Executive Summary

I- Introduction

The project "Information Database and Local Outreach Project for the Restoration of the Hardy River Wetlands, Lower Colorado River Delta, Baja California and Sonora, México" is a binational effort, in which academic institutions, governmental agencies and NGO's are collaborating.

The purpose of this first phase was to integrate a geographic information system, including physical, environmental, biological, and socio-economical data, that could be used as a tool for restoration and management activities. This information system will also support the outreach program, by making information available to local users, and by getting their perceptions on the project, since their participation is a key for the success of restoration efforts.

This phase allowed the documentation of the importance of restoring these wetlands, look at feasibility and safety considerations, and present this information to decision makers and stakeholders.

II The Process

The development of this project considered a multi-disciplinary and multi-institutional approach in order to incorporate diverse perspectives for the identification of critical issues of the Hardy/Colorado Wetlands and for their comprehensive management in Mexico.

Specific tasks in the project included:

- Integration of a Geographic Information System (GIS) of the Colorado River delta.
- Set up of a local outreach program.
- Analysis of water quality from different sources.
- Integration of an historic profile of the Colorado River delta.
- Evaluation of human activities in the wetland and its surroundings.
- Assessment of preliminary considerations for water requirements that could support the delta ecosystems, in order to identify water managemente strategies.
- Identification of preliminary hydraulic considerations for the design of wetland restoration sites in the Colorado River delta.

III-Hardy/Colorado Wetlands (and their influence zone).

The Colorado River is the main source of water for the desert region of the southwest United States, northwestern Mexico, and southern California coastal plain.

The river carries an annual volume of 18.5 thousand million cubic meters, of which 10% is allotted to Mexico. At present day, the Colorado River supports more than 23 million people, 21.5 million along the 7 states of the USA, and the rest in the states of Baja California and Sonora, Mexico (Carrier, 1991; CNA, 1997; Glenn *et al*, 1997).

It's delta, the last portion of one of the most human-developed rivers, is still the largest desert estuary in North America. Historically, it has supported vast riparian, freshwater, and brackish wetlands(Carrier, 1991; INEGI, 1995; Glenn *et al*, 1996).

The Colorado Delta is located between the states of Baja California and Sonora, Mexico, in the area that is actually known as the Mexicali and San Luis Rio Colorado agricultural valleys. The agricultural area covers about 250,000 hectares of land with irrigation rights (INEGI, 1995; CNA, 1997).

Historically, this area has been the most important wetland system in the Sonoran Desert, but today, it is a threatened ecosystem that needs restoration and careful management.

Significant remaining delta wetlands include: the Colorado riparian wetland corridor, the Hardy/Colorado wetlands, the Ciénega de Santa Clara, the El Doctor wetlands, the Laguna del Indio, and large intertidal wetlands supported by the extreme tidal ranges in the Upper Gulf of California. These wetlands provide critical habitat for several endangered species, and for migratory and wintering waterfowl along the Pacific Flyway (Eddleman, 1989; Payne, 1992).

The Wetland System of the Hardy/Colorado River is located on the western side of the Colorado River delta, at the southern portion of the Mexicali Valley.

The Hardy River travels through 26 km, joining the Colorado River downstream. This area was covered by extensive areas of riparian vegetation, surrounded by dense forests of mesquite.

Past and Present of the Hardy/Colorado Wetlands

Past and present of the Hardy and Colorado River delta intermingle scenarios according to the size of the wetland area in them, which is directly related to the quantity and quality of the water they receive.

Wetlands of the Hardy/Colorado River became apparent after the 1930's floods in the delta, when a natural dam or sandbar 35 km upstream from the ocean, blocked the exit of water from the western delta (Glenn *et al*, 1996; Morrison *et al*, 1996).

By 1937, Hoover Dam was completed and Lake Mead began to fill. In 1964 Glen Canyon Dam was built and Lake Powell began to fill. Even though no flood water reached the delta for 35 years, a large wetland area of about 18,200 hectares, was formed north of the sandbar, supporting large areas of emergent vegetation and riparian habitat (Glenn *et al*, 1996; Morrison *et al*, 1996).

After the major flooding on the Colorado in 1983, and until 1989, when Mexico received water excedents through the Colorado River, the Hardy/Colorado Wetlands grew to some 66,400 hectares. Since then, the wetlands shrunk to approximately 1,200 hectares, in part because in 1987, the floods destroyed the natural dam, and the wetlands began to be drained (Glenn *et al*, 1996; Morrison *et al*, 1996).

During the years of intense floods in the 80's, CNA constructed protection levees on each side of the Colorado River banks to prevent the floods in agricultural lands (CNA, 1997) .

The levees surround the main stream of the Colorado River as well as a major part of the Hardy River Basin. Besides of functioning as a flood control structure, the levees have worked for salinity control, and they have also been the delimitation margins between human developed areas and wilderness areas.

