A BINATIONAL APPROACH TO THE WATER MANAGEMENT IN THE LOWER COLORADO RIVER BASIN

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ABSTRACT

The Mexico-United States border is a zone of shared problems for both countries. The Colorado River system stands out among their common rivers, its usefulness benefiting many people, especially if one considers its location in a desert land, the intense competition for the river water has expounded the necessity to come to agreements between both countries, started since 1944.
The Colorado river system is the most important in the United States southwest; supplies water for more than 20 million users and for large extensions of agricultural land. Besides, it is a fundamental water source for Northern Mexico, especially for the irrigation of agriculture lands in the Mexicali Valley. Water is a resource of a very high economical value in the region, because of the growing and large human population of the region, the importance of agricultural crops, and in particular, to the fact that the southern part of the basin is a desert. Inasmuch as there is an intense competition for the river water, although highly controlled, the system's management is of great interest for United States as well as for Mexico, for that reason, it corresponds to both of them.
All these factors make the Colorado River management an important subject that influences the neighborhood relationship between Mexico and United States. In 1944, both countries signed a treaty on the water allotment of the three river systems shared : the Colorado, Tijuana and Bravo. According to this document, Mexico obtained the right to receive an annual delivery of 1.5 million acre-feet of Colorado River water. The construction of several dams in the Colorado River basin in the United States has had great impact on the quantity and quality of the water going to Mexico. During the last three decades, the matters related to the salinity of this water have demanded a permanent attention.

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INTRODUCTION

The Colorado River Basin is one of the main basins in the west of the United States, supplying water for the states of Colorado, Wyoming, Nevada, New Mexico, Utah, Arizona and California, as well as Baja California and a portion of Sonora in Mexico. The Basin has an area of approximately 634,840km2 (247,500 square miles) with an annual average flow of approximately 18,502 millions of cubic meters (Mm3), according to the Santa Fe Treaty (Colorado River Compact) signed in 1922, which are distributed in equal shares between the Upper and Lower Basins.

The Colorado river has been called sometimes, as one of the most controversial and regulated rivers in the world, because it counts with an infinity of rivers and streams that make up its flow; besides it has one of the biggest and more complex storage and diversion dams system. It benefits over 20 million people in both countries, in cities as Los Angeles, Las Vegas, San Diego, Phoenix and Tucson in the United States; as well as Tijuana and Mexicali in Mexico.

This condition of sharing the resources, plus the arid characteristics within the basin and the present economic and population growth, as well as the struggle for the resource between the two countries, among the states users and mainly among the different users, makes the situation even more critical and the process very complex to be handled. The above, had favored changes in legislation and a search and implementation of new alternatives of usage with the goal of guaranteeing the supply of the vital liquid to the cities and also making sure of its quality. In the international arena, this has been a fairly discussed subject and of paramount importance in the bilateral agenda between the two countries in history, to date, the Colorado River problems have been worth of the highest priority in the IBWC agenda.

Mexico was recognized as a Colorado River user after the signing of the 1944 Treaty, allowing for assurance of the development of Northern Baja California and the Northwest of Sonora state in Mexico, the former after a solution framework was presented on the controversies in water and international boundaries matters through agreements or minutes worked out by the International Boundary and Water Commission (IBWC). The Treaty referred, basically allots the river waters among the basin users and does not specify about the water quality. The latter produced a crisis in the sixties culminating with an agreement for its attention in minute 242 of the IBWC, which establishes a salty waters management project through the construction, operation and maintenance of the Wellton-Mohawk Canal which basically disposes of these waters directly to the Gulf of California.

THE COLORADO RIVER WATER RESOURCES

International Agreements And Treaties Between Mexico And The United States.

On the 2nd of February of 1848, in Guadalupe Hidalgo, Mexico and the United States signed the Treaty of Peace, Friendship and Boundaries and on the 30th of December of 1853 the Treaty of Mesilla was signed. With these treaties the Colorado and Bravo Rivers were defined as part of the boundary between both countries and the water use was regulated just for navigational aims.

On the 1st of march of 1889, Mexico and United States signed an agreement to establish an International Boundary Commission that would decide on the matters that would come up due to changes on the Colorado and Bravo river channels. In this way, on the 17th of November of 1891, the International Boundary Commission and on the 8th of February of 1894, the International Boundary (Fluvial) Commission were established.

In 1912, Mexico and the United States founded a commission that would be in charge of analyzing the bases for an equal allotment of the Colorado River waters. However, diplomatic relations were broken in 1914, and the negotiations started again until 1922.

In 1922, the seven states of the basin of the United States established the Santa Fe Agreement, in which Mexico was recognized as the 8th user with a water volume of 1,233 Mm3 per year.

