2 FLOOD CONTROLE AND DRAINAGE IN GENERAL

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2.1 Flood Control and Drainage

(1) Flood Control

To reduce the damage caused by flooding from the rivers and the sea by means of the following:

Structural Measures

1) River Improvement

- Widening, deepening, straitening (cut-off), revetment, etc.
- Dyke (with flood gate, sluice, pumping station, etc as required)
- River facility management (bridge, intake, etc),

2) Storage of Floodwater

- Dam (flood control or multi-purpose),
- Retarding basin Others

Nonstructural Measures

3) Floodplain Management

Land use regulation, zoning (along the rivers, potential flood area), Flood insurance, Flood proofing (reclamation, raising of house floor, etc), Flood fighting, Education

4) Watershed Management

Land use regulation, afforestation, forest reserve, etc, erosion control, storm-water infiltration and storage, education, others

(2) Stormwater Drainage

1) Improvements of the Small Rivers and Artificial Drainage Channels
2) Storage/Infiltration of Storm-water
3) Pumping Station, Floodgate
4) Nonstructural Measures

Land use regulation, flood proofing, stormwater infiltration and storage, education

2.2 Flood Problems in RMR

1) Flooding in the swampy areas along the coast and around the lake where low-income people live. High tides and river flooding affect these areas.

2) Flooding along the rivers/channels, where informal settlements are located, due to the accumulation of solid wastes, aquatic plants and sediments,

3) Increase in flood and sediment runoffs due to unplanned developments in the hilly and sloped areas,

4) Flooding of roads due to inadequate drainage, and

5) Local flooding due to inadequate drainage.

Except in items 4) and 5) a single sector of stormwater drainage alone will not give the complete or sustainable solution of these flood problems, because of their social nature and other factors. Under such conditions, multi-sector projects as well as drainage improvement works are underway. Most of the problems are of flood control rather than drainage.

2.3 Methodology of Flood Control and Drainage in RMR

(1) Planning Conditions

1) Target area where flood damage is to be reduced (flood prone area)

2) Present and future land use for design discharge calculation

3) Design return period of storm

Possibility of land acquisition and Increase in flood runoff due to urbanization in the future should be considered. The design return period of flood is recommend depending on importance of the channel as follows:

Kind of Channel	Design Flood Return Period
1. Rivers and Large Channels	10 to 20 years
2. Small Rivers and Main Open Channels	5 to 10 years
3. Small Channels	5 years
4. Road Surface Drainage	3 years

4) Design rainfall (Daily, Hourly, Intensity-duration curves, Rainfall pattern)

Design rainfall used in the PQA will be used, however, it should be revised in the future. Measurement of rainfall of short duration at about three stations would be required to review the design rainfall. At first, the relationship between daily rainfall and short duration rainfall should be established by using the data in several years to review the design rainfall. The design rainfall (rainfall intensity – duration curves for several return periods) could be established after a long-term measurement.

Design Rainfall in PQA

Equation (I): $I_1 = (T - 1.5)^{0117} \times 456.768 (1 - t^8 \times 4.54 \times 10^{-21}) / (t + 6)^{0.5811}$

Equation (II): $I_2 = 72.153 (T - 1.75)^{0.173} / (t/60 + 1)^{0.74826}$

Where, I = Rainfall intensity for duration of storm "t (minutes)" in mm/hr

T = Return period of storm in years

Calculated values by the above Equation (I) and Equation (II) whichever larger are used.

5) Design tide level

The maximum high spring tide during the rainy season (March to August) is recommended as the lower boundary condition. The maximum spring tide is 2.50 - 1.14 = 1.36 m (say 1.35m) above mean sea level. The spring tide and the flood peak are expected to occur at the same time.

6) Runoff coefficients (C)

For reference, the following runoff coefficients are presented.

- 0.80 for densely populated residential/commercial area
- 0.65 for industrial area with a little vacant lot or residential area with small garden
- 0.50 for residential area with low density
- 0.35 for suburban area

7) Roughness coefficients (n)

In deciding the roughness coefficients, frequent maintenance should not be expected. The values of "n" in the Manning's Formula are as follows.

- 0.03 for the rivers and wide open channels,
- 0.02 for lined open channels
- 0.015 to 0.02 for concrete channels and pipes

(2) Design Discharge

Design discharge is calculated by using the following Rational Formula.

$Q = (1/3.6)\ C\ R\ A$

Where, Q = Design peak discharge in m^3/sec, C = Runoff coefficient,

R = Rainfall intensity for storm duration "t",

A = Drainage area in km^2

(3) Channel Design

Manning's Formula described below can be used.

$$\mathbf{Q = (1/n)\ R^{2/3}\ I^{1/2}\ A}$$

Where, Q = Discharge (m^3/s), n = Roughness coefficient,

R= Hydraulic radius (m), I = Slope (**Hydraulic gradient**), A:= Flow area (m^2)

(4) Drainage Method

1) Drainage by gravity flow to the rivers is applied, in principle, as proposed in the PQA.
2) The areas lower than around 2.0 m are difficult to drain by gravity and considered to be a marsh. Such areas should not be developed unless the area is reclaimed.
3) Drainage by pumping is not recommended for a financial reason.

The ongoing projects managed by the municipalities should be continued.

1) Road surface drainage by the municipality of Recife. A detailed survey of existing facilities has been scheduled.
2) Improvements of the remaining drainage channels in Resife
3) Improvements of the drainage channels in Olinda
4) Redevelopment of the swamp area in Olinda
5) Improvements of the drainage channels in Jaboatao

2.4 Drainage Improvement Case Studies (Concept)

Case studies to show the drainage improvement planning concepts were made by using the available data such as tide tables, topography in 1986, information in the PQA, etc. Therefore, the case studies are not actual plans

(1) Canal Olho d'Agua Basin (Jaboatao)

The Municipality of Jaboatao is going to improve the Canal Olho d'Agua. The improvement should study the following requirements (refer to Fig. 3.4-2):

1) The lagoon flood level rises due to small discharge capacity of the outlet canal (Canal Olho d'Agua). Present canal length can be shortened from 3.3 km to 2.4 km by moving the mouth at the Jaboatao River about 1 km downstream side. Thus the capacity will be increased by 15 %. This will lower the lagoon flood level and flood area around it as a result.
2) The design flood levels of the canal should be approximately 1.35 m at the sea, 1.5 m at the Jaboatao River confluence, 2.0 m at the lagoon and 3.5 to 4.0 m at the Canal Setubal upstream considering the topographic conditions.
3) The lagoon should be dredged in order to store the floodwater from the area upstream. Otherwise, the Canal Olho d'Agua will need a large capacity. The canal has small hydraulic gradient (0.5/2400 or 1/3300 = 0.0002 or 0.00015).
4) It is better to provide the canal along eastern side of the lagoon for its maintenance and limit the house occupation.
5) The canal proposed by the municipality should be of compound cross section to reduce sedimentation in the canal.
6) Providing drainage channels into the lagoon can solve flooding of the areas apart from the lagoon. These areas are relatively high (3 to 4m) in general.

(2) Beberibe River Basin

1) Wet Lands along the Beberibe River and Canal da Malaria

The flooded areas in the coastal strip and the upper Canal do Malaria basin should be reclaimed or redeveloped. Otherwise, the area lower than 2m should not be developed as regulated by the law (refer to Fig. 3.4-3).

2) Design flood levels of the Beberibe River would be about 1.35 m at the sea, 2.0 m at the Canal do Maralia confluence and 2.5 to 3m at the Canal Vasco Da Gama confluence. Width of the Beberibe River shall be kept in accordance with the laws, especially the section between Maralia and Canal Vasco Da Gama, where hydraulic gradient is small and design discharge is not small. A river width of more than 100m would be required for 20-year flood.

(3) Canal Derby Cataruna

The Canal Derby Cataruna has tide gates on its both ends to lower the water level and store the stormwater in the cannel. Hydraulic conditions are as follows:

1) Tidal range is 1.0m to 2.5m (usually twice a day).
2) The maximum water storage volume is about 77,000 m^3 with a maximum water level of about 1.1 m assuming that the tidal range of 2.0 m and channel length of 5.5 km.
3) The storage volume of 77,000 m^3 is equivalent to the water volume of 20mm rainfall from the channel basin of 6.46km^2 assuming runoff coefficient of 0.6. Therefore, after 20 mm storm-rain, the flood level of the channel goes up to that with no gates.
4) The tide gates can lower the water level in the channel by opening the gate during low tide and closing before high tide. Thus drainage is made efficiently up to the rainfall of 20mm.
5) The maximum daily rainfall at Resife during 30 years (1961 to1990) in August was 382 mm (1990) and in May was 235 mm (1986). The 20-year rainfall would be between 235 mm and 382 mm. The design 60-minutes rainfall for 20-year return period is 56 mm to 71mm. When a storm occur during high tide, the gates can drain effectively up to the total rainfall of 20 mm, and after that, situation is the same as that with no gate.

In conclusion,

- The gate is effective for small and frequent flood, however, it is not enough for the design flood of 20-year return period. In the area with heavy rain, the tide gate is not able to drain the design flood without a large storage volume.
- The low areas in the basin should be reclaimed in order to avoid the drainage by pumping.
- Micro drainage around the canal should be improved as proposed in the PQA for the effective use of the gate.

(4) Preparation of River Improvement Plan

In order to design the stormwater drainage facilities, river improvement plans of the Beberibe, Capibaribe, Tejipio and the lower Jaboatao rivers should be prepared. The plans include longitudinal profiles, alignments and cross sections, and require the following information:

- Detailed topography in and around the flood areas and the rivers/channels,
- Cross sections and longitudinal profiles of the rivers and drainage channels,
- Rainfall measurement data daily and for short duration of storm, and
- River flood level and discharge measurement data.

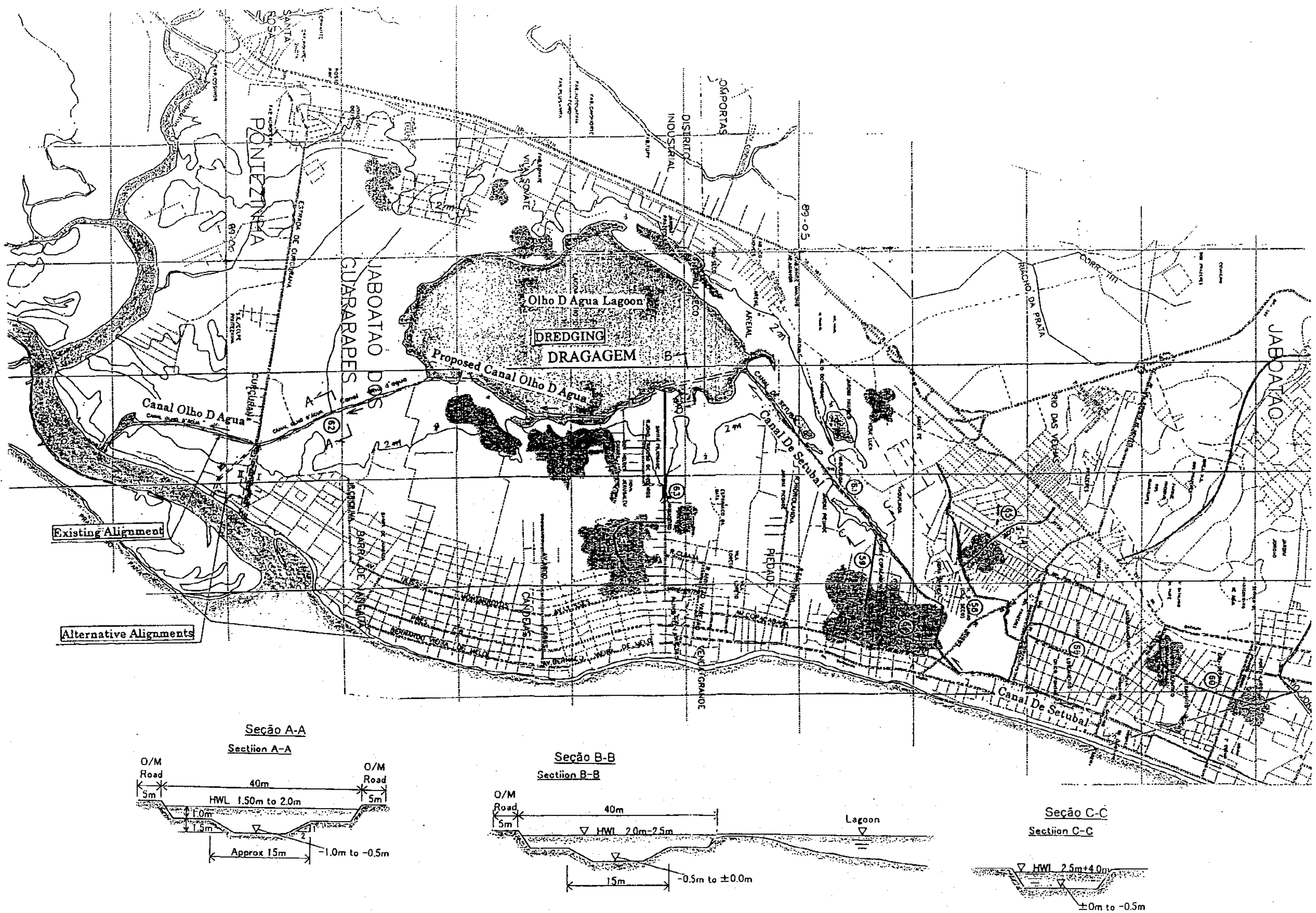

Fig. 3.4-2(1/3) Concept of Drainage Improvement Plan for Canal Olho D Agua

Fig.3.4-2(1/3) Conceito do Plano de Melhoramento de Drenagem para o Canal Olho D'Água

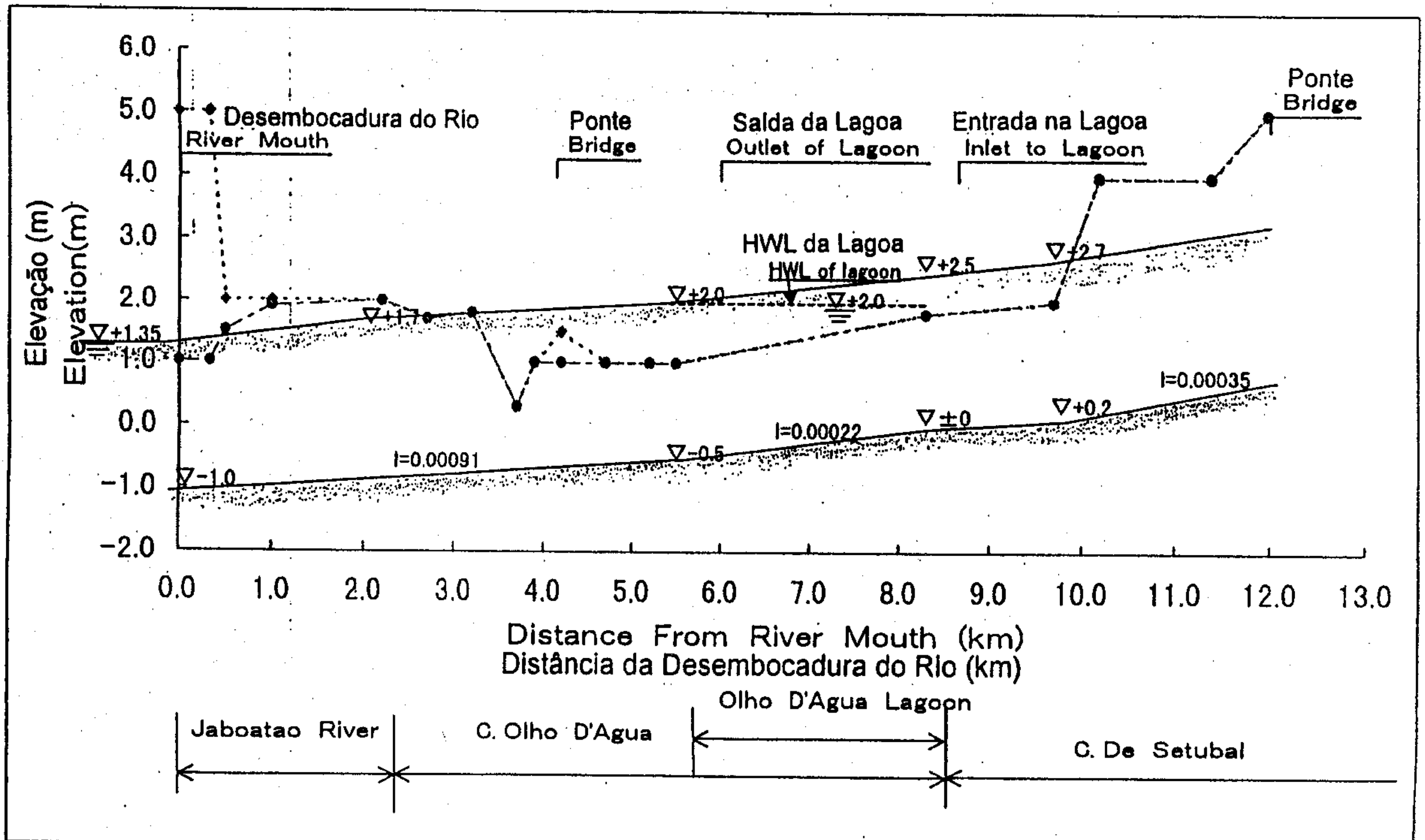

Fig.3.4-2(2/3) Longitudinal Profile Along Jaboatao River—Canal Olho D'Agua—Canal Setubal (Existing Alignment)

