SUPPORTING 3

ENVIRONMENTAL ADMINISTRATION

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

SUPPORTING 3 ENVIRONMENTAL ADMINISTRATION

1. BACKGROUND OF ENVIRONMENTAL CONTROL REGULATIONS

The first effort to regulate Brazil's environmental pollution control was the enactment of the "Water Code in 1934," which regulated norms, rights and limits of water uses. Main water use issues were concerned to power generation and electricity. After 1934, domestic consumption and community use were prioritized. Polluters directly or indirectly responsible for reducing water pollutant loads are required to provide compensation to those affected.

In 1942, the Special Service of Public Health was established to provide financial and technical assistance to local governments for expansion or modernization of sanitation services. After the World War II, management of water and sanitation services under-went several reorganizations during the 1960's and 1970's.

The sanitary financing system was established in 1968, followed by the National Water Supply and Sanitation Plan (PLANASA) in 1971. Under the Plan, investment in infrastructure and percentage of sewer service population increased significantly by 1990, however, sewer services were still inadequate to manage the whole wastewaters produced. From 1977 through 1985, PLANASA accounted for $9 million worth investment in nation's water supply and sewerage services.

2. WATER QUALITY STANDARDS FOR RIVER BASINS

The first attempt to address river basin issues occurred in 1978 when the Special Committee of Integrated Studies of River Basins was created. The Committee consisted of representatives from municipalities, SEPA's electric and sanitation companies. Some studies were completed, but the effort lacked the potential and fiscal autonomy necessary for a long lasting impact.

CONAMA stipulates national environmental standards in its resolutions such as # 003/90 for air quality and # 020/86 for water quality.

Resolution # 020/86 classifies fresh water bodies into five categories: namely, three types of brackish water bodies and two types of saline water bodies. Water bodies are classified based on its uses as water supply, protection of aquatic communities, irrigations, recreation, fish cultivation, and so on. The main parameters listed are BOD, DO, turbidity, color and E. coli (refer to *Table 1* below for classification and *Table 2* attached at the end of this section for maximum permitted harmful substances). The Resolution also stipulates federal effluent standards including pH, temperature, grease, metals, etc.

Table 1 Water Quality Standard for Classification of Water Bodies stipulated in CONAMA Resolution # 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 skiing, 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 skiing, 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: Navigation, esthetics, use for items not controlled by stringent quality standards.
Class 5: Recreation (swimming, water skiing, diving), protection of aquatic lives, and crop cultivations
Class 6: Navigation, esthetics, and recreations without direct water contact.
Class 7: Recreations (swimming, water skiing, diving), protection of aquatic lives.
Class 8: Navigation, esthetics, recreations without direct water contact.

3. WASTEWATER DISCHARGE CONTROL AND PREVENTION LAW

Federal laws have a wide listing for the control of water pollution. After the Environ-mental Special Secretary-SEMA was established in 1973 through Decree 73.030, the enforcement of water pollution control has been tightened.

The major Federal laws and regulations relative to wastewater qualities are as follows:

Executive Law 1413, August 14, 1975, defines the requirements for abatement of environmental pollution caused by industrial wastes;

- Decree 76389, October 3, 1975, defines industrial wastes pollution prevention and control measures concerning the Executive Decree 1413;
- Administrative Rule GM/0013, January 15,1976, defines classification of the Brazilian territory inland waters.;
- Inter-ministry Administrative Rule 090, March 29, 1978, creates the Special Committee for classification of the nation’s watercourses, studies and follow-up of the rational use of the federal river basin waters, to obtain multiple use of each basin and minimize deleterious consequences to ecology;
- Law 6803, July2, 1980, settles the basic guidelines for the industrial zoning in the critical pollution areas. The law defines that areas planned for industrial setting be zoned by urban land zone planning and that industrial activities are to comply with the environmental protection requirements. Concepts of strictly industrial zone-ZEI (not compatible with urban activities) of predominantly industrial use zone-ZUD (complementary activities to the urban activities) are presented;

- Law 6938, August 31,1981, settled the National Environment Policy creating CONAMA; and
- Decree 77351, June 1st 1983, rules Law 6938 and settled the structure of the National Environment System, the constitution and functioning of CONAMA.

CONAMA then issued general or specific "Resolutions" which guide the environmental planning and control activities, including:

- Resolution 001/86, January 23, 1986, settled definitions, responsibilities, basic criteria and guidelines for use and implementation of the Environmental Impact Evaluation as one of the national environmental instruments;
- Resolution 20/86 that was superseded by Rule GM 0013 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 parameters listed are BOD, DO, turbidity, color and E. coli numbers. The Resolution also stipulates federal effluent standards including pH, temperature, grease, metals, etc.; and
- Resolution 005/88, November 16, 1988, settled that the sanitation works, which may cause significant environmental changes are subject to licensing. This Resolution explicitly mentions that trunk collectors, interceptors, lift stations, treatment plants, and outfall sewers, and later environmental authorities will evaluate the need for environmental impact studies, and settling the criteria for licensing.

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

These include:

- Decree-Law 134, June 16 1975, provides on the prevention and the environmental pollution control in the State of Rio de Janeiro and defines the competence of CECA and FEEMA;
- Decree-1633, December 21 1977, rules part of Decree-Law 134, establishing "the Polluting Activities Licensing System."
- Guidelines-Class 100 classifies water bodies and soils, including;
  - DZ 101, Water volumes, favorable uses.
  - DZ 105, Classification of the Guanabara Bay waters. Refer to *Figure 1*)
  - DZ 106, Classification of the receiving water bodies of the Guanabara Bay basin in accordance with the favorable utilizations.
  - DZ 108, Classification of the receiving water bodies. Industrial districts of Duque de Caxias, Campos, Port Real, Nova Iguaçu, Santa Cruz, Palmares, Paciência, Campo Grande, and Fazenda Botafogo.
  - DZ 109, Classification of the receiving water bodies of Jacarepaguá lakes hydrographic basin.
  - DZ 110, Classification of Jacarepaguá lakes.
  - DZ 111, Classification of Piratininga, Itaipu, Maricá, Saquarema, Jaconé, Araruama, Campelo, Feia and Cima lakes.

- DZ 112, Classification of Septiba Bay basin in accordance with the favorable utilizations.
- DZ 115, Classification of Rodrigo de Freitas lake.
- DZ 116, Classification of Rodrigo de Freitas lake hydrographic basin.

- Technical Standards and Guidelines of the “Class 200,” in which the most important ones are NT-200 and DZ205, as described in the following:
  - NT-202. R-10, October 1986, Criteria and Standards to Discharging Liquid Effluents. These standards apply either direct or indirect liquid effluents discharge to inland or coastal waters, ground surface or underground, through any means of discharge, including those from the publicly owned sewer system (Refer to *Table 3*).
  - NT-213. R-4, April 1990, shows criteria and standards for control of toxicity of industrial liquid effluents. These standards apply to the direct or indirect discharging of liquid effluents into inland or coastal waters, ground surface or under ground, through any means of discharge, including the publicly owned sewerage system. These set criteria and standards for control of toxicity in industrial wastewaters, using toxicity tests with live aquatic organisms.

Table 3 Water Quality Criteria for Liquid Effluents (NT-202, R.10)

Parameter	Limits
1. pH	5.0~9.0
2. Temperature	< 40°C
3. Floatable materials	Virtualmente ausente
4. Settleable materials	10mL/L
5. Grease and oil (minerals)	20mg/L
6. Grease and oil (vegetables)	30mg/L
7. Total aluminum	3.0mg/L
8. Total arsenal	0.1mg/L
9. Total barium	5.0mg/L
10. Total boron	5.0mg/L
11. Total cadmium	0.1mg/L
12. Total lead	0.5mg/L
13. Total cobalt	1.0mg/L
14. Total copper	0.5 mg/L
15. Total chrome	0.5mg/L
16. Total tin	4.0mg/L
17. Soluble iron	15.0mg/L
18. Soluble manganese	1.0mg/L
19. Total mercury	0.01 mg/L
20. Total nickel	1.0mg/L
21. Total silver	0.1mg/L
22. Total selenium	0.05mg/L
23. Total vanadium	4.0mg/L
24. Total zinc	1.0mg/L
25. Ammonium	5.0mg/L
26. Active chlorine	5.0mg/L
27. Cyanide	0.2mg/L
28. Indices of phenol	0.2mg/L
29. Fluorescent	10.0mg/L
30. Sulphide	1.0mg/L

<Continued>

Parameter	Limits
31. Sulphite	1.0mg/L
32. Oganic phosphorous pesticides and carbonates	0.1mg/L for composite
33. Organic phosphorous pesticides and carbonates (total pesticides individually analyzed)	10.0mg/L
34. Hydrocarbon aliphatics, halogen volatility, total as 1,1,1 -trichloroethanol; dichloroethanol; trichloroethanol and therachloropethidine.	0.1mg/L for composite
35. Hydrocarbon aliphatics, halogen volatiles total	1.0mg/L
36. Hydrocarbon halogen not listed above, as pesticide and as pesticides and phtalimide-ésteres	0.05mg/L for composite
37. Hydrocarbon halogen total, excluding hydrocarbon aliphatics halogen volatailes	
38. Carbon sulphide	1.0mg/L
39. Substances which react to reagent methylene blue	2.0mg/L
40. Total phosphorous	1.0mg/L
41. Total nitrogen	10.0mg/L

- NT-205, R-5(August 1991) Quality standards for the wastewater discharge to the publicly owned sewers (license by FEEMA). These set forth that in case of discharging to the publicly owned sewerage system, the industries shall provide treatment or technology to reduce pollutants discharge, so as to make the discharge compatible with the public biological treatment systems and with the beneficial utilizations of the receiving water bodies. This also settles that the organic pollutants which undergo the biological treatment systems without being removed (thus being non-biodegradable) cannot be introduced in these systems without a pre-treatment or a technology producing less pollutants. FEEMA's license to the pollution producing activities, in case of discharging industrial wastewaters to the publicly owned collecting systems, is conditioned to evidence of the operation by the responsive body, of the outflow capacity and treatment of the biodegrading organic loads;
- NT-213, R-10 (October 1986) Effluent standards including that discharged from the sewerage system. The parameters include; pH, temperature, settlable/floatable matters, oil, metals, pesticides, sulfides, nitrogen, phosphorous and others;
- NT-213, R-4 (April 1990) "Criteria and Standards for Control of Toxicity in Indus-trial Liquid Effluents." The technical standards apply to the direct or indirect discharging of liquid effluents in inland or coastal waters, ground surface or underground, through any means, including the publicly owned sewerage systems. The standards settle criteria and standards for control of toxicity tests in industrial wastewaters using toxicity tests with live aquatic organisms;
- DZ-215, R-01(April 1994) Standards for non-industrial wastewater effluent quality, as shown below;

Pollutant loads (kg/day)	Minimum removal efficiency (%)	Concentrations	
		BOD (mg/L)	SS (mg/L)
10 or less	30	180	180
25 ~ 50	70	80	80
50 ~100	80	60	60
100 or more	90	30	30

- Guidelines Class 300. State Law of 1989 stipulates that industrial wastewaters be treated at least by a primary treatment process; and
- Constitution of the State of Rio de Janeiro, 1989. Chapter VIII-of Environment, the Art.274 describes "final discharging to the publicly owned and private sanitary sewerage systems shall be preceded at least the complete primary treatment process.

4. WASTEWATER NUTRIENTS CONTROL

As established under NT-202 R-10, the wastewater discharge qualities from the municipal sewerage systems to the public water bodies are subject to control, requiring the concentration limits of 1.0 mg/L and 10.0 mg/L for total phosphorous and total nitrogen respectively. Meeting to these stringent terms with the ordinary secondary treatment processes might not be possible, and hence needs advanced treatment processes, if these are strictly enforced.

5. SEWAGE SLUDGE DISPOSAL

Although no laws and standards directly controlling the use or disposal of sewage sludge are enforced in Brazil, there are several laws and decrees, which are indirectly related to the disposal of obnoxious or hazardous materials that might have been contained in the domestic and industrial wastewaters. Some of the related laws and decrees are summarized in the following subsections:

5.1 FEDERAL LAWS

The Agricultural Ministry provides regulations on fertilizers, correctives, inoculants, stimulators and biofertilizers.

<u>Law No.6,894, December 16, 1980, was changed by Law No.6,934 on July 13, 1981, and Decree-Law No. 1,899, December 21, 1981</u>, which institute rates relative to the activities of the Agriculture Ministry.

The Law describes inspection and characteristics of the production and trade of corrective fertilizers, inoculants, stimulators and biofertilizers, intended for agriculture and gives other provisions. The Article 3rd considers that:

- Fertilizer, the mineral or organic substances, natural or synthetic, supplying one of more vegetal nutrients;
- Corrective, the material able to correct one or more unfavorable characteristics of the ground;
- Inoculants, the substance which has microorganisms favoring the vegetal development; and
- Stimulating or biofertilizer, the product which contains active principle able to improve, directly or indirectly, the plants development.

<u>Decree No.86,955, February 18, 1982</u>, which rules Law No.6,894, December 16, 1980. This Decree adds in its Article 3rd, various types of fertilizers, correctives, etc. besides the above mentioned definitions, and defines nutrient, macronutrients and their loads.

5.2 STATE LAWS

<u>Law 2,661, December 27, 1996</u>, defines in Article 174 of Rio de Janeiro State Constitution concerning the sanitary sewage minimum requirements before disposing to water bodies, and other provisions.

The Article 3rd prohibits in the whole area of Rio de Janeiro State disposing of the substances separated from sanitary sewage treatment systems into all water bodies. Their treatment processes shall be of stabilization or other processes which effluents will not risk human health and environment, in accordance with the requirements as set forth by the environmental control state body.

The Article 9th defines that the municipalities with population equal or higher than 20,000 are to prepare and approve a plan for collection, hauling, treatment and disposal of their sanitary sewage effluents and organic sludge.

The Article 277 requires that the final disposal of public and private sanitary sewage collection systems be treated at least of complete primary treatment in accordance with the law.

DZ-215 R-1 of FEEMA, Control guideline of organic biodegrading load in non-industrial origin liquid effluents. FEEMA shall set out, case by case, the requirements for treatment and disposal of sludge generated in the treatment systems.

DZ-703-R-4 of FEEMA, Routes for submission of projects for liquid effluents treatment. Annex 1-Route 1, 1.1 describes that processes or utilities that originate organic or in-organic sludge are to submit brief description, treatment system and their final disposal, with complete layouts of the systems. Also, Annex II-Route 2 requires to submit a description of the system with drawings in the same manner as mentioned above.

DZ-949 R-0 of FEEMA, implementation guideline of the "Residues Pocket" Program.

DZ-1311 R-4 of FEEMA, guideline for residues destination. Residues are those from pollution control or water treatment systems that treat wastes of any activities or industrial processes, such as hospital, commercial, crop and livestock and others. Residues include sludge and ash, either in solid, semi-solid and/or liquid form, not liable to conventional treatment. Class III residues are allowed to directly dispose of to sanitary landfills if residues are inert, and not recyclable as listed below:

- Industrial wastes such as paper, cardboard, plastics, uncontaminated glasses, shreds, office and mess room wastes;
- Class III sludge industrial waste treatment works, if previously approved by FEEMA;
- Sanitary sewage treatment plant sludge, and septage from septic tanks with moisture content lower than 70 percent, if previously approved by FEEMA;
- Plastic wastes such as uncontaminated packages, and PVC, PE, and Polyamide residues; and
- Disposal in sanitary landfill of any other industrial wastes, not listed above, shall be approved by FEEMA.

As described above, the legislation allows the disposal of domestic sewage sludge to sanitary landfill sites. It should be noted that the state legislation constitutes no other specific suggestion on sewage sludge disposal. The only constraint for the sewage sludge disposal is that the sludge moisture contents be 70 percent or lower.

5.3 OTHER LEGAL REQUIREMENTS

CETESB recently proposed standards for the use of biosolids. The proposal, still under study, deals the application of biosolids to agricultural use, defining the procedures, criteria and requirements for the preparation of project, implementation, operation and issue of authorization for the use of biosolids from biological treatment of public or industrial wastewater for agricultural use.

6. Environmental Procedures

Federal environmental regulations serve as a “minimum standard” for the states. Corresponding to the federal regulations, states may have more stringent or detailed regulatory requirements depending upon their individual actual situation.

The major environmental laws and regulations of the Rio de Janeiro State are summarized in *Table 4*.

The Licensing System of Polluting Activities – SLAP was created by 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

LP is a document issued at the planning stage and authorizes the location of the enterprise on a specific site based on federal, state and municipal land use plans, also establishing basic requirements to be fulfilled during the installation and operation stages.

LI authorizes the start of the enterprise implementation (according to the engineering design specifications in which detail level has to be sufficient for the appraisal) and also specifies the environmental requirements to be fulfilled during this stage.

LO, issued after the confirmation of the LI conditions fulfillment, authorizes the operation or utilization of the enterprise, provided specific conditions are observed.

In the case of a WWTP, the licensing system determines that the responsible party for the treatment station should submit an effluent analysis for FEEMA appraisal each three months.

The license renewal is compulsory in case of license expiration or modification of the licensed project or of the initial conditions.

Penalties are provided through State Law no. 3467 (14/09/2000) which establishes what are harmful behaviors to the environment.

The organization in charge for the approval and control of sewerage works from the environmental point of view is FEEMA (State Foundation of Environmental Engineering), through the DECON/DICAN division (Department of Control / Division of Non Industrial Activities Control).

This division is in charge both for the large-scale CEDAE (or other municipal and / or private sanitation company) works as well as for small-scale treatment plants (shopping malls, housing condominiums, industries, etc.).

The documents that guide the design of the EIA are listed in *Table 5*.

Table 2 Environmental Standards for Harmful Substances stipulated in CONAMA Resolution # 020/86

Item	Standard Values			
	Class 1 and 2	Class 3	Class 5	Class 7
Aluminium (mg/l Al)	0.1	0.1	1.5	-
Non-ionizable Ammonia (mg/l NH_3)	0.02	-	0.4	0.4
Arsenium (mg/l As)	0.05	0.05	0.05	0.05
Barium (mg/l Ba)	1.0	1.0	1.0	-
Beryllium (mg/l Be)	0.1	0.1	1.5	-
Boron (mg/l B)	0.75	0.75	5.0	-
Benzene (mg/l)	0.01	0.01	-	-
Benzo-a-pyrene (mg/l)	0.00001	0.00001	-	-
Cadmium (mg/l Cd)	0.001	0.001	0.005	0.005
Cyanurates (mg/l CN)	0.01	0.02	0.005	0.005
Lead (mg/l Pb)	0.03	0.05	0.01	0.01
Chlorides (mg/l Cl)	250	250	-	-
Residual chlorine (mg/l Cl)	0.01	0.01	0.01	-
Cobalt (mg/l Co)	0.2	0.2	-	-
Copper (mg/l Cu)	0.02	0.5	0.05	0.05
Trivalent chromium (mg/l Cr)	0.5	0.5	-	-
Hexavalent chromium (mg/l Cr)	0.05	0.05	0.05	0.05
1.1 dichloroethanol (mg/l)	0.0003	0.0003	-	-
1.2 dichloroethanol (mg/l)	0.01	0.01	-	-
Tin (mg/l Sn)	2.0	2.0	2.0	-
Phenols (mg/l C_6H_5OH)	0.001	0.3	0.001	0.001
Soluble iron (mg/l Fe)	0.03	5	0.3	-
Fluorides (mg/l F)	1.4	1.4	1.4	1.4
Total phosphate (mg/l P)	0.025	0.025	-	-
Lithium (mg/l Li)	2.5	2.5	-	-
Manganese (mg/l Mn)	0.1	0.5	0.1	-
Mercury (mg/l Hg)	0.0002	0.002	0.0001	0.0001
Nickel (mg/l Ni)	0.025	0.025	0.1	0.1
Nitrate (mg/l N)	10	10	10	-
Nitrite (mg/l N)	1.0	1.0	1.0	-
Silver (mg/l Ag)	0.01	0.05	0.005	-
Pentachlorophenol (mg/l)	0.01	0.01	-	-
Selenium (mg/l Se)	0.01	0.01	0.01	-
Dissolved solids (mg/l)	500	500	-	-
Detergents (mg/l LAS)	0.5	0.5	0.5	-
Sulphates (mg/l SO_4)	250	250	-	-
Sulphides (as non-dissociated H_2S) (mg/l S)	0.002	0.3	0.002	0.002
Thalium (mg/l Tl)	-	-	0.1	-
Tetrachloroethanol (mg/l)	0.01	0.01	-	-
Trichloroethanol (mg/l)	0.03	0.03	-	-
Carbon tetrachloride (mg/l)	0.003	0.003	-	-
2, 4, 6 trichlorophenol (mg/l)	0.01	0.01	-	-
Uranium (mg/l U)	0.02	0.02	0.5	-
Vanadium (mg/l V)	0.1	0.1	-	-
Zinc (mg/l Zn)	0.18	5	0.17	0.17
Aldrin (mg/l)	0.01	0.03	0.003	0.003
Chlordane (mg/l)	0.04	0.3	0.004	0.004
DDT (mg/l)	0.002	1	0.001	0.001
Dieldrin (mg/l)	0.005	0.03	0.003	0.003
Endrin (mg/l)	0.004	0.2	0.004	0.004
Endosulphane (mg/l)	0.056	150	0.034	0.034
Heptachloro-epoxide (mg/l)	0.01	0.1	0.001	0.001
Heptachlorine (mg/l)	0.01	0.1	0.001	0.001
Lindane (gama-BHC) (mg/l)	0.02	3	0.004	0.004
Metoxichlorine (mg/l)	0.03	30	0.03	0.03
Duodecachlorine + Nonachlorine (mg/l)	0.001	0.001	0.001	0.001
PCBs (mg/l)	0.001	0.001	-	-
Toxaphenol (mg/l)	0.01	5	0.005	0.005
Demeton (mg/l)	0.1	14	0.001	0.1
Gution (mg/l)	0.005	0.005	0.01	0.01
Malation (mg/l)	0.1	100	0.1	0.1
Parathion (mg/l)	0.04	35	-	0.04
Carbaril (mg/l)	0.02	70	-	-
Organic phosphate and carbonate compounds as parathion (mg/l parathion)	10	100	10	10
2,4 - D (mg/l)	4	20	10	10
2,4,5 - TP (mg/l)	10	10	10	10
2,4,5 - T (mg/l)	2	2	10	10

