4 From Half-full to Half-empty: the Hydraulic Mission and Water Overexploitation in the Lerma–Chapala Basin, Mexico

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Introduction

This chapter portrays the river basin trajectory of the Lerma–Chapala basin in central Mexico. It analyses the relationship between basin closure and the hydraulic mission, defined as the strong conviction that the state should develop hydraulic infrastructure to capture as much water as possible for human uses (Wester, 2008). In particular, it focuses on the role of the hydrocracy (hydraulic bureaucracy) in the creation of water overexploitation in the basin.

The Lerma–Chapala basin is in serious trouble, with water use at unsustainable levels and severe water pollution. Since the late 1970s, groundwater overexploitation has led to sustained declines in aquifer levels of 2 m/year on average, while surface water depletion has been close to, or has exceeded, annual river runoff in all but the wettest years. This was made possible by the drawing down of water stored in lakes and reservoirs. Twice in the 20th century (in 1955 and 2002), Lake Chapala, the downstream lake into which the Lerma River flows, nearly fell dry, losing more than 80% of its volume on both occasions. Between 2003 and 2008 above-average rainfall lessened the surface water crisis, with Lake Chapala recovering to above 80% of its storage capacity in September 2008, the highest level since 1979. While years of abundant rainfall can temporarily stop the overexploitation of surface water, the long-term consequences of water pollution and groundwater overexploitation are more dramatic and difficult to reverse. Tackling these three water crises requires addressing their interlinkages and the social mechanisms and institutional arrangements that govern water use.

The Lerma–Chapala basin provides a striking example of the complexities of water reforms in closed river basins, where consumptive water use is close to, or even exceeds, the level of renewable water availability (Keller *et al.*, 1996; Seckler, 1996). It is a basin in which many of the policy prescriptions emphasized in international water debates, such as irrigation

 River Basin Trajectories: Societies, Environments and Development (eds Molle and Wester)

management transfer (IMT) (Gorriz *et al.*, 1995; Rap, 2006), integrated river basin management (IRBM) (Mestre, 1997; Wester *et al.*, 2003) and increasing stakeholder participation in water management have been applied. Owing to the important economic and social interests linked to water in the densely populated and economically important Lerma–Chapala basin, it has served as a water policy testing ground for successive Mexican governments. Starting in the early 1990s, the federal government has enacted far-reaching water reforms (decentralization, participatory organizations, a new water law in 1992), accompanied by substantial funding for water treatment plants, support to water organizations, water-saving programmes and public-awareness campaigns. However, these efforts have not reversed environmental degradation in the basin nor led to a reduction in water use, and the three water crises remain dramatic today. This chapter explores why this is so, primarily focusing on surface water.

The next section introduces the basin and describes the process of basin closure. The following three sections provide a broad overview of the trajectory of the Lerma–Chapala basin, focusing on three periods (1500–1910, 1911–1980 and 1981 to the present). For each period, an analysis of the history of water development and the concomitant transformations in terms of water control and management are given. Conclusions are then drawn.

The Main Water Challenges in the Lerma–Chapala Basin

Physical setting of the Lerma–Chapala basin

The Lerma–Chapala basin is named after the Lerma River and the lake into which this river drains, Lake Chapala (see Fig. 4.1). When full, Lake Chapala discharges into the Santiago River, which flows in a north-westerly direction, to meet the Pacific after some 520 km. Since the early 1980s, very little water has flowed naturally from Lake Chapala to the Santiago River, due to dropping lake levels, and the Lerma–Chapala basin has, in effect, become a hydrologically closed basin. Lying between Mexico City and Guadalajara, the basin crosses five states (Querétaro, covering 5% of the basin, Guanajuato (44%), Michoacán (28%), México (10%) and Jalisco (13%)) and covers around 55,000 km^2, nearly 3% of Mexico's land area. Although the average annual runoff in the basin of 5513 Mm^3 (DOF, 2003) is only 1% of Mexico's total runoff, the basin is the source of water for 15% of Mexico's population (11 million in the basin and 2 million each in neighbouring Guadalajara and Mexico City). Located in central Mexico, the basin is an important agricultural and industrial area, containing around 13% of the area equipped for irrigation in the country and generating 9% of Mexico's gross national product (Wester *et al.*, 2005).

Irrigated agriculture, covering some 795,000 ha, is the main water user in the basin. Eight irrigation districts (formerly state managed) cover around 285,000 ha, while some 16,000 farmer-managed or private irrigation systems (termed 'irrigation units' in Mexico) cover 510,000 ha. Twenty-seven reservoirs provide 235,000 ha in the irrigation districts with surface water, while around 1500 smaller reservoirs serve 180,000 ha in the irrigation units. An estimated 17,500 tube-wells provide around 380,000 ha in the basin with groundwater, of which 47,000 ha are located in irrigation districts (CNA/MW, 1999). The area actually irrigated between 1980 and 2001 is a matter of debate, with estimates ranging from 628,000 ha (CNA/MW, 1999) to more than a million ha (INE, 2003) per year.

Lake Chapala, with a length of 77 km and a maximum width of 23 km, is Mexico's largest natural lake. At maximum capacity the lake stores 8125 Mm^3 and covers an area of 1154 km^2 (Guzmán, 2003:110). When full, the average depth of the lake is 7.2 m, making it one of the world's largest shallow lakes. The shallow depth of the lake results in the loss of a large percentage of its storage to evaporation each year, with net evaporation of around 600 Mm^3 per year. Lake Chapala is highly valued by the inhabitants of Jalisco state, where the lake is situated, as well as by some 30,000 foreigners (mostly American retirees) living on its shores, and is a prime tourist destination. In addition, it provides Guadalajara, Mexico's second largest city, with 65% of its water supply.

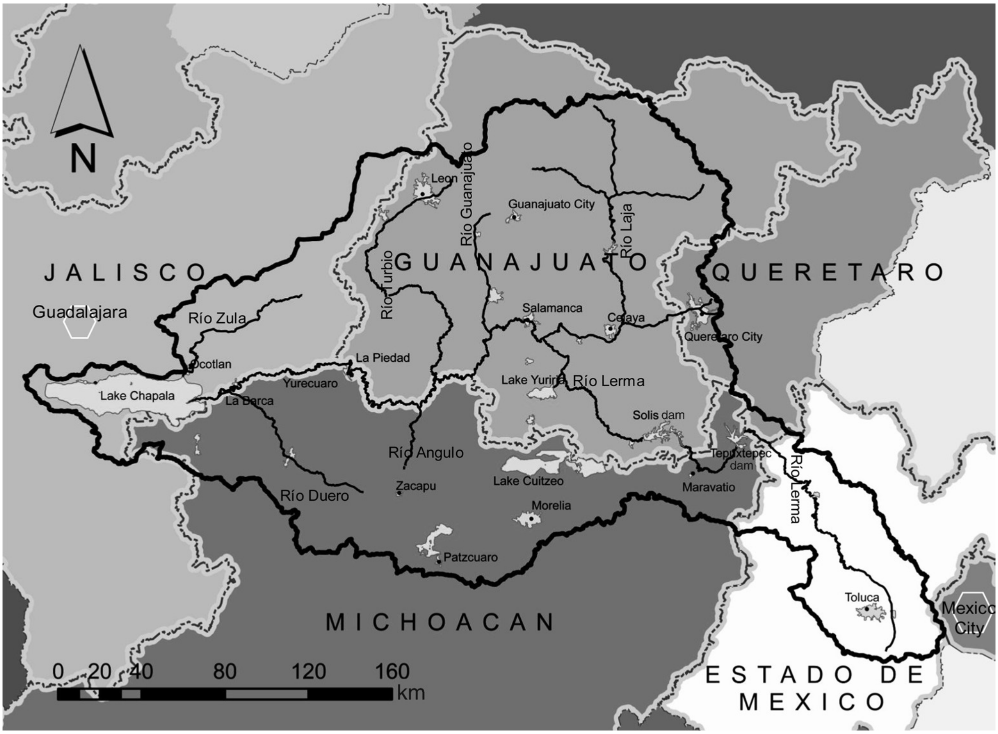

Fig. 4.1. States and rivers in the Lerma–Chapala basin.

Water overexploitation and Basin Closure

Since the early 1980s, surface water and groundwater in the basin have been overexploited. Although average rainfall from 1990 to 2001 (679 mm) was only 6% below the historical average (722 mm) (IMTA, 2002a), the amount of water depleted in the basin exceeded annual renewable water during this period, with no allocations for environmental flows. This was made possible by lowering the interannual stock of water stored in the basin's lakes, reservoirs and aquifers. Groundwater was overexploited, with declines in static aquifer levels of 1–5 m per year due to an estimated annual groundwater deficit of 1336 Mm^3 (IMTA, 2002a), while the consumptive use of surface water exceeded supply in all but the wettest years, nearly leading to the demise of Lake Chapala. Figure 4.2 presents the fluctuations in Lake Chapala's volume from 1934 to 2002, while Table 4.1 relates these fluctuations to developments in the basin. The section on Water Reforms and Water Transfers discusses how the lake fared after 2002.

Starting in 1945, water storage in the lake declined sharply, from an average of 6429 Mm^3 between 1935 and 1945 to 954 Mm^3 in July 1955, due to a prolonged drought combined with significant abstractions (750 Mm^3 per year on average) from the lake for hydroelectricity generation and irrigation (de P. Sandoval, 1994). During this period, around 214,000 ha were irrigated in the basin, mainly with surface water, and the constructed storage capacity in the basin was 1628 Mm^3. However, because of good rains towards the end of the 1950s, the lake recuperated, and storage averaged 7094 Mm^3 from 1959 to 1979.

