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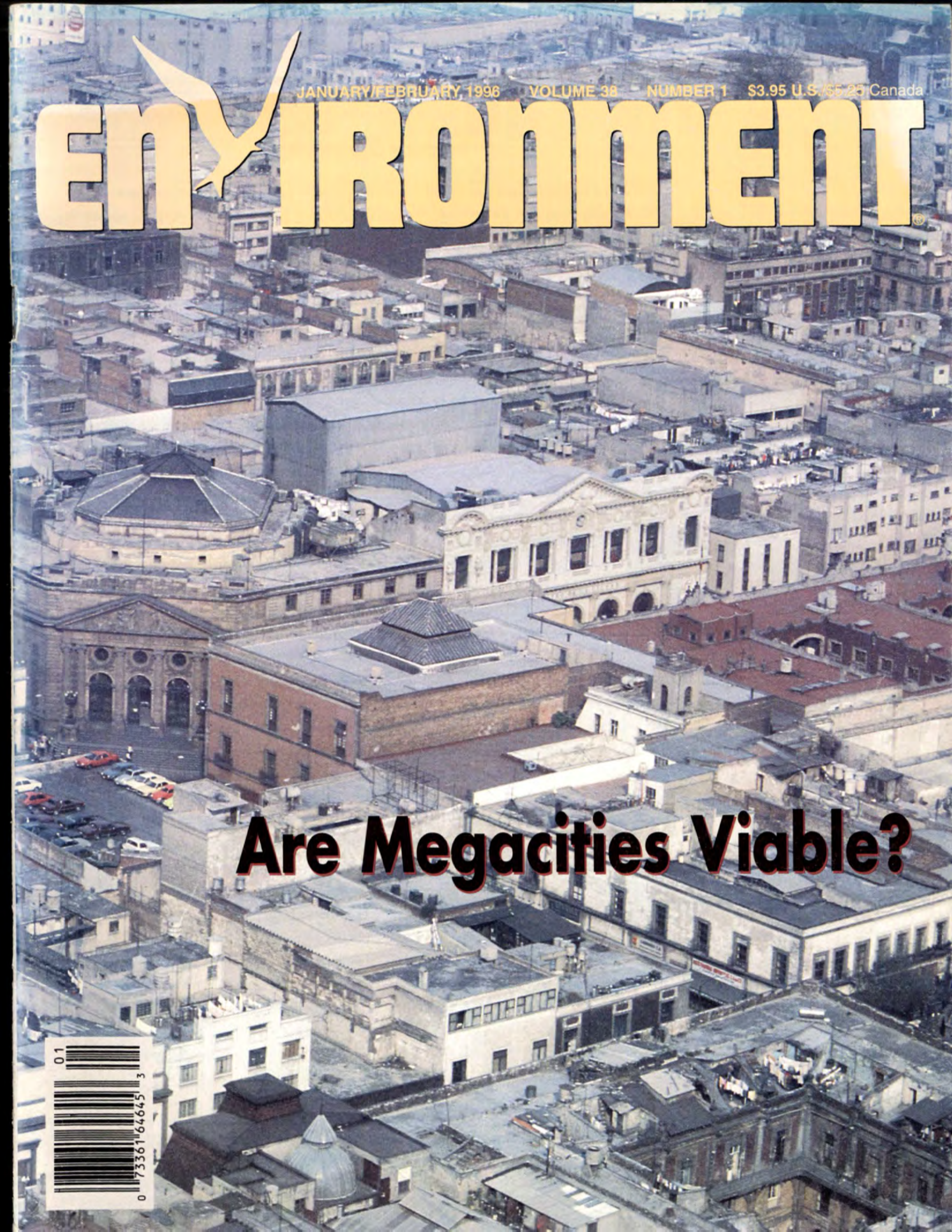

Are Megacities Viable?

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ARE MEGA

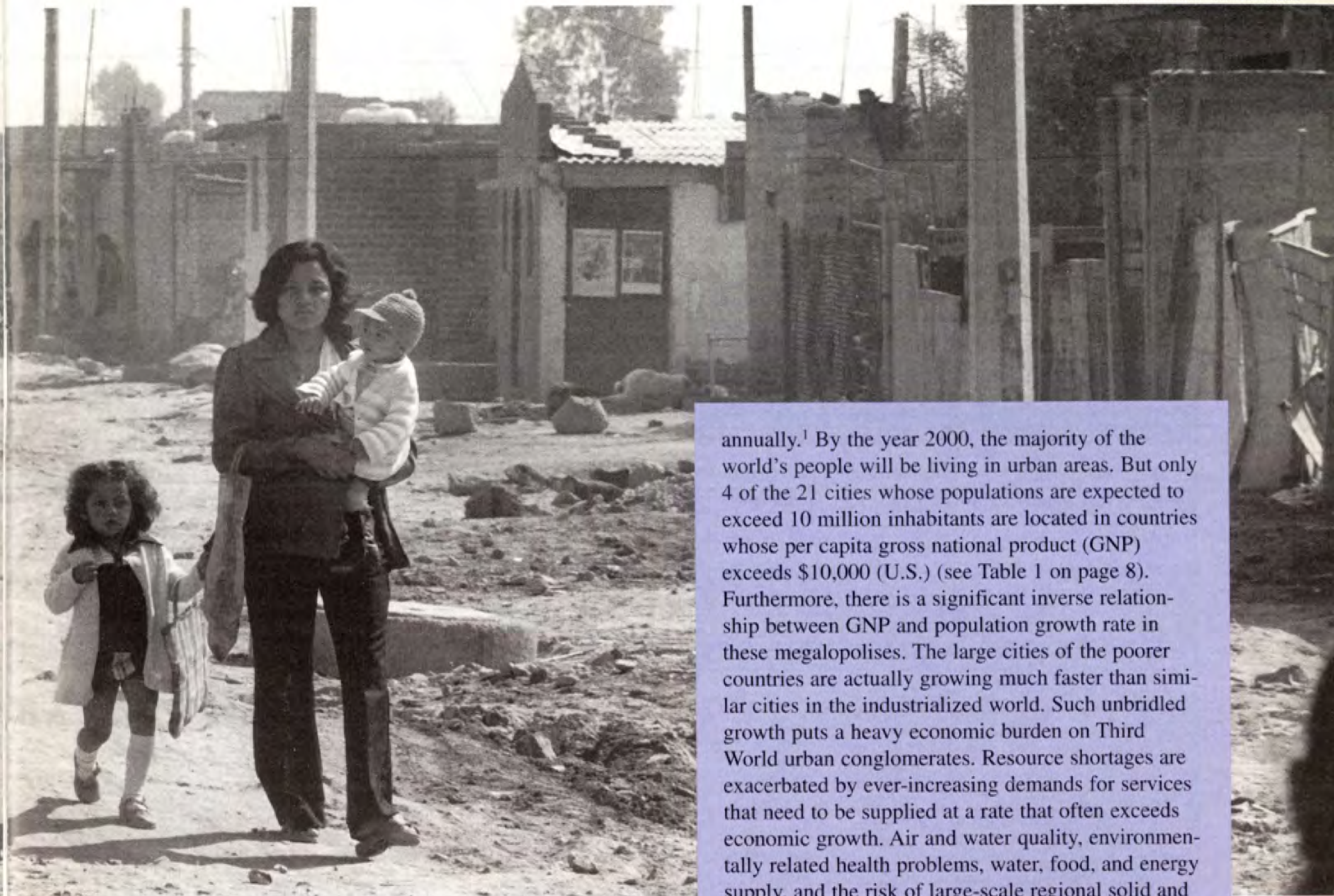
A Cautionary

By Exequiel Ezcurra and
Marisa Mazari-Hiriart

Rural populations' "rush to the cities" has dramatically reshaped the landscape of Third World countries in the second half of this century. The phenomenon of urban concentration itself is not new, but the growth and development of large cities in the nonindustrialized world present a number of new characteristics that merit careful study. The first and perhaps most noticeable of these is centralism. Urbanization in the developed world was characterized by the growth of a large number of medium-sized cities. In the Third World, urban growth has been concentrated in one or a few very large cities, frequently referred to as "megalopolises." The megalopolis is a twentieth-century phenomenon. It is not yet clear how environmentally sustainable these cities will prove to be.

The world's population in 1995 is estimated as 5.76 billion, and it is increasing by some 100 million

PANOS PICTURES—SEAN SPRAGUE



CITIES VIABLE?

Tale from Mexico City

The Ninth Article in The Earth Day Series

annually.[1] By the year 2000, the majority of the world's people will be living in urban areas. But only 4 of the 21 cities whose populations are expected to exceed 10 million inhabitants are located in countries whose per capita gross national product (GNP) exceeds \$10,000 (U.S.) (see Table 1 on page 8). Furthermore, there is a significant inverse relationship between GNP and population growth rate in these megalopolises. The large cities of the poorer countries are actually growing much faster than similar cities in the industrialized world. Such unbridled growth puts a heavy economic burden on Third World urban conglomerates. Resource shortages are exacerbated by ever-increasing demands for services that need to be supplied at a rate that often exceeds economic growth. Air and water quality, environmentally related health problems, water, food, and energy supply, and the risk of large-scale regional solid and liquid waste contamination are all important problems faced by the megalopolis. They have yet to be addressed and resolved in a sustainable manner.

In this article, Mexico City, one of the largest megalopolises on Earth, serves as the focus of an examination of the question of environmental sustainability. Mexico City is in one sense an ongoing experiment. Final conclusions about its environmental sustainability and economic feasibility have yet to be drawn. The problems Mexico City faces are similar to those faced by many Third World megalopolises. Thus, its future is in part a clue to theirs. (Three other authors explore how Mexico City's problems are similar to yet different from those of other megacities in a discussion beginning on page 32.)