Table 4 Major Environmental Laws and Regulations in the Rio de Janeiro State

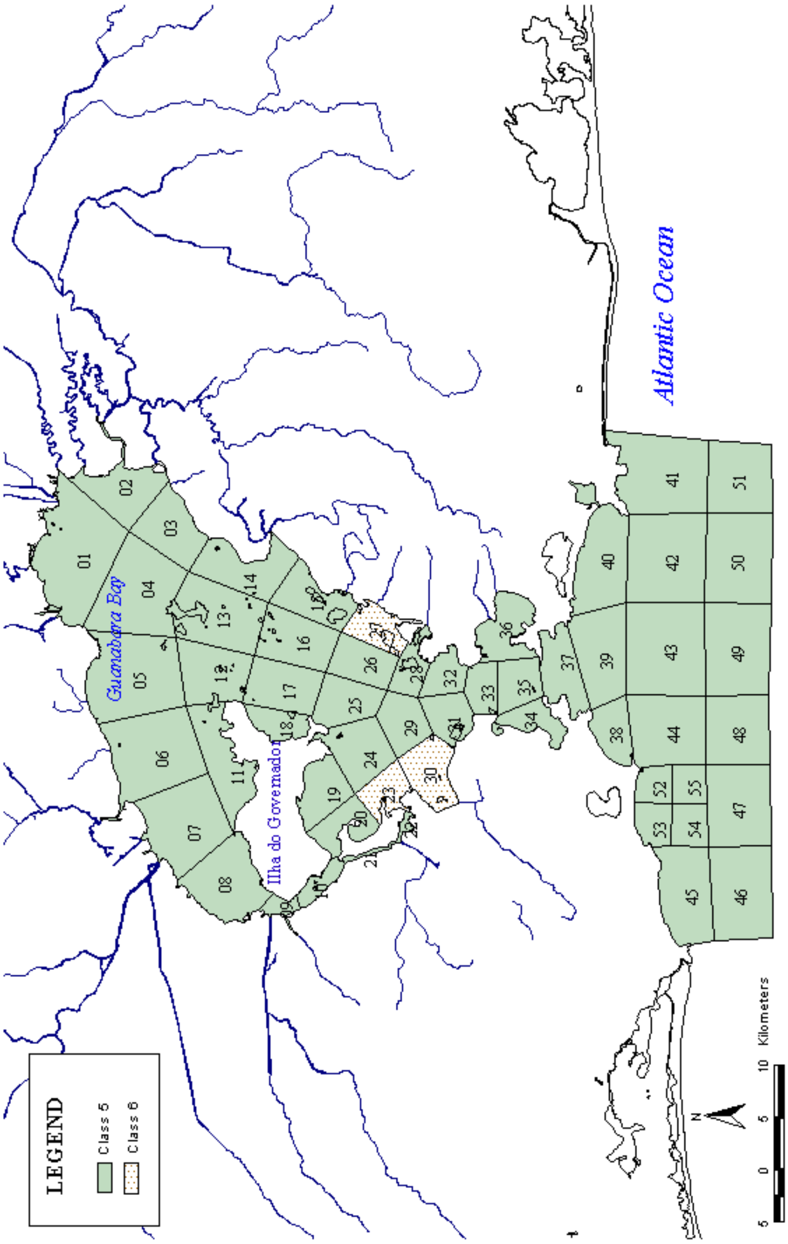
Official Gazette No.	Contents
Decree No. 21.470	Law 1.898, of 26th November 1991 ‘States rules for the environmental auditing’
Decree No. 21.287	Create the ‘Forum for the Environmental policy of the Rio de Janeiro State’
Decree No. 20.356	Law No. 1.893, of 20.11.91, which establishes the necessity of cleaning of water reservoirs in order to achieve the quality standards
Decree No. 19.073	Changes the basic structure of Department of Mineral Resources
Decree No. 11.782	Transforms from the State Institute of Forest into Foundation State Institute of Forests of Rio de Janeiro, and approves its status
Decree No. 10.973	Create a Special Fund for the Environment Control
Decree No. 9.847	Structures the State Secretary of Environment, by changing the State Secretary of Works
Decree No. 8.974	Rules for the penalties in the Decree No. 134 of 16.06.75
Decree No. 2.330	Rules for Decrees Nos. 39, of 24.3.75, and 134, of 16.6.75, and creates the Protection System of Lakes and Water Courses of Rio de Janeiro State, with rules for Fine application
Decree No. 1.633	Rules for Decree No. 134 of 16.06.75 and creates System of Pollutant Activities Licensing – SLAP
Decree No. 1.102	Demarks the range of branches for the public water supply pipeline
Decree No. 201	Creates the Department of Mineral Resources
Decree No. 135	Allows the transfer of budget resources to FEEMA
Decree No. 134	States rules for the prevention and monitoring of Environmental pollution in Rio de Janeiro State
Decree No. 89	States rules for the constitution of the Financial Fund for waste Water in Rio de Janeiro State
Decree No. 39	States rules for the State Indirect Administration and Foundation within the State Secretary of Public Works
Law No. 3.316	Allows the government to establish the System of Treatment for the Waste Water and Solid Waste for the Health Center
Law No.3.239	Water Resources Management; Rules for the State Constitution in its article 261, paragraph 1°, incise VII
Law No. 2.661	Rules for article 274 of the Constitution of Rio State, concerning the minimum and maximum level of waste water treatment before be sent to water bodies
Law No. 1.979	Rules forbidding sand jetting companies in naval industry
Law No. 1.898	States rules for Environmental Auditing
Law No. 1.893	Establishes the Obligation for Cleansing the Water Reservoir
Law No. 1.803	Creates the tax for Water Resources Use in the State Domain, TRH
Law No. 1.796	Establishes the Norms for the settling and functioning of ionizing elements companies, radiation companies, nuclear and radioisotopes companies
Law No. 1.700	Establishes the protection Measures of the Guanabara Bay
Law No. 1.361	Rules for stocking, processing and final disposal of toxics residues
Law No. 1.356	Establishes the procedures for the Environmental Impact Assessment-EIA design, analysis and approval
Law No. 1.315	Creates Rio de Janeiro State Policy for the environment
Law No. 1.060	Creates the State Fund for the Environment Conservation
Law No. 1.018	Establishes a set of conditions for functioning of hot asphalt factories
Law No. 855	Rules for the divulgation of data related to pollution monitoring in the State of Rio de Janeiro
Law No. 690	Rules on the protection of forests, and others natural vegetation
Law No. 650	Rules on State Policy of the defense and protection of the river basin in the State of Rio de Janeiro
Law No. 466	Rules about the industrial zoning in Metropolitan Region Rio de Janeiro State
Law No. 126	Rules about sound pollution in State of Rio de Janeiro and former Guanabara State

Table 5 Documents provided by FEEMA for the Design of EIA-RIMA

Document		Objective
Code*	**Title**	
DZ-41.R-13	Guidelines for the design of the EIA - Environmental Impact Study and the respective RIMA (Report of the Environmental Impact).	To determine the coverage, the procedures and the criteria for the design of the Environmental Impact Study - EIA and the respective RIMA (Report of the Environmental Impact), in the State of Rio de Janeiro, according to the provisions in Law no. 1356/88, further altered by Law no. 2535/96, and according to the CONAMA (National Council of Environment) Resolutions nos. 001/86, 011/86 and 2/96, as part of the Licensing System of Polluting Activities – SLAP.
DZ.215.R-1	Guidelines for the control of Biodegradable Organic Load in Liquid Effluents originating from Non Industrial Activities.	To set, as part of the Licensing System of Polluting Activities - SLAP, requirements for water pollution control that result in the reduction of the biodegradable organic load from non industrial activities.
NA-042.R9	Request, Submittal and Analysis of the Environmental Impact Study (EIA) and of the respective Report of the Environmental Impact (RIMA)	To set FEEMA administrative procedures for the request, submittal and analysis of studies and reports of environmental impact, according to the legislation in force, as part of the Licensing System of Polluting Activities - SLAP
NT-202.R-10	Criteria and Standards for the Discharge of Liquid Effluents	To set criteria and standards for the discharge of liquid effluents as part of the Licensing System of Polluting Activities - SLAP
IT 1835	Technical Instruction for the Presentation of Sewage Treatment Design	To give guidance for the presentation of sewage treatment systems to be submitted in order to get the Installation License, according to Federal legislation (Law no. 6938 of 31/08/81 and Decree-Law no. 134 of 16/06/75 and Decree no. 1633 of 21.12.77), and defined by the CECA (State Commission for Environmental Control) Deliberation no. 1609, of 04.12.89, without releasing from obedience to other legal requirements.

Note: DZ = Guidelines, NA = Administration Note, NT = Technical Note, IT = Technical Instruction

Source: FEEMA, DECON-DICAN, 2002.



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 1 Water Quality Classification of Guanabara Bay by DZ 105

SUPPORTING 4

HYDROLOGICAL ANALYSIS

TABLE OF CONTENTS

Page

SUPPORTING 4 HYDROLOGICAL ANALYSIS

LIST OF TABLES

LIST OF FIGURES

SUPPORTING 4 HYDROLOGICAL ANALYSIS

1. MONITORING NETWORK ON METEO-HYDROLOGY

1.1 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. *Table 1* lists the inventory on monitoring network on meteorology. *Figure 1* shows the location map of all the meteorological stations. A bar chart of available / collected rainfall data is presented in *Table 2*. For identification purpose, new JICA ID has been assigned to each station. Coordinates (latitudes and longitudes) of some of the non-operating stations couldn't be found from SERLA. For those stations, locations have been identified on the map after consultation with local GIS expert. Elevations of all the SERLA stations have been calculated from GIS database of elevation grid with 20 m cell size created from a combination of 20 m and 100 m contours.

The table reveals that previously, SERLA used to observe rainfall data at many locations inside Guanabara Bay basin but at present, only a few of them are operating. It can be seen that most of the stations are and were concentrated in Rio de Janeiro municipality and stations for the rest of the basin are too scarcely distributed. The main objective of most of the rainfall data measured by different agencies is to use for forecasting landslide and flood. 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. This posed great difficulty in developing a comprehensive runoff model

In total, data have been collected at 74 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. However, data from all the old meteorological stations of SERLA had a great value in understanding the meteo-hydrological condition of the Guanabara Bay basin.

1.2 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. Telemetric rainfall data is sent at every 5 minutes, water level data is sent at every 15 minutes and water quality data is sent at every 60 minutes intervals. An inventory on the telemetric stations is presented in *Table 3*. Location map of the stations along with gauged basin boundary is show in *Figure 1*. For identification purpose, new JICA ID has been assigned to each station. Gauged area covered by each station have been estimated based on GIS database prepared using 1/50,000 scale map with a combination of 20 m and 100 m contours. Unfortunately, no information on "0" gauge levels of the stations could be collected from SERLA.

At first, telemetric data was collected at all the stations and after compiling those data, it was found that there are a lot of missing data with a lot of errors, especially the 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 no. 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.

It can be seen that the total gauged area (excluding stations H08 and H20) is about 2,526 km^2, which is about 63% of the total area of all the river basins (excluding islands). The largest one, station H15 at Barragem – CEDAE on Guapi river has a total gauged area of about 1,090 km^2 comprising about 27% of the total river basin. The second largest one, station H21 at Reta Nova on Caceribu river has a total gauged area of about 380 km^2 comprising about 9% of the total river basin. Rest of the stations on other rivers have gauged areas varying from about 14 km^2 at Quartel da PE on Maracanã river to about 130 km^2 at Três Pontes on Aldeia river covering only 0.3% and 3.2% respectively of the total river basin.

2. METEO-HYDROLOGICAL ANALYSIS

2.1 STREAM GAUGE CHARACTERISTICS

Characteristics of SERLA stream gauge stations are presented in *Table 4*. Since 1998, SERLA carries out regular discharge measurement at each of the stream gauge station once or twice in a month with some exceptions. The total number of discharge measurement for each station varies from 34 to 50. Since SERLA doesn't have any rating curve to convert the gauge height values into discharge values, therefore, based on the discharge measurements of SERLA, rating curve at each of the station has been constructed (except station H12 for which, no relation could be found between measured gauge height and discharge). The rating curves are shown in *Figure 2*. The rating curve parameters are presented in *Table 4.*

Considering objective of flow analysis for this Study which is to estimate daily average discharge for a complete year for all the river basins contributing flow into Guanabara Bay, caution has been taken in selecting proper equations for the rating curves such that the rating curves are good enough for the normal flow range (low to medium flow and annual average flow). This implies that for estimating discharges at high water levels, the extrapolation of the rating curves might not be very accurate. 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.

Table 4 also presents altitudes and slopes of gauged basins of each station and also cross-sectional properties of each station. The maximum and minimum average altitudes (El. 716 m and 34 m) and slopes (23 and 3 degrees) are found to be for basins of stations H19 at Cachoeiras de Macacu – II on Macacu river and H10 at Igreja de Santo Antônio on Pavuna river respectively. Stations H21 at Reta Nova on Caceribu river and H09 at Quartel da PE on Maracanã river have the maximum and minimum top widths of 112.8 and 6.0 m respectively. Stations H19 at Cachoeiras de Macacu – II on Macacu river and H20 at Borda do Mato on Joana river have the maximum and minimum depths of 7.02 and 1.34 m respectively.

2.2 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). As mentioned before, no rating curve could be constructed from station H12. No data is available for stations H08 and H20. 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*. The three rainfall stations are Bangu (M02), Teresópolis (M04) and Rio Bonito (M03) and the three stream gauge stations are CIEP - 100 (H02), Quizanga - II (H16) and Ponte de Tanguá (23). Monthly rainfalls and discharges for the same stations are shown in *Figure 4*. The two figures imply that there is a clear variation in discharge by month and the discharge variation resemble the rainfall variation. The two figures also indicate that discharge pattern of same station for year 1999 and 2000 are similar.

Monthly average discharges of all the stations for years 1999 and 2000 are presented in *Table 5.* Station H15 at Barragem - CEDAE on river Guapi has the highest average discharge (about 37 and 39 m^3/s in 1999 and 2000 respectively). It can be seen that for most of the stations, specific discharge varies from 0.03 to 0.04 m3/s/km2. Only station H11 at Avenida Automóvel Clube on Acari river has very high specific discharge of 0.12 $m^3/s/km^2$ due to high contents of urban area (64%) that have high runoff coefficient and short time of concentration. On the other hand, stations H21 to H24, all lying in the Caceribu river basin have quite low specific discharges that vary from 0.003 to 0.01 $m^3/s/km^2$ due to high content of cattle field - pasture land (25 to 62%) that have low runoff coefficient, high storage capacity and long time of concentration.

2.3 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 has been selected as the base year 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 and
- 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 *Figure 5*. It can be seen that annual total rainfalls 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 a rather dry year.

3. RUNOFF ANALYSIS

3.1 INTRODUCTION

The main objective of runoff analysis is 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, some of which are:
  - Divisions of river basins with areas;
  - Basic meteorological data such as daily rainfall and monthly evaporation;
  - Thiessen Polygons representing influenced areas of rainfall and evaporation stations;
  - Basin parameters such as: runoff coefficient and basin storages as a function of landuse type, time of concentration as a function of flow length and flow velocity which in turn is a function of basin slope, base flow as a function of basin area, wastewater flow as function of population etc.
- Estimation of runoff parameters through calibration of rainfall-runoff model against measured discharges at SERLA stream gauge stations for year 2000 and
- Runoff calculation for different scenarios such as for average, dry and wet years.

3.2 THE RUNOFF MODEL

A schematic network diagram of the runoff model is shown in *Figure 6*. 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 7*. 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. Even though, there is an option for inclusion of a simplified groundwater model in the NAM model which enables NAM model to simulate groundwater recharge and base flow, however, considering the objective of the model and due to lack of groundwater data, the groundwater unit of the NAM model has not been used. Also, from past experience, it has been found that the groundwater unit of the NAM model isn't very powerful in simulating base 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.

3.3 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 8*. Details of the river basins are presented in *Table 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. It can be seen that the 4 largest major rivers which are Guapimirim, Caceribu, Iguaçu and Saracuruna have catchment areas of about 1262, 811, 717 and 349 km^2 (3,139 km^2 in total) representing about 31%, 20%, 18% and 9% (77% in total) of total basin area (inculding islands). The islands have a total area of about 46 km^2 representing about 1% of total basin area. Area of the eight bays along the coastline is about 101 km^2, which is about 2% of the total basin area.

Table 6 shows that sub-catchment B1004 (Rio Macacu U/S) has the highest average altitude of El. 517 m. There are 8 sub-catchments with average altitude varying from El. 250 to 350 m and 8 sub-catchments with average altitude varying from El. 100 to 200 m. The rest of the sub-catchments have average altitude of less than El. 100 m. Island group Ilha de Santa Cruz has the lowest average altitude of El. 9 m.

Table 6 shows that sub-catchment B1004 (Rio Macacu U/S) has the highest average slope of 20 degrees. There are 6 sub-catchments with average slope varying from 15 to 17 degrees, 12 sub-catchments with average slope varying from 10 to 14 degrees and the rest have average slope of less than 10 degrees.

3.4 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. Unfortunately, for Teresopolis, no data is available for January of year 2000. Therefore, available data for January of year 1999 has been used for runoff analyses. This has introduced small error in calculation of runoff for the month of January for some part of the Guanabara Bay basin, which is influence by the rainfall of Teresopolis station.

Thiessen polygons of the 7 stations are shown in *Figure 9*. It can be seen that the Thiessen polygons are too coarse and the 7 stations don't represent well the rainfall distribution of the Guanabara Bay basin, especially along the mountainous areas where heavy rainfalls are observed. 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 as follow:

- Step 1: From all the 74 existing and abandoned rainfall stations, 16 representative stations that well describe the rainfall distribution of the Guanabara Bay basin have been selected as shown in *Figure 9*. Thiessen polygons of the selected 16 representative stations are also shown in *Figure 9*.
- Step 2: From daily rainfall data at the available 7 stations, daily rainfalls at the selected 16 stations for year 2000 have been calculated using Thiessen polygon method as shown in *Table 7*. Daily rainfalls at the 7 stations are shown in *Figure 10*.
- Step 3: Adjustment factor at each of the selected 16 rainfall station due to difference in annual average rainfall (1928 – 2002) using data of all the 74 rainfall stations and using data of the 7 daily rainfall stations only have been calculated as show in *Table 8*. GIS database have been used extensively to make all the calculations. It

can be seen that almost all of the adjustment factors are greater that 1.00 which simply implies that rainfall distribution using the 7 daily rainfall stations would result in an underestimation of annual total rainfall over the Guanabara Bay basin.

- Step 4: Daily rainfalls for year 2000 at the 16 selected rainfall stations as calculated in Step 2 have been multiplied by adjustment factors as calculated in Step 3 to get the updated / adjusted rainfalls for year 2000 at the selected 16 rainfall stations.
- Step 5: From the updated daily rainfalls for year 2000 at the selected 16 rainfall stations, daily rainfalls for average, dry and wet years at the selected 16 rainfall stations have been calculated by multiplying the daily rainfalls of 2000 with ratios of 1.127, 0.872 and 1.455 respectively.
- Step 6: Instead of the daily rainfall values at the 7 observed rainfall stations, the updated rainfall values at the 16 selected rainfall stations have been used in the rainfall-runoff model. Such updating procedure of daily rainfall data ensures a well distribution of spatial rainfall for input to the rainfall-runoff model. However, due to insufficient data, no detailed investigation has been carried out on correlation in spatial and temporal distribution of daily rainfall.

Monthly old evaporation data at only 3 available stations have been collected and used for the rainfall-runoff model.

Weights of Thiessen polygons of drainage basins of SERLA stream gauge stations, major river basins and sub-basins for rainfall and evaporation stations are presented in *Table 9* and *Table 10* respectively.

3.5 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. Even though, CIDE has landuse map prepared on 1/50,000 scale, but that map doesn't cover the entire Guanabara Bay basin area whereas 1/100,000 scale landuse map cover the whole Rio de Janeiro state and requires no adjustment. Therefore, instead of using the incomplete 1/50,000 landuse map, the complete 1/100,000 scale landuse map has been used.

There are 19 landuse classifications, which are listed along with areas in *Table 11*. It can be seen that dense ombrophyle forest (also called tropical rainforest) has the highest area of about 1,051 km^2 covering about 26% of total basin area. Secondary vegetartion, cattle field – pasture land and low density urban area also cover wide lands with areas of about 692 (17%), 616 (15%) and 484 (12%) km^2 respectively.

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).

Landuse map with both original 19 landuse classes and 6 re-classes is shown in *Figure 11*.

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 and are presented in *Table 12* and *Table 13* respectively. While extracting landuse areas from landuse map, inconsistencies could be found between the actual areas of basins and areas as obtained from landuse map. This is due to mainly overlapping polygons in the original landuse map, which has been adjusted manually and no change has been made in the GIS database.

3.6 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. The base flow zones are shown in *Figure 12*. 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. The equations for different base flow zones are presented in *Figure 13*. 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 and are presented in *Table 14* and *Table 15* respectively. As a threshold value, a minimum base flow of 0.01 m^3/s has been applied.

Base flow zones I to V have mixed landuse pattern with predominately forest and vegetation whereas base flow zone VI is highly urbanized. For base flow zones I to V, annual minimum daily average discharges of SERLA stations lying within those zones are considered as natural base flows and have been utilized to formulate the base flow equations for those zones. However, for base flow zone VI, annual minimum daily average discharges of SERLA stations lying within that zone couldn't be considered and utilized as natural base flows due to mixing with wastewater flows. Therefore, the lowest annual minimum daily specific discharge of all the SERLA stations which is 0.0003233 $m^3/s/km^2$ is considered to be natural base flow of highly urbanized areas and that specific base flow has been applied for base flow zone VI.

