A DELTA ONCE MORE:

RESTORING RIPARIAN AND WETLAND HABITAT IN THE COLORADO RIVER DELTA

Daniel F. Luecke
Jennifer Pitt
ENVIRONMENTAL DEFENSE FUND
Boulder, Colorado

Chelsea Congdon
Boulder, Colorado

Edward Glenn, Ph.D.
Environmental Research Laboratory,
University of Arizona
Tucson, Arizona

Carlos Valdés-Casillas, Ph.D.
Instituto Tecnológico y de Estudios Superiores de Monterrey
Guaymas, Mexico

Mark Briggs
Sonoran Institute
Tucson, Arizona

June 1999

ENVIRONMENTAL DEFENSE FUND

ISBN 1-58144-356-0

© 1999 Environmental Defense Fund

The Environmental Defense Fund is a leading, national, New York-based, private, non-profit, research and advocacy organization with more than 300,000 members nationwide. EDF's staff includes scientists, economists, engineers, and attorneys who seek practical solutions to a broad range of environmental and human health problems.

Copies of this report may be obtained from:

EDF Publications
1875 Connecticut Avenue, NW
Washington, DC 20009

ACKNOWLEDGMENTS

EDF gratefully acknowledges the contributors who have generously supported its work in the Colorado River Delta region, including the Compton Foundation, the General Service Foundation, the Charles Stewart Mott Foundation, the Catto Foundation, and the Environmental Protection Agency.

Thanks to Elena Chavarria for her intelligent translation of the executive summary. In addition, credit is due to Osvel Hinojosa, Yamilett Carrillo, Jaqueline Garcia and Francisco Zamora for their contributions to research in the Colorado River Delta.

ABOUT THE AUTHORS:

Daniel F. Luecke is an environmental scientist and regional director with the Environmental Defense Fund in Boulder, Colorado. Over the past two decades he has been involved in a number of riverine and aquatic habitat protection projects.

Jennifer Pitt is a senior resource analyst with the Environmental Defense Fund in Boulder, Colorado. From 1994 to 1998 she worked on river restoration for the National Park Service and American Heritage Rivers.

Chelsea Congdon was a senior resource analyst with the Environmental Defense Fund for 11 years. From 1995 to 1998 she worked in EDF's Rocky Mountain office, leading the organization's efforts in the Colorado River delta. She continues to work on delta restoration as a consultant and documentary film producer.

Edward Glenn is a professor in the Soil, Water, and Environmental Science Department at the University of Arizona. He has studied the vegetation and water quality of the delta in collaboration with Mexican scientists over the past decade.

Carlos Valdés-Casillas is the director of the Center for Conservation of Natural Resources (CECARENA), and head of research of the Instituto Tecnológico y de Estudios Superiores de Monterrey (ITESM), Campus Guaymas. He has published several reports on assessment and planning of coastal areas in Mexico, in particular on the Sea of Cortez.

Mark Briggs is the director of research at the Sonoran Institute, Tucson, Arizona. His area of focus is on evaluating the health of riparian ecosystems and developing strategies for improving their overall ecologic condition.

EXECUTIVE SUMMARY

Historically, the Colorado River fed one of the greatest desert estuaries in the world. The Colorado's delta consisted of vast riparian, freshwater, brackish, and tidal wetlands that covered 1,930,000 acres (780,000 ha) and supported a legendary richness of plant, bird, and marine life. Today, conditions are changed. Decades of dam construction and water diversions in the United States and Mexico have reduced the delta to a remnant system of small wetlands and brackish mudflats.

Recently, however, the delta has begun to make a comeback. In the last two decades, floodwater, releases from reservoirs in the United States, agricultural return flows from both countries, and municipal wastewater from Mexico have proved beneficial. Although flood flows are extremely unreliable and irregular, and wastewater is high in salinity and pollutants, this water has begun to restore some areas of the delta. Current conditions have allowed wetlands to flourish on about 150,000 acres (60,000 ha).

The authors believe that key areas of the delta might be saved through more efficient use of water that now flows into the delta. This could be accomplished without adverse effects on other Colorado basin water users. While demand for water by irrigators, cities, and other important constituencies makes it unlikely that a natural flow regime can be restored to the delta, deliberate management of existing water resources, such as agricultural drainage, wastewater, and floodwater, could make a significant difference. Although the delta's ecosystems deserve greater consideration in the allocation of Colorado River resources, the delta's minimum requirements are surprisingly modest.

This report outlines the delta's natural and cultural history, documents recent scientific findings about the delta's partial recovery, reviews its current political context, and makes recommendations for securing, assuring, and managing existing flows to further benefit and sustain the delta's remnant wetland ecosystems.

The authors assessed habitat values in the delta's vegetated riparian areas and wetlands, and found relatively large areas of dense, woody vegetation capable of supporting significant bird populations. In addition, the authors measured the quantity and rate of water flows needed to sustain delta vegetation, and found that annual flows of 32,000 acre-feet (4×10^7 m^3), supplemented by periodic (once every four years on average) flood flows of 260,000 acre-feet (3.2×10^8 m^3), should suffice. Research documenting flows needed to support the fisheries of the delta and the near-shore marine environment of the Gulf of California has not yet been conducted.

Finally, the authors outline recommendations to manage existing flows for the benefit of delta ecosystems; change international institutions and agreements to support delta ecosystems; establish market mechanisms and funding sources for delta preservation; increase public participation; conduct further research; and implement site-specific restoration.

RESUMEN EJECUTIVO

Por tiempos inmemorables, el río Colorado alimentó uno de los mayores estuarios desérticos del mundo. El delta del Colorado consistía en más de 781,060 ha. (1,930,000 acres) cubiertas por bastos humedales riparios de agua dulce, agua salobre y de mareas, que sustentaba una riqueza legendaria de plantas, aves y vida marina. Hoy las condiciones han cambiado; décadas de construcción de presas y desviación de agua en Estados Unidos y México, han reducido el delta a un sistema remanente de pequeños humedales y lodazales salobres.

Recientemente, sin embargo, el delta ha iniciado su regreso. En las dos últimas décadas, la liberación de flujos de agua de las presas de Estados Unidos, las aguas residuales agrícolas de ambos países y el agua de desecho municipal de México, han probado ser benéficas. A pesar de que los flujos de inundación resultan ser extremadamente aleatorios e irregulares, y que las aguas residuales tienen elevada salinidad y contaminación, esta agua ha empezado a restaurar algunas áreas del delta. Las condiciones actuales han permitido el establecimiento de 54,725 ha. (150,000 acres) de humedales.

Los autores confían en que ciertas áreas del delta podrían ser salvadas mediante un uso mas eficiente del agua que fluye ahora a través del él. Esto puede lograrse sin efectos adversos sobre los otros usos del agua del cauce del Colorado. Dado que la demanda de agua para irrigación, ciudades y otros usuarios de importancia, hace remota la posibilidad de que un régimen de flujo natural pueda restaurarse para el delta, el manejo deliberado de los recursos hidráulicos, como drenes agrícolas, aguas residuales y flujos de inundación, podrían lograr una diferencia significativa. A pesar de que los ecosistemas del delta merecen mejores consideraciones en la distribución de recursos del Río Colorado, los requerimientos mínimos del delta son sorprendentemente modestos.

Este reporte describe la historia natural y cultural del delta, documenta los hallazgos científicos mas recientes referentes a la recuperación parcial del delta, revisa el contexto político actual y ofrece recomendaciones para asegurar y orientar el manejo de los flujos existentes hacia el beneficio y sustentabilidad de los ecosistemas de humedales remanentes del delta.

Los autores evaluaron los valores del hábitat en la vegetación riparia del delta y encontraron áreas relativamente extensas de densa vegetación de galería y boscosa capaz de soportar poblaciones significativas de aves. Del mismo modo, los autores realizaron mediciones sobre la cantidad y tasa de flujos de agua requeridos para soportar la vegetación del delta y encontraron que flujos anuales de 4×10^7 m^3 (32,000 acres-pie), acrecentados por flujos de inundación de 3.2×10^8 m^3 (260,000 acres-pie) cada 4 años en promedio , será suficiente. Aun no se ha llevado a cabo la investigacion para establecer los flujos necesarios para las pesquerias en el delta y en el litoral del Golfo de California.

Finalmente, los autores enlistan recomendaciones para el manejo del flujo existente para beneficio de los ecosistemas del delta: cambiar instituciones y acuerdos internacionales para apoyar los ecosistemas del delta, establecer mecanismos de mercadotecnia y recaudar recursos para la preservación del delta; incrementar la participación pública, avanzar la investigación e implementar restauración en sitios específicos.

TABLE OF CONTENTS

EXECUTIVE SUMMARY iv

RESUMEN EJECUTIVO v

1. THE DELTA IN CONTEXT 1
- Overview 1
- The Delta of Yesterday 2
- The Colorado Basin Transformed 2
- The Delta Today—A Contemporary Geography 4
- Recent Research Efforts 7
- Protecting the Interests of the Delta's People 7
- Growing International Interest in the Delta 8

2. WATER SOURCES IN THE DELTA 11
- The Law of the River 11
- Apportioned Freshwater Flows 12
- Tides and Floods 13
- Agricultural Wastewater 15

3. DELTA HABITAT AND RESTORATION POTENTIAL 17
- The Delta's Ecological Significance 17
- The Environmental Defense Fund's Research in the Delta 18
  - Flood Flows and Water Requirements of Delta Vegetation 20
  - Delta Wetlands and Riparian Vegetation 21
- Threats to Delta Habitats 29
- Restoration Objectives 32

4. POLITICAL LANDSCAPE 33
- Values of the Colorado River Delta 33
- Preservation Strategies 33
- Agents of Change 34
  - International Boundary and Water Commission 34
  - International Authorities 35
  - National Agencies 35
  - Tribes, Basin States, and Local Communities 36
  - Nongovermental Organizations 36
  - Other Organizations and Authorities 37
  - Legal Mechanisms 37
- Related Efforts and Opportunities 38
  - Colorado River Entitlements and California's 4.4 Plan 38
  - Salton Sea 38
  - Yuma Desalting Plant 40
  - Lower Colorado Conservation Planning 40
  - All American Canal and Delivery of Water to Mexico 40

5. RECOMMENDATIONS 41
Conclusion 41
Recommendations 41
Manage Existing Flows for the Benefit of Delta Ecosystems 42
Change Institutional Arrangements and Agreements to Support Delta Ecosystems 42
Establish Market Mechanisms and Funding Sources for Delta Preservation 44
Increase Public Participation 45
Conduct Further Research 46
Implement Site-Specific Restoration 46
Colorado River Delta Riparian Corridor (Zones 2–4) 46
Colorado River Delta Riparian Corridor and Wetland (Zone 4) 47
Rio Hardy Wetlands (Zones 4 & 5) 47
La Ciénega de Santa Clara/El Doctor/El Indio (Zone 7) 47

BIBLIOGRAPHY 49

APPENDIX A: SELECTED FLORA AND FAUNA OF THE COLORADO RIVER DELTA A-1

APPENDIX B: MATERIALS AND METHODS B-1

APPENDIX C: PUBLIC INVOLVEMENT C-1

BOXES

Box 1. A Related Issue: Wastewater Treatment for Mexicali— A New Source of Water for the Delta? 13
Box 2. A Related Issue: La Cienega de Santa Clara 16
Box 3. Vegetation of the Colorado River Delta 26
Box 4. A Related Issue: The Yuma Desalting Plant 31
Box 5. A Related Issue: The Salton Sea 39

TABLE

Table 1. Characteristics of the Colorado River Delta Flood plain in Mexico. 28

FIGURES

Figure 1. The Colorado River Delta, 1933 3
Figure 2. The Colorado River Delta, 1999 5
Figure 3. Human Settlements Within the Highest Influence Area of the Colorado River Delta Wetlands 9
Figure 4. Water Flows at the Southern International Boundary, 1997 15
Figure 5. Satellite Image of the Colorado River Delta, July 15, 1997 19
Figure 6. Vegetation Zones of the Colorado River Delta 22

PHOTOS

Photo 1. Rio Hardy 6
Photo 2. Palmer's saltgrass in the Colorado River delta. 8
Photo 3. Aerial view of the Colorado River delta, near where the Colorado meets the upper Gulf of California 14
Photo 4. La Ciénega de Santa Clara. 16
Photo 5. Cottonwood trees and willows in the Colorado River riparian corridor 21
Photo 6. Dry mudflats in the Colorado River delta. 23
Photo 7. Gulls over the delta 25

1 THE DELTA IN CONTEXT

I have never gone back to the Delta of the Colorado since my brother and I explored it, by canoe, in 1922….
For all we could tell, the Delta had lain forgotten since Hernando de Alarcón landed there in 1540….
On the map the Delta was bisected by the river, but in fact the river was nowhere and everywhere, for we could not decide which of a hundred green lagoons offered the most pleasant and least speedy path to the Gulf.

—Aldo Leopold, A Sand County Almanac, 1948

OVERVIEW

Prior to the construction of major dams along its route, the Colorado River fed one of the greatest desert estuaries in the world. Spread across the northernmost end of the Gulf of California,[1] the Colorado River delta's vast riparian, freshwater, brackish, and tidal wetlands once covered 1,930,000 acres (780,000 ha) and supported a legendary richness of plant, bird, and marine life. Because most of the river's flow reached the delta at that time, its freshwater, silt, and nutrients helped create a complex system of wetlands that provided feeding and nesting grounds for birds, and spawning habitat for fish and crustaceans (Glenn et al., 1996). The Gulf's estuary was a source of fertility reaching far from its shallows, and the legendary richness of the entire Gulf can be laid to the delta's productivity as well as its capacity to support marine and bird life. In contrast to the surrounding Sonoran Desert, the Colorado River delta's abundance was striking.

Today, conditions in the delta are changed. Like other desert river deltas, such as the Nile (Stanley and Warne, 1993) and the Indus (Snead, 1987; Leichenko and Wescoat, 1993), the Colorado River delta has been greatly altered by human activity. Decades of dam construction and water diversions in the United States and Mexico have reduced the delta to a remnant system of small wetlands and brackish mudflats. As reservoirs filled behind dams and captured floodwaters, freshwater flows no longer reached the delta. Now that the reservoirs are full, the periodic flood flows that do reach the delta are constricted by levees.[2]

In the 1970's and 1980's, the popular and scientific press referred to the delta as a "dewatered" or "dead" ecosystem (Spamer, 1990).[3] Since 1981, however, the delta has begun to make a slow comeback. From 1980 to 1998, total water releases to the delta have amounted to an estimated 20 percent of the Colorado's total flows over the same period. While most of this is either floodwater or agricultural and municipal wastewater, these flows are proving beneficial. Although flood flows are extremely unreliable and irregular, and wastewater is high in salinity and pollutants, this water has begun to restore some areas of the delta. Current conditions have allowed wetlands and riparian vegetation to flourish on about 150,000 acres (60,000 ha).

This report documents recent scientific findings about the delta's partial recovery and makes recommendations for managing existing flows to further benefit the delta's ecosystems (*see Chapter 3*). The authors believe that key areas of the delta might be saved through deliberate management of water that now flows into the delta. This could be accomplished without adverse effects on other Colorado basin water users. While demand for water by irrigators, cities, and other important constituencies makes it unlikely that predevelopment flows can be restored to the delta in the short term, the purposeful management of existing water resources such as agricultural drainage, wastewater, and floodwater could make a significant difference. Although the delta's ecosystems deserve greater consideration in the allocation of Colorado River resources, the delta's minimum requirements are surprisingly modest.

Even in its present state, the delta is the most significant wetland system in the American Southwest, and a very productive estuary. Increasing population throughout

[1] The Gulf of California is also known as the Sea of Cortez.

[2] For the purposes of this report, a flood is any volume of water that crosses the United States–Mexico international border, either as a result of releases from U.S. reservoirs for flood control purposes (or other reasons), or directly as a result of flooding in the U.S. (e.g., flooding in the Gila basin), in excess of the U.S. delivery obligation to Mexico, and that is delivered at a rate that exceeds Mexico's diversion capacity and inundates land (either within the levees or beyond) that is normally dry.

[3] Reports of the delta's demise include accounts in the popular press such as Philip Fradkin's A River No More (1981), as well as scientific publications.

the region and growing pressures on water, land, and other resources will intensify the strain on the delta. At some point, water users both north and south of the border may be forced to make some difficult choices about Colorado River allocations. The authors' long-term view is that the delta's ecological, social, and economic values will come to be widely recognized in future deliberations over the allocation of surplus waters, and that in-stream flows may be dedicated to sustain it.

THE DELTA OF YESTERDAY

The Colorado River meets the Gulf of California in Mexico, where the states of Baja California and Sonora share a border. The delta once covered over 3,000 square miles (7770 km^2), an area the size of Rhode Island. Highly variable flood cycles on the Colorado created a dynamic and unstable delta populated by a rich array of adaptable and resilient plant and animal species and human communities that lived off this bounty.

For eons, as much as 70 percent of the Colorado River's silt load was carried to the delta,[4] bringing nutrients and spreading the delta ever wider into the upper Gulf. The delta's richness is further increased by the action of tides typically 13 feet (4 m) or higher, an unusually high ebb and flow that extends the tidal estuary 34 miles (56 km) or more upriver (Payne et al., 1992). The interaction of these tidal flows with freshwater from the Colorado River creates a rich breeding ground for the Gulf's marine life, among other benefits. The delta once supported an estimated 200 to 400 species of vascular plants (Ezcurra et al., 1988).

Early explorers reported jaguars, beavers, deer, and coyotes in addition to the legendary abundance of waterfowl, fish, and other marine and estuary organisms (Spamer, 1990; Leopold, 1948). Early explorers also encountered local people known as the Cucapá, or "the people of the river." The Cucapá are descendants of the Yuman-speaking Native Americans and have inhabited the delta for nearly a thousand years. Spanish explorer Hernando de Alarcón made the first recorded contact with the Cucapá in 1540 and reported seeing many thousands. The Cucapá used the delta floodplain extensively, for harvesting Palmer's saltgrass, a wild grain, and for cultivating corn, beans, and squash. Other foods included mesquite—ground into a meal or made into a drink—deer and wild boar, wild geese and ducks, doves, quail, and fish. They lived in rectangular and round huts, and relied on dugouts and rafts for river travel (Williams, 1983).

THE COLORADO BASIN TRANSFORMED

By the nineteenth century, the delta was open for navigation, and steamboats traveled from Yuma, Arizona, through the delta to the Gulf, in an active river trade. This trade ceased in 1877, when the Southern Pacific rail line reached the Colorado River (Sykes, 1937; Williams, 1983). By the early 1900's, farmers in the Mexicali Valley had begun to irrigate their fields, and the desert bloomed. Water's power to transform the dry desert landscape—and its power to create electricity—would make Colorado River water an irresistibly valuable resource through the entire twentieth century. [*See Figure 1.*]

As the West's population and need for water have grown, the Colorado River has been tapped through a system of dams and diversions that begin close to its source in the mountains of Colorado and Wyoming. Over its 1400-mile (2300 km) course, from its headwaters to the end of its main channel at Montague Island in the Gulf of California, the Colorado is interrupted by more than 10 major dams. More than 80 major diversions carry water away from the river for agriculture and other uses.

The construction of Hoover Dam in the 1930's marks the beginning of the modern era for the Colorado delta. For six years, as Lake Mead filled behind the dam, virtually no freshwater reached the delta. Even spring flooding was captured. This ecologically devastating event was repeated from 1963 to 1981 as Lake Powell filled behind the Glen Canyon Dam (Glenn et al., 1996). With these reservoirs now filled, the dams are used to regulate flow so that water can be reliably apportioned among users and its use maximized. Most flood flows can be contained, regulated, and added to the river's capacity to sustain the West's urban centers and agriculture. Floodwaters are released only when the Bureau of Reclamation, the agency managing the dams, predicts flows that exceed the system's capacity for use and storage.

[4] Between 45 million and 455 million metric tons of silt per year were transported through the Grand Canyon between 1922 and 1935 (Minckley, 1991).

Figure 1. The Colorado River Delta, 1933
(Valdés-Casillas et al., 1998a)

Today, the Colorado River irrigates more than 3.7 million acres (1.5 million ha) of farmland in the southwestern United States and Mexico, and supplies water to nearly 30 million people. It is one of the most highly regulated and diverted rivers in North America: virtually every drop is accounted for in the allocation of water among 9 states (7 in the United States and 2 in Mexico) and 27 native tribes that have rights to use it (Pontius, 1997). While irrigated agriculture tops the list of Colorado River water uses in the United States and Mexico, the second largest consumption of water is evaporation from reservoirs.[5] Diversions out of the Colorado basin, such as water piped to Los Angeles, are the third largest draw, and are followed by municipal and industrial uses. Federal hydroelectric plants along the Colorado have a total generating capacity of about 4425 megawatts (MacDonnell and Driver, 1996).

THE DELTA TODAY— A CONTEMPORARY GEOGRAPHY

Where the Colorado River meets the United States–Mexico border, the Morelos Dam stands as the last major structure in the river's mainstem. [*See Figure 2*.] For about eight miles, the border follows the river, after which the river is fully in Mexico. Water managers refer to two reference points along the reach of the Colorado that forms the border: the Northern International Boundary (NIB) at Morelos Dam, and the Southern International Boundary (SIB) where the river leaves the United States.

The Colorado River delta is surrounded today by an area known as the Mexicali and San Luis Rio Colorado agricultural valleys. At present, the delta encompasses approximately 150,000 acres (60,000 ha), in a basin surrounded by nearly 500,000 acres (200,000 ha) of irrigated agriculture land. Two rivers form its core: the Colorado, and also the Rio Hardy, a tributary to the northwest. In addition, water from the Wellton-Mohawk Canal empties into the eastern delta.

These freshwater sources support delta vegetation, found in riparian areas and wetlands. Although constrained by levees, the delta is broadly bound by the Cucapá Mountains to the west, and the Sonoran Mesa to the east. Two islands, Montague and Pelicano, mark where the delta meets the Gulf of California to the south. Another significant feature is the Laguna Salada, a dry depression west of the delta into which Colorado River waters drain when flows are high.

Although the Colorado basin drains 244,000 square miles (632,000 km^2), including 2000 square miles (5200 km^2) in northern Mexico, most of its water does not reach the delta. During the twentieth century, river flows into the delta have been reduced nearly 75 percent, from an annual average between 1896 to 1921 of 16.7 million acre-feet (maf) (20.7×10^9 m^3) (Fradkin, 1981), to an annual average between 1984 and 1999 of 4.2 maf (5.2×10^9 m^3) (Glenn et al., 1999). This reduction in water has resulted in major changes to the delta: less silt, fewer nutrients, higher salinity, and higher concentrations of pollutants.[6] Erosion—rather than accretion—is now the dominant physical process in the delta (Thompson, 1968), a highly unusual condition for a river delta. Like other river deltas at risk, such as the Nile's, the Colorado's delta has actually begun to decrease in size (Stanley and Warne, 1993).

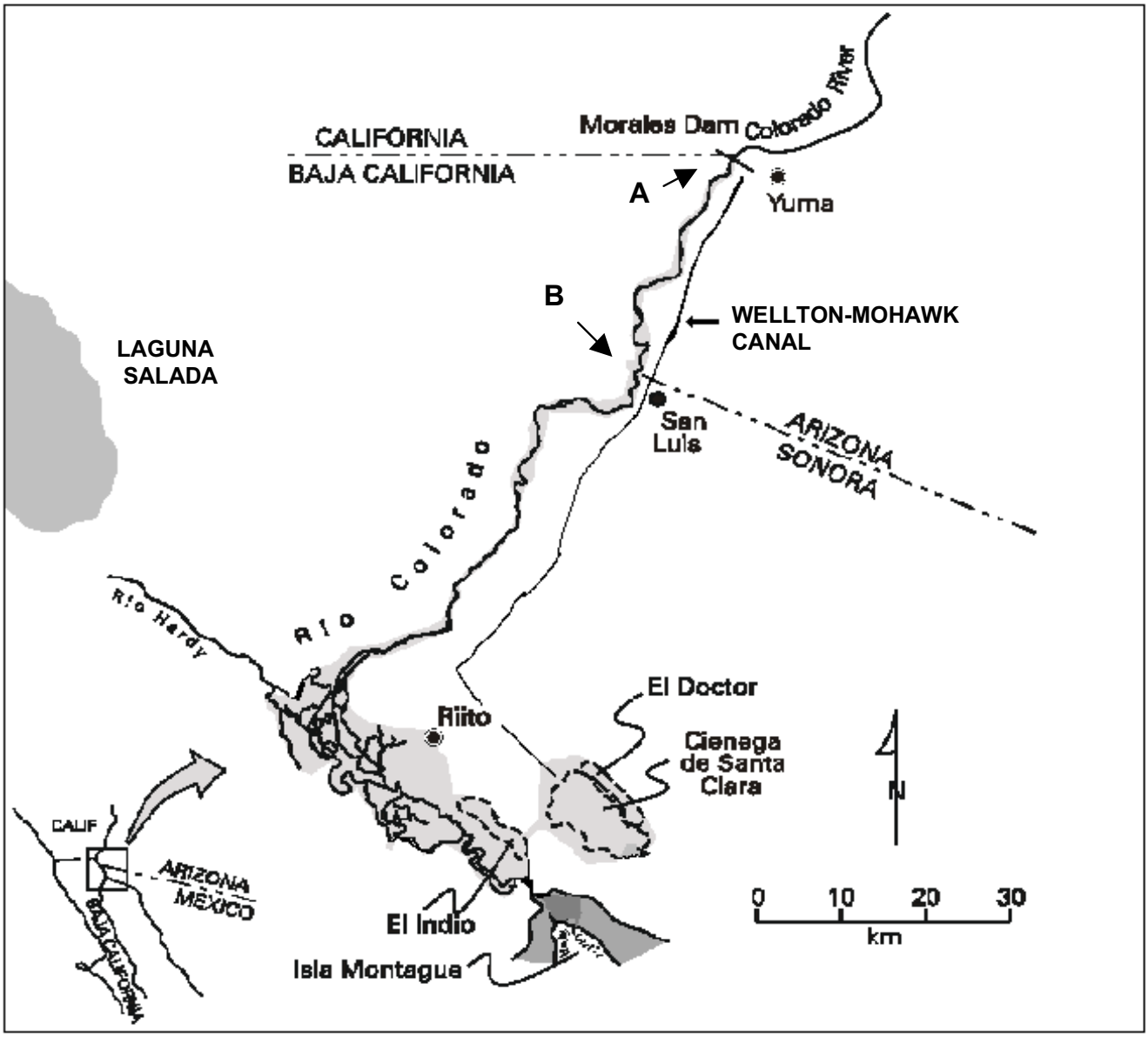
The loss of freshwater flows to the delta over the past century has reduced delta wetlands to about 5 percent of their original extent, and nonnative species have compromised the ecological health of much of what remains. Stress on ecosystems also has allowed invasive plants to choke out native species along Colorado River riparian areas. Native forests of cottonwood and willow have yielded to sand and mudflats dominated by the nonnative tamarisk (also known as salt cedar), arrowweed, and iodinebush, a transformation that has decreased the habitat value of the riparian forest (Briggs and Cornelius, 1997).

The Colorado River delta and its estuary ecosystems may bear the worst effects of the river's heavy upstream use and development, and development in the delta further compromises its health. Much of the upper delta has been converted to irrigated farmland, and levees and channels have changed the physical delta significantly. In the lower delta, where salinity makes agriculture impossible, the effects of upstream water diversion and development are clearly seen.

[5] Allocations made under the laws and compacts that make up the Law of the River (*see Chapter 2*) do not account for 1.5 maf in annual evaporative losses from mainstem reservoirs (Pontius, 1997).

[6] The natural ecology of most of the world's large river systems has been disrupted by dams, flow diversions, channelization of the riverbed, and alteration of riparian zones by agricultural activities which in turn reduce flows, silt accretion, and nutrient loads to their deltas.

Figure 2. The Colorado River Delta, 1999
(Valdés-Casillas et al., 1998a)



A - Northern International Boundary
B - Southern International Boundary

Nevertheless, despite its diminished state, the delta plays a significant ecological role that goes far beyond its bounds. For migratory birds, the delta is a key stop-over along the Pacific Flyway (Payne et al., 1992), and it supports large numbers of wintering waterfowl. Although resident and migratory bird densities have not been studied extensively, the delta is considered a key element of the flyway, and the only significant fresh-water wetland among the Mexican Pacific Coast marshes (*See Appendix A for a list of birds recorded in the delta*). Species under threat elsewhere in the Colorado basin still find refuge in the delta, which is also home to the largest known populations of two endangered species, the desert pupfish and the Yuma clapper rail (Glenn et al., 1996). Delta marshes still have the capacity to provide nursery habitat for marine life that, in turn, supports other marine life across the entire upper Gulf.

Significant riparian areas and wetlands include:

- riparian areas along the Colorado River from the border to the delta (82,000 acres [33,000 ha]), which have recovery potential, in part because gallery forests of cottonwood and willow have shown a capacity for self-restoration during recent floods;
- the Rio Hardy/Rio Colorado wetlands, an area that fluctuates with floods and was recently measured at 23,719 acres (9600 ha), in the western delta near the confluence of the Rio Hardy and the Colorado, supported by flows from the Rio Hardy and Colorado River flood flows;

Photo 1. Rio Hardy

- about 20,000 acres (8,000 ha) of intertidal wetlands, which can be found up to 34 miles (56 km) upstream from the Gulf supported by high tides; and
- la Ciénega de Santa, a wetland in the eastern delta that was unintentionally created by agricultural return flows from the U.S. and Mexico that arrive via drainage canals, and the adjacent El Doctor and El Indio wetlands, both of which are supported by artesian springs—these wetlands encompass some 44,000 acres (18,000 ha).

RECENT RESEARCH EFFORTS

During fieldwork in 1997 and 1998, scientists supported by the Environmental Defense Fund (EDF), the Environmental Research Laboratory (ERL) in Arizona, the Instituto Tecnológico y de Estudios Superiores de Monterrey (ITESM), and the Sonoran Institute documented the extent of surviving ecosystems in the Colorado River, studied their habitat values, and assessed their overall ecological significance. They also determined the quantity and quality of water in the delta. These measurements play a critical role in defining what is needed to secure the viability of these remnant delta ecosystems. This report will detail these findings.

Researchers also examined the size and periodicity of floods in the delta. Floods are known to have high value for riparian and estuary ecosystems (Grimm et al., 1997). The cottonwood for instance, an important riparian species, depends on floods for seed germination. Flood flows that reached the delta from 1980 to 1987 were up to ten times higher than normal, and average excess flows across the border from 1980 to 1993 were three times higher than Mexico's legal entitlement (Glenn et al., 1996).[7] These flows have reestablished an active floodplain, revegetated many areas of the floodplain within irrigation and flood control levees, and helped to reestablish riparian forests. Many marine species depend on freshwater to keep salinity levels low in estuaries so they can breed and lay eggs, and flood flows have improved delta shrimp fisheries (Galindo-Bect, n.d.). Flood releases to the delta can be expected to continue if reservoirs along the Colorado remain full, but a string of dry years could eliminate the fragile ecosystems that have been reestablished.

PROTECTING THE INTERESTS OF THE DELTA'S PEOPLE

People living in the delta region continue to use and depend on the delta, from fishermen in the Gulf to farmers along its northern margins. Approximately 207,000 people live in the 1127 small settlements within 5 km of the delta. Most of these settlements (92 percent) have fewer than 100 inhabitants (Valdés-Casillas et al., 1998a). [*See Figure 3.*] The two largest municipalities in the delta region are Mexicali (pop. 696,034) and San Luis Rio Colorado (pop. 133,140).[8] The economic promise of these border cities has led to high rates of immigration from other regions of Mexico. San Luis Rio Colorado's growth rate exceeds 3.5 percent annually (Carrillo, 1999)

Nearly 2.5 million acres (1 million ha) around the delta are used for agricultural production, relying on water from the Colorado and its tributaries. The irrigation district that includes Mexicali and San Luis Rio Colorado—some 440,000 acres (178,000 ha)—was recently assessed a value of nearly $3 billion in annual crop production (Valdés-Casillas et al., 1998a). The delta region attracts migrants from central Mexico with the economic promise of proximity to the international border and the predominance of irrigated agriculture. Concentrated in wheat, cotton, and alfalfa production, it is the region's largest industry, employing upward of 60 percent of the working population.

