internationally accepted standards, with high alumina cement mortar lining.

4.10 Joints

Infiltration is a major cause of hydraulic overloading of both collection system and treatment plant. Most infiltration occurs through faulty or poor sewer joints. Private house connections to public sewers have in many cases contributed more infiltration than the system itself. It is therefore recommended that MPSP develop a strong and adequate code to control materials and construction of house connections.

Experience in many countries shows that the compression type and rubber gasket type joints show generally very superior performance in preventing groundwater infiltration into sewers. Various proper forms of flexible joints are available on the market. Among them, the most reliable joint which has water tightness, flexibility, and durability is probably the rubber gasket type joint.

In view of the above mentioned comments, the following joints are recommended for different materials of sewer pipe:

(a) Concrete Pipe

Recently concrete pipe manufacturers have successfully employed compression rubber gaskets for bell and spigot, and tongue and groove concrete pipe. A variety of these types of joints are available. It is therefore recommended that all concrete pipe joint be of the rubber-gasket type.

(b) Vitrified Clay Pipe

Vitrified clay pipe can be obtained with factory-applied 'push-fit' joints. These can incooperate polyester rings and a rubber 'O' ring, or they may be of polyurethane with an integral nob. Any of these modern type joints which prevent infiltration would be acceptable.

4.11 Manholes

(a) Location

Manholes shall be installed at the end of each line; at all changes in grade, size, or alignment; and at all intersections.

On larger main sewers, however, which can be entered for cleaning, these changes may be made without the requirement of manholes.

(b) Spacing

Spacings of manhole by size of sewer should not be more than those shown in Table E-5. Manholes should, in any case, not normally be larger than 200 meters apart, so that men working in a sewer can easily reach a manhole in an emergency.

TABLE E-5 Maximum Manhole Spacings

Pipe Dia (mm)	300 or Less	600 or Less	1050 or Less	1500 or Less	1650 or More
Maximum Spacing (m)	50	80	100	150	200

In fixing these maximum spacings, similar cities both in Malaysia and other countries were studied. In case of George Town, where a separate sewerage system has been in operation since 1933, a maximum manhole spacing of 90 meters for sewer sizes up to 600 mm and for larger size sewers spacing up to 150 m have been used as the design standards, without much trouble in cleaning. Spacing should be determined by the type of sewer cleaning equipment used.

The rod type cleaning instruments will be used as the main cleaning device for years to come, instead of highly mechanized equipment such as hydraulic sand ejectors, because of the much lower cost, ease in handling, and plentiful availability of labour and the need to develop employment opportunities for labourers. Accordingly, the spacings, as shown in Table E-5 are recommended, except in cases where modern equipment adequate for greater spacing is provided.

(c) Dimensions

Except for very shallow drains and sewers of less than one meter depth to the invert (special case) all manholes should be of adequate dimensions for entry and for operation of cleaning rods. The internal size of manhole should not be less than 1200 mm; but larger sizes are preferable. The recommended standard classification of manhole diameters and internal sizes are as shown in Table E-6.

TABLE E-6 Recommended Manhole Size (mm)

Minimum Internal Size	Connecting Sewer Diameter
1,200 mm	900 mm or less
1,500	1,200 or less
1,800	1,500 or less

(d) Materials

Watertight manhole covers, either of reinforced concrete or cast iron, are to be used wherever the manholes tops may be flooded by street runoff or high water. The size of manhole cover should be greater than 60 cm.

Generally manholes should be circular, with a reinforced base and reinforced wall construction.

For larger and deeper manholes, it is recommended that a precast concrete base, tapered sections, shaft sections and cover slabs be used in order to sustain heavy loads.

ANNEX SULFIDE CONTROL METHODS

1. Introduction

Hydrogen sulfide and other undesirable gases associated with the operation of sanitary sewers are produced in an anaerobic environment. Therefore, the key to their control is keeping the wastewater aerobic. It has been observed that the rate of hydrogen sulfide buildup is closely related to sludge accumulation in the sewer. In other words, a well-designed, self-cleansing sewers should have little trouble from hydrogen sulfide.

Hence, the following three methods are brought up for sulfide control.

a. Keep sufficient flow velocity to prevent sulfide buildup without special sulfide corrosion protection measures

b. Use anti-sulfide corrosion pipe or lining pipe without special velocity control where sulfide buildup is expected.

c. Inject air to keep sewage aerobic without special considerations on flow velocity and pipe material.

2. Sulfide Controlling Velocities

The equation relating flow velocities to marginal EBOD (effective BOD) is:

$$\text{Marginal EBOD} = 787\ V^{3/4}\ b/P$$

where

$$\text{EBOD} = \text{BOD}_5 \times 1.07^{(T-20)}$$

T : temperature, °C
V : flow velocity, m/sec
b/P: surface width/wetted perimeter, dimention less

The BOD concentration of the sewage for the year 2000 has been estimated at 200 mg/l. Therefore, the equivalent EBOD for the year 2000, at a temperature of 27°C, will be

$$200 \times 1.07^{27-20} = 321 \text{ mg/l}$$

Sulfide control velocity curve for the year 2000 condition was then developed, as shown in Figure E-2 of this Annex.

If peaking factor is expressed as:

$$P.F. = \frac{5}{P^{1/7}}$$

where P: Population (1,000 persons)

and population is estimated at 4,800 persons, the P.F. will be 4. That is, the daily average flow will be one fourth of peak flow in such areas which has population of 4,800. Because, for sanitary sewer, full pipe capacity of the design peak flow rate is provided, the pipe diameter for this population will be 300 mm. (Per capita sewage flow is estimated at 230 l/cap/day). This is the upper limit of VCP market size. The minimum design flow velocity should be determined at least on the basis of the daily average flow velocity of above pipe size. Hence, the minimum design flow velocity is determined at 75 cm/sec.

The Figure indicates that if the minimum design flow velocity is decided at 75 cm/sec, the sulfide generation will be controlled from 0.25 to 0.70 of peak design flow rate. The problem of sulfide control is much more severe during the initial year of service of sewer pipeline when flows are considerably less than future design flows. However, as shown in Figure E-2, it is impossible to keep the sulfide control velocity to meet all flow variations.

Pomeroy-Davy Formula
for Marginal Effective BOD
Marginal EBOD = $787\ V^{4/3}\ b/P$

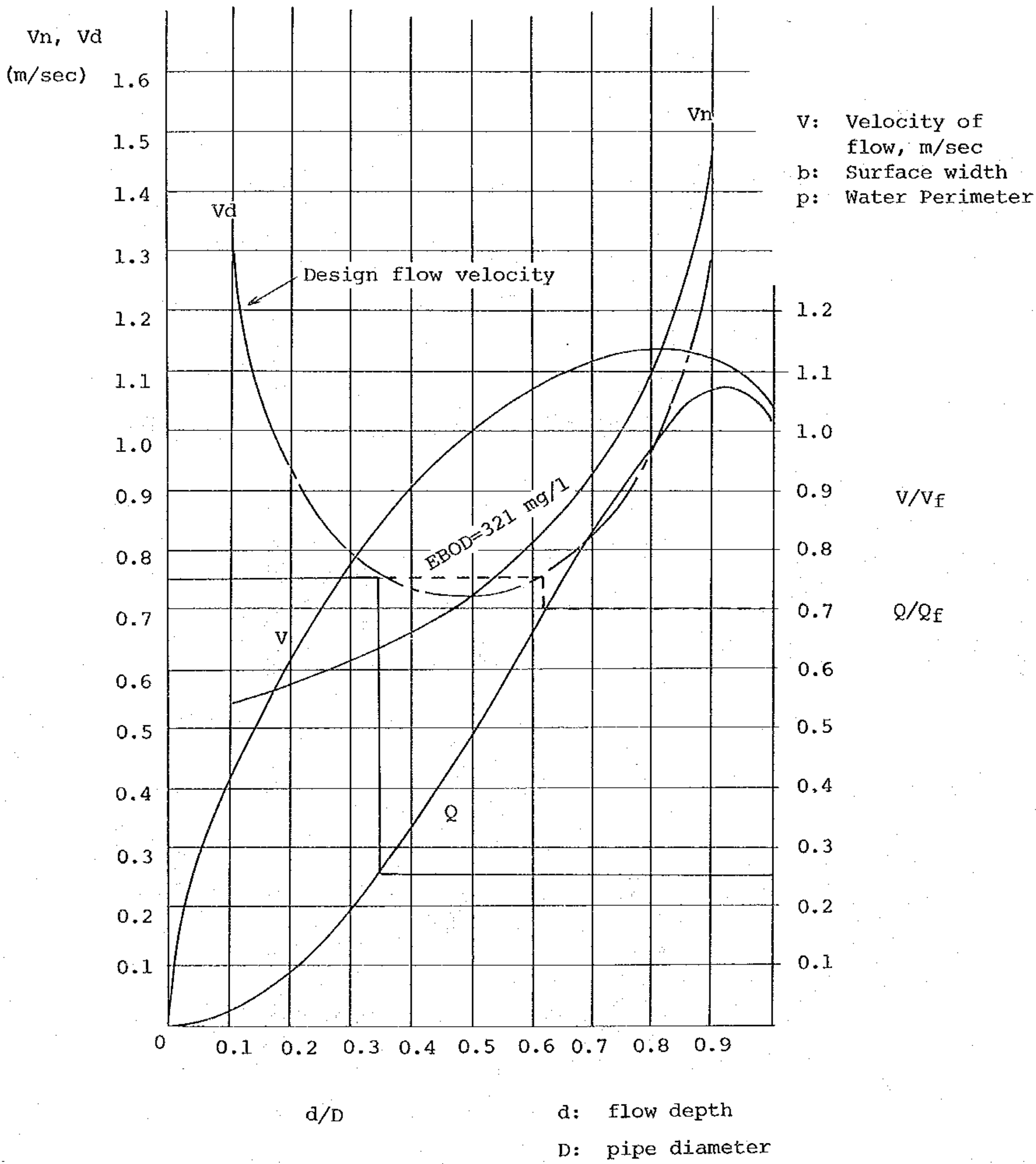


FIGURE E-2 Sulfide control velocity curve

3. Anti-Corrosion Pipe

VCP, RCP, ACP, and Pitch Fibre Pipe are available in Malaysia. Among them VCP is the best pipe against sulfide corrosion. However, the available VCP market size is up to 300 mm in diameter, and larger sewers will be of concrete-bonded pipes, either centrifugally cast or cast in place, which are likely subject to sulfide attack.

Coatings and linings of acid-resistant materials, such as vinyl and epoxy resins, PVC sheet, and high alumina cement mortar, will be effective for protecting concrete pipes against the acid attack.

4. Air Injection to Sewer

This method is useful only in the force main.

5. Conclusions

In view of the above considerations especially for future operation and maintenance problems of the sewerage system, it is concluded that all sanitary sewers shall be so designed and constructed to give mean velocity, when flowing full or half-full, of not less than 60 cm/sec for VCP, and for RCP or any cement-bonded pipe the minimum design flow velocity should be 75 cm/sec, and suitable lining or coating pipes should be used.

APPENDIX F

WASTEWATER CHARACTERISTICS

CHAPTER 1

STUDIES ON DOMESTIC WASTEWATER

1.1 Survey on Domestic Sewage in the Project Area

1.1.1 Description of Survey

As one of the basic information for per capita waste loads and sewage flow rate projection for domestic wastewater, quality and quantity surveys of open ditches in the residential areas selected were performed by survey team in November and December, 1976.

For the domestic wastewater characteristics study, two typical housing blocks were selected. The blocks were surrounded by open concrete ditches and the domestic wastewater was discharged into these distches directly at the sites of each houses by gravity. These blocks, consist of typical residential areas of average level, discharge no night soil into open ditch. Therefore, the waste load by night soil is not estimated in this survey. The location of selected housing blocks are indicated in Figure F-1.

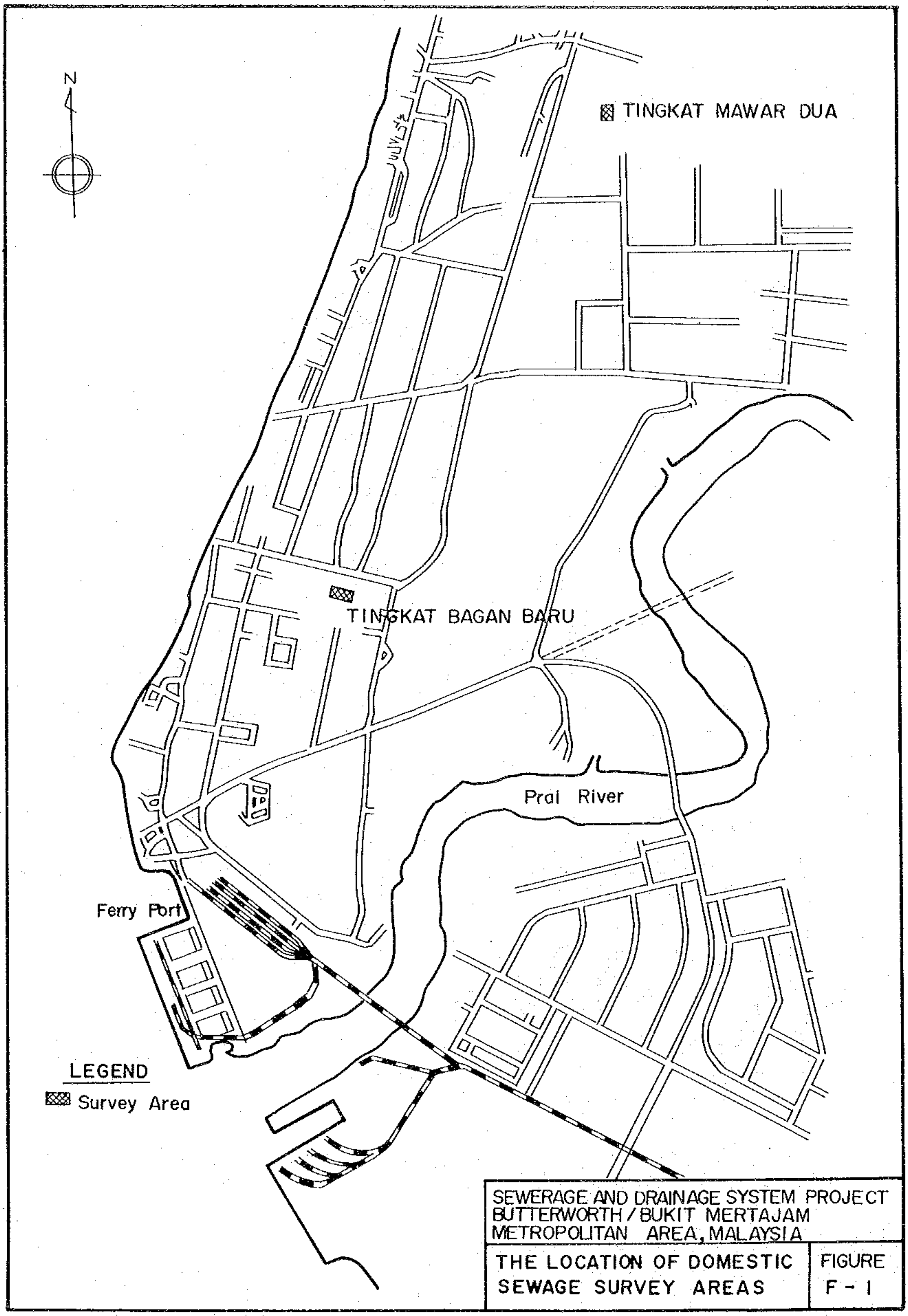
At the outlet of the surrounding ditch, V-notch was installed to measure flow rate every 15 to 30 minutes. The sampling and measurements were carried out. These performances were done during the time of 6:00 a.m. to 12:00 p.m. of the day for every 1 to 2 hours for sampling and every 15 to 30 minutes for wastewater quality measurements. Wastewater temperature, pH, dissolved oxygen (DO), and electric conductivity were measured on by a portable "water quality checker", consisting on thermistor, pH-electrode, DO-electrode, and electric conductivity electrode.

The samples collected were analyzed for biochemical oxygen demand (BOD), chemical oxygen demand (COD-Mn), suspended solids (SS), and chloride ions either at Department of Chemistry or at Indus Laboratories Co., Ltd.

Analytical methods used are as follows:

BOD (5 days)	:	standard method, APHA-AWWA-WPCF
COD-Mn	:	Japanese sewage analytical method, 100°C 30 minutes
SS	:	standard method, APHA-AWWA-WPCF
Chloride	:	standard method, APHA-AWWA-WPCF

Figure F-1


N
TINGKAT MAWAR DUA
TINGKAT BAGAN BARU
Prai River
Ferry Port
LEGEND
Survey Area
SEWERAGE AND DRAINAGE SYSTEM PROJECT
BUTTERWORTH / BUKIT MERTAJAM
METROPOLITAN AREA, MALAYSIA
THE LOCATION OF DOMESTIC
SEWAGE SURVEY AREAS
FIGURE
F - 1

1.1.2 Results and Discussion

The findings of the domestic wastewater survey are shown in Tables F-9 and F-10.

Using the findings of the survey, flow rate, BOD and SS contents of sullage from typical residences in the Project Area were calculated as shown in Table F-1.

TABLE F-1 Flow Rate, BOD and SS Contents of Sullage from the Typical Residences in the Project Area

Block	Flow Rate	BOD		SS	
	l/day/cap	mg/l	g/day/cap	mg/l	g/day/cap
R-1	93	241	22.4	31	3
R-2	95	224	21.3	42	4

Sullage water quantity from the typical residence is approximately 95 l/day/cap, and the BOD ranges from a minimum of 105 mg/l to a maximum of 370 mg/l as shown in Tables F-9 and F-10. The daily BOD load discharged into sullage water is estimated at approximately 22 g/day/cap as shown in Table F-1. The SS contents of the sullage water collected during the survey time are very low. This may be due to settling of SS matters in the surrounding ditches.

In estimation of flow rate and BOD contents of domestic sewage for the sewerage system planning, appropriate allowances should be considered for settling matters in drains and flushing water for water closet.

Night soil is treated by communal septic tank with flushing water at the surveyed blocks. Flushing water quantity used for water closet is estimated at 60 l/day/cap empirically.

Further, the PWA's data on water supply indicate that the monthly variation of domestic water consumption extends to ±7 percent of average monthly water consumption, and that the field surveys mentioned above were done in lower water consumption season, therefore, approximately 15 l/day/cap of allowance is estimated for variation component.

Conclusively, present quantity of domestic sewage production is estimated at approximately 170 l/day/cap on typical residential area, as indicated below.

TABLE F-2 Flow Rate of Domestic Sewage Produced in the Project Area

Water	Flow rate (l/day/cap)
Sullage	95
Flushing	60
Variation allowance	15
Total	170

Because of extremely low concentration of SS in the collected samples as shown in Table F-1, it is expected that BOD matter is removed through settling in the collection system due to low velocities. This is often investigated in the Project Area because the slope of the drains are very flat in ordinary housing areas and also in surveyed blocks. Assuming 10 to 20 percent reduction through settling in a drain during collection of samples, 2 to 4 g/day/cap of BOD should be allowed for BOD production.

Night soil BOD has been estimated at 13 to 20 g/day/cap in Japan and other Asian countries. In this planning, 13 g/day/cap of night soil BOD is applied on the basis of Japanese experience.

Therefore, as summarized below, per capita BOD load is estimated at approximately 37 g/day/cap under present living condition in the Project Area:

TABLE F-3 Per Capita BOD Load Produced in the Project Area

Source	BOD Load (g/day/cap)
Actual measurement on sullage	22
Allowance components for settling	2
Night soil	13
Total	37

Although suspended solids contents of sullage water from the residential blocks surveyed were very low as shown in Table F-1, SS/BOD ratios of total domestic wastewaters are normally extended in the range of 0.8 to 1.3. Therefore, assuming SS/BOD ratio being equal to one for the normal domestic wastewater in the Project Area, per capita SS load is also presumed to be approximately 37 g/day/cap.

The present per capita flow rate and waste load of domestic sewage produced in the Project Area are estimated as shown in Table F-4.

TABLE F-4 Per Capita Flow Rate and Waste Load of Domestic Sewage Produced in the Project Area

Flow Rate (l/day/cap)	Waste Load (g/day/cap)		Concentration (mg/l)	
	BOD	SS	BOD	SS
170	37	37	220	220

1.1.3 Data on Domestic Water Consumption

In addition to direct measures of sullage water at housing blocks, the information obtained by questionnaire which were directed to the selected households in the Project Area for the purpose of the survey on domestic water consumption rate, wastewater disposal system, and night soil disposal system, together with income level and the type of house accommodation, is employed in determining per capita sewage flow.

Table F-5 shows domestic water consumption rate by housing type which shows rough income level (i.e. type A: lower, B: medium, and C: higher).

TABLE F-5 Per Capita Water Consumption Rate

Water Consumption (l/day/cap)	Number of Households			
	A	B	C	Total
less than 100	1	4	0	5
101 - 150	5	12	1	18
151 - 200	5	11	1	17
201 - 250	3	5	2	10
251 - 300	3	6	1	10
301 - 350	0	2	2	4
351 - 400	0	2	0	2
more than 401	1	6	1	8
Total household No.	18	48	8	74
Average Per Capita Water Consumption	171	190	236	196

A: Kampong house (wooden house)
B: Attached terrace house, Flat house
C: Isolated or semi-detached house

Per capita water consumption rate increases from approximately 170 to 240 l/day/cap as income increases, and about 190 l/day/cap of municipal water is consumed by medium income class.

The percentage of each housing types existing in the project area is shown in Table F-6 calculated on the basis of the housing census of Malaysia (1970).

TABLE F-6 Percentage of Each Housing Type Existing in the Project Area

Housing Type	A	B	C
Percentage	65.5	23.6	10.9

By applying the ratio (Table F-6) to the findings of the questionnaire mentioned above, average water consumption rate at present is estimated at 182 l/day/cap in the project area. And it can be considered that the difference between this value and the present per capita sewage generation of 170 l/day/cap estimated in the preceding section may be a part of water used for car-wash, sprinkling, etc.

1.1.4 Daily Variation of Domestic Wastewater Flow Rate

The flow rate of domestic wastewater was measured every 15 to 30 minutes at the selected residential blocks. The results are shown in Figure F-2. Two different patterns, 2 peaks and 3 peaks, were obtained. These patterns reflect each living activities, cooking, bathing, washing, etc., although each peak cannot exactly correspond to each activities.

1.2 Design Values of Domestic Wastewater

1.2.1 Sewage Flow and Strength

The results of the domestic wastewater survey, described in Section 1.1 of this Chapter, state that the present domestic wastewater volume is estimated at 170 l/day/cap. It will increase due to future economic growth, improvement of social services including water supply, toilet facilities, and other factors.

On the basis of the increasing rate of the water supply plan of PWA and other cities' plans, the future sewage flow rate is estimated at 230 l/day/cap for the year 2000.

Although both per capita waste load and water consumption increases due to economic and living standard growth. In general, the increasing rate of latter is slightly higher than that of the former. Therefore, the strength of domestic sewage may slightly decrease in the future. So that, BOD concentration of domestic wastewater is estimated at 200 mg/l for planning purpose.

Using this value and flow contribution of 230 l/day/cap, average BOD load is given as 46 g/day/cap.

1.2.2 Comparison with Design Criteria in Various Countries

Table F-7 shows comparison of characteristics of wastewater in various cities.

