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
(MAIN REPORT)

March 2000

PACIFIC CONSULTANTS INTERNATIONAL
METOCEAN

1157303 (7)

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(as of the end of November 1999)

PREFACE

In response to a request from the Government of the United Mexican State, the Government of Japan decided to conduct a study on "Development of the National Water Quality Monitoring Program in Coastal Areas" and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched a study team headed by Dr. Akira UCHIDA of Pacific Consultants International (PCI) and composed of PCI and Shin-Nippon Meteorological and Oceanographical Consultant Co., Ltd. (METOCEAN) to Mexico 4 times between January 1999 and February 2000. In addition, JICA set up an advisory committee headed by Prof. Takashi HAYASE, Nagasaki University, between January 1999 and March 2000, which examined the study from specialist and technical points of view.

The team held discussions with the officials concerned of the Government of Mexico and conducted field surveys at the study area. Upon returning to Japan, the team conducted further studies and prepared this final report.

I hope that this report will contribute to the promotion of this project and to the enhancement of friendly relationship between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of Mexico for their close cooperation extended to the Team.

20 March 2000

Kimio FUJITA
President
Japan International Cooperation Agency

March 2000

Mr.Kimio FUJITA
President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Dear Sir,

We are pleased to submit to you the final report entitled "The study on Development of the National Water Quality Monitoring Program in Coastal Areas in the United Mexican States." This report has been prepared by the Study Team in accordance with the contracts signed on January 8,1999 and June 4,1999 between the Japan International Cooperation Agency (JICA) and The Study Team, jointly organized by Pacific Consultants International (PCI) and Shin-Nippon Meteorological and Oceanographical Consultant Co., Ltd. (METOCEAN).

The report describes the study results of developing guidelines for the national water quality monitoring program for coastal areas in Mexico and developing a specific coastal water quality monitoring plan for the Tampico area.

The report consists of the Main Report and Summary Report, both in English and Spanish, Supporting Report and Data Book in English,and Technology Transfer Report in Spanish.

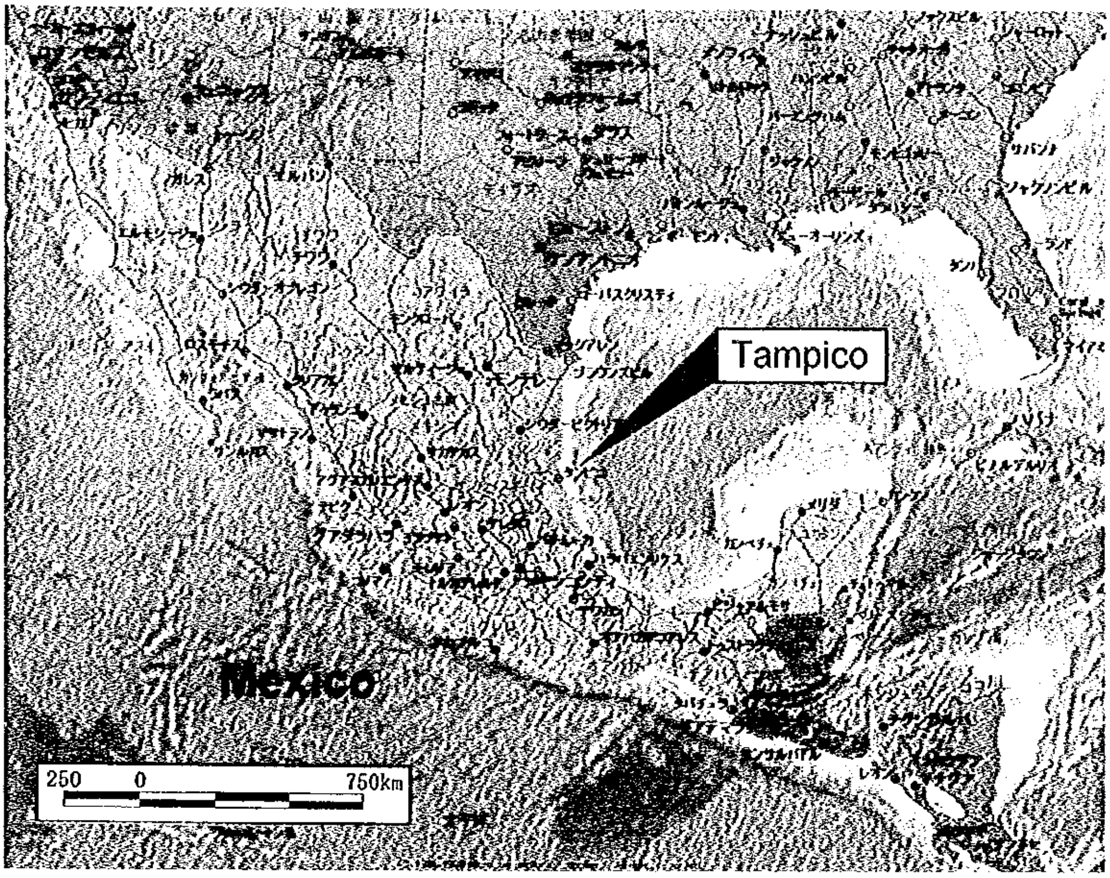
The Main Report presents: i) existing states of coastal environment and water quality monitoring, ii) planning policy for the coastal water quality monitoring, iii) the guidelines for the national coastal water quality monitoring, iv) the coastal water quality monitoring plan for the Tampico area, and v) project implementation schedule. The summary Report presents these results concisely. The Supporting Report describes technical details concerning the methods of coastal water quality monitoring including field surveys, analysis of sea water quality, laboratory management, and data analysis. The Data Book contains detailed information which supports reasoning of developing the monitoring guidelines and the monitoring plan. The Technology Transfer Report describes the various on-the-job and off-the-job training activities carried out in the course of the Study, and their evaluations.

We wish to express grateful acknowledgements to the personnel of your Agency, Advisory Committee, Ministry of Foreign Affairs, Environment Agency, Tokyo Metropolitan Government, and Embassy of Japan in Mexico. We also wish to express sincere appreciation to our counterpart, the National Water Commission (CNA) of Mexico. We hope that the proposed plan and guidelines will contribute to the realization of sustainable development of coastal areas in Mexico.

Yours faithfully,

内田 顕

Dr. Akira UCHIDA
Team Leader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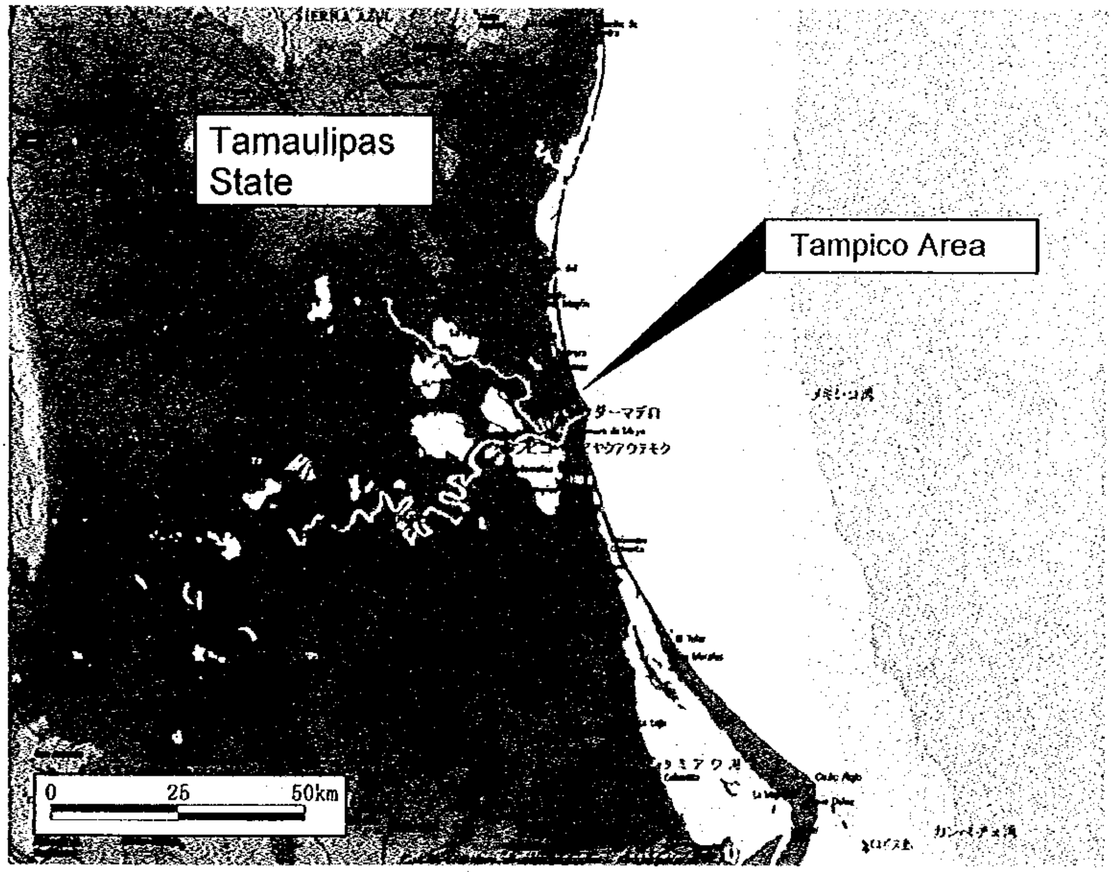
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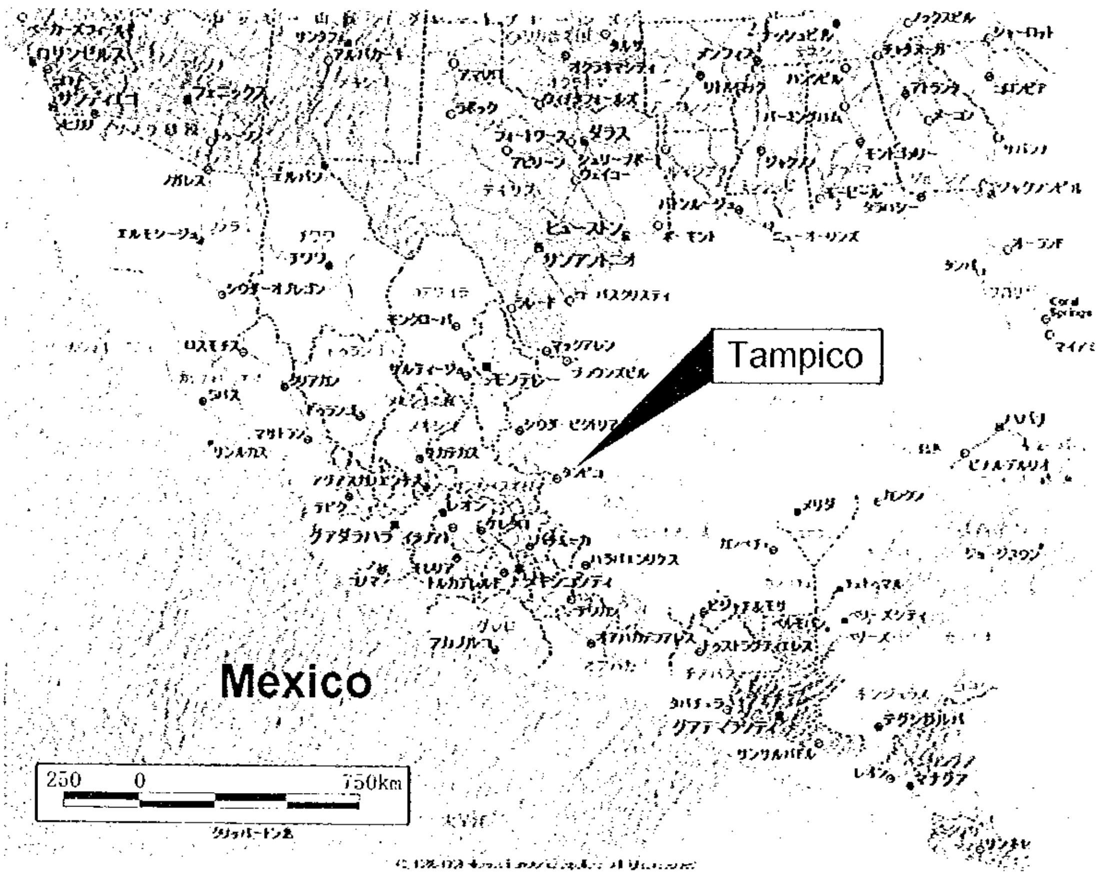
Study Area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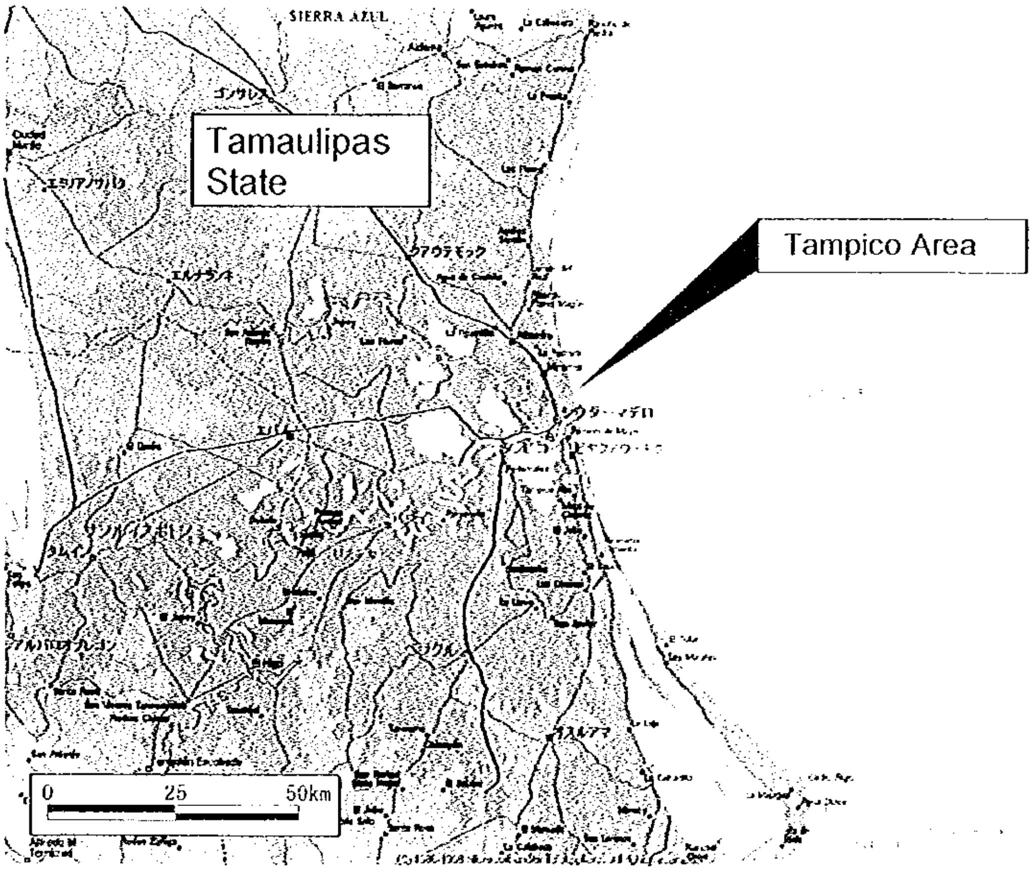
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Study Area

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List of Abbreviations/Acronyms

BOD	biochemical oxygen demand
CNA	*Comision Nacional del Agua* (National Water Comission)
COD	chemical oxygen demand
DO	dissolved oxygen
EEZ	Exclusive Economic Zones
EPA	Environmental Protection Agency
IMTA	*Instituto Mexicano de Technologia del Agua* (Mexican Water Technology Institute)
INE	*Instituto Nacional de Ecologia* (Ecological National Institute)
INP	*Instituto Nacional de la Pesca* (Institute of National Fishery)
JICA	Japan International Cooperation Agency
JIS	Japanese Industrial Standard
MSO	monitoring sites office
NOM	*Norma Oficial Mexicana* (Official Mexican Standard)
ORP	oxidation reduction pond
PHSA	A Practical Handbook of Seawater Analysis
PROFEPA	*Procuraduria Federal de Proteccion al Ambiente* (Federal Procuratorship of Environmental Protection)
PROMMA	*Proyecto de Modernizacion del Manejo del Agua* (Modernization of Water Management Project)
RNM	*Red Nacional de Monitoreo* (National Monitoring Network)
SARH	Hydraulic Resource and Agriculture Chamber
SEMARNAP	*Secretaria de Medio Ambiente, Recursos Naturales y Pesca* (Ministry of Environment, Natural Resources and Fisheries)
SRH	Hydraulic Resources Chamber
SS	suspended solids
T-N	total nitrogen
TOC	total organic carbon
T-P	total phosphate
T-Hg	total mercury
TSS	total suspended solids
UNAM	National Autonomous University of Mexico
VOC	volatile organic carbon

Chapter 1 Introduction

1.1 Background of the Study

Mexico boasts a shoreline of more than 10,000 kilometers that stretches along the Pacific Ocean, Gulf of Mexico, Gulf of California and the Caribbean Sea, making it one of the longest coastal countries in the world. The coastal areas include around a hundred coastal lagoon systems, which represent more than 12,500 km^2 and are significant natural resources for fisheries, tourism and others. The role of the coastal areas in the future development of Mexico has been pointed out as key to the National Program for Development 1995-2000 and the Environmental Program 1995-2000.

However, the coastal areas and all its resources have been showing signs of contamination, mainly due to municipal and industrial wastewater discharges in recent years. The adverse water contamination impacts are affecting not only fisheries and tourism in the area but also the fauna, such as dolphins and whales, and even aquatic birds.

In 1996, the National Water Commission *(CNA: Comision Nacional del Agua)* prepared a report on water quality of coastal areas. The objective of the report was to determine the environmental situation of these zones. However, available information covered only 26 stations located in 10 coastal areas and included few parameters such as BOD, COD and fecal coliform.

Since 1996, the *CNA*, through *PROMMA (Proyecto de Modernizacion del Manejo del Agua)*, has been implementing an institutional program designed to achieve the goals defined in the National Hydraulic Plan 1995-2000. The program aims to establish and strengthen the technical bases required for the management and sustainable development of water resources nationwide. To support the *PROMMA* project, the Mexican Government has borrowed funds from the World Bank under loan 4050-ME, also called *PROMMA*. The *PROMMA* loan supports around one-half of the total *PROMMA* project cost, and the Mexican Government shoulders the rest by fiscal funds.

