Chapter 2 Pollution Load Analysis in the Tampico Area

2.1 Approach of Pollution Load Analysis

2.1.1 Objectives

Within the project of water quality monitoring, pollution load analysis aims to estimate the existing and future pollution loads in the Tampico Area for the formulation of Coastal Water Quality Monitoring Plan. Objectives of this pollution load analysis are:

- to identify existing pollution sources;
- to estimate the existing pollution loads to the Tampico Area; and
- to estimate the future pollution loads to the Tampico Area.

2.1.2 Study Area

The study area for the pollution load analysis is shown in Figure 2.1. The study area includes:

- Coastal Water (extending from Altamira Industrial Port to the river mouth of Panuco River)
- Altamira Industrial Port (including Garrapatas Stream and its watershed)
- Conejo Lagoon and Marismas Lagoon
- Panuco River (from a junction with Tamesi River to the river mouth of Panuco River)
- Pueblo Viejo Lagoon (including Llave River)

The study area covers the downstream from the junction of Tamesi River so that river water volume and water quality at this junction are established as boundary conditions.

2.1.3 Process of Pollution Load Analysis

There are a variety of pollution sources such as factories, agriculture lands, urbanized zones and others. These pollution sources can be divided into point pollution sources and non-point pollution sources in order to estimate pollution load in the study area.

General process of pollution load analysis is shown in Figure 2.2. Pollution load analysis is divided into two stages: estimation of existing pollution load and future pollution load.

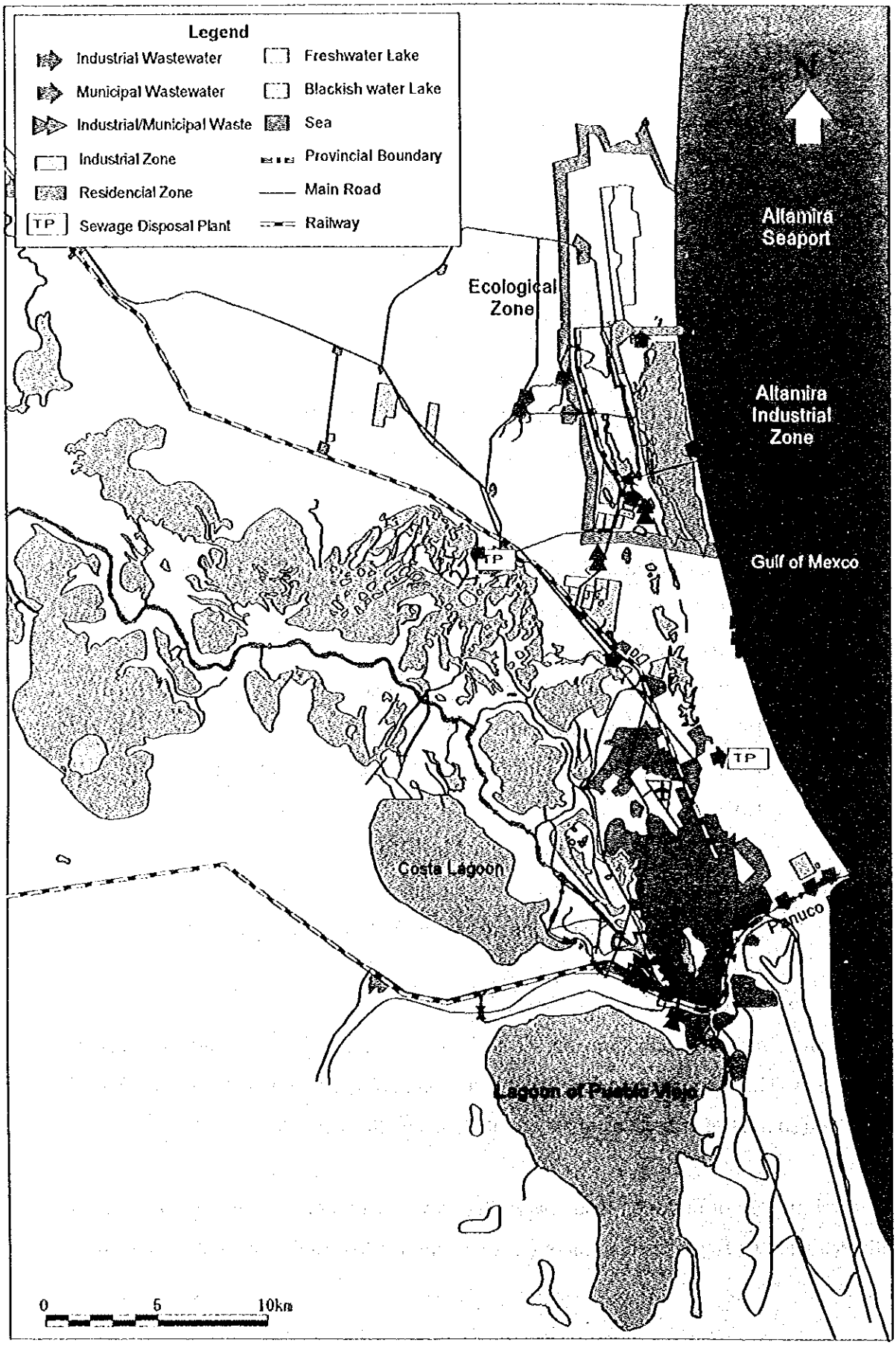


Figure 2.1 Study Area for the Pollution Load Analysis

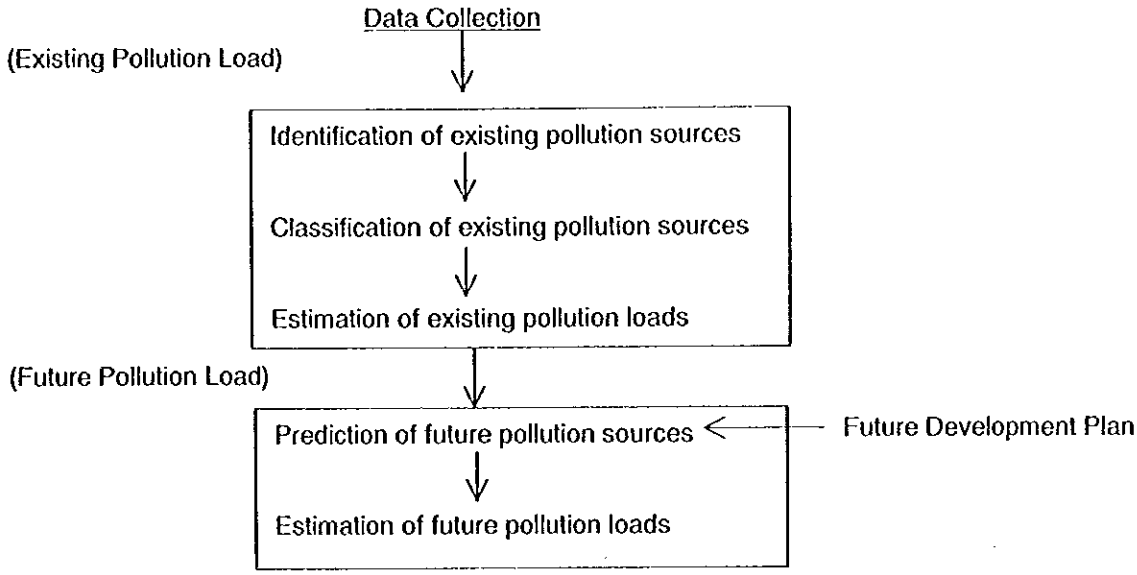


Figure 2.2 General Process of Pollution Load Analysis

2.2 Condition of Water Systems

2.2.1 Meteorology and Hydrology

(1) Meteorology

Mean monthly rainfall in Altamira (from 1979 to 1998), Tampico (from 1979 to 1998), and Chavez in Veracruz State (from 1950 to 1979) are shown in Table 2.1. At the three stations, mean monthly rainfall is more than 90 mm from June to October, and less than 70 mm from November to May. The rainy season is from June to October, and the dry season is from November to May. The highest mean monthly rainfall is in September, and the lowest mean monthly rainfall is in February and March.

Table 2.1 Mean Monthly Rainfall and Mean Monthly Evaporation Observed at Altamira, Tampico, and Chavez

Unit: mm

Meteorological Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Altamira*	50	11	16	25	41	165	121	144	253	107	29	34	983
Tampico*	33	21	16	28	51	177	134	170	270	133	37	49	1118
Chavez**	35	21	15	21	29	185	139	93	370	108	67	35	1120

Location: Altamira 22°25'30"N, 97°56'42"W
Tampico 22°14'19"N, 97°52'44"W
Chavez 22°06'51"N, 97°50'03"W

* data in 1979 - 1998
** data in 1950 -1979

(2) Hydrology

There are the following watersheds in the Tampico Area:

- Altamira Industrial Port with Garrapatas Stream;
- Marismas Lagoon and Conejo Lagoon; and
- Panuco River.

Hydrological conditions of three watersheds are described as follows:

a) Altamira Industrial Port Area

This area is part of Marismas Lagoon. There is only one natural stream, called Garrapatas Stream, which flows into the Gulf of Mexico through the area. Watershed area of Garrapatas Stream is about 66 km^2. POLYCYD (Polymer Synthesis Industry), a thermal power station (Comision Federal de Electricidad) and NEGROMEX (Synthetic Rubber Industry) discharge the wastewater into Garrapatas Stream.

b) Conejo Lagoon and Marismas Lagoon

Conejo Lagoon has a water basin area of 3.4 km^2 without any inflows. An artificial channel connects from Conejo Lagoon to Marismas Lagoon. There are several industries around the southern part of Conejo Lagoon and they discharge wastewater into Conejo Lagoon. There are lots of independent small lagoons around Conejo Lagoon and Marismas Lagoon. These lagoons do not have direct discharge flow into the Gulf of Mexico.

c) Panuco River

Watersheds of Panuco River are shown in Figure 2.3. This watershed is separated into nine sub-watersheds: Tamesi-Chicayan, Guayalejo, Tampaon, Tempoal, Metztitlan, Moctezuma, San Juan, Santa Maria and Rio Verde. The mean annual rainfall, rainwater volume and runoff volume of each watershed are shown in Table 2.2. Total area of Panuco River watershed is 77,206 km^2 and the mean annual rainfall is 953 mm. Total water volume precipitated and flowed into Panuco River watershed are 73,549 million m^3/year, and 16,536 million m^3/year, respectively. Water flow of Panuco River System is shown in Figure 2.4. Tamesi River flows into Panuco River at the border of the Study Area. Pueblo Viejo Lagoon and Chijol channel exchange the water with Panuco River.

- Upstream of Panuco River from the junction of Tamesi River

Upstream of Panuco River from the junction of Tamesi river consists of seven sub-watersheds, Tempoal, Tampaon, Rio Verde, Santa Maria, Moctezuma, San Juan, Meztitlan, and a part of Tamesi-Chicayan (Chicayan), as shown in Figure 2.3.

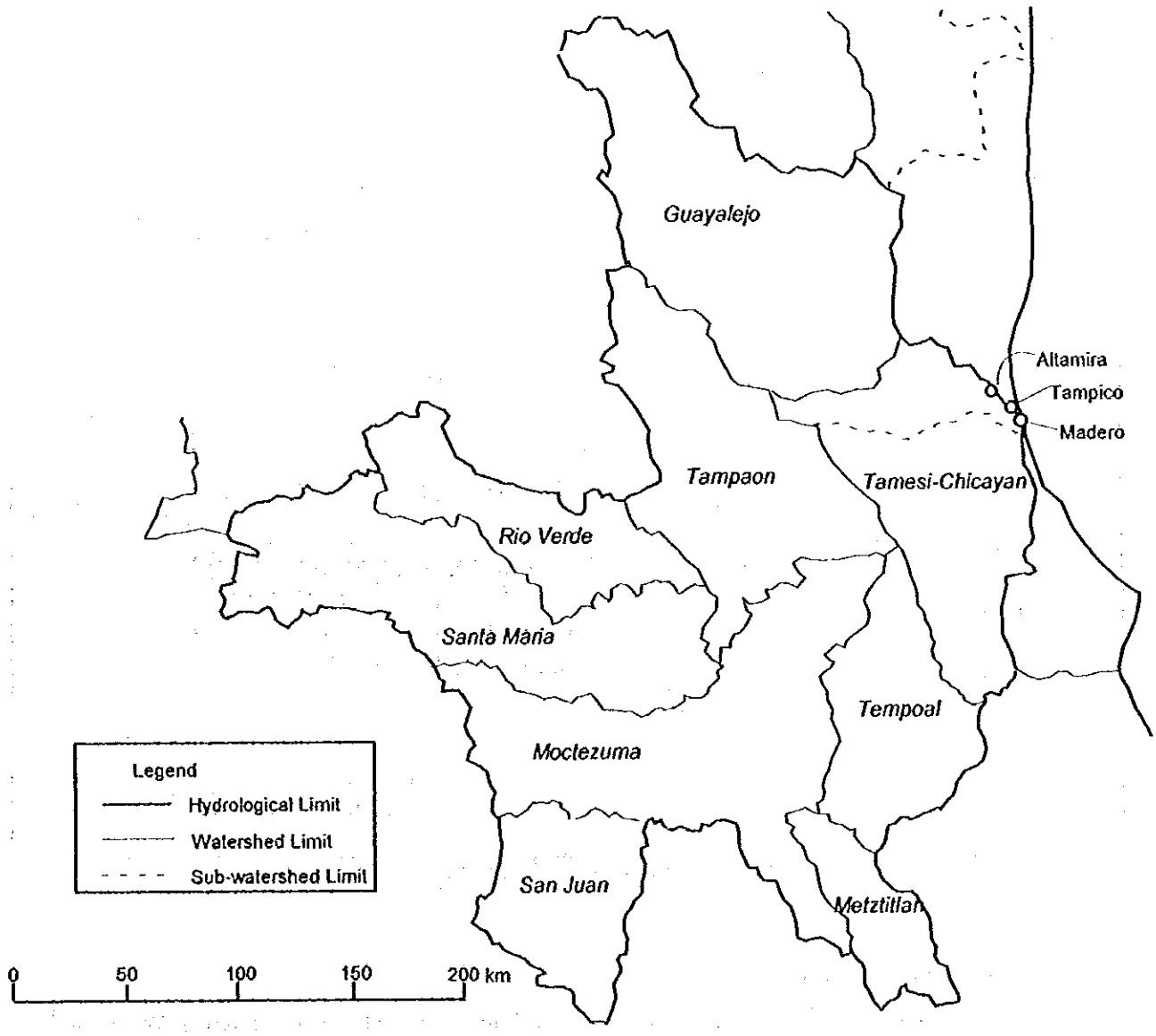


Figure 2.3 Watersheds of Panuco River

Table 2.2 Hydrological Parameters for Watersheds of Panuco River

Watershed	Watershed Area km^2	Mean Annual Rainfall in Watershed mm	Rain Water Volume in Watershed million m^3/year	Runoff Water Volume in Watershed million m^3/year
Tamesi-Chicayan	9,626	990	9,532	2,001
Guayalejo	13,796	829	11,432	2,883
Tempoal	5,853	1,415	8,281	3,112
Tampaon	9,923	1,479	14,679	3,983
Rio Verde	5,408	671	3,626	268
Santa Maria	11,478	651	7,469	1,121
Moctezuma	13,112	1,046	13,720	2,942
San Juan	5,064	608	3,078	78
Meztitlan	2,946	588	1,732	148
Total	77,206	953	73,549	16,536

Source: Diagnostico para la Region Hidrologica IX Golfo Norte (1998), CNA (Gerencia Regional Noreste)

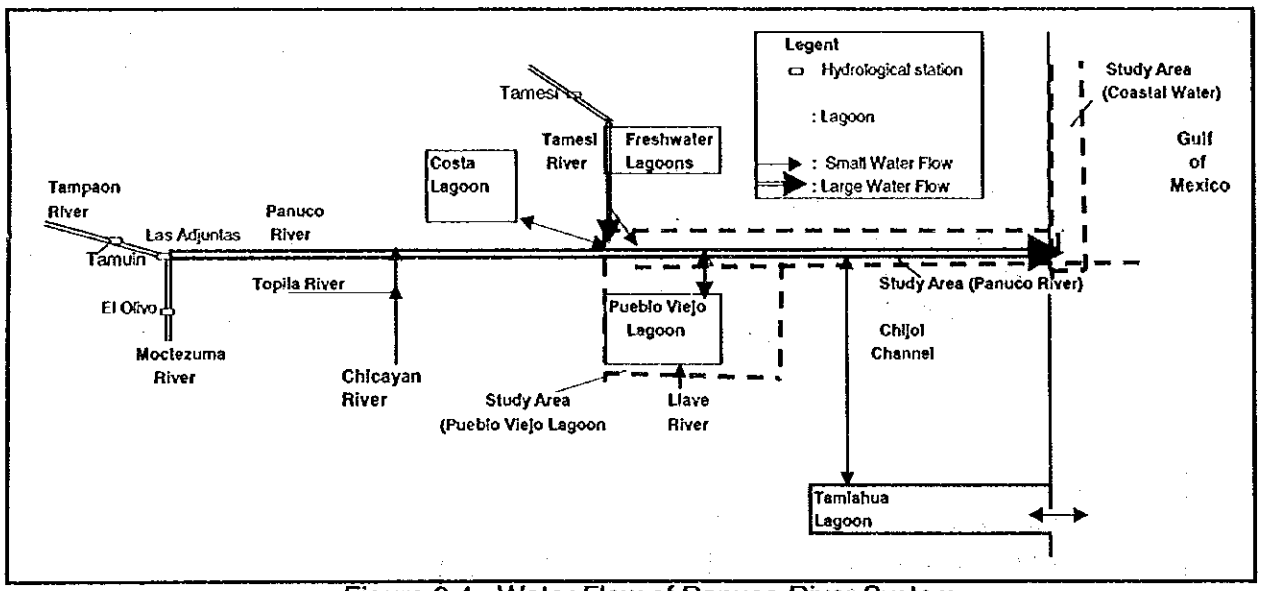


Figure 2.4 Water Flow of Panuco River System

- Tamesi River

Tamesi River receives water from Guayalejo River. The Tamesi River Watershed Area includes Guayalejo River watershed, which has an area of 17,015 km^2. The total water surface area of freshwater lagoons is about 290 km^2, which includes Champayan Lagoon (102 km^2), La Puerta Lagoon (5.3 km^2), Escondida Lagoon (11.8 km^2), Tancol Lagoon (0.48 km^2), and Chairel Lagoon (2.7 km^2). A salt water lagoon, Costa Lagoon, receives the freshwater from Tamesi River and supplies salt

water to Tamesi River near the junction with Panuco River. Costa Lagoon's surface area is 39 km^2.

