RAINFALL USE TO IMPROVE THE SUSTAINABILITY OF THE HYDRAULIC SYSTEM IN THE VALLEY OF MEXICO

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ABSTRACT

This paper is a complementary part of previous papers dealing with water issues in México City and its suburbs. Specifically addresses the system of rain water collecting, as there is still plenty of rainwater volumes which has features to satisfies the needs of the city. After a brief description of the hydrological system characteristics of the valley in order to give an idea of the potential of the sustainability of the rain water resources, it is proposed a set of short and long range actions to retain larger volumes of rain water: a) Construction of underground and surfaces tanks and / or semi-underground storages, b) Construction of an underground and distribution ring storage tank, c) Construction of dams, d) Construction of wells for adsorption, e) Massive cobbled of secondary streets, f) Storage of rainwater in houses, g) Massive reforestation of originally forested areas and construction of new forests, h) Protection of soil with litter i) Construction of a special rain water sewage.

Keywords: rain water, México Valley, hydrology, systemic sustainability

INTRODUCTION

During the last few years, the water service to the Valley of Mexico, especially potable water supply to Mexico City and its suburbs, has been studying and this paper suggest feasible alternatives to increase storage of rainwater, in order to improve and maintain quality of service in a sustainable manner.

The rainfall over the greater metropolitan area in the rainy season, during the months of June, July, August and September are often heavy and usually of short duration, causing water logging and floods in many cases, over several directions, so it is necessary that during the torrential rains simultaneously dislodge the water out of the valley.

It should be emphasized, as already mentioned on other occasions, that the city of Mexico for its geographic location and lack of large and permanent natural rivers, has faced almost always the same problems in providing a good water service problems are aggravated, among other things, by uncontrolled population growth and erratic governance practices on water management.

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Table 1 shows a summary of the main causes of problems currently observed in the process of supplying water to the inhabitants of the valley of Mexico.

Table 1. Some causes of the problems of water supply system

PRIMARY CAUSES			
PHYSIC--HYDROLOGICAL		SOCIO-POLITICAL	
1	Reduction of recharge areas	1	Uncontrolled growth of population
2	Over exploitation of aquifers	2	Four political entities
3	Low rain water collecting	3	Unregulated usage of water
4	Great leaks of water pipes	4	Differential Price rate allowances
5	Mixed drainage	5	Restricted administration
6	Scarce volumes of treated water	6	Absence of water sustainability culture
7	Imported water from others basins	7	Unknown of resilient condition

There are two large sources of water in the Valley of México: Rain water and waste water treatment.

Rainfall and wastewater are two major sources of water that properly exploited, can help solve greatly many of the problems that limit the current service for many years ahead.

a) Only about 25% of the rain water that flushes into the valley, is used for the benefit of the population, while the remainder, is returned to the atmosphere and the other runs out of the valley in combination with wastewater. Figure 1 shows a schematic distribution of rainfall in the Valley of Mexico.
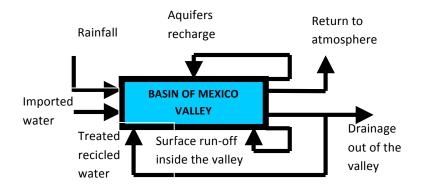
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Fig 1 Schematic distribution of water in the Valley of México

b) In regard to wastewater treatment, only 6% is treated to remove impurities, leaving it to a level that is used only for irrigation purposes and the remaining 94% is left to drain out of the valley .

