JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
THE STATE SECRETARIAT OF ENVIRONMENT AND URBAN DEVELOPMENT (SEMADUR)
THE STATE COMPANY OF WATER AND SEWAGE (CEDAE)

THE STUDY ON MANAGEMENT AND IMPROVEMENT OF THE ENVIRONMENTAL CONDITIONS OF GUANABARA BAY IN RIO DE JANEIRO, THE FEDERATIVE REPUBLIC OF BRAZIL

FINAL REPORT

SUMMARY REPORT

October 2003

PACIFIC CONSULTANTS INTERNATIONAL
in association with
NIHON SUIDO CONSULTANTS

Foreign Currency Exchange Rates Applied in the Study

Currency	Exchange Rate/USD
Brazilian Reals (R$)	2.9
Japanese Yen (JPY)	120.0

(Rate as of July 2002)

PREFACE

In response to a request from the Government of the Federative Republic of Brazil, the Government of Japan decided to conduct the Study on Management and Improvement of the Environmental Conditions of Guanabara Bay in Rio de Janeiro, the Federative Republic of Brazil and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched a study team by a joint venture of Pacific Consultants International (PCI) and Nihon Suido Consultants (NSC), headed by Mr. Akira Takechi, to Brazil during May 2002 to August 2003. In addition, JICA set up an Advisory Committee chaired by Mr. Yoji Okayasu, Water Quality Team, Water Environment Research Group, Public Works Research Institute, between March 2002 and August 2003, which examined the study from specialist and technical point of view.

The team held a series of discussions with the officials concerned of the Government of the Federative Republic of Brazil, and conducted field surveys in the study area. Upon returning to Japan, the team conducted further studies and prepared this final report.

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

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of the Federative Republic of Brazil for their close cooperation extended to the Study.

October, 2003

Kazuhisa Matsuoka
Vice-President
Japan International Cooperation Agency

THE STUDY ON MANAGEMENT AND IMPROVEMENT OF THE ENVIRONMENTAL CONDITIONS OF GUANABARA BAY IN RIO DE JANEIRO, THE FEDERATIVE REPUBLIC OF BRAZIL

October, 2003

Mr. Kazuhisa Matsuoka
Vice - President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Dear Sir,

We are pleased to submit to you the final report entitled “The Study on Management and Improvement of the Environmental Conditions of Guanabara Bay in Rio de Janeiro, the Federative Republic of Brazil”. This report has been prepared by the Study Team in accordance with the contracts signed on 13 March 2002, 24 April 2002, and 19 May 2003 (amended on 17 September 2003) between the Japan International Cooperation Agency and the Joint Study Team of Pacific Consultants International and Nihon Suido Consultants.

The report consists of the Summary, Main Report and Supporting Report. The Summary summarizes the results of all studies. The Main Report contains the existing conditions, reviews of existing master plans, the results of the feasibility study, and conclusions and recommendations. The Supporting Report includes technical details of contents of the Main Report.

All members of the Study Team wish to express grateful acknowledgement to the personnel of your Agency, Advisory Committee, Ministry of Foreign Affairs, Ministry of Land, Infrastructure and Transport, Embassy of Japan in the Republic of Brazil, and also to Brazilian officials and individuals for their assistance extended to the Study Team. The Study Team sincerely hopes that the results of the study contribute to the environmental improvement of Guanabara Bay, and that friendly relations of both countries be promoted further by this occasion.

Yours faithfully,

Akira Takechi
Team Leader of the Study Team

EXECUTIVE SUMMARY

The Study reviewed the master plan aiming at environmental improvement of Guanabara Bay based on Study on Recuperation of the Guanabara Bay Ecosystem, 1994 by JICA (referred to JICA M/P) and the Sewerage Master Plan in Rio de Janeiro Metropolitan Region (referred to CEDAE M/P) 1994 by CEDAE. As a result, a strategic plan to improve the environmental improvement of Guanabara Bay with the sewerage development as its main focus was proposed, and feasibility study was conducted on a priority project that improves severely polluted areas of the Bay.

STRATEGIC PLAN FOR ENVIRONMENTAL IMPROVEMENT

1. REVIEW OF JICA M/P

JICA M/P set up the short term target year 2000, the middle term target year 2010, and the long term target year was not specified because it is not achievable by the currently available technology. It planned to achieve the short and middle targets by developing the sewerage system together with supplemental measures. The sewerage development is expected to reduce a third of the pollutants required to achieve the targets, while the supplement measures, such as stabilization ponds in the estuaries of inflowing rivers, introduction of landuse control and sanitation improvement in Favelas, are supposed to reduce two thirds of the required pollution reduction.

The possibility to achieve the targets, however, is not justified technically because the proposed supplemental measures are not appraisable quantitatively. Also, the target water quality, which was determined from the expected water use in the Bay, seems too ambitious judging from practical and available improvement countermeasures and the project implementing capability of the State of Rio de Janeiro.

It is more practical to address the environmental problems by presently reliable technology and to set up water quality targets that are possible to be achieved by the technology presently available and that are determined by considering improvement priorities.

2. REVIEW OF CEDAE M/P

CEDAE M/P planned to collect and treat wastewater from all the urban areas in the metropolitan region by 32 sewerage districts each of which has one or more wastewater treatment plants (WWTP). Among the 32 sewerage districts, 16 sewerage districts are located in the Guanabara Bay basin, the Study area. Therefore, the Study reviewed only the 16 sewerage districts.

Parts of the CEDAE M/P have been realized as projects of Guanabara Bay Abatement Program (PDBG) and some of the sewerage districts of the M/P have been changed in the course of the project implementation. The study decided to follow the sewerage districts of M/P for the remaining districts and reviewed the population, design sewage flow and capacity of the facilities. As a result, it was judged that no particular changes in the capacity of trunk mains, pumping stations and WWTP would be required, since a difference in the sewage flow between the updated ones and the ones in M/P is negligible.

The project costs were recalculated based on the latest foreign exchange rates, because the foreign exchange rates to US$ had been depreciated to a large extent after the M/P was issued.

Trunk mains are planned not only along roads but along rivers in some districts in M/P. In such districts, rearrangement of the trunk mains will be required in the feasibility study stage. Some WWTP sites proposed in M/P were observed to be occupied and used for other purposes. Hence, land acquisition is an urgent matter.

3. STRATEGY OF ENVIRONMENTAL IMPROVEMENT

Based on the results of the two master plans, the study adopted following strategy of the environmental improvement of the Guanabara Bay:

- The water quality targets would be achieved by the development of sewerage system, since for supplemental measures as proposed in JICA M/P, effects can not be predicted quantitatively, and they are not technical measures to be realized as a project.
- Because CEADE M/P exists and parts of it have been implemented by PDBG, the study proposes a strategic plan based on the results of review of CEDAE M/P.
- Water quality targets are re-established to be technically achievable.
- Thereby, the short term target is set to be BOD less than 10 mg/l in whole Bay area, aiming to remove unpleasant conditions. Although the long term target adopts the environmental standards of CONAMA, it is a nonbinding target without the target year because it is not achievable by the currently available technology. The middle term target, which is the target of the strategic plan, is set to achieve the environmental standards except in presently severely polluted areas. (Refer to *Table 1*)
- While they can not be considered as measures to achieve the targets, dredging, sea surface cleaning and conservation of mangrove and wetland are recommended from viewpoints of general environmental improvement and conservation of natural environment.
- Environmental management should be strengthened.

Table 1 New Water Quality Target and Target Year

Target	Description	Target Year
Short-term	Removal of obnoxious conditions BOD less than 10 mg/l at all the water quality monitoring points in the Bay.	2010
Middle-term	BOD less than 5 mg/l in all areas except western areas.	2020
Long Term	Water Quality Classification DZ105.	Not specified

4. STRATEGIC PLAN OF THE SEWERAGE DEVELOPMENT

Development Area and Facilities Plan

Sewerage system is to be developed in 12 sewer districts among the 16 districts of CEDAE M/P. *Table 2* shows the sewer districts to be developed.

Table 2 Sewer Districts to be Developed and Major Facilities

Sewer system	Area (ha)	Population 2020	Design Wastewater Flow (l/sec)	WWTP		Collection System	
				Nos. of Plants	Total Capacity (l/sec)	Nos. of Pumping Stations	Length of Sewer (km)
1. Pavuna-Meriti*	17,800	1,577,500	3,944	2	4,100	23	1,890
2. Sarapuí*	13,200	993,700	2,480	2	2,685	14	1,320
3. Bangu	3,300	403,600	1,009	1	1,000	1	255
4. Bota	39,200	1,274,400	3,154	5	3,210	0	4,114
5. Iguaçu	18,100	300,400	631	2	640	3	1,826
6. Estrela	35,100	450,500	1,076	4	1,100	1	3,546
7. Roncador	57,100	202,400	287	3	300	2	3,817
8. Macacu	65,600	400,000	845	8	870	3	6,501
9. Guaxindiba	7,100	252,400	554	3	570	2	737
10. Alcâtara	10,600	499,500	928	3	940	4	1,290
11. Imboassu	5,900	336,700	869	2	875	3	810
12. Niteroi*	4000	404,000	1,064	2	1,482	6	600
Total	277,000	7,095,100	16,841	37	17,772	62	26,706

*: Including existing facilities.

Implementation Program

The project implementation schedule was determined based on investment effects, pollution reduction effects and CEADE's priority. Project starts from 2004 and completes in 2035.

Project Costs

Total project cost is US$ 1,548 million as shown in *Table 3.* Operation and maintenance cost is set at 5% of the direct construction cost.

Table 3 Project Cost of Strategic Plan for Sewerage Development

Direct Construction Cost	1,257,247
Land Acquisition Cost	7,881
Administration cost	62,862
Engineering service cost	125,725
Physical Contingency	125,725
Total	1,579,440

(Unit: US$1,000)

Project Evaluation

Considering CEDAE's experience in the operation of WWTP, the project is judged to be operatable by CEDAE's current technology level.

It was confirmed by the water quality simulation model developed in the study that the middle term target can be achieved by the project.

On condition that the State inputs subsidy and CEDAE utilizes 30% of low interest loan and 30% of international level interest loan, FIRR is calculated to be 10.8%; thus, the project is judged to be financially viable.