Fig.3.4-2(2/3) Corte Longitudinal ao longo do Rio Jaboatão - Canal Olho D'Água - Canal Setúbal (Alinhamento Existente)

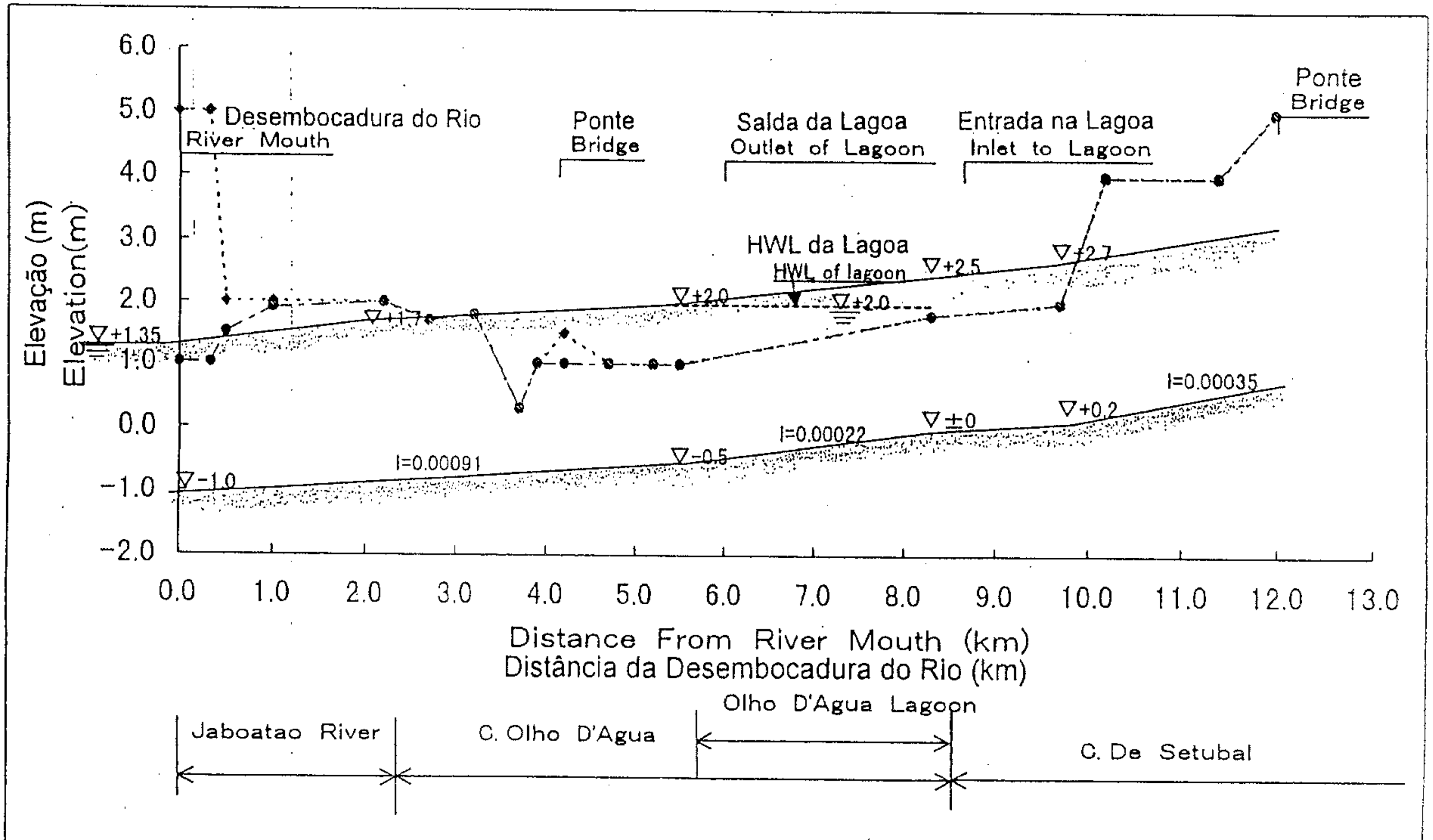

Fig. 3.4-2(2/3) Longitudinal Profile Along Jaboatao River−Canal Olho D'Agua−Canal Setubal (Existing Alignment)

Fig.3.4-2(2/3) Corte Longitudinal ao longo do Rio Jaboatão - Canal Olho D'Água - Canal Setúbal (Alinhamento Existente)

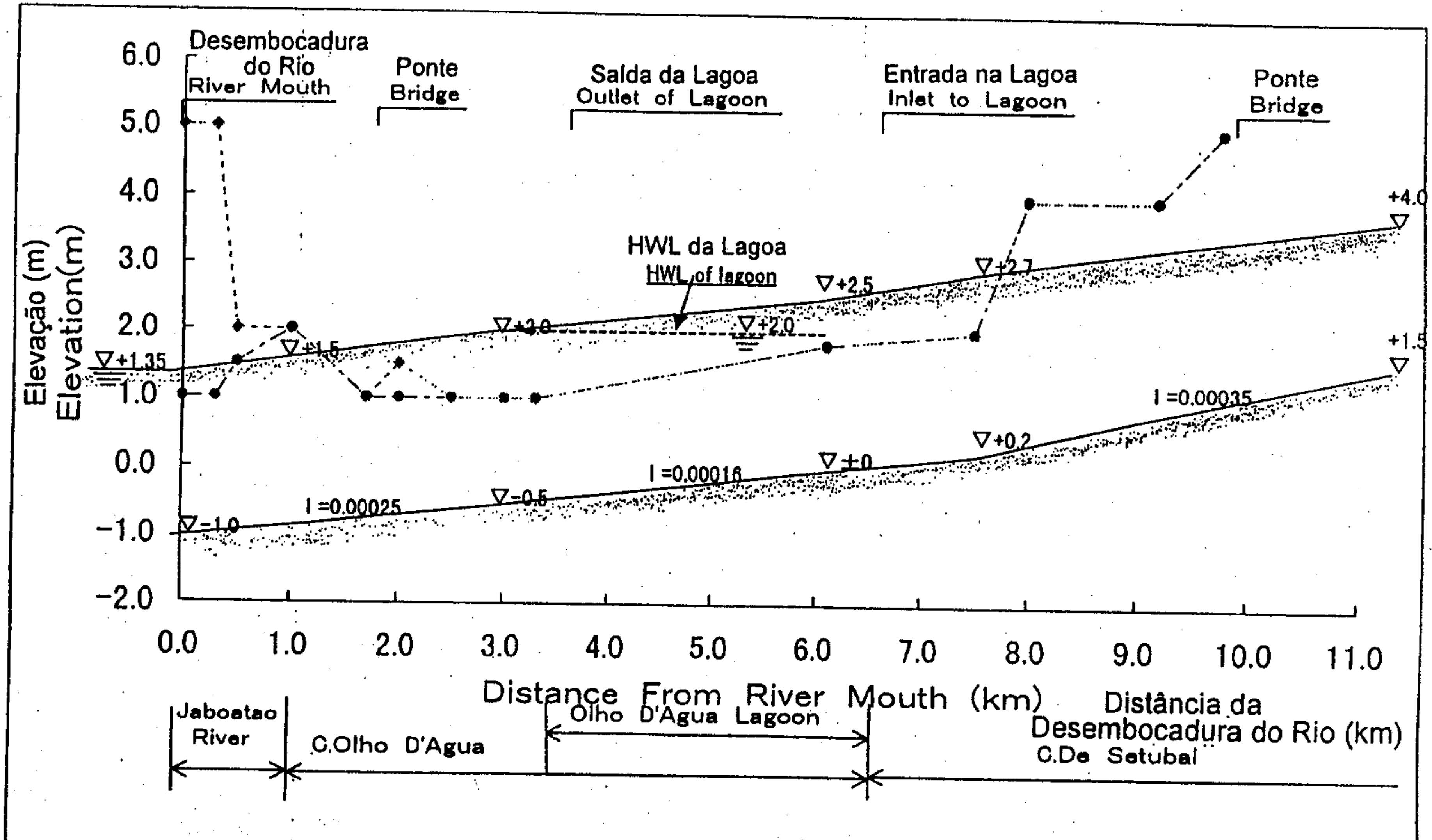

Fig. 3.4-2(3/3) Longitudinal Profile Along Jaboatao River – Canal Olho D'Agua – Canal Setubal (Alternative Alignment)

Fig.3.4-2(3/3) Corte Longitudinal ao longo do Rio Jaboatão - Canal Olho D'Água - Canal Setúbal
(Alinhamento Alternativo)

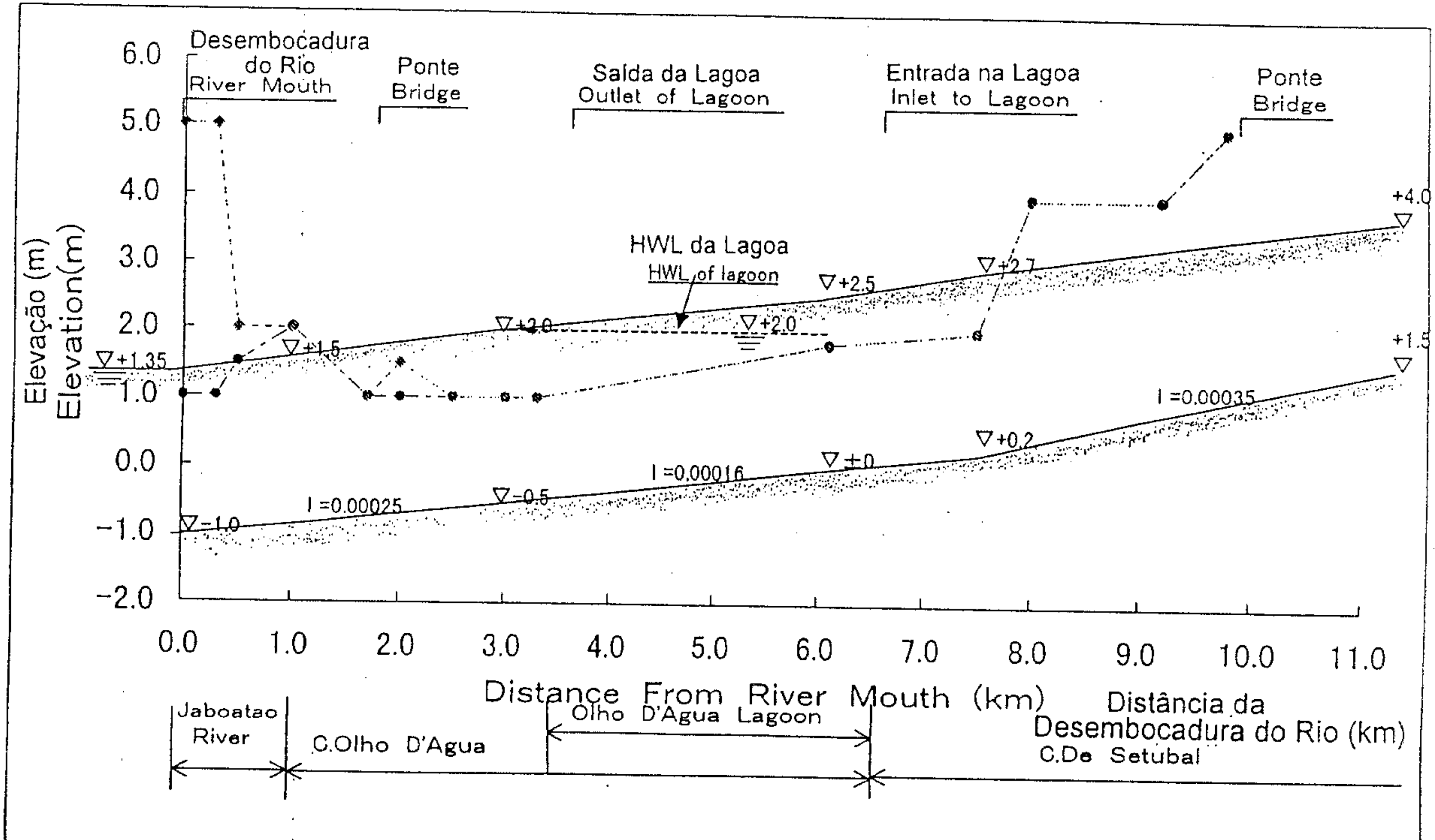

Fig. 3.4-2(3/3) Longitudinal Profile Along Jaboatao River−Canal Olho D'Agua−Canal Setubal (Alternative Alignment)

Fig.3.4-2(3/3) Corte Longitudinal ao longo do Rio Jaboatão - Canal Olho D'Água - Canal Setúbal (Alinhamento Alternativo)

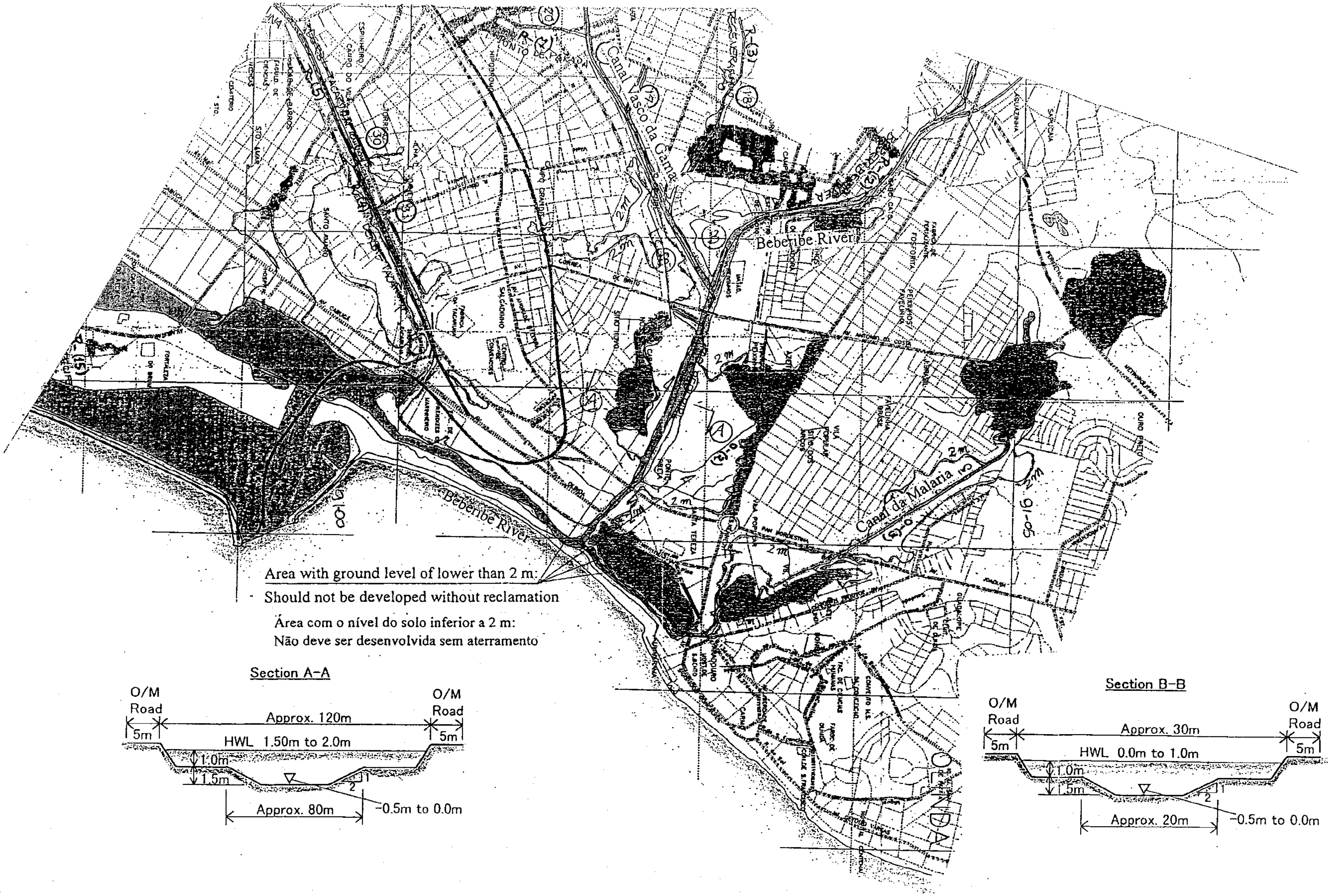

Fig. 3.4-3(1/2) Concept of Drainage Improvement Plan for Beberibe River System

Fig. 3.4-3(1/2) Conceito do Plano de Melhoramento de Drenagem para o Sistema do Rio Beberibe

