Situational Analysis of the Environmental and Economical Factors of the Lerma-Chapala Basin to Recover the Chapala Lake

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Abstract

The Mexican Institute of Water Technology (IMTA) simulated different sceneries to the handling of water in the Lerma-Chapala basin. These scenarios support the necessity of creating a new agreement in the distribution of water in the basin, due to the fact that in recent years there has been an important decrease in the levels of water in the Chapala Lake. In different meetings, it was agreed to select the best scenario under the economical criterion, that is why the variables used in the scenarios would be given an economical value and determine the most profitable scenery. If one of the variables simulated in the sceneries is the Chapala Lake, how is it possible to give an economical value to the lake? Even if there are various methodologies to economically value environmental quality; it was decided to use the Contingent Valuation Method (CVM). This method is based on surveys randomly given to a group of people, with the purpose of getting the Willingness to Pay (WTP) to rescue an environmental good, in this case the Chapala Lake. The purpose of this research is updating the sceneries with information from 2007 to evaluate the most recent simulated scenarios. One of the most important variables within the sceneries is the agricultural production due to the great volumes of water that are used for irrigation, the agricultural production was estimated in 3.40 $\$/m^3$. Relation with water recovery levels of Chapala's Lake (low, medium and high) and Values of Non Consumptive Use were obtained: 1.31 $\$/m^3$, 1.02 $\$/m^3$ and 0.71 $\$/m^3$. The scenario which best supported to the policies of water handling in the basin and the one which turned out to be the best evaluated was the Scenario of Optimal Coordinated Policy (POC 2007) simulated in 2007 with an annual equivalent value of $825, 505, 944 DLS.

Keywords
Willingness to Pay, Contingent Valuation Method, Chapala Lake, Lerma – Chapala basin

Introduction

The Lerma-Chapala basin is located in the central part of Mexico. It is extended from the source of Lerma River to its estuary downstream in the Chapala River. It has an extension of 53,591.3 km^2, which represents the 2.73% of the national territory. (National Institute of Ecology, 2003)

Figure 1. Geographical localization of the Lerma-Chapala basin
Source: Diagnostic of the Lerma-Chapala basin, INE.

Particularly, the Chapala Lake has a maximum length and width of 77km and 23km respectively. When the lake is full, it stores a volume of 8,125 hm^3 and forms a water surface around 111,000 ha with an average depth of 7.2 m. (See figure 2)

Figure 2. Chapala Lake
Source: Satélite Landsat

In the last decade the water levels in the Chapala Lake have decreased nearing the minimum historical levels registered in the 1950's (Mexican Water Technology Institute, 2002). Factors such as the combination of dry years in the basin and the increase of water extraction for supplying water to Guadalajara city have contributed to make the river a natural deteriorated resource. The lake may be dried if actions for profitable management are not taken. (See figure 3)

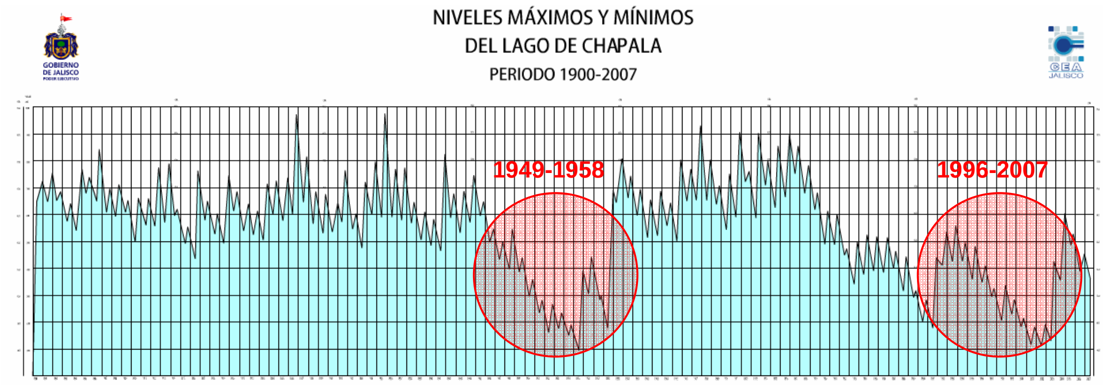


Figure 3. Historic behavior of Chapala Lake´s water levels
Source: Water Bureau of the State of Jalisco

The staff of the Basin Board Auxiliary Group had 13 scenarios of water handling in the Lerma-Chapala basin. These scenarios were the result of simulating different policies of allocation and usage of water in the area, which is formed from parts of the states of Jalisco, Michoacán, Guanajuato, Querétaro and México.

