

C Pond      1.0 m x 1.0 m ,      ø 0.5 m

#### **8.4.5 Bridges**

Almost all the bridges crossing the Sg. Pinang and Sg. Keluang systems are to be reconstructed due to river improvement works by widening and deepening of river channel.

In the Sg. Pinang system, thirty five (35) bridges including 19 wooden bridges are to be reconstructed.

In the Sg. Keluang system, two (2) wooden bridges are to be reconstructed to R.C.T Girder bridges.

New one bridge is also to be constructed across the Relau Diversion Channel.

All the bridges to be reconstructed for urgent projects are summarized in Table 8-3.

# Tables



TABLE 8-1 FEATURES OF PROPOSED RIVER IMPROVEMENT

RIVER IMPROVEMENT

Sg. Pinang System

		CHAINAGE	DISTANCE (m)	RIVER BED SLOPE	RIVER BED WIDTH (m)	WIDTH (m)	WATER DEPTH (m)	DESIGN DISCHARGE (m <sup>3</sup> /s)
Sg. Pinang	P1	0.71 to 0.4	1,110	1/2000	36.50	44.460 ~ 44.304	3.380 ~ 3.302	210
	P2	0.4 to 1.9	1,500	1/2000	36.50	44.304 ~ 40.295	3.302 ~ 3.195	210
	P3	1.9 to 3.1	1,250	1/950	23.00	40.295 ~ 30.400	3.195 ~ 3.100	195
Sg. Air Iiam	I1	0.0 to 1.1	1,100	1/800	18.20	25.4	3.0	160
	I2	1.1 to 3.0	1,900	1/800	16.40	23.6	3.0	145
Sg. Jelutong	J1	0.0 to 1.306	1,330	1/1070	4.70	4.7	2.5	20
	J2	1.306 to 2.015	820	1/1070	2.00	2.0	2.5	6
Sg. Dondang	D1	0.014 to 2.302	2,100	1/680	8.30	14.5	2.5	60
	D2	2.302 to 3.732	1,210	1/680	6.00	12.5	2.5	45
	D3	3.732 to 4.854	1,010	1/190	2.30	8.5	2.5	40

Sg. Keluang System

		CHAINAGE	DISTANCE (m)	RIVER BED SLOPE	RIVER BED WIDTH (m)	WIDTH (m)	WATER DEPTH (m)	DESIGN DISCHARGE (m <sup>3</sup> /s)
Sg. Keluang	K1	0.2 to 1.540	1,740	1/1190	13.90	54.3	3	125
Sg. Ara	A1	1.540 to 2.200	660	1/1190	12.20	50.6	3	110
	A2	2.200 to 2.950	750	1/1190	3.80	26.2	2.5	40
	A3	2.950 to 3.410	460	1/450	2.80	22.4	1.8	40
Sg. Relau	R2	2.410 to 4.045	1,640	1/360	9.70	14.9	2.6	6

DIVERSION CHANNEL

AIR TERJUN DIVERSION CHANNEL

1	DIVERTING POINT	CH3093 of Sg. Air Terjun
2	CATCHMENT AREA OF DIVERTING POINT	7.74 km <sup>2</sup>
3	DIVERSION LENGTH	1740 m
4	CONFLUENCE POINT	CH160 of Sg. Babi
5	DISCHARGE CAPACITY	65 m <sup>3</sup> /S

CROSS SECTION

- C1 : Open Channel 7.4 m (W) x 2.6 m (D) S=1/250
- C2 : Box Culvert 6.3 m (W) x 2.76 m (H) S=1/200
- C3 : Box Culvert 5.5 m (W) x 3.22 m (H) S=1/200

RELAU DIVERSION CHANNEL

1	DIVERTING POINT	CH2410 of Sg. Relau
2	CATCHMENT AREA OF DIVERTING POINT	10.5 km <sup>2</sup>
3	DIVERSION LENGTH	1530 m
4	CONFLUENCE POINT	CH2200 of Sg. Ara
5	DESIGN DISCHARGE	70 m <sup>3</sup> /S

CROSS SECTION

- C1 : Open Channel 10.9 m (W) x 2.6 m (D) S=1/400

Table 8-2 CHARACTERISTICS OF DONDANG RETENTION PONDS

	Area (m <sup>2</sup> )	Ground Level (El. m)	Design High Water Level (El. m)	Design Pond Bed Level (El. m)	Water Depth (m)	Pond Depth (m)	Storage Volume (m <sup>3</sup> )	Inflow (m <sup>3</sup> /s)	Cut Q (m <sup>3</sup> /s)	Outflow (m <sup>3</sup> /s)
Pond A	30,500	21.50	20.28	17.26	3.02	4.24	79,013	40,627	9,500	31,127
Pond B	32,700	15.60	14.00	11.42	2.58	4.18	72,839	37,639	6,000	31,639
Pond C	21,200	13.50	11.47	8.73	2.74	4.77	46,410	43,399	4,500	38,899
Total	84,400						198,262		20,000	

TABLE 8-3-1 BRIDGES TO BE RECONSTRUCTED FOR URGENT PROJECT

NO.	CHR (m)	EXISTING			AREA (sq.m)	TYPE	PIER NO.	LENGTH (m)	WIDTH (m)	PROPOSED AREA (sq.m)	TYPE	PIER NO.	REMARKS
		LENGTH (m)	WIDTH (m)	WIDTH (m)									
1	405	33.0	10.0	330	STEEL TRUSS	0	47.0	10.0	470	R.C. T-GIDER	2	Jalan Jelutong	
2	915	20.0	1.5 x 0.9	120	R.C. GIRDER	0	43.0	6.0	258	R.C. T-GIDER	1	Jalan Sundai	
3	1,265	25.0	10.0	250	R.C. T-GIDER	0	43.0	10.0	430	R.C. T-GIDER	1	Jalan Patani	
4	2,122	18.0	15.0	270	R.C. T-GIDER	0	33.0	15.0	495	R.C. T-GIDER	1	Jalan Perak	
5	2,470	23.0	3.0	69	WOOD	0	33.0	3.0	99	R.C. T-GIDER	1		
6	2,928	12.0	3.0	36	WOOD	0	33.0	3.0	99	R.C. T-GIDER	1		
7	3,128	18.0	16.0	288	R.C. T-GIDER	0	33.0	16.0	528	R.C. T-GIDER	1	Jalan Ayer Itam	

Sq. Pinang

NO.	CHR (m)	EXISTING			AREA (sq.m)	TYPE	PIER NO.	LENGTH (m)	WIDTH (m)	PROPOSED AREA (sq.m)	TYPE	PIER NO.	REMARKS
		LENGTH (m)	WIDTH (m)	WIDTH (m)									
1	1,062	13.0	33.0	429	T-GIDER	0	28.0	33.0	924	R.C. T-GIDER	1	Jalan Scotland	
2	1,493	18.0	25.0	450	R.C. GIRDER	0	16.0	25.0	400	R.C. T-GIDER	0	Jalan Air Itam	
3	1,940	21.8	8.0	174.4	T-GIDER	2	16.0	8.0	128	R.C. T-GIDER	0	Lorong Batu Lintang	

Sq. Air Itam

NO.	CHR (m)	EXISTING			AREA (sq.m)	TYPE	PIER NO.	LENGTH (m)	WIDTH (m)	PROPOSED AREA (sq.m)	TYPE	PIER NO.	REMARKS
		LENGTH (m)	WIDTH (m)	WIDTH (m)									
1	510	9.0	4.0	36	T-GIDER	0	16.0	4.0	64	R.C. T-GIDER	0	Taman Thean	
2	523	9.0	5.0	45	T-GIDER	0	16.0	5.0	60	R.C. T-GIDER	0	Taman Thean	
3	800	7.0	11.0	77	T-GIDER	0	16.0	11.0	176	R.C. T-GIDER	0	Jalan Thean Teik Dua	
4	1,403	6.0	3.0	18	WOOD	0	16.0	3.0	48	R.C. T-GIDER	0		
5	1,649	9.0	3.0	27	WOOD	0	11.0	3.0	33	R.C. SLAB	0		
6	1,883	7.0	5.0	35	T-GIDER	0	11.0	5.0	55	R.C. SLAB	0	Jalan Thean TEIK	
7	2,591	7.5	3.0	22.5	WOOD	0	11.0	3.0	33	R.C. SLAB	0		
8	2,865	9.0	3.0	27	WOOD	0	11.0	3.0	33	R.C. SLAB	0		

Sq. Dorstang

TABLE 8-3-2 BRIDGES TO BE RECONSTRUCTED FOR URGENT PROJECT

Sg. JELUTONG

NO.	CHR. (m)	EXISTING			PROPOSED			REMARKS			
		LENGTH (m)	WIDTH (m)	AREA (sq.m)	TYPE	PIER NO.	LENGTH (m)		WIDTH (m)	AREA (sq.m)	TYPE
1	632	5.0	1.5	7.5 IRON	0	7.0	1.5	10.5	R.C. SLAB	0	JALAN ISMAIL CIK MATT
2	1,509	5.0	1.5	7.5 WOOD	0	7.0	1.5	10.5	R.C. SLAB	0	
3	1,554	5.0	1.5	7.5 WOOD	0	7.0	1.5	10.5	R.C. SLAB	0	
4	1,583	5.0	1.5	7.5 IRON	0	7.0	1.5	10.5	R.C. SLAB	0	
5	1,656	6.0	4.0	24 WOOD	0	7.0	4.0	28	R.C. SLAB	0	
6	1,664	3.1	1.0	3.1 WOOD	0	8.0	1.0	8	R.C. SLAB	0	
7	1,684	3.2	1.5	4.8 WOOD	0	5.0	1.5	7.5	R.C. SLAB	0	
8	1,690	3.2	3.0	9.6 WOOD	0	5.0	3.0	15	R.C. SLAB	0	
9	1,708	3.2	2.0	12.0 WOOD	0	5.0	2.0	10	R.C. SLAB	0	
10	1,739	3.3	2.5	8.25 WOOD	0	5.0	2.5	12.5	R.C. SLAB	0	
11	1,745	3.3	2.0	6.6 WOOD	0	5.0	2.0	10	R.C. SLAB	0	
12	1,751	3.0	2.0	6 WOOD	0	5.0	2.0	10	R.C. SLAB	0	
13	1,771	3.0	2.0	6 WOOD	0	5.0	2.0	10	R.C. SLAB	0	
14	1,843	5.0	4.0	20 R.C.T-GIRDER	0	5.0	4.0	20	R.C. SLAB	0	JALAN VAN PRAAGH
15	1,854	4.0	4.0	16 R.C.T-GIRDER	0	7.0	4.0	28	R.C. SLAB	0	JALAN VAN PRAAGH
16	1,935	3.0	1.5	12.0 WOOD	0	6.0	1.5	9	R.C. SLAB	0	
17	2,070	3.4	1.0	3.4 WOOD	0	5.0	1.0	5	R.C. SLAB	0	

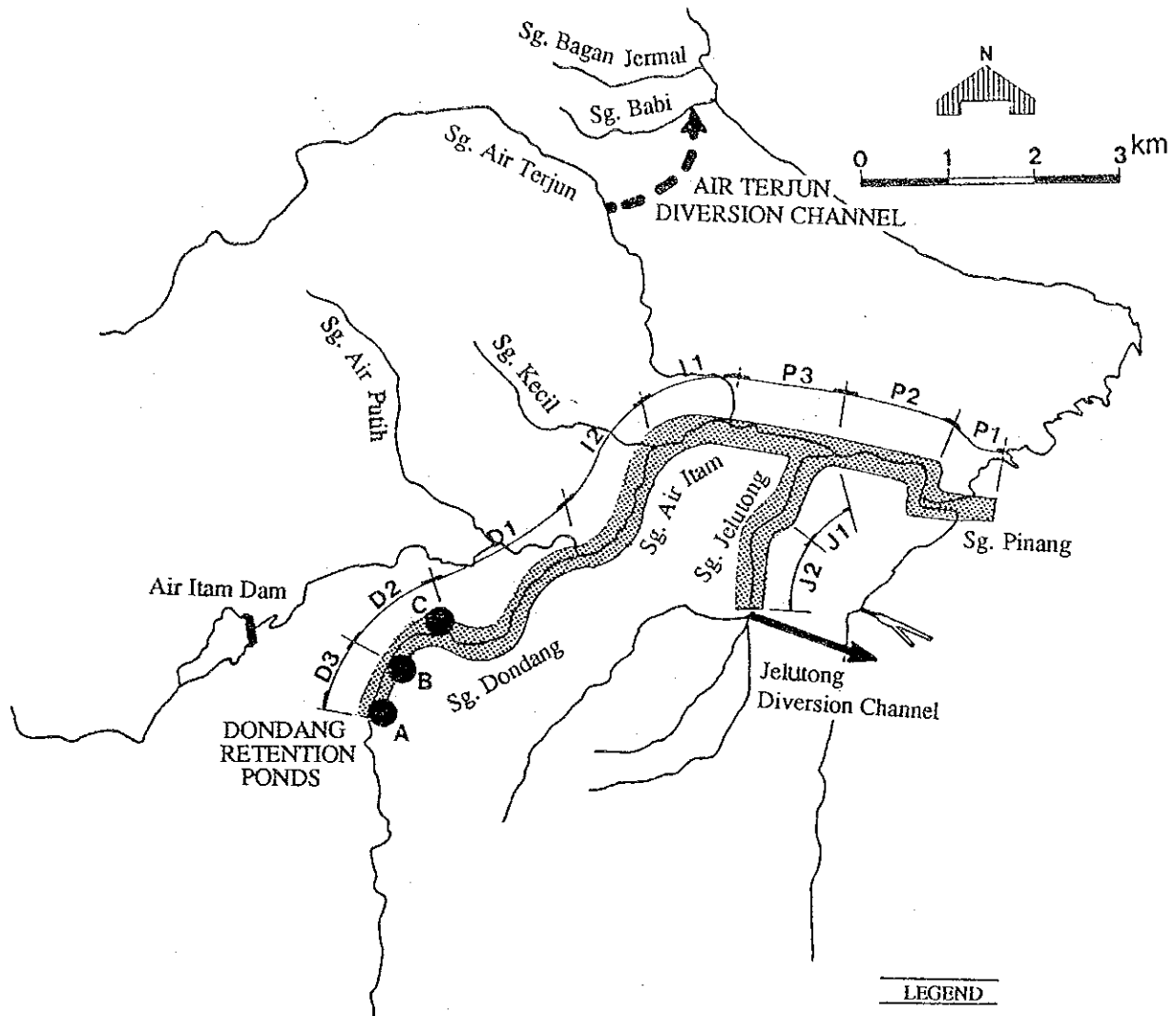
Sg. Keliuang

NO.	CHR. (m)	EXISTING			PROPOSED			REMARKS			
		LENGTH (m)	WIDTH (m)	AREA (sq.m)	TYPE	PIER NO.	LENGTH (m)		WIDTH (m)	AREA (sq.m)	TYPE
1	2,070	22.0	3.0	66 WOOD	0	53.0	3.0	159	R.C. T-GIDER	2	Sg. Ara
2	3,143	16.0	3.0	48 WOOD	0	27.0	3.0	81	R.C. T-GIDER	1	Sg. Ara
3	1,290					17.6	20.0	352	R.C. T-GIDER	1	Relieu Diversion

## Figures







**LEGEND**

- Dam Completed
- Retention Pond
- Diversion Channel Completed
- Diversion Channel
- River Improvement

**RIVER IMPROVEMENT**

PART	CHAINAGE	DISTANCE (m)	RIVER BED SLOPE	RIVER BED WIDTH (m)	WIDTH (m)	WATER DEPTH (m)	DESIGN DISCHARGE (m <sup>3</sup> /s)
P1	0.71 to 0.4	1,110	1/2000	36.50	44.460 - 44.304	3.380 - 3.302	210
P2	0.4 to 1.9	1,500	1/2000	36.50	44.304 - 40.295	3.302 - 3.195	210
P3	1.9 to 3.1	1,250	1/850	23.00	40.295 - 30.400	3.195 - 3.100	195
I1	0.0 to 1.1	1,100	1/800	18.20	25.4	3.0	160
I2	1.1 to 3.0	1,900	1/800	16.40	23.6	3.0	145
J1	0.0 to 1.306	1,330	1/1070	4.70	4.7	2.5	20
J2	1.306 to 2.015	810	1/1070	2.00	2.0	2.5	6
D1	0.014 to 2.302	2,100	1/680	8.30	14.5	2.5	60
D2	2.302 to 3.732	1,210	1/680	8.00	12.5	2.5	45
D3	3.732 to 4.854	1,010	1/190	2.30	8.5	2.5	40

**DONDANG RETENTION PONDS**

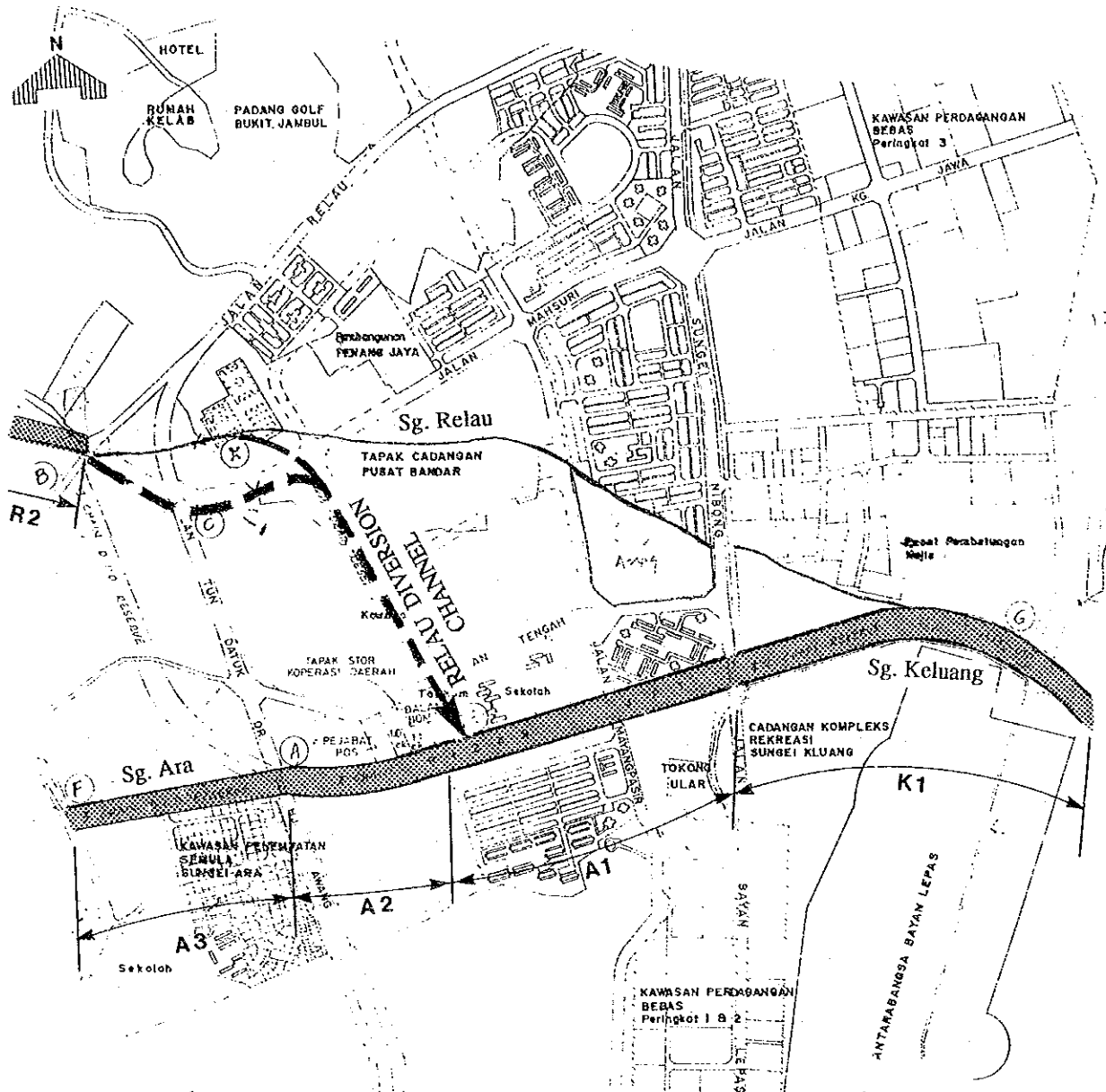
	Area (m <sup>2</sup> )	Pond Depth (m)	Storage Volume (m <sup>3</sup> )	Cut O (m <sup>3</sup> /s)
Pond A	30,500	4.24	79,013	9.500
Pond B	32,700	4.18	72,839	6.000
Pond C	21,200	4.77	46,410	4.500
Total	84,400		198,262	20.000

**AIR TERJUN DIVERSION CHANNEL**

1	DIVERTING POINT	CH3093 of Sq. Air Terjun
2	CATCHMENT AREA OF DIVERTING POINT	7.74 km <sup>2</sup>
3	DIVERSION LENGTH	1740 m
4	CONFLUENCE POINT	CH160 of Sq. Babi
5	DISCHARGE CAPACITY	65 m <sup>3</sup> /S

Fig. 8-1

**FLOOD MITIGATION FACILITIES OF SG. PINANG SYSTEM FOR URGENT PROJECT**



RIVER IMPROVEMENT

PART	CHAINAGE	DISTANCE (m)	RIVER BED SLOPE	RIVER BED WIDTH (m)	WIDTH (m)	WATER DEPTH (m)	DESIGN DISCHARGE (m <sup>3</sup> /s)
K1	-0.2 to 1.540	1,740	1/1190	13.90	54.3	3	125
A1	1.540 to 2.200	660	1/1190	12.20	50.6	3	110
A2	2.200 to 2.950	750	1/1190	3.80	26.2	2.5	40
A3	2.950 to 3.410	460	1/450	2.80	22.4	1.8	40
R2	2.410 to 4.045	1,640	1/350	9.70	14.9	2.6	6

RELAU DIVERSION CHANNEL

1	DIVERTING POINT	CH2410 of Sg. Relau
2	CATCHMENT AREA OF DIVERTING POINT	10.5 km <sup>2</sup>
3	DIVERSION LENGTH	1530 m
4	CONFLUENCE POINT	CH2200 of Sg. Ara
5	DESIGN DISCHARGE	70 m <sup>3</sup> /S

