2.2 SOCIOECONOMIC CONDITIONS

2.2.1 ADMINISTRATIVE SETTING

According to the Brazilian Constitution, Brazil is a Federative Republic comprising the Union of 26 Member States with 5561 municipalities and the Federal District (Brasilia), all autonomous and independent. The Federal Government is made up of executive, legislative and judicial branches, all three independent one from another.

The states also have executive, legislative and judicial branches, organized according to each state constitution, consisting of an elected governor, a body of state legislators and the state tribunals respectively.

The basic public administrative body in the country, however, is the municipality. The functions and competencies of the municipalities are based on municipal "organic law", written in accordance with the state and the federal constitutions. It is important to remark that there is no hierarchy of powers amongst the states and the municipalities, but only a division of competencies.

States have armed police, but municipalities only unarmed guards.

Regarding the protection of the environment, all three types of government bodies (the union, the states and the municipalities) have the right to legislate concurrently.

The State of Rio de Janeiro is organized administratively according to the State Constitution, with a legislative body, a judicial body and the executive body.

The executive body is headed by the governor who appoints the cabinet, today composed of 26 ordinary secretaries. The ordinary secretaries are:

- Executive Secretary of the Governor's Cabinet
- State Secretary of the Civil Cabinet
- State secretary of Government
State Secretary of Governmental Integration
- State Secretary of Economic Development and Tourism
- State Secretary of Administration and Reorganization
- State Secretary of Planning, Control and Management
- State Secretary of Social Action
- State Secretary of Agriculture, Food Supply, Fishing and Development of the Countryside
- State Secretary of Finances
- State Secretary of Science and Technology and Innovation
- State Secretary for Development of the "Baixada Fluminense"
- State Secretary of Civil Defense
- State Secretary of Energy, Navy Industry and Petroleum
- State Secretary of Housing
- State Secretary of the Treasury
- State Secretary of Justice and Citizen Rights
- State Secretary of Public Safety
- State Secretary of the Environment and Urban Development
- State Secretary of Transport
- State Secretary of Education

- State Secretary of Culture
- State Secretary of Health
- State Secretary of Labor
- State Secretary of Penitentiary Administration
- State Secretary of Sports

In addition to the above, there are two judicial institutions holding the status of state secretaries, the Public Defense Office and the General Advocacy.

Regarding the setting of policies and execution of actions on sanitation and environmental control, the secretaries involved and subordinated institutions are:

- State Secretary of the Environment and Urban Development responsible for: (1) CEDAE State Company of Water and Sewage (Compania Estadual de Aguas e Saneamento), (2) PDBG Program for Pollution Control of Guanabara Bay (Programa de Despoluição da Baia de Guanabara), (3) FEEMA State Foundation of Environmental Engineering, (4) SERLA State Superintendence of Rivers and Lagoons, and (5) PROSANEAR Program.
- Executive Secretary of Government Integration (SEIG) Comprised of the "Nova Baixada" program and for the Department of Roads, responsible for the civil works in the same program.

2.2.2 POPULATION

Table 2.1 shows population, area and population density of 16 municipalities in Guanabara Bay basin in 2000. In 2000, the total population of 16 municipalities was about 11 million, and occupied 75% of the Rio de Janeiro State (RJ State).

Table 2.1 Population, Area and Population Density of 16 Municipalities in 2000

	Population (persons)	Share in RJ State (%)	Share in Total (%)	Area (km^2)	Population density ($persons/km^2$)
Rio de Janeiro	*5,851,914*	*40.7*	*54.4*	*1,205.8*	*4,853.1*
Belford Roxo	433,120	3.0	4.0	79.0	5,482.5
Duque de Caxias	770,865	5.4	7.2	468.3	1,646.1
Guapimirim	37,940	0.3	0.4	361.9	104.8
Itaborai	187,127	1.3	1.7	429.2	436.0
Magé	205,699	1.4	1.9	386.8	531.8
Nilópolis	153,572	1.1	1.4	19.4	7,916.1
Niterói	*458,465*	*3.2*	*4.3*	*134.5*	*3,408.7*
Nova Iguaçu	*750,487*	*5.2*	*7.0*	*520.5*	*1,441.9*
Mesquita	*164,879*	*1.1*	*1.5*	*41.6*	*3,963.4*
São Gonçalo	889,828	6.2	8.3	248.7	3,577.9
São João de Meriti	449,229	3.1	4.2	34.7	12,946.1
Tanguá	26,001	0.2	0.2	142.8	182.1
Petrópolis	*286,348*	*2.0*	*2.7*	*797.1*	*359.2*
Cachoeiras de Macacu	*48,460*	*0.3*	*0.5*	*956.8*	50.6
Rio Bonito	*49,599*	*0.3*	*0.5*	*463.1*	107.1
Total of Municipalities	10,763,533	74.9	100.0	6,290.2	1,711.2
RJ State	14,367,083	100.0	-	43,864.3	327.5
Brazil	170,143,121	-	-	8,514,213.5	20.0

Note: In municipalities written in italic figure, parts of territory are included in the Study Area
Source: Informações Gerais Estado do Rio de Janeiro, CIDE
Brasil em números 2001, IBGE

Population of the Rio de Janeiro Municipality (RJ Municipality) was 5.9 million, and occupied 55% of the 16 municipalities. São Gonçalo (8%), Duque Caxias (7%), and Nova Iguaçu (7%) followed it. Some municipalities which are located on the west side of Guanabara Bay had high population density. Especially the three municipalities, São João de Meriti (12,946 persons/km^2), Nilópolis (7,916 persons/km^2) and Belford Roxo (5,482 persons/km^2), had higher population density than that of the Rio de Janeiro Municipality (4,853 persons/km^2).

Table 2.2 shows changes of the population growth rate in 16 municipalities. Population of the 16 municipalities is still growing, but average annual growth rates have been decreasing since 1970s. In 1940, total population of the 16 municipalities was 2.3 million. It increased three times in 30 years (1940-1970), but increased only 1.5 times in next 30 years (1970-2000). Such change is the same as for RJ State and Brazil.

The population growth in 16 municipalities is much greater than that of the RJ State. Average annual population growth rate in 16 municipalities was greater than that of RJ State until 1970s, but the growth rate in RJ State has been greater than that of 16 municipalities since 1980s.

Table 2.2 Average Annual Population Growth Rate in 16 Municipalities

	1950-60	1960-70	1970-80	1980-91	1991-2000
Rio de Janeiro	*3.36*	*2.54*	*1.82*	*0.67*	0.73
Belford Roxo	11.91	9.00	5.01	2.25	2.05
Duque de Caxias	10.17	5.88	2.93	1.36	1.61
Guapimirim	2.08	5.30	4.83	1.73	3.43
Itaborai	5.08	5.49	5.79	3.48	3.32
Magé	5.42	6.93	3.82	1.21	2.57
Nilópolis	7.60	2.86	1.70	0.38	-0.32
Niterói	*2.80*	*2.82*	*2.05*	*0.86*	0.56
Nova Iguaçu	*9.34*	*7.13*	*4.03*	*1.48*	1.96
Mesquita	*7.39*	*4.76*	*2.95*	*1.15*	1.67
São Gonçalo	6.89	5.67	3.64	2.18	1.48
São João de Meriti	9.63	4.66	2.81	0.60	0.60
Tanguá	-0.94	1.51	5.17	1.94	1.25
Petrópolis	*3.51*	*2.58*	*2.56*	*0.98*	1.28
Cachoeiras de Macacu	*5.22*	*2.25*	*0.60*	*1.04*	2.10
Rio Bonito	*0.97*	*2.20*	*1.52*	*1.10*	1.05
Total of 16 municipalities	4.31	3.43	2.38	1.00	1.07
RJ State	3.68	2.97	2.30	1.15	1.28
Brazil	3.06	2.87	2.48	1.93	1.65

Note: Municipalities in Italic Figures means parts of territories are included in the Study Area
Source: Informações Gerais Estado do Rio de Janeiro, CIDE
Brasil em números 2001, IBGE
Annual Statistic Yearbook 1999, IBGE

The RJ Municipality experienced an annual population growth of about 3% which was higher than a national population growth rate in 1940s and 50s. But average annual growth rate in recent 11 years (1990-2001) declined to 0.73%. Some municipalities located to the north of the RJ Municipality also experienced population growth more than 10% in 1940s and 50s. But the recent annual growth rate in such municipalities also dropped to 1 to 2%.

Guapimirim, Itaborai and Magé municipalities, in which population density is still low and face Guanabara Bay, are now having high population growth rates of 2.5 to 3%.

2.2.3 ECONOMIC ACTIVITIES

Table 2.3 shows Nominal Gross Regional Domestic Products (GRDP) in the RJ State and the 16 municipalities. GRDP of the 16 municipalities totaled R$109 billion, and accounted for 75.7% of the RJ State and 10.0% of Brazil. Among the 16 municipalities, the largest GRDP, which was 76%, was generated in the RJ Municipality, followed by the municipalities of Duque de Caxias (6.1%), Niterói (4.1%), São Gonçalo (3.4%) and Nova Iguaçu (2.9%). The shares of the other municipalities were quite low.

Table 2.3 GRDP and GRDP per Capita in 2000

	GRDP (R$1,000)	Share in RJ State (%)	Share in 16 municipal-ities (%)	GRDP per Capita (R$)
Rio de Janeiro	*82,647,268*	*58.8*	*75.7*	*14,123*
Belford Roxo	1,436,188	1.0	1.3	3,316
Duque de Caxias	6,672,459	4.7	6.1	8,656
Guapimirim	154,814	0.1	0.1	4,080
Itaborai	701,609	0.5	0.6	3,749
Magé	633,267	0.5	0.6	3,079
Nilópolis	661,760	0.5	0.6	4,309
Niterói	*4,511,258*	*3.2*	*4.1*	*9,840*
Nova Iguaçu	*3,171,338*	*2.3*	*2.9*	*4,226*
Mesquita	*343,717*	*0.2*	*0.3*	*2,085*
São Gonçalo	3,696,020	2.6	3.4	4,154
São João de Meriti	1,831,941	1.3	1.7	4,078
Tanguá	109,940	0.1	0.1	4,228
Petrópolis	*2,172,852*	*1.5*	*2.0*	*7,588*
Cachoeiras de Macacu	*173,222*	*0.1*	*0.2*	*3,575*
Rio Bonito	*234,459*	*0.2*	*0.2*	*4,727*
Total of 16 municipalities	109,152,112	77.7	100.0	10,141
RJ State	140,496,766	100.0	-	9,779
Brazil	1,086,700,000	-	-	6,387

Note: Municipalities in Italic Figures means parts of territories are included in the Study Area
Source: Informações Gerais Estado do Rio de Janeiro, CIDE
International Financial Statistics (IFS), International Monetary Fund (IMF)

Table 2.4 shows performance of Real GRDP of the RJ State and Brazil since 1994. Average annual growth rate of the RJ State is 4.09%, 1.48% higher than that of Brazil. Annual growth rate of the RJ State since 1994 is higher than that of Brazil, except in 1996 and 1997.

Table 2.4 Real GRDP of RJ State and Real GDP of Brazil

	Unit	1994	1995	1996	1997	1998	1999	2000
Real GRDP index of RJ State	1995=100	95.17	100.00	107.17	109.00	112.03	115.61	121.05
Annual growth rate	%	5.08	7.17	1.71	2.78	3.20	4.71	5.08
Average annual growth rate	%	-	-	-	-	-	-	4.09
Real GDP index of Brazil	1995=100	95.90	100.00	102.70	106.00	106.30	107.10	111.90
Annual growth rate	%	-	4.28	2.70	3.21	0.28	0.75	4.48
Average annual growth rate	%	-	-	-	-	-	-	2.61

Source: Anuário Estatísco do Estado do Rio de Janeiro 2001, CIDE, FIS, IMF

In 1998 and 1999, the Brazilian economy experienced recession which was caused by a financial shock from the Asian Financial Crisis, and the economy had nearly zero GDP growth rate. RJ State economy, however, didn't experience such economic recession, and maintained a high GRDP growth rate at that time. The reason for such a strong economic performance comes from good activity of the petroleum industry[1]. *Table 2.5* shows production index of the mining (mainly representing the petroleum industry) and manufacturing industries in the RJ State. While the production index of mining and manufacturing increased by 31% in 10 years, most of the increase came from an increase of mining production (126%). The RJ State and some municipalities received benefit as royalty revenue from petroleum. In 2001, royalty of RJ State and some municipalities amounted to R$1,812 million, of which R$1,078 million is revenue for the State Government.

On the other hand, manufacturing production decreased 9% at the same time. Moreover, the sales index (retail trade in the metropolitan area) dropped 30% in 1990s. Only petroleum industry led the RJ economy in 1990s.

Table 2.5 Indexes of Mining and Manufacturing and Retail Trade

	Unit	1998	1999	01/2000	02/2000	03/2000
Production index						
Mining and Manufacturing	Average of 1991 = 100	118.65	125.83	121.97	130.57	131.14
Mining	Average of 1991 = 100	177.14	207.80	223.94	233.65	226.55
Manufacturing	Average of 1991 = 100	94.60	92.12	80.04	88.17	91.89
Sales index						
Retail trade in metropolitan area (16 municipalities)	01/1995=100	77.295	74.85	68.92	68.84	70.57

Source: A Economia Fluminense (CD-ROM), CIDE

2.2.4 FINANCIAL CONDITIONS OF RIO DE JANEIRO STATE

(1) Financial Responsibility Law

The Financial Responsibility Law, approved by the Congress in May 2000, sets budgetary planning, execution and reporting. The law is applied to all levels of government, and it regulates the following matters relating to the state and municipality governments:

- The Federal Government shall withhold federal transfers to the states and municipalities that do not effectively collect their own taxes.
- Permanent spending mandates shall be created without corresponding increase in permanent revenues or cuts in other permanent spending items.
- Annual credit disbursements cannot exceed capital spending.
- Personnel spending by the state and municipal governments are limited 60% of net revenue, and the law sets separate ceilings on the personnel spending of the executive, legislative and judicial branches. If state and municipal governments cannot stay within the limit, they cannot receive transfers from the Central Government and credit guarantees from the federal government.
- Each government has to prepare and disclose a balance sheet (every two months) and fiscal report (every four months).

State and municipal governments have to conduct orderly budget operations under the supervision of the Federal Government.

(2) Public Finance of the State Government of Rio de Janeiro

Table 2.6 shows revenue and expenditure of the RJ State from 1998 to 2001. The State Government had been reducing budget deficit until 2000, and the deficit recorded R$-605

[1] According to the Report, “BOLETIM ECONÔMICO DA SEF”, prepared by Secretaria de Estado de Fazenda, production of petroleum and LGN in RJ State occupies 79% of production in Brazil.

million. However it increased to R$-1,264 million, and the proportion of budget deficit to GRDP recorded - 0.7% in 2001

Tax revenue accounted for 60% of the total revenue in three years (1998-2000). ICMS (value added taxes on sales and services) was the most important component in taxation, and accounted for 90% of the tax revenue. Transfer from the Federal Government increased from 11% in 1999 to 20% in 2000. Otherwise State Treasure Bonds decreased from 18% in 1999 to 0 in 2000.

Table 2.6 Public Finance of RJ State

	1998	1999	2000	2001
Revenue (R$ 1000)	11,460,726	11,979,901	15,950,011	16,694,253
Of which				
Tax	59.6	64.4	55.3	60.6
ICMS	54.7	60.0	50.7	55.3
Transfer	15.5	11.0	20.1	9.8
Capital Revenue	22.6	21.5	1.9	3.0
State Treasure Bonds	14.5	17.9	0.0	0.0
Expenditure (R$ 1000)	13,820,065	13,052,217	16,555,766	17,958,649
Of which				
Current Expenditure	75.7	76.0	88.6	87.5
Transfer	41.8	36.9	47.2	47.5
Charges due to Debt	3.7	2.7	5.0	6.6
Capital Expenditure	24.3	24.0	11.4	12.5
Investment	10.6	5.1	9.3	10.0
By State Government Secretariat				
State Secretariat of Sanitation and Water Resources	0.0	1.4	0.7	7.0

Source: Anuário Estatísco do Estado do Rio de Janeiro 2001, CIDE (Unit: percent)

In the distribution of government secretariats, the share of SEMADUR (State Secretariat of Environment and Urban Development) increased rapidly from 1% to 7.0% in 2002. It seems to have risen due to disbursement for sewerage development in PDBG.

Dollar-Real exchange rate, percentage of public sector2 primary balance to GDP, net public debt ratio, and gross external public debt ratio. The percentage of Net Public Debt in GDP has been increasing consistently, from 34.4% in 1996 to 58.9% in 2002.

One of the reasons of such rapid increase comes from depreciation of the Brazilian Real against US Dollar. The value of Real has dropped 42% in five years, from US$1=R$1.005 in 1996 to US$1=R$2.358 in 2001. As shown in *Table 2.7*, the Gross External Public Debt ratio has increased from 10.6% in 1997 to 17.7% in 2001 in accordance with the depreciation of the Real.

Table 2.7 Changes of Statistics on Financial Sustainability

	1996	1997	1998	1999	2000	2001	2002
Real GDP growth rate	2.7	3.3	0.1	0.8	4.4	1.4	1.5
Dollar-real exchange rate	1.005	1.708	1.161	1.815	1.357	2.358	2.930
Primary Balance of Public Sector	0.4	-1.0	0.0	2.2	3.5	3.7	3.9
Net Public Debt ratio	34.4	35.2	43.4	49.4	49.3	53.3	58.9
Gross External Public Debt ratio	-	10.6	12.4	17.1	15.9	17.7	24.7

Source: Press Releases on the Article IV consultation, IMF (Unit: %)
Banco Central do Brasil

[2] Primary Balance is a budget balance of which interest payment in expenditure, and public debt in revenue is excluded.