- Pueblo Viejo Lagoon

Llave River, whose watershed is 850 km^2, connects with Pueblo Viejo Lagoon, collecting water from its watershed (about 1000 km^2). The water of Pueblo Viejo Lagoon flows into the Gulf of Mexico through Panuco River.

- Chijol Channel

This channel is near the river mouth of Panuco River, and connects Panuco River with Tamiahua Lagoon, which directly exchanges water with the Gulf of Mexico. Around this channel, there is a wetland with mangrove forest. The water exchange of Panuco River depends on the tide level between the mouth of Panuco River and Tamiahua Lagoon.

2.2.2 Conditions of Coastal Water, River and Lagoon

(1) Coastal Water

a) Hydrological Condition

The coast of Tampico Area is located in the middle-western part of the Gulf of Mexico. The sediment of seabed near the Tampico Coast is mainly sandy. The tidal range in the relevant sea area is relatively small. The predicted highest sea level and lowest sea level in 1999 are 64 cm and -30 cm above/below the mean low level, respectively (according to the tide table published by the Secretary of Marine).

b) Water Quality

The Secretary of Marine has measured water quality of coastal area at the river mouth of Panuco River and near the Altamira Industrial Port in 1998. The average values of selected parameters are shown in Table B.1 of Appendix B.

(2) River

a) Garrapatas Stream (A/3)

Garrapatas Stream flows into the Altamira Industrial Port. The watershed area of Garrapatas stream is about 66 km^2. The Secretary of Marine has not measured discharge volume and water quality of this stream.

b) Branched Stream Connected with Panuco River

- Upstream Part of Panuco River (C/1)

Table 2.3 shows mean monthly discharge volume averaged from 1980 to 1988 of

Panuco River (Las Adjuntas Hydrological Station), Tampaon River (Tamuin Hydrological Station) and Moctezuma River (El Olivo Hydrological Station). The total monthly discharge volume of the two rivers is larger than the monthly discharge volume of Panuco River. The mean annual discharge volume at El Olivo, Tamuin, and Las Adjuntas are 7,389, 5,299 and 11,116 million m^3/year, respectively. The maximum of mean monthly discharge volume was in September, and the minimum was in March at three stations.

Table 2.3 Mean Monthly Discharge Volume at El Olivo (Moctezuma River), Tamuin (Tampaon River) and Las Adjuntas (Panuco River)

Unit: million m^3

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
El Olivo	250	184	164	194	284	811	1298	847	1896	828	341	271	7369
Tamuin	211	166	160	162	205	524	1001	719	971	641	300	238	5299
Las Adjuntas	419	307	269	285	407	1119	2021	1394	2454	1406	580	455	11116

Source: Gerencia de Aguas Superficiales (CNA)

The water quality of Panuco River upstream at El Alamo Station (85 km downstream from Las Adjuntas) is shown in Table B.2. All parameters of rainy season (from June to October) except BOD_5 were higher than those in the dry season (from November to May). The water quality of Panuco River upstream is shown in Table B.3. This table shows that BOD_5 value increases from downstream of Panuco City, but the BOD level returns to constant level (2.3-2.5 mg/l). Phosphate, organic nitrogen, NH_3 nitrogen, COD levels are stable from Las Adjuntas (about 180 km from the river mouth of Panuco River) to the upstream of Chila Lagoon (34.5 km from the river mouth of Panuco River).

- Tamesi River (C/2)

Tamesi River forms a water system with freshwater lagoons as shown in Figure 2.5. The water volume of this system is 438,000,000 m^3 and its water surface is 293 km^2 (source: Estudio para la Restauracion Ecologia del Sistema Lagunario del Rio Tamesi, CNA, 1992). Tamesi River, Champayan Lagoon, Puerta Lagoon, Tancol Lagoon, and Chairel Lagoon provide potable water for Altamira Municipality, Tampico City and Madero City. These lagoons are also important water sources for local industry and agriculture.

The daily mean flow rate at Tamesi Hydrological Station from the upstream part of Tamesi River is shown in Table 2.4. The daily mean flow rate normally reaches its

peak during June and October. However the water level of Chairel Lagoon becomes the lowest at the beginning of rainy season. Therefore the discharge rate from Tamesi River to Panuco River is greatly different from that at Tamesi Hydrological Station. Discharge volume from Tamesi River to Panuco River has neither been measured nor calculated.

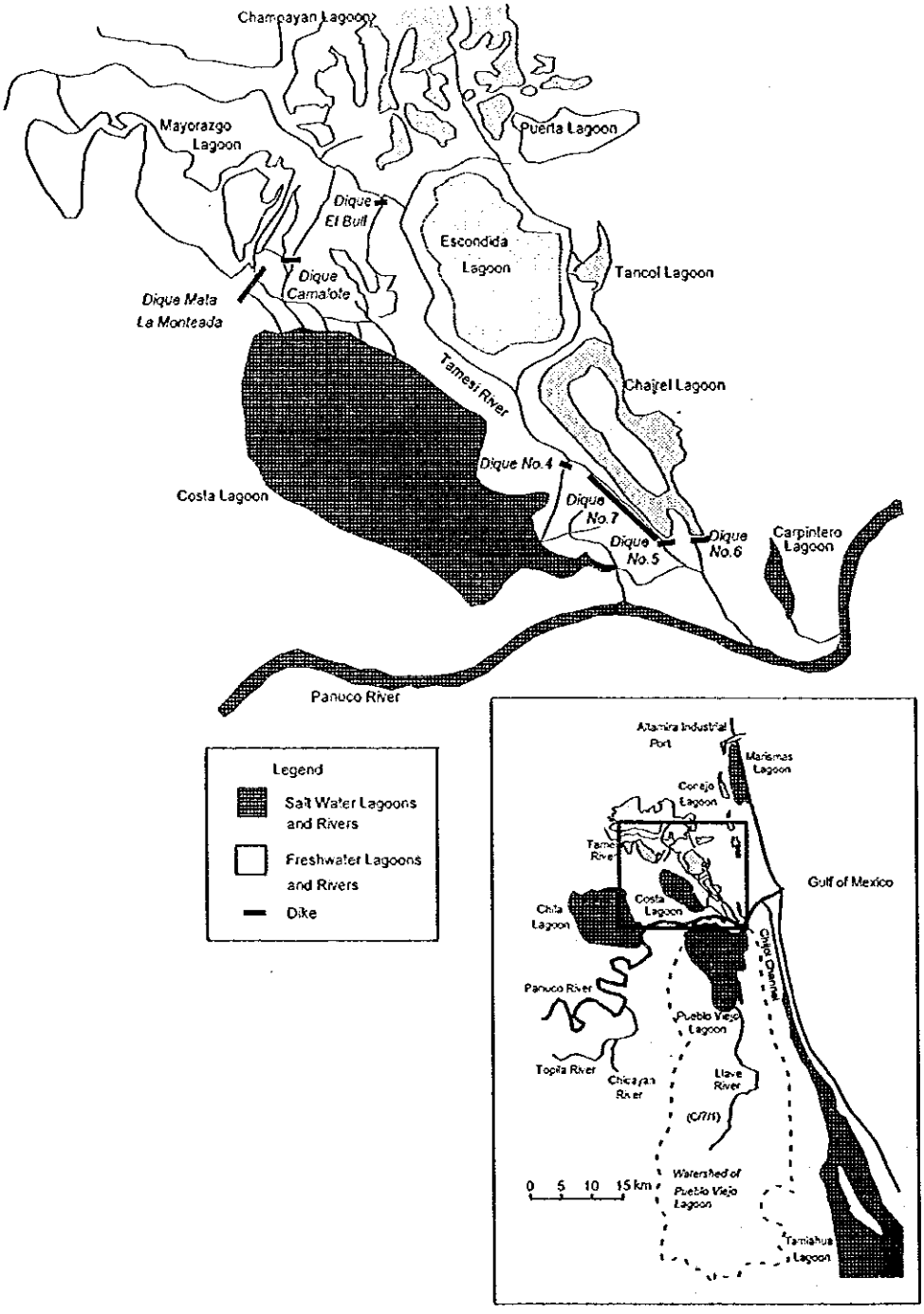


Figure 2.5 Tamesi River Water System

Table 2.4 Mean Monthly Discharge Volume and Flow rate at Tamesi River (1974-1990)

	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Monthly Discharge Volume	Million m^3/month	67	53	48	41	88	345	597	447	552	284	114	96
Mean Flow Rate	M^3/s	25	22	18	16	33	133	223	167	213	106	44	36

Source: Estudio Para La Restauracion Ecologica Del Sistema Lagunario del Rio Tamesi , CNA (1992)

The area around the freshwater lagoons is irrigated. Guayalejo River (upstream part of Tamesi River) flows in the agricultural zone and has two sugar refinery factories in its water basin.

The water quality of Tamesi River and its freshwater lagoons is shown in Table B.4. Tancol Lagoon was more contaminated than Tamesi River and other lagoons except for the level of fecal coliform.

(3) Lagoons

a) Conejo Lagoon (B/1)

Conejo Lagoon (water surface area about 1.6 km^2, and water basin area is about 3.4 km^2) is a freshwater lagoon without any natural inflow streams. The average water depth is about 2 m. The southern part of Conejo Lagoon is an industrial zone. The land uses in the other sides are open grassland and small-scale agriculture. The water in the southern part of Conejo Lagoon is much contaminated compared with the northern part. Probably the wastewater from industrial zone causes the level of contamination

b) Las Marismas Lagoon (B)

Las Marismas Lagoon is 22 km large and 1.8 km wide. Its area is 39.6 km^2 and its capacity is 9,500,000 m^3. There is no stream that supplies water into Las Marismas Lagoon except a channel from Conejo Lagoon. The water in this lagoon is saline and is separated from the Gulf of Mexico with sandbank. According to Proyecto Impacto Ambiental (CNA), in dry season, low water level of Marismas Lagoon is compensated with pumping seawater from the Gulf of Mexico because crabs with commercial value are protected. Water depth of Marismas Lagoon is less than 1 m. The water body of Marismas Lagoon is separated into three parts by one road and Altamira Industrial Port.

Water quality data of Marismas Lagoon, which was sampled on May 10 1996 by CNA, are shown in Table B.5.

c) Costa Lagoon (C/2/1)

Costa Lagoon (water surface area about 39 km^2) is a salt water lagoon. There are some artificial dikes that separate Costa Lagoon from Tamesi River's freshwater lakes. Therefore, the freshwater does not enter this lagoon except in flood periods. Panuco River exchanges water with Costa Lagoon with tide effect.

d) Pueblo Viejo Lagoon (C/7)

Pueblo Viejo Lagoon is connected with the river mouth of Panuco River. Pueblo Viejo lagoon is 14.2 km long, and 6.5 km wide. Its area is 85 km^2, and the average water depth is about 1.6 m. Freshwater inflows into Pueblo Viejo Lagoon are mainly from Llave River, located in the southern part of Pueblo Viejo Lagoon. The water basin area is about 850 km^2. Monthly and annual discharge volume of Llave River is shown in Table 2.5. These mean value is calculated from the data between 1950 and 1979. Annual mean discharge volume is 438.2 million m^3. Monthly mean discharge volume is highest and lowest in September and March respectively. Water quality information of Llave River has not been obtained.

Table 2.5 Flow Rate and Monthly Discharge Volume of Llave River

Annual Discharge Volume: 438.2 million m^3/year

	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flow Rate	m^3/s	3.3	2.4	2.0	2.8	5.8	28.8	23.1	19.1	43.9	20.6	8.2	6.7
Monthly Discharge Volume	Million m^3	8.7	5.7	5.4	7.3	15.5	74.6	62.0	51.1	113.8	55.1	21.2	17.9

Source: Tamacuil Project

2.3 Existing Pollution Sources

2.3.1 Types of Pollution Sources

The pollution sources can be divided into two types from the viewpoint of discharge forms; point pollution sources and non-point pollution sources. For example, wastewater discharge from industry is identified as point pollution source. On the other hand, agricultural lands where pollutants such as fertilizers and pesticides are used are identified as non-point pollution sources.

An inventory of point and non-point pollution sources in Tampico area is shown in Table 2.6. The locations of main point pollution sources are shown in Figure 2.6 (a) – (e). Watershed areas in the Tampico Area are shown in Figure 2.7 (a) and (b).

Table 2.6 Inventory of Pollution Sources

Pollution Source Number*	Name	Activity	Discharge Type
	Gulf of Mexico		
A	Altamira Industry Port		
A/1, S	Administracion Portuaria Integral del Altamira	Service	Point
A/2, I	Pittsburgh Plate Glass Industry	Inorganic Chemical Industry	Point
A/3	Garrapatas Stream		
A/3/1, I	Policyd	Polymer Synthesis Industry	Point
A/3/2, I	Comision Federal de Electricidad	Power Station	Point
A/3/3, I	Negromex (Solucion)	Petrochemical Industry	Point
A/3/4, R	Watershed of Garrapatas Stream		Non-point
B	Marismas Lagoon		
B/1	Conejo Lagoon		
B/1/1, I	BASF Mexicana	Polymer Synthesis Industry	Point
B/1/2, I	Grupo Primex	Polymer Synthesis Industry	Point
B/1/3, I	Internacional Papeles del Golfo	Pulp Industry	Point
B/1/4, I	Fibras Nacionales de Acrilico	Fiber Synthesis Industry	Point
B/1/5, I	GE Plastic (Polimar)	Polymer Synthesis Industry	Point
B/1/6	Park of Small and Medium Industries		
B/1/6(1), I	Operadora y Comercializadora Trevi Plus	Bottle Water Production	Point
B/1/6(2), I	Johns Manville	Insulant and impermeable material	Point
B/1/6(3), I	Tecno Asfalto del Golfo	Asphalt Industry	Point
B/1/6(4), I	Asfaltos y Derivados Mexicanos	Asphalt Industry	Point
B/1/7	Watershed of Conejo Lagoon		Non-point
C	Panuco River		
C/1	Panuco River Upstream		
C/2	Tamesi River System		
C/2/1	Costa Lagoon		Non-point
C/3	Morelos		
C/3/1, I	Sea-food Processing Industry		Point
C/4	Canal la Puntilla		
C/4/1, M	Altavista Water Supply System	Municipal Use	Point
C/4/2, M	Carcamo No 1	Municipal Wastewater Drainage	Point
C/4/3, M	Carcamo No 2	Municipal Wastewater Drainage	Point
C/4/4, M	Carcamo No 3	Municipal Wastewater Drainage	Point
C/4/5, M	Planta de Bombas No 6	Municipal Wastewater Drainage	Point
C/4/6, U	Southwestern Part of Tampico	Urban Area	Non-point
C/4/7, M	Tampico Solid Waste Landfill Site	Municipal Solid Waste	Non-point
C/5, U	Tampico		
C/5/1, M	Planta de Bombas No 1	Municipal Wastewater Drainage	Point
C/5/2, M	Planta de Bombas No 7	Municipal Wastewater Drainage	Point
C/5/3, M	Planta de Bombas No 8	Municipal Wastewater Drainage	Point
C/5/4, M	Sistema de Gravedad No 12	Municipal Wastewater Drainage	Point
C/5/5, M	Southern Part of Tampico	Urban Area	Non-point
C/6, U	Northern Part of Pueblo Viejo	Urban Area	Non-point
C/7	Pueblo Viejo Lagoon		
C/7/1, R	Watershed of Pueblo Viejo Lagoon	Pasture	Non-point
C/7/2, M	Cuauhtemoc Oxidation Pond	Municipal Wastewater Treatment	Point
C/8	Madero	Urban Area	Non-point
C/8/1, M	Sistema de Gravedad No 11	Municipal Wastewater Drainage	Point
C/8/2, M	Planta de Bombas No 9	Municipal Wastewater Drainage	Point
C/8/3, U	Southern Part of Madero	Urban Area	Non-point
C/9	Chijol Channel		Non-point
C/10, I	Refineria Madero	Petroleum Refinery	Point
C/11, I	Quimica del Mar	Inorganic Industry	Point
D	Petrocel		
D(1), I	Petrocel	Synthesis of terephthalic acid	Point
D(2), I	Indelpro	Polymer Synthesis Industry	Point
D(3), I	Hercules	Synthetic Fiber Industry	Point
D(4), I	Tereftalatos Mexicanos	Synthesis of terephthalic acid	Point
D(5), I	Pecten Poliesters	Polymer Synthesis Industry	Point
E, I	Novaquim	Antioxidant, Antiozonant Synthesis	Point
F	Negromex		
F(1), I	Negromex	Synthetic Rubber Industry	Point
F(2), I	Nhumo	Carbon Black Production	Point
G, I	Dupont	Inorganic Color Gradient Industry	Point

I: Industrial, S: Service, M: Municipal, R: Rural, U: Urban, Aqua: Aquaculture
** Las Marismas is not directly inter-connected with Gulf of Mexico

