CHAPTER 6

STRATEGIC PLAN FOR SEWERAGE DEVELOPMENT

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Review of JICA Master Plan in Chapter 4 established new improvement targets as follows: Short-term target with target year of 2010, Mid-term target with target year of 2020 and Long-term target without specific target year. It recommended to achieve Short- and Mid-term targets by sewerage development and proposed to formulate a strategic plan of the sewerage development for the Guanabara Bay environment improvement, based on CEDAE M/P.

In this chapter, the strategic plan is formulated based on the results of the review on CEDAE M/P in Chapter 5 and priority projects are identified from projects of the strategic plan to provide them with a feasibility study described in Chapter 7.

6.1 PLANNING FUNDAMENTALS FOR SEWERAGE SYSTEM

6.1.1 SEWERAGE DEVELOPMENT PLAN

The rationalization of the existing sewerage systems under the Strategic Plan is intended to eliminate the current wastewater disposal problems and improve the bay water quality which already has reached a deplorable level.

One indictor of the sewerage strategic plan objectives is the quantity of wastewater and sludge to be treated and disposed of through the proposed sewerage systems. The present average daily wastewater production rate within the bay basin area is estimated to be about 12.257 m^3/s (upon completion of PDGB Phase I), serving a total population of about 4.3 million. The wastewater flow is expected to increase to 23.50 m^3/s by the year 2020. If no action is taken to prevent this amount of wastewater from flowing into the Bay, the bay water will be further contaminated.

As described in Chapter 5 of this Report, the CEADE M/P planned the bay basin sewerage system comprising 16 independent sewer systems, covering about 2,970 km^2 basin areas with the total sewer service population of 9.4 million in 2020.

6.1.2 SEWER SYSTEM POPULATION

The design sewer system populations in each sewer district estimated based on the 2000 population census data every five years are summarized in *Table 6.1*.

Table 6.1 Sewer System Area and Populations by Stage

Sewer System	Area (ha.)	Sewer System Population by Stage				
		2000	2005	2010	2015	2020
1. Alegria	11,900	1,359,500	1,380,700	1,405,400	1,429,100	1,449,300
2. Penha	4,200	605,300	614,800	625,800	636,300	645,300
3. Pavuna-Meriti	17,800	1,455,600	1,484,700	1,517,600	1,549,000	1,577,500
4. Sarapuí	13,200	854,000	890,900	929,500	962,700	993,700
5. Bangu	3,300	378,500	384,400	391,300	397,900	403,600
6. Bota	39,200	1,010,400	1,093,900	1,167,000	1,226,100	1,274,400
7. Iguaçu	18,100	231,300	247,800	265,800	283,400	300,400
8. Estrela	35,100	334,100	364,700	396,900	424,700	450,500
9. Roncador	57,100	137,000	155,400	175,200	190,000	202,400
10. Macacu	65,600	287,200	321,500	352,100	378,200	400,000
11. Guaxindiba	7,100	196,700	212,100	226,800	240,100	252,400
12. Alcântara	10,600	401,800	427,500	453,200	477,200	499,500
13. Imbassu	5,900	266,900	285,600	303,900	320,900	336,700
14. Niteroi	4,000	366,800	373,600	384,000	394,400	404,400
15. Ilha do Governador	3,500	211,500	214,800	218,700	222,400	225,500
16. Paquetá	100	3,400	3,600	3,600	3,700	3,700
Total	296,700	8,198,100	8,558,900	8,925,900	9,252,300	9,419,300

Note: Estimated by the JICA Study Team based on the 2000 census data.

As shown in the above table, the present population of 8.2 million in the sewerage implementation area is expected to reach at 9.4 million by the year 2020.

6.1.3 WASTEWATER QUANTITIES AND CHARACTERISTICS

(1) Per Capita Wastewater Flows

The design wastewater quantities and qualities expected to flow into the sewerage systems are estimated for the wastewaters of domestic, commercial, industrial and institutional origins, and infiltration/inflow. These are estimated by the sewer district at every five-year period.

The per capita domestic wastewater flow rates are estimated for each sewer district, according to the design criteria which range from 200 to 400 Lpcd. These are estimated on the assumption that 80% of the water consumed becomes the wastewater, including those of commercial and institutional origins, according to the guidelines by ABNT.

Part of industrial wastewater is also included by percentage to the wastewater depending on the condition of sewer district. The wastewaters from such large-scale enterprises and manufacturers as shipbuilders are not accepted to the public sewers, but are required to be separately treat at their own responsibility to the permissible quality level for discharge to the public waters.

The design inflow/infiltration rates range from 0.05 to 1.0 L/s km of sewer length, but where the sewer lengths are not precisely measured, a value of 20 Lpcd may be used for design purposes.

(2) Design Wastewater Flow Rates to Sewers

The overall design wastewater flow rates are then obtained as summarizedbelow.

- Average daily per capita wastewater flow : Per capita water consumption rate x 0.8
- Maximum daily wastewater flow rate : Average daily wastewater flow rate x 1.2
- Maximum hourly wastewater flow rate : Average daily wastewater flow rate x 1.8
- Minimum wastewater flow rate : Average daily wastewater flow rate x 0.5
- Infiltration/Inflow rate to sewer : 0.05 ~1.0 L/s·km of sewer length
- Sewered population: : Total residents x 0.9

The design population, district areas, wastewater flows, etc. in the sewer systems in 2020 are summarized in *Table 6.2*.

(3) Design Wastewater Qualities

The wastewater qualities are estimated in terms of BOD_5 and SS, which are set as 54 g/cpd and 60 g/cpd respectively, in the Norma “NB-570, Item 5.2.” Other waste loads (such as COD, T-N and T-P) are to be determined based on actual data and/or experience obtained for design purposes.

Table 6.2 Populations and Wastewater Flow Rates by Sewer District (2020)

Sewer System	WWTP	Admin. Population (person)	Sewered Ratio	Sewered Population (person)	Average Daily Wastewater Flow: Per capita flow (Lcd)	Average Daily Wastewater Flow: Flow rate (L/s)	Maximum Daily Wastewater Flow: Per capita flow (Lcd)	Maximum Daily Wastewater Flow: Waste water flow rate (L/s)	Maximum Hourly Wastewater Flow: Per capita flow (Lcd)	Maximum Hourly Wastewater Flow: Waste-water flow rate (L/s)
Alegria	Alegria	1,449,300	0.9	1,304,400	300	4,529	356	5,375	524	7,91
Penha	Penha	645,300	0.9	580,800	235	1,580	278	1,869	407	2,73
Pavuna-Meriti	Pavuna	1,144,000	0.9	1,029,600	240	2,860	284	3,384	416	4,957
	Acarí	433,500	0.9	390,200	240	1,084	284	1,283	416	1,879
	Sub-Total	1,577,500		1,419,800		3,944		4,667		6,836
Sarapuí	Gramacho	76,000	0.9	68,400	235	186	278	220	407	322
	Sarapuí	917,700	0.9	825,900	240	2,294	284	2,715	416	3,977
	Sub-Total	993,700		894,300		2,480		2,935		4,299
Bangu	Bangu	403,600	0.9	363,200	240	1,009	284	1,194	416	1,749
Bota	Iguaçu 02	140,000	0.9	126,000	240	350	284	414	416	607
	Madame	12,700	0.9	11,400	240	32	284	37	416	55
	Velhos	39,600	0.9	35,600	250	103	296	122	434	179
	Bota	890,600	0.9	801,500	255	2,366	302	2,802	443	4,110
	Joinville	132,300	0.9	119,100	220	303	260	358	380	524
	Others	59,200		-						
	Sub-Total	1,274,400		1,093,600		3,154		3,733		5,475
Iguaçu	Xerém	11,700	0.9	10,500	220	27	260	32	380	46
	Campos eliseos	263,600	0.9	237,200	220	604	260	714	380	1,043
	Others	25,100		-						
	Sub-Total	300,400		247,700		631		746		1,089
Estrela	1	98,400	0.9	88,600	245	251	290	297	425	436
	2	150,100	0.9	135,100	250	391	296	463	434	679
	3	120,400	0.9	108,400	250	314	296	371	434	545
	4	46,900	0.9	42,200	245	120	290	142	425	208
	Others	34,800		-						
	Sub-Total	450,500		374,300		1,076		1,273		1,868
Roncador	1	19,900	0.9	17,900	220	46	260	54	380	79
	2	80,900	0.9	72,800	225	190	266	224	389	328
	3	22,300	0.9	20,100	220	51	260	60	380	88
	Others	79,300		-						
	Sub-Total	202,400		110,800		287		338		495
Macacu	1	89,500	0.9	80,600	225	210	266	248	389	363
	2	67,900	0.9	61,100	225	159	266	188	389	275
	3	34,500	0.9	31,100	225	81	266	96	389	140
	4	29,100	0.9	26,200	225	68	266	81	389	118
	5	40,000	0.9	36,000	225	94	266	111	389	162
	6	49,000	0.9	44,100	225	115	266	136	389	199
	7	21,100	0.9	19,000	225	49	266	58	389	86
	8	29,500	0.9	26,600	225	69	266	82	389	120
	Others	39,400		-						
	Sub-Total	400,000		324,700		845		1,000		1,463
Guaxin-Diba	1	180,600	0.9	162,500	225	423	266	500	389	732
	2	42,200	0.9	38,000	225	99	266	117	389	171
	3	14,000	0.9	12,600	220	32	260	38	380	55
	Others	15,500		-						
	Sub-Total	252,400		213,100		554		655		958
Alcântara	Trindade	174,300	0.9	156,900	220	400	260	472	380	690
	Alcântara	101,500	0.9	91,400	220	233	260	275	380	402
	Jardim Nazaré	127,400	0.9	114,700	220	292	260	345	380	504
	Others	96,300		-						
	Sub-Total	499,500		363,000		925		1,092		1,596
Imboassu	Sao Gonçalo	261,100	0.9	235,000	280	762	332	903	488	1,327
	Bomba	44,700	0.9	40,200	230	107	272	127	398	185
	Others	30,900		-						
	Sub-Total	336,700		275,200		869		1,030		1,512
Niteroi	Toque Toque	202,200	0.9	182,000	250	527	296	624	434	914
	Icaraí	202,200	0.9	182,000	255	537	302	636	443	933
	Sub-Total	404,400		364,000		1,064		1,260		1,847
Ilha do Governador	Ilha do Governador	225,500	0.9	203,000	220	517	260	611	380	893
Paquetá	aquetá	3,700	0.9	3,300	705	27	842	32	1,253	48
Total		9,419,300		8,135,200		23,491		27,810		40,775

Note: Population distributions are those updated based on the 2000 population census data. Other figures are in principle those used in the CEDAE Master Plan.

Population in 2020 is the basis for planning and does not necessarily mean all the facilities will be constructed by 2020.

6.1.4 SELECTION OF WASTEWATER TREATMENT PROCESS

(1) WWTP Effluent Quality Requirements

The WWTPs are required to produce the wastewater effluent qualities that comply with the permissible effluent quality limits set by "Water Quality Criteria for Liquid Effluents (NT-202, R10)." as summarized in *Table 6.3*.

Table 6.3 Water Quality Criteria for Liquid Effluents (NT-202, R.10)

Parameter	Limits
1. pH	5.0~9.0
2. Temperature	< 40
3. Floatable materials	Not visible
4. Settleable materials	10 mg/L
5. Grease and oil (minerals)	20 mg/L
6. Grease and oil (vegetables)	30 mg/L
7. to 39.	-
40. Total phosphorous	1.0 mg/L
41. Total nitrogen	10.0 mg/L

Note: Items from 7 to 39 as to heavy metals and toxic material compounds are intentionally excluded.

The effluent qualities from WWTPs to the public water bodies are subject to control by the Standards, which require, among others, T-N and T-P to be the levels of lower than 10.0 mg/L and 1.0 mg/L, respectively. The ordinary secondary processes will not be able to meet these strict terms; hence, advanced treatment processes might be needed if these are to be strictly enforced.

The wastewater discharge quality standards "DZ-215, R-01(April 1994) for Non-industrial Wastewater Effluent Quality", shown in *Table 6.4*, define the effluent waste concentrations, discharged either directly or through WWTP to the public water bodies.

Table 6.4 Non-industrial Wastewater Effluent Quality Standards

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

Since even the smallest WWTP of Xerem receives BOD loading of 567 kg/day, all the other WWTPs must treat their influents to the most stringent level shown in the Table.

(2) Existing/Planned WWTP Processes

Existing and planned WWTPs in the area are mostly secondary treatment by activated sludge process, except for old WWTPs with trickling filter and oxidation pond processes. The activated sludge process can achieve waste loads removal rate as high as 95% when properly operated, which could meet the required effluent organic waste loads concentration limits.

The excess sludge is thickened, digested and/or mechanically or naturally dewatered. The sludge cake is hauled to solid disposal sites for final disposal.

It is apparent that such stringent water quality requirements can hardly be met with the secondary treatment processes alone, but the provision of advanced treatment processes beyond the secondary treatment level is mandatory, when such standards are strictly enforced.

Although priority is given to construction of secondary treatment WWTP at present, more stringent control of the effluent quality might be possibly enforced in the future. In selecting appropriate WWTP system that will meet the quality standards –(secondary processes now and upgrading to advanced treatment processes in the future) possible alternative combinations of treatment processes have been evaluated.

(3) Alternative Combinations of Treatment Processes

In selecting appropriate WWTP process, the following process combinations are evaluated, including biological, physical, and chemical processes:

- BOD and SS removals: Conventional activated sludge process
- BOD, SS, T-N removals: Biological nitrification-denitrification process
- BOD, SS, T-N and T-P: Anaerobic-anoxic-aerobic process
- BOD, SS, T-P: Conventional activated sludge plus chemical precipitation.

For the evaluation, the following standard values for wastewater discharge to the receiving water bodies are considered:

- BOD = 30 mg/L (secondary treatment process)
- SS = 30 mg/L (secondary treatment process)
- T-N = 10 mg/L (advanced treatment process)
- T-P = 1.0 mg/L (advanced treatment process)

(4) Selection of Secondary Treatment Process

Given such effluent quality requirements (30 mg/L BOD, 30 mg/L SS), any treatment processes with BOD and SS removal efficiencies lower than 80% (primary treatment processes, trickling filters, etc.) cannot meet such requirements.

Major characteristics of the conventional activated sludge process include:

- High organics removal efficiencies expected (90~95 %)
- Most of the existing publicly owned WWTPs apply conventional activated sludge process, and other processes can not be applied for their expansion or rehabilitation
- Proven process technology, widely used process, particularly for large-scale plants with long operation and maintenance experience
- Requires generally less land areas than other processes

The majority of the existing publicly-owned WWTPs elsewhere in Brazil apply the conventional activated sludge process. The process can produce high quality wastewater effluents, meeting at least the required organic pollutants removals by secondary treatment processes. On account of the present stringent effluent quality standards, the conventional activated sludge or equivalent process is the minimum requirement for the Guanabara Bay Basin wastewater systems.

(5) Upgrading and Expansion of WWTPs

WWTPs expansion may be required in the future to provide additional treatment capacities for the extended sewer networks. Further, there could be regulatory requirements, which will call for better effluent qualities.

The conventional activated sludge process normally produces effluent quality containing about 20 mg/L of BOD_5, 25 to 30 mg/L of total nitrogen, and 2.5 to 3.0 mg/L of total phosphorus. These are not sufficient to clear the effluent nutrients limits (T-N = 10 mg/L and T-P= 1.0 mg/L). The secondary treatment processes may be gradually upgraded on a step by step basis by adding facilities and equipment, when it becomes really necessary and financially practicable.

The removal of phosphorous will be made by adding metal salt such as alum or ferric chloride to the aeration tanks. The process will require a small land area for the chemical storage, dosing and mixing equipment, and auxiliary facilities, which are generally possible to provide within the secondary treatment plant site.

For T-N and T-P removal, either anoxic and oxic (A/O) plus chemical addition, or anaerobic, anoxic and oxic (A2O) process is recommended, but these require some modifications of secondary process facilities.

It would not be a realistic solution to construct the WWTPs with the entire advanced treatment facilities at the initial stage, but it should rather be deferred to a latter stage. At the first stage of the project implementation, the facilities should meet the requirements for secondary processes, and at the second or third stage, advanced treatment facilities may be added or incorporated. Therefore, the requirements for T-N and T-P are set out as ultimate requirements, and under this study these are not applied to the proposed facilities

Representative combinations of treatment processes for upgrading the secondary treatment plants to remove the nutrients are illustrated in flow diagrams, *Figures 6.1, 6.2 and 6.3* shown below.

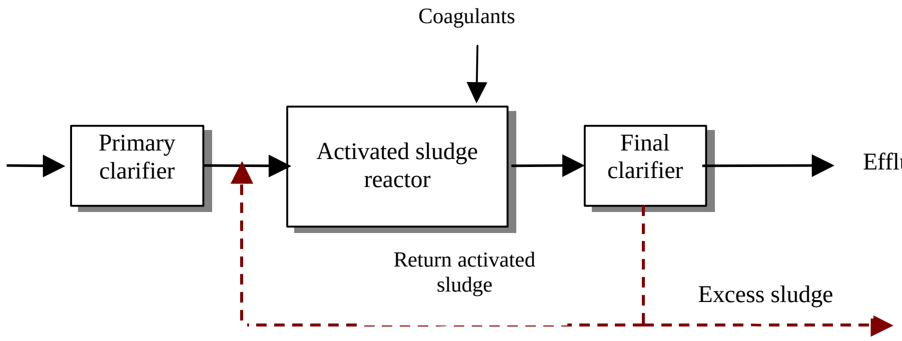

Figure 6.1 Activated Sludge Process Plus Chemical Addition for Organic Materials and T-P Removal

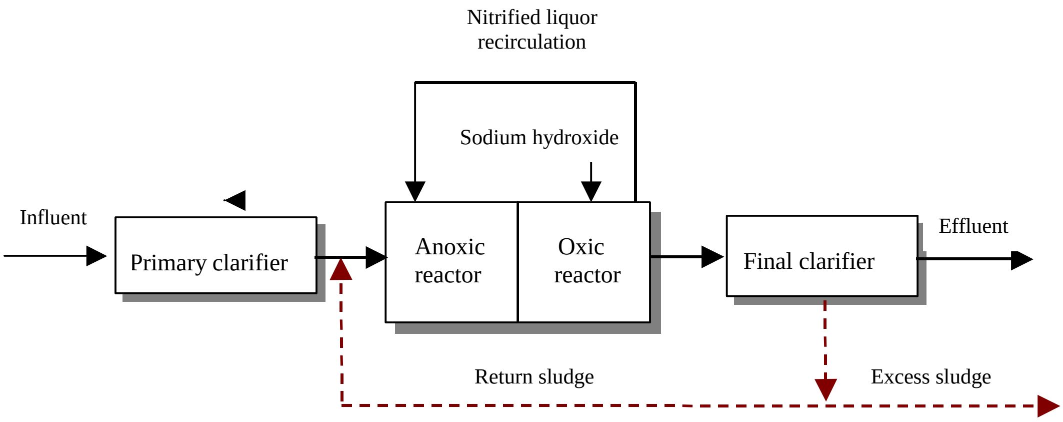

Figure 6.2 AO Plus Chemical Addition for Organic Materials, T-N and T-P Removal

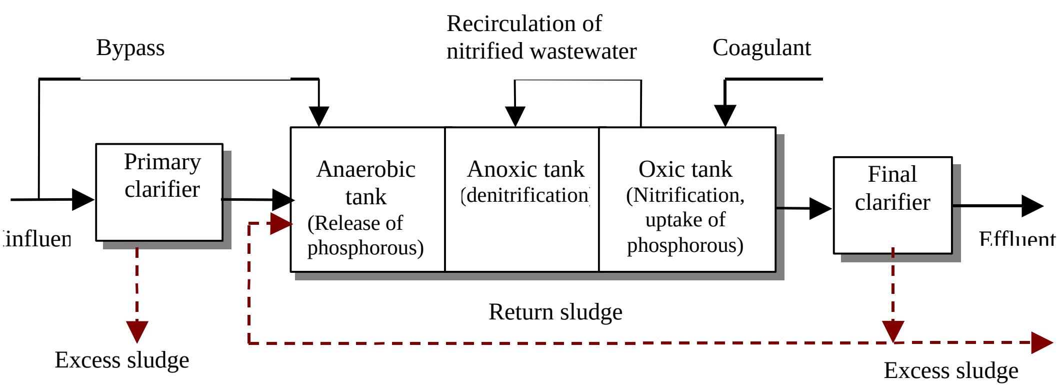

Figure 6.3 A2O for Organic Materials, T-N and T-P Removal

6.2 SEWERAGE SYSTEM PLANNING

6.2.1 SEWER PLANNING CONCEPT

As shown in Chapter 2, there are several schemes for sewerage facilities implemented by the organizations other than CEDAE. However, not all of them are well grasped and coordinated with CEDAE's system. Some of the schemes by SMH (Municipal Secretariat of Housing of Rio de Janeiro City) have WWTPs but their performance is yet to be clarified.