In 1980, a second period of decline set in. By this time, constructed storage capacity in the basin had increased to 4499 Mm^3 and the average irrigated area had grown to around 680,000 ha, with a significant increase in groundwater irrigation. Although abstractions from the lake for hydropower generation had

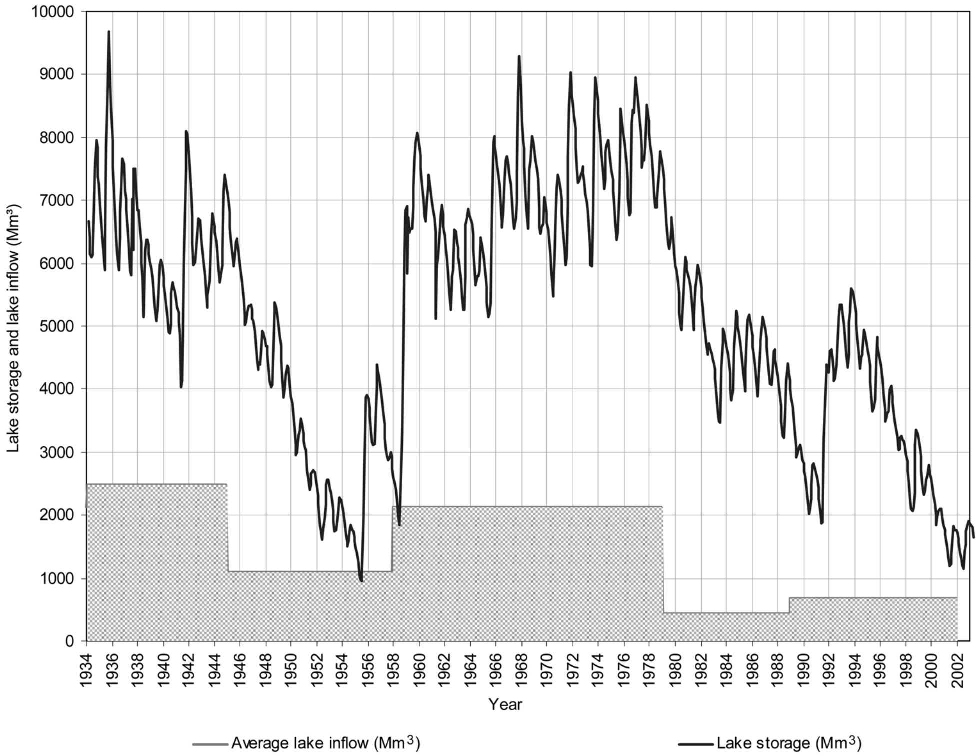

Fig. 4.2. Monthly Lake Chapala storage volumes and average inflows from 1934 to 2002.

Table 4.1. Overview of key water indicators in the Lerma–Chapala basin.

Period	Original (1934–1944)	Dry (1945–1957)	Wet (1958–1978)	Normal (1979–1988)	Latest (1989–2001)
Rainfall (mm/year)[a]	683	626	764	705	679
Inflow to Lake Chapala (Mm^3/year)[b]	2,485	1,085	2,127	429	677
Inhabitants (thousands of people)[c]	2,500 (1940)	3,000 (1950)	4,500 (1970)	8,700 (1990)	11,000 (2000)
Irrigated area (ha)[d]	155,000	214,000	508,000	675,000	689,000

Sources: [a]de P. Sandoval (1994) for all periods, except IMTA (2002a) for rainfall from 1989 to 2001; [b]de P. Sandoval (1994) up to 1988, BANDAS CD-ROMS for 1989 to 2001 (IMTA, 2002b); [c]de P. Sandoval (1994) for 1940, 1950, 1970. Census figures for 1990, 2000 from CNA/MW (1999); [d]Estimates of actual total irrigated area, averaged for the period, from CNA/MW (1999).

ceased, Guadalajara city started drawing large amounts of its urban water supply (between 200 and 400 Mm^3) directly from the lake. The combination of these factors and below-average rainfall (705 mm) resulted in declines in the lake's storage to around 2000 Mm^3 in 1990. After a good recuperation in the early 1990s, with lake storage reaching 5586 Mm^3 in October 1993 (68% of maximum storage), lake storage started declining again, dropping to

1145 Mm^3 in June 2002 (14% of maximum storage), the lowest measured since 1955 (see Fig. 4.2).

Table 4.1 provides further details of the water situation in the basin, showing the sharp drop in inflows to Lake Chapala since 1979. While average rainfall from 1979 to 1988 was higher (705 mm) than from 1934 to 1944 (683 mm), the inflow to Lake Chapala was markedly lower (429 Mm^3 versus 2485 Mm^3). River inflow from 1989 to 2001 was slightly higher (677 Mm^3), due to good rains in the early 1990s, but this was not enough to reverse the decline of Lake Chapala. Thus, the second period of lake decline was mainly due to the overextraction of water for urban use in Guadalajara and agricultural use both upstream and directly from the lake, and partly due to less rainfall. Between 1930 and 2000, the irrigated area in the basin increased fivefold, according to official statistics, and possibly by a factor of 7.5, while the population also increased fivefold during this period. The resulting levels of blue water depletion have made the basin very sensitive to variations in rainfall, with lower than average rainfall directly translating into reduced inflows to the lake. Between 1980 and 2001, the lake experienced a negative annual storage change of 191 Mm^3 on average (IMTA, 2002a), but in years with above-average rainfall, such as 1991, the volume of the lake increased markedly.

To analyse Lerma–Chapala's trajectory, the hydraulic mission concept is used. Based on work by Reisner (1993) and Swyngedouw (1999), Wester defines the hydraulic mission as:

> the strong conviction that every drop of water flowing to the ocean is a waste and that the state should develop hydraulic infrastructure to capture as much water as possible for human uses. The carrier of this mission is the hydrocracy, which sets out to control nature and 'conquer the desert' by 'developing' water resources for the sake of progress and development.
>
> (Wester, 2008:10)

In Mexico, the hydraulic mission, the centralization of water development and the growth of the federal hydrocracy mutually reinforced one another and formed an important component of state formation in post-revolutionary Mexico. Three phases in the centralization of water resources development in Mexico can be identified: the birth of the hydraulic mission in the late 19th century, the rise of the hydraulic mission from the 1920s to the 1940s, and the heyday of the hydraulic mission from the 1950s to the 1970s. The following sections analyse these periods in the case of the Lerma–Chapala basin.

The Granary of Mexico: Water Development before the 1910 Revolution

Irrigation development in the Lerma–Chapala basin significantly expanded with the arrival of the Spaniards and the resulting colonization of the basin. The discovery of silver mines in Guanajuato in the 1550s led to the rapid settlement of the Bajío (a fertile valley in the basin covering most of Guanajuato, and parts of Querétaro and Michoacán) and the development of irrigated agriculture for wheat cultivation, mostly through private initiative and by monasteries (Murphy, 1986). The increasing demand for cereals by Mexico City led to the expansion of irrigation based on run-of-the-river irrigation schemes in the 17th and 18th centuries and the ingenious use of flood water through the construction of *cajas de agua* (embanked field ponds), primarily from tributaries of the Lerma River. This system consisted of interlinked and embanked fields of 5–200 ha each, filled in succession with flood water and with direct runoff from hills. These *cajas* (literally boxes) were drained in a staggered pattern after several months and then sown with wheat, while the larger *cajas* also stored water for supplementary irrigation. This form of controlled flooding was developed to a high degree of complexity in the Bajío (Sánchez, 2005). By the end of the colonial period, the basin's water resources were already intensively used, and by 1900 the run-of-the-river irrigation potential of the tributaries of the Lerma River had been largely developed, covering around 60,000 ha (SRH, 1953).

Towards the federalization of water allocation and development

The hydraulic mission started to gather force in Mexico towards the end of the 19th century, when the federal government began asserting its control over water both to promote commercial agriculture and to arbitrate in water allocation conflicts between *hacendados* (large landowners). Before then, irrigation and drinking water had largely been local affairs, although land and water rights were originally based on royal grants during the colonial period. The first 75 years of the 19th century were a period of turmoil and political unrest, with few new irrigation works in the basin. This changed in the last quarter of the 19th century, with attempts by *hacendados* to turn marshes and lakes into private property for land reclamation purposes.

The Porfirio Díaz regime (1876–1911), known as the Porfiriato, strongly supported private capital and foreign investment, and developed laws that led to extreme forms of land concentration. During the Porfiriato, the federal government established control over the country and focused on mining and railroad construction. An oligarchy of some 250 families, controlling 80% of the nation's land, handsomely profited from the increased production and trade, while an estimated 90–95% of rural households, forming 75% of Mexico's population, were landless according to the 1910 census (Hamilton, 1982). The extreme concentration of land ownership, with eight individuals holding 22.5 million ha in 1910, was a potent ingredient of the revolution that was to follow (Hamilton, 1982).

During the Porfiriato, the scale and number of hydraulic projects increased considerably, and the federal government started to play an active role in water development and the concessioning of water rights. In an excellent historical study, Aboites (1998) traces what he terms the federalization process in water affairs from 1888 to 1946. He indicates that, in the Mexican context, the term federalization refers to the process that led to the concentration of political and legal powers and faculties in the federal government, in short, centralization (Aboites, 1998). Before 1888, communities and municipalities administered water rights and water was controlled locally. This changed in 1888, when congress passed the *Ley General de Vías de Comunicación* (General Law on Communication Routes), which authorized the federal government to regulate the use of navigable and interstate rivers and specified that water concessions could only be issued by the federal government (Aboites, 1998). A decisive step in the federalization of water management was the amendment of Article 72 of the constitution in 1908, which placed rivers in the public domain. Based on this amendment, surface water as private property no longer existed and access to surface water was only possible through concessions issued by the federal government. Thus, in the space of 20 years, in legal terms, water in Mexico passed from being a local affair to falling in the public domain, administered by the federal government (Aboites, 1998).

