CHAPTER 7

STAGING OF IMPLEMENTATION

7.1 Wastewater Programme

The wastewater programme has been divided into two interrelated components the wastewater collection system and the wastewater disposal system. Each component has its own place in the construction programme recommendation, based on estimated requirements for the particular period. It has been assumed that construction will be staged with the First Stage to be completed by 1985 and subsequent three five-year stages after 1985 to the year 2000. This phasing, with the inherent flexibility of the system will permit periodic re-evaluation as required. Staged areas are shown in Figure III-5.

As the first step for determining the staging of sewerage implementation, all the possible alternative construction programmes and priorities were studied, as described in Appendix B and H. From these alternative studies, the most feasible alternative sewerage construction programmes for the First Stage programme was identified for further study.

The finally selelcted First Stage programme, after discussions and studies, includes three different schemes for furnishing sewers, pumping station, and treatment plants, covering the area of 2,195 hectares, where in the sewerage implementation is most urgently required.

After the highest priority areas were selected and the First Stage programme was determined, further studies were made to determin the construction programmes for the consecutive three stages considering the priority of sewerage zones, effective use of investment, and state development programmes.

Bases of selecting the staged sewerage implementation programme for the entire Project Area are discussed in the following paragraphs, together with the various alternatives considered.

7.2 First Stage Programme (1981 to 1985)

As discussed in previous chapters, certain items are essential to the entire wastewater collection and disposal systems. These items, which must be constructed in the First Stage, include (a) the main sewers (b) branch and lateral sewers, (c) house connexions, (d) pumping stations, and (3) sewage treatment plants in zone 1 & 3 of Butterworth, zone 4 of Butterworth, and zone 3 of Bukit Mertajam. These facilities are the essential core elements of the entire Project Area sewerage system. Implementation of this stage is recommended to start 1981, ending by 1985. When this stage is completed, 193,722 persons within a total area of 2,195 hectares will be served by the system in the year 2000.

By 1985, the initial elements of the sewerage system will be functioning. These elements, in addition to the basic items, should include in order of construction. Details of the recommended sewerage facilities will be discussed in "Feasibility Study" which is supposed to prepare by JICA after the Master Plan is completed.

Areas and population to be served in this stage are as follows:

Name of Zone	Area Served (ha)	Population (persons in 2000)
Butterworth, Zone-1	367	45,440
" " -3	457	37,039
" " -4	444	37,514
Bukit Mertajam, Zone-3	927	73,729
Total	2,195	193,722

7.3 Second Stage Programme (1986 to 1990)

With the completion of the sewage collection and disposal systems scheduled for the year 1985, flexibility of action is increased.

Reevaluation of the improvements scheduled for this stage will be appropriate. Based on current projections and priorities for sewerage implementation, the sewerage system components to be constructed during this stage are selected, including main sewers, branch and lateral sewers, house connexions, pumping stations, and treatment plants in zone 2 of Butterworth and in zones 1 & 2 of Seberang Jaya, and in zone 1 of Prai. When this stage is completed, 93,766 persons within a total area of 1,988 hectares will be served by the system.

For zones 1 & 2 of Seberang Jaya and for zone 1 of Prai, development programmes are now underway by State Government, which are scheduled to be developed as residential, commercial, and industrial estates in the near future. Areas and population to be served in this stage are [redacted] as follows:

Name of Zone	Area Served (ha)	Population (persons in 2000)
Butterworth, Zone-2	182	21,840
Seberang Jaya, Zone-1	438	46,748
" 2	305	25,178
Prai, Zone 1	1,063	0
Total	1,988	93,766

7.4 Third Stage Programme (1991 to 1995)

The sewerage system components to be constructed during this stage are selected, including main sewers, branch and lateral sewers, house connexions, pumping stations, and treatment plants in zones 5 & 6 of Butterworth in zone 3 of Seberang Jaya, and zones 4,5, & 6 of Bukit Mertajam. When this stage is completed, 179,318 persons within a total area of 3,230 hectares will be served by the system.

Zone 5 & 6 of Butterworth are included in this stage since these areas have new developed housing estate. Areas and population to be served in this stage are as follows:

Name of Zone	Area Served (ha)	Population (persons in 2000)
Butterworth, zone - 5	551	33,705
" zone - 6	670	37,316
Seberang Jaya, zone - 3	510	26,543
Bukit Mertajam, zone - 4	467	24,917
" zone - 5	459	23,889
" zone - 6	573	32,948
Total	3,230	179,318

7.5 Fourth Stage Programme (1996 to 2000)

By the year 2000, work can be completed on the entire sewerage implementation area, covering 10,854 hectares. This stage includes construction of sewers, pumping stations, and treatment plants in the remaining portions of the entire Project Area, covering totally 3,441 hectares. Areas to be served by the system in this period are:

Name of Zone	Area Served (ha)	Population (persons in 2000)
Seberang Jaya, zone - 4	430	20,818
" zone - 5	368	19,152
Prai, zone - 2	268	13,948
Bukit Mertajam, zone - 1	892	47,512
" zone - 2	715	39,794
" zone - 7	768	39,970
Total	3,441	141,224

CHAPTER 8
CONSTRUCTION AND MAINTENANCE COSTS

8.1 Construction Costs

8.1.1 Main and Submain Sewers

All construction costs for the recommended main and submain sewers has been estimated on the basis of the procedures described in Chapter 2 of Appendix D.

Construction costs for each size of sewer pipe have been derived from unit construction costs which correspond to the design sewer depth.

8.1.2 Branch and Lateral Sewers

For estimating construction costs, the total length of these sewers by sizes are obtained, using per unit area sewer length of the different sewer size derived from the study of new housing scheme.
Then, the construction costs for all the sewer size have been estimated, multiplying the lengths by the unit costs developed on the basis of 1976 Malaysia price levels.

8.1.3 House Connexions

Total length of these pipes are estimated for cost estimates, assuming that each household has 15 metres house connexion pipe within the house plot. Then the total length of these sewers are calculated taking into account the population served and the average size of family in each of the sewerage districts under considerations.

The average construction cost for house connextion is estimated as 30 M$/m.

8.1.4 Pumping Stations

3 pumping stations are proposed to be provided to lift sewage at Butterworth (zone-6), Prai (zone-1) and Bukit Mertajam (zone-1) to convey the dry weather sewage flow to the treatment plants.

All construction costs for these stations have been derived on the basis of the unit costs developed for buildings, and equipment to be imported. It is assumed that most of equipment including pumps, controlling devices, electric facilities, generators, screening and grit removal facilities, gates, and piping materials will be imported, but materials for building and civil works will be available in Malaysia.

8.1.5 Sewage Treatment Plants

18 sewage treatment plants, one is oxidation ditch process in Butterworth zone-1 and 17 is stabilization pond process in remainders.

All construction costs for these plants have been derived on the basis of the unit costs developed for civil works, and equipment to be imported. It is assumed that most of equipment including pumps, controlling devices, electric facilities, aerators, sludge collectors, and others will be imported, but materials for civil works will be available in Malaysia.

8.1.6 Construction Costs by Stage

Estimated sewerage construction cost by stage is as shown in Tables Ⅲ-8 – Ⅲ-11.

TABLE Ⅲ－8　Sewerage Construction Cost by Stage at 1976 Price Level

1st Stage (1981 - 1985)

(1000 M$)

Description	Local Currency	Foreign Exchange	Total Cost	Remarks
a. Main and Submain Sewers	12,930	-	12,930	
b. Branch and Lateral Sewers	119,980	-	119,980	
c. House Connexions	23,890	-	23,890	
d. Pumping Stations	-	-	-	
e. Treatment Plants	33,110	25,240	58,350	
f. Land Acquisition	9,450	-	9,450	
(A) Sub Total	199,360	25,240	224,600	
(B) Contingency			44,920	(A) x 0.20
(C) Engineering Fee				
Design			13,480	(A+B) x 0.05
Supervision			13,480	(A+B) x 0.05
Total			296,480	

Note: Escalation Rate is estimated at 5 percent per year.

TABLE Ⅲ - 9   Sewerage Construction Cost by Stage at 1976 Price Level

2nd Stage (1986 - 1990)

(1000 M$)

Description	Local Currency	Foreign Exchange	Total Cost	Remarks
a. Main and Submain Sewers	15,970	-	15,970	
b. Branch and Lateral Sewers	93,550	-	93,550	
c. House Connexions	23,920	-	23,920	
d. Pumping Stations	4,280	4,270	8,550	
e. Treatment Plants	53,120	22,770	75,890	
f. Land Acquisition	86,400	-	86,400	
(A) Sub Total	277,240	27,040	304,280	
(B) Contingency			60,860	(A) x 0.20
(C) Engineering Fee				
Design			18,260	(A+B) x 0.05
Supervision			18,260	(A+B) x 0.05
Total			401,660	

Note: Escalation Rate is estimated at 5 percent per year.

TABLE III-10 Sewerage Construction Cost by Stage at 1976 Price Level

3rd Stage (1991 - 1995)

(1000 M$)

Description	Local Currency	Foreign Exchange	Total Cost	Remarks
a. Main and Submain Sewers	30,070	-	30,070	
b. Branch and Leteral Sewers	301,940	-	301,940	
c. House Connexions	35,700	-	35,700	
d. Pumping Stations	270	260	530	
e. Treatment Plants	32,200	13,800	46,000	
f. Land Acquisition	29,700	-	29,700	
(A) Sub Total	429,880	14,060	443,940	
(B) Contingency			88,790	(A) x 0.20
(c) Engineering Fee				
Design			26,640	(A+B) x 0.05
Supervision			26,640	(A+B) x 0.05
Total			586,010	

Note: Escalation Rate is estimated at 5 percent per year.

TABLE III-11 Sewerage Construction Cost by Stage at 1976 Price Level

4th Stage (1996 - 2000)

(1000 M$)

	Description	Local Currency	Foreign Exchange	Total Cost	Remarks
a.	Main and Submain Sewers	25,490	-	25,490	
b.	Branch and Lateral Sewers	412,630	-	412,630	
c.	House Connexions	46,780	-	46,780	
d.	Pumping Stations	290	290	580	
e.	Treatment Plants	59,650	25,560	85,210	
f.	Land Acquisition	26,310	-	26,310	
	(A) Sub Total	571,150	25,850	597,000	
	(B) Contingency			119,400	(A) x 0.20
	(C) Engineering Fee				
	Design			35,820	(A+B) x 0.05
	Supervision			35,820	(A+B) x 0.05
	Total			788,040	

Note: Escalation Rate is estimated at 5 percent per year.

8.2 Maintenance Costs

8.2.1 Sewers

Maintenance costs for sewer pipes were derived from data developed on the basis of the experience both in Malaysia and Japan, assuming that all sewers will be cleaned at least every four years by use of trusting rods and/or bucket machines etc. Estimated maintenance costs for sewer pipes are given in detail in Appendix E.

8.2.2 Pumping Stations

Operation and maintenance costs for pumping stations were derived from the current labour and material costs in Penang State, including power, fuel, water for cooling and sealing, lubrication, grit and screening removal, and minor repair of equipment. Needs for this operation and maintenance were estimated on the basis of daily average flow rates. Estimated maintenance and operation costs for pumping stations are given in detail in Appendix E.

8.2.3 Treatment Plants

Operation and maintenance costs for treatment plants were derived from the current labour and material costs in Penang State, including power, water for cooling and sealing, lubrication, and minor repair of equipment. Estimated operation and maintenance costs for treatment plants are given in detail in Appendix E.

8.2.4 Operation and Maintenance Costs by Stage

Estimated sewerage operation and maintenance costs by stage is shown in Table III-12.

TABLE III-12 Sewerage Operation and Maintenance Costs by Stage at 1976 Price Level

(1000 M$)

	1st Stage	2nd Stage	3rd Stage	4th Stage
a. Public Sewers	1,490	1,170	3,760	5,110
b. House Connexions	560	560	850	1,110
c. Pumping Stations	-	200	70	60
d. Treatment Plants	1,470	700	760	1,310
TOTAL	3,520	2,630	5,440	7,590

Note: Escalation Rate is estimated at 5 percent per year.

Chapter 9

Benefits

9.1 Anticipated Benefits

Very significant benefits to public health can be derived from installation of an adequate sewerage system in the sewerage implementation area. Great damage to the health and growth of the population and to the economic progress of the community as a whole can be expected to result from the neglect of sanitation and storm drainage. There appears to be no choice but to consider an adequate sewerage system in the area as an absolute necessity if the Project Area is to have maintained minimum desirable standards of environmental health and cleanliness.

The benefits to be derived from the construction and operation of the recommended sewerage system can be grouped in several categories, namely (1) health benefits, (2) environmental benefits, (3) economic benefits, and (4) general benefits.

All anticipated benefits have been evaluated for the sewerage project on the basis of either quantifiable or nonquantifiable benefits. Since the benefits are not fully quantifiable, nonquantifiable considerations have become important in judging the overall economic justification of the project of this nature.

9.2 Recognition and Measurement of Benefits

Major benefits resulting from the improvement of health conditions and from increases in land values, are delineated and quantified. Associated benefits manifested through a more pleasant community environment, greater potential for tourism, abatement of flood damage, opportunity for more intensive land use, opportunities to facilitate housing and industrial construction, and a cause of other less tangible benefits have been identified.

9.3 Health and Sanitation Benefits

The major benefit from the proposed sewerage system will be the great sanitation improvement resulting from removal of human excreta and other wastes from the community environment.

Anticipated benefits resulting from the sewerage system can be measured if the cause and effect relationship of the sewerage system to incidence of the water-borne diseases and to the levels of mortality and morbidity of the populations served by the system, are determined. Unfortunately, however, there are no historical data indicated relative to the incidence of the water-borne diseases prior to and after construction of the sewerage systems in Malaysia and elsewhere.

Although most of the benefits to be derived from the sewerage construction are not quantifiable, so it is not possible to compare a benefit/cost ratio, some of the health and sanitation benefits can be calculated if reductions of pertinent diseases are estimated on the basis of reasonable assumptions.

A statistic data prepared by MHD indicates that the number of gastro-entritic diseases cases in 1974 was 89. Also, a survey on the cost for treatment of the diseases conducted by NSC under the present project indicates that expenses for treating these diseases, including amounts spent for medical care, cost about M$27 per person per day. To estimate the benefits to be derived from the sewerage systems, if about a half of these is attributable to poor excreta disposal, if this can be eliminated by the sewerage system, and assuming the constant diseases occurred as of 89 and the treatment period as of two weeks per person, then benefit was made on the value of cost during the entire 20 years period up to the year 2000, divided in stages on the basis of occurred diseases in priority areas, as shown in Table III-13.

The result of the benefit obtained represents a quantifiable cost of M$5,872, in terms of the total present values discounted at 10 percent on 1976 basis.

The main elements of indirect cost can also be calculated assuming the average wages lost and the number of man-days lost due to disability.