Natural Features

The Colorado River delta once encompassed several hundred thousand hectares of riparian-wetland habitat, which supported over 400 species of plants and animals and provided a critical ecological interface with the biological rich and productive Gulf of California (Sykes, 1937; Leopold, 1949; Glenn *et al*, 1996). Although much of the Colorado delta has been converted into irrigated farmland, some 250,000 hectares of the delta remain undeveloped at its southern end (Glenn *et al*, 1996).

Considering all remaining wetlands in the Colorado River, the Hardy/Colorado Complex is one of the most important, as it provides a wintering area for migratory birds. This is the only extensive brackish wetland in the delta that has been historically supported by Mexican water, and if proper management strategies are implemented, it represents the largest area subject to potential restoration and habitat improvement in the Colorado River Delta.

IV-Historical Changes

All changes observed during this century along the Colorado River, and especially in the delta, are the result of water control practices within the Colorado ecosystem.

Hydrological Changes

The river is controlled by 20 dams, which have stressed and transformed the aquatic ecosystem over the past 65 years, causing important environmental differences (Morrison *et al*, 1996).

All of the Colorado water that Mexico receives during normal years is used for human activities; mainly for agricultural uses, but also for urban, domestic, and industrial operations (Direccion General de Ecologia, 1995).

Being one of the last portions of the Colorado River Basin, the Hardy River has been used as a run off water reservoir; thus, its stream has not been directly modified by human activities.

The Mexicali Valley has 17 agricultural drains (3 primary and 14 secondary drains) which flow directly into the Hardy/Colorado River System. They carry an annual volume of 6.33×10^7 m^3 (CNA, 1997), with a total of 70,000 tons of fertilizers/year and 400,000 liters of insecticides/year (Dirección General de Ecología, 1995). The average salinity of the drains is of 3 ppm (CNA, 1997), which is not tolerable by most of the native riparian vegetation (Glenn *et al*, in press).

Habitat Changes

The alteration, fragmentation, and destruction of freshwater habitats and water regimes in the region have resulted in a loss of biodiversity and ecosystem functions associated with freshwater, brackish and intertidal wetlands and near-shore marine resources.

Most of the land surrounding the northern edge of the Hardy/Colorado Wetlands has been targeted for agricultural use. Extensive marshes have been desiccated, instead, flat saline plains remain, and many riparian areas have been occupied by saltcedar that has taken advantage of modified habitat that is not suitable for native species.

The mesquite and screwbean forests are the most disturbed habitats, now reduced to few isolated patches spread in the valley. They have been cut down to be used as firewood, as a construction material, and to open areas for the development of agricultural lands and rural towns.

The saltcedar invasion in the Colorado River delta resulted from changes in water quality and

quantity, and it represents significant habitat changes over large areas (de Gouvenain, 1996).

The challenge with this issue is to conserve the riparian areas that are still not covered by saltcedar, by maintaining water quantity and quality; to establish management practices to reduce damage by dense saltcedar infestations along river banks; and to start an evaluation of possible benefits that can be obtained from saltcedar habitat by the local communities.

Dams in the Upper Colorado have trapped all of the river's sediment load, thus the lower half of the river has been transformed into an erosive force, washing away the delta (Morrison *et al*, 1996).

Many native fish species have not adapted well and have fared poorly under the post development conditions. Some 50 fish species have been introduced throughout this century (Minckley, 1991), preyeing upon and competing with the native species, which combined with the physical changes, have drastically reduced native species populations (Carothers and Brown, 1991). Also, marine species now are more commonly found in the area, due the increase of tidal effects.

Reduction in freshwater flow has also cut the influx of nutrients to the sea and reduced critical habitat for nursery grounds. Catches from the upper Gulf shrimp fishery have dropped off steeply, and other fisheries are in decline as well (Glenn *et al,* 1996).

Even with all those changes, this is a resilient and amazingly rich ecosystem when water is added. The events occurring the 1997 floods could be described as the last major habitat change in the delta, due to the re-vegetation of its wetlands, resulting in important wildlife values. The reestablishment of native forest species has been a direct consequence of the return of overbank flooding below Morelos Dam since the filling of Lake Powell.

History of Human Activities in the Colorado River Delta.

Vestiges of antique civilizations testify human settlements in the Colorado River delta since 15 thousand years ago (Ortega-Villa, 1991). This area was inhabited 3,000 years ago by indigenous groups from the Yumana linguistic family (Álvarez de Williams, 1973). Though, the only Indian group remaining today is the Cucapá culture, which flourished under the benefits the delta offered. The total population of indigenous people in the delta, at the arrival of Spaniards colonization (1539) was estimated at about 20,000 inhabitants (Álvarez de Williams, 1973).