TABLE F-7 Comparison of Design Criteria for Various Cities*

Name of City (or country)	Target year	BOD (mg/l)	SS (mg/l)	BOD (g/d/c)	SS (g/d/c)	Flow (l/d/c)	
Butterworth	2000	200	200	46	46	230	Design criteria recommended
Ipoh	1968	370	276	-	-	205	Average
Ipoh	2020	200	250	45	54	227	Design criteria
Kuala Lumpur	1985	250	-	55	-	270	Design criteria
Kuala Lumpur	2002	222	-	60	-	270	Design criteria
San Juan	1967	204	264	45	59	318	
Tema Ghana	1965	280	219	45	36	168	
Seoul	1985	312	374	59	73	232	Design criteria
Japan	1970	-	-	44	40	340	Design mannual
Keelung	1963	200	250	41	50	241	Design criteria

* Modified and rearranged from the followings:

(1) Manila Sewerage Report (1969)

(2) Manicipality of Ipoh Sewerage Feasibility Study; ENNEX (1974)

(3) Kuala Lumpur Master Plan for Sewerage and Sewage Disposal; D. Balsour & Sons (1975)

(4) Japanese Design Manual for Sewerage System (1972)

The value of sewage flow rate in the Project Area is predicted at 230 l/day/cap and similar to the value of Ipoh (2020), Kuala Lumpur (1985), and Seoul (1985). As the sewage flow reflects living pattern of the area, and as it is considered that the social and commercial area would not drastically extend in the Project Area by the year 2000, the above estimated value of 230 l/day/cap is considered to be reasonable.

The estimated value of per capita BOD load is similar to the value of Ipoh (2020), San Juan, Tema Ghana, and Japanese standard (1975), although the values of Kuala Lumpur and Seoul are slightly higher than those of the other cities. Either Kuala Lumpur or Seoul is its nation's capital having highly developed commercial areas which may not be included for comparison in the cities because of the metropolis of the countries. Therefore, the estimated BOD value of 46 g/day/cap is considered to be reasonable.

As the ratio of SS/BOD fluctuates in every cities, it is difficult to predict the figure SS value accurately. Assuming the ratio to be one, the value of per capita SS production is estimated at 46 g/day/cap for planning purpose.

1.2.3 Proposed Design Criteria for Domestic Wastewater

The proposed design value of domestic wastewater for this Project is shown in Table F-8.

TABLE F-8 Proposed Design Criteria of Domestic Wastewater

Volume	Per Capita Waste Load		Concentration	
	BOD	SS	BOD	SS
(l/day/cap)	(g/day/cap)	(g/day/cap)	(mg/l)	(mg/l)
230	46	46	200	200

TABLE F-9 The Findings of Survey for Domestic Wastewater Quantity and Quality (Residential Area - 1)

Time	Q (cu m/d)	T (°C)	pH	DO (mg/l)	BOD (mg/l)	COD-Mn (mg/l)	SS (mg/l)	Cl^- (mg/l)
7:40	-	-		-	365	195	30	16
8:30	6.2	23.8	6.5	2.0	360	455	47	41
9:30	24.8	23.8	6.9	2.4	285	195	39	31
10:30	16.9	27.9	7.8	1.1	300	325	49	29
11:30	19.3	26.4	7.1	1.5	130	195	24	25
13:30	26.2	28.1	5.5	2.3	180	195	24	44
15:30	12.9	27.6	5.3	2.0	315	115	34	37
17:30	18.1	27.0	6.3	0.7	225	155	38	26
18:30	19.3	26.8	6.5	1.2	215	80	23	29
19:30	20.6	26.5	6.8	0.9	240	80	18	37
21:30	7.5	25.9	7.2	0.7	370	115	16	35
23:30	4.4	24.9	6.8	0.3	195	155	34	43

Note; Q : Quantity of Water Flow
T : Water Temperature
DO : Dissolved Oxygen
BOD : Biochemical Oxygen Demand
COD-Mn : Chemical Oxygen Demand
SS : Suspended Solids
\- : not measured

Date : 7 December, 1976
Location: Tingkat Bagan Baru Sepuluh, Butterworth

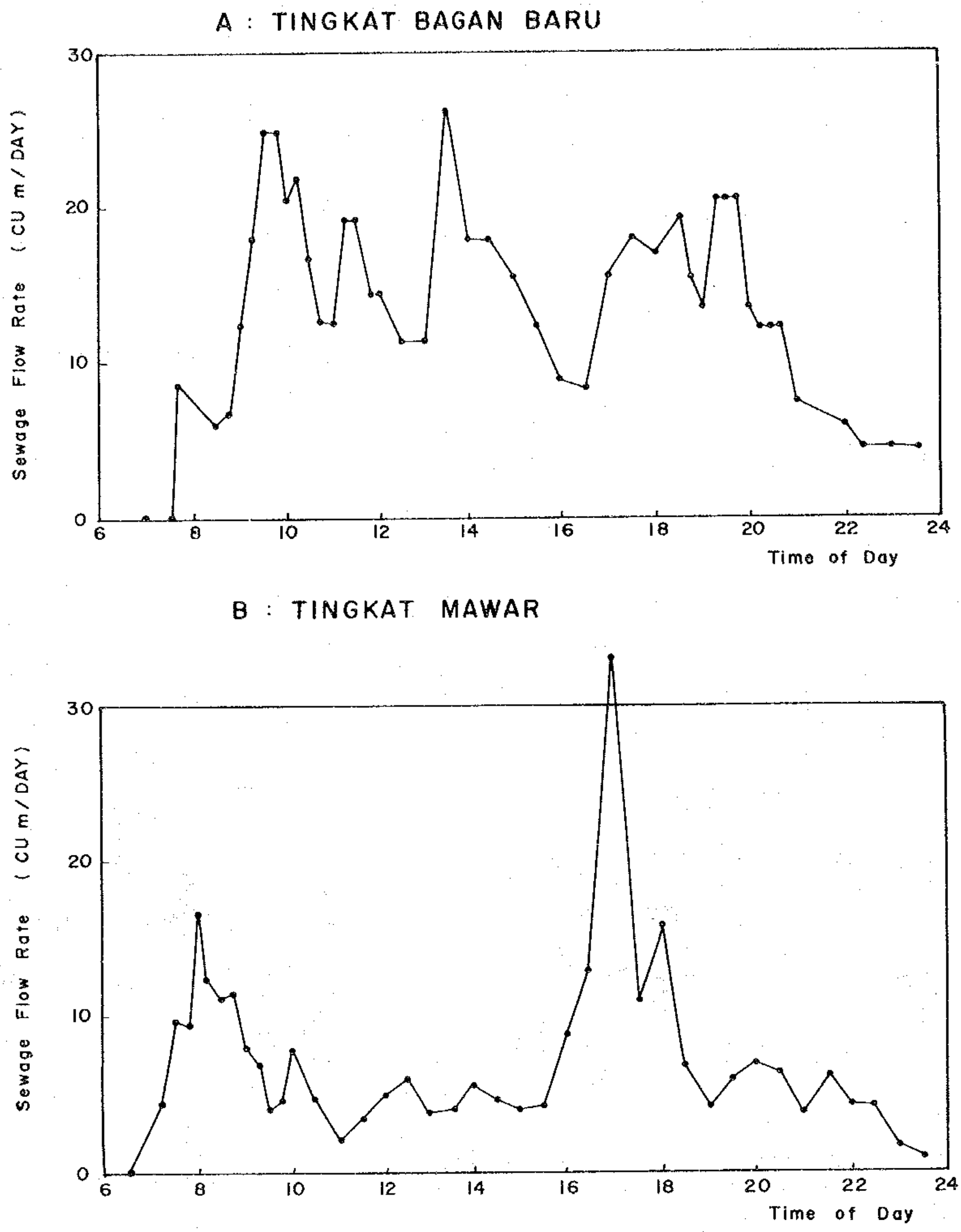
TABLE F-10 The Findings of Survey for Domestic Wastewater Quantity and Quality (Residential Area - 2)

Time	Q (cu m/d)	T (°C)	pH	DO (mg/l)	BOD (mg/l)	COD-Mn (mg/l)	SS (mg/l)	Cl^- (mg/l)
7:30	9.8	26.8	7.2	4.5	105	135	25	34
8:30	10.8	27.0	6.8	4.3	275	145	14	51
9:30	4.0	27.1	6.7	3.9	110	190	35	27
11:30	3.4	28.9	6.2	3.5	125	135	42	70
13:30	4.0	30.6	6.2	4.1	195	180	21	37
15:30	4.2	29.6	7.0	1.5	320	495	86	61
17:30	10.8	28.6	6.7	4.8	255	145	26	43
19:30	6.2	28.4	-	-	320	360	94	64
21:30	6.2	-	-	-	265	450	85	102
23:30	0.9	-	-	-	140	180	31	60

Note; Q : Quantity of Water Flow
T : Water Temperature
DO : Dissolved Oxygen
BOD : Biochemical Oxygen Demand
COD-Mn : Chemical Oxygen Demand
SS : Suspended Solids
\- : not measured

Date : 14 December, 1976
Location: Tingkat Mawar Dua, Butterworth

Figure F-2



SEWERAGE AND DRAINAGE SYSTEM PROJECT BUTTERWORTH / BUKIT MERTAJAM METROPOLITAN AREA , MALAYSIA	
DAILY VARIATION OF DOMESTIC WASTEWATER FLOW RATE	FIGURE F – 2

CHAPTER 2

QUANTITY AND QUALITY OF INDUSTRIAL WASTEWATER

In this chapter, the present and future conditions of industry in the Project Area are described and studies are conducted for both quantity and quality of the industrial wastewater. All data and information used herein the offered by courtesy of Ministry of Environment, MPSP, Department of Chemistry of Penang, PDC, and PWA, together with field survey conducted by survey team through field visits and questionnaires directed to each establishment.

2.1 General

There are 8 industrial areas in Penang State. Five of them are located in the Butterworth/Bukit Mertajam Metropolitan Area. (Ref. Figure F-3)

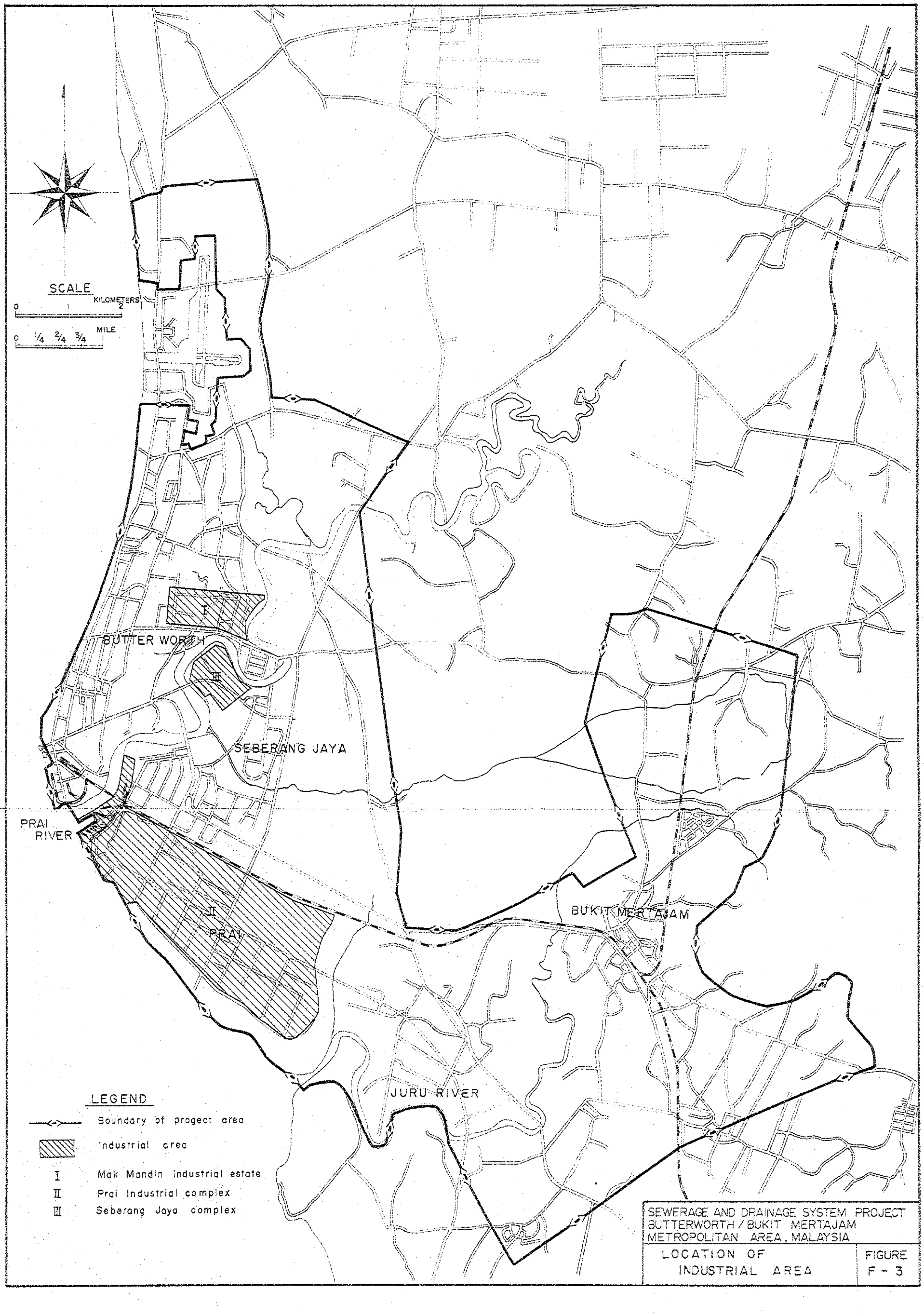
Most of large and medium scale factories are concentrated in the industrial areas of Mak Mandin Industrial Estate, Prai Industrial Complex (*1), and Seberang Jaya Complex. Rest of the larger and medium scale factories are distributed in the Butterworth District, and a few in the other area.

Mak Mandin Industrial Estate covers an area of about 110 ha within the Butterworth town area. The major industry is food processing, while the rest consists of textile, light metal and plastic processing, and others. As of 1976, there are 32 detached-type factories in operation in the Estate, and another 13 allocated sites for future construction. In addition to the detached-type factories mentioned above, there are 48 middle scale factories, which are classified into terraced-type and/or semi-detached-type ones, in operation in MIEL units (*2) constructed in the Estate. The Estate has almost reached full utilization.

(*1) Prai Industrial Complex is, in this report, defined as the whole area including Prai Industrial Estate, Prai Free Trade Zone, Prai Wharves Free Trade Zone, and other industrialized Prai area (see Figure F-3).

(*2) MIEL units are built by private industrial developers who put up ready-built, fully served standard factory buildings for industrialists who are unable to put up their own factories.

Figure F-3


SCALE
KILOMETERS
0 1 2
MILE
0 1/4 2/4 3/4 1
BUTTER WORTH
SEBERANG JAYA
PRAI RIVER
PRAI
BUKIT MERTAJAM
JURU RIVER
LEGEND
Boundary of progect area
Industrial area
I Mak Mandin industrial estate
II Prai Industrial complex
III Seberang Jaya complex
SEWERAGE AND DRAINAGE SYSTEM PROJECT
BUTTERWORTH / BUKIT MERTAJAM
METROPOLITAN AREA, MALAYSIA
LOCATION OF
INDUSTRIAL AREA
FIGURE
F - 3

Prai Industrial Complex covers an area of about 1,000 ha at the southeast part of the Project Area. It is the largest industrial estate in Malaysia, in which food stuff manufacturing will dominate and be followed by textile, light metal and plastic processing, and others. As of 1974, at least 27 factories employing about 6,000 workers were in operation in the area. According to PDC's information, as of end of 1976, there are 77 factories including MIEL units in operation, and 23 factories are additionally allocated in the area. This indicates that industrial development of this area is well in progress.

Seberang Jaya Complex includes an industrial area covering about 50 ha. This complex is under construction for development and only two factories are in operation for production at present.

Number of factories in each industrial area are shown in Table F-11.

In the area outside of the three industrial areas, about 60 middle scale factories and about 700 small scale factories are scattered. Most of them are distributed among residential and/or commercial areas.

TABLE F-11 The Number of Factories by Industrial Classification and their Location (1976)

Class No. ***	Mak Mandin Industrial Estate		Prai Industrial Complex		Seberang Jaya
	Existing	Approved	Existing	Application	Existing
1	11	1	13	4	1
2	4	1	11	1	1
3	2	-	6	3	-
4	4	-	9	4	-
5	-	1	4	1	-
6	5	3	10	5	-
7	-	2	2	-	-
8	1	1	4	4	-
9	5	4	18	1	-
Total	32*	13	77**	23	2

* excluding MIEL units (48 factories)

** including MIEL units

*** Class No. : 1 Food
2 Textile
3 Chemicals
4 Rubber and Plastics
5 Stone and Clay Products
6 Metals
7 Electrics
8 Machinery and Equipments
9 Others

2.2 Industrial Wastewater Survey

2.2.1 Industrial Wastewater Surveys

The Subcommittee on Pollution Control of Penang conducted an industrial wastewater survey in the Prai Industrial Complex in 1976 for a study on the pollution of Kuala Juru with the assistance of MPSP and Department of Chemistry. Questionnaires were sent to 73 factories in Prai Industrial Estate to get information on the volume of water consumed and discharged. Answers to the questionnaires were received from 41 factories, and further, effluent samples from 22 factories suspected to be worst pollutants were taken and analyzed.

In addition to the survey, Ministry of Environment through its Anti-Pollution Committee in Malaysia surveyed the industrial wastewater quality of some factories in the Prai Industrial Complex and the Bukit Mertajam District. These surveys were too simple to estimate the total amount of wastes from the industrial area at present and/or in the future.

For the purpose of estimating present and future industrial wastewater production and its quality in the Project Area, survey team conducted its own industrial wastewater survey in November 1976. Using the list of factories from PDC, the factories were classified into 9 categories and 29 groups as shown in Table F-12. The questionnaires including items on (1) water consumption, (2) wastewater production and disposal, (3) treatment facilities, (4) effluent quality, (5) factory scale and expansion plan, (6) working hours, and (7) main process related to wastewater production, were sent to 47 factories altogether selected from all those classified and grouped accordingly. The staff members followed up with field visits after the questionnaires were sent, and discussed with the persons in charge. Eighty five (85) percent of the questionnaires sent were returned.

Further, 7 effluent samples suspected of bad quality were collected during the visits of the factories, which were analyzed by Department of Chemistry and Indus Laboratories.

2.2.2 Findings of Wastewater Surveys

Concerning with water consumption and discharge, effluent quality, number of employees, and factory site area, the findings of the industrial wastewater surveys carried out independently by Ministry of Environment, MPSP, and by survey team were summarized in Table F-13 with their factory code numbers. All of the data summarized in Table F-13 are based on the year 1976 except some of water consumption data which is that of 1975 from PWA.

Malaysia Science University and MPSP carried out a survey of small scale industry in Butterworth Town through the field visits in 1976. Table F-14 shows a number of small scale factories in Butterworth, which are mainly metal-processing, woodworking, motor-work-shop, and food factories. As most of these factories are as small as home size, it is expected that they would not cause any serious problems in terms of pollution. The similar situation prevails in the other areas regarding the small scale factories.

TABLE F-12 List of Industries Classified

Code No. Class	Code No. Group	Name of Industry Classified	Remarks
1		Foods	
	11	Sea Products	Frozen Foods, Tinned Foods
	12	Oil Products	Palm Oils, Refined Oils
	13	Other Foods	including Feeds
2		Textile	
	21	Spinning	Yarn, Thread
	22	Weaving	Fabrics
	23	Dyeing	
	24	Apparel	
3		Chemicals	
	31	Fertiliser	
	32	Synthetic Chemistry	
	33	Other Chemicals	
4		Rubber and Plastics	
	41	Rubber	Latex
	42	Rubber and Plastics Processing	
5		Stone and Clay Products	
	51	Glass	
	52	Concrete	
	53	Others	Pottery
6		Metals	
	61	Iron & Steel	
	62	Non-Ferous Metals	
	63	Fabricated Metals	
	64	Other Metal Works	
7		Electrics	
	71	Electronics	
	72	Other Electric Goods	
8		Machinery and Equipments	
	81	Machinery	
	82	Assembling	
	83	Others	Parts/Tools Making
9		Others	
	91	Battery	
	92	Plating	
	93	Woodworking	
	94	Other Processing	
	95	Others	

TABLE F-13 Summary of the Industrial Wastewater Surveys

	Quantity		Quality (mg/l)		Number of Employee	Site Area (ha)	Factory Code No.
	Qc*	Qd**	BOD	SS			
1	8,182.8	8,182.8	130.0	61.7	875	28.4	2-23-15
2	3,182.2	2,273.0	-	79.0	739	21.6	3-32-02
3	2,500.0	2,200.0	-	102.5	310	7.1	1-13-11
4	718.3	-	-	-	3,036	4.7	2-22-04
5	609.2	591.0	2.0	70.0	104	2.0	3-33-07
6	609.1	436.4	20.0	30.0	587	4.8	2-21-02
7	371.9	-	-	-	453	2.1	2-22-05
8	318.2	181.8	55.0	30.0	267	2.4	2-21-03
9	308.9	234.1	26.0	49.0	90	4.1	3-32-04
10	297.0	53.5	-	-	440	2.8	6-64-06
11	245.5	122.8	78.6	900.0	50	-	3-33-08
12	218.2	8.1	122.0	42.0	137	6.1	1-12-05
13	216.5	214.9	85.0	171.0	900	8.1	4-42-04
14	136.4	113.7	-	-	-	-	1-11-03
15	131.8	-	-	-	434	16.2	2-21-01
16	113.7	-	410.0	100.0	137	1.6	1-11-02
17	107.7	-	265.0	170.0	147	1.3	1-11-01
18	104.9	104.9	-	-	-	-	2-22-13
19	90.9	27.3	325.0	78.0	47	2.0	3-32-03
20	90.9	78.2	3.0	10.0	108	4.2	6-63-01
21	79.7	76.6	-	-	238	1.0	2-22-07
22	75.8	63.2	-	-	417	2.6	4-42-05
23	73.3	-	15.0	110.0	-	-	1-11-08
24	69.2	41.6	-	-	239	2.4	1-13-09
25	68.2	63.6	2,680.0	12,460.0	96	2.0	1-12-04
26	63.6	-	575.0	10.0	-	-	4-41-01
27	59.1	59.1	120.0	1,260.0	60	2.0	1-13-13
28	58.7	-	5.0	30.0	-	-	9-92-03
29	53.8	53.8	-	-	165	2.8	5-51-01
30	45.5	-	25.5	10.0	79	0.4	9-92-02
31	45.6	-	140.0	230.0	-	-	2-22-16
32	44.6	-	-	-	160	4.1	6-64-05
33	40.2	9.8	25.0	20.0	186	2.0	1-12-06
34	39.1	-	-	-	140	0.4	2-22-08
35	36.8	36.8	-	-	36	0.6	1-11-16
36	36.4	1.8	-	-	27	1.8	3-33-09
37	35.2	16.5	55.0	110.0	-	-	2-22-10
38	29.9	-	25.0	30.0	-	-	9-94-09
39	28.6	28.4	138.0	118.0	216	1.2	9-94-07
40	27.3	-	-	-	118	3.2	2-22-06

(to be continued)

TABLE F-13 Summary of the Industrial Wastewater Surveys

(continued)

	Quantity		Quality (mg/l)		Number of Employee	Site Area (ha)	Factory Code No.
	Qc*	Qd**	BOD	SS			
41	26.4	6.6	-	-	-	-	2-22-12
42	25.6	-	-	2,430.0	110	-	1-13-10
43	25.6	-	3.0	20.0	16	5.1	3-31-01
44	25.0	18.2	-	-	82	1.3	8-82-01
45	24.1	-	-	-	150	4.1	6-64-02
46	22.7	-	-	-	215	0.6	3-33-06
47	20.5	-	-	-	131	4.0	9-93-05
48	20.0	20.0	-	-	210	1.7	9-93-06
49	19.4	-	10.0	40.0	52	3.9	3-33-05
50	19.2	13.6	30.0	65.0	-	-	6-64-08
51	18.4	-	3.0	80.0	-	-	6-64-07
52	18.0	-	615.0	3,455.0	-	-	1-12-07
53	17.3	13.6	-	-	137	6.1	6-64-03
54	16.7	-	-	-	105	1.7	1-13-12
55	15.9	3.2	-	-	-	-	9-95-13
56	14.1	14.1	-	-	-	-	9-94-12
57	13.6	3.0	-	-	-	-	4-42-06
58	13.3	-	-	-	535	2.2	7-71-01
59	12.9	10.3	25.0	20.0	72	0.4	2-22-09
60	11.5	-	-	-	98	0.8	9-93-04
61	11.5	-	20.0	80.0	-	-	1-13-14
62	11.4	-	320.0	130.0	-	-	4-41-02
63	11.4	-	85.0	475.0	-	-	4-41-03
64	10.8	-	740.0	40.0	-	-	2-22-09
65	10.2	10.2	4.0	15.0	64	0.4	8-83-02
66	9.1	9.1	-	-	20	1.2	9-95-10
67	8.0	-	13.0	10.0	-	-	9-91-01
68	7.2	7.2	-	-	157	0.4	6-64-09
69	3.2	3.2	20.0	460.0	-	-	9-94-08
70	1.9	1.0	43.0	113.0	34	0.4	9-94-08
71	0.7	0.7	-	-	-	-	6-64-04
72	0.5	0.5	-	-	-	-	2-22-11
73	0.2	0.2	-	-	-	-	1-11-15

* Q_c : Water Consumption (cu m/day)

** Q_d : Water Discharge (cu m/day)

TABLE F-14 Number of Small Scale Factories in Butterworth

Class* No.	Type of Factories	No. of Factories	Remarks
1	Food	79	
2	Textile (Apparel)	22	
3	Chemicals	15	
4	Rubber & Plastics	31	Manufacturing
5	Stone & Clay Products	15	
6	Metals	121	Manufacturing
7	Precision Equipment	-	
8	Transport Equipment	83	Motor Work Shop
9	Others		
	Woodworking	94	
	Paper	19	Processing
	Printing	8	
	Others	67	
	General Service	15	
	Junk Yard	37	
	Store	28	

After Malaysia Science University and MPSP, "Survey of Small Scale Industries in Butterworth Town" (1976)

* : Industrial Classification Number (see Table F-12)

2.3 Quantity of Industrial Wastewater

2.3.1 Industrial Water Consumption

Review of the information through questionnaires carried out by MPSP and survey team together with those by PWA-data enables to undertake assumption on the existing industrial water consumption in the Area.