The wage lost was estimated to be M$579 as shown in Table III-14, on the basis of total present values discounted at 10 percent. This assumes that the incidence and age distribution of diseases are the same as for the population as a whole and reflect average earnings for each age group, and ratio of workers who are not included unemployed workers, to total population of 32 percent (Ref: PART V) and average wage as of M$250 per person per month.

In addition, other benefits to be derived from the sewerage system, although mostly unquantifiable, are expected, including (1) reduction of discomfort and distress, (2) improvements in environmental aesthetics from elimination of the present strong sewage odours emanating from drains and sludge accumulation therein, deriving from pit privey and septic tank effluents, excreta in drains and rivers, and direct discharge of sullage water, and (3) reduction of groundwater contamination resulting from improves measures for handling sanitary wastes.

TABLE III - 13

Benefit from reduction of direct cost of illness

Year	Numbers of disease occurred (1)	Number of diseases reduced to be expected by the sewerage system (2)	Direct cost reduced (3)	Discounted Benefit (to 1976 at 10 to rate)
1981		5	1,890	1,067
1982		5	1,890	970
1983		5	1,890	882
1984		5	1,890	802
1985		6	2,268	874
Sub-total	57	26	9,828	4,595
1986		0	0	0
1987		1	378	120
1988		1	378	110
1989		1	378	100
1990		1	378	90
Sub-total	7	4	1,512	420
1991		1	378	82
1992		1	378	75
1993		2	756	136
1994		2	756	124
1995		2	756	112
Sub-total	16	8	3,024	529
1996		1	378	51
1997		1	378	46
1998		2	756	84
1999		2	756	77
2000		2	756	70
Sub-total	15	8	3,024	328
Total	89	46	17,388	5,872

(1) Numbers of diseases occurred by stages were estimated by the proportion of population served in the priority area, to the total population of Project Area.

(2) Numbers of diseases reduced by year were estimated as follows. (1)/2 x 5 year

(3) Direct costs reduced were estimated as follow (2) x M$27 x 14 days

TABLE III - 14

Savings in lost due to disability from water borne diseases

Year	Numbers of disease occurred (1)	Number of diseases reduced to be expected by the sewerage system (2)	Direct cost in lost (3)	Discounted Benefit M (to 1976 at 10 rate)
1981		5	187	105
1982		5	187	96
1983		5	187	87
1984		5	187	79
1985		6	224	86
Sub-total	51	26	972	453
1981		0	0	0
1987		1	37	12
1988		1	37	11
1989		1	37	10
1990		1	37	9
Sub-total	7	4	148	42
1991		1	37	8
1992		1	37	7
1993		2	75	13
1994		2	75	12
1995		2	75	11
Sub-total	16	8	299	51
1996		1	37	5
1997		1	37	5
1998		2	75	8
1999		2	75	8
2000		2	75	7
Sub-total	15	8	299	33
Total	89	46	1,718	579

1) Numbers of diseases occurred by Stages were estimated by the proportion of population served in the priority area to the total population of Project Area.

2) Numbers of diseases reduced by were are estimated as follow. (1)/2 x 5 year.

3) Saving costs in lost were estimated as follow (2) x 0.32 M$250 x 14/30 days

9.4 Waste Load Control Benefits

The reduction of waste loads or improvement of water quality in the drains and rivers is another major benefit to be derived from the sewerage system.

From the extensive investigation to the drains and rivers under the present project, (see Appendix G) most of drains in municipal through the Project Area have been polluted and are expected to become much more polluted in the future, also rivers will be polluted from the drain flows.

Currently these atream and river waters are used for the puporse of irrigation and fishing, etc.

Waste loads produced in sewered areas will be reduced through the treatment plant before discharge into waterways, then drain and rivers will be significantly improved.

This will be improvement of environmental aspects and also will make river waters available as new water resources for various purpose.

9.5 Values Added to Land

Investments in sewerage facilities will have the effect of raising the intrinsic values of the parcels of land served by the system. These additional land values constitute a major economic benefit of the project in that, by improving the sanitary and aesthetic quality of the community, they contribute to the quality of life of the residents. The value of such benefits are measured by the additional prices abserved in the areas where similar projects have been carried out, that buyers are willing to pay for properties on which such physical improvements have been made.

On the basis of the experience obtained in project site during 1976, the land values prior to any development programme were M$1.5 per sq. metre for agricultural area, and M$3.0 for areas slightly inhabited. After these areas are improved by development programmes, the land values have been increased to an average M$54.0 per sq. metre. To estimate the benefits of land value to be obtained after the sewerage construction, if an increase of 20 percent in land values as of M$54.0 per metre, can be expected to the availability of sewerage service, on the basis of proportionate shares of estimated infrastructure investments in public utilities.

Then benefit was made on the basis of entire sewerage implementation area with respect to land values, in accordance with the priority determined up to the year 2000.

Table III-15 shows the result of the benefit obtained, this represents a quantifiable cost of M$27,952 on the basis of the total present values discounted at 10 percent on 1976 levels.

TABLE III - 15

Benefit from Increase in Toatl Land Volues

Year	Sewerage Service area (1)	Increase total land Volues (2)	Discounted Benefit (M$) (to 1976 at 10%)
1981	439	4,741	2,676
1982	439	4,741	2,433
1983	439	4,741	2,212
1984	439	4,741	2,011
1985	439	4,741	1,828
Sub-total	2,195	23,705	11,166
1986	397	4,288	1,503
1987	397	4,288	1,366
1988	398	4,298	1,245
1989	398	4,298	1,132
1990	398	4,298	1,029
Sub-total	1,988	21,470	6,275
1991	646	6,977	1,518
1992	646	6,977	1,380
1993	646	6,977	1,255
1994	646	6,977	1,141
1995	646	6,977	1,037
Sub-total	3,230	34,885	6,331
1996	688	7,430	1,004
1997	688	7,430	912
1998	688	7,430	830
1999	688	7,430	754
2000	688	7,430	686
Sub-total	3,441	37,161	4,186
Total	10,854	117,221	27,952

(1) Sewerage service area's were estimated in accordance with the priority area determined.

(2) Increase total land volues were estimated as follow (1) x $^{M\$}54$ x 0.2

9.6 Other Economic Benefits

In the Project Area, there are many development programmes, such as housing and industrial, although the exact construction schedules for these programmes are still unknown. If it is planned to construct during the same as overall project period of provision of sewerage system considered, the cost of constructing septic tank and/or Imhoff tank in new development areas will be avoided by providing the sewerage tank in new development areas will be avoided by providing the sewerage system for the Project Area. Table III-16 shows a comparison of septic tank and sewage treatment recommended in this Master Plan, in accordance with the capital required including costs of construction, maintenance and operation, hence it is found that the cost of inferior alternative sytems such as use of septic tank is higher, and further the septic tank is designed to receive only human excreta (W.C.) and do nothing to resolve the problems of contaminated sullage on industrial wastes water. Thus, the provision of the sewerage system recommended consisting of sanitary sewer and treatment plant would be of benefit to the individual expenditure, in comparison with other sanitary systems such as septic tank.

Another benefits will be derived from joint treatment of industrial wastes with municipal sewerage system which will cover the Mak Mandin industrial area and other isolated industrial areas.

Advantages to be gained are avoidance of the great expense of individual treatment, which appears to be regarded by the Government as warranted if no other solution is found, including the reduced land required for plant construction and lower operating costs because of higher efficiency of larger scale treatment systems.

TABLE Ⅲ-16 Cost Comparison of Alternative Sewage Treatment

Alternatives	Construction Cost (per Capita) M$	Maintenance/Operation Costs (per Capita) M$ per Year
Septic Tank*	166	8.5
Recommended Sewage Treatment	160	3.0

Note: * Data obtained from MCPW.

The cost of recommended sewage treatment was estimated from the Study of Master Plan.

9.7 Benefits Justification

On the basis of the results of evaluations of benefits by the proposed sewerage system for the Project Area, tangible and intangible, it is concluded that the project is definitely feasible. If no sewerage system were provided in the area, sanitary conditions, which are already deplorable in many areas of the city, will become progressively worse. Moreover, if this project is not undertaken at this time, the cost for implementation at later times will become increasing higher. Hence, posing ever increasing difficulties for financing. Thus the accumulated total cost could become so high, the project could become almost unmanageable. The project is indeed timely now.

Although evaluations of the major benefits have been made, with expression of these into money terms, most of the benefits are intangible in nature, and it is not possible to compute a meaningful benefit/cost ratio for sanitary sewerage system programme in terms of money values. Nevertheless, there will be very substantial economic benefits, including avoidance of productivity losses due to water-borne diseases and avoidance of the much higher cost of controlling water pollution by other means.

In view of these results of the study, it is concluded that the earlier the programme is commenced, the greater will be the benefits per unit of investment, and vice versa. Therefore, the earliest possible implementation of the sewerage programme is recommended.

PART IV

DRAINAGE MASTER PLAN

Table of Contents

CHAPTER 1

AREA COVERED BY DRAINAGE SYSTEM

The Project area concerned for consideration of the drainage systems proposed under this Project identical to them for the sewerage systems covering the area of 11,600 hectares inclusive of river surface, mountainous portion higher than + 61 metres (+200 ft) above mean sea level which was taken as non-inhabitable area.

However, it is necessary, for planning purpose, to consider the catchment area, where stormwater inflows from outside of the Project Area due to topographhcal condition for the basis of estimation of stormwater quantities. The total extent of these contributing areas is 1,751 hectares (4,327 acres). Howver to these areas any facility will not be planned.

Thus the area concerned to drainage system planning is summarized as follows ;

The Project Area	.... 11,600 ha	(28,663 acres)
Contributing Area	1,751 "	(4,327 ")
Total	13,351 "	(32,990 ")

On the other hand two development areas, Prai and Seberang Jaya, are not considered for the purpose of drainage master planning, as these two areas have already been served by existing drainage systems and can conviniently be separated from surrounding areas, forming the independent drainage basin.

Further non-inhabitable areas including river surface and mountain zone have to be excluded from the facility planning and construction costs estimates. Exclusive areas are

Prai and Seberang Jaya	..... 980 ha	(2,422 acres)
Non-inhabitable area	..... 746 "	(1,843 ")
Total	1,726 "	(4,265 ")

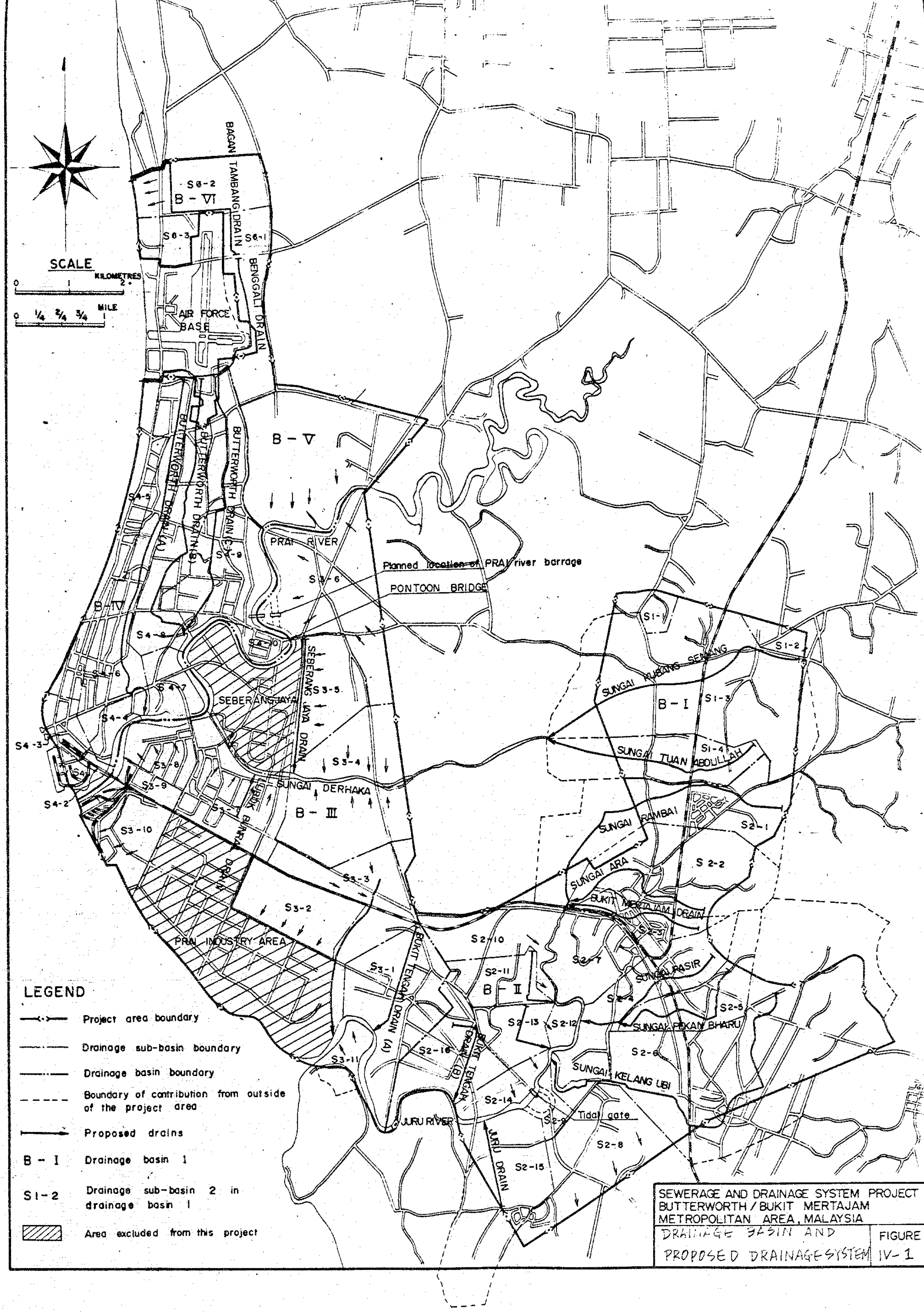
Area to be served by drainage system under this project is ;
13,351 - (1,751 + 1,726) = 9,874 hal 24,398 acres)

In accordance with the proposal in the Assignment Report of WHO and considering existing watershed, drainage conditions and general feature of land use, the Project Area is divided into six drainage basins as shown in Figure IV-1 . In Table IV-1 , the area of individual drainage basin is shown together with contribution area and non inhabitable area.

