THE SYSTEMS SCIENCE APPROACH FOR THE CHARACTERIZATION OF RAINFALL IN THE MEXICO´S VALLEY

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ABSTRACT

The Mexico City population has grown significantly in recent years; the concentration of population in the city has brought greater demand for water for their daily requirements. The natural aquifers basin of Mexico Valley has been overexploited. There is a considerable imbalance in the amount of water needed for natural recharge of the aquifers of the City; the problem arose because the natural recharging system was obstructed by the construction of infrastructure, roads, buildings and unsustainable policies, until the limits of resilience of the water system.

Based on statistics of the area, it shows that the annual rainfall over the basin is far more than needed to meet consumption of the population. However, most of this water is not utilized efficiently, which is not only a serious error, but also helps in increasing the problems of drainage and water extraction from the subsoil of the city.

This paper shows the development of a study to characterize the rainfall in the Valley of Mexico, the results would contribute to comprehensively manage the recharge of groundwater with the use of rainwater and the design of a model of behavior recharge and water extraction. The development of this project is funded by the Institute of Science and Technology of the Federal District (ICyTDF), Mexico.
Keywords: water, rainfall characterization, overexploitation, social problems

INTRODUCTION

Water is the most abundant element on earth ("Blue Planet"), which would make us think that we would have an unlimited supply of this resource. According to United Nations report on the development of water resources in the world, "Water for all. Water for Life" only 2.53% of total fresh water and the rest is salt water and approximately two thirds of freshwater is in glaciers and permanent snow, which undoubtedly affects the availability of it.

Within this context, an important factor is the population-water, which has been changing over the years, we can say that for practical purposes the volume of water is unchanged, but the population itself, and has done disproportionately as a result giving a lower per capita water availability. In recent years environmental pressures imposed by population

growth, urbanization and industrialization have become a major topic of international interest.

The demands on finite water reserves represent a threat to both the quantity and the quality of a commodity for all kinds of social and economic activities, for life and human health.

The general interest in better use and water use has alerted governments around the world. The Metropolitan Area of Mexico City is one of the largest urban areas of the world not only in terms of territory but also in population. In recent history, the city has experienced severe problems of water supply which have worsened lately due to rapid population growth.

Drinking water to cover all the needs of this region of the country is obtained from the Basin of the Valley of Mexico (equity) and the Basins of the upper Lerma and Cutzamala rivers (imported resources). Indeed, to complete all drinking water needs of the city has to be imported from nearby basins, thus causing some disadvantages of such places as high operating costs for high power consumption, social ills among the population and restricting the potential development of the field and industry.

One can see that the problem is complex and it is required to find a solution. One of the most attractive areas which have experienced rapid development in modern science is the quantitative study of the complexity in the systems approach. The complexity has an impact particularly in interdisciplinary fields of mathematics, physics, computer science, biology, medicine, sociology, economics and the environment. As far as addressing the problem described under the complex systems approach can provide good results.

JUSTIFICATION

Almost since its founding, the city of Mexico has had problems with water supply, due to geo-hydrological conditions where it was built. In recent decades the problem has worsened due to rapid population growth and poor planning of urban development, coupled with a culture increasingly poor water management on the part of the population. As a result of this bad urban development, among other things, decreased infiltration areas and forested areas, increasing the depth of water table and the exploitation of aquifers above their natural ability.

The largest contribution to the amount of water supplied comes from the aquifer of the Valley of Mexico, although this latter has to be exploited. Overexploitation for decades has caused differential subsidence at the ground, causing serious damage to underground facilities such as pipelines, and buildings. The high compressibility of the clay extracts of the land coupled with the pumping of groundwater facilitates this phenomenon.

Many of the problems of water supply for the people of the Valley of Mexico would be solved if higher rate of uptake and use of rainwater. In this regard, two roads may be

scrutinized: 1) The decrease in evaporation-transpiration and 2) the storage of large volumes of rainwater.

The rainwater storage has been done by dams located on the west side of metropolitan Mexico City, but only one is used for water supply purposes. The rest of the prisoners are only used to regulate the runoff caused by heavy rainfall, that is, water is stored from the heavy rains for a short period of time and then released slowly. This will avoid possible flooding of the historic center of Mexico City.