Tables F-15 and F-16 show industrial water consumption per capita-employee and per factory-site-area by industrial classification. Although the number of samples are not enough to estimate water consumption by each industrial classification, the figures of water consumption per employee and/or per site area indicates the characteristics of each industry. Both Tables F-15 and F-16 indicate that food, textile, and chemical industries are water-demand type industries.

TABLE F-15 Water Consumption VS. Factory Site Area

Class* No.	Water Consumption (cu m/day)	Site Area (ha)	Per Unit Area Water Consumption (cu m/day/ha)	Number of Samples
1	3,229.8	26.8	120.6	10
2	10,400.2	62.8	165.7	10
3	4,295.3	40.1	104.6	8
4	292.3	10.7	27.3	2
5	53.8	2.8	19.0	1
6	481.1	21.6	22.3	6
7	13.3	2.2	5.9	1
8	35.2	1.7	20.6	2
9	137.1	9.7	14.2	7
Total	18,938.4	179.4	105.6	47

* : Industrial classification number (see Table F-12)

TABLE F-16 Industrial Water Consumption per Capita Employee

Class No.	Water Consumption (cu m/day)	Number of Employees	Per Capita Water Consumption (cu m/day/cap)	Number of Samples
1	3,255.7	1,564	2.08	11
2	10,400.2	6,220	1.67	10
3	4,540.8	1,340	3.39	9
4	292.3	1,317	0.22	2
5	53.8	165	0.33	1
6	481.1	1,152	0.42	6
7	13.3	535	0.02	1
8	35.2	146	0.24	2
9	137.9	788	0.17	7
Total	19,209.5	13,227	1.45	49

Average industrial water consumption per site area of major factories in the Project Area is shown in Table F-15. Total existing factory site area estimated in the Area is estimated at approximately 350 ha. Therefore, total industrial water consumption is estimated as:

105.6 (cu m/day/ha) x 350 (ha) = 36,960 (cu m/day)

2.3.2 Industrial Wastewater Discharge

A part of industrial water used is lost by evapolation (boiler, etc.) and leakage, and the rest is discharged with or without pollutants. In this report, only polluted industrial wastewater is considered.

Industrial wastewater discharged is calculated according to the following procedure:

(1) Calculation of water consumption per site area by using all data obtained (see Table F-15),

(2) Calculation of the ratio of water discharge/water consumption by using all of the sample data obtained (see Table F-17),

(3) Calculation of water discharge by multiplying (1) with (2),

that is, 105.6 (cu m/day/ha) x 0.861 = 90.9 (cu m/day/ha). Therefore, total industrial wastewater discharged by existing factories in the Project Area is estimated as:

90.9 (cu m/day/ha) x 350 (ha) = 31,815 (cu m/day)

TABLE F-17 The Ratio of Water Discharge/Water Consumption by Industrial Classification

	Food	Textile	Chemical	Others	Total
Water Consumption (C)	3,081.5	9,373.9	4,472.6	919.4	17,847.4
Water Discharge (D)	2,496.1	9,019.1	3,250.0	608.4	15,373.4
Ratio (D/C) percent	81.7	96.2	72.7	66.2	86.1
No. of Sample	8	9	6	18	41

2.4 Quality of Industrial Wastewater

As shown in Table E-13, industrial wastewater quality varies between 2.0 and 2,680 mg/l of BOD and between 10 and 12,460 mg/l of SS, depending upon the difference of industry type and wastewater qualities of each factory. Average wastewater qualities of each industry type are shown in Table F-18.

Table F-18 Average Wastewater Quality of Each Industry Type

	Food	Textile	Chemical	Others
Average Concentration (mg/l)				
BOD	200	122	73	67
SS	299	58	106	127
Wastewater (cu m)	2,341	8,828	3,248	336
(percent)	16	60	22	2
Amount of Waste (kg/day)				
BOD	468	1,077	237	26
SS	934	516	345	43
Number of Samples	5	5	5	6

The estimated quality of industrial wastewater is 122 mg/l of BOD and 125 mg/l of SS as shown in Table F-19. Thus, unit wastewater production, which is defined as the amount of wastes produced per site area, is estimated as:

BOD: 122 (g/cu m) x 90.9 (cu m/day/ha) = 11,089.8 (g/day/ha)
say 11 kg/day/ha

SS : 125 (g/cu m) x 90.9 (cu m/day/ha) = 11,362.5 (g/day/ha)
say 11 kg/day/ha

Therefore, total amount of BOD and SS produced by existing factories in the Project Area are estimated as:

11 (kg/day/ha) x 350 (ha) = 3,850 (kg/day) of BOD and SS respectively.

TABLE F-19 Wastewater Loadings

Concentration (mg/l)		Volume* (cu m/day/ha)	Unit Production (kg/day/ha)	
BOD	SS		BOD	SS
122	125	90.9	11	11

* : Based on factory site area

2.5 Estimation of Future Industrial Wastewater Production

Major industrial development in the Project Area is concentrated in three areas. After completion of development, the total of the industrial areas will be 1,289 ha, of which approximately 30 percent has already been occupied by existing factories under operation.

Although detailed planning for the whole industrial areas has not been completed, it is possible to estimate the future condition by studying existing industrial areas on the basis of assumption that the constituent of industrial classification will be kept identical even in the future.

The results of questionnaire survey including visits of major factories representing each industry type show that most of major factories are almost fully working in their capacity, and that the factories under operation and/or construction are equipped with fully advanced installations, which warrant that the unit wastewater production in the future would remain to be constant in the foreseeable future in spite of the accelarated industrialization programme.

On the basis of the above assumption, followings are considered reasonable prediction of the future unit industrial wastewater production:

(a) Increase of industrial wastewater volume would be less than 10 percent in unit area production.

(b) BOD produced from some food factories would be reduced by improvement of their processing, but total BOD produced from entire factories would increase about 30 percent in unit area production as area-productivity is increased.

(c) The ratio of BOD/SS is nearly equal to one for the present industrial condition in the Project Area, and this is similar to the value of highly industrialized countries. Therefore, the ratio is considered to be remained same in the future.

(d) Total factory site area is considered to occupy 80 percent of whole industrial area in the future.

The future industrial wastewater production from unit industrial area is estimated as shown in Table F-20.

TABLE F-20 Future Wastewater Loadings

Concentration (mg/l)		Volume* (cu m/day/ha)	Unit Production (kg/day/ha)	
BOD	SS		BOD	SS
150	150	80	12	12

* : Based on the area including road, drain, etc.

CHAPTER 3

EXTRANEOUS WATER

In spite of the fact that a sewerage system is designed for sewage only, because of many thousands of pipe joints, manholes and inspection covers, etc., a certain amount of extraneous water will find its way into the sewers.

In view of these conditions, for the separate sewer system, an infiltration allowance is considered in determining sewer capacities. The infiltration allowance, 18 cu m/day/km, is considered to be a fair estimate of the extraneous flows to sewers, including ground water and surface water infiltration from public sewers and house connections through manhole covers, etc. This should be adequate since the sewer joints specified for the Project are of rubber ring type for concrete pipes and of the factory applied resilient type for clay pipes.

The infiltration allowance, 18 cu m/day/km, is based on analysis of infiltration from George Town Sewerage Study(*1). George Town Sewerage Study used figure of 0.002 cubic feet per second per acre for infiltration. This is equivalent to 12 cu m/day/ha. In consideration of these conditions, it is recommended that an allowance of 18 cu m/day/km be allowed in addition to peak sanitary sewer flow, and an infiltration allowance by land use is calculated as shown in Table F-21.

TABLE F-21 Infiltration Allowance by Land Use

Land Use	Estimated Total Sewer Length	Infiltration Allowance
Residential		
High density	600 m/ha	12 cu m/day/ha (18 cu m/day/km)
Low density	450 m/ha	8 cu m/day/ha (18 cu m/day/km)
Industrial	250 m/ha	5 cu m/day/ha (18 cu m/day/km)

(*1) George Town Sewerage Study: A Colombo Plan Project for the Government of Canada and the Government of Malaysia, Nov. 1968

APPENDIX G

SEWERAGE SYSTEM CONSIDERATION

CHAPTER 1

BASIC CONSIDERATION

1.1 General

To examine all reasonable alternatives and to select the most cost-effective system therefrom, network models were developed, and sewage treatment methods of sewerage system were considered for application to the Project Area. Using these models, all feasible alternative combinations of sewerage systems were developed and each of the alternatives was studied with respect to its initial investment, operation and maintenance costs as well as effects on flexibility and speed of implementation to identify the most economical system achieving the desired results. The economic analysis considered sewage flow rates and costs incurred over 20-year period to the year 2000.

Result of these studies indicates that an alternative, essentially independent treatment plant to be constructed in each zone, is the most economical sewerage system.

1.2 Sewerage Districts and Zones

Initially, two alternative sewerage systems, the one that whole Project Area to be covered by one comprehensive sewerage system, and the other that more than one sewerage system for the Project Area, are considered. Desirability of either one of the system depends upon the characteristics of the Area with due consideration on economical impact.

The physical characteristics of the Project Area are (1) populated urban areas are limited, (2) huge rural areas still remain at present to be developed in the future, and (3) mostly are flat ground surface.

If comprehensive sewerage system is planned in a huge flat ground surface as described above, large sized deep main sewers are required to convey sewage from individual house all the way to the treatment plant, causing high initial investment in addition to the difficulties in implementing construction programme particularly in the built-up areas. Consequently, immediate implementation of the sewerage system construction will be delayed with added difficulties in obtaining sufficient funds for small sewers such as laterals and branches.

Under the circumstance, it is considered practical, as WHO Assignment Report recommends, that the Project Area be properly divided into districts and zones to be dealt with separately, rather than planning area-wide system to cover the whole Project Area. The advantages of this system considered would be:

(a) It is possible to design sewer facilities according to the characteristics of each of such areas.

(b) Implementation of construction plan will be flexible to adjust according to the degree of requirement and availability of financial resources in the future.

(c) Long conveyance of sewage can be avoided, which will avoid inconvenience in construction and enable better control of sulfide build-up later.

(d) Rural areas, in which no urbanized plan is done, will remain flexible for future modification.

The Project Area has, as indicated earlier, a total of 11,600 ha altogether, but, excluding watercourses, swamps and other non-habitable areas, total area for sewerage planning purpose is 10,854 ha. For the convenience of planning, an attempt is made to divide the total area available into 4 districts, namely, Butterworth, Seberang Jaya, Prai and Bukit Mertajam, in accordance with the geographical conditions. They are further divided into zones with due consideration of the followings.

(i) Population density by area.

(ii) Existence of rivers, railways, and roads.

(iii) Land use situation.

(iv) Administrative boundaries (Mukim boundaries).

(v) Condition of built-up areas.

(vi) Topography.

Several alternative delineations are considered, but with due note of the advantages for smaller delineation as stated earlier, the following is considered to serve the purpose.

TABLE G-1 Sewerage Districts and Zones

	Name of District	Name of Zone	Area (ha)	To be covered by Sewerage (ha)
1.	Butterworth	Zone - 1	390	367
2.		- 2	200	182
3.		- 3	490	457
4.		- 4	450	444
5.		- 5	570	551
6.		- 6	670	670
7.	Seberang Jaya	Zone - 1	480	438
8.		- 2	360	305
9.		- 3	510	510
10.		- 4	430	430
11.		- 5	420	368
12.	Prai	Zone - 1	1,230	1,063
13.		- 2	280	268
14.	Bukit Mertajam	Zone - 1	940	892
15.		- 2	730	715
16.		- 3	980	927
17.		- 4	470	467
18.		- 5	490	459
19.		- 6	660	573
20.		- 7	850	768
	Total		11,600	10,854

NOTE: The area covered by sewerage of 10,854 ha is estimated from excluding non-habitable areas such as mountains, rivers, and cemeteries from the entire Project Area of 11,600 ha.

The detailed descriptions of present condition of each sewerage zone are as follows:

(1) Butterworth Sewerage District

This district is the northern part of the Butterworth/ Bukit Mertajam Metropolitan Area and the southern end is limited by the Prai river. It covers an area of 2,671 ha (excluding the airforce base), with a present population of approximately 109,000. The town area of Butterworth is included within this district. For more detailed planning consideration, the district is deemed appropriate to be divided into 6 zones, on the basis of roads, administrative subdistrict boundaries, and town area boundaries.

TABLE G-2 Butterworth Sewerage Zones

Zone	Area (ha)	Population	Population density (persons/ha)
Zone-1	367	37,920	103
-2	182	3,585	20
-3	457	28,225	62
-4	444	26,332	59
-5	551	3,961	7
-6	670	8,902	13
Total	2,671	108,925	41

Small stormwater drains into which kitchen wastes are discharged directly at present, are provided in the town area. Ground elevations in this district are low, ranging between 1.8 to 3.5 m (5.9 to 11.5 ft) above mean sea water level (RL).

In most of housing areas in the town and new housing development areas, flush toilet systems with septic tanks are used, while in the rural area bucket toilet systems are commonly used. Wastewater produced within this district finally flows into the Prai river through its branches and drains.

Comments on some of the zones are as follows:

(a) Zone-1 covers the center of this district, where exist both commercial and residential areas.

(b) Zones-2 and 3 are covered by residential, industrial, and partly rural areas, and is within town area.

(c) A part of zone-4 belongs to town area, however this zone is still rural at present.

(d) Zones-5 and 6 are rural areas at present, and are partly under housing development programmes.

(2) Seberang Jaya Sewerage District

This district lies between the Prai river and the railway, and covers an area of approximately 2,051 ha with a present population of 28,600. Most areas of this district are under the industrial and housing development plans. The district is proposed to be divided into 5 zones in accordance with new planning roads.

The area, population, and population density by zone at present are as follows:

TABLE G-3 Seberang Jaya Sewerage Zones

Zone	Area (ha)	Population (persons)	Population Density (persons/ha)
Zone-1	438	13,657	31
-2	305	69	0.2
-3	510	2,991	6
-4	430	7,518	17
-5	368	4,369	12
Total	2,051	28,604	14

There are drainage systems including wide and flat grade open channels and pumping station which has not been operated yet. Ground elevations in this district are also low, ranging between 1.5 to 2.5 m (4.9 to 8.2 ft) above mean sea water level (RL).

In new housing development area of this district, flush toilet systems followed by the stabilization pond are installed, while in the rural area bucket toilet systems are commonly used. Wastewater produced within this district is finally discharged into the Prai river through drains.

Comments on these zones are as follows:

(a) New industrial and housing complexes are under construction in zones-1 and 2.

(b) Zones-3, 4 and 5 are covered by rubber farms, rural housing areas, and wilds at present.

(3) Prai Sewerage District

This district is the southwest part of the Metropolitan Area limited by the railway, and covers an area of approximately 1,331 ha with a present population of 3,800. Most of the district is covered by the industrial development plan, and under construction.

The district is proposed to be divided into 2 zones by new planning boundaries of industrial area.

The area, present population and population density by zone are as follows:

TABLE G-4 Prai Sewerage Zones

Zone	Area (ha)	Population (persons)	Population density (persons/ha)
Zone-1	1,063	1,860	2
-2	268	1,974	7
Total	1,331	3,834	3

Ground elevations in this district are low, ranging between 1.1 to 1.8 m (3.6 to 5.9 ft) above mean sea water level (RL). Wide and flat grade open drains and pumping stations (one is functionning and the other is under planning) are installed. Wastewater produced within this area is discharged into the ocean through drains and pumping station.

Comments on these zones are as follows:

(a) Zone-1 is covered by the Prai industrial complex and the industrial development area.

(b) Zone-2 is rural housing area and is wild at present.

(4) Bukit Mertajam Sewerage District

This district belongs to the eastern half of the Metropolitan Area and covers an area of 4,801 ha, with a present population of approximately 96,600. The town area of Bukit Mertajam is included within this district. The district is proposed to be divided into 7 zones on the basis of roads, administrative subdistrict (Mukim) boundaries, town area boundaries, and topographical conditions.

The area, population, and population density by zone are as follows:

TABLE G-5 Bukit Mertajam Sewerage Zones

Zone	Area (ha)	Population (persons)	Population density (persons/ha)
Zone-1	892	7,559	8
-2	715	6,387	9
-3	927	45,540	49
-4	467	6,077	13
-5	459	7,257	16
-6	573	13,840	24
-7	768	9,947	13
Total	4,801	96,607	20

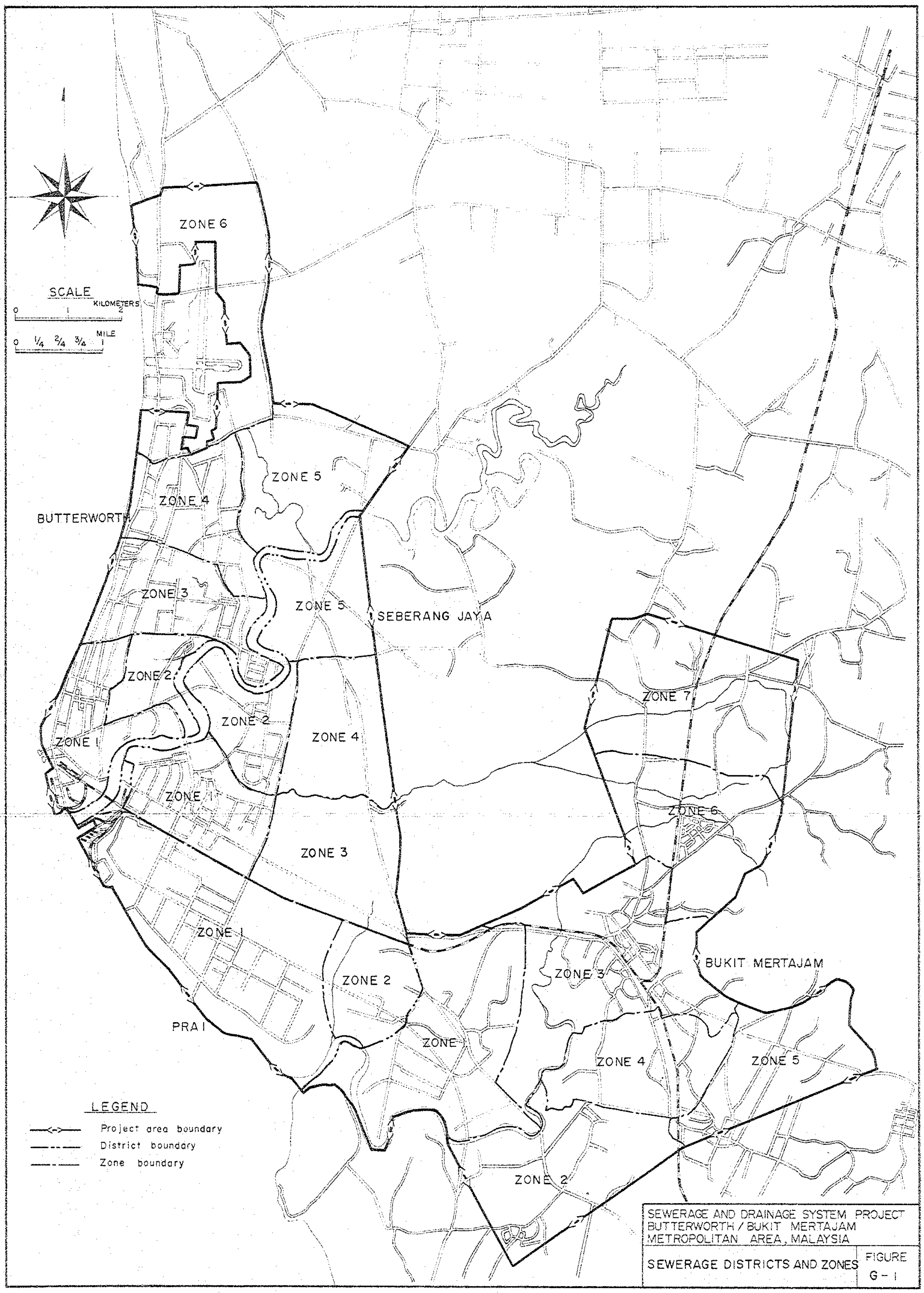
Small stormwater drains consisting mainly of side ditches have been provided in the town areas. In other areas natural drainage systems are functioning well because of adequate slope of ground surface at present. Ground elevations in this district are ranging between 1.8 to 16 m (5.9 to 52.5 ft) above mean sea water level (RL).

Similar to Butterworth Sewerage District, flush toilet systems with septic tanks are installed, in most of housing areas in the town and new housing development areas, while in the rural and mountainous areas bucket or pit privy toilet systems are commonly used. Wastewater produced within this district is discharged finally into the Juru river through its branches and drains.

Comments on some of the zones are as follows:

(a) Town area which is built-up populated area, and new housing development area along the upstream of the Juru river are located in zone-3.

(b) The remainders, Zones-1, 2, 4, 5, 6 and 7 are either rural or mountainous areas at present.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MILE
0 1/4 2/4 3/4 1
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ZONE 5
ZONE 4
BUTTERWORTH
ZONE 3
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SEBERANG JAYA
ZONE 2
ZONE 2
ZONE 4
ZONE 1
ZONE 1
ZONE 7
ZONE 6
ZONE 3
ZONE 1
ZONE 2
BUKIT MERTAJAM
ZONE 3
PRAI
ZONE
ZONE 4
ZONE 5
ZONE 2
LEGEND
Project area boundary
District boundary
Zone boundary
SEWERAGE AND DRAINAGE SYSTEM PROJECT
BUTTERWORTH / BUKIT MERTAJAM
METROPOLITAN AREA, MALAYSIA
SEWERAGE DISTRICTS AND ZONES
FIGURE
G - 1

CHAPTER 2

SYSTEM ANALYSIS

2.1 General

Considering the sewerage master plan objectives, many special investigations were carried out during this study, and evaluation of the results has led to the formulation of general design criteria for desirable optimum system. On the basis of these, alternative systems were designed and cost estimates were made for comparative analysis.

