JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
STATE WORKING GROUP FOR CLEANING UP, CONSERVATION AND DEVELOPMENT FOR THE HAVANA BAY (GTE)
THE REPUBLIC OF CUBA

# THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY IN THE REPUBLIC OF CUBA

# FINAL REPORT

## VOLUME II MAIN REPORT

MARCH 2004

NIHON SUIDO CONSULTANTS CO., LTD.

# THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY IN THE REPUBLIC OF CUBA

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# VOLUME III SUPPORTING REPORT

## ABBREVIATION

| | | |
|---|---|---|
| B/C | = | Benefit Cost Ratio |
| CAP | = | Provincial Administrative Council |
| CAR | = | Cartagena convention |
| CECM | = | Executive Committee of the Council of Ministers |
| CENHICA | = | National Center for Hydrology and Water Quality |
| CIMAB | = | Cuba's Center for Engineering and Environmetal Management of Bays and Coastal Zones |
| CITMA | = | Delegation of the Ministry for Science, Technology and the Environment in Havana City |
| DISM | = | Directorate of Marine Security and Protection |
| DPRH/Havana-City | = | Provincial Delegation of Resources of Havana City of the National Institute for Hydraulic Resources |
| EAH | = | Enterprise of Hydraulic Usage |
| EIA | = | Environmental Impact Assessment |
| EIRR | = | Economic Internal Rate of Return |
| FIRR | = | Financial Internal Rate of Return |
| GDP | = | Gross Domestic Product |
| GEF | = | Global Environmental Facility |
| GNP | = | Growth National Product |
| GOC | = | Government of the Republic of Cuba |
| GOJ | = | Government of Japan |
| GTE | = | State Working Group for Cleaning Up, Conservation and Development for the Havana Bay |
| IDB | = | Inter-American Development Bank |
| IMF | = | International Monetary Fund |
| INRH | = | National Institute of Water Resources |
| ISO | = | International Standards Organization |
| JBIC | = | Japan Bank of International Cooperation |
| JICA | = | Japan International Cooperation Agency |
| LBS | = | Land Based Sources |
| MINAG | = | Ministry of Agriculture |
| MINBAS | = | Ministry of Basic Industry |
| MININT | = | Ministry of the Interior |
| MINSAP | = | Ministry of Health |
| MINTRANS | = | Ministry of Transport |
| MINVEC | = | Ministry of Foreign Investment and Economic Collaboration |
| MIP | = | Ministry of Fisheries |
| MIZC | = | Integrated Management of Coastal Zones |

| | | |
|---|---|---|
| NC | = | Norma Cubanas (National Standard) |
| NGO | = | Non-Governmental Organization |
| NPV | = | Net Present Value |
| O/M, O&M | = | Operation and Maintenance |
| ONAT | = | National Office of Tax Administration |
| Ps | = | Cuban Peso |
| ROA | = | Return on Assets |
| SAMARP | = | National Company for Port Sanitation |
| SCF | = | Standard Conversion Factor |
| SERF | = | Shadow Exchange Rate Factor |
| SWRF | = | Standard Wage Rate Factor |
| UNDP | = | United Nations Development Programme |
| UNEP | = | United Nations Environment Programme |
| UNESCO | = | United Nations Education and Scientific Organization |
| UNICEF | = | United Nations Children’s Fund |
| USA | = | United States of America |
| WRC | = | Wider Caribbean Region |
| WS & S | = | Water Supply & Sewerage |
| WTA | = | Willingness to Accept |
| WTP | = | Willingness to Pay |
| WWTP | = | Wastewater Treatment Plant |

# PART I

## MASTER PLAN

# CHAPTER 1
# INTRODUCTION

## 1.1 BACKGROUNDS

Ciuda de La Habana Province where Study Area is situated, the largest city in the Caribbean, is Cuba's political, cultural and economic center. The total estimated population is about 2,188,000 in year 2000, which represents about 20 % of the total population of 12,000,000 in Cuba.

Havana Bay with an area of 5.0 $km^2$, an average water depth of 9 meters, and a capacity of 47 million $m^3$, plays very important role as commercial seaport and tourist attractions. The extent of the basin is 68 $km^2$. The estimated population within the Havana Bay basin is about 800,000 in 2000, which represents 37% of population of Ciudad de La Habana Province. Due to the Bay characteristics of closed water environment, the water of the Bay is not exchanged easily with seawater in the ocean. The pollutants originated from domestic and industrial wastewaters are discharged into the Bay without proper or enough treatment, which resulted in contaminating the water and accumulating the pollutants at the bottom of the Bay. Recently the water quality of the Bay becomes worse and nutrients levels are high enough to show an eutrophication phenomenon.

Without improved water pollution control measures, the water quality becomes worse and the eutrophication phenomena will be revealed to cause damage to the aquatic ecosystem of the Bay and to the tourism of Havana and the economy of Cuba.

To solve the water pollution and improve water environment of the Bay, GOC established the State Working Group for Cleaning up, conservation and development for the Havana Bay (GTE) to coordinate the government agencies concerned the Havana Bay. GTE is the state authority for planning, organizing, coordinating and controlling the program for the cleaning up and environmental management at local level. During 1995 to 1997, under the cooperation of Global Environmental Facility/UNDP (GEF), who proposed the establishment of GTE, GTE has conducted a study on Water Pollution Control Measures of the Havana Area.

Under the circumstances, to decrease the pollutants loads discharging into the Havana Bay from various pollution sources and to improve the water environment in the Havana Bay, GOC has requested GOJ for technical assistance for formulating the Sewerage and Drainage System Master Plan (M/P) and the Feasibility Study (F/S) for selected sewerage projects in the M/P.

In response to the request of the GOC, the JICA has dispatched the Preparatory Study Team headed by Ms. Keiko Yamamoto, to the Republic of Cuba from February 17 to March 8, 2002 to discuss the Scope of Work for the Development Study on the Improvement of Sewerage and Drainage System for the Havana Bay in the Republic of Cuba. The Scope of Work (S/W) was finally concluded between GTE and JICA.

The objectives of the Study are set as follows:

- To formulate a master plan for improving sewerage and drainage system for the Havana Bay to the target year of 2020;
- To conduct a feasibility study for the priority project(s) selected in the master plan; and
- To pursue technology transfer to the Cuban counterpart personnel in the course of the Study.

Based on the S/W of Study, a Japanese consultants team was selected and authorized as the JICA Study Team, headed by Dr. Harutoshi Uchida of Nihon Suido Consultants Co. Ltd., has started the first work in Cuba since the beginning of July 2002.

The Study is conducted in three phases; “Phase I - Basic Study”, “Phase II - Formulation of Sewerage and Drainage System Master Plan”, and “Phase III – Feasibility Study on Priority Projects”.

All the three phases have been carried out by the JICA Study Team with collaboration work of Cuban counterpart members.

## 1.2 REPORTS

In the course of Study, the following five (5) reports are prepared and submitted to JICA and GTE as shown in the Table 1.1. The Inception report has been submitted before starting the Study at the beginning of July 2002. The Inception Report presented basic methodologies and plan of operation to be adopted to achieve the objectives of the Study; time schedule, proposed organization, composition of the JICA Study Team, and undertaking.

The Progress Report presented the progress of the Study made during the course of “the Phase I – Basic Study” in the Republic of Cuba conducted from July 3 through October 31, 2002. This report includes and incorporates the results of field investigations, surveys, collected data and information, which intend to broadly establish the basis of a sewerage and drainage system master plan to improve the water environment of the Havana Bay and related tributary areas within the Study Area.

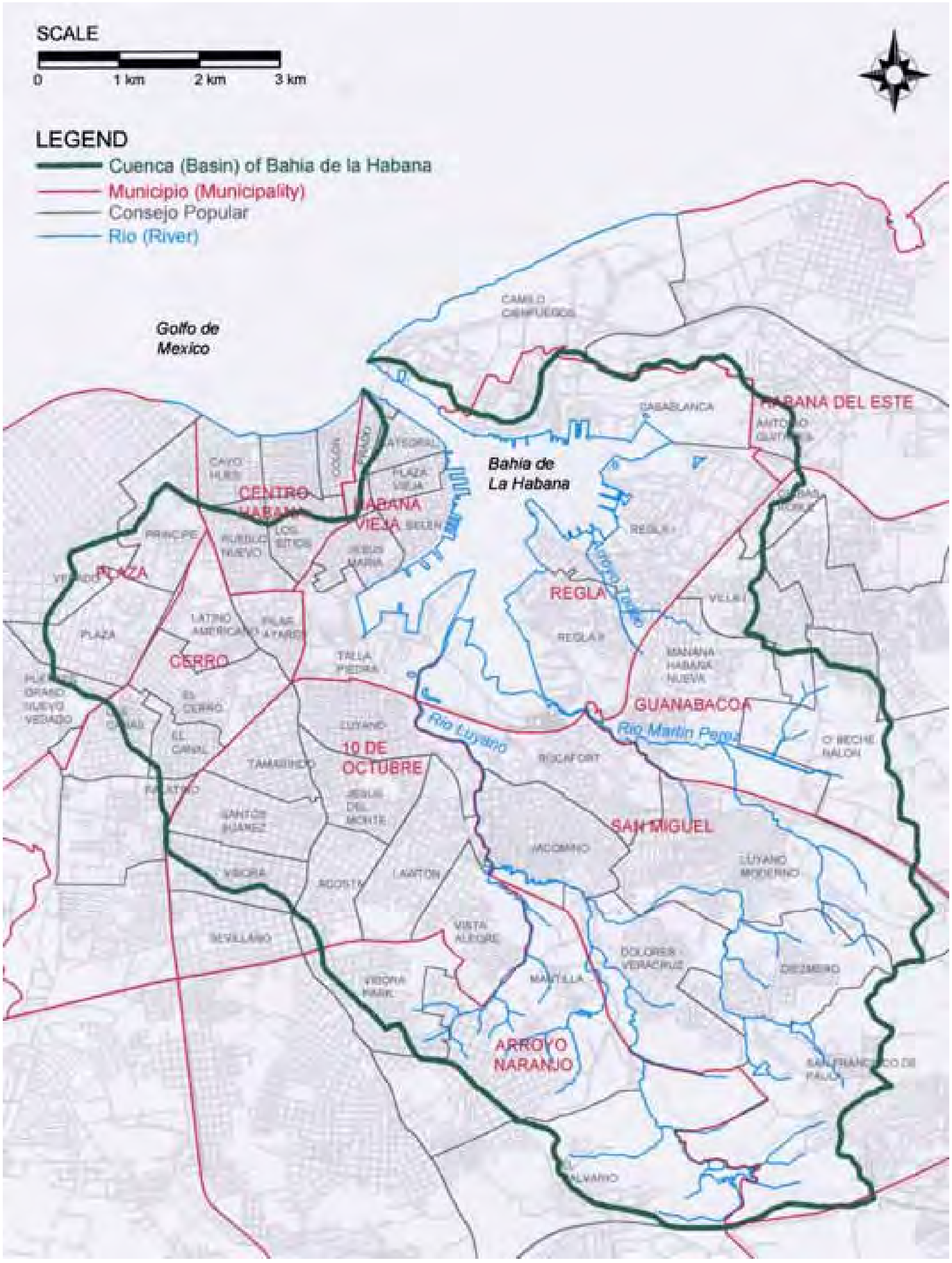
The Interim Report summarizes the work done during Phase I and Phase II Study. It presents the proposed sewerage and drainage master plan (MP) up to the year 2020 to improve the water environment in the Havana Bay and the priority projects identified for feasibility study. A further discussion will be still required to finalize the MP and the proposed priority projects before commencement the study work for the Feasibility Study on priority projects.

**Table 1.1 List of Study Reports**

| **No.** | **Name of Report / Time of Submission** | **Number of Copies** | | **Main Contents** |
|---|---|---|---|---|
| 1) | Inception Report, submitted to GTE on July 4, 2002. | | English 25<br>Spanish 25 | Basic approach and method<br>Time schedule of the Study<br>Staffing schedule of the Study |
| 2) | Progress Report<br>At the end of Basic Study | | English 25<br>Spanish 25 | Study results up to the end of Basic Study in Cuba. |
| **3)** | **Interim Report**<br>At the end of Master Plan Study, by March 2002 | | **English 25**<br>**Spanish 25** | Study results up to the end of Master Plan Study in Cuba |
| 4) | Draft Final Report<br><br>At the end of Feasibility Study in Cuba | Summary….<br><br>Main………<br><br>Supporting...<br>Data and drawings | English 25<br>Spanish 25<br>English 25<br>Spanish 25<br>English 25<br>English 25 | All the study results. |
| 5) | Final Report<br><br>February, 2004 | Summary….<br><br>Main………<br><br>Supporting...<br>Data and drawings | English 50<br>Spanish 30<br>English 50<br>Spanish 30<br>English 50<br>English 50 | All the study results with modifications based on the comments from the Government of Republic of Cuba. |

## 1.3 STUDY AREA

The Study Area is limited to the Bay of Havana and its watershed area, as shown in the Figure 1.1.




THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY

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Figure 1.1 Study Area

# 1.4 STUDY ORGANIZATION AND STAFFING

## 1.4.1 STUDY ORGANIZATION

The First Phase Work in Cuba has been undertaken keeping close cooperation with the counterpart staff of GTE, INRH and DPRH/Havana-city and other concerned agencies. The organizational structure for the Study is shown in the following:

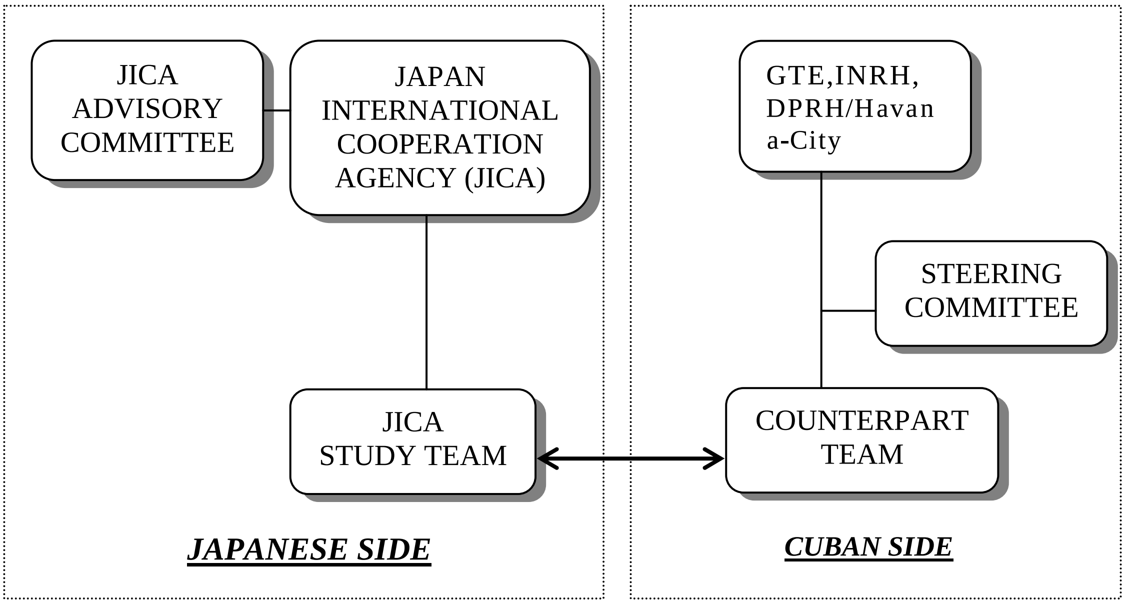



**Figure 1.2 Organization Chart of the Study**

The function of JICA Advisory Committee is to give necessary advice on the Study to JICA. The STEERING COMMITTEE consists of the following members and institutions:

**Table 1.2 Member of Steering Committee**

| Name of Members | Position | Institutions |
|---|---|---|
| 1) Mr. Armando Choy Rodriguez | President | GTE |
| 2) Mr. Angel Valdés Mujica | Vice President | GTE |
| 3) Mr. Daniel Alvarez Zamora | Vice President | GTE |
| 4) Ms. Dolores Merás Morejón | Representative | Division of the Developed Countries, MINVEC |
| 5) Ms. Ileana Rodríquez | Representative | Division of Asia, Middle East and Oceania, MINVEC |
| 6) Mr. Jorge Kalaf Maluf Potts | Executive Director | DPRH/Havana-City |
| 7) Mr. Juan Herrera Cruz | | CITMA/Havana-City |
| 8) Ms. Dalgys Casaña | Specialist | CITMA/Havana-City |
| 9) Ms. Marilyn Fernandéz | Vice Director | GTE |
| 10) Ms. Nelida Pérez | Specialist | Department of Physical Planning, Havana City |
| 11) Ms. Olga E. Alvarez Sánchez | Specialist | GTE |
| 12) Ms. Maricarmen Vásquez | Specialist | Ministry of Economy and Planning |
| 13) Mr. José Lara Paz | Vice Director general | GTE |

### 1.4.2 COUNTERPART STAFF

Throughout the study period the following counterpart staff have been attached to the Study:

**Table 1.3 Counterpart Staff**

| Tasks | Name | Organization |
|---|---|---|
| 1) Study Coordinator | Mr. Jorge Kalaf Maluf Potts | DPRH/Havana-City |
| 2) Study Coordinator | Mr. Angel Valdés Mujica | GTE |
| 3) Water Pollution Analysis, Water Pollution Source, Water Quality Analysis | Mr. José Fransico Santiago | DPRH/Havana-City |
| 4) Water Quality Analysis, Water Pollution Source Control | Ms. Tamara del Castillo | GTE |
| 5) Water Quality Analysis, Water Pollution Source Control, Legal and Social Consideration, Organization and Human Resource Development | Ms. Antonia Lozano | DPRH/Havana-City |
| 6) Water Pollution Analysis, Environmental Impact Assessment | Mr. Reinaldo Regadera | GTE |
| 7) Water Pollution Analysis, Environmental Impact Assessment | Ms. Marlen Pérez | GTE |
| 8) Environmental Education, Legal and Social Consideration | Ms. María de los A. Hernandez | GTE |
| 9) Wastewater Treatment Facilities Planning,, Water Pollution Analysis | Mr. Valdimir Iglesias | DPRH/Havana-City |
| 10)Wastewater Collection Facilities Planning, Drainage Facilities Planning | Ms. Nancy Chávez | DPRH/Havana-City (Empresa Havana) |
| 11)Wastewater Collection Facilities Planning, Drainage Facilities Planning | Ms. Lourdes M. Aguiar | DPRH/Havana-City (Empresa Oeste) |
| 12)Wastewater Collection Facilities Planning, Drainage Facilities Planning | Ms. Maylín Mardone | DPRH/Havana-City |
| 13)Wastewater Collection Facilities Planning, Drainage Facilities Planning, Map Information | Mr. Yosvany Simón | GTE |
| 14)Construction Planning, Cost Estimate | Mr. Sergio Gómez | DPRH/Havana-City |
| 15)Physical Planning | Ms. Maribel Pérez | DPPFA |

### 1.4.3 STUDY TEAM

The Study has been implemented with all the assigned for the Phase I, Phase II and Phase III Study in the Republic of Cuba. Members of the Advisory Committee and the Study Team are shown in the Table below.

**Table 1.4 Member of Advisory Committee and Study Team**

| Name | Designated Task |
|---|---|
| Advisory Committee | |
| 1) Ms. Keiko YAMAMOTO | Chairperson |
| 2) Mr. Takesi SANNOMIYA | Member |
| 3) Mr. Yukihiro YAMAGUTI | Member |
| Study Team | |
| 1) Dr. Harutoshi UCHIDA | Team Leader/ Sewerage Planning |
| 2) Dr. Sivapragasam KUGAPRASATHAM | Water Pollution Analysis/ Environmental Impact Assessment |
| 3) Dr. Ryunan MATSUE | Water Quality Analysis/ Water Pollution Source Control |
| 4) Mr. Jack BANNISTER | Environmental Education/ Legal and Social Consideration/ Organization and Human Resources Development |
| 5) Mr. Yasuo MOTO | Wastewater Treatment Facilities Planning |
| 6) Mr. Motoo YANAI | Wastewater Collection Facilities Planning |
| 7) Mr. Kazuzi SASAKI | Drainage Facilities Planning/Wastewater Collection Facilities Planning |
| 8) Mr. Masamichi HATTA | Construction Planning/ Cost Estimate |
| 9) Mr. Mituhiro DOYA | Socio-economy/ Financial Analysis |
| 10) Mr. Zyouzi YOKOKAWA | Interpreter |
| 11) Dr. Genyong Liu | Study Coordination (/ Water Quality Simulation Model Specialist) |
| 12) Mr. Shozo MORI | Environmental Education/Study Coordination |

## 1.5 STUDY SCHEDULE

### 1.5.1 OVERALL STUDY SCHEDULE

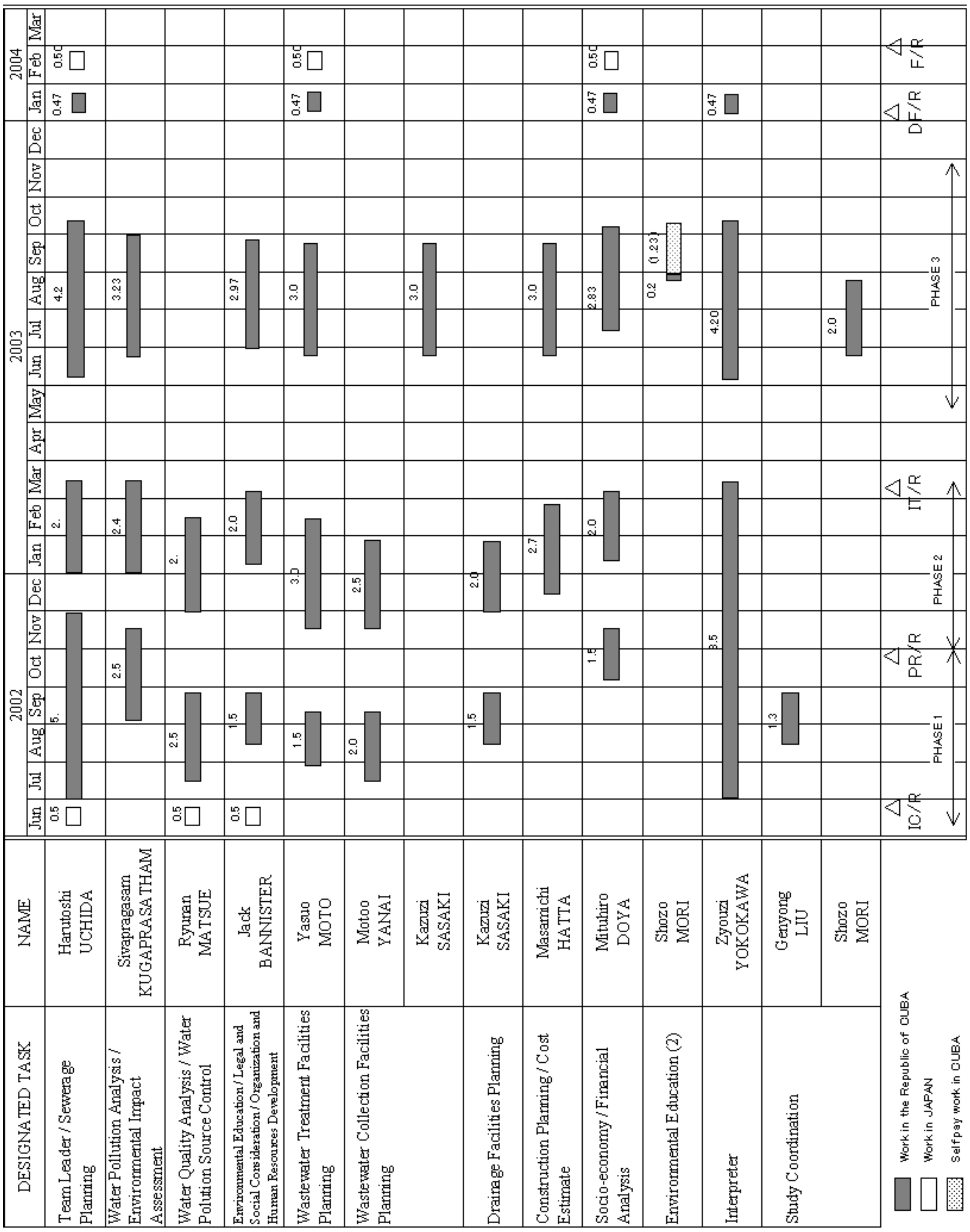
The Study is extended for a period of approximately 19 months, starting from June 2002 to February 2004 and is carried out in both Japan and Cuba. The Study in the Republic of Cuba is executed in three phases in the following:

- Phase I, Basic Study; from July to October, 2002
- Phase II, Master Plan Study, from November 2002 to March 2003
- Phase III, Feasibility Study, from May to October 2003

The results of the three phases are all presented in the Work Shop in January 2004 in Cuba.

### 1.5.2 PHASE 1 AND PHASE II STUDY SCHEDULE

All member of the JICA Study Team have done the tasks in Cuba to collect the data and information, to conduct field surveys to understand the present situation in the Study Area, and prepare sewerage and drainage master plan (MP) up to the year 2020, and proposed priority projects for the Feasibility Study. The assigned staff of JICA Study Team for the Phase I and Phase II Study Work is presented in Figure 1.3, "Staff Assignment Schedule".




| THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY | Figure 1.3<br>Staff Assignment Schedule |
|---|---|
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# CHAPTER 2
# PHYSICAL AND SOCIO-ECONOMIC CONDITIONS
# IN THE STUDY AREA

## 2.1 PHYSICAL CONDITIONS

### 2.1.1 GEOLOGY AND TOPOGRAPHY

The Study Area is predominantly plain ranging from 0.7 m in the lowest areas of the basin (Triscornia Cove shoreline) to about 100 m above mean sea level in the southern parts (around Río Hondo dam).

Bordering on most of the bay is a partially marshy low plain, ranging from 0.7 to 10m, occasionally flooded, seated upon Quaternary deposits, extremely modified clay, silt clay, clayey sand and peat. Most of these lowlands have been artificially filled. The Triscornia area is permanently covered with mangrove.

Skirting these lowlands on the northeast and the west is a terraced plain gently sloping into the sea and composed mainly of coralline limestone dating from the Neógeno and friable deposits from the Quaternary.

Both the central and the southern parts of the basin are formed by a hilly plain crossed by a number of streams feeding the tributary rivers. Geologically it is made of argyrose, arenite, aleurolitas, tufa and marl. A number of hills 60 to 80 meters high rise on sandstone.

On the east there is a plain seated on clayey sand, limey clays and sandstone forming a flish terrígeno dating back from the Higher Cretaceous along with hills ranging from 35 to 70 meters made of serpentine rocks.

The area to the northeast is formed by a denuded cliff carved on limestone, marl and clayey limestone abruptly sloping to the south reaching up to about 60 meters high.

### 2.1.2 METEOROLOGY

The subtropical climate in the Republic of Cuba is strongly influenced by the gentle Northeast Trade winds, which shift slightly to the east in summer. Because of the island's long, tapered shape, few places are far from these moderating sea breezes, and there are no obvious seasonal variations in temperature. The seasons can be divided into two seasons, rainy summer season and drier winter season. The "rainy summer" starts in May lasting until October. And the "drier winter"" is from November to April with relatively low precipitation and humidity.

Except in mountain areas, eastern Cuba is slightly warmer than the west. The mean annual temperature is 25.5°C. The humidity ranges from 81% in summer to 79% in winter. The humidity makes it feel hotter than it actually is. The mean annual rainfall is 1,375mm; in the rainy season the island receives 1,059mm, in the dry season 316mm. The rainiest months are September and October. The rainstorms are often short and heavy.

Hurricane season runs from June to November, with the worst storms in September and October. Hurricanes usually form over the Atlantic east of the Lesser Antilles, then move northwest toward Cuba and north into Florida and the Bahamas. Havana and Pinar del Río are generally hit harder and more frequently than the provinces to the east. Such storms are characterized by winds of over 250km an hour and torrential rain.

In the following sub-section, the climate and weather conditions in the Study Area are summarized.

**(1) Temperatures**

The annual highest average temperature in Havana City is 28.8°C and the annual lowest average is 21.4°C. The highest and lowest temperature recorded was 35.8°C and 8.5°C, respectively. The mean average temperature in the warmest months, August, is 27.3°C, while in the coolest month, February, it is 21.6°C.

**(2) Precipitation and Humidity**

The mean annual rainfall is 1,411mm; in the rainy season, May to October, the Havana receives 70% of the total annual rainfall. The rainiest months are September and October. Relative humidity in general is high with an annual average of 79.5%.

### 2.1.3 HYDROLOGY

Figure 2.1 shows the basin of Habana Bay. Extent of the basin is 68 $km^2$. Area of the bay is 5.0 $km^2$. Table 2.1 shows the extent of the drainage basins and areas.

**Table 2.1 Drainage Basins and Areas of Havana Bay**

| Name of Basin | Area, $km^2$ |
|---|---|
| Habana Vieja | 2.6 |
| Dren Arroyo Matedero | 6.8 |
| Dren Aqua Dulce | 6.5 |
| Rio Luyano | 30.0 |
| Rio Martin Perez | 13.1 |
| Arroyo Tadeo | 2.6 |
| Refinery Area | 3.4 |
| Casa Blanca Area | 2.6 |
| Cabaña Area | 0.4 |
| Total | 68.0 |

Three rivers namely Rio Luyano, Rio Martin Perez and Arroyo Tadeo drain to the bay from southern part of basin with combined river basin area of 45.7 $km^2$. Rio Luyano is the largest in terms of basin area, river length and river flow.

There are no permanent river gauging stations in these rivers. Table 2.2 shows the characteristics of rivers.

**Table 2.2 Characteristics of Tributary Rivers to Habana Bay**

| Item | Rio Luyano | Rio Martin Perez | Arroyo Tadeo | Total |
|---|---|---|---|---|
| Basin area, $km^2$ | 30.0 | 13.1 | 2.6 | 45.7 |
| Length of River, km | 10.1 | 6.4 | 2.3 | |
| Flow in year 2002*, $m^3/d$ | 114,860 | 62,105 | 8,004 | 184,969 |
| Average Yield, $L/km^2/s$ | 0.1214 | 0.1503 | 0.0976 | 0.1283 |

Source : CIMAB, August 2002

Rio Luyano originates from an altitude of approximately 90 m whereas Rio Martin Perez originates from an altitude of 55 m above MSL (mean sea level). Arroyo Tadeo is an urban stream receiving domestic wastewater.

# 2.2 SOCIO-ECONOMIC CONDITIONS

## 2.2.1 POPULATION

The present population of Cuba is approximately 12 million. The area of Cuba is 110,860 $km^2$ giving an overall population density of 101.2 persons/km2 (Source: National Statistics Office May 2001) which is roughly the same as France. Statistics for year 2000 give a total population of 11, 217,100 of which, 8,445,036 (75%), live in urban areas. Cuba is highly urbanized; hence the rural areas are sparsely populated with quite higher densities in urban areas.

Due to colonization, slavery, and waves of immigration, Cuba has a mingling of different races. There are native Cubans, Europeans (mainly Spanish), and Africans. It is officially estimated that about 66% of the population is of European origin, 22% are of mixed race, and 12% African.

Unlike many other Caribbean and Latin American countries, Cuba has the profile of an advanced country. Cuba has a free and advanced education and healthcare system, hence infant mortality is low (7.2 per 1000 born alive in 2000), life expectancy high (74.83 years both male and female) (1994-1995), and fertility low (1.9 children per female). One third of the population is between the ages of 14 and 27 years. (Source: Annual Demography of Cuba 2000)

The City of Havana has a total population of 2,186,632 inhabitants (National Statistics Office, May 2001), which represents about 20% of the total population of Cuba and approximately 26% of its total urban population. The average population density in the City varies from a little over 1,000 persons/ha in the central area, and less than 50 persons/ha in the peripheral zones.

From 1997, the population of the City of Havana has decreased slightly and is getting close to an aging process. It is expected that by the year 2005, the population in the province will be about 2,168,404, which reflects the tendency of a population decrease.

With the exception of the municipality of Plaza de la Revolucion, the population over the period 1996-1999 decreased in the central municipalities (La Habana Vieja, Centro Habana, Cerro, Dies de Octubre and Playa), while in the periphery municipalities and the middle zone the population has increased due to immigration from the central municipalities. (Source: PGOTU 2000. DPPF City of Havana).

**Table 2.3 Population census data and estimates**

| Year | 1981 census | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|
| Population | 1,929,432 | 2,184,990 | 2,204,333 | 2,197,706 | 2,192,321 | 2,189,716 | 2,186,332 |
| % change | | | 0.885 | -0.301 | -0.245 | -0.119 | -0.155 |

DPPFA has estimated the population within the basin of Havana Bay at 795,144 as of 1996. Table 2.4 shows the estimated population within the Havana Bay basin for the year 2000. The study area contains about 35% of population of Ciudad de la Habana Province and 51.6% of the ten municipalities which falls within the basin area. Average population density within the basin is approximately 11,250/$km^2$.


| THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY | Figure 2.1 Havana Bay Basin |
|---|---|
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**Table 2.4 Population within the Havana Bay Basin, Year 2000**

| Municipality | Total Municipal Population | Population within Basin |
|---|---|---|
| Plaza de la Revolucion | 173,416 | 18,359 |
| Centro Havana | 153,878 | 73,684 |
| Havana Vieja | 99,499 | 97,026 |
| Regla | 42,870 | 40,764 |
| Havana del Este | 184,634 | 17,675 |
| Guanabacoa | 106,618 | 24,848 |
| San Miguel del Padron | 154,675 | 145,803 |
| Diez de Octubre | 230,865 | 217,038 |
| Cerro | 135,729 | 97,889 |
| Arroyo Naranjo | 199,317 | 31,676 |
| Total | 1,481,501 | 764,762 |

### 2.2.2 ECONOMIC CONDITIONS

#### (1) Employment and Salaries

The following table shows the total employees in the economy, including the number of people employed in the various sectors, whether of labor age or not. The figures include employees of state organizations and all other sectors of the economy. The table shows the trend since 1996, and compares total employment in mixed and state organizations between Cuba and the City of Havana.

**Table 2.5 Total Employees in the Economy (x 1000 workers)**

| Categories | 1996 | | 2000 | |
|---|---|---|---|---|
| | | % | | % |
| Cuba | | | | |
| Total Employees | 3,626.7 | 100.0 | 3,843.0 | 100.0 |
| State entity | 686.0 | 80.8 | 2,978.2 | 77.5 |
| Non-state entity | 20.7 | 9.2 | 864.8 | 22.5 |
| Mixed enterprises | | 0.4 | 26.8 | 0.7 |
| Mixed & State Organizations | | | | |
| **Total for Cuba** | **2,961.4** | **100.0** | **3005.0** | **100.0** |
| **Total for City of Havana** | **777.3** | **24.9** | **800.5** | **26.6** |

Source: National Statistics for year 2000

As can be seen, the City of Havana with about 20% of the total population has 26.6% of employees in mixed and state organizations.

Regarding salaries, the following table shows the comparison between Cuba and the City of Havana in mixed and state organizations.

**Table 2.6 Salaries in Mixed and State Entities (x millions of Pesos)**

| Location | 1996 | 1996 | 2000 | 2000 |
|---|---|---|---|---|
| | Accrued | Monthly | Accrued | Monthly |
| Cuba | 6,578.4 | 194 | 7,859.8 | 234 |
| City of Havana | 1,756.7 | 203 | 2,396.8 | 246 |

Source: National Statistics for year 2000

The total number of employees in Cuba was estimated to be 3.843 million in 2000, with an average monthly salary of Ps 243. About 77.5% of employees work in state organizations. For the Whole of Cuba, the ratio of male to female workers is 62%/38%, with 47% of males and 66% of females having received high school/college level education.

In the City of Havana, with about 20%, of the total population of Cuba, accrued salaries are about 30% of the total accrued salaries, and Havana has a slightly higher than average monthly salary at Ps 246. In Havana, the ratio of male to female workers is 56%/44%. 64% of males and 75% of females reached high school/college level education.

**(2) Urban Life in the Study Area**

With a population approaching 2 million, the City of Havana is a prime example of an overcrowded Cuban urban complex. The study area covers a large slice of the inner city where it is usual for grandparents, parents and children to share accommodation due mainly to the acute housing shortage.

Due to the housing crisis, young people live with their parents up to and after their marriage. Overcrowding and lack of privacy may be a contributory factor to the high rate of divorce in urban populations. Children are often looked after by their grandmothers when both parents are working, and it is usual for women to carry out all domestic work.

Much of a Cuban’s life is led outdoors, creating a lively urban atmosphere. Cubans are also fond of the beach, but the inadequate transport system means long waits for the crowded “Camello” (Ps 0.20 per trip), or other buses (Ps 0.40 per trip), and it is usual to see many people waiting at strategic places for a lift from motorists.

All Cubans have a “libreta”, or ration book, through which basic foodstuffs and other necessities such as rice, beans, salt, sugar, oil, eggs, coffee, soap, toothpaste etc. may be bought, depending upon availability, at special markets at prices much lower than other markets. All workers receive benefits of one kind or another in addition to their basic salaries, most are provided with lunch (sometimes at a nominal cost). Other benefits may include uniforms, transport, recreational trips, soap etc. Public Utilities provide water, electricity, gas and telephone services at affordable prices, and there are multi-channel radio and TV facilities available.

Because of the transport difficulties, many Cubans spend their leisure time with friends and neighbors. Television is very popular with most Cubans, and the women also listen to the radio, whereas the favorite male pass time is dominoes. Culture and music are also popular at the “Casa de la Culture, and “Casa de la Trova”. Cubans love music and dancing, and it takes little to start up a party where all age groups join in the special Cuban style of dancing.

**(3) Urban Structure of the Study Area**

Out of the 15 municipalities composing Havana City, 10 are either partially or totally within the Study Area. The technical condition of buildings in 1996 was as follows: Good: 37.3 %, Fair: 34.2 %, Poor: 28.5 %. Thus it is estimated that approximately 63 % of buildings are either in a fair or poor condition, deterioration being concentrated mainly in Centro Habana, Regla and Habana Vieja municipalities.

Deterioration is associated both to the old age of buildings and to the lack of adequate maintenance, whereas in other areas it is mainly derived from the characteristics of buildings themselves, including makeshift houses in areas which have ultimately grown to become slums.

Both the pace of construction of new houses by the Government and the availability of materials for maintenance or construction by the population were seriously affected as of 1990. Consequently, deterioration has become evident not only in houses, but in public places as well.

Habana Vieja Historical Center has for some years been involved in a restoration and rehabilitation plan aimed at recovering public places, hotels, houses and services that form part of the tangible memory and the built heritage of the city. Despite all the efforts made, a great number of monuments and buildings valuable from a historical point of view are seriously deteriorated. Thus, urgent measures are required to preserve them.

According to the Plan General de Ordenamiento Territorial y Urbanismo passed by the Provincial Assembly of the People's Power for 2001-2005, it is envisaged to implement an integral rehabilitation of a number of residential areas in Habana Vieja, Centro Habana, Cerro and Diez de Octubre municipalities where deterioration is more serious. To this effect, a number of houses are proposed to be built to replace those beyond repair to be demolished up to the year 2005, while simultaneously rehabilitate and preserve the rest, including the technical infrastructure and the services.

Habana Vieja and Centro Habana municipalities and the historical parts of Cerro and Diez de Octubre municipalities are located in the central area of the city where most of the population within the Study Area lives. There is also a high concentration of equipment and services, as well as high soil occupancy. Old residential buildings are predominant in this area where the population density is high and green areas scarce. In Habana Vieja and Centro Habana municipalities the gross population density in residential areas does not exceed 800 persons/ha, among the highest in the city.

In Cerro and Diez de Octubre municipalities there are a few industrial groups and scattered industries in urban areas, as well as some hospitals.

The shoreline of Habana Vieja municipality, an old commercial port, is undergoing a rehabilitation process to replace its present use with a tourist-recreational use. There is also an industrial area within this municipality historically linked to the port where there stand warehouses and old industries such as Otto Parellada power plant, a gas plant and Hacendados fish processing factory.

Plaza de la Revolución municipality, although also located in the central area, differs from the other three municipalities in the sense that large lots with gardens and public gardens are predominant here along with a mix of one- and two-story houses and taller buildings of a more recent date.

Most of Diez de Octubre municipality and the whole of Arroyo Naranjo, San Miguel del Padrón, Regla y Guanabacoa municipalities are located in the intermediate part of the city characterized by an average soil occupancy and a lower population density, as well as a low concentration of services and a predominance of single houses generally having a porch, a garden and a backyard. In San Miguel del Padrón there are a number of industries located along the banks of Luyanó River.

Regla municipality has lost of late the waterfront area due to the presence of port-related facilities built in public places that degrade the shoreline. In Guanabacoa municipality, on the other hand, there are scattered production facilities and a large area devoted to the long-term industrial development.

Some empty lots, mainly in Arroyo Naranjo, San Miguel del Padrón and Guanabacoa municipalities, are being successfully used for urban agriculture.

### (4) Economic Scale and Growth Rate of the City of Havana

The fall of the Berlin Wall in 1989 and the collapse of the Soviet Union in 1991 dealt a severe blow to the economy of Cuba. 1990 saw the inauguration of the “ Special period in Time of Peace”, heralding hard times for all Cubans. Factories were forced to close as investment was cut back, causing unemployment. Necessary energy saving actions led to power supply cuts by the electricity authority and a cut back in public transport.

