CHAPTER 4
PALNNING CONDITIONS

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This chapter deals with the planning fundamentals for the sewerage system. The planning and design basis for the component facilities except treatment method has been developed in this chapter. Treatment method is discussed, taking into account of the receiving water body, in the following chapter, followed by various alternative plans for possible sanitary systems in the succeeding chapter.

4.1 Population and Land Use

The population projection and the future land use worked out in the Urban Development & Services Study is the basis for the current study. According to that plan, the NCD will have a population of approximately 531,000 persons by the year 2015(refer to Table 4.1). That population is sustainable, and can be housed and employed and served within a sustainable and enjoyable community. However, it is noted that NCD could have a population of 675,000 by 2015 if the PNG government will not enact national urban and population growth rate reduction policies.

The strategy recommended in the Urban Development & Services Study provided short term (to the year 2005) and long term (to the year 2015) development guidelines. In the short term the basic strategy is to consolidate available land resources in existing built-up areas in order to maximize the use of existing infrastructure and community services. The less developed areas of Huhunama/Tovabada, Dogura North, Napa Napa/Daugo Island, Taurama South (southern coastal area) and Taurama/Dogura South will not be consolidated. The preservation of village living was considered very important to the sustainable development of the NCD. Fig.4.5 and Table 4.2 show the land use in 2015.

Water reticulation will be provided to the villages, and in the short term, one standpipe will be provided for every five dwellings. Use of pit latrines will continue until formal reticulation via a sewerage and water supply network is implemented. Full water and sewerage reticulation is expected in 2015.

Based on the foregoing, it is expected that by the year 2000 an additional 2,495 ha of land will be required to meet the needs of the estimated 303,000 population. By 2005 an additional 2,222 ha will be required over the 2,495 already brought into development in 2000. By 2015 some 6,700 ha will be required to accommodate all of the needs of the estimated 531,000 population.

Table 4.1 Population by Planning Zones

	Planning Zones	Population			Land Area
		1995	2005	2015	(ha)
Coastal Region	1.Kaevaga Poreporena	15,346	15,386	16,869	739
	2.Kila Kila Koki Badili	33,287	46,181	50,902	1,262
	3.Napa Napa/Daugo Island	3,216	3,700	4,200	327
	4.Port Moresby/Konedobu	20,098	24,337	27,113	849
	5.Taurama Dogura South	3,333	5,104	6,104	640
	6.Taurama South	10,147	11,050	15,010	1,786
	Subtotal	85,427	105,758	120,198	5,603
Central Region	7.Airport	14,480	27,122	34,652	1,380
	8.Boroko	30,157	36,717	38,396	1,015
	9.University/Tokarara	34,139	50,963	60,015	1,986
	10.Waigani	40,929	59,024	64,655	1,730
	Subtotal	119,705	173,826	197,718	6,111
Periphery Region	11.Dogura North	78	78	8,766	5,894
	12.Eight Mile/Nine Mile	17,206	51,510	120,745	1,543
	13.Gerehu/Waigani Swamp	27,012	45,090	71,285	3,211
	14.Huhunama/Tovabada	812	3,917	12,288	2,698
	Outside NCD	711	711	711	-
	Subtotal	45,819	101,228	213,795	13,346
	Grand-Total	250,951	380,812	531,711	25,060

Source: Urban Development & Services Study

Table 4.2 Classification of Land Use

Land Use Classification	1995		2005		2015	
	Land Area (ha)	Percent Distribution	Land Area (ha)	Percent Distribution	Land Area (ha)	Percent Distribution
Urban Area						
Residential	2,226	38%	3,356	36%	4,437	35%
Non-Residential Use						
Commercial	188	3%	378	4%	551	4%
Industry	241	4%	511	6%	763	6%
Civic and Institutional	1,682	29%	2,446	26%	3,134	25%
Active Recreation	324	6%	554	6%	760	6%
Infrastructure	371	6%	600	6%	806	6%
Road and Street ROW	789	14%	1,475	16%	2,094	17%
Sub-total	3,595	62%	5,964	64%	8,108	65%
Urban Area Sub-total	5,821	100%	9,320	100%	12,545	100%
Non-Urban Area	19,239	-	15,740	-	12,515	-
Total	25,060	-	25,060	-	25,060	-

Source: Urban Development & Services Study

4.2 Sewered and Unsewered Areas

Overall, 62% of households have access to a private toilet, which flushes into the public sewerage system in 1997. In such areas as Boroko, Hohola, Gordon and Gerehu, more than 90% of households are connected to the public sewerage system. Many households in the unsewered areas also desire the sewerage system to be provided and they are willing to pay for it even in low-income brackets as indicated in the inhabitants behavior survey. In the water villages, toilets that dropped directly to the sea are used by 75% of households. This direct drop has deteriorated water environment in the sea. Sewerage system is required not only for improvement of individual sanitary environment but also for conservation of public environment.

However, the conventional sewerage system is not always the best solution to realize satisfactory sanitary condition. Many constraints prohibit the application of the sewerage system, such as physical, environmental, economic and others. A conventional sewerage system, for example, does not function properly if the steady and constant water supply is not ensured as is experienced in some parts of NCD. We believe that the water supply system will be improved by the year 2015 at the latest according to the current plan by EDA RANU so that every household will have continuous reticulated water supply by then.

Other constraint which will not allow sewerage system exists in an area where road network are disorderly and individual tap is not provided, such as in the squatter housing areas or unplanned settlement. The settlement issues seem long neglected by the planning authorities. Only standpipe is provided by the planning authorities as a basic human need. In reality, however, as indicated in the water supply development plan, house owners have developed their own reticulation system. Further, we believe that redevelopment will take place in the squatter housing areas so that sewerage system can be provided.

Besides the conventional sewerage system, there are many technological alternatives, primarily on-site systems. Treated effluent of the on-site systems is expected to be absorbed at the site. This requires good permeability of soil and lower groundwater level. Soil permeability is not particularly high in the coastal areas and in the squatter areas that are usually located on rocky hillsides. Therefore, on-site system application is difficult in NCD and only option of sanitary improvement will be public sewerage system.

However, the most serious constraint to the public sewerage system might be the financial and/or economic conditions of the implementing authorities and beneficiaries. Besides the initial construction costs, the beneficiaries must bear the ongoing operation and maintenance costs. Therefore, although we plan that all NCD areas as sewered areas, depending on affordability, unfavorable on-site system might be considered as an interim measures until the affordability reach to the satisfactory level.

The NCD has a separate storm water drainage system, which is functioning well as the Port Moresby Urban Stormwater Management Study (June 1995, SMEC consultants) investigated. Thus, sewerage system is planned as a separate system from the drainage system.

4.3 Wastewater Quantity and Quality

4.3.1 Unit Wastewater Flow

Unit wastewater flow is examined by reviewing the past studies on water supply and sewerage system in Port Moresby and by measuring actual flows during field survey period.

1) Unit per Capita Water Consumption

The Study on the Port Moresby Water Supply Development Plan, 1994 obtained the per capita water consumption in various housing types, using the actual NCDC's water supply records (see Table 4.3).

Table 4.3 Water Consumption Measurement

Housing Type	Flow (Lcd)
High-cost	371
Flat	371
Low-cost	259
Duplex	272
Domestic quarters	514
Make shift	591

Based on the records, the study estimated per capita water consumption of residential, and non-residential uses, as per the following:

1. Residential water consumption
   High-cost housing 380 Lcd
   Low-cost and informal housing 300 Lcd
   Average 350 Lcd
2. Non-residential water consumption
   Public use 12.9 % of residential consumption
   Commercial use 4.8 % of residential consumption
   Industrial use 12.4 % of residential consumption

2) Unit per Capita Sewage Flow (average dry weather flow)

There are the studies on the sewerage system of Port Moresby, namely,

- Report on the Sewerage of Port Moresby, 1974
- Port Moresby Sewerage Study, 1980
- Environmental Plan - Joyce Bay Sewage Outfall Study, 1988

The Table 4.4 shows summary of unit per capita average dry weather sewage flow in these studies.

Table 4.4 Unit Dry Weather Flow

Source	Adopted Flow (Lcd)	Sewage Flow Measurement	
		Location	Flow (Lcd)
1974 Study	273	-	-
1980 Study	350	Gerehu Lagoon	350
		Stanley E. P/S	420
		Davara P/S	400
		Lawes Road P/S	575
		Boroko Area	300
1988 Study	350	Waigani Catchment	350
		Paga Catchment	163

Spot monitoring of sewage flow at lagoons and manholes connected to sewers in residential areas was implemented during water sampling by JICA Study Team in 1997. The results of flow measurement are shown in Appendix B, and the Table 4.5 shows estimation of dry weather sewage flow per capita at each location.

Table 4.5 Unit Dry Weather Flow Measured

Location			Flow (Lcd)			
			May	August	December	Average
Domestic	Boroko	High cost housing	454	207	149	270
	Gerehu	Mid. Cost housing	788	221	27	345
	Morata	Low cost housing	231	-	494	363
Average			491	214	223	321
Lagoon	Waigani		259	219	140	206
	Gerehu		151	128	131	137
	Morata		289	302	261	284
Average			233	216	177	209

Wide range of fluctuations are observed in data obtained from actual measurement of sewage flow, and dry weather sewage flow per capita is, therefore, hardly estimated by these data, because the measured flows were instantaneous.

3) Planned unit per capita sewage flow (average daily flow)

455 Lcd (350 Lcd for residential use and 105 Lcd for non-residential use) is adopted for this study, since the flow meets the water consumption obtained from water supply records for many years, and other sewerage studies.

4) Planned unit per capita sewage flow (maximum daily flow)

Even though ratio of maximum daily flow to average daily flow was not easily obtained in the suppressed water demand in NCD, JICA water supply study team obtained 1.3 ratio in the unsuppresed area like Gordons in 1993. We follow this ratio of 1.3 for planning purpose.

4.3.2 Unit Wastewater Quality and Pollutant Loads

Among others, BOD (Biochemical Oxygen Demand) and SS (Suspended Solids) are the most important parameters in planning and designing the sewage treatment plant. BOD, in particular, is a key parameter to establish the type of process and performance of the plant.

There are two methods to determine BOD of sewage. The first method is estimation by using unit BOD pollution load per capita and sewage quantity. The second method is, of course, estimation based on the results of water analysis of actual sewage sampling from the existing sewerage system. A series of water sampling and examination was carried out during the field work of this Study and their results were referred to in establishing planned influent sewage quality.

1) Sewage quality estimation

BOD estimation in other countries where many existing data are available, is done using such data and reviewed referring to the values obtained by actual water analysis in the field.

(1) Residential sewage
There are some reports on the study of unit BOD pollution load of domestic sewage stemming from field investigations and Table 4.6 shows the findings and study results.

Table 4.6 Unit Load of Wastewater

(Unit: g/capita/day)

Country	Parameter	Nightsoil	Other Wastewater	Total
a. Japan (in 1990)	BOD	18	39	57
	COD-Mn	10	18	28
	SS	20	23	43
	T-N	9	3	12
	T-P	0.	0.	1.
b. United States	BOD	18	39	57
c. Tropical countries	BOD	22	18	40
d. South East Asia *	BOD-Total	-	-	43
e. India *	BOD-Total	-	-	30 to 45

* Source: Urban drainage and sewage treatment in developing countries by the Ministry of Construction of Japan

As observed above, there are wide ranges of variation reflecting differences in living standards, life style, etc. WHO, however, recommends to apply 45 g/capita/day where there is no available data.

BOD is calculated as follows.

BOD = 45 g-BOD/capita/day / 350 Lcd = 129 mg/L

where, BOD load: 45 g/capita/day

Discharged sewage volume: 350 Lcd

(2) Public use and commercial sewage

In this Study, water demand is categorized into two, residential use and non-residential use. The non-residential use may be further divided into public, commercial and industrial use. Among them, public and commercial uses, which reflect water consumption at offices, restaurants, hotels, etc., are expected to have the similar characteristics with domestic use. Therefore, 45 g/capita/day with BOD load of 129 mg/L is applied in this Study.

(3) Industrial wastewater

According to some reports on industrial wastewater, typical characteristics of wastewater by industry group are described in Table 4.7. There are very wide differences of BOD by industry, and food processing shows the largest, and some industries show very small values. Therefore, average value of BOD is taken as 500 mg/L and is applied for all industrial wastewater, in general.

Table 4.7 Industrial Wastewater Quality

Industry Group	Average BOD (mg/L)
Food Processing	1,374
Mining/Cement/Ceramics	372
Light Processing	463
Mechanical/Electrical	151
Others	500

(4) Mixed sewage

Using the above set values, BOD load is calculated as follows.

1. Residential sewage 129 mg/L
2. Public use sewage (assuming 12.9 % of residential use) 129 mg/L
3. Commercial sewage (assuming 4.8 % of residential use) 129 mg/L
4. Industrial wastewater (assuming 12.4 % of residential use) 500 mg/L
5. Mixed sewage $= \{ 129 \times (1.0 + 0.129 + 0.048) + 500 \times 0.124 \} / (1.0 + 0.129 + 0.048 + 0.124) = 164$ mg/L

2) Planned sewage quality for the existing studies

There are several data available in the study reports, and Table 4.8 shows the summary of sewage quality. The data indicates that BOD is the range of 130 to 187 mg/L and SS is 120 to 270 mg/L.

Table 4.8 Unit Load of Wastewater

(Unit: mg/L)

Study	Adopted Quality		Sewage Quality Measurement		
	BOD	SS	Location	BOD	SS
1980	187	209	-	-	-
1988	150	200	Paga Point	140	180
			Waigani Lagoon	150	270
1997	-	-	Paga Point	130	150
			Badili	170	120
			Kila Kila	52	48

3) Results of water quality examination

Water sampling was carried out at three different localities for domestic sewage and two different factories. The results of water quality survey are shown in Appendix B.

(1) Domestic sewage

Table 4.9 Unit Load of Domestic Wastewater

Sampling Location		BOD (mg/L)		SS (mg/L)	
		August	December	August	December
Waigani Lagoon		194	77	138	107
Gerehu Lagoon		154	109	113	158
Morata Lagoon		304	130	136	194
Average (Lagoons)		217	105	129	153
		161		141	
Boroko	High cost house	143	35	107	63
Gerehu	Mid. cost house	135	268	77	379
Morata	Low cost house	79	14	35	43
Average (Residential Areas)		119	106	73	162
		113		118	

Table 4.9 shows large fluctuations among each sample, particularly those of residential areas. This is because the service area is small and the quality of the raw sewage is largely affected by water usage of that time in the area. Also, sewage of residential areas is lower in BOD and SS than that of lagoons. This seems to be caused by industrial wastewater. Therefore,

it has better to refer the data of lagoons for establishing planned sewage quality.

(2) Industrial wastewater

Table 4.10 Unit Load of Industrial Wastewater

Factory	pH	SS (mg/L)	BOD (mg/L)	COD (mg/L)
Pacific Engineering	6.4	1,700	14,000	20,800
South Pacific Brewery	4.0	190	3,100	3,120

Both industrial wastewater in Table 4.10 shows very high value of BOD and COD which cannot be treated by ordinary process of sewage treatment plant. At present they are diluted by domestic wastewater and treated normally. However, following the development of industries, amount of wastewater will increase and harm the plant. Therefore regulation for industrial wastewater should be introduced so as to protect performance of treatment plants.

4) Planned sewage quality

Sewage quality of BOD 170 mg/L and SS 200 mg/L are adopted for the planned sewage quality based on the above estimation and study on actual water quality survey.

4.4 Industrial Wastewater

At present, there are a limited number of factories in NCD and are mainly food processing and light industries, which rarely discharge wastewater that contain harmful substances for human health. Therefore, industrial wastewater can be included in the proposed sewerage system. It is also unlikely that factories with discharging toxic matters will be established in NCD. Nevertheless, for precaution, some limitations of effluent standard shall be considered because conventional treatment facilities can treat biologically organic matters, solids, pathogens, etc. which constitutes domestic wastewater but cannot remove harmful substances. Therefore, the following substances/items should be pre-treated before discharging to sewerage system.

- Substances related to the protection of human health
- Items related to the protection of living environment
- Substances/items related to the condition and operation of sewage treatment plant

Table 4.11 shows the industrial effluent standard to sewerage system in Japan.

Among these substances/items, water temperature, BOD, SS, N-hexane extracts, nitrogen and phosphorus are restricted by the following conditions and are requested to set strict standards.

- Industrial wastewater exceeds a quarter of total influent of sewage treatment plant.
- Effluent of sewage treatment plant is strictly regulated.

In PNG, effluent standards for sewage treatment plant and industrial wastewater effluent should first be established referring to "Recommended Water Quality Standards for Papua New Guinea", and secondly, effluent standard for industrial wastewater discharging to sewerage system. In 1990, a report "Port Moresby Trade Waste Policy" was drafted providing among others, policy direction/guidelines on the industrial discharges to the sewerage system, however, up to the present time, there has been no official ratification of the report.

Table 4.11 Industrial Effluent Standard to Sewerage System in Japan

(Unit: mg/L)

Substances/Items	Permissible Level
1) Substances related to the Protection of Human Health	
Cadmium and its compounds	0.1 mg/l
Cyanide compounds	1 mg/l
Organic phosphorus compounds	1 mg/l
(parathion, methyl parathion, methyl demeton and EPN only)	1 mg/l
Lead and its compounds	1 mg/l
Hexavalent chrome	0.5 mg/l
Arsenic and its compounds	0.5 mg/l
Total mercury	0.05 mg/l
Alkyl mercury compounds	Not detectable [2]
PCB	0.03 mg/l
Other 13 substances	-
2) Items related to the Protection of Living Environment [1] [2]	
PH	5.0-9.0
BOD	600 mg/l
BOD, COD [3]	160 mg/l (daily average 120 mg/l)
SS	200 mg/l (daily average 150 mg/l)
N-hexane extracts	
Mineral oil	5 mg/l
Animal fat and vegetable oil	30 mg/l
Phenols	5 mg/l
Opper	3 mg/l
Zinc	5 mg/l
Dissolved iron	10 mg/l
Dissolved manganese	10 mg/l
Chrome	2 mg/l
Fluorine	15 mg/l
Nitrogen [4]	240 mg/l (daily average 60 mg/l)
Phosphorus [4]	32 mg/l (daily average 8 mg/l)
3) Substances/items related to the Operation of Sewage Treatment plant	
Water temperature	45
COD	600 mg/l
BOD	600 mg/l
PH	5.0 – 9.0
N-hexane extracts	
Mineral oil	5 mg/l
Animal fat and vegetable oil	30 mg/l

Note : 1) Local government may, by degree, set more stringent standard.
2) The standard values in this table are applied to the effluents from industrial plants and other places of business.
3) The standard value for BOD are applied to public waters other than coastal waters and lakes, while standard value for COD is applied only to effluents discharged into coastal waters and lakes.
4) Standard values for nitrogen and phosphorus are applied to lakes and reservoirs in which problems due to eutrophication may occur.