LEGEND

- ←--- Diversion Canal
- ▨ River Improvement

Fig. 8-2

FLOOD MITIGATION FACILITIES OF SG. KELUANG SYSTEM FOR URGENT PROJECT

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

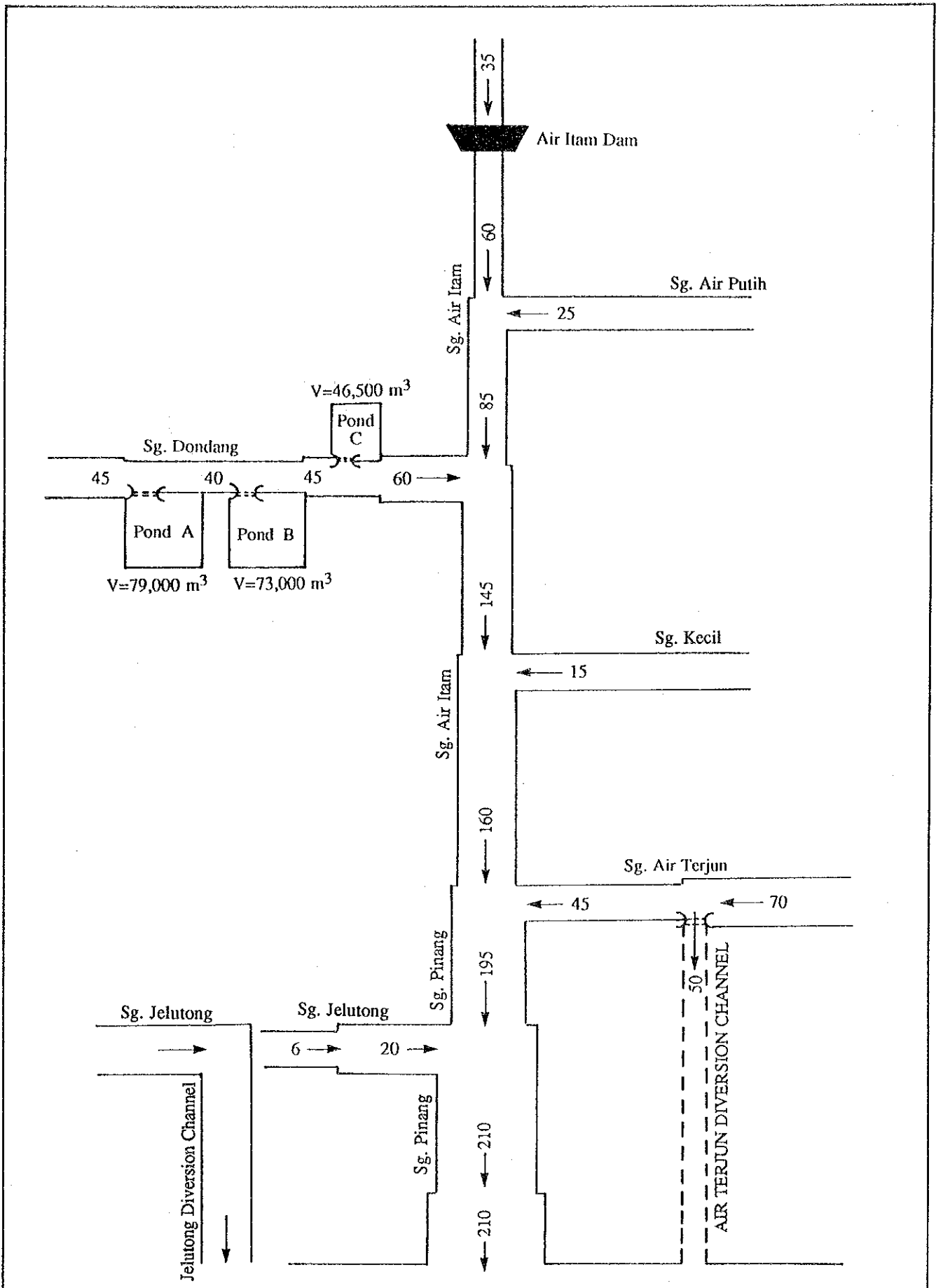


FIG. 8-3

DESIGN FLOOD DISCHARGE DISTRIBUTION OF SG. PINANG SYSTEM

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

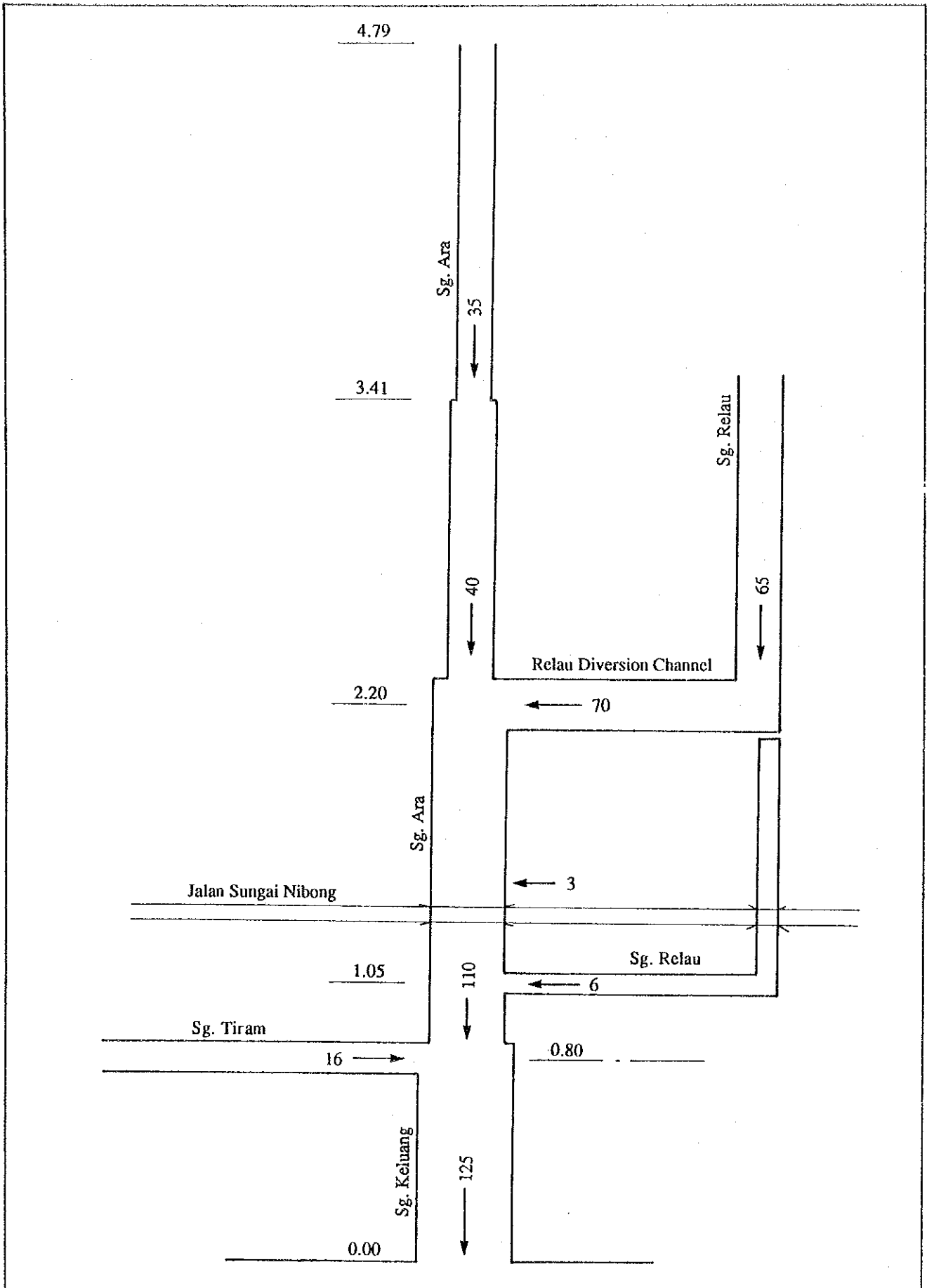
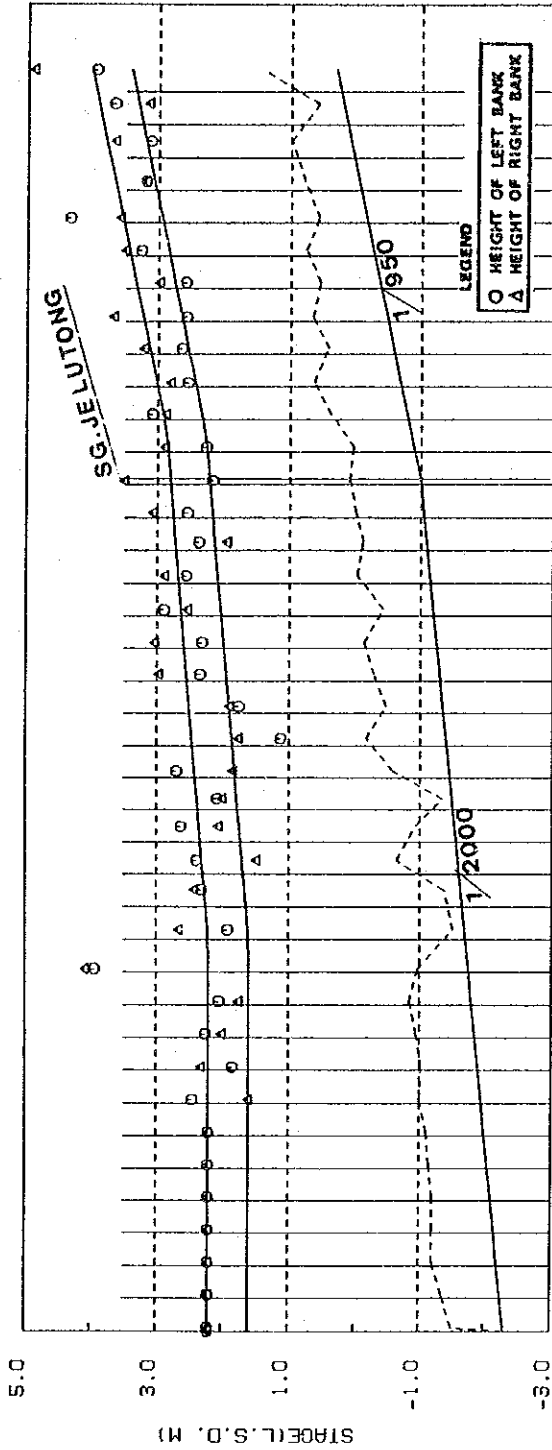
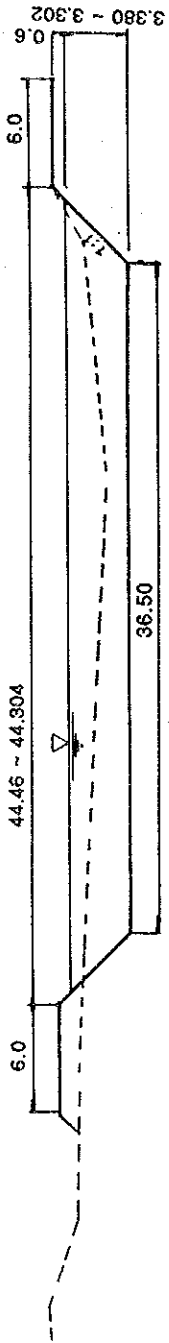


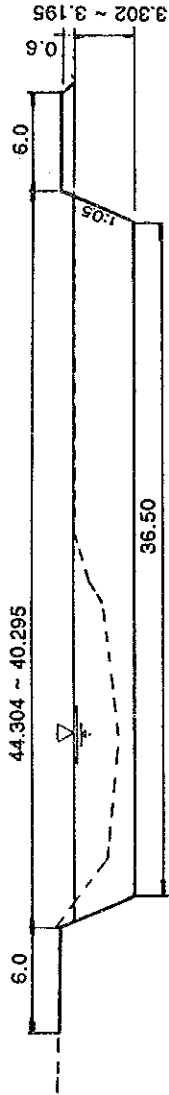
FIG. 8-4 DESIGN DISCHARGE DISTRIBUTION OF SG. KELUANG SYSTEM



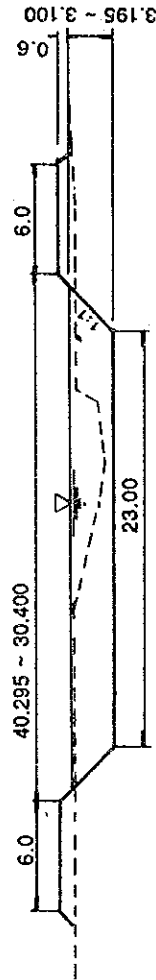
PROPOSED BED LEVEL	DESIGN H.W.L.	PROPOSED BANK LEVEL	DISTANCE	CHAINAGE
-2.30	1.600	2.200	-700.0	10.0
-2.285	1.600	2.200	-600.000	100.000
-2.245	1.600	2.200	-500.000	100.000
-2.195	1.600	2.200	-400.000	100.000
-2.145	1.600	2.200	-300.000	100.000
-2.095	1.600	2.200	-200.000	100.000
-2.045	1.600	2.200	-100.000	100.000
-1.995	1.600	2.200	0.000	100.000
-1.945	1.600	2.200	100.000	100.000
-1.895	1.600	2.200	200.000	100.000
-1.845	1.600	2.200	300.000	100.000
-1.795	1.600	2.200	400.000	100.000
-1.745	1.600	2.200	500.000	119.000
-1.686	1.607	2.207	600.000	122.000
-1.625	1.659	2.259	700.000	92.000
-1.579	1.699	2.299	800.000	105.000
-1.526	1.744	2.344	900.000	87.000
-1.483	1.782	2.382	1000.000	86.000
-1.440	1.819	2.419	1100.000	101.000
-1.389	1.862	2.462	1200.000	99.000
-1.340	1.904	2.504	1300.000	99.000
-1.290	1.947	2.547	1400.000	98.000
-1.241	1.989	2.589	1500.000	100.000
-1.191	2.032	2.632	1600.000	105.000
-1.139	2.078	2.678	1700.000	102.000
-1.088	2.121	2.721	1800.000	89.000
-1.043	2.159	2.759	1900.000	98.000
-0.994	2.201	2.801	2000.000	102.000
-0.945	2.245	2.845	2100.000	102.000
-0.897	2.291	2.891	2200.000	98.000
-0.848	2.321	2.921	2300.000	102.000
-0.799	2.353	2.953	2400.000	97.000
-0.750	2.393	2.993	2500.000	105.000
-0.701	2.447	3.044	2600.000	98.000
-0.653	2.491	3.084	2700.000	99.000
-0.604	2.541	3.131	2800.000	113.000
-0.555	2.591	3.179	2900.000	121.000
-0.506	2.644	3.233	3000.000	114.000
-0.457	2.700	3.293	3100.000	102.000
0.325	2.759	3.358		
0.318	2.818	3.418		
0.098	2.878	3.478		
-0.030	2.938	3.538		
-0.149	3.000	3.600		
-0.263	3.063	3.663		
-0.356	3.128	3.728		
-0.457	3.195	3.795		
-0.559	3.264	3.864		
-0.676	3.336	3.936		
-0.779	3.411	4.011		
-0.887	3.489	4.089		
-0.994	3.570	4.170		
-1.043	3.654	4.254		
-1.088	3.741	4.341		
-1.139	3.831	4.431		
-1.191	3.924	4.524		
-1.241	4.019	4.619		
-1.290	4.117	4.717		
-1.340	4.218	4.818		
-1.389	4.321	4.921		
-1.440	4.427	5.027		
-1.483	4.536	5.136		
-1.526	4.647	5.247		
-1.579	4.760	5.360		
-1.625	4.875	5.475		
-1.686	4.993	5.593		
-1.745	5.114	5.714		
-1.807	5.238	5.838		
-1.868	5.365	5.965		
-1.929	5.495	6.095		
-2.000	5.629	6.229		
-2.078	5.767	6.367		
-2.159	5.909	6.509		
-2.245	6.055	6.655		
-2.285	6.205	6.805		
-2.298	6.359	6.959		
-2.298	6.517	7.117		
-2.298	6.679	7.279		
-2.298	6.845	7.445		
-2.298	7.015	7.615		
-2.298	7.189	7.789		
-2.298	7.367	7.967		
-2.298	7.549	8.149		
-2.298	7.735	8.335		
-2.298	7.925	8.525		
-2.298	8.119	8.719		
-2.298	8.317	8.917		
-2.298	8.519	9.119		
-2.298	8.725	9.325		
-2.298	8.935	9.535		
-2.298	9.149	9.749		
-2.298	9.367	9.967		
-2.298	9.589	10.189		
-2.298	9.815	10.415		
-2.298	10.045	10.645		
-2.298	10.279	10.879		
-2.298	10.517	11.117		
-2.298	10.759	11.359		
-2.298	11.005	11.605		
-2.298	11.255	11.855		
-2.298	11.509	12.109		
-2.298	11.767	12.367		
-2.298	12.029	12.629		
-2.298	12.295	12.895		
-2.298	12.565	13.165		
-2.298	12.839	13.439		
-2.298	13.117	13.717		
-2.298	13.400	14.000		
-2.298	13.687	14.287		
-2.298	13.979	14.579		
-2.298	14.275	14.875		
-2.298	14.575	15.175		
-2.298	14.879	15.479		
-2.298	15.187	15.787		
-2.298	15.499	16.099		
-2.298	15.815	16.415		
-2.298	16.135	16.735		
-2.298	16.459	17.059		
-2.298	16.787	17.387		
-2.298	17.119	17.719		
-2.298	17.455	18.055		
-2.298	17.795	18.395		
-2.298	18.139	18.739		
-2.298	18.487	19.087		
-2.298	18.839	19.439		
-2.298	19.195	19.795		
-2.298	19.555	20.155		
-2.298	19.919	20.519		
-2.298	20.287	20.887		
-2.298	20.659	21.259		
-2.298	21.035	21.635		
-2.298	21.415	22.015		
-2.298	21.799	22.399		
-2.298	22.187	22.787		
-2.298	22.579	23.179		
-2.298	22.975	23.575		
-2.298	23.375	23.975		
-2.298	23.779	24.379		
-2.298	24.187	24.787		
-2.298	24.599	25.199		
-2.298	25.015	25.615		
-2.298	25.435	26.035		
-2.298	25.859	26.459		
-2.298	26.287	26.887		
-2.298	26.719	27.319		
-2.298	27.155	27.755		
-2.298	27.595	28.195		
-2.298	28.039	28.639		
-2.298	28.487	29.087		
-2.298	28.939	29.539		
-2.298	29.395	29.995		
-2.298	29.855	30.455		
-2.298	30.319	30.919		
-2.298	30.787	31.387		
-2.298	31.259	31.859		
-2.298	31.735	32.335		
-2.298	32.215	32.815		
-2.298	32.699	33.299		
-2.298	33.187	33.787		
-2.298	33.679	34.279		
-2.298	34.175	34.775		
-2.298	34.675	35.275		
-2.298	35.179	35.779		
-2.298	35.687	36.287		
-2.298	36.199	36.799		
-2.298	36.715	37.315		
-2.298	37.235	37.835		
-2.298	37.759	38.359		
-2.298	38.287	38.887		
-2.298	38.819	39.419		
-2.298	39.355	39.955		
-2.298	39.895	40.495		
-2.298	40.439	41.039		
-2.298	40.987	41.587		
-2.298	41.539	42.139		
-2.298	42.095	42.695		
-2.298	42.655	43.255		
-2.298	43.219	43.819		
-2.298	43.787	44.387		
-2.298	44.359	44.959		
-2.298	44.935	45.535		
-2.298	45.515	46.115		
-2.298	46.099	46.699		
-2.298	46.687	47.287		
-2.298	47.279	47.879		
-2.298	47.875	48.475		
-2.298	48.475	49.075		
-2.298	49.079	49.679		
-2.298	49.687	50.287		
-2.298	50.299	50.899		
-2.298	50.915	51.515		
-2.298	51.535	52.135		
-2.298	52.159	52.759		
-2.298	52.787	53.387		
-2.298	53.419	54.019		
-2.298	54.055	54.655		
-2.298	54.695	55.295		
-2.298	55.339	55.939		
-2.298	55.987	56.587		
-2.298	56.639	57.239		
-2.298	57.295	57.895		
-2.298	57.955	58.555		
-2.298	58.619	59.219		
-2.298	59.287	59.887		
-2.298	59.959	60.559		
-2.298	60.635	61.235		
-2.298	61.315	61.915		
-2.298	61.999	62.599		
-2.298	62.687	63.287		
-2.298	63.379	63.979		
-2.298	64.075	64.675		
-2.298	64.775	65.375		
-2.298	65.479	66.079		
-2.298	66.187	66.787		
-2.298	66.899	67.499		
-2.298	67.615	68.215		
-2.298	68.335	68.935		
-2.298	69.059	69.659		
-2.298	69.787	70.387		
-2.298	70.519	71.119		
-2.298	71.255	71.855		
-2.298	71.995	72.595		
-2.298	72.739	73.339		
-2.298	73.487	74.087		
-2.298	74.239	74.839		
-2.298	74.995	75.595		
-2.298	75.755	76.355		
-2.298	76.519	77.119		
-2.298	77.287	77.887		
-2.298	78.059	78.659		
-2.298	78.835	79.435		
-2.298	79.615	80.215		
-2.298	80.399	80.999		
-2.298	81.187	81.787		
-2.298	81.979	82.579		
-2.298	82.775	83.375		
-2.298	83.575	84.175		
-2.298	84.379	84.979		
-2.298	85.187	85.787		
-2.298	85.999	86.599		
-2.298	86.815	87.415		
-2.298	87.635	88.235		
-2.298	88.459	89.059		
-2.298	89.287	89.887		
-2.298	90.119	90.719		
-2.298	90.955	91.555		
-2.298	91.795	92.395		
-2.298	92.639	93.239		
-2.298	93.487	94.087		
-2.298	94.339	94.939		
-2.298	95.195	95.795		
-2.298	96.055	96.655		
-2.298	96.919	97.519		
-2.298	97.787	98.387		
-2.298	98.659	99.259		
-2.298	99.535	100.135		
-2.298	100.415	101.015		
-2.298	101.299	101.899		
-2.298	102.187	102.787		
-2.298	103.			