The delta generates significant economic activity in addition to irrigated agriculture. Three communities —El Golfo de Santa Clara, San Filipe, and Puerto Peñasco—continue to rely on fishing as the basis for their culture and economy. Sixteen tourist camps located near the confluence of the Rio Hardy and the Rio Colorado are used by visitors from Mexicali and the United States for fishing, hunting, and other water-based recreation, and local residents work as guides for these visitors. Many communities in the delta rely on riparian forests for fuel wood. One community produces catfish in an aquaculture facility (Valdés-Casillas et al., 1998a).

Today, approximately 600 Native Americans live in the delta region. Of these, some 200 are Cucapá, who own 353,000 acres (143,000 ha) along the Rio Hardy and Rio Colorado (Valdés-Casillas et al., 1998a). No longer able

[7] Delivery requirements to Mexico are discussed at length in Chapter 2.
[8] Population figures are based on 1995 data.

to practice their traditional subsistence of harvesting Palmer's salt grass (*Distichlis palmeri*)—which has limited reproductive capability without regular flooding to disperse seeds—the Cucapá have looked to other harvests the delta supports. Several Cucapá communal agricultural settlements, or *ejidos*, line the Pescaderos River, a tributary of the Colorado now converted to agricultural drainage, and these communities use the Pescaderos for fishing and hunting. Diminished flows in the river have forced many Cucapá to truck their boats miles to reach the nearest waterways, and many travel farther to find work in the agricultural fields of the Mexicali Valley (Boyer, 1998). The Cucapá have the one licensed commercial fishing operation in the delta—the Cucapá Fishing Production Unit—which has tribal rights to fish for Gulf corvina and shrimp. Although subsistence fishing, as well as hunting and gathering, once were common, Cucapá communities now work as hunting and fishing guides, and sell their arts and crafts to tourists (Valdés-Casillas et al., 1998a). Other residents fish commercially in the southernmost Colorado River between Cucapá El Mayor and the river's mouth for bigmouth bass, carp, mullet, catfish, tilapia, and crayfish. Commercial fisheries in the upper Gulf, all dependent on the delta for breeding grounds and/or nutrients, include shrimp, shark, milkfish, and corvina (Valdés-Casillas et al., 1998d).

Photo 2. Palmer's saltgrass in the Colorado River delta.

The success of any effort to preserve delta ecosystems will depend on its ability to identify and include the interests and concerns of local people and communities. As part of the research discussed in this report, social scientists have approached the people of the delta to begin the process of understanding their needs and to provide outreach and education concerning the research effort. In addition, locals are being asked to help scientists understand the delta's ecology and the ways in which it has changed in recent decades. *(Appendix C contains a more complete summary of this outreach effort.*)

GROWING INTERNATIONAL INTEREST IN THE DELTA

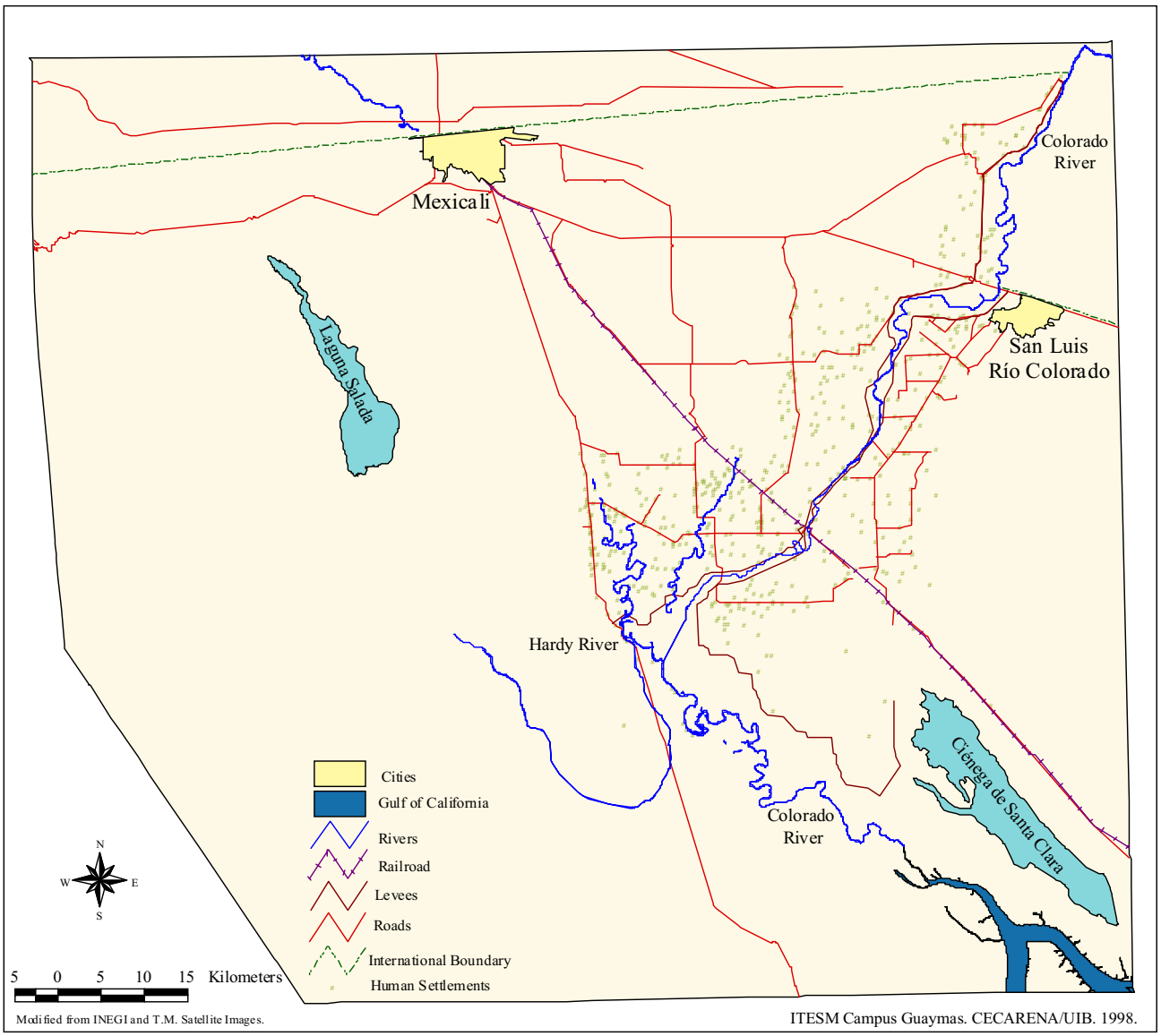
The past decade has brought greater scientific understanding of the Colorado River delta, and it also has brought increased political interest from both sides of the border. In 1993, the delta and the upper Gulf were declared a Biosphere Reserve by the Mexican government. This designation, sanctioned by the United Nations, is designed to protect world-class ecosystems while encouraging continued sustainable economic activity in surrounding buffer areas.[9] The Biosphere Reserve of the Upper Gulf of California and Colorado River Delta covers a total of 2,309,782 acres (934,756 ha)—407,218 acres (164,779 ha) in the core and 1,902,564 acres (769,976 ha) in the buffer. The core area includes la Ciénega de Santa Clara and el Doctor wetlands. The Reserve is designed to protect an estimated 19 percent of the plant species found in Mexico, 22 of the 37 saltwater fish species endemic to the Gulf of California, and the desert pupfish, the only surviving native freshwater fish species of the delta (Centro de Investigaciones Cientificas y Tecnológicas de la Universidad de Sonora, n.d.).[10]

The delta was recognized as part of the Western Hemisphere Shorebird Reserve Network in 1992. In 1994, Mexico joined the U.S. and Canada in the North American Waterfowl Management Plan, and listed the delta as continentally important habitat. In 1996, delta wetlands were listed as a Ramsar site when Mexico became a party to the Convention on Wetlands (also known as the Ramsar Convention) and thereby agreed

[9] Biosphere Reserves, designated by the Mexican government under the authority of the General Law of Ecological Equilibrium and Environmental Protection, can be created to protect areas greater than 25,000 acres (10,000 ha) that contain endemic, threatened, or endangered species (Centro de Investigaciones Cientificas y Tecnológicas de la Universidad de Sonora, n.d.).

[10] The Biosphere Reserve's Management Plan cites significant environmental threats to the region such as reduced flows, illegal fishing, agricultural pollution, illegal hunting, illegal extraction of plants, and overfishing.

Figure 3. Human Settlements Within the Highest Influence Area of the Colorado River Delta Wetlands
(Valdés-Casillas et al., 1998a)



to place a high priority on wetland conservation. As early as 1988, Mexico had joined Canada and the United States in signing the Tripartite Agreement on the Conservation of Migratory Birds, opening the door to funding from the U.S. North American Waterfowl Conservation Act. To date, several inventory projects in the delta have received these funds.

In the past decade, conservation organizations in Mexico and the United States have become increasingly involved in efforts to assess threats to the ecosystems of the delta and upper Gulf, and to identify opportunities for protecting and enhancing these resources.[11] In 1998, the Colorado River Delta was listed as one of the top ten endangered rivers in North America in an annual press release used to generate political interest by the advocacy group American Rivers. Public agencies, resource managers, and water users in both countries also have begun to recognize the importance of a conservation agenda for the region. Mexico's National Institute of Ecology (INE) manages the Biosphere Reserve and is promoting the creation of a binational institution charged with sustainable water use in the delta. The International Boundary and Water Commission (IBWC) is convening a "Delta Taskforce." The U.S. Environmental Protection Agency (EPA) International Office has begun funding projects in the border region. New institutions created as part of the North American Free Trade Agreement may also be able to weigh in on delta issues.[12] One notable exception to this trend is the U.S. Multi-Species Conservation Program for the Lower Colorado River (MSCP). Participants have been encouraged—and have refused—to consider the delta region in their investigation of mitigation measures for the lower river habitats.[13]

Interest in the delta is likely to increase as U.S. policy makers recognize its value. The delta contains thousands of acres of habitats that have become rare elsewhere in the Colorado basin (Glenn et al., 1996; Valdés-Casillas et al., 1998a), and may be the only viable repository for several endangered species. Also, conservation efforts in the delta may prove more productive than elsewhere in the lower basin, and the delta could become a focus for efforts to mitigate the impact of development further north. In any case, the delta is a key component of the lower Colorado riparian zone, which extends from the Grand Canyon to the Gulf of California. Any viable recovery plan for the river's riparian zone must include the delta, regardless of the international border that divides the region. At some point, U.S. environmental policy may obligate the United States to help protect the delta.[14] U.S. water management agencies are directly responsible for the well-being of the delta and northern Gulf fisheries, as the delta ecosystems are almost entirely supported by wastewater flows or flood releases the agencies control.

[11] The Environmental Defense Fund, Ducks Unlimited, the Nature Conservancy, Conservation International, American Rivers, Defenders of Wildlife, the Sonoran Institute, the Pacific Institute, Intercultural Center for the Study of Desert and Oceans (CEDO), and PRONATURA have an ongoing interest in the region.

[12] See Chapter 4 for a discussion of NAFTA-related institutions.

[13] MSCP includes representation from the lower basin states, and water and power users. Representatives of environmental organizations resigned from the MSCP in 1998 when the representatives of the states and water users refused to include the delta in the scope of their program.

[14] For a discussion of U.S. law and environmental policy, see Legal Mechanisms in Chapter 4.

2 WATER SOURCES IN THE DELTA

Curtailment of the surface water supply and its restriction to the cultivated areas and a narrow channel will eventually result in the reversion to the condition of the surrounding deserts of much of the region which is at present occupied by luxuriant vegetation.

—Godfrey Sykes, The Colorado Delta, 1937

THE LAW OF THE RIVER

Use of Colorado River water is governed by a complex set of legal and administrative agreements known collectively as the Law of the River. This body of agreements gives highest priority to consumptive uses of water, and lowest priority to "public good" uses such as maintaining in-stream flows to support fish, wildlife, and habitat.[15] To date, the Law of the River contains no provision for allocating water to support the ecological health of the Colorado's riparian zone or the delta and upper Gulf. However, recent reforms and ongoing negotiations to amend existing water management institutions suggest a potential for securing a dedicated water supply for the delta at some time in the future.

Even within the constraints of the Law of the River, the U.S. federal government and several states have successfully secured flows for habitat and endangered species protection in the basin. In 1987, the Recovery Implementation Plan for the Upper Colorado River Basin was developed to protect and improve in-stream flows, restore habitat, and reduce the adverse effects of nonnative fish species.[16] In the lower basin, water users representing irrigation, municipal, and power interests launched the Lower Colorado River Multi-Species Conservation Program (MSCP) in 1994 to mitigate water development impacts on threatened and endangered species and their habitat.[17] In 1996, the Bureau of Reclamation released a flood of stored water from behind Glen Canyon Dam in an effort to redistribute sediments in the Grand Canyon and re-create eroded beaches.[18] These efforts suggest a growing awareness of the importance of the river's ecological health and show the willingness of water users and their representatives to reform water management practices.

The authors believe, however, that a single-focused effort to gain additional water for the delta could lead to conflicts with U.S. water users and a breakdown of cooperation, as competition for Colorado River water is already high in this fast-growing region. Lower basin states in the U.S. are now—or soon will be—using their full entitlement of water from the river and are working to secure access to additional supplies.[19] Mexico has longstanding concerns over the quantity and quality of water delivered to the border.[20] In addition, Mexico views its Colorado River entitlement as additional to

[15] For detailed discussion of the laws and decisions that comprise the Law of the River, see Charles Meyers's and Richard Noble's articles in the Stanford Law Review (1966 and 1967). The provisions for delivery of Colorado River water to Mexico are set forth in the Treaty with Mexico Respecting Utilization of the Waters of the Colorado and Tijuana Rivers and of the Rio Grande, February 3, 1944. The Law of the River gives priority to 1) the delivery of water to Mexico, 2) "present prefected rights" (or, water rights that were exercised prior to 1922, including the rights of Indian tribes), 3) delivery of water to the lower basin for consumptive uses, 4) consumptive uses in the upper basin, 5) economic, nonconsumptive uses (e.g., power generation), and 6) noneconomic, nonconsumptive uses (e.g., environmental protection). Provisions pertaining to the quality of water the U.S. must deliver to Mexico are the subject of yet another agreement, dating to 1964, Minute 242 to the 1944 Treaty.

[16] The Recovery Implementation Program for Endangered Fish Species in the Upper Colorado River Basin (RIP) is a cooperative effort involving the U.S. Fish and Wildlife Service, Bureau of Reclamation, Western Area Power Administration, the states of Utah, Colorado, and Wyoming, water users, and environmentalists. The recovery program, which is expected to require 15 years, contains five major elements: 1) habitat management designed to identify and acquire in-stream flows, including the change in operation of federal reservoirs in the basin; 2) habitat development based on the development of research methods for creating, protecting, and improving habitat; 3) stocking native fish based on a genetic management plan; 4) nonnative species control; and 5) research, monitoring, and data management programs designed to study various means of recovering fish, monitor long-term population trends, recommend flows, evaluate genetic differences between populations, recommend "refugia" (facilities to hold and protect rare fish), evaluate differences between hatchery and wild fish, establish brood stock, and develop and manage a centralized database. EDF is one of the environmental participants in the RIP and has focused its attention on in-stream flow issues.

[17] See Chapter 1, "Growing International Interest in the Delta," for further discussion of the MSCP.

[18] The 1996 flood helped increase the sandbar volume of 50 percent of the camping beaches measured between Glen Canyon and Hoover dams. The flood bypassed the dam's turbines, and cost approximately $2.5 million in lost hydropower revenues. (Harpman, n.d.)

[19] California already uses more than its allocated share, and Nevada is close to using its allocated share.

groundwater supplies that it can pump in the border region, while California and Nevada have proposed an action—the lining of the All American Canal in California—that would substantially capture water that now recharges this groundwater basin.

Given the relative scarcity of water in the Colorado River basin, it is more likely that the delta's salvation will occur through some level of protection for flows that are presently occurring but are not mandated. This report focuses on steps that can be taken to improve the management of existing flows, rather than steps to increase transboundary water deliveries. In the short term, delta ecosystems will continue their recovery if flows occur at levels recorded in recent years. However, some assurance of these flows, as well as dedicated trans-boundary water deliveries, may be part of the long-term solution.

APPORTIONED FRESHWATER FLOWS

When Colorado River waters were apportioned, first by the 1922 compact and subsequently an Upper Basin compact, court decisions, federal law, and international treaty, the river was overallocated. The problems arising from this overallocation are compounded by the fact that there are very different interpretations of the definition of consumptive use, treatment of evaporation from reservoir surfaces, and the water delivery obligations of the Upper Basin states under the treaty to Mexico (Getches, 1985)

If the Colorado is already *over*allocated because water entitlements were based on optimistic estimations of average annual flow, it may be all the more difficult to secure additional water allocations dedicated to delta ecosystems. This reinforces the importance of finding ways to improve management of existing flows that now reach the delta. In any case, cooperation, accommodation, *and creativity* will be essential, especially as demands for water increase.

Before 1980, while major reservoirs on the Colorado River were still filling, flood flows were nonexistent. The riparian zone of the river from Morelos Dam to the junction with the Rio Hardy was a dry ecosystem, dominated by widely spaced mesquite trees (Valdés-Casillas et al., 1998a).[21] Below the junction of the two rivers, the channel was perennial, due to the discharge of agricultural drain water from the Mexicali Valley and tidewater entering from the Gulf of California.

In the years since 1980, flood flows have been released from Lake Mead (the last major storage on the Colorado River in the U.S.) when flow exceeds storage capacity and upstream use. In years without flooding, the only Colorado River water to reach Mexico is its 1.5 maf (1.8×10^9 m^3) treaty allotment, about 10 percent of the river's average annual flow.[22] The U.S. delivers nearly all of Mexico's water allotment to the Northern International Boundary at Morelos Dam. Mexico diverts this water to the Mexicali and San Luis Rio Colorado irrigation districts by way of the Central Canal,[23] which has a capacity sufficient to divert Mexico's entire allocation. Water in the Central Canal not used for irrigation is routed to Mexicali and Tijuana for municipal use (Ybarra, 1999). The relatively small portion of Mexico's allocation that is delivered at the Southern International Boundary at San Luis Rio Colorado is also diverted for irrigation. During flood-free years, no Colorado River water reaches the remnant delta wetlands below the irrigated farmland (Glenn et al., 1996).[24] The only flows that continue past Mexico's irrigation diversions—and into the delta—are flood flows (*see note 2 and "Tides and Floods" below*). During dry years, the only water reaching the delta comes from groundwater seeps, agricultural drainage, and tidewater. [*See Box 1.*]

---

[20] Mexico has objected to the quality of this water, stating that it is so saline (averaging 1500 parts per million [ppm]) that it reduces yields on the 94,000 acres (38,000 ha) where it is used for irrigation, causing soil deterioration and increasing groundwater salinity. Additionally, Mexico has suggested that this water is possibly contaminated with pesticides. Mexico has requested that its entire entitlement be delivered to the Northern International Boundary (NIB) at Morelos Dam on the river's main channel. The U.S.-Mexico agreement concerning water quality in the Colorado River is found in Minute 242 to the 1944 Treaty. It requires that the average annual salinity of water delivered at the NIB not exceed 115 +/-30 ppm over the annual average salinity of water arriving at Imperial Dam in California (Pontius, 1997). A portion of Mexico's treaty water is sent to the Southern International Boundary (SIB), where agricultural wastewater collected by several drains, and at times augmented by pumped groundwater, is delivered, 2 miles east of the river channel. Water quality at the SIB is not governed by the treaty and has an average salinity of 1500 ppm. Approximately 140,000 acre-feet (1.7×10^8 m^3) of Mexico's 1.5 maf (1.8×10^9 m^3) entitlement is delivered to the (SIB). The salinity of seawater is 35,000 ppm.

[21] These observations are based on inspection of 1972 aerial photographs and interviews with residents.

[22] The average flow (over the historic long term) of the Colorado River is 15 maf (1.8×10^{10} m^3). Flows as low as 6 maf (7.4×10^9 m^3) and as high as 24 maf (3×10^{10} m^3) have been recorded (Pontius, 1997).

[23] Approximately 2 maf (2.4×10^9 m^3) per year are used for irrigation in the Mexicali and San Luis Rio Colorado valleys, with Colorado River water making up the majority of this supply (Valdés-Casillas et al., 1998a).

[24] While the Law of the River gives clear priority to consumptive uses of water, the Colorado River also provides considerable value in terms of recreational and fish and wildlife benefits. However, the ecological needs of the Colorado River have only recently gained legal recognition and protection. Some of these conservation efforts in the U.S. are discussed in Chapter 1.

BOX 1. A Related Issue: Wastewater Treatment for Mexicali—A NEW SOURCE OF WATER FOR THE DELTA?

Each year Mexicali, a Mexican border city, discharges about 40,000 acre-feet (4.9×10^7 m^3) of effluent into the International Boundary Drain, which empties into the New River. The New River originates 22 miles (35 km) south of the international boundary and flows north through Mexicali, crossing the border into California's Imperial Valley. About 45 miles (70 km) to the north, it empties into California's Salton Sea, a closed basin, where evaporation tends to concentrate its pollutants [*see Box 5.*]. Although some of Mexicali's effluent is treated, raw sewage and industrial waste often flow directly into the New River through storm drains and other outlets.

The New River is widely regarded as one of the most polluted rivers in the United States, and it has long been the subject of negotiations between the United States and Mexico. Recently, Mexico and the United States agreed to build a binational wastewater treatment plant to be called Mexicali II. On completion in 2015, the plant will treat more than 37 million gallons per day (mgd) (1645 liters/sec) and serve a projected population of more than half a million people (IBWC, 1996).

A key question in the plant's design is where to discharge its treated water (Eberhardt, 1996). This water could empty into the New River (and could possibly improve water quality conditions in the Salton Sea), or it could be piped to the Rio Hardy basin. Disposal in the Rio Hardy wetlands would help maintain important ecosystems in the Colorado River delta, and the wetlands might even serve as a final step in the treatment process (Renteria and Luecke, 1997).

TIDES AND FLOODS

Two sources of water—tides and floods—continue to sustain parts of the delta much as they have for centuries. Tides are a daily given in the delta, and the topography of the long and narrow Gulf creates an exceptionally high tidal swing of 10 feet (3 m) or greater at its northern end. This allows high tides to flow more than 34 miles (56 km) inland in some places (Glenn et al., 1996) and spread over a total of 81,500 acres (33,000 ha) (Thompson et al., 1968). Tides have sustained vast areas of the delta through the last several decades, although without freshwater flows to dilute the seawater, tides can have a deleterious effect as well.

Since 1980, floods have once again reached the delta, though they are no longer a guaranteed springtime occurrence as they once were. The Colorado's system of dams can regulate much of the variation between wet and dry years, but extraordinarily wet years will probably continue to bring flooding to the delta when releases exceed the capacity of users in the United States and Mexico to divert the water. Since the filling of the Colorado River's reservoirs, these releases have reestablished an active floodplain from Morelos Dam to the tidal zone in the Gulf of California.

Near-record flood releases in the winter of 1983 were at first considered an aberrant event, but occasional flooding has continued, coinciding with El Niño events (Glenn et al., 1996). From 1980 to 1993, average annual flood flows across the border (cross-border flows minus Mexico's treaty allotment) were 3.9 maf (4.8×10^9 m^3). This is nearly three times Mexico's 1.5 maf (1.8×10^9 m^3) treaty allotment, and 25 percent of the historic flow into the delta before dam construction (Glenn et al., 1996). The largest releases occurred in the early 1980's, with flows after 1986 more sporadic and smaller in volume. In 1997–1998, flows exceeding 1.5 maf (1.8×10^9 m^3) were released to the delta (Glenn et al., 1999).[25] [*See Figure 4.*]

Photo 3. Aerial view of the Colorado River delta, near where the Colorado meets the upper Gulf of California

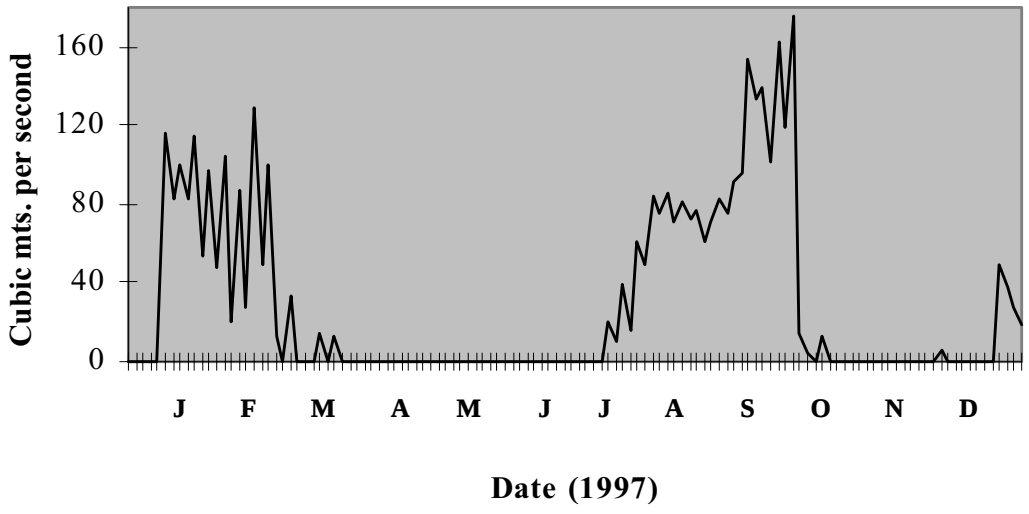
These floods are significant, sustaining the delta's ecosystems through the periodic inundation of its riparian areas and wetlands. Satellite images show a marked decline in summer vegetation during five dry years from 1988 to 1992. Floods in 1993 were followed by three more dry years, but in 1997 scientists observed that midstory trees that appeared to have germinated in 1993 dominated many parts of the delta (Glenn, 1998b). These trees survived three years without river flows. This and other evidence lead researchers to believe that flood flows at three- or four-year intervals could maintain vegetation. These floods also could help sustain upper Gulf shrimp fisheries and other marine species dependent on the delta. Future research on Gulf aquatic species may yield more specific information concerning their dependence on freshwater flows from the delta.

Given the apparent importance of floods, one possible way to support delta ecosystems would be to deliberately manage flood releases for maximum benefit. Water management agreements on the Colorado River include provisions for allocating water under shortage and surplus flow conditions.[26] These agreements could be revised to ensure that a portion of surplus flood flows are stored for, or delivered to, water-dependent ecosystems in amounts and rates, and at times, that would be most beneficial.

[25] It should be noted that annual flow averages and flood release figures do not always reflect the amount of overbank flooding—the inundation of riparian lands—that occurs in the delta. This is more accurately reflected in rate of flow as measured in cubic feet or meters per second.

[26] The U.S. Bureau of Reclamation, the agency responsible for management of the Colorado River dams and flows, reports expected flow conditions to Mexico through the International Boundary and Water Commission (Johnson, 1999).

Figure 4. Water Flows at the Southern International Boundary, 1997
(Valdés-Casillas et al., 1998a)



AGRICULTURAL WASTEWATER

Delta wetlands with significant conservation interest also survive on agricultural wastewater. Seventeen agricultural drains from the Mexicali Valley flow into the Rio Hardy/Colorado River system, carrying an average annual volume of 51,000 acre-feet (6.33 x 10^7 m^3) (Valdés-Casillas et al., 1998a). Another 125,000 acre-feet (1.5 x 10^8 m^3) of mildly saline (3000 parts per million) agricultural wastewater pumped from Arizona's Wellton-Mohawk Irrigation District is delivered to Mexico at the Southern International Boundary. This water is disposed in the eastern delta after travelling 48 miles (77 km) in a concrete canal called the Main Outlet Drain Extension (MODE). MODE water joins about 25,000 acre-feet (3.1 x 10^7 m^3) of agricultural wastewater (from the Riito drain) to support la Ciénega de Santa Clara.

La Ciénega de Santa Clara was once part of a Colorado River channel that ran along the edge of the Sonoran Mesa. As the channel shifted westward, this shallow depression (formed by a branch of the San Andreas fault) nearly dried up. In 1973, before MODE water arrived, the wetland covered only 490 acres (200 ha), fed by artesian springs and the Riito drain (Glenn et al., 1996). After 1977, when the MODE water started emptying into the Santa Clara depression, flows supported wetlands of up to 50,000 acres (20,000 ha). In 1993, floods on the Gila River required the MODE to be closed for repairs for about eight months. As a result, wetlands in la Ciénega de Santa Clara decreased in size to 2700 acres (1100 ha). With the restoration of flows, the marsh returned to its former dimensions within five months (Glenn et al., 1996; Zengel et al., 1995). [*See Box 2.*]

Agricultural wastewater can change ecosystem health since it tends to affect the concentration of pollutants, salts, and minerals. High levels of selenium, for example, are found in many delta areas that receive wastewater, and selenium is known to affect birds and other wildlife. Although agricultural wastewater has been a fairly constant source for la Ciénega de Santa Clara, over the years the MODE canal has carried less water and its salinity has declined. This is due to lower pumping rates and lower groundwater salinity. Wastewater flows from

the Mexicali Valley annually carry 70,000 tons (64,000 metric tons) of fertilizer and 110,000 gallons (400,000 liters) of insecticide (Direccion General de Ecologia, in Valdés-Casillas et al., 1998a). While agricultural wastewater may not be an ideal source of water, its benefits may—for the present—outweigh its liabilities, particularly since there are few other potential sources for restoring delta ecosystems.

One of the chief goals of recent research efforts in the delta has been to examine surviving ecosystems and learn about incidental water supplies, such as wastewater, that support wetlands. In fact, wastewater from geothermal wells forms the headwaters of the Rio Hardy. If wastewater can be deliberately managed, many areas of the delta might be sustained without any new dedicated flows.

BOX 2. A RELATED ISSUE: LA CIÉNEGA DE SANTA CLARA

La Ciénega de Santa Clara (*ciénaga* means wetland in Spanish) is the major marsh wetland in the eastern region of the Colorado River delta. At 50,000 acres (20,000 ha), dominated by cattails, it is home to perhaps the largest remaining populations of the Yuma clapper rails and desert pupfish. It is a major stopover for migratory waterfowl on the Pacific Flyway, and supports guiding, hunting, fishing, and limited ecotourism activities for local communities. In 1992, la Ciénega de Santa Clara was included in the core zone of the Biosphere Reserve of the Upper Gulf of California and the Delta of the Colorado River (*see Chapter 1*).

Photo 4. La Ciénega de Santa Clara.

Historically, an arm of the Colorado River was located where la Ciénega de Santa Clara is today. The banks of the river were covered with willow and cottonwood. Over time, the river channel shifted westward, and after the construction of Hoover Dam the river no longer entered the shallow depression (formed by a branch of the San Andreas fault) that defines the wetland. In 1973, the only water flowing into la Ciénega was supplied by local artesian springs and agricultural drainage water from the Riito drain. La Ciénega de Santa Clara was reduced to a mere 500 acres (200 ha) (Glenn et al., 1996).

Starting in 1977, brackish agricultural drainwater from Arizona has flowed 50 miles south into Mexico via the MODE canal, and drained into the Santa Clara depression. These flows created a wetland of up to 50,000 acres (20,000 ha) of water surface, of which 11,200 acres (4,500 ha) were thickly vegetated. This is considered to be the mature size of the wetland. Flow from the canal was interrupted for eight months in 1993 (following floods), and the vegetated wetland diminished again to 2,750 acres (1,100 ha). The resiliency of the delta marsh systems was demonstrated when flows returned to the MODE canal and the vegetated area assumed its former dimensions (Glenn et al., 1996).

The flows through the MODE were originally intended to be temporary. The U.S. Bureau of Reclamation made other plans for this water as a source for the Yuma Desalting Plant, completed in 1993. [*See Box 4.*] However, the plant is not yet operating. Any viable plan to operate the Yuma Desalting Plant must provide replacement water supplies and other assurances to protect and sustain the remnant wetlands of la Ciénega de Santa Clara which now depend on MODE drainage outflows.

3 DELTA HABITAT AND RESTORATION POTENTIAL

The still waters were of a deep emerald hue…. A verdant wall of mesquite and willow separated the channel from the thorny desert beyond. At each bend we saw egrets standing in the pools ahead…. Fleets of cormorants drove their black prows in quest of skittering mullets; avocets, willets, and yellow-legs dozed one-legged on the bars; mallards, widgeons, and teal sprang skyward in alarm…. At every shallow ford were tracks of burro deer. We always examined these deer trails, hoping to find signs of the despot of the Delta, the great jaguar, el tigre…. We saw neither hide nor hair of him, but his personality pervaded the wilderness….