By surveying the environmental value of "Guanabara Bay with clean water", EIRR is calculated to be 10.0%; thus, the project is judged to be economically viable.

The project provides a possibility of sewerage services to Favelas by including plans to receive wastewater from Favelas.

Preliminary environmental impacts study indicated possible negative impacts, such as noise/vibration and traffic blocking by the construction work and smell problems from the WWTP operation; they were, however, judged to be controllable by selecting proper equipment and construction methods.

Based on the above considerations, the project is judged to be feasible.

5. SELECTION OF PRIORITY PROJECT

Four projects shown in *Table 4* are selected as the priority projects based on the investment effects and achievability of the short term water quality target.

Table 4 Sewer Districts of the Priority Projects

Sewer district	Area (ha)	WWTPs Capacity (L/d)	Required Site Area (ha)	Remarks
1. Pavuna	3,660	1,500	-	Existing capacity not included
2. Acari	3,100	1,100	-	
3. Sarapuí	640	1,000	-	Existing capacity not included
4. Bangu	1,870	1,000	6.5	
Total	9,270	4,600	6.5	

FEASIBILITY STUDY OF PRIORITY PROJECT

1. FACILITY PLANNING

Sewage collection system

Sewage collection system consists of sewers with a total length of 1,833 km and a total of 6 pumping stations. Its breakdown is shown in *Table 5*.

Table 5 Sewage Collection System of Priority Project

Sewer District	Branch Sewer	Trunk Sewer Open Cut	Trunk Sewer Pipe Jacking	Trunk Sewer Pressure Pipe	Total
Pavuna	695,000	7,170	15,642		717,812
Acari	558,000	7,690	16,148	1,010	582,848
Sarapui	96,000	2,090	4,660		102,750
Bangu	411,000	5,770	12,910		429,680
Total	1,760,000	22,720	49,360	1,010	1,833,090

(Unit: m)

Wastewater Treatment Plant

WWTPs of Pavuna and Sarapui are extended while WWTPS of Acari and Bangu are newly constructed. For treatment method, activated sludge method is adopted. Sludge is disposed to a solid waste dumping site after being thickened, mechanically de-watered and dried. Capacity of each WWTP is shown in *Table 6.*

Table 6 Capacity of WWTP

WWTPs	Design Treatment Capacity (L/s)		Influent Qualities BOD/SS (mg/L)	Effluent Qualities BOD/SS (mg/L)
	Existing	F/S		
Pavuna	1,500	1,500	230/250	20/20
Acari	-	1,100	230/250	20/20
Sarapuí	1,500	1,000	230/250	20/20
Bangu	-	1,000	230/250	20/20

2. *PROJECT COST*

Total project cost is US$ 394 million as shown in *Table 7* and operation and maintenance cost is US$ 10.5 million per year.

Table 7 Project Cost of Priority Project

Item	Foreign Cost	Local Cost	Total
Direct Cost	14,852	299,567	314,419
Land Acquisition (Bangu WWTP)	-	650	650
Administrative Expense (5%)	-	15,722	15,722
Engineering Services (10%)	-	31,443	31,443
Physical Contingencies (10%)	-	31,443	31,443
Total of Capital Costs	14,852	378,825	393,677

(Unit: US$1,000)

3. *PROJECT EVALUATION*

It was confirmed that BOD in every monitoring station in the bay will be less than 10 mg/l after the completion of the priority project.

On conditions of the State subsidy, US$ 20 million in 2006 and US$ 4 million per year from 2007 to 2009 and loans (30% in low interest and 30% in international level), FIRR was calculated to be 9.7%; thus, the project was judged to be financially viable.

By counting the environmental value of Guanabara Bay as economic benefit, EIRR was calculated to be 12.9%. Thus the project was judged to be economically viable.

The project was plans to receive and treat wastewater from Favelas, when sewer system is installed there after the street construction by intervention programs.

EIA study, based on the Brazilian environmental law system, indicated possible negative impacts that are considered controllable by proper equipment and construction methods. EIA identified necessary studies during the next stage of the project, detailed designing stage, to address the possible impacts.

Based on the above evaluation, the project is judged to be feasible.

4. *RECOMMENDATION*

The study recommended the enforcement of the environmental management and strengthening of the project implementation and operation capacity.

Enforcement of Environmental Management

The study recommended to built an organization with function of environmental management in SEMADUR. The organization should have capacity and competence to integrate all the information related to the Guanabara Bay environment, to prepare a management plan, to establish the improvement scenarios, to allocate budgets to related organizations, and implement environment projects. The study developed the water quality simulation model and the decision support system to provide the organization with effective tools.

Political support for the environmental policy is an essential factor to make the environmental management policy sustainable. Residents awareness to the environment strongly affects the political support. Hence, the study recommended the implementation of the environmental education and created a home page to disseminate information on the Guanabara Bay environment.

Strengthening of the Project Implementation and Operation Capacity

The study recommended that CEDAE should:

- Take prompt actions to initiate the procedures to implement the priority project.
- Prepare an action plan to increase revenue and decrease operating costs.
- Prepare a maintenance and rehabilitation plan for aged facilities.
- Start monitoring the operation of existing WWTP.

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ABBREVIATIONS

1. ORGANIZATIONS

ABC	Agência Brasileira de Cooperação (Brazilian Cooperation Agency)
ABNT	Associasão Brasileira de Normas Técnicas (Brazilian Association of Technical Standards)
AFB	Agência Financeira da Bacia (Basin Financial Agency)
BC	Banco Central (Central Bank of Brazil)
BID	Banco Interamericano de Desenvolvimento (Inter-American Development Bank - IDB)
BIRD	Banco Internacional de Reconstrução e Desenvolvimento (International Bank for Reconstruction and Development - IBRD)
BNDES	Banco Nacional de Desenvolvimento Econômico e Social (National Bank for Economic and Social Development)
CECA	Comissão Estadual de Controle Ambiental (State Commission for Environmental Control)
CEDAE	Companhia Estadual de Aguas e Esgoto (State Company of Water and Sewages)
CEF	Caixa Econômica Federal (Federal Savings Bank)
CEHAB	Companhia Estadual de Habitação (State Company of Housing)
CET-Rio	Companhia de Engenharia de Trafego do Rio de Janeiro (Traffic Engineering Corporation of Rio de Janeiro)
CIDE	Centro de Informações e Dados do Rio de Janeiro (Rio de Janeiro Data and Information Center)
CODIN	Companhia Distristos Industriais (Industrial District Companies) (Industrial Districts Company)
CODEC	Comissão Coordenadora para Execução do Programa de Despoluiçãoda Baía de Guanabara (Coordinating Commission for Pollution Control of Guanabara Bay Program)
COFIEX	Comissão de Financiamentos Externos (External Financial Commission)
COMLURB	Companhia Municipal de Limpeza Urbana (Municipal Company of Urban Cleaning)
CONTROL	Secretaria de Estado de Planejamento, Controle e Gestão (State Secretariat of Planning, Control and Management)
CPI	Consumer Price Incex
CMN	Conselho Monetário Nacional (National Monetary Council)
CONAMA	Conselho Nacional de Meio Ambiente (National Environmental Council)

DCON	Divisão de Controle de Industriais (da FEEMA) (Division of Industry Control)
DER	Departamento de Estradas de Rodagem (Department of Roads and Highways)
DHN	Diretoria de Hidrografia e Navegao (da Marinha do Brasil) (Hydrographic and Navigation Board (Brazilian Navy))
DILAB	Divisão de Laboratórios (da FEEMA) (FEEMA's Laboratory Division)
DRM-RJ	Departamento de Recursos Mineirais (Department of Mineral Resources)
DSGME	Diretoria de Serviço Geográfico do Ministerio do Exército (Geographical Services Board, Army Ministry)
EMBASA	Empresa Baiana de Águas e Saneamento SA
EMOP	Empresa de Obras Público do Estado do Rio de Janeiro (Rio de Janeiro State Company of Public Buildings)
FECAM	Fundo Especial para o Controle Ambiental (Special Fund for Environmental Control)
FECP	Fundo Estadual de Combate à Pobreza e às Desigualdades Sociais State Fund for Combat to Poverty and Social Inequality
FEEMA	Fundação Estadual para Engenharia do Meio Ambiente (State Foundation for Environmental Engineering)
GEDEG	Grupo Executivo de Despoluição da Baía de Guanabara (Executive Group for Pollution Control of Guanabara Bay)
GERSOL	Grupo Executivo de Resíduos Sólidos (Executive Group for Solid Residues)
GOB	Government of Brazil
GOJ	Government of Japan
IBRD	International Bank for Reconstruction and Development
IBAMA	Instituto Brasileiro do Meio Ambiente e Recursos Naturais Renováveis (Brazilian Institute of Environment, Natural and Renewable Resources)
IBGE	Instituto Brasileiro de Geografia e Estatística (Brazilian Institute of Geography and Statistic)
IDB	Inter-American Development Bank (Banco Interamericano de Desenvolvimento - BID)
IEF	Fundação Estadual de Florestas (State Foundation of Forests)
IMF	International Monetary Fund
IPE INPE	Instituto de Pesquisas Espaciais (Institute of Space Research) (Space Research Institute)
INMET	Instituto Nacional de Meteorologia (Meteorologic National Institute)
INMETRO	Instituto Nacional de Metrologia, Normalização e Qualidade Industrial (National Institute of Metrology, Standardization and Industrial Quality)
INPH	Instituto de Pesquisas Hidroviárias (Institute of Hydro-routes Research) (Hydro-routes Research Institute)
IPEA	Fundação Instituto de Pesquisa Econômica Aplicada (Institute of Applied Economics Research)