CH-710 ~ CH 400



CH 400 ~ CH 1900



CH 1900 ~ CH 3100

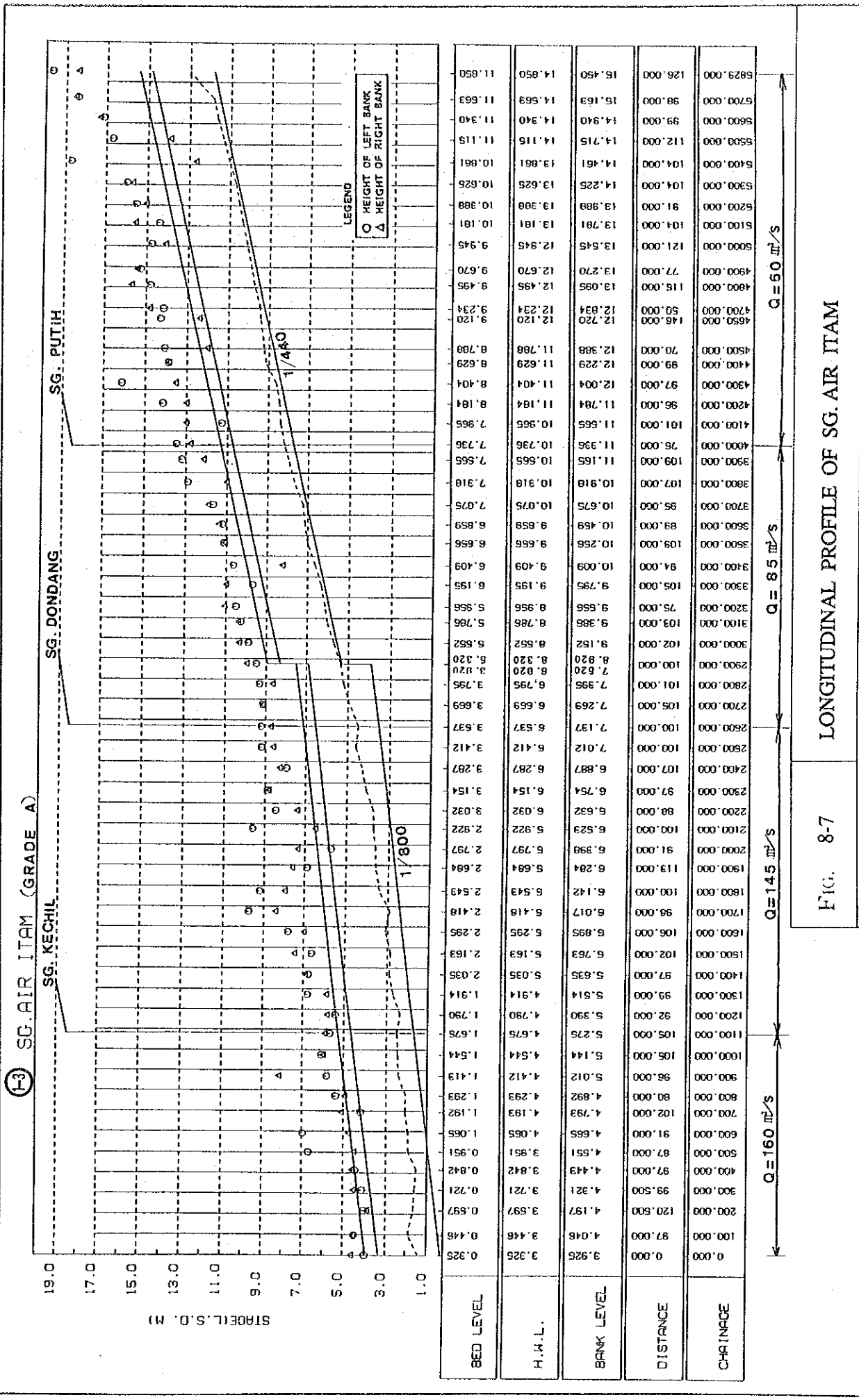
FIG. 8-6 PROPOSED CROSS SECTIONS OF SG. PINANG

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND



LONGITUDINAL PROFILE OF SG. AIR ITAM

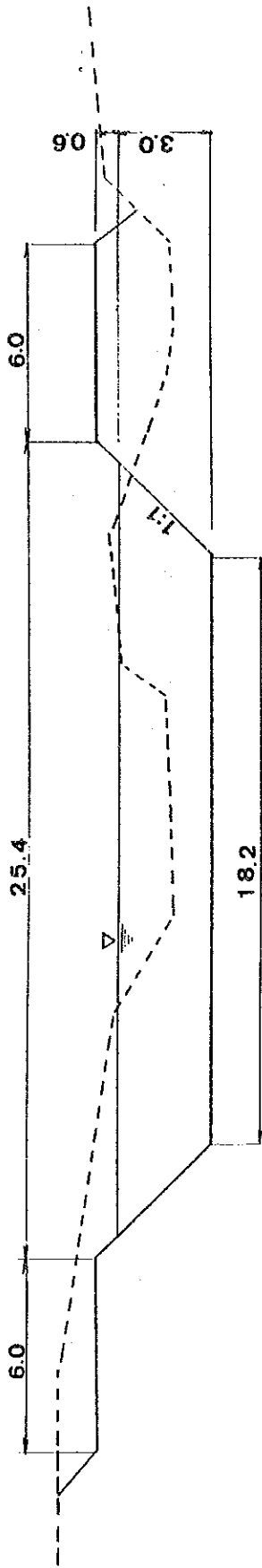
FIG. 8-7 THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND



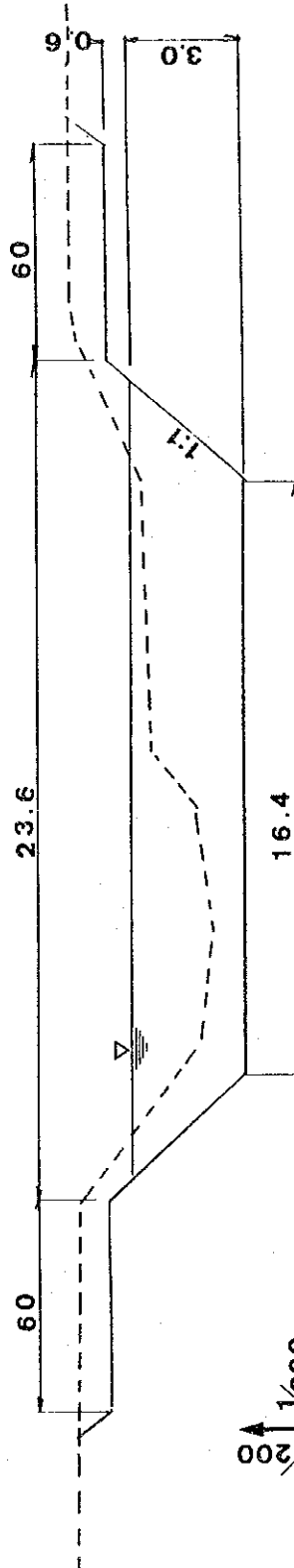
BED LEVEL	H.H.L.	BANK LEVEL	DISTANCE	CHANNEL
0.325	3.325	3.925	0.000	0.000
0.446	3.446	4.046	100.000	97.000
0.597	3.597	4.197	200.000	120.500
0.721	3.721	4.321	300.000	99.500
0.842	3.842	4.443	400.000	97.000
0.951	3.951	4.551	500.000	87.000
1.065	4.065	4.665	600.000	91.000
1.192	4.193	4.793	700.000	102.000
1.293	4.293	4.892	800.000	80.000
1.419	4.412	5.012	900.000	96.000
1.544	4.544	5.144	1000.000	105.000
1.675	4.675	5.275	1100.000	105.000
1.790	4.790	5.390	1200.000	92.000
1.914	4.914	5.514	1300.000	99.000
2.035	5.035	5.635	1400.000	97.000
2.163	5.163	5.763	1500.000	102.000
2.295	5.295	5.895	1600.000	106.000
2.418	5.418	6.017	1700.000	98.000
2.543	5.543	6.142	1800.000	100.000
2.684	5.684	6.284	1900.000	113.000
2.797	5.797	6.398	2000.000	91.000
2.922	5.922	6.523	2100.000	100.000
3.032	6.032	6.632	2200.000	98.000
3.154	6.154	6.754	2300.000	97.000
3.287	6.287	6.887	2400.000	107.000
3.412	6.412	7.012	2500.000	100.000
3.537	6.537	7.137	2600.000	100.000
3.659	6.659	7.269	2700.000	105.000
3.795	6.795	7.395	2800.000	101.000
3.920	6.920	7.520	2900.000	100.000
4.020	7.020	7.620	3000.000	102.000
4.152	7.152	7.752	3100.000	103.000
4.286	7.286	7.886	3200.000	75.000
4.419	7.419	8.019	3300.000	105.000
4.556	7.556	8.156	3400.000	94.000
4.699	7.699	8.299	3500.000	109.000
4.859	7.859	8.459	3600.000	89.000
5.029	8.029	8.629	3700.000	95.000
5.200	8.200	8.800	3800.000	107.000
5.385	8.385	8.985	3900.000	109.000
5.576	8.576	9.176	4000.000	75.000
5.772	8.772	9.372	4100.000	101.000
5.974	8.974	9.574	4200.000	96.000
6.184	9.184	9.784	4300.000	97.000
6.404	9.404	10.004	4400.000	99.000
6.629	9.629	10.229	4500.000	70.000
6.859	9.859	10.459	4600.000	146.000
7.095	10.095	10.695	4700.000	50.000
7.336	10.336	10.936	4800.000	115.000
7.585	10.585	11.185	4900.000	77.000
7.845	10.845	11.445	5000.000	121.000
8.111	11.111	11.711	5100.000	104.000
8.388	11.388	11.988	5200.000	91.000
8.676	11.676	12.276	5300.000	104.000
8.975	11.975	12.575	5400.000	104.000
9.284	12.284	12.884	5500.000	112.000
9.600	12.600	13.200	5600.000	99.000
9.925	12.925	13.525	5700.000	98.000
10.260	13.260	13.860	5800.000	126.000
10.605	13.605	14.205	5900.000	126.000
10.960	13.960	14.560	6000.000	126.000
11.325	14.325	14.925	6100.000	126.000
11.700	14.700	15.300	6200.000	126.000
12.085	15.085	15.685	6300.000	126.000
12.480	15.480	16.080	6400.000	126.000
12.885	15.885	16.485	6500.000	126.000
13.300	16.300	16.900	6600.000	126.000
13.725	16.725	17.325	6700.000	126.000
14.160	17.160	17.760	6800.000	126.000
14.605	17.605	18.205	6900.000	126.000
15.060	18.060	18.660	7000.000	126.000
15.525	18.525	19.125	7100.000	126.000
16.000	19.000	19.600	7200.000	126.000
16.485	19.485	20.085	7300.000	126.000
16.980	19.980	20.580	7400.000	126.000
17.485	20.485	21.085	7500.000	126.000
18.000	21.000	21.600	7600.000	126.000
18.525	21.525	22.125	7700.000	126.000
19.060	22.060	22.660	7800.000	126.000
19.605	22.605	23.205	7900.000	126.000
20.160	23.160	23.760	8000.000	126.000
20.725	23.725	24.325	8100.000	126.000
21.300	24.300	24.900	8200.000	126.000
21.885	24.885	25.485	8300.000	126.000
22.480	25.480	26.080	8400.000	126.000
23.085	26.085	26.685	8500.000	126.000
23.700	26.700	27.300	8600.000	126.000
24.325	27.325	27.925	8700.000	126.000
24.960	27.960	28.560	8800.000	126.000
25.605	28.605	29.205	8900.000	126.000
26.260	29.260	29.860	9000.000	126.000
26.925	29.925	30.525	9100.000	126.000
27.600	30.600	31.200	9200.000	126.000
28.285	31.285	31.885	9300.000	126.000
28.980	31.980	32.580	9400.000	126.000
29.685	32.685	33.285	9500.000	126.000
30.400	33.400	34.000	9600.000	126.000
31.125	34.125	34.725	9700.000	126.000
31.860	34.860	35.460	9800.000	126.000
32.605	35.605	36.205	9900.000	126.000
33.360	36.360	36.960	10000.000	126.000
34.125	37.125	37.725	10100.000	126.000
34.900	37.900	38.500	10200.000	126.000
35.685	38.685	39.285	10300.000	126.000
36.480	39.480	40.080	10400.000	126.000
37.285	40.285	40.885	10500.000	126.000
38.100	41.100	41.700	10600.000	126.000
38.925	41.925	42.525	10700.000	126.000
39.760	42.760	43.360	10800.000	126.000
40.605	43.605	44.205	10900.000	126.000
41.460	44.460	45.060	11000.000	126.000
42.325	45.325	45.925	11100.000	126.000
43.200	46.200	46.800	11200.000	126.000
44.085	47.085	47.685	11300.000	126.000
44.980	47.980	48.580	11400.000	126.000
45.885	48.885	49.485	11500.000	126.000
46.800	49.800	50.400	11600.000	126.000
47.725	50.725	51.325	11700.000	126.000
48.660	51.660	52.260	11800.000	126.000
49.605	52.605	53.205	11900.000	126.000
50.560	53.560	54.160	12000.000	126.000
51.525	54.525	55.125	12100.000	126.000
52.500	55.500	56.100	12200.000	126.000
53.485	56.485	57.085	12300.000	126.000
54.480	57.480	58.080	12400.000	126.000
55.485	58.485	59.085	12500.000	126.000
56.500	59.500	60.100	12600.000	126.000
57.525	60.525	61.125	12700.000	126.000
58.560	61.560	62.160	12800.000	126.000
59.605	62.605	63.205	12900.000	126.000
60.660	63.660	64.260	13000.000	126.000
61.725	64.725	65.325	13100.000	126.000
62.800	65.800	66.400	13200.000	126.000
63.885	66.885	67.485	13300.000	126.000
64.980	67.980	68.580	13400.000	126.000
66.085	69.085	69.685	13500.000	126.000
67.200	70.200	70.800	13600.000	126.000
68.325	71.325	71.925	13700.000	126.000
69.460	72.460	73.060	13800.000	126.000
70.605	73.605	74.205	13900.000	126.000
71.760	74.760	75.360	14000.000	126.000
72.925	75.925	76.525	14100.000	126.000
74.100	77.100	77.700	14200.000	126.000
75.285	78.285	78.885	14300.000	126.000
76.480	79.480	80.080	14400.000	126.000
77.685	80.685	81.285	14500.000	126.000
78.900	81.900	82.500	14600.000	126.000
80.125	83.125	83.725	14700.000	126.000
81.360	84.360	84.960	14800.000	126.000
82.605	85.605	86.205	14900.000	126.000
83.860	86.860	87.460	15000.000	126.000
85.125	88.125	88.725	15100.000	126.000
86.400	89.400	90.000	15200.000	126.000
87.685	90.685	91.285	15300.000	126.000
88.980	91.980	92.580	15400.000	126.000
90.285	93.285	93.885	15500.000	126.000
91.600	94.600	95.200	15600.000	126.000
92.925	95.925	96.525	15700.000	126.000
94.260	97.260	97.860	15800.000	126.000
95.605	98.605	99.205	15900.000	126.000
96.960	99.960	100.560	16000.000	126.000
98.325	101.325	101.925	16100.000	126.000
99.700	102.700	103.300	16200.000	126.000
101.085	104.085	104.685	16300.000	126.000
102.480	105.480	106.080	16400.000	126.000
103.885	106.885	107.485	16500.000	126.000
105.300	108.300	108.900	16600.000	126.000
106.725	109.725	110.325	16700.000	126.000
108.160	111.160	111.760	16800.000	126.000
109.605	112.605	113.205	16900.000	126.000
111.060	114.060	114.660	17000.000	126.000
112.525	115.525	116.125	17100.000	126.000
114.000	117.000	117.600	17200.000	126.000
115.485	118.485	119.085	17300.000	126.000
116.980	119.980	120.580	17400.000	126.000
118.485	121.485	122.085	17500.000	126.000
120.000	123.000	123.600	17600.000	126.000
121.525	124.525	125.125	17700.000	126.000
123.060	126.060	126.660	17800.000	126.000
124.605	127.605	128.205	17900.000	126.000
126.160	129.160	129.760	18000.000	126.000
127.725	130.725	131.325	18100.000	126.000
129.300	132.300	132.900	18200.000	126.000
130.885	133.885	134.485	18300.000	126.000
132.480	135.480	136.080	18400.000	126.000
134.085	137.085	137.685	18500.000	126.000
135.700	138.700	139.300	18600.000	126.000
137.325	140.325	140.925	18700.000	126.000
138.960	141.960	142.560	18800.000	126.000
140.605	143.605	144.205	18900.000	126.000
142				



CH 0.0 ~ CH 1100



CH 1100 ~ CH 3000

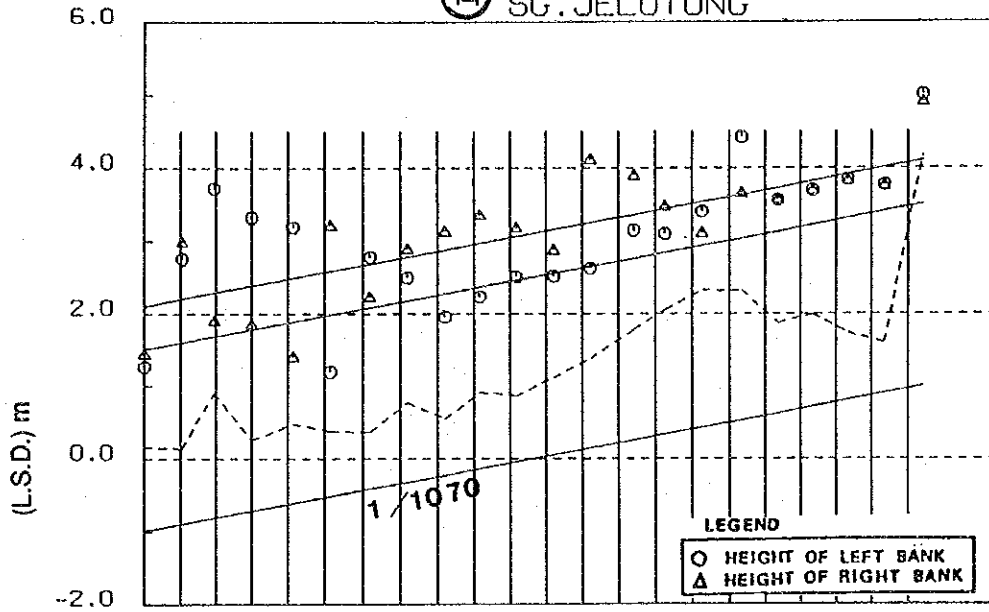


SCALE  
1/200

FIG. 8-8 PROPOSED CROSS SECTIONS OF SG. AIR ITAM

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

(L) SG. JELUTONG



BED LEVEL	-0.994	-0.896	-0.812	-0.719	-0.607	-0.513	-0.415	-0.322	-0.227	-0.138	-0.044	0.054	0.148	0.259	0.339	0.432	0.533	0.627	0.720	0.813	0.909	1.007
H.W.L.	1.600	1.604	1.688	1.787	1.893	1.987	2.085	2.178	2.273	2.362	2.456	2.554	2.648	2.759	2.839	2.932	3.033	3.127	3.220	3.313	3.409	3.507
BANK LEVEL	2.106	2.204	2.288	2.387	2.493	2.587	2.685	2.778	2.873	2.962	3.056	3.154	3.248	3.359	3.439	3.532	3.633	3.727	3.820	3.913	4.009	4.107
DISTANCE	0.000	105.000	90.000	106.000	113.000	101.000	105.000	99.000	102.000	95.000	100.000	105.000	101.000	119.000	85.000	100.000	108.000	101.000	99.000	100.000	102.000	105.000
CHAINAGE	0.000	105.000	195.000	300.000	400.000	500.000	600.000	700.000	800.000	900.000	1000.000	1100.000	1200.000	1315.000	1400.000	1500.000	1600.000	1700.000	1800.000	1900.000	2000.000	2105.000

$Q = 20 \text{ m}^3/\text{s}$

$Q = 6 \text{ m}^3/\text{s}$

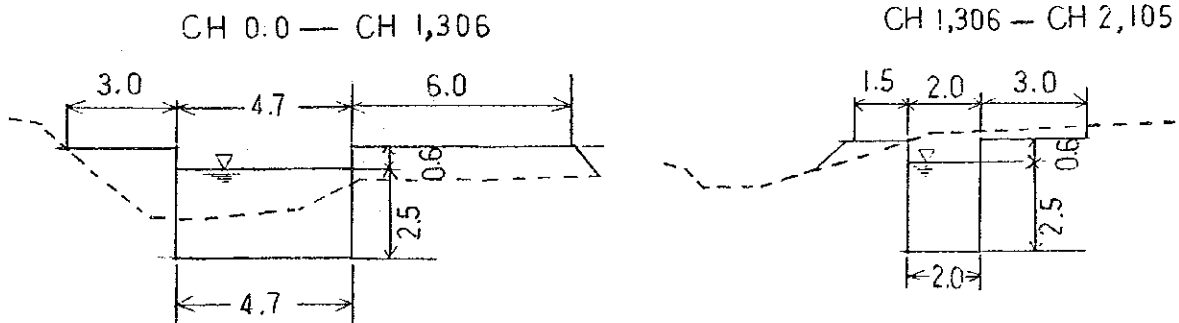
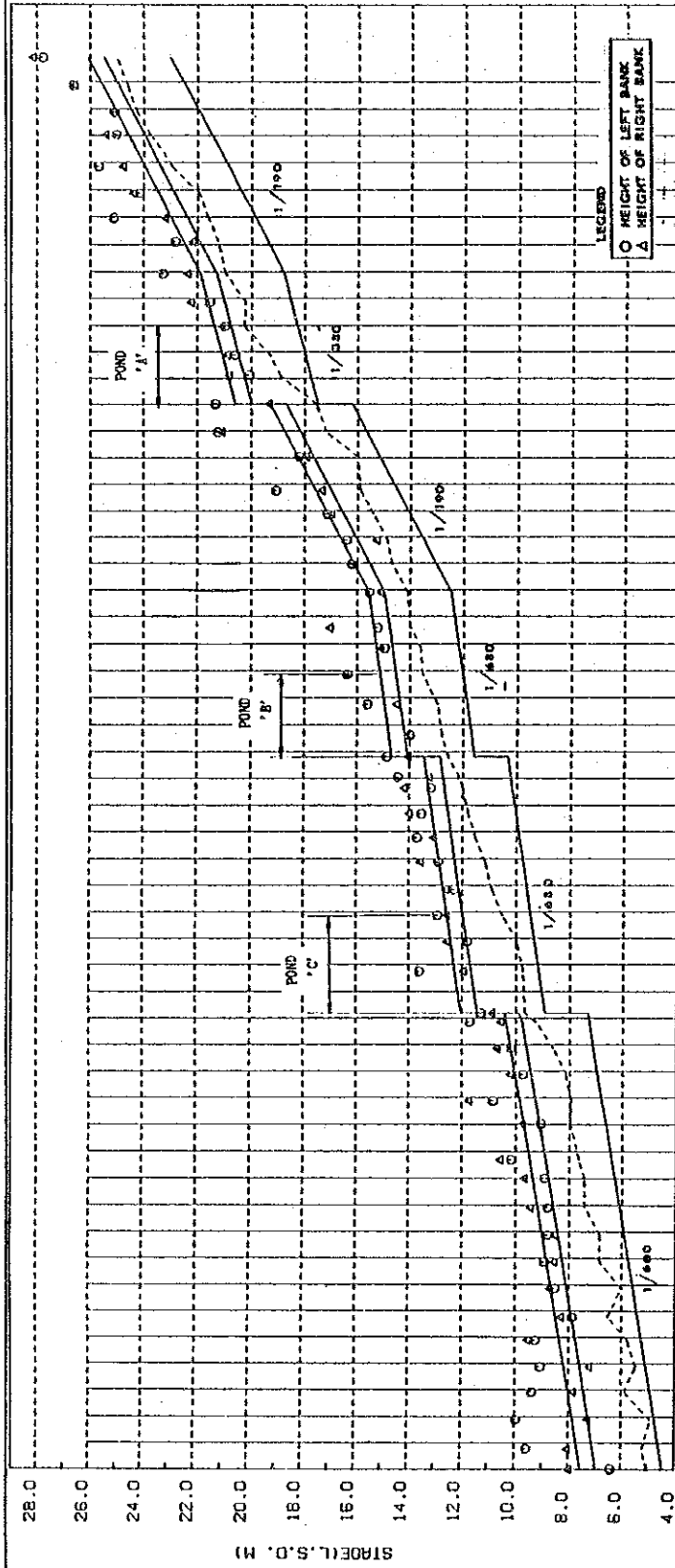