It is apparent that a sewerage system serving the Project Area will involve conveyance and treatment of raw sewage flows and disposal of treated sewage effluents through the combination of most appropriate locations. To examine all reasonable alternatives and to select the most cost-effective system therefrom, a network model was developed to facilitate the analysis. Using this model, all feasible alternative combinations of sewerage systems were defined and each of the alternatives was studied with respect to its initial investment, maintenance and operation costs as well as easiness of implementation and the effect on future flexibility in order to determine the best solution.

2.2 Alternative Sewerage System Considered

2.2.1 Conveyance Network

Initially, on the basis of several reasons as described in Chapter 1 of this Appendix, the entire Project Area was divided into 20 sewerage zones. Then, several cases of conveyance networks were studied on a preliminary basis, considering topographical and economic aspects both for present and future conditions.

As the result of preliminary considerations, followings are concluded:

To avoid high initial investment due to construction of long conveyance system to collect sewage of wide area, and because the sewerage system should be flexible for future development programme, the conveyance networks should be established in each sewerage zone independently.

2.2.2 Sewage Treatment and Disposal System

(1) General

Sewage treatment plant is a facility to convert a raw waste water into an acceptable final effluent, and to dispose of the solid removed in the process. It is fundamental, therefore, first to determine the characteristics of the raw waste water and the required degree of the effluent or the required treatment, before proceeding with the design of treatment plant.

In the design of treatment plants of study area, it is necessary to determine the most desirable treatment system from among the various methods, to meet the degree of the required effluent on the basis of economical analysis.

This section deals briefly with alternative methods of treatment system such as stabilization pond, aerated lagoon and oxidation ditch, and to recommend the desirable treatment method from both the technical and economical view point.

(2) Alternative methods of treatment

1) Stabilization Pond

Stabilization pond has been sucessfully used in many countries, which is sometimes referred as "oxidation pond" or "lagoon".

They are recognized means of sewage treatment and have considerable advantages particularly as regards to the costs and maintenance requirements and the removal of faecal bacteria.

They are without doubt the most important method of sewage treatment in hot climates where sufficient land is available and where the temperature is most favourable for their operation.

On the basis of operational condition, the stabilization ponds are classified into three types, namely, aerobic, faclutative and anaerobic pond. Among them, since aerobic type requires large land area and anaerobic type emits bad odour, facultative pond described below may be the most appropriate type in the Project Area.

a) Facultative Pond

Facultative pond is the system in which the upper layers of the pond are aerobic and the bottom layers are either devoid of dissolved oxygen or are anaerobic. At present most of the existing waste stabilization pond installations are of the facultative type.

The facultative pond is oxygenated principally by the photosynthetic activity of algae under the influence of solar radiation, although in the larger ponds surface aeration by the wind action contributes significantly to the total oxygen budget.

The dissolved oxygen concentration is greater during daylight period than at night. The measurement of oxidation-reduction potential will show the tendency towards either aerobic or anaerobic conditions.

For the facultative pond, temperature is of great importance because it affects the rate of biochemical degradation. The average, daily fluctuations, and yearly variations of temperature influence the biological, physical and chemical processes in the pond.

The practical design of a facultative pond depends on difference of local conditions, but a number of useful and rational design procedures are available. The most important factors on stabilization pond design are areal load of BOD and depth of the pond. On the basis of the K.L. sewage treatment plant operation, 300 kg-BOD/day/ha(*1)

(*1) Ref. "Master Plan for Sewerage and Sewage Disposal" for Kuala Lumpur and Environs.

of areal load and 1.5 m of pond depth are proposed for this study. This corresponds to 10 days of mean retention time.

b) Maturation Pond

The main purpose of maturation pond is to provide a high-quality effluent which is used as a second stage to facultative pond. The principal factor for the design of the maturation pond is detention time, but for efficient reduction of the faecal bacteria it is essential that the pond be arranged in series with the preceding pond. The detention time in the maturation pond, as well as the number of ponds, is determined primarily by the degree of bacterial purification required. In design of maturation pond the reduction of faecal coliform in a pond has been found to follow first order kinetics. The appropriate equation is as follow.

$$Ne = \frac{Ni}{1 + K_{b(t)} T}$$

$$K_{b(t)} = 2.6\ (1.19)^{t-20}$$

where

Ne : effluent coliform, cells/ml

Ni : influent coliforms, cells/ml

$K_{b(t)}$: dieoff coefficient of coliforms at t°C, 1/day

T : retention time, days

From the above mentioned equation the estimated number of effluent coliform from facultative pond (Ne) is 4,500/ml, assuming

$Ni = 4 \times 10^5$/ml, $K_{b(27)} = 8.8\ d^{-1}$, and T = 10 days.

This value (Ne = 4,500/ml) is unsatisfied on sanitary aspects, so that the facultative pond may be followed by a maturation pond (retention time is 3 days) for further reduction of coliforms.

That is

$$Ne = \frac{4 \times 10^5}{(1 + 8.8 \times 10)\ (1 + 8.8 \times 3)} = 164/ml$$

This may be satisfied for environmental protection from coliform contamination by treatment plant effluent.

2) Aerated Lagoon

The aerated lagoon is an activated sludge unit operated without sludge return. This is historically developed from stabilization pond.

Low cost mechanical aeration is the most important matter to be the useful engineering alternative when waste loads increase, when land is limited, and when high-quality effluent is required. Commonly, floating aerator for surface aeration is used to supply the necessary oxygen and mixing power for bio-oxidation and for mixing lagoon contents.

In common with all activated sludge systems, aerated lagoon is not particularly effective in removing faecal colofirms and suspended solids, faecal coliform reduction is only 90-95 percent and further treatment may therefore be necessary, hence it is considered that maturation pond needs for required effluent.

For the design of aerated lagoon in this study, the retention time is assumed as 4 days and the depth of lagoon is assumed at 3.0 m.

3) Oxidation Ditch

The oxidation ditch is a modification of the activated sludge process, generally followed by sedimentation tank except for small size plant. The oxidation ditch is a long continuous channel usually oval in plan and

1.0 - 1.5 m deep. The ditch liquor is aerated by one or more brush or rotors placed across the channel.

At present, there are few oxidation ditches in the hot climate due to the fact that stabilization ponds are usually more favourable both in terms of cost and the removal of faecal coliform, although where there is a reliable electricity supply with insufficient land for pond, they are being increasingly used.

A design of oxidation ditch is purely empirical at the present time. According to the Mara report(*1), the depth is in the range of 1 - 2 m and the volume is dependent on the retention time which in turn is based on the sludge loading factor. This is the weight of BOD applied to the ditch liquor suspended solids per day.

Therefore, the sludge loading factor is given by following equation.

$$r = \frac{Li}{St}$$

where

r = sludge loading factor, 1/d

Li = influent BOD, mg/l

S = ditch liquor suspended solids, mg/l

t = detention time, days

Then, ditch volume is estimated as follow.

$$V = \frac{LiQ}{Sr}$$

where

V = ditch volume, cu m

Q = flow rate, cu m/day

(*1) "Sewage Treatment in Hot Climate", by Duncan Mara

The design values of this study are taken as $r = 0.1\ d^{-1}$, $S = 4,000$ mg/l, $t = 0.5$ days, and depth is assumed at 1.5 m.

(3) Comparison of Alternative Treatment and Disposal Systems

For the purpose of cost comparison of alternative treatment and disposal systems for the (1) stabilization pond, (2) aerated lagoon and (3) oxidation ditch, firstly each type of treatment facilities was designed for daily average flow rate of waste water from 5,000 to 200,000 cu m with associated facilities, due to the required effluent quality.

The waste water quality of each treatment was estimated with the influent BOD at 200 mg/l and that the expected BOD is of 75 - 90 percent removal of influent BOD for the design values.

The each type of treatment was analyzed and/or made of all costs accruing to alternative considered. Each considered type of methods of treatment and disposal systems for alternative study are furnished as described below and illustrated as Figure G-2.

1) Stabilization pond process shall consist of the facultative and maturation ponds in series.

2) Aerated lagoon process shall consist of the aerated lagoon and maturation pond in series.

3) Oxidation ditch process shall consist of oxidation ditch, sedimentation tank, and sludge drying bed.

The capital costs of the each selected alternative of sewage treatment plant on the flow rate from 5,000 to 200,000 cu m (daily average flow) were estimated with associated equipments in plants on the basis of cost functions developed for the purpose of Master Plan as discussed in following Chapter and annual operation and maintenance costs for these facilities were also estimated.

Table G-6 shows the estimation of construction, operation and maintenance costs of the treatment and disposal systems and required land area for the system. All costs are at 1976 level in the Penang site, but no consideration is given to cost escalation for purpose of economic comparison between alternatives.

For comparison purpose, all costs are then expressed on an annual basis, using the following weighted average lives of facilities.

(a) pond, tank 30 years

(b) pump, aerator 7 years

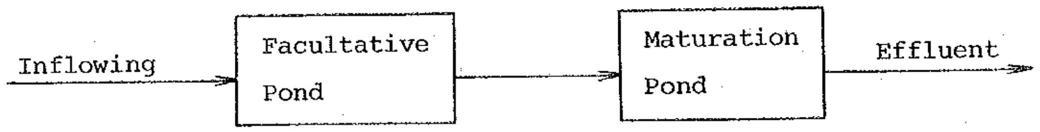
These overall useful lives are estimated on the basis of the useful lives of component facilities, 30 years for civil works and 7 years for machinery of equipment. It is assumed that the fund is available at 10 percent interest rate and that annual depreciation payments into the sinking fund would grow the same rate.

Depreciated capital costs of the alternative systems are summarized in Table G-7, and total annual costs for the alternatives are shown in Table G-8.

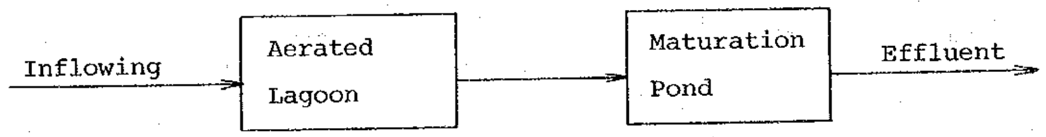
The results of cost analysis indicate that alternative (i) (stabilization pond process) would be the most economical method for treatment and disposal system, in terms of total annual cost.

FIGURE G-2 Flow sheet

(1) Stabilization pond process



(2) Aerated lagoon process



(3) Oxidation ditch process

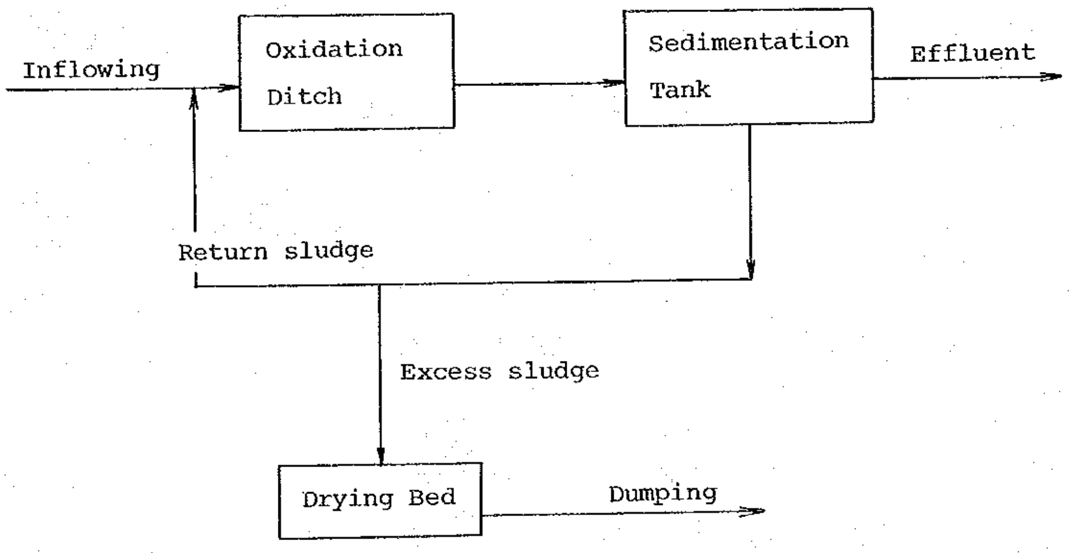


TABLE G-6 Comparison on Alternative Treatment Systems

Alternative	Flow Rate (cu m/day)				
	5,000	10,000	50,000	100,000	200,000
1) Construction Costs (M$ 1,000)					
Alt. I Stabilization Pond Process	524	1,048	5,240	10,480	20,960
Alt. II Aerated Lagoon Process	1,141	2,276	11,350	22,640	45,280
Alt. III Oxidation Ditch Process	982	1,887	9,051	17,333	34,666
2) Operation & Maintenance Cost (M$1,000/year)					
Alt. I Stabilization Pond Process	10.95	11.20	13.50	16.30	21.90
Alt. II Aerated Lagoon Process	28.35	45.76	177.55	344.16	677.39
Alt. III Oxidation Ditch Process	75.98	142.93	588.06	1,101.23	2,167.42
3) Land Area Required (ha)					
Alt. I Stabilization Pond Process	6.0	11.2	52.4	98.7	197.3
Alt. II Aerated Lagoon Process	2.3	4.3	20.2	38.0	76.1
Alt. III Oxidation Ditch Process	0.6	1.1	4.9	9.2	18.5

Note: Estimated construction costs do not include the costs required for land of treatment Plant.

TABLE G-7 Depreciated Costs for Alternative Treatment Systems

(M$ 1,000)

Alternative	Flow Rate (cu m/day)				
	5,000	10,000	50,000	100,000	200,000
Alt. I Stabilization Pond Process	3.19	6.37	31.86	63.72	127.44
Alt. II Aerated Lagoon Process	7.68	15.32	76.39	152.37	304.73
Alt. III Oxidation Ditch Process	45.92	88.24	423.22	810.49	1,620.98

TABLE G-8 Total Annual Cost of Alternative Treatment Systems

(M$ 1,000)

Alternative	Flow Rate (cu m/day)				
	5,000	10,000	50,000	100,000	200,000
Alt. I Stabilization Pond Process	66.8	122.7	571.0	1,131.4	2,252.0
Alt. II Aerated Lagoon Process	150.2	288.8	1,389.3	2,761.2	5,511.4
Alt. III Oxidation Ditch Process	220.1	419.9	1,916.3	3,644.9	7,254.7

CHAPTER 3

COST ESTIMATING PROCEDURES FOR SEWERS

3.1 General

The costs associated with constructing and operating the sewerage system are difficult to estimate for planning purposes. This is true particularly when the planning area includes a variety of geological and topographical features. Also, the costs of treatment processes must be related to the effectiveness of the processes in removing water contaminants to meet a variety of receiving water condition.

In the master planning of the Butterworth/Bukit Mertajam Metropolitan Area Sewerage and Drainage Systems, alternatives should be considered and evaluated in order to establish the most desirable plan. Estimation of costs of these alternatives will be almost impossible in the project duration, unless cost function relationships are developed. The cost functions for conveyance are developed on the basis of 1976 price levels in Penang State.

3.2 Construction Costs

Construction costs of the project may be defined as the sum of all expenditures required to bring the project to completion. These expenditures are divided into direct items and indirect items. The direct items include excavation of trenches, laying and construction of sewers, and all the related construction works including indirect items and any other expenditures expected. In this study, preliminary designs have first been made to obtain quantities and then these have been multiplied by appropriate unit prices to obtain the total costs of project components. For the indirect items, 20 percent was added to the direct items.

3.2.1 Basic Costs

In estimating the construction costs of the facilities, unit costs for domestic items such as labour, materials to be purchased in Malaysia, power, equipment and transportation, materials and equipment to be imported, were collected and checked by both survey team staff and local contractors.

Labourers required for the sewerage constructions may include a wide range of occupational categories, from common labourers to skilled operators for heavy equipment. The current (1976) applicable labour costs for various types of labour in Penang State are from M$ 8 to 20 per day as given in the Table below.

TABLE G-9 Labour Costs

Type of Labourer	M$/day
Common worker	8
Skilled worker	15
Carpenter	12
Stone masonry	12
Plumber	15
Foreman	20

Data source: PWD

Generally, for construction of structures, including pumping stations and treatment facilities, most of the materials required in the project are available, except mechanical equipment which will be imported on an international basis.

Reinforcing bars, timber, sand and gravel for concrete products, vitrified clay pipes, and centrifugally-cast-reinforced concrete pipes (less than 1,800 mm in diameter) are available in Malaysia. The unit price of these basic materials are given in the following Tables.

Land acquisition cost in 1976 price level in the Project Area is estimated on the basis of information obtained from MPSP as shown in Figure G-3.

Table G-10
Table G-11

TABLE G-10 Price of Basic Materials - (1)

Item	Unit	Price (M$)
Cement	ton	109
Sand	cu m	12
Gravel	cu m	27
Steel bar	ton	610
Timber	ton	410
Vitrified clay pipe		
ø150	m	12.99
ø225	m	21.65
ø300	m	32.50

Data source: Local contractor

TABLE G-11 Price of Basic Materials - (2)

Item	Unit	Price (M$)	Remarks
Centrifugally-cast-re-inforced concrete pipe (mm in dia.)			With high alumina cement mortar lin-ings and rubber ring
ø150	m	19.94	
ø225	m	29.45	
ø300	m	36.34	
ø375	m	50.71	
ø450	m	58.85	
ø525	m	70.00	
ø600	m	78.36	
ø675	m	98.85	
ø750	m	109.67	
ø900	m	140.16	
ø1,050	m	178.03	
ø1,200	m	196.89	
ø1,350	m	250.99	
ø1,500	m	290.66	
ø1,800	m	377.87	

Data source: Hume Industry at K.L and K.L Sewerage Master Plan

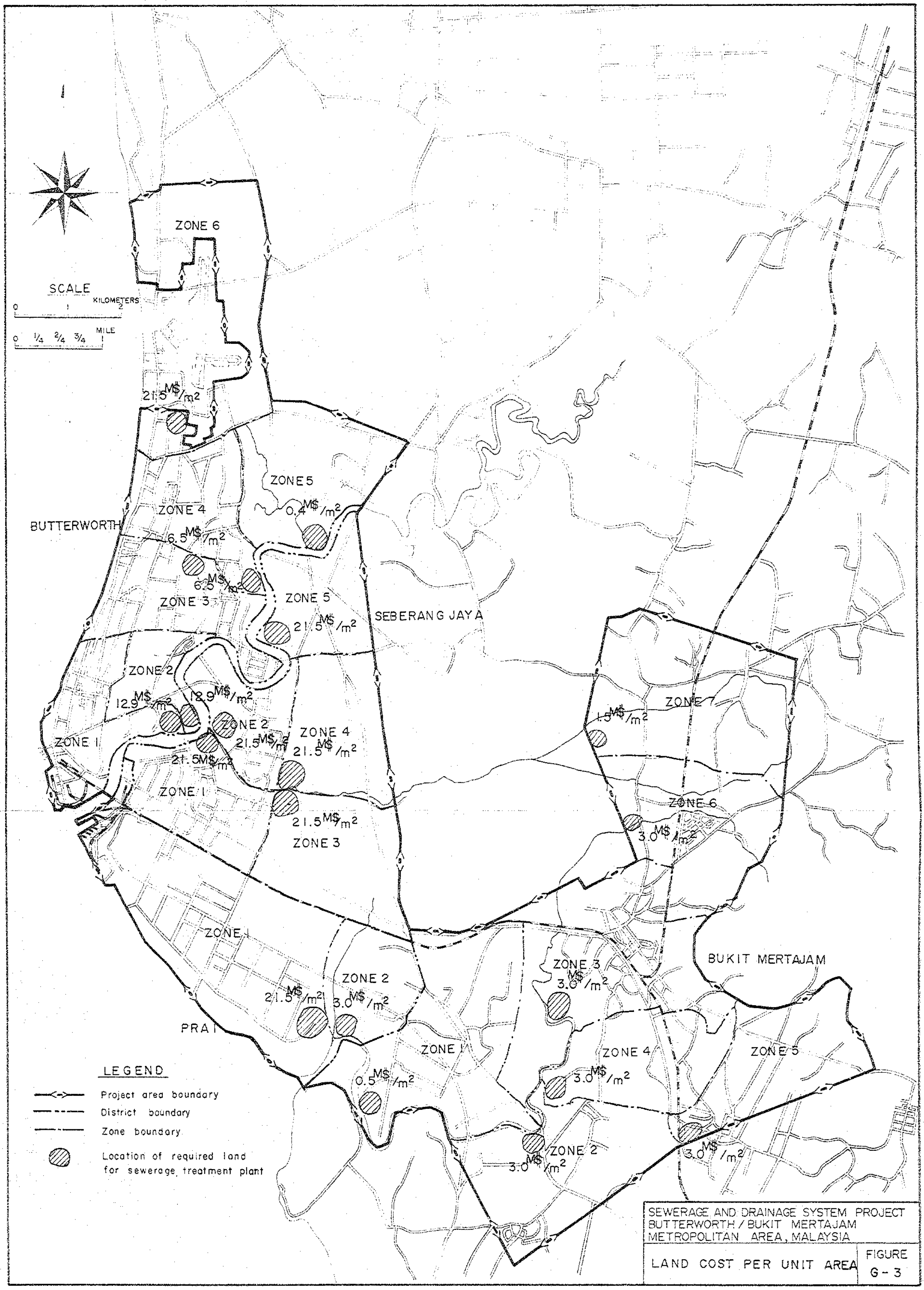
TABLE G-12 Unit Costs for Construction (including labour and materials)

Item	Description	Unit	Cost (M$)
Concrete	mix. 1:2:4	cu m	94.17
"	mix. 1:3:6	"	78.47
Reinforced concrete		"	392.39
Mortar works	mix. 1:2	"	103.60
Surplus soil removal		"	1.96
Excavation	open cut	"	1.96
"	trench (depth 0-1.5m)	"	6.54
"	" (" 1.5-3.0m)	"	9.16
"	" (" 3.0-4.5m)	"	19.62
"	" (" 4.5-6.0m)	"	31.39
"	" (" 6.0-)	"	39.00
Backfilling and compaction			1.57
Bedding	sand bed	"	18.31
"	gravel bed		26.16
Forming		sq m	13.99
Dewatering		hour	5.50
Restoration of paving		sq m	20.00
Sheeting		ton	393.70

Data source: PWD and Local contractor

3.2.2 Unit Costs for Sewerage System

Construction costs were estimated for the sewerage system, taking into account the known or estimated costs of excavation, sheeting, dewatering, bedding, pipe supplying and laying, concrete placing, forming, reinforcing, restoration of paving and contractor's profit and overhead. The cost estimations were developed for normal conditions excluding such additional costs as required for rock excavation, relocation of underground utilities, foundation or dewatering for which special technics are required, and any works required for special conditions.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21.5 M$/m2
ZONE 5
0.4 M$/m2
ZONE 4
BUTTERWORTH
6.5 M$/m2
6.5 M$/m2
ZONE 3
ZONE 5
21.5 M$/m2
SEBERANG JAYA
ZONE 2
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PRAI
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BUKIT MERTAJAM
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ZONE 5
ZONE 2
3.0 M$/m2
3.0 M$/m2
LEGEND
Project area boundary
District boundary
Zone boundary
Location of required land for sewerage treatment plant
SEWERAGE AND DRAINAGE SYSTEM PROJECT
BUTTERWORTH / BUKIT MERTAJAM
METROPOLITAN AREA, MALAYSIA
LAND COST PER UNIT AREA
FIGURE
G-3

Five different sizes of circular pipes, 150 mm, 300 mm, 600 mm, 1,200 mm, and 1,800 mm in diameter, each for different earth covering of 2 m, 4 m, 6 m, 8 m, and 10 m were considered together with estimation of construction costs.

The average unit costs, as estimated for circular pipes, are summarized in the following Table.

TABLE G-13 Estimated Construction Costs of Circular Pipes (including manhole)

(M$/m)

Diameter (m) \ Depth of Excavation (m)	2.0	4.0	6.0	8.0	10.0
0.15	120	220	790		
0.30	160	270	860	2,320	2,860
0.60	270	410	1,070	2,590	3,180
1.20		780	1,540	3,200	3,870
1.80		1,270	2,120	3,950	4,710

3.3 Cost Functions

Cost functions were derived on the basis of the unit costs calculated in the previous paragraphs. The equations to be used for planning were selected, then the functions were developed by the least square method.

