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Information Database and Local Outreach Program for the Restoration of the Hardy River Wetlands, Lower Colorado River Delta, Baja California and Sonora, Mexico

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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 x 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

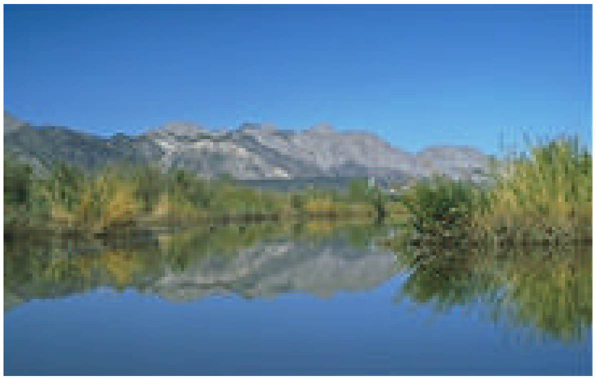
Now that dams upstream are filled, it is expected that periodical flood releases will be part of the normal operation of the dams during wet years. If these releases are properly managed, in coordination with waste water management in the Lower Mexicali Valley, they can become a valuable resource for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

I-Introduction



Conservation challenges of the threatened wetlands in the Colorado River Delta, have been identified in the design of the project "Information System and Local Outreach Program for the Restoration and Management of the Hardy River, Colorado River Delta, Baja California and Sonora, Mexico", and this assessment triggered guidelines for restoration through planning and management of both aquatic and terrestrial components in the area. This is a binational effort, in which academic institutions, governmental agencies and NGO's are collaborating, including ITESM Campus Guaymas, University of Arizona (UofA), Pronatura Sonora, Environmental Defense Fund (EDF), the Mexican Ministry of Environment, Natural Resources and Fisheries (SEMARNAP), state and municipal agencies and local communities.

The Hardy/Colorado Wetlands comprise the largest brackish wetland in the Colorado River Delta. Surrounded by desert, these wetlands provide critical habitat for resident and migratory waterfowl, shorebirds, wading birds and fisheries. Due to dam construction on, and diversion from, the Colorado River has virtually no free-flowing water that reaches the delta nor the Gulf of California, except in extremely wet years. This situation has caused several ecological damages, including the reduction of total wetland area in 95% at the end of the 80's, the invasion of non-native species, and the reduction of critical habitat for endangered species.

These wetlands, located in the western portion of the delta, are currently managed under a waste-water outflow perspective, rather than through a riparian habitat restoration strategy. The latter approach could be a strategy to maintain and restore wetlands through effective management of residual flows and non-conventional water sources. The quantity, quality, and timing of all water potentially available to the wetlands is being identified.

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.

The outreach program is intended to create a kind of association among technical experts, educators, communicators, and all those people who could be affected by the program. The outreach program for the Hardy/Colorado Wetlands restoration started by identifying present human activities in order to build a participatory process for the selection of restoration sites and processes. This phase allowed us to document the importance of restoring these wetlands; look at feasibility and safety considerations, and present this information to decision makers and stakeholders.

Data on the delta wetlands compiled through this project were integrated with information on other critical resources in the area, as a basis for evaluating the needs and opportunities for maintaining and restoring biodiversity, ecological functions, and sustainable economic activities in the Colorado River delta and Upper Gulf of California. The needs and resource users information have been used by a binational consortium of groups and organizations already mobilized to remove institutional barriers to wetland restoration throughout the Colorado River delta. Hence, this project has been a key technical element for a coordinated action agenda towards wetland restoration.

The next step is the implementation of three wetland-management demonstration sites, which will allow Mexico and the United States to establish participatory management techniques for restoring riparian habitat, improving water quality, maintaining and increasing wetland functions and values, as well as establishing a coordinated policy-management structure for multi-institutional and binational participation in the ecosystem management of the lower basin and Colorado River delta.

II-The Process

The work focused on the production of digital cartography and integration into a GIS, evaluation of human activities in the Mexicali Valley, identification of potential management alternatives, and design and implementation of an outreach program. A significant component of the project was the integration of the biological, hydrological, and water chemistry information, as well as habitat assessment alternatives in the Colorado River delta for the identification of potential restoration sites.

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. The project operated in collaboration with the federal offices of SEMARNAP in Baja California and Sonora, the Biosphere Reserve of the Upper Gulf of California and Colorado River Delta Office, the Baja California Ecology and Development State Agency, the Environmental Office of the Mexicali Municipality, the Municipal Delegations (municipal administrative autonomous subdivisions) in the Colorado delta wetlands, Cucapa Tribal Authorities, research/education institutions that are involved with these wetlands systems, like the Autonomous University of Baja California (UABC), The College of the Border (COLEF), the California State University, the Sonoran Institute (SI), the Pacific Institute, the International Sonoran Desert Alliance (ISDA), and the University Museum.

Specific tasks in the project included:

- Integration of a Geographic Information System (GIS) of the Colorado River delta, with the following data layers:
    - Topographic map.
    - Thematic maps, including soil type, climate, and hydrological basins.
    - Human settlements with demographic and socio-economic attributes.
    - Land ownership.
    - Surface and ground water, including cannals and drains.
    - Vegetation and habitat index.
    - Wetland areas and potential restoration sites.
- Set up of a local outreach program with the following components:
    - Identification of stakeholders, related government agencies and officials.
    - Identification of critical issues as related to local communities.
    - Identification of means and tools for public participation in the management process.
- Analysis of water quality from different sources including:
    - selenium
    - cations and anions
    - salinity and total dissolved solids
    - dissolved oxygen
    - pH
- 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.

2.1 Integration of the Geographic Information System (GIS)

The GIS component has been developed through an integrative process of information gathering, in order to generate an information system that supports management and restoration processes.

The GIS development included the definition of the geographic extent of the system, design of metadata, identification of existing information sources, and database integration.

a) The System

The information system was designed and developed based on two scales, for regional level (1:250,000) and for local level (1:50,000), according to the information requirements for restoration and management of the Hardy/Colorado wetlands.

Boundaries of the proposed study area were selected according to the habitat limits and the information requirements for different activities.

The regional level comprise the Lower Colorado River and Delta Basin, including the cities of Mexicali, San Luis Rio Colorado and Yuma, as well as the New River Basin, the Mexicali Agricultural Valley, regional human activities affecting the delta, and the wetland water sources influence area. This level of detail sets the geographic dimension for an integrative evaluation of the Hardy/Colorado influence area.

The local level includes the Hardy River, Pescaderos River, and the western side of the Colorado River delta region along with the surrounding agricultural zone. It is defined with more detailed geographical, biological, environmental, and socio-economical information, so it can be used for management assessment. A minimum influence area from the river up to 5 km around it was considered, which will allowed to trim the population data that affects wetlands more directly.

Certain sites were defined by the presence of water sources, namely a cannal or drain. Their selection and the site assessment were criteria for identification of potential wetland restoration areas within the Colorado River delta. This information is based on the field work and the specific characteristics of each sites. These sites are for the design and testing of a restoration methodology, as well as the baseline for the outreach process, focusing on a participatory process for the selection of objective restoration behaviors, and provide a conceptual framework for management efforts.

b) Spatial Information Acquisition

The primary source of spatial information in Mexico, is the Instituto Nacional de Estadística, Geografía e Informatica - INEGI (National Institute of Statistics, Geography and Systematic Data), for Thematic maps, available only at a 1:250,000 scale including: Vegetation and Land Use, Soil Science, Geology, Ground Waters, Surface Waters and Climatic Effects for the periods of January to May and June to December. The maps from INEGI, available at 1:50,000as the largest resolution scale, with sections of 870 km^2 each, were used for development of the base map in the GIS, and as source of spatial information.

Other maps were obtained from different government agencies were also used, including charts from the National Water Comission (CNA), Secretary of Human Settlements and Public Works of Baja California (SAHOPE), and the Coordination Office of Municipal Delegations (administrative municipal subdivisions).

INEGI has also an aerial photography archive of the Colorado River Delta Region, which has two sequences for the study area; the oldest series from 1973 with color photograph at a 1:33,000 scale. The other sequence from 1990 is a black and white format, scale 1:75,000, which covers all the basin of the Hardy River. More recently, the United States Geological Survey (USGS) and INEGI flew the U.S.-Mexico border to adquire 1:40,000 color infrared photography, but those were not available for distribution.

Other sources of spatial information were considered; satellite imagery obtained from a time series of images resulted from the "North American Landscape Characterization" (NALC). These images are Landsat Multi Spectral type, resampled at 60 m resolution of pixel size. These time series include a set of images from 1977, 1986 and 1992. The images were facilitated by the IMADES, and correspond to the collaboration between the ITESM and the IMADES in the NALC Project. However, a higher pixel resolution suggested the need to use Landsat Thematic mapper (TM)-) Images. Two Landsat TM satellite images were purchased from EarthSat Corp. for the Hardy/Colorado Wetlands region, from February 21, 1997, and July 15, 1997. These images were used to develop the vegetation maps and the identification of riparian habitat.

c) Data Capture

Data capture was done on digitizing tablets 40" x 30" in a PC plataform, and using AutoCad 13 software. All hardcopy maps from INEGI are in the Universal Transverse Mercator projection system (UTM) based on a Clarck's spheroid of 1866, and datum NAD 1927. Maps from other sources and based on other projections were georeferenced and projected into UTM.

d) Data Integration and User Access

Information gathered was integrated into the GIS including changes in the hydraulic constructions and the rivers in the area, potential restoration sites, water quality and human activities.

Digitized maps were imported and formatted into PAMAP-TERRASOFT software. This system has translation routines with many other programs, and offers several modules for information analysis.The final GIS integration was done using ArcView 3.0, in order to have a more common package for display and query used by different laboratories and governmental agencies, and a visual tool for management and restoration support, as well as to have the opportunity to prepare a simplified version that could be used with

ArcExplorer, a “shareware” software for map querying.

As support for the different activities of the project, data within the GIS is available in tabular and spatial formats, data conversion to meet user needs became a standard procedure to promote its access among different sectors involved.

2.2-Field Trips

To accomplish the project goals, eight field trips were conducted. During these field trips, government agencies, research centers and universities were visited in order to get information from the Colorado River delta, to establish collaboration links, and to start the outreach component at this level.

During field work, information was gathered on water flows and water quality; ground truth sites for vegetation classification; and habitat use and taxonomic composition of waterbird communities.

Positions were obtained using three GPS receivers (Magellan Pro Nav 5000, Magellan 200 XL, and Garmin II Plus), a photographic file of the area was developed, and the trips were recorded using video camera. Interviews within local communities for the outreach program also took place during field trips.

Oblique videos were filmed on three overflights of the delta at 1000-1500 m before (May, 1996) and during flood events (February and September, 1997). On each flight the entire flood plain from Morelos Dam to Montague Island in the Gulf of California was filmed.

Eight ground surveys were conducted in February, March, July, September, October, November, 1997, and January and March, 1998, during which all points in the flood plain accessible by vehicle or small boat were inspected (see table 1). On each survey, species composition and relative abundance was determined at numerous sites throughout the delta.

Field trips within the delta require revisiting of monitoring sites, maintaining contact with local communities, and considering climmatic effects and river flow management to access wetland areas. In total, during field trips, 8,000 km were travelled by car and 450 km by boat, and 85 people were contacted, during 41 days invested

Table 1. List of field trips carried out during the project.

Trip	Date	Participants	Activities performed
1	24/Feb/97 - 05/Mar/97	ITESM, UofA, EDF, Pronatura, SI.	Meeting, ecotourist assessment, vegetation surveys, flight survey, visit to desalting plant, water sampling, outreach with local communities and governments, information gathering in Mexicali.
2	19/Mar/97 - 20/Mar/97	ITESM, UofA.	Vegetation analysis, flow surveys, water sampling.
3	07/Jul/97 - 14/Jul/97	ITESM, UofA, Pronatura, SI.	Vegetation analysis, water sampling, road trip in the Hardy/Colorado area, outreach activities, and information gathering in Mexicali.
4	19/Aug/97 - 23/Aug/97	ITESM, UofA.	Flow surveys, water sampling, vegetation analysis, boat trip.
5	03/Sept/97 - 04/Sept/97	ITESM, UofA.	Preparation of TV documentary, aerial survey, vegetation analysis, water sampling.
6	27/Oct/97 - 01/Nov/97	ITESM, UofA, Pronatura.	Institutional meeting, water sampling, road trip, vegetation analysis, outreach activities, information gathering in Mexicali.
7	13/Nov/97 - 15/Nov/97	ITESM, UofA, Pronatura.	Binational conference, water sampling, outreach activities, information gathering in Mexicali.
8	11/01/98 - 15/01/98	ITESM, UofA.	Boat trip, salinity survey, outreach activities.

2.3-Human Activities Evaluation

In order to document and assess human activities, information gathered through visits to government agencies that are related to economic and cultural activities and human settlements. Also, the Delegation Offices were visited. INEGI data were integrated, including maps, population and human activities census, and the Mexicali Municipality Information Books.

Visiting government offices in the Mexicali Civil Center, local universities, and research centers of Baja California, yielded significant information about population, regional and local socio-economical status, local environmental policies and regulations, land use, water use and natural resources use, including maps, graduate thesis and internal unpublished governmental reports.

During field trips, human activities were recorded and evaluated, and the information was complemented with interviews of land and river users.

2.4-Outreach Program

Activities of the project involved gathering and exchanging information among various groups and individuals about the Hardy/Colorado River area, its history, problems and possible solutions. It included several field visits, interviews, consulting with government agencies, conferences, workshops and contacting other individuals who are working in the area or are knowledgeable about wetland restoration. All these activities involved making contacts and sharing information among distinct individuals and groups with the purpose of building trust and making presence for a solid base of the Outreach Project.

The design of the Local Outreach Program consisted of:

- Identification of local stakeholders.
- Surveying stakeholders regarding their present and past land use, their perceptions of the restoration potential for these wetlands and their willingness to participate.
- Conduction of an information campaign of public involvement and awareness.
- Dissemination of information concerning the importance of the Colorado River Delta Wetlands among decision takers, policy makers, stakeholders, and wetland users.
- Involvement of local governmental agencies and community leaders in the restoration process.
- Establishment of collaboration nexus with other agencies, NGO´s, research centers and universities working in the area.
- Participation and promotion in regional and binational workshops, conferences, and meetings regarding the restoration and management of the Colorado River delta ecosystem.

2.5-Vegetation Analysis

Vegetation and potential wildlife habitat value of the Colorado River delta was inventoried for first time since the resumption of flows, in order to determine the potential habitat value of this stretch of river in relation to the upstream stretches in the United States, where current conservation efforts are focused. We conducted field work in 1997 and early 1998, when modest water flows were released to the delta; hence, we were able to observe the vegetation response to flows of known magnitude. This information was essential to identify the quantities of water needed to sustain the delta ecosystem.

a) Delineation of the flood plain

Watercourses and the extent of flooded soils were mapped through a process of manual interpretation and screen digitizing, based on February 21, 1997 satellite image taken when the river was flowing at 100 m^3/sec. The accuracy of the interpretation was checked by overflying the delta at 1,000 m on February 27, 1997, and ground truth sites review

b) Vegetation Mapping

We used satellite imagery, low-altitude aerial videography and ground surveys to map the vegetation by biomass intensity and species composition. We measured biomass intensity based on a spectral analysis of a July 15, 1997 satellite image which was taken during a period of no river flow, following winter releases of approximately 4.0 x 10^8 m^3. Preprocessing and geometric rectification of the image were provided by EarthSat Corporation.

Vegetation was analyzed using a combination of vegetation index image and unsupervised clustering to yield a preliminary map of vegetation communities. The Normalized Difference Vegetation Index (NDVI) was calculated according to Tucker *et a.* (1983) and Marsh *et al* (1992). The Soil Adjusted Vegetation Index (SAVI) was calculated according to Huete (1988). Interactive extraction and comparison of NDVI and SAVI values for selected sites of known vegetation cover in the delta supported the use of SAVI for stratifying the image before running unsupervised clustering techniques. The SAVI image generation yielded a range of values from -0.3787 to 4.801 which were stratified into four classes. The lower range (-0.3787 to -0.1160) comprised open water areas, while the small band of values from -0.1126 to -0.0992 corresponded to area of *Distichlis palmeri* (saltgrass) cover confined to the intertidal zone. The remaining value were divided into two broad classes. The first comprised the remaining in combination with bare soil. The final category encompassed all the positive SAVI values, which included combinations of tree, shrub and understory riparian vegetation, as well as emergent marshland vegetation. The two SAVI classes were individually subjected to unsupervised clustering which yielded 20 clusters each. One cluster in each class was vegetation associated with open water; these corresponded to emergent marsh areas. We recognized two marsh classes: W1, associated with the higher biomass-intensity SAVI class. The remaining clusters were associated with riparian vegetation and were grouped into two subclasses per SAVI class. The four resulting classes were indicative of constrained, relative biomass levels, each broken into two spectrally similar subclasses. These riparian vegetation classes were designated R1, R2, R3 and R4, where R1 was the highest biomass-intensity class and R4 the lowest biomass-intensity class.

The satellite image did not cover the 10 km of river immediately below Morelos Dam. This stretch of river was classified based on inspection of low-level aerial photographs (scale 1:6,000) taken July 31,1997, supplied by the United States Bureau of Reclamation, Yuma Projects Office, Arizona. The vegetation along this stretch of river was dominated by thick, nearly homegeneous stands of *Salix goodingii* which we assigned to the R1 vegetation class. We used the aerial photographs to determine the area of the flood plain covered by *S. goodingii*, bare soil or lower intensity vegetation (species composition undetermined) using a planimeter .

We correlated the biomass classes with specific plant associations based on aerial and ground surveys. The aerial and ground observations were compared to vegetation classes determined by spectral analysis of the satellite image. The intertidal zone was further surveyed by boat during periods of flooding (March, 1997 and January, 1998). Plant associations in the wetlands of the eastern delta were determined by vertical videography and ground surveys in previous studies (Zengel *et al*, 1995). Taxonomic designations of plants follow Felger *et al* (1997).

2.6-Water Flow Assessment

Data for the hydrological analysis included:

- Daily and monthly summaries of flow at the Southern International Boundary (IBWC Station No. 09522200) on the Colorado River, 35 km downstream Morelos Dam, of a 20 year period, from 1977 to 1997, provided by the International Boundary and Water Commission (IBWC), at Yuma, Arizona.

- Mean flows and salinity of the main agricultural drains in the area, from 1995 to 1997, provided by CNA-Baja California Office.

- Data of inflows and outflows of the Hardy/Colorado Wetlands, which were measured during the field trips carried out on March and August 1997, at different stations. Flows were determined by measuring the surface flow speed via timing of drifters and the speed at depth using a flow meter. Cross-sections of water sources were also measured.

Data generated and collected were used in the evaluation of vegetation response during pulse floods and in the identification of water requirements for the maintenance of the Colorado River delta ecosystems. This data is also useful in the identification of preliminary considerations for wetland restoration strategies, and for the development of a long term monitoring plan for water flows in the Hardy/Colorado Wetlands.

2.7-Water Quality Analysis

a) Selenium

Selenium levels were measured in samples of water to determine if concentrations of this contaminant represent a risk to wildlife and the communities of the Hardy/Colorado Wetlands, and to identify preliminary considerations to evaluate if bioaccumulation of selenium represents a hazard to the flora and fauna of the Colorado River delta ecosystem.

Water sampling and analysis followed USEPA (U.S. Environmental Protection Agency, 1980) and Arizona Department of Environment Quality (ADEQ, 1995) procedures.

Sampling stations are located along the Hardy/Colorado Wetlands, and were selected according to their accesibility, the presence of a source of water, evaporative basin, river flow or tidal influence water, and to cover representative sites in the delta.

Water samples were collected at each of the sites on July 7, 1997 and August 20, 1998. At each station, water temperature, dissolved oxygen, salinity, and pH were measured. Temperature and oxygen were measured with an oxymeter (Yellow Springs Instrument model 55), salinity with an electrical conductivity (EC) meter (Yellow Springs Instrument model 32), and pH with a field meter. Location was determined with a Global Positioning System (GPS) unit (Magellan 200XL).

Water was collected in 1 L, nitric-acid washed, plastic bottles. Immediatly after collection, the sample was filtered and withdrawn into an acid-washed plastic bottle, containing 0.1N HNO_3 to acidify the sample to a pH <2. Surface sediments were collected into wide-mouth, acid rinsed plastic bottles from an area of approximately 1 m^2. Samples were transported to the laboratory in an ice-filled cooler.

The samples were analyzed in the laboratory of Soil, Water & Plant Analysis of the Department of Soil, Water and Environmental Science of the University of Arizona. The method 200.9 was used for the determination of trace elements through atomic absorption (Creed *et al*, 1994), using graphic furnace atomic absorption spectrophotometry (GFAA) (Perkin-Elmer Model 503).

Quality control/quality assurance (QC/QA) procedures for selenium included: a) the analysis of the samples in the GFAA by triplicates, b) the digestion and analysis of one laboratory reagent blank and one duplicate for each batch of 12 samples of the same matrix; c) the analysis of one reference sample, and d) one spike procedure for each matrix.

b) Salinity

To complement the data collected along with the selenium samples, other samples were analyzed for salinity on July 7, August 20-22 and November 14, 1997, using a HACH - TDS Meter and a handheld refractometer (America Optical), in order to obtain a more precise overview of water salinity distribution on the Hardy/Colorado Wetlands.

Also, the effect of river flow on salinity in the intertidal and marine zone was determined on January 12, 1998 during a river flow of 202 m^3/s. Water was sampled from a small boat during low tide and salinity was measured using a handheld refractometer (America optical).

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

3.1-Localization and Description

The natural ecology of most of the world´s large river systems has been disrupted by dams, flow diversion, channelization of the river bed and alteration of the riparian zone by agricultural activities (Dynesius & Nilsson, 1994; Nilsson & Dynesius, 1994; Nilsson *et al*, 1997). Arid rivers are especially at risk due to their modest base flows and the many human demands on their waters (Stanley & Warne, 1993; Snead, 1997; Leichenko & Wescoat, 1993; Hart *et al*, 1990). The Colorado River is the main source of water for the desert region of the southwest United States, northwestern Mexico, and the southern California coastal plain.

Its delta, the last portion of one of the most human-developed rivers, is still the largest desert estuary in North America, which provides a critical interface with the marine ecosystem of the Upper Gulf of California. The delta basin covers 7, 085 km^2 (1.11 % of the total river basin area), with 185 km of river stream. Historically, it has supported vast riparian, freshwater and brackish wetlands, which are uniquely valuable due to their high productivity compared to the surrounding desert ecosystems. The Colorado River Delta is the result of one of the greatest accumulations of silt in the world. In pre-development conditions, the river carried a large load of sediment toward the sea, with an average of 380,000 tons a day (Carrier, 1991; INEGI, 1995; Glenn *et al*, 1996).

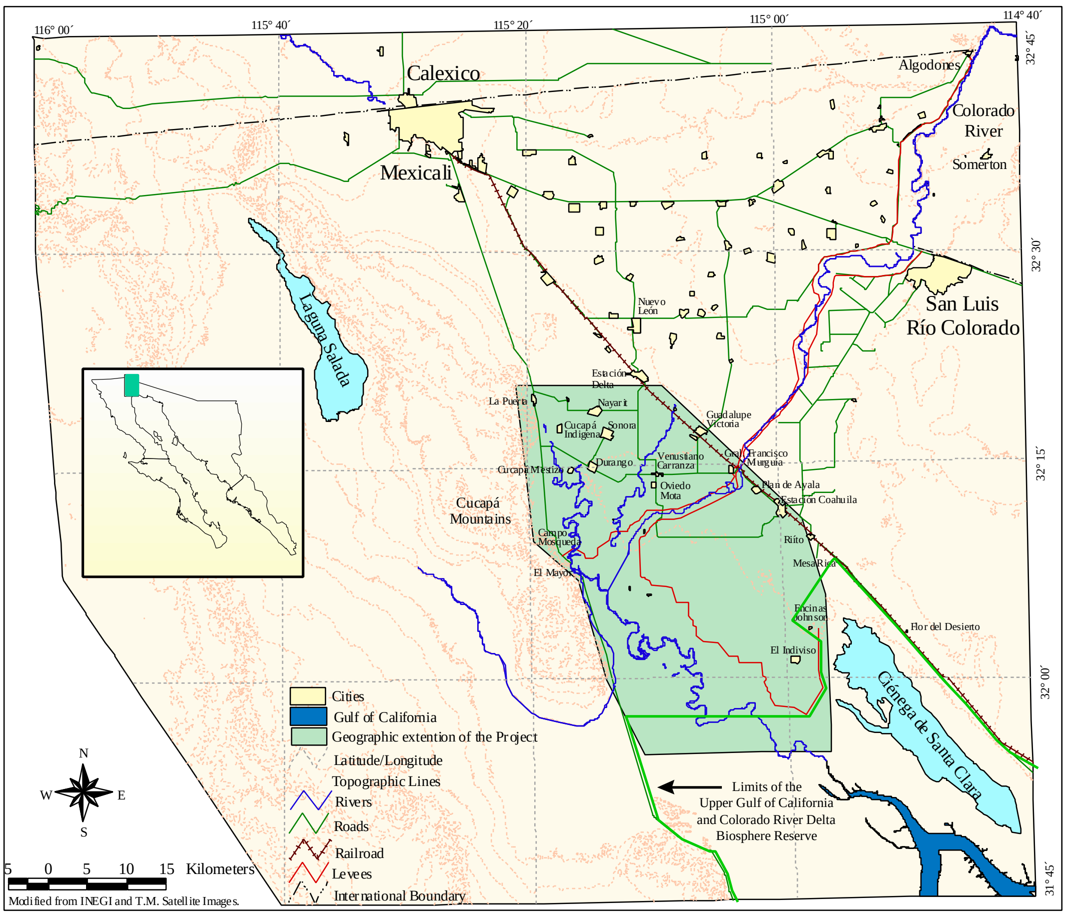
The river water, from its birth to the delta, travels more than 2,730 km, with a gradient of more than 3,000 meters. It carries an annual volume of 18.5 thousand million cubic meters, of which 10 % are allotted to Mexico. At present day, the Colorado River supports more than 23 million people, 21.5 million 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).

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 (see Figure 2). Downstream, the river joins with the Gulf of California, in front of Montague and Pelicano islands. Upstream, the river supports extensive agricultural valleys, as well as major cities, heavy industries and hydropower generation, in the Lower Colorado Basin States (Arizona, California and New Mexico). Further up in the Upper Colorado River States (Wyoming, Utah, Colorado and Nevada), just after it's birth in the Rocky Mountains, the river is tamed by a series of dams and reservoirs, including Glen Canyon Dam, which is considered one of the biggest engineering accomplishments of human kind, and also, one of the biggest mistakes of development (Reisner, 1993; Morrison *et al*, 1996). The Colorado has earned the reputation as the most legislated, litigated, and debated river in the world (Fradkin, 1984; Carrier, 1991; Glenn *et al*, 1996; Morrison *et al*, 1996).

The last part of the river has also been developed, conforming the Irrigation District No. 14 in Mexicali, Baja California, and San Luis Rio Colorado, Sonora. This district consists of a network of cannals with a total length of 2,902 km, and 1,662 km of agricultural drains. The agricultural area covers about 250,000 hectares of land with irrigation rights, from which 207,000 are actually being used, with a total utilization of 2,483.27 million cubic meters/year of water (2 million acre feet/year), which comes from the Colorado River and from underground waters (INEGI, 1995; CNA, 1997).

Fig 1. Agricultural fields in the Mexicali Valley.

Figure 2. The Colorado River Delta,
Baja California and Sonora, Mexico



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Information Database and Local Outreach Program for the Restoration of the Hardy River Wetlands in the Lower Colorado River Delta, Baja California and Sonora, Mexico

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The Mexicali Valley is of great importance for Baja California, since 95 % of the agricultural activities of the state are concentrated in this area (Dirección General de Ecología, 1995), which is only 3.5 % of the total surface of the state.

Most of the region's aquatic resources are also concentrated in this area: the water used in the Mexicali Valley represents 88% of the total water used in the state of Baja California, and the water coming from the Colorado River is 52 % of the total water available for the entire state (Dirección General de Ecología, 1995). This numbers highlight the importance this river has for the economy and development in the state.

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. Natural habitats in the delta include riparian wetlands, extensive floodplain woods, salt marshes, interior tide channels, and arid areas considered of high ecological and economical value.

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 (see Figure 3). These wetlands provide critical habitat for several endangered species including the desert pupfish (*Cyprinodon macularius;* Varela-Romero *et al,* 1987; Abarca *et al,* 1993) and the Yuma clapper rail (*Rallus longirostris yumanensis;* Eddleman, 1989; Abarca *et al*, 1993), and for migratory and wintering waterfowl along the Pacific Flyway (Eddleman, 1989; Payne, 1992). The estuary and marine regions of the delta provide habitat for the totoaba fish (*Cynoscion macdonaldii*) and vaquita porpoise (*Phoceana sinus*), both endangered species (Morales-Abril, 1994; CONABIO, 1997). These wetlands have been declared as a Ramsar site, within the World Network of Relevant Wetlands for Aquatic and Migratory Birds, due its importance for migratory waterfowl and shorebirds (The Ramsar Convention Bureau, 1998).

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, in the Delegations of Cerro Prieto, Estación Delta, Guadalupe Victoria, Venustiano Carranza and Colonias Nuevas, of the Municipality of Mexicali, Baja California, Mexico.

The Hardy River, a tributary of the Colorado River, has two tributaries hitself El Mayor, which has virtually been transformed into an agricultural drain, and Pescaderos, once a meander of the Colorado River, which still has important areas that support wildlife but is also used for agricultural run off.

The Hardy River travels through 26 km, joining the Colorado River downstream, from where they go another 95 km to the Gulf of California. This conforms a basin of more than 35,000 hectares, that were covered before the agricultural development of the valley and the large dams construction by extensive areas of riparian vegetation, dominated by cottonwood (*Populus fremontii*), cattail (*Typha domengensis*) and willows (*Salix goodingii*), surrounded by dense forests of mesquite (*Prosopis* spp.), and arroweed (*Pluchea sericea*), and transitioning into a plain at the southern end where is influenced by tides from the Upper Gulf of California.