The simulation model and the resulting scenarios are the basis of support for the decision-making on water distribution in the basin. The different policies studied turned into different alternatives of productive uses of the water in the basin, and extractions from the lake to supply Guadalajara city and the water levels in Chapala Lake. For improving these instruments in the decision-making, it is necessary to do an analysis of the impact of costs and benefits. This can be done by taking as economical indicator of profitability the current net value, associated to the different scenarios, supporting the development of a new Distribution Agreement of the water in the basin and using better techniques for preserving the hydraulic resources of the basin.

There are appropriate methods used to make this analysis, such as the benefit/cost evaluation and the incorporation of the Contingent Valuation Method (CVM). The first method works with market values expressed in monetary terms. The second one calculates the values of no use or preservation of the natural resources –in this case, the water in the Chapala Lake and the Lerma river- for which there is no price in the market of merchandise and existent services. These values depend on the preferences expressed by the individuals about the water in the lake and the route of the Lerma River in the basin due to the fact that this is an interconnected system.

A lot of effort has been done at the state and government levels to implement different strategies to distribute the superficial water among the users. Nevertheless, there are several difficulties in obtaining the consensus among these groups including the necessity to identify the most acceptable option for everybody and the perception of the negotiations along with the potential social response to the different scenarios.

Environmental Problematic

Nowadays the hydraulic resources are at the limit of their exploitation. The extraction of more superficial or underground water necessarily implies, affecting the exploitations located underwater or the ones that share the renewable aquifers resources existing there. This has put in danger the development achieved in the region and the preservation of the quantity and quality the Chapala Lake.

The problems in the basin are summarized in the following critical global aspects:

- Insufficient offer of water demands
- Overexploitation of aquifers
- Low efficiency in the use of water in the agricultural sector
- Low efficiency in the public urban use of the water
- Degradation of the quality of water
- Inadequate infrastructure for flooding.
- Damage to environmental sustainability
- Decrease of water levels in the Chapala Lake

Hydrologic Model

The Mexican Institute of Water Technology in collaboration with the members of the Auxiliary Group of Distribution and Regulation (GAOD) developed a Dynamic Model for the Lerma-Chapala basin which was calibrated in 2002. This model has been a tool to support the formulation of actions in the handling of the superficial water in the basin and it responds to the need for improvement of the decision-making process of the Lerma-Chapala Basin Council.

In 2002, the Mexican Institute of Water Technology (IMTA) evaluated the performance of the model in regards to the concordance between the predictions of the model, the hydrologic data of the real system, and the sensibility of the model to changes in important parameters. The model was calibrated in each of the 17 sub basins. The discrepancies between the historical data and the ones generated by the model were gradually decreasing based on the modification of the parameters of adjustment in a process of trial and error. This was repeated until it had reached a good approximation of results between the model and the historical data. By the end of this process, the model was declared ready to build hydrologic scenarios corresponding to different conditions of distribution of the superficial water in the basin. These scenarios were also evaluated under economic and social perspectives.

In order to build the scenarios, the perspectives of available offer and the demand of water were taken into account. The use in irrigation and the storage in the Chapala Lake stand out due to their quantity because they are the major consumers or users of the water in the Lerma- Chapa basin. The rest of the uses are less significant and the majority of them are supplied with underground waters.

Analysis of the sceneries in the handling of water in the basin

The scenarios for controlling the offer admit that the Coordination Agreement for the distribution of superficial waters of the basin, which started operations in 1992, has not been sufficient to stabilize the Chapala Lake during periods of low rain. In order to correct this deficiency, different levels of additional restriction were analyzed through the model of the basin, also mentioned in the own Distribution Agreement. Within this analysis the proposal of an additional regulation formulated by the National Water Commission was included (CONAGUA).

The scenarios to control the demand include actions to increase the global efficiencies in districts and units of irrigation. The increase in the global efficiency was established in 20% for all the districts and units of irrigation. This surface is similar to the one used for sowing, which covers 265,000 hectares in districts and 135,000 hectares in small irrigation. The required investment was adjusted to the DR Modernization Program of CONAGUA to a sum of around $330 million DLS in order to be completed in four years, 2003-2006

The scenarios formulated and analyzed by the GAOD have sensitized the kind of global response that the system has under different options of handling the water in the basin. In particular, it has been identified as sustainable scenario one that combines and offers control and demand control actions as well as allows for the preservation of the water in the basin for future generations. These scenarios must be evaluated in terms of benefits and costs to quantify the advantages or disadvantages of each one along with their feasibility.

