Development of the sewage infrastructure under climate changes in the Metropolitan Zone of Mexico City

José Agustin Breña, Universidad Autónoma Metropolitana
Maria Francisca Naranjo Pérez de León, Centro de Investigación del Agua (CIA)
mfnp@yahoo.com

Topic: Floods, Sewage

Introduction

The Basin of Mexico, where Mexico City is currently located, has had a changing history, product of volcanic eruptions, earthquakes, climate changes and environmental modifications induced by the human being.

Located at the end of the Mexican High Plateau, it was from the beginning an exoreic river basin, which was transformed through time and constant volcanic eruptions into an endoreic basin. Nowadays it remains an open drainage basin due to anthropogenic changes.

During the formative period, the surface runoff created 2 systems of lakes. One, located at the northeast of the basin and while the largest was in the southwest. The elevation of the original lakes was at an elevation of 2240 m.a.s.l. but during the last 100 years the soil subsidence has decreased the mean elevation to 2226 m.a.s.l.

The Basin of Mexico was inhabitated 20,000 years ago. Since that time the occupation has been constant and currently several cities are located within it, the Metropolitan Area of Mexico City (MACM) being the largest urban center with a population close to 20 million inhabitants.

At the end of the formative period several droughts occurred in the Basin. Between 750 BC and 100 BC a long drought could have changed the agricultural techniques and the irrigation might have appeared through small canals which diverted the flow from the streams. After 100 BC there was a wet period in which the elevation of the lakes was increased though not in a sufficient manner to be able to enhance agriculture in the lakes. It was not until 1327 AC approximately when the lake level raised enough so agriculture could be practiced again. Thus, from the first century until the 13th there were not archaeological agricultural-related rests in the lakes which imply long drought periods.

As a closed river basin, the variability was not only induced from local changes but also from a global change. Currently, the population has played a decisive role in the environmental change of the river basin conditions.

Human impact in the Basin of Mexico

Since the formation of the Basin of Mexico until the XVII century, the Basin was closed. From the prehispanic times, the control of the levels of the lakes was fundamental for the survival of its people. This was due to the fact that the agricultural intensive systems, feeding source of the cities around the lake, were located around and inside the lake.

Likewise, since early times different hydraulic works were built to adapt the lake system to the inhabitants needs. These works took centuries to be completed.

The water management was done from the mountains through different hydraulic works until the lakes, where a complex system of levees used to control the water levels. During such time, the Basin of Mexico was a huge hydraulic work inducing an integrated water management scheme.

However, floods were also existent. The first flood event was documented in 1325 caused by a heavy storm which raised the level of the lakes, flooding a certain number of cities located inside the lake. Apparently, that was the beginning of a humid period which enhanced the development of new technology by the construction of intensive agricultural systems inside the lakes. These affirmations were obtained by the codex as well through civil and religious documents dating from the colonial times. The flooding problem was related to the construction or destruction of hydraulic works that have modified the natural lakes.

It is known by the chronicles that in 1382 there was a major flood due to the western lakes which acted as reservoirs so the overflow of the whole system led to an important inundation.

The period 1440-1450 AC was characterized by intense, wet events with hail and ice. Consequently, many hydraulic works were built to prevent floods. The first work to be known was a diversion canal from the Cuautitlán River in 1433 which was also used for irrigation purposes.

In 1499 an important dike also known as the “Albarradón of Netzahualcoyotl” was built. Nine years later a significant drought made possible the construction of a waterway to convey water to the city. This waterway began its operation 1466. An important flood was recorded in 1499 not because of heavy rainfall but rather due to the diversion of a spring. Other major floods were observed in 1502, 1510 and 1520.

Floods during the Prehispanic period

YEAR	CAUSE	AFFECTED PARTS
1232		
1327-1328	Rise of the average level of the lakes	
1449		
1440-1450	Extremely wet period, hail and ice Rise of the average level of the lakes	
1433	Flood in the Cuautitlán River	
1449		
1499	¿Rise of the groundwater table?	
1500	Diversion of the springwater	Lake of Mexico
1502		
1510		
1520		

Colonial period

When the Spanish conquerors arrived, most of the hydraulic works were destroyed. Indeed, the conquerors had a different water vision, thus the integrated water management disappeared in the XVI century to adopt a policy using partial approaches. One of the implemented policies was to drain the river basin for flood prevention.

Since the first floods, this is from the XVIth century to the XIX century, the colonial government started to apply some measures. In the beginning, the applied solutions seemed to be temporary however the frequent floods led to an artificial engineering project which would “open” the basin in the northern part and so be able to drain the existent lake system. Furthermore, the flood risk prevention measures enhanced to possibility to transform the former wetlands into agricultural zones as well urban proned areas.