It is required to perform some actions to take better advantage of these two water resources, water rainfall and water treatment, since there is enough liquid to cover the demand of the current population and for many generations to come. As well to avoid the import of water which is necessary for the development of communities where currently matters such water. From annex 1 it was extracted the rainfall distribution show in figure 2.
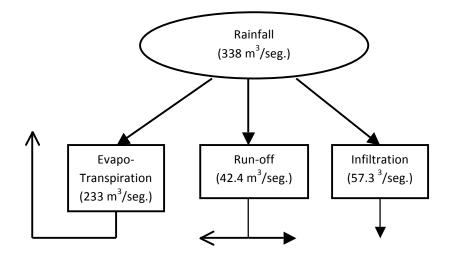

Fig 2. Distribution of rainfall water

THE SERVICE WATER SUPPLY

The service of providing drinking water for the current Metropolitan Zone of Mexico Valley (MZVM), which is the largest concentration of people of the Valley, is generally poor acceptable, even if there are areas like the eastern Iztapalapa, where the service granted is rather deficient.

Among other factors, the quality of this service is hampered because it did not have sufficient volumes of water available to meet the needs of all residents, including miscellaneous services, despite year after year there are abundant rainfall (above 700 mm) and there is imported water from the Lerma and Cutzamala basins.

Based on Table 3 and Fig 2 of the Annex 1, it is shown the presence of a very generous annual rainfall that is enough to cover the needs of the population currently settled in the Valley and for many future years of population growth. To do this, we must handle properly conscious that enormous rainfall that falls to the valley annually.

The analysis of water situation in the Valley, aided by the material presented in annex n.1, is summarized to establish the following assumptions related to primary water availability:

1. The annual average rainfall is abundant, yet the maximum rainfall is torrential and of short duration.

2. A huge volume of water, 70%, returned to the atmosphere by the phenomenon of evaporation - transpiration.

3. The rainwater running on rivers and streams, becomes contaminated quickly because by the same causes drain sewage, that is, to the existing infrastructure does not separate rainwater and used water.

4. The existing reservoirs are of limited storage capacity and have no protections to prevent intruders, pollution and excessive evaporation.

5. The natural recharge of the aquifer in the MZVM, is increasingly limited as it increases day by day constructions of all kinds and paved streets and green areas are disappearing as gardens, parks, forests, etc.

IMPROVING SERVICE DELIVERY OF POTABLE WATER

So, it is clear that to maintain and improve the quality of service for the supply system it must be modified in its infrastructure and administrative processes. For this it is necessary

to conduct serious studies that lead to identify and implement specific actions and well designed projects, which by its nature must be long term and high financial cost.

Such studies have to contemplate the possibilities of having larger volumes of water from rainfall, without resorting to imports which are very costly in several ways. This work focuses on finding alternatives to capture more rainwater annually.

Consider the fact that most of the rainfall returns to the atmosphere without being able to use, so it is necessary to find solutions to bring down the high percentage of water for beneficial purposes to the population.

The evapo-transpiration is a phenomenon that inevitably occurs during the process of heating a volume of water, especially when that volume is attached directly to the rays of the sun and air currents, this means that to reduce this phenomenon, we must maintain water bodies at low temperatures and away from sunlight. In light of this concept, lists a set of actions to conserve water volumes stored somewhere in the valley and especially in the MZVM:

i) Construction of surface tanks and / or semi-ground storage

j) Construction an underground and distribution storage tank

k) Construction of dams

l) Construction of wells for adsorption

m) Massive Cobblestones of secondary streets

n) Storage of rainwater in houses

o) Massive reforestation of originally forested areas and construction of new forests.

p) Protection of soil with litter.

Any program of actions to improve the supply service that is selected shall include as an essential prerequisite, to separate rainwater waste water, waste water tubing and letting the water run free of rain

The action program will be established with all the suggested actions, each to the extent appropriate and consistent with the rest, as none of the actions achieved by itself to increase the volume of water available to improve service delivery

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SUGGESTED ACTIONS

I – Brief description of surface tanks and semi-ground storage

(Fundamental Purpose: To increase the retention of rainwater for later use)

• Tanks should be constructed in the cause of a river or at the confluence of two or more rivers

• Tanks should be sized according to the volume they receive, be fully covered and vented.

