ANNEX

COMPUTATION FOR DESIGN OF SANITARY SEWERS

COMPUTATION FOR DESIGN OF SANITARY SEWERS

Butterworth Zone - 1

Line No.	Sewer Length (m)	Area		Ave. Daily Flow			Peak Flow Total (cum/s)	Design of Sewer				Sewer Invert Elevation		Elevation Grand Surface		Earth Covering		Remark
		Increment (ha)	Total (ha)	Domestic (cum/d)	Industrial (cum/d)	Extraneous (cum/d)		Diam (mm)	Slope of Sewer (o/oo)	Velocity Full (m/s)	Capacity Full (cum/s)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	
BW 1-1	440	9.0		330	-	110	0.019	⌀225	3.0	0.52	0.025							
BW 1-2	210	10.0	19.0	700	-	230	0.038	⌀300	2.4	0.67	0.047							
BW 1-3	640	46.0	65.0	2390	-	780	0.109	⌀450	1.8	0.76	0.121							
BW 1-4	690	35.0	100.0	3680	-	1200	0.159	⌀525	1.5	0.77	0.167							
BW 1-5	1350	220.0	320.0	10450	1600	3700	0.451	⌀900	0.9	0.85	0.543							
	To Treatment Plant																	

COMPUTATION FOR DESIGN OF SANITARY SEWERS

Butterworth Zone - 2

Line No.	Sewer Length (m)	Area		Ave. Daily Flow			Peak Flow Total (cum/s)	Design of Sewer				Sewer Invert Elevation		Elevation Grand Surface		Earth Covering		Remark
		Incre-ment (ha)	Total (ha)	Domes-tic (cum/d)	Indus-trial (cum/d)	Extra-neous (cum/d)		Diam (mm)	Slope of Sewer (o/oo)	Velo-city Full (m/s)	Capa-city Full (cum/s)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	
BW 2-1	380	15.0		410	-	180	0.024	⌀225	3.0	0.62	0.025							
BW 2-2	390	8.0	23.0	640	-	280	0.035	⌀300	2.4	0.67	0.047							
BW 2-3	200	43.0	66.0	1820	-	790	0.087	⌀450	1.8	0.76	0.121							
BW 2-4	550	40.0	106.0	2930	-	1270	0.134	⌀525	1.5	0.77	0.167							
BW 2-5	440	76.0	182.0	5020	-	2190	0.211	⌀600	1.3	0.78	0.221							
	To Butterworth Zone -3																	

COMPUTATION FOR DESIGN OF SANITARY SEWERS

Butterworth Zone - 3

Line No.	Sewer Length (m)	Area		Ave. Daily Flow			Peak Flow Total (cum/s)	Design of Sewer				Sewer Invert Elevation		Elevation Grand Surface		Earth Covering		Remark
		Increment (ha)	Total (ha)	Domestic (cum/d)	Industrial (cum/d)	Extraneous (cum/d)		Diam (mm)	Slope of Sewer (o/oo)	Velocity Full (m/s)	Capacity Full (cum/s)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	
BW 3-1	250	12.0	194.0	5020	960	2250	0.234	ø675	1.3	0.85	0.303							Inflow from BW-2
BW 3-2	350	37.0	231.0	5430	2720	2540	0.293	ø675	1.3	0.85	0.303							
BW 3-3	280	39.0	270.0	6130	3600	2880	0.336	ø750	1.2	0.87	0.386							
BW 3-4	370	200.0	470.0	11650	3600	5320	0.536	ø900	1.0	0.90	0.572							
BW 3-5	250	169.0	639.0	13540	8560	6630	0.714	ø1050	0.9	0.95	0.819							
	To Treatment Plant																	

COMPUTATION FOR DESIGN OF SANITARY SEWERS

Butterworth Zone - 4

Line No.	Sewer Length (m)	Area		Ave. Daily Flow			Peak Flow Total (cum/s)	Design of Sewer				Sewer Invert Elevation		Elevation Grand Surface		Earth Covering		Remark
		Increment (ha)	Total (ha)	Domestic (cum/d)	Industrial (cum/d)	Extraneous (cum/d)		Diam (mm)	Slope of Sewer (o/oo)	Velocity Full (m/s)	Capacity Full (cum/s)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	
BW 4-1	250	12.0		330	–	140	0.020	ø225	3.0	0.62	0.025							
BW 4-2	900	49.0	61.0	1680	–	730	0.082	ø375	2.2	0.75	0.082							
BW 4-3	450	49.0	110.0	3040	–	1320	0.138	ø525	1.5	0.77	0.167							
BW 4-4	500	70.0	180.0	4950	–	2160	0.209	ø600	1.3	0.78	0.221							
BW 4-5	700	90.0	270.0	6550	–	3010	0.270	ø675	1.2	0.81	0.291							
BW 4-6	1550	174.0	444.0	8630	–	4400	0.351	ø750	1.1	0.84	0.369							
	To Treatment Plant																	

COMPUTATION FOR DESIGN OF SANITARY SEWERS

Butterworth Zone - 5

Line No.	Sewer Length (m)	Area		Ave. Daily Flow			Peak Flow Total (cum/s)	Design of Sewer				Sewer Invert Elevation		Elevation Grand Surface		Earth Covering		Remark
		Increment (ha)	Total (ha)	Domestic (cum/d)	Industrial (cum/d)	Extraneous (cum/d)		Diam (mm)	Slope of Sewer (o/oo)	Velocity Full (m/s)	Capacity Full (cum/s)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	
BW 5-1	1000	36.0		430	–	290	0.026	ø225	3.5	0.67	0.027							
BW 5-2	700	29.0	65.0	860	–	540	0.047	ø300	2.5	0.68	0.048							
BW 5-3	500	15.0	80.0	1270	–	720	0.065	ø375	2.2	0.75	0.082							
BW 5-4	500	40.0	120.0	2380	–	1200	0.112	ø450	1.8	0.76	0.121							
BW 5-5	500	154.0	274.0	4440	–	2450	0.196	ø600	1.3	0.78	0.221							
BW 5-6	10	277.0	551.0	7750	–	4700	0.324	ø750	1.1	0.84	0.369							
	To Treatment Plant																	

COMPUTATION FOR DESIGN OF SANITARY SEWERS

Butterworth Zone - 6

Line No.	Sewer Length (m)	Area		Ave. Daily Flow			Peak Flow Total (cum/s)	Design of Sewer				Sewer Invert Elevation		Elevation Grand Surface		Earth Covering		Remark
		Increment (ha)	Total (ha)	Domestic (cum/d)	Industrial (cum/d)	Extraneous (cum/d)		Diam (mm)	Slope of Sewer (o/oo)	Velocity Full (m/s)	Capacity Full (cum/s)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	
BW 6-1	500	30.0		380	-	240	0.023	ø225	3.0	0.62	0.025							
BW 6-2	550	40.0	70.0	890	-	560	0.048	ø300	2.5	0.68	0.048							
BW 6-3	450	91.0	161.0	2480	-	1430	0.120	ø450	1.8	0.76	0.121							
BW 6-4	1500	82.0	243.0	3480	-	2090	0.161	ø525	1.5	0.77	0.167							
BW 6-5	850	42.0	285.0	3980	-	2420	0.180	ø600	1.3	0.78	0.221							
Ⓟ	Pumping Station			3980	-	2420	0.180											
BW 6-6	2550	220.0	505.0	6620	-	4180	0.286	ø675	1.2	0.81	0.291							
BW 6-7	2450	165.0	670.0	8590	-	5510	0.363	ø750	1.1	0.84	0.369							
	To Treatment Plant																	

COMPUTATION FOR DESIGN OF SANITARY SEWERS

Seberang Jaya Zone - 1

Line No.	Sewer Length (m)	Area		Ave. Daily Flow			Peak Flow Total (cum/s)	Design of Sewer				Sewer Invert Elevation		Elevation Grand Surface		Earth Covering		Remark
		Increment (ha)	Total (ha)	Domestic (cum/d)	Industrial (cum/d)	Extraneous (cum/d)		Diam (mm)	Slope of Sewer (o/oo)	Velocity Full (m/s)	Capacity Full (cum/s)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	
SJ 1-1	400	14.0		170	–	110	0.011	⌀225	3.0	0.62	0.025							
SJ 1-2	250	25.0	39.0	610	–	240	0.034	⌀300	2.4	0.67	0.047							
SJ 1-3	505	27.0	66.0	1200	–	630	0.061	⌀375	2.2	0.75	0.082							
SJ 1-4	750	65.0	131.0	2880	–	1380	0.133	⌀525	1.5	0.77	0.167							
SJ 1-5	400	121.0	252.0	5930	–	2760	0.245	⌀675	1.2	0.81	0.291							
SJ 1-6	500	186.0	438.0	10750	160	4920	0.422	⌀900	0.9	0.85	0.543							
	To Treatment Plant																	

COMPUTATION FOR DESIGN OF SANITARY SEWERS

SeberangJaya Zone - 2

Line No.	Sewer Length (m)	Area		Ave. Daily Flow			Peak Flow Total (cum/s)	Design of Sewer				Sewer Invert Elevation		Elevation Grand Surface		Earth Covering		Remark
		Incre- ment (ha)	Total (ha)	Domes- tic (cum/d)	Indus- trial (cum/d)	Extra- neous (cum/d)		Diam (mm)	Slope of Sewer (o/oo)	Velo- city Full (m/s)	Capa- city Full (cum/s)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	
SJ 2-1	400	14.0		100	480	90	0.019	0225	3.0	0.62	0.025							
SJ 2-2	200	28.0	42.0	250	1680	270	0.056	0375	2.2	0.75	0.082							
SJ 2-3	450	37.0	79.0	450	3520	510	0.110	0450	1.8	0.76	0.121							
SJ 2-4	450	36.0	115.0	1260	3840	890	0.155	0525	1.5	0.77	0.167							
SJ 2-5	700	116.0	231.0	4250	4000	2230	0.279	0675	1.2	0.81	0.291							
SJ 2-6	1100	74.0	305.0	5790	4000	3120	0.355	0750	1.1	0.84	0.369							
	To Treatment Plant (at SeberangJaya Zone-4)																	

COMPUTATION FOR DESIGN OF SANITARY SEWERS

Seberang Jaya Zone - 3

Line No.	Sewer Length (m)	Area		Ave. Daily Flow			Peak Flow Total (cum/s)	Design of Sewer				Sewer Invert Elevation		Elevation Grand Surface		Earth Covering		Remark
		Increment (ha)	Total (ha)	Domestic (cum/d)	Industrial (cum/d)	Extraneous (cum/d)		Diam (mm)	Slope of Sewer (o/oo)	Velocity Full (m/s)	Capacity Full (cum/s)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	
SJ 3-1	900	34.0		410	-	270	0.025	ø225	3.0	0.62	0.025							
SJ 3-2	600	48.0	82.0	980	-	660	0.054	ø375	2.2	0.75	0.082							
SJ 3-3	1400	133.0	215.0	2580	-	1720	0.124	ø450	1.9	0.78	0.124							
SJ 3-4	1200	62.0	277.0	3320	-	2220	0.157	ø525	1.6	0.80	0.172							
SJ 3-5	50	233.0	510.0	6110	-	4080	0.267	ø675	1.2	0.81	0.291							
	To Treatment Plant																	

COMPUTATION FOR DESIGN OF SANITARY SEWERS

Seberang Jaya Zone - 4

Line No.	Sewer Length (m)	Area		Ave. Daily Flow			Peak Flow Total (cum/s)	Design of Sewer				Sewer Invert Elevation		Elevation Grand " Surface		Earth Covering		Remark
		Increment (ha)	Total (ha)	Domestic (cum/d)	Industrial (cum/d)	Extraneous (cum/d)		Diam (mm)	Slope of Sewer (o/oo)	Velocity Full (m/s)	Capacity Full (cum/s)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	
SJ 4-1	250	33.0		400	-	260	0.024	⊙225	3.0	0.62	0.025							
SJ 4-2	1200	70.0	103.0	1240	-	820	0.066	⊙375	2.2	0.75	0.082							
SJ 4-3	1050	155.0	258.0	3100	-	2060	0.146	⊙525	1.5	0.77	0.167							
SJ 4-4	1050	85.0	343.0	4580	-	2860	0.208	⊙600	1.3	0.78	0.221							
SJ 4-5	50	87.0	430.0	4790	-	3560	0.249	⊙675	1.2	0.81	0.291							
	To Treatment Plant																	

COMPUTATION FOR DESIGN OF SANITARY SEWERS

Seberang Jaya Zone - 5

Line No.	Sewer Length (m)	Area		Ave. Daily Flow			Peak Flow Total (cum/s)	Design of Sewer				Sewer Invert Elevation		Elevation Grand Surface		Earth Covering		Remark
		Increment (ha)	Total (ha)	Domestic (cum/d)	Industrial (cum/d)	Extraneous (cum/d)		Diam (mm)	Slope of Sewer (o/oo)	Velocity Full (m/s)	Capacity Full (cum/s)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	
SJ 5-1	800	35.0		420	—	280	0.025	ø225	3.0	0.62	0.025							
SJ 5-2	600	35.0	70.0	840	—	560	0.047	ø300	2.4	0.67	0.047							
SJ 5-3	550	80.0	150.0	1800	—	1200	0.091	ø450	1.8	0.76	0.121							
SJ 5-4	500	124.0	274.0	3290	—	2190	0.154	ø525	1.5	0.77	0.167							
SJ 5-5	100	94.0	368.0	4400	—	2950	0.203	ø600	1.3	0.78	0.221							
	To Treatment Plant																	

COMPUTATION FOR DESIGN OF SANITARY SEWERS

Prai Zone - 1

Line No.	Sewer Length (m)	Area		Ave. Daily Flow			Peak Flow Total (cum/s)	Design of Sewer				Sewer Invert Elevation		Elevation Grand Surface		Earth Covering		Remark
		Incre-ment (ha)	Total (ha)	Domes-tic (cum/d)	Indus-trial (cum/d)	Extra-neous (cum/d)		Diam (mm)	Slope of Sewer (o/oo)	Velo-city Full (m/s)	Capa-city Full (cum/s)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	
P 1-1	400	16.0		-	1280	80	0.031	Ø 300	2.4	0.67	0.047							
P 1-2	550	75.0	91.0	-	7280	460	0.174	Ø 525	1.8	0.84	0.182							
P 1-3	500	174.0	265.0	-	21200	1330	0.506	Ø 900	1.2	0.99	0.627							
P 1-4	1450	206.0	471.0	-	37680	2360	0.899	Ø 1050	1.1	1.05	0.906							
Ⓟ	Pumping Station			-	37680	2360	0.899											
P 1-5	950	265.0	736.0	-	38800	3680	1.406	Ø 1350	0.9	1.12	1.601							
P 1-6	2200	327.0	1063.0	-	85040	5320	2.030	Ø 1500	0.9	1.20	2.121							
	To Treatment Plant																	

COMPUTATION FOR DESIGN OF SANITARY SEWERS

Prai Zone - 2

Line No.	Sewer Length (m)	Area		Ave. Daily Flow			Peak Flow Total (cum/s)	Design of Sewer				Sewer Invert Elevation		Elevation Grand Surface		Earth Covering		Remark
		Increment (ha)	Total (ha)	Domestic (cum/d)	Industrial (cum/d)	Extraneous (cum/d)		Diam (mm)	Slope of Sewer (o/oo)	Velocity Full (m/s)	Capacity Full (cum/s)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	
P 2-1	650	33.0		400	–	260	0.024	ø 225	3.0	0.62	0.025							
P 2-2	550	34.0	67.0	800	–	540	0.045	ø 300	2.4	0.67	0.047							
P 2-3	1050	49.0	116.0	1390	–	930	0.074	ø 375	2.2	0.75	0.082							
P 2-4	1150	87.0	203.0	2440	–	1620	0.121	ø 450	1.8	0.76	0.121							
P 2-5	350	65.0	268.0	3210	–	2150	0.154	ø 525	1.5	0.77	0.167							
	To Treatment Plant																	

COMPUTATION FOR DESIGN OF SANITARY SEWERS

Bukit Mertajam Zone - 1

Line No.	Sewer Length (m)	Area		Ave. Daily Flow			Peak Flow Total (cum/s)	Design of Sewer				Sewer Invert Elevation		Elevation Grand Surface		Earth Covering		Remark
		Increment (ha)	Total (ha)	Domestic (cum/d)	Industrial (cum/d)	Extraneous (cum/d)		Diam (mm)	Slope of Sewer (o/oo)	Velocity Full (m/s)	Capacity Full (cum/s)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	
BM 1-1	600	33.0		400	-	260	0.024	ø225	3.0	0.62	0.025							
BM 1-2	350	45.0	78.0	940	-	620	0.051	ø300	2.8	0.72	0.051							
BM 1-3	900	47.0	125.0	1500	-	1000	0.078	0375	2.2	0.75	0.082							
BM 1-4	700	117.0	242.0	3000	-	1960	0.144	ø525	1.5	0.77	0.167							
Ⓟ	Pumping Stations			3000	-	1960	0.144											
BM 1-5	800	79.0	321.0	4070	-	2620	0.185	ø600	1.3	0.78	0.221							
BM 1-6	600	120.0	441.0	5510	-	3580	0.245	0675	1.2	0.81	0.291							
BM 1-7	1450	157.0	598.0	7390	-	4840	0.313	ø750	1.1	0.84	0.369							
BM 1-8	500	294.0	892.0	10930	-	7200	0.451	ø900	0.9	0.85	0.543							
	To Treatment Plant																	