Primary balance recorded a surplus in recent years, and fiscal deficit was not a cause of the increase of Net Public Debt. Primary Balance which is a basis for policy discussion between the Federal Government and the IMF had been increasing gradually, and it exceeded targets decided by the agreement between the two organizations.

The Central Bank of Brazil published a report, entitled "Are there Reasons to doubt Fiscal Sustainability in Brazil?" in June 2002. According to this report, another main reason of debt increase is accumulation of hidden liabilities in the state companies and state banks, etc. The report estimates that Net Public Debt-GDP ratio was 56.0% in 2002. However if exchange rate were constant, it would be 42.5 percent, and if there were no hidden liabilities, it would be 43.2 percent, according to the report.

Table 2.8 shows figures on Public Debt in countries with the same development-level as Brazil. The table shows that level of Net Public Debt-GDP ratio in Brazil is not as high as other countries, and annual public finance is well managed. Net Public Debt-GDP ratio in Brazil is almost the same level as Malaysia, and Net Public External Debt is also almost the same level as Mexico until 2013. But GDP growth rate is different. Brazil economy is weak, and the economy did not experience GDP growth over 5 percent in recent years. This is the reason why Public Debt is one of the major economic issues in Brazil.

Table 2.8 Public Debt in the Upper-Middle Income Countries* in 2000

	GDP growth rate	Net Public Debt-GDP ratio	Net Public External Debt-GDP ratio
Argentina	1.3	49.4	-
Malaysia	8.3	61.4	-
Mexico	6.6	-	15.9

Source: Press Releases on Article IV consultation, IMF (Unit: percent)
Note: * Classified by the World Bank

In order to solve the Public Debt difficulties, it is necessary to carry out three policies. The first one is to maintain a primary balance surplus. The Federal Government submitted the Budget Guideline Law to the Congress. The law aims to increase the medium term primary surplus to 4.25% of GDP from 3.9% in 2003[4]. The current administration also submitted laws about pension and tax reform to the Congress. If the laws were approved, it would contribute to reducing fiscal imbalances and removing inefficiencies that hinder growth.

The second one is to unveil hidden liabilities. Public sector has already conducted some policies such as:

- Debt agreements among the Federal, State and Municipal Governments since 1997
- Fiscal Stabilization Program since 1998
- Fiscal Responsibility Law in 2000

The third one is to stabilize macro economic environment in order to avoid depreciation of the Real. Especially, low inflation rate needs to be maintained to reduce trade deficit[5] and to avoid depression.

[3] Though US Dollar-Brazil Real rate recorded 3.9 in September 2002, Brazil Real was appreciated after that and arrived at 2.8 per 1 US Dollar in July 2003. Therefore Net Public Debt ratio would decrease around 20% in 2003
[4] The Federal Government has been achieving the primary surplus target with the IMF since 1996, the beginning of the Real Plan. The Federal Government has already achieved the primary surplus target in the first half of 2003 until May, arrived at R$37 billion at that time.
[5] In the first half of 2003, Brazil economy recorded US$10.4 billion of trade surplus. Export amount increased 131.3% from the same term last year.

(3) Fiscal Sustainability of the State Government of Rio de Janeiro

Table 2.9 shows Public Debt-GDP ratio of the Rio de Janeiro State. It increased 9.7 points rapidly from 7.9% in 1995 to 17.6% in 1998, and then started to decrease a little after 1999. Financing from state financial institutions, such as Banco do Brasil and Central Bank of Brazil, are major financing sources, and the borrowing amount-GDP ratio increased 13.0 point3, from 2.3% in 1995 to 15.3% in 2000.

Treasury bonds were a major financing source before 1997. However Rio de Janeiro State and the Federal Government made an agreement that reorganizes Public Debt of the State. Consequently, State treasury bonds are substituted with borrowing from the state bank, ususally Banco do Brasil. That is why yeild of treasury bond changed from 7.7% to 0% suddenly, and internal borrowing increased rapidly from 9.3% to 15.3% in 1999.

Table 2.9 Public Debt-GDP Ratio of Rio de Janeiro State

	1995	1996	1997	1998	1999	2000
Total	7.9	7.9	12.1	17.6	16.3	16.1
Internal debt	7.9	7.8	11.9	17.1	15.5	15.3
Treasury bond	5.5	5.6	6.5	7.7	0.0	0.0
Borrowing	2.3	2.2	5.4	9.3	15.5	15.3
External debt	0.0	0.1	0.2	0.5	0.8	0.8
Treasury bond	0.0	0.0	0.0	0.0	0.0	0.0
Borrowing	0.0	0.1	0.2	0.5	0.8	0.8

Source: Secretaria de Estado da Fezenda (Unit: percent)

External debt is very limited. It consists of treasury bonds (R$3.5 million in 2001) and borrowing from international financial institutions such as IDB, World Bank and JBIC.

Table 2.10 shows the fiscal plan from 2002 to 2017, prepared by the Secretaria de Estado da Fezenda (Former State Secretariat of Finance). According to the plan, borrowing from public domestic and international financial institutions will finish in 2004. The State Government disburses R$800-1,300 million for interest payment, and R$500-600 million for capital refund every year. The plan is for budget surplus to be generated every year. In 2002 it will be R$118 million (0.8% of revenue), and increase to R$1,022 million (4.9%of revenue) in 2017. Increase of investment expenditure is limited in the plan, and therefore percentage of investment payment in expenditure will decrease from 11% in 2002 to 9% in 2017. The State Government will have to conduct public investment with limited financial resources.

The State Government prepares such fiscal plan, and discusses it with the Federal Government regularly. If the State Government can't achieve the target in the plan, the Federal Government would institute a sanction, such as prevention or reduction of fiscal transfer.

Table 2.10 Fiscal Plan from 2002 to 2017

	2002	2007	2012	2017
Revenue	14,960	16,729	18,654	20,963
Tax	10,592	12,640	14,848	17,034
Transfer	1,629	1,728	2,090	2,618
Borrowing	746	0	0	0
Expenditure	14,843	16,381	18,052	19,941
Personnel payment	5,573	6,305	7,134	8,071
Interest payment	1,323	1,099	976	874
Capital repayment	532	617	534	471
Investment	1,633	1,695	1,760	1,827
Balance	118	347	601	1,022

Source: Secretaria de Estado de Fezenda (Unit: R$ million)

2.2.5 LANDUSE AND URBAN PLAN

Landuse map, shown in *Figure 2.7*, prepared in 1998 with 1/50,000 scale using images from the Satellite SPOT 1996; it is the only and latest landuse map available for the Study Area. Most of the Study Area (about 75%) is covered by forest and vegetation areas and the built up urban area accounts for about 20%.

All municipalities having a population of more than 30,000 are mandated and required to formulate a master plan for urban planning by the 1988 Constitution. Therefore, all the municipalities in the basin (except Tanguá municipality where population is 26,000) were expected to have an urban plan in effect. The Study Team visited several municipalities to gather information on their plans and learned that none of the municipalities visited, other than Nova Iguaçu, have a master plan in use.

The Study concludes with the following two remarks for further studies:

- In the population projection, the population growth rate of each municipality shall be based on the population density of the urban area.
- The hydrological and pollution load analysis should take the change of landuse pattern into account, at least in São Gonçalo and Itaborai.

2.2.6 FAVELAS

The so-called “Favelas” are generally understood to be settlements that develop spontaneously out of areas that are designated as housing allotment projects, but without proper provision of social infrastructure and public services. According to the last IBGE Census 2000, population living in Favelas accounted for as much as 11.5% of the total population of the municipalities of the Study Area. Favelas, therefore, are not negligible in the sewerage planning of the basin as a potential pollution source, as well as in terms of an equal distribution of social services.

Therefore, Favelas’ characteristics are studied by IBGE 2000 Census and results of People’s Awareness Survey (for details, refer to *Supporting 13*)

(1) IBGE 2000 Census

1) Population

According to the preliminary results of Census 2000, total population living in Favelas in the 16 municipalities is 1,240,638, accounting for 11.53% of the total population of the 16 municipalities. Percentage of Favala population to total municipality population varies from 0 to 18.68% by municipality. The highest percentage, 18.68 %, is observed in Rio de Janeiro, followed by Niteroi, 11.04 % and Mage, 8.13 %. There is no Favela in Guapimirim, Itaborai, Rio Bonito and Tanga.

2) Public Services

Since Favelas are concentrated in the more urbanized municipalities, where ratios of receiving public services, such as water supply, solid waste collection and sewerage service are well developed, average service ratios of Favelas are rather higher than averages of Rio de Janeiro State and the 16 municipalities in the study area, in general.

Remarks supposed to be specific to Favelas are as follows:

- “At the door collection” of solid waste collection rate in Favela is lower than those of the states and the municipalities, but “By a Container” is higher. This may suggest inaccessibility of collection vehicles due to narrow streets and people have to bring their waste to the waste container placed at car accessible streets.

- Although sewerage service coverage ratios are similar among Favelas, state and municipalities, in the sanitation disposal other than sewerage service, "septic tank" is lower and "others" is higher in the Favelas. This may suggest that unsanitary disposal more often occurs in the Favelas.

3) Income Level

In Favelas, the family head income is considerable lower than in the other geographical categories (municipalities of the Study Area and Rio de Janeiro). Those with *No Income* represent 14.2 % of the family heads in contrast to 9.4 % and 9.1 % for municipalities of the Study Area and RJ State, respectively. Also, those in Favelas receiving something up to 3 MW (Minimum Wages) represent 62.5 % while for the municipalities of the Study Area and RJ State this represents 41.4 % and 45.1 % respectively. On the other hand, family heads receiving more than 10 MW represent only 1.2 % in Favelas while for the municipalities of the Study Area and RJ State this represents 15.1 % and 13.2 %, respectively.

(2) People's Awareness Survey

The survey was carried out in 600 residences distributed in the Study Area. The distribution was carried out dividing the samples into three groups of 200. The distribution of the three groups was as follows: Group 1 - Ordinary settlements (excluding favelas) in the municipalities of Belford Roxo, Duque de Caxias, Magé, Nova Iguaçu and Itaboraí; Group 2 - Ordinary settlements (excluding favelas) in Rio de Janeiro city; and Group 3 - Favelas in the municipalities of Magé, São João do Meriti, Nilópolis, Duque de Caxias, Nova Iguaçu and Rio de Janeiro.

As for family income, the higher percentage of families getting less than 3 MW (Minimum Wages) is found in Favelas (58.0 %), closely followed by families in Group 1 municipalities (48.5 %). Likewise, families getting more than 10 MW correspond to 5.5 % and 5.0 % in Group 1 and Favelas, respectively.

Respondents in Favelas and Group 1 are similarly concerned with the lack of infrastructure, mainly sanitation infrastructure, more than the respondents in Rio de Janeiro city for who the main concern is the urban violence problem. The respondents in Favelas and Group 1 are also concerned with the lack of good medical services which shows their vulnerability in terms of illness.

Despite the similarities in terms of basic infrastructure conditions and income level, respondents in Favelas and Group 1 differ as for the willingness to pay for improvements in the sewerage system. Respondents in Favelas are more willing to pay for this while those in Group 1, similar to those in Rio de Janeiro city, are not.

In this survey, willingness to pay for the sewerage service that provides sewage collection service and treatment to reduce pollutants to the Bay was polled. Respondents could have thought it was not only payment to receive sewerage service for their own benefit but also to contribute to the environmental protection. Therefore, low ratio of "having willingness to pay" common among all the group implies low consciousness to the environmental issue.

For more details of the People's Awareness Survey, refer to *Supporting 16*.

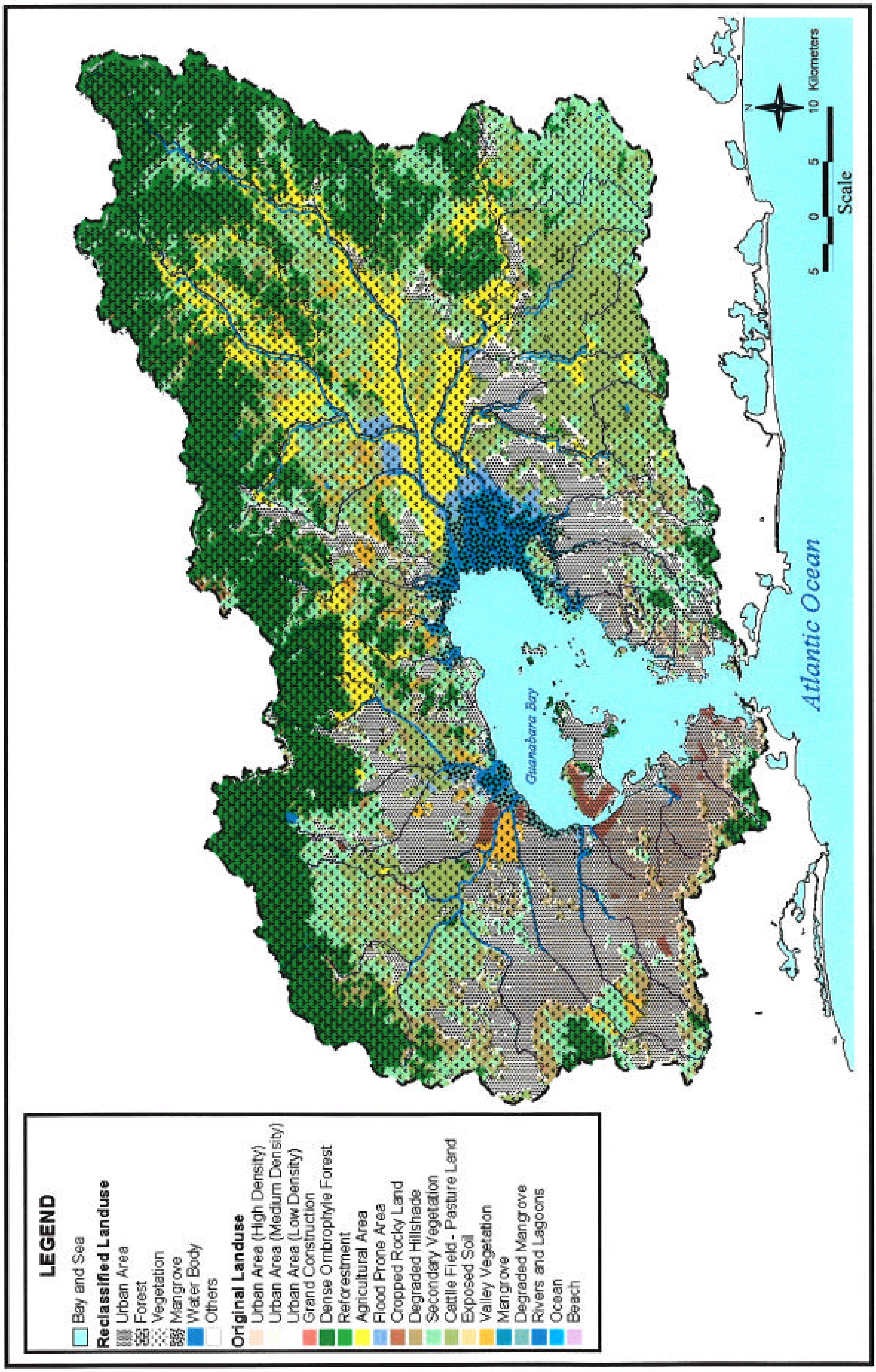

Figure 2.7 Original and Reclassified Landuse Map

2.3 BASIC SANITATION SYSTEM

2.3.1 GENERAL

In Brazil, municipal governments are responsible for water supply and sewerage services. It is, however, more common that public companies under the state governments render such services under agreement with each municipality. *Table 2.11* shows implementation body for water supply and sewerage service in RJ State. CEDAE is responsible for water supply and sewerage service in 60 municipalities. 18 municipalities conduct water supply and sewerage service by themselves, and 12 municipalities have agreements with private companies to conduct such services.

Table 2.11 Water Supply and Sewerage Services in RJ State

Implementation body	No of municipalities
CEDAE	60
Municipality	18
Private Company	12
Combination*	2

Note: In case of combination, CEDAE is responsible for water supply, and municipal government is responsible for sewerage service.

Source: CEDAE

Table 2.12 shows implementing bodies of water supply and sewerage service in 16 municipalities in the Study Area. CEADE is responsible for water supply and sewerage services in 12 municipalities and for water supply service in Cachoeiras de Macacu. Municipal government is conducting such services in Guapimirim, and private companies are conducting services in Niterói and Petrópolis.

Table 2.12 Water Supply and Sewerage Service in 16 Municipalities

Implementing Body		Name of Municipality
CEDAE	West of Guanabara Bay	Rio de Janeiro*, Belford Roxo, Duque de Caxias, Nilópolis, Nova Iguaçu, Mesquita, São João de Meriti
	East of Guanabara Bay	Itaboraí, Magé, São Gonçalo, Tanguá, Rio Bonito
Municipal Government		Guapimirim
Private Company		Niterói, Petrópolis
Combination		Cachoeiras de Macacu

Note: Rio de Janeiro Municipality is divided into 3 parts, West of Guanabara Bay, Coast Region and Septiba Bay and Grand Islands Region. Only West of Guanabara Bay Region is included in the Study Area.

Source: CEDAE

2.3.2 WATER SUPPLY SYSTEMS

As shown in *Table 2.12*, in the Study Area, water supply in 13 out of 16 municipalities are covered by CEDAE, while two municipalities (Niterói and Petrópolis) are covered by private companies and one (Guapimirim) is covered by the Municipal government.