The urban and demographic growth of the Basin of Mexico (the geographic area encompassing Mexico City) represents one of the main worries for environmentalists. The possible consequences of such an immense population concentration and its asymmetric relationship to the rest of the nation accounts for part of this concern. The ecological consequences of approximately 18 million people occupying the same space are another factor. The foreshadowings for natural resource use are ominous. In the eyes of many, the enormity of such growth foreshadows a great ecological catastrophe that will lead to the compulsory decentralization of the megalopolis. Others see the urban concentration as the logical result of industrial development and twentieth-century technological progress and do not view the megalopolis as a problem in itself. In their minds, technological development will provide the solutions to the environmental and health problems created by such unrestrained urban growth. Both sides of the debate are examined in this article. Clearly, an environmental crisis situation in Mexico City will almost certainly be generated by the exhaustion of the water supply, the degradation of the air, the silting up of the drainage system, and citywide flooding resulting from deforestation.

The Environmental Setting

Mexico City is located in an originally closed hydrologic basin, which was artificially opened in the early 1600s. This large natural unit, known as the Basin of Mexico, includes the Federal District and parts of the states of Mexico, Hidalgo, Tlaxcala, and Puebla. It covers an area of 7,500 square kilometers (km^2), and lies within the Central Volcanic Axis, an upland formation of late Tertiary origin. The lowest part, a lacustrine plain, has an average elevation of 2,240 meters above sea level. A succession of elevated volcanic ranges surround the basin on three sides (east, west, and south). To the north, the basin is bounded by a series of low discontinuous ranges. The highest peaks, Popocatepetl and Ixtaccihuatl, with altitudes of 5,465 and 5,230 meters respectively, lie to the southeast.

Before the rise of the Aztec state, the lacustrine system at the bottom of the basin covered approximately 1,500 km^2. It was formed by five shallow lakes that ran in a north-south chain. Before human transformations, nine major environmental zones existed in the basin: the lake system, an important resting habitat for migratory waterfowl; the saline lakeshore, characterized by halophyllous plants; the deep-soil alluvium, covered by sedges and swamp cypresses; the thin-soil alluvium, dominated by grasses and agaves; the upland alluvium, occupied by oaks and acacias; the lower piedmont, cloaked by low oak forests; the middle piedmont, covered by broadleaf oaks; the upper piedmont, occupying elevations above 2,500 meters and characterized by oaks, alders, and madrones; and the sierras, occupying sites above 2,700 meters and harboring temperate plant communities of pines, fir, and junipers.[2] Little of these original ecosystems now remains. The city has gradually overtaken most of the former lakebeds, which have been progressively drained since colonial times, as well as part of the surrounding piedmonts. To the south and west of the city, the urban area now occupies the slopes of surrounding mountains that were once covered by conifer forests.

TABLE 1
POPULATION AND RECENT GROWTH RATES FOR THE WORLD'S MEGACITIES

	Estimated Population 1990	Projected Population 2000	Population Growth Rate 1980–90	Per capita GNP 1991 (U.S. $)
Tokyo, Japan	25.0	28.0	1.4	26,824
São Paulo, Brazil	18.1	22.6	4.1	2,920
Mexico City, Mexico	16.8	20.1	2.0	2,971
New York, USA	16.1	16.6	0.3	22,356
Shanghai, China	13.4	17.4	1.4	364
Bombay, India	12.2	18.1	4.2	330
Los Angeles, USA	11.5	13.2	1.9	22,356
Buenos Aires, Argentina	11.4	12.8	1.4	3,966
Seoul, Korea	11.0	12.9	2.9	6,277
Beijing, China	10.9	14.4	1.9	364
Rio de Janeiro, Brazil	10.9	12.2	2.2	2,920
Calcutta, India	10.7	12.7	1.8	330
Osaka, Japan	10.5	10.6	0.5	26,824
Jakarta, Indonesia	9.2	13.4	4.4	592
Tianjin, China	9.2	12.5	2.4	364
Manila, Philippines	8.9	12.6	4.1	728
Cairo, Egypt	8.6	10.8	2.3	611
New Delhi, India	8.2	11.7	3.9	330
Karachi, Pakistan	7.9	11.9	4.7	383
Lagos, Nigeria	7.7	13.5	5.8	305
Dhaka, Bangladesh	6.6	11.5	7.2	205

NOTE: A megacity is defined as one with a projected population of at least 10 million in 2000. Per capita gross national product (GNP) is provided for purposes of comparison.

SOURCE: World Resources Institute, *World Resources 1994–95* (New York: Oxford University Press, 1994), 400. The data for Mexico City is based on the authors' projections.

Population and Land Use

The population of Mexico City has long been the subject of debate (see the box on the next page). The last official census recorded the city's population as 15 million in 1990. This statistic seems unrealistic, however, when the growth of the urbanized area during the 1980s and the historic trends in population growth rates are taken into account. The present size of the urbanized area, as estimated by remote sensing techniques, multiplied

CYCLES OF POPULATION GROWTH AND DECLINE IN THE BASIN OF MEXICO

Natural resource depletion's contribution to the decline of indigenous cultures in the Basin of Mexico gives many ecologists' pessimism about Mexico City's future historical support.

The basin has been one of the world's most densely populated areas for centuries. Twice in its history (at the height of the Teotihuacan culture in A.D. 650 and prior to the Spanish Conquest in A.D. 1519), the basin's population densities were much higher than those of any comparable region in Europe.[2]

The first large settlements in the basin appeared between 1700 and 1100 B.C. (By 100 B.C., the region's population was around 15,000.) Three of the largest settlements that developed during this period were Texcoco to the northeast, Teotihuacan to the north, and Cuicuilco to the southwest. The southwestern side of the basin typically receives the most rain as well as water from the rivers that descend from the Ajusco range. As a result, Cuicuilco flourished and, for a time, was as important as (if not more so than) the more arid Teotihuacan. However, the eruption of the Xitle volcano around A.D. 100 devastated the city, burying the region's best agricultural soils under an immense lava flow. This catastrophe provided the first indication of the physical limits to development imposed by the region's geologic features. The eruption triggered a demographic collapse and a wave of migration northward.

By A.D. 100, Teotihuacan had some 30,000 inhabitants. Five centuries later, in A.D. 650, its population had reached 150,000.[3] But then in less than a century it collapsed to less than 10,000. Some scholars attribute this decline to the rebellion of subdued groups, others to natural resource exhaustion. Those subscribing to the former view, however, stress the ecological significance of the war tribute gathered by the Teotihuacans—agricultural commodities that provided a vital supplement to the Teotihuacans' own resources. Whatever the immediate cause, a combination of local resource exhaustion and conflicts over the seizure of foreign commodities appear to have been the driving forces behind Teotihuacan's collapse. Overexploitation of natural resources, coupled with the lack of a sufficiently developed technology to exploit the fertile but flood-prone terrain of the basin's lakebeds, were decisive determinants in this civilization's collapse.[4]

Several different cultures made their home around the lacustrine system before and after settlement by the Aztec tribes. A cluster of towns eventually surrounded this system at the bottom of the basin. The development of the *chinampa* agricultural technique, based on the irrigation of raised fields on the floodable lake margins and the construction of canals and flood control systems, precipitated a great increase in population. It is estimated that during the late 15th century the basin's total population reached 1.5 million, distributed over more than 100 towns. At that time, the region was perhaps the largest and densest urban area in the world.

The Aztec's main city, Tenochtitlan, was founded in A.D. 1325. Built on a low, floodable island, it became the political, economic, and religious center of Mesoamerica in just a few centuries.[5] Tenochtitlan's success was not based on the Aztecs' sustainable use of resources, however. Although environmentally diverse, the basin's potential productivity was limited by several factors, including drought, frosts, and floods. To compensate, the Aztecs turned to fishing and hunting, but these activities required a much higher effort per unit of yield than traditional agriculture. Even *chinampa* agriculture, which is less vulnerable than dryland farming, demanded the removal of quantities of soil and mud from ditches to the farming plots.[6] Eventually, overhunting of the native population of large herbivores forced people to eat small animals and insects. It also forced the Aztecs to consume the *chinampa* weeds as a source of protein, a practice still common in Mexico.[7]

Despite these innovative approaches to supplementing the food supply, population growth gradually pressured the Aztecs into wars with neighboring groups. The Aztecs forced the conquered tribes to pay them tribute, and the appropriation of these products became more and more important as the Aztec ruling system evolved. At the height of the Aztec Empire, Tenochtitlan imported annually approximately 7,000 tons of maize, 5,000 tons of beans, 4,000 tons of chia, and 4,000 tons of amaranth.[8] Large quantities of dried chilies, cacao seeds, dried fish, cotton, henequen fibers, vanilla, honey, and fruits were among the other products routinely brought into the city.

The Spaniards used the social conflicts created by this system to their advantage. Cortés and his men forged an alliance with the Tlaxcaltecs, who were among the hardest hit by the Aztecs' demands for agricultural tribute. Because of this alliance, they were able to conquer the Aztec empire with only a handful of Spanish soldiers. A tremendous decline in the basin's population occurred after the conquest, mostly because of the influx of new diseases.[9] A century after the Spaniards' arrival, the basin's population had fallen to below 100,000.