FIG. 8-9

LONGITUDINAL PROFILE AND PROPOSED CROSS SECTIONS OF SG. JELUTONG



BED LEVEL	H.W.L.	BANK LEVEL	DISTANCE	CHAINAGE
4.442	7.542	7.542	13.000	0.014
4.572	7.672	7.672	78.000	0.092
4.757	7.857	7.857	111.000	0.203
4.928	7.428	7.428	103.000	0.335
5.087	7.587	7.587	93.000	0.435
5.253	7.753	7.753	100.000	0.527
5.402	7.902	7.902	89.000	0.620
5.585	8.085	8.085	110.000	0.757
5.752	8.252	8.252	100.000	0.852
5.922	8.422	8.422	102.000	1.059
6.093	8.593	8.593	103.000	1.160
6.277	8.777	8.777	110.000	1.286
6.390	8.890	8.890	68.000	1.413
6.612	9.112	9.112	133.000	1.547
6.775	9.275	9.275	85.000	1.638
6.940	9.440	9.440	99.000	1.731
7.107	9.607	9.607	100.000	1.827
7.272	9.772	9.772	91.000	1.937
7.438	9.938	9.938	97.000	2.000
7.603	10.103	10.103	100.000	2.302
7.770	10.270	10.270	113.000	2.233
7.937	10.437	10.437	127.000	2.159
8.104	10.604	10.604	155.000	2.159
8.272	10.772	10.772	12.257	11.657
8.438	10.938	10.938	11.657	9.157
8.603	11.103	11.103	12.423	11.623
8.770	11.270	11.270	12.423	9.233
8.937	11.437	11.437	12.570	9.470
9.104	11.604	11.604	12.713	9.613
9.272	11.772	11.772	12.854	9.764
9.438	11.938	11.938	12.997	9.917
9.603	12.103	12.103	13.129	10.029
9.770	12.270	12.270	13.272	10.172
9.937	12.437	12.437	13.333	10.233
10.104	12.604	12.604	13.443	10.343
10.272	12.772	12.772	13.443	10.343
10.438	12.938	12.938	13.443	10.343
10.603	13.103	13.103	13.443	10.343
10.770	13.270	13.270	13.443	10.343
10.937	13.437	13.437	13.443	10.343
11.104	13.604	13.604	13.443	10.343
11.272	13.772	13.772	13.443	10.343
11.438	13.938	13.938	13.443	10.343
11.603	14.103	14.103	13.443	10.343
11.770	14.270	14.270	13.443	10.343
11.937	14.437	14.437	13.443	10.343
12.104	14.604	14.604	13.443	10.343
12.272	14.772	14.772	13.443	10.343
12.438	14.938	14.938	13.443	10.343
12.603	15.103	15.103	13.443	10.343
12.770	15.270	15.270	13.443	10.343
12.937	15.437	15.437	13.443	10.343
13.104	15.604	15.604	13.443	10.343
13.272	15.772	15.772	13.443	10.343
13.438	15.938	15.938	13.443	10.343
13.603	16.103	16.103	13.443	10.343
13.770	16.270	16.270	13.443	10.343
13.937	16.437	16.437	13.443	10.343
14.104	16.604	16.604	13.443	10.343
14.272	16.772	16.772	13.443	10.343
14.438	16.938	16.938	13.443	10.343
14.603	17.103	17.103	13.443	10.343
14.770	17.270	17.270	13.443	10.343
14.937	17.437	17.437	13.443	10.343
15.104	17.604	17.604	13.443	10.343
15.272	17.772	17.772	13.443	10.343
15.438	17.938	17.938	13.443	10.343
15.603	18.103	18.103	13.443	10.343
15.770	18.270	18.270	13.443	10.343
15.937	18.437	18.437	13.443	10.343
16.104	18.604	18.604	13.443	10.343
16.272	18.772	18.772	13.443	10.343
16.438	18.938	18.938	13.443	10.343
16.603	19.103	19.103	13.443	10.343
16.770	19.270	19.270	13.443	10.343
16.937	19.437	19.437	13.443	10.343
17.104	19.604	19.604	13.443	10.343
17.272	19.772	19.772	13.443	10.343
17.438	19.938	19.938	13.443	10.343
17.603	20.103	20.103	13.443	10.343
17.770	20.270	20.270	13.443	10.343
17.937	20.437	20.437	13.443	10.343
18.104	20.604	20.604	13.443	10.343
18.272	20.772	20.772	13.443	10.343
18.438	20.938	20.938	13.443	10.343
18.603	21.103	21.103	13.443	10.343
18.770	21.270	21.270	13.443	10.343
18.937	21.437	21.437	13.443	10.343
19.104	21.604	21.604	13.443	10.343
19.272	21.772	21.772	13.443	10.343
19.438	21.938	21.938	13.443	10.343
19.603	22.103	22.103	13.443	10.343
19.770	22.270	22.270	13.443	10.343
19.937	22.437	22.437	13.443	10.343
20.104	22.604	22.604	13.443	10.343
20.272	22.772	22.772	13.443	10.343
20.438	22.938	22.938	13.443	10.343
20.603	23.103	23.103	13.443	10.343
20.770	23.270	23.270	13.443	10.343
20.937	23.437	23.437	13.443	10.343
21.104	23.604	23.604	13.443	10.343
21.272	23.772	23.772	13.443	10.343
21.438	23.938	23.938	13.443	10.343
21.603	24.103	24.103	13.443	10.343
21.770	24.270	24.270	13.443	10.343
21.937	24.437	24.437	13.443	10.343
22.104	24.604	24.604	13.443	10.343
22.272	24.772	24.772	13.443	10.343
22.438	24.938	24.938	13.443	10.343
22.603	25.103	25.103	13.443	10.343
22.770	25.270	25.270	13.443	10.343
22.937	25.437	25.437	13.443	10.343
23.104	25.604	25.604	13.443	10.343
23.272	25.772	25.772	13.443	10.343
23.438	25.938	25.938	13.443	10.343
23.603	26.103	26.103	13.443	10.343
23.770	26.270	26.270	13.443	10.343
23.937	26.437	26.437	13.443	10.343
24.104	26.604	26.604	13.443	10.343
24.272	26.772	26.772	13.443	10.343
24.438	26.938	26.938	13.443	10.343
24.603	27.103	27.103	13.443	10.343
24.770	27.270	27.270	13.443	10.343
24.937	27.437	27.437	13.443	10.343
25.104	27.604	27.604	13.443	10.343
25.272	27.772	27.772	13.443	10.343
25.438	27.938	27.938	13.443	10.343
25.603	28.103	28.103	13.443	10.343
25.770	28.270	28.270	13.443	10.343
25.937	28.437	28.437	13.443	10.343
26.104	28.604	28.604	13.443	10.343
26.272	28.772	28.772	13.443	10.343
26.438	28.938	28.938	13.443	10.343
26.603	29.103	29.103	13.443	10.343
26.770	29.270	29.270	13.443	10.343
26.937	29.437	29.437	13.443	10.343
27.104	29.604	29.604	13.443	10.343
27.272	29.772	29.772	13.443	10.343
27.438	29.938	29.938	13.443	10.343
27.603	30.103	30.103	13.443	10.343
27.770	30.270	30.270	13.443	10.343
27.937	30.437	30.437	13.443	10.343
28.104	30.604	30.604	13.443	10.343
28.272	30.772	30.772	13.443	10.343
28.438	30.938	30.938	13.443	10.343
28.603	31.103	31.103	13.443	10.343
28.770	31.270	31.270	13.443	10.343
28.937	31.437	31.437	13.443	10.343
29.104	31.604	31.604	13.443	10.343
29.272	31.772	31.772	13.443	10.343
29.438	31.938	31.938	13.443	10.343
29.603	32.103	32.103	13.443	10.343
29.770	32.270	32.270	13.443	10.343
29.937	32.437	32.437	13.443	10.343
30.104	32.604	32.604	13.443	10.343
30.272	32.772	32.772	13.443	10.343
30.438	32.938	32.938	13.443	10.343
30.603	33.103	33.103	13.443	10.343
30.770	33.270	33.270	13.443	10.343
30.937	33.437	33.437	13.443	10.343
31.104	33.604	33.604	13.443	10.343
31.272	33.772	33.772	13.443	10.343
31.438	33.938	33.938	13.443	10.343
31.603	34.103	34.103	13.443	10.343
31.770	34.270	34.270	13.443	10.343
31.937	34.437	34.437	13.443	10.343
32.104	34.604	34.604	13.443	10.343
32.272	34.772	34.772	13.443	10.343
32.438	34.938	34.938	13.443	10.343
32.603	35.103	35.103	13.443	10.343
32.770	35.270	35.270	13.443	10.343
32.937	35.437	35.437	13.443	10.343
33.104	35.604	35.604	13.443	10.343
33.272	35.772	35.772	13.443	10.343
33.438	35.938	35.938	13.443	10.343
33.603	36.103	36.103	13.443	10.343
33.770	36.270	36.270	13.443	10.343
33.937	36.437	36.437	13.443	10.343
34.104	36.604	36.604	13.443	10.343
34.272	36.772	36.772	13.443	10.343
34.438	36.938	36.938	13.443	10.343
34.603	37.103	37.103	13.443	10.343
34.770	37.270	37.270	13.443	10.343
34.937	37.437	37.437	13.443	10.343
35.104	37.604	37.604	13.443	10.343
35.272	37.772	37.772	13.443	10.343
35.438	37.938	37.938	13.443	10.343
35.603	38.103	38.103	13.443	10.343
35.770	38.270	38.270	13.443	10.343
35.937	38.437	38.437	13.443	10.343
36.104	38.604	38.604	13.443	10.343
36.272	38.772	38.772	13.443	10.343
36.438	38.938	38.938	13.443	10.343
36.603	39.103	39.103	13.443	10.343
36.770	39.270	39.270	13.443	10.343
36.937	39.437	39.437	13.443	10.343
37.104	39.604	39.604	13.443	10.343
37.272	39.772	39.772	13.443	10.343
37.438	39.938	39.938	13.443	10.343
37.603	40.103	40.103	13.443	10.343
37.770	40.270	40.270	13.443	10.343
37.937	40.437	40.437	13.443	10.343
38.104	40.604	40.604	13.443	10.343
38.272	40.772	40		

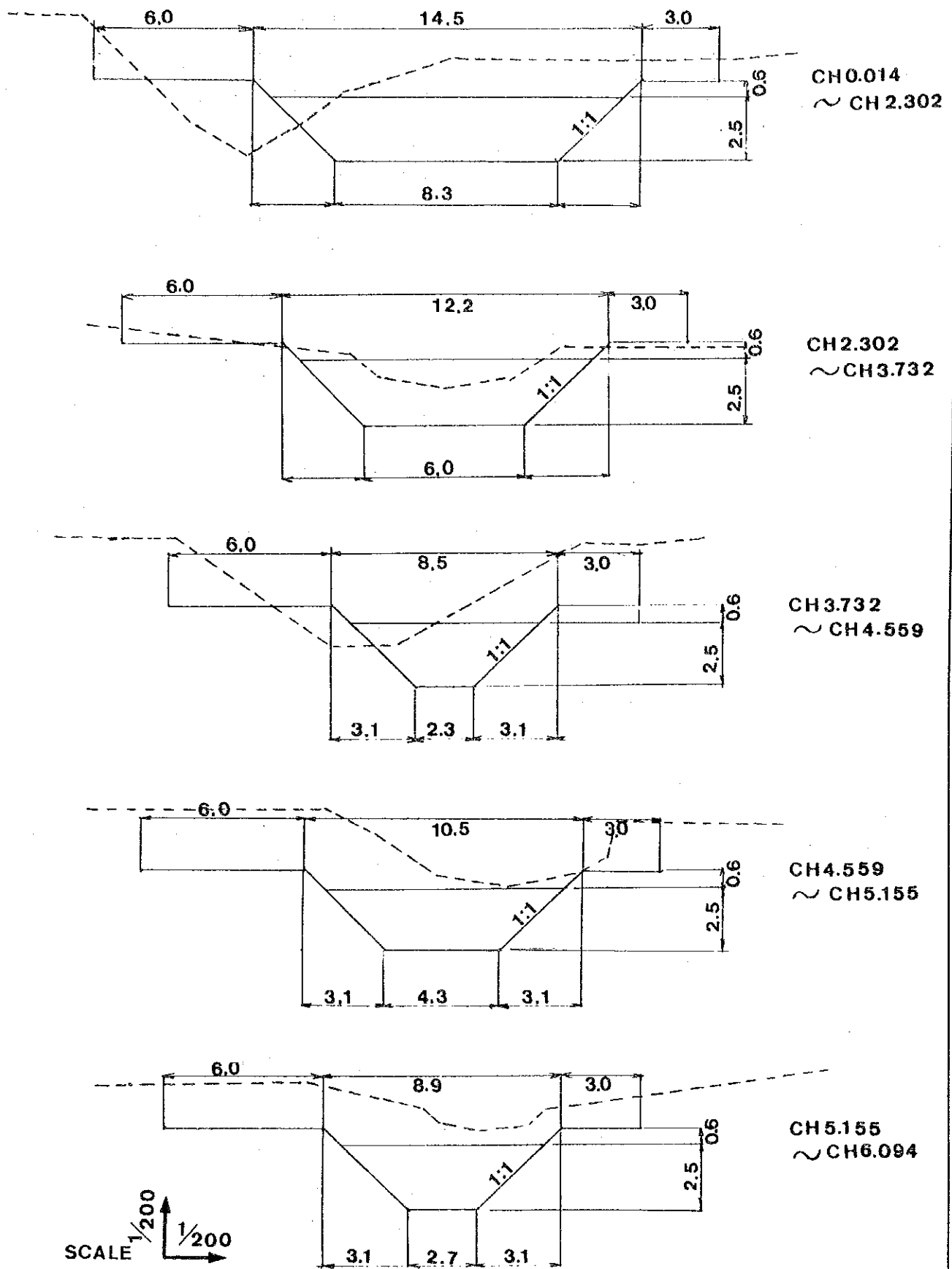
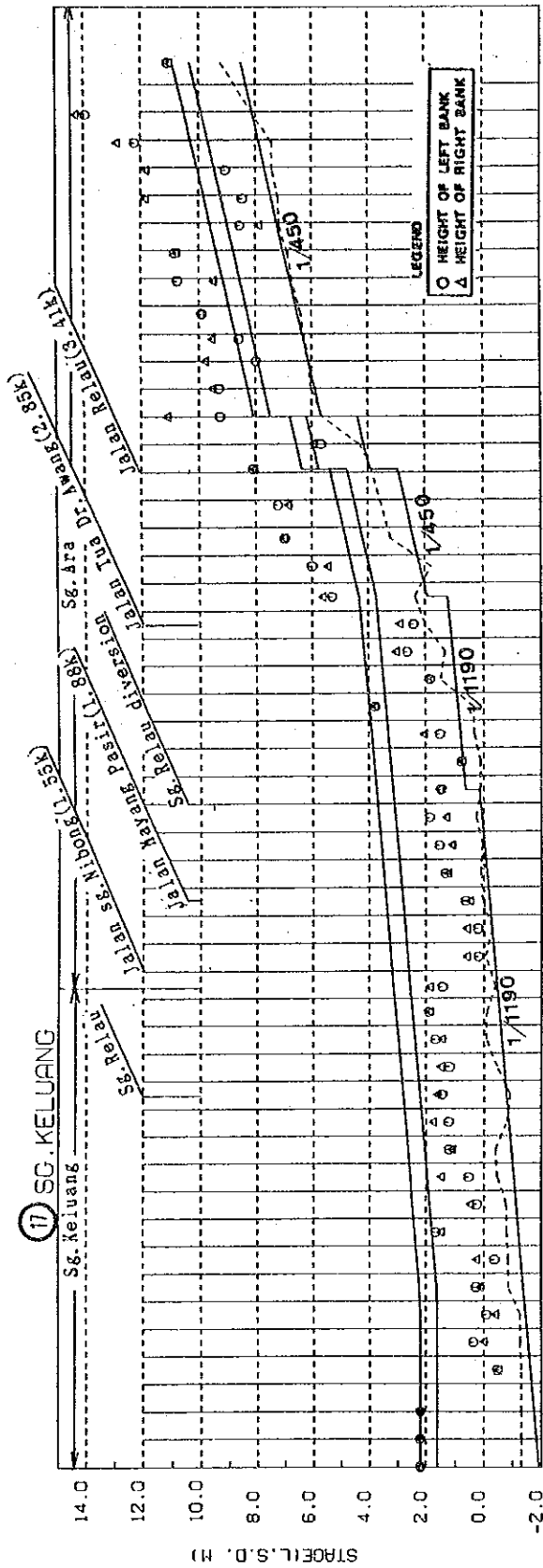


FIG. 8-11

PROPOSED CROSS SECTIONS OF SG. DONDANG



PROPOSED BED LEVEL	DESIGN H.W.L.	PROPOSED BANK LEVEL	DISTANCE	CHAINAGE
1.920	1.600	2.200	0.000	0.000
1.936	1.600	2.200	100.000	100.000
1.752	1.600	2.200	200.000	100.000
1.626	1.600	2.200	300.000	100.000
1.542	1.600	2.200	400.000	100.000
1.458	1.600	2.200	500.000	100.000
1.374	1.626	2.226	600.000	100.000
1.290	1.710	2.310	700.000	100.000
1.206	1.794	2.394	800.000	100.000
1.122	1.878	2.478	900.000	100.000
1.038	1.962	2.562	1000.000	100.000
0.954	2.046	2.646	1100.000	100.000
0.870	2.130	2.730	1200.000	100.000
0.786	2.214	2.814	1300.000	100.000
0.702	2.298	2.898	1400.000	100.000
0.617	2.383	2.983	1500.000	100.000
0.533	2.467	3.067	1600.000	100.000
0.458	2.542	3.142	1700.000	90.000
0.385	2.626	3.226	1800.000	100.000
0.281	2.719	3.319	1900.000	100.000
0.197	2.803	3.403	2000.000	100.000
0.113	2.887	3.487	2100.000	100.000
0.029	2.971	3.571	2200.000	100.000
0.055	3.055	3.655	2300.000	100.000
0.138	3.138	3.738	2400.000	100.000
0.638	3.223	3.823	2500.000	100.000
0.723	3.307	3.907	2600.000	100.000
0.807	3.391	3.991	2700.000	100.000
0.891	3.475	4.075	2800.000	100.000
1.059	3.559	4.159	2900.000	100.000
1.143	3.643	4.243	3000.000	100.000
1.227	3.727	4.327	3100.000	100.000
1.827	3.812	4.412	3200.000	100.000
2.172	3.897	4.497	3300.000	100.000
2.394	3.982	4.582	3400.000	100.000
2.650	4.067	4.667	3500.000	100.000
2.948	4.152	4.752	3600.000	100.000
3.848	4.237	4.837	3700.000	100.000
5.949	4.322	4.922	3800.000	100.000
8.348	4.407	5.007	3900.000	100.000
4.149	4.492	5.092	4000.000	100.000
4.772	4.577	5.177	4100.000	100.000
6.672	4.662	5.262	4200.000	100.000
8.672	4.747	5.347	4300.000	100.000
5.894	4.832	5.432	4400.000	100.000
7.694	4.917	5.517	4500.000	100.000
6.294	5.002	5.602	4600.000	100.000
8.294	5.087	5.687	4700.000	100.000
8.560	5.172	5.772	4800.000	100.000
6.983	5.257	5.857	4900.000	100.000
7.205	5.342	5.942	5000.000	100.000
9.005	5.427	6.027	5100.000	100.000
9.218	5.512	6.112	5200.000	100.000
7.418	5.597	6.197	5300.000	100.000
9.449	5.682	6.282	5400.000	100.000
9.672	5.767	6.367	5500.000	100.000
8.094	5.852	6.452	5600.000	100.000
9.694	5.937	6.537	5700.000	100.000
8.560	6.022	6.622	5800.000	100.000
8.294	6.107	6.707	5900.000	100.000
8.516	6.192	6.792	6000.000	100.000
8.694	6.277	6.877	6100.000	100.000
8.516	6.362	6.962	6200.000	100.000
8.294	6.447	7.047	6300.000	100.000
8.694	6.532	7.132	6400.000	100.000
8.516	6.617	7.217	6500.000	100.000
8.294	6.702	7.302	6600.000	100.000
8.694	6.787	7.387	6700.000	100.000
8.516	6.872	7.472	6800.000	100.000
8.294	6.957	7.557	6900.000	100.000
8.694	7.042	7.642	7000.000	100.000
8.516	7.127	7.727	7100.000	100.000
8.294	7.212	7.812	7200.000	100.000
8.694	7.297	7.897	7300.000	100.000
8.516	7.382	7.982	7400.000	100.000
8.294	7.467	8.067	7500.000	100.000
8.694	7.552	8.152	7600.000	100.000
8.516	7.637	8.237	7700.000	100.000
8.294	7.722	8.322	7800.000	100.000
8.694	7.807	8.407	7900.000	100.000
8.516	7.892	8.492	8000.000	100.000
8.294	7.977	8.577	8100.000	100.000
8.694	8.062	8.662	8200.000	100.000
8.516	8.147	8.747	8300.000	100.000
8.294	8.232	8.832	8400.000	100.000
8.694	8.317	8.917	8500.000	100.000
8.516	8.402	9.002	8600.000	100.000
8.294	8.487	9.087	8700.000	100.000
8.694	8.572	9.172	8800.000	100.000
8.516	8.657	9.257	8900.000	100.000
8.294	8.742	9.342	9000.000	100.000
8.694	8.827	9.427	9100.000	100.000
8.516	8.912	9.512	9200.000	100.000
8.294	8.997	9.597	9300.000	100.000
8.694	9.082	9.682	9400.000	100.000
8.516	9.167	9.767	9500.000	100.000
8.294	9.252	9.852	9600.000	100.000
8.694	9.337	9.937	9700.000	100.000
8.516	9.422	10.022	9800.000	100.000
8.294	9.507	10.107	9900.000	100.000
8.694	9.592	10.192	10000.000	100.000
8.516	9.677	10.277	10100.000	100.000
8.294	9.762	10.362	10200.000	100.000
8.694	9.847	10.447	10300.000	100.000
8.516	9.932	10.532	10400.000	100.000
8.294	10.017	10.617	10500.000	100.000
8.694	10.102	10.702	10600.000	100.000
8.516	10.187	10.787	10700.000	100.000
8.294	10.272	10.872	10800.000	100.000
8.694	10.357	10.957	10900.000	100.000
8.516	10.442	11.042	11000.000	100.000
8.294	10.527	11.127	11100.000	100.000
8.694	10.612	11.212	11200.000	100.000
8.516	10.697	11.297	11300.000	100.000
8.294	10.782	11.382	11400.000	100.000
8.694	10.867	11.467	11500.000	100.000
8.516	10.952	11.552	11600.000	100.000
8.294	11.037	11.637	11700.000	100.000
8.694	11.122	11.722	11800.000	100.000
8.516	11.207	11.807	11900.000	100.000
8.294	11.292	11.892	12000.000	100.000
8.694	11.377	11.977	12100.000	100.000
8.516	11.462	12.062	12200.000	100.000
8.294	11.547	12.147	12300.000	100.000
8.694	11.632	12.232	12400.000	100.000
8.516	11.717	12.317	12500.000	100.000
8.294	11.802	12.402	12600.000	100.000
8.694	11.887	12.487	12700.000	100.000
8.516	11.972	12.572	12800.000	100.000
8.294	12.057	12.657	12900.000	100.000
8.694	12.142	12.742	13000.000	100.000
8.516	12.227	12.827	13100.000	100.000
8.294	12.312	12.912	13200.000	100.000
8.694	12.397	12.997	13300.000	100.000
8.516	12.482	13.082	13400.000	100.000
8.294	12.567	13.167	13500.000	100.000
8.694	12.652	13.252	13600.000	100.000
8.516	12.737	13.337	13700.000	100.000
8.294	12.822	13.422	13800.000	100.000
8.694	12.907	13.507	13900.000	100.000
8.516	12.992	13.592	14000.000	100.000
8.294	13.077	13.677	14100.000	100.000
8.694	13.162	13.762	14200.000	100.000
8.516	13.247	13.847	14300.000	100.000
8.294	13.332	13.932	14400.000	100.000
8.694	13.417	14.017	14500.000	100.000
8.516	13.502	14.102	14600.000	100.000
8.294	13.587	14.187	14700.000	100.000
8.694	13.672	14.272	14800.000	100.000
8.516	13.757	14.357	14900.000	100.000
8.294	13.842	14.442	15000.000	100.000
8.694	13.927	14.527	15100.000	100.000
8.516	14.012	14.612	15200.000	100.000
8.294	14.097	14.697	15300.000	100.000
8.694	14.182	14.782	15400.000	100.000
8.516	14.267	14.867	15500.000	100.000
8.294	14.352	14.952	15600.000	100.000
8.694	14.437	15.037	15700.000	100.000
8.516	14.522	15.122	15800.000	100.000
8.294	14.607	15.207	15900.000	100.000
8.694	14.692	15.292	16000.000	100.000
8.516	14.777	15.377	16100.000	100.000
8.294	14.862	15.462	16200.000	100.000
8.694	14.947	15.547	16300.000	100.000
8.516	15.032	15.632	16400.000	100.000
8.294	15.117	15.717	16500.000	100.000
8.694	15.202	15.802	16600.000	100.000
8.516	15.287	15.887	16700.000	100.000
8.294	15.372	15.972	16800.000	100.000
8.694	15.457	16.057	16900.000	100.000
8.516	15.542	16.142	17000.000	100.000
8.294	15.627	16.227	17100.000	100.000
8.694	15.712	16.312	17200.000	100.000
8.516	15.797	16.397	17300.000	100.000
8.294	15.882	16.482	17400.000	100.000
8.694	15.967	16.567	17500.000	100.000
8.516	16.052	16.652	17600.000	100.000
8.294	16.137	16.737	17700.000	100.000
8.694	16.222	16.822	17800.000	100.000
8.516	16.307	16.907	17900.000	100.000
8.294	16.392	16.992	18000.000	100.000
8.694	16.477	17.077	18100.000	100.000
8.516	16.562	17.162	18200.000	100.000
8.294	16.647	17.247	18300.000	100.000
8.694	16.732	17.332	18400.000	100.000
8.516	16.817	17.417	18500.000	100.000
8.294	16.902	17.502	18600.000	100.000
8.694	16.987	17.587	18700.000	100.000
8.516	17.072	17.672	18800.000	100.000
8.294	17.157	17.757	18900.000	100.000
8.694	17.242	17.842	19000.000	100.000
8.516	17.327	17.927	19100.000	100.000
8.294	17.412	18.012	19200.000	100.000
8.694	17.497	18.097	19300.000	100.000
8.516	17.582	18.182	19400.000	100.000
8.294	17.667	18.267	19500.000	100.000
8.694	17.752	18.352	19600.000	100.000
8.516	17.837</			