Early in the 19th century, explorers and colonizers arrived and began modifying the delta's natural environment, to which tribal groups had adapted their lives. Hence, ethnic extinction began because of reduced natural habitat, water scarcity, crossbreeding, and disease infection.

The history of the Mexicali Municipality is related directly to the development of agriculture in the region. In 1892, the Colorado River Irrigation Co. began using the Colorado River water for agricultural purposes. Though, it was not until early in the 20th when the first human settlements were established in the northern part of the municipality (Sánchez, 1990).

In response to the agricultural crisis of the 60's, in 1968 the Mexican government began the rehabilitation of Mexicali's Irrigation District (Ortega-Villa, 1991). This effort resulted in an increase of 15% of land available for agriculture (Ortega-Villa, 1991). During the last two decades, actions have focused mainly in maintaining existing infrastructure, repairing the damages caused by floods, and preparing the river-bed and levees in order to minimize flood damages (CNA, 1997).

Though Mexicali is one of the most important agricultural valleys in the country, it has been an example of development, but not of sustainable development. Resources have been controlled and used for the benefit of the new incoming population, setting aside environmental issues and native tribes, which are the traditional users of these lands and resources.

V-Today's Conditions

Vegetation

Plant cover in the flood plain varied in intensity, species composition, and habitat value according to its position in the flood plain. We divided the flood plain into 7 zones based on the dominant species associations. Generally, three types of wetland ecosystem type were encountered in the study area: 1) riparian deciduous forest and woodland in areas subject to periodic river flooding (zone1-5), dominated by the mesophytic trees, *Populus* and *Salix* in the north (zone 1-3), but by *Tamarisk* and other salt-tolerant shrubs as the river approached the intertidal zone (zone 4 and 5); 2) maritime submergent mud flats dominated by the endemic salt grass, *Distichlis palmeri* in the intertidal portion of the river (zone 6); and 3) brackish marshlands dominated by *Typha domengensis* (cattails) and other emergent hydrophytes in areas flooded with

agricultural drainage water in the eastern side of the delta (zone 7).

Zone 1, which extended for approximately 10 km south of Morelos Dam, was narrow and contained 170 ha of dense thickets of *Salix*, most of which were below 4 m height with older plants reaching 8-15 m. Although *Populus* trees also were found along this reach, they appeared only as isolated individuals.

Zone 2 was wider than zone 1 and included open water channel-side and channel island riparian habitat occupied by *Populus* and *Salix*, and, on slightly elevated terraces further away from the channel, *Prosopis* shrublands. This zone included large areas of riverbank covered by *Tamarisk* and *Salix* (midstory) or *Tamarisk* and *Pluchea* (understory).

Although the composition and general diversity of the riparian habitat along the river reach defined as zone 3 was similar to zone 2, zone 3 was dominated by *Populus* with mid and understory zones dominated by *Salix* and *Tamarisk*. The largest trees were up to 15 m in height.

In zone 4, the flood plain widened and the river divided into numerous channels, oxbows, backwaters and pond areas downstream of the confluence with the Hardy River. Although numerous pockets of *Populus* and *Salix* were still found along the main river channels in this reach, they constituted a lower proportion of those existing in Zones 1-3. Over 70% of this zone was dominated by a mixture of *Tamarisk, Prosopis* and significant numbers of large *Atriplex lentiformis* (quailbush) plants.

Zone 5 widened to 20 km in some areas. The dominant plant association over most of the zone was a near monoculture of dense thickets of *Tamarisk*. The final 56 km of the river is perennial due to tidal intrusion and the discharge of agricultural drain water into the river (Payne *et al*. 1992). *Typha, Phragmites australis* (comon reed) and other emergent hydrophytes grow along the river banks.

The final 20 km of river constituted the intertidal zone (Zone 6), which supported 442 ha of *Distichlis palmeri* (Palmer's saltgrass). This important species is the only indigenous grass of the Sonoran Desert.

Zone 7 on the south - eastern corner of the Colorado delta, encompassed the Cienega de Santa Clara, El Indio and El Doctor marshes, containing 5,808 ha of emergent, hydrophyte. Vegetation consisted mainly of dense *Typha* and of thin stands of *Typha, Scirpus* and *Distichlis* on the salt-affected, wetland fringes (Zengel *et al*. 1995).

Comparison of these results with 1996 data collected on the stretch of river from Davis Dam to Morelos Dam (Balogh, M., unpublished data, United States Bureau of Reclamation, Boulder, Colorado) shows that the Colorado River delta in Mexico currently present a richer and more diverse set of ecosystems than the stretch of river below Grand Canyon in the United States, even though that stretch is 5 times longer and has a perennial flow of water. The stretch above Morelos Dam contains 33,400 ha of vegetation, compared to 60,000 ha in the delta.