3.7 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 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 11*. The other calibrated surface runoff parameters as presented in *Table 15* are: time constants for routing interflow (CK_{IF}), overland flow ($CK_{1,\ 2}$) and base flow (CK_{BF}), root zone threshold values for interflow (T_{IF}) and overland flow (T_{OF}) all of which 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.

The result of runoff model (surface runoff + base flow) calibration for year 2000 is shown in *Figure 14*. Calibration result at six representative stations from different catchments and base flow zones are presented only. Since, the objective of the runoff model is to estimate runoff for a whole year that would contribute freshwater into the Guanabara Bay, therefore, each event of runoff such as very high and low runoff events haven't been calibrated one by one. Instead, the overall trend of daily runoff (both peak and volume) for a whole year has been looked into while calibrating the runoff model. By comparing observed and simulated runoffs at the six SERLA stations shown in *Figure 14* as well as other SERLA stations not shown in the figure, it is inferred that the runoff model has been satisfactorily calibrated for year 2000 at most of the SERLA stations and can be applied for runoff calculations of different scenarios.

3.8 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 as shown in *Figure 15*. Runoff deficit is defined as the difference between annual minimum daily observed and simulated discharges and can be considered as the result of wastewater flow, which is different from natural runoff. 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 Niterói 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 Niterói areas have been estimated based on population and the estimations have been checked against observed data at urbanized SERLA stations (H01, H02, H10 and H11) lying in the Rio de Janeiro area. Using empirical relation between runoff deficit (D) and urban area (A) as obtained from observed runoff deficit data at the urbanized SERLA stations (D = 0.0472A as shown in *Figure 16*), total runoff deficit or wastewater generation for the urbanized sub-catchments lying in the Rio de Janeiro area is estimated to be 18.03 m^3/s. After discussion with local experts, it was known that the local practice is to use 300 lpcd as wastewater generation rate. Using 300 lpcd, wastewater flow based on population lying in the urbanized sub-catchments of the Rio de Janeiro area is estimated to be 18.46 m^3/s which is almost the same as estimated using the empirical equation. Using the same 300 lpcd, wastewater flow based on population lying in the urbanized sub-catchments of the Niterói area is estimated to be 4.44 m^3/s. The total wastewater flow based on population lying in the urbanized sub-catchments of the Rio de Janeiro and Niterói areas is estimated to be 22.90 m^3/s which is very close to the inter-basin transfer of 25 m^3/s. Therefore, 300 lpcd can be considered as a good assumption and have been applied for wastewater flow estimation based on population. The estimated wastewater flow by urbanized sub-catchments of the Rio de Janeiro and Niterói areas is shown in *Table 16*.

3.9 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 and are presented in *Table 15*. 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 17* and is summarized in *Figure 17*. 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.

3.10 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 and is presented in *Table 18* and *Figure 18*. For Caceribu (B0900) river basin, increase of urban area has been considered for Rio Porto das Caixas (B0902) sub-basin only. The result shows that due to 10%, 20% and 30% increase in urban area, increase in runoffs for Rio Alcantara (B0800) river basin are 0.00%, 2.69% and 7.84% respectively and that for Rio Caceribu (B0900) river basin are 0.06%, 0.42% and 1.09% respectively. The effect of such 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.

4. RECOMMENDATIONS ON MONITORING NETWORK ON METEO-HYDROLOGY

Inside the Guanabara Bay basin, meteorological observations are made by INMET, SERLA, GEO-Rio and some other organizations. Since, major use of most of the rainfall stations is for disaster prevention, especially against landside, therefore, the present networks of rainfall stations are clustered around the populated places and only a few stations are located in the mountainous areas. INMET and SERLA had many rainfall stations previously but most of them are non-operational now. SERLA has 25 telemetric rainfall stations (24 are operational now) but unfortunately, quality of telemetric rainfall data at these stations is very poor and the data have not been compiled and even been verified by SERLA. Finally, the Study used 22 rainfall stations of which only 7 are daily and the rest are monthly (*Table 1*). For developing rainfall-runoff model for the whole Guanabara Bay basin, daily rainfall data at 7 locations was not sufficient and the Study updated daily rainfall data from at 7 locations to 16 representative locations using GIS database and correlation analyses. It is proposed to monitor rainfall regularly at all these 16 locations (at least) that well represent overall rainfall distribution of the Guanabara Bay basin. All the stations are proposed to be of automatic type. The proposed monitoring network on rainfall is shown in *Figure 19*. The rainfall data should be checked and compiled regularly.

Inside the Guanabara Bay basin, hydrological observations are made by SERLA only. SERLA has 25 stream gauge stations (24 are currently operational) at which both telemetric and staff-gauge data on water level are available. Again unfortunately, quality of telemetric water level data at all these stations is quite poor and the data have not been compiled and verified by SERLA. As such, the Study used staff-gauge water level data of the SERLA stream gauge stations. SERLA also measures cross-section and discharge at these stations on an irregular basis. Even though, SERLA observes hydrological data at these stations, but not all of the stations bear equal importance from environmental management viewpoint. Principally, the stream gauge network should well describe the hydrologic condition such as catchment area, topographic and landuse condition, base flow and wastewater contribution etc. of the entire Guanabara Bay basin. The stations should preferably be located downstream of the rivers covering wider catchment areas but upstream of tidal influence and some should be integrated with FEEMA's water quality monitoring stations. From environmental management viewpoint and considering ease of maintenance, it is proposed to continue hydrological observation (regular water level and annual cross-section and discharge measurements) at 16 locations out of the 25 locations. It is proposed that the best locations of the stream gauge stations should be decided by SERLA such that it satisfies the above-mentioned guidelines. However, as a guideline, locations of 16 existing stations that should be monitored regularly are shown in *Figure 19*. All the stations are proposed to be of automatic type. The hydrologic data should be checked and compiled regularly.

Table 1 Inventory on Monitoring Network on Meteorology

Station			Location	Coordinate		Elevation	Agency	Status	Date of	Type	Data
ID	Code	Name	Municipality	Latitude (S)	Longitude (W)	(EL. m)			Establishment		Used
M01	83007	Alto da Boa Vista	Rio de Janeiro	22º57'00"	43º16'00"	347	INMET	O	1-Jun-66	Automatic	DR
M02	83790	Bangu	Rio de Janeiro	22º52'00"	43º28'00"	40	INMET	O	5-Sep-18	Automatic	DR, ME
M03	83048	Rio Bonito	Rio Bonito	22º43'00"	42º37'00"	95	INMET	O	1-Jun-95	Automatic	DR
M04	83744	Teresópolis	Teresópolis	22º27'00"	42º56'00"	874	INMET	O	1-Jan-13	Automatic	DR
M05	83743	Rio de Janeiro	Rio de Janeiro	22º55'00"	43º10'00"	5	INMET	RO	1-Nov-73	Automatic	MR, ME, MC
M06	53569240	Andorinhas	Magé	22º32'36"	43º03'37"	395	SERLA	O	Jul-76		MR
M07	53729120	Cachoeiras de Macacu	Cachoeiras de Macacu	22º28'46"	42º39'28"	40	SERLA	O	Jul-76		MR
M08	81949220	Campo Grande	Rio de Janeiro	22º55'04"	43º32'41"	100	SERLA	O	Jan-65		MR
M09	79989480	Capela Mayrink	Rio de Janeiro	22º57'28"	43º16'40"	454	SERLA	O	Apr-76		MR
M10	79819750	Eletrobrás	Rio de Janeiro	22º55'18"	43º25'12"	40	SERLA	O	Jan-69		MR
M11	53729870	Escola União	Magé	22º35'03"	42º56'27"	20	SERLA	O	Aug-76		MR, ME
M12	53969220	Horto Florestal Niterói	Niterói	22º52'58"	43º06'27"	20	SERLA	O	Jun-76		DR
M13	53729195	Japuíba	Cachoeiras de Macacu	22º33'41"	42º41'37"	20	SERLA	O	May-76		MR
M14	81769250	Mendanha	Rio de Janeiro	22º51'43"	43º32'36"	100	SERLA	O	Jul-70		DR
M15	53729650	Quizanga	Cachoeiras de Macacu	22º31' 13"	42º49'50"	20	SERLA	O	Aug-76		MR
M16	53189120	Realengo	Rio de Janeiro	22º51'57"	43º25'33"	40	SERLA	O	Jan-65		MR
M17	43849740	Rio Mole	Saquarema	22º51'11"	42º33'07"	20	SERLA	O	Dec-78		MR
M18	53769080	Tanguá	Rio Bonito	22º42'29"	42º42'15"	40	SERLA	O	Jun-76		MR
M19	69229210	Torre	Nova Friburgo	22º21'32"	42º34'00"	1,555	SERLA	O	Jun-82		MR
M20	79939950	Via 11 - Sudebar	Rio de Janeiro	22º59'55"	43º21'59"	5	SERLA	O	Jul-70		MR
M21	53329080	Xerém	Duque de Caxias	22º33'03"	43º18'15"	137	SERLA	O	Jun-76		MR
M22		Ilha do Governador	Rio de Janeiro	22º49'03"	43º12'36"	0	GEO-RIO	O			DR
M23	53729010	Apolinário	Cachoeiras de Macacu	22º23'36"	42º34'30"	702	SERLA	NO	Aug-76		MR
M24	55919880	Arpoador	Rio de Janeiro			53	SERLA	NO	May-63		MR
M25	53119880	Arsenal da Marinha	Rio de Janeiro			20	SERLA	NO	Jan-28		MR
M26	79569830	Autódromo do Rio	Rio de Janeiro			16	SERLA	NO	Apr-69		MR
M27	81949130	Batalha	Rio de Janeiro	22º55'51"	43º30'30"	276	SERLA	NO	Jun-72		MR
M28	53149910	Benfica (CCPL)	Rio de Janeiro	22º53'17"	43º14'56"	12	SERLA	NO	Jul-69		MR
M29	79839450	Cafundá	Rio de Janeiro	22º54'29"	43º22'49"	41	SERLA	NO	Feb-69		MR
M30	77879980	Caiçaras	Rio de Janeiro	22º58'45"	43º12'42"	19	SERLA	NO	Aug-72		MR
M31	53139890	Cajú	Rio de Janeiro	22º52'00"	43º13'00"	0	SERLA	NO	Nov-87		MR
M32	79529090	Camorim	Rio de Janeiro	22º57'39"	43º26'50	476	SERLA	NO	Jun-72		MR
M33	45529650	Carangueijo	Maricá	22º54'12"	42º43'26"	20	SERLA	NO	Jan-80		MR
M34	77869180	Chácara do Cabeça	Rio de Janeiro	22º57'36"	43º13'18"	59	SERLA	NO	Oct-67		MR
M35	79859910	Cidade de Deus	Rio de Janeiro	22º56'36"	43º21'04"	20	SERLA	NO	Jan-69		MR
M36	53019550	Cidade Universitária	Rio de Janeiro	22º51'20	43º13'30"	0	SERLA	NO	Sep-70		MR
M37	55309019	Copacabana	Rio de Janeiro			2	SERLA	NO	May-26		MR
M38	53189320	Copeba	Rio de Janeiro	22º53'14"	43º24'32"	66	SERLA	NO	Jul-76		MR
M39	53119090	Elevatória de Botafogo	Rio de Janeiro			2	SERLA	NO	Jan-65		MR
M40	55309020	Elevatória de Copacabana	Rio de Janeiro	22º58'59"	43º11'35"	16	SERLA	NO	Mar-61		MR
M41	77299980	Elevatória do Leblon	Rio de Janeiro	22º59'20"	43º13'39"	24	SERLA	NO	Jun-70		MR
M42	53729520	Fazenda Coqueiro	Cachoeiras de Macacu	22º25'42"	42º48'03"	133	SERLA	NO	Aug-78		MR
M43	53729420	Fazenda Santo Amaro	Cachoeiras de Macacu	22º24'39"	42º43'25"	235	SERLA	NO	Aug-77		MR
M44	79849160	Florianópolis	Rio de Janeiro	22º54'05"	43º21'13"	40	SERLA	NO	Jan-69		MR
M45	53189370	Funabem	Rio de Janeiro	22º53'34"	43º19'27"	60	SERLA	NO	Jan-70		MR
M46	53119950	Gamboa	Rio de Janeiro			40	SERLA	NO	Jan-28		MR
M47	53119790	Glória	Rio de Janeiro			18	SERLA	NO	Jan-28		MR
M48	77849180	Horto Florestal Rio	Rio de Janeiro	22º58'02"	43º14'14"	60	SERLA	NO	Mar-67		MR
M49	77849180	Ilha do Governador	Rio de Janeiro	22º49'02"	43º13'30"	9	SERLA	NO	Dec-65		MR
M50	49939720	Ilha do Modesto	Niterói	22º56'55"	43º03'58"	20	SERLA	NO	Dec-78		MR
M51	53189940	Irajá	Rio de Janeiro	22º49'50"	43º19'46"	20	SERLA	NO	Jan-65		MR
M52	43429950	Jaconé	Saquarema	22º55'02"	42º38'24"	18	SERLA	NO	Oct-79		MR
M53	79399250	Laboratório de Energia Nuclear	Rio de Janeiro	22º59'52"	43º24'54"	19	SERLA	NO	Feb-75		MR
M54	77819880	Lagoa Rodrigo de Freitas	Rio de Janeiro	22º58'05"	43º13'02"	20	SERLA	NO	Nov-85		MR
M55	53159930	Lobo Junior	Rio de Janeiro	22º49'36"	43º16'23"	11	SERLA	NO	Jan-65		MR
M56	53119990	Mangue	Rio de Janeiro			20	SERLA	NO	Feb-28		MR
M57	45199180	Maricá	Maricá	22º55'00"	42º49'00"	20	SERLA	NO	Jan-87		MR
M58	45149990	Mombuca	Maricá	22º54'39"	42º49'19"	20	SERLA	NO	Jan-80		MR
M59	75219180	Mucuiba	Rio de Janeiro	22º57'53"	43º25'14"	81	SERLA	NO	Jun-72		MR
M60	53329890	Nilópolis	Nilópolis	22º47'55"	43º25'14"	20	SERLA	NO	Aug-86		MR
M61	53329780	Nova Iguaçu	Nova Iguaçu	22º42'20"	43º27'44"	69	SERLA	NO	Jun-76		MR
M62	53059550	Paquetá	Rio de Janeiro	22º45'36"	43º03'38"	0	SERLA	NO	Aug-65		MR
M63	53189990	Parada de Lucas	Rio de Janeiro	22º48'52"	43º17'27"	20	SERLA	NO	Oct-64		MR
M64	77219320	Parque da Cidade	Rio de Janeiro	22º58'40"	43º14'23"	162	SERLA	NO	Oct-67		MR
M65	53729710	Posto Garrafão	Magé	22º28'56"	42º59'46"	630	SERLA	NO	Sep-77		MR
M66	53129220	Praça Rocco	Rio de Janeiro	22º55'27"	43º16'05"	86	SERLA	NO	Jan-68		MR
M67	53119089	Praia de Botafogo	Rio de Janeiro			4	SERLA	NO	Jan-38		MR
M68	53129470	Sabóia Lima	Rio de Janeiro	22º56'10"	43º14'04"	97	SERLA	NO	Mar-67		MR
M69	53729320	Sambaetiba	Itaboraí	22º38'22"	42º48'02"	20	SERLA	NO	Aug-77		MR
M70	53329560	São Bento	Duque de Caxias	22º44'34"	43º18'41"	14	SERLA	NO	Aug-86		MR
M71	53129910	São Cristóvão	Rio de Janeiro			20	SERLA	NO	Jan-28		MR
M72	53189420	São Jerônimo	Rio de Janeiro	22º49'09"	43º20'39"	20	SERLA	NO	Jan-70		MR
M73	66669080	Teresópolis	Teresópolis	22º26'00"	42º58'27"	900	SERLA	NO	Dec-73		MR
M74	69229030	Theodoro de Oliveira	Nova Friburgo	22º22'45"	42º33'11"	1,119	SERLA	NO	Jan-82		MR

Note : O = Operational; NO = Non-Operational; RO = Re-Operational
DR = Daily Rainfall; MR = Monthly Rainfall; ME = Monthly Evaporation; MC = Monthly Climate such as Temperature, Relative Humidity.
Elevations of all SERLA stations have been calculated from GIS database of elevation grid with 20 m cell size created from a combination of 20 and 100 m contours.

Table 2 Availability of Rainfall Data (1 of 2)

Station			Agency	Year of Available/Collected Data																																				
ID	Code	Name		1928	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964
M01	83007	Alto da Boa Vista	INMET																																					
M02	83790	Bangu	INMET																																					
M03	83048	Rio Bonito	INMET																																					
M04	83743	Rio de Janeiro	INMET																																					
M05	83744	Teresópolis	INMET																																					
M06	53569240	Andorinhas	SERLA																																					
M07	53729120	Cachoeiras de Macacu	SERLA																																					
M08	81949220	Campo Grande	SERLA																																					
M09	79989480	Capela Mayrink	SERLA																																					
M10	79819750	Eletrobrás	SERLA																																					
M11	53729870	Escola União	SERLA																																					
M12	53969220	Horto Florestal Niterói	SERLA																																					
M13	53729195	Japuíba	SERLA																																					
M14	81769250	Mendanha	SERLA																																					
M15	53729650	Quizanga	SERLA																																					
M16	53189120	Realengo	SERLA																																					
M17	43849740	Rio Mole	SERLA																																					
M18	53769080	Tanguá	SERLA																																					
M19	69229210	Torre	SERLA																																					
M20	79939950	Via 11 - Sudebar	SERLA																																					
M21	53329080	Xerém	SERLA																																					
M22		Ilha do Governador	GEO-RIO																																					
M23	53729010	Apolinário	SERLA																																					
M24	55919880	Arpoador	SERLA																																					
M25	53119880	Arsenal da Marinha	SERLA																																					
M26	79569830	Autódromo do Rio	SERLA																																					
M27	81949130	Batalha	SERLA																																					
M28	53149910	Benfica (CCPL)	SERLA																																					
M29	79839450	Cafundá	SERLA																																					
M30	77879980	Caiçaras	SERLA																																					
M31	53139890	Cajú	SERLA																																					
M32	79529090	Camorim	SERLA																																					
M33	45529650	Caranguejo	SERLA																																					
M34	77869180	Chácara do Cabeça	SERLA																																					
M35	79859910	Cidade de Deus	SERLA																																					
M36	53019550	Cidade Universitária	SERLA																																					
M37	55309019	Copacabana	SERLA																																					
M38	53189320	Copeba	SERLA																																					
M39	53119090	Elevatória de Botafogo	SERLA																																					
M40	55309020	Elevatória de Copacabana	SERLA																																					
M41	77299980	Elevatória do Leblon	SERLA																																					
M42	53729520	Fazenda Coqueiro	SERLA																																					
M43	53729420	Fazenda Santo Amaro	SERLA																																					
M44	79849160	Florianópolis	SERLA																																					
M45	53189370	Funabem	SERLA																																					
M46	53119950	Gamboa	SERLA																																					
M47	53119790	Glória	SERLA																																					
M48	77849180	Horto Florestal Rio	SERLA																																					
M49	77849180	Ilha do Governador	SERLA																																					
M50	49939720	Ilha do Modesto	SERLA																																					
M51	53189940	Irajá	SERLA																																					
M52	43429950	Jaconé	SERLA																																					
M53	79399250	Laboratório de Energia Nuclear	SERLA																																					
M54	77819880	Lagoa Rodrigo de Freitas	SERLA																																					
M55	53159930	Lobo Junior	SERLA																																					
M56	53119990	Mangue	SERLA																																					
M57	45199180	Maricá	SERLA																																					
M58	45149990	Mombuca	SERLA																																					
M59	75219180	Mucuiba	SERLA																																					
M60	53329890	Nilópolis	SERLA																																					
M61	53329780	Nova Iguaçu	SERLA																																					
M62	53059550	Paquetá	SERLA																																					
M63	53189990	Parada de Lucas	SERLA																																					
M64	77219320	Parque da Cidade	SERLA																																					
M65	53729710	Posto Garrafão	SERLA																																					
M66	53129220	Praça Rocco	SERLA																																					
M67	53119089	Praia de Botafogo	SERLA																																					
M68	53129470	Sabóia Lima	SERLA																																					
M69	53729320	Sambaetiba	SERLA																																					
M70	53329560	São Bento	SERLA																																					
M71	53129910	São Cristóvão	SERLA																																					
M72	53189420	São Jerônimo	SERLA																																					
M73	66669080	Teresópolis	SERLA																																					
M74	69229030	Theodoro de Oliveira	SERLA																																					

Table 2 Availability of Rainfall Data (2 of 2)