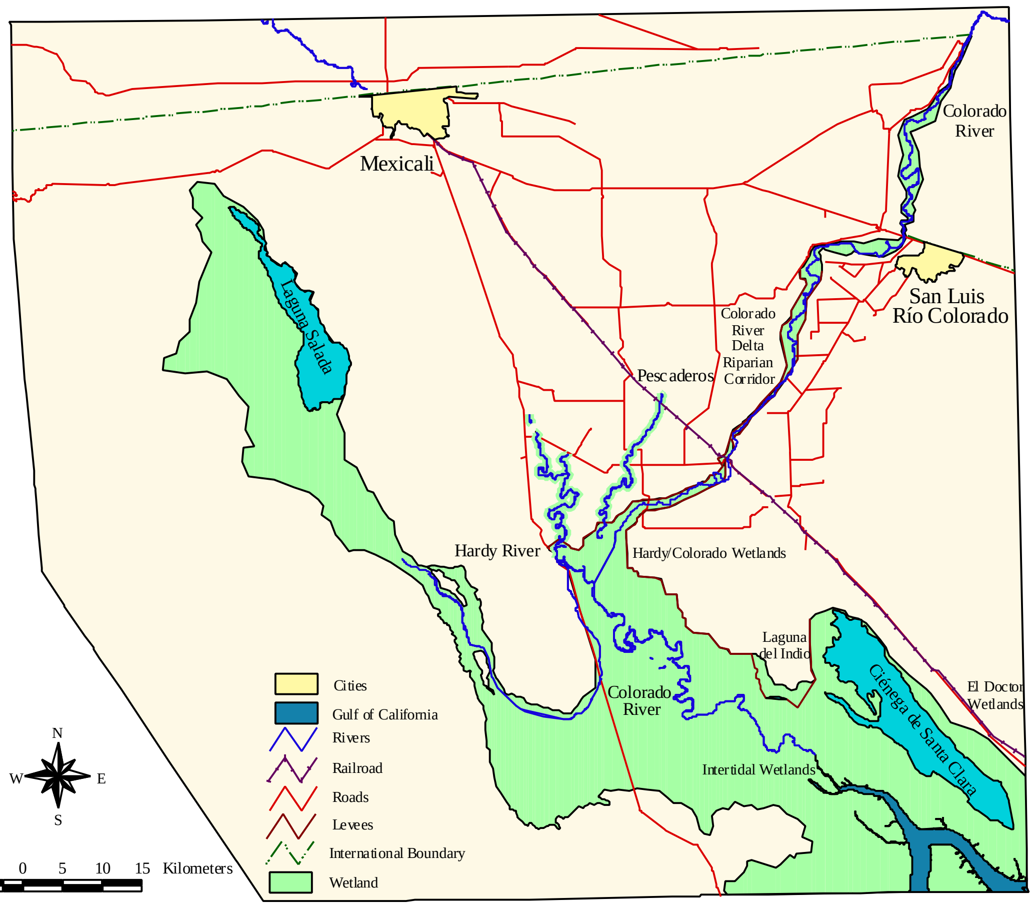
The geographic extent for this project was delimited in order to include the historical and present wetland areas, and the socio-economic influence area for the wetlands, covering in total 224,000 hectares (see Figure 2). It is located within the Hydrological Region No. 7-Colorado River, in the Colorado River Basin and the Bacanora-Mejorada Basin. In the Colorado River Basin, the area extent covers part of Hardy River, Colorado River, Pescaderos River and Lower Colorado River sub-basins. In the Bacanora-Mejorada basin, the study area covers part of the Bacanora-Monumentos sub-basin (SPP, 1981) (see Figure 4).

3.2- 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; some of the impacted areas have recovered their original functions and values as they are flooded again.

Wetlands of the Hardy/Colorado River became apparent after the 1930's floods in the delta (see Figure 5), when a natural dam or sandbar 35 km upstream from the ocean blocked the exit of water from the western delta. When the river was active, such blocks were seasonal, because the next flood event either reopened the channel or created a new outlet elsewhere in the delta (Glenn *et al*, 1996; Morrison *et al*, 1996).

Figure 3. Wetlands of the Colorado River Delta



Modified from INEGI, CNA, and T.M. Satellite Images.

ITESM Campus Guaymas. CECARENA/UIB. 1998.

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Figure 4. Hydrological Basins of the Colorado River Delta

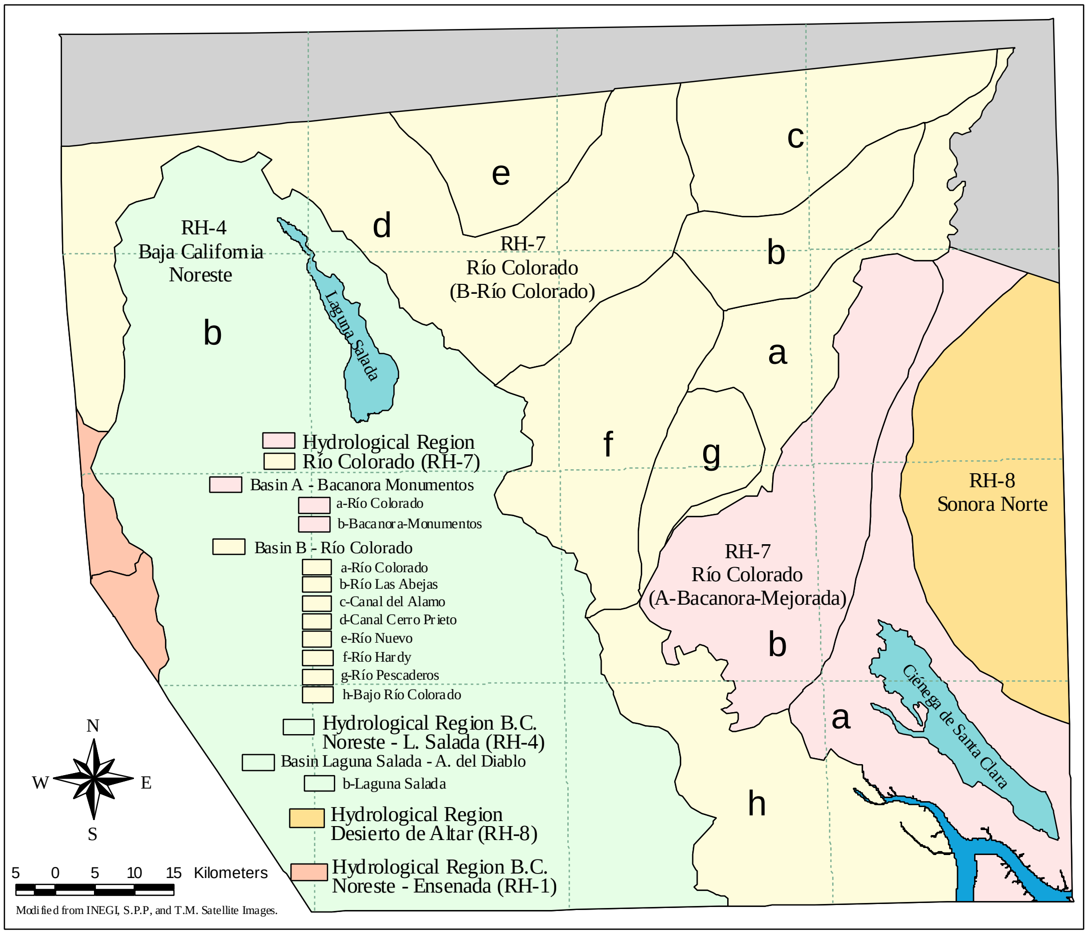

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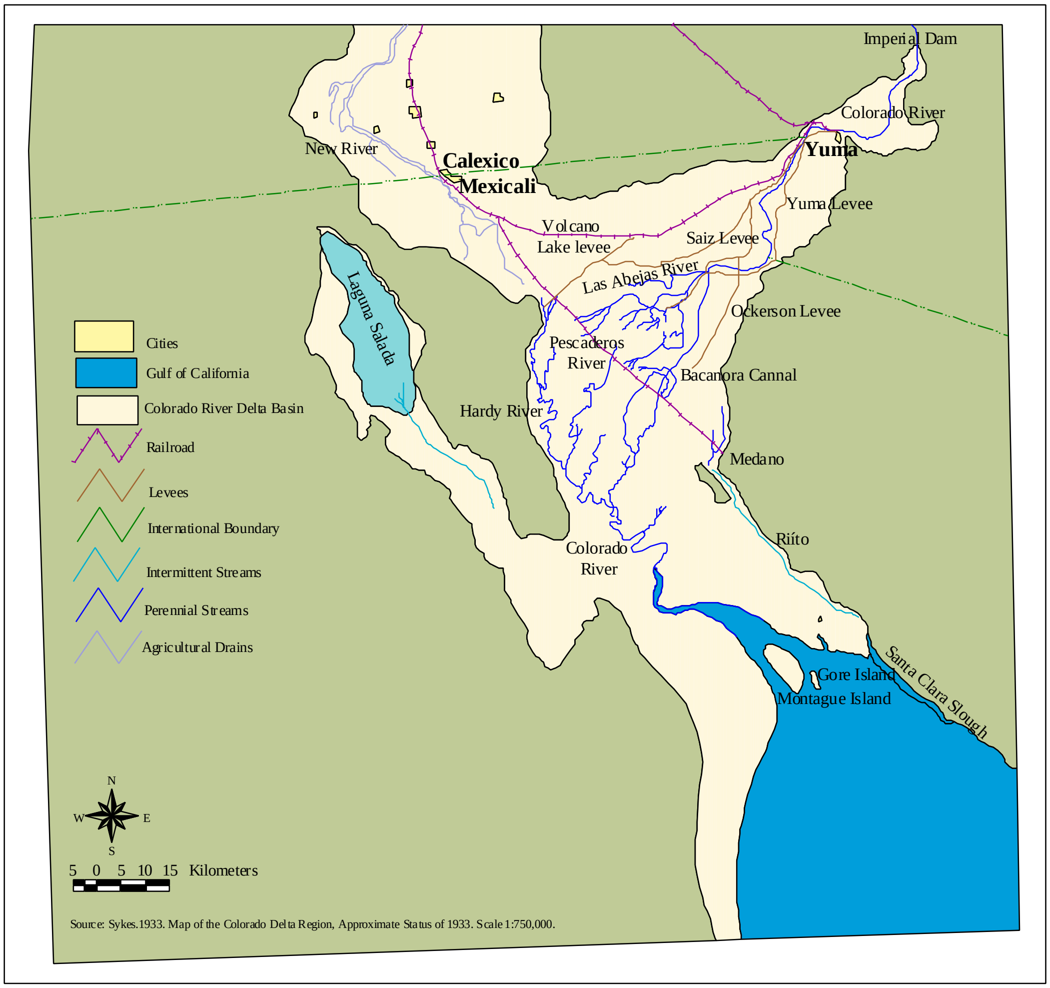
Figure 5. The Colorado River Delta in 1933



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By 1937, however, Hoover Dam was completed and Lake Mead began to fill. Then 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 during this period. It was supported by approximately 130 million cubic meters per year of agricultural return flows from the Mexicali Valley (about the same volume that currently enters the Ciénega de Santa Clara).

The return flows were augmented by geothermal discharge from wells, and other minor sources of water. Though brackish, the wetland supported large areas of emergent vegetation, riparian habitat, migratory and resident waterfowl, endangered species, Cucapá fishing camps, and waterfowl hunting areas (Velez *et al*, 1978; 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 that had backed up the water inflows, and the wetlands began to be drained (Glenn *et al*, 1996; Morrison *et al*, 1996).

As an emergency plan during the floods, water began to be diverted from the southern end of the Colorado River via a cannal to Laguna Salada, the last water diversion from the Colorado River (Fradkin, 1984). The intention was not to drain the Hardy/Colorado Wetlands, but to create a brackish lake that would support fishing and tourism in Laguna Salada (CNA, 1997), similar to what already existed in the Hardy/Colorado Wetlands. The great lagoon was filled with water and supported native wildlife while there was fresh water entering the delta. After the floods the effort failed.

Figure 6. Cannal to the Laguna Salada.

The imported water augmented by flood flows, became hypersaline in the Laguna Salada, which functioned as an evaporative basin, and then scarcely supported wildlife. Most of the time the Laguna Salada is a dry salt flat, and the cannal helped to drain some of the wetland areas during the last years of the 80's (Glenn *et al*, 1996; Morrison *et al*, 1996; CNA, 1997).

Nevertheless, the wetland area has expanded considerably during flood periods, as during the 1992 floods on the Gila River (Glenn *et al*, 1996), and as in 1997, when the Laguna Salada filled again, functioning as a reservoir for fish and habitat for water birds, covering about 10,000 hectares.

The Cucapá community owns the rights over the Laguna Salada, and they intend to establish some restoration and management practices in order to create a suitable area for wildlife and to make a sustainable use of those resources (Monica González, pers. communication).

During the years of intense floods in the 80's, and considering that all the dams along the Colorado River were nearly filled completely and thereby lost their capacity to control water excedents, CNA constructed protection levees on each side of the Colorado River banks to prevent the floods in agricultural lands (CNA, 1997) (see Figure 2).

Flood control structures in Mexican Territory start with the Ockerson levee (right bank of the river), that is 36 km long, from Morelos Dam to Colonia Pescaderos. The Yuma levee conforms the left bank, with 29 km long and located in U.S. territory. The west edge was continued from Colonia Pescaderos, following the Colorado River, and separating from the stream bed south of Vado Carranza, to the Sierra El Mayor, with a total length of 58 km, crossing the Hardy River near Colonia Independencia.

The east bank extends 95 km from the old levee, near Colonia Hidalgo, and continues parallel to the river, downstream of Vado Carranza, where it separates from the river, and ends in the Santa Clara Drain.

There 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, preventing the sea water tidal intrusion to agricultural lands, and they have also been the delimitation margins between human developed areas and wilderness areas. The area potentially subject to restoration in the Hardy/Colorado wetlands is mostly surrounded by these levees, covering 60,000 hectares.

3.3-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) but it was temporarily dewatered by the construction of upstream impoundments (Fradkin, 1981; Richardson and Carrier, 1992), and has been altered during this century by human activities in the Mexicali Valley.

A substantial flow reached the river's mouth at the Upper Gulf of California. This flow not only replenished the delta with silt, but also delivered nutrients that helped support fish and other life forms in the sea. 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).

Since the filling of Lake Powell in 1981, however, occasional flood releases, ranging as high as 1.6×10^{10} m^3/yr in wet years on the watershed (according to data provided by IBWC) have reestablished an active flood plain from Morelos Dam south to the intertidal zone in the Gulf of California.

An additional source of water began entering the delta from the United States in 1977, with the discharge of brackish (2-3 g/l total dissolved solids, TDS) agricultural drain water from the Wellton-Mohawk Irrigation District in Arizona, into the eastern part of the delta (mean flow of 1.7×10^8 m^3/yr; Burnett *et al,* 1993); this water supports the Cienega de Santa Clara, a large *Typha*-dominated wetland adjacent to the intertidal zone (Glenn *et al*, 1992; Zengel *et al,* 1995). Local agricultural drainage of variable volume is also discharged into the delta.

Even in their current threatened state, the delta wetlands are still the largest in the Sonoran desert, providing important resting and feeding grounds for a variety of shorebirds, including peeps, black-bellied plovers, dowitchers, marbled godwit, willet and american avocet. A survey in 1992 counted more than 160,000 shorebirds of 10 different species (Western Shorebird Reserve Network, 1993).

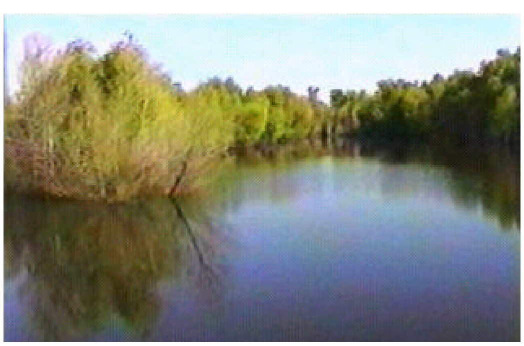


Figure 7. Riparian Habitat of the Colorado Delta.

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, including waterfowl as a relevant animal component. 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.

The Hardy/Colorado wetlands, when flooded, are a major stopover station for waterfowl (Brown 1985). White-fronted goose, lesser snow goose, brant, northern pintail, least bittern, white-faced ibis, snowy plover, long-billed curlew, blue-winged teal, and canvasback could be found in these wetlands.

Several species of egrets, sandpipers, avocets, cormorants, ducks, and seabirds as pelicans, seagulls, and terns are also common in these wetland. In the surroundings, it is common to see desert birds such as quails, pheasants, roadrunners and owls. Eddleman (1989) concluded that this area had the highest populations of migratory and non-migratory waterfowl and shorebirds in the Colorado area.

Several mammals also inhabit these wetlands, including raccoons, skunks, several species of bats, coyote, bobcat, muskrat, rabbit, jackrabbit, and other small animals such as desert rats, gophers, and squirrels. The fish community in the Hardy/Colorado River, as in the whole Colorado River, has been heavily modified. The species commonly found are catfish, carp, tilapia, mullet, and big-mouth bass. Most of the native species are sparsely found, but there are still some important populations of desert pupfish in some backwaters lagoons and cannals (Varela-Romero *et al*, 1987).

The reptile community is more related to the surrounding desert ecosystems, but these animals also use and inhabit the wetlands due the availability of food and the presence of water. The area is a refuge for 5 endangered species (totoaba, vaquita porpoise, bobcat, desert pupfish and Yuma clapper rail), 5 threatened species (Herman's gull, yellow footed gull, elegant tern, reddish egret, and peregrine falcon), 3 with special protection (brant, house finch, and mocking bird), and 1 rare specie (great blue heron), according to the Mexican Environmental Regulations on legal species status (NOM-059-ECOL-1994).

3.4 Functions and values

Some of the ecological functions that the Hardy/Colorado Wetland Complex have include: being one of the most important remnant habitats for wildlife in the Colorado River Delta; providing a winter refuge for migratory waterfowl; it also provides nesting, reproduction, breeding and nursing sites for a great number of organisms, including birds, mammals, fishes and diverse invertebrates, and being a transition zone among the area of intensive human activities in the Mexicali Valley, and the protected area of the Biosphere Reserve of the Upper Gulf of California and Colorado River Delta.

Values associated with the Hardy/Colorado River Wetland Resources are: it has been a traditional fishing and hunting area for both Mexican ethnic groups and U.S. citizens, who have used the area for recreational, commercial and daily consumption fishing; local residents, including native Cucapas, work as hunting and fishing guides, and they also obtain other benefits from the wetlands such as firewood, building materials and diverse food.

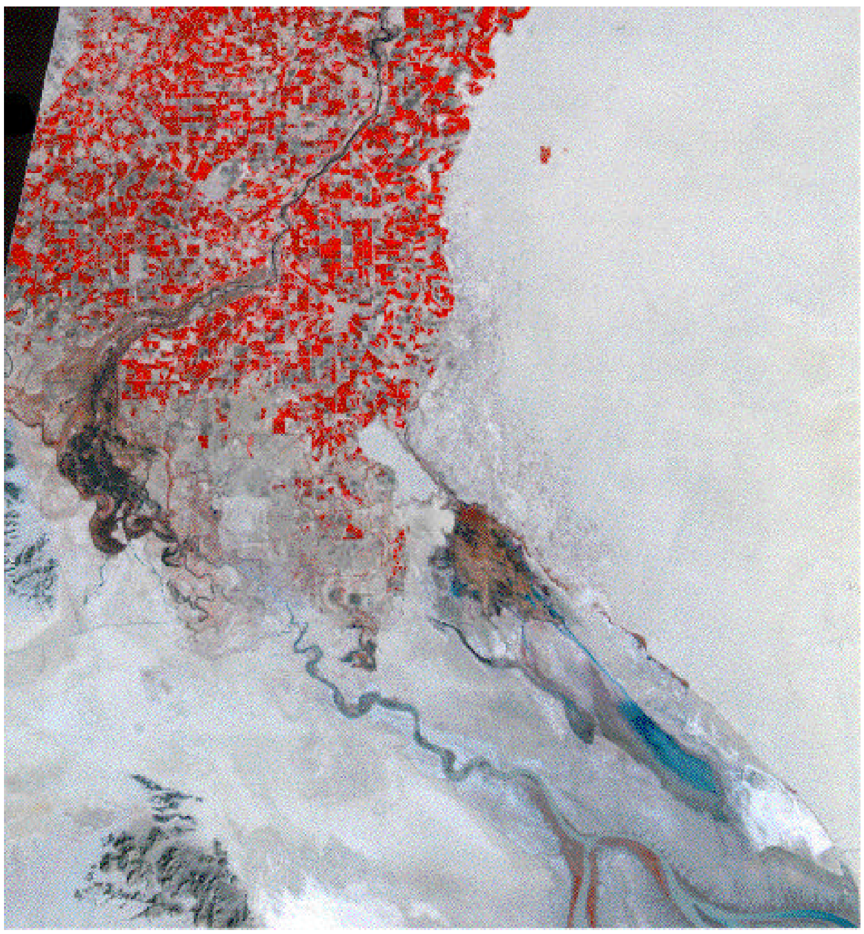


Figure 8. Satellite Image of the Colorado River Delta (July 15, 1997, Landsat T.M.)

IV-Historical Changes

All changes observed during this century along the Colorado River, and especially in the delta, are the result of water management practices within the Colorado ecosystem. Major emphasis has been directed to the total water management and control, for agricultural and urban purposes, as well as for flood control and hydropower generation. In all water policies, treaties, minutes and laws, the river's environment has never been considered as another user. In all these years, the Colorado River Wetlands have survived using "borrowed" and "second hand" water.

4.1-Hydrological Changes

The Colorado River is considered the most heavily plumbed water systems in the world. The river is controlled by 20 dams, which have stressed and transformed the aquatic ecosystem over the past 65 years. This impact has caused important environmental differences from its pre-development conditions, including sediment balance, water temperature and flow, fish species composition, and riparian habitat and wildlife populations (Morrison *et al*, 1996).

The main six dams located in the Colorado River Basin have a total capacity of 80,445 million cubic meters (CNA, 1997) (see table 2). This volume is more than 4.3 times the annual flow of the Colorado River, and has impeded the river to reach the Gulf of California for several decades.

Table 2. Main dams located in the Colorado River Basin.

Dam	River	Maximum Capacity (Mm^3)	Elevation (Meters above Sea Level)	Operations starting year
Roosevelt	Gila	1,705	651.20	1911
Hoover	Colorado	35,200	372.20	1935
Parker	Colorado	800	137.60	1938
Imperial	Colorado	0	54.71	1938
Morelos	Colorado	0	32.80	1950
Davis	Colorado	2,243	197.25	1952
Painted Rock	Gila	5,959	212.30	1959
Glen Canyon	Colorado	34,538	1,131.00	1962

Source: CNA, 1997.

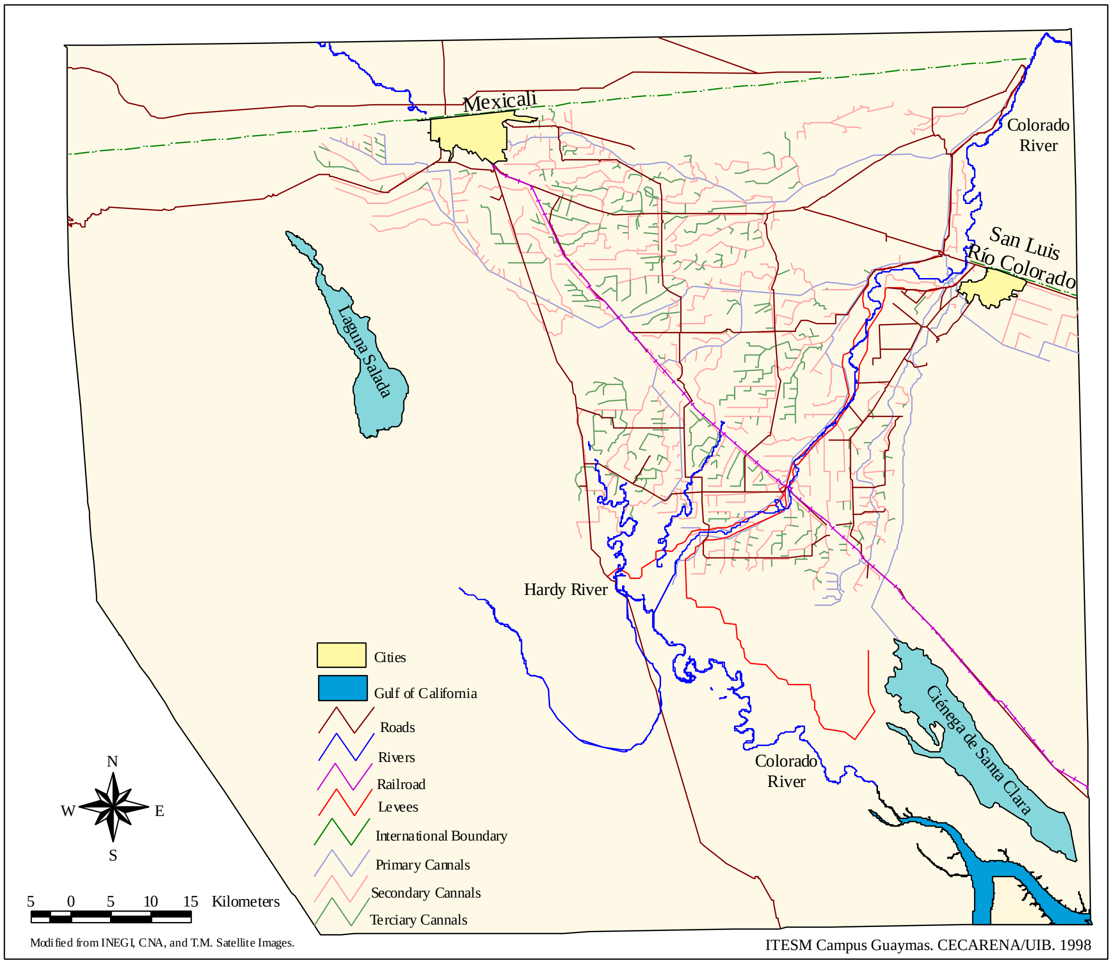
Once in Mexico, river development starts in Morelos Dam, on the Northern International Boundary, within the Mexicali Valley. There are four other minor dams, and the Sánchez-Mejorada Siphon, which is used by farmers in the left margin area to mix waters from the Yuma agricultural drains with water from Morelos Dam (CNA, 1997).

All of the Colorado water that Mexico receives during normal years (1,850 million cubic meters/year) is used for human activities; mainly for agricultural uses, but also for urban, domestic and industrial operations (Direccion General de Ecologia, 1995). Water from the Colorado is distributed in the Mexicali Valley in the network of cannals, which are spreaded in an area of 250,000 hectares (see Figure 9).

The Hardy River being one of the last portions of the Colorado River Basin has been used as a run off water reservoir; thus, its stream has not been directly modified by human activities (i.e. dams, cannals, hydropower generation) but it has been indirectly modified by the human activities developed in the surrounding areas (agriculture and urban development), and areas upriver (i.e. Hoover and Glen Dams).

The main hydraulic constructions in the Hardy River area are the flood protection levees previously described. Although five pumping stations are located along these levees, only two of these are still in operation.

Figure 9. Irrigation Cannals of the
Mexicali Valley, Colorado River Delta



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Information Database and Local Outreach Program for the Restoration of the Hardy River Wetlands in the Lower Colorado River Delta, Baja California and Sonora, Mexico

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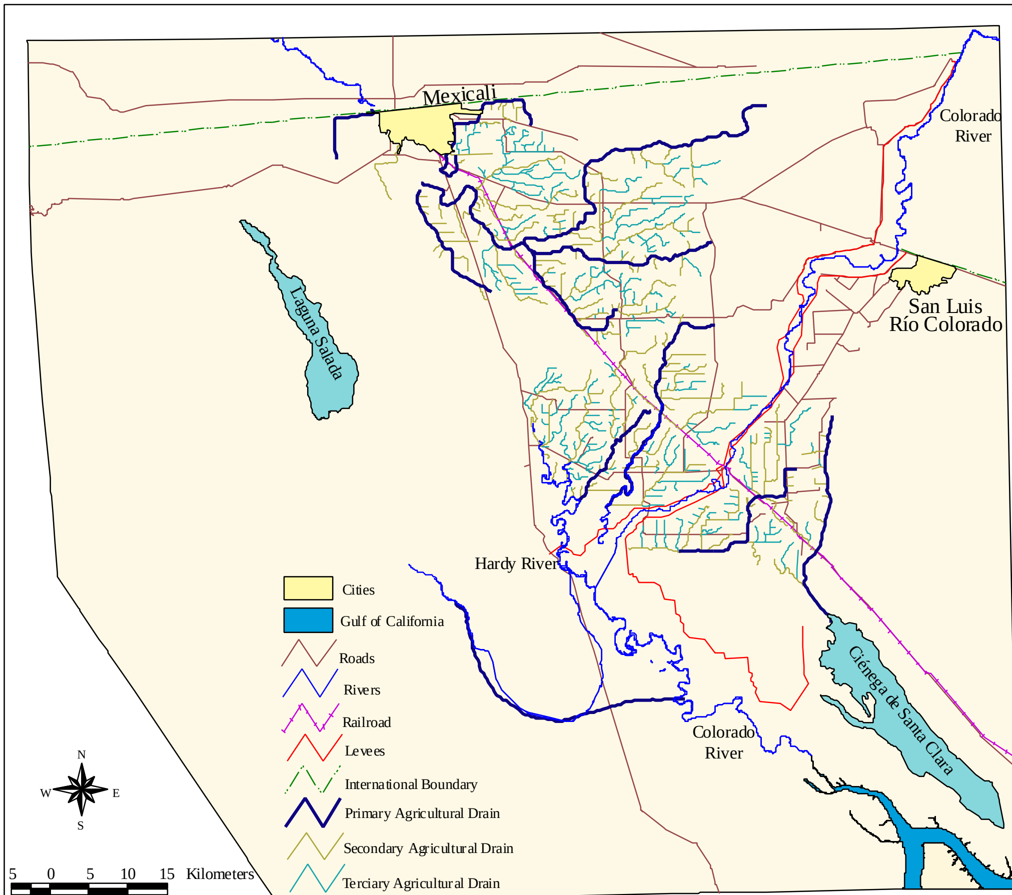
Figure10.Agricultural Drains of the
Mexicali Valley, Colorado River Delta



Modified from INEGI, CNA, and T.M. Satellite Images.