In the first half of the 1990's, Cuba adopted more liberal policies with some degree of free market activities and found economic partners other than the old soviet block, to form joint ventures with foreign capital. Previously 80% of trade was with the soviet block countries. Capital flowed mainly from Canada, Mexico and Europe and joint ventures were initially formed in the oil industry, tourism and the telecommunications and mining sectors.

In the early 1990's Cuba's GNP shrunk by 37%, however, by the middle of the 1990's the economy showed signs of recovery, albeit slow, with increases in the GNP of around 1% between 1994 and 1998. The opening up of all sectors of the economy to foreign investment in 1995 (except defense, health and education), led to the current upward trend. However, external forces, particularly the USA's Helms-Burton Act has restrained willing investors with the threat of the loss of their markets in the USA. Should this threat be removed the Cuban economy is in a position to rapidly expand. The GDP data are summarized as follows:

**Table 2.7 Gross Domestic Product**

| | Year 1996 | Year 1997 | Year 1998 | Year 1999 | Year 2000 |
|---|---|---|---|---|---|
| Total GDP (Million pesos) | | | | | |
| At current prices | 22,815 | 22,952 | 23,901 | 25,504 | 27,635 |
| At constant (1981) prices | 14,218 | 14,572 | 14,754 | 15,674 | 16,556 |
| % change, year on year | 7.8% | 2.5% | 1.2% | 6.2% | 5.6% |
| | | | | | |
| By expenditure (Million pesos at constant 1981 prices) | | | | | |
| Private consumption | 6,085 | 6,120 | 6,315 | 6,599 | 6,904 |
| Government consumption | 4,749 | 4,809 | 4,957 | 5,000 | 5,133 |
| Gross fixed investment | 1,166 | 1,180 | 1,254 | 1,615 | 2,185 |
| External balance | 2,403 | 2,375 | 2,302 | 2,586 | 2,467 |
| Statistical discrepancy | -185 | 87 | -74 | -125 | -132 |
| Total | 14,218 | 14,572 | 14,754 | 15,674 | 16,556 |
| | | | | | |
| By sector (Million pesos at constant 1981 prices) | | | | | |
| Agriculture | 1,075 | 1,074 | 1,018 | 1,123 | 1,253 |
| Industry | 4,949 | 5,314 | 5,490 | 5,843 | 6,168 |
| Mining | 177 | 182 | 184 | 186 | 213 |
| Construction | 539 | 556 | 588 | 632 | 694 |
| Electricity, gas & water sup | 398 | 422 | 427 | 430 | 468 |
| Manufacturing | 3,835 | 4,155 | 4,291 | 4,595 | 4,794 |
| Services | 8,193 | 8,185 | 8,247 | 8,708 | 9,135 |
| Total | 14,218 | 14,572 | 14,754 | 15,674 | 16,556 |

Sources: Banco Central de Cuba

With almost one in five Cubans being residents of Havana, the poor national economic situation was reflected even more so in Havana. There are 5 industrial areas, approximately 13 industrial groups and 2 free zones in Havana City. There are in general 1,961 facilities in the industrial sector covering 21 branches of the economy, among the most important of which are power generation, chemicals, food, fishing, textiles, and liquor production.

The industrial sector was seriously hit in the early 90's. It was then that foreign investment was introduced allowing to boost the industrial sector with the setting up of free zones and the implementation of technological changes.

### (5) Trade Trend

Big export items of Cuba are nickels and sugars. In 2000, export earnings from nickel overtook sugar earnings for the first time. Those two items together account for around 60 percent of total export earnings. Fuel and foodstuffs have been major import items. These two items still account for about one third of total imports. However the recent fall in their shares signifies the diversification of import items.

**Table 2.8 Export and Import Composition**

(Million Pesos)

| | *1994* | *1995* | *1996* | *1997* | *1998* | *1999* | *2000* |
|---|---|---|---|---|---|---|---|
| Export | | | | | | | |
| Sugar | 760 | 714 | 976 | 853 | 599 | 463 | 453 |
| Nickel and other mineral products | 201 | 331 | 423 | 416 | 345 | 410 | 599 |
| Tobacco products | 71 | 102 | 109 | 161 | 192 | 205 | 166 |
| Fish | 100 | 123 | 126 | 128 | 104 | 97 | 92 |
| Agricultural products | 41 | 45 | 39 | 39 | 59 | 43 | 41 |
| Other products | 158 | 177 | 192 | 222 | 214 | 278 | 326 |
| Total | 1,331 | 1,492 | 1,866 | 1,819 | 1,512 | 1,496 | 1,676 |
| | | | | | | | |
| Import | | | | | | | |
| Foodstuffs | 467 | 611 | 718 | 725 | 704 | 722 | 672 |
| Fuel | 773 | 873 | 976 | 990 | 687 | 731 | 1,158 |
| Chemicals | 166 | 308 | 296 | 399 | 420 | 429 | 419 |
| Machinery & equipment | 196 | 427 | 562 | 856 | 1,130 | 1,144 | 1,202 |
| Other imports | 414 | 664 | 1,017 | 1,018 | 1,240 | 1,323 | 1,378 |
| Total | 2,017 | 2,883 | 3,569 | 3,987 | 4,181 | 4,349 | 4,829 |

Source: Anuario Estadistico de Cuba 2000

The trade trend can be also demonstrated by the number of ships arriving at Havana harbor. Arrivals reduced dramatically from 1989 to 1992, coinciding with the international political changes in that period. Annual arrival of ships was halved from 1865 to 905 over this four year period as trade with the Soviet Union collapsed, factory operations were scaled back, and production of export goods, particularly sugar were reduced. Arrivals started picking up in 1993, and by year 2000 had increased by about 70%. However this figure is still about 25% lower than the 1989 total. The figure for 2001 and the information to date for 2002 shows that arrivals have declined to the mid 1990 level. The following table shows the accumulated annual total of ship arrivals:

**Table 2.9 Shipping Arrivals, Havana Harbor**

| **Year** | **1989** | **1990** | **1991** | **1992** | **1993** | **1994** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** | **2001** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of annual arrivals | 1,865 | 1,631 | 1,303 | 905 | 922 | 1,018 | 1,103 | 1,135 | 1,093 | 1,064 | 1,217 | 1,382 | 1,152 |

Source: GTE

### (6) Tourism Industry Trends

The Tourism industry was one of the first sectors of the economy to be involved with foreign capital. Since the creation of the Ministry of Tourism in 1994, and the passing of the Foreign Investment Law in 1995, 13 major organization, including mixed enterprises and international operators have been formed, including Cubanacan Corporation SA, Turism Group Gaviota SA, Hotel Group Gran Caribe, and Horizon Hotels.

Tourism has become a priority area in the Cuban economy with its ability to generate foreign currency and to expanding employment opportunities. Varadero provides for “sun and sand” holidays but Havana provides its World Heritage Center and other tourist areas, namely Marina Hemingway, Monte Barreto, Vedado and Playas del Este.

The following tables show the statistics for tourist arrivals, accommodation, and income:

**Table 2.10 No. of Tourists and Tourist Income (In Millions)**

| **Cuba** | **1994** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** |
|---|---|---|---|---|---|---|---|
| International Arrivals | 0.619 | 0.745 | 1.004 | 1.170 | 1.416 | 1.603 | 1.774 |
| Total Tourists | 0.617 | 0.742 | 0.999 | 1.153 | 1.390 | 1.561 | 1.741 |
| Tourism Income (US$) | 0.850 | 1.100 | 1.333 | 1.515 | 1.759 | 1.901 | 1.948 |

Source: National Statistics for year 2000

**Table 2.11 Statistics for Tourist Accommodation**

| **Cuba** | **1994** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** |
|---|---|---|---|---|---|---|---|
| No. of Tourist Hotels etc. | 191 | 222 | 237 | 252 | 269 | 285 | 288 |
| Total No. of Rooms | 27 401 | 30 387 | 31 952 | 33 338 | 38 156 | 39 890 | 40 303 |
| Total No. of Beds | 56 108 | 63 006 | 65 543 | 66 813 | 76 514 | 82 368 | 83 753 |
| Occupancy Rate % | 52.7 | 55.9 | 64.9 | 77.9 | 78.3 | 73.1 | 74.3 |
| **Havana** | | | | | | | |
| Total No. Tourist Hotels etc. | 50 | 54 | 58 | 64 | 69 | 69 | 70 |
| Total No. of Rooms | 9 374 | 10 666 | 10.208 | 10 661 | 11 770 | 11 781 | 11 947 |
| Total No. of Beds | 19 538 | 21 277 | 20 274 | 21 038 | 23 454 | 23 770 | 23 839 |

Source: National Statistics for year 2000

The majority of tourists are from Canada and Europe and in consideration of the past trend, the total number of tourist arrivals is likely to continue to increase, with a corresponding increase in revenue which will, by now, have exceeded US$ 2 billion per year.

Havana has about 28% of the rooms/beds in Cuba, compared to Varadero, which has about 30%. Tourism revenue has increased by 230% from 1994 to 2000, with a corresponding 150% increase in the number of beds. The current occupancy rate of about 75% leaves some room for a further increase in tourist revenue as the accommodation expands.

### 2.2.3 PUBLIC HEALTH CONDITIONS

Cuba is a healthy country. Yellow fever. Polio, malaria, diphtheria, measles and mumps, and leprosy were eradicated. Same as in developed countries, the main causes of death are heart disease, strokes, and malignant tumors.

One of the high-risk potentials to the public health may be air pollution. The emissions of particles, smokes, gases from the factories and vehicles may cause air pollution and give risks to the public health. A continuous air pollution monitoring system has not been established in the Study Area.

Data of diseases whose morbidities are relevant to the development of water supply and sewerage were collected. Acute diarrhea, typhoid fever, viral hepatitis, and acute respiratory disease are traceable among those diseases. Table 2.12 shows comparative incidence data of Cuba, the Havana City, and 10 municipalities in the study area. The morbidities in the same areas are presented in Table 2.13. The tendencies are depicted in Figure 2.2. Collected data covers the years 1999 through 2001. It should be noted that nationwide incidences of all those disease show a decrease in the year 2001 compared with the year 1999 despite the population increase. In the Havana City however, the population has decreased over that period. On the contrary, the incidence of acute respiratory disease in the same area has increased. Municipality-wise, Regla stands out from others in a sense that the incidences of acute diarrhea, viral hepatitis, and acute respiratory disease have increased although the population has decreased. During this period Cuba has been recovering the industrial activity in general. A likely reason is that the population of Regla has been more exposed to environmental contamination than other areas because of the proximity to various industrial activities. It can be said that the development of sewerage system would be helpful in reducing the incidences of those diseases.

## Table 2.12 Incidence of Diseases Related to Water Supply and Sewerage

| Disease | Year | Total Cuba | Total Havana City | Habana Vieja | Regla | Habana del Este | Plaza | Centro Habana | Guanabacoa | San Miguel | Diez de Octubre | Cerro | Arroyo Naranjo |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Acute diarrhea | 1999 | 953,696 | 261,412 | 10,121 | 2,435 | 21,063 | 13,762 | 13,197 | 7,830 | 13,082 | 19,926 | 8,981 | 21,414 |
| | 2000 | 862,580 | 244,574 | 10,767 | 2,274 | 16,209 | 10,807 | 9,588 | 6,259 | 11,156 | 18,181 | 8,356 | 20,159 |
| | 2001 | 868,477 | 249,329 | 9,360 | 2,994 | 16,326 | 11,001 | 8,751 | 5,794 | 10,733 | 18,887 | 8,717 | 23,842 |
| Typhoid fever | 1999 | 131 | 7 | 1 | 0 | 3 | 0 | 2 | 1 | 0 | 0 | 0 | 0 |
| | 2000 | 37 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2001 | 24 | 5 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 1 | 0 | 0 |
| Viral hepatitis | 1999 | 18,119 | 4,327 | 125 | 122 | 233 | 251 | 130 | 141 | 219 | 272 | 215 | 401 |
| | 2000 | 18,317 | 3,264 | 97 | 55 | 226 | 119 | 150 | 161 | 402 | 266 | 208 | 355 |
| | 2001 | 14,850 | 2,210 | 83 | 144 | 206 | 93 | 157 | 183 | 253 | 161 | 140 | 156 |
| Acute respiratory Disease | 1999 | 5,216,286 | 1,125,798 | 41,936 | 12,456 | 106,128 | 61,297 | 55,501 | 44,780 | 58,634 | 99,762 | 46,348 | 100,615 |
| | 2000 | 4,823,831 | 1,140,390 | 45,292 | 13,250 | 97,700 | 57,748 | 51,061 | 39,224 | 56,712 | 99,983 | 44,869 | 91,524 |
| | 2001 | 4,873,390 | 1,175,258 | 45,031 | 19,763 | 99,162 | 61,346 | 47,430 | 38,039 | 53,468 | 95,771 | 50,571 | 94,781 |
| Population | 1999 | 11,180,099 | 2,189,716 | 96,479 | 42,988 | 183,857 | 173,479 | 156,152 | 106,838 | 154,791 | 232,828 | 135,809 | 199,206 |
| | 2000 | 11,217,100 | 2,186,632 | 95,499 | 42,870 | 184,634 | 173,416 | 153,878 | 106,618 | 154,675 | 230,865 | 135,729 | 199,317 |
| | 2001 | 11,243,358 | 2,181,535 | 94,966 | 42,390 | 185,468 | 172,045 | 150,877 | 106,374 | 154,323 | 229,626 | 135,261 | 199,720 |

Source: Havana City

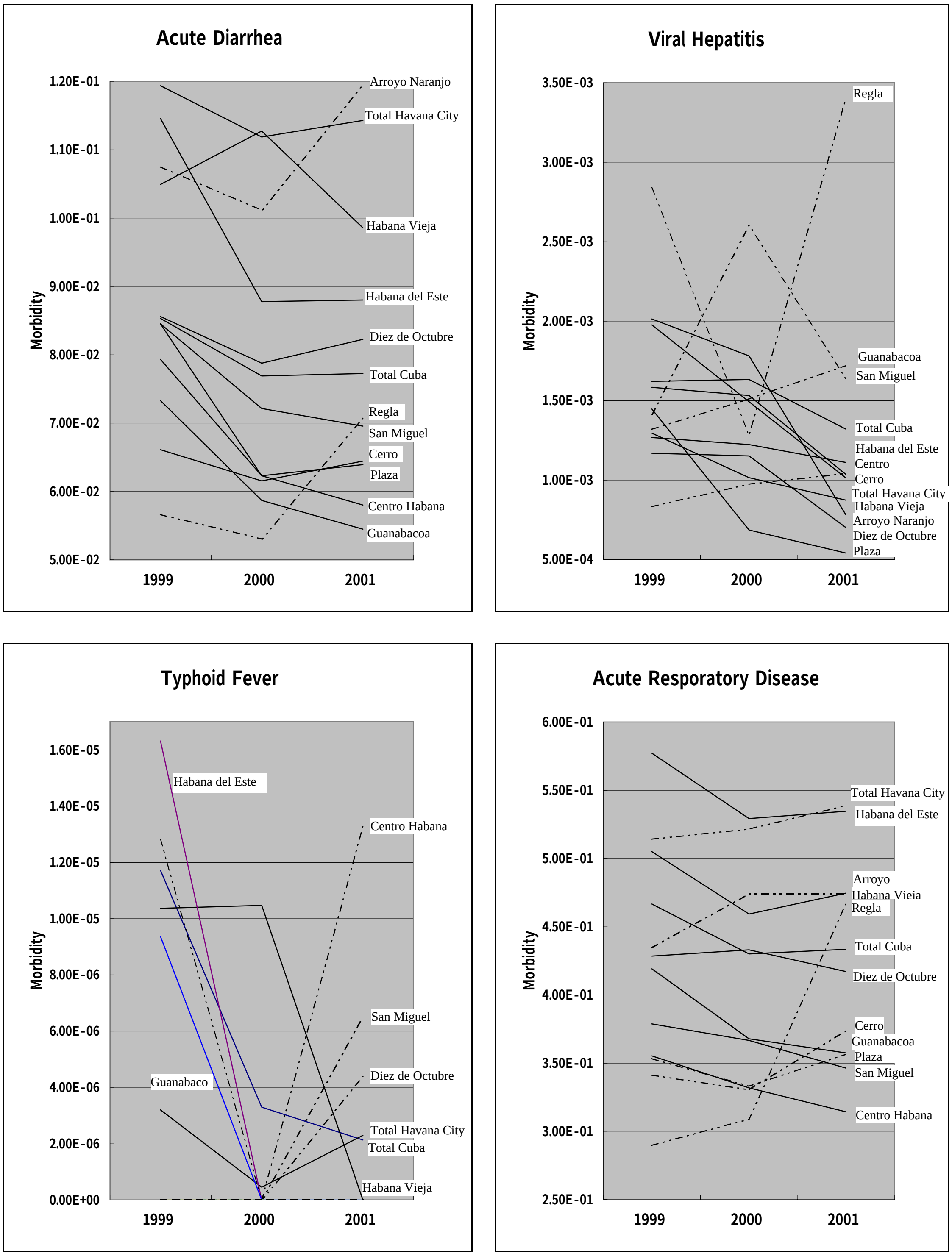
## Table 2.13 Morbidity of Diseases Related to Water Supply and Sewerage

(figures per 1,000,000 inhabitants)

| Disease | Year | Total Cuba | Total Havana City | Habana | Regla | Habana del | Plaza | Centro | Guanabacoa | San Miguel | Diez de | Cerro | Arroyo |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Acute diarrhea | 1999 | 85,303 | 119,382 | 104,904 | 56,644 | 114,562 | 79,329 | 84,514 | 73,289 | 84,514 | 85,582 | 66,130 | 107,497 |
| | 2000 | 76,899 | 111,850 | 112,745 | 53,044 | 87,790 | 62,318 | 62,309 | 58,705 | 72,125 | 78,752 | 61,564 | 101,140 |
| | 2001 | 77,244 | 114,291 | 98,562 | ***70,630*** | 88,026 | 63,943 | 58,001 | 54,468 | 69,549 | 82,251 | 64,446 | ***119,377*** |
| Typhoid fever | 1999 | 12 | 3 | 10 | 0 | 16 | 0 | 13 | 9 | 0 | 0 | 0 | 0 |
| | 2000 | 3 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2001 | 2 | 2 | 0 | 0 | 0 | 0 | ***13*** | 0 | ***6*** | ***4*** | 0 | 0 |
| Viral hepatitis | 1999 | 1,621 | 1,976 | 1,296 | 2,838 | 1,267 | 1,447 | 833 | 1,320 | 1,415 | 1,168 | 1,583 | 2,013 |
| | 2000 | 1,633 | 1,493 | 1,016 | 1,283 | 1,224 | 686 | 975 | 1,510 | 2,599 | 1,152 | 1,532 | 1,781 |
| | 2001 | 1,321 | 1,013 | 874 | ***3,397*** | 1,111 | 541 | ***1,041*** | ***1,720*** | ***1,639*** | 701 | 1,035 | 781 |
| Acute respiratory Disease | 1999 | 466,569 | 514,130 | 434,665 | 289,755 | 577,231 | 353,340 | 355,429 | 419,139 | 378,795 | 428,479 | 341,273 | 505,080 |
| | 2000 | 430,043 | 521,528 | 474,267 | 309,074 | 529,155 | 333,003 | 331,828 | 367,893 | 366,653 | 433,080 | 330,578 | 459,188 |
| | 2001 | 433,446 | ***538,730*** | ***474,180*** | ***466,218*** | 534,658 | ***356,570*** | 314,362 | 357,597 | 346,468 | 417,074 | ***373,877*** | 474,569 |

Note: Bold and italic figures denote that the morbidity increased in the year 2001 compared with the year 1999.

Source: Havana City




THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY

JAPAN INTERNATIONAL COOPERATION AGENCY

Figure 2.2 Tendency of Morbidity of Sewerage Related Diseases

# 2.3 URBAN INFRASTRUCTURE

## 2.3.1 URBAN PLANNING AND LAND USE

Present land use in the Study is summarized in the table below.

**Table 2.14 Present Land Use**

| Land use | Area ($km^2$) | Ratio (%) |
|---|---|---|
| 1. Residential and commercial areas | 40.55 | 61 |
| 2. Industrial area | 13.20 | 20 |
| 3. Agriculture | 6.25 | 10 |
| 4. Parks and green areas | 4.00 | 6 |
| 5. Reserved area | 2.00 | 3 |
| Total | 66.00 | 100 |

Source: Estudio de caso: Bahía de La Habana, Cuba, under "Proyecto GEF/RLA/93/G41Proyecto Regional Planificación y Manejo de Bahías y Areas Costeras Fuertemente Contaminadas del Gran Caribe"

The ratio of residential, commercial and industrial areas reached more than 80%, indicating high urbanization.

## 2.3.2 WATER SUPPLY CONDITIONS AND FUTURE PLAN

Water supply conditions and future plans are described below based on a series of interview survey and the report of the city of Havana prepared by INRH.[1]

Present public water supply system provide the service to about 2.2 million people of 15 municipalities in the city of Havana.

There are 53 water sources for water supply and their total intake volume is about 480.7 million $m^3$/year (1.317 million $m^3$/day). Forty water sources are appropriate for drinking water having intake volume of 475 million $m^3$/year (1.30 million $m^3$/day), and 13 water sources are brackish having intake volume of 5,694 x 1,000 $m^3$/year (15,600 $m^3$/day). Thirty-seven out of forty water sources are groundwater of deep wells and the remaining three water sources are surface water of reservoirs.

The groundwater is treated by chlorine gas or sodium hypochlorite for disinfections, and then conveyed by transmission main and buster pumping stations and distributed directly by pumps or through high-elevated distribution tanks. The surface water is treated at the water purification plant, Planta de Filtros, by the rapid sand filtration process, using aluminum sulfate as a coagulant, lime as for pH adjustment and chlorine gas as disinfectant. The design capacity of the plant is 600 l/sec (51,840 $m^3$/day) and actual production capacity is 500 l/sec (48,400$m^3$/day). Thus the daily water volume taken or produced at water resources is summarized as follows: the total water volume of 1,317,000$m^3$/day, the treated surface water volume at the purification plant is 48,400 $m^3$/day, the remaining groundwater volume of 1,268,600$m^3$/day. The percentage of groundwater source is more than 96.6%, thus the almost all of water supplied to the city is groundwater origin.

The water taken and treated is conveyed through transmission main and distributed water distribution networks. The water transmission main developed are 374 km in total length, having the diameter of 12"" to 78" (300 mm to 2,000 mm). The distribution pipes installed are 3,594 km in total length. Pipe materials are cast iron and center-steel used for transmission main and cast iron and asbestos cement used for distribution pipes.

[1] Estudio sobre los ciclos del agua en la Habana,1997

From the total intake volume of 4,806 million $m^3$/year (1.32 million $m^3$/dy), the unit water volume supplied by capita can be calculated as 604 liter per capita per day (lpcd) with the service population of 2,180,000. The figure of unit supply volume is not small compared the same scale of cities. However, in the actual situation, the intake water is lost through the production process, transmission mains, pumps and water distribution networks. A hearing survey estimates about 50% of intake water is lost through transmission mains due to the lack of capacity and age.

Water supply conditions in the city of Havana, 24 hours continuous water supply is limited, intermittent water supply, averagely about 10 hours supply, is commonly practiced. Thus individual water storage tanks are commonly used.

The Cuban water supply standards (Norm) set a per capita water supply volume: 220 lpcd of domestic water in the city having 500,000 population and 470 lpcd including water for institutional and public purposes parks, roads.

A future plan for improving the water supply conditions and water supply system is prepared for the city of Havana by INRH under the finance of Europa-Union.[1]

### 2.3.3 Solid Wastes Management

The solid wastes management is responsible for Havana City. An appropriate solid wastes management is essential for healthy urban life and for tourist industry.

A study on solid wastes management "MANEJO DE RESIDUOS SÓLIDOS URBANOS, RECINTO PORTUARIO DE LA HABANA, Ciudad de La Habana, diciembre 2001" reports estimated solid wastes production in an area of Havana Bay and proposes an efficient solid wastes management to solve the ever increasing solid wastes.

The study report estimated the solid wastes production and characteristics as shown in the table below:

**Table 2.15 Production and Characteristics of Solid Wastes in the Port Enclosure**

| Generating | Population Equivalent | Unit production rate, (kg./ capita/day) | Weight (ton/day) | Volume ($m^3$/day) | Density (kg/$m^3$) | Percentage in weight (%) |
|---|---|---|---|---|---|---|
| Port facilities | 3,267 | 0.4 | 1.3 | 9.9 | 131 | 25 |
| Chemical industry | 1,122 | 0.4 | 0.4 | 3.8 | 104 | 8 |
| Petroleum industry | 2,184 | 0.4 | 0.9 | 7.4 | 121 | 17 |
| Food industry | 1,748 | 0.4 | 0.7 | 4.5 | 156 | 13 |
| Other indutry | 3,381 | 0.4 | 1.4 | 12.3 | 114 | 27 |
| Domestic | 1,331 | 0.4 | 0.5 | 4.0 | 126 | 10 |
| TOTAL | 13,033 | | 5.2 | 41.9 | | 100 |

Source: "MANEJO DE RESIDUOS SÓLIDOS URBANOS, RECINTO PORTUARIO DE LA HABANA, Ciudad de La Habana, diciembre 2001"

Table 2.16 summarizes characteristics of main land disposal sites in Havana City. Table 2.17 shows distance of land disposal sites from the municipalities concerned. The figures in these tables were prepared in 1990, these figures needs to be updated but the magnitudes may be

[1] Estudio sobre los ciclos del agua en la Habana,1997

useful to consider. disposal plans of sludge produced in the wastewater treatment plans to be constructed in the Havana Bay basin. The table 2.16 presents that the location of the sites are closed to the municipalities concerned and the expected usage time is very limited. Therefore, to secure the prominent land disposal sites is very important for the city authority.

The study on solid wastes management "MANEJO DE RESIDUOS SÓLIDOS URBANOS, RECINTO PORTUARIO DE LA HABANA, Ciudad de La Habana, diciembre 2001" proposes: an introduction of selective collection of solid wastes, valuable and possible to use recycled, and construction of primary treatment facilities aiming recycle use of solids wastes.

**Table 2.16 Features and Characteristics of Main Solid Wastes Land Disposal Sites in the Havana City**

| Name of Disposal Site | Time limits (year) | Number of year used | Soil type | Depth of ground water level | Daily Disposal Capacity (ton/day) | Equipments installed |
|---|---|---|---|---|---|---|
| Guanabo East | 2000 | 22 yrs | Rocky | 8 m | 154.1 | 4 Bulldozer |
| 8 Vias East | 2003 | 22 yrs | Clay | 10 m | 32.6 | 3 Bulldozer |
| Jaimanitas West | 2005 | 20 yrs | Rocky | 7 m | 20.0 | 3 Bulldozer |
| Barrera Este | 2005 | 20 yrs | Rocky | 8 m | 20.0 | 2 Bulldozer |
| Calle 100 West | 2010 | 20 yrs | Clay | 4 m | 615.0 | 5 Bulldozer |

Source: Dilección Provincial de Servicios Comunales, 1990, Ministry of Public Health

**Table 2.17 Distance of Public Wastes Disposal Sites from Municipalities concerned**

| Name of Disposal Site | Municipality, discharging solid wastes | Distance (km) |
|---|---|---|
| Guanabacoa (Este ) | Guanabacoa,<br>Habana del Este,<br>San Miguel del Padrón,<br>Regla | 0 - 5<br>6 -12<br>6 -10<br>4 - 7 |
| 8 Vias( East ) | Industries from the 15 Municipalities | 0 -20 |
| Jaimanitas ( West) | Playa<br>La Lisa<br>Marianao<br>Plaza | 0 - 8<br>3 - 7<br>3 - 5<br>7 -10 |
| Barrera (East ) | Habana del Este<br>Guanabacoa<br>Regla | 0 - 9<br>3 - 9<br>4 - 6 |
| Calle 100 (west) | Habana Vieja<br>Centro Habana<br>Cerro<br>Plaza<br>10de Octubre<br>Arroyo Naranjo<br>Boyeros<br>La Lisa<br>Marianao<br>Playa | 14-17<br>10-15<br>4 - 8<br>5 - 8<br>5 -10<br>6 -12<br>3 -14<br>5 -10<br>2 - 6<br>6 -10 |

Source: Dirección Provincial de Servicios Comunales, 1990, Ministry of Public Health

# CHAPTER 3
# ENVIRONMENTAL CONDITIONS, LAWS AND STANDARDS

## 3.1 GENERAL

Quality of tributary rivers and the bay is briefly reviewed in this chapter based on information available in annual reports of GTE and GEF Project Reports for which investigations were carried out by CIMAB.[1) to 4) and 8) to 11)] Results of the surveys carried out by JICA Study Team on tributary rivers and the bay are summarized. Current situation of the industrial wastewater, one of major pollution source to the Havana Bay, is also studied and reported through an industrial wastewater survey in this Study. Laws and standards on water pollution control in Cuba are also summarized in this chapter.

## 3.2 TRIBUTARY RIVERS

There are three (3) tributary rivers flowing into Havana Bay. Table 3.1 shows major characteristics of these tributary rivers.

**Table 3.1 Major Characteristics of Tributary Rivers**

| Item | Rio Luyano | Rio Martin Perez | Arroyo Tadeo |
|---|---|---|---|
| Length (km) | 10.1 | 6.4 | 2.3 |
| Catchment Area of the Basin ($km^2$) | 30 | 13.1 | 2.1 |
| Population in the Basin (person, in 2000)) | 242,000 | 73,000 | 14,000 |
| Flow Rate ($m^3$/d) (at river mouth) | 71,970 (1985)<br>79,666 (1990)<br>120,960 (1996)<br>114,860 (2002) | 26,093 (1981-1985)<br>35,597 (1996)<br>39,819 (Sep., 2001)<br>62,105 (May, 2002) | 5,247 (1981-1985)<br>8,004 (2002) |
| Major Pollution Sources | Domestic wastewater, industrial wastewater and rain water (in case of rainfall | Domestic wastewater, industrial wastewater and rain water (in case of rainfall | Domestic wastewater, and rain water (in case of rainfall) |

Source: CIMAB [1), 2),4)]

### 3.2.1 EXISTING DATA OF RIVER WATER QUALITY

There is no periodic monitoring system for monitoring water quality of tributary rivers, however, CIMAB and CENHICA etc. have analyzed the rivers water quality in some projects financed by GTE, GEF and Enterprise of Hydraulic Usage (EAH).

<u>Organics and Nutrients</u>: Results reported by CIMAB for Rio Luyano, Rio Martin Perez and Arroyo Tadeo (Reference1, 2 and 3) are summarized in Table 3.2 for observations carried out in the year 2000/2002.

**Table 3.2 Water Quality of Tributary Rivers in Year 2000-2002**

| Parameter | Rio Luyano | | Rio Martin Perez | | Arroyo Tadeo (n=1) | Cuban Standard NC-27 (C) | Japanese Environ. Standard for Rivers (E) |
|---|---|---|---|---|---|---|---|
| | Wet season (n=29) | Dry Season (n=30) | Wet season (n=27) | Dry Season (n=27) | | | |
| Temp., °C | 29.0 (27.0-32.0) | 26.6 (23.5-29.4) | 29.0 (24.4-33.0) | 29.5 (25.9-34.4) | - | < 50 | - |
| pH | 7.58 (7.30-7.82) | 7.83 (7.65-8.04) | 7.91 (7.03-8.64) | 7.51 (6.44-8.02) | - | 6 - 9 | 6.0 – 8.5 |
| DO, mg/L | - | - | 2.82 (0.0-5.4) | 1.15 (0.63-4.25) | - | - | >2.0 |
| $BOD_5$, mg/L | 53 (6-205) | 46 (16-80) | 16 (8-26) | 22 (8-48) | 192 | < 60 | <10 |
| COD, mg/L | 90 (16-1,116) | 72 (35-117) | 25 (14-47) | 45 (18-81) | 320 | < 120 | - |
| SS, mg/L | 21 (6-80) | 46 (5-97) | 19 (6-62) | 18 (10-47) | 10 | - | No floating wastes |
| T-N, mg/L | - | - | 5.55 | - | 12.4 | < 20 | - |
| TKN, mg/L | 6.72 (1.12-15.68) | 12.88 (6.72-19.04) | 4.48 (2.24-17.92) | 4.48 (2.24-7.84) | - | - | - |
| $NH_3$-N, mg/L | 4.66 (0.93-9.42) | 7.14 (5.22-8.68) | 1.77 (0.28-3.08) | - | - | - | - |
| Organic-N, mg/L | 2.15 (0.1-10.08) | 5.75 (0.28-11.95) | 2.05 (0.02-16.52) | - | - | - | - |
| T-P, mg/L | 0.36 (0.07-0.81) | 4.09 (0.71-15.89) | 0.59 (0.07-2.04) | 0.69 (0.21-4.8) | 5.1 | < 10 | - |
| Oil and Grease, mg/l | 2.6 (0.30-18.0) | 0.74 (0.04-1.73) | 0.06 (0.0-70.1) | 0.3 (0.02-2.35) | 0.02 | <30 | - |

Note: 1 Median value is shown along with maximum and minimum values in parenthesis, when available and n is the number of data.
2 Sampling periods for Rio Luyano were Jun./Jul. 2000 for wet season and Feb./Mar. 2001 for dry season, and for Rio Martin Perez were Sep./Oct. 2001 for wet season and May/Jun. 2002 for dry season. For Arroyo Tadeo it was in 2002.
3 NC-27 is the discharge standard to inland surface waters, and Class C is applied for the receiving water for industrial water supply purpose. Comparison is made considering rivers as a discharge and not be construed as an environmental standard for river.
4 Japanese water environmental standard for rivers (E), the lowest level, is applied for Class 3 of industrial water supply and environmental protection.
5 TKN (Total Kjeldahl Nitrogen) is at times reported as T-N.

As shown in Table 3.2, the concentrations of BOD and COD in Luyano, Martin Perez and Arroyo Tadeos show very high values. The concentrations of T-N and T-P are also considered to be a relative high level. Water quality of the rivers shows serious organic and nutrient pollution.

Table 3.3 shows general trend of organic and nutrient quality of rivers. Water quality improvement from 1985 to 1996 may be attributed to economic slowdown. Between 1996 and 2002, water quality degradation is evident except in Rio Luyano, which was mainly due to decreased industrial discharge of distillery wastewater through process modifications in the distillery.

**Table 3.3 Water Quality of Tributary Rivers 1985-2002**

| Parameter | Rio Luyano | | | Rio Martin Perez | | | Arroyo Tadeo | |
|---|---|---|---|---|---|---|---|---|
| | 1985 | 1996 | 2002 | 1985 | 1996 | 2002 | 1985 | 2002 |
| Flow, $m^3$/d | 71,970 | 120,960 | 114,860 | 26,093 | 35,597 | 62,105 | 5,247 | 8,004 |
| $BOD_5$, mg/L | 546 | 236 | 83 | 22 | 10 | 20 | 36 | 192 |
| COD, mg/L | 1,205 | 402 | 138 | 56 | 27 | 43 | 88 | 320 |
| T-N, mg/L | - | 39.7 | 9.3 | - | 9.0 | 3.8 | 61.0 | 12.4 |
| T-P, mg/L | - | - | - | - | 5.1 | 0.8 | 34.3 | 5.1 |
| SS, mg/L | 117 | 94 | 33 | 14 | 35 | 17 | 54 | 10 |

Source: CIMAB [1) and 3)]

Heavy Metals: Table 3.4 shows heavy metal concentrations measured in Rio Luyano over a period of 30 days in Jun./Jul 2000 and the maximum limits set for discharge to sewers in Cuban standard NC27 and NC93-105 which set environmental quality for sea water used for fishing. For reference, Japanese standards for the wastewater discharging to sewers and on environmental quality are also shown. None of the measured heavy metals exceeded the NC27, however it should be noted that NC27 as shown in the table is pertinent to discharge to sewers and therefore not construed as acceptable environmental level.

**Table 3.4 Heavy Metal Concentration in Rio Luyano**

| Parameter | Rio Luyano (n=36) | Cuban Standards | | Japanese Standards | |
|---|---|---|---|---|---|
| | | NC93-105, Sea water for fishing | NC27, Discharge to Sewers | Discharge to Sewers | Environmental Quality |
| Cadmium (Cd), mg/L | <0.005 – 0.018 | 0.01 | < 0.3 | 0.1 | 0.01 |
| Chromium (Cr), mg/L | <0.020 – 0.054 | - | 2.0 | 2 | - |
| Copper (Cu), mg/L | <0.010 – 0.034 | - | < 5.0 | 3 | - |
| Mercury (Hg), mg/L | <0.02 | 0.005 | <0.01 | 0.005 | 0.0005 |
| Nickel (Ni), mg/L | <0.013 – 0.093 | - | - | - | - |
| Lead (Pb), mg/L | <0.10 | 0.1 | 1.0 | 0.1 | 0.01 |
| Zinc (Zn), mg/L | <0.013 – 0.234 | - | 5.0 | 5 | - |

Source: CIMAB [1)], Sampling period was Jun./Jul. 2000 for wet season and the number of samples was 36.

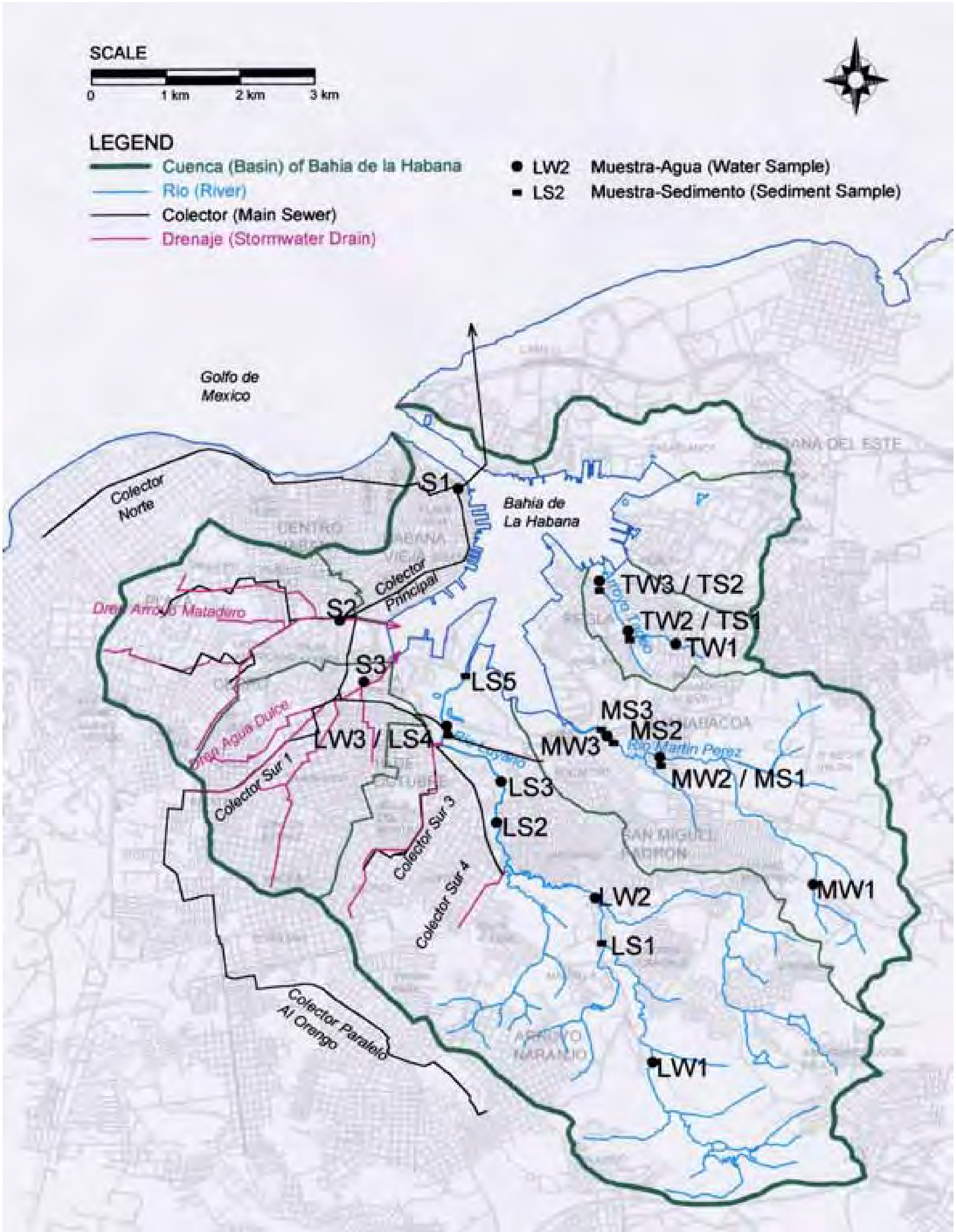
Pathogenic Indicators: Fecal coliform concentration in Rio Martin Perez was in the range of 3.3 $x10^5$ to 7.6 $x10^5$ MPN/100 ml in the year 2000,[2)] which indicates high level of sewage pollution. Similar or higher values are expected in Rio Luyano and Arroyo Tadeo which also receive domestic wastewater discharges.