After solving many political and diplomatic obstacles, in 1943, the negotiations within the International and Boundary Commission (IBC) between Mexico and United States concluded, setting up the bases for an International Waters Treaty. The treaty was signed on the 3rd of February of 1944, in Washington, DC , ruling over the water allotment of the two international rivers between Mexico and the United States, and establishing as well the International Boundary and Water Commission (IBWC).

Water Resources In The United States

The first hydraulic resource is located at the end of "Glenn Canyon", where a hydropower dam of the same name was built, creating Lake Powell, with a capacity of 30,000 Mm3. Hoover Dam was built at the end of Black Canyon, creating the artificial Lake Mead with a storage capacity of 33,769 Mm3, and 80 km downstream Davis Dam was built, forming Lake Mohave, with a storage capacity of 2,232.4 million of cubic meters. After crossing several valleys, at about 135 km downstream from Davis Dam, Parker Dam was built, and created the artificial Lake Havasu with a storage capacity of 764 Mm3, from this place 1250 Mm3 of water are released for supplies for Los Angeles, Calif. Further downstream at about 230 km is Imperial Dam. From this dam water is diverted to the All American Canal, a short distance downstream from this place is

Laguna Dam. The Colorado River receives water from the Gila River before it gets to the international reach. In the Gila River there are several storage works that as a group add up to a capacity of 6,953 million of cubic meters. (figure 1)

Water Resources In Mexico

The International Waters Treaty signed between Mexico and the United States in February of 1944, established an annual guaranteed allotment of 1,850.234 Mm3 and up to a quantity not to exceed 2,096.931 Mm3 a year. These volumes are delivered to Mexico in two different places: Morelos Dam or the Northerly International Boundary (NIB) and the Southerly International Boundary (SIB) through the Sanchez Mejorada Canal, receiving respectively, 1,677 and 173 Mm3 per year. These quantities are used in the states of Baja California and Sonora, mainly for agricultural use and in a lesser scale for domestic use as water supply for the cities of Mexicali, Tijuana and Tecate, Baja California. The second water resource that supplies an annual average flow of 700 Mm3 are the underground waters form 725 deep wells located in the Irrigation District 014, in the Mexicali Valley. A third water resource are the 67 wells of the Mesa Arenosa system in San Luis Rio Colorado, Sonora, which supply 197 Mm3 per year.

SILTATION PROBLEMS

The Colorado River waters are characterized for transporting a great volume of sediments along its course from Wyoming to the Gulf of California, mainly in the states of Colorado, Nevada and Arizona where the erosion process and the sediment transport has increased considerably. The silt control in the Lower Basin of the Colorado River in the United States is carried out immediately downstream of Imperial Dam. In this place the sediment is removed at the desilting basins from waters to be sent to southern California mainly.
The Colorado and Gila Rivers have an important potential for sediment transport which has been modified from its natural form by the construction and operation of the dam system built in these rivers, modifying the flow downstream, increasing the occurrence of extraordinary sediment transport events.
The sediment transport towards Mexican territory is a antropogenic process that has been taking place for decades (figure 2), usually during the flood periods, as it happened at the beginning of 1993, when intense rains in the Lower Basin of the Colorado River in United States territory, caused an increase of the storage levels of the dam system, generating discharges from Painted Rock Dam to the Gila River and then to the Colorado River. This situation, forced Mexico to take measures to protect the river banks because the conveyance capacity of the river in the Mexican reach was limited to 700 m3/s approximately. The record flows