In response to the request of the Government of the United Mexican States, the Government of Japan, decided to conduct "The Study on Development of the National Water Quality

Monitoring Program in Coastal Areas in the United Mexican States" through Japan International Cooperation Agency (JICA), in accordance with the Agreement on Technical Cooperation between the Government of Japan and the Government of Mexico signed on December 2, 1996 in Tokyo, Japan.

1.2 Performance of the Study

(1) Activities of the Study

The Study was conducted from January 1999 to March 2000 in accordance to the workflow shown in Figure 1.1. It was divided into four stages of site work in Mexico, with the rest of the work carried out in Japan.

The Study Team undertook the following activities in cooperation with *CNA*:

Table 1.1 Major Activities of the Study

Stages	Major Activities
Site Work I	• **Collection of existing data and information** • **Field reconnaissance** • **Pilot Water Quality Monitoring during the Dry Season** • Preparation of Primary Equipment Development Plan
Site Work II	• **Pilot Water Quality Monitoring during the Rainy Season** • Study on future trend of water and land use • Pollution load analysis • Investigation of regional laboratories
Site Work III	• **Explanation and discussion of the Interim Report** • Preparation of Optimal Water Quality Monitoring Plan

Source: JICA Study Team

(2) Submission of Reports

In the course of the Study, the Study Team submitted the following reports to *CNA*: Progress Report I, Progress Report II, Interim Report and Draft Final Report.

This Final Report is composed of four separate volumes, as follows:

- Vol. 1: Summary (English and Spanish)
- Vol. 2: Main Report (English and Spanish)
- Vol. 3: Supporting Document
- Vol. 4: Data Book

(3) Technology Transfer

In order to have a more effective development of the human resource aspect of *CNA* for coastal water quality monitoring, various on-the-job and off-the job training have been conducted. The former was facilitated by the office and fieldwork activities of the Study Team, while the latter was effected through the following technical seminars:

Table 1.2 Achievements of Technology Transfer

Date	Titles	Sites
February 12	• Technical Seminar at Tampico Laboratory - Navigation and GPS for Coastal Monitoring - Results of Preliminary Field Survey	Tampico Laboratory
March 19	• Conference on World Water Day* • Introduction of the JICA Study	Tampico City
March 24	• 1st Coastal Water Quality Monitoring Technical Seminar	Mexico City
June 29	• Evaluation Meeting for *CNA*'s Coastal Water Quality Monitoring Performance of May	Tampico City
July 28	• Technical Seminar for Hydrological Survey	Tampico City
August 26, 27	• 2nd Coastal Water Quality Monitoring Technical Seminar	Tampico City
August 31 - September 2	• Technical Seminar for Water Quality Simulation	Mexico City
November 11 - 12	• Technical Seminar for Water Quality Sampling • (including lecture and field practice)	Tampico City

*: This was conducted by *CNA* and Tamaulipas State Gov't and was opened to the general public.

1.3 Implementation of the Study

A team of consultants formed by JICA conducted the Study, together with a counterpart team from *CNA*. A Steering Committee was established by *CNA* in order to provide comments on the activities and output the Study, while JICA constituted an Advisory Committee. The members of the respective committees and teams are listed in Table 1.3 and Table 1.4.

Table 1.3 Composition of the *CNA* Steering Committee and Counterpart Team

Steering Committee

Name	Position
Dr. Alberto Jaime P.	Deputy Director General (Technical Area)
Mr. César Herrera Toledo	Deputy Director General (Planning Area)
Mr. Ignacio Castillo Escalante	General Manager (Sanitation and Water Quality Office)
Mr. Salvador Aguilera Verduzco	General Manager (Financial Office)
Mr. Alfredo Mora Magaña	Regional Manager (Regional Golfo Norte Office)

Mexican Counterpart

Name	Position
Dr. Jesús García Cabrera	Head Manager (Sanitation and Water Quality Office)
Mr. Ignacio D. González Mora	Head of Department (Sanitation and Water Quality Office)
Ms. Carolina C. Molina Segura	Hydraulic Specialist (Sanitation and Water Quality Office)
Mr. Homero A. Ramírez Serrano	Hydraulic Specialist (Sanitation and Water Quality Office)
Mr. José Ma. de la Torre Wolf	Head Manager (Financial Office)
Mr. Guillermo Gutiérrez G.	Head of Department (Financial Office)
Mr. Enrique López Pérez	Technical Head Manager (Regional Golfo Norte Office)
Ms. Evangelina Mancinas Mena	Head of Department (Regional Golfo Norte Office)
Ms. Francisca Robledo Muñiz	Head of Laboratory (Regional Golfo Norte Office)
Mr. Jorge Alberto Rodriguez Galindo	Hydraulic Specialist (Regional Golfo Norte Office)
Ms. Lilia Mercedes Campos Martínez	Hydraulic Specialist (Regional Golfo Norte Office)
Ms. Liliana Longoria Bolean	Hydraulic Specialist (Regional Golfo Norte Office)
Ms. Mónica Miguel Gil	Hydraulic Specialist (Regional Golfo Norte Office)
Ms. Lilia Mercedes Gómez Gallardo	Hydraulic Specialist (Regional Golfo Norte Office)

Technical Supporting Group

(Tampico laboratory):

Ms. Ma. del Carmen de la Garza Ramos	Mr. Carlos Alberto Rojas Flores
Ms. Ma. Natividad Cervantes Morales	Ms. Luz María Hernández Escobedo
Mr. Francisco Sergio Nieto Treviño	Mr. Celestino Ortega Méndez
Ms. Elda López Martínez	Mr. Anastacio Mendoza Ramírez
Mr. Baudelio Huerta Medina	Mr. Eusebio González del Angel
Mr. Eustorgio Guerrero Baldazo	Ms. Florenciana Cruz Hernández
Mr. Mérido Romero Salvador	Ms. Emelia Rivera Sánchez
Ms. Marta Ortega Méndez	

Source: JICA Study Team

Table 1.4 Composition of the JICA Advisory Committee and Study Team

Name	Position / Assignment
JICA Advisory Committee	
Prof. Takashi Hayase	Chairman
Mr. Wanami Kazuo	Technical Adviser
JICA Study Team	
Dr. Akira Uchida	Team Leader
Mr. Akinori Sato	Deputy Team Leader/Environmental Conservation, Water Quality Monitoring Plan
Dr. Hisashi Joh	Water and Sediment Quality (1)
Mr. Kenichi Kuramoto	Water and Sediment Quality (2)
Mr. Fujio Kojima	Hydrology/Hydraulics/Oceanography
Dr. Kazuhiko Ikeda	Water Pollution Analysis
Mr. Masao Itoi	Hydrodynamics and Water Quality Simulation
Mr. Tsuyoshi Ito	Regional Development Plan/Socioeconomics
Ms. Atsuko Otsuka	Administration

Source: JICA Study Team

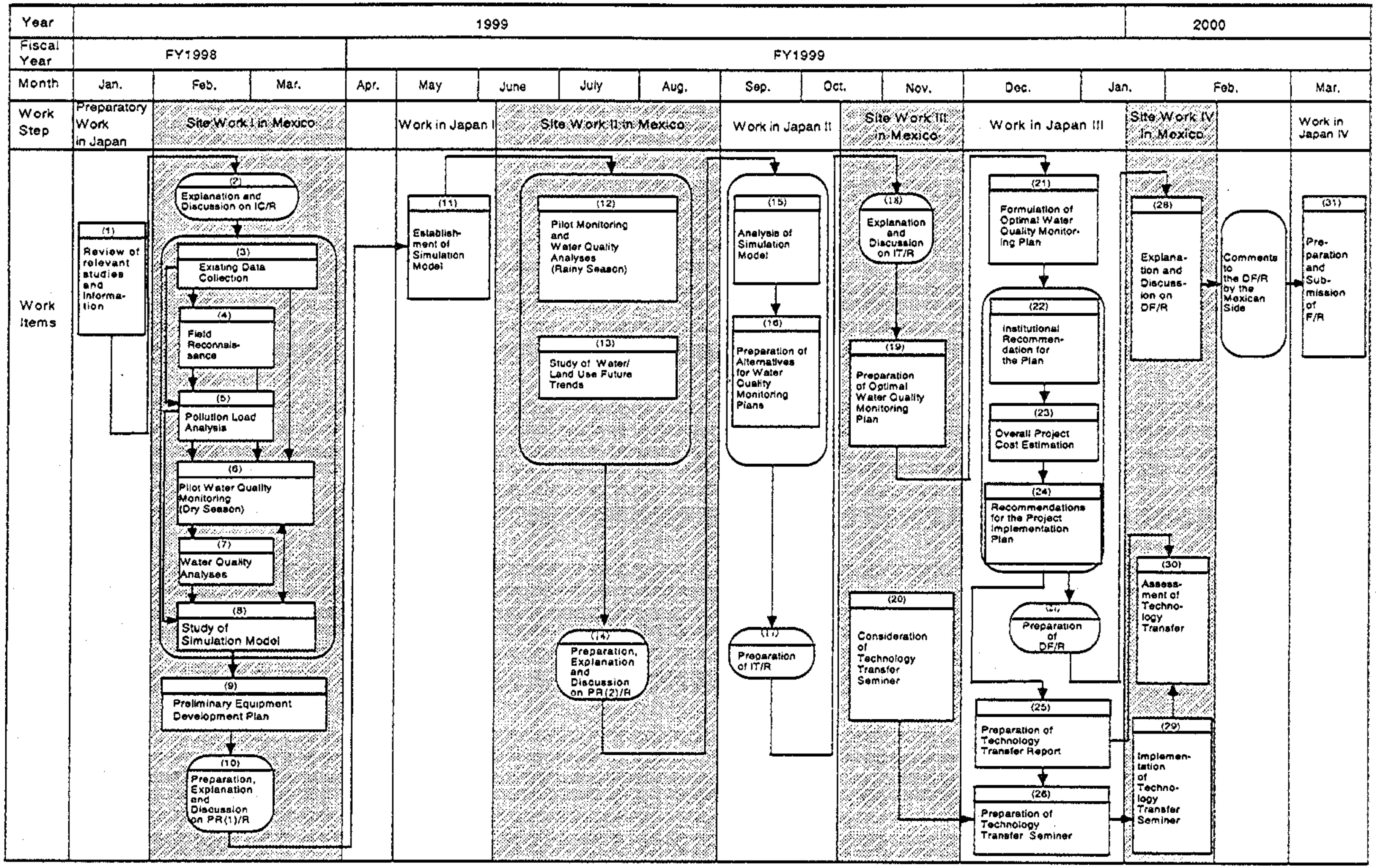

Figure 1.1 Workflow of the Study

Chapter 2 Existing Water Quality Monitoring System

2.1 Existing Water Quality Management

There are two standards for conservation of water and water areas, namely, the Ecological Criteria for Water Quality and the NOM-001-ECOL-1996 Effluent Standard. They are briefly described as follows:

(1) Ecological Criteria for Water Quality

The Ecological Criteria for Water Quality, *Criterios Ecologícos de Calidad del Agua*, CE-CCA-001/89, was established by the Ministry of Urban Development and Ecology (*Secretaria de Desarrollo Urbano y Ecologia*) in 1989. It aims to evaluate water areas for use as potable water supply and recreational areas, for use in agriculture and irrigation, pasture, and aquaculture (e.g. Tilapia, Carp, Barge, Trout Acro-iris, Langostine, Shrimp, Mollusk Bivalve) and for the conservation of aquatic life.

In determining the quality of water, the criteria cover 29 general parameters, 12 parameters on heavy metals, 75 parameters on toxic organic compounds and 2 parameters on radioactive material.

(2) Effluent Standard

The effluent standard, *Norma Oficial Mexicana NOM-001-ECOL-1996,* was established by *SEMARNAP* in 1996. It provides the maximum permissible limit of wastewater as it aims to conserve Mexico's water and land areas. Effluent standard is dependent on the areas of discharged waters, as shown in Table 2.1. The parameters of effluent standard include 8 basic parameters (excluding organic compounds) and 9 heavy metal parameters on toxicity.

Table 2.1 Classification of Water Areas for Effluent Standard

Water Areas	Purposes
River	• agriculture and irrigation • urban public use • protection of aquatic biota
Natural and artificial reservoir	• agriculture and irrigation • urban public use
Coastal water	• fish exploitation, navigation and other uses • recreation • estuary
Wetland	-
Soil	• agriculture and irrigation

Source: NOM-001-ECOL-1996

2.2 Related Agencies to Coastal Water Quality Monitoring

The following agencies conduct water quality monitoring in the coastal areas of Mexico. Strictly speaking, however, their activities could not be called monitoring because monitoring requires periodic data collection and a standard method to follow.

(1) Ministry of Navy (*Secretaria de Marina*)

This office conducts oceanographic surveys offshore, but the surveys are not done periodically. In Tampico coastal area and Altamira seaport, monthly water quality monitoring started in August 1998. Monitoring parameters include 16 parameters, such as water temperature, transparency, SS, and DO.

(2) Ministry of Communication and Transportation (*Secretaria de Communicaciones y Transportes*)

This ministry is responsible for the management of port areas. Although water discharged from vessels is inspected, the ministry does not conduct periodic monitoring of ambient water quality.

(3) Academic Institutes

Some of the academic institutes, such as National Autonomous University of Mexico (*UNAM*), conduct research on water quality and other factors, including biological parameters in coastal areas. These researches, however, are done for scientific purposes, not for coastal management. In general, surveys are not undertaken regularly, and the survey method and analysis are not fixed.

2.3 National Water Commission *(CNA)*

2.3.1 Functions and Roles of *CNA*

The National Water Commission is under the Ministry of Environment, Natural Resources and Fishery *(SEMARNAP: Secretaria de Medio Ambiente, Recursos Naturales y Pesca)* as a federal executive power branch. *SEMARNAP* has the following agencies (see Figure 2.1):

- National Water Commission (*CNA: Comision Nacional del Agua*);
- Mexican Water Technology Institute (*IMTA: Instituto Mexicano de Tecnologia del Agua*);
- Ecological National Institute (*INE: Instituto Nacional de Ecologia*);
- Federal Procuratorship of Environmental Protection (*PROFEPA: Procuraduria Federal de Proteccion al Ambiente*); and
- Institute of National Fishery (*INP: Instituto Nacional de la Pesca*).

Established in 1989 under *SEMARNAP*, *CNA* has been responsible and has authority over water resource management. *CNA* has the following six subdirectorates: Administration Subdirectorate, Water Administration Subdirectorate, Operation Subdirectorate, Programming Subdirectorate, Construction Subdirectorate, and Technical Subdirectorate. Coastal water quality monitoring is implemented by the Technical Subdirectorate (see Figure 2.2).

2.3.2 Water Quality Monitoring of *CNA*

The installation of monitoring stations along the coastal water was proposed by *PROMMA*, and *CNA* is to implement coastal water quality monitoring. But in reality, *CNA* has never actually done such activity. At present, *CNA* does not even have any seawater sampling guidelines and manuals on water quality and sediment samples, or any standard method of seawater quality and sediment on seabed analysis.

2.3.3 Tampico Water Quality Laboratory

(1) Establishment of Tampico Water Quality Laboratory

In 1972, the laboratory of the Panuco River Survey Comission started operating under the Hydraulic Resources Chamber located in Tampico, Tamaulipas State. Its main objective was to monitor water quality in the low river basin of Panuco River, including the rivers, watercourses, lagoons, barrages and underground waters of Tamaulipas, Veracruz, San Luis Potosi and Hidalgo States. On December 28, 1974, the Hydraulic Resources Chamber *(SRH)* was renamed Hydraulic Resource and Agriculture Chamber *(SARH)* for the purpose of integrating governmental agencies.

Tampico Water Quality Laboratory, which was established in 1974, became a Regional Laboratory under the *CNA* Regional Office. However, it was not operational during some parts of 1996, 1997 and 1998 due to insufficient electrical installation.

