery, infrastructure and ultimately to ecosystems and human life. This situation is aggravated by deforestation upstream as well as human settlements located in flood prone areas.[15]

With more than 85% of the Mexican land area defined as arid or semi-arid and a highly variable interannual rainfall Mexico is also prone to droughts, especially in the northern areas. The most severe droughts in Mexico in recent decades coincide with the variations in Pacific sea-surface temperatures associated with El Niño. The economic and social and environmental impacts of droughts in Mexico are notable. In 1996, four years of below normal rainfall produced farms losses estimated at US$1 billion and interstate political between Sonora and Sinaloa.[16]

Potential climate change impacts



Sea surface skin temperature anomalies in November 2007 showing La Niña conditions

In parts of Mexico climate change is projected to produce a decrease in water flow. Furthermore, an increase on water demand is expected due to increasing temperature and extreme weather conditions such as droughts and floods due to El Niño Southern Oscillation and La Niña are expected to become more frequent.

The IPCC considers various scenarios with increases in temperatures ranging between 1 and 6 degrees Celsius. By 2050, the Mexican Institute of Water Technology expects a 7-12% decrease in precipitation in the southern basins, 3% in the Mexican Golf basin, and 11% in the central basin. Precipitation is estimated to continue to decrease over the next 50 years. An increase in category 5 hurricanes is also expected.[17]

During some El Niño/La Niña years, winter precipitation may be so great that stream flow and water levels in dams may exceed those observed during summer. In contrast, summer droughts during these events can lead to serious deficits in reservoir levels and in rain-fed maize production. In Mexico during 1997, the estimated costs of climate anomalies associated with El Niño were 900 million US dollars, particularly in agricultural activities, when 20,000 km² (5 million acres) were affected by a severe drought.[18]

In 2007, SEMARNAT (http://www.semarnat.gob.mx/Pages/inicio.aspx) together with the Instituto Mexicano de Tecnología del Agua (http://www.imta.gob.mx/) published a study "Climate Change Effects on Water Resources in Mexico (http://www.imta.gob.mx/gaceta/anteriores/g07-11-2007/gaceta-imta-07.pdf)." The main findings are summarized below.

Qualitative vulnerability to climate change by hydrologic-administrative region

Hydrological Region	Change in demand	Change in availability	Scarcity	Hurricane, storms	Droughts	Change in sea level	Observations
Baja California	Major	Decrease	Very vulnerable	Not very vulnerable	Vulnerable	Not very vulnerable	The basin depends on water flowing from the US, which is expected to reduce
Northeast	Major, agriculture biggest water use	Decrease	Very vulnerable	Not very vulnerable	Vulnerable	Sea intrusion on coastal aquifers	One of the most vulnerable regions in Mexico
North Pacific	Major, agriculture biggest water use	Unknown	Vulnerable	Vulnerable	Unknown	Sea intrusion on coastal aquifers	Need further studies
Balsas	Major	Probable decrease	Vulnerable	Very vulnerable in the coastal region Guerrero and Michoacan	Vulnerable	Sea intrusion on Rio Balsas	Severe effects on agriculture in Tlaxcala and highlands
South Pacific	Major	Unknown. Some models expect increased precipitation	Specially on high mountain	Very vulnerable, coastal region	Not very vulnerable	Not very vulnerable	One of the most vulnerable to storms
	High due to	Expected					One of the most

Rio Bravo	increased population and temperature	decrease on flows and aquifer recharge	Very vulnerable	Not very vulnerable	Very vulnerable	N/A	important basins and most vulnerable to scarcity and droughts
Central north basins	High, due to increased temperature	Expected decrease on flows and aquifer recharge	Very vulnerable	N/A	Very vulnerable	N/A	One of the most vulnerable basins to scarcity and droughts
Lerma-Santiago-Pacifico	Medium	Unknown, models predict few changes	Very vulnerable due to high use	Not very vulnerable	Vulnerable, high natural variability	Not very vulnerable	Need further research due to high vulnerability and uncertain models
North Gulf	High, due to increased temperature	High probability of increasing, according to most of the models	Not very vulnerable	Vulnerable	Not very vulnerable	High vulnerability on several rivers' mouths	Probable need to revise design of hydraulic infrastructure, dams, and flooding control.
Center Gulf	High, due to increased temperature	High probability of increasing, according to most of the models	Not very vulnerable	Vulnerable	Not very vulnerable	High vulnerability on several rivers' mouths	Probable need to revise design of hydraulic infrastructure, dams, flooding control, and landslide
South frontier	High, due to increased temperature	Few changes due to high availability	Not very vulnerable	Very vulnerable, especially on coastal Chiapas	Not very vulnerable, but need for new regulation works	High vulnerability especially on Grivalda and Campoton estuaries	Probable need to revise design of hydraulic infrastructure, dams, flooding control, and landslide
Yucatán	High, due to increased temperature	Vulnerable due to lack of regulation	Vulnerable due to lack of regulation	Very vulnerable, especially on coastal area	Vulnerable due to seasonal droughts	Vulnerable, due to sea intrusion on aquifers	Need of detailed research due to unique geology
Valley of			Very		Not very		Already on water deficit, in need of

Mexico	Low	Low	vulnerable	Vulnerable	vulnerable	N/A	high coast adaptation measures

Source: SERMANAT (2007)

External cooperation

The World Bank is currently contributing with US$28.5 million, to an Adaptation to Climate Change Project in the Gulf of Mexico ([1] (http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2007/09/24/000021271_20070925143034/Rendered/PDF/Project0Inform1ment010Concept0Stage.pdf)). This project aims at formulating and implementing adaptation policy actions and specific measures in representative systems of Gulf of Mexico wetlands in order to protect their environmental functions and their rich biodiversity from climate change related impacts, and improving the knowledge base to ascertain with a higher level of certainty the anticipated impacts from climate change on the country's water resources, with a primary focus on coastal wetlands and associated inland basins. The

In November 2007, the Inter-American Development Bank approved a US$200,000 project to support a program for flood emergency in Tabasco. In September 2007 it approved a US$200,000 project to support a program to relief damages caused by Hurricane Dean.

See also

- Electricity sector in Mexico
- Water supply and sanitation in Mexico
- Irrigation in Mexico
- Water resources in Mexico

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External links

- Centro Virtual de Informacion del Agua (http://www.agua.org.mx/)

- CONAGUA official website (http://www.conagua.gob.mx/Default.aspx)