Depth = 2.0 m $C_p = 222.2\,D^2 + 166.7\,D + 90$

= 4.0 $C_p = 173.5\,D^2 + 300.3\,D + 168$

= 6.0 $C_p = 150.7\,D^2 + 516.6\,D + 702$

= 8.0 $C_p = 175.9\,D^2 + 714.7\,D + 2{,}093$

= 10.0 $C_p = 175.5\,D^2 + 860.8\,D + 2{,}591$

Where:

C_p : Construction cost, M$/m

D : Pipe diameter, m

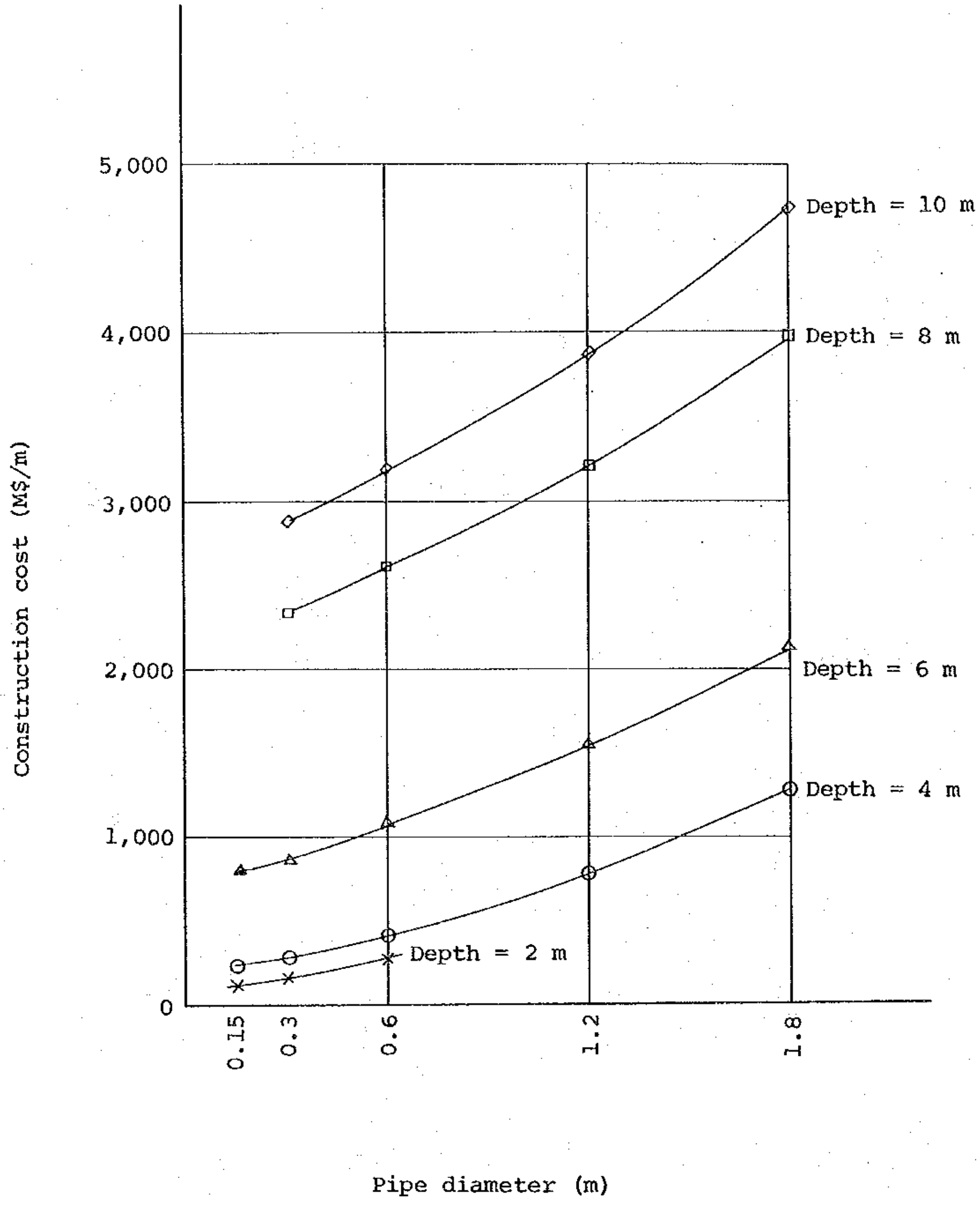


FIGURE G-4 Estimated construction cost of circular pipe, including manhole

CHAPTER 4

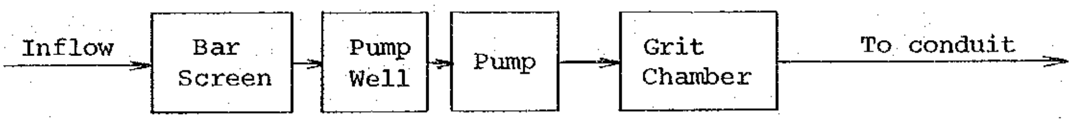
COST FUNCTIONS FOR PUMPING STATIONS

4.1 General

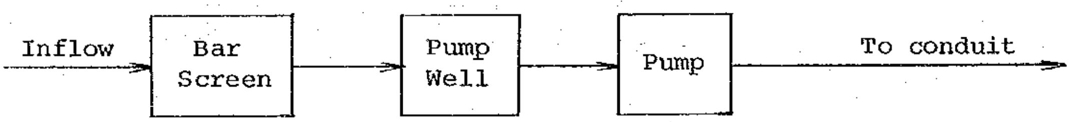
In developing cost functions for pumping stations, cost estimates were made for six stations, different capacities of 0.05 cu m/sec, 0.2 cu m/sec, 0.5 cu m/sec, 0.87 cu m/sec (75,000 cu m/day), 1.73 cu m/sec (150,000 cu m/day), and 8.68 cu m/sec (750,000 cu m/day) for depth of inflowing conduit at 10 m (assumed average depth of pumping station).

The pumping stations which have capacity larger than 0.5 cu m/sec consist of gates, screens, grit chambers, grit removal facilities, pump well, building for pumping equipment and controling devices, piping, etc., but for the smaller pumping stations with capacity less than 0.5 cu m/sec, no grit chambers are installed.

A flow sheet for the station which capacity larger than 0.5 cu m/sec is given as follows:



A flow sheet for the station with capacity less than 0.5 cu m/sec. is given as follows:



4.2 Construction Costs

Construction costs including 20 percent of overhead are estimated for each of the 6 cases for their civil works, pipings, buildings, equipments, electrical and controlling devices, and other appurtenances, and are summarized in Table G-14.

TABLE G-14 Construction Costs of Pumping Stations of 10m Depth by Capacity

(M$ 1,000)

Capacity (cu m/sec)	Civil works & Building	Machinery & Electricity	Total	Remarks
0.05	108	76	184	without grit chambers
0.2	170	137	307	"
0.5	237	227	464	"
0.87	2,411	1,881	4,292	with grit chambers
1.73	2,954	4,015	6,969	"
8.68	9,668	11,325	20,993	"

4.3 Cost Functions

As illustrated in Figures G-5 and 6 the cost function of a pumping station may be expressed in a linear form such as:

$$C_p = a\,Q + b$$

where

C_p : Construction cost, M$ 1,000

Q : Peak flow rate, cu m/sec.

a, b : Constants

The values of "a" and "b" are obtained by the least square method. Hence, the cost functions may be expressed as:

$$C_p = 608.1\,Q + 166 \quad (Q \leq 0.5 \text{ cu m/sec})$$

$$C_p = 2{,}092.0\,Q + 2{,}885 \quad (Q > 0.5 \text{ cu m/sec})$$

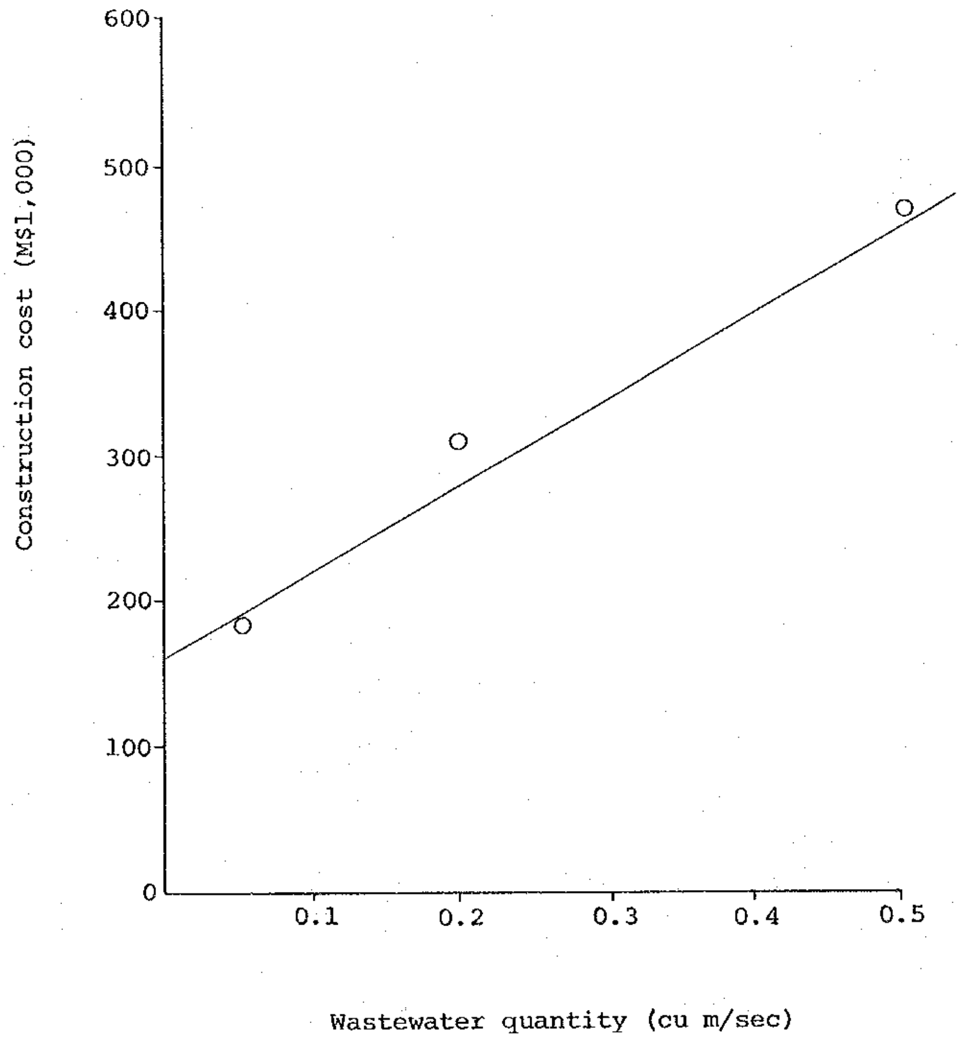


FIGURE G-5 Construction cost for pumping station of 10 m depth by capacity (less than 0.5 cu m/sec)

Figure G-6

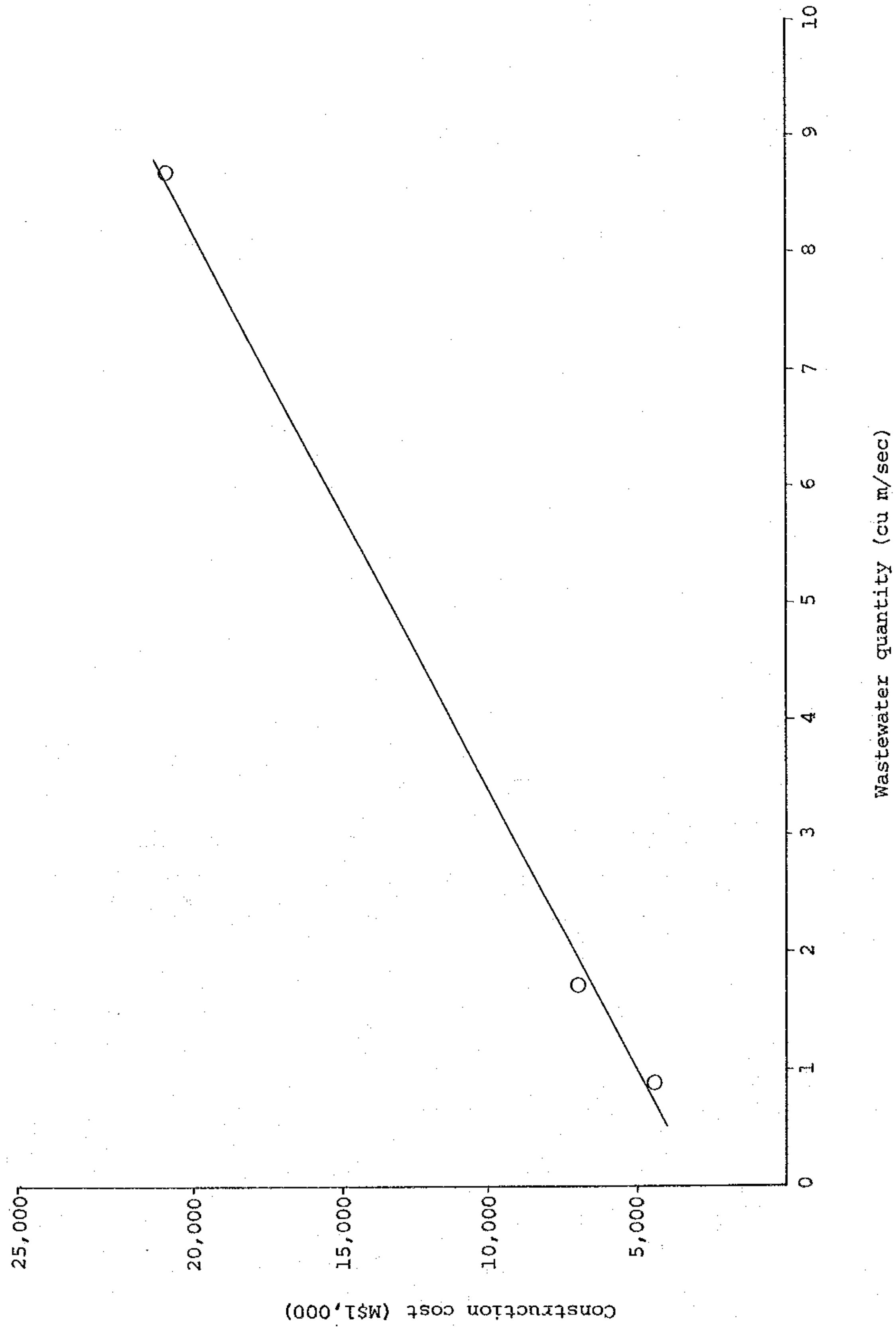


FIGURE G-6 Construction cost for pumping station of 10 m depth by capacity (larger than 0.5 cu m/sec)

CHAPTER 5

COST FUNCTIONS FOR TREATMENT PLANTS

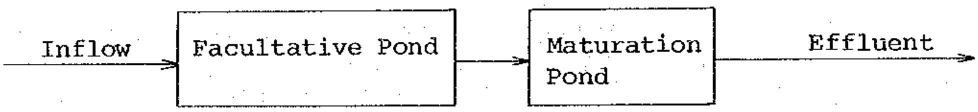
5.1 General

Development of a relationship between capacity and cost of treatment in the form of a cost function is the most practicable approach in sewerage system planning since various alternatives can easily be estimated.

The construction costs of three different treatment processes, stabilization pond, aerated lagoon, and oxidation ditch, at five different capacities, 5,000 cu m/day, 10,000 cu m/day, 50,000 cu m/day, 100,000 cu m/day, and 200,000 cu m/day, were evaluated. Hereafter, cost functions were developed.

5.2 Stabilization Pond Process

A flow sheet of the stabilization pond process is given as follows:



The construction costs of civil works were on the basis of material costs at 1976 Penang State price levels. Costs for equipment were estimated based on costs in Japan but adjusted by adding shipping charge and customs duties.

Table G-15 shows estimated construction costs including 20 percent overhead.

TABLE G-15 Construction Cost for Stabilization Pond Process by Capacity

(M$ 1,000)

Item \ Capacity (cu m/day)	5,000	10,000	50,000	100,000	200,000
Civil works & Building	524	1,048	5,240	10,480	20,960
Machinery & Electricity	-	-	-	-	-
Total	524	1,048	5,240	10,480	20,960

As illustrated in Figure G-7, the cost function of a stabilization pond process may be expressed as linear form in the logarithmic diagram.

$$C_s = a\,Q^b$$

where

C_s : Construction cost, M$ 1,000

Q : Daily average flow, cu m/day

a, b: Constants

The values of "a" and "b" are obtained by the least square method. Thus, the cost function may be expressed as:

$$C_s = 0.1048Q$$

where

C_s : Construction cost, 1,000 M$

Q : Capacity, cu m/day

5.3 Aerated Lagoon Process

A flow sheet of the aerated lagoon process is given as follows:

Construction costs including 20 percent overhead are tabulated in Table G-16.

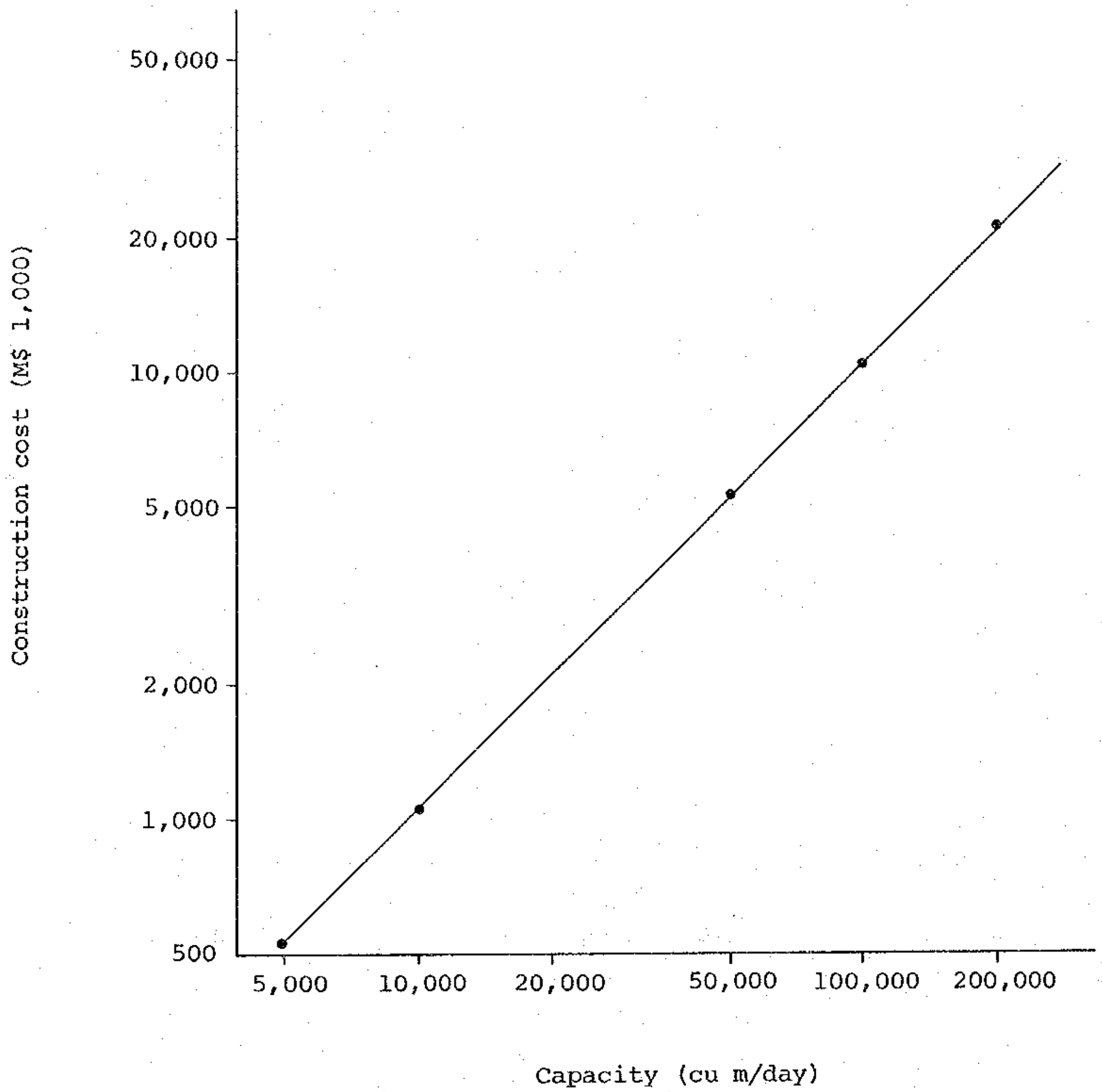


FIGURE G-7 Construction cost for stabilization pond process

TABLE G-16 Construction Cost for Aerated Lagoon Process by Capacity

(M$ 1,000)

Item \ Capacity (cu m/day)	5,000	10,000	50,000	100,000	200,000
Civil works & Building	1,081	2,162	10,810	21,620	43,240
Machinery & Electricity	60	114	540	1,020	2,040
Total	1,141	2,276	11,350	22,640	45,280

Similarly, the cost function may be expressed as:

$$C_A = 0.2323\ Q^{0.998}$$

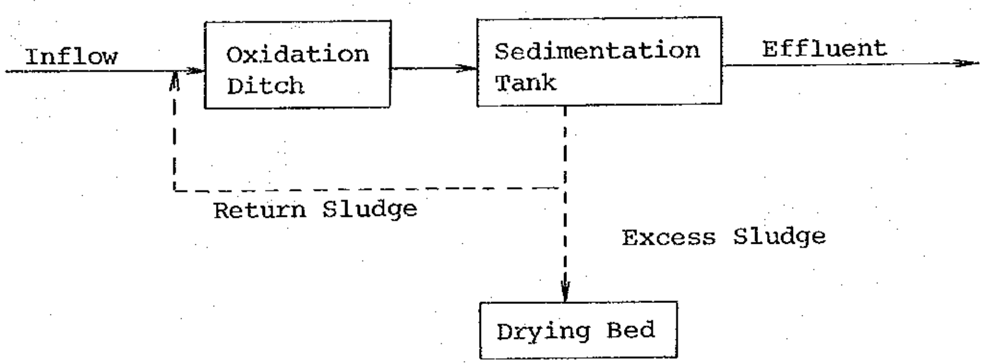
where

C_A: Construction cost, M$ 1,000

Q : Capacity, cu m/day

5.4 Oxidation Ditch Process

A flow sheet of the oxidation ditch process is given as follows:



Construction costs including 20 percent overhead is shown in Table G-17.