CEDAE's water supply system, covering most of the study area, is operated by two operating divisions with boundary between Duque de Caxias and Magé. They are:

- Região Metropolitana e Costa Verde covering west part of the area
- Região Metrpolitana Leaste covering east part of the area.

(1) Região Metropolitana e Costa Verde

This water supply system covers Rio de Janeiro city and Baixada Fluminence and supplies water to 95% of the population in the covered area. The system consists of three subsystems with interconnection: Sistema de Linha Pretas, Usina de Fontes and Guandu.

Sistem de Linhas Pretas subsystem is the oldest water supply system and intakes water from 47 small streams located in the northwestern mountainous areas (Serra do Macuco/Serra do Oregon) in the basin. The system has a total capacity of 3,500 l/sec. Water is supplied after disinfection by chlorine.

Usina de Fontes intakes water from a dam located on the Ribeirão das Lajes river, which is outside of the basin. It supplies water after chlorine disinfection and has a capacity of 5,500 l/sec.

Water for Guandu subsystem is pumped up from Paraiba do Sul river, which locates outside of the basin. The subsystem has a conventional water treatment plant with capacity of 42,000 l/sec.

(2) Região Metrpolitana Leaste

The region correspods to the east half of the catchment. While the water spply system in Região Metropolitana e Costa Verde is considered one system consisting of three sub-systems, water supply in this region is operated by relatively small indivudial systems, most of which covers one municipality.

Water supply systems in this region are shown in *Table 2.13.*

Table 2.13 Water Supply Systems in the Eastern Part of the Study Area

Name of System	Municipalities covered	Population Covered
São Gonçalo	São Gonçalo, Alcântara	903,333
Ila de Paquetá	Ila de Paquetá	4,900
Itaboraí	Itaboraí	192,649
Magé	Magé, Piabeta	210,861
Guapimirim	Guapimirim	39,153
Cacheoiras de Macau	Cacheoiras de Macau	49,473
Tanguá	Tanguá	26,665
Rio Bonito	Rio Bonito	50,144
Maricá	Maricá	80,175
Niteroí*	Niteroí	461,204

Source: CEDAE

Note: * Operated by a private company.

2.3.3 SEWERAGE SYSTEMS

CEDAE is by far the main provider of sewerage service in the Study Area, being responsible for the sewage collection and its treatment in all the municipalities except for Niterói, where there is a private concessionaire.

Despite this fact, there are many other initiatives from some of the municipalities in the Study Area that provide sanitation service with their own funds or with funds from federal grants. Furthermore, there are many instances when private land developers and large commercial developers, like shopping centers and supermarkets, when located in areas without public sewerage system, are required to have their own sewerage facilities according to the State of Rio de Janeiro legislation.

(1) Existing Sewerage Facilities by CEDAE

There are 11 sewerage systems in operation by CEDAE in the Guanabara Bay Basin as shown in *Figure 2.12.* Brief descriptions of each system are as follows:

1) Alegria System

The system is situated in the south of the Timbó-Faria basin. Its natural water drainage is toward the Bay. The total area is approximately 9,639 ha. The Alegria system is separated longitudinally by the central railroad of Brazil along which are located the neighborhoods of Saó Francisco Xavier, Rocha, Tiachuelo, Sampaio, Engenho de Dentro, Encantando and Piedade.

WWTP is planned to serve a population of about 1.5 million with an average daily treatment capacity of 432,000 m^3/d (or 5 m^3/s), and has primary treatment facilities (as of August 2002) achieving average 30% pollutant removal efficiency. The current flow rate to the WWTP is approximately 1.0 m^3/s. WWTP expansion works are now ongoing to upgrade the present primary system to the conventional activated sludge process. Totally, about 1,069 km of sewers exist within the system.

2) Penha System

This sewer system is situated in the northeast limit of Rio de Janeiro City adjoining the Irajá Basin. The total area of this district is about 3,231 ha. WWTP was constructed in 1960 adopting a high rate trickling filter process, originally having 434 L/s average treatment capacity. Since 1965 the wastewater flow exceeded the maximum WWTP capacity of 600 L/s. As the result, the excess raw wastewater flow has been discharged to public waters.

In October 1979, an activated sludge process of 1,000 L/s treatment capacity was added to WWTP, thereby, reaching the present capacity of 1,600 L/s. The district's sewer service population is estimated at 576,000. Under PDGB Phase I, a sludge dewatering system was added to WWTP. The system has now 388 km of sewers and five intermediate pumping stations.

3) Pavuna System

This system covers a total of 4,630 ha urban districts, serving a total of 323,000 residents. The present 1,500 L/s capacity WWTP with primary treatment plus chemical addition will be upgraded to secondary treatment with activated sludge process under PDGB Phase I. The Pavuna system comprises six pumping stations, and 448 km of sewers.

4) Sarapuí System

The present primary WWTP in the system has a 1,500 L/s treatment capacity, serving about 346,000 inhabitants within the service area of 4,380 ha. In the process, ferric chloride is added ahead of primary clarifiers. As of July 2002, the construction of 1,500 L/s capacity activated sludge treatment facilities is underway. The Sarapuí system consists of eight pumping stations and 505 km of main and reticulation sewers.

5) São Gonçalo System

The system serves 2,100 ha urban districts, with sewered population of 142,000. The system has a total 243.24 km of sewer networks and four lift stations. WWTP of a pure oxygen activated sludge process has a treatment capacity of 765 L/s.

6) Icaraí System

This system serves 172,000 inhabitants within the district of 1,550 ha. Under PDGB Phase I, the initial capacity of 660 L/s was to be increased with rehabilitation of primary treatment facilities. The plant uses ferric chloride to the incoming wastewater of 800 L/s. The existing sewerage system has a total of 6.6 km of sewer networks.

7) Ilha de Governador System

The system covers totally 2,416 ha areas servicing the population of 154,000 with about 180.8 km of sewer reticulations. The oxidation ditch WWTP was constructed in 1971 to treat a 200 L/s wastewater inflow. Although the WWTP capacity has more than doubled to 525 L/s under PDGB Phase I, the treatment capacity cannot meet the demand due to the rapid population increase. Implementation of a new sludge drying system in WWTP is under consideration.

8) Ilha do Paquetá System

The system has a sewer service area of 55 ha serving 15,000 residents through one km of sewers. A new WWTP was constructed under PDGB Phase I and started its operation in 2000. WWTP is now treating the wastewater inflow of 25 L/s, using deep shaft activated sludge process.

9) Acarí System

The Acarí sewer system covers areas of 7,350 ha with 70 km of sewer reticulations. WWTP is to be located in the tributary of the Acarí River running across Rio de Janeiro City, belonging to the Acarí sub-system in the Pavuna System. While the nominal WWTP treatment capacity is 210 L/s, the inflowing wastewater reaches 1,500 L/s. Under such condition, a significant quantity of the raw wastewater has been directly discharged to the nearby river.

10) Gramacho System

The stabilization pond WWTP situated in Duque City close to the Sarapuí River mouth has an average treatment capacity of 185 L/s, treating the wastewater from the Gramacho sub-system serving 825 ha areas and 87,800 residents, which is a part of the Sarapuí System.

11) Marina da Glória System

With new sewer pipes are directly connected to the ocean interceptor and the wastewater from 89,000 residents is to be discharged directly into the Ipanema ocean outfall.

12) Existing WWTPs

The existing 10 WWTPs were either constructed or rehabilitated under PDBG to increase treatment capacities and improve treatment efficiencies. Thus the overall wastewater treatment rate is expected to increase from the present 13% to 51% of the total wastewater coming from about five million residents.

Upon completion of such works, the total WWTP capacity is estimated to reach 14,756 L/s (2035) with the overall BOD removal rate of 48%. CEDAE M/P estimates and the existing conditions of sewer districts and WWTPs are shown in *Table 2.14*.

Table 2.14 WWTPs (CEDAE M/P and Present Conditions)

System	WWTP	2035 (by CEDAE M/P)			Present Condition (2000)		
		Population	Av. flow (L/s)	Per capita flow (lcd)	Av. flow (L/s)	Capacity (L/s)	Treatment Method
Alegria	Alegria	1,414,560	4,438	271	820	5,000	Primary. Secondary (in 2003)
Penha	Penha	658,907	1,889	248	1,610	1,600	Secondary
Pavuna-Meriti	Pavuna	587,418	1,694	249	1,000	1,500	Sedimentation + chemical
	Acarí	1,189,983	3,095	225	210	210	Secondary
Sarapuí	Gramacho	76,179	216	245	185	185	Stabilization ponds
	Sarapuí	495,395	1,408	246	1,000	1,500	Sedimentation + chemical
Imbossau	São Gonçalo	223,147	955	370	120	765	Secondary (pure oxygen)
Niterói	Icaraí	172,743	506	253	800	952	Sedimentation + chemical
Ilha do Governador	Ilha do Governador	164,008	526	277	525	525	Secondary
Paquetá	Paquetá	15,490	29	162	25	27	Secondary + ocean
		4,997,830	14,756		6,295	12,254	

Source: CEDAE

(2) Other Sewerage Facilities

Information about these small and scattered systems was identified through the environmental licensing system of the State of Rio de Janeiro, since all the public sewerage systems are required to apply in FEEMA for the Installation License (LI) and for the Operational License (LO)

Most of the licensed systems registered at FEEMA are very small, in comparison with the CEDAE systems, but in total there are, today, over 1,300 ones, with LI or LO, the majority being septic tanks and anaerobic filters constructed by private enterprises.

Out of all the small and medium size systems, the most relevant ones are: 1) Sewerage Systems in Favelas in Rio de Janeiro City - (a) Favela-Bairro program, financed by IDB and (b) the PROSANEAR program, financed by the World Bank; 2) “Nova Baixada Program” also financed by IDB; 3) the systems built in the Municipality of Itaboraí; and 4) the systems under construction by the private concessionaire Águas de Niterói in the municipality of Niterói.

1) Sewerage Systems in Favelas of Rio de Janeiro City

Table 2.15 presents the sewerage systems in the Study Area constructed and/or planned by the Rio de Janeiro City government, within its housing programs for low income population, whose main program is the FAVELA-BAIRRO program. The operation and maintenance of these sewerage systems were supposed to be carried out by Rio Águas Foundation, a municipal organization under the Rio de Janeiro City Secretariat of Civil Works, created in June 1998. This foundation and CEDAE signed an agreement and the first one should carry out the operation & maintenance of the sewerage systems including WWTP constructed by the municipal government. In return, CEDAE should transfer funds to Rio Águas Foundation for this purpose. It was reported, however, that these transfers stopped in January/2001 and thus the operation & maintenance of these systems have not been carried out since.

Table 2.16 presents the information about the sewage works in the Study Area carried out under PROSANEAR program while still under CEDAE responsibility. The PROSANEAR program encompassed the provision of water supply and sewerage in Favelas. These sewerage systems were designed to be connected to CEDAE's main trunks. Upon an evaluation of this program, SEDUR, which took the responsibility to continue this program, decided to extend the scope of works to other components (drainage, street paving, among others). The name of the program then changed to VIDA NOVA COM SAÚDE (new life with health) program. The communities where works were carried out under this new program are listed in the last three positions of the list: Bairro Santo André and Comunidade 48 (Bangu / Rio de Janeiro City), and Pedreira Sinimbu (São Cristovão / Rio de Janeiro City).

2) Nova Baixada Program (PNB)

Sewerage systems in PNB are being implemented in 11 neighborhoods (barrios) in Baixada Fluminense municipalities to which Sarapuí and Bota systems in PDBG are related. The sewage works executed and planned for the 1^{st} and 2^{nd} phases of PNB are presented in *Table 2.17*. Sewers in the neighborhoods within Sarapuí system have been constructed by PNB and collected sewage will flow into and be treated at Sarapuí WWTP. In Bota system, sewers within PNB area and three WWTPs (Joinville, Babi and Orquídea) have been partly constructed. The details of WWTPs are as follows.

Joinville WWTP

First phase facility with the capacity of 0.1 m^3/sec. that targeted 2010 was completed but has not been transferred to CEDAE yet. The plant has primary sedimentation, sludge treatment facility of thickening, digestion and drying. The beneficiaries are 35,000 people with 2,000 house connections. Several households in a plot share one connection to the public sewer. The ultimate capacity of 0.34 m^3/sec. with activated sludge process will target 2035. It has been not decided yet which organization should be responsible for the upgrading and extension.

Babi WWTP

Its detail design is finished and the plant will be constructed in the near future.

Orquídea WWTP

Its design is in progress.

Table 2.15 Sewerage Systems Constructed by the Municipal Secretariat of Housing (SMH) of Rio de Janeiro City in the Study Area

Status	No.	Name of the System	Neighborhood	Treat-ment Station	Pumping Station	Network Extension	Benefitted Residences	Benefitted Population	Type of Treatment
				(un)	(un)	(m)	(un)	(inhab)	
Agreement with CEDAE (currently not in operation)	1	Parque Royal	Ilha do Governador	-	1	3,106	1,382	5,039	-
	2	Quinta do Caju	Caju	-	1	2,680	873	3,230	-
	3	Camboatá	Barros Filho	1	1	835	300	1,500	Extended Aeration
	4	Portus I and II	Costa Barros	1	1	520	654	3,270	Extended Aeration
	5	Vila Pinheiros	Bonsucesso	-	2	4,963	677	3,385	-
	6	Parque Boa Esperança	Caju	-	2	5,669	1,392	6,960	-
	7	Tuiuti	São Cristóvão	-	1	7,770	1,777	6,575	-
	8	Agric. de Higienópolis	Inhauma	-	1	1,660	390	1,516	-
	9	Adeus/Piancó	Complexo do Alemão	-	2	4,210	1,520	7,600	-
	10	Fazenda Palmeiras	Inhauma	1	1	800	499	2,495	Batch Treatment
	11	Dique	Pavuna	-	3	6,082	1,202	4,447	-
	12	Nova Aliança	(*)	1	1	6,984	2,260	11,300	(*)
	13	Cerro-Corá	Laranjeiras	-	1	752	369	1,365	-
Under construction	1	Portus III	Costa Barros	1	1	4,000	2,500	12,500	Extended Aeration
	2	Vila Conchita	Realengo	-	1	113	26	130	-
	3	Carumbé	Realengo	1	-	1,497	298	1,490	(*)
To be constructed	1	Vila Santo Antonio	Ramos	-	1	(*)	155	569	-
	2	Vila Moreti	Bangu	1	-	3,156	491	2,435	(*)
	3	Fazenda Botafogo	Barros Filho	1	1	(*)	2,396	8,600	(*)

Source: "Fundação Rio Aguas", as of September of 2002
Note: (*) Information yet to be provided by SMH

Table 2.16 Summary of PROSANEAR Works in Favelas in the Study Area

No.	Community	Neighborhood / Municipality	Design Population (inhab.)	*Sewerage (km)*
1	Chico Mendes	Costa Barros / Rio de Janeiro	15,800	***36***
2	Campinho	Campinho / Rio de Janeiro	5,000	***3***
3	Providência	Santo Cristo / Rio de Janeiro	9,780	***19***
4	Morro União	Coelho Neto / Rio de Janeiro	7,000	***0***
5	Arroz	Centro / Niterói	2,600	***3***
6	Juramento	Tomaz Coelho / Rio de Janeiro	18,250	***50***
7	Estado	Centro / Niterói	6,000	***9***
8	Complexo do Andaraí	Andaraí / Rio de Janeiro	9,080	***31***
9	Bananal	Tijuca / Rio de Janeiro	170	***1***
10	Fubá	Campinho / Rio de Janeiro	3,605	***6***
11	Mangueira	São Cristovão / Rio de Janeiro	21,510	***38***
12	Marui Grande	Barreto / Rio de Janeiro	4,000	***6***
13	Complexo do Alemão	Ramos / Rio de janeiro	135,000	***35***
14	Vila Cruzeiro	Penha / Rio de Janeiro	7,000	***9***
15	Borel	Tijuca / Rio de Janeiro	20,000	***28***

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No.	Community	Neighborhood / Municipality	Design Population (inhab.)	*Sewerage (km)*
16	Pq. Boa Esperança	Caju / Rio de Janeiro	5,700	***6***
17	Lagartixa	Costa Barros / Rio de janeiro	20,000	***13***
18	Complexo do Urubu	Pilares / Rio de Janeiro	12,800	***4***
19	Vila Cascatinha	Penha / Rio de Janeiro	3,500	***2***
20	Pq. União del Castilho	D.Castilho / Rio de Janeiro	5,000	***6***
21	Pq. Vila Isabel	Vila Isabel / Rio de Janeiro	8,880	***16***
22	Morro dos Macacos	Vila Isabel / Rio de Janeiro	7,300	***11***
23	Pq. Jardim Beira Mar	P. Lucas / Rio de Janeiro	21,000	***0***
24	Ramos/Roquete Pinto	Ramos / Rio de janeiro	18,000	***20***
25	Pq. Prol. de Vigário Geral	V.Geral / Rio de Janeiro	21,000	***0***
26	Complexo de Manguinhos	Manguinhos / Rio de Janeiro	19,200	***20***
27	Morro da Formiga	Tijuca /Rio de Janeiro	9,000	***22***
28	*Bairro Santo André*	*Bangu / Rio de Janeiro*	*13,840*	***1***
29	*Comunidade 48*	*Bangu / Rio de Janeiro*	*10,560*	***1***
30	*Pedreira Sinimbu*	*São Cristovão / Rio de Janeiro*	*720*	***0***

Source: SEDUR – Rio de Janeiro State Secretariat of Urban Development, as of 29 of October, 2002.