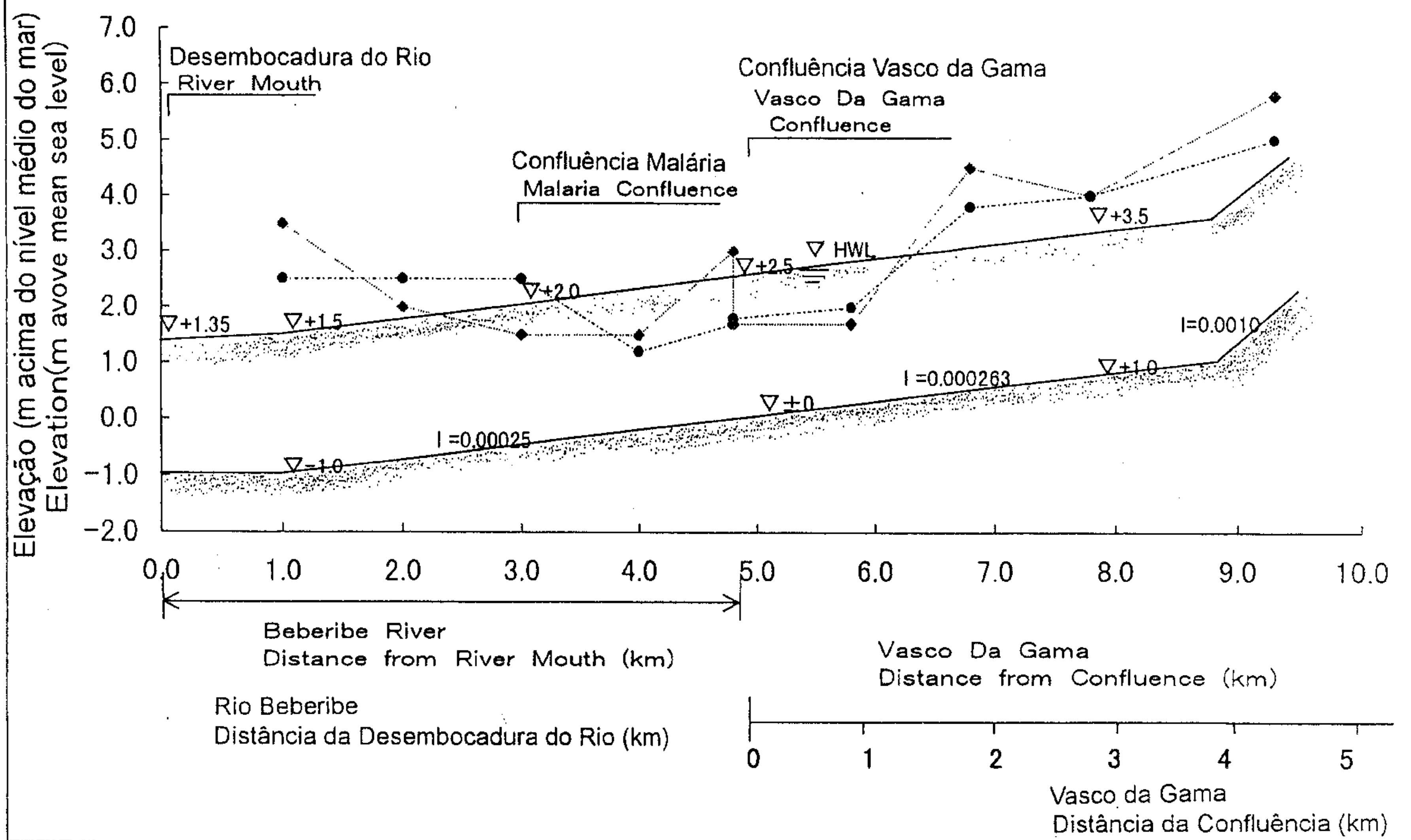

Fig. 3.4-3(2/2) Longitudinal Profile Along Beberibe River−Canal Vasco da Gama

Fig.3.4-3(2/2) Corte Longitudinal ao longo do Rio Beberibe - Canal Vasco da Gama

3 SEWERAGE PLAN TOWARD 2020

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3.1 Pollution Sources and Pollution Load

The pollution sources in the RMR are municipal and industrial wastewater, which are mostly distributed in the urban areas of about 300 km^2. This sewerage study, therefore, has focused on control of the municipal wastewater.

(1) Municipal pollution load

The municipal organic pollution loads (BOD) in 1997 are calculated for 11 river basins.

Present Pollution Load (BOD) Generated in RMR

River Basin	Population	Generated Pollution Load (kg/day)	Served Population	Load (1) (kg/day)	Unserved Population (Poor residents)	Load (2) (kg/day)	Total Load (1)+(2) (kg/day)	Rate of Pollution Runoff
Beberibe	576,643	30,827	120,368	658	456,275	21,305	21,963	0.71
Botafogo	7,221	390	0	0	7,221	234	234	0.60
Capibaribe	667,933	37,209	28,208	275	639,725	24,701	24,976	0.67
Igarassu	67,966	3,670	1,297	18	66,669	2,160	2,178	0.59
Ipojuca	58,621	3,166	0	0	58,621	1,899	1,899	0.60
Jaboatao	501,382	27,075	3,008	32	498,374	20,226	20,258	0.75
Jaguaribe	8,269	447	0	0	8,269	268	268	0.60
Paratibe	98,797	5,335	21,151	228	77,646	2,535	2,763	0.52
Pirapama	84,313	4,553	11,037	119	73,276	2,374	2,493	0.55
Tejipio	493,273	26,526	13,906	75	479,367	19,302	19,377	0.73
Timbo	387,628	20,953	118,747	642	268,881	8,712	9,354	0.45
Total	2,952,046	160,151	317,722	2,047	2,634,324	103,716	105,763	0.66

The total load is 105,763 kg/day out of the generated load of 160,151 kg/day with a runoff coefficient of 0.66. Large sources are the basins of Beberibe, Capibaribe, Tejipio, Jaboatao and Timbo, which account for 91 % of the total load.

(2) Industrial pollution load

Industrial wastewater is controlled by CPRH based on the criteria on effluent water quality (less than 60 mg/l for BOD).

3.2 Proposed Sewerage System

(1) Proposed Sewerage System for Whole Urban Area of RMR

In the PQA 266 sewerage collection units were proposed for the target year of 2020 based on the following conditions:

- Drainage basin for sewerage collection
- Topography
- Existing infrastructures such as buildings and drainage channels

The 266 sewerage units were combined to 86 sewerage sub-systems based on the following conditions:

- To avoid transporting sewage outside the own drainage basin,
- To use existing sewerage facilities as much as possible,
- To minimize the total cost of construction and O/M of the sewerage facilities

(2) Proposed Sewerage Subsystems for the Master Plan

In the Study the above mentioned 86 sewerage subsystems have been studied and fifty five (55) sub-systems among them are proposed for the Master Plan based on the following criteria.

- Area with collection systems with no treatment facility,
- Area with a large population load,
- Area with a large number of low-income population,
- Area with a population density more than 30 persons per ha in 2020.
- Area with large public facilities such as airport and public zones are excluded.

Main features of the Master Plan are summarized as follows:

Number of subsystems:	55 subsystems
Served population in 2020:	3.293 million
Sewerage area in 2020:	29,985 ha (100%)
● New construction area	4,878 ha (16.1%)
● Expansion area	16,564 ha (55.3%)
● Area covered by existing system	8,516 ha (28.4%)

Capacity of existing treatment facilities 210,102 m^3/day

Sewerage flow in 2020:

- Daily average: 530,710 m^3/day
- Daily Max: 611,682 m^3/day
- Hourly Max: 852,970 m^3/day

3.3 Comparison between PQA and Proposed Master Plan

Planning Item	PQA	Master Plan
1. Target year	2020	2020
2. Sewerage service area	36,321 ha	36,425 ha: Revised after checking
3. Population served	3,635,040	3,635,040
4. Unit sewage volume	100 – 200 l/day	100 – 200 l/day
5. Unit pollution load **BOD** **SS**	 54 g/person/day Not planned	 54 g/person/day, 60 g/person/day proposed,
6. Industrial wastewater	To be regulated by CPRH	To be regulated by CPRH
7. No. of subsystems for whole urban area	87 subsystems	86 subsystems: Revised after checking
8. Plan for 2020 **1) No. of subsystems** **2) Population served**	 57 subsystems 2.88 million (80 % of whole urban)	 55 subsystems: Revied and revised by excluding the low density areas 3.29 million: reviewed and revised (90 % of whole urban)
9. Secondary treatment	Not clearly proposed	Proposed in Phase 1
10. Disinfecting	Proposed in Phase 2	Proposed in Phase 1, but implementation will be decided in the F/S stage according to the environmental guidelines.
11. Phase 1 projects **1) No. of subsystems** **2) Population served**	 41 subsystems. 2.05 million (71 % of whole urban)	 25 subsystems 2.75 million: 83 % of whole urban population in 2020)
12. Phase 2 projects **1) No. of subsystems** **2) Population served**	 16 subsystems, 1.25 million	 30 subsystems, 0.55 million in 2020,

3.4 Level of Sewage Treatment

(1) Secondary treatment

In the PQA, the primary and secondary treatment methods were studied, however, timing of implementation of the secondary treatment was not stated clearly. In this Master Plan, it is proposed that every sub-system will be provided with secondary treatment facilities according to the phased program.

(2) Disinfecting

In the PQA, the treated sewage was proposed to be disinfected in the Phase 2. It is proposfor the treated sewage to be disinfected according to the phased program. However, the timing of disinfecting is proposed to be decided in the F/S stage, because it will be necessary for the treated sewage to meet the requirements of the discharge standards to avoid adverse effects on the river water quality.

4. SEWERAGE FACILITY DEVELOPMENT PLAN TOWARD 2020

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4.1 Development Scheme of Sewerage Facilities

(1) Basic Scheme

The sewerage facility plan proposed herewith is a structural measure to attain the goals of the Master Plan toward 2020.

New installation of sewerage facilities are called in the area where are isolated from sewerage provisions at present. Meanwhile, the existing sewerage facilities are seriously damaged in many places. To implement economically the sewerage development, the use of existing facilities as much as possible is regarded as the essential thing. Accordingly, the proposed plan of sewerage development in the RMR are comprised of the following dual schemes:

a) Rehabilitation works of existing sewerage, which are defined as the works to restore the original functions and capacities of facilities by means of the replacement of equipment and parts, supplement provisions of necessary components, etc., and

b) Expansion works, which are defined as the works to expand the functions and capacities by means of new installation of facilities, additional provisions of necessary equipment, etc.

(2) Basic Planning Conditions

The rehabilitation and expansion works will be undertaken for the selected 55 sewerage subsystems. The basic planning conditions for them are represented as follows:

a) Sewage collection method:

Completely separate-sewerage system will be applied. Accordingly, only wastewater excluding stormwater is handled by the sewerage facilities.

b) Sewerage area:

- Sewerage area in 2020: 29,960 ha in total
- Existing sewerage area at the present: 8,520 ha in total
- Total sewerage area to be developed in 2020: 21,440 ha

c) Sewage flow in 2020:

- Daily average flow: 531,000 m^3/day in total
- Daily maximum flow: 612,000 m^3/day in total
- Hourly maximum flow: 853,000 m^3/day in total

d) Influent sewage qualities:

- BOD: 340 mg/l on the average of the RMR
- SS : 370 m/l on the average of the RMR

e) Removal rate of pollutants:

- BOD: Over 90 %
- SS : Over 90 %

The treated sewage will be disinfected, if necessary. The necessity of disinfecting will be studied in the F/S stage.

f) Sludge treatment:

The sludge to be generated from sewage treatment will be dewatered into cake-shape in the treatment station, by using a mechanical dehydrator or a natural drying bed.

4.2 Rehabilitation of Existing Facilities

(1) Sewage Collection and Transport Facilities

Sewage collection and transport facilities consist of pumping stations and sewage pipes.

Total 96 pumping stations are working at present in four major sewerage system, accommodating total 167 sets of different-type pumps. The site investigation has revealed that almost all pumping stations have been damaged in a certain. Accordingly, a significant portion of collected sewage are discharged into the nearby water courses without treatment.

As the results of the site survey and the review of the data prepared by COMPESA, the rehabilitation items, which are necessary for respective pumping stations in response to their current damages, were identified. They include the works ranging from the supplement of new pumps to the replacement of component parts.

On the other sides, sewage pipes are calling for urgent rehabilitation, because they have also broken in many points, mainly due to aging. Together, the silting in pipes is found to be serious, resulting into the lowering flow capacity. Based on the data prepared by COMPESA and the site investigation, the quantities of repair and cleaning works for the existing sewers and pumping stations to be used in selected 55 subsystems are estimated as the rehabilitation works. They include the supplement of pipelines, the repair of pipe connections, the inspection of silting, the cleanings, etc.

(2) Sewage Treatment Facilities

As of today, 44 sewage treatment stations altogether are working in four major sewerage systems. Of them, 24 stations are planned to be used in selected 55 subsystems. Most of treatment stations need the rehabilitation, partly or totally, to meet the functions and the capacities required for the original functions and capacities. In addition, most of existing treatment stations are suffering from different kinds of damage at the present.

Taking the above situation into account, necessary rehabilitation works for treatment facilities for respective subsystems will be undertaken.

4.3 Expansion of Sewage Collection and Transport Facilities

The sewer networks for collection and transport are comprised of collectors, branch sewers, trunk sewers and pressure sewers.

Fig. [illegible] shows the concept on the arrangement of sewers and other related facilities in sewerage subsystems. Sewerage areas are comprised of several UEs (the abbreviation of Sewerage Unit in Portuguese), which are the minimum units of sewage discharge and collection to be defined by topographical conditions and others. Sewage generated is collected through house connections by collectors, which are called condominial collectors in the areas covered by condominial systems and sidewalk collectors in the other areas. Then, sewage is led to trunk sewers by branch sewers. At the downstream end of trunk sewers, a pumping station is installed in the UEs, at one place as a rule. Through pressure sewers, sewage is sent to the next UE by pumping.

The total length of sewers to be expanded reaches about 5,900 km and the total shaft power of pumping stations some 9,700 CV. They are summarized in the following table:

Summary of Overall Work Volume of Sewage Collection and Transport Facilities

Items			Units	Quantities
Sewers	Condominial collectors	Pipe length	(km)	530
	Sidewalk collectors	Pipe length	(km)	3,077
	Branch sewers	Pipe length	(km)	2,063
	Trunk sewers	Pipe length	(km)	133
	Pressure sewers	Pipe length	(km)	65
	Total	Max. diameter	(mm)	ND 1000
		Pipe length	(km)	5,868
Pumping station		Total set number	(set)	441
		Total shaft power	(CV)	9,748

4.4 Expansion of Sewage Treatment Facilities

(1) Examination on Sewage Treatment Process

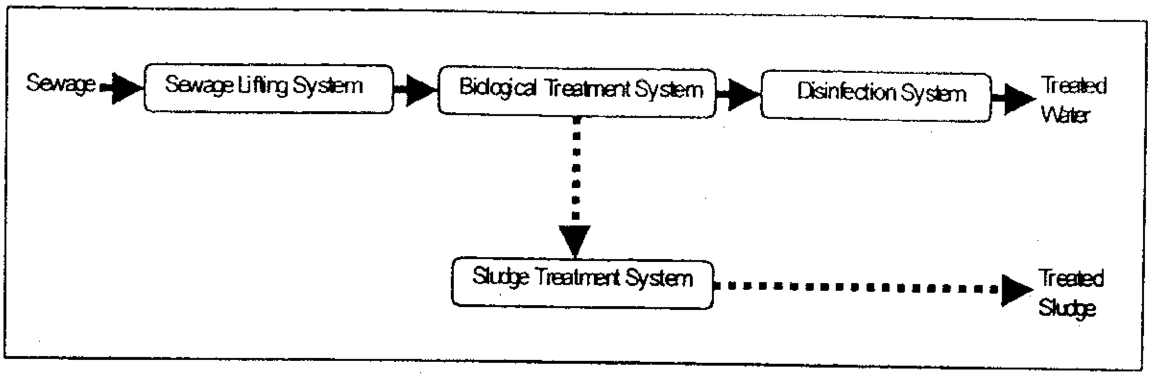
In general, sewage treatment facilities are comprised of influent system, biological treatment system, disinfection system and sludge treatment system as shown below.

A diverse kind processes are available in biological treatment system, disinfection system and sludge treatment system. To select optimum ones applicable to the RMR, the following examinations were made.

1) Biological Treatment System

Biological treatment system is a major component, which remove pollutants in sewage like BOD and SS. The following options of biological processes were compared from the point of technical and economical view: a) activated sludge process, b) oxidation ditch process, c) aerated lagoon, d) bio-filtration process, e) RAFA + lagoon process, and f) RAFA+bio-filtration process.

General Flow of Sewage Treatment



Among the processes mentioned above, aerated lagoon process and sole bio-filtration process cannot be adopted due to the inferior BOD removal (less than 90 %). Other processes were comparatively examined by using the weighing evaluation method, which allocates the following weighing points: i) 5 for construction cost, ii) 3 for energy consumption, iii) 3 for sludge generation rate, iv) 5 for easiness of operation and maintenance, and v) 5 for required land space.

Evaluation of Biological Treatment Process

Comparison Items		Weighing Points	Optional Processes			
			Activated Sludge	Oxidation Ditch	RAFA + Lagoon	RAFA + Bio-Filtration
Construction Cost	Raw Point	5	1	1	5	3
	Score		5	5	25	15
Energy Consumption	Raw Point	3	1	1	5	3
	Score		3	3	15	9
Sludge Generation Rate	Raw Point	3	1	3	5	5
	Score		3	9	15	15
Easiness of O and M	Raw Point	5	1	3	5	3
	Score		5	15	25	15
Required Land Space	Raw Point	5	5	3	1	5
	Score		25	15	5	25
Total Score			41	47	85	79

Note: The raw points stand for: 5 to "excellent", 3 to "medium" and 1 to "inferior".

As evident from this comparison, RAFA process attached by lagoon or bio-filtration indicates significant advantage. This result is attributed to:

a) RAFA process is of anaerobic treatment, which needs no aeration requiring large energy,

b) The BOD space loading rate of RAFA process is extremely high (some 1.5 kg-BOD/m^3/day) as compared to other process, and

c) Sludge generation rate in RAFA process is very low.