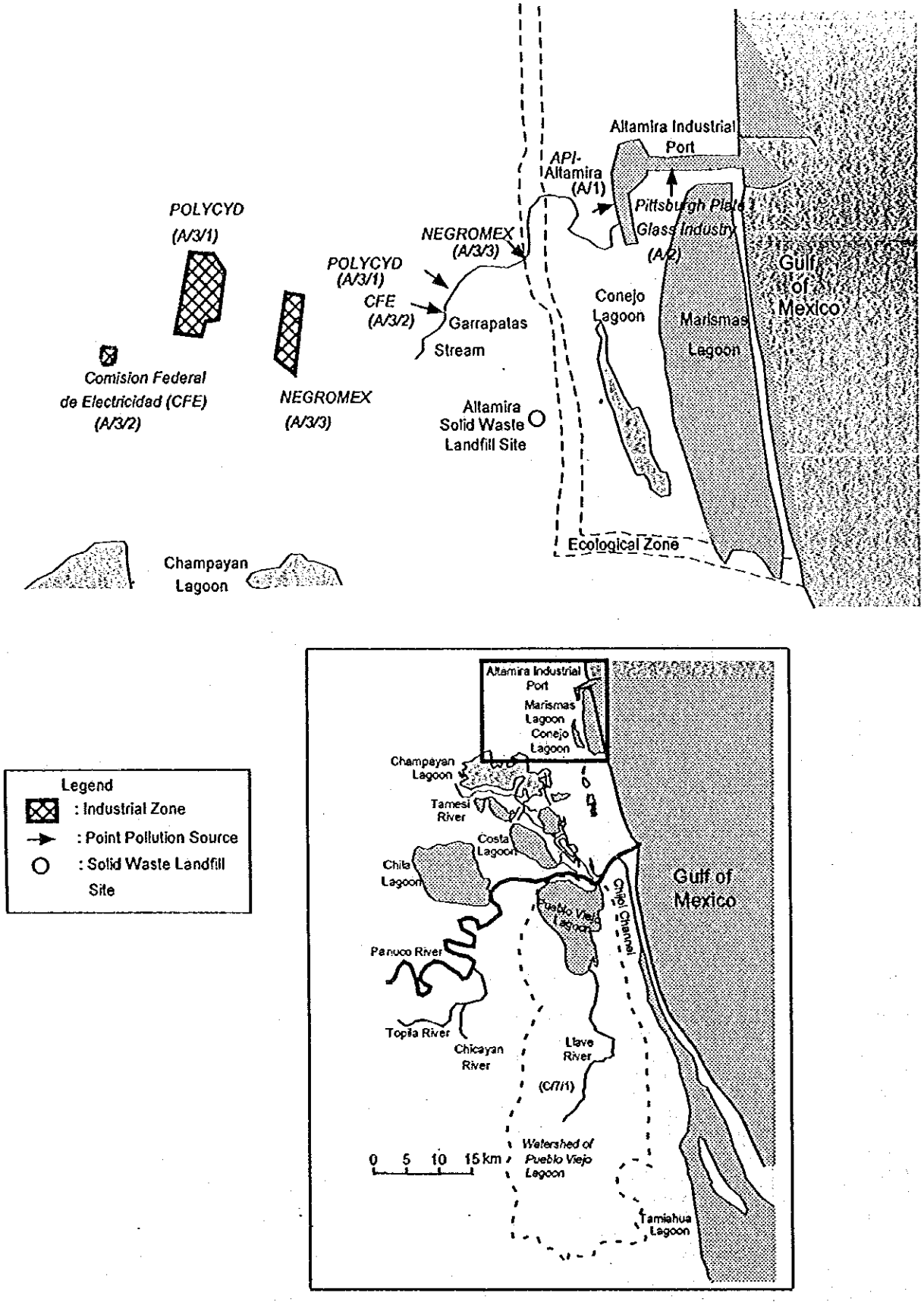


Figure 2.6(a) Point Pollution Sources Discharging into Altamira Industrial Port and Garrapatas Stream