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1. T. M. Whitmore and B. L. Turner II, "Population Reconstruction of the Basin of Mexico: 1150 B.C. to Present," Technical Paper No. 1 in *Millenial Longwaves of Human Occupance Project* (Worcester, Mass.: Clark University, 1986), 53; T. M. Whitmore, B. L. Turner II, D. L. Johnson, R. W. Kates, and T. R. Gottschang, "Long-term Population Change," in B. L. Turner II et al., eds., *The Earth as Transformed by Human Action: Global and Regional Changes in the Biosphere over the Past 300 Years* (Cambridge, Mass.: Cambridge University Press, 1991), 25–39; E. Ezcurra, "Basin of Mexico," ibid., pages 577–88; and E. Ezcurra, "Crecimiento y colapso en la Cuenca de México," *Ciencias*, no. 25 (1992): 13–27.

2. Whitmore and Turner and Whitmore et al., note 1 above.

3. R. Millon, "Teotihuacan: Completion of a Map of the Giant Ancient City in the Valley of Mexico," *Science* 170 (1970): 1077–82; and J. R. Parsons, "Settlement and Population History of the Basin of Mexico," in E. R. Wolf, ed., *The Valley of Mexico: Studies in Prehispanic Ecology and Society* (Albuquerque, N. Mex.: University of New Mexico Press, 1976), 69–100.

4. M. Cook, "The Interrelation of Population, Food Supply, and Building in Pre-Conquest Central Mexico," *American Antiquity* 8, no. 1 (1947): 45–52; and E. Ezcurra, second citation, note 1 above. See also W. T. Sanders, J. R. Parsons, and R. S. Stanley, *The Basin of Mexico: Ecological Processes in the Evolution of a Civilization* (New York: Academic Press, 1979).

5. E. E. Calneck, "Settlement Pattern and Chinampa Agriculture at Tenochtitlan," *American Antiquity* 36 (1972): 104–15.

6. P. Armillas, "Gardens in Swamps," *Science* 174 (1971): 653–61.

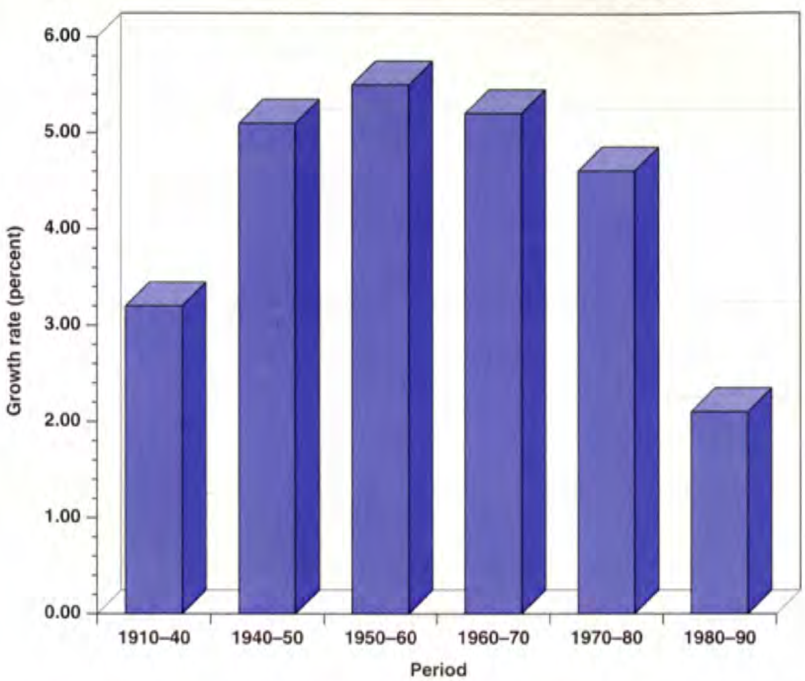
7. C. Niederberger, *Paléopaysages et archéologie pré-urbaine du Bassin de Mexico*, 2 vols. (Mexico, D.F.: Centre d' Êtudes Mexicaines et Centraméricaines, Coleccion Êtudes Mésoaméricaines, 1987), 855; and B. Ortiz de Montellano, "Empirical Aztec Medicine," *Science* 188 (1975): 215–20.

8. D. López Rosado, *El abasto de productos alimenticios en la Ciudad de México* (Mexico, D.F.: Fondo de Cultura Económica, 1988), 582.

9. M. León-Portilla, A. M. Garibay, and A. Beltrán, *Visión de los vencidos: Relaciones indígenas de la conquista* (Mexico, D.F.: Universidad Nacional Autónoma de México, 1972), 220.

by the historic population density (14,500 persons per km^2), suggests a total population of about 16.8 million in 1990 and 18.5 million in 1995. A projection of 1980 population values at a conservatively low growth rate of 1.5 percent (the growth rate between 1940 and 1980 has always been well above 2 percent) gives a total population of 16 million for 1990 and 17.3 million for 1995. This figure accords with the findings of one demographer who concluded that the national census underestimated the total population of the country by 2 to 6 million people.[3] The current total use of water in the city (63 cubic meters per second (m^3/s)) combined with the historic per capita use (300 liters per day) also suggests a total population of approximately 18.1 million for 1995. Thus, we may assume that the population of greater Mexico City in 1995 was some 18 million people.

Figure 1. Mexico City's population growth rates, 1910–90.



SOURCE: Instituto Nacional de Estadística, Geografía e Informática, *XI Censo general de población y vivienda* (México, 1991); Instituto de Geografía, "Sistema urbano, crecimiento espacial de las principales ciudades," in *Atlas nacional de México*, (México, D.F.: Universidad Nacional Autónoma de México, 1989); Gerencia de aguas del Valle de México, *Informe interno: Uso del agua* (México, D.F., 1995); and the authors' projections.

Between 1950 and 1980, Mexico City's average annual growth rate was 4.8 percent. The population, however, has grown more quickly in the industrial zone of the state of Mexico, north of the Federal District. There, the average rate of increase between 1950 and 1980 was 13.6 percent, compared with 3.3 percent in the Federal District. The continuous arrival of migrants from economically depressed rural areas accounts for much of the high growth rate.[4] Between 1950 and 1980, 5.43 million immigrants arrived in Mexico City. This influx was responsible for 38 percent of the city's growth.[5] However, between 1970 and 1980 alone, 3.25 million immigrants made their way to Mexico City.[6] Eliminating the effects of immigration, the intrinsic annual growth rate of the city for that decade can be calculated as approximately 1.8 percent, considerably lower than the national average for the same period, which was around 3.0 percent. Immigration, not reproduction, has maintained Mexico City's high rate of population increase.[7] Assuming that a population of 18 million in 1995 is correct, the growth rate for the 1980s was around 1.8 percent, markedly lower than the rates for the previous decades. Although the population is still growing, it is clearly experiencing a demographic transition and the growth rates seem to be slowing down (see Figure 1 on this page).

Historically, Mexico City's net population densities have been comparatively high (see Table 2 on page 11). While slightly denser than Tokyo or Caracas, Mexico City presently duplicates the densities of New York, São Paulo, and Buenos Aires. It has three times the density of Paris and four times that of London. Only some Asian cities like Bombay, Calcutta, and Hong Kong have higher population densities.[8]

From 1953 to 1980, the average growth rate of Mexico City's urban area was 5.2 percent. In 1940, urban settlements covered 90 km^2 (0.9 percent of the basin). In 1950, they occupied 240 km^2, in the 1960s 384 km^2, in 1980 838 km^2, and in 1990 1,161 km^2.[9] At present, the metropolis covers more than 12 percent of the basin, making up 16 *delegaciones* or boroughs in the Federal District and 26 municipalities in the state of Mexico.

The city's growth has had four stages in this century (see Figure 2 on page 12). During the first stage, from 1900 to 1930, the downtown area grew, increasing in both population and commercial activity. During the second stage, between 1930 and 1950, peripheral expansion took place and the city swelled to encompass the *delegaciones* of the Federal District that surrounded the central area. (Sometime between 1930 and 1940, the first municipality of the state of Mexico became part of the conurbation.) Accelerated growth took place during the third stage, 1950 to 1980, as the city expanded northwards into several municipalities in the state of Mexico and the population soared with access to cheaper land, recently installed communications, and basic services. At the beginning of the fourth stage in 1980, Mexico City was formed by the aggregation of 16 *delegaciones* in the Federal District and 17 municipalities in the state of Mexico. This ongoing phase involves the merging of several metropolitan areas in the Mexican Highlands: Mexico City, now composed of 16 *delegaciones* and 26 municipalities; Toluca in the state of Mexico, formed by six municipalities; the larger Puebla metropolitan area, including the cities of Puebla and Tlaxcala and composed of 8 municipalities; and the urban complexes of Cuernavaca-Temixco-Jiutepec and Cuautla-Yautepec, formed by the aggregation of small metropolitan areas in the state of Morelos, south of Mexico City.[10] Mexico City developed into a megalopolis in the mid-1980s by associating regionally with Toluca and Cuernavaca. An example of this larger conurbation is Huixquilucan, between Mexico City and Toluca. Through this municipality, both cities are now joined to form an overlapping urban conglomerate.[11]

As Mexico City expanded, it did not replicate the old patterns of urbanization. The new developments are more dense, less planned, and generally include less open space. Many developments are now built on hillsides, generating a considerable amount of soil erosion and a significant increase in runoff and flash floods after rainstorms.[12] In 1950, the urban area included a large proportion of agro-pastoral fields, together with numerous empty lots, parks, and public spaces. The relative frequency of these open spaces within the city has decreased considerably with the new industrial style of urbanization. Mexico City's open spaces are rapidly disappearing, but at different rates. Agro-pastoral fields, once vital as dairy farms and domestic maize fields, have been disappearing at an average annual rate of 7.4 percent and are now practically nonexistent within the city. Most of these areas are now occupied by industrial buildings and housing developments. Parks, private gardens, and public spaces have been somewhat better conserved, vanishing at an average rate of 1.5 percent. New roads have accounted for most of the loss. Overall, the number of "green" areas has decreased at an annual rate of 3.7 percent.