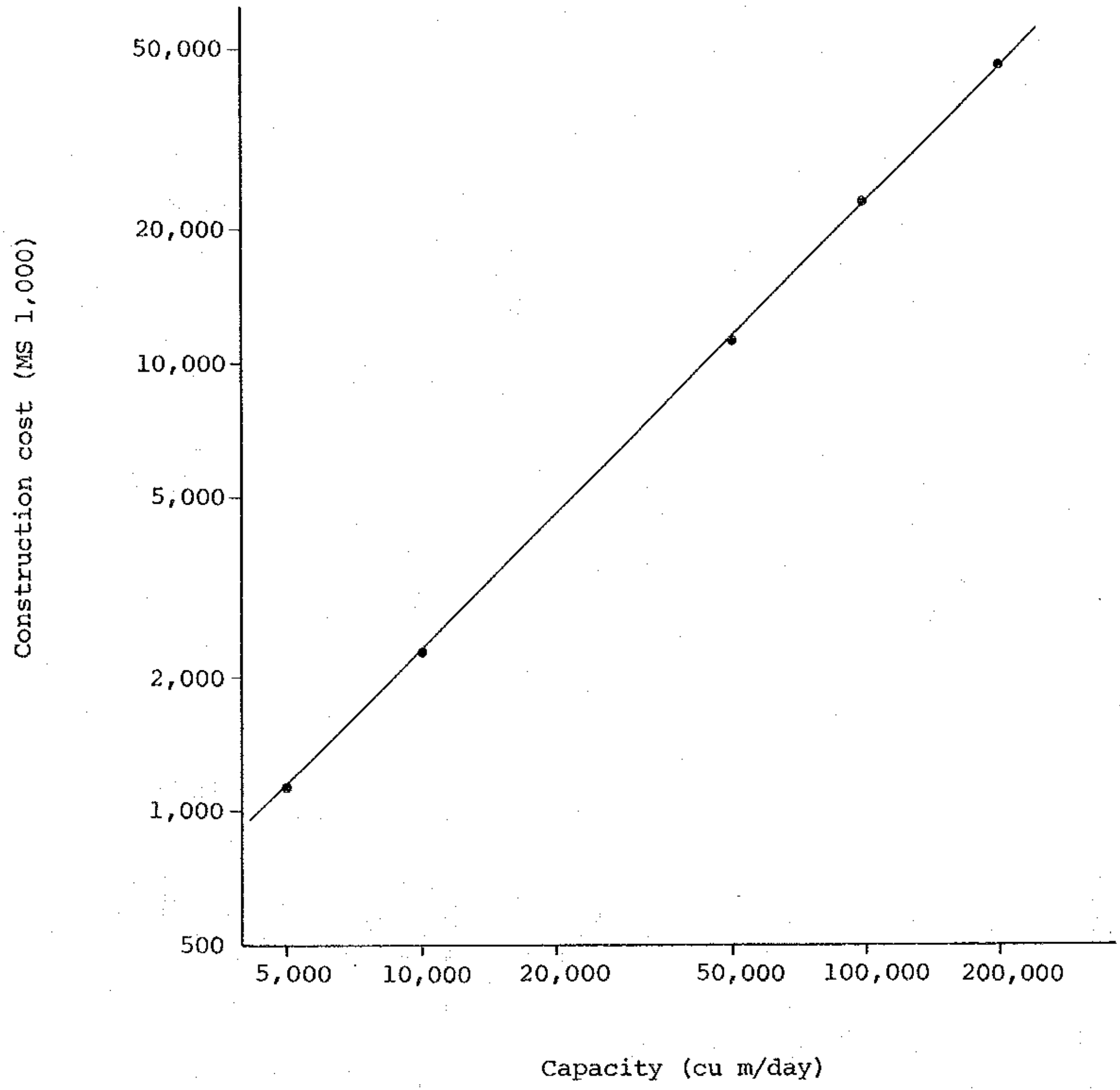


FIGURE G-8 Construction cost for aerated lagoon process

TABLE G-17 Construction Cost for Oxidation Ditch Process by Capacity

(M$ 1,000)

Item \ Capacity (cu m/day)	5,000	10,000	50,000	100,000	200,000
Civil works & Building	213	426	2,130	4,260	8,520
Machinery & Electricity	769	1,461	6,921	13,073	26,146
Total	982	1,887	9,051	17,333	34,666

The cost function may be expressed as:

$$Co = 0.2614\ Q^{0.966}$$

where

Co: Construction cost, M$ 1,000

Q : Capacity, cu m/day

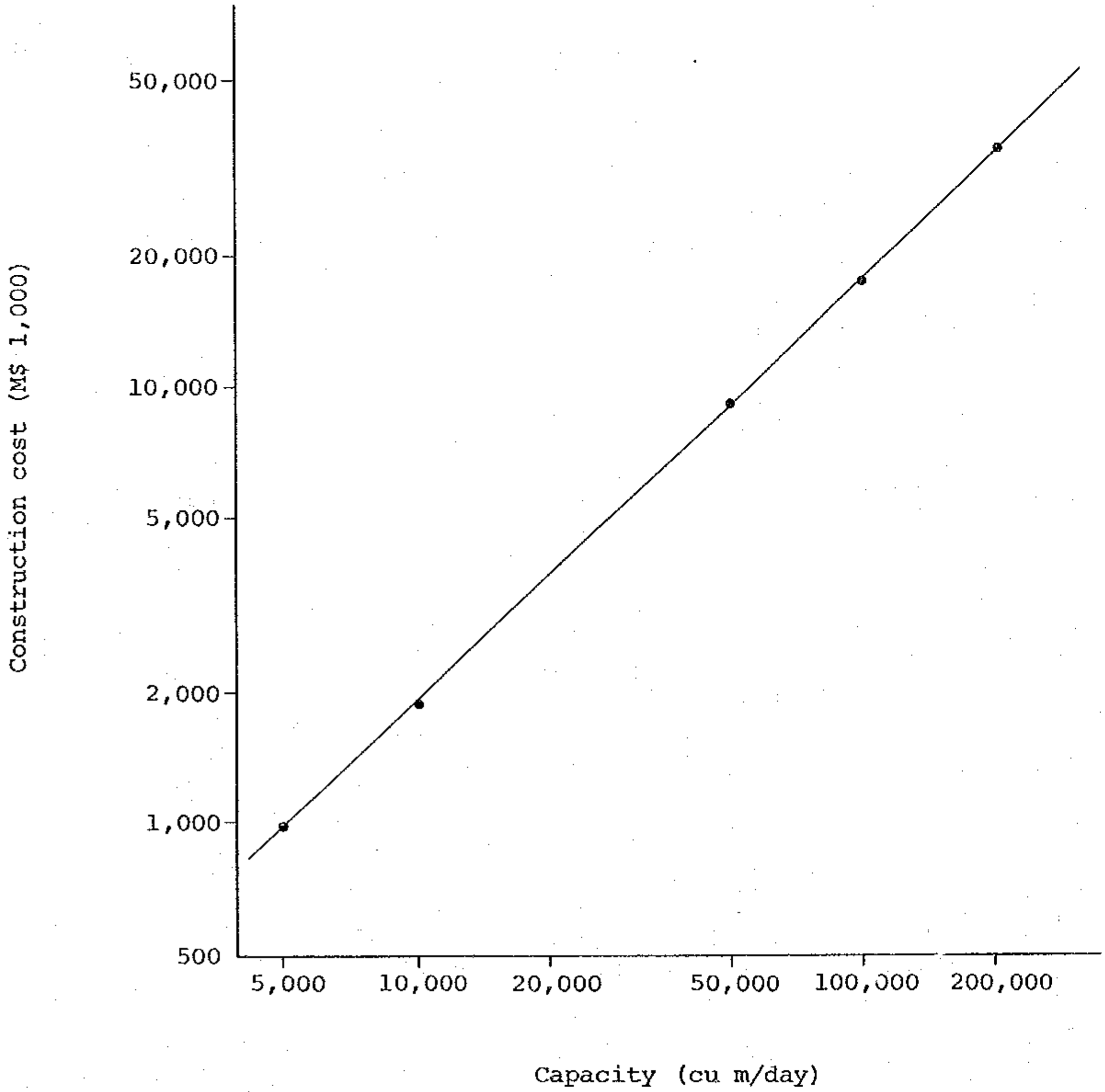


FIGURE G-9 Construction cost for oxidation ditch process

CHAPTER 6

OPERATION AND MAINTENANCE COSTS

6.1 General

Generally, comprehensive sewerage system consists of sewers, pumping stations, and treatment facilities. In order to maintain these facilities significant expenditures are required. They are salary for operators and labours, electricity, purchase of equipment and machine oil, repairing cost, etc.

Cost functions for sewer maintenance, operation and maintenance of pumping stations and treatment facilities are developed respectively.

6.2 Sewers

Maintenance costs for sewers were estimated based on the following assumptions:

(a) Frequency of cleaning for public sewers is once in every four years.

(b) Ability to clean by one team for public sewers is 150 m/day.

(c) Useful life of the cleaning equipment is 10 years.

(d) Team member for public sewers is 6 persons.

(e) Fifty percent of equipment cost include costs for parts, repairing, overhauling, etc.

(f) Annual rehabilitation cost of sewer is 0.5 percent of construction cost.

(g) Working days and hours

Working days are 300 days/year.

Working hours are 6 hours/day.

(h) Labour cost is 8.00 M$/day.

(i) Price of machine

Power driven bucket machine is 121,000 M$/set.

Flexible rod type equipment and high pressure cleaning machine is 77,000 M$/set.

Based on the data and assumptions above, it was estimated that M$ 1.70 will be necessary for maintenance of one meter of public sewers per year.

6.3 Pumping Stations

According to the capacity, different system is considered for pumping station, that is, no grit chamber is installed for station with capacity less than 0.5 cu m/sec. Therefore, two cost functions, one for capacity larger than 0.5 cu m/sec and the other for capacity less than 0.5 cu m/sec, are developed.

In developing the cost functions, followings are assumed in advance.

(a) For station with capacity larger than 0.5 cu m/sec, daily average number of operator is 1 (one) person per station,

(b) For station with capacity less than 0.5 cu m/sec, daily average number of operator is 0.1 person per station, and

(c) Electricity is assumed at M¢8/kWh, and average salary of operator is assumed at M$15/day.

The operation and maintenance costs by capacity were then estimated as shown in Table G-18 and Figure G-10.

TABLE G-18 Operation and Maintenance Costs for Pumping Station by Capacity

(M$ 1,000)

Item \ Capacity (cu m/sec)	0.05	0.2	0.5	0.87	1.73
Salary	0.5	0.5	0.5	5.5	5.5
Electricity, etc.	15.3	23.7	52.3	102.0	127.2
Total	15.8	24.2	52.8	107.5	132.7

On the basis of these figures and Figure G-10, vost functions for operation and maintenance of pumping station were obtained as follows:

$$C_{MP} = 84.1\ Q_P + 9.9 \quad (Q_P \leq 0.5 \text{ cu m/sec})$$

$$C_{MP} = 29.3\ Q_P + 82.0 \quad (Q_P > 0.5 \text{ cu m/sec})$$

Figure G-10

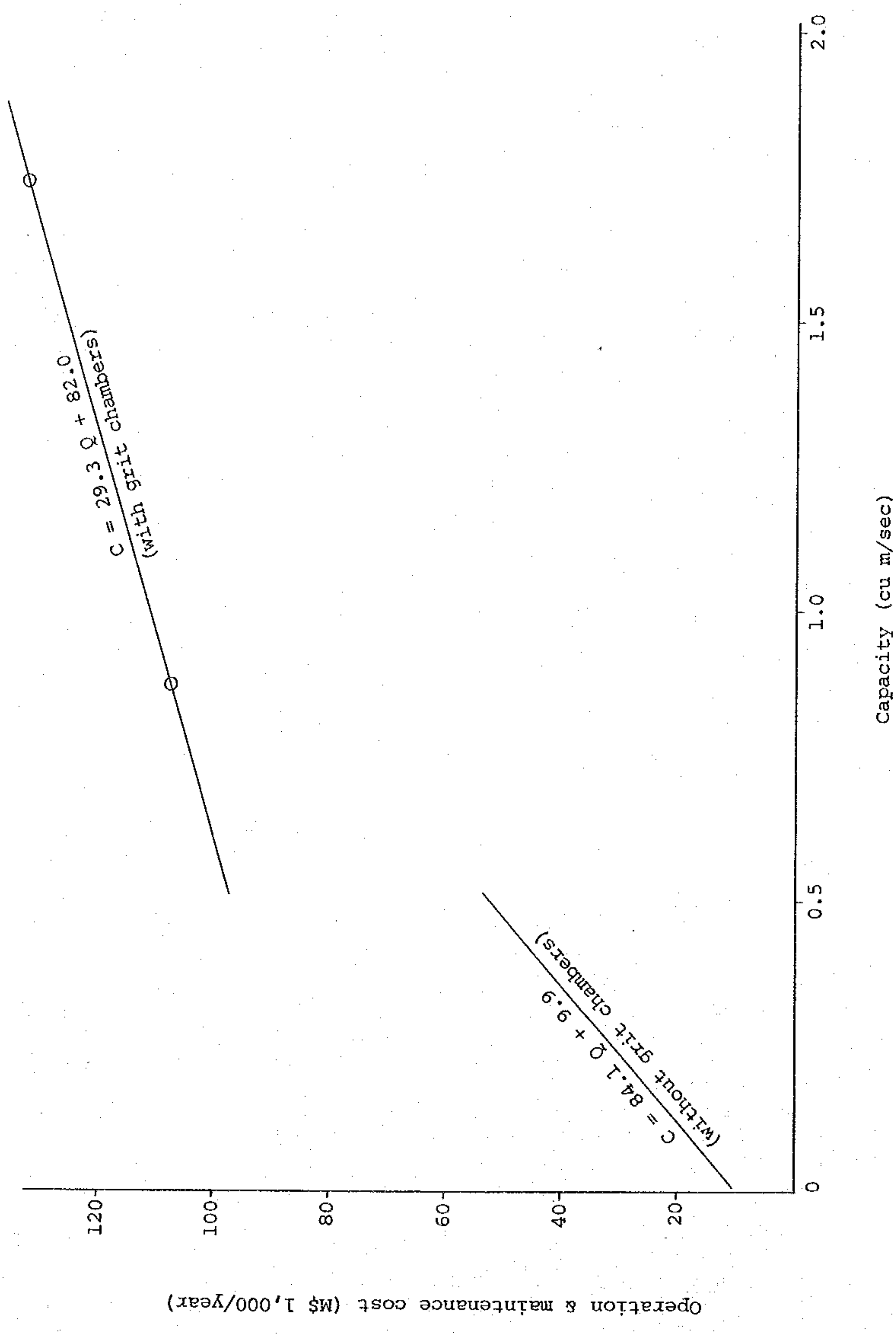


FIGURE G-10 Operation and maintenance cost of pumping station where

Q_{MP}: Operation and maintenance cost, M$ 1,000/year

Q_p : Peak flow, cu m/sec

6.4 Treatment Plants

Cost functions for three different treatment processes, stabilization pond, aerated lagoon, and oxidation ditch, are developed.

In developing the cost functions for treatment plants followings are assumed in advance.

(a) Daily average number of operator is 2 (two) persons for 5,000 cu m/day plant and 4 (four) persons for 200,000 cu m/day plant for stabilization pond and aerated lagoon processes. For oxidation ditch process 4 (four) persons for 5,000 cu m/day plant and 20 persons for 200,000 cu m/day plant are required.

(b) Electricity is M¢8/kWh and average salary of operator is M$15/day.

The operation and maintenance costs by capacity and treatment process were then estimated as shown in Table G-19 and Figures G-11, 12, and 13.

TABLE G-19 Operation and Maintenance Costs for Treatment Plants by Capacity and Treatment Process

(M$ 1,000/year)

Item \ Capacity (cu m/day)	5,000	10,000	50,000	100,000	200,000
(a) Stabilization Pond					
Salary	10.95	11.20	13.50	16.30	21.90
Electricity, etc.	-	-	-	-	-
Total	10.95	11.20	13.50	16.30	21.90
(b) Aerated Lagoon					
Salary	10.95	11.20	13.50	16.30	21.90
Electricity, etc.	17.40	34.56	164.05	327.86	655.49
Total	28.35	45.76	177.55	344.16	677.39
(c) Oxidation Ditch					
Salary	21.90	32.85	43.80	54.75	109.50
Electricity, etc.	54.08	110.08	544.26	1,046.48	2,167.42
Total	75.98	142.93	588.06	1,101.23	2,167.42

On the basis of these figures in Table G-19 and Figures G-11, 12 and 13, cost for operation and maintenance of treatment plant were obtained as follows:

(i) For stabilization pond process

$$C_{MS} = 5.292 \times 10^{-5} Q + 9.33$$

(ii) For aerated lagoon

$$C_{MA} = 3.327 \times 10^{-3} Q + 11.80$$

(iii) For oxidation ditch

$$C_{MO} = 1.067 \times 10^{-2} Q + 35.95$$

where

C_{MS}, C_{MA}, C_{MO}: Operation and maintenance costs, M$ 1,000/year

Q: Daily average flow, cu m/day

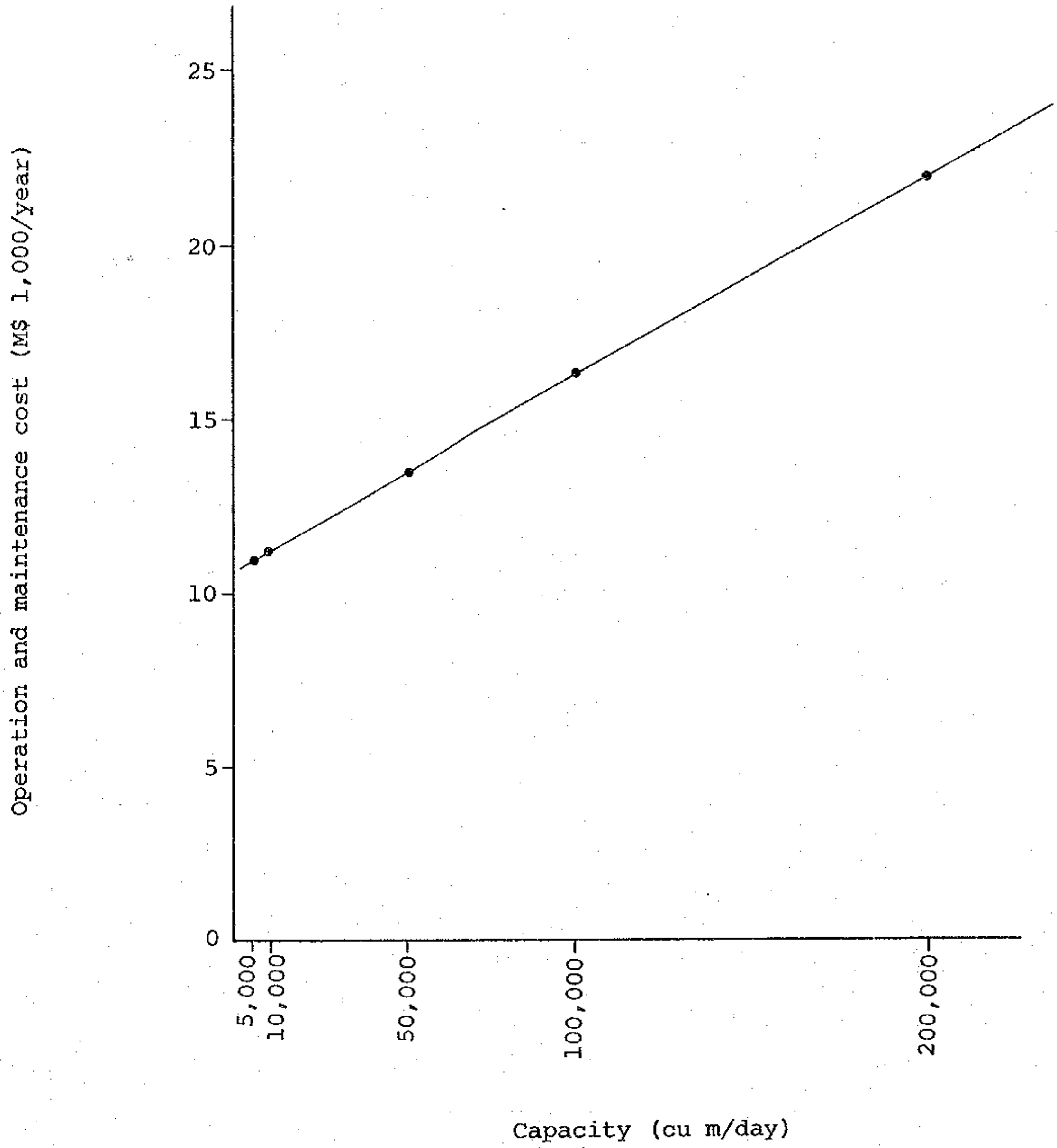


FIGURE G-11 Operation and maintenance cost for stabilization pond process

Figure G-12

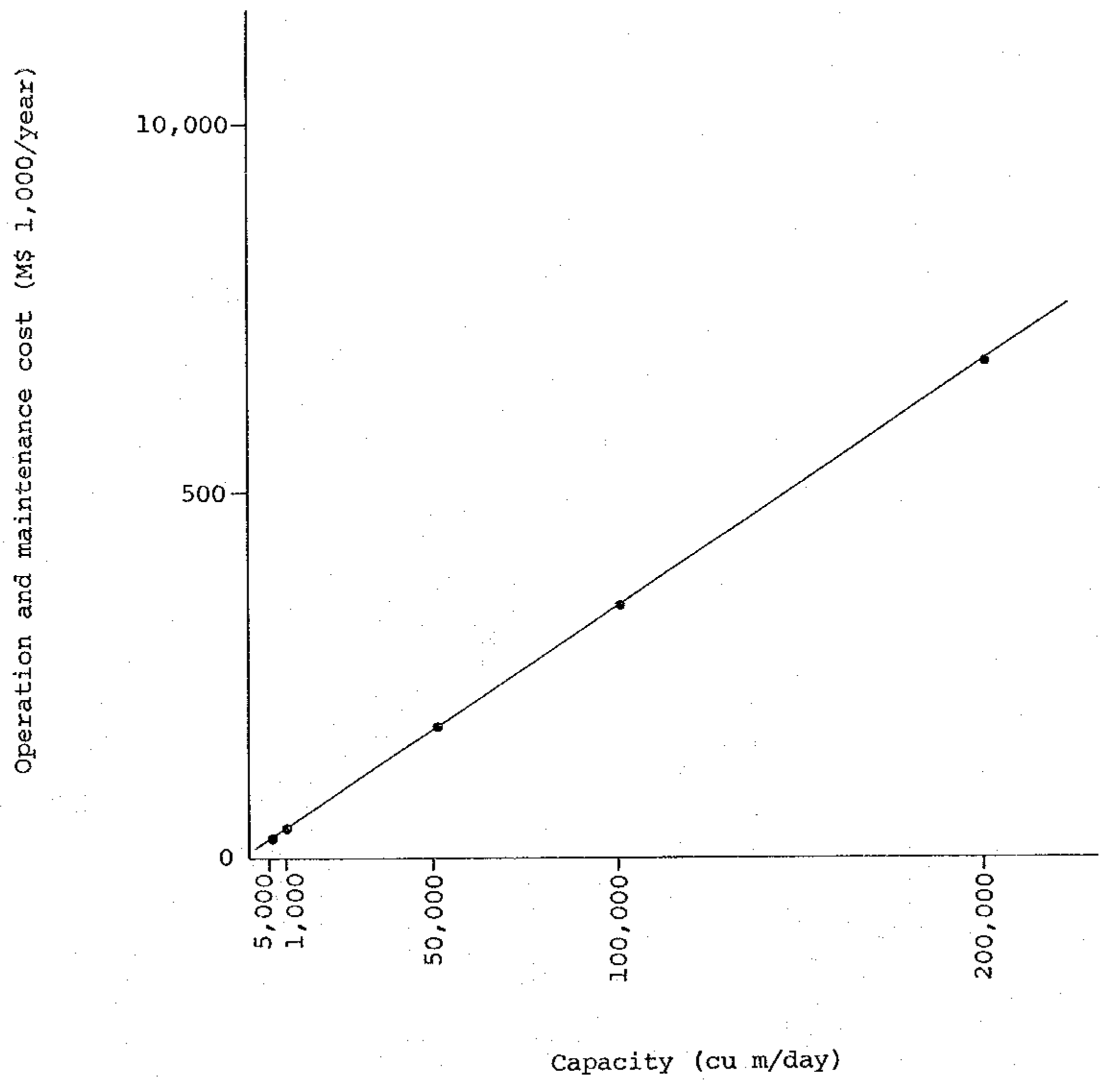


FIGURE G-12 Operation and maintenance cost for aerated lagoon process

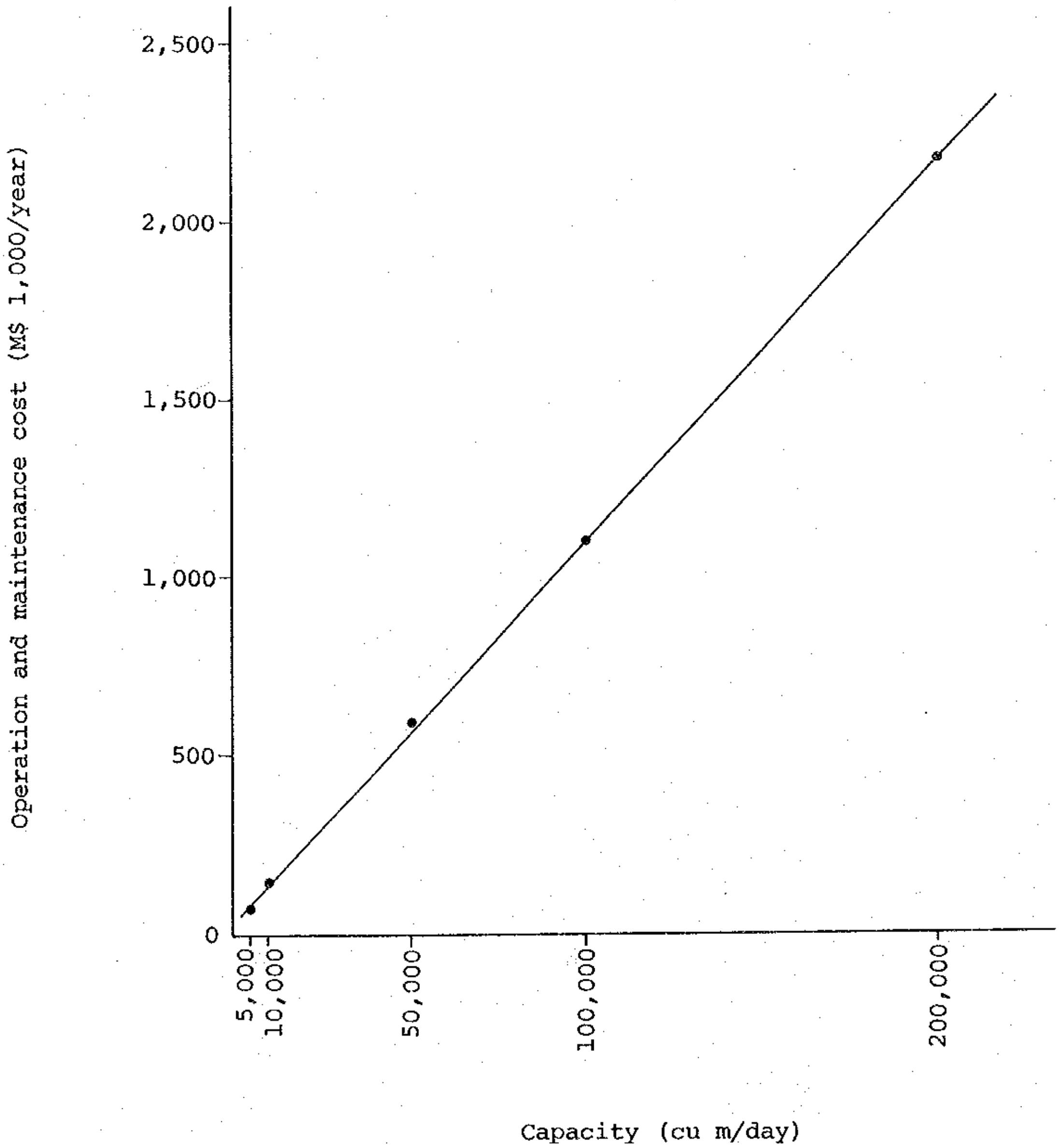


FIGURE G-13 Operation and maintenance cost for oxidation ditch process

CHAPTER 7

LAND REQUIREMENTS FOR SEWERAGE FACILITIES

7.1 General

Most of sewers are laid on the public roads, therefore no land acquisition is required. However, a large piece of land is needed for construction of treatment plant and pumping station, and such land is usually private property which needs cost for acquisition.