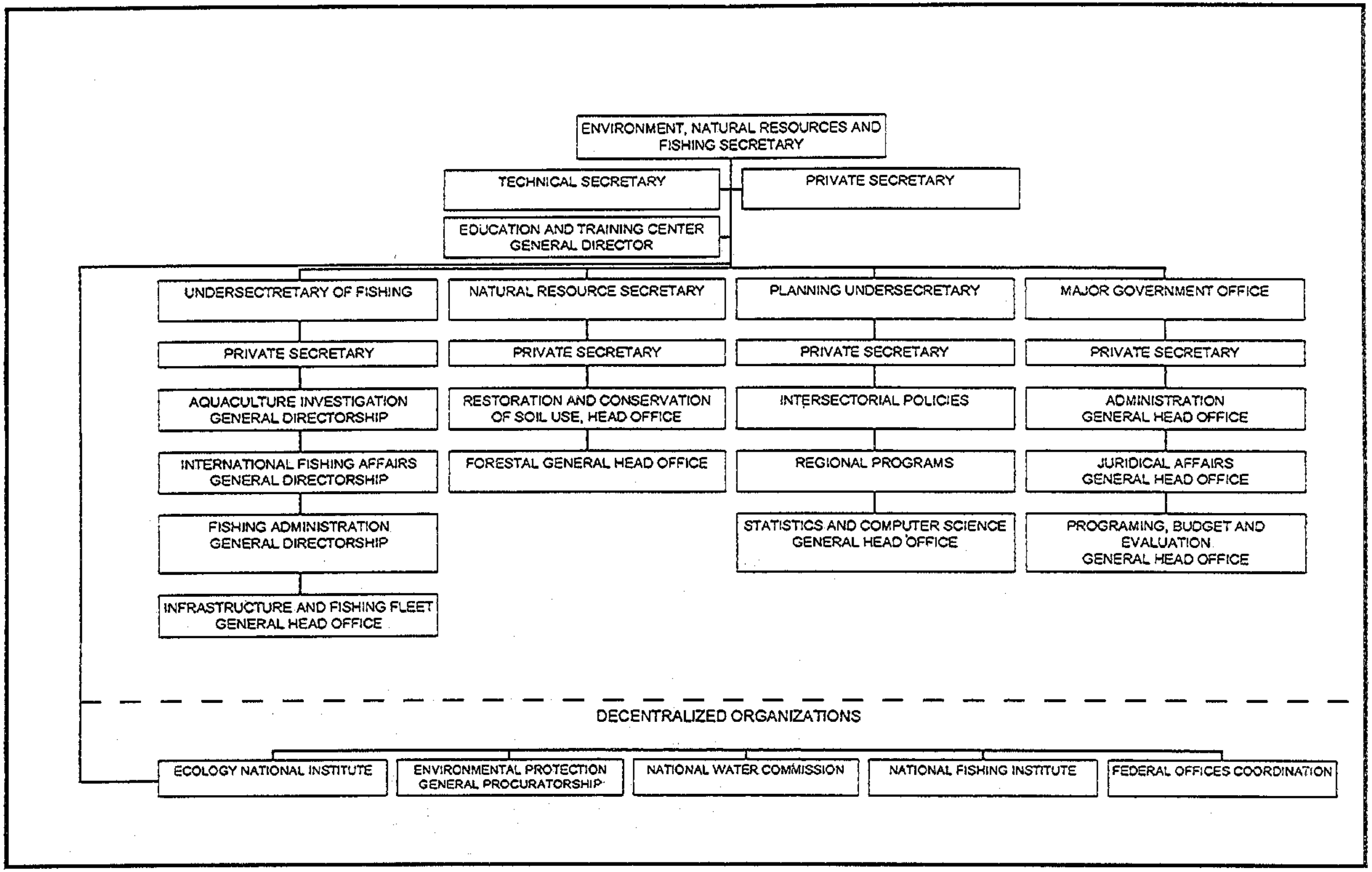

Figure 2.1 Organizational Chart of *SEMARNAP*

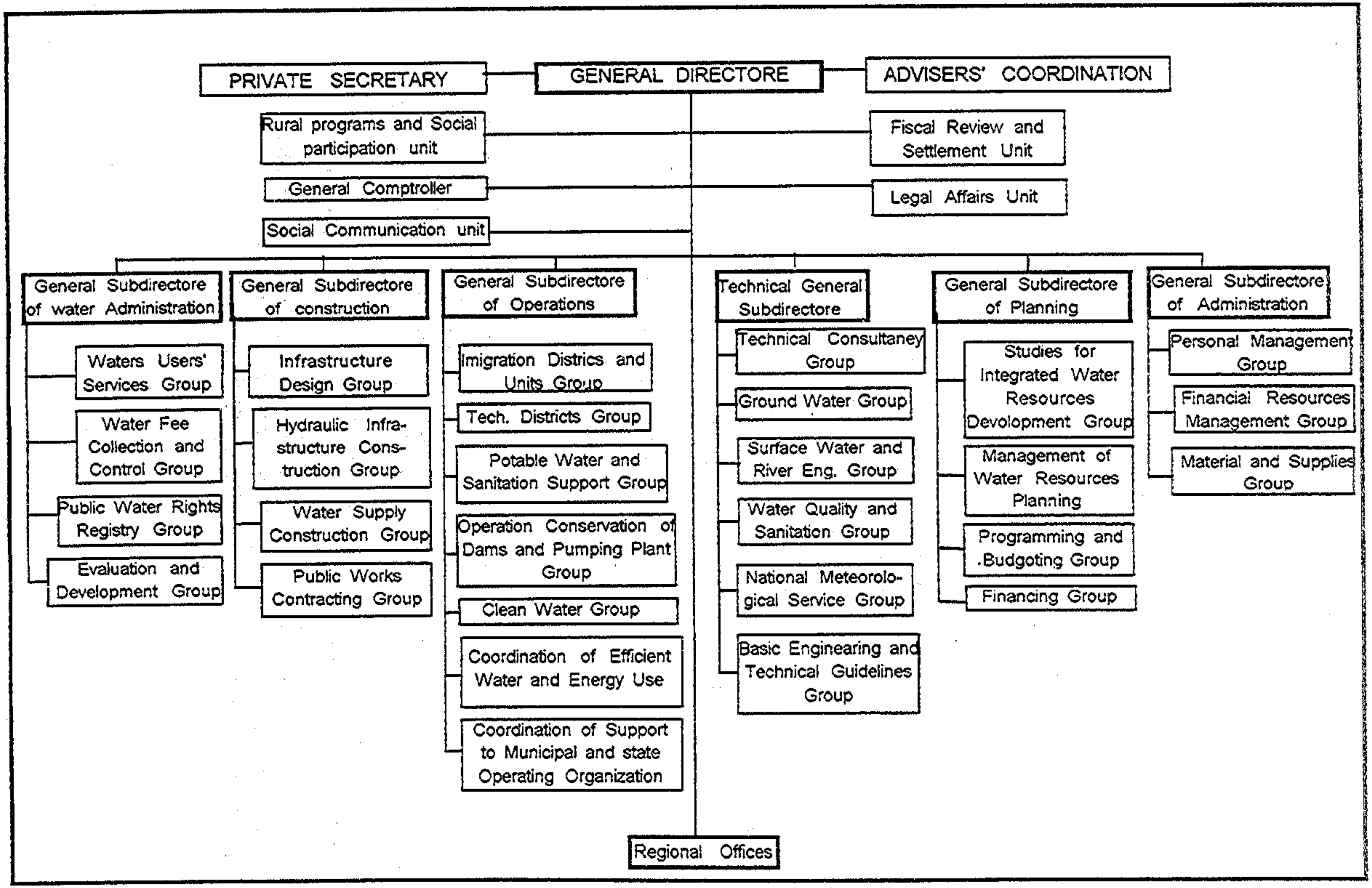

Figure 2.2 Organizational Chart of *CNA*

(2) Organization of Tampico Water Quality Laboratory

CNA has 13 regional offices under the General Director of *CNA*. One of the regional offices, Gulf North Region, covers Tamaulipas, north of Veracruz, west of San Luis Potosi, Queretaro and Hidalgo States. Tampico is under the Head of Project for Environmental Impact Area of the Gulf North Region.

Tampico Water Quality Laboratory has three sections and an analysis group (refer to Figure 2.3). The three sections have different responsibilities pertaining to operation and laboratory work as follows:

Monitoring Section

- to prepare equipment and reagents for field survey
- to conduct water quality monitoring

Quality Control Section and Assurance Section

- to arrange and manage samples for the analysis groups
- to manage quality control through supervision of calibration curves and blank test
- to surpervise staff members

Storage Section

- to manage reagents and laboratory equipment.

The analysis group is subdivided into the following: Physical-Chemical Analysis Group, Organic Matter Analysis Group, Nutrient Salt Analysis Group, Toxic and Harmful Substances Analysis Group and Bacterial Analysis Group (see Table 2.2).

Table 2.2 Responsibility of Analysis Groups of Tampico Water Quality Laboratory

Analysis Groups	Assigned Parameters
Physical-Chemical Analysis Group	pH, Conductivity, Turbidity, Color, Oil and Grease, SS, Minerals salts, Hardness, Alkalinity Sulphate
Organic Matter Analysis Group	DO, BOD, COD
Nutrient Salt Analysis Group	Inorganic Nitrogen, Total Nitrogen, Inorganic Phospate
Toxic and Harmful Substances Analysis Group	Methylene Bule Active Substances (MBAS), Chromium hexavalent, Phenold
Bacterial Analysis Group	Coliform bacteria

Source: *CNA*

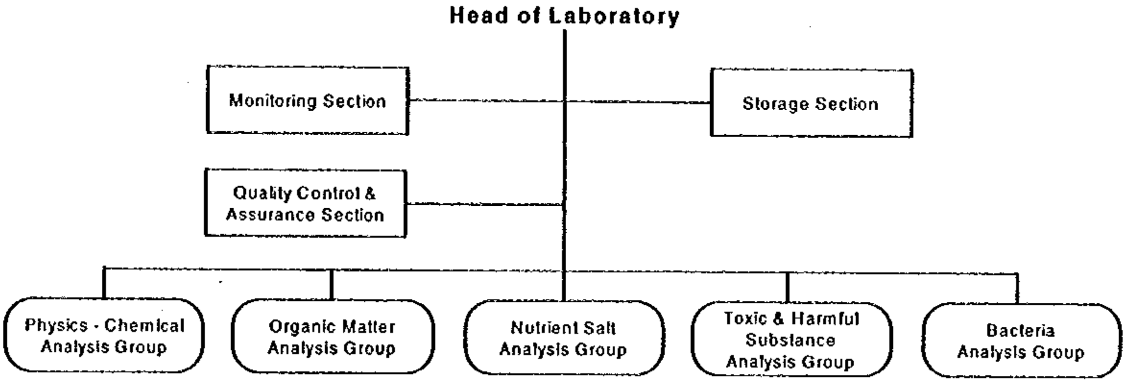

Figure 2.3 Organizational Chart of Tampico Water Quality Laboratory

(3) Availability of Analysis Parameters

The parameters analyzed at Tampico Water Quality Laboratry, shown in Table 2.3, can be grouped into two, namely, fresh water samples and industrial wastewater samples. Although most of the samples are fresh water, several samples of industrial wastewater had been analyzed in 1998. Basic parameters were mainly analyzed for fresh water samples, such as pH, conductivity, SO_4^{-2}, NO_3-N.

(4) Major Laboratory Equipment

The major laboratory equipment for analysis of Tampico Laboratory are listed in Table 2.4. Most of the equipment had been bought 15 to 20 years ago. Although the equipment for analysis have been maintained well, it can be said that there are problems from the viewpoints of efficiency and quality control. There is a lack of fixtures and glass equipment such as pipettes and tubes, among other things. The Study Team had procured new laboratory equipment such as atomic absorption spectrophotometer, gas chromatography, spectrophotometer, total organic carbon analyzer and others.

(5) Building and Basic Facilities

Tampico Laboratory is located within the residential area of Madero City in Tamaulipas State. The building was originally constructed as a residential house in 1979, but it was converted to an office when the Hydraulic Resource and Agriculture Chamber (*SARH*) had occupied the structure. Then the building was turned over to *CNA* and renovated for laboratory work in 1992. The layout of Tampico Laboratory is shown in Figure 2.4.

The facilities of the building include the following:

a) Water Supply

Supplier	:	Comision Municipal de Agua Potable y Alcantarillado (COMAPA)
Water source	:	Chairel Lagoon
Consumption of Water	:	65 m^3/month
Water Treatment	:	1) flocculation, 2) sedimentation, 3) sand filtration, 4) chlorine disinfectant

b) Electricity

Total Capacity	**127,000 watts**
for sockets and light (110V)	9,818 watts
for air conditioner (220V)	39,200 watts
for laboratory equipment (110/220V)	77,982 watts
Consumption of Electricity	1,135 kw/month

Table 2.3 Available Parameters and Number of Samples Analyzed, 1998

Type of Sample	Available Parameters	Number of Samples
Fresh Water	pH	595
	Total Alkalinity	357
	Fenolftaleina Alkalinity	273
	HCO_3	304
	CO_3	246
	Cl^-	370
	Residual Chlorine	92
	Color	491
	Turbidity	465
	Conductivity	623
	Sedimentary solids	201
	Total solids	263
	Total suspended solids	251
	Total dissolved solids	466
	Total fixed solids	248
	Total volatile solids	247
	Fixed suspended solids	247
	Volatile suspended solids	247
	Phenols	203
	Total hardness (or solidity)	460
	Calcium hardness(or solidity)	407
	DO	311
	BOD	279
	DQO	396
	Oils and Grease	256
	SAAM	202
	PO_4-	430
	Orthophosphoric acid	329
	NO_3-N	533
	NH_3-N	270
	Organic nitrogen	31
	Total coliform bacteria	15
	Fecal coliform bacteria	385
	V CH	21
	SO4	591
	Cr	393
	Ca	307
	Mg	321
Industrial Wastewater	pH	4
	PO_4^-	3
	Cr^{+6}	3
	SAAM	1
	DQO	1
	DBO	4
	DO	4
	Oil and Grease	4
	Total Dissolved Solids	1
	Total Suspended Solids	3
	Sedimented Solids	3
	Fecal coliform bacteria	4
	Total coliform bacteria	1
	Organic nitrogen	3
	NH_3-N	3
	NO_3-N	3

Source: *CNA*

Table 2.4 (1) Major Monitoring Equipment of Tampico Water Quality Laboratory

NAME	MODEL	DATE OF BUY	NUMBER
1. Digital Analytical Balance 160 g	Ohaus. Galaxy TM-160		2
2. Granatarial Balance	Ohaus. 7505		1
3. Range Conductimeter	YSI. 31		2
4. Nefelometer	Monitek. TAI		1
5. Digital Potentiometer for specific ions with electrodes of pH, NO3, F-4 and CN-	Corning Ion Analyzer 250		1
6. Digital Potentiometer for specific ions	Orion. 720 A	December 1998	1
7. Spectrophotometer UV-VIS (analogic) with two interchangeable photo tubes	Bausch & Lomb. Spectronic 20		1
8. Colorimeter with a disc integrated in Units Pt-Co	Orbeco-Hellige. Aqua Tester		1
9. Colorimeter with two interchangeable discs in units Pt-Co	Orbeco-Hellige. Aqua Tester	June 1998	1
10. Commercial Refrigerator 12 cubic ft.	Nieto. R-30		1
11. Wet bath for 8 tubes with steel top	Felisa. 373		2
12. Wet bath of 19 liters	Presicion.184	June 1996	4
13. Incubator for DBO	Precision. FU019ARW2		1
14. Camp, bacteriological incubator	Millipore. MF		1
15. Electric oven for drying	HQR-1330		1
16. Heat extraction Multiunit of 6 units	Lab-Line.5000	Dec. 2, 1998	3
17. Centrifuge with horizontal head with 4 arms	Clay Adams.420101		1
18. Vertical Autoclaves with automatic Control	Aesa.VC-300		2
19. Electric Oven/Bacteriological Incubator with a range of 220°C	Felisa.Fe 292ª		1
20. Muffle Oven with a range of 1000°C	Thermolyne. F.627		1
21. Magnetic agitators with porcelain grid	Corning.PC-353		1
22. Heating grid with metallic plate with a range of 800°C	Thermolyne.HPA 2245M		1
23. Heating grid with metallic plate with a range of 800°C	Precision.P/5		1
24. Heating grid with a 6 position agitation	Scorpion Scientific.A6025L12D	June 1998	1
25. Heating grid with 6 heating jackets	Acorpion Scentific. 8025 DI	June 1998	1
26. Digital Rotation vapor	Bucci.RE-121		1
27. Toxic Vapor Extraction Hood	.CP-15	June 1996	1
28. Industrial Voltage Regulator	Sola.2313210		1
29. Salt and temperature measuring device	YSI.33		1
30. Salinometer	YSI.30-10FTSN		1
31. Fluxmeter	General Oceanics Icc.		1
32. Electronic gauge for flow measurement	Global Water		1
33. Water Sampler	Wildco		2
34. Dredge	E Kman		3
35. Dredge	Megamed		1

Table 2.4 (2) Major Monitoring Equipment of Tampico Water Qaulity Laboratory

NAME	MODEL	DATE OF BUY	NUMBER
36. Secchi Disc for transparency measurement: a) sedimentary solids b) chlorine c) dissolved oxygen d) pH	Hach.STPL-WRT		1
37. Contamination detector kit for: a) residual chlorine b) Phenols c) Total copper d) Detergents e) Color f) Turbidness. g) pH	La Motte.SSDK		1
38. Oximeter with electrodes for measurements of: a) pH b) conductivity/ total dissolved solids c) dissolved oxygen	Corning.Checkmate 90		2
39. Oximeter with range sensor. 0-20 mg/L	YSI.58		1
40. Salt gauge with electrodes for: a) salinity b) dissolved solids c) conductivity	ORION.130		1
41. Sampling Net for plankton with the case	Kahlsico.008 WA685L		1
42. Digital manual Potentiometer	Lamotte.pH Testr 1		1
43. Multiple gauge to measure: a) ph b) conductivity c) turbidness d) dissolved oxygen e) temperature f) salinity	Horiba.U-10		1

Source: *CNA*

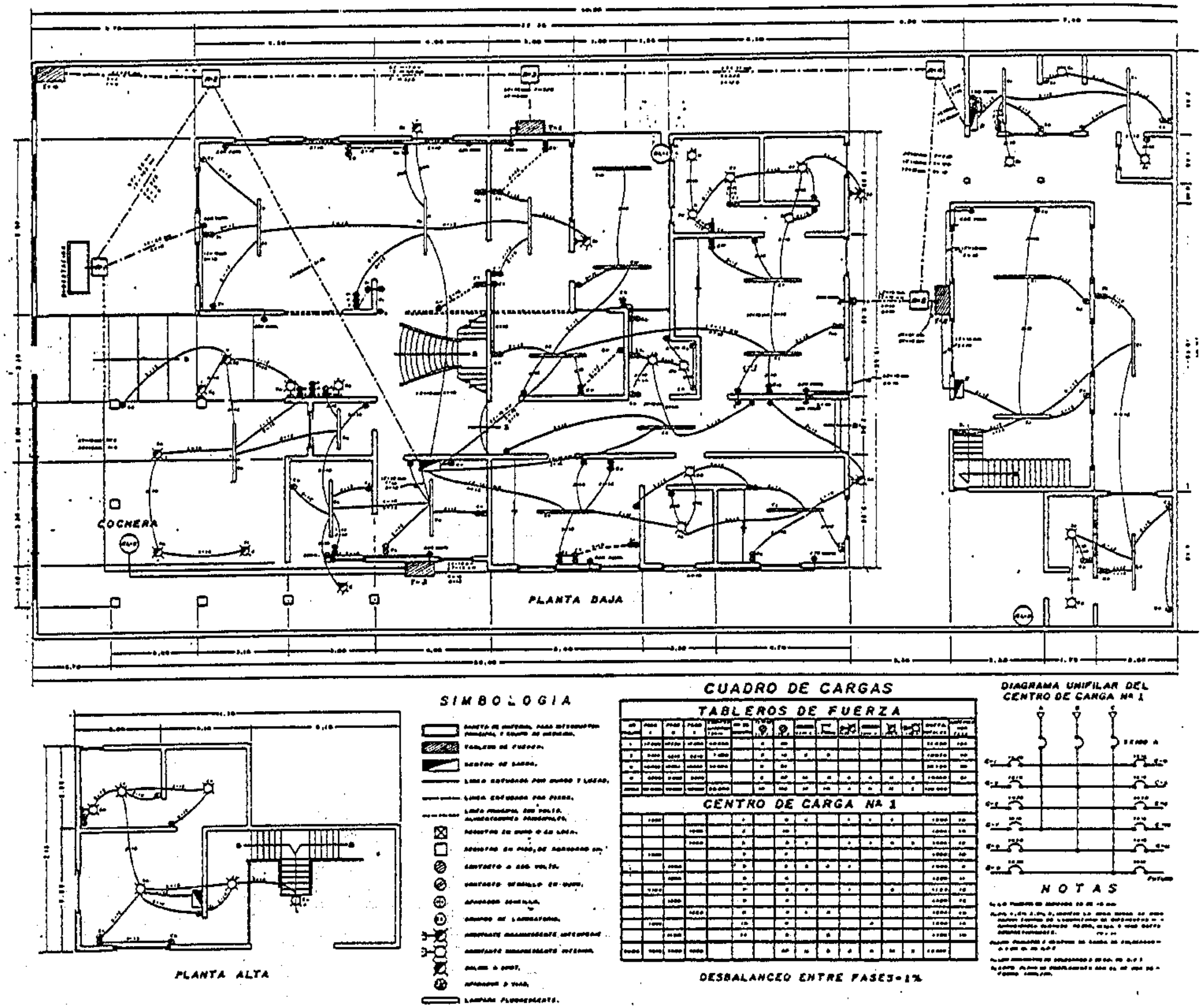

Figure 2.4 Layout of Tampico Water Quality Laboratory

(6) Human Resource

a) Staff members

Tampico Laboratory has 19 employees, including the Head of Laboratory, as of 1999. Seven (7) employees have a background in chemistry, 2 in pharmacology, while 10 are high school graduates, as shown in Table 2.5.