EDA RANU has to implement regular monitoring on the quality of industrial wastewater effluent to sewerage system in conjunction with DEC. In case of improper effluent flowing into the sewerage system, EDA RANU has to enforce Section 18 "Discharge of Trade Wastes" of the Sewerage Regulation (Public Health Act), that is, to reject the nature of the waste and to impose the corresponding penalties or fines. For this monitoring, EDA RANU should establish a section with a chemist and a laboratory.

4.5 Collection Option

The collection options are provided below:

- Conventional sewerage system
- Small bore effluent system
- Vacuum sewerage system

4.5.1 Conventional Sewerage System

The conventional sewerage system is one of the most reliable sewerage systems, and much experience is available in planning, design, construction, and operation and maintenance. This system is most widely applied throughout the world and NCD.

The conventional sewer system has much merit; it provides the greatest convenience of all waste disposal systems, since it permits the discharge of a large amount of water. Secondly, it does not pose any risks to health when functioning properly. Thirdly, it generally operates with few service interruptions or emergencies.

Yet, this system also has some disadvantages. It is, first, expensive to construct. It requires skilled contractors for construction, organization for operation and maintenance, and a substantial amount of flushing water, which adds to the operating costs.

Given the high convenience level of the conventional sewerage system and considering the present situation of the sea, where the conventional system has a long history and operated for a few decades without any serious problems, this system is the most appropriate system.

4.5.2 Small-bore Effluent System

The small-bore effluent system, which carries settled effluent only, is one possibility for a less expensive sewerage system. The system is designed to receive only the liquid portion of household wastewater for off-site treatment and disposal. Grit, grease and other troublesome solids which might cause obstruction in the sewers are separated from the wastewater flow in interceptor tanks installed upstream of every connection to the sewers, and the solids which accumulate in the tanks are removed periodically for safe disposal.

This system was introduced to improve environment in the developing countries where financial source is limited. On the other hand, this system is susceptible to clogging of sewers by sands and other solids entered the pipes. Due to smallness of pipes to reduce a construction cost, clogging of pipes cause this system in operable. Considering the prevailing rubbish problem in NCD, this system is not recommended now.

4.5.3 Vacuum Sewerage System

A vacuum sewerage system collects sewage using vacuum as the method of sewage transport. The vacuum system suits large flat areas where there is little grade available for a conventional sewerage system, which would require a number of pumping stations. Low level foreshore and water village development are particularly suited to the vacuum system where otherwise a small pump would be required for each group of houses. Nevertheless, a flat area is limited in size so that this system is not adopted for NCD.

4.6 Design Criteria

4.6.1 Sewers

1) Maximum design capacity of sewer

The following peak factor is applied according to contributing population.

Contributing Population	Peak factor
Up to 5,000 persons	2.00
Between 5,000 to 10,000	1.80
Between 10,000 to 20,000	1.60
Beyond 20,000	1.50

2) Minimum design for self cleansing velocity

Minimum velocity required for self-cleansing is 0.6 m/sec against the following flows;
450 Lcd × Population × 0.5 (Minimum factor)

3) Hydraulic calculation

The Manning formula is adopted in case of the gravity flow sewer, and Hazen Williams formula is adopted in case of the pressure sewer.

Manning formula

$Q = A \times V$, $V = 1/n \times R^{2/3} \times I^{1/2}$

Where,
- Q : Flow (m^3/sec)
- V : Velocity of flow (m/sec)
- n : Roughness coefficient
- R : Hydraulic radius (m)
- I : Hydraulic gradient
- A : Section area (m^2)

Hazen William Formula

$Q = A \times V$, $V = 0.84935 \times C \times R^{0.63} \times I^{0.54}$

Where,
- Q : Flow (m^3/sec)
- V : Velocity of flow (m/sec)
- C : Flow velocity coefficient
- R : Hydraulic radius (m)
- I : Hydraulic gradient
- A : Section area (m^2)

Standard coefficients to be used for the type of material are in Table 4.12.

Table 4.12 Coefficient for Sewer Design

Type of Pipe	N (Roughness Coefficient)	C (Flow velocity coefficient)
Concrete Pipe / RC Pipe	0.013	110
Vitrified Clay Pipe	0.013	110
PVC Pipe / Plastic Pipe	0.010	120
Coated Steel Pipe	0.009	130

4.6.2 Pumping Station

Location and capacity of pumping stations are determined based on sewer planning. Pump type is submersible pump without grit chamber as is the same as the existing type. However, the large capacity pumps like Paga and Kila Kila have grit chambers. Capacities of pump well has approximately 10-15 minutes retention period. Pump wells dimensions and number of pumps are decided as is shown in Table 4.13 according to design flow.

Table 4.13 Pumping Station Type

Design Flow (m^3/min)		1.5		3.0		6.0			15.0			30.0
Type		I	II		III		IV			V		
Type of Pumping Station		Circular Type Pumping Station					Simplified Type Pumping Station			Standard Type Pumping Station		
Pump Well		Circular ø 1.5 m	Circular ø 1.8 m		Circular Ø 4.0 m		Rectangular 7 × 7			Rectangular 7 × 14		
Grit Removal		None	None		None		None			Sand Pump		
Screening Removal		None	None		None		Manual			Automatical		
Pump	Discharge Diameter (mm)	100	100	100	100	150	150	200	250	300	350	400
	Nos	2 (1)	2 (1)	3 (1)	3 (1)	3 (1)	4 (1)	4 (1)	4 (1)	4 (1)	4 (1)	4 (1)

Nos: 3(1) denotes that there are 3 pumps and (1) of which is for stand by.

Each pumping station has the following facilities.

1. Civil Structure
   - Type I, II and III: Circular type
   - Type IV and V: Rectangular type.
2. Mechanical Equipment
   - Pump: Submersible pump, stationary wet installation with guide bars and automatic connection
   - Valve: A delivery valve (gate valve) and a check valve for each pump.
   - Piping Materials: Ductile/cast iron pipes and fittings within pumping station
3. Electrical Equipment
   - Control Panel: Self-standing out-door type, including power receiving, control and instrumentation
   - Operation: Automatic operation by water level measured by level sensors/switches.

4.6.3 Sewage Treatment Plant (STP)

1) Planned water quality and receiving water body

The water quality of effluent have been decided, taking into account the condition of the receiving water bodies, and the BOD/SS target levels are determined as listed in Table 4.14.

Table 4.14 The Water Quality of Effluent

Receiving Water Body / Item	River/Swamp	Ocean	
		On Shore	Off Shore
BOD_5	30 mg/L	30 mg/L	120 mg/L
SS	40 mg/L	40 mg/L	150 mg/L
Proposed Treatment Level	Secondary Treatment	Secondary Treatment	Primary Treatment

2) Major design concept

The following criteria are applied in this Study to select the most suitable treatment method:

- Requirement of effluent quality,
- Availability of site,
- Less cost of construction and O & M (operation and maintenance),
- Less power consumption, and
- Ease of operation and maintenance.

In addition, the existing STP shall basically apply the current treatment method due to its structural constraints and the abundant experience of its staff for operation and maintenance.

3) General approach to select the treatment method

There are some popular sewage treatment methods which are used in the developing countries particularly in hot climates, such as:

1. Primary Treatment
   - Sedimentation.
2. Secondary Treatment
   - Oxidation Ditch,
   - Aerated Lagoon, and
   - Stabilization Pond.

Table 4.15 exhibits the general comparison of the above mentioned treatment methods.

Judging from the above table, the stabilization pond method should be applied for the secondary treatment if there is no land restriction.

Table 4.15 Feature of Secondary Treatment Method

Treatment Method			O & M	Sludge Removal	Cost	Land Requirement
Primary Treatment	Sedimentation	Circular Type	easy	every day	low	extra small
		Rectangular Type	easy	every week	extra low	extra small
Secondary Treatment	Oxidation Ditch		fair	every day	high	small
	Aerated Lagoon		fair	every year	fair	medium
	Stabilization Pond		easy	every 2 year	low	large

Note : The circular type sedimentation tank has a sludge collector and a sludge pump.
The rectangular type sedimentation basin has only a sludge pump.

4.6.4 Secondary Treatment System

Effluent standards of sewage treatment plant exist in some developed countries. Table 4.16 shows major parameters of the standards in Japan, the United States and European Union. Since the standard does not exist in PNG, similar values are applied for the planned effluent value of the sewage treatment plant in this study.

Table 4.16 Effluent Standard of Treatment Plant

(Unit: coliform - MPN/100ml)

Parameters	Japan	USA [2]	EU	Target
BOD (mg/L)	20	45	25	30
SS (mg/L)	70	45 [3]	35 [5]	40
Coliform100 [1]	30,000	F - 200 [4]	-	-

Note : 1) Coliform F means Fecal Coliform.
2) Trickling filters and stabilization ponds : 30-day average
3) The state may adjust the SS limits for ponds subject to EPA approval.
4) Not defined in federal secondary treatment equivalency regulations but permits typically include cited levels, often only on seasonal basis.
5) The concentration of total suspended solids from lagooning shall not exceed 150 mg/L.

Considering the fact that the existing three (3) treatment plants have been in operation under the stabilization pond method more than 25 years with good performance, the stabilization pond method can be recommended where the secondary treatment method is applied. From the comparison of other methods widely used in the hot climate countries, the same can be said. The stabilization pond method offers many advantages. In particular, this is an ideal sewage treatment method for Port Moresby, since the advantage shall be emphasized remarkably in hot climate condition. On the other hand, the necessity of a large area is the sole disadvantage of this method. In this respect, there is no fundamental problem, since each existing STP is surrounded by government land which would be adequate for the STP expansion area.

Figure 4.1 shows the flow diagram of the stabilization pond method proposed in this Study. The settled sludge of each pond shall be removed at least every 2 year and will be substituted for fertilizer through drying process.

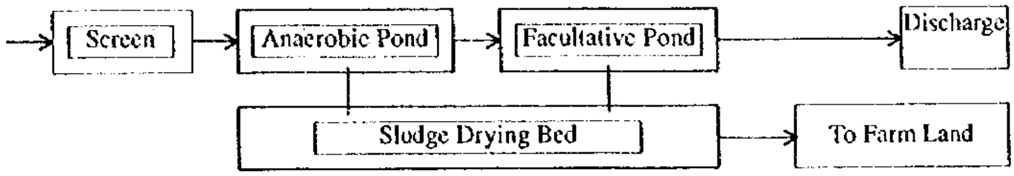


Fig. 4.1 Sewage and Sludge Treatment Flow Diagram for Inland Area

Table 4.17 shows the design criteria of the stabilization pond method.

Table 4.17 Design Criteria for Stabilisation Pond Method

Design Criteria		Anaerobic Pond	Facultative Pond	Total
Water Depth (m)		2.0 to 2.5	1.5 to 2.0	-
Retention Time (day)		2.0	4.0	6.0
Pollutant Removal (%)	BOD	60	70	88
	SS	50	80	90

4.6.5 Primary Treatment System

1) Process

The basic concepts for primary treatment system are as follows:

- To avoid the mechanical equipment to a certain extent to reduce the construction, operation and maintenance cost as well as manpower for maintenance.
- To reuse the dried sludge not only in view of resource recycling but to enable sustainable sludge disposal.
- To ensure the facility size/process fits the land which is possible to acquire.

Figure 4.2 and 4.3 show the flow diagrams for typical STP conditions. In these figures, each sedimentation basin has a thickening function.

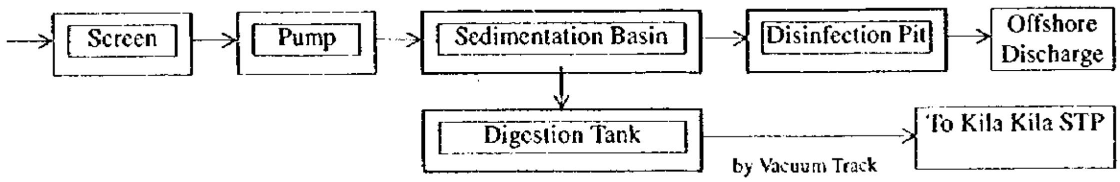


Fig. 4.2 Proposed Paga Point STP (Sedimentation and Desludging)

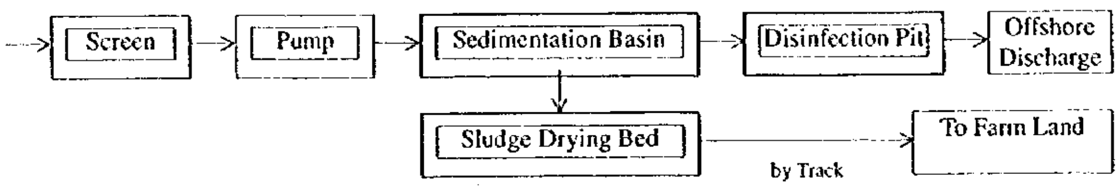
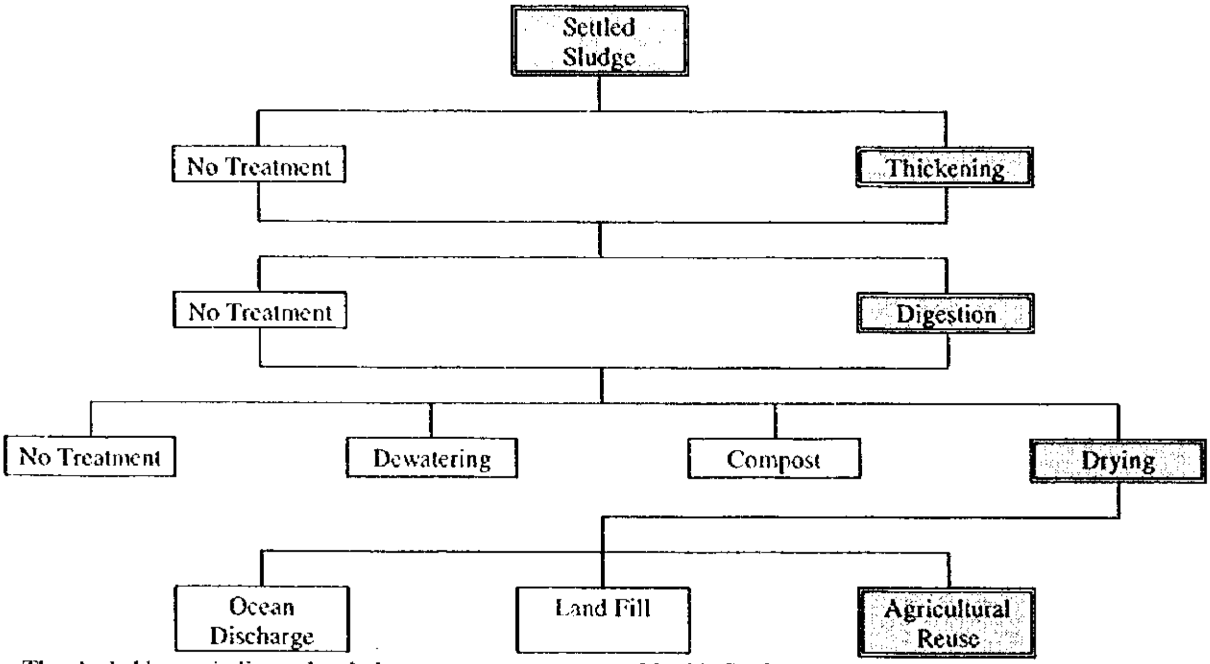


Fig. 4.3 Proposed Kila Kila STP (Sedimentation and Sludge Drying)

The sludge generation ratio of the sedimentation method is large compared to the stabilization method. Therefore, the establishment of adequate sludge treatment and disposal is an essential item to be studied in order to enable the sustainable maintenance of the system. There are various sludge treatment processes as well as different combinations for dealing with the sludge generated from sedimentation method. They are shown in the Figure 4.4. The shaded boxes indicate the sludge treatment process used in this Study.



The shaded boxes indicate the sludge treatment process used in this Study.

Fig. 4.4 Sludge Treatment Processes

(1) Thickening process
Due to its remarkable economical advantage, the thickening process is included in the Study. Through the thickening process, the moisture content of the sludge will be reduced from 98% to 96%; also, the volume of the sludge will be reduced by 50%. Therefore, the thickening process contributes to drastically minimizes the subsequent process volume requirements and sludge transportation frequency.

(2) Digestion process
The purpose of the digestion process is stabilization and reduction of the volume of the sludge itself through the gasification of organic matter.
Advantages for sludge characteristic stabilization
- To mitigate offensive odor
- To control vermin generation such as fly and so on
- To ease handling for fertilizer

Advantages for sludge volume reduction
- To minimize the sludge drying bed size
- To reduce the sludge disposal frequency

Hence, there is a high possibility that the process will enable economical and easy operation

and maintenance as well as providing thickening.
The capacity of the sedimentation basin and the disinfection tank are established based on daily maximum sewage flow per hour which is calculated as 1.3 times as much as daily average sewage flow. The capacities of other facilities such as storage tank, digestion tank and sludge drying bed are established based on daily average sewage flow, without the peaking factor times the contributing population and the corresponding retention time.