In this chapter, the relationship between required site area and capacity of pumping station and treatment plant is discussed.

7.2 Pumping Stations

In developing equations for areas of lands required, 7 stations, which different capacities of 0.05 cu m/sec, 0.2 cu m/sec, 0.5 cu m/sec, 0.87 cu m/sec, 1.73 cu m/sec, 3.0 cu m/sec, and 5.0 cu m/sec, were considered. From layouts of the 7 stations, site areas as shown in Table G-20 were obtained.

TABLE G-20 Required Site Area for Pumping Station

Peak flow, cu m/sec	0.05	0.2	0.5	0.87	1.73	3.0	5.0
Area, sq m	50	120	155	1,600	1,700	1,800	2,400

The relationship between peak flow and site area is illustrated in Figure G-14. The equation may be expressed as:

$$S_p = 216.7\ Q_p + 54 \qquad (Q_p \leqq 0.5 \text{ cu m/sec})$$

$$S_p = 192.3\ Q_p + 1,365 \qquad (Q_p > 0.5 \text{ cu m/sec})$$

where

S_p: Site area, sq m

Q_p: Peak flow, cu m/sec

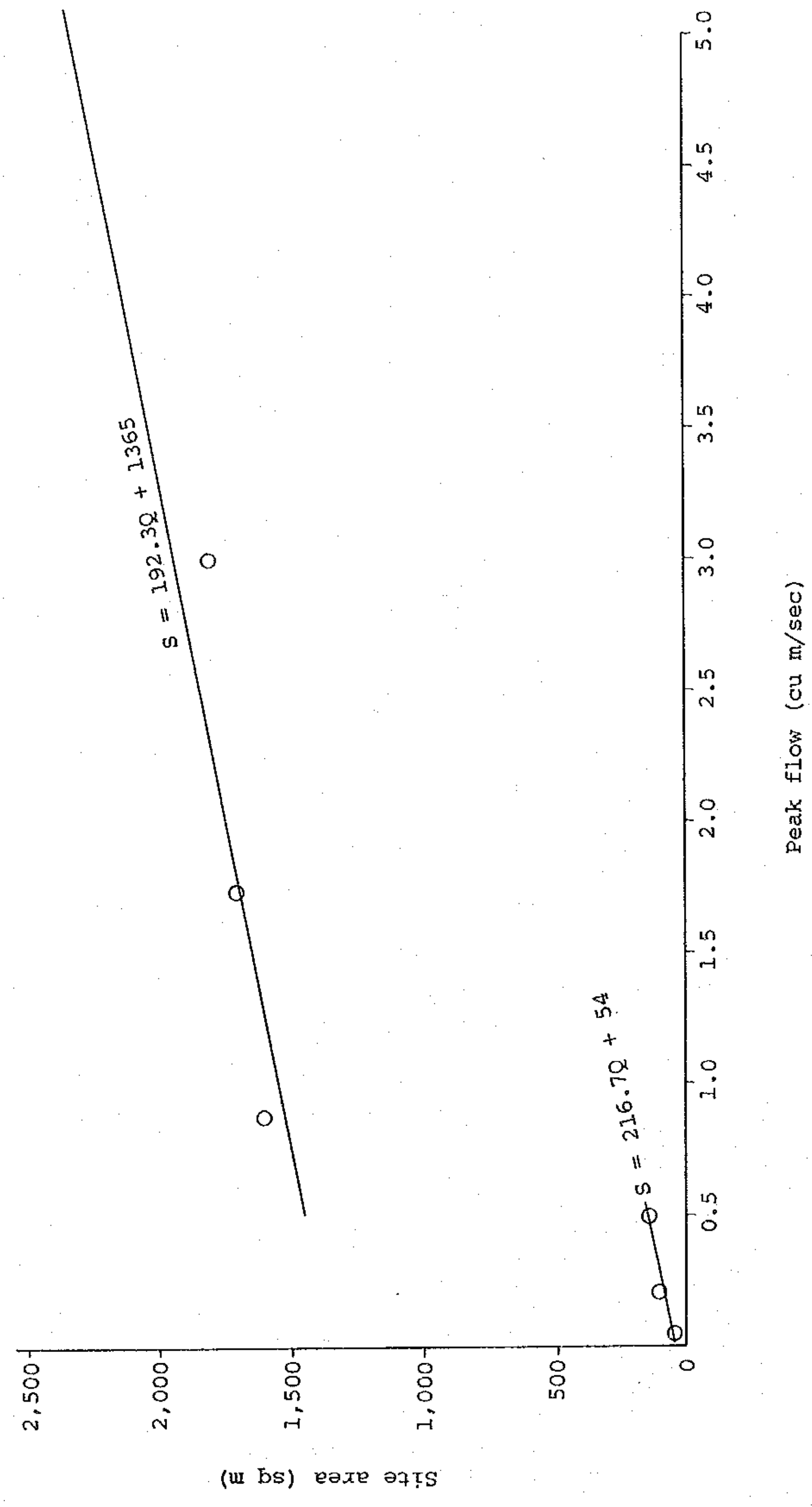


FIGURE G-14 Required site area for pumping station

7.3 Treatment Plants

On the basis of plant layouts of 5 different capacities, 5,000 cu m/day, 10,000 cu m/day, 50,000 cu m/day, 100,000 cu m/day, and 200,000 cu m/day, required site areas for different treatment processes are obtained as shown in Table G-21 and Figure G-15.

TABLE G-21 Required Site Area for Treatment Plant by Process

(hectare)

Treatment process \ Capacity (cu m/day)	5,000	10,000	50,000	100,000	200,000
Stabilization pond	6.0	11.2	52.4	98.7	197.3
Aerated lagoon	2.3	4.3	20.2	38.0	76.1
Oxidation ditch	0.6	1.1	4.9	9.2	18.5

From this Table, equations were developed as follows:

(a) Stabilization pond process

$$S = 0.00186\ Q^{0.947}$$

(b) Aerated lagoon process

$$S = 0.00070\ Q^{0.948}$$

(c) Oxidation ditch process

$$S = 0.00022\ Q^{0.927}$$

where S: Required land area, ha

Q: Daily average flow, cu m/day

Total site area for treatment plant is obtained by adding the site area for pumping station which is calculated based on the peak flow instead of daily average flow.

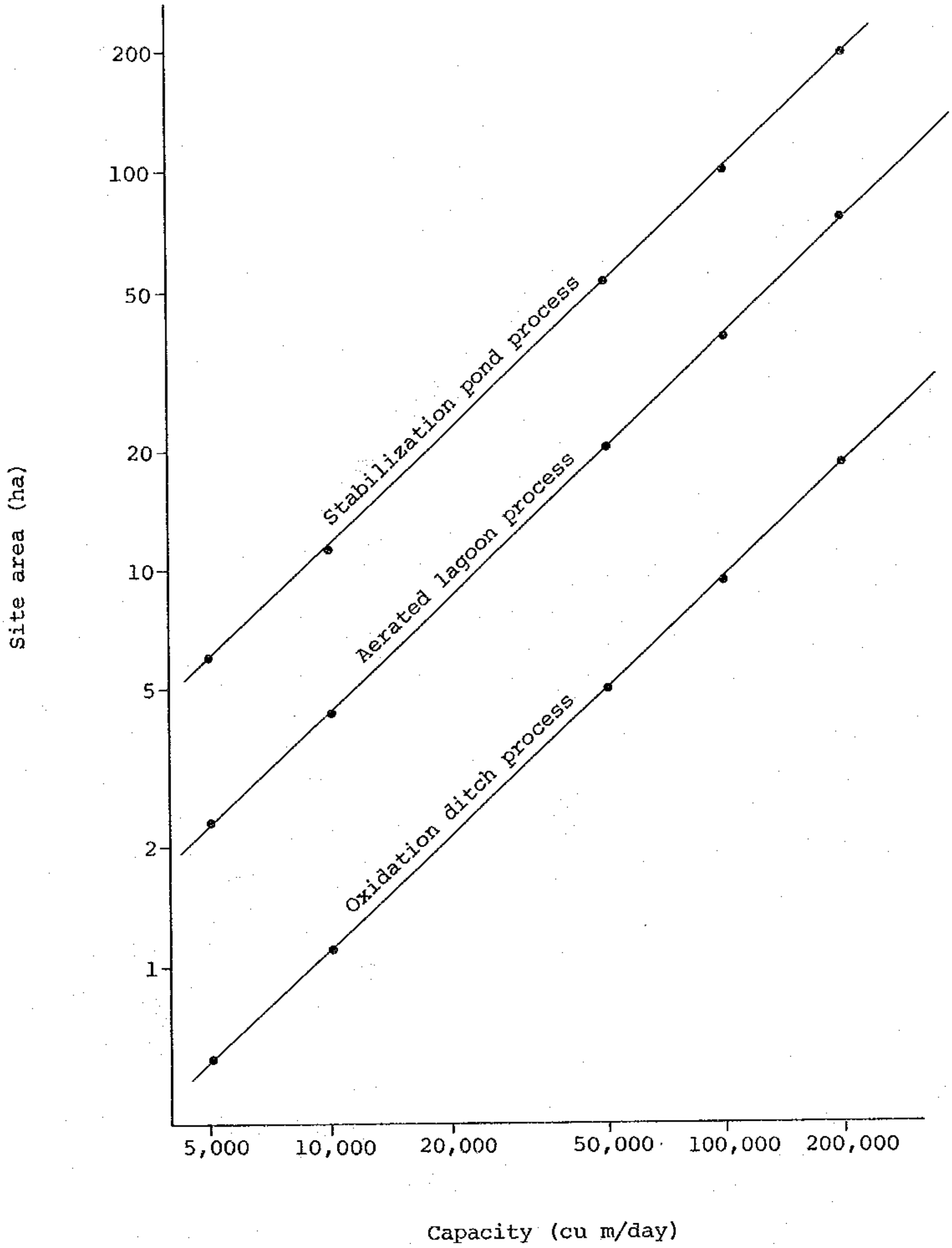


FIGURE G-15 Required site area for treatment plant

CHAPTER 8

COST ANALYSIS OF SYSTEMS

8.1 General

Economic analysis was made of the alternative sewerage systems, which would indicate competitive solutions for provisions of sewerage facilities in the sewerage implementation area up to the year 2000. Descriptions of the physical features and comparative analysis of these alternatives are presented in this chapter, and conclusions are drawn as to the most effective sewerage system. In the analysis, sewage flows and costs incurred are studied over 20-year period to the year 2000.

8.2 Design Basis of Facilities

Design basis used in this study is presented in chapter 5. part III, "Sewerage Master Plan". The possible routes of conveyance facilities and locations of sewage treatment sites for the sewerage system are shown in Figure G-16. Ground elevations and sewer service areas for each of these sewer lines are estimated on the basis of the available topographic maps in the scale of 1:7500 to 1:25000, and sewage flow rates in this sewer lines are computed to determine the size of the facilities. The design criteria used are summarized in Table G-22.

For the cost estimates, sewage quantities for the conveyance facilities are estimated from the projected populations as presented in Table G-24. Table G-25 shows sewage flow rates for the year 2000.

TABLE G-22 Estimated Wastewater Flow Rates (in 2000)

Type of Wastewater	Estimated Flow Rates
1. Per Capita Sewage Flow	230 liter/day
2. Industrial Wastewater	80 cu m/day/ha
3. Infiltration	
o Residential of High density	12 cu m/day/ha
o " of Low density	8 cu m/day/ha
o Industrial	5 cu m/day/ha

TABLE G-23 Estimated Population Density (in 2000)

(persons/ha)

Land Use	Residential		Social and Commercial	Industrial
	High density	Low density		
Population Density	160-120	52	0, 120, 160	0

TABLE G-24 Population of Sewerage Zone (in 2000)

Name of Sewerage Zone		Area (ha)	Population
Butterworth	1	367	45,440
	2	182	21,840
	3	457	37,039
	4	444	37,514
	5	551	33,705
	6	670	37,316
Sub-Total		2,671	212,854
Seberang Jaya	1	438	46,748
	2	305	25,178
	3	510	26,543
	4	430	20,818
	5	368	19,152
Sub-Total		2,051	138,439
Prai	1	1,063	0
	2	268	13,948
Sub-Total		1,331	13,948
Bukit Mertajam	1	892	47,512
	2	715	39,794
	3	927	73,729
	4	467	24,917
	5	459	23,889
	6	573	32,948
	7	768	39,970
Sub-Total		4,801	282,759
Total		10,854	648,000

TABLE G-25 Design Sewage Flow Rate of Sewage Zone (in 2000)

Sewerage Zone		Area (ha)	Wastewater		Extraneous (cu m/day	Total (cu m/day)
			Domestic (cu m/day)	Industrial (cu m/day)		
Butterworth	1	367	10,450	1,600	3,700	15,750
	2	182	5,020	-	2,190	7,210
	3	457	8,520	8,560	4,440	21,520
	4	444	8,630	-	4,400	13,030
	5	551	7,750	-	4,700	12,450
	6	670	8,580	-	5,510	14,090
Sub-Total		2,671	48,950	10,160	24,940	84,050
Seberang Jaya						
	1	438	10,750	160	4,920	15,830
	2	305	5,790	4,000	3,120	12,910
	3	510	6,110	-	4,080	10,190
	4	430	4,790	-	3,560	8,350
	5	368	4,400	-	2,950	7,350
Sub-Total		2,051	31,840	4,160	18,630	54,630
Prai	1	1,063	-	85,040	5,320	90,360
	2	268	3,210	-	2,150	5,360
Sub-Total		1,331	3,210	85,040	7,470	95,720
Bukit Mertajam						
	1	892	10,930	-	7,200	18,130
	2	715	9,150	-	5,870	15,020
	3	927	16,960	-	8,920	25,880
	4	467	5,730	-	3,770	9,500
	5	459	5,500	-	3,670	9,170
	6	573	7,580	-	4,770	12,350
	7	768	9,190	-	6,110	15,300
Sub-Total		4,801	65,040	-	40,310	105,350
Total		10,854	149,040	99,360	91,350	339,750

(a) Collection System

In determining the required capacities of conveyance facilities, the following factors are considered.

i) Peak flow rates of domestic sewage

ii) Peak flow rates of industrial wastewater.

iii) Groundwater infiltration

iv) Depth of excavation

v) Location of treatment facilities

vi) Pumping requirement

vii) Design velocities and other design criteria.

(b) Pumping Stations

Pumping stations are designed to raise sewage from deep sewers, generally those with more than 7m of earth covering, to higher elevation sewers in order to permit continuous flow by gravity. These intermediate pumping stations are provided with suitable structures, grit and/or debris facilities, and pumping equipment to lift the peak sewage flow rates.

(c) Sewage Treatment Facilities

For comparison purposes, sewage treatment plants are considered at the terminal of each zone. In determining locations and process of treatment for treatment plants for each zone, an evaluation is made of the effects of the waste discharges on the receiving water environment.

For practical purposes for cost comparisons, the costs are determined using the cost functions for treatment facilities for all treatment plants discharging to rivers and waterways. The design capacities of these plants are determined on the basis of the daily average flow.

8.3 Cost Estimates of the Systems

On the basis of the designed sewerage systems, costs of sewage conveyance, pumping stations, and treatment facilities are estimated for cost comparison.

The cost estimating procedures are on the basis of cost functions developed in Chapter 3, 4, 5 and 6 of this Appendix based on recent costs for constructing major projects in the State of Penang, and from up-to-date materials cost quotations from manufactures in Malaysia.

Proposed sewerage facilities by zone (illustrated in Figure G-16), construction cost, and operation and maintenance cost at 1976 price of proposed sewerage system is tabulated in Tables G-26, 27 and 28 respectively.

FIGURE G-16

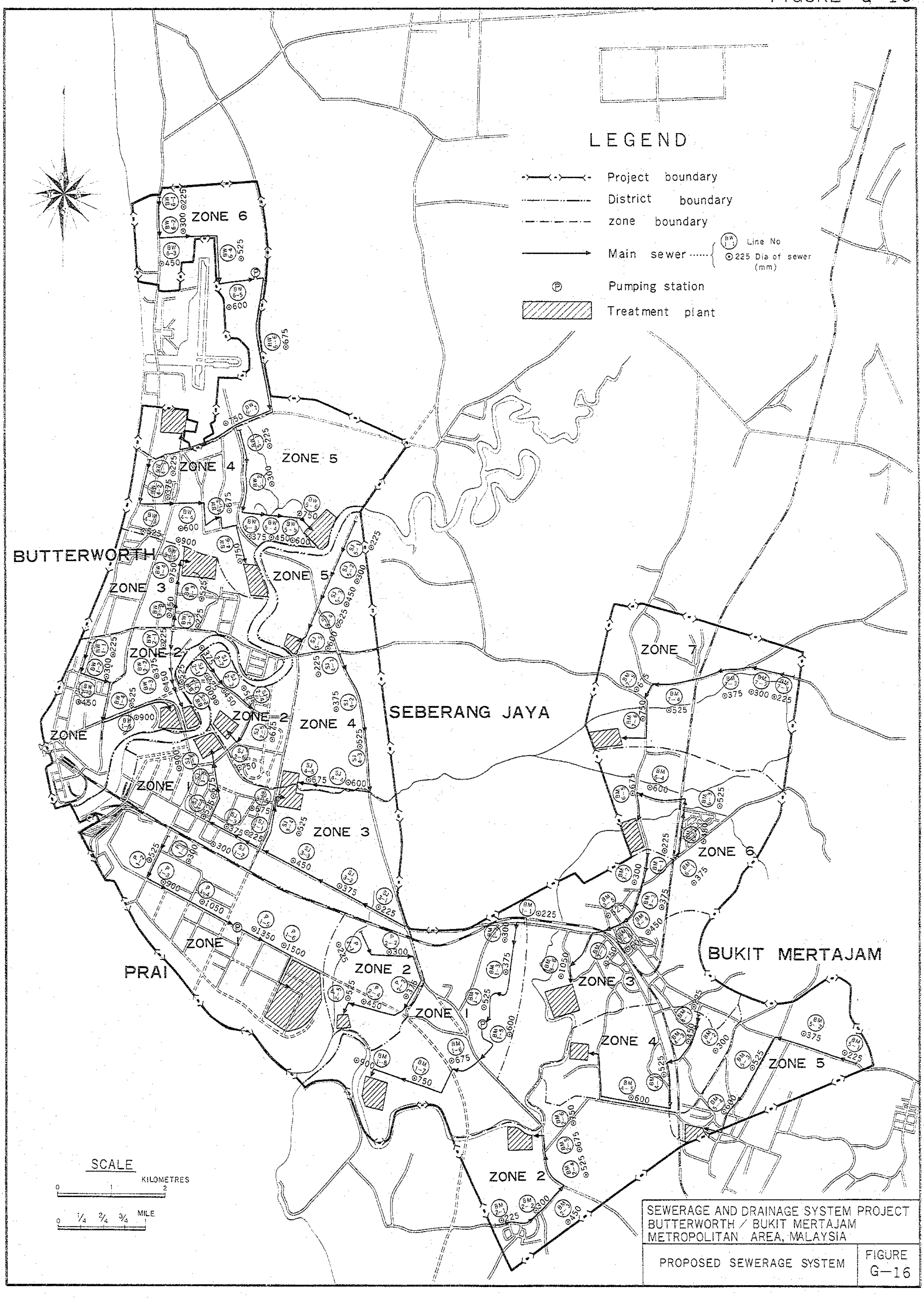

LEGEND
Project boundary
District boundary
zone boundary
Main sewer
Line No
⊙225 Dia of sewer (mm)
Pumping station
Treatment plant
BUTTERWORTH
SEBERANG JAYA
BUKIT MERTAJAM
PRAI
ZONE 1
ZONE 2
ZONE 3
ZONE 4
ZONE 5
ZONE 6
ZONE 7
SCALE
KILOMETRES
MILE
SEWERAGE AND DRAINAGE SYSTEM PROJECT
BUTTERWORTH / BUKIT MERTAJAM
METROPOLITAN AREA, MALAYSIA
PROPOSED SEWERAGE SYSTEM
FIGURE G-16