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The pumps were installed when the sandbar in the Colorado River maintained the wetlands flooded, keeping a higher water level inside the levees than outside, impeding the outside river flow from entering (upstream-downstream). The pumps moved the water inside the levees, in order to allow it to flow downstream. This issue should be considered if dam construction is going to be an effective restoration alternative for the Hardy/Colorado wetlands.

There are 17 agricultural drains (3 primary and 14 secondary drains) which flow directly into the Hardy/Colorado River System (see Figure 10). The Hardy River receives the direct discharge from 11 drains, in 9 sites. One is a primary drain (Dren Colector del Sur) and 10 are secondary drains (Cucapá, Mestizo, Nayarit, Mariana and 6 more without a name).

There are 5 drains that discharge in 2 sites along the Colorado Stream in this area. Dren Plan de Ayala is a primary drain, and Ortega, Camachito, Camacho and one without name are secondary drains. In the Pescaderos Stream there is only one drain flowing, the Dren Principal del Sur, which could be considered as the northern section of this tributary.

These drains bring agricultural wastewater from the Mexicali Valley Irrigation District. They carry an annual volume of 6.33 x 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).

Fig 11. Agricultural drain of the Mexicali Valley

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). When the drain water is mixed with that from the Colorado River, the quality of water that wetlands receive is suitable for the development of their functions and values; unfortunately most of the times, agricultural waste water is the only permanent and reliable source of water for the Hardy/Colorado Wetlands.

4.2-Habitat Changes

Figure. 12 Land use change in the Colorado River delta: former wetland areas has been transformed into agricultural fields.

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. Nevertheless, these ecosystems continue to provide important environmental and economic benefits to the region (Environmental Defense Fund, 1996; 1997).

On the lower Colorado River, from Davis Dam (below the Grand Canyon) to the international border with Mexico, flow regulation since 1937 has largely prevented overbank flooding which previously germinated seeds and washed excess salts from river banks (Briggs, 1996; Bush and Smith, 1995; Stromberg and Patten, 1991; Szaro, 1989). As a consequence, along most of the river, the native mesophytic riparian forest dominated by *Populus fremontii* (cottonwood) and *Salix goodingii* (willow) trees, has been replaced by drought and salt - tolerant shrub vegetation; the most common plant along the rivers is now an exotic species, *Tamarisk ramosissima* (saltcedar) (Ohmart *et al*, 1988). The dramatic decline of the native forest vegetation has reduced the habitat value of the riparian zone for much of the native fauna (Ohmart *et al*, 1988).

The Colorado River delta has been significantly modified from its natural conditions as well; 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.

Vegetation of the north-eastern portion of the Hardy/Colorado Wetlands supports one of the most valuable habitats in the Lower Colorado region, with dense stands of cottonwood and willow that have prevailed the droughts and intense floods in the delta. This stands are surrounded by saltcedar with arroweed, iodine bush (*Allenrolfia occidentalis*) and quailbush (*Atriplex lentiformis*) in disturbed areas (along roads, levees, and drains), which work as a buffer and transition zone to the non-disturbed areas. In the southern portion, where the tidal influence begins, vegetation is composed mainly by saltcedar with arroweed, common reed (*Phragmytes asutralis*) and cattail. This area could be considered the most disturbed zone of the remaining wetlands, because the increase in salinity due the tidal influence has displaced cottonwoods and willows, allowing saltcedar to establish freely. Further south, near the river mouth, the dominant vegetation is the endemic salt grass *Distichlis palmeri*, which covers extensive flood plains.

The influence of tides has gone further upstream in this century, because there is less fresh water coming down from the river that could counter act the effects of tides, causing habitat changes described. When there are water surplus to Mexico through the Colorado River, salinity levels are low, with 0 ‰ 10 km from the river mouth.

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. It has optimally occupied an environment disturbed by humans, to the detriment of native vegetation. Saltcedar was introduced to North America in the beginning of the XIX century as an ornamental and erosion control tree. Seasonally altered flooding regimes brought about by the dams and flood control structures along the river, have provided suitable conditions for its establishment, reproduction, and spread (de Gouvenain, 1996).

Saltcedar has several characteristics that contribute to its success in these ecosystems: when mature, they are remarkably tolerant to a variety of stress conditions, including heat, cold, drought, flood, and high concentration of dissolved solids. They can also survive in complete submergence conditions for as long as 70 days. This tree has an extensive root system, which also allows vegetative growth. Their flowering and fruiting cycles provide a continuos supply of available seeds, thus, they can exploit suitable germinating conditions over a longer period of time (DiTomaso, 1996).

It can resprout vegetatively after fire, severe flood or treatment with herbicides, and are able to accommodate wide variations in soil and mineral gradients. Saltcedar can survive in areas where groundwater concentration of dissolved solids approaches 15‰, and with a soils salinity up to 36‰, whereas growth of cottonwood and willow is inhibited by salinity greater than 1.5‰. A saltcedar tree exude excess salt crystals from opening in it's leaves. These salts are eventually deposited in the ground, sometimes forming a hard crust that inhibit the germination of native plants. *Tamarisk* species are also capable of extracting soil moisture from less saturated soils in areas with deeper water tables. This is an ability that most of the native vegetation from the Colorado Delta does not have (DiTomaso, 1996; Wiesenborn, 1996).

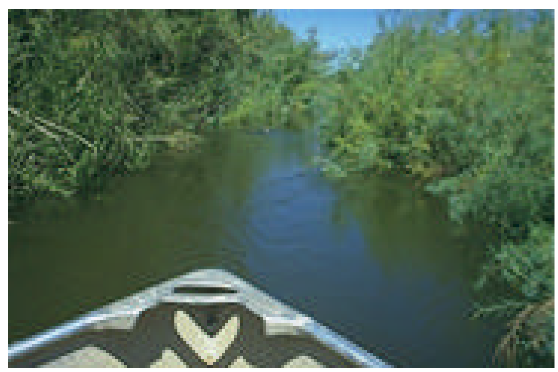


Fig 13. Saltcedar stands in the Colorado River Delta.

In the delta wetlands, the main problem is the competition of new saltcedar trees with new native riparian trees, in the areas where river conditions have changed because of increased salinity due to tidal influence, reduced flows, and river banks deforestation. Saltcedar trees grow faster under these conditions, becoming the dominant specie.

Dense stands of saltcedar have increased the maintenance cost of drains and cannals, because, in prevention of floods in pre-rain seasons, saltcedar stands are removed in critical areas along the Colorado River in the delta. These actions also cause damage to adjacent stands of cottonwoods and willows, with severe habitat loss along the river banks.

The invasion of saltcedar has also caused changes in bird life. Almost none of the cavity-nesting or other species dependent on cottonwood-willow habitat occur in these new saltcedar habitats. Only few species have apparently adapted well to the spread of saltcedar along the Lower Colorado River (Rosenberg *et al*, 1991). Nevertheless, several species, as white winged doves, can reach a maximum nesting density in saltcedar habitat, in areas surrounded by native vegetation (Rosenberg *et al*, 1991). Also, saltcedar stands were found with higher insect biomass than native riparian vegetation, but with less diversity. This suggests that the major food items in the diets of insectivorous birds corresponds to those available in saltcedar stands (Anderson, 1997).

It could be say that saltcedar in the Colorado River delta has become a dominant specie in extensive areas, not because they have inhibited the growth of native vegetation, but because this plant has the characteristics to survive, grow and reproduce under the new Colorado River delta scenario, with increased salinity, reduced perennial flows, and sporadic intense floods. In fact, they have provided habitat in areas that could not be covered by native vegetation.

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, such as closing of river cannals and reduction of the capacity of the main stream in specific sites; and to start an evaluation of possible benefits that can be obtained from saltcedar habitat by the local communities. This will help to protect native riparian vegetation stands adjacent to saltcedar, and to use wisely and consider the functions and values of these new type of human induced habitat in the Colorado River delta.

Dams in the Upper Colorado have trapped virtually all of the river's sediment load, leaving the river clear and green, thus the lower half of the river has been transformed into an erosive force, because little sediment is deposited to replace what the river carries away, causing sandbars and beaches to disappear. Instead of building the delta area, the river is now washing it away (Morrison *et al*, 1996).

The changes in the river have favored biological productivity in the Lower Colorado River, which is considerable higher than 65 years ago. This is caused mainly by the growth of algae, favored by the river clearness due to the lack of sediment, which allow the penetration of sunlight to considerable depth. The algae bloom serves as food for the introduced species that are well adapted to the river's new conditions. Thus, biomass production on the river is high, but diversity is low. Nevertheless, fish species composition of the Lower Colorado River is still one of the most unique fish fauna in North America, with 75 % of its 32 species recognized as endemic (Carothers and Brown, 1991; Minckley, 1991).

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, either purposefully or accidentally, to bring the total number in the Colorado Basin to about 80 (Minckley, 1991). Many introduced species both preyed upon and compete with the native species, and combined with the physical changes brought about by dams, have drastically reduced native species populations. Catfish and carp were introduced into the Colorado River drainage in the late 1800's, and by 1963 were the most common fishes in the river (Carothers and Brown, 1991). Rainbow trout replaced carp as the dominant species in the late 1970's, after Glen Canyon Dam created ideal river conditions for its expansion (Morrison *et al*, 1996).

This alteration has seriously affected the fish composition in the delta area, since the introduced fish constantly reach the area with water excedents released from the upper dams; also, marine species now are more commonly found in the area, due the increase of tidal effects.

The changes in the Colorado River System, specifically the 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).

But we have documented that 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.

Inspection of past satellite and aerial photographic images shows that delta vegetation has been created and maintained by water flows from the United States over the past 20 years (Glenn *et al*, 1996). For example, a 1972 series of aerial photographs showed that the riparian zone at that time was dominated by bare soil and widely spaced *Prosopis* trees. A satellite image from May, 1992, taken after four years without flow in the river, showed that high-intensity vegetation in Zones 1-5 (further described on Chapter V) was confined to the edges of river channels, whereas the present study, which followed a year of flow releases, showed that R1 vegetation occupied approximately 30% of the floodplain, and there was evidence of widespread seed germination of the native trees as well as *Tamarisk*. We conclude that the reestablishment of native forest species in Zones 1-3 has been a direct consequence of the return of overbank flooding below Morelos Dam since the filling of Lake Powell. 1997 and 1998 data show that peak flows of 100-200 m^3/s are sufficient to inundate almost all of the flood plain between the levees system below Morelos Dam and to significantly dilute the salinity of ocean water in the intertidal zone, whereas in the absence of flooding the marine influence extends 56 km upriver from the mouth (Payne *et al*, 1992).

4.3- History of Human Activities in the Colorado River Delta.

Vestiges of antique civilizations, such as stone-carved figures and tools, 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.

Their communities lied just beneath the Colorado River stream and between the Hardy River and the Cucapá Mountains. This geographic setting created the differentiation of two groups, the Cucapá from the river and the Cucapá from the mountains. The total population of indigenous people in the delta, at the arrival of Spaniards colonization was estimated at about 20,000 inhabitants (Álvarez de Williams, 1973).

In September 27th 1539, the first Spanish explorer, Francisco de Ulloa, arrived to the delta. In 1540, Fernando de Alarcón reached the Colorado River's mouth, and traveled upstream. In this year, indigenous groups from the Colorado River delta met colonizers, but because of the region's geographic characteristics, they continue isolated, preventing the establishment of missions (De León-Portilla, 1989). In 1541, Melchor Díaz reached by land the lowest portion of the delta, near what today is the city of San Luis Río Colorado (Jordan, 1980). Through 1701 and 1702, priest Francisco Eusebio Kino traveled within the region exploring it (Sánchez, 1990). In 1827, explorer R.W. Hardy visited the Gulf of California in search of corals and pearls, and traveled over the delta (Kunz, 1993).

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.

México signed the agreement called "Treaty of Peace, Friendship and Limits" with the United States in February 2nd 1848, under which the Colorado River was declared to be used for navigation purposes by U.S. citizens (Sánchez, 1990). In 1852, the boats "Sierra Nevada", "The Explorer", "Cucapá", and "Mojave" traveled the river from Yuma, Arizona down to its mouth in the Gulf of California (Sánchez, 1990). Because of the Mesilla Treaty, since December 30th 1853, 29 km of the river became international borderline. In 1877, navigation ceased when the South Pacific Train railway reached the area. On March 1st 1889, the International Border and Water Commission (IBWC) was created in order to resolve possible discrepancies between of the US.-México border and international waters located in between (SEP, 1987).

In 1892, the Colorado River Irrigation Co. began using the Colorado River water for agricultural purposes. Though it was until early in the 20th century when the Mexicali valley was born, on behalf of the beginning of the irrigation infrastructure of the lower portion of the Colorado River delta. Once the conversion of Alamo river was finished as a conductive water channel, the first human settlements were established in the northern part of the municipality (Sánchez, 1990).

The history of the Mexicali Municipality is related directly to the development of agriculture in the region. Many colonizers arrived attracted by the possibility of using land as agricultural fields. The proximity of irrigation systems and the confluence of the Hardy River with the Colorado River, impulsed the creation of the Mexicali Valley, as an important urban community sustained by agricultural activities.

During the 20's and 30's, governmental land expropriation (taken land legally from private owners for public interests) and distribution for agricultural activities, benefited Mexican farmers (Sánchez, 1990). In April 14th1936 the Colorado River Land Co. subscribed with the Agricultural Ministry of México, a colonizing contract under which this company agreed to sell 12,208 Ha of its land. As it was not the total of its land, several agricultural communities from Rancho Llamada, Estacion Delta, Pueblo Nuevo, and Colonia del Pacifico, formed the Farmer's Confederation, asking the government to turn the unsold land into common holding land (i.e. ejidos). This movement was known as "Asalto de las Tierras", or Land Assault, and with it, land expropriation activities in the delta were completed (Sánchez, 1990).

In 1939, the Colorado River Irrigation District began to operate, covering a total of 203,055 Ha (Sánchez, 1990). Of them, 176, 006 Ha are located in the Municipality of Mexicali, in the State of Baja California, and the lasting 27,049 Ha are located in the Municipality of San Luis Río Colorado, in the State of Sonora. Today, this irrigation district covers 250,000 Ha (Walther-Meade, 1991).

Several factors favored population growth in the delta region, and all of them were strongly related with the economic, social and political development, brought about by the Sonora-Baja California railroad construction. Morelos Dam completion was another important event in the delta's history, which began water diversion in 1950. Another important event was the expansion of the irrigation channel network system in the Colorado River delta during the 70's (CNA, 1997).

The Mexicali agricultural valley produced several grains and vegetables, but the most important product was cotton. Hence, as the Korea War raised the demand and price of cotton in the international markets, this agricultural valley was directly benefited.

Despite this prosperity in the 60's, two events turned back this growth. The first was the crisis in the agricultural valley originated by the higher salinity levels in irrigation water coming from the USA, and the second was the price-drop of cotton in international markets due to demand's contraction. These events originated migration of the agricultural valley's population toward the city of Tijuana.

Other problems appeared in the irrigation district. Most of the hydrologic infrastructure of water distribution and drainage was build without a general planning, making its maintenance economically unfeasible because users quotas weren't enough to cover real costs. This meant a loss of at least 50% of the irrigation water, and generated more problems such as the presence of high soil salinity levels and difficulties to move out drainage water (Ortega-Villa, 1991).

In response to this agricultural crisis, in 1968 the Mexican government began the rehabilitation of Mexicali's Irrigation District (Ortega-Villa, 1991). As part of this process, in 1973 several changes began:

- The irrigation area was concentrated in 250,000 Ha, which included the parcels with the best soil quality;
- 1,800 km. channel coating was done in order to distribute irrigation water without leakages;
- 1,500 km. of drainage channels were improved;
- 1,100 km of rural roads were built;
- 140,000 Ha were leveled;
- Improved Infrastructure of irrigation and its control, i.e. new irrigation wells were drilled.

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, caused by water releases from dams upstream (CNA, 1997).

Present Mexicali is one of the most important agricultural valleys in the country, the city has been growing, attracting other economic activities as industry and commerce, which have became Colorado water users too; and it has become an important social and industrial pole center in Norhwestern Mexico, in part due its close relation to cities in the United States.

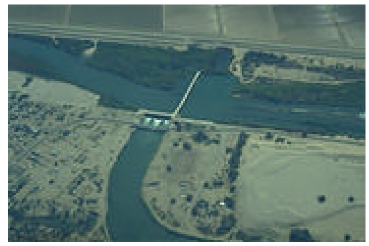
This region has been an example of development, but not of sustainable development. Resources have been controlled and used for the benefit of the new incoming population, letting aside environmental issues and native tribes, which are the traditional users of these lands and resources

V-Today's Conditions

5.1-Vegetation

The flood plain is the broad area along the river which was inundated during the 1997 flows, plus the wetlands in the southeastern delta which receive agricultural drainage water (Figure 3). The east and west boundaries of the flood plain are defined by a system of the earthen levees; at the southern end the flood plain empties into the Upper Gulf of California. The riparian zone is a narrow strip as it passes through the agricultural area in the northern part of the delta, then it widens at the confluence with the Rio Hardy. The river divides into numerous subsidiary channels in the wide zone, but these recombine into a single channel before the river reaches the sea. The main (navigable) course of the river was explored by running the river in a small boat during floods; but it is not wider than other channels.

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 (Figure 14). 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 glass, *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). Although it was never a dominant species, it was noteworthy that the mesophytic shrub, *Baccharis salicifolia* (seep willow), occurred as a bankside shrub throughout zone 1-4 (see table 3).



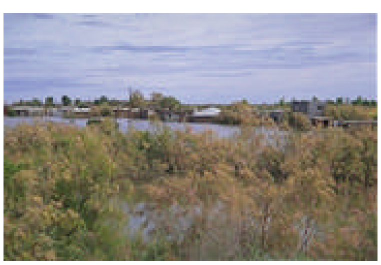
Zone 1, which extended for approximately 10 km south of Morelos Dam, was narrow and contained 170 ha (68 % of the area of flood plain) of dense thickets of *Salix*, most of which were below 4 m height with older plants reaching 8-15 m. Although *Populus* trees also were found along this reach they appeared only as isolated individuals. The vegetation consisted predominantly of midstory (0.6-4.5 m) plants with relatively little overstory or understory vegetation. Areas of flood plain not covered by *Salix* were occupied by bare soil (i.e., the river channel) or scrub vegetation dominated by *Tamarisk* and *Pluchea*.

Zone 2 was wider than zone 1 and included open water (or bare soil when the river was not running), channel-side and channel island riparian habitat occupied by *Populus* and *Salix*, and, on slightly elevated terraces further away from the channel, *Prosopis* shrublands. The R1 land cover class occupied 248 ha and had a high diversity of mid- and understory components in the R2-R4 classes, including 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 had a much higher proportion of R1 vegetation (1,232 ha or 25% of the flood plain), which was dominated by *Populus* with mid and understory zones dominated by *Salix* and *Tamarisk*. We classified the R1 vegetation as open gallery forest. Natural regeneration of *Populus* and *Salix* along parts of the Zone 3 reach was substantial. In some sections, carpets of seedlings of these species dominated near-channel areas, giving way to progressively older stands of trees on slightly more elevated areas. Seed germination, observed in July, 1997, was presumed to be in response to the 1997 flood releases. The presence of multiple age classes of trees shows that sporadic flow releases have produced conditions amendable to the regeneration and long-term survival of the native riparian species. The largest trees were up to 15 m in height.

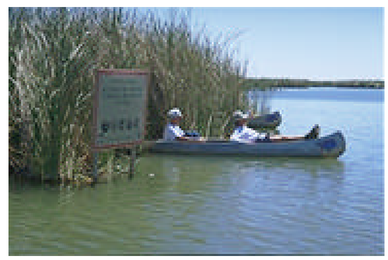
In zone 4, the flood plain widened and the river divided into numerous channels, oxbows, backwaters

and pond areas downstream of the confluence with the Rio Hardy. We were only able to inspect a small portion of this zone on the ground, due difficulty of access. The R1 vegetation was a mixture of plant associations. Although numerous pockets of *Populus* and *Salix* were still found along the main river channels in this reach, they constituted a lower proportion of the R1 vegetation than 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, either intermixed with *Tamarisk* or growing in nearly homogeneous stands on terraces removed from the main channels of the river.



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.* Mesophytic vegetation was no longer common and the lower-intensity vegetation in Zone 5 consisted of widely-spaced, stunted (1 m) *Tamarisk* plants mixed with the succulent halophyte, *Allenrolfia occidentalis* (iodine bush), that grew in segregated stands separated by patches of bare soil that was often covered by a salt crust. The final 56 km of the river, bellow the confluence with the Rio Hardy in Zone 5, 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 and its grain was harvested by the Cucapa people (Kniffen, 1931).



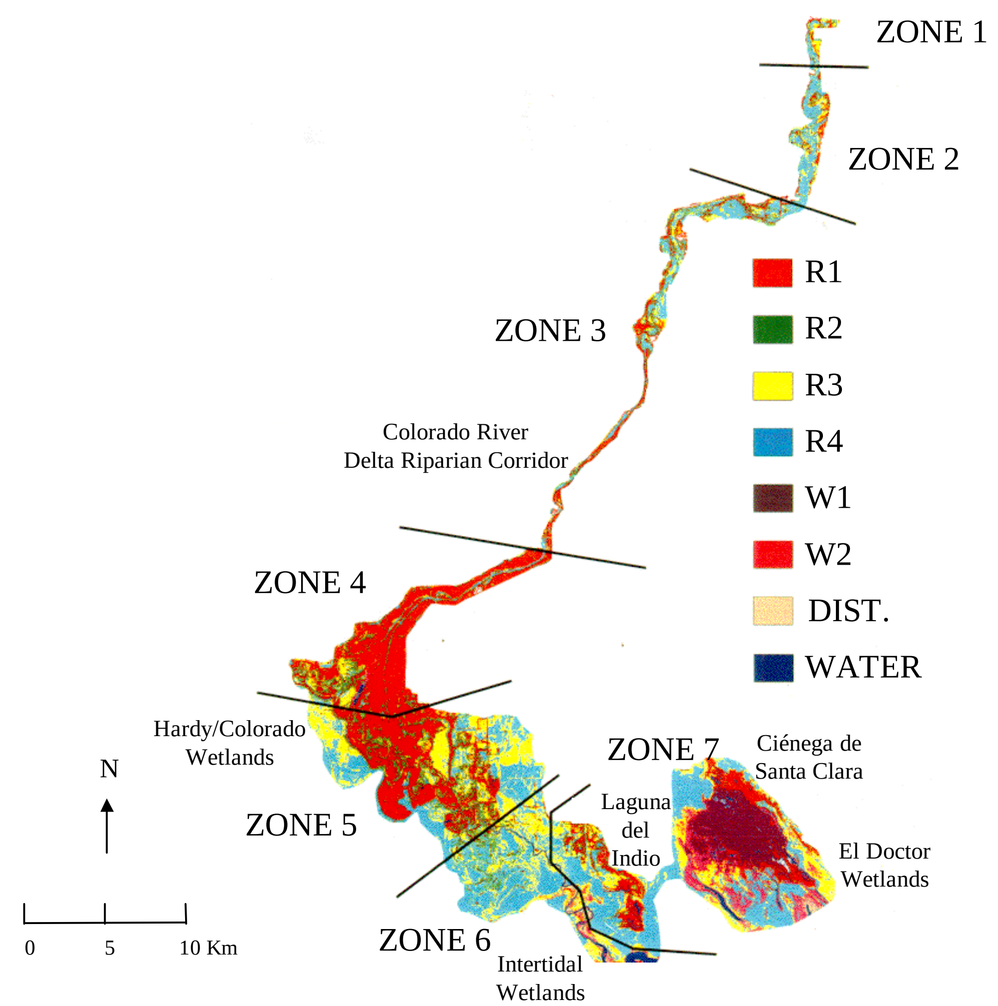
Zone 7 on the south - eastern corner of the Colorado delta, encompassed the Cienega de Santa Clara, El Indio and El Doctor marshes, which contains 5,808 ha of emergent, hydrophyte vegetation plus 2,274 ha of R1 vegetation. The W1 vegetation consisted mainly of dense *Typha* stands while the W2 vegetation consisted of thin stands of *Typha, Scirpus* and *Distichlis* on the salt-affected, wetland fringes (Zengel *et al*. 1995). The Cienega de Santa Clara is the largest brackish wetland of the delta (4200 ha dense, *Typha*-dominated, hydrophyte vegetation), and is supported by agricultural drain water from the Wellton-Mohawk district in the United States (Zengel *et al*, 1995).

The smaller El Indio wetland (aproximately 1900 ha), southwest of the Cienega de Santa Clara, is supported by agricultural return flows from local (Mexico) agricultural fields. Its vegetation is dominated by *Tamarisk* with pockets of *Typha* and other hydrophytes in flooded areas. The El Doctor wetlands are created by natural springs and comprise approximately 750 ha of marsh containig 22 different wetland and riparian plant species along the southeastern escarpment of the delta (Zengel *et al.* 1995); they support an overstory of *Propopis* trees and were classified as R1 land cover in this study.

Table 3. Characteristics of the Colorado River delta floodplain in Mexico. Vegetation zones were defined by floristic components based on ground surveys, while Land Cover Classes were determined by spectral analyses of satellite images; number after cover class refer to biomass intensity where 1 is highest and 4 is lowest.

Characteristics	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Total
Area by Land Cover Class(ha)								
Riparian 1	170	248	1232	5199	5816	148	2274	15087
Riparian 2	NA	301	1136	1072	2479	826	474	6288
Riparian 3	NA	424	608	589	3837	2797	3142	11397
Riparian 4	NA	1075	1561	292	3999	5189	5722	17838
Wetland 1	NA	3	56	20	22	0	3429	3530
Wetland 2	NA	13	59	100	113	359	2379	3023
Distchlis Flats	NA	0	8	29	16	442	377	872
Open water	NA	1	15	61	45	534	399	1055
Agriculture	NA	29	159	26	4	0	17	235
Total	**246**	**2094**	**4834**	**7388**	**16331**	**10295**	**18213**	**59401**
Principal Overstory	Sg	Pf/Sg	Pf/Sg	Tr/Pf/Sg	Tr	None	None	
species (>4.5 m)*								
Principal Midstory	Pa	Sg/Tr	Tr/Bs	Bs/Pspp/Al	Tr	Tr	Td/Tr	
species (0.6-4.5 m)*								
Principal Understory	None	Ps	Ps/Pf	Ps/Al	Ao	Dp/Ao	Numerous	
species (< 0.6 m)*								
Vertical Structure	III	I	II	III	IV			
*Sg = Salix goodingii; *Pf = Populus fremontii; *Tr=Tramarisk ramosissima; *Bg = Baccharis salicifolia ; *Pspp= Prosopis spp;								
*Al = Atriplex lentifomis; *Td= Typha domengesis; *Ao= Allenrolfia occidentalis; *Dp= Distichlis palmeri.								

Figure 14.Vegetation Zones of the Colorado River Delta.



Classification of vegetation communities, using spectral analysis of a satellite image (July 15, 1997). R1 - R4 include riparian vegetation, with R1 having the higher biomass level. W1 and W2 include marsh vegetation, wth W1 having the higher biomass level. DIST refers to the areas covered with *Distichlis palmeri* (salt grass), and WATER refers to open water areas.

The large area (8,864 ha) occupied by the low – intensity, R3 and R4 land cover classes in Zone 7 consisted mainly of stunted *Tamarisk* and *Allenrolfia* plants which colonized large flats of wet, saline soil in the supralittoral zone. Zone 7 also contained 377 ha of *Distichlis palmeri* in the intertidal area below Cienega de Santa Clara, which received both agricultural drain water exiting the marsh and tide water entering from the Gulf of California.

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. Other studies have described the vegetation (Glenn *et al*, 1992; Zengel *et al*, 1995; Burnett *et al*, 1993) of the delta marshes in detail and have documented their value as habitat for resident and migratory water birds (Mellink *et al*, 1996, 1997; Ruiz-Campos and Rodriguez-Meraz, 1997), as well as for two endangered species, the Yuma clapper rail (Eddleman 1989) and the desert pupfish (Zengel and Glenn, 1996). Some of these wetlands were included in the core zone of the Biosphere Reserve of the Upper Gulf of California and Colorado River Delta (Morales-Abril 1994). We do not make a comparison between the United States and Mexico river stretches to imply that a choice between the two should be made, but to emphasize the importance of the delta region to the overall lower Colorado River ecosystem.

5.2-Water

a) Water Flows

The Northern International Boundary is at the Algodones border, where Morelos Dam is located, controlling all Colorado River water in normal years for agricultural, industrial, and domestic uses. Thirty kilometers of river meanders constitute the Internatiol Boundary, until it passes next to San Luis Río Colorado, where the Southern International Boundary (SIB) is located. 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.