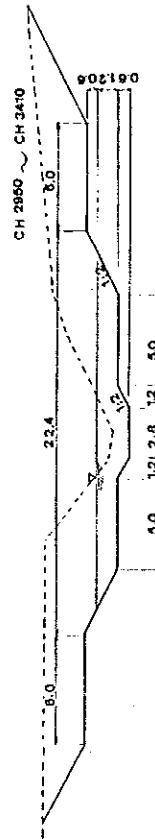
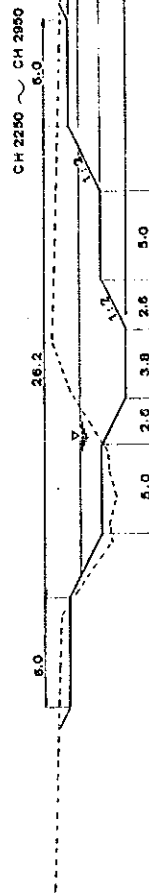
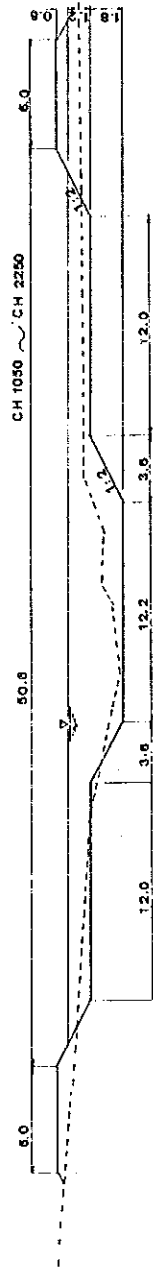
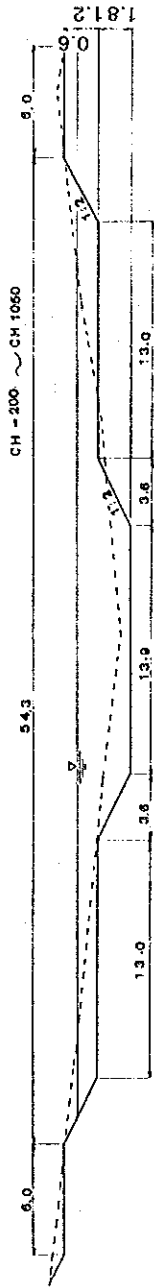
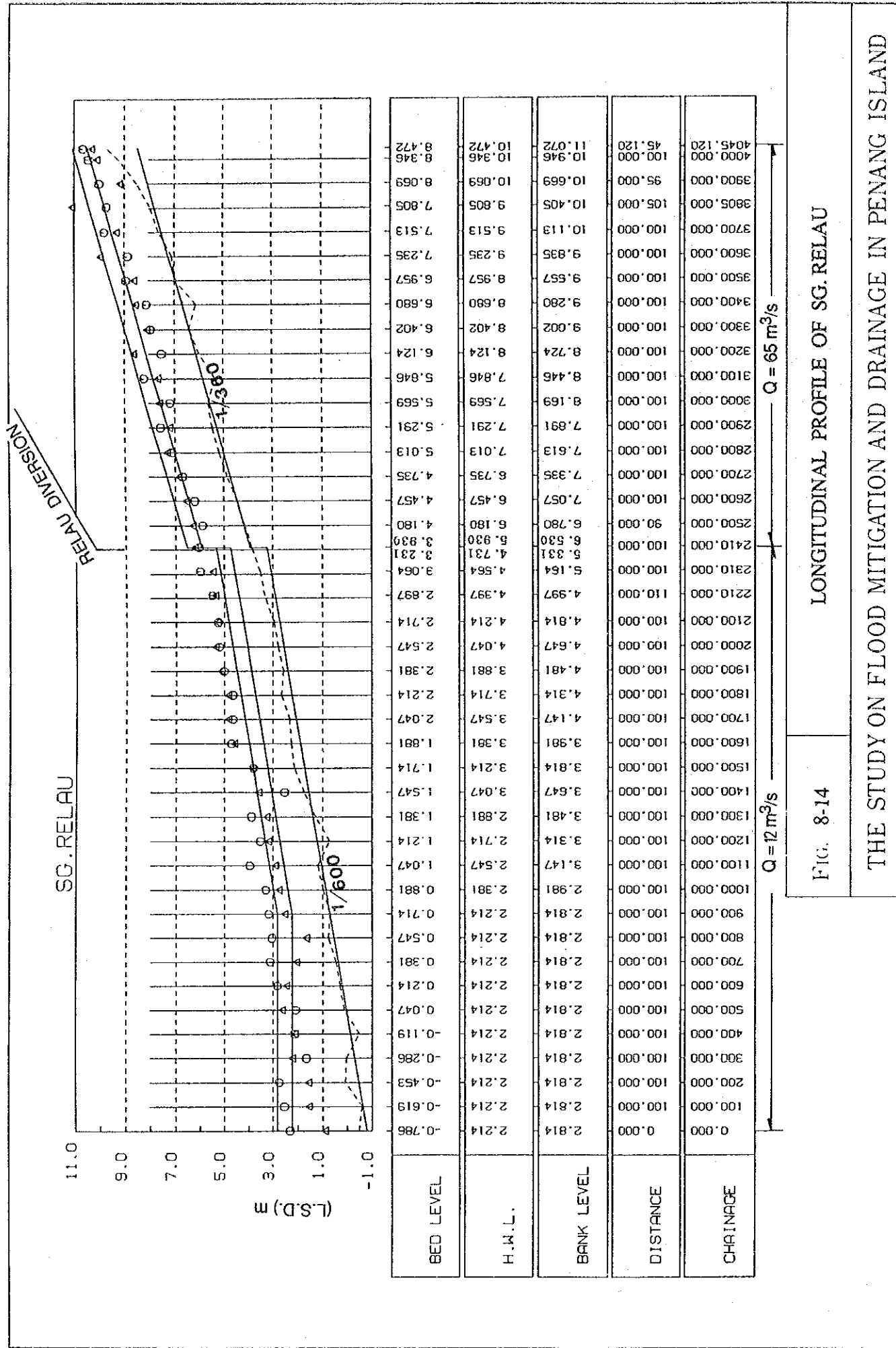


FIG. 8-13

PROPOSED CROSS SECTIONS OF SG. KELUANG

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND



LONGITUDINAL PROFILE OF SG. RELAU

FIG. 8-14

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND



### Typical Cross Section of SG. RELAU

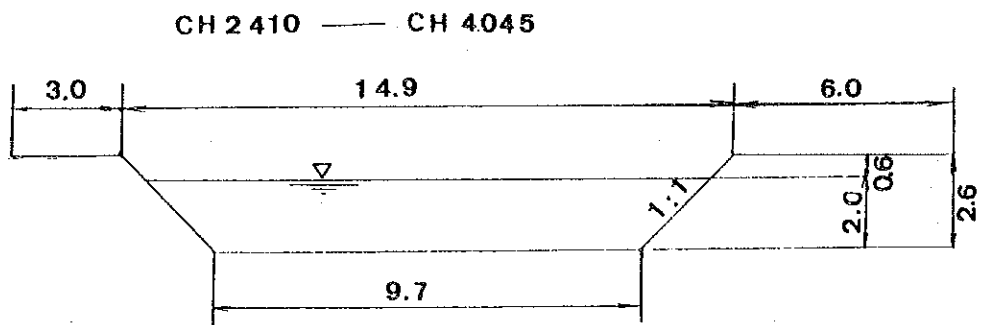


FIG. 8-15

PROPOSED CROSS SECTIONS OF SG. RELAU

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND



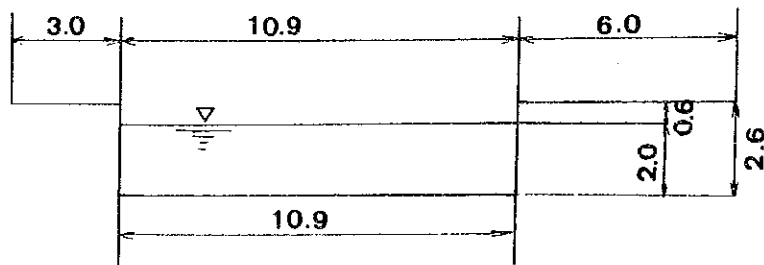
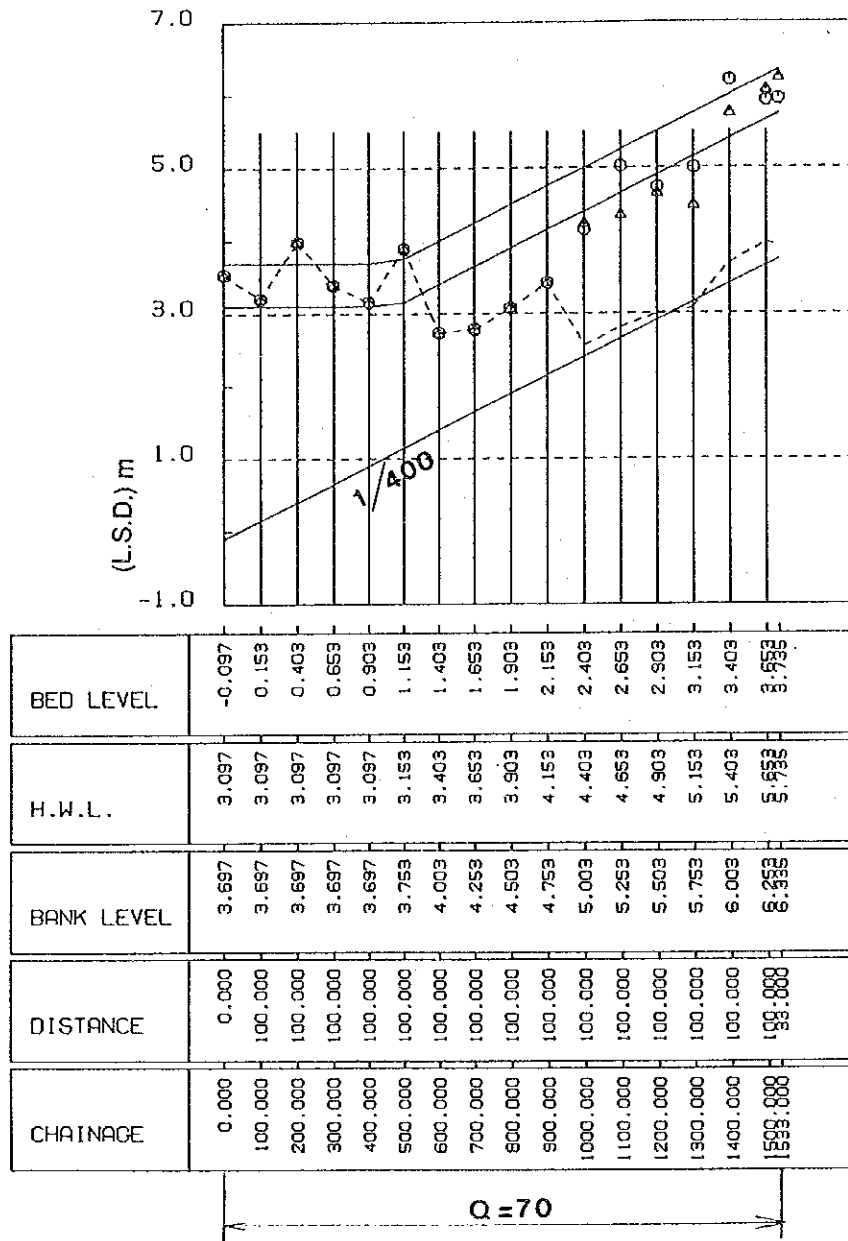
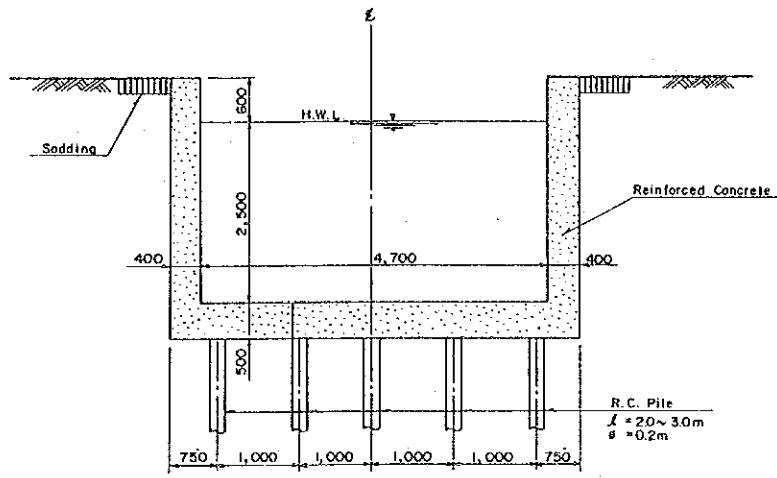
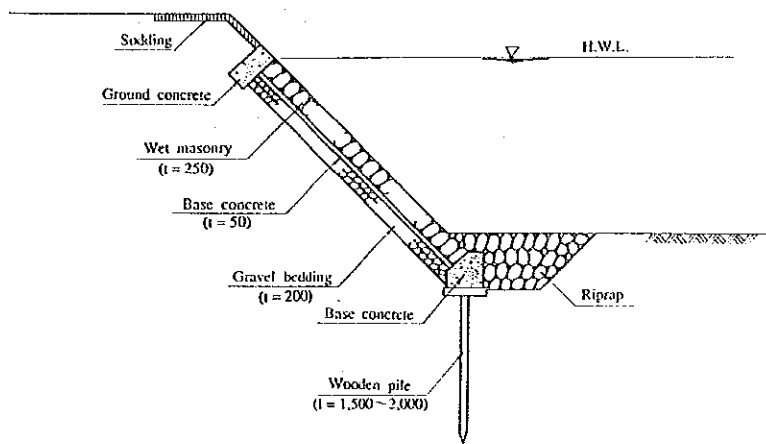


FIG. 8-16

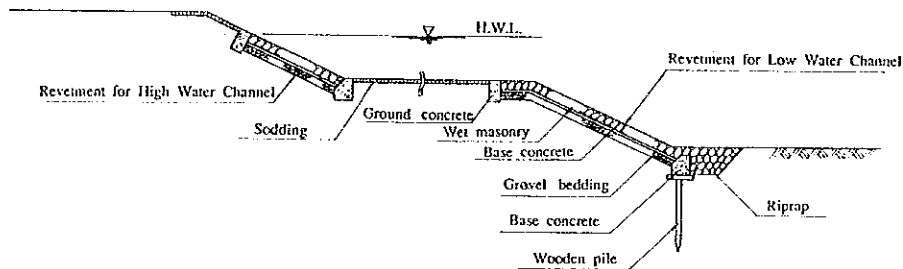
LONGITUDINAL PROFILE AND PROPOSED CROSS SECTION OF SG. RELAU DIVERSION CHANNEL



Typical Cross Section of Revetment (Concrete Section)



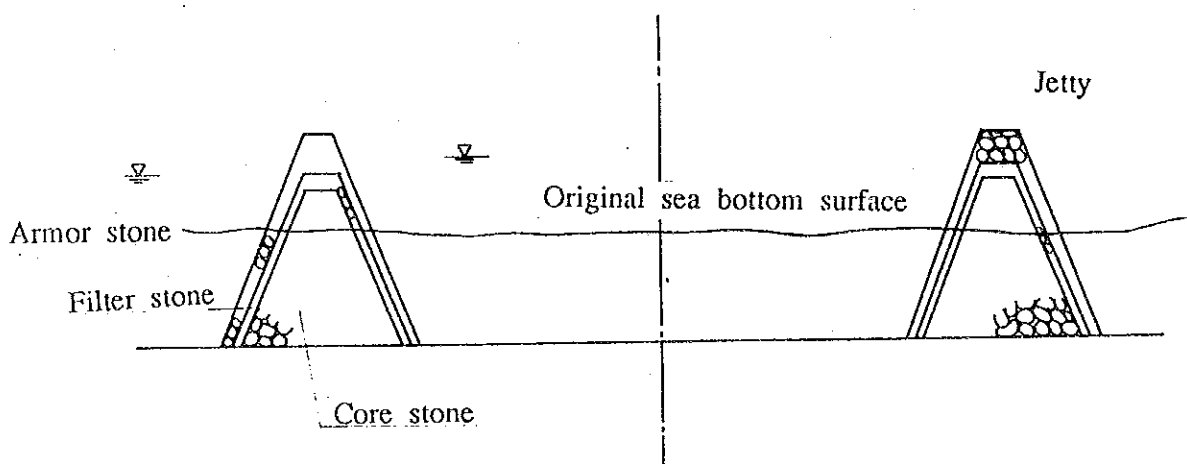
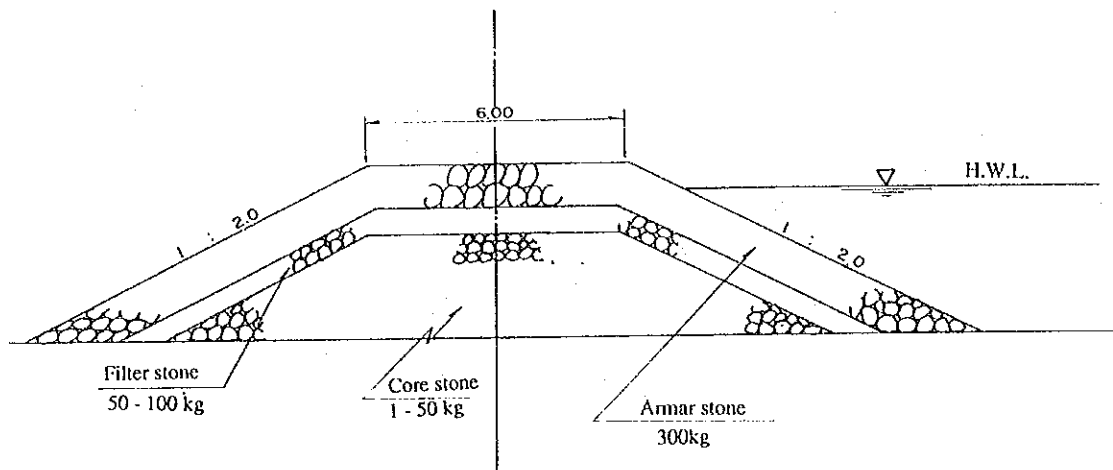
Typical Cross Section of Revetment (Single Section)



Typical Cross Section of Revetment (Compound Section)