2) Water Quality and Pollutant Removal Efficiency

Sewage Quality	Influent Quality	Pollutant Removal Efficiency	Effluent Quality
BOD (mg/L)	170	40 %	102
SS (mg/L)	200	40 %	120

3) Design Criteria for the Sludge Treatment Facility

(1) Sludge surface load and/or retention time

Facility	Thickener	Digestion Tank	Sludge Drying Bed
Load/Time	60 - 90 kg/day/m^2	30 days	20 days

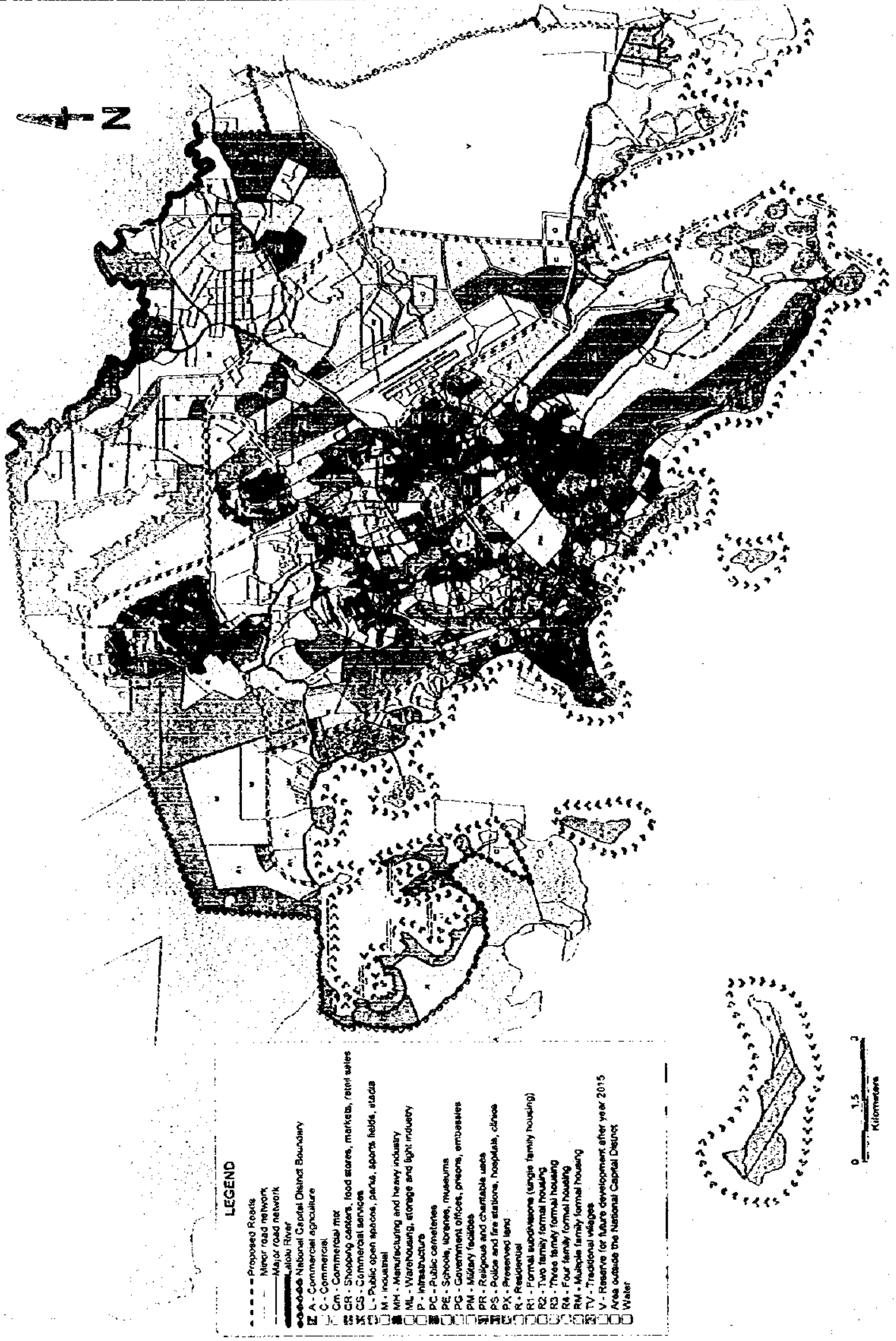
(2) Sludge moisture content

Sludge	Settled	Thickened	Digested	Dried
Moisture Content	98 %	96 %	96 %	60 %

(3) Sludge generation ratio

Sludge	Settled	Thickened	Digested	Dried
Weight (t/day)	0.80	0.80	0.56	0.56
Volume (m^3/day)	40.0	20.0	14.0	1.4

The sludge generation ratio is given based on flow and influent quality of the sewage as 10,000 m^3/day and 200 mg/L (SS) respectively.



Source : Urban development & services study for the National Capital District, November 1996

Date	Title	Fig.
May 1998	National Capital District Land Use Plan, 2015	4.5

THE STUDY ON SEWERAGE SYSTEM OF PORT MORESBY IN PAPUA NEW GUINEA

TOKYO ENGINEERING CONSULTANTS in association with NIPPON JOGESUIDO SEKKEI

CHAPTER 5

THE RECEIVING ENVIRONMENT AND SEWERAGE DISPOSAL OPTIONS

CHAPTER 5 THE RECEIVING ENVIRONMENT AND SEWERAGE DISPOSAL OPTIONS

5.1 The Need For Municipal Wastewater Treatment In Port Moresby

5.1.1 Environmental Objectives

Urban areas are characterized by their concentration of commercial and industrial activities, human population, and similarly for the discharge of wastes into the environment. The transformation of the natural environment to provide housing and commercial/industrial buildings, transport, along with the volume and type of wastes generated on a daily basis, normally exceeds the ability of the environment to assimilate them. The collection, treatment methods and disposal, therefore, are necessary which will prevent adverse impacts to the health and well-being of the residents, and to the ecological systems which sustain them.

The objective of sewage disposal is the return of wastewater to a receiving body with an acceptable quality. In PNG, there are a number of legislation that ensure the attainment of this objective as presented in Section 5.6. Noteworthy, is the Water Resources Act (1982) and Environmental Planning Act (1978). The former Act requires permits to be issued for any works disposing effluent to natural waters. In the case of a submarine outfall, an Environmental Plan is required.

The ultimate goal in providing a sewerage system is to keep the water resources suitable for their designated uses. The term "environmental value" or "beneficial use" is used to describe the designated use such as drinking, bathing, protection of aquatic life, and others. PNG is still in the process of finalizing water quality standards, the "Recommended Water Quality Standards for Papua New Guinea" based on this "environmental value concept". This requires the designation or classification of marine and freshwater bodies as to their protected environmental values (PEVs) to attain water quality objectives of these resources. The standards are: i) for raw water used for drinking, ii) for protection of aquatic ecosystem (fresh water), iii) for protection of aquatic ecosystem (marine waters), and iv) for recreation and aesthetic values. These standards are also expected to protect other environmental values such as cultural, industrial and agricultural applications.

The effluent level, therefore, shall not be decided by effluent standard of sewage, even if it is available, but be decided by the required level or water quality objective of a receiving water body. However, due to its draft stage, all the water bodies in the country have not been classified as to their PEV or beneficial use. In the absence of this classification, the Study Team attempts to tentatively classify the water bodies as to its PEV based on existing uses and conditions to determine the quality of effluent of the proposed disposal system. If, in the near future, the tentative classification does not coincide with the official designation by the Department of Environment and Conservation, the proposed disposal method has to be reviewed accordingly.

5.1.2 The Receiving Waters

In the Study Area, the Waigani swamp and the sea will continue to be receiving bodies. In addition, the Laloki river could become a receiving body for sewage from Bomana (8-mile and 9-mile) development.

Proper wastewater treatment entails reducing the volume and concentration of pollutants to levels that will not cause degradation to the receiving environment. This requires improvement in existing sewerage and sanitation facilities in the City. Port Moresby, as in most cities of the world situated along the coastal area, has seas as one of its final discharge point of wastewater. The Australian Water and Wastewater Association (AWWA) in its position paper on ocean disposal of wastewater states that "The marine disposal of wastewater is a valid option provided fundamental goals are achieved, such as eliminating pollutants harmful to biota, maintaining or improving beneficial uses for the receiving water and conserving water resources."

Given this option, there is a "need for baseline monitoring of disposal sites and ongoing monitoring after installation, to ensure that environmental quality is maintained." While this study on sewerage system of Port Moresby fully recognizes the need to maintain a sustainable environment, the cost entailed to put up the best possible solution of waste disposal must also be understood.

5.2 Applicable Sewage Treatment Processes

5.2.1 Major Categories

Treatment processes or methods should be selected based on the requirement of receiving water bodies. The following are the major categorized processes for sewage treatment.

1) Screening/Grit Removal

Screens are made of steel bars setting certain distances to remove floatable objects in sewage. Grit removal is done by settling grit, silt etc. in channels with moderate stream.

2) Primary Treatment

Primary treatment is a physical process that involves gravity separation of settleable and floatable solids from the influent sewage stream. Removal of settleable solids takes out some associated pollutants, including organic matter, nutrients, heavy metals, toxic organics and pathogens.

3) Secondary Treatment

Secondary treatment or biological treatment systems use a diverse culture of microorganisms to break down organic matter in the wastewater, oxidizing a portion and converting the remainder into biological solids. Organic contaminants are removed by bio-degradation and volatilization. Non-degradable suspended contaminants are removed by physical entrapment and subsequent removal with the generated biomass. Some nutrient removal occurs through incorporation into generated biomass. Biological treatment systems convert some influent organic nitrogen and urea to ammonia, thereby increasing the ammonia concentration making it more biologically available upon effluent discharge.

4) Nutrient Removal

Wastewater treatment systems can be configured to remove the nutrients nitrogen and/or phosphorus. Nitrogen removal is accomplished by an extension of the conventional biological system to incorporate the biochemical processes of nitrification and denitrification. Nitrification is the oxidation of ammonia and organic nitrogen to nitrate nitrogen, and the nitrate nitrogen is reduced to nitrogen gas and then released into the atmosphere by the denitrification.

Phosphorus removal can be accomplished by chemical or biological means. High-dose metal salts addition results in phosphorus removal. Alternatively, biological phosphorus removal can be accomplished through the selection of high phosphorus content microorganism, resulting in a greater mass of phosphorus in the excess biological solid removed.

5.2.2 Pollutants Removal Rate

The above mentioned treatment processes, in general, can be expected to remove pollutants with the percentages described in Table 5.1.

Table 5.1 Pollutants Removal Rate of Sewage Treatment

Pollutants	Primary Treatment	Secondary Treatment	Nutrient Removal
BOD (%)	30 - 50	90 - 95	90 - 95
COD (%)	30 - 50	70 - 85	85 - 95
T-SS (%)	40 - 60	90 - 95	90 - 95
T-N (%)	10 - 30	20 - 40	60 - 70
T-P (%)	20 - 40	30 - 50	70 - 80

5.3 Waigani Swamp as a Receiving Waterbody

5.3.1 Setting and Recommended Protected Environmental Value

Waigani swamp is the final receiving water for the wastewater generated from the three (3) sewage treatment lagoon facilities of the Port Moresby Sewerage System, namely: the Waigani, the Gerehu I (Morata), and the Gerehu II. Fig.5.1 shows the location of the Waigani swamp and the existing sewage treatment facilities. The swamp is now serving as a tertiary treatment system before the water flows into the Laloki River. This is gleaned from the water quality examination by the Study Team where COD concentration of the influent was a high 109 mg/L, while that of the swamp water was 65.8 mg/L and finally, the effluent at Zooland creek inlet was 72.0 mg/L. Thus, COD concentration of the swamp effluent is reduced owing to the natural purification process of the swamp and this concentration is equivalent to the derived values applying linear equation related to the retention time of the swamp (refer to Appendix H for the calculations). Other uses of the swamp are for sustenance fishing and as habitat for native fauna. Dense reedbeds dominate the vegetation. The macrophytes (waterlilies) are confined to the peripheral area of the lake.

From the calculation of the Study Team, the total catchment area of the swamp is estimated to be 88.3 km^2 with a maximum depth of 1.521 m. Survey results indicated a mean depth of 0.7 m. The swamp volume is calculated at 1.82 million cubic meters.

5.3.2 Environmental Investigation

To know the existing water quality condition of the wastewater receiving body, a survey was conducted in July and December 1997 at the influent stream of Waigani swamp, at the swamp itself, and at the effluent stream of the swamp. Analysis was undertaken on the physico-chemical and microbiological characteristics such as, temperature, pH, suspended solids (SS), DO, total COD (T-COD), soluble COD (S-COD), BOD, total nitrogen (T-N), total phosporous (T-P) and faecal coliforms. The cross-sectional profile and the water stage of the stream were also measured at the flow measurement (see to Table 5.2). A current meter was used to measure flow velocity. Fig.5.2 indicates the water sampling and flow measurement stations in Waigani swamp and Laloki river.

Table 5.2 Water Quality Examination Result

(mg/L)

Month	Location	pH	SS	BOD	COD	S-COD	DO	T-N	T-P
July '97	Waigani Swamp	7.8	81	12	124	-	14.0	6.4	0.18
Dec. '97	Jackson Creek	7.2	134	9	91	58	1.3	2.8	0.54
	Waigani Swamp	8.2	58	9	80	66	6.1	4.6	1.87
	Zooland Creek	7.0	8	37	53	72	2.0	5.8	3.95
	Laloki River	7.4	28	5	54	61	3.9	3.5	0.25

From the result of the water quality survey conducted by the Study Team in July and December 1997, the swamp exhibits the phenomenon of eutrophication as indicated by the high concentration of nutrients, such as T-N and T-P. In addition, BOD of the swamp also indicates that there is massive growth of phytoplanktons. But, so far, from interviews of local fishermen, there is no reported massive fish kills in the swamp due to the problem of deoxygenation of the water column. Appendix B provides a detailed presentation of the results of the survey including the wastewater quantity and load.

An analysis of the existing and predicted pollutant load balance of Waigani swamp and Laloki river using a water quality simulation model was undertaken by the Study Team taking into account two (2) scenarios: with sewage treatment plant during dry and wet seasons, and without sewage treatment (dry and wet). The results are shown in Figs.5.3 and 5.4.

Appendix H provides a detailed assessment of water quality including pollution load run-offs model to predict the water quality of the receiving waterbody.

The results presented in the preceding figures indicate the followings:

- Waigani swamp effluent has not affected water quality of the Laloki River (behind junction) at present.
- Adequate expansion/improvement of the STPs will contribute to improvement of the water quality of the Laloki River (behind junction) in the future.
- In case of no sewage treatment, Waigani swamp effluent worsen the water quality of the Laloki River (behind junction) both at present and in the future.

As with the rest of the waterbodies of the country, Waigani swamp has not been officially classified as to its PEV. The surrounding area of the Waigani swamp however, has been designated as preserved land based on the recommended urban development plan (2015) of the Urban Development and Services Study. The Study Team proposes that Waigani swamp continues its normal function as a tertiary treatment and shall be preserved as a recreational area (except for direct contact activities). Although not yet formally adopted, the recommended standards for these uses can be tentatively applied to the receiving waters (refer to Table 5.3 for the standards).

5.3.3 Disposal Options vs. Environmental Objectives

The Waigani swamp is currently used only for local fishing without any adverse effect. The existing three lagoons are discharging their effluent, after treatment, to this swamp. These existing secondary treatment as stabilization pond method are to be continued

If eutrophication problem is tackled in the future, an advanced treatment is required to reduce nutrients content. Because removal ratio of nutrients, particularly nitrogen and phosphorus is low in this treatment method. Naturally, it will incur a construction cost as well as O/M cost. As earlier stated, Waigani swamp is proposed to continue its actual function as a tertiary treatment because it is difficult to justify construction of high-cost advance treatment in the foreseeable future.

A water quality sampling for the Waigani swamp confirms no adverse effect to few downstream users even for drinking purpose, although this practice has to be avoided or strictly regulated and fish production has not declined. Rather, it contributes in the prevention of contamination of Laloki river, the main water source of this area, because the swamp works as a tertiary treatment of natural wetland by removing SS, BOD and nutrients.

However, to safeguard the health and well- being of the downstream users, it is proposed that toxic substances, if any, from effluent of factories shall be pre-treated before discharging to the sewer pipes and shall be diligently monitored.

Table 5.3 Recommended Water Quality Standards for Papua New Guinea*

Parameter	Recommended Standards		
	Protection of Fresh Water Aquatic Life	**Protection of Marine Aquatic Life**	**Recreational & AestheticsUses in Marine and Fresh Waters**
Microbiology			
Faecal coliform			200/100mL (geometric mean)
E. coli			150/100mL (median)
Nuisance organisms			
Sewage fungus			Should not be present
Blue green algae			Direct contact activities be discouraged if algae levels of 15,000-20,000 cells/mL
Leeches and worms			Should not be present in excessive amount
Aquatic plants			Should not be present in excessive amount
Physico-chemical			
Dissolved oxygen (mg/L)	6.0 mg/L	>6.0[1] (>80-90 saturation)	
pH (units)	6.5-9.0	<0.2 unit change from normal pH	5.0-9.0
Salinity (psu)		<5% change from seasonal mean background level	
Turbidity (NTU)	<10%change	<25 NTU	<5.0 increase over natural level
Temperature (^{0}C)		<2^0C increase from background temperature	15-35
Total Suspended Solids (mg/L)	<10%increase from background levels	25.0	
Clarity			Secchi disc visible at 1.2m
Colour	<10%change in natural color		Natural color should not be changed by more than 20%
Oil/Grease			None noticeable as visible film & deposits or detected by odor
Taste			Unobjectionable
Odour			Unobjectionable
Toxicants		mg/L	
Ammonia	0.02 - 0.03		
Arsenic	0.05	0.05	
Cadmium (ug/L)	<0.66 in <50 mg/L hardness	0.002	
Chlorine	0.001		
Chromium (VI)	0.01	0.05	
Copper (ug/L)	<6.5 in <50mg/L hardness	0.005	
Cyanide (Free)	0.005	0.005	
Cyanide (WAD)	0.01	0.01	
Lead (ug/L)	<1.3 in <50mg/L hardness	0.004	
Manganese	0.5	2.0	
Mercury	0.0001	0.0001	
Potassium	5.0		
Sulfide	0.002	0.002 in Hydrogen sulphide form	
Zinc (ug/L)	<180.0	50.0	

Source: Recommended Water Quality Standards for Papua New Guinea, Discussion Paper-Revised Draft, Department of Environment and Conservation, PNG.

Notes: * Recommended water quality standards is still in a draft form.
[1] Measured over at least one, but preferable several, diurnal cycles.
All concentrations are for totals unless otherwise stated.
Shaded portions represent either no indicated value or not applicable.

5.3.4 Assessment of Environmental Impacts

1) Potential Positive Impacts

(1) Improved Quality of Effluent Discharged
The additional release of treated effluent to Waigani swamp will affect the quality of water, which in turn will affect the viability of aquatic life. However, certain species, such as tilapia and carp, which are equipped to thrive in this kind of environment, will continue to flourish and will still be the main source of protein in the diet of the families of fishermen in the area.

From interviews, the eutrophication of the swamp has not diminished fish productivity.

(2) Effects on Downstream Water Use of Laloki river
Laloki river upstream is already heavily polluted with BOD of 11 mg/L concentration. This indicates that Waigani swamp effluent is of better water quality than that of Laloki river. The swamp drains into the river where dilution and assimilation take place resulting in an improved water quality of the river downstream. This can be seen from the fact that downstream, some families still get drinking water from the river. Special attention should be made, however, to the villages downstream who still use the river for drinking purposes. It should be noted that there are other sources that contribute to the pollution load of Laloki river other than the treatment lagoons.

Likewise, the assessment result of the pollution load modeling prepared by the Study Team indicates that the Waigani swamp effluent has not affected the water quality of the Laloki river (behind junction) at present. Improvement of the STPs will add to the improvement of the water quality of the river (behind junction) in the future.

Port Moresby water supply intake in Bomana is located upstream of the planned STP and therefore will not affect the water source of the city.

(3) Effects on Beneficial Use for Recreation
Expansion of the treatment lagoons provides habitat to waterfowls and birds that lead to an increase in their population. The swamp and the treatment lagoons are favorable habitats for a number of waders and birds because they feed on insects and worms in the lagoons and fishes on the swamp. The area surrounding the swamp has been designated as a preserved recreation area where bird watching would again be popularized. Waigani swamp and environs were once the most popular bird watching site in the city.

(4) Improved Aesthetics
Aesthetic gains from the provision of wastewater treatment and disposal facilities are: prevention of foul odor emanating from improper sewage disposal, maintenance of clean and healthy surroundings, and avoidance of open canals which become breeding ground for disease carrying insects. Without these facilities, the surrounding communities would possibly be used the wetland as discharged point of untreated sewage.