IPEM	Instituto de Pesos e Medidas (Institute of Weights and Measures)
IPLANRIO	Instituto de Planejamento Municipal (Institute of Municipal Planning) (Municipal Planning Institute)
IPP	Instituto Municipal de Urbanismo Pereira Passos (Pereira Passos Municipal Institute of Urbanism)
JBIC	Japan Bank for International Cooperation
JICA	Japan International Cooperation Agency
JSWA	Japan Sewage Works Association
MMA	Ministério do Meio Ambiente (Ministry of the Environment)
MPO	Ministério do Planejamento, Orçamento e Gestão (Ministry of Planning, Budget and Management)
MRE	Ministério das Relações Exteriores (Ministry of Foreign Affairs)
NGO	Non-Governmental Organization
OECF	Overseas Economic Cooperation Fund
OIM	Organização Internacional Marítima (International Maritime Organization)
ONG	Organização Não Governamental (Non-Governmental Organization)
SABESP	Companhia de Saeamento Básico do Estado de São Paulo
SEDUR	Secretaria de Estado do Desenvolvimento Urbano (State Secretariat of Urban Development)
SEF	Secretaria de Estado de Fazenda (State Secretariat of Finance)
SEF	Secretaria de Estado de Finanças (State Secretariat of Finance)
SEMADUR	Secretaria de Estado de Meio Ambiente e Desenvolvimento Urbano (State Secretariat of Environment and Urban Development)
SEMAN	Secretaria de Meio Ambiente (State Secretariat of Environment)
SEMAMPE	Secretaria Estadual de Meio Ambiente e Projetos Especiais (State Secretariat of Environment and Special Projects)
SEPDET	Secretaria de Estado de Planejamento, Desenvolvimento Econômico e Turismo (State Secretariat of Planning, Economical Development and Tourism)
SEPURB	Secretaria de Política Urbana - Ministério do Planejamento, Orçamento e Gestão (Secretariat of Urban Policy - Ministry of Planning, Budget and Management)
SERLA	Fundação Superintendência Estadual de Rios e Lagoas (State Authority for Rivers and Lagoons)
SESRH	Secretaria de Saniamento e Recursos Hídricos (State Secretariat of Sanitation and Water Resources)
SINS	Sisitema Nacional de Informações sobre Saneamento (National Information System on Sanitation)

SMH	Secretaria Municipal de Habitação da Cidade do Rio de Janeiro (Municipal Secretariat of Housing of Rio de Janeiro City)
SSPU	Subsecretaria Superintendência de Planejamento (Undersecretariat of Urban Planning)
UERJ	Universidade Estadual do Rio de Janeiro (State University of Rio de Janeiro)
UFRJ	Universidade Federal do Rio de Janeiro (Federal University of Rio de Janeiro)
WB	World Bank

2. TERMINOALOGY

AD	Advection Dispersion Model
As	Arsenic
APM	Área de Proteção de Mananciais (Water Catchment Protection Area)
BOD (5)	Biochemical Oxygen Demand, (5-day, 20ºC)
C	Carbon
Cd	Cadmium
CDL	Chart Datum Level
Chl-a	Chlorophyll-a
CIF	Cost, Insurance and Freight
Cl^-	Chlorine Ion
CN^-	Cyanide Ion
COD	Chemical Oxygen Demand
Coliform	Coliform Group Bacteria
Cr (6+)	Chromium Sexavalent
Cu	Copper
DBOD	Dissolved Biochemical Oxygen Demand
DC	Detritus Carbon
D/D	Detailed Design
DHWL	Design High Water Level
DO	Dissolved Oxygen
DLWL	Design Low Water Level
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
EL	Elevation
EU	Eutrophication Model
FC	Foreign Currency
F. coli	Fecal Coliform Bacteria
FIRR	Financial Internal Rate of Return
F/M	Food-to-Microorganisms Ratio
F/S	Feasibility Study
GIS	Geographic Information System
GDP	Gross Domestic Product
GRDP	Gross Regional Domestic Product

HD	Hydrodynamic Model
H_2S	Hydrogen Sulfide
Hg	Mercury
HHW	Highest High Water
HW	High Water
IL	Ignition Loss
ICMS	Imposto sobre Circulação de Mercadorias (Value Added Taxes on Sales and Services)
INPC	Índice Nacional de Preços ao Consumidor (National Consumer Price Index)
K	Mineralization Constant, 1/day
L_{BOD}	Specific BOD load, $kg/km^2/day$
L_{TN}	Specific TN load, $kg/km^2/day$
L_{TP}	Specific TP load, $kg/km^2/day$
L_{PO4}	Specific PO_4-P load, $kg/km^2/day$
L_{DIN}	Specific DIN load, $kg/km^2/day$
L_{TOTAL}	Total pollution before self purification, ton/day
L_{MON}	Monitored load to Bay, ton/day
$L_{WWTP\text{-}DIS}$	Load from WWTP, ton/day
$L_{POP.\ WITHOUT\ SEWER}$	Load from population without sewer, ton/day
L_I	Load from large industries, ton/day
L_M	Load from small scale treatment units, ton/day
L_{AREAL}	Natural background load, ton/day
L_{RIVER}	Load to river, ton/day
LC	Local Currency
LLW	Lowest Low Water
LW	Low Water
MBAS	Methylene Blue Active Substance
MHWN	Mean High Water Neaps
MHWS	Mean High Water Spring
MIKE 21	Model System from DHI Water and Environment
MLSS	Mixed Liquor Suspended Solids
MLWN	Mean Low water Neaps
MLWS	Mean Low Water
MPN	Most Probable Number
MSL	Mean Sea Level
MW	Minimum Wage
N	Nitrogen
NAM	Precipitation Run-off Model
NH_4- N	Ammonia Nitrogen
NH_2-N	Nitrite Nitrogen
NO_3-N	Nitrate Nitrogen
NPV	Net Present Value
NTU	Nephelometric Turbidity Units
OM or O/M	Operation and Maintenance
P	Phosphorus
PAR	Photosynthetic Active Radiation

Pb	Lead
PC	Phytoplankton Carbon
PCB	Polychlorinated Biphenyls
PDBG	Progama de Despoluição da Baía de Guanabara (Guanabara Bay Pollution Abatement Program)
pH	The Reciprocal of the Logarithm of the Hydrogen-ion Concentration (potential of hydrogen ion)
PIS	Programa de Integração Social (Employees’ Profit Participatio Program)
PLANASA	Plano Nacional de Saneamento (National Plan of Sanitation)
PMSS	Plano de Modernização do Setor de Saneamento(do Ministério do Planejamento) (Modernization Plan for the Sanitation Sector [of the Ministry of Planning)
PNB	Programa Nova Baixada (Nova Baixada Program)
$PO_4^{-}P$	Phosphate Phosphorus
PPA	Programa Plurianual (4-year Plan)
PROSANEAR	Programa de Saneamento para a População de Baixa Renda (Sanitation Program for the Low Income Population)
PVC	Polyvinyl Chloride
Q_S	Specific Discharge, l/km^2/sec
SRT	Solids Retention Time
SS	Suspended Solids
SS (IL)	Ignition Loss of Suspended Solids
SUS	Sistema Único de Saúde (Unified Health System)
TDP	Total Dissolved Phosphorus
TDH	Total Dynamic Head
THg	Total Mercury
TIN	Total Inorganic Nitrogen
TIP	Total Inorganic Phosphorus
TN	Total Nitrogen
TNK	Total Kjeldahl Nitrogen
TOC	Total Organic Carbon
TON	Total Organic Nitrogen
TOP	Total Organic Phosphorus
TP	Total Phosphorous
TR (IL)	Ignition Loss of Total Residue
TS	Total Solids
Turb.	Turbidity
VTS	Volatile Total Solids
TSS	Total Suspended Solids
UV	Ultra Violet
VSS	Volatile Suspended Solids
VTS	Volatile Total Solids

WTP	Willingness to Pay
WWTP	Wastewater Treatment Plant
WQ	Water Quality Model
Zn	Zinc

3. UNITS

cm	centimeter
cm^2	square centimeter
g	gram
g/m^3	gram per cubic meter
ha	hectare
km^2	Square kilometer
kg	kilogram
kg/d	kilogram per day
km	kilometer
kW	kilowatt
L	liter
L/d	liter per day
Lpcd	liter per capita per day
L/s	liter per second
$L/km^2/sec$	liter per square kilometer per second
m^2	square meter
m^3	cubic meter
m^3/d	cubic meter per day
m^3/h	cubic meter per hour
m^3/m	cubic meter per minute
m^3/s	cubic meter per second
mm^2	square millimeter
$m^3/m^2/d$	cubic meter per square meter per day
m	meter
mg	milligram
mg/L	milligram per liter
ml	milliliter
mm	millimeter
m/s	meter per second
s	second
t	ton (1,000 kg)
W	watt
R$	Brazilian Currency, Real
¥	Japanese Currency, Yen
US$	United States Currency, Dollar
%	Percent

Currency exchange rate adopted is the two digits half currency adjust of monthly average exchange rate in July, 2002, when actual cost estimates work started.

R$2.9 = US$1 =120 Yen

1. INTRODUCTION

1.1 GENERAL

In response to the request of the Government of the Federative Republic of Brazil (GOB) in 2000, the Government of Japan (GOJ) agreed to conduct the Study on Management and Improvement of the Environmental Conditions of Guanabara Bay in Rio de Janeiro, the Federative Republic of Brazil (Study). Accordingly the Japan International Cooperation Agency (JICA), the official agency responsible for the implementation of the technical cooperation programs of GOJ, was assigned to undertake the Study in close cooperation with the authorities of GOB.

JICA dispatched a preparatory study team to the Federative Republic of Brazil for the preliminary survey as well as discussion of the Scope of Work for the Study. The Scope of Work and the Minutes of Meeting were agreed upon between the State Secretariat of Sanitation and Water Resources, the State of Rio de Janeiro (SESRH) and JICA on November 7, 2001. JICA appointed a joint venture, Pacific Consultants International in association with Nihon Suido Consultants, to conduct the Study and formed the Study Team in March 2002. The Study Team commenced the Study work in Rio de Janeiro in May 2002 and completed in August 2003.

1.2 BACKGROUND OF THE STUDY

Guanabara Bay in Rio de Janeiro has highly regarded beautiful scenery and is at the base of the statue of Christ the Redeemer, a national symbol of Brazil, which elevates the city's value as an international tourist destination in Brazil. However, in the 1990's, untreated sewage discharge and illegal solid waste dumping caused degradation of water quality in Guanabara Bay.

JICA undertook the "Study on Recuperation of the Guanabara Bay Ecosystem" formulating the Master Plan (JICA M/P) in 1994. Also in 1994, the State Company of Water and Sewage (CEDAE) conducted the "Sewerage Master Plan in Rio de Janeiro Metropolitan Region" (CEDAE M/P). CEDAE has implemented Guanabara Bay Pollution Abatement Program (PDBG) led by the Inter-American Development Bank (IDB) with co-financing of Japan Bank for International Cooperation (now JBIC, then OECF).