For the evaluation of the scenarios the IMTA, which built and operates the hydrological model of the basin, provided the annual values of 57 years of simulation of the volumes of water assigned to irrigation districts and units of small irrigation. The annual resultant levels reached by the Chapala Lake are the result of those allocations or rules of operation in the system due to the fact that the lake is the final destination of the system itself.

Thirteen alternatives are proposed as a result of several work meetings along with the GAOD and the definition of a series of simulated scenarios with the dynamic model of the Lerma-Chapala basin. In the model of simulation these alternatives have produced a historical performance of rain, simulating its occurrence for the next 57 years. It is important to mention that the scenarios chosen as alternatives are totally theoretical. However, these alternatives are comparable and allow for the distinguishing of the advantages and disadvantages as well as their tendencies among them.

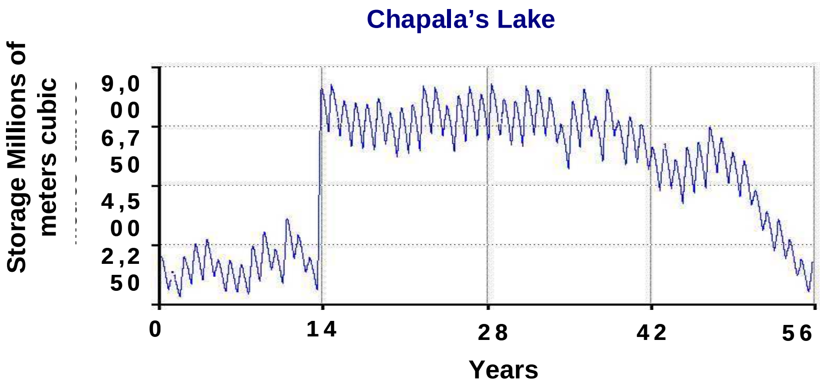
Next, there is an example of the results obtained in the simulation. The scenario 1, also called *Reference* or *Base* because the present conditions were simulated without applying a new policy of water distribution, is shown.

Scenery 1 Suggests the simulation of the Agreement for the Distribution of Superficial Waters in the Basin. The scenario is suitable to observe if the distribution of the superficial water in the basin is equitable in regular and humid years as well as in years with dry or very dry periods. As it can be seen, the storage tendency level of the Chapala Lake shows that the agreement does not allow the appropriate distribution of the resource in dry periods, which motivates the deficit between the supply and demand and therefore low levels in the main storage of the basin.

Table 1. Scenery 1 (Reference)

Scenery Variable	Status
Agreement	Activated 100%
Agreement PI	Activated
Regulations	Deactivated
Emergency Level Oct	Does not apply
Emergency Level Jun	Does not apply
Initial Storage Chapala	1,771 Mm3
Evaporation Control Chapala	Does not apply
Surface DR	Free
Efficiency DR	Current
Handling of savings	Does not apply

Indicator	Value
Chapala Storage	4,905
Solis Storage	187
Yuriria Storage	135
Districts Volume	1,292
Small Irrigation Volume	1,156
Chapala Evaporation	1,687
Numbers of years lowers to 3,100hm^3	15
Numbers of years lowers to 4,500hm^3	19



In different meetings it was agreed that the selection of the best scenario would be based on the economic criterion. For that reason, the variables used in the scenarios would be given an economic value and would determine the one with the best profitability.

If one of the simulated variables in the scenarios is the Chapala Lake, how is it possible to assign an economic value to it? Even there are different methodologies to economically value the environmental quality, the Contingent Valuation Method (CVM) was chosen. The other variable, which is important due to the huge volumes of water that consumes, is the agriculture. For this reason, a detail of how the value of the Lake and the value of the agriculture were calculated will be given.

The Contingent Valuation Method (CVM)

The CVM is based on surveys randomly given to a group of people with the purpose of obtaining the Willingness to Pay (WTP) in order to recover an environmental asset, in this case the Chapala Lake. This hypothetical and direct method allows obtaining estimations of the effect that certain actions have in the wellbeing of the individuals. It is based on the construction of a hypothetic market in which the individuals normally have to express their maximum WTP for a change in the quality or quantity of the environmental actives.