2) Potential Negative Impacts

(1) Effluent Discharged to the Waigani Swamp
The additional discharge may cause severe eutrophication of the lake or swamp because the lake is not stratified. Since it is shallow, bottom temperature is almost the same as that of the surface. In this condition, there is no chance of nutrients being trapped at the bottom of the lake, thus, making the nutrients easily available for algal growth at the surface area of the lake/swamp.

(2) Hygiene Issue Due to Presence of Faecal Coliforms in the Effluent
Information on the retention period or time needed for bacterial die-offs in the existing facilities and/or self-cleansing mechanism of the swamp are an essential for this issue.

5.4 Laloki River as a Receiving Waterbody

5.4.1 Setting and Recommended Protected Environmental Value

Laloki river which bisects the northern portion of Port Moresby, has multiple uses: upstream, it is used for water supply and power; and downstream, for drinking, washing, bathing and in some portion as discharge point of wastes, both in solid and liquid state. Further downstream, it is used for fishing activities. The ecology of the river, especially the portion that passes through the city, has already been severely disturbed by urban run-off and discharge from both point and non-point pollution sources. At the portion before it reaches the Waigani wetland, high level of turbidity/sedimentation was observed due to soil erosion in nearby quarry sites and hills. Fig.5.5 shows the location of the Laloki river and the planned sewage treatment plant.

There is no specific water use downstream of the discharge point so that the beneficiary use is proposed for protection of aquatic ecosystem (fresh water).

5.4.2 Environmental Investigation

1) Water Quality Survey

As a potential wastewater receiving body, a survey was undertaken in Laloki river, with the sampling point at Laloki bridge (refer to Fig.5.2 for the location of the sampling station). Analysis on the physico-chemical and microbiological characteristics such as, temperature, pH, SS, DO, T-COD, BOD, T-N, T-P, and faecal coliforms was conducted. Flow measurements were also conducted along with the water sampling. The cross sectional profile was measured along the flow measurement line. The water stage was read at the flow measurement. Appendix B provides a detailed presentation of the results of the survey including the wastewater quantity and load.

5.4.3 Disposal Options vs. Environmental Objectives

Effluent is proposed to be discharged to the Laloki river between the Bomana pumping station and the bridge on the Hiritano highway from the planned treatment plant. As stated, Laloki river is proposed for protection of fresh water aquatic ecosystem.

The drought flow in the Laloki river is around 9 m^3/s and BOD concentration is around 10 mg/L according to the JICA Water Supply Master Plan (1994), while the discharge flow from the plant will be about 0.5 m^3/s in the year 2015. Therefore, the BOD load of 170 mg/L in the influent will become 17 mg/L with 18 times dilution effect in the river. This level is not adequate for the tentative designated PEV so that secondary treatment process is proposed.

5.4.4 Assessment of Environmental Impacts

1) Potential Positive Impacts

(1) Improved Quality of Water Discharged
With wastewater treatment and disposal facilities, polluted water will no longer contaminate the Laloki river. The natural habitat conditions of the river can be maintained or at least prolonged. Under this condition, the river will continue to support fish and other living organisms and existing water-related production opportunities. If the present pollution goes on unchecked, the capability of the river to support livelihood opportunities goes down.

Nutrient contents of the effluent will have no significant impact on the aquatic life. Accumulation of these nutrients in the discharged point is not expected because the river has a good flushing capability.

(2) Improved Habitat Condition of Aquatic Life Downstream
Downstream, a number of people is still involved in sustenance fishing in the river. Since, they have limited facilities and equipment, they cannot go far out into the sea to avoid polluted grounds.

(3) Improved Aesthetics
The planned facilities is expected to eliminate bad odor emanating from discharge of raw sewage in the river. It will create a sanitary environment.

2) Potential Negative Impacts

(1) Increased Concentration of Pollutants Downstream
As the pollutants are carried downstream, the anticipated negative impacts include increased concentrations of nutrients leading to blooms of phytoplankton or macrophytes; destruction of fish and aquatic life, and elimination of recreational activities and elimination of the fishing activities. It should be noted, that fish population is also dependent on the type of fishing method used or practiced.

(2) Introduction of Toxic/Hazardous Chemicals
Toxic and hazardous materials from trade wastes may enter into the riverine ecosystem which will result in bioaccumulation in aquatic organisms. This will have considerable negative impact on human consumers. This type of waste should not find its way into the sewerage system. The quality of trade waste that enters into the system must be regulated. At present, industries are allowed to operate without any waste treatment facilities.

5.5 The Coastal Water as a Receiving Waterboby

5.5.1 Setting and Recommended Environmental Values

Majority of the wastewater generated in the coastal area of Port Moresby is conveyed through a sewer network system or treated at the point of their production. The latter typically consists of septic tanks or pit latrines for residential buildings. The treatment process usually provides only a partial decomposition of organic wastes and consumption of pathogenic organisms and in many instances, there may be a total absence of treatment as in the case of pit latrines. In some villages and near-shore settlements (houses on stilts), however, human excreta is disposed either by pan system where overflows often occur or direct discharged into the sea ("drop method"). The resulting impact is induced stress on the marine environment in the form of contaminated marine waters.

The coastal waters of Port Moresby includes the Harbour, Walter Bay, Koki Bay, Joyce Bay, and other smaller bays, and further, the Papuan Lagoon surrounded by Daugo island, Sinavi reef, and Nateara reef, and then the sea reaches the ocean (Coral sea). The waters already show signs of stress due to its multiple use as a recreational area, fishing ground, sea lane, and especially as a depository of domestic and industrial wastewater and occasionally solid wastes. Domestic pollution in the form of solid refuse such as plastic bags and sewage outfalls are common sights. A preliminary water quality prediction in the coral lagoon was implemented and the detail is shown in Appendix H.

Meanwhile, the coral reefs dotting the coastal seascape of Port Moresby are major features that offer economic returns, such as fisheries and tourism, as well as natural protection of the mainland from destructive waves. The Papuan Barrier Reef, classified as a marine biodiversity conservation priority area, is threatened with overfishing, sedimentation, pollution and other related developments of Port Moresby. In the inner lagoon, coral reefs have been degraded from siltation of the near-shore waters due largely to man induced erosion of upland areas. With all these identified threats, there is a need to draw up a coastal resource management program to ensure protection and conservation of these resources. As a starting point, an inventory and assessment of the biological resources including reefs and seagrass bed have been undertaken. A coral reef assessment in areas to be impacted by the marine sewage outfall is undertaken. A detailed description of the characteristics of this habitat is presented in Appendix G; Coral Reef Assessment.

The Study Team assumes that the PEVs of the Papuan Lagoon, which is the receiving water for the treated effluent, will be for the protection of aquatic ecosystem in marine waters and for recreation and aesthetic uses in areas near beaches.

5.5.2 Environmental Investigation

1) Water Quality Survey

The existing water quality condition of the receiving body which encompasses the bays of Walter, Koki, and Joyce. The result of water quality survey in Papuan Lagoon and coral sea (outside of the lagoon) are shown in Table 5.4.

Table 5.4 Water Quality in the Sea in 1997

(unit : mg/L)

Location	COD-Mn	T - N	T - P
Paga discharge (01)	1.3	0.13	0.009
Kila Kila discharge (02)	1.4	0.25	0.009
Coral Sea (001)	1.3	0.09	0.008

Water quality near shore and offshore was determined. Analysis was undertaken on the physico-chemical and microbiological characteristics such as, temperature, pH, EC, suspended solids, DO, T-COD, total nitrogen, total phosporous, chloride, and faecal coliform. Fig.5.6 indicates the sampling stations in the coastal waters and Appendix B provides a detailed presentation of the results of the survey

2) Preliminary Water Quality Prediction

Water quality on the receiving body is predicted due to sewage discharge upon the completion of Port Moresby sewerage system development in 2015. Vertical and horizontal diffusion prediction model is used for examination of dilution of sewage; complete mixing box model is applied for prediction of change of water quality in long term.

Appendix H provides the detailed assessment of water quality of the receiving body including a simulation model to predict the water quality with the introduction of wastewater.

(1) Diffusion Prediction

In this prediction, diffusion during floatation from the bottom to surface is examined. The results of the prediction are summarized in Table 5.5.

Table 5.5 Water Quality in the Coastal Water in 2015 (After Vertical Diffusion)

Item	Paga	Kila Kila
Floating point (down stream)m	25	30
Dilution ratio	299	290
CODMn mg/L	1.6	1.6
T-N mg/L	0.32	0.32
T-P mg/L	0.021	0.022
Coliform /100mL	8.0×10^5	8.3×10^5

At floating point of Paga, T-N and coliforms exceed the recommended standard. T-N, however, exceeds only 0.02 mg/L and it can be easily diluted by current and turbulent at surface. At Kila Kila, there is similar dilution characteristic to Paga's. Since flow of each nozzle is about double, but the depth of the diffuser pipe is 10 m deeper, almost same dilution ratio is obtained in Kila Kila.

Since vertical diffusion or initial dilution could not make coliforms (approx. 8.0×10^5 MPN/100mL) within allowable water standard, further diffusion by horizontal diffusion (Subsequent Dilution) is examined on coliforms.

Trends of coliforms and dilution ratio in Paga and Kila Kila are calculated in Table 5.6 and 5.7.

Table 5.6 Dilution Ratio and Coliforms Die-off by horizontal Diffusion (Paga) in 2015

Distance (m)	500	1,000	1,500	2,000	2,500	3,000	3,500	4,000
Dilution Ratio	0.048	0.034	0.028	0.024	0.022	0.020	0.018	0.017
Days	0.058	0.116	0.174	0.231	0.289	0.347	0.405	0.463
Die-off ratio	0.670	0.450	0.301	0.202	0.136	0.091	0.061	0.041
Coliform (/100mL)	26,107	12,409	6,799	4,950	2,369	1,450	900	565

Table 5.7 Dilution Ratio and Coliforms Die-off by horizontal Diffusion (Kila Kila) in 2015

Distance (m)	500	1,000	1,500	2,000	2,500	3,000	3,500	4,000
Dilution Ratio	0.070	0.050	0.041	0.035	0.032	0.029	0.027	0.025
Days	0.058	0.116	0.174	0.231	0.289	0.347	0.405	0.462
Die-off ratio	0.670	0.450	0.301	0.202	0.136	0.091	0.061	0.041
Coliform (/100mL)	38,936	18,505	10,138	5,889	3,541	2,162	1,342	842

Coliforms will be within the standard (1000 MPN/100 mL) after flowing of approx. 3.5 km down stream from Paga outfall and approx. 4.0 km of Kila Kila outfall.

(2) Complete Mixing Box Model Prediction in Papuan Lagoon

Table 5.8 shows T-N and T-P values in the year of 2015. In the year of 2015, T-N will be 0.18 to 0.22 mg/L and T-P will be 0.016 to 0.021 mg/L, and the values are less than the standard. Additionally the coastal water standard in Japan is listed in Table 5.9 as reference.

Table 5.8 Water Quality in the Coastal Water in 2015

	Standard	Box 1	Box 2	Box 3
T-N (mg/L)	0.3	0.22	0.22	0.18
T-P (mg/L)	0.03	0.020	0.021	0.016

Note : Box 1 – Port Moresby Harbor
Box 2 – Northwestern half of Papuan Lagoon
Box 3 – Southeastern half of Papuan Lagoon

Table 5.9 Coastal water - Category A (Fishery class 1 and bathing) Standard in Japan

Item	Standard
COD-Mn	< 2.0 mg/L
Coliform	< 1000 MPN/100 mL
T-N	< 0.3 mg/L
T-P	< 0.03 mg/L

3) Coral Reef Assessment

As a component of this Study, a coral reef assessment was carried out by the Motupore Island Research Department, University of Papua New Guinea to provide information on the distribution, occurrence and general status of the coral reef ecosytem fronting the coastal areas of Paga Point, Koki, Badili, Joyce Bay and Pari. The areas are shown in Fig.5.7 and the surveyed details are contained in Appendix G. The gathered information from this rapid appraisal will serve as basis if any change occurs in the local reefs due to the installation of a sewage outfall. The results can also be used for preparing environmental impact assessments and for planning, designing, and managing future sewerage outfalls for Port Moresby harbor as well as in other PNG coastal towns and cities.

(1) The Current Uses of the Area and The Impacts

During the survey, the team confirmed the sources of anthropogenic stresses on the marine environment. They are more concentrated nearer to shoreline.

Fishing. The two bays and the reefs are the fishing grounds for the local population. There is considerable fishing within the bays and the adjacent reefs. Line fishing, gill nets and spear fishing are the main fishing methods.

Disposal Practices. Observations indicate that the Bays are already severely polluted due to inadequate sewage system and improper solid waste disposals. Human feces and garbage from stilt households, and the existing untreated outfalls of the city are responsible for the contamination of the beaches and the shore waters. This imposes a risk of ciguatera (fish food poisoning), considering that the main supply of fish at the fishmarket comes from the survey site and the environs.

Recreational uses. The city residents heavily use the sandy beach on the windward side of Manubada as a picnic place. The shore waters are used for yachting and canoe racing.

Transportation. Ocean liners and container ships anchor in the Walter Bay. Anchor-damage may be minimal but increased shipping activities bring in other risks such as the discharge of oil and rubbish.

(2) Potential Impacts of the Ocean Outfall

There will be some disturbance to the coral, fish and benthic communities during construction, regardless of the route of the pipelines. The extent of the disturbance is unknown because specific roles of many component species in the marine community are not yet well-understood. It is however, well-known the coral reefs provide sanctuary of many fish species of high economic value. Any disturbance will have differential effects on the component species. In worst ecological scenario, there will be a shift in the biodiversity of the marine community towards undesirable species composition. The risk of an adverse impact would however be greatly minimized if the outfall is located well beyond the outer reef where water circulation is strong.

The results of rapid ecological survey results show that the ecosystems in the Walter and Joyce Bay areas are heavily polluted because of improper waste disposal practices and increasing industrial and economic activities. Despite the anthropogenic stresses, the marine environment still maintains a moderate level of biodiversity.

The release of pathogenic organisms from the sewage discharge has health risks. Low rates of dilution and flushing by the water circulation regime can deplete oxygen levels to the point of killing fish. It can raise nutrient levels, causing undesirable plant growth that may foul the water or smother reefs.

The net effect on the near-shore communities will be the reduction in the level of contamination, if and when the entire localized sewage disposal are connected to the proposed system. The proposed distance and depth of the outfall from the shore would help reduce the present level of stress. Acceptability of the discharge again depends upon the assimilative capacity and flushing of the receiving waters.

The present conditions in the lagoon is still keeping high oxygen and low nutrient levels, which will not cause the problems of killing fishes and raising undesirable plant growth that may foul the water or smother reefs. The preliminary water quality prediction indicates this level of water quality will continue at least the year 2015.

5.5.3 Disposal Options vs. Environmental Objectives

There are three locations for sewage disposal in the sea, namely; onshore (bay and harbour), offshore (Papuan Lagoon), and ocean. Standards for protection of aquatic ecosystem (marine waters) are adopted for the whole sea, while standards for recreational and aesthetic values are particularly applied for Papuan Lagoon.

1) Onshore

Port Moresby Harbour extends from southeast at Paga Point to northwest with 3 km width, 7 km length and 24 m depth at deepest, while half of the harbor have less than 10 m in depth. Walter Bay is located between Paga Point and Vabukori, having 12 m at deepest. The whole Joyce Bay is a tidal flat or inner lagoon and the bay is shallow.

Walter Bay, where Koki and Badili are located, and Joyce Bay are the water bodies to which raw sewage is presently discharged show a high degree of contamination. Water quality in this Study at Joyce Bay exhibits high concentration of SS, COD, T-N and T-P. This fact indicates that there is very poor flushing of raw sewage discharge onshore resulting to easy contamination of seawater. Standards for recreational and aesthetic values are applied.

Onshore discharge to a harbour or a bay may cause eutrophication in the future if the water body is comparatively small and effluent is large. In order to prevent this phenomenun, nutrients removal process might be required in addition to the proposed stabilization pond process.

Chlorination is inexpensive, widely available, and has a long history of proven effectiveness. The onshore discharge point is close to the coast of the city and pathogens may reach to the coast. Therefore, chlorination facility is installed but its usage and dosing rate shall be determined with great care. This is due to organic compounds typically present in sewage can combine with chlorine to form toxic chloro-organic compounds and excess free-chlorine is toxic to many aquatic species.

2) Offshore

Papuan Lagoon is divided into two parts by Loloruа Island at the center. The western part is 4 km in width, 12 km in length and with depths ranging from 5 to 15 m. The latter depth covers most of this part. The eastern part is almost of similar size, but 20 to 30 m in depth. The lagoon is surrounded by reefs and islands. There are three narrow passages that connect to the ocean (Coral sea): at the east end, the center, and the west end with widths of 0.5 to 1 km. The lagoon can be classified as a closed water body and has a limited capacity of accepting huge volume of sewage continuously.

The proposed treatment method is sedimentation basin + Disinfection. Even offshore discharge to the coralline Papuan Lagoon can cause eutrophication in the future if effluent is increased significantly. Periodical water analysis of seawater in the lagoon should be carried out to monitor the signs of eutrophication.

Sedimentation basin needs land and high capital cost, especially land availability in Paga point is very difficult. However, sedimentation basin can remove settleable solids taking out some associated pollutants, including organic matter, nutrients, heavy metals, toxic organics and pathogens, it will contribute to prevent water pollution in Papuan Lagoon.

However, offshore discharge point, the centre of Papuan Lagoon is close to coast of the city and pathogens may reach to the coast. Chlorination facility is installed but its usage and dosing rate shall be determined with great care.

3) Ocean

The ocean (part of the vast Coral sea) exists outside of Sinavi and Nateara reefs. The depth sharply increases from sea level to more than 500 m within a 2 km distance. If a sewage is discharged to the ocean, only a grit chamber is sufficient.

5.5.4 Assessment of Environmental Impacts

Both potential positive and negative impacts on the receiving water are evaluated.

1) Potential Positive Impacts

The potential positive impacts are: i) improved quality of effluent discharged, and ii) improved appearance and aesthetics.

(1) Improved Quality of Effluent Discharged
The water quality survey and the coral reef study indicates that Joyce Bay and Walter Bay are already severely polluted due to inadequate sewerage system and improper solid waste disposal. It can be safely predicted, that the impact of the discharge to the Papuan Lagoon of treated effluent from the improvement of the sewerage facilities on the aquatic environment and on the interest of public health would be beneficial, given the already severely affected nature of the area.

The final effluent from the proposed STPs will be chlorinated. The DEC draft guideline for coliform concentrations in effluent discharge will be strictly followed. Faecal coliform count for recreational and aethetics uses of marine waters is set at 200MPN/100mL, while E. coli count is 150MPN/100mL. With disinfection by chlorination, there will be decreased in pathogens such as faecal coliforms. Chlorination, however, is injurous to some marine organisms, mostly sessile, if concentration of residual chlorine is high. To mitigate this, longer outfall and diffuser (3 km discharge farther offshore) is provided for minimizing chlorination, and for higher dilution and improved dispersal to open ocean where biological communities is less (subject for confirmation awaiting the results of the coral reef study).