Table 2.17 Sewerage Works of the PNB 1st and 2nd Phases

Design Works	Works carried out (97 to 98)	Complementary works in progress and to be carried out (2000 and in progress)
264,575 m of pipelines	206,544 m of pipelines	96.40 m of pipelines
52,100 household connections	19,713 household connections	20,600 household connections
24,400 household internal connections	14.862 household internal connections	8,000 household internal connections
17.5 km of Main Collectors	-	17.5 km of Main Collectors
10 Pumping Stations	3 Pumping Stations (not finished)	Activation of pump stations and construction of another 7 units
Pump Station in Jardim Metrópole	Reactivation (PDBG)	
8 km of pressure collectors	-	8 km of pressure collectors
Crossing over Sarapuí river	Crossing (PDBG)	-

Source: "Consolidated Diagnosis of Socio-Environmental Conditions and Institutional and Sustainability Aspects of the Nova Baixada Program", Dec/2001

3) Itaborai Systems

The municipality of Itaborai built several small or single dwelling systems and two public systems with Federal Grant funds. The systems are composed of a sewerage network and an extended aeration activated sludge plant, operating automatically. The first one, serving around 7,000 inhabitants in the neighborhood known as "Reta" in the "Venda das Pedras" district was put in operation last year (2001) and the second one, known as "Itambi" serves about 15,000 inhabitants of the communities of "João Caetano" and "Grande Rio". This last one has just been put in service.

The systems, including the treatment stations, are under the responsibility of the Transportation Secretary of Itaborai Municipality.

4) Águas de Niterói Systems

The private concessionaire of Niterói is at this moment operating two systems: the Mocangue system, built in the past in a Navy base along the Rio-Niterói bridge, and the Camboinhas system, built outside the study area, but with some influence in it, since it is located in the Atlantic Ocean area, since it is the Itaipu system, and is under construction.

Other systems, relevant to this study since they are being built in areas close to the Guanabara Bay shore line, are the Toque-Toque and Barreto systems, scheduled to be put in operation in 2003 and 2004 respectively.

Table 2.18 lists the public facilities of sewage treatment under responsibility of the municipalities or the private concessionaires that have been identified in the Study Area.

Table 2.18 Relevant Sewage Treatment Facilities in the Study Area Other than CEDAE's

Municipality	Location	Operational status	Operator	Design Capacity	Type of System
Rio de Janeiro			Nova Baixada Program		
Itaborai	Venda das Pedras (Reta)	In service	PM Itaboraí	18.5 l/s	Activated Sludge Batch Reactor
Itaborai	Itambi (Joao Caetano)	In Service	PM Itaborai	40 l/s	Activated Sludge Batch reactor
Niteroi	Mocanguê Naval Base	In service	Aguas de Niteroi	20 l/s	
Niteroi	Camboinhas (2)	In service	Aguas de Niteroi	100l/s	UASB[1)], bio filter and tertiary treatment
Niteroi	Toque-Toque	In construction (operation in Dec. 2003)	Aguas de Niteroi	260 l/s	UASB[1)], bio filter
Niteroi	Barreto	In construction (operation in Dec. 2004)	Aguas de Niteroi	260 l/s	UASB[1)], bio filter
Niteroi	Itaipu (2)	In construction (operation in Dec. 2003)	Aguas de Niteroi	100l/s	UASB[1)], bio filter and tertiary treatment

Note: 1) Up flow Anaerobic Sludge Blanket

2.3.4 SOLID WASTE SYSTEM

Solid waste management, in Brazil, is under the responsibility of the municipal governments which do it with their own personnel and equipment, through municipal companies or, as it happens more often today, by private firms that do the collection and street sweeping activities under service contract with the municipalities.

Solid waste management in the Guanabara Bay basin area follows the above pattern, usually reflecting the institutional and economic development level of each locale: Rio de Janeiro city by far has the most developed system, Niteroi coming next, followed by Duque de Caxias, and Nova Iguaçu. The other less developed municipalities, from the economic and institutional point of view, also have less efficient solid waste management systems, such as the municipalities of Cachoeiras de Macacu, Belford Roxo, Magé, etc.

Some of the municipal institutions in charge of solid waste management are public companies, owned by the municipalities, such as COMLURB, in Rio de Janeiro, CLIN, in Niteroi, EMLURB in Nova Iguaçu. In the other municipalities solid waste is managed directly by a municipal department or municipal secretary, usually the public works, public services or the environment department.

Refuse collection, in the urbanized areas is made door-to-door, three times a week, usually by compactor trucks. In the area of favelas and other low income neighborhoods the collection is made using containers and dump trucks. Overall, the collection of refuse can be rated as reasonably good, as it is made by private companies contracted out by the municipalities, or by municipal companies.

In the municipalities of Duque de Caxias, Magé, Guapimirim, Niteroi, Nilopolis, São Gonçalo, and São João de Meriti, Rio de Janeiro State has provided, through the PDBG, collection trucks and other facilities to improve refuse collection. Furthermore, through the same PDBG, Rio de Janeiro State is improving the sanitary landfills of Niteroi, São Gonçalo and Magé, and constructing recycling and composting plants and hospital wastes incinerators in Niteroi and São Gonçalo.

Concerning the amount of refuse generated in each municipality, *Table 2.19* shows the refuse collected in each one. It should be remarked that, in fact, the figures were obtained at the several disposal sites, where there usually are weighing scales. This means that the amount of refuse recorded is the refuse collected, not exactly the refuse generated, the exact amount of this being difficult to find, unless the collection rate were 100%.

On average, collection coverage can be assumed as something around 90%, which leaves around 1000 ton/day uncollected. Some of this amount is thrown in the rivers (and small creeks that feed these rivers) that discharge into Guanabara Bay and some are washed into the rivers and directly to Guanabara Bay when there are the storm rains, most frequently in the summer time (December to March).

The most visible part of this situation are the floating debris, usually plastic bottles made of PET – Polyethylene Tharaftalate and PVC – Polyvinyl chloride, and also wood debris, glass bottles, etc. that appear on the shoreline and in the beaches, especially after rainstorms.

It should be noted that the non-collected waste also poses a serious problem for the drainage of storm rain network, since these debris and refuse clog the channels and pipes that are not designed to receive these wastes.

Concerning disposal of waste, the situation is much more critical than the collection activities. At this moment there is only one licensed sanitary landfill, which is the Nova Iguaçu Landfill in the neighborhood of Adrianopolis. Furthermore, the most important disposal place, the Gramacho Landfill, which is responsible for the disposal of about 80 % of the waste collected, is almost reaching its saturation and shall be closed in the next two years.

Due to the present situation, most of the municipalities are trying to upgrade their disposal facilities, or to find alternative disposal sites and facilities. In fact, many improvements have been made in the last five years in the construction of sanitary landfills and treatment facilities, some still under construction. Today, as it can be seen in *Table 2.19*, there is one fully licensed sanitary landfill and other landfills with sanitary conditions, but not licensed by FEEMA.

These recent improvements have been made, basically with the help of PETROBRAS which granted money to the municipalities of Belford Roxo, Duque de Caxias, Itaborai, Niteroi, Nova Iguaçu, São Gonçalo São João de Meriti, Tangua, Petropolis, and Rio Bonito to improve their refuse disposal facilities.

Other disposal sites fall in the category of “controlled landfill” or “open dumps”. The controlled landfills are those facilities that do not comply with all the rules requested by FEEMA to render an environmental license but where the refuse is deposited in layers, compacted and covered, (at least weekly), scavenging is controlled, and there are facilities to collect and sometimes to treat the gaseous (biogas) and liquid (leachate) effluents. Open dumps, in turn, are places where the refuse is disposed without any control, being only spread from time to time and where the presence of scavengers and domestic animals is frequent.

The financing of the municipal systems is usually made by municipal funds, which, in turn, are collected through the property taxes, in an amount much below the cost of the services.

A table summarizing the situation concerning waste generation and disposal methods in the Guanabara Bay Basin municipalities is presented below.

Table 2.19 Population (2000), Rate of Waste Generation, Amount Produced and Disposal Method in 16 Municipalities in 2003

Municipality	Population (inhab.)	Rate of waste generation kg/cap/day	Amount of waste produced ton/day	Present waste disposal method and facilities
Rio de Janeiro	*5,851,914*	*1.3*	7700	Sanitary Landfill Unlicensed (Gramacho)
Belford Roxo	433,120	0.5	216	Open Dump; Recycling and Composting plant abandoned
Duque de Caxias	770,865	0.5	388	Sanitary Landfill Unlicensed (Gramacho)
Guapimirim	37,940	0.5	18.3	Open Dump leading to Controlled Landfill
Itaboraí	187,127	0.5	93.6	Controlled Landfill; Recycling and Composting plant under licensing process
Magé	205,699	0.5	107	Open Dump
Nilópolis	153,572	0.6	97	Sanitary Landfill (Gramacho)
Niterói	*458,465*	*0.8*	*396*	Controlled Landfill; Hospital waste incinerator, Recycling and Composting plant under construction
Nova Iguaçu	*750,487*	*0.7*	*566*	Licensed Sanitary Landfill
Mesquita	*164,879*	*0.5*	*80.3*	Sanitary Landfill Unlicenced (Gramacho)
São Gonçalo	889,828	0.7	630	Controlled Landfill leading to Sanitary Landfill; Hospital waste incinerator, Recycling and Composting plant, under construction
São João de Meriti	449,229	0.9	432	Controlled Landfill (Gramacho)
Tanguá	26,001	0.5	7.2	Open Dump
Petrópolis	*286,348*	*1.0*	*300*	Controlled Landfill
Cachoeiras de Macacu	*48,460*	*0.4*	*20.4*	Open Dump
Rio Bonito	*49,599*	*0.5*	*28.6*	Sanitary Landfill Unlicensed; Recycling and Composting plant operating
Total	10,763,533	1.02	11080.40	

2.4 INSTITUTIONAL ISSUES

2.4.1 ENVIRONMENTAL ADMINISTRATION

(1) Roles of Organizations Related to Environmental Administration

Both institutions, SERLA (State Superintendence of Rivers and Lakes or Superintendencia Estadual de Rios e Lagoas) and FEEMA (Environmental Engineering State Foundation or Fundacao Estadual de Engenharia do Meio Ambiente) are state foundations and belong to the Secretary of the Environment and Urban Development of the Rio de Janeiro State (SEMADUR), the primary organization responsible for the environmental management and urban environment.

Concerning the environmental administration, the activities of SERLA and FEEMA are the following:

- FEEMA: Responsible for control of wastewater discharge from WWTP and industries through the licensing their activities. Environmental licensing system is explained in the subsequent section. FEEMA is also responsible for monitoring the quality of the water of the rivers in the Rio de Janeiro State, of the beaches and of the other bodies of water such as Guanabara Bay.
- SERLA: Responsible for the cleaning up and dredging of the state rivers and channels, many of them sewage carriers, and thus very much affected by the sedimentation of solid matter in the streambed.

While FEEMA and SELRA are under SEMADUR, SEMADUR does not have a function in their organization to integrate various activities for environmental management.

Finally, it should be noted that there is no public regulatory institution to deal with environmental management in the State.

(2) Law System

1) Federal

CONAMA stipulates national environmental standards in its resolutions such as No. 003/90 for air quality and No. 020/86 for water quality.

Resolution No. 020/86 classifies fresh water bodies into five categories: brackish water bodies into three and saline water bodies into two. Water bodies are classified based on its uses; water supply, protection of aquatic communities, irrigations, recreation, fish cultivation and so on. The main water quality parameters listed are BOD, DO, turbidity, color and E. coli as shown in *Table 2.20.*

Table 2.20 Water Quality Standard for Classification of Water Bodies Stipulated in CONAMA Resolution No. 020/86

Item	Standard Values							
	Fresh waters				Salt waters		Blackish waters	
	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8
Floating material	V.A.	V.A.	V.A.	V.A.	V.A.	V.A.	V.A.	V.A.
Oils and greases	V.A.	V.A.	V.A.	iridescence not visible	V.A.	iridescence not visible	V.A.	iridescence not visible
E. coli (MPN/100ml)	not more than 200	not more than 1000	not more than 4000	-	not more than 1000	not more than 4000	not more than 1000	not more than 4000
Total coliform (MPN/100ml)	not more than 1000	not more than 5000	not more than 20000	-	not more than 5000	not more than 20000	not more than 5000	not more than 20000
BOD (mg/l O_2)	not more than 3.0	not more than 5.0	not more than 10.0	-	not more than 5.0	not more than 10.0	not more than 5.0	-
DO (mg/l O_2)	not less than 6.0	not less than 5.0	not less than 4.0	not less than 2.0	not less than 6.0	not less than 4.0	not less than 5.0	not less than 3.0
pH	between 6.0 to 9.0	between 6.0 to 9.0	between 6.0 to 9.0	between 6.0 to 9.0	between 6.5 to 8.5	between 6.5 to 8.5	between 6.5 to 8.5	between 5.0 to 9.0

Note: VA- not visible.
Class 1; For drinking use after casual treatment, protection of aquatic lives, recreations (swimming, water ski, diving), irrigation for vegetables and fruit trees, and crop cultivations.
Class 2; For drinking use after casual treatment, protection of aquatic lives, recreations(swimming, water ski,diving), irrigation for vegetables and fruit trees, and crop cultivations.
Class 3; for drinking use after normal treatment, irrigations for trees, cereals and pasture, and animal breeding.
Class 4; Navigations, esthetics, use for items not controlled by stringent quality standards.
Class 5; Recreations(swimming, water ski, diving), protection of aquatic lives, and crop cultivations
Class 6; Navigation, esthetics, and recreations without direct water contact.
Class 7; Recreations (swimming, water ski, diving), protection of aquatic lives.
Class 8; Navigation, esthetics, recreations without direct water contact.

2) State

Environmental Procedures

The Licensing System of Polluting Activities – SLAP was created by the State Decree No. 1633 (21/12/1977) in accordance with Decree-Law No. 134 of 16/June/1975.

SLAP provides for three types of environmental licenses, all of them compulsory:

- Previous License - LP
- Installation License - LI
- Operation License - LO

Water Quality Classification for Guanabara Bay

DZ 105 of Guidelines-Class 100 specifies the classification of the Guanabara Bay waters as shown in *Figure 2.8.*

Effluent Standards

CECA (State Environmental Committee) licenses activities that possibly discharge pollutants to the environment and issues guidelines and enforces them. FEEMA (State Foundation for Environmental Technologies) is a technical section of CECA and inspects possible polluting activities on behalf of CECA.

2.4.2 SEWERAGE ADMINISTRATION

(1) Roles of Organizations Related to Sewerage Administration

Organizations related to the sewerage administration in State of Rio de Janeiro, but not limited to Rio de Janeiro and mostly common to other states, are classified into two groups. One group is implementation bodies of water supply and sewerage services and another is authorities to control the water supply and sewerage service operations.

Characteristics of major organizations related to the sewerage administrations are as follows:

1) CEDAE

CEDAE has concession contracts with several municipalities of the Rio de Janeiro Metropolitan Region for potable water supply and sewage management, the only exception being the municipality of Niteroi that since 1999 is being served by a private concessionaire.

CEDAE activities, however, are concentrated in Rio de Janeiro city, where since the times of the Brazilian empire, there have been several investments in the sewerage network and in some treatment and disposal facilities, like the Sewage treatment Plant of Penha and the Ipanema sub-marine outfall.

In contrast, in most of the other municipalities of the Metropolitan region, prior to PDBG there has been almost no investment in the sewerage network or in sewage treatment.

Even in Rio de Janeiro city, the presence of CEDAE is mainly observed in the center and in the South zone of the city, since in the west zone of the city and in part of the north zone, there are very few facilities managed by CEDAE and almost no sewerage.

For residents that live in the sewered area, a tariff is charged for the value of the supplied potable water.

Finally, it is important to note that until the year 2000 CEDAE used to deal with sewerage and sewage treatment by functional directorates (such as “Sewage Directorate”, “Commercial Directorate” and “Water Operations Directorate”, etc.). In the year 2001 it was decided by the Administration Board to split the administrative organization of CEDAE into geographic areas (such as “West Guanabara Bay Directorate”, “East Guanabara Bay Directorate”, “Oceanic Regional Directorate”, etc.) instead of the former organization.

2) Other State Institutions

In the recent past, other state institutions have been charged with the responsibility to construct sewerage networks in the CEDAE area, mainly in some low-income areas of Rio de Janeiro city and in some municipalities of the metropolitan region bordering Rio de Janeiro city.

These institutions and responsibilities are:

- SEDUR - (State Secretariat of Urban Development or Secretaria Estadual de Desenvolvimento Urbano) - this state secretary is in charge of the Baixada-Viva project, financed by the Inter American Development Bank. Formerly (until two years ago) this project was being conducted by an independent unit of CEDAE
- SEPDET - (State Secretariat of Planning and Tourism or Secretaria Estadual de Planejamento, Desenvolvimento e Turismo) - in this case, the civil works concerning pipe laying and sewage treatment plant construction are made by the Department of Roads of Rio de Janeiro state, and SEPDET is responsible for coordination and supervision of the project.

3) Municipalities

Despite of the responsibility of CEDAE for sewage management in the municipalities where there is a concession contract for water supply, it is a common practice for the construction of sewerage to be handled by the municipalities in the Rio de Janeiro Metropolitan region.

The municipal intervention in sewage concerns usually is restricted to construction of sewerage networks, and thereafter they turn over the systems to CEDAE to maintain and operate, as well as to charge customers their "sewage bill" together with their "water bill".