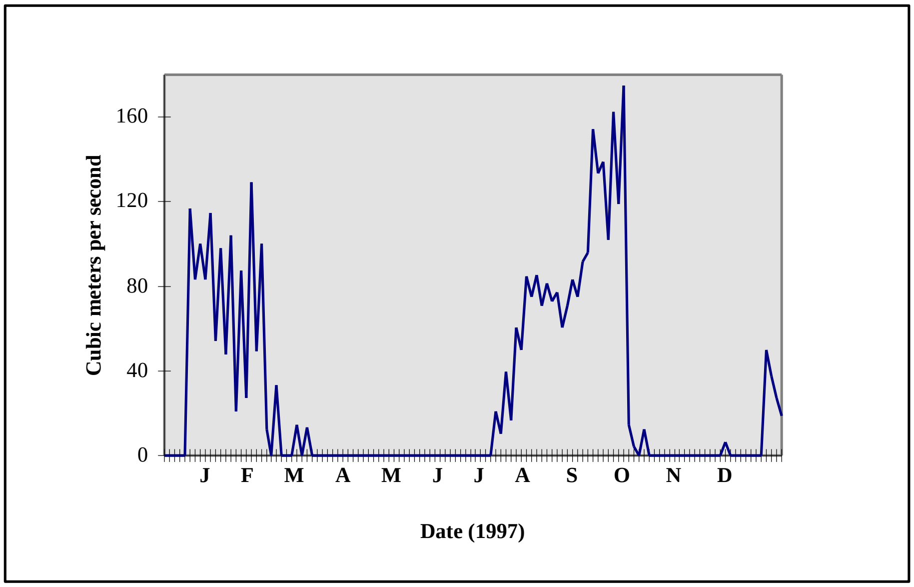
To say that the flow at the SIB is variable is an understatement. The annual mean of the daily discharge (calculated from summarizing the monthly means) range from 0 to 495 m^3/s (CMS), during the 20 year period from 1977 to 1996 (see Figure 16). Peak daily discharges have about twice the range from 0 to 934 CMS. Nearly, 40 % of the monthly means of the daily discharge are zero. About 50 % of the observed monthly flows are greater (or lesser) than 2 CMS. Over this period the highest flows generally occurred during January and the lowest during April (see Figure 16).

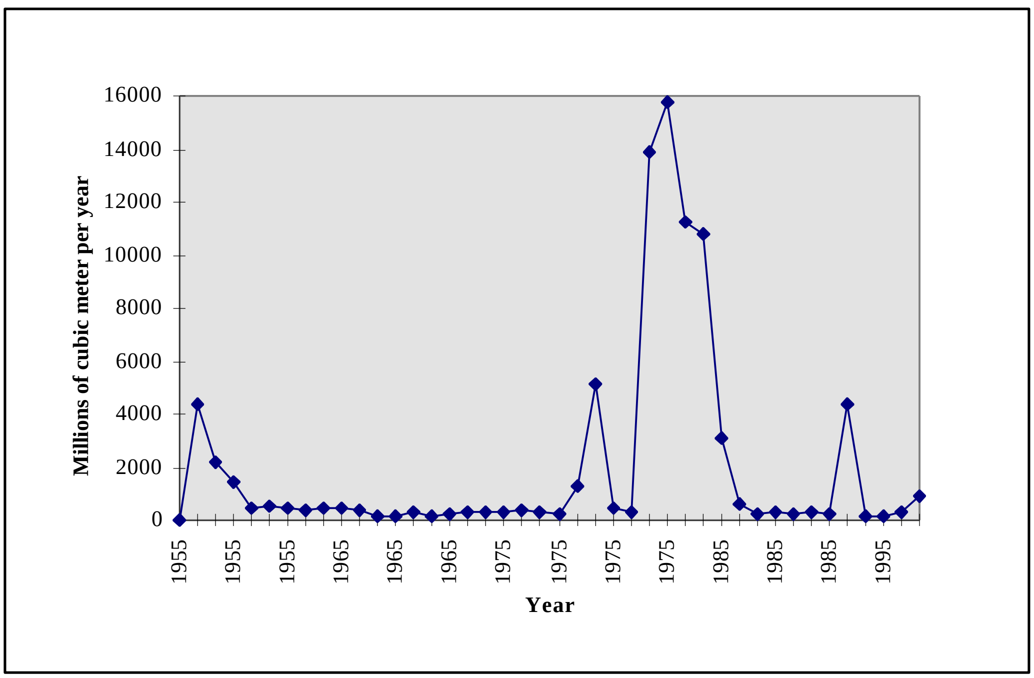
Figure 15. Flows of the Colorado River at Vado

Carranza, during a flooding event (left), and during no flows at the SIB (right).

The 1983 flood resulted in mean annual flow rates in excess of 300 CMS from 1983 through 1986. The years of 1980, 1987 and 1993 had annual mean flows greater than 100 CMS. The only year in which no flow at the SIB was recorded was 1996. However, most of the 1982, 1989, 1990, 1991, 1992, 1994, and 1995 had little recorded flow, when the mean annual discharge was 0.37, 1.08, 0.05, 0.09, 0.88, 0.12, and 2.36 CMS, respectively.

Figure 16. Water Flows at the Southern International Boundary during 1997, and from 1955 to 1997





The releases from 1980 to 1987 were up to ten times the 1944 treaty allotments to Mexico, and in some years approached the pre-Hoover Dam flow rates. The average flows to the delta from 1980 to 1993 were 4.8×10^{9} m^3/year, which is three times the treaty allotment and approximately 25 % of the pre-dams flow into the delta. These flows flooded a maximum area of 60,000 ha in the Hardy area, in 1983 (Glenn *et al*, 1996).

The high variability on the river´s flows is not a new event on the delta: instantaneous flows ranged from 0 to 6,000 m^3/s, with an annual flow average of 20.7 x 10^9 m^3 from 1896 to 1921. All of this water used to reach the delta, until 1896, when diversions for agriculture and domestic use started (Sykes, 1937).

During the January - April and August – October, 1997, water releases to the delta in about 4 x 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 via the river and overland flow onto the tide flats. This flows continued on early 1998, but are programmed to be stopped. No high excedent flows are expected during the rest of 1998.

Other water sources entering the flood plain are agricultural drain cannals discharging the Rio Hardy on the west side of the flood plain. During 1997, the main drains discharging on the Hardy/Colorado Wetlands had a mean flow of 6.33 x 10^7 m^3. From 1995 to 1997, these flows were in the range of 6.33 to 6.9 x 10^7 m^3, with a mean flow of 6.54 x 10^7 m^3 (see table 4). This flows represent 3.6 % of the treaties water allotment to Mexico (1.8 x 10^9 m^3 per year), and 0.36 % of the water of the Colorado River Basin (ca. 18 x 10^9 m^3 per year). Adding the flows to the Cienega de Santa Clara (1.74 x 10 ^{8} m^3 per year) (Burnett *et al*, 1993), which are also regular flows, only near 13 % (2.39 x 19 ^{8} m^3) of the water that used to reach the delta in pre-development conditions now regularly enters these wetlands, including both the Hardy and the Cienega de Santa Clara regions, and with a drastically reduced water quality.

Table 4. Yearly mean flows and salinity of the agricultural drains discharging in the Hardy/Colorado Wetlands.

	1995		1996		1997	
Agricultural Drain	Mean Flows Mm^3/year	Salinity (ppt)	Mean Flows Mm^3/year	Salinity (ppt)	Mean Flows Mm^3/year	Salinity (ppt)
Drain Plan de Ayala	15.53	3.99	19.00	4.08	18.72	3.46
Drain Principal del Sur	30.33	3.09	23.58	3.09	22.16	2.02
Drain Carranza	5.18	3.07	2.45	2.76	3.09	2.47
Drain Nayarit	4.55	3.96	4.34	3.29	5.42	2.67
Drain Colector del Sur	10.97	3.97	10.29	4.11	10.18	3.92
Dren Cucapá	2.50	6.78	4.38	5.69	3.82	4.44
Total Flow (Mm^3/yr) - Salinity Avrg.(ppt)	69.06	3.62	64.04	3.73	63.39	2.97

Source: CNA, Baja California Office

b) Water Quality

Selenium

One of the major threats of the Colorado River delta wetlands is the bioaccumulation of selenium. These riparian wetland areas receive irrigation return flows that deteriorate them by the presence of high levels of potential toxic elements, among them is selenium, which is present throughout the Lower Colorado River ecosystems (Presser *et al*, 1994; King *et al*, 1993; Radtke *et al*, 1988).

Selenium can be bioaccumulated to toxic levels for wildlife as in the Kesterson Reservoir, CA where aquatic birds presented high rates of embryonic mortality and deformity (Ohlendorf *et al*, 1986). To prevent further occurrences, research on identification of selenium levels have been carried out in most of the western United States (Presser *et al*, 1994). Elevated levels of selenium were found in water, sediment and fish tissues from the lower Colorado River with the highest concentrations occurring in oxbow lakes and backwaters (Welsh and Maughan, 1994; King *et al*, 1993; Radtke *et al*, 1988).

The Colorado River delta wetlands have similar physical and chemical characteristics as those observed at Kesterson Reservoir (Presser *et al*, 1994). The following list describe the most important ones:

- An arid to semi-arid climate with evaporation much greater than precipitation leading to salinization of soils;

- Irrigated agriculture supported by irrigation-drainage facilities to leach salts;

- Saline groundwater aquifers resulting mainly from alluvial clay layers that impede downward movement of irrigation water and that cause waterlogging of the crop root zone; and,

- Drainage by natural gradient or through buried tile drain networks to migratory-bird refuges, wetland areas, or other areas in receipt of federal waters.

In addition, the Colorado River has been found to be the major source of selenium in the lower Colorado River Valley (Welsh, 1992; Radtke *et al*, 1988). Despite the potential for further accumulation in ecosystems South Imperial Dam, only one study have reported the levels of selenium in the west side of the Colorado River delta in Mexico (Mora and Anderson, 1995). Investigations in the Rio Hardy wetlands, detected low concentrations of mercury in fish and clams (Gutierréz-Galindo *et al*, 1988). However, high levels of selenium, boron and arsenic were found in birds from the same area (Mora and Anderson, 1995).

Selenium was detected in all of the samples analyzed, results are shown on table 5 (see Figure 18). 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). National baselines are not associated with toxicity concentrations or regulatory standards, but provide a reference value to identify areas of potential concern. Concentrations were 45-355 times higher than normal background levels in freshwater environments (< 0.2 µg/L) (Maier and Knight, 1994), and 4.5 - 35.5 times higher than the level at Imperial Dam (2 µg/L) (Radtke *et al*, 1988).

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 flows through the Colorado River mainstream (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 (Hardy and Pescaderos) (18 - 41µg/L).

Selenium concentrations are lower in areas which receive water from irrigation channels (site 1 and 3 from Augsut 20, 1997 samples). Eventhough 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 (3 µg/L at Morelos Dam) (USGS, 1973-87). This could probably be influenced by the fact that over the past 20 years, these stream has retained low levels of water or even becomed dry (Glenn *et al*, 1996), causing selenium to concentrate.

Beside the micro-evaporative basins (El Mayor 1 & 2), the agricultural drains were found to have the highest levels of selenium. This contrast with the geothermal drain, which also has a high selenium level (16 µg/L), but it is half the value than the average of the agricultural drains, and despite what it may be thought, it is not the main selenium source for the wetlands. The riparian areas influenced by these drains were also found with high selenium levels.

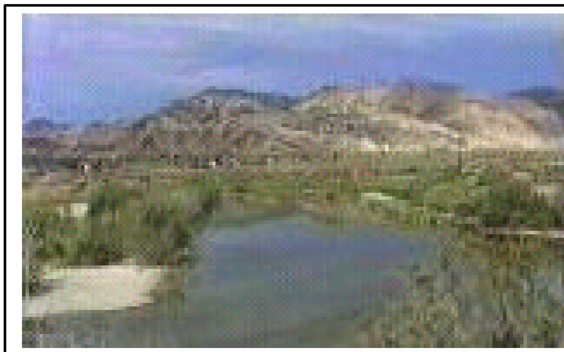


Fig 17. Sampling site El Mayor 1.

The result 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. This could be seen in the micro - evaporative basins with no tidal influence, as this sites have the highest salinity values and the highest selenium levels within the sampled sites.

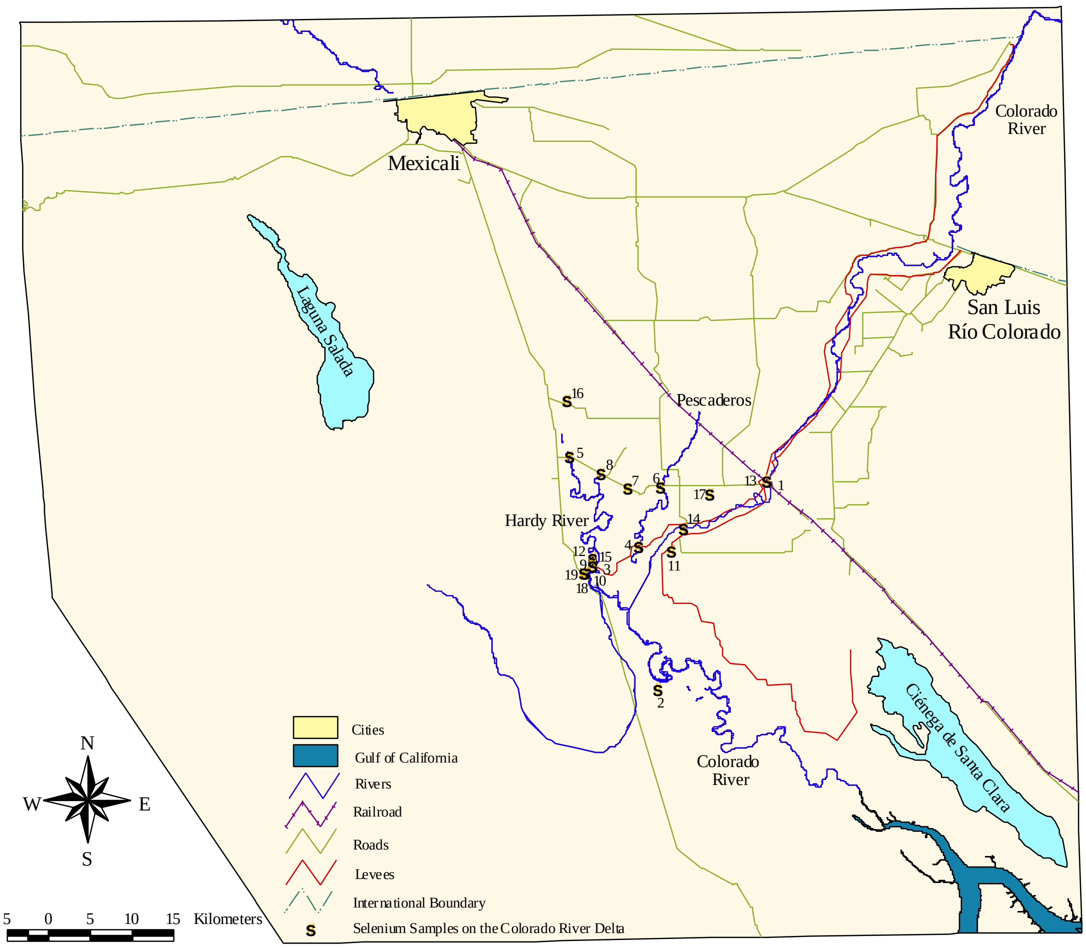
Selenium tends to concentrate in consumer organisms from their food sources in aquatic ecosystems (Maier and Knight, 1994). Documented cases have shown that chronic toxicity in fish occurred when selenium biomagnifies from 100 to 30,000 times the waterborne concentration, depending on the tissue and fish species. However, normal biomagnification factors in whole body do not exceed 2,000 (Lemly, 1986). In a similar study carried out at the Cienega de Santa Clara in the Colorado Delta (Garcia, 1998), bioaccumulation factors for several fish species ranged from 350 to 900 times than the average waterborne concentration, depending on the tissue and specie.

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.

Table 5. Selenium levels (mg/L) and salinity (ppt) of water samples collected at different sites in the Hardy/Colorado Wetlands.

Sample No.	UTM Easting	UTM Northing	Date Sampled	Site Name	Salinity (ppt)	Selenium levels (µg/L)
Rivers which not receive agricultural drainage influence						
1	683410	3568939	7/07/97	Colorado Stream Fco. Murgía	1.81	32
Rivers which receive agricultural drainage influence						
2	670391	3543957	7/07/97	Colorado - Yurimuri	4.09	26
3	662413	3558720	7/07/97	Hardy - Campo Mosqueda	3.36	27
4	667963	3561135	7/07/97	Pescaderos	2.56	27
5	659773	3571790	7/07/97	Northern Hardy River	9.27	28
Drains						
6	670615	3568250	7/07/97	Ag-drain Colector del Sur	3.17	28
7	666704	3567980	7/07/97	Ag-drain Nayarit South	3.96	34
8	663451	3569789	7/07/97	Ag-drain Nayarit	3.37	41
Micro-Evaporative Reservoirs						
9	661649	3557840	7/07/97	El Mayor 2	26.69	64
Rivers which not receive agricultural drainage influence						
10	662500	3559300	20/08/97	Mosqueda Lake	0.76	9
11	671880	3560570	20/08/97	Colorado Stream Glez. Ortega	0.68	10
12	662400	3559700	20/08/97	Aquaculture Channel	2.16	11
13	683410	3568939	20/08/97	Colorado Stream Fco. Murgía	0.56	14
14	673438	3563231	20/08/97	Colorado Stream Col. Carranza	0.59	15
Rivers which receive agricultural drainage influence						
15	662413	3558720	20/08/97	Hardy - Campo Mosqueda	4.02	18
Drains						
16	659345	3578513	20/08/97	Geothermic Drain	0.95	16
17	676666	3567359	20/08/97	Ag-drain Carranza	3.01	25
Micro-Evaporative Reservoirs						
18	661649	3557840	20/08/97	El Mayor 2	11.97	29
19	661450	3557850	20/08/97	El Mayor 1	16.58	71

Figure 18. Selenium Sampling Sites on the Colorado River Delta.



Modified from INEGI, CNA, and T.M. Satellite Images.

ITESM Campus Guaymas. CECARENA/UIB. 1998.

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Information Database and Local Outreach Program for the Restoration of the Hardy River Wetlands in the Lower Colorado River Delta, Baja California and Sonora, Mexico

ITESM Campus Guaymas

THE UNIVERSITY OF ARIZONA
TUCSON, ARIZONA

PRONATURA SONORA

Sonoran Institute

Environmental Defense Fund

California State University Dominguez Hills

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, according to the obligations stated in the 1944 treaties (Secretaría de Relaciones Exteriores, 1975; CNA, 1997).

Several efforts have been made to evaluate the salinity in the mouth of the Colorado River, but on research projects focused more on the marine ecosystem of the Upper Gulf of California (Hendrickson, 1973; Martínez-Rojas Reynoso, 1990).

Also, several analysis have been carried out in the Cerro Prieto area, and on ground water, in order to evaluate salinity in the water table for agricultural purposes and possible impacts of the Geothermal Plant (Trujillo-Camacho, 1996; Moises-Domínguez, CNA, pers. communication).

Salinity monitoring related to ecological and biological functions of the Colorado River delta has been related to biological surveys, where salinity was one of the environmental parameters measured (Zengel *et al,* 1995; Abarca *et al,* 1993; Varela-Romero *et al,* 1987).

Also, it has been related to monitoring of contaminants (García, 1998), and with hydrologic and geologic assessments (Burnett *et al*, 1993). All of these surveys have been carried out mostly in the eastern side of the Colorado River delta (Ciénega de Santa Clara and nearby cannals). Efforts to determine salinity levels within the Hardy/Colorado wetlands and its relation with habitat functions and restoration opportunities have not been documented.

In order to get a general overview of the distribution of salinity levels in water sources and within the Hardy/Colorado Wetlands, salinity surveys were carried out, so that restoration strategies and water management recommendations could be identified.

Salinity levels were identified in key areas of the Hardy/Colorado Wetlands, considering water sources as indicators of water quality before the water enters into wetland areas (see Figure 20). Salinity levels from the sampling sites in the Hardy/Colorado Wetlands are shown on table 7. Data provided by CNA regarding salinity on agricultural drains in the Hardy/Colorado region is shown in table 4.

Figure 19. Water sampling at Drain Nayarit.

Salinity surveys were carried out on July 7, 1997, August 20-22, 1997, and November 14, 1997. During July 7, 1997, there were no excess flows to the delta. However this area received 4 x 10^8 m^3 during the last 5 months, with maximum flows of 150 m^3/s.

During August 20-22, 1997, the excess flows were of 50 m^3/s, with a total of 4 x 10^8 m^3 received that year. During November 14, 1997 there were no excess water flows to the delta, however maximum flows of 175 m^3/s were received the month before, and about 5 x 10^8 m^3 were received during the previous three months.

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 (average of 0.61 ppt, range 0.56-0.68) related to salinity in the Lower Colorado River and Delta, which is reported to be (average, ppt) 0.865 at Imperial Dam, 1.01 at Morelos Dam, and 1.4 at the Southerly International Boundary (CNA, 1997).

Salinity on these sites was even lower than salinity on Irrigation channels, like Cannal Nuevo Delta, that presented a salinity of 1.75 ppt. During the times when no flows were received, but there was water in the area from previous water releases (July and November) salinity increased to 1.81 ppt in certain sites (Colorado Stream Fco. Murgía).

Salinity in areas that has influence of agricultural drains of the Mexicali Valley was 7.2 times higher in average (mean salinity of 4.41 ppt, range of 2.16 to 9.27) than Colorado River water, areas that only receive agricultural discharges (Hardy and Pescaderos rivers) were 8.7 times saltier (5.28 ppt, avrg.) than Colorado River Water, and places that receive influence of both waters were 6.9 times saltier (4.21 ppt, avrg.) than Colorado River water.

Mean salinity on agricultural drains was 3.72 ppt (range 2.30 - 5.10 ppt), suggesting that evaporation on river basins is causing an important increase in salinity (1.4 times). In certain places, like El Mayor 1 & 2, where water is retained without outflow, salinity increases to higher levels (22.09 ppt, avrg.), in similar conditions than the increase of contaminants.

Data on the salinity levels in the area around the river mouth and Montague and Pelicano islands are shown on table 6. These sites 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 contrasts 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).

Table 6. Salinity (ppt) on sampling sites from the Gulf of Santa Clara into the Colorado River.

Sample No.	UTM Easting	UTM Northing	Sampling Site Commentaries	Salinity (ppm)
1	736248	3507991	Gulf of Santa Clara	36
2	732783	3509534	-	37
3	729837	3510798	-	37
4	726933	3511781	Pelicano Island	36
5	724233	3512020	-	34
6	721422	3512338	Montague Island	35
7	719591	3514147	Between Islands	32
8	716593	3515761	Tide beginns to rise	32
9	714551	3518878	-	26
10	712847	3521526	North Montague Island	25
11	709779	3522561	Northern Tip of Montague	22
12	707679	3522037	Entering River Mouth	20
13	704935	3525817	Distichlis flats	18
14	702671	3527566	Corvina Area	15
15	700349	3528325	Coyote on River Bank	10
16	698959	3528161	Mud falling from riverbank	8
17	697564	3528300	Higher River Banks	6
18	696587	3529230	Waves formed by tide vs river	7
19	694229	3530105	Tamarisk & Allenrolfia	2
20	694246	3532706	Reserve Sign-Ending Point	0

Figure 20. Salinity Sampling Sites on the Colorado River Delta.

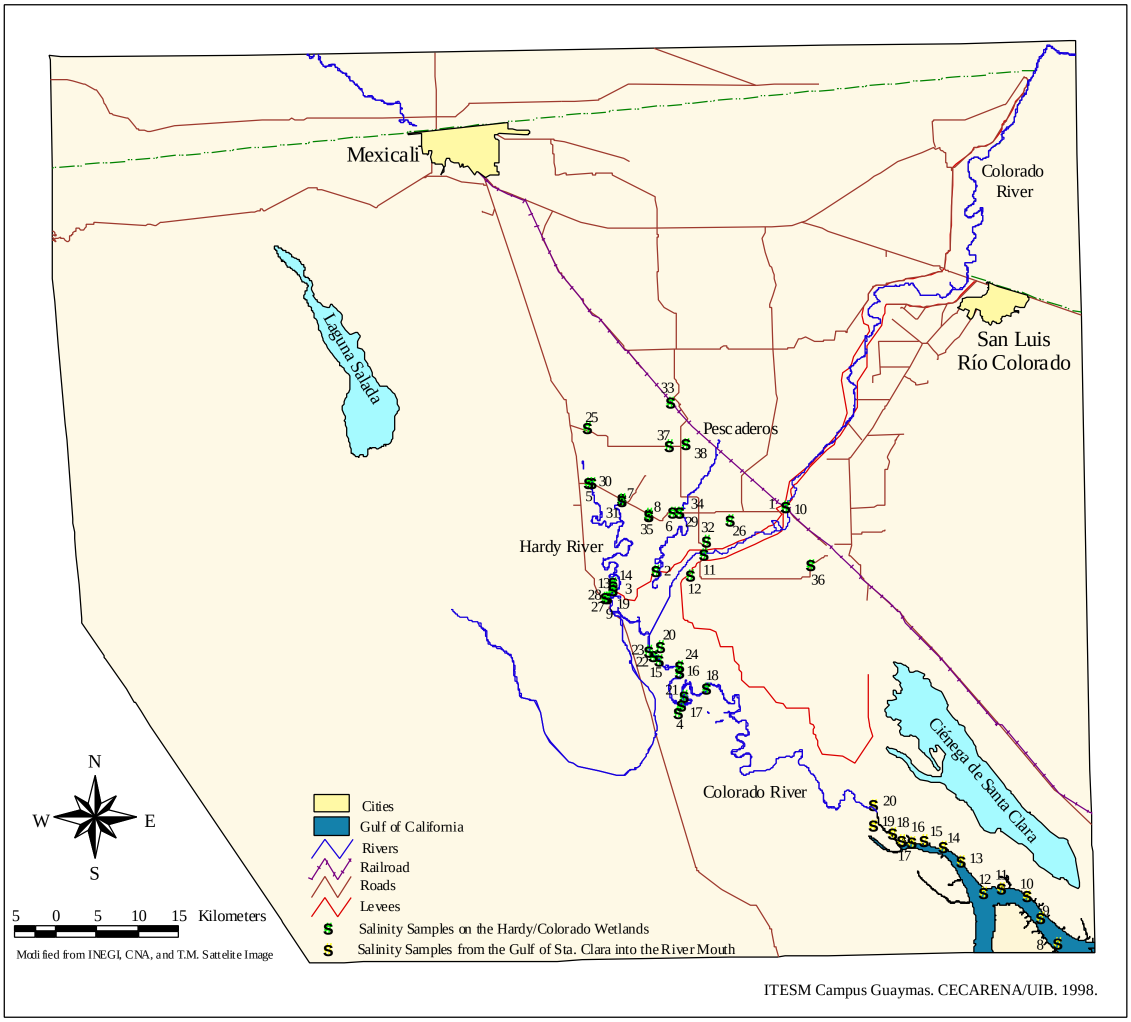

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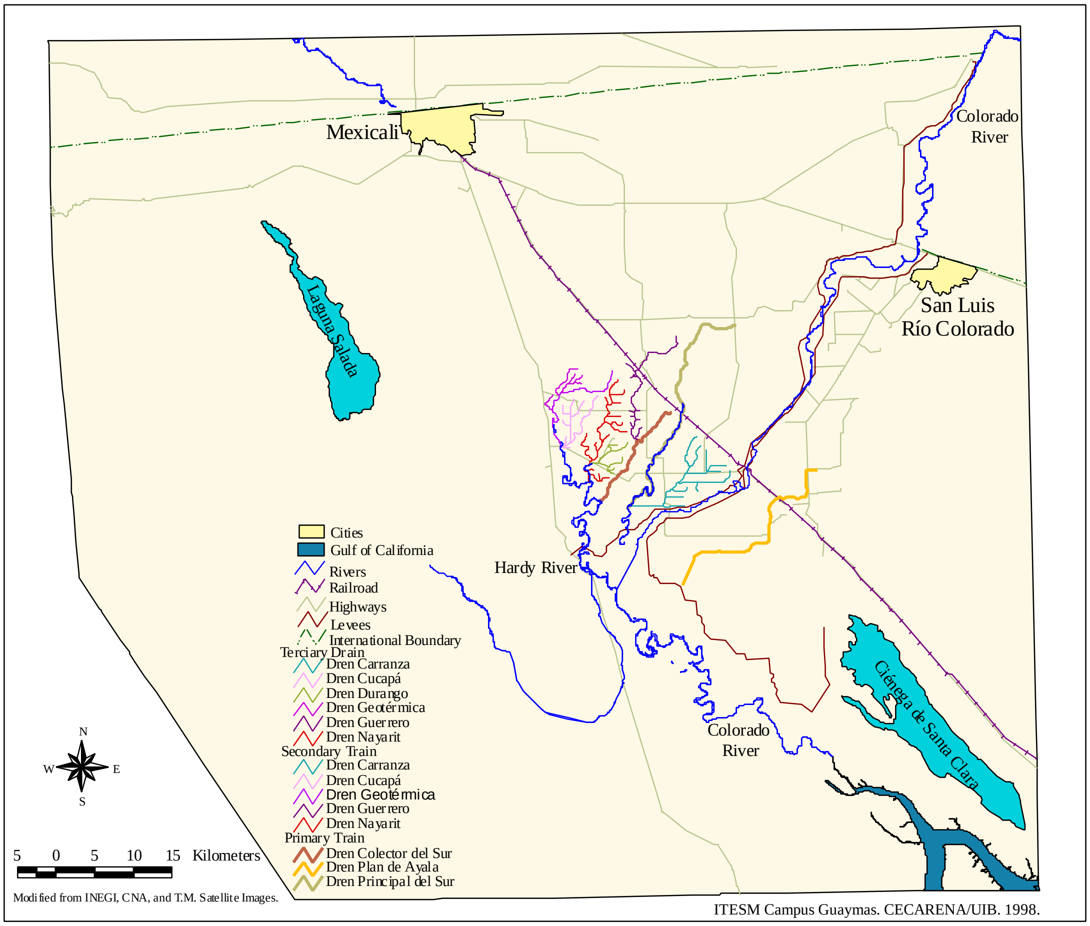
Table 7. Salinity (ppt) on sampling sites in the Hardy/Colorado Wetlands area.