Table 2.5 Background and Years of Experience of Tampico Water Quality Laboratory Staff, 1999

unit: person

Years of Experience	Chemistry	Chemical Engineering	Chemical Analysis	Biological Pharmacology	High School Graduates	Total
0 – 5				2		2
6 – 10						0
11 – 15			1		1	2
16 – 20			3		1	4
21 –	1	2			8	11
Total	1	2	4	2	10	19

Source: *CNA*

b) Staff Training

The staff of Tampico Laboratory undergoes two types of training: on-the-job training and off-the-job training. As mentioned earlier, the laboratory has five analysis groups; on the job, the group leaders train their respective members through daily work. Off-the-job training includes seminars, training programs and symposiums. However, only a few opportunities for skills training exist and most of them are for college graduate level. As such, only a few could attend these programs, because half of Tampico Laborabory's staff members are high school graduates only. Table 2.6 shows the training programs that were conducted during 1997 and 1998.

Table 2.6 Training Programs of Tampico Water Quality Laboratory, 1987 and 1998

Training Program	No. of Staff Members who Attended	Duration	Conducted by
Analysis Equipment	1	Nov. 10 -14, 1997	Tula-Tepeji Technological Univ.
Gen. Law for Environmental Protection and Ecological Balance	2	Aug. 28 - 29, 1997	*SEMARNAP*
Municipal Water Treatment Plants	1	Sept. 2 - 5, 1997	*CNA*
Chemical Analysis	1 1	Nov. 10, 1997 Dec. 19, 1997	*UNAM*, funded by *PROMMA*
Analysis for Human Internal Worm in Raw Residual Waters	2	May 4 - 6, 1998	*IMTA*
Redesign of Water Quality Monitoring Network	1	June 22 - 26, 1998	*PROMMA*
Quality Control for Analysis Data	1	Oct. 12 - 16, 1998	*UNAM*, funded by *PROMMA*

Source: *CNA*

(7) Budget of Tampico Water Quality Laboratory

The budget of Tampico Laboratory suffered a drastic cutback in 1996 and 1997, as shown in Table 2.7.

Table 2.7 Budget of Tampico Water Quality Laboratory, 1995 - 1999

Year	Budget (Pesos)
1995	179,000
1996	47,000
1997	69,550
1998	120,000
1999	330,000

Source: CNA
Note: excluding salaries

2.4 Modernization of Water Management Project *(PROMMA)*

Commenced in 1996, the Modernization of Water Management Project (*PROMMA*: *Proyecto de Modernizacion del Manejo del Agua*) has been targeted for completion in year 2001. However, this schedule has been extended to 2003 because of financial problems. The original plan of *PROMMA*, the visualization of strategic instrument, is to contribute to the implementation of the policy embodied in National Hydraulic Plan 1995 – 2000. Under the responsibility of *CNA*, *PROMMA* faces the challenge of resolving the hydraulic resource concerns of Mexico. Such concerns pertain to management efficiency, quantity and quality control in the different hydrological cycle phase, modernization of the measurement and consolidation system, as well as the management and information system.

The program is oriented towards the establishment and strengthening of the technical bases required for the management and sustainable development of water resources in the whole country. Included within the program are the following:

- strengthening of human resources,
- modernization of infrastructure for monitoring and data management,
- integration of hydraulic resource management, and
- decentralization of administration, distribution and control of water use.

For the execution of *PROMMA*, the Mexican Government requested a loan from the World Bank to pay for the partial costs of the different activities to fulfill the objectives of *PROMMA*. Since the establishment of *PROMMA* in 1996, World Bank has financed about 54.5 % of its total investments.

PROMMA comprises water quality monitoring, hydrology and climate. The Modernization of the National Laboratory Network, the National Monitoring Network and the Water Information System, as sub-components of *PROMMA*, have obtained a significant advance of agreement with the last evaluation done late 1998 by a World Bank Mission, comprising a multidisciplinary group of international consultants.

The National Monitoring Network of Water Quality is to comprise several components, each one with specific objectives. The Primary Network component will periodically assess the conditions of water bodies that are important to the different regions of the country. There are two criteria for defining such importance: (1) the uses of water body, and (2) its susceptibility to pollution impacts. This component will give the long-term tendency of water quality changes. The Primary Network has been designed and activities have been started from 1999.

The Secondary Network component is tasked with the generation of data to enhance contamination control activities. Specifically, it aims to identify the pollution loads of water bodies receiving wastewater discharged by industries, municipalities, and the agricultural sector which contain heavy metals and toxic substances, organic compounds, such as organophosphoras compounds and organochlorine compounds and others. The Secondary Network will assist in determining the degree of compliance with the Effluent Standard NOM-001-ECOL-1996. Priority sites will be identified for this network as additional result of the applied procedure for the calibration of the Primary Network.

The other components include Special Studies, which involve very intensive and particular monitoring studies to assess the water quality or to identify causes of pollution and their impacts. The last component is called Hydroecological Emergencies, which is concerned with several sudden events that impact the water quality and put to risk the ecosystem and human health. On the other hand, rehabilitation of the National Reference Laboratory has started in 1999, including design studies and engineering specification for prototype design of regional laboratories. Two regional laboratories have been selected such as Valle de Mexico Regional Laboratory (Lomas Estrella) and Lerma Santiago Pacífico Regional Laboratory (Guadalajara).

2.4.1 National Monitoring Network

Under the new concept for redesign of the National Monitoring Network (*RNM*: *Red Nacional de Monitoreo*), the necessity of local and regional response must be considered as a federal water quality monitoring program. The goal of *RNM,* as a monitoring program, is to contribute the necessary information for the conservation of "water," in such a way that the water bodies, as national properties, remain in an equilibrium situation that does not compromise the users assigned to the resource and its use as receptor bodies of wastewater discharges. The redesign strategy of the *RNM* is, on one side, through the establishment of components with specific objectives and, on the other side, through the evaluation of the problem of water quality from the perspective of an integral monitoring.

A total of 803 monitoring stations belong to the National Monitoring Network (before redesigning the *RNM*), and in 1996 *PROMMA* suggested 402 monitoring stations (see Table 2.8). Monitoring parameters were recommended based on the type of water body, while the frequency of monitoring is dependent both on the type of water body and the monitoring parameters (see Tables 2.9 and 2.10). However, the parameters in Table 2.9 are future recommendations to the Primary Network. At present, due to lack of capability, the *RNM* has recommended the analysis for a small group of basic parameters in freshwater systems: BOD, COD, $N\text{-}NH_3$, $P\text{-}PO_4$, conductivity, DO, TSS and fecal coliforms

Table 2.8 Number of Primary Network Monitoring Stations by *PROMMA*

Area	Number of Monitoring Stations
Surface Water Stations	**201**
rivers	143
streams and brooks	3
dam	29
lakes and lagoons	20
channels and discharges	6
Underground Stations	**103**
Coastal Stations	**98**
bays and port	52
lagoons	22
isles	3
estuaries, capes and points	21
Total	**402**

Source: *PROMMA*

Table 2.9 Parameters of Water Quality Monitoring by *PROMMA*

Water body	Uses (classification)		
	Supply Source (domestic, industrial and livestock)	Life Protection Aquatic/ Recreation	Agricultural Irrigation
Rivers	• measured parameters on field • SST • Chlorophyll a • NO3-N / NO2-N • BOD • coliform bacteria • major ions • pesticides	• measured parameters on field • SST • Chlorophyll a • NH3-N • PO4-P • BOD • coliform bacteria • heavy metals • bio-monitoring • bio-accumulation	• measured parameters on field • SST • major ions
Reservoirs or Artificial Lakes	• measured parameters on field • SST • Chlorophyll-a • NO3-N / NO2-N • BOD • coliform bacteria • major ions • pesticides	• measured parameters on field • SST • Chlorophyll-a • NH3-N • PO4-P • BOD • coliform bacteria • heavy metals • bio- monitoring • bio- accumulation	• measured parameters on field • SST • major ions
Aquifers	• measured parameters on field • NO3-N / NO2-N • coliform bacteria • major ions • COV's		• measured parameters on field • major ions
Coastal Areas and Estuaries		• measured parameters on field • SST • Chlorophyll a • NH3-N • BOD • Coliform bacteria • Heavy metals • Bio- monitoring • Bio- accumulation	

Source: *PROMMA*

Note: Measured parameters on field include water temperature, dissolved oxygen, electric conductivity, color, pH and odor
Major ions are Sodium, Potassium, Calcium, Magnesium, Bicarbonate, Chloride, Sulfate. Heavy metals include Cadmic, Lead, Mercury, Arsenic, Copper, Chrome, Nickel, and Zinc. SST means total suspended ions; COVs are volatile organic compounds

Table 2.10 Frequency of Water Quality Monitoring by *PROMMA*

Water Bodies	Physical-Chemical Test	Biological Test
River	12 times/year	2 times/year
Reservoirs	4 times/year	2 times/year
Aquifers	2 times/year	-
Coastal Area	7 times/year*	2 times/year

Source: *PROMMA*

*: during peak tourist seasons: from the end of December until the middle of January, Holy Week, from the end of June, July, August and the beginning of September.

2.4.2 Modernization of National Laboratory Network

The Modernization of National Laboratory, which is a sub-component of *PROMMA,* aims to accomplish the following three objectives:

- to standardize, operate and sustain a laboratory network in order to develop studies and projects for management and conservation of hydraulic resource in the country;
- to secure the analytical requirement for operation of the National Monitoring Network and water quality studies; and
- to obtain usable data that are accurate, precise, verifiable and trustworthy.

The original plan of the National Laboratory Network comprises the following:

- 1 Central Laboratory
- 13 Regional Laboratories
- 20 State Laboratories

All three types of laboratories are under *CNA* (refer to Figure 2.5). However, *PROMMA* proposed that the 20 state laboratories be closed due to lack of funds. Therefore, *CNA* redeveloped the Central Laboratory and the remaining13 Regional Laboratories. Table 2.11 presents the Laboratory Development Plan under *PROMMA*, which shows four laboratory classifications such as Reference Laboratory and Levels 1, 2 and 3 Laboratories based on the arrangement of laboratory equipment.

Although *CNA* must cover the whole country, which has more than 10,000 km of shoreline, it only has a Central Laboratory and 13 Regional Laboratories. To reinforce the coverage of water quality monitoring, *CNA* plans to introduce a Mobile Laboratory, which is a laboratory vehicle. The Mobile Laboratory will be of two types, one is for preservation of samples for coliform during transportation, and the other is for conduct of inorganic analysis onboard the vehicle. However, there are several problems of coverage for regional monitoring areas by mobile laboratory.

The Study Team pointed out the following problems:

a) Transportation

In the plan for Mobile Laboratory, there would be one mobile laboratory for one region. However, since regional coastal areas are quite large, there might be times that the vehicle would have to traverse not only coastal roads but also mountainous areas. Under these rough conditions, it would be difficult for one Mobile Laboratory to cover a whole region.

b) Precise laboratory equipment

It would be difficult to maintain the precision of laboratory equipment considering the rough condition of mountainous and coastal roads. The different pieces of equipment such as balance, thermometer, pH meter, salinometer, spectrophotometer and others are very sensitive to conditions of the working environment. They should be kept from vibration and high/low temperatures.

It seems reasonable to suppose that owing to the limited use of a Mobile Laboratory, it is not fit as a complementary tool for coastal water quality monitoring. If a Mobile Laboratory can be arranged at strategic areas, it may have a reasonable use during intensive monitoring of rivers, dams, reservoirs and lagoons, or conduct of urgent surveys.

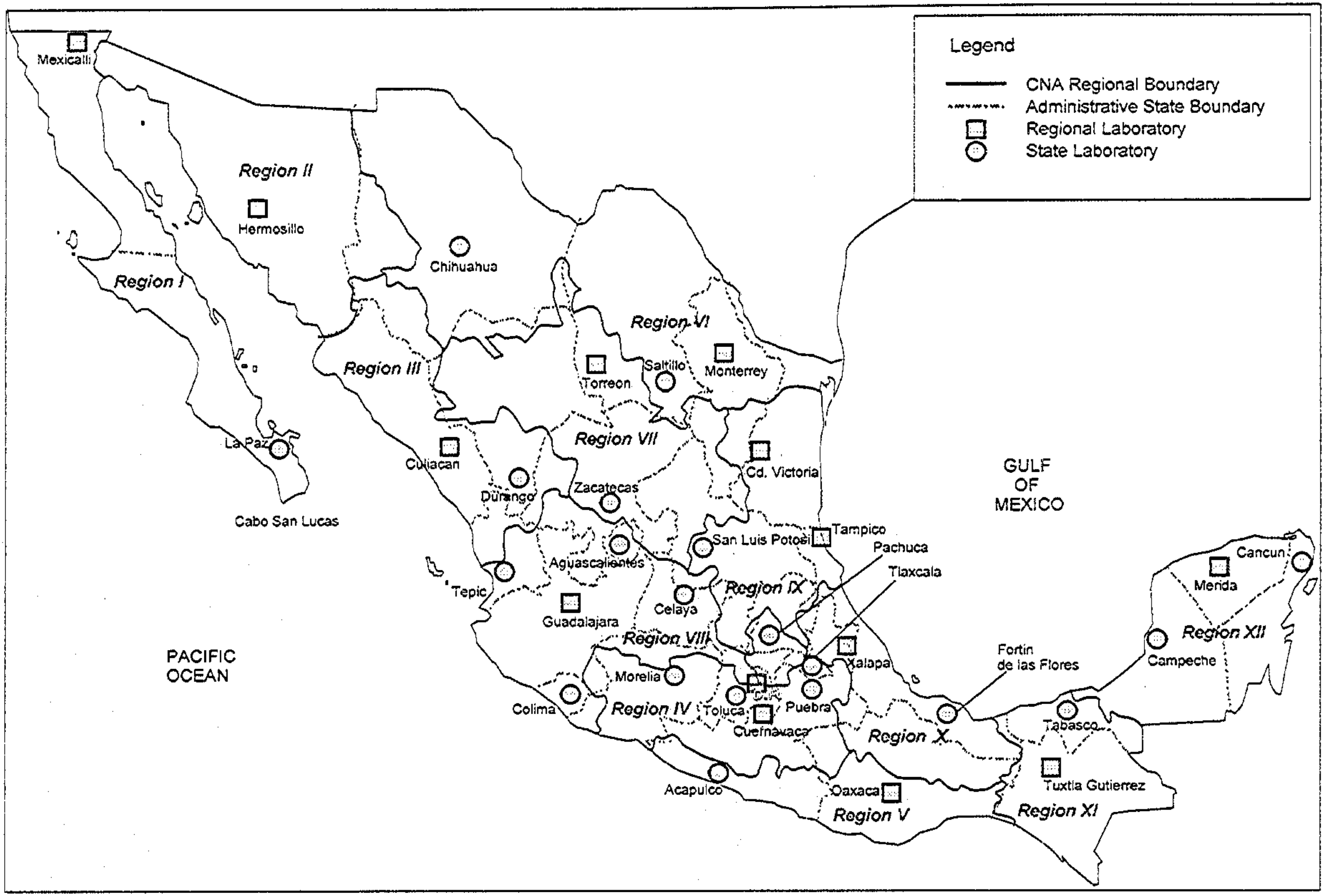

Figure 2.5 Location of Regional and State Laboratories of *CNA*

2.5 Findings on Coastal Water Quality Monitoring Problems

Problems for implementation of coastal water quality monitoring have been found through interview survey, questionnaire survey, pilot monitoring and investigation of regional laboratories. These problems from the viewpoint of coastal water quality monitoring can be divided into three, as follows:

- lack of basic facilities,
- inadequate laboratory equipment, and
- arrangement of personnel.

(1) Laboratory Building

In spite of the renovations that were undertaken in 1992, *CNA*'s laboratory building is still unsuitable for chemical analysis work. The following problems are pointed out from the viewpoint of operational efficiency of the laboratory:

- ill-fitting building (dusty in side rooms);
- inadequate space for analysis of samples and storage of equipment and samples;
- insufficient water pressure;
- insufficient electric power;
- inadequate lighting for laboratory work; and
- poor air conditioning.

(2) Laboratory Facilities and Equipment

Problems regarding laboratory facilities and equipment can be divided into two types: lack of basic facilities and inadequate laboratory equipment, as follows:

a) Lack of basic facilities

There is difficulty in doing even the most basic process for analysis owing to lack of laboratory facilities and equipment, such as wastewater treatment facilities, draft chamber, thermostat, and shaker, among other things.

A distilled water maker is a minimum laboratory requirement for water quality analysis. Distilled water is used for washing glassware and preparing reagent and calibration curve. It is therefore necessary that the distilled water maker produce purified water of the same quality. However, the distilled water makers at some regional laboratories are broken; they also have limited production capacity. Normal sea water have low levels of nutrient salt and pollutants, such as heavy metals and organic compounds, so that distilled water should be kept at the required quality.

Although *CNA* has functions of water pollution control, laboratory wastewater treatment facilities are not set-up in some of the regional laboratories. Chemical analysis requires toxic reagents and standards for the preparation of calibration curve, which contains heavy metals and toxic substances. At present, most of the wastewater from laboratory work is discharged directly into public water areas without treatment. Laboratory wastewater contains acid, alkaline, heavy metals and organic solvents. It is possible that discharging of laboratory wastewater could give rise to water pollution, even though the discharge volume is small.

b) Inadequate laboratory equipment

Most of the equipment of the Tampico Water Quality Laboratory is outdated, having been in use for the past 15 to 20 years. It is possible, therefore, that obtained data are unstable from the viewpoint of analytical precision. It is reasonable to suppose that other *CNA* laboratories suffer the same situation.