Land reclamation projects in the Lerma–Chapala basin during the Porfiriato

Water development in the Lerma–Chapala basin during the Porfiriato mainly consisted of land reclamation, hydroelectricity projects and some irrigation development. These projects were undertaken by large landowners, sometimes in conjunction with foreign capital, and with an increasingly active involvement of the federal government in the funding and approval of these initiatives. The drainage of the Chapala and Zacapu marshes, and the proposals to drain the Lagunas de Lerma and the Cuitzeo and Yuriria lakes (see Fig. 4.1 for locations) stand out as examples of the land reclamation efforts (Wester, 2008). The expansion of run-of-the-river irrigation works on tributaries of the Lerma River also received attention, but the main incursion of the federal government in this area consisted of the formulation of river regulations.

The drainage of the Zacapu marsh (Ciénega de Zacapu), located in Michoacán near the headwaters of the Angulo River, is exemplary of how land reclamation projects were undertaken during the Porfiriato. As in other land reclamation projects, there was an important link between foreign capital, the federal bureaucracy and large *hacendados*. The Zacapu marsh, covering an area of around 150 km^2, was up to 8 m deep and surrounded by several haciendas and farming communities (Guzmán-Ávila, 2002). Eduardo Noriega, a *hacendado* and friend of Porfirio Díaz, obtained a concession from the federal government in 1900 to drain the marsh and construct a hydroelectricity plant near the exit of the marsh. As the Angulo was not navigable and did not form a boundary between two states and thus did not legally fall under federal jurisdiction, other *hacendados* challenged this concession, but to no avail. On the reclaimed land of 12,000 ha, Noriega developed an irrigation system, which started functioning in 1907, with a large loan from the federal government (Guzmán-Ávila, 2002).

The land reclamation fever rapidly spread throughout the basin during the Porfiriato, and various proposals were submitted to the federal government by *hacendados* to drain the Lagunas de Lerma and the Yuriria and Cuitzeo lakes. However, due to local opposition or struggles between *hacendados*, these works were not executed. A land reclamation project that was to have a lasting impact on Lake Chapala was the draining of the Ciénega de Chapala (Lake Chapala marsh). Until the late 19th century, Lake Chapala remained in its natural state, but this changed dramatically during the Porfiriato, as described below.

In 1894, a hydroelectricity plant, the first in Latin America and the second in the world, was constructed on the Santiago River at El Salto, some 60 km downstream of Lake Chapala, to provide Guadalajara with electricity. This plant received its water from Lake Chapala, which flowed into the Santiago River if the lake level was above *cota*[1] 95.00. The sill at the mouth of the Santiago River stopped the flow of water if the lake dropped below this level, while the form of the outlet to the Santiago River and the sediments deposited there by the Zula River, which joins the Santiago River just below Lake Chapala, restricted the amount of water leaving the lake above this level. This effectively blocked the outflow from the lake during the rainy season and could head up the water in the lake by 2–3 m. In one of the first studies on Lake Chapala, Miguel Quevedo y Zubieta shows that, on average, the lake reached *cota* 97.13 in the rainy season and would then fall to an average of *cota* 95.82 in the dry season, based on measured lake levels from 1896 to 1904 (Quevedo y Zubieta, 1906:18). As the average elevation of the Ciénega was *cota* 96.20, a large part of it would flood each year, depending on river inflows. When the Ciénega was flooded, Lake Chapala would reach a length of 100 km, a surface area of 1600 km^2 and would store around 9400 Mm^3 (de P. Sandoval, 1994:26).

During the dry season, when the lake dropped below *cota* 96.00, the little water that flowed into the Santiago was held up at the Poncitlán rapids. This led to the construction of a barrage at Poncitlán, completed in 1903, by which the level of Lake Chapala could be kept at *cota* 97.80. This made it possible to prolong high levels of storage in the lake, to be gradually released throughout the dry season for the El Salto hydroelectricity plant. However, it also entailed that the Ciénega de Chapala remained flooded longer. This led to complaints from *hacendados* with land in the Ciénega and motivated one of them, Manuel Cuesta-Gallardo, to develop plans to embank and drain the Ciénega de Chapala. He hired Luis P. Ballesteros to develop a plan for the reclamation and subsequent irrigation of the Ciénega, and in 1903 obtained a concession from the federal government to do so (Boehm, 1994). In 1905, work started on constructing embankments with a length of 95 km to separate the Ciénega from Lake Chapala, which was completed in 1910. A total area of 500 km^2 (50,000 ha) was cut off from the lake, reducing its storage capacity by some 1500 Mm^3 and leading to its current normal operating storage capacity of 7900 Mm^3 at *cota* 97.80 (Boehm, 1994).

Besides the land reclamation projects, the federal government became actively involved in drawing up river regulations. Based on the 1894 law, existing water rights had to be reconfirmed on rivers falling under federal jurisdiction, and the federal government had to approve new water concessions. Kroeber (1983) and Aboites (1998) provide a detailed account of how the Fifth Section of the *Secretaría de Fomento* drew up an increasing number of river regulations and how this led to increased federal control over water. In the Lerma–Chapala basin, the Laja River, a tributary of the Lerma in Guanajuato, provides an example of this process (Sánchez, 1999). In 1895, *hacendados* with colonial water rights on the Laja River requested that the federal government settle a water allocation dispute.

The federal government quickly established a commission to study the dispute, and in May 1897 decided that a complete study of the river was necessary to regulate all the water rights on the river. In 1901, the federal government enlarged the mandate of the study commission, to confirm and formalize all existing water rights and to conduct a full study of the river to verify if new water concessions could be awarded. Interestingly, the Laja was not a river falling under federal jurisdiction, but this did not prevent the Fifth Section from proposing a detailed river regulation in 1906 and establishing a permanent federal commission to inspect water withdrawals from the river. Although this was resisted by the haciendas drawing water from the Laja, the river was gradually brought under federal control (Sánchez, 1999).

This section has reviewed how the federal government increased its control over surface water during the Porfiriato. Through changes in the legal framework, the federal jurisdiction over rivers and lakes was expanded and the federal government became involved in confirming existing water rights and the formulation of river regulations. More importantly, large *hacendados* were granted concessions to drain lakes and to construct irrigation and hydroelectricity works, which frequently entailed the dispossession of previous water rights holders, primarily *campesinos* and *indigenas*, and also other *hacendados*. This oligarchic form of water resources development meant that the federal government itself did not construct water works, but rather supported a clique of *hacendados* with loans and water concession to do so. This changed after the Revolution of 1910–1920, as detailed below.

The Hydraulic Mission and the First Lake Chapala Crisis

The hydraulic mission of the hydrocracy and the bureaucratic–authoritarian state that developed in Mexico after the revolution of 1910–1920 strongly influenced water development in the Lerma–Chapala basin. The centralization of water development in Mexico accelerated in 1926 with the creation of the *Comisión Nacional de Irrigación* (CNI: National Irrigation Commission) and continued until the 1970s. These 50 years witnessed a large increase in the irrigated area in the Lerma–Chapala basin, intertwined with the formation and expansion of a strong hydrocracy with a keen sense of its hydraulic mission. The logo of the CNI and its successor, the *Secretaría de Recursos Hidráulicos* (SRH: Ministry of Hydraulic Resources), formed in 1946, contains the bold mission statement of Mexico's hydrocracy, namely *Por la Grandeza de México* (for the Greatness of Mexico). A more apt summary of the hydraulic mission is hard to come by.

The rise of the hydraulic mission: from oligarchic to revolutionary irrigation

The trend towards stronger federal control over water initiated under Porfirio Diaz's regime was consolidated in Article 27 of the 1917 Constitution. This article defined natural resources, including oil, land and surface water, as the inalienable property of the nation and established the *ejido* (common property) form of land tenure for the redistribution of land. Article 27 also established that the only way to gain access to surface water was through a concession granted by the federal government. Based on Article 27, the centralization of water management began in earnest in the 1920s, when President Calles launched a programme for the construction of large-scale irrigation districts and created the CNI as a semi-autonomous agency within the federal *Secretaría de Agricultura y Fomento* (SAyF: Ministry of Agriculture and Development). The CNI rapidly established itself as a competent hydrocracy and by 1935 was constructing 11 irrigation districts (IDs) throughout Mexico.

The CNI set out to develop 'revolutionary' irrigation systems, as opposed to the promotion of 'oligarchic' irrigation under the Porfiriato (Aboites, 1998). The revolutionary aspect initially consisted of using the construction of irrigation systems by the federal government to break up haciendas and colonize them with yeoman farmers, working and owning medium-sized irrigated farms (20–100 ha). The aim of the federal government was that this new rural middle class would gradually replace the large haciendas and would bring prosperity and stability to the countryside. Aboites (1998) has termed this 'revolutionary irrigation', as the post-revolutionary regime initially focused on using irrigation instead of land reforms to achieve the revolutionary promise of 'land and liberty', mainly in northern Mexico. With the more radical land reforms of the 1930s, attention shifted to supporting the *ejidos* (land reform communities) with irrigation works. In 1930, *ejidos* controlled only 15% of the land in irrigation districts, but by 1940 this had increased to 60% (Wionczek, 1982:370). Although the beneficiaries of the revolutionary irrigation policy were different, what remained the same was that the federal government led this social transformation process, by funding, designing and constructing the irrigation systems (Aboites, 1998). The management of the irrigation districts also became increasingly centralized from the 1930s onwards, although the water laws promulgated between 1926 and 1947 contained provisions for the creation of water boards to manage irrigation districts (Rap *et al.*, 2004). However, the CNI frequently took control of the irrigation districts, as detailed below for the Lerma–Chapala basin.

