Table 14-3- 3 Current issues of the Software-Type Measures

Component of Measures	Details of Each Component
(1) Administrative System	The state govenment's environmental policy. SEMAMPE's leadership. Efficient use of FECAM's fund. Activation of FEEMA, SERLA and IEF by financial back-up.
(2) Legislative System	Restudy of existing water area classfication and water quality standards in the Bay. Putting the effluent standards and EIA legislation into practice. Early signing of Annex 4 and 5 of MARPOL -73 by the Brazilian government. Adequate intervention of improper land use by means of taxation system, land expropriation system and so on.
(3) Agreement & Approval System	
(4) Economic System	Establishment of sufficient system for effluent charge system. Review for the introduction of an economic incentive systems.
(5) Financial System	Preferential low interest loans for installation of anti-pollution equipment.
(6) Resident Participation System	
(7) Education System	Systematic environmental education to residents and enterprises.

14.4 Agreement and Approval System

An agreement system means that anti-pollution countermeasures are agreed upon by potential polluting firms and local governments in a written agreement and the firm does its best to uphold the agreement. This system needs a strong support and/or pressure from citizens for it to work effectively.

Moreover, a permission or approval system controls industrial activity by giving administrative agencies the power to grant permission and authorization.

A permission system for the operation of potential pollution activities is done by CECA in Brazil.

14.5 Economic System

Two kinds of system are considered here to prevent the discharge of pollutants. One is an economic incentives system and the other is a Pollutor Pays Principle (PPP) system.

The PPP system is that polluters should bear the responsibility for the expense necessary for the protection of pollution and the most fundamental and important principle as an environmental pollution measure.

For example,the system operates by regulating the concentrations of pollutants discharged from pollution sources by charging the polluter. However, this system does not look going well because of the lack of sufficient support for the charges.

Recently FEEMA decided to introduce a new effluent charge system (called TCPHA). Each industry category, as mentioned previously, is to be charged by the amount of pollutants.

The economic incentive system e.g. subsidy system and tax reductio system, is not well know in Brazil.

14.6 Financial System

Though there are some financing banks providing industrial companies with low interest loans such as BNDS (Banco Nacional de Desenvolvimento Social) and AFB (Agence Fianceiro de Bassin), it is very difficult to get financial support for the installation of anti-pollution equipment because of rigorous examinations by the banks.

14.7 Resident Participation System

It is important to recognize that consensus between residents and public agencies should be reached through the participation of the residents in the implementation stage of the policy.

Resident participation in Brazil is seen in various ways such as participation in RIMA public hearings, declaration of opinion and/or presentation of written opinion in the planning phase of a project and demand for information to the public.

Resident participation is mainly done by resident associations, environmental groups (NGOs) and men of learning and experience.

14.8 Education System

Environmental education plays an important role in the improvement of the environment.

In the State of Rio de Janeiro two organizations, an environmental education section (Educacao Ambiental) of the State Secretariat of Education and SEMAMPE, systematically carry out environmental education.

Educacao Ambiental runs education programs in the state secondary schools (stage 5 to stage 8).

SEMAMPE, including FEEMA, SERLA and IEF, looks after the education of primary school students (stage 1 to stage 4) through municipal environment department. These organizations establish the environmental sections in municipalities and train primary school teachers. They also prepare the necessary teaching materials.

Regarding environmental education for the recuperation of the ecosystem of Guanabara Bay; FEEMA together with CODEG through the IDB project, intends to educate the following people:

(1) Students from primary and secondary schools
(2) Municipal officers
(3) Resident associations including NGOs
(4) Churches and clubs such as Rotary and Lions
(5) Owners of enterprises
(6) Workers

As a methodology, FEEMA plans to use various kind of tools which are most suitable to the area and/or people such as a town meeting system and an audio-visual system. They also plan to put the universities, NGOs and other organizations like IBAM, RODA VIVA, ISER and Rio Cine to practical use.

CHAPTER 15

REVIEW AND EVALUATION

OF

HARDWARE-TYPE MEASURES

CHAPTER 15

REVIEW AND EVALUATION OF HARD-WARE TYPE MEASURES

Development and actual application of wastewater treatment technologies (hardware-type measures) are indispensable for the improvement of water quality. This chapter reviewed, among established technologies, the ones actually employed, and examined the applicability which were not yet applied but considered to be appropriate in view of prevailing natural and socioeconomic conditions in Guanabara bay and its basin.

15.1 Characteristics of the Hardware-Type Measures

We call the techniques that remove pollutants from the water discharged from pollution sources "hardware type measures"; they are classified into the following four groups: (A) techniques which reduce the generation and discharge of pollutants from the basin (B) techniques which remove pollutants in the rivers and canals, (C) techniques which remove pollutants deposited in the closed water bodies, and (D) techniques which carry the pollutants out to the open sea.

Of the four groups, (A) is the most severe and permanent measure. When there are many pollution sources, however, it is not always effective to apply this measure to each pollution source from a cost-effectiveness point of view.

Consequently, the technique which treats the wastewater from a district in mass was developed. When this technique is applied, the scale of the treatment area is decided based on the distribution density of the pollution sources, the area necessary for the facilities and so on. Maintenance of these treatment facilities is comparatively easy and the cost of maintenance is fixed and low, when the wastewater quality is adequate for the treatment, it is desirable that domestic and industrial wastewater are treated separately, as it is more efficient because industrial wastewater requires different treatment processes.

Laying of the sewer pipes, purchasing the required land and the construction of the plant, are necessary for this kind of treatment. A lot of time and a large investment are necessary when the scale of the treatment area become larger.

Techniques which directly purify river and sea water (C) are applied when the people want to improve the water quality in a certain area as soon as possible. In this case, however, treatment efficiency is generally low and enormous energy is required, because many kinds of pollutants derived from various pollution sources are mixed, natural runoff and sediments are also included. Consequently, the techniques which directly purify the river and sea water should only be applied to limited areas, where urgent improvement is needed.

Techniques which carry the waste water out of the basin without treatment are also well developed. Though these techniques are appealing in respect to the fast improvement of the environs; if a disposal site can be secured and pollution prevention around it is implemented. These techniques, however, are flawed in that proper environmental preservation awareness is not conveyed to the polluters.

For the treatment of wastewater, it is important to choose the correct techniques considering the suitability of each technique, plus also the natural and social conditions of the area.

The principles (1), advantages (2), deficiencies (3), examples and things to pay attention to when the technique is applied (4), applicability to the Guanabara Bay basin (5), are described in the following sections.

15.2 Measures Applicable to the Basin

A-1 Reduction of Domestic Effluent Load

A-1-1 Septic tank (small size)

A septic tank is a treatment facility for domestic wastewater and is applied to areas without accessibility to the public sewer system. Small sized septic tanks for each house and large communal sized ones are well developed.

(1) A highly efficient septic tank working by means of gravity separation, biological decomposition, oxidation, etc., functions as well as a general sewage treatment plant, the quality of treated water is less than 20 mg/l of BOD. It has additional advantages, too, in that it is flexible to fluctuations in the amount of inflowing load and it is easy to maintain.

(2) Reduction in effluent load occurs immediately after installation of the septic tank. It is manufactured in a factory. Unlike the sewage treatment plant, a large site is not required for its installation.

(3) A septic tank with a high pollutant removal ratio for five people costs more than US$ 5,000 in Japan, including its construction cost. The maintenance cost necessary for electricity and cleaning cannot be ignored. Consequently, it is difficult to construct a septic tank for low income people. As the tank and discharged water are not clearly visible periodic cleaning and inspection are easily forgotten in ordinary dwellings.

(4) The examination of products based on distinct criteria, installation maintenance and water quality examination should be done by authorized engineers, because common people do not have the technical know-how.

(5) In the State of Rio de Janeiro, domestic wastewater discharged in areas without a public sewer system is to be treated by septic tanks. This is specified by the Brazilian industry standards No.7 229(1982). But the functions of the septic tank are limited to settling and anaerobic treatment without aeration, therefore, the removal efficiency of pollutants remains low if periodical cleaning of sludge deposited in the tank is neglected.

Consequently, the application of septic tanks to the Guanabara Bay basin for the reduction of the domestic effluent load will fail without an improvement in its efficiency and the establishment of maintenance routines. Further, the popularization of septic tanks is difficult without a public assistance scheme because of the high cost of purchase, installation and maintenance.

A-1-2 Soil Treatment

(1) Soil treatment utilizes the self-purification ability of the soil, such as filtration, absorption, a certain extent of base substitution by soil grains, decomposition and ingestion by soil bacteria, and absorption of nitrogen and phosphorous by plants. The waste water infiltrates the soil directly from the ground surface or through diffusion pipes buried at a shallow depth after pretreatment; such as sedimentation, screening, sand settling etc..

(2) Facilities for soil treatment are simple and it do not require added energy. When the soil has high adsorption capacity for phosphorous, this method has also high reduction efficiency for nutrient salts.

(3) Treatment efficiency per unit area is low because the active metabolism of aerobic bacteria is limited to near the surface of the ground. Consequently a large lot is necessary for treatment. Further, treatment generally takes time because the treatment reaction in the soil is slow. As the porosity of soil is low, jamming occurs easily and it makes the continuous use of the same soil difficult. Other disadvantages of soil treatment are its susceptibility outbreaks of pathogenic bacteria and offensive odors.

(4) The self purification ability of soil depends on: soil type, particle size composition, porosity, content of humus and other factors. Consequently, a preliminary study on the soil properties at the site is necessary to clarify its suitability for waste water treatment.

(5) Most of the soil distributed in the Guanabara Bay basin is sandy and rich in quartz grains derived from Precambrian rocks and granite. Therefore, its adsorption capacity for pollutants may be low and thus not suitable for soil treatment.

A-1-3 Irrigation of Agricultural Land

(1) Irrigation of agricultural land is the technique in which the waste water irrigated fertilizes the crops and is purified by the self-purification capacity of soil.

(2) This technique serves a triple purpose, that is waste water treatment, effective use of water resources and increase in agricultural production. Another advantage is energy savings.

(3) Application of this technique is difficult without sufficient space for farmland, crops much in demand or a soil with high adsorption capacity for pollutants.

The easy outbreak of pathogenic bacteria, offensive odor and ground water contamination is feared as is the case with soil treatment. Further, the infiltration efficiency is low when the groundwater surface is shallow.

(4) Because sugar cane is very much in demand in Brazil, as a raw material for the production of alcohol, an irrigation system for wastewater in a sugar cane field is applicable from a practical view point. It is reported that 90 - 99 % of BOD, 90 % of T-N and 80 - 99% of T-P could be removed from the wastewater through this method.

Pretreatment is necessary to remove heavy metals and toxic substances because wastewater is absorbed by crops.

(5) This technique is applicable to the Guanabara Bay basin if sufficient farmland is available.

A-1-4 Stabilization Pond

(1) A stabilization pond is usually 2 to 3 meters deep and treatment is through anaerobic and facultative processes, sedimentation, fermentation in an aerobic pond, decomposition by facultative bacteria and decomposition by aerobic bacteria activated by algae are the main treatment processes, 95 % of BOD and 50 - 60% of nutrient salts can be removed through multiple type stabilization ponds with a retention time of 30 days.

(2) As special mechanics or energy is unnecessary, the initial cost is not expensive and maintenance of the facility is easy.

(3) An extensive lot is necessary.

(4) In Brazil, stabilization ponds are widely used because land prices are not so high, meteorological conditions are suitable for this treatment and the construction and maintenance costs are cheap. A large scale stabilization pond (92 ha) was constructed in Joinville Municipality, Santa Catarina five years ago and it works without any problems.

Aerobic ponds, however, are inadequate for the treatment of wastewater with high concentrations of pollutants because increased breeding of algae makes the SS and BOD concentrations of the effluent water higher. But, it is applicable as a post-treatment facility for high concentration industrial wastewater.

(5) A stabilization pond is an effective measure for domestic wastewater treatment in areas where land costs are low in the Guanabara Bay basin.

Some people proposed that the natural lagoons situated along the coast facing to the Atlantic Ocean should be used as stabilization ponds, however, many people opposed the idea from the view point of the protection of the natural environment.

A-1-5 Contact Oxidation Ditch

(1) In this system, waste water is introduced into the elliptic or circular ditch 1.5 to 2 m deep, and mixed with a large quantity of activated sludge. Waste water is purified while it circulates with the activated sludge in the ditch. Retention time is usually one or two days.

(2) As this system works with low load and a long aeration time, it is strong against fluctuations of load. Sludge production is less and offensive odor does not often occur. Sludge generated from this system is easy to dry and dehydrate, and the treated sludge can be channelled to farmland. The structure of this system is simple and daily maintenance is easy.

(3) As it requires an extensive site for the ditch, application is difficult when not enough land is secured.

(4) In Brazil, contact oxidation ditches have been applied to small sized cities where the land is easily aquired, and it gains public favor because construction cost is low an its operation is stable.

Selection of the right type of aeration system is important. The shape of the ditch is not set, but one without sharp corners is recommended to avoid sedimentation of the sludge.

(5) This treatment method was applied to the plant in Ilha do Governador (ETAR-TECA). The contact oxidation ditch method should be applied more often since it has many strong points, as mentioned above, in spite of the little worse water quality after treatment compared to the activated sludge method.

A-1-6 Activated Sludge Treatment

(1) In this system, organic substances in the wastewater decompose by activated sludge in the aeration tank without filter media. Activated sludge is returned to the aeration tank after being separated from the treated water in the settling tank.

(2) This system is able to treat large volumes of waste water at high speeds because a large amount of activated sludge is mixed with the wastewater. In this system, the sludge deposited in the final settling tank is returned to the aeration tank. Then, the removal ratio can be kept constant when the concentration of waste water has changes.

(3) The system's removal ratio of nutrient salts is low. It is difficult to concentrate and dehydrate excess sludge continuously generated from this system, and its disposal is a very serious problem. The lot required for this system is more extensive and the construction cost is more expensive than physico-chemical treatment systems. Some specialists are required to calculate the amount of the return sludge and to deal with the bulking.

(4) This system had been applied to many cities in the world as a highly efficient treatment method for domestic waste water. Inflow of waste water containing toxic substances

or wastewater with high acid or alkaline content, in this system, reduces the purification ability of the activated sludge. Consequently, it is important to prevent the inflow of such waste water, mainly those of industrial origin.

(5) Four (4) of the eight (8) sewage treatment plants in the Guanabara Bay basin use this method, and their removal ratio exceeds 90 % in BOD. Though these plants are maintained in a good state, bulking and sludge disposal are serious problems. Further, the improvement of the removal ratio of nutrient salts is an urgent problem to solve, to stop the eutrophication of Guanabara Bay.

A-1-7 Trickling Filter Method

(1) In this system, wastewater is sprinkled on the floor covered by a filter media, and dissolved organic substances decompose by bacteria forming on the surface of the filter media. Development of plastic filter media has made it possible to construct multi-layered filter floors, and have made great progress in the quantity treated and treatment rate.

(2) Control of sludge is unnecessary because bacteria clings to the surface of the filter media. Multi-layered filter floors can save the lot.

(3) As the amount of bacteria cannot be controlled factitiously, it is difficult to adjust this system to fluctuations in concentrations of inflow sewage. The inside of the trickling filter is apt to develop an anaerobic condition due to reduced natural ventilation, thus resulting in the clogging of the filter and the occurrence of offensive odors.

(4) Recently, the trickling filter method has been given a second look in Europe since ventilation and clogging of the filter floor have improved by the multi-layered type of filter floor.

(5) The Penha treatment plant, supervised by CEDAE, uses the trickling filter method in addition to activated sludge treatment. But pooling occurs since macadams are used as a filter media, and the treatment speed is low because of one layer filter floor. Treatment efficiency will be improved when the multi-layered filter floor covered by a plastic filter media is introduced.

A-1-8 Advanced Treatment (Tertiary Treatment)

(1) In this system, nutrient salts, organic substances, pathogenic bacteria and other pollutants remaining after the secondary treatment are removed.

Phosphorous is removed by the coagulation settling method; organic substances, suspended solid, bacteria and virus are removed by the active-carbon absorption process, ozonization process or coagulation setting method; and inorganic salts are removed by the ion-exchange method and reverse osmosis process.

In addition to such physicochemical methods, biological treatment is also applicable. 7 % of nitrogen and phosphorous can be removed by the standard activated sludge method assisted by biological treatment.

(2) Through the application of advanced treatment, the prevention of eutrophication in the water body, recycling the treated sewage and circulation use of industrial wastewater becomes possible.

(3) The construction and maintenance cost of tertiary treatment is higher than that of secondary treatment. Further, special engineers to maintain its facility, are necessary.