The total rate of change of green areas varies considerably from one sector of the city to another.[13] The area experiencing the most rapid change lies to the east of the city, where the larger working-class settlements lie. There, between 1950 and 1980, nearly 6 percent of the open space disappeared each year. Open spaces are disappearing most slowly in the old center of the city. Rates of green area disappearance are affected by the social position of the inhabitants and when the areas were established. In the poorer and more recently established areas, vacant land quickly becomes lots for new houses, leaving less green area per person than in wealthier neighborhoods. The distribution of green areas, like the distribution of wealth, is currently very uneven. Although some quarters have more than 10 square meters (m^2) of park land per person, others have much less. Azcapotzalco, an industrial quarter with a population of some 700,000, has at present 0.9 m^2 of green area per inhabitant.[14]

Water supply

Water management has been a fundamental factor in the establishment and evolution of the different cultures of the basin. In pre-Hispanic times, the Aztecs used water from artesian wells located within the lacustrine zone and were completely self-sufficient in their use of water resources.[15] Groundwater extraction began in 1847 and provided enough water to supply the inhabitants of Mexico City until the mid-1960s.[16] Since that time, additional water has been pumped from two external watersheds, the Lerma and the Cutzamala River basins. Currently, Mexico City depends on these external sources for one-third of its water supply. As is the case with other natural resources, during this century the basin has gone from a high level of self-sufficiency in water resources to a strong dependence on imports from other parts of Mex-

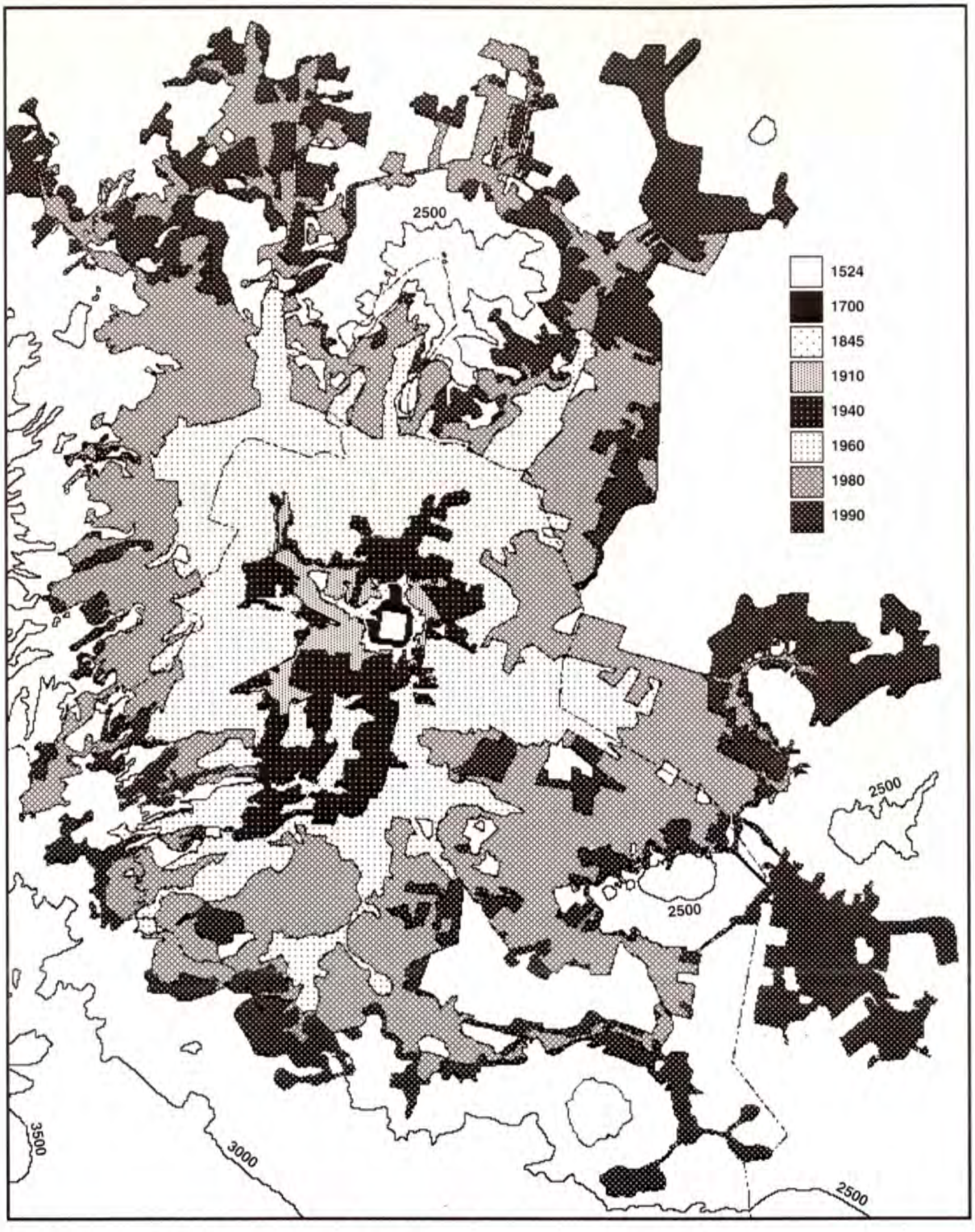
TABLE 2
MEXICO CITY'S POPULATION, URBAN AREA GROWTH AND DENSITY, AND WATER USAGE, 1910–90

Year	Total Population (millions)	Urban Area (km^2)	Density (persons per km^2)	Groundwater (m^3/s)	Imported Water (m^3/s)	Total Water Use (m^3/s)	Per capita Use (L/day)
1910	0.70	29.65	24.28	1.70	0	1.70	210
1940	1.80	90.30	21.37	4.30	0	4.30	206
1950	3.00	*	*	11.00	0	11.00	317
1960	5.20	383.85	14.09	16.60	3.50	20.10	334
1970	8.70	*	*	28.70	12.30	41.00	407
1980	13.80	838.07	16.47	36.00	14.00	50.00	313
1990	17.00	1,160.92	14.64	43.50	19.50	63.00	320

* Not available.

SOURCES: Instituto Nacional de Estadística, Geografía e Informatíca, *XI Censo general de poblacíon y vivienda* (México, 1991); Instituto de Geografía, "Sistema urbano, crecimiento espacial de las principales ciudades," in *Atlas nacional de México*, (México, D.F.: Universidad Nacional Autónoma de México, 1989); Gerencia de aguas del Valle De México, *Informe interno: Uso del agua* (México, D.F., 1995); and the authors' projections.

Figure 2. Growth of the Mexico City metropolitan area, 1524–1990.



NOTE: The numbered lines indicate elevation contour in meters.

SOURCE: Instituto de Geografía, "Sistema urbano, crecimiento espacial de las principales ciudades," in *Atlas nacional de México* (México, D.F.: Universidad Nacional Autónoma de México, 1989).

ico. The best soils are now occupied by houses and much of the surface water is either contaminated or at risk of becoming so. This is obvious in the satellite town of Xochimilco, south of the city, where the practice of *chinampa* agriculture (irrigated raised fields) is quickly disappearing because of the descending water table and the contamination of the canal waters.

Current water use in Mexico City is 63 m^3/s.[17] Of this volume, 1.5 m^3/s come from the few surviving surface systems within the basin while 42 m^3/s are extracted from aquifers. The remainder comes from the Lerma and the Cutzamala basins (6.0 m^3/s of groundwater from the former and 13.5 m^3/s of surface water from the latter).[18] Thus, of the total amount of water used in Mexico City, 69 percent is obtained from within the basin and 31 percent from external watersheds (see Figure 3 on page 14). This has a considerable impact on the Lerma and the Cutzamala basins, where water is also very scarce. The Lerma Basin feeds Chapala Lake in Jalisco, the largest freshwater body in the nation. Chapala's water levels have been dropping for the last 20 years (the accumulated decrease is approximately 5 meters), and this phenomenon is at least partly attributable to the pumping of water in the Basin of Mexico.


PHOTOGRAPHERS ASPEN—DAVID HISER

Chinampa agriculture in satellite towns like Xochimilco pictured here suffers from the steady deterioration of the Basin of Mexico's water resources.