COMPUTATION FOR DESIGN OF SANITARY SEWERS

Bukit Merajam Zone - 2

Line No.	Sewer Length (m)	Area		Ave. Daily Flow			Peak Flow Total (cum/s)	Design of Sewer				Sewer Invert Elevation		Elevation Grand Surface		Earth Covering		Remark
		Increment (ha)	Total (ha)	Domestic (cum/d)	Industrial (cum/d)	Extraneous (cum/d)		Diam (mm)	Slope of Sewer (o/oo)	Velocity Full (m/s)	Capacity Full (cum/s)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	
BM 2-1	350	14.0		290	–	140	0.018	ø225	3.0	0.62	0.025							
BM 2-2	500	28.0	42.0	850	–	420	0.046	ø300	2.4	0.67	0.047							
BM 2-3	750	89.0	131.0	2170	–	1200	0.104	ø450	1.9	0.78	0.124							
BM 2-4	750	159.0	290.0	4070	–	2470	0.185	ø525	1.9	0.87	0.187							
BM 2-5	200	255.0	545.0	7130	–	4510	0.308	ø675	1.4	0.88	0.315							
BM 2-6	50	170.0	715.0	9150	–	5870	0.386	ø750	1.3	0.91	0.401							
	To Treatment Plant																	

COMPUTATION FOR DESIGN OF SANITARY SEWERS

Bukit Mertajam Zone - 3

Line No.	Sewer Length (m)	Area		Ave. Daily Flow			Peak Flow Total (cum/s)	Design of Sewer				Sewer Invert Elevation		Elevation Grand Surface		Earth Covering		Remark
		Increment (ha)	Total (ha)	Domestic (cum/d)	Industrial (cum/d)	Extraneous (cum/d)		Diam (mm)	Slope of Sewer (o/oo)	Velocity Full (m/s)	Capacity Full (cum/s)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	
BM 3-1	530	14.0		320	–	150	0.020	0225	3.0	0.62	0.025							
BM 3-2	110	34.0	48.0	870	–	460	0.046	0300	2.4	0.67	0.047							
BM 3-3	450	30.0	78.0	1310	–	720	0.067	0375	2.2	0.75	0.082							
BM 3-4	300	63.0	141.0	2300	–	1280	0.111	0450	1.8	0.76	0.121							
BM 3-5	190	39.0	180.0	3300	–	1740	0.150	0525	1.7	0.82	0.177							
BM 3-6	270	122.0	302.0	5780	–	2970	0.248	0600	1.7	0.90	0.253							
BM 3-7	1330	257.0	559.0	10080	–	5340	0.400	0750	1.3	0.91	0.401							
BM 3-8	50	368.0	927.0	16960	–	8920	0.633	01050	0.7	0.83	0.722							
	To Treatment Plant																	

COMPUTATION FOR DESIGN OF SANITARY SEWERS

Bukit Mertajam Zone - 4

Line No.	Sewer Length (m)	Area		Ave. Daily Flow			Peak Flow Total (cum/s)	Design of Sewer				Sewer Invert Elevation		Elevation Grand Surface		Earth Covering		Remark
		Increment (ha)	Total (ha)	Domestic (cum/d)	Industrial (cum/d)	Extraneous (cum/d)		Diam (mm)	Slope of Sewer (o/oo)	Velocity Full (m/s)	Capacity Full (cum/s)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	
BM 4-1	320	9.0		110	-	70	0.008	0225	3.0	0.62	0.025							
BM 4-2	300	58.0	67.0	800	-	540	0.045	0300	2.4	0.67	0.047							
BM 4-3	600	99.0	166.0	2130	-	1380	0.105	0450	1.9	0.78	0.124							
BM 4-4	780	118.0	284.0	3550	-	2310	0.167	0525	1.8	0.80	0.182							
BM 4-5	2250	183.0	467.0	5730	-	3770	0.256	0600	1.8	0.92	0.261							
	To Treatment Plant																	

COMPUTATION FOR DESIGN OF SANITARY SEWERS

Bukit Mertajam Zone - 5

Line No.	Sewer Length (m)	Area		Ave. Daily Flow			Peak Flow Total (cum/s)	Design of Sewer				Sewer Invert Elevation		Elevation Grand Surface		Earth Covering		Remark
		Increment (ha)	Total (ha)	Domestic (cum/d)	Industrial (cum/d)	Extraneous (cum/d)		Diam (mm)	Slope of Sewer (o/oo)	Velocity Full (m/s)	Capacity Full (cum/s)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	
BM 5-1	400	15.0		180	-	120	0.012	0225	3.0	0.62	0.025							
BM 5-2	1100	130.0	145.0	1740	-	1160	0.088	0375	2.5	0.79	0.088							
BM 5-3	1700	158.0	303.0	3640	-	2420	0.171	0525	1.7	0.82	0.177							
BM 5-4	900	156.0	459.0	5500	-	3670	0.246	0600	1.6	0.87	0.246							
	To Treatment Plant																	

COMPUTATION FOR DESIGN OF SANITARY SEWERS

Bukit Mertajam Zone - 6

Line No.	Sewer Length (m)	Area		Ave. Daily Flow			Peak Flow Total (cum/s)	Design of Sewer				Sewer Invert Elevation		Elevation Grand Surface		Earth Covering		Remark
		Increment (ha)	Total (ha)	Domestic (cum/d)	Industrial (cum/d)	Extraneous (cum/d)		Diam (mm)	Slope of Sewer (o/oo)	Velocity Full (m/s)	Capacity Full (cum/s)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	
BM 6-1	200	88.0		1070	–	710	0.058	0375	2.2	0.75	0.082							
BM 6-2	800	45.0	133.0	2000	–	1170	0.100	0450	1.8	0.76	0.121							
BM 6-3	150	53.0	186.0	2920	–	1660	0.137	0525	1.5	0.77	0.167							
BM 6-4	850	189.0	375.0	5190	–	3180	0.229	0600	1.5	0.84	0.238							
BM 6-5	600	198.0	573.0	7580	–	4770	0.319	0675	1.5	0.91	0.326							
	To Treatment Plant																	

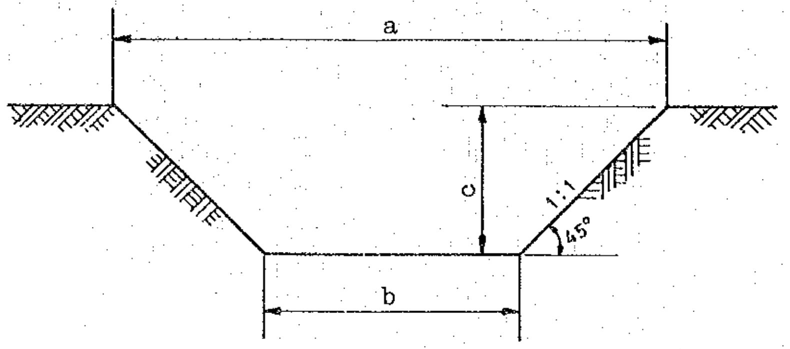
COMPUTATION FOR DESIGN OF SANITARY SEWERS

Bukit Mertajam Zone - 7

Line No.	Sewer Length (m)	Area		Ave. Daily Flow			Peak Flow Total (cum/s)	Design of Sewer				Sewer Invert Elevation		Elevation Grand Surface		Earth Covering		Remark
		Increment (ha)	Total (ha)	Domestic (cum/d)	Industrial (cum/d)	Extraneous (cum/d)		Diam (mm)	Slope of Sewer (o/oo)	Velocity Full (m/s)	Capacity Full (cum/s)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	Upper End (m)	Lower End (m)	
BM 7-1	400	29.0		350	–	230	0.022	0225	3.0	0.62	0.025							
BM 7-2	450	13.0	42.0	500	–	340	0.036	0300	2.4	0.57	0.047							
BM 7-3	850	95.0	137.0	1640	–	1100	0.085	0375	2.4	0.78	0.086							
BM 7-4	950	146.0	283.0	3400	–	2260	0.171	0525	2.0	0.89	0.192							
BM 7-5	750	230.0	513.0	6160	–	4100	0.368	0675	2.0	1.05	0.376							
BM 7-6	1200	255.0	768.0	9190	–	6110	0.391	0750	1.8	1.07	0.472							
	To Treatment Plant																	

APPENDIX C

DRAINAGE SYSTEM CONSIDERATION

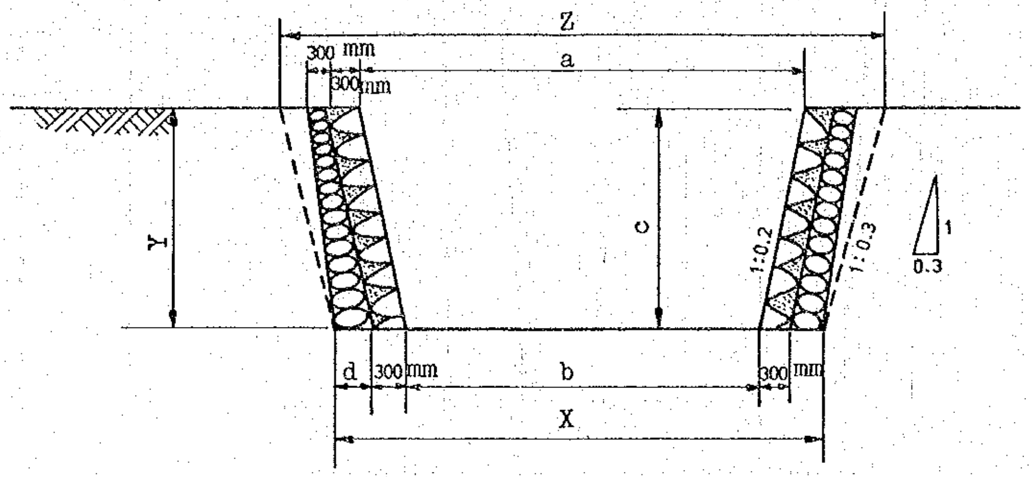


Size of cross Section (mm)	Dimension (mm)			Volume of elemental work			
	a	b	c	Excavation (m^3)	Excess soil (m^3)	Slope compaction (m^2)	Bed leveling(m^2)
1,000 500 x 250	1,000	500	250	18.75	18.75	70.71	50.00
2,000 1,000 x 500	2,000	1,000	500	75.00	75.00	141.42	100.00
3,000 1,500 x 750	3,000	1,500	750	168.75	168.75	212.13	150.00
4,000 2,000 x 1,000	4,000	2,000	1,000	300.00	300.00	282.84	200.00
5,000 2,500 x 1,250	5,000	2,500	1,250	468.75	468.75	353.55	250.00
6,000 3,000 x 1,500	6,000	3,000	1,500	675.00	675.00	424.26	300.00
7,000 3,500 x 1,750	7,000	3,500	1,750	918.75	918.75	494.97	350.00
8,000 4,000 x 2,000	8,000	4,000	2,000	1,200.00	1,200.00	565.69	400.00
9,000 4,500 x 2,250	9,000	4,500	2,250	1,518.75	1,518.75	636.40	450.00
10,000 5,000 x 2,500	10,000	5,000	2,500	1,875.00	1,875.00	707.11	500.00
12,000 6,000 x 3,000	12,000	6,000	3,000	2,700.00	2,700.00	484.53	600.00

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

EARTH DRAIN SECTION

FIGURE
C-1

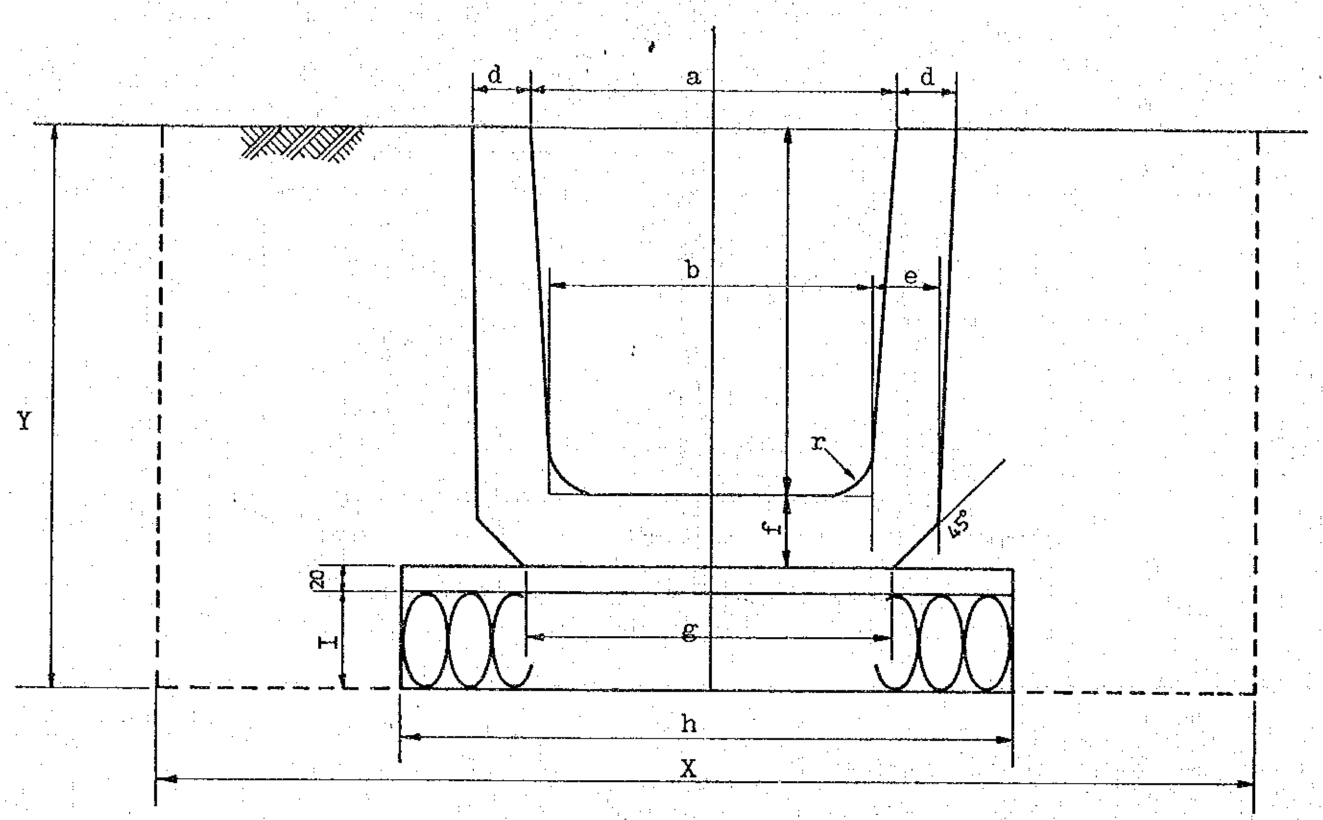


Size of cross Section (mm)	Dimension (mm)							Volume of elemental work (per 100 m)				
	a	b	c	d	X	Y	Z	Excavation (m^3)	Back filling (m^3)	Excess soil (m^3)	Masonry (m^2)	Bed leveling (m^2)
660 500 x 400	660	500	400	400	1,900	400	2,140	80.80	5.60	75.20	81.58	50.00
1,320 1,000 x 800	1,320	1,000	800	400	2,400	800	2,880	211.20	14.40	196.80	163.17	100.00
2,640 2,000 x 1,600	2,640	2,000	1,600	400	3,400	1,600	4,360	620.80	41.60	579.20	326.34	200.00
3,960 3,000 x 2,400	3,960	3,000	2,400	600	4,800	2,400	6,240	1,324.80	129.60	1,195.20	489.50	300.00
5,280 4,000 x 3,200	5,280	4,000	3,200	600	5,800	3,200	7,720	2,163.20	198.40	1,964.80	652.67	400.00
6,600 5,000 x 4,000	6,600	5,000	4,000	800	7,200	4,000	9,600	3,360.00	360.00	3,000.00	815.84	500.00
7,920 6,000 x 4,800	7,920	6,000	4,800	800	8,200	4,800	11,080	4,627.20	470.40	4,156.80	979.01	600.00
9,240 7,000 x 5,600	9,240	7,000	5,600	850	9,300	5,600	12,660	6,148.80	621.60	5,527.20	1,142.18	700.00
10,560 8,000 x 6,400	10,560	8,000	6,400	850	10,300	6,400	14,140	7,820.80	761.60	7,059.20	1,305.34	800.00