The overall water supply rate in Favelas is 92% that is higher than the average rate for the whole Rio de Janeiro State of 80%, which means that a considerable amount of sewage is generated there regardless of water supply service level. The generated wastewater is discharged to public water bodies through stormwater drains.

Favelas have been developed without city planning and few roads are available for sewers construction. Also some roads are very narrow and in very steep hilly areas. While establishing city planning to implement urban infrastructure facilities in an orderly manner, inevitably generated wastewater has to be removed from the living environment by means of interceptors that then flow into public sewers.

By the year 2035, the wastewater of domestic, industrial and institutional origins generated in the sewerage implementation area, which are of the acceptable qualities and quantities to the system, are to be collected through the public sewers and treated to the permissible qualities for the public watercourses. Any sewerage system with no treatment other than CEDAE's systems is supposed to be incorporated into CEDAE's system. For that purpose, WWTP capacities are to include wastewaters from all the other systems with no treatment.

The concept of the sewerage system improvement strategy plan suggests a phasing implementation of collection system and WWTP facilities, which will provide an immediate benefit to a significant portion of the sewerage implementation area population and commensurate with economic limitations.

This long-range sewerage improvement plan encourages the continued use and proper maintenance of the existing sewerage facilities. Existing septic tanks or other sanitation facilities in the sewerage implementation area, where the sewers are not readily be available yet, will remain in use until such time when the public sewers are extended and become accessible.

The benefits derived from the new sewerage system would be an improvement in the environment, in particular water quality improvement of the Guanabara Bay, which in turn, would result in a significant improvement in the health of the people and economics in the Guanabara Bay Basin.

6.2.2 CONSIDERATIONS ON SANITATION IMPROVEMENT MEASURES

In the undeveloped low-income districts scattered throughout the implementation area, where the public sewer system may not be implemented soon, the generated wastewater and other wastes could not be safely collected to the sewers. These wastes could be managed by temporary measures, either by on-site sanitation facilities, or through collecting sewers leading to the nearby public sewers.

The collecting sewers for these areas will comprise wastewater inlet chambers with manual screens that collect the wastewaters downstream of stormwater and/or natural drains in which such wastewaters are disposed of. The wastewaters will be led through the collecting sewer pipes to the public sewers running near the sites. These systems are somewhat similar to combined sewers to collect both the dry and wet weather flows. Thus, most of such sanitary wastewaters and certain amount of stormwater runoff could be collected together during rainfalls.

The sparsely populated hilly/mountain and wasteland areas, which are unlikely to be inhabited in the foreseeable future, are excluded from sewerage implementation area. Since the areas in the north of the Bay are predominantly either pasture or agricultural land, only part of such urban areas is planned to be sewered. The remaining areas may be covered by on-site sanitation improvement plans to be undertaken in parallel with the sewerage programs.

Sludge dumping facilities may be attached to the sewer systems at convenient locations for the disposal of collected sludge from on-site sanitation facilities, but the provision of such individual sanitary facilities is left to the private owners' responsibility.

6.2.3 SEWERAGE FACILITIES DESIGN BASES

(1) Sewers

The sewer system is to be planned in principle to flow the wastewater by gravity, reducing to the maximum extent the energy need to pump up the wastewaters; consequently, the operation and maintenance of the system is easy and costs are low. All the sewers are to be designed to have flow allowances of 30% to 100% of the pipe capacity during the peak flow rates. This will allow interior of sewers to supply sufficient ventilation to avoid anaerobic conditions of the wastewaters in the sewers thereby prevent possible sulfide buildup.

The pumping stations are either dry-well or wet-well type, but for the pumping stations serving small areas, manhole-type submersible pumps will generally be used. Pump-wells are reinforced concrete structures with the provision for easy removal of pumps without dewatering wet-wells and with continuity of operation of the other units.

(2) WWTP Facilities Design Bases

The conventional activated sludge treatment process sequence generally consists of the following components:

- Preliminary treatment: screening and grit removal
- Primary treatment: sedimentation
- Secondary treatment: conventional activated sludge
- Sludge management: anaerobic digestion, thickening and dewatering.

A diagram of the conventional activated sludge process is shown in *Figure 6.4*.

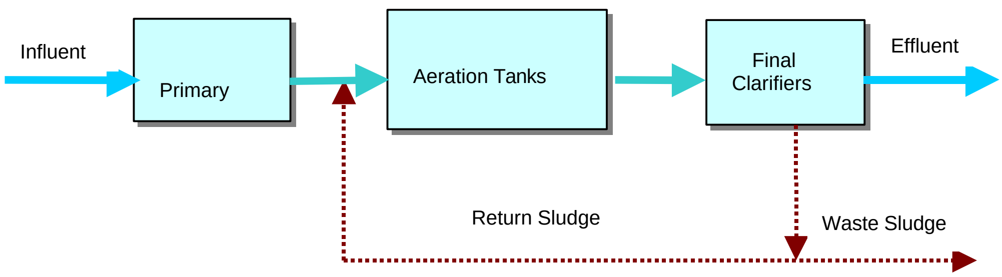

Figure 6.4 A Schematic of Conventional Activated Sludge Process

The expected pollutants removal efficiencies and qualities by the primary, secondary and overall processes are as summarized in *Table 6.5*.

Table 6.5 Expected Treatment Efficiencies of Conventional Activated Sludge Process

Parameter	Removal Efficiency (%)			Wastewater Quality (mg/L)		
	Primary treatment	Secondary treatment	Overall removal	Raw waste water	Primary effluent	Secondary effluent
BOD	30	90	93.0	(*)270	119	18
SS	40	85	91.0	(*)240	102	20

Note: Wastewater qualities are of representative values. (*) Including sidestream waste loads.

6.2.4 SEWERAGE SYSTEM COMPONENT FACILITIES

(1) Sewers

The system comprises existing and new sanitary sewers, consisting of mains, sub-mains, ocean outfalls, branch and lateral sewers with auxiliary facilities.

The wastewaters collected from households through house connections flow by gravity to the branch/lateral sewers, then are led to the sub-main or main sewers. The wastewaters from flat areas in central districts reach intermediate pumping stations, from where they are transmitted through pressure mains either to main sewers or WWTP(s). In other sewer districts, most of the wastewater could be conveyed by gravity.

Although profiles for sewers were not prepared for the master plan review purpose, some major sub-main and main sewers were checked to examine whether such sewers could receive the wastewater from the upstream sewers or the most remote locations in the tributary areas.

(2) Pumping Stations

A total of 70 wastewater intermediate pumping stations will be provided throughout in the sewerage systems to lift the wastewater and continuously transmit to the WWTPs. The wastewater will be lifted to an elevation sufficiently high to continue the gravity flow to the WWTP.

(3) Wastewater Treatment Plants (WWTPs)

Under the Strategic Plan, 42 WWTPs in total are to be built throughout the implementation areas. Each sewer district is planned to have the WWTP(s) of the activated sludge process to produce the wastewater effluents meeting the required effluent qualities to the public water bodies.

6.2.5 PLANNING

Sewerage planning is outlined in *Table 6.6* by each sewer district for the whole Study area (for the location, refer to *Figure 5.1*). The whole sewered area will be 285,500 ha with the served population of 8,135,200 persons in 2020. The sewerage planning was made based on the population forecast for 2020. The total wastewater flow will be 24,924 L/s or 2,150,300 m3/day that will be treated in 42 WWTPs. All the pumping stations, trunk sewers and WWTPs in Alegria, Penha, São Gonçalo, Icarai, Ilha do Governador and Paquetá are supposed to be completed within PDBG Phase I. Gramacho was completed outside PDBG Phase I. In Pavuna and Sarapuí districts, WWTPs and sewers have been partly implemented also in PDBG Phase I.

Table 6.6 Planning Outline by Sewer District

Sewer System	WWTP	Sewered Area	Sewered-Pop	Wastewater Flow	WWTP Capacity (L/s)			Collection System	
		(ha)	(person)	(l/s)	Planned	Existing	To be Extended	Pumping Station	Sewers (m)
Alegria	Alegria	11,900	1,304,400	4,529	5,000	5,000	0	4	1,785,000
Penha	Penha	4,200	580,800	1,580	1,600	1,600	0	0	630,000
Pavuna-Meriti	Pavuna	8,600	1,029,600	2,860	3,000	1,500	1,500	18	1,290,000
	Acarí	4,000	390,200	1,084	1,100	0	1,100	5	600,000
	Sub-Total	12,600	1,419,800	3,944	4,100	1,500	2,600	23	1,890,000
Sarapuí	Gramacho	900	68,400	186	185	185	0	3	135,000
	Sarapuí	7,900	825,900	2,294	2,500	1,500	1,000	11	1,185,000
	Sub-Total	8,800	894,300	2,480	2,685	1,685	1,000	14	1,320,000
Bangu	Bangu	1,700	363,200	1,009	1,000	0	1,000	1	255,000
Bota	Iguaçu 02	4,300	126,000	350	350	0	350		473,000
	Madame	400	11,400	32	40	0	40		44,000
	Velhos	1,200	35,600	103	110	0	110		132,000
	Bota	27,400	801,500	2,366	2,400	0	2,400		3,014,000
	Joinville	4,100	119,100	303	310	100	210		451,000
	Others	1,800	-	0	0	0	0		
	Sub-Total	39,200	1,093,600	3,154	3,210	100	3,110	0	4,114,000
Iguaçu	Xerém	700	10,500	27	30	0	30	1	77,000
	Campos eliseos	15,900	237,200	604	610	0	610	2	1,749,000
	Others	1,500	-	0	0	0	0		
	Sub-Total	18,100	247,700	631	640	0	640	3	1,826,000
Estrela	1	7,700	88,600	251	260	0	260		847,000
	2	11,600	135,100	391	400	0	400	1	1,276,000
	3	9,400	108,400	314	320	0	320		1,034,000
	4	3,700	42,200	120	120	0	120		407,000
	Others	2,700	-	0	0	0	0		
	Sub-Total	35,100	374,300	1,076	1,100	0	1,100	1	3,564,000
Roncador	1	5,600	17,900	46	50	0	50		616,000
	2	22,800	72,800	190	190	0	190	2	2,508,000
	3	6,300	20,100	51	60	0	60		693,000
	Others	22,400	-	0	0	0	0		
	Sub-Total	57,100	110,800	287	300	0	300	2	3,817,000
Macacu	1	14,600	80,600	210	210	0	210	1	1,606,000
	2	11,100	61,100	159	160	0	160	1	1,221,000
	3	5,700	31,100	81	90	0	90		627,000
	4	4,800	26,200	68	70	0	70		528,000
	5	6,600	36,000	94	100	0	100		726,000
	6	8,000	44,100	115	120	0	120	1	880,000
	7	3,500	19,000	49	50	0	50		385,000
	8	4,800	26,600	69	70	0	70		528,000
	Others	6,500	-	0	0	0	0		
	Sub-Total	65,600	324,700	845	870	0	870	3	6,501,000
Guaxindiba	1	5,100	162,500	423	430	0	430	2	561,000
	2	1,200	38,000	99	100	0	100		132,000
	3	400	12,600	32	40	0	40		44,000
	Others	400	-	0	0	0	0		
	Sub-Total	7,100	213,100	554	570	0	570	2	737,000
Alcântara	Trindade	3,700	156,900	400	400	0	400	1	555,000
	Alcântara	2,200	91,400	233	240	0	240	1	330,000
	Jardim Nazaré	2,700	114,700	292	300	0	300	2	405,000
	Others	2,000	-	0	0	0	0		
	Sub-Total	10,600	363,000	925	940	0	940	4	1,290,000
Imboassu	Sao Gonçalo	4,600	235,000	762	765	765	0	2	690,000
	Bomba	800	40,200	107	110	0	110	1	120,000
	Others	500	-	0	0	0	0		
	Sub-Total	5,900	275,200	869	875	765	110	3	810,000
Niteroi	Toque Toque	2,000	182,000	527	530	0	530	3	300,000
	Icaraí	2,000	182,000	537	952	952	0	3	300,000
	Sub-Total	4,000	364,000	1,064	1,482	952	530	6	600,000
Ilha do Governador	Ilha do Governador	3,500	203,000	517	525	525	0	1	525,000
Paquetá	Paquetá	100	3,300	27	27	27	0	3	15,000
Total		285,500	8,135,200	23,491	24,924	12,154	12,770	70	29,679,000

Note: Number of pumping stations and length of sewers include existing ones.

6.3 PROJECT IMPLEMENTATION PRIORITY

6.3.1 GENERAL

Obviously it is prudent to build the required facilities in stages, according to the urgency of needs and benefits to be derived from the sewerage provision. The staged construction will spread capital expenditures over an extended period of years, as well as saving interest on borrowed capital and reducing initial costs.

A study has therefore been made to determine the priority of sewerage implementation based on reasonable assumptions and evaluation procedure. The evaluation includes various elements that may affect developmental, environmental, sanitary and socio-economic conditions in each sewer district.

The whole sewerage implementation area is divided into 16 sewer systems, in view of the existing sewer layouts, sewer districts and administrative boundaries, topographic conditions, and other developmental programs as outlined in the M/P, and sewer systems consists of sewer district(s). Here the unit of sewer service area connected to a WWTP is termed “sewer district.”

The sewer system in Niterói City was privatized and is no longer administered by CEDAE. Hence, the Niterói sewer district/system is not included in further priority analysis along with completed systems/districts listed in the previous section.

6.3.2 BASIS FOR PRIORITY EVALUATION

In determining the priority of sewer district implementation, the following conditions are taken into account:

- The wastewater in unsewered areas would be collected and treated either through wastewater or sanitation systems to be provided separately under other sanitation improvement programs, including such facilities as communal sanitation systems, or on-site disposal systems.
- The sewer districts/systems are to be implemented in three consecutive implementation phases: First stage from 2004 through 2010, Second stage from 2011 through 2020, and Third stage from 2021 through 2035.

6.3.3 EVALUATION OF INVESTMENT EFFICIENCY

For the examination of the priority of project implementation, each sewer district is first evaluated for its population.

- Considering the scale economy, the larger the WWTP scale, the higher the investment efficiency shall be.
- Similarly for sewers, the higher the population density, the higher the investment efficiency shall be.

(1) Population

The 2020 sewered population in each sewer district is estimated on the basis of the 2000 population, as discussed in Chapter 5.

The investment and pollutant removal efficiencies are generally higher in the districts with large service populations and high-population density. The highly-urbanized sewer districts are those situated in Rio de Janeiro; São João de Meriti, Nilópolis, Mesquita in the north; Belford Roxo in the west; and Niterói and São Gonçalo in the east of Guanabara Bay.

The sewer district/systems covering highly urbanized districts with high population densities are Penha, Alegria and Bangu sewer district/systems in the Western Region, and Niterói in the Eastern Region.

Table 6.7 shows the service area, and the planned population and density in each sewer system:

Table 6.7 Area, Population and Population Density in Sewer Systems

Sewer system	Area (ha)	Population (2020)	Density (Person/ha)	Remarks
1. Alegria	11,900	1,449,300	122	Completed
2. Penha	4,200	645,300	154	Completed
3. Pavuna-Meriti	17,800	1,577,500	89	
4. Sarapuí	13,200	993,700	75	
5. Bangu	3,300	403,600	122	
6. Bota	39,200	1,274,400	33	
7. Iguaçu	18,100	300,400	17	
8. Estrela	35,100	450,500	13	
9. Roncador	57,100	202,400	4	
10.Macacu	65,600	400,000	6	
11.Guaxindiba	7,100	252,400	36	
12.Alcâtara	10,600	499,500	47	
13.Imboassu	5,900	336,700	57	
14.Niteroi	4,000	404,400	101	Completed
15.Ilha do Governador	3,500	225,500	64	Completed
16.Paquetá	100	3,700	37	Completed
Total	296,700	9,419,300	32	

Note: “Completed” means either already completed or to be completed within PDBG I.

Since five systems of Alegria, Penha, Niterói, Ilha do Governador and Paquetá are either already completed or to be completed, these systems are excluded from the evaluation.

(2) Overall Evaluation of Tangible Considerations

The investment efficiency analysis has led to the following conclusions:

- Bangu, Sarapuí and Pavuna-Meriti sewer systems are considered high priority districts when population and its density are taken as indicators.
- The sewer districts with high population density could contribute significantly to the pollution alleviation of the Bay water, and improve sanitary conditions in the service areas as well. Thus, a high effect on public appeal, per the government’s eagerness for the environmental improvement, could also be expected.
- These high priority districts cover large population; thus, the implementation of these districts would give a significant positive impact to a large number of residents to understand and appreciate the public administration's efforts to achieve environmental protection.

The policies and constraints for the selection of high priority districts are for all the sewer districts construction that could not be done without appropriate financial assistance/subsidy. Such other non-quantifiable factors as appeal to the public for the government’s effort to achieve environmental/sanitation protection are also important.

6.3.4 COMPARISON OF INTANGIBLE CONSIDERATIONS

In view of the lack of a clear distinction among the sewer districts on a cost efficiency basis, non-quantifiable considerations also become of importance in the selection of the system construction priority.

The most important non-quantifiable considerations have been identified, and the evaluation made of the degree to which each is responded to by the sewer districts analyzed. Some of the districts rated as lower priority for the tangible considerations are not included for further intangible evaluations.

The non-quantifiable considerations deemed of major importance in selecting among the sewer districts are among others:

- Implementability
- Land availability
- Flexibility
- Community/environmental impact
- Conditions of present sewer district/system
- Other developmental and socio-economic conditions.

(1) Implementability

Sarapuí, Pavuna, Bangu, Acarí and Bota sewer districts represent the higher priority for implementation in terms of cost efficiency. The lands for these WWTPs are either ready for use or will soon be made available, unlike other WWTP sites in small-size sewer districts.

In addition, these high priority sewer districts have been mostly sewered, and the residences in the districts could be easily connected to the sewers without difficulty as compared with other smaller sewer districts.

The expansion of Pavuna, Acarí and Sarapuí WWTPs will entail certain advantages in the new plant facility operations. The new systems could start their operations in a relatively short period because most of the influent sewers already exist. Also, the plant staff already has operational experience gained from the similar biological treatment process, and easily will become accustomed to the new system operation and management.

The sewer districts, where large mains, force mains, and pump stations are yet to be constructed, would surely require a considerable time to complete them. There would be a considerable delay in receiving the services in such districts from far removed WWTPs, delaying implementation of the systems.

In view of these points, the relatively large high priority sewer districts are substantially superior to other systems in terms of capability to rapidly alleviate the existing sanitation/water pollution problems, and so these are rated excellent in this regard.

(2) Availability of WWTP Sites

Sufficiently wide land areas for Sarapuí, Pavuna and Acarí WWTPs have already been secured for the construction or expansion of facilities. Although the wide land areas of either wasteland or pasture are available as the possible candidate sites for Bangu, Bota and Bomba WWTPs, the lands are not acquired yet.

The originally proposed sites for Bangu, Bota and Bomba WWTPs are either not found or already encroached on by housing complexes, and so suitable alternative lands should be found near the originally proposed lands. Land acquisition requires considerable time and legal procedures to settle. In this respect, Bangu, Bota and Bomba districts is inferior to other large-scale WWTPs. Locations of some other proposed WWTP sites could not be identified.

The present status of other proposed major WWTP sites are summarized *Table 6.8*.

Table 6.8 WWTP Site Conditions

Sewer System	Sewer District	Present Condition	Remarks
1. Bota	Igua u 02, Madame	Originally planned site is not identified	
2. Bota	Velhos	Originally planned site is already urbanized	
3. Alcântara	Jardim Nazaré	Insufficient area for plant facilities	
4. Bangu	Bangu	Originally planned site is already urbanized	Another site available
5. Alcântara	Trindade	Originally planned site is not identified	Ditto
6. Imboassu	Bomba	Originally planned site is already urbanized	Ditto

Note: Inspection results of candidate sites by CEDAE and Study Team.

(3) Flexibility

Large-scale existing WWTPs (such as Sarapuí, Pavuna and Acarí) have less flexibility for expansion of facilities, as these were already designed and partly constructed following the original plans.

Small-scale WWTPs, on the other hand, are more flexible. If future experience shows that the capacity of the plants needs to be expanded beyond the original capacity, for example, the expansion of the plants could be made or deferred substantially in time or possibly not required at all.

Deferral of investments in facilities to treat such flows will provide an opportunity to better assess the effectiveness of present efforts to direct patterns of growth within the currently suburban isolated areas. These deferred small-scale WWTPs systems would offer the opportunity to take advantage of technological advances.

(4) Community/Environmental Impacts

As a detailed environmental impact assessment (EIA) will be conducted under the feasibility study, the environmental impacts related to sewer district/system construction, and operation and maintenance are briefly assessed through an initial environmental examination (IEE).

Social impacts can be best measured by the readiness with which sewerage facilities are accepted by the community. Although such facilities are not generally a desirable addition to any community, an assessment of the relative impact of alternatives could be made to select a system with least impact to the communities.

Sarapuí, Pavuna, and Acarí sewer district/systems are rated as "good" in terms of community impact because the treatment facilities already existed with rather remote communities surrounding the sites, and need no further land areas.