PDBG is considered as part of CEDAE M/P and PDBG projects are going to be completed in 2003. CEDAE is now planning further improvement of the water environment of Guanabara Bay by the extension of the sewerage systems and GOB has requested GOJ to conduct the Feasibility Study for this project.

1.3 OBJECTIVES OF THE STUDY

The objectives of the Study are:

- To review the Master Plan that was formulated through the "Study on Recuperation of the Guanabara Bay Ecosystem"
- To review the portion related to Guanabara Bay Basin of the "Sewerage Master Plan in Rio de Janeiro Metropolitan Region"
- To conduct a feasibility study (F/S) on priority project(s) selected in the study on sewerage system in Guanabara Bay Basin
- To pursue technology transfer to the counterpart personnel in the course of the Study.

1.4 STUDY AREA

The Study area covers the Guanabara Bay basin which is shown in *Figure 1.1*. The whole basin is located within the Rio de Janeiro State boundary and covers 16 municipalities.

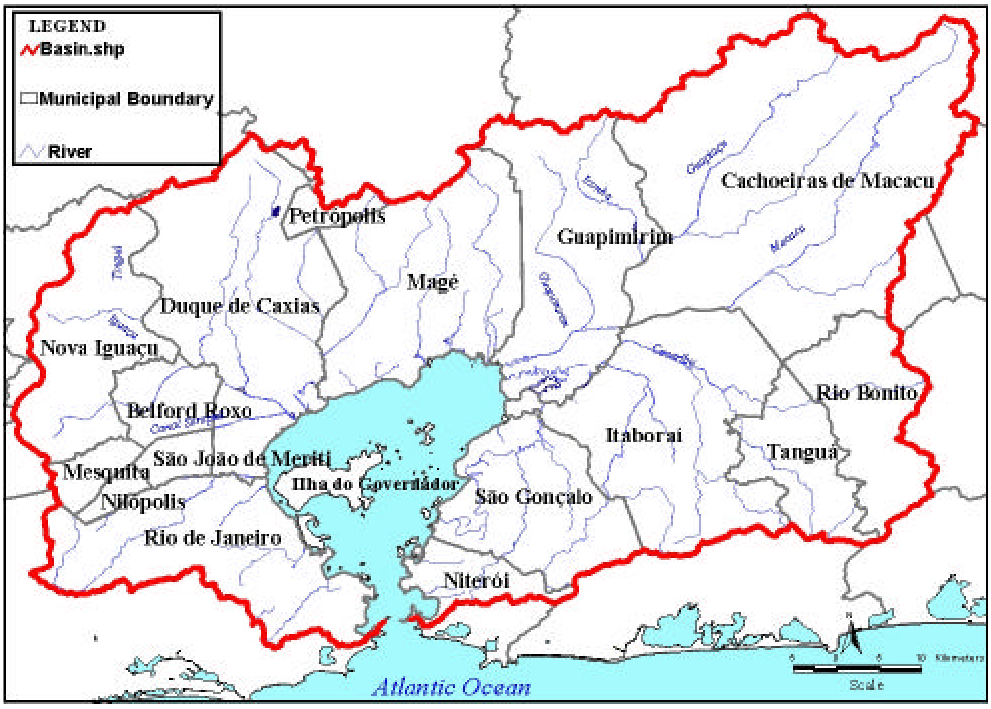

Figure 1.1 Study Area

1.5 STUDY SCHEDULE

The Study schedule is shown in *Figure 1.2*. The Study will be completed within 18.5 months between the middle of March 2002 and the end of September 2003, in five work stages. The Study consists of two phases: Phase I: Review on Master Plans and Phase II: Feasibility Study.

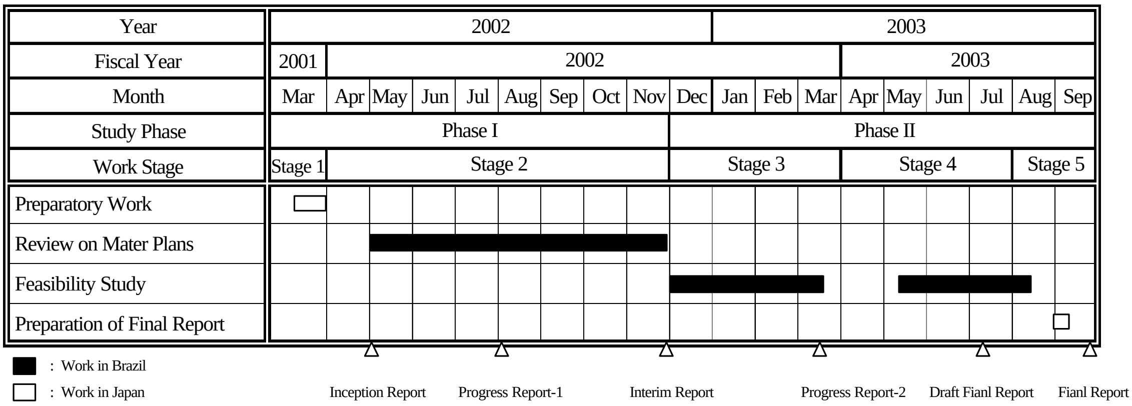

Figure 1.2 Time Schedule of the Study

1.6 STUDY ORGANIZATION

The Study is conducted under the following organizational scheme in *Figure 1.3*.

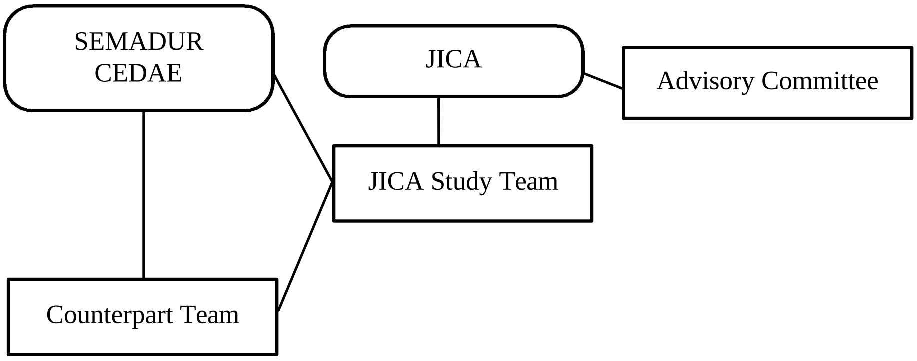

Figure 1.3 Study Organization

Member of JICA Study team and the Advisory Committee are shown as follows.

JICA STUDY TEAM

Assignments	Name
Team Leader/Water quality restoration	Akira TAKECHI
Pollution analysis A	Erik Kock Rasmussen
Pollution analysis B	Thomas Uhrenholdt
Pollution analysis C	Sivapragasam Kugaprasatham
Hydrological analysis	Sabbir Hassan
Wastewater Planning	Shohei SATA
Sub-Team Leader/Wastewater treatment design	Masakazu NAKAO
Sewer design	Seiichi HANAFUSA
Organization and Institution	Jose Henrique Penido Monteiro
Database	Ryo MATSUMARU
Economic and financial analysis	Yoji SAKAKIBARA
Environment Impact	Tetsuji KAWAMURA
Social consideration	Ione Marisa KOSEKI CORNEJO
Interpreter A	Keiko FUJISAWA
Interpreter B	Cesar MATONO
Social consideration B/Study Coordination	Chiho OCHIAI

JICA ADVISORY COMMITTEE

Assignments	Name
Chairman of the committee	Yuji OKAYASU
Committee member	Masami MIZUGUCHI

Counterpart members are shown as follows.

From January 2003

Assignment	Name	Organization
Chief Counterpart	Rafael Carvalho Oliveira Santos	PDBG, CEDAE
Water Quality Restoration	Fátima de Freitas Lopes Soares	DEP (Water Quality Division), FEEMA
Pollutant Analysis	Elisabeth Lima	DEP (Water Quality Division), FEEMA
Hydrology	André Pinhel	SERLA
Wastewater Planning	Marcos Antonio Coimbra do Nascimento	DRO (West Regional Directory), CEDAE
Wastewater Design	Sérgio Pinheiro de Almeida	PDBG, CEDAE
Sewer Design	Marcos Vinícios M. Fagundes	DRO (East Regional Directory), CEDAE
Database	Vera Lucia de Souza Pinheiro	PDBG, CEDAE
Environmental Impact	Isabel Hirsch de Alcântara	DECON (Non Industrial Activities Division), FEEMA
Social Consideration/ Environmental Education	Dionê Maria Saldanha Marinho	PAC SSA-PA/SEMADUR
Solid Waste	José Maria de Mesquita Jr.	SSA-PA/SEMADUR
Representative of SEMADUR	Alexandre Augusto Furlanetto	Under Secretary of Environment Assistant, SEMADUR
SEMADUR	Alberto José Mendes Gomes	Under Secretary of Environment SEMADUR
Representative of CEDAE	Breno Marinho Junqueira	PDGBG, CEDAE

FORMER COUNTERPART TEAM

Until December 2002

Assignment	Name	Organization
Chief Counterpart	Luis Edmundo Cascão Silva	PDBG, CEDAE
Water Quality Restoration	Celso Bredariol	DEP (Water Quality Division), FEEMA
Pollutant Analysis	Elisabeth Lima	DEP (Water Quality Division), FEEMA
Hydrology	Mônica Miranda Falcão	SERLA
Wastewater Planning	Ciro Lacerda Correia Fillho	DRO (West Regional Directory), CEDAE
Wastewater Design	Rafael Santos	PDBG, CEDAE
Sewer Design	Marcos Vinícios M. Fagundes	DRO (East Regional Directory), CEDAE
Database	Vera Pinheiro	PDBG, CEDAE
Environmental Impact	José M. Mesquita Jr.	DECON (Non Industrial Activities Division), FEEMA
Economic/Financial Analysis and Social Consideration	José Stelberto Porto Soares	SEPDET
Study Administration	Gladstone de Castro	SESRH

2. POLLUTION ANALYSIS

2.1 INTRODUCTION

Pollution analysis consists of following four components and its concept is shown in *Figure 2.1*

- Hydrological analysis to give fresh water input to the hydrodynamic module of the water quality simulation model.
- Pollution load analysis to calculate the pollution input to the water quality simulation model based on information on pollution sources in the basin.
- Development of water quality simulation model to estimate the water quality of the bay based on the estimated pollution load discharge from the basin.
- Development of decision support system based on pollution load database to enable the estimation of the bay water quality by inputting information on pollution sources in the basin.

