社会開発調査部報告書

JAPAN INTERNATIONAL COOPERATION AGENCY
NATIONAL WATER COMMISSION

THE STUDY ON DEVELOPMENT OF THE NATIONAL WATER QUALITY MONITORING PROGRAM IN COASTAL AREAS IN THE UNITED MEXICAN STATES

FINAL REPORT
(DATA BOOK)

March 2000

PACIFIC CONSULTANTS INTERNATIONAL
METOCEAN

Table of Contents

List of Tables and Figures

Chapter 1

Chapter 2

Chapter 3

Chapter 4

Chapter 1 Coastal Environmental Profile

1.1 Coastal Environmental Profile of Mexico

1.1.1 Natural Environmental Conditions

(1) Topography

a) Coastal topographical features and their definitions

The definition of the term "coastal zone" has generated various discussions among scientists of every academic field and various resource administrators. Without having neither international nor national agreement to limit the properties of this zone, the term has been used according to the interest of each organization. The Department of International Economy and Social Affairs of the United Nations (UNDIESA) defined "the coastal zone as the zone of interaction between land and sea, including terrestrial component, submerged lands in the continental platform, and the adjacent sea waters." For administration purposes, the coastal zone in Mexico has been legally defined as the region utilized by the Federal Maritime and Terrestrial Zone (FMTZ) and the Exclusive Economic Zone (EEZ). The first one is defined in the Regulation for Territorial Water Use, Navigation Routes, Beaches, FMTZ and Commercial Land in the General Law of the National Warfare, while the other in the Federal Law of the Sea. FMTZ determines its boundary as a strip of 20 m wide firm land measured from the highest limit of the tide observed in a lapse of 30 days, while EEZ extends its limit to 200 marine miles (380,400 m) from where the width of the Territorial Sea is measured.

In this zone of interaction between solid and fluid media, constant energy interference between wind, tide, wave action and seaward sediment accumulation account the most for the dynamic coastal topography.

Beaches and cliffs are the submergenal lands, which act as a buffer against the erosive force of waves. Sand dunes may develop along dissipative coastlines with strong onshore winds and ample sediment (sand) supply. In the tropical coasts of the country, fine sediment (mud) accumulation with halophytic (salt resistant) vegetation cover on the salt water table is found as salt marsh. Between latitudes of 30°N and 30°S, mangrove communities largely replace the shoreline's marsh vegetation. Both develop along the low-energy tidal shorelines and inhabit diverse biological creatures. Tidal lagoons are water bodies entrapped behind coastal barriers. The water exchange between the lagoons and the sea defines the salinity and water level of the lagoons. In this report, references to tidal lagoons vary according to salinity levels, as follows: less than 0.5 salinity are freshwater lagoons, between 0.5 to 35 are brackish water lagoons, salinity greater than 35 are saltwater/saline lagoons. Swamps are generally used to refer to water bodies smaller than lagoons regardless of their salinity level. The term swamp, as used herein, signify coastal water bodies. Estuaries are semi-enclosed water bodies connected to the sea, within which seawater is diluted by freshwater (Carter, Coastal Environments, 1989). Wetland covers a broader scope of water bodies and its surrounding environmental unit both in interior and coastal land, including lakes, swamps, marshes, and lagoons of every level of salinity.

b) Characteristics of shoreline

Mexico's coastline spans 11,592.77 km in total length, of which 1,567,300 ha are covered by surface estuaries. About 674,500 ha of these estuaries are in the coastal zone of the Gulf of Mexico, and 892,800 ha in the Pacific Coast. The mangrove swamps, which include the seawater area, cover a total of 525,000 ha in the Pacific Coast and 660,000 ha in the coast of the Gulf of Mexico (Contreras, Ecosistemas Costeros Mexicanos, 1993).

Mexico has more than 130 coastal lagoons and estuaries with diverse geographic features, hydrological regimes, ecosystems and environmental problems.

The Gulf of Mexico extends 4,000 km from the Florida Bay in the USA to the Catoche Cape in Yucatan State of Mexico. The coastlines of the following three states along the Pacific Coast and the of Mexican Gulf are longer than 1,000 km: Baja California Norte (1,555 km), Baja California Sur (2,705 km), Sonora (1,207 km). The west coast of the Baja California Peninsula has several small coastal lagoons and inlets.

(2) Climate

a) Temperature

Mexico has a variety of climate types ranging from very hot to mildly cold, and from humid to dry. The annual average temperature falls between 10 and 25°C over most of the territory. The climate of 37% of the Mexican territory is hot, with annual average temperatures beyond 22°C, while 39% of the territory has warm climate, with annual average temperatures between 18°C and 22°C. About 23% is semiwarm, with annual average temperatures between 12°C and 18°C. The remaining 1% is mildly cold, where the annual average temperatures are lower than 12°C (CONABIO, La Diversidad Biologica de Mexico: Estudio de Pais, 1998).

b) Wind

Over vast marine and terrestrial landscapes in Mexico, huge wind movements and atmospheric disturbances are commonly observed. Trade winds originate in the Gulf of Mexico, bringing rains upon entering the country over the continental zone.

The northern side of the country is located underneath the extra-tropical chains of high atmospheric pressure, where the wind descends inducing cloud formations and rain. On the other hand, the southern side of the country is influenced by trade winds that cross the narrowest portion in the continent. The consequence of this climatic pattern presents a dry climate with great thermal oscillations in the north, and higher humidity and stable temperature regime in the south.

c) Rainfall and water

Of the total country surface area, 52% is arid or semiarid, 13% is tropical dry, 20% is mild and 15% is tropical humid. The annual average rainfall in Mexico is 777 mm, equivalent to 1,522 km^3 of water mass. From this volume, 72 % returns to the atmosphere by evaporation (SEMARNAP, Estadistics Medio Ambiente Mexico, 1997). Depending on the geographic location, the annual rainfall within the nation is very variable ranging from about 100 mm up to 4,000 mm (see Figure 1.1). Per capita precipitation in Mexico reaches about 5,000 m^3 per year. This volume is equivalent to 14 normal water tanks per day per person for all water use. This quantity is comparable to half of the water usage in the USA. The available water "per capita" in Mexico is placed on an intermediate level among the countries around the world (CONABIO, La Diversidad Biologia de Mexico: Estudio de Pais, 1998).

(3) Oceanography

a) Seabed

The Gulf of Mexico is a basin separated from the Caribbean Sea by a strait approximately 2,500 m depth. It expands over a total area of 1,768,000 km with more than 3,400 m deepest regions. On its northern side, the Gulf of Mexico belongs to the U.S. economic zone, where the continental platform is widely developed, especially in the Florida Peninsula. Nevertheless, within Mexico's national territory is very narrow, except from the Yucatan Peninsula (Oceanografia de Marces Mexicanos, 1991).

b) Tides

The tides in the Gulf of Mexico are dominated by diurnal tide, with some portion of mixed tides in the North East and North West zones of the Gulf (Texas-Louisiana and Florida). The presence of mixed tides and semi-diurnal tides in some locations of the Gulf of Mexico could be mainly due to the interaction between the tidal wave and dominant topography of each place. For example, the North East of the Gulf zone constituted by Florida's continental platform presents a slope and different topographic irregularities that could provoke the formation of mixed tides, and of wind influence in the region.

In terms of the sea level, there is a network of tidal level observation under the UNAM in the Gulf of Mexico, and monitoring has been conducted since 1950. According to the monitoring data, the highest sea level values (from 189 cm to 213 cm) were recorded in Coatzacoalcos and Veracruz. This is due to the morphologic characteristics of the Coatzacoalcos estuary that favor tidal wave heights.

The Caribbean Mexican coast present mixed tides; but there is no information in terms of the height of the sea and its changes. In the Gulf of California, the determination of the annual tide pattern is not easy because it is very much influenced or modified by the discharge and drainage of rivers, mainly during the rainy season and mostly in the coasts of Sinaloa and Sonora (Oceanografia de marces mexicanos, 1991).

c) Currents

The Gulf Stream is originated in the Atlantic Ocean. Regulating the terrain temperature not only of Mexico but also of the USA are the strong maritime streams running along the gulf coast. Detached from Japanese currents, the California Stream regulates the temperature in northwestern Mexico. The rainfalls show California's influence during the winter over the west coast of Baja California.

The Gulf of Mexico has more than 300 km^3 of water volumes. The ropelike current in the east portion, and anti-cyclone movement through the west frontier characterizes the circulation in the Gulf of Mexico. The ropelike current covers the Yucatan current and its extension in the direction of the flow penetrating the Gulf, and leaving by the Florida Strait (Oceanografia de marces mexicanos, 1991).

d) Waves

The Gulf of Mexico plays an important role in dissipation of tide energy along the coast. A certain portion of this energy is consumed in the vertical mix and the generation of internal waves, which is called Kelvin Waves, and produces a change in mass distribution. Close to the entrance to the Gulf of California, the internal waves present a longitude of approximately 1,000 km in a period of approximately 6.6 days and a propagation velocity of 1.75 m/second.

The Gulf of California is one of the most important tidal energy submerging points in the Northeastern Pacific Ocean, which is compatible to other places such as the Gulf of Panama, the Alaskan Coast, and Fundy Bay in Canada (Oceanografia de Marces Mexicanos, 1991).

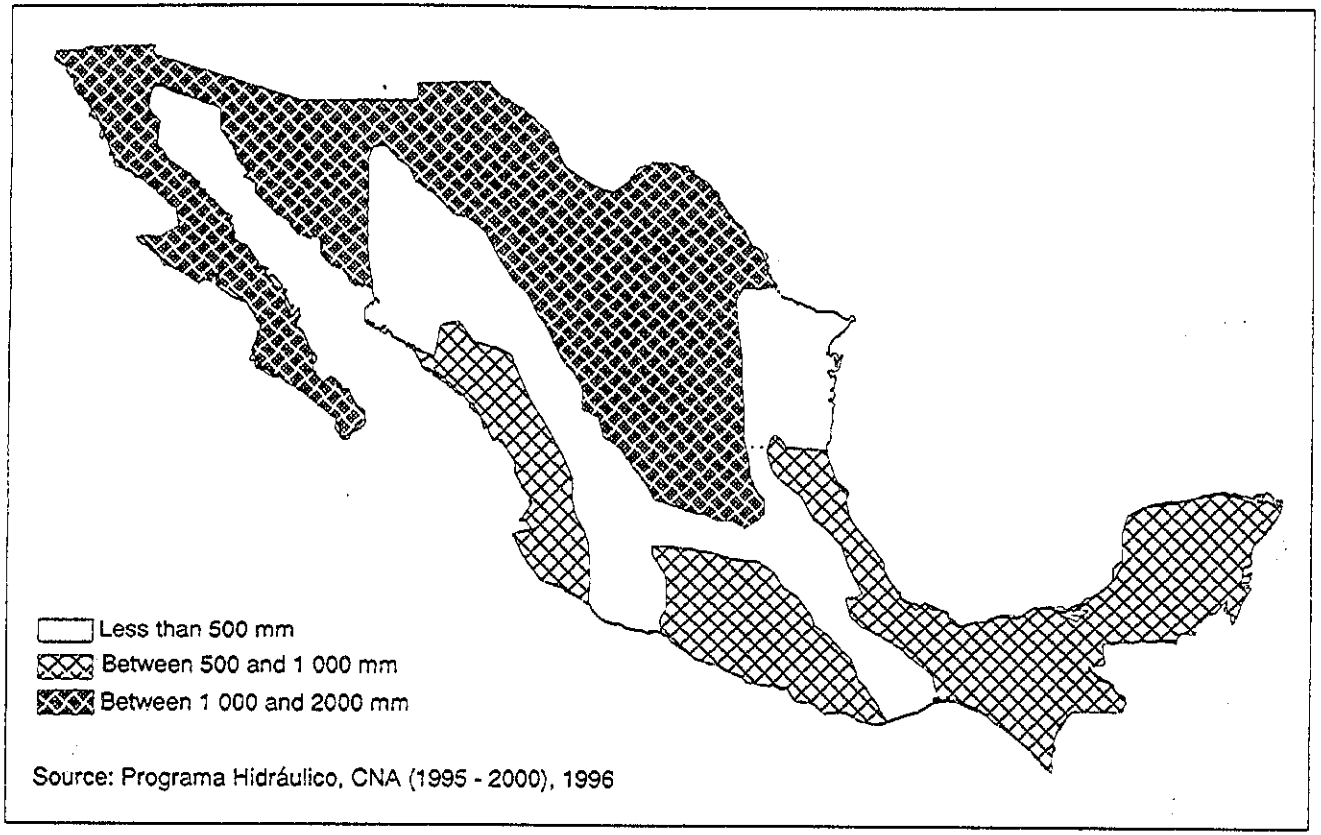


Figure 1.1 Annual Average Rainfall

(4) Terrestrial Hydrological Conditions

Mexico receives an average annual rainfall of 777 mm, which is equivalent to 1522 km^3 of water volume. The precipitation is unequally distributed in Mexico, where the northern region receives only 3% of the total precipitation while occupying 30% of the Mexican territory and the southeast region, which accounts for 20% of the national surface, receives 50% of the total precipitation in Mexico. Precipitated water flows into the Pacific Ocean, the Gulf of Mexico, the Caribbean Sea, and the inner lagoons. This report describes terrestrial hydrological conditions relating only to the coastal area. Mexican coastal area is divided into the following regions:

- Pacific Ocean coastal region;
- Gulf of Mexico coastal region; and
- Yucatan Peninsula coastal region.

a) Pacific Ocean coastal region

Pacific Ocean coastal region consists of the following states, Baja California, Baja California Sur, Sonora, Sinaloa, Nayarit, Jalisco, Colima, Michoacan, Guerrero, Oaxaca and Chiapas (see Figure 1.2.).

The western part of Baja California Peninsula has several small coastal lagoons and inlets (Ojo de Libre Lagoon, San Ignacio Lagoon, Todos Santos Inlet, Magdarena Inlet and so on). From Sonora to Nayarit, there are many plain deltas, which are formed by the rivers of Colorado, Sonora, Yaqui, Mayo, Fuerte, Sinaloa, Culiacan, San Lorenzo, Acaponeta, San Pedro, Lerma Santiago and Ameca. Yaqui River has three large artificial lakes (Angostula, Alvaro, Obregon and Novillo). Other rivers also have artificial lakes. There are also many coastal lagoons and inlets like Agua Bravo Lagoon into which Acaponeta River flows. From Jalisco to Oaxaca, the coastal area is characterized by narrow plains. There are the rivers of Coahuayana, Balsas, Papagayo, and Verde. Balsas River has a large artificial lake called *infiernillo*. There are also a number of coastal lagoons such as Cuyutlan, and Tres Palos. From Oaxaca to Chiapas, wide plains formed by the discharge of Tehuantepec River characterize the area. These plains become narrower toward the south. Coastal lagoons, such as Superior, Inferior, and Mar Muerto, are developed.

Surface area and runoff volume of some watersheds in the Pacific Ocean coastal region are shown in Table1.1. Lerma Santiago and Balsas watersheds have large surface areas and populations. Runoff volume per watershed area increases from north to south.

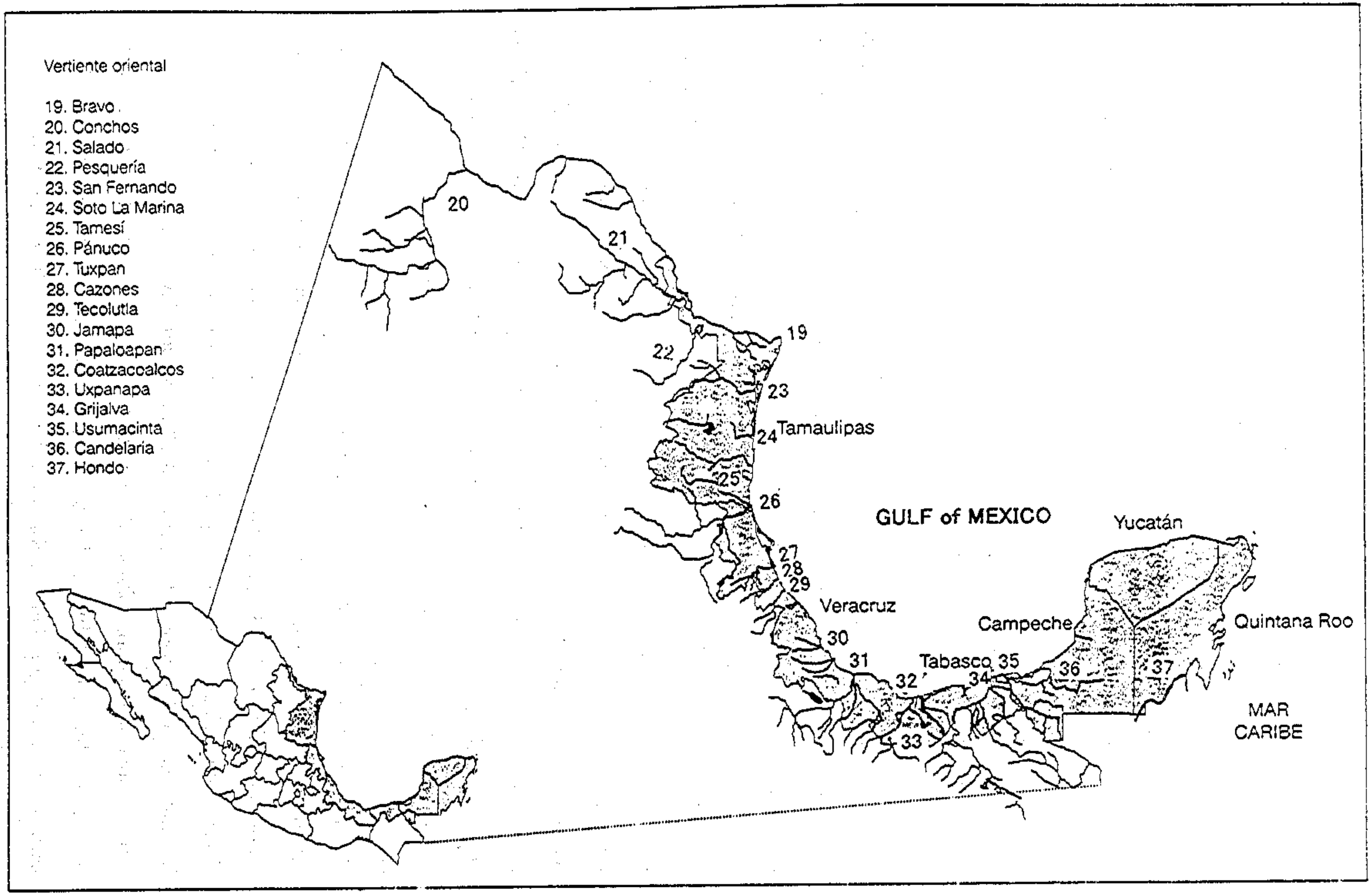


Figure 1.2 Rivers in the Gulf of Mexico Coastal Area

Table 1.1 Characteristics of Watersheds in the Pacific Ocean Coastal Region

Name of Watershed	Surface Area (km²)	Runoff Volume (million m³)	Population
Colorado	5,180	16	489,634
Concepcion	25,477	49	198,764
Sonora	28,885	216	322,981
Yaqui	72,590	1,682	445,791
Fuerte	33,590	5,007	386,057
San Pedro	26,480	224	578,623
Lerma Santiago	129,263	7,277	11,344,467
Ameca	12,436	2,337	395,856
Armeria	9,975	1,327	469,848
Coahuayana	7,301	1,842	282,667
Balsas	111,300	14,045	7,280,632

Source: Control de la Contaminacion del Agua en Mexico, SEDUE (1988)

b) Gulf of Mexico coastal region

The Gulf of Mexico coastal region includes Tamaulipas, Veracruz, Tabasco, and one part of Campeche as shown in Figure .3. Its coastal plains continue from the north part of Tamaulipas State to the southeast of Campeche State, interrupted only by the Transversal volcanic system (Cofre de Perote) in Veracruz State. A river delta is formed with El Bravo, Conchos, Salado, San Fernando, Soto la Marina, Guayalejo, Panuco, Tuxpan, Cazones, Tecolutla, Jamapa, Papaloapan, Coatzacoalcos, Uxpanapa, Grijalva, Usumacinta, and Candelaria. These coastal plains have very limited drainage systems, promoting the formation of coastal lagoons such as Madre, Pueblo Viejo, Tamiahua, Catemaco, Carmen, and Terminos Lagoons.