An improvement in the quality of shellfish and fishes collected for eating in the tidal flats due to the improved quality of water in which they live will occur. The elimination of short outfalls and the provision of a longer outfall will result to a decreased possibility of contamination of shellfish and fishes of microbial pathogens and other trace contaminants. Also, an improvement of turbidity levels especially in nearshore areas where these short outfalls are located is expected. This will result to an increased in light penetration and correspondingly to an increased biological growth of marine organisms.

(2) Improved Appearance and Aesthetics
Effluent discharge should not be visible to people in the shore. The construction of a long outfall where there is sufficient dilution mitigates the adverse aesthetics effects of effluent discharge. With the elimination of short outfalls where during low tide periods these are exposed, floating solids of wastewater origin in the tidal flats would be removed through screening and sedimentation tanks.

Coral die-back may be due to light limitation which is caused by solids discharged in raw sewage, and the risk of the die-back will be mitigated by these treatment.

Because of its high BOD loading, untreated sewage being discharged into these tidal flats causes excessive plankton growth and then decays resulting to emission of foul odor. Coupled by the smell of raw sewage from short outfalls, the odor level becomes very unpleasant. With the construction of STPs and a longer outfall, BOD loading nearshore would significantly be decreased.

2) Potential Negative Impacts

The potential negative impacts are: i) effluent discharge to Papuan Lagoon, ii) disposal of waste sludge and iii) air pollution (odour), aesthetics, noise and vibration.

(1) Treated Effluent Discharge to Papuan Lagoon
The release of treated effluent coming from the proposed STP will result in a localised increase of nutrients, organic matter, and toxic substances at the sewer outfall during regular operation of the wastewater treatment facility. Nutrients such as nitrogen and phosporous are not significantly removed even with secondary treatment. Excessive inputs of these nutrients cause euthrophication, loss of seagrass and algal beds, and damage to coral reefs.

High nutrient concentrations promote algal blooms which result to oxygen depletion, growth of toxin producing algae (red tide, blue-green tide phenomena), and obnoxious odor during die-offs.

Complete mixing box model prediction in Papuan Lagoon indicates that expected T-N and T-P in 2015 are lower than those of the standard, and the risk of eutrophication is minimum.

5.6 Regulatory Environment

A summary of the relevant acts and regulations pertaining to the protection and conservation of the water resources and sewerage development is shown below. Specifics of these legislation are presented in Chapter 10, Initial Environmental Examination.

Legal Framework	Administered by Department/Authority	Purpose
- Environmental Planning Act	Department of Environment and Conservation	Protection and management of environmental systems; Control of environmental critical or sensitive development projects through approval of environmental plans
- Environmental Contaminants Act	Department of Environment and Conservation	Control of discharges of environmental contaminants into the environment through licensing
- Water Resources Act	Bureau of Water Resources, Department of Environment and Conservation/ Water Resources Board	Protection and management of all water resources through a system of permits
- Public Health Act	Department of Health	Consolidates regulations pertaining to public health including sewerage regulations
- National Capital District Commission Act	National Capital District Commission	Management of Port Moresby's resources and services
- National Capital District Water Supply and Sewerage Act	EDA RANU	Planning, design , construction and management of water and sewerage facilities in NCD

1) Department of Environment and Conservation (DEC)

The DEC oversees the protection and conservation of the country's natural resources. It reviews and approves environmental plans of projects that will have significant impact to the environment. DEC determines if a project requires an Environmental Plan (EP). All developers cannot implement a project if an EIS or Plan is required or until such a Plan is accepted. At present, however, there is no guideline on what type of development projects/activities is covered by the Environmental Plan.

Permission has to be obtained from DEC for the construction of STPs, sewage marine outfall, and reclamation works along the coastal areas of Joyce Bay and Paga Point. In relation to this, the Waterboard had prepared an Environmental Plan for the Joyce Bay Sewage Outfall Study in 1988. However, early discussions with DEC officials indicated the need to conduct additional baseline studies, specifically, coral reefs assessment in the coastal waters to be impacted by the development.

Corollary to this activity, a licence to discharge wastewater into the Papuan Lagoon must also be obtained from DEC. Reference should be made to the Environmental Contaminants Act, Section 16.

2) Bureau of Water Resources, DEC and Water Resources Board

The discharge of contaminated water is one of the major concerns of the Water Resources Board. The approval of the Board is required for all water permits for water investigation purposes and water usage. Reference should be made to the Water Resources Act, Sections 15, 19 and 28.

3) Department of Health (DOH)

The DOH is responsible in monitoring, promoting, and maintaining community health. This includes the provision and monitoring of general health care services, and the monitoring of water supply, sanitation and sewerage. Of particular public health concerns are the enforcement of the Sewerage Regulation of the Public Health Act and the maintenance of safe bathing beaches as well as contamination of edible fisheries. The Chief Health Inspector of the National Capital District Commission, who is the appointed Local Medical Authority in NCD, is responsible in overseeing the implementation of the Sewerage Regulation of the Public Heath Act.

The disposal of wastewater and trade waste into the drain or sewer is covered under this Regulation. Reference is made to the Public Health Act, Sewerage Regulation, Sections 17 and 18.

4) National Capital District Commission (NCDC)

The NCDC through its Health Division is charged with the management of Port Moresby,s services and resources. It conducts routine bacteriological tests of the sea water along the coastal areas of Port Moresby. When high cases of faecal contamination occurs, the Commission provides public warnings to avoid swimming, washing and fishing in the sea due to potential health hazard.

5) EDA RANU

EDA RANU maintains and operates the public sewerage system in NCD. On the basis of the Public Health Act and the Environmental Contaminants Act, the quality of its effluent must comply with the regulations.

5.7 Monitoring Plan

This section provides a framework for monitoring the receiving environment and the effluent. Monitoring plan, as a component of the environmental management program for the Port Moresby Sewerage Development Project shall be introduced.

The monitoring plan can serve as a management tool within which the operator of the sewerage system (EDA RANU), the DEC, and the DOH would be able to administer their area of responsibilities. Specifically, it will provide directions in the management of effluent and in the maintenance of the water quality objectives of receiving waters.

The plan is drawn up for major activities: water quality (chemical) analysis and biological studies. A chemical analysis or water quality monitoring will have to be implemented to determine and control the quality of the effluent discharges as well as the receiving waterbodies. However, chemical analysis, although important and necessary, does not provide all the information required in pollution assessments. Biological studies are of more particular value in providing a realistic assessment of pollution. But it should be understood that these items cannot be taken exclusively with each other, rather, it should be complementary.

5.7.1 Water Quality Monitoring

Monitoring should be undertaken on the effluent quality and the water quality of the receiving waterbodies. As a preventive measure to control contamination of toxic and hazardous materials into the sewerage system, water quality must also be regularly undertaken in industrial establishments.

1) Sampling Locations

Sampling locations have to be established in pumping stations, treatment plants, receiving bodies of water, and at discharge points of factories.

2) Frequency

Based on assessment and needs of the existing situation, monitoring can be done on different ways:

(1) Scheduled monitoring involves an arranged site visit. The monitoring schedule should include a thorough sampling and inspection in accordance with a predetermined schedule at least once a month, and collection of composite samples and checks of flow rate measurements.

(2) Unscheduled monitoring involves an unannounced site visit and is used to spot check water quality. Grab samples may be taken and flow measurement checked.

(3) Investigative monitoring is conducted in response to a known or suspected high pollution levels from professional observations, public complaint or problems detected within the sewerage system. Monitoring may be undertaken within the sewerage system and/or at the waste generating premises.

3) Method and Analysis

Samples must be taken by appropriately trained staff using sampling equipment and methods that are valid for the analysis required. Samples should be analyzed by qualified chemists in the laboratory of EDA RANU. If validation has to be made, samples have to be sent to an accredited laboratory for analysis.

The final plan will include the parameters that have to be regularly monitored based the result of the survey. It will provide cost estimates and the required laboratory equipment and materials to conduct the analysis.

Specific to this system, is the monitoring of the ocean outfall. The AWWA Position Paper on Ocean Disposal of Wastewater provides a comprehensive approach starting from commissioning up to operation. Right after completion of the outfall, the following must be undertaken:

(1) a series of test using dye or other tracers to confirm that the outfall is performing as predicted. Generally such tests are undertaken over 2 to 4 weeks as part of commissioning the outfall. Several tests should be conducted to confirm the distribution of effluent discharge along the diffuser and the minimum initial dilution under weak and typical current condition.

(2) long term monitoring of head losses to detect any problems due to sediment accumulation or blockage of the pipes. This will include: i) biological monitoring in the vicinity of the outfall diffuser, along the principal directions of travel of the effluent field and at a suitable control site/s; ii) routine sampling and analysis of effluent composition; and iii) regular inspections of the pipeline to detect corrosion or decline in structural integrity.

Furthemore it is recommended that all outfalls should be inspected by an engineer-diver every 2 years and a report on the condition of the outfall be submitted. Particular items which should be included in the inspection are: i) ports-open or clogged/marine growths; ii) sediment accumulation inside diffuser; iii) damage to coatings; iv) corrosion; v) scour and undercutting; vi) objects attached to outfall-anchors; and vii) lack of anchors or of attachment to piles.

5.7.2 Biological Studies

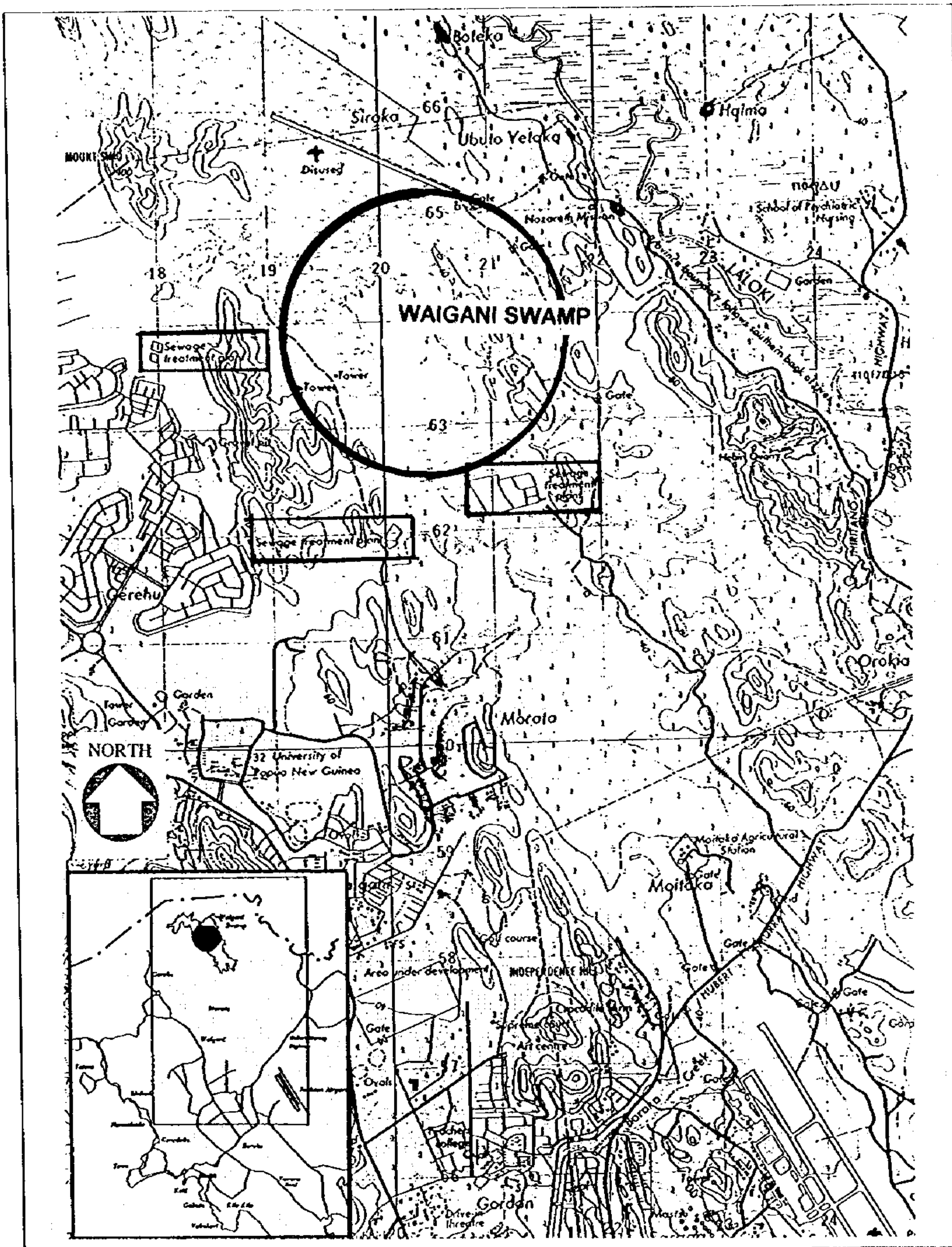
1) Monitoring of Coral Reefs

The 3 km outfalls in Paga Point and Joyce Bay will have to be monitored at least 4 times in the first year to document the rate and type of change in the community structure. Baseline data on the coral reef survey are used extensively in identifying critical areas which will serve as monitoring station aside from the stations.

The line intersent transects (LIT) stations, or the stations for long term monitoring of coral health are proposed in Figure 6 of Appendix G.

2) Monitoring of Waigani Swamp and Laloki River

Periodic detailed study on the effects of effluent disposal on the aquatic life, specifically, the phytoplanktons shall be implemented in conjunction with the Biology Department, UPNG, who has been monitoring the status of the swamp.



Date	Title	Fig.
May 1998	Waigani Swamp and Its Environs	5.1

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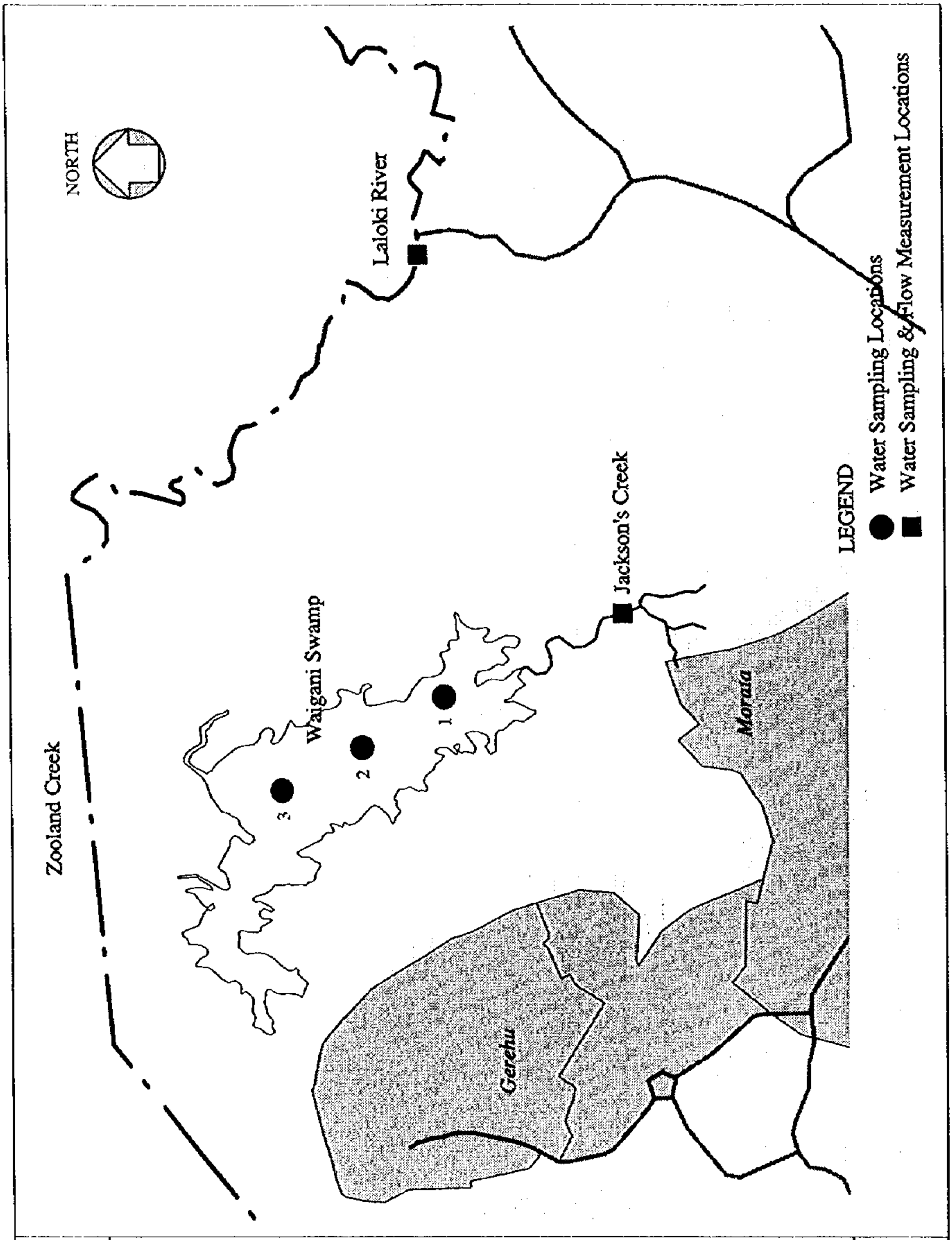

Date	Title	Fig.
May 1998	Water Sampling and Flow Measurement Sites, Waigani Swamp and Laloki River	5.2