### 3.2.2 WATER AND SEDIMENT QUALITY SURVEY OF RIVERS

Water and sediment quality survey of rivers was carried out during October to December 2002 in tributary rivers by CENHICA/CIMAB under the contract with JICA Study Team. Sampling locations are shown in Figure 3.1. Water quality sampling locations were selected to compare the water quality along the river. Sediment quality locations were selected immediately downstream of major industrial discharges along the river reaches in order to understand the effects of industrial wastewater. Table 3.5 shows the details of sampling.

**Table 3.5 Water and Sediment Quality Survey of Tributary Rivers**

| River and Drainage Pipes | Water Sampling Locations and Date | | Sediment Sample Locations and Date |
|---|---|---|---|
| | Wet Season | Dry Season | |
| Rio Luyano | 3 locations (LW1, LW2 and LW3) 17 October 2002 (8:00 to 19:00) | 3 locations (LW1, LW2 and LW3) 22 December 2002 (8:00 to 20:00) | 5 locations (LS1, LS2, LS3, LS4 and LS5) 17 October 2002 |
| Rio Martin Perez | 3 locations (MW1, MW2 and MW3) 18 October 2002 (8:00 to 19:00) | 3 locations (MW1, MW2 and MW3) 21 December 2002 (8:00 to 20:00) | 3 locations (MS1, MS2 and MS3) 18 October 2002 |
| Arroyo Tadeo | 3 locations (TW1, TW2 and TW3) 19-20 October 2002 (8:00 to 7:00) | 3 locations (TW1, TW2 and TW3) 23-24 December 2002 (8:00 to 7:00) | 2 locations (TS1 and TS2) 18 October 2002 |
| Total | 9 locations | 9 locations | 10 locations |




| THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY | Figure 3.1 Location Map for Water and Sediment Quality Survey of Rivers and Wastewater |
|---|---|
| JAPAN INTERNATIONAL COOPERATION AGENCY | |

One composite sample was made at each location combining samples taken at hourly proportional to the river flow. Analytical parameters are as follows:

Water samples: pH, Water Temperature, conductivity, COD, $BOD_5$, DO, SS, $SO_4^{2-}$, T-N, $NH_4^+$-N, $NO_2^-$-N, $NO_3^-$-N, T-P, $PO_4^{3-}$-P, $SiO_2$, Petroleum Hydrocarbon, Fecal Coliform, Phenol, Arsenic (As), Cadmium (Cd), Cobalt (Co), Copper (Cu), Iron (Fe), Total Mercury (Hg), Manganese (Mn), Nickel (Ni), Lead (Pb), Vanadium (V), and Zinc (Zn)

Sediment samples: Water Content, Grain Size Distribution, Total Volatile Solids, T-N, Total Organic Matter, T-P, Petroleum Hydrocarbon, Clostridium Perfringens, Arsenic (As), Cadmium (Cd), Cobalt (Co), Copper (Cu), Iron (Fe), Total Mercury (Hg), Manganese (Mn), Nickel (Ni), Lead (Pb), Vanadium (V), and Zinc (Zn)

**(1) Survey Results of Water**

**Flowrates**: Results of flow measurement at mouth of tributary rivers are shown in Figure 3.2. Comparing with the existing data (see Table 3.1), the average flowrates in Rio Luyano and Rio Martin Perez show higher values, especially in Rio Luyano. The reasons are presumed as following:

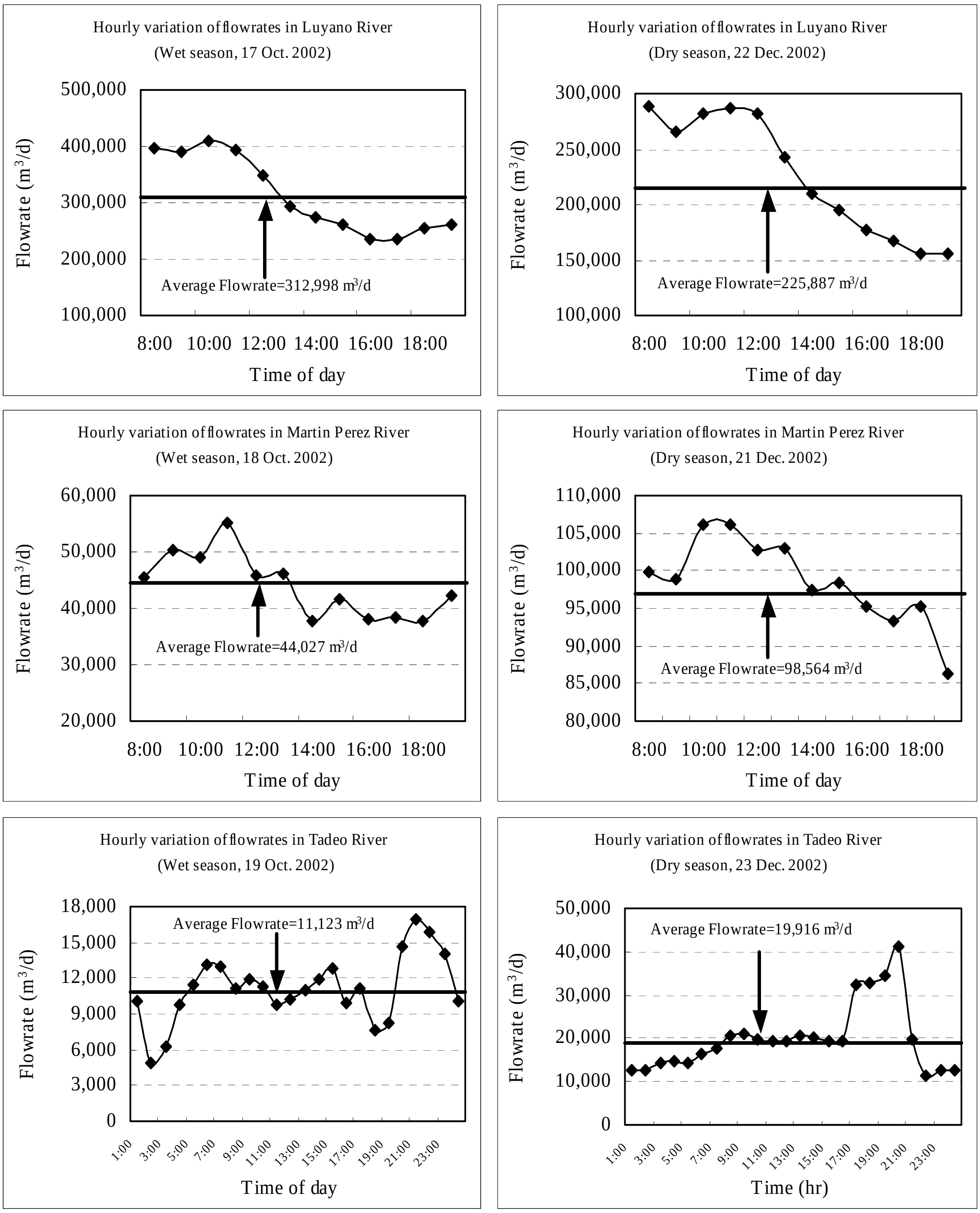
- Average flowrates are calculated by the results measured in daytime. Considering the fact that wastewater (especially domestic wastewater) contributes the greater part of river flowrate, and that minimum flow usually occurs during the early morning hours, calculated average flowrates in rivers may have higher values than that of 24-hour average.
- The delayed inflow of stormwater has to be considered because there was a rainfall a few days ago when rivers flowrates were measured in Oct. and Dec. 2002.

In addition, hourly variations of flowrates in Rio Luyano and Rio Martin Perez show a peak value in the morning (10:00 to 12:00), while the peak flowrate in Arroyo Tadeo is presented in the evening (20:00 to 21:00) indicating a similar pattern with domestic wastewater.

**DO**: Variations of DO, organics (BOD and COD) and nutrients (T-N and T-P) in downstream, midstream and upstream of three tributary rivers are illustrated in Figure 3.3. DO is important to aquatic life because detrimental effects can occur when DO levels drop below 4 to 5 mg/l. As shown in Figure 3.3, DO is reduced sharply from 6 mg/l in upstream to 2 mg/l in downstream of Rio Luyano and Rio Martin Perez, which indicates higher level of pollution in downstream of two rivers. For Arroyo Tadeo, DO in all of sections shows a lower level (1 to 3 mg/l) because domestic wastewater contributes the majority of flowrate.

**Organics**: BOD and COD concentrations of Rio Luyano and Rio Martin Perez show a increasing trend from upstream to downstream, which results in decrease of DO levels. However, comparing with the existing data of BOD concentration of 46 to 53 mg/l and COD concentration of 72 to 90 mg/l shown in Table 3.2, the survey results of BOD and COD concentrations at the mouth of Rio Luyano show lower, 7 to 11 mg/l and COD of 26 to 34 mg/l, respectively. In Arroyo Tadeo and Rio Martin Perez, similar results are observed. These results may indicate the wastewater diluted by delayed inflow and with stormwater.

**Nutrients**: As shown in Figure 3.3, T-N and T-P concentrations of Rio Luyano and Rio Martin Perez show an increasing trend from upstream to downstream, which means that water quality is getting worse from upstream to downstream due to inflow of industrial and domestic wastewater along Rio Luyano and Rio Martin Perez.




| | |
|---|---|
| THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY | Figure 3.2 Results of Flowrates Measurement at River Mouths |
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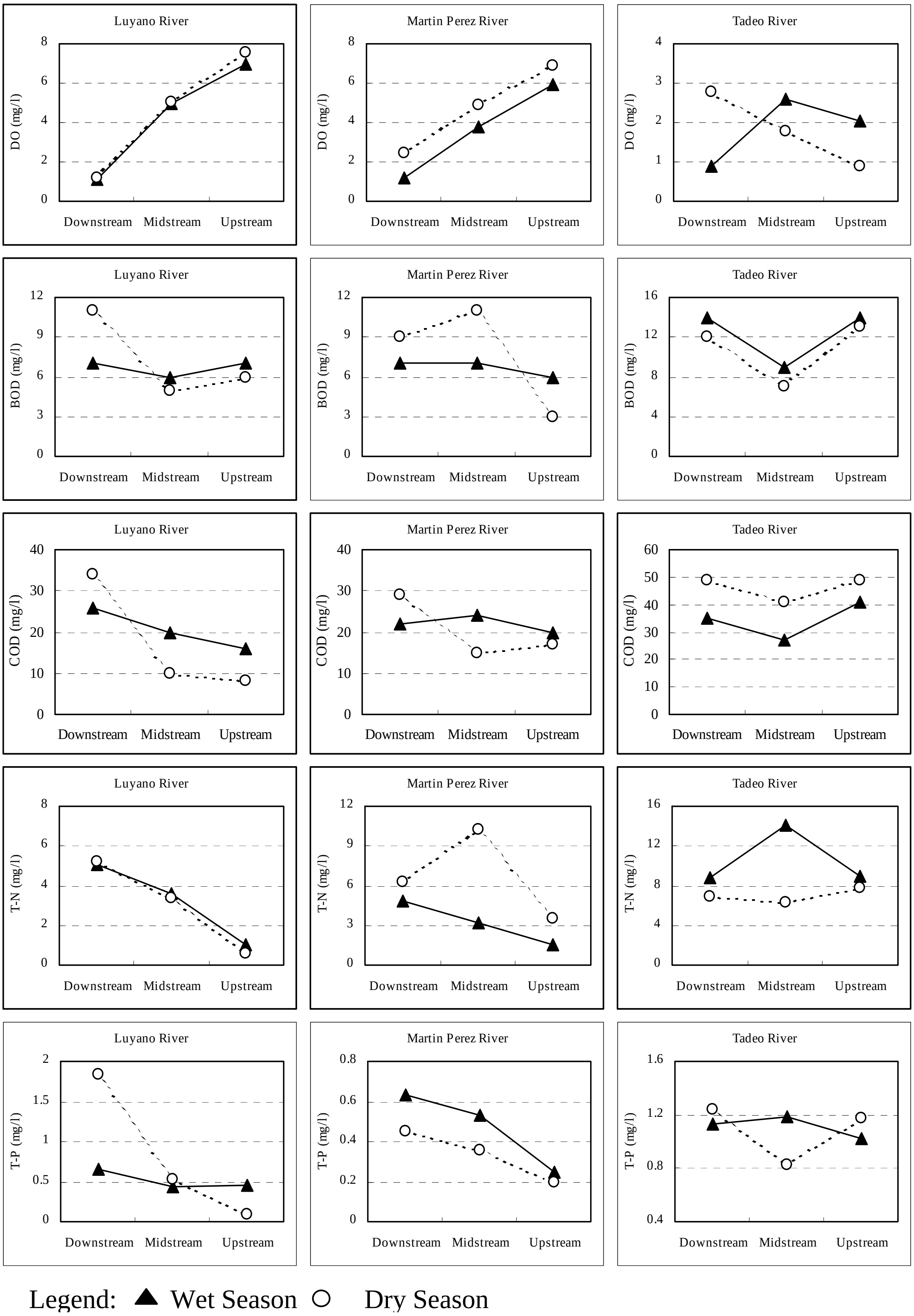


THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY

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Figure 3.3 Variations of DO, Organics and Nutrients in Tributary Rivers

However, this trend is not observed in Arroyo Tadeo. Actually, even at upstream of Arroyo Tadeo domestic wastewater is discharged into the river without any treatment, which results in higher nutrients concentration. Unlike BOD and COD, T-N (5 to 8 mg/l) and T-P (0.5 to 1.8 mg/l) concentrations at the mouth of three rivers show same levels as existing data shown in Table3.2.

In addition, nutrients concentrations in the effluent of rivers have exceeded by far Class IV (T-N<1.0 mg/l; T-P<0.09 mg/l), which is the lowest level of Japanese seawater environmental standards for eutrophication of seawater. Therefore, the influent of river water polluted by T-N and T-P may cause eutrophication of Havana Bay.

**Heavy Metals**: Analysis results of heavy metals indicate that the concentrations of heavy metals in almost samples are below the detection limit, and no abnormal values are detected. A preliminary survey results on industrial wastewater under the Study will also explain the survey results that there are no factories currently using heavy metals for production in three river basins.

**Pathogenic Indicators**: Fecal coliform concentrations at mouth of Rio Luyano, Rio Martin Perez and Arroyo Tadeo are measured to be 2.4 to 30 x $10^5$, 0.8 to 17 x $10^5$, 13 to 160 x $10^5$ MPN/100 ml, respectively. Same as the results of previous monitoring, it is considered that these three rivers are polluted by raw sewage, especially for Arroyo Tadeo.

### (2) Survey Results of Sediment Quality

Very limited data are available on sediment quality of the tributary rivers. A unique study on river sediment quality (only heavy metals at three locations) was carried out by Havana University between 1999 and 2000. However, analysis method of heavy metals used by Havana University is different with that of this Study, therefore, it is impossible to compare the results of this Study with the results of Havana University.

In order to identify current situations of sediment quality in the tributary rivers, especially to grasp the effects of heavy metals from industrial wastewater on sediment of rivers, 10 samples were taken in immediately downstream of industrial wastewater discharging outlets. The resulted concentrations of heavy metals in rivers sediments are summarized in Table 3.6. Since no Cuban standards for river sediment or soil are available, EU soil standard for heavy metals are shown in the table for the reference.

**Table 3.6 Heavy Metals Contents of Rivers Sediments**

Unit: mg/kg dry weight

| Metal | Rio Luyano | | | | | Rio Martin Perez | | | Arroyo Tadeo | | EU Soil |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | LS1 | LS2 | LS3 | LS4 | LS5 | MS1 | MS2 | MS3 | TS1 | TS2 | Standard* |
| As | 0.3 | 0.4 | 0.3 | 0.3 | 0.3 | 0.2 | 0.3 | <0.2 | <0.2 | 0.2 | – |
| Cd | 3.0 | **5.3** | **5.4** | **4.1** | **9.9** | **3.5** | **4.6** | **5.1** | **5.1** | **4.3** | 1 – 3 |
| Co | 15.4 | 15.3 | 14.2 | 14.9 | 13.5 | 15.7 | 16.3 | 23.8 | 24.2 | 14.9 | – |
| Cu | 141 | 94 | 105 | 136 | **168** | 87 | **161** | 89 | 146 | 135 | 50 – 140 |
| Hg | <5.0 | <5.0 | <5.0 | <5.0 | <5.0 | <5.0 | <5.0 | <5.0 | <5.0 | <5.0 | 1 – 1.5 |
| Ni | 43.9 | 42.9 | 45.5 | 48.8 | 47.9 | 53.5 | 65.6 | **286.0** | **381.0** | 68.9 | 30 – 75 |
| Pb | 96 | 144 | 124 | 189 | 227 | 131 | 190 | **479** | 134 | 189 | 50 – 300 |
| Zn | 168 | 211 | 286 | **359** | **414** | 202 | **422** | **333** | **326** | **304** | 150 – 300 |

Max. Admissible Concentration for EU, 86/278/EC Appendix 1A

As shown in Table 3.6, for all of samples As and Co are detected in the range of 0.2 to 0.4 mg/kg, 13.5 to 24.2 mg/kg, respectively, which is considered to be normal level because common concentration of As and Co in soil is 1 to 50 mg/kg.

Concentrations of Cd, Cu, Ni, Pb and Zn are detected as high concentrations in downstream of Rio Luyano (LS5), Rio Martin Perez (MS2 and MS3) and Arroyo Tadeo (TS1), however, no extraordinary high values are detected. As for the mercury, the detection limit of total mercury (Hg) of 5.0 mg/kg is higher than the value of EU soil standard, it is difficult to evaluate Hg concentration in rivers sediments.

## 3.3 HAVANA BAY

### 3.3.1 EXISTING DATA

Water and sediment quality of Havana Bay is monitored by CIMAB twice a year during wet season and dry season at five locations as shown in Figure 3.4. Two locations outside the Bay, one near the existing sewer outfall at Playa del Chivo and the other at Caleta de San Lázaro, are also monitored for water quality. Atares, Marimelena and Guasabacoa are located in where polluted water from urban drains, industries and rivers are discharged and tidal circulation is poor comparing to Centro de la Bahía and Canal Entrada.

**DO and Nutrients**: Figure 3.5 shows vertical variations of the DO and nutrients in dry season of year 2001. Low DO and high nutrients indicate higher level of pollution. Comparing with Playa del Chivo and Caleta de San Lázaro, pollution level is high at Atares, Marimelena and Guasabacoa. At Centro de la Bahía and at Canal Entrada, DO and mineral nitrogen levels are similar to that outside the Bay but $PO_4$-P and T-P levels are higher than that outside the bay. Ratio of mineral nitrogen ($NH_3$-N+$NO_2$-N+$NO_3$-N) to mineral phosphorous ($PO_4$-P) is between 0.7- 4.8 within the Bay compared to 6.4 – 11.7 at Caleta de San Lázaro. Optimal N/P ratio by weight is around 7 and the N/P ratio suggests nitrogen limitation in the bay.

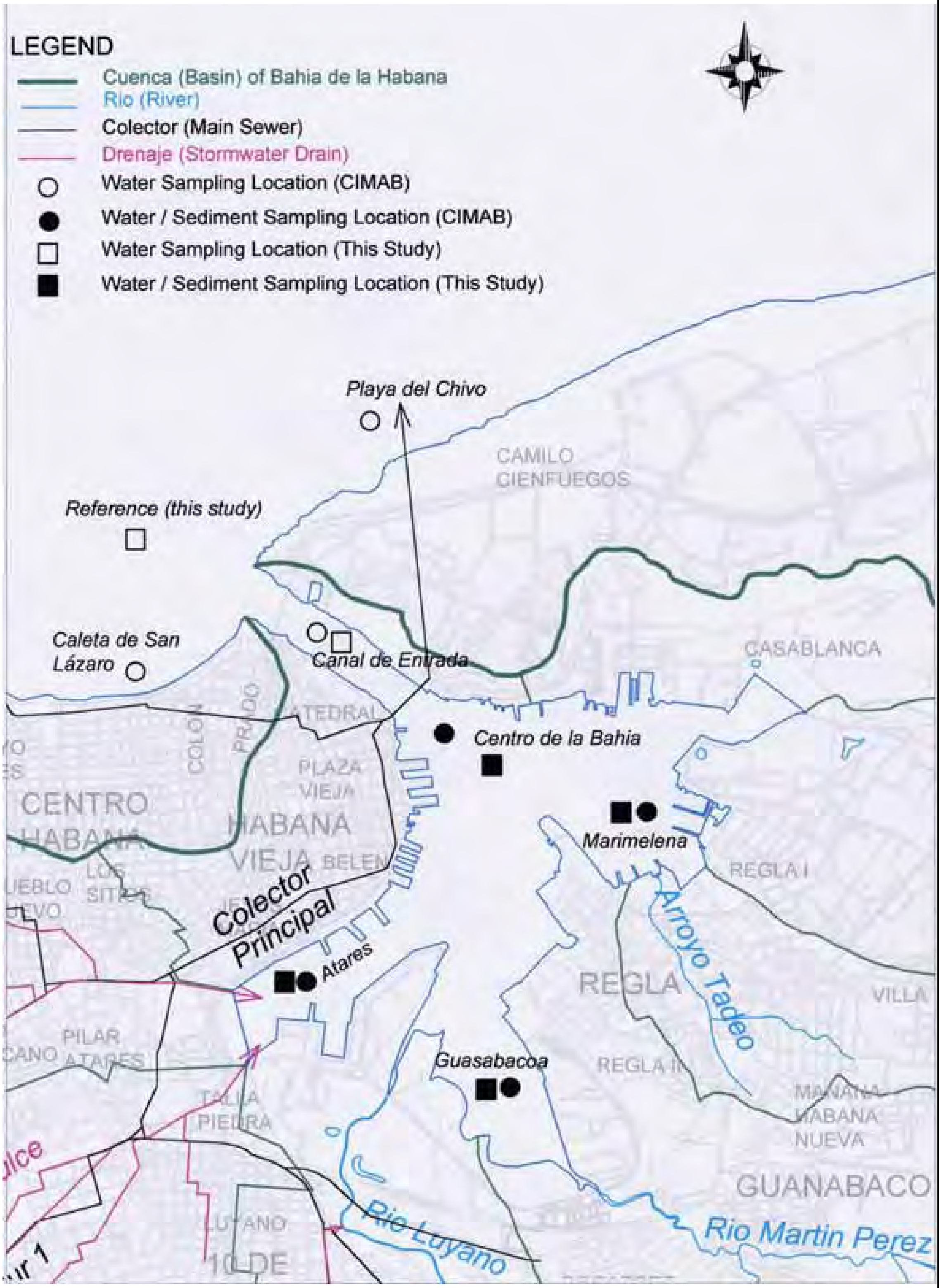
Figure 3.6 shows the variations of DO and major nutrients during year 1986-2001. Pollution level decreased between 1986-90 and 1996 showed by increase in DO and decrease in nutrients (T-P). Between 1996 and 2001, there is a slightly increasing trend in the concentration of nutrients.

Suspended solids data reported were in the range of 98-285 mg/L during year 1986-2001 which is considered to be rather high and contradictory compared with visual observation and the observed transparency (1- 4 m) during the sampling in October 2002.

**Chlorophyll-a** : Variation of chlorophyll-a which is an indicator of eutrophication is 31.2 (1980-83), 6.5(1996) and 25.7 (1999) $mg/m^3$ which shows that eutrophication is on the increasing trend from a low registered in 1999.

**Heavy Metals**: Figure 3.7 shows the variation at Atarés, Guasabacoa and at Marimelena in comparison with the “reference heavy metal content” which is that of sediment obtained within 3-4 m from the Bay bed at respective location. At all locations, heavy metal content is higher than reference heavy metal content and there is gradual increase of heavy metal content at all locations except for lead (Pb) at Atarés and Nickel (Ni) at Marimelena. Higher than reference level shows external input from urban activities including industries.

Table 3.7 shows variation of heavy metal content in the surface sediments in Havana Bay between 1991-2001. It also shows the standards adopted in Netherlands and Canada for sediments which is considered to be polluted. Zinc (Zn) at Atarés, copper (Cu) at Atarés and Centro de la Bahía has exceeded the Dutch standard values requiring intervention.




| | |
|---|---|
| THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY | Figure 3.4<br>Bay Water and Sediment Quality Monitoring Locations |
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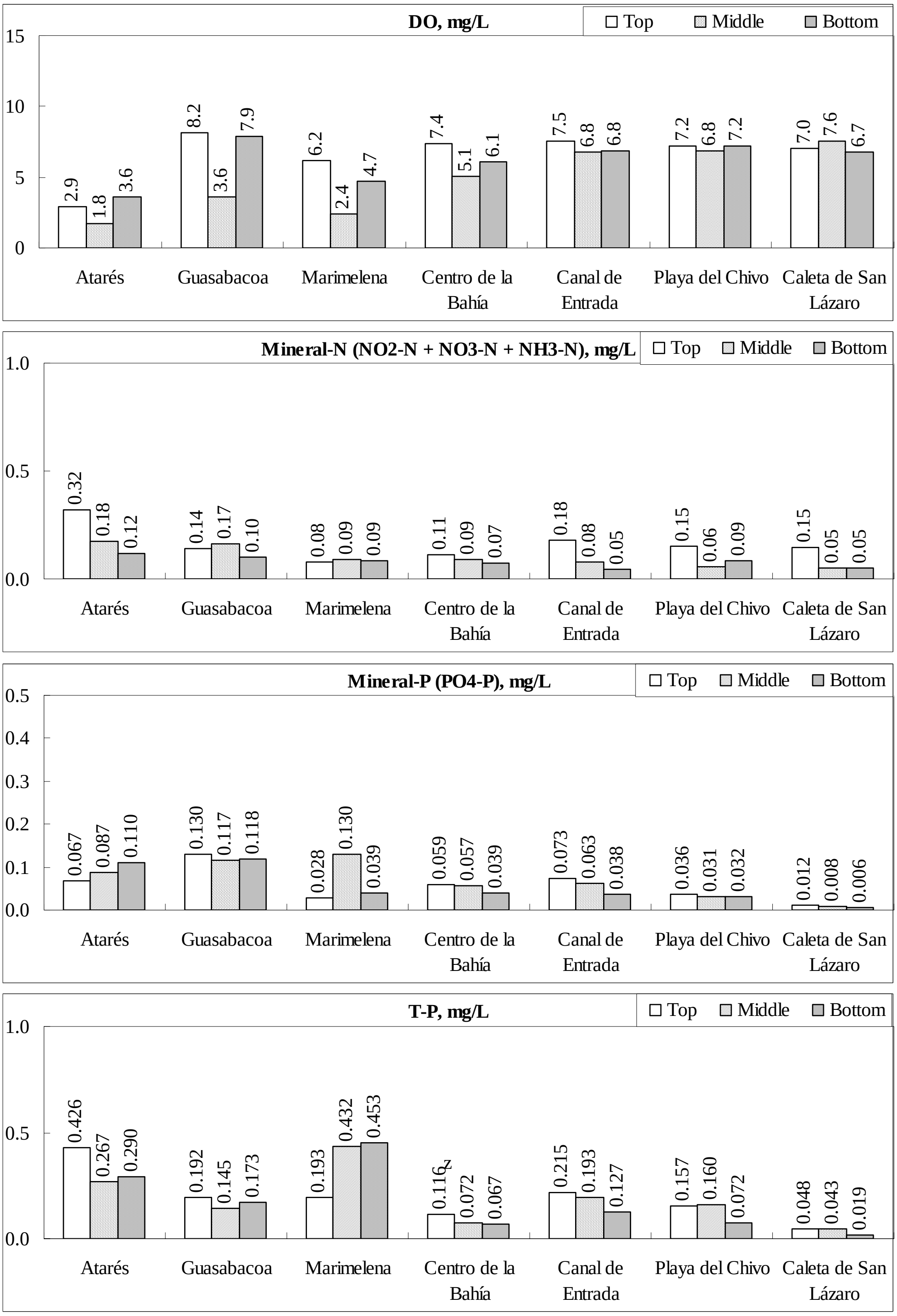


Source: CIMAB

| THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY | Figure 3.5 Vertical Variations of DO and Nutrients in Havana Bay (November 30, 2001) |
| --- | --- |
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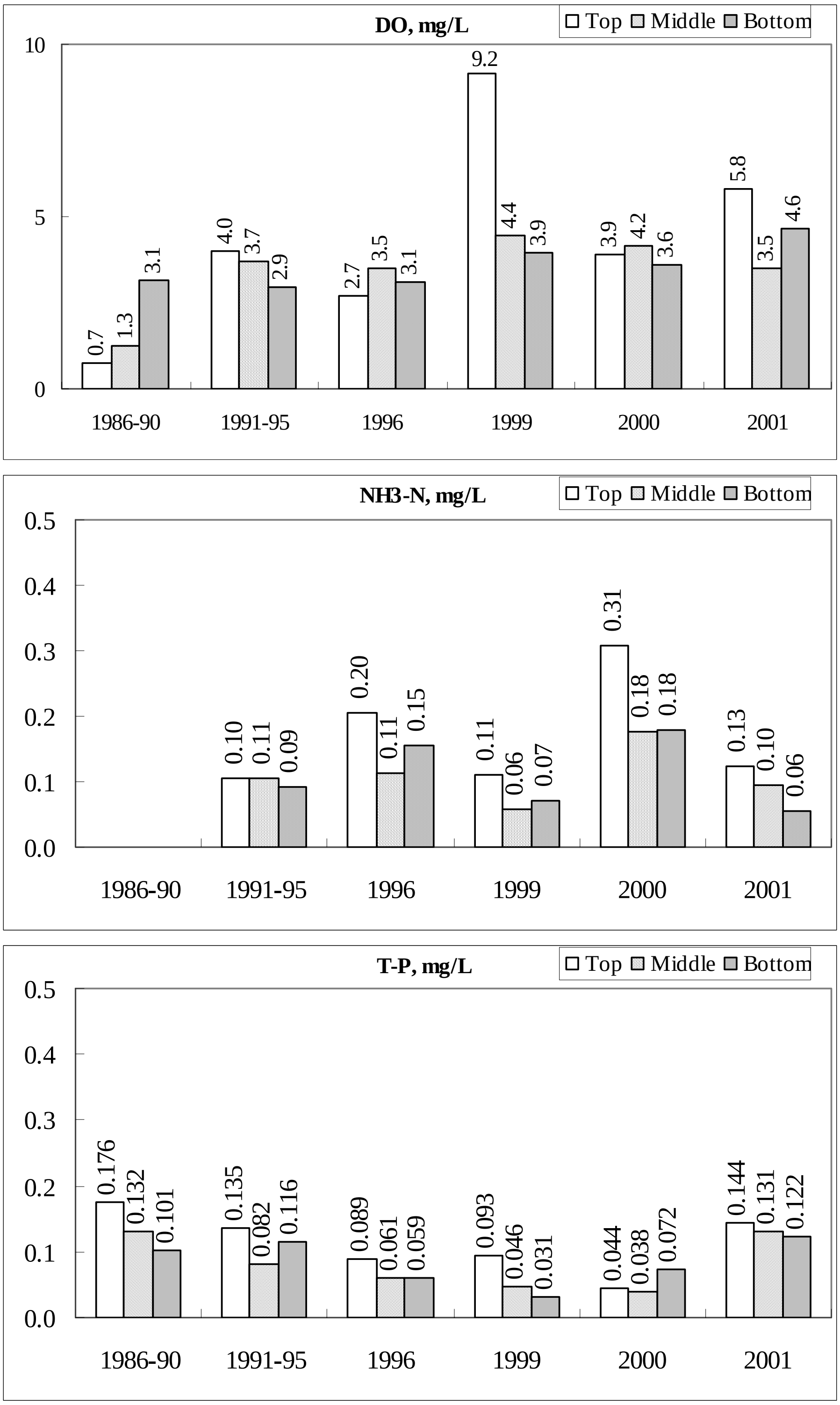


Source: CIMAB

| THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY | Figure 3.6 Variations of DO and Nutrients in Havana Bay, 1986-2001 |
|---|---|
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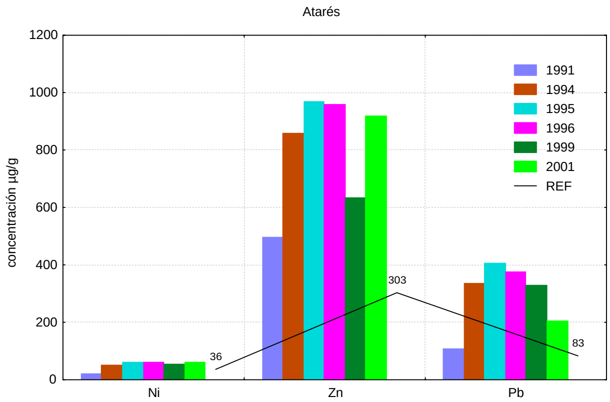
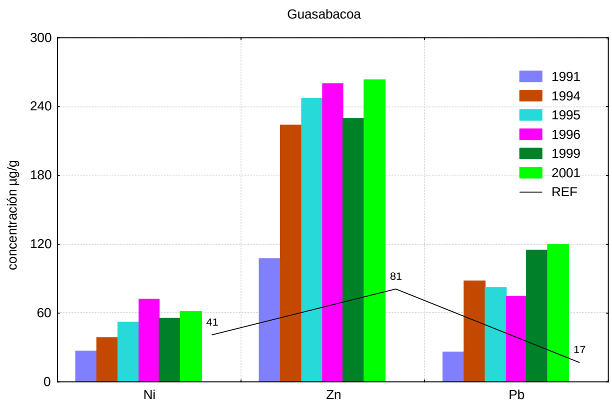
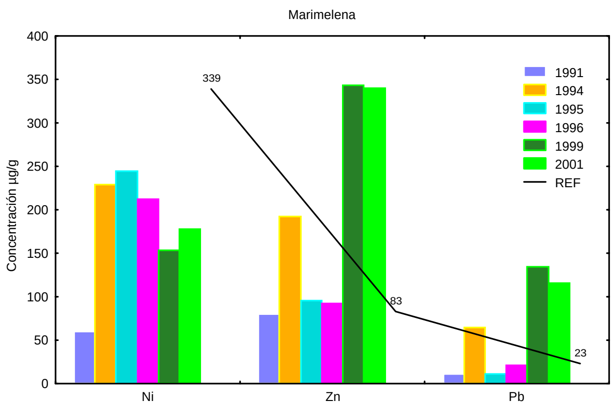
## Atarés




## Guasabacoa




## Marimelena




Note : The ranges shown in the graphs above are not identical for all three locations.
Reference value is that of sediment taken between a depth 3-4 m below bay bed.

Source : CIMAB

| THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY | Figure 3.7 Variations of Heavy Metals in Sediments in Havana Bay, 1991-2001 |
|---|---|
| JAPAN INTERNATIONAL COOPERATION AGENCY | |

**Table 3.7 Surface Sediment Quality of Havana Bay 1991-2001**

| Parameter | Atarés | | | Guasabacoa | | | Marimelena | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1991-1996 | 1999 | 2001 | 1991-1996 | 1999 | 2001 | 1991-1996 | 1999 | 2001 |
| Nickel (Ni), mg/kg | 19 – 61 | 53 | 59 | 27 – 72 | 55 | 61 | 60 – 244 | 153 | 178 |
| Lead (Pb), mg/kg | 109 – 405 | 328 | 205 | 26 – 88 | 15 | 120 | 11 – 65 | 135 | 116 |
| Zinc (Zn), mg/kg | 497 – **969** | 635 | **918** | 107 – 260 | 230 | 263 | 80 – 192 | 343 | 340 |
| Chromium (Cr), mg/kg | – | 63 | 73 | – | 65 | 82 | | 148 | 159 |
| Copper (Cu), mg/kg | 209 – **329** | 128 | 166 | 65 – 122 | 78 | 92 | 66 – 146 | 190 | 170 |
| Cobalt (Co), mg/kg | 5 – 8 | 20 | 24 | 8 – 13 | 18 | 26 | 11 – 29 | 23 | 24 |
| Iron (Fe), % | 0.87 – 2.15 | 1.04 | 2.23 | 2.01 – 3.59 | 2.04 | 3.75 | 2.65 – 4.88 | 1.98 | 3.47 |
| Manganese (Mn), % | 252 – 308 | 415 | 380 | 252 – 308 | 415 | 510 | 432 – 473 | 500 | 510 |
| Organic Content, % | 20.3 – 30.2 | 15.8 | 21.2 | 14.3 – 24.7 | 13.8 | 14.6 | 13.3 – 19.9 | 18.0 | 16.2 |

| Parameter | Centro de la Bahía | | | Canal Entrada | | | Dutch Std. | Canada Std. |
|---|---|---|---|---|---|---|---|---|
| | 1991-1996 | 1999 | 2001 | 1991-1996 | 1999 | 2001 | | |
| Nickel (Ni), mg/kg | 13 – 29 | 63 | 61 | 15 – 44 | 60 | - | 210 | - |
| Lead (Pb), mg/kg | 31 – 69 | 238 | 236 | 68 – 95 | 138 | - | 530 | 112 |
| Zinc (Zn), mg/kg | 64 – 189 | 698 | 550 | 217 – 333 | 248 | - | 720 | 271 |
| Chromium (Cr), mg/kg | - | 90 | 103 | - | 65 | - | 380 | 160 |
| Copper (Cu), mg/kg | 28 – 84 | **238** | **259** | 146 – **286** | 85 | - | 190 | 108 |
| Cobalt (Co), mg/kg | 4 – 11 | 18 | 24 | 2 – 4 | 15 | - | | |
| Iron (Fe), % | 1.44 – 3.76 | 1.5 | 2.92 | 1.52 – 2.41 | 0.90 | - | - | |
| Manganese (Mn), % | 241 – 462 | 253 | 365 | 137 - 241 | 158 | - | - | |
| Organic Content, % | 8.7 – 18.6 | 17.7 | 15.1 | 16.2 – 18.1 | 9.8 | - | | |

Note: All concentrations are based on dry weight.
Dutch standard, the Netherlands (2000) assuming 10% organic matter and 25% clay shows the intervention value. Canada standard shows the probable effect level of Canadian Sediment Quality Guidelines for Protection of Aquatic Life (1999). Values shown as **238** are above Dutch Intervention Value.

Source: CIMAB and JICA Specialist Report, 2002

**Pathogenic Indicator**: Variation of fecal coliform is shown in Table 3.8. Fecal coliform concentrations at all of five locations are decreased gradually from 1996 to 2001, but even so fecal coliform at Atarés shows a very high level indicating a remarkable effect of domestic wastewater.

However, the data on *Clostridium Perfringens* in sediments as shown in Table 3.9 shows an increase of their content. Unlike fecal coliforms, *Clostridium Perfringens* attached to fecal matter and settles as sediment indicating fecal contamination.

**Table 3.8 Fecal Coliform Concentration in Havana Bay Water, 1991-2001**

| Location | 1991-1994 | 1995-1996 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|
| Atarés | $1.0 \times 10^6$ | $4.6 \times 10^6$ | $4.4 \times 10^6$ | $1.6 \times 10^6$ | $2.8 \times 10^5$ |
| Guasabacoa | $4.3 \times 10^4$ | $4.3 \times 10^5$ | $2.4 \times 10^4$ | $2.5 \times 10^4$ | $8.0 \times 10^3$ |
| Marimelena | $2.0 \times 10^3$ | $2.8 \times 10^5$ | $3.6 \times 10^3$ | $1.0 \times 10^3$ | $1.1 \times 10^3$ |
| Centro de la Bahía | $1.5 \times 10^5$ | $1.2 \times 10^6$ | $5.6 \times 10^4$ | $1.6 \times 10^4$ | $3.1 \times 10^3$ |
| Canal Entrada | $1.5 \times 10^5$ | $2.2 \times 10^6$ | $2.7 \times 10^4$ | $2.1 \times 10^3$ | $6.3 \times 10^3$ |

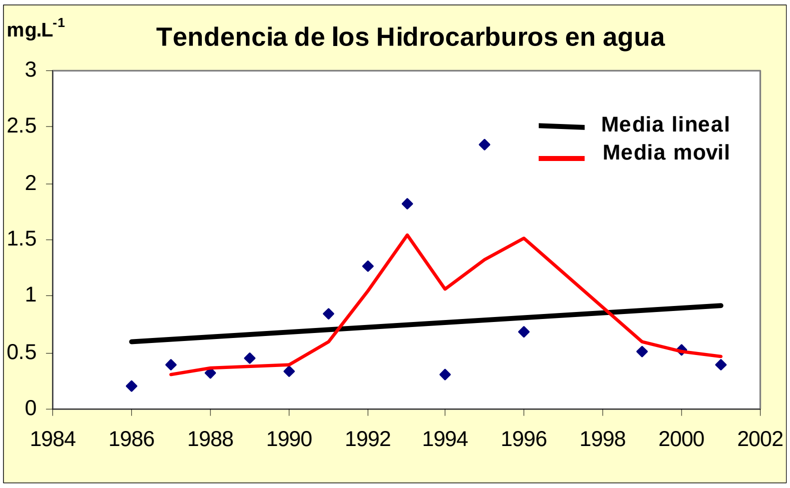
Source: CIMAB

**Table 3.9 *Clostridium Perfringens* in Sediments of Havana Bay, 1991-2001**

| Location | 1991 | 1999 | 2001 |
|---|---|---|---|
| Atarés | $7.3x10^5$ | $3.6x10^4$ | $2.4x10^6$ |
| Guasabacoa | $1.1x10^5$ | $3.6x10^3$ | $2.4x10^5$ |
| Marimelena | $9.3x10^3$ | $1.1x10^3$ | $4.6x10^4$ |
| Centro de la Bahía | $9.3x10^4$ | $2.3x10^4$ | $2.4x10^5$ |
| Canal Entrada | $1.5x10^3$ | $9.1x10^1$ | - |

Source: CIMAB

**Petroleum Hydrocarbons**: One of the most visible pollution affecting the Bay is due to petroleum hydrocarbons discharged to the Bay and its yearly variation in the surface of the Bay is as shown below. Following the increasing trend until 1995, it is decreasing mainly due to improvements made at the refinery.