Surface area and runoff volume of some watersheds in the Gulf of Mexico coastal region are shown in Table 1.2. Runoff volume per watershed area increases from the north to the south.

Table 1.2 Characteristics of Watersheds in Gulf of Mexico Coastal Region

Name of Watershed	Surface Area km²	Runoff Volume million m³	Population
Bravo	8,750	88	515,288
Conchos	71,964	1,079	832,828
Salado	61,347	328	689,389
Panuco	67,872	11,810	17,751,888
Guayalejo	17,084	2,198	317,080
Jamapa	3,974	583	592,403
Papaloapan	32,678	25,388	1,399,635
Coatzacoalcos	21,214	12,902	282,667
Grijalva	64,156	42,143	1,977,180

Source: Control de la Contaminacion del Agua en Mexico, SEDUE (1988)

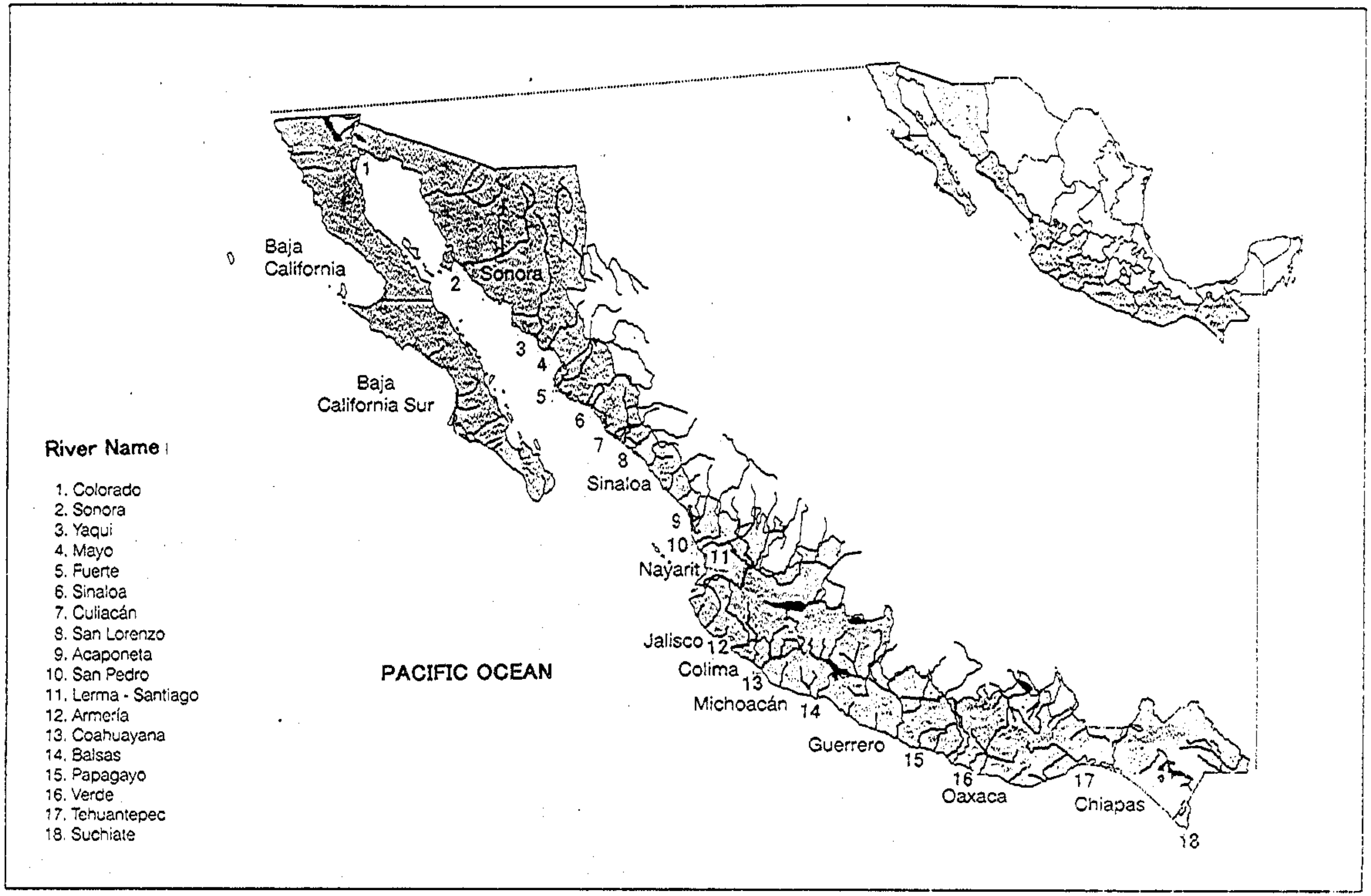


Figure 1.3 Rivers in the Pacific Ocean Coastal Area

c) Yucatan Peninsula coastal region

Yucatan Peninsula coastal region contains the west part of Campeche State, Yucatan State and Quintana Roo State. A large part of Yucatan Peninsula lacks river systems, because a calcareous platform of marine origin is developed, and water easily infiltrates into the stratum. Therefore, almost all the water flows as groundwater.

(5) Coastal Ecosystems

a) Biodiversity of Mexico

Mexico is noted for its extensive biodiversity owing to its location in the transitional zone of two different biographical regions of the planet coverage: the Nearctic and the Neotropical.

While there are the most arid deserts and severe snow mountains with hardly any vegetation, the country has exuberant jungles with annual precipitations greater than 4,000 mm. Between these extremes, flora and fauna of the North and South America are mixed, creating one of the mega-diverse countries in the world. For example, Mexico has the most diverse reptile species, and has the second longest list of mammalian species in the world (INEGI & SEMARNAP Estadísticas del Medio Ambiente México, 1997). Besides, the nation is distinguished for having a great amount of endemic species, which are distributed exclusively within the limit of the border. For example, more than 1200 succulents (plant family with thick leaves like cacti) and more than 900 vertebrates are endemic in Mexico. The total number of species registered in Mexico is approximately 64,878. However, the number only counts the species with scientific names in published data. The knowledge about actual genetic variability of the wild species is very limited. Especially the states in the southern part of the country (Gerrero, Oaxaca, Veracruz, and Chiapas) are supposed to have an important potential of species richness for further study. It is estimated that over 200,000 species exist in the nation yet to be found (CONABIO, La Diversidad Biologica de Mexico: Estudio de Pais, 1998).

b) Vegetation

The main vegetation communities of the country has been classified with various systems and names, but the majority are based on topographical, meteorological, pedological, ecological and evolutional factors that characterize the community. Among them, the classification by Rzdowski (Vegetacion de México, 1978) is most commonly adopted. According to the classification, 38% of the Mexican territory is covered with xerophyte scrub forest, 19% with coniferous/oak forest, and 14% with tropical deciduous forest. The national vegetation map is shown in Figure 1.4.

According to the information obtained from satelite image by Secretary of Agriculture and Hydroraulic Resources (SARH, Inventario Nacional Forestal Periódico 1994) the total area of 141,742,169 ha, equibalent to 72.05% of the national territory are covered with forests. However, it should be mentioned that not all the forestal surface are original vegetation. In relation to the total national territory, excluding the perturbed or fragmented areas, it only leaves 55.5% of the land surface coverd by intact forests and jungles.

Specifically for the coastal vegetation, there has hardly been any integral research of the acuatic flora nationwide. However, as a national level investigation of the determination of coastal habitat distribution, one attempt was made in 1990 to identify and map the priority wetlands in the nation using the distribution of aquatic vegetation and major rivers as indicators in satellite images. As a result of this project, 32 wetlands were designated as priority wetlands (Table 1.3). The next effort had been made by the National Forest Inventory Project by SARH, which was to associate the vegetation and wetlands with their size and location. (SARH, Inventrio National Forestal Periódico, 1994)

c) Coastal wetlands

A broad range of fauna and flora species can be observed in different types of water bodies in the Mexican territory. Along the 11,593 km of Mexican coast, 1,567,300 ha are covered by surface estuaries, of which 892,800 ha in the Pacific coast and 674,500 ha in the Gulf of Mexico. The mangrove forests cover a surface between 525,000 ha to 660,000 ha (Contreras, Ecosistemas Costeros Mexicanos, 1993). Mexico has 130 lagoons along its coastline, among which ones in Tamaulipas (Laguna Madre), South Baja California (Bahía Magdalena), Campeche (Laguna de Términos) stand out for the surface areas (CONABIO, La Diversidad Biologica de Mexico: Estudio de Pais, 1998). Although these aquatic environments are origins of rich biological resources, attention has not been paid enough compared to the terrestrial biodiversity (Beatley, Protecting Biodiversity in Coastal Environments: Introduction and Overview, 1991). Nevertheless, it has been known that the coastal lagoons, swamps, mangrove forests, seagrass beds and reefs are closely inter-communicated, creating a large cycle of energy flow. The dissolved nutrients from a swamp flow into a sea glass bed, favoring its primary production. Marine prairies and mangroves provide feeding place for the reef fauna, as well as habitats for diverse stratum of marine organisms. It does not only qualify the ecological importance of the coastal water systems but the economical one (Botello *et al.* Ecología, Recursos Costeros y Contaminación en el Golfo de México, 1996).

d) Coral reefs

Coral reefs act as a buffer to dessipate current energy and therefore contribute to the prevention of beach erosion and the creation of calm coastal landscape with rich marine fauna and flora. Along the Mexican coast, 157 coral species are registered in Mexico, majority being found in the coast of Gulf of Mexico and the Caribbean Sea. In terms of physical structure, coral reefs of the region are the most developed in the world (Botello *et al.* Ecología, Recursos Costeros y Contaminación en el Golfo de México, 1996). In the Pacific region on the other hand, there are numerous coral reef formations that are not limited to the hot and tropical waters of the Caribbean Sea. Coral patches can be found in the Mexican Pacific coast. Although they are not considered as coral reefs in a strict sense, but they are as relevant as coral communities (see Figure 1.5). The region of Cabo Pulmo in Baja California Sur is a typical example. (CONABIO, La Diversidad Biologica de Mexico: Estudio de Pais, 1998).

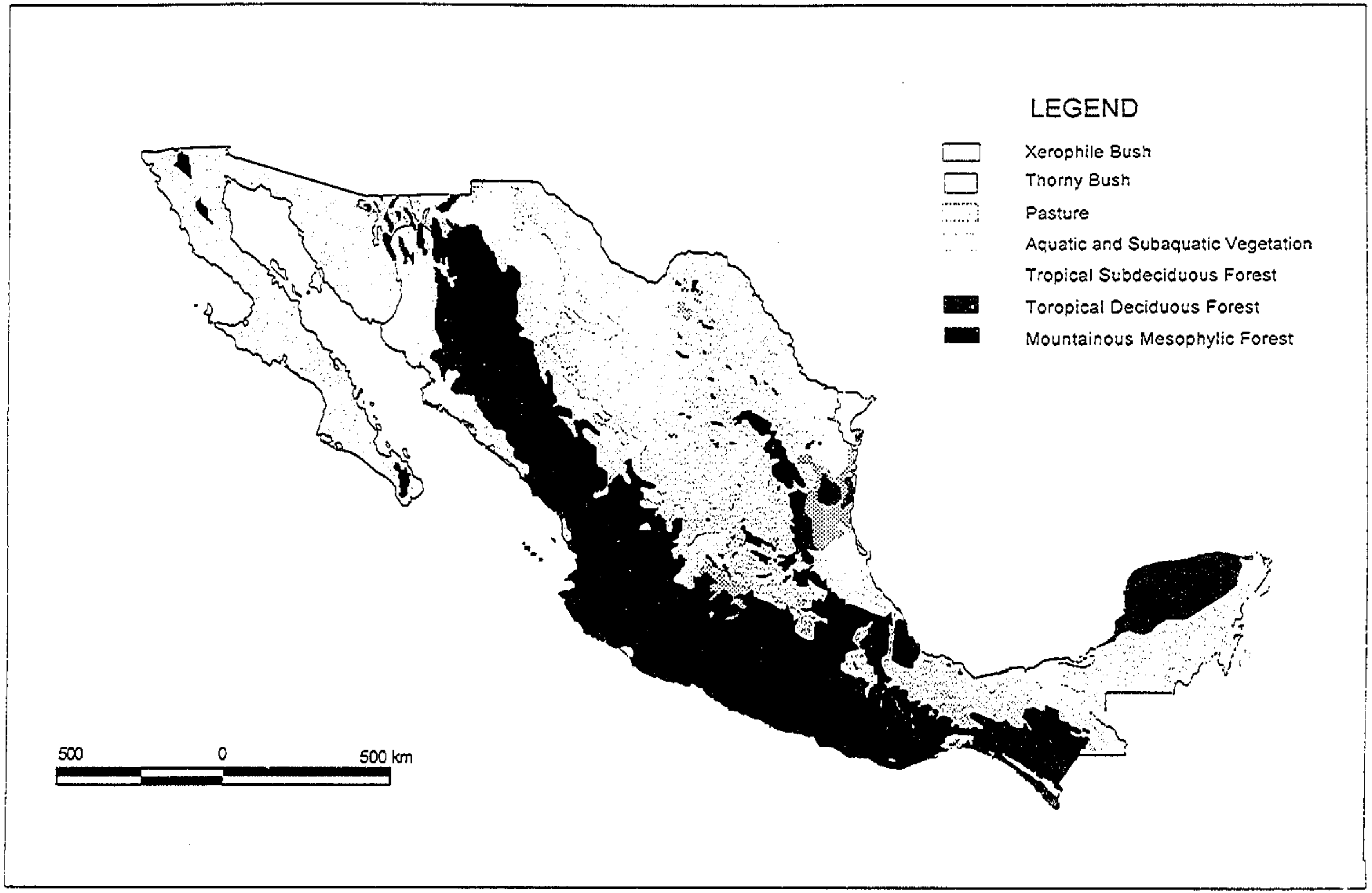


Figure 1.4 National Vegetation Map

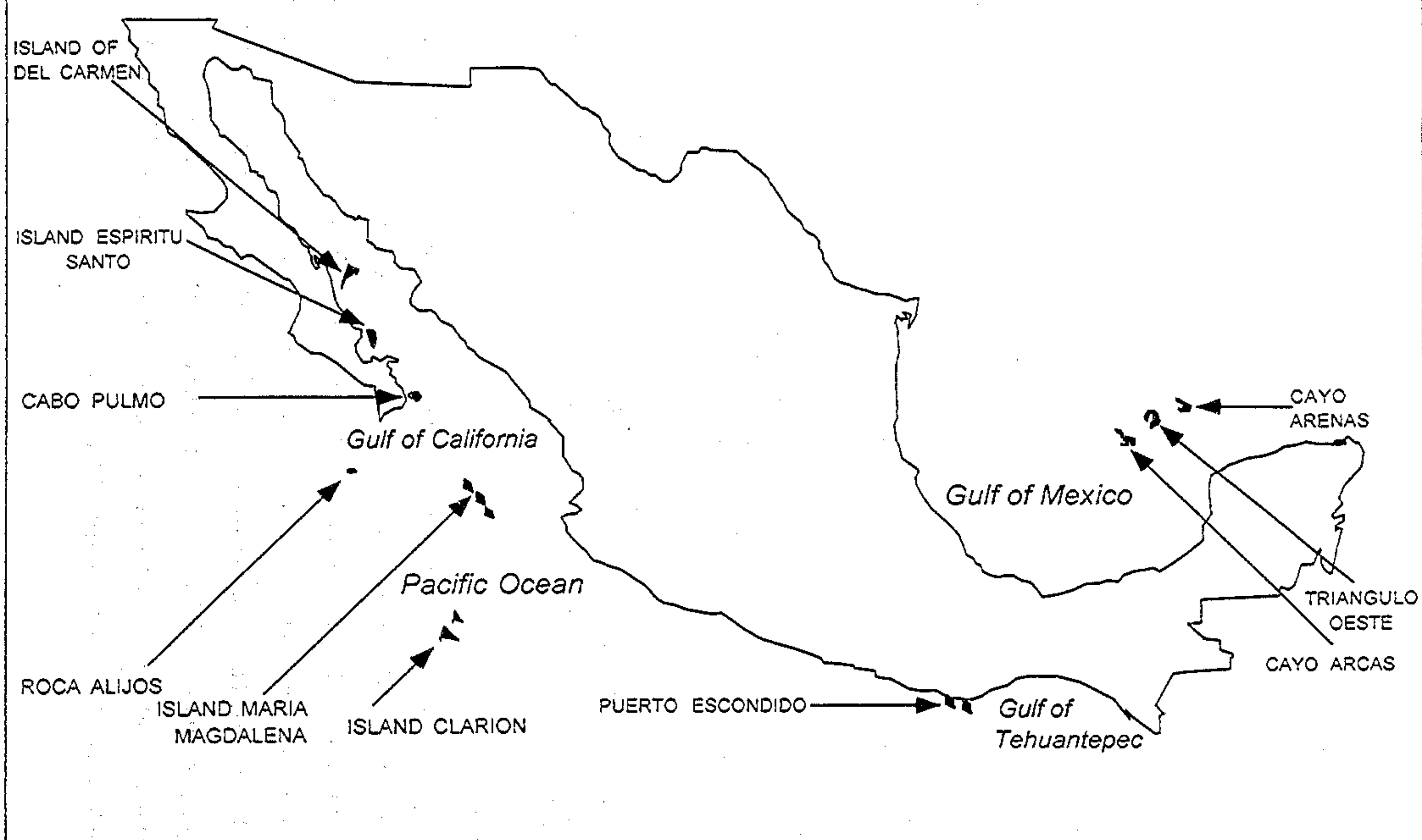
Table 1.3 Priority Wetlands in Mexico

Name	State	Surface Area (ha)
Ensenada del Pabllón	Sinaloa	80,000
Complejo Lagunar Topolobanpo	Sinaloa	55,000
Laguna de Santiaguillo	Durango	30,740
Laguna Madre	Tamaulipas	200,000
Pantanos de Centla	Tabasco	302,700
Ría Lagartos	Yucatán	48,000
Marismas Nacionales	Nayarit y Sinaloa	20,000
La Escrucijada	Chiapas	80,000
Complejo Lagunar de Alvarado	Veracruz	280,000
Laguna de Babicora	Chihuahua	20,000
Laguna Los Mexicanos	Chihuahua	3,000
Zonas Húmedas de Guanajuato	Guanajuato	12,000
Bahía de Santa María	Sinaloa	138,000
Lago de Cuitzeo	Michoacán	45,000
Lago de Chapala	Jalisco	112,000
Delta del Río Colorado	Sonara y Baja California	200,000
Laguna de Términos	Campeche	100,000
Laguna Tamiahua	Veracruz	105,000
Humedal de Tláhuac	Mexico D.F.	800
Bahía de Santa María	Sinaloa	138,000
Laguna de Bustillos	Chihuahua	10,000
Laguna Fierro Redonda	Chihuahua	80
Celestún	Yucatán	60,000
Laguna Ojo de Libre	Baja California Sur	50,000
Bahía San Ignacio	Baja California Sur	60,000
Bahía Magdalena	Baja California Sur	170,000
Presa Guadalupe Victoria	Durango	280
Estero El Soldado	Sonora	200
El Palmar	Yucatán	40,177
Cuatrociénegas	Coahuila	110,000
Zona Húmedas de Sian Ka'an	Quintana Roo	450,000
Yalahau	Quintana Roo	85,000

Source: INE, 1993

e) Island Ecosystems

Islands are another extension of national territory, with 371 distributed along the Mexican coast. Due to its closed ecosystem, the biological attribute is unique to each island. Especially, the islands in the Gulf of California are reported to have unperturbed environments, which shelter diverse species including many endemic and rare ones. The archipelagos of the Gulf have 600 to 650 different plant species, which accounts for 2% to 3% of total plants registered in Mexico. About 40% of mammals and 50% of cactus on the islands are endemic (CONABIO, La Diversidad Biologica de Mexico: Estudio de Pais, 1998). .