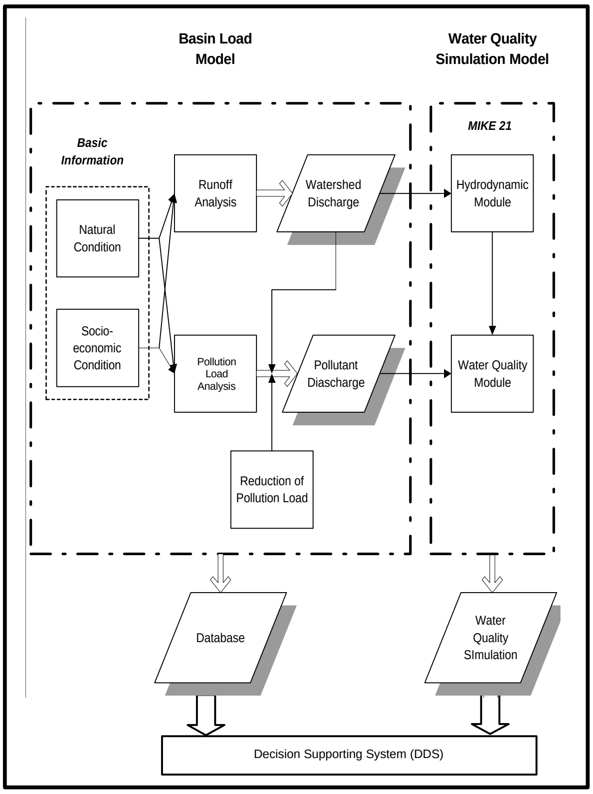

Figure 2.1 Concept of the Pollution Analysis

2.2 HYDROLOGICAL ANALYSIS

Purposes of the hydrological analysis are to estimate daily flow rates of each river in the basin to input freshwater to the hydrodynamic module of the simulation model.

(1) Data Used in the Analysis

Meteorological data was collected from INMET, SERLA and website of GEO-RIO. While all data collected was used in the hydrological analysis, daily rainfall data, which is required for the runoff analysis, were available at only seven stations.

Hydrological data and runoff observation data were collected from SELRA's records of manual staff gauge reading at 23 stations in 1999 and 2000. Rating curves, which calculate discharge measurements for readings of the gauge, were generated by the Study Team using SELRA's records of regular discharge observations.

(2) Runoff Calculation

The basin is divided into 24 river systems and five island groups. Daily flow rates of each of the 24 rivers are calculated for the wet, average and dry years. The wet, average and dry years were defined as follows, as results of probability analysis on annual total rainfall of the Study area for 36 years:

- Average Year : annual total basin rainfall has a 50% non-exceedence probability
- Dry Year : annual total basin rainfall has a 10% non-exceedence probability
- Wet Year : annual total basin rainfall has a 90% non-exceedence probability.

Major findings in addition to the flow rate calculation are as follows:

- Total runoffs (surface runoff + base flow + wastewater flow) from the entire study area for year 2000, Dry, Average and Wet Years are obtained as 113, 96, 131 and 183 m^3/s respectively. Therefore, 2000 was inbetween Dry and Average Years.
- Base flow and wastewater flow, which are constant flows for the total Study area obtained as 29 and 23 m^3/s respectively.
- For an Average Year, base flow, wastewater flow and surface runoff constitute 22%, 17% and 61% of total runoff respectively.
- Maximum runoff occurs from Rio Guapimirim basin (B1000). For an Average Year, Rio Guapimirim, Rio Iguaçu, Rio Saracuruna and Rio Caceribu constitute 35%, 22%, 8% and 7% (73% in total) of runoff from the entire Study area respectively.

2.3 POLLUTION LOAD ANALYSIS

Purposes of the pollution load analysis are: i) to inventory the pollution sources in the basin, and ii) to estimate present and future pollution load reaching the bay through each river basin.

Estimates have been made for 2000, 2010 and 2020. Further, different load reduction scenarios have been defined and used for simulation of the water quality.

(1) Category of Pollution Sources

Pollution sources are categorized as follows:

Point sources

- Generation of pollution load by population, which is calculated by a unit pollution load per capita (54 BOD g/day/capita, 10 g TN/day/capita, 2.5 g TP/day/capita).
- Pollution load discharge by WWTP, which is calculated from design pollution load and removal efficiency.
- Pollution load discharge by large industries, which is estimated from FEEMA's database of industrial pollution load of major polluters.
- Pollution load discharged by small-scale treatment units for shopping centers, hospitals, schools etc, which is estimated from FEEMA's registration.

Non-Point sources

- Areal pollutant load reaching the river due to natural, agricultural and urban origin, which is estimated by the water quality data at Macacu River at FEEMA Monitoring location MC-967 which coincides with SERLA river gauging station 18.

(2) Estimation of Pollution Load to Reach to the Bay

The pollution load generated in the basin reaches the bay through the rivers where a fraction of the load will be mineralized or immobilized. The pollution load to reach to the Bay (the input of the water quality simulation model) is calculated by the following equations:

$$L_{RIVER} = L_{WWTP\text{-}Dis} + L_{POP\text{-}without\ sewerage} + L_I + L_{NI} + L_{AREAL}$$
$$L_{BAY} = L_{RIVER} * e^{K*t}$$

L_{RIVER} : pollution load to rivers.
$L_{WWTP\text{-}Dis}$: pollution load discharged from WWTP.
$L_{POP\text{-}without\ sewerage}$: pollution load from population not covered by sewerage system.
L_I : pollution load from large industries
L_{NI} : pollution load from small scale treatment units
L_{AREAL} : areal pollution load
T : average retention time for each river basin
K : mineralization rate

The resulting loads in 2000, 2010 and 2020 and for a series of scenarios are presented in *Table 2.1*.

(3) Estimation of Future Load Scenarios

A range of future load scenarios has been defined to be able to estimate the load giving a maximum concentration of 10 and 5 mg BOD/l in the bay and to be able to predict the future water quality after implementation of different plans for treatment. The plans in question are PDBG1, a Feasibility study and the Strategy Plan, as shown in *Table 2.1*.

2.4 WATER QUALITY SIMULATION MODEL (WQSM)

A mathematical model of the Guanabara Bay aquatic system has been developed. The model is utilized to assess the present state of Guanabara Bay with respect to certain water quality parameters and to assess the impact of selected priority sewerage projects within the Guanabara Bay Basin.

(1) Modeling Approach

The adopted modeling approach combines a hydrodynamic model and an advection-dispersion model with process models describing the biological-chemical processes affecting the water quality parameters. Furthermore a depth-integrated approach has been selected corresponding to mainly two-dimensional flow where stratification can be neglected.

For this purpose the MIKE 21 modeling system is applied. This modeling system is structured with the hydrodynamic (HD) module, the advection-dispersion (AD) module, the water quality (WQ) module and the eutrophication (EU) module. In *Figure 2.2* the inter-dependencies of the applied modules of the MIKE 21 are presented.

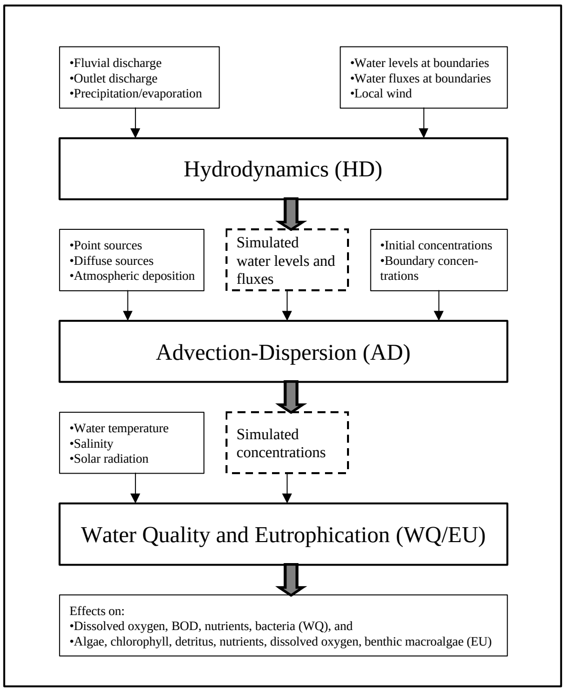

Figure 2.2 Inter-Dependency of Modules of Water Quality Simulation Model

(2) Hydrodynamic and Advection-Dispersion Modeling

The main characteristics of the model area and discretization are summarized below.

Model origin	23° 00' S; 43° 19' W
Model extension	33.1 x 39.8 km^2
Grid spacing (DX)	330 m
Grid dimensions	101 x 121
Time step (DT)	80 sec

The calibration of the hydrodynamic model and the advection-dispersion model has been finalized by tidal calibration and the salinity calibration.

(3) Eutrophication Modeling

EU module describes the carbon-C, nitrogen-N, phosphorus-P and oxygen-O_2 cycles in a eutrophicated water body. The model simulates the growth and fate of phytoplankton as function of loads of nutrients and dead organic material.

EU module includes components:

State variables	:	phytoplankton (C, N, P), detritus (C, N, P), zooplankton (C, N, P) inorganic N & P and oxygen.
Dominant Process	:	net primary production of phytoplankton and oxygen, death and mineralization of phytoplankton and detritus
Others	:	pool of detritus, picking up of inorganic nutrients (N &P) by phytoplankton growth, oxygen consumption by detritus mineralization.

The EU model is calibrated against measured values of BOD, chlorophyll, total N &P, inorganic N & P form seven monitoring stations in the Bay. *Figure 2.3* shows the calibration of BOD and Chlorophyll.

2.5 DATABASE DESIGN AND DECISION SUPPORT SYSTEM (DSS)

Database was built with following two purposes:

- To use as the input data source of the water quality simulation.
- To use as a tool of the decision support system

For the first purpose, Arcview based database was developed by incorporating spatial data and tabulated data of basin information such as topographic map, administration boundary, basin boundary, sewer district, landuse, population and location of major pollution sources, which determine the pollution load from the basin.