• Each tank trap corresponds to a solid entry, and a water treatment plant to the output.
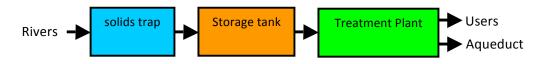

Fig 2 covered storage tank

• The outflow is driven by the conduit to be controlled as appropriate, or, to a specific sector of the population.

II - Construction of a big underground and distribution storage tank

(Fundamental Purpose: To increase the retention of rainwater for later use)

The underground tank will have a ring-shaped arrangement, because in this way, a greater volume for storage and less difficulty in its construction. Fig 3
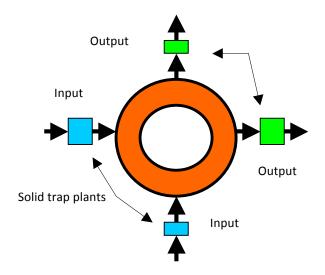

Fig 3 underground ring tank

• The peripheral should be built below ground so that runoff from both sides fall by gravity into the ring. All funds must have the same level for sea level so as to avoid areas of high pressure.

• The ring will be peripheral to the MZVM without exceeding the limits of the city, so as to achieve the greatest benefit to the service of supply.

• It will have multiple entries depending on the formation of runoff. Before each entry must have a solid retainer plant

• You have multiple outputs depending on the needs of service delivery. After each output should have a water treatment plant.

III - Construction of reservoirs

In the valley there are two potential reservoirs, lakes and ponds and dams. The latter are found only within the limits of the MZVM, are of limited capacity and are designed to control the bodies of water from rainfall, whose characteristics are of much water in a short period of time.

• Reconstruction, as far as possible, some of the lakes that once formed part of the geography of the Valley. • Use of treated water to assist in maintaining the permanence of lakes and lagoons.

• Continuation of the missing stages of the project of Lake Texcoco.

• Conditioning of the MZVM dams to store, maintain cleanliness and reduce levels of evapo-transpiration, rain water.

IV - Construction of wells for adsorption

(Fundamental Purpose: To increase the recharge of the aquifer and prevent waterlogging)

• Identification of areas of severe flooding in all directions of the MZVM and the degree of infiltration of each area.

• Construction of wells in selected areas and the recommended design features.

V- massive cobblestones of secondary streets

(Fundamental Purpose: To increase the retention of rainwater for later use)

• The streets of heavy traffic, main and specific purposes will remain paved or cemented, but changing a hydraulic cement.

• The secondary traffic streets, and primarily those of the colonies on the periphery of the MZVM, will be paved.

• The streets paved in its entirety (stream, sidewalk and median) allow rainwater runoff, avoiding any possibility of infiltration.

• Brooks pavers, sidewalks paved partially or fully cemented and landscaped or wooded ridges, allowing infiltration

• The cobbled streets must be drained, but with gentle slopes to allow for infiltration and avoid long-term waterlogging.

• The resulting infiltration stay longer as they remain at greater depths and with the possibility of continuing his march to the aquifer.

VI - Home storage of rainwater

(Fundamental Purpose: To increase the storage of rainwater)

• Each individual home has to have its own system for storing rainwater that falls on your property (roofs and patios) for later use. Older homes require a feasibility study. New homes must incorporate this system into your project.

• In the same way, each multi-family should have its own system for storing rainwater that falls on your property. One system for a housing composed of several buildings.

• The system is composed of rain water tank located on the roof of the building, water collection, storage tank located below the floor level of the site and pumping equipment, fig 4.

• The storage tank will be sized to monitor the amount of water rushing average per year (the authorities must provide this information).
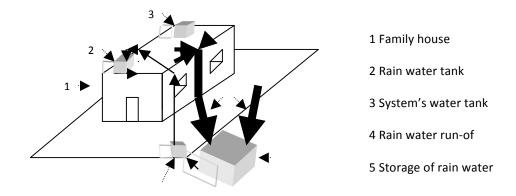
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1 Family house

2 Rain water tank

3 System's water tank

4 Rain water run-of

5 Storage of rain water

Fig 4 water collecting system for a home

VII - Massive reforestation originally forested areas and construction of new areas.