Irrigation development in the Lerma–Chapala basin under the CNI

The following provides an overview of irrigation development in the Lerma–Chapala basin during the CNI era. Attention is mainly paid to the creation of the Alto Río Lerma Irrigation District (ARLID) in the Middle Lerma region, which was to become the largest irrigation district in the basin, and brief mention is made of developments in the Lower Lerma region. This brings out how the CNI increased its control over water in the basin and set in motion the process leading to water overexploitation.

Before the CNI started developing water resources in the basin, around 60,000 ha were already irrigated in the basin, with numerous run-of-the-river irrigation systems and *cajas de aguas* (SRH, 1953). Shortly after the CNI was formed, heavy rainfall in 1926 led to extensive flooding in the Lerma–Chapala basin. The CNI immediately focused its attention on the basin and formed two internal commissions to develop plans for the development of irrigation districts and hydroelectricity plants in the basin. In their combined proposal, published in 1927, they recommended the construction of the Corrales dam on the Lerma River on the border of the Middle and Lower Lerma (see Fig. 4.3), to complement the Tepuxtepec dam, then under construction on the border of the Upper and Middle Lerma (Cuevas-Bulnes, 1941). The Corrales dam, with a planned storage capacity of between 750 and 1500 Mm^3, would serve to irrigate the lands of the Lower Lerma region, including the Ciénega de Chapala, and to generate hydroelectricity using the 150 m drop of the Zoró falls on the Lerma. They also recommended the construction of a new dam downstream of Tepuxtepec, to store more water for irrigation. It was estimated that 261,000 ha could be irrigated in the basin with surface water if these two new dams were built. Figure 4.3 presents the area currently irrigated in the basin and the main irrigation schemes and dams discussed in this chapter.

When the CNI presented its master plan, the construction of the Tepuxtepec dam had just started. In October 1926, a contract was signed between SAyF and the *Compañía de Luz y Fuerza del Suroeste de México* (Light and Power Company of Southwest Mexico), granting it an annual water concession of 750 Mm^3 for hydroelectricity generation and permission to construct the dam. The dam was completed in 1936, with a storage capacity of 370 Mm^3 (Santos-Salcedo, 1937). Between 1970 and 1973, the SRH elevated the dam's crest and increased its storage capacity to 585 Mm^3 (Garcia-Huerta, 2000).

After the construction of the Tepuxtepec dam, the amount of water flowing in the Lerma River increased during the winter season. This led to an increase in the irrigated area from some 36,000 ha in 1927 to some 46,575 ha in 1937 in the area that was to become the Alto Río Lerma irrigation district (Santos-Salcedo, 1937:160). This increase occurred mainly because the CNI had started rehabilitating the old run-of-the-river canals and constructing new ones on the Lerma River below the dam. In 1933, the CNI formed the Alto Río Lerma irrigation district, to fully develop the lands that could be irrigated with water from the Tepuxtepec dam. However, this created conflicts, and water users on already existing canals resisted the intrusion of the CNI. During

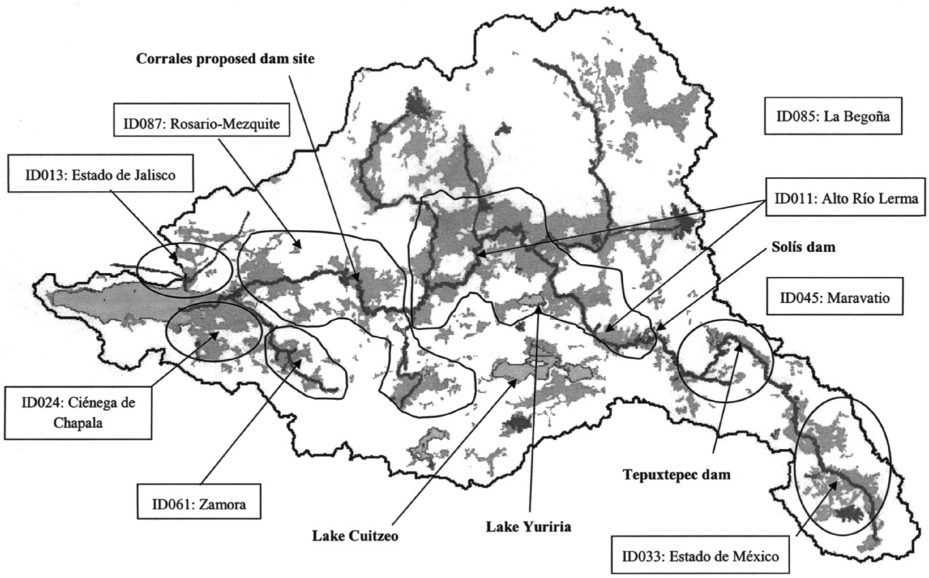

Fig. 4.3. Main dams and irrigation districts (IDs) in the Lerma–Chapala basin.

the 1920s, the *Dirección de Aguas* of SAyF had drawn up water distribution regulations for the run-of-the-river canals along the Lerma, including the canals of Acámbaro, Salvatierra, Valle de Santiago and Jaral de Progreso.

For these canals *Juntas de Aguas* (water boards) were established, based on the 1926 irrigation law, and the *Dirección de Aguas* attempted to regulate their water withdrawals by confirming existing water rights. In November 1933, an agreement was signed between the CNI and the *Dirección de Aguas*, in which control over all the irrigated areas from the Tepuxtepec dam to the city of Salamanca was passed to the CNI, to fall under the newly created Alto Río Lerma irrigation district. Through this agreement the CNI gained control over an irrigated area that until then had been managed locally for nearly 400 years. The increasing intrusion of the CNI led to protests from the existing *Juntas de Aguas*. Their protest was to cost them dearly. In February 1938, the CNI reacted by suspending all the *Juntas de Aguas* and taking over their responsibilities. It was not until the irrigation management transfer programme in the 1990s that these *Juntas de Aguas* were re-established, this time as water user associations (WUAs). Until then, the hydrocracy controlled the irrigation district.

While establishing its control over the run-of-the-river canals, the CNI also started work on the construction of the Solís dam, some 10 km upstream of Acámbaro in Guanajuato. The purpose of this dam was to improve flood control and store the water released (for hydroelectricity generation) from the Tepuxtepec dam for irrigation. Construction of the Solís dam, with a capacity of 800 Mm^3, started in 1939 and was completed in 1949. The CNI also built several large new canals to more than double the area under irrigation in ID011 to around 76,000 ha in 1946, up from 36,000 ha in 1927 (Wester, 2008). By 1940, the CNI had also developed plans for the further expansion of irrigation in the state of Guanajuato, including the Coria canal, to bring 25,000 ha under irrigation, and the Begoña dam on the Laja River, to irrigate some 18,000 ha. Owing to the first Lake Chapala crisis (see below) these works were delayed but were completed by the end of the 1970s.

A similar process occurred in the Lower Lerma region, where the CNI took control of the Ciénega de Chapala through the construction of irrigation and drainage works under the leadership of Ballesteros. Vargas-González (1993) provides a detailed account of how these developments interrelated with the redistribution of land in the area and how this led to increased federal control over the area. Ballesteros joined the CNI in 1926 as chief engineer of the Lower Lerma region and vigorously promoted the construction of the Corrales dam to increase the irrigated area in the Lower Lerma. In the end, the Corrales dam was not built, initially due to financial constraints and later because the proposed dam turned out to be sited on a geological fault. None the less, the water resources development plan presented by Ballesteros in 1927 was to guide developments in the basin until the late 1970s, and most of the works he and his CNI colleagues proposed in the 1930s were eventually constructed. This has led Pérez-Peña (2004) to speak of the 'Ballesteros school' in the development of the Lerma–Chapala basin, whose objective was the full utilization of the basin's water.

The above section has outlined how the CNI increased its role in water development in the Lerma–Chapala basin, by taking over the control of irrigation systems that had previously been managed locally, through both legal means and the construction of hydraulic infrastructure. In particular, the dissolution of the *Juntas de Aguas* in ID011 was a harbinger of the centralized water control that was to develop after the 1940s. The land reform partly helped the CNI to establish its control, but a stronger drive was its hydraulic mission to make good the promises of the revolution by developing 'revolutionary irrigation'. This mission was to reach its zenith between 1946 and 1976, with the creation of the SRH and the continued expansion of the irrigation frontier in the Lerma–Chapala basin.

The heyday of the hydraulic mission: river basin development and the SRH

During the 1940s, the concept of river basins as a unit of development started to gain force in Mexico, based on the Tennessee Valley Authority (TVA) model. During the election campaign of Miguel Alemán in 1946, the CNI lobbied the presidential candidate to initiate projects for regional development in various Mexican river basins and to form an overarching ministry of water resources. Directly after Alemán became president this happened, with the creation of the *Secretaría de Recursos Hidráulicos* (SRH: Ministry of Hydraulic Resources) in December 1946 to replace the CNI. The objective of the SRH was the comprehensive development of water resources and the concentration of the government's efforts in this field in a single organization.

Along with the concentration of water resources development in the SRH, river basin commissions were created by presidential decrees between 1947 and 1950 for several of Mexico's key basins, such as the Papaloapan, Tepalcatepec, Fuerte and Grijalva (Barkin and King, 1970). These commissions were to pursue comprehensive river basin development, based on the TVA model, but with the SRH minister as their president. The emphasis on comprehensive river basin development was to characterize the heyday of the hydraulic mission. From 1946 to 1976, the SRH vastly expanded its activities and mandate, with the river basin commissions serving to bypass state governments and other federal agencies. The SRH came to believe it was responsible for achieving 'the greatness of Mexico', not only through water resources development but also through regional development based on river basins. The hydraulic mission reached its zenith in the early 1970s with the passage of a new water law and the formulation of a national hydraulic plan.