Based on these results, RAFA process is placed at the highest priority, as follows:

a) In case there is no limitation in the land space of treatment station:

RAFA Reactor + Lagoon (Stabilization Pond)

b) In case there is a certain limitation in the land space of treatment station:

RAFA Reactor + Bio-Filtration (including sedimentation)

In the application of RAFA process, the special attention and proper measures should be paid to the generation of offensive odor, especially in the densely populated area. Fig. 2 and Fig. 3 shows a typical application of the above-mentioned RAFA process and typical configuration of RAFA reactor, respectively.

2) Sludge Treatment System

At present, all the existing sewage treatment stations in the RMR rely on sludge drying beds to treat the sludge generated. The characteristics of sludge drying process are evaluated like: i) it requires large land space due to the low-rate drying, and ii) it might generate offensive odor, which give environmental concerns to the surroundings.

Considering the above-mentioned characteristics of sludge drying, sludge treatment process was reexamined in accordance with the following criteria:

a) A certain mechanical dehydration should be introduced in the sewage treatment stations that are limited in land space, or that are sited in the densely populated area.

b) A natural drying bed will continue to be applied in the sewage treatment stations that are not constrained by land space and that are not concerned about the surrounding.

The sludge quantity to be generated in the RMR in 2020 is estimated at some 64 ton-Dry Solid/day (130 ton/day on the wet-base, when 50 % moisture is assumed after natural drying). As for the final disposal of sludge, almost all of generated sludge is disposed to the dumping sites at present, except for a very little amount of sludge used for gardening. In light of the constituents contained in sludge and the agricultural activities in the RMR, the agricultural use of sludge as a fertilizer or a soil conditioner should be promoted in the future, as it takes place in developed countries as one of beneficial uses. To realize this beneficial use of sludge, the sewage and generated sludge quality, especially for toxic substances like heavy metals, pathogens, etc. must be monitored in the periodical base.

(2) Expansion of Sewage Treatment Facilities

1) Expansion Methods

In sewerage subsystems in which existing facilities are not available, the whole treatment station will be installed along with the examination results of optimum processes mentioned in the previous section. In case the existing facilities are working at present, the disinfection system will be added in all the subsystems. Both the sewage lifting system and the sludge treatment system will be added to the existing one, if their capacities are not enough for the given conditions in 2020.

As for the biological treatment system, of all the existing sewage treatment facilities, some will continue to be used and others are abolished. In this judgement, the following criteria for the expansion methods are adopted:

a) The existing facilities, which consist of oxidation ditch, extended aeration or RAFA plus lagoon, continue to be used, because their water quality performance meet the given requirement in 2020 (over 90 %). If their hydraulic capacities are less than the given requirement in 2020, another train employing RAFA plus lagoon or bio-filtration process will be constructed additionally.

b) The existing facilities consisting of septic tanks are abolished and replaced by new facilities using RAFA plus lagoon or bio-filtration process, because they do not satisfy the water quality performance in 2020.

c) The existing facilities, which consist of bio-filters, aerated lagoons, stabilization ponds and sole RAFA reactors, will be altered into RAFA plus Lagoon process or bio-filtration process. As a rule, aerated lagoons and stabilization ponds are used as the lagoons as the post treatment of RAFA, after modified.

2) Expansion Works of 55 Sewage Treatment Facilities

Based on the results of the examination above-mentioned, the proposed specific expansion plan of sewage treatment facilities over all 55 subsystems has been formulated.

As for the locations of sewage treatment stations, the existing sites will continue to be used as a rule, unless there are particular reasons. The new sites in the subsystems without existing stations have been selected, considering: a) accessibility to the watercourses for treated sewage, b) topographic conditions to collect and transfer sewage easily, c) land use situation of the surroundings, and d) accessibility to sites from main roads.

3) Specific Expansion Works of Three Major Subsystems

Specific treatment stations in three major subsystems: Janga, Peixinhos and Cabanga Subsystem will be expanded as follows:

a) Janga Sub-system: (as shown in Fig. 4 and Fig. 7)

The existing train of oxidation process will continue to work as it is. The new train consisting of RAFA reactors plus lagoons will be constructed adjacent to existing facilities, for the incremental inflow. A disinfection tank will be added. In the sludge treatment system, a part of drying beds will be added to the existing ones.

b) Peixinhos Subsystem: (as shown in Fig. 5 and Fig. 8)

To upgrade its BOD removal performance and hydraulic capacity, RAFA reactors, additional bio-filters and additional secondary sedimentation tanks will be installed. The existing primary sedimentation tanks will be abolished. A disinfection tank will be added. In the sludge treatment system, sludge thickener and sludge dehydrators will be newly constructed. Existing sludge digesters, a gasholder and a biogas burner will continue to work after rehabilitated, and sludge drying beds will be abolished.

c) Cabanga Subsystem: (as shown in Fig. 6 and Fig. 9)

To upgrade its performance, RAFA reactors and bio-filters will be added. The existing primary sedimentation tanks will be converted into secondary sedimentation tanks after rehabilitated. A disinfection tank will be added. In the sludge treatment system, sludge thickener and sludge dehydrators will be newly constructed. Existing sludge digesters, a gasholder and a biogas burner will continue to work after rehabilitated, and sludge drying beds will be abolished to provide the installation space for RAFA reactors and bio-filters.

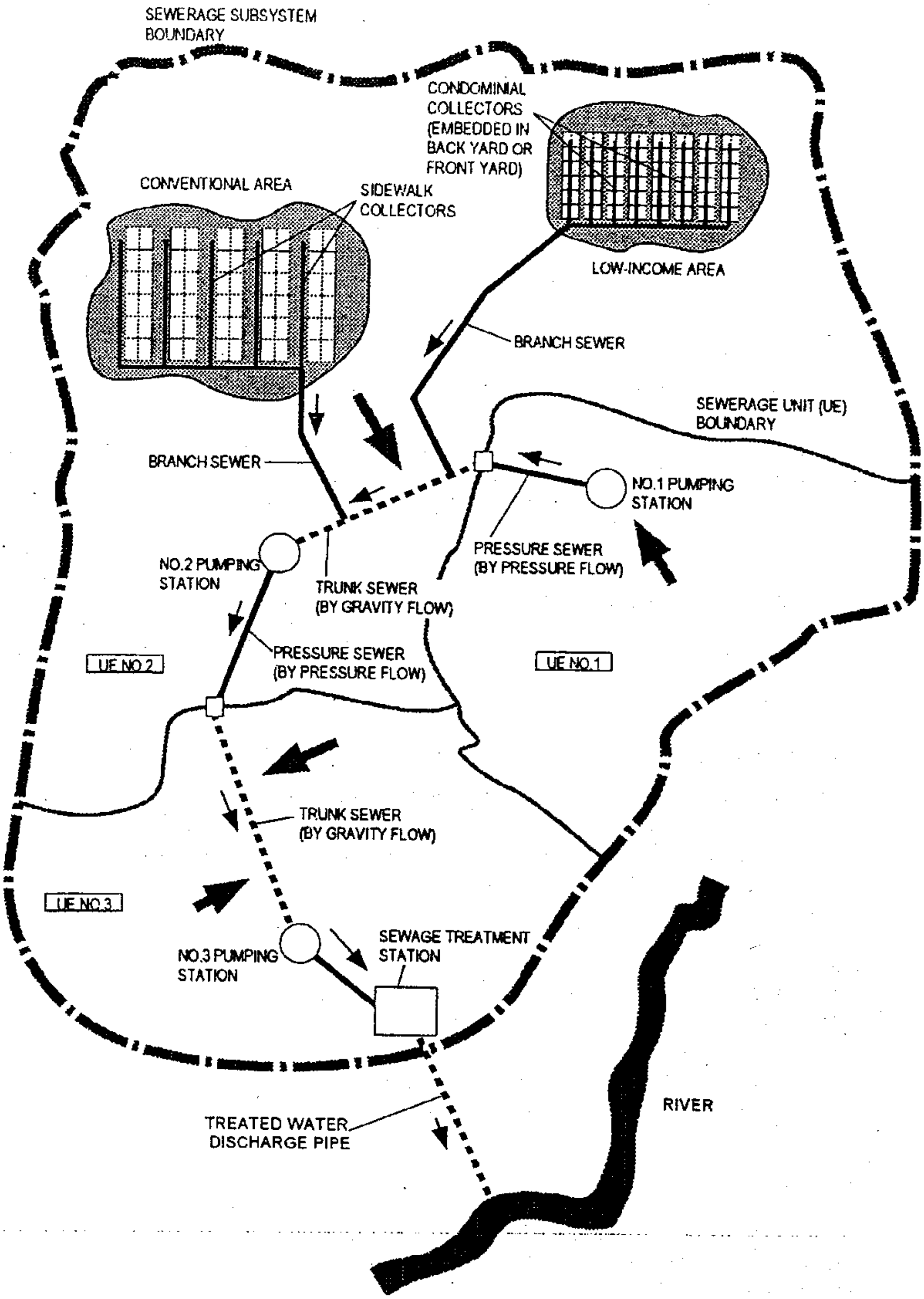


Fig. 1	Conceptual Layout of Sewage Collection and Transport Facilities

THE STUDY ON STORMWATER DRAINAGE AND SEWERAGE MANAGEMENT PLAN FOR RMR

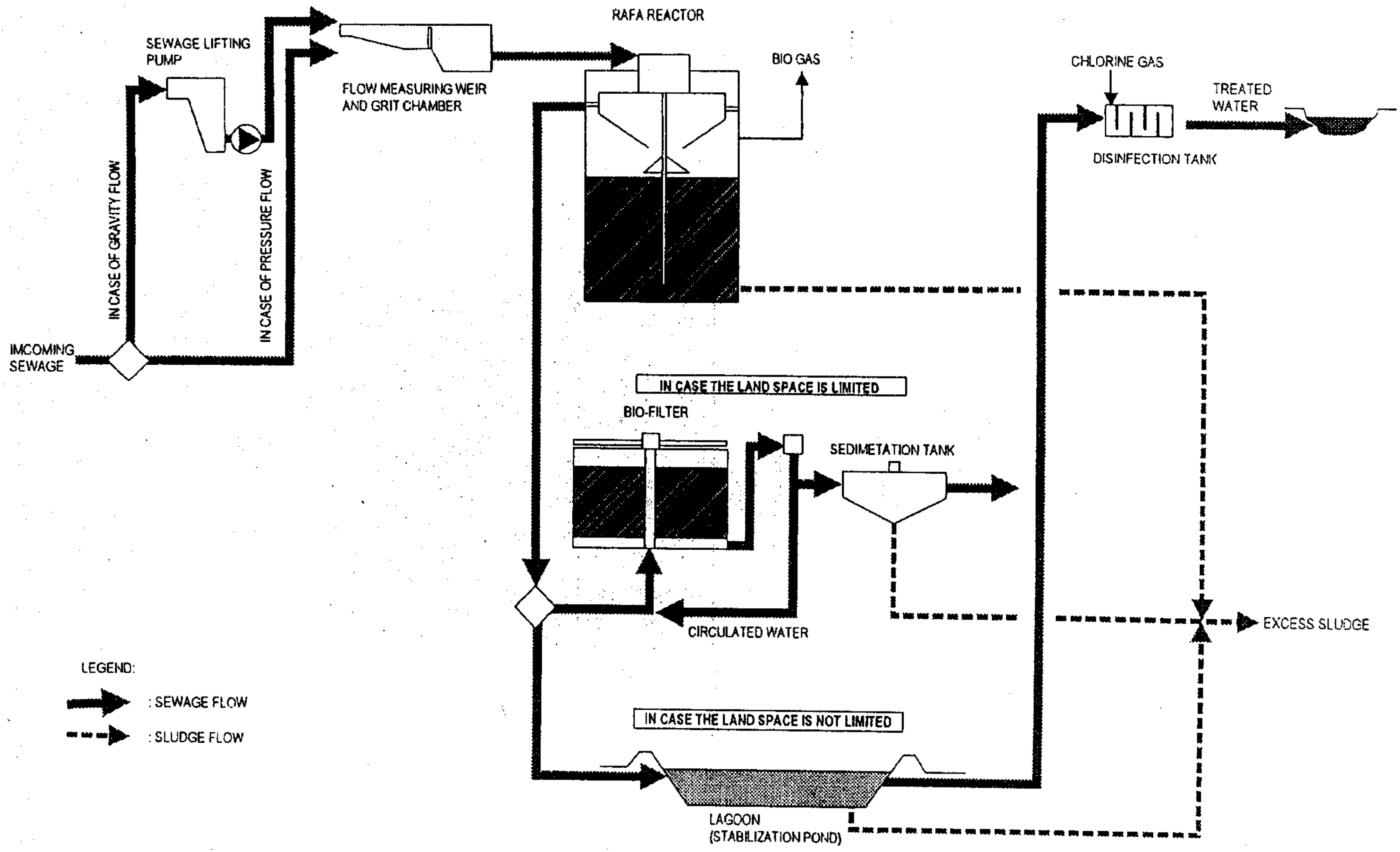
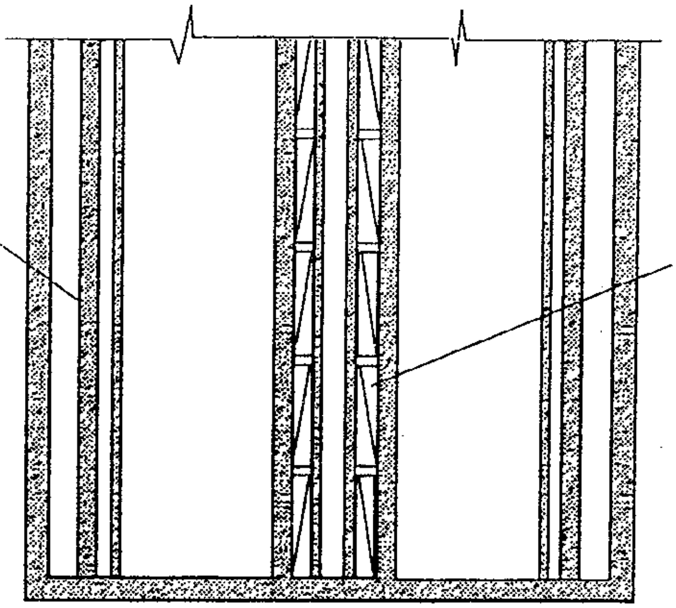
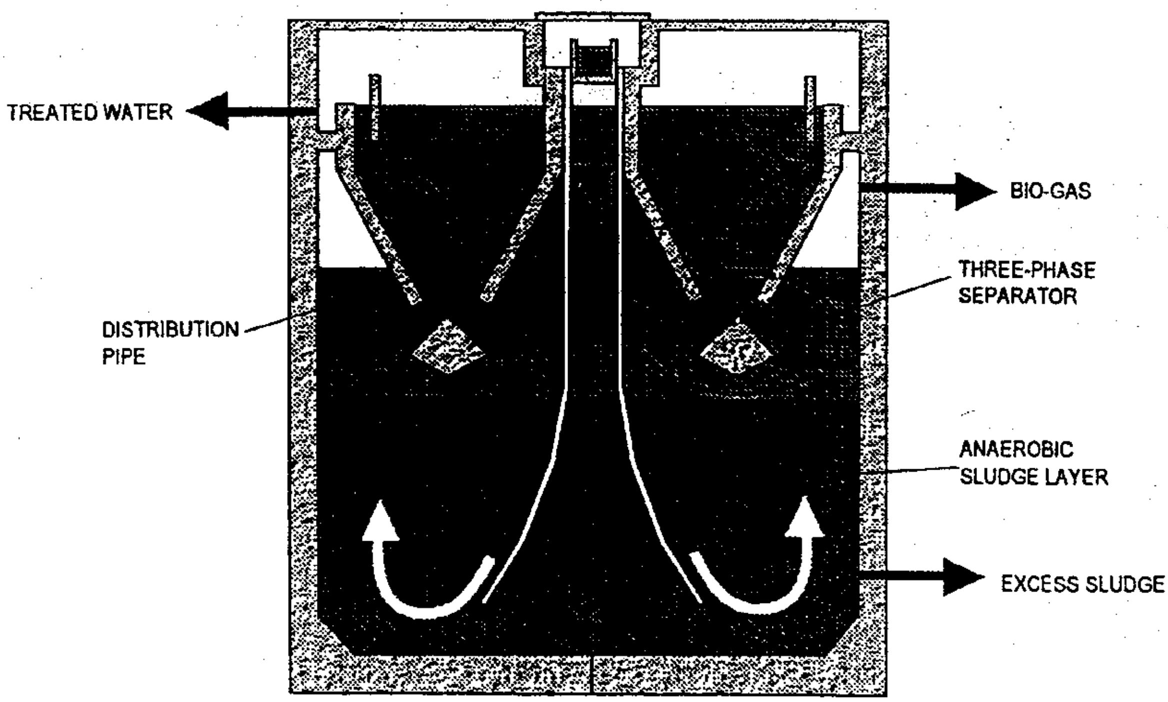


Fig. 2	Flow Diagram of RAFA Process

THE STUDY ON STORMWATER DRAINAGE AND SEWERAGE MANAGEMENT PLAN FOR RMR



PLAN VIEW



SIDE VIEW

NOTE: RAFA IS THE ABBREVIATION OF REATOR ANAEROBICO DE FLUX ASCENDENTE IN PORTUGUESE.