## 3.3.2 WATER AND SEDIMENT QUALITY SURVEY OF HAVANA BAY

Water quality survey of the Bay was carried out by CIMAB during October 3-12, 2002 for wet season and December 18-20, 2002 for dry season under this Study. Figure 3.4 shows six sampling locations. Water samples were taken at three depths (0, 5 and 10 m) at each location. Sediment samples were taken from four locations within the bay. Analysis parameters are as follows:

Water samples: pH, Water Temperature, conductivity, salinity, COD, $BOD_5$, DO, SS, $SO_4^{2-}$, T-N, $NH_4^+$-N, $NO_2^-$-N, $NO_3^-$-N, T-P, $PO_4^{2-}$-P, $SiO_3$-Si, Petroleum Hydrocarbon, Fecal Coliform, Chlorophyll-a, Plankton, Phenol, Cadmium (Cd), Cobalt (Co), Copper (Cu), Iron (Fe), Manganese (Mn), Nickel (Ni), Lead (Pb), Vanadium (V), Zinc (Zn), Total Mercury (Hg) and Arsenic (As),

Sediment samples: Water Content, Grain Size Distribution, Total Volatile Solids (TVS), T-N, TON, Total Organic Matter, T-P, Petroleum Hydrocarbon, *Clostridium Perfringens*, Cadmium (Cd), Cobalt (Co), Copper (Cu), Iron (Fe), Manganese (Mn), Nickel (Ni), Lead (Pb), Vanadium (V), Zinc (Zn), Total Mercury (Hg) and Arsenic (As)

**(1) Survey Results of Water Quality**

Cuban Standard NC93-105, 1987 stipulates water quality standards for marine and fresh water used for fishing as shown in Table 3.29. However, there are no standards for seawater environmental protection, especially for the prevention of eutrophication. In the following, Japanese seawater environmental quality standard (DO and COD) related to water pollution, and standards (T-N and T-P) to protect eutrophication are used to evaluate the results of water quality.

**DO**: Concentrations of DO, organics (BOD and COD) and nutrients (T-N and T-P) at three deferent depths in six sampling locations are shown in Figure 3.8 for wet season and Figure 3.9 for dry season, respectively. As shown in Figure 3.8, in wet season DO concentrations inside of the bay (Atares, Guasabacoa, Marimelena and Centro) are very low, especially those in the surface and middle layers. The results are lower than the lowest level of Japanese seawater standards of Class C, DO>2.0 mg/l, which is applied only for conservation of living environment.

However, Figure 3.9 shows that DO concentrations inside of the bay are relatively high in dry season except at Atares and also shows that DO concentrations in the bottom layers and middle layers are lower than those of surface layers. The existing and survey results confirmed that Atares is the worst within the bay.

**Organics**: Figure 3.8 shows BOD concentrations within the bay in wet season are relatively high, especially at Atares, indicating high level pollution. However, in dry season BOD concentrations are lower at all locations except in the surface layer of Atares.

Concentration of COD within the bay both in wet and dry seasons are lower than the Japanese environmental standard of Class C, COD<8.0 mg/l, except in the surface layers of Atares and Centro in wet season.

**Nutrients**: As shown in Figure 3.8 and Figure 3.9, T-N concentrations in all of samples exceeded 1.0 mg/l of Class IV set as the lowest level of Japanese environmental standard to prevent eutrophication of seawater. Atares shows highest in T-N concentration among other locations. Such a high level of T-N may stimulate algal and aquatic growth and cause eutrophication of Havana Bay. Figures also show that T-N concentrations both in wet and dry seasons are increased gradually from surface to bottom. This trend may indicate nutrients are released from sediments (see the section of survey results of sediment quality).

In wet season T-P concentrations in all of samples are lower than 0.09 mg/l of Class IV, which is lowest level of Japanese environmental quality standard for the prevention of eutrophication of seawater. In dry season, however, T-P concentrations in almost of locations are over 0.09 mg/l, which may cause eutrophication of Havana Bay.

**Chlorophyll-a and Plankton**: Figure 3.10 shows vertical variations of Chlorophyll-a in wet season and dry season. At Atares in wet season, a very high level (42 to 65 mg/$m^3$) of Chlorophyll-a concentration is observed at three depths, which indicates that eutrophication at Atares area is at high level in wet season.

On the other hand, in dry season high Chlorophyll-a concentration (9.4 to 93.8 mg/$m^3$) are observed in surface layers of all locations. High values (4,048 to 12,256 x$10^3$ cell/l) of plankton biomass observed in the surface layers at all locations within the bay support that eutrophication are being occurred in the upper layer.

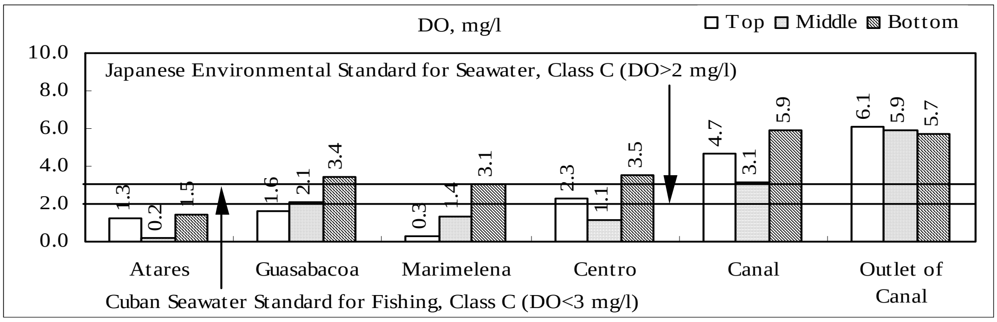
**Heavy Metals**: The concentrations of heavy metals at all locations (wet season and dry season) are briefly summarized in Table 3.10. Heavy metals of As, Cd, Co, Cr, Hg and Pb are not detected in the analytical methods used. A certain level of Cu, Ni and Zn concentrations are identified at some samples, however, it is considered to be within the range of permissible.

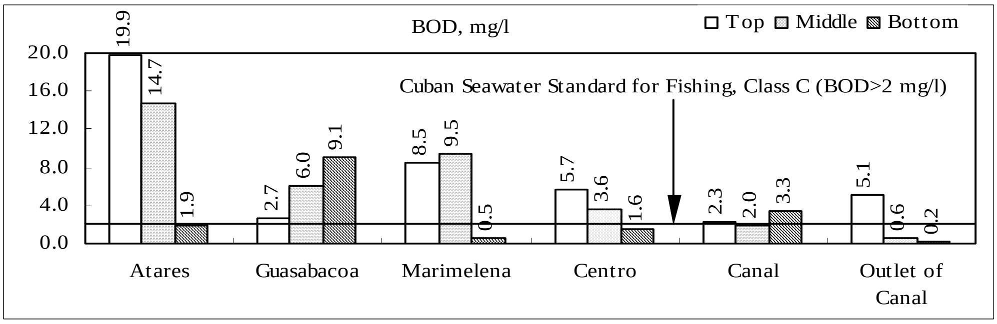
**Table 3.10 Heavy Metal Concentration in Seawater of Havana Bay**

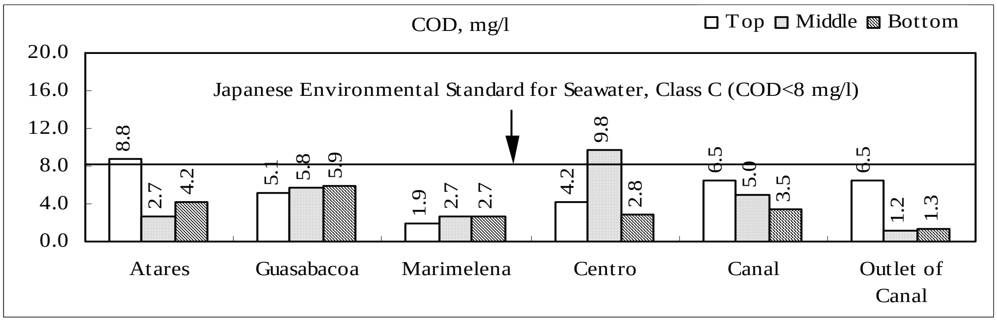
| Parameter | Five locations Inside the Bay (Three Depths) | Cuban Standard (NC93-105) for Seawater for Fishing |
|---|---|---|
| Arsenic (As), mg/L | <0.080 | 1 |
| Cadmium (Cd), mg/L | <0.005 | 0.01 |
| Cobalt (Co), mg/L | <0.010 | 0.05 |
| Chromium (Cr), mg/l | <0.020 | - |
| Copper (Cu), mg/l | <0.010 – 0.041 | - |
| Mercury (Hg), mg/L | <0.020 | 0.005 |
| Nickel (Ni), mg/l | <0.010 – 0.022 | - |
| Lead (Pb), mg/L | <0.10 | 0.1 |
| Zinc (Zn), mg/L | <0.010 – 0.172 | - |

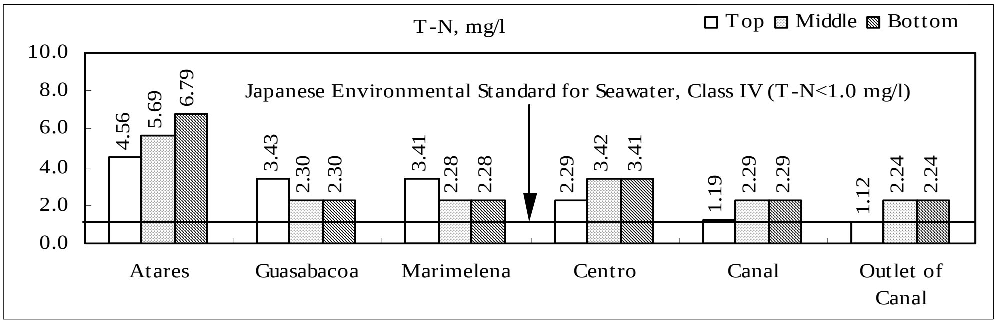
**Pathogenic Indicator**: Vertical variations of Fecal Coliform at each location both in wet season and dry season are sumarized in Figure 3.10. Similar to the previous results, Fecal Coliform at Atares shows a very high level particularly in the surface layer, indicating effect of domestic wastewater discharge.

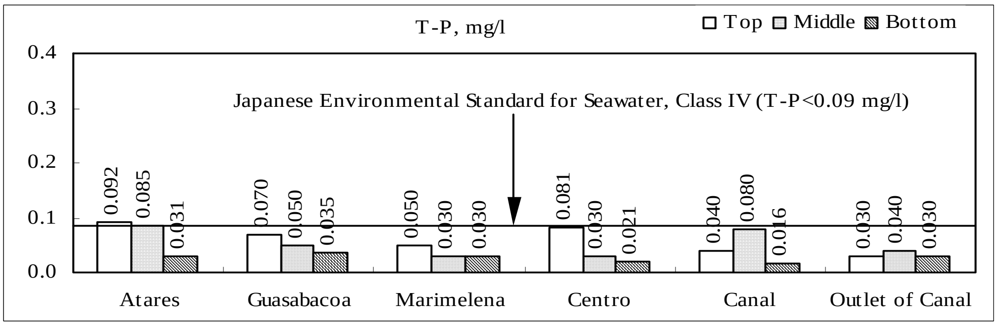
**Petroleum Hydrocarbons (HC)**: In the wet season, the resulted concentrations of petroleum hydrocarbons in the surface layers of Atares and Marimelena are 0.84 mg/l and 0.73 mg/l, respectively, which is similar to existing monitoring results in 2001. Nico Lopez, an oil refinery factory, plays an important role in petroleum hydrocarbon pollution.



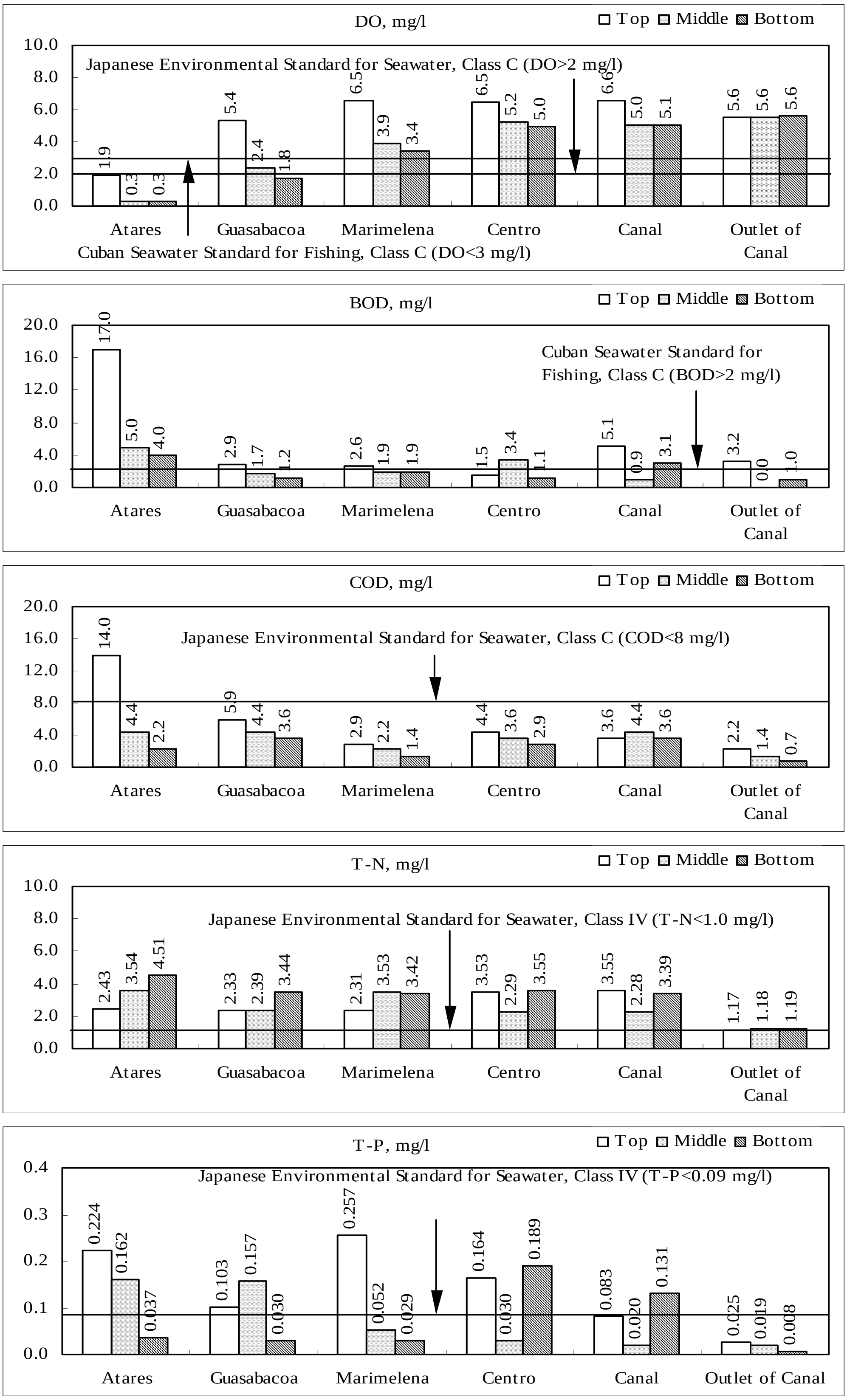



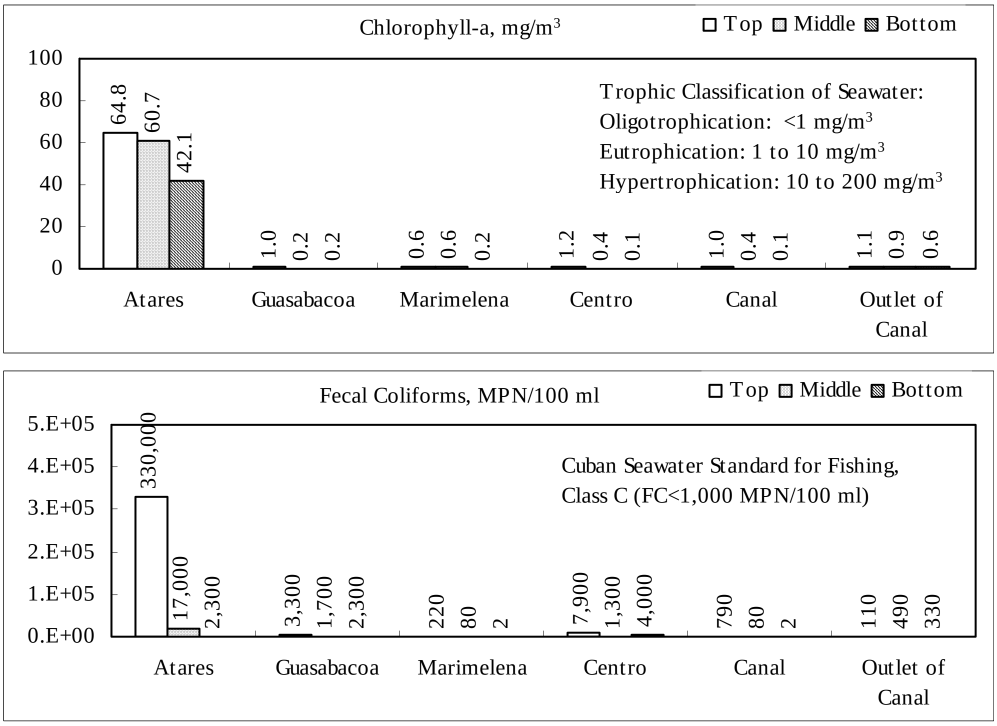

| THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY | Figure 3.8 Vertical Variations of DO, Organics and Nutrients in Havana Bay in Wet Season |
|---|---|
| JAPAN INTERNATIONAL COOPERATION AGENCY | |



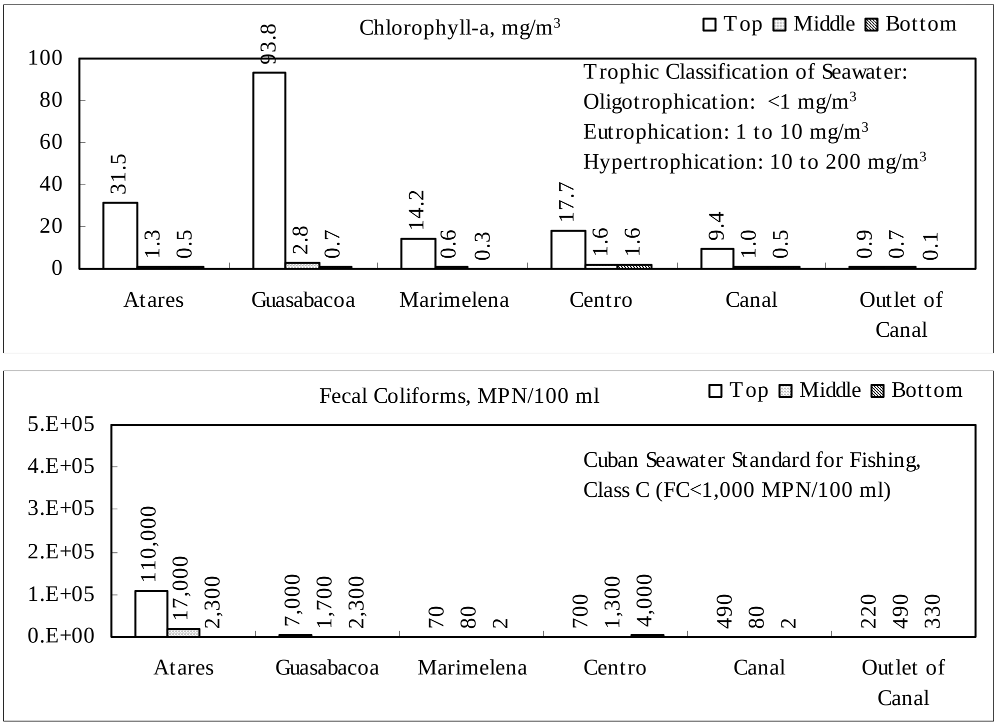

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY

JAPAN INTERNATIONAL COOPERATION AGENCY

Figure 3.9 Vertical Variations of DO, Organics and Nutrients in Havana Bay in Dry Season




**Wet Season**




**Dry Season**

| THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY | Figure 3.10 Vertical Variations of Chlorophyll-a and Fecal Coliforms in Havana Bay in Wet and Dry Season |
|---|---|
| JAPAN INTERNATIONAL COOPERATION AGENCY | |

### (2) Survey Results of Sediment Quality

**Organics**: The survey results of sediment quality in four locations are summarized in Table 3.11. Table 3.11 shows COD concentrations in all sediment samples are very high as 24,000 to 170,000 mg/kg, which indicates that eutrophication in Havana Bay presents severe state. Because typical COD concentrations in eutrophication water are in the range of 5,000 to 30,000 mg/kg. It also shows that high concentrations of organics (COD and TOC) at Atares show the worst situation.

**Table 3.11 Summary of Sediment Quality in Havana Bay**

| Parameter | Atares | Guasabacoa | Marimelena | Centro |
|---|---|---|---|---|
| COD, mg/kg-dry weight | 170,000 | 94,000 | 24,000 | 70,000 |
| TOC, mg/kg-dry weight | 128,800 | 34,400 | 41,900 | 67,700 |
| T-N, mg/kg-dry weight | 5,000 | 1,400 | 1,100 | 1,600 |
| T-P, mg/kg-dry weight | 664.2 | 94.8 | 40.3 | 194.5 |
| HC, mg/kg-dry weight | 1,759 | 1,230 | 1,660 | 1,290 |
| *Clostridium Perfringens*, MPN/100 ml | $20x10^3$ | $11x10^3$ | 40x10 | $40x10^2$ |

Source: JICA Study Team

**Nutrients**: As shown in Table 3.11, T-N and T-P concentrations are very high at Atares. The high T-N concentration in the sediment may cause the higher T-N concentration in the bottom layer compared to that of surface layer water at Atares, as mentioned in the previous section on water quality.

**Heavy Metals**: Table 3.12 shows the resulted concentrations of major heavy metals in the sediments. The concentrations at all locations present a relatively low level except Zn at Atares, where Zn concentration (764 mg/kg) exceeds slightly Dutch Intervention Value.

**Table 3.12 Concentrations of Major Heavy Metals in Sediments of Havana Bay**

| Parameter | Atares | Guasabacoa | Marimelena | Centro | Dutch Standard |
|---|---|---|---|---|---|
| Arsenic (As), mg/kg | 6 | 3 | 11 | 15 | - |
| Cadmium (Cd), mg/kg | 1 | <0.005 | <0.005 | <0.005 | - |
| Cobalt (Co), mg/kg | 23 | 25 | 26 | 21 | - |
| Chromium (Cr), mg/kg | 63 | 55 | 46 | 41 | 380 |
| Copper (Cu), mg/kg | 149 | 82 | 73 | 49 | 190 |
| Mercury (Hg), mg/kg | <5.00 | <5.00 | <5.00 | 29 | - |
| Nickel (Ni), mg/kg | 63 | 63 | 63 | 52 | 210 |
| Lead (Pb), mg/kg | 194 | 40 | 2 | 304 | 530 |
| Zinc (Zn), mg/kg | **764** | 160 | 107 | 133 | 720 |

Source: JICA Study Team

**Pathogenic Indicator**: No significant difference for *Clostridium Perfringens* is observed comparing with the existing monitoring data as shown in Table 3.9.

**Petroleum Hydrocarbons (HC)**: As shown in Table 3.11, the concentration of petroleum hydrocarbons at each location presents a relatively uniform distribution, and shows similar value comparing with the results (1,043 to 1,623 mg/kg) of existing data.[3)]

# 3.4 INDUSTRIAL WASTEWATER

## 3.4.1 PREVIOUS SURVEYS

It is reported that there are 110 factories of various sizes and types in the Study area[5)]. Among these factories, 55 of them discharge the wastewaters directly into Havana Bay area and 23 discharge the wastewaters into Havana Bay through Rio Luyano. The others discharge the wastewaters into Havana Bay through Rio Martin Perez, Arroyo Tadeo, as well as existing sewers and drainage channels.

The main industrial pollution sources in the Study area are oil refinery and food processing factories, especially, Nico Lopez, an oil refinery plant, plays an important role in pollution sources.

No periodical monitoring system for industrial wastewater has been established due to financial constraints. However, on a study basis industrial wastewater characteristics have been investigated. CIMAB and CENHICA have analyzed the industrial wastewater quality of the major factories in the Study area under some projects such as CUB/80/001, GEF/RLA/93/G41 and GTE-Bahia Habana etc. [4 and 5)]. The results of pollution sources survey conducted in 1997 indicated that industrial wastewater contributed one third of total BOD load [5)].

The previous surveys analyzed the following water quality parameters: BOD, COD, TS, TSS, T-N, T-P, Total Hydrocarbons and Heavy Metals.

Table 3.13 summarizes available information of industrial wastewater on the factories related to the Study Area by receiving water bodies.

## Table 3.13 Summary of Factory in the Study Area (1/2)

### Receiving Water Body: Havana Bay

| No. | Name of Factories | Type of Industry | Flow Rate ($m^3/d$) | Working Hour | Treatment Process | Relocating Plan | Remarks |
|---|---|---|---|---|---|---|---|
| 1 | Muelles Sierra Maestra 1, 2 y 3. | Dock | Low | | | | |
| 2 | Muelle lancha Habana-Regla. | Dock | Low | | | | |
| 3 | Muelle de bomberos. | Fire fighting | | | | | |
| 4 | Muelle Flota camaronera. | Dock | Low | Closed | | | GTE 2002 |
| 5 | Muelle Margarito Iglesias. | Dock | Low | | | | |
| 6 | Muelle Aracelio Iglesias. | Dock | Low | | | | |
| 7 | Muelle Juan Manuel Díaz. | Dock | Low | | | | |
| 8 | Muelle La Coubre. | Dock | Low | | | | |
| 9 | Servicios marítimos. | Service company | Low | | | | |
| 10 | Asociación flota cubana de pesca (Pesport). | Fish processing | 2 | | | | |
| 11 | Central Termoeléctrica Otto Parellada. | Thermoelectric Plant | 312 | 24H | No | Year 2005 | 1 Outlet, CIMAB 2002 |
| 12 | Muelle de Tallapiedra. | Custom office | Low | | | | |
| 13 | Muelle de la Pesca (Pesport). | Washing | Low | | | | |
| 14 | Muelle de cemento a granel. | Cement | Low | | | | |
| 15 | T N E Juan Ronda. | Electricity | 3 | | | | |
| 16 | Puerto pesquero de la Habana. (pumped to sewer) | Fish processing | 400 | 24H | No | | GEF Report |
| 17 | Empresa industrial pesquera Hacendados (Indal) | Fish processing | 400 | 8H | No | | 2 Outlets, GEF1996 |
| 18 | Empresa de laboratorios farmacéuticos Mario Muñoz. | Medicine | 26 | | | | GEF Report |
| 19 | Planta de gas Evelio R. Curbelo. | Gas | 1,010 | 16H | Lagoon | | 1 Outlet, GEF Report |
| 20 | Terminal Haiphong. . | Dock | Low | | | | |
| 21 | Terminal de contenedores (MELFI). | Dock | Low | | | | |
| 22 | Empresa de Recuperación de Materias Primas. | Recycling | Low | | | | |
| 23 | Organización Desmanteladora de equipos. | Recycling | Low | | | | |
| 24 | Empresa recuperadora (CUREF). | Recycling | Low | | | | |
| 25 | Destañadora Alfredo Gamonal. | Metal recycling | | Closed | | | GTE, 2002 |
| 26 | Talleres de grúas terrestres ETMH. | Truck repairing | | Closed | | | GTE, 2002 |
| 27 | Vertedero de Cayo Cruz. | Garbage incineration | | Closed | | | GTE, 2002 |
| 28 | Obras Marítimas 1. | Construction | Low | | | | |
| 29 | Instalación TRANSCARGO | Office (bus) | Low | | | | |
| 30 | Molinos de trigo José A. Echevarría. | Food | Low | | | | |
| 31 | Almacenes de la Empresa Química (USEQUI). | Health Public | Low | | | | |
| 32 | Fábrica de fertilizantes Gerardo Granda. | Heavy industry | 20 | | | | |
| 33 | Empresa distribuidora de combustible Habana. | Service company | Low | | | | |
| 34 | Muelle Manuel Porto Pena. | Dock | Low | | | | |
| 35 | Terminal portuaria Andrés González Lines | Dock | Low | | | | |
| 36 | Molinos de granos Turcios Lima. | Dock | Low | | | | |
| 37 | Fábrica de pienso Habana 12. | Dock | Low | | | | |
| 38 | Refinadora de aceites Alberto Alvarez. | Food oil processing | 205 | 24H | Bio-treatment | | 2 Outlets, GEF Report |
| 39 | Atraques 21, 22 y 23. | Dock | Low | | | | |
| 40 | Derretidora de sebo (Alse). | Food | 100 | Closed | | | GEF Report, CIMAB |
| 41 | Central termoeléctrica Antonio Maceo. | Power generation | 880 | Closed | | | CIMAB, 2002 |
| 42 | Embarcadero de lanchas de Regla. | Dock | Low | | | | |
| 43 | Terminal de ómnibus de Regla. | Bus terminal | 36 | | | | GEF Report |
| 44 | Obras Marítimas 2. | Construction | Low | | | | |
| 45 | Entidades del Poder Popular. | Office | | Closed | | | |
| 46 | Empresa industrial pesquera de Regla (Prodal). | Food processing | 360 | 24H | No | | 3 outlets, GEF Report |
| 47 | Varadero de embarcaciones de Regla. | Custom office | Low | | | | |
| 48 | Empresa de transporte de la Pesca (DIMER). | Fish processing | 40 | | | | |
| 49 | Obras Marítima 3. | Construction | Low | | | | |
| 50 | Refinería de petróleo Ñico López. | Petrochemistry | 62,134 | 24H | API, Lagoon | | 7 outlets, GEF Report |
| 51 | Central Termoeléctrica Frank País. | Thermoelectric Plant | | Closed | | | GTE, 2002 |
| 52 | Incinerador del puerto y atraque de SAMARP. | Garbage incineratio | 10-15 | | No | | Study team, 2002 |
| 53 | Empresa Nacional de Astilleros (ENA). | Ship repairing | 266 | | No | | Study team, 2002 |
| 54 | Empresa militar industrial (EMI) Granma. | Military factory | Low | | | | |
| 55 | Astilleros Galainena (ASTIGAL) | Dock | Low | | | | |

## Table 3.13 Summary of Factory in the Study Area (2/2)

### Receiving Water Body: Rio Luyano

| No. | Name of Factories | Catalogue | Flow Rate ($m^3/d$) | Working Hour | Treatment Process | Relocating Plan | Remarks |
|---|---|---|---|---|---|---|---|
| 1 | Destileria de alcohol Habana | Alcohol | 675 | Closed | No | | GEF Report |
| 2 | Fabrica de Levadura Heroes de Bolivia | Food | 432 | Closed | | | GEF Report |
| 3 | Fabrica de ron Ronera Occidental | Rum | 156 | 8H | No | | 1 Outlet, GEF Report |
| 4 | Establecimiento Antonio Maceo | Fish packing | 1,000 | Closed | No | | GEF Report |
| 5 | Matadero Jesus Menendez? | Food (milk) | 156 | Closed | | | GEF Report |
| 6 | Pasteurizadora Lucero | Food (milk) | 500 | 24H | No | | 1 Outlet, GEF Report |
| | | | 500 | | | | CIMAB, 2001 |
| 7 | Licuadora Luis Pauste | Food | 100 | Closed | | | GTE, 2002 |
| 8 | Empacadora Julio A. Mella | Food | 173 | Closed | | | GEF Report |
| 9 | Funicion Miguel Suarez | Light industry | 26 | | | | GEF Report |
| 10 | Fabrica de toallas ANTEX | Dye | | Closed | | | CIMAB, 2002 |
| 11 | Empressa Central de Laboratorio (LACEMI) | Laboratory | 78 | | | | GEF Report |
| 12 | Terminal de Omnibus Lawton | Bus washing | | | | | |
| 13 | Empresa de herramentaje Miguel Saavedra | Metal plating | | | | | |
| 14 | Taller principal de Vagones Fco. Vega Saanche | Train repair | 203 | | | | CIMAB, 2000 |
| 15 | Taller Central de la Empresa Geofisica | Machinery repair | | | | | |
| 16 | Unidad Basica de Produccion Empresarial Paquito Rosales | Chemistry | <5 | | | | GEF Report |
| 17 | Planta Andres Lujan Vazquez | Metal plating | | Closed | | | CIMAB, 2002 |
| 18 | Empresa Portuaria (PORTRANS) | Washing | | | | | |
| 19 | Fca. Vietnam Heroico | | 16 | | | | GEF Report |
| 20 | Constructora de Motores Taino | Machine | 13 | | No | | Study Team, 2002 |
| 21 | Empresa Inoxidable Emrique Jose Varona | Tank manufacture | 55 | | No | | Study Team, 2002 |
| 22 | ICIDCA | Laboratory | | | | | |
| 23 | Fabrica de Siphorex Camilo Cienfuegos | Construction | | | | | |
| 24 | Fabrica Beatriz | Food (milk) | 370 | | No | | Close in 2002 Oct. |

### Receiving Water Body: Rio Martin Perez

| No. | Name of Factories | Catalogue | Flow Rate ($m^3/d$) | Working Hour | Treatment Process | Relocating Plan | Remarks |
|---|---|---|---|---|---|---|---|
| 1 | Emp. Fundicion No Ferrosa Sergio Gonzalez | Metal plating | <5 | | | | GTE, 1993 |
| 2 | Establecimiento Martires de Panama | Construction materials | <5 | Closed | | | CIMAB, 2002 |
| 3 | Emp. Semiremolque Ramon Pefia | Truck washing | <10 | | | | |
| 4 | Taller Emilio Perez Olivera | Metal plating | <5 | Closed | | | CIMAB, 2002 |
| 5 | Establecimiento Habana | Bottle washing | <5 | Closed | | | CIMAB, 2002 |
| 6 | Tenerfa Cesar Escalante | Tanning | 216 | Closed | | | GEF Report |

### Receiving Water Body: Arroyo Tadeo

| No. | Name of Factories | Catalogue | Flow Rate ($m^3/d$) | Working Hour | Treatment Process | Relocating Plan | Remarks |
|---|---|---|---|---|---|---|---|
| 1 | Fbea de calzado Aracelio Iglesias | Shoe making | <5 | Closed | No | | Closed; GTE 2002 |
| 2 | Fb Elio Llerena | Aluminum processing | 5-10 | | No | | GTE, 2002 |

### Receiving Water Body: Drainage Channels

| No. | Name of Factories | Catalogue | Flow Rate ($m^3/d$) | Working Hour | Treatment Process | Relocating Plan | Remarks |
|---|---|---|---|---|---|---|---|
| 1 | DEBON-Suchel Plant (to Matadero) | Detergent produce | 60 | 14H | No | | 1 Outlet, CIMAB |
| 2 | JAIPER-Suchel Plant (to Agua Dulce) | Detergent produce | 40 | 12H | No | | 1 Outlet, CIMAB |

### 3.4.2 INDUSTRIAL WASTEWATER SURVEYS

#### (1) Objective

The objectives of industrial wastewater survey are:

- To identify current situations and problems of industrial wastewater management in the Study Area based on existing information;
- To grasp industrial wastewater pollution loads to the Havana Bay based on a survey of 10 selected factories

#### (2) Methodology

The procedure of industrial wastewater survey is illustrated in Figure 3.11. These survey works are carries out by the Study Team and counterpart members with hired technical assistants from CIMAB, and water quality analysis is conducted at the laboratory of CIMAB.

**1) Collection and analysis of existing information**

The following information is collected: type of industry, operation situation, receiving water body, wastewater quantity, wastewater quality, treatment process, and relocation plan etc.

**2) Selection of 10 factories**

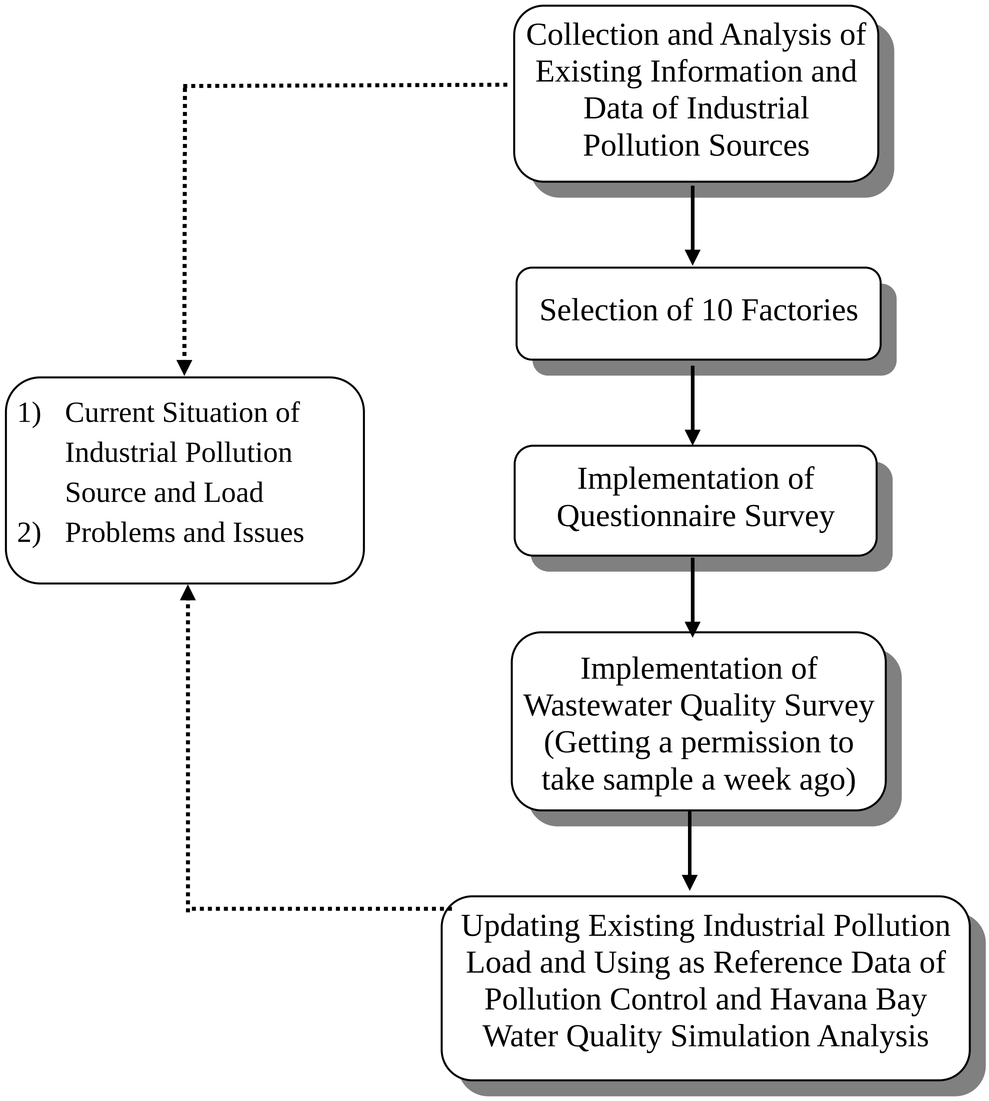
To select major factories, the following selection criteria are taken into account:

- Larger pollution load (BOD, T-N, T-P, Hydrocarbon etc.);
- Representative factory for local industry;
- Heavy metals in effluent, and
- Possibility of sampling and flow-rate measurement

Based on existing information and discussion with GTE and DPRH/Havana-City, the following 20 factories, as shown in Table 3.14, are selected firstly as candidate.

**Table 3.14 Major 20 Factories Selected as Candidate for Detailed Survey**

| Factory Name | Type of Industry | Receiving Body | Factory Name | Activities | Receiving Body |
|---|---|---|---|---|---|
| 1. Nico Lopez | Oil Refinery | Havana Bay | 11. Ronera Occidental | Rum | Rio Luyano |
| 2. Curbelo | Gas Production | Havana Bay | 12. Alcohol Habana | Alcohol | Rio Luyano |
| 3. Prodal | Food | Havana Bay | 13. Antonio Maceo | Fish Packing | Rio Luyano |
| 4. Indal | Fishery Processing | Havana Bay | 14. Motores Taino | Machie | Rio Luyano |
| 5. Alberto Alvarez | Food Oil Processing | Havana Bay | 15. Vaga Saanchez | Train Repairing | Rio Luyano |
| 6. Otto Parellada | Electricity | Havana Bay | 16. Fabrica Beatriz | Milk Processing | Rio Luyano |
| 7. Puerto Pesquero | Fishery Processing | Havana Bay | 17. Debon-Suchel | Detergent Production | Matadero Drainage Channel |
| 8. SAMARP | Garbage Incineration | Havana Bay | 18. Jaiper-Suchel | Detergent Production | Agua Dulce Drainage Channel |
| 9. ENA | Ship Repairing | Havana Bay | 19. Aracelio Iglesias | Shoe Making | Arroyo Tadeo |
| 10. Lucero | Milk Processing | Rio Luyano | 20. Fb Elio Llerena | Aluminum Processing | Arroyo Tadeo |




| | |
|---|---|
| THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY | Figure 3.11<br>Procedure of Industrial Wastewater Survey |
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A preliminary survey was carried out by the Study Team, counterpart members from GTE and DPRH/Havana-City to confirm the possibility of sampling and flow-rate measurement. Finally 10 factories were selected for industrial pollution sources survey, based on the results of above preliminary survey and discussion with GTE and DPRH/Havana-City. The general information of the 10 selected factories is summarized as Table 3.15, and the location of the 10 selected factories is shown in Fig. 3.12.