In the Lerma–Chapala basin, the creation of the SRH coincided with the first Lake Chapala crisis, which lasted from 1945 to 1958. The following sections show how the hydraulic mission led to the 'overbuilding' of the basin, by reviewing the Lerma–Chapala–Santiago basin study commission created by the SRH in 1950, the controversies surrounding the first Lake Chapala crisis, and the continued expansion of the irrigation frontier in the 1960s and 1970s.

The Lerma–Chapala–Santiago study commission

In 1950, the SRH formed the Lerma–Chapala–Santiago basin study commission. This was strongly related to the first Lake Chapala crisis. In April 1947, the lake dropped below *cota* 95.15, at which point water no longer flowed to the Santiago River, for the first time since 1916. Hence, the three hydroelectricity plants on the Santiago, which depended on Lake Chapala, frequently had to stop operating. As these plants, owned by the *Nueva Compañía Eléctrica Chapala* (New Electricity Company of Chapala), were the only sources of electricity for Guadalajara, this led to strong demands from industrialists and the inhabitants of Guadalajara that the lake should be kept full by restricting irrigation in the basin. This led Orive-Alba, the SRH minister, to form a commission consisting of respected SRH engineers to study the problems of the basin. This commission set itself the task:

> … to achieve a complete regularization of the existing water use systems [in the basin] and a better planning of those that can be realized in the future; arrive at a full understanding of the available water resources and their potential; and effectuate a more equitable water distribution in the basin through an adequate and combined operation [of existing infrastructure].
>
> (Vallejo-Ivens, 1963:5)

In a report published in December 1953, the commission set forth its recommendations for solving the lack of hydroelectricity and for fully utilizing the basin's water (SRH, 1953). The commission proposed the construction of a large hydroelectricity dam on the Santiago River, downstream of the confluence of several of its tributaries, to replace the plants that depended on Lake Chapala. It also recommended the construction of the Corrales dam on the Lerma River, with a storage capacity of 500 Mm^3, and the construction of the La Begoña dam on the Laja River, with a capacity of 180 Mm^3. Its other proposals consisted of plans to drain lakes throughout the basin to 'suppress unnecessary evaporation'. Thus, the commission recommended constructing a 20 km long and 6 m high embankment in Lake Chapala to reclaim 25,000 ha for agriculture. It also recommended draining Lake Cuitzeo by constructing a canal connecting it to the Lerma River, thus reclaiming 45,000 ha for agriculture, and draining Lake Yuriria to reclaim 7000 ha (SRH, 1953).

Although the execution of these plans would have a devastating effect on Lake Chapala, there was consensus in the commission on their desirability; the hydraulic mission was clearly in high gear. However, a contentious issue that the commission had to deal with was the sinking of deep tube-wells near the headwaters of the Lerma River to supply drinking water to Mexico City. In the 1940s, work started on canalizing the mountain streams feeding the Lerma and transferring this water to Mexico City through a tunnel. In addition to this transfer, it was proposed to sink deep tube-wells near the Lagunas de Lerma to augment the supply to Mexico City. The representative of the state of Mexico in the study commission strongly opposed this project (Santos, 2006). Guanajuato's representative also opposed the interbasin transfer, arguing it would have negative consequences for agriculture in Guanajuato. However, the government of the federal district persevered and succeeded in increasing the number of groundwater wells surrounding the Lerma wetlands. In the early 1950s, some 4 m^3/s (126 Mm^3/year) were transferred to Mexico City, increasing to 10 m^3/s (315 Mm^3/year) by the 1970s (Alba, 1988:163). These transfers affected the hydrologic cycle of the basin by sucking dry the Lerma River at its headwaters. After the interbasin transfer started, the Lagunas de Lerma and the wetlands of the upper Lerma quickly fell dry, to only partly fill during the rainy season. Another, even more contentious issue the study commission had to deal with was the sharp drop in the water levels in Lake Chapala. It had largely been created in 1950 to deal with this crisis, but, as the next section shows, in many ways its actions made the crisis worse.

The first Lake Chapala crisis (1945–1958)

From 1945 onward a period of lower than average rainfall (see Table 4.1), combined with extractions from Lake Chapala for hydroelectricity generation (520 Mm^3/year), resulted in the first Lake Chapala crisis. The response of the federal government to this crisis was strongly influenced by the hydraulic mission mind-set of the time and primarily consisted of efforts to secure the water supply of the hydroelectricity plants on the Santiago. As during the second Lake Chapala crisis (see Water Reforms and Water Transfers), the hydrocracy blamed the desiccation of the lake on the drought and the lake's high evaporation losses (de P. Sandoval, 1981). However, the extractions from the lake by the *Eléctrica Chapala* Company of some 520 Mm^3 a year, combined with 215 Mm^3 for irrigation, contributed strongly to the decline of the lake. Without these abstractions, the lake would not have fallen below *cota* 96.00 throughout the 1945–1958 period (de P. Sandoval, 1994). The efforts of the SRH and the Lerma–Chapala–Santiago study commission focused on ensuring these abstractions by a succession of hydraulic interventions in the lake. The majority of these works were planned and executed by the *Eléctrica Chapala* Company with authorizations from the SRH, while some were directly executed by the SRH. It is clear that the Lerma–Chapala–Santiago study commission, staffed by SRH hydrocrats, viewed Lake Chapala as an unaffordable luxury for Mexico and believed that its water should be used to the fullest extent possible.

A civil protest movement developed in Guadalajara during the first Lake Chapala crisis, just as it did decades later (see Water Reforms and Water Transfers), which went against the hydraulic mission of the SRH. Pérez-Peña (2004) provides a detailed account of the origin and activities of the *Comité de Defensa del Lago Chapala* (Committee for the Defence of Lake Chapala). This committee initially consisted of four people, with the author Ramón Rubín as its driving force, and was formed to protest against the 18 December 1953 presidential decree that authorized the Lerma–Chapala–Santiago commission to reduce the size of the lake's area by 25,000 ha. In January 1954, the committee sent an open letter to the president requesting the withdrawal of his decree. Throughout 1954, a range of academics, intellectuals and influential politicians joined the committee and pressured the Jalisco governor to stop the desiccation of the lake. Owing to pressure from the committee, the implementation of the presidential decree was stopped (and finally revoked in 1983). With the recovery of the lake in 1955, the activity of the committee lessened, and by 1958 it had faded away (Pérez-Peña, 2004).

Although the Lerma–Chapala–Santiago commission failed to construct a new embankment in Lake Chapala, it did sow the seeds for the second Lake Chapala crisis, by making the decision to use Lake Chapala for Guadalajara's water supply. In 1953, at the height of the first Lake Chapala crisis, the commission started work on developing the Atequiza–Las Pintas aqueduct to withdraw water from Lake Chapala for Guadalajara. The aqueduct's starting-point was the Ocotlán pumping station, which pumped water from Lake Chapala into the Santiago River, from where it flowed 40 km to the Atequiza canal. At the end of the Atequiza canal, water was pumped up 22 m to the newly dug Las Pintas canal (25 km long), which brought the water to the city's main water supply system. The initial capacity of this work was 1 m^3/s, but it was later increased to 9 m^3/s. The aqueduct entered into operation in 1956, although at that time the lake was nearly empty (de P. Sandoval, 1981).

In July 1955, the lake dropped to its lowest recorded level, namely *cota* 90.8 (954 Mm^3), resulting in a very erratic electricity supply to Guadalajara. However, very good rains in the autumn brought relief, and the lake recovered sufficiently to restart electricity production. By 1958, the lake had again dropped dangerously low, but another autumn of very good rainfall caused it to recover by nearly 5 m and the lake remained relatively full until 1979. The heavy rains of 1958 caused extensive flooding in the basin and serious damage to the Solis dam. As a result, between 1958 and 1982, the Solís dam was not filled to its full storage level but kept around 500 Mm^3. The water in excess of this storage was passed on to Lake Chapala until 1982, when the reconstruction of the Solís dam was completed.

Although the first Lake Chapala crisis had demonstrated that the basin had already reached its limits concerning water availability, the construction of new dams and the expansion of the irrigation frontier throughout the basin continued unabated during the 1960s and 1970s. Many of the works planned by the commission in 1953 were constructed by the SRH, and groundwater irrigation became increasingly important. The dam storage capacity in the basin more than doubled, from 1817 Mm^3 in 1959 to 3840 Mm^3 in 1979, the largest increase in the history of the basin (de P. Sandoval, 1994), while the irrigated area grew from 390,000 ha in 1960 to 640,000 ha in 1980, primarily in irrigation units (CNA/MW, 1999). The details of these developments will not be recounted here, but they clearly bear out that the hydrocracy took little heed of the warning of the first Lake Chapala crisis, but rather took it as an affirmation of its hydraulic mission to fully develop the water resources of the basin.

Water Reforms and Water Transfers: from Central Control to Negotiated Uncertainties

The drive by the federal government to mobilize ever more water through the construction of hydraulic infrastructure started to falter in the late 1970s, leading to the demise of the hydraulic mission in the 1980s and 1990s. In 1976, the river basin commissions were disbanded, and President López-Portillo merged the SRH with the Ministry of Agriculture to create the *Secretaría de Agricultura y Recursos Hidráulicos* (SARH: Ministry of Agriculture and Hydraulic Resources). This resulted in bureaucratic struggles and a politically expressed demand for renewed autonomy on the part of the hydrocrats, which they regained in January 1989, when the *Comisión Nacional del Agua* (CNA: National Water Commission) was created (Rap *et al.*, 2004). Also, the focus on river basins was kept alive in the National Hydraulic Plan commission, where a group of water resource planners developed policy ideas on decentralized river basin management (Wester, 2008).