Zone 1 is notable for its dense willow stands which are now so rare that they are no longer listed as a habitat class along the river above Morelos Dam. Zones 2 and 3 contain approximately 1,500 ha of *Populus* and *Salix* gallery forest, considered to be the most valuable habitat type on the river (Ohmart *et al*, 1988), but only 100 ha of gallery forest remain on the United States' stretch of river. Altogether, *Populus* and *Salix* are the dominant species on 1,650 ha in Zones 1-3, whereas above Morelos Dam these trees are rarely dominant and are present at 10% or greater abundance on only 1,460 ha of the riparian zone.

In addition to riparian forest, the delta contains over 5,800 ha of marshes supported by agricultural drainage water, compared to 4,180 ha of marshlands above Morelos Dam.

Water

a) Water Flows

The Southern International Boundary (SIB) is located at San Luis Río Colorado Border. Water flow below Morelos Dam is potential water for wetland restoration, therefore, water flow at the SIB is a good indicator of water reaching the delta ecosystem.

To say that the flow at the SIB is variable is an understatement. The annual mean of the daily discharge (calculated from summarizing the monthly means) range from 0 to 495 m^3/s (CMS), during the 20 year period from 1977 to 1996. Peak daily discharges have about twice the range from 0 to 934 CMS.

During the January - April and August – October, 1997, water releases to the delta in about 4×10^8 m^3/year, with average daily flow of about 126 m^3/s, inundated an area of approximately 60,000 ha and excess water exited the delta into Laguna Salada and into the Gulf of California. This flows continued in early 1998, but are programmed to be stopped.

Other water sources entering the flood plain are the agricultural drains. During 1997, the main drains discharging on the Hardy/Colorado Wetlands had a mean flow of 6.33×10^7 m^3. Adding the flows to the Cienega de Santa Clara, only near 13% of the water

that used to reach the delta in pre-development conditions now regularly enters these wetlands.

b) Water Quality

Selenium

One of the major threats of the Colorado River delta wetlands is the bioaccumulation of selenium, which can be bioaccumulated to toxic levels for wildlife, causing high rates of embryonic mortality and deformity (Ohlendorf *et al*, 1986). Elevated levels of selenium were found in water, sediment, and fish tissues from the lower Colorado (Welsh and Maughan, 1994; King *et al*, 1993; Radtke *et al*, 1988). Selenium tends to concentrate in consumer organisms from their food sources in aquatic ecosystems (Maier and Knight, 1994).

Selenium was detected in all of the samples analyzed. Dissolved selenium in water (range 9-71 µg/L) exceeded by 1.8 - 14.2 times the U.S. EPA's criterion of 5 µg/L for the protection of freshwater aquatic life (USEPA, 1987) as well as the 85 % national baseline of 1 µg/L found in the main U.S. rivers (Smith *et al*, 1987), and the Mexican Regulation of 8 µg/L for protection of freshwater aquatic life (CNA, 1996).

Dissolved selenium levels from samples of the sites located in the Hardy River, on the Colorado River below its confluence with the Hardy (inside the levee) in evaporative reservoirs, and in agricultural drains, were 1.7 times higher than the levels of the sites located on the main stream of the Colorado River (inside the levee) before its confluence with the Hardy River, in periods of high flow (August 1997). When there were no high flows (July 1997) sites located inside the levee in the Colorado River, upstream and below its confluence with the Hardy, presented twice the selenium concentration, at levels within values of agricultural drains, and sites influenced by them.

Selenium concentrations are lower in areas which receive water from irrigation channels. Even though selenium concentrations on sites along the main Colorado Stream inside the levees decrease when there are high water flows, the levels are still higher than levels at Morelos Dam.

Beside the micro-evaporative basins, the agricultural drains were found to have the highest levels of selenium. The riparian areas influenced by these drains were also found with high selenium levels.

The results suggest that selenium contamination, besides reaching high levels from the Colorado River, is being magnified by the agricultural practices on the Mexicali Valley, and by evaporation in certain sites where standing water remains without renewing.

With values of dissolved selenium exceeding the EPA criterion for protection of wildlife in the Hardy/Colorado wetlands, bioaccumulation of selenium throughout the food chain is likely to occur. However, further sampling of biota in the area is needed to determine the specific risk at which fish, birds, and humans are exposed due to this component.

Salinity

Salinity in the Colorado River delta has been a major concern during the second half of this century, specially associated with the Mexicali Agricultural Valley, and the water deliveries of the U.S. to Mexico through Morelos Dam (Secretaría de Relaciones Exteriores, 1975; CNA, 1997).

Salinity levels were identified in key areas of the Hardy/Colorado Wetlands. Salinity surveys were carried out on July 7, 1997, August 20-22, 1997, and November 14, 1997.

Salinity on the samples of the Colorado River before its confluence with the Hardy River (without influence of agricultural drains) during the flooding event of August 1997 was low related to salinity in the Lower Colorado River and Delta.