**Table 3.15 General Information of 10 Selected Factories**

| Factory Name | Type of Industry | Flowrate ($m^3$/d) | Major Pollutants | Receiving Body |
|---|---|---|---|---|
| 1. Nico Lopez | Oil Refinery | 62,000 | Oil, BOD | Havana Bay |
| 2. Curbelo | Gas Production | 1,010 | Oil, BOD | Havana Bay |
| 3. Prodal | Food | 360 | BOD, SS, N, P, oil and grease | Havana Bay |
| 4. Indal | Fishery Processing | 400 | BOD, SS, N, P, oil and grease | Havana Bay |
| 5. Alberto Alvarez | Food Oil Processing | 205 | SS, BOD, N, P | Havana Bay |
| 6. Otto Parellada | Electricity | 312 | Cu, Zn, Pb, Cr etc. heavy metals | Havana Bay |
| 7. Lucero | Milk Processing | 500 | BOD, SS, N | Rio Luyano |
| 8. Vaga Saanchez | Train Repairing | 200 | COD, SS, Oil | Rio Luyano |
| 9. Debon-Suchel | Detergent Production | 60 | BOD, SS, N | Matadero Drainage Channel |
| 10. Jaiper-Suchel | Detergent Production | 40 | BOD, N, SS | Agua Dulce Drainage Channel |

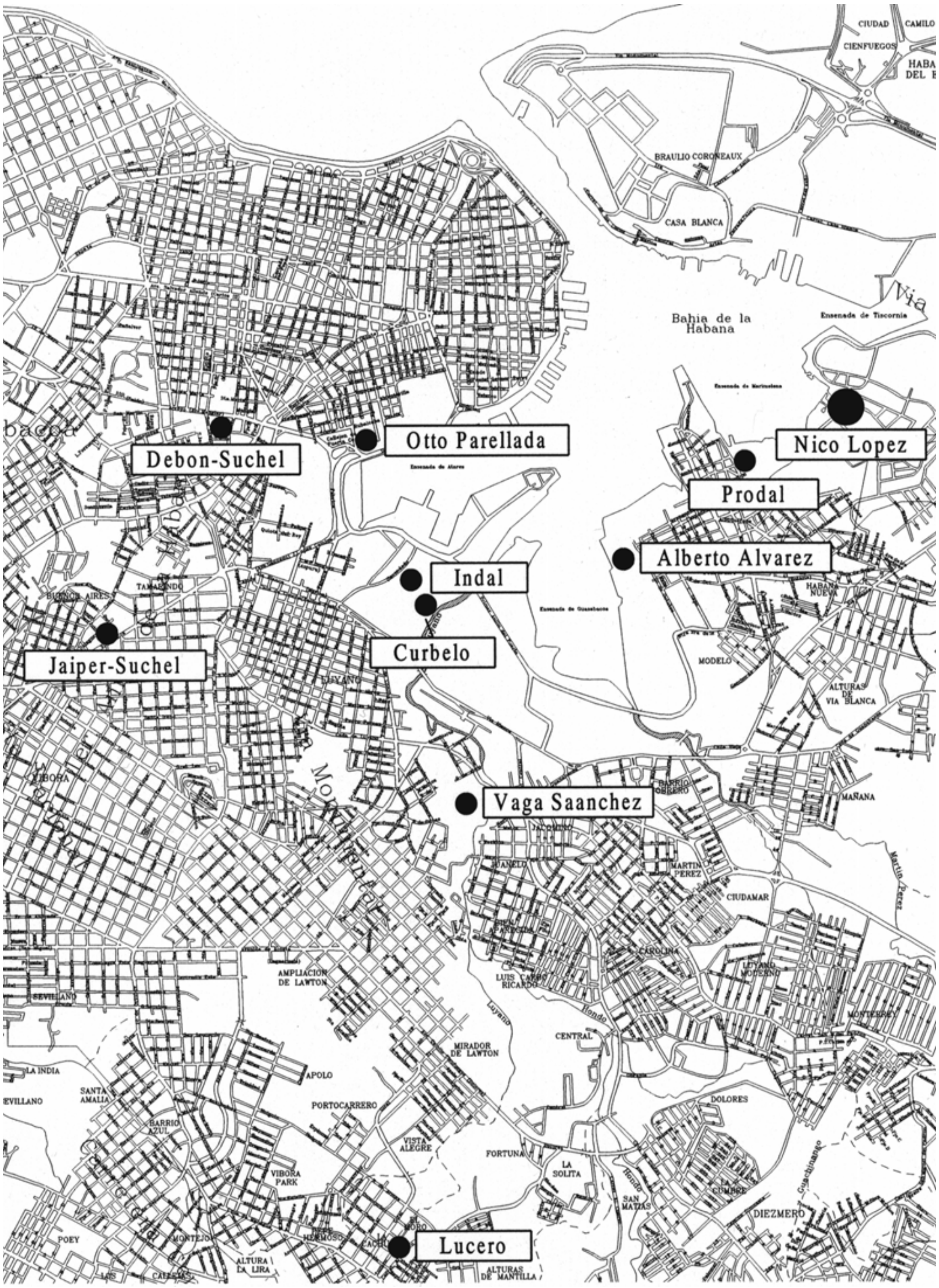
**3) Questionnaire survey of the 10 selected factories**

A questionnaire survey is implemented by the Study Team, GTE and DPRH/Havana-City. This questionnaire includes following contents:

- Outline of the factory (number of employees, working hours, site area, main raw materials, main products and production capacity etc.);
- Sources of water (river, groundwater, pipe water and circulating water etc.);
- Water consumption (cooling water, flushing water and daily life water etc.);
- Wastewater quantity (flowrate and time zone of discharging wastewater etc.);
- Wastewater quality (pH, Temp., SS, color, BOD, COD, T-N, T-P and heavy metals etc.), and
- Treatment process and future plan (treatment process, capacity, number of outlet, receiving water body and major problems in operation and maintenance etc..

The questionnaire survey for the 10 selected factories identified that almost every factory does not measure the daily water consumption and wastewater production/discharge quantity. Thus, the information of wastewater quality is very limited.

Among the 10 selected factories, only one factory (Alberto Alvarez, food oil processing) possesses a secondary-treatment system (physical, chemical and biological treatment process), other 9 factories discharge the wastewater into receiving bodies after primary-treatment or without any treatment.




| THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY | Figure 3.12<br>Location Map of 10 Selected Factories for Industrial Wastewater Survey |
|---|---|
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**4) Wastewater quality survey**

The wastewater quality survey includes a flow measurement, sampling and wastewater quality analysis.

The following flow measuring methods are used:

- Flow meter method;
- Dye and floats method, and
- Capacity method

The flow measuring frequency is at 1-3 hours intervals in each point of the sampling stations for one working day (8 to 24 hours).

Three to four grab wastewater samples are taken on the same day at the outlet (discharging point), then one composite sample is made for each factory by combining the grab samples based on the ratio of measured flowrate.

Twenty three (23) water quality parameters are analyzed as shown below:

**Table 3. 16 Industrial Wastewater Quality Parameters Analyzed**

| Classification | Parameters |
|---|---|
| General Items | pH, Temperature |
| Organic Substances | BOD, COD |
| Nutrients | T-N, $NH_4$-N, $NO_2$-N, $NO_3$-N, T-P, $PO_4$-P |
| Toxic Items | Phenol, Cd, Co, Cu, Ni, Pb, V, Zn, Hg, As |
| Other Items | SS, SO4, Hydrocarbon |

Analysis methods are according to "Standard Method for the Examination of Water and Wastewater, APHA, 1998."

**(3) Results**

The main features of 10 selected factories and the results of water quality survey are summarized in Table 3.17 and Table 3.18, respectively. Based on the results of water quality survey, pollution loads of major pollutants are calculated and illustrated in Figure 3.13.

**Table 3.17 The Main Features of 10 Selected Factories**

| | Nico Lopez | Curbelo | Prodal | Indal | Alberto Alvarez | Parellada | Lucero | Vega Saanchez | Debon Suchel | Jaiper Suchel |
|---|---|---|---|---|---|---|---|---|---|---|
| Type of Industry | Oil refinery | Gas production | Food processing | Fishery processing | Food oil | Electricity | Milk processing | Train repairing | Detergent | Detergent |
| Main Raw Materials | Crude oil | Naphtha and natural gas | Fresh fish, shrimp and chicken meat | Fresh fish | Raw oil | Fuel oil | Fresh Milk, Powder Milk and Soybean | - | Sulfonic Acid, Sodium Tripolyphosphate and Sodium Sulfate | - |
| Main Products and Volume of Production | Gasoline and derivates, 1.6 Mton/year | Gas, 125.4 $Mm^3$/year | Sausage and various deep-fried foods, 6,500 ton/year | Canned fish, 4 to 5 ton/day | Vegetable oil, 100 ton/day | 64 MW/h | Pasteurized milk, 40 $m^3$/d; soy milk, 30 $m^3$/day | - | Detergent, 13,000 ton/year | Soap, shampoo and toothpaste etc., 11,700 ton/year |
| The Number of Employees | 1,326 | 137 | 926 | 300 | 180 | 243 | 350 | 350 | 270 | 600 |
| Operation Time | 24 hours continuous operation | 24 hours continuous operation | 24 hours continuous operation | 8 hours | 24 hours continuous operation | 24 hours continuous operation | 24 hours continuous operation | 12 hours | 16 hours | 12 hours |
| Total Water Consumption ($m^3$/d) | 156,804 | 708 | About 800 | 214 | About 200 | About 300 | - | About 200 | 460 | About 40 |
| Water Consumption of Production ($m^3$/d) | 150,425 | 330 | - | - | - | - | - | - | 47 | - |
| Other Water Consumption ($m^3$/d) | 6,379 | 378 | - | - | - | - | - | - | 413 | - |
| Wastewater Treatment Process | Gravity separator etc. | Gravity separator and lagoon | No treatment facilities | No treatment facilities | Biological treatment process | No treatment facilities | No treatment facilities | No treatment facilities | No treatment facilities | No treatment facilities |

**Table 3.18 The Results of Industrial Wastewater Quality Survey**

| Parameters \ Factory | Nico Lopez | Curbelo | Prodal | Indal | Alberto Alvarez | Parellada | Lucero | Vega Saanchez | Debon Suchel | Jaiper Suchel |
|---|---|---|---|---|---|---|---|---|---|---|
| Flowrate, $m^3/d$ | 139,381 | 175 | 217 | 43 | 350 | 1,000 | 667 | 259 | 380 | 39 |
| pH | 6.9 - 7.4 | 7.8 - 8.2 | 8.47 | 7.7 - 8.1 | - | 8.1 | 7.4 | 7.5 | 8.9 - 10.6 | 8.3 - 8.4 |
| Water Temp, ℃ | 28.2 | 36.2 | 29 | 29.6 | - | 25 | 31.0 | 30.5 | 28.8 | 29.3 |
| COD, mg/L | 38.39 | 234 | 4284 | 455 | 863 | 16 | 1632 | 490 | 81 | 184 |
| $BOD_5$, mg/L | 18 | 175 | 800 | 200 | 240 | 6 | 500 | 235 | 10 | 130 |
| SS, mg/L | 260 | 11 | 356 | 72 | 533 | 82 | 945 | 30 | 13 | 52 |
| $SO_4^{2-}$, mg/L | 527.87 | 4.41 | 8.88 | 10.86 | - | 16.08 | 1.81 | 6.74 | 12.34 | 1.81 |
| T-N, mg/L | 3.41 | 7.21 | 26.14 | 18.54 | 18.7 | 7.19 | 15.88 | 9.39 | 9.32 | 9.32 |
| Organic-N, mg/L | 0.28 | 1.4 | 10.83 | 11.95 | 4.3 | 2.06 | 13.54 | 7.38 | 3.18 | 3.08 |
| $NH_4^+$-N, mg/L | 1.96 | 0.84 | 1.49 | 1.49 | 12.50 | 0.18 | 2.14 | 1.58 | 0.18 | 0.28 |
| $NO_2^-$-N, mg/L | 0.07 | 0.07 | 0.22 | 0.20 | 0.10 | 0.41 | 0.20 | 0.03 | 0.07 | 0.07 |
| $NO_3^-$-N, mg/L | 1.10 | 4.90 | 13.60 | 4.90 | 1.80 | 4.54 | 8.48 | 0.40 | 5.89 | 5.89 |
| T-P, mg/L | 31.56 | 5.53 | 31.49 | 8.94 | 5.3 | 4.03 | 7.92 | 9.37 | 1.37 | 11.14 |
| $PO_4^{3-}$-P, mg/L | 0.06 | 1.02 | 2.84 | 0.84 | - | 2.28 | 1.15 | 0.42 | 0.39 | 0.35 |
| Hydrocarbon, mg/L | 42 | 0.48 | 56 | 5.8 | 236 | 0.09 | 13.4 | 3.7 | 8 | 13.5 |
| Phenol, mg/L |  | 62 | 32.00 | 61.00 | - | <0.1 | 1.00 | 5.00 | 8.00 | 3.00 |

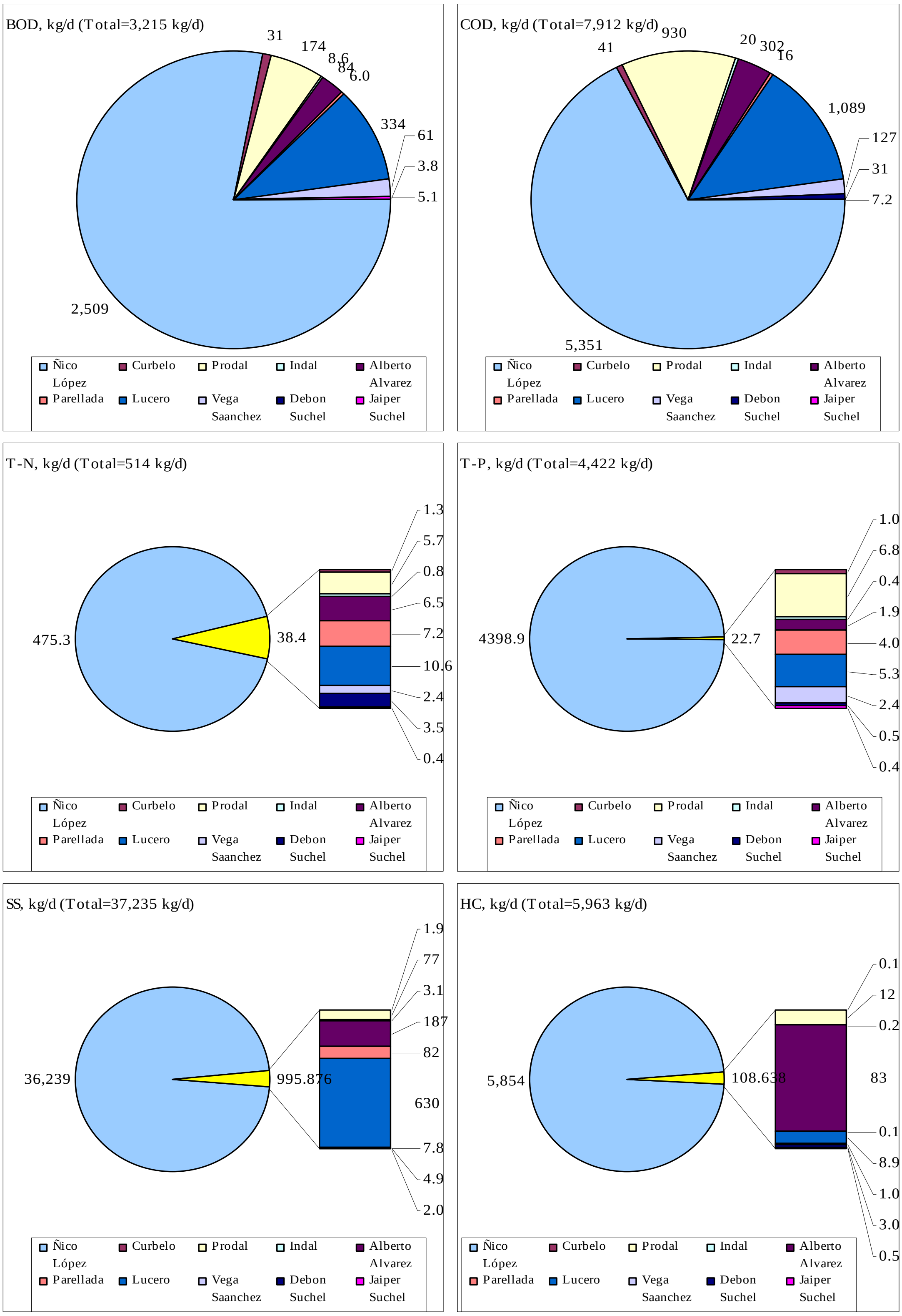


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Figure 3.13
Summary of Industrial Pollution Load from the 10 Selected Factories

### 3.4.3 SUMMARY OF SURVEYS

Major findings of the survey results are highlighted in the followings:

(1) The main industrial pollution sources in the Study Area are the oil refinery factory (Nico Lopez) and the food processing factories (Prodal and Lucero).

(2) The wastewater quantity discharged from Nico Lopez is 139,381 $m^3$ per day which contributes 97.8% of total wastewater quantity of the 10 selected factories (142,511 $m^3$/d). Therefore, Nico Lopez contributes the greater part (68% to 99%) of pollutant (BOD, COD, T-N, T-P, SS and HC) loads although the concentrations of these pollutants in the effluents have declined sharply comparing with the results measured by GEF in 1997.

(3) The wastewater quantity discharged from Lucero is 667 $m^3$ per day which contributes 0.5% of total wastewater quantity of the 10 selected factories (142,511 $m^3$/d). The concentrations of BOD and COD in the effluent of Lucero are 500 mg/l and 1,632 mg/l, respectively, which is considered to be a relative high level. Therefore, Lucero contributes 10.4% of total BOD load and 13.8% of total COD load.

(4) The wastewater quantity discharged from Prodal is 217 m3 per day which contributes 0.2% of total wastewater quantity of the 10 selected factories (142,511 $m^3$/d). The concentrations of BOD and COD in the effluent of Prodal are 800 mg/l and 4,284 mg/l, respectively, which is considered to be a relative high level. Therefore, Prodal contributes 5.4% of total BOD load and 11.7% of total COD load.

(5) Taking account of the survey results and existing situation, it is recommended to install a second-stage treatment facility (such as coalescing gravity separator or dissolved air flotation system) at Nico Lopez to remove emulsified oil, and install a pretreatment process at Prodal and Lucero to remove pollutants before discharging into municipal sewerage system.

# 3.5 LAWS AND STANDARDS ON WATER POLLUTION CONTROL

## 3.5.1 ENVIRONMENTAL LAW (GENERAL LAW)

Cuba has a hierarchy of legal provisions more complex than a simple division into "Laws" and "Regulations". The legal provisions are as follows:

- Full implementing laws (leyes) presented to and passed by the full National Assembly, whose members are elected from candidates proposed by labor, farm, and other citizen organizations
- Decree Law (Decreto Ley) which may be proposed by CITMA or another ministry but is presented to and approved by the Council of State (Consejo del Estado), the executive body of the Assembly which sits in permanent session
- Decree (Decreto) proposed by a single ministry but approved by the Council of Ministers (Consejo de Ministros), the executive ministry heads
- Resolution, adopted by an agency on its own initiative, and with, as a rule, effect limited to the agency itself

Cuba gives special attention to the protection of the environment within the context of its development policy. Article 27 of the constitution of 1976 declares that:

"The state protects the nation's environment and national resources and recognizes their close relationship with sustainable economic and social development to make human life more rational and ensure the survival, well being and security of present and future generations. It is the responsibility of proper governmental agencies to apply this policy. It is the duty of the citizens to contribute to the protection of the water, atmosphere, and the conservation of the soil, wild flora and fauna and all the rich potential of nature".

Decree Law No. 138 of 1$^{st}$ July 1993 sets out the responsibility of INRH regarding terrestrial waters, with the objective of developing the basic principles stated in the constitution of the Republic of Cuba and in the Environment Protection and National Resources Natural Use Law on surface and underground waters.

Provincial Delegations of INRH, for example, the Provincial Delegation of Resources of The City of Havana of the National Institute of Hydraulic Resources (DPRH), have the role of implementing the law and the legal base on water resources, environment and optimization in the substructure exploitation.

Law No. 81 of 1999 is the Law of the Environment. The purpose of the Law is to establish the legal principles to govern environmental policy and the basic legal requirements to regulate environmental management.

The State's Authority under this law and other environmental legislation in matters of environmental management will be exercised by the governmental bodies of the Central Administration of the State, other state bodies and the Local Bodies of the Popular Power, in accordance with this law and environmental legislation in general.

The Ministry of Science, Technology and Environment (CITMA) is the governmental agency of the Central Administration of the State in charge of proposing environmental policy and guiding its execution through the coordination and control of the nation's environmental management, promoting its coherent integration in order to contribute to sustainable development.

### 3.5.2 WATER POLLUTION CONTROL

**(1) General**

In the Law of the Environment (No. 81), Chapter IV – Waters and Aquatic Ecosystems it is stated that:

"All discharges of substances into watercourses, bays, coastal waters, lacustrine waters, reservoirs, underground waters or any other type, that are capable of causing contamination, of affecting other foreseen or unforeseen uses or of altering the balance of the ecosystem, should be the object of proper treatment".

As previously states INRH in coordination with other related agencies and bodies, controls the management of terrestrial waters. CITMA in coordination with the Ministries of the Fishing Industry, Transport, and Agriculture has overall responsibility for marine waters and resources. The Structures and Functions of CITMA and INRH, are given in Figure 3.15.

**(2) Industrial Wastewater**

Law No 81, Law of the Environment, does not have a specific chapter on pollution from industrial wastewater but there are many general references that clearly apply to industry.

All discharges of substances into watercourses, bays, coastal waters, lacustrine waters, reservoirs, underground waters etc., should be the object of proper treatment. In addition it is also stated that wastewater from economic activities, before being released into the environment, must receive the appropriate treatment so that they will not pollute reservoirs or terrestrial or maritime bodies of water.

Law No. 81 also provides for the issue of Environmental Licenses for all activities capable of producing significant environmental effects, and CITMA has the authority to temporarily or permanently suspend any activity that does not comply with the license. New projects, including industrial development are subject to an Environmental Impact Assessment (EIA) and the subsequent issue of an Environmental License.

### 3.5.3 STANDARDS

Standards for water supply and sanitation are many and varied, and cover all aspects within the sector. Standards may be divided into State, or National Standards (Normas Cubanas), which are mandatory in areas of the national economy, and Area Standards that are technical specifications and are mandatory in the specific area in question.

The main (State) National Standards concerning this study are:

**(1) Community Hygiene**

- NC 93-02 Drinking Water; Sanitary requirements and sampling
- NC 93-03 Public Water Supply System; Sanitary requirements
- NC 93-11 Public Water Supply Source; Sanitary quality and inspection
- NC 93-12 Water Treatment Installations; Sanitary requirements

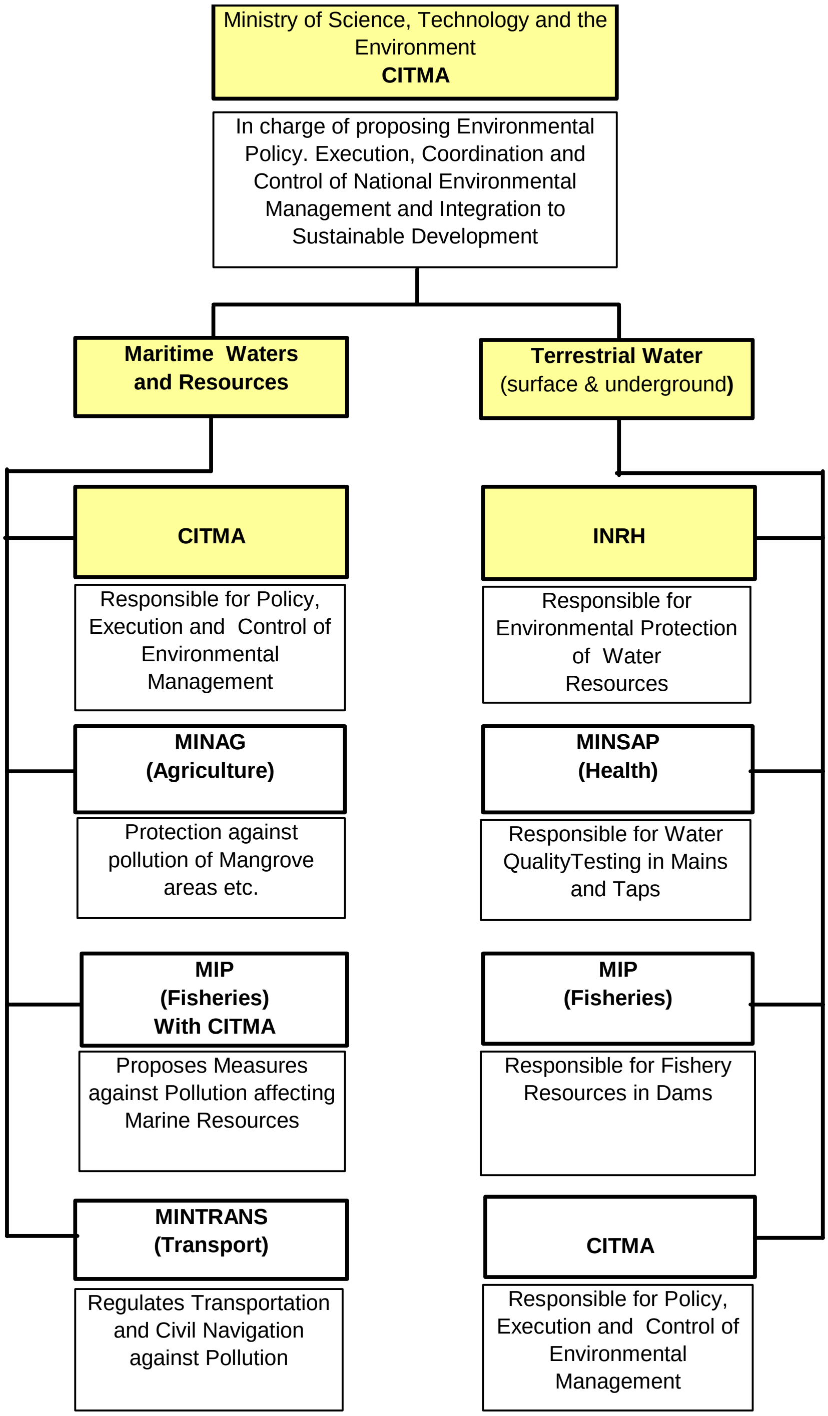


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Figure 3.14
Environmental Law – Structures and Functions

**(2) Standards for the Environmental Protection System**

- NC 93-01-102 Classification of Water Related Objects
- NC 93-01-103 Classification of Domestic Waters
- NC 93-01-208 Requirements for the Protection of Groundwater
- NC 93-01-209 Requirements for the Calculation of Sanitary Protection Areas for Groundwater Sources
- NC 93-01-210 General Requirements for the Protection of Surface and Groundwater from Contamination by Petroleum and its Derivatives
- NC 93-01 Final Disposal of Liquid Wastes in Domestic Water Bodies; Authorization Procedures
- NC 93-01 Requirements for the Selection and Assessment of the Sources of Supply of Potable Groundwater to Communities and Industries

Many more National Standards have been created (NC 22: 1999 – NC 39: 1999), plus the adoption of certain ISO-14000 standards

Among these, NC 27: 1999 governs the discharge of wastewater into sewers and is described in section 3.5.5 of this report.

A National Standard (NC) for the discharge of wastewater into seawater is in preparation and details of this standard, which are particularly relevant to this study, will be described in the Draft Final Report.

Regarding Area Standards relevant to industrial wastewater, the Ministry of Basic Industry has issued two standards to industries in the City of Havana on wastewater quality pending the finalizing of the National Standard for discharge of wastewater into seawater.

### 3.5.4 DISCHARGE QUALITY STANDARDS TO SEWERS

Table 3.19 shows permissible levels for discharges to public sewers as stipulated in Cuban Standard NC27, 1999 and that stipulated by Havana City. The latter include several parameters and stricter than national standard.

**Table 3.19 Permissible Level for Discharges to Public Sewers**

| Parameter | Limits | |
|---|---|---|
| | National Standard (NC27, 1999) | Havana City |
| pH | 6 - 9 | 6 - 9 |
| Temperature, $^{o}C$ | 50 | 40 |
| Conductivity, S/m | 0.4 | - |
| $BOD_5$, mg/L | 300 | 300 |
| COD, mg/L | 700 | 700 |
| Total nitrogen (T-N), mg/L | - | 50 |
| Organic nitrogen (Org-N), mg/L | - | 20 |
| Ammonium nitrogen ($NH_4$-N), mg/L | - | 30 |
| Nitrite nitrogen ($NO_2$-N), mg/L | - | 0.05 |
| Nitrate nitrogen ($NO_3$-N), mg/L | - | 0.2 |
| Total Phosphorous (T-P), mg/L | - | 10 |
| Phosphates, mg/L | - | 1 |
| Oil and grease, mg/L | 50 | 20 |
| Methylene blue reactive substance(surfactant), mg/L | 25 | 20 |
| Settleable solids, mg/L | 10 | 4 |
| Total solids (TS), mg/L | - | 500 |
| Total volatile solids (TVS), mg/L | - | 350 |

| | | |
|---|---|---|
| Total non-volatile residue, mg/L | - | 150 |
| Suspended solids (SS), mg/L | - | 300 |
| Volatile suspended solids (VSS), mg/L | - | 250 |
| Non-volatile suspended solids residue, mg/L | - | 50 |
| Total dissolved solids (TDS), mg/L | - | 200 |
| Volatile dissolved solids (VDS), mg/L | - | 100 |
| Non-volatile dissolved solids, mg/L | - | 100 |
| Total dissolved salts, mg/L | - | 10,000 |
| Chlorides ($Cl^-$), mg/L | - | 100 |
| Aluminum (Al), mg/L | 10 | 10 |
| Iron (Fe), mg/L | - | 5 |
| Arsenic (As), mg/L | 0.5 | 0.5 |
| Cadmium (Cd), mg/L | 0.3 | 0.3 |
| Cyanide ($CN^-$), mg/L | 0.5 | 0.5 |
| Copper (Cu), mg/L | 5 | 5 |
| Total Chromium (Cr), mg/L | 2 | 2 |
| Hexavalent chromium (Cr), mg/L | 0.5 | 0.5 |
| Trivalent chromium ($Cr^{3+}$), mg/L | - | 2.5 |
| Mercury (Hg), mg/L | 0.01 | 0.01 |
| Lead (Pb), mg/L | - | 1 |
| Zinc (Zn), mg/L | - | 5 |
| Nickel (Ni), mg/L | - | 0.5 |
| Cobalt (Co), mg/L | - | 1 |
| Manganese (Mn), mg/L | - | 1 |
| Hydrogen sulfide ($H_2S$), mg/L | - | 1 |
| Sulfate base dyes, mg/L | - | 25 |
| Synthetic dyes, mg/L | - | 25 |
| Phenols, mg/L | 5 | 5 |
| Hydrocarbons ($C_nH_n$), mg/L | - | 25 |
| Formaldehyde ($CH_2O$), mg/L | - | 25 |
| Aniline ($C_6H_6NH_2$), mg/L | - | 6 |
| Acetaldehyde ($CH_3CHO$), mg/L | - | 20 |
| Acetone ($(CH_3)_2CO$), mg/L | - | 40 |
| Butric Acid ($C_6H_5COOH$), mg/L | - | 15 |
| Butanol, mg/L | - | 10 |
| Methanol, mg/L | - | 30 |
| Propanol, mg/L | - | 12 |
| Ethanol, | - | 14 |
| Glycerin, mg/L | - | 90 |
| Toluene, mg/L | - | 15 |
| Acetic acid ($CH_3COOH$), mg/L | - | 25 |
| Diethyl-hexane ($C_6H_{14}$), mg/L | - | 6 |
| Aluminum oxide ($Al_2O_3$), mg/L | - | 0 |

### 3.5.5 EFFLUENT QUALITY STANDARDS

Cuban Standard NC-27, 1999 stipulates effluent quality depending on the receiving water.

**Table 3.20 Discharge Standards to Inland Surface Waters, NC27**

| Parameter | Receiving Water and its Water Use | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | River and Dams | | | Partial Saturation Area | | | Saturation Area | | |
| | A | B | C | A | B | C | A | B | C |
| pH | 6.5-8.5 | 6 - 9 | 6 - 9 | 6 - 9 | 6 - 9 | 6 - 10 | 6 - 9 | 6 - 9 | 6 - 10 |
| Temperature, $^{o}C$ | 40 | 40 | 40 | 40 | 40 | 50 | 40 | 40 | 50 |
| Conductivity, S/m | 0.14 | 0.20 | 0.35 | 0.15 | 0.20 | 0.40 | 0.15 | 0.20 | 0.40 |
| $BOD_5$, mg/L | 30 | 40 | 60 | 40 | 60 | 100 | 30 | 50 | 100 |
| COD, mg/L | 70 | 90 | 120 | - | - | - | - | - | - |
| Total nitrogen (T-N), mg/L | 5 | 10 | 20 | 5 | 10 | 15 | 5 | 10 | 15 |
| Total Phosphorous (T-P), mg/L | 2 | 4 | 10 | 5 | 5 | 10 | 5 | 5 | 10 |
| Oil and grease, mg/L | 10 | 10 | 30 | 5 | 10 | 30 | ND | 10 | 20 |
| Flotable solids | ND | ND | - | ND | ND | ND | ND | - | ND |
| Settleable solids, mg/L | 1 | 2 | 5 | 1 | 3 | 5 | 0.5 | 1 | 5 |

Note: Water uses: A – water supply, B – irrigation and C – industrial water supply, ND-not detectable.

### 3.5.6 ENVIRONMENTAL QUALITY STANDARDS FOR FISHING WATERS

Cuban Standard NC93-105, 1987 stipulates environmental quality standards for marine and fresh water used for fishing as shown in Table 3.25.

**Table 3.21 Environmental Quality Standards for Fishing Waters, NC93-105**

| Parameter | Limits | |
|---|---|---|
| | Freshwater | seawater |
| pH | 6.5 – 8.5 | 8 – 9.5 |
| , % | 10 – 100 | 20 – 100 |
| Salinity, % | | 1 – 3.5 |
| $BOD_5$, mg/L | 3 – 8 | 1 – 2 |
| $COD_{Mn}$, mg/L | 15 – 30 | |
| DO, mg/L | 2 – 5 | 3 – 5 |
| Ammonium nitrogen ($NH_4$-N), mg/L | 1 – 3 | 0.03 – 0.05 |
| Nitrite nitrogen ($NO_2$-N), mg/L | 0.1 – 3 | 0.05 – 1.5 |
| Nitrate nitrogen ($NO_3$-N), mg/L | 10 – 80 | 0.01 – 0.6 |
| mg/L | 0.1 – 3 | 0.05 – 0.20 |
| Suspended solids (SS), mg/L | 100 – 300 | 100 – 300 |
| Total coliforms, No/100 mL | $5x10^3 – 5x10^4$ | $2x10^2 – 1x10^3$ |
| Fecal coliforms, No/100 mL | - | $7x10^2 – 1x10^3$ |
| Arsenic (As), mg/L | - | 1 |
| Cadmium (Cd), mg/L | - | 0.01 |
| Mercury (Hg), mg/L | - | 0.005 |
| Lead (Pb), mg/L | - | 0.1 |
| Cobalt (Co), mg/L | - | 0.05 |

**References :**

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# CHAPTER 4
# PRESENT POLLUTION LOAD ANALYSIS AND WATER QUALITY SIMULATION MODEL OF HAVANA BAY

## 4.1 GENERAL

### 4.1.1 POLLUTION LOAD ANALYSIS

Deterioration of water quality of Havana Bay is due to pollution load received by rivers, wastewater collectors and urban drains discharging to the bay or through direct discharges from sources located along the shore of the bay. Pollution load generated undergo transformation processes during treatment prior to discharge and during their transport between the point of generation and to the point of discharge to the bay. Pollution load discharged to the bay further undergoes transformation within the bay through several physical and bio-chemical processes and dilution by tidal exchange with the outlying sea. Understanding the mechanism beginning from the sources of pollution load generation, pollution load discharge to the bay and its transformation within the bay is a basic requirement to undertake any pollution control measures effectively.

### 4.1.2 WATER QUALITY SIMULATION MODEL OF HAVANA BAY

Water quality of Havana Bay is influenced by complex processes within the bay and thus behavior of water quality of the bay is also complex. Water quality simulation model to describe these complex processes is an effective tool to characterize the water pollution of the bay and to evaluate the pollution control measures such as reduction in pollution load to the bay through improvement of sewerage system. Constructing a water quality simulation model can also be used as a management tool for decision making in the future.

Water quality simulation model based on MIKE3 has been developed and will be transferred to WASP6/DYNHYD5. Description of the development of model in this chapter is based on available data. Model is being updated with the results of current measurement survey and water quality surveys carried out in this Study.

## 4.2 POLLUTION LOADS

### 4.2.1 METHODOLOGY

Pollution sources : Pollution load generation is classified as due to wastewater generated through domestic, institutional and industrial activities.

Pollution load: Pollution load is estimated at the point of generation and at the point of discharge to the bay. Estimates of pollution load generation are made based on unit pollutant load. Pollutant load discharge to the bay is estimated based on the monitoring data at the most downstream end of drains and rivers draining to bay. Industries along the periphery of the bay and discharging directly is also estimated based on monitoring data. Figure 2.1 shows nine basins constituting the Havana Bay basin and the estimation of loads are made for each of the nine basins for the year 1996 and year 2000.

Relationship between pollution load generation and pollution load discharge in each basin will be utilized to estimate the future pollutant loads discharged to the bay.

Unit Pollution load: Results of the investigation carried out on the unit pollution load generation of domestic origin indicate that the unit per capita $BOD_5$ generation was 43 gpcd (Ref. 1) in 1978 and 29.3 gpcd in 1996 (Ref. 2) respectively investigated for a vocational training school and for a small community in outskirts of Havana City. The decrease was explained due to the economic slowdown during "special period". There are no recent investigations on the unit pollutant load and an estimate is made at 40 gpcd to reflect the present conditions.

### 4.2.2 POLLUTION LOAD GENERATED

Estimates are made for the year 1996 and year 2000. Table 4.1 shows the population estimate for the basin for the year 1996 and 2000. Table 4.2 shows the domestic pollution load generation based on unit pollutant loads. Table 4.3 shows domestic, institutional and industrial pollutant load generation in terms of $BOD_5$. Institutional pollutant load is estimated as a percentage of total domestic load generated in proportion to domestic and institutional water consumption. Total institutional load will be distributed among the basins following the identification of 'grand consumers' (more than 900 $m^3$ of average monthly water consumption). Industrial load is based on monitoring data of CIMAB.

**Table 4.1 Population within the Havana Bay Basin, Year 1996 & 2000**

| Basin | Area, ha | Population 1996, GEF/ DPPFA | Population Density 1996, person/ha | Population 2000 | Population Density 2000, person/ha |
|---|---|---|---|---|---|
| Habana Vieja | 257 | 110,641 | 430 | 101,015 | 392 |
| Dren Arroyo Matadero | 679 | 128,160 | 189 | 120,189 | 177 |
| Dren Agua Dulce | 648 | 148,581 | 229 | 139,185 | 215 |
| Rio Luyano | 2,995 | 252,223 | 84 | 241,927 | 81 |
| Rio Martin Perez | 1,309 | 72,797 | 56 | 72,916 | 56 |
| Rio Tadeo | 256 | 14,059 | 55 | 13,966 | 55 |
| Refinery Area | 342 | 21,946 | 64 | 22,793 | 67 |
| Casa Blanca | 259 | 12,991 | 50 | 14,231 | 55 |
| Cabaña | 44 | 639 | 15 | 671 | 15 |
| Total | 6,790 | 762,037* | 106 | 726,893 | 107 |

Note: * Population estimate revised based on the limits of Havana Bay Basin

**Table 4.2 Domestic Pollution Load Generation, Year 1996 & 2000**

| Basin | Year 1996 | | | Year 2000 | | |
|---|---|---|---|---|---|---|
| | $BOD_5$ | T-N | T-P | $BOD_5$ | T-N | T-P |
| | kg/d | kg/d | kg/d | kg/d | kg/d | kg/d |
| Habana Vieja | 4,426 | 819 | 210 | 4,041 | 748 | 192 |
| Dren Arroyo Matadero | 5,126 | 948 | 244 | 4,808 | 889 | 228 |
| Dren Agua Dulce | 5,943 | 1,099 | 282 | 5,567 | 1,030 | 264 |
| Rio Luyano | 10,089 | 1,866 | 479 | 9,677 | 1,790 | 460 |
| Rio Martin Perez | 2,912 | 539 | 138 | 2,917 | 540 | 139 |
| Rio Tadeo | 562 | 104 | 27 | 559 | 103 | 27 |
| Refinery Area | 878 | 162 | 42 | 912 | 169 | 43 |
| Casa Blanca | 520 | 96 | 25 | 569 | 105 | 27 |
| Cabaña | 26 | 5 | 1 | 27 | 5 | 1 |
| Total | 30,481 | 5,639 | 1,448 | 29,076 | 5,379 | 1,381 |

Note: Unit pollutant loads for BOD5, T-N and T-P are assumed at 40, 7.4 and 1.9 gpcd.