A-2 Reduction of Industrial Effluent Load

A-2-1 Wastewater Treatment for the Food Industry

(1) Wastewater being drained from food processing plants (including beverage bottling plants) carries high concentrations of BOD, COD, organic nitrogen (protein), animal and vegetable oil (normal-hexane extracts), suspended solids, etc. and is being treated mainly by biological treatment such as the activated sludge method.

When the oil content is extraordinarily high, preliminary treatment becomes necessary where the oil contents are separated by the floatation method with the addition of a coagulant or centrifuging while heating the wastewater.

If the drainage is in smaller quantities and when the organic content only is high; anaerobic treatment in 2.5m to 3.0m deep ponds is workable. Since this method does not require special equipment and facilities or additional energy and as maintenance and supervision are quite simple, it is applicable to smaller scale plants.

(2) Generally speaking, since wastewater being drained from food processing plants does not contain toxic substances, excess sludge which remains after the biological treatment can be used as a fertilizer if dewatered and dried.

(3) The anaerobic treatment, however, requires a longer detention time and it also generates offensive odors.

(5) Many marine product processing plants and meat processing plants are operating within the Guanabara Bay basin but none of them are executing adequate oil separation from the wastewater thus making subsequent biological wastewater treatments ineffective.

A-2-2 Wastewater Treatment for the Paper and Pulp Industry

(1) Wastewater being discharged from the paper and pulp plants is characteristic by its high concentration of BOD, COD and SS. Wastewater from pulp plants, in particular, exhibits a higher COD content due to its high lignin content and is colored black.

Although its BOD content can be removed by the activated sludge method, the COD content cannot be removed unless a coagulation process is used in combination. As for the treatment of the COD content, it is more economical to collect and incinerate the treated effluent after a steam reduction process. The reduced material holds the major part of the COD content.

(5) Although the number of paper and pulp plants in the Guanabara Bay basin is small, the total drainage load is very high which substantially influences the water quality of particular rivers.

A-2-3 Wastewater Treatment for the Organic Chemical Industry

(1) Since there is a great diversity of products being handled by the organic chemical industry, wastewater treatment methods must fit the requirements of individual plants. Also, even within a single plant, the nature of wastewater significantly differs depending on each process.

For example, in a petroleum refinery, wastewater from the desalting unit exhibits high levels of salt and oil while wastewater being discharged from the contact decomposition unit has high levels of ammonia and sulfur compounds. And cooling water does not contain oil at all. Consequently, it is essential to have separate wastewater treatments for each process.

Wastewater being discharged from petrochemical plants where naphtha and natural gas are used as raw materials contains higher BOD and COD concentrations as well as some SS, heavy metal, acid and alkaline contents. For removal of the floating oil content and suspended solids, gravity separation equipment and pressure flotation equipment are widely employed in the industry. Also, if the oil contents are in an emulsion form, chemical treatments such as coagulation settling are effective for the removal of oil.

(5) Many petroleum-related chemical plants are located in certain areas around the Guanabara Bay basin, discharging wastewater containing refractory organic substances mixed with oil. At REDUC, the largest plant of its kind in the area, is employing an oxidation pond equipped with an aeration facility and an oil separation system for the removal of the load but their effects are yet to be proved. Moreover, many gas-stations located along the main roads in these areas are also discharging substantial quantities of this type of wastewater.

A-2-4 Wastewater Treatment for the Inorganic Chemical Industry

(1) Wastewater from inorganic chemical plants where products are usually processed by means of the reaction controls using inorganic acids and alkalis, etc. mainly contain such pollutants as acids, alkaline substances and suspended solids and

frequently, heavy metal salts. Therefore, it is more popular to treat wastewater by adjusting the pH level by neutralization treatment before solid-liquid separation using hydrochloric acid and ammonia.

A-2-5 Wastewater Treatment for the Fiber Dyeing Industry

(1) Wastewater from the fiber dyeing plants is said to be the most difficult industrial wastewater to treat due to sharp fluctuations in the quantity and quality of this wastewater and furthermore, to malodors and coloring characteristics of the wastewater from these plants. Since none of the single-processing methods has proved successful, many plants in the industry are combining oxidation treatment using ozone, chlorine and light, charcoal adsorption treatment, biological treatment and coagulation treatment to improve the results.

A-3 Reduction of Effluent Load from Non-Point Sources

A-3-1 Prevention of Soil Erosion

(1) Countermeasures to prevent the washing out of soil and attached pollutants are: the avoidance of a large scale clear felling in the forests, prohibition of housing development, the mining of clay or gravel on steep slopes susceptible to hazardous erosion, and the introduction of contour farming on undulating land.

A-3-2 Improvement of Garbage Collection Rate

(1) The amount of residual garbage is generally large in the urban areas. Slums are particularly influential sources for increased runoff loads in a freshet time, because of the low garbage collection rate. If residual garbage in the basin were reduced, through the improvement of the garbage collection rate; runoff load into rivers, in a freshet time, would be reduced.

15.3 Measures Applicable to the Rivers and Channels

B-1 Improvement of Channels

(1) A measure to improve the water quality in urban channels by constructing sedimentation reservoirs to settle granular pollutants and by filling up contact filtration filters for the biological decomposition of pollutants.

(3) Substantial expense is necessary for the cleaning and the inspection of the facility and for the removal of sediments. Also, standing water in these constructed facilities may breed mosquitoes.

B-2 Direct Purification of River Water

B-2-1 Contact Oxidation Tank with Cobbles

(1) This method uses a tank filled with filter media (natural cobbles were used at first, but plastic filter media have often been used recently). River water passes through this tank after it is given the required oxygen in an aeration tank. This method is a biofilm processe since organic pollutants are decomposed by bacteria on the surface of the filter media.

(2) Cobbles found in rivers can be used as filter media. Secondary pollution is unlikely to occur because the purification method of this system is similar to the self-purification function of rivers. Removal of sludge is necessary at intervals of once in five years on average except when the SS concentration of the river water is high. The maintenance cost is comparatively low.

(3) This method is inadequate for rivers with large flows and high SS concentration because sludge accumulates fast in the tank. Activity of bacteria decreases when the water quality exceeds 80 mg/l of BOD or the water temperature is lower than 15°C, resulting in a decrease in the treatment capacity of this system. The removal effect of nutrient salts is generally very low.

(4) This system has been installed in the Nogawa River (Japan) and 1.0 m^3/sec of the river's mean dry season flow (1.15 m^3/sec) is taken into the facility. The removal ratio of this system is 73.6 % of BOD and 87.8 % of SS.

The water quality improvement effect is different by river depending on the flow regime and the characteristics of water quality. Consequently, a trial test is necessary prior to the implementation.

(5) Though several small scale urban rivers suitable for this system are found in Rio de Janeiro City, effective treatment cannot be expected because the flow of these rivers increases suddenly and includes a large amount of garbage in freshet times. To acquire land for this system is also difficult in the urban area.

B-2-2 Living Filter

(1) The living filter method utilizes the ability to absorb nutrients and the natural filtering effect of aquatic plants such as water hyacinth, ditch reed and others. Periodically overgrowth due to nutrient salts must be weeded out from the aquatic area.

(2) No secondary pollution is likely in this system.

(3) The reaction rate is slow in this system and the settling time is longer. Further, aquatic plants grow too thick and mosquitoes easily generate.

(4) A removal and disposal method of aquatic plants should be examined prior to the implementation of this system.

(5) Since natural marshlands covered by thick aquatic plants are still surviving along the coast of Guanabara Bay, to use it to improve the water quality in the rivers is a more practical idea(B-2-3).

B-2-3 Induction into Marshland

(1) In this method, river water is partially inducted into marshlands, where aquatic plants grow luxuriantly, and flows back into the river from the marshland downstream. The removal principle of pollutants is the same as that of the living filter.

(2) The marshland will keep its purification ability for a long time if it does not receive excess load. Further, it does not require labor, energy or high costs to maintain. Though intake, separation and drainage facilities are necessary to satisfactorily use the purification ability of the marshland, their construction cost is low in comparison with that of the waste water collection system of sewage work.

(3) Offensive odors are easily generated near the intake due to the stagnation of water and deposition of solid waste.

(4) Treated water from a sewage treatment plant was induced to ditch reed fields near Lake Baraton, Hungary. Inflowing water into the ditch reed fields contains 45 mg/l of T-N and 6.2 mg/l of T-P, while outflow water contains 1.9 mg/l of T-N and 0.25 mg/l of T-P.

The feasibility of this system is limited by the vegetation, meteorology, topography and other natural conditions of the objective area. It is, therefore, important to study the suitability of the district and to confirm the safety of the area from floods.

(5) Marshland with luxuriant aquatic plants subsists widely around Guanabara Bay. It may be possible to prevent eutrophication of the Bay if the waste water is induced into this marshland, a natural tertiary treatment system.

B-2-4 Induction of Dilution Water

(1) Improving the water quality in channels and conduits by dilution using water diverted from other rivers with better water quality.

(2) By the addition of water rich in dissolved oxygen, the decomposition of organic substances is accelerated in addition to the effect of dilution.

(3) Since the induction of water for dilution equal to the overall flow volume of the river to be treated is necessary when reducing the pollutant concentration by one half, this method is difficult to apply to rivers with a large flows. Although the pollutant concentration may decrease by dilution, the load itself does not decrease contrary to expectations. Moreover, the flow of the river from which the water for dilution is being induced naturally decreases.

(5) The most heavily polluted rivers in the Guanabara Bay basin run through metropolitan Rio de Janeiro. There are no other rivers clean enough and large enough to supply the water necessary for dilution to the polluted rivers, in the vicinity. Consequently, it is difficult to apply this measure to the basin of Guanabara Bay.

B-3 Prevention of River Load Flowing into the Bay

B-3-1 Diversion of Rivers

(1) In this method, inflow load to the Bay is reduced by changing the course of the rivers.

(2) Since this method is effective in achieving a total reduction in the load of a river, it is highly effective for water quality improvement. The measure is also effective in preventing floods.

(3) The water quality in the area of water into which flows the water of the river being treated deteriorates.

(4) It is difficult to employ this measure to rivers running through urban districts due mainly to the difficulty of securing the necessary land.

(5) There are no rivers in the Guanabara Bay basin which may be able to improve the water quality of the Bay and with which channel diversion work is possible.

B-3-2 Retardation Pond

(1) A retardation pond is made to store a part or all of the river water at freshet time. Large amounts of particular pollutants in the river water at freshet time which are deposited into this pond are later removed. This method is effective for the reduction of phosphorous and COD because pollutants from roads and off land are discharged during the first flush.

(2) A retardation pond is effective in removing P and COD whose ratio, in particular, is high in river water.

(3) As an extensive lot is necessary, retardation ponds are difficult to construct in urban areas. In Tokyo and Osaka, however, large scale of retardation ponds have been constructed underground to prevent floods by middle and small scale rivers with large runoff ratios, and the top of the pond is used as a park or a residential area.

(4) The site and the scale of a retardation pond should be decided on the basis of river discharge at freshet time, run-off features, topography in the basin and so on.

(5) Inundation often occurs along the rivers in Rio de Janeiro City after the heavy rain in summer. Therefore, flood control is an important subject for the Rio de Janeiro Municipality and the State Government.

Although SELRA is implementing measures to discharge river water into the Bay as soon as possible by excavating river channels, constructing concrete embankments and straightening the courses of the rivers in order to lessen the possibility of flood damage, they have not been very successful up to now because of increasing outflows due to urbanization in the surrounding areas, filling of rivers with solid waste and to the fact that the majority of them happen to be tidal rivers. It is therefore necessary to study a method whereby flood waters are temporarily retained using water retention ponds to let pollutants settle before discharging during the ebb-tide.

B-3-3 Swirl Separation Tank

(1) This is a cylindrical water tank designed to separate pollutants contained in river water by swirling the water. River water is led into the water tank through an intake conduit along the wall and swirls around inside the tank. The heavier pollutants are drawn towards the center and the lighter pollutants up to the surface. Pollutants gathered in the center are taken out together with a portion of the river water through a take-out duct in the bottom of the cylindrical tank and that floating on the surface is caught and taken away by a scum ring. River water freed from pollutants is then returned to the river through a conduit in the upper part of the tank.

(2) It consumes little energy. It also has lower construction expenses and easy maintenance and supervision while its effect in removing pollutants is comparatively high. Moreover, it does not require a large site, unlike water retention ponds. The tank may be used as a water retention pond or as a countermeasure against first flush(?) for rivers with a small flow.

(3) As there is a limit in the size of the water tank, this method is not applicable to rivers with larger flows.

(4) The City of Matsuyama (Japan) employed a swirl separation tank with a diameter of 29.6m and a depth of 7.4m at a sewage treatment plant as a measure to cope with excess sewage. It worked successfully to reduce the number of days when untreated sewage was discharged by one half and the volume of untreated discharge to one third and to reduce the overall annual drainage load of BOD by about 10 %.

(5) This method is expected to become an effective measure for reducting the loads of medium to smaller rivers in metropolitan Rio de Janeiro in rainy weather in locations it is difficult to secure the necessary load for the construction water retention ponds.

B-3-4 Removal of Sludge Deposited in the River

(1) Removal of sludge deposited into the rivers contributes to a reduction of inflow load into the Bay and the elusion load from bottom sediments. It is especially important to remove the sludge in the tidal zone of the river because deposition of floating materials and decomposition of organic substances easily occurs in this zone where fresh water and sea water mix.

(2) This measure also helps to prevent inundation.

(3) There are many cases where a treatment or disposal site for sludge is difficult to secure.
The effect of this measure is only temporary except if the flow of pollutants into the rivers is prevented.

(4) It is necessary to survey the distribution area, the thickness and the mechanical properties of the sludge as well as the dredging method and the disposal site prior to the implementation.

(5) In City of Rio de Janeiro, removal of sludge is not carried out to improve water quality in the rivers but to prevent inundation.

Improving the garbage collection rate of solid waste is necessary to prevent inundation as well as improving the water quality because the dredged material is mainly composed of solid waste.

15.4 Measures Applicable to the Bay

C-1 Improvement of Flow Regime within the Bay

C-1-1 Widening of the Bay Mouth

(1) Enlarging the cross section at the mouth of the Bay facilitates the smoother inflow and outflow of sea water, thereby improving the water quality within the Bay.

(2) Once the bay mouth is widened, no particular facility or maintenance personnel is needed afterwards.

(3) It, however, may exert significant influences on aquatic organisms owing to the resultant changes to the inner bay environment.

(4) An environmental assessment study is necessary because of the large impact on the ecosystem in the Bay.

(5) The bay mouth widening work is expected to be a troublesome due to the hard rock-beds exposed above the surface at the mouth of Guanabara Bay and also because of the frequent cruise vessels. It also changes the spectacle.

C-1-2 Excavation or Widening the Channel

(1) The excavation of a waterway accelerates the flow rate and prevents deposition of fine gained bottom sediments which easily absorb pollutants.

(2) It is possible to move the sludge deposited on the sea bed without constructing facilities.'

(3) Monitoring and repeated dredging are necessary to maintain the channel because it will fill up due to waves and the current.

(5) In Guanabara Bay, dredging has been carried out sometime in the central fairway and frequently in the harbor to maintain the water depth. However, it has not been carried out to improve the water quality in the Bay.

Excavating a channel is not difficult in the inner part of the Bay since it is shallow. It is expected that the resulting accelerated flow will carry out polluted mud which is distributed widely in the inner part of the Bay.

C-1-3 Removal of Obstacles (reefs, sunken vessels and others)

(1) This is a measure to remove shore reefs and sunken ships impeding the in-bay currents thus improving the current flow to facilitate discharge of pollutants into the open sea.

(5) Although there are many sunken ships in Guanabara Bay, there are only two large ones and they are not impeding the current flow to a large extent.

C-2 Preservation and Improvement of Self-Purification Ability

C-2-1 Restoration of Sand Beaches

(1) A large volume of sea water infiltrates into and seeps out of sand beaches, as the tidal level fluctuates, due to the high permeability of the sand layer. Aerobic bacteria grow on the surface of sand grains, receiving enough oxygen, and decomposes organic substances existing in the sea water. Restoration of sand beaches having such self-purification abilities contributes to water quality improvement.

(2) No special facility is necessary to construct.

(4) The following facts on the self-purification ability of sand beaches were made clear by a study in Japan. The removal ability becomes higher as temperature increases, and lower with an increased COD concentration in sea water. The removal ratio of COD in summer reaches 70 % to 80 %. Its ability to decompose organic nitrogen is especially high as it evident from the rapid change of NH_4 to NO_3.