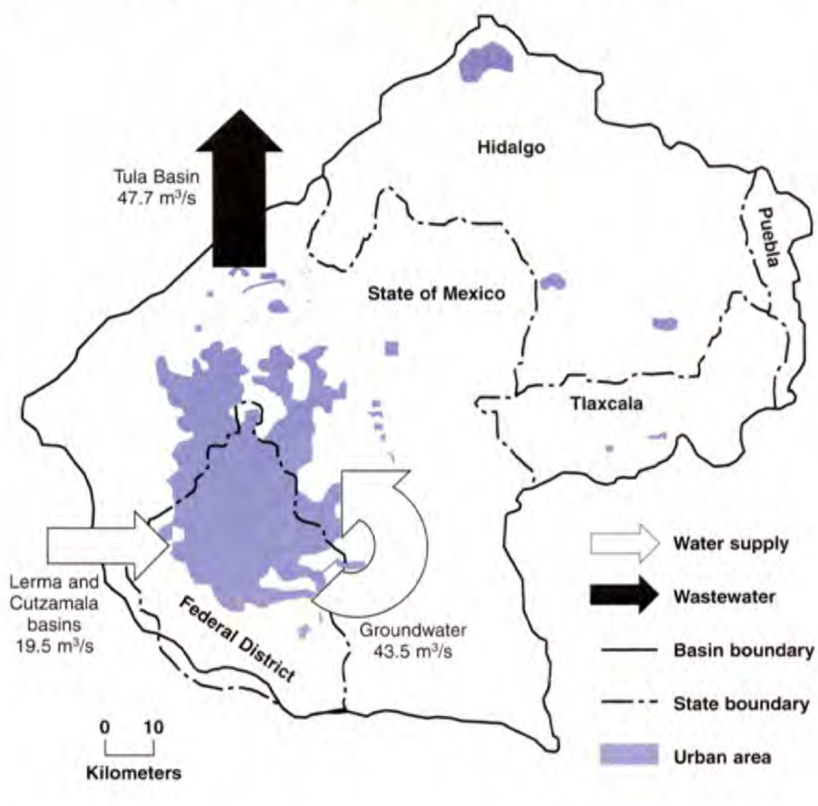
The mean annual input of rainwater into the basin is 744.2 million m^3 (23.6 m^3/s). Approximately 50 percent of this infiltrates the subsoil and recharges the aquifers. Some water also makes its way into the aquifers from leaks in the distribution system.[19] Leakage may be as much as 25 percent of the distributional flow in the city, on the order of 16 m^3/s. Thus, the total recharge of the basin's aquifers is some 28 m^3/s or less. Total extraction from the basin's aquifers is 55.5 m^3/s. Of this, 42.0 m^3/s are used by the city; the rest is used for agriculture within the basin.[20] Thus, while recharge replaces roughly 50 percent of the extraction volume, there is a deficit of more than 800 million m^3 per year. The average daily supply of water in Mexico City is around 300 liters per person, more than in many European cities. Many parts of the city suffer from chronic water shortages, however. Industry's use of water is very inefficient, and only 7 percent of wastewater is recycled. At least 25 percent of the water supply is lost through deficient pipe systems.

Early in this century, Mexico City started sinking because of ground water overexploitation. In 1954, a ban on new wells in the city area was issued and some existing wells were relocated to the north and south of the basin. Since then, the rate of sinking has stabilized at about 6 centimeters per year (cm/year) in the central area. Nevertheless, along the borders of the urban area, sinking velocities now reach 15 to 40 cm/year. Some areas of downtown Mexico City have sunk nine meters since the beginning of the century.[21]

A number of vulnerable hydrogeological areas have been pinpointed as potential routes for the transport of groundwater contaminants.[22] The transition zones between the hillsides and the clay bottom of the basin are highly permeable, and contaminants released on the surface there could easily migrate downwards toward the aquifers. The lacustrine clays or the fractured basalt, which may be more permeable than has been assumed, are two other potential risk areas for groundwater contamination. In the past, the clay materials were considered an effective barrier to the downward migration of pollutants from sources such as contaminated lakes and lixiviates from sanitary landfills. The integrity of the clays, however, may have been compromised by excessive pumping of the aquifer coupled with the natural fracturing of the now drier clays, putting the quality of the groundwater at risk.[23]

Bacteriological, physical, and chemical monitoring of the water in Mexico City has shown deterioration in quality that can be attributed to overexploitation of groundwater and extraction of water from geologic formations with high concentrations of certain ions (e.g., iron or manganese). High bacterial counts have been observed in some wells, but these have been attributed to the lack of seals to protect against infiltration of surface runoff along the casing.[24] Water may also become contaminated during distribution by variation in the pressure of the supply lines, which can cause leakage from, or infiltration into, pipelines. Government offices constantly monitor water quality, but the information is not published and is not readily available to the public.[25] Little attention is given to organic compounds in groundwater even though industrial solvents and aromatic hydrocarbons from petroleum products are widely used in industrial areas. In Mexico City, home to almost 50 percent of the country's industries, these types of compounds are generated and disposed of within the city area. No examination of the risks that these new types of contaminants may pose has been undertaken.

Figure 3. The flow of water into and out of Mexico City.



SOURCE: Gerencia de aguas del Valle de México, *Informe interno: Uso del agua* (México, D.F., 1995).

Wastewater Treatment

The contemporary wastewater system of Mexico City includes several unlined sewer canals, sewers, reservoirs, lagoons, pumping stations, and a deep drainage system.[26] About 75 percent of the population has access to this system; the rest dispose of their sewage through septic tanks and absorption wells.[27] The domestic wastewater that is collected from the sewer system is combined with industrial wastewater and, during the rainy season, with stormwater runoff. Approximately 90 percent of liquid industrial wastes, which add up to approximately 1.5 million tons annually, are discharged untreated into the city's sewer system. Since the sewage system conveys considerable amounts of domestic and industrial waste, the possibility exists that the sewers and unlined canals may release significant amounts of contaminants into the subsurface, and the potential for downward migration is high. Field investigations conducted to assess specific organic contaminant migration beneath some of the canals demonstrated that some organic compounds are indeed migrating downwards toward the aquifer.[28]

A total of 27 wastewater treatment plants treat a portion of the wastewater generated in Mexico City. These plants generally operate at less than 50 percent efficiency and treat approximately 4.3 m^3/s, or about 7 percent of the city's total wastewater.[29] This wastewater flows northward into several reservoirs, whence some is used for irrigation in an area of about 58,000 hectares in the state of Hidalgo.[30] Wastewater is also used to generate electricity at the Zimapán Dam in the Tula Basin, which has an installed capacity of 280 megawatts (MW).[31] Ultimately, the wastewater makes its way to the Gulf of Mexico through the Tula-Moctezuma-Panuco river system.

Air quality

The high levels of atmospheric pollution that have existed in Mexico City for more than 20 years are another serious problem associated with the city's uncontrolled growth, and Mexico City's problem highlights some of those of other megacities.[32] The situation becomes particularly critical during the cold season (December to February) when low temperatures stabilize the atmosphere above the basin and air pollutants accumulate in the stationary mass of cold air.[33] Studies of lead and bromine in the air have shown quantitatively that most of the air contamination comes from automobile exhaust.[34] During the 1980s, the number of cars in the city increased at an annual rate above 5 percent. (In 1979, there were some two million cars; by 1994, the number had more than doubled.) Suspended particles were the worst pollutant in the early 1980s, and in some parts of the city their concentration exceeded the Mexican and international air-quality standards more than half of the time.[35] Between 1991 and 1994, ozone was the most significant air contaminant, and its concentration exceeded the air-quality standards more than 90 percent of the time (345 days above the admissible threshold of 220 micrograms per cubic meter ($\mu g/m^3$) were reported for 1995). The problem became so alarming that in the early 1990s the newly created National Commission on Human Rights asked a working group to compile a detailed report on the subject. That report remains one of the most comprehensive analyses of the problem available.[36]

Until 1986, lead was probably the most harmful pollutant in the atmosphere.[37] Previously, only leaded gasoline was sold in Mexico City and the concentration of lead in the air increased steadily with the number of cars, reaching values of 5 $\mu g/m^3$ in 1968 and around 8 $\mu g/m^3$ in 1986 (5 times the Mexican standard of 1.5 $\mu g/m^3$).[38] Among its many deleterious effects, high concentrations of lead in the blood retard the intellectual development of children and, in general, alter human neural development.[39] The lead problem became so severe in September 1986 that the national oil company PEMEX substituted low lead-content fuel (in which synthetic oxidizing additives partly replaced leaded compounds) for the gasoline it was selling. Independent reports show that as a result of this effort lead levels did decrease dramatically. It is estimated that atmospheric emissions of lead decreased from approximately 2,000 tons/year in 1986 to around 150 tons/year in 1994. As a result, a sustained decrease in the proportion of schoolchildren with high levels of lead in their blood has been observed.

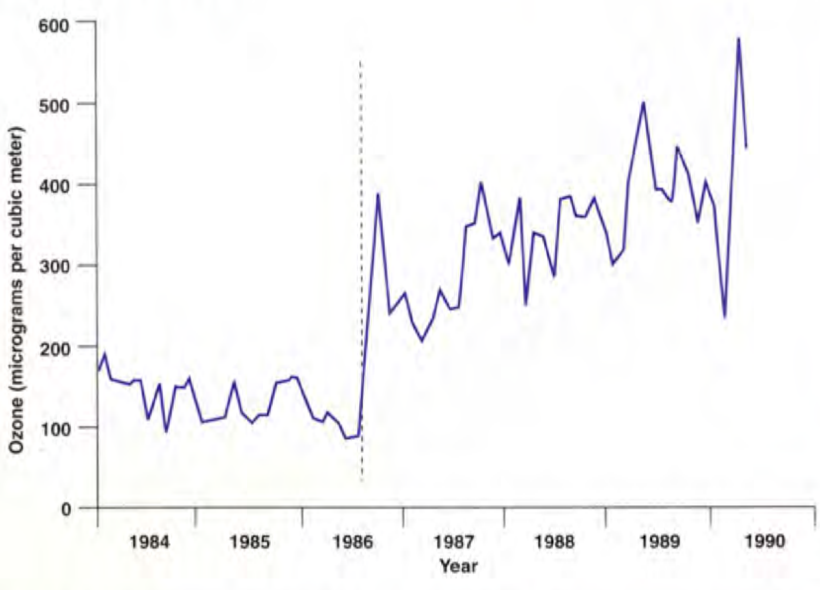
Unfortunately, however, the new gasoline had unexpected and harmful side effects. While the atmospheric concentration of lead did indeed fall, photochemical smog increased (see Figure 4 on this page). Because of a reaction between ultraviolet radiation from the sun, atmospheric oxygen, and combustion residues from the unleaded or low-lead gasolines, ozone concentrations in the city quickly rose.[40] At present, the mean ozone concentration is around 0.15 parts per million (ppm), 10 times the natural atmospheric concentration and almost twice the maximum permitted in the United States and Japan.[41] This level is high enough to damage most urban vegetation.[42]

Ozone is formed through a complex chain of reactions involving solar radiation, reactive organic compounds (e.g., partially combusted hydrocarbons), and inorganic compounds like nitrogen oxide.[43] The chain reaction occurs gradually, however, not instantaneously. Consequently, the highest ozone concentrations occur around noon on sunny days. Because the prevailing winds blow from the northeast, ozone contamination mostly affects the residential southwestern section of the city. The more industrialized areas to the north and the central areas of dense vehicular traffic are not so dramatically affected. During 1994, ozone levels in the southwestern section exceeded the maximum allowable standard (0.11 ppm or 220 $\mu g/m^3$) on 345 days and generated continuous health complaints from the population.[44] On 95 days, ozone concentrations were above 0.24 ppm (480 $\mu g/m^3$), a level that is universally considered hazardous for humans and plants. In the early 1990s, catalytic converters became mandatory on new cars sold in Mexico. It was hoped that the converters would lower emissions of the reactive organic compounds that are by-products of the combustion of unleaded gasoline. Ozone concentrations, however, have persistently remained high. Slow renovation of existing vehicles and poor maintenance of the converters themselves may be two factors contributing to the slow response to the new automobile standards. A 5 percent annual growth in the number of vehicles has also played a negative role.