—Aldo Leopold, A Sand County Almanac, 1948

THE DELTA'S ECOLOGICAL SIGNIFICANCE

Productivity and diversity in the delta have declined over the last century, but the delta ecosystem remains an important biological resource nevertheless. It remains an oasis of life in the midst of the arid Sonoran Desert. Although reduced flows and the construction of levees have transformed the delta, floodwaters, agricultural drainage, municipal wastewater, and seawater in the tidal zone continue to support large riparian areas and marshes. The size of these areas tends to vary dramatically from one season to the next: during the period from 1973 to 1993, freshwater and brackish wetlands ranged from 2300 to 25,500 acres (5800 to 63,000 ha). In 1997, flood releases reestablished native vegetation along the delta's Colorado River floodplain and riparian zones as well as in southeastern delta wetlands (Valdés-Casillas et al., 1998c).

The delta supports a variety of wildlife, including several threatened and endangered species. Mexico's Environmental Regulations on Endangered Species lists the following endangered species found in the terrestrial and aquatic regions of the delta (Diario Officiel, 1994):

- the desert pupfish, also listed as an endangered species in the U.S.—the largest remaining population anywhere is in La Ciénega de Santa Clara;
- the Yuma clapper rail, also listed as an endangered species in the U.S.;
- the bobcat;
- the vaquita porpoise, the world's smallest marine mammal, listed as a species of special concern by the U.S. Marine Mammal Commission; and
- the totoaba, now virtually extinct, a steel-blue fish that grows up to seven feet (2 m) and 300 pounds (136 kg), and once supported a commercial fishery that closed in 1975 (Postel et al., n.d.).

In addition, Mexico lists five threatened species: the yellow-footed gull, Heermann's gull, elegant tern, reddish egret, and peregrine falcon; three species for special protection: the brant, house finch, and mockingbird; and one rare species: the great blue heron.

Although not extensively studied, the delta's significance for migratory birds is indisputable, as it is the principle freshwater marsh in the region. From 1980 to 1985, some 45,000 ducks and 200 geese wintered in the delta (Payne et al., 1992). A 1992 winter survey found more than 160,000 birds in the delta, of which some 9000 were avocets and 8000 were willets (the remainder being smaller species such as sandpipers) (Morrison et al., 1992 in Mellink et al., 1997). A series of delta surveys in 1993–1994 documented 21 seabird species, with more than 16,000 individuals; 6 heron species, and more than 220 individuals; 20 shorebird species, and nearly 150,000 individuals (Mellink, et al., 1997). The delta also provides nesting, breeding, and nursing sites for egrets, sandpipers, avocets, cormorants, ducks, pelicans, gulls, and terns. (*See Appendix A for a selected species lists*.)

In addition to bird counts, there is evidence that delta habitats are of greater value to birds than riparian habitat upstream (in the United States) on the Colorado River (*see discussion of Delta Wetlands and Riparian Vegetation below*). Tree species composition is known to be critical in avian habitat selection, particularly in desert, riparian habitats (Rice et al., 1984). On the lower Colorado River, birds prefer gallery forests of cottonwood and willow, both native species, over screw bean and mes-

quite. More cottonwood-willow habitat exists in the delta than in the riparian forests upstream (Ohmart et al., 1988).

Delta wetlands provide habitat for a number of mammals, including raccoons, skunks, bats, coyotes, bobcats, muskrats, rabbits, jackrabbits, desert rats, gophers, and squirrels (Valdés-Casillas et al., 1998a).

The tidal zone and near shore marine habitats of the Gulf of California also support endangered species and important fisheries. Fish species include catfish, carp, tilapia, mullet, and largemouth bass, and the last remaining populations of desert pupfish, which still survive in backwaters and lagoons (Valdés-Casillas et al., 1998a). The delta is a negative estuary (where the salinity is greater than the ocean's due to evaporation that exceeds precipitation and river flow) that is a rich breeding ground for marine species and has a significant influence on fish populations, possibly throughout the entire Gulf. Reduction of freshwater flows into the Gulf has reduced the transport of nutrients and changed the characteristics of this critical nursery habitat. Nutrient concentrations are higher than most of those reported in the literature for estuaries and negative estuaries, perhaps due to the strong mixing caused by tides of great amplitude (Hernandez-Ayon et al., 1993). The shrimp fishery has dropped off steeply and other fisheries are in decline. The totoaba is now virtually extinct, and the vaquita porpoise is thought to number only a few hundred (Marine Mammal Commission, 1996).

The loss of upper Gulf fisheries may be the most costly effect of reduced flows to the delta. Overfishing certainly contributes to the problem, but scientists have noted a correlation between shrimp catches and flood flows to the delta.[27] This corroborates anecdotal evidence and reports from local fishermen that indicate trends such as a temporary increase in the number of fish species observed in the mid-1980's after high flood flows reached the delta (Postel et al., n.d.).

THE ENVIRONMENTAL DEFENSE FUND'S RESEARCH IN THE DELTA

In 1997 and 1998, staff from the Environmental Defense Fund, the Environmental Research Laboratory (ERL), the Instituto Tecnológico y de Estudios Superiores de Monterrey (ITESM) and the Sonoran Institute conducted fieldwork to evaluate the potential for restoration of delta habitat. This was the first serious attempt to study delta habitat since the restoration of flows. The team quantified the effects of a flood release of known magnitude, and inventoried vegetation. They were able to observe the response of vegetation to flows as a basis to define the amount of water needed to sustain delta ecosystems. In addition, they assessed the potential for existing vegetative cover to support wildlife,[28] particularly in comparison to the upstream stretches where current conservation efforts are focused.[29] The findings also serve as a baseline for evaluating the quality and extent of habitat that could be restored and maintained with a dedicated supply of water and a program for managing that water. [*Appendix B details the methods used in this study*.]

To conduct its inventory, the research team used satellite imagery, low-level aerial videography, and ground surveys to map channels and plant life. [*See Figure 5*.] The main (navigable) course of the river was found by exploring its channels in a small boat during floods. The team also surveyed the marshlands supported by agricultural drain water. They assessed the relative potential and importance of restoring and managing wetlands in the delta, basing its assessment on habitat values, degree of environmental threat, and the importance of each area to local people who use the wetland resources and may be willing to help protect them.[30] The results of this fieldwork are summarized below, followed by a number of restoration objectives.

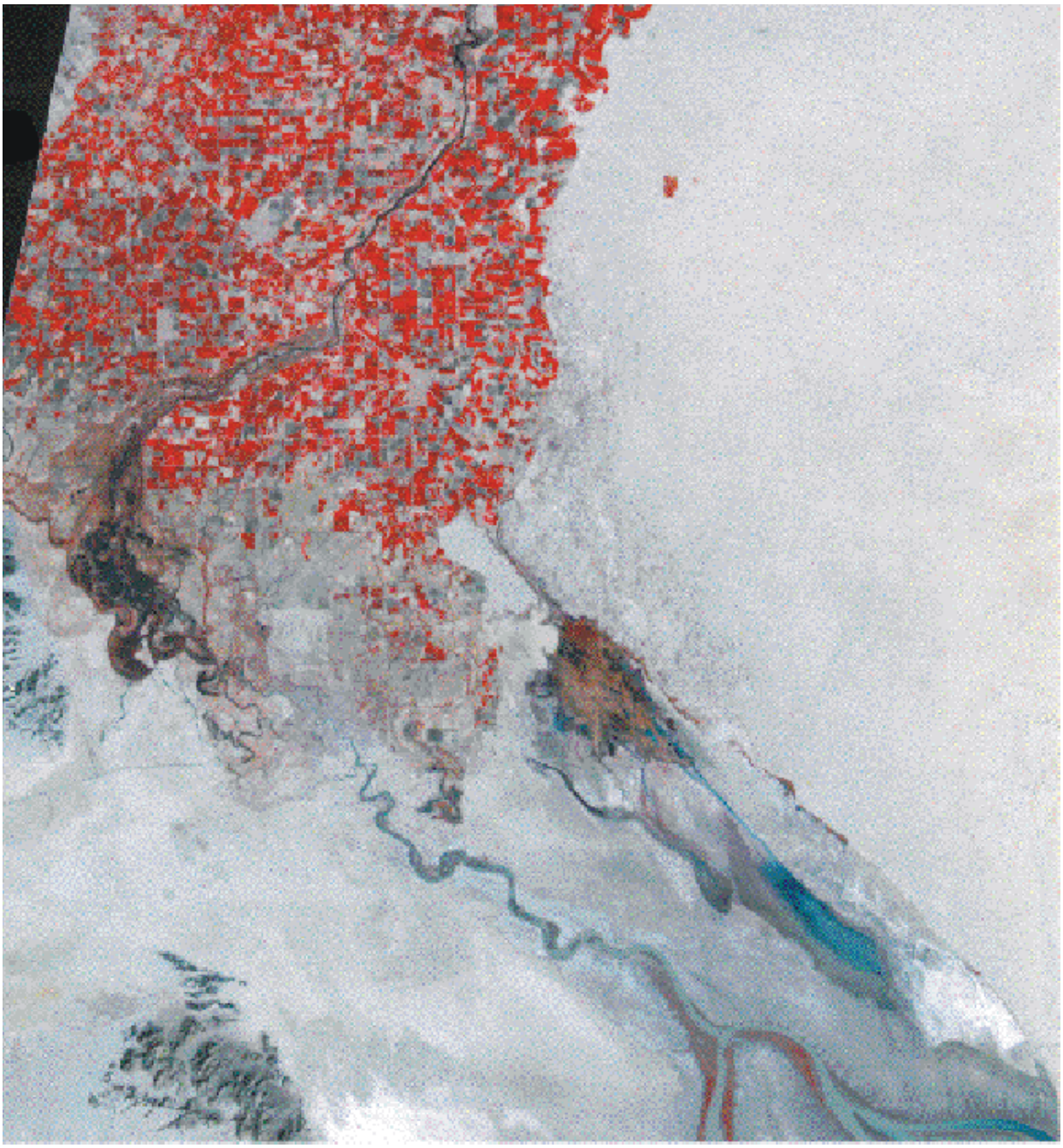
[27] Data correlating shrimp landings at San Felipe, Baja California, the nearest shrimping station to the delta, with discharges from the Colorado River to the northern Gulf of California show a significant correlation since the resumption of flows (Galindo-Bect et al.).

[28] Previous research has inventoried the extent and habitat values of the Ciénega de Santa Clara wetland in the southeast portion of the delta and the wetlands of the Rio Hardy/Rio Colorado confluence. See Glenn et al., 1992, and Glenn et al., 1996.

[29] Conservation efforts on the Colorado River are discussed in Chapter 1.

[30] These scientific findings are in manuscript, and will be published (Valdés-Casillas et al., 1998c), and are presented in a report the North American Wetland Conservation Council prepared by scientists from ITESM and others (Valdés-Casillas et al., 1998a).

Figure 5. Satellite Image of the Colorado River Delta, July 15, 1997
(Valdés-Casillas et al., 1998a)



The colors in this Landsat image reflect sensitivity to heat (red depicts vegetation).

Flood Flows and Water Requirements of Delta Vegetation

Water deliveries below Morelos Dam since 1980 have been extremely variable in frequency and volume. Furthermore, knowledge of the vegetation is based on a single snapshot inspection in 1997. Hence, it is not possible to determine the vegetation response to a particular flow regime without further study. However, inspection of the vegetation that exists in the delta now and the recent flow history allows some inferences about the water requirements.

Since 1980, there have been two prolonged periods without flow: a four–year period from 1988 to 1993, and a three-year period from 1994 to 1997. However, the 1997 inspection showed cottonwood and willow trees dating back to both the 1980's and 1993 flow events. It appears that germination correlates with flood flows. It also appears that annual flood events are not necessary for survival of the native tree species. They are capable of surviving at least three-to-four-year intervals between major flow events in the delta floodplain. It is not clear whether their survival depends on local agricultural return flows or other sources that may recharge the riparian zone during periods in which water does not flow from the United States. Apparently, delta riparian vegetation can survive a period of several years without water deliveries from the United States, once flood flows have allowed the seeds to germinate.

The vegetation analysis (*see Delta Wetlands and Riparian Vegetation below*) was based on a satellite image from July 1997, plus field inspections. The analysis was conducted following flood releases in January–April 1997 of approximately 260,000 acre-feet (3.2×10^8 m^3) of water at flow rates from approximately 3500 to 7000 ft^3 per second (100 to 200 m^3 per second) below Morelos Dam. A February 21, 1997, satellite image, plus low-level aerial and ground surveys during February flows, showed that the 1997 winter flood was sufficient to cause overbank flooding of the Colorado River channels throughout the floodplain between the levees. In addition, this flood produced runoff from the floodplain into the Gulf of California and Laguna Salada, a dry depression in the delta. During these flows, ocean salinity was diluted to less than half the salinity of seawater at the northern tip of Montague Island. It appears that flow rates of 3500 to 7000 ft^3 per second (100 to 200 m^3 per second) are sufficient to inundate the floodplain. In addition, annual volume releases totaling 260,000 acre-feet (3.2×10^8 m^3) in winter and spring are sufficient to produce a vegetation response in summer. The extent to which the July 1997 vegetation response was due to early 1997 water releases, and how much might have occurred without flooding, is not known. However, copious emergence of seedlings following the floods was observed, so it is possible to conclude that this volume of water was sufficient to support the existing vegetation and stimulate new growth along the floodplain.

The entire floodplain between the levees is 150,000 acres (60,000 ha), of which about 25 percent supported high-density vegetation in July 1997. Potential evapotranspiration by wetland and riparian vegetation in the floodplain is as high as 8 feet (2.5 m) per year. The high-density vegetation, which consists mainly of cottonwood, willow, mesquite, salt cedar and cattail, can use approximately 304,000 acre-feet (3.75×10^8 m^3) of water per year. This is greater than the flows recorded during January through April 1997. The 1997 vegetation response may indicate that the floodplain is recharged by local aquifers in addition to river flows from the United States.

Based on these observations, it is apparent that irregular flows since 1980 have contributed to revegetation of the floodplain despite three-to-four-year intervals of no cross-border flows. The flood releases from Lake Mead by the Bureau of Reclamation[31] produce sufficient flows to inundate the remaining floodplain area in the delta and produce a vegetation response the following summer.

Preliminary observations suggest that large, continuous flows of water in the river are not necessary to support the remaining delta riparian habitats. Conservation and restoration goals might be achieved through two assurances: 1) that when surpluses (as defined by the current capacity for use) arise in the Colorado River system, they will be delivered as flood flows to the delta; and 2) that agricultural waste flows will continue to be conveyed there.

[31] The Bureau of Reclamation terms these floods "Stage 1 and Stage 2 space-building releases."

Delta Wetlands and Riparian Vegetation

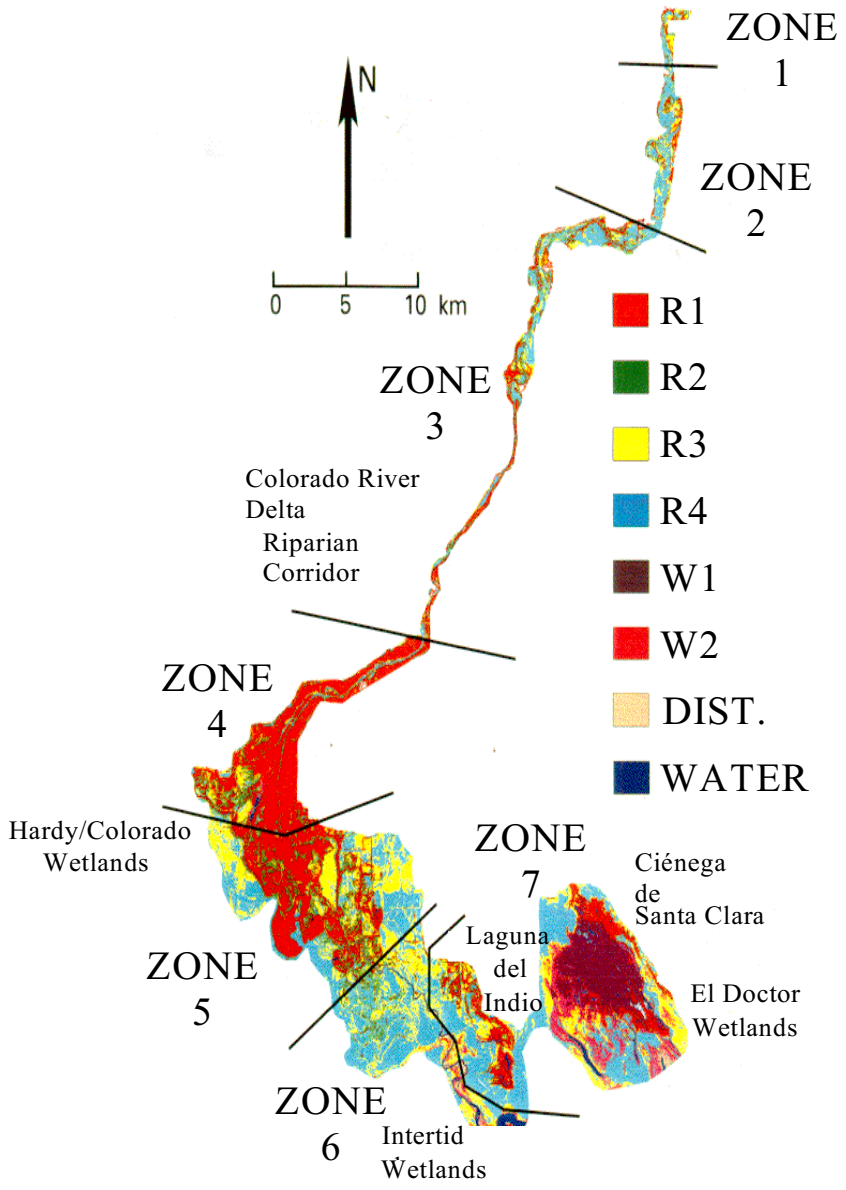
South of the international border, the Colorado River's riparian zone narrows as it passes through a system of earthen levees built to protect irrigated agriculture from floods.[32] The Rio Hardy also is channeled, and at their confluence, the combined Colorado and Hardy rivers widen once again. Downstream the river divides into numerous subsidiary channels, which then recombine into a single channel before reaching the sea.

Plant cover in the floodplain varies in intensity, species composition, and habitat value according to its position in the floodplain. In this study, researchers divided the floodplain into seven zones based on the dominant plant species associations identified through ground surveys. [*See Figure 6.*] The intensity of biomass (land cover) was determined by spectral analyses of satellite images with the number 1 referring to the highest intensity and the number 4 referring to the lowest intensity. (For example, R1 refers to riparian vegetation with high biomass

Photo 5. Cottonwood trees and willows in the Colorado River riparian corridor

[32] Unless otherwise noted, the findings in this section are summarized from a report by Carlos Valdés-Casillas and others (1998c) that has not yet been published.

Figure 6. Vegetation Zones of the Colorado River Delta
(Valdés-Casillas et al., 1998a)



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

intensity; W1 refers to wetland vegetation with high biomass intensity.) [*See Table 1 and Box 3*.]

Generally, the team found three types of wetland ecosystem in the study area:

1) riparian deciduous forest and woodland in areas subject to periodic river flooding (Zones 1–5) dominated by the mesophytic cottonwood and willow trees in the north (Zones 1–3), and by the phreatophyte tamarisk and other salt-tolerant shrubs as the river approached the tidal zone to the south (Zones 4 & 5).

2) maritime, submergent mud flats dominated by the endemic Palmer's salt grass in the tidal portion of the river (Zone 6).

3) brackish marshlands dominated by cattails and other emergent hydrophytes in areas flooded with agricultural drainage water in the eastern side of the delta (Zone 7).

Dense gallery forests of cottonwood and willow in the northeastern delta (Zones 1–3) are considered among the most valuable habitat types in the lower Colorado River region (Ohmart et al., 1988). These trees have prevailed through droughts and intense floods.[33] Above

Photo 6. Dry mudflats in the Colorado River delta.

[33] Zone 1 is notable for its dense willow stands, which are now so rare they are no longer listed as a habitat class along the river above Morelos Dam. Zones 2 and 3 contain approximately 3700 acres (1500 ha) of cottonwood and willow gallery forest, while only 250 acres (100 ha) of gallery forest remain on the United States' stretch of river.

Morelos Dam, these native trees are rarely dominant. Only about 250 acres (100 ha) of cottonwood-willow forests remain in the Colorado's floodplain in the United States. The Rio Hardy/Rio Colorado complex (Zones 1–5) provides critical habitat for wildlife [*see Appendix A*].

Zones 4 and 5, the Rio Hardy/Rio Colorado wetlands, are the largest brackish wetland in the delta (23,719 acres [9600 ha]). At the turn of the century, this area was described as a gallery forest of cottonwoods and willow, transitioning to a tidal plain of salt grass and other halophytes interspersed with screw bean and mesquite trees (Glenn et al., 1996). By 1977, with the elimination of freshwater flows and their replacement with brackish irrigation return flows, the gallery forest was gone and salt-tolerant plants dominated the vegetation.

The Rio Hardy/Rio Colorado wetlands have undergone significant changes in the last several decades. From 1947 to 1983, the wetlands covered approximately 45,000 acres (18,000 ha) and were sustained by geothermal springs and agricultural wastewater that backed up behind a natural sand dam in the channel. Floods in 1983 increased the size of the wetlands to 156,000 acres (63,000 ha) but finally broke through the dam, and the wetlands shrunk nearly in half to 79,000 acres (32,000 ha). In 1986, Mexico began to improve flood control systems in the Mexicali Valley, building up the levees along the main Colorado and creating drainage canals. These improvements further reduced the wetlands to only 2900 acres (1175 ha) of scattered marshlands. Floods on the Gila River in 1992 restored part of the northern portion of the wetlands, but only temporarily.

Zone 7 (which includes la Ciénega de Santa Clara) is separate from the main channel of the Colorado, and its wetlands are fed mostly by agricultural drainage from the MODE and Riito canals and small artesian springs. Overall, Zone 7 contains 14,350 acres (5808 ha) of emergent, hydrophytic vegetation and 5620 acres (2274 ha) of R1 vegetation. The W1 vegetation consists mainly of dense cattail stands, while the W2 vegetation consists of sparse stands of cattail, bulrushes, and Palmer's salt grass on the salt-marsh fringes. A large area occupied by the low-intensity R3 and R4 land-cover classes consists mainly of stunted tamarisk and iodine bush that have colonized large flats of wet, saline soil in the supralittoral zone. Zone 7 also contains 932 acres (377 ha) of Palmer's salt grass in the tidal area below la Ciénega de Santa Clara, which received both agricultural drain water exiting the marsh and tidewater entering from the Gulf of California.

Based on this fieldwork, researchers believe that the delta can potentially support 68,000 resident and 49,000 nonresident summer birds in the R1 vegetation of Zones 1 to 5.[34] In the United States, the entire Colorado River is estimated to support fewer than half as many birds (Ohmart et al., 1988). Because the research team did not include other delta habitat classes, this estimate of the delta's capacity to support bird life is almost certainly an underestimate.[35] At 150,000 acres (60,000 ha), the Colorado's vegetated floodplain in Mexico is nearly twice the size of the river's vegetated floodplain in the United States (84,000 acres [34,096 ha]) (Balogh, 1996).

[34] This calculation is based on the work of Anderson and Ohmart (1986).

[35] The comparison between river reaches in the United States and Mexico is made to emphasize the importance of the delta region to the overall lower Colorado River ecosystem.

Photo 7. Gulls over the delta

BOX 3. Vegetation of the Colorado River Delta
[*See Table 1 for vegetation data.*]

Zone 1: Riparian Zone South of Border

Zone 1 extends about six miles south of Morelos Dam at the international border. The vegetated area is narrow, covering 68 percent of the floodplain and totaling 420 acres (170 ha). This riparian area is dominated by dense thickets of willow, most of which are shorter than 13 feet (4 m), with older plants reaching 25 to 50 feet (7 to 15 m). Although cottonwood trees are also found, they appear only as isolated individuals. Plants are predominantly midstory in height (2 to 15 feet [0.6 to 4.6 m]) with relatively little over- or understory vegetation. The floodplain not covered by willow is bare soil or is covered by scrub vegetation dominated by tamarisk and arrowweed. These dense willow stands are a notable feature of Zone 1 because they are now so rare elsewhere along the Colorado River. Willow stands are no longer even listed as a habitat class above Morelos Dam (in the United States).

Zone 2: Riparian Corridor

The riparian corridor as it widens and extends farther south into the delta is designated Zone 2. Much of the land in this zone is subject to inundation when the river is flowing, and much of it is bare flats when the channels are dry. Cottonwood and willow line the sides of the channels and cover many of the islands. On higher ground, mesquite shrublands are common. Closed gallery forests of cottonwood cover 613 acres (248 ha) and are classed as R1 (high-density riparian). Zone 2 is notable for the diverse range of heights among its shrubs and trees, particularly compared to Zone 1. Midstory and under-story vegetation in the R2 to R4 classes include tamarisk and willow (midstory) and tamarisk and arrowweed (understory). This creates a wider variety of habitats than Zone 1.

Zone 3: Colorado River Delta Riparian Corridor

The composition and general diversity of Zone 3 is very similar to that of Zone 2 but with a much higher proportion of R1 vegetation. Here it covers 3044 acres (1232 ha) or 25 percent of the floodplain. Again, this R1 vegetation is dominated by cottonwood, with mid- and understory zones dominated by willow and tamarisk.[36] Cottonwood and willow appear to regenerate well in many areas of Zone 3. In some sections, carpets of seedlings of these species dominate the near-channel areas, giving way to progressively older stands of trees in slightly more elevated areas. Seed germination, observed in July 1997 and March 1998, is presumed to be a result of the 1997 flood releases. The presence of trees in a range of ages shows that sporadic flood releases have produced conditions that support regeneration and long-term survival of these native riparian species. The largest trees were up to 50 feet (15 m) tall. Zone 3 would be expected to support twice the density of resident summer birds as Zones 1 and 2, due to its vertical complexity (the variety of shrub and tree heights).

[36] R1 vegetation is classified as open gallery forest.

Zone 4: Rio Colorado/Rio Hardy Confluence and Wetlands

As the Rio Colorado and Rio Hardy converge, the floodplain widens and the river divides into numerous channels, oxbows, backwaters, and ponds. The research teams were able to inspect only a small portion of this zone on the ground, due to the difficult access. Numerous pockets of cottonwood and willow line the main river channels, but they are found in smaller proportion to other R1 vegetation. Here R1 vegetation is more mixed. Over 70 percent of this zone is dominated by a mix of tamarisk, mesquite, and many large quail bush that also grow in nearly homogeneous stands on terraces removed from the main river channels.

Zone 5: Rio Hardy/Rio Colorado Wetlands

Here the delta widens significantly—to 12 miles (19 km) in some areas—and the dominant plant association is a near monoculture of dense tamarisk thickets. Overall, mesophytes tend to give way to wetland species in Zone 5. Areas with less plant density tend to be populated by widely spaced and stunted tamarisk (three feet [1 m] in height) mixed with the succulent halophyte iodine bush growing segregated in stands separated by patches of bare soil often covered by a salt crust. Tidal flows and agricultural drain water maintain a perennial supply of water to many areas of Zone 5 (Payne et al., 1992). Cattail, common reed, and other emergent hydrophytes grow along the riverbanks.

Zone 6: Intertidal Zone

This final 12 miles (19 km) of river is strongly affected by tides that commonly rise and fall more than 15 feet (4.5 m). During the fieldwork, unusually high river flows (7000 cfs [202 m^3 sec-1]) diluted the salinity of ocean water in the tidal zone. At low tide the freshwater zone reached as close as 6 miles (9.7 km) to the mouth of the river. Ocean water at the northern end of Montague Island was diluted from normal sea salinity of 35 parts per thousand (ppt) to 20. The tidal zone supports 1092 acres (442 ha) of Palmer's salt grass. This important species is the only indigenous grass of the Sonoran Desert, and the Cucapá people harvested its grain (Williams, 1983).

Zone 7: La Ciénega de Santa Clara/El Indio

Wetlands along the southeast margin of the delta include la Ciénega de Santa Clara [*See Box 2*], and El Indio and El Doctor wetlands. These marshes fall within the boundary of the international Biosphere Reserve. La Ciénega de Santa Clara is now supported by annual flows of 130,000 acre-feet (1.6×10^8 m^3) of agricultural wastewater from Arizona's Welton-Mohawk district carried by the MODE canal. Its 10,400 acres (4200 ha) of brackish wetland support dense, cattail-dominated, hydrophytic vegetation. In all, there are 22 wetland plants species in la Ciénega de Santa Clara and along its edges, including Palmer's salt grass. El Indio, a smaller wetland (about 4700 acres [1900 ha]) to the southwest, is supported by agricultural return flows from farms nearby in San Luis Rio Colorado. Tamarisk dominates its vegetation, with pockets of cattail and other hydrophytes in flooded areas. El Doctor wetlands (about 4700 acres [750 ha]) are fed by natural springs and support 22 wetland and riparian plant species, including an overstory of mesquite trees (classified as R1 land cover in this study) (Zengel et al., 1995).

Table 1. 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; numbers after cover class refer to biomass intensity where 1 is highest and 4 is lowest. Estimates of bird diversity and density were based on the vertical vegetation structure and species composition using methods developed for lower Colorado River riparian ecosystems.

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
Distichlis 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 Species (>4.5 m)*	Sg	Pf/Sg	Pf/Sg	Tr/Pf/Sg	Tr	None	None	
Principal Midstory Species (0.6-4.5 m)*	Pa	Sg/Tr	Tr/Bs	Bs/Pspp/Al	Tr	Tr	Td/Tr	
Principal Understory Species (<0.6 m)*	None	Ps	Ps/Pf	Ps/Al	Ao	Dp/Ao	Numerous	
Vertical Structure	III	I	II	III	IV			
Avifauna Habitat Value:								
Estimated diversity of key summer birds								
Resident	9 of 9	7 of 9	8 of 9	9 of 9	9 of 9	NA	NA	
Nonresident	9 of 9	8 of 9	8 of 9	8 of 9	6 of 9	NA	NA	
Estimated density of summer birds per 40 ha								
Resident	279	140	432	224	159	NA	NA	
Nonresident	163	132	198	150	143	NA	NA	

*Sg=*Salix goodingii*; Pf=*Populus fremontii*; Tr=*Tamarixramosissima*; Bg=*Baccharis salicifolia;* Pspp=*Prosopis spp.*; Al=*Atriplex lentiformis*; Td=*Typha domengensis;* Ao=*Allenrolfia occidentalis*; Dp=*Distichlis palmerii*

In summary, the delta's wetlands and riparian zone currently cover 150,000 acres (60,000 ha). A quarter of this is high biomass, woody riparian vegetation, and 16,000 acres (6500 ha) is emergent marshland dominated by cattail and other hydrophytes. Most of the remaining area is more sparsely vegetated by scrub associations such as tamarisk, arrowweed, and halophyte shrubs. Approximately 2200 acres (900 ha) of salt flats in the tidal portion of the river are covered by Palmer's salt grass, a grass endemic to the northern Gulf of California. The woody riparian vegetation is dominated by the native cottonwoods and willow in the northern part of the riparian zone, but by the more salt-tolerant tamarisk, a nonnative, in the southern part of the delta as the river approaches the tidal zone. The riparian zone of the Colorado River in Mexico has larger areas of native riparian forest and marsh habitats than the upstream stretch in the United States. Based on projections from other studies on the lower Colorado River, delta riparian vegetation can potentially support 120,000 migratory and resident summer birds. Marsh habitat supports several endangered avian and fish species. These observations point to the high ecological value of the Colorado River delta.

THREATS TO DELTA HABITATS

The principal threats to delta habitats are insufficient and unreliable water supplies and their relatively poor water quality. Satellite and aerial photography indicates that most of the present delta vegetation has been restored and maintained by flood releases over the last 20 years (Glenn et al., 1996). A 1972 series of aerial photographs showed that most of the riparian zone was bare soil and sparse mesquite trees. A satellite image taken in May 1992 after four years without flow in the river showed high-density vegetation in Zones 1 to 5 confined to the edges of the river channels. Increased salinity due to tidal flows had allowed tamarisk to invade.

By contrast, after flood releases in 1997 and early 1998, high-intensity riparian vegetation (R1) occupied approximately 30 percent of the floodplain, with evidence of widespread seed germination of native trees as well as tamarisk. Data for 1997 and 1998 also show that peak flows of 3500–7000 cfs (100–200 m^3/s) are sufficient to inundate nearly the entire floodplain between the levee system below Morelos Dam, and to dilute significantly the salinity of ocean water in the tidal zone. In the absence of such flooding, the marine influence extends 34 miles (56 km) upriver from the mouth (Payne et al., 1992). Thus, it appears that the reestablishment of native forest species in Zones 1 to 3 has been a direct consequence of the return of overbank flooding below Morelos Dam since the filling of Lake Powell.