FIG. 8-17

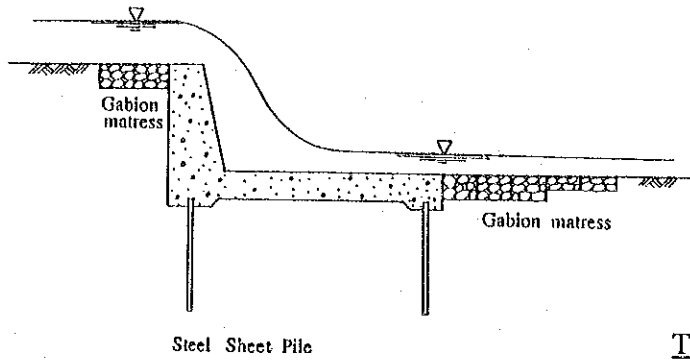
TYPICAL CROSS SECTION OF RIVER IMPROVEMENT



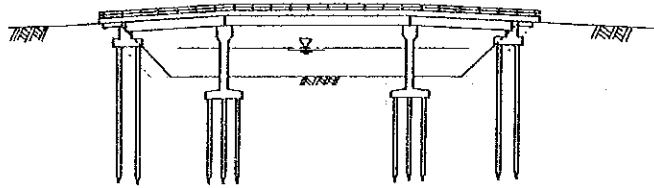
Typical Cross section of Jetty

FIG. 8-18

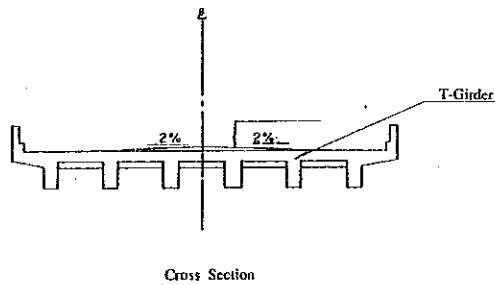
TYPICAL CROSS SECTIONS OF JETTY AT SG. PINANG MOUTH



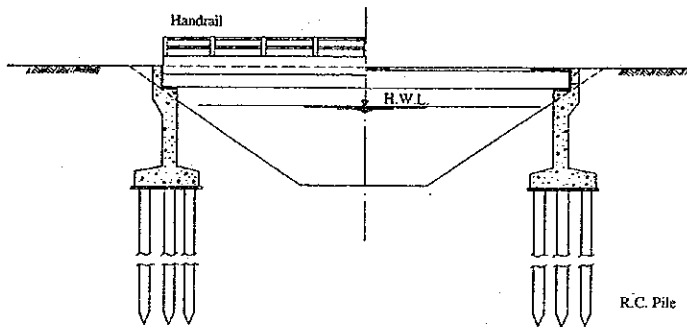
Typical Section of Drop Structure



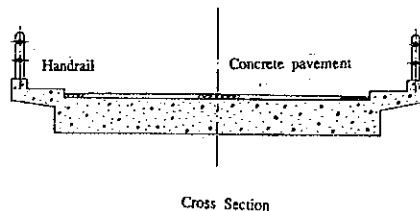
Longitudinal Section of T-Girder Bridge (I)



Typical Section of Bridge (I)



Longitudinal Section of R.C. Slab Bridge (2)



Typical Section of Bridge (II)

FIG. 8-19

TYPICAL SECTION OF DROP STRUCTURE AND BRIDGE

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

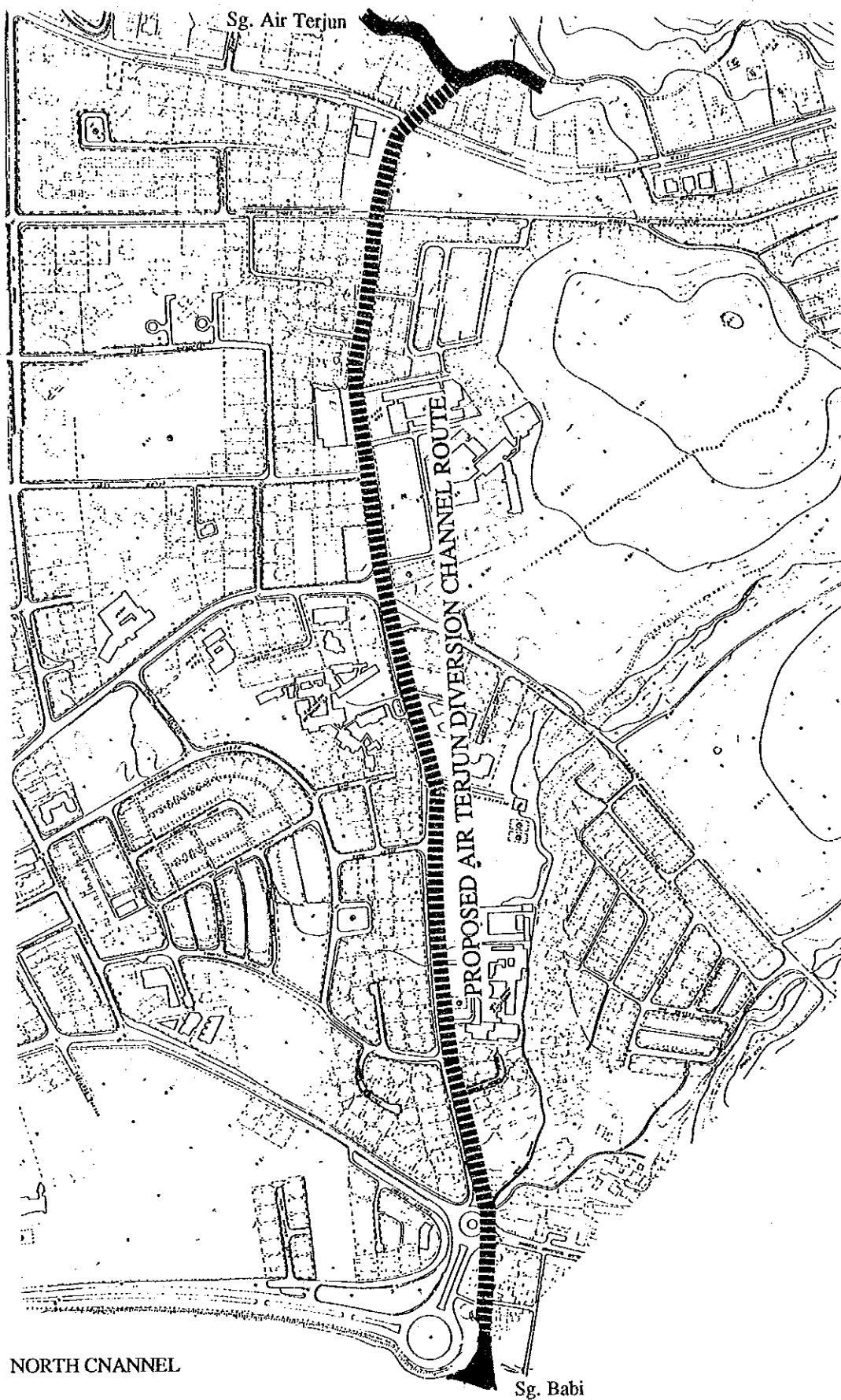
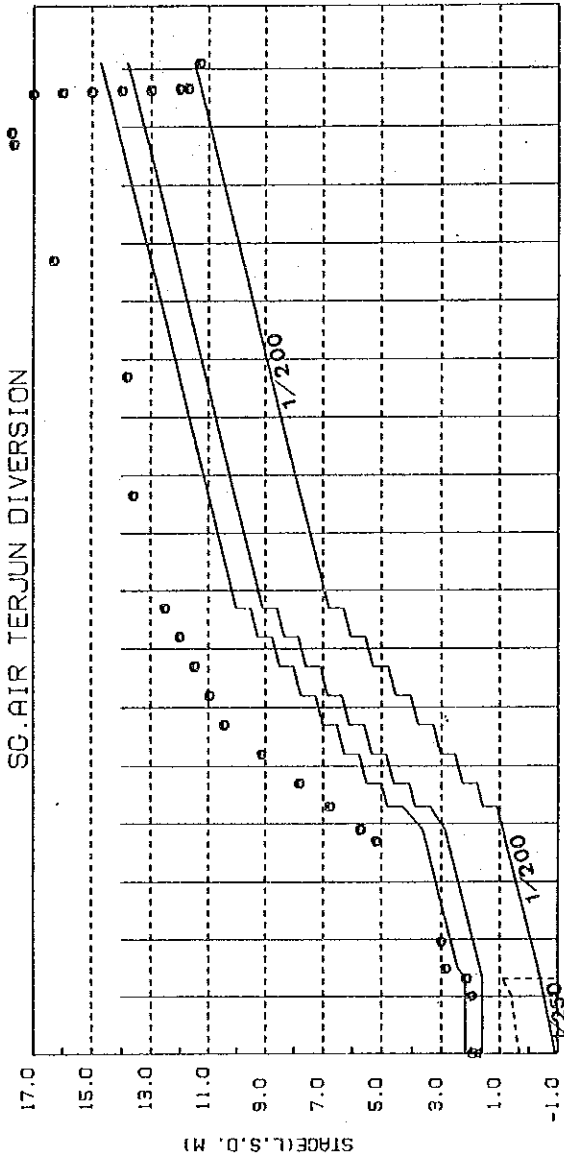


FIG. 8-20

PLAN OF PROPOSED AIR TERJUN DIVERSION CHANNEL ROUTE

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

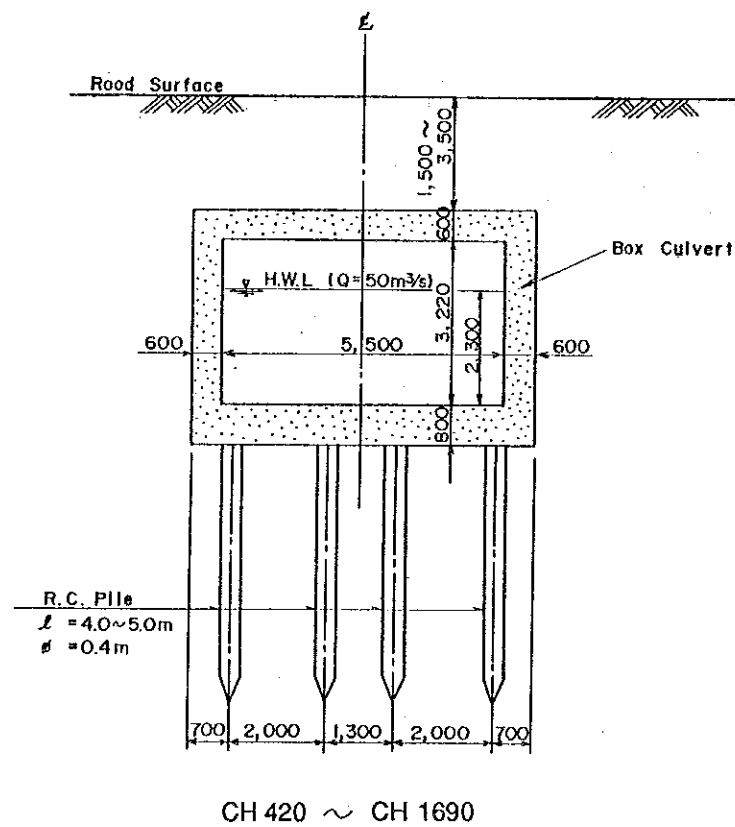
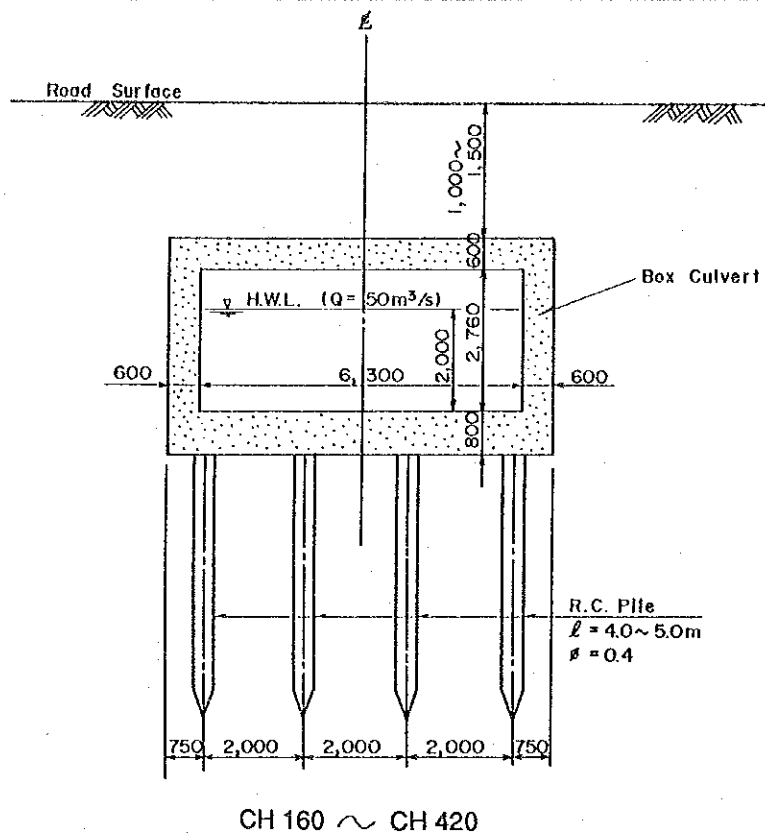


PROPOSED COPING LEVEL	1.600	2.200	2.200	2.250	2.885	2.800	2.850	3.550	3.650	4.020	4.820	5.820	6.270	6.850	7.270	7.820	8.820	8.850	8.850	8.850	8.800	9.800	10.770	11.100	12.020	12.100	13.020	14.020	14.720					
PROPOSED H.W.L.	1.600	1.600	1.600	1.600	1.925	2.800	2.900	3.550	3.650	4.020	4.820	5.820	6.270	6.850	7.270	7.820	8.820	8.850	8.850	8.850	8.800	9.800	10.770	11.100	12.020	12.100	13.020	14.020	14.720					
PROPOSED INVERT LEVEL	-0.520	-0.310	-0.100	-0.100	-0.075	0.800	0.900	1.550	1.650	2.020	2.820	3.820	4.270	4.850	5.270	5.820	6.820	6.850	6.850	6.850	6.800	7.800	8.770	9.100	9.800	9.800	10.720	11.720	12.420					
EXISTING GROUND LEVEL	1.940	1.980	2.650	2.650	3.010	3.500	3.500	4.150	4.250	4.620	5.420	6.420	6.870	7.450	7.870	8.420	9.420	9.450	9.450	9.450	9.400	10.400	11.370	11.700	12.600	12.600	13.520	14.520	15.200					
DISTANCE	0.000	100.000	100.000	18.000	47.000	125.000	20.000	40.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000				
CHAINAGE	0.000	100.000	118.000	186.000	225.000	400.000	420.000	460.000	510.000	560.000	610.000	660.000	710.000	760.000	810.000	860.000	910.000	960.000	1010.000	1060.000	1110.000	1160.000	1210.000	1260.000	1310.000	1360.000	1410.000	1460.000	1510.000	1560.000	1610.000	1660.000	1710.000	1740.000