Source: CONABIO La Diversidad Biológica de México: Estudio País, 1998

Figure 1.5 Coral Reef Distribution in Mexico

(6) Coastal Conservation Areas

a) Coastal environmental management legislation

The legislation of management and conservation of natural environment in Mexico is based on the concept of sustainable use and development, as elaborated and implemented according to the General Law of Ecological Equilibrium and Protection of Environment (LGEEPA, Diario Oficial de la Federación, 28 Jan. 1988) In order to complement the legal frame, the federal legislation issued the official standards of Mexico (Normas Oficiales Mexicanas: NOM). Of the 87 NOMs regarding environmental issues, 50% are concerned with the control of water contamination.

The administration works of national environmental management and conservation have been integrated to one governmental organization, the Secretary of Environment, Natural Resources and Fishery (SEMARNAP). The restoration and conservation of coastal environment is one of the most important interests of the secretary. During the period between 1995 to 1997, the SEMARNAP initiated a national program to integrate the information of the resources in littoral zones. In conjunction with the Regional Investigation Center of Fishery (CRIPS), biological investigation about local fish fauna, it elaborated an environmental diagnostics and database for the coastal region. Also an attempt was made for the evaluation and characterization of the natural and socioeconomic environment for the following five lagoon systems.

- Huizache-Caimanero (Oaxaca)
- Cuyutlán (Colima)
- Teacapán-Agua Brava-Marismas Nacionales (Nayarit)
- Chacahua-Pastoría (Oaxaca)
- Nichupté-Bojórquez (Quintana Roo)

The SEMARNAP plans to undertake the corresponding management program for each lagoon system, and organize a data base of the coastal environmental information according to the Reseachers Network of Coastal System (RISCO).

The Program of Fishery Infrastructure of the SEMARNAP has concentrated its attention on the restoration of environmental condition of coastal lagoons. The program carried out canal dredging and estuary / jetty protection for the following lagoon systems.

- The mouth of Oro-Laguna de Corralero, canals in the Inferior, Oriental, and Mar Muerto lagoon (Oaxaca)
- La Joya-Buenavista and Cabeza del Toro-San Marcos (Chiapas)
- The mouth of Santa Isabel and El Mezquital in Laguna Madre (Tamaulipas)
- Huizache-Caimanero and Agua Grande-Tapo Revolución (Sinaloa)
- Chaguin-Chuiga (Nyarit)

The secretary is going to continue the rehabilitation program for the lagoon system around the country, which is estimated to improve the environment for the area of 6950 ha, benefitting 1,314 families in the fishing industry. The annal production is estimated to increase by 1,080 tons, which is equilavalent to 15 million Mexican pesos (1.5 million U.S. dollars) (SEMARNAP, Programa de Torabajo, 1999).

b) Natural Protected Area (NPA)

The first natural protected area (NPA) in Mexico was the Desierto de los Leones. When it was established in 1876, the forest area was considered as a special zone of attention because of its great importance as a water supply source for Mexico City. Afterwards in 1917 the desert was designated as the first National Park in the country. There are now a total of 111 natural protected areas in the country legislated under the General Law for Ecological Balance and Protection to the Environment, or LGEEPA (see Figure 1.6). The category of management, characteristics and administration of NPAs are summarized in Table 1.4

The objectives in the creation of the Natural Protected Areas are to:

- Preserve the representative natural environments of the different biogeographical and ecological regions of the country, as well as its most fragile ecosystems.
- Assure the balance and continuity of the evolutional and ecological processes.
- Assure the preservation and sustainable use of biodiversity in its three levels of organization, particularly endangered, endemic, rare, species subject to special protection or in extinction process.
- Provide proper fields for scientific investigation and the study of ecosystems.
- Preserve the knowledge, practices, and technology that will facilitate the conservation of the national biodiversity.
- Protect the natural surroundings of these areas, monuments, archaeological, historic and artistic treasures, as well as tourism zones and other areas of importance for recreation, culture and representative aspects of the national identity of indigenous groups.

The 111 natural protected areas administered by the National Ecology Institute (INE) cover a total surface of approximately 11,796,969 ha (including decreed aquatic environments). This surface area represents approximately 6% of the national territory. The 21 existing biosphere reserves represent 68.8% of the protected surface in the country, while National Parks account for 63 areas, or 11.7% of the NPAs. The 9 protected areas of flora and fauna comprise 14.1% of the total protected surface.

Table1.4 Category of Management, Characteristics and Administration Authority of the NPAs in Mexico

Category	Characteristics	Administration
Biosphere Reserve	Areas of national biogeographical relevance, which include more than one well-conserved ecosystem, inhabits endemic, threatened, or endangered species; ecosystems or natural phenomenon of special importance; flora or fauna which require special protection	Federal
National Park	National representative biogeographical areas with more than one ecosystem with scenic beauty, scientific, educational, recreational, and historical values. Also the areas protect and preserve the marine ecosystems, regulate the sustainable use of the aquatic flora and fauna	Federal
Natural Monument	Areas which contain unique / exceptional natural elements, incorporating an absolute protection regime.	Federal
Natural Resource Protection Area	Areas designated for the preservation and protection of soil, water basin, water, and general natural resources localized in forest terrain.	Federal
Flora and Fauna Protection Area	Places which contain habitats, whose equilibrium and preservation depends on the existence, transformation and development of the wild flora and fauna species	Federal
Sanctuary	Areas with a considerable richness of flora and fauna, or with the presence of species, subspecies or habitat of limited distribution, or areas with caverns, natural wells, coves, or other topographical units, which require preservation and protection.	State
Parks and State Reserve	Areas of state and federal level relevance, which are comparative to biosphere reserve and national parks.	Municipal
Ecological Preservation Zone in the Population Center	Registered in accordance with the local legislation body.	Municipal

Source: CONABIO, La Diversidad Biologia de Mexico: Estado de Pais, 1998

Biosphere Reserves of Sian Ka'an in Quintana Roo and El Vizcaino in Baja California Sur have been registered as World Natural Heritage sites in the coastal area of Mexico. The first one is distinguished for its intact natural environment with great biodiversity in tropical forest and coral reef, and the other has enormous surface area (2,546,790 ha) and scenic landscape of Vizcaino Bay, which is designated as a whale conservation area (CONABIO, La Diversidad Biologia de Mexico: Estado de Pais, 1998). Representative NPAs in the coastal environment are listed in Table 1.5.

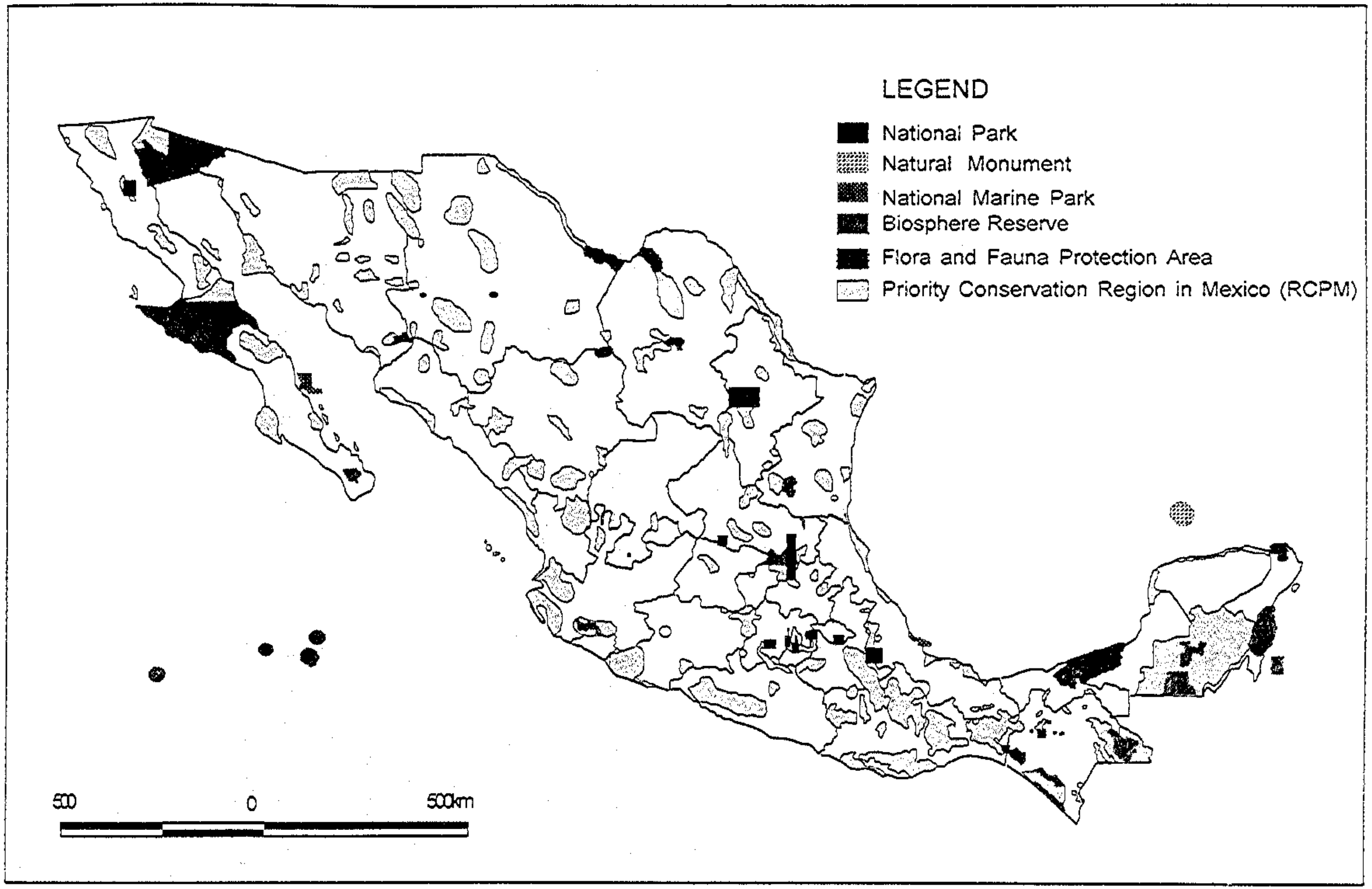


Figure 1.6 Natural Protected Areas and Priority Conservation Region in Mexico

Table 1.5 Representative Coastal Protected Areas in the Mexican States

Name	State	Area	Description
Biosphere Reserve			
Alto Golfo de California y Delta del Rio Colorado	Baja California, Sonora	934,756	Mountain xerophile, coastal dune vegetation, marine and estuary ecosystem
Archiperago de Revillagigedo	Colima	686,685	Coastal halophyte vegetation, jungle, pasture, bush
Arrecifes de Sian Ka'an	Quintana Roo	34,927	Coral reef
Banco Chinchorro	Quintana Roo	144,360	Coral reef
Calakmul	Campeche	723,185	Low deciduous, medium subperrenial forest, aquatic vegetation
Chamela-Cuixmala	Jalisco	13,142	Lower jungle, medium subperrenial forest, coastal dunes
El Vizcaino	Baja California Sur	2,546,790	Mountain xerophile, pine forest, marine areas, mangrove forest
La Encrucijada	Chiapas	144,868	Mangrove, inundated jungle, tular-popal community, lagoon system
Pantanos de Centla	Tabasco	302,707	Swamps, mangrove
Sian Ka'an	Quintana Roo	528,148	Medium jungle and low subperrenial, low deciduous forest, mangrove, swamps, coastal dune vegetation
National Forest			
Alcranes	Yucatan	338,768	Coral reef
Cozumel	Quintana Roo	11,988	Coral reef
Puerto Morelos	Quintana Roo	9,067	Coral reef
Bahia de Loreto	Baja California Sur	206,581	Mangrove, coastal dunes, bushes
Cabo Pulmo	Baja California Sur	7,111	Coral reef
Costa Occidental de Isla Mujeres, Punta de Cancun y Punta Nizuc	Quintana Roo	8,673	Coral reef
Isla Contoy	Quintana Roo	5,126	Mangrove, deciduous jungle, coastal dune
Isla Isabel	Nayarit	194	Deciduous jungle, coastal dune
Lagunas de Chacahua	Oaxaca	14,187	Medium perennial jungle, mangrove, coastal dune vegetation

Source: CONABIO, La Diversidad Biologia de Mexico: Estado de Pais ,1998, Annex 6.1

c) Priority Conservation Areas

The National Commission for the Use and Understanding of the Biodiversity (CONABIO) has organized a workshop for identification of Priority Regions for the Conservation in Mexico (RPCM). The criteria for the qualification are 1) biological importance of the region, 2) threats to the ecosystems, and 3) possibilities of conservation activities. As a result of the workshop, 155 regions of 40,715,183 ha in total were identified throughout the nation (see Figure 1.6). The identified distribution of RPCM corresponds well to that of NPAs, and includes a considerable extent of coastline.

In order to recognize the status of aquatic diversity, its biological value, threats and potential of marine conservation, the CONABIO also launched a workshop to identify priority conservation area in the lagoon, coast, sea, and hydrological regions. With the participation of investigators and NGOs, the workshop designated 110 lagoons and 70 marine and coastal areas as priorities for conservation. Among them, 64 lagoons and 44 coastal/marine areas have been evaluated to be under certain threats.

The SEMARNAP has also carried out a project for the identification of critical regions for conservation based on social condition of the region as well as the degree of environmental richness and deterioration. Based on the result of identification, corresponding conservation effort shall be implemented. The tasks and the achievements of this project are summarized in Table 1.6.

Table 1.6 Conservation Priority Regions Identified by SEMARNAP

Name of the Region	State of Locality	Environmental Hazards	Corresponding Project
National Park Chacahua Lagoon	Oaxaca	Forest destruction, forest fire, lake water quality degradation	Employment program for forest conservation, canal dredging
Chapala Lake and Lerma River Basin	Guanajuato, Queretaro, Mexico D.F., Michoacan	Water quality degradation, overexploitation of water resource depletion of fishery and aqua-culture resource	Installation of domestic water treatment plant, improvement of water use efficiency, soil conservation, aquatic species conservation with funds of OECF, FAO, Canadian Environment, and the Gov. of Vienna
Nichupte Lagoon System	Quintana Roo	Vulnerable ecosystem affected by wastewater discharge, illegal settlement, and beach erosion	Ecological ordination program, integral regional development plan including conservation of mangroves, reefs, sea turtles, natural areas, and solid and liquid waste treatment
Patzcuaro Lake	Michoacan	Sediment accumulation, deforestation in the higher part of the basin, water and soil quality deterioration, forest fire, illegal settlement, fishing resource depletion	Fire prevention, reforestation, soil conservation, partial prohibition of fishing and elimination of unauthorized fishing nets.
Sea of Cortes	Sonora, Sinaloa, Baja California, Baja California Sur	Impact of industry, agriculture, fishery, and urbanization, and electric generation.	Establishment of regional ecological ordination program (POERMAC) for the sustainable development of the region

Source: Programa de Trabajo, SEMARNAP, 1999

1.1.2 Natural Resource Uses

(1) Population distribution

Mexico's population reached 91,158,290 in 1995, which is distributed all over the national territory, both in urban and rural districts. Nevertheless, the largest population distribution is found around the capital city such as District Federal, Mexico State, and Puebla State. Also, the population is concentrated in the economically developed states such as Jalisco, Nuevo Leon and industrial development areas such as Veracruz State. The distribution among federal entities is unequal to its territorial space. Mexico State, Federal District of Mexico, Veracruz State, Jalisco State, and Puebla State occupy only 10.7% of the national surface, while embracing 41.2% of the country's total population.

Population density in 1995 was 46 persons per km^2, which is twice as much as 1970's. The Federal District has the highest density exceeding 5,663 persons per km^2, while Baja California Sur State has the lowest at 5 persons per km^2. Entities with major densities within this vast range are Mexico State, Tiaxcala State, Morelos State, Puebla State, Guanajuanto State, and Aguascalientes State. According to recent estimations by CONAPO, the national population density will increase from 46 to 57 persons per km^2 by 2010 (see Figure 1.7). Mexico, Tiaxcala, Morelos and Aguascalientes are expected to become densely populated states in the near future.

(2) Economic activities

a) Industry

In Mexico, industrialization and urbanization are the most advanced in the Federal District, Mexico State, Jalisco State, Nuevo Leon State, which account for 50% of GDP and 39% of total employment of the country. Only Jalisco State has coastal area among the three.

Under the national industrialization strategy that aims to create job opportunities, establishment of export assembly plants has been promoted since 1980's. The strategic installation of the relevant infrastructure on the northern border states of Mexico facilitated the reduction of the parts transportation costs and closer communication with the USA. As a result, almost 80 % of the assembly plants in the nation have been clustered within the five northern border states by 1996. These border states (with their shares of assembly plants) are Baja California (32.9 %); Chihuahua (15.4 %); Tamaulipas (12.7 %); Coahuila (8.8 %); and Sonora (8.0 %). Three states among them have long coastlines along their state borders.