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

WET MASONRY DRAIN SECTION

FIGURE
C-2

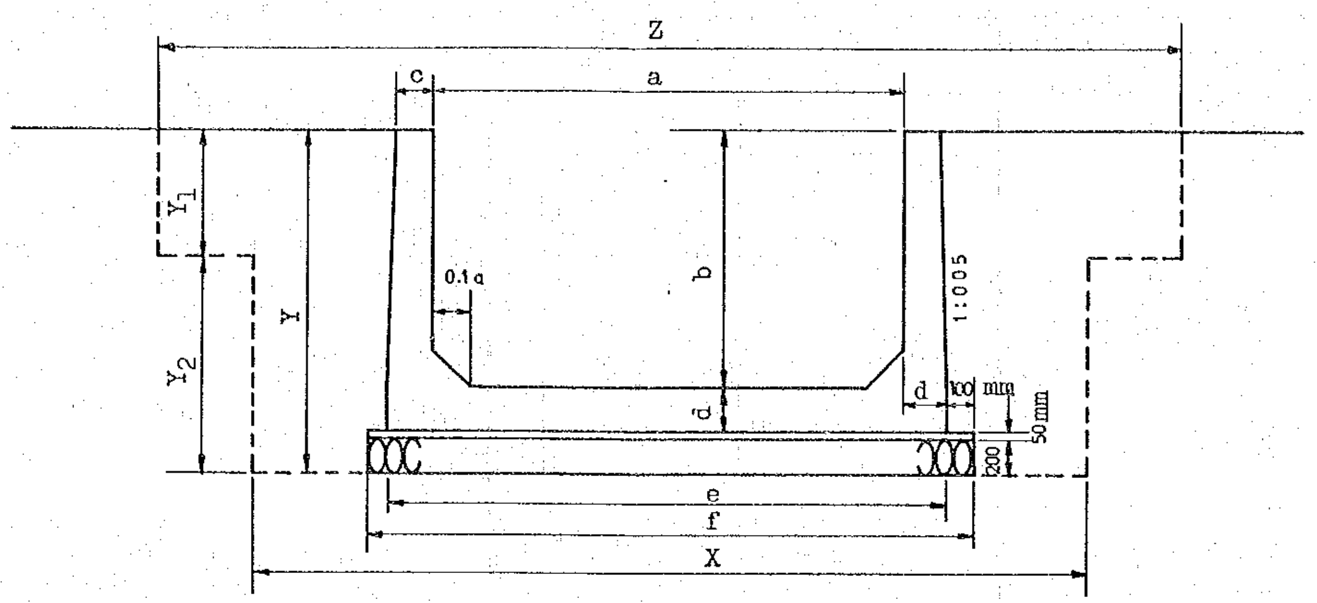


Name	Dimension (mm)									Volume of elemental work (per 100 m)						Dimension (mm)	
	a	b	c	d	e	f	g	h	I	Piece (Number)	Cobble stone (m^3)	Mortar (m^3)	Excavation (m^3)	Excess soil (m^3)	Back filling (m^3)	X	Y
240	240	220	240	45	50	50	240	440	100	166.67	4.40	0.88	34.44	14.71	19.73	840	410
300 A	300	260	240	50	60	60	300	500	100	166.67	5.00	1.00	37.80	17.70	20.10	900	420
300 B	300	260	300	50	60	60	300	500	100	166.67	5.00	1.00	43.20	20.04	23.16	900	480
300 C	300	260	360	50	60	65	300	500	100	166.67	5.00	1.00	49.05	22.58	26.47	900	545
360 A	360	310	300	50	65	65	360	560	100	166.67	5.60	1.12	46.56	23.15	23.41	960	485
360 B	360	310	360	50	65	65	360	560	100	166.67	5.60	1.12	52.32	25.85	26.47	960	545
450	450	400	450	55	70	70	430	630	100	166.67	6.30	1.26	65.92	36.16	29.76	1,030	640
600	600	540	600	70	80	80	600	800	100	166.67	8.00	1.60	96.00	58.56	37.44	1,200	800

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

PRE-CAST "U" SHAPE DRAIN SECTION

FIGURE
C-3

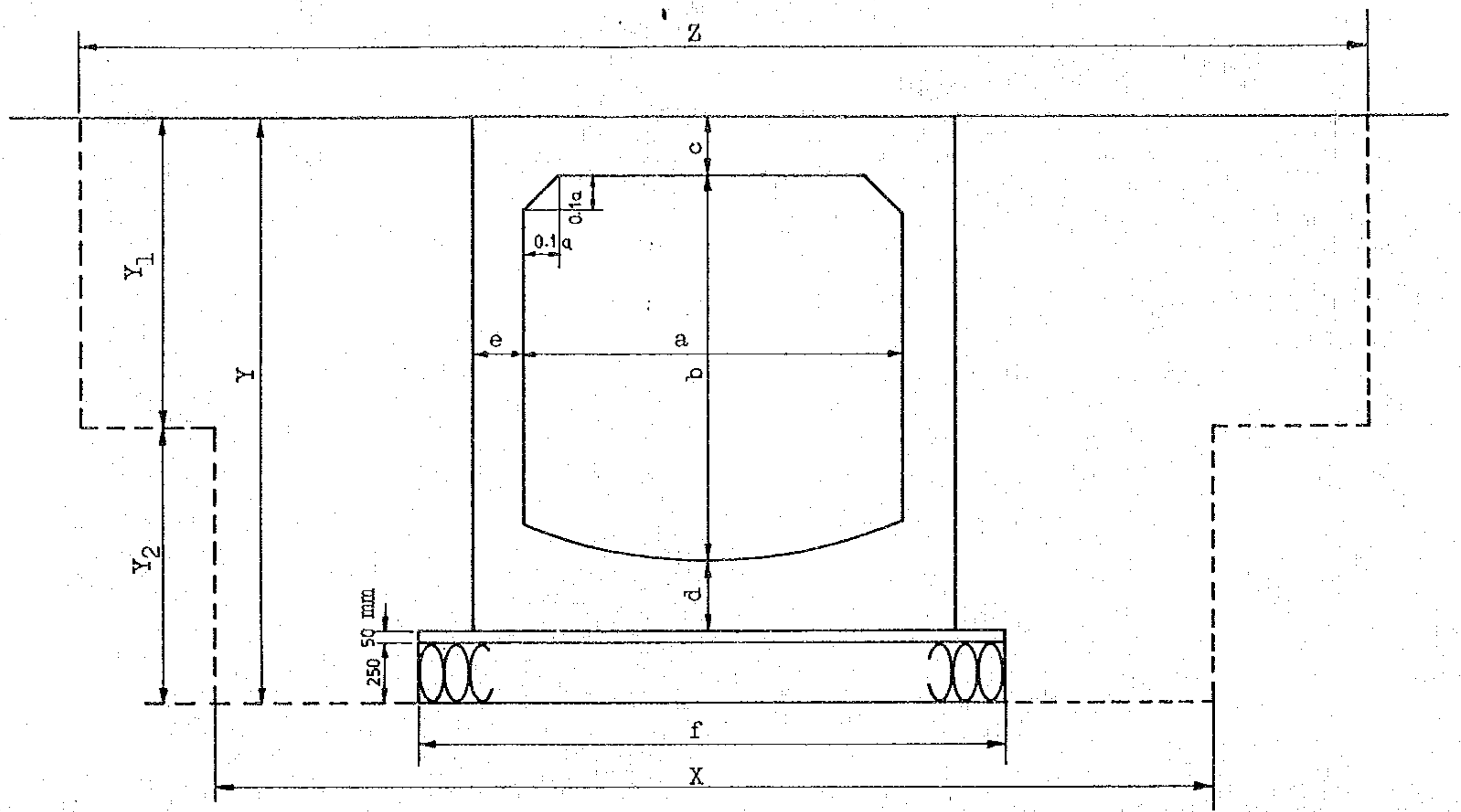


Size of cross section (mm)	Dimension (mm)											Volume of elemental work (per 100 m)							
	a	b	c	d	e	f	Y_1	Y_2	Y	X	Z	Excavation (m^3)	Back filling (m^3)	Excess soil (m^3)	Cobble stone (m^3)	Lean concrete 1:3:6(m^3)	Form work (m^3)	Concrete 1:2:4 (m^3)	Timbering (m^3)
500x400	500	400	150	150	800	1,000	-	-	800	1,500	-	120.00	51.00	69.00	20.00	5.00	222.20	24.50	-
1,000x600	1,000	600	150	150	1,300	1,200	-	-	1,000	1,700	-	170.00	42.50	127.50	24.00	6.00	359.20	38.50	-
2,000x1,000	2,000	1,000	150	200	2,400	2,600	-	-	1,450	3,100	-	449.50	102.50	347.00	52.00	13.00	638.50	86.00	-
3,000x1,400	3,000	1,400	200	270	3,540	3,740	-	-	1,920	4,240	-	814.08	141.09	672.99	74.80	18.70	919.70	168.49	-
4,000x1,800	4,000	1,800	200	290	4,580	4,780	-	-	2,340	5,280	-	1,235.52	177.62	1,057.90	95.60	23.90	1,201.00	234.40	-
5,000x2,200	5,000	2,200	200	310	5,620	5,820	-	-	2,760	6,320	-	1,744.32	215.82	1,528.50	116.40	29.10	1,482.20	308.00	1,075.00
6,000x2,600	6,000	2,600	200	330	6,660	6,860	180	3,000	3,180	7,360	8,360	2,358.48	298.68	2,059.80	117.20	29.30	1,763.50	389.30	1,524.00
7,000x3,000	7,000	3,000	200	350	7,700	7,900	600	3,000	3,600	8,400	10,400	3,144.00	417.20	2,726.80	158.00	39.50	2,044.70	478.30	2,051.00
8,000x3,400	8,000	3,400	200	370	8,740	8,940	1,020	3,000	4,020	9,440	11,440	3,998.80	544.48	3,454.40	178.80	44.70	2,325.90	574.90	2,656.00
9,000x3,800	9,000	3,800	200	390	9,780	9,980	1,440	3,000	4,440	10,400	12,400	4,905.60	637.90	4,267.70	199.60	49.90	2,607.20	679.20	3,339.00
10,000x4,200	10,000	4,200	200	410	10,820	11,020	1,860	3,000	4,860	11,520	15,520	6,342.72	1,176.02	5,166.70	220.40	55.10	2,888.40	791.20	4,100.00
11,000x4,600	11,000	4,600	200	430	11,860	12,060	2,280	3,000	3,000	5,280	12,560	77543.68	1,392.28	6,151.40	241.20	60.30	3,169.70	910.90	4,939.00

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

CAST-IN-PLACE REINFORCED CONCRETE DRAIN SECTION

FIGURE
C-4



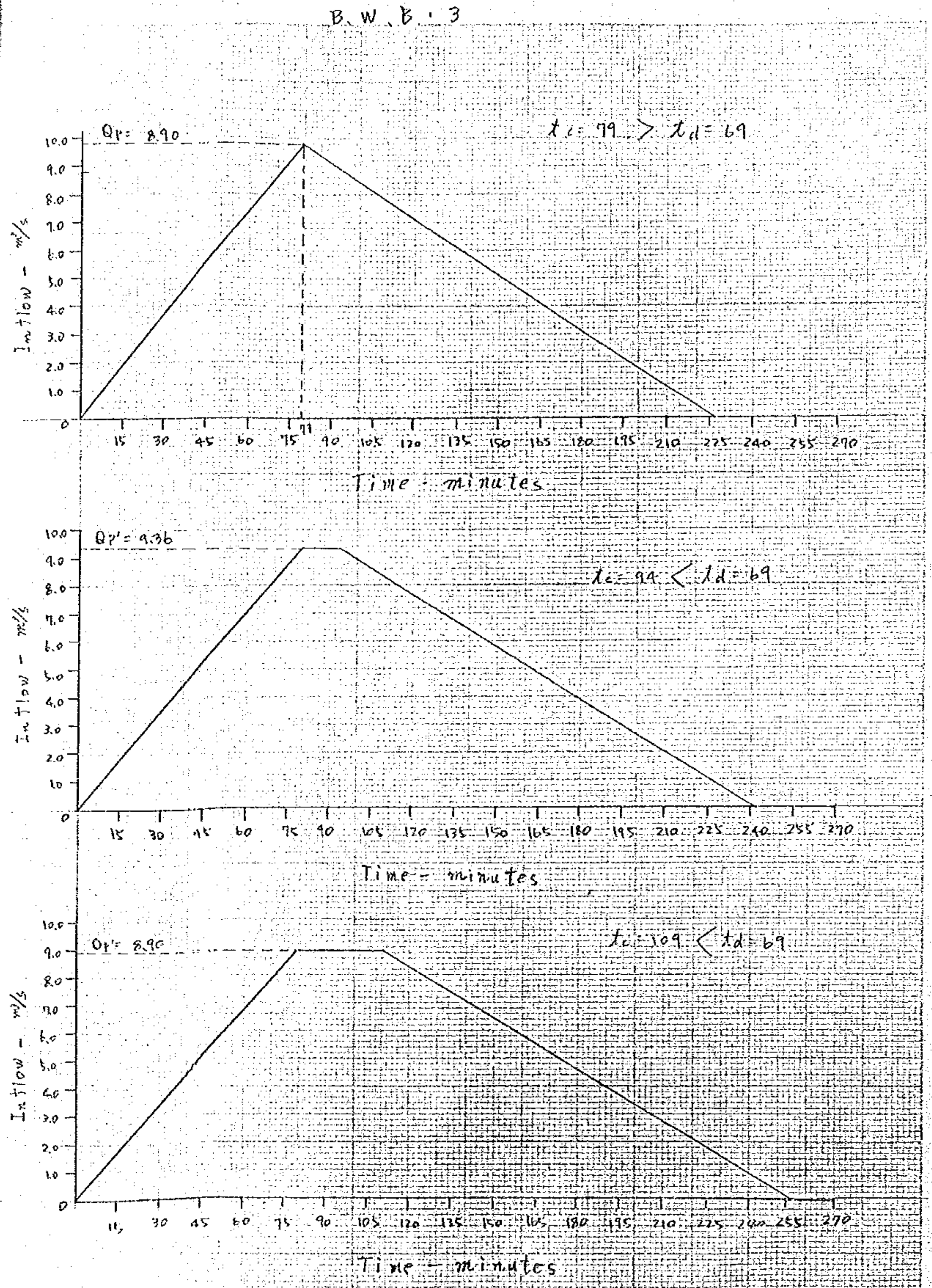
Size of cross section (mm)	Dimension (mm)											Volume of elemental work (per 100 m)							
	a	b	c	d	e	f	Y_1	Y_2	Y	X	Z	Excavation (m^3)	Back filling (m^3)	Excess soil (m^3)	Cobble stone (m^3)	Lean concrete 1:3:6(m^3)	Form work (m^3)	Concrete 1:2:4 (m^3)	Timbering m^3)
1,000x1,000	1,000	1,000	200	250	150	1,500	-	-	1,750	2,300	-	402.50	169.00	233.50	37.50	7.50	565.70	91.60	96.90
1,400x1,400	1,400	1,400	230	250	200	2,000	-	-	2,180	2,800	-	610.40	212.00	398.40	50.00	10.00	761.80	148.50	189.90
1,800x1,800	1,800	1,800	270	290	230	2,460	-	-	2,660	3,300	-	877.80	270.60	607.20	61.50	12.30	968.10	219.40	313.90
2,250x2,250	2,250	2,250	320	390	260	2,970	1,000	2,260	3,260	3,800	5,800	1,438.80	529.80	909.00	74.30	14.90	1,212.60	329.20	490.70
2,700x2,700	2,700	2,700	360	390	290	3,480	1,000	2,750	3,750	4,300	6,300	1,812.50	576.50	1,236.00	87.00	17.40	1,434.30	452.20	679.40
3,000x3,000	3,000	3,000	390	420	330	3,860	1,100	3,000	4,110	4,700	6,700	2,147.00	636.70	1,510.30	96.50	19.30	1,588.80	522.50	872.00
3,600x3,600	3,600	3,600	450	490	390	4,580	1,840	3,000	4,840	5,400	9,400	3,349.60	1,223.70	2,125.90	114.50	22.90	1,899.80	733.10	1,255.40
4,200x4,200	4,200	4,200	500	580	470	5,340	2,580	3,000	5,580	6,200	10,200	4,491.60	1,617.50	2,874.10	133.50	26.70	2,212.80	1,005.40	1,708.60