(5) There are many pocket beaches in Guanabara Bay, and they are contaminated with oil near the harbor and industrial zones and with decomposed organic substances near the mouth of rivers and storm water drains. Therefore, it is thought that the self-purification ability of sand beaches has decreased remarkably. Though it is difficult to quantify the self-purification ability of these sand beaches, their restoration is beneficial for water quality improvement in the Bay.

C-2-2 Restoration of Salt Marshes

(1) Reed stands develop and a large number of benthos, including Helice sp., live in the salt marshes. Bottom sediments in salt marshes are abundant in oxygen and have high osmosis because they are always disturbed by the benthos. Roots of

reeds absorb nutrient salts in the sea water, and bacteria on reed stalks ingests and decomposes organic substances. Restoration of salt marshes having such self-purification abilities contributes to water quality improvement.

(4) Nitrogen and phosphorous in reeds are at their maximum in summer (July) and the amount reached 24 g/m^2 of T-N and 2.4 g/m^2 of T-P in a salt marsh in Japan.

It is necessary to cultivate reeds for the removal of nutrient salts by using their biological characteristics. Consequently, labor and the treatment method of cultivated reeds should be prepared.

(5) Salt marshes also exist widely around Guanabara Bay and the characteristic ecosystem consisted of halophytic vegetation subsists (mangroves, benthos, fish and birds). Consequently, the restoration of salt marshes is desired to preserve the ecosystem as well as to purify water in the Bay.

C-3 Direct Purification of Sea Water

C-3-1 Artificial Lagoon

(1) An artificial lagoon is made by the construction of permeable banks made of concrete blocks or rabble. The quality of the water enclosed in this lagoon is improved by the aeration effect of waves breaking, absorption of nutrient salts by attached weeds, the filtration effect and the bio logical decomposition of organic substances.

(4) An artificial lagoon was constructed in Osaka Bay to purify the leachate from a solid waste disposal site. The lagoon has an area of 20,000 m^2 and holds about 100,000 m^3 of water. Five aerators are also installed. Though the water quality of the inflow contains 150-400 mg/l of BOD, 150-300 mg/l of COD and 160-170 mg/l of T-N, the treated water contains 20-40 mg/l of BOD throughout the year.

(5) Aesthetically this system is not suited to the natural scenery of Guanabara Bay.

C-3-2 Air Lifting Pump (Aerator)

(1) An air lifting pump causing forced water circulation by sending air to the deep layer and pumping up this water. At high temperatures, stratification of water increases and the bottom layers become anaerobic. The air lifting pump breaks the stratification and supplies oxygen to the bottom layers, thus eliminating the anaerobic condition. Eutrophication is also prevented because phytoplanktons are forced into the deeper layers and their proliferation is prevented because of the weak photosynthesis.

(2) This technique is effective in improving the water and bed sediment quality, and in preventing eutrophicaiton, in sufficiently deep semi-closed water bodies.

(3) The efficiency of forced circulation is low when the water body is shallow because stratification of the water mass is easily broken by wind and the aphotic layer is thin.

(4) In Japan, air lifting pumps have been adopted in several reservoirs in which water quality has deteriorated due to eutrophication, and their efficiency has been demonstrated.

On the other hand, vertical water circulation was not improved in Toyoura Bay (Japan) although an aerator was installed. Possible reasons are the weak closed water body, horizontal dispersion of lifted water and the influence of tides. Consequently, application of an air lifting pump is not always successful.

C-4 Improvement of Sea Bottom Sediments

C-4-1 Removal of Sludge

(1) Sea bottom sludge endangers aquatic life and deteriorates the living environment of benthos. The living environment of the sea is also affected by the offensive odor of the sludge. Removal of the sludge by dredging can improve the aquatic environment.

(2) Removal of sludge is effective in maintaining the function of harbor and fairway because the water depth is increased.

(3) A method of skimming the surface sludge has not yet been devised.

(4) It is necessary to survey the site for dangerous and buried objects and to adopt the dredging method suitable for the soil condition.

(5) The arrival of ships into the Port of to Rio de Janeiro is hampered by the sedimentation of soil and solid waste inflowing from the Mangue Canal. As dredging of sludge in the port has not been done for the past four years, the depth near the wharfs has become shallow. Consequently, ships arriving in port are limited to less than 50,000 tons in displacement, so the loading and unloading of bigger ships is done outside of the port. Consequently, dreading in the port brings rehabilitation of the port's function as well as the removal of pollutants.

C-4-2 Sand Covering

(1) Sand covering prevents the release of pollutants from the sea bottom.

(3) Sands for covering are often difficult to obtain.

(4) Sand covering was carried out in Mikawa Bay (Japan), the covering was 50 cm thick over an area of 100 m x 150 m. According to a study, the aerobic condition was maintained and species of benthos increased ten (10) months after the sand covering. This technique, however, is still in its experimental stage and its durability is unknown.

15.5 Measures Applicable to the Open Sea

A. Outfall system for Wastewater

(1) Domestic wastewater is transported by pipelines or submerged tunnels and discharged directly into the open sea.

(2) As domestic wastewater is rich in nutrient salts, this method is particularly effective for the improvement of the water quality of semi-closed water areas where internal production

load plays an important role in the deterioration of water quality. Outfall of domestic wastewater increases the fish catch in the open sea where it is generally oligotrophic. Maintenance is easy and the maintenance cost is lower than that of sewage treatment plants with secondary treatment.

(3) The initial cost is large. This technique is very effective in the removal of wastewater from an area, however if no often measures are taken sanitary conditions at the local level may not improve.

(4) Outfall of domestic wastewater is used in many cities in the world. In Sydney (Australia), three drainage tunnels to 3 km offshore with a depth of 60 to 80 m discharge the domestic wastewater of five (5) million people. The wastewater is discharged from diffusion pipes (inside diameter: 3.5m) connected to drainage tunnel at 20 to 25 m intervals. In addition, this technique is used in San Francisco (USA), Santa Cruz (USA), Archacon (France), Mohammed (Morroco) and other cities.

Removal of heavy metals and polymeric compounds are necessary before discharge. It is also necessary to clarify the flow regime of the littoral sea and to be certain that the discharged wastewater will not pollute the coast.

(5) A portion of the domestic wastewater generated in Rio de Janeiro city is discharged from a drainpipe of 2.4 m in diameter outflowing 4.3 km off the Ipanema coast. Discharge volume is about 6.2 m^3/sec. Discharged wastewater, however, pollutes the coast because the wastewater leaks from the joints of the drainpipe. In Brazil, this technique has been applied to six cities apart from Rio de Janeiro.

15.6 Evaluation of Hardware-type Measures

As mentioned in clauses 15.2 through 15.5, various hardware-type measures are available for water pollution controls. Among them, the measures that are fundamentally and permanently effective are the ones (A-1 through A-3) applicable to the source of the pollution. Those measures which aim at direct purification of water in the Bay and the rivers, and at excavation of bottom sediments should be applied to limited areas where emergency measures are necessary, from the viewpoints of the desired results and energy requirements, as referred to in Clause 15.1. A water pollution control project should always take the aforementioned points into consideration.

On the other hand, even identical measures may have substantially different effects depending on the natural and socioeconomic conditions of the districts where the measures are being implemented. Therefore, it is important to judge if a particular measure fits the natural and socioeconomic conditions and the technical capability available in the district, appreciating the advantages and shortcomings of each measure.

Table 15.6-1 shows relative evaluations of the characteristics of individual measures with subsequent comprehensive judgments of their applicability to the Guanabara Bay basin.

Paragraph (a) evaluates the construction, maintenance and supervision expenses of the basic facilities required for the implementation of individual measures. Needless to say that measures requiring less expenses are more desirable for countries and municipalities with low financial resources. However, the initial investments may be covered by loans from overseas or international banking organizations, while the maintenance and supervision expenses are usually born by the nation or the municipality itself for a long period of time. Therefore, those measures which require a high initial investment and low maintenance and supervisory expenses are more suitable.

Paragraph (b) evaluates the area requirements of the sites for construction of the necessary facilities. In the Guanabara Bay basin, the land prices in urban districts are high and only a little land is still undeveloped, but there is still a lot of undeveloped land at lower prices in the suburban areas. In these areas, those measures that require long detention times and larger areas can be applied.

Paragraph (c) evaluates the case of maintenance and supervision of individual measures. In areas, where labor costs are low, those measures which do not require highly sophisticated skills and techniques are more suitable even if more people are needed for maintenance and supervisory work.

Paragraph (d) evaluates the time required from planning a measure and making the necessary surveys until implementation. Needless to say the shorter the better, and the quicker the appearance of effect the better the measure.

Paragraph (e) indicates the major pollutants removed by the measure. It is necessary that the pollutants to be removed are the main cause of the water pollution in the area concerned.

Paragraph (f) evaluates the degree of bad influences on the neighborhood environments anticipated to be caused by each measure. Since some of water quality improvement measures tend to cause secondary pollution e.g. the contamination of soil and underground water, breeding of noxious insects, pathogenic bacteria and offensive odors, it is important to have previous knowledge of the anticipated influences of each measure.

Paragraph (g) shows the types of relevant development projects. If a measure suits the existing land utilization plan, river improvement plan, sewage treatment plan or water area utilization plan, the administrative organization and residents should immediately accept the measure. However, when a measure requires some changes and modifications to these plans, implementation of the measure will not be easy.

Paragraph (h) indicates the success in Brazil or in the Guanabara Bay basin of each measure. Selection of a measure which was already been successful in districts with similar natural and socioeconomic conditions should be extremely advantageous since the effects of the measure can be accurately anticipated.

Paragraph (i) makes comprehensive evaluations of the applicability to the Guanabara Bay basin of each measure based on the results of evaluations of items (a) through (h). The evaluations, however, are subject to change if the socioeconomic conditions in the Guanabara Bay basin areas change.

Table 15.6- 1 Evaluation of Hardware-Type Measures

Classification of Measures	a	b	c	d	e	f	g	h	i
	Evaluation Items								
A. Measures applicable to the basin									
A-1 Reduction of domestic effluent load									
A-1-1 Septic tank (small size)	●	◎	○	◎	BO	○	ST	◎	△
A-1-2 Soil treatment	○	○	○	◎	BO+NS	○	ST	○	△
A-1-3 Irrigation to agricultural land	○	●	○	●	BO+NS	●	LU	○	○
A-1-4 Stabilization pond	◎	●	○	○	BO+NS	●	ST	◎	◎
A-1-5 Contact oxidation ditch	○	○	○	●	BO	○	ST	◎	◎
A-1-6 Activated sludge (standard)	●	○	●	●	BO	○	ST	◎	○
A-1-7 Trickling filter	○	○	○	●	BO	○	ST	◎	○
A-1-8 Tertiary treatment system	●	○	●	●	NS	○	ST	x	△
A-2 Reduction of industrial effluent load Waste water treatment for									
A-2-1 Food industry	●	◎	●	○	BO	○	LU	◎	○
A-2-2 Paper and pulp industry	●	◎	●	○	BO+SS	○	LU	○	○
A-2-3 Organic chemical industry	●	◎	●	○	RO+OL	○	LU	◎	○
A-2-4 Inorganic chemical industry	●	◎	●	○		○	LU	○	○
A-2-5 Fiber dyeing industry	●	○	●	○		○	LU	○	○
A-3 Reduction of eff. load from non-point sources									
A-3-1 Prevention work for soil erosion	●	●	◎	●	BO+NS	○	LU	◎	○
A-3-2 Improvement of garbage collect ion and dispopsal systems	●	●	○	●	◎	●	LU	◎	◎
B. Measures applicable to the rivers and cannals									
B-1 Improvement of cannals	●	◎	○	○	BO	○	FC	x	△
B-2 Direct purification of river water									
B-2-1 Contact oxidation tank with cobbles	●	●	○	○	BO	○	FC	x	△
B-2-2 Living filter	◎	●	○	○	BO+NS	○	FC	○	△
B-2-3 Induction into marshland	◎	●	○	○	BO+NS	○	FC	x	○
B-2-4 Induction of dilution water	●	○	○	●	--	●	FC	x	△

Classification of Measures	a	b	c	d	e	f	g	h	i
	Evaluation Items								
B-3 Prevention of river load flowing into the bay									
B-3-1 Diversion of river channel	●	●	○	●	◎	●	FC	○	△
B-3-2 Retardation pond	○	●	○	●	◎	●	FC	x	○
B-3-3 Swirl separation tank	○	○	○	○	◎	○	ST	x	○
B-3-4 Removal of sludge deposited in the river	○	●	--	○	BO+NS	●	FC	◎	◎
C. Measures applicable to the bay									
C-1 Improvement of flow regime within the bay									
C-1-1 Widening of the bay mouth	●	●	--	●	--	●	WU	x	△
C-1-2 Excavation or widening a channel	●	●	--	●	--	○	WU	x	◎
C-1-3 Removal of obstacles	○	●	--	○	--	○	WU	◎	○
C-2 Preservation or improvement of self-purification ability									
C-2-1 Restoration of sand beaches	○	●	○	●	BO	○	--	x	○
C-2-2 Restoration of salt marshes	○	●	○	●	BO+NS	○	--	x	○
C-3 Direct purification of sea water									
C-3-1 Artificial lagoon	●	●	○	●	BO	○	WU	x	△
C-3-2 Air lifting pump (Aerator)	●	◎	●	○	BO	○	WU	x	△
C-4 Improvement of sea bottom sediment									
C-4-1 Removal of sludge	●	●	--	○	BO+NS	●	--	◎	◎
C-4-2 Sand covering	●	●	--	○	--	○	--	x	△
D. Measures applicable to the open sea									
D-1 Ocean outfall of sewage	●	●	●	●	◎	●	WU	◎	◎

Legend for Table 15.6-1

a : Treatment cost including construction cost for essential facilities and running cost
● High ○ Intermediate ◎ Low

b : Dimensions of site for treatment
◎ Limited ○ Intermediate ● Extensive

c : Operation and Maintenance of Facility
◎ Free ○ Easy but indispensable ● Specialists are necessary

d : Term necessary for planning and construction of basic facilities
● Long (more than three years) ○ Medium (one to three years)
◎ Short (less than a year)

e : Pollutants mainly removed or decomposed without SS
◎ Many kinds BO : Biologically decomposed organic substances
RO : Refractory organic substances NS : Nutrient salt OL : Oil
HM : Heavy metal

f : Harmful impact on the adjacent areas
○ Little in many cases ● Large according to circumstances

g : Relational development plan
LU : Land use plan FC : Flood control plan
ST : Sewage treatment plan WU : Water area utilization plan

h : Experiences in Brazil (especilly in the study area)
◎ Sufficient ○ a little x Nothing

i : Applicability to the study area
◎ Optimum ○ Applicable △ Inadequate

PART VIII

MASTER PLAN FOR THE RECUPERATION OF THE GUANABARA BAY ECOSYSTEM AND RECOMMENDATIONS FOR ITS IMPLEMENTATION

CHAPTER 16

MASTER PLAN

FOR THE RECUPERATION

OF

THE GUANABARA BAY ECOSYSTEM

CHAPTER 16

MASTER PLAN FOR THE RECUPERATION OF THE GUANABARA BAY ECOSYSTEM

In this chapter, a Master Plan for the Recuperation of the Guanabara Bay Ecosystem is presented. A final outcome of the Master Plan is an "Optimum Combination of the Measures for the Recuperation of Guanabara Bay" after examining several alternatives in a strategic manner (see 16.9 and 16.10).

With the diversified natural, social and economic conditions in the basin in mind, and based on the in-depth analyses on the conditions, we classified the sub-basins into three categories, namely "Influential Sub-Basins", "Potentially Critical Sub-Basins" and "Other Sub-Basins" so that we could duly place the priority for actions. The Influential Sub-Basins are the area with significant impacts on water quality in the Bay and therefore need urgent and intensive countermeasures. The Potentially Critical Sub-Basins are those with comparatively low impacts at present but will have critical impacts in near future because of anticipated future development and therefore call for measures focusing land-use planning and so forth.

Water areas are not homogeneous but rather diversified. Reflecting the pressure from the basins behind, water quality differs from area to area, and the use of the water areas shows also diversification ranging from water bathing to fishery or the use for dumping of garbage. In some areas, people can enjoy benefits derived from clean water whereas in other many areas people suffer from water pollution thereby being prohibited from utilizing water areas. This situation made us to classify the water areas based on the present water quality and potential use value.

We set up a target water quality for each classified water area mentioned above particularly taking into account the potential use value which might be realized through the comprehensive measures presented in the Master Plan.