Table IV-1 Area in Individual Drainage Basin (in ha)

Name of Drainage Basin	Area to be served by Drainage System	Area excluded from the Project	Sub total	Contribution Area	Total
B-I	980	93	1,073	55	1,128
B-II	3,591	202	3,793	1,166	4,959
B-III	2,632	1,332	3,964	23	3,987
B-IV	1,576	80	1,656	42	1,698
B-V	551	19	570	0	570
B-VI	544	0	544	465	1,009
Total	9,874	1,726	11,600	1,751	13,351

FIGURE IV-1



SEWERAGE AND DRAINAGE SYSTEM PROJECT
BUTTERWORTH / BUKIT MERTAJAM
METROPOLITAN AREA, MALAYSIA

DRAINAGE BASIN AND PROPOSED DRAINAGE SYSTEM

FIGURE IV-1

CHPATER 2

BASIS OF DRAINAGE PROGRAMME

2.1 Open or Closed Ditches

Existing drains in the Project Area are open channels. Open channels have considerable advantages over closed condits, the main ones being the east of maintenance, the lack of requirement of manholes, the comparatively shallow construction required and the fact that road kerbs and gulleys are not necessary to accept runoff frame roads. Among merits above, the shallow construction requirement would result in avoidance of newmerous crossing with sewer pipes in the separate system adopted here. The major disadvantages in that open channels provide easy, although illegal, means for the disposal of refuse, which results in blockages. However, this disadvantage can deal with, although it would take time, an advertising campaign to ban the disposal of refuse into open channels. Anti-litter campaign are now proceeded in the area and this would be preferable measure to protect open channels from clogging rather than appling closed condits. It is acceptable to consider that in case of closed ones the disposal of refuses into them would be reduced. But once refuses dunpt into under ground conduits, even if the volume of them is very small, the maintenance work would become more difficult and costy.

On the other hand, closed condits have merits wich conserve spaces for road and other utilities. Thus, in the highly developed areas closed condits would be preferable. The Project Area has been delineated to be the area which would not be developed so densely to warrant the underground conduits. However, open channels can also preserve spaces for other utilities by covering them when it becomes feasible.

On the basis of situations above, open channels have been adopted for the Project Area.

2.2 Land Filling or Pumping Up

As described previously, majority parts of the Project Area are low-lying and influenced by a backing-up of the sea water. Therefore, the ruling factor in selecting the proper drainage methods is the sea water level to be used for the planning.

As is described in section 2-3, the highest recorded sea level is + 1.68 metres (+5.5 ft) and mean high water level of spring tide is + 1.10 metres (+3.6 ft).

As a result of back water computation, it was found that flooding will be occurred when the sea level goes up as high as + 1.68 metres (+5.5 ft), and at the same time, there is a rainfull event with intensity of 5-year frequencies. To cope with this flooding there are two methods, land filling and pumping up of stormwater runoff. However, the return period of + 1.68 metres sea level is considered to be very long.

It is likely to happen that pumping stations, if constructed, would not have been operated for years. It is acceptable to conclude that the provision of pumping stations to cope with flooding due to the recorded highest sea level of + 1.68 metres, is not warranted under this planning.

Therefore, land filling is recommended for the areas flooded when the highest sea level accompanied with rainfall event of 5-year frequency intensity appears.

The construction of pumping stations was considered as the counter-measure to flooding due to backing up of the mean high sea level water of + 1.10 metres (+ 3.6 ft) which is expected to appear at least once a year.

2.2.1 Recommended Elevation Up to Which Land Be Filled

The water level in the Prai and Juru river under the critical situation in which the river is flooded with heavy rains while influenced by the highest sea level of + 1.10 metres, has to be estimated for the purpose of identifing the elevation up to which land is to be filled.

The planned flood water level in the Prai river at the time of mean high water level, +1.10 metres, is available in the the "Project Report on Drainage and Reclamation of Sungai Prai Basin".

The planned flood water level 1/ in the Prai river which is influenced by the tide with mean high sea level of +1.10 metres, is available in the "Project Report on Drainage and Reclamation of Sungai Prai Basin" prepared by JICA, in 1973. According to the Report, the water level at the point of Prai barrage, is +1.37 metres (+4.5 ft) under the tidal level of +1.10 metres (+3.6 ft). The gradient of river water surface at that time is 0.000035.

It was considered that the use of 0.000035 for a gradient of water surface expected in the flooded river influenced by the tide of +1.68 metres (+5.5 ft) yielded the result of safe side for the estimation of river water level.

The distance from the estuary of the Prai river to the boundary of the Project Area is about 13 kiro metres. Estimated waterlevel at the bouandary of the Project Area, therefore, is $1.68 + 0.455 = 2.14$ ($0.000035 \times 13\ 10^3 = 0.455$ m). If allowances in branches and main drains are added, the water level at upstream of the drainage channels would be about +2.30 metres (+7.5 ft).

1/ : The mainfull intensity applied is that of 10-yr frequency.

On the other hand the calculated back water level in Butterworth drain is about +2.30 metres (Ref. Section 2-5). These two results clarify the elevation up to which land should be filled. It may recommended, therefore, the elevation of land filling in the tributary of the Prai river be +2.30 metres (+7.5 ft).

In the tributary of the Juru river, land filling is also necessary for areas with least elevation. No data is available as to the water level in the Juru river in its flooded time.

As to the Juru river, it is required to be studied and develop the master plan comprising needed cross section, water level at unusual time under the intense rainfall and/or the highest see level and the effect of existing Cidal gate for the river water level. Those studies will clarify the required land elevation to be filled.

2.3 Survey Datum

The reference level used in this report is Malaysian Survey Ordinance Datum of which the zero point is mean sea level (1912 determination).

The ground elevation in this report has been expressed as reduced level (RL) which has the same zero point with survey ordinance datum. The sea level as a design basis of this project has been determined on the basis of records during 1952 - 1967. The applied figures, described below, have been used in the "Project Report on Drainage and Reclamation of Sungai Prai Basin ", too. The project above has verious relations with the drainage plan in the Project Area. Therfore it was cosidered that the use of the same design sea level will be prefferable. The applied sea level is shown below.

HHWL (highest recorded level)	SOD	+1.10 m	(+5.5 ft)
MHWL (spring tide)	"	+0.37 "	(+3.6 ft)
Mean sea level	"	+0.15 "	(+0.5 ft)
MLW (spring tide)	"	-0.79 "	(-2.6 ft)

SOD: servey ordinance datum which is the hight above
mean sea level at Port Swettenham in 1912.
It is expressed as,
mean sea level (in 1912) .... SOD + 0.00

Note: Data sauce ...... Servey Department

2.4 Design Basis

2.4.1 Storm-water Quantities

As the basis of the engineering design of storm drainage facilities, stormwater quantities have to be estimated as accurate as possible. Many formulae and methods have been developed for the estimation mentioned above. The purpose of this section is to develop the various factors which have been used as a basis of design for this project. The development has been done in association with the national standards of Malaysia and on the basis of studies described in Appendix D.

A Runoff Formulae

The "Rational Formula" is widely used as current practice for computing quantities of stormwater runoff. Although, it is the majority case of applications of the "Rational Method" that no storage effects inside ditches have been weighted, however, the Malaysian standards recommend the use of the "Rational Method" with a storage coefficient as described follow.

$$Q = \frac{1}{360} CsCIA \quad \text{--------------------}$$

where

- Q : the peak discharge in cum per second
- I : the average intensity of rainfall in mm per hour
- A : the catchment area in hectares
- C : a runoff coefficient
- Cs: a storage coefficient which is expressed as;

$$Cs = \frac{2tc}{2tc + td}$$

tc : the time of concentration

td : the time of flow in the drain

The application of a runoff formula modified by a storage coefficient is preferable in the Project Area which is totally flat and low-lying.

The relation between Cs, tc and td has been derived on the basis of the theory acceptable internationally and the result of practical application on four drainage basins in KL was in close agreement with those obtained by the more elaborate routing procedure in which a processing with the computor is common. The derivation of Cs as a function of tc and td is explained in "Flood Estimation for Urban Areas in Peninsular Malaysia", Hydrological Procedure No.16, published by Ministry of Agriculture and Rural Development Malaysia. With the background above, "Rational Method" with storage coefficient Cs, ei, Q = 1/360 CsCIA was adopted in this Project.

B. 2 Rainfall Formula

On the basis of the analysis of the rainfall records, rainfall formulae with specific frequencies are developed and checked regarding their suitability for use with the observed rainfall intensities.

The comparison between the formula developed under this Project and that in George Town proposed by DID has been carried out and following formulae are recommended.

Two-year frequency $$I_2 = \frac{8,400}{t + 57}$$

Five-year frequency $$I_5 = \frac{10,700}{t + 69}$$

Ten-year frequency $$I_{10} = \frac{12,900}{t + 79}$$

Details refer to Appendix D.

C ~~5.2.3~~ Rainfall Frequencies for Design

In an ideal situation, storm drains could be designed to carry the runoff from the most severe storm, predicted for a given location. However, when construction costs of the required sewers are considered, the selection of a rainfall frequency becomes necessary. The national standards as for rainfall frequencies as a basis for the design of urban drainage systems are two years for residential areas and five years for commercial and industrial areas. These figures are acceptable for the size of municipatities like the Project Area and also in the range of accepted design practicies. For this Project, therefore, the same rainfall frequencies as that of the national standards was applied. However, for major drains flowing through varied land use areas, the five years was considered as design rainfall frequencies. The design rainfall frequencies are summeried as follows:

Residential area	2 years
Commercial area	5 years
Industrial area	5 years
Major drains	5 years

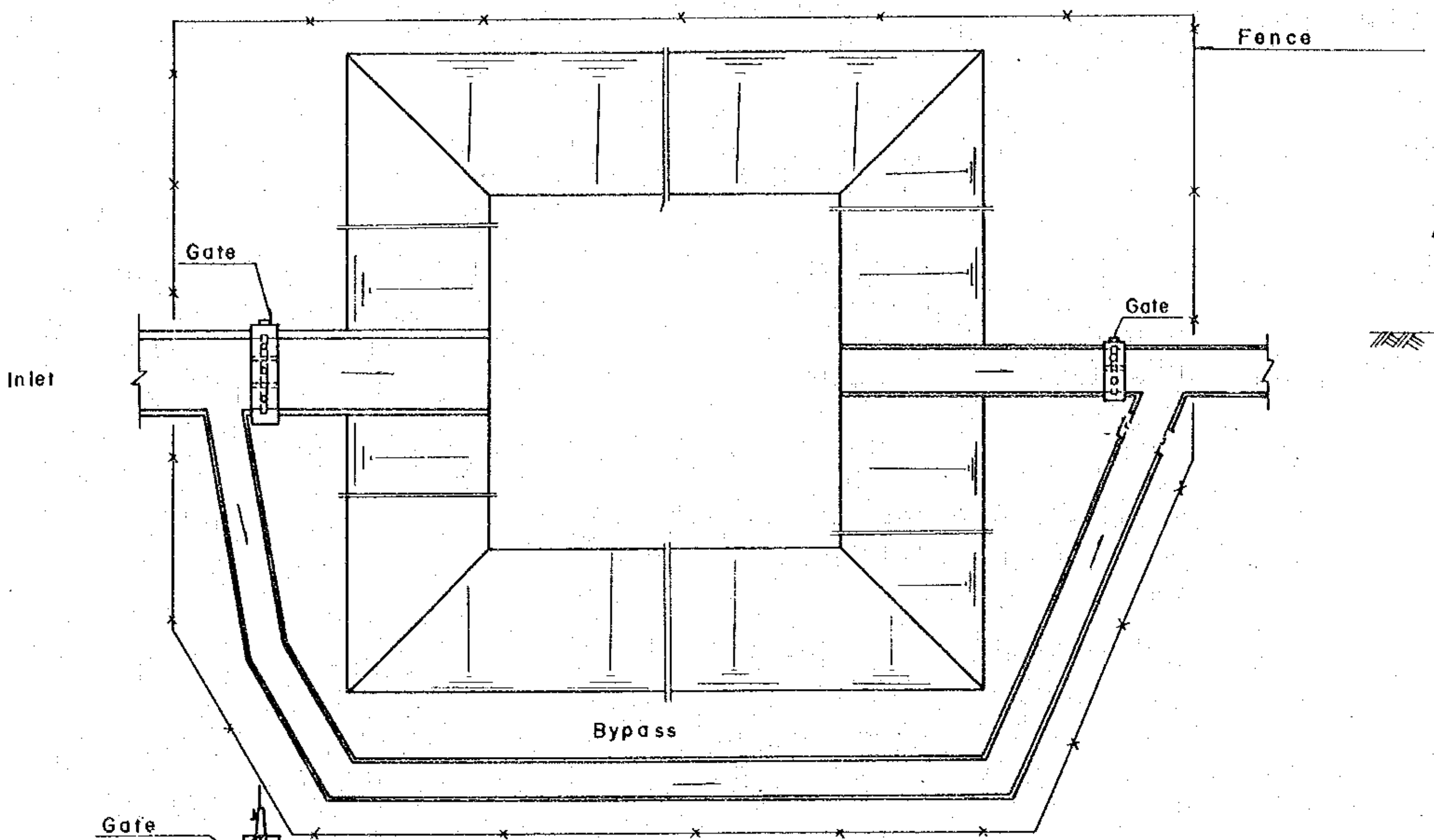
D ~~2.5.4~~ Runoff Coefficient

Runoff coefficients to be used for drainage design are determined, taking into account the different types of surface of the Project Area. The recommended coefficients for the area by types of future land use are as follows:

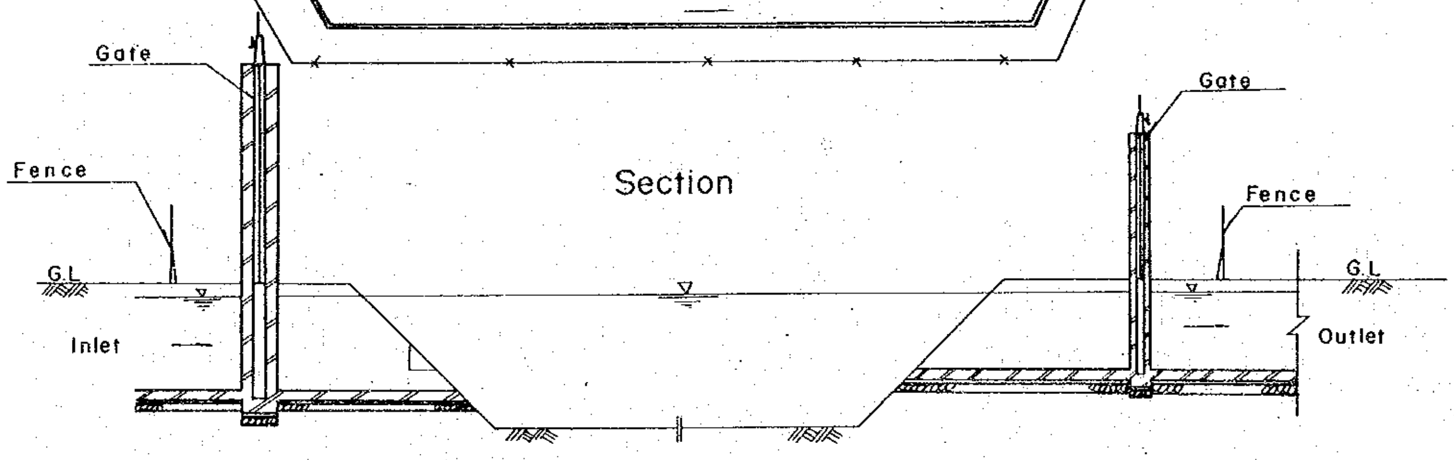
Land Use		Runoff Coefficient
Residential area	Densely inhabited	0.70
	Sparsely inhabited	0.35
Commercial area		0.85
Industrial area		0.50
Agricultural area		0.10
Mountainous area		0.50

Details refer to Appendix .