Fig. 3	Configuration of RAFA Reactor

THE STUDY ON STORMWATER DRAINAGE AND SEWERAGE MANAGEMENT PLAN FOR RMR

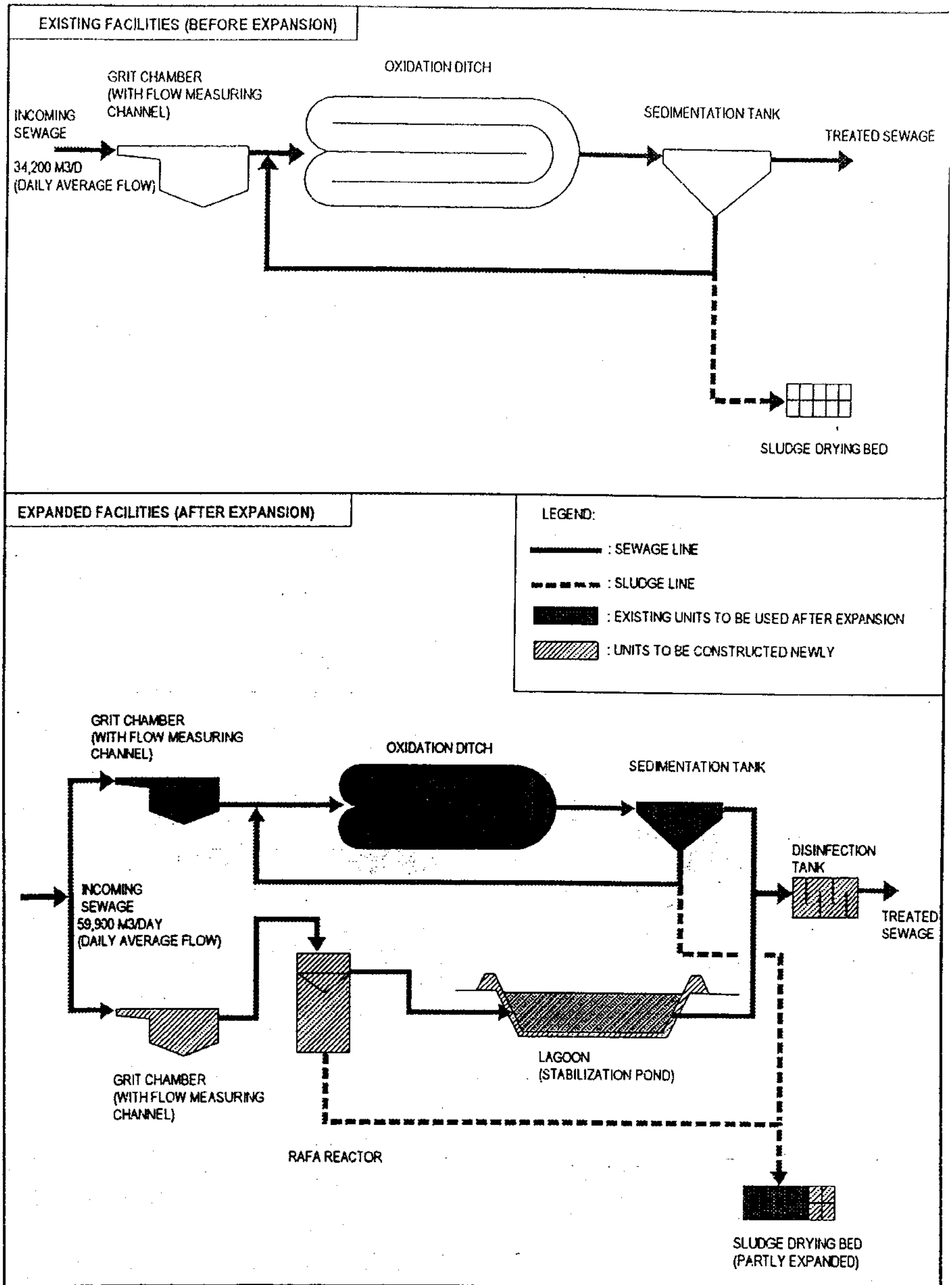


Fig. 4 **Flow Diagram of Janga Sewage Treatment Station**

THE STUDY ON STORMWATER DRAINAGE AND SEWERAGE MANAGEMENT PLAN FOR RMR

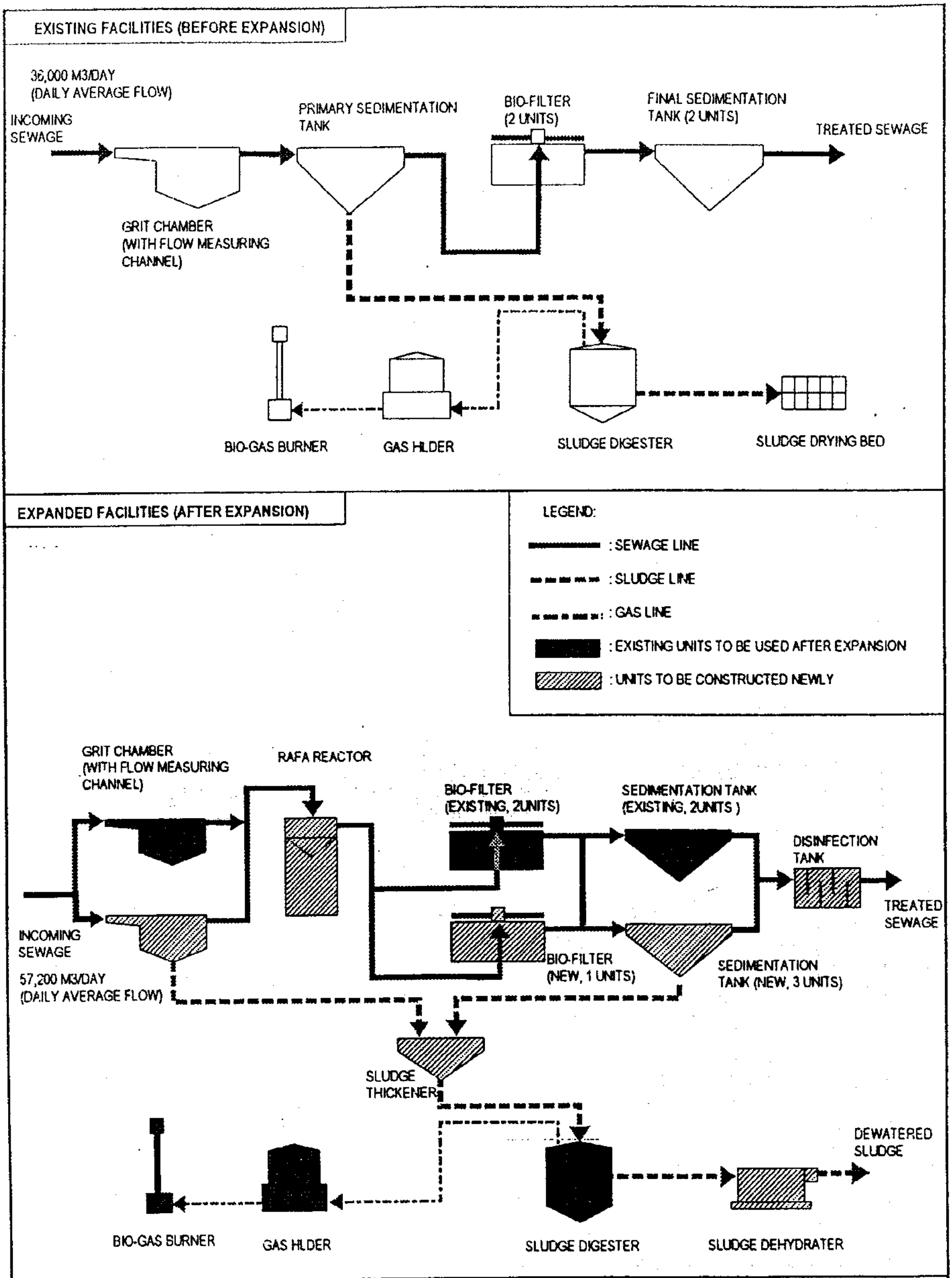


Fig. 5 **Flow Diagram of Peixinhos Sewage Treatment Station**

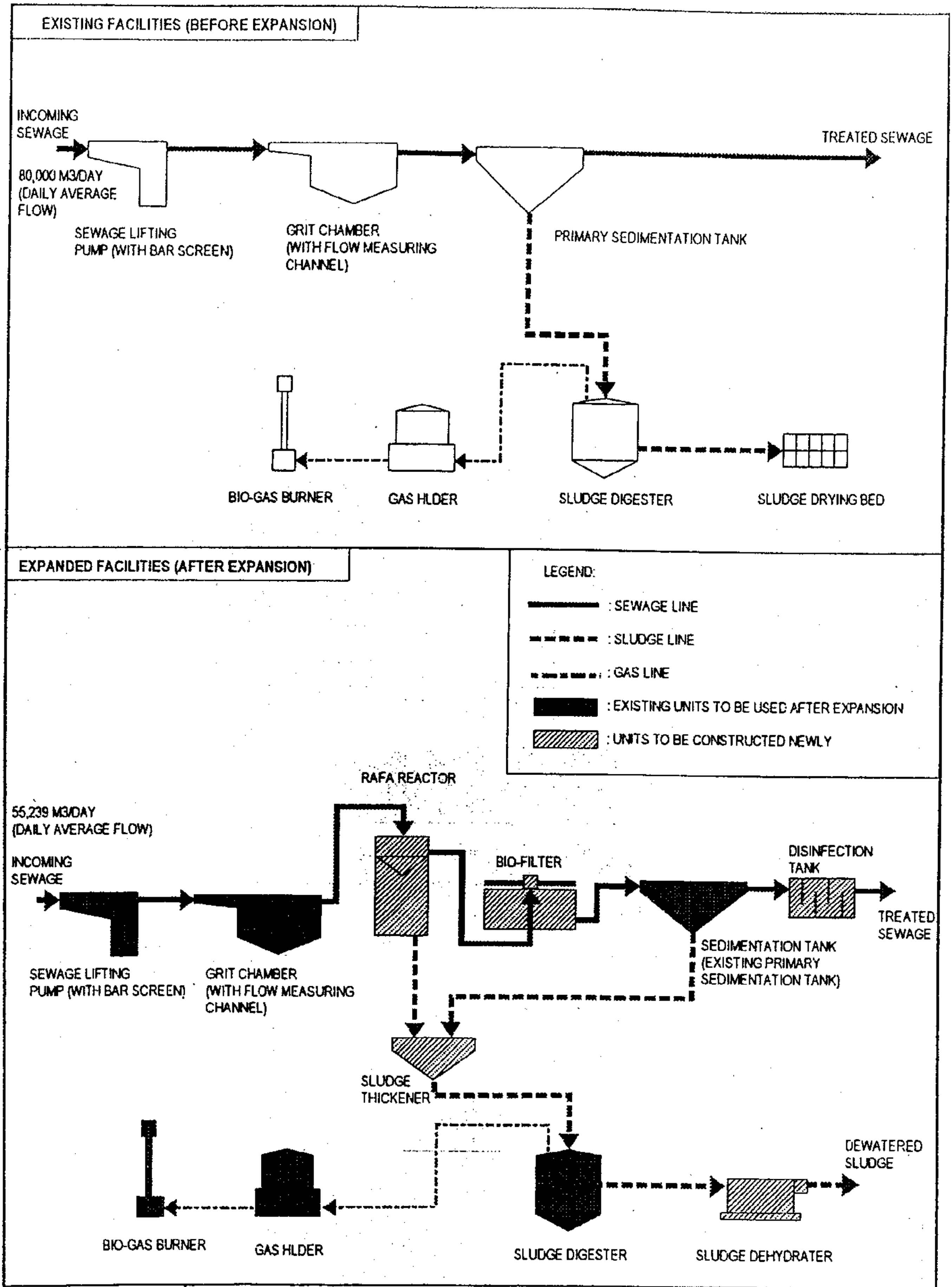


Fig. 6	Flow Diagram of Cabanga Sewage Treatment Station

THE STUDY ON STORMWATER DRAINAGE AND SEWERAGE MANAGEMENT PLAN FOR RMR

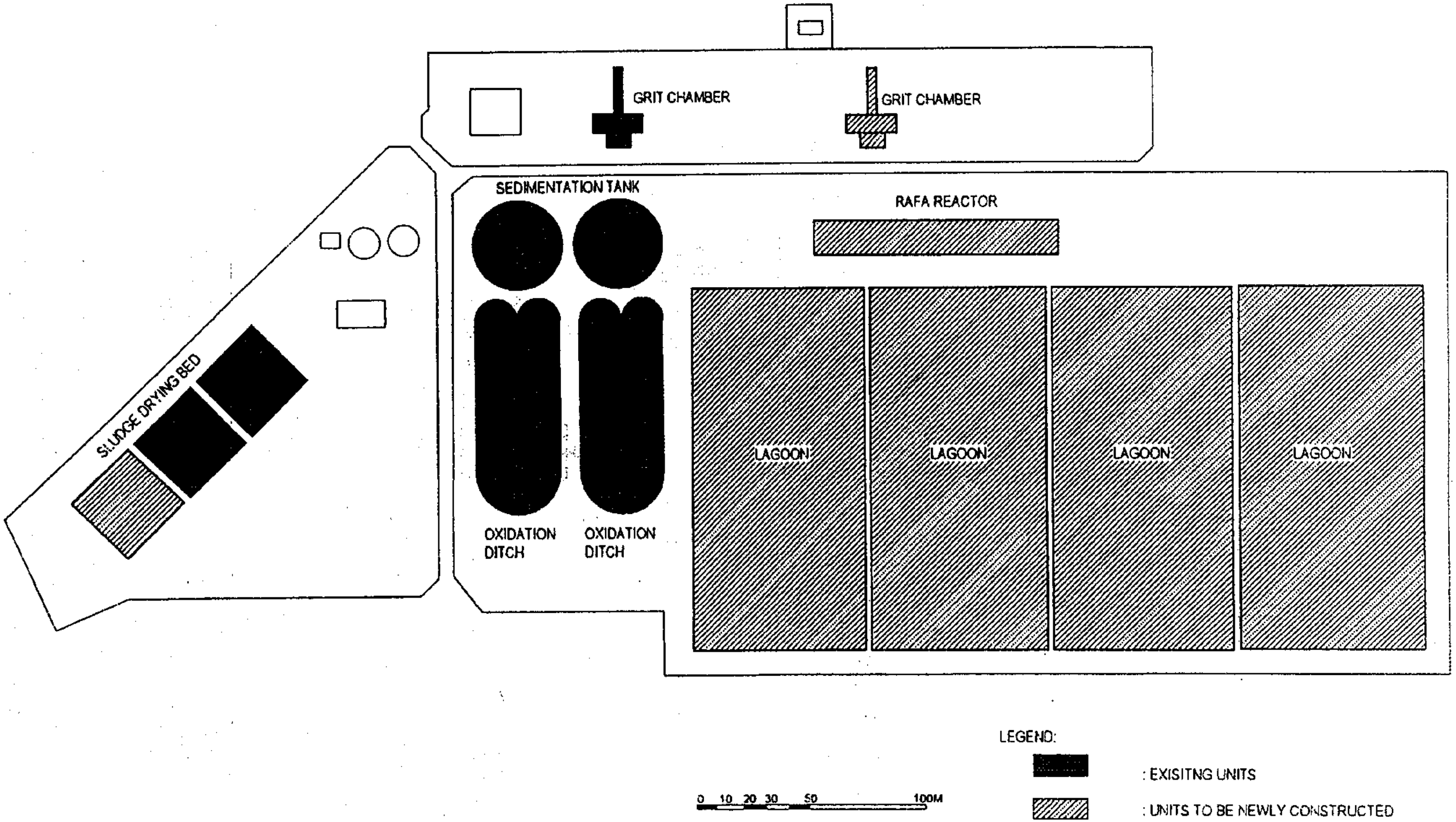


Fig. 7	Layout Plan of Janga Treatment Station

THE STUDY ON STORMWATER DRAINAGE AND SEWERAGE MANAGEMENT PLAN FOR RMR

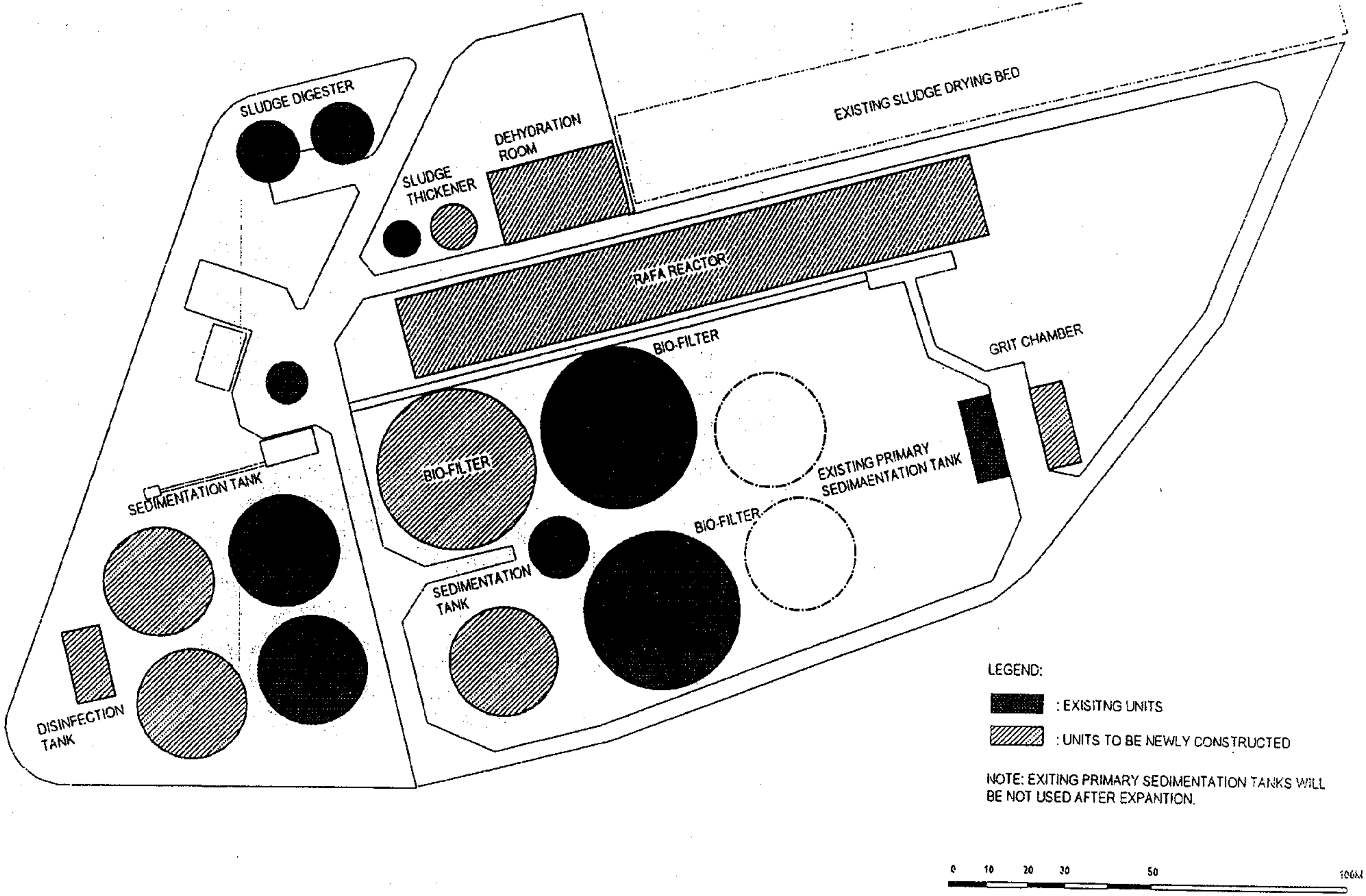


Fig. 8	Layout Plan of Peixinhos Treatment Station
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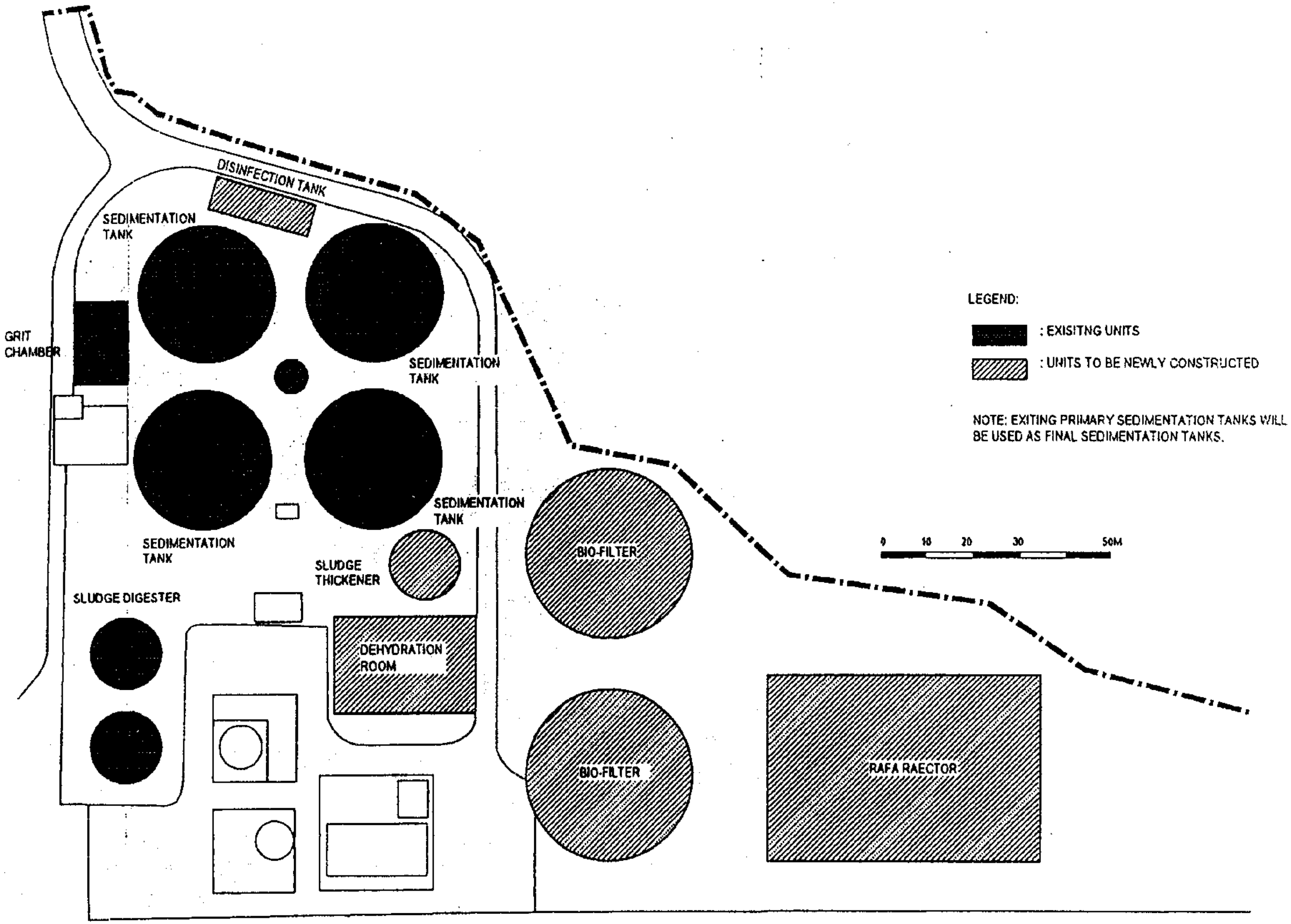

Fig. 9	Layout Plan of Cabanga Treatment Station

THE STUDY ON STORMWATER DRAINAGE AND SEWERAGE MANAGEMENT PLAN FOR RMR

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

BRAZILIAN COOPERATION AGENCY (ABC),
STATE SECRETARIAT OF PLANNING AND SOCIAL DEVELOPMENT,
STATE OF PERNAMBUCO (SEPLANDES)
FEDERATIVE REPUBLIC OF BRAZIL

SEMINAR – 2

for

THE STUDY

ON

STORMWATER DRAINAGE AND SEWERAGE MANAGEMENT PLAN FOR RECIFE METROPOLITAN AREA

IN

THE FEDERATIVE REPUBLIC OF BRAZIL

—— CONTENTS ——

DECEMBER 2000

PACIFIC CONSULTANTS INTERNATIONAL, TOKYO

THE STUDY ON STORMWATER DRAINAGE AND SEWERAGE MANAGEMENT PLAN FOR RECIFE METROPOLITAN AREA IN THE FEDERATIVE REPUBLIC OF BRAZIL

Seminar-2
(December 2000)

1 OUTLINE OF THE STUDY

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<u>Figure Number</u>

•

1. OUTLINE OT THE STUDY

1.1 Introduction

This text give a general outline of the result of the Study on "the Study on Stormwater Drainage and Sewerage Management Plan for Recife Metropolitan Area in the Federative Republic of Brazil", including priority projects identified in the Master Plan.

The Study Area is the Recife Metropolitan Region (RMR), which covers 2,766 km^2 with a population of 3.1 million (in 1996), composing of 14 municipalities and 11 major river basins, and the urban area covers 302 km^2 (Fig.1).

The current RMR is characterized by a heavy concentration of population in the urban area, a wide distribution of the poverty areas (or informal settlements) and a scarcity of basic infrastructures such as sewerage systems and drainage systems.

According to the 1996 census about 40% (3,0 million) of the population of the State Pernambuco, which was 7.4 million, are located in the RMR and 83% of the population of the RMR are living in the five central municipalities, i.e., Recife, Olinda, Jaboatão dos Guararapes, Paulista and Camagibe.

The population in the poverty areas is estimated to be more than 40% of the total urban population and the poverty areas have been developed in the hilly areas and low-lying area along rivers and water bodies. They are usually lack of basic infrastructure like drainage and sewerage facilities, accelerating the devastation of the urban environment.

In the RMR the sewerage services are backward. There are sewer systems and treatment facilities located in the central part of the RMR, which were mostly constructed before the 1980s

The households connected to the sewer systems are estimated to be 36 % of the whole households, but those connected to the sewage treatment systems are 21 % of the whole households. Due to being superannuated and also poorly maintained, the existing sewerage systems are partly inactive. Accordingly a large part of the domestic wastewater is discharged directly or indirectly into the rivers or water bodies without roper treatment.

The drainage channels rivers and other water bodies, especially in the central part of the RMR, have been polluted by the wastewater that causes bad effects on the health of inhabitants and also stagnation of the tourism industry, which is the leading industry in the State, and the sewerage management is one of the most urgent measures for the State Government to solve.

1.2 Master Plan

The fundamental measures for improvement of the stormwater drainage and sewerage management systems in the RMR have been studied and urgent measures selected as priority projects in order to restore the environmental conditions of the urban area.

1.2.1 Framework

The framework of the Master Plan was formulated for the target year 2020 as follows:

- Urban population: 3,635 thousand inhabitants
- Urbanized area: 364.25 square km
- GRDP of the State: R$ 65 billion (at 1997 constant prices). This is 2.8 times of that of 1997 (R$ 23.26 billion). The growth rate is expected to be 3.2 % in 2020, which is larger than the rate (2.7 %) in 1997.
- GRDP per capita: R$ 7,600 at 1997 constant prices. This is 2.4 times of that of 1997 (R$ 3,100). It is projected to be 79 % of the national average, which will have increased by 58 % since 1997.

1.2.2 Sewerage System Development Plan

The 86 sewerage systems were proposed for the RMR in the PQA. The Study has selected 55 sewerage systems for the Master Plan (Fig. 2) based on the PQA plan and the following conditions.

<u>Conditions</u>

- Sewerage systems without sewage treatment facilities,
- Sewerage system require to improve the existing sewage treatment facilities,
- Sewerage system with a high population density of low income class,
- Sewerage system having a high pollution loads,
- Located in the major river basin,

After completion of the 55 sewerage systems the sewerage service population of the RMR will cover 91 % of the urban population.

1.2.3 Stormwater Drainage Management Plan

The major problem areas of stormwater drainage in the RMR are located in the low-lying areas along the rivers and water bodies in the municipalities of Olinda, Recife and Jaboaten.

The drainage facilities planned for Olinda, Recife and Jaboatao in the PQA are proposed to be implemented for the time being, and the river and drainage improvement plan for the RMR should be prepared in future after observation of basic hydrological data and conducting river morphological survey.

Though there are 30 rainfall stations in the RMR, which are measuring only daily rainfall. For more accurate calculation of the design discharges, observation of short duration (10 min, 30 min, 60 min, 120 mini, etc) for many year will be required.

1.2.4 Effect of the Master Plan

It will expand the sewerage service area from 8,516 ha to 29,985 ha in 2020 and increase the sewage treatment level from no more than 20 % of the urban population (in 1996) to about 90 % in 2020. By the expansion of sewerage service areas, living and sanitary conditions in the RMR will be improved.