	Station		Agency	Year of Available/Collected Data																																	
ID	Code	Name		1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
M01	83007	Alto da Boa Vista	INMET																																						
M02	83790	Bangu	INMET																																						
M03	83048	Rio Bonito	INMET																																						
M04	83743	Rio de Janeiro	INMET																																						
M05	83744	Teresópolis	INMET																																						
M06	53569240	Andorinhas	SERLA																																						
M07	53729120	Cachoeiras de Macacu	SERLA																																						
M08	81949220	Campo Grande	SERLA																																						
M09	79989480	Capela Mayrink	SERLA																																						
M10	79819750	Eletrobrás	SERLA																																						
M11	53729870	Escola União	SERLA																																						
M12	53969220	Horto Florestal Niterói	SERLA																																						
M13	53729195	Japuíba	SERLA																																						
M14	81769250	Mendanha	SERLA																																						
M15	53729650	Quizanga	SERLA																																						
M16	53189120	Realengo	SERLA																																						
M17	43849740	Rio Mole	SERLA																																						
M18	53769080	Tanguá	SERLA																																						
M19	69229210	Torre	SERLA																																						
M20	79939950	Via 11 - Sudebar	SERLA																																						
M21	53329080	Xerém	SERLA																																						
M22		Ilha do Governador	GEO-RIO																																						
M23	53729010	Apolinário	SERLA																																						
M24	55919880	Arpoador	SERLA																																						
M25	53119880	Arsenal da Marinha	SERLA																																						
M26	79569830	Autódromo do Rio	SERLA																																						
M27	81949130	Batalha	SERLA																																						
M28	53149910	Benfica (CCPL)	SERLA																																						
M29	79839450	Cafundá	SERLA																																						
M30	77879980	Caiçaras	SERLA																																						
M31	53139890	Cajú	SERLA																																						
M32	79529090	Camorim	SERLA																																						
M33	45529650	Carangueijo	SERLA																																						
M34	77869180	Chácara do Cabeça	SERLA																																						
M35	79859910	Cidade de Deus	SERLA																																						
M36	53019550	Cidade Universitária	SERLA																																						
M37	55309019	Copacabana	SERLA																																						
M38	53189320	Copeba	SERLA																																						
M39	53119090	Elevatória de Botafogo	SERLA																																						
M40	55309020	Elevatória de Copacabana	SERLA																																						
M41	77299980	Elevatória do Leblon	SERLA																																						
M42	53729520	Fazenda Coqueiro	SERLA																																						
M43	53729420	Fazenda Santo Amaro	SERLA																																						
M44	79849160	Florianópolis	SERLA																																						
M45	53189370	Funabem	SERLA																																						
M46	53119950	Gamboa	SERLA																																						
M47	53119790	Glória	SERLA																																						
M48	77849180	Horto Florestal Rio	SERLA																																						
M49	77849180	Ilha do Governador	SERLA																																						
M50	49939720	Ilha do Modesto	SERLA																																						
M51	53189940	Irajá	SERLA																																						
M52	43429950	Jaconé	SERLA																																						
M53	79399250	Laboratório de Energia Nuclear	SERLA																																						
M54	77819880	Lagoa Rodrigo de Freitas	SERLA																																						
M55	53159930	Lobo Junior	SERLA																																						
M56	53119990	Mangue	SERLA																																						
M57	45199180	Maricá	SERLA																																						
M58	45149990	Mombuca	SERLA																																						
M59	75219180	Mucuiba	SERLA																																						
M60	53329890	Nilópolis	SERLA																																						
M61	53329780	Nova Iguaçu	SERLA																																						
M62	53059550	Paquetá	SERLA																																						
M63	53189990	Parada de Lucas	SERLA																																						
M64	77219320	Parque da Cidade	SERLA																																						
M65	53729710	Posto Garrafão	SERLA																																						
M66	53129220	Praça Rocco	SERLA																																						
M67	53119089	Praia de Botafogo	SERLA																																						
M68	53129470	Sabóia Lima	SERLA																																						
M69	53729320	Sambaetiba	SERLA																																						
M70	53329560	São Bento	SERLA																																						
M71	53129910	São Cristóvão	SERLA																																						
M72	53189420	São Jerônimo	SERLA																																						
M73	66669080	Teresópolis	SERLA																																						
M74	69229030	Theodoro de Oliveira	SERLA																																						

Table 3 Inventory on Monitoring Network on Hydrology

Station			Location		Coordinate		Gauged Area	"0" Gauge Level	Date of	Type of	Observation Items of Telemeters		
JICA ID	Code	Name	River	Municipality	Latitude (S)	Longitude (W)	(km^2)	(El. m)	Establishment	Measurement	Rainfall	Water Level	Water Quality
H01	59500001	Heliópolis	Da Bota	Belford Roxo	22º 44' 10"	43º 24' 41"	58.04		Oct-98	Telemetric	O	O	O
H02	59500002	CIEP - 100	Sarapuí	Belford Roxo	22º 46' 50"	43º 24' 00"	87.66		Sep-98	Telemetric	O	O	
H03	59500003	Clube Catavento	Iguaçu	Nova Iguaçu	22º 39' 11"	43º 24' 33"	98.86		Nov-98	Telemetric	O	O	O
H04	59500004	Estrada da Conceição	Suruí	Magé	22º 36' 42"	43º 06' 11"	36.18		Dec-98	Telemetric	O	O	
H05	59500005	Ponte de Ferro - Capivari	Capivari	Duque de Caxias	22º 39' 09"	43º 20' 00"	88.44		Sep-98	Telemetric	O	O	
H06	59270000	Santa Cruz da Serra	Saracuruna	Duque de Caxias	22º 38' 30"	43º 17' 15"	94.89		Sep-98	Telemetric	O	O	O
H07	59500006	Ponte de Ferro - Piabetá	Inhomirim	Magé	22º 37' 38"	43º 09' 41"	92.09		Sep-98	Telemetric	O	O	O
H08	59500007	São Cristóvão	Maracanã	Rio de Janeiro	22º 54' 44"	43º 13' 37"			Sep-98	Telemetric	O	O	O
H09	59500008	Quartel da PE	Maracanã	Rio de Janeiro	22º 55' 17"	43º 14' 08"	13.96		Sep-98	Telemetric	O	O	
H10	59500009	Igreja de Santo Antônio	Pavuna	Rio de Janeiro	22º 48' 15"	43º 21' 45"	35.56		Oct-98	Telemetric	O	O	
H11	59305028	Avenida Automóvel Clube	Acari	Rio de Janeiro	22º 50' 48"	43º 21' 35"	57.78		Sep-98	Telemetric	O	O	
H12	59500010	Estrada Velha da Pavuna	Faria	Rio de Janeiro	22º 52' 23"	43º 16' 08"	23.28		Sep-98	Telemetric	O	O	
H13	59500011	Orindi	Iconha	Cachoeiras de Macacu	22º 32' 52"	42º 53' 53"	66.53		Nov-98	Telemetric	O	O	
H14	59500012	Parque São Miguel	Roncador	Magé	22º 36' 48"	43º 02' 17"	89.70		Oct-98	Telemetric	O	O	
H15	59500013	Barragem - CEDAE	Guapi	Itaboraí	22º 39' 25"	42º 56' 04"	1,089.36		Oct-98	Telemetric	O	O	O
H16	59245002	Quizanga - II	Guapi'Açu	Cachoeiras de Macacu	22º 33' 52"	42º 50' 57"	350.47		Sep-98	Telemetric	O	O	O
H17	59242000	Duas Barras	Guapi'Açu	Cachoeiras de Macacu	22º 26' 18"	42º 45' 40"	82.58		Oct-98	Telemetric	O	O	
H18	59237000	Japuíba - II	Macacu	Cachoeiras de Macacu	22º 33' 37"	42º 41' 37"	255.65		Sep-98	Telemetric	O	O	O
H19	59235002	Cachoeiras de Macacu - II	Macacu	Cachoeiras de Macacu	22º 28' 46"	42º 39' 27"	147.32		Sep-98	Telemetric	O	O	
H20	59305056	Borda do Mato	Joana	Rio de Janeiro	22º 55' 25"	43º 16' 03"			Nov-98	Telemetric	O	O	
H21	59500014	Reta Nova	Caceribu	Itaboraí	22º 42' 46"	42º 48' 30"	379.92		Oct-98	Telemetric	O	O	O
H22		Reta Velha	Iguá	Itaboraí			95.42			Non-Operational	O	O	
H23	59500016	Ponte de Tanguá	Caceribu	Tanguá	22º 43' 37"	42º 43' 34"	237.20		Dec-98	Telemetric	O	O	
H24	59500017	Três Pontes	Aldeia	Itaboraí	22º 45' 14"	42º 54' 19"	129.48		Oct-98	Telemetric	O	O	
H25	59500018	Columbandê	Columbandê	São Gonçalo	22º 50' 34"	43º 00' 28"	55.26		Jan-98	Telemetric	O	O	
All of SERLA Stations (except 8 and 20)							2,525.86						
Total Area of River Basins without Islands							4,024.78						
Percent of SERLA Stations							63%						

Note : At all the stations, there are staff gauges for taking manual readings of water levels at two times a day, at 7 AM and at 5 PM.
Telemetric rainfall data is sent at every 5 minutes, water level data is sent at every 15 minutes and water quality data is sent at every 60 minutes intervals.
Water quality data comprise of temperature, dissolved oxygen (DO), conductivity and pH.
Gauged area covered by each station have been estimated based on GIS database prepared using 1/50,000 scale map with a combination of 20 and 100 m contours.
"0" Gauge Level couldn't be collected from SERLA.

Table 4 Characteristics of SERLA Stream Gauge Stations

Unit : Gauge Height (m)

Station				Gauged	Rating Curve Parameters			Altitude of Basin			Slope of Basin			Cross-Sectional Properties						
No.	Code	Name	River	Area	c	a	b	(El. m)			(degree)			Lowest Bed	Left Bank	Right Bank	W.L.	Top Width	Depth	Date of
				(km2)				Min.	Max.	Avg.	Min.	Max.	Avg.	(m)	(m)	(m)	(m)	(m)	(m)	Survey
H01	59500001	Heliópolis	Da Bota	58.0	5.1554	-0.15	2.392	20	860	94	0	62	6	-0.15	4.45	3.28	0.45	22.45	3.43	8-Nov-00
H02	59500002	CIEP - 100	Sarapuí	87.7	14.663	0.47	2.721	20	960	187	0	68	11	0.47	4.65	5.87	1.02	48.80	4.18	8-Nov-00
H03	59500003	Clube Catavento	Iguaçu	98.9	1.1340	0.17	4.225	20	1,440	126	0	56	10	0.17	7.64	6.60	1.07	30.60	6.43	15-Dec-00
H04	59500004	Estrada da Conceição	Suruí	36.2	0.8674	-0.48	2.882	20	1,220	208	0	73	15	-0.48	5.12	3.96	1.00	27.47	4.44	5-Dec-00
H05	59500005	Ponte de Ferro - Capivari	Capivari	88.4	3.8772	0.31	1.639	20	1,320	374	0	65	17	0.31	4.01	3.94	1.19	17.70	3.63	13-Dec-00
H06	59270000	Santa Cruz da Serra	Saracuruna	94.9	0.9047	0.10	4.624	20	1,500	434	0	69	18	0.10	4.39	4.39	1.40	22.45	4.29	13-Dec-00
H07	59500006	Ponte de Ferro - Piabetá	Inhomirim	92.1	1.3790	-0.24	3.778	20	1,740	434	0	79	19	-0.24	6.70	6.24	1.24	35.00	6.48	14-Dec-00
H08	59500007	São Cristóvão	Maracanã		6.8278	-0.20	2.454							-0.20	3.53	3.42	0.40	16.95	3.62	10-Dec-00
H09	59500008	Quartel da PE	Maracanã	14.0	18.077	-0.20	2.901	20	820	288	0	57	22	-0.20	4.01	4.01	0.10	6.00	4.21	11-Oct-00
H10	59500009	Igreja de Santo Antônio	Pavuna	35.6	6.9472	0.14	1.522	20	140	34	0	40	3	0.14	3.69	3.69	0.54	9.70	3.55	7-Nov-00
H11	59305028	Avenida Automóvel Clube	Acari	57.8	5.5149	0.31	2.545	20	920	82	0	61	6	0.31	2.69	7.62	1.31	61.30	2.38	7-Nov-00
H12	59500010	Estrada Velha da Pavuna	Faria	23.3				20	480	84	0	52	7	-1.04	3.41	3.47	-0.74	12.20	4.45	17-Oct-00
H13	59500011	Orindi	Iconha	66.5	1.0358	-0.75	6.201	20	1,651	306	0	76	18	-0.75	4.34	4.29	0.55	34.90	5.04	7-Dec-00
H14	59500012	Parque São Miguel	Roncador	89.7	0.4658	-0.69	4.422	20	2,100	438	0	75	20	-0.69	6.10	5.41	0.73	32.90	6.10	14-Dec-00
H15	59500013	Barragem - CEDAE	Guapi	1,089.4	97.1530	1.10	1.057	20	2,220	274	0	76	14	-1.40	4.58	3.69	1.20	74.00	5.09	18-Oct-00
H16	59245002	Quizanga - II	Guapi'Açu	350.5	4.0020	-0.74	1.787	20	2,060	296	0	76	16	-0.72	6.40	5.06	0.63	37.70	5.78	7-Dec-00
H17	59242000	Duas Barras	Guapi'Açu	82.6	8.8739	-0.37	1.938	40	2,060	660	0	76	23	-0.37	6.46	7.12	0.43	41.30	6.83	7-Dec-00
H18	59237000	Japuíba - II	Macacu	255.6	5.3765	-0.37	2.529	20	2,220	517	0	74	20	-0.37	6.50	7.08	0.48	42.50	6.87	10-Nov-00
H19	59235002	Cachoeiras de Macacu - II	Macacu	147.3	0.3899	-1.09	8.113	40	2,220	716	0	74	23	-1.09	6.62	5.93	0.16	36.55	7.02	10-Nov-00
H20	59305056	Borda do Mato	Joana		32,146	-0.04	27.685							-0.04	2.49	1.30	0.55	8.60	1.34	16-Oct-00
H21	59500014	Reta Nova	Caceribu	379.9	1.1632	-0.59	5.201	20	960	157	0	58	11	-0.57	4.88	5.03	0.27	112.80	5.45	20-Oct-00
H22		Reta Velha	Iguá	95.4	1.1540	0.04	1.875	20	440	81	0	51	8	0.04	4.92	4.90	0.24	31.70	4.86	20-Oct-00
H23	59500016	Ponte de Tanguá	Caceribu	237.2	0.9599	-0.46	4.905	20	960	193	0	58	12	-0.46	1.04	1.06	0.52	10.60	1.50	9-Nov-00
H24	59500017	Três Pontes	Aldeia	129.5	1.1013	-0.36	6.354	20	500	81	0	58	7	-0.36	5.02	3.62	0.34	45.40	3.98	19-Oct-00
H25	59500018	Columbandê	Columbandê	55.3	3.9505	0.15	2.419	20	400	96	0	50	11	0.15	4.79	5.06	0.51	27.10	4.64	9-Nov-00
All of SERLA Stations (except 8 and 20)				2,525.9																

Note : No. of discharge measurements used in constructing the rating curves vary from 34 to 50 during 1998 to 2001.

Equation of Rating Curve : $Q = c (H - a)^b$

where : Q = discharge (m^3/s)

H = gauge height (m)

c = constant

b = exponent

a = minimum bed level where flow is zero (except for Station H15 where "a" represents gauge height corresponding to stagnent water level of CEDAE dam)

Altitudes and slopes have been calculated from GIS database of elevation grid with 20 m cell size created from a combination of 20 and 100 m contours.

Table 5 Monthly Discharges for Year 1999 and 2000

Year 1999

Month	Monthly Mean Discharge (m^3/s) by Station for Year 1999										
	H01	H02	H03	H04	H05	H06	H07	H09	H10	H11	H13
Jan.	3.58	4.93	4.97	1.57	3.92	2.66	5.18	1.11	1.45	6.60	4.58
Feb.	1.99	3.46	3.11	1.22	2.75	1.67	4.11	0.90	1.26	5.88	2.55
Mar.	1.73	3.81	2.48		4.96	3.60	3.07	0.63	1.08	5.53	3.14
Apr.	1.42	2.53	1.47		1.73	1.03	2.13	0.59	0.65	5.81	2.42
May	1.42	2.69	0.94		0.90	4.14	1.18	0.64	0.69	5.75	1.53
June	1.56	2.76	1.49		1.49	3.01	1.21	0.80	1.03	5.87	1.52
July	1.54	2.96	1.60	0.65	1.43	3.63	1.60	0.79	0.65	7.05	1.47
Aug.	1.40	2.76	1.13	0.56	1.45	1.27	1.64	0.69	0.76	6.30	1.00
Sep.	1.42	2.83	1.14	0.69	1.46	2.80	2.56	0.70	0.92	6.34	1.55
Oct.	1.45	2.92	1.06		4.05	7.93	4.06	0.70	0.95	5.69	3.66
Nov.	1.82	3.43	1.64	1.42	5.02	5.66	6.50	0.68	1.00	6.59	3.43
Dec.	2.45	4.76	1.99	2.40	4.97	4.92	9.08	0.68	1.07	15.04	4.98
Annual	1.81	3.32	1.92	1.22	2.84	3.52	3.53	0.74	0.96	6.87	2.65
Sp. Q ($m^3/s/km^2$)	0.031	0.038	0.019	0.034	0.032	0.037	0.038	0.053	0.027	0.119	0.040

Month	Monthly Mean Discharge (m^3/s) by Station for Year 1999										
	H14	H15	H16	H17	H18	H19	H21	H22	H23	H24	H25
Jan.	4.41	61.40	21.99	6.96	15.42	11.28	6.42	0.93	6.13	1.37	2.69
Feb.	3.50	31.43	13.98	4.76	8.42	5.42	2.51	0.19	1.80	0.86	0.51
Mar.	6.52	53.91	18.25	5.58	11.43	9.58	3.72	0.54	3.72	1.41	4.56
Apr.	4.37	31.59	12.19	4.57	9.04	5.79	1.68	0.05	1.44	0.25	0.59
May	2.03	22.77	8.59	3.50	6.01	3.32	1.57	0.07	1.49	0.35	0.67
June	1.75	29.33	8.34	3.62	5.75	3.08	1.92	0.09	1.67	0.27	0.95
July	1.64	20.91	6.82	3.24	4.58	3.39	0.89	0.08	1.03	0.25	0.73
Aug.	1.13	25.58	7.24	3.04	5.18	2.92	0.89	0.08	1.04	0.37	1.27
Sep.	2.90	25.73	6.47	2.93			0.62	0.10	0.95	0.21	
Oct.	4.25	34.90	9.98	4.24	6.13	3.13	0.88	0.09	1.18		0.55
Nov.	7.08	52.45		5.52	11.28	3.82	2.65	0.15	3.40	0.26	
Dec.	8.46	55.02	14.71	3.94	10.33	4.90	2.30	0.31	3.25	0.31	1.49
Annual	4.00	37.08	11.69	4.33	8.51	5.15	2.17	0.22	2.26	0.54	1.40
Sp. Q ($m^3/s/km^2$)	0.045	0.034	0.033	0.052	0.033	0.035	0.006	0.002	0.010	0.004	0.025

Year 2000

Month	Monthly Mean Discharge (m^3/s) by Station for Year 2000										
	H01	H02	H03	H04	H05	H06	H07	H09	H10	H11	H13
Jan.	1.79	4.24	3.22	2.36	4.47	8.85	8.29	0.60	1.01	6.31	5.26
Feb.	2.16	3.03	1.65	2.59	3.05	7.53	4.98	0.77	0.96	5.51	4.40
Mar.	2.11	4.66	1.92	1.77	3.69	9.09	5.30	0.72	1.22	5.63	5.73
Apr.	1.52	3.46	1.08	1.04	3.66	5.52	3.94	0.71	1.02	5.42	2.00
May	1.28	3.07	0.78	0.52	1.64	2.27	1.90	0.66	1.08	5.84	1.50
June	1.21	3.02	0.95	0.38	1.01	6.21	1.17	0.57	1.00	9.90	1.14
July	1.86	3.83	1.11	0.82	1.85	3.69	2.86	0.65	1.35	7.91	1.14
Aug.	1.35	3.35	0.80	0.58	2.04	2.61	2.26	0.58	1.01	5.96	1.35
Sep.	1.93	4.86	1.18	2.07	5.53	6.46	7.27	0.59	1.39	5.30	1.89
Oct.	1.38	3.57	0.51	0.69	1.88	1.39	1.88	0.61	1.33	5.73	1.36
Nov.	1.52	4.07	2.31	2.22	2.80	5.96	6.90	1.04	2.16		1.79
Dec.	1.58	3.88	1.91	1.84	4.72	11.78	10.18	0.94	1.49		4.39
Annual	1.64	3.75	1.45	1.41	3.03	5.95	4.74	0.70	1.25	6.35	2.66
Sp. Q ($m^3/s/km^2$)	0.028	0.043	0.015	0.039	0.034	0.063	0.051	0.050	0.035	0.110	0.040

Month	Monthly Mean Discharge (m^3/s) by Station for Year 2000										
	H14	H15	H16	H17	H18	H19	H21	H22	H23	H24	H25
Jan.	6.13	56.50	16.85	5.67	12.03	6.67	6.79	0.74	1.65	0.95	2.80
Feb.	3.93	50.34	14.30	4.18	11.85	4.47	6.87	0.27	1.23	1.02	2.24
Mar.	5.33	44.32	13.54	4.63	12.23	5.80	9.69	0.09	1.49	0.41	3.13
Apr.	4.04	42.33	13.29	4.29	11.60	6.21	5.25	0.15	1.70	0.23	1.44
May	1.36	20.99	6.30	2.22	6.70	3.15	0.80	0.05	0.95	0.24	0.71
June	0.95	33.62	4.27	1.63	4.91	2.55	0.62	0.04	0.65	0.41	0.39
July	1.95	24.66	6.00	2.40	5.60	2.22	0.88	0.05	0.95	0.43	2.41
Aug.	1.40	33.62	7.21	3.44	7.82	4.45	1.85	0.23	0.95	0.67	2.24
Sep.	3.00	45.90	10.59	4.15	9.92	2.83	4.50	0.70	1.61	0.67	2.11
Oct.	1.45	26.19	7.09	2.42	5.25	2.62	0.75	0.08	0.90	0.28	0.54
Nov.	4.21	31.28	7.91	2.95	6.30	2.31	2.49	0.25	1.67	1.08	3.89
Dec.	4.75	53.66	15.55	4.63	9.34	3.85	3.77	0.51	2.02	0.74	2.00
Annual	3.21	38.62	10.24	3.55	8.63	3.93	3.69	0.26	1.31	0.59	1.99
Sp. Q ($m^3/s/km^2$)	0.036	0.035	0.029	0.043	0.034	0.027	0.010	0.003	0.006	0.005	0.036