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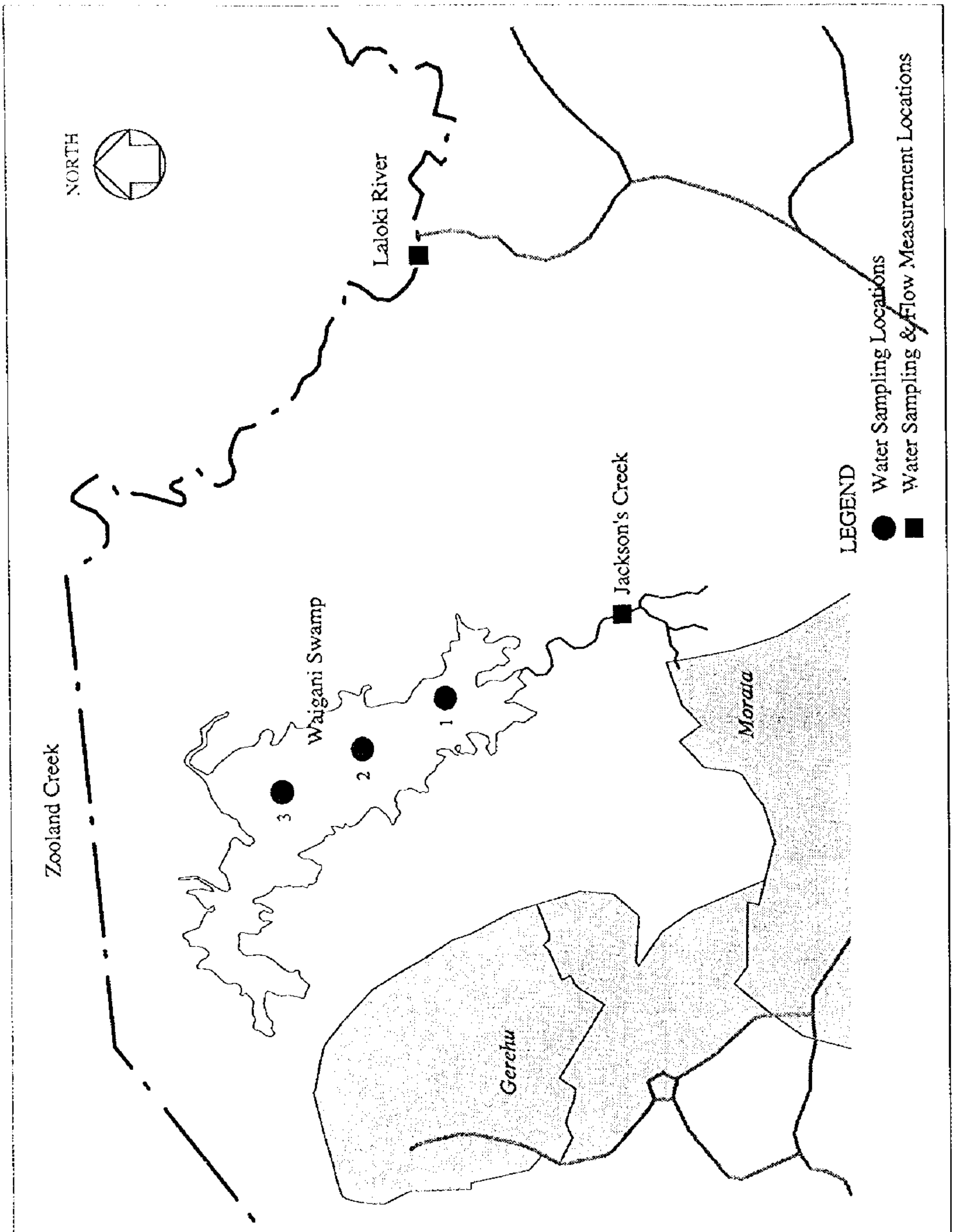

Date	Title	Fig.
May 1998	Water Sampling and Flow Measurement Sites, Waigani Swamp and Laloki River	5.2

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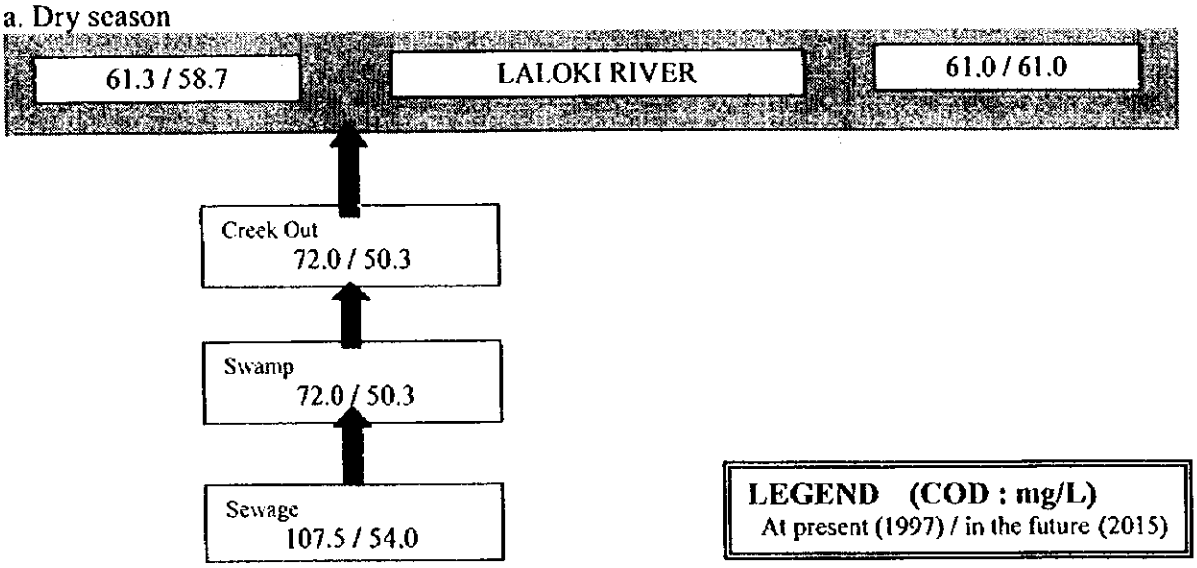
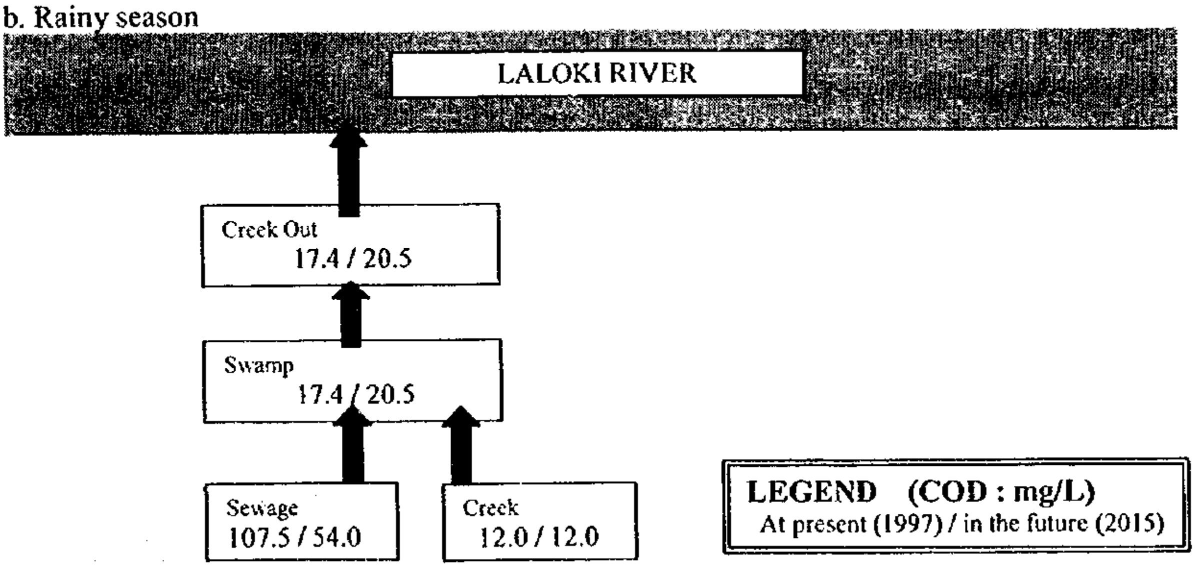
(1) Scenario 1: With sewage treatment

a. Dry season



b. Rainy season



Date	Title	Fig.
May 1998	The Result of Pollutant Load Balance Analysis (Scenario 1)	5.3

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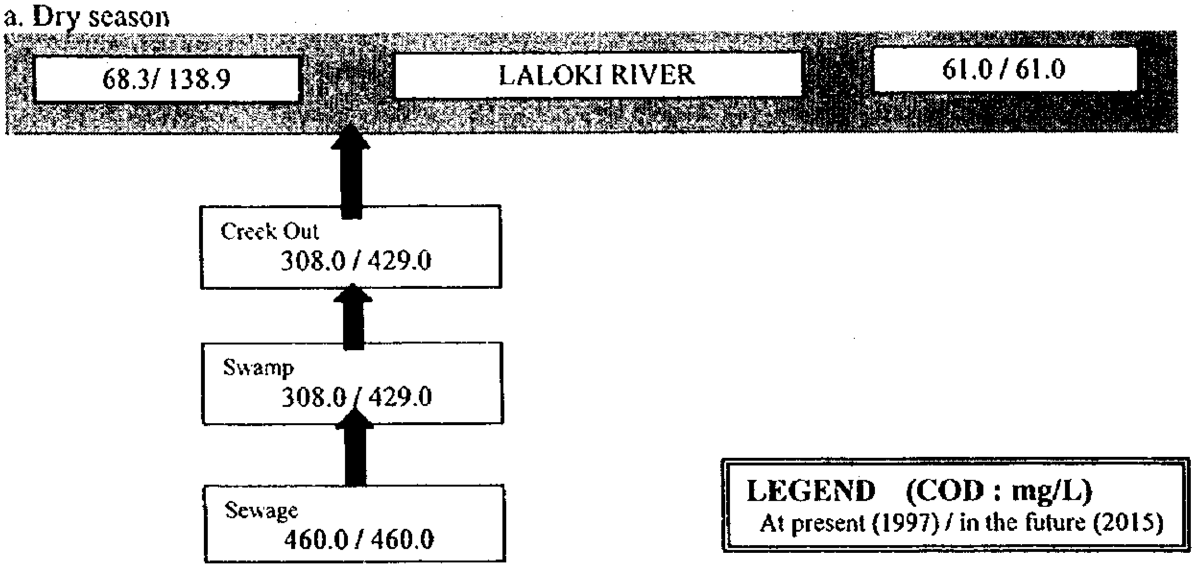
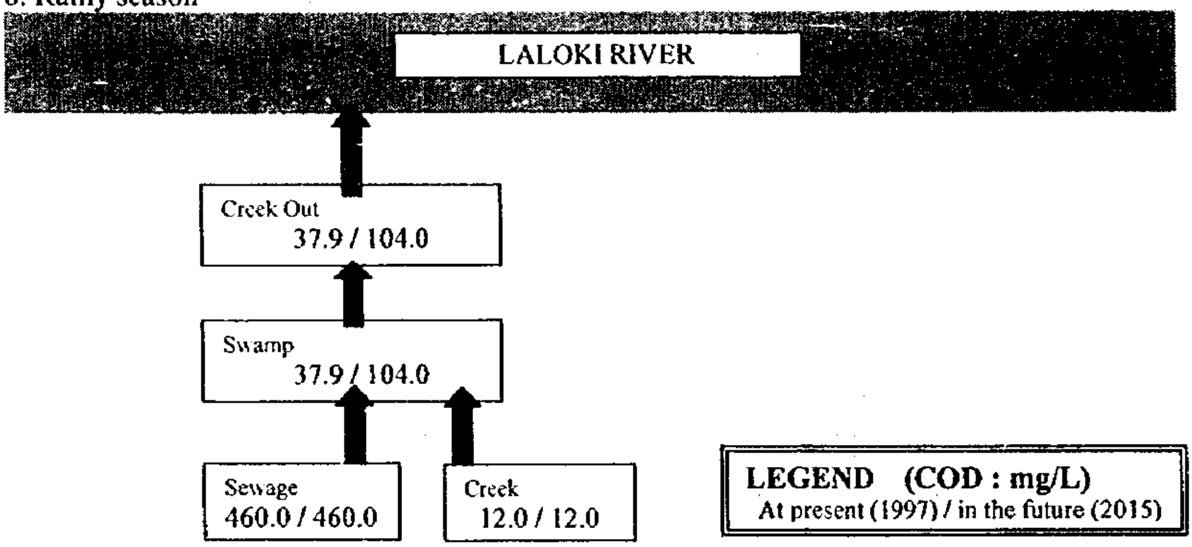
(2) Scenario 2: Without sewage treatment

a. Dry season



b. Rainy season



Date	Title	Fig.
May 1998	The Result of Pollutant Load Balance Analysis (Scenario 2)	5.4

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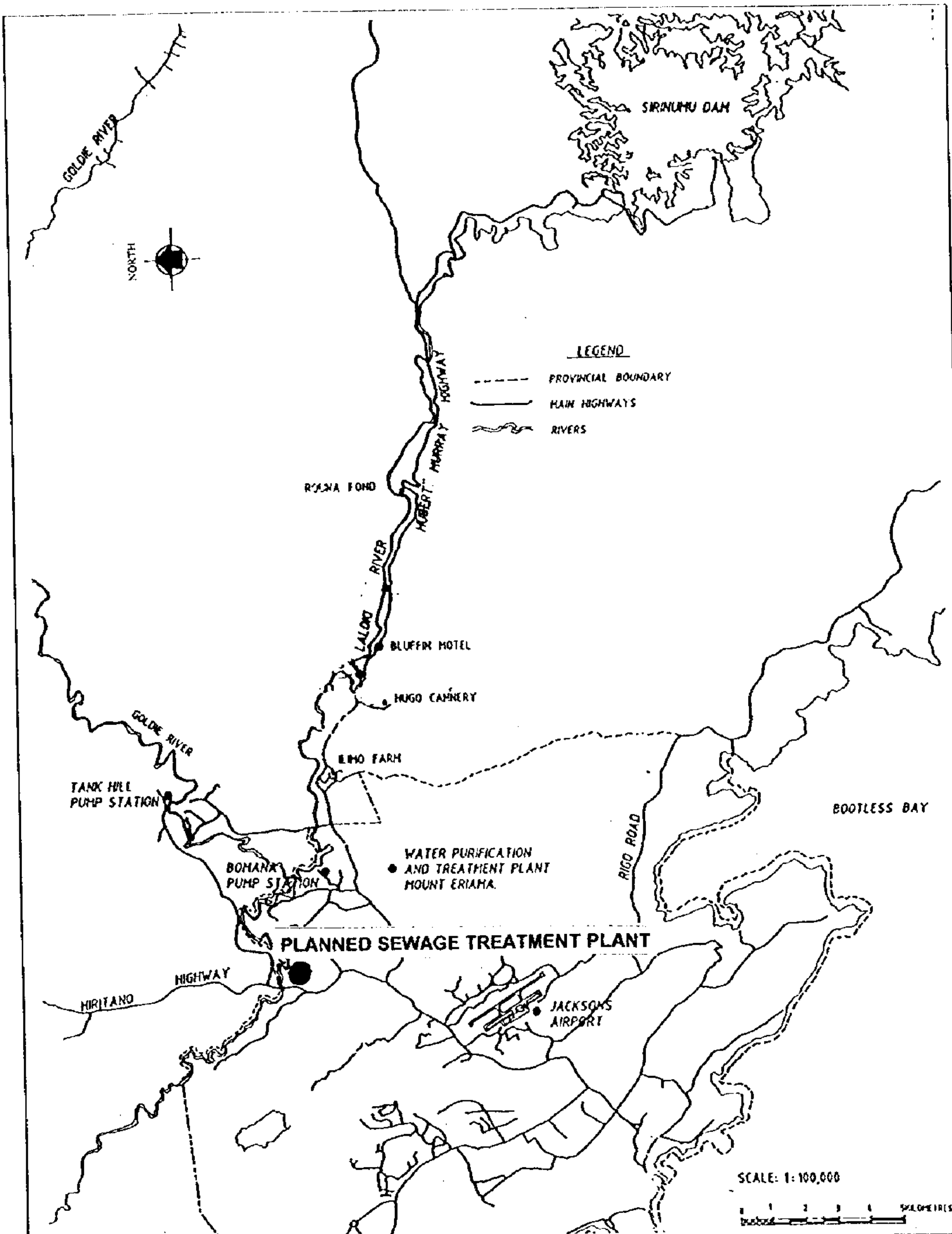

Date	Title	Fig.
May 1998	Location of the Laloki River and the Planned Sewage Treatment Plant	5.5

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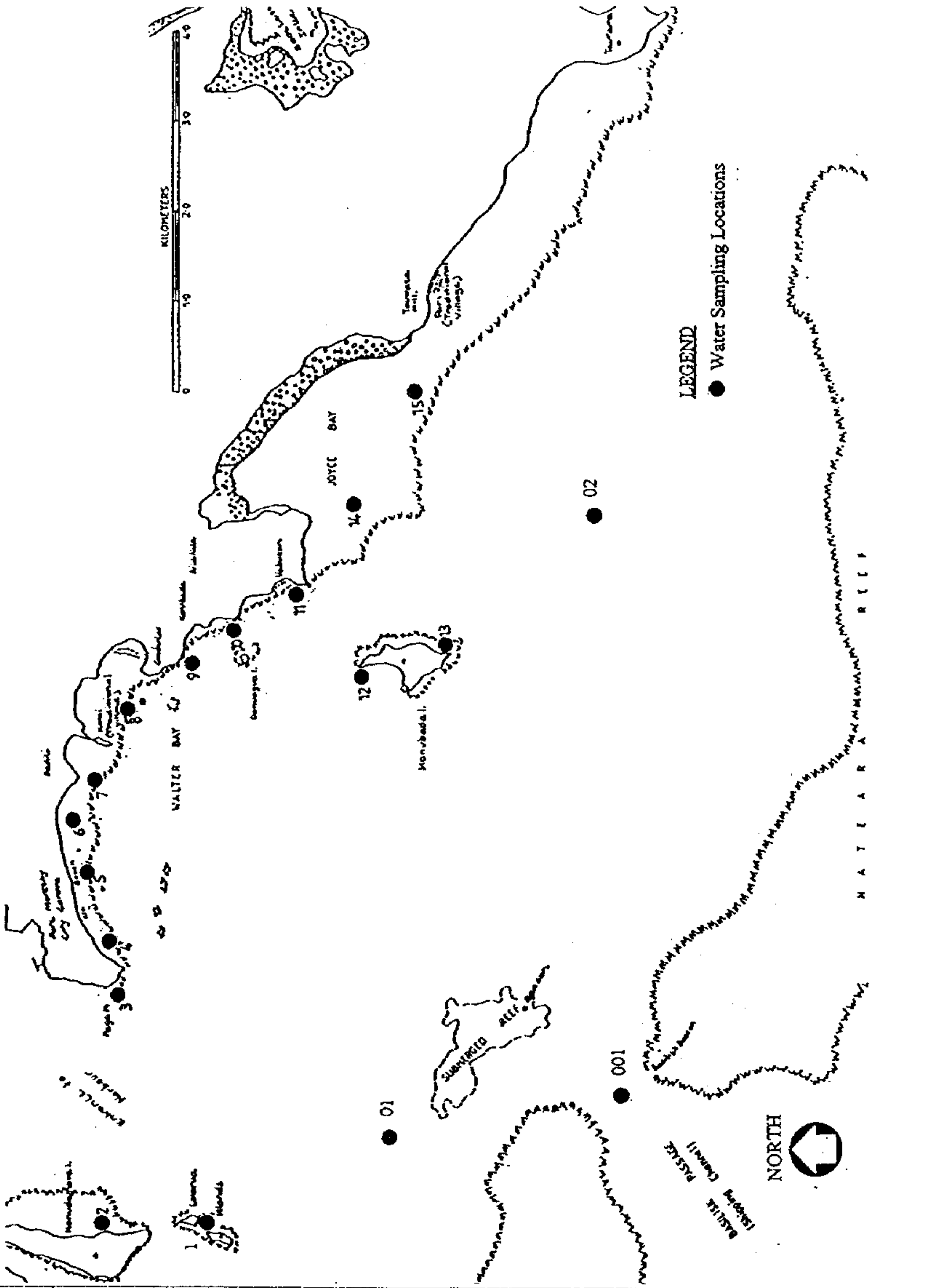