Mexico's conquest was carried out in 1521 and the destruction of the hydraulic infrastructure produced 4 catastrophic floods in the city so the new authorities thought about changing the capital of the country to another place. The first flood occurred in 1553, the second started the September 17 of 1555 until 1578. The two last floods in the XVIth century occurred in 1579 and 1580 respectively. Due to these circumstances the Spaniards decided to drain the lake by constructing a drainage system.

During the XVIIth century the floods were more intense and long. In August 1604 a one year flood occurred followed by another one in June 1607. In 1608 the Huehuetoca drainage system started to operate but despite this in 1629 the most severe flood in the history was held during seven years until 1936. The city was partially left and the government started to look for new solutions. According to the chronicles in 1674 extraordinary precipitation events were observed but the city was not flooded. The XVIIIth century was marked by six significant floods and an earthquake in 1714 which partially destroyed the drainage system.

Floods during the Colonial period

YEAR	CAUSES	AFFECTED REGIONS
1553		
1555, September 17th- October 23rd		
1556 Flood works postponed after the flood		
1579, August		
1580		
1602, June 29	Heavy rainfall in the Lake of Chalco	South-East of the city
1604, August	Cuautitlán River. Levee break	Low parts of the city. Buildings devastated
1605		
1607, June 14 - June 29	June 29, Chalco Waterway	South-East of the city
1623	The flood works in Huehuetoca were suspended	City
1627, October 29		City
1629-1633	The access to the discharge canal of the Rio Cuautitlán was closed	City
1637		
1674		
1703, August 24		
1707-1708	Drainage(?)	
1711		
1713, September		
1714, July	Earthquake and destruction of hydraulic works. Break of the albarradón of Coyotepec	
1715, August 15		
1719, August		
1724, 1 September		
1732		
1734, August 13		

1738, September		
1743		
1747-48,september and December		
1752, February 29		
1761, September		
1762, August 27		
1763-1764	Heavy rainfall in the south. Damages in canals and levees	South of the city
1764-1766	Heavy rainfall. The lake of Texcoco raised and overflowed San Lázaro, until Candelaria.	
1770		
1772, June - September		
1775		
1779, October		
1781		
1783, September		
1787		
1792, June 17 - 18	Sewage	Main streets
1795	Sewage. Heavy rainfall in the West	
1796		
1797		
1798, August 2		
1799		
1801		
1806		
1810, march 17		
1817		
1819, September 26-28	Heavy rainfall	North of the City

XIX & XX centuries

At the end of the XIXth century, the arrival of the pumps in Mexico started a new period characterized by the intensive and large scale groundwater withdrawal for water supply purposes. Thus, the terrain subsidence caused by the excessive extraction made the drainage system difficult to operate so it had to be done with the help of pumping systems as well.

The soil subsidence brought again the problem of floods. In the XIX century 4 floods were recorded. Mexico City was growing rapidly and the water supply need was steadily increasing. The soil subsidence was observed until the beginning of the XXth century. In 1925 the subsidence rate in some zones of Mexico City was reaching 25 cm/year. This new problem was added to the permanent risk of the earthquakes. In the XXth century 10 major floods occurred despite the enlargement of the hydraulic works started in the XVIth century and the construction of new ones.

FLOODS XIX & XX CENTURIES

YEAR	CAUSE	AFFECTED REGIONS
1821		
1823, August 6		
1826, October 26		
1827, July 16		
1828-1829, started June 28		
1830, February 26	Heavy rainfall	South-eastern
1831, August 9		Low regions
1846		
1848, July 29 - September 26		South-eastern
1853, August 24 and 31		City
1857		City
1862, August 26		City
1864, from August to October		
1865, from August to October	Heavy rainfall	
1866, July 27		
1869, June 20		
1874, June 26 to July 2 and July 21		
1874, October		
1875	Heavy rainfall	
1876		
1878, June, July 20 and September		
1882, June 30		
1885, October 3-6		
1886, September 25	Rainfall spread over the whole city	
1887, June 27 and October		
1888, August and September		
1889, September 7		

YEAR	CAUSE	AFFECTED REGIONS
1890, may 6 and 25		
1893, June, July and September		
1895, July 16		
1897		South of the city
1898, August		
1900, July		
1901		
1910 July and September		
1925	Land subsidence	
1937		
1941 two floods		
1942	River overflowing	
1944		Main streets
1950 June, September and October	Heavy rainfall	
1951 July and August		
1980, September 1	Rainfall spread over the whole city	
1980, September 4	River overflowing	
1980, September 6	Hail and rainfall	
1980, September 7	Storm	
1981, may 30	Storm	
1981, July 4	Storm	North
1981, July 6	Storms	Across the Basin
1981, July 8	Storm. Dam overflow	North
1982, July 26		East
1982, July 28	Heavy rainfall in the eastern part of Mexico City	South & East
1983, July 8	Chalco canal overflowing	North & East
1983, July 12	Heavy rainfall	Across the Basin
1983 July 14	Heavy	Across the Basin
1984, July 26	Heavy Rainfall	West
1986, may 30	Storms in the western & eastern zones	North & Center
1987 may 28	Storm in the northern zone	North