Site No.	UTM Easting	UTM Northing	Date Sampled	Site Name	Salinity (ppt)
Waters which not receive agricultural drainage influence					
1	683410	3568939	7/07/97	Colorado Stream Fco. Murgía	1.81
Waters which receive agricultural drainage and/or tidal influence					
2	667693	3561135	7/07/97	Pescaderos	2.56
3	662413	3558720	7/07/97	Hardy - Campo Mosqueda	3.36
4	670391	3543957	7/07/97	Colorado - Yurimuri	4.09
5	659773	3571790	7/07/97	Northern Hardy River	9.27
Drains					
6	670615	3568250	7/07/97	Ag-drain Colector del Sur	3.17
7	663451	3569789	7/07/97	Ag-drain Nayarit	3.37
8	666704	3567980	7/07/97	Ag-drain Nayarit South.	3.96
Micro-Evaporative Reservoirs					
9	661649	3557840	7/07/97	El Mayor 2	26.69
Waters which not receive agricultural drainage influence					
10	683410	3568939	20/08/97	Colorado Stream Fco. Murgía	0.56
11	673438	3563231	20/08/97	Colorado Stream Col. Carranza	0.59
12	671880	3560570	20/08/97	Colorado Stream Glez. Ortega	0.68
13	662400	3559700	20/08/97	Mosqueda Lake	0.76
Waters which receive agricultural drainage and/or tidal influence					
14	662463	3559339	20/08/97	Aquaculture Channel	2.16
15	667939	3550201	22/08/97	Colorado Stream Campo Parra	3.00
16	670587	3548772	22/08/97	Colorado Stream Los Amigos	3.00
17	670725	3544765	22/08/97	Colorado Stream La Ramona	3.00
18	673863	3546879	22/08/97	Colorado Southern Stream	3.00
19	662413	3558720	20/08/97	Hardy - Campo Mosqueda	4.00
20	668146	3551913	22/08/97	Colorado Arm Choropo	4.00
21	671045	3545975	22/08/97	Colorado Stream Riñon	4.00
22	667230	3550862	22/08/97	Colorado Stream South Flores	5.00
23	666799	3551314	22/08/97	Colorado Campo Flores	6.00
24	670645	3549523	22/08/97	Campo Miramar	7.00
Drains					
25	659345	3578513	20/08/97	Geothermic Drain	0.95
26	676666	3567359	20/08/97	Ag-drain Carranza	3.01
Micro-Evaporative Reservoirs					
27	661649	3557840	20/08/97	El Mayor 2	11.97
28	661450	3557850	20/08/97	El Mayor 1	16.58
Waters which not receive agricultural drainage influence					
29	669692	3568217	14/11/97	Canal Nuevo Delta	1.75
Waters which receive agricultural drainage and/or tidal influence					
30	659558	3571822	14/11/97	Northern Hardy River	7.25
Drains					
31	663442	3569725	14/11/97	Ag-drain Durango	2.30
32	673821	3564705	14/11/97	Ag-drain Carranza	3.10
33	669463	3581694	14/11/97	Ag-drain Guerrero	3.20
34	670614	3568194	14/11/97	Ag-drain Principal del Sur	4.17
35	666737	3567939	14/11/97	Ag-drain Colector del Sur	4.62
36	686507	3561867	14/11/97	Ag-drain Plan de Ayala	5.00
37	669333	3576393	14/11/97	Ag-drain Nayarit	5.10
Micro-Evaporative Reservoirs					
38	671381	3576511	14/11/97	Pond at ag- drain Delta	23.00

Figure 21. Monitored Agricultural Drains in the Colorado River Delta.



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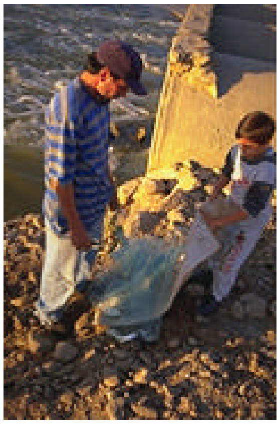


5.3-Human Activities and Population.

a) Population

Social and Cultural Aspects

The Colorado delta wetlands are located within two states, Baja California and Sonora, in northwest México. Baja California has 4 municipalities, but the Colorado River delta belongs only the municipality of Mexicali. Sonora has 72 municipalities, but only the municipality of San Luis Río Colorado borders the delta (INEGI, 1996c).

Wetlands of the Colorado River delta cover a little over 60,000 km^2, around them 97 communities are located with a total of 30,000 inhabitants, whose lives are strongly related to the wetlands ecosystems (INEGI, 199f; INEGI, 1996g). Unfortunately, information of population is available for only 11 of those localities.

Table 8 summarizes population statistics in the area within 5 km. from wetlands (see figure 22). As is shown, population is balanced by gender, most of the people live in the state of Sonora (62%), and they are relatively young as 32% of the total population in the area is less than 15 years old. Notice that Indian population has little representation in the total population, and it's important to point out that most of them belong to the Cucapá community.

Table 8.- Population rates by selected groups. Settlements within a ratio of 5km or less from wetlands.

	Number	Percentage
1995 Total Population	206, 977	100%
Men	104,852	50.66%
Women	102,125	49.34%
Population aged 15 or more	140,765	68.01%
Indian population	595	0.29%
Population located in Baja California	77,174	37.29%
Population located in Sonora	129,803	62.71%

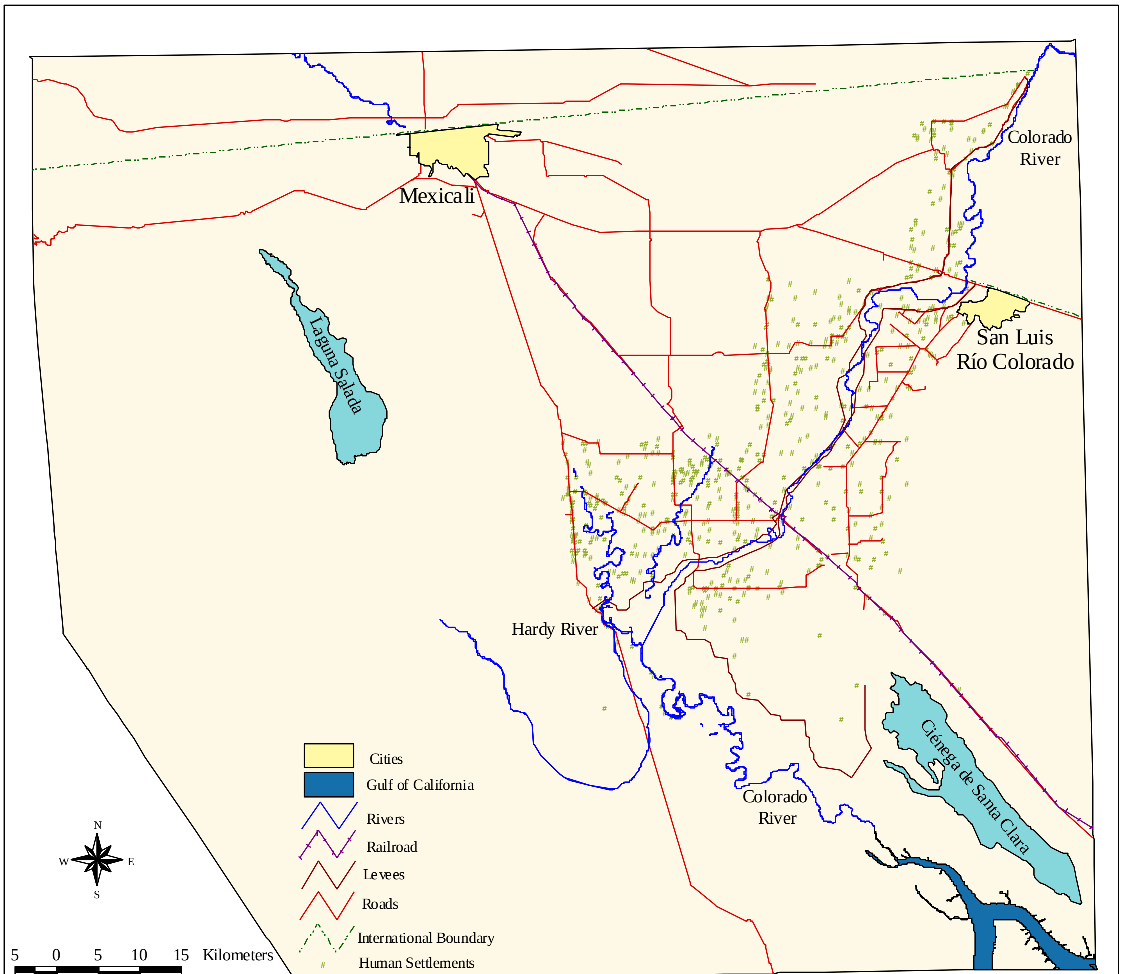
Source: INEGI.1996. Conteo Poblacional y de Vivienda 1995. Baja California y Sonora. CD-ROM.

Table 9.- Population rates by size of human settlements located within 5 km away from the wetlands.

	Total Human Settlements	1995 Total Population	% of Human Settlements	% of Total Population
Total Human Settlements	1,127	206,977	100%	100%
Settlements with more than 1,000 inhabitants	19	174,527	1.69%	84.32%
Settlements with less than 1,000 but more than 100 inhabitants	70	25,238	6.21%	12.19%
Settlements with less than 100 inhabitants *	1,038	7,212	92.10%	3.48%
Settlements located in Baja California	768	77,174	68.15%	37.29%
Settlements in Sonora	359	129,803	31.85%	62.71%

Source: INEGI.1996. Conteo Poblacional y de Vivienda 1995. Baja California y Sonora. CD-ROM.
71.09% of this human settlements have no data available.

Figure 22. Human Settlements within the highest influence area of the Colorado River Delta Wetlands.



Modified from INEGI and T.M. Satellite Images.

ITESM Campus Guaymas. CECARENA/UIB. 1998.

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Table 9 presents population statistics by human settlements size for the communities located within 5 km. from the delta wetlands, considering from the northern international boundary to the river mouth. The table shows, 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. An important consideration is that, even though Baja California has most of the human settlements, 68.15%, it is inhabited by only 32% of total population, which means that population is concentrated in the State of Sonora, mainly in the city of San Luis Río Colorado.

Also, is important to notice that even though within 5 km away from the delta wetlands exist 1,127 human settlements, only 309 communities belong to the Hardy/Pescaderos/Colorado River area[1] located within the same 5km, which are inhabited by 20% of total population near the delta wetlands in an area of 1,332 km^2. Twenty of these communities are the ones whose inhabitants (36,503 persons) live with a stronger relationship with the wetlands. (INEGI, 1996f; INEGI, 1996g).

Table 10 shows the comparison of total population in 1990 and in 1995 for those human settlements with more than 1,000 inhabitants, and that are located within this range of 5 km or less from delta wetlands. Notice the high population growth rate of about 3.44% per year, which means that in this 5-year period, the total increase in population was slightly higher than 18%. The area has special human migration patterns, it attracts population from central México because of the international boundary, but also because it is an important center for agriculture. Even though migration is fluctuating every year, the trend is to increase. Fluctuation exists also because of the arrival of foreign fishermen during fishing seasons, who stay in the area for about 3 or 4 months per year. U.S. citizens also arrive to the area for hunting and fishing, but they stay just few weeks or weekends.

Growth rates among the Colorado River delta communities from 1990 to 1995 were highly variable, ranging from annual growth rates of 20%, to negative growth rates of 18%. Those with higher rates were mainly small towns with less of 1,000 inhabitants. The higher growth rates among important human settlements were in Patzcuaro (15.87%), Durango (6.94%), Luis B. Sánchez (4.31%), Guadalupe Victoria (4.15%), Plan de Ayala (2.12%), and Estación Coahuila (1.12 %). Undoubtedly, San Luis Río Colorado represents the most important population growth in the region, with a annual growth rate of 3.9 %, that represents a population increase of 10,000 inhabitants. These rates are caused by economical prosperity in these communities, attracting people from nearby towns, which have diminished their populations.

Fig 23. San Luis Río Colorado.

Some communities registered negative growth rates, like Cucapá Mestizo (-0.9%), Francisco Murgía (-1.09 %), Ejido Cucapá Indígena (-1.96%), Riíto (-3.11), El Indiviso (-3.45%), Luis Encinas Johnson (-3.78%), González Ortega (-4.8%), Pescaderos (-5.39), and Campo Mosqueda (-17.32%). Some of these communities have lost their agricultural lands due salinity problems or floods, like El Indiviso and González Ortega, and because the lack of opportunities to develop other activities based on the wetland resources, they have moved to other towns in search for work in agricultural fields and food processing plants.

Because of the extent of the Mexicali municipality, it is divided by delegations, and each delegation includes several locations, which can be ejidos, colonies, farms, or towns (see figure 24). Following is a description of the delegations and their localities related to the Hardy/Colorado River wetlands.

Delegation Venustiano Carranza

This delegation covers an area of 1,092.5 km^2 and has 14 agricultural colonies, 14 ejidos, 16 tourist camps, 1 ethnic community, 1 ranch, and 4 towns. It is estimated to have a total population of 13,761 inhabitants (XV Ayuntamiento de Mexicali, 1998). Table 11 presents those colonies and ejidos located within the influence area of the Hardy/Colorado wetlands.

[1] It considers only those wetlands located under the railroad line.

Figure 24. Delegations of the Mexicali Valley, Colorado River Delta.

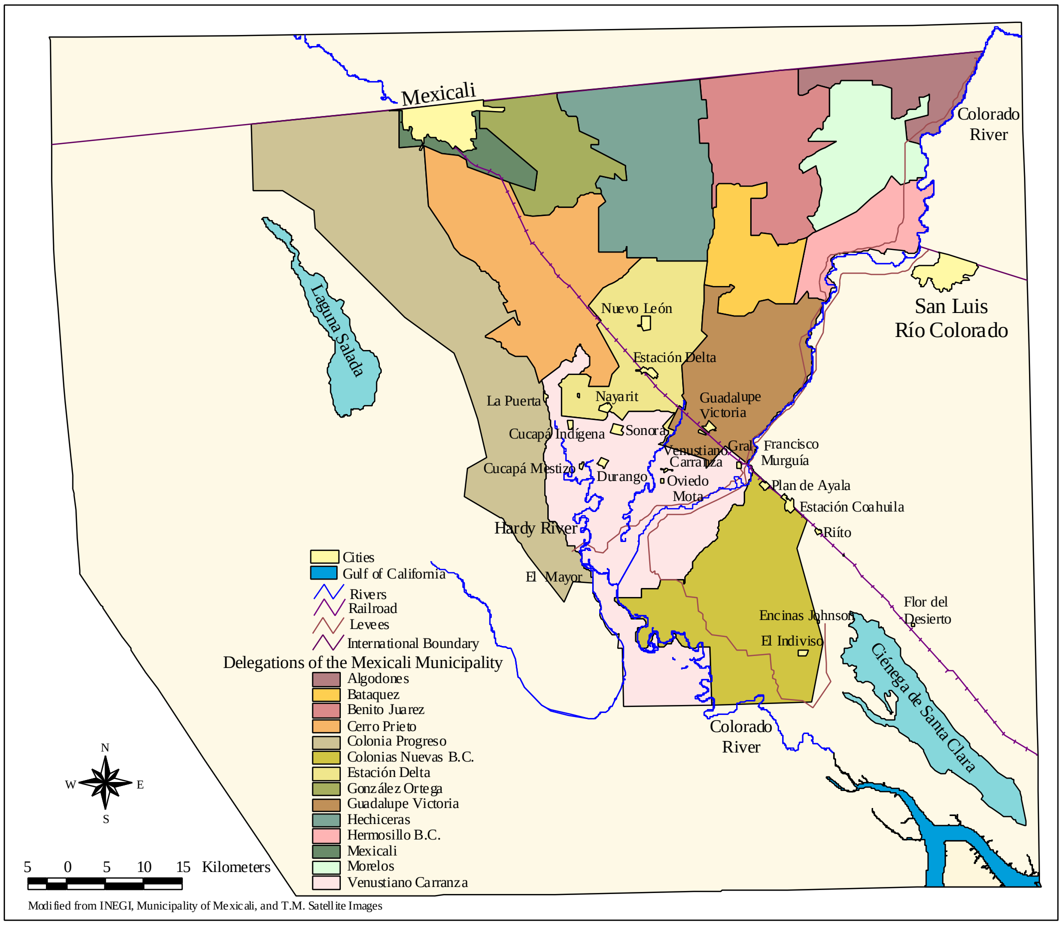

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Table 10.- Population rates for human settlements with more than 1,000 inhabitants.

1990 Total population	147,354
1995 Total population	174,527
Annual avg. growth rate	3.44
5-year growth rate	18.44

Source: INEGI.1996. Conteo Poblacional y de Vivienda 1995. Baja California y Sonora. CD-ROM.

Table 11.- Communities of Delegation of Venustiano Carranza related to the Hardy/Colorado River wetlands.

Colonies	Colonies	Ejidos	Tourist Camps	Tourist Camps
Alvarado	La Mariana	Choropo	Campo Azul	Campo Río Mayor
Baja California	Leona Vicario	Cucapá Indigena	Campo Escondido	Campo Sonora
Camacho	La Puerta	Cucapá Mestizo	Campo Flores	Campo Thy-Thy
El Mayor	Nuevo Michoacán	Durango	Campo Gabriel	Campo Acapulco
El Muñoz	Rentería	El Marítimo	Campo Las 3 B	Campo Los Amigos
Espinoza	Robertson	González Ortega 3	Campo Mosqueda	Campo Camino Real
González Ortega	San Felipe	González Ortega 2	Campo Muñoz	
Independencia	Terrenos Indios		Campo Parral	
Independencia 2	Venustiano Carranza	Oviedo Mota	Campo Buenos Tiempos	
Independencia Economica		Sonora	Campo Río Hardy	

Source: XV Ayuntamiento de Mexicali- Coordinación de Delegaciones. 1998.

Within this delegation lie part of the Cucapá Mountains, the Hardy River and the Colorado River. Hence 16 tourist camps can be found by these rivers, providing recreation and fishing services. As the Cucapá community is located here, this delegation support the Cucapá cultural museum, where part of their history is presented, as well as their arts and crafts.

This delegation has agriculture as it main activity, and receives water from the Irrigation District No.8. This district provides its services to 137 farmers, and covers a maximum of 2,149 cultivating hectares. The main products cultivated in here are wheat, cotton, alfalfa, asparagus, vegetables, white corn, sorghum, rye grass, and barley (XV Ayuntamiento de Mexicali, 1998). Other economic activities in the delegation are tourism, aquaculture, and fishing.

Delegation Estacion Delta.

This delegation has an extension of 267 km^2 with 17,227 inhabitants. It is divided in 8 ejidos, 2 agricultural colonies, 3 ranches, and 3 towns, but the wetland influence area include only the following 11 ejidos and colonies (XV Ayuntamiento de Mexicali, 1998) (see table 12).

The agricultural land pertaining to this delegation receives its water from 3 different irrigation modules: No. 7, 10, and 11. It has 14,000 cultivable hectares, owned by 773 beneficiaries, who’s lands produce wheat, rye grass, cotton, alfalfa, asparagus, vegetables, corn, melon, watermelon, and barley. This delegation has 6 processing plants for fruit and vegetables, which buy the crops of local farmers. (XV Ayuntamiento de Mexicali, 1998).

Delegation of Guadalupe Victoria.

This delegation has an extension of 290.8 km^2, and a total population of 23,023 inhabitants distributed in 5 ejidos, 16 agricultural colonies and 7 towns (XV

Ayuntamiento de Mexicali, 1998), and table 13 shows which are located in the wetland influence area.

Table 12.- Communities of Delegation Estacion Delta, related to the Hardy/Colorado River wetlands.

Colonies	Ejidos	Ejidos
Alvarado	El Saltillo	Nayarit
	Guerrero	Nuevo
	Hidalgo	Oaxaca
	Jalapa	Pátzcuaro
	Morelia	Tlaxcala

Source: XV Ayuntamiento de Mexicali. Coordinación de Delegaciones. 1998.

Table 13.- Communities in Delegation Guadalupe Victoria related to the Hardy/Colorado River wetlands.

Colonies	Colonies	Ejidos
Bravo	Juarez	Aguascalientes
Chapultepec	Madero	
Chausoe	Merino	
Elias	Primavera	
El Triar	Victoria	
Gutiérrez		

Source: XV Ayuntamiento de Mexicali. Coordinación de Delegaciones. 1998.

The agricultural area of this delegation covers 18, 211 hectares, corresponding to the irrigation modules No. 8, 9"A", and 9"B". Wheat, white corn, rye grass, alfalfa, canola, sorghum, and vegetables are the main crops of this delegation. It has 11 vegetable-processing plants and two dairy farms (Holstein), among other cattle farming facilities. (XV Ayuntamiento de Mexicali, 1998).

Delegation of Cerro Prieto.

This delegation has an area of 421 km^2 with 12, 734 inhabitants living in 15 agricultural colonies, 17 urban colonies, 11 ejidos, 14 ranches, and 5 (XV Ayuntamiento de Mexicali, 1998). Population centers located near the Hardy and Colorado River wetlands are those shown in table 14.

The agricultural area of this delegation receives water from the irrigation modules No. 19 and 20, and has 14,404 cultivable hectares and 681 beneficiaries. The main activities practiced here are agriculture, cattle raising, and non-renewable resource exploitation, such as firewood. A geothermal plant is located in here, which is one of the biggest around the world, having a generation power of 1,420 megawatts, enough to satisfy all the power requirements of Baja California and even export its surpluses (XV Ayuntamiento de Mexicali, 1998).

Delegation of Colonias Nuevas.

This delegation has an extension of 1,080,400 km^2, with 15, 171 inhabitants (INEGI, 1990) are distributed. It includes 10 ejidos, 3 towns, 9 ranches, and 4 agricultural (XV Ayuntamiento de Mexicali, 1998). Table 15 shows the colonies and ejidos included in the wetland influence area.

Table 14.- Communities in Delegation of Cerro Prieto related to the Hardy/Colorado River wetlands.

Colonies	Ejidos
Cerro Prieto	Chihuahua

Lázaro Cárdenas	Heriberto Jara
Número Cinco	Hipólito
Número Seis	Michoacán

Source: XV Ayuntamiento de Mexicali. Coordinación de Delegaciones. 1998.

Table 15.- Communities in Delegation of Colonias Nuevas related to the Hardy/Colorado River wetlands.

Colonies	Ejidos
Lerma	Grupo Colorado
Sonora	Plan de Ayala
Zacatecas	Oviedo Mota

Source: XV Ayuntamiento de Mexicali. Coordinación de Delegaciones. 1998.

Colonias Nuevas has been a development center of the Mexicali valley since the last decade. An important issue is vicinity of the ejido Luis B. Sánchez, in the state of Sonora, being separated just by a street. This has several implications, the most important is the opportunity to implement a joint urban development program for the area.

The agricultural land pertains to irrigation modules No. 21 and 22, and has 1,050 km^2, owned by 665 beneficiaries. Over 12,000 of the total hectares are cultivable and are used to produce wheat, corn, canola, barley, cotton, citrics, asparagus, and vine. (XV Ayuntamiento de Mexicali, 1998).

Locality of Luis B. Sánchez. (State of Sonora)

Luis B. Sánchez is a locality from the State of Sonora, and has a population of 4,127 inhabitants. This community represents 24.7% of the total population of the Hardy and Colorado River wetlands influence area (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, in several rural towns and farms, such as Tecolote, Pozo Vicente, Cipriano or Mayor in the Hardy River margins; and El Batequi, Codornices, Borrego, La Draga, among others isolated settlements, in the margins of the Colorado River (Álvarez de Williams, 1973).

The Cucapá community has 143,000 Ha, almost all of them uneasy to reach most part of the year and far away from El Mayor, located on the km 55 of the Mexicali-San Felipe Highway. There are only 82 people of this ethnic group in the state of Baja California, 50% of them women (INEGI, 1996f). Ethnic extinction has rose as a major threat in the last decades mainly because of economic, political, and social problems, in which the loss of ethnic identity has been an important factor when considering the shift of economic activities that forces them to move to other cities.

Before water became scarce, the natural resources this ecosystem provided to the Cucapá community, were enough to sustain it fairly, according to their traditions and culture. Several plants provided them food such as the seeds from mesquite and iron wood; seeds and pods from screw beans; seeds from several halophyte shrubs and salt grasses; quelite leaves and seeds; cattail roots and bulbs; dates, melons, wild pumpkins, biznagas, and agaves. These same plants also provided them with the tools and building materials for their houses and canoes, or for making other tools. They also used to cultivate corn, beans, and pumpkins in the flooding area. Fish, migratory birds, rabbits, rodents, wild boar, mule deer, and big-horn sheep were their source of meat (Álvarez de Williams, 1973).

Most of their food traditions are still practiced, except that today's meat availability is lesser, as mule deer and big-horn sheep almost disappeared from the Cucapá territory. Due to water scarcity, traditional economic activities are not enough to survive, fishing is not enough to satisfy the families' needs, and agriculture is not possible most of the year, but still they collect seeds and certain plants for food. To increase family income, some Cucapá members are now employed as hunting and sport fishing guides, mainly by USA tourists. Others, mainly women, are artisans and sell their arts and crafts made of chaquira (colorful glass or plastic bead) to tourists who visit the community museum.

Today, they mix occidental was of living with traditional uses. They have a traditional authority, who is in charge of securing Cucapá culture, but they also observe Mexican laws. They still build some of their houses, tools and canoes as they did hundreds years ago, but they also use today's materials, such as concrete. They eat traditional dishes, use traditional musical instruments, and maintain religious ceremonies.

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 use properly wetlands resources. Low water flows and low water quality diminish their probabilities to succeed.

b)Human Activities.

Mexicali.

Mexicali's economically active population is 47.9% of its total population over 12 years (427,317). Of this percentage, 27.9% are women. This women represent the 35.4% of Baja California's total female population. In the economically inactive population rates, the masculine population is formed mainly by students (56.8%), and the corresponding female population is formed mainly by house keepers (70.3%). Of the total active population, 16.6% is working in agricultural and cattle raising activities, 55% of them are day laborers, 15.2% are manufacturer workers and artisans; 11% work in an office; and 10.2% work on commerce. (INEGI, 1996b).

San Luis Río Colorado

San Luis Río Colorado have a total population of 133,140 inhabitants (INEGI,1996c), which means 6.4% of Sonora's total population, 50.3% of them are men. From 1990 to 1995, the average growth rate in this municipality was of 3.3%, bigger than the Sonora's rate (2.4%). Of San Luis's total population, 61.6% is aged between 15 and 64 years, and 34.4 % is aged under 14 years (INEGI,1996c).

The economically active population of San Luis Río Colorado is about 34,713 persons, half of them are women. Of the total economically active population, 45% works on tertiary activities, such as commerce; in secondary activities works the 24.7% of them; and 27.8% of the total active people works in agricultural activities (INEGI, 1996c).

The agricultural district No. 14, include lands from the Mexicali and the San Luis Río Colorado municipalities. It is one of the most important agricultural valleys in México, and produces several crops. Table 16 shows amounts produced, cultivated land, and market value by crops. As it can be seen, the crop with more market value was onion, even though it was not the biggest production (in tons). The second product with high market value was wheat, which correspond with the greater cultivated area and production. Cotton was the third crop in importance in both market value and tons produced.

Table 16.- Crop Production in Irrigation District No. 14

Crop	Cultivated Land (Ha)	Production (Tons)	Market Value of Crop*
Canola	2,432	5,228	9,933,200
Barley	434	1,537	1,767,550
Wheat	**79,743**	**500,771**	703,718,463
Rye-Grass	5,658	217,833	41,322,920
Onion	5,035	61,905	**846,860,400**
Alfalfa	19,512	329,564	411,955,000
Asparagus	2,723	10,838	182,425,216
Vineyard	1,203	11,989	64,303,650
Fruits	418	7,592	8,988,807
Cotton	41,606	257,179	657,349,524
Sorghum (grain)	13,800	39,347	43,182,939
Corn	5,500	7,898	11,924,470

Source: Secretaría de Agricultura, Ganadería y Desarrollo Rural. 1998. Cédula de Cultivo Ciclo 1996-97.
* Market value is given in thousands of pesos.

y/Colorado Wetlands

Human activities carried out in the Hardy/Colorado Wetlands are mainly related to agriculture and cattle ranching, as in most of the Mexicali Valley, but an important difference 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:

This activities are carriedout by local communities, including the Cucapa community of El

Mayor, Colonia Baja California, Campo Sonora, Ejido Donato Guerra, Ejido Durango, Colonia Carranza, Ejido Oviedo Mota, Ejido Cucapá Mestizo, El Indiviso, Campo Flores, Campo San Miguel, and Estación Coahuila. Members of these communities visit the wetlands periodically to perform recreational and subsistence fishing and hunting, as well as other aquatic activities, as swimming and water ski.

Apiculture is another activity carried out at a low scale level, with few apiculture farms spread in the area. There are some facilities located around the Pescaderos region, in the remnant mesquite stands. Also, there are some facilities located in dense saltcedar stands, since saltcedar flowers are used by bees for honey production.

Other low scale activities include the utilization of wood as a construction material for fences, houses and stables; and, as fire wood. The vegetation most commonly used are willows, mesquite, cottonwood, saltcedar, and arroweed.

Fisheries

At a commercial level, fisheries are carried out in the area mainly by the Unidad de Producción Pesquera Cucapá (Cucapá Fishing Production Unit), which groups all the Cucapá fishermen, and is leaded by Mónica González. 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. Since they are the only native tribe in the delta, they are the only ones with rights to fish in this area. They use chinchorros (sweeping nets) that are placed along the river, and the main fisheries are gulf corvina (*Cynoscion othonopterus*) and shrimp (*Penaeus* spp.), which populations heavily depend on the flows from the Colorado River. They also capture big mouth bass, carp, mullet, catfish, tilapia, and crayfish. Most of the time, the products are enough only for the community, but on good fishing seasons of corvina and shrimp, they sell to Mexicali and San Luis Río Colorado markets. The Cucapá community also fish in the Laguna Salada when it is flooded, and they have exclusive rights to use the resources in this lagoon, as it is part of their territory.

There are other fishermen groups that fish on the Colorado River delta, as the Unión de Pescadores Ribereños de San Felipe (Union of Artisan Fishermen of San Felipe) located in San Felipe, B.C.; Sociedad Cooperativa de Producción Pesquera “El Desemboque” (Cooperative Society of Fishing Production “El Desemboque”) located in El Indiviso, B.C.; and the Federación de Sociedades Cooperativas de Producción Pesquera “Alianza de Pescadores” (Federation of Cooperative Societies of Fishing Production “Alianza de Pescadores”) located in the Gulf of Santa Clara, Son.