Several potential changes could effect the precarious health of the delta. Reductions in water supplies available to the delta could occur under several scenarios. Additional storage and diversion projects in the basin (e.g., the Animas-La Plata in Colorado) are still under consideration. Were such projects built, they could virtually eliminate the kind of flows that have been found to support the regeneration of native trees in the delta. Similarly, a proposal by California to change the criteria used by the Bureau of Reclamation to define periods of surplus and shortage would trigger greater releases for consumptive use and increase the frequency of periods without flood releases. Finally, if the Yuma desalting plant comes on line, it will have devastating consequences for la Ciénega de Santa Clara, which will receive the plant's concentrated brine waste (Glenn et al., 1992). [*See Box 4.*]

Water quality threats to the delta include high concentrations of selenium in the Rio Hardy/Rio Colorado wetlands and la Ciénega de Santa Clara,[37] and high salinity. Selenium is present throughout the lower Colorado River watershed as a naturally occurring trace element that is harmless in low concentrations but can be toxic to fish and wildlife at higher concentrations as it accumulates in the food chain (Presser, 1994; Presser et al., 1994; Ohlendorf, 1986). It often is found in soils in arid and semiarid climates, particularly in ancient seabeds. Selenium is dissolved by irrigation water, and then evaporation can increase its concentration in both water and sediments. In the lower Colorado, selenium levels are highest in oxbow lakes and backwaters

[37] Water sampling and analysis was carried out at 19 sites along the Rio Hardy/Rio Colorado wetlands in July and August 1998, and at 10 sites in la Ciénega de Santa Clara in 1996 and 1997. The sampling and analysis followed EPA and Arizona Department of Environmental Quality procedures. The results for the Rio Hardy/Rio Colorado are summarized in "Information Database and Local Outreach Program for the Restoration of the Hardy River Wetlands, Lower Colorado River Delta, Baja California and Sonora Mexico" (Valdés-Casillas et al., 1998a). The results of research on water quality in the Ciénega are summarized in "Bioaccumulation of Selenium in the Ciénega de Santa Clara. Colorado River Delta. Sonora, Mexico." (Garcia-Hernandez, 1998).

(Valdés-Casillas et al., 1998a). The highest concentrations in the delta are found in the Rio Hardy, in the Colorado River downstream of the Rio Hardy confluence, in evaporative basins, and in agricultural drains in Zone 4 (Valdés-Casillas et al., 1998a). Delta selenium levels have been found to be 1.8 to 14.2 times the U.S. EPA limit of 5 micrograms per liter (ug/l) for freshwater aquatic life. Levels also exceed the Mexican limit of 8 ug/l. Agricultural return flows in the Mexicali Valley appear to be the biggest contributor to delta selenium levels. Because selenium bioaccumulates in the food chain, high concentrations of selenium underscore the need for further sampling and analysis to determine selenium levels in a range of delta species (Garcia-Hernandez, 1998).

Research in la Ciénega de Santa Clara (Zone 7) in 1996 and 1997 found that selenium concentrations in drain water entering the marsh are 2.5 times higher than those in water at Imperial Dam in the United States. At the southern end of the wetland, concentrations range from 5 to 19 micrograms per liter. Samples of sediments, plants, and fish showed concentrations not considered hazardous for wildlife or humans.[38] However, further deterioration of water quality could lead to higher levels of selenium in fish and wildlife, and additional monitoring of la Ciénega is warranted.

Salinity concentrations in delta wetlands have been monitored in various biological surveys, often in conjunction with monitoring of other contaminants. Most of this work has focused on la Ciénega de Santa Clara (Valdés-Casillas et al., 1998a). Salinity sampling in the Rio Hardy/Rio Colorado wetlands was conducted in July, August, and November 1997. The results show that salinity is highest in areas that receive agricultural drain water (the Hardy and Pescaderos rivers) and in areas influenced by tidal flows. As salinity has increased, so has tamarisk, which has become dominant in delta riparian areas. While flood flows have allowed some native species to regain a toehold, tamarisk is extremely competitive and, with its deep roots, a great consumer of water.

[38] Results showed selenium concentrations of 0.8–1.8ug/l in sediments, 0.03–1.17 ug/l in plants and 2.5–6.4 ug/l in fish (Garcia-Hernandez, 1998).

BOX 4. A Related Issue: The Yuma Desalting Plant

The Yuma Desalting Plant is a $260 million water treatment plant built by the U.S. Bureau of Reclamation (BOR) in Yuma, Arizona, about 20 miles (32 km) from the international border. Authorized by the Colorado River Basin Salinity Control Act (CRBSCA) of 1974, the plant was built to treat agricultural drainage from the Wellton-Mohawk Irrigation District in Arizona. Under the original plan, this treated water would be delivered to Mexico as part of its water right. This right is defined in a 1944 treaty, and subsequently amended with Minute 242, which defines maximum salinity levels for U.S. water deliveries to Mexico.

The CRBSCA also authorized construction of the Main Outlet Drain Extension canal (MODE) to carry the Wellton-Mohawk drainage flows into Mexico while the plant was under construction (Pontius, 1997). Since its completion in 1977, MODE has carried about 130,000 acre-feet (1.6×10^8 m^3) of wastewater per year. This water is dumped into the large wetlands named la Ciénega de Santa Clara, in the heart of the Biosphere Reserve of the Upper Gulf of California and Colorado River Delta, which has actually benefited from this wastewater that is too salty to meet delivery requirements to Mexico. To meet U.S. water delivery obligations to Mexico that cannot be fulfilled by the wastewater in the MODE, the U.S. Bureau of Reclamation has lined 49 miles of the Coachella Canal in California. This has reduced leakage from the Coachella Canal, conserving the 130,000 acre-feet of water. Significantly, under the CRBSCA (Section 102), the U.S. obtained only a temporary right to the water saved by lining the Coachella Canal. The "interim period" allowing for the bypass of Wellton-Mohawk water to the MODE will expire if and when there is not enough water to meet California's demands, including demands for surplus water (Pontius, 1997).

The Yuma Desalting Plant was completed in 1992, and has never been operated. At an operating cost of $1.5 million annually, it stands in "ready-reserve" status. Before BOR can begin using it, the agency will need to complete an Environmental Impact Statement. At full capacity, the plant is designed to produce 68,000 acre-feet (8.4×10^7 m^3) of treated water per year. The cost of the water will depend on whether the plant operates at full capacity and how capital costs are recovered, but estimates place operating costs between $370 and more than $600 per acre-foot (McAleese, 1999). BOR is analyzing options for operating the plant and exploring possible markets, including California and the Middle East via supertanker. The City of Yuma has the right of first refusal on the water.

A decision to operate the Yuma Desalting Plant and divert Wellton-Mohawk drain water from MODE could have disastrous consequences for la Ciénega de Santa Clara. The reduction in inflow would shrink the wetland by 40 percent, affecting both wildlife populations and the residents of the nearby Johnson *ejido*. If water is diverted from this important wetland in the core zone of the Biosphere Reserve, a substitute source of water must be found.

Salinity also may have a profound influence on a keystone species of the northern gulf. Shrimp populations are believed to increase with flood flows from the delta. Researchers have demonstrated a positive correlation between freshwater discharges to the Gulf of Mexico and shrimp catches (Galindo-Bect et al.). Shrimp in the northern Gulf take a year to reach harvest size, and since 1981 the size of the northern Gulf shrimp catch has corresponded with freshwater flows of the previous year (Glenn et al., 1998). Research indicates that 25 percent of the variability of the shrimp catch is attributable to river flows (Galindo-Bect et al.). Before dam building, Colorado River floods may have affected salinity across a wide area of the upper Gulf. Recent flood events have affected salinity at the mouth of the river near Montague and Pelicano islands.[39] In January 1998, freshwater flows of 7135 cfs (202 m^3/s) were found to have diluted ocean water at the northern end of Montague Island to a salinity of 20 parts per thousand (ppt). Further research is needed to quantify the relationship between freshwater flows and Gulf near-shore marine species.

RESTORATION OBJECTIVES

The flows of 1997 helped restore vegetation to the delta, and the research team considered this a major change in the habitat value and health of the delta. It demonstrates the resilience of delta ecosystems and offers hope for the future. It also is worth noting that even in its diminished state, the delta has richer and more diverse ecosystems than the Colorado River between the Grand Canyon and Morelos Dam, a stretch of river five times greater in length and with a perennial flow of water (Balogh, 1996).[40]

The 1997 fieldwork suggests that modest annual flows (below Morelos Dam) of 32,000 acre-feet (4×10^7 m^3) could maintain and even improve the cottonwood-willow habitat in Zones 1 to 3. Further, pulse flows on a par with January to April 1997 releases, which are likely to occur on average every four years under the present Colorado River management regime, could sustain an area that includes Zones 4 and 5 as well. The 1997 winter flood totaled 260,000 acre-feet (3.2×10^8 m^3), which was discharged at 3500–7000 cfs (100–200 m^3/s), a rate sufficient to inundate the delta's floodplain. This flow regime (that is, 260,000 af every four years) represents less than 1 percent of the Colorado's average annual flow. Due to the resilience of the delta's native riparian vegetation, the most important ecosystem functions can likely be supported by only a fraction of the historic flows, much of which could be derived from resourceful use of agricultural wastewater. However, due to sustained flood flows during 1998 and 1999, it is not yet possible to quantify with certainty the required volume and frequency of these floods. In addition, freshwater flow needs of delta fisheries and Gulf near-shore marine species have not been quantified, and should be considered as the delta's water needs are determined.

The importance of the timing of flood releases is not yet known. Although the Colorado's predevelopment flow regime would flood the delta after spring snowmelt (April–July) and again during monsoons (August), the 1997 flood occurred in late winter (January–April). These floods were successful in stimulating vegetation, and one factor may be the mild climate in the delta.

Water quality problems in some riparian wetlands will require mitigation, if only to protect humans who come into contact with the water or eat the local wildlife and fish. Continued monitoring of water quality in Zones 4, 5, and 7 should be designed to identify the need for periodic flushing flows or the procurement of alternative water sources. Specific recommendations for improving the management of water supplies and water quality are provided in the final chapter.

Understanding its ecological needs is an important component of preserving the delta, but good science alone will not suffice. The greatest threat to the health of the delta may be the absence of any formal provisions between Mexico and the United States recognizing the ecological values in the delta and providing water to support them as part of the overall apportionment of Colorado water. Resource and environmental management agencies in the United States tend toward the position that their responsibility for ecosystem protection ends at the international border. The challenge is not only one of water management, but also one of mustering the political will and cooperation to manage the delta as a transnational resource. The following chapter discusses the numerous institutions that must be considered during the process of policy reform, as well as several related issues that may provide strategic opportunities to improve conditions in the delta.

[39] During flood events, the salinity of the Colorado River, upstream of the confluence with the Rio Hardy, was low (average of 0.61 ppt) compared to salinity in the Colorado River at Imperial Dam in the U.S. (average 0.865 ppt) and at Morelos Dam (average 1.01 ppt).

[40] The stretch above Morelos Dam contains 82,500 acres (33,400 ha) of vegetation, compared to 150,000 acres (60,000 ha) in the delta.

4 POLITICAL LANDSCAPE

The old ideas continue to rule most of western water. But reform will come. There are too many physical, economic, and social imperatives for vested interests to hold the existing structure in place indefinitely.

—Charles F. Wilkinson, The Eagle Bird: Mapping a New West, 1992

VALUES OF THE COLORADO RIVER DELTA

A century of development in the Colorado River basin has degraded the delta, yet, as documented throughout this report, its vestigial wetland and riparian ecosystems remain ecologically, economically, and socially important. Delta ecosystems harbor migratory shorebirds traveling along the Pacific Flyway; serve as a breeding ground for marine species in the Gulf of California; provide habitat for a number of endangered species; improve the quality of water that flows in from various sources and out to the Gulf; deliver a steady flow of fresh water to near-shore marine (brackish) environments in the Gulf, improving breeding and nursery grounds for the endangered vaquita; and produce vegetation important to indigenous peoples (Glenn et al., 1992 and 1999). In addition to these environmental services, the delta historically has been a source of income for surrounding communities, supporting lucrative fisheries. Although local communities no longer rely as extensively on fishing for income due to the recent decline of shrimp, totoaba, and other traditional harvests, some have generated income by working as guides for visitors who wish to hunt and fish. Interest in ecotourism as a sustainable use of delta wetlands is growing (Valdés-Casillas et al., 1998a). Finally, the delta's social value cannot be overlooked. The social fabric of many small communities, *ejidos,* and Cucapá settlements in the delta region would disintegrate with the collapse of delta ecosystems (Williams, 1983; Valdés-Casillas et al., 1998a). The small delta communities will literally "dry up" if the wetlands disappear.

PRESERVATION STRATEGIES

As demonstrated by the analysis of flood flows and vegetation, preserving the delta's wetland habitats will require relatively modest, yet secure, supplies of good-quality water each year, as well as periodic, but assured, flushing flows. Partial recovery after recent floods demonstrates that delta ecosystems can be sustained even with limited water resources. Although more water would without doubt further improve the habitat, what is most critically required now is not *more* water, but water delivered on a reliable schedule. This would require a commitment from the U.S. (and the myriad stakeholders in the U.S.) to release flood waters at critical intervals to support the newly established habitats of the delta. Together with the monitoring and management of water quality, these releases could bring some delta ecosystems back to health.

One short-term strategy is to provide regular flood releases every few years to saturate riparian and wetland areas. This could be done with little or no impact on current water allocations. Effectively, this will require the managers of the Biosphere Reserve, working with research institutions, to determine the best flow regime for existing water to benefit delta wetlands. Once established, this plan for optimum flows could be used by the Mexican federal government to develop a strategy to achieve them based on recent hydrologic data. Finally, implementation of any such plan would require coordination among the many agencies and authorities with a stake in management of these resources. For the long term, delta ecosystems may require the allocation of additional water supplies secured through negotiations and cooperative management agreements among governments and water users in the United States and Mexico.

The apparent simplicity of maintaining present flows is false: securing these flows will not be easy. Allocation of water in the Colorado River has a long and contentious history. A long-term solution will involve binational institutions, nine states in two nations, dozens of tribes, and innumerable stakeholders, and may necessitate changes to the treaty. Ultimately, the best preservation strategy will treat the delta and the

river upstream as one ecological whole, overcoming the obstacles presented by an international boundary. The delta is part of a regional ecosystem that includes the remaining wetland and riparian ecosystems described in this report, as well as the Salton Sea (*see below*), and the New and Alamo rivers, and connecting wildlife corridors in the United States and Mexico. Any management plan for the delta and lower Colorado River ecosystem must take into account the effects on components of the larger ecosystem as well.

The growing interest in preserving delta ecosystems on both sides of the border may offer a window of opportunity. In the past few years, representatives of universities, government agencies, and environmental groups have met in cities along the border (Mexicali, San Luis Rio Colorado, El Paso, Tucson, and Yuma) to discuss preservation of the delta. New opportunities for funding, research collaboration, and even international agreements, stemming from bi- and trinational environmental organizations have been established in the wake of the North American Free Trade Agreement.

The opportunity to design and implement preservation strategies for the delta is also enhanced by the current status of water development and use in the Colorado River basin. At present, mainstem reservoirs are full. The era of building dams on the Colorado is over, and there will be little, if any, additional storage on the river. Upper basin states (Wyoming, Colorado, New Mexico, and Utah) do not presently use their full entitlement of Colorado River water, and, with the exception of Colorado, it is not likely that they will in the next several decades. Existing storage capacity, combined with unused entitlements in the upper basin (some or all of which may be freed up with the implementation of conservation measures such as California's 4.4 plan [*see below*]) mean that water will continue to flow in the river and into the delta.[41] In other words, the time may be right. In this climate of opportunity and interest, there may be sufficient political will to secure the delta's future.

AGENTS OF CHANGE

The list of numerous agencies with some jurisdictional authority over the delta, Colorado River water, and border-related environmental issues, is daunting. Successful, long-term preservation of the Colorado River delta will require cooperation between Mexico and the United States, among states and resource agencies, tribes, and the active involvement of nongovernmental organizations, communities, and citizens. While an exact course for institutional action is impossible to chart, this section offers brief descriptions of the myriad authorities that could be a part of the solution. In addition, it details several long-standing resource management issues that may offer these institutions (and others) strategic opportunities for improving management of the delta.

International Boundary and Water Commission

The only institution with binational authority over surface water resources in the border region is the International Boundary and Water Commission (IBWC), known as Comision Internacional de Limites y Aguas (CILA) in Mexico. Created in 1889,[42] the IBWC is charged with applying provisions of various boundary and water treaties. The scope of its work includes boundary maintenance, reclamation projects, allocation of transboundary water resources, construction and maintenance of sewage and sanitation works, and the resolution of treaty and water quality disputes (Meyers, 1967). Today, the IBWC's mission is to "provide environmentally sensitive, timely, and fiscally responsible boundary and water services along the United States and Mexico border in an atmosphere of binational cooperation and in a manner responsive to public concerns" (Valdés-Casillas et al., 1998a). In practice, the IBWC has limited its focus to problems of water supply and quality along the border, leaving issues of environmental protection to the jurisdiction of other Mexican and U.S. agencies.

[41] A severe, sustained drought would change these circumstances, but its eventuality should not constrain action at this time.

[42] The International Boundary Commission was formed in 1889, and renamed the IBWC following the United States–Mexican Water Treaty of 1944 (Mumme, 1996).

International Authorities

In 1983, the United States and Mexico negotiated the U.S.-Mexico Border Environmental Cooperation Agreement—commonly known as the La Paz Agreement—creating workgroups that bring together environmental authorities from both countries to address environmental issues in the border region.[43] These workgroups were reinvented as the Border XXI program under the Integrated Border Environmental Plan, created in 1992 and revised in 1996.[44] In addition to facilitating communication, Border XXI has funds to support research projects of priority to the Border XXI workgroups, and also serves as an important vehicle for public input into transboundary environmental management (Mumme, 1996).

Several international organizations were established with the 1993 signing of the North American Free Trade Agreement (NAFTA). The North American Commission for Environmental Cooperation (CEC) was created with a broad mandate to promote regional cooperation, prevent environmental disputes, and promote effective enforcement of environmental laws. The CEC facilitates cooperation between the three NAFTA nations (Mexico, Canada, and the U.S.A.)—specifically through exchange of information, promotion of scientific research, and access to information and public participation at a regional level—on priority projects of their environmental agencies. The CEC funds projects through the North American Fund for Environmental Cooperation (Mumme and Duncan, n.d.).

The Border Environmental Cooperation Commission (BECC) was established at the same time as, although not formally a component of, NAFTA or its related environmental side accord.[45] BECC is designed to promote and certify "environmental infrastructure" projects in the U.S.-Mexican border region, and while it neither develops nor manages the projects, it aids local communities (through technical assistance and coordination) in their efforts to improve environmental conditions. Under BECC guidelines, states, municipalities, NGOs, and other public or private entities are invited to design projects that meet local needs. BECC's aid to communities can include developing watersupply, waste- water-treatment, and solid-waste management infrastructure. Finally, BECC can certify these types of projects for loans from the North American Development Bank (NADBank)[46] or other financial agencies and institutions (Varady et al., 1996).

National Agencies

National agencies with programs in the border region include several U.S. agencies, including the U.S. Environmental Protection Agency (EPA) and Department of the Interior (DOI), and Mexico's Secretariat of the Environment, Natural Resources, and Fisheries (SEMARNAP). Through Border XXI, these agencies work together on the Natural Resources Workgroup to identify and address priority environmental needs in the border region. Participants focus on managing natural areas, promoting environmentally sound economic development, and improving education, training, law enforcement, and research (Mumme, 1996).

In Mexico, SEMARNAP has jurisdiction over environmental protection, natural resource management, and the management of marine resources, and it helps develop and implement the nation's Ecology Law (Mumme, 1996). SEMARNAP's National Institute of Ecology (INE) carries out environmental research and development, evaluates Mexico's environmental policies, and implements its natural resource programs. INE administers the National System of Protected Natural Areas and has responsibility for establishing and managing all natural areas, including the Biosphere Reserve, in the upper Gulf and delta.[47] The Biosphere Reserve has a management team that includes law enforcement, as well as staff for the research station in el Gulfo de Santa Clara. INE also oversees the System of Wildlife Management Units (SUMA), which establishes small wildlife refuges that can be managed for the economic benefit of local communities (Valdés-Casillas et al., 1998a).[48]

[43] The U.S.-Mexico Border Environmental Cooperation Agreement, known as the La Paz Agreement, created six binational workgroups to deal with border environmental issues of air, hazardous waste, water, pollution prevention, contingency planning, and emergency response (Mumme, 1996).

[44] Released in 1992, the IBEP identifies priority environmental issues in the border area and projects aimed at addressing those issues.

[45] The commission was conceived as a mechanism to win support for the trade pact among U.S. border states, the rationale being that environmental infrastructure improvements could mitigate any potential environmental degradation associated with NAFTA's promised economic development.

[46] NADBank acts as the lead bank in the financial packaging of BECC-certified border projects.
The bank was created to finance both environmental investments and NAFTA-related "community adjustment and investment."

[47] Other protected areas include national parks, national marine parks, areas for protection of vegetation and wildlife, and natural monuments.

[48] Land protected by regulation under SUMA includes public, private, and common holding (i.e., *ejido*) lands.

Also within SEMARNAP is the National Water Commission (CNA), which has nearly complete jurisdiction over water resources and planning in Mexico. CNA builds potable water, sanitation, wastewater-treatment, irrigation, drainage, and flood control systems. It administers Mexico's system of water rights and pumping permits, and shares (with INE) responsibility for the nation's water quality. CNA has recently attempted to decentralize its decision making by establishing local watershed councils. State and municipal governments have little local control over water resources (Mumme, 1996).[49]

In the U.S., myriad agencies have some jurisdiction over activities in, or impacting, the delta. Of these, the most influential include the U.S. Environmental Protection Agency, which regulates water quality, and is mandated to participate in international efforts such as Border XXI. Two U.S. Department of Interior agencies play critical roles. The U.S. Fish and Wildlife Service (FWS) administers the Endangered Species Act, and is mandated to review federal actions for adverse impacts to endangered species (Mumme, 1996). The Bureau of Reclamation (BOR) operates the dams on the Colorado River in the U.S., and is planning to conduct a needs assessment of the Colorado River delta in cooperation with Mexican agencies under the auspices of the IBWC (Johnson, 1999). The Lower Colorado Multi-Species Conservation Program (MSCP) was created by the FWS with lower basin states and water users to address endangered species concerns in the lower basin (Pontius, 1997). MSCP has been asked to consider impacts of management on the delta, but declined (Johnson, 1999).

Tribes, Basin States, and Local Communities

Beyond the federal governments, numerous authorities play a role in Colorado River management. Thirty-two tribes reside within the basin, and many have Colorado River water rights that date to the establishment of their reservations or to more recent court decisions. Together these tribes assert rights to more than 2 maf (2.5×10^9 m^3) of water[50], but little has been developed. Many tribes are looking for ways to secure economic benefits from their entitlements other than traditional water supply development. For example, the ten tribes of the Colorado River Tribal Partnership formed a coalition to secure, develop, and market their water rights (Colorado River Tribal Partnership, n.d.). Any negotiation over management of Colorado River water for the benefit of delta ecosystems that affects tribal rights will require tribal participation.

The seven U.S. states wield considerable decision-making power over water allocations, flows, storage, management of endangered species concerns, and environmental restoration. The two Mexican states play a more limited role, with most decision-making authority resting with CNA (Mumme, 1996). Local communities in the delta region as yet have a limited voice, but they are likely to become a more vocal presence as conservation interests engage them and inform them of the impacts of water management on their lives. EDF, in collaboration with others, has convened outreach workshops with communities in the delta to increase communication between conservation interests and local people (*see Appendix C*).

Nongovernmental Organizations

A number of nongovernmental organizations (NGO's) that focus on the environment, as well as academics from universities in both the U.S. and Mexico, have invested time and effort in documenting the values and challenges of the Colorado River delta. While these organizations cannot directly affect how the resource is managed, they are important voices in the debate over the future of the resource.

Of the many Mexican and U.S. NGO's that have worked on the delta, several may play a critical role as alternatives are analyzed and discussed. Based in the U.S., EDF will continue to devote staff time and resources to the challenge of sustaining the delta's ecosystem. Developing a field-tested water balance model for the delta is a current research priority. NGO's engaged in delta conservation include the Sonoran Institute, the Pacific Institute for Studies in Development, the Environment, and Security (Pacific Institute), the Defenders of

[49] In an attempt to enhance the influence of user groups and allow some local control of water resources, Mexico has District Water Committees (Comités Hidráulicos) composed of water users. In addition, River Basin Councils were created in 1992 to help decentralize water management. CNA sits on both the irrigation district committees and the river basin councils.

[50] This figure represents rights asserted by the tribes rather than adjudicated rights.

Wildlife (Defenders), Conservation International (CI), the Nature Conservancy (TNC), the Southwest Center for Biodiversity, and others. In Mexico, the Intercultural Center for the Study of Deserts and Oceans (CEDO), plays a key role in creating local awareness of the delta by publishing a bilingual newsletter on the science and policy issues affecting the delta. CEDO also serves as a center for research and instruction in delta ecology. The largest nongovernmental organization in Mexico with an interest in nature conservation is PRONATURA. The local chapter, PRONATURA Sonora, has, in collaboration with EDF, hosted a number of outreach workshops, providing delta communities with access to information on the delta (*see Appendix C*). Mexican NGO's are particularly important to delta conservation efforts as they are uniquely equipped to conduct public outreach in delta communities.

Of note, two university-based research centers have been the source of important studies that document current delta conditions, including the data in this report. Faculty at the Environmental Research Laboratory (ERL) at the University of Arizona and at the Instituto Tecnológico y de Estudios Superiores de Monterrey (ITESM) have made appreciable efforts to increase the body of knowledge concerning delta ecosystems, economies, and communities. Governments and nongovernmental organizations alike depend on the work of these individuals and institutions to provide credible, scientific data.

Other Organizations and Authorities

Several special designations focus attention on the delta, in addition to the Biosphere Reserve. In 1992, the Colorado River delta was recognized as part of the Western Hemisphere Shorebird Reserve Network. In 1996, it was designated as a Ramsar site, and Mexico agreed to make conservation and wise use of the wetlands the primary strategy of any management and restoration plan to be applied to the delta. The Tripartite Agreement on the Conservation of Migratory Birds and Their Habitats[51] and the North American Waterfowl Conservation Act encourage conservation and sustainable development of the wetlands (Valdés-Casillas et al., 1998a).

Several initiatives that could impact preservation of the delta are new or newly proposed.[52] In 1997, the U.S. Department of the Interior and SEMARNAP signed a letter of intent for joint work in natural protected areas near the border, with special priority given to the Sonoran Desert (Babbitt and Carabias, 1997). Also in 1997, the Biosphere Reserve, through INE, proposed the Binational Program for the Sustainable Use of Water in the Lower Colorado River (PUSARC). PUSARC would require the Mexican federal government to establish a permanent minimum flow for la Ciénega de Santa Clara and a minimum flow for the delta and to the sea (Valdés-Casillas, 1998a). Others have discussed new management regimes for the river that include water marketing, the transfer of U.S. federal services on the river to regional authorities, and the elevation of ecosystem preservation as a priority in the management of the Colorado River (MacDonnell and Driver, 1996).

Legal Mechanisms

There may be opportunities to address delta preservation needs through the U.S. legal system. Under the Endangered Species Act, U.S. federal agencies may not take actions that harm endangered species. There is nothing in the Act that discounts harm to species that occurs across an international boundary.[53] The National Environmental Policy Act (NEPA) requires U.S. federal agencies to consider the environmental impacts of their actions. In 1997, the Council on Environmental Quality issued a memo directing all U.S. federal agencies to consider the environmental impacts of their actions, regardless of where those impacts might occur (McGinty, 1997), although this memo appears not to have changed agency management practices.

Mexican law offers fewer possibilities. The Mexican Constitution includes the Colorado River in the definition of national waters (Constitutión Politica de los Estados Unidas Mexicanos, art. 27), but sets no policy for instream flows. However, the National Water Law (of 1992) clearly gives CNA authority over such waters, and the regulations (of 1994) that implement the law provide for the use of national waters for ecological conservation purposes (Ley de Aguas Nacionales, su Reglamento y Ley Federal del Mar). The General Law

[51] The Tripartite Agreement is signed by the U.S., Mexico, and Canada.

[52] In 1996, the U.S. Fish and Wildlife Service, SEMARNAP, and the Canadian Wildlife Service signed the Cooperative Agreement on the Conservation and Management of Wildlife Ecosystems (Valdés-Casillas et al., 1998a).

[53] The Supreme Court heard a case on this subject, but it declined to rule on the matter (Defenders of Wildlife v. Hodel, 1990).

of Ecological Equilibrium and Environmental Protection authorizes Biosphere Reserves, which are established to protect areas of great biological diversity and unique ecological characteristics (Valdés-Casillas et al., 1998a). To the extent that the ecological value of the Biosphere Reserve in the delta is found in its wetlands, this law might serve as a tool to secure or protect adequate flows, which would be managed under the authority of CNA for their conservation.

RELATED EFFORTS AND OPPORTUNITIES

Given the many competing demands for water in the Colorado River basin, prospects for improving water management to benefit the delta might be found in conjunction with other, related efforts. Several resource management issues that have been the focus of international attention may offer strategic opportunities for improving management of the delta.

Colorado River Entitlements and California's 4.4 Plan

The amount of water that reaches the delta at present is a function of water use and development upstream. The existing regime of agricultural wastewater and periodic flood releases will likely continue to sustain some areas of the delta. Conservation measures taken upstream (perhaps encouraged by market-based payments for saved water) may result in increased flows. Deliberate management of these flows could make a significant difference in securing—and improving—the health of delta ecosystems.

States in the upper basin (Wyoming, Colorado, Utah, and New Mexico) do not at present use their full allotment, and (with the exception of Colorado) are unlikely to develop significant new uses for Colorado River water in the foreseeable future. California, a lower basin state, currently uses about 5.2 maf (6.4×10^9 m^3) a year, including surplus upper basin water and a diminishing quantity of unused lower basin entitlements. Recently, California made a commitment to reduce its use of Colorado River water to its original allotment of 4.4 maf (5.4×10^9 m^3). Although its implementation remains disputed, and California's "4.4 plan" is not yet operable or even fully defined, once implemented (projected in 2010-2015) approximately 800,000 acre-feet (9.9×10^8 m^3) of water could remain in the basin in normal years.[54] Moreover, the period of mainstem storage construction and reservoir filling is past. While this condition of excess water in the system does not guarantee delivery of water to Mexico, flows reaching delta ecosystems are likely to be comparable to those of the last decade as long as these conditions prevail.

Salton Sea

To solve pollution problems in the Salton Sea, resource managers have proposed pumping Salton Sea water to the Laguna Salada, a dry depression in the delta, or to the Gulf of California. The Salton Sea and Laguna Salada have become, in essence, evaporation basins that concentrate pollutants and salts, and they are a hazard to birds and other wildlife. [*See Box 5*.] Any consideration of management options involving discharge of Salton Sea water to the delta or Gulf of California will require Mexican involvement, and thus may present an opportunity for Mexico and the U.S. to consider binational measures for enhancing delta ecosystems.[55] If the effluent and wastewater now dumped in these closed basins were managed with care in the open delta, they might actually bring some benefit to wetland ecosystems. Flood flows could flush away any buildup of pollutants or salinity.

[54] Under the Law of the River, California has the right to 4.4 maf in normal years and up to 1 million acre-feet of surplus water in years when the Secretary of the Interior determines that the water is available. California water users have been diverting 5.2 maf or more from the river for many years. The Department of the Interior and other Colorado River basin states support California's 4.4 Plan, announced in 1996. California water users, however, have yet to agree on how to implement these changes within the state (Metropolitan Water District of Southern California, 1999).

[55] Any strategy to use delta wetlands to treat or remove pollutants or salinity in Salton Sea water (disposed there) must be carefully studied to avoid adverse impacts on delta habitats and the species that inhabit them.