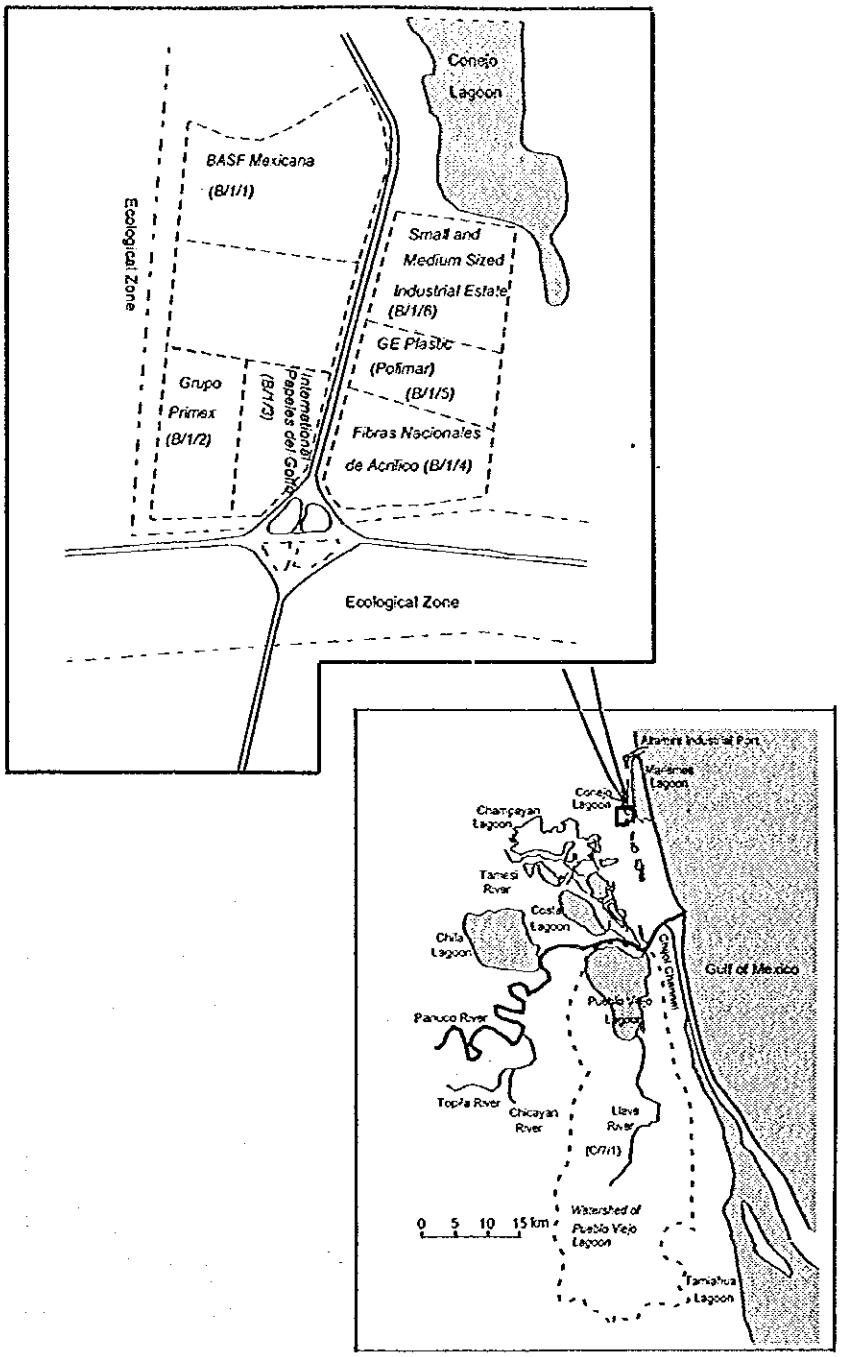


Figure 2.6(b) Point Pollution Sources Discharging into Conejo Lagoon

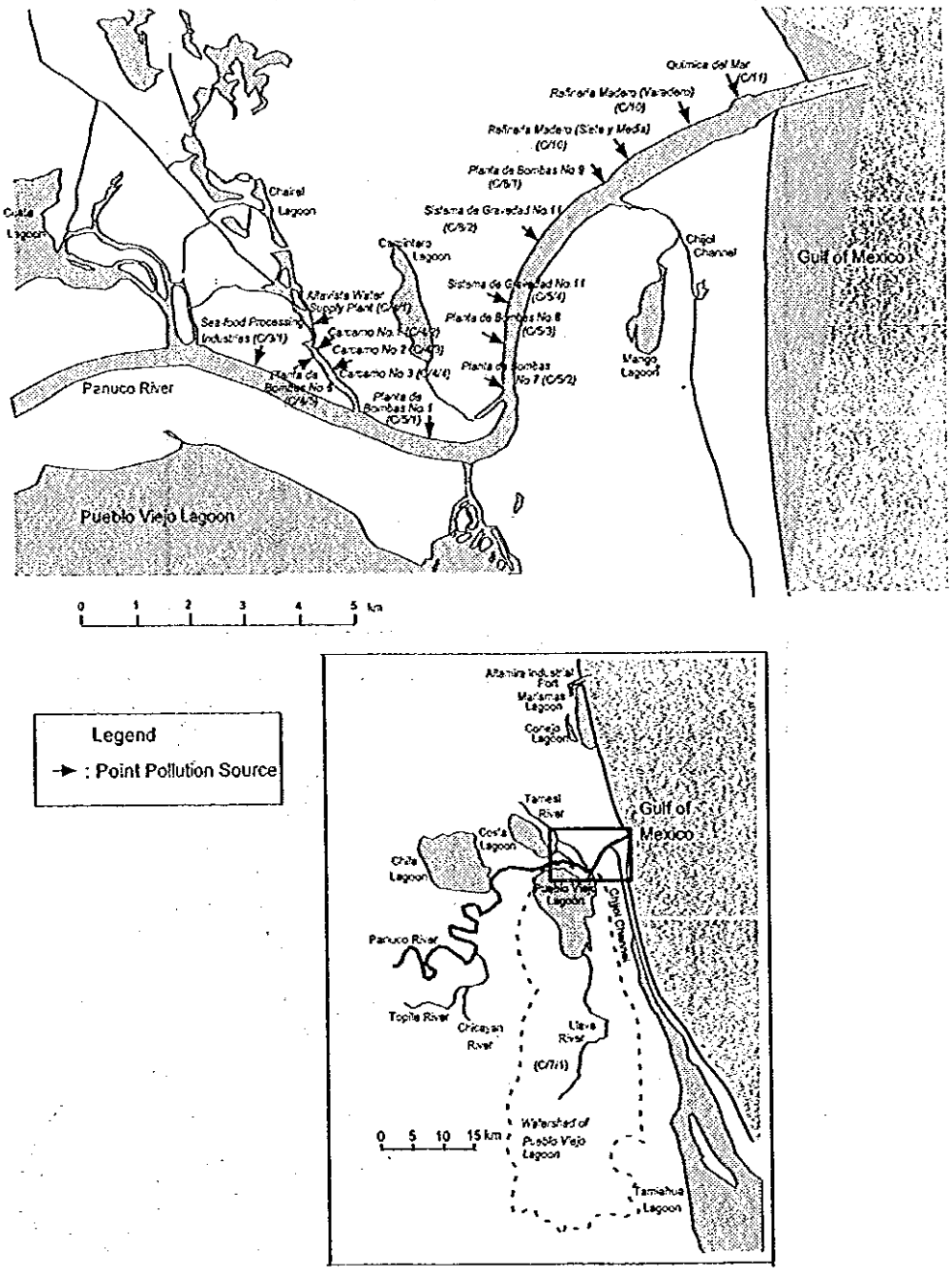


Figure 2.6(c) Point Pollution Sources Discharging into Panuco River

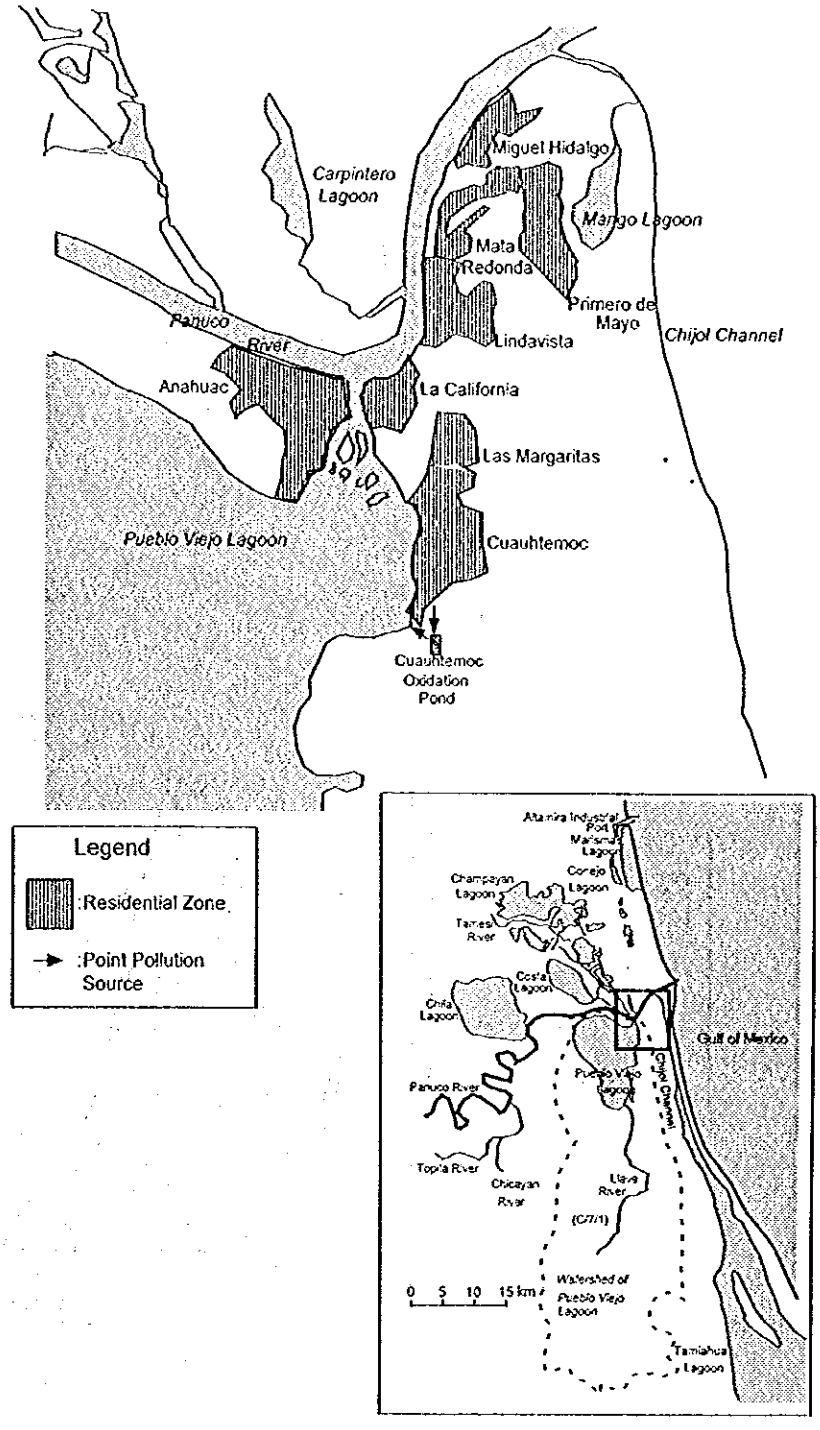


Figure 2.6(d) Point Pollution Sources Discharging into Pueblo Viejo Lagoon

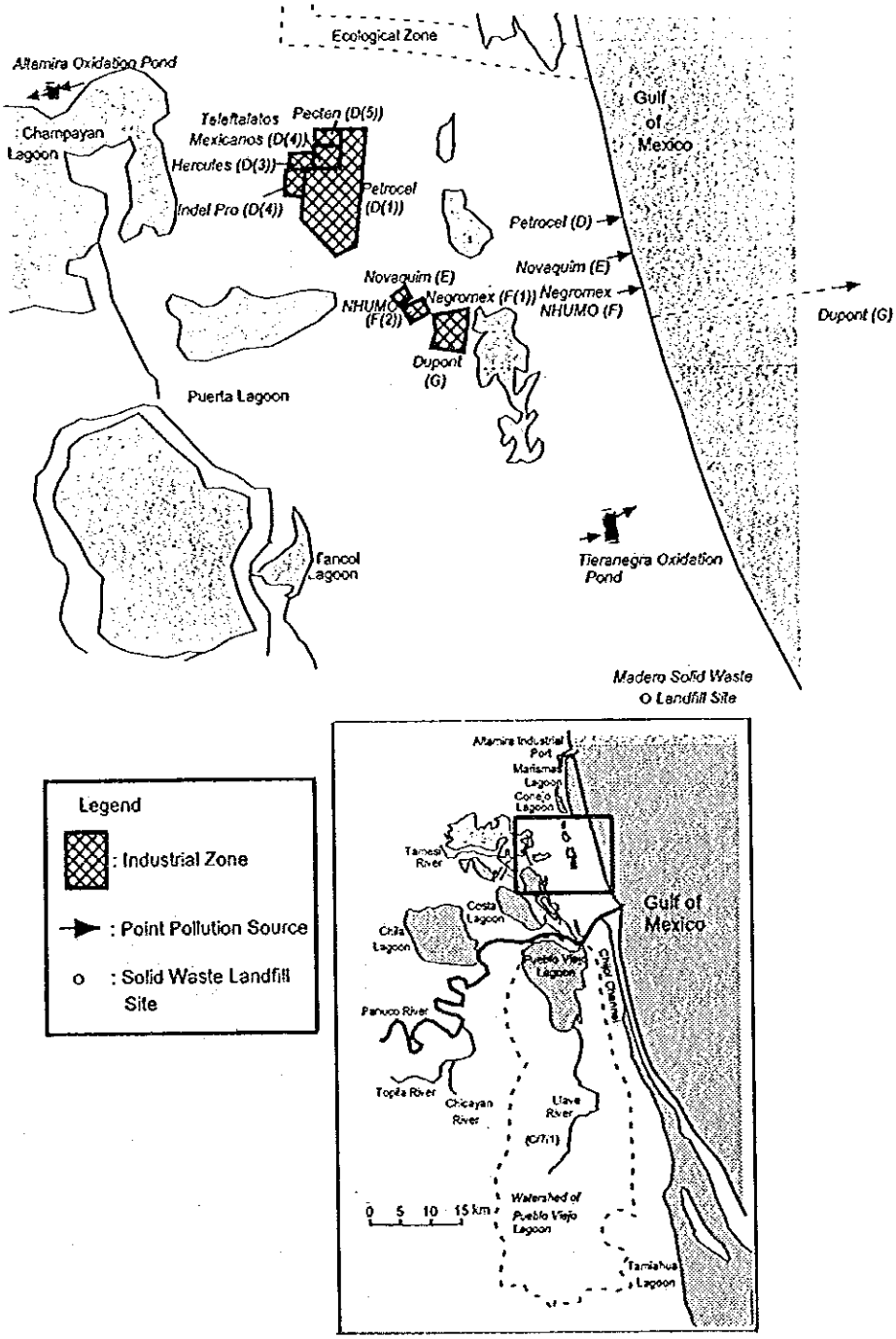


Figure 2.6(e) Point Pollution Sources Discharging into Gulf of Mexico

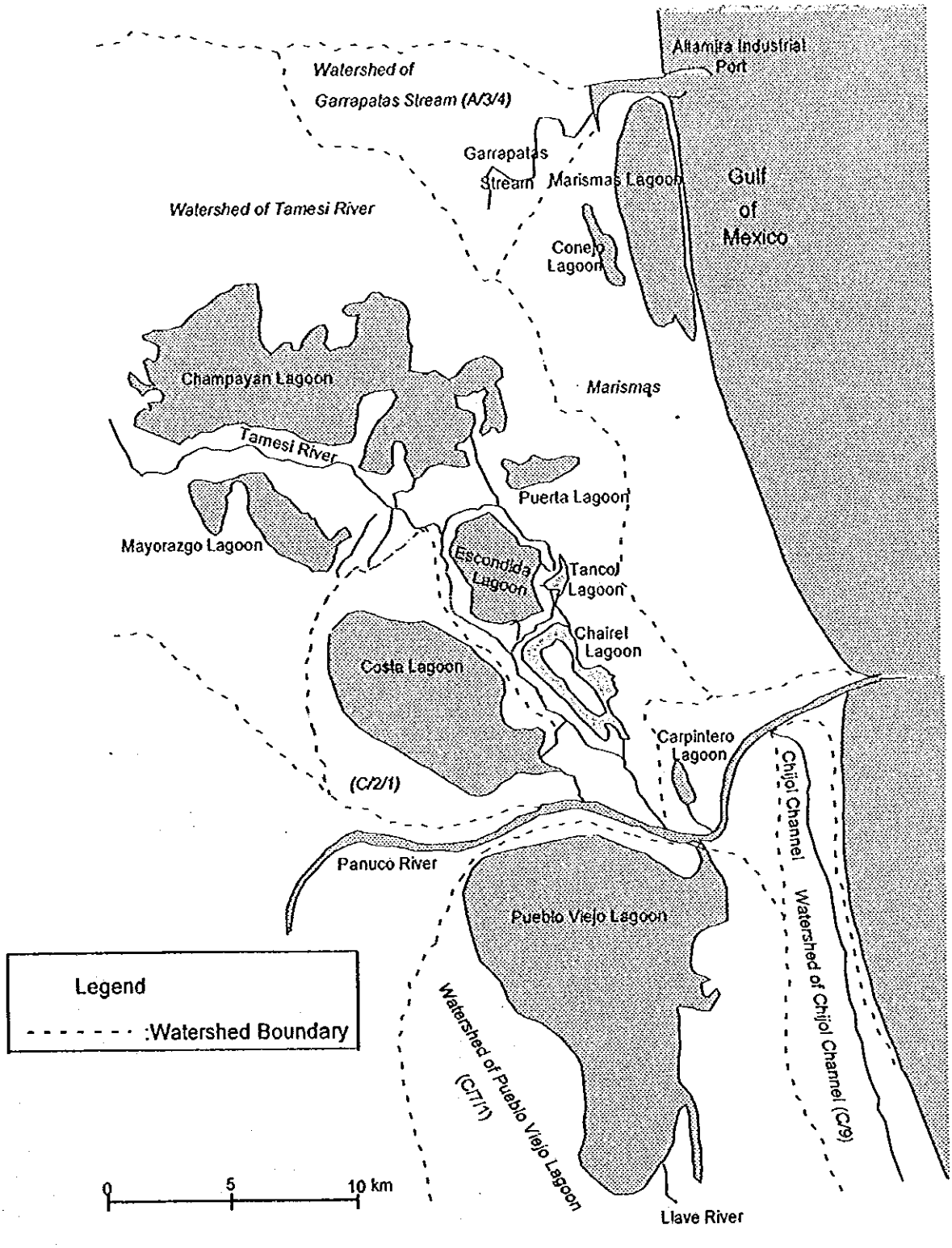


Figure 2.7(a) Non-point Pollution Sources (Watershed Areas)

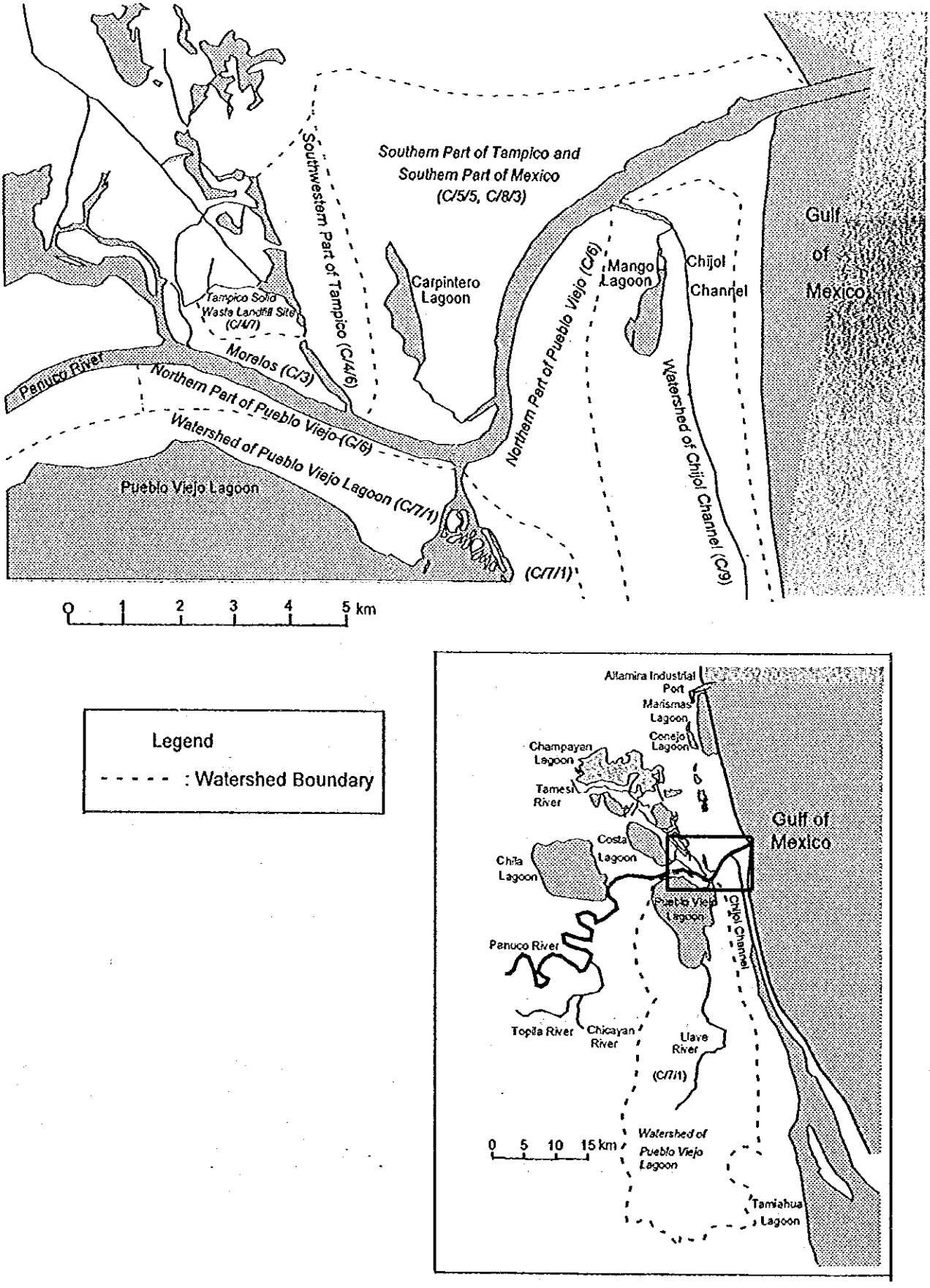


Figure 2.7(b) Non-point Pollution Sources (Watershed Areas) along Panuco River

2.3.2 Point Pollution Sources

Point pollution source in the Tampico Area is industrial and municipal wastewater.

(1) Industrial Wastewater

Some industrial entities utilize treatment facilities before discharging wastewater into water bodies. These wastewater treatment facilities are shown in Table 2.7.

Table 2.7 Treatment Plants of Industrial Wastewater

Pollution Source Number	Name of plant	Type of Industry	Flow rate(L/s)	Type of treatment	Discharge site
A/2	PPG industries	Inorganic Chemical Industry	37.72	Secondary (Physio-chemical, biological)	Gulf of Mexico
A/2	PPG industries	Inorganic Chemical Industry	0.14	Secondary (Physio-chemical, biological)	Gulf of Mexico
A/3/1	Policyd	Polymer Synthesis Industry	15.43	Secondary (Physio-chemical)	Garrapatas
A/3/2	CFE thermal power plant	Themal Power Plant	168.00	Secondary (Physio-chemical)	Garrapatas
A/3/3	Negromex	Synthetic Rubber Industry	10.80	Secondary (Physio-chemical, biological)	Garrapatas
B/1/1	Basf Mexicana	Polymer Synthesis Industry	11.57	Secondary (Physio-chemical, biological)	Conejo Lagoon
B/1/2	Grupo Primex	Polymer Synthesis Industry	60.00	Secondary (Physio-chemical, biological)	Conejo Lagoon
B/1/4	Finacril	Synthetic Fiber Industry	40.00	Secondary (Physio-chemical, biological)	Conejo Lagoon
B/1/5	GE Plastic	Polymer Synthesis Industry	18.40	Secondary (Physio-chemical, biological)	Conejo Lagoon
B/1/5	GE Plastic	Polymer Synthesis Industry	1.14	Secondary (Physio-chemical, biological)	Conejo Lagoon
C/10	Pemex Ref. Madero	Refinery of Petroleum	330.70	Primary (Physical)	Rio Panuco
D(1)	Petrocel	Synthesis of Terephthalic Acid	104.16	Secondary (Biological)	Gulf of Mexico
E	Novaquim	Synthesis of Antioxidant	10.00	Primary (Physical)	Gulf of Mexico
F(1)	Negromex	Synthetic Rubber Industry	28.66	Primary (Physical)	Gulf of Mexico
F(2)	Nhumo	Carbon Black Synthesis	13.15	Secondary (Physio-chemical)	Gulf of Mexico

Source: Memorandum of CNA (March 1999)

a) Altamira Industrial Port (A) and Garrapatas Stream (A/3)

There are two discharge paths of wastewater: One is directly discharged into Altamira Industrial Port, and the other is discharged into Altamira Industrial Port through Garrapatas Stream. The situation of wastewater discharge in each individual entity is described as follows:

- Administracion Portuaria Integral del Altamira (A/1, S)

The information on wastewater quality is shown in Table B.6. The type of wastewater is domestic. A septic tank is used for the treatment of the wastewater. There is no information on total nitrogen and total phosphorus of wastewater. The wastewater is discharged directly into the Altamira Industrial Port. The number of employees has currently been seven times higher than that in the report. Information on recent water quality of wastewater has not been obtained. Therefore, the annual

discharge volume was estimated at 28,000 m^3/year, obtained from the original volume in the report (4,000 m^3/year) multiplied by the increase rate of employees.

- Pittsburgh Plate Glass (PPG) Industry (A/2, I)

PPG industry produces silica materials (30,000 ton/year). The wastewater is discharged directly into Altamira Industrial Port. The information on wastewater quality is shown in Table B.7. The factories have not reported total-nitrogen and total-phosphorus. Total suspended solids in the discharged wastewater exceed the Effluent Standard of Mexico on contaminants (Mexican Official Standard NOM-001-ECOL-1996). According to the standard, monthly average of suspended solid discharge should be less than 100 mg/l. BOD_5 is below the Effluent Standard (100 mg/l). Heavy metals are necessary to be monitored for the PPG Industry. "Extractable" in Table B.7 means metal components that can be dissolved into an aqueous phase under the natural condition. Concentrations of heavy metals are below the Effluent Standard.

- POLYCYD (A/3/1, I)

A product of POLYCYD is polyvinylchloride resin. Raw materials are vinyl chloride and polyvinyl alcohol. After a secondary (physio-chemical) treatment, the wastewater of POLYCYD is discharged into the Altamira Industrial Port through Garrapatas Stream. The wastewater quality and discharge volumes in 1996-1998 are shown in Table B.8. Mean monthly discharge volume has increased since 1996. Water quality has not deteriorated during the period; except that the measured values of grease and oil are below the maximum permissible level of wastewater.

- Comision Federal de Electricidad (A/3/2, I)

The plant of Comision Federal de Electricidad generates a 100-MW electric energy and 800,000 lbs/hr of water vapor. The wastewater is discharged after a secondary (physio-chemical) treatment and flows into the Altamira Industrial Port through Garrapatas stream. The wastewater quality and discharge volume are shown in Table B.9. The measured parameters have been changed since 1997. Measured total suspended solids and grease and oil have surpassed the Effluent Standard of Mexico in July 1995.

- NEGROMEX (A/3/3, I)

Products of NEGROMEX are polybutadiene rubber (20,000 ton/year), ethylene-butadiene rubber (110,000 ton/year), acrylonitrile-butadiene rubber (2,000 ton/year), and thermoplastic rubber (17,000 ton/year). Raw materials are butadiene, styrene,

acrylonitrile and so on. The wastewater is discharged with primary (physical) treatment and flows into the Altamira Industrial Port through Garrapatas Stream. The wastewater quality and discharge volume are shown in Table B.10. The wastewater quality was below the Effluent Standard of Mexico. Heavy metals have been detected in the wastewater, but their concentrations have not exceeded the Effluent Standard of Mexico. In comparison with the wastewater quality of the Hules Mexicanos (NEGROMEX) factory, which produces the same products and discharges wastewater into the coastal water of Gulf of Mexico, wastewater quality of NEGROMEX is better than the Hules Mexicanos (BOD_5 concentration: one third, COD: one tenth).

b) Conejo Lagoon (B/1) and Marismas Lagoon (B)

Wastewater is discharged into Conejo Lagoon from the industrial factories such as BASF Mexicana, Grupo PRIMEX, Fibras Nacionales de Acrilico, GE Plastic (Polimar), and Internacional Papeles del Golfo. The water of Conejo Lagoon flows into Marismas Lagoon if the water level of Conejo Lagoon is high.

Small and medium scale industrial estates are located in the south of Conejo Lagoon and their wastewater is also discharged into Conejo Lagoon through a waterway.

- BASF Mexicano (B/1/1, I)

The products of BASF Mexicano are acrylic dispersant (25,000 ton/year), textile auxiliary (5,000 ton/year), textile colorant (2,000 ton/year), crystal polystyrene (143,000), and polymers of styrene (130,000 ton/year). Raw materials are styrene, butyl acrylate, acrylonitrile, methacrylamide, ethyl acrylate, methyl acrylate, and butadiene. The wastewater is discharged after a secondary (physio-chemical and biological) treatment. The wastewater quality and discharge volumes in 1996-1998 are shown in Table B.11. The wastewater of this industry is discharged into the southern part of Conejo Lagoon. Monthly discharge volume has increased since 1996. The water quality fluctuates within the same year. For example, BOD_5 varies from 4.7 mg/l to 114.6 mg/l in 1997 and from 6.7 mg/l to 269 mg/l in 1998. Grease and oil, total suspended solids, and BOD_5 exceeded the Effluent Standard of Mexico. Total nitrogen and total phosphorus were measured only in January of 1997. Heavy metals (cadmium, copper, lead, and zinc) have been normally detected, but the level of cadmium, copper, lead, and zinc did not exceed the Effluent Standard of Mexico.

- Grupo Primex (B/1/2, I)

The products of Grupo Primex are polyvinyl chloride resin (185,000 ton/year),

polyvinyl chloride compounds (31,000 ton/year), Phthalic anhydride (32,000 ton/year), and dioctyl phthalate (35,000 ton/year). Raw materials are vinyl chloride and o-xylene. The wastewater is discharged after a secondary (physio-chemical and biological) treatment, and flows into the southern part of Conejo Lagoon. The wastewater quality and discharge volumes are shown in Table B.12. Discharge volume was not indicated in from 1994-1995. All monthly or quarterly average values of BOD_5 have exceeded the Effluent Standard of Mexico, likewise for total suspended solids and grease/oil.. Heavy metals (cadmium, arsenic, copper, chromium, mercury, lead and zinc) have been detected, but the concentration has been below the Effluent Standard. Total nitrogen and total phosphorus are also at acceptable levels. The large fluctuation of concentration of parameters has not been observed according to the data.

- Internacional de Papeles del Golfo (B/1/3, I)

Internacional de Papeles del Golfo produces pulp from pulpwood. The wastewater quality and authorized discharge volume is shown in Table B.13. The wastewater is discharged into the southern part of Conejo Lagoon. Authorized annual discharge volume is 108,000 m^3/year. Organic component parameters such as COD, BOD_5, grease and oil have indicated high concentrations. BOD_5 has surpassed the Effluent Standard. Grease and oil and total suspended solids have also exceeded the Standard.

- Fibras Nacionales de Acrilico (FINACRIL) (B/1/4, I)

The product of FINACRIL is acrylic fiber (60,000 tons/year). Raw material is acrylonitrile. The wastewater is discharged into the southern part of Conejo Lagoon after a secondary (physio-chemical and biological) treatment. The wastewater quality and discharge volume are shown in Table B.14. Discharge volume decreased especially in 1998. BOD_5 exceeded the Effluent Standard of Mexico in 1997 and in 1998. Grease and oil, and total suspended solids might have accidentally exceeded the Effluent Standard in 1997. Zinc has been constantly detected but its concentration has not exceeded the Effluent Standard.