Salinity on these sites was even lower than salinity on Irrigation channels. During the times when no flows were received, but there was water in the area from previous water releases (July and November) salinity increased substantially in certain sites.

Salinity in areas that have influence of agricultural drains of the Mexicali Valley was 7 times higher in average than Colorado River water, and areas that only receive agricultural discharges were 9 times saltier than Colorado River Water. Data on agricultural drains suggests that evaporation on river basins is causing an important increase in salinity (1.4 times). In places where water is retained without outflow, salinity increases to higher levels.

Salinity levels in the area around the river mouth and Montague and Pelicano were analyzed on January, 1998, during a flow of 202 m^3/s. During this flooding events, the fresh water zone extended within 10 km of the river mouth at low tide, and ocean water (36 ppt) at the northern end of Montague Island was diluted to 20 ppt.

These data contrast with descriptions of salinity levels in the same area carried out during 1989, when excess flows from the Colorado River to the delta were quite reduced, with mean annual discharges of

1.08 m^3/s. The area was described to have high salinity levels all year around, ranging from 35.3 to 39.2 ppt, and salinity levels at 10 km within the river mouth ranged from 35.3 to 37 ppt (Martínez Rojas-Reynoso, 1990).

Human Activities and Population

a) Population

Social and Cultural Aspects

The Colorado delta wetlands are located within two municipalities in two states, Mexicali, Baja California and San Luis Río Colorado, Sonora, in northwest México.

The delta communities (located within a ratio of 5 Km from the wetlands) have a total population of 206,977 inhabitants within 1,127 human settlements (INEGI, 199f; INEGI, 1996g). Growth rate in the area is of about 3.44% per year, which means that in this 5-year period, the total increase in population was slightly higher than 18%.

Only 1.69% of total human settlements have more than 1,000 inhabitants, in contrast with the 92% of total settlements with less than 100 inhabitants. Population is concentrated in the State of Sonora, mainly in the city of San Luis Río Colorado.

The delegations of the Mexicali municipality related to the Hardy/Colorado wetlands are Venustiano Carranza, Colonias Nuevas, Guadalupe Victoria, Estación Delta, and Cerro Prieto, but only 309 communities belong to the Hardy/Colorado Wetlands. Twenty of these communities are the ones whose inhabitants (36,503 persons) live with a stronger relationship with the wetlands. (INEGI, 1996f; INEGI, 1996g).

Ethnic groups

The Cucapá community is the only native group living in the delta, at the margins of the Hardy and the Colorado River, concentrating in the locality of El Mayor. There are only 82 people of this ethnic group in the state of Baja California, 50% of them women (INEGI, 1996f). Ethnic extinction has risen as a major threat mainly because of economic, political, and social problems.

Due to water scarcity, traditional economic activities are not enough for this community to survive, but they still collect seeds and certain plants for food. They also sell their arts and crafts made of chaquira.

Like the wetlands, Cucapá Culture struggles for survival, and they are carrying out several economic activities for their community development, such as fishing and aquaculture, trying to properly use wetlands resources. Low water flows and low water quality diminish their probabilities to succeed.

b) Human Activities.

The agricultural district No. 14 includes lands from the Mexicali and the San Luis Río Colorado municipalities. Its crop with more market value is onion, even though it was not the biggest production (in tons). The second product with high market value is wheat, which corresponds with the greater cultivated area and production. Cotton was the third crop in importance in both market value and tons produced.

Human Activities in the Hardy/Colorado Wetlands

Human activities carried out in the Hardy/Colorado Wetlands are mainly related to agriculture and cattle ranching, but an important issue is the possibility to develop alternative economic activities modestly performed today, due to the presence of the wetland natural resources that support them.

Low scale and subsistence activities:

These activities are done by local communities, which perform recreational and subsistence fishing and hunting, as well as other aquatic activities, as swimming. Apiculture is another activity carried out at a low scale level, with few apiculture farms spread in the area.

Fisheries

At a commercial level, fisheries are carried out in the area mainly by the Unidad de Producción Pesquera Cucapá (Cucapá Fishing Production Unit). Their fishing grounds are located in the southern part of the river, from Cucapá El Mayor to the river mouth into the Biosphere Reserve Core Zone. They are the only ones with rights to fish in this area and in the Laguna Salada. The main fisheries are gulf corvina and shrimp, whose populations heavily depend on the flows from the Colorado River. On good fishing seasons, they sell their surpluses to Mexicali and San Luis Río Colorado markets.

There are other fishermen groups that fish on the Colorado River delta, who mostly fish in the Upper Gulf of California, nearby Montague Island and the river mouth for shrimp, shark, milkfish and corvina.

Aquaculture

The most important aquaculture facility in the area is located at Campo Mosqueda. It consists in a semi-intensive channel cat-fish culture (*Ictalurus punctatus*). They have a complete aquaculture cycle, including breeding and fingerling production.