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

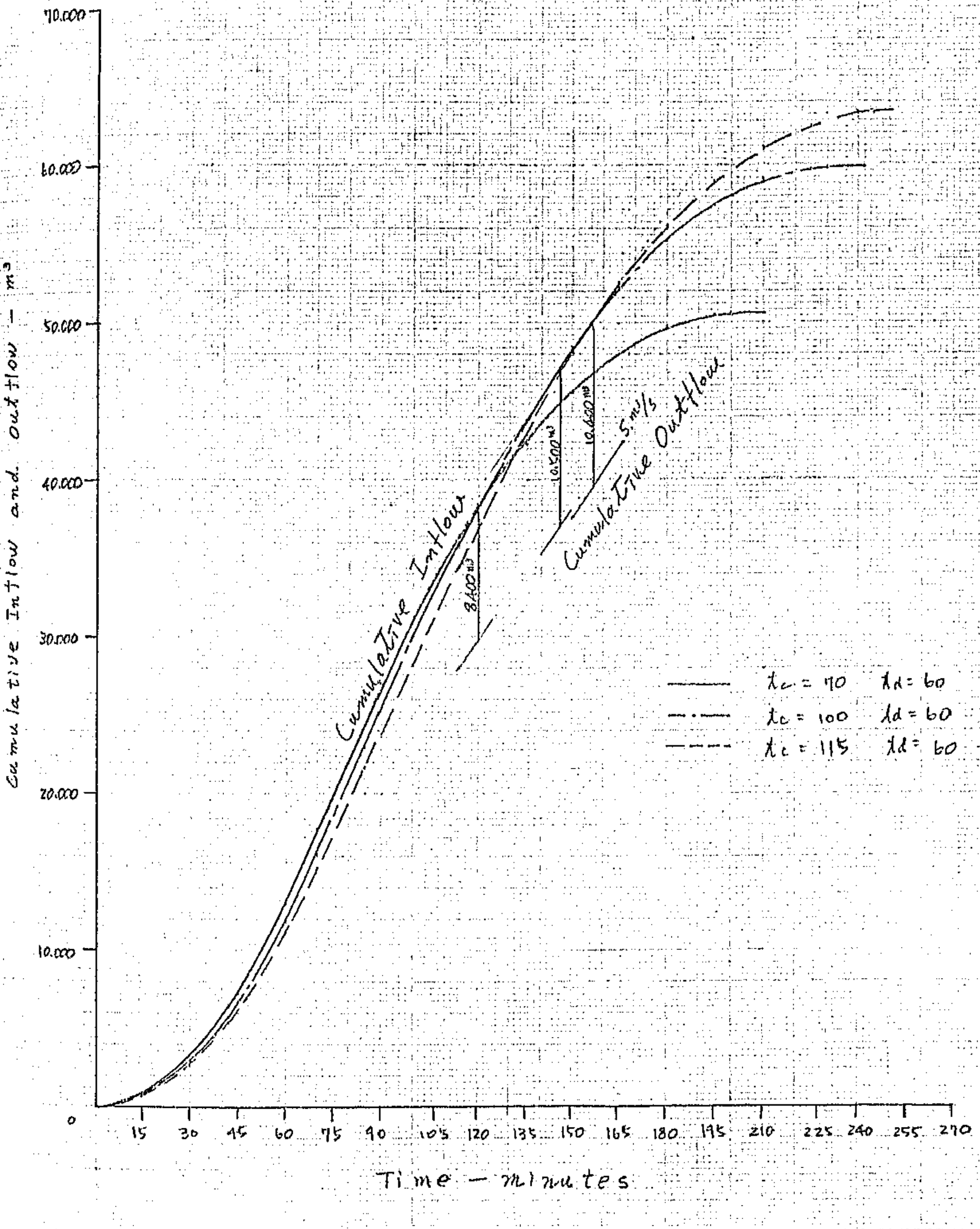
CAST-IN-PLACE REINFORCED BOX CULVERT SECTION

FIGURE
C-5

FIGURE C-6



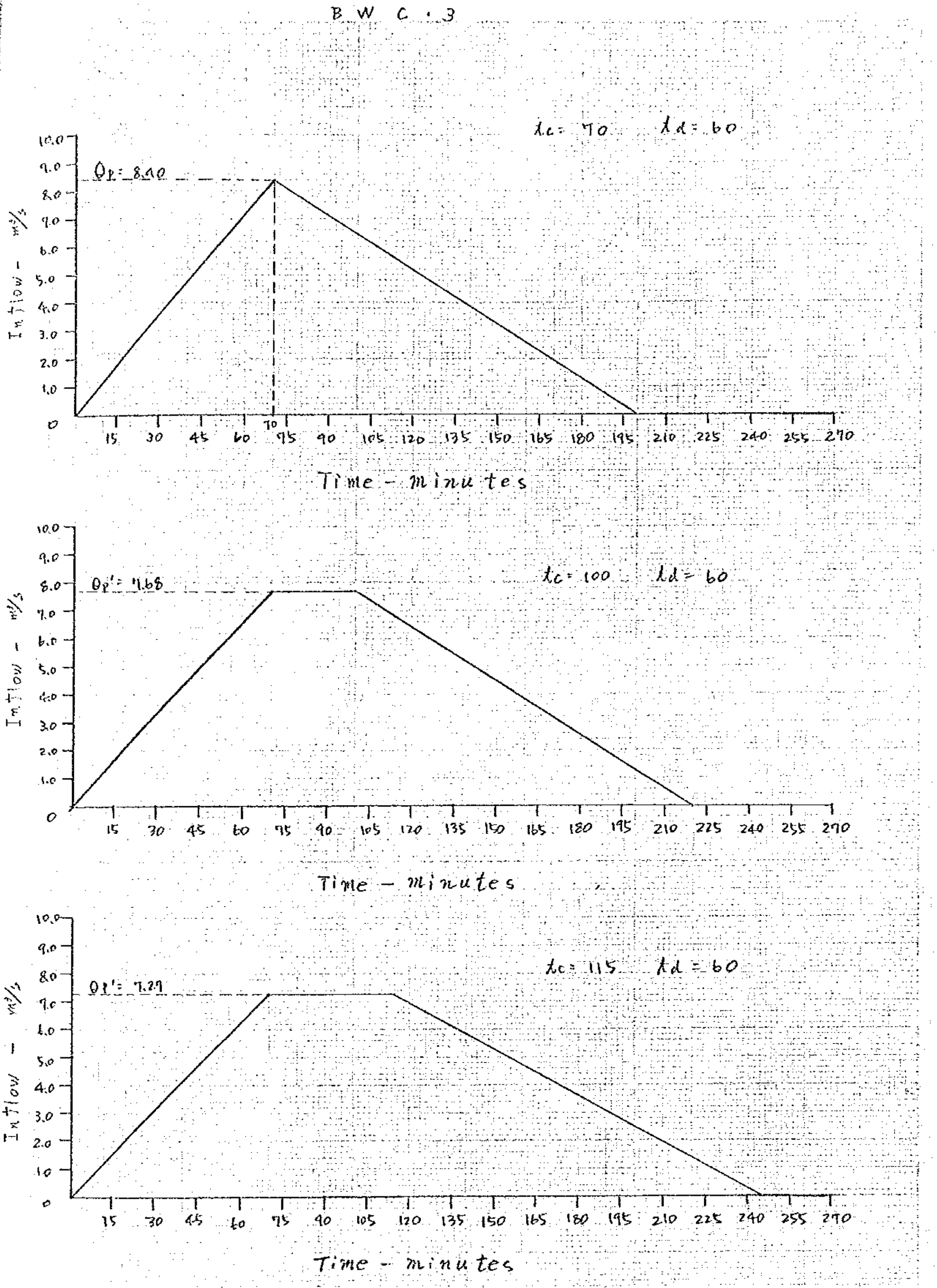
INFLOW HYDROGRAPH OF RESERVOIR (IN BUTTERWORTH DRAIN B)	FIGURE C-6



ESTIMATION OF RESERVOIR VOLUME
(IN BUTTERWORTH DRAIN C)

FIGURE
C-7

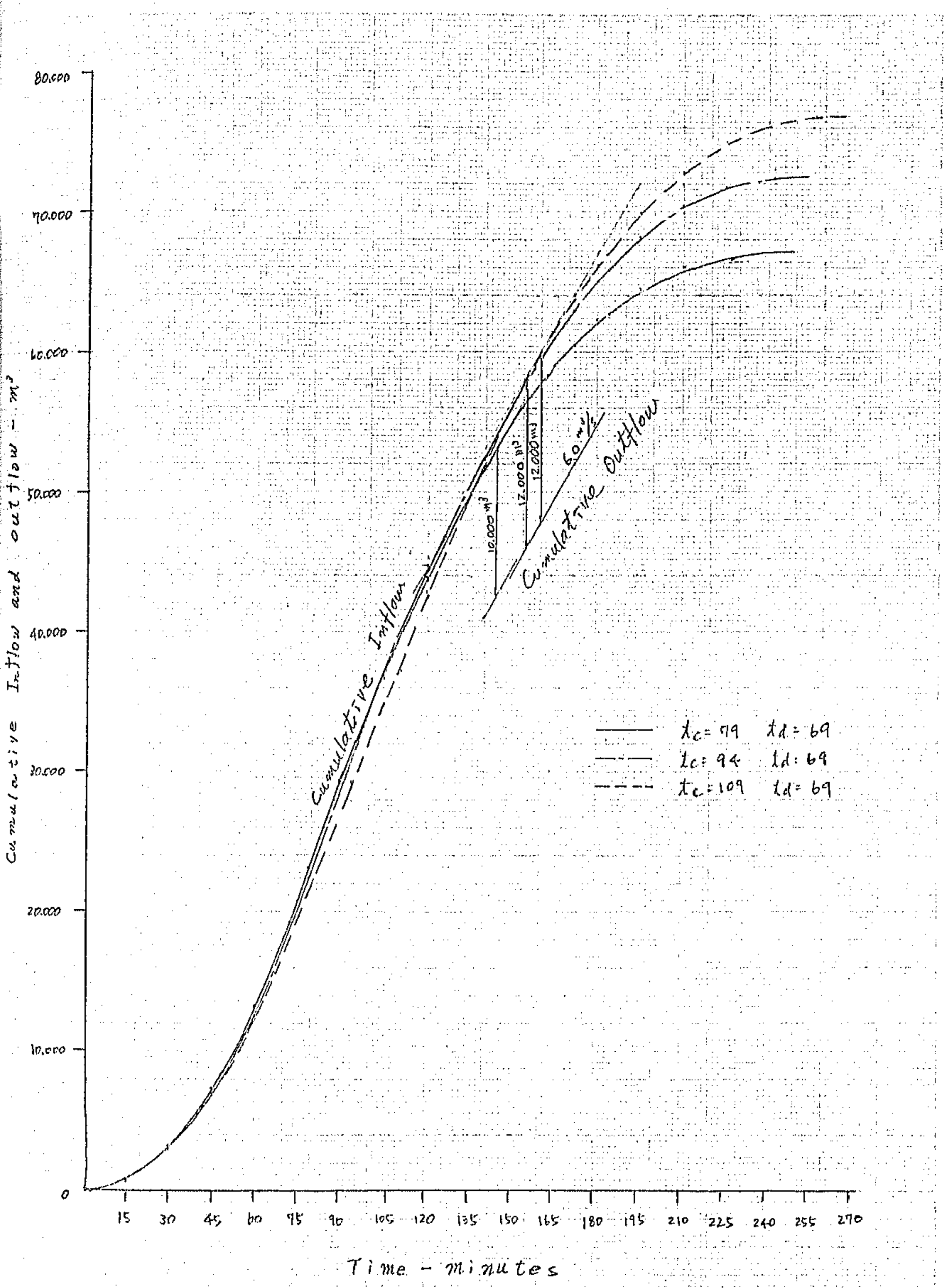
FIGURE C-8



INFLOW HYDROGRAPH OF RESERVOIR
(IN BUTTERWORTH DRAIN C)

FIGURE
C-8

FIGURE C-9



ESTIMATION OF RESERVOIR VOLUME
(IN BUTTERWORTH DRAIN B)

FIGURE
C-9

APPENDIX D

DESIGN DATA

Table of Contents

CHAPTER 1

FUNCTIONAL DESIGN DATA

1.1 Summary

In this chapter, the design bases necessary to design sanitary and storm water conduits, covering flow friction formulae, sizes of structures of facilities, hydraulics of sewers, materials of facilities, and measures needed for control of sulfides have been studied and criteria developed for this project as summarized below:

(a) The manning formula should be used for design of pipes and channels.

(b) No public sanitary sewer shall be less than 22.5cm (9 in) in diameter, but for house connexion pipes 15 cm (6 in) in diameter may be allowed.

(c) Earth covering of public sewers should not be less than 1 metre unless special protection measures against the expected load are provided.

(d) All sanitary sewers shall be so designed and constructed to give mean velocities, when flowing full or half-full, of not less than 60 cm/sec for VCP, based on the Manning formula using an 'n' value of 0.013. For RCP or any cement-bonded pipe material, for an 'n' value of 0.013, the minimum flow velocity should be 75 cm/sec (2.5 ft/sec).

(e) For storm sewers the velocity of flow shall be not less than 80 cm/sec (2.6 ft/sec). For open channels, where ground surface slopes are low, flatter slopes may be allowed.

(f) For sanitary sewers, full pipe capacity of the design peak flow rate should be provided.

(g) Minimum sewer slopes for different sewer pipe sizes are recommended, so that in no case, the velocity of flow will be less than 75 cm per second for AC and Concerete pipe, and 60 cm per second for VCP.

(h) Sewers should generally be laid with straight alignment between manholes. Exceptions should be allowed only when there is assurance the available cleaning methods will be workable in the curved sections.

(i) When a smaller sewer joints a larger sewer, the crown of both sewers should be placed at the same elavation.

(j) Sanitary sewers of smaller size up to 300 mm in diameter should normally be of vitrified clay. For larger size sewers up to 1,800 mm (70 in) in diameter, centrifugally-east reinforced concrete pipes, conforming to internationally accepted standards, should be used.

(k) Joints of concrete pipe should be the rubber-gasket type, and factory applied 'push-fit' resilient type joints should be used for vitrified clay pipes.

(l) Manhole spacing should not be more than 200 metres (656 ft).

1.2 Design Factors

In determining the required capacities of sanitary and storm sewers the following factors should be considered:

(a) Sanitary Sewers

1) Peak flow rate of domestic sewage.
2) Additional maximum sewage or waste flow from industrial plants.
3) Ground water infiltration.
4) Depth of excavation.
5) Location of treatment plant.
6) Pumping requirements.
7) Design velocities needed to assure self-cleaning and prevention of sulfide buildup.

(d) Storm Sewers

1) Peak storm water runoff for the designed return period of rainfall.

2) Topography of area.
3) Condition of rivers for inlet design.
4) Pumping requirements.

1.3 Flow Friction Formulae

For determining sewer capacities, a wide variety of equations have been developed. Among the equations widely used are:

(a) The Chezy and Darcy-Weisbach equations
(b) The Manning equation
(c) The Kutter equation, and
(d) The Hazen-Williams equation.

The Kutter and the Manning equations are most widely used for pipes and conduits of all shapes, flowing either full or partly full. Although the use of the Kutter equation has been extensive and the graphs and tables for the equation are available, its popularity is declining because of its empirical and cumbersome nature. The Manning equation tends to be used very extensively, because of its simplicity and because the "n" value is essentially the same as used in Kutter's equation.

A comparison was made between the velocities of circular pipes calculated by means of three different equations namely; Kutter, Manning, and Hazen-Williams. The velocities for full flow in sewer pipes from 225 mm to 1,800 mm in diameter were calculated using a friction coefficient 'n' value of 0.013 for the Kutter and Manning equations, and a 'C' value of 110 for Hazen-Williams which corresponds to 'n' value of 0.013.

As shown in Table D-1, the results of the calculations indicate that the velocities given by the three equations are essentially the same, but with some minor variations. In smaller sewers the Kutter's equation gives the lowest values, but the values become practically the same as the sewer size increases, and the order is then reversed for the larger sewer pipes. It is not possible to judge the adaptability of the equations by such calculations; however, it is clear that Manning's equation gives intermediate values, hence appears to be the best choice for general application and has been adopted for use on this project.

TABLE D-1 Comparison of Flow Velocities in Pipes
Calculated by Different Formula (Metre/second)

Pipe diam. and slope (1)		Kutter (n=0.013)	Manning (n=0.013)	Hazen-Williams (C=110)
225 mm	0.0045	0.700	0.758	0.824
300	0.0035	0.770	0.809	0.862
375	0.0026	0.784	0.809	0.845
450	0.0022	0.825	0.841	0.866
525	0.0018	0.835	0.843	0.857
600	0.0016	0.866	0.869	0.874
675	0.0014	0.881	0.879	0.876
750	0.0013	0.914	0.909	0.899
900	0.0011	0.955	0.944	0.922
1,050	0.0009	0.960	0.946	0.912
1,200	0.0008	0.991	0.975	0.931
1,350	0.0007	1.004	0.987	0.932
1,500	0.0007	1.078	1.058	0.996
1,800	0.0007	1.218	1.195	1.118
2,000	0.0007	1.306	1.239	1.194

Note: (1) Recommended minimum slopes for sanitary sewers.

In view of these facts the Manning equation is recommended for the design of sewers and channels. The equation is expressed as;

$$V = \frac{1}{n} . R^{2/3} . S^{1/2}$$

where: n = coefficient of roughness
R = hydraulic radius, m
S = Slope

Care must be used in selecting the friction coefficient. In general, 'n' values from 0.013 to 0.015 are used in sewer design, depending upon the type of joint and the pipe material. Table E-2 is a summary of friction coefficients for different sewer materials for use with the Manning formula.

Table D-2 Values of 'n' to be used with the Manning Equation

Conduit Materials	Manning 'n' Value
1. Closed Conduits	
Asbestos-cement pipe	0.010 - 0.015
Brick	0.013 - 0.017
Cast iron pipe	
Uncoated (new)	
Cement-lined & seal coated	0.011 - 0.015
Concrete (manolithic)	
Smooth forms	0.012 - 0.014
Rough forms	0.015 - 0.017
Concrete pipe	0.011 - 0.015
Plastic pipe (smooth)	0.011 - 0.015
Vitrified clay pipes	0.011 - 0.015
2. Open Channels	
Lined channels	
Brick	0.012 - 0.018
Concrete	0.011 - 0.020
Vegetal	0.030 - 0.040
Excavated or dredged	
Earth, straight and uniform	0.020 - 0.030
Earth, winding, fairly uniform	0.025 - 0.040
Rock	0.030 - 0.045
Unmaintained	0.050 - 0.140
Natural channels (minor streams, top width at flood stage 100 ft)	
Fairly regular section	0.030 - 0.070
Irregular section with pools	0.040 - 0.100

Note: WPCF Design Mannual of Practice No. 9 (1970).

Factors which affect the choice of a coefficient are conduit material, Reynolds number, size and shape of conduit, and depth of flow. In addition to these interrelated factors the following should be considered;

(a) Rough, opened, or offset joints,
(b) Poor alignment and grade due to settlement or lateral soil movement.
(c) Deposits in sewers
(d) Amount and size of solids being transported,
(e) Coatings of grease or other matter on interior of sewer,
(f) Tree roots, joint compounds, and mortar dams resulting from poor or deteriorated jointing and other protrusions, and
(g) Flow from laterals disrupting flow in the sewer.

The values are commonly used for sewer design and hence are higher than the values obtained in laboratory tests with clear water and clear conduits. The range in coefficients for a given pipe material is explained partially by the disturbing influences mentioned previously in the general discussion of coefficients.

It is recommended that Manning's n of 0.013 be used for all proposed and future sewer and 0.015 be used for all existing sewers. Higher values of n should be used for existing sewers if available data indicate deterioration, deposits, or inferior workmanship.

The 'n' value of 0.013 for proposed and future sewer is based on the use of pipe units having not less than 5-ft laying lengths, with true and smooth inside surfaces, and on the assumption that only first-class construction procedures will be followed.

1.4 Sewer Design and Construction

1.4.1 Minimum Size of Sewer

The adoption of a minimum size of sewer is necessary, because experience has shown that comparatively large objects, such as scrub bushes, and also tree roots, sometimes get into sewers and that stoppage resulting from them as much less likely if sewers are not smaller than 22.5 cm. Smaller pipes experience more frequent troubles in cleaning of settled debris, roots, etc., especially where slopes are flat.