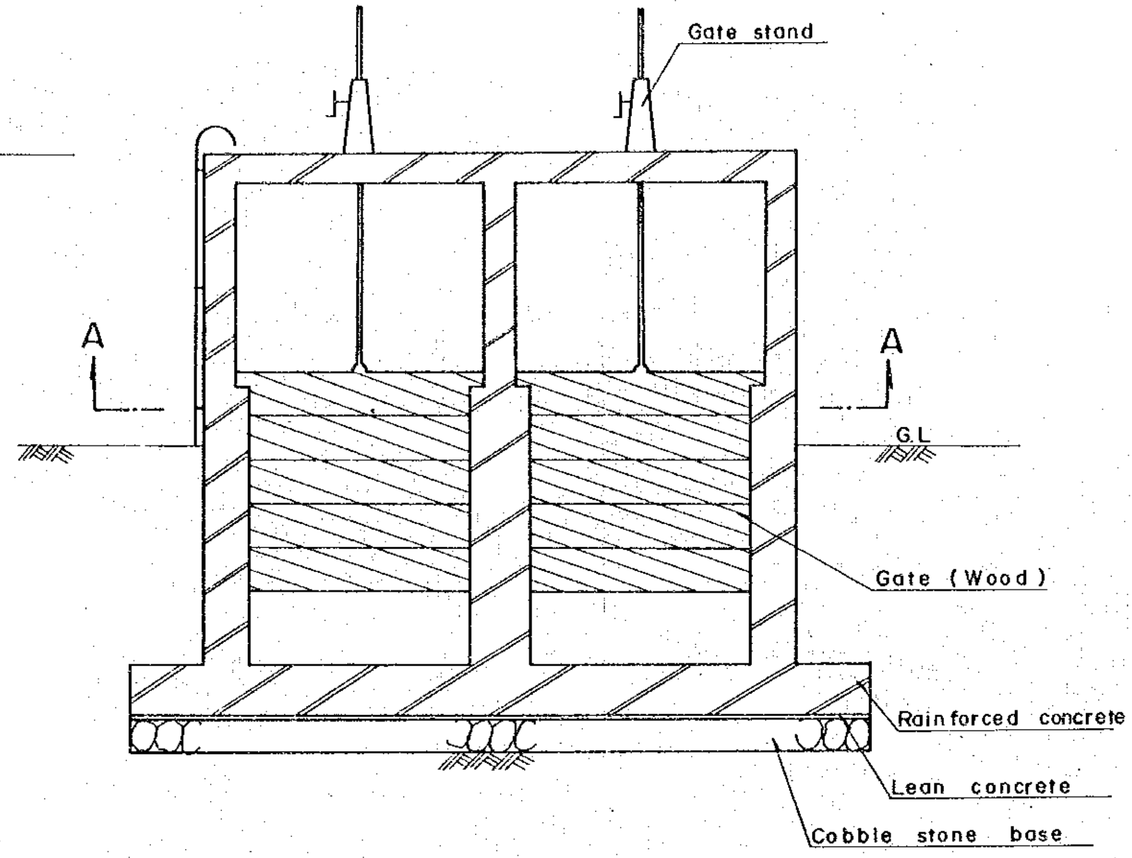
Plan



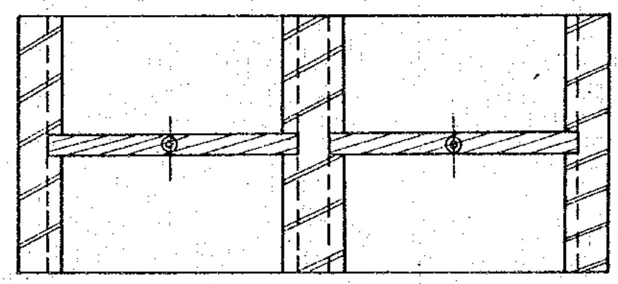
Section



Section of gate



Section A - A



SEWERAGE AND DRAINAGE SYSTEM PROJECT BUTTERWORTH / BUKIT MERTAJAM METROPOLITAN AREA, MACAYSIA	
DESIGN SKETCHES OF RESERVOIR	FIGURE IV-

2.4.2 Design Criteria

A. Hydraulic Design of Open Channels

i. Manning Formula

For the hydraulic design of open channels, Manning Formula is applied and expressed as follows:

$$V = \frac{1}{n} R^{2/3} \cdot I^{1/2}$$

where,

V	:	velocity in metre per second
n	:	roughness coefficient
R	:	hydraulic radious
I	:	gradient

The value of "n" is defined as follows:

cart-in-place concrete channel	n = 0.015
pre-cast channel	n = 0.013
wet masonry channel	n = 0.025
earth channel	n = 0.030

ii. Type of Cross Section

As a results of cost comparison, it became clear that the earth channel is the cheapest. So it would be preferable that earth drains are used as much as possible in the proposed drainage system. However, earth drains are specified usual trapezoidal cross section which result in requirements for under space than rectangular type. So, in the case of sufficient spaces are not available for drains, stone mansonny channels or rectangular concrete channels are to be applied.

In case of smaller road-side drains pre-cast "U" shape channels are to be used taking advantages of the shorter construction time required. In Figure C.1 - C.5, the individual type of channels is shown with required materials. (Ref. Appendix C.)

iii. Storage Type Drains

It would be preferable to apply storage type drain here, because the rainfall characteristics are that of tropical zone, heavy and short duration thunder storm, and the Project Area is low-lying and flat. In order to avoid the provision of larger size drains to be design for intence rainfall with shorter duration, it would be wise to make velocity in drains slow as much possible and time of concentration long. With this procedure, it becomes possible to provide drains to cope with stormwater runoff with moderate intensity. Further, if the time of concentration becomes longer, the storage coefficient "C_s" (Ref. Section 2-4.1.) would be smaller.

On the other hand, slower velocity flow needs less energy resulting in avoidance of pumping stations. However, these slow flow type of drainage system requires the larger land space. Except highly populated area, it is considered that adoption of drainage system wide slow flow type would be feasible for the Project Area.

B. Reservoirs

i. Calculation of Volume

The volue of reservoirs is calculated by following processes:

- develop inflow hydrograph
- develop cumulative inflow curve
- develop cumulative outflow curve
- read the maximum volume required

In usual case, the volume of reservoir is selected among those resulted from two types of inflow hydrograph, one is for the situation of $tc > te$ and another of $tc < te$ (Ref. Appendix C.). Thus, maximum volume required would be found.

ii. Equipment of Reservoir

Standard section of the reservoir is shown in Figure
As can be seen from the figure, two gates, one at inlet portion and another at outlet, be provided to privent inflow of dry weather flow which would cause pollution problem in the reservoir. The causions maintenance which does not allow the mosquito bleeding has to be intended. By these two gates, the dry weather flow will pass through by-pass furnished for the reservoir. The outlet structure would be specified to be overflow weather which gives minimum head loss and is free from the problems of clogging.

2.4.3 Materials and Methods of Construction

A. Construction Materials

Cements, sands and gravels are available with adequate quantities in Malaysia. Any extra costs will not be required to collect those materials. It is able to get stones for construction masony channel rather easily and they have been used here as favorable materials with less cost.

All materials used for the construction of proposed drainage system could be produced locally. It is confirmed that any type of pre-cast concrete channel could be made here by existing firms.

B. Construction Methods

Machine excavation, steel sheet piling and any other mechanical works required for the construction of drainage systems can be done with equipments available here.

Discussions with government staffs and observation on various civil works which are on-going in Penang State, drew out conclusion that any up-dated construction method could be applicable for the Project.

On the other hand, the condition of construction sites would be another factor to be accounted when construction methods are screened. In the case of areas undeveloped now, it could be possible to apply variety of construction metod because of adquate spaces for works.

However, in case of built-up area, such as Butterworth, some constraints on the selection of construction methods would be imposed due to inadquate space and access. Maintenance of traffic flow during construction works has also to be kept in mind. For the purpose of preparation of the Master Plan, these factors are not investigated deeply and the cost for those expectation are included in contengencies.

2.5 1.2. Alternative Drainage System Considered

For the purpose of identifining the preferable ~~method~~ drainage system to prevent or alleviate flooding in the individual drainage basin within the Project Area, alternative drainage systems have been weighted on the basis of the economical and technical viewpoints.

Because of the absence of town or regional planning proposals on which drainage master plans depend, in some areas the studies of alternative systems are not viable and no comparison has been carried out.

The unban area with considerable population density and systematic road network are Butterworth and Bukit Mertajam. However, Bukit Mertajam area can be delineated to be steep and high and in which no pumping up of storm water is required and any change of the routs of existing natural water couses is unwarranted because they have been fixed exclusively due to steep topographical conditions. Therefore, the weighting of alternative drainage systems has been carried out in Butterworth area accounting following matter.

a. Because the area is low-lying, it is preferable for the drainage systems proposed here to have characteristics in which the least head loss is required, in other words the grade of water surface should be as small as possible.
   The type of drainage system described above would make it possible to gravitate stormwater runoff into the Prai river or the sea. Thus the construction of pumping stations would be avoided, resolting in the sayings of the initial costs.

b. For the lowest parts, it has been considered that filling-up of land would be inevitable.

c. The involvement of constructions of reservoirs on parts of drainage systems has been taken into consideration.

On the basis of situations described above, following three alternatives have been investigated and described below.

Alternative-I (plan: refer to Figure IV-8 .)
(profile: refer to Figure .)

Except slight alighnment of meandering parts, existing routs of major drains are left unchanged. However, extention of the Butterworth drain (hereafter it will be expressed as B.D) in its upstream portion was proposed for making smooth collection and removing of stormwater runoffs of the tributary area. Because the considerable parts of the area have already been built-up, the land availability would have limitations to such degree with which the application of trapezoidal cross section were not able to be afforded. The reinforced concrete rectangular channel, therefore, was proposed to use.

~~Existing channels of this alternative is that the water level in points and low-lying.~~

It was found, as a result of investigation, that existing channels have to be windened and deepened considerably. The water level in designed ditch comes up as high as +1.92 metres (+6.30 ft) at the area of lowest ground elevation of about +1.80 metres (+5.9 ft). Land fill up to +2.30 metres (+7.55 ft) 1/

1/: head loss for branches was assumed to be 0.30 m.

will be required around this area in order to cope with expected flooding due to backing up resulted from the highest sea water level of +1.68 metres (+5.5 ft). In other areas the land fill is also required, but the elevation to be filled up is less than +2.30 metres (+7.55 ft). It can be concluded that the current recommendation of DID for land fill saying that the newly developed areas should be filled up to +2.286 metres (+7.5 ft), is completely justified with this investigation.

The construction costs of this alternative is lower than costs required for alternative-2.

Alternative-II (plan : refer to Figure IV-7)
(profile: refer to Figure)

The diversion channels of B.D. (A), (B) and (C) were weighted in this alternative. Because the space for the construction of diversion ditaches is not available except existing major roads, a construction of box culverts has been considered and the costs were estimated.

As can be seen from Table IV-2, the construction costs are higher than other alternatives.

It was found that the cross section at down stream of individual drain is not reduced by the diversion to the sea of discharges from upstream tributaries. For example drain 1.D.5 with drainage area of 437 hectares in alternative-I conveys stormwater runoff of 20 cu.m/sec and after the divertion of the upstream parts to the sea, the same drain with 212 hectares, designated 2.D.2 in alternative-II, has still to convey runoff of 17 cu.m/sec which is 85 percent of the 20 cu.m/sec. This means that although the drainage area were reduced to about 50 percent of the alternative-I, stormwater runoff quantities are reduced only 15 percent. The results might have been derived mainly from characteristics of rainfalls in the tropical zone, i.e., intense and short shower type. It is apparent that the effect of diversion to reduce the cross section in down stream is not conspicuous.

The engineering difficulties expected in the alternative are the construction of box culverts under trunk roads for considerably long period and the countermeasure to be considered for priventing accumulation of sea sands at the outfall of diversion drains.

Serious inconveniences for the traffic, are expected at the time of constructions of box culverts. On top of that the space assigned for roads will be occupied by the diversion culverts with large cross sections required and least space for other utilities can be expected.

From Table IV-2 , it is understood the construction of box culverts hikes the total initial costs of the alternative. Shallow shoreline of Butterworth makes it difficult to construct any deep structures without problems of sand accumuration to them. The constructions of larger outfalls of divertion ditches will be accompanied with initial cost up and difficulties on maintenance work.

Alternative-III

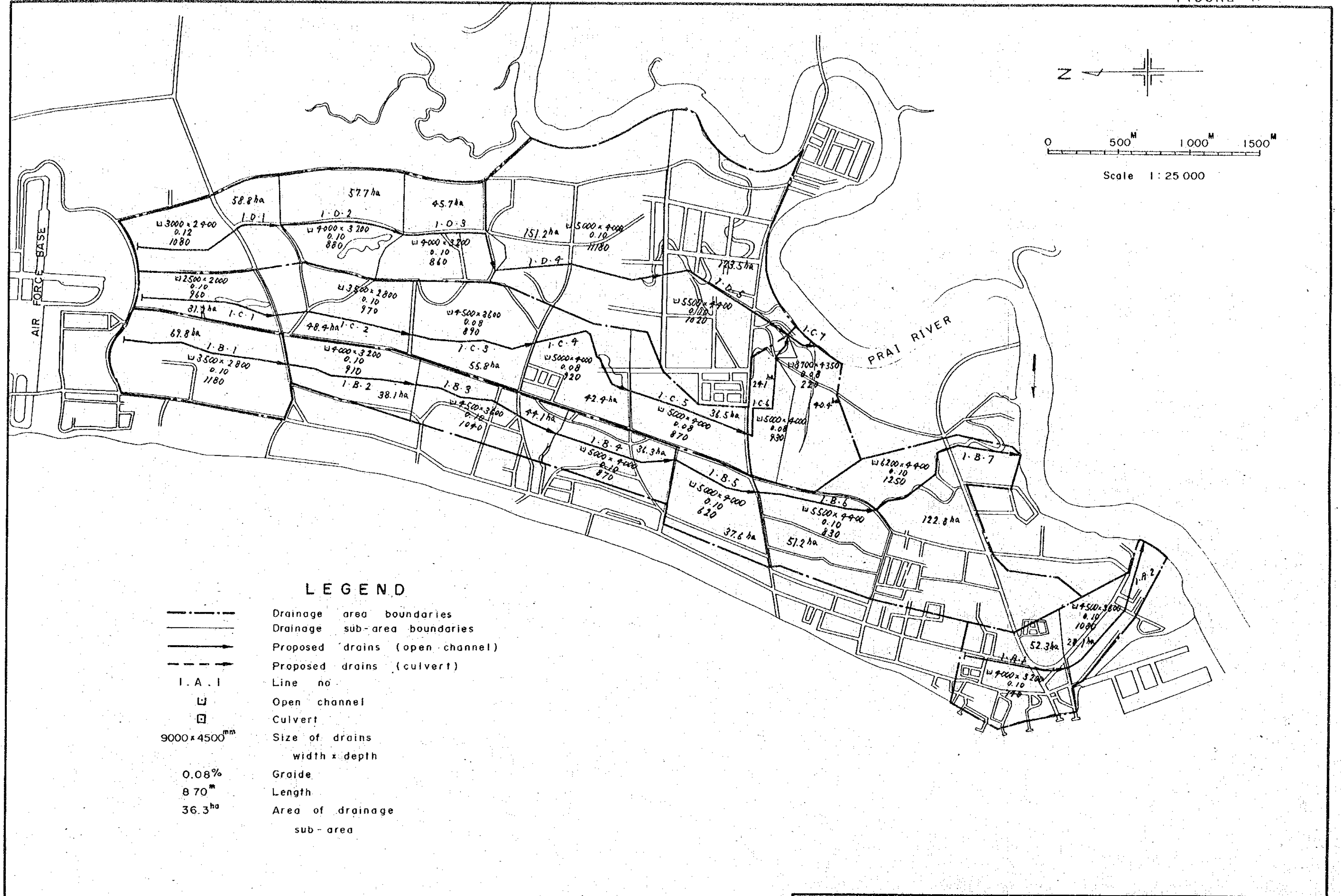
Reservoirs are inset in the alternative-I and the alternative-III was borne. The total construction costs of this alternative is lowest among three alternatives. Any special technical problem will not be expected.