Water for the culture is from an irrigation cannal, and if extra water is needed, they use that from the Hardy River. Production is targeted to local markets in the valley, and to the city of Mexicali. They also have a good market for the surplus of fingerling production.

Recently, the Cucapá community started a cat fish aquaculture project with cages on the river stream, at Cucapá El Mayor.

Tourism

Along the river banks, there are 16 tourist camps that are used by people from Mexicali and the U.S. The main touristic activities are aquatic sports, recreational fishing, hunting expeditions, and environmental and archeological hiking.

The best tourist facilities are located at Campo Mosqueda. Some facilities are also located at Campo Sonora. The Cucapá community of El Mayor also represents a tourist attraction in the area, with the Cucapá Museum. There is a big potential for eco-tourist activities in this area, but community capability to perform the required activities needs to be built.

VI-Environmental Regulations on the Colorado River Delta

Implications of Environmental Regulations in the Hardy/Colorado River Wetlands

National environmental laws and international agreements regulate the Colorado River delta. In this way, the Hardy/Colorado wetlands become an issue of international concern.

Since 1992, the Colorado River delta was recognized as part of the Western Hemisphere Shorebird Reserve Network (WSHRN,1998). In March, 1996, the delta was listed as a Ramsar Site (The Ramsar Convention Bureau, 1998b). By this means, México agreed that every management and restoration plan to be applied in these ecosystem should consider as it's main strategy, the conservation and wise use of these wetlands.

The Tripartite Agreement on the Conservation of Migratory Birds and their Habitats and the North America Waterfowl Conservation Act derived from the North American Waterfowl Management Plan. By this means, Canada, the United States, and México established the path toward the wise use of the delta's natural resources. This will mean not only habitat restoration, but public involvement in the protection and wise use of wetlands and associated wildlife.

The laws, agreements, and programs share a common problem; delta's people are not aware of them. Frequently, national programs are known only by name, so local people do not know what kind of support is available, nor who and where to contact. Environmental law enforcement is difficult to implement, therefore the final goal of wise use of the delta's natural resources is difficult to achieve.

State and local land use planning and environmental laws lack of publicity, of adequacy to rural social conditions, of natural resources availability, and of economic activities present in the area.

The National Water Commission, the governmental agency that controls water in México, has complete authority to decide the future of wetlands, as they control the levees and water diversion among several users. This condition should be changed.

Hardy/Colorado wetlands are subject to laws and international agreements that consider Colorado River water as a resource apart from the ecosystem, which it is not. In fact water is part of the whole ecosystem; therefore, the ecosystem should be considered as another user of water. This should be included in every law and agreement in force.

México's water allotment was planned in 1944. 54 years later, water scarcity is a great problem in the delta, as human settlements in México have increased, and the Hardy/Colorado River wetlands have diminished, affecting not only wildlife habitat, but also opportunities of local communities that depend on wetlands functions and values. Intensive water controls have also affected marine fisheries in the Gulf of California, fisheries decline and salinity levels increase. Therefore, a new allotment should be negotiated, and international agreements need to be updated in order to restore damaged wetland and marine habitats and satisfy local communities needs.

Further Issues and Opportunities.

The Binational Program for the Sustainable Use of Water

The Binational Program for the Sustainable Use of the Water for the Lower Basin of the Colorado River (PUSARC) has been proposed by The Biosphere Reserve of the Upper Gulf of California and Colorado River Delta to the International Boundary and Water Commission in the United States (IBWC) (Barrera, 1997).

This projected program highlights the environmental and ecological aspects of the Colorado River that should be considered, and includes four basic components: The promotion of the social participation on planification and sustainable use of

its water stream; water allocation should satisfy the basic needs of the delta region, which imply the negotiation of water supply; the establishment of a permanent minimum flow for the Cienega de Santa Clara and a minimum flow for the delta and to the sea; and finally, recognizing the environment as another user of the river stream and allocation of its water to support the delta's ecosystems (Barrera, 1997).

System of Wildlife Management Units (SUMA's-Sistema de Unidades de Manejo Ambiental)

The National Program for Wildlife Conservation and Rural Productivity Diversification 1997-2000 enables the establishment of a System Wildlife Management Unit (SUMA), which will be conformed by public, private, or common holding land (i.e. ejidos), where production will be regulated to ensure the wise use of its resources and an appropriate habitat management program.

Management of each UMA within the Colorado River delta will result in the conservation of wildlife and natural habitats, reducing illegal commercialization of species at risk, alleviation of poverty levels in rural communities through the wise use of its resources, and increasing rural social welfare without natural resource depletion.

VII-Outreach Program

Getting people involved and educated in a process of a "Community based initiative for wetland restoration, which validates the environment as another user of the Colorado River water flow," is the long term foundation on this project. The program seeks for the communities to assume responsibility and change behaviors on water uses. This principle on community commitment is the leading policy of the outreach program.