The most important investment made by a municipality in the metropolitan region can be found in Rio de Janeiro city, where quite a large network of sewers and a treatment sewage treatment stations has been built in the west part of the city, an area where there has been recent rapid development.

The institution in charge of the construction of the sewage system in the Rio de Janeiro city is Rio-Águas Foundation. This foundation has the objectives to plan, organize, execute and coordinate sanitation activities as well as to control and prevent urban floods.

Rio-Águas was created in June 1998, as an autonomous organization, administratively subordinated to the Rio de Janeiro city Public Works secretariat. The main motive for its creation was cyclic flooding problems that plagued Rio de Janeiro city, especially during the summer season. The sewage related activities were also contracted to Rio-Águas, according to the municipal authorities, in face of the lack of response from CEDAE to solve sewerage problems in several areas of the city.

The activities of Rio-Águas regarding sewage and sewerage are concentrated in the west part of the city, (therefore outside of the Guanabara bay basin): namely at,

- Recreio dos Bandeirantes: the system consists of 92 km of sewers, 4 lifting stations and one sewage treatment station (50 liters/second capacity, 90% organic load reduction, deep shaft system). This system is already made and four more lift stations and 26 km more of sewers will be constructed by 2003.
- Vargem Grande: the system consists of 18 km of sewers, one lifting station and one treatment station. The system is under construction, and is to be completed by 2003.
- Vargem Pequena e Camorim: the system consists of 11 km of sewers, 3 lifting stations and 2 sewage treatment stations. The system is under construction, and is to be completed by 2003

The budget for all the works above is R$14 million, funded by Rio de Janeiro city municipal treasury and from the Pro-Sanitation (Pro-Saneamento) program of the Federal Government, managed by Caixa Economica Federal.

Concerning municipalities outside the metropolitan area, interventions in sewage matters are generally limited to construction of sewers in poor neighborhoods, without any coordination with CEDAE. These sewers are usually made as a response to critical problems posed by open sewers in populated areas.

The sewage collected throughout these networks usually is conducted to open channels or rivers, thus aggravating the pollution problems of the receiving bodies of water, including Guanabara Bay.

The extent and location of these networks are not known, since there are no records in the municipalities of the works done in CEDAE or in the state organizations related to sewage and sewerage or environmental control.

(2) CEDAE's Management

1) Organization of CEDAE

CEDAE is a State Public Company, and belongs to State of Rio de Janeiro, being under the administrative jurisdiction of the State Secretariat of Sanitation and Water Resources (SESRH). Organization of CEDAE consists of President's Office and eight divisions. Three divisions (Administration, Judiciary & Human Resources, Production and Treatment and Enterprise) are organized by functions, and five divisions (Guanabara Bay West, Guanabara Bay East, Coast, Septiba Bay and Grand Islands, Inland) are organized by service area. The 16 municipalities, which have service from CEDAE, are divided in two divisions (West Guanabara Bay and East Guanabara Bay) as shown in *Table 2.21*.

Table 2.21 Organization of CEDAE as of May 2002

	Manager	Employee	Total
President's Office	158	60	218
Administration Division	424	582	1,006
Judiciary and Human Resource Division	202	57	259
Enterprise Division	38	95	133
Production and Treatment Division	150	1,535	1,685
Guanabara Bay West Division	263	1,029	1,292
Guanabara Bay East Division	131	396	527
Coast Division	94	354	448
Septiba Bay and Grand Islands Division	143	578	721
Inland Division	220	887	1,107
	1,823	5,573	7,396

Source: CEDAE

Number of staff in CEDAE was 7,396 in May 2002. The number has decreased over three years as follows: 8,729 in March 1999, 8,269 in March 2000, and 7,859 in March 2001.

2) Water Bill System

Water bill system of CEDAE consists of four tariff tables: namely, Tariff A with sewerage, Tariff A without sewerage, Tariff B with sewerage, and Tariff B without sewerage. Tariff A with sewerage and Tariff B with sewerage were applied in almost all municipalities[1], which belong to the Metropolitan Area[2].

Water bill payers in each tariff table are classified into four categories: namely, Household, Commercial, Industrial, Public and State Government. "Commercial" includes companies and factories that don't use water as materials of their output. Otherwise "Industrial" include factories that use water as one of the materials of their output. *Table 2.22* shows the example of water bill in case of Household and Tariff A with sewerage, and *Table 2.23* shows examples of water bills based on *Table 2.22.*

[1] Tariff A with sewerage is used in eight districts in the Metropolitan Area, and Tariff B with sewerage is used in other 12 districts in the Metropolitan Area.

[2] The RJ State Government divides municipalities into eight regions. The Metropolitan Region includes 19 municipalities. 13 Municipalities, excluding Petrópolis, Cachoeiras de Macacu and Rio Bonito are included in the region.

Table 2.22 Example of Water Bill (Tariff A with sewerage, Household)

Volume of water in a month (m^3)	Tariff (R$)	Multiplier	Example	
			Volume	Tariff
0-15	0.792046	1.00	15	11.88
16-30	1.742501	2.20	30	38.01
31-45	2.376138	3.00	45	73.65
46-60	4.752276	6.00	60	144.93
60-	6.336368	8.00	70	208.29

Source: CEDAE

Table 2.23 Example of Water Bill (Tariff A with Sewerage and Tariff B with Sewerage, Household*)

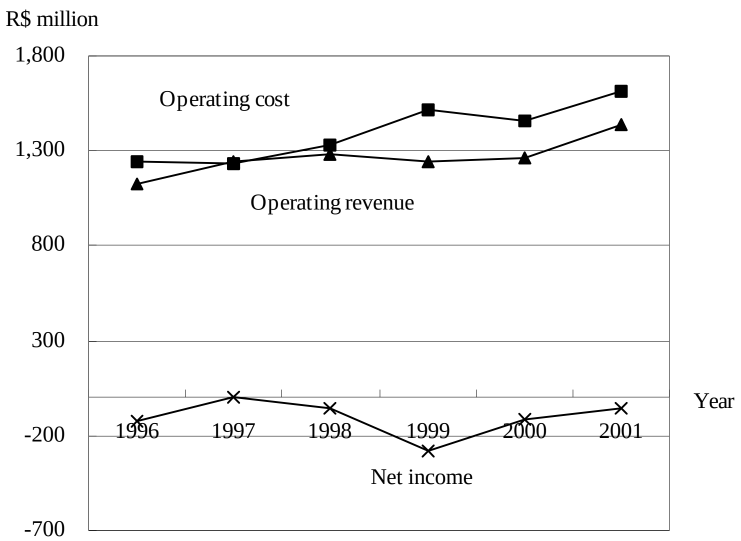
Water consumption in a month (m^3)	Tariff A with sewerage (R$)	Tariff B with sewerage (R$)
Less than 15	20.72	18.18
20	38.56	33.40
25	54.87	47.71
30	71.18	62.01

Note: * If household income is less than five times in a month, water bill less than 15m^3 isn't fixed but proportionally increased (0.691+0.691, case of Tariff A with sewerage, and 0.606+0.606, case of tariff B with sewerage).

Source: CEDAE

3) Business Situation of CEDAE

As shown in *Figure 2.9*, Net income has been minus except for 1997 in recent years. It recorded R$-281 million in 1999, and R$-55million in 2001.



Source: CEDAE

Figure 2.9 Operating Revenue, Operating Cost and Net Income of CEDAE

Table 2.24 shows business situation of CEDAE, SABESP and EMBASA. The following remarks are highlighted regarding the business environment of CEDAE.

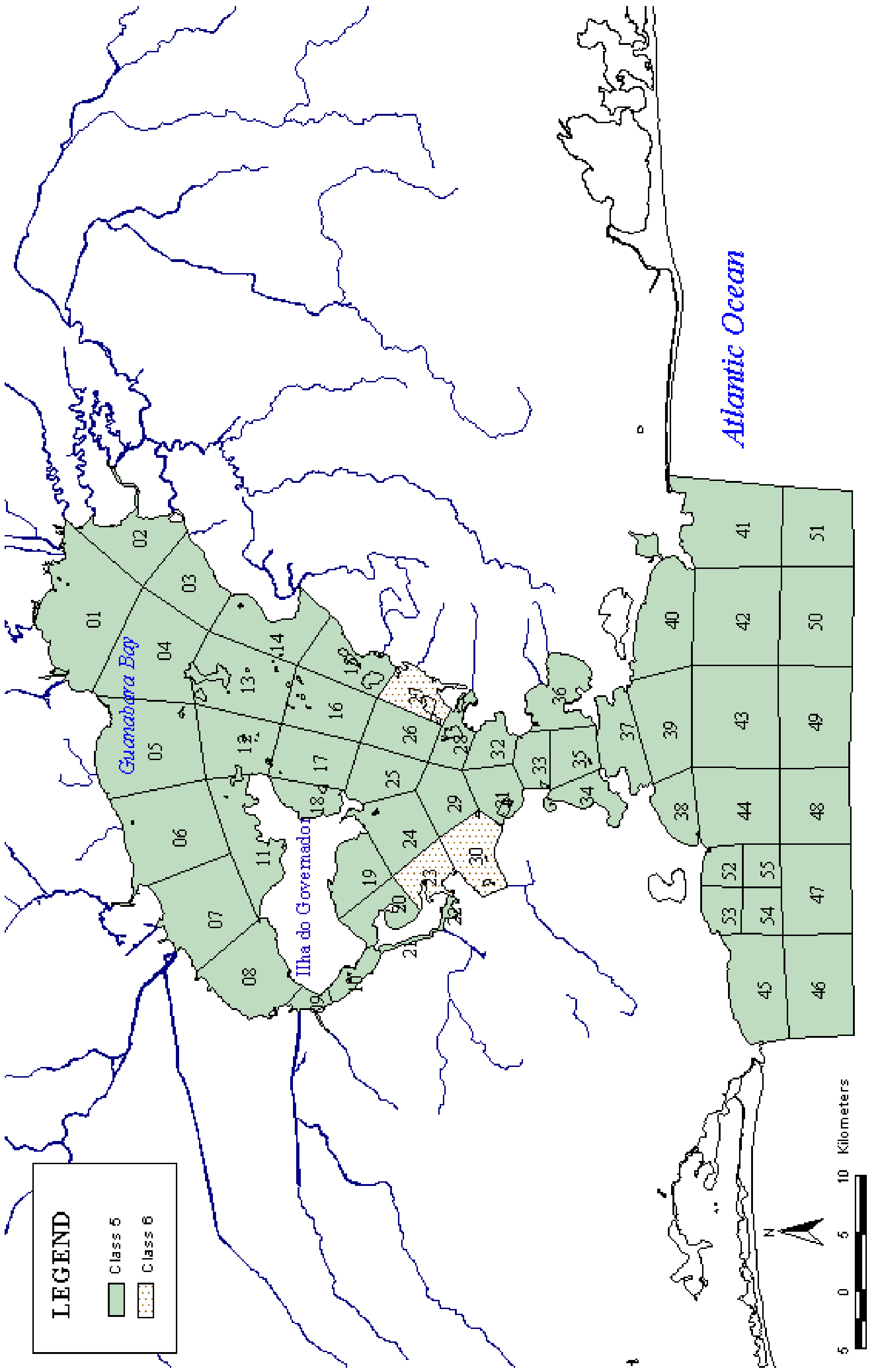
- Number of household per employee (457) is nearly the same level as SABESP (461) and EMBASA (345).
- Water consumption per household in CEDAE service area (27.0) is extremely high compared to those of SABESP (15.5) and EMBASA (14.5). That supposedly comes from water leakage and/or over-consumption.
- In the total liability and capital, percentage of fixed liability (71%) is higher than those of SABESP (40%) and EMBASA (29%). Otherwise, percentage of net equity (17%) is much lower than those of SABESP (54%) and EMBASA (62%). This means that financing of CEDAE depends on borrowing, in which interest and capital have to be paid back in future, more than SABESP and EMBASA.
- Operating revenue of CEDAE (R$-192 million) is worse than that of EMBASA (R$-119 million). On the other hand, SABESP earned a big profit (R$1,412 million of operating revenue and R$521 million of net income).
- Water bill per m^3 (1.05) and cost per m^3 (1.20) is almost same level as SABESP (1.19 and 1.13, respectively). But revenue per m^3 is lower than that of SABESP, considering higher percentage of uncollected water bills (54.3%) than SABESP (31.4%) and EMBASA (39.2%)

Table 2.24 Comparison of Business Situation

	CEDAE	SABESP	EMBASA
General			
Population having water supply service (million persons)	5.495	15.330	1.320
No of residents having sewerage service (million persons)	2.889	6.636	1.818
Service cover ratio (Sewerage, %)	47.4	80.0	19.9
No of Employment (persons)	8,416	18,324	4,006
No of household per adjusted employment* (household)*	457	461	345
Consumption per household (m^3)	27.0	15.5	14.5
Balance Sheet (R$ million)			
Total Asset	3,065	15,192	2,846
Current Asset	802	1,525	175
Intangible Fixed Asset	50	214	68
Tangible Fixed Asset	2,212	13,454	2,603
Current Liability	357	790	262
Fixed Liability	2,172	6,134	831
Net Equity	522	8,268	1,753
Profit and Loss (R$ million)			
Sales (total amount of invoice)	1,268	3,458	399
From Sewerage	481	1,365	42
Total expenditure	1,425	3,161	569
Operating Revenue	-192	1,412	-119
Net Income	-115	521	-156
Percentage of uncollected water bill (water Supply, %)	54.3	31.4	39.2
Bill per m^3 (Water supply and sewerage, R$)	1.05	1.19	0.87
Cost per m^3 (Water supply and sewerage, R$, R$)	1.20	1.13	1.43
Bill per m^3 (Sewerage, R$)	1.10	1.28	0.59

Note: * In adjusted employment, number of employment is estimated as if each company conducts all works including outsourcing works

Source: DIAGNÓSTICO DOS SERVIÇOS DE ÁGUA E ESGOTOS 2000, SISTEMA NACIONAL DE INFORMAÇÕES SOBRE SANEAMENTO (SNIS)



Note:
Class 5; Recreations(swimming, water skiing, diving), protection of aquatic lives, and crop cultivations
Class 6; Navigation, esthetics, and recreations without direct water contact.
(Refer to CONAMA Resolution # 020/86 for detail.)

Figure 2.8 Water Quality Classification of Guanabara Bay by DZ 105

CHAPTER 3

POLLUTION ANALYSIS

CHAPTER 3 POLLUTION ANALYSIS

3.1 INTRODUCTION

3.1.1 CONCEPT OF POLLUTION ANALYSIS

Pollution analysis consists of following two components:

- Basin load model to estimate the discharge of pollution load from the basin to the bay.
- Water quality simulation model to estimate the water quality of the bay based on the estimated pollution load discharge from the basin by the basin load model.

The final outputs of the pollution analysis will present bay water quality for several scenarios of improvement measures, which mainly involve development of sewerage system.

The concept of pollution analysis is shown in *Figure 3.1*. Outputs of the basin model are a hydrological discharge and a pollution load discharge. Hydrological discharge is one of factors to determine fluctuation of pollution discharge, as well as major input to the water quality simulation model. Both hydrological discharge and pollution load generation are determined by the natural and socio-economic conditions of the basin.

The pollution generation becomes the pollution discharge, and is affected by natural and socio-economic conditions and controlled by pollution reduction measures.

3.1.2 PURPOSE OF POLLUTION ANALYSIS

A primary purpose of the pollution analysis in the Study is for evaluation of improvement measures to be discussed in the Study.

The process of pollution analysis could also be utilized by the Rio de Janeiro State when they plan further improvement of the bay. Moreover, the lack of such analysis in history of improvement activities is an urgent issue to be addressed together with the implementation of structural measures. Therefore, the Study proposes that the State utilize the pollution analysis as a support tools for decision making concerning Guanabara Bay improvement.

3.1.3 SUPPORTING TOOLS FOR DECISION MAKING

In the pollution analysis of the Study, the water quality simulation model will be given as a set of modules developed on MIKE21, the basin model; however, this is just a calculation of various data.

To make the basin model into a support tool, it is necessary to develop a process form that can be used repeatedly. The Study is doing this by establishing a database to accumulate all the information required for basin discharge, as shown in *Figure 3.1*.