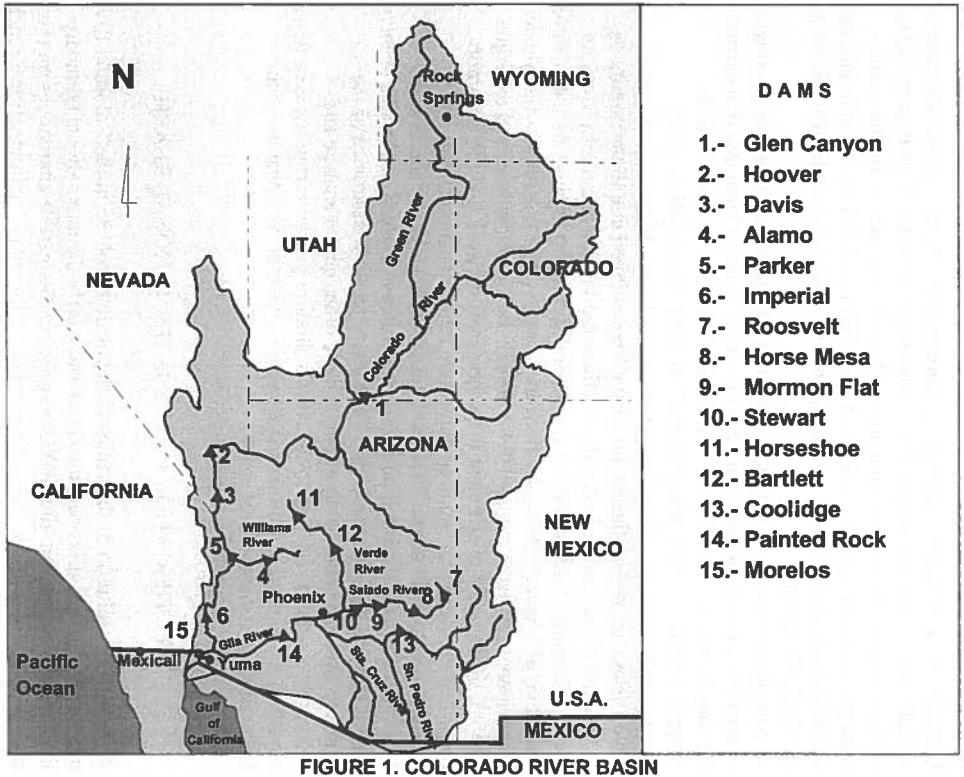

FIGURE 1. COLORADO RIVER BASIN

of the Gila River during the first months of 1993 deposited an approximate volume of 3.358 millions of cubic meters on the Colorado River and the network of canals of the Irrigation District 014, in Mexico (figure 3).
The sediment deposition in Morelos Dam risked the adequate diversion of Mexican waters. For that reason, IBWC carried out immediately, a series of meetings to coordinate the joint execution of the sediment removal works at the Colorado River Channel upstream of Morelos Dam. An agreement was reached on July 16th, 1994, and minute 291 " Improvements to the Conveyance Capacity of the Colorado River in its International Reach" was signed. In this minute, both governments agreed to carry out short and long term studies and removal works in the Colorado River channel from its confluence with the Gila River to the Gulf of California.
In compliance to minute 291, both countries carried out sediment removal works in the river's international reach upstream from Morelos Dam. Mexico carried out similar works in its territory, as well as in the canals network of the Irrigation District 014 in Mexicali, B.C., in the Colorado River reach downstream from the railway bridge and in the Canal Alimentador Central, nevertheless, at present these works have been nullified due to the continuos sediment transport putting on risk the efficient diversion and use of Mexican water, affecting Morelos Dam operation and starting to impinge on the adequate operation of Mexico's hydraulic network of canals. For this reason, the Mexican Government started in august 1996, through the Comisión Nacional del Agua (CNA), the removal of sediment from the canals network and the Colorado River bed in places that required immediate removal action (figure 4).
In the framework of minute 291, the International Boundary and Water Commission established two binational task forces to attend jointly this problem, one of them to propose short term alternatives to allow assurance of the Mexican diversions in Morelos Dam and the other one to analyze and recommend solution options to the river's siltation problem from the Gila River mouth to the Gulf of California considering as well the rectification of the Colorado River international reach.

RECTIFICATION OF THE INTERNATIONAL REACH

As part of the solution of the sediment deposition problem in the Colorado River international reach, it is needed to mark out clearly the international boundary line, and for this reason the IBWC is analyzing the feasible alternatives on this matter. In October 1995, Mexico carried out a survey of the international reach of the Colorado River and presented the first options. The United States Section of the IBWC is in consultations with the Bureau of Reclamation (USBR) on the sediment transport on the Colorado River from its confluence with the Gila River to the Gulf of California.