Another factor determining the minimum size of pipe is construction coat, which may be greatly affected by topographical conditions. Where the ground surface slope in the area is flat, ranging between 0.1 and 0.3 metre per thousand metres, sewer must be deeper. Consequently, the construction cost will also be increased. For example, to keep the verocity of flow more than 75 cm/sec in a 22.5 cm pipe, the slope must be 0.0045, but for a 15 cm pipe the slope would be 0.0076 for the same velocity of flow, and the difference of depth will be 3.1 metre per one km of sewer length. Hence, the construction cost for 15 cm pipes would hardly be cheaper than 22.5 cm pipes, because the increased cost of excavation will overcome the reduced cost to be gained by the use of smaller pipes. For these reasons, the minimum size of sanitary sewers for this project, except house connections, should be 22.5 cm.

For house connections, smaller sizes may be used; however, house connection pipes should be larger than the building sewers, so that articles which pass through the building sewers may readily pass through the building connection pipes. Experience shows that a diameter of more than 15 cm is usually satisfactory for house connection pipes, except for large buildings which have terminal pipes of more than 15 cm in diameter.

1.4.2 Minimum Depth of Sewer

Enough earth covering should be left between the top of the sewer and paved surfaces to protect the sewers from traffic loads and to avoid undue interference with other underground facilities. The minimum allowable cover may depend on the size of pipe, soil conditions, pavement and traffic loads.

The calculation indicates that for one metre of earth covering under a 20 ton truck load, pipes laid on continuous concrete cradle bedding will be used at least one metre of earth covering for sewer pipe in the Project Area.

Another factor to be considered in deciding the required earth covering for public sewer pipes, is the length and slope of private sewers to be connected. Where the private sewers are deep, it may be more economical pump from the buildings than to lower the public sewers to such depths. Deeper house sewers may be caused either because of low ground elevation or because the houses are located far from the street.

An estimation was made for new developed housing area, to check the depth of private sewer pipes. At the representative house, with a plot of 30 metres of frontage and depth, assuming an average slope of pipe at 2 percent and minimum earth covering at the starting point of the sewer as 30 cm, the minimum earth covering of the public sewer would be one metre to receive the sewage from the house by gravity.

In view of the above mentioned results, it is recommended that the earth covering of public sewers by not less than one metre except for specific situations where studies show that shallower depths are feasible.

1.4.3 Velocity of Flow

(a) Minimum Velocity

Sewage should flow at all times, with sufficient velocity to prevent settlement of solid matter and consequent loss of sewer capacity. This is particularly important in the Project Area because of the flat slopes. The most significant factors to be considered are discussed below:

i) The commonly accepted minimum velocity for self-cleansing of sanitary sewers is 60 cm/sec. A velocity of 60 cm/sec can prevent most deposits of solids in sewers.

ii) Ground surface slopes in the area except in the part of Bukit Mertajam District generally range between 0.01 and 0.03 percent. Sewer slopes are generally steeper than the ground surface slopes and sewers will become deeper, and costs for construction will be significantly increased if higher minimum velocities are used. A minimum slope for 225 mm sewer pipe to give a flow velocity of 60 cm per second is 0.30 percent, based on an 'n' value of 0.013, but for 75 cm per second, 0.45 percent is necessary. In case of a ground surface slope of 0.03 percent, the difference of construction cost between two different velocities may be M$40,000/km of pipe length.

iii) An important consideration in selecting the design flow velocities for sanitary sewers in regions of hot climate, including tropical areas like Malaysia, is the problem of deposition of solids and generation of sulfides because of the high temperatures. This is especially important where concrete or other cement-bonded pipe is used as the sewer material, because unless controlled in the sulfides will attack and dissolve the cement which binds the pipes material together, so that sooner or later the pipe may be suffer structural failure. Experience with this problem in other countries has shown that the most effective method of sulfide control is to use a design velocity at average flow not less than 75 cm/second, and preferably more. (Refer Annex). At velocities of 75 cm/second or more the oxygenation capacity of the flow will neutralize sulfide generation and also virtually eliminate deposition. For purposes of final design more precise methods should be used for evaluating the sulfide hazard (which is a function of BOD and temperature as well as flow velocity) on a case by case basis, but the general rule noted above should be sufficient for master planning. Another solution to the sulfide problem, where concrete or other corrodable materials are used, is to protect the pipe with suitable linings or coating.

iv) Sulfides tend to be an especially severe problem in sewer force mains, and proper control of this problem usually requires the injection of compressed air into the force main to oxidize these sulfides. This serves not only to protect the force main itself from sulfide attack but also to prevent the discharge of sulfide-laden sewage from the force main into cement-bonded structures (pipes, pumping stations, treatment plants) which may then be attacked, and also to prevent undesirable odor unisances at such points of discharge.

v) For storm water, a higher velocity is preferable, because stormwater generally contains heavier solids such as gravel or larger sand, for which a higher clean velocity is necessary. For open channels, a flatter slope may be allowed where necessary, because it is comparatively inexpensive to remove silt deposits from open channels.

In view of above mentioned comments, the following criteria are recommended:

All sanitary sewers shall be so designed and constructed to give mean velocities when flowing full or half-full, or not less than 60 cm/sec for VCP, based on the Manning formula using an 'n' value of 0.013. For RCP or any cement-bonded pipe material, for an 'n' value of 0.013, the minimum design flow velocity should be 75 cm/sec and suitable lining or coating pipes should be used. Compression air injection facilities should be provided to prevent sulfide buildup in the force mains.

In storm sewers, the velocity shall not be less than 80 cm/sec. For open channels, where ground surface slopes are comparatively flat, a velocity of 30 cm/sec may be allowed if removal of deposits is easy and inexpensive.

(b) Maximum Velocity

The maximum velocity should not exceed 3.0 m/sec, to protect sewer erosion. Where the ground surface slope is steep and velocities of more than 3.0 m/sec may result, special provision should be made to protect against displacement by erosion and shock.

1.4.4 Design Depth of Flow

Average temperature in Penang State is around 27 degrees C and the sewage temperature will also be high, hence fresh sewage tends to rapidly become anaerobic and to generate sulfides. As noted in the previous descussions, among the measures available for solving sulfide problems, it is believed the effective method for use in the Project Area is to use flow velocities to prevent sulfide development or to use suitable linings or coatings pipes. However, there is an exception, namely in the design of force mains where aeration is the effective and widely used method of control. For ventilation reasons, full pipe capacity should be more than the design peak flow for sanitary sewers.

The survey on sewage fluctuation in selected representative districts indicated (see Appendix E) that peak flows usually occur around 8:00 a.m. and 5:00 p.m., each lasting about one hour. The rest of the day, the sewage flow rate is less than the peak rate, therefore, if the sewer pipe is designed on the basis of 100 percent of the design peak flow, there will be some space above the water surface elevation in the pipe most of the day.

Considering the above mentioned conditions, all circular pipes are recommended to be designed on the basis of 100 percent full capacity.

1.4.5 Slope

Sewer sections and slopes should be designed so that the velocity of flow will not be less than 60 cm/sec for clay pipes and 75 cm/sec for cement-bonded pipes, each pipe section will be separately evaluated to determine the minimum design velocity necessary to control sulfide.

The following are the minimum slopes which should generally be provided; however slopes greater than these are desirable:

TABLE D-3 Minimum Slope for Sanitary Sewers

Sewer Size (mm)	Minimum Slope m/1,000 m		Velocity m/sec	
	VC pipe	Concrete	VC pipe	Concrete
225	3.0	4.5	0.619	0.758
300	2.2	3.5	0.642	0.809
375	1.7	2.6	0.655	0.809
450	1.4	2.2	0.671	0.841
525	1.2	1.8	0.688	0.843
600	1.1	1.6	0.720	0.869
675	1.0	1.4	0.743	0.879
750	0.9	1.3	0.756	0.909
900	0.8	1.1	0.805	0.944
1,050 and larger	0.7 or less	0.9 or less	0.834 and more	0.946 and more

Note: Manning formula using an 'n' value of 0.013.

1.4.6 Alignments

Sewers should generally be laid with straight alignment between manholes. Laying curved sewers should be avoided, unless the available sewer cleaning equipment can handle curvilinear alignments. Also, curvilinear alignments are acceptable for large trunks where physical access inside the sewers is readily accomplished.

1.4.7 Increasing Size

When a smaller sewer joins a larger one, the invert of the larger sewer should be a sufficiently lower elevation to maintain the same energy gradient. There are four methods which may be used:

a) To place the crown of both sewers at the same elevation.
b) To place the water surface of both sewers at the same elevation.
c) To place the centre of both sewers at the same elevation.
d) To place the invert of both sewers at the same elevation.

From the hydraulical reason the method (b) is the most desirable, however it is impossible to construct both sewers at the same water surface elevation to meet hourly flow rate variation.

Because of the sewer depth, construction cost using the method(d) will be the lowest and the method (c) will be second lowest. But, the difference will not be significant in the area of average topographic condition. It is therefore recommended to use the method (a), which has hydraulic advantages, with only small extra cost.

1.4.8 Type and Material of Conduit

Sewer pipes are most commonly made of clay or of concrete. Asbestos-cement, and other materials are also suitable for sewer pipes, but may not be avialable locally at competive price.

Pipes currently available in Malaysia are limited both in sizes and materials. The following pipes are produced and available on markets in Malaysia:

(a) Clay pipe up to 300 mm in diam.
(b) Centrifugally cast reinforced concrete pipe up to 1,800 mm in diam.
(c) Asbestos-cement pipe up to 600 mm in diam.
(d) Pitch-fibre pipe 100 and 150 mm in diam.

For the selection of sewer materials for the Project, careful considerations should be given to the problem of corrosion of pipes by sulfide build-up in sewers. Even though the sewer system should be designed and operated to be sulfide-free, such corrosion might not be completely prevented in all sewers. Preference should therefore be given to corrosion-resistant materials, such as vitrified clay pipe or linings or coatings pipe.

The resistance of vitrified clay pipe to corrosion from acids, alkalies, and virtually all corrosive substances gives it a distinct advantage over other materials as well as excellent resistance to erosion and scour. Disadvantages of vitrified clay pipe are the limited range of sizes and strengths and the fact that it is more brittle than other pipe.

Centrifugally-cast reinforced concrete pipe is available in the market in sizes up to 1,800 mm in Malaysia. The advantages of concrete pipe are the relative ease with which the required strength may be provided and the wide range of sizes and laying lengths available. A disadvantage is that all cement-bonded pipes are subject to corrosion, hence a higher design flow velocities must be used to prevent sulfide corrosion problems. Higher velocities require more slope, hence greater excavation and pumping cost.

TABLE D-4 Price of Sewer Pipe (M$/m in 1976)

Diameter (mm)	Pipe Material		
	Centrifugally Cast Reinforced Concrete	Centrifugally Cast Reinforced Concrete High Alumina Cement Mortar Lining (1/2 in)	Vitrified Clay
150	11.47	18.85	12.99
225	17.05	28.36	21.65
300	20.98	35.25	32.50
375	30.33	49.34	
450	35.25	57.87	
525	42.46	68.69	
600	47.57	76.88	
675	63.44	97.21	
750	70.82	107.70	
900	92.95	137.54	
1,050	122.95	174.75	
1,200	136.23	192.79	
1,350	179.84	246.07	
1,500	208.85	283.77	
1,800	281.47	369.67	

Pitch fibre pipes are also available in Malaysia in sizes 100 and 150 mm diameter. The pipes are generally of good quality and meet internationally accepted standards.

In view of the above mentioned conditions, the following considerations should be taken into account in selecting sewer materials:

(a) Sanitary sewers of smaller sizes up to 300 mm in diameter should normally be vitrified clay pipe, this pipe is available locally at competive prices.

(b) Sanitary sewers of 375 mm or more in diameter should be of centrifugally cast reinforced concrete pipes conforming to internationally accepted standards, with high alumina cement mortar coatings.

(c) For storm sewers, vertically-cast reinforced concrete pipes may be used provided the strength and structure of the pipes are of high quality and acceptable for Project Use.

1.4.9 Joints

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

Experience in many countries shows that the compression-type and rubber gasket 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. 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 '0' ring, or they may be of polyurethane with an integral nob. Any of these modern type joints which prevent infiltration would be acceptable.

1.4.10 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 trunk sewers, however, which can be entered for cleaning, these changes may be made without the requirement of manholes.

(b) Spacing

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

Table D-5 Maximum Manhole Spacings

Pipe Diam (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 studies. In George Town, where a separate sewerage system has been in operation since 1933, a maximum manhole spacing of 90 metres for sewer sizes up to 600 mm and on larger sized sewers spacing up to 150 m has been used as a design standard, without much trouble in cleaning of sewer pipes. Spacing should be dictated 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 in Table E-5 are recommended, except in cases where modern equipment adequate for greater spacing is provided.

(d) Dimensions

Except for very shallow drains and sewers of less than 1 metre 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 120 cm; but larger sizes are preferable. The recommended standard classification of manhole diameters and internal sizes are as follows:

Table D-6 Recommended Shapes, and Manhole Diameter and Internal Sizes (mm)

Type of Manhole	Shape	Size	Connecting Sewer Diameter
1	Circular	1,200	225 to 600
2	"	1,200	900 or less
3	"	1,500	1200 or less
4	"	1,800	1500 or less
5	Rectangular	2,100x1,200	1800 or less

(c) 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.

CHAPTER 2

COST ESTIMATING PROCEDURES FOR SEWERS

2.1 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 to 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.

2.2 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.

2.2.1 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 NSC 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 D-7 Labour Costs

Type of Labourer	M$/day	Remarks
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 Butterworth Municipal Dept. as shown in Figure D-1.

TABLE D-8 Price of Basic Materials - (1)

Item	Unit	Price (M$)	Remarks
Cement	ton	109	
Sand	cu m	12	
Gravel	cu m	27	
Steel bar	ton	610	
Timber	ton	410	
Vitrified clay pipe			
ϕ150	m	12.99	
ϕ225	m	21.65	
ϕ300	m	32.50	

Data source: Local contractor

TABLE D-9 Price of Basic Materials - (2)

Item	Unit	Price (M$)	Remarks
Centrifugally cast concrete pipe			with high alumina cement mortar linings and rubber ring
ϕ150	m	19.94	
ϕ225	m	29.45	
ϕ300	m	36.34	
ϕ375	m	50.71	
ϕ450	m	58.85	
ϕ525	m	70.00	
ϕ600	m	78.36	
ϕ675	m	98.85	
ϕ750	m	109.67	
ϕ900	m	140.16	
ϕ1,050	m	178.03	
ϕ1,200	m	196.89	
ϕ1,350	m	250.99	
ϕ1,500	m	290.66	
ϕ1,800	m	377.87	

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

TABLE D-10 Unit for Construction,
including Labour and Materials

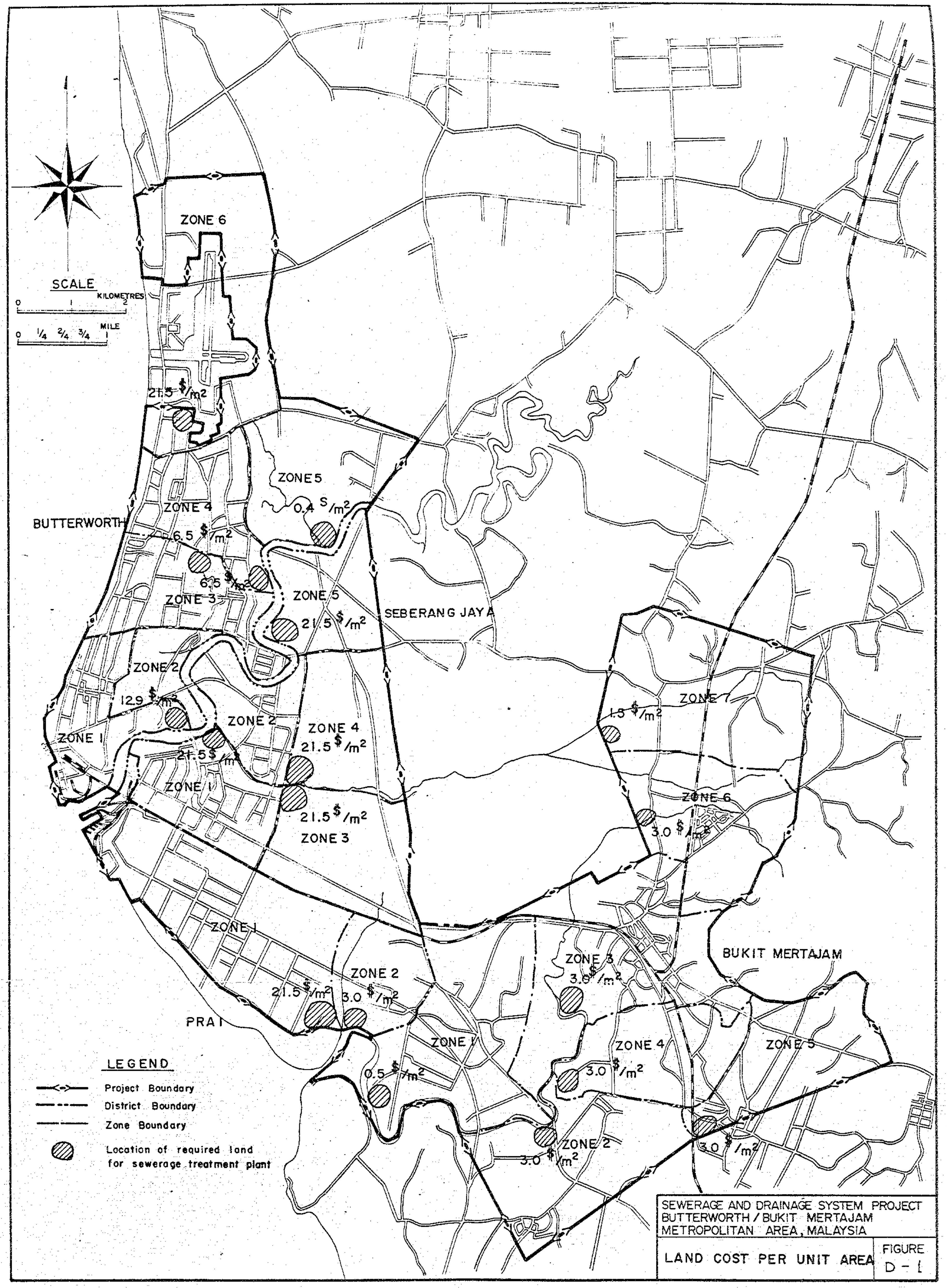
Item	Description	Unit	Cost (M$)
Concrete	mix. 1:2:4	cu m	94.17
"	mix. 1:3:6	"	78.47
Reinforced concrete		"	392.39
Mortar works	mix. 1:2	"	103.60
Surplus soil removal		"	1.96
Excavation	open cut	"	1.96
"	trench (depth 0-1.5m)	"	6.54
"	" (" 1.5-3.0m)	"	9.16
"	" (" 3.0-4.5m)	"	19.62
"	" (" 4.5-6.0m)	"	31.39
"	" (" 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 & Local contractor

2.2.2 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

FIGURE



LEGEND

- Project 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
D - 1

and overhead. The cost estimations were developed for normal conditions excluding such additional costs as required for rock excavation, relocation of under-ground utilities, foundation or dewatering for which special technics are required, and any works required for special conditions.