In the case of a spectrophotometer, when measuring is done by absorption coefficient, precision is dependent on the selection of appropriate measuring wave-length and cell; otherwise, there will be an error in analysis. Most spectrophotometers that are used by *CNA* have the following problems from the viewpoint of precision and accuracy:

- The most sensitive wave-length could not be used for analysis because of the poor selection of wave-length. As a result, precise data could not be obtained.
- It was impossible to detect small changes in color because of the high degree of transparency of the glass cell used, which is inappropriate for precision analysis. Quartz cell is recommendable because seawater contains low levels of nitrogen, phosphate and metals.
- The use of a cylinder-type cell is also inappropriate because of the diffusion of light which makes detection difficult. It is recommended that a square pillar-type cell be used for the spectrophotometer.

(3) Arrangement of personnel

a) Lack of necessary knowledge

Those in charge of chemical analysis do not have enough knowledge of water quality monitoring activities, such as washing of laboratory ware, handling of measuring flask, and preparing calibration curve. For example, the different processes involved in water quality analysis should be undertaken carefully. There are several types of measuring glassware, such as komagome pipette, measuring pipette and volumetric pipette. The verification tolerance of these pipettes varies, and the question of which one to use will depend on the requirement. Someone who has a basic knowledge of chemical analysis would be able to select and handle the appropriate pipette.

b) Lack of opportunity for training

Those in charge of water quality monitoring should possess the expertise required to handle chemical analysis and sampling. However, half of the laboratory employees cannot participate in the training programs because these are open only to college graduates. Periodic training is required even for staff members who have been doing their work for more than 10 years, in order to continuously sharpen their skills.

c) Working formation

At *CNA*'s laboratories, the assignment of each laboratory technician as to parameters to analyze is fixed, because it is believed that this practice ensures accurate and precise levels of obtained data. However, the Study Team considers this practice ineffective for laboratory work from the viewpoint of data management and operation of laboratory, as gleaned from the following situations:

- When the person in charge of a certain parameter goes on leave, no one can take over his work. It is very important for monitoring that data are obtained regularly.
- Even if a substitute could be found to analyze the said parameter, the accuracy and precision would change because the substitute has not been regularly analyzing the said parameter. There would always be comparison between the work results of the one in charge and the substitute.
- The laboratory chief or personnel cannot train newcomers, because they do not know the analysis method and other technical know-how; also, newcomers cannot consult with their colleagues. It is expected that capability building for analysis cannot develop in this kind of work set-up.

As a result, the analysis may not develop technically. It is therefore recommended that the laboratory personnel conduct actual work on several parameters.

Table 2.11 Laboratory Equipment for Regional Laboratories under *PROMMA*

	Region	Location	Laboratory Level			Mobile Laborat	Mobile Laborator
			Level 1	Level 2	Level 3	BETEX	Inorganic
	Mexico City	Mexico City					
I	Peninsula de Baja Californi	Mexicali	X				X
II	Noroeste	Hermosillo		chromatography			X
III	Pacifico Norte	Culiacan		AAS			X
IV	Balsas	Cuernavaca			X		X
V	Pacifico Sur	Oaxaca	X				X
VI	Rio Bravo	Monterry			X	X	
VII	Cuencas Centrales del Nor	Torreon		AAS		X	
VIII	Lerma Santiago Pacifico	Guadalajara			X	X	
IX	Golfo Norte	Cd. Victoria			X	X	
X	Golfo Centro	Xalapa			X	X	
XI	Fontera Sur	Tuxtla Gutierrez		chromatography			X
XII	Peninsula de Yucatan	Merida	X				X
XIII	Valle de Mexico	La Estrella			X	X	
	Total		3	4	6	6	7

Level 1: Laboratory equipment for Basic Parameter will be arranged
Level 2: Chromatography or AAS will be arranged
Level 3: Chromatography and AAS will be arranged

AAS: Atomic Absorption Spectrophotometer

Chapter 3 Coastal Environmental Profile

3.1 Coastal Environmental Profile of Mexico

3.1.1 Natural Environmental Conditions

(1) Topography

Along the 11,593 km of Mexican coast, a water surface of 1,567,300 ha is estuarine zone, where seawater is mixed with river water. Of the total estuarine zone, 892,800 ha are on the Pacific Coast and 674,500 ha, in the Gulf of Mexico. Mexico has 130 lagoons along its coastline and numerous rivers pouring into the Pacific Ocean, the Gulf of Mexico, the Caribbean Sea, and inner lagoons (see Figure 3.1).

(2) Climate

The annual temperature in Mexico varies between 10 and 25°C depending on the region. 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 (*SEMARNAP, Estadísticas del Medio Ambiente, 1997*), and the volume varies with the geographic location ranging from 100 to 4000 mm (see Figure 3.2). The northern region receives only 3% of the total precipitation while occupying 30% of the Mexican territory. The southeast region, which accounts for 20% of the national surface, has 50% of the total precipitation in Mexico. As for the wind regime, trade winds from the Gulf of Mexico generates rains upon entering over the national continent. The northern side of the country is located underneath the extra-tropical chains of huge pressure. This wind pattern contributes to the formation of arid climate accompanied by great thermal oscillations in the north and the humid and persistent temperature regime in the south.

(3) Oceanography and Hydrology

The expansion of the Gulf of Mexico is about 1,768,000 km^2 with more than 300 million km^3 of water volume and its deepest part exceeds 3,400 m in depth. Most part of the tides in the Gulf of Mexico is dominated by diurnal with some mixed tides in the northern part of the gulf (Texas-Louisiana-Florida). The highest sea level (from 189 to 213 cm) was recorded in Coatzacoalcos and Veracruz. The loop current in the eastern gulf, and anti-cyclone movement through the west frontier characterizes the circulation in the Gulf of Mexico. The Gulf Stream originating in the Atlantic Ocean regulates the temperature along the coast. The

Caribbean Mexican coasts present mixed tides, but there is no information in terms of the sea level and its changes. In the Gulf of California, the annual tide pattern is hardly determined because the tide is strongly influenced by river water discharge during rainy season. Detached from Kuroshio and its extension, the California currents regulate temperature in northwestern Mexico. The rainfall is also influenced especially during the winter over the west coast of Baja California. The tide energy is greatly dissipated in the Gulf of California, which is one of the most important tidal energy dissipation points in the northeastern Pacific Ocean. Close to the entrance of the Gulf of California, internal waves are present with a wave length approximately 1,000 km, a period of 6.6 days and a propagation velocity of 1.75 m/second *(Oceanografía de mares mexicanos, 1991).*

Mexican coastal area is divided into three regions; the Pacific Ocean coastal region, the Gulf of Mexico coastal region, and theYucatan Peninsula coastal region. The first two coastal regions have surface runoff systems, which divide the region into 11 and 9 watersheds respectively. The Yucatan Peninsula coastal region has hardly any river system and the water flows as groundwater in the stratum of calcareous platform.

(4) Coastal Ecosystems

Mexico is noted for its extensive biodiversity, which is gifted from its location in the transitional zone of the Nearctic and the Neotropical biographical region. A broad range of fauna and flora species can be observed in different types of water bodies in the Mexican territory. The mangrove forests cover the surface of around 600,000 ha *(Contreras, Ecosistemas costeros mexicanos, 1993)*, providing habitats to aquatic organisms in every taxon. It has been known that the coastal lagoons, swamps, mangrove forests, seagrass bed and reefs are closely inter-communicated, creating a large cycle of energy flow. The dissolved nutrients from a swamp flow into a seagrass bed, favoring its primary production. Macrophytic bed and mangroves provide feeding place for 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). Coral reefs along the coastal areas of the Gulf of Mexico and the Caribbean Sea are one of the most developed in the world. Owing to the physical and biological functions of coral reefs, calm coastal landscape and habitats of rich marine fauna and flora are created along the Mexican coastal area. (Botello et al. Ecología, Recursos Costeros y Contaminación en el Golfo de México, 1996). Islands are another extension of national territory, counting 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 environment, which shelters diverse species including many endemic and rare ones.

On the other hand, expanding human activities have been imposing great impact to the natural ecosystem in this country. A recent GIS survey has revealed that 72% of the national territory is covered with forests of various vegetation categories, but only 55% of the land surface is intact forests and jungles without significant human disturbance *(SARH, Inventario Nacional Forestal Periódico 1994)*. However, the lack of information about the status of local fauna and flora is restricting the development of conservation programs in the nation.

(5) Coastal Conservation Areas

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*). In order to complement the legal frame, the Federal legislation issues official standards of Mexico (*Normas Oficiales Mexicanas* : *NOM*). A total of 111 natural protected areas cover a surface of approximately 11,796,969 ha (equivalent to 6% of the national territory) with the legislative background of the *LGEEPA* (see Figure 3.3). Among these, 21 existing biosphere reserves[1] represent 68.8% of the protected surface. In addition, 63 national parks[2], 9 flora and fauna protection areas[3], 7 natural resource protection areas[4], and 3 natural monuments[5] are under the Federal administration.

The environmental importance of the Natural Protection Areas in Mexico has also been internationally appreciated. For instance, the biosphere reserves of Sian Ka'an in the States of Quintana Roo and El Vizcaino in Baja California Sur have been registered as World Heritage sites *(CONABIO, La Diversidad Bíologica de Mexico: Estado de País, 1998)*.

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[1] Areas of national biogeographic relevance which include well-conserved ecosystem(s) and / or rare / endangered species.
[2] National representative biogeographical areas with scientific, educational, recreational, historical and esthetic values
[3] Areas with habitats of wild fauna and flora, which require special protection
[4] Areas designated for the preservation and protection of soil, water basin, water and other natural resources in the forestal terrain
[5] Areas with unique or exceptional natural elements which incorporate an absolute protection regime

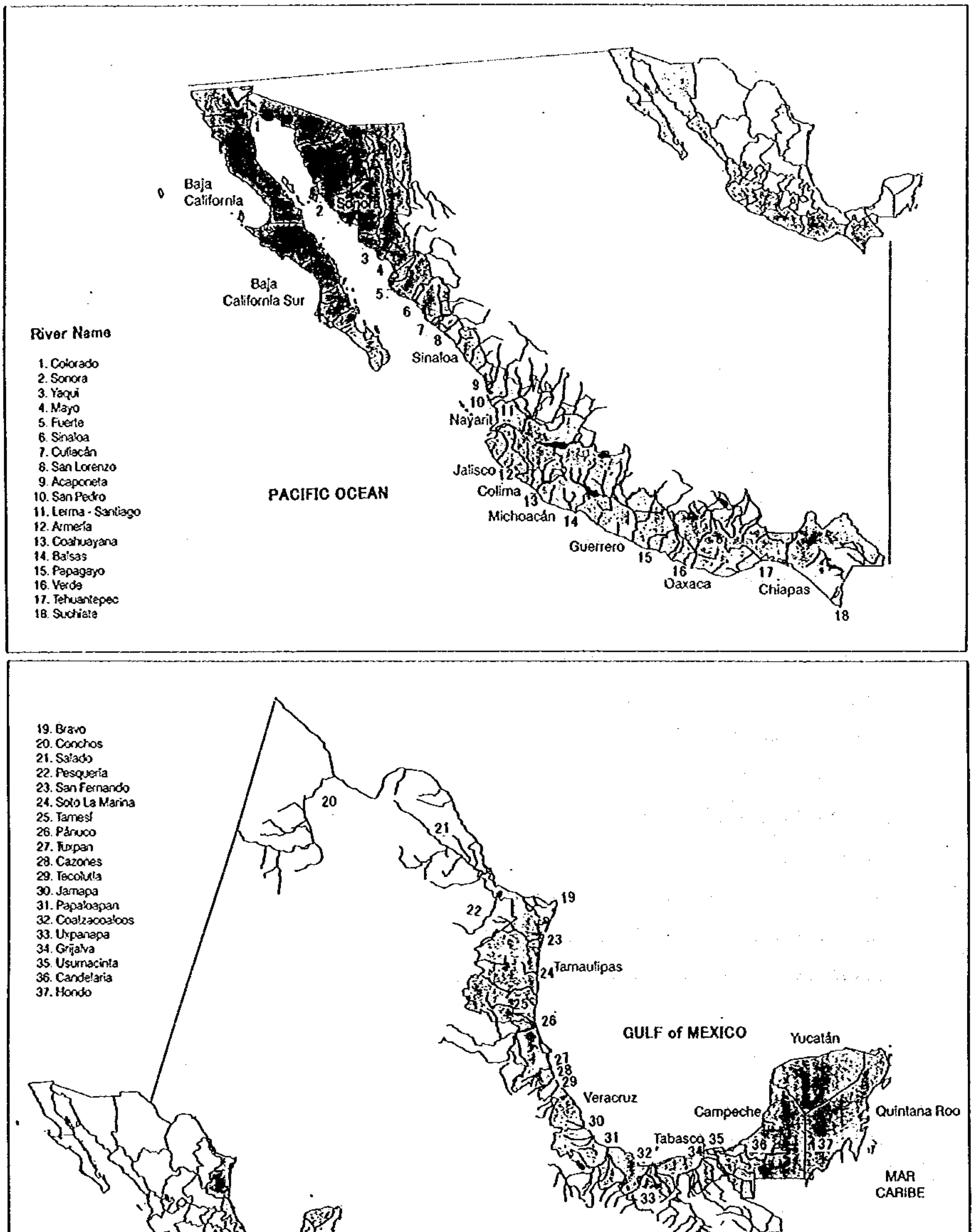


Figure 3.1 Rivers in the Coastal Areas of Mexico

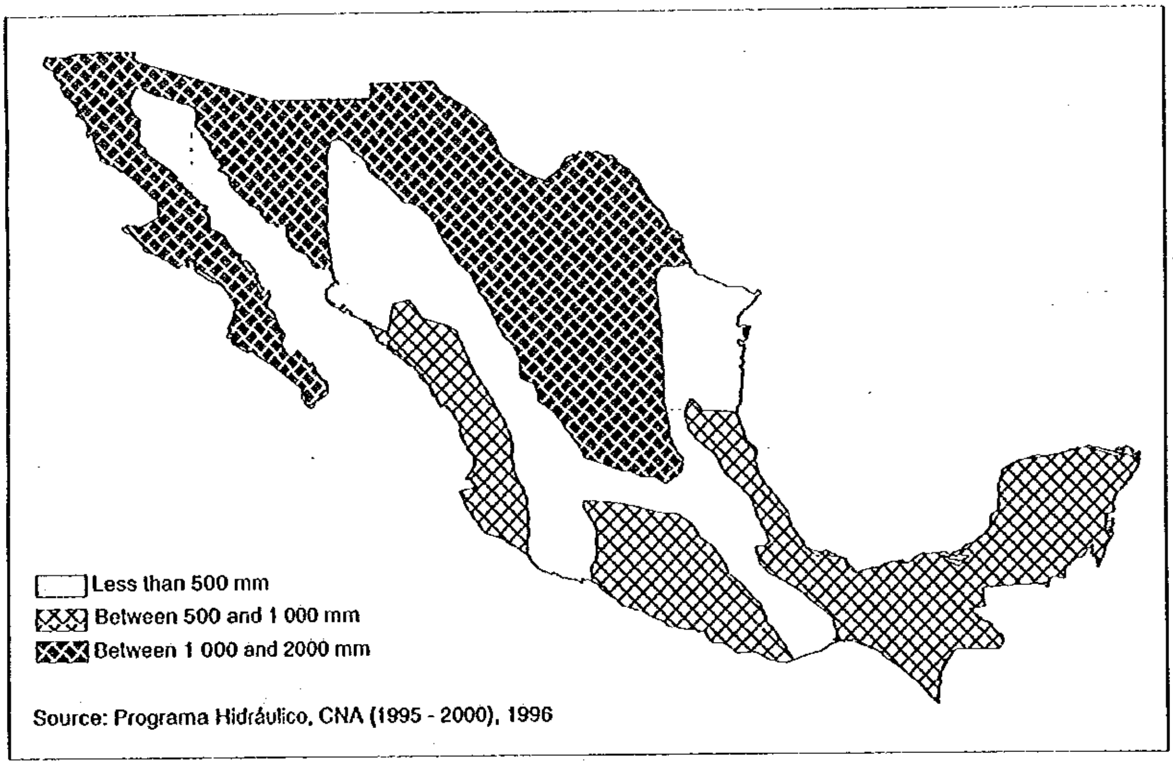


Figure 3.2 Annual Average Rainfall in Mexico

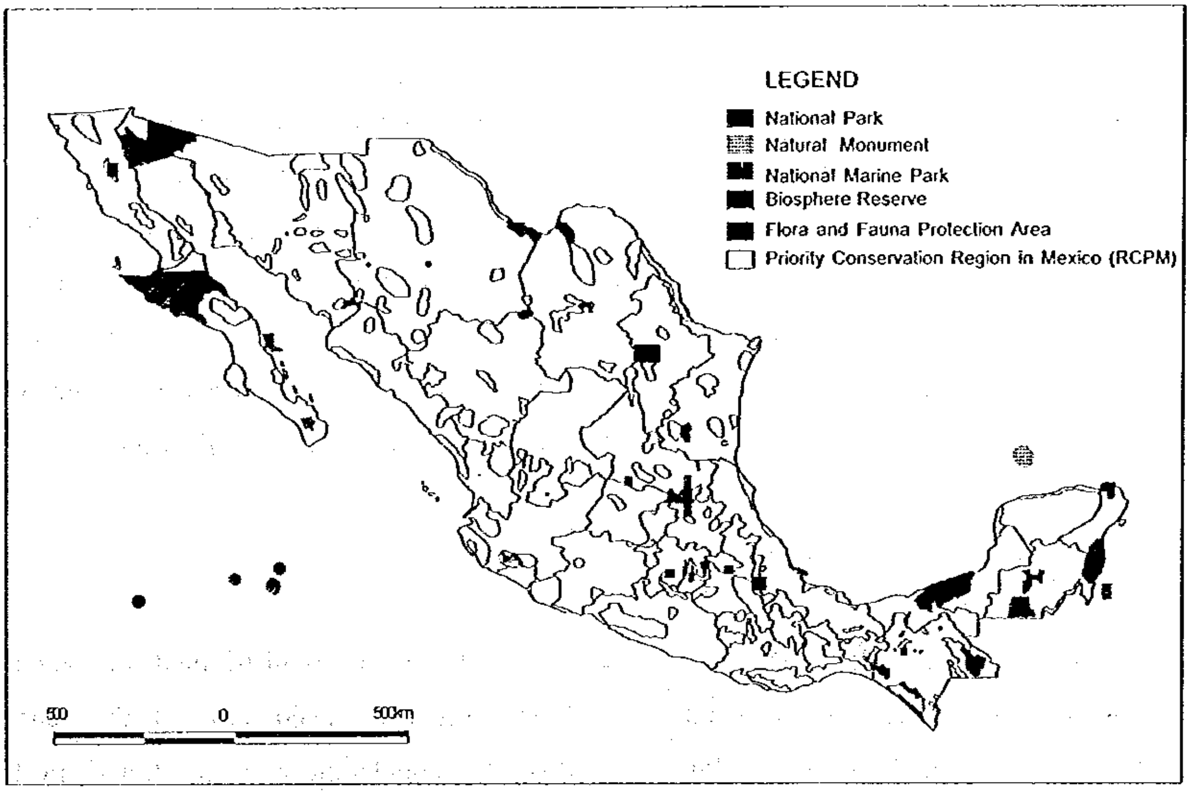


Figure 3.3 Natural Protected Areas and Priority Conservation Region in Mexico

3.1.2 Natural Environmental Resources

(1) Fishery Resources

There is a wide variety of commercial fish species in Mexico. In the 1980's, the largest catches of marine fish species were of sardine and tuna. Also small pelagic species, such as shrimp, were caught mainly in the Pacific Coast. Mexico has Exclusive Economic Zones (EEZ) in the Pacific Ocean as well as in the Gulf of Mexico.