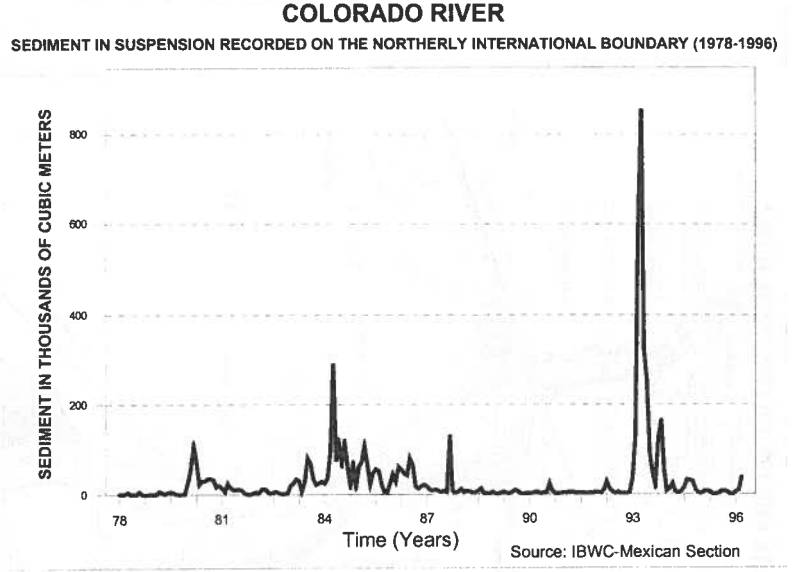

FIGURE 2

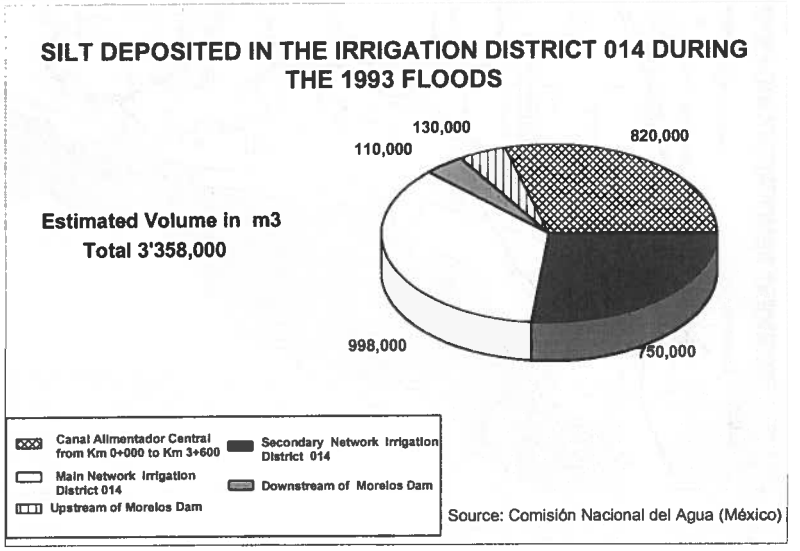

FIGURE 3

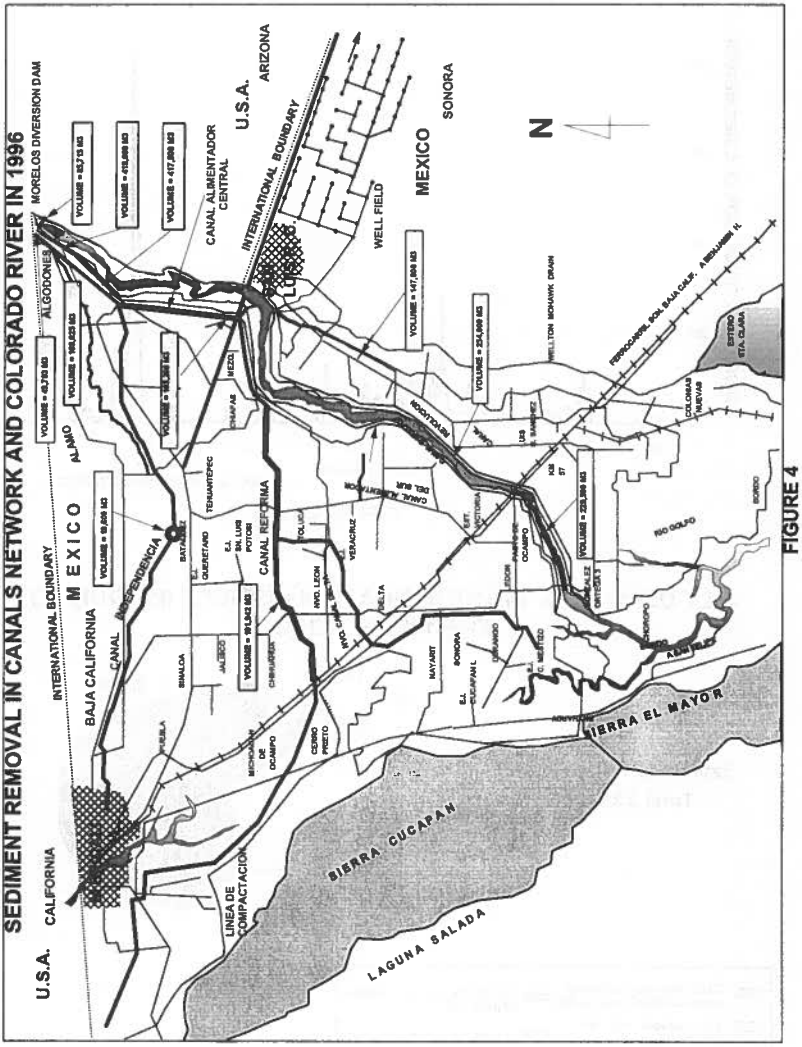
SEDIMENT REMOVAL IN CANALS NETWORK AND COLORADO RIVER IN 1996
U.S.A.
CALIFORNIA
INTERNATIONAL BOUNDARY
MEXICO
BAJA CALIFORNIA
MORELOS DIVERSION DAM
ALGODONES
ALAMO
CANAL INTERNACIONAL
CANAL ALIMENTADOR CENTRAL
U.S.A.
ARIZONA
INTERNATIONAL BOUNDARY
YUMA
WELL FIELD
MEXICO
SONORA
N
CANAL REFORMA
SIERRA CUCAPAN
LAGUNA SALADA
SIERRA EL MAYOR
LINEA DE COMPACTACION
RIO COLORADO
RIO GOLFO
FERROCARRIL SON. BAJA CALIF. A MEXICALI H.
WILLTON BONAIRE DRAIN
COLONIAS NUEVAS
ESTERO STA CLARA