Candidate WWTP sites for Bangu, Campos Eliseos, and Trindade are less acceptable than other large-scale WWTP sites because some sites are located close to residential areas and presently some part of the proposed sites have already been encroached, and other alternative site may have to be found.

Where the sites are located near the communities, due considerations for minimizing hazards and nuisance would be required, such as provision of buffer zones and fences, and noise, vibrations, odor, and aerosol abatement. In view of these conditions, these WWTP sites are rated lower than other districts.

(5) Conditions of Present Sewer district/systems

CEDAE has selected Pavuna and Sarapuí sewer district/systems as the highest priority systems among other systems, and are partly implemented under PDBG Phase-1. The constructed facilities are WWTPs both with 1,500 L/s treatment capacity and the relevant main sewers connecting to the WWTPs. The plant capacities proposed are 3,000 L/s for Pavuna and 2,500 L/s for Sarapuí.

The priority of WWTPs and sewers extension in these districts appears to be high because of the expected high cost-effectiveness of facilities because: i) WWTP sites have already been acquired and ready for the extension, ii) all the plant common facilities, such as administration buildings, influent facilities, common conduits, pumping stations, etc., are already built, and iii) most of trunk sewers are already or will be available soon to flow the wastewater to the WWTPs.

Bota and Iguaçu sewer districts, and Trindade district in Alcântara sewer system are on comparatively flat areas, where the trunk sewers were planned in the M/P to run on the low-lying areas along the rivers. No road exists nor is planned along the rivers so far, thus making it difficult to install trunk sewers on such locations.

As Jardim Nazaré sewer district in Alcântara sewer system is located on the hilly side with sharp land undulations, an increased number of pumping stations would be required if the area is served by a single WWTP. The sewer district/system could be provided in a more economical and effective way if the area is divided into several sub-districts. Before the implementation of sewerage program in these sewer districts, a study on selecting the optimum trunk sewer routes is to be made first since these districts are less favorable than other districts for early implementation.

In Acarí sewer district, a WWTP of 210 L/s capacity was constructed in 1974. Out of the existing six reactor units, only three units have been in operation. Part of mechanical equipment of three units were allegedly removed and used for rehabilitation of other three reactor units.

Another WWTP exists called “Realengo” constructed in the 1950s, which had been operated until 1999. The wastewater used to be flowing into the WWTP is now being either bypassed or sent to Acarí WWTP.

More detailed information on the existing and planned sewers particularly in the central part of this district are yet to be obtained before implementing sewerage construction. The extension of sewer service areas will surely require considerable time for the site investigation and study on physical and hydraulic conditions of sewers. Considering these conditions, the district is inferior to other comparable districts in terms of implementability.

(6) Other Development Programs (Nova Baixada, etc).

Under the Nova Baixada Program, construction of three WWTPs is planned in Bota sewer system as shown in *Table 6.9*.

Table 6.9 WWTPs under Nova Baixada Program

Sewer district/systems	Features of the Systems
1. Joinville	A WWTP of 100 L/s capacity with the primary treatment facilities was constructed five years ago, but has not been operated so far due to structural problems and absent of house connections to collect the wastewater.
2. Orquidea	WWTP system construction is underway.
3. Babi	Design was completed and construction is expected to start soon.

All the above three WWTPs are located within Bota sewer system. Although the system started its service for the Nova Baixada Program areas, it may take some time until the WWTPs can start their operation. For this reason, Bota sewer system is rated low implementation priority district.

(7) Evaluation of Implementation Priority of CEDAE

CEDAE has considered that priority projects would be selected from seven sewer systems out of twelve shown in *Table 6.10*. Seven systems were evaluated based on the most important factors from the following sewerage planning viewpoints: availability of WWTP site, urbanization level, and availability of trunk sewer route. The results are also shown in *Table 6.10*. It was concluded that the feasibility study is possibly for the six districts of Pavuna, Acarí, Sarapuí, Bangu, Alcântara and Bomba from the above mentioned viewpoints.

Table 6.10 Evaluation on Physical/Developmental Conditions in Sewer Districts

Sewer System	Sewer District	Site for WWTP	Urbanization Level	Trunk Sewer Route	Remarks	Priority
Pavuna -Meriti	**Pavuna**	○	○ Highly urbanized	○	Partly implemented under PDBG I	○
	Acarí	○	○ Highly urbanized	△	WWTP, constructed in 1970s, under operation	○
Sarapuí	**Sarapuí**	○	○ Highly urbanized	○	Partly implemented under PDBG I	○
Bangu	**Bangu**	○	○ Highly urbanized	○	Highly prioritized, as located at upstream of the Rio Acarí and district is mostly urbanized	○
Bota	**Iguaçu 02**	× Not Identified	× Undeveloped	×	Scattered colonies. Further investigation on district needed.	×
	Madame	× Not Identified	× Undeveloped	×	Scattered colonies. Further investigation on district needed.	×
	Velhos	× Already Urbanized	○ Highly urbanized	×	Location of WWTP and trunk sewer route be further studied.	×
	Bota	○	○ Highly urbanized	×	Two WWTPs, Babi and Orquidea, to be constructed under PNB	×
	Joinville	○ Changed	○ Highly urbanized	-	WWTP constructed five years ago under PNB. Not operated yet	×
Iguaçu	**Xerém**	○	× Undeveloped	×	Scattered colonies. Further investigation needed.	×
	Campos Elíseos	○	× Undeveloped	×	Flat district. District could be divided into sub-districts.	×
Alcântara	**Trindade**	○ Changed	○ Highly urbanized	×	Flat district. District could be divided into sub- districts	×
	Alcântara	○	○ Highly urbanized	○	Most viable district in eastern region of Bay.	○
	Jardim Nazaré	× not sufficient	○ Highly urbanized	×	Located in mountain areas and many pumps needed. Can be divided into sub-districts	×
Imboassu	**Bomba**	○ changed	○ Highly urbanized	○	WWTP site to be selected.	○

Note: 1. PNB for Nova Baixada Program
2. Priority : ○ high, △ medium , × low.
3. Site for WWTP; ○ does not necessarily mean that the site is already acquired.

6.3.5 IMPLEMENTATION PROGRAM

Among seven sewer systems including fifteen sewer districts which CEDAE raised for priority projects, six districts of Pavuna, Acarí, Sarapuí, Bangu, Alcântara and Bomba can be prioritized from technical viewpoints as shown in *Table 6.10.* However, taking the huge amount of construction work into account, it was judged that four districts of Pavuna, Acarí, Sarapuí and Bangu are recommended for first stage program. Another eleven districts out of fifteen will be implemented in the second stage and the rest in the third stage.

It is assumed that the first stage construction will start in 2004 and be completed by 2010, the second stage from 2011 through 2020, and the third stage from 2021 to 2035 as shown in *Figure 6.5* below.

This arrangement then permits the Guanabara Bay Basin area a maximum flexibility in construction arrangements. This phasing, with the inherent flexibility of the system, will permit periodic re-evaluation of the implementation plan as required.

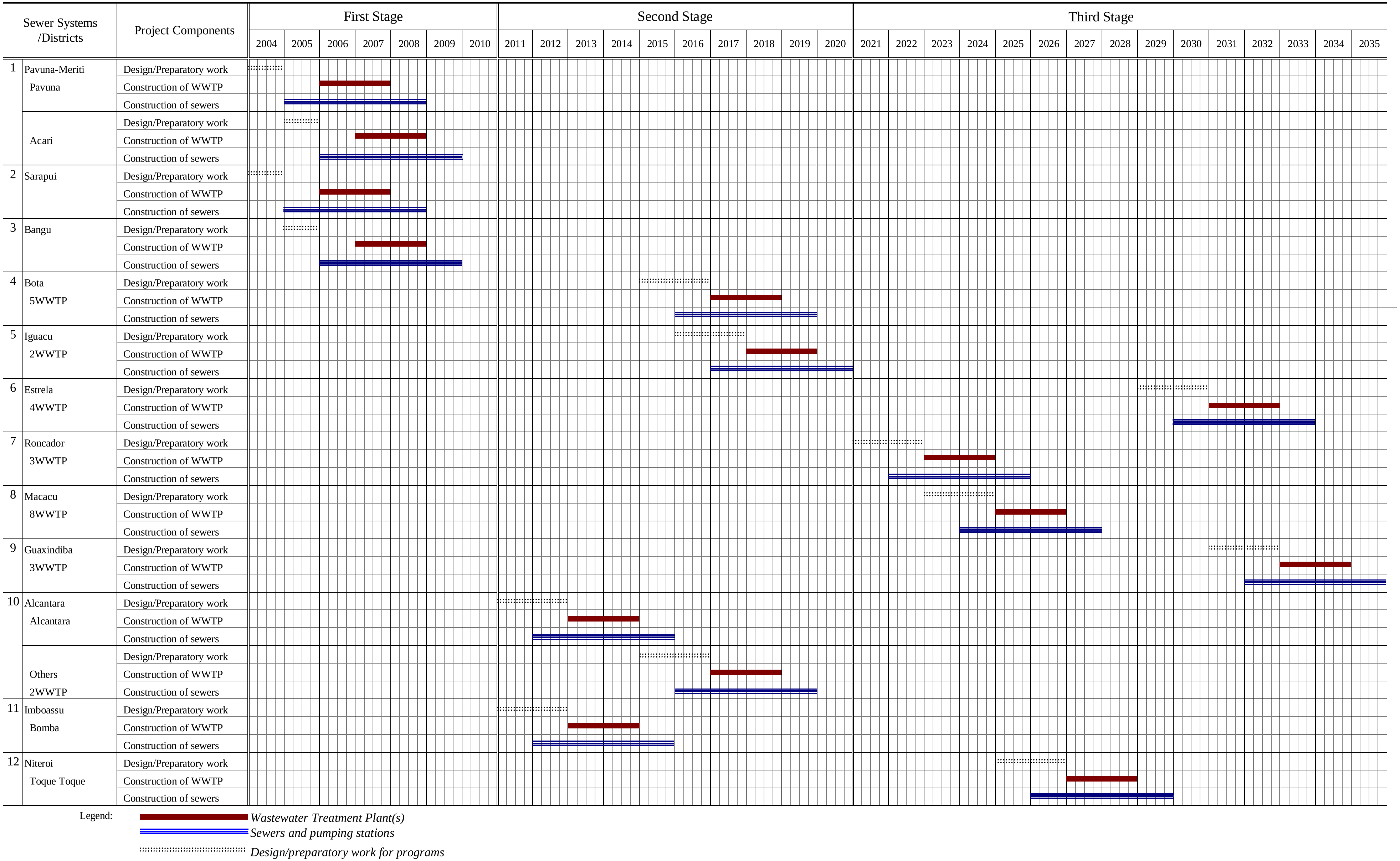

Figure 6.5 Project Implementation Schedule

6.4 PROJECT COST ESTIMATES

6.4.1 CONSTRUCTION RESOURCES

(1) Construction Materials/Equipment

Most of the construction materials for civil and architectural works, such as cement, aggregate, ready-mixed concrete, reinforcing steel bars, sewer pipes, and concrete blocks for manholes and auxiliary facilities, are available in Rio de Janeiro. Certain particular types of equipment such as electronics, instrumental and mechanical equipment for WWTPs and pumping stations, will be imported.

The equipment and materials for sewer construction works, such as excavator, dozer, wheel loader, mobile generator, submersible pumps, etc., are readily available in the Region with experienced operators except for shield and jacking methods.

(2) Capability of Contractors

The sewerage project involves the construction of large-scale and complex facilities, including pumping stations and activated sludge WWTPs, which require skills and experience of the contractors. Several sewerage and water supply constructions are currently ongoing under the PDGB Phase I, including WWTPs, shield tunneling, and pipe jacking by local contractors.

Hence, it is judged that the local contractors have sufficient experience in the sewerage facility construction works, with equipment and key staff to carry out the construction works. Although a considerable labor force will be needed when the new sewerage project starts, there would be no difficulties in finding skilled engineers, technicians and laborers.

(3) Construction Methods

Sewer pipes will be installed by either open-cut or tunneling methods depending upon the local conditions. The open-cut method is applicable where the sewer size is small and the traffic condition allows doing it. Most of the small-size sewers could be laid using this method.

The shield tunneling/pipe jacking methods may be used for large and deep sewer constructions, and where traffic is heavy and cannot be detoured. These methods may be applied particularly for deep main/interceptor sewer constructions.

Since pumping station structures generally become deep, sheeting and bracing are to be provided to prevent cave-in of the excavation walls or subsidence of adjacent area.

As most of the construction sites for WWTPs are rather removed from residential or commercial zones, the works may not give serious adverse impacts to the surrounding areas. The excavation for WWTP facilities may be carried out by open-cut method.

It is expected that the groundwater elevation is generally high with weak ground conditions in low-lying areas. Therefore, appropriate dewatering methods should be practiced all through the construction works, particularly for those of deep structures.

6.4.2 PROJECT COSTS

(1) Project Cost Components

The sewerage project costs consist of the following components:

- Direct construction costs
- Land acquisition
- Administrative expenses
- Engineering services
- Physical contingency

(2) Basis for Cost Estimates

The project costs are estimated for the following conditions:

- All the base costs are expressed under the economic conditions in July 2002 prevailed in the Region.
- The currency exchange rates - at mid-2002 price level - applied for the cost estimates are: One United States Dollar (US$) = 2.9 Brazilian Real (R$) = 120 Japanese Yen (\).
- The engineering service costs include those for basic planning, detailed design, tender documentation/assistance, and construction supervision, which are assumed to be 10% of the direct costs.
- Government administration costs, including those for personnel and organization for the project management, commissions for external loan, etc. should be prepared by the government and/or executing agency. For the master planning purpose, the rate is assumed to be 5% of the direct construction costs.
- The physical contingency allowance is assumed to be of 10% of the direct costs.
- Material and equipment direct costs already include ICMS of 17%.

(3) Direct Costs

The direct construction costs for each component are estimated taking into account the following conditions:

- The direct construction costs of WWTPs, pumping stations and main sewers are estimated either by the cost-capacity formulae developed for the Project or based on the actual contracted costs for recent construction works.
- The land requirements for new WWTPs are estimated using area-capacity function as developed for M/P purpose.

Construction costs comprise all the following necessary expenses:

- Mobilization and demobilization costs
- Preparatory works
- Miscellaneous works
- Main works.

The costs for civil and architectural works are estimated by multiplying the quantity of works by unit construction costs. However, if no published standard market prices for the special mechanical/electrical equipment for WWTPs or pumping stations, appropriate equipment prices are determined by quotations obtained from the manufacturers that have similar work experience in Brazil and/or neighboring countries. Both indirect costs of site expenses, and overhead/profit of the main works are added.

Estimated costs are summarized in *Table 6.11*. Total costs are around US$ 1,257 million of which cost for WWTPs construction accounts for 39% and that for sewers construction for 61%.

Table 6.11 Construction Costs by Sewer District

Sewer System	Sewer District	Service area (ha)	WWTP capacity (L/s)	Land required (m^2)	Unit Cost US$/$m^2$	Direct Cost: WWTPs	Direct Cost: Sewers	Direct Cost: Pumping St	Direct Cost: Sub-Total	Land Acquisition	Total
Alegria	Alegria										
Penha	Penha										
Pavuna-Meriti	Pavuna	4,100	1,500			14,872	90,449		105,321		105,321
	Acarí	3,800	1,100			28,293	72,918		101,211		101,211
	Sub-Total	7,900	2,600			43,165	163,367		206,532		206,532
Sarapuí	Gramacho										
	Sarapuí	600	1,000			11,741	14,416		26,157		26,157
	Sub-Total	600	1,000			11,741	14,416		26,157		26,157
Bangú	Bangú	1,700	1,000	53,400	10	26,285	54,795		81,080	650	81,730
Bota	Iguaçu		350	32,000	10	17,951	23,707		41,658	320	41,978
	Madame		40	11,200	10	3,742	2,709		6,451	112	6,563
	Velhos		110	18,200	10	7,775	7,451		15,226	182	15,408
	Bota		2,400	81,700	10	72,198	162,565		234,763	817	235,580
	Joinville		210			12,408	14,224		26,632	0	26,632
	Others										
	Sub-Total		3,110	143,100		114,074	210,656	0	324,730	1,431	326,161
Iguaçu	Xerém		30	9,700	10	3,039	1,446	159	4,644	97	4,741
	Campos eliseos		610	42,000	10	26,822	29,407	3,233	59,462	420	59,882
	Others										
	Sub-Total		640	51,700		29,861	30,853	3,392	64,106	517	64,623
Estrela	1		260	27,700	10	14,480	20,149		34,629	277	34,906
	2		400	34,200	10	19,770	30,998		50,768	342	51,110
	3		320	30,700	10	16,825	24,799		41,624	307	41,931
	4		120	19,000	10	8,280	9,299		17,579	190	17,769
	Others										
	Sub-Total		1,100	111,600		59,355	85,245	835	145,435	1,116	146,551
Roncador	1		50	12,400	10	4,397	3,138		7,535	124	7,659
	2		190	23,800	10	11,542	11,925		23,467	238	23,705
	3		60	13,600	10	5,016	3,766		8,782	136	8,918
	Others										
	Sub-Total		300	49,800		20,955	18,829	1,036	40,820	498	41,318
Macacu	1		210	25,000	10	12,408	17,564		29,972	250	30,222
	2		160	21,900	10	10,194	13,382		23,576	219	23,795
	3		90	16,600	10	6,725	7,527		14,252	166	14,418
	4		70	14,600	10	5,608	5,854		11,462	146	11,608
	5		100	17,400	10	7,257	8,363		15,620	174	15,794
	6		120	19,000	10	8,280	10,036		18,316	190	18,506
	7		50	12,400	10	4,397	4,182		8,579	124	8,703
	8		70	14,600	10	5,608	5,854		11,462	146	11,608
	Others										
	Sub-Total		870	141,500		60,477	72,762	1,643	134,882	1,415	136,297
Guaxindiba	1		430	35,400	10	20,831	30,055		50,886	354	51,240
	2		100	17,400	10	7,257	6,989		14,246	174	14,420
	3		40	11,200	10	3,742	2,796		6,538	112	6,650
	Others										
	Sub-Total		570	64,000		31,830	39,840	318	71,988	640	72,628
Alcántara	Trindade		400	34,200	10	19,770	27,731	436	47,937	342	48,279
	Alcántara		240	26,700	15	13,666	16,638	261	30,565	401	30,966
	Jardim nazare		300	29,700	10	16,058	20,798	326	37,182	297	37,479
	Others										
	Sub-Total		940	90,600		49,494	65,167	1,023	115,684	1,040	116,724
Imboassu	Sao Gonçalo										
	Bomba		110	18,200	10	7,775	5,663	635	14,073	182	14,255
	Others										
	Sub-Total		110	18,200		7,775	5,663	635	14,073	182	14,255
Niteroi	Toque Toque		530	39,200	10	24,230	5,752	1,128	31,110	392	31,502
	Icaraí										
	Sub-Total		530	39,200		24,230	5,752	1,128	31,110	392	31,502
Ilha do Governador	Ilha do Governador										
Paquetá	Paquetá										
Total		10,200	12,770	763,100		486,427	752,929	10,010	1,249,366	7,881	1,257,247

(Unit: US$ 1,000)

(4) Project Costs

The total project cost for the whole sewerage system is estimated to be US$ 1,579 million, whereas the Phase I project costs for Sarapuí, Acarí, Pavuna, and Bangu districts/system is US$ 360 million.

The breakdown of the project costs by components is shown in *Table 6.12*.

Table 6.12 Project Costs (in US$ 1,000)

Components		Costs by Stage			Remarks
		First Stage	Future Stage	Total	
I	**Direct Costs**				
1.1	**WWTPs**	81,841	404,586	486,427	
1.2	**Collection systems**	232,578	530361	762,939	
	Total of direct costs	**314,419**	**942,828**	**1,257,247**	
II	**Indirect Costs**				
2.1	Land acquisition	650	7,231	7,881	
2.2	Administrative expenses	15,722	47,140	62,862	5% of direct costs
2.3	Engineering services	31,443	94,282	125,725	10% of direct costs
2.4	Physical contingency	31,443	94,282	125,725	10 % of direct costs
	Total of indirect costs	**79,258**	**242,935**	**322,193**	
III	**Total Project Costs**	**393,677**	**1,185,763**	**1,579,440**	

Note: Costs at mid-2002 price level. Percentages for indirect costs determined by JICA Study Team.

(5) Operation and Maintenance Costs

Major portions of the sewerage system O/M costs are those for electric power charge, personnel, equipment, chemicals, repairs, cleaning, and other miscellaneous purposes. Since the CEDAE's average annual O/M expenses for the sewerage systems is reportedly at about 5% of the direct costs, the annual O/M cost for the Phase I facilities is estimated to be US$18 million per a year.