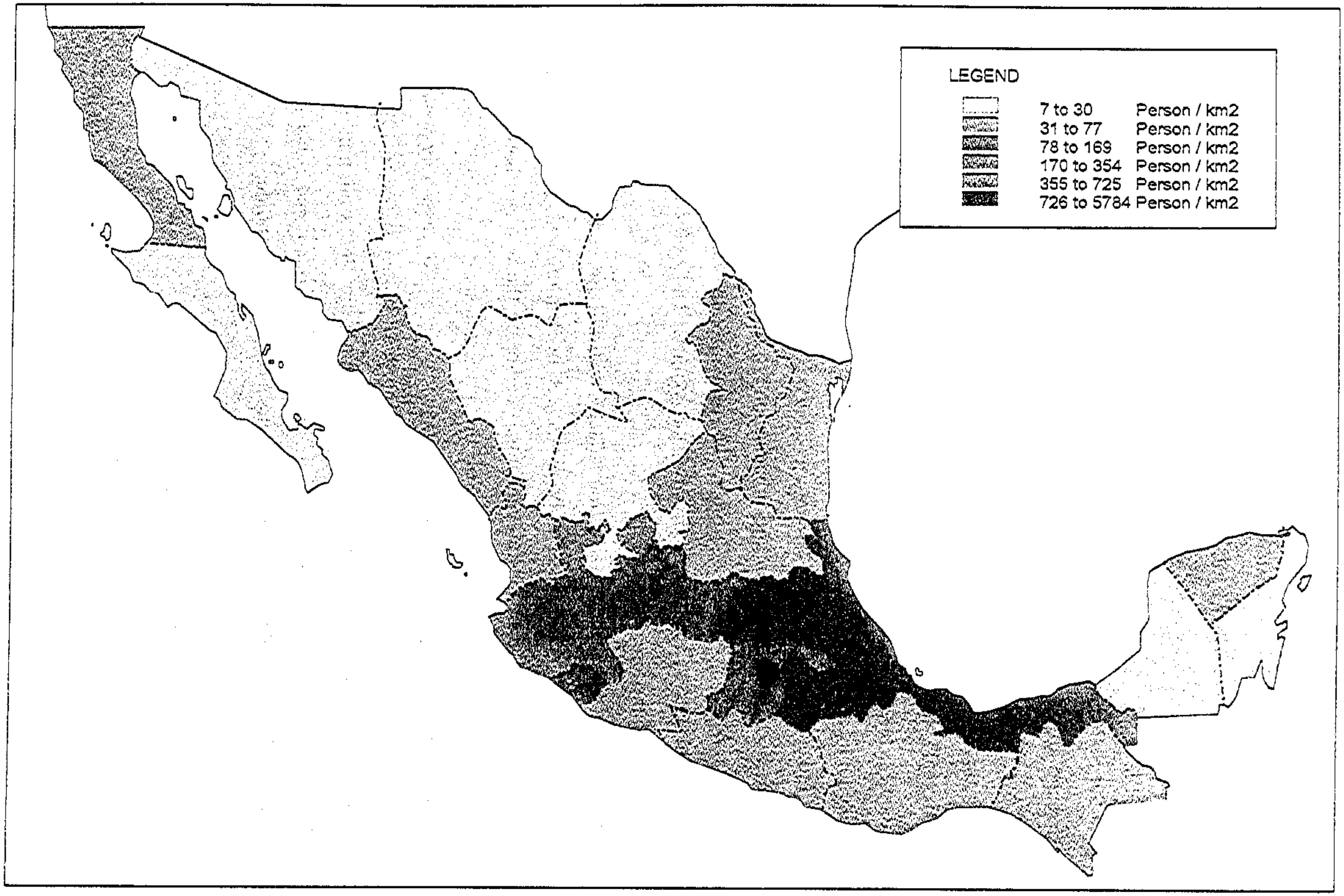


Figure 1.7 Population Density Projection of Mexico in 2010

In terms of manufacturing sector in Mexico, the sector activities are concentrated in the Federal District (10.6%) and the following seven states: Puebla (9.1%); Mexico State (8.5%); Jalisco (6.8%); Veracruz (5.6%); Michoacan (5.6%); Guanajuato (5.4%); and Yucatan (5.0%). More than 56% of GDP in the manufacturing sector is achieved in these states, including four coastal states.

b) Agriculture

About 18.7 million ha of harvest land occupied the following states in 1995: Chiapas, Jalisco, Michoacan, Oaxaca, Sinaloa, Tamaulipas, Veracruz, and Zacatecas. It accounts for 51% of the total harvest land of Mexico. The most important crops in terms of harvest land (48.6% of the national total) as well as production value (28% of the national total) were cereals, as of 1995. Also, the principal fruit productions in Mexico are avocado, lemon, mango, orange, and banana.

The vast extension of arid pasture in Mexican territory is suitable for livestock activities. Of the total surface of Mexico, 107.8 million ha are destined to dairy farms, which represent 55.2% of the national territory. About 65% of the stockbreeding farms are dedicated to cattle production. Chihuahua State has the largest livestock lands of the country, with 17.8 million ha oriented to cattle feeds and poultry farming. In the coastal states, the livestock production in Sonora, Baja California, and Tamaulipas are noticeable.

c) Fishery

There is a wide variety of commercial fish species in Mexico. The marine fishery species of the largest catch were sardine and tuna in 1980's. Also the small pelagic species such as shrimp are caught mainly in the Pacific Coast region.

In 1996, the total registered fishing value in Mexico was 7,629.8 million pesos, which is a 22.8% increase from 1995. The major species of the production were tuna fish and shrimp. Sonora State and Sinoloa State in the Pacific Coast are the most productive fishery states.

In terms of aquaculture, the gross production in 1994 exceeded 170,000 tons, of which approximately 150,000 were produced by semi-intensive method and 20,000 by intensive method. The intensive aquaculture in salt water is conducted in more than 16,000 ha, of which 98% is dedicated to shrimp culture. The oyster cultivation is practiced primarily in the coast of the Gulf of Mexico, especially in Veracruz State and Tabasco State.

d) Tourism

Mexico is one of world-famous tourism countries for its geographical location, rich natural environment, and archeological importance. Figure 1.7 shows main coastal tourism destination areas in Mexico. These areas provide tourism facilities of international standard.

(3) Coastal use

a) Main economic activity areas

Mexico is composed of 31 states, which include 17 coastal states and a Federal District (Mexico City). Mexico City is the most important economic and financial center of the country. Monterrey and Guadalajara are Mexico's next important cities as main industrial and commercial centers, which are located in inland areas of the country.

In terms of the oil industry, some of the world's largest petro-chemical industrial facilities are concentrated along the Gulf of Mexico, mainly in the cities of Tampico, Coatzacoalcos, Poza Rica and Ciudad del Carmen. Fishing and agricultural activities are also important in the Mexican Gulf region. On the other hand, the Pacific Coast region boasts important tourist resorts such as Acapulco, as one of the income sources besides the primary industries like agriculture and fishery. In Yucatan Peninsula region, Cancun is well known as one of the newly-developed international tourism areas.

b) Development zones

In Mexico, there is a sustainable regional development program to improve the technical capabilities of the utilization of natural resources and to integrate community organizations. This program gives special attention to priority regions in the rural zones of Mexico. Figure 1.9 shows the 30 priority regions of 18 states, which were selected in 1998 for the program. The target people are mostly composed of farmers and indigenous citizens, who are living in economically-depressed areas but have rich and important natural resources.

In terms of marine fishery activities, Mexico has Exclusive Economic Zones (EEZ) in the Pacific Ocean as well as the Gulf of Mexico (see Figure 1.10).

c) Conservation zones

Mexico has a long stretch of coastline exceeding 11,000 km with 130 coastal lagoons. Especially in Tamaulipas State, Baja California Sur State and Campeche State, there are a number of large coastal lagoons.

A total of 152 species of rocky reefs have been observed in Mexico. In the Gulf of California, major diversified coral reef areas are found, especially in the islands of Carmen, Espiritu Santo, and Cabo Pulmo. There are some coral reef formations in the Gulf of Mexico. However, in the Pacific Ocean side, formation of coral reef is rare.

(4) Coastal infrastructure

a) Road and highway network

Mexico's road and highway network serves 98% of passengers and 60% of cargo transport. In 1990, the national highway network had a total length of 239,298 km in which only 35% were paved. In 1996, the total national highway length increased by 29.7% (310,292 km), but the ratio of paved highways decreased by 32%.

The road and highway network connects all main cities and major ports of the country, but only few coastal highways.

b) Seaport network

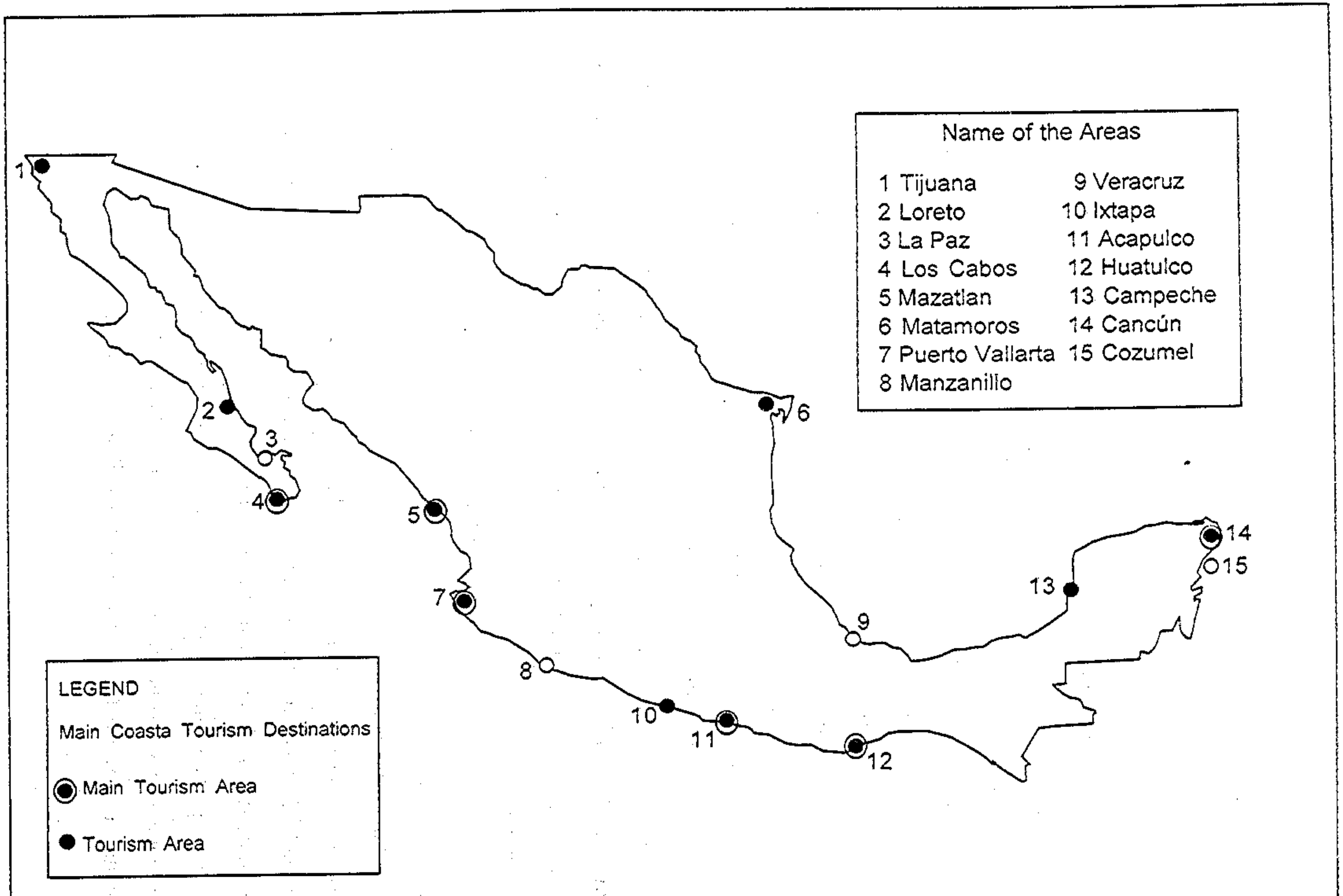
The 11,500 km of long Mexican coastline has driven the development of a vast port network of the country. As of 1996, there are 76 maritime ports, which include deep-sea ports, commercial ports, ferryboats stations, and fishing ports (see Figure 1.11). The commercial ports of Manzanillo and Lazaro Cardenas in the Pacific Coast, and Altamira and Veracruz in the Gulf of Mexico, stand out since they handle 60% of total maritime cargo. These ports are important due to their proximity to large urban and industrial centers, their infrastructure and their relatively high productivity in cargo handling.

With respect to maritime fleet, Mexico had only three vessels for transporting chemical products and eight tankers by 1994.

c) Airport network

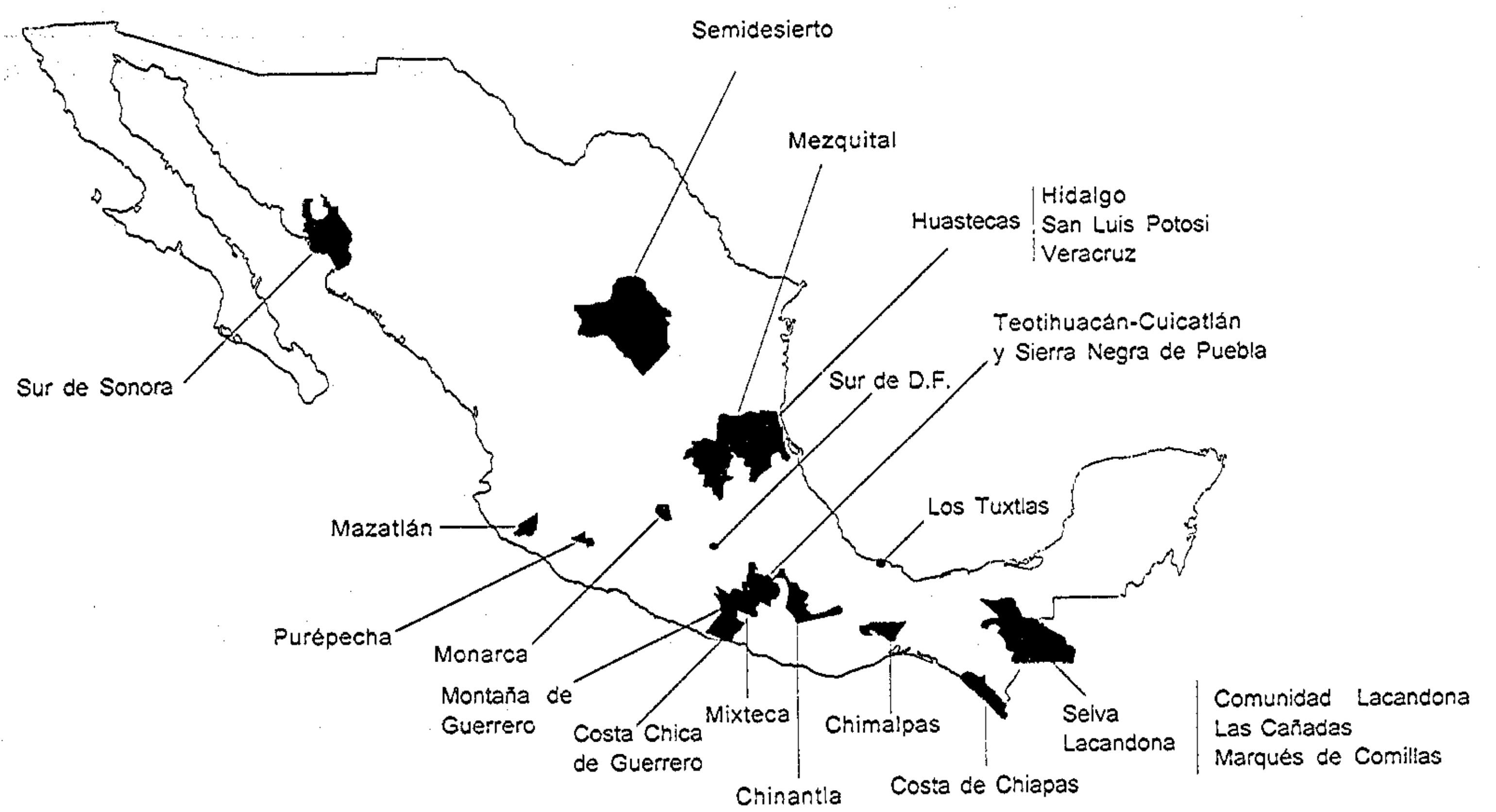
Mexico's airport network consists of 78 airports serving cities with more than 500,000 population. The 58 airports are managed by the Federal Government and the rest, by state and municipal governments.

The important airports are located in Mexico City, Monterrey, Guadalajara, and Tijuana, as well as in tourist centers such as Puerto Vallarta, Acapulco and Cancun. Figure 1.12 shows the coastal airport distribution in Mexico.



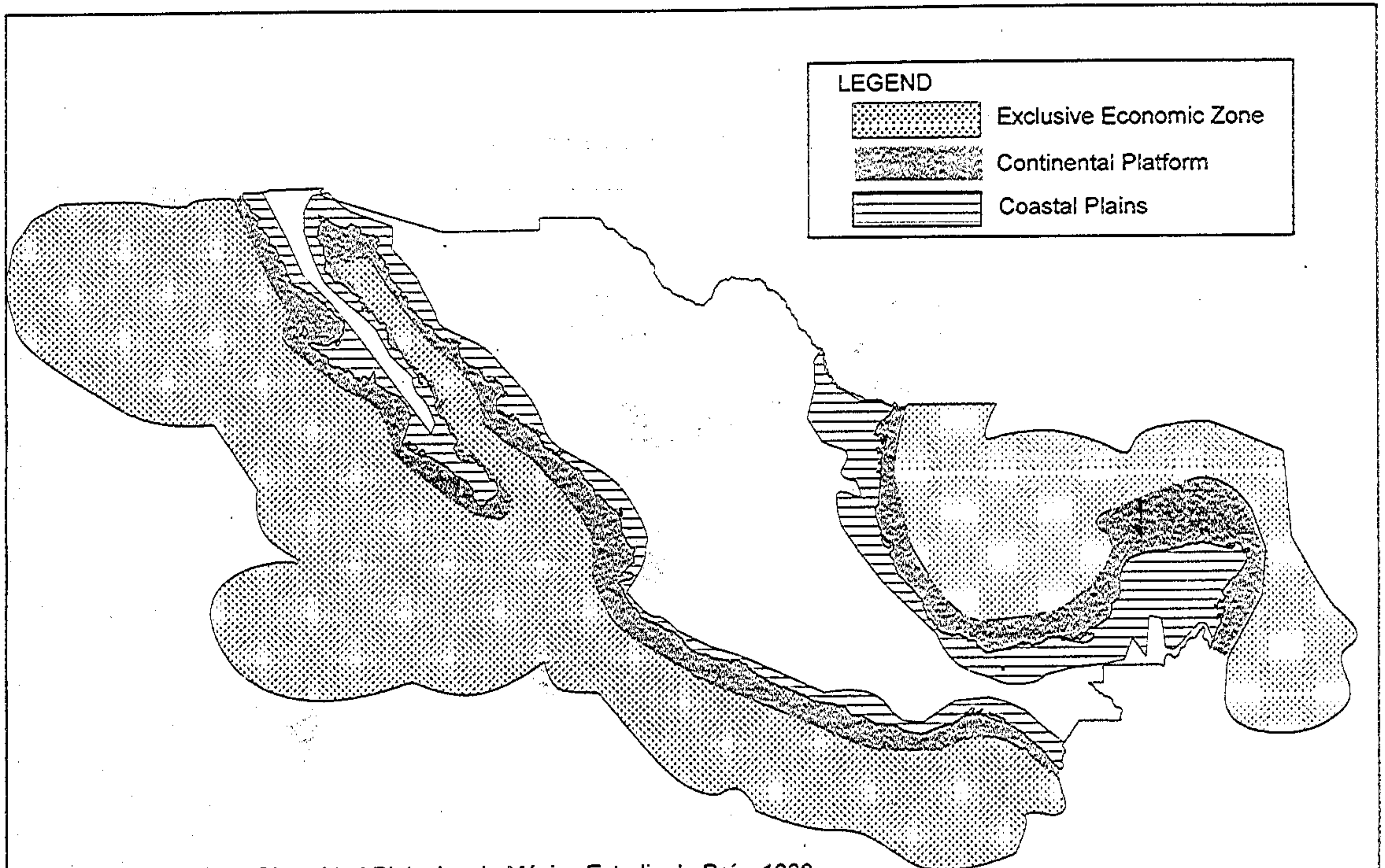
Source: JICA Study Team for National Tourism Development Project in México

Figure 1.8 Coastal Tourism Destinations in Mexico



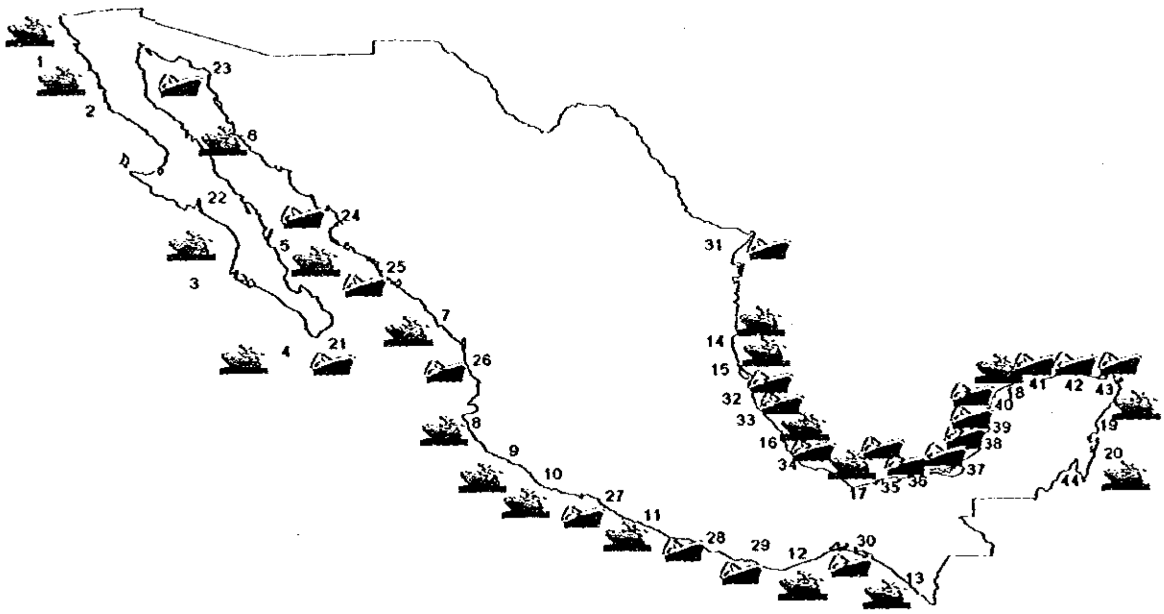
Source: SEMARNAP, 1996.