Although the 1960s and 1970s were the heyday of dam construction in the basin, with storage capacity more than doubling, the 1980s also saw some continued dam construction. The strengthening and raising of the Solís dam was important and was completed in 1982, which increased its storage capacity to 1200 Mm^3. Together with some minor dams, this increased storage capacity in the basin to 4499 Mm^3 by the end of the 1980s, which was nearly equivalent to the annual average surface water runoff in the basin. The elevation of the Solís dam coincided with the start of the second Lake Chapala crisis and was one of the contributing factors to the crisis, together with lower than average rainfall and the over-concessioning of surface water rights.

Another important development that affected Lake Chapala was that Guadalajara increased its withdrawals from the lake for its urban water supply. In the 1980s, a 42 km long pipe aqueduct was built to directly connect Lake Chapala with Guadalajara, fed by a pumping station with a capacity of 7.5 m^3/s on the shores of Lake Chapala. This aqueduct started functioning in 1992 and was intended to replace the Atequiza–Las Pintas aqueduct, constructed in the 1950s. However, Guadalajara continued to use both aqueducts and withdrew more than its annual concessioned volume of 240 Mm^3 from Lake Chapala. Guzmán (2003) estimates that Guadalajara withdraws around 450 Mm^3 from the lake each year, while an additional 130 Mm^3 are withdrawn from the lake for irrigation. These withdrawals are significant, as the average annual storage change in Lake Chapala from 1980 to 2001 was −191 Mm^3 (IMTA, 2002a). However, the Jalisco state government has consistently blamed the desiccation of Lake Chapala on excessive irrigation withdrawals upstream in Guanajuato and claims that it has reduced its withdrawals from Lake Chapala.

Concern about water quantity and quality in the Lerma–Chapala basin increased in the 1980s with the start of the second Lake Chapala crisis (1980–2002). The pace of institutional reforms increased after 1988, when the newly elected president of Mexico, Carlos Salinas, gave high priority to water issues (Rap *et al.*, 2004). This materialized in the creation of the CNA in 1989, the transfer of government irrigation districts to users starting in 1989, and a new Water Law in 1992. These water reforms and larger political changes in Mexico in the 1990s, such as the transition to multi-party democracy and decentralization policies, led to a growing influence of new water actors in the basin, such as state water commissions, WUAs and environmental organizations. With the demise of the hydraulic mission and the rise of environmental issues, the demands and pressures on the hydrocracy changed fundamentally, from water supply development to water demand management.

This section analyses the attempts by the hydrocracy to deal with basin closure in the Lerma–Chapala basin in the 1990s and 2000s in this changed context, focusing on surface water allocation at basin level and groundwater regulation.

Attempts to bend down the water overexploitation curve

The main water management challenge in fully closed basins is bending down the water depletion curve. In the Lerma–Chapala basin, the hydrocracy made an attempt to bend the curve down in the 1990s by defining surface water allocation mechanisms at river basin level and by increasing the participation of state governments and, later on, of water users, in river basin management. In April 1989, the Mexican president and the governors of the five states in the basin signed a coordination agreement to improve river basin management and to 'rescue' Lake Chapala. The agreement contained commitments to modify water allocation mechanisms, to improve water quality, to increase water-use efficiency and to conserve the basin's ecosystems. In September 1989, a consultative council (CC) was formed to translate the agreement into action. Achievements of the CC include the formulation of a river basin master plan in 1993; a wastewater treatment programme, initiated in 1991; and a surface water allocation agreement, signed by the governors of the five basin states and the federal government in August 1991 (Mestre, 1997). However, these changes were carried out in a top-down manner, in which the political context considerably influenced how the policies were realized. This resulted in the exclusion of Lake Chapala as a 'water user' from the water allocation rules in the surface water allocation agreement (Wester *et al.*, 2004).

The achievements of the CC led to the inclusion of an article in the 1992 Water Law on river basin councils (RBCs), defined as coordinating and consensus-building bodies between the CNA, federal, state and municipal governments, and water users. While responsibility for water management was retained by the CNA, the RBCs were conceived as important mechanisms for conflict resolution. The Lerma–Chapala CC became the Lerma–Chapala River Basin Council in January 1993. Currently, it consists of a governing board made up of the CNA Director, the five state governors and six representatives for water-use sectors (agriculture, fisheries, services, industry, livestock, urban). The RBC also includes a monitoring and evaluation group (MEG) and several specialized working groups. The MEG meets on a regular basis and is charged with preparing council meetings and applying the 1991 surface water allocation agreement (Wester *et al.*, 2003).

In the Lerma–Chapala basin, surface water is allocated annually, based on concession titles and the surface water allocation agreement of August 1991. The concession titles set out the maximum volume that concession holders are entitled to, but the CNA may adjust the quantity that each user receives, based on water availability. The objective of the agreement was to save Lake Chapala, primarily to secure Guadalajara's domestic water supply. It sets out three allocation policies, namely *critical*, *average* and *abundant*, based on whether the volume of water in the lake is less than 3300 Mm^3, between 3300 and 6000 Mm^3, and more than 6000 Mm^3, respectively. For each allocation policy, formulas are used to calculate water allocations to the irrigation schemes in the basin, based on the surface runoff of the previous year. While no provisions for environmental flows were included in the agreement, the algorithms of the three allocation policies were designed to ensure sufficient carry-over storage in the basin's reservoirs. If adhered to, the modelling runs showed that this would generate sufficient spillage from reservoirs during the rainy season, and thus provide river inflows to Lake Chapala (Wester *et al.*, 2005). However, a flaw of the agreement was that it was only based on rainfall data from 1950 to 1979, thus excluding the dry years in the 1940s and the 1980s. As a result, estimations of annual water availability, and hence water allocations, were too high, as become clear in the 1990s.

Since 1991, the MEG has met each year to apply the water allocation rules of the 1991 treaty, closely adhering to its provisions. According to CNA data, WUAs in the irrigation districts never used more water than allocated to them under the treaty (Wester *et al.*, 2005). None the less, Lake Chapala's volume more than halved between 1994 and 2002. This led to intense debates in the RBC, with environmentalists and the Jalisco state government blaming the upstream irrigation districts in Guanajuato for using too much water. However, other contributing factors to the reduced inflows from the Lerma River to the lake are the following: CNA's weak control over surface water use in the small irrigation units, direct pumping from the river and Lake Chapala for irrigation, 10 years of lower than average rainfall, and reduced river base flows due to groundwater overexploitation (Wester, 2008). In addition, the 1991 treaty itself is partly at fault since it overestimated annual water availability and did not explicitly define environmental flows, which would have ensured a base flow in the Lerma River and hence inflows to Lake Chapala.

Water transfers and farmer initiatives to save water

Since 1999, political conflicts and negotiation processes surrounding the allocation of surface water have dominated the Lerma–Chapala RBC. Although stakeholder participation in water management has been broadly accepted in Mexico, the relationships between social and government actors are strongly influenced by a long tradition of concentration of political and decision-making power at the federal level (Vargas and Mollard, 2005). Negotiations in the past were common, albeit with the federal authority as the central actor, commanding patronage and corporatist relationships. The traditional coalition between farmers (to obtain subsidies from the government), the administration (dependent on politicians, also at the local level) and elected representatives (to avoid unrest in their states) continues to be strong, alongside stakeholder participation, decentralization and multi-party elections in Mexico. Currently, the decentralization of water management to river basins entails the creation of different spaces for social participation, which changes conflict-solving and negotiation practices.

In November 1999, because of critically low lake levels, and under pressure from Jalisco to secure Guadalajara's water supply, the CNA transferred 200 Mm^3 from the Solis dam, the main water source of the largest irrigation district in the basin, to Lake Chapala. This was the first time that surface water was physically transferred from the agriculture sector to the urban and environmental sectors under the 1991 treaty. A second transfer of 270 Mm^3 followed in November 2001, as lake levels continued to decline. These water transfers were met with staunch resistance from farmers, mostly from the middle of the basin, and undermined the legitimacy of the RBC. Farmers felt that their water was being stolen, as they received no compensation and because the 1991 treaty did not outline procedures for water transfers. In contrast, environmentalists and the Jalisco state government argued that much more water had to be transferred to save the lake, as around 10 Mm^3 were needed to raise the lake level by 1 cm. This led many in Jalisco to refer to the water transfers as 'aspirins' for the lake's headaches, with the media calling for much stronger medicine to cure the lake.

Before 1999, none of the WUA leaders in the Alto Río Lerma irrigation district were actively involved in the RBC. However, the water transfers galvanized these leaders to act. In May 2000, the presidents of WUAs from Jalisco, Guanajuato and Michoacán met one another for the first time to discuss ways to strengthen their position in the RBC. Until then, WUAs had only dealt with the CNA, and there were no horizontal linkages between WUAs from different irrigation districts. In 2001, the WUAs established a new working group in the RBC, under the leadership of the representative for agricultural water use on the RBC. Until the end of 2002, this *Grupo de Trabajo Especializado en Planeación Agrícola Integral* (GTEPAI: Specialized Working Group on Integral Agricultural Planning) attempted to strengthen the negotiation position of irrigators in the RBC. A central element of GTEPAI's strategy was to show that the irrigation sector was serious about saving water and hence a credible negotiation partner. The cooperation of government agencies, agro-industries and producers under the GTEPAI initiative resulted in a change in cropping patterns during the winter season of 2001/02. Throughout the basin, GTEPAI facilitated the conversion from wheat (four irrigation turns) to barley (three irrigation turns) on 47,000 ha. This resulted in a record production of barley, reduced imports for breweries, and claimed water savings of 60 Mm^3 (Paters, 2004). While GTEPAI improved farmer representation and participation in the RBC, its efforts to save water went unrecognized by the other members of the RBC.