The numerical simulation models established in this study played a very important role in examining the effect of measures. With these models, we identified the load of pollutants which were needed to meet the target water quality set in each classified water area. Considering the great influence of eutrophication on water quality in the Bay, we tried, on top of BOD, to determine the necessary reduction load of nutrient salts, namely Phosphorus.

Optimum combination of measures were examined after in-detail examination of feasibility of each measures listed in Chapter 15 considering costs for construction and maintenance and so forth. In addition to hardware-type measures, indispensable software-type measures for the basins in their characteristics were examined.

16.1 Socioeconomic Background of Environmental Change in and around Guanabara Bay

Development in the Guanabara Bay basin has caused various socioeconomic losses such as flooding and slope failure, the degradation of the residential environment, the pollution of coastal recreation zones and the decrease in the commercial value of aquatic life. These socioeconomic losses have resulted in a decrease in revenue and an increase in countermeasure costs for the state government and municipalities, causing a vicious circle resulting in financial hardship. The causal relationship between environmental deterioration and socioeconomic losses is shown in **Fig. 16.1-1.** The following things are specifically mentioned.

As we have seen in Chapter 7, the urban area has expanded and massive forests have become extinct with the continued development in the Guanabara Bay basin. Consequently, decreased river flows on fine days have resulted in deterioration of the water quality, while on rainy days the deterioration of water quality was brought about by the flush of wastewater and garbage. Whereas, an increase in peak river flows during freshet periods causes inundation.

A typical disaster resulting from inundation and slope failure due to heavy rain occurred on February 28, 1988, causing 281 deaths in Rio de Janeiro and Petropolis.

The sanitary services of the municipalities in the basin are insufficient as described in Chapter 3. Therefore, most sewage and solid waste flow into the rivers and the Bay without treatment.

Furthermore, development of the coastal areas has accelerated the deterioration of water and sediment quality because it has increased direct inflow into the Bay, destroying the sand beaches and swamps which have natural purification capabilities. The degradation of the current water circulation by reclamation of coastal areas, especially in the channel areas, has badly influenced water quality in the inner part of the bay.

Environment problems in the Guanabara Bay basin cannot be discussed without talking about "favelas", or slums, which are lower class housing areas illegally developed on occupied lands, 1.05 million or about 80 % of the total favela population in the Guanabara Bay basin live in the City of Rio de Janeiro. The actual number is estimated to be more than twice of this (Chapter 3).

There are no sewage systems in the favelas, and the collection of solid waste is inadequate due to the narrow roads. Besides, the residents of favelas deforest the area to gather firewood. Therefore, massive amounts of waste water and solid waste are emitted during freshet periods and there is a high possibility of inundation and slope failure in downstream areas.

Recently, inundation accompanied by slope failure occurred around the Tijuca Forest in March 1993. COMLURB is said to have removed 18,000 ton of debris and solid waste. The Rio de Janeiro municipal environment department and IEF concluded that this disaster was caused by deforestation by the residents of the favelas, the population of which amounts to 100,000 in 37 favelas in the Tijuca Forest alone. The environment department reported that the felled area of the Tijuca Forest accelerated gradually from 9,625 hectares in 1972, to 10,624 hectares in 1978, and to 19,874 hectares in 1984, and that this felled area is not eligible for compensation from the forest development programs sponsored by the World Bank.

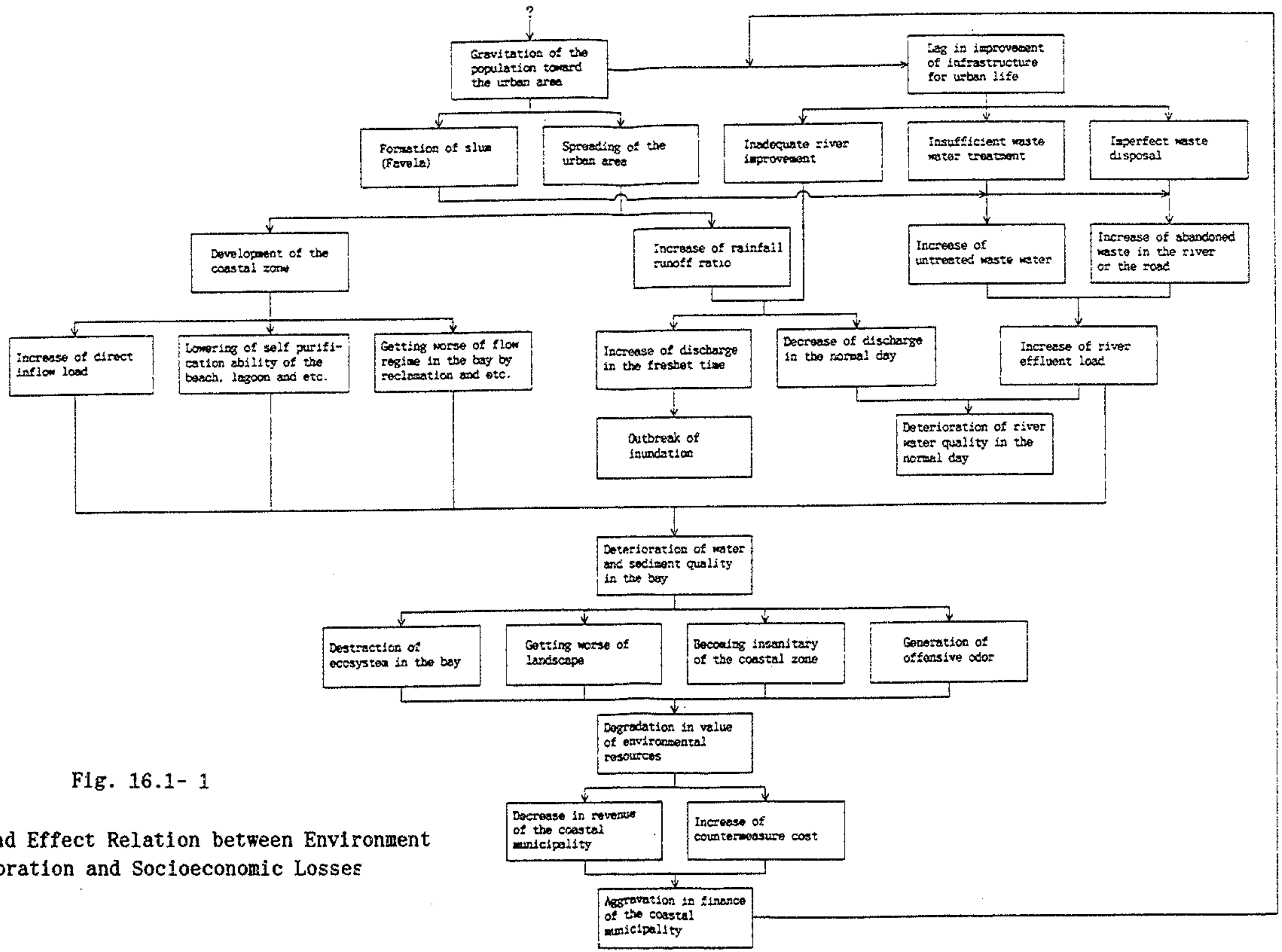


Fig. 16.1- 1

Cause and Effect Relation between Environment Deterioration and Socioeconomic Losses

16.2 Benefits from the Recuperation of the Guanabara Bay Ecosystem

16.2.1 Classification of Benefits

The value of water areas lies mainly in their use as a resource like the supply of tap and agricultural water and for fishing. Recently, high value has been placed on the water environment e.g. the function of coastal recreational fields and the purification and dilution of polluted water.

The value of a water resource is measured from economic standpoints and its function in the environment is gauged by the satisfaction it gives to people. A strong interest does not seem to have arisen regarding the purification and dilution of polluted water.

Apart from the question of whether the various values of the water areas can be discussed using the same economic values, the socioeconomic benefits of Guanabara Bay are summarized in **Table 16.2-1.** Although the socioeconomic benefits extend to the entire basin, this table shows only the benefits in the Bay.

Socioeconomic losses can be socioeconomic benefits to put them the other way around. Therefore, we see the damages that are presently evident in the Bay.

Based on the state of present uses of the water areas in Guanabara Bay, the following damages have occurred in the Bay due to the deterioration of the water.

Visible Damage

(1) Direct Use	:	Destruction of ecosystem Decrease in fish/shellfish hauls (Decrease in fishermen's income) Damage to mangroves Deterioration of industrial water Deterioration of seaside resorts Damage to marine sports facilities
(2) Indirect Use	:	Loss of aesthetic value Deterioration of residential environment Moving of residential housing (Decrease in real estate value) Decrease in number of tourists (Decrease in tourist income)
(3) Others	:	Increase in countermeasure costs

Invisible Damage

(1) Potential Use: No possibility of long-term plan
(2) Non-Use : Depletion of natural environment as a heritage for future generations
Loss of fields for studying nature

The damage caused by the direct and indirect effects of water pollution in Guanabara Bay, as described above, can still be repaired so that the residents can enjoy a great deal of socioeconomic benefits from the water resources and the water environment.

Although only the socioeconomic benefits to the Bay are discussed here, it goes without saying that many more benefits will be gained through the restoration of the water quality in the rivers extending over the entire basin.

Table 16.2- 1 Socioeconomic Benefits of Guanabara Bay

Visible Benefit	Direct Use	Water Use	Industrial Waters, Fishery, Navigation
		Recreation	Sea Bathing, Fishing, Yachting, Sightseeing Cruises
	Indirect Use	Recreation Aesthetics Relaxation	Picnic, Walking, Bird-Watching, Sightseeing, Residential Environment
		Others	Natural Purification Capacity
Invisible Benefit	Potential Use	Optional Value	Possibility for Long-Term Use
	Non-Use	Existing Value	Heritage (Natural Preservation), Study Field

16.2.2 Evaluation Method of the Benefits

Evaluation of a purely environmental improvement project poses serious difficulties in the practical application of recently developed theoretical concepts. These difficulties range from the lack of reliable and sufficiently long time-series data, to the unproven methods of data collection due to the general lack of consciousness about environmental problems among the people, who will ultimately determine the success of an environmental improvement project.

In the case of Guanabara Bay, potential benefits to be derived from improving its water quality have been studied for nearly 20 years by Mr. Victor Coelho of FEEMA who incorporated the basic concepts of recent theoretical evaluation methods into practical calculation procedures which are easily understood.

Of the many benefits estimated by FEEMA, the following benefits were only estimated quantitatively;

(1) Water contact recreation benefits
(2) Land value appreciation
(3) Fish production increase

16.2.3 Water Contact Recreation Benefit

These benefits refer to the value of recreation in the Guanabara Bay beaches. Benefit estimation is based on the saturation population of beaches, the hourly value of recreation, and the cost of transportation.

(1) Saturation population

The saturation population is a function of the beach area. **Table 16.2-2** lists the beaches in Guanabara Bay, along with the estimated width and length. Then the total beach area in Guanabara Bay was estimated at 1,111,500 m^2.

The beach area per person was worked out at 5m^2 for Flamengo, Botafogo, Icarai and San Francisco, and 10m^2 per person at the other beaches. The total saturation population of the Guanabara Bay beaches was estimated at 152,950 (**Table 16.2-2**).

(2) Number of potential beach users per year

The number of potential beach users was estimated using the following assumptions.

Hot months (November to April)

Sunday: 100% of the saturation population (26 days)
Saturday: 70% of the saturation population (26 days)
Weekdays:
Summer vacation (3 months): 30% of sat. pop.(65 days)
Other months (3 months): 15% of sat. pop.(65 days)

Cool months (May to October)

Sunday: 70% of the saturation population (26 days)
Saturday: 50% of the saturation population (26 days)
Weekdays:
Winter vacation (2 weeks): 20% of sat. pop. (10 days)
Other months: 10% of sat. pop. (120 days)

The right end column in **Table 16.2-2** shows that the number of potential beach users in Guanabara Bay is 18,147,518.

(3) Value of recreation

The value of recreation is estimated by assuming the following.

- Salary : US$100 per month
- Monthly working hours : 176
- Hourly wage : US$0.57/hr.
- Value of recreation : 1.5 hourly wage = US$0.85
- Family size : 5 of which 2 are wage earners
- Transportation cost : US$2.00 per person per round trip
- Time spent at the beach: 2 hours

Then, the value of recreation is the following.

2 hours X 2 persons X US$0.85	= US$ 3.40
2 hours X US$2.00 (transp.)	= US$10.00
Total 5 persons	US$13.40

The value per person per visit would be US$13.40 divided by 5, that is, US$2.68. This value is then multiplied by the number of potential beach users per year.

US$ 2.68 X 18,147,518 persons = US$ 48,635,348/year

If it is arbitrarily assumed that one fourth of potential beach users will be induced to practise water contact recreation by the cleaner water in Guanabara Bay, then the benefits from the Project would amount to US$ 12,158,837 per year.

Table 16.2- 2 Saturation Population of Beaches and Potential Beach users

Beach	Width (m)	Length (m)	Area (m^2)	Saturation Population	Potential Beach User per Year
Flamengo	100	1450	145000	29000	3440850
Botafogo	140	600	84000	16800	1993320
Ramos	50	600	30000	3000	355950
Vermelha	10	200	2000	200	23730
Barreto	50	400	20000	2000	237300
Adao e Eva	50	100	5000	500	59325
Urca	40	100	4000	400	47460
Flexas	100	1000	100000	10000	1186500
Icarai	140	1200	168000	33600	3986640
S.Francisco	30	700	21000	4200	498330
Charitas	30	700	21000	2100	249165
Jurujuba	40	350	14000	1400	166110
Pedrinhas	50	750	37500	3750	444938
Anil	10	1000	10000	1000	118650
Maua	20	2000	40000	4000	474600
Sub Total		11150	701500	111950	111950
I. Governador					
Tubiacanga	20	1200	24000	2400	284760
Gaegos	30	1500	45000	4500	533925
Dende	50	1300	65000	6500	771225
Rosa	20	1100	22000	2200	261030
Pelonias	50	600	30000	3000	355950
Grande	10	800	8000	800	94920
Saco da Rosa	50	600	30000	3000	355950
Bananal	5	700	3500	350	41528
Guanabara	20	1500	30000	3000	355950
Cocota	10	800	8000	800	94920
Bandeiro	20	500	10000	1000	118650
Pitangueiras	10	700	7000	700	83055
Zumbi	5	400	2000	200	23730
Engenhoca	10	700	7000	700	83055
Ribeira	10	600	6000	600	71190
Jequia	20	1200	24000	2400	284760
Brava	10	500	5000	500	59325
Bica	30	1900	57000	5700	676305
Eng. Velho	5	700	3500	350	41528
S. Bento	5	800	4000	400	47460
Galeao	5	1300	6500	650	77123
Sub Total		19400	397500	39750	4716338
I. Paqueta					
J. Boticario	5	1300	6500	650	77123
Moreninha	5	500	2500	250	29663
Gaivotas	5	350	1750	175	20764
Lameiras	5	350	1750	175	20764
Sub Total		2500	12500	1250	148313
TOTAL		33050	1111500	152950	18147518

16.2.4 Land Value Appreciation

The appreciation of the value of the land surrounding a water body is a summation of all the beneficial effects of the water quality improvement. The land value appreciation depends on the unit value of land and the distance from the shore. The benefit estimation is based on the following.

(1) Unit value of land (US$/$m^2$)

Values provided by realtors

Flamengo	US$1,260/$m^2$
Botafogo	US$1,160/$m^2$
Ramos	US$ 725/m^2
Urca	US$1,525/$m^2$
I. do Governador	US$ 485/m^2
Maua	US$ 5/m^2

Assumed values

Icarai	US$ 500/m^2
San Francisco	US$ 500/m^2
Remaining beaches	US$ 50/m^2
Non-beach	US$ 1/m^2

(2) Distance from the beach

A study by the Environmental Protection Agency in the United States found that an improvement in water quality affected the value of the land surrounding the water body. The appreciation of the land ranges from 8% to 24%, and the value appreciation disappears beyond 4,000 ft. from the shore.

The estimation of value appreciation is based on the following assumptions.

Distance from the beach	Value appreciation
Up to 100 m	24%
100m - 500 m	15%
500m - 1000 m	8%

(3) Total value

Table 16.2-3 shows that the total value of land appreciation amounts to US$ 1,733,858,000.