(Fundamental Purpose: To increase the average humidity of the Valley and especially the MZVM)

• Reforestation of formerly forested areas and especially in the mountains surrounding the Valley, places with abundant rainfall.

• Construction of new woodlands in many parts of the Valley including the MZVM.

• Construction of new green areas as parks, gardens, recreation and sports centers, etc.

• Settlement of existing green areas, including those located in the streets and avenues as medians, sidewalks, etc..

• Revitalization of diseased trees and replace those outdated to be removed.

VIII - Protection of soil with litter

(Fundamental Purpose: To decrease the evapo-transpiration in the Valley, including the MZVM)

• The Valley growing areas must be covered with a layer or more litter.

• The litter that forms in the forest and green areas of the MZVM must remain in place unless the environment is seen deteriorated.

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CONCLUSIONS

The story goes that the captain Hernán Cortés ordered to build 13 two-masted vessels, known as brigs, to conquer the city of Tenochtitlan (López & Perez 2010), surrounded by huge lakes, as well, such was the amount of water that periodically rushed into this city, which kept flooded for long periods of time, the most serious of these events lasted five years. It was decided then, big mistake, all these lakes disappear through artificial drains out of the valley and, therefore, the entire region has been changing to hydraulic deterioration increasingly large, ie, hydraulic toward chaos.

Thus, the Valley of Mexico region had enough water to accommodate a large population and indeed, there arose a great city, Tenochtitlan before and after Mexico City, which has had over time, a spectacular development and now is the center of a vast area known as the. At present it is said that no longer has enough water for the stock and this great country, but this is only partially true, since the annual rains are still quite generous, what we really need is to find mechanisms to obtain the best use.

A summary of the main factors that describe the water supply problem in the Valley today, and more specifically of the MZVM is the following:

a) major rainfall occur annually, holds little water, much water comes out of the Valley.

b) The main aquifers are overexploited Valley and pollute more each day, mostly to the aquifer in the MZVM.

c) The decrease recharge areas each year: less green areas, fewer trees, more paved roads

d) The MZVM grows out of control and rational, consistent and gradually, the water problems are enlarged and water services are deteriorating. We import water to meet growing demand, despite the high cost of this solution.

e) The drainage of the MZVM has not been definitively resolved despite the operation of deep drainage system, ie, you have many booster (almost there have been no deletions), new and increased waterlogging and, worst of all, is that most of the rivers leading combined water.

f) Water recycling is very poor since only small volumes of wastewater are treated and even fewer are used directly.

All this leads to say that the Valley of Mexico basin has enough water to sustainability, providing a good service. It is only necessary to have the will to do what is not able or wanted to do earlier, carry out studies to decide properly undertake major actions that modify the current structural and operational conditions, make large investments and, finally, adequately and efficiently handle own hydraulic resources of the Basin.

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ANNEX 1

HYDROLOGICAL CHARACTERISTICS OF THE VALLEY

a) Size area and population. The Valley of Mexico basin has an area of 9674 km2, which is divided into four parts that correspond to political entities involved in the Valley. The biggest territories possess the states of Mexico and Hidalgo with an area of 7698 km2 (80%), while a larger population, 19,298,559 inhabitants (97%), settle in the state of Mexico and Federal District , Table 2, fig. 2

b) Metropolitan Area of the valley of Mexico. The Metropolitan Area of the valley of Mexico (MZVM) is comprised of 16 delegations of Mexico City and 59 municipalities of the State of Mexico, not all conurbations but highly related to Mexico City and covers an area closed in numbers approximately 7800 Km2.

Fig. 2. Political entities make up the Valley of Mexico

Table 2. States settled in the valley of Mexico.