While the farmer representatives took the lead, the threat of civil disobedience by farmers decreased. However, in November 2002, when the CNA decided that a third water transfer of 280 Mm^3 was to take place during the summer of 2003, tensions increased and farmers warned that they would occupy the Solis dam to prevent the transfer. Simultaneously, the representative of agricultural water use on the RBC was pressured to resign from the RBC during the MEG meeting in November 2002. The disappointment of farmer representatives and others involved with GTEPAI was such that they decided to dissolve the GTEPAI and to revert to interest group politics.

During the summer of 2003, unexpected heavy rains coincided with the third water transfer, causing floods in many parts of the basin. Instead of being accused of stealing irrigation water from farmers, the CNA was blamed for aggravating flooding through the water transfer. Although the very good rains of 2003 led to a spectacular recovery of Lake Chapala, with stored volumes jumping from 1330 Mm^3 in June 2003 to 4250 Mm^3 in January 2004 (see Fig. 4.4), this did not cool down tempers, as Jalisco wanted a full lake and had secured CNA's support for this. In November 2003, the Jalisco representative on the RBC again demanded the transfer of water from upstream dams to Lake Chapala, fuelling the anger of farmer representatives and further straining the relationship with Guanajuato. None the less, the CNA announced that 205 Mm^3 would be transferred, representing 50% of the unallocated water stored in the basin's reservoirs, and on 27 November 2003 opened the Solís dam. However, the CNA denied that this was a transfer, arguing that it was necessary for the hydraulic security of the Solís dam. The WUAs in the Middle Lerma did not buy

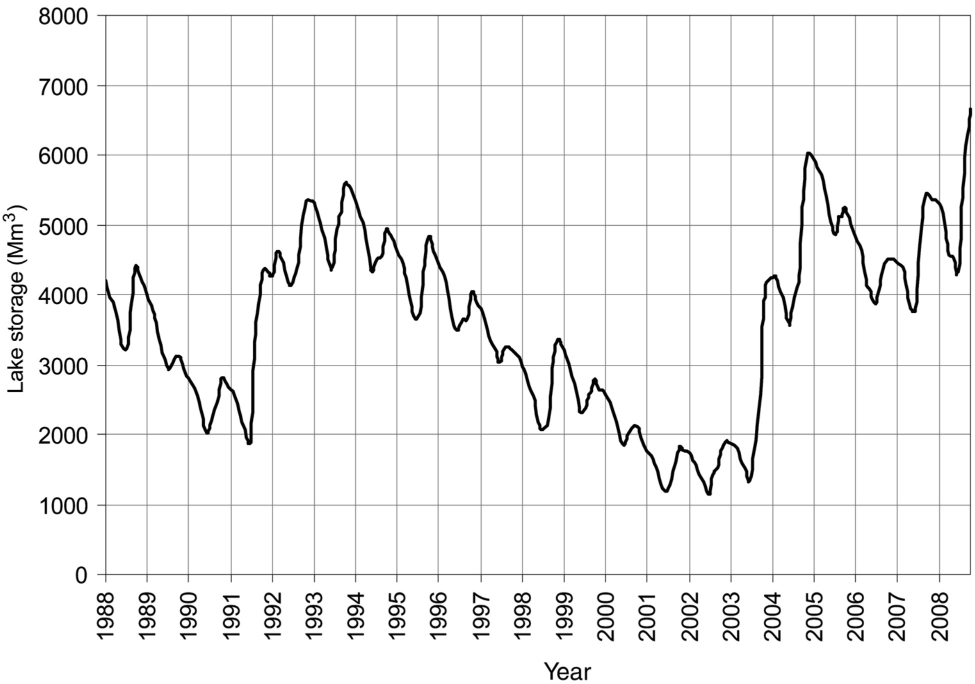

Fig. 4.4. Monthly Lake Chapala storage volumes from January 1988 to October 2008.

into this excuse and, for the first time, took the issue to court on 12 December 2003. The judge of the Celaya district court ruled in favour of the farmers and ordered that the transfer be stopped. However, by the time the judge forbade the transfer, the water had already flowed, with 174 Mm^3 reaching the lake.

Under pressure from Jalisco, 955 Mm^3 was transferred from reservoirs in the basin to Lake Chapala between 1999 and 2004, of which 817 Mm^3 arrived (Dau-Flores and Aparicio-Mijares, 2006). Although these water transfers were insufficient to 'save' the lake and could be seen as an instance of symbol politics, they did have consequences. First, around 100,000 ha could have been irrigated with this 'excess' water. The reduced allocations to the irrigation districts negatively affected farmers' livelihoods, the larger agricultural economy and the performance of the WUAs that depended for their income solely on irrigation service fees. In addition, the leadership of the WUAs was severely questioned by water users because of the lack of water for irrigation, although there was water available. Second, Jalisco could claim that it was saving the lake, as without the transfers Lake Chapala would have dropped to 746 Mm^3 in July 2002, 208 Mm^3 less than the lowest level in 1955 (Dau-Flores and Aparicio-Mijares, 2006:68). Third, the CNA reaffirmed its position as the central decision maker in the basin, although the transfers damaged its legitimacy and reputation. Last, farmer representatives became actively involved in negotiations at the river basin level and developed an initiative to switch to less water-demanding crops.

Renegotiating the surface water allocation agreement

Throughout this period, a parallel process was underway to revise the 1991 water allocation agreement. In this process, the controversies and conflicts in the basin came together, such as the conflict between agricultural interests and those defending the lake (environmentalists and Guadalajara/Jalisco state), the decentralization struggles between the CNA and the states in the basin, and the clash between a technocratic approach to allocating water and a negotiated agreement approach. In 1999, the members of the council decided to revise the agreement, as it was clear that it was not rescuing Lake Chapala. This was attributed to weaknesses in the 1991 agreement, including an overestimation of water availability in the basin, an underestimation of the area under irrigation and the lack of mechanisms to control the clandestine use of water (Güitrón, 2005). In 1999 and 2000, detailed hydrological studies were carried out by a consultant hired by the CNA to develop a new model for calculating surface runoff, without this leading to major changes in the water allocation agreement.

In March 2002, the Jalisco representative on the RBC requested a full revision of the 1991 allocation agreement, leading to the creation of a new working group, called the *Grupo de Ordenamiento y Distribución* (GOD: Ordering and Distribution Group). This group consisted of the CNA, government officials of the five states in the basin and consultants hired by Jalisco and Guanajuato. To develop consensus in this group, it was felt necessary to contract a 'neutral' outsider to execute the hydrological studies and develop a new water allocation model. Thus, it was decided to contract IMTA (Instituto, Mexicana de Tecnología del Agua), Mexico's water research institute. This proved to be important, as IMTA became a mediator and provided the negotiation parties with updated and revised hydrological data and water allocation scenarios (IMTA, 2002a). Until the end of 2003, little progress was made in the negotiations, although the detailed studies and their discussion in the RBC did lead to a new consensus on hydrological data and the design of the water allocation model.

Behind the scenes, the revision of the surface water agreement became linked to negotiations surrounding the construction of two new dams in the Santiago basin, both located in Jalisco. The Arcediano dam on the Santiago River is to provide Guadalajara with water, so that the city can stop withdrawing water from Lake Chapala. The second dam will be located on a tributary of the Santiago River, and will provide León, the largest city in Guanajuato, with water. However, to receive this water Guanajuato must guarantee that it will allow the return flows from León to flow to Lake Chapala. The discussions on the financing of these dams became increasingly linked to the water allocation negotiations, to such an extent that political brokerage at high levels was needed to reach a simultaneous deal on both issues. In early 2004, President Fox made the allocation of federal funds to the construction of these two dams conditional to the signing of a new water allocation agreement (Campillo, 2004).

Thus, the last phase of the negotiations was entered into under a charged political atmosphere. At an RBC meeting held in May 2004, the CNA regional office presented an 'optimized' water allocation scenario that did not include the need for water transfers. Instead, it was proposed that the volume stored in the reservoirs of the basin would not exceed their normal storage capacity, by keeping the emergency flood storage empty. Hence, any excess storage water would be discharged to Lake Chapala. The 'optimized' allocation scenario also showed that, irrespective of Lake Chapala's volume, farmers would always receive at least 50% of their concessioned volume. The good rains of 2004, with Lake Chapala reaching 75% of its capacity in November, helped pave the way for the signing of a new surface water allocation covenant in December 2004. The revised agreement entails further reductions in allocations to irrigation if water levels in Lake Chapala are low, but it does not explicitly contain provisions for environmental flows. The resistance of farmer representatives to the new covenant decreased after the presentation of the 'optimized' water allocation scenario, and after the inclusion of an article in the covenant that it could be revised each year. The pressure exerted by the Mexican president and the issue linkage with the construction of new dams were also important elements that led to the signing of the new covenant. However, without the good rains of 2003 and 2004 the story would have been quite different, and it remains to be seen how well the new water allocation covenant will function when the next dry period occurs.

The invisible water crisis: groundwater overexploitation

A more pressing issue than surface water allocation in the Lerma–Chapala basin is the serious overdraft of the basin's aquifers, estimated at 1336 Mm^3 per year (IMTA, 2002a). The situation in the Middle Lerma region is particularly acute, with extractions exceeding recharge by 40% (CEAG, 2006). As some 380,000 ha in the basin are irrigated with groundwater, and industrial and domestic uses depend almost entirely on groundwater, the long-term consequences of continued groundwater overexploitation overshadow those of Lake Chapala drying up. However, efforts to reduce groundwater extractions have yielded few results to date.