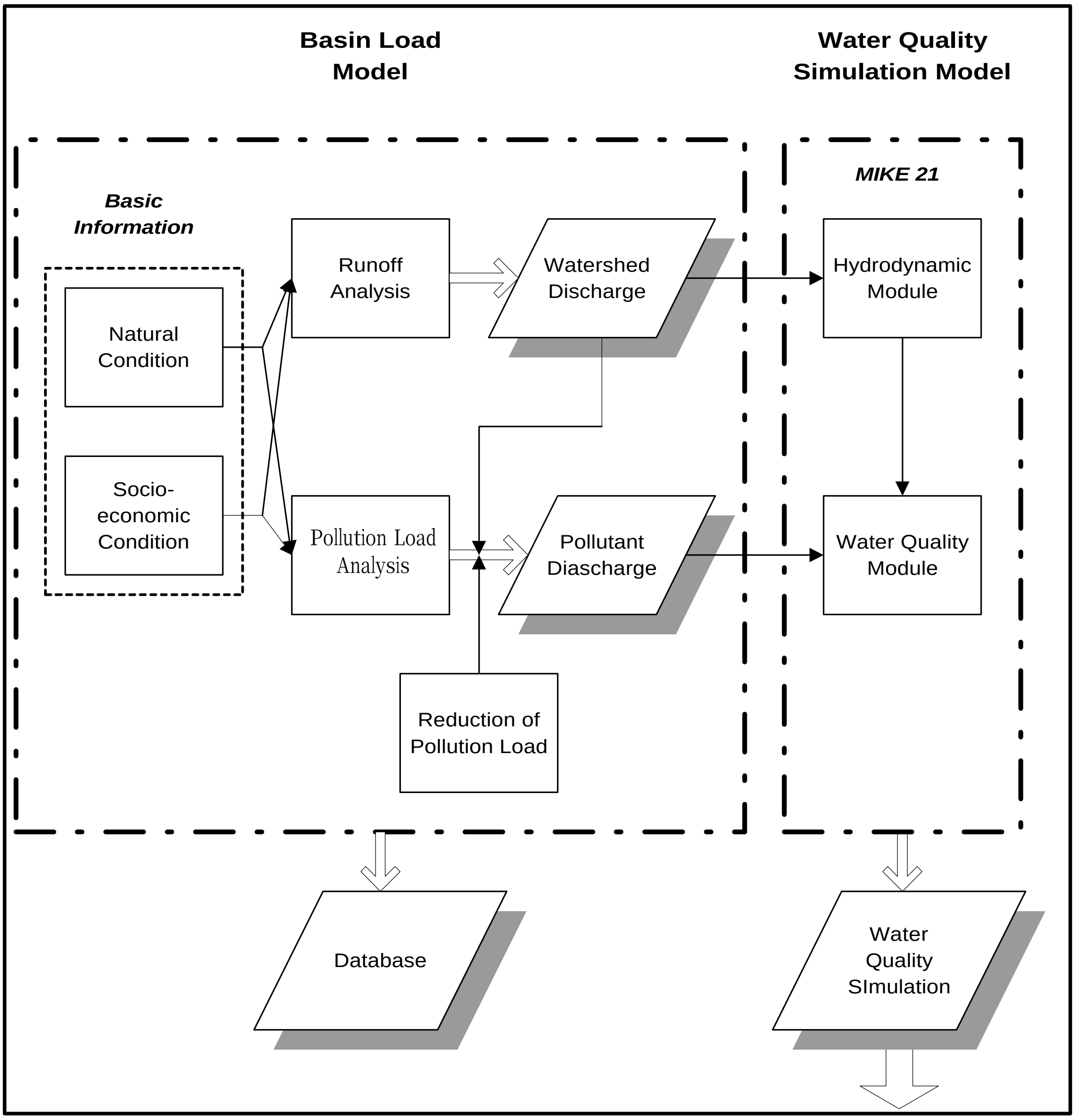


Figure 3.1 Concept of Pollution Analysis

3.2 HYDROLOGICAL ANALYSIS

3.2.1 MONITORING NETWORK ON METEO-HYDROLOGY

(1) Monitoring Network on Meteorology

Basically, 3 types of meteorological data, ranging from 1928 - 2002 have been collected from INMET, SERLA and web side (internet) of GEO-Rio. Those are: daily and monthly rainfalls and monthly evaporation data. Besides that, general climate data such as monthly average rainfall, temperature and relative humidity have also been collected from CIDE for period 1973 - 1990.

In total, data have been collected at 73 meteorological stations: 5 from INMET, one from GEO-Rio and 68 from SERLA. Among the 68 SERLA stations, only 16 are presently operational with irregular measurements. Daily rainfall data for year 2000 could be collected only at 7 stations inside Guanabara Bay basin. No evaporation data inside Guanabara Bay basin for year 2000 could be collected. Monthly old evaporation data have been collected only at 3 stations inside Guanabara Bay basin. Location map of all the meteorological stations are show in *Figure 3.2*.

(2) Monitoring Network on Hydrology

River flow data could be obtained only from SERLA. There are 25 telemetric hydrological stations operated by SERLA where water level, rainfall and water quality data (temperature, dissolve oxygen, conductivity and pH) are measured. All of the telemetric stations have been installed in 1998 under PDBG project. Location map of the stations along with gauged basin boundary is show in *Figure 3.2*.

At first, telemetric data was collected at all the stations and after compiling the data, it was found that there are a lot of missing data with a lot of errors, especially rainfall data. So, none of the telemetric data was used. Fortunately, SERLA keeps a record of manual staff gauge readings for 23 stations where water level readings are taken at two times a day: 7 A.M. and 5 P.M. Manual staff gauge readings on water levels at all the 23 stations (from stations nos. H01 to H25 except H08 an H20) for years 1999 and 2000 have been collected and analyzed. These data have also been used for calibrating the runoff model.

3.2.2 Meteo-Hydrological Analysis

(1) Stream Gauge Characteristics

Since 1998, SERLA carries out regular discharge measurement at each of the stream gauge station once or twice in a month with some exceptions. Since SERLA doesn't have any rating curve to convert the gauge height values into discharge values, therefore, a rating curve at each of the station based on the discharge measurements of SERLA has been constructed (except station H12 for which, no relation could be found between measured gauge height and discharge) and has been applied for converting gauge height to discharge. The general equation of the rating curves is as follows:

$$Q = c(H - a)^b$$

where: Q = discharge (m^3/s); H = gauge height (m); c = constant;

b = exponent and a = minimum bed level where flow is zero.

(2) Seasonal Variation in Rainfall and Discharge

Based on the rating curves and observed gauge heights, daily discharges at all the SERLA stream gauge stations have been calculated for years 1999 (except H12 and H20) and 2000 (except H08 and H12). To illustrate comparison between rainfall and discharge, daily rainfalls for year 2000 at three rainfall stations and daily discharges for years 1999 and 2000 at three stream gauge stations close to those three rainfall stations are shown in *Figure 3.3*. The figures imply that there is a clear variation in discharge by month and the discharge variation resemble the rainfall variation.

(3) Probable Rainfall

For runoff model of the Guanabara Bay basin and also for 2-D hydrodynamic, water quality and eutrofication models of the Guanabara Bay, year 2000 have been selected as the base for calibration. Three scenarios have been selected for modeling purpose which are defined below:

- 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.

To get rainfall distribution for the above three scenarios, probability analysis on annual total rainfall for the total Guanabara basin area has been carried out. Annual total rainfall for the total basin for 36 years (1965 - 2000), generated using raw meteorological data and GIS database have been used. Log-Normal probability distribution has been applied and the goodness of fit has been checked by Thomas Plotting Position formula. The result of probability analysis is presented in *Table 3.1* below:

Table 3.1 Probable Annual Total Rainfall of Guanabara Bay Basin

Non-Exceedence Probability (%)	Annual Total Probable Rain (mm)	Ratio with Year 2000 Rain
1	927	0.708
10	1,142	0.872
50	1,476	1.127
70	1,638	1.251
80	1,746	1.333
90	1,906	1.455
99	2,348	1.792

It can be seen that annual total rainfall for average, dry and wet years are 1476, 1142 and 1906 mm respectively. The ratio of annual total rainfall between year 2000 (1310 mm) and average, dry and wet years are calculated as 1.127, 0.872 and 1.455 respectively which implies that year 2000 was rather a dry year.

3.2.3 RUNOFF ANALYSIS

(1) Introduction

The main objective of runoff analysis was to develop a runoff model for estimating daily runoff from daily rainfall for a complete year for the total Guanabara Bay basin area for different scenarios that would contribute as freshwater input to the 2-D hydrodynamic model of the Guanabara Bay. The major three steps followed in developing the runoff model are:

- Database development for input to the runoff model
- Estimation of runoff parameters through calibration of rainfall-runoff model against measured discharges at SERLA stream gauge stations for year 2000
- Runoff calculation for different scenarios such as for average, dry and wet years.

(2) The Runoff Model

A schematic network diagram of the runoff model is shown in *Figure 3.4*. In total, runoff calculation has been made on 29 major river basins (including islands) that contribute runoff directly to the Guanabara Bay and also on 22 sub-basins lying inside the major river basins.

As for the software, Danish Hydraulic Institute's runoff model called NAM model has been used. NAM is a conceptual rainfall-runoff model that utilizes simple representation of different storages of hydrologic cycle. A schematic diagram of NAM model is shown in *Figure 3.5*. NAM model simulates three types of flow: overland flow (surface runoff), interflow (horizontal sub-surface flow) and groundwater flow (base flow). For simplicity, in this Study, interflow has been combined with overland flow. The runoff model developed in this Study involves calculations of:

- Surface Runoff: Has been calculated using NAM model through calibration of the model against measured discharges at SERLA stream gauge stations. Since, the contribution of interflow is almost negligible, therefore, interflow has been included into surface runoff.
- Base Flow: Has been calculated from empirical equations developed using measured base flow data at the SERLA stream gauge stations.
- Wastewater Flow: Has been calculated using correlation between wastewater flow and basin population.

Base flow and wastewater flow have been calculated separately and added to the surface runoff to get the total runoff.

(3) Divisions of River Basins

Following the JICA 1994 sub-divisions and also the river basin divisions that came with CIDE GIS database, drainage basins of the river system of the Guanabara Bay have been identified on a 1/50,000 scale map with a combination of 20 m and 100 m contours as shown in *Figure 3.6*. The total basin area of the Guanabara Bay has been divided into 24 major river basins and 5 grouped island basins. Among the 24 major river basins, 4 have been sub-divided into 22 sub-basins. Therefore, in total, there are 47 individual sub-catchments.

(4) Meteorological Data

Daily rainfall data could be collected at only 7 available stations for year 2000, which has been selected as the base year for runoff model calibration. Runoff analyses using basin average rainfall data based on those 7 stations result in a very poor calibration of the runoff model. Therefore, daily rainfall data have been updated to ensure a well distribution of spatial rainfall for input to the rainfall-runoff model. Please refer to *Supporting 4* on Hydrological Analysis for details on the updating procedure. Monthly old evaporation data at only 3 available stations have been collected and used for the rainfall-runoff model.

(5) Landuse Data

A complete GIS database of landuse map, prepared by CIDE in 1998 on 1/100,000 scale using 1996 SPOT satellite image is the latest landuse map available for the Study area and has been used in this Study. There are 19 landuse classifications, which are listed along with areas in *Table 3.2*. For simplification, the original 19 landuse classes have been reclassified by groupings into the followings 6 landuse classes:

- Urban Area (high, low and medium density areas and grand constructions) comprise of about 868 km^2, which is about 21% of the total basin area.
- Forest Area (dense Ombrophyle forest and reforestment) comprise of about 1,052 km^2, which is about 26% of the total basin area.
- Vegetation Area (agricultural and flood prone areas, cropped/projected rocky land, degraded hillshade, secondary vegetation, cattle field – pasture land, exposed soil and valley vegetation) comprise of about 2,024 km^2, which is about 50% of the total basin area.
- Mangrove Area (mangrove and degraded mangrove areas) comprise of about 104 km^2, which is only 2.5% of the total basin area.
- Water Body (rivers, lagoons and ocean) comprise of about 23 km^2, which is only 0.5% of the total basin area.
- Others (beach) have almost negligible areas (0.4 km^2 in total).

Utilizing vector overlay technique of GIS database, landuse areas by drainage basins of SERLA stream gauge stations, major river basins and sub-basins have been calculated. Please refer to *Supporting 4* on Hydrological Analysis for detailed landuse areas.

(6) Base Flow

Through comparison of discharge hydrographs for year 2000, base flows (defined as the minimum annual daily average discharge of year 2000) and landuse distributions of the basins of SERLA stream gauge stations, six different zones have been identified for base flow calculations. Based on the base flows at the SERLA stream gauge stations, empirical equations have been developed for the six zones that correlate base flow with basin area. Please refer to *Supporting 4* on Hydrological Analysis for details on the base flow zones and equations. Based on the base flow equations for different zones, base flows by drainage basins of SERLA stream gauge stations, major river basins and sub-basins have been calculated. As a threshold value, a minimum base flow of 0.01 m^3/s has been applied.

(7) Calibration of Runoff Model

Item numbers (3) to (5) above present detailed descriptions on the data needed for developing the surface runoff model including interflow. Item number (2) describes the surface runoff parameters to be calibrated. By utilizing all the data and through trial and error method, the surface runoff model has been satisfactorily calibrated against observed daily discharges for year 2000 at 22 SERLA stream gauge stations. The three basic surface runoff parameters namely overland flow runoff coefficient (CQ_{OF}), maximum water contents in root zone storage (L_{max}) and surface storage (U_{max}) and their calibrated values as functions of landuse types are presented in *Table 3.2*. All of the calibrated parameters have been correlated with physical basin parameters such as landuse type, average basin slope, overland flow length etc. Therefore, all the calibrated runoff parameters can be estimated under different / changing landuse and basin conditions. Please refer to *Supporting 4* on Hydrological Analysis for details on the calibrated runoff parameters.

(8) Wastewater Flow

As presented in article (7), the runoff model is satisfactorily calibrated at most of the SERLA stations of which the catchments are closed to natural condition and are not influence by human interferences such as inter-basin transfer of water. However, while calibrating the runoff model at SERLA stations (Station Nos. H01, H02, H10 and H11) that have highly urbanized catchments and are influenced by inter-basin transfer of water, runoff deficit could be observed between the observed and simulated runoffs at those stations. Even though, there is no data on inter-basin transfer of water, however, from investigations, the JICA team came up with the answer that around 25 m^3/s discharge is being transferred to Guanabara Bay basin from adjacent basin(s). It is assumed that this 25 m^3/s discharge, which is different from natural runoff is being consumed by the Rio de Janeiro and Niteroi urban areas for different uses and generates wastewater that is finally discharged into Guanabara Bay.

Wastewater flow by the urbanized sub-catchments in the Rio de Janeiro and Niteroi areas have been estimated based on population and the estimations have been checked against observed data at urbanized SERLA stations lying in the Rio de Janeiro area. Using 300 lpcd (liters/capita/day), the total wastewater flow based on population lying in the urbanized sub-catchments of the Rio de Janeiro and Niteroi areas is estimated to be 22.90 m^3/s which is very close to the inter-basin transfer of 25 m^3/s.

(9) Results of Runoff Model for Different Scenarios

Through calibration of the surface runoff (NAM) model against measured discharges at 22 SERLA stream gauge stations, equations and correlations for estimating different runoff parameters have been determined. By applying those equations and correlations, runoff parameters for all the major river basins and sub-basins have been estimated. Utilizing all the basin data and the estimated runoff parameters, empirical equations and correlations, surface runoff for different scenarios using the NAM model as well as constant base flow and wastewater flow from each of the major river basin and sub-basin has been calculated. The result of runoff model is presented in *Table 3.3* and is summarized in *Figure 3.7*. Key outputs from the runoff model are summarized below:

- Total runoffs (surface runoff + base flow + wastewater flow) from the entire study for Year 2000, Dry, Average and Wet Years are obtained as 113, 96, 131 and 183 m^3/s respectively. Therefore, Year 2000 was in-between Dry and Average Years.
- Base flow and wastewater flow, which are constant flows for the total Study area are 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.

(10) Effect of Urbanization on Runoff

The runoff model has been calibrated and runoff for different scenarios have been calculated using 1996 landuse condition, prepared by CIDE in 1998 and that is the latest landuse map available now. The calculated runoff has been applied in developing the 2D hydrodynamic, water quality and eutrofication models of the Guanabara Bay using MIKE 21. Since, runoff is a function of landuse condition, therefore, effect of future urbanization on runoff has been investigated using NAM model. Assuming that urbanization will take place mainly in the south-eastern part of the Guanabara Bay basin namely in Rio Alcantara (B0800) and Rio Porto das Caixas (B0902) lying in Rio Caceribu (B0900) river basins, increase in runoff due to increase in urban area by 10%, 20% and 30% compared to 1996 urban area has been calculated using NAM model. The result shows that the effect of increase in runoff due to change in landuse on the total runoff for the Guanabara Bay basin can be considered as negligible. Therefore, the runoff model developed in this Study is applicable for future landuse condition as well.