Table 6 Divisions of River Basins

Major River Basin			Sub-Basin			Altitude (El. m)			Slope (degree)		
ID	Name	Area (km^2)	ID	Name	Area (km^2)	Minimum	Maximum	Average	Minimum	Maximum	Average
B0100	Bay - Charitas	9.46				0	340	90	0	61	16
B0200	Canal Canto do Rio	6.21				0	200	52	0	44	10
B0300	Bay - Catedrar	7.57				0	200	25	0	47	7
B0400	Bay - Norte Centro	9.26				0	280	81	0	45	12
B0500	Rio Bomba	26.78				0	220	37	0	49	7
B0600	Rio Imboaçu	29.43				0	300	48	0	43	5
B0700	Bay - Itaoca	8.54				0	260	25	0	40	5
B0800	Rio Alcantara	173.07				0	400	53	0	50	5
B0900	Rio Caceribu	811.34				0	960	101	0	58	7
			B0901	Rio Guará-Mirim	77.79	0	40	17	0	20	0
			B0902	Rio Porto das Caixas	188.47	20	500	64	0	58	5
			B0903	Rio Iguá	165.75	20	440	56	0	51	5
			B0904	Rio Caceribu L/S	85.68	20	680	103	0	51	8
			B0905	Rio Caceribu R/S	293.66	20	960	173	0	58	12
B1000	Rio Guapimirim	1,262.03				0	340	90	0	61	16
			B1001	Rio Guapimirim D/S	49.76	0	220	21	0	37	1
			B1002	Rio Guapi	12.10	20	80	20	0	30	0
			B1003	Rio Macacu - D/S	250.49	20	740	115	0	57	9
			B1004	Rio Macacu - U/S	255.61	20	2,220	517	0	74	20
			B1005	Rio Iconha	224.02	20	1,651	150	0	76	11
			B1006	Rio Guapiaçu	350.44	20	2,060	296	0	76	16
			B1007	Rio Guapimirim U/S	119.60	20	2,200	289	0	72	11
B1100	Canal de Magé	17.08				0	140	19	0	41	2
B1200	Rio Roncador	115.19				0	2,100	349	0	75	17
B1300	Rio Iriri	19.63				0	320	34	0	46	6
B1400	Rio Suruí	84.44				0	1,220	119	0	73	13
B1500	Bay - Maua	17.92				0	200	28	0	43	6
B1600	Rio Saracuruna	348.88				0	1,740	259	0	79	13
			B1601	Rio Estrela	19.52	0	80	21	0	37	2
			B1602	Rio Inhomirim	139.57	20	1,740	294	0	79	14
			B1603	Rio Saracuruna	189.80	20	1,500	257	0	74	12
B1700	Rio Iguaçu	716.72				3	1,580	148	0	68	9
			B1701	Rio Iguaçu D/S	83.79	2	140	23	0	38	2
			B1702	Rio Iguaçu M/S	37.50	20	200	29	0	42	5
			B1703	Rio Capivari	103.25	20	1,320	324	0	65	15
			B1704	Rio Tinguá	114.07	20	1,580	276	0	68	17
			B1705	Rio Iguaçu U/S	100.20	20	1,440	124	0	56	10
			B1706	Rio da Bota	116.05	20	900	65	0	62	5
			B1707	Rio Sarapuí	161.87	3	960	117	0	68	8
B1800	Bay - Cabo do Brito	19.72				0	80	12	0	32	1
B1900	Rio Sâo Jão de Meriti	154.26				0	920	50	0	61	4
B2000	Rio Irajá	50.95				0	316	40	0	47	5
B2100	Canal do Cunha	70.23				0	1,018	86	0	62	8
B2200	Bay - São Cristóvão	6.41				0	80	15	0	29	2
B2300	Canal do Mangue	37.95				0	820	146	0	57	13
B2400	Bay - Botafogo	21.68				0	740	79	0	57	11
B2500	Ilha do Governador	36.28				0	80	18	0	42	3
B2600	Ilha do Fundão	5.35				0	40	3	0	33	1
B2700	Ilha de Paquetá	2.21				0	60	10	0	38	6
B2800	Ilha do Engenho	0.98				0	60	16	0	45	9
B2900	Ilha de S. Cruz	1.10				0	40	9	0	29	5
Area of Major River Basins		4,024.78									
Area of Islands		45.92									
Total Basin Area		4,070.70									
Area of Guanabara Bay		351.54									
Total Study Area		4,422.24									

Note : U/S = Upstream; M/S = Midstream; D/S = Downstream; L/S = Leftstream; R/S = Rightstream
Altitude and Slope have been calculated from GIS database of 1/50,000 scale and 20 m contour interval.

Table 7 Thiessen Polygons of the Selected 16 Rainfall Stations

Selected Station	Weight of Thiessen Polygons of the 7 Daily Rainfall Stations							Total
	Teresopolis	Rio Bonito	Alto da Boa Vista	Bangu	Ilha do Governador	Horto Floresta Niteroi	Mendanha	
M01			1.00					1.00
M02				1.00				1.00
M03		1.00						1.00
M04	1.00							1.00
M11	0.81	0.16				0.02		1.00
M12						1.00		1.00
M13	0.26	0.74						1.00
M21	0.11			0.06	0.84			1.00
M23	0.29	0.71						1.00
M38			0.11	0.80	0.09			1.00
M43	0.97	0.03						1.00
M49					1.00			1.00
M61				0.80	0.07		0.14	1.00
M62		0.05			0.29	0.66		1.00
M65	1.00							1.00
M70				0.13	0.87			1.00

Table 8 Adjustment Factors for Annual Average Rainfalls at the Selected 16 Stations

Selected Station	Annual Average Rainfall (mm) at the Selected 16 Stations (Year 1928 - 2002)		Adjustment Factor
	Using all the 74 Rainfall Stations, R_{all}	Using only the 7 Daily Rainfall Stations, R_{7stn}	R_{all}/R_{7stn}
M01	1464.2	2245.0	0.652
M02	1367.6	1247.0	1.097
M03	1237.5	1328.0	0.932
M04	2011.6	1661.0	1.211
M11	1793.4	1593.2	1.126
M12	1279.9	1132.0	1.131
M13	1742.9	1413.6	1.233
M21	1795.6	1174.3	1.529
M23	2386.1	1423.1	1.677
M38	1379.0	1339.6	1.029
M43	2277.2	1650.0	1.380
M49	1163.7	1108.0	1.050
M61	1367.5	1235.9	1.107
M62	1341.5	1135.8	1.181
M65	2229.6	1661.0	1.342
M70	1288.1	1125.4	1.144

Table 9 Thiessen Polygons of Drainage Basins of SERLA Stream Gauge Stations

SERLA Station			Weights of Thiessen Polygons for Rainfall and Evaporation Stations																				
ID	Name	Area	Selected 16 Rainfall Stations																	Evaporation Stations			
		(km2)	M01	M02	M03	M04	M11	M12	M13	M21	M23	M38	M43	M49	M61	M62	M65	M70	Total	C.P. Rio de Janeiro	Bangu	Escola União	Total
H01	Heliópolis	58.04													1.00				1.00		1.00		1.00
H02	CIEP - 100	87.66		0.87											0.12			0.02	1.00		1.00		1.00
H03	Clube Catavento	98.86													1.00				1.00		1.00		1.00
H04	Estrada da Conceição	36.18					0.92									0.16	0.84		1.92			1.00	1.00
H05	Ponte de Ferro - Capivari	88.44								1.00									1.00		0.73	0.27	1.00
H06	Santa Cruz da Serra	94.89								1.00									1.00		0.15	0.85	1.00
H07	Ponte de Ferro - Piabetá	92.09								0.70						0.07	0.23		1.00			1.00	1.00
H09	Quartel da PE	13.96	1.00																1.00	1.00			1.00
H10	Igreja de Santo Antônio	35.56		0.32								0.57						0.11	1.00		1.00		1.00
H11	Avenida Automóvel Clube	57.78		0.17								0.83							1.00		1.00		1.00
H13	Orindi	66.53				0.29	0.30										0.42		1.00			1.00	1.00
H14	Parque São Miguel	89.70					0.28										0.72		1.00			1.00	1.00
H15	Barragem - CEDAE	1,089.36				0.10	0.18		0.39		0.11		0.22						1.00			1.00	1.00
H16	Quizanga - II	350.47				0.19	0.05		0.22				0.53						1.00			1.00	1.00
H17	Duas Barras	82.58											1.00						1.00			1.00	1.00
H18	Japuíba - II	255.65							1.00										1.00			1.00	1.00
H19	Cachoeiras de Macacu - II	147.32							0.05		0.73		0.22						1.00			1.00	1.00
H21	Reta Nova	379.92			1.00														1.00			1.00	1.00
H22	Reta Velha	95.42			0.63		0.10									0.27			1.00			1.00	1.00
H23	Ponte de Tanguá	237.20			1.00														1.00			1.00	1.00
H24	Três Pontes	129.48						0.26								0.74			1.00	0.55		0.45	1.00
H25	Columbandê	55.26						1.00											1.00	1.00			1.00

Table 10 Thiessen Polygons of Major River Basins and Sub-Basins

Major River Basin and Sub-Basin			Weights of Thiessen Polygons for Rainfall and Evaporation Stations																				
ID	Name	Area	Selected 16 Rainfall Stations																	Evaporation Stations			
		(km^2)	M01	M02	M03	M04	M11	M12	M13	M21	M23	M38	M43	M49	M61	M62	M65	M70	Total	C.P. Rio de Janeiro	Bangu	Escola União	Total
Major River Basin																							
B0100	Bay - Charitas	9.46						1.00											1.00	1.00			1.00
B0200	Canal Canto do Rio	6.21						1.00											1.00	1.00			1.00
B0300	Bay - Catedrar	7.57						1.00											1.00	1.00			1.00
B0400	Bay - Norte Centro	9.26						1.00											1.00	1.00			1.00
B0500	Rio Bomba	26.78						0.87								0.13			1.00	1.00			1.00
B0600	Rio Imboaçu	29.43						0.24								0.76			1.00	1.00			1.00
B0700	Bay - Itaoca	8.54														1.00			1.00	0.70		0.30	1.00
B0800	Rio Alcantara	173.07						0.32								0.68			1.00	0.67		0.33	1.00
B0900	Rio Caceribu	811.35			0.54		0.15	0.04	0.01							0.26			1.00	0.12		0.88	1.00
B1000	Rio Guapimirim	1,262.02				0.09	0.26		0.32		0.08		0.18			0.01	0.06		1.00			1.00	1.00
B1100	Canal de Magé	17.08					0.36									0.64			1.00			1.00	1.00
B1200	Rio Roncador	115.19					0.37									0.08	0.55		1.00			1.00	1.00
B1300	Rio Iriri	19.63					0.07									0.93			1.00			1.00	1.00
B1400	Rio Suruí	84.44					0.21									0.61	0.18		1.00			1.00	1.00
B1500	Bay - Maua	17.92												0.35		0.53		0.12	1.00	1.00			1.00
B1600	Rio Saracuruna	348.89								0.67						0.07	0.06	0.20	1.00	0.17	0.06	0.77	1.00
B1700	Rio Iguaçu	716.73		0.11						0.24		0.00			0.40			0.25	1.00	0.03	0.97		1.00
B1800	Bay - Cabo do Brito	19.72												0.07				0.93	1.00	1.00			1.00
B1900	Rio Sâo Jão de Meriti	154.26		0.18								0.58		0.01				0.23	1.00	0.04	0.96		1.00
B2000	Rio Irajá	50.95										0.28		0.70				0.03	1.00	0.58	0.42		1.00
B2100	Canal do Cunha	70.23	0.70									0.08		0.22					1.00	0.83	0.17		1.00
B2200	Bay - São Cristóvão	6.41	0.32											0.68					1.00	1.00			1.00
B2300	Canal do Mangue	37.95	0.95					0.05											1.00	1.00			1.00
B2400	Bay - Botafogo	21.68	0.56					0.44											1.00	1.00			1.00
B2500	Ilha do Governador	36.28												1.00					1.00	1.00			1.00
B2600	Ilha do Fundão	5.35												1.00					1.00	1.00			1.00
B2700	Ilha de Paquetá	2.21														1.00			1.00	1.00			1.00
B2800	Ilha do Engenho	0.98						1.00											1.00	1.00			1.00
B2900	Ilha de S. Cruz	1.10						1.00											1.00	1.00			1.00
Sub-Basin																							
B0901	Rio Guará-Mirim	77.79					0.14									0.86			1.00			1.00	1.00
B0902	Rio Porto das Caixas	188.47					0.18	0.17								0.65			1.00	0.39		0.61	1.00
B0903	Rio Iguá	165.75			0.39		0.43		0.02							0.16			1.00			1.00	1.00
B0904	Rio Caceribu L/S	85.68			1.00														1.00			1.00	1.00
B0905	Rio Caceribu R/S	293.66			1.00														1.00			1.00	1.00
B1001	Rio Guapimirim D/S	49.76					0.76									0.24			1.00			1.00	1.00
B1002	Rio Guapi	12.10					1.00												1.00			1.00	1.00
B1003	Rio Macacu D/S	250.49					0.15		0.85										1.00			1.00	1.00
B1004	Rio Macacu U/S	255.61							0.42		0.44		0.14						1.00			1.00	1.00
B1005	Rio Iconha	224.02				0.22	0.64		0.01								0.13		1.00			1.00	1.00
B1006	Rio Guapiaçu	350.44				0.20	0.05		0.23				0.56						1.05			1.00	1.00
B1007	Rio Guapimirim U/S	119.60					0.63										0.37		1.00			1.00	1.00
B1601	Rio Estrela	19.52																1.00	1.00	1.00			1.00
B1602	Rio Inhomirim	139.57								0.57						0.18	0.15	0.10	1.00	0.10		0.90	1.00
B1603	Rio Saracuruna	189.80								0.81								0.19	1.00	0.17	0.13	0.70	1.00
B1701	Rio Iguaçu D/S	83.79								0.10								0.90	1.00	0.16	0.84		1.00
B1702	Rio Iguaçu M/S	37.50								0.11					0.73			0.16	1.00		1.00		1.00
B1703	Rio Capivari	103.25								0.86								0.14	1.00		0.77	0.23	1.00
B1704	Rio Tinguá	114.07								0.65					0.35				1.00		1.00		1.00
B1705	Rio Iguaçu U/S	100.20													1.00				1.00		1.00		1.00
B1706	Rio da Bota	116.05													0.93			0.07	1.00		1.00		1.00
B1707	Rio Sarapuí	161.87		0.46								0.02			0.14			0.39	1.00	0.05	0.95		1.00

Table 11 Landuse Classification and Calibrated Basic Runoff Parameters

Reclassified Grouped Landuse	Original Landuse Classification: ID	Portuguese	English	Description	Landuse Area by ID (km^2)	by ID (%)	by Group (km^2)	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 12 Landuse Areas by Drainage Basins of SERLA Stream Gauge Stations

SERLA Station			Landuse Area (km²) by ID																		
ID	Name	Area (km²)	Ia	Ib	Im	Pn	Fo	Re	Ag	Ai	Ar	Ed	Fs	P	Se	V	M	Md	Ma	Oceano	Areia
H01	Heliópolis	58.04		35.94	1.32	0.21	0.07					13.02	4.94	2.54							
H02	CIEP - 100	87.66		3.68	30.18	0.10	13.47		0.00		0.51	9.37	24.71	2.61		3.04					
H03	Clube Catavento	98.86		7.99			33.14		0.36			22.98	23.56	10.67	0.13				0.03		
H04	Estrada da Conceição	36.18					18.67		7.28		0.17	3.91	4.60	1.31		0.24					
H05	Ponte de Ferro - Capivari	88.44		1.93		0.12	49.72		0.40			9.14	16.94	10.11	0.07				0.01		
H06	Santa Cruz da Serra	94.89		10.23		0.39	58.88				0.36	5.31	17.83	1.29					0.60		
H07	Ponte de Ferro - Piabetá	92.09		6.92	0.53		63.45		12.09		0.76	3.63	4.16	0.45					0.09		
H08	São Cristóvão																				
H09	Quartel da PE	13.96	3.11	0.05			6.77				0.46	0.64	2.72	0.20							
H10	Igreja de Santo Antônio	35.56		8.00	12.01	0.13						4.16	7.29			3.96					
H11	Avenida Automóvel Clube	57.78	6.14	7.94	22.54	1.82	1.97					10.71	6.64		0.02						
H12	Estrada Velha da Pavuna	23.28	17.40				0.16					4.48	1.24								
H13	Orindi	66.53		1.07			47.15		7.10		0.31	2.19	4.95	3.31	0.06				0.39		
H14	Parque São Miguel	89.70		5.16			50.51		3.66		2.34	6.44	14.10	3.84		3.63			0.03		
H15	Barragem - CEDAE	1,089.36		11.54	1.41		522.82	0.25	176.97	8.48	3.55	35.23	154.45	152.67	0.84	15.29			5.87		
H16	Quizanga - II	350.47					202.57		60.35		2.18	17.15	35.26	28.47		3.37			1.12		
H17	Duas Barras	82.58					68.10		3.08		0.37	0.67	8.46	1.90							
H18	Japuíba - II	255.65		2.92			172.50	0.25	16.05		0.34		35.89	26.03	0.36				1.30		
H19	Cachoeiras de Macacu - II	147.32		1.45			116.00	0.15	0.73		0.30		19.69	8.07	0.33				0.59		
H20	Borda do Mato																				
H21	Reta Nova	379.92		13.22	0.24		58.69	0.11	34.29		0.39	2.20	137.90	130.09	0.54	1.83			0.41		
H22	Reta Velha	95.42		2.57			2.34		7.45		0.08		23.30	59.00					0.67		
H23	Ponte de Tanguá	237.20		6.21			46.83		18.36		0.28		105.10	58.15	0.34	1.90			0.02		
H24	Três Pontes	129.48		14.80			5.94	0.51	5.39		0.33	9.88	30.01	61.55		0.52			0.55		
H25	Columbandê	55.26		18.51			8.07				0.02	5.41	22.38	0.79	0.07						
All of SERLA Stations (except 8 and 20)		2,525.86	26.65	148.48	68.23	2.77	894.67	0.87	247.89	8.48	8.97	146.51	496.77	437.12	1.67	28.51			8.26		

Note : Landuse data was prepared by CIDE in 1998 on a scale of 1/100,000 based on SPOT satellite image of year 1996.
Landuse data by each station has been calculated using vector overlay method utilizing GIS database.

Table 13 Landuse Areas by Major River Basins and Sub-Basins

Major River Basin and Sub-Basin			Landuse Area (km^2) by ID																	
ID	Name	Area (km^2)	Ia	Ib	Im	Pn	Fo	Re	Ag	Ai	Ar	Ed	Fs	P	Se	V	M	Md	Ma	Oceano	Areia
Major River Basin																					
B0100	Bay - Charitas	9.46		3.00	1.09		2.20				0.57	0.20	2.24	0.02	0.02						0.12
B0200	Canal Canto do Rio	6.21	3.04	0.32	0.18							1.08	1.45	0.14							0.01
B0300	Bay - Catedrar	7.57	3.45	2.70								0.17	1.06	0.19							
B0400	Bay - Norte Centro	9.26	3.44	0.88	0.21		0.45					0.90	3.06	0.33							
B0500	Rio Bomba	26.78	1.69	3.87	12.82							4.22	3.47	0.45				0.17	0.03	0.06	
B0600	Rio Imboaçu	29.43		10.64	5.13		0.24			0.99		1.40	6.08	0.11			0.71	3.66	0.48		
B0700	Bay - Itaoca	8.54		0.32								0.47	4.38	0.09			2.61	0.65	0.00	0.01	
B0800	Rio Alcantara	173.07		77.04	5.22	0.06	8.07			3.75	0.02	14.89	34.04	8.97	0.07		13.33	6.69	0.93		
B0900	Rio Caceribu	811.35		82.67	0.25		68.68	0.62	96.93	12.62	0.82	13.08	202.24	291.98	0.55	3.27	27.50	3.95	6.19		
B1000	Rio Guapimirim	1,262.02		32.68	1.41		562.68	0.30	200.21	15.04	6.56	46.15	182.30	174.44	1.05	23.67	2.62	5.94	6.96		
B1100	Canal de Magé	17.08		4.70	1.15				0.09			2.11	2.27	3.68			2.06	0.79	0.19	0.03	
B1200	Rio Roncador	115.19		7.82	0.10		52.79		3.66		2.34	10.10	17.52	12.08		4.54	1.89	2.02	0.32		
B1300	Rio Iriri	19.63		1.92			1.71				0.13	3.34	3.36	2.78		3.16	1.39	1.60	0.23		
B1400	Rio Suruí	84.44		7.59			29.47		10.41	0.19	0.33	11.76	16.20	3.19	0.02	1.47	0.47	3.01	0.33		
B1500	Bay - Maua	17.92		7.19			1.09				0.13	1.01	6.18	0.89		0.34	0.44	0.62	0.03		
B1600	Rio Saracuruna	348.89		72.84	3.73	0.39	144.43		13.01	3.84	1.69	25.41	39.18	29.65		4.40	4.25	4.21	1.84		
B1700	Rio Iguaçu	716.73		125.07	83.09	6.14	161.62		0.90	0.22	0.51	102.09	132.19	83.25	0.20	16.88	0.12	1.52	2.91		
B1800	Bay - Cabo do Brito	19.72		0.72	6.18	1.07				0.47		0.25	0.62			0.00	1.57	8.40	0.42	0.02	
B1900	Rio Sâo Jão de Meriti	154.26	22.23	29.38	58.73	2.40	1.97			0.12		17.49	15.32	0.07	0.02	3.96	0.22	1.07	1.27		
B2000	Rio Irajá	50.95	33.17	1.04	5.69	2.97				0.15		3.62	4.05				0.12	0.03	0.12		
B2100	Canal do Cunha	70.23	47.65	0.05	2.79	1.11	3.59				0.13	11.51	3.16						0.24		
B2200	Bay - São Cristóvão	6.41	6.15			0.00							0.26								
B2300	Canal do Mangue	37.95	20.31	0.37	0.57	1.44	7.27				0.51	2.38	4.90	0.20							
B2400	Bay - Botafogo	21.68	11.83		0.37	2.29	1.27				0.40	0.93	4.33								0.25
B2500	Ilha do Governador	36.28		5.93	14.76	8.70	2.95			0.21			0.61	2.52	0.53	0.05		0.02			
B2600	Ilha do Fundão	5.35		4.71	0.02			0.09					0.14	0.34			0.04				
B2700	Ilha de Paquetá	2.21		0.03	0.75		0.44				0.06		0.50				0.40		0.03		
B2800	Ilha do Engenho	0.98			0.03		0.05					0.38	0.42	0.10							
B2900	Ilha de S. Cruz	1.10		0.71									0.39								
Sub-Basin																					
B0901	Rio Guará-Mirim	77.79		12.95					7.33	11.16		0.31	2.77	9.09			27.50	3.95	2.73		
B0902	Rio Porto das Caixas	188.47		40.86			6.15	0.52	12.65		0.34	10.60	32.41	82.15		1.34			1.47		
B0903	Rio Iguá	165.75		15.61			2.49		42.03	1.46	0.08		28.62	73.81		0.05			1.60		
B0904	Rio Caceribu L/S	85.68		2.66			2.54	0.04	2.58		0.11	0.60	25.24	51.60					0.31		
B0905	Rio Caceribu R/S	293.66		10.59	0.25		57.50	0.07	32.35		0.29	1.57	113.19	75.35	0.55	1.88			0.08		
B1001	Rio Guapimirim D/S	49.76		4.37			2.32		17.67	3.46		0.27	6.39	4.53		1.41	2.62	5.94	0.77		
B1002	Rio Guapi	12.10							9.35	2.30		0.14	0.01						0.30		
B1003	Rio Macacu D/S	250.49		7.56	1.41		69.75		48.36		0.70	3.56	46.64	67.27	0.42	3.27			1.55		
B1004	Rio Macacu U/S	255.61		2.90			172.51	0.25	16.04		0.34		35.88	26.03	0.36				1.29		
B1005	Rio Iconha	224.02		1.07			78.03		46.05	6.20	0.33	14.38	36.65	30.87	0.06	8.65			1.72		
B1006	Rio Guapiaçu	350.44					202.57		60.32		2.18	17.15	35.26	28.47		3.37			1.11		
B1007	Rio Guapimirim U/S	119.60		16.78			37.49	0.05	2.42	3.07	3.01	10.65	21.47	17.26	0.21	6.97			0.22		
B1601	Rio Estrela	19.52		3.15						1.80		2.23	1.64	0.27		2.47	4.15	3.13	0.66		
B1602	Rio Inhomirim	139.57		17.96	1.38		67.34		12.09		0.93	12.32	10.06	16.62		0.14	0.10	0.17	0.46		
B1603	Rio Saracuruna	189.80		51.73	2.35	0.39	77.09		0.92	2.04	0.76	10.86	27.48	12.76		1.79		0.91	0.72		
B1701	Rio Iguaçu D/S	83.79		34.16	3.04	5.42	0.68		0.14			5.63	6.63	18.26		7.82	0.05	0.79	1.16		
B1702	Rio Iguaçu M/S	37.50		1.29			0.83					8.54	11.96	14.56					0.32		
B1703	Rio Capivari	103.25		2.23		0.12	49.72		0.40			13.60	20.59	16.32	0.07				0.19		
B1704	Rio Tinguá	114.07		5.32			63.71					12.22	20.02	12.77					0.03		
B1705	Rio Iguaçu U/S	100.20		8.16			33.14		0.36			23.37	23.88	11.10	0.13				0.07		
B1706	Rio da Bota	116.05		55.41	10.33	0.21	0.07					23.96	18.49	7.27					0.31		
B1707	Rio Sarapuí	161.87		18.50	69.72	0.39	13.47			0.22	0.51	14.77	30.62	2.97		9.06	0.07	0.73	0.83		
Total of River Basins		4,071	152.9	484.2	204.3	26.6	1,050.9	1.0	325.2	37.6	14.2	275.0	691.9	615.5	2.5	61.8	59.7	44.4	22.5	0.1	0.4
Total of Islands		46		11.4	15.6	8.7	3.4	0.1		0.2	0.1	0.4	2.1	3.0	0.5	0.1	0.4	0.0	0.0		
Total of Study Area without Bay Area		4,117	152.9	495.6	219.8	35.3	1,054.4	1.1	325.2	37.8	14.3	275.3	694.0	618.5	3.0	61.8	60.2	44.4	22.6	0.1	0.4
Percent of Landuse (%)		100%	3.7%	12.0%	5.3%	0.9%	25.6%	0.0%	7.9%	0.9%	0.3%	6.7%	16.9%	15.0%	0.1%	1.5%	1.5%	1.1%	0.5%	0.0%	0.0%