This alternative has been proposed as the drainage system in Butterworth area, because of its least initial cost and being free from special engineering difficulties.

Tâble 5-2 Construction Costs of Individual Alternative

(in Malaysian $)

	Open channel	Box Culvert	Land Acquisition	Total
Alternative 1	34,575,264	-	1,646,550	36,221,814
" 2	22,422,502	20,947,721	1,146,724	44,516,947
" 3	31,973,278	387,000 (Reservoir)	1,823,872	34,184,150



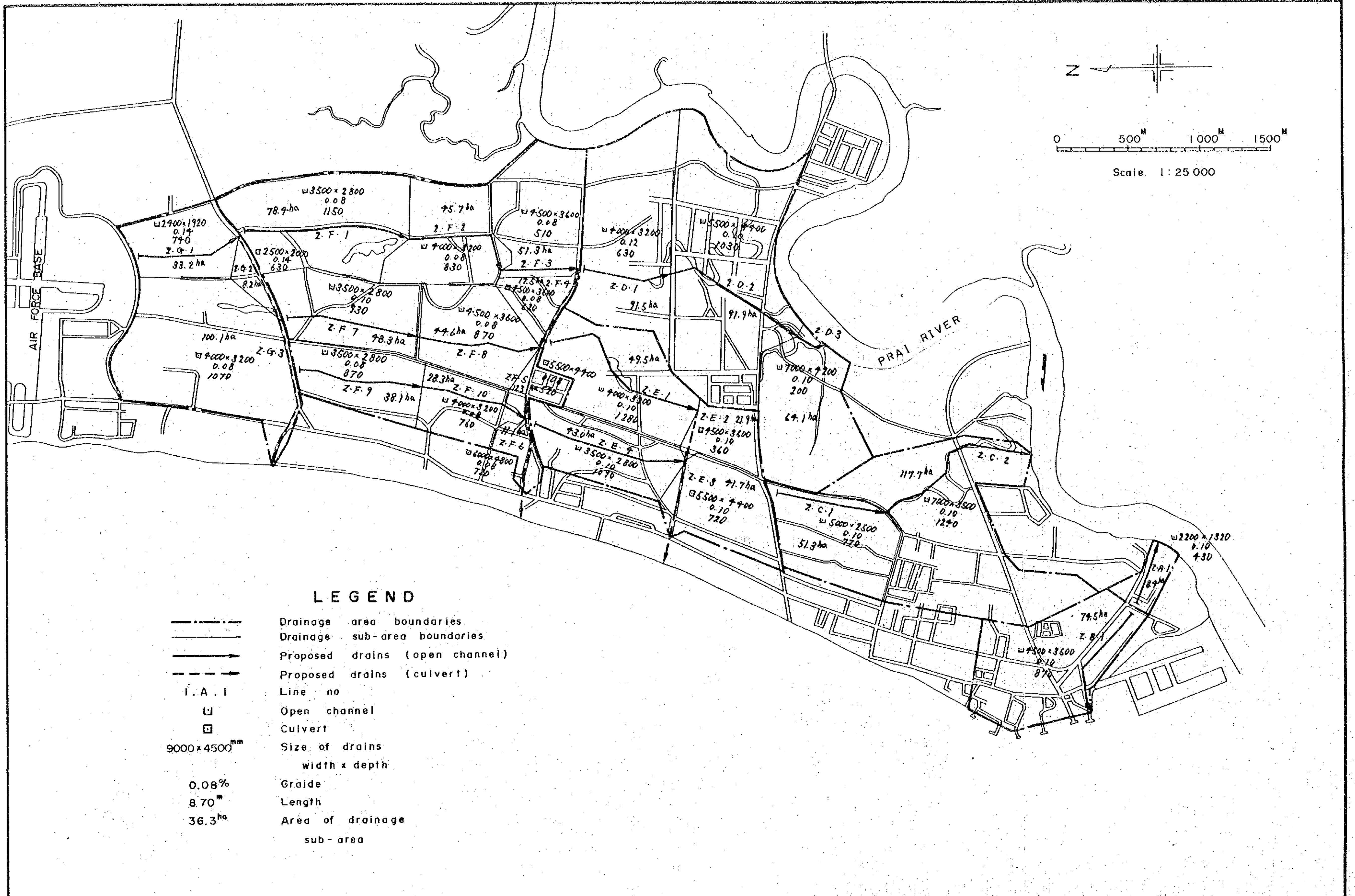
LEGEND

—·—·—	Drainage area boundaries
———	Drainage sub-area boundaries
——→	Proposed drains (open channel)
– – –→	Proposed drains (culvert)
I.A.I	Line no
⊔	Open channel
⊡	Culvert
9000×4500mm	Size of drains width × depth
0.08%	Graide
870m	Length
36.3ha	Area of drainage sub-area

SEWERAGE AND DRAINAGE SYSTEM PROJECT BUTTERWORTH / BUKIT MERTAJAM METROPOLITAN AREA, MACAYSIA

DRAINAGE SYSTEM IN BUTTERWORTH AREA (3-IV) ALTERNATIVE - I

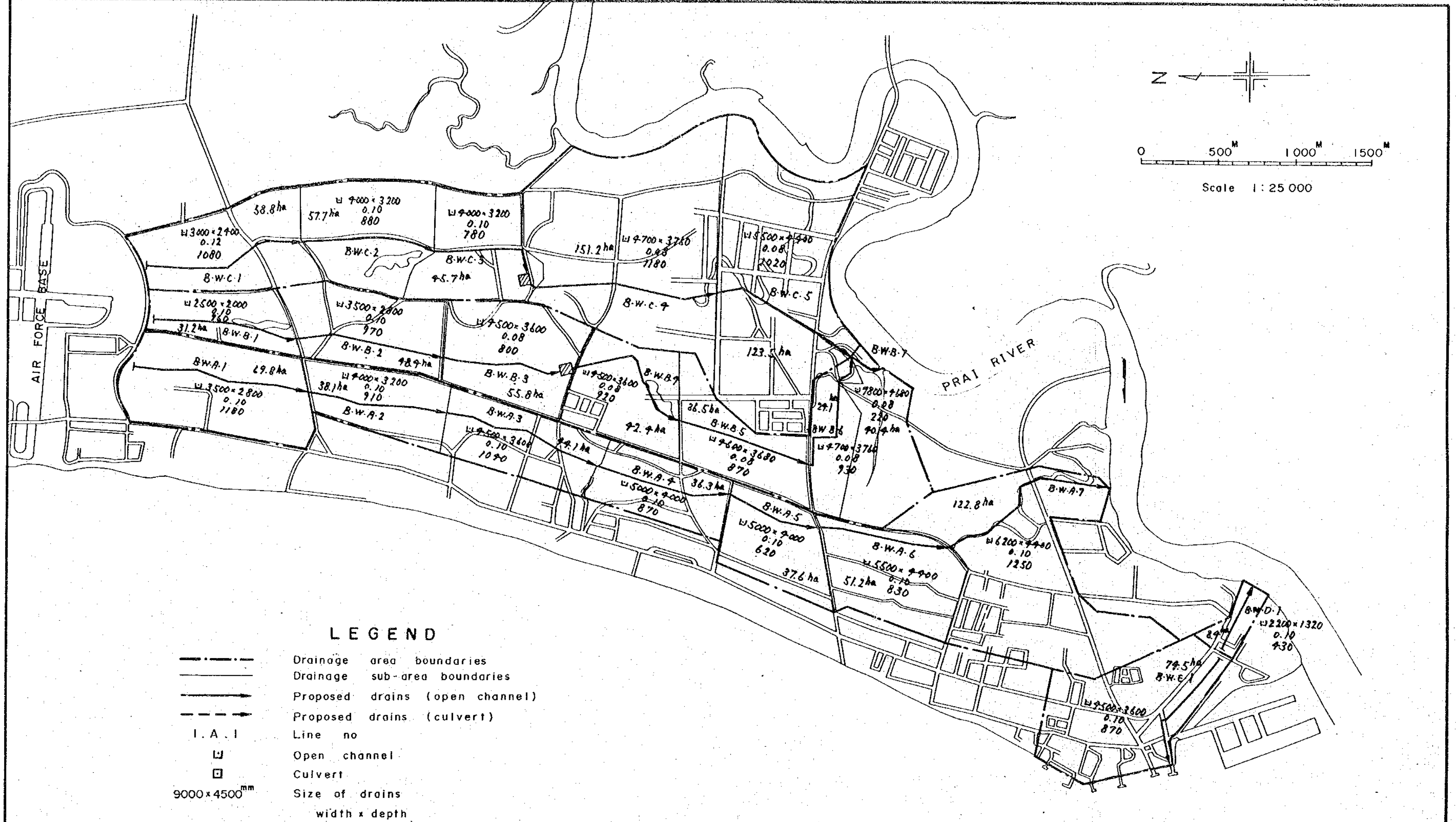
FIGURE IV-3



SEWERAGE AND DRAINAGE SYSTEM PROJECT BUTTERWORTH / BUKIT MERTAJAM METROPOLITAN AREA, MACAYSIA

DRAINAGE SYSTEM IN BUTTERWORTH (B-IV) ALTERNATIVE - II

FIGURE IV-9



LEGEND

—·—·—	Drainage area boundaries
———	Drainage sub-area boundaries
——→	Proposed drains (open channel)
—·—→	Proposed drains (culvert)
I.A.I	Line no
⊔	Open channel
⊡	Culvert
9000×4500^{mm}	Size of drains width x depth
0.08%	Graide
870^{m}	Length
36.3^{ha}	Area of drainage sub-area
▨	Reservoir

SEWERAGE AND DRAINAGE SYSTEM PROJECT BUTTERWORTH / BUKIT MERTAJAM METROPOLITAN AREA, MACAYSIA	
DRAINAGE SYSTEM IN BUTTERWORTH (B – IV) ALTERNATIVE – III	FIGURE IV-10

CHAPTER 3

RECOMMENDED DRAINAGE PROGRAMME

3. 1 Description of Individual Drainage Basin

A. Drainage Basin I

The basin is situated in the northeastern part of the Project Area. It has steep terrain with plam and rubber tree cover and without flooding problems. The outlet are Kubang Semang drain and Tuah Abdullah drain, both of them are upstream of Derhaka river flowing through paddy fields and Sebrang Jaya area eventually to Prai river. Elevations range between a high of 55 metres(180 ft) in the east boundary and a low of 5 metres(18 ft) in the west edge. No sizeable communities are found within the basin, however, scattered houses are present.

Kubang Semang and Tuah Abdullah drain are natural watercourse with enough grade and adequate capacity at the present time.

Recommendations for storm-water systems within Basin I consist primarily of improvement of the existing drains including alignment and lining by stones.

B. Drainage Basin II

The basin occupies a part of Mukim 6, 8 ~ 11, 15 and 17 and the total area is 3,793 hectares(9,372 acres). The northern boundary is a watershed between Tuah Abdullah and Rambai drain and the southern and eastern ones are coincide with that of the Project Area. The western border is the watershed of Bukit Tengah Drain (A) as shown in Figure IV-1 . The whole part of area except sub-basin S2-8 is the tributary of Juru river.

The ground level in the east side of the railway ranges from 229 metres(751 ft) to 5.0 metres(16.4 ft) in the west limits of Bukit Mertajam town. Bukit Mertajam is mixture of commercial and densely populated residential area. Existing major drains in the area are Rambai, Ara, Pasir, and Klang Ubi drains which discharge to Juru river. They are natural watercourse in their majority part and piece meal improvement within town limit. These drains have steep grade, which result in sufficient capacity. Thus in the area flooding problem does not come up. Several small housing developments are under way in the vicinity of Bukit Mertajam town and considerable development is further expected in the future.

The west side of the railway is flat and low-lying area tributary to Juru river. Plam and rubber tree plantation and paddy field are predominant.

Elevations are in the range of 1.1 metres(3.6 ft) and 2.9 metres(9.5 ft). Comparing mean high water in the sea level of 1.10 metres(3.6 ft), it is understood that this area is very low. Development is planned in swampy strip enclosed by Juru river in the east and an existing irrigation drain in the west in Mukim 11. Open earth channel of irrigation drainage are existed and ~~served~~ serving as conveyance of paddy field wastewaters in the northern zone.

Recommendations in the area include leaving existing major drains such as Rambai, Ara, Bukit Mertajam, Pasin, Pekan Bharu and Kelang Ubi drains for a time being with minor piecemeal improvement if necessary until the time when they can't accommodate increased stormwater due to development of areas any more.

In sub-basin S2-9, existing major irrigation drain, drain, will be converted to a stormwater drain in the future by diverting paddy field discharges to Juru river in the upstream of the existing drain. For sub-basin S2-10 and S2-11 new outlet drains are proposed respectively, Juru and Bukit Tengah drain. Runoff in sub-basin S2-8 is conduct to the outside of the Project Area and it is recommended that an outlet drain as long as the river nearby be provided when the area is developed.

Recommended new major drains are specified to be trapezoidal earth ones with low velocity resulting in the larger cross section. Network of small roadside drain consists of "U" shaped concrete ditch which will be favorable for maintenance and smaller space than trapezoidal one. In order to shorten the construction time pre-cast ditchs will be preperable.

Land recramation is also recommended in the low-lying and/or swampy areas. The recommended level of landfilling is based on the estimated Juru river during heavy rainstorm with return period of 50 years.