Table 16.2- 3 Total Value of Land Appreciation Amounts

Beach	Land Area up to 1 km from the Shore					Land Value Appreciation			
	Length (m)	To 100 (m2)	To 500 (m2)	To 1000 (m2)	Total (1000m2)	To 100 (US$)	To 500 (US$)	To 1000 (US$)	Total (1000US$)
Flamengo	1450	145000	580000	725000	1450	43848000	109620000	73080000	226548
Botafogo	600	60000	240000	300000	600	16704000	41760000	27840000	86304
Ramos	600	60000	240000	300000	600	10440000	26100000	17400000	53940
Vermelha	200	20000	80000	100000	200	240000	600000	400000	1240
Barreto	400	40000	160000	200000	400	480000	1200000	800000	2480
Adao e Eva	100	10000	40000	50000	100	120000	300000	200000	620
Urca	100	10000	40000	50000	100	3660000	9150000	6100000	18910
Flexas	1000	100000	400000	500000	1000	1200000	3000000	2000000	6200
Icarai	1200	120000	480000	600000	1200	14400000	36000000	24000000	74400
S.Francisco	700	70000	280000	350000	700	8400000	21000000	14000000	43400
Charitas	700	70000	280000	350000	700	840000	2100000	1400000	4340
Jurujuba	350	35000	140000	175000	350	420000	1050000	700000	2170
Pedrinhas	750	75000	300000	375000	750	900000	2250000	1500000	4650
Anil	1000	100000	400000	500000	1000	1200000	3000000	2000000	6200
Maua	2000	200000	800000	1000000	2000	240000	600000	400000	1240
Subtotal	11150	1115000	4460000	5575000	11150	103,092,000	267,730,000	171,820,000	532,640
I.Governador									
Tubiacanga	1200	120000	480000	600000	1200	13968000	34920000	23280000	72168
Gaegos	1500	150000	600000	750000	1500	17460000	43650000	29100000	90210
Dende	1300	130000	520000	650000	1300	15132000	37830000	25220000	78182
Rosa	1100	110000	440000	550000	1100	12804000	32010000	21340000	66154
Pelonias	600	60000	240000	300000	600	6984000	17460000	11640000	36084
Grande	800	80000	320000	400000	800	9312000	23280000	15520000	48112
Saco da Rosa	600	60000	240000	300000	600	6984000	17460000	11640000	36084
Bananal	700	70000	280000	350000	700	8148000	20370000	13580000	42098
Guanabara	1500	150000	600000	750000	1500	17460000	43650000	29100000	90210
Cocota	800	80000	320000	400000	800	9312000	23280000	15520000	48112
Bandeiro	500	50000	200000	250000	500	5820000	14550000	9700000	30070
Pitangueiras	700	70000	280000	350000	700	8148000	20370000	13580000	42098
Zumbi	400	40000	160000	200000	400	4656000	11640000	7760000	24056
Engenhoca	700	70000	280000	350000	700	8148000	20370000	13580000	42098
Ribeira	600	60000	240000	300000	600	6984000	17460000	11640000	36084
Jequia	1200	120000	480000	600000	1200	13968000	34920000	23280000	72168
Brava	500	50000	200000	250000	500	5820000	14550000	9700000	30070
Bica	1900	190000	760000	950000	1900	22116000	55290000	36860000	114266
Eng. Velho	700	70000	280000	350000	700	8148000	20370000	13580000	42098
S. Bento	800	80000	320000	400000	800	9312000	23280000	15520000	48112
Galeao	1300	130000	520000	650000	1300	15132000	37830000	25220000	78182
Subtotal	19400	1940000	7760000	9700000	19400	225816000	564540000	376360000	1166716
I.Paqueta									
J.Boticario	1300	130000	520000	650000	1300	1560000	5700000	2600000	9860
Moreninha	500	50000	200000	250000	500	600000	2100000	1000000	3700
Gaivotas	350	35000	140000	175000	350	420000	2400000	700000	3520
Lameiras	350	35000	140000	175000	350	420000	3900000	700000	5020
Subtotal	2500	250000	1000000	1250000	2500	3000000	14100000	5000000	22100
Total Beach	33050	3305000	13220000	16525000	33050	331,908,000	836,370,000	553,180,000	1,721,458
Non-beach	100000	10000000	40000000	50000000	100000	2400000	6000000	4000000	12400
TOTAL	133050	13305000	53220000	66525000	133050	334,308,000	842,370,000	557,180,000	1,733,858

16.2.5 Fish Production Increase

(1) Present state of the fishing industry

Total No. of Fishermen working in the Bay : 5,000 persons
Number of Colonies : 4 colonies
Maximum Commercial Fish Production in the Bay : 6 tons/day
Mussel Production : 1 ton/day

(2) Income

Set Net and Bamboo Screen : US$3,000./year (US$200. to 400./month)
Mesh Net (Shrimp) : US$7,500./year, 3 ton/year (US$25./operation,10 kg/operation)
Mussel Meat : US$250,000./year

Total : US$260,500./year

(3) Beneficial effects from water quality improvement

On the completion of the First Stage of the Project : 20 % increase in catch
By the year of 2010 : 100 % increase in catch

(4) Total beneficial value

If we assume the unit price of fish production as 1.5 times of the present price, the total beneficial value is estimated to be US$ US$390,750. per year.

16.3 Selection of Priority Areas

16.3.1 Basic Policy for the Selection of Priority Areas

In order to restore the ecosystem in Guanabara Bay and enhance the benefits examined in previous section, a long-term plan consisting of both hardware-type and software-type measures is necessary along with sufficient funds to realize it. Since there is a limit to the amount of funds which can be raised in a given period, investment should focus the influential sub-basins which contribute to the improvement of water quality in the entire Bay.

On the other hand, early improvement of the beaches and water areas, which are in great demand from utilization and sanitation standpoints, will bring large socioeconomic benefits. Moreover, if we put off improving the precious mangrove and other water areas, it will be, from ecological point of view, difficult to restore the ecosystem there. Therefore, it is necessary to give high priority to these important beaches and water areas.

The above-mentioned sub-basins and water areas are important from the viewpoint of improving the present state of water quality in the Bay. In addition, there are some other areas expected to be designated as important areas in the near future, from the viewpoint of water quality in the bay, although they do not yet present a serious threat to the quality of water in the Bay. Such areas are designated as potentially critical sub-basins.

When selecting priority areas, priority is given to Influential Sub-Basins which have a large effect on the water quality in Guanabara Bay from the standpoint of the estimated runoff loads for each sub-basin (Chapter 9) as well as from the estimated effluent loads from pollution sources (Chapter 8). Secondly Important Beaches and Water Areas were chosen taking utilization, sanitation and the ecosystem in the Bay into account. Lastly, Potentially Critical Sub-Basins were investigated based on recent changes in the distribution of population and land use.

16.3.2 Influential Sub-Basins

As was shown previously (Chapter 9), the rivers in the Western Basin supply 49 % of the inflow load in terms of BOD into Guanabara Bay. The Meriti (Sub-Basin No. 19), Cunha (No. 21), Iraja (No. 20) and Mangue (No. 23) are the major rivers, ranking 1st, 3rd, 5th and 6th, respectively, in terms of daily mean effluent load out of all the rivers flowing into the Bay.

The BOD value of the Meriti River was around 25 mg/l on average and over 40 mg/l during the worst conditions, and that of the Cunha, Iraja and Mangue rivers is extremely bad around 40 mg/l to 50 mg/l in terms of BOD despite their small basin areas.

The basins for the Cunha, Iraja and Mangue rivers have a common characteristic in that many favelas are located in them. Therefore, it is thought that inadequate garbage collection and sewage treatment are highly probable causes of the high effluent loads in the rivers.

As for the Northwestern Basin, the Sarapui (No. 17-6), Iguacu (No. 17-1.5) and Estrela (No. 16) are the major rivers, ranking 2nd, 4th and 10th, respectively and they supply 29 % of the inflow load into the bay.

The BOD value of the Sarapui was around 25 mg/l on average and over 40 mg/l during the worst conditions. The water quality of the Iguacu river was comparatively good recording less than 10 mg/l (mean). However, there are many chemical plants in the basin and it is estimated that industrial effluent loads exceed domestic effluent loads in terms of COD. PETROBRAS's refinery (REDUC) at the mouth of the Iguacu river always discharges a great deal of warm water heavy in oil into the river.

On the other hand, the rivers in the Northeastern Basin account for only 13 % of the effluent loads compared with their 35 % of total discharge. The Alcantra River (No. 8) has exceptionally bad water quality, ranking 7th in terms of effluent load. This is caused by three plants situated near the observation point which discharge large effluent loads.

The Guapimirim River (No. 10) enters the Bay through a vast mangrove forest. While having the largest discharge in the Guanabara Bay basin the Guapimirim has a low mean value of BOD; less than 3 mg/l. Even though the water quality in the Cacerebu river (No. 9), which ranks 3rd in terms of discharge, is still low at less than 10 mg/l in terms of BOD, it is feared that the load will increase in the future due to the recent increase in population along with changes in land use in the basin.

The rivers in the Eastern Basin and Islands account for only 7 % and 2 % in terms of total effluent load, respectively. The Bomba river (No. 5) has the largest effluent load of the rivers in the Eastern Basin (ranked 11th), and it should be noted that industrial loads greatly exceed domestic loads in this river.

Consequently, the sub-basins shown in **Table 16.3-1** were selected as influential sub-basins from the viewpoint of effluent loads in terms of BOD discharged into Guanabara Bay and these sub-basins are listed according to the order of the load in BOD (for the location of the sub-basins, refer to **Fig. 16.3-1**). This table summarizes the natural and socioeconomic features for each sub-basin as well as the generation and effluent characteristics of pollution loads.

Table 16.3- 1 Natural and Socioeconomic Features of the Influential Sub-Basins

No.	Sub-basin (1) River Name (2) Area (km²) (3) Pop.(x10³)	Effluent Load (1) BOD(t/d)(%) (2) TN (t/d)(%) (3) TP (t/d)(%)	Municipality (Area) (Popu) (%) (%)	River (1) Meaured Max.Discharge (2) Mean Water Quality(BOD) (3) Innundation
19	(1) Meriti (2) 164.5 (3) 1492	(1) 64.33(19.5) (2) 20.59(17.7) (3) 4.01(19.7)	RJ(82.7)(82.0) SJ(6.1)(8.4) DC(5.8)(6.2) NP(5.3)(3.4)	(1) 56.07 m³/s (Oct.1992) (2) 24.7 mg/l (3) I (Middle) II (Upper, Lower)
17 6	(1) Sarapui (2) 165.5 (3) 1012	(1) 43.40(13.1) (2) 13.94(12.0 (3) 2.66(1.31)	NI(42.0)(24.9) RJ(19.5)(74.5) DC(17.0)(14.7) SJ(15.3)(11.9) NP(6.3)(4.8)	(1) 43.83 m³/s (Nov.1992) (2) 25.9 mg/l (3) I (Middle) II (Upper, Lower)
21	(1) Cunha (2) 63.6 (3) 815	(1) 35.66(10.8) (2) 11.62(10.0) (3) 2.30(11.3)	RJ	(1) 17.69 m³/s (Nov.1992) (2) 50.1 mg/l (3) I (Middle)
17 1-5	(1) Iguacu (2) 562.8 (3) 758	(1) 31.94(9.7) (2) 11.26(9.7) (3) 1.80(8.8)	NI(57.0)(94.0) DC(43.0)(16.0)	(1) 75.75 m³/s (Nov.1992) (2) 9.2 mg/l (3) I-II (Middle) III (Lower)
20	(1) Iraja (2) 35.7 (3) 500	(1) 22.04(6.7) (2) 7.26(6.2) (3) 1.44(7.1)	RJ	(1) 5.37 m³/s (June.1992) (2) 50.0 mg/l (3)
23	(1) Mangue (2) 42.8 (3) 501	(1) 21.96(6.6) (2) 7.20(6.2) (3) 1.42(7.0)	RJ	(1) 8.69 m³/s (Nov.1992) (2) 44.4 mg/l (3)
8	(1) Alcantara (2) 144.6 (3) 470	(1) 20.07(6.1) (2) 6.60(5.7) (3) 1.20(5.9)	SG(76.3)(67.6) NR(21.0)(31.8) IB(2.6)(0.6)	(1) 0.121 m³/s (Mar.1993) (2) 287.1 mg/l (3)
4-6	(1) Imboassu (2) 64.6 (3) 359	(1) 15.94(4.8) (2) 5.24(4.5) (3) 1.01(5.0)	SG(76.9)(79.0) NR(23.1)(21.0)	(1) 6.49 m³/s (Mar.1993) (2) 8.8 mg/l (3)

Table 16.3-1 (Cont.)

Sanitary Condition (1) Existing Treatment Plant (2) Favela Population (%) (3) Collect. R.of Solid Waste	Ind. Pollution Sources (1) Effluent Load (BOD) (2) Major Industry (3) Ind./Dom. (Bod, COD)	Land use (1) Urban Area (%) (2) Forest (%) (3) Mangrove+Swamp(%)
(1) Acari, Realengo (2) 10.9 (3) City:90%, Favela:40%	(1) 5.50 ton/day (2) Food, Chemicals (3) 0.07, 0.24	(1) 68.5 (2) 3.1 (3) 1.8
(1) Nil (2) 7.4 (3) 27% (Nova Iguacu)	(1) 4.10 ton/day (2) Food, Textile (3) 0.08, 0.14	(1) 55.6 (2) 16.0 (3) 5.7
(1) Nil (2) 25.3 (3) City:90%, Favela:40%	(1) 14.03 ton/day (2) Food, Beverage (3) 0.37, 1.44	(1) 75.2 (2) 0.8 (3) 2.0
(1) Nil (2) 5.5 (3) 27% (Nova Iguacu)	(1) 8.45 ton/day (2) Chemical, Food (3) 0.21, 1.77	(1) 29.6 (2) 32.0 (3) 3.1
(1) Penha (2) 32.8 (3) City:90%, Favela:40%	(1) 2.28 ton/day (2) Pharmaceutical (3) 0.10, 0.20	(1) 52.1 (2) 24.5 (3) 1.4
(1) Nil (2) 22.6 (3) City:90%, Favela:40%	(1) 2.28 ton/day (2) Pharmaceutical (3) 0.10, 0.20	(1) 52.1 (2) 24.5 (3) 4.2
(1) Nil (2) 0.0 (3) 21%(San Goncalo)	(1) 1.02 ton/day (2) Food, Textile (3) 0.04, 0.16	(1) 45.7 (2) 10.2 (3) 14.0
(1) Nil (2) 1.4% (3) 21%(San Goncalo)	(1) 16.64 ton/day (2) Food (3) 0.85, 1.06	(1) 61.2 (2) 3.4 (3) 9.9

Table 16.3-1 (Cont.)

Trend of Development (1) Population Increase (2) Urban Area Increase (3) Forest Decrease	Benefit Use of Water Area (1) River (2) Beach and Bay (3) Demand	Preservation Area (1) Basin No. (2) Area Name (3) Managing Agency
(1) 0.66%(1) Aesthetic (Rio de Janeiro) (2) + 4.2 km² (3) + 0.9 km²	(1) Aesthetic (2)	(1) 19-2 (2) Pedra Branca State Park (3) IEF
(1) 1.53% (Nova Iguacu) (2) + 5.3 km² (3) - 1.7 km²	(1) Aesthetic Preservation of Nature (2)	
(1) 0.66% (2) - 0.1 km² (3) + 0.2 km²	(1) Aesthetic (2) Navigation channel	
(1) 1.53% (Nova Iguacu) (2) + 16.4 km² (3) - 15.6 km²	(1) Aesthetic Preservation of nature Industrial water supply	(1) 17-3, 4 (2) Tijuca National Park (3) IBAMA
(1) 0.66% (2) + 1.8 km² (3) - 0.2 km²	(1) Aesthetic (2) Navigation channel	
(1) 0.66% (2) - 0.1 km² (3) + 1.9 km²	(1) Aesthetic (2) Port	(1) 23 (2) Tijuca National Park (3) IBAMA
(1) 2.16% (2) +11.1 km² (3) - 5.2 km²	(1) Aesthetic Preservation of nature (2) Environment Protection	(1) 8 (2) Guapimirim Env.Prot.Area
(1) 2.16% (2) + 6.2 km² (3) - 2.7 km²	(1) Aesthetic (2) Fishery Port	

Table 16.3-1 (Cont.)