6.5 PROJECT EVALUATION

Strategic Plan to improve the Guanabara Bay by the sewerage system development has been proposed. Viability of the plan is evaluated from following viewpoints in this section:

- Technical appropriateness
- Achievement of the improvement target
- Economic and financial soundness
- Social consideration
- Organizational and institutional aspects
- Environmental impact consideration

6.5.1 TECHNICAL EVALUATION

(1) General

The proposed strategic plan is based on the maximum use of the existing and new sewers, which will convey the wastewater mostly by gravity to WWTPs. The proposed WWTPs are of the conventional activated sludge process that are generally situated at the farthest removed locations from high population-density urban districts to minimize adverse impacts to the existing and future residences.

The technical soundness of the proposed wastewater management system project is examined with regard to the following viewpoints:

- Appropriate technology levels
- Likely ease of project implementation
- Soundness of operation and maintenance required running the proposed system.

(2) Overall Pollutant Load Reduction

Upon completion of the proposed sewerage improvement program, the sewerage system will cover about 2,970 km^2 area with about 8.14 million population by the year 2020. Out of the expected 440 ton/day BOD produced from the average daily wastewater flow of 24 m^3/s, about 90 percent or 396 ton/day would be removed. Thus, the sewerage system, when the entire improvement plan completed, would significantly contribute to the improvement of Gunabara Bay water quality and urban sanitary conditions.

(3) Proposed Sewerage Facilities

The proposed sewerage project represents the effective alternative plan meeting the wastewater and environmental management requirements in Rio de Janeiro City and its surrounding areas. Each of the component facilities is evaluated and confirmed its appropriateness and soundness for the implementation.

1) Wastewater Collection System

The proposed wastewater collection system is of the separate system that intends to collect the dry weather flows, but no stormwater runoff is collected. The collection systems are planned in principle to flow the wastewater by gravity to the maximum extent practicable to reduce the energy needs to pump up the wastewaters; thus, making the system operation and maintenance easy and less costly.

For the areas without access to the public sewer system, provisions will be made to collect the sanitary wastes that are disposed of either directly or through pipes to the nearby surface drains or rivers. The wastes will be collected through intakes and led to the public sewers running near such areas. These facilities not only reduce the uncontrolled wastes discharges, but contribute to improve sanitary conditions.

2) Wastewater Treatment Plants (WWTPs)

The conventional activated sludge process is applied for the WWTPs. The process has a high performance of waste loads reduction, which is one of the best presently available secondary treatment process options for the Guanabara bay water quality improvement. Furthermore, the process can be easily upgraded for removing such nutrients as nitrogen and phosphorous in the wastewaters, if and when it becomes desireable. The whole excess sludge, after being stabilized, will be dewatered and may be safely disposed of to the municipal disposal places.

3) Implementation Schedule

The project will be implemented by stage according to the urgency of needs and benefits to be derived from the sewerage provision, thus spreading capital expenditures over an extended period. The whole project would be implemented in three consecutive stages from 2004 through 2035.

As the highest priority areas for program implementation, four sewer districts (namely, i) Pavuna, ii) Acarí), iii) Sarapuí, and iv) Bangu are selected for the First Stage Project. It is planned that the first stage project will be implemented over a period of seven years starting in 2004 with full completion being achieved by the end of the year 2010.

Interim commissioning of the project facilities is to be carried out during the first stage period to enable earliest possible utilization of the new facilities and early introduction of cost recovery measures.

It is envisaged that the implementation of the project will proceed rapidly, since the major works will be carried out under several parallel works covering the construction of the wastewater collection and treatment facilities.

4) Land Acquisition And Rights

The main sewers and pumping stations will be constructed within the road reserves or on government-owned lands. Most of the high priority WWTPs sites are already owned by CEDAE or ready to be acquired, in particular for those under the first stage project. There would be no significant resettlement problems for the land acquisitions and adverse environmental impacts to the surrounding areas for using the lands as the WWTP sites.

For some WWTPs in the latter stages, lands would have to be secured at early stages when the plans are finally decided so that no resettlement will occur, and adverse environmental impacts could be avoided. The WWTP land sites for the first stage project are already acquired or available to acquire.

5) Overall Technical Evaluation

The proposed sewerage project will help alleviate the existing adverse water quality and sanitary conditions in Gunabara Bay tributary. The proposed sewerage improvement project will provide cost-effective wastewater collection and treatment facilities to service the most densely populated and severely degraded urban districts in Rio de Janeiro and its neighboring areas, which are compatible with a long-term strategy to serve the entire Area.

From the foregoing facts and discussions, it is evident that the proposed first stage project is justified, technically sound, and will contribute to a large extent to the improvement of currently deteriorated sanitation and environmental conditions of Rio de Janeiro City and its surrounding districts.

6.5.2 WATER QUALITY IMPROVEMENT

Water quality of the strategic plan is to achieve the middle term target by 2020. To evaluate the effect of the strategic plan, water quality simulation was carried out under the condition where generated pollutant load is based on 2020 conditions and all the systems to be completed by 2020 are in operation. *Figure 6.7* shows the result of the simulation. Figure shows the result of the simulation for the systems completed with advanced treatment, too, for reference purposes.

In the middle-term target, the bay water quality is expected to be BOD less than 5 mg/l except western and deep eastern areas where BOD is expected to be less than 10 mg/l. *Table 6.13* compares the monitoring points between the estimated water quality and the middle-term target quality. Although not completely, the strategic plan is judged to almost achieve the middle-term target.

Table 6.13 Comparison of Water Quality of Strategic Plan and Middle-Term Water Quality Target

Monitoring Points[1)]	Water Quality by Strategic Plan	Middle-Term Target (BOD less than mg/l)
GN-064	2	5
GN-022	4	5
GN-043	8	10
GN-040	10	10
GN-020	8	10
GN-042	6	5
GN-000	6	5
GN-026	5	5

Note: For the location of each monitoring point, refer to *Figure 4.34.*

6.5.3 FINANCIAL AND ECONOMIC ANALYSIS

(1) Financial Analysis

Although CEDAE and the State Government of Rio de Janeiro are separate financial bodies, they are treated as a single financial body in this chapter. Because the State Government has to support CEDAE in case of management crisis, such assumption makes analysis easier. Project period is set as 17 years, from 2004 to 2020.

1) Calculation of Cash Outflow

Cash outflow consists of construction cost, operation and maintenance cost, and residual value which is listed only in the end of the project period, 2020.

Construction Costs

Construction costs are divided into direct cost (wastewater treatment plant (WWTP) and sewer), contingency (10% of direct cost), administration cost (5% of direct cost), engineering service cost (10% of direct cost).

O&M Costs

The Study Team set the following assumptions for operation and maintenance costs (O&M costs):

- O&M costs consist of direct O&M cost and additional O&M cost.
- Direct O&M cost is used for operation and maintenance of facilities, and it consists of personnel expense, energy cost, and expense for chemicals. It is 5% of direct construction cost.
- Additional O&M cost is user for administration, and issuance and collection of water bill. It costs 50% of direct O&M cost[1].

Residual Value

Introduction of lifetime of sewerage facilities is calculated under the assumptions in *Table 6.14*. Construction of WWTP is divided into civil works and building works, mechanical equipment and electrical equipment, and each cost occupies 40%, 50% and 10% respectively, according to experience in PDBG and other sewerage developments. On the other hand, lifetime of each

[1] According to the financial statement in 2001, proportion of administration cost to facility O&M cost was 25%. Proportion of commercial cost to facility O&M cost was 65%, but additional commercial cost will be lower than the level, because CEDAE has already have the system for invoicing and collection of water bill.

facility is 50 years, 15 years, and 15 years. Then weighted lifetime of 29 years is adopted as the lifetime of WWTPs. The result is calculated from:

$$40\% \times 50 + 50\% \times 15 + 10\% \times 15 = 29$$

Construction of sewer network consists of only civil works, and lifetime of sewer is estimated to be 50 years. Thus, 50 years lifetime is adopted for the sewerage network.

Residual value is calculated from difference between lifetime and the period of operation until 2020. Diminishing method is adopted here; thus, construction cost of facilities is divided by lifetime and divided value, construction cost per year, is accumulated by the rest of lifetime after 2020. Residual value is calculated in every Sewer District.

According to the implementation plan of *Figure 6.5*, Pavuna Sewer District and Bangu Sewer District will start operation in 2008, and other Sewer Districts will start operation one after another after 2009. Total residual value calculated under the lifetime assumption is US$713.5 million, and it is listed at the end of the project period.

Table 6.14 Cost Structure and Lifetime of Sewerage Facilities

Facilities		Cost Share (%)	Lifetime of Facilities (Year)	Adopted lifetime (Year)
WWTP	Civil and Architectual works	40	50	29
	Mechanical equipment	50	15	
	Electrical equipment	10	15	
Sewers	Civil works	100	50	50

Source: JICA Study Team

2) Cash Inflow

Cash inflow comes from operational revenue. It will be generated from 2008 when WWTP and sewer network starts operation[2]. The Study Team set the following assumptions for the operational revenue:

- CEDAE can collect user charge which is R$1.14 (US$0.39) per 1 m^3. It is the same level as average wastewater bill rate in 2001.
- Unearned water bill rate will decrease by 11%, from 21%to 10% until 2008.
- Volume of wastewater follows the result of the analysis in the *Supporting 7*.

3) Net Cash Flow of the Strategic Plan

Table 6.15 reports cash outflow, cash inflow and net cash flow. FIRR, which is calculated from net cash flow, is only 0.5%.

[2] In 2008 Pavuna WWTP and Sarapuí WWTP will start operation. It is assumed that WWTPs can work more than 90% of capacity, by use of existing sewer network, although sewer network in these districts has developed 75% of completion at that time.

Table 6.15 Cash Flow: Case 1

Year	Cash outflow	Cash inflow	Net cash flow
2004	3,287	0	-3,287
2005	37,416	0	-37,416
2006	86,431	0	-86,431
2007	116,806	0	-116,806
2008	112,773	13,187	-99,587
2009	65,914	37,286	-28,627
2010	27,506	45,655	18,150
2011	23,345	46,048	22,704
2012	29,724	46,443	16,719
2013	41,837	46,841	5,003
2014	41,837	47,240	5,403
2015	43,413	50,241	6,827
2016	109,930	58,998	-50,932
2017	202,721	59,667	-143,054
2018	218,920	60,350	-158,570
2019	162,074	102,840	-59,234
2020	-630,854	103,550	734,404

Source: JICA Study Team (Unit: US$1,000)

4) Impacts of Other Financial Sources on Net Cash Flow

The Study Team examined the following impacts on the Strategic Plan. The first one is investment expenditure of the State Government. The second one is financial improvement of CEDAE. The Study Team will calculate FIRR of under combinations of these conditions.

Investment Expenditure

As for investment expenditure, the following cases are set:

- Case 1: Non investment Expenditure from the State Government.
- Case 2: Financial Support from the State Government.

In Case 1, it is assumed that the State Government would not disburse any investment expenditure for the strategic plan. In that case, cash inflow, cash outflow and net cash flow remains as shown in *Table 6.15.*

In Case 2, it is assumed that the State Government will disburse US$4 million (R$12 million) for the strategic plan. The State Government disbursed the same amount for PDBG in 2001 and in 2002. In Case 2, disbursement will start after 2005 when the State Government will disburse all local portions of PDBG.

Financial Improvement of CEDAE

The Study Team tried to add two financial sources which are strongly related to management improvement of CEDAE. The first one is decrease of unearned water bill rate[3]. And the second one is decrease of non-revenue water rate[4]. As written in the section 2.4.2, unearned water bill

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[3] Unearned water bill rate is percentage of unearned water bill amount to total invoiced amount. The reason of unearned water comes from refusing payment by users, and uncollected water bill, etc.

[4] Non-revenue water rate is percentage of non-revenue water volume to total production volume. The reason of non-revenue water comes from illegal connection, water leakage and unbilled water charge, etc.

rate of CEDAE in 2001 is 21%. It is more than 10% higher than SABESP and EMBASA. Non-revenue water rate in is also very high level (57% in 2001), and more than 20% higher than SABESP and EMBASA.

If unearned water bill rate decreases to 10%, and 50% of generated cash is allocated to the strategic plan, then US$9.7 million (R$28.1 million) of new cash inflow is listed on the cash flow table every year. And if non-revenue water rate will decrease to 35%, and 15% of generated cash new cash flow is allocated to the strategic plan, US$25.7 million (R$74.6 million) of new cash inflow is listed on the cash flow table every year.

The Study Team set up the following four cases:

- Case a: Unearned water bill rate and non-revenue water rate stays current level (refer to Figure 6.6(a)).
- Case b: Unearned water bill rate decreases to 10% (refer to Figure 6.6(b)), and 50% of generated cash is allocated to the strategic plan.
- Case c: Non-revenue water rate decreases to 35% (refer to Figure 6.6(c)), and 15% of generated cash is allocated to the strategic plan.
- Case d: combination of Case b and Case c (refer to Figure 6.6(d)).

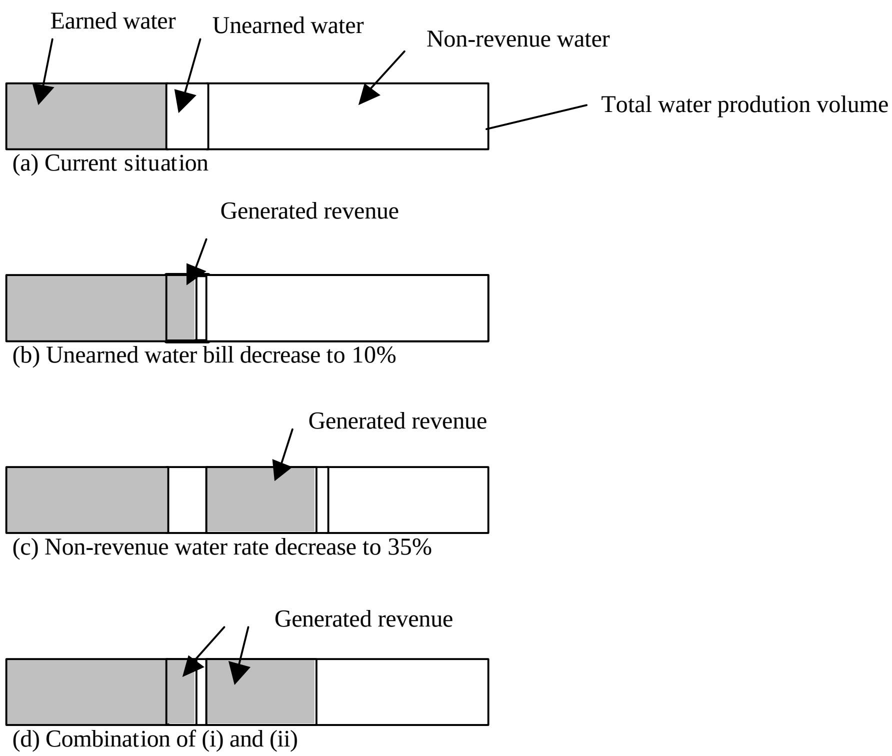
Combination of Two Impacts

Table 6.16 shows eight patterns of additional cash flows outside the Priority Projects. The table "Case 1a" means the combination of "Case 1 (non public investment)" and "Case (a) (Unearned water bill rate and non-revenue water rate stays current level)". FIRR of each case is calculated and evaluated in the sub-section 6).

Table 6.16 Combination of Two Impacts

	Case 1: Non investment Expenditure	Case 2: Investment Expenditure
Case a: Unearned water bill rate and Non-revenue water rate stays current level	1a	2a
Case b: Unearned water bill rate decreases to 10%	1b	2b
Case c: Non-revenue water rate decreases to 35%	1c	2c
Case d: Combination of Case b and Case c	1d	2d

Source: JICA Study Team



Source: JICA Study Team

Figure 6.6 Change of Unearned Water Bill Rate and Non-revenue Water Rate

5) User Affordability

In this financial analysis, rise in water bill rate is not considered. Therefore sewerage users could accept the strategic plan easily, and user burden is an affordable level.

Indeed, new sewerage users have to pay user charge, but it is the same rate with existing users. Some persons have financial burden by the decrease of unearned water bill rate and non-revenue water rate. But such users should pay water bill equable to services they have, and all users should bear the cost burden of sewerage service. Of course CEDAE has to consider introducing and improving special water bill system for poor families, just as the commercial department is planning to introduce in *Favela* area.

6) Evaluation and Conclusion

As of June 2003, the difference between SELIC rate (basic interest rate in Brazil) and IPCA (representing indicator of Consumer Price Index, CPI) is 8.53%. Loan conditions of state banks for CEDAE are summarized in *Table 6.17*. Therefore the Study Team estimated that long-term real interest rate for CEDAE and the State Government is set as 8%.

Table 6.17 Loan Conditions of Sewerage Network Construction

Name	Real interest rate	Loan period	Grace period
Caixa Econômica Federal	6.5	120 months	24 months
Banco do Brasil	10.12	240 months	None

Source: CEDAE

Table 6.18 shows FIRR of the strategic plan in eight cases. In the following two cases, FIRR exceeds 8%:

- "The State Government disburses investment expenditure", and "Non-revenue water rate will decrease to 35%" (FIRR is 8.3%).
- "The State Government disburses investment expenditure," "Unearned water bill rate will decrease to 10%", and "Non-revenue water rate will decrease to 35%" (FIRR is 10.8%).

Table 6.18 Comparison of FIRR

Case	Case 1: Non investment Expenditure	Case 2: Investment Expenditure
Case a: Unearned water bill rate and Non-revenue water rate stays current level	0.5	1.6
Case b: Unearned water bill rate decreases to 10%	2.8	4.0
Case c: Non-revenue water rate decreases to 35%	5.3	8.3
Case d: Combination of Case b and Case c	7.7	10.8

Source: JICA Study Team (Unit: %)

The result of FIRR reports indicate that the priority projects are feasible in case the State Government continues disbursing US$4 million (R$12 million) for the strategic plan. But it may be difficult for the State Government to continue it, due to limited financial resources.

In case the State Government cannot continue disbursement, CEDAE has to obtain loans from banks. Financial feasibility with bank loans is analyzed in the financial analysis of the Priority Projects of the next chapter.

Table 6.18 also shows that additional financial sources, which are generated from management improvement of CEDAE, have a big impact on improvement of FIRR. Therefore it is important for CEDAE to carry out management improvement along with the implementation of the strategic plan.

(2) Economic Analysis

Economic benefit is evaluated as Economic Internal Rate of Return, and it is calculated in the following procedure: conversion of project costs into economics cost, measurement of economic benefits, analysis of cash inflow and cash outflow, and evaluation of EIRR. In this analysis, project period is assumed to be 17 years, from 2004 to 2020, the same as financial analysis of the strategic plan.

1) Cash Outflow

Cash outflow consists of construction costs, operation and maintenance cost, and residual value, the same as financial analysis. In economic analysis, these costs are converted to economic cost.

Construction Costs

Primary, taxes imposed on construction costs are removed. As shown *Table 6.19*, construction of WWTP is divided into the three components: civil and building work, mechanical equipment and electrical equipment. Construction of sewer network consists of only civil and building work. The following taxes are imposed on each component:

- Custom for imported goods (20%)
- IDT[5] for civil and building work (5%)
- ICMS[6] and IPI[7] for mechanical equipment and electrical equipment, which are produced in Brazil (12%+7%).

Cost structure of the components is presented in *Table 6.19.* And only mechanical equipment includes imported goods, percentage of which is 40%.

Table 6.19 Cost Structure and Tax Rates

Items		Cost share	Share of imported goods
WWTP	Civil and building work	40	0
	Mechanical equipment	50	40
	Elwctrical equipment	10	0
Sewer	Civil and building work	100	0

Source: JICA Study Team (Unit: %)

Based on the assumption above, taxation on the construction costs is removed. If construction cost of WWTP and sewer network are 100 units, construction cost without tax payment for WWTP is 87 units, and for sewer network is 95 units. Economic cost of WWTPs is calculated with the following formula:

$$40 \times 50\% + 50 \times 50\% \times (12+5)\% + 50 \times 40\% \times 20\% + 10 \times (12+5)\% = 87.5$$

Second, unskilled labor cost is evaluated by opportunity cost. According to data of PDBG, unskilled labors receive R$336 per month, 60% higher than minimum wage at that time, but opportunity cost of them is less than minimum wage, R$200 per month. If personnel expenditure occupies 30% of total construction cost, and 50% of it is used for payment to unskilled labor, then economic construction cost of sewer network will decrease more than 10%. Therefore it is assumed that economic construction cost of WWTP is 87% of original cost, and that of sewer network is 85% of original cost.

5 IDT is tax for municipal governments and imposed on civil works.
6 ICMS is tax for State Governments. It is like a value added tax, and also imposed on trading of goods, communication and transportation services.
7 IPI is tax for the Federal Government. It is imposed on industrial goods.

Third, land acquisition cost is removed, because planned construction sites for WWTPs are not used for production activity now. Total land acquisition cost amounts to US$7,881, and occupies 0.6% of total direct cost.

O&M Costs

The same as financial analysis, the Study Team set up the following assumptions.

- O&M cost consist of direct O&M cost and additional O&M cost.
- Direct O&M cost is used for operation and maintenance of facilities, and it consists of personnel expense, energy cost, and expense for chemicals. Direct O&M Cost is 5% of direct construction costs.
- Additional O&M cost is used for administration, and issuance and collection of water bill. It costs 50% of direct O&M cost[8].