- GE Plastic (POLIMAR) (B/1/5, I)

The products of GE Plastic are synthetic resins (34,000 ton/year). Raw materials are styrene, acrylonitrile, butadiene, additives, and dyes. Wastewater is discharged after secondary (physio-chemical and biological) treatment, and flows into the southern part of Conejo Lagoon. Wastewater quality is shown in Table B.15. BOD_5 and COD show constantly low levels of concentration, which may be due to the wastewater

treatment. Total suspended solids, and grease and oil has kept at low level.

- Small and Medium Sized Industrial Estate (B/1/6)

Wastewater from small and medium sized industrial estate is collected to waterways and discharged into Conejo Lagoon. The following factories were established within this industrial estate:

- Operadora y Comercializadora Trevi Plus: mineral water production (B/1/6(1))
- Johns Manville: insulation and impermeable material (B/1/6(2))
- Tecno Asfalto del Golfo: asphalt industry (B/1/6(3))
- Asfaltos y Derivados Mexicanos: asphalt industry (B/1/6(4))
- Concretos Monterrey: distribution of concrete (B/1/6(5))
- Triturados y Premesclados Altamira: distribution of concrete (B/1/6(6))
- Sintesis de Tampico (B/1/6(7))
- Tecno Servicios: cleaning and maintenance of machine (B/1/6(8))
- Dragados de Veracruz: dredging work (B/1/6(9))
- Bermur Construcciones: insulation and impermeable materials (B/1/6(10))
- Aislamientos y Refractarios Diversos: insulant material (B/1/6(11))
- Schlumberger Dowell (B/1/6(12))
- Hilda Gas: LP gas (B/1/6(13))
- Transportes SARU: transportation (B/1/6(14))
- Transportes Jose Luis Huerta: transportation (B/1/6(15))
- D.M.Transportes: transportation (B/1/6(16))

Table B.16 shows the wastewater quality of four industries in the estate.

i) Operadora y Comercializadora Trevi Plus (B/1/6(1), I)

This is a mineral water production factory. There is no information on annual discharge volume of wastewater. Grease and oil has exceeded the Effluent Standard.

ii) Johns Manville Industrial (B/1/6(2), I)

Insulation and impermeable materials are produced. Raw material is asphalt. Annual discharge volume of wastewater is 2,770 m3/year. COD concentration is higher than the Standard.

iii) Tecno Asfalto del Golfo (B/1/6(3), I)

This is an asphalt production factory. Annual discharge volume of wastewater is 303 m^3/year. BOD_5, grease and oil, and total suspended solids exceeded the Effluent Standard. The wastewater has high total coliform level.

iv) Asfaltos y Derivados Mexicanos (B/1/6(4), I)

Annual volume of wastewater is 438 m^3/year. Total coliform shows a high level.

c) Panuco River (C)

Point pollution sources from which pollutants flow into Panuco River are shown in Figure 2.6(c). The following industrial wastewater is discharged into Panuco River:

- Seafood Processing Industries (C/3/1)

Seafood Processing Industries discharge wastewater after treatment with septic tanks. Some of them are Camarones del Golfo (C/1/3/1, I), Basilio Reynaga Martinez (C/1/3/2, I), Luis Gonzalez Aranda (C/1/3/4, I), Impulsora de Pescados y Mariscos (C/1/3/5, I), Exportadores Asociados (C/1/3/6, I), Pescafina Tampico (C/1/3/7, I), Francisco Javier Marquez Zapata (C/1/3/8, I) and a restaurant (Restaurant el Pollo Marino) (C/1/3/3, S)). The water quality of their wastewater is shown in Table B.17. BOD_5 and COD concentrations are remarkably high. BOD_5 concentration of Pescafina Tampico exceeded 1,000 mg/l. Fecal coliform of Luis Gonzalez Aranda's wastewater exceeded 2000 MPN/100 ml. Discharge volume of these seafood processing industries are not large in comparison with industrial factories, but the concentrations of BOD_5 and COD are important contributors of pollution loads. Total suspended solids also exceeded the Effluent Standard for Camarones de Golfo, Basilio Reynaga Martinez, and Pescafina Tampico.

- Refineria Madero (C/10, I) (Siete y Media, Varadero, and four other small discharge points)

Refineria Madero produces crude refinery (195,000 barrels/day), sulfur (20,000 ton/year), butadiene (55,000 ton/year) and styrene (30,000 ton/year). The wastewater is discharged after a primary (physical) treatment. Refineria Madero has the following two industrial wastewater discharge points (Siete y Media and Varadero) and four domestic wastewater discharge points.

i) Siete y Media

Water quality of wastewater is shown in Table B.18. Grease and oil, total suspended solids, and fecal coliform exceeded the Effluent Standard. Discharge volume decreased from 1996 to 1998. Some parameters of wastewater, such as grease and oil, fluctuated. Zinc was detected, but its concentration was lower than the effluent limit.

ii) Varadero

Water quality of wastewater is shown in Table B.19 (in 1996-1998). Discharge volume of Varadero is several times larger than that of Siete y Media. Discharged volume decreased from 1996 to 1998. Grease and oil,

total suspended solids, BOD_5, total nitrogen, and fecal coliform sometimes exceeded the Effluent Standard of Mexico. Ammoniac concentration of Varadero's wastewater was ten times lager than that of Siete y Media.

With respect to four domestic wastewater discharge points from Refineria Madero, discharge volume is very small in comparison with Siete y Media and Varadero. Therefore, the pollution loads of four domestic wastewater points are neglected.

d) Coastal Area of the Gulf of Mexico

The following four sources of industrial wastewater are directly discharged into the coastal area of the Gulf of Mexico.

- Discharge Point 1 (discharge at the coastline) (D) (22°23'21"N, 97°50'32"W):

The following five factories discharge the wastewater into Discharge Point 1.

i) PETROCEL (D(1), I)

The products of PETROCEL are dimethyl terephthalate (390,000 tons/year) and terephthalic acid (36,000 ton/year), and the raw materials are para-xylene and methanol.

ii) INDELPRO (D(2), I)

The product of INDELPRO is polypropylene (135,000 tons/year), and the raw materials are propylene, catalyzer, and additives.

iii) Hercules (D(3), I)

The product of Hercules is polypropylene fiber (15,000 tons/year), and raw material is propylene.

iv) Tereftalatos Mexicanos (D(4), I)

The product of Tereftalatos Mexicanos is terephthalic acid (350,000 tons/year), and raw material is para-xylene.

v) Pecten Poliesters (D(5), I)

The product of Pecten Poliesters is PET for bottles, and the raw material is terephthalic acid.

The wastewater discharge of the above mentioned five factories are controlled by PETROCEL. The wastewater is discharged after a secondary (biological) treatment. Wastewater quality is shown in Table B.20. Data from Nov 1995 to Jan 1997 are available. All the parameters fulfilled the Effluent Standard. Zinc and nickel have been detected, but their concentrations are much lower than the Effluent Standard.

- Discharge Point 2 (E): (22°21'43"N, 97°49'58"W):

The following two factories discharge wastewater into Discharge Point 2.

i) NOVAQUIM (E, I)

The products of NOVAQUIM are antioxidants (1,000 tons/year), antiozonants (3,000 tons/year), and accelerants (5,000 tons/year), and the raw materials are dimethylamine, aniline, and o-toluidine. The wastewater is discharged after a primary (physical) treatment. The wastewater quality is shown in Table B.21. The concentration of BOD_5 exceeded the Effluent Standard. Total suspended solids, grease and oil, and total nitrogen also exceeded the Effluent Standard. Copper is detected, but its concentration was much lower than the Effluent Standard.

- Discharge Point 3 (F): (22°21'37"N, 97°49'57"W)

The wastewater of the following factories flows into Discharge Point 3.

i) NEGROMEX (Hules Mexicanos) (F(1), I)

The products of Hules Mexicanos are polybutadiene rubber, styrene-butadiene rubber, acrylonitrile-butadiene rubber, and thermo-plastic rubber. The raw materials are butadiene, acrylonitrile, and styrene. The wastewater is discharged after a primary (physical) treatment. The wastewater quality is shown in Table B.22. Total suspended solids, and grease and oil exceeded the Effluent Standard.

ii) NHUMO (F(2), I)

NHUMO's product is carbon black, and raw material is natural gas. Wastewater is discharged after a secondary (physio-chemical) treatment. The quality of wastewater is shown in Table B.23. Annual discharge volume is 248,565 m^3.

- Discharge Point 4 (G) (discharges the wastewater between 2.5 and 3 km from coastline, 15m deep from sea level):

The wastewater of Dupont flows into Discharge Point 4

i) Dupont (G, I)

The products of Dupont are titanium dioxide and iron dioxide. The raw materials are ilmenites, chlorine, synthesized rutile, coke, sodium aluminate, and sodium silicate. The wastewater quality is shown in Table B.24. Heavy metals dissolved in the wastewater because of low pH values. High concentration of chloride ion may have interfered with COD

measurement, resulting in the high COD level in 1992-1993. A considerable amount of heavy metal has been discharged into the Gulf of Mexico. Especially, iron concentration in wastewater has increased.

(2) Municipal Wastewater

a) Tampico, Madero, and Altamira

There are three pathways of sewerage system in Tampico, Madero, and Altamira City according to CNA:

- First, wastewater is generated in the central urban zone of Altamira City and flows into Altamira Oxidation Ponds. The water quality of influent and effluent of this oxidation pond is shown in Table B.25. BOD_5 is reduced to 32% in this process. The treated wastewater is discharged into Champayan Lagoon .
- Second, wastewater is generated in the southern part of Altamira City (Miramar) and the northern part of Tampico and Madero City. The wastewater flows into Tieranegra Oxidation Ponds, which has 355 l/s of discharge volume and a 24% of municipal wastewater. But this oxidation pond does not function well. The water quality of influent and effluent of this oxidation pond is shown in Table B.26. The effluent flows into a small lagoon in Marismas. Environmental condition of the lagoon has not been investigated.
- Thirdly, the wastewater is generated in the southern part of Tampico City and Madero City, and is directly discharged into Panuco River without treatment (1,043 l/s, 70.5%). Quality of the municipality wastewater is shown in Table B.27.

Illegal settlers in the three municipalities and Pueblo Viejo Municipality live near lagoons and rivers. The houses of the illegal settlers do not have access to the sewerage system. They use latrines or septic tanks, and wastewater infiltrates into soil.

Three municipal water supply plants (Altamira, Puerta, and Altavista) generate other types of municipal wastewater in the process of filter washing.

- Altamira Water Supply Plant produces 4.9 l/s of wastewater. The water quality of wastewater is shown in Table B.28. The wastewater is discharged into Champayan Lagoon.
- Puerta Water Supply Plant produces 16 l/s of wastewater. The water quality of wastewater is shown in Table B.28. The wastewater is discharged into Puerta Lagoon.

- Altavista Water Supply Plant produces 88 l/s of wastewater. The wastewater is discharged into Canal la Puntilla. Water quality of wastewater from this plant is shown in Table B.27.

b) Pueblo Viejo Municipality

The condition of water supply and wastewater is not clear. Only 680 families (1992) in Cuautemoc (see Figure 2.6 (d)) have access to the drainage system (about 5.7% of Municipality population, according to Comision Municipal de Agua Potable y Saneamiento). This drainage system is connected with an oxidation pond (Cuauhtemoc Oxidation Pond), which is capable to eliminate 81% of BOD_5 in the wastewater. The treated water is discharged over the surface soil and flows toward Pueblo Viejo Lagoon, while most of the water infiltrates into the subsurface. The other residents of Pueblo Viejo Municipality use latrines or septic tanks, letting wastewater directly infiltrate into the ground.

2.3.3 Non-point Pollution Sources

The Study Team identified land use categories for the pollution load analysis. Aerial photographs (1995), topographical map, information from SAGAR (Secretaria de Agricultura, Ganaderia y Desarrollo Rural) and land use map of urban development plan of Southern Panuco River Metropolitan Area. The land use categories are:

ii) Low density residential area: below 400 persons per hectare
iii) Medium density residential area: from 400 to 1000 persons per hectare
iv) Commercial area including Tampico Commercial Port
v) Industrial area including Altamira Industrial Port
vi) Recreational/open lands in urban area
vii) Cropland/pasture area including open lands (agriculture) and shrub, brushland
viii) Streams and lakes
ix) Wetlands (including swamps, mangroves, freshwater marshes, saltwater marshes, and non-vegetated wetlands)

Non-point pollution sources, which contaminates the Tampico Area, are shown in Table 2.8 and described below:

Table 2.8 Non-point Pollution Source and its Area

unit: ha

Land Use Category	Pollution Source Number									
	A/3/4	B/1/7	C/2/1	C/3	C/4/6	C/4/7	C/5/5, C/8/3	C/6	C/7/1	C/9
Low density residential	50	-	60	150	-	510	1278	140	310	90
Medium density residential	-	-	-	-	-	-	267	-	-	-
Commercial	-	-	-	-	-	-	106	-	-	-
Industrial	240	80	-	-	50	-	304	120	-	-
Recreation/open	-	-	-	-	50	-	126	-	-	-
Crop-land/pasture	6550	260	4000	-	-	-	-	580	94100	2130
Lakes and stream	-	-	300	-	-	-	80	-	-	60
Wetland	-	-	1700	-	-	-	-	25	4160	370
Total	6840	340	6060	150	100	510	2161	865	98570	2650

- Watershed of Garrapatas Stream (A/3/4, R): Crop-land/Pasture area are predominant in the watershed of Grarrapatas stream. There are low density residential area (Ricardo Flores Magon) and industrial area (Altamira Industrial Port).
- Watershed of Conejo Lagoon (B/1/7, R): Crop-land/pasture area and industrial area are predominant.
- Watershed of Costa Lagoon (C/2/1, R): wetland and crop-land/pasture are predominant. There are small lagoons and low density residential areas (Moralillo, Panuco Municipality).
- Morelos (Tampico) (C/3, U): its land use is low density residential area.
- Tampico Solid Waste Landfill Site (C/4/6, M): Tampico solid waste landfill site, approximately 32 ha, has been operated since 1991. The landfill site is identified as an industrial area.
- Southwest Part of Tampico (C/4/7, U):its land use is low density residential area.
- Southern Part of Tampico and Southern Part of Madero (C/5/5, U and C/8/3, U): This area consists of low and medium density residential area, commercial area, industrial area, recreational area and a lake.
- Northern Part of Pueblo Viejo Municipality (C/6): This area is consist of low density residential area, crop-land/pasture, and industrial area.
- Watershed of Pueblo Viejo Lagoon (C/7/1): crop-land/pasture is the dominant land use. There are wetland and low density residential area (some part of Pueblo Viejo Municipality).
- Chijol Channel (C/9): Its land use is crop-land/pasture, wetland, lagoon, and low density residential areas.

2.4 Existing Pollution Load Analysis

2.4.1 Methods of Pollution Load Analysis

There are two sources of pollution: point pollution sources and non-point pollution sources. Pollution load has been analyzed separately for point pollution sources and non-point pollution sources. The calculation flow of the pollution load analysis is shown in Figure 2.8.

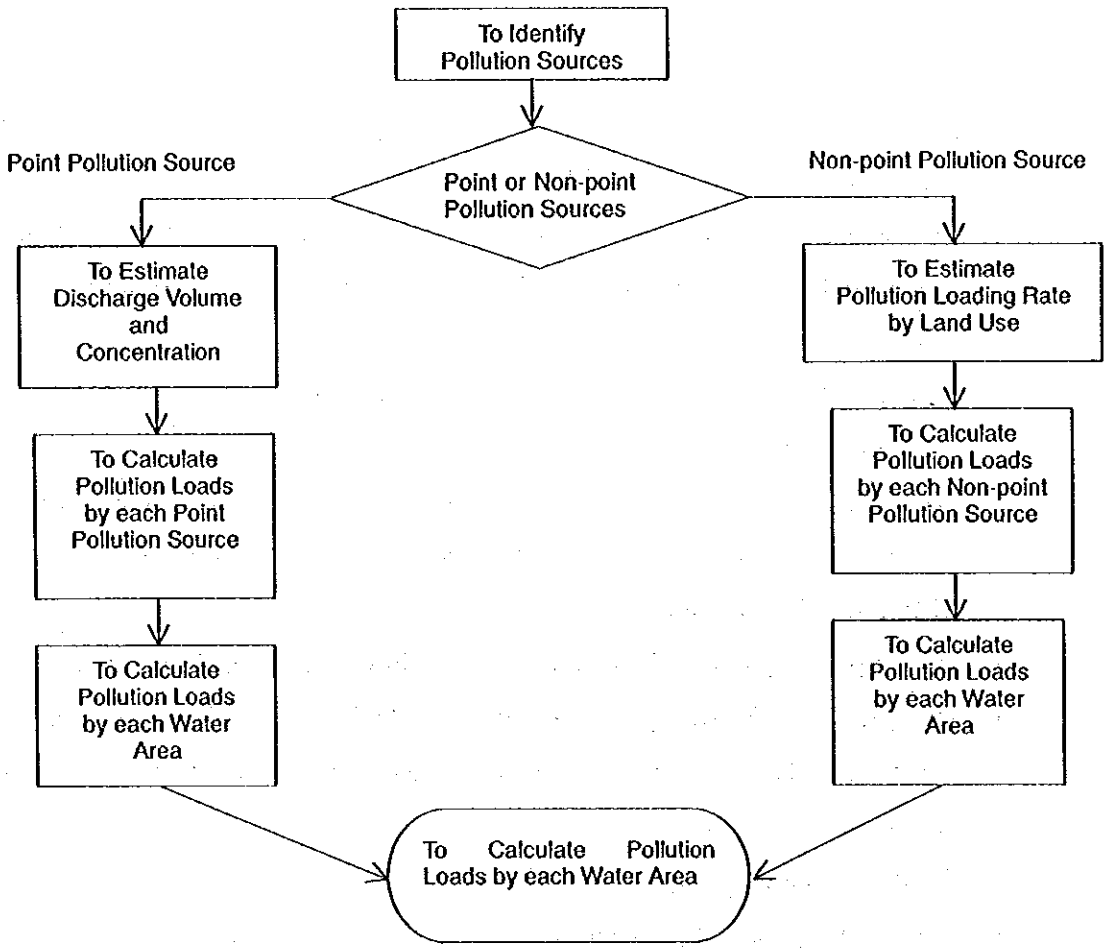


Figure 2.8 Outline of Pollution Load Analysis

(1) Point Pollution Source

Water quality and discharge volume of industrial wastewater were collected from documents of CNA. Data of years 1997 and 1998 were principally used for existing pollution load analysis. But COD has not been measured for industrial wastewater in 1997 and 1998. Some factories did not measure other parameters such as total nitrogen. The lack of data was compensated by the estimation from older data set.