Note : Landuse data was prepared by CIDE in 1998 on a scale of 1/100,000 based on SPOT satellite image of year 1996.
Landuse data by each sub-catchment has been calculated using vector overlay method utilizing GIS database.

Table 14 Calibrated Runoff Model Parameters of the SERLA Stream Gauge Stations

SERLA Station			Calibrated Basin Parameters for Runoff (NAM) Model									
ID	Name	Catchment Area A (km^2)	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)	Overland Flow Length L_{OF} (km)	Time Constant for Routing Interflow CK_{IF} (hr)	Time Constant for Routing Overland Flow $CK_{1,2}$ (hr)	Root Zone Threshold Value for Overland Flow T_{OF}	Base Flow: Zone No.	Base Flow: Discharge Q_{BF} (m^3/s)	Base Flow: Time Constant for Routing Base Flow CK_{BF} (hr)
H01	Heliópolis	58.04	0.53	33	10	11.9	331	13	0.53	VI	0.51	331
H02	CIEP - 100	87.66	0.49	71	14	18.6	287	11	0.49	VI	0.77	287
H03	Clube Catavento	98.86	0.37	98	14	12.5	231	5	0.37	V	0.35	231
H04	Estrada da Conceição	36.18	0.37	105	14	7.8	90	5	0.37	IV	0.29	90
H05	Ponte de Ferro - Capivari	88.44	0.33	124	15	17.7	205	5	0.33	V	0.19	205
H06	Santa Cruz da Serra	94.89	0.38	121	15	19.8	196	5	0.38	IV	0.66	196
H07	Ponte de Ferro - Piabetá	92.09	0.39	115	14	11.4	113	5	0.39	IV	0.64	113
H09	Quartel da PE	13.96	0.47	101	14	5.3	43	5	0.47	VI	0.52	43
H10	Igreja de Santo Antônio	35.56	0.54	45	12	17.0	787	31	0.54	VI	0.31	787
H11	Avenida Automóvel Clube	57.78	0.63	32	10	13.4	372	15	0.63	VI	0.51	372
H13	Orindi	66.53	0.36	125	15	14.5	336	13	0.36	III	0.97	336
H14	Parque São Miguel	89.70	0.37	116	15	14.2	141	5	0.37	IV	0.62	141
H15	Barragem - CEDAE	1,089.36	0.34	112	15	52.0	481	19	0.34	III	11.51	481
H16	Quizanga - II	350.47	0.35	115	14	26.9	340	14	0.35	III	3.90	340
H17	Duas Barras	82.58	0.35	140	15	9.7	112	5	0.35	III	1.14	112
H18	Japuíba - II	255.65	0.33	132	16	25.7	210	5	0.33	III	2.92	210
H19	Cachoeiras de Macacu - II	147.32	0.34	141	16	15.6	144	5	0.34	III	1.81	144
H21	Reta Nova	379.92	0.26	111	18	24.8	203	1216	0.52	II	0.38	25
H22	Reta Velha	95.42	0.27	110	19	19.4	359	2156	0.54	II	0.03	45
H23	Ponte de Tanguá	237.20	0.20	115	18	16.4	380	2278	0.40	II	0.26	47
H24	Três Pontes	129.48	0.28	97	17	21.3	329	1972	0.56	II	0.11	41
H25	Columbandê	55.26	0.42	81	14	10.4	241	5	0.42	I	0.28	241

Note : By trial and error method, the runoff parameters have been calibrated and the following rules have been established for estimating the runoff parameters :

(1) Overland Flow Runoff Coefficient (CQ_{OF}), Upper Limit of Root Zone Storage (L_{max}) and Upper Limit of Surface Zone Storage (U_{max}) are functions of Landuse Type as shown in Landuse Classification Table.

(2) Time Constant for Routing Interflow (CK_{IF}) = 0.5 x Overland Flow Length (L_{OF}) / Average Slope of Basin (S_{AVG}), for all stations

(3) Time Constant for Routing Overland Flow ($CK_{1,2}$) = Time Constant for Routing Interflow (CK_{IF}) / 25, for all stations
except for stations H21 to H24 for which : $CK_{1,2}$ = 6 x CK_{IF}

(4) Root Zone Threshold Value for Interflow (T_{IF}) = 0.0, for all stations

(5) Root Zone Threshold Value for Overland Flow (T_{OF}) = Overland Flow Runoff Coefficient (CQ_{OF}), for all stations
except for stations H21 to H24 for which : T_{OF} = 2 x CQ_{OF}

(6) Time Constant for Routing Base Flow (CK_{BF}) = Time Constant for Routing Interflow (CK_{IF}), for all stations
except for stations H21 to H24 for which : CK_{BF} = CK_{IF} / 8

Table 15 Runoff Model Parameters of Major River Basins and Sub-Basins

Major River Basins

Sub-Basin			Basin Parameters for Runoff (NAM) Model									
ID	Name	Area (km2)	Overland Flow Runoff Coefficient CQ_{OF}	Upper Limit of Root Zone Storage L_{max} (mm)	Upper Limit of Surface Zone Storage U_{max} (mm)	Overland Flow Length L_{OF} (km)	Time Constant for Routing Interflow CK_{IF} (hr)	Time Constant for Routing Overland Flow $CK_{1,2}$ (hr)	Root Zone Threshold Value for Overland Flow T_{OF}	Base Flow Zone No.	Base Flow Discharge Q_b (m3/s)	Base Flow Routing Time CK_{BF} (m3/s)
B0100	Bay - Charitas	9.46	0.49	73	13	3.1	36	5	0.49		0.05	36
B0200	Canal Canto do Rio	6.21	0.63	40	12	3.3	61	5	0.63		0.03	61
B0300	Bay - Catedrar	7.57	0.66	32	12	3.5	81	5	0.66		0.04	81
B0400	Bay - Norte Centro	9.26	0.56	59	13	5.7	88	5	0.56	I	0.05	88
B0500	Rio Bomba	26.78	0.62	32	11	4.2	97	5	0.62		0.13	97
B0600	Rio Imboaçu	29.43	0.51	50	12	6.7	207	5	0.51		0.15	207
B0700	Bay - Itaoca	8.54	0.32	95	15	2.2	68	5	0.32		0.04	68
B0800	Rio Alcantara	173.07	0.46	58	12	22.7	701	14	0.46		0.87	701
B0900	Rio Cacerebu	811.35	0.29	95	16	49.1	1,137	6819	0.59	II	0.57	142
B1000	Rio Guapimirim	1,262.02	0.34	108	15	63.1	730	15	0.34	III	13.3	730
B1100	Canal de Magé	17.08	0.40	64	13	7.0	324	6	0.40		0.17	324
B1200	Rio Roncador	115.19	0.36	110	15	23.4	271	5	0.36		0.78	271
B1300	Rio Iriri	19.63	0.35	81	13	6.5	201	5	0.35	IV	0.18	201
B1400	Rio Suruí	84.44	0.39	92	13	17.1	264	5	0.39		0.59	264
B1500	Bay - Maua	17.92	0.43	72	14	3.0	69	5	0.43		0.17	69
B1600	Rio Saracuruna	348.89	0.40	96	14	29.0	448	9	0.40	III	2.3	448
B1700	Rio Iguaçu	716.73	0.43	80	13	33.7	624	12	0.43	V	9.4	624
B1800	Bay - Cabo do Brito	19.72	0.50	50	10	2.2	204	5	0.50		0.01	204
B1900	Rio Sâo Jão de Meriti	154.26	0.65	30	10	23.8	1,102	22	0.65		0.05	1,102
B2000	Rio Irajá	50.95	0.76	20	10	17.1	528	11	0.76		0.02	528
B2100	Canal do Cunha	70.23	0.74	24	10	10.6	245	5	0.74	VI	0.02	245
B2200	Bay - São Cristóvão	6.41	0.83	14	10	4.3	398	8	0.83		0.01	398
B2300	Canal do Mangue	37.95	0.65	52	12	9.5	147	5	0.65		0.01	147
B2400	Bay - Botafogo	21.68	0.68	39	11	4.9	76	5	0.68		0.01	76
B2500	Ilha do Governador	36.28	0.66	32	10	1.5	69	5	0.66		0.01	69
B2600	Ilha do Fundão	5.35	0.55	31	11	0.5	46	5	0.55		0.01	46
B2700	Ilha de Paquetá	2.21	0.49	77	13	0.3	8	5	0.49	VI	0.01	8
B2800	Ilha do Engenho	0.98	0.37	79	14	0.3	5	5	0.37		0.01	5
B2900	Ilha de S. Cruz	1.10	0.49	56	14	0.3	8	5	0.49		0.01	8
Total of River Basins		4,025	0.40	88	14							
Total of Islands		46	0.63	36	10							
Total of Study Area		4,071	0.40	88	14							

Sub-Basins

Sub-Basin			Basin Parameters for Runoff (NAM) Model									
ID	Name	Catchment Area A (km^2)	Overland Flow Runoff Coefficient CQ_{OF}	Upper Limit of Root Zone Storage L_{max} (mm)	Upper Limit of Surface Zone Storage U_{max} (mm)	Overland Flow Length L_{OF} (km)	Time Constant for Routing Interflow CK_{IF} (hr)	Time Constant for Routing Overland Flow $CK_{1,2}$ (hr)	Root Zone Threshold Value for Overland Flow T_{OF}	Base Flow Zone No.	Base Flow Discharge Q_b (m^3/s)	Base Flow Routing Time CK_{BF} (hr)
B0901	Rio Guará-Mirim	77.79	0.39	59	11	10.0	926	5,556	0.79		0.01	116
B0902	Rio Porto das Caixas	188.47	0.31	86	16	31.7	978	5,870	0.61		0.20	122
B0903	Rio Iguá	165.75	0.29	85	16	31.5	972	5,833	0.57	II	0.17	122
B0904	Rio Caceribu L/S	85.68	0.20	114	19	18.4	426	2,556	0.40		0.01	53
B0905	Rio Caceribu R/S	293.66	0.29	111	17	24.6	380	2,278	0.58		0.31	47
B1001	Rio Guapimirim D/S	49.76	0.39	62	12	9.0	833	17	0.39		0.80	833
B1002	Rio Guapi	12.10	0.47	23	10	4.7	435	9	0.47		0.41	435
B1003	Rio Macacu D/S	250.49	0.31	103	16	29.7	550	11	0.31		2.87	550
B1004	Rio Macacu U/S	255.61	0.33	132	16	25.4	235	5	0.33	III	2.92	235
B1005	Rio Iconha	224.02	0.35	99	15	19.5	361	7	0.35		2.60	361
B1006	Rio Guapiaçu	350.44	0.35	115	14	26.4	306	6	0.35		3.90	306
B1007	Rio Guapimirim U/S	119.60	0.37	96	15	34.2	528	11	0.37		1.52	528
B1601	Rio Estrela	19.52	0.41	59	11	6.4	593	12	0.41		0.18	593
B1602	Rio Inhomirim	139.57	0.38	102	14	19.9	263	5	0.38	IV	0.94	263
B1603	Rio Saracuruna	189.80	0.41	95	14	24.5	378	8	0.41		1.25	378
B1701	Rio Iguaçu D/S	83.79	0.45	55	13	16.2	1,500	30	0.45		0.12	1,500
B1702	Rio Iguaçu M/S	37.50	0.29	93	16	10.1	312	6	0.29		0.04	312
B1703	Rio Capivari	103.25	0.33	118	15	22.2	294	6	0.33	V	0.41	294
B1704	Rio Tinguá	114.07	0.34	121	15	14.7	170	5	0.34		0.57	170
B1705	Rio Iguaçu U/S	100.20	0.37	98	14	13.2	244	5	0.37		0.37	244
B1706	Rio da Bota	116.05	0.51	42	11	19.5	602	12	0.51	VI	0.03	602
B1707	Rio Sarapuí	161.87	0.55	53	12	33.7	780	16	0.55		0.05	780

Table 16 Wastewater Flow Estimation for Runoff Model

Rio de Janeiro Area

Sub-Basin ID	Runoff Deficit based on Observed Data		Wastewater based on Population	
	Urban Area (km^2)	Estimated Runoff Deficit or Wastewater[1)] (m^3/s)	Population of Year 2000	Wastewater using 300 lpcd[2)] (m^3/s)
B1706	65.74	3.10	694,812	2.41
B1707	88.23	4.16	1,172,773	4.07
B1900	110.35	5.21	1,397,082	4.85
B2000	39.89	1.88	682,128	2.37
B2100	50.49	2.38	899,762	3.12
B2200	6.15	0.29	30,459	0.11
B2300	21.25	1.00	440,731	1.53
Total	382.10	18.03	5,317,747	18.46

[1)] : *Runoff Deficit, D (m^3/s) = 0.0472 x Urban Area, A (km^2)*

[2)] : *Wastewater generation of 300 lpcd is the local practice*

Niteroi Area

Sub-Basin ID	Wastewater based on Population			
	Population of Year 2000		Wastewater using 300 lpcd (m^3/s)	
	Sub-Basin	Grouped Basin	Sub-Basin	Grouped Basin
B0100	30,559	283,779	0.11	0.99
B0200	90,467		0.31	
B0300	91,390		0.32	
B0400	71,363		0.25	
B0500	241,536	401,212	0.84	1.39
B0600	157,098		0.55	
B0700	2,578		0.01	
B0800	593,440	593,440	2.06	2.06
Total	1,278,431	1,278,431	4.44	4.44

Table 17 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

Table 18 Effect of Increase in Urbanization on Monthly Runoff

Month	Monthly Average Runoff (m^3/s) by River Basin due to Increase in Urban Area Compared to Urban Area of Year 1996							
	Year 1996 Landuse		Urban Area Increased by 10%		Urban Area Increased by 20%		Urban Area Increased by 30%	
	B0800 Urban Y1996	B0900 Urban Y1996	B0800 10%+ Urban	B0900 10%+ Urban	B0800 20%+ Urban	B0900 20%+ Urban	B0800 30%+ Urban	B0900 30%+ Urban
Jan.	2.22	1.71	2.22	1.71	2.34	1.73	2.55	1.75
Feb.	5.40	6.13	5.41	6.13	5.76	6.20	6.26	6.27
Mar.	4.69	11.54	4.68	11.57	4.74	11.64	4.88	11.77
Apr.	3.81	23.24	3.81	23.20	3.83	23.24	3.88	23.34
May	1.95	0.88	1.95	0.88	1.93	0.88	1.93	0.88
June	1.25	0.77	1.25	0.77	1.24	0.77	1.24	0.77
July	1.21	1.85	1.21	1.85	1.22	1.84	1.27	1.83
Aug.	1.62	3.24	1.61	3.24	1.67	3.24	1.81	3.24
Sep.	2.06	12.00	2.07	12.03	2.12	12.08	2.22	12.19
Oct.	1.30	1.61	1.30	1.61	1.31	1.61	1.35	1.61
Nov.	1.65	7.05	1.64	7.06	1.71	7.07	1.87	7.10
Dec.	2.54	14.30	2.54	14.34	2.62	14.37	2.77	14.51
Annual (m^3/s)	2.48	7.03	2.48	7.03	2.54	7.06	2.67	7.10
Annual (%)	0.00%	0.00%	0.00%	0.06%	2.69%	0.42%	7.84%	1.09%

Note : For Caceribu river basin (B0900), increase in urban area is for Rio Porto das Caixas (B0902) sub-basin only.