Residual Value

Residual value is calculated from lifetime of WWTP and sewer. The methodology is the same as financial analysis. Thus;

- The same lifetime of facilities (29 years for WWTPs and 50 years for sewer network) is used.
- Construction cost of facilities is divided by lifetime and rest of lifetime after 2020 and divided value, construct cost per a year, is accumulated for the rest of the lifetime.

The residual value amounts to US$609 million.

2) Cash Inflow

In this economic analysis, economic benefit was defined as "the value Guanabara Bay with improved water quality". The Study Team introduced Contingent Valuable Method (CVM) to assess the value, and conducted "Economic Benefit Survey" from June to August in 2003.

Economic Benefit of the Strategic Plan

In the Economic Benefit Survey, the Study Team classified beneficiaries into three categories: residents (people living in Rio de Janeiro State), Brazilian tourists, and international tourists. Willingness to pay of a person is based on the following question to interviewees, which consist of 238 residents, 103 Brazilian tourists and 58 international tourists.

"A Foundation constructs wastewater treatment plant near the bay and operates it to clean seawater. The plant is constructed and operated by contributions from households in Rio de Janeiro State and tourists. This project would improve water quality of Guanabara Bay, and people could have the following benefits:

- *People will enjoy swimming in beaches (Botafogo, Flamengo Niteroi, Copacabana, Ipanema, and Leblon). People won't doubt water quality.*
- *Eco-system in Guanabara Bay will recover and people can see more fishes and marine creatures in the bay.*
- *People won't smell bad odors and won't see dirty seawater."*

[8] According to the financial statement in 2001, proportion of administration cost to facility O&M cost was 25%. Proportion of commercial cost to facility O&M cost was 65%, but additional commercial cost will be lower than the level, because CEDAE has already have the system for invoicing and collection of water bill.

Results of the survey indicate that willingness of pay per a person is R$8 (residents), R$13 (Brazilian tourists), and R$25 (international tourists). Detailed methodology and result of the survey are indicated in the *Supporting 17*.

Assumed Economic Benefit

The status of water quality of Guanabara Bay in the questionnaire means the target of the strategic plan in 2020. Therefore "willingness of pay times number of persons" means "assumed economic benefit," if water quality of Guanabara Bay were improved to the same level as 2020. However, the sewerage development is proposed year by year in the Strategic Plan, and the target will be achieved only in 2020. Therefore economic benefit generated every year comes from proportion of treated wastewater volume to the volume in 2020.

3) Net Cash Flow and Economic Internal Rate of Return

Cash inflow, cash outflow and net cash flow of the strategic plan are summarized as *Table 6.20* and Economic Internal Rate of Return (EIRR) is 10.0 %.

Table 6.20 Cash Flows of the Strategic Plan

Year	Cash outflow	Cash inflow	Net cash flow
2004	2,807	0	-2,807
2005	31,235	0	-31,235
2006	73,822	0	-73,822
2007	100,248	0	-100,248
2008	95,936	26,064	-69,872
2009	56,742	58,977	2,235
2010	24,082	62,519	38,437
2011	21,130	64,558	43,427
2012	26,553	66,398	39,846
2013	36,899	68,303	31,404
2014	36,899	70,275	33,376
2015	38,232	76,263	38,031
2016	94,957	80,689	-14,268
2017	173,858	97,753	-76,106
2018	188,301	99,853	-88,448
2019	142,812	171,066	28,254
2020	-537,556	174,815	712,371

Source: JICA Study Team (Unit: US$ 000)

4) Sensitivity Test

The Study Team tested sensitivity of economic analysis in the following four cases:

- Case 1: Willing ness to pay of resident increases 50% to R$12 per a year
- Case 2: Construction cost increases 10 %
- Case 3: O&M cost increases 10%
- Case 4: Combination of Case1 and Case 2.

Table 6.21 shows results of sensitivity analysis. If willingness to pay of residents increases to R$12, EIRR will increase 2.8 points. On the other hand, construction cost and O&M cost increases 10 %, EIRR will down to 8.7% and to 9.4%, respectively. In combination of Case 1 and Case 2, EIRR will rise 1.3 points.

Table 6.21 Results of Sensitivity Analysis

Cases	EIRR
Case1: Willingness to pay of resident increase R$12	12.8
Case 2: Construction cost increases 10%	8.7
Case 3: O&M cost increases 10%	9.4
Case 4: Combination of Case 1 and Case 2	11.3

Source: JICA Study Team (Unit: %)

5) Marginal Opportunity Cost of Capital in Brazil and Conclusion of Economic Analysis

Marginal opportunity cost of capital in Brazil is set as 10%, reflecting low economic growth rate in recent years.

The value of EIRR is on the real opportunity cost of capital, and fulfills economic feasibility at minimum level. However, it is under the real opportunity cost if cash outflow increases. On the other hand, increase of willingness to pay will improve EIRR a lot. Case 1, willingness to pay of residents increases R$12, improves EIRR 2.8 point, and Case 4 improves EIRR 1.3 point.

Compared with Brazilian tourists and international tourists, willingness to pay of residents seems to be low. That comes from residents low awareness of the environment of Guanabara Bay. Environmental education program will enable residents to be aware of the importance of environment of Guanabara Bay, and to increase their willingness to pay to improve water quality of Guanabara Bay.

6.5.4 ADDRESSING THE SOCIALLY VULNERABLE

At the beginning of the Study, Favelas are envisaged to receive poorer public services compared to average people living in normal areas and thus special consideration to Favelas are required in planning of the sewerage development.

However, analysis of IBGE Census 2000 and the people’s awareness survey conducted in this study revealed that ratios of the public services in Favelas, such as water supply, sewerage and solid waste collection, are rather higher than the averages of Rio de Janeiro State and 16 municipalities in the Study area. This is supposed to be because Favelas are concentrated in more urbanized areas where naturally public service covering ratios are high and there are many intervention programs, which often have the implementation of the basic infrastructures as their components. As one of the negative characteristics of Favelas regarding public services, disordered and narrow streets are recognized.

As for the sewerage services, the people’s awareness survey showed a sewerage coverage rate in Favelas of approximately 85%. Therefore, a major concern in the sewerage system planning is technical matters rather than social consideration of equity of the public service. There are two types of sewerage systems in Favelas: one is an independent type which has a treatment facility and has no connection to the CEDAE system and another is a system relies on CEDAE’s system, collecting sewage from Favelas and to discharging to CEDAE’s trunk sewers.

Considering the above mentioned situation, the strategic plan adopted the following concepts for the sewerage development in Favelas:

- Existing treatment facilities are left as it is by encouraging the improvement of their operation.
- Since sewer cannot be installed in disordered street, intervention programs install sewer when they improve streets.
- New intervention programs collect sewage and discharge it to CEDAE's trunk sewer.
- To enable the above, planning of sewer makes allowance for this sewage.

6.5.5 ORGANIZATIONAL AND INSTITUTIONAL CONSIDERATION

Currently, CEDAE is operating several wastewater systems and implementing construction of wastewater facilities in general. Therefore, CEDAE is judged to have a potential capability to manage the wastewater development proposed in the strategy plan. However, several issues to be addressed are found in the course of the Study. They cover a wide range from relation to the State to daily operation. In this section, issues related to the implementation of the project proposed in the strategy plan and operation of the facilities after the project are discussed; more general issues will be discussed in the next chapter.

(1) Project Implementation Stage

The most critical issue would be budgetary steps for financing the project. The strategy plan project is supposed to be implemented by the state budget, not by CEDAE's own budget, like a current PDBG project. Considering a delay of PDBG project due to shortage of local finance, in such wastewater development project to continue several years, a system to secure budget for continuing projects, not affected by policy change, is required.

There seems no division or section that controls planning of the sewerage development in CEDAE. Therefore, projects are being implemented without coordination with other projects. This may cause a lack of consistency of projects and loss of project resources.

In the progress of PDBG projects, scope of completed projects or to be completed projects differ much from the original scope. It is natural that there happen to be scope changes in the course of the implementation. However, many scope changes do not seem to have rational justification, resulting in unnecessary increase of the construction costs and delay of the construction. This is mostly because of improper planning and designing.

(2) Operation Stage

From a technical viewpoint, since CEDAE is operating several WWTP with primary process or secondary and sludge treatment process, in principal, it is judged that facilities of the strategy plan can be operated by the present skill of CEDAE. However, it may be necessary to provide intensive training to refresh the present skill of the present operators and to increase the number of operators.

There is no division or section to control the existing facilities and operational conditions. This causes and allows a critical failure of the sewerage operation that discharges untreated sewage to water bodies without consciousness of problems. Boost of awareness is essential.

Also this issue is a major cause of a lack of planned maintenance, rehabilitation and modification of facilities and improper operation of facilities.

Cost control of the operation does not exist. Cost-consciousness should be encouraged in sewerage operations.

Tariff system and tariff collection system should be improved to maintain fairness among the users and to increase revenue.

6.5.6 ENVIRONMENTAL CONSIDERATIONS

(1) General

Under the present study an initial environmental examination (IEE) has been conducted for the possible high priority sewer districts/systems throughout the study area, and identified the present environmental conditions in/around the project sites.

Based on the survey results, the possible positive and adverse impacts due to the sewerage project are identified, and the necessary investigations are proposed that are to be conducted under the environmental impact assessment (EIA) that would be carried out in the feasibility study.

The reduction of wastewater pollutant loads presently reaching the public water courses will significantly improve the quality of inhabitants living/sanitary conditions in the area, in addition to the improvement of the Guanabara Bay water quality.

The reliance on cesspits and simple septic tank units for the disposal of sanitary wastes in the districts of extremely high population density, and on-site treatment of waste of the unmanaged discharge of waste into the nearby rivers or ground, have resulted in high pollutant loads.

The sewerage improvement project is planned to collect and treat a part of the wastewaters in the unsewered low-income areas by providing wastes collector sewers at appropriate locations. These provision will significantly contribute to the improvement of unsanitary conditions in high population density low-income areas.

(2) Socio-economic Impacts

Although the large-scale industrial wastewaters are to be separately treated and disposed of directly to the public water bodies, the proposed sewerage system will receive portion of the industrial wastewaters of permissible small quantities and qualities within the sewer systems. This will surely reduce the amount of industrial pollutants, which otherwise would outflow to the bay, rivers and ground.

The improved system will result in reduced overall costs for factories in comparison to on-site treatment, although it will mean higher operating costs for factories that are currently spending inadequate amounts on treatment or have no treatment facility at all. Factories and commercial operations will also be required to pay for the costs of their connection to the trunk sewer or interceptors.

(3) Public Health Improvement

Some areas have above average incidence of water-related diseases, which are felt most keenly by the lower income groups. Low-income families tend to live in high population density areas, and suffer from greater exposure to wastewaters and poorer sanitation facilities.

The sewerage project will provide to some extent means for collection and removal of the wastewater from low-income areas, resulting in improvement in the poor environment currently experienced by poor families.

The effectiveness of the project in improving the health of the people of the area will be greatly be enhanced by combining a reduction in the source of pathogens with a reduction in the means of their transmission to humans. Other major benefits for the residents will be the reduction in noxious odors.

(4) Negative Impacts

Negative impact may potentially arise from the procurement of lands for WWTP facilities and through the disruption caused by the construction of wastewater collection facilities, particularly sewers and pumping stations in the urban districts.

Although the construction scale of the first stage is significant as a whole, it requires relatively large main sewers, the laying of which may cause disruption to some extent in what is already a heavily congested urban area. Contractors will be required to reduce disruption by working at nights to construct pipelines under the roads.

WWTP system itself may generate a certain level of pollution in the form of noxious odors from settling tanks, wastewater storage areas, and in the form of noise pollution arising from the operation of plant. The proposed WWTP sites have been chosen to minimize the effects of pollution on the residents or commercial activities in the surrounding areas.

The WWTP sites for the first stage project are selected generally removed more than 300 meters from the current residential areas except in some districts. However, it is quite likely that there would be some urban encroachment in the future, when the surrounding areas of the sites are developed as residential districts. The WWTPs are planned to minimize the creation of unnecessary noise and air pollution from plants operation.

6.5.7 OVERALL PROJECT EVALUATION

The proposed strategic plan covers sewerage development of entire study areas and improve the Guanabara Bay environment, achieving the middle term water quality target that eliminates the existing obnoxious conditions and further approaches to the Environment Standard by CONAMA.

Improvement of sanitation conditions of the basin and environment conditions generates an economic benefit and the plan is judged to be economically viable. Although investment costs would be a burden to the State and operation costs would worsen the CEDAE’s financial situation, it is possible to make it viable by improving the tariff system and collection.

From operational and manageable viewpoints, the plan can be managed and operated by CEDAE because CEDAE has worked out similar projects, in principal. However, there are several issues to be addressed to improve the management and operation capabilities.

The plan is equipped with the provision to Favela areas. While the implementation of the plan may cause minor negative impacts such as land acquisition for the WWTP sites, large scale construction work and noise and order around the WWTP sites, which will be investigated in details in the next phase of the study, so far is not expected to produce any major negative impacts.

In conclusion, the strategic plan is judged to be viable.

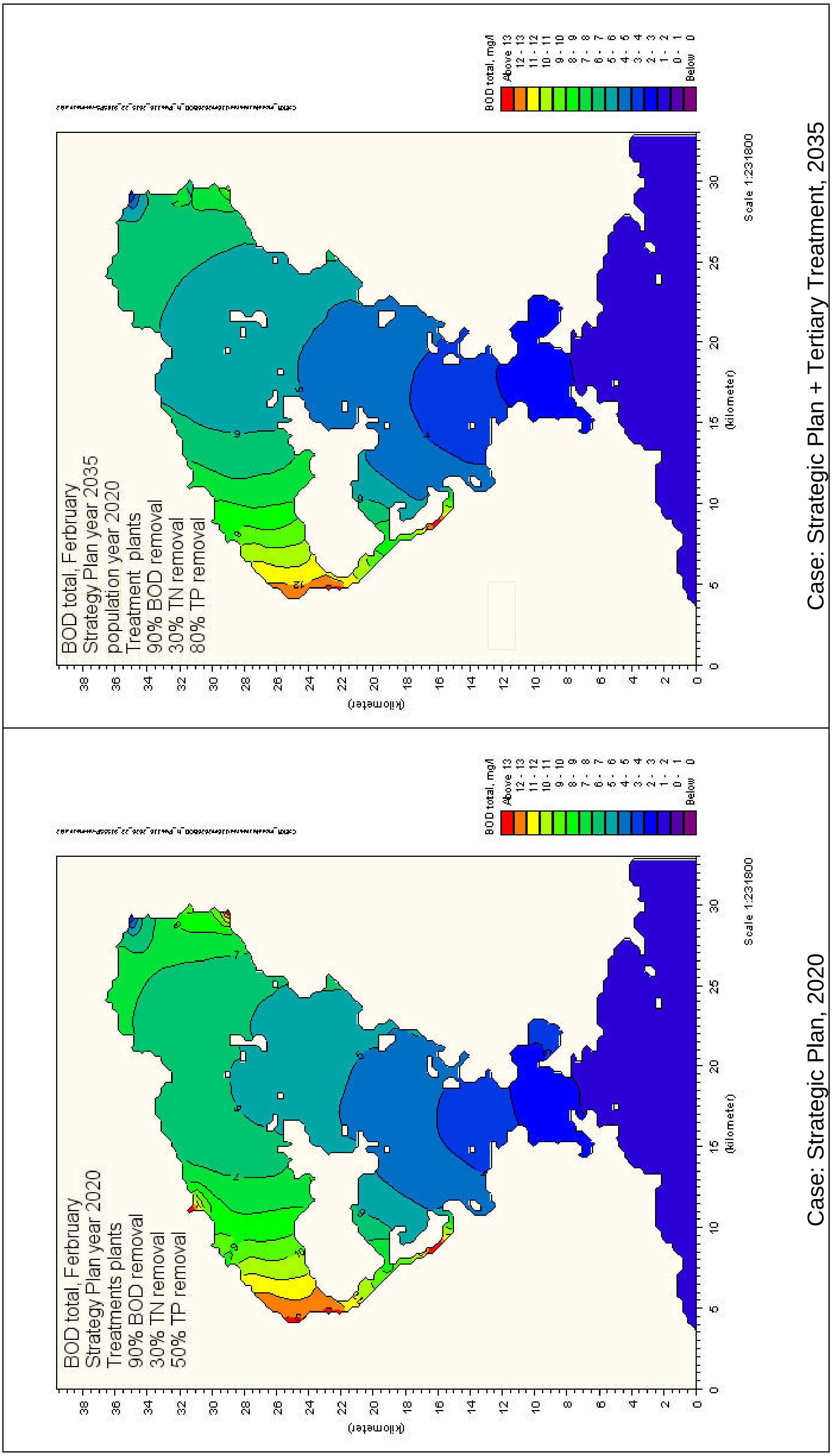


Figure 6.7 Result of Water Quality Simulation (Case: Strategic Plan, 2020 and Strategic Plan + Advanced Treatment, 2035)

6.6 SELECTION OF PRIORITY PROJECT

6.6.1 PRIORITY FROM ACHIEVEMENT SHORT-TERM TARGET

As discussed in Chapter 4 of this report, water quality in the western part of the Bay will never improved without pollutant reduction in the west zone of the basin. In the preliminary study in Chapter 4, BOD reduction rate of 80% has been adopted. This means that almost all the west zone of the basin is covered by the sewerage system.

Currently there are 5 systems (Alegria system, Penha system, Pavuna system, Acarí system and Sarapuí system) in the west zone. Among them, Alegria and Penha systems cover whole area with sewer system. However, in Acarí, Sarapuí and Pavuna systems, there are considerable areas that are not covered by sewer system. Moreover, Bangu system has neither sewer system nor WWTP. Therefore, expansion of Acarí, Sarapuí and Pavuna system and new installation of Bangu system could have higher priority to increase the pollutant load reduction rate from water quality viewpoint.

6.6.2 PRIORITY FROM SEWERAGE DEVELOPMENT PLANNING

As discussed in section 6.3, priority of each sewer district was investigated from technical viewpoints taking the following terms into account:

- population size
- population density
- availability of WWTP site
- availability of trunk sewer site
- application of experienced technology
- cost-effectiveness

Four sewer districts (namely, Pavuna, Sarapuí, Acarí and Bangu) were selected for priority projects. Former three have been partly implemented and the extension of WWTPs is highly cost effective with a considerable size of sewered population. The fourth one is a district with no existing facilities. Cost effectiveness is high because of high population density and sites for trunk sewers and WWTP are readily available.

6.6.3 WATER QUALITY IMPROVEMENT EFFECT OF PRIORITY PROJECT

Figure 6.8 shows result of the water quality simulation based on the load conditions under priority projects and *Table 6.22* shows comparison of estimated water quality at the monitoring point and the short-term target.

The short-term target aims to achieve BOD less than 10 mg/l over the whole Bay area. As shown in *Figure 6.8*, while BOD less than 10 mg/l is achieved in most of the Bay area, higher BOD appears in the strip along the northwestern coast. It should be noted that this area is shallow since such water depth goes down less than 20 cm during low tide and the area is calculated as river in the simulation model. Thus dilution by seawater does not happen. However, in the actual conditions, mixing with seawater could happen, diluting river water. Therefore, actual water quality is purposed to be lower than the simulated value.

In conclusion, it is judged that the short-term target could be achieved by the priority projects.

Table 6.22 Comparison of the Estimated Water Quality after Priority Project and the Short-Term Target

Monitoring Points [1)]	Estimated Water Quality (BOD mg/l)	Short-Team Target (BOD mg/l)
GN-064	3	10
GN-022	4	10
GN-043	8	10
GN-040	10	10
GN-020	8	10
GN-042	6	10
GN-000	6	10
GN-026	5	10

Note: 1) For the location of each monitoring point, refer to *Figure 4.3*.

6.6.4 CONCLUSION

Three sewer districts of Pavuna, Sarapuí and Bangu were selected as priority areas for sewerage implementation. It was judged that the priority project will be able to considerably reduce the pollutants and to achieve the short term water quality target in the Bay with technical appropriateness.

Table 6.23 summarizes the features of prioritized three sewer districts. Their location is shown in *Figure 6.9.*

Table 6.23 Proposed Priority Projects (2004 to 2010)

Sewer district	Sewered Population (person)	Sewered Area (ha.)			WWTPs Capacity (L/s)		
		Existing	Priority Projects	Total	Existing	Priority Projects	Total
1. Pavuna	1,029,600	4,900	3,660	8,560	1,500	1,500	3,000
2.Acarí	390,200	730	3,100	3,830	0	1,100	1,100
3. Sarapuí	825,900	7,300	640	7,940	1,500	1,000	2,500
4. Bangu	363,200	0	1,870	1,870	0	1,000	1,000
Total	2,608,900	12,930	9,270	22,200	3,000	4,600	7,600

Note: 7,300 ha in Sarapuí includes PNB area but does not necessarily discharge all the expected wastewater at present.

Source: The figures are obtained from CEDAE and adjusted updated by the M/P review results.