Then, DSS was developed based on the database to be equipped with following functions:

- GUI for viewing and editing the GIS database
- Calculation of pollution load and preparation of input data file for water quality simulation by MIKE 21
- Simulation of Guanabara Bay water quality by MIKE 21
- Display and evaluation of the results of water quality simulation based on pre-set criteria.

Table 2.1 Generated Load and Load to Bay (BOD_5 , TN & TP) Together with Total Population and Population Connected Treatment Plants for Present and Future Scenarios

Scenario	BOD Generated Ton/day	TN Generated Ton/day	TP Generated Ton/day	BOD to Bay Ton/day	TN to Bay Ton/day	TP to Bay Ton/day	Population No.	Population No. with sewage treatment
Water quality response on load to Bay								
Year 2000	474.8	93.9	22.9	275.4	72.0	18.4	8,290,200	2,058,900
Year 2000 80% BOD, 30 % TN, 50 % TP	474.8	93.9	22.9	64.0	52.7	9.6	8,290,200	
Year 2000 90% BOD, 35 % TN, 80 % TP	474.8	93.9	22.9	35.9	49.1	4.1	8,290,200	
Year 2000 90% BOD, 80 % TN, 80 % TP	474.8	93.9	22.9	35.9	16.4	4.1	8,290,200	
Year 2010	520.3	103.9	25.2	300.6	78.7	20.2	9,013,000	2,165,300
Year 2010 80% BOD, 30 % TN, 50 % TP	520.3	103.9	25.2	69.1	57.4	10.5	9,013,000	
Year 2010 90% BOD, 35 % TN, 80 % TP	520.3	103.9	25.2	38.5	53.5	4.5	9,013,000	
Year 2020	557.9	112.0	27.1	321.2	84.0	21.6	9,619,500	2,262,100
Year 2020 90% BOD, 35 % TN, 80 % TP	557.9	112.0	27.1	40.6	57.0	4.7	9,619,500	
Sector treatment								
Year 2000, E sector 80% BOD, 30 % TN, 50 %TP	474.8	93.9	22.9	253.4	70.3	17.8	8,290,200	
Year 2000, NE sector 80% BOD, 30 % TN, 50 %TP	474.8	93.9	22.9	253.8	69.3	17.8	8,290,200	
Year 2000, NW sector 80% BOD, 30 % TN, 50 %TP	474.8	93.9	22.9	232.3	67.9	16.8	8,290,200	
Year 2000, W sector 80% BOD, 30 % TN, 50 %TP	474.8	93.9	22.9	155.5	62.4	14.7	8,290,200	
PDBG1								
Year 2000 PDBG1	474.8	93.9	22.9	214.3	69.9	17.8	8,290,200	3,488,600
Year 2010 PDBG1	520.3	103.9	25.2	238.3	76.3	19.5	9,013,000	3,627,700
Year 2020 PDBG1	557.9	112.0	27.1	257.8	81.4	20.9	9,619,500	3,752,400
Feasibility study								
Year 2010 Feasibility Study	520.3	103.9	25.2	194.3	73.8	18.3	9,013,000	5,003,900
Year 2010 Feasibility Study, 90% BOD, 30% TN, 50% TP	520.3	103.9	25.2	181.3	72.9	17.2	9,013,000	5,003,900
Strategy Plan								
Year 2020 Strategy Plan	557.9	112.0	27.1	182.8	76.9	20.3	9,619,500	6,700,200
Year 2035 Strategy Plan, population year 2020	557.9	112.0	27.1	125.3	79.2	20.7	9,619,500	7,914,000
Year 2035 Strategy Plan, 90% BOD, 30% TN, 80% TP	557.9	112.0	27.1	125.3	76.0	10.8	9,619,500	7,914,000

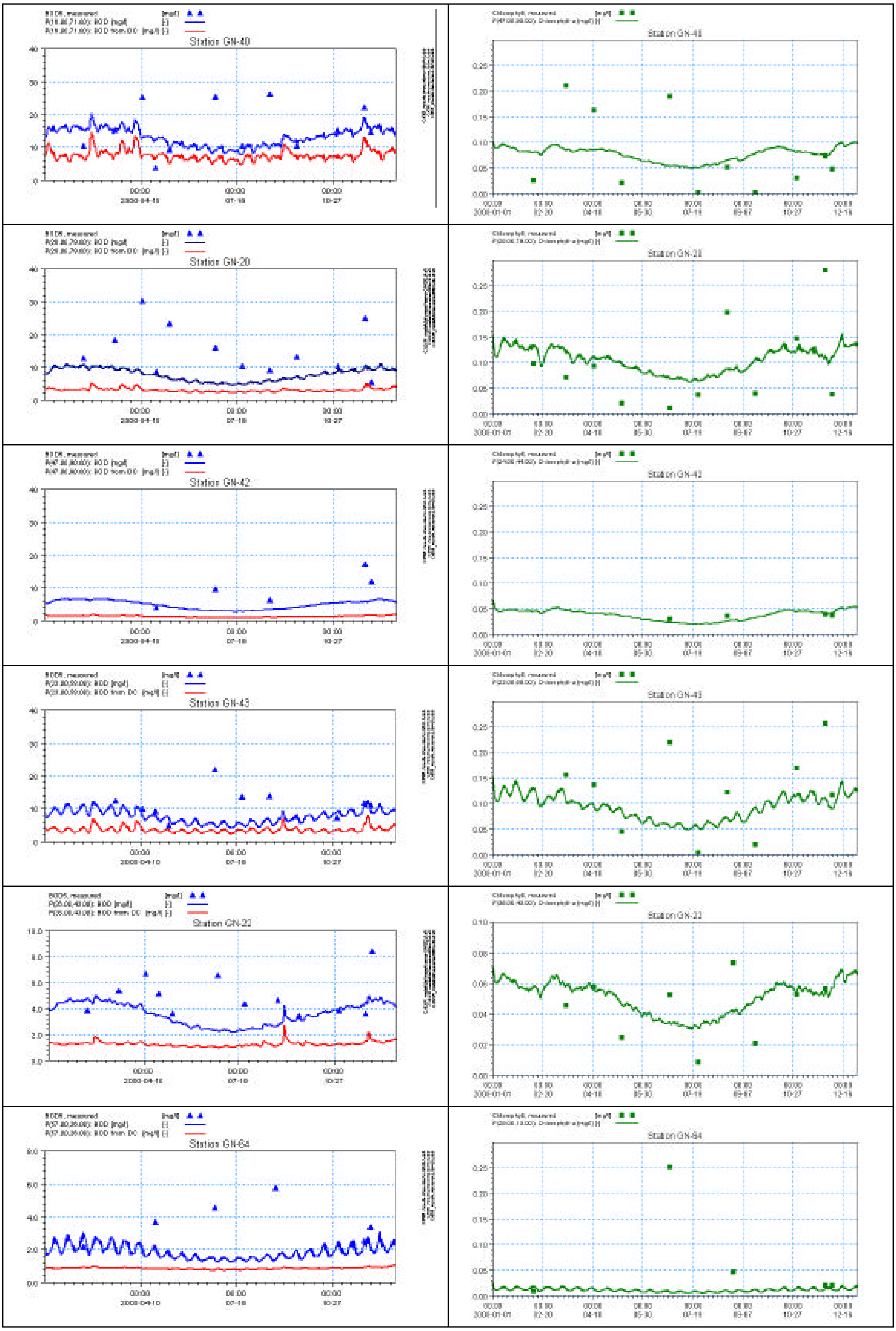

Figure 2.3 Measured and Simulated total BOD, BOD from Detritus (left), Chlorophyll (right)

3. REVIEW OF JICA MASTER PLAN

3.1 INTRODUCTION

"The Study on Recuperation of the Guanabara Bay Ecosystem" conducted by JICA in 1994 proposed a comprehensive water quality control plan (hereinafter referred to as "JICA M/P"). JICA M/P was reviewed to evaluate the effect of wastewater system development and to make the plan more effective by adjusting it to the present conditions that had considerably differed from the ones forecast in JICA M/P.

JICA M/P was reviewed to propose the strategy for the Guanabara Bay environment improvement with emphasis on the reality.

3.2 REVIEW OF SOCIO-ECONOMIC CONDITIONS

JICA M/P estimated the population based on the 1991 Census. This was reviewed using the population data of the latest Census 2000.

The present population (8,290,300 in 2000) in the basin is about 4% lower and, accordingly, the population in 2010 (9,013,026) is 6% lower when compared to the projections made in the JICA MP.

While JICA M/P estimated the economic growth rates by industrial classification, the economic growth rates were updated by this Study based on the Secretaria de Estado da Fazenda (SEF)'s forecast. SEF's forecast gives a rather low growth rate of 1.5 % from 2011 to 2017, looking at the slowdown of the petroleum industries that have been a driving force of the State's economic growth.

3.3 OUTLINES OF JICA M/P

(1) Targets

JICA M/P set target years for the improvement as follows:

Short term target	:	2000
Medium term target	:	2010
Long term target	:	Not specified

JICA M/P set a water quality target for each target year except for the water quality target of the long term plan. Instead, the Plan mentioned "a level where the ecosystem in Guanabara Bay will be recuperated" and this is supposed to correspond to the conditions prior to mid 1960's.

JICA M/P estimated allowable pollution load conditions to achieve the water quality target. Although the Plan did not directly indicate the required pollution load reduction, it was summarized based on the estimated data in the Plan as shown in *Table 3.1*.

Table 3.1 Target Pollutant Load Reduction Estimated in JICA M/P

Basin		Estimated Allowable [1] External Pollution Load to Achieve the Medium Term Water Quality Target (ton/year)	Estimated Pollution [2] Loads from each basin (ton/year)		Target Pollution Load [3] Reduction (ton/year)	
			2000	2010	2000	2010
Total	BOD	232	375.39	415.33	143.39	183.33
	T-P	13.2	23.25	25.69	10.05	12.49

Note: 1) and 2) are data estimated in JICA M/P. 3) is calculated in this Study (= 2) – 1))

(2) Countermeasures

To achieve the improvement targets, JICA M/P proposed an "Optimum Combination of Measures by Basin" (referred to as the "countermeasures"), which are summarized in *Table 3.2.*

Among the countermeasures, the development of wastewater treatment has already been realized as components of PDBG (Guanabara Bay pollution Abatement Program).