In 1996, the total registered fishing value of Mexico was 7,629.8 million pesos, an increase of 22.8% over 1995. The major species of marine fish production in Mexico were tuna fish, shrimp, carp and sardine.

The major fishing states are Sonora and Sinoloa in the Pacific Coast, Veracruz in the Gulf of Mexico, and Baja California and Baja California Sur in Pacific Coast.

In terms of aquaculture, the fishery production of Mexico has exceeded 170,000 tons, of which approximately 150,000 tons were produced by semi-intensive method and 20,000 by intensive method. Intensive aquaculture in salt water has been conducted in more than 16,000 ha, of which 98% are dedicated to shrimp culture. Oyster cultivation has been practiced primarily on the coast of Gulf of Mexico, especially in the states of Veracruz and Tabasco.

(2) Mineral Resources

Mexico is rich in mineral resources and is the leading oil-producing country in Central America. The economy of the country is still basically dependent on oil industry, which has been developed along the Gulf of Mexico, mainly in the cities of Tampico, Coatzacoalcos, Poza Rica and Ciudad del Carmen (see Figure 3.4). Mexico is also the world's largest producer of silver, nonferrous metals and sulfur. Since the production of these products involves the discharge of hazardous pollutants to the terrestrial and coastal environments, appropriate measures should be taken to deal with the possible water contamination.

3.1.3 Socioeconomic Conditions

(1) Population distribution

In 1995, the population of Mexico reached 91,158,290, which is distributed all over the national territory. The largest population is found around the major cities in the Federal District, states of Mexico and Puebla. Also, the population is concentrated in the economically-developed states such as Jalisco, Nuevo Leon and industrial development areas such as State of Veracruz. The national population is not evenly distributed over the states. The Federal District, states of Mexico, Veracruz, Jalisco, and Puebla all together occupy

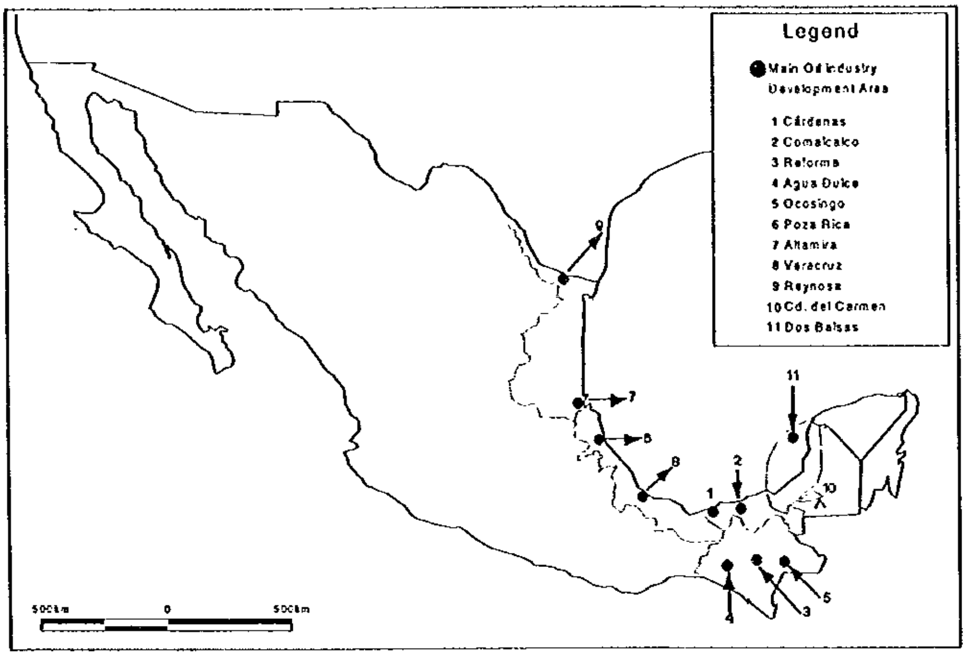
10.7% of the land surface, while holding 41.2% of total population.

The population density of Mexico in 1995 of 46 persons per km^2 is almost twice as much as that of 1970. The Federal District has the highest density over 5,663 persons per km^2, followed by the states of Mexico, Tlaxcala, Morelos, Puebla, Guanajuanto, and Aguascalientes. Baja California Sur, is far behind with only 5 persons per km^2. According to the recent estimation by *CONAPO*, the national population density will increase from 46 to 57 persons per km^2 in 2010 (see Figure 3.5). The states of Mexico, Tiaxcala, Morelos and Aguascalientes are expected to become densely populated in the near future.

(2) Main Economic Activity Areas

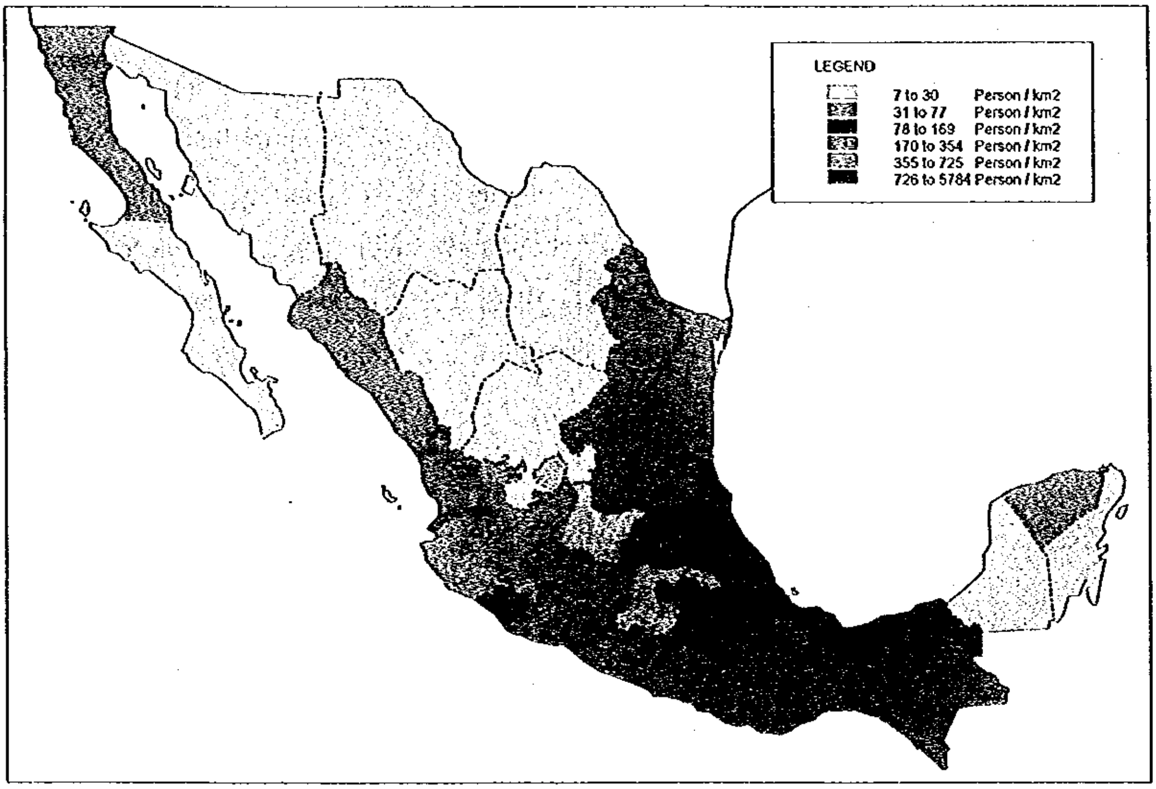
Mexico is composed of 31 states, including 17 coastal states, and the Federal District (Mexico City). Mexico City is the most important economic, financial, commercial and cultural center of the country. Monterrey and Guadalajara in inland areas are Mexico's second important cities as main industrial and commercial centers. Fishing and agricultural activities are also important in these Mexican Gulf regions. On the other hand, the Pacific Coast region boasts important industries such as tourism, agriculture, and fishery. In Yucatan Peninsula Region, Cancun is internationally known as one of the newly-developed tourism areas.

The modern Mexican economy can be described by the relationship between GDP and employment structure. Agriculture and service sectors, which employ more than 50% of the national labor force, generate only less than 25% of the GDP. In contrast, manufacturing, commerce and financial services, which employ about 25% of the labor force, account for more than 50% of the GDP. Table 3.1 shows the GDP at 1993 price base by major economic sectors of Mexico from 1995 to 1997. Economic activities in Mexico have been stagnant in the past three years.



SOURCE: Pemex, Anuario Estadístico 1996, México, 1997.

Figure 3.4 Main Oil Industry Development Areas in Mexico



Source: CONAPO, 1997

Figure 3.5 Population Density Projection of Mexico in 2010

Table 3.1 GDP by Major Economic Sectors (1993 prices) 1995-1997

Unit: Million Mexican Pesos

Major Economic Sectors	1995	1996	1997
Agriculture, Livestock, Forestry and Fishery	74,005	76,646	77,744
Mining	16,223	17,538	18,286
Manufacturing Industry	217,581	241,385	264,955
Construction	45,958	50,448	55,575
Electricity, Gas and Water	19,613	20,551	21,742
Commerce, Restaurants and Hotels	226,959	237,854	261,434
Transport, Storage and Communications	111,081	120,000	131,358
Financial Services, Insurance, Real Estate and Leasing	192,528	193,626	204,484
Communal, Social and Personal Services	261,055	263,651	272,905
Imputed Banking Services	- 33,415	- 31,696	- 35,103
Total (GDP at Basic Values)	1,131,599	1,190,007	1,273,383

Source: *INEGI*, System of National Accounts, 1998

(3) Industries

a) Industry

Industrialization and urbanization are the most advanced in Mexico City and the states of Mexico, Jalisco, and Nuevo Leon, which combine for 50% of GDP and 39% of the total employment of the country. Among these states, only Jalisco has coastal areas.

Under the national strategy for industrialization that aims to create job opportunities, the establishment of export assembly plants has been promoted since the1980's. The strategic installation of the relevant infrastructure in the northern border states of Mexico facilitated the reduction of parts transportation costs and brought closer communication with the USA. As a result, almost 80% of Mexico's assembly plants have clustered within the five northern border states by 1996. These boarder states with shares of assembly plant numbers are Baja California (32.9%), Chihuahua (15.4%), Tamaulipas (12.7%), Coahuila (8.8%), and Sonora (8.0%). Only Baja California, Tamaulipas and Sonora have coastlines.

Manufacturing activities were concentrated in the Federal District (10.6% of total manufacturing factories) and the following 7 states: Puebla (9.1%), States of Mexico (8.5%), Jalisco (6.8%), Veracruz (5.6%), Michoacan (5.6%), Guanajuato (5.4%), and Yucatan (5.0%). About 56% of the country's total number of manufacturing establishment are located in these states, which includes 4 coastal states.

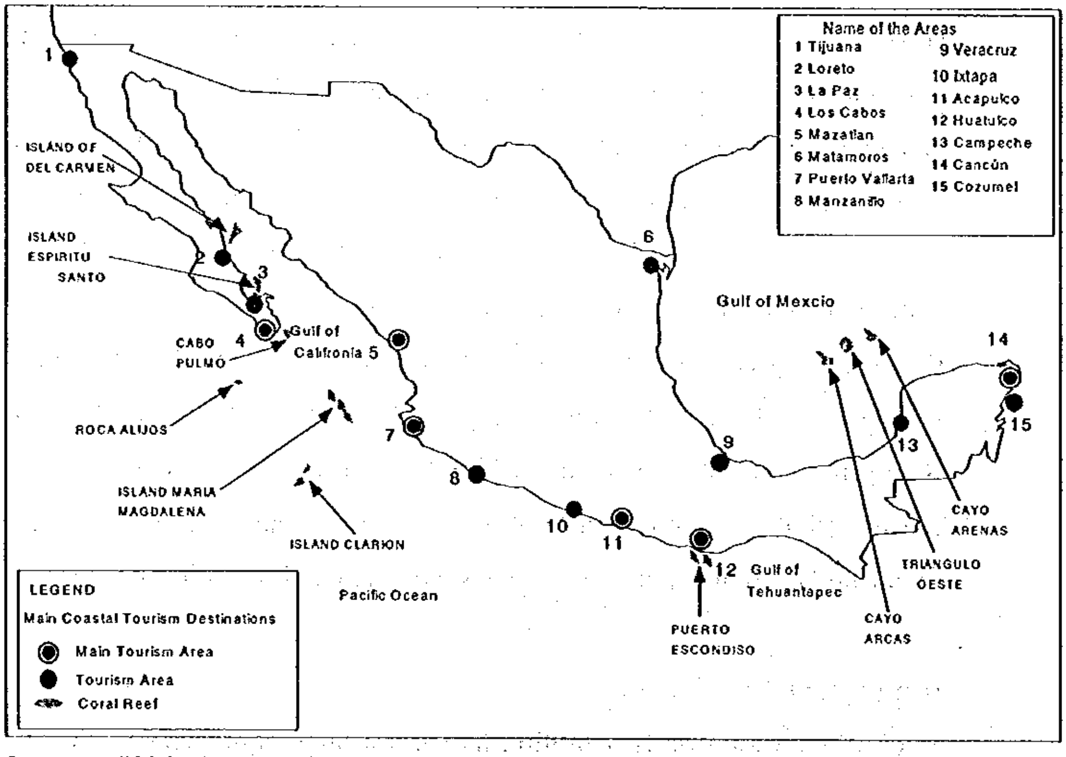
b) Agriculture and livestock

As of 1995, a total of 18.7 million ha harvest land, equivalent to 51% of the total harvest land of the country, had been exploited in the states of Chiapas, Jalisco, Michoacan, Oaxaca, Sinaloa, Tamaulipas, Veracruz, and Zacatecas. Tamaulipas, Veracruz, Chiapas, and Jalisco have long coastlines along the state territories. The most important crops in terms of the cultivated acreage (48.6% of the national total) and the production value (28% of the national total) were cereals. Also, the principal fruits 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 is destined for dairy farms, which represent 55.2% of the territory. About 65% of the stockbreeding farms are dedicated to cattle production. The State of Chihuahua has the largest livestock land in the country, with 17.8 million ha oriented to cattle feeding and poultry farming. In the coastal states, the livestock production in Sonora, Baja California, and Tamaulipas are noticeable.

c) Tourism

Mexico is considered as one of the world's largest tourism countries due to its geographical location, abundant natural resources and historical sites. Figure 3.6 shows main tourism destination areas in the Mexican coast. These areas provide some international class tourism facilities.

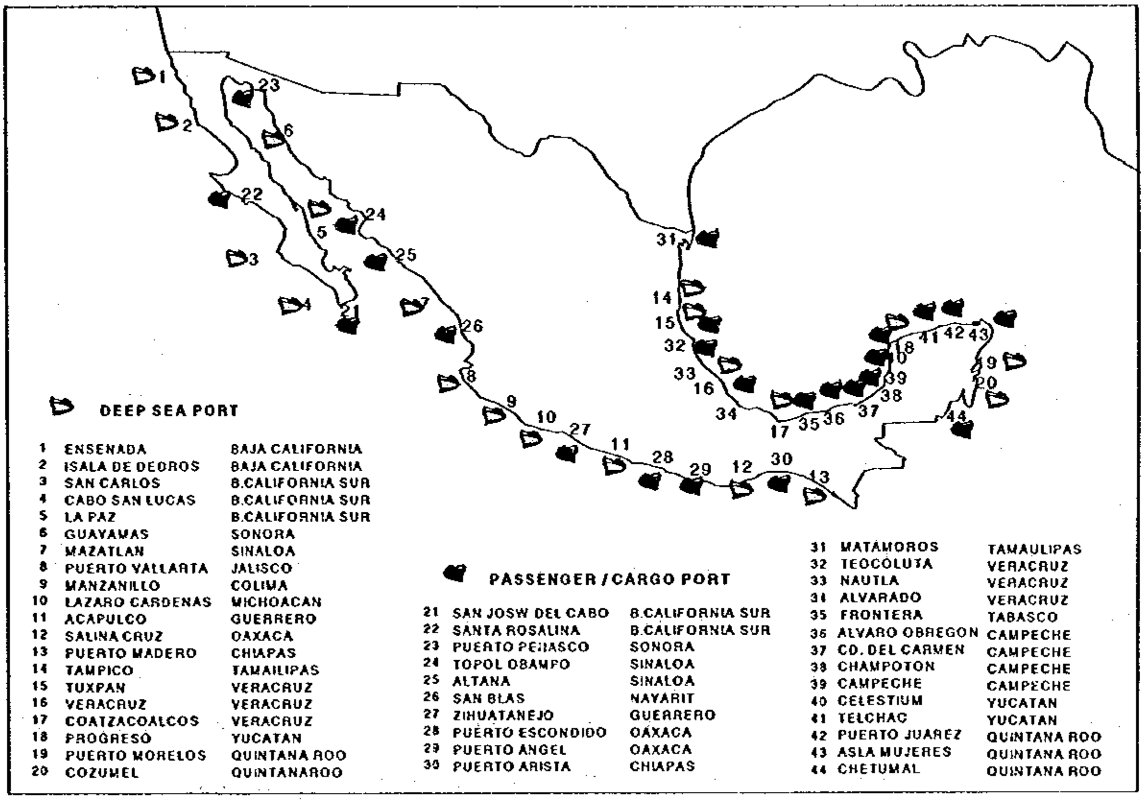


Source: JICA Study Team for National Tourism Development Project in Mexico
CONABIO La Diversidad Biologicade Mexico: Estudio Pais, 1998

Figure 3.6 Distribution of Coastal Tourism Destinations and Coral Reef in Mexico

(4) Coastal Infrastructure

The 11,500-km long coastline has driven the development of a vast port network in Mexico. The country has established 76 maritime ports by 1996, including deep-sea ports, commercial ports, ferryboats stations, and fishing ports (see Figure 3.7). The commercial ports of Manzanillo and Lazaro Cardenas in the Pacific Coast, and those of 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. With respect to maritime fleet, by 1994, Mexico only has three vessels for transporting chemical products and eight tankers.