Characteristics in Generation and Effluent of Polluants
The proportion of urban area is large, forest & swampy areas are small by contrast. Mean water quality is not as bad as Cunha & Iraja, but changeable because of tidal rivers and sometimes attains 40 mg/l. Though domestic loads are predominant, there are many food & chemical factories along the Rio Acari. Floodprone areas are those along the Rio Meriti, Acari & Pedras.
Three quarters of the population lives in Rio de Janeiro & one quarter in Nova Iguacu. As the rate of population increase in Nova Iguacu is high, urbanization is expected to increase in Nova Iguacu where the sanitation services are still bad. Mean water quality is not as bad as Cunha & Iraja, but changeable because of tidal rivers, and sometimes attains 40 mg/l. Domestic loads are predominant. Floodprone areas are in the middle reaches. A wide swampy area called Fluminense Low-Land is on the left side of the lower reaches.
The proportion of urban area is large and population is at saturation levels, in particular the population rate of the favelas is high. Though the river discharge is not large, water quality is very bad from the upper reaches. There are many food & chemical factories in the basin and industrial loads are higher than domestic loads for COD.
Though the proportion of urban area is still small, the increase in population and changes in landuse are substantial in Nova Iguacu where sanitation services are still bad. The upper area is designated as a biological protection area and a vast forest is preserved. In the lower reaches, industrial loads are designated domestic loads for COD, because of the petro-chemical factories. REDUC at the river-mouth continually discharges a great deal of warm water rich in oil into the Iguacu River.
The proportion of urban area is almost 90% and population is in saturation, in particular population rate of the favelas is high. Though the river discharge is small, water quality is bad because of the retention effect of the tidal river. The Penha sewage treatment plant, services a population 750,000, is operated in this sub-basin. Therefore, the treatment rate of domestic loads is the highest in the Guanabara Bay basin. Industrial wastewater is discharged directly into the river.
The proportion of forest area is large because of the Tijuca National Park and the population rate of the favelas is high. The river discharge is small, while water quality is bad. Main effluent loads are domestic loads plus some medical factories and most of them are treated at the Penha sewerage system.
Though the portion of urban area is till less than 50%, recent increases in population and changes in landuse have been large in San Goncala where the sanitation services are presently bad. Bad water quality in the upper reaches is caused by factories with large effluent loads situated near the observation point. A large mangrove forest is located near the river-mouth.
Urbanization has already progressed, increases in population and changes in landuse are expected to continue from now on in San Goncalo, where the sanitation services are presently bad. Food factories, mainly processing marine products, discharge wastewaters rich in organic matter. Therefore, the industrial loads is very high.

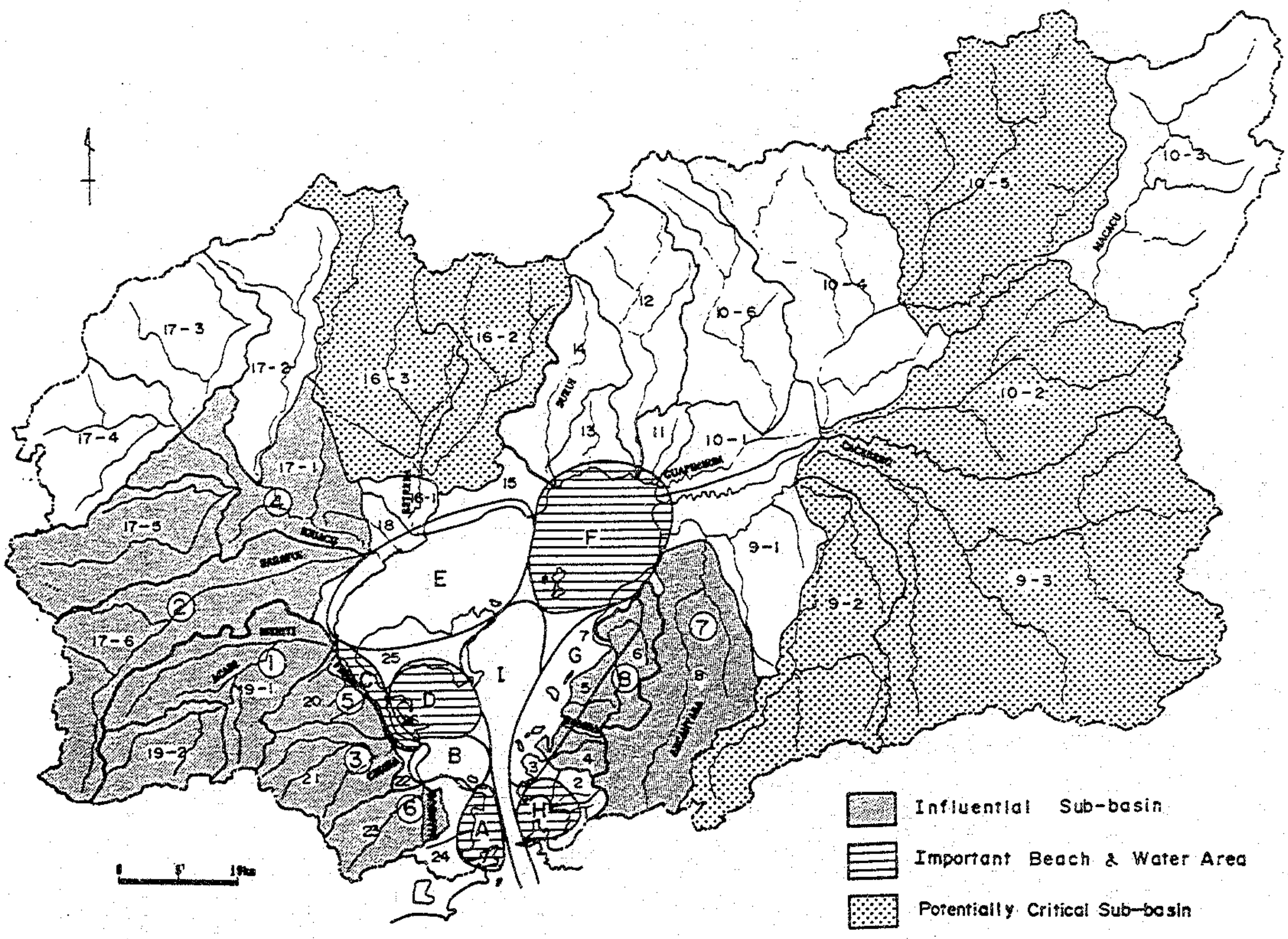


Fig. 16.3- 1 Priority Areas for Countermeasure

16.3.3 Important Beaches and Water Areas

When selecting priority areas in Guanabara Bay, the present state of the water quality and use, the beneficial use and demand for future utilization should all be considered as well as from an ecological point of view.

The present beneficial uses and corresponding water areas in the Guanabara Bay are as follows;

(1) Areas for Ecological Conservation

Mangroves	: Guapimirim and Jequia
Aquatic Life	: Particularly in the inner part of the Bay

(2) Areas for Recreational Resorts

Rio de Janeiro Area	: Botafogo, Flamengo and Gloria
Niteroi Area	: Icarai and Jurujuba
Paqueta Island	: West coast of the island
Governador Island	: South coast of the island
Mage Area	: Anil

(3) Areas for Water Circulation
Channel between the mainland and Governador Island
Channel between the mainland and Fundao Island

(4) Fishing Areas
Water areas along the central fairway
The inner part of the Bay

(5) Port and Harbor Areas

Port	: Rio de Janeiro Port
Fishing Ports	: Caju, Ramos, Jurujuba etc.
Ferry Ports	: Praca Quinze, Niteroi and Paqueta
Port Facility Area	: Barreto (Niteroi)

(6) Energy Generation Areas
Central part of the Bay (D'agua Island)

(7) Fairway and Anchorage Areas
Central part of the Bay

The following areas are important from health standpoints;

(8) Important Areas for Health Reasons

Oil Pollution Area		: River-mouth of Iguacu
Heavy Metal Pollution Areas:		
Cr	Pollution	: River-mouth of Iguacu and Sarapui
Cu	Pollution	: River-mouth of Estrela
Hg	Pollution	: River-mouth of Acari and Meriti

Meanwhile, the following three desires for the restoration of the Guanabara Bay area are very strong according to the results of a questionnaire carried out during the course of this study:

1) To restore the water area as a fishing ground

2) To restore the water area for sea bathing

3) To restore the water area for marine sports

Here, we divided the water area of the Bay into nine (9) groups (A to I) as shown in **Fig. 16.3-2.** For each water area, we evaluated its importance in terms of economic and social benefits as well as from an ecological point of view as shown in **Table 16.3-2.**

As a result of the evaluation, five (5) water areas, Groups A, C, D, F and H, were selected as important beaches and water areas in Guanabara Bay.

Current Use of Coast and Water Area of the Guanabara Bay
Uso Atual da Costeira e da Espelho da Água da Baia de Guanabara

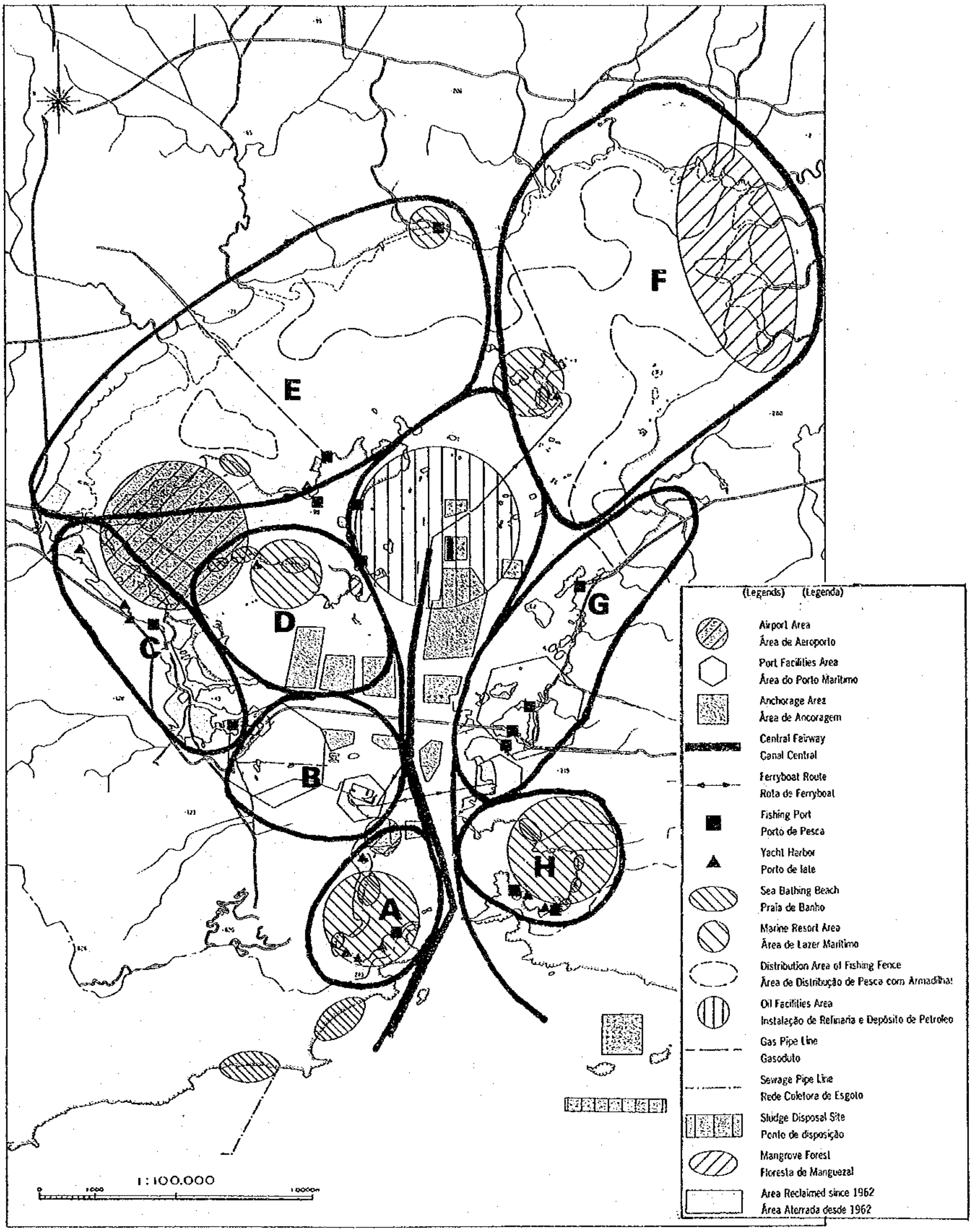


Fig. 16.3- 2 Water Area Division in Guanabara Bay

Table 16.3- 2 Criteria for Selection of Important Beaches and Water Area

Water Area	Utilization	Economic Effect	Expected Sanitation/Improvement	Social Effect	Conservative Ecosystem	Biological Effect	Degree of Importance
A	Recreational Resort Botafogo Flamengo Gloria	◉	Sanitation for Sea Bathing Mitigation of Offensive Odors Improvement of Aesthetics	◉		□	◉
B	Port.Fairway Anchorage Area	□	Mitigation of Offensive Odors Improvement of Aesthetics	O		□	□
C	Fairway(SmallBoat) Fishing Port (Caju, Ramos) Water Circulation	O	Mitigation of Offensive Odors(including Sediment) Improvement of Aesthetics Increase of Circulation	◉	Big Influence Effect to Ecosystem all over the Bay	◉	◉
D	Recreational Resort Governador Anchorage Area Fishing Field	◉	Sanitation for Sea Bathing Improvement of Sediment	O	Mangrove in Juquia Nekton & Benthos Improvement of Anoxic Waters & Sediment	◉	◉
E	Fishing Field Fishing Port Recreational Resort A nil	O	Sanitation for Sea Bathing and Fishermen	O	Nekton & Benthos Improvement of Anoxic Waters & Sediment Prevention of Heavy Metal & Oil Pollution	◉	O
F	Fishing Field Recreational Resort Paqueta	◉	Sanitation for Sea Bathing	O	Mangrove in Guapimirim Nekton & Benthos Improvement of Anoxic Waters & Seiment	◉	◉
G	Fishing Port Port Facility	O	Mitigation of Offensive Odors(including Sediment)	O		□	O
H	Recreational Resort Icarai Jurujuba	◉	Sanitation for Sea Bathing Mitigation of Offensive Odors Improvement of Aesthetics	◉		□	◉
I	Fairway Anchorage Area Fishing Field Energy Facility D'agua	O		□	Nekton & Benthos Improvement of Polluted Waters Prevention of Oil Pollution	O	□

[Note] ◉ : great significant/interest/efficient
O : significant/interest/efficient
□ : not-significant/interest/efficient

16.3.4 Potentially Critical Sub-Basins

Influential sub-basins and important beaches and water areas as seen in the foregoing, have been selected as areas which are mainly influential and important from the standpoint of present effluent loads and beneficial uses of water areas. In addition to these sub-basins and water areas, there are some areas which are a cause for concern with respect to future effluent loads. Consequently, these sub-basins have been named Potentially Critical Sub-Basins.

When selecting potentially critical areas in the Guanabara Bay basin, attention was paid to recent trends in development such as population increases, increased urbanization and deforestation. **Table 16.3-3** shows data for all the sub-basins except the influential sub-basins selected in the foregoing section.

Consequently, Sub-Basins No. 9-3 in Itaborai and Rio Bonito, Sub-Basin No. 9-2 in Itaborai and San Goncalo, Sub-Basin No. 16-3 in Duque de Caxias, Mage and Petropolis, Sub-Basin No. 16-2 in Mage and Petropolis and Sub-Basin No. 10-5 in Cachoeiras de Macacu, were selected as Potentially Critical Sub-Basins because of the rather significant changes in urban and forest areas observed so far.

Moreover, Sub-Basin No. 10-2 in Cachoeiras de Macacu and Itaborai was selected because of the industrial park planned there, Sub-Basins Nos. 1, 2 and 3 in Niteroi were chosen because of the recreational resort at Icarai and Jurujuba, while Sub-Basin No. 24 in Rio de Janeiro was also selected because of the recreational resorts at Botafogo and Flamengo. The specific features in these Potentially Critical Sub-Basins are summarized in **Table 16.3-4** (for the location of these sub-basins, refer to **Fig. 16.3-1**).

These potentially critical sub-basins are broadly divided into four (4) groups. Group I consisting of Sub-Basins Nos. 1, 2 and 3 threatens the recreational resorts of Icarai and Jurujuba, Group II of Sub-Basins Nos. 9-2, 9-3, 10-2 and 10-5 threatens the mangrove area at the mouth of the Guapimirim APP, Group III of Sub-Basins Nos. 16-2 and 16-3 threatens the inner part of the Bay, and Group IV of Sub-Basin No. 24 threatens the recreational resorts at Botafogo and Flamengo.