It will improve the sanitary conditions of the poverty areas of some 885,000 inhabitants by providing with the sewerage system.

1.2.5 Initial Environmental Examination (IEE)

The IEE has been conducted for the priority projects based on the Manual of Guidelines for Evaluation of Environmental Impacts by the CPRH, 1998 and the Environmental Guidelines by JICA, 1994,

No significant adverse impacts by the construction of the priority projects are to be expected on air quality, hydrological situation, ecological resources and water quality, however, a further study on the impacts by the sewage treatment facilities of the priority projects will be required for the following:

- The wastewater treatment facilities may give an offensive odor to the surrounding settlement areas,
- The effluent discharge may cause adverse impacts on the river environment,
- The construction of the projects may have adverse impacts on ecology,

The environmental impact study has been conducted in the F/S stage.

1.2.6 Implementation Organization

For implementation of the project, a leading agency will be required to coordinate the organizations and agencies concerned with the proposed projects and also to make arrangement with the federal government and international financing organizations in order to procure financial sources for the project.

The Study proposed that SEPLANDES as a leading agency should take the responsibility for implementation of the projects proposed in the Master Plan and should establish a Project Management Unit (PMU) for implementation of the project. The PMU should have a coordination committee including representatives of agencies concerned in addition to the executive secretariat.

1.2.7 Priority Projects

The Priority Projects for F/S were selected from the sewerage systems in the major river basins for restoration of the urban environment, because about 91 % of the BOD pollution loads from the urban area was estimated to be discharged into the five major rivers, i.e., the Capibaribe, Beberibe, Jaboatao, Tejipio and Timbo rivers, which are located in the central part of the RMR. Improvement and extension of the existing sewerage systems is effective for the RMR to reduce the pollution loads from these five river basins and thus restore the urban environment. For selection of priority projects for F/S the following sewerage systems were selected as the priority projects for F/S (Fig.3).

Priority Projects for F/S

System	River basin	Municipality	Service Population
1. Conceicao	Timbo	Paulista	62,440
2. Janga	Timbo	Paulista	322,450
3. Cabanga	Capibaribe	Recife	306,690
4. Boa Viagem	Tejipio	Recife	157,010
5. Cordeiro	Capibaribe	Recife	109,230
6. Prazeres	Jaboatao	Jaboatao dos Guararapes	233,400
7. Curcurana	Jaboatao	Jaboatao dos Guararapes	150,160
Total			1,341,380

Note: The priority projects do not include systems in the Beberibe River Basin because the Beberibe River Basin has already been selected for the Pro-Metropole Project (Project of Infrastructure in Low-income Areas of the RMR) financed by the World Bank, which includes the construction or improvement of drainage and sewerage systems.

1.2.8 Action Plan

The Study has planned for implementation of the projects to establish a Project Management Unit (PMU) and to complete the projects by 2020 in two phases as follows:

- Phase 1 (2001-2010): To complete 25 sewerage systems and others,
- Phase 2 (2011-2010): To complete 30 sewerage systems and others.

The tasks required in each phase are as follows:

(1) Tasks in the Phase 1 (2001-2010)

(Sewerage)

- Implementation of the phase 1 projects (25 sewerage systems including 7 priority sewerage systems),
- Execution of routine O&M activities after the sewerage systems completed,
- Promotion of the non-structural measures.

(Drainage)

- Installation of automatic rain gauges and observation of rainfall of short duration,
- Implementation of the drainage facilities proposed in the PQA,
- Promotion of non-structure measures,
- Preparation of river improvement plan for the major reaches.

(2) Tasks in the Phase 2 (2011-2020)

(Sewerage)

- Implementation of the projects in Phase 2,
- Execution of routine O&M activities,
- Promotion of non-structural measures.

(Drainage)

- Establishment of design conditions based on the rainfall data of short duration,
- Implementation of stormwater and flood control plan.

1.3 Feasibility Study on the Priority Projects

1.3.1 General Facility Plan

The sewer networks and major facilities for the seven sewerage systems are planned based on the topographic maps (1:10,000) provided by FIDEM and the design criteria and planning policies, which are in principle as the same as the Master Plan.

The proposed facilities are summarized as follows:

- Trunk sewer: 125.4 km
- Pump stations: 81 stations (including 38 existing ones),
- Sewage treatment station: 7 stations.

The basic data for the seven sewerage systems are summarized and shown in the following tables:

Basic Data and General Facility Plan

Planning Item		Conceicao	Janga	Cabanga	Boa Viagem	Cordeiro	Prazeres	Curcurana
Service Area	(ha)	853	3,954	2,671	1,203	1,053	1,570	1,160
Population	(person)	62,440	322,450	306,690	157,010	109,230	233,400	150,160
Daily Average Flow	(m^3/day)	13,135	64,464	57,381	27,087	19,308	32,677	24,795
Daily Maximum Flow	(m^3/day)	14,900	73,585	66,374	31,337	22,245	38,218	28,762
Hourly Maximum Flow	(m^3/day)	20,508	102,382	93,791	44,408	31,091	53,936	40,638
Inlet BOD	(mg/l)	257	270	304	315	305	386	327
Inlet SS	(mg/l)	285	300	338	350	339	429	363

The general facility plans for the seven sewerage systems are summarized and shown in the following tables:

Sewerage Facilities Plan for the Priority Projects

Description				Conceicao	Janga	Cabanga	Boa Viagem	Cordeiro	Prazeres	Curcurana	Total
Sewerage Facility	Pipe (km)	Trank Sewers	Gravity Flow	6.5	11.9	2.5	15.9	8.7	13.9	10.5	69.9
			Pressure Flow	1.7	16.8	6.8	4.5	2.1	7.5	7.5	46.9
			Rihabilitation	0	3.6	3.2	0	0	1.8	0	8.6
			Total	8.2	32.3	12.5	20.4	10.8	23.2	18	125.4
		Side walk and Branch Pipes		110.9	426.4	188.2	168.4	132.3	215.9	157	1399.1
	Pump Stations (Spot)	New Construction		4	5	6	5	6	5	12	43
		Rihabilitation (Existing)		1	13	20	0	2	2	0	38
		Total		5	18	26	5	8	7	12	81
	S.T.F(Spot)			1	1	1	1	1	1	1	7

Note:

-1 the trunk sewers are mainly planned along public roads and the sewage new pump sites were selected and confirmed with representatives of the respective municipalities.

-2 The sewage treatment facilities (STF) are planned basically at the sites predetermined in the PQA except the STF site for Curcurana, of which a new site was selected due to the future land use plan of the municipal government.

-3 The field surveys (ground survey, soil investigation and environmental survey) for the STF sites were conducted during the field study from May through August 2000.