C. Drainage Basin III

The basin covers an area of 3,964 hectares(9,795 acres). Its topographycal feature is low-lying with ground elevation ranging from 2.20 metres(7.2 ft) to 0.11 metres(0.36 ft). The eastern portion is slightly higher compared with that in the western portion which extend along downstream of Prai River and sea shore in which Prai industrial and Seberang Jaya development area are situated. In these two newly developed areas, elaborate drainage system comprising trapezoidal earth open channel of large cross section with low velocity of flow and pumping station has been provided. Because of flatness of the area it is difficult and not warranted to construct steep grade drainage system, thus application of drain type with low velocity resulting in large cross section can not be avoided. The criteria used in two areas are those proposed by DID. Other drain existed is Derhaka river which receives discharges from paddy field extended in the east zone of this basin. Downstream from the boundary of Seberang Jaya development area, Derhaka river has been improved by widening and alignment of the meandering part. Rainstorm in S3-4 and S3-5 area has been discharged into the river. Development are rapid in the form of government project in this basin and these development area provided with previously planned elaborate drainage system. Landfillings in the lowest areas are usual at the time of development.

Recommended storm-water facilities consist of trapezoidal earth open channel and concrete lined roadside drain. Seberang Jaya drain has to be enlarged to have enough capacity for receiving discharges from S3-5 sub-basin. In areas where no major drains are required for removing storm-water because of short distance to the river or sea to which the areas are tributed, only a typical network of road-side small drains is shown(Figure-   ) and construction costs based on the network mentioned above are estimated as is described in Section 3-3-1.

D. Drainage Basin IV

The entire Butterworth town limit is included in this basin. The northern boundary is the southern limit of Butterworth air field at the point existing major drains have their heads. The west border faces to the channel between Penang Island and Province Wellesley and the east to Prai river. This basin is the most urbanized and densely populated throughout the Project Area.

It occupies the whole area of Mukim 14 and 15, with the population of , in 1970 and , in 2000 which is per cent of the whole projected population. Existing surface elevations vary between 3.8 metres (12.5 ft) at the basin's northern extremity and 1.8 metres (5.9 ft) at the southern limit near the ferry port. The ground surface is waved from west to east and in the top portion roads are situated and along the bottom existing drains flow from north to south in parallel each other. The length of those drains are 4.5 Km (2.8 miles) - 6.6 Km (4.1 miles). The shape of individual catchment area of drains is that of narrow and long.

Butterworth drain A, B and C are piece meal improvement and heavily silted. In case of drain B and C, even the routes of streams are not clear at portion of the swampy area to which they are dispersing. In areas along these three drains, small scale housing developments are under way. It was found that in some areas along major drains are consumed by housing plot or wrong alignment or replaced by a smaller section supposedly without weighting discharges from upstream. It seems that the culverts under neath roads have not sufficient capacity, on top of that refuses dumped into drains by residents are accumulated upstream of culverts and cause the clogging resulting in flooding in upstream areas.

Drain D is served as conveyance of storm-waters born in commercial and densely populated residential areas in the vicinity of the ferry port. The drain is inadequate with impaired capacity due to over-built and silting up. Recommended facility in the basin consist of concrete lined cast- in -place open channel of rectangular section, taking into consideration the minimum land acquisition cost which will be influencing factors in urban areas. However, if the circumstance allow, the trapezoidal stone masonry open channel will be used, because of its less construction costs.

The diversion of Butterworth drain A, B and C was weighted together with various routes to the sea, ~~and the alternative in which diversion channels passing through Jalan and Jalan ______ is recommended.~~ Existing roadside drains are in satisfactory condition. The shape of drain is specified to be "U" shape because of its advantage in less space requirement with larger capacity when compared with "V" shape drain used in the area at present.

Drainage Basin V

Basin V, 570 hectares (1408 acres) in extent, is situated in the east of basin IV and lies in exclusively ~~in~~ Mukim 16. Runoff in the area discharges into two sizable irrigation waterways eventually flowing into Prai river. Existing ground elevation is less than 0.9 metres (3 ft) and totally flat. Ground cover in the area is mixed with swamp and plam tree forest.

A housing development plan is now putting forward by a private developer. Inside and around the development area planned, an elaborated drainage system has been designed by the developer and scrutinazed by the municipality. Because a flow rate of the irrigation waterways is not clear, any recommendation for the irrigation waterways is beyond the scope of this project. Consequently only construction costs of a network of smaller roadside drain were estimated and presented in this report.

Drainage Basin VI

In the extremity of northern position of the Project Area, the basin VI is situated and occupies portions of Mukim 7 and 9. The area extend 544 hectares (1,344 acres) excluding the air field portion and the population is , in 1970 and , in year 2000. Ground cover consists of paddy field and palm trees. Only one sizable community is found in the northwestern corner of the basin. Surface elevation is about 4.0 metres (13 ft) with northern portion slightly higher than southern.

Runoff of the area is now discharged together with wastewater from paddy fields by existing Benggali drain going toward south from approximately mid area eventually discharging into Prai river, and Abdul drain flowing from south to north with an outfall to the sea. These two drains take courses along a fringe of the air port zone resulting in cutting stormwater runoff flowing from outside to inside the air port. Thus an improvement of these two drains was recommended as a basis for protecting the air port from flooding and reliefing flooding in the basin VI.

3.2
~~2.2~~ Recommended Facilities

3.2.1
~~2.2.1~~ Main Drains

Plans and ~~profiles~~ sections of the main drains are shown in Figure IV-11 and Table ~~Figure~~ IV-3 . These plans ~~and profiles~~ are based on data contained in available topographical and other maps and on available results of prior topographical surveys.

Flows were estimated on the basis of criteria proposed in section 2.4.1 ~~5.2 and 5.3, Part III.~~

The shape of cross section of main drains has been determined with the principle in which the width of proposed drains will not exceed that of existing channels as much as possible, thus land acquisition costs will be minimum.

In densely populated areas such as Butterworth and Bukit Mertajam areas reinforced concrete rectangular or stone masonry trapezoidal channel ~~has~~ is predeminantly ~~been~~ used.

For remaining areas where developments have not been taken place and there are chances for drainage facilities to be allocated with surfficient space, trapezoidal earth channels have been proposed.

3.2.2
~~2.2.2~~ Network of Smaller Drains

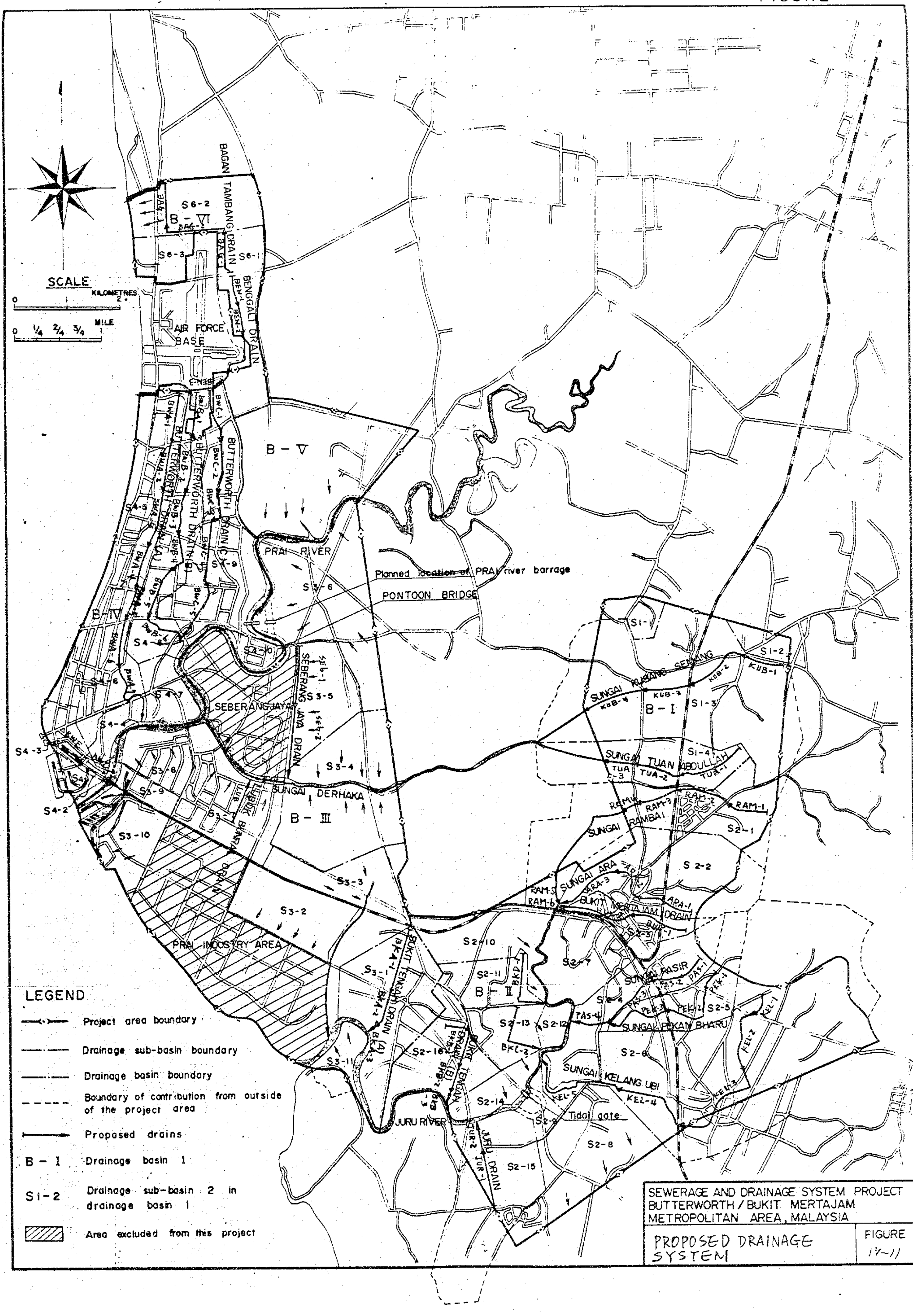
In Figure 未 , the typical network of smaller drains in residential area and industrial area are shown.

Pre-cast "U" shape drains in sizes from 240 x 240 mm to 9,000 x 9,000 mm are used and for larger sizes cast-in-place reinforced concrete rectangular channels are adopted, because of advantages in which valuable real estate will be conserved and maximum development will be permitted. The network of smaller drains shown in Figure is intended to be illustrative and estimate the unit construction cost in terms of \$/ha.

3.2.3 Reservoir

The locations of proposed reservoirs are shown on Figure IV-10 and in more detail on Figure IV-7 . In order to avoid water pollution problem and mosquitos breeding in the proposed reservoir, bypass channels for dry weather flow with stop gates are provided.

FIGURE IV-11



SEWERAGE AND DRAINAGE SYSTEM PROJECT
BUTTERWORTH / BUKIT MERTAJAM
METROPOLITAN AREA, MALAYSIA

PROPOSED DRAINAGE SYSTEM

FIGURE IV-11

Table IV-3 ANALYSIS OF PROPOSED DRAINAGE SYSTEM

YEAR 1976 — YEAR 2000

Line No.	YEAR 1976: Total Area (ha)	Runoff Coefficient	Storage Coefficient	Runoff (m³/s)	YEAR 2000: Total Area (ha)	Runoff Coefficient	Storage Coefficient	Runoff (m³/s)	Details of Proposed Drains to accept runoff: Length (m)	Slope of Sewer (‰)	Velocity (m/s)	Time of Concentration (min)	Capacity (m³/s)	Size (m)	Existing Drain Size (m)	Existing Capacity (m³/s)
KUB-1	181	—	—	—	181		0.93	18.5	1020	2.80	2.2	41.6	18.8	M ⊔ 4.6/3.7 × 2.3	—	—
-2	325	—	—	—	325		0.87	27.1	1230	2.60	2.4	50.1	28.0	M ⊔ 6.0/5.0 × 2.4	—	—
-3	499	—	—	—	499		0.84	37.1	870	2.20	2.4	56.1	38.8	M ⊔ 7.0/5.9 × 2.8	—	—
-4	854		0.73	13.6	854		0.77	45.5	1200	0.12	0.7	84.7	49.1	E ⊔ 22.0/13.2 × 4.4	E ⊔ 10.0 × 1.3	12.1
TUA-1	85	—	—	—	85		0.84	7.5	1360	3.50	1.9	31.9	7.6	M ⊔ 2.9/2.2 × 1.7	—	—
-2	153	—	—	—	153		0.80	11.9	940	2.80	2.0	39.7	12.9	M ⊔ 4.0/3.2 × 2.0	—	—
-3	206		0.77	4.2	206		0.76	13.2	660	0.20	0.7	55.4	14.8	E ⊔ 11.0/4.4 × 3.3	E ⊔ 3.2/3.0 × 1.1	2.8
RAM-1	95	—	—	—	95		0.88	11.3	780	0.80	1.8	27.9	11.4	R ⊔ 3.0 × 2.4	—	—
-2	215	—	—	—	215		0.80	21.2	990	0.70	1.4	39.7	21.9	M ⊔ 7.0/5.9 × 2.8	—	—
-3	258	—	—	—	258		0.77	21.4	860	0.70	1.4	49.9	21.9	M ⊔ 7.0/5.9 × 2.8	—	—
-4	300		0.77	15.3	300		0.75	22.0	330	0.14	0.6	59.1	22.7	E ⊔ 16.0/9.6 × 3.2	E ⊔ 1.3 × 1.2	1.0
-5	552		0.72	15.3	552		0.70	22.0	660	0.14	0.6	126.0	22.7	E ⊔ 16.0/9.6 × 3.2	E ⊔ 5.2 × 1.7	10.0
-6	1000	-	0.72	30.4	1000		0.70	38.1	70	0.14	0.7	127.7	41.1	E ⊔ 20.0/12.0 × 4.0	E ⊔ 5.9 × 1.8	12.4
ARA-1	78	—	—	—	78		0.87	8.8	970	2.00	2.3	28.3	9.2	R ⊔ 2.1 × 2.1	—	—
-2	128		0.82	8.0	128		0.83	14.8	830	1.70	2.6	33.6	15.1	R ⊔ 2.2 × 3.0	E ⊔ 2.3 × 1.4	4.2
-3	448		0.77	22.2	448		0.78	39.6	1220	0.90	1.8	44.9	41.7	M ⊔ 8.5/7.1 × 3.4	E ⊔ 2.3 × 1.4	4.2
BUK-1	44	—	—	—	44		0.87	5.2	1090	7.50	2.4	28.4	5.4	M ⊔ 2.4/1.9 × 1.2	—	—
-2	120		0.84	9.1	120		0.81	16.4	1390	4.00	2.5	37.7	17.6	M ⊔ 4.2/3.4 × 2.1	R ⊔ 4.8/2.2 × 1.2	12.5
PAS-1	64	—	—	—	64		0.90	8.6	660	2.00	2.3	25.9	8.9	R ⊔ 2.3 × 1.8	—	—
-2	106		0.83	8.5	106		0.85	12.2	660	1.50	2.4	30.5	15.6	R ⊔ 3.0 × 2.4	E ⊔ 3.8/3.1 × 1.7	5.1
-3	186		0.77	9.2	186		0.79	76.9	980	1.00	1.5	41.4	17.4	M ⊔ 6.0/5.0 × 2.4	E ⊔ 6.6 × 1.7	10.0
-4	503		0.72	15.0	503		0.74	31.5	780	0.16	0.7	70.2	33.2	E ⊔ 18.0/10.8 × 3.6	E ⊔ 9.0 × 1.5	7.4
PEK-1	71	—	—	—	71		0.92	9.8	410	2.00	2.4	24.7	9.9	R ⊔ 2.4 × 1.9	—	—
-2	157		0.79	9.3	157		0.81	14.6	1260	1.40	1.6	37.8	16.3	M ⊔ 5.5/4.6 × 2.2	E ⊔ 3.1 × 1.2	3.4
-3	210		0.74	8.2	210		0.77	15.8	1320	1.40	1.6	51.6	16.3	M ⊔ 5.5/4.6 × 2.2	E ⊔ 5.9 × 1.2	6.4
KEL-1	88	—	—	—	88		0.88	11.0	590	1.60	1.6	27.6	11.1	M ⊔ 4.2/3.4 × 2.1	—	—
-2	167	—	—	—	167		0.79	14.3	1530	1.50	1.7	42.6	15.4	M ⊔ 4.8/3.8 × 2.4	—	—
-3	515		0.75	24.6	515		0.75	36.1	1920	1.00	1.8	60.4	37.4	M ⊔ 8.0/6.7 × 3.2	E ⊔ 4.5 × 0.9	7.7
-4	1097		0.73	37.9	1097		0.72	51.4	1550	0.11	0.7	99.3	52.9	E ⊔ 23.0/13.8 × 4.6	E ⊔ 6.0 × 1.6	11.9
-5	1345		0.70	31.6	1345		0.70	51.4	2050	0.11	0.7	146.1	52.9	E ⊔ 23.0/13.8 × 4.6	E ⊔ 7.5 × 2.7	13.6
BKD	132		0.70	2.8	132		0.71	9.7	1300	0.10	0.5	53.3	11.0	E ⊔ 13.0/7.8 × 2.6	E ⊔ 8.0/3.0 × 2.5	4.6
BKC	113		0.70	1.7	113		0.70	7.6	1360	0.10	0.4	66.7	8.1	E ⊔ 10.0/4.0 × 3.0	E ⊔ 8.0/3.0 × 2.5	4.6
BKB-1	50	—	—	—	50		0.71	3.3	1230	0.10	0.4	61.3	3.8	E ⊔ 7.5/3.0 × 2.3	—	—
-2	169	—	—	—	169		0.69	12.7	820	0.10	0.5	88.6	13.4	E ⊔ 14.0/8.4 × 2.8	—	—
-3	224	—	—	—	224		0.69	17.3	50	0.10	0.5	90.3	19.2	E ⊔ 16.0/9.6 × 3.2	—	—
JUR-1	331	—	—	—	331		0.88	7.5	1030	0.10	0.4	153.8	8.1	E ⊔ 10.0/4.0 × 3.0	—	—
-2	439	—	—	—	439		0.84	11.4	660	0.10	0.5	175.8	13.4	E ⊔ 14.0/8.4 × 2.8	—	—