BOX 5. A Related Issue: The Salton Sea

The Salton Sea is the largest lake in California. Located 40 miles north of the border in the Imperial and Coachella valleys, this closed basin was once the northernmost reach of the Colorado River delta, though it was dry by 1901 when the first large canal began to bring Colorado River water to the Imperial Valley. In 1905, floods breached the canal walls, and for two years, before repairs could be made, the entire Colorado flowed into the Salton Depression, creating the Salton Sea.

In 1930, the U.S. Fish and Wildlife Service established a wildlife refuge on the southern end of the Sea, stocking it with freshwater fish. However, after years of serving as a repository for agricultural and municipal waste from surrounding higher-elevation lands, the Salton Sea is now 50 percent more saline than ocean water. Researchers have found evidence of dangerous contamination levels, and California has warned residents to limit their consumption of Salton Sea fish. Anaerobic conditions produced by fertilizers in agricultural drain water running into the Sea have led to massive fish and bird kills. Since 1992, an estimated 200,000 birds have died from avian botulism, cholera, and other diseases. More than 14,000 pelicans died in 1997 (Glenn et al., 1998).

Notwithstanding these conditions, the Salton Sea remains an important stopover for migratory waterfowl along the Pacific Flyway. The ecosystems of the Sea and the Colorado River delta are linked by riparian corridors along the Colorado, Hardy, New, and Alamo rivers, and by desert corridors through the Cucapá and Coyote mountains. Water quality problems in the Salton Sea affect wildlife across the entire region, and concerns about the Sea have brought together scientists, agricultural interests, government officials, and environmental groups. In August 1997, the U.S. Department of the Interior sponsored a workshop on "Saving the Salton Sea," which was attended by 50 scientists and other interested parties, and identified major problems relating to the Sea. In 1998, the U.S. Congress passed legislation requiring federal authorities to study the Salton Sea's problems and make recommendations for its restoration. Several proposals are under discussion: one would control salinity by draining Salton Sea water into the Gulf of California and replacing it with water pumped from the Gulf (this could have an impact on delta ecosystems [Glenn et al., 1998]). Another proposal is to build dikes within the Sea to allow evaporation and removal of salts and contaminants. To date, Mexico has not been included in the discussion of these proposals, nor has there been assessment of their impacts on Colorado River delta ecosystems or the region's wildlife populations.

A new wastewater treatment plant in Mexicali—to be constructed in 2001— will improve the quality of some of the effluent now sent via the New River to the Salton Sea.

[*See Box 1.*] The plant is presently designed to discharge treated effluent into the New River, where it will empty into the Salton Sea. If instead this treated effluent is discharged into the Rio Hardy basin, the Rio Hardy wetlands might serve as part of the wastewater treatment process. Both the Mexican government and the U.S. EPA have indicated an interest in exploring options for using treated water to enhance delta environments (Eberhardt, 1996; Peñas, 1999).

Yuma Desalting Plant

A proposal by the BOR to operate the Yuma Desalting Plant and market the water would divert agricultural wastewater flows from la Ciénega de Santa Clara and replace them with concentrated brine. [*See Box 4.*] This would reduce the area of the wetland by 40 percent, impacting wildlife, as well as the residents of nearby Johnson *ejido* who serve as local ecotour guides. Any decision to operate the Yuma Desalting Plant will require an environmental assessment and should require that water be found to support la Ciénega de Santa Clara. This water should not be counted against the U.S. treaty obligation to deliver Colorado River water to Mexico.

Lower Colorado Conservation Planning

The lower Colorado River basin has recently become a focus for cooperative conservation efforts in the U.S., but to date, participants have been reluctant to include the delta in planning efforts for the lower basin. One potential source of support for delta ecosystems could be a system of off-site mitigation or mitigation banking for lower basin water users whose diversions and deliveries affect endangered species. Because delta wetlands are more extensive and in better condition than riparian areas along the U.S. stretch of the Colorado River, the delta is an important reservoir of species and habitats that are threatened or endangered elsewhere. The U.S. Fish and Wildlife Service is the lead federal agency in the process, and could make the determination to include the delta in the scope of its overall conservation program for the lower Colorado.

All American Canal and Delivery of Water to Mexico

Colorado River water is guaranteed to Mexico in the 1944 water treaty with the United States.[56] Mexico relies on groundwater pumped from the border region to augment its supplies, but plans by California and Nevada to line the nearby All American Canal will reduce seepage into these aquifers. Mexico has opposed these plans on the grounds that the seepage is "grandfathered"—in other words, a known condition that existed at the time the original treaty was negotiated, and therefore water to which Mexico is entitled. In addition, Mexico has requested that its entire allocation of water from the Colorado River be delivered at the Northern International Boundary, one of two sites where water is currently delivered.[57] Resolution of these issues will require negotiations between the two countries and a possible amendment to the 1944 treaty.

[56] See Chapter 2, notes 15 and 20 for an explanation of U.S. treaty obligations to Mexico.
[57] See Chapter 2 for further discussion.

5 RECOMMENDATIONS

The goal [of modern efforts to manage nature] is to get humanity's role in nature back to the right size, neither too big nor too small, neither too powerful nor too powerless.

—Patricia Nelson Limerick, The Legacy of Conquest, 1987

CONCLUSION

Preservation of the Colorado River delta ecosystems will be a complex task. In recent years, consistent base flows and periodic flood flows have restored relatively small but significant remnants of the once extensive delta marsh wetlands and riparian areas. These restored habitats support wildlife and provide a number of other ecologically important goods and services. None of these flows, however, are guaranteed in the future and they are likely to diminish even further absent affirmative arrangements to preserve and assure them. The quantification of the delta ecosystems' minimum water needs, presented in this report, represents an important step in developing a binational program to restore and protect these ecosystems for the benefit of wildlife and people.

Although the basic mandate—keep sufficient water in the river—seems simple, the means to this end will require the alignment of numerous institutions, agreements, and organizations. Further research is needed, to improve both understanding and documentation of the delta's water needs. Perhaps the most fundamental recommendation is that public attention needs to be—and remain—focused on the significance and value of the delta ecosystems. The massive institutional commitments required to ensure the delta's future will require both international stakeholders and local communities to develop strong and vigilant voices demanding that attention be paid to the Colorado River delta.

The scale at which change needs to take place is large, and conservation of the delta appears to be a vast challenge, yet there appears to be a strategic moment of opportunity at present. The delta itself has recovered from years without flood flows. Heightened awareness of the delta and its values is spreading from traditional environmental interests, to the communities that depend on the delta, and to the large institutions that manage water in the Colorado basin and deal with international relations between the U.S. and Mexico. Any one of a number of related issues that will be investigated, discussed, and negotiated in the near future may offer an avenue to address the delta's ecological needs. Armed with these facts and the knowledge that the Colorado River delta is worth protecting, individuals and organizations concerned with its future should be able to make a difference.

RECOMMENDATIONS

Most of the recommendations we propose for restoration of the Colorado River delta can neither be achieved in a short time frame, nor by any one stakeholder. However, some changes will be easier to pursue than others, so we have separated near-term and long-term actions.

There are numerous roles to play for the many Colorado River delta stakeholders. For those recommendations with clear jurisdictions and interests, we have listed agencies and organizations that should be involved. In addition, we recognize that many of these recommendations should be pursued by the nongovernmental organizations and research institutions described in this report (and surely also for some that are not). These groups play a significant role in the delta's restoration, but out of respect for their independence, we have not taken the liberty of assigning roles.

MANAGE EXISTING FLOWS FOR THE BENEFIT OF DELTA ECOSYSTEMS

As documented in this report, remnant delta riparian and wetland ecosystems can be sustained with a modest amount of freshwater and continued use of agricultural wastewater. Current hydrologic conditions and the level of water development in the basin suggest that excess water will continue to be available for some time. Nevertheless, restoring and protecting the delta's ecological viability requires some assurance that the current regime is not changed to decrease flows south of Morelos Dam. Existing flood flows can be managed to good advantage if they are released as pulse flows at a rate sufficient to flush pollutants and encourage seed germination with overbank flooding. Irrigation return flows and wastewater are important perennial sources, and should be preserved. With water quality monitoring and improvements, wastewater flows would be of even greater benefit to delta ecosystems.

- Protect perennial and pulse flows in the delta. Based on our preliminary analysis of past flows, we estimate that remnant riparian habitat could be supported by a perennial flow of 32,000 acre-feet (4×10^7 m^3), supplemented by a flood flow of 260,000 af (3.2×10^8 m^3). The flood flow should be released at 3500–7000 cfs (100–200 m^3/s), a rate sufficient to inundate delta riparian areas within the levees. This pulse flow should occur on average once every four years, which is the average periodicity for floods under the current regime of Colorado River development and management. Perennial flows should maintain a core area of 150,000 acres (60,000 ha) of riparian and wetland habitat. Periodic pulse flows should saturate 250,000 acres (100,000 ha), contained within the existing systems of levees. On an annualized basis, these perennial and pulse flows would represent less than 1 percent of the base flow of the Colorado River. *(See recommendation below to Change Institutional Arrangements and Agreements to Support Delta Ecosystems.)*

- Assure release of flood flows to sustain delta ecosystems during extended periods of drought. Precipitation in the Colorado River basin in the years since major upstream dams have filled has produced flood flows in the delta on average every 4 years. However, there is evidence in the long-term hydrologic record that significant drought periods are likely to occur, possibly enduring 8 or 10, or even 20 years. The delta's water needs should be met during drought periods through a mix of dedicated and purchased water deliveries, at the volumes and frequencies detailed above. (See recommendation to Establish Market Mechanisms and Funding Sources for Delta Preservation below.)

- Abandon plans to operate the Yuma Desalting Plant. Under no circumstances should la Ciénega de Santa Clara be dewatered through the diversion of wastewater from the MODE canal. The Bureau of Reclamation is considering proposals to allow the plant to be used to treat agricultural wastewater from California's Imperial Irrigation District. This plan can be supported if it does not affect water supplies to la Ciénega de Santa Clara. *BOR, SEMARNAP-INE, CNA, IBWC*

- Develop and implement water quality monitoring programs. Wetlands supported by wastewater are in danger of accumulating toxins at levels poisonous to resident fauna. Water quality monitoring is needed in the agricultural drains that flow into la Ciénega de Santa Clara, the Rio Hardy/Rio Colorado wetlands, and El Indio marsh. Monitoring should focus on the levels of pesticides, nutrients, selenium, arsenic, boron, and other contaminants discharged by these drains. *CNA, SEMARNAP, BOR, Wellton-Mohawk Irrigation District*

CHANGE INSTITUTIONAL ARRANGEMENTS AND AGREEMENTS TO SUPPORT DELTA ECOSYSTEMS

The 1997 research documented in this report captured a snapshot of the delta returning to ecological health, yet precariously dependent on water that is not dedicated to its ecosystems. Current upstream use, reservoir management, agricultural drainage, and hydrologic conditions have produced sustaining perennial and pulse flows. But just as natural systems are dynamic, so are the man-made systems and arrangements that determine use of Colorado River water. Restoring and protecting the delta's ecological viability will require assurance that flows south of Morelos Dam are not diminished.

Near-term recommendations could be implemented within the framework of existing agreements and the law of the river but would require some regulatory and management changes:

- Develop better coordination between the United States and Mexico for the management of flood flows. Mexico should be given more notice of impending releases, and management authorities on both sides of the border should look for opportunities to divert and store floodwaters for conservation purposes. *IBWC, CNA, SEMARNAP-INE*
- Create or designate a Mexican institution to guarantee the delivery of any waters earmarked for environmental restoration to the target ecosystem. This will require the establishment of environmental water rights protected against the demands of irrigators. This entity will need to administer and manage water intended for delta ecosystems, determine how it is to be secured (e.g., contract, fee-simple purchase, lease), determine who will hold the water on behalf of the environment, and be accountable to stakeholders. (See recommendation below to Establish Market Mechanisms and Funding Sources for Delta Preservation.) *IBWC, CNA, SEMARNAP-INE*
- Create or designate a binational commission to promote the sustainable use of water in the delta and encourage greater public participation in decisions that effect the lower basin and delta.[58] The commission should conduct all necessary and appropriate studies of water needs and use in the delta, establish minimum flow requirements, and make arrangements for obtaining reliable water supplies. Such a commission also may be the appropriate entity to assume management and coordination authority over all transboundary water movement. *IBWC, SEMARNAP-INE, CNA, BOR*
- Review the Border XXI program, including its indicators, and propose changes that might bring greater benefit to delta ecosystems and the communities that depend on them. *EPA*
- Create a task force on resources in the border region, as proposed by IBWC. This task force should bring together resource agencies, researchers, and private groups, and should solicit public input to help it define its mission. *IBWC, CEC*
- Designate the Rio Hardy/Rio Colorado wetlands, which are outside the Biosphere Reserve, as a wildlife management unit. Mexico's National Program for Wildlife Conservation and Rural Productivity Diversification provides for a special land designation called the Wildlife Management Unit (SUMA). These areas are designed to protect natural resources while allowing certain economic activities to continue. Effectively, a SUMA can serve as a buffer to areas under greater protection, such as the core zone of the Biosphere Reserve. The Rio Hardy/Rio Colorado wetlands can be managed as a SUMA by local communities. *SEMARNAP-INE, PRONATURA*

Long-term recommendations are likely to require changes to the laws and agreements governing water allocation in the Colorado basin,[59] as well as persistence and patience:

- Negotiate an amendment to the 1944 water treaty to address water needs for delta ecosystems. This enormous task is not without precedent (the best-known example is Minute 242, which establishes water quality standards). Many compacts and court decisions—in general the Law of the River—have created entitlements to Colorado River water that cannot be ignored. A treaty amendment establishing the use of market mechanisms, plus sufficient funding, would allow change to occur on a voluntary, compensated basis, while recognizing existing entitlements.

  Yet until United States authorities come to see conservation of delta resources as a matter of high concern, the United States will not give strong support to such an amendment. United States interest in the idea may increase if it can be shown that the habitat and wildlife resources in the delta are a significant "reservoir" of species that are endangered in the United States. An amendment supporting conservation of delta ecosystems will gain even more support if those ecosystems can be used in mitigation programs that offset the loss of species elsewhere in the basin. Pressure on the United States to negotiate an amendment may increase as water

[58] Proposal by INE–Programa de Uso Sustentable del Agua en la Cuenca Baja del Rio Colorado, Mexico, April 1997.
[59] For information on the Law of the River, see note 15.

management practices in the United States are directly implicated in the decline of sensitive species in the delta and upper Gulf.[60] The success of any such amendment would hinge on Mexico's ability to guarantee that flows dedicated to delta ecosystems were properly delivered, as well as Mexico's ability to contribute resources to the delta's ecosystems. *IBWC, U.S. and Mexico secretaries of state*

- Identify sources of water to meet the terms of this amendment. The U.S. Department of the Interior could secure water through the reallocation of excess water now used by California or other waters saved through conservation measures, and lease this water to Mexico. (See recommendation below to Establish Market Mechanisms and Funding Sources for Delta Preservation.) *DOI, basin states, CNA, IBWC*

- Negotiate new criteria for allocating surplus water among users, and establish delta ecosystems as a legitimate user of this surplus. The Colorado River is managed according to "Criteria for Coordinated Long-Range Operation of Colorado River Reservoirs," which determine surplus and shortage conditions and guide the allocation of surplus water among users. The Department of the Interior must prepare a yearly plan for how reservoirs in the system will be managed and whether a surplus or shortage exists. New criteria should redefine surplus and shortage conditions to include environmental considerations in the annual determination of where surplus flows are allocated (Postel et al.). There already is precedent for this in the Colorado basin.61 Issues to be resolved include formal recognition of minimum flows needed for delta preservation, identification of the entity that would hold these allocations and manage the rights, logistics of storing and releasing the water, and the level of priority that ecosystem resources would enjoy. One possible opportunity to negotiate these criteria is in conjunction with California's 4.4 plan (*See section in Chapter 4 on Colorado River Entitlements and California's 4.4 Plan.). DOI, states, tribes, IBWC, SEMARNAP-INE*

ESTABLISH MARKET MECHANISMS AND FUNDING SOURCES FOR DELTA PRESERVATION

Virtually all recommendations in this report have a cost, some greater than others. Finding water in drought years will no doubt be one of the most challenging and costly challenges of delta preservation. One way to ensure equity in the allocation of these costs is to establish mechanisms that allow the transfer of water resources and collection of restoration fees according to market forces:

- Extend provisions for off-stream water banking in the United States to include banking by environmental resource agencies or private groups. These provisions should be designed to protect critical habitats from being dewatered during periods of drought. Any such program will need to designate entities eligible to bank water for the environment, implement water transfer and purchasing programs, and support new water-banking regulations that meet the timing needs of environmental releases. *BOR, EPA, SEMARNAP-INE, states, tribes, IBWC*

- Negotiate provisions for interstate and interbasin water transfers to allow reallocation of developed water supplies to meet environmental demands. States in the lower basin already have proposed several approaches for marketing water among themselves. In the upper basin, Utah has expressed an interest in marketing its undeveloped Central Utah Project water to downstream users (Smith, 1996). At least one senior water rights holder in the lower basin has expressed an interest in marketing water to an entity that would deliver water to the delta.[62] New provisions and regulations would have to address how water could be transferred across the international boundary, and they would have to open the market to allow participation by entities representing nonconsumptive environmental and recreational uses. They also would have to define parameters for the price of water for environmental uses, and duration of the transferred water right. *DOI, states, tribes, IBWC*

[60] Mexico has maintained that the diminished freshwater flows to the Gulf of California are partially responsible for the decline in various fisheries in the Gulf and for the near disappearance of the vaquita porpoise. The Council on Environmental Quality in the United States has issued an interpretation of the National Environmental Policy Act (NEPA) asserting that U.S. agencies can be held accountable for the impacts of their actions outside of the United States even when the precipitating action takes place within the United States. (McGinty, 1997)

[61] See note 16 for an explanation of the RIP. In the case of the Green River, changes in the operation of Flaming Gorge Dam have already been made to enhance peak flows and reduce and stabilize winter flows. In the Colorado River, water users, the state of Colorado, federal agencies, and environmentalists continue negotiations over the establishment of a mechanism that will ensure protection of flow releases from the federal reservoirs.

[62] The Cibola Irrigation District in Arizona has offered to sell 22,560 acre-feet (2.8×10^7 m^3) of marketable Colorado River water (Israel, 1997).

- Establish mitigation and restoration surcharges on all water and power used in the basin, to begin a process of internalizing ecosystem damage costs and to provide a reliable and broad-based source of funds for delta restoration. An alternative version of this idea is to levy a surcharge (in water or money) against all U.S. transfers of Colorado River water, with revenues going to restore critical habitat in U.S. and Mexico or to purchase water for the delta. Water purchased or leased for environmental purposes should not be subject to these surcharges.

  Any fees would be earmarked to protect the "public-good" values of the river, such as habitat, wildlife, and recreation, including protection and restoration of the delta and upper Gulf. Revenues could be collected by an entity authorized to represent environmental uses in the water market (i.e., buying or leasing water for the environment) and/or spend monies for habitat restoration projects. Eligible entities might include a binational river commission representing environmental interests throughout the entire river basin. This entity could then administer funds to organizations that undertake conservation activities. *DOI, states, tribes*

- Revise environmental regulations in the United States to allow mitigation and mitigation banking programs to support delta habitats. Healthy delta habitats could offset damage to threatened species and habitats elsewhere in the lower Colorado basin. In some instances, it may be easy to demonstrate that greater benefits would accrue from conservation measures in the delta than in other areas of the basin. *CEQ, DOI, EPA, USFWS, IBWC, SEMARNAP-INE*

Until delta restoration is funded through revenue generated from consumptive uses of Colorado River water, there will be a continued need for support from public agencies and foundations. Considerable advocacy and grassroots organizing will be necessary to keep delta restoration a priority.

- Establish delta restoration as a priority for funding programs dedicated to the United States–Mexico border environment. CEC, an international funding institution established in the wake of the North American Free Trade Agreement (NAFTA), should ensure that money is available for delta restoration. *CEC*

- Support entities currently working to restore the delta. Foundations and public agencies that have sponsored research and advocacy for delta restoration should continue their support, and foundations with relevant missions should be solicited by advocacy groups for funds. The Mexican Fund for the Conservation of Nature is one possible source of funding. *Foundations, EPA, USFWS, CEC*

- Coordinate restoration efforts. The organizations that receive funding to conduct various conservation activities for the delta should be vigilant in coordinating their work.

INCREASE PUBLIC PARTICIPATION

Public interest groups on both sides of the border have worked well to coordinate their response to delta threats. U.S.-based conservation groups have joined in partnership with Mexican groups to conduct research, educate, forge coalitions, encourage dialogue, and address the needs of people who live near the delta and depend on its resources. Two Mexican organizations, PRONATURA and the Intercultural Center for the Study of Deserts and Oceans (CEDO), have been particularly effective in soliciting the involvement of local communities. No entity, however, has yet emerged as the primary facilitator of local involvement and advocate for local interests. The success of our recommendations to preserve the delta will require a concerted effort to communicate these issues, to solicit information about the delta, and to build grassroots support. We encourage continued public participation in policy and management decisions and recommend coordination among the various involved organizations to ensure that efforts are not duplicated.

- Listen to delta communities. The agencies and organizations working on delta restoration should seek input from communities in the delta concerning strategies to improve delta ecosystems. Successful delta restoration must recognize and include the concerns and needs of the local population. *All organizations with an interest in the delta*

- Establish a coalition of organizations interested in the delta. There are many groups in Mexico and the U.S. presently working on delta restoration. An internet-based communications network would allow the sharing of research results and ideas, and would strengthen the overall effort. *All organizations with an interest in the delta*

CONDUCT FURTHER RESEARCH

This report documents a significant investigation of the dynamics of the Colorado River delta. There are many questions relevant to the delta's restoration that remain unanswered, and more questions are sure to arise. At present, several areas of research stand out as priorities.

- Develop a water budget for the delta. More research is needed on water availability, consumption, and demand in the delta so that an accurate water budget can be created. All stakeholders need to agree on accounting techniques for the development of a water budget. A water budget would help in the search for ways to preserve delta ecosystems, and it would answer key questions about the amount, quality, and timing of water releases to satisfy basic ecological needs. A water budget developed with credible accounting measures will play a key role in bringing various stakeholders together in the search for alternatives for delta preservation. More accurate information also would provide a foundation for any negotiations for additional water or for changes in water management. *IBWC, SEMARNAP-INE, BOR, CAN, research institutions*

- Run experimental flushing flows. Pulse flows are clearly important to the sustainability of delta riparian and wetland vegetation, but the role of pulse flows in flushing accumulated pollutants and silts is not well understood. A demonstration and testing program of artificial floods should be designed to increase freshwater flows in wetland and riparian areas, particularly where human contact occurs (Zones 4 & 5). This demonstration should test a flow of 300,000 af (3.7×10^8 m^3), at a rate of 3500–7000 cfs (100–200 m^3/s), to determine its efficacy in purging accumulated pollutants and prompting revegetation in riparian areas. *SEMARNAP-INE, CNA, IBWC, BOR, EPA, PRONATURA*

- Investigate the effects of flood release timing on delta vegetation. Although pre-development floods occurred primarily in late spring, observed winter flood releases were successful in stimulating the growth of delta vegetation. Today's floods are predictable to the extent that the BOR can plan reservoir releases. The impacts of flood flows on delta vegetation and other biota should be studied in order to document the variability of response according to timing, and an optimal season for floods should be determined. *SEMARNAP-INE, CNA, IBWC, BOR, EPA, PRONATURA, research institutions*

- Identify ways to sustain native vegetation in riparian and wetland areas. More research is needed on recruitment and growth of cottonwood and willow trees. *IBWC, CNA, BOR, EPA, SEMARNAP-INE*

- Inventory resident and migratory birds in the delta. Although some work has been done to identify species that use delta habitats, there is no comprehensive study of birds that depend on them. In particular, this work should focus on birds in the cottonwood-willow riparian areas that have been identified as high habitat value. *Research institutions*

- Quantify the relationships between freshwater flows and delta and Gulf aquatic species. Further study is needed to determine the needs of aquatic species, including endangered species, commercial fisheries and others. *Research Institutions, FWS, SEMARNAP-INE*

- Explore opportunities for ecotourism. Further study of the economic potential of ecotourism in the delta and the Sonoran Desert region could help attach an economic value to healthy ecosystems and create strong local constituencies in favor of their protection. Researchers from the University of Arizona, Biosphere Reserve managers, and members of the Johnson *ejido* have begun to promote birding, canoeing, kayaking, and other activities to bring economic benefit to local communities. *Local communities, SEMARNAP-INE*

IMPLEMENT SITE-SPECIFIC RESTORATION

(*Zones are defined in Chapter 3. See Figure 6.*)

Colorado River Delta Riparian Corridor (Zones 2–4)

- Identify measures to restore a perennial source of water in riparian and wetland areas to support cottonwood-willow habitat and its high biodiversity value. *IBWC, CNA, BOR, EPA, SEMARNAP-INE*

- Develop a stream channel maintenance program with CNA to stop or minimize the removal or disturbance of wetland vegetation. *IBWC, CNA, BOR, SEMARNAP-INE*

Colorado River Delta Riparian Corridor and Wetland (Zone 4)

- Identify measures to restore a perennial source of water to riparian corridor and wetlands to support cottonwood-willow habitat and its high biodiversity value. *IBWC, CNA, BOR, SEMARNAP-INE,*
- Evaluate the possibility of routing treated wastewater from Mexicali to wetlands downstream of the Rio Colorado/Rio Hardy confluence. The Mexicali II wastewater treatment plant is currently in the advanced planning stage. Unanswered questions include the quantity and quality of wastewater available, the cost of pumping wastewater to the Rio Hardy basin (if the plant is located outside the basin), the environmental consequences of using the wastewater, and the potential for sharing the wastewater with agricultural users in the Mexicali Valley. *IBWC, CNA, EPA, SEMARNAP-INE*
- Identify the potential for delta wetlands to serve as a component of the Mexicali wastewater treatment process. This alternative could save treatment costs and provide a perennial source of water for some portion of delta wetlands. Unanswered questions include the cost of the system, the environmental impact, and the value of this water to wetland habitat and species. *SEMARNAP-INE, EPA, CNA*

Rio Hardy Wetlands (Zones 4 & 5)

- Monitor levels of selenium, boron, arsenic, and salinity to determine if water is safe for activities such as water skiing, swimming, fishing, agriculture, and aquaculture. Pay particular attention to levels at Campo Mosqueda, Cucapá El Mayor, Cucapá Complex, the Colorado River riparian corridor, the Pescaderos River, Campo Sonora, and El Mayor. *SEMARNAP-INE, EPA, CNA, PRONATURA*
- Use monitoring to identify ways to improve water quality, particularly in areas frequented by people. *SEMARNAP-INE, ITESM, PRONATURA*
- Restore stream capacity of the Colorado River, just below its confluence with Rio Hardy (in the Cucapá El Mayor–Cucapá Complex), for storing water in wetlands used by the Cucapá for fishing. *CNA*
- Identify opportunities to use floodwater or pulse flows released into the levee system along the Hardy and Colorado rivers at Campo Sonora and El Mayor to reestablish flows and flush selenium. *CNA, PRONATURA, research institutions*
- Erect signs to warn of water quality problems. *SEMARNAP-INE, PRONATURA*

La Ciénega de Santa Clara/El Doctor/ El Indio (Zone 7)

- Maintain the water supply to la Ciénega de Santa Clara by ensuring that the Yuma Desalting Plant does not begin to divert wastewater from the MODE canal. The Bureau of Reclamation is considering proposals to allow the plant to be used to treat agricultural wastewater from California's Imperial Irrigation District. This plan can be supported if it would not effect water supplies to la Ciénega de Santa Clara. *BOR, SEMARNAP-INE, CNA, IBWC*
- In the event that agricultural drainage is diverted to the Yuma treatment plant, ensure it is replaced with another source of water. Substitute sources might include groundwater pumped at the border, water now delivered to the Southern International Boundary (if Mexico negotiates delivery of its full treaty amount at the Northern International Boundary), or agricultural return flows collected and treated (if necessary) in Mexico. *BOR, CNA, IBWC*
- Begin monitoring for selenium in water flowing into la Ciénega de Santa Clara. Also monitor levels in sediments, plants, and vertebrates and track changes in selenium concentrations that might indicate toxic hazards to fish and wildlife. Conduct a study to model the mass balance of selenium throughout the ecosystem. *SEMARNAP-INE, US EPA*

ACRONYMS AND ABBREVIATIONS USED IN RECOMMENDATIONS

BOR	U.S. Bureau of Reclamation
CEDO	Intercultural Center for the Study of Deserts and Oceans, known in Mexico as Centro Intercultural de Estudios de Desiertos y Océanos
CEQ	U.S. Council on Environmental Quality
CNA	Mexico's National Water Commission
DOI	U.S. Department of the Interior
EPA	U.S. Environmental Protection Agency
IBWC	International Boundary and Water Commission, also known as Comision Internacional de Limites y Aguas (CILA) in Mexico
INE	Mexico's National Institute of Ecology
NGO's	Nongovernmental organizations
PRONATURA	PRONATURA, A.C. (a Mexican conservation organization)
SEMARNAP	Mexico's Secretariat of the Environment, Natural Resources, and Fisheries

BIBLIOGRAPHY

Allen, John P. 1996. Bureau of Reclamation. Personal communication, November.

Anderson, B. W., and R. D. Ohmart. 1986. "Vegetation." Pp. 639–660 in A. Y. Cooperrider, R. J. Boyd, S. Hanson, and S. McCulloch, eds. Inventory and Monitoring of Wildlife Habitat. U.S. Department of the Interior, Bureau of Land Management, Washington, D.C.

Babbitt, Bruce, and Julia Carabias Lillo. 1997. "Letter of Intent Between the Department of Interior of the United States and the Secretariat of Environment, Natural Resources and Fisheries of the United Mexican States for Joint Work in Natural Protected Areas on the United States–Mexico Border." May, 5, 1997.

Balogh, M. 1996. Unpublished data. United States Bureau of Reclamation, Boulder, Colorado. Cited in Edward Glenn, Christopher Lee, Richard Fegler, and Scott Zengel. 1996. "Effects of Water Management on the Wetlands of the Colorado River Delta, Mexico." Conservation Biology 10(4): 1175–1186.

Boyer, Peggy Turk. 1998. "Colorado River Water." Centro Intercultural do Estudios de Desiertos y Océanos, A.C. (CEDO) News 8(2): 25–27.

Briggs, Mark K., and Steve Cornelius. 1997. "Opportunities for Ecological Improvement Along the Lower Colorado River and Delta: Final Report." Defenders of Wildlife.

Carrillo, Yamilett. 1999. Instituto Tecnólogico y de Estudios Superiores de Monterrey (ITESM) Campus Guaymas. Personal communication.

Centro de Investigaciones Cientificas y Tecnólogicas de la Universidad de Sonora. n.d. "Programma de Manejo de la Reserva de la Biosfera del Alto Golfo de California y Delta del Rio Colorado Resumen Ejecutivo." Sonora, Mexico.

Chavarrià-Correa, Elena. 1998. "Public Involvement in the Management and Restoration of the Colorado River Delta: Community Strategies and Goals." Unpublished manuscript.

Colorado River Tribal Partnership. n.d. "Position Paper of the Ten Indian Tribes with Water Rights in the Colorado River Basin."

Constitution Politica de los Estados Unidas Mexicanos (Mexican Constitution). Art. 27

Defenders of Wildlife v. Hodel. 911 F. 2d 117 (1990).

Diario Officiel, 1994. Norma Oficial Mexicana. NOM-059-ECOL-1994. Que determina la S P P y especies y subespecies de flora y fauna silv. Terrestres y acuáticas en peligro de extinction amenazades, raras y las sujetas para su proteccion especial, especificaciones para su proteccion. D. O. F. 16 de mayo de 1994.

Direccion General de Ecologia del Estado de Baja California. 1995. Plan de Ordenamiento Ecologico del Estado do Baja California. Gobierno de Baja California. Cited in Carlos Valdés-Casillas et al., 1998a. "Information Database and Local Outreach Program for the Restoration of the Hardy River Wetlands, Lower Colorado River Delta, Baja California and Sonora, Mexico." A report to the North American Wetlands Council.

Eberhardt, Doug. 1996. Water Management Division, US EPA Region IX. Personal communication, July.

Ezcurra, E., R. S. Felger, A. D. Russell, and M. Equiha. 1988. "Freshwater Islands in a Desert Sand Sea: The Hydrology, Flora, and Phytogeography of the Gran Desierto Oases of Northwestern Mexico." Desert Plants 9(2): 35–44, 55–63.

Fradkin, Philip L. 1981. A River No More: The Colorado River and the West. University of California Press.