Table 3.2 Landuse Classification and Calibrated Basic Runoff Parameters

Reclassified Grouped Landuse	ID	Portuguese	English	Description	by ID (km²)	by ID (%)	by Group (km²)	by Group (%)	Overland Flow Runoff Coefficient CQ_{OF}	Maximum Water Content in Root Zone Storage L_{max} (mm)	Maximum Water Content in Surface Storage U_{max} (mm)
Urban Area	Ia	Area Urban (Alta Densidade)	Urban Area (High Density)	Mainly consists of dense high raised buildings.	152.9	3.8%	868.0	21.3%	0.85	10	10
	Ib	Area Urban (Baixa Densidade)	Urban Area (Low Density)	Consists of degraded vegetation, secondary forests, cattle fields etc.	484.2	11.9%			0.60	20	10
	Im	Area Urbana (Media Densidade)	Urban Area (Medium Density)	Consists of predominately low rised buildings with few high rised buildings.	204.3	5.0%			0.75	15	10
	Pn	Grandes Construcoes	Grand Construction		26.6	0.7%			0.85	0	5
Forest	Fo	Floresta Ombrofila Densa	Dense Ombrophyle Forest	Also known as "Tropical Rain Forest". Developed in rainy areas where dry season is less than 60 days.	1,050.9	25.8%	1,052.0	25.8%	0.35	150	15
	Re	Reflorestamento	Reforestment	Once deforested for paper, celulose and wood industries, again systematically reforested by substituting primary vegetation with pines and eucalyptas trees.	1.0	0.0%			0.40	120	15
Vegetation	Ag	Area Agricola	Agricultural Area	Consists of natural primitive vegetation, permanent or temporary cultivated areas etc. Mainly used for crop cultivation.	325.2	8.0%	2,023.6	49.7%	0.45	25	10
	Ai	Area Inundavel	Flood Prone Area	Low areas closed to the rivers, suffer from periodical inundation due to intense rainfall in the highland and high tide. Good for agricultaural use, sometimes residencial areas can be found.	37.6	0.9%			0.50	20	10
	Ar	Afloramento Rochoso	Cropped / Projected Rocky Land	Mainly rocky but may consist of decomposed material, vegetal covers of several kinds etc.. Can be found in some islands.	14.2	0.3%			0.80	10	10
	Ed	Encosta Degradada	Degraded Hillside	Basically was forest but had been substituted by agricultaral land and then had been abandoned. Recently, intense urbanization is taking place.	275.0	6.8%			0.50	20	5
	Fs	Vegetacao Secundaria	Secondary Vegetation	Also known as "Capoeira". When there is a selective cutting of trees for industry, the remaining vegetation is called "Secondary Vegetation". After reforesting, such areas might appear as a new kind such as Ombrophyle Forest.	691.9	17.0%			0.30	120	20
	P	Campo-Pastagem	Cattle Field - Pasture Land	Consists of artificial vegetation replacing primitive vegetation. Suffers from soil erosion.	615.5	15.1%			0.10	120	20
	Se	Solo Exposto	Exposed Soil	Comprise of devagitated and abandoned areas.	2.4	0.1%			0.50	10	5
	V	Vegetacao de Vareza	Valley Vegetation	Consisits of sediment deposited and flood prone areas along / close to rivers and lagoons. Vegetation density depends on flood season.Vegetation varies from small bushes to big trees. Now a day, it's very rare to find such vegetation in it's primary condi	61.8	1.5%			0.30	80	15
Mangrove	M	Mangue	Mangrove		59.7	1.5%	104.1	2.6%	0.30	80	10
	Md	Vegetacao de Mangue Degradao	Degraded Mangrove	Vegetation has been removed for cooking woods etc. Remaining areas are used for garbage disposal and also for urban occupation.	44.4	1.1%			0.30	80	10
Water Body	Ma	Rios, Lagos, Lagoas etc.	Rivers and Lagoons		22.5	0.6%	22.7	0.6%	1.00	0	0
	Oceano	Oceano	Ocean		0.1	0.0%			1.00	0	0
Others	Areia	Praia	Beach		0.4	0.0%	0.4	0.0%	0.05	0	0
Total					4,071	100%	4,071	100%			

Source : Land use data is from GIS database of 1/100,000 scale landuse map of Rio de Janeiro state prepared by CIDE in 1998 using 1996 SPOT satellite image data.
Calibrated basic runoff parameters are obtained by calibration of the runoff model at 22 SERLA stream gauge stations through trial and error method.

Table 3.3 Result of Runoff Model for Different Scenarios

Major River Basin			Sub-Basin			Constant Flow		Average Surface Runoff from NAM Model for Different Scenarios, Q_d				Total Runoff for Different Scenarios $Q_t = (Q_d + Q_b + Q_w)$			
ID	Name	Area (km^2)	ID	Name	Area (km^2)	Base Flow, Q_b (m^3/s)	Wastewater Flow, Q_w (m^3/s)	Year 2000 (m^3/s)	Dry Year (m^3/s)	Avg. Year (m^3/s)	Wet Year (m^3/s)	Year 2000 (m^3/s)	Dry Year (m^3/s)	Avg. Year (m^3/s)	Wet Year (m^3/s)
B0100	Bay - Charitas	9.46				0.05	0.11	0.12	0.08	0.14	0.25	0.27	0.24	0.30	0.41
B0200	Canal Canto do Rio	6.21				0.03	0.31	0.08	0.05	0.10	0.17	0.42	0.40	0.44	0.52
B0300	Bay - Catedrar	7.57				0.04	0.32	0.10	0.07	0.12	0.22	0.45	0.42	0.48	0.57
B0400	Bay - Norte Centro	9.26				0.05	0.25	0.10	0.07	0.13	0.23	0.39	0.36	0.42	0.52
B0500	Rio Bomba	26.78				0.13	0.84	0.35	0.23	0.43	0.75	1.32	1.20	1.40	1.72
B0600	Rio Imboaçu	29.43				0.15	0.55	0.32	0.21	0.41	0.74	1.01	0.90	1.11	1.43
B0700	Bay - Itaoca	8.54				0.04	0.01	0.10	0.07	0.13	0.22	0.15	0.12	0.18	0.27
B0800	Rio Alcantara	173.07				0.87	2.06	1.61	1.10	2.14	3.81	4.54	4.02	5.06	6.74
B0900	Rio Caceribu	811.34				0.57		6.43	4.15	8.86	15.89	6.99	4.72	9.42	16.46
			B0901	Rio Guará-Mirim	77.79	0.01		0.79	0.55	1.03	1.72	0.80	0.56	1.04	1.73
			B0902	Rio Porto das Caixas	188.47	0.20		4.80	0.00	5.46	7.34	5.00	0.20	5.65	7.54
			B0903	Rio Iguá	165.75	0.17		1.63	1.08	2.20	3.81	1.80	1.25	2.37	3.98
			B0904	Rio Caceribu L/S	85.68	0.01		0.73	0.49	1.01	1.81	0.74	0.50	1.02	1.82
			B0905	Rio Caceribu R/S	293.66	0.31		2.72	1.83	3.69	6.47	3.03	2.14	4.00	6.78
B1000	Rio Guapimirim	1,262.03				13.29		25.66	18.69	32.81	53.11	38.95	31.98	46.10	66.40
			B1001	Rio Guapimirim D/S	49.76	0.80		0.78	0.57	1.00	1.65	1.58	1.37	1.80	2.45
			B1002	Rio Guapi	12.10	0.41		0.28	0.22	0.35	0.54	0.70	0.63	0.77	0.96
			B1003	Rio Macacu - D/S	250.49	2.87		4.73	3.42	6.09	9.90	7.60	6.29	8.96	12.77
			B1004	Rio Macacu - U/S	255.61	2.92		7.23	5.42	9.10	14.15	10.15	8.34	12.02	17.07
			B1005	Rio Iconha	224.02	2.60		4.32	3.11	5.59	9.22	6.92	5.71	8.19	11.82
			B1006	Rio Guapiaçu	350.44	3.90		9.25	6.80	11.66	18.45	13.15	10.70	15.56	22.35
			B1007	Rio Guapimirim U/S	119.60	1.52		2.40	1.74	3.07	5.02	3.92	3.26	4.59	6.54
B1100	Canal de Magé	17.08				0.17		0.21	0.15	0.28	0.49	0.38	0.31	0.45	0.66
B1200	Rio Roncador	115.19				0.78		2.46	1.76	3.16	5.17	3.24	2.54	3.94	5.95
B1300	Rio Iriri	19.63				0.18		0.22	0.15	0.29	0.50	0.40	0.33	0.47	0.68
B1400	Rio Suruí	84.44				0.59		1.14	0.78	1.50	2.60	1.73	1.37	2.09	3.19
B1500	Bay - Maua	17.92				0.17		0.21	0.14	0.27	0.46	0.38	0.32	0.44	0.63
B1600	Rio Saracuruna	348.88				2.25		6.83	5.04	8.70	13.85	9.08	7.30	10.95	16.10
			B1601	Rio Estrela	19.52	0.18		0.25	0.18	0.32	0.52	0.43	0.36	0.50	0.70
			B1602	Rio Inhomirim	139.57	0.94		2.63	1.92	3.38	5.47	3.56	2.86	4.31	6.40
			B1603	Rio Saracuruna	189.80	1.25		3.88	2.89	4.93	7.82	5.13	4.14	6.18	9.07
B1700	Rio Iguaçu	716.72				9.41	6.48	9.94	7.23	12.85	20.99	25.83	23.12	28.75	36.88
			B1701	Rio Iguaçu D/S	83.79	0.12		1.08	0.79	1.38	2.23	1.20	0.91	1.50	2.35
			B1702	Rio Iguaçu M/S	37.50	0.04		0.43	0.30	0.58	0.98	0.47	0.34	0.62	1.02
			B1703	Rio Capivari	103.25	0.41		2.21	1.65	2.80	4.42	2.62	2.06	3.21	4.83
			B1704	Rio Tinguá	114.07	0.57		2.15	1.59	2.75	4.39	2.72	2.16	3.32	4.96
			B1705	Rio Iguaçu U/S	100.20	0.37		1.10	0.77	1.47	2.50	1.47	1.14	1.84	2.86
			B1706	Rio da Bota	116.05	0.03	2.41	1.44	1.04	1.89	3.09	3.89	3.48	4.33	5.54
			B1707	Rio Sarapuí	161.87	0.05	4.07	1.80	1.27	2.38	4.04	5.92	5.39	6.50	8.16
B1800	Bay - Cabo do Brito	19.72				0.01		0.29	0.21	0.37	0.59	0.30	0.22	0.38	0.60
B1900	Rio Sâo Jão de Meriti	154.26				0.05	4.85	1.87	1.36	2.42	3.96	6.77	6.26	7.31	8.86
B2000	Rio Irajá	50.95				0.02	2.37	0.71	0.52	0.92	1.50	3.09	2.91	3.30	3.88
B2100	Canal do Cunha	70.23				0.02	3.12	1.04	0.74	1.35	2.20	4.19	3.89	4.50	5.34
B2200	Bay - São Cristóvão	6.41				0.01	0.11	0.09	0.07	0.12	0.20	0.21	0.18	0.24	0.31
B2300	Canal do Mangue	37.95				0.01	1.53	0.53	0.38	0.69	1.17	2.07	1.92	2.24	2.71
B2400	Bay - Botafogo	21.68				0.01		0.26	0.18	0.35	0.59	0.27	0.19	0.36	0.60
B2500	Ilha do Governador	36.28				0.01		0.58	0.43	0.73	1.13	0.59	0.44	0.74	1.14
B2600	Ilha do Fundão	5.35				0.01		0.09	0.07	0.11	0.17	0.10	0.08	0.12	0.18
B2700	Ilha de Paquetá	2.21				0.01		0.04	0.03	0.05	0.07	0.05	0.04	0.06	0.08
B2800	Ilha do Engenho	0.98				0.01		0.02	0.01	0.02	0.03	0.03	0.02	0.03	0.04
B2900	Ilha de S. Cruz	1.10				0.01		0.02	0.01	0.02	0.04	0.03	0.02	0.03	0.05
Total of Major River Basins		4,025				28.88	22.90	60.65	43.43	78.53	129.66	112.43	95.22	130.31	181.44
Total of Islands		46				0.05		0.75	0.56	0.93	1.44	0.80	0.61	0.98	1.49
Total of Study Area		4,071				28.93	22.90	61.40	43.99	79.46	131.10	113.23	95.82	131.29	182.93