Figure 1.9 Sustainable Development Areas in Mexico



Source: CONABIO La Diversidad Biologica de México Estudio de País, 1998.

Figure 1.10 Exclusive Economic Zone in Mexico



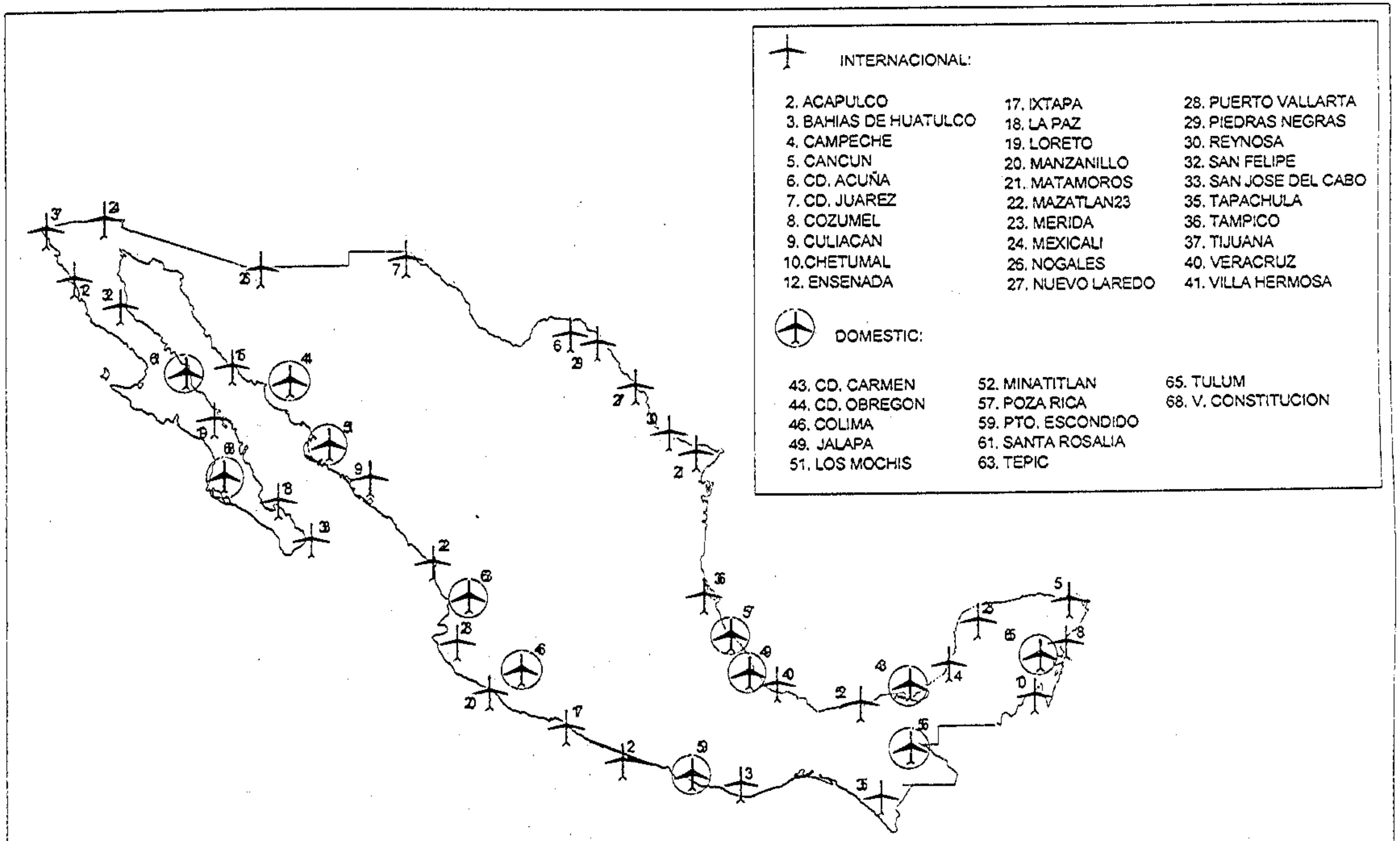
DEEP SEA PORT

1 ENSENADA	BAJA CALIFORNIA
2 ISLA DE DEDROS	BAJA CALIFORNIA
3 SAN CARLOS	B. CALIFORNIA SUR
4 CABO SAN LUCAS	B. CALIFORNIA SUR
5 LA PAZ	B. CALIFORNIA SUR
6 GUAYMAS	SONORA
7 MAZATLAN	SINALOA
8 PUERTO VALLARTA	JALISCO
9 MANZANILLO	COLIMA
10 LAZARO CARDENAS	MICHOACAN
11 ACAPULCO	GUERRERO
12 SALINA CRUZ	OAXACA
13 PUERTO MADERO	CHIAPAS
14 TAMPICO	TAMAULIPAS
15 TUXPAN	VERACRUZ
16 VERACRUZ	VERACRUZ
17 C OATZACOALCOS	VERACRUZ
18 PROGRESO	YUCATAN
19 PUERTO MORELOS	QUINTANA ROO
20 COZUMEL	QUINTANA ROO

PASSENGER / CARGO PORT

21 SAN JOSE DEL CABO	B. CALIFORNIA SUR
22 SANTA ROSALINA	B. CALIFORNIA SUR
23 PUERTO PEÑASCO	SONORA
24 TOPOLOBAMPO	SINALOA
25 ALTATA	SINALOA
26 SAN BLAS	NAYARIT
27 ZIHUATANEJO	GUERRERO
28 PUERTO ESCONDIDO	OAXACA
29 PUERTO ANGEL	OAXACA
30 PUERTO ARISTA	CHIAPAS
31 MATAMOROS	TAMAULIPAS
32 TEOCOLUTA	VERACRUZ
33 NAUTLA	VERACRUZ
34 ALVARADO	VERACRUZ
35 FRONTERA	TABASCO
36 ALVARO OBREGON	CAMPECHE
37 CD. DEL CARMEN	CAMPECHE
38 CHAMPOTON	CAMPECHE
39 CAMPECHE	CAMPECHE
40 CELESTIUM	YUCATAN
41 TELCHAC	YUCATAN
42 PUERTO JUAREZ	QUINTANA ROO
43 ISLA MUJERES	QUINTANA ROO
44 CHETUMAL	QUINTANA ROO

Figure 1.11 Seaport Distribution in the Coastal Area of Mexico



Source: SEMARNAP, 1996

Figure 1.12 Airport Distribution in the Coastal Area of Mexico

1.2 Coastal Environmental Profile of Tampico Area

1.2.1 Natural Environmental Conditions

(1) Topography

a) Characteristics of coastal area

Tampico Area is located in the center of a broad plain which is bounded in the west and south-west by the mountain range of Madere, in the south by the mountain of Tan Tima, and in the north by high mountains reaching a maximum height of 1500m. The east side of the plain faces the Gulf of Mexico; the plain is roughly 30,000 km^2. Many lagoons surrounding Tampico Area accumulate water in the basin. Panuco River, which originates around Mexico City, flows from west to east toward the Gulf of Mexico. Along the shore, large reefs and tidal inlets develo; the largest is in Tamiahua Lagoon, with an area of roughly 500km^2. San Andres Lagoon located 30km north from Tampico is also a narrow tidal inlet, which extends north-south.

The largest lagoon around Tampico City is Pueblo Viejo Lagoon, which has an area of about 100km^2. The salty water of the lagoon is attributed to the connection of its northern edge to Panuco River. Many lagoons located north-west of Tampico City are protected from the intrusion of salt by dikes constructed downstream; they are important freshwater resources.

Collected topographic maps are shown in Table 1.7.

Table 1.7 List of Collected Topographic Maps

Title, ID No	Scale	Editor	Editing	Revision
Carta Topografica, Matamoros G14-6-9-12	1:250,000	DETENAL	1st Ed.1980	-
Carta Topografica, Tampico F14-3-6	1:250,000	INEGI	2nd Ed.1997	
Carta Topografica, La Pesca F14B14	1:50,000	DETENAL	1st Ed.1980	-
Carta Topografica, La Coma F14B24	1:50,000	DETENAL	1st Ed.1980	-
Carta Topografica, Zamorina F14B34	1:50,000	DETENAL	1st Ed.1980	-
Carta Topografica, Nuevo Progreso F14B44	1:50,000	DETENAL	1st Ed.1980	-
Carta Topografica, Rancho de Piedra F14B54	1:50,000	DETENAL	1st Ed.1980	-
Carta Topografica, Lomas del Real F14B64	1:50,000	DETENAL	1st Ed.1980	-
Carta Topografica, Tampico Norte F14B74	1:50,000	DETENAL	1st Ed.1980	-
Carta Topografica, Tampico Sur F14B84	1:50,000	DETENAL	1st Ed.1980	-

Source: INEGI: Instituto Nacional de Estadistica Geografica e Informatica/Direccion General de Geografia, Mexico. DETENAL: Direccion General de Estudios del Territorio Nacional, Mexico

b) Characteristics of shoreline

The shoreline in Tampico area stretches nearly straight from north and south. Almost all its shores are characterized by wide backshores, and coastal terraces are located at each side of Altamira Port.

According to the littoral drift research conducted by the Autonomous Tamaulipas University, the north shore of Altamira Port shows a depositing tendency, and the south shore shows an eroding tendency. Plus, at the mouth of Panuco River the north shore shows a depositing tendency and the south shore shows an eroding tendency. ('Proceso Costero' Evaluacion del Transporte Litoral y Calided del Agua en el Puerto Industrial de Altamira, Division de Estudios de Posgrado e Investigacion, 1985)

It is supposed that these shoreline changes are caused by intercepting littoral drift by jetties. A long-term net littoral drift is suggested to be directed southward.

(2) Climate

Meteorological data observed at Tampico and Altamira were collected. The locations of meteorological stations and collected meteorological elements are shown in Table 1.8.

The CNA-supplied data covers temperature, rainfall and evaporation, and wind direction/speed. Monthly data of each element were collected for a period of twenty years from 1979 to 1998.

Table 1.8 Location of Meteorological Stations in Tampico Area and Collected Elements

Name of Station	Location		Elevation	Collected Meteorological Elements
	Latitude	Longitude		
Tampico	22°14'19"N	97°52'44'W	40MTS S.N.M.	Temperature
				Rainfall
				Evaporation
				Wind Direction/Speed
Altamira	22°25'30"N	97°56'42'W	10MTS S.N.M.	Temperature
				Rainfall
				Evaporation

Source: CNA

a) Temperature

The statistics of monthly temperature at Tampico and Altamira are shown in Table 1.9 and Table 1.10. At Tampico the annual average temperature is 24.8°C, the highest monthly average temperature is 28.8 in June and August, and the lowest monthly average temperature is 18.7°C recorded in January. The highest temperature is 41.0 •, and the lowest temperature is -1.5°C for the period of twenty years from 1979 to 1998. At Altamira the annual average temperature is 24.4°C, the highest monthly average temperature is 28.4°C in June, and the lowest monthly average temperature is 18.3°C in January. The highest temperature is 41.0 •, and the lowest temperature is 0°C for the period of twenty years from 1979 to 1998.

b) Wind

The monthly statistics on wind direction/speed at Tampico are shown in Table 1.11. The annual average wind speed is 3.4 m/s, the highest monthly mean wind speed is 4.2 m/s in March, and the lowest monthly average wind speed is 2.8 m/ in September.

The dominant wind directions from November to February are north, and those from March to October are east.

Table 1.9 Monthly Temperature Recorded in Tampico from 1979 to 1998 unit: •

Item	Jar	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average temperature	18.7	20.0	22.7	25.3	27.7	28.8	28.5	28.8	27.9	26.0	22.9	20.0	24.8
Average maximum temperature	28.8	30.9	34.4	35.5	34.9	34.9	34.1	34.3	34.5	33.7	31.7	29.8	37.4
Average minimum Temperature	8.7	9.8	12.4	16.1	20.7	22.4	22.3	22.7	21.1	17.2	13.1	8.8	6.9
Maximum temperature	33.0	36.5	41.0	40.5	41.0	38.5	36.0	35.5	38.0	36.0	34.5	35.5	41.0
Minimum temperature	4.0	3.0	8.0	12.0	16.5	20.0	20.5	21.0	18.5	11.5	9.5	-1.5	-1.5

Source: The hydrological record of Climatological Office/CNA

Table 1.10 Monthly Temperature Recorded in Altamira from 1979 to 1998 unit: •

Item	Jar	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average temperature	18.3	20.0	22.4	25.0	27.3	28.4	28.1	28.3	27.1	25.4	22.4	19.5	24.4
Average maximum temperature	29.0	31.4	34.4	35.6	36.0	35.5	34.5	35.1	34.5	33.5	32.4	30.1	37.8
Average minimum temperature	7.0	8.2	9.8	14.1	18.6	21.6	22.0	21.8	19.2	15.0	10.4	7.4	4.3
Maximum temperature	32.0	34.5	41.0	40.0	41.0	38.0	39.0	38.0	39.0	36.0	35.0	36.0	41.0
Minimum temperature	2.0	2.0	2.5	7.0	16.0	17.0	20.0	19.0	16.0	10.0	5.0	0.0	0.0

Source: The hydrological record of Climatological Office/CNA

Table 1.11 Monthly Wind Direction/Speed Recorded in Tampico from 1979 to 1998

Item	Jar	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean
Mean wind Speed, m/s	3.7	4.0	4.2	3.4	3.7	3.3	3.0	3.1	2.8	3.1	4.0	3.8	3.4
Dominant wind Direction	N	N	E	E	E	E	E	E	E	E	N	N	E

Source: The meteorological database of CNA

c) Rainfall and Evaporation

The statistics of monthly rainfall at Tampico and Altamira are shown in Table 1.12 and Table 1.13. At Tampico the average annual rainfall is 1117.9 mm, the maximum of average monthly rainfall is 269.6 mm in September, and the minimum of average monthly rainfall is 15.7 mm in March. At Altamira the average annual rainfall is 983.4 mm, the maximum of average monthly rainfall is 252.7 mm in September, the minimum of average monthly rainfall is 10.9 mm in February. The statistics of monthly evaporation at Tampico and Altamira are shown in Table 1.14 and Table 1.15. The annual evaporation averages in Tampico and Altamira are 1456.8 mm and 1662.5 mm respectively. Monthly average evaporation in the rainy season is higher than that in dry season. The averages of monthly rainfalls and evaporations observed at Tampico and Altamira from 1979 to 1998 are shown in Figure 1.13. The table shows that the monthly rainfall average in Tampico during those years is almost the same as in Altamira, the same with evaporation. The average monthly rainfalls in the rainy season are very different from those in the dry season. There is a drastic increase in June and the peak is felt in September. On the contrary, the change of monthly evaporation is gentle. The monthly evaporation gently increases from spring to summer and decreases from autumn to winter.

The difference between rainfall and evaporation gives an important information about the hydro-dynamics of closed water systems like lakes. Monthly rainfall, the average monthly evaporation and the difference between the two values are shown in Figure 1.14. The negative difference becomes the maximum in April or May before the rainy season, indicating that the evaporation well exceeds the rainfall during that period. In September, on the other hand, the rainfall overwhelms the evaporation for most of the rainy months of a year. The annual rainfalls and the annual evaporation observed at Tampico and Altamira from 1979 to 1998 are shown in Figure 1.14. The tendencies of rainfall and evaporation are quite similar between Tampico and Altamira. The annual rainfall has fluctuated greatly during the twenty-year period. At Tampico the maximum annual rainfall was1632 mm in 1993, and the minimum annual rainfall was 602 mm in 1982.

The monthly rainfalls of five most rainy years between 1979 and 1998 are shown in Figure 1.15, while the five driest years in the 20-year period are shown in Figure 1.16. The annual rainfalls are especially intensive in rainy season. In the five driest years, each monthly rainfall in the rainy season falls below the average for a period of thirty-nine years. On the contrary, in the five wet years, almost every monthly rainfall in the rainy season exceeds the monthly average for a period of thirty-nine years. Especially in the wet years the annual rainfall is increased by intensive rainfall in one particular month of the year.