(a) Sewers and Open Channels

Average unit costs per meter of circular pipe, square cast-in-place culvert, and trapezoidal open channels of various sizes were developed, taking into account the local conditions such as availability of materials, efficiency of labour, and soil conditions.

i) Circular Pipes

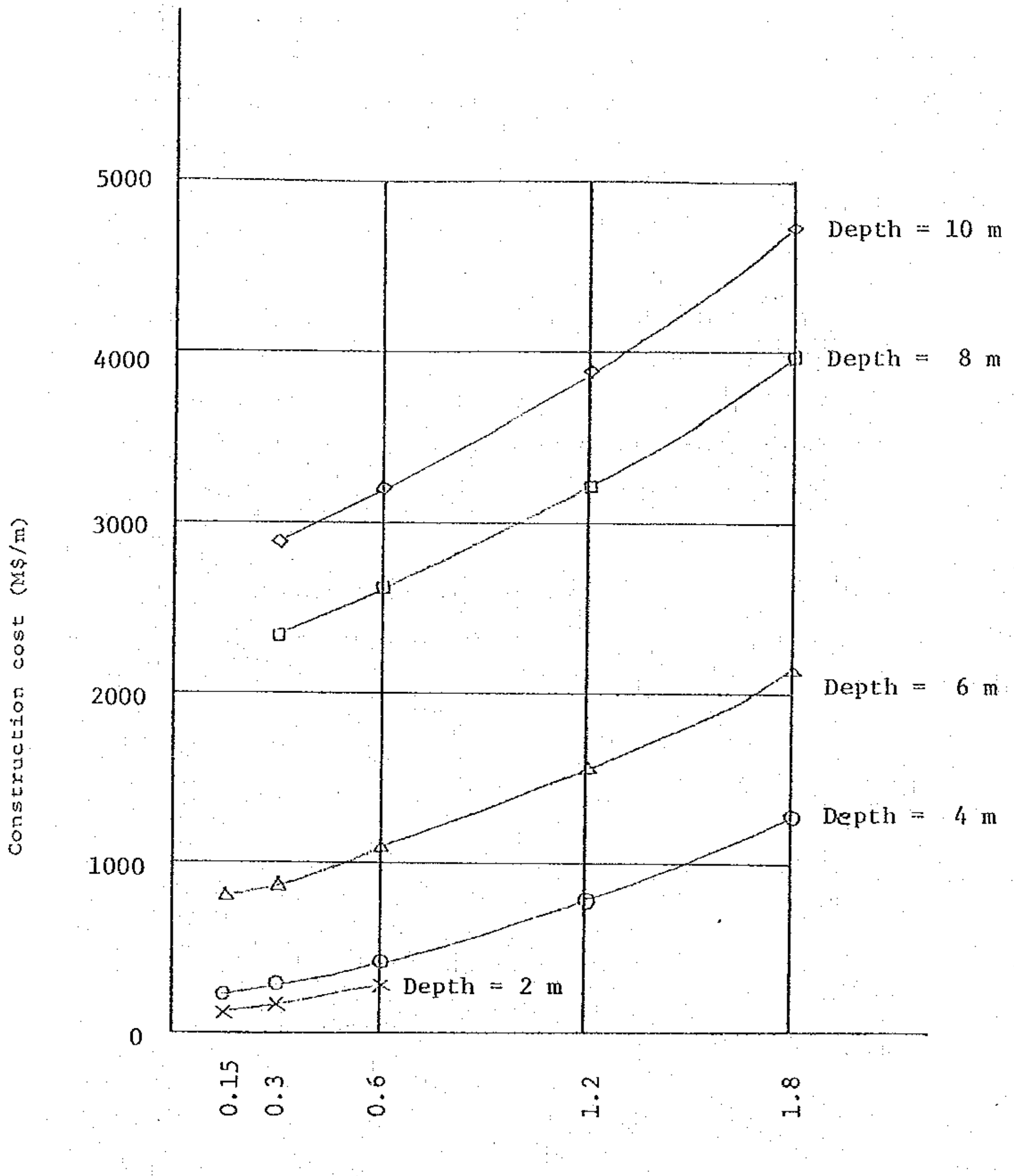
Five different sizes of circular pipes, 15 cm, 30 cm, 60 cm, 120 cm, and 180 cm in diameters, each for different earth covering of 2 m, 4 m, 6 m, 8 m, and 10 m were considered, together with estimation of construction costs.

The average unit costs, as estimated for circular pipes, are summarized in the following table:

TABLE D-11 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

ii) Open Channels



Pipe diameter (m)

FIGURE D-2 Estimated construction cost of Circular pipe, including manhole

2.3 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

CHAPTER . 3

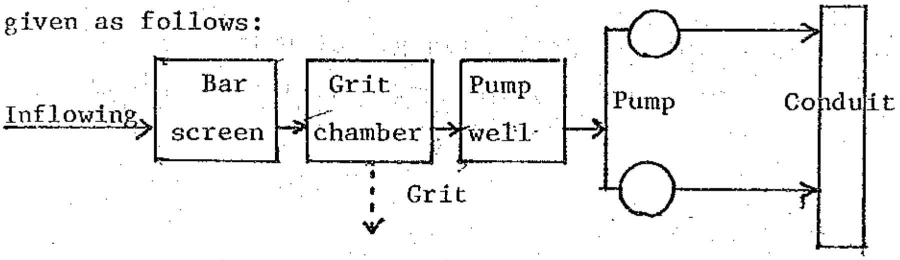
COST FUNCTIONS FOR PUMPING STATIONS

3.1 General

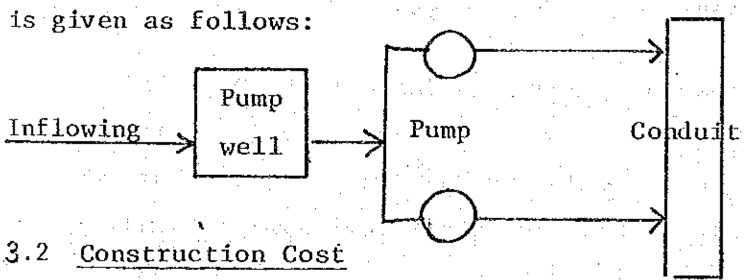
In developing cost functions for pumping stations, cost estimates were made for six stations, different capacities of 0.05 cum/sec, 0.2 cum/sec, 0.5 cum/sec, 0.87 cum/sec. (75,000 cum/day), 1.73 cum/sec (150,000 cum/day), and 8.68 cum/sec (750,000 cum/sec) for depth of inflowing conduit at 10m (assumed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

The pumping stations which have capacity of more than 0.5 cum/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 of less capacity than 0.5 cum/sec, no grit chambers are installed.

A flow chart of the station of more capacity than 0.5 cum/sec is given as follows:



A flow chart of the station of less capacity than 0.5 cum/sec. is given as follows:



3.2 Construction Cost

Construction costs including 20 percent of over head are estimated for each of the 6 cases for their civil works, piping, buildings, equipment, electrical and controling devices, and other appurtenances, and are summarized in the following table.

TABLE D-12 Construction Costs of Pumping Stations of 10m Depth by Capacity

Unit : 1000 M$

Capacity (cum/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	

3.3 Cost Function

As illustrated in Figures D-3&4,the cost function of a pumping station may be expressed in the linear foam as :

$$C_p = a\ Q + b$$

where c, b : Constants

C_p : Construction cost, 1000 M$

Q : Peak flow rate, cum/sec.

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

$$C_p = 608.1\ Q + 166 \qquad (Q \leqq 0.5 \text{ cum/sec})$$

$$C_p = 2{,}092.0\ Q + 2{,}885 \qquad (Q > 0.5 \text{ cum/sec})$$

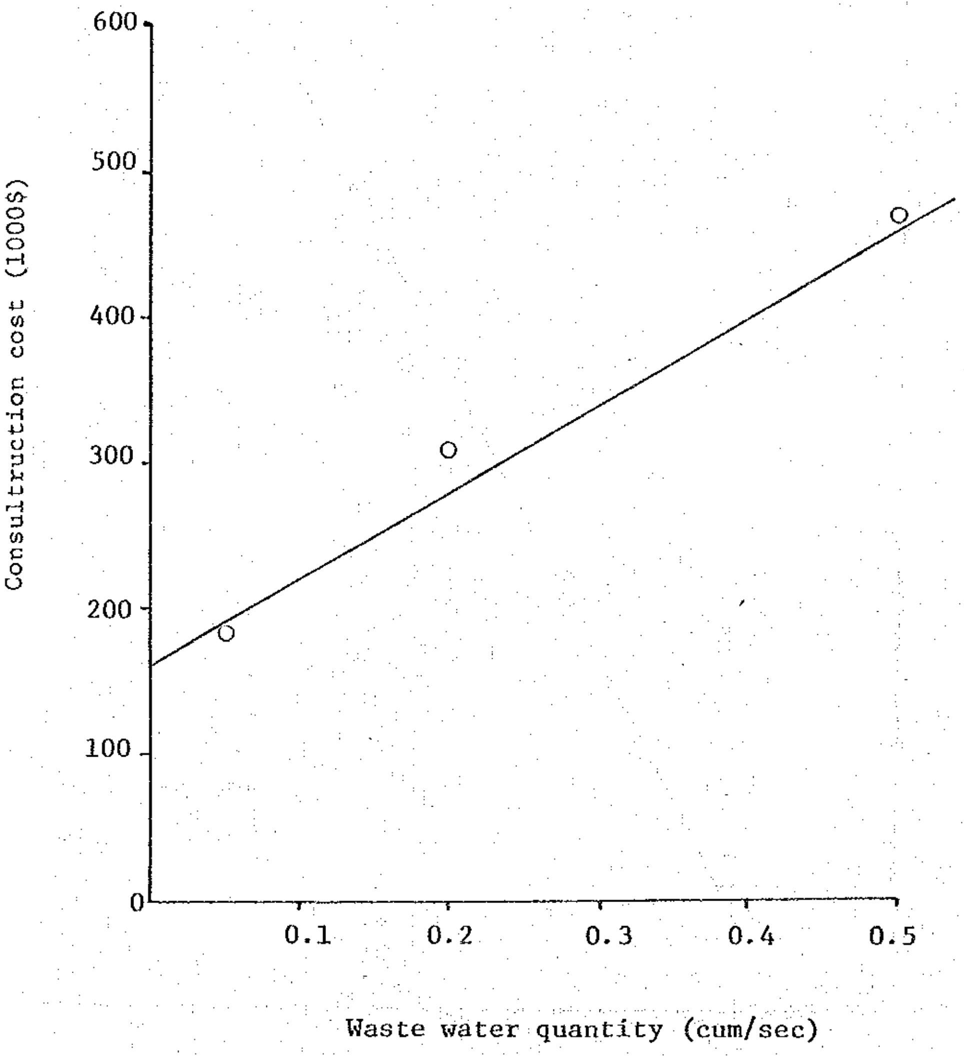


FIGURE D-3 Construction cost for pumping station of 10 m depth by capacity (less than 0.5 cum/sec)

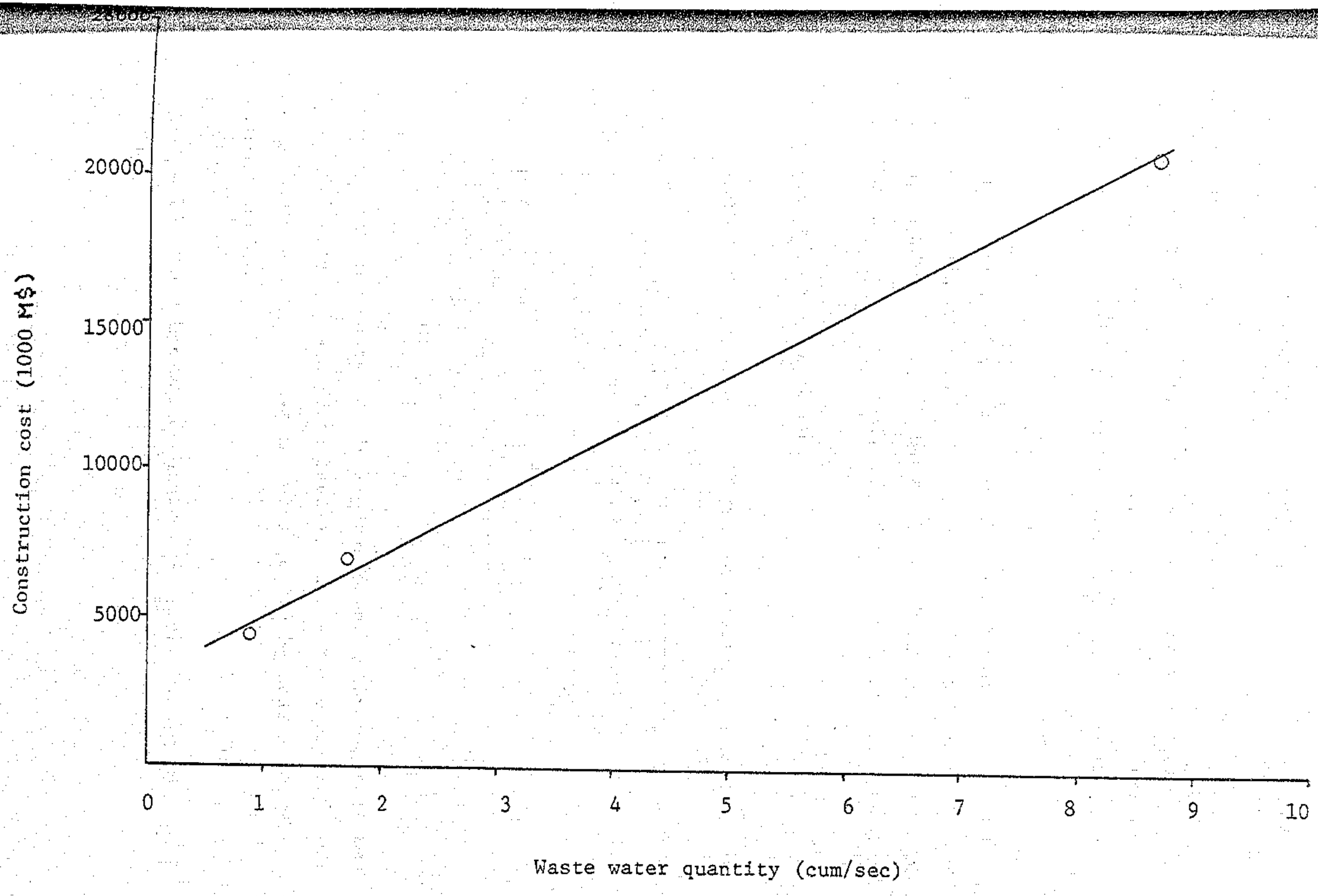


FIGURE D-4 Construction cost for pumping station of 10 m depth by capacity (more than 0.5 cum/sec)

CHAPTER 4

COST ESTIMATING PROCEDURE FOR TREATMENT FACILITIES

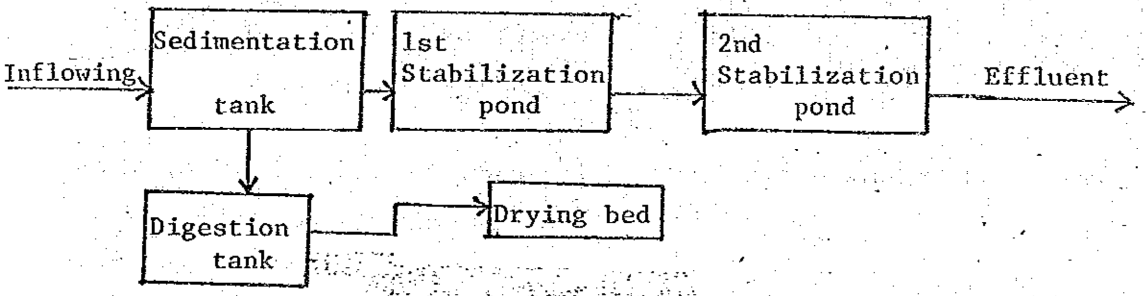
4.1 General

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 so that various alternative 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 cum/day, 10,000 cum/day, 50,000 cum/day, 100,000 cum/day, and 200,000 cum/day, were evaluated, then cost functions were developed.

4.2 Stabilization Pond Process

A flow chart 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 D-13 shows estimated construction costs including 20 percent of over head.