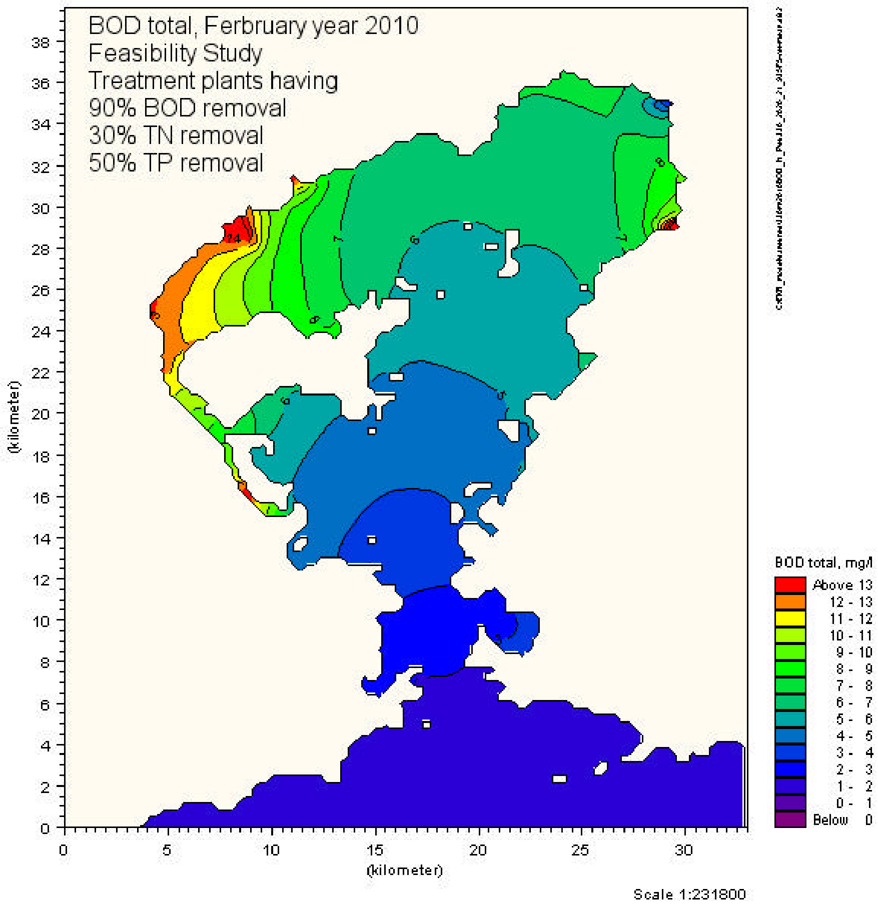


Figure 6.8 Result of Water Quality Simulation for the Priority Projects

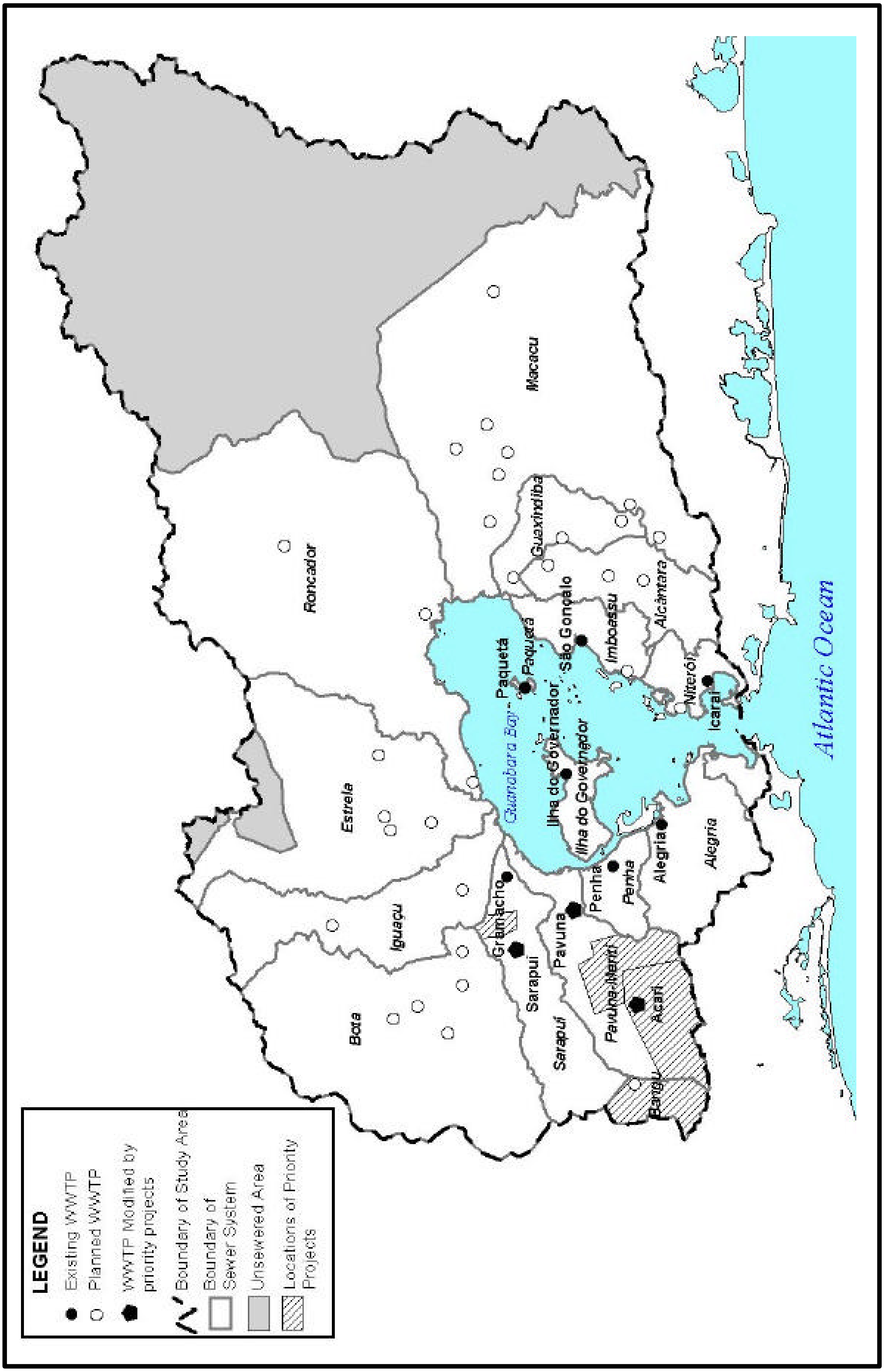


Figure 6.9 Location of priority Projects

CHAPTER 7

FEASIBILITY STUDY ON THE PRIORITY PROJECT

CHAPTER 7 FEASIBILITY STUDY ON THE PRIORITY PROJECT

7.1 INTRODUCTION

7.1.1 GENERAL

Under the long-term sewerage system improvement plan, the staged sewerage system implementation program has been envisaged and the high priority sewer districts were selected for the Priority Project (the “Project”).

The Project plans to construct the wastewater collection and treatment systems in four sewer districts: namely, i) Pavuna, ii) Acarí, iii) Sarapuí, and iv) Bangu. Basically, the Project encompasses the expansion of existing systems and construction of new facilities.

7.1.2 OBJECTIVES OF THE FEASIBILITY STUDY

The objectives of the Feasibility Study are:

- To prepare preliminary engineering design of the proposed sewerage systems
- To estimate the Project costs
- To prepare the implementation schedule of the Project
- To analyze feasibility of the Project and confirm that the selected program is economically, environmentally, financially and technically feasible to implement immediately
- To pursue technology transfer to the counterpart personnel in the course of the Study.

7.1.3 FEASIBILITY STUDY AREA

The F/S covers the four high priority sewer districts with the area of 9,270 hectares in the Guanabara Bay Basin as shown in *Figure 7.1*.

7.2 PRELIMINARY DESIGN

7.2.1 DESIGN FUNDAMENTALS

(1) Study Area

A sewer district is defined as an area that is covered by sewers, and the collected wastewater is treated by one WWTP. Boundaries of districts are determined taking the following conditions into account:

- Since the wastewater is in principle collected by gravity and conveyed to WWTPs, sewer districts boundaries are topographically almost the same as those of river basin watersheds.
- The areas with low population density and grassland, and much wastewater productions are not expected, therefore even in the future, are excluded from the district.

Even within a sewer district boundary, no sewer is required for certain areas without residents and where no significant urban development is expected to take place in the future. It is a 600 ha military asset in Acarí sewer district, from which no wastewater is or will be generated.

Pavuna and Sarapuí sewer districts are partly sewered under PDBG along with partly constructed WWTPs. In addition, Sarapuí sewer district has been partly sewered by Nova

Baixada Program, and 730 ha in Acarí sewer district was already sewered in 1970s. These sewered areas are excluded from the F/S as summarized in *Table 7.1* below.

Table 7.1 Existing and F/S Areas in Sewer Districts

Sewer System	Sewer District	Existing Sewered Area	F/S Area	Green Belt and Others	Total Sewer Dist.
Pavuna	Pavuna	4,900	3,660	0	8,560
-Meriti	Acarí	730	3,100	600	4,430
	Sub-Total	5,600	6,760	600	12,990
Sarapuí	Sarapuí	7,300	640	0	7,940
Bangu	Bangu	0	1,870	0	1,870
Total		12,930	9,270	600	22,800

(Unit: ha)

(2) Design Population

Design population to be sewered is estimated as follows:

- The population of each municipality is allocated to related sewer districts as shown in *Table 7.2*. Allocation ratio is determined taking the area and urbanization level into account.
- 90% of the allocated population is supposed to be sewered. Sewered population is shown in *Table 7.3*. The rest of it, or 10% of the allocated population is supposed to live in the area where it is topographically difficult to connect to the sewers. The area will be served by onsite sanitation systems. The ratio of 90% is the same as applied in CEDAE Master Plan.

Table 7.2 Design Population by Sewer District

Sewer System	Sewer District	2000	2005	2010	2015	2020
Pavuna	Pavuna	1,055,600	1,076,700	1,100,600	1,123,300	1,144,000
-Meriti	Acarí	400,000	408,000	417,000	425,700	433,500
	Sub-Total	1,455,600	1,484,700	1,517,600	1,549,000	1,577,500
Sarapuí	Sarapuí	788,700	822,800	858,400	889,100	917,700
Bangu	Bangu	378,500	384,400	391,300	397,900	403,600
Total		2,622,800	2,691,900	2,767,300	2,836,000	2,898,800

(Unit: person)

Table 7.3 Sewered Population by Sewer District

Sewer System	Sewer District	2000	2005	2010	2015	2020
Pavuna	Pavuna	950,000	969,000	990,500	1,011,000	1,029,600
-Meriti	Acarí	360,000	367200	375,300	383,100	390,200
	Sub-Total	1,310,000	1,336,200	1,365,800	1,394,100	1,419,800
Sarapuí	Sarapuí	709,800	740,500	772,600	800,200	825,900
Bangu	Bangu	340,700	346,000	352,200	358,100	363,200
Total		2,360,500	2,422,700	2,490,600	2,552,400	2,608,900

(Unit: person)

(3) Design Wastewater Flow Rates

Wastewater flow rates are estimated by multiplying per capita wastewater flow by population. Per capita wastewater flow rate is set referring to the CEDAE Master Plan, which estimated the wastewater flow rate based on the water supply data:

- Average daily per capita wastewater flow rate =220Lpcd
- Maximum daily wastewater flow rate = Average daily wastewater flow rate x 1.2
- Maximum hourly wastewater flow rate = Average daily wastewater flow rate x 1.8

The maximum hourly flow rate is applied for the collection system and connecting pipes within WWTPs, and average daily flow rate for most facilities of WWTPs.

ABNT (The Brazilian technical standards) guidelines recommend that the groundwater inflow rate be estimated based on per unit length of sewers, but the preliminary engineering of sewers does not give the exact length of sewers. The F/S therefore uses 20 Lpcd for the groundwater infiltration estimates, which is almost equal to 10% of the average daily per capita wastewater flow rate. The infiltration rate of 20 Lpcd is applied equally for the average daily, maximum daily and maximum hourly flows for the hydraulic calculations of sewerage facilities. For reference, JSWA (Japan Sewage Works Association) guidelines recommend to apply the ratio of 10 to 20 % of per capita wastewater flow rate.

Thus, the wastewater flow rates applied for the hydraulic calculations of the sewerage system are:

- Average daily flow rate is: 220+20 = 240 (Lpcd)
- Maximum daily flow rate is: (1.2 x 220)+20 = 284 (Lpcd)
- Maximum hourly flow rate is: (1.8 x 220)+20 = 416 (Lpcd)

Estimated average and maximum flow rates and maximum hourly flow rates of each system are shown in *Tables 7.4*, *7.5* and *7.6*, respectively.

Table 7.4 Average Daily Wastewater Flow Rates

Sewer System	Sewer District	2000	2005	2010	2015	2020	(2020) (in L/s)
Pavuna	Pavuna	228,000	232,560	237,720	242,640	247,104	(2,860)
-Meriti	Acarí	86,400	88,128	90,072	91,944	93,648	(1,084)
	Sub-Total	314,400	320,688	327,792	334,584	340,752	(3,944)
Sarapuí	Sarapuí	170,352	177,720	185,424	192,048	198,216	(2,294)
Bangu	Bangu	81,768	83,040	84,528	85,944	87,168	(1,009)
Total		566,520	581,448	597,744	612,576	626,136	(7,247)

(Unit: m^3/day)

Table 7.5 Maximum Daily Wastewater Flow Rates

Sewer System	Sewer District	2000	2005	2010	2015	2020	(2020) (in L/s)
Pavuna	Pavuna	269,800	275,196	281,302	287,124	292,406	(3,384)
-Meriti	Acarí	102,240	104,285	106,585	108,800	110,817	(1,283)
	Sub-Total	372,040	379,481	387,887	395,924	403,223	(4,667)
Sarapuí	Sarapuí	201,583	210,302	219,418	227,257	234,556	(2,715)
Bangu	Bangu	96,759	98,264	100,025	101,700	103,149	(1,194)
Total		670,382	688,047	707,330	724,881	740,928	(8,576)

(Unit: m^3/day)

Table 7.6 Maximum Hourly Wastewater Flow Rates

Sewer System	Sewer District	2000	2005	2010	2015	2020	(2020) (in L/s)
Pavuna -Meriti	Pavuna	395,200	403,104	412,048	420,576	428,314	(4,957)
	Acarí	149,760	152,755	156,125	159,370	162,323	(1,879)
	Sub-Total	544,960	555,859	568,173	579,946	590,637	(6,836)
Sarapuí	Sarapuí	295,277	308,048	321,402	332,883	343,574	(3,977)
Bangu	Bangu	141,731	143,936	146,515	148,970	151,091	(1,749)
Total		981,968	1,007,843	1,036,090	1,061,799	1,085,302	(12,561)

(Unit: m^3/day)

7.2.2 COLLECTION SYSTEM

(1) Design Criteria

In providing preliminary engineering design of sewerage facilities, ABNT and other international standards/specifications have been used wherever considered practicable. Conditions prevailing in the study area and design elements accepted by CEDAE determine the actual design. The design also took into account elements such as environmental compatibility, treatment efficiency, energy conservation, reliability of operation, and ease of system operation and maintenance (O&M).

The major design criteria and parameters applied for the sewer design are as follows:

- Velocity Formula (Manning’s formula, by ABNT)

  $v = (R^{2/3} I^{1/2})/n$

  where, ‘v’ is velocity in m/s., ‘R’ is radius (flow section divided by wetted perimeter) in meters, ‘I’ is gradient and ‘n’ is roughness coefficient (see *Table 7.7.*).

- Velocity limit and minimum flow (by ABNT)

  Minimum velocity is calculated so that the tractive force is greater than 1.0 Pascal to prevent solids from depositing.
  Maximum velocity should be lower than 5.0 m/s.
  Minimum flow capacity at the upstream is greater than 1.5 L/s.

- Water depth limit (by ABNT)

  Maximum water depth should be less than 75% of the pipe diameter.

- Earth cover (CEDAE)

  More than 1.5 m from river bottom.
  More than 0.5 m from drainage bottom.
  More than 2.0 m from railroad facility.

(2) Pipe Materials

For the selection of sewer materials, considerations are given to the problems of corrosion of pipes by sulfide buildup in sewers. Preference is given therefore to corrosion resistant and low roughness coefficient materials. Pipe materials are selected in general according to diameter, as shown in *Table 7.7.*

Table 7.7 Pipe Materials and Roughness Coefficients

Material	Diameter (mm)	Manning Formula’s Roughness Coefficient
PVC	150, 200, 250	0.010
Ceramics	300, 350	0.013
Concrete	400 to 2000	0.015
Cast iron	For all pressure pipes	0.012

Rubber gasket bell and spigot joint are to be used because of the ease and speed of jointing. Experience shows that the compression type and rubber gasket joints have in general superior performance in preventing groundwater infiltration into sewers.

(3) Route Selection of Trunk Sewers

For alternative engineering analysis of major facilities, such elements as routing of trunk sewer, capital and O&M costs, and foreseeable future developmental condition have been evaluated and compared each other to select the optimum plan.

The slope requirements to maintain gravity flow can require deep excavations in hilly or flat terrain, driving up construction costs. Sewage pumping stations may be necessary according to the slope requirements for conventional gravity sewers, which result in a system terminus (i.e., low spot) at the tail of the sewer, where sewage collects and must be pumped to a collection system. Pumping stations themselves require additional construction cost but possibly decrease the total construction costs of collection system.

Manholes associated with conventional gravity sewers are a source of inflow and infiltration, increasing the volume of wastewater to be carried, as well as the size of pipes and pumping stations, and, ultimately, increasing costs.

Sewers are in principle laid on the right-of-way, while in some cases, sewers are to be installed under vacant lots in order to avoid unnecessary detour. It needs to be ascertained that such vacant lots will not be used for housing or other developments in the future, and if there are any road construction plans. Crossing of rivers, drains and railroads have to be minimized because they are costly in both construction and maintenance.

Obtaining the legislature approval for pipe crossing works of public infrastructures may be time consuming work and require special considerations at the time of design and implementation. In particular, for river crossings, the number of crossing points is to be minimized, since the sewers are required to run 1.5 m below the riverbed, which in turn makes the sewer earth covering greater (*See Figure 7.2*).

It should be studied which method is easier to construct and less costly for construction and maintenance: case a) wastewater flows by gravity and earth cover becomes greater after river crossing, case b) wastewater is pumped before river crossing with smaller earth cover afterward.

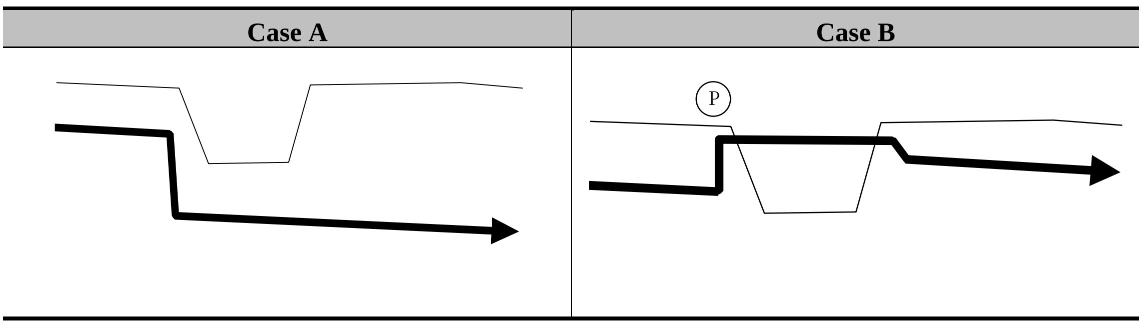


Figure 7.2 Alternative River Crossing of Sewers

Considerations to be taken in selecting the trunk sewer route are as follows:

- Pipe jacking method will be applied for the trunk sewers constructions in most cases since trunk sewers have large diameters and greater earth covers. Therefore, roads under which they are installed are preferably large in width and straight.
- More than two trunk sewers in parallel should be avoided. One of them is regarded as trunk sewer and the other as sideline sewers.

Shallow sewers are generally laid by means of open trench method. For deep sewers with earth coverings of more than 3 to 3.5 m, open trench method will be difficult to apply because of deeper excavation and prolonged construction period, which may cause traffic congestion and increase construction costs.

When earth coverings exceed 3 to 3.5 m, the pipe jacking method is applied for which no road surface excavation is required except for starting and arriving shafts. Soil cutting machine is introduced through starting shaft and excavates soil. Concrete pipes follow the machine with jacking apparatus behind. Pipes are continuously set until the first one reaches the arriving shaft where the machine is recovered as well.

Alignments of main and trunk sewers are checked in the field after preliminary delineation of routes so that the actual conditions of the area can be reflected in the design and cost estimate. For the areas where exact locations of road network are not available, sewer routings are determined on the basis of field reconnaissance, available city plans, other development programs, and consultation with CEDAE and other concerned authorities.