Date	Title	Fig.
May 1998	Water Quality Sampling Stations, Coastal Waters	5.6

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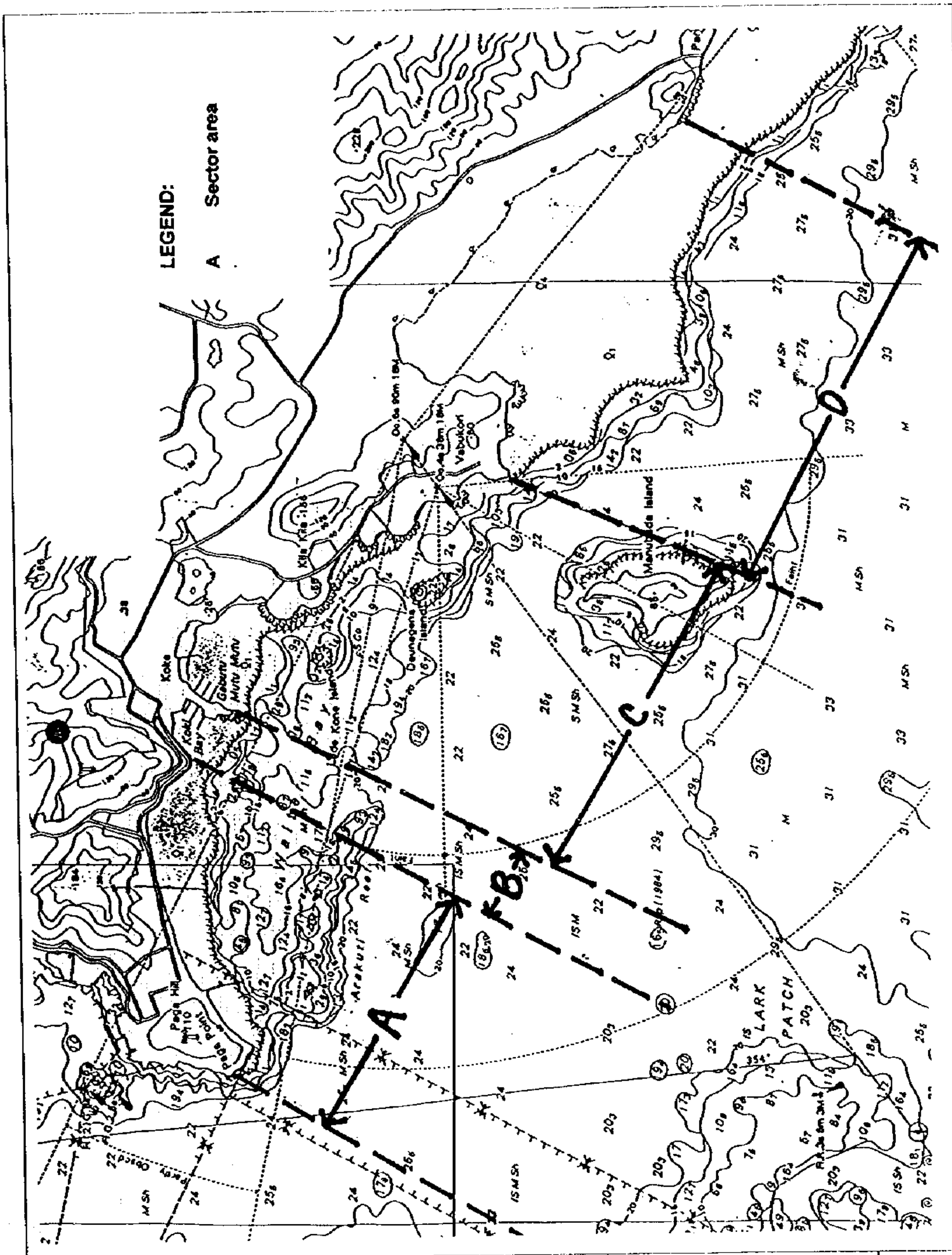

Date	Title	Fig.
May 1998	Coral Reef Assessment Study Area	5.7

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CHAPTER 6

PROPOSED SEWERAGE SYSTEM

CHAPTER 6 PROPOSED SEWERAGE SYSTEM

6.1 Sewerage Zones

The present and the planned urban areas known as the planned sewerage area are divided into eight zones, namely; Waigani, Morata, Gerehu, Bomana, for the inland area, and Paga Point, Kila Kila, Vetorogo, Dogura Kohu, for the coastal area. The locations of the planned sewerage area are shown in Fig. 6.1.

6.1.1 Inland Area

The three zones of the inland area, such as Waigani, Morata and Gerehu have an existing sewerage system and three sewage treatment plants of their own. The STPs are situated in a government land where there are sufficient areas for expansion. The future sewerage system in the three zones will follow the existing sewerage layout with improvement and expansion to meet the increased demand.

The newly planned Bomana zone (8-Mile to 9-Mile area) is separated topographically from the three mentioned zones by a ridge and slopes down gently from south to north toward the Laloki River. This zone is proposed to have a separate sewerage system with a treatment plant near the Laloki River.

The planned design flow of each zone is shown in Table 6.1 below.

Table 6.1 Design Flow in Inland Area

Name of Zone	Population in 2015	Design Flow (m^3/day) in 2015	
		Daily Average	Daily Maximum
Waigani	192,757	86,741	112,763
Morata	33,834	15,225	19,793
Gerehu	40,040	18,018	23,423
Bomana	88,638	39,887	51,853
Total	355,269	159,871	207,832

6.1.2 Coastal Area

The population in the coastal area is localized and concentrated in a narrow stretch. Except for the Paga Point zone where raw sewage after screening and grit removal is discharge via a 3 km outfall, Kila Kila zone, and 6 other smaller catchments discharge raw sewage directly into the shoreline via short outfalls.

The Vetorogo and Dogura Kohu zones located at the extreme ends of the coastal area are yet to be developed so that the necessity of a separate system is premature. Therefore, these two zones are planned as independent zones to be developed when the needs arise. The Vetorogo zone is planned mainly as an industrial area. The Dogura Kohu zone is divided into three sub-zones by two ridges. Separate STPs are required near the mouth of the bay, and 2 pumping stations are proposed for collection of wastewater.

To provide an efficient sewerage facilities, four alternative analyses will be described in the succeeding section to select the most viable option.

The planned design flow of each zone is shown in Table 6.2.

Table 6.2 Design Flow in Coastal Area

Name of Zone	Population in 2015	Design Flow (m^3/day) in 2015	
		Daily Average	Daily Maximum
Paga Point	35,981	15,923	20,700
Kila Kila	70,140	31,563	41,032
Vetorogo	29,145	13,115	17,050
Dogura Kohu	40,465	18,209	23,672
Total	175,731	78,810	102,454

6.1.3 Proposed System

The analysis of alternatives has proposed a sewerage system of the study area as described below. The major components of the proposed sewerage system are shown in Fig. 6.1 while the sizes and lengths of trunk sewers in each sewerage system are shown in Table 6.4. A total length of 80,300 m of trunk sewers with diameters ranging from 200 mm to 600 mm is to be constructed using centrifugal reinforced concrete pipes.

The force mains are to be designed including pumping stations and trunk sewers. The total length of force main approximately 21,600 m with diameters ranging from 150 mm to 800 mm are to be installed using ductile iron pipe.

Several pumping stations are proposed with design capacities and locations shown in Table 6.5 and Fig. 6.2 respectively. All pumps to be used are submersible-type, some existing civil structures where a retention time of the planned sewage flow is more than 9 minutes will be utilized. Those pumping stations are Koki, Lawes Road, Davara and Yacht Club. Other pumping stations are to be demolished and rebuilt.

Stabilization pond method of wastewater treatment will be used such that the 3 existing STP's at Waigani, Morata and Gerehu will be expanded and 3 new stabilization ponds will be built for Bomana, Vetorogo and Dogura Kohu. Sedimentation basins are proposed for Paga Point and Kila Kila before discharge via sea outfall of an adequately safe distance from the coast.

Table 6.3 shows the receiving body of each STP.

Table 6.3 Receiving Water Body

Area	Zone or STP	Receiving Water Body			
		Fresh Water Discharge		Ocean Discharge	
		River	Swamp	On Shore	Off Shore
Inland Area	Waigani		O		
	Morata		O		
	Gerehu		O		
	Bomana	O			
Coastal Area	Paga Point				O
	Kila Kila				O
	Vetorogo			O	
	Dogura Kohu			O	

Note: O means applicable.

Table 6.4 Proposed Trunk Sewers and Force Mains

	Inland Area				Coastal Area				Total
	Waigani	Morata	Gerehu	Bomana	Paga Pont	Kila Kila	Vetorogo	Dogura Kohu	
1.Sewer Network (m)	4,900ha	720ha	810ha	3,680ha	332ha	317ha	1,210ha	1,680ha	13,649ha
	12,600	63,000	56,000	515,200	33,320	44,380	235,200	169,400	1,129,100
2.Trunk Sewer (m)									
200mm	0	0	0	0	3,930	6,231	0	0	10,161
250mm	0	0	0	0	246	57	0	0	303
300mm	463	0	949	8,800	2,580	910	5,000	2,900	21,602
350mm	2,320	0	0	7,700	270	0	4,400	2,600	17,290
400mm	2,212	1,712	1,362	2,900	110	200	1,600	1,000	11,096
450mm	0	912	0	1,900	640	0	1,200	700	5,352
500mm	3,337	712	0	4,500	1,181	52	0	1,600	11,382
600mm	0	0	0	900	0	2,216	0	0	3,116
S-Total	8,332	3,336	2,311	26,700	8,957	9,666	12,200	8,800	80,302
3.Force Main (m)									
150mm	0	0	0	0	960	1,160	0	0	2,120
200mm	0	0	0	0	0	3,500	0	1,700	5,200
250mm	0	0	0	0	0	0	500	0	500
300mm	0	0	0	0	350	1,736	500	1,500	4,086
350mm	0	0	0	0	220	0	0	2,000	2,220
400mm	0	0	0	0	0	0	0	0	0
450mm	0	0	0	0	2,480	1,160	0	1,200	4,840
500mm	0	0	0	0	303	0	0	0	303
600mm	0	0	0	0	0	0	0	2,000	2,000
700mm	0	0	0	0	0	0	0	0	0
800mm	0	0	0	0	0	360	0	0	360
S-Total	0	0	0	0	4,313	7,916	1,000	8,400	21,629
4.Ocean Outfall (m)									
					3,650				3,650
S-Total	0	0	0	0	3,650	0	0	0	3,650

Table 6.5 Capacity for the Pumping Facilities

Zone	Pumping Station			Planned Sewage Flow						Pump Head (Hazen's Formula, C=110)						Pump Specification					Remark
	Name		No. in	Population	Qd_{ave}	Peak Factor	Qh_{max}		Type*	Suction WL	Discharge WL	H_{actual}	H_{loss}	H_{pump}	Total	Nos.	Q	Dia	Output Calc.	Output STD.	
			Fig.6.2	Person	m³/day	-	m³/day	m³/min		M	M	m	m	m	m	-	m³/min	mm	Kw	Kw	
Vetorogo	Vetorogo	No.1	1	6,000	2,700	1.8	4,860	3.38	III	0.0	5.0	5.0	3.72	1.5	10.22	2 (+1)	1.69	100	5.0	5.5	New
		No.2	2	10,000	4,500	1.6	7,200	5.00	III	0.0	5.0	5.0	3.16	1.5	9.66	2 (+1)	2.50	150	7.0	7.5	New
Paga Point	Tatana	No.1	3	2,750	1,238	2.0	2,475	1.72	III	-0.5	10.0	10.5	5.65	1.5	17.65	2 (+1)	0.86	100	4.4	5.5	New
		No.2	4	2,825	1,271	2.0	2,543	1.77	III	-2.6	-0.5	2.1	19.97	1.5	23.57	2 (+1)	0.88	100	6.0	7.5	New
		No.3	5	5,547	2,496	1.8	4,493	3.12	III	0.0	10.0	10.0	6.43	1.5	17.93	2 (+1)	1.56	100	8.1	11.0	New
		No.4	6	6,453	2,904	1.8	5,227	3.63	III	-9.4	1.0	10.4	0.77	1.5	12.67	2 (+1)	1.81	100	6.6	7.5	New
	Hanuabada	No.1	7	8,264	3,719	1.8	6,694	4.65	III	-1.0	5.2	6.2	0.72	1.5	8.42	2 (+1)	2.32	150	5.6	7.5	New
		No.2	8	17,464	7,859	1.6	12,574	8.73	IV	-4.5	9.0	13.5	3.65	1.5	18.65	3 (+1)	2.91	150	15.7	18.5	New
	Konedobu	No.1	9	8,639	3,888	1.8	6,998	4.86	III	-0.4	0.0	0.4	0.62	1.5	2.52	2 (+1)	2.43	150	1.8	0.0	New
		No.2	10	27,330	12,299	1.5	18,448	12.81	IV	-0.1	10.9	11.0	5.01	1.5	17.51	3 (+1)	4.27	200	21.6	22.0	Rebuild
	Yacht Club		11	545	245	2.0	491	0.34	I	1.5	13.6	12.1	0.13	1.5	13.73	1 (+1)	0.34	100	1.3	0.0	Rehabilitate
	Stanley		12	32,160	14,472	1.5	21,708	15.08	V	-1.0	15.9	16.9	1.23	1.5	19.63	3 (+1)	5.03	200	28.4	30.0	Rebuild
	Paga		13	35,384	15,923	1.5	23,884	16.59	V	-1.9	5.0	6.9	0.72	1.5	9.12	3 (+1)	5.53	200	13.5	15.0	Rebuild
	Davara		14	2,592	1,166	2.0	2,333	1.62	III	-1.4	1.8	3.2	1.15	3.5	7.85	2 (+1)	0.81	100	1.8	0.0	Rehabilitate
	Lawes		15	1,713	771	2.0	1,542	1.07	II	-0.3	0.7	1.0	0.53	2.5	4.03	1 (+1)	1.07	100	1.2	0.0	Rehabilitate
Kila Kila	Koki		16	4,634	2,085	2.0	4,171	2.90	III	-2.1	8.0	10.1	0.77	1.5	12.37	2 (+1)	1.45	100	5.2	0.0	Rehabilitate
	Badili		17	20,348	9,157	1.5	13,735	9.54	IV	-1.8	25.0	26.8	3.37	1.5	31.67	3 (+1)	3.18	150	29.0	30.0	Rebuild
	Gabutu	No.1	18	999	450	2.0	899	0.62	I	-3.5	15.0	18.5	0.95	1.5	20.95	1 (+1)	0.62	100	3.8	5.5	New
		No.2	19	2,668	1,201	2.0	2,401	1.67	II	-1.5	22.0	23.5	2.91	1.5	27.91	2 (+1)	0.83	100	6.7	7.5	New
		No.3	20	629	283	2.0	566	0.39	I	-3.5	22.0	25.5	0.27	1.5	27.27	1 (+1)	0.39	100	3.1	5.5	New
	Vabukori	No.1	21	5,135	2,311	1.8	4,159	2.89	III	-13.5	14.0	27.5	3.97	1.5	32.97	2 (+1)	1.44	100	13.7	15.0	New
		No.2	22	1,819	819	2.0	1,637	1.14	II	-3.5	14.0	17.5	4.30	1.5	23.30	1 (+1)	1.14	100	7.6	11.0	New
		No.3	23	16,511	7,430	1.6	11,888	8.26	IV	-3.5	5.5	9.0	22.41	1.5	32.91	3 (+1)	2.75	150	26.1	30.0	New
	Kaugere		24	28,436	12,796	1.5	19,194	13.33	IV	11.0	20.9	9.9	0.31	1.5	11.71	3 (+1)	4.44	200	15.0	15.0	Rebuild
	Kila kila		25	53,629	24,133	1.5	36,200	25.14	V	-2.1	5.5	7.6	0.38	1.5	9.48	3 (+1)	8.38	250	21.3	22.0	New
	Pari		26	2,430	1,094	2.0	2,187	1.52	III	-0.3	9.0	9.3	16.10	1.5	26.90	2 (+1)	0.76	100	5.9	7.5	New
Dogura Kohu	Dogura Kohu	No.1	27	3,000	1,350	2.0	2,700	1.88	III	0.0	15.0	15.0	3.71	1.5	20.21	2 (+1)	0.94	100	5.5	5.5	New
		No.2	28	3,000	1,350	2.0	2,700	1.88	III	0.0	13.0	13.0	8.91	1.5	23.41	2 (+1)	0.94	100	6.3	7.5	New
		No.3	29	6,000	2,700	1.8	4,860	3.38	III	0.0	14.0	14.0	4.59	1.5	20.09	2 (+1)	1.69	100	9.8	11.0	New
		No.4	30	12,100	5,445	1.6	8,712	6.05	IV	0.0	22.0	22.0	8.50	1.5	32.00	3 (+1)	2.02	100	18.6	22.0	New
		No.5	31	20,200	9,090	1.5	13,635	9.47	IV	0.0	5.0	5.0	3.44	1.5	9.94	3 (+1)	3.16	150	9.0	11.0	New
		No.6	32	38,200	17,190	1.5	25,785	17.91	V	0.0	5.0	5.0	4.58	1.5	11.08	3 (+1)	5.97	200	19.1	22.0	New
Morata	Morata		33	6,720	3,024	1.8	5,443	3.78	III	0.0	5.0	5.0	4.58	1.5	11.08	2 (+1)	1.89	100	6.0	7.5	Rebuild

Type*: refer to Appendix C.2

6.2 Sewerage for Inland Area

6.2.1 Collection System

1) Waigani Zone

The flow capacity of the existing trunk sewer in the largest Waigani zone was evaluated for the design year 2015 (refer to Appendix C). The results of the evaluation showed that the capacity of trunk sewer was inadequate by approximately 9,000 m of pipeline. Parallel trunk sewers are proposed for the inadequate sections. The size of the additional trunk sewers was decided such that the velocity of pipes at the full-flow rate is approximately 1.0 m/s. The required trunk sewers for the Waigani zone are as follows:

300 mm – 463 m, 350 mm – 2,320 m, 400 mm – 2,212 m,
500 mm – 3,337 m, 900 mm – 487 m

The land use plan for 2015 shows that approximately 90 ha., of additional land will be urbanized in this zone by 2015. To determine the size of sewer pipes required for the 90 ha. Land, the sewer pipe density was calculated by selecting nine locations in the existing sewered area. The average sewer pipe density was computed at 140 m/ha., indicating a total requirement of 12,600 m (90 m × 140 m/ha.) length of sewer with diameters between 150 mm to 200 mm.

2) Morata Zone

The Morata zone is rather small with a present urban area of 270 ha., and a population of about 8,500 in 1995. The topography generally shows mountainous terrain in the west and low land in the east, with a single trunk sewer carrying sewage from west to east to the Morata STP.