Friederici, Peter. 1998. "Stolen River: The Colorado and Its Delta Are Losing Out." Defenders 2: 10–33.

Galindo-Bect, Manuel S., et al. n.d. "Analysis of Penaeid Shrimp Landings in the Upper Gulf of California in Relation to Colorado River Discharge." Unpublished manuscript.

Garcia-Hernandez, J. 1998. "Bioaccumulation of Selenium in the Ciénega de Santa Clara, Colorado River Delta, Sonora, Mexico." M.Sc. thesis, Department of Soil, Water and Environmental Science, Graduate College, University of Arizona.

Getches, David H. 1985. "Competing Demands for the Colorado River." University of Colorado Law Review 56: 413–479.

Glenn, Edward. 1998a. "Water Policies to Serve Environmental and Human Needs in the Colorado River Delta, Mexico." Unpublished manuscript.

Glenn, Edward. 1998b. "Importance of United States' Water Flows to the Colorado River Delta and the Northern Gulf of California, Mexico." Unpublished manuscript.

Glenn, Edward, R. Felger, A. Burquez, and D. Turner. 1992. "Ciénega de Santa Clara: Endangered Wetland in the Colorado River, Sonora, Mexico." Natural Resources Journal 32: 817–824.

Glenn, Edward, Christopher Lee, Richard Fegler, and Scott Zengel. 1996. "Effects of Water Management on the Wetlands of the Colorado River Delta, Mexico." Conservation Biology 10(4): 1175–1186.

Glenn, Edward, Chelsea Congdon, and Jaqueline Garcia. 1997. "New Value for Old Water." The World & I, April, 1997: 204–211.

Glenn, Edward, Michael Cohen, Jason Morrison, Carlos Valdés-Casillas, and Kevin Fitzsimmons. 1998. "Salton Sea Restoration: The No Project Alternative." Unpublished manuscript.

Glenn, Edward, Jaqueline Garcia, Rene Tanner, Chelsea Congdon, and Dan Luecke. 1999. "Status of Wetlands Supported by Agricultural Drainage Water in the Colorado River Delta, Mexico." Horticultural Science 34(1): 16–21.

The Grand Canyon Trust. 1996. Proceedings from the Colorado River Workshop. Flagstaff, Arizona.

Grimm, Nancy B., Stuart G. Fisher, Stanley V. Gregory, G. Richard Marzolf, Diane McKnight, Frank J. Triska, and H. Maurice Valett. 1997. "Sustainability of Western Watersheds: Nutrients and Productivity." Pp. 31–43 in W. L. Minckley, ed. Proceedings of the Aquatic Ecosystems Symposium. Western Water Policy Review Commission.

Harpman, David A. n.d. "The Economic Cost of the 1996 Controlled Flood." In Robert H. Webb, G. Richard Marzolf, John C. Schmidt, and Richard A. Valdez, eds. Floods and River Management: The 1996 Flood on the Colorado River in Grand Canyon. American Geophysical Union, Geophysical Monograph Series. Forthcoming.

Hernandez-Ayon, J., M. Galindo-Bect, B. Flores-Baez, and S. Alvarez-Borrego. 1993. "Nutrient Concentrations are High in the Turbid Waters of the Colorado River Delta." Estuarine, Coastal, and Shelf Science 37:593–602.

International Boundary and Water Commission (IBWC). 1996. "Fact Sheet on the Mexicali Sanitation Project, November 7, 1996."

Israel, Dan. 1997. Attorney for the Cibola Irrigation District. Personal communication.

Johnson, Robert. 1999. U.S. Bureau of Reclamation. Personal communication.

Leichenko, R. M., and J. L. Wescoat. 1993. "Environmental Impacts of Climatic Change and Water Development in the Indus Delta Region." International Journal of Water Resource Development 9: 247–261.

Leopold, Aldo. 1948. A Sand County Almanac. Ballantine Books.

Limerick, Patricia Nelson. 1987. The Legacy of Conquest: The Unbroken Past of the American West. W. W. Norton and Company.

MacDonnell, Larry, and Bruce Driver. 1996. "Institutional Options." In Proceedings from the Colorado River Workshop. Phoenix, Arizona.

Marine Mammal Commission. 1996. "Vaquita." Pp. 76–78 in Marine Mammal Commission: Annual Report to Congress, 1996.

McAleese, Paul. 1999. Bureau of Reclamation, Yuma Desalting Plant Operations Division. Personal communication.

McGinty, Kathleen A. 1997. "Memorandum to Heads of Agencies on the Application of the National Environmental Policy Act to Proposed Federal Actions in the United States with Transboundary Effects."

Mellink, Eric, Eduardo Palacios, and Salvador Gonzalez. 1997. "Non-Breeding Waterbirds of the Delta Rio Colorado, Mexico." Journal of Field Ornithology (Winter) 68: 113–123.

Meyers, Charles J. 1966. "The Colorado River." Stanford Law Review 19: 1–75.

Meyers, Charles J., and Richard L. Noble. 1967. "The Colorado River: The Treaty with Mexico." Stanford Law Review 19: 367–419.

Minckley, W. L. 1991. "Native Fishes of the Grand Canyon Region: An Obituary?" In Committee to Review the Glen Canyon Environmental Studies, Water, Science, and Technology Board. Colorado River Ecology and Dam Management. National Acadamy Press.

Morrison, Jason I., Sandra L. Postel, and Peter H. Gleick. 1996. "The Sustainable Use of Water in the Lower Colorado River Basin." The Pacific Institute for Studies in Development, Environment, and Security, Oakland, California.

Mumme, Stephen P. 1996. "The Institutional Framework for Transboundary Inland Water Management in North America: Mexico, Canada, the United States, and Their Binational Agencies." Commission on Environmental Cooperation.

Mumme, Stephen P., and Pam Duncan. n.d. "The Commission on Environmental Cooperation and the U.S.-Mexican Border Environment." Unpublished manuscript.

Ohlendorf, H. M., D. J. Hoffman, M. K. Saiki, and T. W. Aldrich. 1986. "Embryonic Mortality and Abnormalities of Aquatic Birds: Apparent Impacts by Selenium from Irrigation Drainwater." Science of the Total Environment 52: 49–63.

Ohmart, R. D., B. W. Anderson, and W. C. Hunter. 1988. "The Ecology of the Lower Colorado River from Davis Dam to the Mexico–United States International Boundary: A Community Profile." U.S. Fish and Wildlife Service, September.

Palacios, E., and Mellink, E.. 1993. "Additional Records of Breeding Birds from Montague Island, Northern Gulf of California." Western Birds. 24:259–262

Payne, Jack M., Frederic A. Reid, and Eduardo Carrere Gonzalez. 1992. "Feasibility Study for the Possible Enhancement of the Colorado Delta Wetlands, Baja California Norte, Mexico." Ducks Unlimited, Inc., and Ducks Unlimited of Mexico.

Peñas, Carlos. 1999. International Boundary and Water Commission. Personal communication, April.

Peresbarbosa, E., and E. Mellink. 1994. "More Records of Breeding Birds from Montague Island, Northern Gulf of California." Western Birds 25:201–202

Pontius, Dale. 1997. "Colorado River Basin Study: Final Report to the Western Water Policy Advisory Commission." Western Water Policy Advisory Commission.

Postel, Sandra, Jason I. Morrison, and Peter H. Glick. n.d.. "Allocating Fresh Water to Aquatic Ecosystems: The Case of the Colorado River Delta." Unpublished manuscript.

Presser, Theresa S. 1994. "The Kesterson Effect." Environmental Management (18)3: 437–454.

Presser, Theresa S., Marc A. Sylvester, and Walton H. Low. 1994. "Bioaccumulation of Selenium from Natural Geologic Sources in Western States and its Potential Consequences." Environmental Management 18(3): 423–436.

Renteria, Carlos de la Parra, and Daniel F. Luecke. 1997. "Ecoparque: An Innovative Low-Tech Approach for Water Use and Resource Enhancement in the Tijuana River Valley." Environmental Defense Fund.

Rice, Jake, Bertin W. Anderson, and Robert D. Ohmart. 1984. "Comparison of the Importance of Different Habitat Attributes to Avian Community Organization. Journal of Wildlife Management 48(3): 895–911.

Rosenberg, V., R. Ohmart, W. Hunter, and W. Anderson. 1991. Birds of the Lower Colorado Valley. University of Arizona Press.

Schwartzlose, Richard A., D. Alvarez-Millan, and P. Brueggeman. 1992. "Gulf of California: Bibliography of Marine Sciences." Universidad Autonoma de Baja California.

Smith, Rodney T. 1996. "Water Marketing: Building Flexibility into Water Allocations." In Proceedings from the Colorado River Workshop. Phoenix, Arizona.

Snead, R. E. 1987. "Man's Response to Change in the Coastal Zone of Pakistan." Resource Management and Optimization 4: 371–401.

Spamer, E. E. 1990. Bibliography of the Grand Canyon and Lower Colorado River from 1540. Publication of the Grand Canyon Natural History Association, Grand Canyon, Arizona.

Stanley, D. J., and A. G. Warne. 1993. "Nile Delta: Recent Geological Evolution and Human Impact." Science 260: 628–634.

Sykes, Godfrey. 1937. The Colorado Delta. Carnegie Institution of Washington and American Geographical Society of New York.

Tanner, Rene, Jaqueline Garcia, Donald Baumgartner, Edward Glenn, and James Riley. 1997. "Evapotranspiration of *Typha* in the Ciénega de Santa Clara: Water Volume Requirements and Salinity Effects. Selenium Findings in Soil, Water, Plant and Animal Tissue with Recommendations." U.S. Bureau of Reclamation #1425-97-PG-81-65258.

Thompson, R. W. 1968. "Tidal Flat Sedimentation on the Colorado River Delta, Northwestern Gulf of California." Memoir 107. Geological Society of America.

Valdés-Casillas, Carlos, O. Hinajosa-Huerta, M. Muñoz-Viveroz, F. Zamora-Arroyo, Y. Carrillo-Guerrero, S. Delgado-Garcia, M. López-Camacho, E. Glenn, J. Garcia, J. Riley, D. Baumgartner, M. Briggs, C. T. Lee, E. Chavarrià-Correa, C. Congdon, and D. Luecke. 1998a. "Information Database and Local Outreach Program for the Restoration of the Hardy River Wetlands, Lower Colorado River Delta, Baja California and Sonora, Mexico." A report to the North American Wetlands Council.

Valdés-Casillas, Carlos, Edward Glenn, Mark Briggs, Chris Lee, and Chelsea Congdon. 1998b. "Revegetation of the Colorado River Delta, Mexico, through Pulse Flooding and Disposal of Agricultural Waste Waters." Unpublished manuscript.

Valdés-Casillas, Carlos, Edward Glenn, Mark Briggs, Christopher Lee, Chelsea Congdon, Don Baumgartner, Yamilett Cassillo-Guerrero, Elena Chavarria-Correa, Jaqueline Garcia, Osvel Hinojosa-Huerta, Pat Johnson, Judy King, Dan Luecke, Manuel Muñoz-Viveros, and Jim Riley. 1998c. "Vegetation Habitat Value and Water Requirements of Wetlands in the Flood Plain of the Colorado River Delta, Mexico." Unpublished manuscript.

Valdés-Casillas, Carlos, O. Hinajosa-Huerta, Y. Carillo-Guerrero, F. Zamora-Arroyo, M. Muñoz-Viveros, S. Delgado-Garcia, M. López-Camacho, E. Glenn, J. Garcia, J. Riley, D. Baumgartner, M. Briggs, C. T. Lee, E. Chavarrià-Correa, C. Congdon. 1998d. "Wetland Management and Restoration in the Colorado River Delta: The First Steps." Unpublished manuscript.

Varady, Robert G., David Colnic, Robert Meredith, and Terry Sprouse. 1996. "The U.S.- Mexican Border Environmental Cooperation Commission: Collected Perspectives from the First Two Years." Journal of Borderland Studies XI(2).

Wilkinson, Charles F. 1992. The Eagle Bird: Mapping a New West. Pantheon Books.

Williams, Anita Alvarez de. 1983. "Cocopa." Pp. 99–113 in Alfonso Ortiz, ed. Handbook of North American Indians. Vol. X. Smithsonian Institution Press.

Ybarra, Robert. 1999. International Boundary and Water Commission, personal communication.

Zengel, S., V. Mertetsky, E. Glenn, R. Felger, and D. Ortiz. 1995. "Ciénega de Santa Clara, a Remnant Wetland in the Rio Colorado Delta (Mexico): Vegetation Distribution and the Effects of Water Flow Reduction." Ecological Engineering 4: 19–36.

APPENDIX A

SELECTED FLORA AND FAUNA OF THE COLORADO RIVER DELTA

1. Vegetation

(Valdés-Casillas, et al., 1998a)

Common Name	Scientific Name
Iodinebush	Allenrolfia occidentalis
Quail Bush	Atriplex lentiformis
Mule's Fat	Baccharis salicifolia
Palmer's Salt Grass	Distichlis palmerii
Common Reed	Phragmites australis
Arrowweed	Pluchea sericea
Cottonwood	Populus fremontii
Screw Bean	Prosopis pubescens
Willow	Salix spp.
Bulrush	Scirpus spp.
Tamarisk	Tamarix chinensis
Five-Stamen Tamarisk	Tamarix ramosissima
Cattail	Typha domengensis

2. Birds

(Brown, 1985 as cited in Valdés-Casillas et al., 1998a; Eddleman, 1989, cited in Glenn et al., 1992; Mellink et al., 1997; Palacios and Mellink, 1993; Peresbarbosa and Mellink, 1994; Western Shorebird Network, 1993, cited in Valdés-Casillas et al., 1998a)

Common Name	Scientific Name
Large-billed Sparrow	Ammodramus sandwichensis rostratus
Northern Pintail	Anas acuta
American Wigeon	Anas americana
Cinnamon Teal	Anas cyanoptera
Northern Shoveler	Anas clypeata
Blue-winged Teal	Anas discors
White-fronted Goose	Anser albiferens
Great Egret	Ardea alba
Great Blue Heron	Ardea herodias
Canvasback	Aythya valisineria
Brant	Branta bernicla
Canadian Goose	Branta canadensis

Green-backed Heron	Butorides striatus
Peep, Sandpiper	Calidris spp.
Gambel's Quail	Callipepla gambelii
Willet	Catoptrophorus semipalmatus
Belted Kingfisher	Ceryle alcyon
Snowy Plover	Charadrius alexandrinus
Lesser Snow Goose	Chen caerulescens
Northern Harrier	Circus cyaneus
Yellow-billed Cuckoo	Coccyzus americanus
Yellow Warbler	Dendroica petechia
Snowy Egret	Egretta thula
Willow Flycatcher	Empidonax trailii
Peregrine Falcon	Falco perigrinus
American Coots	Fulica americana
Common Moorhens	Gallinula chloropus
Common Loon	Gavia immer
Greater Roadrunner	Geococcyx californianus
American Oystercatcher	Haematopus palliatus
Bald Eagle	Halieatus leucocephalus
Black-necked Stilt	Himantopus mexicanus
Yellow-breasted Chat	Icteria virens
Least Bittern	Ixobrychus exilus
Laughing Gull	Larus atricilla
Ring-billed Gull	Larus delawarensis
Heermann's Gull	Larus heermanni
Dowitcher	Limnodromus spp.
Marbled Godwit	Limosa fedoa
Red-breasted Merganser	Mergus serrator
Long-billed Cerlew	Numenius americanus
Black-crowned Night Heron	Nycticorax nycticorax
Ruddy Duck	Oxyura jamaicensis
Osprey	Pandionm hiliaetus
American White Pelican	Pelecanus erythrorhynchos
Brown Pelican	Pelicanus occidentalis
Double-Breasted Cormorant	Phalocrocorax auritus
Abert's Towhee	Pipilo aberti
Summer Tanager	Pirangra rubra
White-faced Ibis	Plegadis chihi
Black-bellied Plover	Pluvialis squatarola
Pied-billed Grebe	Podilybus podiceps
Soras	Porzana carolina
Vermilion Flycatcher	Pyrocephalus rubinus
Virginia Rails	Rallus limicola
Yuma Clapper Rail	Rallus longorostris yumanensis
American Avocet	Recurvirostra americana
Black Skimmer	Rhynchops niger

Caspian Tern	Sterna caspia
Forster's Tern	Sterna forsteri
Royal Tern	Sterna maxima
Gull-billed Tern	Sterna nilotica
Crissal Thrasher	Toxostoma crissale
Bell's Vireo	Vireo bellii
White-winged Dove	Zenaida asiatica
Mourning Dove	Zenaida macroura

3. Mammals

(Valdés-Casillas et al., 1998a)

Common Name	Scientific Name
Bat (several spp.)	
Coyote	Canis latrans
Skunk	Conepatus mesoleucus
Bobcat	Felis rufus
Jackrabbit	Lepus spp.
Desert Rat	Neotoma spp.
Muskrat	Ondatra zibethicus
Raccoon	Procyon lotor
Squirrel	Spermophilus spp.
Rabbit	Sylvilagus audubonii
Gopher	Thomomis spp.

4. Fish and Other Aquatic Species (including some found in the near-shore marine environment of the Gulf of California)

(Valdés-Casillas et al., 1998a)

Common Name	Scientific Name
Totoaba	Cynoscion macdonaldii
Corvina	Cynoscion xanthalus
Desert Pupfish	Cypranodon macularius
Carp	Cyprinus carpio
Catfish	Ictalurus spp.
Big-mouth bass	Micropterus samoides
Mullet	Mugil cephalus
Vaquita Porpoise	Phoceana sinus
Tilapia	Tilapia spp.
Shrimp	

APPENDIX B

APPENDIX B Materials and Methods Used in the Study of the Vegetation, Habitat Value, and Water Requirements of Wetlands in the Flood Plain of the Colorado River Delta, Mexico (Valdés-Casillas et al., 1998b)

Delineation of the Floodplain

Watercourses and the extent of flooded soils were mapped through a process of manual interpretation and screen digitizing based on a February 21, 1997, satellite image taken when the river was flowing at 100 m^3 sec-1 (Fig. 1). The accuracy of the interpretation was checked by overflying the delta at 1000 m on February 27, 1997. All cross-border water flow data were supplied by the International Boundary Water Commission, Yuma, Arizona. Flows in the river below Morelos Dam were measured at the Southern International Boundary (SIB) 35 km downstream from the dam. These flows required three to five days to reach the Gulf of California (Goeff, A., personal communication, IBWC, Yuma, Arizona). We determined the effect of river flow on salinity in the intertidal and marine zone on January 12, 1998, during a flow of 202 m^3 sec^{-1}. Water was sampled from a small boat during low tide and salinity was measured using a handheld refractometer (American Optical).

Vegetation Mapping

We measured biomass intensity based on a spectral analysis of a July 15, 1997, satellite image taken during a period of no river flow, following winter releases of approximately 4.0×10^8 m^3. Preprocessing and geometric rectification of the images 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 al. (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 0.4801, 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 areas of *Distichlis palmeri* (salt grass) cover confined to the intertidal zone. The remaining values were divided into two broad classes. The first comprised the remaining negative values, which included areas dominated by scrubby vegetation 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 that 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, and W2, associated with the lower biomass-intensity 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 1:6000) taken July 31, 1997, supplied by the United States Bureau of Reclamation, Yuma Projects Office, Yuma, Arizona. The vegetation along this stretch of river was dominated by thick, nearly homogeneous stands of *Salix goodingii* which we assigned to the R1 vegetation class. We used the aerial photographs to determine the area of the floodplain covered by *Salix*, 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. 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 floodplain 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 floodplain accessible by vehicle or small boat were inspected. On each survey, species composition and relative abundance were determined at numerous sites throughout the delta, with positions located using a Global Positioning System. 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).

POTENTIAL AVIAN HABITAT VALUE OF THE RIPARIAN PLANT ASSOCIATIONS

We classified the high-intensity riparian (R1) vegetation according to its species composition and vertical structural complexity using the system developed for evaluating wildlife habitat on the lower Colorado River in the United States (Anderson and Ohmart, 1986). We did not use quantitative, transect methods to evaluate the vegetation because of the large area involved and limitations of resources available to conduct the surveys. However, in most cases the vegetation could be unambiguously assigned to one of the broad categories recognized by Anderson and Ohmart (1986). In March 1998, we inspected approximately 25 sites along the main channel of the river from Morelos Dam to the tidally influenced portion of the river, to characterize the high biomass-intensity (R1) vegetation. We used an aerial videograph of the river from Morelos Dam to Montague Island, filmed in September 1998, to determine break points in vegetation types.

The vertical structure of the riparian vegetation was assigned to one of six possible types based on the percent of foliage density estimated to fall into understory (<0.6 m), midstory (0.6-4.5 m), and overstory (>4.5 m) vegetation layers. Only four classes were commonly encountered in our study: Type 1 (open gallery forest, consisting of broken overstory vegetation alternating with open areas dominated by midstory and understory vegetation); Type II (closed gallery forest, consisting of a closed overstory canopy with sparse midstory and understory vegetation); Type III (scrub thickets dominated by midstory vegetation); and Type IV (broken midstory scrub thickets alternating with patchy understory shrub vegetation). The vegetation was further classified into one of the six common species associations recognized by Anderson and Ohmart (1986), based on the dominant tree or shrub species present. The major associations we encountered in areas delineated as R1 vegetation were: 1) *Populus fremontii-Salix goodingii* (cottonwood-willow) mix; 2) *Tamarix ramosissima-Prosopis glandulosa var. torreyana-Prosopis pubescens-Pluchea sericea* (salt cedar-mesquite-arrowweed) mix; and 3) near-monocultures of *Tamarix.* We found an additional association-*Salix goodingii* thickets with occasional, individual specimens of *Populus*-which is not listed in Anderson and Ohmart (1986), apparently because it is no longer found above Morelos Dam.

The potential habitat value of the R1 vegetation was estimated using data in Anderson and Ohmart (1986) for nine key species each of resident and nonresident summer birds. The avifauna density has been found to be a good indicator of overall habitat value along the lower Colorado River (Ohmart et al., 1988). The expected density of each species per 40 ha patch was determined based on both species composition and vertical structure. The data in Anderson and Ohmart (1986) represent three years of field study and a multivariate analysis of bird distribution in lower Colorado River riparian habitats (Rice et al., 1980, 1983, 1984). We did not independently study bird density, but the species composition of the avifauna in the Mexicali Valley in Mexico shares continuity with that of the lower Colorado River in the United States (Ruiz-Campos and Rodriguez-Merez, 1997). We did not use the Anderson and Ohmart (1986) system for classifying emergent, hydrophyte vegetation in the marshes, because the system was not designed to estimate these specialized habitats.

Literature Cited

Anderson, B. W., and R. D. Ohmart. 1986. "Vegetation." Pages 639-660 in A.Y. Cooperrider, R.J. Boyd, S. Hanson, and S. McCulloch, eds. Inventory and Monitoring of Wildlife Habitat. U.S. Department of the Interior, Bureau of Land Management, Washington, D.C.

Felger, R., B. Broyles, M. Wilson, and G. Nabhan. 1997. "The Binational Sonoran Desert Biosphere Network and Its Plant Life." Journal of the Southwest 39: 411-560.

Huete, A. R. 1988. "A Soil-adjusted Vegetation Index (SAVI)." Remote Sensing of the Environment 25: 295-309.

Marsh, S. E., J. L. Walsh, C. T. Lee, L. R. Beck, and C. F. Hutchinson. 1992. "Comparison of Multi-temporal NOAA-AVHRR and SPOT-XS Satellite Data for Mapping Land-cover Dynamics in the West African Sahel." International Journal of Remote Sensing 13: 2997-3016.

Ohmart, R., B. Anderson, and W. Hunter. 1988. "Ecology of the Lower Colorado River from Davis Dam to the Mexico-United States Boundary: A Community Profile." National Technical Information Service, Alexandria, Virginia.

Rice, J., B. W. Anderson, and R. D. Ohmart. 1980. "Seasonal Habitat Selection by Birds in the Lower Colorado River Valley." Ecology 61: 1402-1411.

Rice, J., B. W. Anderson, and R. D. Ohmart. 1983. "Habitat Selection Attributes of an Avian Community: A Discriminant Analysis Investigation." Ecological Monographs 53: 263-290.

Rice, J., B. W. Anderson, and R. D. Ohmart. 1984. "Comparison of the Importance of Different Habitat Attributes to Avian Community Organization." Journal of Wildlife Management 48: 895-911.

Ruiz-Campos, R., and M. Rodriguez-Merez. 1997. "Composicion Taxonomica y Ecologica de la Avifauna de los Rios El Mayor y Hardy, y Areas Adyacentes, en el Valle de Mexicali, Baja California, Mexico." Anales del Instituto de Biologia (Universidad Nacional Autonomade Mexico, Serie Zoologia) 68: 291-315.

Tucker, C., C. Vanpraet, E. Boerwinkel, and A. Gaston. 1983. "Satellite Remote Sensing of Total Dry Matter Production in the Senegalese Sahel." Remote Sensing of the Environment 13: 461-474.

Zengel, S., V. Mertetsky, E. Glenn, R. Felger, and D. Ortiz. 1995. "Ciénega de Santa Clara, a Remnant Wetland in the Rio Colorado Delta (Mexico): Vegetation Distribution and the Effects of Water Flow Reduction." Ecological Engineering 4: 19-36.

APPENDIX C: Public Involvement in the Management and Restoration of the Colorado River Delta

Community and Institutional Strategies and Goals

Contents

Page

I. Presentation to Public Involvement Workshops C-2

II. Institutional Workshops for the Management and Restoration of the Colorado River Delta Wetland C-3

- Institutional Presentations
- Institutional Perception of the Management and Restoration of the Colorado River Delta Wetlands
- New Collaborative Links for the Management and Restoration of the Colorado River Delta Wetlands
- Community Needs
- Environmental Needs
- The Next Steps in Institutional Participation

III. Public Involvement Workshops 1 & 2 for the Management and Restoration Of the Colorado River Delta Wetlands Workshops C-13

- 1st Series of Public Involvement Workshops
- 2nd Series of Public Involvement Workshops

IV. Public Involvement Workshop 3 for the Management and Restoration of the Colorado River Delta Wetlands C-16

- Community Opinions Concerning the Management and Restoration Recommendations for the Riparian Corridor of the Colorado River delta, Hardy/Colorado Wetlands, and El Indio Wetland System
- Community Strategies for Implementing the Recommendations of Management and Restoration

V. Work Party for the Management and Restoration of the Natural Resources of the Flor del Desierto Ejido C-20

- The Ejido´s Current Situation
- Recommendations for the Flor del Desierto Ejido

VI. Directory of Contacts and Participants C-22

I. Presentation to Public Involvement Workshops (PIW)

The public involvement workshops integrate the community outreach component of the project "Manejo y Restauracion del Delta del Rio Colorado, Baja California y Sonora, Mexico" (Management and Restoration of the Colorado River Delta, Baja California and Sonora, Mexico), that is carried out by the ITESM Campus Guaymas, Pronatura Sonora, The University of Arizona, and the Sonoran Institute, in coordination with la Biosfera del Alto Golfo de California y Delta Rio Colorado (Upper Gulf of California and Colorado River Delta Biosphere).

The objective of the PIW's is to initiate a process with those who work in agriculture and those who live on river banks in the swamp areas and the delta region, that allows them to be involved in the decision making process concerning the resources that exist in their wetlands and the irreplaceable benefits they gain from the environment in it's natural state. Therefore, creating a conscience on a binational level about the importance of considering the Colorado River as a user of its own waters and expressing a solution for the management of its flow is a fundamental objective of the effort that has been initiated through the PIW.

The focus of the first three workshops, conducted during the course of this year, was to characterize the wetland systems on the banks of the Colorado River, the Pescadores River, the Hardy River, and the Cienega de Santa Clara, by analyzing their ecological functions, the wetland services recognized by the community, and the resources and their users.

II. Institutional Workshop for the Management and Restoration of the Colorado River Delta Wetlands

Mexicali, Baja California

The workshop objectives included the establishment of foundations for dealing with the means of sustainable development within the sphere of the Colorado River delta community; the identification of institutional perceptions of their respective agendas as they relate to the management of the delta wetlands; the establishment of collaborative bonds between government agencies, academic institutions, and NGO's, as well as the identification and link between the necessities of the participants in the management of the Colorado River delta with the already existent institutional programs, and to initiate other programs.

The most significant result was the exchange of interinstitutional information that allowed for the generation of areas of intersectorial opportunity, in order to integrate, in the best possible way, planning under the current scenario. The participants identified how the next collaborative level should be to link government agencies, academic institutions and NGO's around the diffusion of achievements and the challenges resulting from this process; as well as the dissemination of information about the situation of the natural resources of the Colorado River delta, among the communities motivated to participate and the general public.

Institutional Presentations:

At the initiation of the workshop, representatives of government, non-government, and academic institutions presented the institutional focus that they each represent in regard to the general objective of this event. The following are some of those presentations:

"This is one of those jobs that will probably be of importance to the municipality. We know of the wetland zone and the thousands of hectares with great potential for recuperation that cover the surface of the Colorado River delta. Surely they will be positively effected as a result of this workshop. Furthermore, we trust that the municipality will support the exchange of information. We are at your disposition."

-- Sergio Montes Montoya --
Director of Catastro, Control Urbano y Ecologia (Urban Control and Ecology)
XVI City Council of the Municipality of Mexicali

"With the passage of time there are greater initiatives around the problems and protection of the environment. Being aware of the fundamental aspect of this Secretariat, which is the protection of the environment, I urge the necessity of generating a multiplying interinstitutional effect and directing this effort toward the general society. It is our task to generate a new culture around the environment and the rational use of natural resources. The delegation of SEMARNAP in Baja California is willing to comply with whatever initiative these workshops lead to."

-- Hugo Abel Castro Bojorquez --
Delegado Federal de SEMARNAP (SEMARNAP Federal Delegate)

"The first user has the first right. The Colorado River delta was the first user of the water. Returning the rights to the original user is the best way to restore the environment."

-- Francisco Oyarzabal Tamargo --
Gerente Regional de la Peninsula de B.C.
(Regional Manager of the Baja California Peninsula)
Comision Nacional del Agua (National Water Commission)

"We manage the waters for the Mexicali, Ensenada, and Tijuana zones. The importance of this event to us is obvious."

-- Jose Alberto Casteñeda --
Director de la Comision de Servicios
de Agua del Estado (COSAE)
(Director of the Commission of State Water Services)

"Whatever effort will be channeled toward scientific training and knowledge is appreciated and encouraged by the Direccion de Ecologia (Ecology Office). We consider education to be the foundation of solutions for all environmental problems."

-- Adolfo Gonzalez --
Director de Ecologia del Estado (Director of State Ecology)

"We support environmental conservation efforts."

-- Frank Zadroga --
U.S. Agency for International Development (AID)

"Our responsibility is to receive water that is passed over to us from the United States. We are coordinating binational groups for the awareness of border problems with volume and drainage of the Colorado River."

-- Francisco Bernal --
Subdirector Tecnico Operativo (Technical Operation Subdirector)
Comision Internacional de Limites y Aguas
(International Commission of Water and Boundary)

"We work in order to generate and validate technology, which, in the case of agrochemicals, we are yet to be fully aware of eventual side effects. Surely, to know more about these other ecological aspects will help us to learn a form of technological design for agriculture without the side effects, which present themselves in wildlife areas such as wetlands."

-- Abelardo Reynosa Vega --
Director Regional INIFAP-CIRNOR
(Regional Director INIFAP-CIRNOR)

"One of the important aspects that has to be seen in terms of the wetlands, community, and environment, is education. CECADESU is at your disposal in order to collaborate together with the education sector for the generation of a didactic focused on sustainable development."

-- Talpa Dolores Lara Moreno --
Jefe del Centro de Educacion y Capacitacion
para el Desarrollo Sustentable CECADESU
SEMARNAP Deleg. B.C.
(Manager of the Center for Education and Training for Sustainable Development
CECADESU-SEMARNAP Delegation Baja California)

"Currently we are making efforts in order to promote aquaculture activities in the canals of the Mexicali Valley and the Hardy River."

-- Victor Roman Miranda --
Direccion de Pesca del Gobierno del Estado
(Office of State Government Fisheries)

"INEGI generates statistical and geographic information. The coverage of the geographic area 1:50000 and 1:250000, as well as the aerial photographs are at your disposal. The advantage of working with INEGI is the monitoring it is able to provide for the analysis of this zone. As well as the institutional focus that has me here, I have a personal interest, as I am a user of the Hardy River. The involvement of the people that live here is a decisive factor in the success of these projects. I ask the municipality to incorporate some very prominent element for the restoration and participation of the Mexicali society in the Municipal plan of Development and, together, with local universities, to promote the creation of careers focused on the environment."