Some of the reasons why the captured water is not used for the benefit of the population are: wastewater discharges through the same storm water runoff to dams, pollution caused by garbage that is thrown both runoff as dams, low-maintenance and monitoring.

It is advisable to develop integrated coverage that would allow a more efficient uptake of water from rainfall, and later remove drinkable and lead to the various centers of consumption.

Any alternative, or combination of alternatives, are feasible to increase the water use of annual rainfall and it should be considered the desirability of separating the storm water waste water, tubing, preferably the wastewater.

The water supply service to Mexico City can be maintained at acceptable levels of cost, as well as its quality, as long as they manage the water resources of the basin more effectively and responsibly. Furthermore, efficient development and implementation of new ideas, gradually dispense with import water from other basins or entities, and can avoid the political costs and social conflicts that arise from that activity.

It is urgent to take appropriate action on the problems of water supply, since as noted by the Human Rights Commission of Mexico city (CDHDF) the first outbreaks of violence by water scarcity have already appeared, and as the lack water increases, so will the violent episodes, warned the president of the CDHDF.

Based on the above, it can be seen the need to design methodologies for the development of suitable models to improve the methods of collection and efficient use of water in order to ensure an adequate supply of the vital fluid and results focus in sustainability. Furthermore, the development of more effective methods of recruitment will decrease the costs incurred by the concept of importing water from elsewhere, it will also ensure the supply of water demanded by the City of Mexico and reduce social conflicts arising from this problem.

OBJECTIVE

The overall objective of this study is to characterize the dynamics of the rainfall in the Valley of Mexico, applying methods and techniques of statistical mechanics, in order to

understand the behavior presented, based on the identification and characterization of their statistical parameters.

METHODOLOGY

To achieve each goal, it is to be developed a methodology, with a systemic approach, appropriate for the specific case. The typical stages of scientific methodology employed in this project are presented in the diagram in Figure 1. Some of the challenges facing the development of the research are: identification of the parameters involved in the phenomenon under investigation, obtaining relevant information and building the simplest possible model, relieving the physical essence, and application of the development model of new and more effective methods to solve the problem.