According to the NOAA (1993) and the Riera (1994) panels, the different phases of a CVM study can be observed in the following chart.

Table 2. Phases of a CVM practice

1	Accurately define the element to be valuated and its monetary units
2	Define the relevant population
3	Concrete the simulation elements in the market
4	Decide the type of interviews
5	Select the sample
6	Formulate the questionnaire
7	Do the interviews
8	Statistically explode the results
9	Presentation of results

The CVM is based on the consumer rational selection theory, which is based on the assumption that the individuals take consumption decisions that maximize their wellbeing. The CVM can be defined as the maximum amount of money that an individual can obtain in order to keep the same level of wellbeing they had before the improvement of the environmental quality. In other words, the CVM allows knowing the Willingness to Pay (WTP) in order to improve the environmental quality.

Finally, it is important to point out that even the CVM presents many advantages; this has been object of several critics as a consequence of the possible slants that can appear during its implementation. Examples of these slants could be the ones that happen because of the hypothetical character of the market, the ones derived from the possible strategic behavior of the interviewed people and others related with the market design, etc. For this reason, it is necessary to avoid if possible, any kind of slant in order to obtain honest answers from people about their appreciation of the economic value of the environmental resources.

Nevertheless, and additional advantage of the CVM is its high flexibility in approaching all kinds of public property and situations. It can also be used to value situations that have not occurred yet, ex-post valuation, like in the case of the public policies evaluation. Therefore, the CVM allows estimating the non-use values, which can not be indirectly observed in any market related to public property.

The function held by the CVM in the cost-benefit analysis, is to determine the environmental value of the benefits provided by the environmental asset that can not be observed in the market. That is why the price intended to be obtained from the surveys is the maximum price that people would be WTP for a specific asset. In the cost-benefit analysis is necessary to determine the costs as well as the benefits expressed in monetary units coincident in the time. The internal costs are estimated in a conventional way. The environmental benefits are intended to be reflected by the CVM.

Methodology

The study zone for the research is the Lerma – Chapala Basin, because of its natural delimitation and its hydrological characteristics. Also because the draining produced in the basin strongly influence the storage levels in the Chapala Lake.

In order to achieve all the objectives of the study, it was considered that the smallest important indicator was a proportion of around 17% for both domains, of study. Also, taking into account that the survey should allow the calculation with a maximum relative error of 20%, a level of trust of 95%, a response rate of 15% and a design effect of 2%; it was determined a sample size of approximately 1105 homes by domain of study using the following formula:

$$n = \frac{Z^2_{\alpha/2}(1-P)}{r^2 P}\frac{deff}{TR}$$

Where:

n Sample size
P Proportion to be estimated
$Z^2_{\alpha/2}$ Normal distribution
r Maximum relative error
deff Design effect, which is the loss or profit in the efficiency of the design
TR Rate of response expected

This sample size was rounded to 1,115 homes for each study zone. The relevant population for the study was distributed along two zones; each of them was defined according to the valuation target to be followed. These zones were:

- Zone 1: High and Middle Lerma
- Zone 2: Low Lerma and ZMG

Zone 1 covers the places with 60% or more of their area within the geographic limits in the High or Middle Lerma (boundaries fundamentally established under hydrological criteria)

Zone 2 covers the places with 60% or more of their area within the geographic limits in the Low Lerma (boundaries fundamentally established under hydrological criteria). Guadalajara city and Tonalá, Zapopan and Tlaquepaque form the ZMG (See figure 4)

Zone 1: High and Middle Lerma (Red and Green areas)
Zone 2: Low Lerma and ZMG (Icon and yellow area)