-- Antonio Solano Larrañaga --
Coordinador Estatal de INEGI
(National Institute of Statistics, Geography, and Computing INEGI State Coordinator)

Institutional Perception of the Management and Restoration of the Colorado River Delta Wetlands:

The wetlands of the Colorado River delta are the direct and indirect targets of the ecological, social, economic, and cultural agendas of the institutions contributing to this workshop. Their integral planning and proactive connections ought to be a tool for the support of the communities in their management and restoration. Below is a list of institutions related to this initiative and their focus, resulting from the interinstitutional dialogue conducted during this event:

CNA (National Water Commission)

- Regulates, coordinates, operates, guards and administers hydrologic resources (e.g. water quality and environmental impact)
- Grants federal lands and waters
- Involved in the building of irrigation channels and drains
- Involved in protection against inundation
- Has a monitoring program in order to establish conditions of discharge for residual waters toward national bodies of water
- Monitors the carrying out of environmental impact studies
- Executes mitigation measures of the infrastructure created by CNA
- Inspects residual water discharge

SAGAR (Secretary of Agriculture, Ranch Catering, and Hydraulic Resources)

- Regulates aquaculture programs
- Executes federal support for farmers and livestock among others
- Regulates agrochemicals used in agriculture

Direccion de Pesca (State Fishing Office)

- Promotes and encourages commercial fishing
- Involved in projects of productive aquaculture in the Mexicali Valley

INEGI (National Institute of Statistics, Geography, and Computing)
- Conducts interviews and produces statistics of population, agriculture, and economics
- Produces Geographic Information Systems (GIS) data

PROCEDE (Communal Lands Certification Program)
- Collects and generates geographic information on a national scale
- Generates cartographic data of national territory and statistical information
- Measures and takes censuses of communal lands

SIAF (Agricultural and Forestry Information System)
- Generates, validates, and diffuses information concerning the primary farming and ranching sector
- Updates information for managers and users providing them with knowledge of advances in regard to the ecology as part of the agricultural area (farming & ranching)
- Updates urban and rural plans as well as topographic maps

SEDENA (Secretary of National Defense)
- Treats waste waters for use in the fields and military zones
- Constructs waste water treatment plants

CETYS (High-level and Technical Studies Center)
- Educates and trains personnel in regard to environmental administration
- Does not rely on a specific program, but is willing to collaborate

SEMARNAP Deleg. B.C. (Secretary of Environment, Natural Resources and Fishing)
- Regulates, legislates, and educates concerning ecology and the environment
- Involved in rural aquaculture, restoration of the environment and biodiversity, Border XXI Program, and trains foundational groups.

INE-SEMARNAP Unidad Coordinadora de Areas Protegidas (UCANP) (Center for Education and Training for Sustainable Development CECADESU-SEMARNAP Delegation Baja California)
- Protects the Reserve and its resources, provides economic alternatives to communities in and around the Reserve, supports research initiatives, restoration and sustainable use of the biodiversity and natural resources in the Reserve

Involved in the following:
- Management and administration of the Upper Gulf of California and Colorado River Delta Reserve
- Environmental Politics of the country and Ecological Regulation
- National Environmental Program (1995-2000)
- National Wildlife Program (fish, aquaculture, hydrologic resources)
- Reserve Management Program (1995)
- Protection of biodiversity and regulation of natural resource use
- Border XXI Environmental Program
- Northern Border Program -- World Bank
- Sisters Reserve Committee -- Mexico/U.S.

CILA (International Water and Boundary Commission)
- Monitors international agreements and trade regarding water volume and quality
- Produces hydrometry data and monitors water quality
- Coordinates binational institution groups and the implementation of the hydrometry bulletin

ISE-SALUD (State Health Institute)
- Coordinates actions of environmental health and basic clean up in Baja California
- Monitors water quality and distribution to the populace
- Supervises adequate management of domestic solid waste

Comite de Manejo y Restauracion del Rio Hardy (Committee for the Management and Restoration of the Hardy River)
- Involved in conservation of the Hardy River
- Participates in community organizing in order to analyze the environmental problem
- Generates and promotes possible solutions
- Promotes and negotiates for the conservation of natural resources before the appropriate authorities, the Mexicali community, the republic states and international communities, and shows the benefits and the potential for ecotourism and fishing, among other activities in the Hardy River zone.

INFORMA, A.C.
- Consults and supports users of natural resources and agrosystems
- Consults groups that develop activities in the following zones: Sombrerete 1, Camacho, Col. Vicario, Grupo Lerma Norte, and Plan de Ayala
- Involved in the restoration of the natural environment with respect to planting, harvesting, and germination of mesquite seeds
- Provides consultation in regard to the reuse of drained agricultural water

Direccion General de Ecologia (General Agency of Ecology)
- Faculty that grants authorization for the installation of competing state companies
- Regulates emissions into the atmosphere and the discharge of residual water into the environment

U.S. AID (American International Development)
- Supports activities for the conservation of the biological diversity of Mexico and mitigation of climate change
- Supports the strengthening of Mexican environmental organizations
- Supports the Upper Gulf of California and Colorado River Delta Reserve, protected areas, fish, and management of coastal zones

New Collaborative Links for the Management and Restoration of the Colorado River Delta Wetlands:

Creating greater inertia for the encouragement of the management and restoration of the Colorado River delta wetlands is an obligatory path for this project, in order to escalate sectorial co-responsibility and to encourage its integration. In order to fulfill this objective at the workshop, the following dynamics were considered:

- Identification of areas of sectorial co-responsibility among institutions and agreement (if there is any), concerning the needs of the community and the environment of the Colorado River delta.
- Identification of opportunities for connecting with others in the areas of sectorial co-responsibility.

Community Needs

Institutions of the state of Baja California and the Mexicali Municipality continue to show the possibility for collaborative links based on the following community necessities, identified during the first and second series of PIW's in the Colorado River delta.

Maintaining the greatest volume of water in the rivers and assuring that the quality of water is adequate for the inhabitants and the wildlife of the Colorado River delta.

INEGI
Generates cartographic data of subterranean and surface hydrology and houses aerial photographs.

CILA MEX-E.U. - Seccion Mexicana (International Water and Boundary Commision - IBWC)
Documents the impacts in Mexico as a result of the use of the Colorado River in the United States; CNA collaborates with CILA´s program that assigns water volume. The IBWC discusses the use of the river with United States users.

INE-SEMARNAP
Establishes or calculates a basic cost for environmental effects.

CNA
Promotes programs of efficient water use and supports all who are interested in raising public awareness. Conducts physical, chemical, and biological analysis of water, taking turns with CILA as an attendant in the American government in case of failure to comply with the accords established for each case.

INEGI/ CNA/ CILA
CNA monitors and supervises the flow of water. INEGI registers, analyzes and publishes the generated data. CILA verifies that the accords have been carried out.

D.G.E. (General Ecology Office) B.C. (Baja California)/ INE-SEMARNAP/ SEMARNAP
The General Ecology Office in Baja California keeps an eye on regulations in regard to the quality of water.
INE-SEMARNAP regulates and monitors the population and wildlife
SEMARNAP Delegation in Baja California is involved in regulation and environmental vigilance

Preventing and correcting the presence of clandestine dumping and preventing the burning of garbage and sheaf.

Iniciativa Privada (I.P.) (Private Initiative)
Reports and issues sanitation complaints of detected clandestine dumping of garbage.

INEGI
Provides thematic cartography with technical support for the identification of clandestine dumping.

CNA/ SAGAR/ INEGI
Devise coordinated programs of vigilance and promote legislation for the application of fines for offenders. INEGI informs CILA and CNA of the presence of clandestine dumping and discharges of residual waters noticed on aerial photographs.

ISE-SALUD
Receives complaints of sanitation problems in the jurisdiction in order to track and resolve them. Applies the current official regulations in concordance with the Department of Public Services and the Legal Department and City Council of Mexicali. Provides recommendations for the construction of land fills and adequate facilities among communities that present problems. Offers information to the populace that present their complaints in the Jurisdiction of Public Health of Mexicali.

INE-SEMARNAP
Negotiates training and assistance for those communities that decide to manage their solid waste.

SEMARNAP Deleg. B.C. (SEMARNAP Delegation Baja California)
Raises public awareness, regulation, and training.

Supporting the training of people regarding themes related to the sustainable use of resources, such as hunting, fishing, tourism, alternative agricultural, and aquacultural activities, among others.

I.P - Hunting Organizer (Private Initiative)
Coordinates with SEMARNAP and PROFEPA to offer courses on the sustainable use of flora and fauna. Participates in international forums that deal with issues of sustainable development of our resources.

ISE-SALUD
Coordinates with SEDECO (Secretary of Community Development); provides consultation for aquaculture certification; provides information about the criteria of the General Office of Environmental Health, and the FDA, in order to obtain certification for aquacultural areas for the production of products for exportation.

INEGI
Coordinates with SECTUR (Secretary of Tourism) to make tourist maps for the Colorado River zone.

CILA
Links the exchange of information and technology with agencies and user organizations of United States water.

CNA
Coordinates with INEGI to prepare environmental regulations, water treatment plants, and the control of municipal sewage discharge.

SEMARNAP Deleg. B.C. (CECADESU)
Offers courses and workshops in regard to environmental topics.

Comite de Usuarios del Rio Hardy
Supports the development of infrastructure and projects for the training and strengthening of activities (e.g. aquaculture).

INFORMA A.C.
Involved in the mesquite project.

INE-SEMARNAP
Offers courses, workshops and discussions concerning the users of the Reserve resources, publication of material for the support of training and public awareness.

Promoting community projects focused on the sustainable use of natural resources

I.P. (Private Initiative)
Offers information and opportunities for the formation of human resources in the hunting organization with the support of SEMARNAP and through SAGAR with the "Alianza para el Campo" (El Campo Alliance) program.

Gobierno del Estado de Baja California (Secretaria de Fomento Agropecuario)
Supports agricultural projects.

INE-SEMARNAP
Supports specific projects (ecotourism, aquaculture, and fishing).

SEMARNAP Deleg. B.C. (Delegation Baja California)
Involved in rural aquaculture projects.

CNA/ INEGI/ CILA CNA/ INEGI
Provide information for community projects and academicians that coordinate with the CILA project "Saneamiento de las Aguas del Rio Colorado" (Cleaning the Colorado River Water).

Promoting the integral development of communities.

CNA/ ISE-SALUD/ GOB. MPAL.
Monitor residual chlorine in water supplies as part of the activities of CNA's "Agua Limpia" (Clean Water) program, in which ISE-SALUD and the municipal Government participate.

Environmental Needs

Institutions of the state of Baja California and the Mexicali Municipality continue to show the possibility for collaborative links based on the following environmental necessities, identified during the first and second series of PIW's in the Colorado River delta.

Receiving large quantities of water from the United States with environmental objectives.

I.P. (Private Initiative)
Supports the presentation of petitions to rural agricultural organizations.

CILA
Deals in international negotiations.

CNA/ INEGI/ SAGAR/ D.G.E.
Each office provides support and information.

Obtaining recognition from the general public of the ecological importance of the delta (e.g. government, communities, academicians, researchers, NGO's).

CILA/ CNA (Comunicacion Social)/ INEGI
Provide information to the UABC (Autonomous University of Baja California) for the spreading of information.

ISE-SALUD
Prevents and corrects the inadequate regulation insecticide packs.

Obtaining legal protection of the delta wetlands that exist outside of the reserve, primarily those locales within the system of levees, which includes: the Riparian Corridor of the Colorado River delta, the Hardy/Colorado Wetlands, and El Indio Wetland System.

CNA
Reviews land tenure along the length of the Colorado River in order to propose a more convenient legal form of protection.

Promoting management programs that consider the environment as another user of the River.

CILA
Seeks this promotion through international negotiations.

SAGAR
Supports this goal through the "Alianza para el Campo" (El Campo Alliance) program's component that deals with the environment as another user of the River.

Supporting hydrologic infrastructure for ecological restoration including dredging, reopening of old river beds, and creation of open water zones.

ISE-SALUD
Conducts investigations of atmospheric contamination and, in relation to this, justifies the necessity of restoring wetlands (such as the production of erosive particles that effect Mexicali).

CILA
Participates in dredging with binational participation for the removal of sediment.

CNA
Reviews and validates suitable projects for the ecological restoration of river beds.

Working so that the United States Government might recognize the importance of this ecosystem as an essential part of the Lower Colorado River Basin.

CILA/ CNA/ SEMARNAP/ United States Agencies/ NGO's
Currently working on this aspect.

CILA
Through binational working parties, forms forums in order to discuss this point.

CNA/ INEGI/ SAGAR/ D.G.E
Each office provides information for the elaboration of support documentation.

The Next Steps in Institutional Participation:

The consensus of the fertile discussion moderated during the round table session of this workshop, is to initiate the diffusion of information concerning the environment and its principle challenge: acquiring financial resources.

Therefore, SEMARNAP, through CECADESU, offers its periodically published environmental gazette, in spite the limited number of copies.

It has been agreed upon that the diffusion of information concerning the environment ought to be directed by governmental organizations toward community committees through the medium of specialized channels. Such channels can be facilitated by academic institutions and non-government institutions. The required funding can be obtained through joint proposals headed by one principal organization. The objective of this "beginning" is to diffuse the achievements and challenges of this communal and interinstitutional effort to the general public, as well as providing knowledge to interested communities about the fragility of the natural resources and about the possibilities and implications of restoring the Colorado River delta.

The concern of various participants for the impossibility of Mexico to acquire this practice doesn't overshadow communities' desires and the civil interest expressed by others not hindered by a lack of financial resources. As far as government organizations are concerned, the budget for public expenditure by the end of this century will be reduced, thus, right now, they must define the difference between urgent and important.

Currently, environment information is available to those who, for work and academic responsibilities, have to manage it in order to fulfill their obligations. Because of this they are able to involve individuals and communities in whatever manner they are willing to participate for the generation of information concerning the environment. However, to what extent can we be sure that they understand what they are looking for? To what extent will these people and their communities be convinced to carry out the conclusions, objectives, aims, and activities of these government, non-government, and academic programs? Information about the environment ought to be the axis that maintains units of attribution of each governmental, non-governmental, and academic organization, as well as the community in general.

We imagine that we form part of a pyramid where at the top are those primary users of the information, primary participants in the decision making process, and those responsible in terms of the use of public expenditure. The middle part of the pyramid is where organizations interested in the environment which, in one form or another, provide some information to the community in general according to their funds. Finally, the base of the pyramid consists of common people who use the natural resources everyday and neither have a complete understanding of nor easy access to information about the environment, because the NGO's, academicians, and government lack sufficient resources to adequately diffuse the information.

III. Public Involvement Workshops 1 & 2 for the Management and Restoration of the Colorado River Delta Wetlands

The public involvement activities included two series of workshops, divided in two work areas. The first area is located in Baja California in the Mexicali Valley (Mexicali municipality) and includes communities from around the Colorado River, Pescaderos River and Hardy River. The second area is located in Sonora at Cienega de Santa Clara (San Luis Rio Colorado municipality) and specifically works with communities settled in the Biosphere Reserve buffer zone. For in Mexicali Valley, Campo Mosqueda was selected to carry out this and subsequent public events in Baja California and Cienega de Santa Clara workshops Ejido Luis Encinas-Johnson, Ejido Mesa Rica, and Ejido Flor del Desierto were chosen to carry out this and subsequent public events in Sonora.

During workshops group focused strategies are developed for building teams from different productive sectors, including fishermen, farmers, government agencies, tourist promoters, research and education centers, and non government organizations. The various groups' ideas and perceptions concerning the management strategies for the wetlands are considered in order to reach an integral and sustainable development.

1st Series of Public Involvement Workshops:

People came to the first "TIP" series and began working on a detailed description of these environments; the resources they have, their values, functions, and conflicts. The goal of these community gatherings was to make a clear connection between people, present threats to the environment, and a common future vision of their restoration: community stewardship being the base line. The expected results from this stage are the first steps from each community, whatever they decide them to be, towards wetland restoration along the Colorado river delta.

Community members produced the following key information:

- Extensive list of common resources, and their users
- A visual distribution of these resources in local charts and maps
- Environmental priority problems resulting from human impact, through the use and abuse of such resources
- Alternative productive activities to sustain the current use of these resources
- A detailed written description of a future vision of the environment and their quality life, addressing specific attributes which imply a present change of attitude

Thus far, 52 peoples have participated, their ages ranging from 12 to 85 years old with an average of 27. Men and women are equally represented. Represented sectors include agriculture, aquaculture, fishing, tourism, hunting, ethnic groups, and local government officials.

Other related issues affecting wetlands in the Colorado River delta have been identified by the communities during the workshop, including:

- Inappropriate and forbidden fishing techniques and tools
- Increasing number of clandestine garbage dumps
- Inadequate disposal of pesticides
- Garbage burning

- Invasion of federal lands
- Lack of law enforcement

Regardless of the overwhelming list of obstacles, participants at the workshops have expressed their willingness to be involved in the decision making processes toward the vision they have stated regarding the natural environment:

> "To be able to have a reforested landscape, with native plants and allow the river to flow constantly, avoiding sedimentation. To become skilled to use more efficient tools for commercial fishing and to be able to develop an aquaculture site at Laguna Salada. To attract national and foreign tourism and conduct with them activities focused on environmental enhancement like hunting ranches. To plant dates, figs, and mesquite fields associated with apiculture. To promote goat and quail nurseries."
>
> Farmers, fishermen, Cucapa people, tourist promoters at Campo Mosqueda

> "People from Cienega de Santa Clara would like to be nationally and internationally recognized by their resource management practice and that the cienega would maintain its natural conditions to support fish and bird life. The current productive projects (aquaculture and ecotourism) are growing and better, generating jobs and resources to provide the community with water supply, telefono and roads, a sports center, a health center and a secondary school; everything constantly guarded."
>
> Teachers, farmenrs, fishermen, ecotourism promoters al Cienega de Santa Clara

2nd Series of Public Involvement Workshops:

During the second series of workshops 45 people participated, men and women equally represented, there ages ranging from 17 to 75. This group represented ejidos, cooperative fisheries, tourism promoters, government agencies, indigenous communities, farmers, ranchers, and the media.

The proposal of the second workshop was to establish a foundation for beginning the process of management participation of these wetlands, defining criteria, and common objectives.

The result was the identification of the most imminent negative impacts generated by the communities of the delta.

Negative Impacts:

- The community has observed other fisherman using prohibited nets.
- Fisherman leave their nets in the water for more than 12 hours pulling spoiled fish out.
- Fishing in the nuclear zone.
- Cleaning fish and dumping the waste into the river.
- Fishing with electric cables.
- Discharging waste water.
- Industrial and agriculture wastes (herbicides, insecticides, fumigants, fertilizers, etc.).
- Solid wastes (garbage, paper, plastic, cans, etc.).
- Air pollution (tire burning, bonfires, agriculture residues, poorly maintained autos, factory outputs).
- Construction of latrines in communities with no sanitary drainage.

In order to be able to begin activities that directly solve environmental problems, it is necessary to form committees for the diffusion of ideas aimed at negative impacts.
Before defining the work agenda, the members of this workshop coincided to initiate activities of diffusion that will form a head organization in order to address the carrying out of these activities, as they relate to themes of the environment. Therefore, with the goal of achieving a good organization that can amply disseminate solutions for negative impacts and provide the facts, it was agreed that a committee should be formed for organization and dissemination. It ought to be in constant communication with those present, awarding, first of all, their names, addresses and telefono numbers where they can be reached.

Moreover, the participants directed messages to the managers of the waters in Mexico and the United States:

> "Nobody has the right to destroy life, nor to deprive the privilege that life gives us, to see running water in the rivers and lakes, that is the initial point of life. Yes, the construction of dams originated certain benefits for the country to the north; this does not mean that it is the same for Mexico. Request them to have a conscience; they are killing us little by little avoiding that the Colorado River has flows as before. We only request that you send us a little bit of this vital liquid, that nature has produced for all the world, not just for a few."

As well as the commitments that will be acquired if water is received through the Colorado River:

> "…I would promise to use water in an efficient way and would look for the formula optimum use in order to obtain maximum economic benefit the would increase the level of life of the inhabitants of the region, without hurting the environment and on the contrary, to try that all wildlife generated with the water might be managed or improved in ways that might remain and grow for the benefit of their own inhabitants of the delta by means of moderate development, regulated and scientific, for their development instead of their extinction."

IV. Public Involvement Workshop 3 for the Management and Restoration of the Colorado River Delta Wetlands

Campo Mosqueda, Baja California

The objective of the third workshop was to present more recent information and results, obtained during two years of research, for evaluation, and discussion. In this manner, the points of view and recommendations of the inhabitants of the river were obtained, in order to stimulate solutions for the environmental problems, which were identified in earlier workshops. Moreover, in this workshop a more direct dialogue between the river communities and the governmental (PROFEPA) and non-governmental institutions was developed. Time was also dedicated to the tracking of activities and finding the range of responsibility of the Committee for the Restoration of the Hardy River, which is organized as a medium of expression and participatory commitment for the use of all the river inhabitants. The result was a laying out of management strategies for the wetlands of the Colorado River, the strengthening of community participation focused on better use of resources, generation of a petition directed to the United States in order to receive support for international flows of the Colorado River so that the delta may be protected. Finally, a consensus was reached concerning the need to create a community committee in April of 1999 (tentative date).

Community Opinions Concerning the Management and Restoration Recommendations:

In order to be able to analyze the recommendations, it was suggested that the participants give their point of view and identify strategies for management and restoration that they are able to apply in each zone.

The zones of management for the wetlands of the Colorado River delta are divided in the following manner:

1. Riparian Corridor of the Colorado River delta
2. Hardy/Colorado Wetlands
3. El Indio Wetland System

Riparian Corridor of the Colorado River delta

This zone is the northern area of the delta wetlands. It is fed by the Colorado River Stream, which is bordered by levees, creating a narrow and defined wetland.

Their management and restoration strategies include:

Maintaining fresh water inputs through the Colorado River at 4.0×10^7 m^3 every year, with excess flows of 4.0×10^8 m^3 every four years (Mexico receives $\mathbf{18 \times 10^8}$ $\mathbf{m^3}$ annually). Instigating and discussing these topics in international forums, with the support of academic institutions, research centers, and non-government organizations from both sides of the border.

- Establishing a protected natural area, in order to change the current perspectives of both American and Mexican authorities that this is an area of waste water.

- Those affected should have a process for communication and coordination with, for the management of the area. This is a critical point because CNA is responsible for the maintenance of drains and drainage and the control of water flows, but carries out it's activities without environmental consideration.

- Promoting the sustainable use of wetland resources, maintaining traditional activities that are of little impact and are carried out in traditional places.

Hardy/Colorado Wetlands

This wetland area is located in the middle of the delta, with the influence of excess flows, agricultural drain water and tides. This is an extensive area with diverse habitats including a vegetation type of cottonwood and willow that makes a transition into a saltcedar and cattail zone.

Management and restoration strategies include:

- Creating infrastructure for the betterment of the habitat, recommending the construction of a diverting dam at the confluence of the Hardy and Colorado rivers in the Bocana Baja zone for the distribution of the water from both rivers and for the assurance of a sufficient volume of flow to Laguna Salada as in Bocana Baja. Both places are of great importance to the development of fishing activities as well as the generation of work for local communities like the Cucapá, in coordination with local communities and CNA. This will also include the dredging of sediment deposits of the streams in Campo BBB, Campo Flores, El Choropa, Campo Guajardo, Campo Solano, and Campo Muñoz, opening old river beds that have been closed during CNA activities, and the construction of small water reservoirs or lagoons. The necessity for dredging sedimented streams of the Hardy River and building hydrologic infrastructure in Bocana Baja is important. With this we will be able to store, control, and distribute water to the lower parts of the river avoiding low levels or inundation. With a controlled depth we will be able to assure that users that develop activities like fishing, hunting, or tourism, will have the objective of searching for sustainable development in their areas of exploitation.

- Human activities in this area are very much related to the wetland resources above all the neighboring communities along the river that use wetland resources for their subsistence. The principle activities include: tourism, commercial and sport fishing as well as hunting. The maintenance of this kind of resource use is recommended under a controlled management and development program for each activity.

- Another strategy is that local communities implement and direct alternative sustainable activities, thus diversifying the use of resources and eliminating inadequate practices.

El Indio Wetland System

This wetland systems extends to the limits of the Biosphere Reserve. Water inputs are mainly agricultural drains and tides with the influence of excess flows only when their volume is high. The dominant vegetation is saltcedar, cattail, and common reed with extensive salt grass flats.

Strategies for management and restoration include:

- Promoting the importance of these wetlands among government agencies, especially CNA, and affected communities with respect to establishing new areas of protection.

- Establishing coordinated efforts for the use of agricultural drainage water with the intention of maintaining the functions and value of the wetlands, in this way eliminating the destruction caused by hydrologic infrastructure modification.
- Other strategies include directing and maintaining water in strategic ways in order to enhance habitat value.

- Human activities are very limited because access and traveling is difficult within the wetland area. Only certain areas are used for sport or subsistence hunting and fishing by few people. The maintenance of this type of resource use is recommended under a management and development program for each activity.

Community Strategies for Implementing the Recommendations of Management and Restoration:

- The conclusions reached should be made known to CNA and CILA in order to facilitate the administration of adequate water volumes for the sustainable development of the region.

- A request before concerned government institutions, must be made in order to initiate the dredging, thus being able to utilize the surplus water in Bocana Baja and Laguna Salada while also maintaining good volumes of water during times of low levels contributing to the social and economic development of the zone and the appropriate use of the resources.

- To negotiate with the corresponding office, the reforestation of the wetland zone with native plants and trees, in order to catalyze activities such as tourism, hunting, and fishing.

- In order to create stronger links between community organizations and government institutions we need to make the most of the options given by SEMARNAP in order to establish ourselves as Unidades de Manejo Ambiental (Environmental Management Units).

- In order to organize a committee we should initiate a pre-committee that could be entrusted to gather members together in order to legally establish a committee, made up primarily of representatives from all the diverse social sectors and productive persons involved with the resources of the Hardy River. Once the committee is organized it will establish relations with governmental, non-governmental, and academic institutions, seeking recognition in the institutional sphere. Finally, for the committee to already have itself established and recognized it will be able to propose and dictate work for the initiation of the management and restoration of the Hardy River wetlands.

- It is required that the pre-committee increase coordinators responsible for gathering members in order to be able to legally establish a committee in April 1999 (tentative date).

- The structure of the committee could be composed of subcommittees, where one of them could be entrusted to execute a project for the construction of spillways, evaluating both the positive and negative impacts of these actions.

- The committee ought to have a recommendation for surveillance recognized by PROFEPA, which would respect the prohibitions and official regulations as a team and the art of fishing.

- PROFEPA recommends the formation of a local committee for the facilitation of the process of denouncing clandestine activities.

- The creation of a local organization is necessary, either as a committee or another sector, in order to prevent or correct situations like the presence of a drainage in the San Luis Colorado River zone, which dumps industrial and urban (including hospitals) waste waters, which will effect, with the passage of time, the activities of fisherman, hunters, and tourist promoters. We do not know the magnitude that chemical substances or biologic wastes will have on the natural resources. We will only be able to defend our natural heritage if we organize as a community entity.

Specific actions during the workshop included the signing of a petition in support of international flows of the Colorado River in order to protect the delta and the encouragement of more people to be coordinators of the pre-committee. Those responsible for gathering members in order to be able to legally establish a committee are : **Juventino Flores** (Col. Carranza, Tel. 651-66444, Unidad Peaquera Desemboque); **Francisco Jimenez** (Col. Independencia #1 Lote 26, Tel. 65-685080); **Lucio Luano** (Campo BBB); **German Muñoz** (Campo Muñoz); **Alvaro Lara Gutierrez**.

V. Work Party for the Management and Restoration of the Natural Resources of the Flor del Desierto Ejido

Cienega de Santa Clara, Sonora

The objective of this meeting was to establish current conditions in the ejido, identify the events that led to the current situation, and to propose alternatives for the management of the natural resources of the ejido. In this manner the points of view and recommendations of the Flor del Desierto Ejido concerning the promotion of solutions for environmental problems were obvious. The result was to work under the framework of the Unidad de Manejo Ambiental (Environmental Management Unit) proposal by SEMARNAP relying on the technical consultation of the Upper Gulf of California and Colorado River Delta Reserve.

The Ejido's Current Situation:

- There is no potable water.
- There are no electric lights.
- The current population is 2 families and 3 people.
- The lack of work in the ejido caused a migration of the people toward San Luis Rio Colorado, Mexicali, and the U.S., leaving Flor del Desierto without a population.
- We need incentives, and help in general, in order to generate a source of work in the ejido which would attract our people.
- CNA cancel permission to extract water from the wells. this ejido is dependent on agricultural activities.
- The range of activities in our ejido are for sustenance, not commercial, which should favor authorization for the appropriate use of subterranean waters.
- As for the flora and fauna of the wetlands of Flor del Desierto, they were affected by the recent diversion of the mouth of the Wellton-Mohawk canal, leaving hundreds of hectares without water, drying out flora, and leaving both local and migratory fauna without habitat. Flor del Desierto requires that the mouth of the Wellton-Mohawk be returned to its original position, thus permitting the re-establishment of the wetlands of this zone.
- Currently we have sufficient water in the wetlands of the ejido. This is not permanent but rather periodic with low water volumes occurring in spaces of 4 and 5 years and surplus volumes occurring in spaces of 1 and 2 years. We have to construct hydraulic infrastructure in order to maintain and control low or surplus volumes and to favor the restoration of the wetland and economic development of Flor del Desierto.
- As a last resort for obtaining institutional support, the ejido commissioner of Flor del Desierto, Mr. Gaston Fernandez Hallal, gave the SEMARNAP delegate in the state of Sonora, Juan Carlos Rubio, a proposal soliciting technical and economic support, in order to develop the following points:
  - Developing hunting activities, with the intent that the ejido might be the hunting organizer with the ejido's own guides. Relying on a calendar and a specific logbook for the zone, generating an updated and true regulation in order to optimize the sustainable use of the natural resources.
  - Developing sport fishing, taking advantage of the systems for hunting activities and other systems below budget.
  - Maintaining sustenance fishing for no commercial benefits for the inhabitants of the ejido.
  - Aquaculture has a great potential under an extensive scale in the first stage, which might generate resources for other specialized installations. The Secretariat for the Promotion of Fishing could be a link for technical assistance.

- Developing local flora nurseries, suggesting restoration of mesquite taking advantage of this zone especially for the species. Apart from the governor, canutillo (horse tail) and other vegetation species can be to give alternatives under a good market research focused on the creation of micro businesses.

The National Ecology Institute (INE) is able to provide mesquite for the start of activities of the nursery. The mesquite plantations favor the development of apiculture (beekeeping), generating the highest quality honey (grade "A").

- Ecotourism is an alternative area of opportunity for the generation of extra resources in which we require consultation in order to provide this service adequately. The margin for hunting in Flor del Desierto or Laguna de los Gansos are considered as good examples for the development of nature based tourism. The option is to alternate different areas for hunting and ecotourism. Consulting could come from the Sonoran Institute, Biosphere Reserve, NAWCC, and Ruta de Sonora (Sonora Route).

- Development of Palmera Datilera, Higo Nopal, Tunas, Hortalizas, Eucalipto, and Paplonia among others under the betterment program for Flor del Desierto.

- Development of Huertos Comunitarios with the objective of obtaining food self-sufficiency, taking advantage of the wells of the Colorado River Company, for which we require to initiate the procedure with CNA.

- Developing the arts which use clay, giant reed, and tule.

- Raising ostrich for its skin, feathers, and meat.

- The following infrastructure is necessary:

  - Construction of housing with the option of a water treatment plant.
  - Installation of a recycling and compost complex.
  - Construction of a nursery for endemic plants.
  - Transportable jetty.
  - Boats and 4-wheel drive vehicles.

Recommendations for the Flor del Desierto Ejido:

The initiative to create work parties within the ejidos and between ejidos should be a permanent intention since the shortage of water and other resources are not only in the delta, but is rather something faced throughout the world, wherefore we obligated to share the resources and optimize their utilization. The benefits of team work don't have a price, since this activity strengthens the image of the communities in the eyes of the Mexican and American governments, facilitating the recognition of united communities and their objectives. They also facilitate the range of proposed goals and knowledge of the environment. To create a common front for talking about the interests of the swamp the ejidos will be able to participate in meetings about the negotiation of water volumes or revision of the plan of management for the reserve.