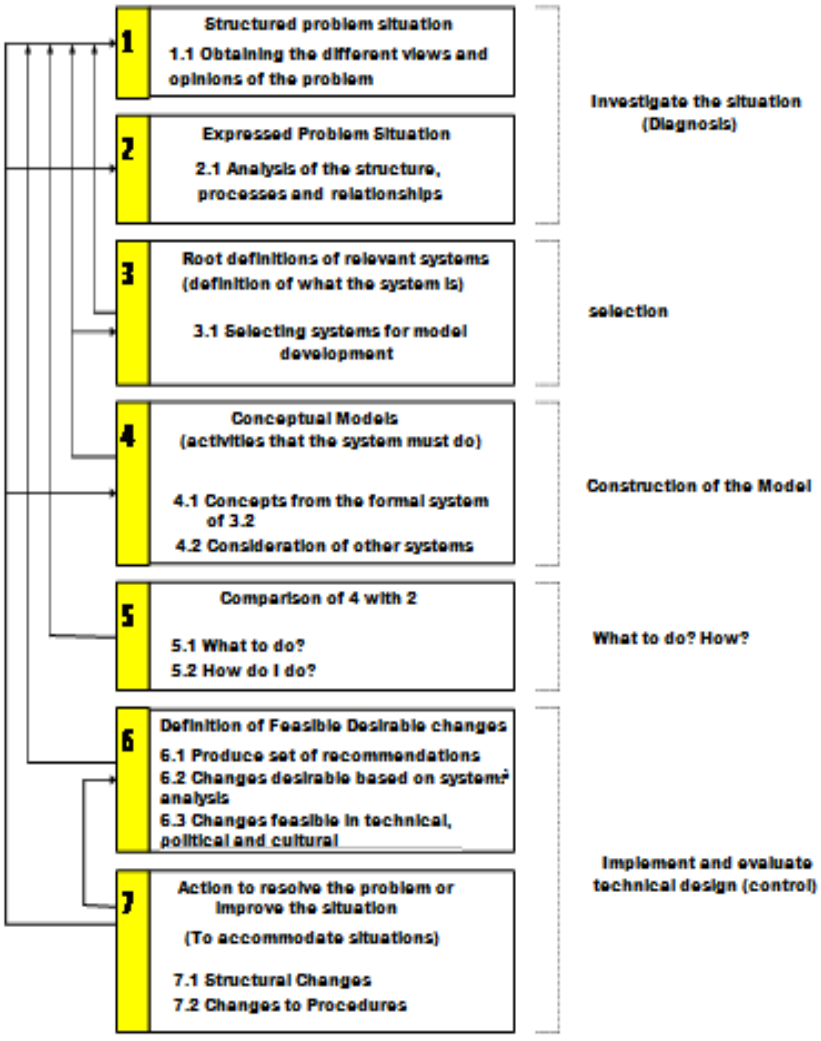

Figure 1. Methodology for the development of the investigation

DEVELOPMENT

Mexico City suffers from a shortage of water increased and caused by the inefficient administration of the liquid from its collection, its use and distribution as well as by inadequate culture of the population for efficient use of the liquid. The city government invests heavily in subsidizing the actual cost of supplying water to the City, because it must be imported from distant places, the main supply is the Cutzamala system.

Table 1 shows the collection and use of water derived from rainfall in the Valley of Mexico are very low; in other words it is wasted a lot of rainwater. What motivates the search and design methods to improve the collection and allow better use of the liquid. The efficient capture and collection of water could reduce the problems of shortage and contribute in the future, to achieve sustainability of the City of Mexico.

Table 1. Statistics of rainfall in the valley of mexico.

EVENT	FLOW (m^3/s)	FLOW RATE* (%)	INPUT FLOW (m^3/s)	OUT OF FLOW (m^3/s)
Precipitation	216.4	100	216.4	
Evapo-Transpiration	149.3	69.0	-------	-------
Groundwater Recharge	36.8	17.0	-------	-------
Runoff	27.3	12.6	-------	-------
Export	-------	1.4	-------	27.4
Import	-------		19.8	-------
Total	-------		236.2	27.4

* For Precipitation Source: Statistics on Water, 2005c CONAGUA

It is known that water is an essential element for life, so it is essential to guarantee its supply. Though this is a very complex problem, especially in an area like Mexico City, with a large population and a number of problems involved. Considering the solution of the problem from a holistic perspective will provide a set of satisfactory solutions, which may reduce the problem of supply and some inherent problems that are beginning to emerge in different parts of the city, caused by the shortage of the vital liquid.

Further, the availability of water allocated by the National Water Commission (CNA) for each of the four political entities that share geo-hydrological Basin of the Valley of Mexico is given in Table 2. It should be noted that this allocation of water corresponds to what each entity may make available resources of the basin (64.1 m^3 / s), and their own. Note that in the present situation, the volume of water corresponding to the metropolitan area of Mexico City is not sufficient to meet the requirements.

Table 2. Water allocation to the political entities of the Valley of Mexico.

DRINKING WATER					
Population			Assigne Volume		
Entity Federal	Population (Millons)	Consumption* (m^3/s)	Surface (m^3/s)	Underground (m^3/s)	Total (m^3/s)
Distrito Federal	8.81	34.67	9.84	25.85	35.69
Estado de México	10.68	42.03	16.23	30.4	46.63
Hidalgo	1.30	5.12	7.36	2.60	9.96
Tlaxcala	0.07	0.28	0.05	0.42	0.47
Total	**20.86**	**82.10**	**33.48**	**59.27**	**92.75**

* Based on 340 l / inhab. / Day average and 30% losses. Source: Statistics on Water, CNA, 2005c

Rapid population growth over the Valley lakes, including Lake of Mexico, where the city was built dried the lakes. This caused some inconveniences such as reduced atmospheric humidity, aridity of the land, abundant dust storms, reduction of green areas and, more seriously, significant increase in evaporation-transpiration. The problem in this regard is further aggravated due to indiscriminate felling of trees.