FIGURE 4

SALINITY PROBLEMS

During the first seventeen years of Treaty enforcement, Mexico received its water allotment from the Colorado River, with a water quality similar to the one of the water used by the farmers in Imperial Valley, California and the Yuma, Arizona, region. At that time the salinity difference between the waters in Imperial Dam and Morelos Dam was similar and did not exceed 900 ppm. During the 1960's, there was an increase in the salinity of the waters above 2500 ppm, this was because the United States had drilled and started to operate many wells in the Wellton-Mohawk Valley, in order to control and reduce the water table,. The salty waters pumped from the underground were then discharged to the Gila River and later through the Colorado River reached Mexican territory. In attention to the above, on March 22nd of 1965, minute 218 was signed in the IBWC. Based on this agreement, United States started the construction of a concrete lined canal, with a conveyance capacity of 10 m3/s, which started operations on November 16th of 1965. This canal, on Mexico's choice, was design to discharge to the Colorado River the waters from the pumping in the Wellton-Mohawk Valley, in two points located upstream and downstream of Morelos Dam.

Once more, in 1966-67, there was a significant increment in the salinity of the water from the Southern Gila Region. Mexico then carried out a series of exertions during meetings in Mexico City as well as in Washington, DC that ended up with the signing of minute 242. This minute stipulates that the salinity difference between the waters delivered to Mexico in Morelos Dam and the Colorado River waters in Imperial Dam, would not be over 121 ppm +/- 30 ppm, Mexican count. (figures 5 and 6).

At present, the salinity of the waters delivered to Mexico in the NIB have an annual average of 883 ppm, nevertheless, in some days during the low demand months, it could be above 1200 ppm. The annual average salinity of the waters that Mexico receives in the SIB exceed 1500 ppm and for this reason they have to be mixed with part of the waters received in the NIB and underground waters, so it can be used in agriculture, however, at the present time damage to the soils and low crops yield are observed.

Another situation that at present is of concern for the Mexican users are the daily variations of the salinity (salinity peaks), due to the adverse effects of these on the agricultural production. In order to detect opportunely these variations and ask for the corresponding adjustments to the United States, Mexico installed at its own expense, automated systems for the continuous recording of the salinity in Morelos Dam and the Sanchez Mejorada Canal.

In the same way, to give integral attention to the salinity problem the IBWC established a binational task force, which analyzes the following options set up by Mexico: In a short term to improve the quality of the waters that Mexico