A study conducted by several pathologists evaluated histopathologic changes in the nasal mucosa of the inhabitants of the southwestern section of the city.[45] In a carefully

(continued on page 26)

Figure 4. Mean monthly ozone concentrations in southwestern Mexico City, 1984–90.



NOTE: The vertical broken line marks the date (September 1986) when the concentration of lead tetraethyl was lowered in regular gasoline.

SOURCE: L. Calderón-Garcidueñas et al., "Histopathologic Changes of the Nasal Mucosa in Southwest Metropolitan Mexico City Inhabitants," *American Journal of Pathology* 140, no. 1 (1992a): 225–32; and H. Bravo, La contaminación del aire en México (Mexico, D.F.: Fundación Universo Veintiuno, 1987), 296.

Are Megacities Viable?
(continued from page 15)

designed experiment, they compared the nasal mucosa from three groups of health workers and navy employees. Group 1 was made up of long-term residents of the port of Veracruz (a low-ozone environment), Group 2 of people originally from nonpolluted locations who had lived in the city for less than 31 days, and Group 3 of people who had lived in southwestern Mexico City for more than two months. (The mean residence time of this group was approximately 10 years.) Ninety-eight percent of all patients from Group 3 exhibited basal cell hyperplasias (excessive multiplication of normal cells in an organ or tissue) compared with only 5 percent of Group 1. Furthermore, the hyperplasias of Group 1 patients only formed small patches occupying less than 25 percent of the biopsy surface. In Group 3 patients, by contrast, they covered more than 50 percent of the sampled tissue in nearly half of the patients evaluated. While none of those in Group 1 showed additional effects, Group 3 patients showed varying degrees of squamous cell metaplasia (55 percent of the patients), keratinization (23 percent), epithelial dysplasias (81 percent), vascular submucosal proliferation (100 percent), and submucosal chronic inflammation (98 percent). All the patients in Group 2 showed intermediate degrees of incidence with respect to the other groups. Although the authors suggest that high ozone levels could be the main cause of these histopathologic changes, they do not discard the hypothesis "that other potential environmental carcinogens are most likely to be involved" in the extremely high incidences of respiratory tract tissue anomalies found in Mexico City inhabitants.

Other pollutants also impact considerably on Mexico City's atmosphere, but their spatial distribution is quite different from that of ozone. Suspended particles and sulfur dioxide are found in their greatest concentrations in the industrial area to the north and northeast of the city.[46] In the central part of the city where vehicular traffic is more intense, carbon monoxide concentrations are much higher. A recent study demonstrated that the concentration of carbon monoxide in central Mexico City ranges between 34 and 132 μg/m^3, well above official standards and sufficiently high to affect humans physiologically in less than one hour.[47]

Atmospheric contamination also influences the quality of rainwater. From 1983 to 1986, the acidity of rainwater in Mexico City increased significantly because of increasing concentrations of sulfur and nitrogen oxides in the air.[48] In the urban parts of the basin, the average pH of rainwater is around 5.5. In a few cases, however, values as low as 3.0 have been recorded. The effects of air pollution are not restricted to the urban areas, however. Air pollution has had a considerable impact on the natural ecosystems surrounding Mexico City. Phytopathologists have discovered, for example, that ozone produced in the city and carried by wind to the Sierra del Ajusco southwest of the basin, has significantly reduced the chlorophyll content and the growth of the dominant pine species in the high mountains around the basin.[49] These forests collect water for the city. At present, there is a striking level of forest dieback in the mountains surrounding the basin. Scolytid bark-beetles that attack the conifers are the immediate cause, but many foresters associate the new and increased aggressiveness of this pest (which in the past never proved capable of producing widespread tree mortality) on the stressful environmental conditions generated by high ozone levels, coupled with the effects of acid rain. Clearly, atmospheric pollution may have had a considerable impact on the already disrupted water balance, especially on the hillsides of the basin, and thus on the long-term availability and quality of potable water.

Centralism and Ecological Subsidies

The rapid rise and enormous power of the Aztec state were based on their political control of much of Mesoamerica and

STILL PICTURES—MARK EDWARDS

As the city continues to overtake available land, the forests that once covered surrounding peaks and hills are disappearing.

on the subordination of hundreds of different groups that paid tribute to the emperor. Aztec wealth depended to a great extent on the concentration of high-quality goods (e.g., metals, obsidian, tropical fruits, high protein food) and labor collected as tribute from such groups. The Basin of Mexico, where Aztec culture first emerged, became a subsidized ecosystem, receiving inputs of natural resources and energy from other areas.

This tradition, maintained under Spanish rule, has now reached immense proportions. Few ecosystems in the world are so far from being self-sufficient as the Basin of Mexico.[50] With much of the forests cut, most of the *chinampa* lands turned into urban developments, and practically all of the lakes dried up, the supply of raw materials and energy generated within the basin is insufficient for even a small fraction of its 18 million residents. Consequently, vast amounts of food, energy, wood, water, building materials, and many other products are imported from other ecosystems to augment the energy and material flows. With 20 percent of the nation's population, the basin consumes approximately one-third of the country's oil and electricity.

In spite of the severe environmental problems, the Mexican model of development has given priority to improving the quality of life in the large cities (where social demand is more concentrated) rather than in the rural areas (which have become comparatively poorer). From 1950 to 1980, the basin experienced marked improvement in demographic and domestic indicators of the quality of life. However, at the national level, these same indicators have reflected slower change. This difference in trends is more marked if the developments in the basin are compared to those in the depressed rural areas where most of the immigrants come from. Despite the health problems generated by contamination, indicators such as life expectancy at birth and infant mortality are better for Mexico City than for the rest of the country.[51] Although mortality rates have declined significantly between 1950 and 1990, there has been a marked shift in the principal causes of death (see Table 3 on this page). In the first half of the century, infectious diseases were the most common cause of death. Now diseases associated with modern industrial life and environmental contamination, such as heart disease and cancer along with pneumonia and gastroenteritis, two infectious diseases also associated with the degradation of air and water, rank in the top five.

Through the system of ecological subsidies, many of the problems generated by the growth (or the sheer size) of Mexico City are in effect exported to neighboring areas. Chronic water shortages, for example, are in great part transferred to the Lerma and Cutzamala basins, from which water is imported. Wastewater, on the other hand, is drained into the Tula Basin in the state of Hidalgo, where it flows until reaching the Gulf of Mexico. In this way, contamination from untreated wastewater spreads into other geographical regions. In the Tula Basin, Mexico City's wastewater is used to irrigate a variety of crops, including

TABLE 3

LEADING CAUSES OF DEATH IN MEXICO IN 1955–57 AND 1980

1955–57

Cause of death	Rate	Percent
1. Gastroenteritis	227.5	17.5
2. Influenza and pneumonia	202.0	15.5
3. Early childhood diseases	135.3	10.4
4. Heart disease	91.4	7.0
5. Malaria	66.4	5.1
6. Accidents	48.1	3.7
7. Homicides	38.0	2.9
8. Malignant tumors (cancer)	37.8	2.9
9. Bronchitis	31.7	2.4
10. Tuberculosis	31.2	2.4
Other	390.0	30.2