TABLE G-26 Proposed Sewerage Facilities by Zone

Name of Sewerage Zone	Public Sewer		House Connection		Pumping Station		Treatment Plant		
	Dia. (mm)	Length (m)	Dia. (mm)	Length (m)	Peak flow (cu m/s)	Req'd land area (sq m)	Pro-cess	Average flow (cu m/day)	Req'd land area (ha)
Butterworth, Zone-1	225-900	92,200	150	110,800			S.P.	15,800	17.6
2	" -600	54,600	"	65,500			"	7,200	8.4
3	" -900	116,800	"	125,700			"	21,500	23.6
4	" -750	133,200	"	111,100			"	13,000	14.6
5	" -750	165,300	"	98,200			"	12,500	14.1
6	" -750	201,000	"	108,000	0.18	100	"	14,100	15.8
Seberang Jaya, Zone-1	225-900	131,000	"	140,000			"	15,800	17.6
2	" -750	82,000	"	88,700			"	12,900	14.5
3	" -675	153,000	"	76,500			"	10,200	11.6
4	" -675	129,000	"	70,800			"	8,400	9.7
5	" -600	110,400	"	55,200			"	7,400	8.6
Prai, Zone-1	225-1,500	116,900	"	148,800	0.89	1,540	"	90,400	92.0
2	" - 525	80,400	"	40,200			"	5,400	6.4
Bukit Mertajam, Zone-1	225 - 900	267,600	"	137,200	0.14	90	"	18,100	20.0
2	" - 750	214,500	"	115,200			"	15,000	16.8
3	" -1,050	278,100	"	217,800			"	25,900	28.1
4	" - 600	140,100	"	71,900			"	9,500	10.9
5	" - 600	137,700	"	68,900			"	9,200	10.5
6	" - 675	171,900	"	95,600			"	12,400	14.0
7	" - 750	230,400	"	115,200			"	15,300	17.1

Note: S.P. ---------- Stabilization Pond

TABLE G-27 Construction Cost of Proposed Sewerage System at 1976 Price Level

(M$ 1,000)

Name of Sewerage Zone	Sewer			Pumping Station		Treatment Plant			Total		
	Public (Main) *	Public (Branch & Lateral)	House Connec-tion	Land Cost *	Const'n Cost *	Process	Land Cost *	Const'n Cost *	(1)	(2)	(1)+(2)
Butterworth,											
Zone - 1	6,370	8,820	3,320			S.P.	2,270	2,100	10,740	12,140	22,880
2	2,480	5,350	1,970			"	1,080	1,050	4,610	7,320	11,930
3	6,290	10,290	3,770			"	1,530	2,750	10,570	14,060	24,630
4	7,690	13,050	3,330			"	950	1,740	10,380	16,380	26,760
5	8,710	16,200	2,950			"	60	1,670	10,440	19,150	29,590
6	13,570	19,700	3,240	0.3	230	"	3,400	1,870	19,070	22,940	42,010
Seberang Jaya,											
Zone - 1	7,150	12,820	4,200			"	3,780	2,080	13,010	17,020	30,030
2	4,970	7,500	2,660			"	3,120	1,730	9,820	10,160	19,980
3	7,830	14,990	2,300			"	2,490	1,400	11,720	17,290	29,010
4	6,740	12,640	2,120			"	2,090	1,200	10,030	14,760	24,790
5	5,690	10,820	1,660			"	1,850	1,070	8,610	12,480	21,090
Prai, Zone - 1	19,910	-	4,460	40	4,750	"	19,780	16,610	61,090	4,460	65,550
2	3,580	7,880	1,210			"	190	830	4,600	9,090	13,690
Bukit Mertajam,											
Zone - 1	13,300	26,220	4,110	0.3	200	"	100	2,340	15,940	30,330	46,270
2	9,400	21,020	3,460			"	500	1,970	11,870	24,480	36,350
3	12,130	27,250	6,530			"	840	3,270	16,240	33,780	50,020
4	6,300	13,730	2,160			"	330	1,320	7,950	15,890	23,840
5	6,120	13,490	2,070			"	320	1,280	7,720	15,560	23,280
6	7,490	16,850	2,870			"	420	1,660	9,570	19,720	29,290
7	10,170	22,580	3,460			"	260	2,010	12,440	26,040	38,480
Total	165,890	281,200	61,850	40	5,180		45,360	49,950	266,420	343,050	609,470

Note: (1) --- government contribution
(2) --- private contribution
(*) --- included in (1)

TABLE G-28 Operation and Maintenance Cost of Proposed Sewerage System at 1976 Price Level

(M$1,000/year)

Name of Sewerage Zone	Sewer		Pumping Station	Treatment Plant	Total
	Public Portion	Private Portion			
Butterworth, Zone-1	50	190	-	60	300
2	30	110	-	40	180
3	70	210	-	70	350
4	70	240	-	50	360
5	80	270	-	40	390
6	100	320	30	50	500
Sub-Total	400	1,320	30	310	2,080
Seberang Jaya, Zone-1	70	260	-	60	390
2	50	150	-	50	250
3	80	230	-	40	350
4	70	200	-	40	310
5	60	170	-	40	270
Sub-Total	330	1,010	-	230	1,570
Prai, Zone-1	200	100	110	160	570
2	40	130	-	30	200
Sub-Total	240	230	110	190	770
Bukit Mertajam, Zone-1	140	420	20	60	640
2	110	340	-	50	500
3	140	480	-	70	690
4	70	220	-	40	330
5	70	210	-	40	320
6	90	270	-	50	410
7	120	350	-	50	520
Sub-Total	740	2,290	20	360	3,410
Total	1,710	4,870	160	1,090	7,830

ANNEX G-1

COMPUTATION FOR DESIGN OF MAIN SEWERS

The following table is a computation form for design of a part of main sewers in Butterworth Zone-1 as illustrated in Figure G-3. Other main sewers, branch, and lateral sewer are also designed in same manner.

COMPUTATION FOR DESIGN OF MAIN SEWERS

Butterworth Zone -1

Line No.	Sewer Length (m)	Area		(1) Ave. Daily Flow			(2) Peak Flow Total	Design of Sewer				Sewer Invert Elevation		Elevation Ground Surface		Earth Covering		Remark
		Increment (ha)	Total (ha)	Domestic (cu m/d)	Industrial (cu m/d)	Extraneous (cu m/d)	(cu m/s)	Dia. (mm)	Slope of Sewer (o/oo)	Velocity Full (m/sec)	Capacity Full (cu m/s)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	
BW1-1	440	9.0	-	330	-	110	0.019	⊙ 225	3.0	0.62	0.025	1.215	-0.105	2.44	2.55	1.00	2.13	
BW1-2	210	10.0	19.0	700	-	230	0.038	⊙ 300	2.4	0.67	0.047	-0.180	-0.684	2.25	2.20	2.13	2.58	
BW1-3	640	46.0	65.0	2,390	-	780	0.109	⊙ 450	1.8	0.76	0.121	-0.834	-1.986	2.20	2.45	2.58	3.99	
BW1-4	690	35.0	100.0	3,680	-	1,200	0.159	⊙ 525	1.5	0.77	0.167	-2.061	-3.096	2.45	2.41	3.99	4.98	
BW1-5	1,350	220.0	320.0	10,450	1,600	3,700	0.451	⊙ 900	0.9	0.85	0.543	-3.471	-4.686	2.41	2.10	4.98	5.89	

To Treatment Plant

Note: (2) = (1) x Peaking factor (See Appendix E)

ANNEX G-2

DISCHARGE TABLE FOR CIRCULAR PIPE

(by Manning Formula using 'n' value of 0.013)

Following tables are used for determining the required pipe diameter and slope based on the sewage flow rate.

Dia. of Sewer (m)	0.150		0.225		0.300		0.375		0.450		0.525		0.600	
Sectional area (sq.m)	0.018		0.040		0.071		0.110		0.159		0.216		0.283	
Wetted perimeter (m)	0.471		0.707		0.942		1.178		1.414		1.649		1.885	
Hydraulic radius (m)	0.037		0.056		0.075		0.094		0.112		0.131		0.150	
Slope of sewer (o/oo)	Velocity Full (m/s)	Capacity Full (cu m/s)	Velocity Full (m/s)	Capacity Full (cu m/s)	Velocity Full (m/s)	Capacity Full (cu m/s)	Velocity Full (m/s)	Capacity Full (cu m/s)	Velocity Full (m/s)	Capacity Full (cu m/s)	Velocity Full (m/s)	Capacity Full (cu m/s)	Velocity Full (m/s)	Capacity Full (cu m/s)
14.0	1.020	0.018	1.336	0.053	1.619	0.114	1.878	0.207	2.121	0.337	2.351	0.509	2.569	0.727
13.0	0.983	0.017	1.288	0.051	1.560	0.110	1.810	0.200	2.044	0.325	2.265	0.490	2.476	0.700
12.0	0.944	0.017	1.237	0.049	1.499	0.106	1.739	0.192	1.964	0.312	2.176	0.471	2.379	0.673
11.0	0.904	0.016	1.184	0.047	1.435	0.101	1.665	0.184	1.880	0.299	2.084	0.451	2.278	0.644
10.0	0.862	0.015	1.129	0.045	1.368	0.097	1.587	0.175	1.793	0.285	1.987	0.430	2.172	0.614
9.0	0.818	0.014	1.071	0.043	1.298	0.092	1.506	0.166	1.701	0.270	1.885	0.408	2.060	0.583
8.5	0.795	0.014	1.041	0.041	1.261	0.089	1.464	0.162	1.653	0.263	1.832	0.396	2.002	0.566
8.0	0.771	0.014	1.010	0.040	1.224	0.086	1.420	0.157	1.603	0.255	1.777	0.385	1.942	0.549
7.5	0.746	0.013	0.978	0.039	1.185	0.084	1.375	0.152	1.552	0.247	1.720	0.372	1.881	0.532
7.0	0.721	0.013	0.945	0.038	1.145	0.081	1.328	0.147	1.500	0.239	1.662	0.360	1.817	0.514
6.5	0.695	0.012	0.910	0.036	1.103	0.078	1.280	0.141	1.445	0.230	1.602	0.347	1.751	0.495
6.0	0.668	0.012	0.875	0.035	0.060	0.075	1.230	0.136	1.389	0.221	1.539	0.333	1.682	0.476
5.5	0.639	0.011	0.838	0.033	1.015	0.072	1.177	0.130	1.329	0.211	1.473	0.319	1.611	0.455
5.0	0.609	0.011	0.799	0.032	0.967	0.068	1.123	0.124	1.268	0.202	1.405	0.304	1.536	0.434
4.5	0.578	0.010	0.758	0.030	0.918	0.065	1.065	0.118	1.203	0.191	1.333	0.288	1.457	0.412
4.0	0.545	0.010	0.714	0.028	0.865	0.061	1.004	0.111	1.134	0.180	1.256	0.272	1.373	0.388
3.5	0.510	0.009	0.668	0.027	0.809	0.057	0.939	0.104	1.061	0.169	1.175	0.254	1.285	0.363
3.0	0.472	0.008	0.619	0.025	0.749	0.053	0.869	0.096	0.982	0.156	1.088	0.236	1.189	0.336
2.8	0.456	0.008	0.598	0.024	0.724	0.051	0.840	0.093	0.949	0.151	1.051	0.228	1.149	0.325
2.6	0.439	0.008	0.576	0.023	0.698	0.049	0.809	0.089	0.914	0.145	1.013	0.219	1.107	0.313
2.5	0.431	0.008	0.565	0.022	0.684	0.048	0.794	0.088	0.896	0.143	0.993	0.215	1.086	0.307
2.4	0.422	0.007	0.553	0.022	0.670	0.047	0.778	0.086	0.878	0.140	0.973	0.211	1.064	0.301
2.2	0.404	0.007	0.530	0.021	0.642	0.045	0.745	0.082	0.841	0.134	0.932	0.202	1.019	0.288
2.0	0.385	0.007	0.505	0.020	0.612	0.043	0.710	0.078	0.802	0.128	0.888	0.192	0.971	0.275
1.9	0.376	0.007	0.492	0.020	0.596	0.042	0.692	0.076	0.781	0.124	0.866	0.187	0.947	0.268
1.8	0.366	0.006	0.479	0.019	0.580	0.041	0.674	0.074	0.761	0.121	0.843	0.182	0.921	0.261
1.7	0.355	0.006	0.466	0.019	0.564	0.040	0.655	0.072	0.739	0.118	0.819	0.177	0.895	0.253
1.6	0.345	0.006	0.452	0.018	0.547	0.039	0.635	0.070	0.717	0.114	0.795	0.172	0.869	0.246
1.5	0.334	0.006	0.437	0.017	0.530	0.037	0.615	0.068	0.694	0.110	0.769	0.167	0.841	0.238
1.4	0.322	0.006	0.423	0.017	0.512	0.036	0.594	0.066	0.671	0.107	0.743	0.161	0.813	0.230
1.3	0.311	0.005	0.407	0.016	0.493	0.035	0.572	0.063	0.646	0.103	0.716	0.155	0.783	0.221
1.2	0.299	0.005	0.391	0.016	0.474	0.033	0.550	0.061	0.621	0.099	0.688	0.149	0.752	0.213
1.1	0.286	0.005	0.375	0.015	0.454	0.032	0.527	0.058	0.595	0.095	0.659	0.143	0.720	0.204
1.0	0.273	0.005	0.357	0.014	0.433	0.031	0.502	0.055	0.567	0.090	0.628	0.136	0.687	0.194
0.9	0.259	0.005	0.339	0.013	0.410	0.029	0.476	0.053	0.538	0.086	0.596	0.129	0.651	0.184
0.8	0.244	0.004	0.319	0.013	0.387	0.027	0.449	0.050	0.507	0.081	0.562	0.122	0.614	0.174
0.7	0.228	0.004	0.299	0.012	0.362	0.026	0.420	0.046	0.474	0.075	0.526	0.114	0.575	0.162
0.6	0.211	0.004	0.277	0.011	0.335	0.024	0.389	0.043	0.439	0.070	0.487	0.105	0.532	0.150
0.5	0.193	0.003	0.253	0.010	0.306	0.022	0.355	0.039	0.401	0.064	0.444	0.096	0.486	0.137
0.4	0.172	0.003	0.226	0.009	0.274	0.019	0.317	0.035	0.359	0.057	0.397	0.086	0.434	0.123

Dia. of Sewer (m)	0.675		0.750		0.900		1.050		1.200		1.350		1.500	
Sectional area (sq.m)	0.358		0.442		0.636		0.866		1.131		1.431		1.767	
Wetted perimeter (m)	2.121		2.356		2.827		3.299		3.770		4.241		4.712	
Hydraulic radius (m)	0.169		0.188		0.225		0.262		0.300		0.337		0.375	
Slope of sewer (o/oo)	Velocity Full (m/s)	Capacity Full (cu m/s)	Velocity Full (m/s)	Capacity Full (cu m/s)	Velocity Full (m/s)	Capacity Full (cu m/s)	Velocity Full (m/s)	Capacity Full (cu m/s)	Velocity Full (m/s)	Capacity Full (cu m/s)	Velocity Full (m/s)	Capacity Full (cu m/s)	Velocity Full (m/s)	Capacity Full (cu m/s)
14.0	2.779	0.995	2.982	1.317	3.367	2.142	3.731	3.231	4.079	4.613	4.412	6.315	4.733	8.364
13.0	2.678	0.958	2.873	1.269	3.245	2.064	3.596	3.114	3.930	4.445	4.252	6.086	4.561	8.060
12.0	2.573	0.921	2.760	1.220	3.117	1.983	3.455	2.991	3.776	4.271	4.085	5.847	4.382	7.744
11.0	2.464	0.882	2.643	1.168	2.985	1.899	3.308	2.864	3.615	4.089	3.911	5.598	4.195	7.414
10.0	2.349	0.841	2.520	1.113	2.846	1.810	3.154	2.731	3.447	3.899	3.729	5.337	4.000	7.069
9.0	2.228	0.797	2.391	1.056	2.700	1.717	2.992	2.591	3.270	3.699	3.537	5.063	3.795	6.706
8.5	2.166	0.775	2.323	1.026	2.624	1.669	2.907	2.518	3.178	3.594	3.438	4.921	3.688	6.517
8.0	2.101	0.752	2.254	0.996	2.545	1.619	2.821	2.442	3.083	3.487	3.335	4.774	3.578	6.323
7.5	2.034	0.728	2.182	0.964	2.464	1.568	2.731	2.365	2.985	3.376	3.229	4.622	3.464	6.122
7.0	1.965	0.703	2.108	0.931	2.381	1.515	2.639	2.285	2.884	3.262	3.120	4.466	3.347	5.914
6.5	1.894	0.678	2.032	0.898	2.294	1.460	2.543	2.202	2.779	2.143	3.006	4.303	3.225	5.699
6.0	1.820	0.651	1.952	0.862	2.204	1.402	2.443	2.115	2.670	3.020	2.888	4.134	3.099	5.476
5.5	1.742	0.623	1.869	0.826	2.110	1.343	2.339	2.025	2.557	2.891	2.765	3.958	2.967	5.242
5.0	1.661	0.594	1.782	0.787	2.012	1.280	2.230	1.931	2.438	2.757	2.637	3.774	2.829	4.998
4.5	1.576	0.564	1.690	0.747	1.909	1.214	2.116	1.832	2.312	2.615	2.501	3.580	2.683	4.742
4.0	1.486	0.532	1.594	0.704	1.800	1.145	1.995	1.727	2.180	2.466	2.358	3.376	2.530	4.471
3.5	1.390	0.497	1.491	0.659	1.683	1.071	1.866	1.616	2.039	2.307	2.206	3.158	2.367	4.182
3.0	1.287	0.460	1.380	0.610	1.559	0.992	1.727	1.496	1.888	2.135	2.042	2.923	2.191	3.872
2.8	1.243	0.445	1.333	0.589	1.506	0.958	1.669	1.445	1.824	2.063	1.973	2.824	2.117	3.740
2.6	1.198	0.429	1.285	0.568	1.451	0.923	1.608	1.392	1.758	1.988	1.901	2.722	2.040	3.604
2.5	1.175	0.420	1.260	0.557	1.423	0.905	1.577	1.365	1.724	1.949	1.864	2.669	2.000	3.534
2.4	1.151	0.412	1.235	0.545	1.394	0.887	1.545	1.338	1.689	1.910	1.827	2.615	1.960	3.463
2.2	1.102	0.394	1.182	0.522	1.335	0.849	1.479	1.281	1.617	1.829	1.749	2.503	1.876	3.316
2.0	1.051	0.376	1.127	0.498	1.273	0.810	1.410	1.221	1.542	1.744	1.668	2.387	1.789	3.161
1.9	1.024	0.366	1.098	0.485	1.240	0.789	1.375	1.190	1.503	1.699	1.625	2.327	1.744	3.081
1.8	0.997	0.357	1.069	0.472	1.207	0.768	1.338	1.159	1.463	1.654	1.582	2.264	1.697	2.999
1.7	0.969	0.347	1.039	0.459	1.173	0.746	1.300	1.126	1.421	1.607	1.537	2.201	1.649	2.915
1.6	0.940	0.336	1.008	0.445	1.138	0.724	1.261	1.092	1.379	1.559	1.492	2.135	1.600	2.828
1.5	0.910	0.326	0.976	0.431	1.102	0.701	1.221	1.058	1.335	1.510	1.444	2.067	1.549	2.738
1.4	0.879	0.315	0.943	0.417	1.065	0.677	1.180	1.022	1.290	1.459	1.395	1.997	1.497	2.645
1.3	0.847	0.303	0.909	0.401	1.026	0.653	1.137	0.985	1.243	1.406	1.344	1.924	1.442	2.549
1.2	0.814	0.291	0.873	0.386	0.986	0.627	1.092	0.946	1.194	1.351	1.292	1.849	1.386	2.449
1.1	0.779	0.279	0.836	0.369	0.944	0.600	1.046	0.906	1.143	1.293	1.237	1.770	1.327	2.344
1.0	0.743	0.266	0.797	0.352	0.900	0.572	0.997	0.864	1.090	1.233	1.179	1.688	1.265	2.235
0.9	0.705	0.252	0.756	0.334	0.854	0.543	0.946	0.819	1.034	1.170	1.119	1.601	1.200	2.121
0.8	0.664	0.238	0.713	0.315	0.805	0.512	0.892	0.772	0.975	1.103	1.055	1.510	1.131	1.999
0.7	0.621	0.222	0.667	0.295	0.753	0.479	0.834	0.722	0.912	1.032	0.987	1.412	1.058	1.870
0.6	0.575	0.206	0.617	0.273	0.697	0.443	0.772	0.669	0.844	0.955	0.913	1.307	0.980	1.732
0.5	0.525	0.188	0.563	0.249	0.636	0.405	0.705	0.611	0.771	0.872	0.834	1.193	0.894	1.581
0.4	0.470	0.168	0.504	0.223	0.569	0.362	0.631	0.546	0.689	0.780	0.746	1.067	0.800	1.414

APPENDIX H

STAGING OF SEWERAGE CONSTRUCTION

CHAPTER 1

INTRODUCTION

The provision of a complete sewerage and drainage system for an area of the size of the Project Area with its large and expanding population, is a task of tremendous magnitude.

Therefore, it is only prodent and sound to build the required facilities in stages, according to the urgency of need and benefits to be derived. Stage construction will spread capital expenditure over an extended period of years, as well as saving interest on borrowed capital and reducing initial costs. In addition, experience gained in the early construction programme will permit necessary review and re-evaluation of the plan for any continuing construction programme.

A study has therefore been made to determine the priority of work and the desirable stages of sewerage construction, taking into account the various important elements which affect sanitary conditions in the Project Area, based on use of a reasonable rating procedure.

CHAPTER 2

RATING OF SANITARY CONDITIONS

2.1 Basic Considerations for Rating

The elements considered in selecting the priority of sewerage districts for implementation of sewerage construction up to the year 2000 include the following six items, each of which has impacts on environmental sanitation in the Project Area.

1) Population Density
2) Waste Load
3) Excreta Disposal System
4) Flooding
5) Availability of Water Supply
6) Incidence of Water Borne Diseases

The above-mentioned six elements are each assigned by the different evaluation points to reflect their relative importance to the sanitation, and each of the twenty sewerage zones, divided out of Butterworth, Seberang Jaya, Prai, and Bukit Mertajam sewerage districts, is evaluated carefully and graded according to the rating for each element for the purpose of establishing sewerage priority for implementation.

In addition to these six elements, another important element, housing and industrial development programme conducted by State Government is taken into account on staging of sewerage implementation. The areas under development programme will be given high priority on the request of State Government not concerned with the result of this rating procedure.

2.2 Application of Rating System

For the purpose of rating system, a total of 1,000 points is assigned to each of the six major elements, according to order of importance, as described below.

(1) One of the most important factors is the number of persons who will be benefited by the system. It is therefore particularly significant to provide sewerage facilities in high population density area, in order to gain the maximum benefit to the maximum population with the minimum expenditures thus making

the benefit-cost ratio higher. Hence, highest point is assigned for the population density.

(2) Second highest point is assigned for the waste load production aspects. According to the current situation of Project Area, waste loads produced from the housing, commercial and industrial area are generally discharged into drains and rivers without passing through the treatment plant. Except for septic tanks, no comprehensive water pollution control programme covering the whole area has been provided, hence it is necessary to give high priority on the control of the waste load currently discharged into drains and rivers.

(3) Except for a few local systems, there is almost no sanitary sewerage system in the Project Area. All of the excreta produced in the area is disposed of either by septic tank, bucket, pit privy or directly to waterways. As the existing excreta disposal system is not satisfactory from the viewpoint of environmental sanitation, the third highest point is assigned to this item.

(4) Although the government has undertaken improvement of existing streams and drains, flooding has frequently occurred causing damage to the built-up urban areas. These areas, which have been significantly affecting the sanitary conditions, should be improved by provision of sewerage system. Therefore, flooding factor is given the fourth highest weighted points.

The remaining elements, namely, availability of water supply, and incidence of water borne diseases also affect sanitation problems but these are less critical than the preceding four categories. Same weighted points are given to both of them.

In view of these factors, the six elements, all of which affect sanitary conditions, are given points arbitarily according to their importance for the rating for the year 1976 and 2000. The rating points are shown as followings:

a)	Population Density	400
b)	Waste Load	250
c)	Excreta Disposal System	150
d)	Flooding	100
e)	Availability of Water Supply	50
f)	Incidence of Water Borne Disease	50
	Total	1,000 points

Further comments on these factors are discussed in the following section.