Table 3.2 Optimum Combination of Countermeasures to Achieve the Water Quality Targets in 2010 proposed in JICA M/P

Basin	Measures	
	Physical Measures	Non-physical Measures
Eastern	➢ Wastewater Treatment (Primary) ➢ Wastewater Treatment (Tertiary) ➢ Treatment of fish processsing industires	
Northeastern	➢ Stablization ponds	➢ Landuse control
Northwestern	➢ Wastewater Treatment (Primary) ➢ Stablization ponds ➢ Treatment of fish processsing industires	➢ Landuse control
Western	➢ Wastewater Treatment (Primary) ➢ Ocean outfall	➢ Improvement of sanitation service in Favelas
Islands	➢ Wastewater Treatment (Tertiary)	➢
All Basins		➢ Strengthening of industrial wastewater control

Source: JICA M/P

The estimated pollution load reduction is about a third of the required reduction. The remaining required reduction can be achieved by the proposed additional and supplemental measures. JICA M/P thus presented the conclusion as the "Optimum Combination of Measures by Basin".

3.4 Evaluation of JICA M/P Realizations

Only wastewater systems development (among the countermeasures proposed in JICA M/P) was realized as a component of PDBG. Although its effect has not yet to be known because of limited information, it is estimated that the target pollution reduction will be achieved after the completion of PDBG.

As for the water quality, since PDBG has not started full operations, no improvement effects have been observed yet. As shown in *Table 3.3,* in some monitoring points of the Bay water quality are far from reaching the target.

Table 3.3 Comparison of the Present Water Quality and the Short-Term Target

Monitoring Points	Present Water Quality[1)] (BOD mg/l)	Short-Team Target of JICA M/P (BOD mg/l)
GN-064	4.3	3
GN-022	5.6	5
GN-043	**12.7**	**10**
GN-040	**22.8**	**10**
GN-020	**19.3**	**8**
GN-042	**13.7**	**8**
GN-000	**7.6**	**5**
GN-026	5.9	5

Note: 1) Average of water quality monitoring by FEEMA, 2000

To estimate the effects of PDBG, the water quality was simulated through a water quality simulation model, by assuming the pollution load conditions after the completion of PDBG as shown in *Figure 3.1*. As a result, a considerable improvement effect is expected, but a severely polluted area remains in the westernmost part of the Bay.

3.5 STRATEGY OF IMPROVEMENT OF GUANABARA BAY ENVIRONMENT

(1) General

It was concluded that JICA M/P should be modified so that the targets and the countermeasures are consistent with each other and are still viable. The Study adopts the following strategies to make the JICA M/P viable:

- To position the wastewater system development as the main focus of the improvement measures.
- To reestablish the water quality targets to make them achievable through viable measures.

(2) Main Focus of the Improvement Measures

The Study adopts the wastewater system as the main focus of the measures to achieve water quality target because the wastewater system is the only method which effects that can be forecast quantitatively.

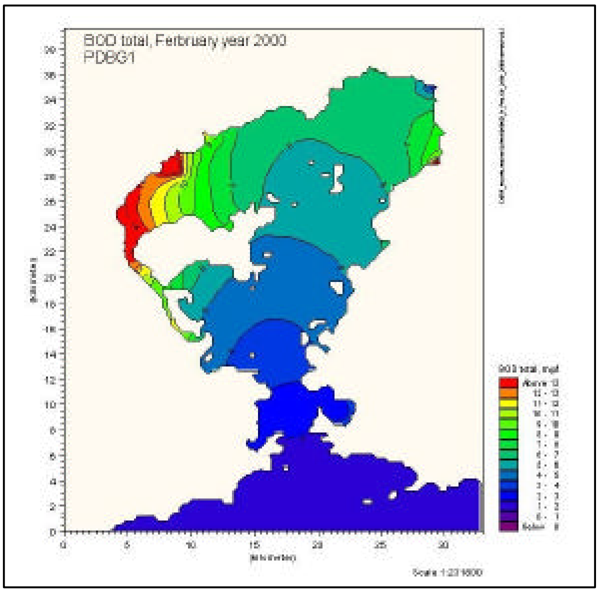

Figure 3.1 Result of Water Quality Simulation (Case:PDBGI, 2000)

"Plano Diretor de Esgotamento Sanitário da Região Metropolitana do Rio de Janeiro" (referred to as "CEDAE M/P") covers the whole metropolitan area of Rio de Janeiro, including the entire Guanabara Bay basin. CEDAE M/P covers the Guanabara Bay basin with 16 wastewater systems. Some of the 16 systems have been implemented as parts of PDBG. Consecutive implementation of CEDAE M/P could become the improvement measures of the Guanabara Bay environment.

Therefore, CEDAE M/P is reviewed in Chapter 5 of the Main Report. It is updated to meet the actual conditions and it is proposed in Chapter 6 of the Main Report as the strategy to achieve the water quality target and also the improvement of Guanabara Bay environment.

(3) Supplemental Improvement Measures

While the strategy to be proposed does not adopt countermeasures other than the sewerage to achieve the water quality target, it is still worth to consider such countermeasures to supplement environmental improvement by the sewerage development.

Sediment removal and garbage removal are recommended from the viewpoint of improving the unpleasant conditions,andmangrove preservation and wetland conservation are recommended as supplemental measures to reduce the pollutant load from the basin, as well as for the purpose of nature conservation.

(4) Re-establishment of Water Quality Target

The removal of the extremely unpleasant conditions existing in the Bay should have higher priority than the restoration of the utility value of the Bay. The improvement target is studied by evaluating the viability and is reestablished based on the balance between the target from the present bay conditions and the viability of the wastewater system development. New targets were established as shown in *Table 3.4.*

Table 3.4 New Water Quality Target and Target Year

Target	Description	Target Year
Short-term	Removal of obnoxious conditions BOD less than 10 mg/l at all the water quality monitoring points in the Bay.	2010
Middle-term	BOD less than 5 mg/l in all areas except western areas.	2020
Long Term	Water Quality Classification DZ105.	Not specified

3.6 CONCLUSION

By reviewing JICA M/P, the status of the realization of the Master Plan is as follows:

- JICA M/P proposed to improve the Guanabara Bay environment by the Combination of Countermeasures which consist of wastewater system development and other supplemental improvement measures.
- It planned to reduce a third of the pollutant load reduction required to achieve the target by the wastewater system development and to reduce the remaining two thirds by supplemental measures.
- Since JICA M/P was carried out, only the wastewater system development countermeasure has been realized as one of the components of PDBG. The scope of the wastewater system development of PDBG has already exceeded the one proposed by JICA M/P.
- However, no improvement effect has been recognized yet because the PDBG project was not completed. Moreover, it is forecast that on-going wastewater system development would not achieve the improvement target proposed in JICA M/P as the “short term target”.

Based on the above observation, the Study concludes a strategy for Guanabara Bay environment improvement as follows:

- Since the supplemental measures proposed in JICA M/P are not quantitatively appraisable in terms of improvement effect, and thus can not be components of a plan subject to be realized, the Study adopts further wastewater system development as the major means of the improvement.
- Since CEDAE M/P exists and some of it has been implemented by PDBG, the Study reviews CEDAE M/P and consequently proposes a strategy for the wastewater system development to improve the Guanabara Bay environment.
- On condition that a principal improvement measure adopts wastewater system development, water quality target is reestablished based on technical viability.
- As a result, Water Quality Classification of Guanabara Bay DZ 105 has been adopted as the long-term nonbinding target without specific target year and removal of the obnoxious conditions (represented by “BOD less than 10 mg/l any place in the Bay) has been adopted as the short term target for 2010. The middle-term target for 2020 has been established to be achieved by further improvement of the Bay environment after the short-term target is achieved.

4. Review of CEDAE Master Plan

"Plano Diretor de Esgotamento Sanitário da Região Metropolitana do Rio de Janeiro, Agosto 1994" (Sewerage Master Plan in Rio de Janeiro Metropolitan Region; referred to as "CEDAE M/P")" is reviewed to update the design basis and to make it the main focus of the Guanabra Bay improvement measures.

For the purpose of the Guanabara Bay wastewater improvement plan, the scope of the CEDAE M/P review is limited to the 16 sewer systems located within the Guanabara Bay Basin area.

CEDAE master plan has set its target year by year 2035, however, the study team revised its target year to year 2020.

4.1 Overview

CEDAE MP divided the whole area into 32 sewer systems, out of which 16 sewer systems are located within the Guanabara Bay basin (Study Area). Some systems have more than one treatment plant as shown in *Figure 4.1*.

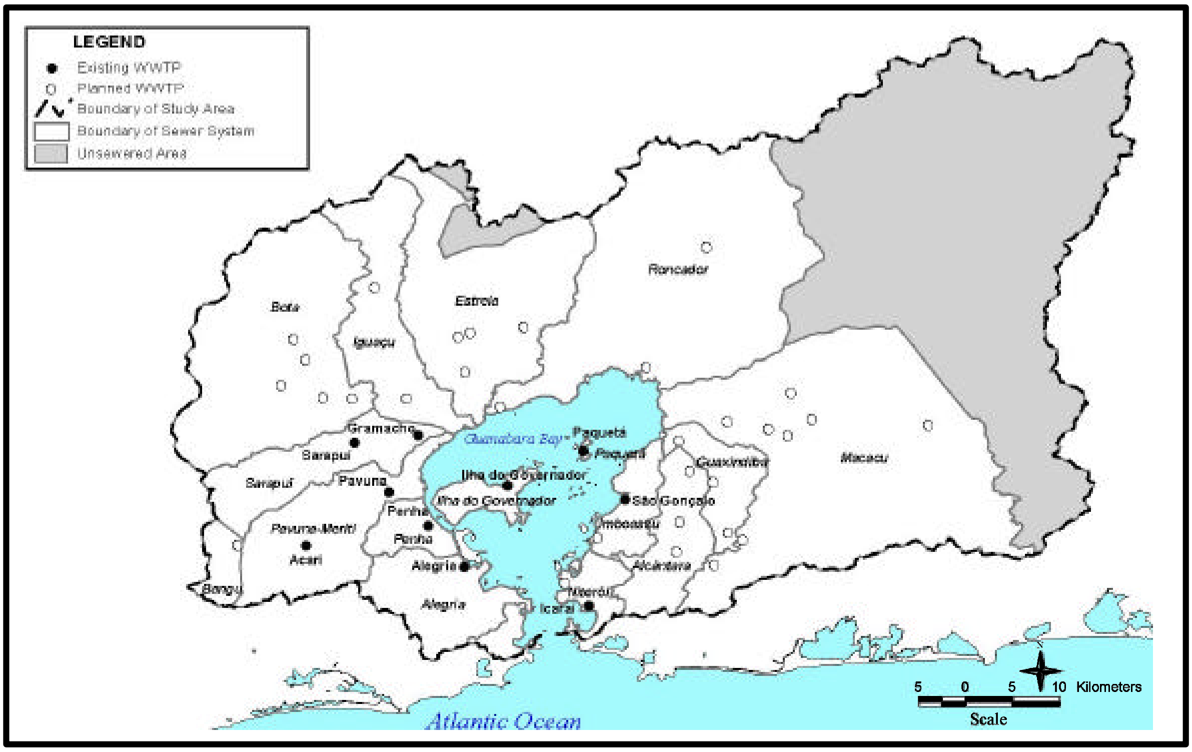

Figure 4.1 Sewer Systems and Wastewater Treatment Plants in CEDAE M/P

4.2 Planning Basis

(1) Population

The sewer service populations in sewer districts/systems were estimated in the CEDAE M/P on the basis of the 1991 population census data, and forecast for every five-years from 1993 through 2035.