(2) Non-point Pollution Source

The pollution load from non-point pollution source depends on the amount of rainfall. As Tampico Area has dry and rainy seasons, it is necessary to analyze the pollution load separately for the two seasons.

A procedure of the calculation is as follows:

i) Identify land use by each watershed;
ii) Define pollution loading rate;
iii) Calculate pollution loads from non-point pollution sources within each watershed for dry season and rainy season;
iv) Define reduction parameter (R) which depends on physical obstacles and chemical and biochemical transformation on the pathway of pollutant's movement; and
v) Calculate the pollution loads of a water body.

2.4.2 Unit Pollution Load

COD, BOD_5, total nitrogen, and total phosphorus are selected as pollution parameters for the pollution load analysis. Unit pollution load of these parameters by each pollution source is shown below.

(1) Point Pollution Source

Average water quality and discharge volume, which was provided from each factory, are the basis of the calculation.

a) Altamira Industrial Port (A)

Table 2.9 shows the average daily discharge volume and concentration of identified pollutants into the Altamira Industrial Port Area.

Table 2.9 Average Daily Discharge Volume and Concentration of Pollutants into Altamira Industrial Port

Pollution Source Number	Point Pollution Source	Discharge Volume m^3/day	BOD_5 mg/l	COD mg/l	Total Nitrogen Mg/l	Total Phosphorus mg/l	Data
A/1, S	Administracion Portuaria Integral del Altamira	77.0	28.0	117.6	-	-	Table B.6
A/2, I	Pittsburgh Plate Glass(PPG) Industry	3,011	1.2	17.0	-	-	Table B.7
A/3/1, I	POLYCYD	1,037	17.8	39.5*	2.1	0.7	Table B.8
A/3/2, I	Comision Federal De Electricidad	4,771	5.2	81.0**	0.5	1.5	Table B.9
A/3/3, I	NEGROMEX (Planta Solucion)	456	14.8	41.4***	0.7	2.7	Table B.9

* Correlation coefficient: 0.753 from data in 1996 (Table B.8)

** concentration of COD is from data in 1993

***Correlation coefficient: 0.91from data in 1995-1996 Table 2.10

b) Conejo Lagoon (B/1) and Marismas Lagoon (B)

Table 2.10 shows the average daily discharge volume and concentration of identified pollutants into the above lagoons.

Table 2.10 Average Daily Discharge Volume and Concentration of Pollutants into Conejo Lagoon

Pollution Source Number	Point pollution sources	Discharge Volume M3/day	BOD_5 Mg/l	COD mg/l	Total Nitrogen mg/l	Total Phosphorus mg/l	Reference
B/1/1, I	BASF Mexicano	718	34.0	153.2*	21.0**	0.864**	Table B.11
B/1/2, I	Grupo Primex	3,589	511.5	958.8***	2.90	0.46	Table B.12
B/1/3, I	Internacional de Papeles Del Golfo	296	172.0	400.0	-	-	Table B.13
B/1/4, I	Fibras Nacionales de Acrilico	2,386	71.2	138****	19.5	3.3	Table B.14
B/1/5, I	GE Plastic	767	8.9	46.4	-	-	Table B.15 (1995)
B/1/6(1), I	Operadora y Comercializadora Trevi Plus	-	0.8	36.1	-	-	Table B.16
B/1/6(2), I	Johns Manville Industry	7.59	26.4	197.0	-	-	Table B.16
B/1/6(3), I	Tecno Asfalto del Golfo	0.83	125	261	-	-	Table B.16
B/1/6(4), I	Asfaltos y Derivados Mexicanos	1.20	4.2	30.0	-	-	Table B.16

* Average Concentration of COD in 1996 (Table B.11)

**Concentrations of total N and total P are calculated from the data of Jan/1997

*** COD has a correlation with BOD (0.67) from data in 1994-1995 (Table 2.12).

**** COD has a correlation with BOD (0.63) in 1996 (Table 2.14).

c) Panuco River Upstream

The identification of average daily discharge volume and concentration of pollutants in the upstream of Panuco River is shown in Table B.31.

d) Tamesi River and Freshwater Lagoons (C/2)

Tamesi River and its freshwater lagoons are separated from the downstream of

Panuco River by dikes. Dikes No.4, No5, No.6, No.7 and El Bull function to prevent the seawater intrusion from the freshwater system. And the dikes of El Bull, Camalote, and Mata de la Monteada function as water storage.

In order to identify the pollution loads from Tamesi River, it is necessary to take account of dike systems that regulate the discharge volume of the river. Details of the estimation of the discharge volume of Tamesi River are shown in Appendix B.2

Table 2.11 shows the average discharge volume in dry season and rainy season. The average concentration of pollutants is shown in Table B.32.

Table 2.11 Average Discharge Volume in Dry Season and Rainy Season From Tamesi River to Panuco River

Unit: m^3/s

	Jan-94 to Oct-94	Nov-94 to Oct-95	Nov-95 to Oct-95	Nov-96 to Oct-97	Nov-97 to Oct-98	Nov-98 to Dec-98	Average
Dry season	15.1	4.5	2.7	2.4	10.3	43.9	13.9
Rainy season	69.6	40.6	29.9	29.5	40.5		42.0

e) Seafood Processing Industries (C/3/1)

The annual discharge volume and concentration of pollutants from the seafood processing industry are shown in Table 2.12.

f) Municipal Wastewater from Tampico City and Madero City

The daily discharge volume and concentration of pollutants from each discharge point are shown in Table 2.13. In order to estimate the total nitrogen and total phosphorus, pollution parameter ratios based on sampling data by COMAPA were employed (see Table 2.14).

Table 2.12 Annual Discharge Volume and Concentration of Pollutants from Seafood Processing Industries

Parameter	Unit	Camarones de Golfo		Basilio Reynaga Martinez		Restaurant el Pollo Marino
		Discharge 1	Discharge 2	Discharge 1	Discharge 2	
COD	mg/l	312	564	1,008	484	69
BOD_5	mg/l	287	545	935	467	-
Total phosphorus	mg/l	-	-	-	-	-
Kjeldhal N	mg/l	-	-	-	-	-
Annual discharge Volume	m^3/year	207	2,193	1,683	4,862	3,636
Parameter	Unit	Luis Gonzalez Aranda	Impulsora De Pescados y Mariscos	Exportadores Associados	Pescafina Tampico	Francisco Javier Marquez
COD	mg/l	258	203	1,440	2,526	-
BOD_5	mg/l	234	36.8	405	1,860	8.07
Total phosphorus	mg/l	11.8	-	32.5	-	-
Kjeldhal N	mg/l	64	-	-	-	-
Annual discharge Volume	m^3/year	455	14,602	2,400	3,600	2,090

Source: Document on Wastewater Quality and Discharge (CNA)

Table 2.13 Discharge Volume and Concentration of Pollutants from Municipal Wastewater Which Flows into Panuco River

Parameter	Unit	C/4/1, M Planta Altavista	C/4/2, M Carcamo No.1	C/4/3, M Carcamo No.2	C/4/4, M Carcamo No.3	C/4/5, M Bonbas No.6	
COD	mg/l	80	470	400	440	870	
BOD_5	mg/l	55.4	202	188	166	599	
Total nitrogen*	mg/l	-	64.0	57.2	56.0	156	
Total phosphorus*	mg/l	-	8.0	7.2	7.0	19.5	
Flow	m^3/day	7,580	3,161	4,827	2,067	3,751	
	m^3/sec	0.088	0.037	0.056	0.024	0.043	
Parameter	Unit	C/5/1, M Bombas No.1	C/5/2, M Bombas No.7	C/5/3, M Bombas No.8	C/5/4, M Grav. No.12	C/8/1, M Grav. No.11	C/8/2,M Bombas No.9
COD	mg/l	430	550	450	280	470	420
BOD_5	mg/l	320	398	415	125	207	205
Total nitrogen*	mg/l	81.4	102	98.7	39.0	64.9	61.3
Total phosphorus*	mg/l	10.2	12.8	12.3	4.9	8.1	7.7
Flow	m^3/day	34,884	9,725	7,218	1,383	11,383	11,675
	m^3/sec	0.404	0.113	0.084	0.016	0.132	0.135

Source: Document on Wastewater Quality and Discharge (CNA)

Estimated from the data in Table 2.14. (Total nitrogen)=[0.338(BOD_5)+0.127*(COD)]/2

(Total phosphorus) = [0.042*(BOD_5)+0.016*(COD)]/2

Table 2.14 Ratio of Pollution Parameters in Municipal Wastewater of Tampico and Madero in 1993

Ratio of two parameters	
(COD)/(BOD_5)	2.662
(Total Nitrogen)/(BOD_5)	0.338
(Total Phosphorus)/(BOD_5)	0.042
(Total Nitrogen)/(COD)	0.127
(Total Phosphorus)/(COD)	0.016

Source: COMAPA (1994)

g) Cuauhtemoc Oxidation Pond (C/7/2, M)

In Cuauhtemoc, there is a drainage system and an oxidation pond. Most of the discharged water seeps into the soil after treatment, and from the pond, a small pollution load gets into Pueblo Viejo Lagoon. In Lindavista and Mataredonda, there are a few channels to receive the wastewater from this residential zone, but there is no information on quality and quantity of waste discharge (see Figure 2.6 (d)). In dry season, the wastewater does not flow into the Panuco River, and infiltrates into under the ground. In rainy season, the accumulated wastewater and wastes in the channels are discharged into Panuco River. The Cuauhtemoc oxidation pond collects the wastewater from 680 households.

h) Refineria Madero (C/10, I)

The average daily discharge volume and concentration of pollutants from Refineria Madero are shown in Table 2.15. The pollution load unit of COD is estimated based on the correlation between COD and BOD_5 in 1996/1997, which was identified in Tables B.18 and Table B.19, and the average concentration of BOD_5 in Table 2.15.

Table 2.15 Average Daily Discharge Volume and Concentration of Pollutants of Wastewater from Refineria Madero into Panuco River

Parameter	Unit	Siete y Media	Vanadero
BOD_5	mg/l	43.1	99.7
COD*	mg/l	599	1090
Total Nitrogen	mg/l	10.5	57.0
Total Phosphorus	mg/l	0.81	1.03
Discharge	m^3/day	935	5470

i) Industrial wastewater by Quimica del Mar (C/11, I)

This factory does not operate at present.

j) Industrial wastewater flows into the Gulf of Mexico

The average daily discharge volume and concentration of pollutants from the factories are shown in Table 2.16.

Table 2.16 Average Daily Discharge Volume and Concentration of Pollutants from Chemical Factories into Coastal Water

Pollution Source Number	Point Pollution Source	Flow rate	BOD_5	COD	Total N	Total P
		m^3/day	mg/l	mg/l	mg/l	mg/l
D	Petrocel*	8,274	35.8	82.3	0.5	-
E	Novaquim**	348.5	304.2	571.0	58.0	-
F(1)	Negromex ***	2,648	63.1	487.2	21.5	-
F(2)	NHUMO	681	51.0	100.0	3.0	-
G	Dupont****	5,721	21.0	-	-	-

* Data from Nov/95 to Jan/97
** Data from Jan/96 to Dec/96
*** Data from Apr/95 to Oct/95
**** Data from Dec/92 to Mar/93

(2) Non-Point Pollution Sources

There is no available information in terms of the pollution loading rate by non-point pollution sources in Mexico. Therefore, pollution loading rates, which were applied in Florida (USA), were employed for this analysis. Mean annual rainfall around the rivers of St. Marks and Wakalla in Florida is 1473 mm. Mean annual rainfall in Tampico City and adjacent area is 1077 mm. The pollution loading rates are modified in proportion to the precipitation (see Table 2.17). The pollution loading rate of COD is estimated by the following equations:

For urban area

(Pollution loading rates of COD) = 1.9 x (Pollution load rates of BOD_5)

(Stormwater Public Information of City of Shreveport, Louisiana, 1999)

For rural area

(Pollution loading rates of COD) = 3 x (Pollution load rates of BOD_5)

(Based on data from small rivers in Panuco River system, Puente el Naranjo (El Salto River), and Cementos Anahuac (Choy River))

Table 2. 17 Pollution Loading Rates for Non-point Pollution Sources

Land Use	T-N (kg/ha/year)	T-P (kg/ha/year)	BOD (kg/ha/year)	COD* (kg/ha/year)
Low density residential	4.72	0.61	13.21	25.10
Medium density residential	8.28	1.34	30.51	57.96
Commercial	17.29	2.57	107.29	203.85
Industrial	14.67	2.54	78.68	149.49
Recreation/open	2.26	0.10	2.62	4.98
Crop-land/pasture	7.29	1.08	11.94	35.83
Lakes and stream	6.75	0.57	8.76	26.29
Wetland	3.72	0.44	10.93	32.78
Spoil/barren	3.33	0.33	19.22	57.66

* COD is estimated from BOD_5: pollution load rate of COD is 1.9 times (urban) and 3 times (rural) larger than that of BOD_5.
Source: St.Marks and Wakulla Rivers Resource Assessment and Greenway Protection Plan (1994) (Pollution load rates are corrected in proportion to precipitation)

2.4.3 Pollution Load Analysis by Each Point Pollution Point Source

(1) Point Pollution Sources

Table 2.18 shows the daily discharge volume and daily pollution loads from each point pollution source of municipal wastewater and independent industrial wastewater.

The daily discharge volume and daily pollution loads from Panuco River Upstream and Tamesi River are shown in Table 2.19 (in dry season) and in Table 2.20 (in rainy season). Detailed information is shown in Table B.29 (industries whose wastewater is discharged into Altamira Industrial Port), A.30 (industries whose wastewater is discharged into Conejo Lagoon), A.31 (Panuco River Upstream), A.32 (Tamesi River), A.33 (sea-food processing industries), A.34 (municipal wastewater into Panuco River), A35 (Refineria Madero), and A.36 (industries whose wastewater is discharged into the coastal water of Gulf of Mexico)

(2) Non-point Pollution Sources

Pollution loads from the following non-point pollution sources are identified in Table 2.19 for dry season and in Table 2.20 for rainy season.

Detailed information is shown in Table B.37 (watershed of Garrapatas Stream), A.38 (watershed of Conejo Lagoon), A.39 (watershed of Costa Lagoon), A.40 (Morelos), A.41 (Tampico solid waste landfill site), A.42 (southwestern part of Tampico), A.43 (southern part of Tampico and southern part of Madero), A.44 (northern part of Pueblo Viejo), A.45 (watershed of Pueblo Viejo Lagoon), and A.45 (Chijol Channel).

Table 2.18 Daily Discharge Volume and Daily Pollution Loads in Industrial and Municipal Wastewater at Present

Pollution Source Number	Pollution Source	Daily discharge volume (m^3/day)	Daily Pollution Load (kg/day)			
			BOD_5	COD	Total nitrogen	Total Phosphorus
A/1	API-Altamira	77	2.1	9.1	-	-
A/2	PPG Industry	3,010	3.6	51.2	-	-
A/3/1	POLYCYD	1,040	18.5	41.0	2.2	0.77
A/3/2	CFE	4,770	25.0	386	2.5	7.09
A/3/3	NEGROMEX	456	6.7	18.9	0.3	1.25
B/1/1	BASF	718	24.4	110	15.1	0.62
B/1/2	Grupo Primex	3,590	1,840	3,440	10.4	1.64
B/1/3	Internacional de Papeles del Golfo	296	52.1	118	-	-
B/1/4	Finacril	2,390	170	329	46.6	7.95
B/1/5	GE Plastic	767	6.8	35.6	-	-
B/1/6(2)	Johns Manville Industry	7.59	0.2	1.5	-	-
B/1/6(3)	Tecno Asfalto del Golfo	0.83	0.1	0.2	-	-
B/1/6(4)	Asfaltos y Derivados Mexicano	1.20	0.005	0.036	-	-
C/3/1	Sea-food Processing Industries	250	110	202	-	-
C/4/1	Altavista Water Supply Plant	7,580	420	606	-	-
C/4/2	Carcamo No.1	3,160	639	1,490	202	25
C/4/3	Carcamo No.2	4,830	909	1,930	276	35
C/4/4	Carcamo No.3	2,070	344	909	116	14
C/4/5	Bombas No.6	3,750	3,260	3,260	587	73
C/5/1	Bombas No.1	34,880	11,200	15,000	2,840	356
C/5/2	Bombas No.7	9,730	3,870	5,350	994	124

Table 2.18 (Cont'd) Daily Discharge Volume and Daily Pollution Loads in Industrial and Municipal Wastewater at Present

Pollution Source Number	Pollution Source	Daily discharge volume (m^3/day)	Daily Pollution Load (kg/day)			
			BOD_5	COD	Total nitrogen	Total Phosphorus
C/5/3	Bombas No.8	7,220	3,000	3,250	712	89
C/5/4	Grav. No.12	1,380	173	387	54	6.8
C/7/2	Cuauhtemoc Oxidation Pond	-	-	-	-	-
C/8/1	Grav. No.11	11,383	2,360	5,350	739	92
C/8/2	Bombas No.9	11,675	2,390	4,904	716	90
C/10(1)	Refineria Madero (Siete y Media)	935	40	560	9.8	0.75
C/10(2)	Refineria Madero (Vanadero)	5,470	545	6,540	312	5.61
D	Petrocel	8,270	296	681	4.5	-
E	Novaquim	349	106	199	20.2	-
F(1)	NEGROMEX	2,650	167	1290	57	-
F(2)	NHUMO	681	34	68.1	2	-
G	Dupont	5,720	120			-