**Table 4.3 Total $BOD_5$ Load Generation, Year 1996 & 2000 (Preliminary)**

| Basin | Year 1996 | | | | Year 2000 | | | |
|---|---|---|---|---|---|---|---|---|
| | Domestic | Inst./com | Industrial | Total | Domestic | Inst./com | Industrial | Total |
| | kg/d | kg/d | kg/d | kg/d | kg/d | kg/d | kg/d | kg/d |
| Habana Vieja | 4,426 | | 29 | 4,455 | 4,041 | | 29 | 4,070 |
| Dren Arroyo Matadero | 5,126 | | 0 | 5,126 | 4,808 | | 0 | 4,808 |
| Dren Agua Dulce | 5,943 | | 0 | 5,943 | 5,567 | | 0 | 5,567 |
| Rio Luyano | 10,089 | | 26,505 | 36,594 | 9,677 | | 3,010 | 12,688 |
| Rio Martin Perez | 2,912 | | 273 | 3,185 | 2,917 | | 820 | 3,737 |
| Rio Tadeo | 562 | | 1,719 | 2,281 | 559 | | 340 | 899 |
| Refinery Area | 878 | | 22,823 | 23,701 | 912 | | 21,723 | 22,634 |
| Casa Blanca | 520 | | 23 | 542 | 569 | | 23 | 592 |
| Cabaña | 26 | | 0 | 26 | 27 | | 0 | 27 |
| Total | 30,481 | 15,241 | 51,372 | 81,853 | 29,076 | 14,538 | 25,946 | 55,021 |

Note: Institutional and commercial load is preliminary and will be distributed among the basins following the analysis of water consumption and location data.

### 4.2.3 POLLUTION LOAD DISCHARGED

Table 4.4 shows the pollutant load discharged directly to the bay through rivers and drain. Table 4.5 shows the total pollution load discharged directly to the bay which includes the pollutant load discharged by the industries on the periphery.

**Table 4.4 Pollution Load through Rivers and Drains in Year 1996/97 & 2002**

| Basin | 1996/97 | | | | 2002 | | | |
|---|---|---|---|---|---|---|---|---|
| | Flow | $BOD_5$ | T-N | T-P | Flow | $BOD_5$ | T-N | T-P |
| | $m^3/d$ | kg/d | kg/d | kg/d | $m^3/d$ | kg/d | kg/d | kg/d |
| Habana Vieja | 7,516 | 801 | 16 | 13 | 8,554 | 1,291 | 144 | 77.5 |
| Dren Arroyo Matadero | 78,126 | 20,015 | 3,918 | 1,326 | 77,760 | 8,942 | 610 | 1,053 |
| Dren Agua Dulce | 46,152 | 5,630 | 1,099 | 356 | 43,226 | 6,770 | 529 | 1,171 |
| Rio Luyano | 120,960 | 28,500 | 4,800 | N/A | 114,860 | 9,476 | 1,068 | N/A |
| Rio Martin Perez | 35,597 | 356 | 320 | 180 | 62,105 | 1,245 | 239 | 49 |
| Rio Tadeo | 8,004 | 1,537 | 99 | 41 | 8004 | 1,537 | 99 | 41 |
| Refinery Area | - | - | - | - | - | - | - | - |
| Casa Blanca | - | - | - | - | - | - | - | - |
| Cabaña | - | - | - | - | - | - | - | - |
| Total | 296,355 | 56,839 | 10,252 | 4,616 | 314,509 | 29,261 | 4,622 | 2,391 |

Note: Total load includes that discharged directly to bay by the industries. Load data for the industries discharging directly is not available for all major industries in 1996/97 and the data for 2002 is assumed. Data shown as 610 indicates unbalanced concentration of nitrogen and phosphorous. N/A indicates data not available. The total is obtained by assuming similar proportion of BOD:N as Rio Martin Perez for data N/A. Unbalanced values are adjusted with 96/97 data. Totals shown with underline 4,616 are adjusted values for unbalanced values and N/A.

**Table 4.5 Total Pollution Load Discharged to the Bay in Year 1996/97 & 2002**

| Basin | 1996/97 | | | | 2002 | | | |
|---|---|---|---|---|---|---|---|---|
| | Flow | $BOD_5$ | T-N | T-P | Flow | $BOD_5$ | T-N | T-P |
| | $m^3/d$ | kg/d | kg/d | kg/d | $m^3/d$ | kg/d | kg/d | kg/d |
| Habana Vieja | 7,619 | 830 | 86 | 15 | 8,657 | 1,320 | 214 | 79 |
| Dren Arroyo Matadero | 78,126 | 20,015 | 3,918 | 1,326 | 77,760 | 8,942 | 610 | 1,053 |
| Dren Aqua Dulce | 46,152 | 5,630 | 1,099 | 356 | 43,226 | 6,770 | 529 | 1,171 |
| Rio Luyano | 121,955 | 29,803 | 6,738 | N/A | 115,417 | 9,784 | 1,627 | N/A |
| Rio Martin Perez | 36,070 | 629 | 838 | 186 | 62,578 | 1,518 | 757 | 55 |
| Rio Tadeo | 8,585 | 3,256 | 2,396 | 156 | 8,517 | 1,812 | 595 | 46 |
| Refinery Area | 475 | 22,823 | 54 | 1 | 475 | 21,723 | 54 | 1 |
| Casa Blanca | 80 | 23 | 54 | 1 | 80 | 23 | 54 | 1 |
| Cabaña | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 299,062 | 83,009 | 15,184 | 4,820 | 316,710 | 51,893 | 6,373 | 2,433 |

Note: Total load includes that discharged directly to bay by the industries. Load data for the industries discharging directly is not available for all major industries in 1996/97 and the data for 2002 is assumed.

### 4.2.4 FURTHER WORK

Table 4.6 shows the preliminary results of the relationship between $BOD_5$ generation and discharge. Pollution load generated in Habana Vieja basin, Dren Arroyo Matadero basin and and Dren Agua Dulce basin is intended to be collected by Colector Principal and discharged outside the bay near Playa del Chivo. However, due to illegal connections to stormwater drains and interconnection/overflow between Principal Colector and stormwater drains, pollution load generated in those areas are discharged to the bay through stormwater drains. In addition, the Colector Paralelo Orengo (Figure 5.1) serves areas outside the Havana Bay Basin and connected to Principal Colector, from which part of wastewater is discharged to the bay through stromwater drains. Further investigation will be necessary to quantify wastewater discharge from collectors to stormwater drains in these areas. Further, estimated pollutant load generation is smaller than the discharged load for Arroyo Tadeo which also needs further investigation.

**Table 4.6 Relationship between Generation and Discharge (Preliminary)**

| Basin | Estimated $BOD_5$ Generation, kg/d | | Intended Discharge to Bay | Actual Discharged $BOD_5$, kg/d | | Remarks |
|---|---|---|---|---|---|---|
| | 1996 | 2000 | | 1996/97 | 2002 | |
| Habana Vieja | 4,455 | 4,070 | 0 | 830 | 1,320 | Wastewater is intended to be collected by Colector Principal. |
| Dren Arroyo Matadero | 5,126 | 4,808 | 0 | 20,015 | 8,942 | |
| Dren Agua Dulce | 5,943 | 5,567 | 0 | 5,630 | 6,770 | |
| Rio Luyano | 36,594 | 12,688 | | 29,803 | 9,784 | |
| Rio Martin Perez | 3,185 | 3,737 | | 629 | 1,518 | |
| Rio Tadeo | 2,281 | 899 | | 3,256 | 1,807 | Requires investigation |
| Refinery Area | 23,701 | 22,634 | | 22,823 | 21,723 | |
| Casa Blanca | 542 | 592 | | 23 | 23 | |
| Cabaña | 26 | 27 | | 0 | 0 | |
| Total | 81,853 | 55,021 | | 83,009 | 51,888 | |

# 4.3 WATER QUALITY SIMULATION MODEL

## 4.3.1 METHODOLOGY

Figure 4.1 shows the flowchart of the water quality simulation for Havana bay. The water quality simulation is divided into two phases; one of which is model establishment and another one is future water quality prediction. In the phase of model establishment, identifying and analyzing the most important hydraulic phenomenon and water pollution characteristics of the bay is carried out prior to the construction of the hydrodynamic (hereinafter referred to as HD) and water quality (hereinafter referred to as WQ) model respectively. In the calibration of the models, parameters are identified to reproduce measured conditions for the calibration period. With the application of the calibrated models, allowable load to reach the water environment target is estimated. Finally, future water quality of the bay respondent to the alternatives will be predicted and evaluated.

## 4.3.2 HYDRODYNAMIC SIMULATION OF HAVANA BAY

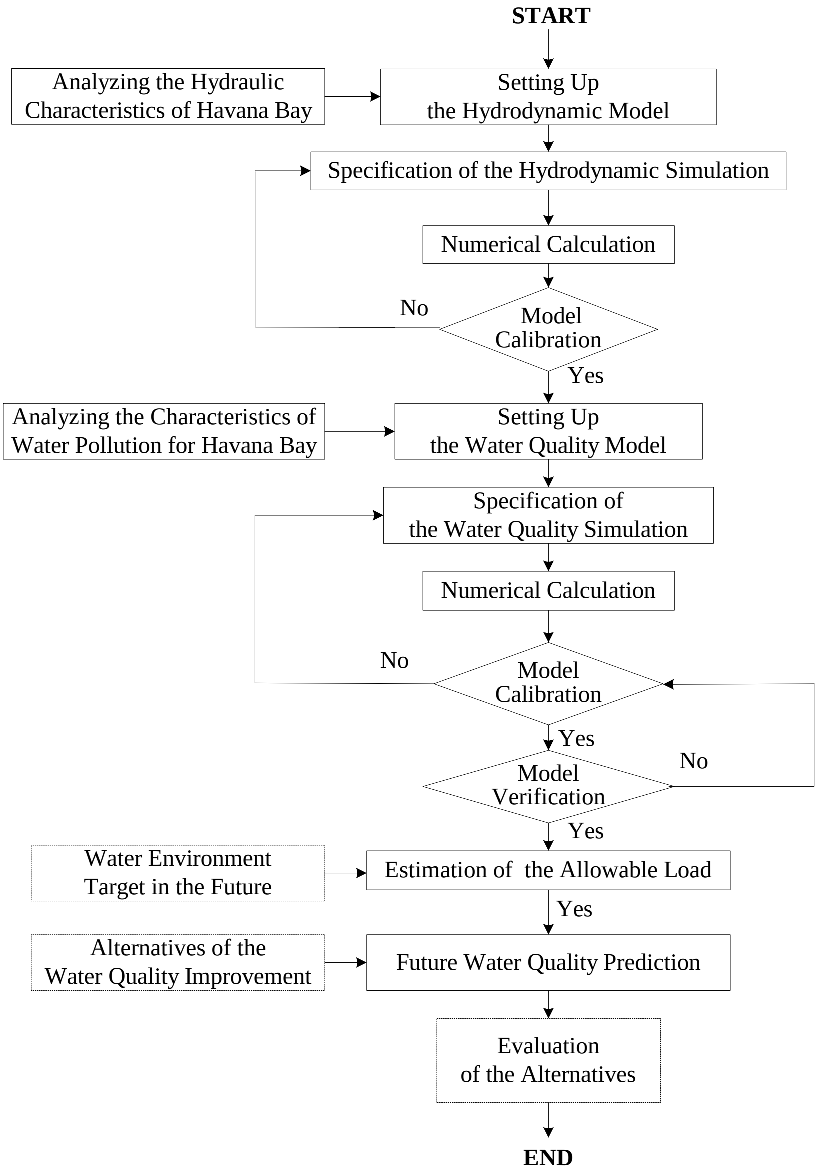
### (1) Setting up the Model

Before setting up of the hydrodynamic models, it is necessary to identify the most important hydraulic phenomena and factors that affect the pollutant transportation in the bay. Generally, current in estuarine and coastal region consists of tidal stream, tidal residual flow, drift current (wind generated current), density driven flow, slope current and wave, etc. Among these currents, tidal and density flow play an important role in the transportation of pollutants in the seawater of bay. Especially for the shallow water area of the bay, inflow of fresh water from rivers and other sources usually causes a remarkable density flows occurring, which promote the resuspension and release of sediment pollutants. According to the investigation results in the past, important hydraulic characteristics of Havana bay can be concluded as follows.

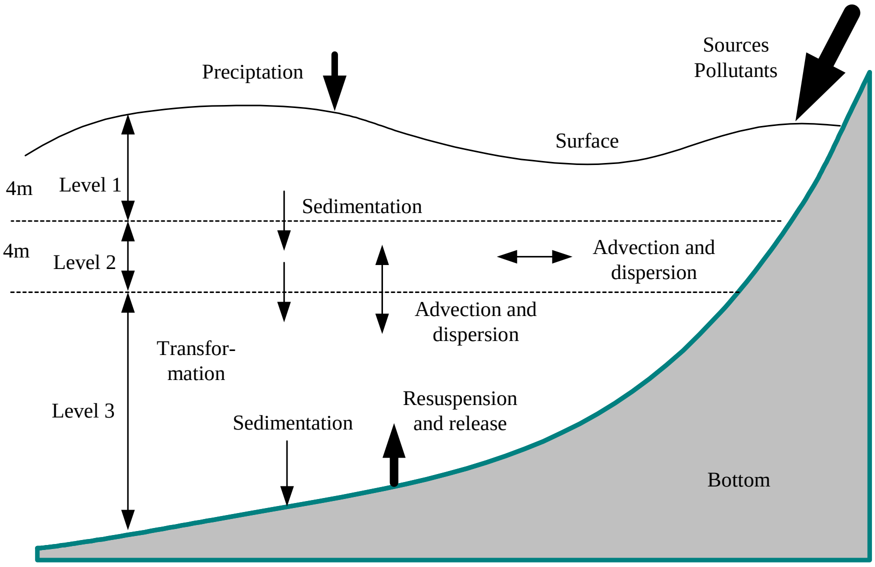
- Tidal currents inside the bay is relatively little, due to the narrow entrance (270m in width) and low tidal amplitude (0.29m in average) in the bay.
- Retention time of the fresh water in the bay is approximately 4 months and water exchange between the bay and the open sea is relatively small.
- The average and maximum water depth of the bay is 9 and 17 meters respectively. Therefore, water temperature stratification would be broken up easily by wind blown or strong currents. On the other hand, density flow both in horizontal and vertical directions could be strong in some estuaries such as Atares and Guasabacoa, due to a large quantity of fresh water inflow from rivers and drainage.
- Heat exchange between seawater and atmosphere would be one of the most important factors to the water temperature inside the bay.
- Precipitation, especially in the rain season, could promote the generation of the density currents in the bay.

Basing upon the hydraulic characteristics mentioned above, a three-dimensional hydrodynamic model is selected in this simulation. Three main current components as tidal stream, drift current and density driven flows are taken into account in the model. Figure 4.2 shows the sketch of the model applied in the simulation.

The fundamental equations applied in the hydrodynamic model are shown in the Appendix at the end of this chapter.




| THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY | Figure 4.1<br>Flow Chart for the Water Quality Simulation of Havana Bay |
|---|---|
| JAPAN INTERNATIONAL COOPERATION AGENCY | |




THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY

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Figure 4.2
Sketch of the Model Applied in the Simulation

### (2) Calculation conditions for the Hydrodynamic Simulation

Calculation conditions for the hydrodynamic simulation includes bathymetry, boundary, initiation, source, as well as the parameters of the model. Specifications for each condition will be described as follows.

Bathymetry : Calculation area for the hydrodynamic simulation is whole water area of Havana bay. Referred to the sea chart of La Habana port [(3)], the calculation area is illustrated in Figure 4.3. The area of the bay is 5.2 $km^2$ and the volume is $47x10^6$ $m^3$. Mesh division for the area is shown in Figure 4.4 and the mesh size is 30×30 m in horizontal direction. In vertical direction, the area is divided into 3 levels (layers) with each level 4 m. Distribution of water depth for the area is shown in Figure 4.5. Average water depth for the area is 9 m and the maximum is 17 m respectively.

Open boundary : Open boundary is determined considering the objective of the simulation, current characteristics of Havana bay as well as the locations of current and water quality observation stations. In the HD and WQ simulations, boundary is positioned at the mouth of the bay shown as in Figure4.4.

Height of Tide : Tidal observation station of Havana bay is located at Punta Santa Catalina with the latitude of 23˚08.6'N and longitude of 82˚20.3'N (Figure 4.2). The predicted height of tide is used as the water level of the boundary [(2)].

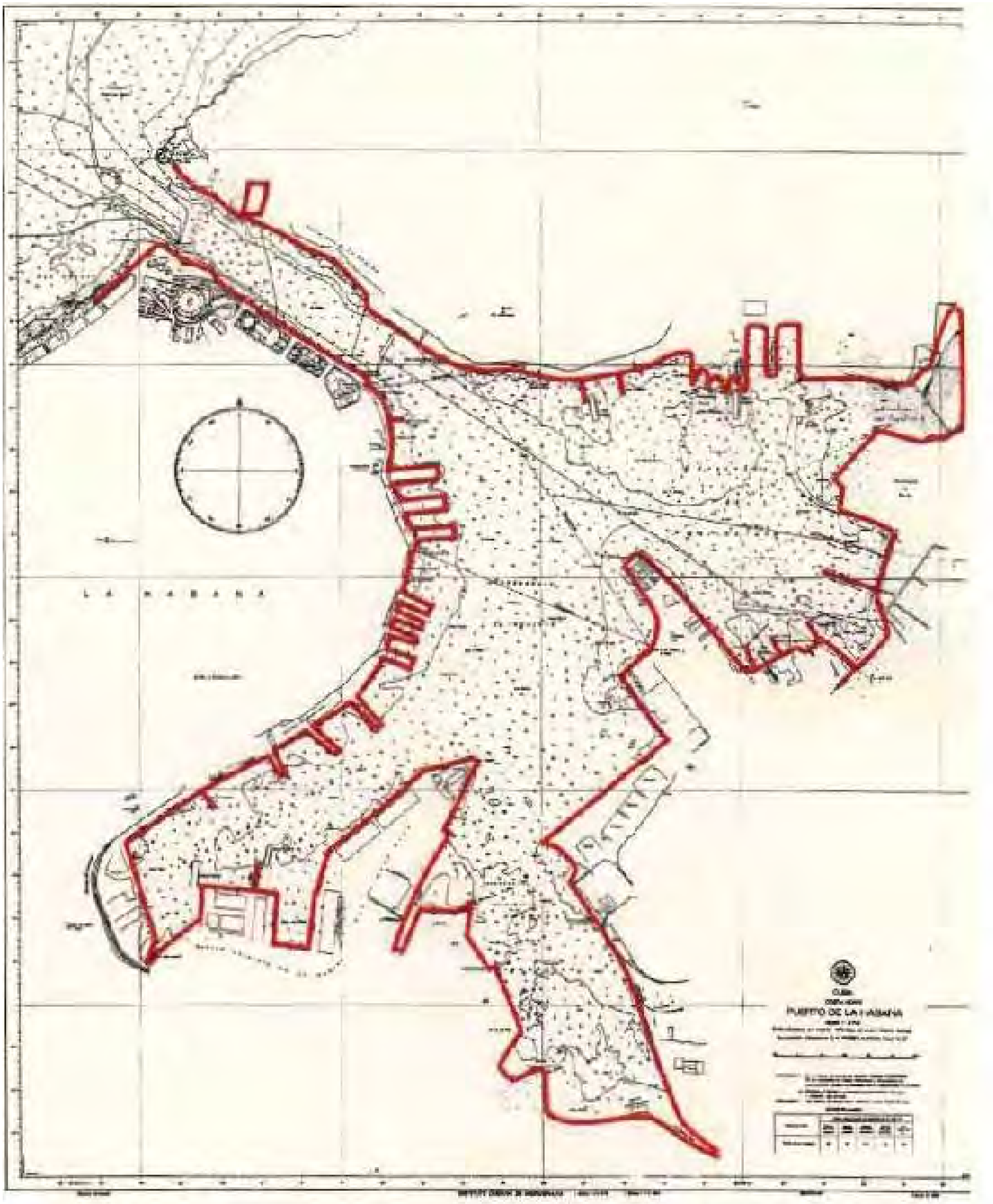
Meteorological Conditions : Air temperature, precipitation, wind velocity and direction are specified using observed meteorological data provided by Havana meteorological observatory. Daily averaged temperature, precipitation, wind velocity and wind direction are used in the hydrodynamic simulation.

Initial Conditions : It is needed to specify the initial water level, temperature and salinity before the simulation. These conditions are specified according to the existed observation data. The values for these parameters are shown in Table 4.7.

**Table 4.7 Initial conditions for the hydrodynamic simulation**

| Items | Rain season | Dry season |
|---|---|---|
| Water level (m) | 0.16 | 0.20 |
| Temperature (℃) | 28.5 | 26.8 |
| Salinity (psu) | 33.3 | 33.1 |

Source : Ten sources are take into accounted in the hydrodynamic simulation, in which 4 industrial wastewater, 3 rivers as well as 3 drainage channels are included. Location of the sources is shown in Figure 4.4. Usually, source conditions are specified based upon the proper monitoring data, which represents the typical state of the sources. Because of the limitations in the number of source data and large variation in the results of the different observation, it is difficult to grasp the outflow characteristics of the sources. Therefore, the latest surveyed results are directly utilized here to specify the source condition, although the observation period is different from the simulation. Table 4.8 shows the results of the source specification.




| THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY | Figure 4.3<br>Objective Area for Hydrodynamic and Water Quality Simulation of Havana Bay |
|---|---|
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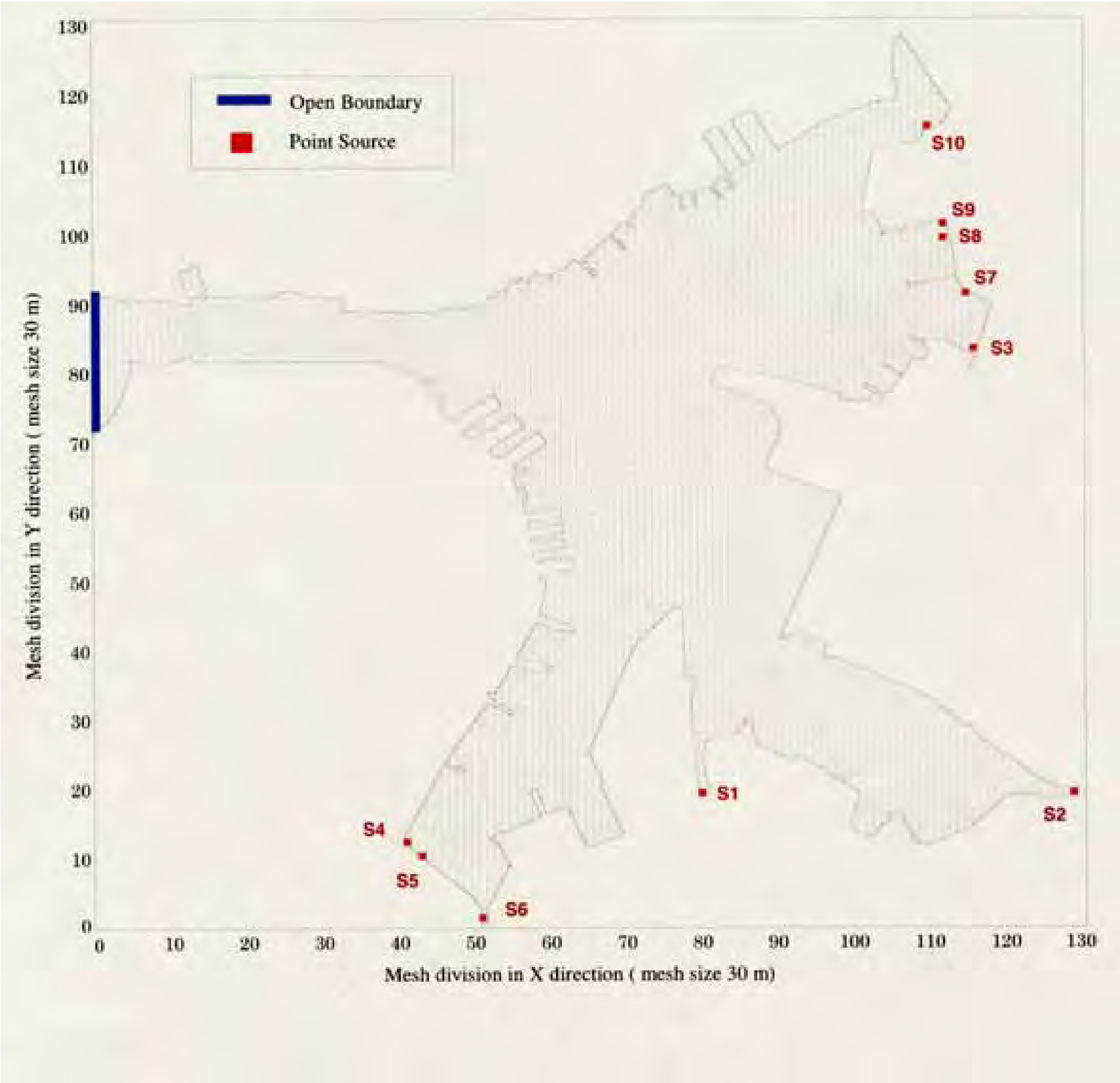


| THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY | Figure 4.4<br>Location of the Open Boundary and Point Sources |
|---|---|
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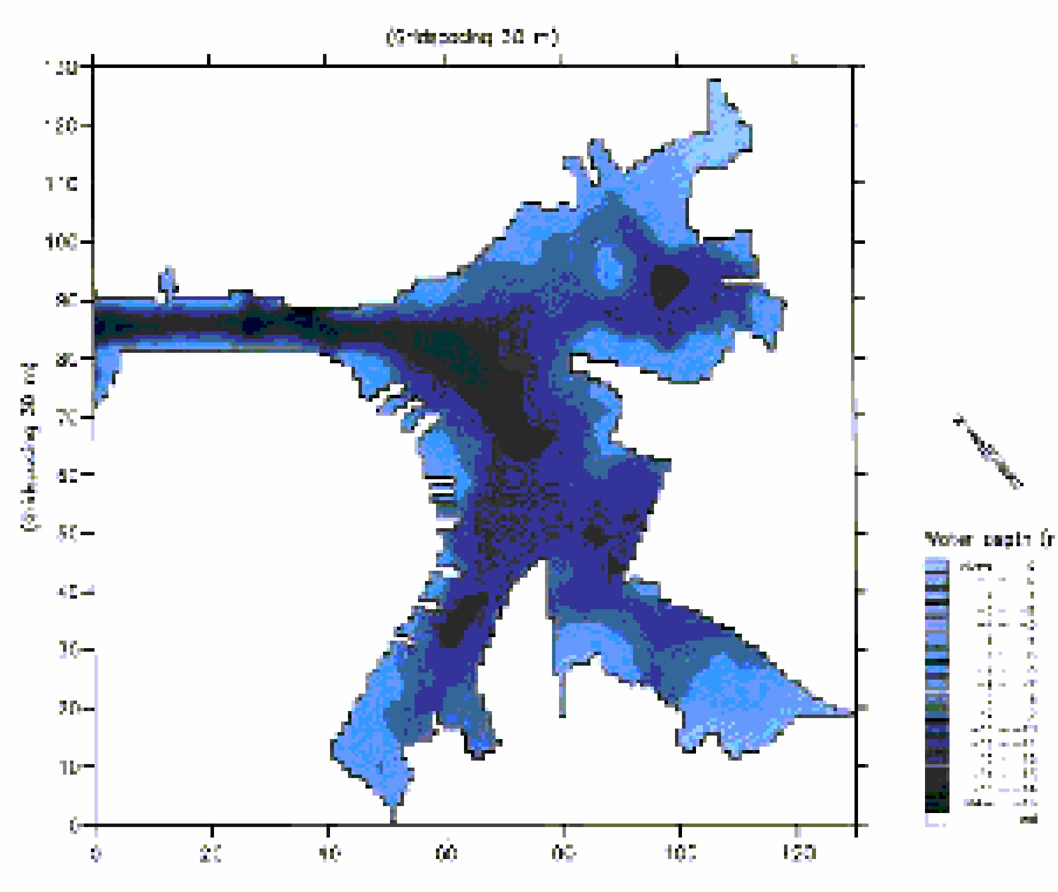

| | |
|---|---|
| THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY | Figure 4.5<br>Water Depth Distribution of Havana Bay |
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**Table 4.8 Specification of the Source condition for the Hydrodynamic Simulation**

| Classification | Sources | NO. | Inflow point | | | Flowrate (m3/s) | Temperature (°C) | Salinity (‰) |
|---|---|---|---|---|---|---|---|---|
| | | | X | Y | Z | | | |
| Rivers | Luyano | S1 | 80 | 19 | 3 | 1.329 | 27 | 1 |
| | Martin Perez | S2 | 129 | 19 | 3 | 0.719 | 27 | 1 |
| | Tadeo | S3 | 116 | 82 | 3 | 0.093 | 27 | 1 |
| Drainage channels | San Nicolas | S4 | 41 | 12 | 3 | 0.099 | 27 | 1 |
| | Arroyo Matadero | S5 | 43 | 10 | 3 | 0.900 | 27 | 1 |
| | Agua Dulce | S6 | 51 | 1 | 3 | 0.500 | 27 | 1 |
| Industrial wastewater | Refinería de petróleo Ñico López* | S7 | 115 | 91 | 3 | 0.010 | 27 | 1 |
| | | S8 | 112 | 99 | 3 | 0.037 | 27 | 1 |
| | | S9 | 112 | 101 | 3 | 0.037 | 27 | 1 |
| | | S10 | 110 | 115 | 3 | 0.010 | 27 | 1 |

* Net discharge of fresh water is take into accounted here.

Parameters of the Model : Model parameter, eddy viscosity, bed roughness, slip factors, dispersion factors of temperature and salinity need to be specified. Table 4.9 shows the calibrated values of the parameters for the hydrodynamic model.

**Table 4.9 Calibrated Parameters of the Hydrodynamic model**

| Parameters | value | Parameters | value |
|---|---|---|---|
| Eddy viscosity ($m^2/s$) | 3.0 | Constants in Dalton's law | 0.5 |
| Bed roughness (m) | 0.05 | Wind coefficient in Dalton's law | 0.9 |
| Slip factors for the water surface | 1.0 | Relative humidity (%) | 71 |
| Slip factors for the sea bottom | 1.0 | Clearness coefficient (%) | 0.7 |
| Slip factors for the wall | 1.0 | Beta in Beer's law | 0.3 |
| Dispersion factors of temperature | 0.1 | Light extinction coefficient | 1.0 |
| Dispersion factors of salinity | 0.1 | | |

Numerical calculation conditions : Considering the stability of numerical calculation, accuracy of the results and the time used in the calculation, time step is set to be 120 seconds. Periods of simulation for the rain season and dry season are two months respectively.

Conditions described above are summarized in the Table 4.10.

**Table 4.10 Summarization of the Calculation Conditions**

| Classification | Items | Specified values |
|---|---|---|
| Bathymetry | Objective area | Havana bay |
| | Mesh division (X×Y) | 130×130 |
| | Mesh size (△X×△Y) | 30m |
| | Level(layers) in vertical direction | 3 |
| | Layer height | First layer<br>(surface layer) :4.0 m<br>second layer: 4.0 m<br>third layer: remaining depth |
| Boundary | Boundary location<br>(X1 to X2):(Y1 to Y2): (Z1 to Z2) | (0,0):(72,91):(0,3) |
| | Height of tide | predicated |
| | Salinity | Observation data |
| | Water temperature | Observation data |
| | Air temperature | Observation data |
| | Precipitation | Observation data |
| | Wind velocity and direction | Observation data |
| Initiation | Water level | 0.16m (Rain season); 0.20m (Dry season) |
| | Salinity | 33.3psu (Rain season); 33.1psu (Dry season) |
| | Water temperature | 28.5°C(Rain season); 26.8°C(Dry season) |
| Others | Simulation period | 2 months (Rain season and dry season respectively) |
| | Time step | 120 seconds |

### (3) Calibrating and verifying the hydrodynamic model

Data used in the calibration and verification : Two kinds of data will be used in the calibration and verification of the HD model. One of them is existed data before this study and another one is the survey results of this study.

Because there is no data on current observation is available for recent years, results investigated by PNUD-PNUMA-UNESCO in 1985 are utilized in the current calibration (4). Current velocity and direction of Havana bay in the tidal fall are illustrated in the Figure 4.6.

Temperature and salinity are measured by CIMAB in their regular survey on the water quality of Havana bay (3). However, the survey is carried out only once in the rainy season and dry season respectively, it is difficult to grasp the characteristics of spatial and temporal variation of temperature and salinity. Therefore, parts of the results reported by PNUD-PNUMA-UNESCO are also used here as an assistant verification data (5). In the Tables 4.11 to 4.14, available data on temperature and salinity data are summarized.

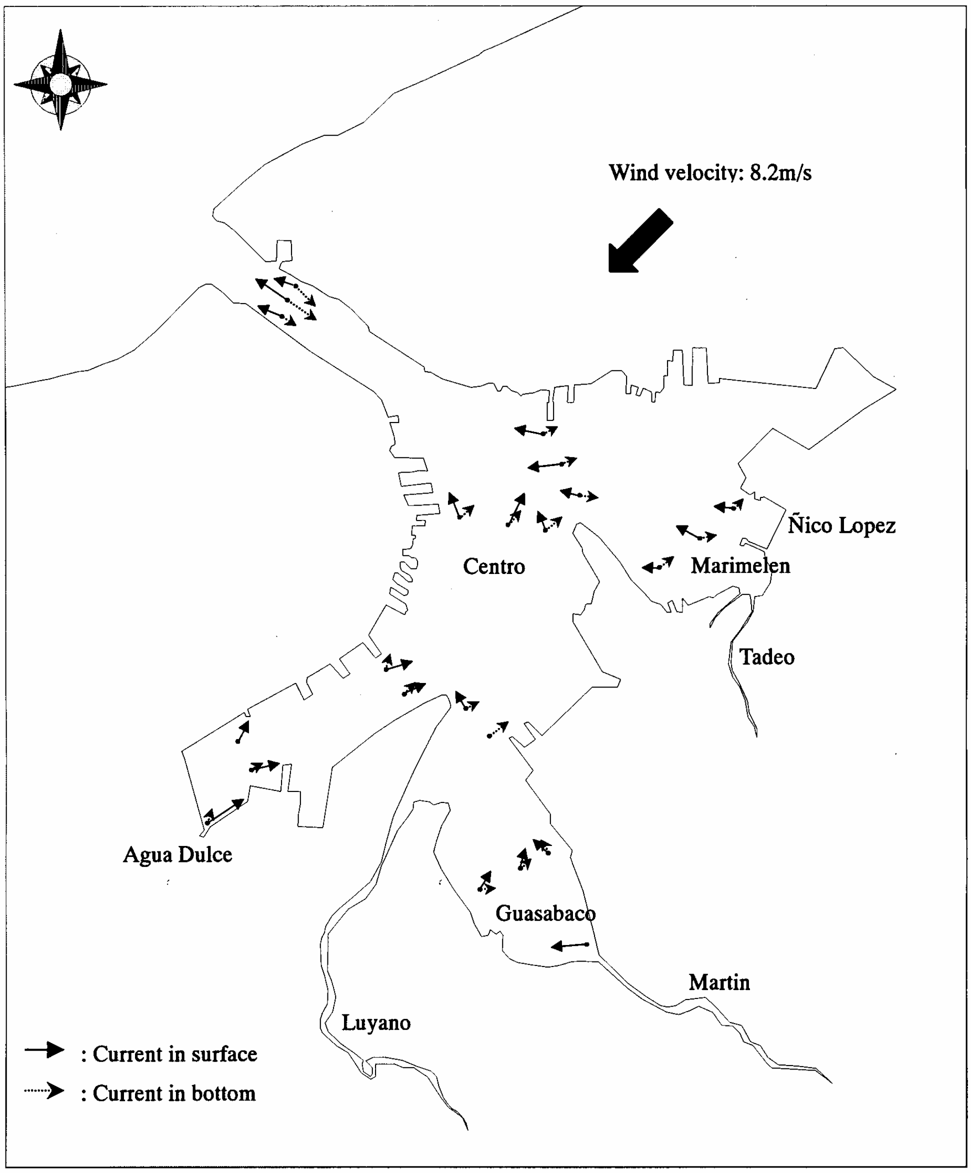



**Figure 4.3.6 Observation results of currents in Havana bay**

Source: Ref 4 - PNUD-PNUMA-UNESCO,1985

| | |
|---|---|
| THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY | Figure 4.6<br>Observation Results of Currents in Havana Bay |
| JAPAN INTERNATIONAL COOPERATION AGENCY | |

**Table 4.11 Results of Temperature and Salinity observation**

| Locations | Positions | 2001/6 | | High tide(2001/11) | | Low tide(2001/11) | |
|---|---|---|---|---|---|---|---|
| | | Temp. (℃) | Sali. (‰) | Temp. (℃) | Sali. (‰) | Temp. (℃) | Sali. (‰) |
| Canal de Entrada | surface | 28.3 | 33.37 | 27.0 | 35.46 | 26.2 | 34.53 |
| | middle | 28.2 | 35.33 | 26.8 | 36.27 | 27.0 | 36.41 |
| | bottom | 28.6 | 36.41 | 26.4 | 36.25 | 27.0 | 36.29 |
| Atares | surface | 28.3 | 29.93 | 27.0 | 27.11 | 26.4 | 21.37 |
| | middle | 28.6 | 35.86 | 27.0 | 36.09 | 26.8 | 36.33 |
| | bottom | 28.1 | 36.21 | 27.0 | 36.19 | 27.0 | 35.16 |
| Guasabacoa | surface | 28.1 | 34.12 | 27.2 | 36.03 | 27.0 | 35.57 |
| | middle | 28.6 | 36.00 | 27.0 | 36.19 | 26.8 | 35.52 |
| | bottom | 28.7 | 36.13 | 27.0 | 36.33 | 26.6 | 35.87 |
| Marimelena | surface | 28.3 | 35.15 | 27.0 | 36.15 | 26.8 | 35.77 |
| | middle | 28.4 | 35.55 | 27.0 | 36.22 | 27.0 | 36.00 |
| | bottom | 28.8 | 35.46 | 27.0 | 36.11 | 27.0 | 36.26 |
| Centro de la Bahía | surface | 28.7 | 33.57 | 27.0 | 35.02 | 26.8 | 34.87 |
| | middle | 28.9 | 33.99 | 26.8 | 36.00 | 27.0 | 35.97 |
| | bottom | 28.6 | 36.13 | 26.8 | 35.92 | 26.8 | 36.32 |
| P. del Chivo | surface | 28.3 | 35.56 | - | | 27.0 | 35.46 |
| | middle | 28.4 | 33.09 | - | | 26.8 | 36.35 |
| | bottom | 28.5 | 36.74 | - | | 26.8 | 36.41 |
| Caleta de San Lázaro | surface | 28.3 | 36.00 | - | | 27.0 | 36.10 |
| | middle | 28.6 | 36.41 | - | | 27.0 | 36.33 |
| | bottom | 28.8 | 36.36 | - | | 27.0 | 36.43 |

Data source: CIMAB reports-a

**Table 4.12 Range of Temperature and Salinity for Havana bay**

| Position | Temperature(℃) | | | Salinity(‰) | | |
|---|---|---|---|---|---|---|
| | Maximum | Minimum | Average* | Maximum | Minimum | Average* |
| Surface | 32.2 (Sep.) | 24.6 (Jan.) | 28.2 | 34.3 (Dec.) | 27.4 (Jan.) | 32.4 |
| Bottom | 28.8 (Sep) | 24.3 (Feb.) | 26.5 | 36.4 (Apr.) | 34.4 (Sep.) | 35.7 |

*Note: annually average.
Data source: UNESCO reports

**Table 4.13 Temperature Distribution in Vertical Direction**

| Water depth zone | Atares | Guasabacoa | Marimelena | Centro | Canal | Litoral |
|---|---|---|---|---|---|---|
| 0-5 | 3.1 | 3.3 | 2.9 | 2.5 | 2.1 | 0.6 |
| 5-bottom | 0.6 | 0.6 | 0.8 | 0.8 | 0.6 | 0.2 |
| 0-bottom | 3.7 | 3.8 | 3.7 | 3.3 | 2.7 | 0.8 |

Data source: UNESCO reports

**Table 4.14 Salinity Distribution in Vertical Direction**

| Water depth zone | Atares | Guasabacoa | Marimelena | Centro | Canal | Litoral |
|---|---|---|---|---|---|---|
| 0-5 | 12.9 | 13.3 | 3.3 | 4.9 | 3.8 | 0.9 |
| 5-bottom | 1.1 | 0.9 | 0.8 | 0.9 | 0.7 | 0.1 |
| 0-bottom | 14.0 | 14.2 | 4.1 | 5.8 | 4.5 | 1.0 |

Data source: UNESCO reports

Calibration of the HD model : Hydrodynamics simulation of Havana bay is conducted with the input conditions and the calibrated parameters presented in Table 4.9. Simulation results of the currents are illustrated in Figure 4.7 and 4.8. According to the reproductive performance of the currents, effectiveness of the hydrodynamic model is evaluated as follows.