In 1993, the Lerma–Chapala RBC signed a coordination agreement to regulate groundwater extraction in the basin, but progress on the ground has been limited (CNA, 1993). The weak control of the CNA over groundwater extractions and the high social and political costs of reducing groundwater exploitation are primary obstacles. Although the constitution mandates the federal government to intervene in overexploited aquifers by placing them under *veda* (prohibition), thereby prohibiting the sinking of new wells without permission from the federal government, the experience with *vedas* has been disappointing (Arreguín, 1998). For example, the number of wells in Guanajuato alone increased from approximately 2000 in 1958 to 16,500 in 1997, although the drilling of new wells in the whole state was already forbidden in 1983 (Guerrero, 2000).

Based on the recognition that *vedas* had not worked and to counter the continued depletion of groundwater in the basin, the CNA started promoting the formation of *Comités Técnicos de Aguas Subterráneas* (COTAS: Technical Committees for Groundwater) in selected aquifers in the Lerma–Chapala basin in 1995 (Wester, 2008). Through the establishment of COTAS, the CNA sought to organize aquifer users, with the aim of establishing mutual agreements for reversing groundwater depletion. Based on developments in the state of Guanajuato, where the *Comisión Estatal de Agua de Guanajuato* (CEAG: Guanajuato State Water Commission) enthusiastically promoted the creation of COTAS (Guerrero, 2000; Wester, 2008), the structure of the COTAS has been defined at the national level in the rules and regulations for RBCs (CNA, 2000). In these rules, the COTAS are defined as water user organizations, whose membership consists of all the water users of an aquifer. They are to serve as mechanisms for reaching agreement on aquifer management, taking into consideration the needs of the sectors using groundwater (CNA, 2000).

As with the RBC, government has played an active role in forming and promoting the COTAS but with a much larger involvement of state governments. In the state of Guanajuato, 14 COTAS (of which 11 fall in the Lerma–Chapala basin) have been formed with the financial, logistical and technical support of CEAG (Hoogesteger, 2004; Sandoval, 2004). While CEAG has encouraged the COTAS to set their own agenda, it has retained an important influence on the COTAS. Because agriculture is the major groundwater consumer, most of the discussions in the COTAS in Guanajuato revolve around increasing irrigation efficiencies and reducing water use by the agriculture sector.

On paper, COTAS are platforms where all the users of an aquifer meet to reach agreements on aquifer management. However, user participation has been quite low, notwithstanding attempts by the state water commissions to involve as many stakeholders as possible. In part, this is due to a lack of reliable information on the owners of pumps in an aquifer and the lack of infrastructure and human resources on the part of the COTAS, making it difficult to summon all the users. Hence, during the formative stage of the COTAS only well-known people were invited to participate (Wester, 2008). In the majority of cases, the representatives of the agriculture sector in the COTAS are commercial farmers or agro-industrialists. This procedure, which has not brought together all the pumpers in an aquifer but rather builds on a small group of leaders who are not necessarily representative, has hamstrung the effectiveness of the COTAS. Although nearly all stakeholders agree that the situation is grave, this has not yet translated into a multi-stakeholder process to reach a negotiated agreement on reductions in groundwater extractions. Hence, the overall impact of the COTAS has been minimal. None has yet devised mechanisms to significantly reduce groundwater extractions, and the tough issue of how to reach agreement on an across-the-board reduction in pumping has not yet been broached.

Furthermore, many participants and staff of the COTAS and CEAG have become frustrated because the COTAS have little power to make a real difference in groundwater extractions. This is because they have no faculties to control groundwater extractions and have to rely on the goodwill of users and other institutions, particularly the CNA. As the CNA is the only government agency that can issue pumping permits, and is responsible for the enforcement of aquifer regulations, groundwater users are keen to maintain good relations with the CNA. In addition, the CNA has taken a back seat in the COTAS, and has emphatically not given them a mandate, thus sending the message to groundwater users that the COTAS are irrelevant. The CEAG has continued to promote the COTAS, in the hope that it can wrestle some control over groundwater away from the CNA. However, as long as the CNA continues to give preference to the lucrative business of legalizing 'irregular' pumps instead of throwing its weight behind the COTAS, the chances of a negotiated agreement on reductions in groundwater extractions are bleak.

Conclusions

This chapter shows how the hydraulic mission, embedded in the various manifestations of the hydrocracy in Mexico, led to the 'overbuilding' of the Lerma–Chapala basin and the concomitant overexploitation of water. The trajectory of the Lerma–Chapala basin is comparable to that of many other closing river basins, starting with small-scale, local water management, and then progressing to large dams and irrigation schemes funded, built and operated by the state. Technology development has been an important driving force of the hydraulic mission, as without reinforced concrete and hydrocarbon-fuelled machinery most of the large hydraulic works could not have been constructed. Other important drivers were the availability of labour and capital, which were frequently constraining factors in the history of the Lerma–Chapala basin. The specifics of how the Lerma–Chapala basin was overbuilt have been detailed above, and have led to the current challenges the basin is facing, such as environmental degradation, overexploitation of water, increasing social conflicts and the need for all involved actors to develop new ways to negotiate their way out of basin closure.

The closure of the Lerma–Chapala basin is a combination of increasing human pressures on water, the overconcessioning of water rights, and rainfall fluctuations. However, the creation of water overexploitation in the basin was not inevitable or an automatic process, but the outcome of the hydraulic mission of the federal government's hydrocracy. In its efforts to 'develop' the basin, the hydrocracy was strongly supported by state governments and water users to achieve the fullest utilization of water for the greatness of Mexico. The conviction that every drop of water evaporating from Lake Chapala is a 'waste' is still strong today among farmers and hydrocrats; it partly explains the lack of concerted efforts to reduce consumptive water use in irrigated agriculture. If Lake Chapala had not been the main source of water for Guadalajara and an important tourist destination, it is doubtful whether the state of Jalisco would have made an effort to 'rescue' the lake.

Another important finding presented in this chapter is the role of water abstractions from Lake Chapala. It is probable that the first and second Lake Chapala crises would not have occurred if no abstractions from the lake had taken place. This is an important point as, throughout the years, hydrocrats have argued that the cyclical declines in Lake Chapala were due to years of drought. While years of less rainfall obviously lead to lower inflows to the lake, the yearly abstraction of 520 Mm^3 from the lake during the 1940s and 1950s for hydroelectricity generation were an important cause of the first Lake Chapala crisis. The relatively wet period in the 1960s and 1970s made it possible for the hydrocracy to execute the water infrastructure development plans it had formulated since the 1930s. In particular, the elevation of the crest of the Solís dam in 1982 was important, as this increased the storage capacity in the Middle Lerma region. However, irrigation is not fully to blame for the second Lake Chapala crisis. From 1980 to 2001, the overall negative annual storage change of the lake was 191 Mm^3, while withdrawals from the lake for Guadalajara's water supply were at least 240 Mm^3 and possibly as high as 450 Mm^3 per year. Without these withdrawals the lake would not have declined.

The presence of Lake Chapala at the downstream end of the Lerma–Chapala basin poses special challenges for water management in the basin. This revolves around the extent of fluctuations in the lake's volume that are regarded as acceptable. Before the hydraulic interventions of the 20th century, high lake levels resulted in outflows discharging to the Santiago River. The hydraulic modifications of Lake Chapala and the construction of dams upstream largely cancelled these outflows and, depending on rainfall levels, resulted in the retraction or expansion of the lake's volume. The above-average rainfall between 2003 and 2008 led to a good recovery of the lake, showing how sensitive it is to variations in rainfall. In effect, it has temporarily reopened the basin from a surface water perspective. With a lake that is so sensitive to rainfall variations, the determination of the range of acceptable variations in its volume is subjective and its quantification raises political difficulties. In years with lower rainfall, farmers need more water while there is less water available, leading to reduced inflows to the lake. To stop the lake from falling below critical levels, water needs to be transferred from dams precisely when farmers need it most. This calls for the design of compensation mechanisms for farmers to forgo irrigation in dry years, but this option has not yet been considered in the Lerma–Chapala basin.

The key finding of this chapter is how difficult it is to reduce consumptive water use in closed basins, even if a range of water reforms are attempted and serious efforts are made to arrive at negotiated agreements on surface water allocation mechanisms. The three responses to river basin closure identified by Molle (2003), namely allocation, conservation and supply augmentation, are clearly in evidence in the Lerma–Chapala basin. Part of the answer as to why it is so difficult to reduce consumptive water use is because of the 'overbuilding' of the basin and the hydro-social-networks (Wester, 2008) constituted around, and by, the hydraulic infrastructure in the basin. The construction of hydraulic infrastructure tends to ensure that water is withdrawn from the hydrological cycle into the hydro-social cycle, thereby creating constituencies dependent on water for their livelihoods. For example, the widespread hydraulic modifications to Lake Chapala changed it from a natural lake into a managed storage reservoir, on which Guadalajara depends for its urban water supply. The political and economic repercussions are such that it is very difficult to reduce withdrawals from the lake, while the existence of the Chapala–Guadalajara aqueduct provides 'easy' water, which precludes attempts to increase water delivery efficiencies in the city. Similarly, the dams, irrigation canals and tube wells constructed in the basin have led to the development of numerous hydro-social-networks that are bent on continuing the abstraction of water for irrigation. Left to their own devices, these hydro-social-networks will continue withdrawing more water than is sustainable.

Note

1 The depth of Lake Chapala is measured with a locally defined benchmark, originally called the *acotación* (elevation mark) and later the *cota* (benchmark). This benchmark was established around 1897, with *cota* 100 defined as the bottom of the keystone of the sixth arch of the bridge over the Santiago in Ocotlán (destroyed in 1965 when a new bridge was built). This elevation of this point was later determined to be 1526.80 m above sea level. At present, the lake's normal maximum operating level is at *cota* 97.80, while at around *cota* 90.00 it is nearly empty.

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