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

Figure 3.7 Seaport Distribution in Mexico

3.1.4 Coastal Environmental Problems in Mexico

(1) Red Tide

Red tide is a natural phenomenon that occurs in temperate and tropical coasts around the world. It is a temporal bloom of phytoplankton species, which produce red pigment in the process of photosynthesis. Among the hundreds of different species that have been known to cause red tide, certain planktons produce toxic substances. The toxin can cause serious problems to the human body, both through primary contact and consumption of contaminated shellfish. In the coast of Mexico, the oldest incident of red tide was recorded in the State of Veracruz in 1979. 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. The Secretary of Health carries out the monitoring of toxic plankton density at the reported detection of the tide, but there is no regular monitoring system of red tides in the nation

(2) Oil Problems

The littoral of Gulf of Mexico has abundant oil fields, either inland or open sea. The hydrocarbon pollution often occurs in the coastal area of the Gulf of Mexico. Oil spill and residual water from tanker washing are also responsible for the presence of pitches and tars in littorals of Mexican beaches. Furthermore, the maritime transportation from Central and South America helps to spread the pollution even in the waters without oil fields, such as the Mexican Caribbean. As evidence of the impact of oil pollution in organisms, Mussel (*Mytilus californianus*) in the northwest coast of Peninsula of Baja California were shown to have 385.3 ppm petroleum hydrocarbon in its body. High levels of hydrocarbon contamination are also reported in water and sediment in the water areas of the Gulf of Mexico and Peninsula of Yucatan.

(3) Heavy Metals

High contamination levels of heavy metals in water and sediment have been reported in the southern Gulf of Mexico. The water and sediment contain high mercury level in the estuaries of Coatzacoalcos River, and high lead concentration in the coastal areas of Veracruz, Tabasco and Campeche. Few available data regarding the heavy metal concentration in the Pacific Ocean coastal area hinders the discussion of the contamination level in the area.

(4) Pesticide Problems

The applications of pesticides in Mexico for agriculture and public sanitation purposes have been practiced since 1946. Water flow and wind carry down the pesticides from the site of application to the coastal area. Contamination levels of organochloride pesticides in Mexican coastal area are especially high in the states of Tabasco and Campeche.

(5) Eutrophication

Eutrophication is defined as the fertilization process of water bodies due to the increase of nutrient load (Horne & Goldman, Limnology, 1983). When nutrients (mainly nitrogen and phosphorus) are excessively added into water bodies from agricultural use or municipal wastewater, it can cause a direct disturbance to plant growth, as well as the deterioration of the ecological equilibrium of the water bodies. Ensenada Lagoon in the State of Sinaloa, Nuxco Lagoon in Guerrero State, Tuxpan Estuary, Tampamachoco Lagoon, Alvarado Lagoon, Mandinga Lagoon, and Ostion Lagoon in the State of Veracruz, Celestun Lagoon in the State of Yucatan showed high levels of nitrogen nutrients. Ensenada Lagoon in the State of Sinaloa, Madre Lagoon in Tamaulipas, Pueblo Viejo Lagoon and Ostion Lagoon in Veracruz, and Celestun Lagoon in Yucatan showed high levels of orthophosphate.

3.2 Coastal Environmental Profile of the Tampico Area

3.2.1 Natural Environmental Conditions

(1) Topography

The Tampico Area is located in the center of a broad plain, bounded by mountain ranges to its north, west, and south. The eastern side of the plain faces the Gulf of Mexico, where a straight coastline extends south and north. The Tampico Area lowland retains water as fresh and brackish water lagoons, reefs, and tidal inlets scattered within the Area. The largest brackish lagoon in the Tampico area is Pueblo Viejo Lagoon, which has an area of about 100 km^2. Many freshwater lagoons located northwest of Tampico City are protected from the salt intrusion by dikes constructed along the downstream.

(2) Climate

The annual average temperature at Tampico is 24.8 °C, the highest monthly average is 28.8 °C in June and August, and the lowest is 18.7 °C in January. The highest temperature is 41.0 °C, and the lowest is -1.5 °C between 1979 to 1998. 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 is 2.8 m/ in September. The dominant wind direction from November to February is north, and that from March to October is east.

The average annual rainfall in Tampico is 1,117.9 mm, and the average monthly rainfall fluctuates from 15.7 mm (March) to 269.6 mm (September). The average annual evaporation is 1456.8 mm at Tampico. The monthly average evaporation in the rainy season is higher than in dry season. The rainfall shows a sharp increase in June (176.8 mm) and has its peak in September (269.6 mm). On the contrary, the change of the monthly evaporation is moderate. The monthly evaporation gradually increases from spring to summer, and autumn to winter. Generally speaking, the difference between the average monthly rainfall and the average monthly evaporation has a hydrological significance for lakes, where the inflow/outflow rate is relatively small. In the Tampico Area, the negative difference between the average monthly rainfall and evaporation is the largest in April or May before the rainy season, and the positive difference reaches the maximum in September in rainy season. The annual rainfall had largely fluctuated for the last twenty years. At the Tampico Area, the maximum annual rainfall is 1,632 mm in 1993, and the minimum annual rainfall is 602 mm in 1982.

(3) Oceanography

Along the coast of the Gulf of Mexico, the continental shelves narrowly develop in the south and widen toward the north. The coast of the Tampico Area has relatively narrow continental shelves, although it is 50 km offshore from the shoreline where the water depth exceeds 100 m. The bed slope in the coastal section in the Tampico area is relatively steep near shore, followed by progressive downhill in offshore. The slope of the seabed is especially steep at the bottom deeper than 200 m. It is at 150 to 200 km offshore from the shoreline where the sea bottom hits as deep as 2,000 m.

The texture of the seabed along Tampico coast is mainly sandy. Reefs and tidal inlets develop along the shore, representing the dominance of littoral drift. The tidal range in the relevant sea area is relatively small. The predicted maximum high tide and minimum low tide in 1999 are 64 cm and 30 cm respectively. The reference level for the tide is the Mean Low Water Level (MLWL). The diurnal tide dominates compared with the semi-diurnal tide. The tidal range in the north side is larger than that in south side in the relevant sea area.

According to "The Figure of Physical Oceanography" published by the Institute of Geography, currents in a synoptic scale in the Gulf of Mexico is clockwise. An energetic flow belt exists throughout the year. That flow enters the eastern part of the Gulf from the Caribbean Sea through the Yucatan Peninsula, bends eastward, and pours into the Atlantic Ocean through the Florida Peninsula, creating the Gulf Stream. Another less energetic clockwise circulation exists in the western 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 order of 20 cm/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 it is supposed that the current regime near the coast is different from offshore. Actually, the dominant direction of near shore currents is southward. The direction of littoral drift near Tampico coast indicates this southward current. 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 toward the south. According to the salinity survey performed in the pilot monitoring by *CNA* and the JICA Study Team, the direction of fresh water from Panuco River pouring into the sea s southwards. The report of the National Institute of Ecology shows that the mean wave height in the Tampico Area falls between 0.6 to 0.8 m, and the mean wave period between 6 to 7 second. On the occasions of hurricane, waves of 5.0 to 6.0 m high with the periods of 11 to 13 second attack the Tampico Area. *(Diseño Ejecutivo del Emisor Submarino para la Disposicion Final de las Aguas Residuales del Puerto Industrial del Altamira, TAMS., 1992)*

(4) Hydrological Condition

There are three major watersheds around the Tampico Area as shown in Figure 3.8; Altamira Industrial Port area, Conejo Lagoon and Marismas Lagoon area, and Panuco River area. Panuco River watershed area is consists of the following three components: 1) Upstream part of Panuco River, 2) Tamesi River and its surrounding freshwater lagoons, and 3) Estuary of Panuco River including Costa Lagoon, Pueblo Viejo Lagoon, and Chijol channel.

Altamira Industrial Port area (about 66 km^2) has only one natural stream called Garrapatas, which flows into the Altamira Seaport. This watershed area is lower than 30 meters above sea level. Discharge volume and water quality of this stream have not been reported.

Conejo Lagoon and Marismas Lagoon areas are located south of Altamira Industrial Port. The area has several small lagoons, but no natural streams flow into this area. The surface of Conejo Lagoon is about 1.6 km^2, and water basin area is about 5.8 km^2. Las Marismas Lagoon has an area of 39.6 km^2 with its volume exceeding 9,500,000 m^3. The lagoon is separated into three parts by an industrial road and Altamira Port; therefore its surface area has been reduced. Although it is separated by sandbank without any water channel connected to the Gulf of Mexico, Las Marismas Lagoon has a saline water body. Only the outflow from Conejo Lagoon supplies water to Las Marismas.

The total area of Panuco River watershed is 77,206 km^2, and its annual average rainfall is 953 mm. The volume of precipitation in the watershed area is 73,549 million m^3/year, 80% of which infiltrates into the area. The annual mean water discharge from the upstream part of Panuco River is 421 m^3/s at the hydrological station of Las Adjuntas. The minimum monthly discharge is 120.41 m^3/s in May and the maximum is 1095 m^3/s in September. In Tamesi River and the freshwater lagoon system, the accumulated water volume reaches 438,000,000 m^3. The lagoon fresh waters supply the cities of Tampico, Madero, Altamira, Panuco and Gonzalez for industrial, residential and agricultural uses. Panuco River exchanges water with Costa Lagoon, Pueblo Viejo Lagoon, Carpintero Lagoon, and Chijol channel depending on tidal flow.

(5) Coastal Ecosystems

In the coast of the Gulf of Mexico, there has been a rising problem of water pollution, which is anticipated to exert harmful influences to the local ecosystem *(Botello et al. Ecología, recuros costeros y contaminacion en el Golfo de México, 1996).* The impact of water pollution is supposed to be especially intense in the Tampico Area, where a petrochemical industry has been developed. However, at present, the most basic biological information such as species composition and distribution is very limited in this area, not to speak of the evidential information about the impact of water pollution on the local ecology. The situation is making it impractical to discuss the relationship between the water quality and ecosystem in the region. Under this situation, the JICA Study Team, in cooperation with the University of Noreste (Tampico, Tamaulipas), carried out a biological research in the Tampico Area. The research included field observation and bibliography survey on zooplankton, phytoplankton, benthos, nektons (fish), aquatic birds, and higher aquatic plants in the area. The survey area was designated correspondingly to the area of interest in the pilot monitoring carried out by the JICA team and *CNA*. The result of the survey is expected to provide information on the status of fauna and flora. It can be the basis to evaluate the biological environment in the region in the context of the impact of the water quality on local ecosystems. Following is the summary of findings from the survey during the rainy season in 1999. The natural vegetation in the Tampico Area is generally characterized as low deciduous forest, mangrove, and salt marsh covered with a community dominated by vascular plants. However, the majority of the area presents the secondary vegetation which is perturbed or strongly influenced by human activities. The introduced species such as *Mimosa pigra* and *Acrostichum aureum* indicated the disturbance of local vegetation. The principal aquatic plant community is composed of mangrove species, especially in Pueblo Viejo Lagoon. In the estuary of the Panuco River, there was hardly any higher plants observed but macroscopic algae. In this survey, 110 higher plants had been identified, but no protected species registered in NOM-59[6] was found.

As for the plankton flora and fauna, Copepoda was the most diverse and abundant class of zooplankton, and Chrysophyta of phytoplankton. In Pueblo Viejo Lagoon, the phytoplankton species that indicate a eutrophic water condition were also observed at high relative density. Sediment samples were collected for the analysis of benthos, and it was found that the species variety of Polychaeta was high in the samples from coastal bottom, which was close to a wastewater discharging point in the coastal area off Miramar Beach. It may indicate the necessity of further studies concerning benthos fauna in relation to water and sediment quality in this region.

The investigation of nekton fauna has identified a total of 166 species in 52 genera in the water bodies of the Tampico Area. Especially, this survey was the first attempt ever made to integrate the knowledge about fish species in Conejo Lagoon. It showed that most of the species in the lagoon were exotic ones introduced mainly from Africa. The coastal area was proved to have the richest fish species diversity in the Tampico Area, although more detailed and large scale investigation is required to conclude this issue.

Coastal lagoons and estuaries in the Tampico Area provide an important habitat also for aquatic birds. Although it was not the season of bird migration, which is between October to March, diverse and abundant bird fauna (28 species) was observed including 3 species that are listed in NOM-59.

[6] *Norma Oficial Mexicana*, Article 59. This article defines the wild species under national protection.

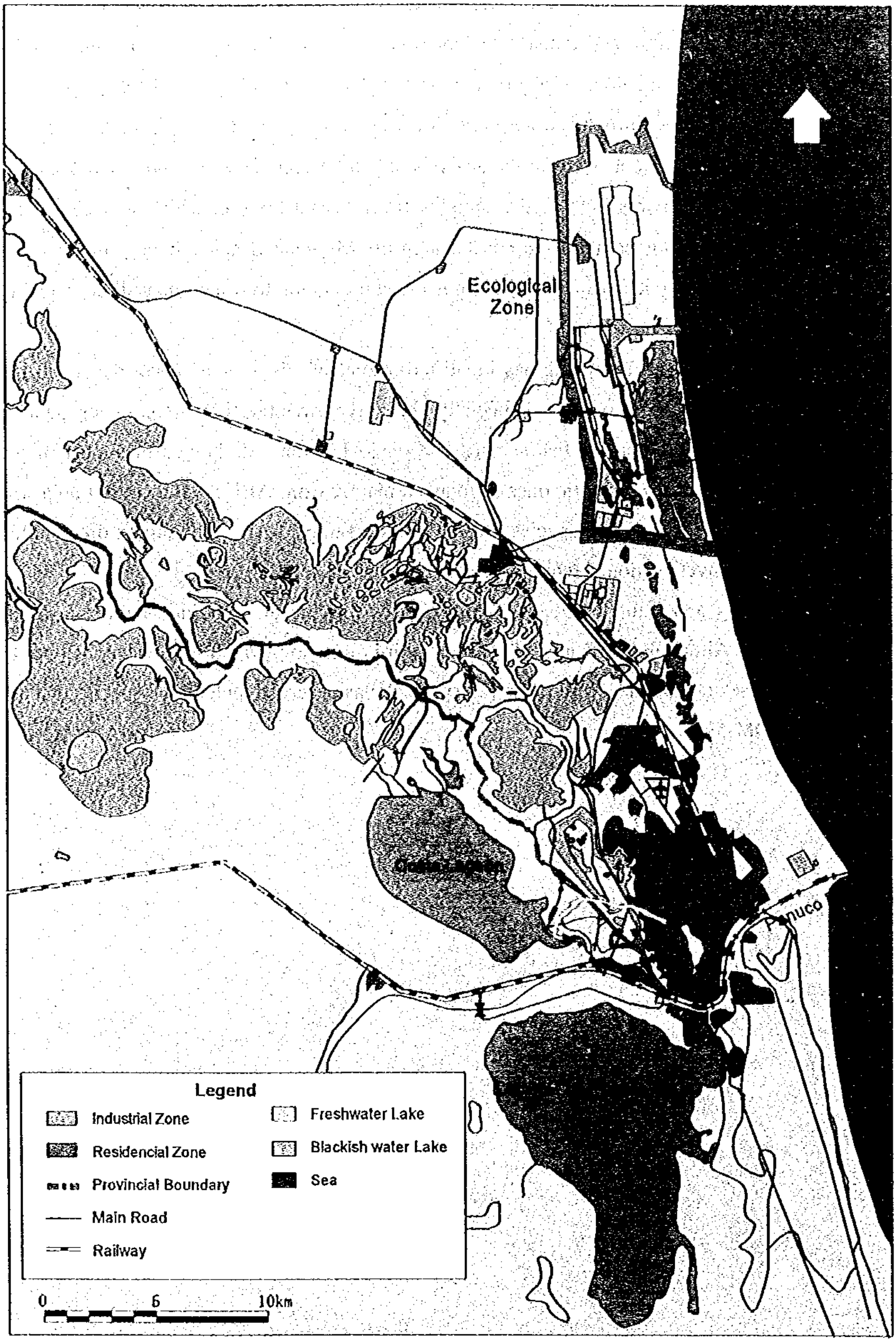


Figure 3.8 Watershed Around the Tampico Area

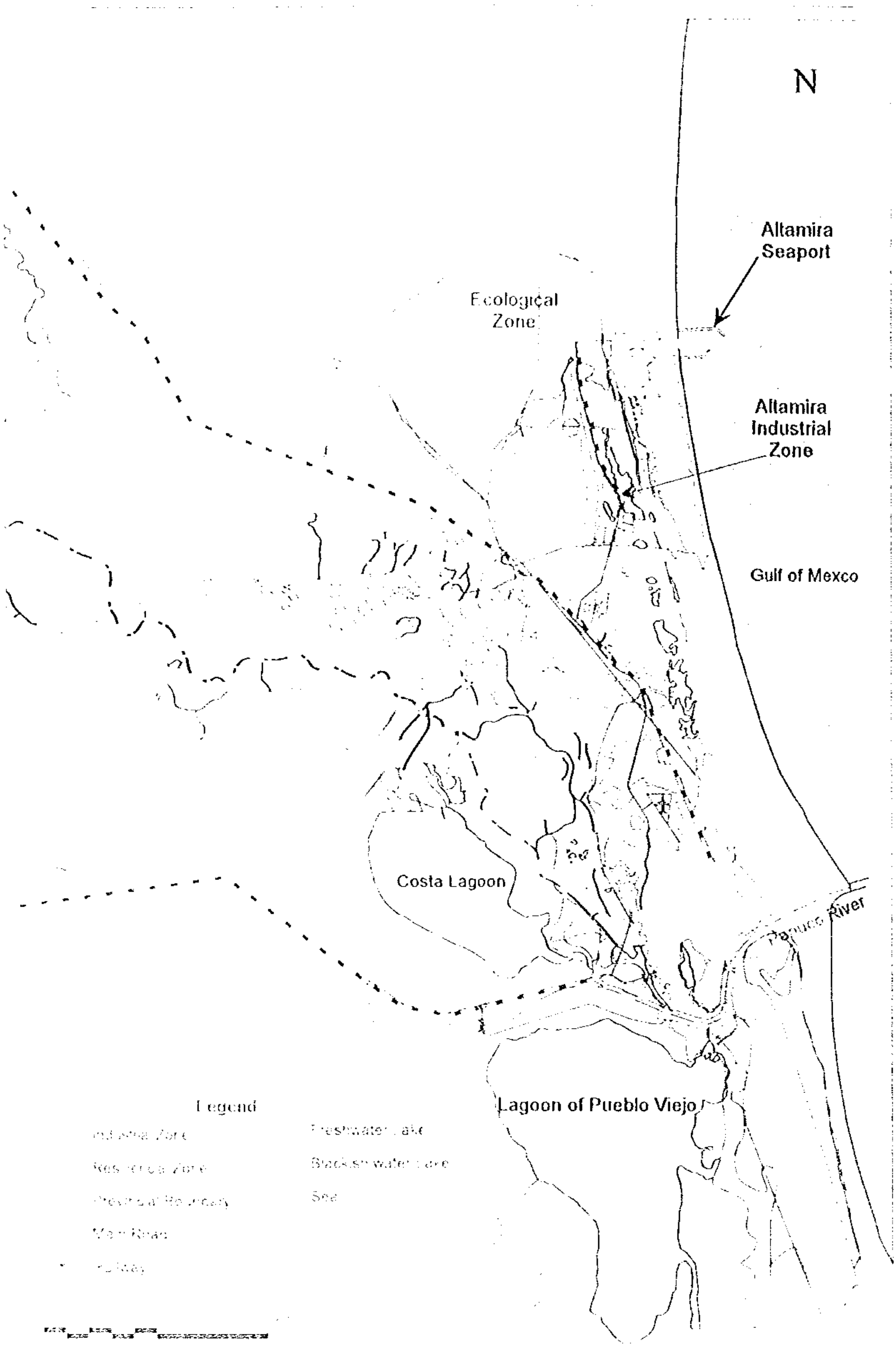


Figure 3.8 Watershed Around the Tampico Area

3.2.2 Natural Environmental Resources

(1) Fishery Resources

Owing to its long coastline along the fecund gulf and vast extension of interior/coastal lagoons, the State of Tamaulipas has benefited from the rich fishery resources.