-4 Sewage treatment stations were planned to comprise secondary treatment, disinfection and sludge treatment systems.

1.3.2 Sewage Collection Facility Plan

The existing sewer system consists of gravity flow, pressure flow and mixed flow systems. The existing sewer pipes need to be replaced because of lack of flow capacity. According to COMPESA, 10-15 % of the existing sewer pipes needs to be replaced because of damage, it is proposed for COMPESA to conduct a survey on the existing sewer networks as a part of the routine O&M activities.

As for pumping facilities all the pumping stations connected to the existing Janga and

Cabanga sewage treatment facilities and the other sewerage systems (independent small systems) have been investigated. Many of the existing pump facilities have been damaged or broken by garbage and grit, and are inactive because of lack of proper maintenance and preventive measures such as bar screens and grits chambers. For the proposed sewer networks, 38 of the existing pumping stations require rehabilitation.

1.3.3 Sewage Treatment Facility Plan

Rehabilitation of the existing sewage treatment facilities at Janga and Cabanga sewerage systems and five new treatment facilities at the other five sewerage systems are planned.

1) Biological treatment system

- STF has a certain limitation of land space::

  "RAFA + bio-filtration" process is applied.

  The process is applied for Cabanga, Boa Viagem and Cordeiro.

- STF has no limitation of land space:

  "RAFA + aerated lagoon + polishing pond" process is applied.

  This process is applied for Conceicao, Janga, Prazeres and Curcurana.

2) Disinfection System

To reduce coliform group bacteria in biologically treated sewage, various disinfection processes such as chlorine, ultra-violet, ozone and others are generally used. Among them, the chlorine process is the most advantageous in terms of economic efficiency. However, the residual chlorine and generated chlorine compounds might produce adverse impacts on the aquatic ecosystem. Though a specific policy of disinfection method has not been established in the RMR yet, the ultra violet process is planned to be applied for the seven sewage treatment facilities to avoid any adverse effects on the aquatic ecosystem including mangroves growing along the rivers and also to consider future regulation by the CPRH.

3) Sludge Treatment System

- A certain mechanical dehydration is applied at the STFs where land space is limited or which are located in densely populated area.

  This method is applied for Cabanga, Boa Viagem and Cordeiro sewage treatment facilities.

- A natural drying bed is applied at the STFs, which have enough land or which are not located in densely populated area.

  This method is applied for Conceicao, Janga, Prazeres and Curcurana sewage treatment facilities.

1.3.4 Environmental Impact Assessment

The environmental impacts by the implementation of the proposed seven sewage treatment facilities have been studied based on the Manual of Guidelines for Evaluation of Environmental Impacts by the CPRH, 1998 and the Environmental Guidelines by JICA, 1994.

The environmental impacts on the rivers caused by effluent discharge of the proposed sewage treatment facilities are evaluated to be insignificant as follows:

- The effluent discharge would not cause any significant adverse impacts on the river environment
- The wastewater treatment facilities would not give any significant offensive odor to the surrounding settlement areas except the Cabanga sewage treatment facility and the Cabanga STF could reduce the odor by installation of a green belt and other countermeasures.
- The construction of the projects would not have any significant adverse impacts on ecology, because there are no species of flora and fauna at risk of extinction in the project sites.

According to the CONAMA Resolution dated January 23, 1986, any new project shall be accorded environmental licenses by the state government in accordance with the procedures specified. The project is categorized under "Item 4: Wastewater Projects" under Environmental Licensing Manual, 1998 (CPRH). The project should get environmental licenses ("Preliminary license", "Installation license" and "Operation license") from the CPRH before implementation. These environmental licenses are to be issued separately.

1.3.5 Effect of the Project

It will expand the sewerage service area from 8,516 ha to 12,464 ha in 2010 and increase the sewage treatment level from no more than 20 % of the urban population to about 37 %. By the expansion of sewerage service areas, living and sanitary conditions in the RMR will be improved.

It will improve the sanitary conditions of the poverty areas by developing the sewerage system to provide for some 324,000 inhabitants in these areas.

1.3.6 Institutional Organization

SEPLANDES as an umbrella agency for implementation of the project shall establish a PMU with a committee organized by the representatives from SEPLANDES, SEIN, SRH, COMPESA, CONDEPE, FIDEM, ITEP and CPRH. The PMU should be established before the detailed design stage. Immediately after the Study SEPLANDES should organize a preparation committee for the project.

1.3.7 O&M Plan

In the State of Pernambuco, the sewerage systems are to have been under COMPESA since 1971. COMPESA should start the routine O&M activities for the existing sewerage facilities and prepare O&M tools and detailed O&M plans for the seven sewerage systems during the detailed design stage.

COMPESA is considered to be responsible for O&M of the sewerage systems in the State and should train the staff for the routine O&M activities required for the projects after the completion of them.

1.3.8 Implementation Plan

The basic policy for implementation of the projects is as follows:

(1) SEPLANDES as an umbrella agency (or as a general coordination organization) should establish a Project Management Unit (PMU) before implementation of the projects.
(2) The preparation of the detailed design (including tender documents) of the projects and the supervision of the construction works should be done by a team of consultants procured through a guideline of the financing agency.
(3) Contractors procured through a guideline of the financing agency should do the construction of the projects.
(4) Human resources development should be done through On-the-Job-Training in principle through the detailed design and supervision.

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2 SEWAGE SLUDGE TREATMENT AND DISPOSAL PLAN

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Sewage Sludge Treatment and Disposal Plan

1. Introduction

A sewage treatment plant is a combination of a water treatment facility and a sludge treatment facility. Sewage treatment is completed after the sludge evolving from water treatment is effectively treated and disposed of.

The method of treating sludge depends on how the sludge will be finally disposed. Thus, sludge treatment is the process that comes before its final disposal. For the disposal of sludge, it is desirable to establish its policy after considering the usage of sludge, such as:

- Its effective use as a resource.
- Decomposition in the natural cycle, without disturbing the ecosystem.

When using transient methods such as landfills, it should be borne in mind that the securing of disposal sites will reach a limit.

2. Basic Unit Process of Sludge Disposal

The basic unit process of a sludge treatment system is as follows:

(1) Concentration

The volume of sludge is decreased by decreasing the amount of the water in the sludge (reduction of the water content of sludge). This is the important first stage processing whereby increasing the capacity of the facility and treatment efficiency in the later stages.

(2) Digestion

This is a process to reduce sludge volume and to stabilize the sludge by decomposing part of the organic matters within the sludge into inorganic matters such as methane gas, carbon dioxide and water by the activities of the microorganism.

The anaerobic digestion method, eliminating oxygen provides the following advantages:

- Reduces and stabilizes the sludge.
- Makes it hygienically safe by killing bacteria.
- Eliminates odor through the stabilization of sludge.

- Makes it for easy dewatering.
- May be effectively used in gas power generation and thermal energy.
- Provides shock-absorbing qualities to the sludge treatment facility.

(3) Dewatering

This is a process to change the sludge from a liquid form to a solid form in order to further remove the water from the concentrated sludge and to facilitate the disposal process. Dewatering using machinery may eliminate 70 to 80% of the water in the sludge.

(4) Final Treatment

The final treatment of sludge will depend on its product. As the dewatered sludge cake will be unsuitable for landfills and farmland use, they may be separated into the following:

- Farmland use (compost)
- Landfill use (by incineration or solidification)
- Construction material (incinerated or melted form)

3. Deciding The Treatment and Disposal System

The unit process for treating and disposing the sludge shall be as follows:

(1) Analyzing the social and natural conditions of the region concerned:

Restrictions regarding final disposal:

- Possibility of disposing sludge as sludge cake (landfill and farmland use).

Maintenance and management system:

- Availability of engineers capable of operating and managing the facility.

Characteristics of the inflowing sewage:

- Presence of matters in the sewage harmful to the environment, fauna and flora, such as arsenic, cadmium and mercury.

Geographical conditions of the disposal plant:

- Whether or not the size, shape or ground conditions will restrict the disposal methods.

Conditions of the surrounding environment:

- Necessity to prepare measures to prevent secondary pollution such as noise or odors.

Size of the treatment plant:

- Capability of handling material in collaboration with other treatment plants (scale merit).

Weather conditions:

- Whether or not the temperature, wind or rain will affect the treatment method.

(2) The treatment and disposal system shall be considered from a technical viewpoint, starting backwards from the final treatment method. The following are the seven items for evaluation:

Stability of disposal method:

- Capability of maintaining stable performance.
- Possible effects of regional weather conditions.

Flexibility of treatment method:

- Adaptability to load fluctuations.
- Adaptability to future changes in condition.

Technical management:

- Necessity of high level technical management.
- Popularity of equipment dissemination.
- Quantity of parts and portions needing inspection or repair.
- Necessity of special qualifications.
- Clear management guidelines.
- Amount of effect on water disposal system.

Operation management:

- Ease of operation.
- Small number of necessary workers.
- Ease of obtaining chemicals.
- Possible danger in operation.

Construction costs:

- Low construction cost.
- Size of site.
- Necessity of building.

Operation costs:

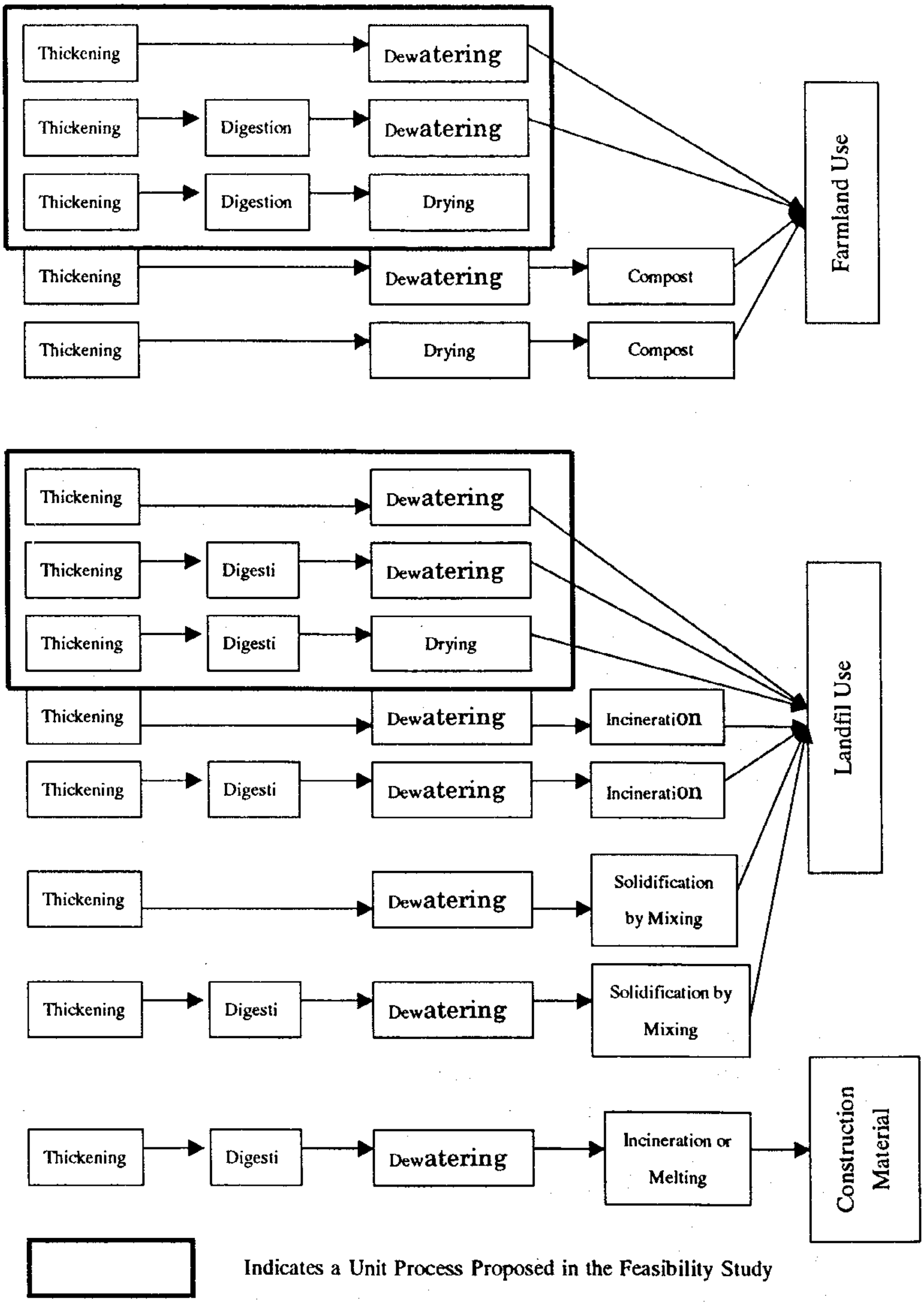
- Amount of lighting, fuel, water, chemicals.
- Possibility of resource and energysaving.

Surrounding environment:

- Possibility of creating unhealthy working conditions.
- Possibility of creating secondary pollution.

As priority and importance will differ according to each site, the conditions for sludge treatment and disposal will be evaluated according to the above seven points.

4. Sludge Treatment and Disposal System



5. Use in Farmland

As sludge is composed of fertilizing elements such as nitrogen and phosphorus as well as organic and inorganic matters, it has great utility value as organic supplying material for farmland. Although its form will depend upon the conditions of the land and method of use, sludge cakes and sludge compost are in great demand.

- Use of sludge cakes:
  Sludge cakes just out of dewatering facilities have insufficiently decomposed organic matters and sludge cakes with water content of 70 to 80% are difficult to handle. Furthermore, due to the strong odor, the farmland should be away from city areas.

- Use of compost:
  Sludge composting decomposes and stabilizes organic matters in the sludge, thereby decomposing rapidly immediately after it is supplied on to the farmland. It does not prove harmful to the growth of plants, acting as an effective fertilizer and may be easily transported and stored. The heat evolving from the manufacture of compost also helps to eliminate harmful microbes. Thus, from the point of view of quality and hygiene, it is suitable for use on farmland.

6. Quality as a Fertilizer

The quality of compost products are as follows:

1) According to its use, it should promote the growth of crops and plants concerned, preventing damages. The following fall under this category: Organic matters (勇気分=有機分では??)(ignition loss), effective fertilizing elements (nitrogen, phosphorus, potassium), PH, carbon, nitrogen, calcium (alkali).
2) It should possess storage and handling qualities, such as appearance, odor, water content, BOD, grain size.
3) The heavy metals contained in the compost product should not accumulate on the soil or crops, such as arsenic, cadmium and mercury.

7. Landfill Cover Material

The sludge should be used as resource as much as possible. Sludge that cannot be effectively used on farmland or in construction material are filled in. Landfills are divided into two types. There are two types of sludge to be filled in: sludge itself and sludge mixed with other waste products. In both cases, the final landfill site should be provided with sufficient measures by considering its effects on the surrounding environment such as air pollution, water pollution, noise, vibration and odors. The landfill site is provided with a storage facility, sealing works, leachate drainage facility, leachate treatment facility, incoming sludge control facility, monitoring facility, control building, access road, scatter proof facility and emergency facility. It should be able to secure a living environment and prevent such matters as outflow of leachate, ground water contamination, scattering of garbage, emission of gas and growth of harmful animals and insects.

If the amount of sludge that cannot be used for farmland or construction material continues to increase, the limited landfill site will be used over a long period. In that case, sludge needs to be incinerated to decrease its volume.