With regard to urban development, the city and its surrounding grew in a rather anarchic way. There were many buildings, streets cemented or paved, single drain rainwater and wastewater, insufficient green spaces, etc. Similarly rampant population growth, which has worsened the situation not only in the water supply in the Valley of Mexico, but also a variety of problems that should be addressed in a comprehensive and high level of willingness policy for its solution.

This research collected data from rain gauges installed in the Valley of Mexico by CNA. Figure 2 shows the areas where the rain gauges are located, whereas Figure 3 shows a graph showing the average values of data from rain gauges installed, where it can be observed that the rains so far are periodic with little variation from region to region and month to month, which is an advantage because plans and programs can be created based on the results to improve water uptake.

Figure 2. Network of rain gauges in areas of the Valley of Mexico. Source: Own elaboration based on INEGI. 2005 municipal geostatistical framework Average monthly and annual data from rain gauges in the Valley of Mexico.

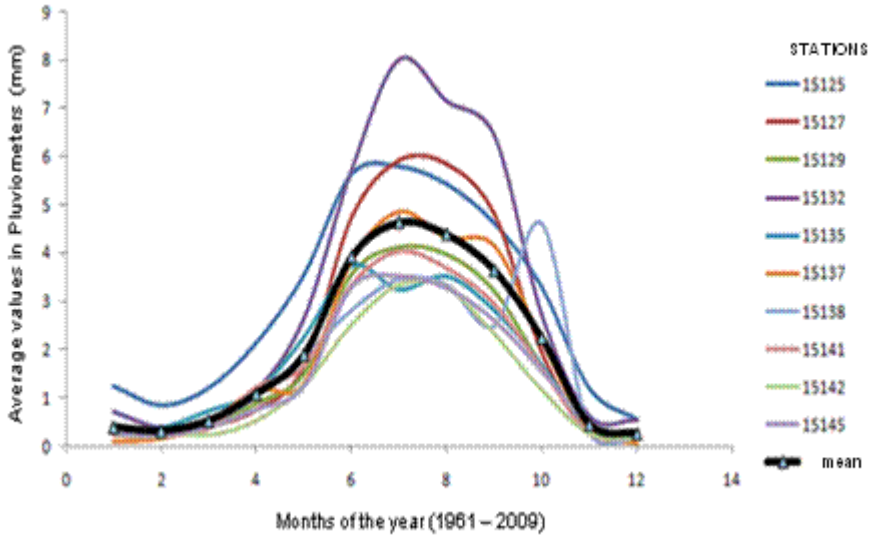

Figure 3. Average Annual and Monthly Data from rain gauges in the Valley of Mexico. The X-axis shows the months to several years, while in the Y axis shows the mean values in mm of rain gauges, which are displayed with their password to them by CNA.

The development of this research is in its first phase, and it aims to generate new methods and techniques that contribute to a more efficient recharge of aquifers in Mexico City, it also suggests possible recommendations to the appropriate authorities, which undoubtedly help in the solution of water problems.

CONCLUSIONS

Considering the solution of the problem from a holistic perspective will provide a set of satisfactory solutions that may reduce the problem of supply and also some inherent problems that are beginning to emerge in different parts of the city, caused by the shortage of the vital liquid.

Rainwater that falls in the Valley of Mexico basin has 4 locations: evaporation-transpiration (69%), groundwater recharge (17%), surface runoff (12.6%) and the remainder (1.4%) for export.

Water for the benefit of the inhabitants of the valley comes from groundwater recharge (36.8 m^3 / s) plus the runoff (27.3 m^3 / s) giving 64.1 m^3 / s. Whichever number is compared against rainfall, it can be seen that overall, it is only used about 30% of the rainfall. This is a paradoxical situation, because even though the rainfall is abundant, its use is very low. It is appropriate, then, further research in this direction to take greater advantage of this resource. It is imperative the need to design and develop new methods and technologies for better use of rainwater.

The development of this project is in the initiation stage (70%), which is why this paper is practically the first analysis of what is planned. **The project is funded by the Institute of Science and Technology of Mexico city (ICyTDF).**

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