Table 16.3- 3 Trends in the Development of Sub-Basins
(for Selection of Potentially Critical Sub-Basins)

Basin No.	Area (Km^2)	Population (person)	Increasing Rate[1] of Population (%)	Urban Area[2] Increase(km^2)	Forest Area[3] Decrease(km^2)	Impor-[4] tance
1	9.4	53,310	0.84(NR)	+0.2	+0.1	●
2	7.4	41,745	0.84(NR)	+0.3	-0.6	●
3	7.8	37,458	0.84(NR)	+0.4	-0.4	●
7	6.4	31,925	2.16(SG)	+0.5	-0.3	
9-1	110.9	74,463	1.26(MG)-3.17(IB)	+2.3	+0.7	
9-2	191.4	151,356	2.16(SG)-3.17(IB)	+4.6	-9.0	O
9-3	544.4	110,374	1.26(MG)-6.27(RB)	+6.4	-43.8	◎
10-2	246.7	12,475	1.04(CM)-3.17(IB)	+0.4	-0.9	●
10-3	256.0	18,577	1.04(CM)	+0.8	-0.7	
10-4	215.4	10,312	1.04(CM)-1.26(MG)	+1.3	+2.2	
10-5	349.5	8,983	1.04(CM)	+0.7	-10.4	O
10-6	132.4	17,911	1.26(MG)	+0.1	+2.4	
11	18.3	8,458	1.26(MG)	+0.5	-1.3	
12	11.4	36,370	1.26(MG)	+0.8	-0.3	
13	27.8	10,684	1.26(MG)	+0.2	-1.4	
14	68.8	12,910	1.26(MG)	+0.7	-1.7	
15	28.9	8,541	1.26(MG)	+1.8	-1.2	
16-1	17.5	24,216	1.26(MG)	+0.6	-0.4	
16-2	139.0	84,106	0.97(PP)-1.26(MG)	+2.7	-3.4	O
16-3	186.0	194,173	0.97(PP)-1.26(MG)	+5.8	-5.0	O
17-2	104.4	19,388	1.32(DC)	+0.5	-4.3	
17-3	115.7	12,243	1.32(DC)-1.53(NI)	+0.4	-2.8	
17-4	103.1	94,852	1.53(NI)	+2.4	-1.1	
18	27.0	132,091	1.32(DC)	+2.5	0.0	
22	6.6	60,011	0.66(RJ)	+0.7	0.0	
24	26.0	358,622	0.66(RJ)	+1.0	+0.4	●
25	38.2	153,903	0.66(RJ)	+3.4	+0.1	
26	5.4	5,277	0.66(RJ)	+0.4	0.0	
27	1.7	3,254	0.66(RJ)	+0.4	-0.1	

[Note] (1) : Increasing rate between 1980 and 1991
(2),(3): Increasing area between 1984 and 1991
(4) : ◎ : great significant
O : significant
● : significant from the standpoint of recreational resorts in front of the basins and future land-use plan of the basin.

Table 16.3- 4 Natural and Socioeconomic Features of Potentially Critical Sub-Basins

Sub-Basin No. 1 River Name 2 Area 3 Population	Trend of Development 1 Population Increase 2 Urban Area Increase 3 Forest Decrease	Beneficial Use of Downstream Area and/or Development Plan	Domestic Generation Load Industrial Effluent Load (BOD)	Group of Critical Sub-Basins
1 — 1 B.Charitas 2 9.4 km^2 3 53,310.	1 0.84% 2 +0.2 km^2 3 +0.1 km^2	Recreational Resort Jurujuba	2.67 ton/day 2.13 ton/day	I
2 — 1 Canto do Rio 2 7.4 km^2 3 41,745.	1 0.84% 2 +0.3 km^2 3 -0.6 km^2	Recreational Resort Icarai & Jurujuba	2.09 ton/day -	
3 — 1 B.Catedrar 2 7.8 km^2 3 37,458.	1 0.84% 2 +0.4 km^2 3 -0.6 km^2	Recreational Resort Icarai	1.87 ton/day -	
9-2 — 1 Aldeia 2 191.4 km^2 3 151,356.	1 0.84% - 3.17% 2 +4.6 km^2 3 -9.0 km^2	Mangrove Area Guapimirim APP	8.11 ton/day	II
9-3 — 1 Cacerebu 2 544.4 km^2 3 110,374.	1 3.17 - 6.27% 2 +4.6 km^2 3 -43.8 km^2	Mangrove Area Guapimirim APP	5.71 ton/day 0.48 ton/day	
10-2 — 1 Macacu 2 246.7 km^2 3 12,475.	1 1.04 - 3.17% 2 +0.4 km^2 3 -0.9 km^2	Mangrove Area Guapimirim APP Industrial Park Plan	0.61 ton/day -	
10-5 — 1 Guapi Acu 2 349.5 km^2 3 8,983.	1 1.04% 2 +0.7 km^2 3 -10.4 km^2	Mangrove Area Guapimirim APP	0.41 ton/day -	
16-2 — 1 Inhomirim 2 139.0 km^2 3 84,106.	1 0.97 - 1.26% 2 +2.7 km^2 3 -3.4 km^2	Fishing Field	4.28 ton/day 0.92 ton/day	III
16-3 — 1 Sarascuruna 2 186.0 km^2 3 194,173.	1 0.97 - 1.32% 2 +5.8 km^2 3 -5.0 km^2	Fishing Field	9.17 ton/day 6.09 ton/day	
24 — 1 B.Botafogo 2 26.0 km^2 3 358,622.	1 0.66% 2 +1.0 km^2 3 +0.4 km^2	Recreational Resort Botofogo & Flamengo	18.62 ton/day 5.15 ton/day	IV

16.4 Target Year

In order to set a target year for the water pollution control plan, due consideration should be paid to on-going plans/projects and the degree of deterioration in present water quality.

With respect to "The basic sanitation program of the Guanabara Bay basin", conducted by the State Government of Rio de Janeiro with the help of a loan from the Inter-American Development Bank and the Overseas Economic Cooperation Fund (IDB/OECF Program), the first stage of the program extends from 1993 to 2000 and the second stage to 2007, and involves the implementation of five major projects including a sewerage improvement project.

It should be noted, however, that since the ecosystem surrounding Guanabara Bay is delicately balanced, it will be extremely difficult to restore it once it has collapsed. As we have seen in the foregoing chapters, environmental problems in the Guanabara Bay basin have, unfortunately, come to the fore in various aspects, making it hard to deny that much time will be needed to recuperate the ecosystem.

With the above time factor, it is proposed that the following three target years for the short-term, mid-term and long-term plans of this Master Plan are set:

Target Year for Short-Term Plan	: 2000
Target Year for Mid-Term Plan	: 2010
Target Year for Long-Term Plan	: not-specified

The target year for the short-term plan coincides with that of the first stage of the IDB/OECF Program and attaches deep significance to urgent measures. The mid-term plan is aimed at restoring a desirable level for sea bathing and aquatic lives by the target year.

The long-term plan aims at achieving the most desirable water quality in order to restore the ecosystem in Guanabara Bay and, the final target of this Master Plan; that is to improve the water quality in Guanabara Bay as it was in the first half of 1960's.

16.5 Target Water Quality

16.5.1 Significance of Target Water Quality

In order to draw up a water quality improvement plan, it is first necessary to establish a water quality target based on the degree by which the water quality needs to be purified, in the Bay, by the target year already mentioned. Stringency of regulations and the amount of investment needed will differ considerably depending on the level of the water quality target set. Generally, the higher the target quality, the more investment and time required.

Since there are so many variables for evaluating water quality, suitable ones need to be selected for evaluating the water quality in each area. We discussed and proposed indices for evaluating water quality from the standpoint of health, living environment, aquatic life, eutrophication and so forth.

Since the bay water quality and use of coastal areas vary by locality, the beneficial uses and target water quality vary as well. Therefore, the target water quality for each water area was set for the master plan after the areas were classified.

It should be noted and stressed that the target water quality proposed herein is not in accordance with the administrative standard at the federal level, CONAMA No. 20, but was set specifically for Guanabara Bay providing certain goals to be met by the measures proposed in the master plan.

16.5.2 Water Quality Indices

It is very difficult to say conclusively and quantatively whether or not the water quality in some areas meets the beneficial uses set. Therefore, representative indices obtained from past experience are used as a guide for evaluating the water quality. Once a new pollutant is found and scientifically established to have harmful effects on the situation, the index should be added and/or the standard be amended.

In Brazil, water quality standards for each beneficial use have been established for fresh water, salt water and brackish water in 1986 as per CONAMA No. 20. The indices used to set these standards are: pH, BOD, TDS, DO, Number of Coliform Groups and Turbidity on living environment (TDS and Turbidity are for fresh water only), while effluent standards are made up of 34 health items.

While with these indices, the following points still need to be discussed. That is, (1) BOD is the only index used for organic matter, (2) an index for eutrophication is not established, and (3) an index for oil is not included.

Organic Matter

In Europe, the U.S.A. and Japan, the amount of oxygen consumed through oxidation of organic matter such as BOD and/or COD is used as the index for organic pollution instead of the organic matter themselves. However, several analytical methods are used to determine BOD and COD factors, each having merits and demerits. Furthermore, there is a big difference in the values obtained by each method, because the amount of oxidation and reaction to chlorine ions in salt water differs.

Therefore, it has recently been proposed that organic matter itself will be measured instead of BOD and COD. In response to this a TOC (Total Organic Carbon) index is advisable which can quickly and easily be measured using an automatic analyzer. TOC, however, is not widely used because the analyzer is expensive and problems occur when the samples contain suspended substances.

In view of this, BOD and COD must still be used as tentative indices of organic pollution, though introduction of TOC is recommended in the future. In Brazil, BOD is widely used as an index for the water quality management of sewage treatment systems and for the monitoring of industrial wastewater. Therefore, BOD still needs to be used as a tentative index for organic matter until TOC is introduced.

Eutrophication

In semi-closed coastal areas, the progress of organic pollution by eutrophication should be taken into consideration. In particular, Guanabara Bay has a shallow water depth (5.7 m on average), a narrow bay-mouth (1.8 km) and is situated in the subtropical zone having a mean temperature of 26.5 °C in the summer. On top of this, a large quality of wastewater rich in nutrient salts flows constantly into the Bay. Under these circumstances, the decreased organic load does not contribute directly to the improvement of organic pollution in the Bay because of the internal production of organic pollutants due to plankton growth. Therefore, we propose adding T-N (Total Nitrogen) and T-P (Total Phosphorus) nutrient salts as water quality indices in order to monitor the degree of eutrophication.

Oil

Oil refineries and facilities are located in coastal areas and on islands in the Bay, resulting in a lot of tanker and other vessel traffic. There are also many pollution sources like petro-chemical and food processing plants which discharge oil into the basin. Oil pollution in the water areas is devastating to aquatic life damaging the beaches and affecting sea bathing as well as the aesthetic beauty of the place. Therefore, we propose to add n-Hexan Extracts as a water quality index for the purpose of monitoring oil pollution.

Although the chemical indices mentioned above are superior in terms of quantitative evaluation, complicated instruments and experts are necessary for analyzing the water quality and the values obtained are only representative of the water quality at sampling time. Ideally, we should use indices that anyone can measure easily, without using complicated instruments.

From this standpoint, we propose adding transparency, which has a good correlation with turbidity and chlorophyll-a and biotic community. These indices have the advantage of showing accumulated water qualities over a relatively long span of time. For the biotic community index, we need to determine suitable biotic indices that are sensitive to water quality later on. It is also desirable to add oil film, floatage and water color as supplementary indices.

With all above, we propose the indices as shown in **Table 16.5-1** for monitoring the water quality in the Guanabara Bay basin.

Table 16.5- 1 Proposed Monitoring Indices for Water Quality in the Guanabara Bay Basin

Item	Monitoring Indices
Environmental Water Quality Index (Principal Index)	pH, BOD(TOC)*1, DO T-N, T-P No. of Coliform Group (Fecal) SS, n-Hexane Extracts
Environmental Control & Management Index (Supplementary Index)	Transparency Biotic Community *2 Oil-film, Floatage Water Color

[Note]

BOD(TOC)*1 : BOD is a tentative index for organic matters until TOC is introduced.

Biotic Community *2 : We need to determine suitable biotic indices sensitive to water quality later on.

16.5.3 Water Area Classification

The present water quality standard (CONAMA No. 20)for salt water in Brazil divides the Guanabara Bay into two (2) classes, Class 5 for most of the Bay and Class 6 for the limited polluted area (see **Fig. 14.3-2**).

Judging by the present state of water quality and beneficial use of water resources in Bay, it appears reasonable to divide the water resources in the Guanabara Bay into four (4) classes as shown in **Table 16.5-2** including the saprobic waters, which exist in the western part of the Bay. Among these classes, D Class is indispensable due to the present bad water quality in some areas. Desirable water use is interdicted until effective measures are taken in the near future. D Class area should, therefore, be re-designated as Class C as early as possible.

In this table, we used different denominations with the existing standard, CONAMA No. 20, because of the different beneficial uses of the water areas.

In classifying the water area based on the beneficial use of water resources in Guanabara Bay, the present state of the water quality and the needs of the residents should be taken into consideration as well as future utilization plans by the administration and the future water quality estimated, using a hydrodynamic model, to be attained by measures.

Desirable uses of Guanabara Bay are: (1) a fishing area rich in diverse species of marine life, (2) a safe recreation area for residents and tourists, (3) a fairway and anchorage for shipping. In particular, many people desire that sanitation in the Bay area is improved for recreational purposes like swimming.

When classifying the water area in Guanabara Bay, two types of classification were considered corresponding to the short-term and mid to long-term target years, taking the gradual improvement of the water quality in the Bay into account.

Fig. 16.5-1 depicts the water area classification for the short-term plan for Guanabara Bay, whereas **Fig. 16.5-2** shows the water area classification for the mid to long-term plan.

In making the classification, a special consideration has been given to the following four bathing areas because of their value as recreational areas of primary contact with high priority; namely Flamengo, Botafogo, Icarai and Paqueta.

Table 16.5- 2 Proposed Classification and Beneficial Use of Water Resources in Guanabara Bay

Class	Purpose of Water Use
A	Fishery (Class 1) Recreation (Primary Contact) Uses listed in Class 5 - 6
B	Fishery (Class 2) Recreation (Secondary Contact) Conservation of Natural Environment Uses listed in Class 6
C	Commercial Navigation Industrial Water Conservation of Environment
D	Waste Dilution and Circulation

[Note]

1. Fishery
   Class 1 : Diverse aquatic lives including benthic shellfishes
   Class 2 : Specific mesotrophic aquatic lives
2. Conservation of natural Environment
   : Conservation of aesthetic points and other natural resources
3. Conservation of Natural Environment
   : No unpleasantness is caused to the people in their daily lives
4. Class D : Desirable water uses are interdicted, until mesures are taken in the near future.