Table 1.12 Monthly Rainfall in Tampico from 1979 to 1998

unit: mm

Item	Jar	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average monthly rainfall	33.2	20.5	15.7	28.1	50.6	176.8	134.1	170.3	269.6	132.6	37.3	49.1	1117.9
Maximum monthly rainfall	212.8	73.0	71.0	83.5	152.5	558.5	367.6	537.3	616.0	391.4	78.3	252.0	1632.3
Minimum monthly rainfall	0.0	4.9	0.0	0.0	0.0	18.8	9.4	17.9	25.4	2.2	3.8	1.7	602.4

Source: The hydrological record of Climatological Office/CAN

Table 1.13 Monthly Rainfall in Altamira from 1979 to 1998

unit: mm

Item	Jar	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average monthly rainfall	50.2	10.9	16.0	24.8	41.1	164.6	121.4	144.3	252.7	106.7	28.6	33.8	983.4
Maximum monthly rainfall	373.4	34.1	77.1	68.0	92.3	534.1	236.6	388.3	509.5	236.5	74.7	182.0	1489.6
Minimum monthly rainfall	0.0	0.0	0.0	0.0	0.0	19.0	30.0	42.2	87.1	6.3	1.0	0.2	469.6

Source: The hydrological record of Climatological Office/CAN

Table 1.14 Monthly Evaporation in Tampico from 1979 to 1998

unit: mm

Item	Jar	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average monthly evaporation	70.8	84.0	125.0	143.1	161.7	164.7	158.1	152.2	125.6	117.7	85.4	68.7	1456.8
Maximum monthly evaporation	96.0	116.2	152.7	175.9	206.4	210.5	202.8	201.9	150.8	149.6	105.5	84.4	1694.4
Minimum monthly evaporation	31.9	57.6	98.5	113.7	79.7	117.8	125.9	70.4	84.5	93.4	51.5	36.5	1271.7

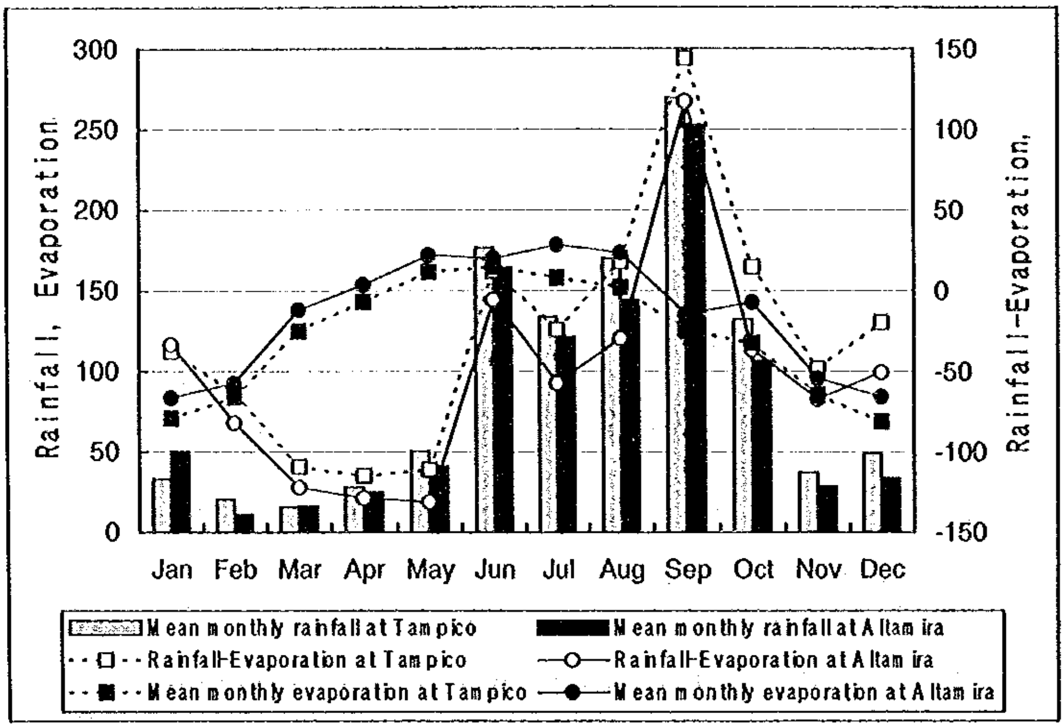
Source: The hydrological record of Climatological Office/CAN

Table 1.15 Monthly Evaporation in Altamira from 1979 to 1998

unit: mm

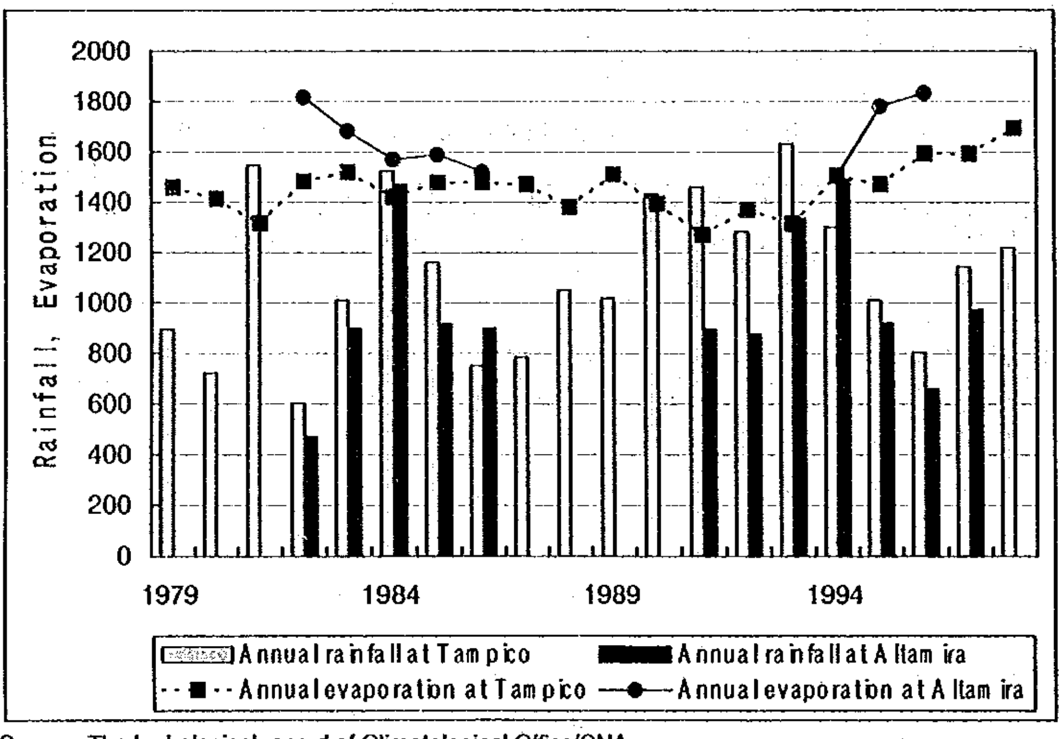
Item	Jar	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average monthly evaporation	83.6	92.7	138.1	153.7	172.2	170.1	178.5	173.6	135.4	143.0	95.7	84.3	1662.5
Maximum monthly evaporation	108.1	119.9	190.3	200.9	197.0	223.1	231.3	227.1	173.6	157.5	126.4	107.0	1834.8
Minimum monthly evaporation	52.2	55.0	115.1	115.4	143.7	144.4	137.3	136.8	84.0	92.0	68.2	51.6	1505.3

Source: The hydrological record of Climatological Office/CNA



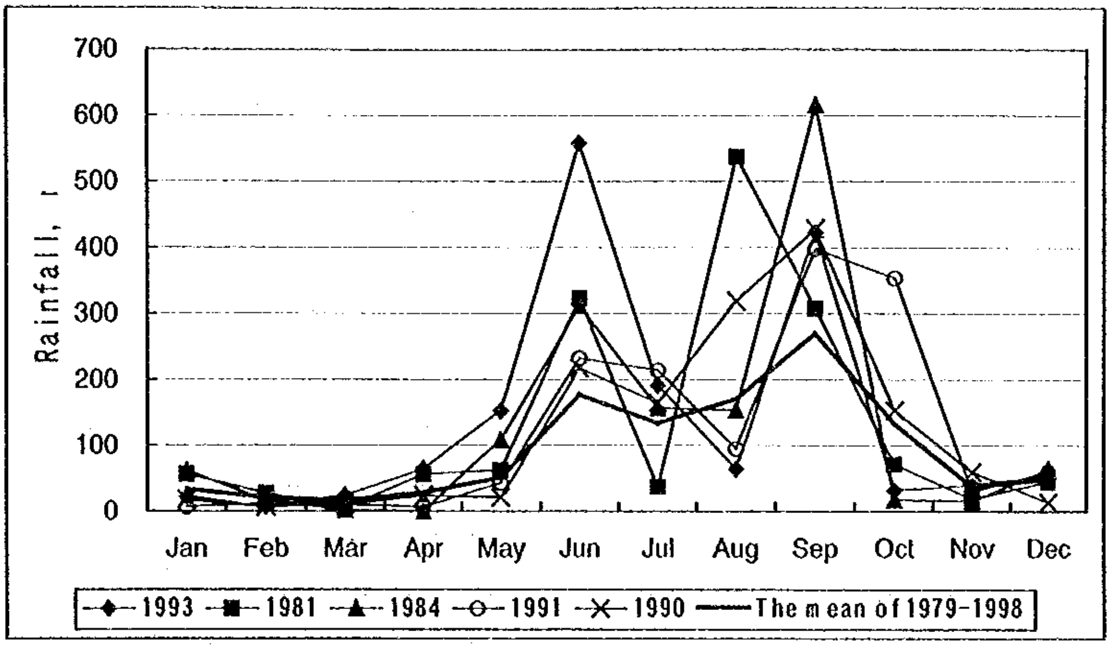
Source: The hydrological record of Climatological Office/CAN

Figure 1.13 Average Monthly Rainfall and Evaporation in Tampico and Altamira from 1979 to 1998



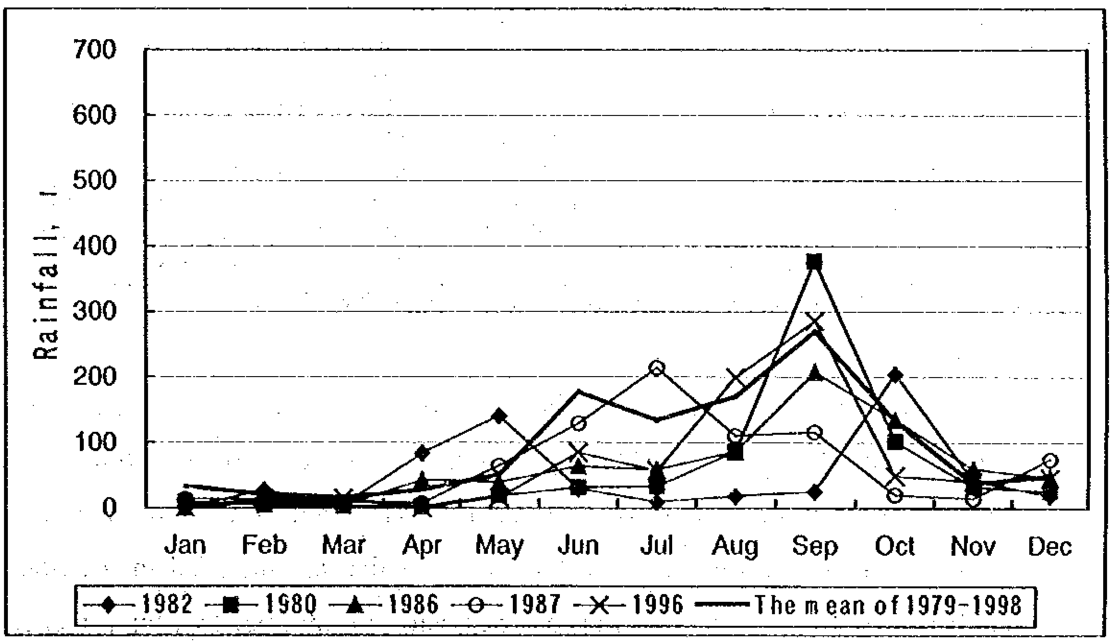
Source: The hydrological record of Climatological Office/CNA

Figure 1.14 Annual Rainfall and Evaporation in Tampico and Altamira from 1979 to 1998



Source: The hydrological record of Climatological Office/CNA

Figure 1.15 Monthly Rainfall at Tampico in the Wet Years from 1979 to 1998



Source: The hydrological record of Climatological Office/CNA

Figure 1.16 Monthly Rainfall in Tampico in the Dry Years from 1979 to 1998

(3) Oceanography

a) Seabed

A continental shelf develops along the coast of the Gulf of Mexico. Width of the continental shelf is relatively small in the Gulf and broadens toward the north. The relevant sea area along Tampico coast is the area with relatively small width of the continental shelf, yet the water depth hits 100m at 50km off the shoreline. The bed slope is steep where it is deeper than 200m. The water depth becomes 2,000m at 150 to 200km off the shoreline. Bed slope in the coastal section within the continental shelf near Tampico is relatively steep near shore, and is gentle offshore, i.e. at a water depth of 10 meters located 1.5 to 2km offshore, and 20m located nearly 7km offshore respectively. Moreover, a depth contour line of 50 meters is located nearly 30km offshore from the coast. The texture of seabed near Tampico coast is mainly sandy. Reefs and tidal inlets develop along the shore, representing the dominance of littoral drift. Collected chart maps are shown in Table 1.16.

Table 1.16 Collected Charts

Title, ID No	Scale	Editor	Editing	Revision
Rio Bravo a Tampico, S.M.700	1:600,000	SM	1stEd. Dec-1992	Dec-1995
La Pesca a Punta Jerez,S.M.721	1:100,000	SM	1stEd. Sep-1981	Sep-1997
Punta Jerez a Tampico, S.M.722	1:100,000	SM	1stEd. Jul-1980	May-1997
Puerto de Altamira, S.M.727	1:10,000	SM	1stEd. Mar-1998	-
Rio Panuco Puerto de Tampico, S.M.728	1:20,000	SM	1stEd. May-1980	Jul-1996
Tampico a Progreso, S.M.800	1:1,023,400	SM	5thEd. Oct-1972	Mar-1997
Tampico a Punta del Morro, S.M.810	1:250,000	SM	3rdEd. Oct-1980	Jul-1997

Source; SM: Secretaria de Marina, Direccion General de Oceanografia Naval, Mexico

b) Tides

Tidal range in the relevant sea area is relatively small. The predicted maximum high and minimum low tides in 1999 are 64cm and –30cm respectively. Reference level for the tide is the Mean Low Water Level (MLWL). Table 1.17 shows the harmonic constants of tide in Tampico and Altamira Port that are included in the tide table published by the Secretary of Marine (Secretaria de Marina, Direccion General de Oceanografia Naval). Constituents with a subscript 2 indicate the semi-diurnal tides that have periods of nearly 12 hours and constituents with subscript 1 indicate the diurnal tides that have periods of nearly 24 hours. This table clearly shows the dominance of the diurnal tide over the semi-diurnal tide. The main diurnal tides, which have large potential force inducing tides, are K_1 and O_1 constituents. Both constituents in Altamira Port are larger than those in Tampico. This indicates that the tidal range in the north side is larger than that in the south in the relevant sea area.

Table 1.17 Harmonic Constants of Tide in Tampico and Altamira Port

Constituent	Tampico		Altamira	
	Amplitude Meters	Phase Degree	Amplitude Meters	Phase Degree
M_2	0.073	74.27	0.084	124.30
S_2	0.023	75.85	0.023	281.90
N_2	0.018	63.31	0.018	266.30
K_1	0.131	291.93	0.170	245.60
O_1	0.130	294.25	0.158	80.90
P_1	0.041	296.05	0.056	310.30

c) Currents

According to the Figure of Physical Oceanography published by the Institute of Geography, currents in the Gulf of Mexico flow clockwise all year long. An energetic flow belt exists, entering east of the Gulf from the Caribbean Sea through the Yucatan Strait, bends eastward, and outflows into the Atlantic Ocean through the Florida Strait. This energetic flow is called the Gulf Stream. Another less energetic clockwise circulation exists in the west part of the Gulf, thus the current offshore along the west coast of the Gulf flows toward the north. The current off Tampico is also northward, and this direction is relatively stable in both summer and winter seasons. The velocity of this northward current is in order of 20cm/s in the summer season and 10 cm/s in the winter season. However, these currents only represent a synoptic scale more than 50 to 100 km offshore, thus more near shore currents are considered to differ from the offshore current. According to the Autonomous Tamaulipas University, the dominant direction of near shore currents is southward. Evidence suggesting this southward current direction is the direction of littoral drift near Tampico coast. Long jetties extending 2 km offshore have been constructed at the mouth of Panuco River. The shoreline at the north side of the jetty is located considerably offshore than the shoreline at the south side of the jetty. This suggests that long-term net littoral drift is directed southward. Another evidence suggesting the southward current direction in the relevant sea area is the field survey of this study. The plume of fresh water from Panuco River flowing out into the sea was shown to have a little southward tendency in the salinity survey.

d) Waves

There is no permanent facility for ocean wave observation in Tampico Area. According to the National Institute of Ecology report, the mean wave height ranges from 0.6 to 0.8 m, and the mean wave period ranges from 6 to 7 sec in Tampico Area. Additionally, hurricanes with waves of 5.0m to 6.0m in height and periods of 11 sec to 13 sec ravage Tampico Area. (Diseno Ejecutivo del Emisor Submarino para la Disposicion Final de las Aguas Residuales del Puerto Industrial del Altamira, TAMS, 1992) The Study has observed that the dominant wave direction of swell is ESE.

(4) Hydrological condition

The following watershed areas are located around Tampico Area (see Figure 1.17), Altamira Industrial Port area, Conejo Lagoon and Marismas Lagoon area and Panuco River watershed area.

a) Altamira Industrial Port area

Altamira Industrial Port has been constructed in the Marismas Lagoon area. There is only one natural stream, Garrapatas stream, which flows into the Gulf of Mexico through Altamira Industrial Port. This stream collects water from a watershed, whose area is about 66 km^2. This watershed area is below 30 meters above sea level. Discharge volume and water quality of this stream have not been reported.

b) Conejo Lagoon and Marismas Lagoon area

Conejo Lagoon and Marismas Lagoon are located in the south of Altamira Industrial Port. In the south of Conejo Lagoon and Marismas Lagoon there are several lagoons, such as San Jaure, Gringo Lagoon, Aguada Grande Lagoon and Patos Lagoon. These lagoons are not directly connected with the Gulf of Mexico, and are separated by dunes.

Conejo Lagoon (water surface area is about 1.6 km^2 and water basin area is about 5.8 km^2) is a freshwater lagoon without any natural streams. The average water depth is about 2 m. The south part of Conejo Lagoon is an industrial zone.

Las Marismas Lagoon is 22 km long and 1.8 km wide. Its area is 39.6 km^2 and the capacity is 9,500,000 m^3. The water body of Marismas Lagoon is separated into three parts by a road and Altamira Industrial Port, thereby reducing its surface area This lagoon has a saline water body and is separated from the Gulf of Mexico with a sandbank. Neither river nor stream supplies water into the lagoon except a channel from Conejo Lagoon.

c) Panuco River watershed area

The total area of Panuco River watershed is 77,206 km^2; mean annual rainfall in Panuco River watershed is 953 mm. Total water volume precipitated and flowed in Panuco River watershed are 73,549 million m^3/year, and 16,536 million m^3/year, respectively.

Around Tampico area, Panuco River is separated into three components:

- Upstream part of Panuco river;
- Tamesi river and its freshwater lagoons; and
- Estuary of Panuco River including Costa Lagoon, Pueblo Viejo Lagoon and Chijol channel.

The annual mean water discharge from the upstream part of Panuco River at the hydrological station (Las Adjuntas of Panuco River) is 421 m^3/s (average value from 1957 to 1994). The minimum monthly mean discharge is 120.41 m^3/s in May and the maximum is 1095 m^3/s in September.

Tamesi River and its freshwater lake system is separated from Panuco River by dikes or other facilities in order to prevent the freshwater from mixing with the brine water of Panuco River. The water volume of this system is 438,000,000 m^3. Champayan, Puerta, Tancol, and Chairel lagoons have surface areas of 10,251 ha, 526 ha, 48 ha, and 269 ha, respectively. The freshwater is supplied as industrial, municipal, and agricultural use for Tampico, Madero, Altamira, Panuco and Gonzalez. Panuco River receives water from Tamesi River near the border of Tampico municipality with Panuco municipality.

Panuco River exchanges water with Costa Lagoon, Pueblo Viejo Lagoon, Carpintero Lagoon and Chijol channel by tidal flows, as described below:

- Costa Lagoon receives freshwater from Tamesi River and its freshwater lagoons only during flooding. Its water surface area is about 39 km^2.
- Pueblo Viejo Lagoon receives freshwater from its watershed (about 1000 km^2), mainly from Llave River. Pueblo Viejo Lagoon is connected with the Panuco River mouth. Pueblo Viejo lagoon is 14.2 km long, and 6.5 km wide. Its area is 91 km^2, and the capacity is 136,500,000 m^3.
- Carpintero Lagoon receives stormwater from one part of Tampico municipality through a drainage system. Carpintero Lagoon is 2,000-m long and 400-m wide. Its surface area is 80 ha.
- Chijol channel connects Panuco River and Tamiahua Lagoon, which exchange water with Gulf of Mexico.