TABLE D-13 Construction Cost for Stabilization Pond Process by Capacity

Unit: 1000 M$

pacity	5000cum/day	10,000cum/day	50,000cum/day	100,000cum/day	200,000cum/day
works uilding	1,278	2,209	9,665	18,227	35,860
inery ricity	260	377	422	818	1,610
l	1,538	2,586	10,087	19,045	37,470

As illustrated in Figure D-5, the cost function of a stabilization pond process may be expressed as linear form in the logarithmic diagram.

$$C_s = a\ Q^b$$

where a, b : constants

C_s : Construction cost, 1000 M$

Q : Daily average flow, cum/day

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

$$C_s = 0.939\ Q^{0.863}$$

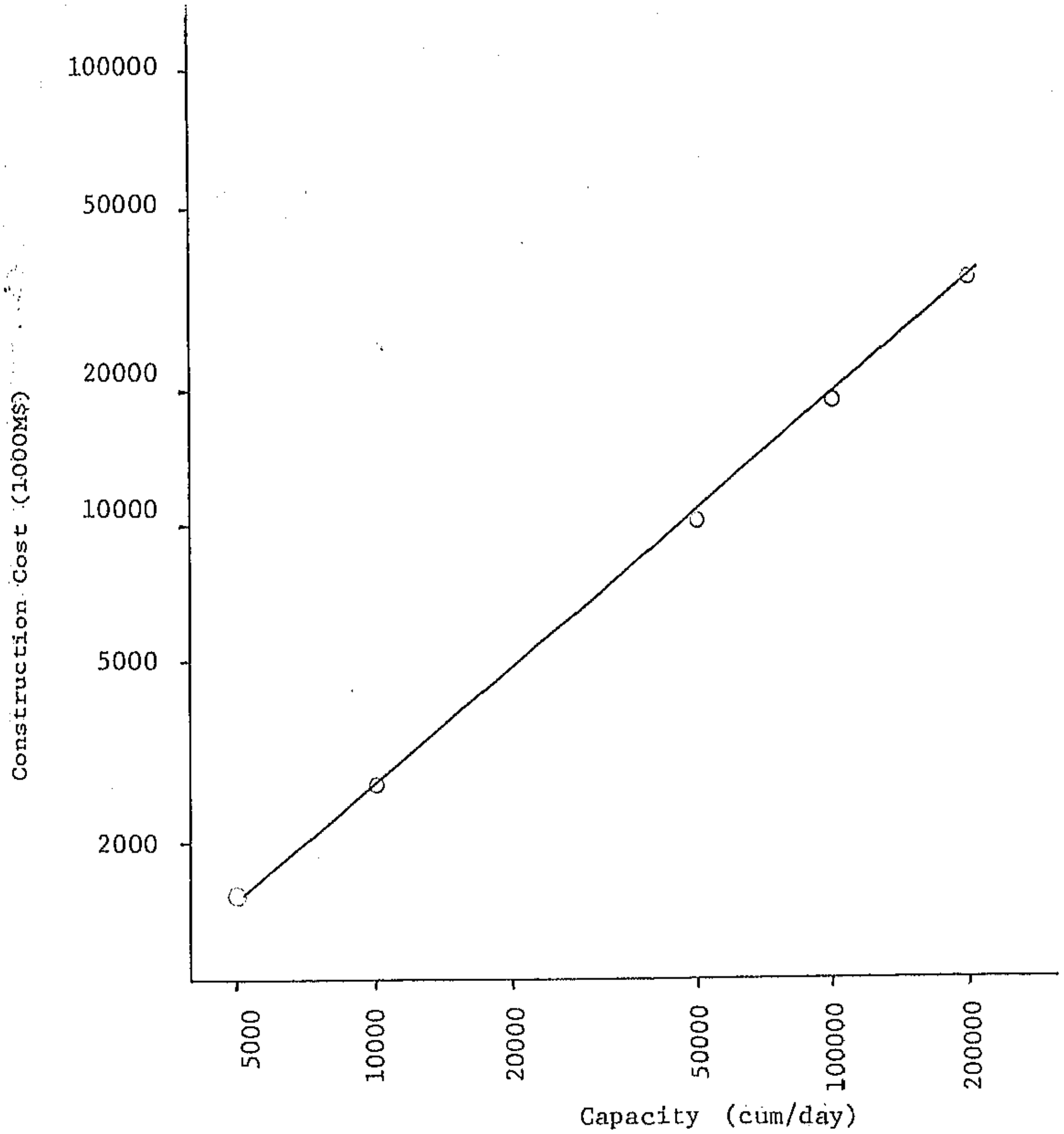
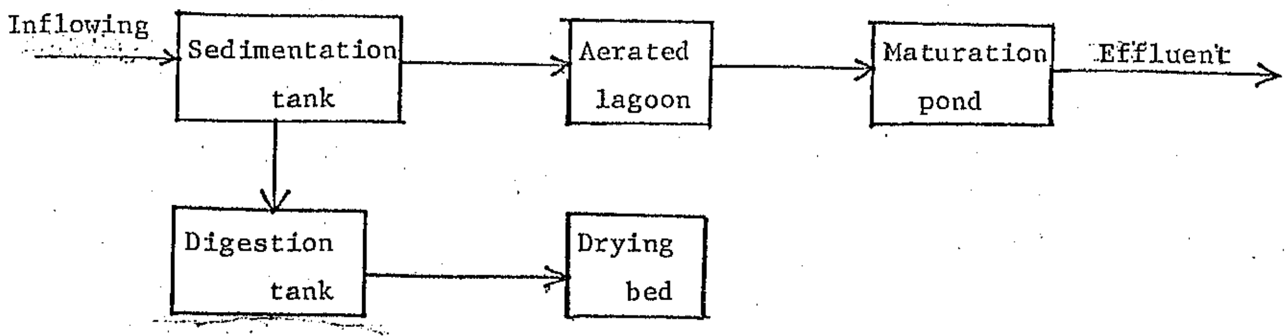


FIGURE D-5 Construction cost for stabilization pond process by capacity

4..3 Aerated Lagoon Process

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



Construction costs including 20 percent of over head is tabulated in Table D-14.

TABLE D-14 Construction Cost for Aerated Lagoon Process by Capacity

Unit: 1000 M$

apacity	5,000cum/day	10,000cum/day	50,000cum/day	100,000cum/day	200,000cum/da
ll works ilding	4,052	6,701	23,856	43,361	81,347
inery ricity	319	494	1,010	1,994	3,964
l	4,371	7,195	24,866	45,355	85,311

The cost function may be expressed as:

$$C_A = 4,583\ Q^{0.801}$$

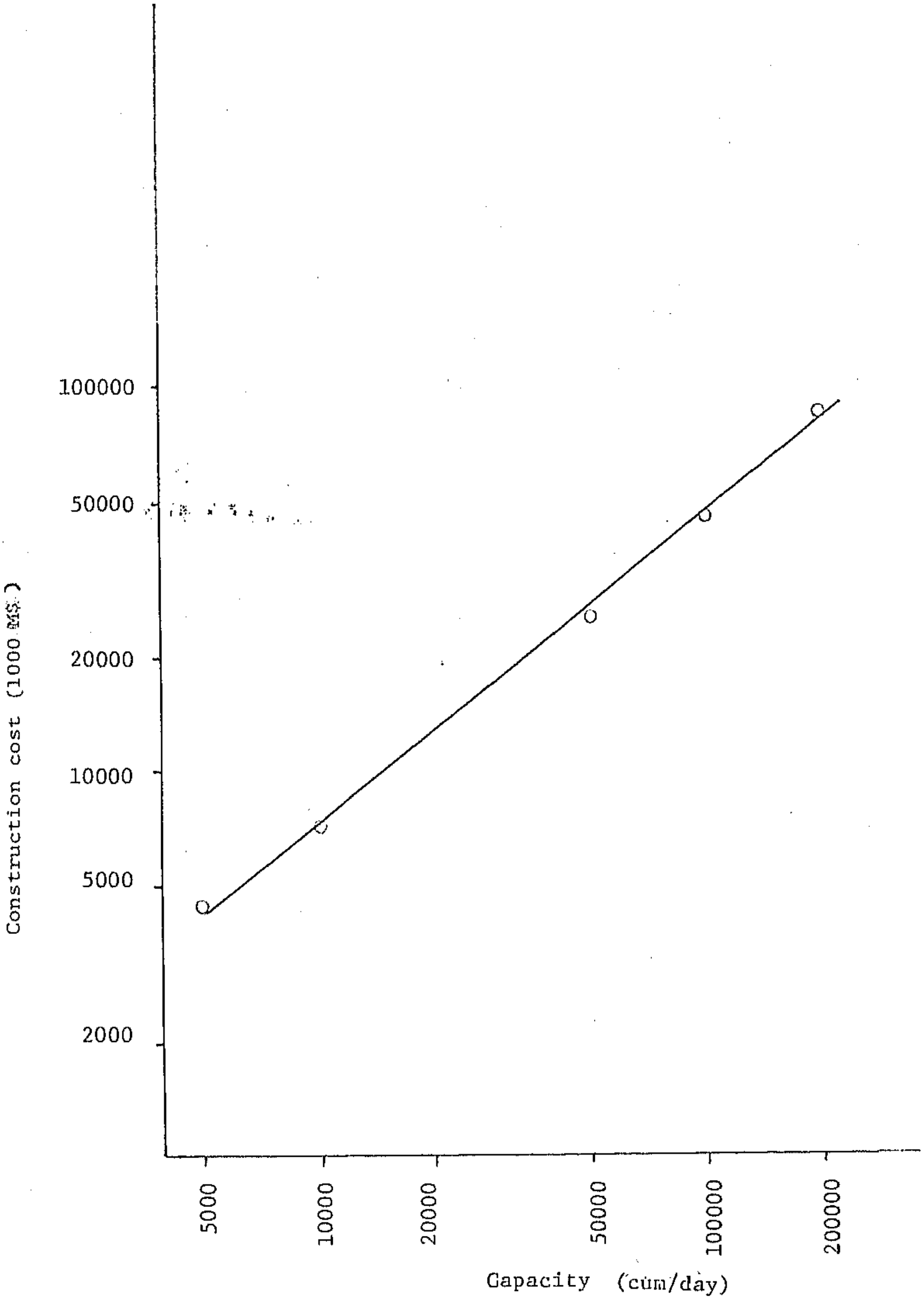
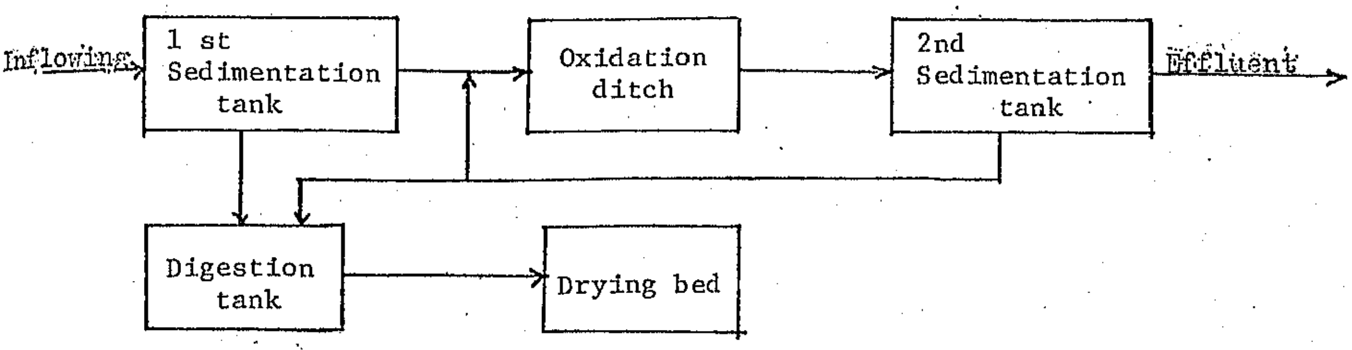


FIGURE D-6 Construction cost for aerated lagoon process by capacity

4.4 Oxidation Ditch Process

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



Construction costs including 20 percent of over head is tabulated in Table D-15.

TABLE D-15 Construction Cost for Oxidation Ditch Process by Capacity

Unit: 1000 M$

Item \ Capacity	5,000 cum/day	10,000 cum/day	50,000 cum/day	100,000 cum/day	200,000 cum/day
Civil works & Building	1,966	3,385	14,489	28,540	56,318
Machinery & Electricity	2,916	5,549	25,739	51,329	102,499
Total	4,882	8,934	40,228	79,869	158,817

The cost function may be expresse as:

$$Co = 1,522\ Q^{0.944}$$

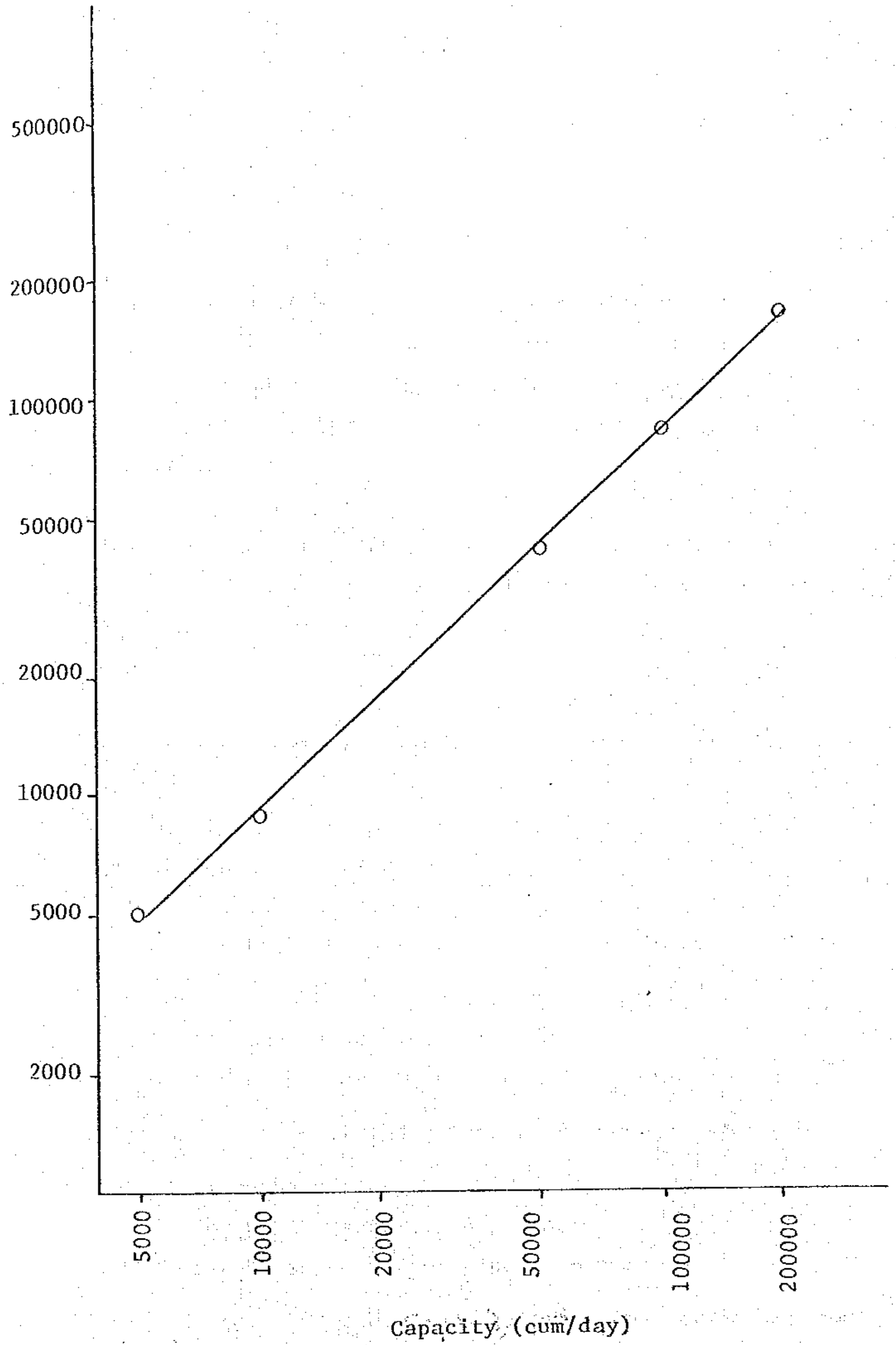


FIGURE D-7 Construction cost [illegible] for oxidation ditch process by capacity.

CHAPTER 5

OPERATION AND MAINTENANCE COSTS

5.1 General

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

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

5.2 Sewers

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

(i) Frequency of cleaning
  for public sewers: once in every 4 years
  for house connexion pipes: once in every 10 years

(ii) Ability to clean by one team
  for public sewers: 150 m/day
  for house connexion pipes: 2.5 hours/connexion

(iii) Useful life of the cleaning equipment: 10 years

(iv) Team members
  for public sewers: 6 persons
  for house connexion pipes: 6 persons

(v) Others: 50 percent of equipment cost including costs for parts, repairing, overhauling, etc.

(vi) Annual rehabilitation cost of sewer: 0.5% of construction cost

(vii) Working days and hours
Working days: 300 days/year
Working hours: 6 hours/day

(viii) Worker cost: 8.00 M$/day

(ix) Price of machine
Power driven bucket machine: 121,000 M$/set
Flexible rod type equipment & high pressure cleaning machine: 77,000 M$/set

Based on the data and assumption above, it was estimated that 1.70 M$ will be necessary for maintenance, one metre of public sewers per year, and 0.70 M$ for house connexion.

5.3 Pumping Stations

According to the capacity, different system is considered for pumping station, that is, no grit chamber is installed for station of smaller capacity than 0.5 cum/sec. Therefore, two cost functions, for more capacity than 0.5 cum/sec and for less capacity than 0.5 cum/sec, are developed.

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

(a) For station of more capacity than 0.5 cum/sec, daily average number of operator or labour is 1 (one) person per station,

(b) For station of less capacity than 0.5 cum/sec, daily average number of operator or labour is 0.1 person per station, and

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

The operation and maintenance costs by capacity was then estimated as shown in Table E-16 and Figure E-7.