LEGEND

E: Earth Drain

M: Masonry Drain

R: Reinforced Concrete Drain

⊔: Open Channel

Table IV-3 ANALYSIS OF PROPOSED DRAINAGE SYSTEM

continued

Line No.	YEAR 1976 Total Area (ha)	Runoff Coefficient	Storage Coefficient	Runoff (m^3/s)	YEAR 2000 Total Area (ha)	Runoff Coefficient	Storage Coefficient	Runoff (m^3/s)	Details of Proposed Drains to accept runoff: Length (m)	Slope of Sewer (‰)	Velocity (m/s)	Time of Concentration (min)	Capacity (m^3/s)	Size (m)	Existing Drain Size (m)	Existing Capacity (m^3/s)
BKA-1	58	—	—	—	58		0.71	3.3	1230	0.10	0.4	61.3	3.8	E 7.9 / ⊔ 3.0 × 2.3	—	—
-2	275	—	—	—	275		0.70	12.7	820	0.10	0.5	88.6	13.4	E 14.0 / ⊔ 8.4 × 2.8	—	—
-3	381	—	—	—	381		0.70	17.3	50	0.10	0.5	90.3	19.2	E 16.0 / ⊔ 9.6 × 3.2	—	—
SEB-1	107		0.71	1.8	107		0.71	6.2	1150	0.10	0.4	57.9	7.1	E 9.5 / ⊔ 3.8 × 2.9	E 10.4 / ⊔ 5.0 × 2.3	6.3
-2	216		0.69	2.5	216		0.69	10.4	1310	0.10	0.4	101.6	11.0	E 13.0 / ⊔ 7.8 × 2.6	E 10.4 / ⊔ 5.0 × 2.3	6.3
LUB	220		0.75	11.2	220		0.78	32.0	960	0.50	1.3	22.3	32.9	M 10.0 / ⊔ 8.8 × 3.0	E 10.0 / ⊔ 6.0 × 1.8	11.2
BWA-1	70	—	—	—	70		0.73	5.0	1180	0.10	0.7	38.1	6.1	R ⊔ 3.5 × 2.8	—	—
-2	108		0.69	2.5	108		0.71	8.2	910	0.10	0.8	57.1	8.7	R ⊔ 4.6 × 3.2	E 2.3 / ⊔ 1.1 × 1.3	1.2
-3	152		0.68	2.4	152		0.70	10.9	1040	0.10	0.8	78.8	11.9	R ⊔ 4.5 × 3.6	E 2.3 / ⊔ 1.1 × 1.3	1.2
-4	188		0.68	3.0	188		0.69	12.7	870	0.10	0.9	94.9	15.7	R ⊔ 5.0 × 4.0	E 3.5 / ⊔ 2.0 × 1.6	0.8
-5	226		0.68	3.7	226		0.69	14.7	620	0.10	0.9	106.4	15.7	R ⊔ 5.0 × 4.0	E 5.5 / ⊔ 4.0 × 1.9	2.1
-6	277		0.68	4.7	277		0.69	17.0	830	0.10	0.9	121.8	20.3	R ⊔ 5.5 × 4.4	M 7.5 / ⊔ 5.5 × 0.9	1.3
-7	400		0.68	6.4	400		0.69	23.2	1250	0.10	1.0	142.6	24.0	R ⊔ 6.2 × 4.4	E 10.5 / ⊔ 7.0 × 1.5	3.4
BWB-1	31	—	—	—	31		0.73	2.3	960	0.10	0.6	36.7	2.5	R ⊔ 2.5 × 2.0	—	—
-2	80	—	—	—	80		0.71	6.0	970	0.10	0.7	59.8	6.1	R ⊔ 3.5 × 2.8	—	—
-3	135	—	—	—	135		0.70	9.8	800	0.08	0.7	78.9	10.6	R ⊔ 4.5 × 3.6	—	—
-4	178	—	—	—	178		0.69	9.4	920	0.08	0.7	100.8	10.6	R ⊔ 4.5 × 3.6	—	—
-5	214	—	—	—	214		0.69	6.0	870	0.08	0.8	118.9	12.0	R ⊔ 4.6 × 3.7	—	—
-6	238	—	—	—	238		0.68	6.0	930	0.08	0.8	138.3	12.6	R ⊔ 4.7 × 3.8	—	—
-7	279	—	—	—	279		0.68	11.0	220	0.08	1.0	142.0	31.7	R ⊔ 7.8 × 4.7	—	—
BWC-1	59	—	—	—	59		0.74	4.3	1080	0.12	0.7	35.7	4.4	R ⊔ 3.0 × 2.4	—	—
-2	117	—	—	—	117		0.71	7.0	880	0.10	0.8	54.0	8.7	R ⊔ 4.0 × 3.0	—	—
-3	162	—	—	—	162		0.70	8.4	780	0.10	0.8	70.3	8.7	R ⊔ 4.0 × 3.2	—	—
-4	313	—	—	—	313		0.69	12.1	1180	0.08	0.8	98.4	12.6	R ⊔ 4.7 × 3.8	—	—
-5	437	—	—	—	437		0.69	17.8	1020	0.08	0.8	119.7	18.1	R ⊔ 5.5 × 4.4	—	—
BWD	8		0.72	0.5	8		0.77	1.1	430	0.10	0.5	24.3	1.2	R ⊔ 2.2 × 1.3	E 3.3 / ⊔ 1.5 × 0.6	0.3
BWE	75	—	—	—	75		0.76	10.9	870	0.10	0.8	28.1	11.9	R ⊔ 4.5 × 3.6	—	—
BEN-1	90	—	—	—	90		0.71	5.5	1030	0.10	0.4	51.2	6.1	E 9.0 / ⊔ 3.6 × 2.7	—	—
-2	225	—	—	—	225		0.69	5.5	1040	0.10	0.4	92.8	6.1	E 9.0 / ⊔ 3.6 × 2.7	—	—
-3	253	—	—	—	253		0.68	7.7	2170	0.06	0.4	146.2	8.6	M 9.0 / ⊔ 7.9 × 2.7	—	—
BAG-1	83	—	—	—	83		0.72	5.4	850	0.10	0.4	45.4	6.1	E 9.0 / ⊔ 3.6 × 2.7	—	—
-2	121	—	—	—	121		0.69	5.7	1130	0.10	0.4	92.5	6.1	E 9.0 / ⊔ 3.6 × 2.7	—	—
-3	380	—	—	—	380		0.68	11.3	1300	0.10	0.5	135.8	13.4	E 14.0 / ⊔ 8.4 × 2.8	—	—

LEGEND

E: Earth Drain
M: Masonry Drain
R: Reinforced Concrete Drain
⊔: Open Channel

3.3 Construction and Maintenance Costs

3.3.1 Construction Costs

A. Main Drains

i. Unit Cost

The unit cost estimates used in preparing the drainage programme and presented herein are based on the known units costs of labour, materials, power, equipment and transportation, as applicable in Penang in 1976. As is described in Section 2-4-2, ~~three~~ four types of open channles were recommended for this Project. For individual type of drains cost curve was developed for the construction of channel and reservoir, taking into account the known or estimated costs of excavation, sheeting, shoring, dewatering, reinforcing, forming, concrete spreading and restoration of paving. They do not include unusual soil and dewatering problems or any other extra costs. The standard section for trenching is shown in Figure IV-12. In Figure IV-13, developed curves of unit cost are presented.

ii. Construction Costs of System

Construction costs of main drains have been estimated on the basis of designed cross section and unit construction cost mentioned in previous section. The construction costs shown in Table IV-4, consist of direct labour and material costs, overheads of 20 percent of the direct cost, contingencies of 20 percent and 10 percent engineering fee. Land acquisition costs include that for maintenance roads as shown in Figure IV-14. In Butterworth area it was compared to other areas, consequently in this area average of 2.0 metres were allocated for maintenance roads. Because the sites through which main drains flow are apart from existing roads in their majority cases, the construction work would be accompanied by various difficult conditions and or extra costs, therefore, 20 % contingencies were estimated as described previously

B. Network of Smaller Drains

i. Unit Costs

Unit construction cost of network of smaller drains was estimated on the basis of street plan in the housing development area and industrial area. These are shown in Fig and 今 . The required size of individual road-side drain was calculated and construction costs were estimated depending on cost curves shown in Figure IV-13. It was considered that the commercial and densely populated residential area would be the same character in terms of layout of smaller drains. The costs of industrial area has been estimated, too. It was considered the costs in sparsely inhabited residential areas with population density of 53 persons per hectare could be approximated by the following equation.

$$Cs = \frac{53}{120} \times Cd$$

where

Cs = construction costs in sparsely inhabited residential area with population density 53 person/ha.

Cd = construction cost in densely inhabited residential area with population density 120 persons/ha

* Calculated unit construction costs are summerized as follows:

Residential area	
densely populated	32,400 $/hr
sparsely populated	14,300 "
Commercial area	32,400 "
Industrial area	30,000 "

Table IV-4, gives construction costs of the network of smaller drains together with other facilities in individual drainage basin.

C. Reservoir

The construction of reservoirs were considered in Butterworth area with construction costs of reservoir itself, a bypass channel and gates in inlet and outlet points. In Table IV-4, costs required to reservoir is shown.

3.3.2 Maintenance Costs

Maintenance work for drains consists mainly of removing of deposits from drains and carving those wastes from the sites to assigned dumping places. Repairing of broken parts of channels are also included in the maintenance work. For the purpose of estimating maintenance cost, it was assumed that the cost for removing deposits from drains is the same as that of excavation. From main drains machine excavation will be applied and for smaller ones had excavation. For the carving costs of removed materials from the site to planned dumping places, the costs of desposing of excess soil is applied.

On the basis of assumptions above, the unit cost for maintenance is estimated to be $5/$m^3$. The average volume of deposits in drains is estimated roughly on the assumption which the depth of accumulation of silt to be removed would be 10 % of the structure hight. The representative dimension of the average cross section area proposed as main drains, is 5.0 x 4.0 metres. The deposit volume, therefore, is 5.0 x 0.4 = 2.0 cum per one meter of drains.

The unit maintenance cost for smaller drains is expressed as dollars per one hectare. The representative dimension of smaller drain is 1.2 x 0.96 metres with the average volume of deposits of 0.12 cu m per unit length.