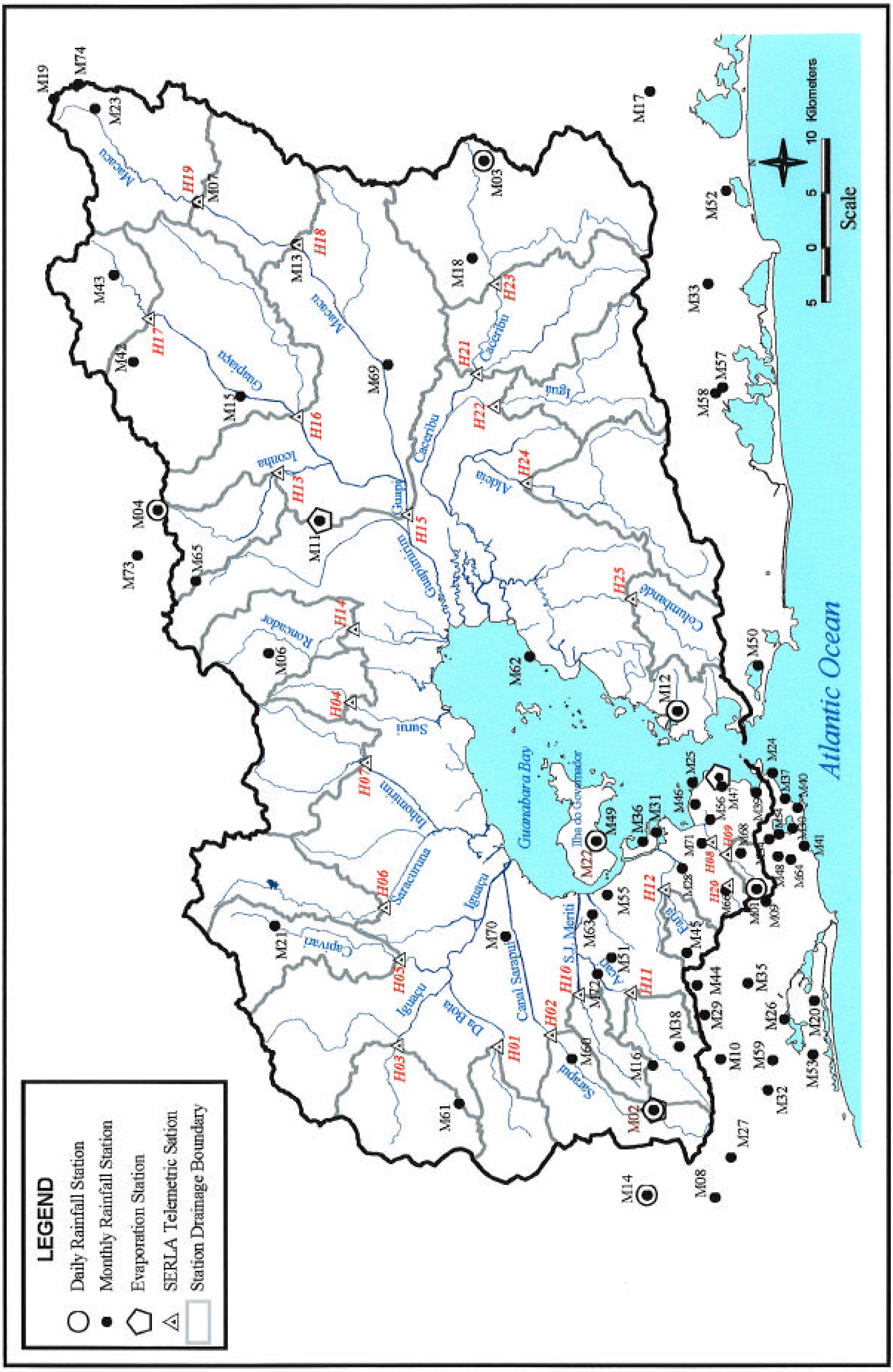


Figure 3.2 Monitoring Network on Meteo-Hydrology

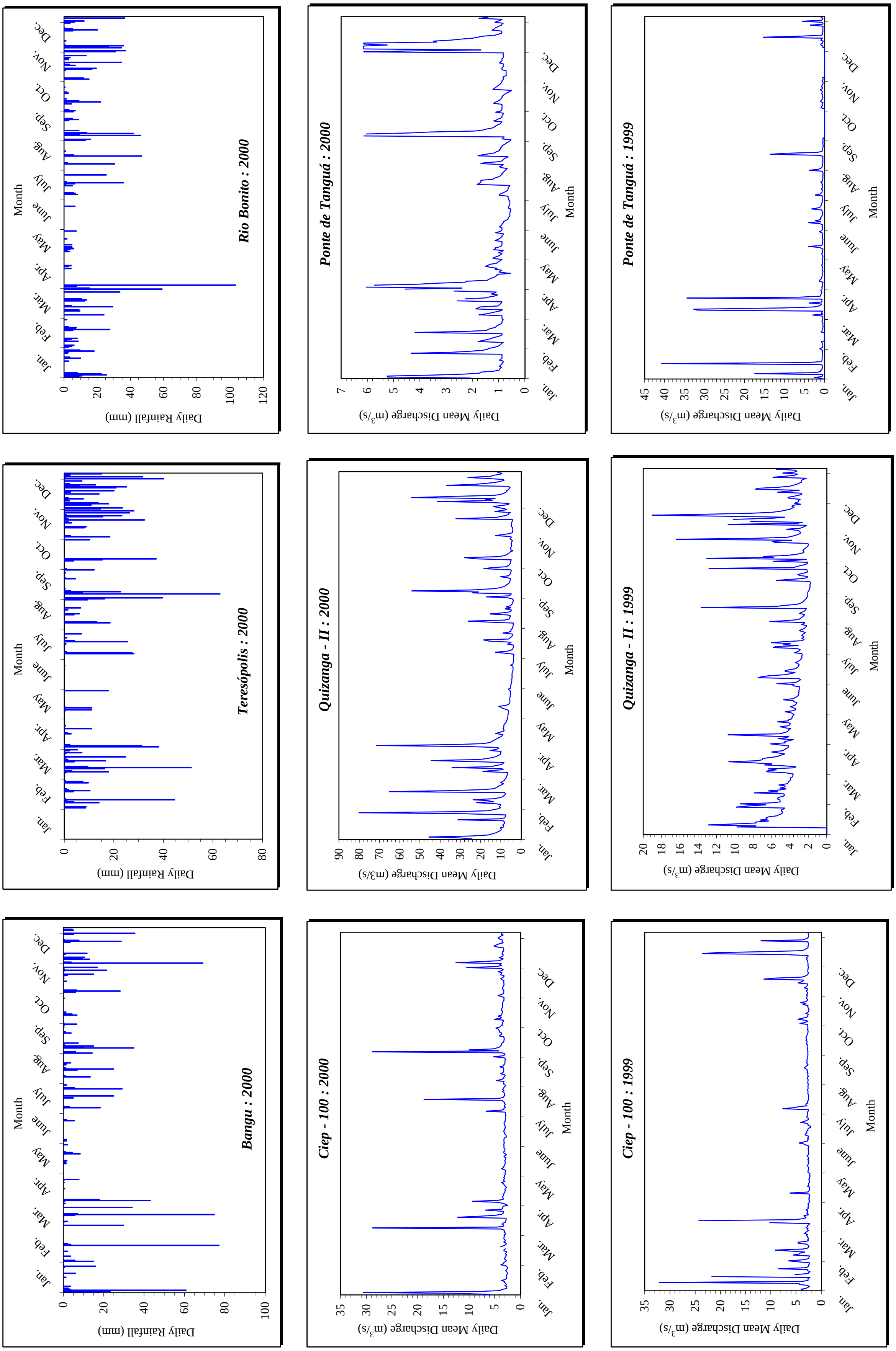


Figure 3.3 Daily Rainfalls and Discharges for Years 1999 and 2000

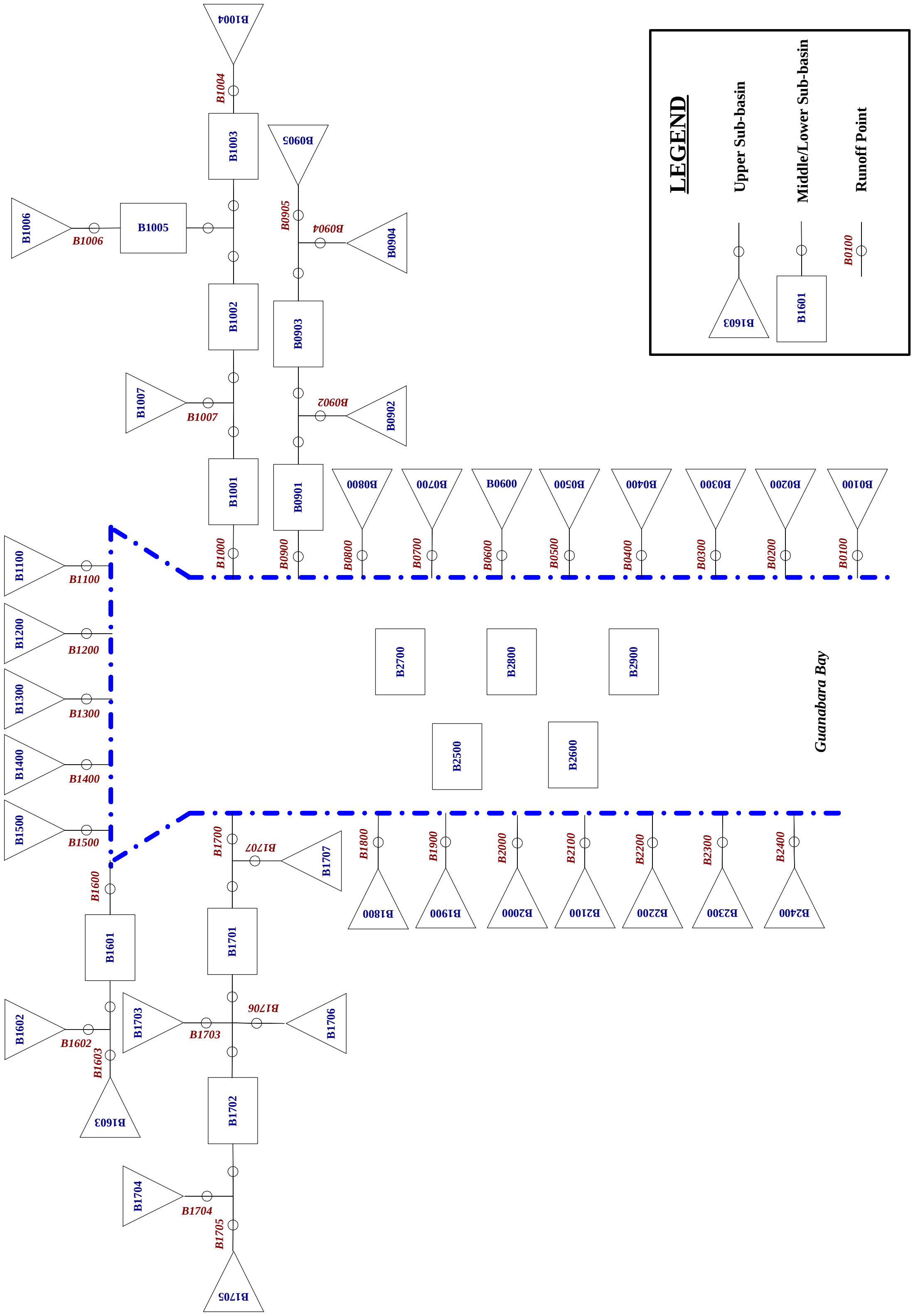


Figure 3.4 Network Diagram of Runoff Model

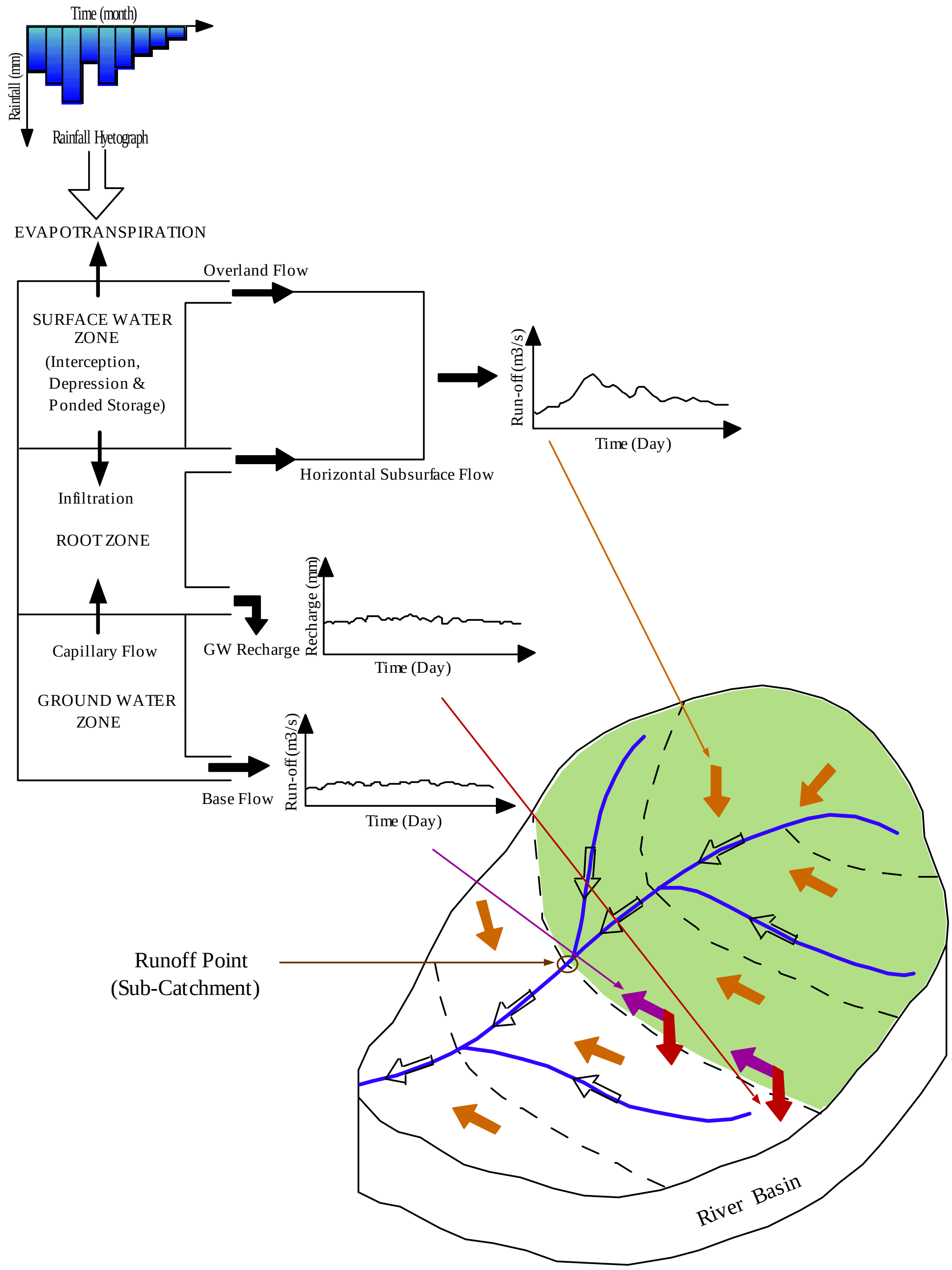


Figure 3.5 Schematic Diagram of Rainfall-Runoff (NAM) Model

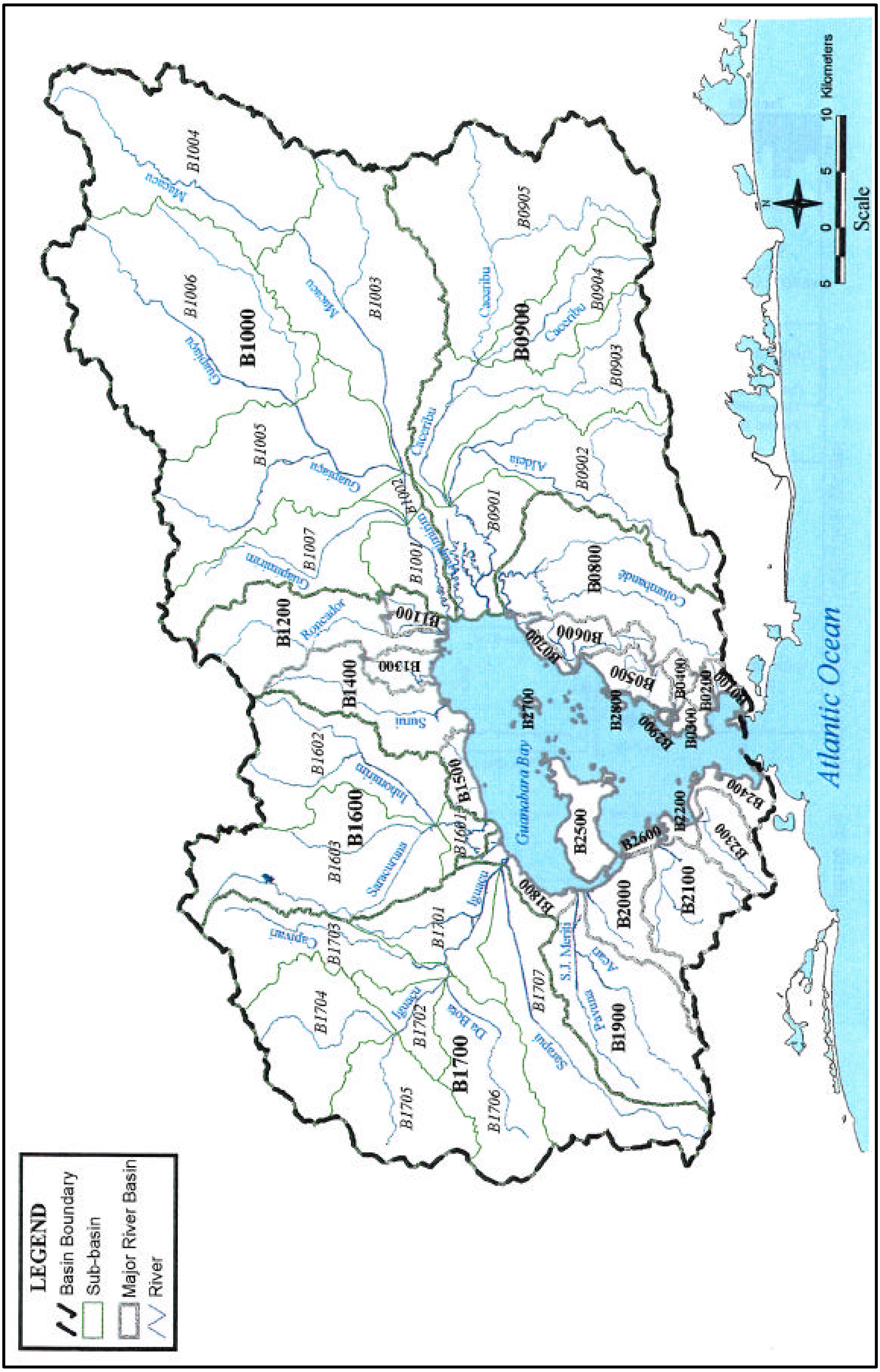
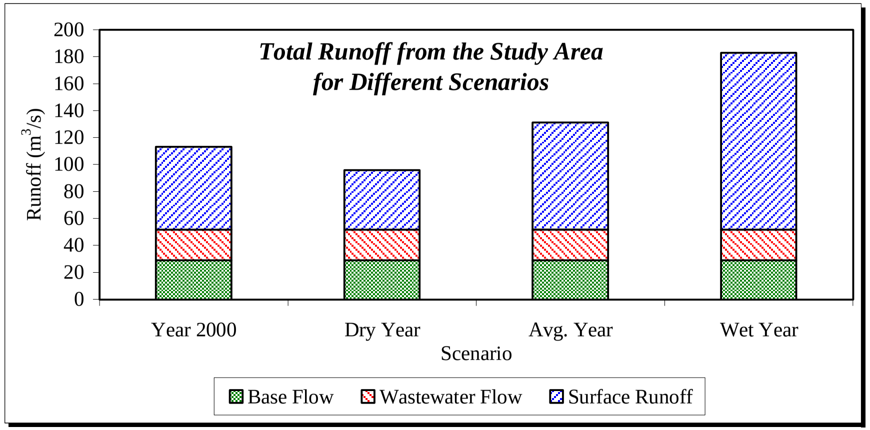


Figure 3.6 Divisions of River Basins

Total Runoff from the Study Area

Runoff	Runoff for Different Scenarios (m^3/s)			
	Year 2000	Dry Year	Avg. Year	Wet Year
Base Flow	28.93	28.93	28.93	28.93
Wastewater Flow	22.90	22.90	22.90	22.90
Surface Runoff	61.40	43.99	79.46	131.10
Total Runoff	113.23	95.82	131.29	182.93

Runoff	Runoff for Different Scenarios			
	Year 2000	Dry Year	Avg. Year	Wet Year
Base Flow	26%	30%	22%	16%
Wastewater Flow	20%	24%	17%	12%
Surface Runoff	54%	46%	61%	72%
Total Runoff	100%	100%	100%	100%



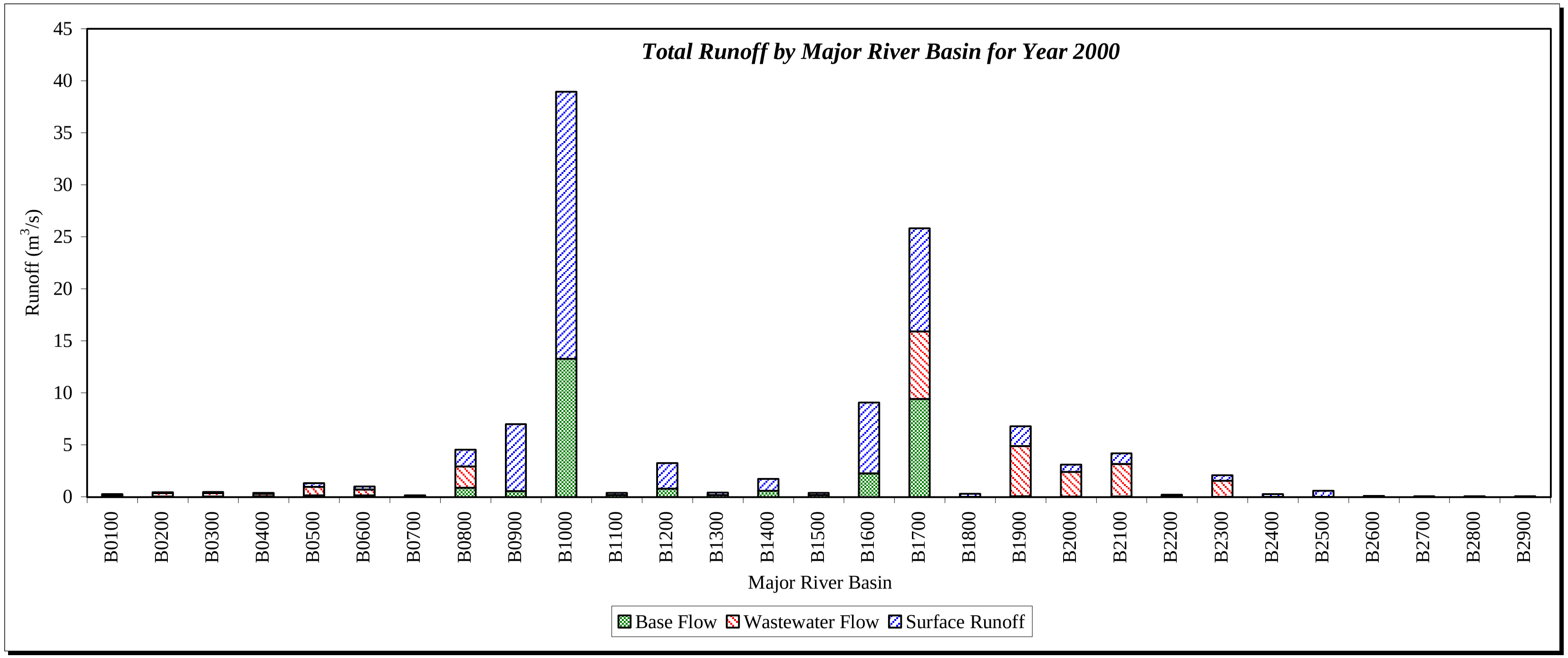


Figure 3.7 Summary of Result of Runoff Model