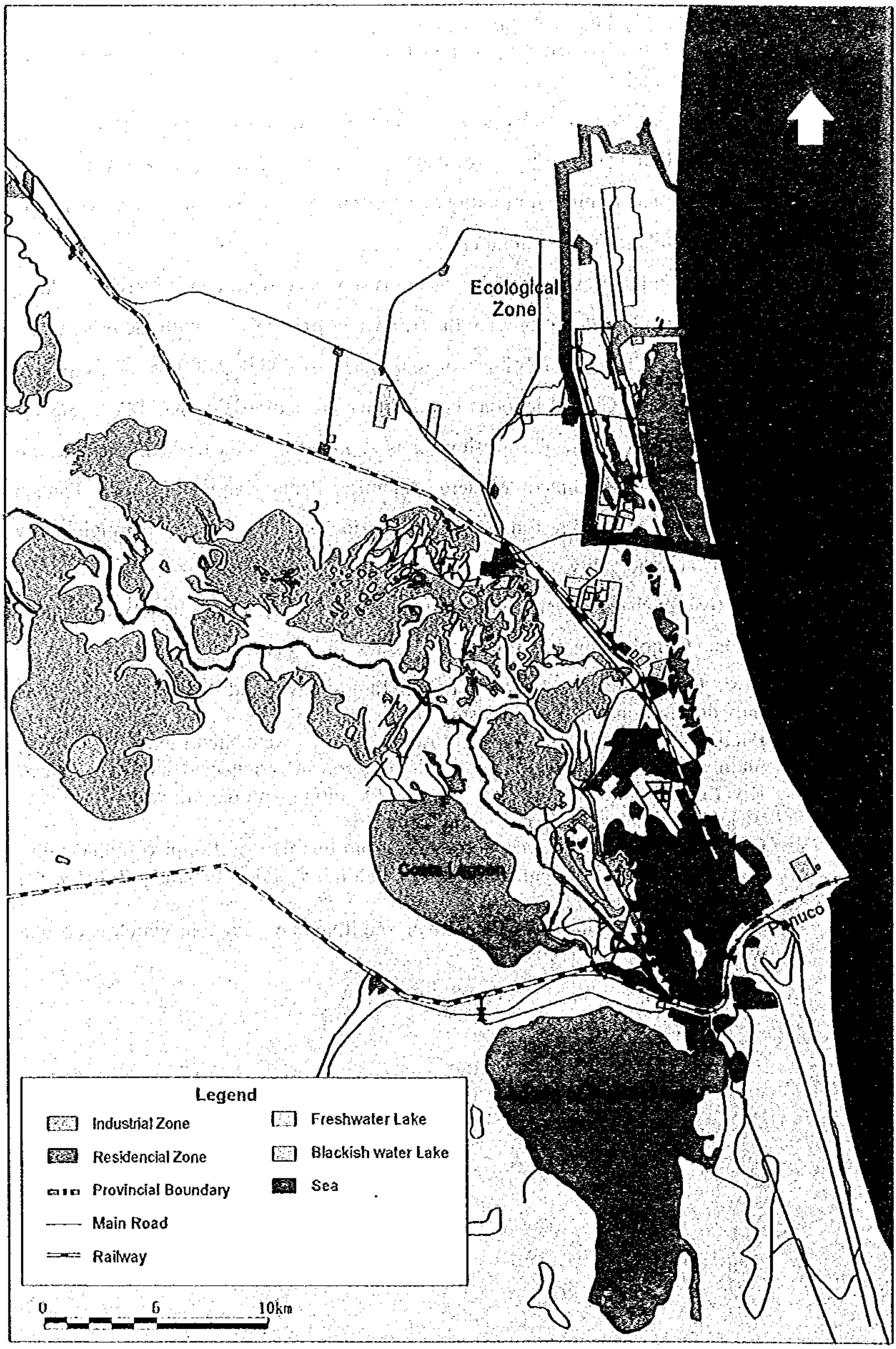


Figure 1.17 Watersheds around Tampico Area

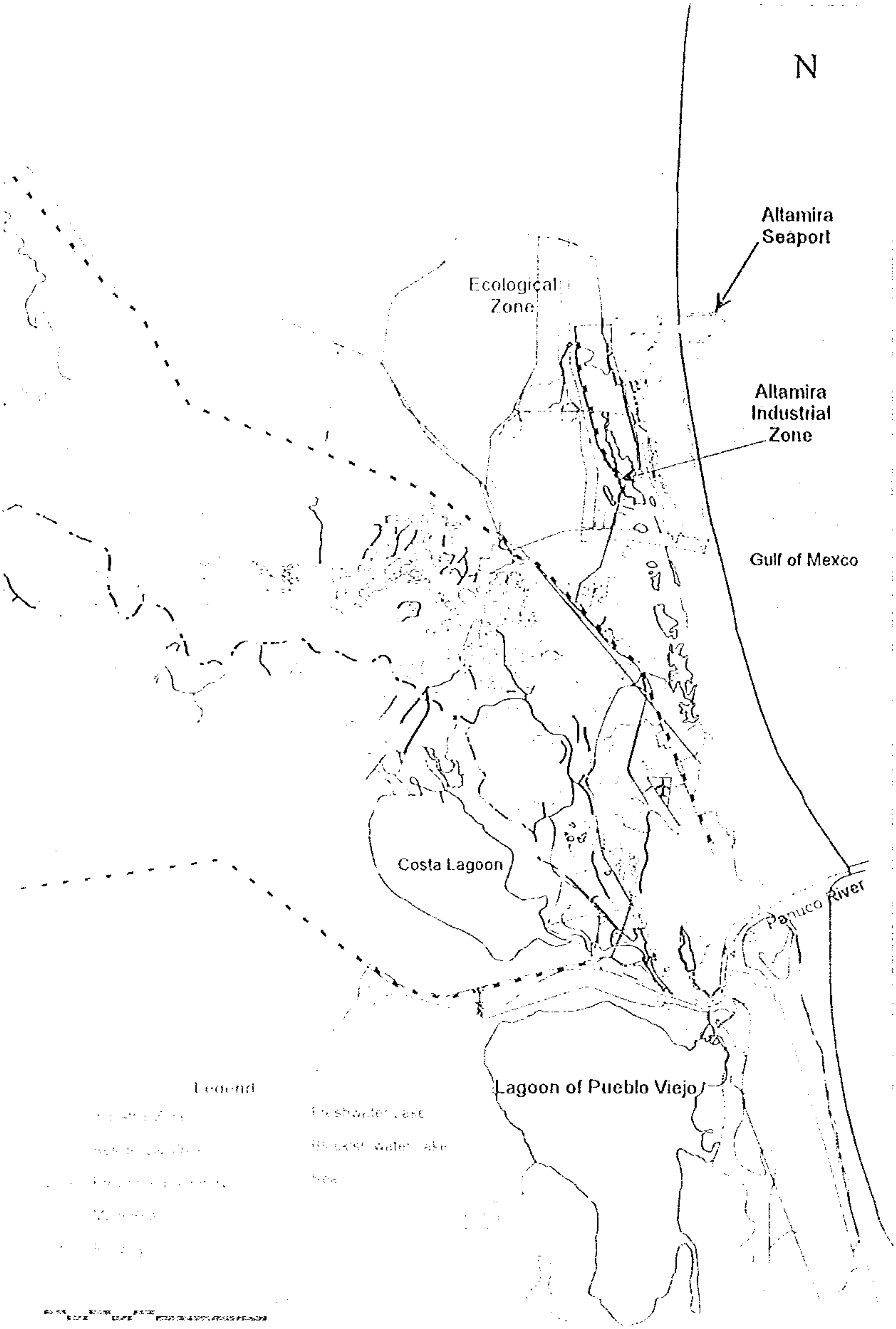


Figure 1.17 Watersheds around Tampico Area

(5) Coastal Ecosystems

a) Ecological division of the Tampico Area

Southern Tamaulipas is under sub-humid, low extra-tropical climate, within the ecological region of Mexican xenofile. The vertebrate fauna is considered within the Herptofauna region in the Neotropical kingdom. The dominant terrestrial vegetation is thorny-brushwood consisting of *Randia aculeata, Pithecellobium brevifolium, and P. Flexicaute.*

Within and around the Tampico Area in the southern Tamaulipas coast are various forms of water bodies, from river (Panuco River), freshwater lagoons (e.g. El Conejo Lagoon), brackish lagoons with salt marshes (e.g. Pueblo Viejo Lagoon, Las Marismas Lagoon), to seawater of the Gulf of Mexico that is fringed by shallow plains of Miramar Beach.

b) Biodiversity

Located in the Panuco River delta, the heterogeneous aquatic environment of Tampico Area accommodates diverse living organisms including some species registered as rare or endangered by the Mexican standard of ecology (Norma Oficial Méxicana-ECOL No.059). Among those registered as an endangered species is the crocodile (*Crocodilus moreletii, C. acutus*) which inhabits the rivers and freshwater lagoons in this area. Sea turtles are another endangered species that are found in the Study Area, especially Kemp's ridley (*Lepidochelys kempii*). This most endangered sea turtle has its principal nesting sites along the coast of southern Tamaulipas from Rancho Nuevo to Altamira. For the conservation of Kemp's ridley, the National Institute of Fishery (Instituto Nacional de la Pesca) has conducted a study and activities of coastline protection in cooperation with the government of United (Institute Nacional de la Pesca, Conservacion y Manejo de la Tortuga Lora. 1995 - 1998, 1998). Other rare or endangered vertebrates reported within the area of southern Tamaulipas are listed in Table 1.18 (SEDUE, Diario Oficial de la Federación, 17 de Mayo de 1992). However, special attention is required to interpret the list because majority of local biologists believes that some of the species may have already become extinct in the locality. The lack of scientific investigation in the region has resulted in the failure to recognize the total number of endangered species.

c) Wetland Ecosystem in the Tampico Area

In southern Tamaulipas, the surface water bodies of every gradation of salinity are mainly surrounded by Popal - Tula and mangrove vegetation groups. Popal - Tula group, represented by rush (*Juncus* sp.), water lily (*Nymphaea mexicana*), and waterhyacinth (*Eichhorhia crassipens*) occupies 70% of the total vegetation in the municipality centering on freshwater lagoons. The vegetation of mangroves, represented by white and red mangroves (*Laguncularia racemosa* and *Rhizophora mangle*, respectively) covers 10% of Tampico Area around brackish water (INEGI, Cuaderno Estadístico Municipal Tampico, Tamaulipas 1996).

Both are typical vegetation groups in wetlands, which attribute higher biodiversity in the marginal area of terrestrial and aquatic ecosystems. Floating around the edge of water area, the vegetation offers habitats and sustenance for aquatic fauna, and consequently attracts predator birds and animals. The most extensive study has revealed that there are at least 28 species of aquatic bird species within the area of Las Marismas Lagoon and El Conejo Lagoon. The observation list includes white and brown pelicans (*Pelecanus erythrorynchus, P. occidentalis*), helons (*Carmerodius albas, Egretta*. Sp.), and white ibis (*Eduocimus albus*) (Hugo Montiel, Personal Communication). Flamingo is as well observed in this area on rare occasions. The coastal area of the Gulf of Mexico is also an important route for migratory birds. The wetlands in the Study Area provide ideal stop-over areas and reproduction sites for migratory species such as white wing dove (*Zenaida asiatica asiatica*) (Torres and Zamora, Evaluacion de los Parametros Biologicos de la Palma de Alas Blancas en la Colonia de Anidacion Parras de la Fuente en Abasolo TAM. Mexico, 1992). Bird population and diversity in the coastal habitats, as a consequence, vary by season.

d) Marine ecosystem of the Gulf of Mexico

The Gulf of Mexico is a derivation of rich marine resources that yield almost 400 thousand tons per year for the nation (SEMARNAP, Anuario estadístico de pesca, 1995-1996. Directión de Estadística y Registros Pesqueros, 1997). Nurtured by the warm Gulf stream, huge populations of phytoplankton and zooplankton create an inexhaustible diet for predator vertebrates. Mullusca and echinodermata abundance is reported in the coastal area off Altamira (Fregoso Gonzalez, Contribution al conocimiento de la fauna malacologica de la costa del estado de Tamaulipas, 1986, Martinez Perez de Ayala, Contribution al conocimiento de las estrellas de mar regulares e irregulares del puerto industrial de Altamira y aguas adyacentes, 1991)

This fecund water basin has made fishery one of the most important industries in southern Tamaulipas. Among the principle species of commercial value, shrimps

(*Penaeus* sp.) contribute the most to the total production followed by white mullet (*Mugil curema*) and blue crow crab (*Callinectes sapidus*) (INEGI Anuario Estadistico del Estado de Tamaulipas 1998). Oyster (*Crassostrea virginica*) is another species of commercial importance, which is produced principally in Pueblo Viejo Lagoon in Veracruz State. Other than the above mentioned species, red snapper (*Lutjanus campechanus*), striped mullet (*Mugil cephalus*), and croaker (*Leistomus xanthurus*) are the major catch for the inshore fishery of this area.

Supported by these diverse fish populations, sea mammals represented by Tonina dolphin (*Tursiops truncatus*) inhabit off southern Tamaulipas. The existence of manatees was also reported off Altamira, but the survivors of this endangered marine mammal are not confirmed recently.

Table 1.18 Rare, Threatened and Endangered Species found within the Area of Altamira, Tamaulipas

Scientific name	Common Name	Status
Mammals		
Felis pardalis	Ocelot	T
Felis weiddi	Tiger cat	T
Coendu mexicanus	Porcupine	T
Felis yagouaroundi	Jaguarundi	T
Galictis vittata		E
Ateles geoffroyi	Spider monkey	E
Lynx rufus	Bobcat	S
Trichechus manatus	Manatee	S
Felis concolor	Puma	S
Birds		
Charadrius melodus		T
Agamia amagi	Agamia helon	T
Falco peregrinus	Peregrino hawk	E
Reptiles		
Crocodilus moreletii	Cocodrilo de pantano	S
C. actus	River Crocodile	S
Lepidochelys kempii	Parrot turtle	S
Dermochlys coriacea	Leatherback	S
Caretta caretta		S
Fishes		
Ictalurus australis	Panuco cat fish	R
Ictalurus mexicanus	Panuco cat fish	R
Poecilialati punctata		R

R = rare; T = threatened; E = endangered; S = special attention

Source: SEDUE, Diario Oficial de la Federación, 17 de Mayo de 1992.

1.2.2 Natural Resource Uses

Tampico Area is located in the southern part of Tamaulipas State and the northern part of Veracruz State. The area administratively belongs to the cities of Tampico, Madero, and Altamira in Tamaulipas State as well as the municipalities of Panuco, Pueblo Viejo, and Tampico Alto.

(1) Population distribution

Tamaulipas State consists of 43 municipalities/cities. Its population in 1995 was approximately 2.5 million. The population concentrated in 11 municipalities/cities, including Tampico City, Madero City, and Altamira City. The population of the Tampico Area represents 28.47% of the state's total (see Table 1.19).

Table 1.19 Population in the Tampico Area

City and Municipality	Population in 1995	Ratio of the State Total (%)	Annual Growth Rate 1990-1995 (%)
Tampico City	278,933	11.04	0.45
Madero City	171,091	6.77	1.30
Altamira City	113,810	4.50	6.62
Panuco Municipality	93,414	3.70	2.60
Pueblo Viejo Municipality	48,054	1.90	3.60
Tampico Alto Municipality	14,009	0.55	-
Tampico Area Total	719,311	28.47	-

Source: INEGI, XI Censo General de Poblacion y Vivienda 1990, y Conteo de Poblacion y Vivenda 1995

(2) Economic activities

a) Industry

The urban zone south of Tampico, Madero and Altamira has been characterized by the industrial development related to oil. It includes an oil refinery and a petrochemical complex. The PEMEX Refinery is located in Madero City; the petrochemical complex has a processing capacity of about 200,000 barrels of oil per day. It produces gasoline, kerosene, diesel, fuel oils, asphalt, and secondary petrochemical products. In this industry zone, there are 16 private enterprises belonging to the chemical and petrochemical sector, representing 17% of the Mexican private investment in this sector. In 1994, with the exception of PEMEX, 18 industrial plants produced about 1.5 million tons of diverse chemical and petrochemical products. This output represented about 25% of Mexico's total chemical and petrochemical private sector production.

Main industries of Tampico City are petrochemical, textile, food, metallurgical, and fisheries-related. Service sector activities such as tourism and banks are vital to Tamaulipas State's commercial success.

b) Agriculture

Tamaulipas has an extensive farming district. Approximately 20% is dedicated to agriculture. In 1995, more than 1.2 million ha had been exploited as croplands, of which 506,000 ha were irrigated.

According to 1998 SEDIC data, the annual agricultural production volume was almost 7 million tons in 1995 fiscal year. Sorghum, corn, wheat, sugar cane, and citrus have been representative national crops. Led by citric production, these crops yielded 81% of national vegetable production, which is equivalent to 337,000 tons per year. Similarly the sugarcane production is important in this country. About 51,661 ha were destined for the production of this crop, which yields more than 2.6 million tons per year; Tamaulipas occupies 5th place in the national sugarcane production.

In addition, Tamaulipas State has favorable conditions for livestock exploitation. About 58% of the state's territory, or 4.65 million ha, is dedicated to livestock activity. Of this total, 3.65 million ha is summer pasture. Livestock such as cattle and goat are commercialized in the national and international markets.

In the Tampico Area, main agriculture products are cotton, sorghum, corn, soybeans, pepper and tomato. Some farmers raise cattle and chickens in Tampico City. In Panuco municipality, main agriculture products are sugar cane, corn, grain, bean, soy, chili pepper, watermelon, banana, and rice. Main livestock production is beef. The principal crops of Pueblo Viejo municipality are corn, beans, watermelon, orange, and banana. The main livestock productions in the area are beef, pork, and chickens.

c) Fishery

In Tamaulipas State, the 420 km coastline along the Gulf of Mexico and 380,000 ha of coastal water bodies play an important role in fishery. The Tampico Area has the coastal area at the western part of the Gulf of Mexico and downstream of Panuco River, where a variety of fish resources are available. Typical commercial fish species in the Tampico Area are shrimp, white mullet, and crabs. In Madero City, tilapia, shrimp, and oyster represent the fishery products. A large brackish water lagoon in the southern portion of Tampico Area, called Pueblo Viejo Lagoon, is one of the main oyster production grounds in the State. In terms of aquaculture, it is reported that Tamaulipas State has more than 380,000 ha of interior waters with potential aquaculture productivity. In recent years, 854 ha of the state's water area have been exploited for 21 aquaculture production units.

d) Tourism

Tamaulipas State holds high potential of eco-tourism based on its rich natural resources.

In the coastal plain of Tamaulipas, there are a lot of tourists attractions, especially in the areas as Tampico, La Pesca, Barra del tordo, Laguna Madre and Matamoros. Biological richness and natural integrity can add tourism value to the coastal zones of these areas. In terms of tourism facilities, there are several hotels in the downtown areas of Tampico City and Madero City. One large five-star resort hotel is located fronting the Gulf of Mexico.

(3) Coastal use

a) Main economic activities zone

Main economic activities in the Tampico Area are petrochemical and oil industry. The industrial corridor is located along the coastal area in the southern part of Tampico, Madero and Altamira.

b) Conservation zone

At present there are no marine conservation areas, such as fish sanctuary, ecological protection area, nor marine park, in the Tampico Area. No exclusive fishing zone nor fisherman's cooperative exists in the Area, except for eight exclusive shrimp catch areas along the shoreline from Matamoros to La Pesca in the northern part of Tamaulipas State. Only one lagoon conservation project in Laguna Madre has designated an exclusive fishing zone as well as an eco-tourism zone.

Marine fishing areas, which include municipal fishery, commercial fishery, and sports fishing, are identified in five nautical miles zone from the shoreline. No exclusive marine fishery zone exists in the near shore of the Tampico Area. There is open access to marine fishing.

(4) Coastal infrastructure

a) Industrial and commercial port

The Tampico Area has two deep-water ports along 42 km of the coastline. One is the Altamira Industrial Port and the other is the Tampico Commercial Port. The Altamira Industrial Port has 6 terminals. Two of these are all-purpose, with a total capacity of 10,000 containers over a space of 15,000 m^2. The Port also has a territorial reserve of over 3,000 ha designed for the establishment of chemical, petrochemical, steel, and metal/mechanic industries.