YEAR	CAUSE	AFFECTED REGIONS
1987, June 6	Sewage	
1987, July 4	Fissure in the Levee San Buenaventura	North & East
1988, June 17	Heavy rainfall	South
1988, June 28	Heavy rainfall	Across the Basin
1988, July 1		Across the Basin
1988, July 8	Heavy rainfall	Across the Basin
1988, July 10	Heavy rainfall	North
1989, July 2	Heavy rainfall	North & East
1990, July 15	Heavy rainfall	North & East
1990, July 19	Constant rainfall	South & East
1991, July 15		West & South
1991, June 16	Heavy rainfall	South
1991, June 18		South
1991, June 30		East, North & South
1992, August 15	Heavy rainfall	South, Center & North
1992, August 16	Heavy rainfall	Across the Basin
1993, June 24	Three days of heavy rainfall	North & East
1994, July 2	Storms	South & East
1994, July 31	Heavy rainfall and hail	West & Center
1994, August 7		North, Center & South
1995, June 29		North & East
1995, July 1	Heavy rainfall	South
1995, July 11		East
1996, September 1	Storm and hail	North & East
1997, August 18	Storm	South
1997, August 28	Storm	South & East
1998, June 27		Álvaro Obregón
1998, July 27		West
1998, September 30	Rainfall during 72 hours	West-East
1999, July 3		West
2000, may 29		East
2000, June 17	Break of the manhole E. de Oriente	

Currently, the sewage system of Mexico City is composed by the following hydraulic infrastructure:

The deep sewage system has 7 water collectors, whose diameters vary from 4 to 5 meters and lengths from 5 to 27km. Besides, there is a semi-deep sewage system with 3 collectors with a diameter of 3.1 meters and lengths that vary from 0.75 to 11km. The semi-deep and the deep sewage systems flows enter to a main waterway with a diameter of 6.5 m and a length of 49km known as the "Emisor central" which flows to El Salto River and its dam. The main goal of the sewage system is to avoid floods by conveying the wastewater and storm water flows out of the urban area. Moreover, an important amount of this polluted flows are being used for irrigation purposes.

3. Climate change

According to the Intergovernmental Panel for Climate Change (2001) the continental regions locates in middle latitudes will suffer a decrease in the water quantity and quality. An increase of the magnitude and frequency of topical hurricanes will bring higher possibilities that their effects occurred within the Mexican high plateau.

The temperature changes, in the country, are expected to be inconsistent. In the worst case scenario the annual runoff will decrease from about 50 to 150mm by 2050 while for a soft scenario, the runoff would rise by 25 to 50 mm yearly.

In the same scenario, the mean temperature increase in the Basin of Mexico would be about 2 degrees centigrade resulting in a rainfall decrease of 23 mm/year approximately. By 2080, the worst scenario indicates an increase of 2.8°C and a rainfall decrease of 30mm.

The rainfall trends for Mexico City show several variability rainfall periods from 1877 to the present. Thus, from 1877 to 1920 and from 1941 to 1955 there was a dry period in contrast to the observed wet periods from 1921-1940 and from 1955 to the present.

4. Conclusions

As seen previously water management in the Basin of Mexico can be divided into two periods, the first when the Basin was open and its management integrated, during the prehispanic times. The other period, from 1521 which remains today and that is characterized by partial and unsustainable solutions. During its history, the Basin of Mexico has suffered several climate changes but despite these facts it has remained inhabitant. Populations have been able to adapt themselves throughout history by finding solutions for these phenomena. According to the recent studies, the Basin of Mexico is not included among the most affected regions in Mexico. The sewage system is not expected to be particularly struck since moderate droughts are expected. However, the water supply could be affected by the forecasted drought in the Balsas river Basin which is an additional source of water to the Basin of Mexico through the Cutzamala System

The problems of the Basin of Mexico must be solved by the Mexico City authorities as well by the state governments of Mexico and Hidalgo. The addition of a new issue as climate change even though it does not represent a significant change will make water management even more complex.

5. Recommendations

Some models as the CCM and the MTC forecast a higher occurrence of heat waves and low rainfall rates though extreme maxima rainfall events cannot be underestimated. This phenomenon can be observed in the ancient records.

Other global climate models as the GFDLR 30 indicates a higher number of rainfall maxima events. This would imply the construction or rehabilitation of hydraulic works designed for larger floods.

Specific studies on the impacts of climate change in the Basin of Mexico as well for neighbors catchments located in the Lerma and Cutzamala River Basins. Furthermore adaptation plans and middle term strategies based on the water resources capacity of each catchment are necessary to stop the unsustainable water management in the Basin of Mexico (e.g. the Basin of Mexico has a maximum capacity to provide water for only 6 millions inhabitants). Reallocating water consumptive uses as agriculture and enhancing the mobility of the population to neighbor cities located in adjacent river basins should be considered.