1980

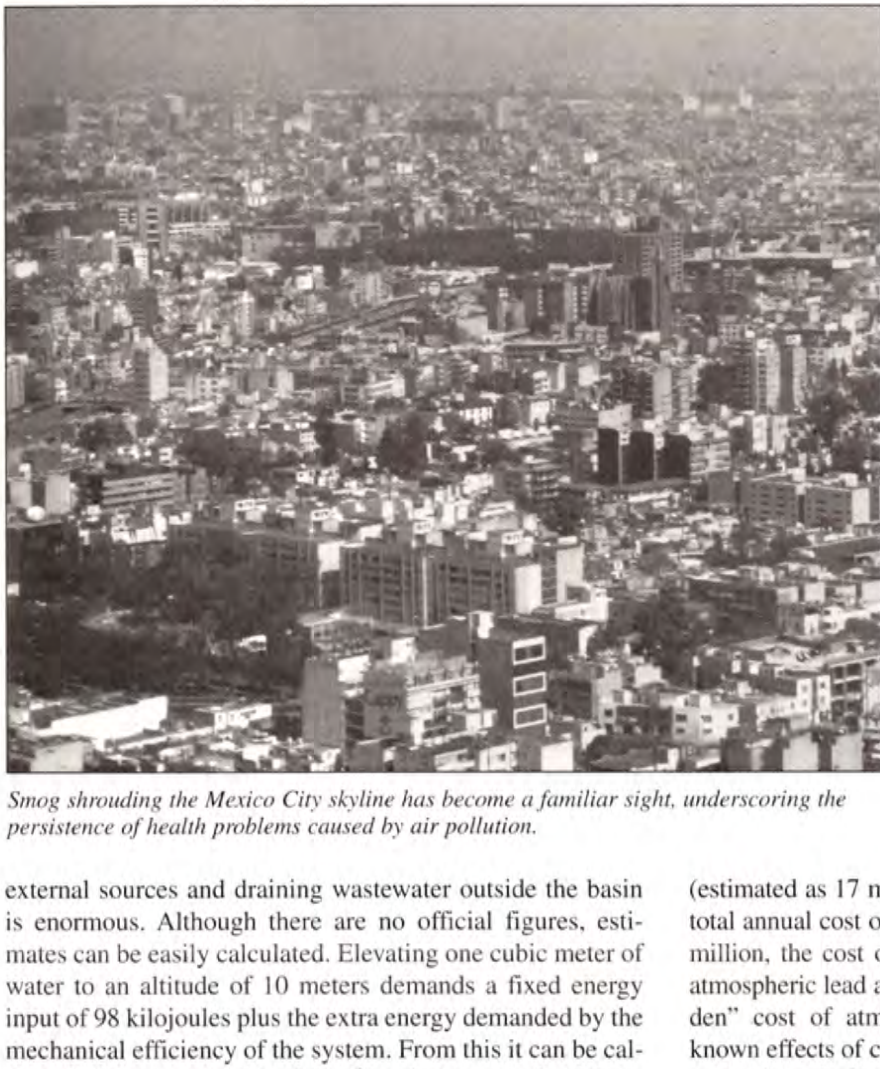
Cause of death	Rate	Percent
1. Heart disease	74.9	11.7
2. Accidents	71.1	11.1
3. Influenza and pneumonia	56.9	8.9
4. Enteritis and diarrhetic diseases	55.1	8.6
5. Malignant tumors (cancer)	39.2	6.1
6. Perinatal afflictions	39.2	6.1
7. Cerebrovascular diseases	22.6	3.5
8. Cirrhosis and other chronic diseases	22.1	3.5
9. Diabetes	21.7	3.4
10. Nephritis and nephrosis	10.5	1.6
Other	231.6	35.4

NOTES: The first column shows the mortality rate per 10,000 persons, the second the percent distribution of the various causes.

SOURCES: C. Santos-Burgoa and L. Rojas Bracho, "Los efectos de la contaminación atmosférica," in I. Restrepo, ed., *La contaminación del aire en México: Sus causas y efectos en la salud* (México, D.F.: Comisión Nacional de Derechos Humanos, 1992), 205–50.

vegetable plots. This practice has contributed to the spread of parasitic diseases like amoebiasis and cysticercosis. It also has polluted good agricultural soils. In one year, as much as 2,300 kilograms of detergents or 750 kilograms of boron find their way into the soil.[52] Although the use of wastewater to irrigate vegetable crops has been legally banned in the region, farmers have no ready alternatives and continue to use the contaminated water.

Because of the Mexican highlands' rugged topography, the energy cost of supplying water to Mexico City from external sources and draining wastewater outside the basin is enormous. Although there are no official figures, estimates can be easily calculated. Elevating one cubic meter of water to an altitude of 10 meters demands a fixed energy input of 98 kilojoules plus the extra energy demanded by the mechanical efficiency of the system. From this it can be calculated that to move the 43.5 m^3/s of water obtained from within the basin, the 19.5 m^3/s drawn from external watersheds, and the wastewater in the deep drainage system, an average of approximately 370 MW is needed.[53] This represents a daily cost of almost $900,000 to supply water and adds 20 cents to the cost of each cubic meter of water.



PANOS PICTURES—LIBA TAYLOR

Smog shrouding the Mexico City skyline has become a familiar sight, underscoring the persistence of health problems caused by air pollution.

Apart from the ecological interpretation of these subsidies, the urban concentration of Mexico City has also involved the concentration of wealth and an implicit economic subsidy from the rest of the nation to the capital's residents. Public transportation in Mexico City now costs approximately 7 cents per trip, regardless of the distance traveled. The subway, used by approximately 4 million passengers per day, thus generates a revenue of $280,000 per day. In 1986, the real cost of operating the system was on the order of $1.5 million per day; now it is probably more than $2 million.[54] The difference is ultimately met by all taxpayers, many of whom do not benefit directly from the service.

It costs around 30 cents per cubic meter to distribute water in Mexico City. This price reflects the high cost of pumping water into the city from the Lerma Basin.[55] The government spends approximately $450 million annually to supply water to Mexico City. The revenue obtained from the service is on the order of $42 million, less than 10 percent of the total cost. Other services, such as electricity, gas, garbage collection, and road maintenance are subsidized for the whole country—not only for the Basin of Mexico. However, because the city receives these services in a higher proportion than the rest of the nation, it receives a higher share of the subsidy. This asymmetry is, again, particularly true for rural areas that export their produce to the city but do not benefit from the cheap urban services.

Air pollution also has a large hidden cost. In a recent study, a researcher quantified the health effects of pollutants in Mexico City by means of standard dose-response curves and calculated the economic costs of contamination by integrating the average individual cost associated with each pollutant (in terms of treatment costs, lost wages, or premature death) for the city's whole population (estimated as 17 million in 1992).[56] This study estimated the total annual cost of particulate matter contamination as $850 million, the cost of ozone as $102 million, and the cost of atmospheric lead as $125 million. Thus, the aggregated "hidden" cost of atmospheric pollution, as estimated by the known effects of contamination on human health, amounts to approximately $1.1 billion per year. (While the impact of lead seems to have decreased since 1992, it is likely that the health effects related to ozone have increased.)

The ultimate monetary costs of the effects of air pollution on the basin's forests have not been calculated but in all likelihood they will be high. Trees play vital roles in controlling erosion, conserving biological diversity, regulating the water cycle, and recharging the aquifers. Because of the groundwater imbalance in the basin, no one has calculated in detail either the future costs of overexploiting the aquifers or the future value of the recharging that is being prevented by defor-

STILL PICTURES—MARK EDWARDS

Untreated sewage outflow pouring into one of the city's drainage canals pollutes the metropolitan water supply as well as croplands in outlying suburbs where wastewater is used for irrigation.

estation. This deficit calls into question the mid-term sustainability of the basin and acts to limit future development.

Even though water treatment and reuse have not been main components of Mexico City's water management, there have been governmental efforts to improve wastewater discharges since 1956, when the first wastewater treatment plant was installed. The two most common treatment systems are stabilization ponds and activated sludge. In 1993, installing a wastewater treatment plant based on the activated sludge system, with a capacity of 1 m^3/s, cost between \$20 million and \$30 million. In 1994, the cost of treating water, including the cost of operation and recovery of the investment, was about 20 cents per cubic meter.[57] If the 27 wastewater treatment plants in Mexico City operated at 100-percent efficiency instead of the current 50 percent, they could handle approximately 8.6 m^3/s of wastewater at an annual cost of \$55 million.[58] Until recently, the government subsidized wastewater treatment. New legislation is now being implemented that transfers rights and obligations to the users of national water resources and makes the private sector responsible for discharging wastewater of acceptable quality.[59]

Sustainability Problems and Governmental Response

Judging from the state of both air and water resources in the Basin of Mexico, and from the immense economic and natural resource subsidies that the whole country has to provide to maintain this area, one can conclude that the megalopolis of Mexico City is highly unsustainable in its present condition. If groundwater use, which is double the current recharge, is projected into the future, the basin will experience large-scale water shortages sometime in the next 30 years. These shortages would be worsened by future population increases and continued urban growth. Water-use conflicts with neighboring watersheds are already important issues. If more water is drawn from external sources, it is likely that these conflicts could become more severe. Water quality is already below drinking standards in some areas, and the increasing amounts of both wastewater and contamination do not presage any short-term improvement. Degrading water quality will be a major health concern in the next decades. In spite of efforts to reduce exhaust emissions, the rapid growth in the number of cars (almost 100 percent per decade) also calls into question the capacity to improve the basin's atmospheric quality. Furthermore, some 48 percent of all Mexican industries are located in the basin. This fact suggests that there will be increasing demands on natural resources, air, and water as well as growing amounts of liquid and solid waste for which there are no adequate treatment and disposal systems.

Mexico City's problems are so important that they have gotten increasing attention from policymakers. In 1972, a Subsecretariat of Environmental Protection was created within the federal government's Secretariat of Health. In 1982, the Secretariat of Urban Development and Ecology was created to deal with matters linked to urban environmental quality. This new secretariat was also assigned some responsibilities for the protection of natural resources. In 1992, a sewer system in Guadalajara exploded because of spillage of fuel waste products into the pipelines. As a result, hundreds of people died. In the aftermath, the federal environmental administration was divided into two new offices: a National Institute of Ecology, authorized to draft environmental regulations, administer environmental protection efforts, and coordinate natural resource management; and an Environmental Attorney General, created to oversee enforcement of environmental legislation.


PHOTOGRAPHERS ASPEN—DAVID HISER

Algal blooms that spread across the surface of Lake Texcoco eloquently attest to the widespread contamination of Mexico City's water reservoirs.

As a result of citizen protests about the basin's deteriorating air quality, the Department of the Federal District, which administers a large part of Mexico City, created a Metropolitan Commission for the Protection of Air Quality in 1992. The government of the state of Mexico and federal authorities participated in this move. Water management in the basin is coordinated by a complex set of state and federal government organizations, including the Department of the Federal District and the Commission for Water and Sanitation of the state of Mexico (at the state level) and the National Water Commission and the Secretariat of Health (at the federal level).