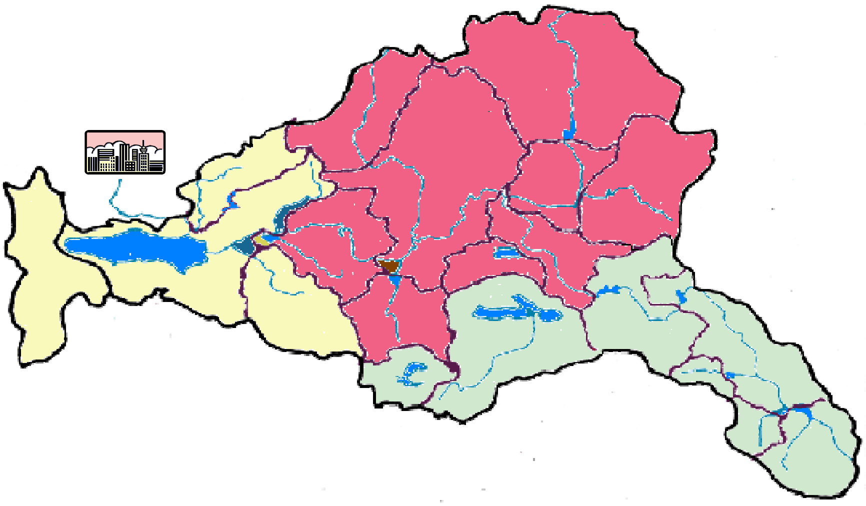


Figure 4. Zones of distribution
Source: Mexican Institute of Water Technology

The survey distribution among the states is shown in the following chart:

Table 3. Survey Distribution

State	No. of surveys
Guanajuato	725
Jalisco	925
Michoacán	225
Querétaro	150
Edo. México	200
Total	**2225**

Field survey

According to the sampling done by specialists of the National Institute of Public Health (INSP) it was decided to do 1,100 surveys in each stratum**.** The surveys were carried out in 10 days after a 3-day training process in which a group of professional interviewers from the INSP were familiarized with the questionnaire. Then the research group of the IMTA followed up the fieldwork, and carried out several feedback meetings in order to clarify doubts and listen to comments.

Once the final questionnaire was designed and the interviews were done, the next step was transferring all the information from questionnaires to a manageable data base with statistical software. In this data base rows are considered as the correspondent observations for each questionnaire or interviewed person and columns as the different variables included in the questionnaires. For this study, 125 relevant variables were defined and classified.

Information Analysis

The purpose of this research is updating the study carried out in 2003 with information from 2007 in order to evaluate the most recent simulated sceneries. For this reason, two exercises of the VCM were done, one in 2003 and an adjustment in 2007.

The surveys were depurated according to the inconsistencies and protest answers defined in the VCM. A clean data base was obtained and a comparative calculation between the 2003 and 2007 surveys was done.

In the following chart, it is shown the WTP obtained in the two phases:

Table 4. Comparative WTP

	Survey 2003	**Survey 2007**
Rescue level	**WTP** ($/housing/month)	**WTP** ($/housing/month)
Low	24.51	31.94
Medium	35.98	55.71
High	49.58	69.43

To introduce the WTP into the model, it is necessary to calculate the Value of Non Consecutive Use (VNCU) in $\$/m^3$ and not in ($/housing/month). It is important to mention that there were three starting points for measuring the level of the lake that is why the values high, medium and low were used in the surveys. These values were related to the numbers of houses and the recovering volume.

According to the results a new VNCU, extracted from the survey done in November 2007, can be observed.

Table 5. VNCU Comparative

	VNCU ($\$/m^3$)	
Levels	**2003 survey**	**2007 survey**
Low	1.00	1.31
Middle	0.66	1.02
High	0.51	0.71

Note: Current Prices of the year the survey was made.

Agricultural Productivity Calculation

The first study got an agricultural productivity of 1.61 $\$/m^3$ which was used only in the 1998-1999 agricultural cycle. In general this parameter can be used as reference in order to know the approximate productivity behavior although it would not be the real total basin productivity. Therefore, this updating is very important because the agricultural productivity was calculated with information from 1997-2006. The new results showed an agricultural productivity of 3.40 $\$/m^3$.

To calculate the agricultural productivity three fundamental aspects were taken into account:

1. The Irrigation District
2. The Agricultural Cycle
3. The Farming Type

These aspects were used to valuate the economical cost of the water transference for agricultural purposes in the Chapala Lake. They also helped to quantify the agricultural production value for each scenario.

An economical analysis was carried out according to the productivity statistics in the irrigation districts considered in the simulation model:

- 011 (Alto Lerma)
- 013 (Jalisco State)
- 024 (Ciénega de Chapala)
- 033 (Estado de México)
- 045 (Tuxpan)
- 061 (Zamora)
- 085 (La Begoña)
- 087 (Rosario Mezquite)

More important variables used in the economical model

1. Value of non consecutive use in the Lerma-Chapala Basin
2. The average water productivity in agriculture
3. The costs of operation, administration and maintenance of the irrigation districts
4. The investment in rehabilitation and modernization
5. The supplying and purification costs
6. The economical value of fishing, recreation and real state
7. The payment of rights in the Metropolitan zone of Guadalajara

Results

In the following chart, the results gotten from the last simulated scenarios are shown along with the most important profitability measurements.