FIG. 8-21 PROPOSED LONGITUDINAL PROFILE OF AIR TERJUN DIVERSION CHANNEL

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND





**Cross Section of Air Terjun Diversion Channel**

FIG. 8-22

TYPICAL CROSS SECTION OF AIR TERJUN DIVERSION CHANNEL

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

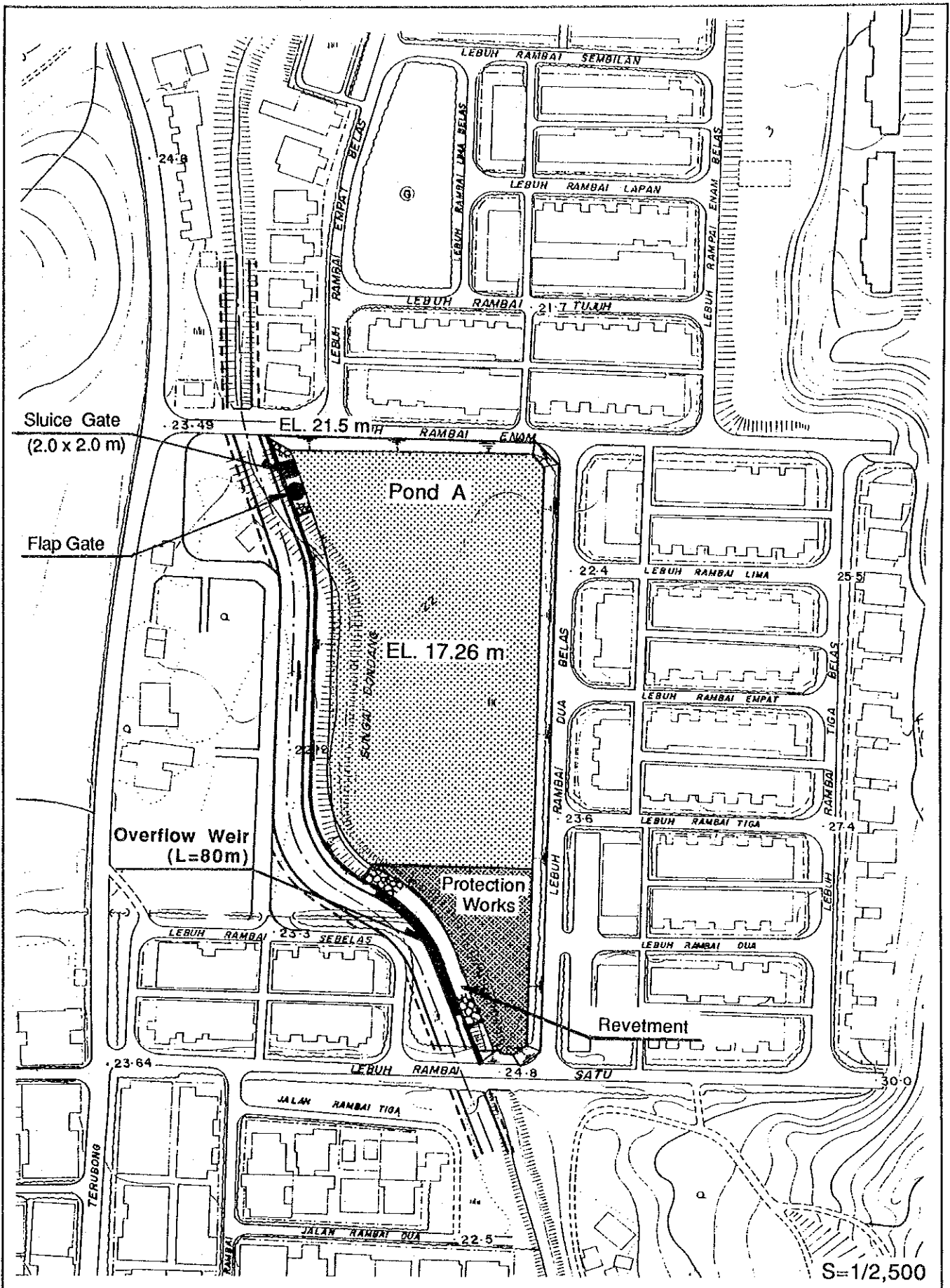


FIG. 8-23

GENERAL PLAN OF RETENTION POND A



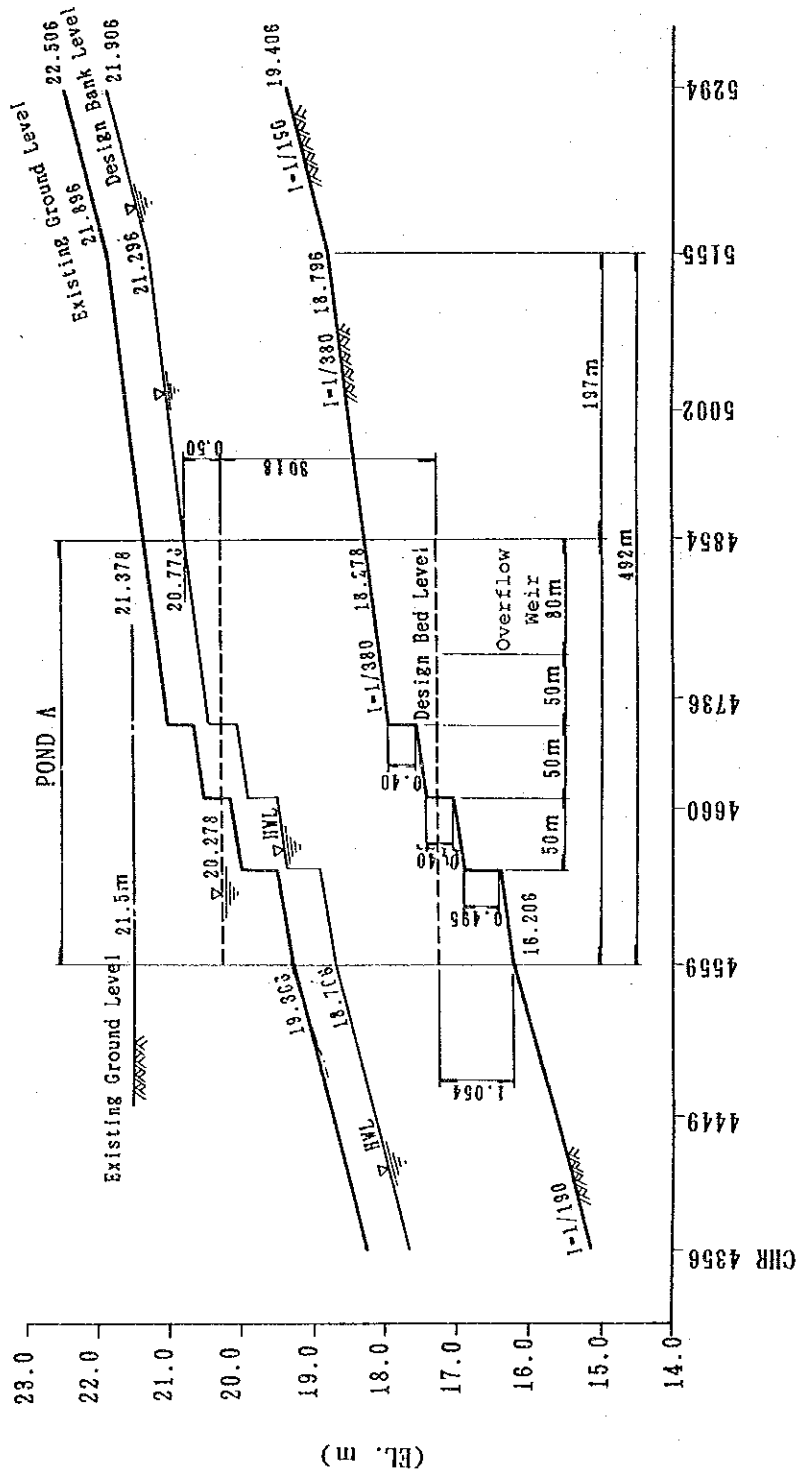


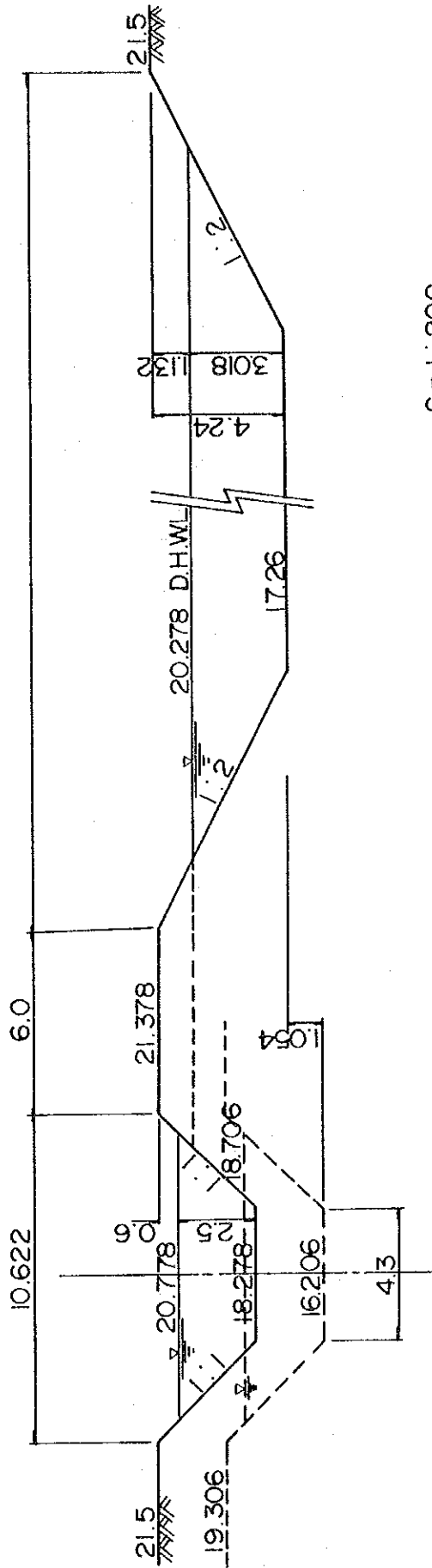
FIG. 8-24 LONGITUDINAL SECTION OF RETENTION POND A

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND



POND A

Sg. Dondang  
↓



S = 1:200

FIG. 8-25 TYPICAL CROSS SECTION OF RETENTION POND A

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND



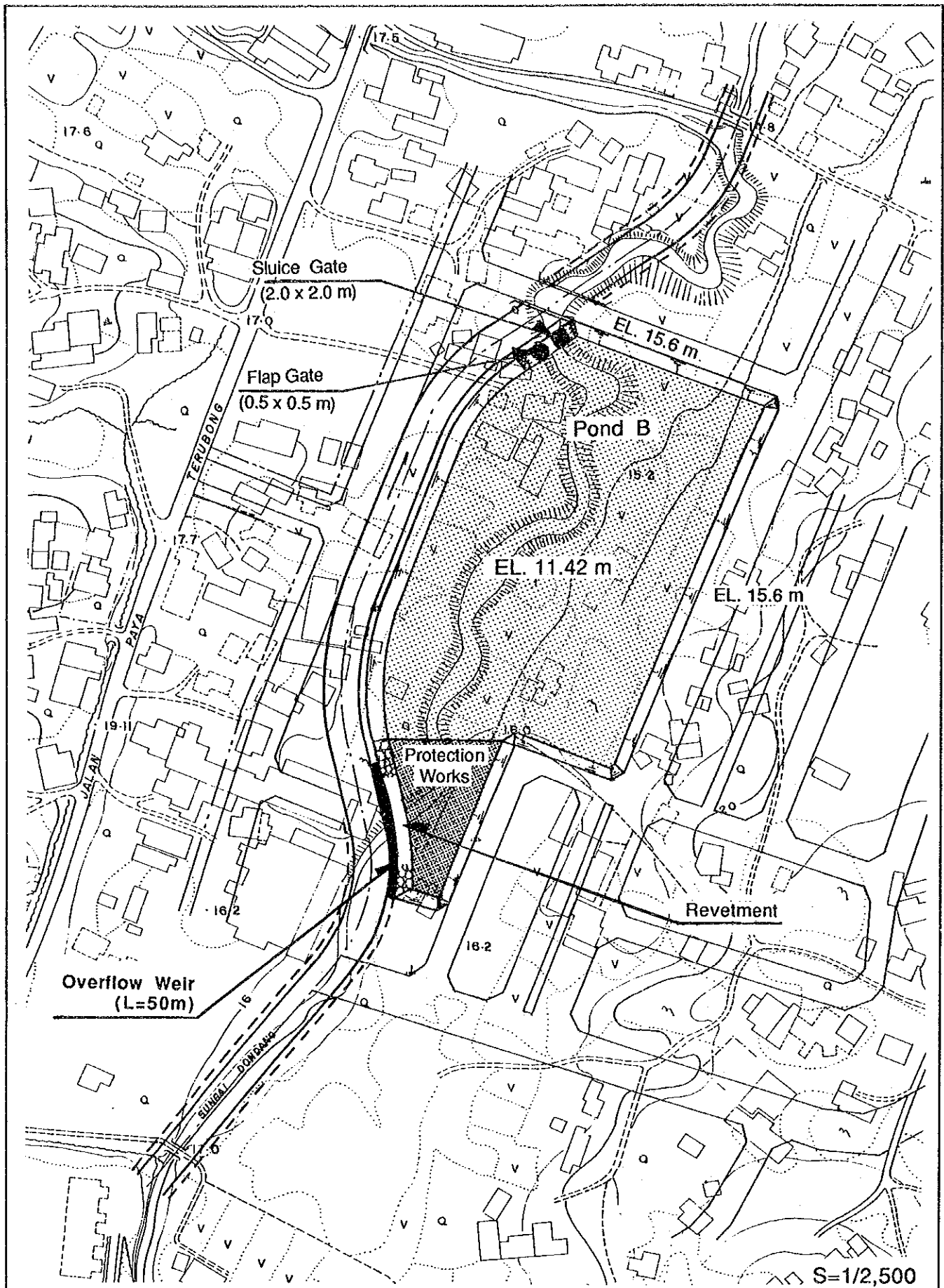


FIG. 8-26

GENERAL PLAN OF RETENTION POND B

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

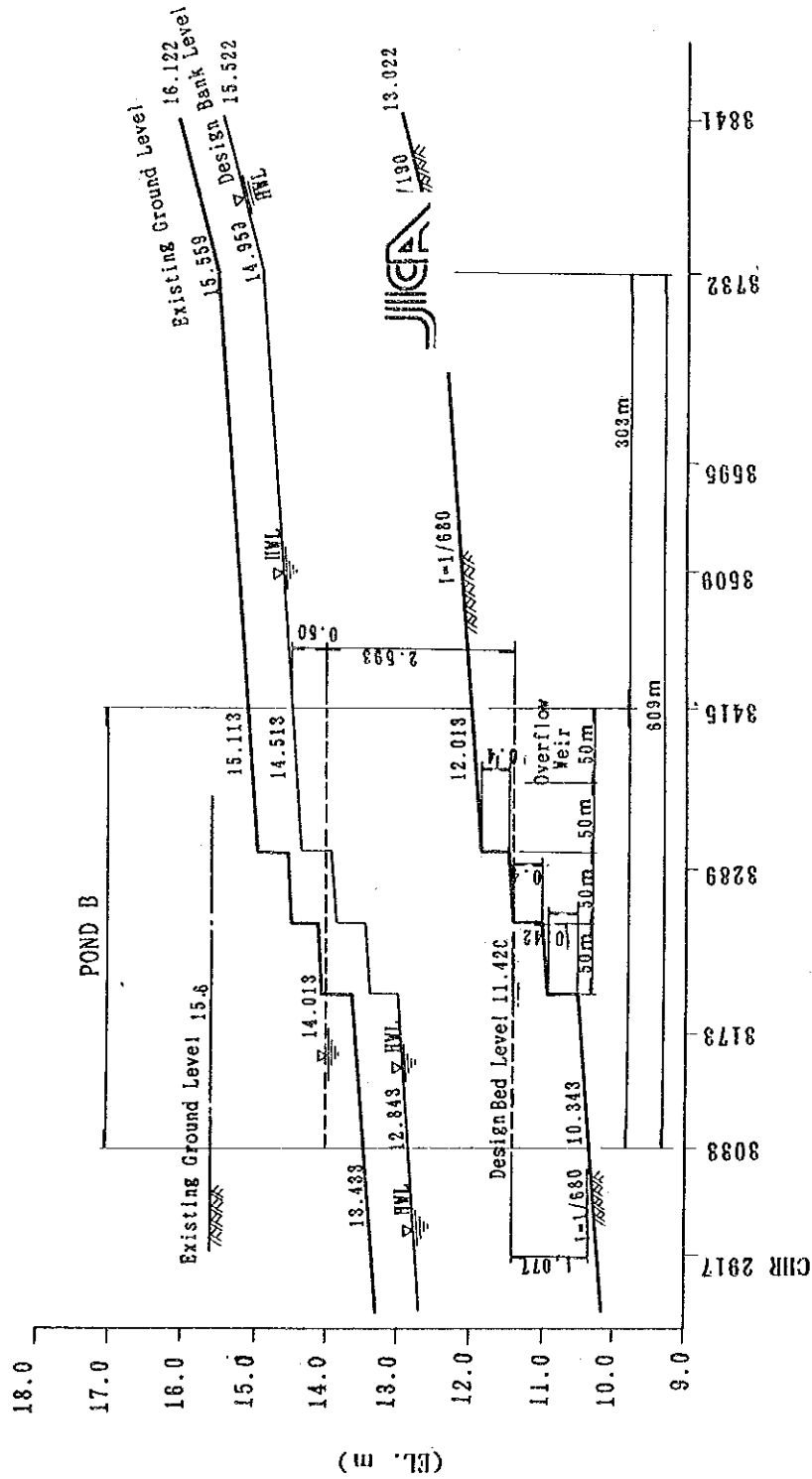


FIG. 8-27 LONGITUDINAL SECTION OF RETENTION POND B

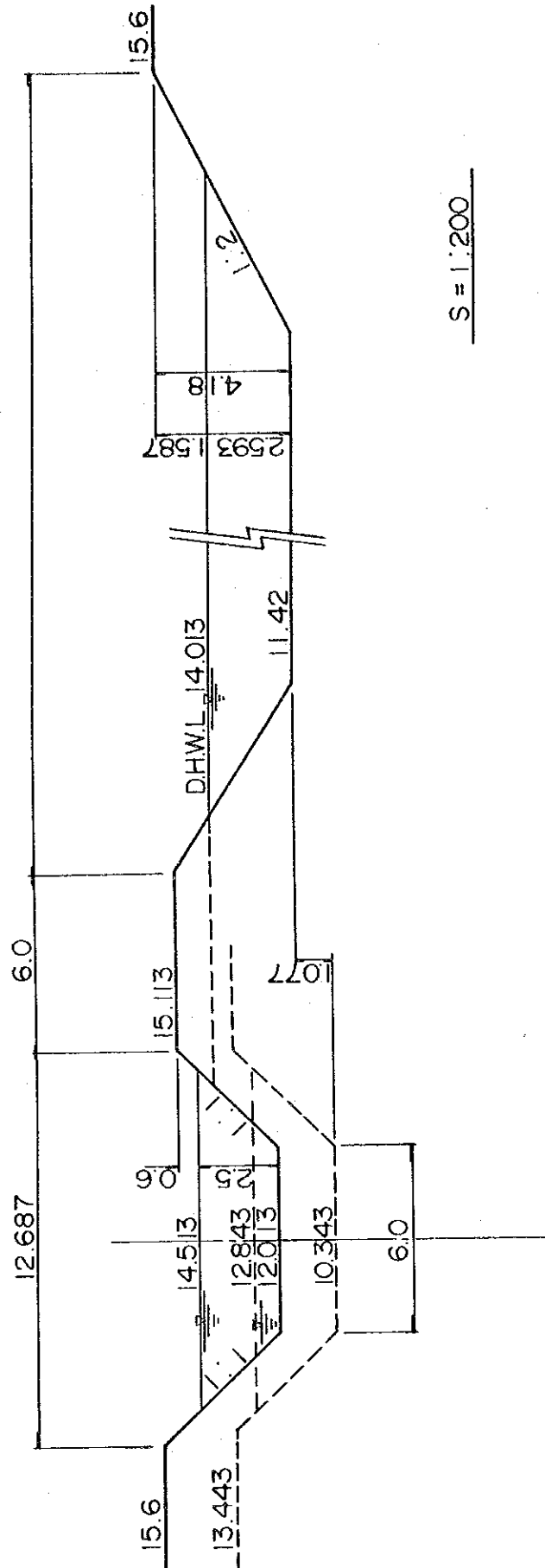
THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND



Sg. Dondang



POND B

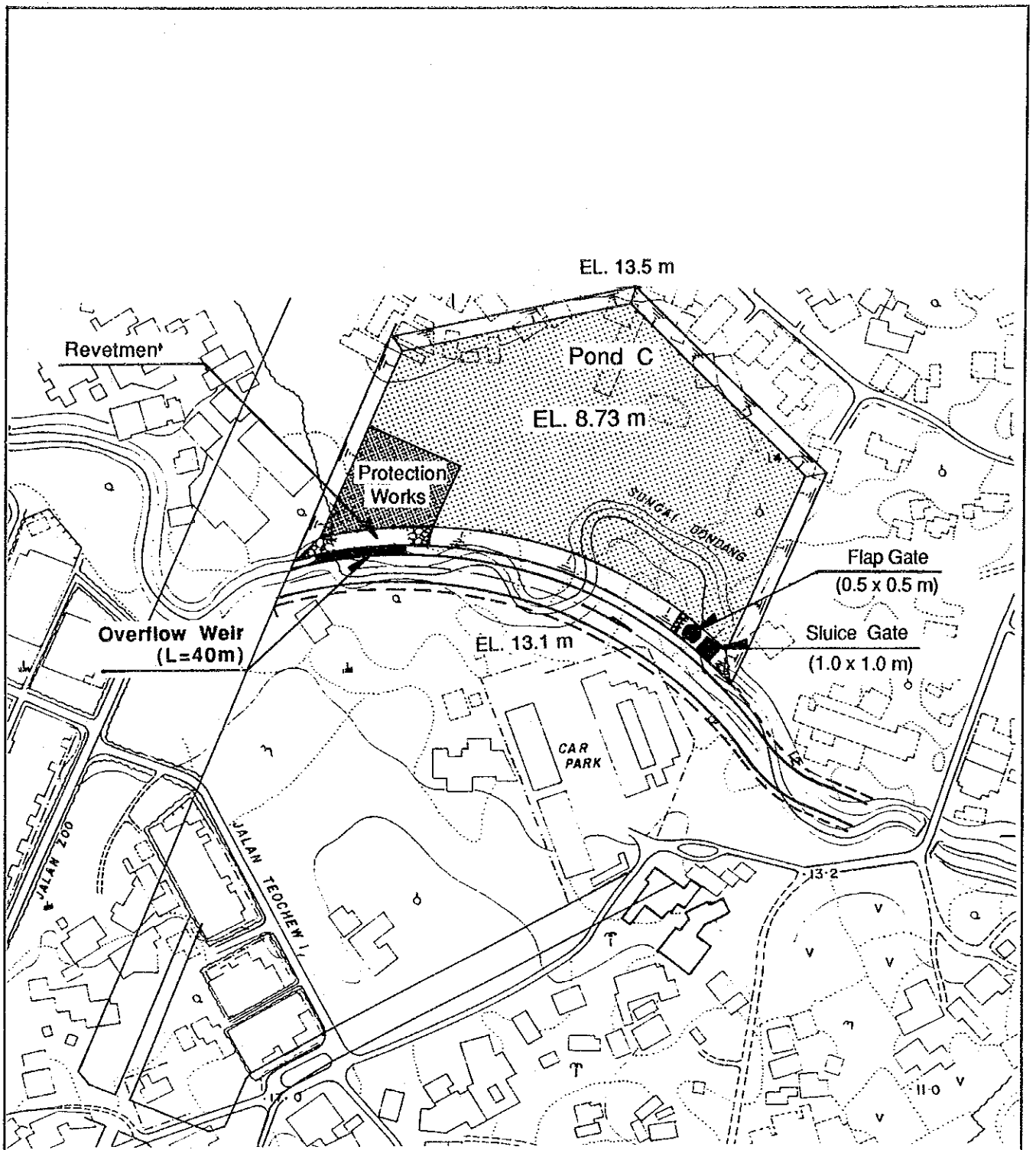


S = 1:200

FIG. 8-28 TYPICAL CROSS SECTION OF RETENTION POND B

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND





S=1/2,500

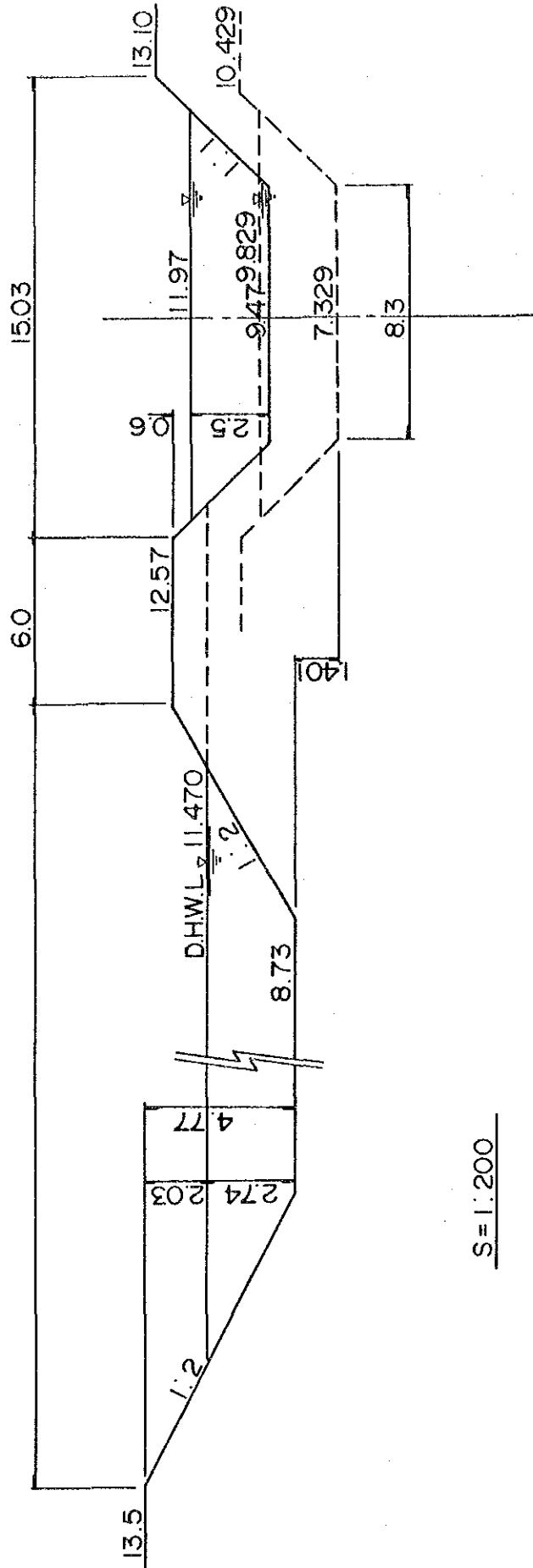
FIG. 8-29

GENERAL PLAN OF RETENTION POND C



POND C

Sg. Dandang



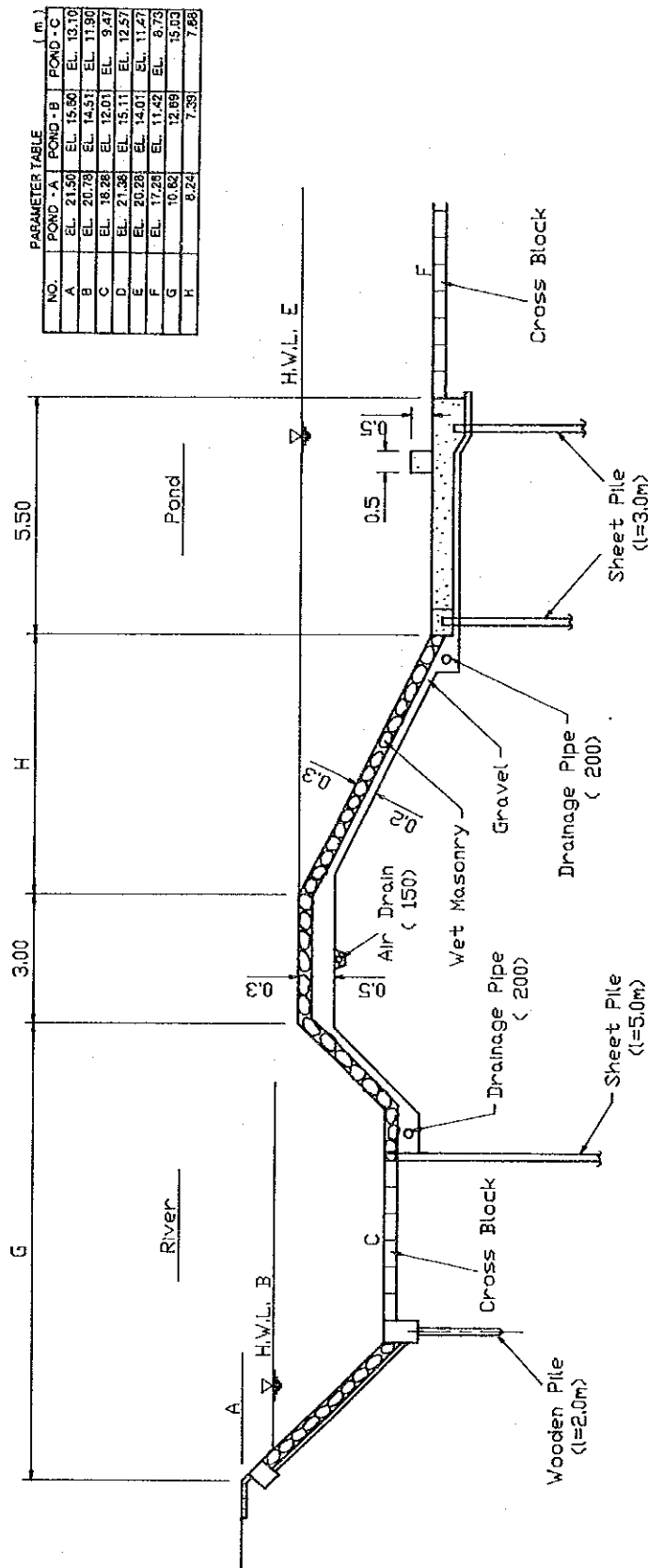
S = 1:200

FIG. 8-31 TYPICAL CROSS SECTION OF RETENTION POND C

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND





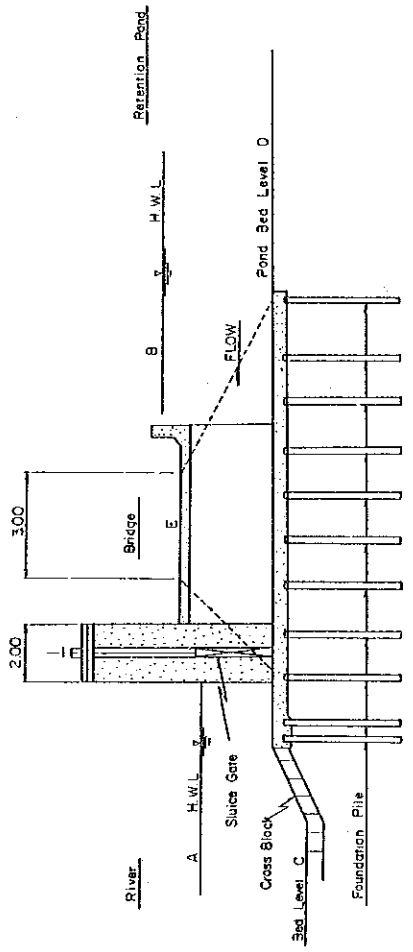


PARAMETER TABLE (m)			
NO.	POND - A	POND - B	POND - C
A	EL. 21.50	EL. 15.60	EL. 13.10
B	EL. 20.78	EL. 14.51	EL. 11.90
C	EL. 18.28	EL. 12.00	EL. 9.47
D	EL. 21.98	EL. 15.11	EL. 12.57
E	EL. 20.28	EL. 14.01	EL. 11.47
F	EL. 17.28	EL. 11.42	EL. 8.73
G	10.82	12.89	15.03
H	8.24	7.38	7.85