These groups mostly fish in the Upper Gulf of California, nearby Montague Island and the river mouth for shrimp, shark, milkfish and corvina. Some problems have rose with the Cucapá community and the Biosphere Reserve, due the special rights of the indigenous community to fish on the reserve core zone, specially on corvina season, when other fishermen also want to fish in that area. Something similar is occurring on the Laguna Salada, where fishermen from Mexicali and San Felipe frequently try to fish.

Since corvina is not a protected species by Mexican government, and it is not included in the regulations of the Biosphere Reserve because populations were so low that it was not a significant fishery when the management plan was originally designed, some problems with the use of this resource have rose, as it is difficult to enforce fishing regulations during the spawning season.

The Biosphere Reserve has been promoting a series of meetings among fishermen groups to discuss these issues, and try to reach some management solutions. Although, there is still much work to be done to arrive to the solution to this issues. Fisheries management will be one of the major points to discuss on the public involvement workshops of the project’s second phase.

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 with a total duration of 10 months. The stock density in the ponds is 3.5 to 4 organisms/m^2. Survival rate of fingerling production is 85 %, and 95 % in the stocking ponds. This allow yield results of 3 tons/hectarea, with organisms of 1 pound. The final weight of the fish is variable depending on the market, and some times it may reach 3 pounds. Artificial food is provided in Purina pellets for cat-fish.

Water for the culture is from an irrigation cannal, and if extra water is needed, they use that from the Hardy River. Water exchange is done twice per week, and the requirement is of 50,000 m^3/week. An splashing aeration system designed by the farm owners is used on the ponds.

The size of the farm is of 2.5 hectares, which include two stocking ponds, one raising pond, and the fingerling production laboratory, that has a capacity for 300 breeding females. The works for expanding the aquaculture facilities to 18 hectares already started, and they are planning to begin operations in 1999. An important issue is that this expansion is not being done on actual wetland area, but on fields which are not suitable for agriculture.

The production is targeted to local markets in the valley, and to the city of Mexicali, where they are highly demanded. With the facilities expansion, they will try to export to the U.S. They also have a good market for the surplus of fingerling production, which is sent to SEPESCA (Fisheries Ministry) and regional research centers on aquaculture.

Attempts by the Cucapa community to develop extensive type of aquaculture on the river stream have been destroyed by intense water flows, because they were constructed by setting rustic dams with vegetation, that held fish in certain area, allowing water flow.

More recently, the Cucapá community started a cat-fish aquaculture project with cages on the river stream, at Cucapá El Mayor. This effort is being supported by local and federal governments, and with significant work of the community. Institutions involved on this project will provide technical support, as this is one of the potential restoration sites, and this activity consider benefits from wetland resources without causing damage to the environment, and will also be supported by the restoration activities.

Tourism

Along the river banks, there are several tourist camps that are used by people from Mexicali and U.S. visitors in vacations, holidays, and in the hunting season (autumn-winter) in the search of ducks and other migratory waterfowl. These activities require the Cucapas as hunting guides. The main touristic activities are aquatic sports, as skiing and swimming, recreational fishing, hunting expeditions, and environmental and archeological hiking.

The best tourist facilities are located at Campo Mosqueda, with lodges for rent located aside the Hardy River; a lake formed by the river, where water sports can be practiced; boat rental, restaurant, and fishing and hunting expeditions. Some facilities are also located at Campo Sonora, aside El Mayor River, with some palapas (wooden shades), a restaurant, and a grocery store. The Cucapá community of El Mayor also represent a tourist attraction in the area, with the Cucapá Museum, where the community sells they arts and crafts, beside of showing their history and traditions.

There is a big potential for eco-tourist activities in this area, but community capability to perform the required activities needsto be built. This is one of the goals in the future steps on this long-term process of restoring the Hardy/Colorado wetlands, establishing within communities a sustainable development framework.

Several economic activities are identified in this project report as suitable for the delta ecosystem, and that could yield the improvement of rural communities living conditions. The promotion of controlled outdoor activities for tourists (national and international) is an important area of opportunity, and can include ecotourism, camping, guided tours in the wetlands, field trips for students, and ornithology study trips. Aquaculture of some commercial species could be an important option for these communities. Also, waterfowl hunting activities could become a formalized economic activity, with the appropriate legal controls, respecting hunting seasons and quotas allowed.

VI-Environmental Regulations on the Colorado River Delta

6.1. International Concern

a) Legal Framework

The Colorado River spans 2,730 km (CNA, 1997), supplying water to nearly 30 million people (Powell Consortium, 1995), and irrigating more than 1.5 million hectares of farmland (Morrison *et al*, 1996) in seven states from the USA and the Mexicali Valley in México. Because of this resource share, management of its stream has been of great concern for both countries. In 1889, the governments of United States and México created the International Boundary and Water Commission (IBWC), named in México as "Comisión Internacional de Límites y Aguas (CILA)," with the purpose of "applying the provisions of various boundary and water treaties, and settle differences arising from such applications through a joint international commission located at the border"(IBWC, 1998). The IBWC's jurisdiction covers the United States-México boundary and inland into both countries where they may have international boundary and water projects. Its mission is to "provide environmentally-sensitive, timely, and fiscally responsible boundary and water services along the United States and México border, in an atmosphere of binational cooperation and in a manner responsive to public concerns" (IBWC, 1998).

The legal and institutional framework in the United States for management of the Colorado River is the "Law of the River," negotiated in 1922 by 7 states from the United States (Wyoming, Colorado, Utah, New México, Arizona, Nevada and California) and the USA federal government. This Law divided the Colorado River basin in an upper and lower basins, releasing, on both, the responsibility of providing water to México in equal quantities.

México (through CILA) and the U.S. (through IBWC) signed in February 3rd 1944 the International Boundary and Water Treaty, which stated that México will receive 1.5 maf (1,850 Mm^3) per year of the Colorado River water, and when surplus exists, México would receive 200,000 acre-feet additional per year (244 Mm^3). Unfortunately, it mentioned nothing about the quality of the water México would receive. Until 1973, through a separate agreement, this problem of water quality was explicitly resolved, establishing that the water allocated to the Morelos Dam in México, should have salinity levels no more than 0.115 ‰ higher than the water arriving at Imperial Dam, Arizona (Morrison *et al*, 1996).

b) Agreements in Force

The Colorado River provides important services to a great variety of users; human settlements and wildlife are the most recognized beneficiaries under these agreements, however, the delta's ecosystem as a whole has been poorly considered. Management of the Colorado River stream is subject to several binational and international agreements, in which its tributaries and related wetlands, as well as its delta and the Colorado estuary, are also under such considerations. Today, several agreements support wetland programs in México:

<u>*The North American Waterfowl Management Plan*</u>

The North American Waterfowl Management Plan was signed by the United States and Canada in 1986, and is managed by the North American Waterfowl Management Committee. It's mission is to protect and restore 6 million acres of wetlands, and the main goal of this plan is the restoration of waterfowl populations at least toward the numbers registered in the early 70's, considering the continental approach as the optimum to get the conservation of North American waterfowl (USFWS, 1998b). Therefore, México joined the plan and became a contracting party since 1994, being represented by the National Institute of Ecology (INE). The plan considers that the recovery and safeguard of waterfowl populations depends on the restoration and conservation of the associated wetlands and ecosystems in North America.

This plan considers the wetlands and waterfowl to be the most valuable inheritance from North America and the use of them should be in harmony with its conservation in the long run. In this way, wetland restoration and protection should be the strategies for a long-term management plan, so as to increase waterfowl populations. The main instruments are the joint projects of private organizations, individuals, and government agencies. This plan lists those important waterfowl habitat areas in North America, including the Colorado River delta. Hence, the wetlands and inland surrounding this delta, are subject to habitat protection, restoration, and wise use, considering that this is a breeding and nurturing place of migratory waterfowl, sustaining great biodiversity of species within ecological processes of high relevance.

Tripartite Agreement on the Conservation of Migratory Birds and their Habitats.

México is also partner of the Tripartite Agreement on the Conservation of Migratory Birds and their Habitats, signed in 1988. By this means, México agreed to work with Canada and the United States in the conservation of migratory bird populations, through collaborative projects undertaken by each country's federal agencies. For México, the actions and projects that are done as part of this Tripartite Agreement should also help to improve the welfare of people living in rural communities as part of a sustainable rural development. This agreement includes the generation of management plans for critical marshland and other wetland habitats that could help recover migratory birds population as well as providing a way to improve the living conditions of local people. In the case of México, the application of this agreement goes a little farther than the NAWMP, as it considers the use of these resources no only for recreation and subsistence activities, but also as income earning activities in rural areas.

North American Wetlands Conservation Act

The North American Wetlands Conservation Act (NAWCA, 1989) has as purpose, the promotion of "long-term conservation of North American wetland ecosystems, the waterfowl and other migratory birds, fish and wildlife, that depend upon such habitat. Principal conservation actions supported by NAWCA are acquisition, creation, enhancement and restoration of wetlands and wetlands-associated habitat (NAWCC, 1998; USFWS, 1998a)." This Act provides funding and administrative direction to support the implementation of the North American Waterfowl Management Plan and the Tripartite Agreement on Wetlands between Canada, U.S. and México. Thus, the North American Wetlands Conservation Council was established to review the merits of wetlands conservation proposals submitted for funding under this Act.

To apply for NAWCA funding there are three review periods, any project should be submitted for its review in the months of April, September, and December. A copy of the proposal should be sent to The National Institute of Ecology (INE, México), Wetlands International-México Program (WI, México), and the U.S. Fish and Wildlife Service (USFWS; USA). The Council will review the proposals recommended by INE in the months of March, July, and December, and the projects approved by the Council will then be proposed to the Migratory Bird Conservation Commission (MBCC), which provide the final approval. Then a financial contract between the U.S. Fish and Wildlife Service (the agency in charge of the programs) and the proposing party is signed (NAWCC, 1998; USFWS, 1998a).

There are at least two projects supported by the Act in the Colorado River delta that provide tangible benefits for the ecosystem: the one that is being described, and another applied in the Upper Gulf of California and Colorado River delta Biosphere Reserve, where this Act is funding the inventory and management of the wetlands located in the core zone of this Reserve, which include La Ciénega de Santa Clara and El Doctor wetlands. This inventory will serve in the design of further management plans and will convey the establishment of quantitative measures and goals of protection/restoration of its flora and fauna. For example, it will let the managers of the reserve know the specific situation of some endangered or threatened, such as the yuma clapper rail and the desert pupfish, which are also internationally protected species. Therefore it could be possible to know the status of this populations, their habitat needs, their feeding customs and the rate of change for this population, before and after the implementation of managing/protecting programs are in place.

Western Hemisphere Shorebird

Reserve Network

The Western Hemisphere Shorebird Reserve Network (WHSRN) began in 1985 as an effort of the World Wildlife Fund, the International Association of Fish & Wildlife Agencies, and the Academy of Natural Sciences of Philadelphia. Today, there are more than 120 wildlife agencies working together in this network, which links wetland and upland sites that are essential to migratory shorebirds in a "voluntary, non-regulatory program of research, training, and collaborative effort for habitat management, environmental education, and protection" (WHSRN, 1998).

Shorebirds migrate across the hemisphere passing through wetlands of high importance to wildlife and associated human activities as well. These critical sites along the hemisphere are included in this Network, and have the advantages that each site gains acknowledgment and support for local conservation initiatives.

The Network has several goals, the ones that apply to the Hardy/Colorado wetlands are (WHSRN, 1998):

- To identify and protect sites critical to the Hemisphere's migratory shorebirds. Through this process, the Colorado River delta became part of the Network in 1992.

- To promote and support the development of conservation organizations and their efforts to protect shorebirds and their habitats. Which is strongly needed in this area, because of the biodiversity that this ecosystem sustains.

- To use education and public awareness to build public support for wetlands and shorebirds. It is necessary to make the users of the Lower Colorado/Hardy River wetlands aware of their high ecological and economical value, and enhance their participation within conservation and protection programs.

- To help in development of international, national, and local policies, by providing them support to ensure the long term protection and management of this critical sites. Policies that would regulate and control wetlands uses are needed, as population growth is becoming higher, as well as the need of native users to find out new alternative uses that could help them improve their living conditions without depleting their resources.

- And finally, to compile, to analyze and to spread information about shorebird distribution, migration paths, and habitat use. A census and monitoring program for shorebird migration and distribution in the delta would allow the establishment of policies for the wetlands use in the Hardy/ Colorado Rivers.

Ramsar Convention.

Continuing in the international context, México is a Contracting Party of the Ramsar Convention, whose mission is "the conservation and wise use of wetlands by national action and international cooperation, as a means to achieving sustainable development throughout the world" (The Ramsar Convention Bureau, 1998a). As a Contracting Party, México agreed "to formulate and implement its planning so as to promote, as far as possible, the wise use of wetlands in its territory" (The Ramsar Convention Bureau, 1998b). This concept of wise use means that human usage under sustainable basis is completely compatible with wetland conservation.

México agreed also to integrate the strategies of conservation and wise use of wetlands into national, provincial, and local planning and decision-making on land use, groundwater management, catchment/river basin, coastal zone planning, and all other environmental management plans (The Ramsar Convention Bureau, 1998b). The country also agreed to list its priority wetlands on the Ramsar List, in order to be considered as a " Ramsar Sites". A Ramsar Site is a wetland of international relevance, specially as habitat for waterbirds, because of the ecological processes it sustains, as well as its richness in flora and fauna.

U.S.-México Border XXI Program

The U.S.-México Border XXI Program is another binational effort that brings together those federal entities from the United States and México that are responsible for the environment their borderlands. The main goal of this program is to promote sustainable development in the border region, considering social and economic factors under an environmental framework (SEMARNAP, 1998a; EPA 1997). To achieve this complex goal, the Border XXI Program promotes cooperation in protecting human health and the environment, as well as the proper management of the natural resources in both countries.

The Program's general strategies include: Decentralization of environmental management through building of municipal and state capacity; public involvement; and, improved communication among the agencies in all government levels (local, state and federal). Within this program, a system of protected areas was developed under the North Border Environmental Project, and Colorado River delta is considered as part of a comprehensive strategy for management of natural resources along the border region between México and the United States. Its nine binational workgroups mentioned before are: Air; Contingency Planning and Emergency Response; Cooperative Enforcement and Compliance; Environmental Health; Environmental Information Resources; Hazardous and Solid Waste; Natural Resources; Pollution Prevention; and Water. They will develop yearly the Border XXI Annual Implementation Plan, which will identify federal funding levels for each year based upon available funds. The Plan should describe specific projects that will advance the long-term objectives outlined in the Final Framework Document for the U.S.-México Border XXI Program.

6.2. Federal Concern

a) Legal Framework

The General Law of Ecological Equilibrium and Environmental Protection

The General Law of Ecological Equilibrium and Environmental Protection (LGEEPA) is the regulatory instrument of México's Political Constitution in the theme of preservation and restoration of the ecological equilibrium of the country's natural resources. It's goal is to set the guidelines for achieving the country's sustainable development, seeking to warrant its citizens the right to live in an adequate environment for its development, health, and livelihood (Chapter I, Article 1). This law states the principles of the country's environmental policy as well as the instruments needed to enforce it. (Congreso de los Estados Unidos Mexicanos, 1997).

Some of the principles of this environmental policy include (Chapter 3, Article 15): The consideration of ecosystems as the society's common inheritance over whose equilibrium depend life and productive capacities of the country alike; ecosystems and their elements should be used wisely, such that its productivity could be optimized and sustained, being compatible with its equilibrium and safeguard; biodiversity and its supporting habitats should be maintained; and finally, the costs of environmental pollution and natural resource depletion over a year, should be calculated so as to generate the Net Ecological Domestic Product for the same year.

As the LGEEPA states, the main instruments of México's Environmental Policy are the National Development Plan 1995-2000 (and the programs and agreements of cooperation derived from it), the Ecological Land Use and Ocean Planning, the economic instruments such as licenses, hunting permits, fishing quotes, fiscal incentives (ex. subsidies), human settlement regulations, environmental impact assessments, Mexican Official Norms on Environment (NOM-ECOL), social participation; and, environmental education and research. (Congreso de los Estados Unidos Mexicanos, 1997).

b) Environmental Policy Instruments and Programs

The National Development Plan 1995-2000

The National Development Plan 1995-2000 states the environmental guidelines that should be considered along with the economic and social strategies for achieving México's development objectives for this 5-year period. It's goal is to join the economic, social, and environmental objectives such that economic development of each region should be compatible with the carrying capacity of its natural resources, throughout a wise use approach. It also recognize the need to stop or prevent the deterioration of the environment along with the alleviation of poverty (Secretaría de Gobernación, 1995). Derived from this plan, several sectoral programs emerged, like the National Program for the Environment 1995-2000, the National Hydraulic Program 1995-2000, the National Program for Fisheries and Aquaculture, and the National Program for Wildlife Conservation and Rural Productive Diversification 1997-2000.

National Program for the Environment 1995-2000

According to The National Development Plan 1995-2000, the Environmental Program 1995-2000 has as its main objective: "... breaking of the trends that damage the environment, the ecosystems, and natural resources, and the setting of the basis for an ecological restoration and recovery process that will allow the promotion of social and economic development of México with sustainability criteria."

Briefly, the environmental strategies that apply to the Colorado River delta are (SEMARNAP, 1998c):

1)Conservation and sustainable use of biodiversity of Protected Natural Areas (PNA), promoting and consolidating their management and operation.

2) Land Use Planning, as a strategic instrument for a sustainable regional development, offering spaces of inter-governmental concurrence with the private sector, universities, and social organizations, to plan and regulate the land use and the sustainable use of ecosystems and natural resources.

3) Productive diversification and wildlife use in the rural sector is proposed as a strategy that joins conservation with the search for new opportunities of rural development, based on the wise use of species of eco-zootechnical, cynegetic, nourishing, and pharmaco-chemical interest.

4) Environmental protection of coastal zones and ecosystems, like the case of mangrove swamps, reefs and lagoons, demands a great effort for monitoring, conservation, and restoration activities by means of new alternatives of environmental information and management.

This last two strategies are the ones that could turn out to be a more complete answer to the needs of the Hardy/Colorado River wetlands. Their protection and restoration is a priority action to achieve waterfowl, aquatic resources, wildlife in general, and human settlements alike. An equilibrium between human use of the water that feeds the Hardy/Colorado River (and their wetlands resources), and the environmental needs of water for the whole ecosystem to survive, should be agreed and respected. By no means, the resolution of existing conflicts between human uses of wetlands and the ecological cycles of the ecosystem should be a "zero-sum game"[2].

The National System of Protected Natural Areas

The second title of the General Law of Ecological Equilibrium and Environmental Protection (LGEEPA, art. 44th-77th.) is focused in biodiversity, specifically in the description of the National System of Protected Natural Areas (PNA's). This system of PNA is responsible of the establishment and management of those natural areas with great biodiversity and unique ecological characteristics, to be considered sites of special relevance for our country and in need to be protected by law. Accordingly to the 44th. article from the LGEEPA, those areas are portions of the national territory, over which the Nation has sovereignty and jurisdiction, whose original environment had not been significantly altered by human activities, or those areas who are to be preserved and restored.

The objectives of this PNA system are (Congreso de los Estados Unidos Mexicanos, 1997): To preserve the most representative biogeographic and ecological regions of México, the fragile ecosystems, and the genetic diversity of the species; to ensure the continuity of the evolutive and ecological processes; and at the same time, create the conditions for the wise and sustainable use of the resources throughout scientific research and technology development. The conservation and protection of the environment that surrounds human settlements and those artistic, historic, and archeological monuments of great cultural relevance, is also an objective of this PNA system.

The LGEEPA classified these protected areas in 8 different categories: Biosphere Reserve, Special Biosphere Reserve, National Park, National Marine Park, Area of Protection for Vegetation and Wildlife, and Natural Monument. The area of the Upper Gulf of California and Colorado River Delta was decreed a within the category of biosphere reserve in June 10th, 1993, as such, it has four underlying criteria: It should: incorporate local people and institutions in the conservation of the germoplasma; take into account the socioeconomic problems of the Colorado River delta both, while doing research and while planning the development of this region; be managed by an administrative-independent research institution; and finally, it should be considered as part of a global strategy for conservation. The establishment and management of this PNA should be done with the active participation of the community, local authorities, native tribes, and other social, public, or other related private organizations. In this way, the development of this region could be achieved through the protection and preservation of ecosystems and biodiversity (47th. art.).

Accordingly to this PNA system, the National Commission for the Use and Understanding of Biodiversity (CONABIO) and PRONATURA A.C., organized jointly in February 1996, the National Workshop for Identification of Priority Regions for Conservation. The main purpose of this workshop was to identify those regions in México which based on biological characteristics, should be the focus of federal conservation efforts. Identification of these areas was done through the assessment of different cartographic and bibliographic materials, along with the expertise and knowledge of workshop participants (CONABIO, 1998).

Being the borderline that separates the states of Sonora and Baja California, the Colorado River was recognized as one of this priority regions for conservation, including wetlands from the Hardy/Colorado Rivers. Restoration efforts in the area are completely supported by several national programs, and the identification of delta as a priority zone for conservation, reflects the need to develop a management plan for its natural resources, considering the threats they have or will have in the future.

The Hydraulic Program 1995-2000

The main goal of The Hydraulic Program 1995-2000, in accordance with the objectives stated in the National Development Plan 1995-2000, stresses the role played by water in attention to: a) human consumption, hygiene and care of public health; b) population groups and zones of greater poverty; c) services provided to improve living standards and social welfare; d) agriculture, industry, trade, and other economic activities as an input; and, e) the full utilization of natural resources within a framework of sustainability (SEMARNAP, 1998b). This program considers that the hydraulic resources are used today mainly for the following ends: domestic, agricultural, industrial, electric power generation, aquaculture, fisheries, recreation, tourism and navigation, however it states that water should be also seen as a vital input for ecosystems, considering them as other users of this valuable resource. This last statement is not considered

[2] Economics Game Theory, the term "zero-sum game" is a used to describe a situation in which two opposite partners play, but one gains more than what the other lost, so at the end of the game, the former compensates the latter in such a way that nobody looses and possibly more than one gains.

yet in the policies that regulate directly the use of water of the Hardy/Colorado Rivers, neither those from United States nor those from México, turning critical the delta and wetlands situation.

The National Strategy for Wetlands

The National Strategy for Wetlands promotes the principle of managing wetlands in conjunction with other natural resources, under a long-term framework of rational use. It seeks to establish the technical guidelines for the conservation, wise use, management, and protection of México's wetlands. Its goals include: The development of methods for controlling the quality deterioration of biotic and abiotic elements of wetlands; prevention of wetland pollution through environmental impact assessment; selection of those wetlands in critical conditions, which are subject to priority restoration or conservation, taking into account the legal status of the flora and fauna each one sustains and their habitat conditions; enhancement of alternatives in the use of wetlands and its resources, promotion of activities that are non-disruptive to wildlife and associate habitats; and the generation of education and public involvement programs in wetlands conservation and restoration, among others.

The Program for Fisheries and Aquaculture

The Program for Fisheries and Aquaculture has 4 main objectives: To enhance the sustainable and wise use of fisheries without damaging the renovation capacity and the environmental quality of those habitats; to establish the ordinances of economic activities in this sector that promote a responsible fishing; and to promote economic and social development within the communities depending on these resources. It is focused on those diversified processes that would lead a wise use of fisheries and aquatic resources, which at the same time, are consistent with environmental conservation and with the improvement of living conditions of the people depending on them (SEMARNAP, 1998d). This program enables the restoration, protection, and conservation of those habitats in which commercial and non-commercial fisheries live, permanently or seasonally.

The National Program for Wildlife Conservation and Rural Productive Diversification 1997-2000

The purposes of the National Program for Wildlife Conservation and Rural Productive Diversification 1997-2000 include: The establishment of incentives to link public and private interests in the conservation of ecosystems and associated wildlife and in generating alternative economic activities in the rural zones. It is intended not only to avoid species extinction, but also to establish recovery plans for those endangered, through the establishing management and monitoring plans and the continuity of the natural processes in all the ecosystems. (INE-SEMARNAP, 1997).

The instruments of this program consist in the conservation and recovery of priority species (and their habitat), which include: internationally considered to be in risk; those with a high economic and cultural value; whose protection would indirectly yield the conservation of other species and their habitats; and finally, those considered to be charismatic species. In this way, economic development of rural communities would be achieved throughout a sustainable basis, if they could establish those economic activities suitable for their environment. This program is highly related with the Tripartite Agreement on the Conservation of Migratory Birds and their Habitat and with the North American Waterfowl Management Plan, as waterfowl is considered internationally as a priority specie for conservation.

6.3. Local Concern

The Colorado River delta is located partly in the municipality of San Luis Río Colorado in the state of Sonora, but most of it is within the municipality of Mexicali, state of Baja California. The governmental agencies involved in the environmental protection of the area are:

State of Baja California:

Federal Offices in the State:

*State Delegation of the Ministry for Environment, Natural Resources, and Fisheries (SEMARNAP)
*Secretariat of Agriculture
*National Water Commission (CNA)
*International Boundary and Water Commission (CILA-Regional Office)

State Offices:

*Secretariat of Human Settlements and Public Infrastructure (SAHOPE)
*Secretariat of Economic Development
*General Direction of Ecology
*Secretariat of Tourism
*Direction of Public Registry of Land Ownership (Cadastral System)
*State Commission of Public Services
*State Water Service Commission

Municipal Offices

- Municipal Government
- Mexicali Delegations Coordination

State of Sonora

Federal Offices in the State:

•State Delegation of the Ministry for Environment, Natural Resources, and Fisheries (SEMARNAP)

State Offices:

*Secretariat Urban Infrastructure and Ecology (SIUE)
*Secretariat of Economic Development
*General Direction of Ecology
* Secretariat of Tourism
*Direction of Public Registry of Land Ownership
*Secretariat of Agriculture
*State Commission of Public Services

Municipal Offices:

•Municipal Government

The federal, state, and municipal governments are the ones in charge of enforcing the General Law of Ecological Equilibrium and Environmental Protection (4th. art.). Although the federal government is the one who defines and directs the environmental policy for the country in general, the LGEEPA encourages the states and municipalities to participate in the "preservation and restoration of ecological equilibrium" by issuing their own laws and regulations, such as the State Law of Ecological Equilibrium and Environmental Protection, and the Statewide Land Use Plan (Congreso de los Estados Unidos Mexicanos, 1997).

State of Baja California's Law of Ecological Equilibrium and Environmental Protection

In January 1992, the Baja California Congress approved its own Law of Ecological Equilibrium and Environmental Protection (LEEPA), which yield to the creation of the Statewide Land Use Plan (August, 1995), as a regulatory instrument that establishes the environmental guidelines and general principles of the state's environmental policy. It's main objective is "to prevent the negative effects of human activities over the environment and to warrant the wise use of the state's natural resources" (Gobierno del Estado de Baja California, 1995). Several plans have been generated under this land use plan, like the State's Emission Regulatory Plan, the Hydraulic Plan, the State's Clean Water Plan, Comprehensive Management Plan for Solid Wastes and Raw Materials, and the Plan for Prevention and Control of Environmental Contingencies and Emergencies.

According to this plan, Baja California has seven natural protected areas, and the Land Use Plan identifies the establishment of 3 more. Each one of them is considered an Environmental Management Unit (Unidad de Gestion Ambiental- UGA), whose land use planning is in process.

The "Environmental Management Unit No.3 (UGA3. Mexicali Valley)", within the Plan's zoning framework, is the one in which the Hardy River is located. The general policy that apply to it is "Promoted Use" in order to incentive productive activities in the area. It has 3 more specific policies, the "Regulated Use", which refers to an area in which industry growth is not recommended, neither human settlements and it applies to the valley area; the geothermoelectric plant of Cerro Prieto, including the dunes from Los Algodones, and the southern portion down to the limits of the Biosphere Reserve of the Upper Gulf of California and Colorado River delta.

The next specific policy, "Development Consolidation Use," applies to the urban area of Mexicali, describing a zone in which population growth and productive activities were developed without any kind of land use plan, but process is in place. The last specific policy, "protection with active use" applies to the portion of this UGA3 zone that is located within the Biosphere Reserve, is intended to promote several activities that could be done in the area, such as manipulative research, cynegetic activities, sport fishing, photography, camping (limited area), and ecotourism. Cattle ranching and agricultural activities are not allowed, neither those classified as secondary sector activities. Forest exploitation is allowed only for those species with established management programs. No new towns can be built.

The "Environmental Management Unit No. 4 (UGA4. Colorado River delta)", covers the Colorado River Delta and Upper Gulf of California Biosphere Reserve, whose general policy is protection with active use, and whose particular policies are the protection with passive use (in the core zone of the reserve) and prevention of impacts (when needed). The policy of "Protection with active use" means the same as in the UGA3, described before. "Protection with passive use" means that recreation can be done in limited areas, manipulative research is allowed, rural roads can be built, flora and fauna collect is forbidden, its natural resources could be used only by local communities, and the number of visitors is limited. This category allowed activities such as: photography, swimming, recreational diving, and camping. In the zones with preservation, or complete conservation as its particular policy, no vehicle could enter, no building could be established, recreational and productive activities are forbidden, only non-manipulative research could be done, access is restricted to researchers with approved permit only.

Although included in the UGA3, the Hardy River and its wetlands should be proposed to the State's Congress as an area that should share with the

Biosphere Reserve, the specific policy of "protection with active use", considering the biodiversity it sustains, and the importance for being restored and conserved, not only for the rural communities depending on it, but because it is also an important area for breeding and nurturing of internationally protected migratory waterfowl and associated wildlife.

Mexicali Municipal

Development Plan 1996-1998

At the municipal level, Mexicali has its own Municipal Development Plan 1996-1998, which is divided in several phases: situation diagnosis; definition of objectives; and finally, strategies and instruments for its implementation. As a result of the assessment of Mexicali's environmental situation, the attention to water, air, and land pollution was considered a priority, as well as the creation of mechanisms to increase the ecological culture within the population.