Table 6. Hierarchy of the Evaluated Scenarios

Number	Scenario	VPN	VAE	B/C	PR
1	9a	69,747,166,051	8,384,358,004	23.43	0
2	9	69,377,722,001	8,339,946,864	22.38	1
3	**POC 2007**	68,602,403,273	8,255,059,441	17.38	1
4	POC 2003	68,420,655,468	8,233,189,377	16.25	1
5	5	68,207,615,572	8,199,287,511	14.74	1
6	5a	68,065,369,798	8,182,188,042	14.39	1

7	9b	67,427,742,693	8,105,538,420	31.61	0
8	9c	66,921,058,984	8,044,629,600	32.53	0
9	1 Base	66,409,754,037	7,991,213,731	9.88	1

Note: The POC 2003 and POC 2007 were evaluated for 52 years, the rest of scenarios were evaluated for 56 years. In a long term horizon this difference does not affect the results.

Conclusion

This research is the result of several years of investigation with the purpose of rescuing the Chapala Lake. The objective of this paper is to show in detail the problematic in the Chapala Lake and the Lerma-Chapala Basin, also justify a methodology and propose a solution to the problem.

Two main water consumers were identified in the basin. These are the agriculture and the Chapala Lake because both of them consume great quantities of water from the basin. In order to analyze the water consume between these users, the economical criterion was used. In the case of the agriculture the agricultural productivity was calculated and for the Chapala Lake the Contingent Valuation Method (CVM) was used to economically valuate the lake.

In order to know people's opinión about the environmental problematic in the Chapala Lake and the Basin a questionnaire was designed. According to the questionnaires there is a strong concern from people to rescue the levels in the Chapala Lake. Also they said that they are willing to pay a monthly fee in order to rescue the lake.

The VCM is different from other methods since in Mexico there are no sufficient statistical data. It has the advantage of giving an economical value to an environmental asset and also allows the direct extraction of the social perception taking into account people's opinion on an environmental problem. Therefore, this can be used to apply a public policy.

The analysis of the agricultural productivity was improved since in the first research the agricultural production of one cycle (1998-1999) was taken into account. This resulted in 1.61 $\$/m^{3.}$ For updating the data, the agricultural productivity from 1997 to 2006 was analyzed. This time the results were more reliable because there were more statistic data.

Scenario 9a and the the Scenario of Optimal Coordinated Policy (POC) are derived from scenario 9. Scenario 9a is the most profitable with a VPN of $69,747,166,051 and a VAE of $8,384,358,004. But even it got the best result in the economical evaluation; it was discarded because of restrictions and possible social, administrative and political repercussions in the Lerma-Chapala Basin.

The POC 2007 Scenario with a VPN of $ 68,602,403,273 and a VAE of $8,255,059,441 is more profitable than the POC 2003. Any policy derived from the results is better than the current one. This can be observed in the previous chart where the scenario in the last place is scenario 1. The profitable measurements of this scenario are VPN $66,409,754,037 and VAE of $7,991,213,731.

The government in its three levels has lost credibility with the inhabitants of the watershed because there is distrust about the management of resources. That is way two tendencies came out of the surveys:

a. People with positive WTP who consider the money should be administered by a non governmental organization.
b. People with negative WTP who consider the government should pay

In both cases people showed dissatisfaction and distrust because they said that the government is not clear in the application of policies and unreliable when handling social programs. They also said that they were tired of the bad administration of resources. The majority of people said the following: “Why should I pay? They better take the money from the public servers’ salary”. This answer was constantly repeated.

This research can be improved and used for future studies. The use of controversial or innovative methodologies offers the possibility to keep on researching the social perception and the economical value of an environmental wellbeing.

It was necessary a consensus among all the participants involved in the environmental problem. In this case, users, government branches, public and private institutions as well as universities, were asked to participate because all of them make use of the water in the Lerma-Chapala basin.

Finally, it is important to emphasize that all the information generated over the last years is very reliable that is why an invitation to the authorities is made in order to create a new Law of Distribution and Management of Water in the Basin. Besides the law it is important to go beyond because when some users do not obey the agreement there is no penalty for them. This situation would not happen if there were a law. The foundation of results is very useful to make a proposal, therefore it is the authorities’ responsibility to change the paradigms and use new tools in the decision-taking.

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