The Tampico Area is located in the coastal area of the northwestern part of the Gulf of Mexico and downstream of Panuco River, where a variety of fish resources are available. Typical commercial fish species in Tampico City are shrimp, white mullet, and crab. In Madero City, tilapia, shrimp, and oyster are the representative fishery products. A large brackish water lagoon (Pueblo Viejo Lagoon) is one of the main oyster production grounds in the State of Tamaulipas. It is reported that the State of Tamaulipas also has the potential of providing more than 380,000 ha of interior waters for aquaculture. In recent years, 854 ha have been exploited and organized into 21 production units with 5 cages of 855 m^2.

At present, the Tampico Area does not have any marine conservation area such as fish sanctuary area, ecological protection area or marine park. There is no exclusive fishing zone in the Tampico Area, although there are eight exclusive shrimp fisheries along the shoreline, from Matamoros to La Pesca in the northern part of the State of Tamaulipas. Only one lagoon conservation project has been identified so far as a fishery exclusive zone as well as an eco-tourism zone in Laguna Madre of Tamaulipas. Within the Tampico Area, only four oyster fishery cooperatives in Pueblo Viejo Lagoon have functioned at present.

With respect to fishing, municipal fishery, commercial fishery, and sports fishing are conducted within a 200-mile fishing zone. There is no exclusive fishery zone in the near shore of the Tampico Area. Fishing can also be conducted under the open access principle.

(2) Mineral Resources

Oil refineries are located mainly in the south of Tampico-Madero-Altamira industrial corridor near the coast (see Figure 3.9). However, there are only a few oil extraction sites in the Tampico Area.

(3) Coastal Infrastructure

a) Industrial and commercial port

The Tampico Area has two deep-water ports along its 42-km of coastline. One is the Altamira Industrial Port, which has 6 terminals. Two of these are all-purpose terminals, 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. Figure 3.10 shows the Altamira Industrial Port Development Areas.

The other one is the Tampico Commercial Port, which transports more than 8 million tons of cargo annually. Its main ports of destination are in the Eastern United States, Europe, Central and South America.

b) Proposed intracoastal canal

In order to satisfy the increased flow of merchandise at lower transportation costs, the State of Tamaulipas proposed the construction of an intracoastal canal. The Tamaulipas Intracoastal Canal is expected to unite the cities of Tampico and Matamoros, and to extend to the Brownsville Port, which is the beginning of the 45,000-km USA waterway system.

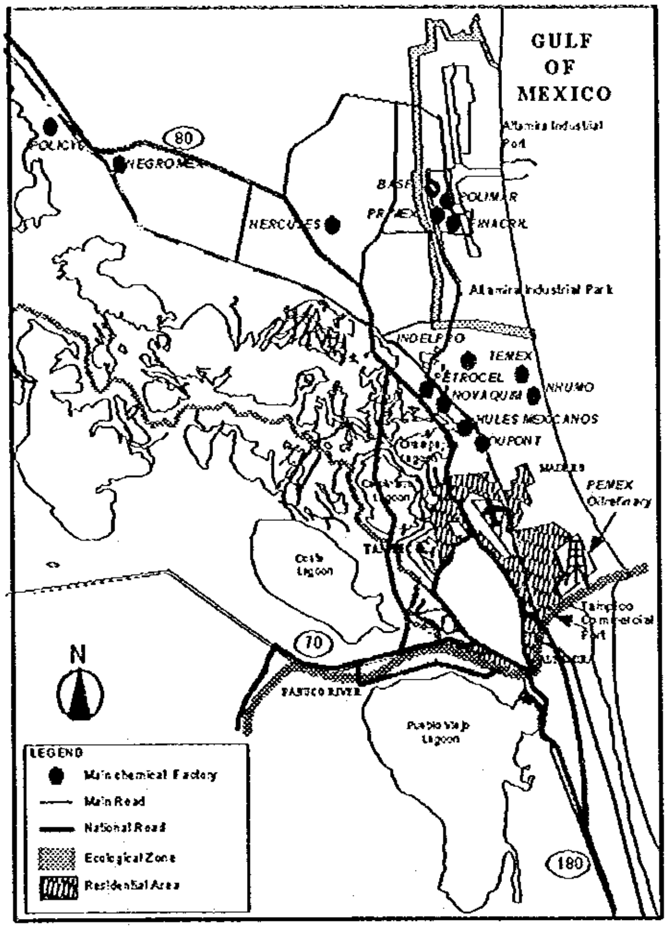


Figure 3.9 Distribution of Oil Refineries in the Tampico Area

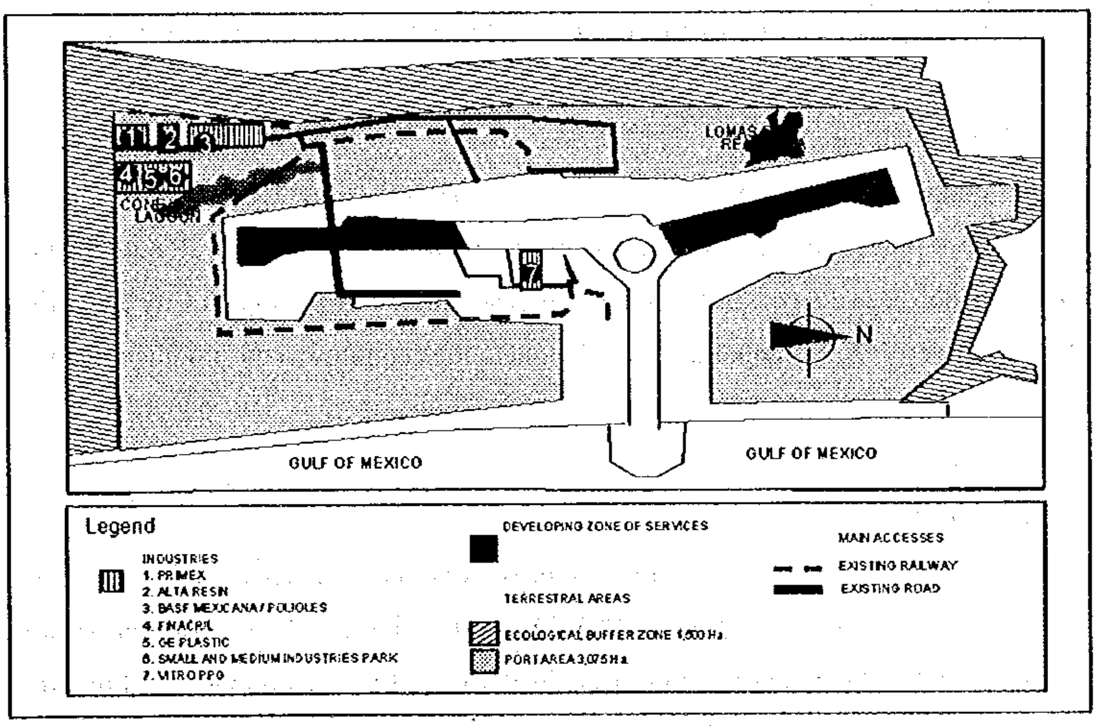


Figure 3.10 Altamira Industrial Port Development Area

3.2.3 Socioeconomic Conditions

The Tampico Area is located in the southern part of Tamaulipas and the northern part of Veracruz. The Area includes the administrative zones of Tampico, Madero and Altamira City in the State of Tamaulipas as well as the municipalities of Panuco, Pueblo Viejo, and Tampico Alto in the State of Veracruz.

(1) Population Distribution

The total population of Tamaulipas in 1995 was approximately 2.5 million. The State of Tamaulipas consists of 43 municipalities/cities. Its population is 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 total. Table 3.2 gives the population of each municipality/city in the Tampico Area.

Table 3.2 City and Municipal Populations in the Tampico Area

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	-
The 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) Main Economic Activities

One of the main economic activities in the Tampico Area is provided by the petrochemical industry. These industrial activities are conducted mainly in the south of Tampico-Madero-Altamira corridor near the coast. The town and beach tourism of Tampico City and Miramar Beach respectively, are also important contributors to the economy in the Tampico Area.

(3) Industries

a) Industry

The leading industries of the Tampico Area are chemical and petrochemical. Eighteen companies, excluding *PEMEX*, produced about 2.3 million tons of diverse chemical and petrochemical products in 1996; total production increased by 20% the following two years. With regard to *PEMEX*, it has brought about a stable production in the oil refinery industry in recent years. Notwithstanding their economic contribution, it is possible that wastewater discharged by these companies is one of the main water pollution sources in the Tampico Area. Other important industries are assembly plants, which include the textile assembly plant sector, and the food industry. These industries also pose a risk of polluting public water in the Area.

b) Agriculture and livestock

Table 3.3 shows the main agriculture productions in the State of Tamaulipas in 1996. The total production of the main crops accounted for 1.7 mil tons in 1996, while the annual total agriculture production in 1994 was about 7.1 million tons.

In the Tampico Area, the main agricultural products are cotton, sorghum, corn, soybeans, pepper and tomato. Many farmers raise cattle and chickens especially in the southern municipalities of the Tampico Area. In Panuco municipality, the main agriculture products are sugar cane, corn, grain, bean, soy, chili pepper, watermelon, banana, and rice. Panuco municipality has many proposed irrigation projects along the middle basin of the Panuco River. The principal crops of Pueblo Viejo municipality are corn, beans, watermelon, orange, and banana.

Table 3.3 Main Agricultural Productions in the State of Tamaulipas in 1996

Crops	Harvest Area (ha)	Production (ton)
Basic crops		
Sorghum	1,064,886	2,597,938
Corn	128,419	225,427
Wheat	21'478	17,311
Beans	7,143	3,954
Rice	1,141	5,545
Soybean	30,841	27,406
Cotton	21,426	29,607
Safflower	26,924	12,950
Vegetables		
Onion	6,028	131,391
Tomato	762	8,793
Okra	1,132	4,833
Other	3,946	36,951
Fruits		
Citric	22,926	179,190
Melon	957	13,252
Mango	1,012	4,959
Papaya	248	3,258
Avocado	171	1,093
Other	2,722	31,705
Industrial Crops		
Sugar	51,661	2'608,880
Aloe	2,073	93,285
Henequen	8,055	161,100
Grass	18,986	783,162
Total	336,573	1,775,172

Source: *SEDIC, 1998*

Table 3.4 shows the livestock production in the State of Tamaulipas as a whole. The annual total livestock production in 1996 exceeded 70 thousand tons. Main livestock production in the Tampico Area is beef.

Table 3.4 Livestock Production in the State of Tamaulipas in 1996

Products	Inventory (number of heads)	Production
Beef	918,972	63825 ton
Pork	176,067	6968 ton
Sheep	120,541	485 ton
Goat	255,595	637 ton
Fowl	679,869	1031ton

Source: *SEDIC*,1998

c) Fishery

Table 3.5 shows fishery yields by total weight adjacent to the Tampico Area from 1990 to 1998. According to the *SEMARNAP* data, fishery yields in the Area have been stagnant for the past nine years.

Table 3.5 Fishery Yields by Total Weight in the Tampico Area 1990-1998

Unit: ton

	1990	1991	1992	1993	1994	1995	1996	1997	1998
Total Production	9,590	9,772	10,412	13,023	9,732	14,214	12,149	10,831	10,623

Source: *SEMARNAP* Tampico Office, 1999

d) Tourism

The Tampico Area has a high potential for eco-tourism development based on its rich natural resources. In the coastal plain of the Area, calm and wide beach areas and countless lagoons with diverse wildlife provide attractive destinations for tourists, who are especially identified as "nature oriented." Miramar Beach in Tampico City and Altamira Beach adjacent to Altamira Industrial Port have the potential in future tourism development. In terms of tourism facilities, there are some hotels of international standard and several local hotels in downtown areas of Tampico City, Altamira City, and Madero City. Table 3.6 shows the number of registered hotels in these cities. One large five-star resort hotel is located fronting the Gulf of Mexico. In the municipalities in the southern portion of the Tampico Area such as Panuco Municipality, there are less than 10 inns or hotels being operated at present.

Table 3.6 Hotels in the Cities of Tampico, Altamira and Madero

City	Hotel Total	5 star	4 star	3 star	2 star	1 star	Others	Room Total
Tampico	417	12	47	61	70	88	139	15,687
Altamira	338	4	33	50	68	69	114	11,444
Madero	340	4	33	50	67	69	117	11,461
Total	1,093	20	113	161	205	226	370	38,589

Source: Secretary of Industrial, Commercial and Tourism Development, Tampico

Note:

1) Tourism Department of Mexico is in charge of ranking hotels, but it is not based on international standard.
2) The data of Tampico City and Madero City are as of 1995, while 1993 data is used for Altamira City.

(4) Land Use

Except the urban area of the Tampico City and wetlands areas, terrestrial lands are mainly used as croplands and pasturelands. Table 3.7 shows the present agricultural land use pattern in the southern municipalities of the Tampico Area.

Table 3.7 Agricultural Land Use in the Southern Municipalities of the Tampico Area

Unit: ha

Municipality Land use category	Panuco	Pueblo Viejo	Tampico Alto
Agriculture Total	71,239	4,230	5,248
Irrigated	27,885	465	-
Non irrigated	43,354	3,765	5,248
Livestock Total	205,957	9,110	69,940
Natural pasture	18,182	2,549	27,616
Artificial pasture	187,775	6,561	42,324
Forest land	9,502	2,174	3,826
Unproductive land	3,271	100	222
Reserved area	1,800	179	1,677
Multiple use area	36,012	12,831	21,822
Total	327,781	28,624	102,735

Source: Agriculture Department, Panuco Municipality, 1995

3.2.4 Coastal Environmental Problems in the Tampico Area

(1) Industrial Wastewater Discharge to Surrounding Water Bodies

The coastal ecosystems, mainly the one in the Gulf of Mexico, are considerably exposed to effects of the industrial wastewater. The coastal area in the State of Tamaulipas is one region that illustrates the typical pressures on coastal and marine ecosystems in this country. The wastewater from a chemical industry within the Altamira Industrial Corridor is discharged directly to the offshore of Miramar Beach. The seawater is discolored due to iron ion compounds, and the "patch" sometimes diffuses to cover 10 km^2 of water surface around the outlet. The environmental impact from this discharge has not been sufficiently analyzed. However, there are several works dedicated for the analysis of heavy metal concentrations in aquatic plants and shellfish in the coastal zone of Tampico Area (Ramirez Cruz, 1994; Sanchez Leyton, 1996; Vicente Medecigo, 1994; Palacios Castan, 1994; Tabares Soto, 1994)

(2) Domestic Waste Water Discharge

Marine and coastal contamination caused by domestic and urban waste are the most common problems in the area. It is attributed to insufficient wastewater treatment plants, which consequently allow the wastewater to be discharged to open waters without treatment. This is supposed to provoke three main impacts as follows (*Botello et al., Ecologia, Recursos Costeros y Contamination* in the Gulf of Mexico, 1996*):*

- Physical impacts, e.g. alternation of bottom topography and water circulation regime.
- Chemical impacts, e.g. addition of nutrients, decrease of dissolved oxygen.
- Biological impacts, e.g. habitat reduction of photosynthetic productivity, benthos coverage, destruction of plankton and benthos composition and increase of bacteria and pathogenic organisms.

In Pueblo Viejo Lagoon, a serious coliform pollution has been caused by wastewater discharge from Tampico, Madero and Villa Chauthtemoc. This problem is limiting the commercial value of oysters produced in the lagoon (Contreras, Ecosistemas Costeros Mexicanos, 1996). This alarming concentration of coliform has been hindering the utilization of the water resource in this Area.

(3) 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, which are located close to Panuco River in Tampico City and the northern part of the Altamira City. There is no treatment of dumped wastes so that soil and groundwater pollution is of high concern. The impact of this issue, however, has not yet been investigated.

(4) Illegal Settlements

It is reported that illegal settlers reside within the Study Area, for instance, in the area along the down stream of Panuco River and the adjacent area of Miramar Beach. These houses do not have on-site wastewater treatment system. It is anticipated that the uncontrolled discharge of domestic water from the illegal houses may aggravate the water pollution in this area.

(5) Conflicts in Resource Use in Pueblo Viejo Lagoon

In Pueblo Viejo Lagoon, there are four fisherman cooperatives with a total membership of 435. The Lagoon was divided into four fishing grounds, but there is no physical boundary between them. Therefore, conflicts arise in the utilization of fishing grounds among the fishermen in the different cooperatives.