It is estimated that the drain length per one hectare in densely populated residential area is about 155 metres. The volume of deposits to be removed is 0.12 x 155 = 18.6 cu m. It is summarized as follows:

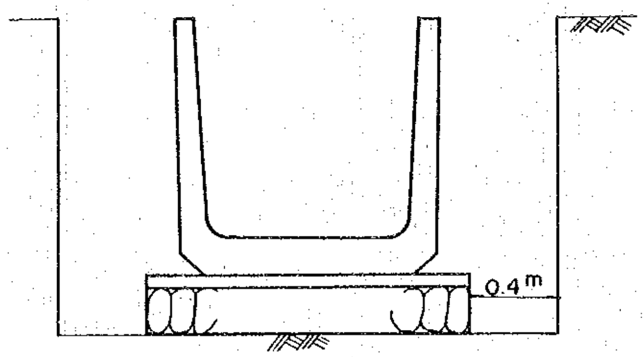
Maintenance costs of main drains	:	10 $/m
Maintenance costs of network of smaller drains	:	95 $/ha

TABLE IV-4 Construction Cost of Drainage Basins at 1976 Price Level

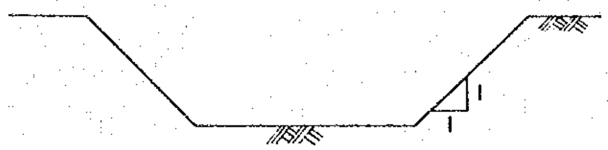
(1000 M$)

Description	Basin I	Basin II	Basin III	Basin IV	Basin V	Basin VI	Total	Remarks
a. Main Drains	5,814	27,214	3,088	38,367	-	6,194	80,677	
b. Network of Smaller Drains	14,112	52,653	44,153	30,186	6,869	7,559	155,532	
c. Reservoir	-	-	-	464	-	-	464	
d. Land Acquisition	65	1,205	231	1,824	-	1,318	4,643	
(A) Sub Total	19,991	81,072	47,472	70,841	6,869	15,071	241,316	
(B) Contingency	3,998	16,216	9,493	14,170	1,374	3,014	48,265	(A)x0.20
(C) Engineering Fee								
Disign	1,199	4,865	2,847	4,251	412	904	14,478	(A+B)x0.05
Supervision	1,200	4,864	2,848	4,250	412	904	14,478	(A+B)x0.05
Total	26,388	107,017	62,660	93,512	9,067	19,893	318,537	

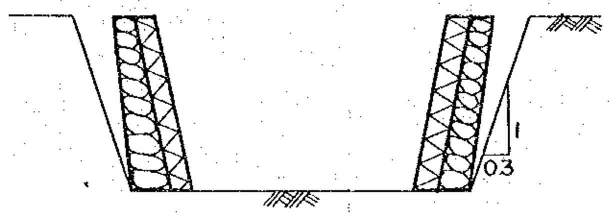
"U" Shape concrete drain



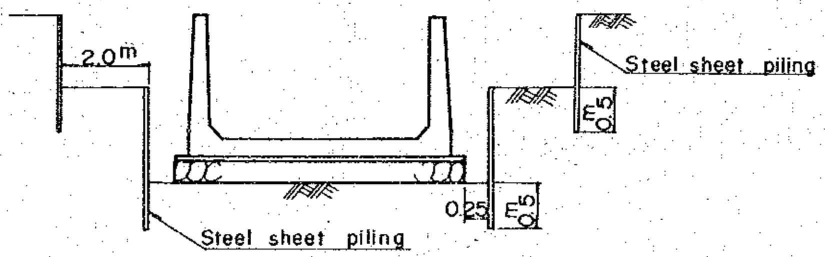
Earth drain



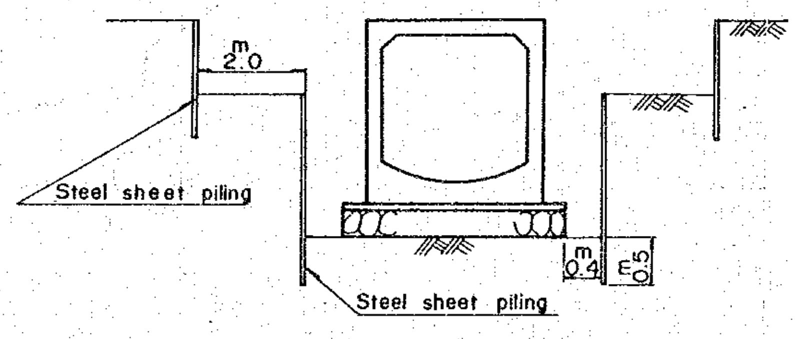
Wet masonry drain



Rectangular reinforced concrete drain

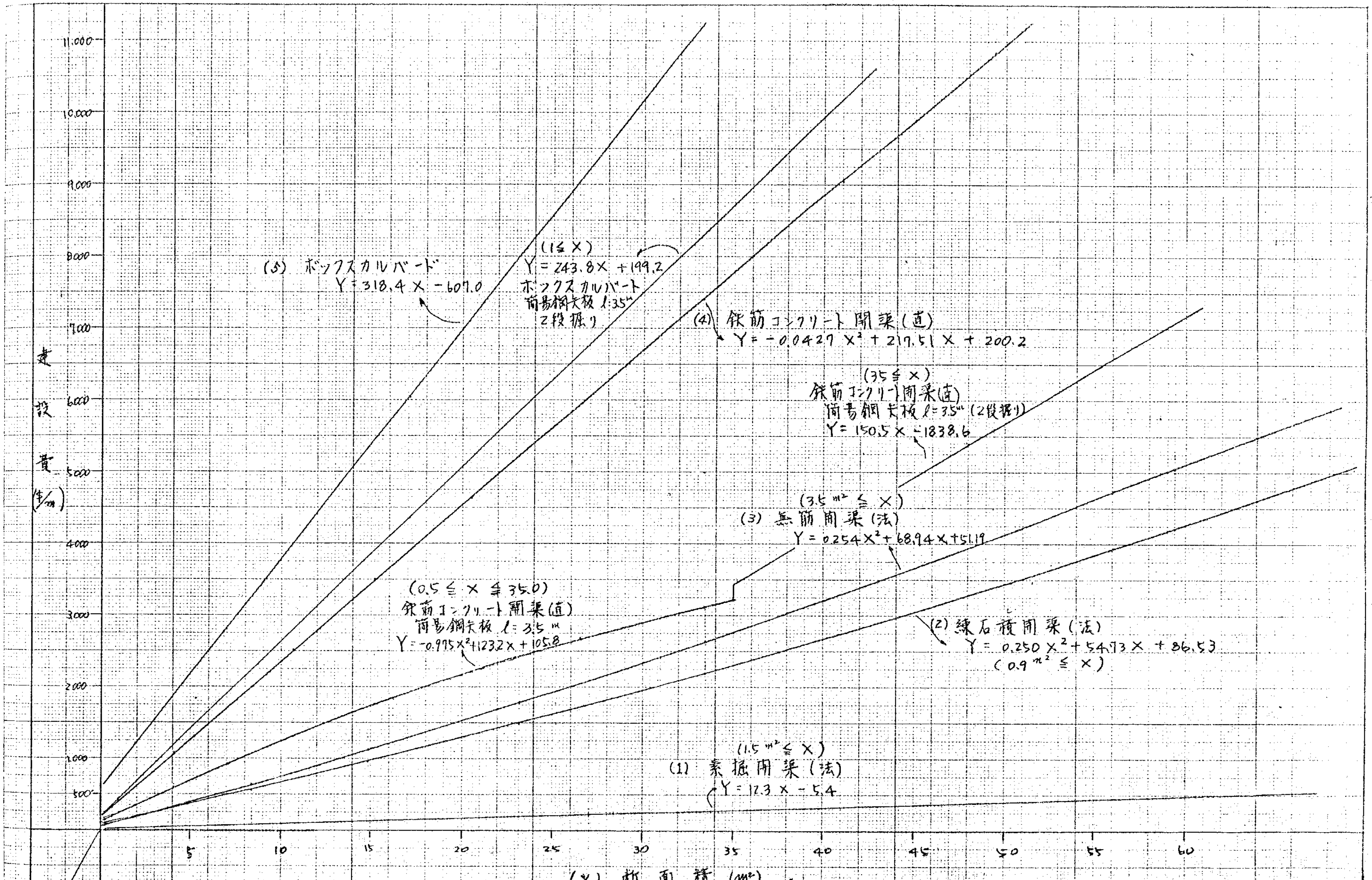


Reinforced concrete box culvert



SEWERAGE AND DRAINAGE SYSTEM PROJECT BUTTERWORTH / BUKIT MERTAJAM METROPOLITAN AREA, MALAYSIA

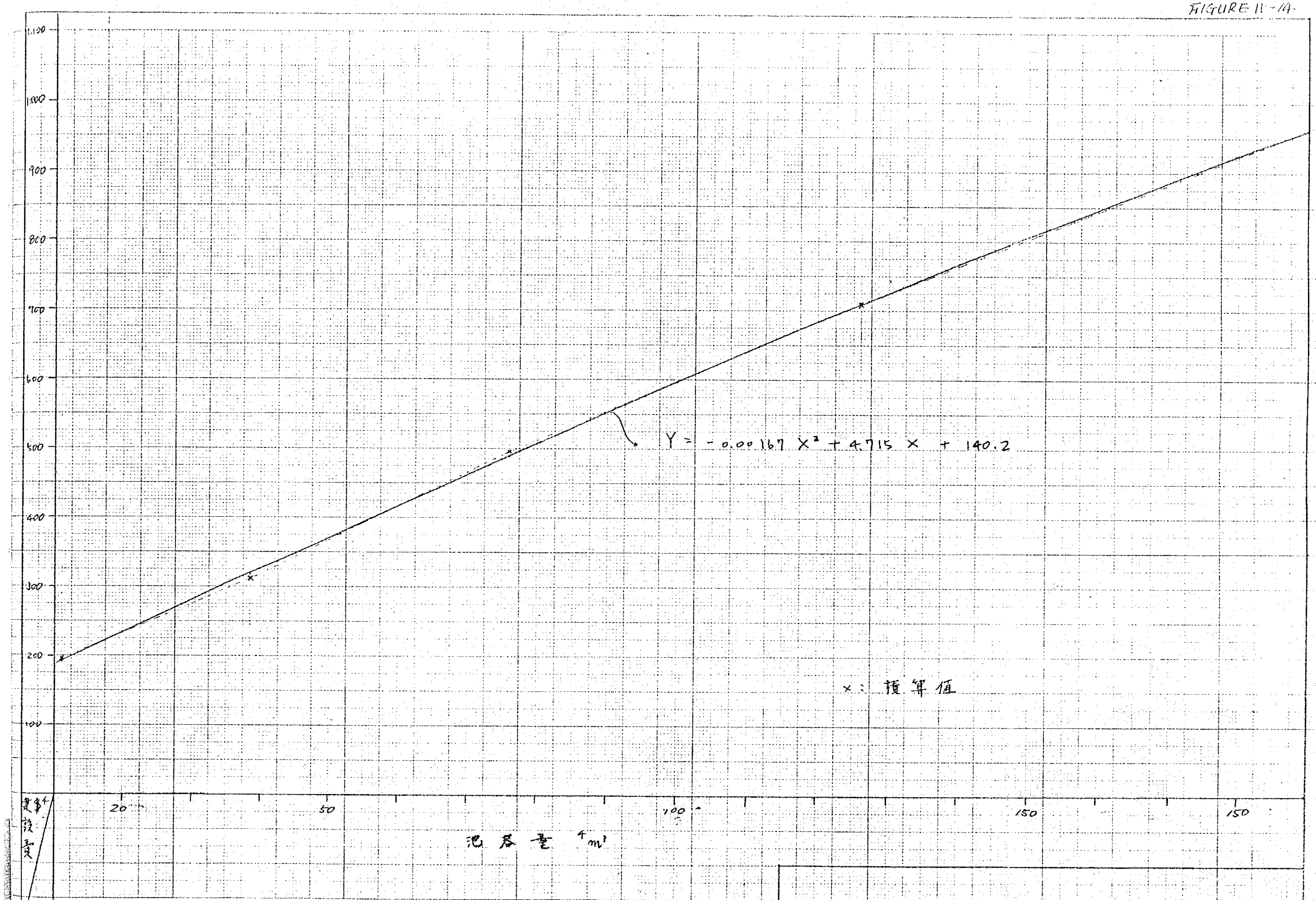
FIGURE



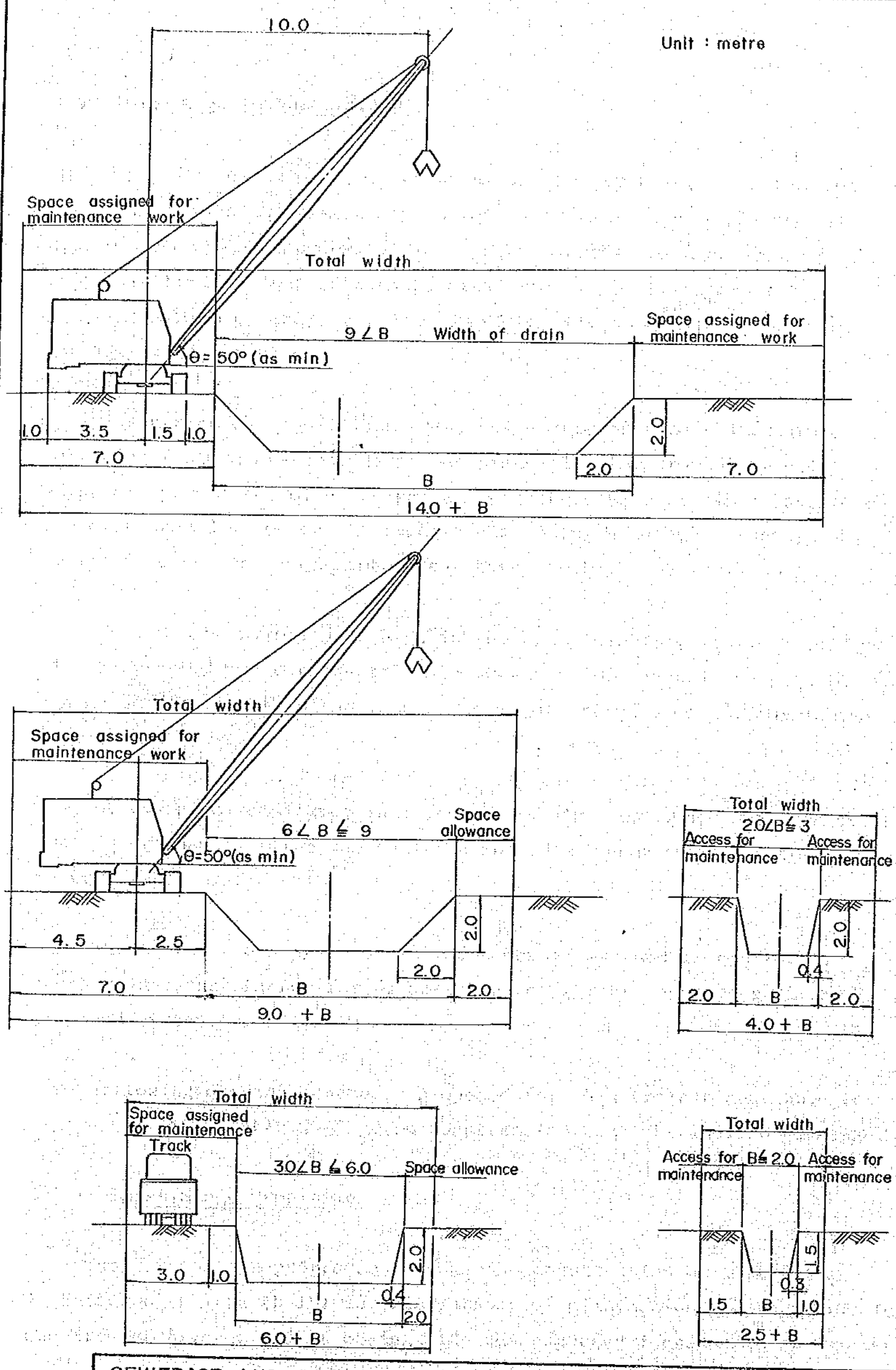
SEWARAGE AND DRAINAGE SYSTEM PROJECT, BUTTERWORTHY
BUKIT MERTAJAM METROPOLITAN AREA, MALAYSIA

開渠建設費

FIGURE IV-13



調整池建設費 FIGURE IV-14



SEWERAGE AND DRAINAGE SYSTEM PROJECT BUTTERWORTH / BUKIT MERTAJAM METROPOLITAN AREA, MACAYSIA

STANDARD SECTION FOR MAINTENANCE ACCESS	FIGURE IV-15