Assuming that 90% of inhabitants will be served by sewers, the 2000, 2020 and 2035 census-based sewered populations are estimated and compared with the CEDAE M/P estimates as shown in *Table 4.1*.

Table 4.1 Sewer Service Populations by M/P and 2000 Census Data

Estimate Bases	2000	2020	2035	Remarks
The M/P population (1994)	7,367,923	8,371,675	9,695,403	In Guanabara bay basin area
2000 census-based population(*)	7,290,000	8,477,370	-	Population in administrative units x 0.9

Note : (*) This Study

It appears that the sewer service populations estimated in the CEDAE M/P are generally in accordance with that in the 2000 census data and those estimated based on this last census.

(2) Wastewater Characteristics

The CEDAE M/P estimated wastewater flow rates for each sewer district for every five-years until 2035. The domestic wastewater generation rates were estimated based on the annual average water consumption rates per capita per day, assuming that 80% of the consumed water would flow into it; this is termed "average daily flow rate." The industrial wastewaters are assumed to be included in the domestic wastewater.

The CEDAE M/P estimated the average daily per capita wastewater flow rates for sewer district groups ranging between 200 and 400 Lpcd.

Infiltration to the sewer was assumed to be 0.05~1.0 L/s km of sewer length.

The major parameters for the wastewater pollutant loads, in terms of BOD_5 and SS, were set as shown in *Table 4.2*.

Table 4.2 Design Wastewater Qualities

Degree of WWTP Processes	BOD (mg/L)	SS (mg/L)
WWTP influent	220	200
Secondary effluent	25	30

4.3 DISTRICTS BOUNDARIES AND WASTEWATER COLLECTION SYSTEM

Because of the changes that have actually taken place in the population distributions and urban developments, parts of the originally planned sewer district boundaries, WWTP site locations, etc. had to be modified. Some sewer districts were either separated or integrated in the course of implementation.

Wastewater collection system was planned to convey the maximum hourly flow that is 1.8 times the daily average flow. *Table 4.3* summarizes populations and flow rates by sewer district.

Table 4.3 Populations and Wastewater Flow Rates by Sewer District (2020)

Sewer System	WWTP	Sewered Population (person)	Average Daily Wastewater Flow		Maximum Hourly Wastewater Flow	
			Per capita flow (Lcd)	Wastewater flow rate (L/s)	Per capita flow (Lcd)	Wastewater flow rate (L/s)
Alegria	Alegria	1,304,400	300	4,529	524	7,911
Penha	Penha	580,800	235	1,580	407	2,736
Pavuna- Meriti	Pavuna	1,029,600	240	2,860	416	4,957
	Acari	390,200	240	1,084	416	1,879
	Sub-Total	1,419,800		3,944		6,836
Sarapuí	Gramacho	68,400	235	186	407	322
	Sarapuí	825,900	240	2,294	416	3,977
	Sub-Total	894,300		2,480		4,299
Bangu	Bangu	363,200	240	1,009	416	1,749
Bota	Iguaçu 02	126,000	240	350	416	607
	Madame	11,400	240	32	416	55
	Velhos	35,600	250	103	434	179
	Bota	801,500	255	2,366	443	4,110
	Joinville	119,100	220	303	380	524
	Others	-				
	Sub-Total	1,093,600		3,154		5,475
Iguaçu	Xerém	10,500	220	27	380	46
	Campos Elíseos	237,200	220	604	380	1,043
	Others	-				
	Sub-Total	247,700		631		1,089
Estrela	1	88,600	245	251	425	436
	2	135,100	250	391	434	679
	3	108,400	250	314	434	545
	4	42,200	245	120	425	208
	Others	-				
	Sub-Total	374,300		1,076		1,868
Roncador	1	17,900	220	46	380	79
	2	72,800	225	190	389	328
	3	20,100	220	51	380	88
	Others	-				
	Sub-Total	110,800		287		495
Macacu	1	80,600	225	210	389	363
	2	61,100	225	159	389	275
	3	31,100	225	81	389	140
	4	26,200	225	68	389	118
	5	36,000	225	94	389	162
	6	44,100	225	115	389	199
	7	19,000	225	49	389	86
	8	26,600	225	69	389	120
	Others	-				
	Sub-Total	324,700		845		1,463
Guaxindiba-	1	162,500	225	423	389	732
	2	38,000	225	99	389	171
	3	12,600	220	32	380	55
	Others	-				
	Sub-Total	213,100		554		958
Alcântara	Trindade	156,900	220	400	380	690
	Alcântara	91,400	220	233	380	402
	Jardim Nazaré	114,700	220	292	380	504
	Others	-				
	Sub-Total	363,000		925		1,596
Imboassú	São Gonçalo	235,000	280	762	488	1,327
	Bomba	40,200	230	107	398	185
	Others	-				
	Sub-Total	275,200		869		1,512
Niterói	Toque Toque	182,000	250	527	434	914
	Icaraí	182,000	255	537	443	933
	Sub-Total	364,000		1,064		1,847
Ilha do Governador	Ilha do Governador	203,000	220	517	380	893
Paquetá	Paquetá	3,300	705	27	1,253	48
Others		-				
Total		8,135,200		23,491		40,775

Note: Population distributions are those updated based on the 2000 population census data.
Other figures are in principle those used in the Master Plan.
Population in 2020 is the basis for planning and does not necessarily mean that all the facilities will be constructed by 2020.

4.4 WASTEWATER TREATMENT PLANTS (WWTPS)

The amount of wastewater flowing into WWTPs was assumed to be daily average flow.

The M/P calculated WWTP capacities based on the future sewered population, wastewater quantity and qualities forecast for the year 2035. The target year was changed to 2020 in the review.

Sludge is to be thickened and dewatered by mechanical dewatering equipment in each WWTP. The moisture contents of dewatered sludge is expected to be 75%.

4.5 CONSTRUCTION COSTS

The costs in US$ estimated in the M/P are apparently high when converted into Brazilian Real using the present exchange rate. The major reason for this is probably because the denomination took place in July 1994. In addition, no economy of WWTP scale was taken into account in the M/P.

All the necessary costs are estimated based on mid-2002 price levels in the review. The capital costs consist of those for sewers, pumping stations and WWTPs construction, and land acquisition. The currency applied is US Dollar at the following exchange rates:

US$ 1 = R$ 2.9 = ¥120

In the review, the indirect costs other than direct costs are added since they were not considered in the M/P.

(1) Sewers

The costs in the M/P were estimated in US Dollars and seem to be very high as compared with the actual construction costs. The ratio is at around 50 %, but 70 % is applied for the cost estimates for safety reasons.

As for Sarapui, Pavuna, Acarí and Bangu sewer districts, unit construction cost per hectare of sewer district is applied to the areas except for those constructed under PDBG. The unit construction cost is:

Cs = US$ 28,000/ha   Cs: Sewer Construction Cost (US$)

(2) Pumping Stations

70 % of the construction costs in the M/P is applied for the construction of pumping stations except for Sarapui, Pavuna, Acari and Bangu Sewer Districts. In these districts, sewer construction costs are considered to have already included those for pumping stations.

(3) WWTPs

The cost-capacity formula for a complete conventional activated sludge treatment plant is expressed in the form:

$$Cw = 260\ Q^{0.7229}$$

where,

C = Capital costs of WWTP, in US$1,000
Q = wastewater flow rate, in L/s

(4) Land acquisition for WWTPs

Land requirement for the conventional activated sludge plant is:

$$A = 1{,}855Q^{0.4864}$$

where

A = area required, in m^2

Q = flow rate, in L/s

The current land prices for the WWTP sites range between US$ 3 and 12 per m^2. For the master plan purpose, the land acquisition cost is estimated at US$15/$m^2$ for Alcântara and at US$10/$m^2$ for other WWTPs.

4.6 O/M COSTS

O/M costs were not calculated in the M/P. In the review, the O/M costs are supposed to be 5% of the direct construction costs.

4.7 CONCLUSIONS

The major points of conclusion are as follows:

- The comparison of population estimates by the CEDAE M/P and by this study indicates that the population within the sewer districts has moderately increased in the last decade, but in some built-up central urban districts the population growth rates have either stabilized or are slightly declining.
- The wastewater quantities and characteristics estimated in the CEDAE M/P are apparently within the medium range that may not cause severe hydraulic/pollutant overloading, provided that the facilities were designed and constructed according to the criteria proposed in the CEDAE M/P.
- The proposed WWTPs with conventional or modified activated sludge process are capable of producing stable and high quality effluents if properly operated, resulting in a significant reduction of the organic loads inflowing to the Bay.
- Sewers are installed under public roads in general. CEDAE M/P proposed sewer installations along the rivers even where no roads are available. In such cases, the collection system plans have to be reinvestigated and/or sewer district boundaries have to be modified.
- Some of the WWTPs sites have already been urbanized and some site locations could not be identified, because these areas have been neither secured nor purchased. Alternative WWTP sites should be found and secured.