Leadership in restoration should take place through the involvement of 20 communities with more than 36,000 people who have a direct stake in the current state and future of the Hardy/Colorado wetlands. However, the outreach program will begin with three pilot sites with those communities who still live upon the traditional uses of the environment: outdoor recreation and tourism in Campo Mosqueda; fishing and hunting in the Cucapa region; and enhancement of water quality in the Hardy/Colorado confluence area. A supportive, educated and active community will be the stronger support of future scenarios.

Strong collaboration nexus have already been built with several organizations, regarding conservation and wetland restoration along the Colorado River delta. These initial agreements bring the project under a myriad of opportunities, including: binational dialogue; a long term vision and continuity (trascending Mexican governmental administrations); and a multidisciplinary multicultural background.

Delegation offices of the Mexicali municipality visited include Cerro Prieto, Colonias Nuevas, Estación Delta, Guadalupe Victoria, and Venustiano Carranza. All delegates were interviewed and their immediate recommendations, priority actions, contacts and collaboration opportunities enlightened us to proceed with community workshops for the identification of improvement opportunities for environmental conditions.

VIII-Management Opportunities and Recommendations

Conservation of the delta ecosystem is threatened by several actions proposed in the United States, which would impact the flow of water across the border. First, the flow of agricultural drainage water into Cienega de Santa Clara is scheduled to be diverted to the Yuma desalting plant, which would replace the flow to the Cienega with concentrated brine (Glenn *et al*, 1992). Second, off-stream storage projects have been proposed to capture some of the flood water that currently enters the delta in wet years (Anonymous, 1997). Third, the delta ecosystems are not included in a multispecies conservation program designed to protect endangered species on the Lower Colorado River riparian zone (Worthley, 1998).

The treaties governing water allocation between the United States and Mexico did not incorporate environmental considerations, hence water management and environmental agencies in the United States take the position that their responsibility for ecosystem protection essentially ends at the international border (United States Bureau of Reclamation, 1996). However, scientific ecosystem management principles to which United States agencies subscribe (Christensen *et al*, 1996), require that an ecosystem such as the Lower Colorado River must be considered as a whole, including both the river and its delta. It is essential that water management and environmental protection agencies in both the United States and Mexico develop mechanisms for binational monitoring and protection of the delta ecosystems, and with a strong community support, a bi-national long term committment is required.

Restoration Opportunities

During this decade, the Colorado River delta wetlands are for the first time perceived in terms of

environmental management, and the governmental agencies and society are finally appraising the importance and values of these areas (Payne *et al,* 1992, Morrison *et al,* 1996; Briggs and Cornelius, 1997).

The opportunity to restore wetlands in the delta is now feasible since upstream water impoundments are filled and flood flows are once again being directed to the delta; however effluent waters must be relocated to the wetlands rather than to evaporative basins. These wetlands can be maintained and restored through effective management of such residual flows and other non conventional water sources within the delta.

The sustainable use of water seems more feasible considering all the research done, which has identified key concepts and supports economic prosperity while maintaining ecological integrity. One of the most important opportunities regarding this concern is the increasing number of people motivated who share the desire of a sustainable future, and who agreed upon how this might take place (Barrera, 1996; Morrison *et al*, 1996).

Potential Areas for Restoration and Management in the Colorado River Delta

Potential areas for restoration and management were selected according to their habitat value, the urgency and importance of their environmental problems, and the presence of local people that use wetland resources and that are willing to protect them and use them wisely. Efforts and management strategies described will be part of the next steps in this process for the restoration of the Colorado River delta ecosystem.

Campo Mosqueda

Campo Mosqueda is a private owned tourist camp, located along the banks of the Hardy River. They use the river for recreational activities including swimming, water skiing, and fishing. Other activities include agriculture, aquaculture, and recreational hunting. This area has high salinity levels, as well as high selenium concentrations, which can be a hazard to wildlife and human activities. Hence, further analysis in this area should be carried out in order to determine safety conditions for these activities, to identify safety recommendations for the use of this water, and to identify activities for the improvement of water quality for both, humans and wildlife.

Cucapá El Mayor & Cucapá Complex

Cucapá El Mayor is the main population settlement of the native Cucapá tribe. It is located aside the Colorado River, just after its confluence with the Hardy River. Land tenure is held by the community, in an ejido-type organization.

This stretch of the river has water flowing permanently, however most of the time remains shallow. This condition makes the river difficult to use. Management efforts in this site will be focused in the restoration of river stream capacity for flowing and storing water, as well as to function as a navigation canals. Reduction of the concentration of contaminants and salts can be accomplished by replacing standing water. Also, efforts will be established to improve the socio-economical status of the Cucapá community, and to restore their culture as one of the best wetland resource users.