Source: CNA

Table 2.19 Daily Discharge Volume and Daily Pollution Load from Rivers and Non-point Pollution Sources in Dry Season at Present

Pollution Source Number	Pollution Source	Daily discharge volume (m^3/day)	Daily Pollution Load (kg/day)			
			BOD_5	COD	Total nitrogen	Total phosphorus
A/3/4	Watershed of Garrapatas Stream	-	27.1	68.6	11.7	1.78
B/1/7	Watershed of Conejo Lagoon	-	4.36	8.95	1.07	0.18
C/1	Panuco River Upstream	16,000,000	29,000	332,000	12,600	1,440
C/2	Tamesi River	1,200,000	2,280	18,300	967	89
C/2/1	Watershed of Costa Lagoon	-	22.5	67.1	10.9	1.43
C/3	Morelos	-	1.18	2.24	0.421	0.054
C/4/6	Tampico Solid Waste Landfill Site	-	4.00	7.61	1.43	0.18
C/4/7	Southwest Part of Tampico City	-	2.42	4.59	0.503	0.078
C/5/5 And C/8/3	Southern Part of Tampico City and Southern Part of Madero City	-	36.5	69.7	9.13	1.33
C/6	Northern Part of Pueblo Viejo Municipality	-	7.85	16.5	2.22	0.35
C/7/1	Watershed of Pueblo Viejo Lagoon	-	134	400	74.3	10.8
C/9	Chijol Channel	-	8.06	23.4	4.18	0.58

Table 2.20 Daily Discharge Volume and Daily Pollution Loads from Rivers and Non-point Pollution Sources in Rainy Season at Present

Pollution Source Number	Pollution source	Daily discharge volume (m^3/day)	Daily pollution load (kg/day)			
			BOD_5	COD	Total nitrogen	Total phosphorus
A/3/4	Watershed of Garrapatas Stream	-	141	357	60.9	9.3
B/1/7	Watershed of Conejo Lagoon	-	22.7	47	5.59	0.92
C/1	Panuco River Upstream	66,600,000	68,000	1,645,000	17,500	9,930
C/2	Tamesi River	3,630,000	4,260	59,300	2,250	265
C/2/1	Watershed of Costa Lagoon	-	118	350	56.9	7.4
C/3	Morelos	-	6.14	11.7	2.19	0.28
C/4/6	Tampico Solid Waste Landfill Site	-	20.9	39.7	7.46	0.96
C/4/7	Southwest Part of Tampico City	-	12.6	23.9	2.62	0.41
C/5/5 And C/8/3	Southern Part of Tampico City and Southern Part of Madero City	-	190	364	47.6	6.92
C/6	Northern Part of Pueblo Viejo Municipality	-	43.5	91.6	12.3	1.9
C/7/1	Watershed of Pueblo Viejo Lagoon	-	743	2,220	412	60
C/9	Chijol Channel	-	44.7	130	23.1	3.2

(3) Total Amount of Pollution Load

a) Altamira Industrial Port Area (A)

Daily discharge volume and pollution loads of COD, BOD_5, total nitrogen, and total phosphorus from pollution sources into Altamira Industrial Port are shown in Figures B.1, B.2, B.3, B.4 and B.5, respectively. Figure 2.9 shows an outline of daily pollution loads in this area.

- Discharge volume

Watershed area and rainfall data indicate that daily discharge volume of Garrapatas Stream is 35,000 – 140,000 m^3/day in rainy season, and 5,000 – 20,000 m^3/day in dry season. In dry season, Polycyd, the thermal power plant, and Negromex release the major discharge volume into Garrapatas Stream. Daily discharge volume of point pollution sources are shown in Figure B.1. The thermal power plant discharges 4,771 m^3/day of wastewater (51% of total discharge volume from point sources). Pittsburgh Plate Glass Industry discharges 3011 m^3/day (32% of total discharge volume from point sources).

- COD

Pollution load of COD from point pollution sources is 88% in dry season and 59 % in rainy season, or 73% in a whole year. The major source of COD into Altamira Industrial Port is the thermal power plant (67% in dry season and 45% in rainy season, or 55% in a whole year).

- BOD_5

Pollution load of BOD_5 from point pollution sources is 67% in dry season, 28% in rainy season, and 43% in a whole year. The major sources of BOD_5 are Polycyd and the thermal power plant.

- Total nitrogen

No information on pollution load of total nitrogen from Administracion Portuaria Integral del Altamira and Pittsburgh Plate Glass Industry has been obtained. Normally pollution load of total nitrogen is lower than BOD_5. Taking this condition into account, Pittsburgh Plate Glass (PPG) Industry is supposed to discharge the same or lower level of total nitrogen than that of Polycyd. Pollution load of total nitrogen from point pollution sources is 30% in dry season and 8% in rainy season, or 13% in a whole year, if the pollution load from PPG Industry is not considered. Major sources of nitrogen are non-point pollution sources.

- Total phosphorus

Information on pollution load of phosphorus from Administracion Integral del Altamira and PPG Industry has not been obtained. Normally pollution load of phosphorus is lower than that of total nitrogen. The major source of total phosphorus is the thermal power plant.

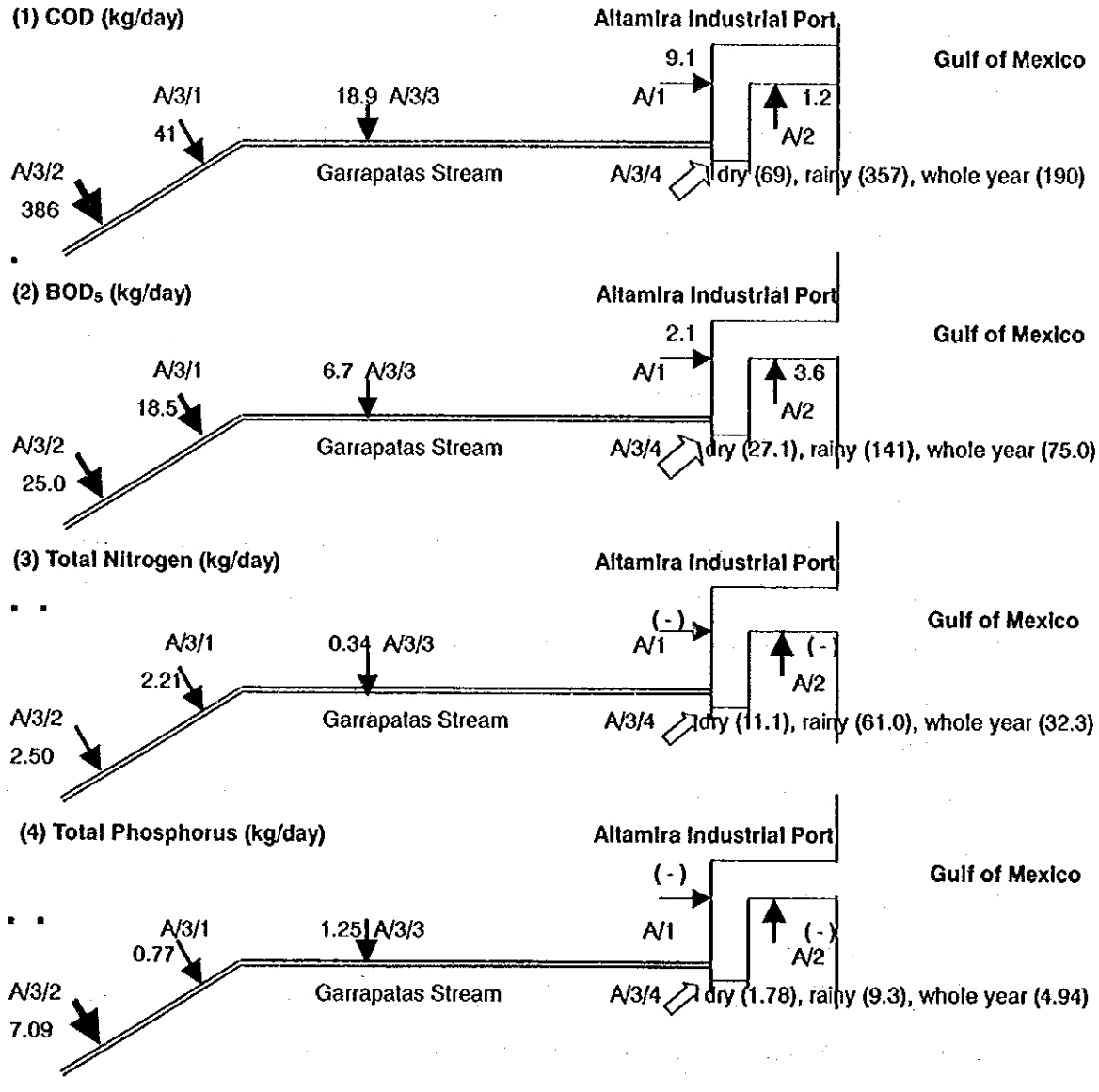


Figure 2. 9 Daily Pollution Loads into Altamira Industrial Port

b) Conejo Lagoon (B/1)

Daily discharge volume, daily pollution loads of COD, BOD_5, total nitrogen, and total phosphorus from pollution sources into Conejo Lagoon are shown in Figures B.6, B.7, B.8, B.9 and B.10, respectively. Figure 2.10 shows an outline for pollution loads in Conejo Lagoon.

- Discharge volume

Information on discharge volume from watershed to Conejo Lagoon has not been obtained. Daily discharge volume from point pollution sources into Conejo Lagoon is shown in Figure B.6. The major sources are Grupo Primex (46%) and Fibras Nacionales de Acrilico (31%). Total discharge volume from point pollution sources to Conejo Lagoon (7766 m^3/day) is lower than that to Altamira Industrial Port (9286 m^3/day). Discharge volume from Small and Medium Sized Industrial Estate (B/1/6) is much less than that of large industries near Conejo Lagoon.

- COD

Daily pollution load of COD from point pollution sources is 99.8% in dry season and 98.9% in rainy season, or 99.4% in a whole year. The major source is Grupo Primex (about 84 – 85%). Total pollution load of COD from point pollution sources to Conejo Lagoon (4035 kg/day) is much larger than that from point pollution sources to Altamira Industrial Port (498 kg/day).

- BOD_5

Daily pollution load of BOD_5 from point pollution sources is more than 99% of total daily pollution load. A major source is Grupo Primex (about 87%). Total daily pollution load of BOD_5 from point pollution sources to Conejo Lagoon (2090 kg/day) is much larger than that from point pollution sources to Altamira Industrial Port (54 kg/day).

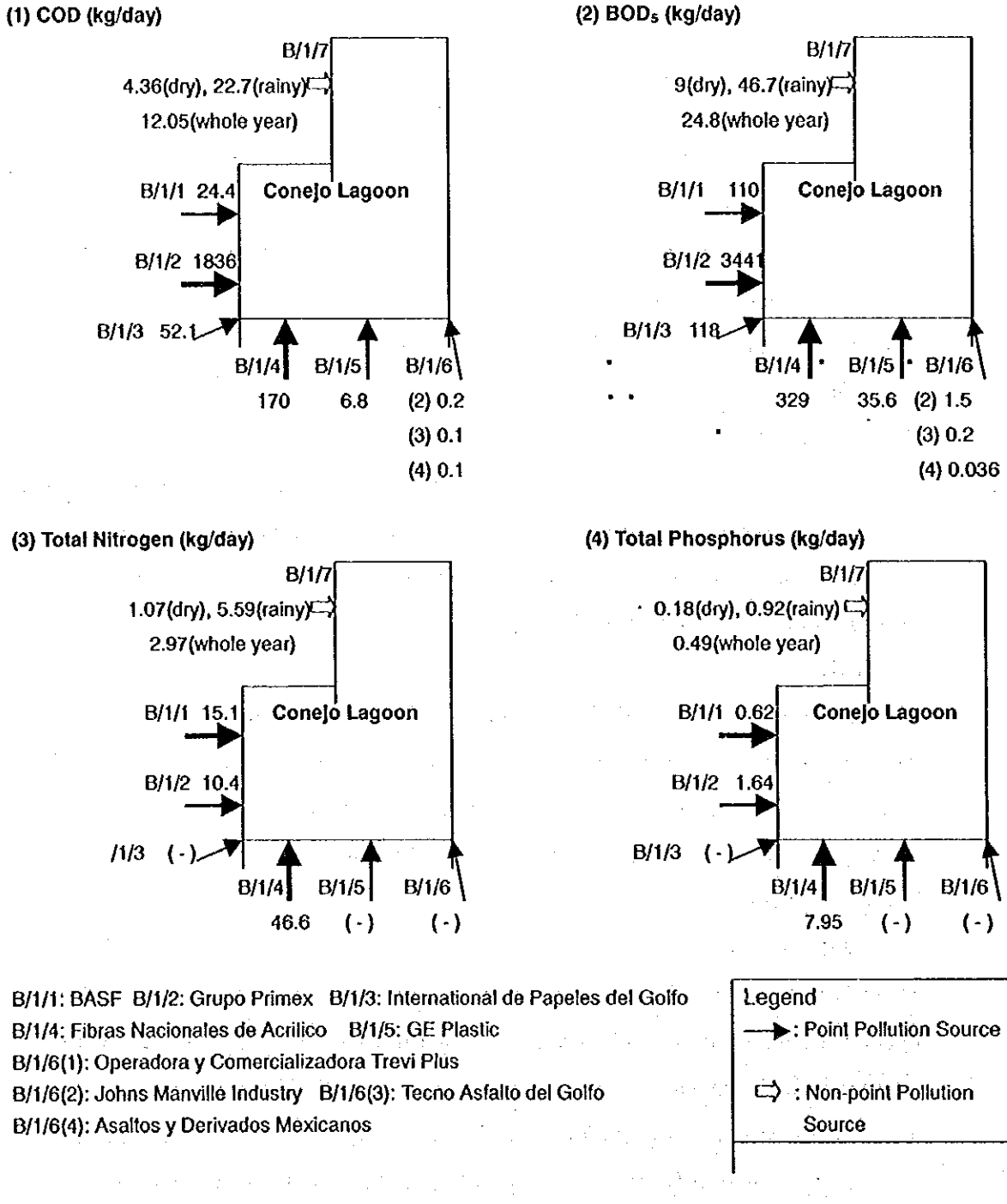
- Total nitrogen

There is little information on total nitrogen from point pollution sources to Conejo Lagoon. Generally daily pollution load of total nitrogen is lower than that of BOD_5. Internacional de Papeles del Golfo may discharge pollution load of total nitrogen lower than BASF. Daily pollution load of total nitrogen from point pollution sources may be lager than 90% of total daily pollution load of total nitrogen. The major source is Fibras Nacionales de Acrilico.

- Total phosphorus

There is little information on total phosphorus from point pollution sources to Conejo

Lagoon. Generally daily pollution load of total phosphorus is lower than that of total nitrogen. Internacional de Papeles del Golfo may discharge pollution load of total phosphorus less than Grupo Primex. Daily pollution load from point pollution sources is larger than 90% of the total load. A major source is Fibras Nacionales de Acrilico.



B/1/1: BASF B/1/2: Grupo Primex B/1/3: International de Papeles del Golfo
B/1/4: Fibras Nacionales de Acrilico B/1/5: GE Plastic
B/1/6(1): Operadora y Comercializadora Trevi Plus
B/1/6(2): Johns Manville Industry B/1/6(3): Tecno Asfalto del Golfo
B/1/6(4): Asaltos y Derivados Mexicanos

Figure 2.10 Daily Pollution Loads into Conejo Lagoon

c) Panuco River

Daily discharge volume (flow rate), daily pollution loads of COD, BOD_5, total nitrogen, and total phosphorus from pollution sources into Panuco River in dry season, in rainy season, and in a whole year are shown in Tables B.47, B.50, and B.53, respectively. Percentage of pollution loads from pollution sources in dry season, in rainy season, and in a whole year are shown in Table B.48, B.51, and B.54, respectively. Here, pollution loads from Costa Lagoon, Pueblo Viejo Lagoon, and Chijol Channel to Panuco River are not considered, because their pollution load is very small in the total pollution loads into Panuco River and tide effect makes the distribution of pollution load complex.

- Discharge volume

Rivers (upstream of Panuco River and Tamesi River) discharge more than 99.4% in total discharge volume. Municipal wastewater discharges from Tampico and Madero are 0.52% in dry season and 0.13% in rainy season, or 0.23% in a whole year. Altavista Water Supply Plant and Refineria Madero discharges 0.04% in dry season and 0.01% in rainy season, or 0.02% in a whole year.

- COD

The percentages of daily pollution load of COD from major pollution sources are illustrated in Figure 2.11 (1) (in dry season), 6.11 (2) (in rainy season), and 6.11 (3) (in whole year). Daily pollution load of COD from the upstream of Panuco River is 83.5% in dry season, 93.9% in rainy season, and 91.4% in whole year. Municipal wastewater discharges of COD from Tampico and Madero are 10.5% in dry season, 2.38% in rainy season, and 4.33% in a whole year. Tamesi River discharges 4.61% in dry season, 3.38% in rainy season, and 3.68% in a whole year. Daily pollution load of COD from Refineria Madero is 1.13% in dry season and 0.26% in rainy season, or 0.46% in a whole year. Pollution load of COD from non-point pollution sources is 0.03% as shown in Tables B.49 (in dry season), B.52 (in rainy season), and B.55 (in a whole year). Pollution load of COD from point pollution sources into Panuco River is twelve times larger than that into Conejo Lagoon.

- BOD_5

The percentages of daily pollution load of BOD_5 from major pollution sources are illustrated in Figure 2.11 (1) (in dry season), 2.11 (2) (in rainy season), and 2.11 (3) (in a whole year). Daily pollution load of BOD_5 from the upstream end of Panuco River is 48.7% in dry season and 67.5% in rainy season, or 59.0% in a whole year.