In pollution issues, the objectives in this plan include: The enforcement of the law, the promotion of waste management and landfill sites, and implementation of recycling programs that could lead to wise use of natural resources. The strategies for achieving these goals are: Generation of a Municipal Ecological Land Use Plan that could identify those regions subject to conservation, restoration, and wise use; recognition of biodiversity and ecosystems within the planning process towards sustainable development; the promotion of social participation in urban waste water reutilization; restoration of polluted sites; establishment of an ecological and landscape norms for the creation and protection of "green areas"; and finally, the establishment of a municipal regulation for ecology and environmental protection. (COPLADEM, 1996)

Stimulating an ecological culture that could make citizens aware of the environmental issues and participants of the ecological equilibrium, was intended to improve their own livelihood. Strategies planned to achieve this goal include: The support for research on waste classifying methods; use of educational plans and communication media to increase social participation; establishment of ecology courses in all academic levels; generation of a continuous updating process for the program of natural resources protection, and finally, promotion of recycling and wise use of natural and artificial resources (COPLADEM, 1996).

Rural development is another section of Mexicali's Municipal Development Plan 1996-1998. The assessment of rural conditions found a lack of water management efficiency, suggesting the need for rehabilitation and conservation of hydraulic infrastructure in irrigation, such as agricultural wells with low water levels and definition of water delivery schedule and water quotas that meet the farmers requirements.

The strategies planned for this goal include: Working toward the improvement in water quality that comes from the Colorado River and that is used as drinking water by rural communities; promoting the investment in rehabilitation and maintenance of irrigation infrastructure; programming irrigation according fresh water availability and to the cultivation seasons; attracting financial resources for the rehabilitation of hydraulic infrastructure; promoting of cynegetic and tourism activities; and finally, eagering the opposition toward the lining of the Mode Channel (COPLADEM,1996)

Although this is a comprehensive Municipal Development Plan, it does not provide specific activities for the Hardy River. This ecosystem should be considered as part of this plan, as it is another source of water and provides the necessary resources to satisfy the needs for food and drinking water, for rural communities located near to it. It's wetlands and natural resources need restoration activities, that could be designed in a management/conservation plan that responds to the full potential of this ecosystem that sustain human settlements, as well as wildlife.

6.4. 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), as well as to the concerning Mexican authorities (CILA) and other federal agencies (Barrera J.C., 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 J.C., 1997). An important element of this program is the need to cover the lack of information over the water uses and users at the delta, the quality, quantity and temporality of the water demand, could ensure sustainable opportunities for of the ecological processes. Therefore, binational negotiations could begin and local participation should be established.

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. In this way, the UMA's System could be a complement of the Protected Natural Areas System (INE-SEMARNAP, 1997).

The establishment of several wildlife management units in rural communities located in the delta, it could accomplished their economic development in a sustainable path. Every UMA under this program, will consist in the management of nursing and breeding places (intensive or extensive) for fauna in risk, and in the management of greenhouses or plant nurseries. In these areas, reproduction of those species will be the strategy for its conservation and the basis for legal commercialization of their products. In order to be accepted as part of this Program, each proposed UMA in the study region should (INE-SEMARNAP, 1997):

- Register the species, products, and subproducts in which it will be working on, and have control of them. It could be a farm for some species of waterfowl, whose products could be the meat and feathers, if suitable for the area; other communities will work better with aquaculture farms, again for commercial species, relating extensive aquaculture programs with sport fishing activities of target species.

- Manage the habitat so as to maintain its natural conditions and the increase in species population, those of direct economic value, protecting those species that have other uses or values. As the owner would be the one who will invest in the conservation of the habitat, it will be just that the earnings of its commercialization should be for the owner of that natural resource. This could be done also in a community manner, the farm could be placed on common land, and its members should designate the staff responsible.

- Manage every kind of wildlife (except those whose population need first to be recovered); population screening of its species of interest; have a management plan; and, certify and mark its production .

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.

6.5. Implications of Environmental Regulations in the Hardy/Colorado River Wetlands

National environmental laws and international agreements regulate the Colorado River delta. Laws refer mainly to specific resources as the Colorado River water, or the international borderline, meanwhile, international agreements tend to broaden and strength the national laws. To both types of regulations, 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). Meeting the biological criteria of importance for shorebirds, the delta is considered as an International Reserve, as it hosts more than 100,000 shorebirds annually (or 30% of a species' flyway population). This reflects the delta's importance in the Pacific Flyway, being a critical wetland area.

As a recognition of this international importance, the delta was listed as a Ramsar Site in March, 1996 (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 main strategy, the conservation and wise use of these wetlands. If conceived within a sustainable development path, economic activities in this rural area are completely compatible with México's agreements with the Ramsar Convention.

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 took an important step in this international responsibility upon wetland areas, thus including the delta. In this way, the path toward the wise use of the delta's natural resources was established. The projects sponsored by this international effort could promote waterfowl populations to increase, but moreover, they could identify economic activities suitable to the ecosystem that could yield to rural sustainable development of the communities depending on the Hardy/Colorado River wetlands. This will mean not only habitat restoration, but public involvement in the protection and wise use of wetlands and associated wildlife.

At the national level, México's Development Plan 1995-2000 considers several strategies and actions concerning the environment, the ones that apply to the Hardy River wetlands are: Clean up programs for the main hydrological systems; creation of economic instruments that stimulate both, producers and consumers, to take decisions that support the protection of the environment and promote a sustainable development with special attention in rural areas; consolidate and enforce the legal environmental framework; and finally, the most relevant strategy, restoration of those sites that are critical for achieving the protection and conservation of biodiversity (Secretaria de Gobernacion, 1995).

The project presented in this report is completely compatible with the objectives of the National Development Plan and the National Program for Fisheries and Aquaculture, as long as they seek the protection and restoration of streams, like the Hardy/Colorado River wetlands, which, although unstable in the quantity of its flow, is the most important mean of getting food and economic income for many rural communities. An example of the importance of the Hardy/Colorado River wetlands for a community could be found in the Cucapá community, El Mayor, whose inhabitants use this river for irrigating some little family parcels; fishing their food and sometimes a little surplus to sell; and finally, for some people, it is also a source of drinking water.

Local communities depending directly on the Hardy/Colorado River wetlands could establish their own Wildlife Management Unit (UMA), with the opportunities mentioned before. As this program is considered a priority within Mexican Environmental Policy, national and international support and funding can be found in order to implement this kind of wildlife management. There are regulatory programs behind an UMA, and several requirements should be met in order to be accepted and considered, including an analysis of the CITES[3] guide to include the special considerations that should be taken for the species listed in it and that are suitable for being farmed. There are good opportunities to achieve the goals seek by national and international environmental regulations.

The laws, agreements, and programs analyzed in this chapter share a common problem; delta's people are not aware of them. Therefore, it is very difficult for local communities to access to support and grants, even though they have good ideas on what should be done in the delta, as they live there and know their resources. 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. Under this conditions, they have no access to laws updates, they cannot benefit from national programs, nor from international agreements. 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 publicity. Most of the time, environmental laws and planning in rural areas accomplished at a distance without a real knowledge of what local communities need. They are based usually on what central planners and governments think I's better, but this process results in laws that are not being implemented and unrealistic management plans. Most of them lack adequacy to rural social conditions, natural resources availability, and 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 means that this agency is a major player in the decision making for changes in the habitat, for example, when floods are coming, they clean the river bed and nearby land, destroying wildlife habitats, difficult to be restored. This activity should include criteria for habitat management, a comprehensive assessment of the situation is required, and it should consider the needs of all users: human settlements, wildlife, and the ecosystem itself.

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

Political boundaries and international limits separate the management of this ecosystem. The

[3] CITES: Convention on International Trade in Endangered Species of Wild Fauna and Flora. The CITES guide lists all species threatened with extinction which are or may be affected by trade, those not threatened yet but that could be in such status because of trade, and other species subject to regulation. Contracting Parties of CITES agreed not to allow trade in specimens of species listed in this guide.

almost total water control existing in the Colorado River in the USA and México make this resource scarce, lessening wetland habitat and thus, wildlife conditions. 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 affected marine fisheries in the Gulf of California. As long as no fresh water reaches the sea, fisheries decline, and salinity levels increase in the Gulf, affecting habitat and nursing grounds of marine species. 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.

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, and agreements need to be adapted under a comprehensive regional approach.

VII-Outreach Program

Restoration is not a process we humans can create, but what we can certainly do is act, and with our example, teach others about what we need to do in order to allow it to happen. 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.

An outreach program with this mission, should begin by recognizing all possible mechanisms to link the need of restoration of the Hardy/Colorado wetlands to the quality of live among those communities directly related to the river. The program seeks the communities to assume responsibility and change behaviors on water uses. This principle on community commitment is the leading policy of the outreach program This commitment should be free from any national and international pressure.

Leadership in restoration should take place through the involvement of 20 communities with more than 36,000 people who are at direct stake in the current 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. The program logistics will provide the appropriate opportunity for participation into decisions which affect their lives, opening channels of communication so their voices can be heard, gain momentum and reach gradually the rest of the Delta communities.

We have integrated a small work team with an extensionist from a conservation NGO, a technical assistant from a University in Sonora, a technical assistant from a University in Arizona, a man and a woman from each of the three pilot sites and the participation from elders. We have consultants in Anthropology, Wetland Ecology a Restoration, Geography, Economics and Technology, and we began outreach by bringing communities together and providing a forum to discuss and identify concrete "ideal" restoration behaviors in which they can engage:

- more effective use of waste water
- access to information
- wetland education

During the first workshop (July 1998) the work team will integrate wetland restoration perspectives from the community at each one of the three pilot sites (guided forum dynamic), and will state the general objective of the outreach program in means and ends.

A second workshop (September 1998), will set up the mechanisms to define "ideal" wetland restoration behaviors only among participants of each community site; and the specific, explicit and observable actions that will be carried out by them to get the expected results. All community participants and the work team will proceed the workshop designing the underlying work plan, including actors, links, expected results and time frame.

With the resulting plan already in practice, the community will be encouraged to use all possible means of communication to advertise the process among a "primary" audience, constituted by people who can validate, enhance and support their behavior among all delegations: Cerro Prieto, Colonias Nuevas, Delta, Guadalupe Victoria and Venustiano Carranza.

This communication campaign should address what the communities are doing themselves, not what the program is doing for the community. For instance: "Motivate members of all delegations to save water" or "improve water delivery systems, drainage facilities and water control structures in Campo Mosqueda," does not say what the actors are doing. "Installation of five fish screens," "Installation of an open forum next Friday to select the format of GIS we can use" are more explicit actions.

These first steps can be implemented right away without having to wait until water policy matures. However strategies that focus on wetlands restoration legislation within the program are also required and they might be subjected to years of negotiation before a long term perspective can be implemented. A supportive, educated and active community will be the stronger support of future scenarios.

An emphasis of the outreach program is to participate international forums, conferences, meetings and workshops, where other agencies gather to support, listen and dialogue on issues regarding the Colorado River delta. Potential partners at these events include the Environmental Defense Fund, the Biosphere Reserve of the Upper Gulf of California and Colorado River Delta, the International Boundaries and Water Comission and the National Water Commission (Mexico), the Pacific Institute, Defenders of Wildife, the Southwest Center for Biological Diversity, the Binational Commission Arizona-Sonora, Arizona Game and Fish Department, U.S. Fish and Wildlife Service, the Bureau of Reclamation, among others.

Strong collaboration nexus have already been built with several of these organizations, regarding conservation and wetland restoration along the Colorado River delta, including the Pacific Institute, the Sonoran Institute, the International Alliance of the Sonoran Desert and the Biosphere Reserve of the Upper Gulf of California and 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); monitoring and follow up guidelines within a management plan of a Biosphere Reserve, which includes restoration of the Hardy/Colorado Wetlands among the top priorities and exposes issues and concerns at national and international levels; a wider umbrella for financing; and a multidisciplinary, multicultural background.

The motivation for involvement among governmental agencies was achieved through several informative visits, where the scope of the project, and its ecological relevance were discussed. Staff from these agencies was interviewed; their perceptions about the restoration efforts and their management recommendations were considered for the community pilot programs.

Feasible opportunities were identified for a collaborative effort toward the improvement of the environmental, social and economic conditions of the delta, among the following agencies:

- Ayuntamiento de Mexicali (Mexicali Municipality).
- Comision de Cooperacion Ecologica Fronteriza (Border Environment Cooperation Commission).
- Comision Internacional de Limites y Aguas (International Boundaries and Water Commission).
- Comision Nacional del Agua (National Water Commission)
- Comisión de Turismo y Convenciones de Mexicali - COTUCO (Tourism and Conventions Commission of Mexicali).
- Consejo Estatal de Poblacion (Population State Council)
- Consejo para la Planeacion del Desarrollo Municipal de Mexicali (Council for the Municipal Development Planning in Mexicali).
- Departamento de Planeacion Urbana y Ecologia de Mexicali (Department of Urban Planning and Ecology of Mexicali).
- Direccion General de Ecologia del Estado de Baja California (General Direction of Ecology of Baja California).
- Instituto del Medio Ambiente y Desarrollo Sustentable de Sonora (Institute of Environment and Sustainable Development of Sonora).
- Reserva de la Biosfera Alto Golfo de California y Delta del Rio Colorado (Biosphere Reserve of the Upper Gulf of California and Colorado River Delta).
- Secretaria de Asentamientos Humanos y Obras Publicas del Estado de Baja California (Human Settlements and Public Works Secretariat of Baja California).
- Secretaria de Medio Ambiente, Recursos Naturales y Pesca, Delegacion Federal Baja California (Ministry of Environment, Natural Resources and Fisheries, Federal Delegation in Baja California).
- Secretaria de Salud (Health Ministry)

For details see Contact List - Appendix 1.

Delegation offices of the Mexicali municipality visited include Cerro Prieto, Colonias Nuevas, Estación Delta, Guadalupe Victoria, and Venustiano Carranza (see table 17). All delegates were interviewed and their immediate recommendations, priority actions, contacts and collaboration opportunities enlighted us to proceed with community workshops for the identification of improvement opportunities for environmental conditions as community health. Community priority issues will also support the design and implementation of the next steps of the outreach program.

Table 17. Contacted delegates of the Mexicali Municipality.

Delegation of the	Delegate

Mexicali Municipality	
Venustiano Carranza	Sr. José Anaya Fernandez
Guadalupe Victoria	Dr. Federico López Magaña
Colonias Nuevas	Sr. Carlos Vladimir Viveros Adame
Cerro Prieto	Sr. Rodolfo Solano Chávez
Estación Delta	Lic. Hidalgo Contreras Covarrubias

Members of the following communities have already demonstrated trust, understanding, commitment and leadership in the program: El Mayor, Campo Mosqueda, Campo Flores, Campo Las Tres B's, Campo San Miguel, La Ramona, Venustiano Carranza, Oviedo Mota, Luis B. Sanchez, Estacion Coahuila, Guadalupe Victoria, Plan de Ayala, El Faro, Francisco Murgia, El Indiviso, Campo Sonora, El Caiman, Colonia Baja California, Cucapa Mestizo, Ejido Reacomodo, and Ejido Gonzalez Ortega (see Figure 26).

Initial efforts to document this process include the publication of articles in the following newsletters, journals and magazines: "Humedales," "Waterfowl 2000," "Pronatura," "Science," "Natural Resources Journal," "CEDO news," "Conservation Biology," and "Voces del Mar," at local, regional, national and international level; the contribution to outstanding exhibits like "The Colorado: Water of Life", presented at the University Museum of Baja California, and the preparation of a TV documentary about the Colorado River delta in collaboration with the Tucson local TV channel (Appendix VI).

Figure 25. Municipal Delegation of Colonias Nuevas

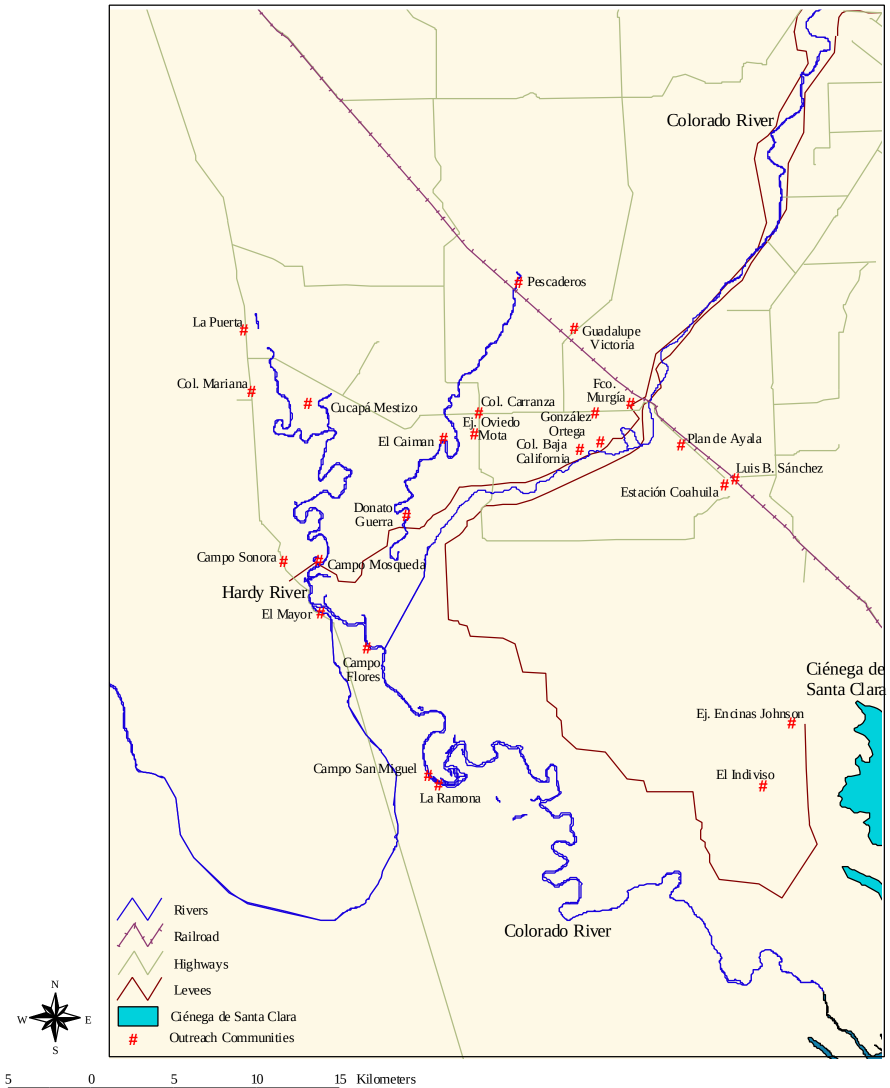
With the support and participation the State Ministry of Education in Sonora, teachers from the municipality of San Luis Río Colorado have taken three steps in wetland education. The first one on teacher training, the second one on developing a "multiplying strategy" to teach other teachers, and the current initiative on leading community participatory management projects on wetland conservation.

As a result of this project, teachers, kids and their parents from elementary schools, have experienced a very rich, continuous and deep process of ongoing education, including a year long creative curriculum design and implementation, field trips to la Ciénega de Santa Clara and El Doctor Wetlands and training and advise to design and develop collective pilot projects (fully financed) on participatory management for wetland conservation.

Community action on wetland restoration is the level of education and involvement reached by these teachers, under the PIE initiative ("Public Involvement and Education," a statewide program on wetland conservation lead by Pronatura Sonora and ITESM Campus Guaymas), as they become involved in the outreach program. The implementation of PIE Activities in the Mexicali Municipality is being coordinated with the Baja California State Ministry of Education

Concurring agendas have been analyzed in order to strengthen the regional efforts. These include: Desarrollo Integral de la Familia (DIF), Biosphere Reserve of Upper Gulf of California and Colorado River Delta, Red Fronteriza Salud y Ambiente, Pronatura Sonora, Pronatura Baja California, and Instituto Nacional Indigenista. To consolidate the institutional links between organizations towards community work for the restoration of the Colorado River delta wetlands will be one of the tasks of the Outreach Program in the near future.

Figure 26. Communities of the Colorado River Delta Involved in the Outreach Program.



Modified from INEGI, CNA, and T.M. Satellite Images.

NAWCC

Information Database and Local Outreach Program for the Restoration of the Hardy River Wetlands in the Lower Colorado River Delta, Baja California and Sonora, Mexico

PRONATURA SONORA

ITESM Campus Guaymas

THE UNIVERSITY OF ARIZONA TUCSON, ARIZONA

EDF

California State University Dominguez Hills

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.

8.1-Restoration Opportunities

The riparian zone along the stretch of lower Colorado River that lies in the United States is now regularly monitored and attempts are underway to restore areas of critical habitat (Anderson and Ohmart, 1985, 1986; Ohmart *et al*, 1988; Briggs and Cornelius, 1997; Worthley, 1998). Few studies however, have been conducted on the impacts of water management on the riparian ecosystems of the stretch of river that lies in Mexico where the river forms its delta with the Gulf of California (Glenn *et al*, 1996).

Nevertheless, 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).

When the waters of the river were divided over 70 years ago, none of them were explicitly developed to maintain healthy ecosystems; indeed, ensuring ecosystem health was not a concept given to much consideration. However, as all the legally apportioned water for human uses is utilized by basin states, there is great uncertainty as to what will happen to the ecosystem. Increasing international concerns are promoting the participation of society, the public and non-governmental organizations on both sides of the border. Water demand will continue to grow, this issue suggest the need for efficiently use and identification of environmental water requirements. Any solution has to address the need for additional water for habitat protection.

Binational efforts have been made to preserve and restore the wetlands of the Colorado River Delta, with the participation of universities, government agencies, and non-governmental organizations. Research has been done to evaluate the opportunities for ecological improvement along the lower Colorado River and Delta (Briggs and Cornelius, 1997), and the effects and impacts of water management on the wetlands of the Colorado River Delta (Glenn *et al*, 1996; Glenn *et al*, 1997).

Several meetings have taken place along the border (Mexicali, San Luis Río Colorado, Tucson, Yuma, and El Paso) in which water management agencies from Mexico and the United States, along with scientists and environmentalists, have discussed the future of the Colorado River Delta, specially related to water management issues for ecosystem restoration. As a result of these meetings, the different groups have reached a consensus that wetland restoration is desirable and achievable, and not necessarily in conflict with the economic development priorities of the region.

Today, several opportunities for wetland restoration of the Lower Colorado River Basin have emerged (Briggs and Cornelius, 1997); being the Ciénega de Santa Clara and the Hardy/Colorado Wetlands the most promising (Payne *et al*, 1992; Morrison *et al*, 1996; Glenn *et al*, 1997; Glenn and García, 1997). This portion of the river has been selected for restoration because of the presence of riparian vegetation, its importance for resident and migratory waterbirds, its higher productivity compared with the surrounding desert ecosystems, and the possibility of considering it as a wildlife corridor. However, these areas depend on water releases from the U.S., and on allocation from other sources, namely urban and agricultural runoffs.

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. Substantial flows of water still enter the area, but they are managed as disposable wastewater rather than to sustain the valuable wetland habitats. These wetlands can be maintained and restored through effective management of such residual flows and other non conventional water sources within the delta. Therefore, it is necessary to identify the quantity, quality and timing of any additional water that may be needed to protect these resources.

The sustainable use of water seems more feasible considering all the research done which have been made to identify key concepts and to support the economic prosperity while maintaining the ecological integrity. One of the most important opportunities 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).

8.2-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 uses wetland resources and that are willing to protect them and use them wisely (see Figure 27).. Efforts and management strategies described will be part of the next steps in this process for the restoration of the Colorado River delta ecosystem.

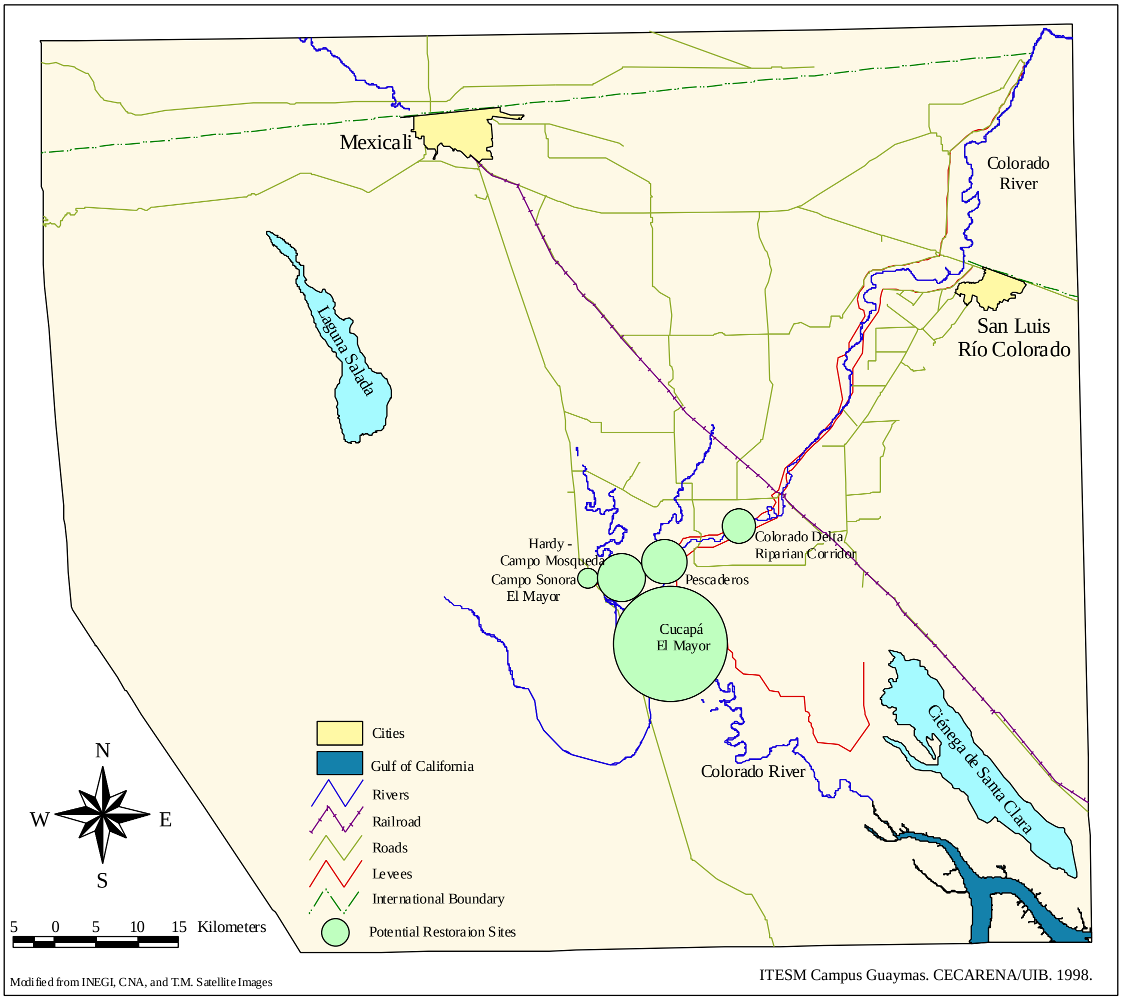
Campo Mosqueda

Campo Mosqueda is a private owned tourist camp, located along the banks of the Hardy River, before it enters the levees. They have used the levee as a reservoir wall, creating a small lake of the river that is used for recreational activities including swimming, water skiing and fishing. Other activities performed at Campo Mosqueda include agriculture, aquaculture, and recreational hunting.

This site is located on Zone 4. The dominant species are saltcedar, with cattails, common reed, and arroweed. Birds can be found in important quantities all year long, including egrets, herons, grebes, loons, pelicans, gulls, terns, cormorants, and shorebirds. Large groups of ducks can be found in winter. Also, this area is considered as important Yuma Clapper rail habitat on the western side of the delta (Eddleman, 1989). This site has become an important feeding ground for birds since is one of the few places that has flowing water all year long, with reliable fish and crayfish populations.

Water in the river came mainly from agricultural discharges of the Mexicali Valley. As described before, this area has high salinity levels, as well as high selenium concentrations, which can be a hazard to wildlife and human activities. Since this area is devoted to tourism activities that require full-body contact with water, and since there are food production activities for the region, 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.

Figure 27. Potential Restoration Sites in the Colorado River Delta.



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Information Database and Local Outreach Program for the Restoration of the Hardy River Wetlands in the Lower Colorado River Delta, Baja California and Sonora, Mexico

ITESM
Campus Guaymas

THE UNIVERSITY OF
ARIZONA
TUCSON, ARIZONA

PRONATURA
SONORA

Sonoran Institute

EDF
Environmental Defense Fund

California State University
Dominguez Hills

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, in the wetland area inside the levees. This locality is a minor part of the Cucapá territory, which covers some 143,000 ha, including the Laguna Salada. Land tenure is held by the community, in an ejido-type organization.

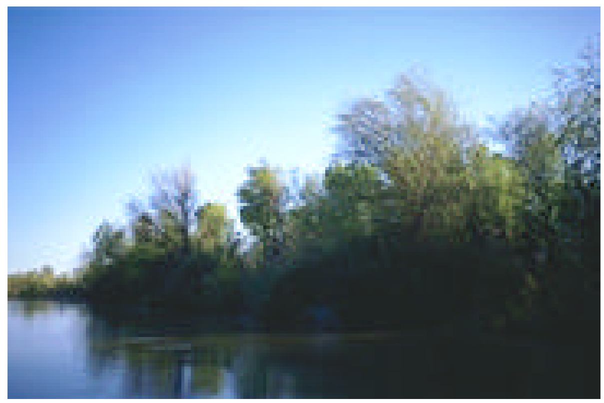
The Cucapá community livelihood is based on the wetland resources, including fishing, hunting, and guiding services to tourists. This stretch of the river has water flowing most of the time, since it receives water directly coming from the Hardy River, however most of the time it remains shallow. This condition makes the river difficult to use, since navigation is not possible, fish populations decline with reduced water flows, and salinity and contaminants increase. Fishing grounds of the Cucapá extend to the river mouth, and to the Laguna Salada, so they have to travel long distances from their town to their fishing sites, which are not suitable for living due to the lack of any kind of facilities and the risk of flooding events; and with no much water on the river, the travelling is harder.