Federal entities	Area (Km^2)	Population (inhabitants)
Distrito Federal	1 484	8 813 705
Hidalgo	2 652	597 271
México State	5 046	10 484 854
Tlaxcala	492	68 224
Total	9 674	19 964 054

c) Sierras. The Valley of Mexico was originally a closed basin, ie, no natural outlet of water, surrounded by mountain ranges with the following configuration, the mountains north Tezontlalpan and Pachuca, east Chichucuatlan saws, Teposan, Calpulalpan, Rio Frio and Nevada, in the north the mountains of Chichinautzin and at west the Las Cruces saws, the Monte and Tepotzotlan.

Inside there are smaller mountains called The whistles, Patlachique and Guadeloupe. Due to the absence of natural outlets for the removal of water from the valley, Mexico City was having severe periodic flooding, causing great inconvenience and loss of property, until it was built some exits, first with a slash and then tunnels.

d) Rain. The rainy season in this region extends from May to October and the rest of the year is dry. The rain is abundant and of short duration during the months of July, August and September and in October the rainfall intensity is in accordance with meteorological phenomena that occur at this time of year, such as hurricanes, cyclones, tropical storms , etc.

The average annual rainfall in the plain walks about 700 mm (reported for the period 1941-2000 annual normal precipitation 737.1, CONAGUA Precipitation), being more intense in the south (80 to 90% of the total annual precipitation) In the north, while the rainfall is more pronounced over the mountains to the south and west, where they are up to values ranging between 1200 and 1500 mm.

e) Distribution of rainfall. The rain rushes from year to year over the valley, it basically has

three parts which are, evaporation and transpiration which returns to the atmosphere, surface runoff, which are largely conducted outside the valley and the underground runoff which are used to recharge aquifers. Table 3 shows that the water situation for 2004 reported CONAGUA, considering the period 1941-1997.

Column 2 at table 3 is the direct measurement, in accordance with the standards, the rain, in columns 3 and 4 show the amount of rain that crashed in a year and a second, respectively. These last units of measurement are given, because they are the most commonly used in the practice of Hydraulic Engineering.

Table 3. Distribution of rainfall

Concept	Quantity			Percentage over the precipitation
	mm/año	hm^3/año	m^3/seg.	
Rainfall	650	10 654	338.0	----------
Evapo-transpiration	448	7 350	233.0	68.9 (70%)
Runoff	82	1 337	42.4	12.5 (13%)
Groundwater discharge	110	1 806	57.3	16.9 (17%)

Source: CONAGUA

Fig 3 shows the distribution of rainfall in numbers and in percent so as to have a clearer picture of what happens to any water source.
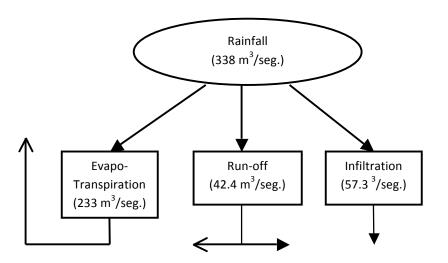
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Fig 2. Distribution of rainfall

f) Rivers. In the region there are about 38 small rivers or streams, of which 28 remain dry during the dry season and rainy weather are short-term rainfall characteristics. Runoff form with rainwater and wastewater, so that there is a flow of highly contaminated water. The total average annual runoff of the valley is about 400 million m3.

g) Lakes. For many years, since the valley formed its current structure, formed large lakes coming to cover 7% of the surface of the valley, but due to the flooding problem that periodically ravaged the city of Mexico decided to drive out all that water. Table 5 shows the lakes of the valley before the conquest of Tenochtitlan, referring to Lake Texcoco, being the lowest part of the Valley.