In December 1994, a new secretariat was created to encompass all federal environmental functions, including those dealing with "brown ecology" (environmental pollution) and "green ecology" (natural resource management). Functions that were previously dispersed among various federal agencies were centralized under the Secretariat of Environment, Natural Resources and Fisheries. Their mandate covered the protection and management of natural resources; waste management and pollution control; the management of national parks and other protected natural areas; and environmental law enforcement. Decentralized governmental agencies like the National Institute of Ecology, the Environmental Attorney General, and the National Water Commission all came under the jurisdiction of this powerful federal secretariat. The ever increasing complexity and size of environmental authorities highlights the growing concerns about environmental quality and natural resource degradation in Mexico in general and in the basin in particular.

Insights for the Future

Although most of the environmental problems in the Basin of Mexico have reached critical proportions in the late 20th century, industrial development is not solely to blame. Urban and political centralism have been a tradition in Mexican society since the Aztec empire. The Basin of Mexico, for nearly two millennia one of the most densely populated areas of the world, has historically used its preeminent administrative and political position to obtain advantages over other areas of the nation. Modern industrialization, however, has exaggerated this trend to dramatic proportions, and is indeed responsible for the disproportionate urbanization and the biased distribution of population and wealth. Although population growth in the basin is clearly decelerating, natural resource use is already highly unsustainable with the current population density. Fossil fuel consumption, the number of cars, deforestation, and the pumping of groundwater from a critically depleted aquifer are all increasing at a rate that often exceeds that of population growth.

In the past, resource exhaustion through improper land use has produced large declines in population, showing that there are limits to population growth in a closed basin with a given technological level. Air pollution, water shortages, the urban area's unbridled growth, and the ever-increasing economic and natural resource costs of maintaining the megalopolis suggest that a similar process of population limitation or even decline may occur in the future. In Mexico City, the use of air, water, and soils as a commons is clearly unsustainable, and the city's residents may soon confront hard and painful decisions. In our opinion, it is clear that in the future the subsidies will have to be eliminated and that the cost of living and the quality of life in the city will worsen. Government authorities have made several attempts over the past six years to set the price of water closer to its real cost, but popular protests have aborted these initiatives. However, the capacity to subsidize water use is becoming more and more constrained and will soon reach a limit. Health problems typical of developed societies (like heart disease and malignant tumors) coexist with problems related to air and water pollution (such as pneumonia and enteritis) that are more typical of the developing world. Although there is no data on this problem, Mexico City's decreasing growth rates suggest that for some sectors of the population emigrating outside the basin into medium-sized cities is already an advantageous alternative.

Growing conflicts over water use, air pollution, waste disposal, environmentally related health problems, and natural resource depletion are all problems shared by most Third World megalopolises. Mexico City is thus a laboratory where many of the processes that drive population, natural resource, and land-use changes in the less-developed nations are being tested. It provides both fascinating and terrible insights into what the future may hold for many of the megalopolises of Latin America and the Third World.

ACKNOWLEDGMENTS

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PANOS PICTURES—LIBA TAYLOR

Living conditions in the poorer sections of Mexico City demonstrate the ill effects of unchecked population growth and natural resource abuse.

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Mexico City: Metaphor for the World's Urban Future

Exequiel Ezcurra and Marisa Mazari-Hiriart's article aptly summarizes the conditions that have made Mexico City a metaphor for megacities throughout the developing world. Of course, many of Mexico City's problems are also shared by megacities in the developed world. For instance, land subsidence related to pumping groundwater is a notable problem in cities like Venice, and the air quality in Los Angeles can be almost as unpleasant as in its Third World counterparts. All the same, because the megacities of the developing world are at a different developmental stage, they present a separate set of challenges to sustainability.[1] For this reason, I shall first consider the question of sustainability for large urban areas in general and then illuminate the different challenges facing the megacities of the developed as opposed to the developing world.

As Ezcurra and Mazari-Hiriart correctly imply, the existence of a self-sufficient ecosystem within the city limits is too narrow a criterion for determining the sustainability of large urban areas. For example, Xian, China's ancient walled capital, has never been self-sufficient in this sense, but it has been a sustainable urban area for at least 3,000 years because of its relationship with the surrounding countryside. Thus, sustainability does not connote constancy but rather continuity and resilience in the face of change—that is, the successful management of change in ways amenable to human well-being, including the maintenance of and reasonable access to open spaces and the preservation of ecosystems. To be sure, megacities as a group now have such a substantial environmental impact that their problems can no longer be dealt with in isolation. The sustainability of the Earth, not just its cities, is the issue. Population growth, rising real incomes, and global environmental change present ever-changing and increasing challenges to the sustainability of large urban areas despite the counterbalancing effect of improved technologies.[2]

The problems of large urban complexes in the developed world, such as the "Bosnywash Corridor" (Boston/New York/Washington) in the United States, can be alleviated through wise management and the use of available resources. What is required is careful resource allocation, innovation, and the application of management skills to accommodate rising populations and incomes to available natural resources. Pollution control is perhaps the most formidable challenge these megacities will have to face over the next 25 years. But, in all probability, they will also have to meet more socially sophisticated challenges. For example, in Europe, it is increasingly difficult to go anywhere that is not in some sense developed or at least manicured. The landscape and cityscapes of the Netherlands, for instance, are almost entirely human-made. As urban areas and their hinterlands grow, the psychological and social alternatives available to people will diminish. In the interest of social health, then, urban managers should tackle not only the difficult issues of infrastructure improvement, emissions control, schools, and equity for disadvantaged segments of the population, but also the preservation and expansion of natural areas. As urban areas throughout the world continue to expand, the problem of disappearing green space needs to be given as much weight as the need for housing and other forms of infrastructure.

For the most part, megacities in the developing world face much more basic problems. They need to create infrastructure where little or none exists, and they need to ensure adequate water supply, sewage treatment, health care, transportation, and environmental management. The familiar pattern of population growth outstripping resources and leading to environmental degradation has yet to be altered in this part of the world.

The magnitude of the problems that cities in the Third World face raises the specter of staggering expenditures to bring them up to currently acceptable standards

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and suggests the continuing need for large international transfers. It also indicates the need for enormous investments in human capital, especially the training of engineers, social workers, transportation planners, health professionals, and ecosystem managers. Whereas most developed countries have the resources to deal with their megacities' problems, in most developing countries this will not be the case for years to come. People there face the prospect of continuing misery as management structures, skills, and services develop incrementally. There is hope, however, for at least a gradual improvement: As Ezcurra and Mazari-Hiriart point out, some of the quality-of-life indicators in Mexico City have risen.

Successful management of megacities must take into account issues of global environmental change along with regional concerns. The unknown probability of environmental catastrophes with significant implications for megacities, such as rapid changes in ocean circulation patterns and sea levels, are factors in the equation.[3] Even gradual environmental change will create unfamiliar challenges. For instance, the hydrologic processes that urban water planners have comfortably regarded as stationary will, in fact, change continually over time. Thus, there may be a hitherto unrecognized need for international conventions regarding urban growth and management to complement existing environmental and natural resource conventions. Managing megacities over the next 25 years and beyond will be a stringent and continuing test of our civilization's intellectual and moral courage.

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1. For a review of some concepts of sustainability, see World Resources Institute in collaboration with the United Nations Environment Programme and the United Nations Development Programme, *World Resources 1992–1993* (New York: Oxford University Press, 1992), chapter 1. For a discussion of urbanization, see B. J. L. Berry, "Urbanization," in B. L. Turner II et al., eds., *The Earth as Transformed by Human Action: Global and Regional Changes in the Biosphere over the Past 300 Years* (Cambridge, Mass.: Cambridge University Press, 1990), chapter 7.

2. For essays exploring the patterns of human-environment interaction, see L. Arizpe, M. P. Stone, and D. C. Major, eds., *Population and Environment: Rethinking the Debate* (Boulder, Colo.: Westview, 1994).

3. For information on recent studies of circulation patterns in the North Atlantic and their response to changes in freshwater input resulting from climate change, see A. J. Weaver, "Driving the Ocean Conveyor," *Nature* 378, no. 6553 (9 November 1995): 135–36; S. Rahmstorf, "Bifurcations of the Atlantic Thermohaline Circulation in Response to Changes in the Hydrological Cycle," ibid., pages 145–49; and S. Manabe and R. J. Stouffer, "Simulation of Abrupt Climate Change Induced by Freshwater Input to the North Atlantic Ocean," ibid., pages 165–67.

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Mexico City has exerted so much pressure on its regional environment that it is arguably unsustainable. But this is nothing new. Historically, great cities have pushed up against the limits of survivability. London, for example, faced fuel crises in the late 13th century, the Black Death in the 14th, the Plague and the Great Fire in the 17th, cholera epidemics in the 19th, and the disastrous smog of 1952 in the 20th.[1] One may argue that each of these situations arose from pressures placed on the environment by an extreme density of human activity. For example, the energy requirements and sanitary problems of medieval London, a city only two miles in diameter, provoked a crisis. Although changes in urban technology overcame these limitations, new problems invariably arose as the city grew.

Each crisis required a unique solution, but these solutions were responses to disasters rather than the products of conscious efforts to lessen environmental pressure and disruption. Because London and many major European cities reached the height of their growth during the 19th century, they have escaped the keenest edge of the problems facing growing megacities in the late 20th century. The developing world in particular has had to grapple with pressures that have pushed cities to the edge of a new crisis.

Despite more ecologically sensitive administration, however, contemporary