Municipal wastewater discharges of BODs from Tampico and Madero are 45.5% in dry season and 26.9% in rainy season, or 35.3% in a whole year. Tamesi River discharges 3.84% in dry season and 4.23% in rainy season, or 4.05% in a whole year. Refineria Madero discharges 0.98% in dry season and 0.58% in rainy season, or 0.76% in a whole year. Daily pollution load from non-point pollution sources is 0.09% in dry season (Table B.49) and 0.27% in rainy season (Table B.52), or 0.19% in a whole year (Table B.55). Pollution load of BOD_5 from point pollution sources into Panuco River is thirteen times larger than that into Conejo Lagoon.

- Total nitrogen

The percentages of daily pollution load of total nitrogen from major pollution sources are illustrated in Figure 2.11 (1) (in dry season), 6.11 (2) (in rainy season), and 6.11 (3) (in a whole year). The upstream end of Panuco River discharges 59.5% of total nitrogen in dry season and 63.8% in rainy season, or 61.5% in a whole year. Total nitrogen from the municipal wastewater of Tampico and Madero is 34.2% in dry season, 26.4% in rainy season, and 30.5% in a whole year. Tamesi River discharges 4.57% in dry season, 8.21% in rainy season, and 6.32% in a whole year. Refineria Madero discharges 1.52% in dry season, 1.17% in rainy season, and 1.35% in a whole year. Daily pollution load from non-point pollution sources is 0.06% in dry season (Table B.49), 0.26% in rainy season (Table B.52), and 0.16% in a whole year (Table B.55). Daily pollution load of total nitrogen from point pollution sources into Panuco River is 100 times larger than that into Conejo Lagoon.

- Total phosphorus

The percentages of daily pollution load of total phosphorus from major pollution sources are illustrated in Figure 2.11(1) (in dry season), 6.11(2) (in rainy season), and 6.11 (3) (in a whole year). The upstream end of Panuco River discharges 58.8% of total phosphorus in dry season and 89.3% in rainy season, or 82.2% in a whole year. Daily loads from the wastewater of Tampico and Madero is 37.0% in dry season and 8.15% in rainy season, or 14.9% in a whole year. Tamesi River discharges 3.63% in dry season and 2.38% in rainy season, or 2.68% in a whole year. Refineria Madero discharges 0.26% in dry season and 0.06% in rainy season, or 0.11% in a whole year. Daily pollution load of total phosphorus from non-point pollution sources is 0.08% in dry season (Table B.49) and 0.09% in rainy season (Table B.52), or 0.09% in a whole year Table B.55). Daily pollution load of total phosphorus from point pollution sources into Panuco River is 90 times larger than that into Conejo Lagoon.

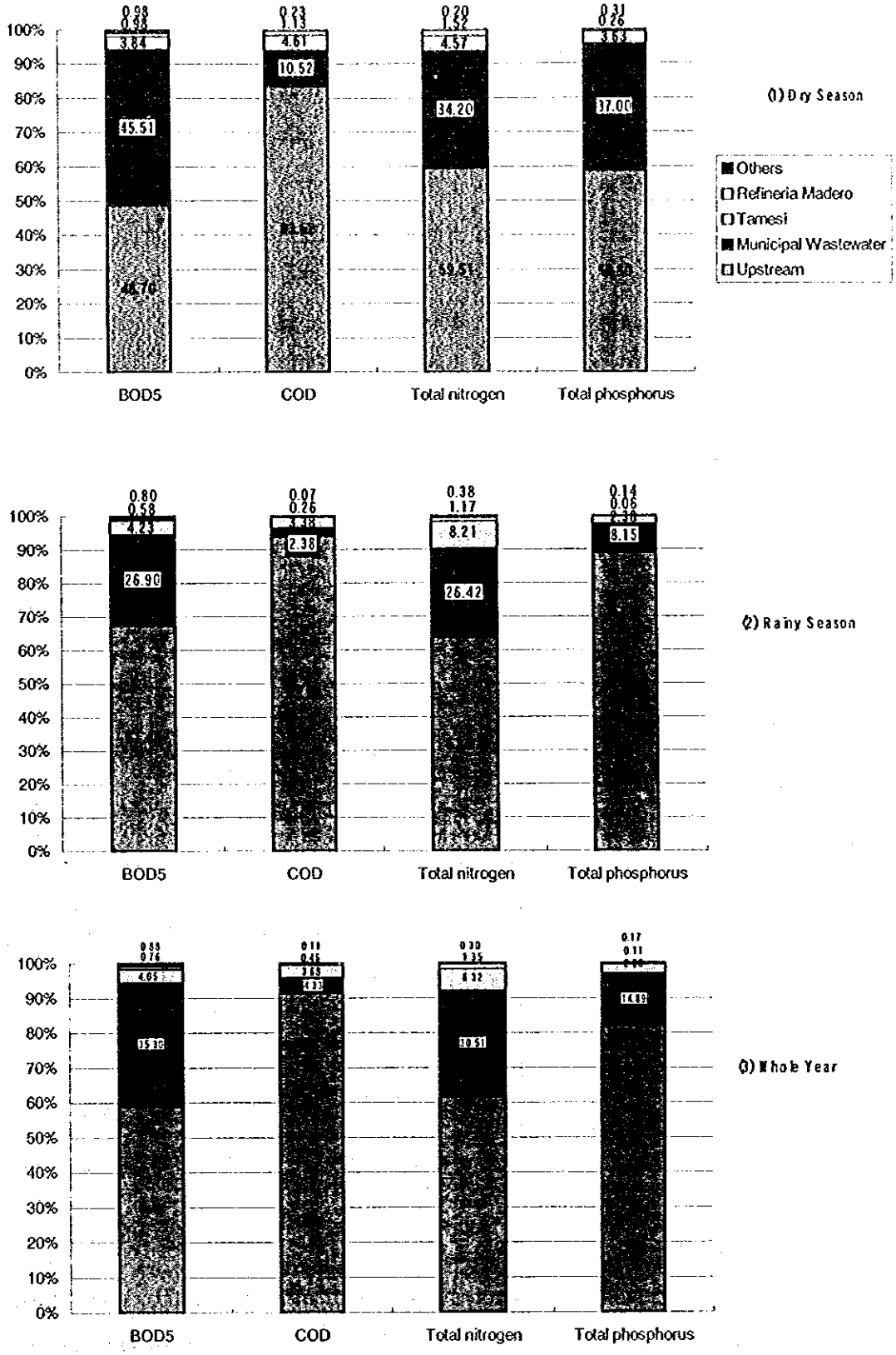


Figure 2.11 Principal Sources on Pollution Load into Panuco River

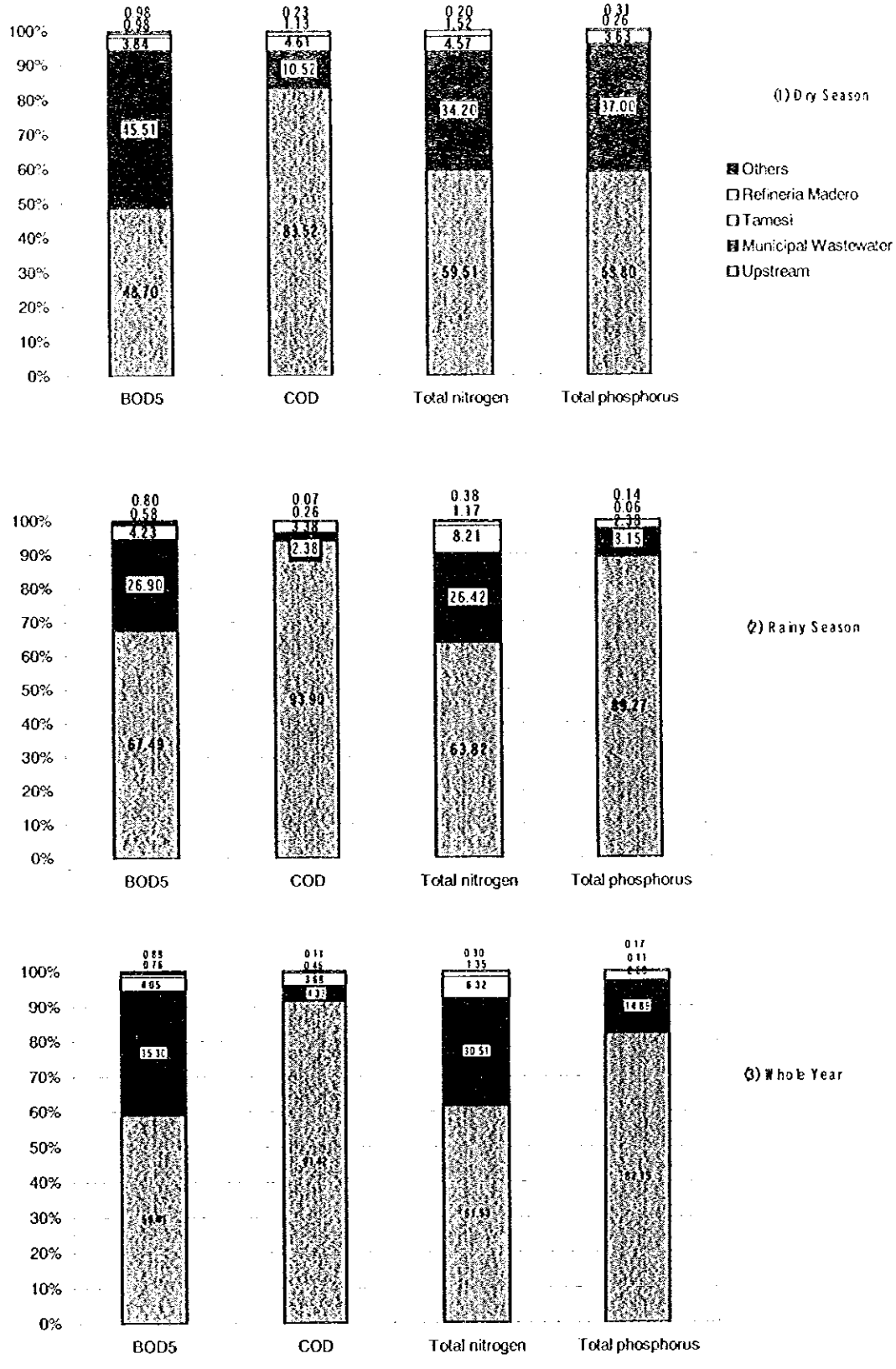


Figure 2.11 Principal Sources on Pollution Load into Panuco River

d) Pueblo Viejo Lagoon

Daily pollution loads of COD, BOD_5, total nitrogen, and total phosphorus from pollution sources into Pueblo Viejo Lagoon are shown in Table 2.21. The majority of people in Pueblo Viejo Municipality use septic tanks and latrines. Some part of wastewater is discharged into channels and dried up except under heavy rains. This type of wastewater infiltrates into soil. Pollution load from this type of wastewater and from Panuco River is not considered in Table 2.21. Daily pollution loads from Cuauhtemoc oxidation pond into Pueblo Viejo Lagoon is negligible at present, because most treated effluent from Cuauhtemoc Oxidation Pond infiltrates into the ground. Most of the daily pollution loads come from non-point pollution sources at present except those from Panuco River.

Table 2.21 Pollution Loads from Point and Non-Point Sources to Pueblo Viejo Lagoon

Pollution Source Number	Pollution Source	Type	BOD_5		COD		Total Nitrogen		Total Phosphorus	
			(kg/day)	(%)	(kg/day)	(%)	(kg/day)	(%)	(kg/day)	(%)
(Dry Season)										
C/7/2	Cuauhtemoc Oxidation Pond	Point	negligible							
C/7/1	Watershed of Pueblo Viejo Lagoon	Non-point	134	100.0	400	100.0	74.3	100.0	10.75	100.0
	Total		134	100.0	400	100.0	74.3	100.0	10.75	100.0
(Rainy Season)										
C/7/2	Cuauhtemoc Oxidation Pond	Point	negligible							
C/7/1	Watershed of Pueblo Viejo Lagoon	Non-point	743	100.0	2,215	100.0	412	100.0	60	100.0
	Total		743	100.0	2,215	100.0	412	100.0	60	100.0
(Whole Year)										
C/7/2	Cuauhtemoc Oxidation Pond	Point	negligible							
C/7/1	Watershed of Pueblo Viejo Lagoon	Non-point	389	100.0	1,161	100.0	216	100.0	31.4	100.0
	Total		389	100.0	1,161	100.0	216	100.0	31.4	100.0

c) Coastal Area

Daily discharge volume, daily pollution loads of COD, BOD_5, total nitrogen, and total phosphorus from pollution sources into the coastal area of Gulf of Mexico are shown in Table B.56 for dry season, Table B.57 for rainy season, and Table B.58 for a whole year. Figure 2.12 shows an outline of daily pollution loads in this area.

- Discharge volume

The majority of daily discharge volume is from Panuco River as shown in Tables B.56, B.57, and B.58.

- COD

Most of daily pollution load of COD is from Panuco River as shown in Figure 2.12 (1). The concentration of COD in the river mouth of Panuco River is similar to that of the junction with Tamesi River. Daily pollution load of COD from the wastewater of Petrocel (D), Novaquim(E), Negromex (F), NHUMO (F) and Dupont (G) is much smaller than that from Panuco River.

- BOD_5

Most of daily pollution load of BOD_5 is from Panuco River as shown in Figure 2.12 (2). Discharges from upstream of Panuco River and Tampico - Madero urban areas determine the concentration of BOD5 in the river mouth of Panuco River. Pollution load of BOD_5 from the wastewater of Petrocel (D), Novaquim(E), Negromex (F), NHUMO (F) and Dupont (G) is much smaller than that from Panuco River.

- Total nitrogen

Most of daily pollution load of total nitrogen is from Panuco River as shown in Figure 2.12 (3). Discharges from upstream of Panuco River and Tampico – Madero urban areas determine the concentration of total nitrogen in the river mouth of Panuco River. Pollution load of total nitrogen from the wastewater of Petrocel (D), Novaquim(E), Negromex (F), NHUMO (F) and Dupont (G) is much smaller than Panuco River.

- Total phosphorus

Most of daily pollution load of total phosphorus is from Panuco River as shown in Figure 2.12 (4). The discharge from Panuco River Upstream and Tampico – Madero urban areas determine the concentration of total phosphorus in the river mouth of Panuco River. Information on pollution load of total phosphorus from Petrocel, Novaquim, Negromex, and NHUMO and Dupont has not been obtained.

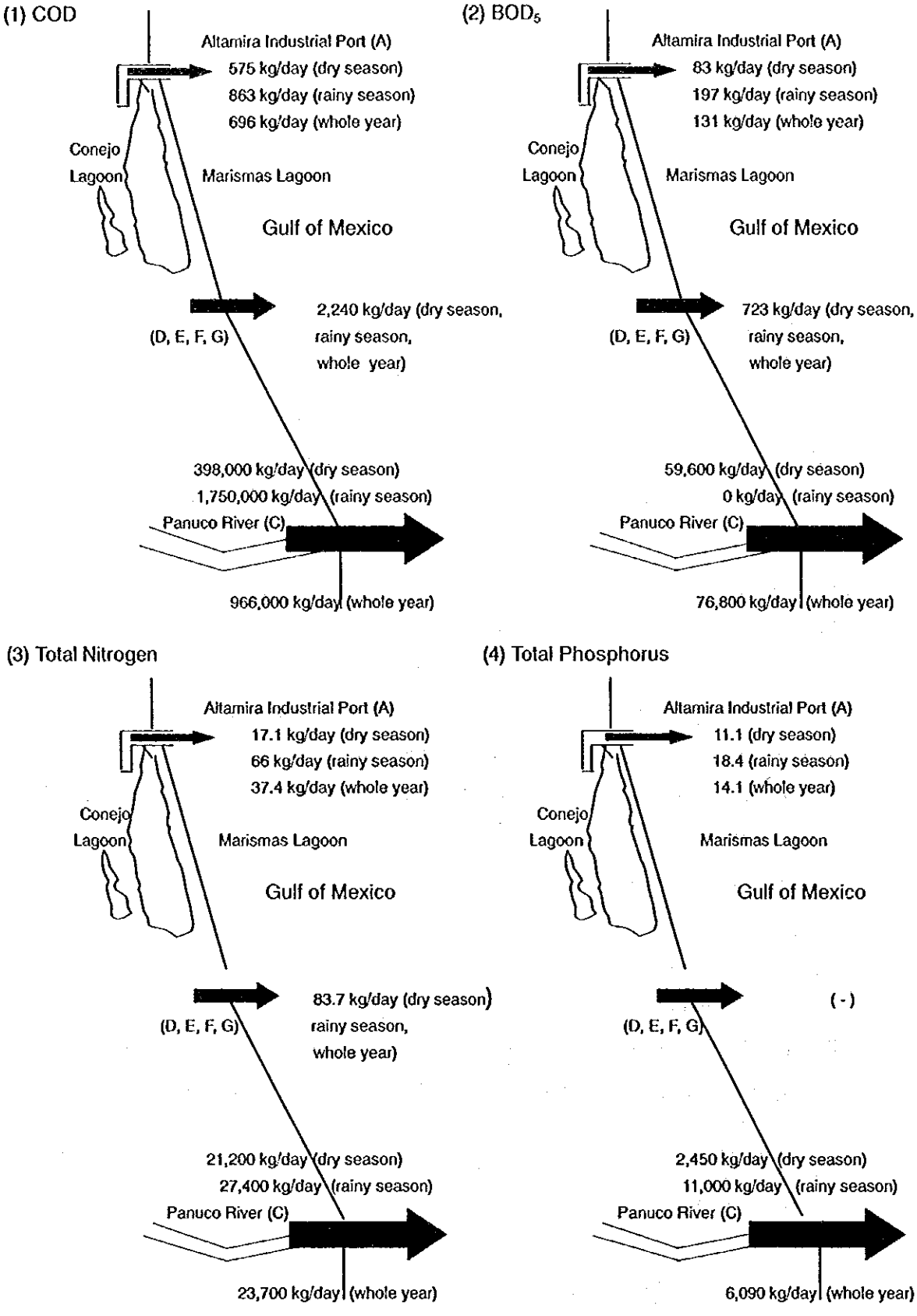


Figure 2.12 Daily Pollution Loads into the Coastal Area of Gulf of Mexico