Table 4. Ancient Lakes Valley of Mexico

LAKE	SURFACE (Km^2)	DEPTH MEDIA (m)	HEIGHT ABOVE TEXCOCO (m)
Chalco	114	2.0	3.0
Xochimilco	63	2.1	3.1
Texcoco	238	1.8	0.0

México	90	2.0	1.0
Xaltocan	121	0.4	3.5
Zumpango	26	0.6	6.1
Total area of lakes	652 Km^2		

It is currently only have a few small reservoirs, with average capacity of about 200 Hm3. Table 5 shows the main characteristics of the lakes and ponds that are currently in the valley.

Table 5. Current Lakes Valley of Mexico

Lake	Área of basin (ha)	Average storagevolumen (m^3/seg)	Municipality	Federal entity
Xochimilco	33490	0.30	Xochimilco	DF
Bosque de Chapultepec	16	0.01	Miguel Hidalgo	DF
Bosque de Sn. Juan de Aragón	12	0.03	Gustavo A. Madero	DF
Dr. Nabor Carrillo	1000	1.14	Texcoco	México
Guadalupe	430	2.09	Cuautitlan Izcalli Nicolás Romero	México
Xalapango	280	0.18	Texcoco	México
Churubusco	280	0.18	Texcoco Nezahualcoyotl	México
Regulación horaria	150	0.10	Nezahualcoyotl	México

Texcoco norte	35	0.10	Texcoco	México
Recreative	25	0.10	Texcoco	México
Laguna de Zumpango	--------	2.38	Zumpango	México
Total	35718	202.64	----------	---------

h) Surface Water. Table 6 shows the eleven hydrological zones which has divided the basin of the valley, for purposes of planning and control.

Table 6. Hydrological characteristics of the valley

Hydrologic Zone	Name	Length (Km)	Runoff volume (hm^3/ año)		
			Annual Average	Rain	Dry season
I	Xochimilco	46	ND	ND	ND
II	Churubusco	28	5	3.9	0
III	Cd. de México	57	51 66	37 61	5.4 0.6
IV	Cuautitlan	60	87 598	78 270	6.0 150
V	Pachuca	123	2	1	0
VI	Teotihuacan	39	101	50	26
VII	Texcoco	48	436	170	126
VIII	Chalco	90	6	5	0
IX	Apan	39	1	1	--
X	Tochac	25	--	--	--

XI	Tecomolulco	7	1	1	--

i) Groundwater. In the river basin have identified seven aquifers, five of which are currently overexploited, as shown in Table 7. MZVM's aquifer is by far the most exploited, while aquifers and Apan Tecocomulco whilst posing no deficit, together with an availability of 3.76 m3/sec water almost half of the recharge of MZVM.

Table 7. Valley Aquifers

Aquifer	Recharge	Assigned volume	Average Availability	Deficit
	(m^3/seg)			
ZMCM	8.85	39.61	0.00	-30.76
Tecocomulco	0.88	0.00	0.86	0.00
Apan	3.15	0.25	2.90	0.00
Chalco-Amecameca	2.35	2.86	0.00	-0.52
Texcoco	1.54	2.93	0.00	-1.39
Cuautitlan-Pachuca	6.43	7.72	0.00	-1.28
Soltepec	0.60	0.56	0.04	0.00
Totales	23.81	53.95	4.16	- 33.95

j) Sources of water supply for the MZVM. Table 8 shows the current sources (1998) of drinking water used by the authorities to give service to the MZVM.

Table 8. Sources of water for the MZVM

Raw Water Source		Mexico City (m³/seg.)	Mexico State (m³/seg.)	Total (m³/seg.)	%
Groundwater	Mexico Valley	22.7	20.3	43.0	71.3
	Lerma	4.3	1.0	5.3	8.8
Groundwater total		27.0	21.3	48.3	80.1
Agua superficial	Cutzamala System	7.6	3.0	10.6	17.6
	Río Magdalena	0.2	0.0	0.2	0.3
	Presa Madín	0.0	0.5	0.5	0.8
	Springs and thawing	0.5	0.2	0.7	1.2
Total surface water		8.3	3.7	12.0	19.9
Total water supply		35.3	25.0	60.3	100.0