The Tampico Commercial Port transports more than 8 million tons of cargo annually. The cargoes are mainly destined to the Eastern United States, Europe, and Central and South America.

b) Proposed intra-coastal canal

In order to satisfy the increased demand for lower transportation costs, Tamaulipas State proposed the construction of an intra-coastal canal. The Tamaulipas Intra-coastal Canal is expected to unite the cities of Tampico and Matamoros, and to extend to the Brownsville Port, from where the 45,000 km of the USA waterway system continues ahead through the country.

1.3 Coastal Environmental Problems in Mexico

(1) Red Tide

Red tide is a natural phenomenon that occurs in temperate and tropical coasts worldwide. It is a temporal bloom of phytoplankton species of dinofragella, diatom, and cyanobacteria, which produce red pigment in the process of photosynthesis. Among others, certain responsible species represented by *Gymnodinnans brevis* are known for its toxin production that can cause serious problems to human body, both through primary contact and consumption of contaminated shellfishes. In most of the cases rain proceeds the bloom due to the consequential outflow of terrestrial nutrients to seawaters. Also, the higher water temperature in summer season favors the rapid growth of the unicellular organisms. Once reaching its density saturation of the plankton species, oxygen concentration decreases in the seawater and provokes a massive fish mortality of asphyxiation. Although the fishes die from physical suffocation, not from the chemical toxins, they are not appropriate for human consumption because the microorganisms remaining in the fish body can cause diarrhea, nausea, stomach and muscular aches, and excessive perspiration. Also, the red tide brings damage in water culture industry of mollusks (oysters, clams and mussels), which accumulate the dinofragellas in their body through the filter feeding. Biological accumulation of the toxic organisms turns the commercial marine products into pieces with poisonous potential (Nota Informativa en Relacion a Marea Roja y Medidas de Recomendacion, SEMARNAP, 1997).

In the coast of Mexico, the oldest incident of red tide was recorded in Veracruz in 1797. Up to now the tide has caused serious impacts in the fishery and tourism of the coastal areas, especially in the State of Guerrero, off Acapulco (Mr. Hugo Montiel, SEMARNAP, personal interview). The red tide case in Tamaulipas and a part of Veracruz in October 1996 lasted for more than three weeks over the area of 2.5 x 20 km along the state coast (Evaluation de la Toxicidad de la Maria Roja Frente a las Costas del Estado de Tamaulips, 1997). Once again in 1997, red tide attacked the coast of the Mexican Gulf, along the coast of Tamaulipas. This time the tide has reportedly killed 40 tons of fishing resource.

The Secretary of Health carries out the monitoring of toxic plankton density at the reported detection of the tide, with administrative advice of SEMARNAP. However, there is no regular monitoring system in the nation to observe red tides.

(2) Oil Problems

The littoral of Gulf of Mexico has an abundant oil field, both inland and in open seas. Therefore, hydrocarbons are often found in the coastal area of Gulf of Mexico. Washing residues and leaks from oil tankers are also responsible for the pollution in the Gulf.

Another pollution source is maritime transportation from Central and South America; it facilitates the dissolution and dispersion of hydrocarbons in waters where oil fields do not exist, such as Mexican Caribbean. Hydrocarbon contamination has been reported in the Gulf of Mexico and Yucatan Peninsula, and contamination levels are shown in Table 1.20 Ostion Lagoon, Coatzacoalcos River, Tonala River, Mecoacan Lagoon, Terminos Lagoon, and Nichupte Lagoon are contaminated. Sediments of the Gulf of Mexico and Mexican Caribbean are also contaminated with hydrocarbon.

Table 1.20 Petroleum Hydrocarbon Content in Water, Sediments and Organisms of Gulf of Mexico and Yucatan Peninsula Area

Location	State	Water (ppb)	Sediments (ppm)	Organisms(ppm)	Year
Madre Lagoon	Tamaulipas	-	26	-	1982
Pueblo Viejo Lagoon	Veracruz	-	53	-	1982
Tamiahua Lagoon	Veracruz	-	31	-	1982
Alvarado Lagoon	Veracruz	-	18	-	1982
Ostion Lagoon	Veracruz	18.4	120	850[c]	1984
Coatzacoalcos river	Veracruz	-	680	6[a], 1.8[b], 7.5[c]	1989
Tonala river	Veracruz	-	1148	-	1989
Carmen Lagoon	Tabasco	4	45	-	1982
Machona Lagoon	Tabasco	7	45	-	1982
Mecoacan Lagoon	Tabasco	5	88	-	1982
Terminos Lagoon	Campeche	-	85	-	1982
Terminos Lagoon	Campeche	48	37	2.3	1985
Bojorquez Lagoon	Quintana Roo	4.4	12		1985
Nichupte Lagoon	Quintana Roo	-	93	-	1986
Continental Shelf of Campeche	-	-	43.3	-	1987
Gulf of Mexico	-	11	94	-	1984
Mexican Caribbean	-	15	70	-	1987
Permissible Limit*	-	10	70	-	1976

* UNESCO's Value [a] fishes, [b] crustaceans, [c] mollusks

Contamination levels of Pacific Ocean area are shown in Table 1.21. In the Pacific Ocean area, Salina Cruz Port, Gulf of Tehuantepec, the continental shelf of Guerrero and Michoacan were investigated and found contaminated with hydrocarbons.

Mussels (*Mytilus californianus*) were analyzed in the northwest coast of Peninsula of Baja California. Mean concentration of petroleum hydrocarbon in this organism was 385.3 ppm, which indicated the oil contamination in the region.

Table 1.21 Petroleum Hydrocarbon Content in Water, Sediments and Organisms of Pacific Ocean Area

Location	State	in Water (ppb)	in Sediments (ppm)	Organisms (ppm)	Year
Salina Cruz Port	Oaxaca	76.5	219.5	144[a], 39.8[b]	1991
Open sea of Salina Cruz	Oaxaca	-	7.8	-	1991
Gulf of Tehuantepec	-	-	15-114	-	1984
Shelf of Guerrero and Michoacan	-	-	9-298	-	1989
Chautengo Lagoon	Geurrero	-	7	-	1980
Mitla Lagoon	Geurrero	-	16	-	1980
Superior and Inferior Lagoon	Oaxaca	-	1.5	-	1980
Northwest of Peninsula of Baja California	-	-	-	385.3[b]	1990
Permissible Limit*	-	10	70	-	1976

* UNESCO's Value [a] crustaceans, [b] mollusks

(3) Heavy Metals

High levels of heavy metal contamination in water and sediments have been reported south of the Gulf of Mexico. In estuaries of Coatzacoalcos River, there is mercury contamination in water and sediments, as shown in Table 1.22. In many coastal areas of Veracruz, Tabasco and Campeche States, high lead concentration in water and sediments has been reported as shown in Table 1.23. Mean concentration of lead and cadmium in water and sediments of Pacific Ocean area were analyzed and results are shown in Table 1.24. It is difficult to conclude the contamination level of heavy metals in Pacific Ocean coastal area because there is few available data.

Table 1.22 Mean Concentration and Standard Deviation (S.D.) of Mercury in Water and Sediments of Gulf of Mexico Area

Location	State	(micro-g/l) in Water		(micro-g/g, dry weight) in Sediments		Year
		mean	S.D.	mean	S.D.	
Tampamachoco Lagoon	Veracruz	<0.2	-	0.011	0.005	1983
Mandinga Lagoon	Veracruz	<0.2	-	0.028	0.012	1983
Coatzacoalcos river	Veracruz	30	10	0.585	1.41	1973
Coatzacoalcos river	Veracruz	7	15	8.31	14.6	1975
Coatzacoalcos river	Veracruz	12	3	51.3	6.7	1984
Coatzacoalcos river	Veracruz	-	-	0.125	-	1986
Carmen Lagoon	Tabasco	0.4	0.1	-	-	1981
Carmen Lagoon	Tabasco	<0.2	-	0.009	0.003	1983
Machona Lagoon	Tabasco	0.4	0.3	-	-	1981
Mecoacan Lagoon	Tabasco	0.3	0.2	-	-	1981
Atasta Lagoon	Campeche	0.2	-	<0.007		1983
Maximum Permissible Limit*	-	0.5	-	-	-	-

* SEDUE's Value

Source: Lagunas Costeras y el Litoral Mexicano, Guadalupe de la Lanza Espino and Carlos Carceres Martinez (1994)

Table 1.23 Mean Concentration and Standard Deviation (S.D.) of Lead in Water and Sediments of Gulf of Mexico Area

Location	State	(micro-g/l) in Water		(micro-g/g, dry weight) in Sediments		Year
		mean	S.D.	mean	S.D.	
Tampamachoco Lagoon	Veracruz	46	29	3.94	3.01	1983
Mandinga Lagoon	Veracruz	125	356	3.34	3.25	1983
Alvarado Lagoon	Veracruz	-	-	20.15	14.77	1986
Ostion Lagoon	Veracruz	-	-	not detect	-	1986
Coatzacoalcos river	Veracruz	17	7	-	-	1973
Coatzacoalcos river	Veracruz	-	-	43.5	17.1	1986
Blanco river	Veracruz	-	-	32.5	8.1	1986
Carmen Lagoon	Tabasco	40	78	-	-	1981
Carmen Lagoon	Tabasco	43	55	6.5	5.2	1983
Machona Lagoon	Tabasco	100	104	-	-	1981
Mecoacan Lagoon	Tabasco	91	91	-	-	1981
Ilusiones Lagoon	Tabasco	-	-	159	93	1989
Tonala river	Tabasco	-	-	not detect	-	1987
Atasta Lagoon	Campeche	38	20	0.29	0.25	1983
Terminos Lagoon	Campeche	3	1	34	18	1988
Maximum Permissible Limit*	-	6	-	-	-	-

* Sedue (1986) Source: Lagunas Costeras y el Litoral Mexicano, Guadalupe de la Lanza Espino and Carlos Carceres Martinez (1994)

Table 1.24 Mean Concentration of Lead and Cadmium in Water and Sediments of Pacific Ocean Area

Location	State	Lead		Cadmium		Year
		in water (micro-g/l)	in sediments (micro-g/g, dry weight)	in water (micro-g/l)	in sediments (micro-g/g, dry weight)	
Gulf of California	-	-	41.3	-	4.98	1988
Mazatlan Port	Sinaloa	-	30.3	-	1.21	1986
Inlet of Salina Cruz	Oaxaca	-	49.5	-	6.32	1986
Inlet of Salina Cruz	Oaxaca	not detect	34.3	not detect	-	1991
Continental Shelf of Isthmus of Tehuantepec	Oaxaca	-	22.7	-	-	1991
Superior Lagoon	Oaxaca	-	4.4	-	1.47	1991
Maximum Permissible Limit*	-	6	-	0.9	-	1986

* Sedue (1986)
Source: Lagunas Costeras y el Litoral Mexicano, Guadalupe de la Lanza Espino and Carlos Carceres Martinez (1994)

(4) Pesticide Problems

Application of pesticides in Mexico for agriculture and public sanitation purposes has been practiced since 1946. The pesticides outflow from the applied area to the coastal area through groundwater, river, wind and so on. Contamination levels of organochloride pesticides in the Mexican coast area are shown in Table 1.25. The figures indicate that pesticide contamination levels are high in Tabasco and Campeche States.

Table 1.25 Contamination Level of Organochloride Pesticides in Sediments of Coastal Area

Location	State	Concentration in Sediments (ng/g)	Year
Pueblo Viejo Lagoon	Veracruz	16.2	1979
Alvarado Lagoon	Veracruz	0.66	1979
Alvarado Lagoon	Veracruz	20	1990
Ostion Lagoon	Veracruz	3.6	1986
Carmen Lagoon	Tabasco	17.2	1979
Carmen Lagoon	Tabasco	17.3	1990
Machona Lagoon	Tabasco	10.2	1990
Carmen - Machona Lagoon	Tabasco	138	1986
Mecoacan Lagoon	Tabasco	97	1986
Terminos Lagoon	Campeche	17	1979
Terminos Lagoon	Campeche	83	1990
Nichupte Lagoon	Quintana Roo	0.47	1979
Bojorquez Lagoon	Quintana Roo	58	1992
Inlet of San Quitin	Baja California	4.1	1988
Yavaros	Sonora	11.1	1983
Huizache-Caimanero	Sinaloa	5.91	1983

Source: Lagunas Costeras y el Litoral Mexicano, Guadalupe de la Lanza Espino and Carlos Carceres Martinez (1994)

(5) Eutrophication

Eutrophication is defined as the fertilization process of water bodies due to the increase of nutrient load (Horne & Goldman, Limnology, 1983). It can cause a number of detrimental effects on water bodies. If nutrients such as nitrogen and phosphorus are excessively added into water bodies from farmlands and municipal wastewater, it may disturb the plants' development and the structure of local ecology. Therefore, nitrogen and phosphorus concentration is closely related with eutrophication. Table 1.26 shows the ranges of concentration of nutrients in Mexican coastal lagoons. These nitrogen nutrients have a nitrogen cycle, and concentration of each nitrogen form such as ammonium ion, nitrite ion, nitrate ion, or organic nitrogen varies with time. The phosphorus nutrients also have a phosphorus cycle. The ortho-phosphate concentration also varies. Ensenada Lagoon in Sinaloa State, Nuxco Lagoon in Guerrero, Tuxpan Estuary, Tampamachoco Lagoon, Alvarado Lagoon, Mandinga Lagoon, and Ostion Lagoon in Veracruz State, Celestun Lagoon in Yucatan showed high levels of nitrogen nutrients. Ensenada Lagoon in Sinaloa State, Madre Lagoon in Tamaulipas State, Pueblo Viejo Lagoon and Ostion Lagoon in Veracruz, and Celestun Lagoon in Yucatan State showed high levels of orthophosphate.

Table 1.26 Ranges of Concentration of Nutrients in Mexican Coastal Lagoon

Location	State	NH_4-N micro-g/l	NO_2-N micro-g/l	NO_3-N micro-g/l	PO_4-P micro-g/l	Year
Inlet of Todos Santos	Baja California Norte	-	-	0.0-8.9	0.9-1.9	1988
Inlet of San Quintin	Baja California Norte	-	-	<0.5-12.6	<0.5 - 3	1982
Inlet of Magdalena	Baja California Sur	-	-	<0.5 - 15	3.0 - 6.0	1975
Ensenada Lagoon of Pabellon-Altata	Sinaloa	2.2-25.0	nd-6.2	nd-16.0	1.2-12.0	1992
Huizache-Caimanero Lagoon	Sinaloa	1.4-2.7	-	0.4-2.3	0.3-1.5	1993
Mezcaltitan Lagoon	Nayarit	2.7-4.9	-	-	1.2-6.4	1986
Coyca de Banitez Lagoon	Guerrero	5.7-16.6	nd-2.4	nd-7.9	nd-2.4	1986
Nuxco Lagoon	Guerrero	nd-36.3	nd-0.6	nd-6.6	<0.5-1.4	1976
Mitla Lagoon	Guerrero	nd-13.2	not detect	not detect	<0.2-0.5	1976
Apozahualco	Guerrero	nd-18.7	nd-2.4	nd-7.9	<0.5-7.7	1976
Madre Lagoon	Tamaulipas	-	-	1.6-4.5	5.6-12.7	1989
Pueblo Viejo Lagoon	Veracruz	0.8-9.1	-	0.7-14.6	0.3-13.1	1989
Tamiahua	Veracruz	nd-5.5	-	0.7-5.9	0.6-2.0	1989
Tuxpan Estuary	Veracruz	0.8-37.9	nd-1.5	nd-19.4	nd-2.5	1983
Tampamachoco	Veracruz	nd-27.1	nd-2.1	0.4-40.8	nd-1.4	1983
Alvarado Lagoon	Veracruz	nd-5.5	nd-13.2	nd-16.5	nd-9.8	1993
Mancha Lagoon	Veracruz	1.4-14.3	-	1.5-8.8	2.4-8.9	1989
Mandinga Lagoon	Veracruz	4.8-23.8	-	0.9-5.5	0.5-2.8	1989
Ostion Lagoon	Veracruz	4.0-33.7	-	0.9-4.5	1.0-32.6	1989
Terminos Lagoon	Campeche	nd-1.4	nd-0.6	nd-1.6	nd-7.5	1993
Celestun Lagoon	Yucatan	nd-9.0	-	<1.0-27.0	<0.5-11.5	*
Bojorquez	Quintana Roo	1.7-6.8	nd-0.9	nd-3.6	0.7-1.7	1989

Source: Lagunas Costeras y el Litoral Mexicano, Guadalupe de la Lanza Espino and Carlos Carceres Martinez (1994)

1.4 Coastal Environmental Problems in Tampico Area

(1) Industrial Wastewater Discharge to Surrounding Water Bodies

The coastal ecosystems, mainly the one in the Gulf of Mexico, are exposed to considerable impacts of the industrial wastewater. The coastal area in Tamaulipas State is one region that illustrates the typical pressures on coastal and marine ecosystems in this country. Wastewater from the industrial corridor of Altamira region is discharged to the surrounding water bodies, evoking serious environmental contamination. As for the sea area, wastewater from a chemical industry within the Altamira Industrial Corridor is discharged directly to seawater off Miramar Beach. In this area, water pollution is observed as daily occurrence. There is water discoloration due to ironic ion compounds, and the "patch" sometimes diffuses to cover $10km^2$ of water surface centering the outlet. The environmental impact from this discharge is not sufficiency analyzed. However, there are five published reports about heavy metal concentration in organisms in the coastal zone of Tampico Area, and each one has indicated heavy metal contamination in coastal dune plants (Ramirez Cruz. 1994), mangrove species (Sanchez Leyton, 1996), crustaceans (Vicente Medecigo 1994), and fishes (Palacios Castan, 1994, Tabares Soto, 1994)

(2) Domestic wastewater discharge

Marine and coastal contamination caused by domestic and urban wastewater is the most common problem in the area. This is due to insufficient wastewater treatment plants, which consequently allow the wastewater to be directly discharged to open waters. This is supposed to provoke three main impacts as follows:

- Physical impacts such as alternation of bottom topography and water circulation regime;
- Chemical impacts such as addition of nutrients and decreased dissolved oxygen
- Biological impacts such as habitat reduction of photosynthetic productivity, benthos coverage, destruction of plankton and benthos composition, and increase of bacteria and pathogenic organisms

In Pueblo Viejo Lagoon, the coliform pollution is serious due to wastewater from Tampico, Madero and Villa Chauthtemoc. This problem has limited the commercial value of oyster produced in the lagoon (Contreras, Ecosystemas Costeros Mexicanos, 1996). Total and fecal coliform levels reached 770, which is 3,339 times higher than the maximum permissible limit in Panuco River and Carpintero Lagoon respectively (CNA, 1996). This alarming concentration of coliform has been hindering the utilization of water resource in this area.

(3) Conflicts in Resource Use in Lagoon of Pueblo Viejo

There are four fisherman's cooperative unions in Pueblo Viejo Lagoon with a total membership of 435. The lagoon is divided into four fishing grounds for each union. Although the boundaries of each fishing ground are designated by the cooperatives, there is no physical construction for the boundary. Therefore, there are conflicts in the utilization of fishing grounds between the fishermen in different cooperatives.

(4) Solid Waste Disposal

Within the Study Area, there are some problems regarding solid waste disposal. Solid wastes are collected without any separation method and dumped to either designated or illegal dumping sites. There is no treatment of dumped wastes raising much concern over soil and ground water pollution. The impact of this issue, however, is not yet investigated.

(5) Illegal Settlement

It was found that illegal settlers have been residing within the Study Area, for instance in the area along the down stream of Panuco River and the adjusting area of Miramar Beach. These illegally settled houses do not have on-site wastewater treatment system. This may aggravate the water pollution in the Study Area by uncontrolled domestic water discharges.