(4) Length of Branch/Lateral Sewers

Length of branch/lateral sewers is estimated based on the following assumptions:

- Road lengths of one hectare in each sewer district are 147 m, 135 m, 113 m and 169 m for Pavuna, Acarí, Sarapuí and Bangu districts, respectively.
- Considering that some roads are wide and two sewers are needed on both sides of the roads, 1.3 times the road length is the length of branch sewers.

Estimated total length of branch/lateral sewers of each district are as shown in *Table 7.8.*

Table 7.8 Branch Sewer Length per ha. in Each Sewer District

Sewer District	Road Length (m/ha)	Branch Sewer Length (m/ha)
Pavuna	147	190
Acarí	135	180
Sarapuí	113	150
Bangu	169	220

It is also assumed that 150 mm diameter pipe accounts for 90% of total length, 200 mm for 4%, 250 mm for 3% and 300 mm for 3%.

(5) Boring and Jacking

For all the national and state roads and other utility crossings, and where sewer open cut excavation depth becomes over 3.5 m, sewer pipes are in general to be designed by boring and jacking method. In sizes smaller than 800 mm in diameter, rigid steel or concrete pipe can be pushed for reasonable distances through the ground and the earth removed by mechanical means under the control of operator at the shaft or pit location.

In cases where utility conflicts occur, rock or other obstructions prevent crossing by boring and jacking, other methods may be used. The design criteria for gravity sewers shall apply to the hydraulic design of jacking pipeline where it is justified appropriate. For jacking pipe, sufficient jacks will be applied so that adequate force is generated to overcome friction and weight of pipe, by positioning jacks to apply the resultant force along the centerline of the pipe.

Excavation of jacking and receiving pits are to be sheathed, shores, sloped or braced to firmly support the jacking reactions. Pipe is to be jacked in conformity with the design lines and grades. Excavation for the pipe is to be accomplished by boring or by hand digging.

If obstructions such as boulders are expected, it may be more economical first to install an oversize lining by conventional tunnel or jacking methods. The smaller pipe then can be placed within the liner pipe and the remaining space backfilled with sand, cement grout, or concrete. The carrier pipe installation within the casing is to be made in accordance with the requirements for the normal sewer pipes.

There are several types of earth augers on the market. The boring and jacking method shall be in accordance with the manufacturer’s standard design dimensions and tolerances.

(6) Branch and Lateral Sewers

Since the objectives of the design are to establish broad technical and economic policy, upon which the succeeding detailed design can be based, the preliminary design does not specify routings, capacities and profiles of small sewers such as branch and laterals, but the plans for those of 400 mm or larger (main and trunk sewers) are provided.

Branch sewers are to be generally laid following, insofar as possible, lines of maximum available surface slope. Major branch and lateral sewers which are influential in determining the invert elevations of main and submain sewers, profiles of the possible deepest lines are checked to examine whether main or submain sewers can receive the wastewater from the tributary without deepening the main/submain sewer depths.

Sufficient earth covering is left between the top of the sewer and the bottom of the roadway surface to protect the sewers from traffic loads and to avoid undue interference with other underground facilities. The minimum earth covering of 1.2 m is applied, except for specific situations where shallower depth is feasible. The maximum depth of sewers is generally 3 to 3.5 m.

All branch and lateral sewers are designed with circular sections, with a minimum diameter of 150 mm.

(7) Manholes

Manholes are to be installed at the end of each line; at all changes in grade, size, or alignment; and at all intersections. Spacing of sewer manholes are determined depending on the sewer diameters as proposed in the original design but not be more than 120 m.

Except for very shallow sewers, all manholes are planned to have adequate dimensions for entry and for operation of cleaning equipment. The internal size of manholes is 90 cm or larger, and they are designed for future expansion of the sewers.

Watertight manhole covers, either reinforced concrete or cast iron, are to be used wherever the manholes tops may be flooded by street runoff or high water. The size of manhole cover should be greater than 60 cm. Generally, manholes should be circular, with a reinforced concrete base and brick mortar wall construction. Special care is to be taken in wall construction in places where high groundwater is expected.

Prefabricated manholes with 30 cm diameter made of vinyl chloride are used in Japan for smaller depth. They are called “machine holes” because they are so designed that maintenance machineries can enter them. Smaller manholes themselves not only reduce the sewers construction cost but also ease their construction since they can be installed within the excavation width.

(8) Pumping Stations

Pumping stations will be either of the following types:

- Submersible pump station with guide rail pump removal system
- Package-type enclosed.

All stations will have a minimum of two pumps of equal capacity, and be capable of handling flows in excess of the expected peak flow. Where three or more pumps are required, they are to be of such capacity that with any one unit out of service, the remaining units will have capacity to handle peak wastewater flows. Where pumping stations may be designed to handle larger future flows, the wet-well, piping, electrical equipment, etc. shall be sized to accommodate the future flow.

Pumping station piping shall be sized to maintain flow velocities between 0.75 and 1.5 m/s. Force main sizing shall be such to provide a minimum velocity in the force main of 0.6 m/s and a maximum velocity of 1.2 m/s.

Sewer air release valves shall be provided at all high points where gas pockets may accumulate. Combination air/vacuum valves shall be located where the force main is subject to draining and filling.

Wastewater pumping stations, structures, electrical equipment, etc. shall be protected from physical damage by site selection no less than 30 cm above the predicted 100 year flood water elevation. Stations shall remain fully operational and accessible during the 100-year flood.

All pumping station sites shall be fenced for security. Pumping stations located in remote areas shall have a chain link fence. Stations that are adjacent to residential and commercial areas shall have a wooden shadow box style fence.

7.2.3 Wastewater Treatment Plants (WWTPs)

(1) Treatment Process

Conventional activated sludge process is applied to treat the wastewater. The process is reliable with high BOD and SS removal efficiencies of more than 90%, and can be easily upgraded to further remove nutrients in the future.

The diagram of conventional activated sludge process is shown in *Figure 7.3*.

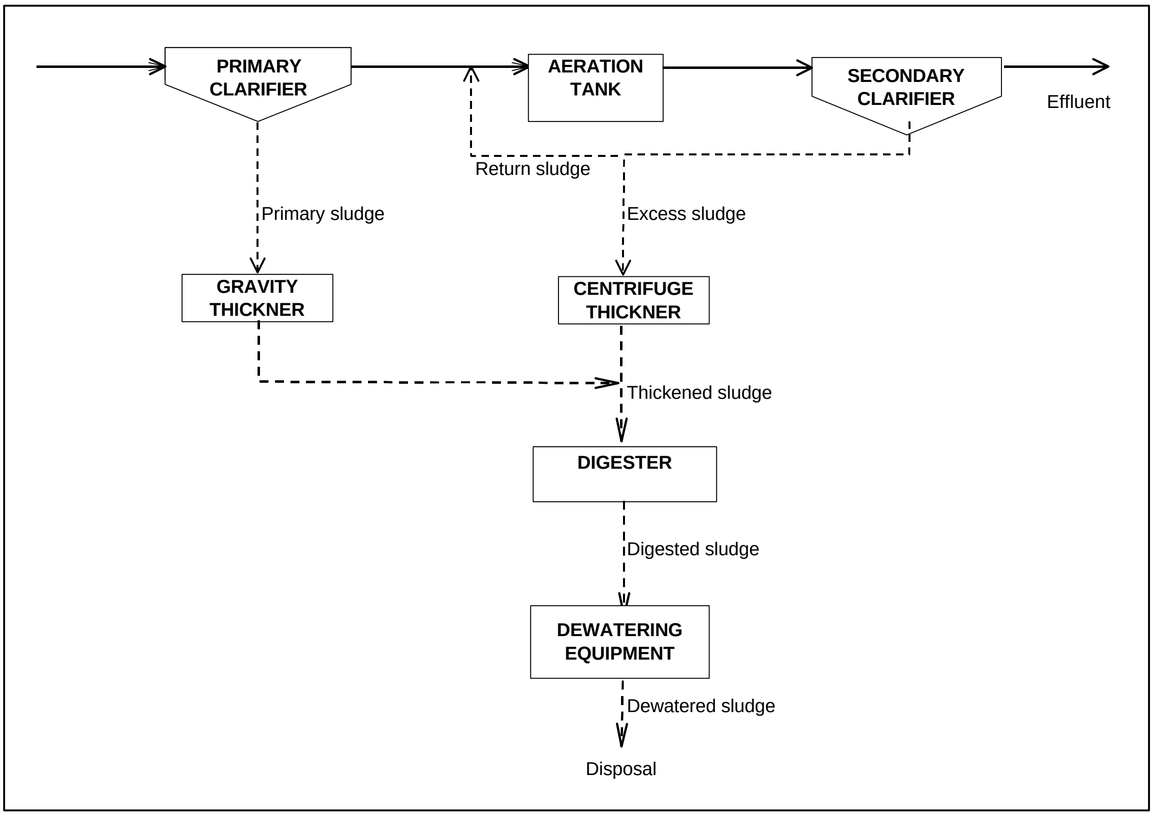


Figure 7.3 Diagram of Conventional Activated Sludge Process

Screens and grit chambers may be installed prior to primary clarifiers.

The primary clarifier removes BOD and SS by 30% to 50%. The primary effluent then flows into the aeration tank where it is mixed with the return sludge and air is diffused from the bottom of tank. Biological decomposition occurs in aeration tank and consequent solid-liquid separation takes place in the secondary clarifier. The separation finally gives 90% or more BOD and SS removal efficiencies.

In Acarí and Bangu WWTPs, the sludge withdrawn from the primary clarifier is thickened by gravity and the excess sludge by centrifugal thickener. Both gravity and centrifuge thickened sludges are then digested to obtain stable and reduced sludge. Some 50% of organics contained in the fed sludge is decomposed through digestion process. The digested sludge is then dewatered by centrifuge and dewatered sludge is expected to have the moisture content of around 75%.

In Pavuna and Sarapuí WWTPs, both the primary and excess sludges are thickened by centrifugal thickener and dewatered without digestion process. Instead, lime is added to the dewatered sludge to obtain chemically stable sludge.

The dewatered sludge is disposed of at the landfill site or receives further reduction by processes such as thermal drying.

Thermal drying system of the dewatered sludge is introduced to Pavuna and Sarapuí WWTPs to lower sludge moisture content as low as 20%. The preliminary design of Acarí and Bangu WWTPs will include the heat drying system as well.

(2) Influent Quality

The wastewater qualities are estimated in terms of BOD and SS, whose daily per capita loadings are set as 54 g and 60 g, respectively, in the ABNT "NB-570, Item 5.2." The per capita wastewater flow rate is 240 L/s, thus, the wastewater quality is calculated as follows:

- BOD = (54/240)x1,000 = 225 mg/L , use 230 mg/L
- SS = (60/240) x1,000 = 250 mg/L

(3) Effluent Quality

The effluent quality standard "DZ-215, R-01(April 1994) for Non-industrial wastewater effluent quality" defines the effluent concentrations of 30mg/L for BOD and SS with minimum removal efficiency of 90%.

Since better effluent qualities are expected for early water quality improvement of Guanabara Bay, effluent BOD and SS concentrations are set to be 20 mg/L for Acarí and Bangu WWTPs. Efforts should be made to obtain better effluent qualities in actual WWTPs operation in spite of these target water qualities.

(4) Design Criteria

Design criteria for major treatment facilities of Acarí and Bangu WWTPs, namely primary clarifier, aeration tank and secondary clarifier, are as follows:

- Overflow rate in primary clarifier of 50 m3/m2/day to treat the average daily flow.
- Aeration time of 6 hours for the average daily flow.
- Overflow rate in secondary clarifier of 25 m3/m2/day for the average daily flow.

Primary treatment facilities in Pavuna and Sarapuí WWTPs were designed and already started their operation with the similar design criteria mentioned above. The secondary treatment facilities in these WWTPs were already designed, and are now under construction as of May 2003. Their operation is expected to start by the end of PDBG. Design criteria of primary and secondary clarifiers in Pavuna and Sarapuí WWTPs are shown in *Tables 7.12* and *7.24*. They are nearly the same as those for Acarí and Bangu WWTPs.

Although the aeration period of 3.5 hours designed for these WWTPs is shorter than 6 hours, the design for expansion of Pavuna and Sarapuí WWTPs will follow the PDBG criteria. If it is proven that the aeration period of 3.5 hours is not sufficient from performance data, the WWTPs shall be expanded. It is vitally important to collect plant performance data and to verify whether or not the applied design parameters are appropriate.

7.2.4 PRELIMINARY DESIGN OF EACH DISTRICT

(1) Pavuna Sewer District

1) Collection System

Table 7.9 summarizes the major technical issues in selecting the trunk sewer routes, solutions and recommendation for the alternative designs in the Pavuna sewer district:

Table 7.9 Considerations in Pavuna Sewer District

Issues	***Solutions and recommendations***
The wastewater in the area of southern part of Rio Acarí should primarily flow into No.4-4 Trunk Sewer that is not planned to include it. However, large capacity pumping station is required if the sewer conveying the wastewater crosses Rio Acarí and is connected to No.4 Trunk Sewer.	The wastewater in the area is to flow into No.4 Trunk Sewer at the same point where No.4-4 Trunk Sewer connect to No.4 Trunk Sewer. The diameter and earth cover of No.4-4 Trunk Sewer should be changed so as to include the wastewater in F/S area. However, it was found that No.4-4 Trunk Sewer was already partly constructed without including the wastewater in F/S area. No.2 trunk sewer has to be extended until it reaches No.4 trunk sewer along No.4-4 Trunk Sewer..
The wastewater from the right bank of Rio Pavuna is not planned to be included in No.4 Trunk Sewer. Therefore, another trunk line has to be planned at the right bank.	No.1 Trunk Sewer is planned to install at the right bank of the river. However, the wastewater in the area surrounded by the trunk line and the river is hard to collect by gravity. Several small submersible pumps might be required.
To install sewer where no road is available for its site	No.2 Trunk Sewer – 2 points 1) It was judged that a sidewalk is available for sewer construction.[*1] 2) An open space is available for sewer constuction.[*2] No.1 Trunk Sewer – 1 point A road under planning is available for sewer construction. [*3]

Notes *1, *2 and *3: Refer to *Figure 7.4*.

The sewer length and intermediate pump capacity are shown in the *Table 7.10*.

Table 7.10 Collection System in Pavuna Sewer District

	Branch Sewer			Trunk Sewer					
				Open Cut		Pipe Jacking		Pressure Pipe	
	Dia.	Ratio	Pipe Length	Dia.	Pipe Length	Dia.	Pipe Length	Dia.	Pipe Length
	(mm)	(%)	(m)	(mm)	(m)	(mm)	(m)	(mm)	(m)
	150	90.0	7.25,000	400	2,910	500	1,760	100	
A= 3,660 ha	200	4.0	28,000	500	1,650	900	1,920	150	
Per ha 190 m/ha	250	3.0	21,000	700	2,040	1200	7,180		
L= 695,000 m	300	3.0	21,000	900	570	1500	4,782		
						2000			
	Sub-Total		695,000	Sub-Total	7,170	Sub-Total	15,642	Sub-Total	
Total Length 717,812 m									

Pumping Station	(m^3/min)
EE-1	7.70
Total	7.70

Figure 7.4 shows boundary of sewer district and layout of trunk sewers, pumping stations and WWTP in Pavuna sewer district.

Table 7.11 shows trunk sewer length in Pavuna sewer district.

Table 7.11 Trunk Sewer Length in Pavuna Sewer District

No of Trunk Sewer	Dia. (mm)	Length (m)
No.1 Trunk Sewer	400-1200	5,120
No.1-1 Trunk Sewer	400	280
No.1-2 Trunk Sewer	400	1,060
No.2 Trunk Sewer	500-1500	5,110
No.3 Trunk Sewer	1000-1500	8,762
No.3-1 Trunk Sewer	400-500	2,480
Total		22,812

2) WWTP

Design parameters of major facilities and equipment are shown in the following *Table 7.12*. It is defined that major treatment facilities and equipment are primary clarifier, aeration tank, secondary clarifier, gravity thickener and digester, inlet pumps, blowers, centrifugal thickener, centrifuge for dewatering and sludge dryer.

The overflow rates of primary and secondary clarifiers are 52 and 26 m^3/m^2/day, respectively, that are greater than those of Acarí and Bangu WWTPs, but they are judged to be within permissible range.

Both primary and excess sludges are thickened by centrifugal thickener and dewatered by centrifuge for dewatering. Sludges are not digested here. Dewatered sludge is added with lime and further dried by thermal dryer.

Table 7.12 Design Parameters of Major Facilities and Equipment of Pavuna WWTP

Facility/equipment	Design Parameters
Primary clarifier	Overflow rate: 52 m^3/m^2/day Primary effluent SS/BOD : 147/47
Aeration tank	BOD-SS loading : 0.4 kg-BOD/kg-SS/day MLSS : 2,500 mg/L Return sludge ratio : 60% maximum Return sludge SS : 7,000 mg/L
Secondary clarifier	Overflow rate : 26 m^3/m^2/day Secondary effluent SS/BOD : 20/8
Centrifugal thickener	1.6% sludge to be thickened to 5%
Centrifuge for dewatering	5% sludge to be dewatered to 25%
Sludge dryer	25% sludge to be dried to 80%

Tables 7.13 and *7.14* summarize the results of design works. All the facilities and equipment are constructed to increase the WWTP capacity from 1.5 m^3/s. (or 129,600 m^3/day) to 3.0 m^3/s. (or 259,200 m^3/day).

Table 7.13 Dimensions of Major Facilities of Pavuna WWTP

Facility	Dimension (unit : meter)	Number of units Existing	F/S	Total
Primary clarifier	(dia)40x(D)4	2	2	4
Aeration tank	(W)24x(L)48x(D)5.5	4(3)	2(3)	6(6)
Secondary clarifier	(dia)46x(D)4	3	3	6

Note: dia. is diameter, D is water depth, W is width of tank and L is length of tank. Numbers in parentheses show those of mechanical equipment. Primary and secondary clarifiers are equipped with sludge scrapers.

Table 7.14 Capacities of Major Equipment of Pavuna WWTP

Facility	Capacity per unit	Existing	F/S	Total
Inlet pump	70 m^3/min	4	2	5+1 (1 for standby)
Blower	200 Nm^3/min.	4	3	6+1 (1 for standby)
Centrifugal thickener	47 m^3/hour	2	1	2+1 (1 for standby)
Centrifuge for dewatering	26 m^3/hour	2	-	1+1 (1 for standby)
Sludge dryer	-	1	1	2

Layout plan of Pavuna WWTP is shown in *Figure 7.5*.

(2) Acarí Sewer District

1) Collection System

Table 7.15 summarizes the major technical issues in selecting the trunk sewer routes, solutions and recommendation for the alternative designs in the Acarí sewer district:

Table 7.15 Considerations in Acarí Sewer District

Issues	*Solutions and recommendations*
How to convey the wastewater to WWTP generated from the downstream area located at the eastern part of the railway.	A pumping station is needed. There are two options where the pumping station is to be located. The second option was selected mainly to avoid siphon structure. Op.1 : Near the point where two rivers joint *1 Op.2 : Near the railroad *2
How to determine the trunk line route for the left bank of Rio Merinho	It might be possible to install the trunk line along Av. Brasil and to cross the river near WWTP. It was decided, however, that Rio Merinho is crossed at its upstream for the following reasons. 1) Wastewaters are separately generated at the upstream and the downstream and no wastewater is expected to flow for the 2000 m long at the middle part of the trunk line. 2) Sewers construction along Av. Brasil seems rather difficult since the area is hilly with expected rocky soil.
How to convey the wastewater from the area at the left bank of Rio Merinho	Pumping facility is to be constructed before crossing the river to connect to the existing sewer.Because,the existing sewer is not deeper than the river.
How to deal with the upstream part of No.1 Trunk Sewer	This part of existing sewer is to be demolished and substituted by a new one, since it was built more than 30 years before and has already become too old to use. The new one has to be in the same route and at the same level as the existing one because it will be connected to No.1 Trunk Sewer just like before.

Notes *1 and *2: Refer to *Figure 7.6*.

The sewer length and intermediate pump capacity are shown in the *Table 7.16*.

Table 7.16 Collection System in Acarí Sewer District

				Trunk Sewer					
	Branch Sewer			Open Cut		Pipe Jacking		Pressure Pipe	
	Dia.	Ratio	Pipe Length	Dia.	Pipe Length	Dia.	Pipe Length	Dia.	Pipe Length
	(mm)	(%)	(m)	(mm)	(m)	(mm)	(m)	(mm)	(m)
	150	90.0	502,000	400	3,300	500	8,043	100	480
A= 3,100 ha	200	4.0	22,000	500	1,570	900	3,965	150	410
Per ha 180 m/ha	250	3.0	17,000	700	1,910	1200	3,640	500	120
L= 558,000 m	300	3.0	17,000	900	910	1500	500		
						2000			
	Sub-Total		558,000	Sub-Total	7,690	Sub-Total	16,148	Sub-Total	1,010
			Total Length			582,848 m			

Pumping Station	(m^3/min)
EE-1	4.16
EE-2	8.79
EE-3	0.99
EE-4	13.40
Total	27.34

Figure 7.6 shows boundary of sewer district and layout of trunk sewers, pumping stations and WWTP in Acarí sewer district.