This site is located within zone 5 of the vegetation map. Vegetation along river bank is dominated by good size saltcedar (2-3 m), arroweed, common reed and few cattails. This area supports large numbers and diversity of birds, including water birds as sandpipers, plovers, cormorants, rails, egrets, herons, moorhens, coots, and osprey; and resident and summer resident birds as mourning and white tipped doves, gambel's quails, vermilion flycatchers, sparrows, warblers, tanagers, blackbirds, grosbeaks, phoebes, vireos, swallows, owls, hummingbirds, cuckoos and orioles. This area is a possible good site for Yuma clapper rail, as well for Willow flycatcher.

This site is adjacent to the middle of the wetland area, where there are dozens of river meanders, and small lagoons, which include the most southern dense stands of tall (>10 m) cottonwood and willows in the Colorado River delta. The area is visited by few people, and access is very hard due the thickness of vegetation. The routes to get to these places are well known by Cucapá guides. To this point, land ownership is federal.

Management efforts in this site will be focused on the restoration of river stream capacity for flowing and storing water, as well as to function as a navigation cannals. 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.

ColoradoRiver 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. This riparian corridor has been revitalized by pulse floods during 1997. The Colorado River still have one main stream at this point, before its confluence with Pescaderos and Hardy River, and before it splits into different channels. Water that supports this vegetation comes mainly from pulse floods of water excedents in the Colorado River, and small amounts came from agricultural drains and urban drains.

Since this site is confined between the levees, and access is restricted by the dense vegetation, 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 for this area is the lack of a perennial source of water that could support this highly valuable riparian corridor. Efforts in this area 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, including treated sewage effluents. A demonstration of the value of these habitats supporting high biodiversity values of wildlife will be carried out. 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 in zone 4, between the Colorado Complex and the Hardy River at Campo Mosqueda. Pescaderos is an old Colorado course, which main sources of water now are also agricultural drains. This river crosses several ejidos, and there are a few communities settled at its side, such as Ejido Donato Guerra, located before it enters the levees.

Vegetation is dominated by cattail, common-reed and saltcedar. This stream supports large fish populations, including large mouth bass, carp, mullet and tilapia; this supports important populations of birds, including Yuma clapper rail; muskrats can be easily found along the river, and local residents claim the presence of beaver. Inside the levee, the Pescaderos water supports some of the cottonwood-willow riparian corridor.

This tributary in its northern part is considered mainly for agricultural drainage purposes, but at it's southern part, it is used for fishing and hunting by local communities. As the Hardy River, 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. This recreational camp is inside the Cucapá territory, but it has been granted to the González Family to be operated. It has a restaurant, palapas (wooden shades), a small dock and recreational boats. Other human activities include hunting and fishing.

Since it is located far out of the flood plain inside the levee area, it is not located in the vegetation classification zones, but El Mayor ends at the levee, nearby Campo Mosqueda, in zone 4. Vegetation on river banks is dominated by saltcedar, cattails, common reed, and arroweed. This site has a beautiful scenic view, with the Cucapá Mountains, and potential for eco-tourism is high, but there is a lack of infrastructure and institutional capability to perform this activity.

As the Hardy and Pescaderos, 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, concentrating selenium and salts.

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.

8.3-Wildlife Management Units (UMAS)

More than a restoration of a natural area, and then managing the Hardy/Colorado Wetlands as a Natural Protected Area, the efforts could be focused towards the implementation of a System of UMAS (described in the Environmental Regulations section), which are "Units for the Conservation and Sustainable Use of

Wildlife", that belong to the National Program for Conservation of Wildlife and Productive Diversification in Rural Areas (SEMARNAP, 1997).

The purpose of the UMAs is to reinforce and make compatible the conservation of biodiversity with the production and socio-economical development needs of rural areas in Mexico, looking to promote alternative productive scenarios that could be compatible with the environment, through a rational and planned use of natural resources, stopping and reverting environmental damage.

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, including sport fishing and hunting, eco-tourism, aquaculture, environmental education and research.

The UMAS will be extensive wildlife management units that will operate with techniques of habitat conservation and management, monitoring of wildlife populations and reproduction of species with specific purposes, establishing by this means, a conservation plan of the species and their associated habitat.

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. They will need to have the technical and logistical support for the implementation of the UMAs.

8.4-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

River flow in the delta area is highly variable. During normal years, no river water reach the wetlands, but in wet years, water entering the delta exceeds the capacity of the river stream, causing severe floods and damage. Annual average of the daily discharges varied from 0 to 495 m^3/s in the period of 1977 to 1996 at the Southern International Boundary, with a range of the top daily flows from 0 to 934 m^3/s.

Historically, CNA has done maintenance actions in the river stream, to prevent extreme flooding during wet years. These actions include the clearing of wetland vegetation, dredging and levees construction and repairs, which causes severe impacts to wetland habitats.

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 (winter stops, reproduction, breeding, nesting, hatching, hunting seasons, and ground water recharge).

b) Waste water from Mexicali

The city of Mexicali has a waste water treatment plant with a capacity of 111 million cub feet, consisting of a primary treatment of anaerobic tanks, 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. This represents 1% of the water that flows from the Colorado River through the Southern International Boundary to the wetlands in flooding years, 30 times the volume of the flow passing through in slightly wet years, or the difference between receiving or not receiving any water in normal years. 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. There are 17 agricultural drains (3 primary and 14 secondary) that flow directly into the Hardy/Colorado River System. Their characteristics have been described in the section of "Water Flows".

8.5-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. In order to take advantage of this water, it will be necessary to make hydraulic changes along the river, probably small reservoirs and a series of cannals to conduct water to selected sites that could work as core wetland areas.

Notwithstanding the institutional constraints in both the United States and Mexico to the use of Colorado River Water for habitat protection, 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. Zones 1-3 contained approximately 10% of the R1 vegetation, hence an annual maintenance flow of 4.0×10^7 m^3 should be sufficient for this stretch, 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 (ca. 20×10^9 m^3/yr). 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.

Selenium concentration in the water of the Colorado River delta is at levels that may represent a high risk to wildlife and to human communities of the area, since many people rely on the river fisheries, and also several aquaculture projects are operating with these water sources.

The source of selenium is the Colorado River water, but the problem is magnified by the agricultural practices in the Mexicali Valley; the presence of several backwater reservoirs that function as small evaporative basins; and, the fact that there is not enough water to flush out salts and contaminants on this ecosystem. Further studies on contaminant concentrations are needed, including the analysis of sediments, plants, invertebrates, fish and birds, in order to evaluate bioaccumulation through trophic levels, and determine possible effects of selenium in the delta.

Water management strategies should be put in practice, in order to prevent ecological damage in these ecosystems. This would need to include the cannalization 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.

Besides of alloting water to the wetland area directly through the Colorado River stream, also some extra flows should be cannalized through the agricultural drains and their influenced rivers (Hardy and Pescaderos) to wash away salts and contaminants.

Some hydraulic adecuations should be done in certain areas to allow water flow, as dredgings, channel construction, and passes from outside the levee to the inside, as well as for the habitat enhancement, including water control structures that could maintain a system of ponds in between the levees.

IX-Financial Statement

Summary Report
Comparison of Federal and Non-Federal Contributions
Information Database and Local Outreach Program for the Restoration of the Hardy River Wetlands in the Lower Colorado River Delta, Baja California and Sonora, Mexico
Agreement Number: 14-48-98210-97-G027

Category Description	NAWCC CONTRIBUTIONS		NON-FEDERAL CONTRIBUTIONS	
Income/Expense	**Budget**	**Actual**	**Budget**	**Actual**
Expenses				
Personnel	$57740	$56790	$155934	$155934
Travel	$15148	$19141	$0	$0
Equipment	$6475	$5841	$500	$500
Material/ Supplies	$12280	$11443	$0	$0
Other	$26000	$24428	$80900	$80900
Indirect Costs ITESM	$16153	$16153	$11744	$11744
Indirect Costs UofA	$7335	$7335	$13356	$13356
Total	**$141131**	**$141131**	**$262434**	**$262434**
OVERALL TOTAL	**$0.00**		**$0.00**	

Summary Report by Account

Information Database and Local Outreach Program for the Restoration of the Hardy River Wetlands in the Lower Colorado River Delta, Baja California and Sonora, Mexico

Agreement Number: 14-48-98210-97-G027

Category	NAWCC		ITESM		U of A		EDF		Pronatura		OSU		Total	
Income/Expense	**Budget**	**Actual**	**Budget**	**Actual**	**Budget**	**Actual**	**Budget**	**Actual**	**Budget**	**Actual**	**Budget**	**Actual**	**Budget**	**Actual**
Expenses														
Personnel	$57740	$56790	$0	$0	$25934	$25934	$90000	$90000	$4000	$4000	$0	$0	$173674	$172724
Travel	$15148	$19141	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$15148	$19141
Equipment	$6475	$5841	$0	$0	$0	$0	$0	$0	$500	$500	$0	$0	$6475	$5841
Material/ Supplies	$12280	$11443	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$12280	$11443
Other	$26000	$24428	$62000	$62000	$10000	$10000	$0	$0	$900	$900	$8000	$8000	$106000	$104428
Indirect Costs ITESM	$16153	$16153	$11744	$11744	$0	$0	$0	$0	$0	$0	$0	$0	$27897	$27897
Indirect Costs UofA	$7335	$7335	$0	$0	$13356	$13356	$0	$0	$0	$0	$0	$0	$20691	$20691
Total	**$141131**	**$141131**	**$73744**	**$73744**	**$49290**	**$49290**	**$90000**	**$90000**	**$5400**	**$5400**	**$8000**	**$8000**	**$362165**	**$362165**
OVERALL TOTAL	**$0.00**		**$0.00**		**$0.00**		**$0.00**		**$0.00**		**$0.00**		**$0.00**	

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Appendix

Appendix I. List of Contacts

Local Communities

Campo Mosqueda
Sr. Jesús Mosqueda/Ing. Javier Mosqueda - Owners.
Campo Mosqueda. Mexicali, B.C..
Tel (65) 661520 Fax (65)610474

Comunidad Tradicional Tribu Cucapá (Traditional Community Cucapá Tribe)
Sr. Onésimo González Saiz - Traditional Chief of the Tribe
Comunidad Cucapá El Mayor - Campo Flores, Mexicali, B.C

Ejido Comunididad Indígena El Mayor
Victor Navarro Saiz- Commissary
Pasaje Chapala No. 1088, Col. Centro Cívico. Mexicali, B.C.
Tel (65)573307

Ejido Cucapá Mestizo
Delfino Barrera Hernández- Commissary
Héctor Mendoza B. - Head of the Local Council for Community Improvement. Tel (652)34698
Ejido Cucapá Mestizo, Mexicali, B.C.

Ejido Luis Encinas Johnson
Sr. Juan Butrón - Secretary and President of Ecotourism.
Ejido Luis Encinas Johnson, San Luis Río Colorado, Sonora.

Unidad de Producción Pesquera Cucapá (Cucapá Fisheries Unit)
Mónica González Portillo - Representative
Comunidad Cucapá El Mayor, Mexicali, B.C..

Regional NGO's

Centro Intercultural de Estudios de Desiertos y Océanos - CEDO (Intercultural Center for the Study of Deserts and Oceans)
Peggy Turk Boyer - Director
Apdo. Postal 53. Puerto Peñasco, Sonora. CP 83550
Tel/Fax (638) 20113
P.O. Box 249, Lukeville, AZ 85341
Fax: (52) 638 20113
e-mail: cedo@infotec.net.mx

ECO-SOL
Q.I. Jesús Jiménez Rafael, Environmental Advisor
Río Colorado 836 Col. Revolución, C.P. 22400, Tijuana, B.C.
Tel / fax: (66) 86 3687

Pronatura Península de Baja California
Dr. Roberto Enriquez - Director
M. C. Gustavo D. Danemann - Project Coordinator
López Mateos y granada 2025, Plaza Península, Local 201, Ensenada, B.C.
Tel: (61) 77 3060 Fax: (61) 76 4688
e-mail: pnbaja@el_vigia.microsol.com.mx

Regional Universities

El Colegio de la Frontera Norte (College of the Northern Border)
Sr. Francisco Lara
Calle Campodonico 303 Col. Granja Apdo. Postal 339-A Nogales, Sonora 84080
Tel: (631) 30426 Fax: (631) 32185

Universidad Autónoma de Baja California (Baja California Autonomous University)
M.C. Manuel Salvador Galindo Bect - Researcher
Instituto de Investigaciones Oceanológicas
Ap. Postal 453. Ensenada, BC. Tel (617) 44601 Fax (617) 45303
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Dr. Gorgonio Ruiz Campos - Researcher
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Biól. José Delgadillo Rodríguez - Biologist - Botanist
Facultad de Ciencias - Herbario BCMEX
Km 106 Carret. Tijuana-Ensenada. Ensenada, B.C. Tel/Fax (61) 744560
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Ing. Adalberto Walther Meade - Director
Instituto de Investigaciones de Geografia e Historia.
Ing. Oscar Sánchez - Researcher
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Instituto de Investigaciones Sociales
Edificio de Investigación y Posgrado, 3er. Piso. Blvd. Benito Juárez. Ap. Postal 3-136. Mexicali, BC.
Tel/Fax (65) 662985. Tel (65) 661800.

Claudia Schroeder - Museum Director
Universitary Museum. Reforma y Calle L s/n. Mexicali, B.C. CP 21100
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M.C. José Luis Fermán Almada - Director of Research and Graduate Studies
Blvd. Benito Juárez. Mexicali, BC. Tel (65) 663633
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Universidad de Sonora (University of Sonora)
Departamento de Investigaciones Científicas y Tecnológicas de la Universidad de Sonora (DICTUS)
MC Alejandro Varela Romero - Research Associate
Blvd. Luis Encinas. Col. Centro. Hermosillo, Sonora. CP 83000

Local Governments
Ayuntamiento de Mexicali (Mexicali Municipality)
Arq. Antonio Méndez Ocampo - Head of the Department of Urban Planning and Ecology
Pasaje Jalapa No. 1006. centro Cívico C.P. 21000, Mexicali, B.C.
Tel: (65) 560636 Fax: (65) 58 1600 ext. 1790

Ocean. Enrique Villegas Ibarra - Coordinator of the Area of Ecology and Environment.
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M.C. David Fuentes Romero - General Coordinator of the Council for the Planning of Municipal Development. COPLADEM - Plaza Cholula No. 1090. Centro Cívico y Comercial. Mexicali, BC.
Tel (65) 572824 Fax (65) 572826

Eduardo Aguilar Robles Maldonado - Counselor for Rural Development.
Casa Municipal Centro Cívico 2do Piso. Mexicali, B.C. CP 21100.
Tel (65) 581600 ext 1801 - 1793

Alfredo Arenas - Counselor for Tourist Development.
Casa Municipal Centro Cívico 2do Piso. Mexicali, B.C. CP 21100.
Tel (651) 68083

Adolfo Preciado Osobampo - Head of the General Archives
Casa Municipal Centro Cívico 2do Piso. Mexicali, B.C. CP 21100.
Tel (65) 581600 ext 1687

Lic. Patricia Hernández - Information and Statistics Manager
Comisión de Turismo y Convenciones de Mexicali - COTUCO (Tourism and Conventions Commission of Mexicali).Blvd. López Mateos y Calle Compresora s/n. Mexicali, B.C.
Tel (65) 572161 Fax (65) 525077

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Appendix II - List of Maps used for the GIS.

Table 1. INEGI Topographic Maps 1: 50,000 included in the GIS.

Code	Elaboration year	Name
I11D64	1977	El Centinela
I11D65	1977	Mexicali
I11D66	1977	Islas Agrarias
I11D67	1977	Ciudad Morelos
I11D74	1974	La Poderosa
I11D75	1974	Sierra Cucupa
I11D76	1974	Guadalupe Victoria
I11D77	1982	San Luis Río Colorado
I11D84	1974	Arroyo del Sauz
I11D85	1974	Guardianes de la Patria
I11D86	1974	Plan de Ayala
I11D87	1982	Oviedo Mota
H11B14	1974	El Rayo
H11B15	1974	José Saldaña
H11B16	1974	El Oasis
H11B17	1981	El Doctor
Total 1:50,000 charts: 16		

Table 2. INEGI Thematic Maps 1:250,000 included in the GIS.

Theme	Code	Edition Year	Name
Topographic	I11-12	1980	Mexicali
	H11-3	1980	San Felipe
Vegetation and Land Uses	I11-12	1982	Mexicali
	H11-3	1982	San Felipe
Soils	I11-12	1982	Mexicali
	H11-3	1982	San Felipe
Surface Waters	I11-12	1981	Mexicali
	H11-3	1981	San Felipe
Underground Waters	I11-12	1981	Mexicali
	H11-3	1981	San Felipe
Geology	I11-12	1983	Mexicali
	H11-3	1982	San Felipe
Climatic Effects May-Oct	I11-12	1984	Mexicali
Data from 1921-1980	H11-3	1985	San Felipe
Climatic Effects Nov-Apr	I11-12	1984	Mexicali
Data from 1921-1980	H11-3	1985	San Felipe

Appendix III - List of GIS Themes

Table 3. List of themes included in the Geographic Information System.

Map	Theme	Description
Topographic (1:250,000)	Cover type	Sand, wood, cities, rivers
	Main cities	Population statistics
	Communication media	Highways, roads, tracks, railroads
	Channels and drains	Cannals and drains network
	Topography	Elevation model
Topographic	Cover type	Sand, wood, cities, rivers, agricultural areas
(1:50,000)	Human settlements	Population statistics
	Communications media	Highways, roads, tracks, railroads
	Channels and drains	Channels and drains network
	Seasonal flows	Natural drains
	Topography	Elevation model
Soil science	Soil science	Soil units
Ground water	Filtration areas	Geohydrological units
Surface Water	Drain areas	Drain coefficient
	Annual isotherms	Annual average isotherms
	Annual precipitation	Annual average precipitation
	Hydrological basins	Region limits, hydrological basins and sub-basins.
	Ground waters	Overlay of the last maps
Geology	Geological units	Substrate formation age
Water quality	Rivers and channels	Regional hydrologic system
	CNA sampling sites.	CNA sampling sites with seasonal data
	Project sampling sites.	Project sampling sites with seasonal data

Appendix IV - Population Database

The database of human population developed for the project is enclosed in a CD (popdelta.xls - Microsoft Excel 7.0). It includes data for human settlements located in the highest influence area of the wetlands of the Colorado River delta. The fields of the data base are: name, state, longitude, latitude, altitude, total population in 1990, total population in 1995, yearly growth rate, total growth rate from 1990 to 1995, population estimates for 1998, total male population, total female population, population 6 to 14 that reads, population aged older than 15 that reads, indigenous population, total dwellings, average inhabitants per dwelling, dwellings with electricity, dwellings with drinking water, dwellings with sewage facilities, population from 0 to 4 years, population aged 5 years or more, population from 6 to 14 years, and population aged 15 years or more.

Appendix V - Web Page

An Internet Web Page was designed for the project. It can be located on

http: //uib.campus.gym.itesm.mx/hardy/hardy/index.htm

The page includes information on the what is being done on this project. It also includes information of the history of the wetlands of the Colorado River delta, its natural features, human activities, a profile of the saampling sites, links to other pages related to the Colorado River delta, and a virtual discussion forum. At the moment, the page is in Spanish, but soon it will also be included in English.

Appendix VI - Video

A video with highlights of the fields trips, boat trips, and aerial surveys was prepared, and is enclosed in a VHS cassette. Also, a copy is enclosed of the TV documentary prepared by Arizona Illustrated (Tucson Local TV Channel), with the participation of staff of the project Table 4 shows a description of the video images.

Table 4. Description of enclosed video.

Time	Description
00:11	Start - Presentation
00:43	Aerial survey - Colorado River, Yuma area.
1:09	Morelos Dam, Zone 1.
2:45	San Luis Río Colorado, Zone 2.
2:56	Bridge San Luis-Mexicali.
3:43	Moving to Zone 3.
4:25	Railroad bridge at Fco. Murgía, moving to Vado Carranza, Zone 4.
4:56	Vado Carranza.
5:08	Railroad bridge at Fco. Murgía.
5:21	Activities at Vado Carranza: Water flows and quality surveys, fishing, and swimming.
7:22	Vado Carranza II with water.
8:21	Water sampling at the Geothermal Drain.
9:35	View of the area of the Geothermal Drain.
10:00	Sampling site El Mayor 1.
10:36	Cannal to the Laguna Salada, aerial view.
11:20	Yurimuri, Zone 5.
11:31	Hardy/Colorado Wetlands, Cucapá Mountains, cannal to the Laguna Salada.
11:50	Zone 5, East levee.
12.13	Aerial view of the Hardy/Colorado Wetlands from East to West.
12:22	Aquaculture at Mosqueda Camp.
13:03	Mosqueda wetland.
14:15	Aquaculture ponds at Mosqueda Camp.
14:34	Agricultural drain.
14:40	Campo Flores.
14:56	Aerial view, zone 3.
15:42	Boat trip, starting at Campo Flores.
16:12	Boat trip at “El Riñón”.
16:32	River bank clearings near Vado Carranza.
18:46	Trash field near Vado Carranza.
19:10	Colorado dry stream in the riparian corridor, zone 4.
19:57	Willow stands at Zone 4.
20:11	Catlle egret.
20:31	Vado Carranza II - dry.
20:55	Lagoons at east levee, zone 5.
21:04	Burrowing owl.
21:32.	Boat trip from the Gulf of Santa Clara into the Colorado River, dolphins.
23:35	River banks, zone 6.
23:59	Water sampling and analysis.
24:42	Coyote on *Distichlis* flats.
25:01	River water coming down.
25:08	Reserve signal. Bernabé Rico (Reserve Ranger) waiting for us.
25:17	Laguna del Indio.
26:06	End.
26:32	Arizona Illustrated Video on the Colorado River Delta.
35:32	End.

Appendix VII - GIS CD

A copy of the GIS is enclosed in a CD, in a version prepared in ArcView 3.0, ready to be used with ArcExplorer, which is a free shareware software, which can be donwloaded from the ArcExplorer Download Page: **http://nt1.esri.com/scripts/production/esri/marketing/arcexplorer/aedownload1.cfm**
To consult the system, the folder named "Hardy" of the CD, should be placed in your hard disk C.
This GIS version is included in the CD as an ArcExplorer project (gis.aep) with the following layers ready to be consulted:

Table 5. Layers of the ArcExplorer GIS project enclosed.

Layer	**Description**
LatLong. AAT	Latitude (15°) and Longitude (20°) Lines.
Selen	Selenium Sampling Sites.
Vsalinidad	Salinity Sampling Sites in the River Mouth Area.
Salt	Salinity Sampling Sites in the Hardy/Colorado Area.
Mexicali.Pat	Mexicali and San Luis Río Colorado.
DrenTerciario	Terciary Drains of the Mexicali Valley.
DrenSecundario	Secondary Drains of the Mexicali Valley.
DrenPrimario	Primary Drains of the Mexicali Valley.
CanalTerciario	Terciary Canals of the Mexicali Valley
CanalSecundario	Secondary Canals of the Mexicali Valley.
CanalPrimario	Primary Canals of the Mexicali Valley.
Princity	Main Human Settlements of the Mexicali Valley.
Pobladel	Human Settlements Located Within the Highest Influence Area of the Wetlands of the Colorado River Delta.
Outreach2	Communities involved in the Outreach Program.
Outreach	Communities involved in the Outreach Program.
Tren	Baja California-Sonora Railroad.
Bordo1	Levees
Highways	Main Highways of the Mexicali Valley.
Indio	Open Water Area of the Laguna del Indio.
Salada	Laguna Salada.
Rios2	Rivers.
Costadel	Coast Line, Sea Water and Montague Island.
Cienega	Ciénega de Santa Clara.
Lim_Int	International Boundary.
Cotas	Topographic Lines.
AreaEstudio	Project's Borderlines.
Humedal	Wetlands of the Colorado River Delta.
Aaguas.pat	Hydrological Basins of the Colorado River Delta.
Delegdel.	Municipal Delegations of the Mexicali Valley.
Suelos	Soil Types of the Colorado River Delta.
Marcopol.pat	Frame.

Appendix VIII - Map 1:50,000

A map in 1:50,000 scale is enclosed, showing the project's borderlines, the wetland area, and the main human settlements in the region.

Appendix IX - Photo CD

Enclosed is the Photo CD with pictures (PCD Files) from the field trips, boat trips, aerial surveys, and figures. Table 5 shows the list of photographs, its title, date and photographer.

Photographers: CVC - Carlos Valdés Casillas, YCG - Yamilett Carrillo Guerrero, MMV - Manuel Muñoz Viveros, OHH - Osvel Hinojosa Huerta, EG - Edward Glenn.

Table 6. Photographs included in the Photo CD.

Picture No.	Title	Date	Photographer
1	Yuma Desalting Plant	Feb-97	CVC
2	C.R. South of Algodones	Mar-98	YCG
3	C.R. Bridge-SLRC	Mar-98	CVC
4	Cerro Prieto Cannal	Jul-97	CVC
5	Geothernic Plant Drain	Mar-97	CVC
6	Railroad crossing	Jul-97	MMV
7	Pescaderos river	Ago-97	CVC
8	Pescaderos pumping station	Jul-97	CVC
9	Mesquite stand	Ago-97	CVC
10	Agricultural area	Jul-97	CVC
11	Main Southern Drain	Jul-97	CVC
12	Drain	Mar-97	CVC
13	Abandoned irrigation cannal	Jul-97	MMV
14	Hardy starting point	Mar-97	CVC
15	Hardy River	Jul-97	CVC
16	Willow & Cottonwood (W-CW)	Mar-97	CVC
17	Vado Carranza with water	Mar-97	CVC
18	Vado Carranza dry	Jul-97	CVC
19	River bank near Vado Carranza	Oct-97	CVC
20	Vado Carranza cobert	Mar-97	CVC
21	Vado Carranza vegetation	Ago-97	MMV
22	Willow-Cottonwood on river bank	Mar-98	CVC
23	Mosqueda Camp	Mar-97	CVC
24	Mosqueda Lake	Ago-97	CVC
25	Mosqueda pumping station	Jul-97	MMV
26	Colorado joining Hardy	Sep-97	CVC
27	Cottonwood (CW) on river bank	Mar-98	CVC
28	W-CW East Side of levee	Mar-98	CVC
29	W-CW East side of levee	Mar-98	CVC
30	Aquatic grass	Mar-98	CVC
31	Thick cattail stand	Mar-98	CVC
32	3 Streams of the Colorado delta	Mar-98	CVC
33	Colorado River at the camps	Mar-97	CVC
34	Campo Flores	Sep-97	OHH
35	Touristic Camp	Mar-97	CVC
36	Flooded camp	Mar-98	CVC
37	Saltcedar stands	Ago-97	CVC
38	Colorado drain	Ago-97	MMV
39	Extensive aquaculture	Sep-97	CVC
40	Mesquite on River Bank	Sep-97	CVC
41	Colorado River south El Riñon	Oct-97	CVC
42	Laguna Salada Cannal	Mar-97	CVC
43	Flooded Laguna Salada Cannal	Mar-98	YCG
44	Floods at Laguna Salada Cannal	Mar-98	CVC
45	Floods at Laguna Salada Cannal	Mar-98	CVC
46	Dry Laguna Salada	Sep-97	CVC
47	Dry salt flats	Mar-97	CVC
48	Faro at Zone 6	Mar-97	CVC
49	Floodplain of the Colorado delta	Mar-98	EG
50	Distichlis area	Feb-97	CVC
51	Gulf of Santa Clara	Mar-97	CVC
52	Saltcedar	Mar-98	OHH
53	Insect on willow	Ago-97	MMV
54	Burned cottonwood	Oct-97	MMV
55	Cucapá girl	Sep-97	CVC
56	Cucapá boat	Mar-97	CVC
57	Cucapá museum	Jul-97	MMV
58	Cucapá museum (house)	Jul-97	MMV
59	Agriculture and birds in Yuma	Mar-97	CVC

60	Apiculture	Ago-97	MMV
61	Fishing boys	Oct-97	MMV
62	Swimmer kids	Ago-97	CVC
63	Fishing at Vado Carranza	Ago-97	CVC
64	Ecotours at La Cienega	Mar-97	CVC
65	MODE Cannal	Ene-93	CVC
66	Matamoros dam	Mar-98	CVC
67	Map of the Colorado delta	Mar-98	YCG
68	Risk zone advertise	Ago-97	CVC
69	Teamwork discussion	Jul-97	MMV
70	Teamwork discussion at field trip	Mar-98	CVC
71	Mapping work on field trip	Mar-98	CVC
72	Flow survey	Mar-97	CVC
73	Salinity sampling points	Mar-97	CVC
74	TV documentary preparation	Oct-97	CVC
75	Boat trip	Mar-98	CVC
76	Boat trip	Ago-97	CVC
77	Satellite image of floodplain	Mar-98	YCG
78	Flight trip	Mar-97	CVC
79	Destroyed road	Mar-98	YCG
80	Flooded town	Mar-98	CVC
81	Trash in drain	Mar-97	CVC
82	Trash area in the delta	Mar-97	CVC
83	Footprints	Mar-98	CVC
84	Morelos aerial view	Ago-97	CVC
85	San Luis Río Colorado aerial view	Mar-97	CVC
86	Geothermic Plant Lagoon	Mar-97	CVC
87	Agricultural Area aerial view	Mar-97	CVC
88	Pescaderos River aerial view	Ago-97	CVC
89	Pescaderos River aerial view	Ago-97	CVC
90	Zone II aerial view	Mar-97	CVC
91	Hardy River aerial view	Ago-97	CVC
92	Vado Carranza aerial view	Ago-97	CVC
93	Zone 3 aerial view	Ago-97	CVC
94	Zone 4 aerial view	Mar-97	CVC
95	Hardy/Colorado Wetlands	Mar-97	CVC
96	Zone 5 aerial view	Ago-97	CVC
97	Zone 5 aerial view	Ago-97	CVC
98	East side of levee, aerial view	Ago-97	CVC
99	Montague Island, aerial view	Feb-97	CVC
100	Vegetation zones	Mar-98	EG
101	Cienega de Santa Clara	Mar-97	CVC
102	Graphic of water flows	Mar-98	EG
103	Table of vegetation zone	Mar-98	EG
104	Graphic	Mar-98	EG
105	Graphic	Mar-98	EG