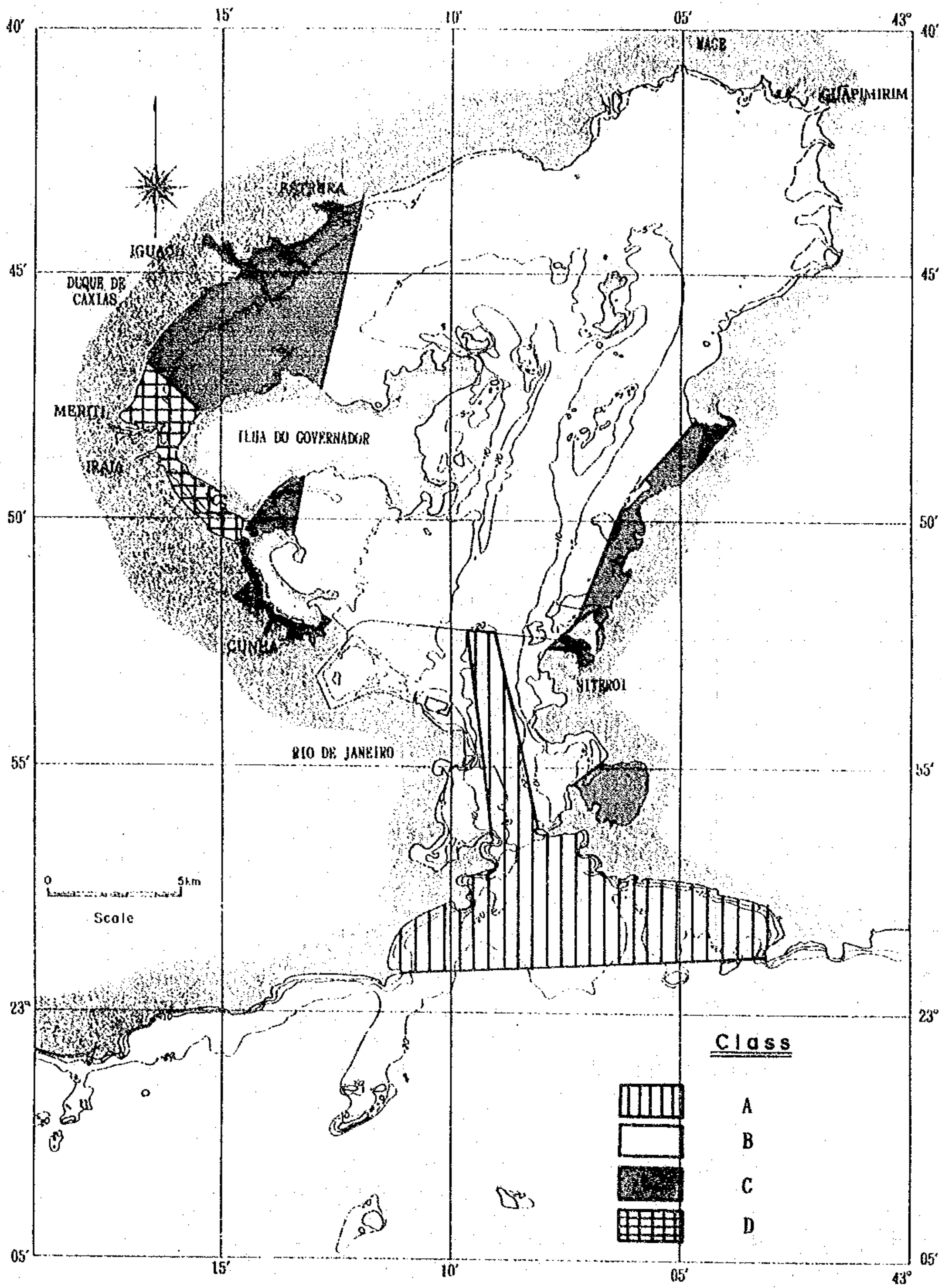


Fig.16.5- 1 Proposed Water Area Classification for Short-Term Plan

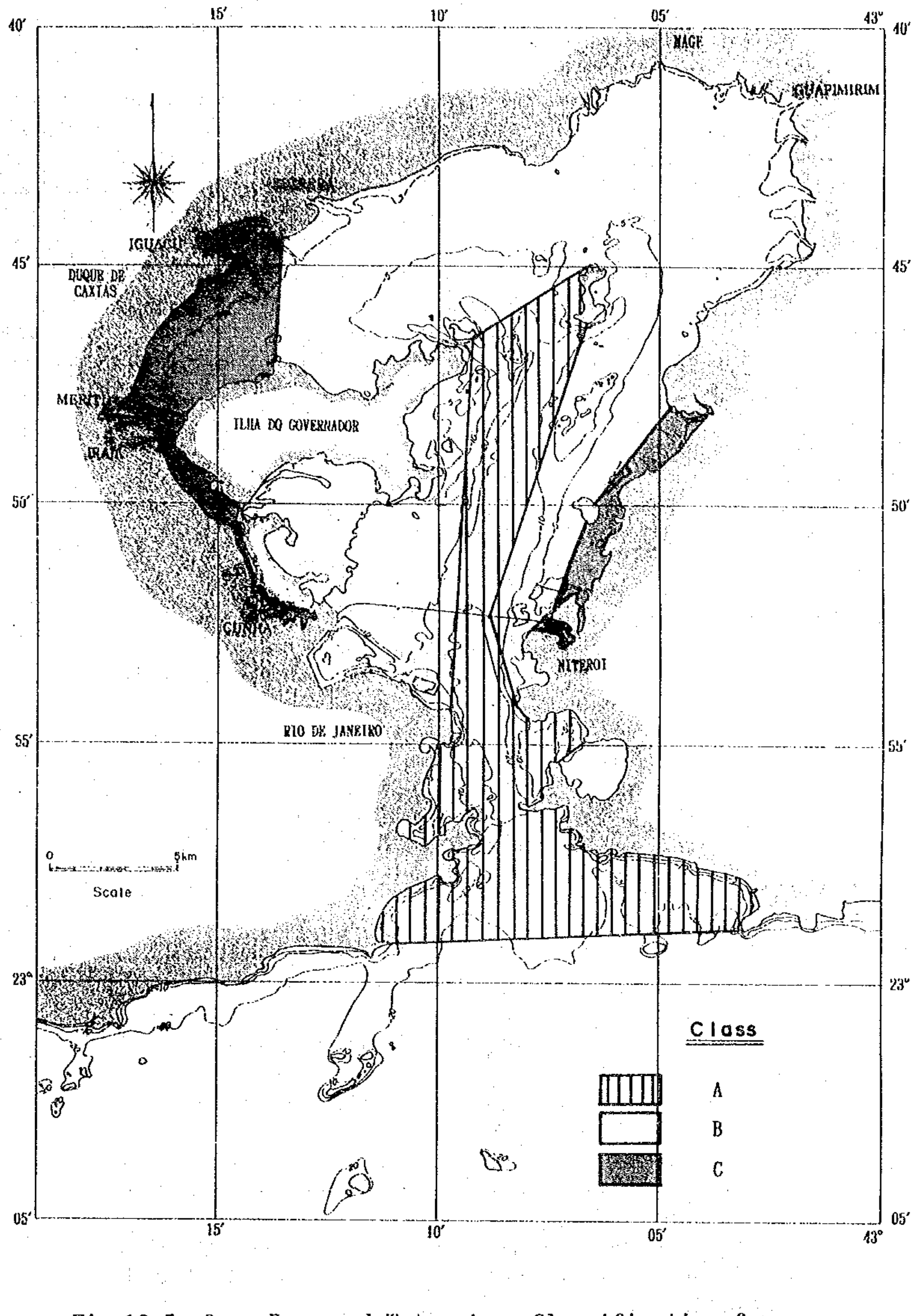


Fig.16.5- 2 Proposed Water Area Classification for Mid to Long-Term Plan

16.5.4 Target Water Quality

A lot of studies are required before the target water quality for each beneficial use is scientifically established. For example, the permissible concentration of pollutants in water areas for recreational use requires epidemiological studies to determine the relationship between pollutants and health, while biological studies for fishing purposes are required to determine the relationship between pollutants and aquatic organisms.

Regarding the principal indices of water quality, the following information of water levels corresponding to water uses is available at present.

(1) Biological Oxygen Demand (BOD)
- 2.5 mg/l or less : Oligotrophic water area
- 2.5 mg/l - 5.0 mg/l: Eutrophic water area
- 5.0 mg/l - 10 mg/l: Polyeutrophic water area
- 10 mg/l or more : Saprobic water area

(2) Dissolved Oxygen (DO)
- 4.3 mg/l or more : Most desirable environment for aquatic lives including benthic, fishes and shellfishes.
- 4.3 mg/l - 3.6 mg/l: Environment which shellfishes can live.
- 3.6 mg/l - 2.1 mg/l: Environment which benthic fishes can live.
- 2.1 mg/l - 1.4 mg/l: Environment which Polychaeta etc. can live.

(3) Total Nitrogen (T-N), Total Phosphorus (T-P)
- 0.2 mg/l or less (T-N), 0.02 mg/l or less (T-P)
  : Desirable level for the preservation of natural environment.
- 0.3 mg/l or less (T-N), 0.03 mg/l or less (T-P)
  : Desirable level for sea bathing.
  Most desirable environment for aquatic life including benthic fish and shellfish.
- 0.3 mg/l - 0.6 mg/l (T-N), 0.03 mg/l - 0.05 mg/l (T-P)
  : Undesirable environment for some benthic fish and shellfish.
- 0.6 mg/l - 1.0 mg/l (T-N), 0.05 mg/l - 0.09 mg/l (T-P)
  : Undesirable environment for most benthic fish and shellfish.
- 1.0 mg/l or more (T-N), 0.09 mg/l or more (T-P)
  : Undesirable environment for aquatic life.

(4) Suspended Solids (SS)

25 mg/l or less : No detrimental influence to fishery.

(5) Transparency

6 m or more : Desirable level for sea bathing.

With the scientifically established data and the state of water quality, we propose the target water quality in Guanabara Bay as shown in **Table 16.5-3**. As can be seen, the target water quality consists of the principal indices and the supplementary indices.

It should be noted that in this master plan, the target water quality shall be considered as the values at the surface for all indices except Dissolved Oxygen (DO), because the surface is generally worse than the bottom layer for all indices. But with respect to Dissolved Oxygen (DO), it shall be considered on the bottom, because the DO value in the bottom layer strongly affects benthic fish and shellfish.

Regarding the frequency of observations it is desirable to monitor more than once a month in order to attain the reliable data throughout a year. When 75 % of observed values at a monitoring point meet the target water quality, it will be considered that this point meets the target water quality.

It shall be stressed once again that the water quality proposed here is not a water quality standard for Brazil, but the target water quality for Guanabara Bay as part of the Master Plan for restoring the ecosystem in the Bay.

In the event that the target water quality is not attained by the target year, we recommend extending the target year rather than changing the target water quality.

Table 16.5- 3 Target Water Quality for Guanabara Bay

Principal Index

Class	pH	Biological Oxygen Demand (BOD)	Dissolved Oxygen (DO)	Total Nitrogen (T-N)	Total Phosphorus (T-P)	Number of Coliform Groups (Fecal)	Suspendid Solids (SS)	N-Hexane Extracts
A	7.8 | 8.3	3 mg/l or less	7.0 mg/l (4.5 mg/l) or more	0.3 mg/l or less	0.03 mg/l or less	1,000 MPN /100ml or less	10 mg/l or less	Not Detectable
B	7.0 | 8.5	5 mg/l or less	6.0 mg/l (3.5 mg/l) or more	0.6 mg/l or less	0.05 mg/l or less	1,000 MPN /100ml or less	25 mg/l or less	Not detectable
C	6.5 | 8.5	8 mg/l or less	4.0 mg/l (2.5 mg/l) or more	1.0 mg/l or less	0.09 mg/l or less	4,000 MPN /100ml or less	50 mg/l or less	-
D	6.5 | 8.5	10 mg/l or less	2.0 mg/l (1.5 mg/l) or more	1.5 mg/l or less	0.13 mg/l or less	-	50 mg/l or less	-

[Note] 1. Values given in parentheses for DO are target water qualities in the bottom layers.
2. With regard to the number of coliform groups for recreation (primary contact), fecal coliforms shall be less than 250 MPN/100 ml.
3. With regard to the number of coliform groups for recreation (secondary contact), fecal coliforms shall be less than 500 MPN/100 ml.

Supplementary Index

Class	Transparency	Oil Film	Floatage	Water Colour	Biotic Comunity
A	5 m or more	Not Observed	Not Observed	Greenish (Not Brownish)	Diverse Species
B	3 m or more	Not Observed Ordinarily	Not Observed Ordinarily	Greenish (Not Brownish)	Existence of Benthonic lives
C	1.5 m or more	-	-	-	-
D	1 m or more	-	-	-	-

16.6 Target Reduction Load

16.6.1 Significance of Target Reduction Load

In order to provide a basis for effective measures to meet the target water quality, an evaluation of effects of the reduction of effluent loads on the Bay water quallity was carried out using a numerical simulation method.

Fig. 16.6-1 shows the estimated future water quality for BOD in the Bay. The shaded areas represent areas where the target water quality for mid to long-term plan set in the previous section (see **Fig. 16.5-2** and **Table 16.5-3**) is not attained.

In the year 2010 (case: without measure, **Fig. 16.6-1 (a)**), the channel area on the western side of the Bay and near the mouth of the Rio Iguacu, belonging to Class C, show more than 8 mg/l of BOD and thus do not meet the target water quality.

For Class B, the wide areas near the mouth of the Rio Estrela and in the northeastern part show more than 5 mg/l and so do not attain the target water quality. Some parts of Jurujuba inlet and near the mouth of the Rio Imbuacu also do not meet the target water quality.

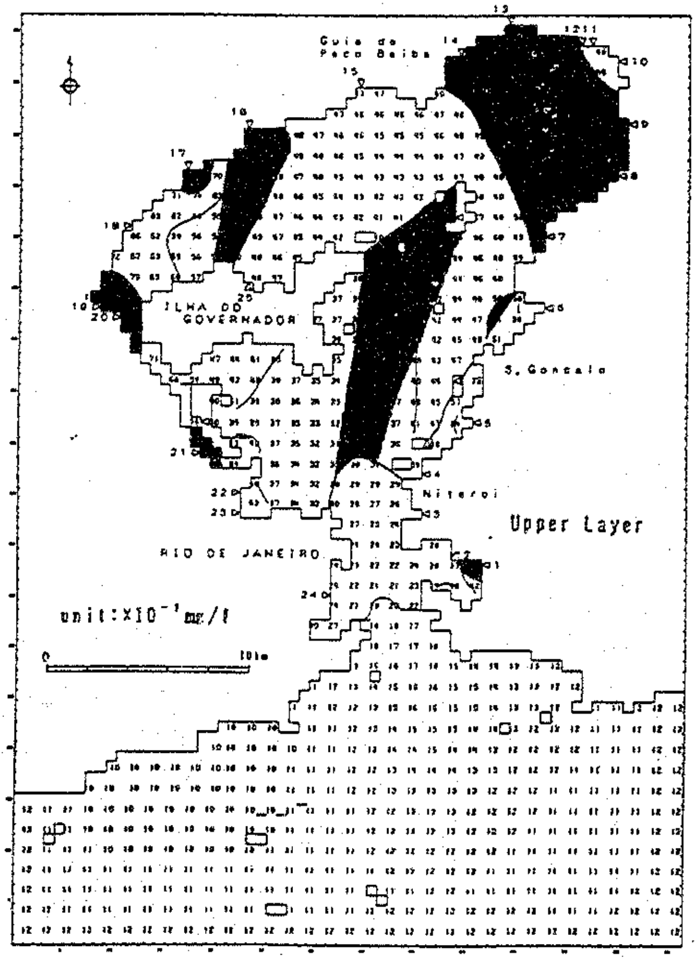
The central part of the Bay, which was set as Class A, is worse than the target water quality (3 mg/l).

Even if the IDB/OECF program is implemented with secondary treatment system, vast areas still do not meet the target water quality (**Fig. 16.6-1(b)**).

Though water quality in the western and eastern parts except the mouth area of Rio S.J. de Meriti will improve under the IDB/OFCF program, the northwestern, northeastern and central parts of the Bay will still show comparatively high values of BOD.

This means that more effective measures are necessary in order to meet the target water quality and to restore the ecosystem in Guanabara Bay.

(a) In 2010 (without measure)



(b) IDB/OECF Program (Secondary Treatment)

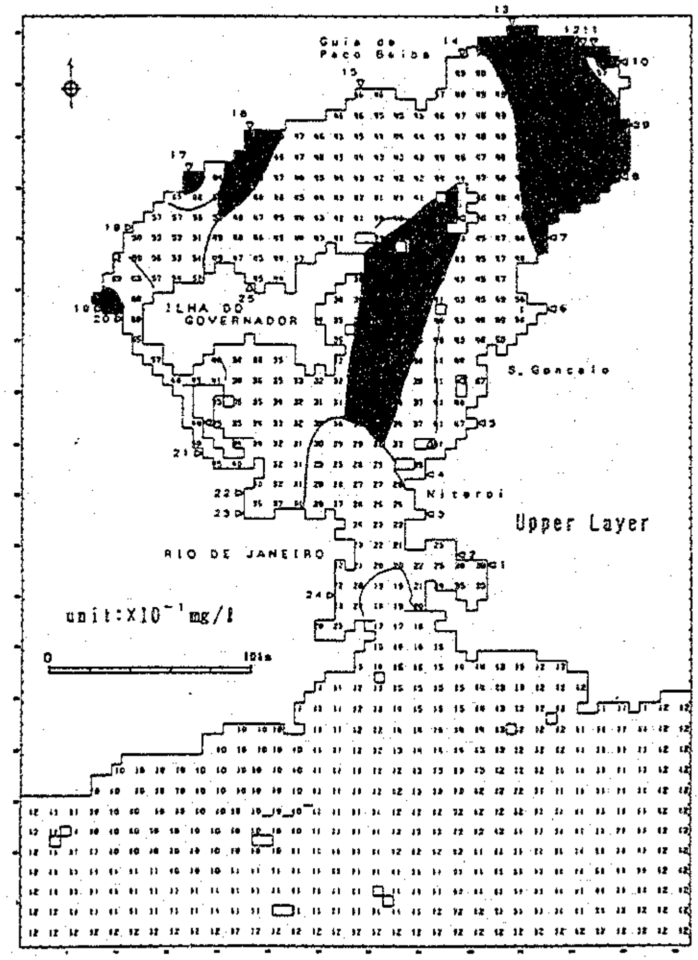


Fig. 16.6- 1 Future Water Quality (BOD)