TABLE D-16: Operation and Maintenance Costs for Pumping Stations by Capacity

Unit: 1,000 M$/year

Capacity Item	0.05 cum/sec	0.2	0.5	0.87	1.73
Salary	0.5	0.5	0.5	5.5	5.5
Electricity,etc.	5.3	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 E-7, cost functions for operation and maintenance of pumping station were obtained as follows:

$$C_{MP} = 84.1\ Q_P + 9.9 \quad (Q_P \leqq 0.5 \text{ cum/sec})$$

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

where

Q_P : Peak flow, cum/sec

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

5.4 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 or labour is 2 (two) persons per plant, and

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

The operation and maintenance costs by capacity by treatment process was then estimated as shown in Table D-17 and Figure D-8, D-9, and D-10.

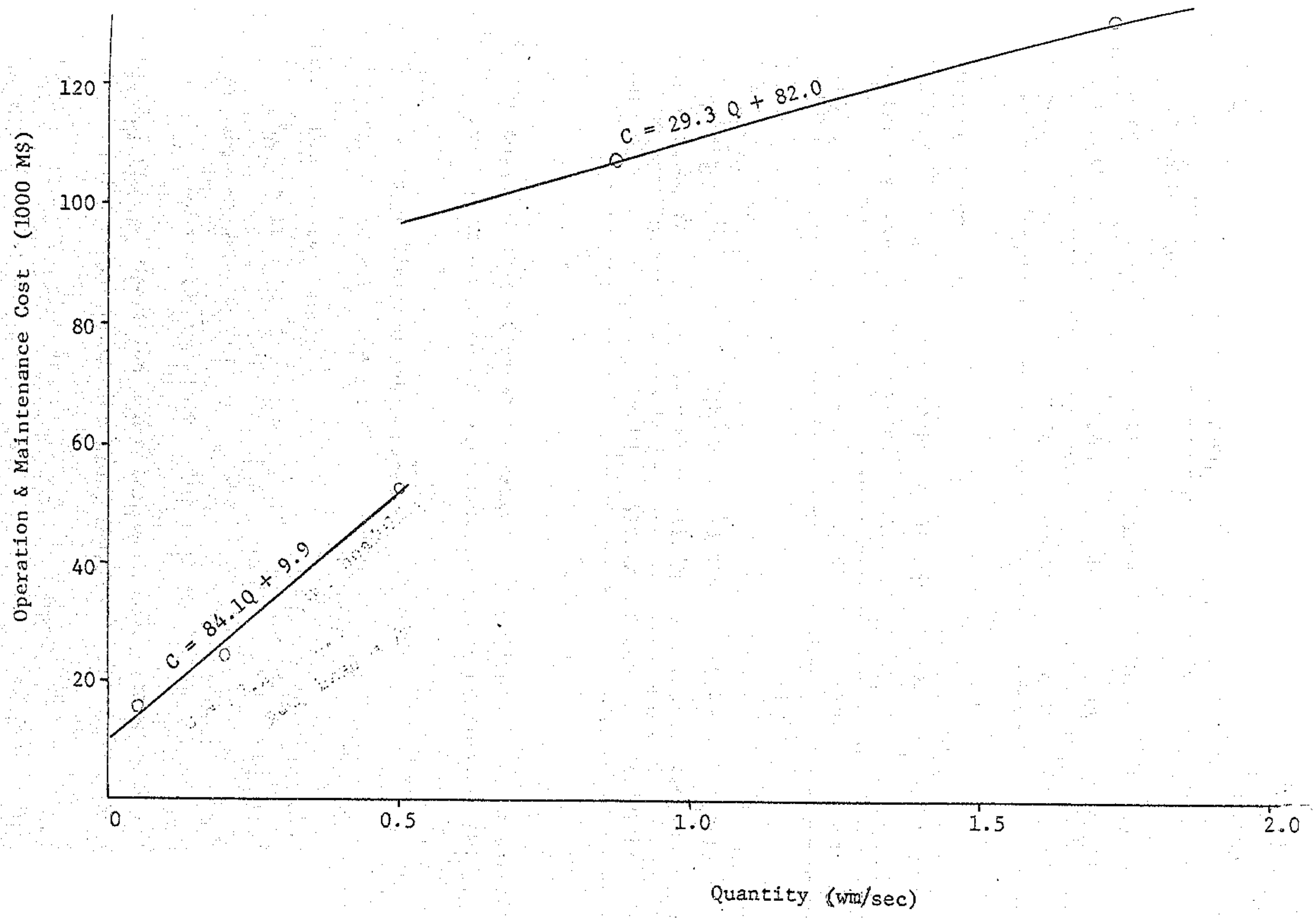


FIGURE D-8 Operation & Maintenance Cost of Pumping Station

TABLE D-17 Operation and Maintenance Costs for Treatment Plants by Capacity by Treatment Process

unit: 1000M$/year

Item \ Capacity	5,000 cum/day	1,000	50,000	100,000	200,000
(a) Stabilization Pond					
Salary	10.95	10.95	10.95	10.95	10.95
Electricity, etc.	3.45	4.09	5.89	9.61	16.99
Total	14.40	15.04	16.84	20.56	27.94
(b) Aerated Lagoon					
Salary	10.95	10.95	10.95	10.95	10.95
Electricity, etc.	28.67	54.55	258,17	514,18	1,026.14
Total	39.62	65.50	269.12	525.13	1,037.09
(c) Oxidation Ditch					
Salary	10.95	10.95	10.95	10.95	10.95
Electricity, etc.	207.17	411.52	2,031.61	4,061.01	8,119.81
Total	218.12	422.47	2,042.56	4,071.96	8,130.76

On the basis of these figures in Table and Figure , cost functions for operation and maintenance of treatment plant were obtained as followes:

(i) For stabilization pond process

$C_{MS} = 6.89 \times 10^{-5} Q + 13.9$

(ii) For aerated lagoon

$C_{MA} = 5.11 \times 10^{-3} Q + 13.9$

(iii) For oxidation ditch

$C_{MO} = 4.05 \times 10^{-2} Q + 15.2$

where C_{MS}, C_{MA}, C_{MO} : Operation and maintenance cost, 1000M$/year

Q : Daily average flow, cum/day

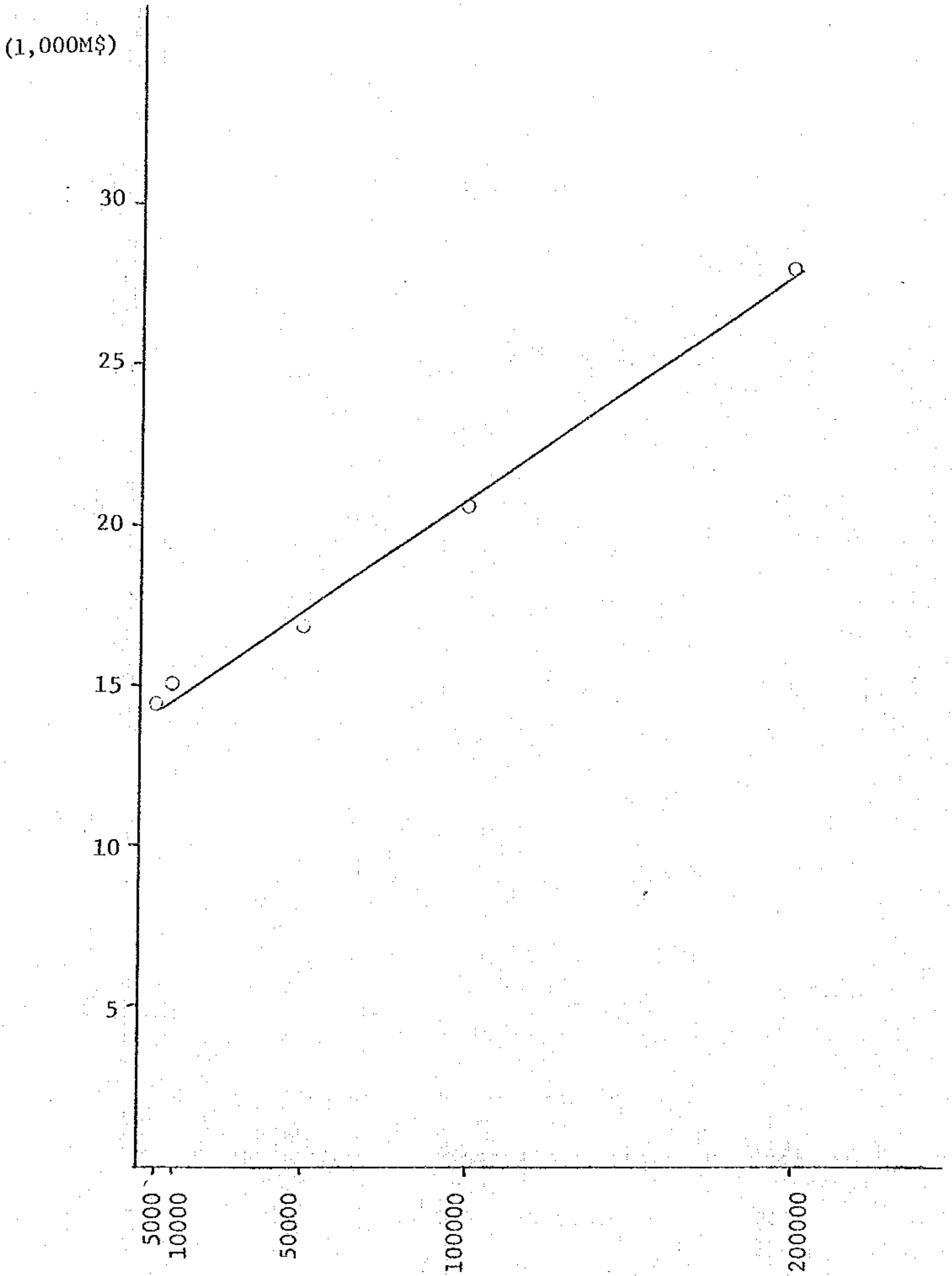


FIGURE D-9 Operation & Maintenance Cost for Stabilization pond process

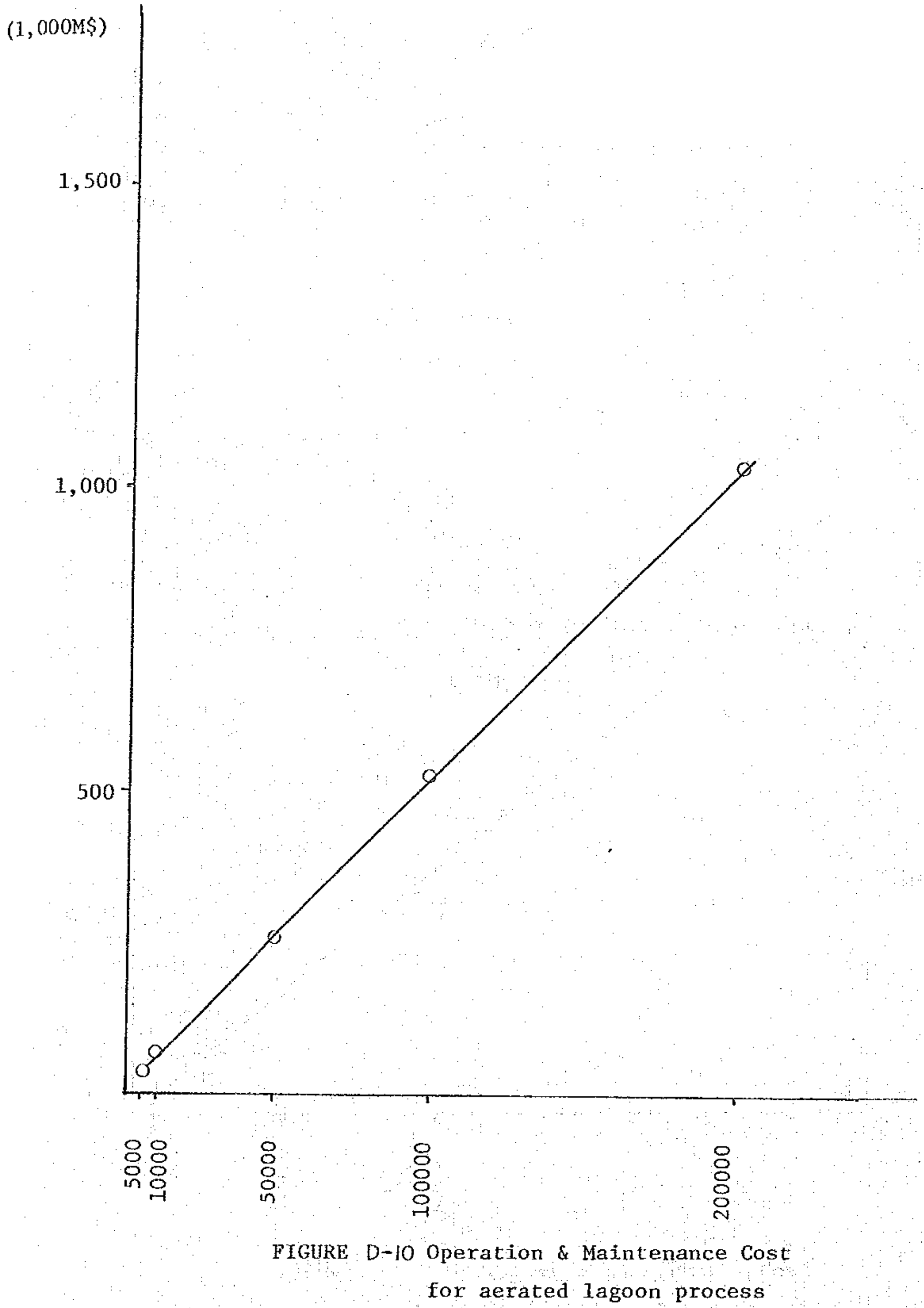


FIGURE D-10 Operation & Maintenance Cost for aerated lagoon process

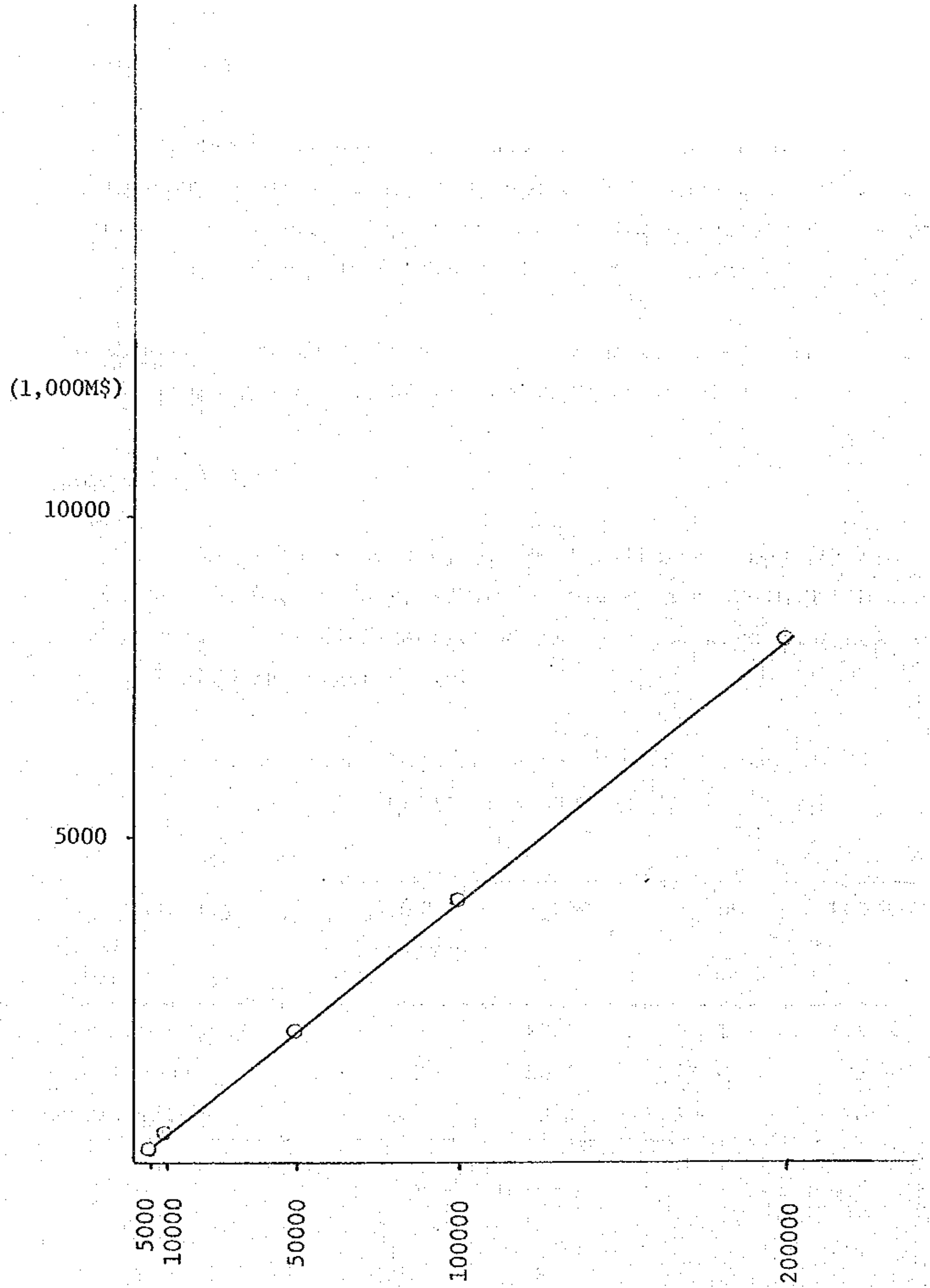


FIGURE D-11 Operation & Maintenance Cost for oxidation ditch process