Table 7.17 shows trunk sewer length in Acarí sewer district.

Table 7.17 Trunk Sewer Length in Acarí Sewer District

No of Trunk Sewer	Dia.(mm)	Length(m)
No.1 Trunk Sewer	500-1500	3,940
No.1-1 Trunk Sewer	500-700	2,033
No.2 Trunk Sewer	500-1200	4,070
No.2-1 Trunk Sewer	500-700	1,900
No.2-2 Trunk Sewer	400	890
No.3 Trunk Sewer	400-500	1,630
No.3-1 Trunk Sewer	500	930
No.4 Trunk Sewer	400-1200	7,400
No.4-1 Trunk Sewer	500-900	2,055
Total		24,848

2) WWTP

Design parameters of major facilities and equipment of Acarí WWTP are shown in *Table 7.18*. Major facilities and equipment listed are primary clarifier, aeration tank, secondary clarifier, gravity thickener, inlet pumps, blowers, centrifugal thickener, digester and centrifuge for dewatering.

Primary sludge is thickened by gravity and excess sludge is thickened by centrifuge. The thickened sludges are digested and then dewatered by centrifuge. The dewatered sludge is further dried by sludge drier.

Table 7.18 Design Parameters of Major Facilities and Equipment of Acarí WWTP

Facility/equipment	Design Parameters
Primary clarifier	Overflow rate : 50 m^3/m^2/day Primary effluent SS/BOD : 140/160
Aeration tank	BOD-SS loading : 0.25 kg-BOD/kg-SS/day MLSS : 2,500 mg/L Return sludge ratio : 60% maximum Return sludge SS : 6,000 mg/L
Secondary clarifier	Overflow rate : 25 m^3/m^2/day Secondary effluent SS/BOD : 20/20
Gravity thickener	Solids loading : 60 kg/m^2/day 1% sludge to be thickened to 4%
Centrifugal thickener	0.6% sludge to be thickened to 5%
Digester	50% of organics to be decomposed of
Centrifuge for dewatering	3.5% sludge to be dewatered to 25%
Sludge dryer	25% sludge to be dried to 80%

Tables 7.19 and *7.20* summarize the results of design works. All the facilities and equipment are constructed with the capacity of 1.1 m^3/sec., or 95,040 m^3/day.

Table 7.19 Dimensions of Major Facilities of Acarí WWTP

Facility	Dimension (unit : meter)	Units to be Constructed
Primary clarifier	(dia)25x(D)3.5	4
Aeration tank	(W)13x(L)50x(D)5	8
Secondary clarifier	(dia)35x(D)4	4
Gravity thickener	(dia)8x(D)3.5	4
Digester	(dia)16.5x(D)17.5	4

Note: Primary and secondary clarifiers are equipped with sludge scrapers.

Table 7.20 Capacities of Major Equipment of Acarí WWTP

Equipment	Capacity per Unit	Number of Units
Inlet pump	39.6 m^3/min	3+1 (1 for standby)
Blower	166 Nm^3/min.	4+1 (1 for standby)
Centrifugal thickener	47 m^3/hour	2+1 (1 for standby)
Centrifuge for dewatering	21 m^3/hour	1+1 (1 for standby)
Sludge dryer	-	1

Layout plan of Acarí WWTP is shown in *Figure 7.7*.

(3) Sarapuí Sewer District

1) Collection System

Table 7.21 summarizes the major technical issues in selecting the trunk sewer routes, solutions and recommendation for the alternative designs in the Sarapuí sewer district:

Table 7.21 Considerations in Sarapuí Sewer District

Issues	*Solutions and recommendations*
The area between the downstream end of FS area and WWTP site is almost flat and little inhabited. If the trunk line is planned with gravity flow, the earth cover of sewers tends to be large.	The trunk line is planned with gravity flow and the earth cover is planned as small as possible.
There is PNB (Nova Baixada Program) area at the east side of F/S area.	The wastewater flow can be included in the No 1-1 Trunk Sewer.
To install sewer where no road is available for its site	No.1 Trunk Sewer Though no road can be seen on the map, a small road was found on site. *1

Note *1: Refer to *Figure 7.8*.

The sewer length and intermediate pump capacity are shown in *Table 7.22*.

Table 7.22 Collection System in Sarapuí Sewer District

			Branch Sewer			Trunk Sewer					
						Open Cut		Pipe Jacking		Pressure Pipe	
			Dia.	Ratio	Pipe Length	Dia.	Pipe Length	Dia.	Pipe Length	Dia.	Pipe Length
			(mm)	(%)	(m)	(mm)	(m)	(mm)	(m)	(mm)	(m)
			150	90.0	86,400	400	500	500	330	100	
A=	640	ha	200	4.0	3,800	500	420	900	4,330	150	
Per ha	150	m/ha	250	3.0	2,900	700	490	1200			
L=	96,000	m	300	3.0	2,900	900	680	1500			
								2000			
			Sub-Total		96,000	Sub-Total	2,090	Sub-Total	4,660	Sub-Total	
					Total Length			102,750 m			

Figure 7.8 shows boundary of sewer district and layout of trunk sewers, pumping stations and WWTP in Sarapuí sewer district.

Table 7.23 shows trunk sewer length in Sarapuí sewer district.

Table 7.23 Trunk Sewer Length in Sarapuí Sewer District

No of Trunk Sewer	Dia.(mm)	Length (m)
No.1 Trunk Sewer	400-900	5,530
No.1-1 Trunk Sewer	500-900	1,220
Total		6,750

2) WWTP

Design parameters of major facilities and equipment are shown in *Table 7.24*. Major facilities listed there are grit chamber, primary clarifier, aeration tank, secondary clarifier, gravity thickener, inlet pumps, blowers, centrifugal thickener and centrifuge for dewatering.

The overflow rates of primary and secondary clarifiers are 57 and 26 m^3/m^2/day, respectively, that are greater than those of Acarí and Bangu WWTPs, but they are judged to be within permissible range.

Primary sludge is thickened by gravity and excess sludge is thickened by centrifuge. The thickened sludges are dewatered by centrifuge. Sludges are not digested in Sarapuí WWTP.

Table 7.24 Design Parameters of Major Facilities and Equipment of Sarapuí WWTP

Facility/equipment	Design Parameters
Primary clarifier	Overflow rate : 57 m^3/m^2/day Primary effluent : SS/BOD 147/47
Aeration tank	BOD-SS loading : 0.4 kg-BOD/kg-SS/day MLSS : 2,500 mg/L Return sludge ratio : 60% maximum Return sludge SS : 7,000 mg/L
Secondary clarifier	Overflow rate : 26 m^3/m^2/day Secondary effluent SS/BOD : 20/8
Centrifugal thickener	1.6% sludge to be thickened to 5%
Centrifuge for dewatering	5% sludge to be dewatered to 25%
Sludge dryer	25% sludge to be dried to 80%

Tables 7.25 and *7.26* summarize the results of design works. All the facilities and equipment are constructed to increase the WWTP capacity from 1.5 m^3/s. (or 129,600 m^3/day) to 2.5 m^3/s. (or 216,000 m^3/day).

Table 7.25 Dimensions of Major Facilities of Sarapuí WWTP

Facility	Dimension (unit : meter)	Number of Units		
		Existing	F/S	Total
Primary clarifier	(dia)40x(D)4	2	1	3
Aeration tank	(W)24x(L)48x(D)5.5	4(3)	2(2)	6(5)
Secondary clarifier	(dia)46x(D)4	3	2	5

Note: Numbers in parentheses show those of mechanical equipment. Primary and secondary clarifiers are equipped with sludge scrapers.

Table 7.26 Capacities of Major Equipment of Sarapuí WWTP

Equipment	Capacity per Unit	Existing Units	F/S Units	Total
Inlet pump	84 m^3/min	3	1	3+1 (1 standby)
Blower	200 Nm^3/min.	4	2	5+1 (1 standby)
Centrifugal thickener	47 m^3/hour	2	1	2+1 (1 standby)
Centrifuge for dewatering	26 m^3/hour	2	-	1+1 (1 standby)
Sludge dryer	-	1	1	2

Layout plan of Sarapuí WWTP is shown in *Figure 7.9*.

(4) Bangu Sewer District

1) Collection System

Table 7.27 summarizes the major technical issues in selecting the trunk sewer routes, solutions and recommendation for the alternative designs in the Bangu sewer district:

Table 7.27 Considerations in Bangu Sewer District

Issues	*Solutions and recommendations*
Where to cross Rio das Tintas (No.1 Trunk Sewer)	Two possible options : one right after crossing Av. Brasil and the other near WWTP. The latter was selected for the following reasons. 1) The former gives 5 meter earth cover due to river crossing and 2 km pipe jacking is needed to reach WWTP. 2) The wastewater from the right bank area of Rio Sarapuí needs to be conveyed crossing the river. This can decrease crossing river points from two to one.
Suppose the trunk sewer is installed under the road in Rio das Sardinhas basin, its length with greater earth cover exceeds 1.2 km.	No.3 Trunk Sewer line is planned along the channel. There is no road nor housing there for the time being. It is legally possible to install sewers within river administration areas.
To install sewer where no road is available for its site	No.3 Trunk Sewer : one point (described above) There is space available along the channel. *1

Note *1: Refer to *Figure 7.10*.

The sewer length and intermediate pump capacity are shown in *Table 7.28*.

Table 7.28 Collection System in Bangu Sewer District

	Branch Sewer			Trunk Sewer					
				Open Cut		Pipe Jacking		Pressure Pipe	
	Dia.	Ratio	Pipe Length	Dia.	Pipe Length	Dia.	Pipe Length	Dia.	Pipe Length
	(mm)	(%)	(m)	(mm)	(m)	(mm)	(m)	(mm)	(m)
	150	90.0	370,000	400	3,680	500	3,050	100	
A= 1,870 ha	200	4.0	16,400	500	780	900	6,095	150	
Per ha 220 m/ha	250	3.0	12,300	700	590	1200	3,765		
L= 411,000 m	300	3.0	12,300	900	720	1500			
						2000			
	Sub-Total		411,000	Sub-Total	5,770	Sub-Total	12,910	Sub-Total	
Total Length					429,680 m				

Pumping Station	(m^3/min)
EE-1	2.30
Total	2.30

Figure 7.10 shows boundary of sewer district and layout of trunk sewers, pumping stations and WWTP in Bangu sewer district.

Table 7.29 shows trunk sewer length in Bangu sewer district.

Table 7.29 Trunk Sewer Length in Bangu Sewer District

No of Trunk Sewer	Dia. (mm)	Length (m)
No.1 Trunk Sewer	500-1200	7,940
No.1-1 Trunk Sewer	500	560
No.1-2 Trunk Sewer	400-900	2,610
No.2 Trunk Sewer	500-900	2,370
No.2-1 Trunk Sewer	400-500	740
No.3 Trunk Sewer	400-900	2,560
No.3-1 Trunk Sewer	400-500	850
No.3-2 Trunk Sewer	400	1,050
Total		18,680

2) WWTP

Design parameters of major facilities and equipment are shown in *Table 7.30*. Major facilities listed there are grit chamber, primary clarifier, aeration tank, secondary clarifier, gravity thickener, inlet pumps, blowers, centrifugal thickener, digester and centrifuge for dewatering.

Primary sludge is thickened by gravity and excess sludge is thickened by centrifuge. The thickened sludges are digested and then dewatered by centrifuge.

Table 7.30 Design Parameters of Major Facilities and Equipment of Bangu WWTP

Facility/equipment	Design Parameters
Primary clarifier	Overflow rate : 50 m^3/m^2/day Pimary effluent SS/BOD : 140/160
Aeration tank	BOD-SS loading : 0.25 kg-BOD/kg-SS/day MLSS : 2,500 mg/L Return sludge ratio: 60% maximum Return sludge SS: 6,000 mg/L
Secondary clarifier	Overflow rate: 25 m^3/m^2/day Secondary effluent SS/BOD : 20/20
Gravity thickener	Solids loading: 60 kg/m^2/day 1% sludge to be thickened to 4%
Centrifugal thickener	0.6% sludge to be thickened to 5%
Digester	50% of organics to be decomposed of
Centrifuge for dewatering	3.5% sludge to be dewatered to 25%
Sludge dryer	25% sludge to be dried to 80%

Tables 7.31 and *7.32* summarize the results of design works. All the facilities and equipment are constructed with the capacity of 1.1 m^3/s. or 95,040 m^3/day.

Table 7.31 Dimension of Major Facilities of Bangu WWTP

Facility	Dimension (unit : meter)	Units to be Constructed
Primary clarifier	(dia)24x(D)3.5	4
Aeration tank	(W)12x(L)48x(D)5	8
Secondary clarifier	(dia)33x(D)4	4
Gravity thickener	(dia)8x(D)3.0	4
Digester	(dia)16.5x(D)16	4

Note: Primary and secondary clarifiers are equipped with sludge scrapers.

Table 7.32 Capacities of Major Equipment of Bangu WWTP

Equipment	Capacity per Unit	Number of Units
Inlet pump	39.6 m^3/min	3+1 (1 for standby)
Blower	152 Nm^3/min.	5+1 (1 for standby)
Centrifugal thickener	47 m^3/hour	2+1 (1 for standby)
Centrifuge for dewatering	21 m^3/hour	1+1 (1 for standby)
Sludge dryer	-	1

Layout plan of Bangu WWTP is shown in *Figure 7.11*.

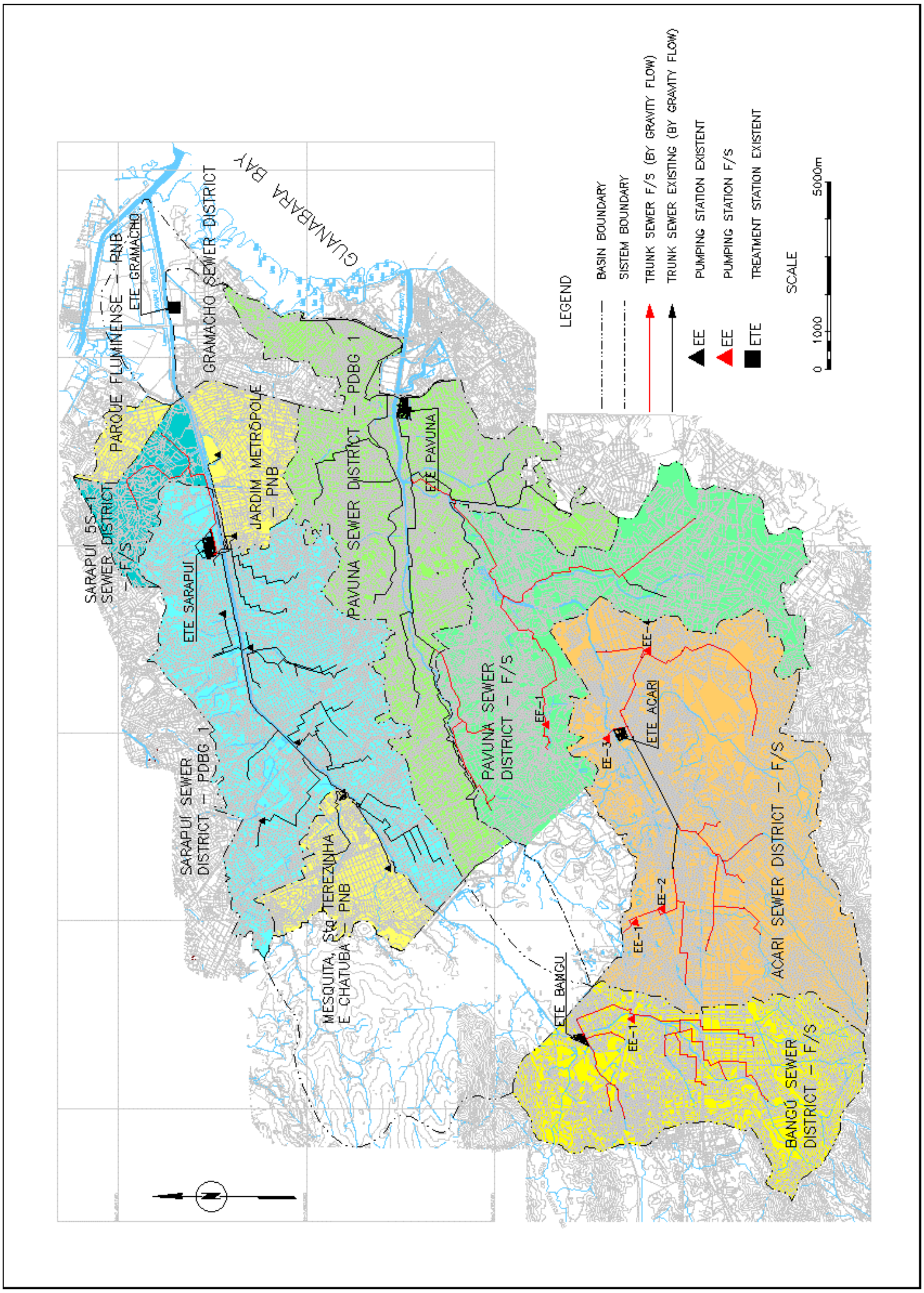


Figure 7.1 Feasibility Study Area

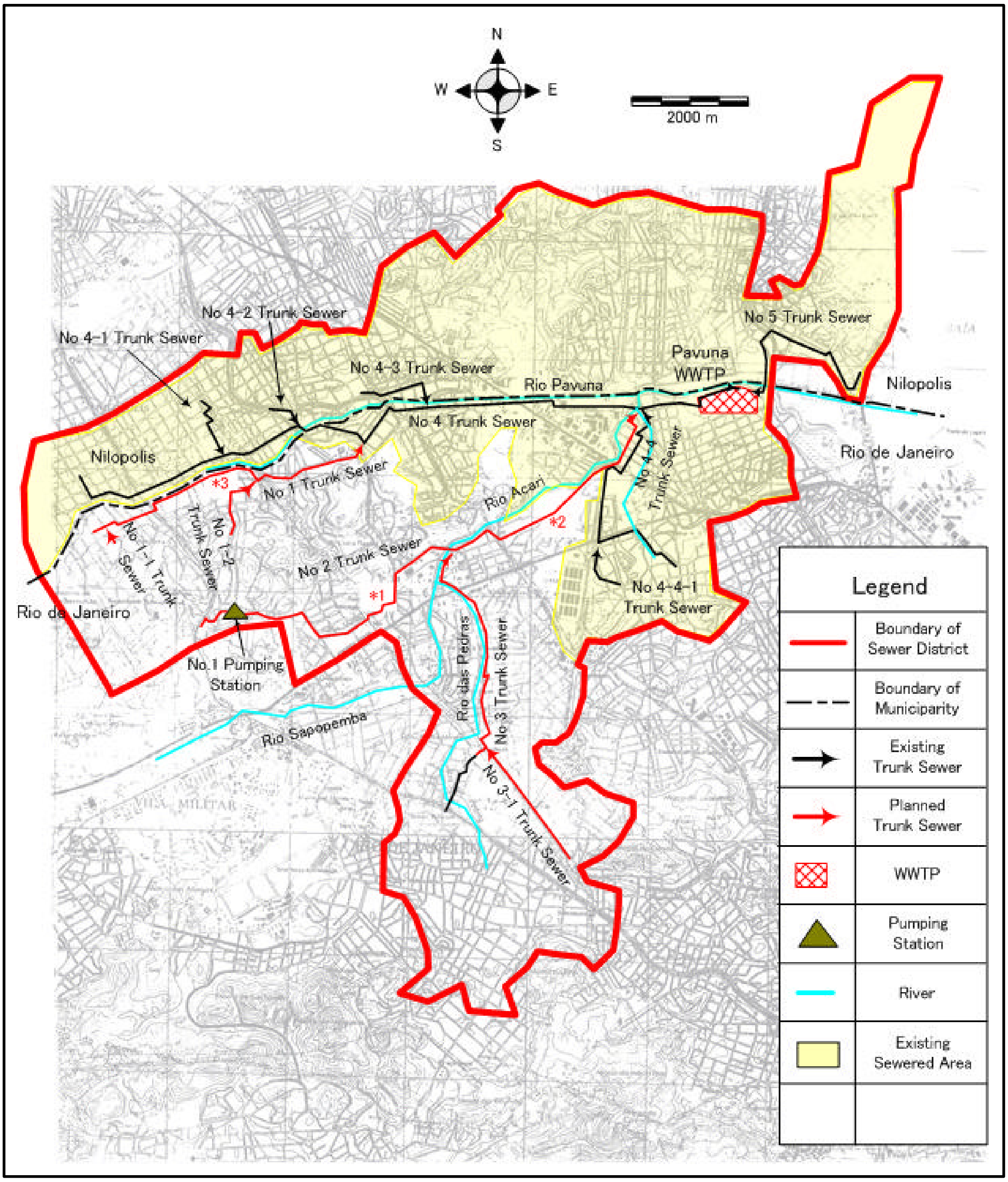


Figure 7.4 Layout Plan of Pavuna Sewer District