THE STUDY ON STORMWATER DRAINAGE AND SEWERAGE MANAGEMENT PLAN FOR RECIFE METROPOLITAN AREA IN THE FEDERATIVE REPUBLIC OF BRAZIL

Seminar-2
(December 2000)

3 FUNCTION OF PUMP and MAINTENANCE for PUMP

Table of Contents

ポンプの機能及びメンテナンス

1．はじめに

下水道施設は大きく分けて、管渠、ポンプ場、下水処理場に分類されるが、この中でポンプを必要とする下水道施設はポンプ場、下水処理場である。
下水道施設の中でのポンプの機能としては、
1、集水された下水の揚水
2、高地区あるいは遠方への圧送
があげられる。
このように集水された下水を揚水、あるいは圧送する役目を持つポンプは下水道施設の中でも重要な施設である。このポンプが止まれば下水を用水、あるいは圧そうすることができなくなり、下水がマンホールから溢れ出すことになり、マンホール付近の環境に与える影響は大きなものがある。
したがって、ポンプの機能を損なうことなく使用することは下水道にとっては非常に重要なことである。

今回のﾌﾟﾛｼﾞｪｸﾄでは、既存のポンプ場３８箇所、新設されるポンプ場４３箇所、使用されるポンプの数は全部で２１０台となる。
又、処理場７箇所で使用されるポンプ台数は１００台を超える。

ポンプの定期的な保守点検を行い、必要ならばポンプの耐用年数未満でもオーバーホールを行う事を考える必要もある。

２．　ポンプの種類

一般にポンプ場、及び下水処理場において使用される用水ポンプの種類には次のようなものがある。

１、渦巻きポンプ	Volute Pump
２、斜流ポンプ	Mixed Flow Pump
３、軸流ポンプ	Axial Flow Pump
４、水中ポンプ	Submersible Pump
５、スクリュウポンプ	Screw Pump

渦巻きポンプは大容量の下水を高揚程まで上げるために使用され、斜流ポンプは大容量の下水を送水できるが渦巻きポンプとは異なり、高揚程まではあげら

れない。軸流ポンプの送水可能容量は斜流ポンプと同じであるが、斜流ポンプほどの揚程は上げられない。水中ポンプは低容量の下水をある程度の揚程まで送水するのに使用される。スクリュウポンプは大容量の下水を低揚程に揚水するのに使用される。
今回のﾌﾟﾛｼﾞｪｸﾄに使用されるポンプの大部分は水中ポンプである。

３．　ポンプの構造

ポンプの構造は主に以下の５つのパーツからなる。

1, Impeller

Impeller にはいろいろな形が有り、この形の違いによってポンプ内の水の流れが変化し、渦巻き、軸流、斜流のポンプタイプに分かれる。Impeller の回転により下水をポンプ内に吸引し、揚水、圧そうする。

2, Casing

Impeller を包み込む筒状のもので、Impeller と Casing の間を下水が流れる。

3, Main Shaft and Bearings

Main Shaft は Bearings によって支持され、モーターの回転力を Impeller に伝える役目を持っている。

4, Axial Thrust and Axial Thrust Balancing Device

水流による圧力に対して疎の力に対抗する装置

5, Shaft Sealing Device

Shaft Sealing Device には Gland Packing と Mechanical Seal が有る。両者とも外からの水の進入や空気の侵入を阻止する役目を持つ。
水中ポンプの構造断面図を図－１に載せる。

４．　ポンプの故障の原因

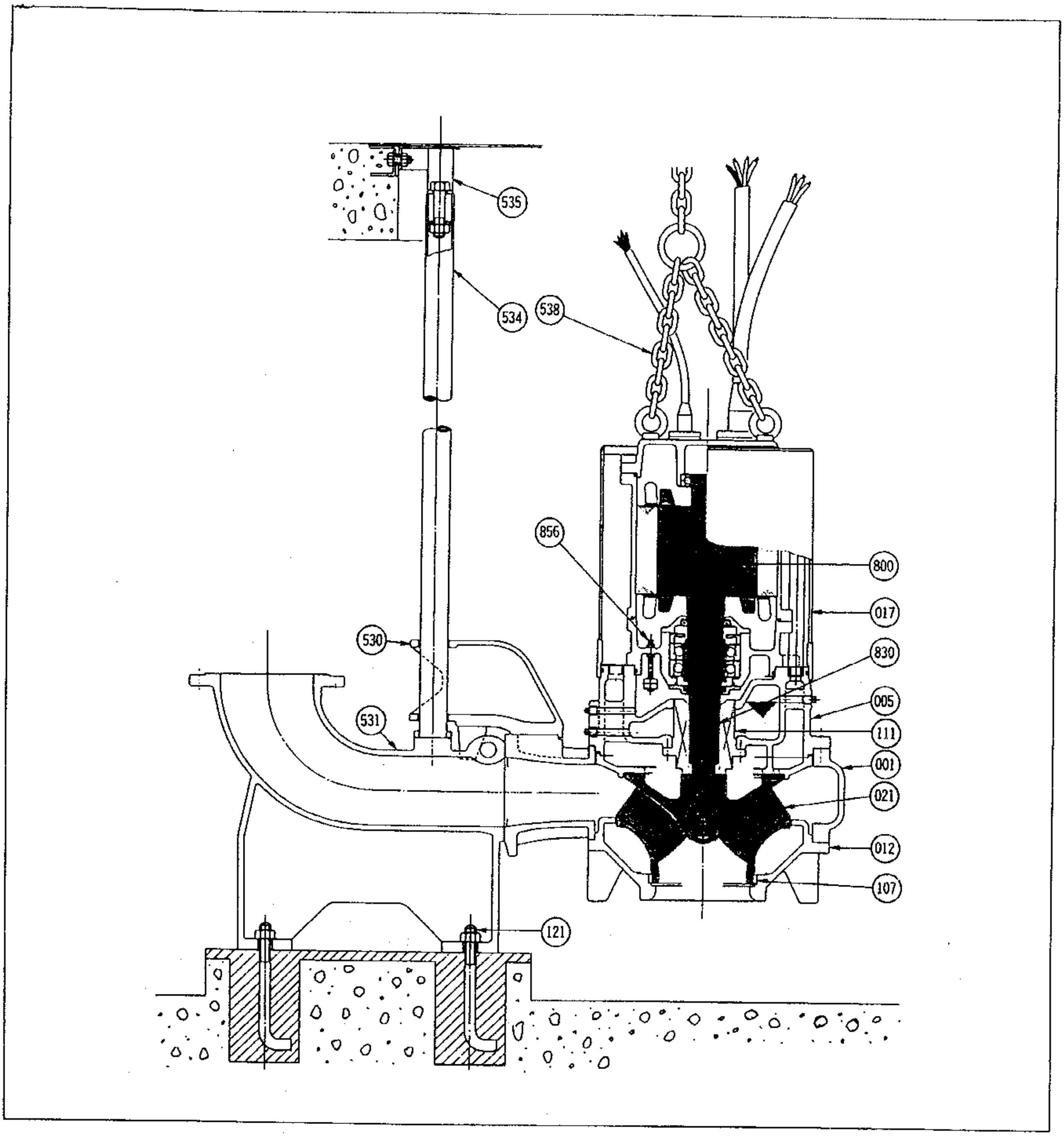
ポンプの故障の主な原因としてはポンプの腐食とポンプの磨耗が考えられる。

４．１　ポンプの腐食

ポンプの腐食として考えられるものとして以下のものが上げられる。

１、全面腐食　（黒鉛化腐食、ガルバニックコロージョン）

FIG.1 - SEÇÃO DE UMA BOMBA SUBMERSÍVEL



número	peça
001	corpo da bomba
005	corpo intermediário
012	corpo de sucção (somente no modelo 4TW)
017	aletas de refrigeração
021	rotor
107	O'Ring
111	vedação mecânica
121	parafuso de ancoragem

número	peça
530	guia de deslizamento
531	tubo receptor da guia
534	tubo guia
535	fixação metálica para tubo guia
538	corrente para içamento
800	motor submersível
830	eixo principal
856	sensor de infiltração de água

2、応力腐食われ　（腐食疲労、フレッテングコロージョン）
3、孔食、隙間腐食
4、粒界腐食
5、エロージョン、コロージョン

1．全断面腐食

全面腐食としての例として、ポンプ部品の代表的な材質である鋳鉄は、塗装皮膜が無くなると黒鉛化腐食が発生する。此れに流速の要因が加わると腐食速度が促進され修理不能の状態にまで至る場合もある。全断面腐食を促進させる要素としては、汚染に伴う「PH 値の低下」、「水温の上昇」、「塩素イオン、硫酸イオン、硫黄イオン、鉄イオン、銅イオンの増加」等がある。
全断面腐食は再塗装により防止可能なので、塗装皮膜耐用年数の周期で補修塗装が必要になってくる。又、水質管理のデータに基づく早期オーバーホールを行い、リポキシライニング等修理技術の併用により対処することが必要となる。
全断面腐食によるポンプの機能停止は腐食によるポンプ機能停止の約４０％を占める。

2、応力腐食割れ

応力腐食は温度があり、応力のかかるポンプ部品に多く発生する現象である。
金属材料が腐食環境下にあって、応力を受ける場合に起こり、付加応力が小さくても経年により割れることがある。
環境の腐食性が強くなくても、表面皮膜が不安定な場合に起こりやすい。
応力腐食割れが起因するポンプ機能停止は腐食に起因するものの約２０％を占める。

3、孔食、隙間腐食

此れはステンレス鋼特有の局部腐食現象であり、孔食はピンホール状に、隙間腐食は隙間に沿った洋皿状の腐食形態である。これらは不導体皮膜の局所的な破壊（塩素イオンが主）が発生の原因である。
孔食、隙間腐食に起因するポンプ機能停止は腐食に起因するものの約２０％を占める。

4、粒界腐食

粒界腐食もステンレス孔特有の腐食現象である。クロム炭化物が析出し、耐食性に寄与するクロムが減少し、結晶粒界に沿って腐食が進行する形態である。
此れに起因する割合は約１０％を占める。

５、エロージョン

a. キャビテーションエロージョン

此れは高速流体中に生じた空洞現象による蒸気泡の発生と、疎の崩壊が繰り返されてインペラに損傷を与えるものである。

この現象はポンプにとってきわめて有害なので、騒音、振動等日常点検による運転管理が大切となる。

b. サンドエロージョン

流体中に固体粒子が存在するとき、ポンプ部品の表面が流速粒子により磨耗浸食される現象であり、粒子が砂の場合サンドエロージョンと呼ぶ。

雨水、汚水、排水ポンプ等は砂が混入しやすく、混入した場合各部品の腐食速度を著しく増加させる。この現象はポンプの耐用年数を短くさせる。

エロージョンに起因する割合は約１０％である。

腐食例の写真を P.1-P.3 にあげる。

４－２　ポンプの磨耗

ポンプの磨耗としては下記の４つが上げられる。

a. 経年磨耗
b. 異物混入磨耗
c. 腐食磨耗
d. 流体磨耗

中でも異物混入磨耗では、砂、木片、空き缶の流入により磨耗が進行するものである。この現象はポンプの前にスクリーン等の施設が無い場合、異物が混入しやすいために発生するものである。

異物混入例の写真を　P.4　－　P.6　に上げる。

５．ポンプの運転管理

ポンプの運転管理にあたっては、ポンプの設置目的、仕様、特性等を熟知し、異常な運転状態のままで運転を続けることの無いようにしなければならない。

又、ポンプの構造、制御方法等についても良く理解し、日常、分解、手入れ、点検、清掃等の作業が円滑に行えるように心がける必要がある。

汚水ポンプは雨水ポンプに比べ小型で、通常予備のポンプを設置することが多いが、このために偏った運転をすることは避けるべきである。特に、下水中の異物によってインペラ（羽根車）が磨耗したり、詰まったりして、振動、発熱、過負荷等の故障が発生しやすいので注意する必要がある。
一般的取り扱いとしては、ポンプの構造や操作方法を理解し、保守、点検及び修理が容易に行えるようポンプの構造図、取り扱い説明書等必要なものをすぐに取り出せるように整理しておく必要がある。
又、各ポンプに付いては、正常時の状態を良く把握し、異常の早期発見に努め事故を予防するよう心かける。

運転中及び、定期点検の点検項目、内容及び周期の例を表—１，２にあげる。

表—１　運転中の点検項目、内容及び周期の例

点検項目	点検内容	点検周期
１．外観	異常の有無	毎日１回以上
２．振動、異常音	異常の有無	
３．軸受温度	室温＋４０Ｃ以下か	
４．潤滑油面	適正範囲か	
５．グランド部の発熱	封水（給水）が正常か	
６．ｸﾞﾗﾝﾄﾞパッキンからの漏水量	絶えず水が漏れている状態か	
７．運転中の電流	正常値か	
８．運転中の圧力	正常圧か	
９．運転日誌	異常の有無の検討	

表一２　定期点検の項目、内容及び周期の例

点検項目	点検内容	点検周期
１．軸受の潤滑油 ２．ｸﾞﾗﾝﾄﾞパッキンの磨耗	汚れ、量 シール部分の漏水	１ヶ月
３．軸受の潤滑油の交換 ４．ｸﾞﾗﾝﾄﾞパッキンの交換 ５．固定部分締めつけボルトのまし締め ６．フローリレー、圧力スイッチ、温度スイッチなどの保護装置の確認 ７．ポンプと原動機との直結状態の確認 ８．立軸ポンプの振動の測定	運転時間が多い場合に行う。 初回は１５日程度で交換 軸継ぎテボルトの緩み	１年
９．分解又は整備 １０．　機器全体の再塗装または塗油	回転しゅう動部の磨耗 接液部の腐食状況	不定期

APOIO DE EIXO VERTICAL (bomba de eixo vertical)

Foto 01

Item		Medidas tomadas
material	FC 25	repintura
ambiente	águas pluviais e esgoto	
tempo de utilização	aprox. 6 anos	
conservação	totalmente corroído	

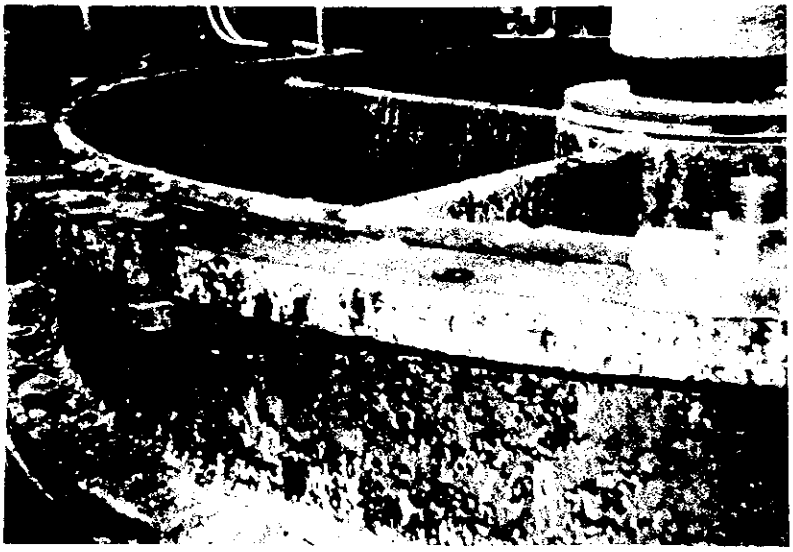


Foto 02

Item		Medidas tomadas
material	FC 25	repintura
ambiente	águas pluviais e esgoto	
tempo de utilização	aprox. 8 anos	
conservação	totalmente corroído	

ROTOR (bomba de eixo vertical)

Foto 03

Item		Medidas tomadas
material	FC 25	reparo
ambiente	esgoto	
tempo de utilização	aprox. 6 anos	
conservação	parcialmente corroído	

Foto 04

Item		Medidas tomadas
material	FC 25	substituição da peça
ambiente	esgoto	
tempo de utilização	aprox. 8 anos	
conservação	Totalmente corroído	

EIXO VERTICAL (bomba de eixo vertical)

Foto 05

Item		Medidas tomadas
material	S 35 C	substituição da peça
ambiente	esgoto	
tempo de utilização	aprox. 8 anos	
conservação	Totalmente corroído	

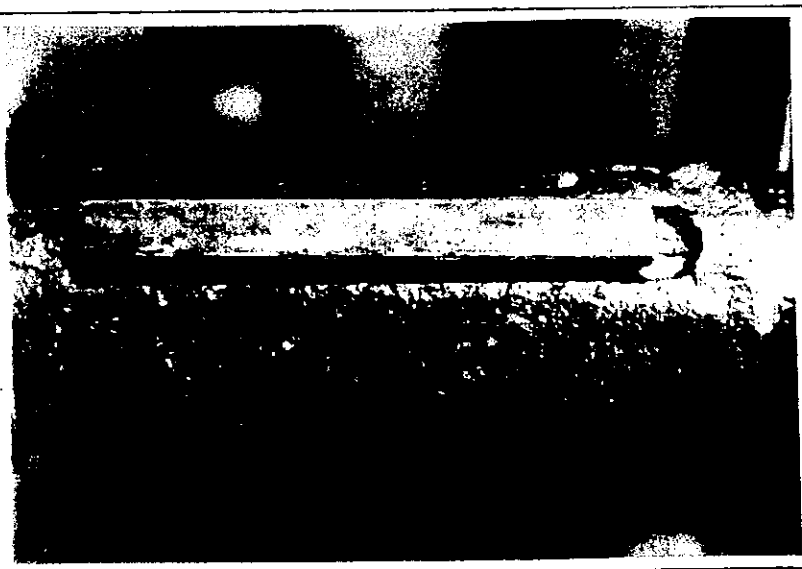


Foto 06

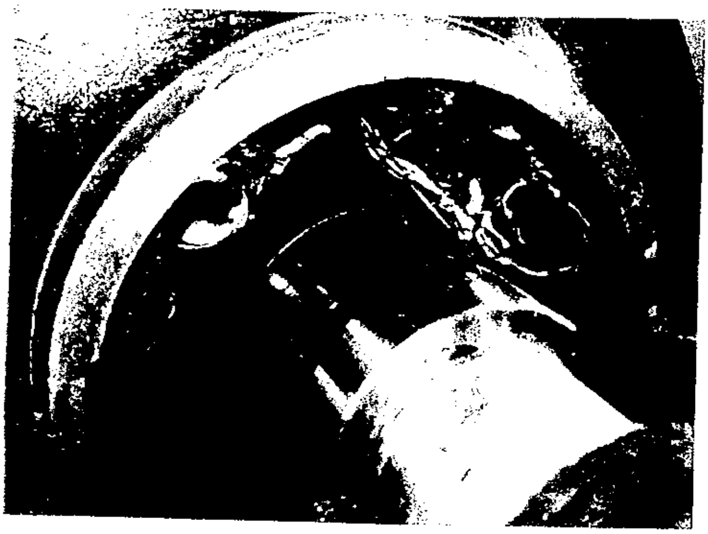
Item		Medidas tomadas
material	S 35 C	substituição da peça
ambiente	esgoto	
tempo de utilização	aprox. 8 anos	
conservação	Totalmente corroído	

Fotos 01

SITUAÇÃO INTERNA DA BOMBA DE DESCARGA

(bomba centrífuga de dupla sucção)

Entrada do rotor obstruído por latas vazias



Entrada do rotor obstruído por latas vazias

Latas vazias e pedaço de madeira retirado da entrada do rotor

Fotos 02

SITUAÇÃO INTERNA DA BOMBA DE DESCARGA (bomba de eixo horizontal)

Areia, sacos plásticos e outros materiais retidos no interior da bomba

Fotos 03

SITUAÇÃO INTERNA DA BOMBA DE DESCARGA (bomba de eixo vertical)

Pedaços de madeira presos entre o rotor e o corpo da bomba