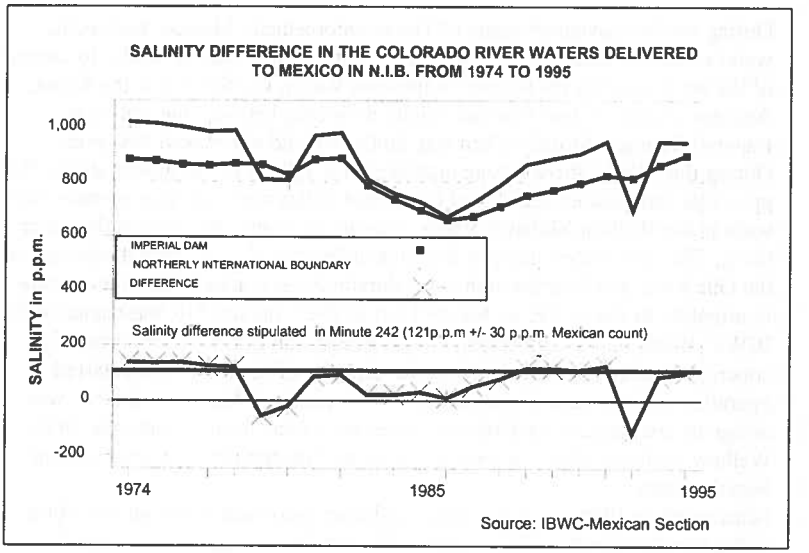

FIGURE 5

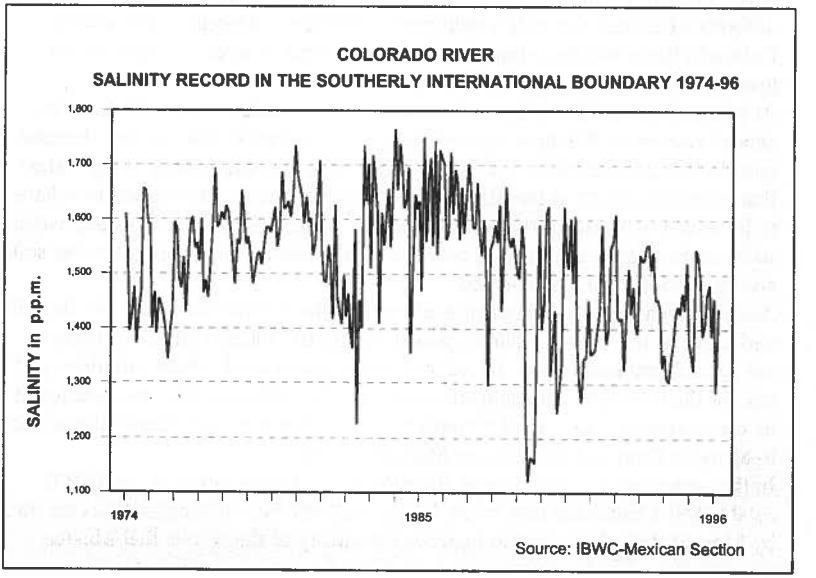

FIGURE 6

receives in the SIB, and in a long term, that all the water allotted to Mexico would come from Imperial Dam and be delivered in the NIB.

CONCLUSIONS

At present the management of the water in the Colorado River, the intensive use of this resource, and the geographical location of the Mexican basin, have an impact on Mexico in several matters as: the waters quality, water supply for domestic and agricultural use, the hydraulic system operation, a null flow of the river on Mexican territory, the Colorado River Delta and the environment in general (Table 1 and figure 7), making water management difficult. Although a Treaty and several minutes have been signed respect to the Colorado River waters allotment, the salinity and the sediments continue to demand the highest priority in order to secure a beneficial use of these waters in Mexico.
Because of the origin and nature of these problems, its solution should be shared by both countries, based on the procedures that they would established concurrently through the IBWC. These procedures should contemplate the jointly development of the actions that could allow in a short term to improve the water quality that Mexico receives in the Southerly International Boundary and to carry on the sediment removal in critical points of the Colorado River hydraulic system that would guarantee diversion, distribution and usage of the Colorado River waters that belong to Mexico. Likewise, they should contemplate the achievement of an integral study that would take into account all the factors that are involved in these problems, (tables 2,3, and 4), establishing jointly plans for its attention in a middle and long term.