- With a comparison of the calculated currents with the observed results (Figure 4.6), it can be seen that the calibrated model gives a good result to reproduce the current velocity and direction both in the entrance and inside of the bay.

- Current direction varies periodically along with the variation of the tide height in the bay. Both calculation and observation results show that current direction is towards the bay during tidal rise and reverse flow occurs during tidal fall.

- For the location of Canal de Entrada and Centro de la Bahia, surface current velocity and direction are approximately same with the observed data. In the period of tide rise and tide fall, approximately 0.05 to 0.15m/s current occurred with a direction of SE and NW respectively. Current in middle (second) layer is reverse to the surface and the velocity is slightly lower compared with the surface.

- For the current velocity near to the estuarine of Luyano river, several discrepancies between the calculation results and the observations exist. One of the main reasons of these discrepancies would be attributed to the inflow velocity specification of the river. Inflow velocity of the rivers will be surveyed in this study and the reproductive performance of the currents for these areas will be improved with the application of these survey results.

Water temperature and salinity in the bay are dependent upon a lot of factors such as the fresh water discharges from the sources, air temperature, precipitation, temperature/salinity of boundary (open sea) and etc. It is considerable that temperature and salinity vary along with the passage of time. Because detail measurement data for the temperature and salinity is only available for June in the rain season shown in Table 4.11, while simulation result is for the August and September. On the other hands, from the observation data shown in Table 4.12 to 4.3.14, it is possible to grasp the characteristics of spatial and temporal variation of temperature and salinity roughly. Therefore the model reproductive capacity for the temperature and salinity is indirectly evaluated based upon the comparison of the simulation result both with the detail data (Table 4.11) and summarized results (Table 4.12 through Table 4.14).

Calculation results of the temperature and salinity in the tidal rise and tidal fall are illustrated in Figure 4.9 to 4.12. Reproduce trends in time and spatial gradients for temperature and salinity are shown as follows.

- Trend of temperature and salinity variation in horizontal and vertical directions is approximately agreed with the observation data.

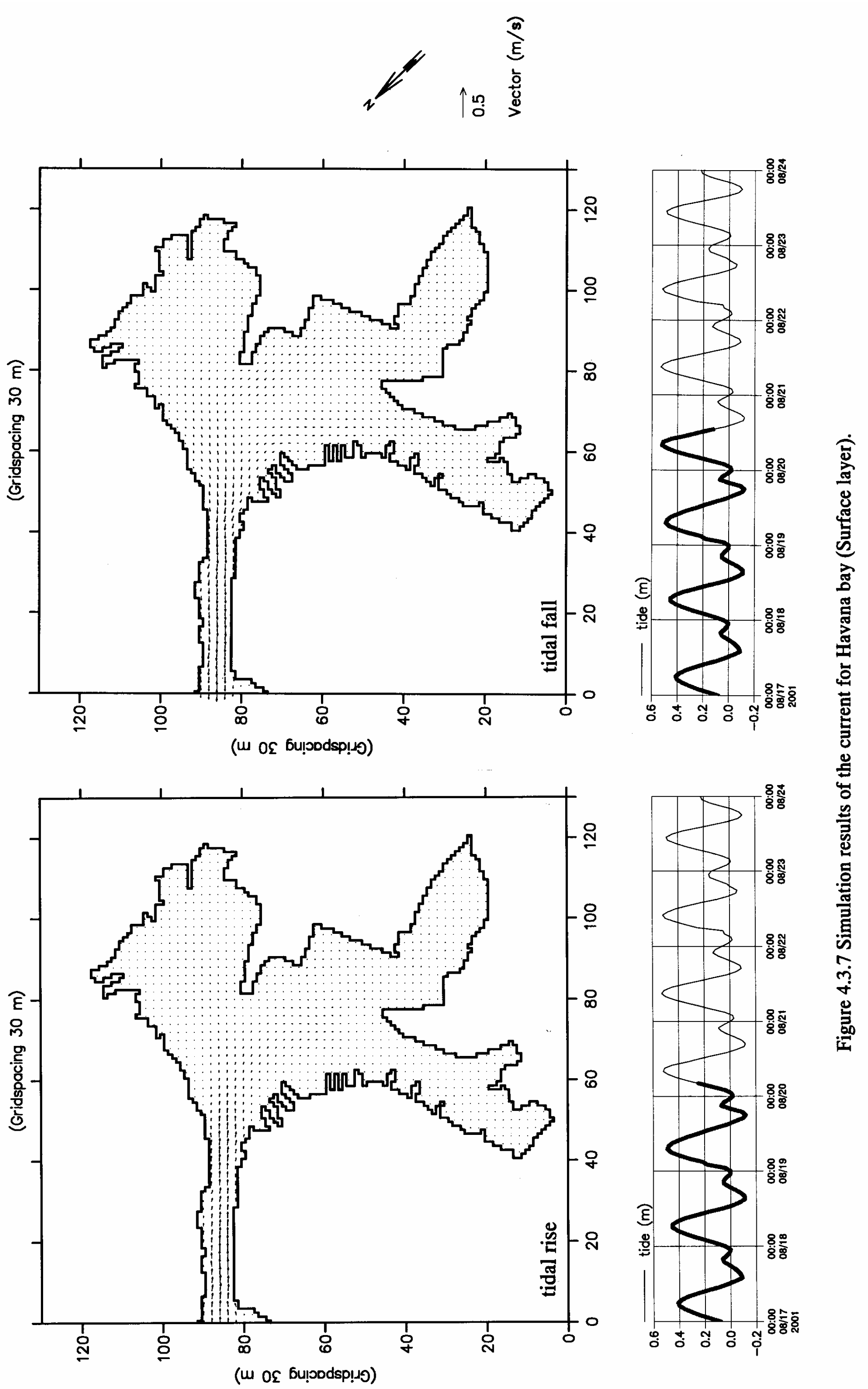
- For the results of surface layer (Figure 4.9), shallow water area such as Marimelena (the east of the bay) and Guasabacoa (the south of the bay) shows a higher temperature than other areas. On the contrary, area near to the boundary and center of the bay shows a lower temperature. For the shallow water area, water temperature is more easily influenced by the heat exchange with atmosphere, and the water temperature is sensitive to the variation of air temperature. Another reason for the higher temperature of these areas could be contributed to that they are far from the boundary, in which a low temperature is specified.

- Water temperature in the high tide shows a lower value than the low tide, duo to a lower temperature water inflow from the boundary in the tide rise. For the surface layer, temperature in the most area of the bay increase from 29.5℃ to 30℃ as tide vary from the high tide to low tide.

- Water temperature decreases along with the water depth. Temperature difference between the surface layer and second layer is nearly 2℃, which is larger than the temperature differences in horizontal direction.

- Salinity gradient both in horizontal and vertical direction occurs, due to the inflow of fresh water from the rivers and drainage channels. Area near to the entrance of the bay shows a higher salinity concentration compared with the estuaries of Luyano river, Martin Perez rivers as well as the drainage channels.

- Salinity varies periodically along with the tide conditions. Salinity difference between the high tide and low tide is nearly 1.0 psu for the surface layer, while the difference for the second layer is negligible. It means that second layer is less influenced by the fresh water discharged from the sources.




| THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY | Figure 4.7<br>Simulation Results of the Currents in Havana Bay (Surface Layer) |
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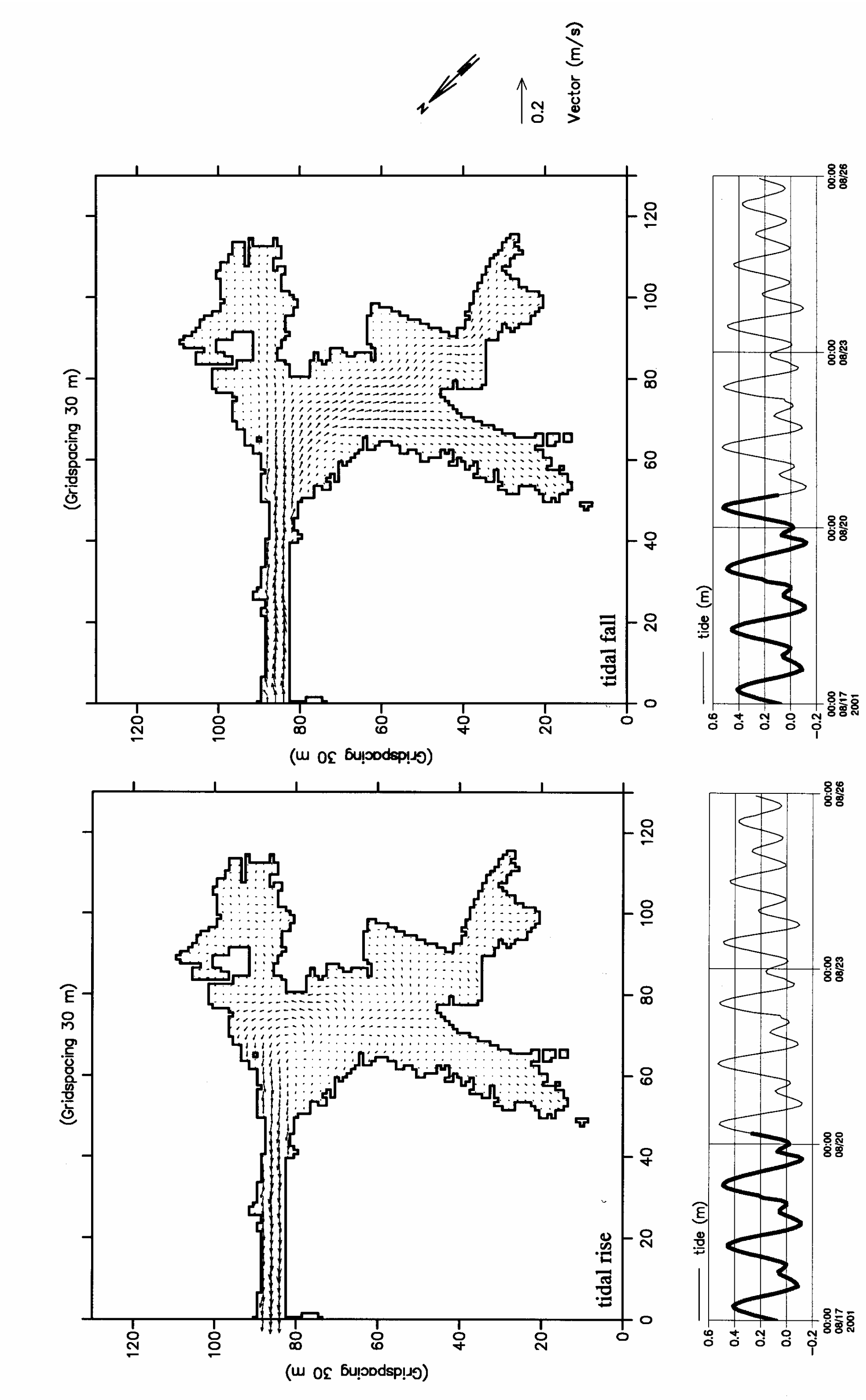


**Figure 4.3.8 Simulation results of the current for Havana bay (Second layer).**

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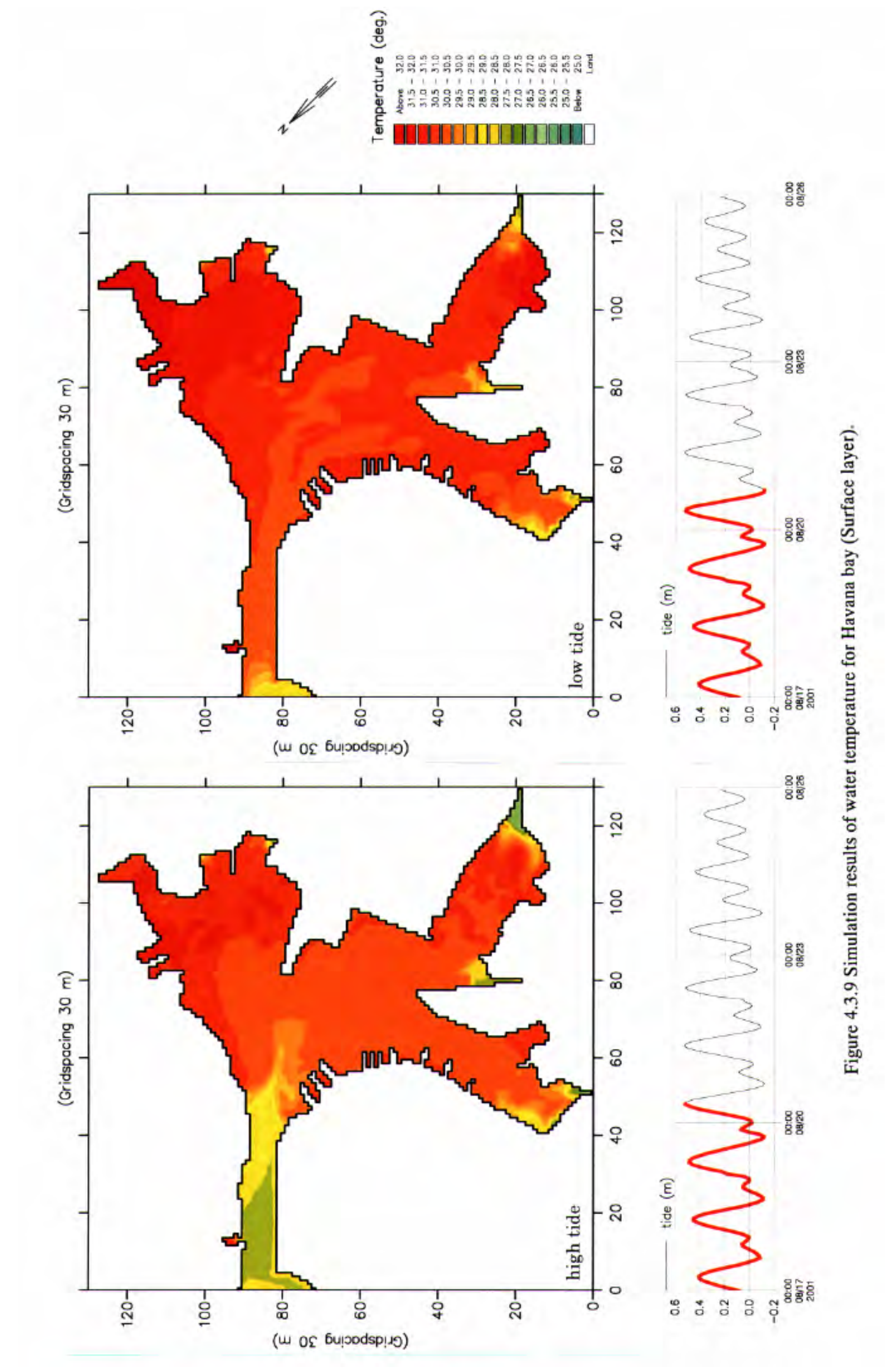
| THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY | Figure 4.8<br>Simulation Results of the Currents in Havana Bay (Second Layer) |
| JAPAN INTERNATIONAL COOPERATION AGENCY | |




| THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY | Figure 4.9<br>Simulation Results of Water Temperature in Havana Bay (Surface Layer) |
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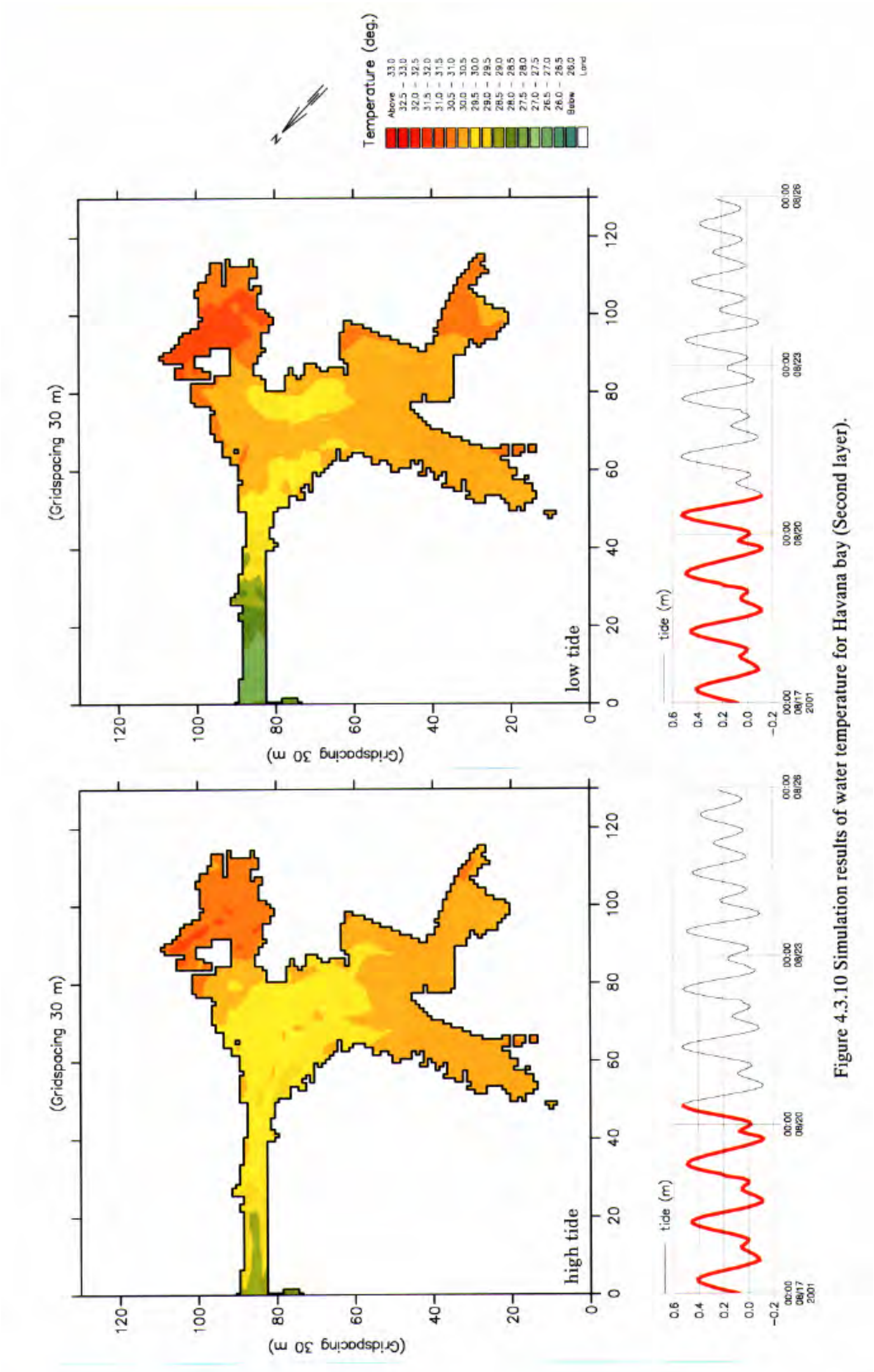


Figure 4.3.10 Simulation results of water temperature for Havana bay (Second layer).

| THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY | Figure 4.10<br>Simulation Results of Water Temperature in Havana Bay (Second Layer) |
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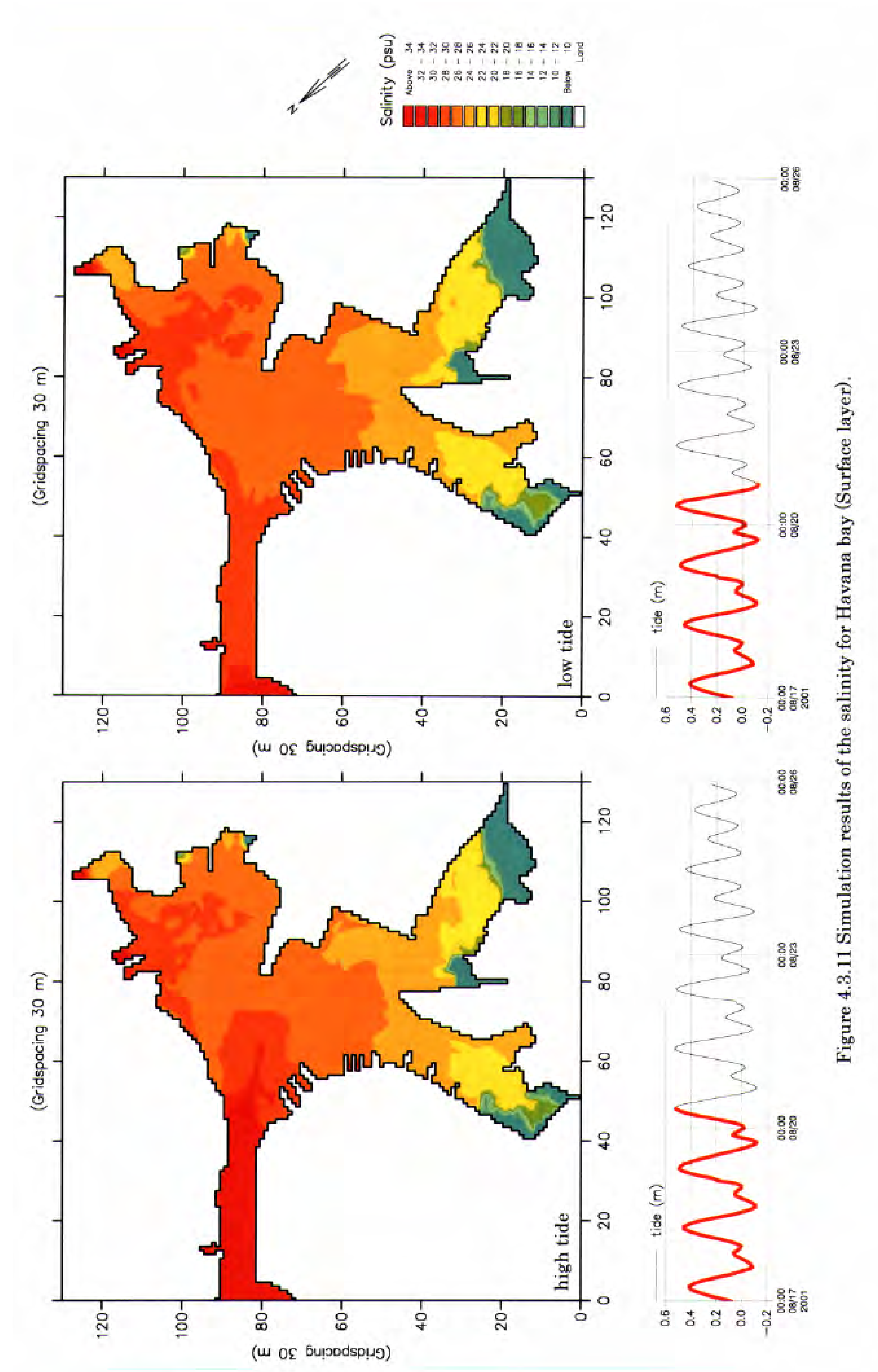
| JAPAN INTERNATIONAL COOPERATION AGENCY | |

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| THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY | Figure 4.11<br>Simulation Results of Salinity in Havana Bay (Surface Layer) |
| JAPAN INTERNATIONAL COOPERATION AGENCY | |

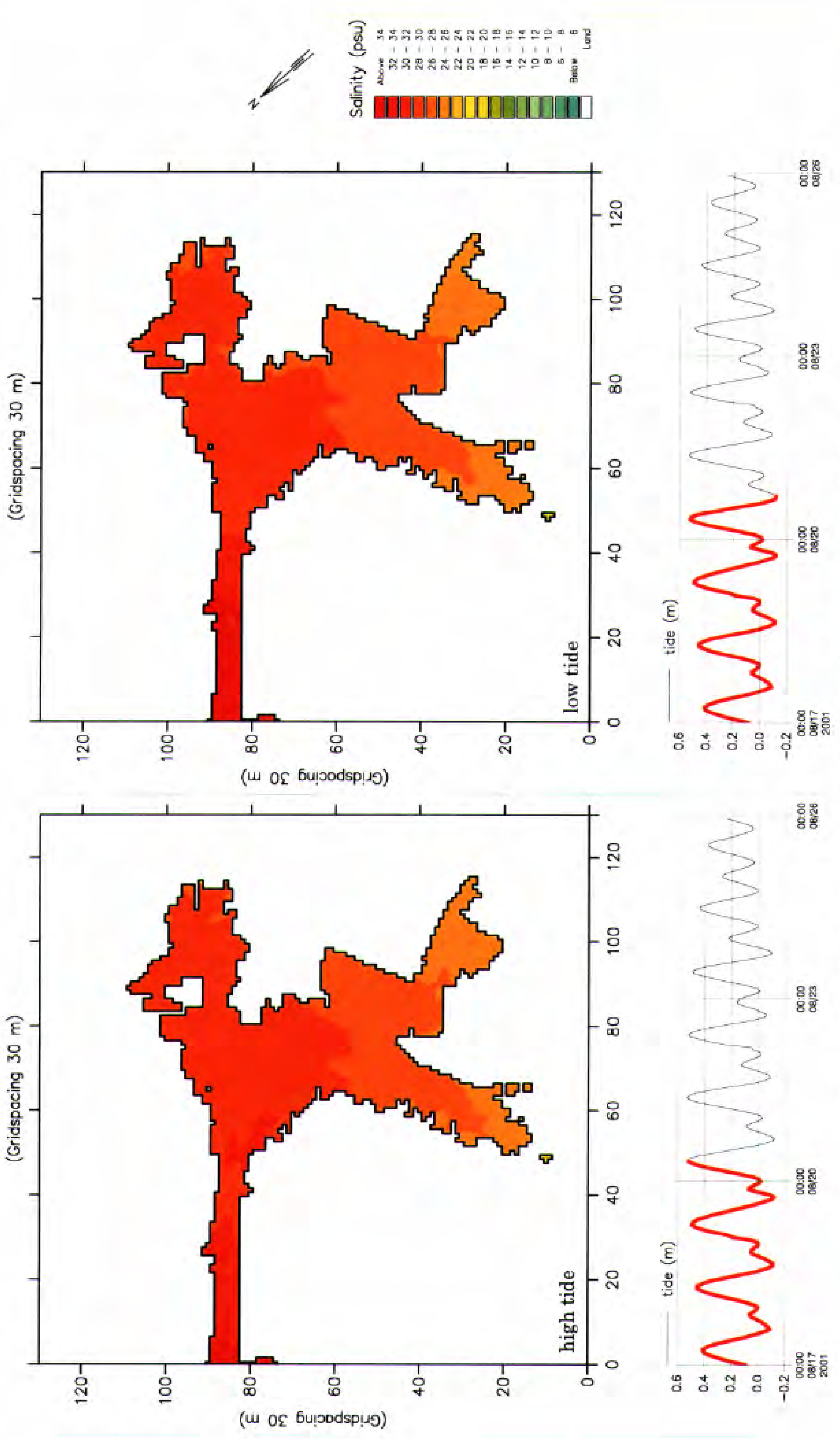


Figure 4.3.12 Simulation results of salinity for Havana bay (Second layer).

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| THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY | Figure 4.12<br>Simulation Results of Salinity in Havana Bay (Second Layer) |
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### 4.3.3 WATER QUALITY SIMULATION OF HAVANA BAY

**(1) Characteristic of Water Pollution in Havana bay**

In the investigation of marine environment by CIMAB, water quality of Havana bay was reported. Figure 3.2 shows the monitoring locations of CIMAB. Playa del Chivo and Caleta de San Lázaro are located outside the bay. Based upon the observation results of 2001, variation water quality of Havana bay is illustrated in Figure 4.13 through 4.15. Water quality data for the two recent sampling events, during tidal rise (Nov. 28, 2001) and tidal fall (Nov. 30, 2001) were available. According to these results of water quality and other reported data, characteristic of water pollution in Havana bay can be concluded as follows.

- DO concentrations is different significantly for the five sampling locations. Generally, water areas adjacent to the estuaries within the bay and source inflows show lower DO concentration. Particularly for the locations of Atares and Marimelena, in which drainage of sewage and industrial wastewater are discharged, DO depletion is remarkable. In the rainy season, DO drops very much and DO level for the two locations are as low as 2.0 mg/L. Low DO condition particularly in the seabed would results in excess release of nutrients from the sediments, as well as suffocation of living resources. These nutrients would promote the growth of phytoplankton and cause eutrophication of the waterbody.

- Phosphorous concentration in the bay varied seasonally and spatially. Both for the phosphate and total phosphorous, the dry season shows a high concentration than the rain season. In the areas of Atares, Marimelena and Guasabacoa, a high concentrations of phosphorous are observed. From the concentration gradient, it can be deduced that the main external source of phosphorous is the discharge from the rivers and drainage channels.

- High concentration of ammonia was observed in the bay's inner parts such as Atares, Marimelena and Guasabacoa. Particularly in the area of Atares, $NH_4$-N concentration both in the surface and second layer is as high as 0.5 mg/L. Concentration of $NO_2$-N and $NO_3$-N and their variation among the locations are comparatively small. Therefore, it can be considered that ammonia distribution is more dependent on the pollutant load of the source inflow and the release from sediment, while the nitrite and nitrate are more relied on the nitrification process occurring within the bay.

- High SS concentration is observed at Atares and Guasabacoa compared to other areas. This is similar to other parameters and can be attributed to the inflow of the suspended water via the rivers and drainage channels.

- Although phytoplankton and chlorophyll-a, as two very important parameters to evaluate the eutrophication level, were measured, inconsistency in the results of the two parameters makes it difficult to grasp the characteristics of the primary production in the bay. As a general tendency, Canal de Entrada and Centro de la Bahia show a higher concentration of chlorophyll-a. Phytoplankton concentrations at Canal de Entrada and Atares are relatively high. Comparing with the nutrient (inorganic nitrogen and phosphate) level in the bay, it can be said that the chlorophyll-a concentration is relatively low.

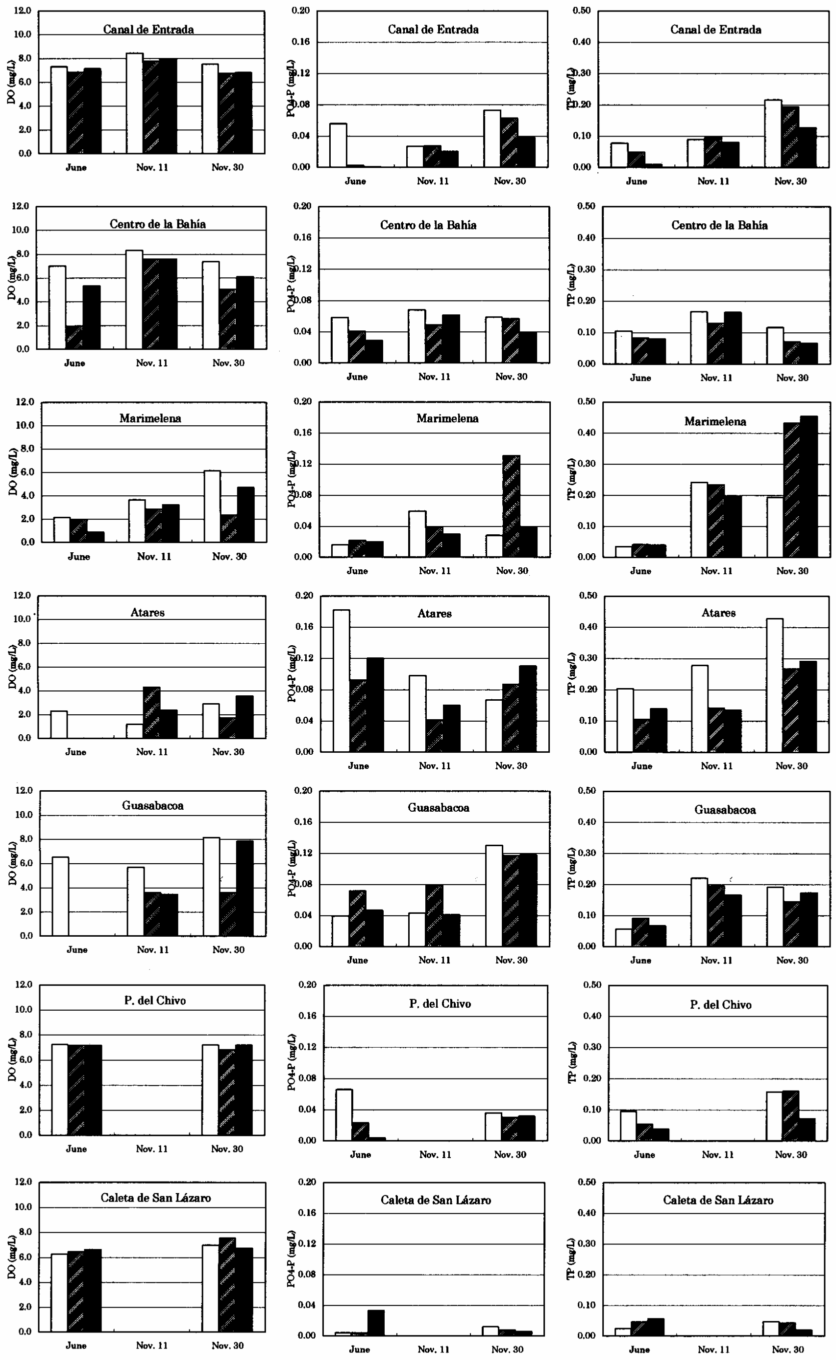


**Figure4.3.14(a) Water quality observation results of Havana bay (▭ surface, ▬ middle, ▬ bottom)**

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| THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY | Figure 4.13<br>Water Quality Observation Results of Havana Bay |
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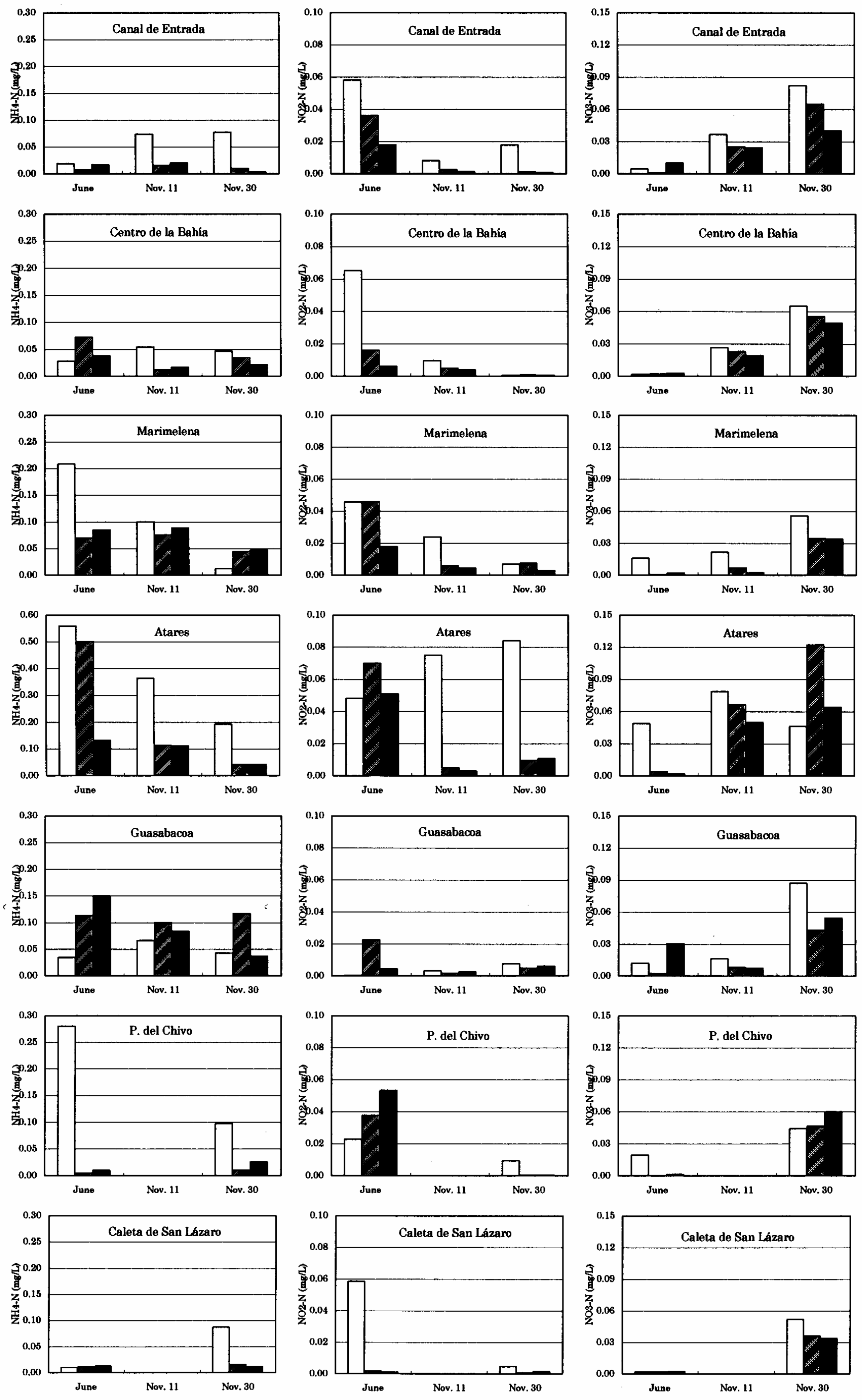


**Figure4.3.14(b) Water quality observation results of the Havana bay ( ▭ surface, ▨ middle, ■ bottom)**

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| THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY | Figure 4.14<br>Water Quality Observation Results of Havana Bay |
| JAPAN INTERNATIONAL COOPERATION AGENCY | |

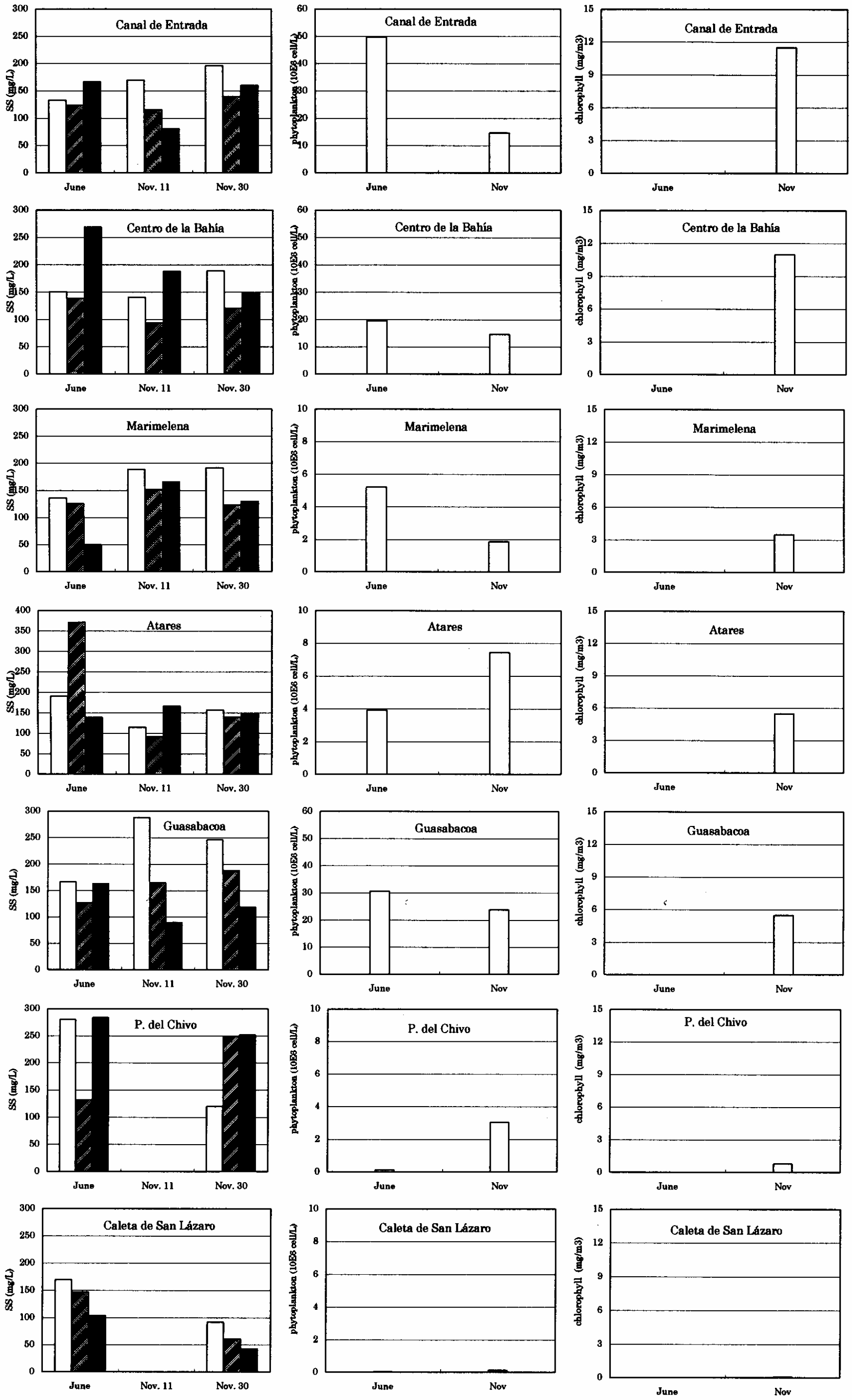


**Figure4.3.14(c) Water quality observation results of the Havana bay ( surface, middle, bottom)**

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| THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY | Figure 4.15<br>Water Quality Observation Results of Havana Bay |
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**(2) Setting up the model**

Based upon the characteristics of water pollution analyzed above, it is necessary to build a model, in which following sub-models of transportation and transformation are composed.