The land use plan for 2015 shows that an additional 450 ha. of land is to be developed from east to west of the present urban area. The population in 2015 is expected to reach 34,000 which is four times the existing population with the flow rate estimated to increase from 3,875 m^3/day to 15,225 m^3/day. The existing trunk sewer will be under capacity by approximately 3,400 m.

It is proposed to install additional trunk sewers parallel to the existing in the area where the capacity is inadequate. The results showed the requirements as follows:

400 mm – 1,712 m, 450 mm – 912 m, 500 mm – 712 m

By the year 2015, the 450 ha. of land to be developed would require a total length of 63,000 m (450 ha × 140 m/ha) of sewer with diameters ranging from 150 mm to 200 mm.

The existing Morata Pumping Station has a flow rate of 1.55 m^3/min. The total inflow rate by the year 2015 is estimated to increase to 3.78 m^3/min, indicating a huge shortfall in capacity. To cope up with this increase improvement to the existing facilities or an additional pumping station will be required.

However, because of the huge difference in capacities, both proposals are difficult to implement since a large imbalance is likely to occur. Therefore, by abolishing the existing pumping facilities, a new pumping station is to be constructed to include an additional 450 m rising main at diameter 250 mm.

3) Gerehu Zone

The Gerehu zone lies on the northernmost part of the present urban area. With the Gerehu Sewerage Treatment Plant (stabilization pond) nearby, the Gerehu zone measures 410 ha. with the population of about 20,000.

The land use plan for 2015 envisages development of an additional 400 ha. Further north with the population estimated to reach 40,000. The sewage flow rate is estimated to increase from 8,826 m^3/day to 18,018 m^3/day. Based on these figures, the existing trunk sewer will have a shortfall of about 2,300 m.

It is proposed to lay a new trunk sewer parallel to the existing in the area where the capacity is inadequate. The results of the study indicated the requirements as follows:

30 0mm – 949 m, 400 mm – 1,362 m

The 400 ha. development will require 150 mm to 200 mm total sewer reticulation of about 56,000 m estimated at 140 m/ha.

4) Bomana Zone

The Bomana zone is a wide low flat land bounded by hills to the east of the present urban area. Generally, the zone slopes down gently from south to north towards the Laloki River.

According to the land use plan for 2015, large-scale development is anticipated with the following estimated figures; developed area at 3,680 ha., estimated population at 40,465, estimated sewage flow rate at 39,887 m^3/day. The industrial area is located at the centre of the population.

In as much as there is no detailed development plan available, the sewerage plan for Bomana zone is proposed based on the aspect that the sewage will be topographically collected and treated at the STP (stabilization pond) located near the Laloki River.

The total sewer reticulation is 515,200 m computed at 150 m/ha. The length and diameter of the trunk sewers were computed based on the area as follows:

300 mm – 8,800 m, 350 mm – 7,700 m, 400 mm – 2,900 m, 450 mm – 1,900 m,
500 mm – 4,500 m, 600 mm – 900 m

Similar to the Waigani zone the sewerage will gravitationally flow from south to north.

6.2.2 Sewage Treatment System

The existing stabilization ponds will continue to be used with modification and expansion. In the Waigani STP, the existing anaerobic ponds are adequate to meet the 2015 flow while the facultative pond will be augmented with an additional pond having a capacity of approximately 30,000 m^3/day to be located at the adjacent area. Expansion to the Morata and Gerehu STPs, are inevitable. The existing facultative ponds will be converted into anaerobic ponds to meet the increase of flow and large facultative ponds shall be constructed. The expansion plans for the existing STPs and the new Bomana STP are presented in Table 6.6. Figs. 6.3 to 6.6 show the layout plans for each STP.

Table 6.6 Expansion Plans for the Existing and new Bomana STP

STP	Estimated Sewerage Flow(m^3/day)	Pond	Capacity (m^3/day)		Remarks
			Existing	Planned	
Waigani	86,741	AP	103,800	103,800	As it is
		FP	57,175	86,800	Construct Additional FP
Morata	15,225	AP	5,400	16,350	Convert Existing FP to AP
		FP	5,475	15,300	Construct new FP
Gerehu	18,018	AP	9,750	24,400	Convert Existing FP to AP
		FP	7,325	18,100	Construct new FP
Bomana	39,887	AP	-	39,900	Site;574m x 292m
		FP	-	39,900	=167,700m^2

Note: AP: Anaerobic pond, FP: Facultative pond.

In addition, the improvement plans for the existing STPs are as follows:

- Installation/rehabilitation of screening equipment.
- Installation of flow meter.
- Improvement of the ponds structure for ease in desludging.
- The sludge drying bed site and accessibility to be ensured.

6.3 Sewerage for Coastal Area

6.3.1 Collection System

1) Coastal Area

The Coastal zone is divided into seven sub-zones based on administrative boundaries, urban development, sewerage development, topography, etc. The seven sub zones of the coastal area with their corresponding population are as follows:

Zone	Area (ha.)	Population (1995)	Population (2015)
1. Tatana/Baruni	70	3,654	5,575
2. Idubada/Hanuabada	168	9,299	11,416
3. Konedobu/Town	94	11,371	18,393
4. Koki/Badili	134	15,727	21,039
5. Gabutu/Vabukori	14	5,125	15,915
6. Kila Kila	160	20,251	31,354
7. Pari	9	2,330	2,430
Total	**649**	**67,757**	**106,122**

(1) Alternative

The sewerage system for Idubada/Hanuabada and Konedobu/Town will continue to function with all the sewage to be collected will be discharge via the Paga Point outfall. Due to the non-availability of land for STP facilities, the Koki/Badili sewage can be diverted either to Paga Point or to the proposed Kila Kila STP. The sewage from Gabutu/Vabukori will be collected and treated together with that of Kila Kila at the proposed Kila Kila STP. Pari can have an independent system with a STP on site or its sewage can be diverted to Kila Kila.

For the above considerations, eight alternatives were formulated/compared as shown in Table 6.7 (refer to Appendix D).

Case 1	Koki is merged with Paga Point.
Case 2	Koki is merged with Kila Kila.
Case A	Four STPs are planned in Tatana, Pari, Kila Kila and Pari.
Case B	Three STPs are planned in Paga, Kila Kila and Pari. Tatana is merged with Paga.
Case C	Three STPs are planned in Tatana, Paga and Kila Kila. Pari is merged with Kila Kila.
Case D	Two STPs are planned in Paga and Kila Kila. Tatana is merged with Paga and Pari is merged with Kila Kila.

Details of pumping stations and force mains necessary for each alternative are given in Appendix D.

Table 6.7 Comparison of Alternatives for Coastal Area

Alternative	1-A	1-B	1-C	1-D	2-A	2-B	2-C	2-D
	Tatana	Tatana	Tatana	Tatana	Tatana	Tatana	Tatana	Tatana
		↓		↓		↓		↓
	Paga	Paga	Paga	Paga	Paga	Paga	Paga	Paga
	↑	↑	↑	↑				
	Koki	Koki	Koki	Koki	Koki	Koki	Koki	Koki
					↓	↓	↓	↓
	Kila Kila	Kila Kila	Kila Kila	Kila Kila	Kila Kila	Kila Kila	Kila Kila	Kila Kila
			↑	↑			↑	↑
	Pari	Pari	Pari	Pari	Pari	Pari	Pari	Pari
Construction Cost	C	B	C	A	C	B	C	A
O & M Cost	A	C	B	C	A	C	B	C
Impact on the Environment	C	A	C	A	C	A	C	A
Flexibility for Future development	A	B	B	C	A	B	B	C
Ease of Land Acquisition	C	B	B	A	C	B	B	A
OVERALL	C	B	B	A	C	B	B	A

Note: A-good or less expensive; B-satisfactory; C-poor or expensive

The following factors are considered for comparative study; construction cost, O&M cost, impact on the environment, flexibility to future development and ease of land acquisition. The former two factors are essential from a viewpoint of economy. Impact on the marine environment is essential in the Study Area. Flexibility to future development is necessary because future progress is to some extent uncertain in NCD due to the absence of legislative power to enforce the "Urban Development Plan." Land acquisition issue is also important because land dispute still exist particularly on the "customary land."

The results of comparison given above indicate that both alternatives of 1-D and 2-D could be the best. However, case 2-D is selected. Ratings of the alternatives are explained below.

a) Construction and O&M Costs

Table 6.8 Comparison of Alternative for Construction and O&M Cost

(Unit: Kina 1,000)

Alternative		1-A	1-B	1-C	1-D	2-A	2-B	2-C	2-D
Construction Cost	Sewer	8,225	8,662	8,929	9,366	8,239	8,676	8,943	9,380
	Pump station	2,647	2,941	2,766	3,060	3,146	3,438	3,163	3,455
	STP	13,022	10,586	11,232	8,797	12,186	9,835	10,393	8,042
	Outfall	4,290	4,290	3,650	3,650	4,918	4,918	4,278	4,278
	Total	28,183	26,479	26,577	**24,873**	28,489	26,867	26,777	**25,155**
O & M cost	Pump station	540	614	555	628	695	755	721	780
	STP	853	912	862	921	722	766	731	775
	Total	**1,393**	1,526	1,417	1,549	**1,418**	1,521	1,453	1,556

Note; The above costs are for comparison only and do not cover entire project costs.

As shown in Table 6.8, the construction cost is high for case 1-A and case 2-A. Both cases have independent STP in Tatana and Pari aside from the two STPs in Paga and Kila Kila while O&M costs are low. On the other hand, both case 1-D and case 2-D have only two STPs, diverting sewage from Tatana and Pari to Paga and Kila Kila, respectively so that both cases are cheap in construction cost but high in O&M cost. Considering the difference in O&M cost, it is best to select either 1-D or 2-D.

In cases 1-A to 1-D where Koki/Badili is combined with Town (Paga STP), then selecting the route for laying the force main along the roadside of Ela Beach will be difficult. An embankment has to be constructed along the seashore for laying the pipeline, and various problems are anticipated. In cases 2-A to 2-D, the pipeline can be avoided along Ela Beach since the sewage for Koki/Badili will be diverted to Kila Kila.

b) Impact on the Environment

The sewer network in Town was installed during the time when the area was developed. The sewage collected was discharged at Paga Point. However, the rapid urbanization in the area resulted to various marine pollution problems in the vicinity. In order to minimize pollution problem, the sewage outfall was extended about 3 km from Paga Point to reach to the middle of Papuan Lagoon. In a similar context the outfall at Koki was abandoned; instead the sewage was diverted to Badili outfall. At 6 different locations including Badili, sewage is discharged 50 to 100 m offshore so that marine pollution is defected particularly near the outfalls.

One of the solutions to marine pollution is biological treatment of sewage before discharging to the sea. In as much as the effluent volume is limited, the problem could be solve to some extent, however the only concern is the dilution and flushing effect. The Port Moresby Harbour, where the effluent for the Idubada/Hanuabada and Tatana/Baruni are to be discharged lies in an enclosed bay with one outlet in the south end so that dilution effect is rather small. With the conventional treatment, organic load and pathogen is removed effectively, however removal of nitrogen (N) and phosphorous (P) cannot be expected. Therefore, accumulation of P&N in the Harbour will lead to eutrophication, detrimental to marine ecosystem. Treatment plant with facilities removing nitrogen and phosphorus may be constructed but the high construction and O&M cost can not be warranted. Therefore, cases A and C are assigned "C" and cases B and D are assigned "A."

c) Flexibility for Future Plans

Considering the future development plans, there is a strong possibility that the Vetorogo zone will be connected to Tatana zone because of its proximity. Dogura Kohu zones will have an independent sewerage system.

For other areas, a unified system is likely to result in higher cost because of topographical restrictions. Therefore, the advantage of a treatment facilities complementing each other is eliminated.

d) Ease of Land Acquisition

Land acquisition for site of the treatment facilities is a major problem except in three areas of Tatana, Kila Kila and Pari, where there are substantial open spaces available. Practically there is no available site for treatment facilities at Paga Point although a site can be created by land reclamation. The greater the need for facilities of a STP is, the greater the area required on shore for installing the facilities, which makes the selection poor.

(2) Result of Alternatives

The comparative analysis of the 8 alternatives for the Coastal Zone sewerage system had resulted in the selection of case 2-D consisting of Paga and Kila Kila basin.

The Paga basin will have a total population of about 35,400 in year 2015. Starting upstream, the Tatana/Baruni areas would require 4 pumping stations to collect and lift the sewage into the nearby Idubada/Hanuabada area. Due to its topographical features, 2 pumping station will be installed along the Idubada/Hanuabada area in order to pump all the accumulated sewage into the existing Konedobu P.S. The sewage collected from the existing reticulation system at the Konedobu/Town area will then be pumped finally into the Paga Point P.S., intercepting, the sewage pumped from the Stanley Esplanade P.S. and Davara (Ela Beach) P.S.

The Kila Kila basin will have a total population of about 70,000 in year 2015. Northeast of this basin are the existing sewerage systems of Koki/Badili areas, which will be pumped into the existing Kaugere P.S. and finally into the proposed Kila Kila STP. The existing Badili outfall will be abandoned, while the existing Kaugere P.S. will be upgraded/improved. The Gabutu/Vabukori area sewage will be pumped into the Kila Kila STP for treatment. The sewage collected from the farthest Pari area will be pumped through a 3 km pipeline into the Kila Kila STP.

2) Vetorogo Zone

The Vetorogo zone frontling the Port Moresby Habour is planned for industrial development. Part of the shoreline has been reclaimed and site development work has started. However, no detailed development plans are available. The present topographic features indicate a relatively flat area. No special factors need to be considered for the collection system. It is proposed to install a separate sewerage network based on data of nearby areas with details of system as follows:

3) Dogura-Kohu Zone

The development in this zone is expected to take place in the almost enclosed surrounding Bootless Bay. The topographical features indicate steep mountains stretching to the shoreline, dividing the area roughly into thee section. The biggest section to be developed will have an area of 1,680 ha., planned population of 40,565, and the planned sewage flow rate of 18,209 m^3/day.

Topographically, it is difficult to connect other zone and it is therefore preferable to provide independent treatment facilities. Considering the almost-enclosed area surrounding the treatment facilities are proposed to be close to the mouth of the bay as possible. The descriptions of the various facilities are given below.

(1) Sewer network

The estimated density of pipeline in the developed area is 140m/ha. that gives a total length of the sewer network at 235,340 m.

(2)	Trunk Sewer:	300 mm – 2,900 m, 400 mm – 1,000 m, 500 mm – 1,600 m	350 mm – 2,600 m, 450 mm – 700 m,
(3)	Force Main:	200 mm - 1,700 m, 350 mm - 2,000 m, 600 mm - 2,000 m	300 mm - 1,500 m, 450 mm - 1,200 m,

(4) Pumping Station:
Q1= 1.88 m^3/min, H=20 m, Dia.=100 mm, Capacity = 5.5 kW
Q2= 1.88 m^3/min, H=23 m, Dia.=100 mm, Capacity = 7.5 kW
Q3= 3.88 m^3/min, H=20 m, Dia.=100 mm, Capacity = 11.0 kW
Q4= 6.05 m^3/min, H=32 m, Dia.=100 mm, Capacity = 22.0 kW
Q5= 9.47 m^3/min, H=10 m, Dia.=150 mm, Capacity = 11.0 kW
Q6=17.91 m^3/min, H=11 m, Dia.=200 mm, Capacity = 22.0 kW

6.3.2 Sewage Treatment System

The scope of this study does not include an analysis on wastewater outfall from coastal areas, but references were made to previous studies made. Based on these studies it is proposed to install offshore outfall. The most significant reference was made on the Environmental Plan - Joyce Bay Outfall Study published in June 1988 by the Waterboard of PNG. The study analyzed Joyce Bay Outfall from various aspects such as bacteriological analysis before and after the Paga Point Outfall construction, dyes tracing, current metering, drogue tracking and estimation of outfall performance. As for the water quality aspect, the study explained dissolved oxygen (DO) and micronutrients as follows:

- *An indicative value of DO at the surface in the vicinity of the outfall is 7.0 mg/L. If BOD is 150 mg/L for the effluent, then after rising from the diffuser to the surface plume, the BOD will be diluted to approximately 0.2-mg/L. Further dilution will then ensure. The effect of effluent discharge on DO levels will be barely detectable.*

- *With levels of nitrogen and phosphorus in Port Moresby sewage measured at 11.0 mg/L and 2.02 mg/L respectively, the addition of these nutrients to the lagoon (after initial dilution) at outfall site is 0.014 mg/L and 0.003 mg/L respectively. Hence, the diluted level of nutrients is lower than background level. Existing reef and plant communities are several kilometers away. Based on the analysis, the recommended facilities for outfall consist of only grit chamber, coarse screen, fine screen, pumps and outfall pipeline (450 mm Dia., 3 km)."*

In June 1997, investigation and maintenance works for the existing Paga Point Outfall were done by EDA RANU. Through recorded videotape and a hearing with the divers, the following problems were observed:

- Clogging of holes on diffuser pipe by plastic bags, textile and other non-biodegradable object.
- Deposition of silt and sludge in the diffuser pipe.

Considering the associated problems mentioned above and the risk of environmental contamination of the Coral Sea, necessitate the provision of primary treatment (sedimentation) before pumping sewage into the outfall. Therefore, the primary treatment facilities recommended for offshore outfall include the following: Grit chamber, Screen, Pumps, Sedimentation tank, Chlorination and Outfall pipeline.

The sedimentation method has the capacity to prevent blockages of the effluent pipe from accumulated silt and other debris and could also minimize environmental pollution.

Details of the proposed STP at Paga Point and Kila Kila are presented in Table 6.9 below and roughly shown in Figs. 6.7 to 6.10.

Table 6.9 STP in Paga Point and Kila Kila

STP		Paga Point	Kila Kila
Sedimentation Basin	Train	4	4 to 6
	Water H (m)	2.0	2.0
	Width (m)	4.5 x 40.4	7.0 x 39.6
	Length (m)	8.5 x 40.5	7.0 x 41.1
Digestion Tank	Train	2	-
	Water H (m)	5.0	-
	Diameter (m)	10.1 to 13.9	-
Sludge Drying Bed	Train	-	4 to 6
	Sludge (m)	-	0.4
	Width (m)	-	10.0 x 66.9
	Length (m)	-	10.0 x 100.3
Site	Width (m)	38 x 93	60 x 194
	Length (m)	54 x 103	80 x 173
	Area (m^2)	3,600 to 5,600	11,700 to 13,800

Since it is less feasible to construct a long offshore outfall in the Vetorogo and Dogura Kohu areas, short outfalls with secondary treatment before discharge near shore are proposed. Table 6.10 below is the overview of the proposed STP for the above areas as roughly presented in Figs. 6.11 & 6.12.

Table 6.10 STP in Vetorogo and Dogura Kohu

STP	Estimated Sewerage Flow (m^3/day)	Pond	Planned Volume (m^3)	Planned Site Size
Vetorogo	13,115	Anaerobic	26,230	290m x 238m
		Facultative	52,460	= 69,000m^2
Dogura Kohu	18,209	Anaerobic	36,418	330m x 267m
		Facultative	72,836	= 88,000m^2