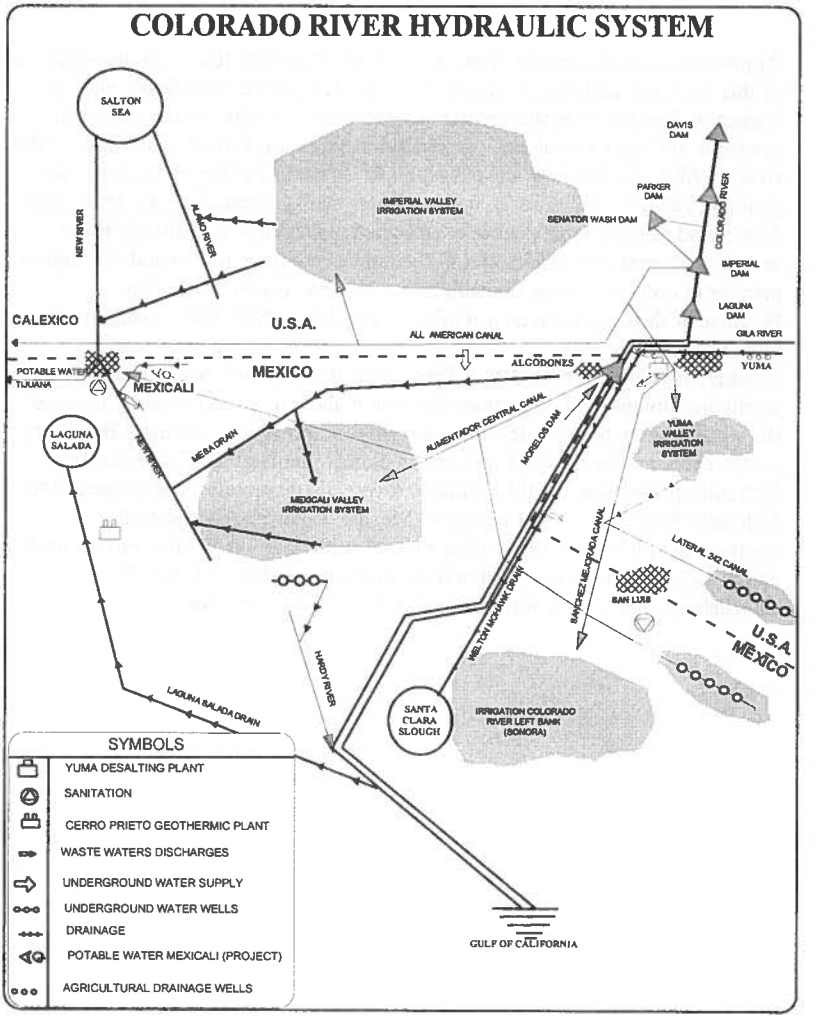
COLORADO RIVER HYDRAULIC SYSTEM
SALTON SEA
NEW RIVER
ALAMO RIVER
IMPERIAL VALLEY IRRIGATION SYSTEM
SENATOR WASH DAM
DAVIS DAM
PARKER DAM
COLORADO RIVER
IMPERIAL DAM
LAGUNA DAM
GILA RIVER
CALEXICO
U.S.A.
ALL AMERICAN CANAL
ALGODONES
YUMA
POTABLE WATER TIJUANA
NO.
MEXICALI
MEXICO
LAGUNA SALADA
NEW RIVER
MEXICALI VALLEY IRRIGATION SYSTEM
ALAMO DRAIN
ALAMEDA CENTRAL CANAL
MORELOS DAM
YUMA VALLEY IRRIGATION SYSTEM
LATERAL 242 CANAL
SANCHEZ MEJORADA CANAL
SAN LUIS
U.S.A.
MEXICO
HARDY RIVER
MILTON MOHAWK DRAIN
LAGUNA SALADA DRAIN
SANTA CLARA SLOUGH
IRRIGATION COLORADO RIVER LEFT BANK (SONORA)
GULF OF CALIFORNIA
SYMBOLS
YUMA DESALTING PLANT
SANITATION
CERRO PRIETO GEOTHERMIC PLANT
WASTE WATERS DISCHARGES
UNDERGROUND WATER SUPPLY
UNDERGROUND WATER WELLS
DRAINAGE
POTABLE WATER MEXICALI (PROJECT)
AGRICULTURAL DRAINAGE WELLS

FIGURE 7

IMPACTS THAT FALL IN THE COLORADO RIVER PROBLEMS	
No.	IMPACTS
1	LOCAL POLITICS
2	INTERNATIONAL POLITICS
3	WATER QUALITY
4	DELIVERY OF WATER TO MEXICO
5	AGRICULTURE
6	WATER SUPPLY
7	PUBLIC HEALTH
8	SAFETY PUBLIC
9	HYDRAULIC SYSTEM OPERATION
10	ENVIRONMENT
11	UNDERGROUND WATERS

TABLE 1

CONDITIONS THAT INTEGRATE THE COLORADO RIVER PROBLEMS AS A FUNCTION OF FLOW CONDITIONS	
No.	CONCEPTS
1	MASS BALANCE
2	ALIMENTADOR CENTRAL CANAL
3	MESA DRAIN
4	FLOODING AREAS
5	SEDIMENT DEPOSITION
6	SEDIMENT CONTROL IN USA
7	FLOOD CONTROL
8	FLOOD PLAIN ENCROACHMENT
9	INTERNATIONAL BOUNDARY LINE
10	IMPERIAL DAM
11	LAGUNA DAM
12	SENATOR WASH DAM
13	PAINTED ROCK DAM
14	MORELOS DAM
15	SANCHEZ MEJORADA CANAL
16	WELLTON-MOHAWK DRAIN
17	ALL AMERICAN CANAL
18	242 LATERAL CANAL
19	WATER SUPPLY
20	SALINITY
21	IRRIGATION AREAS
22	NEW RIVER
23	LAGUNA SALADA
24	HARDY RIVER
25	AGRICULTURAL DRAINAGE
26	MEXICALI DRAIN
27	SANTA CLARA SLOUGH
28	YUMA DESALTING PLANT
29	CERRO PRIETO GEOTHERMIC PLANT
30	SALTON SEA
31	SANITATION OF MEXICALI
32	UNDERGROUND WATERS
33	TOXICS, SOLIDS AND GARBAGE MANAGEMENT