Colorado River Delta Riparian Corridor

This site is located in the north-western area of zone 4, in between the levees among the locality of Francisco Murgía at the Railroad Crossing, and Col. Carranza, at the road through the levees. This area supports the largest dense stands of cottonwoods and willows in the Lower Colorado River Basin, which have been established by flood releases during the last 15 years. Human activities are very limited inside this area. Activities include fishing and swimming in certain river spots, hunting and wood utilization are also carried out. Land ownership is federal.

The main environmental concern is the lack of a perennial source of water. Efforts will focus on trying to establish the minimum flows of water and the frequency required to sustain these wetlands. Also, alternate sources of water during non-flood years will be considered to be used. Finally, water management regimes to support the riparian habitat, using a dedicated cross-border river flow, will be defined.

Pescaderos River

This site is located between the Colorado Complex and the Hardy River. Pescaderos is an old Colorado course, which main sources of water are agricultural drains. This river crosses several ejidos, and there are a few communities settled at its side.

In the northern part, it is used mainly for agricultural drainage purposes, but at it's southern part, it is used for fishing and hunting by local communities. Pescaderos also has selenium problems, and since it is being a source of food for local people, further analysis should be done to determine the safety of these activities, and to identify alternative solutions.

Campo Sonora - El Mayor

Campo Sonora is located aside El Mayor, a side channel of the Hardy River that has been used as well

for agricultural drainage purposes. The main activity is tourism. Other human activities include hunting and fishing. Potential for eco-tourism is high, but there is a lack of infrastructure and institutional capability to perform this activity.

Selenium is one of the threats of Campo Sonora - El Mayor, which is increased because this river does not have an outflow to the Colorado River, since it ends at the levee, where it forms two small lagoons that function as evaporative basins.

Efforts in this area will be focused in the re-establishment of the river flow into the levees to the Colorado, and to establish water management practices to flush away selenium. Also, the eco-tourist activities will be supported through the improvement of local capabilities.

Wildlife Management Units (UMAS)

Efforts could be focused towards the implementation of a System of UMAS (described in the Environmental Regulations section).

The main factors that suggest this strategy as a suitable management tool for the area are:

- This zone has been heavily modified.
- Resource uses (water and soil) are intensive.
- The tendency of users and governments is to have a total domain over all the river issues.
- With the units, it will be possible to have areas for wildlife conservation, and to diversify human activities.

Local communities considered in which the units could be established (ejidos, tourist camps, and native Indian communities) will have the responsibility and rights over the management and use of these resources.

Water Allocation

For the restoration of the Rio Hardy Wetlands, three major potential sources of water were identified: Water coming from the Colorado River, waste water from Mexicali, and agricultural runoffs.

a) Water from the Colorado River

In order to make this water useful for wetland restoration, it is necessary to implement management strategies for its control, as the maintenance of certain flow of water for the environment, and guarantee a minimum amount of water for critical seasons.

b) Waste water from Mexicali

The city of Mexicali has a waste water treatment plant, after which water is discharged in the Río Nuevo, route to the United States. A bi-national project is being established in order to increase the capacity through the Mexicali II plant, to a maximum of 3.06 m^3/s, which means 96 million cubic meters per year. The possibility of using some of this water for environmental purposes should be carefully assessed.

c) Agricultural waste water

Agricultural drains could represent, and historically have been, the main and most perennial source of water for these wetlands.

Water Management

Now that dams upstream are filled, it is expected that periodical flood releases will be part of the normal operation of the dams during wet years. If these releases are properly managed, in coordination with waste water management in the Lower Mexicali Valley, they can become a valuable resource for the restoration and development of the Hardy/Colorado Wetlands.

The present results suggest that modest annual flows could maintain and perhaps enhance the *Populus – Salix* habitat in Zones 1-3, whereas occasional pulse flows every 4 years, similar in magnitude to the 1997 releases could sustain the larger area of habitat including Zones 4 and 5. An annual maintenance flow of 4.0×10^7 m^3 should be sufficient for Zone 1-3, while the magnitude of the 4-year flood should be at least 4×10^8 m^3 based on 1997 results. On an annualized basis, the flow required for maintenance of delta ecosystems calculates to be 1.3×10^8 m^3/yr cycle, which is less than 1% of the base flow in the river. The results show that important ecosystem functions in an arid river delta can be protected and maintained by only a small amount of the native river flow, supplemented with "poor" quality water unsuited for human use, such as agricultural return flows.

Water management needs to include the canalization of more water to flush away selenium and other contaminats, and the management of the evaporative basins, to get inflows and outflows to prevent higher concentrations of selenium. These strategies would also prevent the accumulation of salts that inhibit growth of native vegetation.

As functions and values of the Hardy/Colorado wetlands provide benefits that do not consider political boundaries, management and restoration should be seen as a shared responsibility. Therefore, support from international, national, state, and local environmental laws, programs, agreements need to be adapted under a comprehensive regional approach.