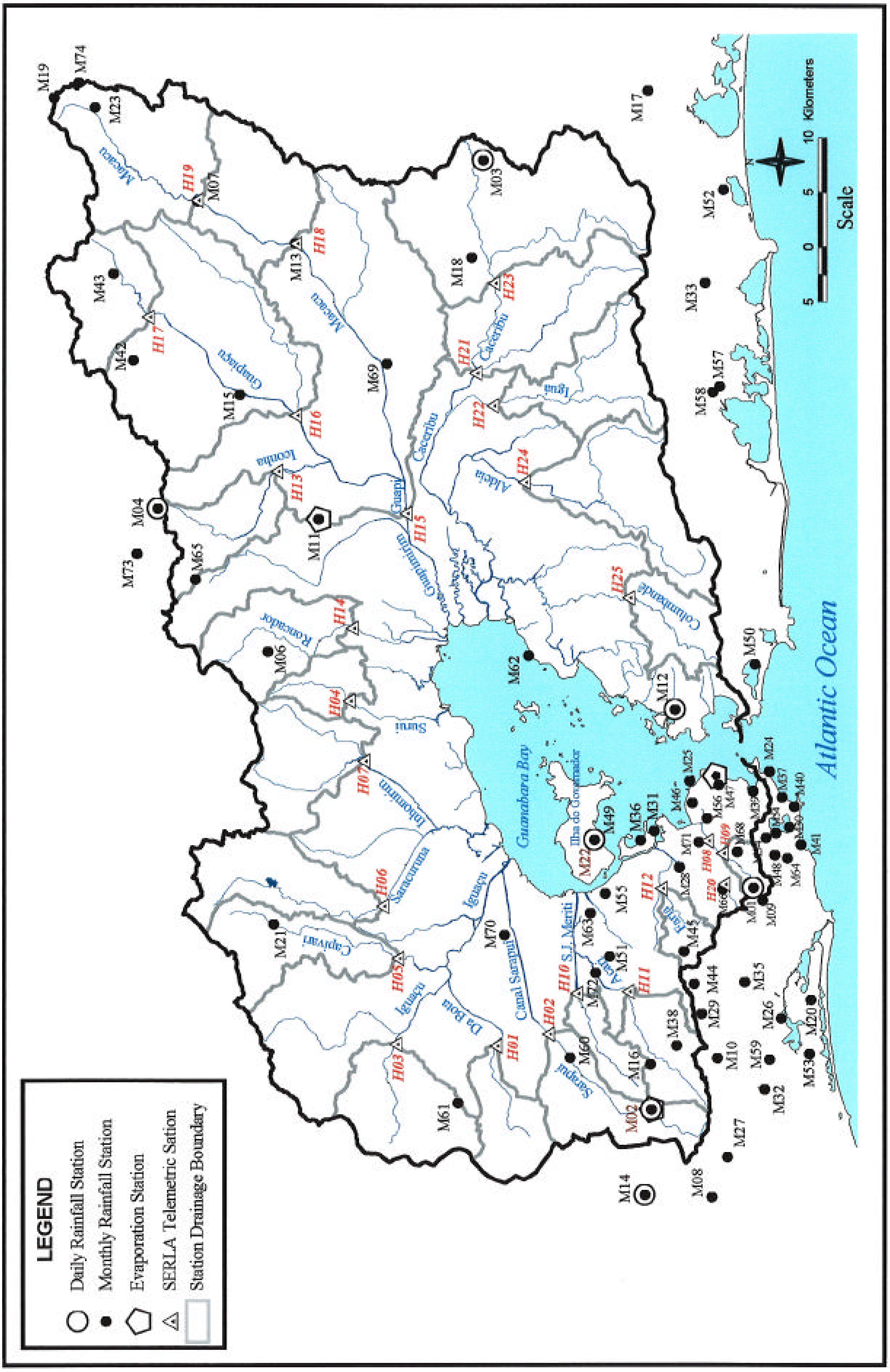
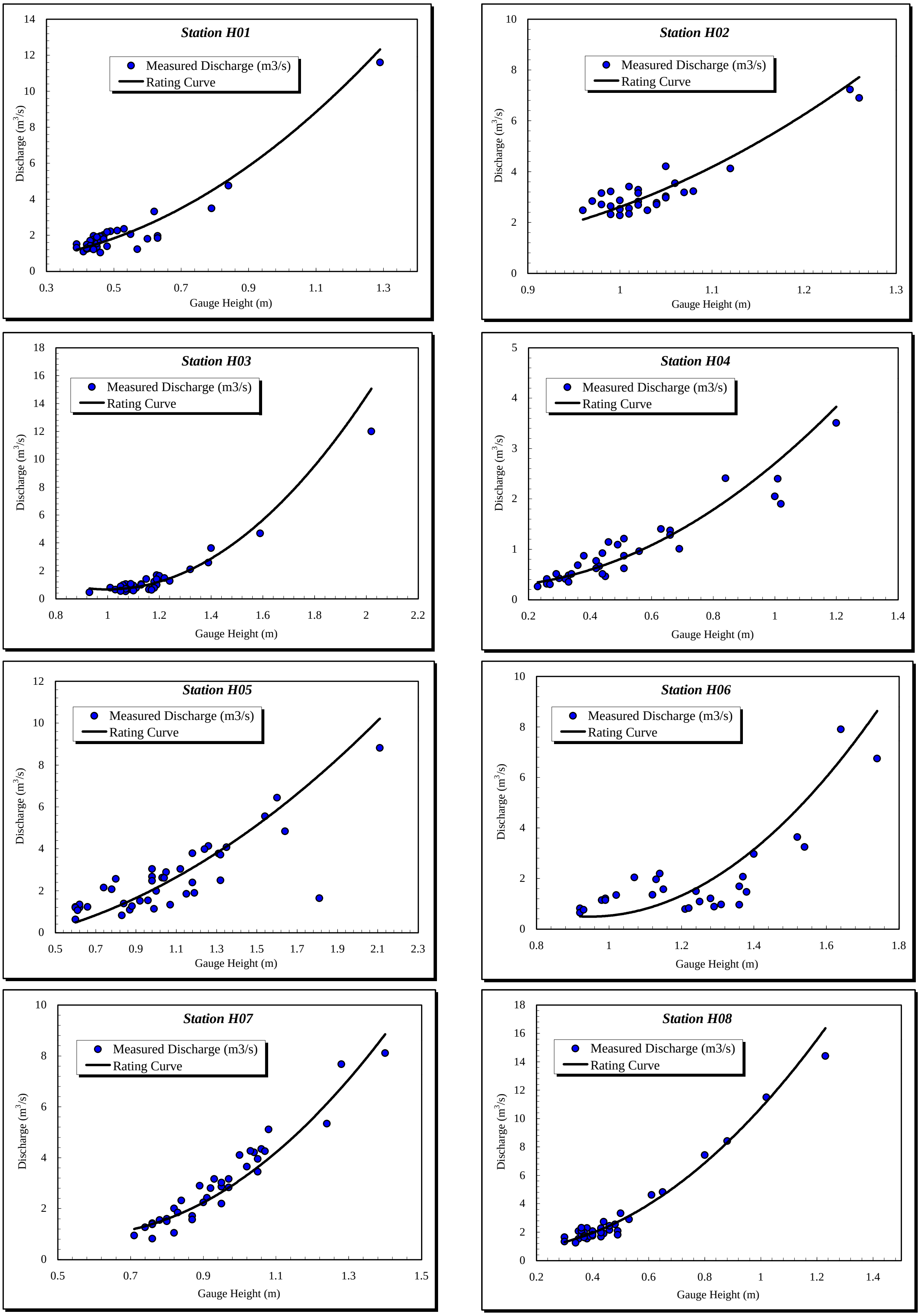
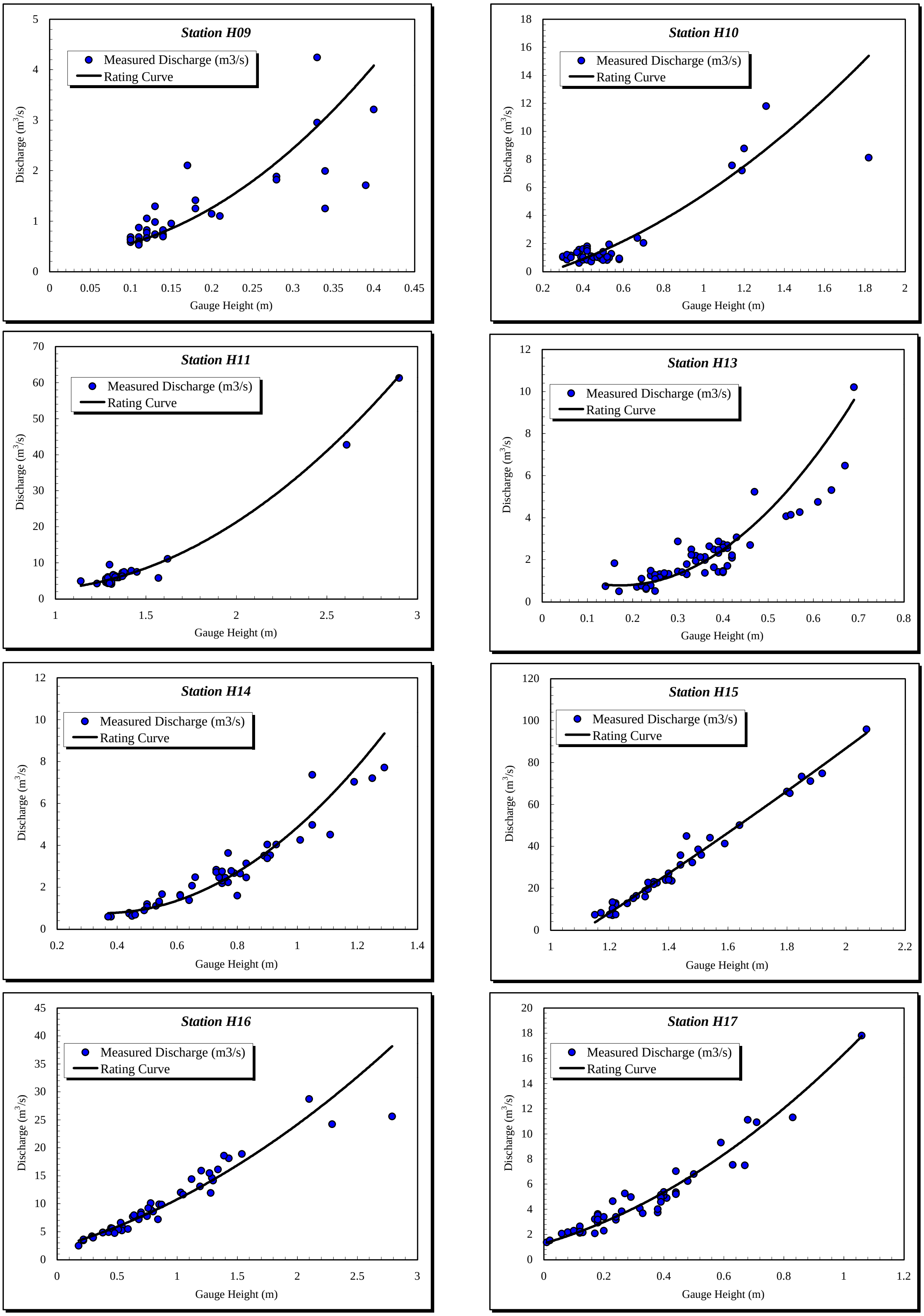


Figure 1 Monitoring Network on Meteo-Hydrology



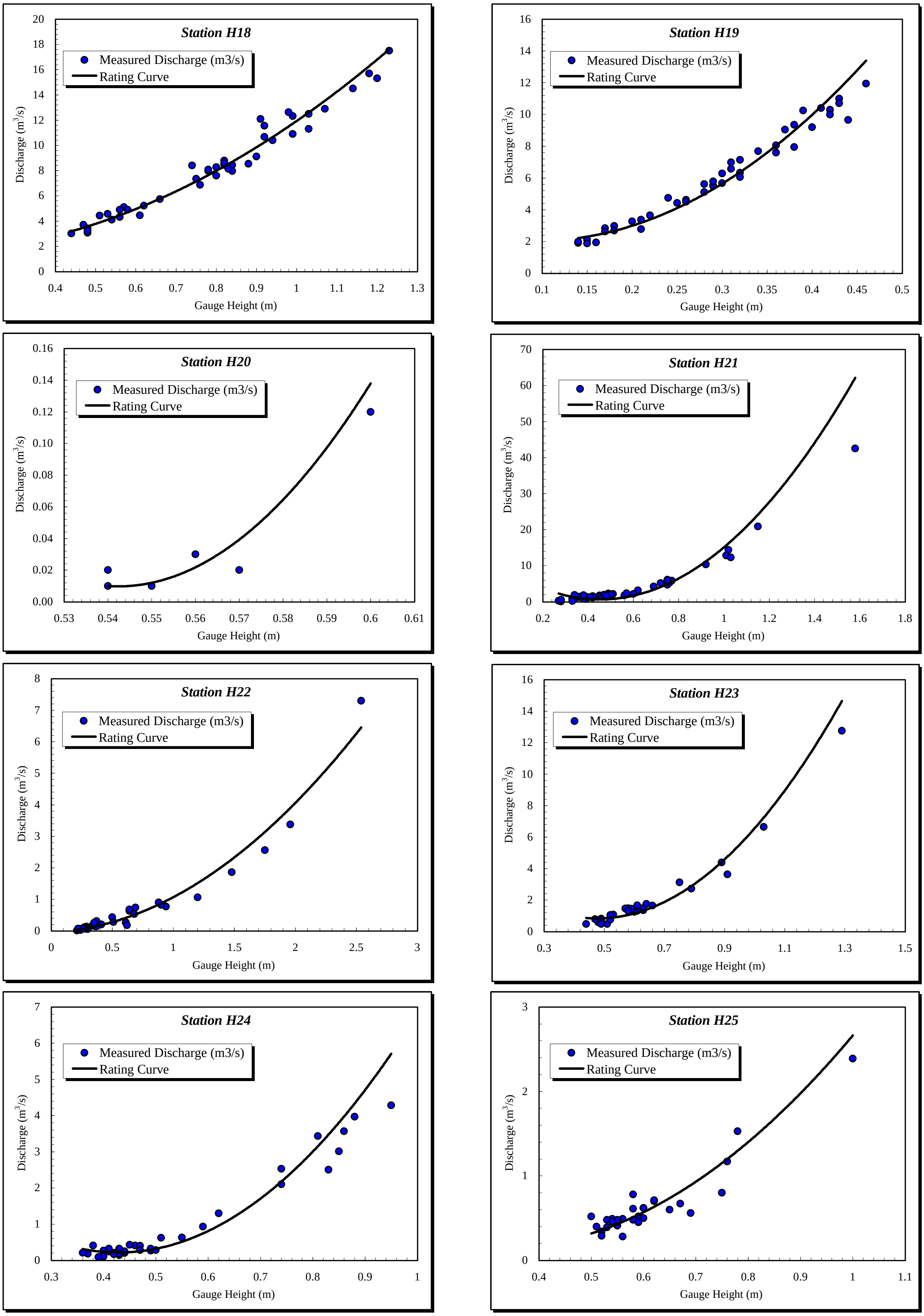
Data Source: SERLA
Rating Curves: Constructed by Present Study

Figure 2 (1/3) Rating Curves of SERLA Stream Gauge Stations



Data Source: SERLA
Rating Curves: Present Study

Figure 2 (2/3)   Rating Curves of SERLA Stream Gauge Stations



Data Source: SERLA
Rating Curves: Present Study

Figure 2 (3/3) Rating Curves of SERLA Stream Gauge Stations

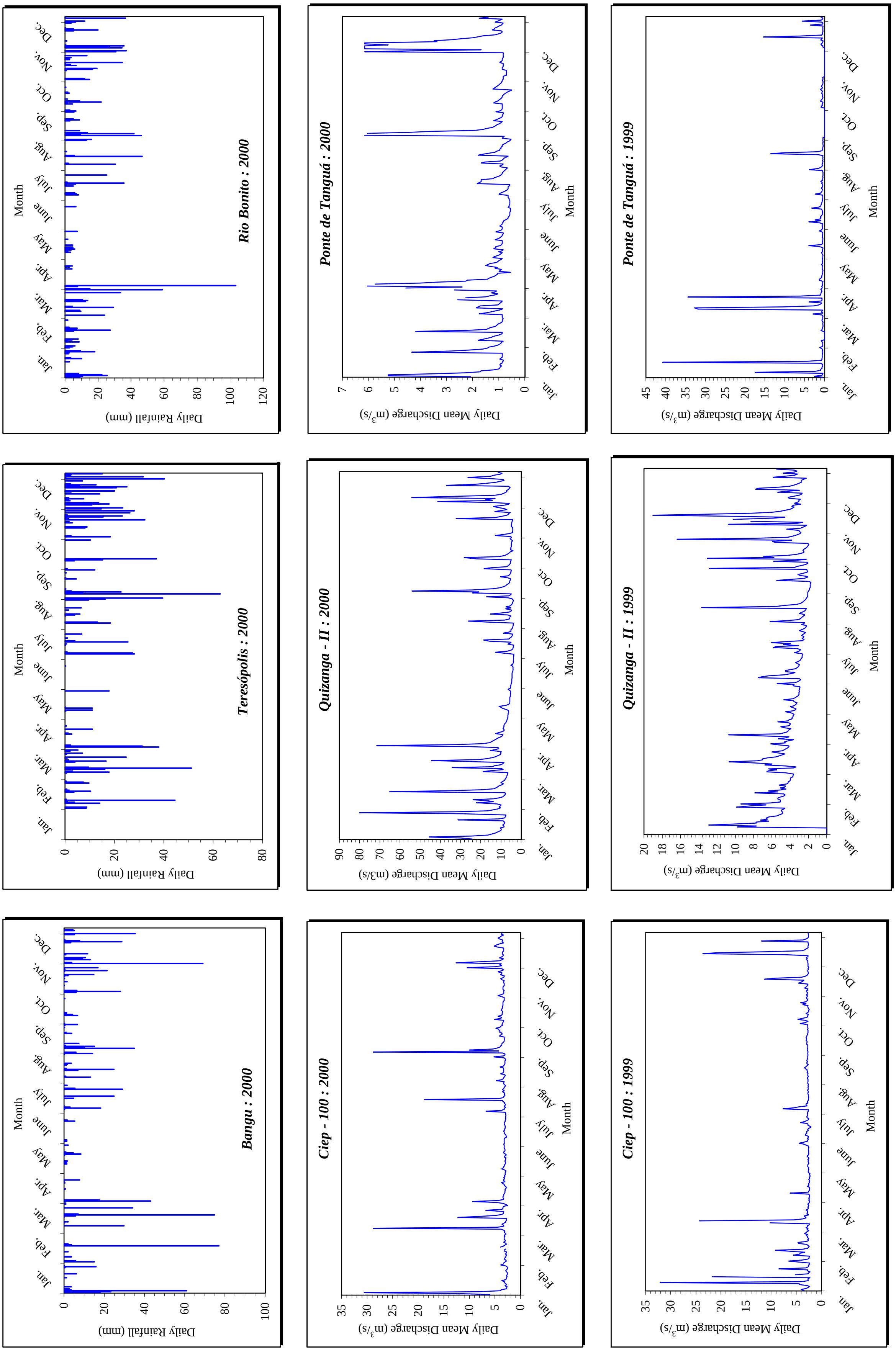


Figure 3 Daily Rainfalls and Discharges for Years 1999 and 2000

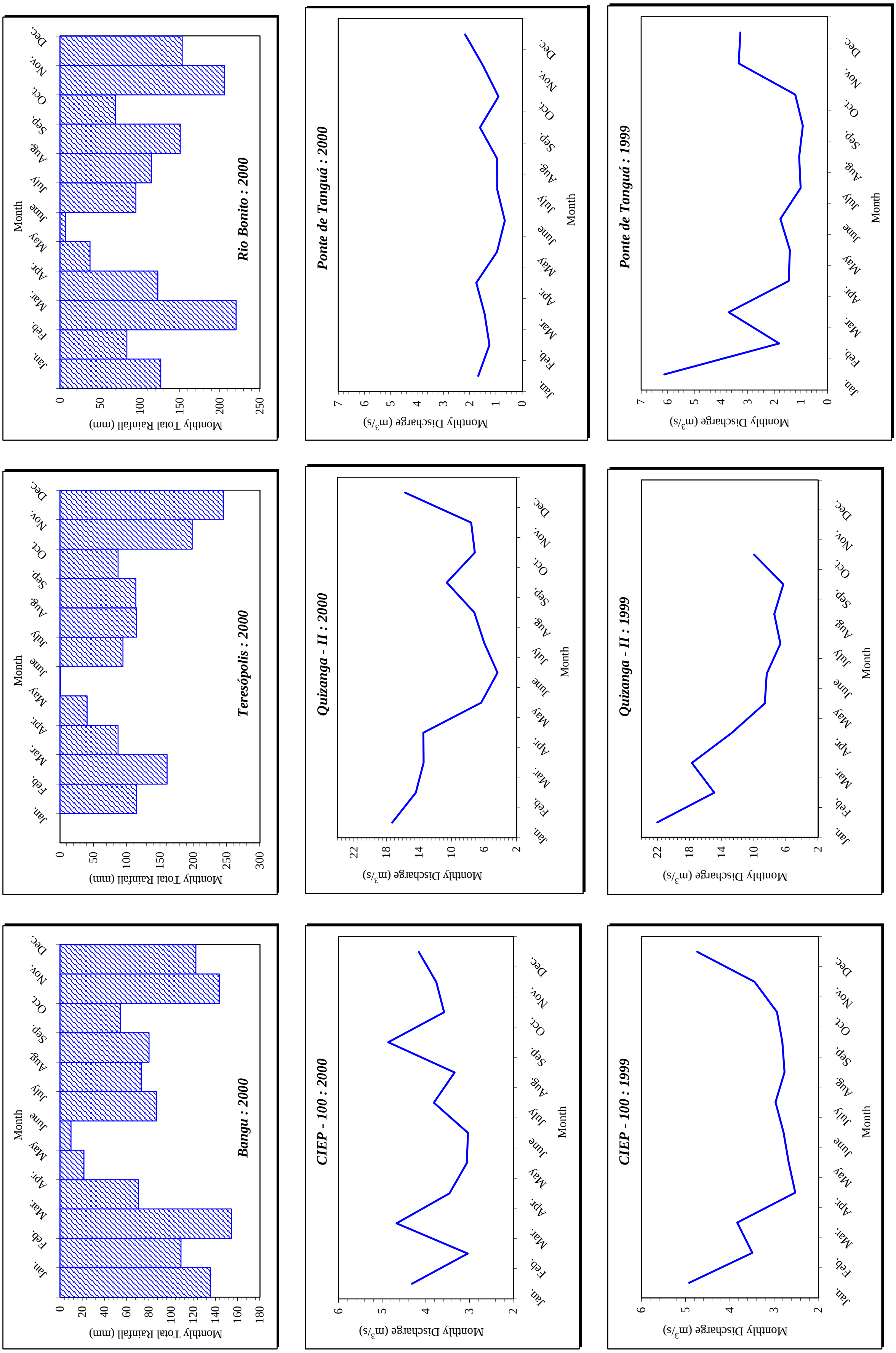
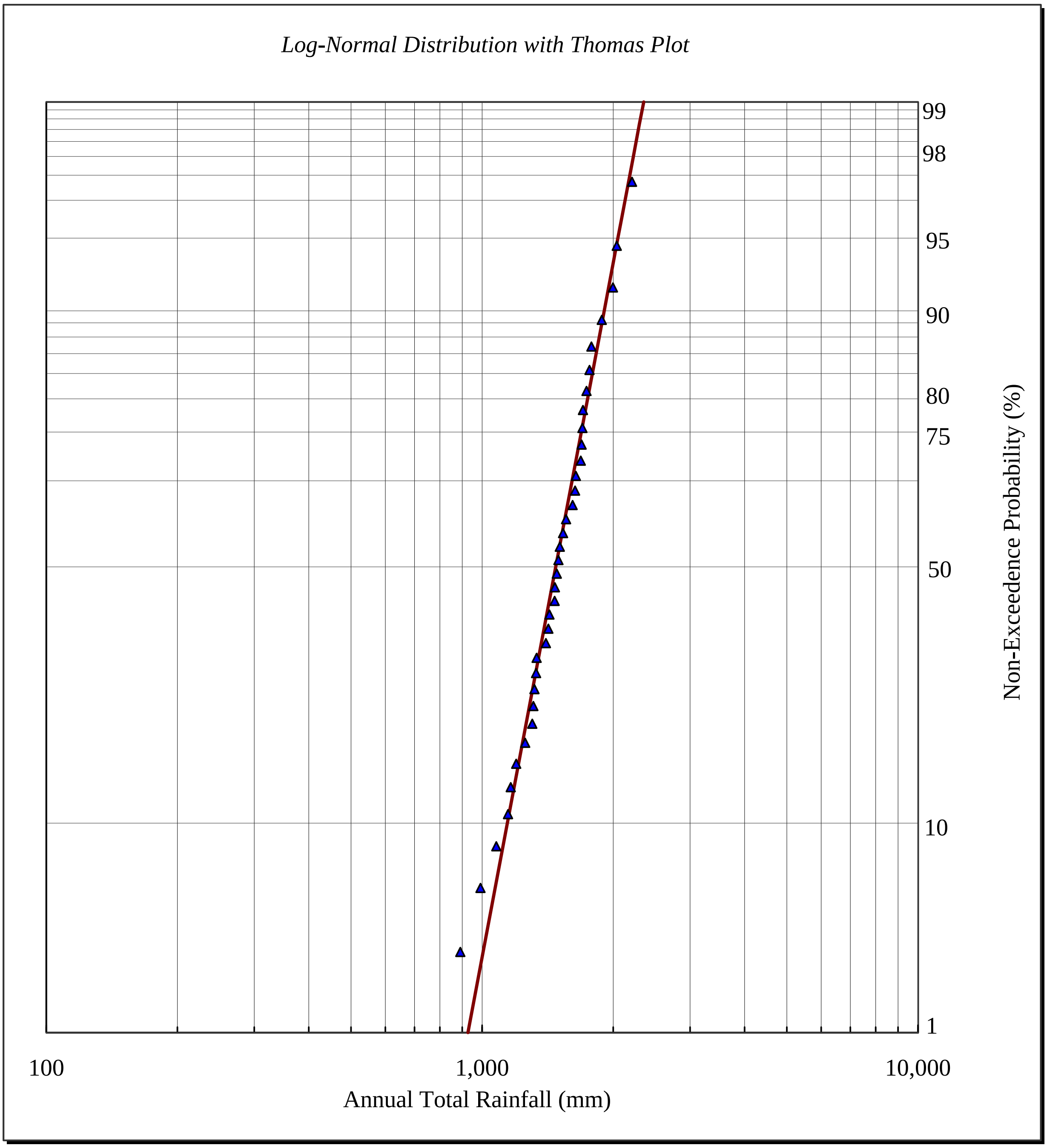


Figure 4 Monthly Rainfalls and Discharges for Years 1999 and 2000



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

Source : Annual total basin rainfall data for 36 years (1965 - 2000) generated using different stations' meteorological data and GIS database.