TABLE 2

CONDITIONS THAT INTEGRATE THE COLORADO RIVER PROBLEMS AS A FUNCTION OF FLOW CONDITIONS
NORMAL

CONCEPTS	IMPACTS										
	1	2	3	4	5	6	7	8	9	10	11
1 MASS BALANCE											
2 ALIMENTADOR CENTRAL CANAL				●		●			●		
3 MESA DRAIN											
4 FLOODING AREAS											
5 SEDIMENT DEPOSITION											
6 SEDIMENT CONTROL IN USA	●	●	●			●			●		
7 FLOOD CONTROL											
8 FLOOD PLAIN ENCROACHMENT											
9 INTERNATIONAL BOUNDARY LINE		●									
10 IMPERIAL DAM		●		●					●		
11 LAGUNA DAM			●								
12 SENATOR WASH DAM		●		●							
13 PAINTED ROCK DAM		●	●						●		
14 MORELOS DAM	●	●		●	●	●			●		
15 SANCHEZ MEJORADA CANAL											
16 WELLTON-MOHAWK DRAIN											
17 ALL AMERICAN CANAL	●	●		●		●			●		●
18 242 LATERAL CANAL		●	●	●	●				●		
19 WATER SUPPLY											
20 SALINITY	●	●	●		●						
21 IRRIGATION AREAS											
22 NEW RIVER	●	●	●		●		●			●	
23 LAGUNA SALADA										●	
24 HARDY RIVER									●		
25 AGRICULTURAL DRAINAGE		●		●	●						●
26 MEXICALI DRAIN	●	●					●			●	
27 SANTA CLARA SLOUGH	●	●								●	
28 YUMA DESALTING PLANT		●	●	●							
29 CERRO PRIETO GEOTHERMIC PLANT							●			●	
30 SALTON SEA		●							●		
31 SANITATION OF MEXICALI											
32 UNDERGROUND WATERS	●	●			●						
33 TOXICS, SOLIDS AND GARBAGE MANAGEMENT	●	●					●			●	

TABLE 3

CONDITIONS THAT INTEGRATE THE COLORADO RIVER PROBLEMS AS A FUNCTION OF FLOW CONDITIONS

FLOODS

CONCEPTS	IMPACTS										
	1	2	3	4	5	6	7	8	9	10	11
1 MASS BALANCE											
2 ALIMENTADOR CENTRAL CANAL				●	●	●			●		
3 MESA DRAIN		●			●						●
4 FLOODING AREAS	●	●			●			●	●		
5 SEDIMENT DEPOSITION	●	●			●	●			●		
6 SEDIMENT CONTROL IN USA	●	●									
7 FLOOD CONTROL	●	●	●	●	●	●		●	●		●
8 FLOOD PLAIN ENCROACHMENT									●		
9 INTERNATIONAL BOUNDARY LINE		●									
10 IMPERIAL DAM		●		●					●		
11 LAGUNA DAM											
12 SENATOR WASH DAM											
13 PAINTED ROCK DAM	●	●	●	●		●			●		
14 MORELOS DAM	●	●		●	●	●		●	●		
15 SANCHEZ MEJORADA CANAL		●	●	●					●		●
16 WELLTON-MOHAWK DRAIN	●	●							●	●	
17 ALL AMERICAN CANAL	●	●		●		●			●		●
18 242 LATERAL CANAL		●	●	●	●				●		
19 WATER SUPPLY											
20 SALINITY											
21 IRRIGATION AREAS											
22 NEW RIVER	●	●	●		●		●			●	
23 LAGUNA SALADA									●	●	
24 HARDY RIVER								●	●		
25 AGRICULTURAL DRAINAGE		●		●	●						●
26 MEXICALI DRAIN	●	●					●			●	
27 SANTA CLARA SLOUGH	●	●								●	
28 YUMA DESALTING PLANT		●	●	●							
29 CERRO PRIETO GEOTHERMIC PLANT							●			●	
30 SALTON SEA		●							●		
31 SANITATION OF MEXICALI	●	●					●			●	
32 UNDERGROUND WATERS	●	●			●						
33 TOXICS, SOLIDS AND GARBAGE MANAGEMENT	●	●					●			●	

TABLE 4