- Advection and dispersion of the pollutants
- Biological degradation and chemical reaction processes
- Eutrophication

In these sub-models, following transformation processes are incorporated.

- Degradation of organic matters exited as dissolved and suspended state.
- Sedimentation of suspended organic matters and resuspension of the sediments
- Exchange of oxygen between the atmosphere and seawater
- Oxygen demand in the degradation of dissolved and suspended organic matters
- Oxygen production in the photosynthesis and photosynthetic respiration
- Ammonification and nitrification as well as denitrification process
- Release of nitrogen and phosphorous in the degradation of organic matters
- Uptake of nitrogen and phosphorous by bacteria and plants
- Release of inorganic nitrogen and phosphorous from the sediments

In order to simulate and calibrate these processes, nine water quality items are selected as the state variables in the model, which are dissolved BOD ($BOD_d$), suspended BOD ($BOD_s$), BOD in the sediment ($BOD_b$), DO, ammonia ($NH_4$-N), nitrite ($NO_2$-N), nitrate ($NO_3$-N), phosphate ($PO_4$-P) and chlorophyll-a. The principles of the WQ model applied in this study are illustrated in Figure 4.16.

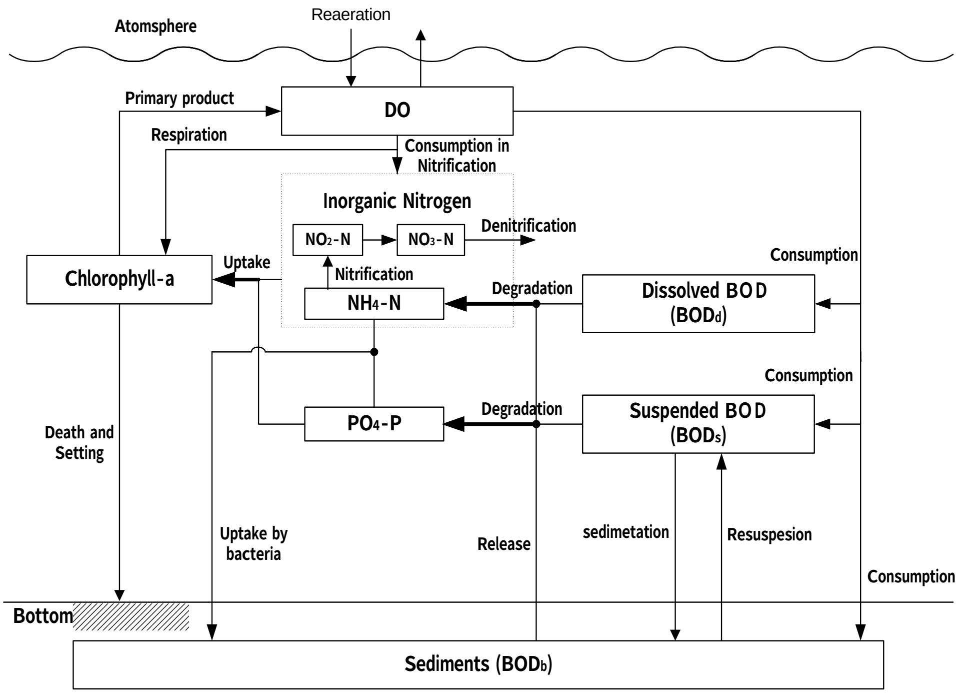


Figure 4.3.15 Principles of the WQ model applied in this study.

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|---|---|
| THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY | Figure 4.16<br>Schematic of the Processes Included in the WQ Model Applied in this Study |
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### (3) Calculation Conditions for the Water Quality Simulation

Water quality simulation is carried out simultaneously with the hydrodynamic simulation. Except for the items described in follows, the calculation conditions are basically same with the hydrodynamic simulation.

Loading condition from the Sources : Ten point sources including three rivers and three drainage channels as well as an industry discharging at four locations are considered in the water quality simulation. Water quality of the source is specified based upon the loading rate for $BOD_5$, total nitrogen and total phosphorous, which are calculated from the latest monitoring data by CIMAB. Table 4.15 shows the specified results for the water quality of the sources.

**Table 4.15 Pollutant Source Input Specification for the Water Quality Simulation**

| Name of Source | Source No. | Flowrate, $m^3/s$ | $BOD_5$, mg/l | DO, mg/L | $NH_4$-N, mg/L | $NO_2$-N, mg/L | $NO_3$-N, mg/L | $PO_4$-P, mg/L |
|---|---|---|---|---|---|---|---|---|
| Rio Luyano | S1 | 1.329 | 83 | 3.0 | 2.1 | 0 | 1.0 | 0.17 |
| Rio Martin Perez | S2 | 0.719 | 20 | 1.6 | 2.0 | 0 | 1.5 | 0.59 |
| Arroyo Tadeo | S3 | 0.093 | 192 | 2.0 | 2.2 | 0 | 0.6 | 3.20 |
| Dren San Nicolas | S4 | 0.099 | 151 | 1.0 | 7.4 | 0 | 1.9 | 0.29 |
| Dren Arroyo Matadero | S5 | 0.900 | 115 | 1.0 | 1.7 | 0 | 0.4 | 3.10 |
| Dren Agua Dulce | S6 | 0.500 | 190 | 1.0 | 2.2 | 0 | 0.5 | 6.30 |
| Ñico López | S7 | 0.010 | 1,810 | 0 | 50 | 0 | 0 | 10 |
| | S8 | 0.037 | | | | | | |
| | S9 | 0.037 | | | | | | |
| | S10 | 0.010 | | | | | | |

Source : Based on monitoring data of CIMAB

Nutrient Loading from Sediments : There is no experimental data available for the nutrient release from the sediments of Havana bay. Inorganic nitrogen and phosphorous release rates are estimated indirectly based on the relationship of organic content of sediments with the nutrient release rate. The following rates are used.

Release rate of inorganic nitrogen =94.0 $mg/m^2/d$

Release rate of phosphate=6.6 $mg/m^2/d$

Boundary and Initial Conditions : Boundary and initial conditions are specified based upon the water quality measurement results of Havana bay implemented by CIMAB in 2001(Table 4.16).

**Table 4.16 Water Quality in Boundary and Initiation**

(in mg/L)

| | BODd | BODs | DO | $NH_4$-N | $NO_2$-N | $NO_3$-N | $PO_4$-P | Chlo.-a* |
|---|---|---|---|---|---|---|---|---|
| Boundary | 2 | 2 | 8 | 0.015 | 0.01 | 0.002 | 0.004 | 0.002 |
| Initiation | 5 | 5 | 5 | 0.15 | 0.05 | 0.02 | 0.05 | 0.005 |

*chlo.-a:chlorophyll-a

Parameters of the Model : Parameters for the water quality model are identified according to the calibration results of the model. Table 4.17 shows the values of the parameters for each reaction processes.

Others : Same as the hydrodynamic simulation, time step of the numerical calculation is set to be 120 seconds and periods of simulation is two months both for the rains season and dry season.

**Table 4.17 Parameters of the WQ model**

| Process | parameter | Unit | Value |
|---|---|---|---|
| COD/DO related | Degradation constant for $BOD_d$ | 1/day | 0.05 |
| | Degradation constant for $BOD_S$ | 1/day | 0.02 |
| | Sedimentation rate for $BOD_S$ | 1/day | 0.2 |
| | Nitrification rate | 1/day | 0.05 |
| | Photosynthetic product rate | $mgO_2$/l/d | 3.5 |
| | Light extinction coefficient | 1/m | 7.4 |
| Nutrient related | Uptake rate of nitrogen by plankton | $gN/gO_2$ | 0.066 |
| | Uptake rate of nitrogen by bacteria | $gN/gO_2$ | 0.109 |
| | Halfsaturation concentration of $NH_4$-N | $gN/m^3$ | 0.05 |
| | $(NO_2)$Nitrification rate | 1/day | 1.0 |
| | Denitrification rate | 1/day | 0.1 |
| | Uptake rate of phosphorous by plankton | $gP/gO_2$ | 0.0091 |
| | Uptake rate of phosphorous by bacteria | $gP/gO_2$ | 0.015 |
| | Halfsaturation concentration of $PO_4$-P | g $P/m^3$ | 0.005 |
| Chlorophyll-a related | Death rate of phytoplankton | 1/day | 0.01 |
| | Sedimentation rate of phytoplankton | m/day | 0.15 |
| | Carbon ratio of chlorophyll and phytoplankton | mg/l | 0.02 |
| | Carbon to oxygen ratio at primary product | $gC/gO_2$ | 0.0133 |
| | Halfsaturation concentration for inorganic nitrogen | mg/l | 0.05 |
| | Halfsaturation concentration for phosphorous | mg/l | 0.01 |

### 4.3.4 CALIBRATING AND VERIFYING THE WATER QUALITY MODEL

#### (1) Data used in the Calibration and Verification

Observation results of water quality described in section 4.3.3(1) are used as verification data in the model calibration. Six items including DO, ammonia, nitrite, nitrate, phosphate, phosphorous and chlorophyll-a are used to calibrate the model. Because there is no observation data available for the simulation period of August and September 2001, data observed in June 2001 is utilized as a substitute for the rain season. For the dry season, data which was measured in the end of November (28 Nov.2001 and 30 Nov. 2001) are used in the verification.

#### (2) Comparison of Calculated Results with Observed Data

Water quality simulation results in high tide and low tide are illustrated in Figure 4.17 to 4.24. Because of the large fluctuation in source data and the inconsistent period between the source and water quality data in the bay, the calibration here is performed primarily based upon the levels of water quality rather than the exact concentration values. According to the comparison of the simulation results with the observations, the reproductive performance of the water quality model could be concluded as follows.

- DO concentration levels are approximately reproduced for the five observation locations in the bay (Figure 4.21). Same as the observed data, Atares and Marimelena locations show lower DO concentration compared with other locations. At the low tide, surface DO level of the two locations drops below 2.0mg/L and the DO depletion occurred in the lower layer of the water column. It means that extremely high level organic matters would exist, as well as some organic substance would be resuspended from sediments in these areas.

- Distribution of ammonia concentration in the bay is also agreement with the observation results approximately (Figure 4.20). Water areas near to the inflow location of the sources show a high concentration of ammonia. Comparing the results of DO and ammonia would find that location with a lower DO is correspondent to a high level of ammonia. It could be estimated that the low DO level for the areas is mainly caused by the degradation of organic matters as well as the nitrification of ammonia.

- For the nitrite and nitrate, although calculated results seem to be little high than the observed data, the concentration levels are almost reproduced (Figure 4.21 to Fig4.22).

- Reproducing phosphate concentration for the location of Atares (Figure 4.23) was not complete. Comparing the phosphate concentrations for the location of Atares could find that simulation results give a high value than the observed data. According to the phosphorous cycle indicated in Figure 4.16, phosphate concentration is relied upon the two opposite processes of generation and uptake after it is discharged into the seawater. For the generation process, phosphate is released both from the BOD degradation reaction and from the sediments. And for the uptake process, phosphate is consumed in the growth of plankton and bacteria. Based upon the reaction and stoichiometric parameter of these processes, it was failure in the feting of the simulation results with the observed data. As one of the possibilities, the low phosphate concentration could be contribute to some other reaction process such as adhesion to the suspended solid and sedimentation, etc.

- The reproductive performance of chlorophyll-a is different for the five locations. For the location of Atares, Guasabacoa and Centro de la Bahia, the level of chlorophyll-a predicted is generally in agreement with the measurement results. However for the location of Canal de Entrada and Marimelena, several discrepancies between the calculation and the observation was founded. Comparing the nutrient level and chlorophyll-a concentration for the five locations would find that the chlorophyll-a concentration is inconsistent with the nutrient level. Therefore, there is a possibility that the light extinction coefficient were different from location to location and the locations like Canal de Entrada shows a low extinction coefficient than other locations.

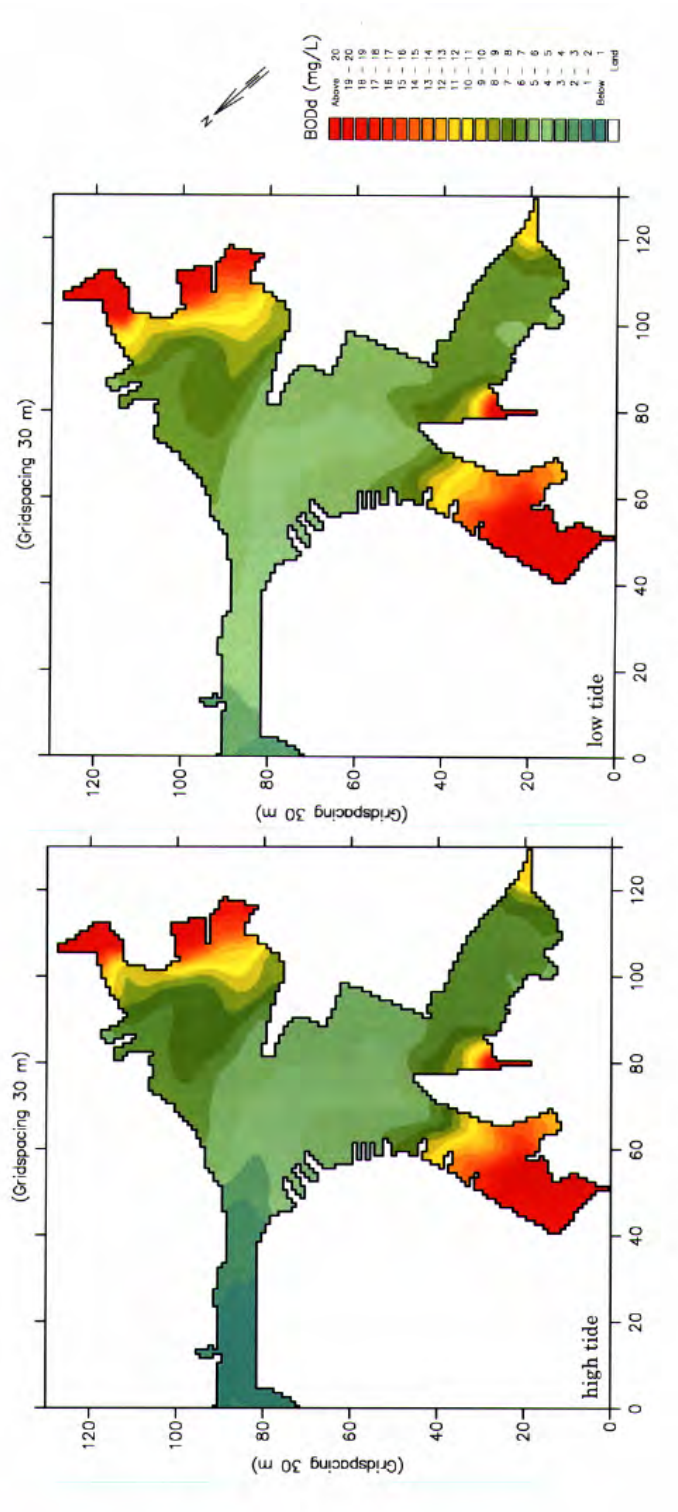


Figure 4.3.16 Concentration distribution of dissolved BOD (BODd) in Havana bay (Surface layer).

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| THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY | Figure 4.17<br>Concentration Distribution of Dissolved BOD (BODd) in Havana Bay (Surface Layer) |
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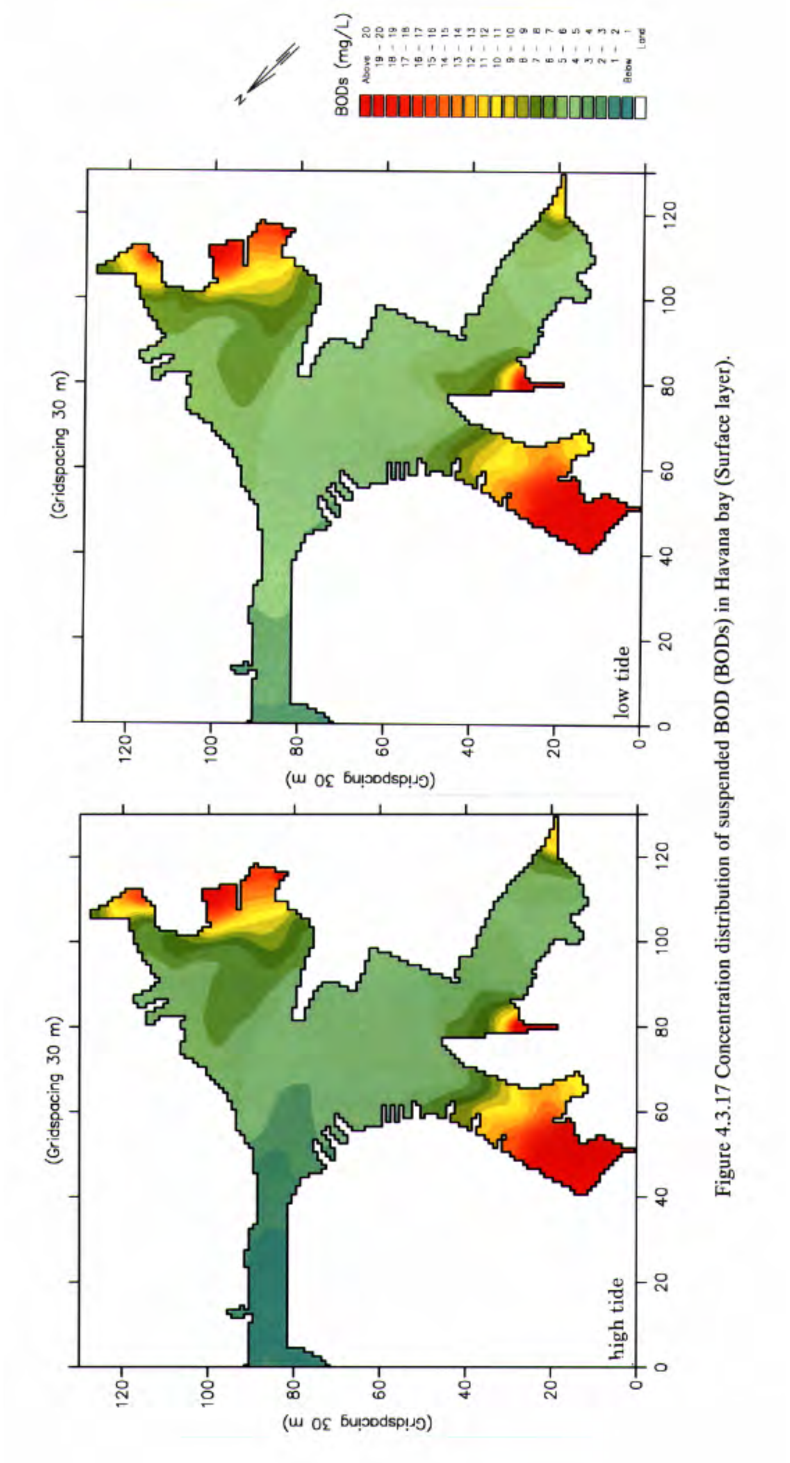


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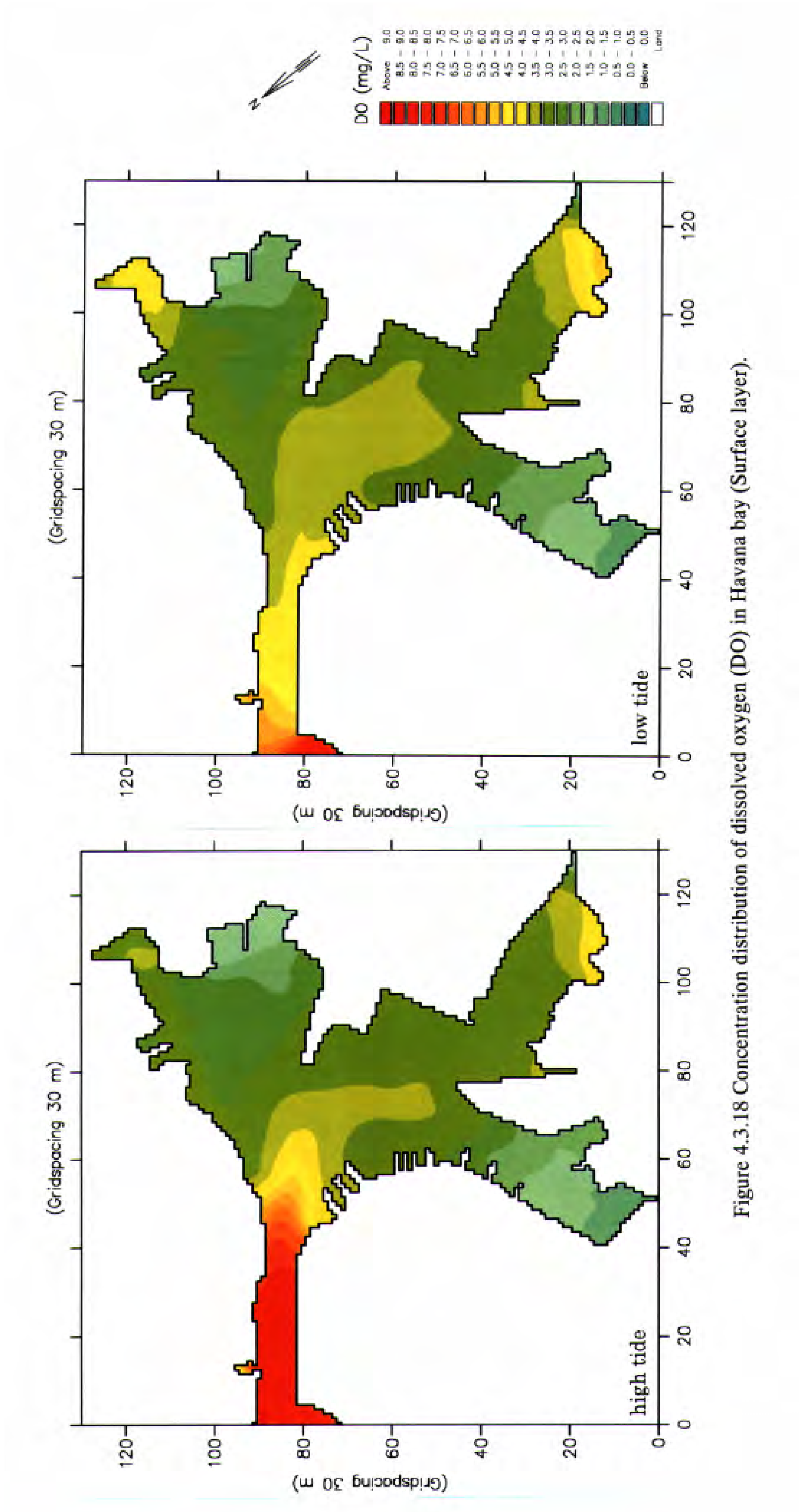
| THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY | Figure 4.18<br>Concentration Distribution of Suspended BOD (BODs) in Havana Bay (Surface Layer) |
| JAPAN INTERNATIONAL COOPERATION AGENCY | |




| THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY | Figure 4.19<br>Concentration Distribution of Dissolved Oxygen (DO) in Havana Bay (Surface Layer) |
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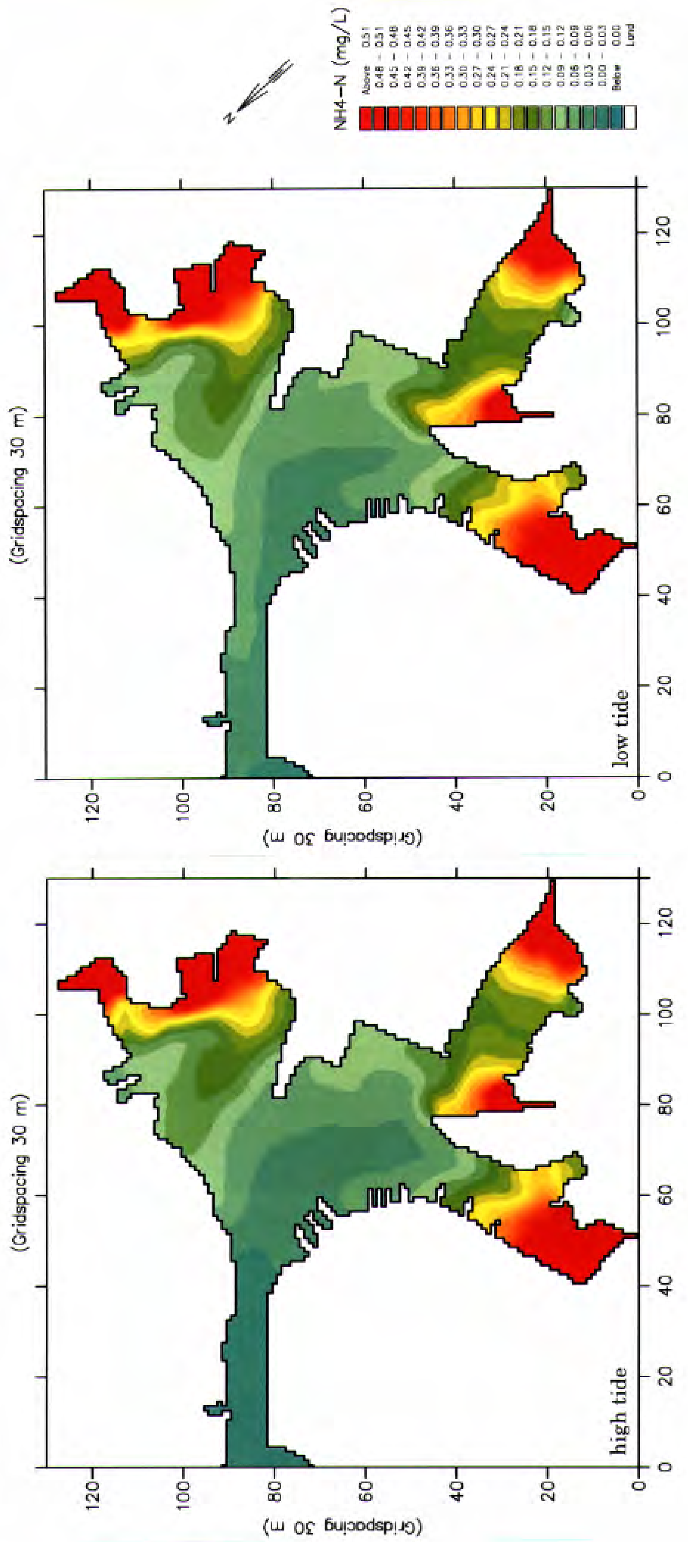


Figure 4.3.19 Concentration distribution of ammonia in Havana bay (Surface layer).

| THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY | Figure 4.20<br>Concentration Distribution of Ammonia in Havana Bay (Surface Layer) |
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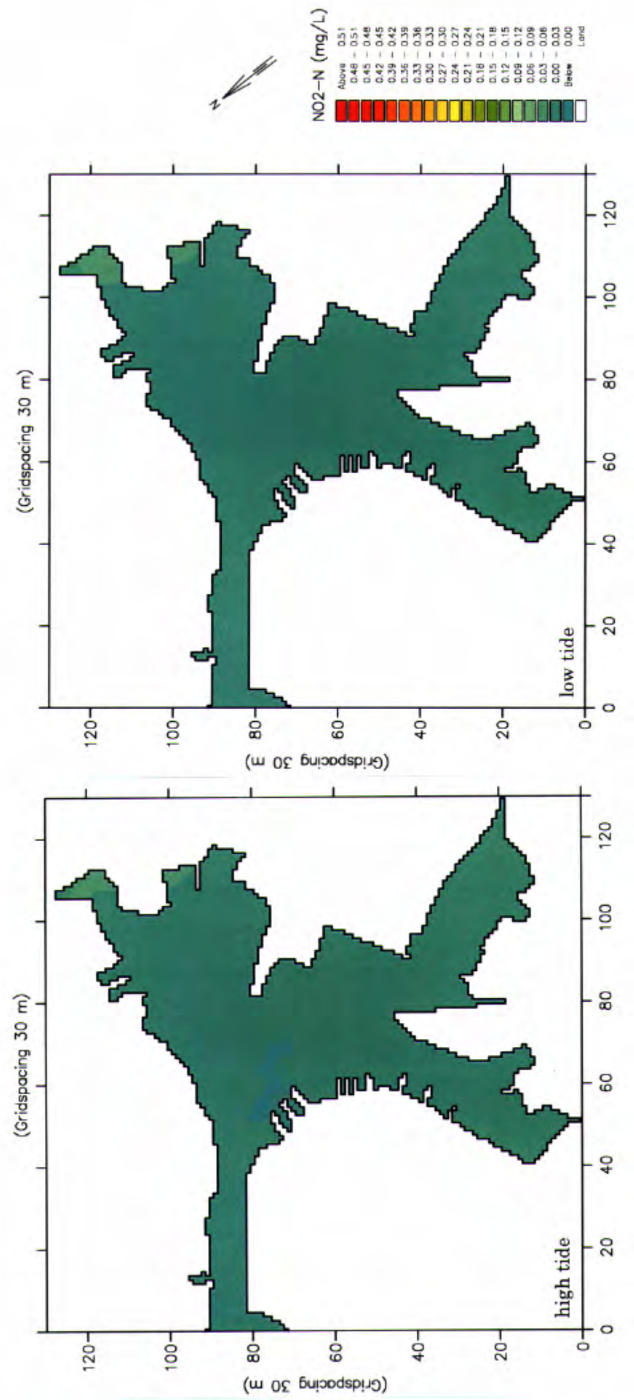


Figure 4.3.20 Concentration distribution of nitrite in Havana bay (Surface layer).

| THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY | Figure 4.21<br>Concentration Distribution of Nitrite Nitrogen ($NO_2$-N) in Havana Bay (Surface Layer) |
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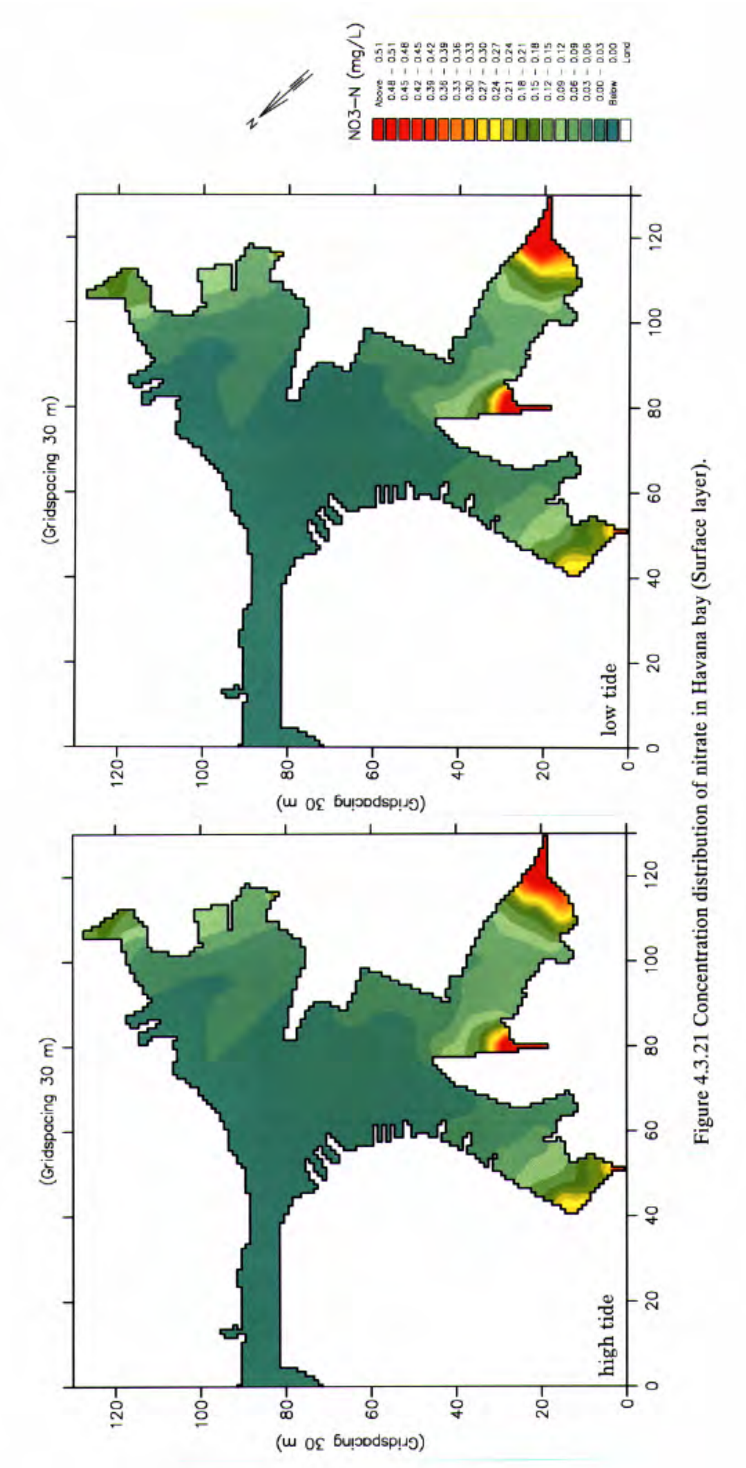


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| THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY | Figure 4.22<br>Concentration Distribution of Nitrate Nitrogen ($NO_3$-N) in Havana Bay (Surface Layer) |
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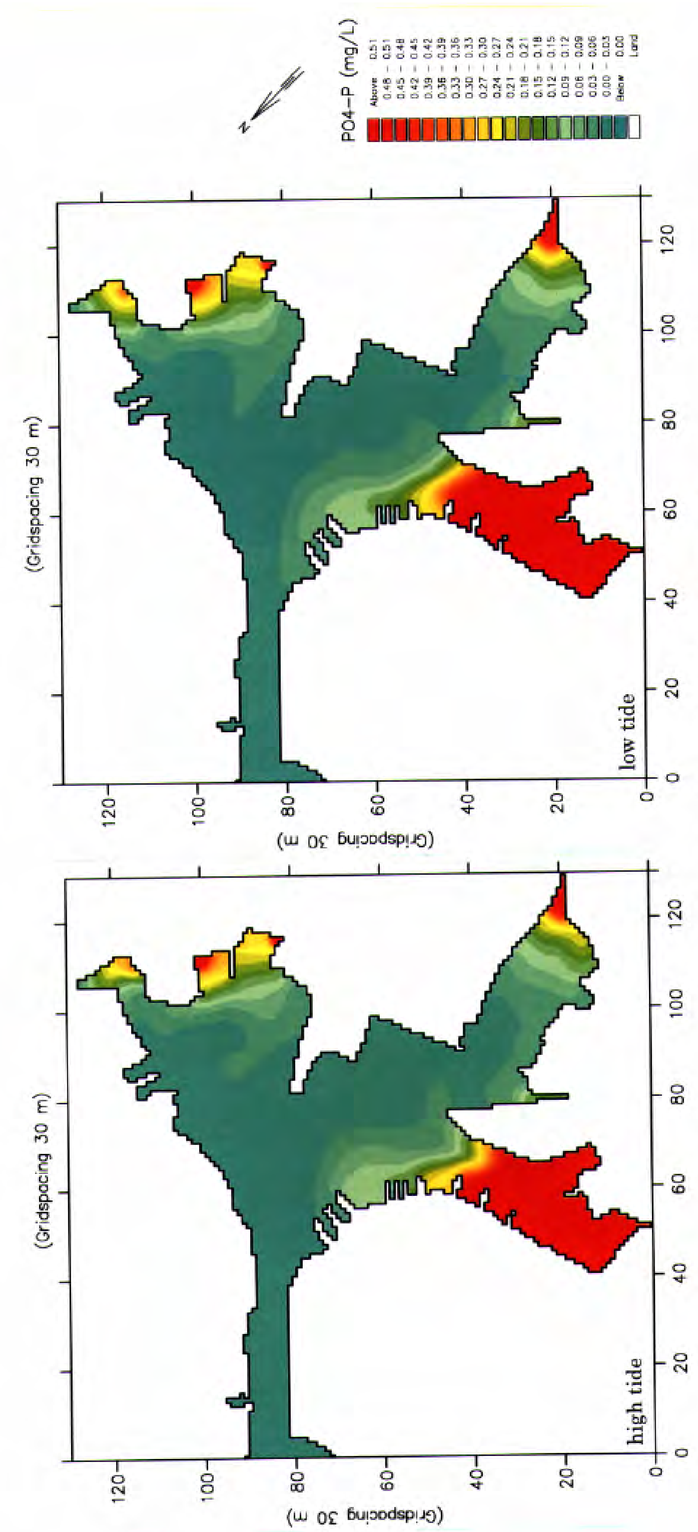


Figure 4.3.22 Concentration distribution of phosphate in Havana bay (Surface layer).

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| THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY | Figure 4.23<br>Concentration Distribution of Orthophosphate ($PO_4$-P) in Havana Bay (Surface Layer) |
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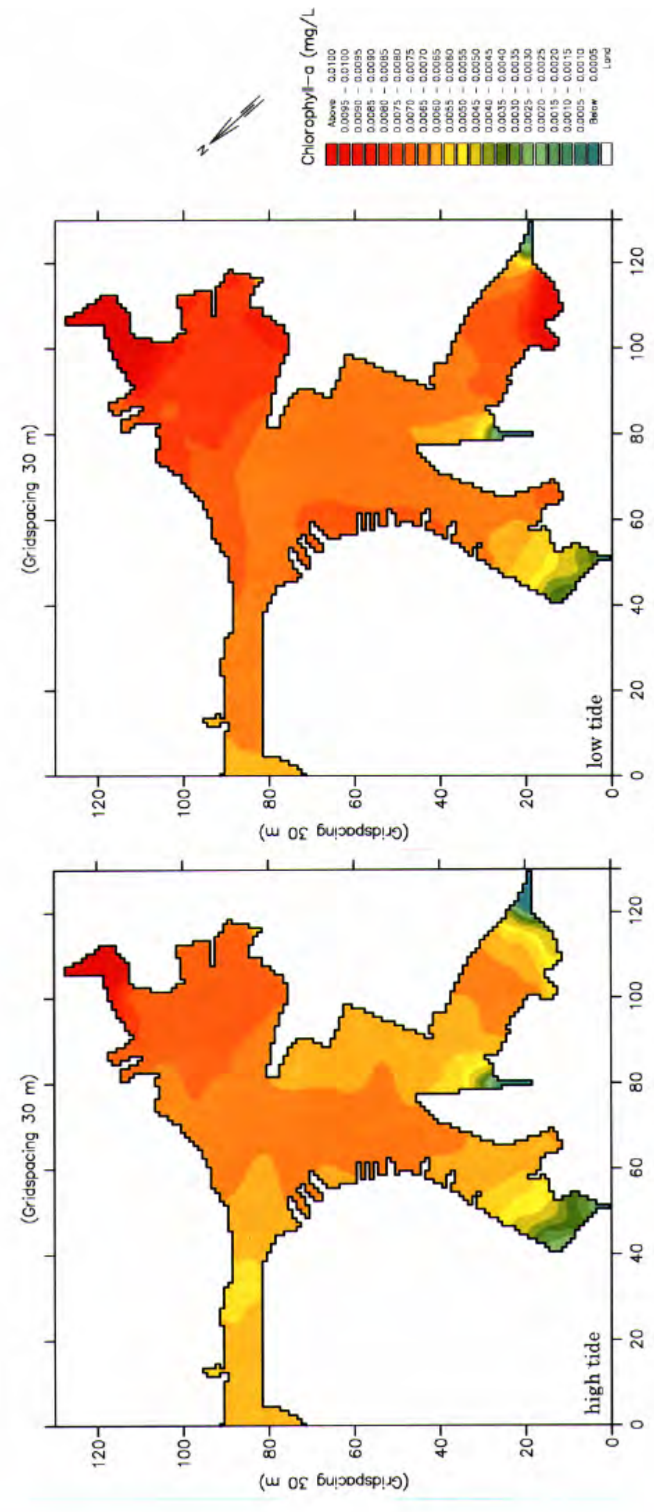


Figure 4.3.23 Concentration distribution of chlorophyll-a in Havana bay (Surface layer).

| THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY | Figure 4.24<br>Concentration Distribution of Chlorophyll-a in Havana Bay (Surface Layer) |
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