Through the Technical Coordinator of the Upper Gulf of California and Colorado River Delta Biosphere Reserve, biologist Jose R. Campoy Favela, the petition will be presented before the National Ecology Institute (INE-SEMARNAP) in order to create an Environmental Management Unit on the ejido lands. To be within the institutional program it is easier to access a whole universe of possibilities in terms of alternative environments, with which they will be able to develop the options that identify themselves in the previous proposal.

In a parallel manner there is the necessity to reinitiate the dialogue between the ejidos of Santa Clara Swamp in order to establish the bases for co-participation focused on the creation of an ejido alliance for advantageous control and harmonious existence of Santa Clara Swamp. The problems among the various ejidos could be resolved in the form of treaties drawn up in the plenary assemblies of each ejido, together with governmental and non-governmental as well as Reserve, ITESM, Pronatura, IMADES, and C.I. representatives, in order to inform all the cooperatives about the alternatives for development and inter-cooperative rules in order to be successful in this enterprise.

VI. Directory of Contacts and Participants

Gobierno del Estado de Baja California

Lic. Alejandro Gonzalez Alcocer
Gobernador Constitucional del Estado de Baja California
Edif. Poder Ejecutivo 3er. Piso Czda. Independencia y Paseo de los Heroes, Centro Civico.
Mexicali, Baja California.
Teléfono (65) 581128 fax 581178

Secretarias del Gobierno del Estado de Baja California

- **Secretaria de Asentamientos Humanos y Obras Públicas del Gobierno del Estado**

Ing. Fernando Aceves Salmon
Secretario de Asentamientos Humanos y Obras Públicas del Estado
Edif. Poder Ejecutivo 4to. Piso, Czda. Independencia y Paseo de los Heroes Centro Civico.
Mexicali, Baja California.
Teléfono (65) 581116 y 581000 ext. 1116

- **Secretaria de Fomento Agropecuario**

Ing. Genaro Lopez Bojorquez
Secretario de Fomento Agropecuario
Calle Calafia y Pasaje Coyoacán 675, Centro Civico.
Mexicali, Baja California.
Teléfono (65) 554930 al 36 fax 554992

- **Secretaria de Educacion y Bienestar Social del Gobierno del Estado**

M. C. Lorenzo Gomez-Morin Fuentes
Secretario de Educacion y Bienestar Social
Edif. Poder Ejecutivo 2do. Piso, Czda. Independencia y Paseo de los Heroes Centro Civico.
Mexicali, Baja California.
Teléfono (65) 581120 y 581000 ext. 1120

- **Secretaria de Desarrollo Económico del Gobierno del Estado**

Lic. Juan A. Martinez Zaragoza
Secretario de Desarrollo Económico
Edif. Poder Ejecutivo 4to. Piso, Czda. Independencia y Paseo de los Heroes Centro Civico.
Mexicali, Baja California.
Teléfono (65) 581119 y 581000 exts. 1119 y 1048

Biol. Victor Roman Miranda
Secretaria de Desarrollo Económico del Gobierno del Estado
Edif. Avila, 1er. Piso, Blvd. Lazaro Cardenas y Medusas No. 1800
Ensenada, Baja California.
Teléfono (61) 773375 fax 773390

Lic. Victor Manuel Nuza Montaño
Delegado de la Secretaria de Desarrollo Económico Gobierno del Estado de Baja California
Edif. Avila, 1er. Piso, Blvd. Lazaro Cardenas y Medusas No. 1800
Ensenada, Baja California.
Teléfono (61) 773375 fax 773390

- **Secretaria de Turismo**

Lic. Juan B. Tintos Funcke
Secretario de Turismo del Estado de Baja California
Paseo de los Heroes 10289, 4to. Piso Esq. Jose Ma. Velazco,
Edif. de Nacional Financiera, Zona del Rio.
Tijuana, Baja California.
Teléfono (66) 346330, 346873, 346918 y 343085

C. Carlos Guillin Armenta
Delegado de la Secretaria de Turismo en Mexicali
Pasaje Tuxpan 1089, Centro Civico.
Mexicali, Baja California.
Teléfono (65) 554110 fax 554952

Instituciones Descentralizadas Estatales

- **Colegio de Bachilleres de B. C.**

Lic. Jose Luis Marquez Gomez
Director General
Colegio de Bachilleres de B. C.
Blvd. Anahuac No. 963, Col. Anahuac.
Mexicali, Baja California.
Teléfono (65) 574001 al 07

- **Comision de Servicios de Agua del Estado**

Ing. Jose Alberto Castañeda Estrada
Director de la Comision de Servicios de Agua del Estado
Czda. Anahuac 1016, Col. El Vidrio.
Mexicali, Baja California.
Teléfono (65)572061 fax 569303

- **Sistema Estatal DIF - Desarrollo Integral de la Familia**

C. Rosalba Magallon de Gonzalez Alcocer
Presidenta del Sistema Estatal DIF
Desarrollo Integral de la Familia
Av. Obregon 1290 esq. Calle "E", Col. Nueva.
Mexicali, Baja California.
Teléfono (65) 535634 fax 536066

- **motora Estatal para el Desarrollo de las Comunidades Rurales y Populares**

M. V. Z. Jose Manuel Salcedo Sañudo
Director General Promotora Estatal
para el Desarrollo de las Comunidades Rurales y Populares
Calle 4ta. y Rio Bravo 2699, Col. Gonzalez Ortega.
Mexicali, Baja California.
Teléfono (65) 613504 fax 610352

Comision de Planeación para el Desarrollo del Estado de B. C.

Dr. Victor Adan Lopez Camacho
Coordinador General de la Comision de Planeación
para el Desarrollo del Estado de B. C.
Edif. Poder Ejecutivo 4to. Piso, Czda. Independencia y Paseo de los Heroes, Centro Civico.
Mexicali, Baja California.
Teléfono (65) 581118 ext. 1118 fax 581162 ext. 1162

Unidad Estatal de Proteccion Civil

C. Alfredo Escobedo Ortiz
Secretario Tecnico de la Unidad Estatal de Protección Civil
Alejandro Humbolt 17508, fracc. Garita Mesa de Otay.
Tijuana, Baja California.
Teléfono (66) 243442 al 53 fax 243454 y 55

Direcciones Generales del Estado de Baja California

- **Direccion General de Ecologia del Estado**

Armando Arteaga King
M. C. Adolfo Gonzalez Calvillo
Director de la Direccion General de Ecologia del Gobierno del Estado
Edif. Poder Ejecutivo Pta. Baja, Centro de Gobierno,
Vía Oriente No. 1, Zona del Rio.
Tijuana, Baja California.
Teléfono (66) 242095 y 242000 exts. 2274 y 2272

Ocean. Enrique Villegas Ibarra
Delegado de la Direccion General de Ecologia del Gobierno del Estado
Plaza Baja California 10-b, Czda. Independencia y Calle Calafia.
Mexicali, Baja California.
Teléfono y fax (65) 554980 ó 554981

Arq. Esther Martinez Gutierrez
Directora de Planeación de Desarrollo Urbano y Ecologia
Vía poniente 4014, Col. Anexa 20 de noviembre.
Tijuana, Baja California.
Teléfono (66) 834226 y 27 fax 834237

I.Q. Eva Isabel Rojas B.
Direccion General de Ecologia del Gobierno del Estado
Local 10a, Plaza Baja California, Centro Civico.
Mexicali, Baja California.
Teléfono y fax (65) 554980 (casa) 660212
Domicilio Particular: Calle Rio Fuerte No. 1400, Col. Pro-hogar.

Leticia Jimenez Ramirez
Direccion General de Ecologia del Gobierno del Estado
Local 10a, Plaza Baja California, Centro Civico.
Mexicali, Baja California.
Teléfono y fax (65) 554980 y 81

Isabel Rojas
Direccion General de Ecologia del Gobierno del Estado
Local 10a, Plaza Baja California, Centro Civico.
Mexicali, Baja California.
Teléfono y fax (65) 554980 y 81

Subdirector de Ecologia del Estado de Sonora
Dpto. de Infraestructura Urbana y Ecologia.

Ing. Ramón Castillón
Subdirector de Ecologia
Dpto. de Infraestructura Urbana y Ecologia.
San Luis Rio Colorado, Sonora.

- **Direccion del Registro Publico de la Propiedad y del Comercio**

Lic. Rosario Ramirez Hernández
Directora del Registro Publico de la Propiedad y del Comercio
Edif. Poder Ejecutivo 2do. Piso, Czda. Independencia y Paseo de los Heroes Centro Civico.
Mexicali, Baja California.
Teléfono (65) 581126 y 581000 ext. 1126

Ayuntamiento de Mexicali

Arq. Victor Hermosillo
Presidente Municipal del XVI Ayuntamiento de Mexicali
Mexicali, Baja California.
Teléfono (65) 541657 fax 536525

- **Direccion de Catastro, Control Urbano y Ecologia**

Arq. Sergio Montes Montoya
Director de Catastro, Control Urbano y Ecologia
Casa Municipal 2do. Piso, Czda. Independencia y Paseo de los Heroes, Centro Civico.
Mexicali, Baja California.
Teléfono (65) 581631 ext. 1651 fax ext. 1790

- **Fideicomiso para el Desarrollo Urbano de Mexicali.**

Ing. Héctor Jose Gomez Rodríguez
Director General FIDUM
Fideicomiso para el Desarrollo Urbano de Mexicali.
Palacio Federal 2o. Nivel Cuerpo "B",
Paseo de los Heroes y Av. de los Pioneros, Centro Civico.
Mexicali, Baja California.
Teléfono (65) 560262 ó 560353 fax 581790 ext. 1901

Organismos Descentralizados Federales

Comision Federal de Electricidad – División Baja California

Ing. Enrique Guzmán Sánchez
Gerente Divisional de la Comision Federal de Electricidad, División B. C.
Blvd. Benito Juárez y Lazaro Cardenas.
Mexicali, Baja California.
Teléfono (65) 661775 fax 661717

Comision Nacional del Agua - Gerencia Regional de la Peninsula de B. C.

Dr. Francisco Oyarzábal Tamargo
Gerente Regional de la Peninsula de B. C.
Comision Nacional del Agua
Av. Reforma y Calle "L", Col Nueva.
Mexicali, Baja California.
Teléfono (65) 528682 fax 540790

Ing. Jose Trejo Alvarado
Sub-Gerente Regional de Operación
C.N.A. Gerencia Regional de la Peninsula de B.C.
Av. Reforma y Calle "K" s/n.
Mexicali, Baja California.
Teléfono (65) 523337 ext. 139 y 172 fax 540704

Lic. Teresa de Jesús Sol Uribe
Jefe del Proyecto de Calidad del Agua e Impacto Ambiental
C.N.A. Gerencia Regional de la Peninsula de B.C.
Mexicali, Baja California.
Teléfono (65) 523337 ext. 126 fax 547590

Gerencia de Módulos de Riego

Ing. Rodrigo Sánchez Limón
Gerente de Módulos de Riego
Mexicali, Baja California.
Teléfono (65) 800960 y 800964

Jose Abelardo Arce
Gerencia de Módulos de Riego
Distrito de Desarrollo Rural 002, Rio Colorado.
Mexicali, Baja California.
Teléfono (65) 535140, 540513, 800960 y 800964

Instituto Nacional de Estadistica, Geografia e Informatica - Delegacion Baja California

Lic. Antonio Solano Larrañaga
Delegado en Baja California de INEGI
Av. Reforma y Calle "G" no. 1500, Col. Nueva.
Mexicali, Baja California.
Teléfono (65) 573914

Geol. Humberto Larrañaga Cunningham
INEGI - PROCEDE
Fco. I. Madero 1130, Col. Nueva.
Mexicali, Baja California.
Teléfono y fax (65) 528489

Ing. Alfredo Gonzalez Montoya
INEGI - PROCEDE
Av. Reforma y Calle "G" 1200.
Mexicali, Baja California.
Teléfono (65) 528489 y 528740

Humberto Alvarado Uribe
INEGI
Av. Reforma y Calle "G" 1200.
Mexicali, Baja California.
Teléfono (65) 633271
Domicilio particular: Av. Presa Miguel Hidalgo 1376, Col. Granjas Nuevas.

Lic. Oscar René Sánchez
INEGI
Palacio Federal 2o. piso, Centro Civico.
Mexicali, Baja California.

Ing. Juan Ramón Nuñez
INEGI
Av. Reforma y Calle "G" no. 1500, Col. Nueva.
Mexicali, Baja California.
Teléfono (65) 608096 y 528489

Instituto Nacional Indigenista – Delegacion Estatal Baja California

Ing. Juan Ramón Valdez Flores
Delegado Estatal del Instituto Nacional Indigenista en B. C.
Av. Coral 286, Fracc. Nueva Ensenada.
Ensenada, Baja California.
Teléfono (61) 771737 fax 770500

Lic. Victor Hugo Toral
Director del Centro Coordinador Indigenista en B. C.
Vicente Guerrero 139, Fracc. Bahía.
Ensenada, Baja California.
Teléfono (61) 770500 y 771955

Instituto Mexicano del Seguro Social – Delegacion Regional

Lic. Jesús Aureliano Cruz Monreal
Delegado Regional del Instituto Mexicano del Seguro Social
Czda. Cuauhtemoc 300, Col. Aviación.
Mexicali, Baja California.
Teléfono (65) 555015 al 17 fax 555018

Delegado Estatal del ISSSTE
Dr. Cipriano Aguilar Aguayo
Delegado Estatal del ISSSTE
Av. Lerdo 1580 edif. Multifamiliar, Col. Nueva.
Mexicali, Baja California.
Teléfono (65) 541718 fax 534023

Instituto de Servicios de Salud Pública

Dr. Marco Antonio Castillo Torres
Director General del Instituto de Servicios de Salud Pública
Palacio Federal 3er. Piso, Centro Civico.
Mexicali, Baja California.
Teléfono (65) 572820 fax 573681

Q.F.B. Hector Mendoza Benitez
Coordinador Estatal de Saneamiento Basico de la Direccion de Regulación Sanitaria
ISE - SALUD en B.C.
Palacio Federal 2o piso, Centro Civico.
Mexicali, Baja California.
Teléfono (65) 561547 fax 561367

Delegaciones Federales en el Estado de Baja California

Secretaria de Agricultura, Ganadería y Recursos Hidráulicos

Ing. Manuel Real Lizardi
Delegado Estatal de SAGAR
Av. Reforma y Calle "L", Col. Nueva.
Mexicali, Baja California.
Teléfono (65) 540109 fax 542659

Secretaria de la Defensa Nacional

Gral. de Bgda. D. E. M. Rigoberto Castillejos Adriano
Comandante de la 2/A Región Militar
Secretaria de Defensa
Campo Militar 2-B, Col. Orizaba.
Mexicali, Baja California.
Teléfono (65) 571095

Secretaria del Medio Ambiente, Recursos Naturales y Pesca

Lic. Hugo Abel Castro Bojorquez
Delegado Federal en B.C. de la SEMARNAP
Av. Madero 537, Zona Centro.
Mexicali, Baja California.
Teléfono y fax (65) 524998 ó 524986

Lic. René Mendivil Acosta
Sub Delegado de Medio Ambiente
SEMARNAP Deleg. B.C.
Av. Madero 537, Zona Centro.
Mexicali, Baja California.
Teléfono y fax (65) 524998 ó 524986

Ocean. Talpa Dolores Lara Moreno
Jefe del Centro de Educacion y Capacitacion
para el Desarrollo Sustentable CECADESU
SEMARNAP Deleg. B.C.
Ave. Electricistas y Calle "S" # 1799
Mexicali, Baja California.
Teléfono (65) 518700 (directo) 518713 (casa) 572833

Ing. Julian Torres Ruiz
Jefe de Programas de Medio Ambiente
SEMARNAP Deleg. B.C.
Av. Madero 537, Zona Centro.
Mexicali, Baja California.
Teléfono y fax (65) 524998 ó 524986

Biol. Jose Luis Aguilar
Jefe de Áreas Protegidas
SEMARNAP Deleg. B.C.
Av. Madero 537, Zona Centro.
Mexicali, Baja California.
Teléfono y fax (65) 524998 ó 524986

Dr. Baltazar Solano Larrañaga
SEMARNAP Deleg. B.C.
Av. Madero 537, Zona Centro.
Mexicali, Baja California.
Teléfono y fax (65) 524998 ó 524986

Lic. Jose Luis Samaniego Leyva
Unidad Coordinadora de Asuntos Internacionales
Secretaria de Medio Ambiente, Recursos Naturales y Pesca
Cd. de Mexico.
Teléfono (5) 6280650 fax 6280653

Instituto Nacional de Ecologia (INE – SEMARNAP)
Reserva de la Biosfera del Alto Golfo de California y Delta del Rio Colorado, Sonora – Baja California

Ocean. David Ortiz Reina
Coordinador de Involucramiento Publico
Reserva de la Biosfera del Alto Golfo de California y
Delta del Rio Colorado, Sonora – Baja California
INE - SEMARNAP

Ave. Reyes y Aguascalientes Esq. Col. San Benito
Hermosillo, Sonora, Mexico C.P. 83190
Teléfono (62) 159864 y 159881 Fax 146508
Apdo. Postal 452

San Luis Rio Colorado, Sonora, Mexico C.P. 83400
Teléfono (653) 63757 fax 42207

Estación de Campo Golfo de Santa Clara/ IMADES
Km 105 carret. S.L.R.C. – Golfo de Santa Clara
Golfo de Santa Clara, Sonora, Mexico
Teléfono y fax (653) 23676

Ocean. Jose R. Campoy Favela
Coordinador de Involucramiento Publico
Reserva de la Biosfera del Alto Golfo de California y
Delta del Rio Colorado, Sonora – Baja California
INE - SEMARNAP
Ave. Reyes y Aguascalientes Esq. Col. San Benito
Hermosillo, Sonora, Mexico C.P. 83190
Teléfono (62) 159864 y 159881 Fax 146508
Apdo. Postal 452
San Luis Rio Colorado, Sonora, Mexico C.P. 83400
Teléfono (653) 63757 fax 42207
Estación de Campo Golfo de Santa Clara/ IMADES
Km 105 carret. S.L.R.C. – Golfo de Santa Clara
Golfo de Santa Clara, Sonora, Mexico
Teléfono y fax (653) 23676

Procuraduria Federal de Protección al Ambiente en B. C.

Ing. Fco. Antonio Sandoval Sánchez
Delegado Estatal de la Procuraduria Federal de
Protección al Ambiente en B. C.
Calle Lic. Alfonso García Gonzalez 555, Col.
Profesores Federales.
Mexicali, Baja California.
Teléfono (65) 617491 ext. 101 fax 617930

Ing. Tobias Contreras Trejo
Lomas de San Merino
Calle Bahia Acapulco 856
Ensenada, Baja California
Telefono (61) 764099 Fax 765000

Secretaria de Relaciones Exteriores
Lic. Julieta Olmeda Garcia
Delegada Federal de la Secretaria de Relaciones Exteriores
Calle Pedro F. Pérez y Ramirez No. 202, Zona Centro.
Mexicali, Baja California.
Teléfono (65) 534558 fax 542865 y 534562

Comision Internacional de Limites y Aguas

Ing. Fco. Alberto Bernal Rodríguez
Subdirector Tecnico Operativo
Comision Internacional de Limites y Aguas
Av. Madero 1401, Col. Nueva.
Mexicali, Baja California.
Teléfono (65) 526385 fax 542481

Ing. Jose Humberto Sillas Arredondo
Coordinador del Proyecto de Saneamiento
Comision Internacional de Limites y Aguas CILA
Av. Madero 1401, Col Nueva.
Mexicali, Baja California.
Teléfono (65) 541621 y 526385 casa 631412 fax 542481
cilamxli@sahuaro.mxl.cetys.mx y guillermosillas@usa.net

Organismos Empresariales

C. Juan Ramon Lopez Naranjo
Presidente de la CANACO de Mexicali
Calzada Independencia No. 1199 Esquina, Blvd. Anahuac
Centro Civico
Mexicali, B.C. 21000
(65) 57-0005
Fax: 57-1006

Lic. Hector Rubio Montoya
Director de Relaciones y Servicios de la CANACO de Mexicali
Calzada Independencia No. 1199 Esquina, Blvd. Anahuac
Centro Civico
Mexicali, B.C. 21000
(65) 57-0005
Fax: 57-1006

Lic. Manuel Vizcarra Gomez
Vicepresidente de Turismo
CANACO
Calz. Independencia 1199 esq. Blvd. Anahuac.
Mexicali, Baja California.
Teléfono (65) 570005 fax 571006

Centros de Investigación y Enseñanza Superior

C. P. Victor Beltrán Corona
Rector de la Universidad Autónoma de Baja California
Av. Obregon y Julián Carrillo s/n, Col Nueva.
Mexicali, Baja California.
Teléfono (65) 534461 54-2200 ext. 112, fax 522379

Ing. Adalberto Walther Meade
Director del Instituto de Investigaciones de Geografía e Historia
Universidad Autónoma de Baja California
Edif. de Investigaciones y posgrado, 3er. piso, Blvd. Benito Juárez.
Mexicali, Baja California.
Teléfono y fax (65) 662985

Ing. Oscar Sánchez
Investigador del Instituto de Investigaciones de Geografía e Historia
Universidad Autónoma de Baja California
Edif. de Investigaciones y posgrado, 3er. piso, Blvd. Benito Juarez.
Mexicali, Baja California.
Teléfono y fax (65) 662985

Mtro. Fco. Javier Mendieta Jimenez
Director General del CICESE
Km 107 Carretera Tijuana-Ensenada
Ensenada, B.C.
(61) 74-4900 y 74-4400
Fax: 74-4880

Dr. Enrique Carrillo Barrios Gomez
Rector del CETYS Universidad
Calzada CETYS s/n
(Apdo. Postal No. 3-797)
Mexicali, B.C.
(65)67-3730 Conmutador: 67-3700
Fax: 67-3705

Ing. Enrique Carlos Blancas de la Cruz
Director General del CETYS Campus Mexicali
Calzada Cetys s/n
(Apdo. Postal No. 3-797)
Mexicali, B.C.
(65) 67-3729 Conmutador: 67-3700

Dr. Isaac Azuz Adeath
CETYS
Km. 1 camino microondas Trinidad
Ensenada, Baja California.
Teléfono (61) 745599
iazuz@orca.ens.cetys.mx

Cecilia Contreras Trejo
Maestra CETYS
Calzada Cetys s/n
(Apdo. Postal No. 3-797)
Mexicali, B.C.
Email: ceci@infox.cetys.com

INIFAP - CIRNOR

Ing. Abelardo Reynosa Vega
Director Regional
INIFAP - CIRNOR
Norman Borlaug Km 12.
Ciudad Obregon, Sonora.
Teléfono (64) 145681 fax 145914

Dr. Jorge Santibañez Romellon
Presidente del Colegio de la Frontera Norte
Blvd. Abelardo L. Rodríguez No. 2925
Zona del Rio
Tijuana, B.C. 22320

Mtro. Alfonso Andres Cortez Lara
Director Regional Mexicali del Colegio de la Frontera Norte
Av. Reforma No. 1646
Col. Nueva
Mexicali, B.C. 21100
(65)54-7447 y 54-7445

Dra. Maria Esther Uriegas
Directora Académica de la Facultad Internacional de Ciencias de la Educacion (FICED)
Guanajuato No. 2413
Col. Cacho
Tijuana, B.C. 22150
(66) 38-8346

Arqueol. Maria Julia Bendimez Patterson
Directora del Centro Regional del INAH
Av. Reforma No. 1333
Col. Nueva
Mexicali, B.C. 21100
(65) 52-3591 y 52-8279

Lic. Evangelina Davila Rivera
Coordinación del Centro Regional del INAH
Av. Ryerson No. 99
Zona Centro
Ensenada, B.C. 22800
(65) 78-2531

Lic. Rosa Maria Romero Cuevas
Directora de la Red de Educadores Ambientales del Noroeste de Mexico
Jose Antonio Torres esq. Rio Mocorito s/n, Col. Independencia Magisterial.
Mexicali, Baja California.
Teléfono y fax (65) 662060

Lic. Rosa Maria Romero Cuevas
Coordinadora del Programa de Educacion Ambiental - EDUCAM
de la Universidad Pedagógica
Jose Antonio Torres esq. Rio Mocorito s/n, Col. Independencia Magisterial.
Mexicali, Baja California.
Teléfono (65) 668727 fax 662060

Organizaciones No Gubernamentales

Movimiento Ecologista de Baja California, A. C.

Srita. Naachiely Lopez Hurtado
Presidente del Movimiento Ecologista de Baja California, A. C.
Del Risco 1143 Jardines del Sol, Playas de Tijuana.
Tijuana, Baja California.
Teléfono y fax (66) 809575

Comite Para el Manejo y Restauracion del Rio Hardy

Ing. Fco. Javier Mosqueda
Coordinador del Comite Para el Manejo y Restauracion del Rio Hardy
Rio Atoyac y Calle 5ta. 824, Col. Glz. Ortega.
Mexicali, Baja California.
Teléfono (65) 610616 y 697984

Abel Gaspar Gallegos
Algodonera Cachanilla, S.A. de C.V.
Km. 39.5 carret. a San Luis Rio Colorado.
Mexicali, Baja California.
Teléfono (65) 651-42195 y 42196

Comite de Divulgación Ecologica

Sr. Fernando Medina Robles
Director del Comite de Divulgación Ecológica
Mexicali, Baja California.
Teléfono (65) 522080

Eco-Sol Educacion y Cultura Ecologica

Q.I. Jesús Jimenez Rafael
Asesor Ambiental
Eco-Sol Educacion y Cultura Ecológica
Rio Colorado 836, Col Revolución.
Tijuana, Baja California.
Teléfono y fax (66) 863687

U.S. Agency for International Development - AID/ Mexico

Dr. Frank Zadroza
Director
AID/ Mexico
Paseo de la Reforma 305, Col Cuauhtemoc.
Mexico D.F.
Teléfono (5) 2110042 fax 2077558

International Sonoran Desert Alliance – ISDA

Ocean. Carlos Yruretagoyena
Presidente
International Sonoran Desert Alliance - ISDA
PO BOX 687, 37 Plaza, Suite A.
Tucson, Arizona.
Teléfono y fax (00) 520- 3876823

Friends of Pronatura

Sr. Carlos Nagel
President
Friends of Pronatura
240 East Limberlost
Tucson, Arizona.
Teléfono (00) 520- 8871188 ó 8871575

Colegio de la Frontera Norte

Sr. Oscar Romo
Colegio de la Frontera Norte
Blvd. Abelardo L. Rodríguez 2925, Zona del Rio.
Tijuana, Baja California. Teléfono (66) 300411 fax 84879595

Pronatura Peninsula de Baja California

Dr. Roberto Enriquez Andrade
Director de Pronatura Peninsula de Baja California
Lopez Mateos y Granada 2025, Plaza Peninsula, Local 201.
Ensenada, Baja California.
Teléfono (61) 773060 fax 764688

INFORMA, A.C.

Sr. Jose Zavala Álvarez
Director General - INFORMA
Instituto para el Fomento Rural y
el Medio Ambiente, A. C.
Priv. Verónica No. 631, Fracc. Punta Estrella.
Mexicali, Baja California.
Teléfono (65) 619292

Sonoran Institute

Steve Cornelius
Joaquin Murrieta
7650 E. Broadway, Tucson, AZ 85710
Telefono (520) 2900828

Centro Cultural de Estudios de los Océanos y Desiertos

Sra. Peggy Turk Boyer
Directora
Centro Cultural de Estudios de los Océanos y Desiertos
Puerto Peñasco, Sonora.
Teléfono (638) 35403

Conservation International
M. C. Maria de los Angeles Carvajal
Directora del Programa Golfo de California
Conservation International
Miramar No. 59 - A, Col. Miramar.
Guaymas, Sonora.
Teléfono (622) 10194 fax 12030

Comision de Cooperación Ecológica Fronteriza

Ing. Edgardo Tovilla Carrillo
Director de Proyecto
Comision de Cooperación Ecologica Fronteriza
Blvd. Tomás Fernandez No. 7940, Torres Campestres 6to. piso.
Cd. Juárez, Chihuahua.
Teléfono (16) 292395 ext. 115 fax 16-292397

Participantes de los Talleres Comunitarios

El Ranchito
Pedro Jimenez

El Caiman
Don Jose
Gustavo Armenta Garcia

El Barranco Pescaderos – Carranza
Servando Arana
Telefono (65) 650577

Campo 3B
Rafael Gutierrez Bastida
Telefono (65) 570643
Lucio Ruano Sanchez

Refugio Servin
Genaro Torrez Gonzalez
Telefono (65) 570643

Poblado Ricardo Mazon Guerrero
Alvaro Lara Gutierrez

Campo Turistico Muñoz
German Muñoz
Telefono (65) 609146

Poblado Cucapa Meztizo
Miguel Mejia
Av. Republica de Uruguay 986
Fracc. Sonora, Mexicali, B.C.

Terrenos Indios
Francisco Guzman de Dios

Campo Turistico – Paralelo 32
Atanasio Mesa
Ejido Oviedo Mota
Ruben Martinez
Jose Luis Alcantara
Andres Mayoral
Martin Limon Orozco
Gabriel Villalobos
Agustin Gutierrez

Ejido Donato Guerra
Luz Elena Acosta
Telefono (65) 573307
Onesimo Gomez Ramirez
Telefono (65) 573307
Comunidad Indigena El Mayor Cucapa
Armida Gonzalez
Victor Portillo
Hilario Felix
Jose Alejandro Saiz
Francisco Ceceña Diaz
Doña Juanita
Matias Saiz
Diego E. Saiz
Maria de Jesus Saiz
Teodoro Sanchez Gonzalez
Maria de los Angeles Carrollo Olivares
Mirta Lorena Guerra
Monica Gonzalez
Onesimo Gonzalez
Santana Luna Coronado
Maria Isabel Gonzales Portilla
Francisco Gonzales Portilla
Francisco Zamora Ortiz
Jesus Silva Almeida
Octavio Schlemmer Medrano
Ruben Serna Acosta
Hilda Hurtado
Gerardo Macias
Ines Hurtado
German Hurtado
Imelda Guerra
Juan Antonio Guerra
Rita Hurtado
Antonio Guerra
Javier Esqueda Delgado

Ejido Durango
Alfonso Agundez Navarro
Jose Valdez Sarabia

Delegacion Colonias Nuevas
Carlos Viveros Adame

Campo Mosqueda
Don Jesus Mosqueda
Ing. Javier Mosqueda

Colonia Baja California
Juan Manuel Garcia

Col. Carranza
Delfino Garcia
Asencion Siqueiros Arredondo
(Ejido Reacomodo)
Jose Moreno Jimenez
(Poblado El Maritimo)
Francisco Jimenez
Florentino Flores
Marcelino Gonzalez
Carlos Ochoa Guevara
Guadalupe Ochoa Guevara
Jose Saldaña

Herminio Saldaña Hernandez
La Bocana
Jesus Mejia

Poblado Gonzalez Ortega 1
Jose Ortega
Benigno Reyes
Col. Hidalgo
Telefono (65) 897064
Antonio Zavala Alcaraz
Col. Hidalgo

Delegacion Colonia Carranza
Jose Anaya

Ejido Luis Encinas-Johnson
Juan Butron
Maria Guadalupe Santos Castro
Roberto Castillo
Benito Rocha
Jose Juan Butron

Javier Cortez
Mauricio Butron
Salvador Aceves
Miguel Cruz
Rodolfo Rodriguez
Vidal Brimbida Martinez
Alma Azucena Tapia
Claudia Tapia
Celina Lara
Carmen Quiñonez
Pedro Molina
Antonio Contreras

Ejido Mesa Rica
Franco Lopez Arredondo
Eufrasia Alvarez Medina
Gariela Lopez Arredondo
Silvia Romero Alvarez
Maria Jesusita Valladolid
Margarita Lopez
Gaston Cano Fernandez
Jesus Camarillo
Ricardo Quiroz Siqueiros
Rosalio Torres
David Ramirez Rodriguez
Francisca Fimbres

Ejido Flor del Desierto
Teresa Monzon
Pedro Cruz
Gaston Fernandez Hallal

Ayuntamiento de S.L.R.C.
Ramón Castillon
Departamento de Ecologia
Telefono (653) 45578

Campo El Prado
Armando Duron del Prado
Calle Norte 593 Col. Bella Vista.
Mexicali, Baja California.

Ron Klein
233 Paul Lin St. 8020
Calexico, Ca.
Telefono (909) 9963501