Figure 5 Probable Annual Total Rainfall of the Guanabara Bay Basin

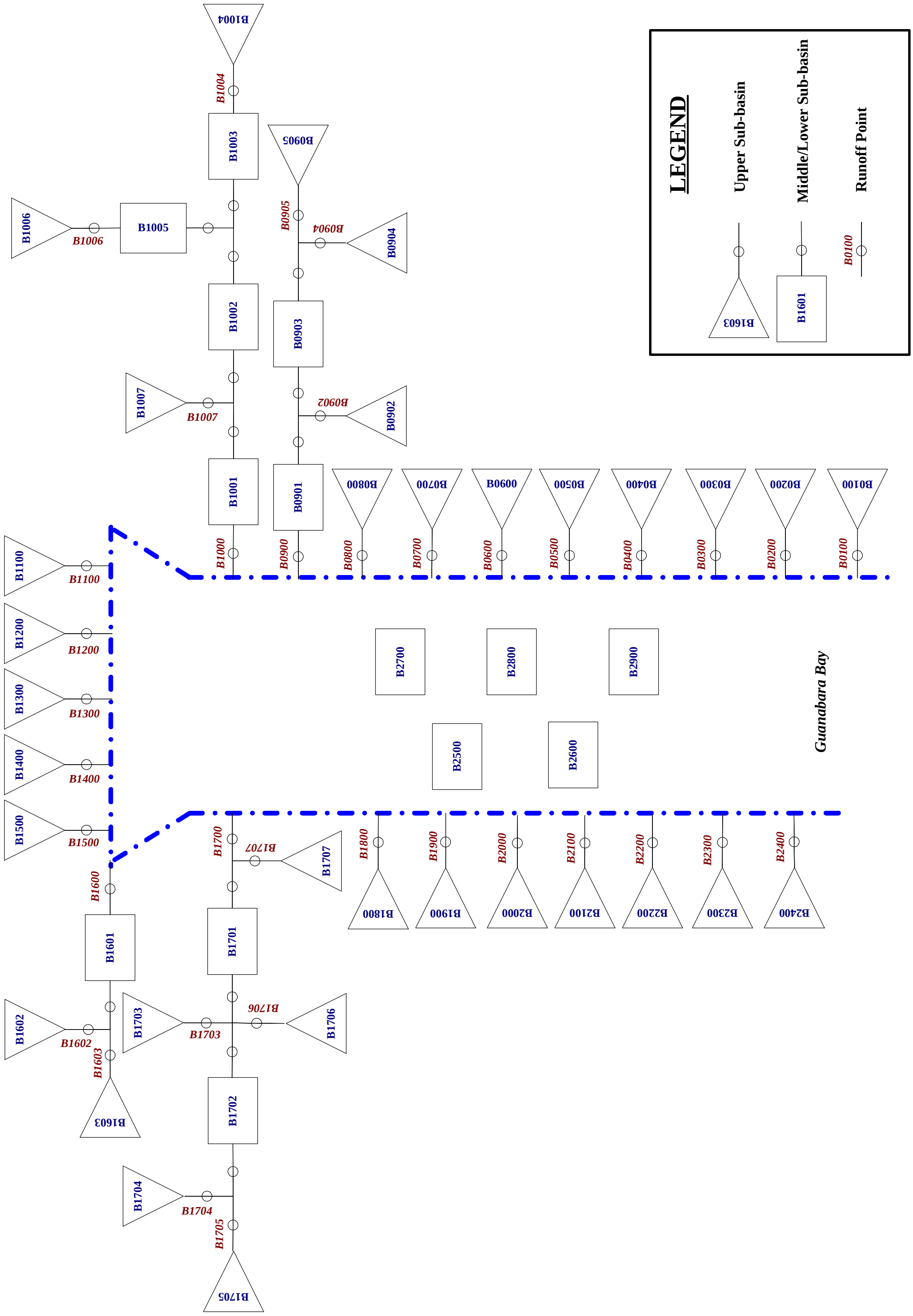


Figure 6 Network Diagram of Runoff Model

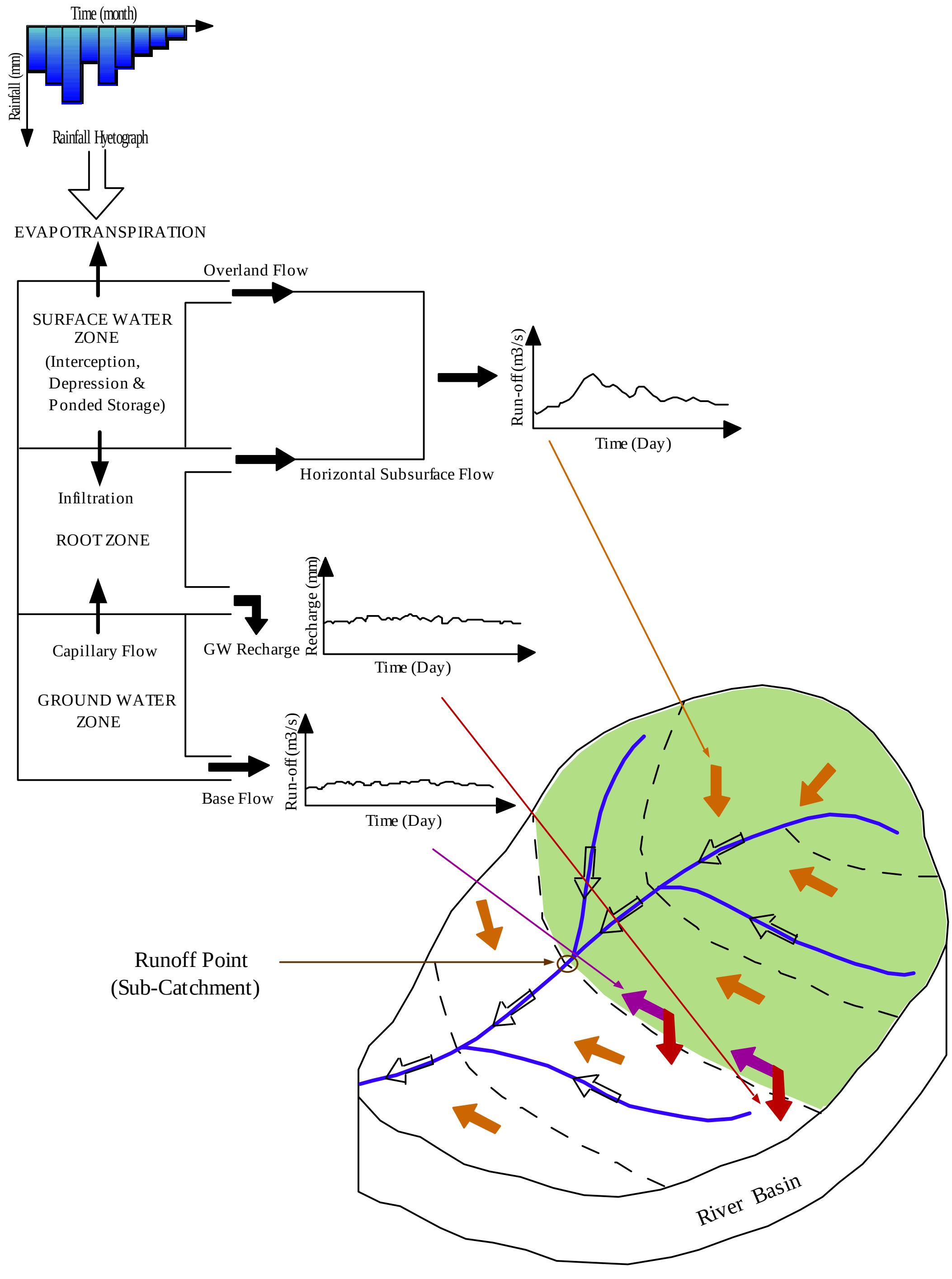


Figure 7 Schematic Diagram of Rainfall-Runoff (NAM) Model

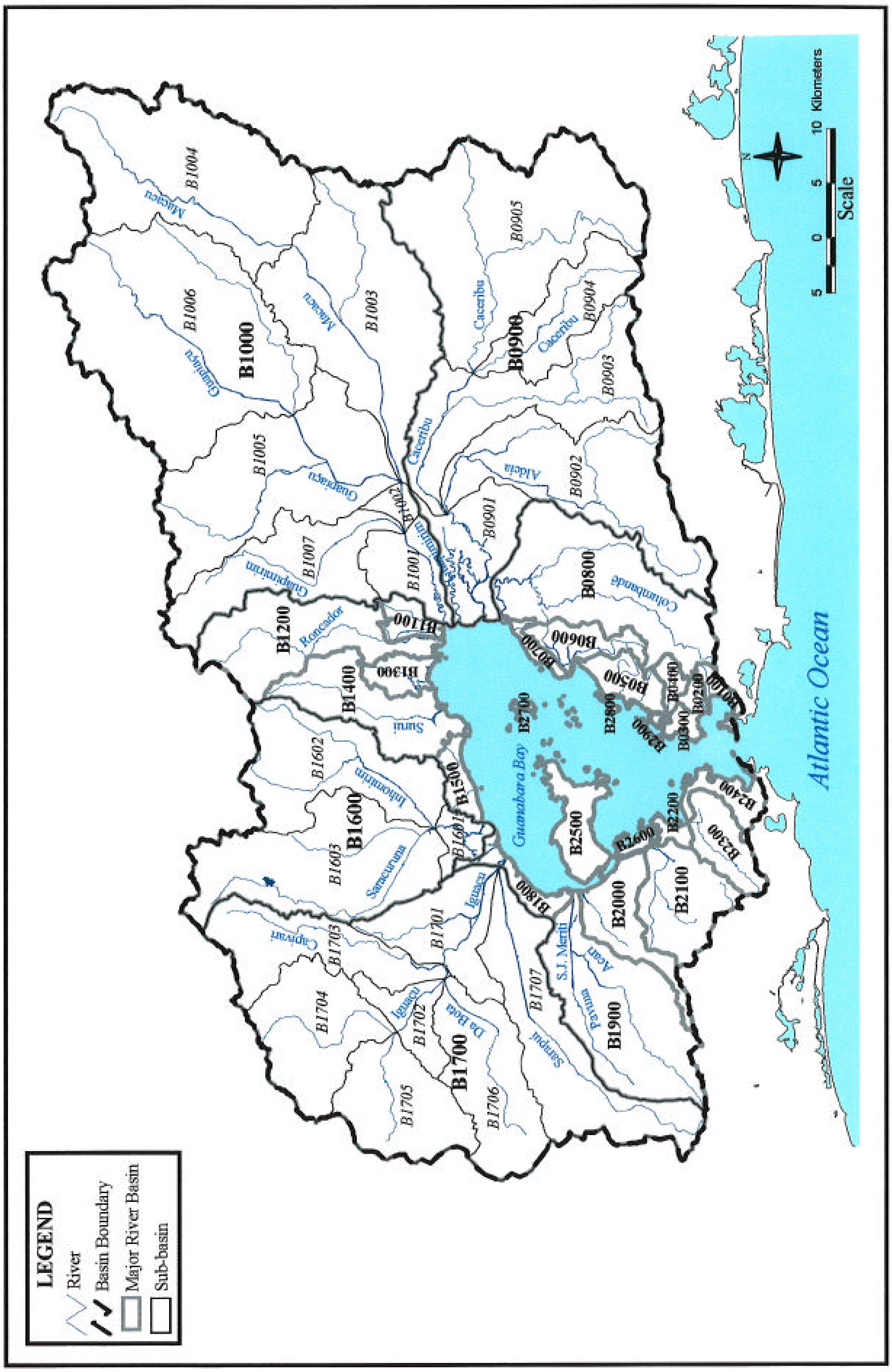


Figure 8 Divisions of River Basins

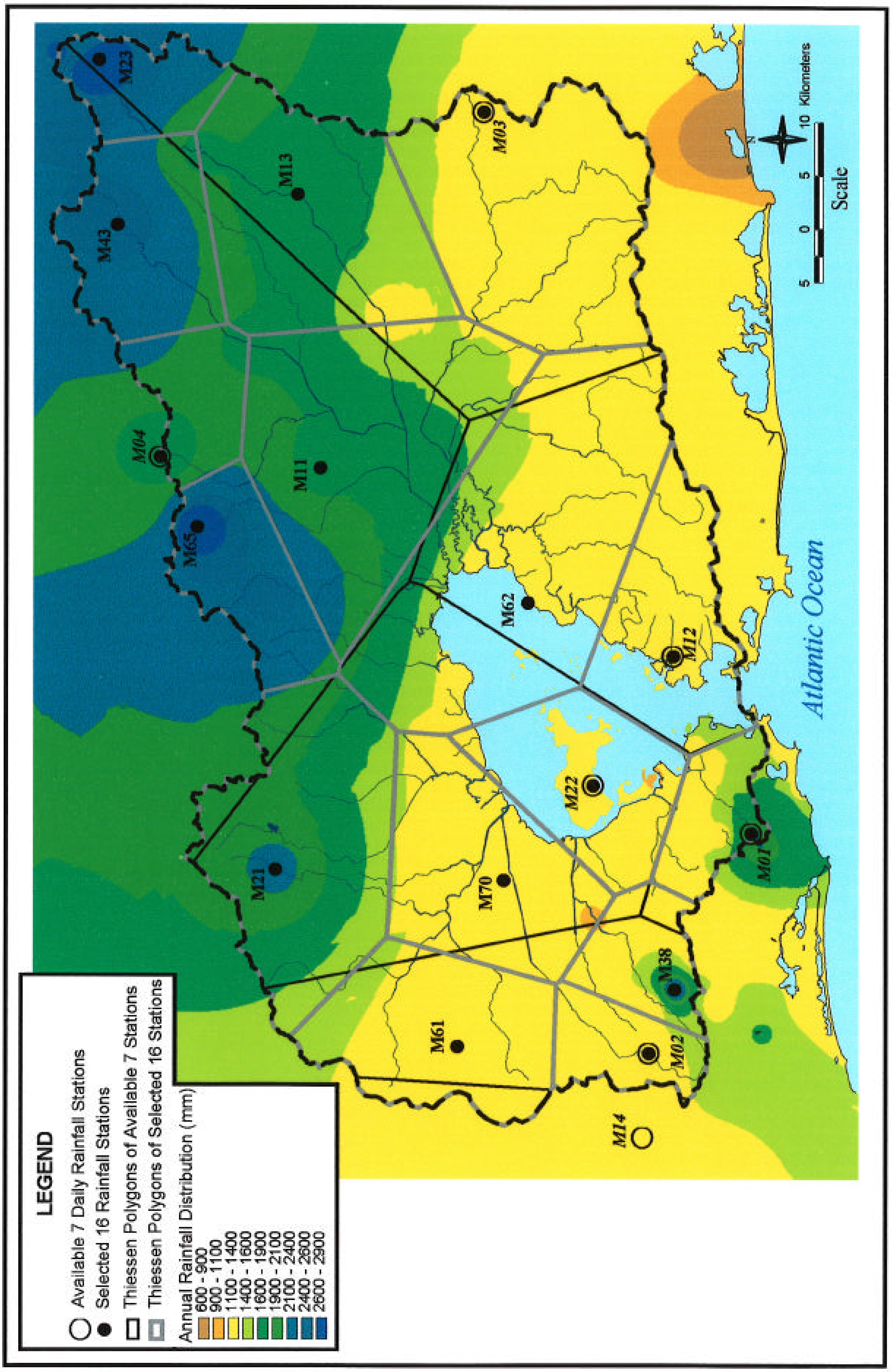
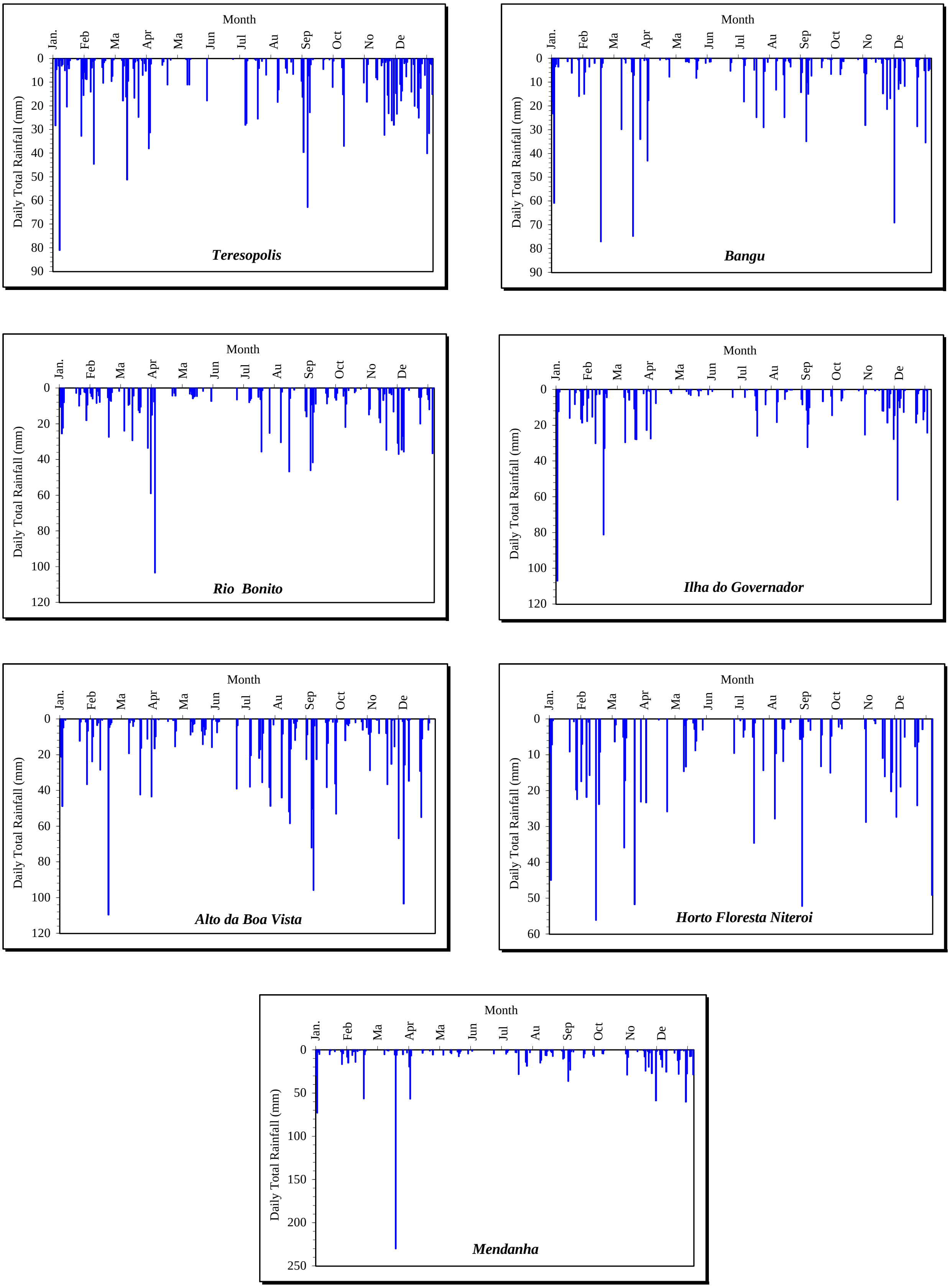


Figure 9 Thiessen Polygons of Daily Rainfall Stations



Note : For Teresopolis, no data is available for January of year 2000. Therefore, availbale data for January of year 1999 has been used for runoff analyses.

Figure 10 Daily Rainfalls for Year 2000 at 7 Available Rainfall Stations