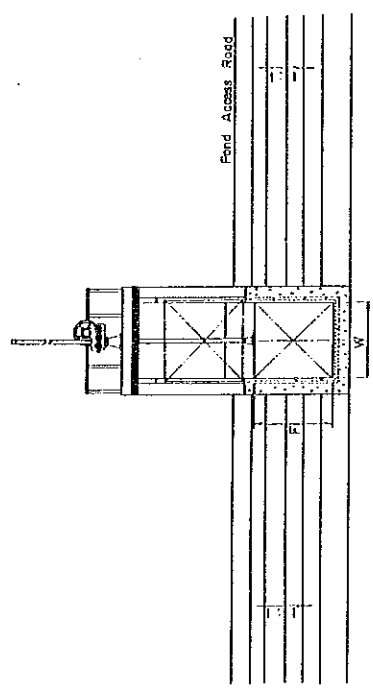
FIG. 8-32. LONGITUDINAL SECTION OF OVERFLOW WEIR

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND



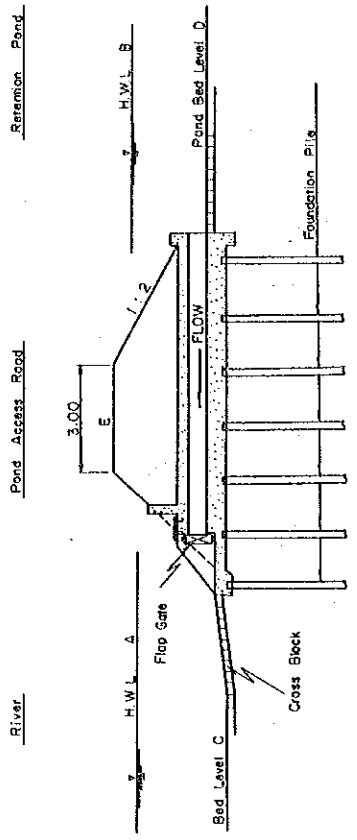


Profile of Sluice Way

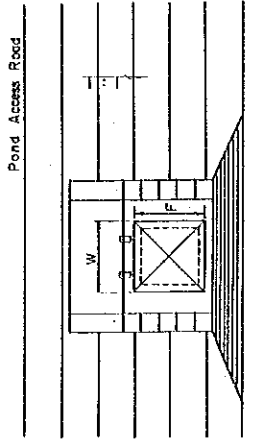


Front View of Sluice Gate

PARAMETER TABLE (m)		
NO.	POND-3	POND-C
A	EL. 18.71	EL. 12.84
B	EL. 20.28	EL. 14.01
C	EL. 16.21	EL. 10.34
D	EL. 17.25	EL. 11.42
E	EL. 19.31	EL. 13.44
F	2.00	2.00
W	2.00	2.00



Profile of Flap Gate



Front View of Flap Gate

PARAMETER TABLE (m)		
NO.	POND-4	POND-2
A	EL. 18.71	EL. 12.84
B	EL. 20.28	EL. 14.01
C	EL. 16.21	EL. 10.34
D	EL. 17.25	EL. 11.42
E	EL. 19.31	EL. 12.44
F	0.50	0.50
W	0.50	0.50

LONGITUDINAL AND CROSS SECTIONS OF OUTLET GATE OF RETENTION POND

FIG. 8-33

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND





**Chapter 9      URGENT DRAINAGE PLAN**



## CHAPTER 9 URGENT DRAINAGE PLAN

### 9.1 INTRODUCTION

The center of Georgetown suffers from recurrent floods and needs the immediate implementation of flood mitigation works. After completion of urgent flood mitigation works for Sg. Pinang, all drainage areas in Georgetown will be released from flooding problems due to overflow from the river. However, many drains still have flooding problems due to poor drainage system.

These problems are very serious especially in the large drainage basins in lowlying areas.

The feasibility study for the Drainage Plan was carried out for such priority areas.

### 9.2 SELECTION OF PRIORITY AREAS FOR THE FEASIBILITY STUDY

For the priority areas of Urgent Drainage Projects, three major drainage basins in Georgetown were selected. They are S-10 (Prangin Road), S-18 (Macalister Road), and N-12 (Jalan Pangkor). Fig.9-1 shows the study areas for Urgent Drainage Projects. The reasons for selection are as follows:

- i S-10 and S-18 basins have lowlying areas which are affected by high tides and become inundated without any rainfall.
- ii In S-10 and S-18 basins, drainage by gravity is impossible during high tides. Drainage by pumping is required.
- iii S-10 and S-18 basins are located in the central part of Georgetown, and have a high priority for solving rainage problems.
- iv In S-12 basin, there is a lowlying area which is commonly inundated due to the inadequate flow capacity of the drain.

### 9.3 DESIGN CONCEPT AND CONDITIONS FOR DRAINAGE PLAN

#### 9.3.1 Flood Protection Level

For the Urgent Drainage Plan, the design flood protection level of 10-year return period was adopted.

Because stagewise construction of these types of facilities is extremely difficult and costly, especially in built-up urban areas.

### 9.3.2 Determination of Pump Capacity and Storage Capacity of Retention Pond

For the optimum combination of drainage pump and retention pond, simulation studies on the relationship between given run-off hydrograph, pump capacity and pond volume were carried out.

More details of the simulation studies are described in APPENDIX K.

The relationship between the required retention pond volume and pump capacity is shown in Fig.9-5.

Alternative cost comparison for S-10 and S-18 drainage areas was carried out and is shown in Table 9-1.

The combined construction cost of pump and retention pond is almost the same for each case.

Finally, for the S-10 drainage basin, the pump capacity of 6 m<sup>3</sup>/s, which is similar to the existing one, was selected, while, for the S-18 drainage basin, the pump capacity of 2 m<sup>3</sup>/s was selected considering maintenance problems and cost.

## 9.4 PROPOSED DRAINAGE FACILITIES

The major construction works of Urgent Drainage Projects consists of the improvement of main drains of about 3.6 km stretches, the construction of two pump stations and two retention ponds.

### 9.4.1 Main Drain

The objective main drains for each catchment flow along the main road in the city and consist of concrete open channels or box culverts.

#### (1) S-10

The lowest ground level in this catchment is 1.4 m above M.S.W.L. To protect this lowlying area, the D.H.W.L. of the channel was decided upon below the lowest ground level. The water level in this channel will not be affected by high tides after the installation of the tidal gates which will be closed during high tides.

The type of the channel section will be either concrete open channel or box culvert according to the use conditions of the land nearby.

The existing inadequate section of the channel was planned to be improved by widening and deepening.

The plan of proposed S-10 drains is shown in Fig.9-2.

**(2) S-18**

The outfall of this drain was extended up to S-18 retention pond. For this stretch, two routes were compared. Route 1 flows along LEBOH SANDILANDS and has a shorter length as compared to Route 2. Route 2 is located along the Sg. Pinang and needs land acquisition. Considering the construction cost and hydraulic condition, Route 1 was selected. The existing flow capacity of the S-18 main drain is extremely small; the channel should be improved over the entire stretch. Fig.9-3 shows the plan of the proposed S-18 drains.

**(3) N-12**

As shown in Fig.9-4, the N-12 drainage system consists of two main drains along Jln. PERAK and LEBOH RAYA PEEL, and a trunk drain of about 250 m in length along Jln. PANGKOR.

The outfall of this drain is planned to be extended 36 m considering the proposed future Ring Road.

These two drains are of concrete box culvert type and are to be constructed under the existing road or footpath.

The existing ground level of these routes is between 3.1 to 4.5 m and, basically, is not affected by high tides.

**9.4.2 Retention Pond**

The retention pond will be planned to store the run-off discharge from the catchment during high tides. Under normal condition without any rainfall this run-off discharge is small and it is possible to store all of it in the retention pond remaining enough capacity without pumping. However, when rainfall intensity exceeds a certain degree, the pump will be operated to drain inner water.

The location of the retention ponds for the S-10 and S-18 drainage basins was selected considering the following conditions:

- (i) Availability of land for retention pond and land acquisition cost.
- (ii) Environmental impacts on the surrounding areas
- (iii) Location of the areas to be protected.
- (iv) Future Land Use Plan for the Coastal Area.

The S-18 Retention Pond is located outside the proposed Coastal Road. This site presents no major



environmental problems either during or after construction, and no land acquisition costs are required. However, it will be necessary to construct the dyke for the retention pond.

As for the S-10 Retention Pond Site, the area outside the proposed Coastal Road was also selected.

The general plans for the S-10 and S-18 Retention Ponds are shown in Fig.9-6 and Fig.9-7.

The design high water level of the pond will be decided by referring to the lowest ground level to be protected in the catchment and the hydraulic gradient. The lowest ground level in the S-10 and S-18 basins is +1.4 m.

The H.W.L. in the pond was set at 1.20 m.

The design low water level of the pond was set at -0.80 m by referring to M.L.W.S (Mean Low Water Spring).

The bottom level of the pond was set at about 30 cm lower than the design L.W.L. for the purpose of retaining the free storage capacity for sediment.

The effective depth of the pond is 2.0 m for both the S-10 and S-18 ponds.

By closing the sea about 4.3 ha by considering a 720 m dyke outside the proposed Coastal Road, it is planned to create storage capacity required for drainage purpose.

Each retention pond is surrounded by this closing dyke and the proposed Coastal Road.

The closing dyke consists of earth embankment with a rubble revetment and cut off sheet piles.

The dyke is about 3.4 m high and its formation level is 2.2 m having a 60 cm freeboard above the E.H.W.S.

The top of the dyke is paved and serves as a maintenance road. The inner surrounding of the retention pond is planned to have a twenty meter wide green belt for screening and preventing odor problems.

Fig.9-8 shows a typical cross section of the dyke.

### **9.4.3 Pump Station**

#### **1) Pump Facilities**

The major facilities of each pump station consists of pumps, a tidal gate, pump house, box culvert, outlet tank and screen. The S-18 pump station is planned to have two horizontal axial flow pumps with a capacity of 1 m<sup>3</sup>/s each.

While the S-10 pump station has three pumps of the same type with a capacity of 2 m<sup>3</sup>/s.

The general plan and longitudinal section of the S-10 and S-18 pump stations are shown in Fig.9-9 and 9-10.

## **2) Tidal Gate**

The sluice gate will be installed near the outlet tank to prevent the inflow of sea water during high tides.

Two 3.0 m x 3.1 m maintenance gates are to be installed at each outlet of sluice way.

Under normal conditions at low tide, these gates are to be kept open. They will only be operated during high tide.



## Tables



TABLE 9-1 ALTERNATIVE COST COMPARISON OF RETENTION POND AND PUMP STATION

S-18

CASE NO.	PUMP CAPACITY (m <sup>3</sup> /sec.)	RETENTION POND (1000 M\$)	PUMP STATION (1000 M\$)	TOTAL COST (1000 M\$)
1	2.0	2,477	3,242	5,719
2	4.0	1,930	3,742	5,672
3	6.0	1,512	4,092	5,604
4	8.0	1,291	4,732	6,023

S-10

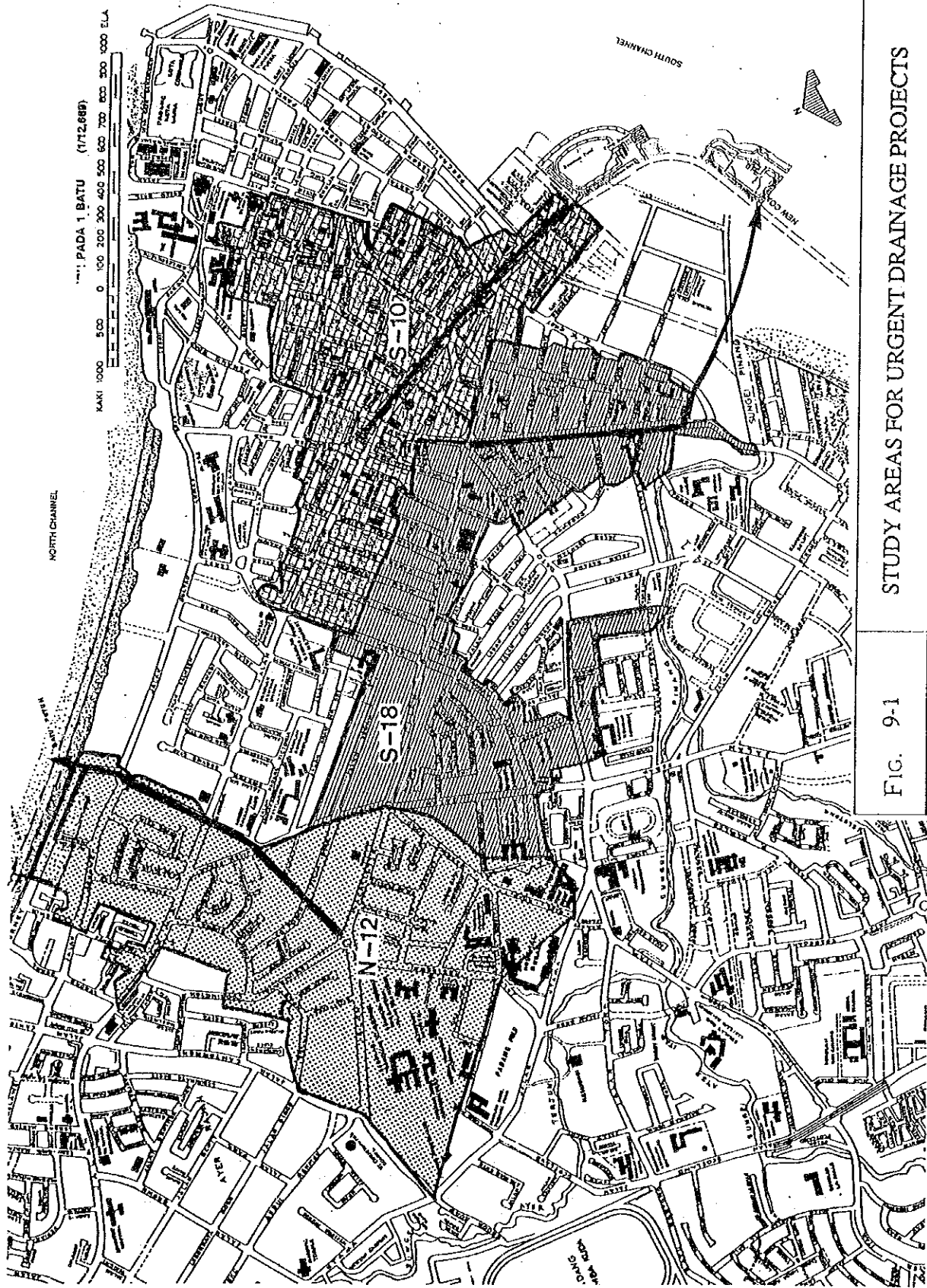
CASE NO.	PUMP CAPACITY (m <sup>3</sup> /sec.)	RETENTION POND (1000 M\$)	PUMP STATION (1000 M\$)	TOTAL COST (1000 M\$)
1	2.0	2,528	3,242	5,770
2	4.0	2,296	3,742	6,038
3	6.0	2,144	4,092	6,236
4	8.0	1,871	4,732	6,603



## Figures







STUDY AREAS FOR URGENT DRAINAGE PROJECTS

FIG. 9-1

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND



FIG. 9-2

PLAN OF PROPOSED S-10 DRAINS

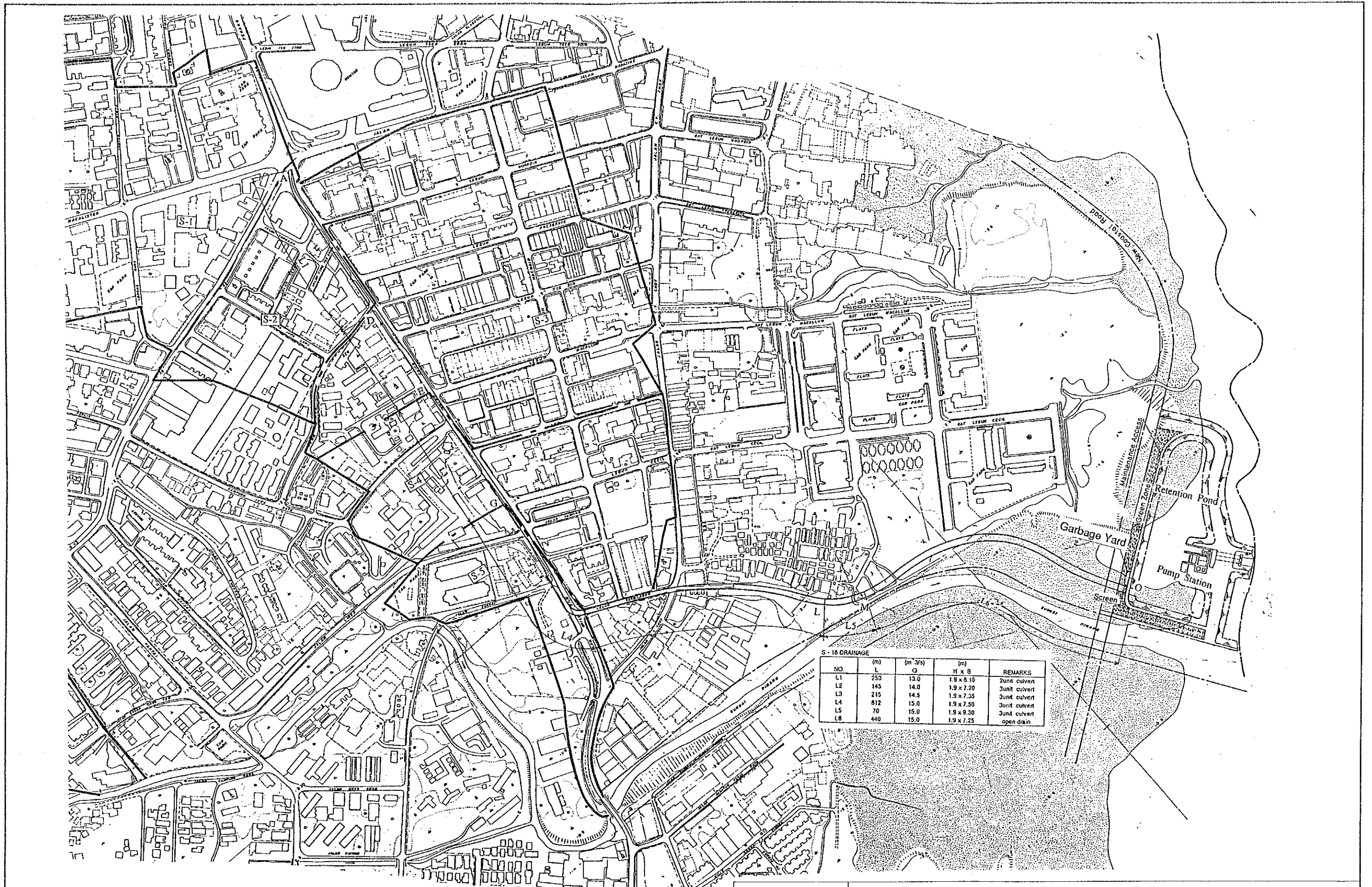


FIG. 9-3

PLAN OF PROPOSED S-18 DRAINS





FIG. 9-4

PLAN OF PROPOSED N-12 DRAINS



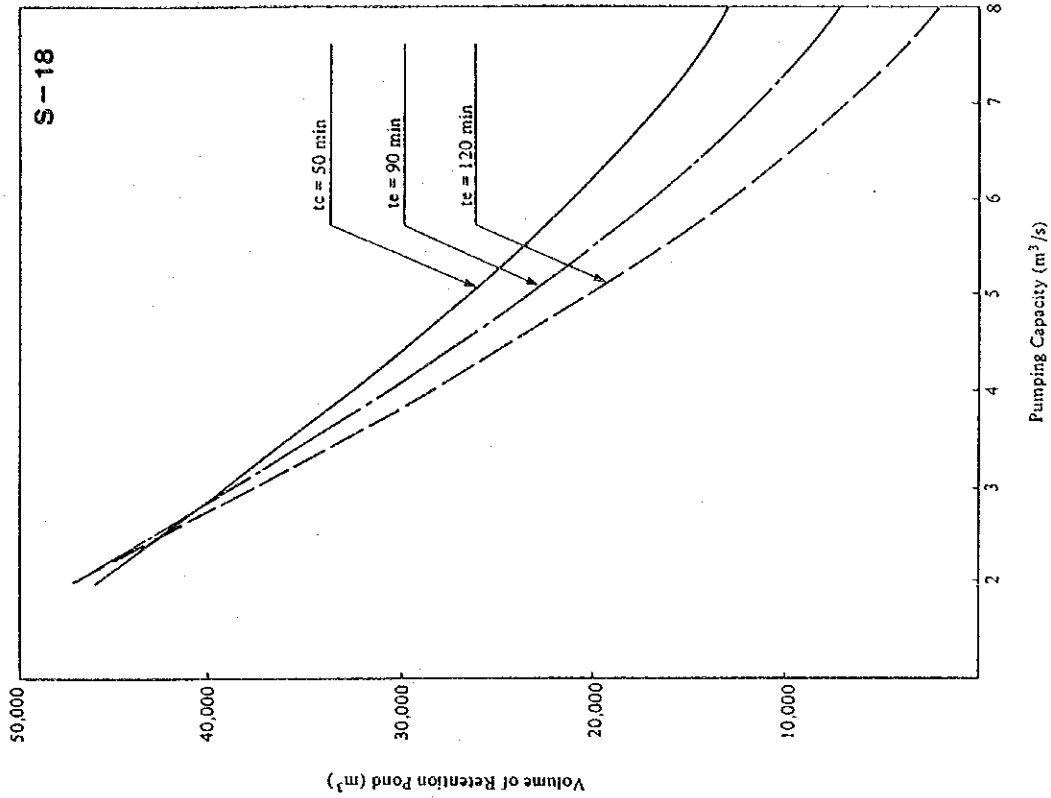
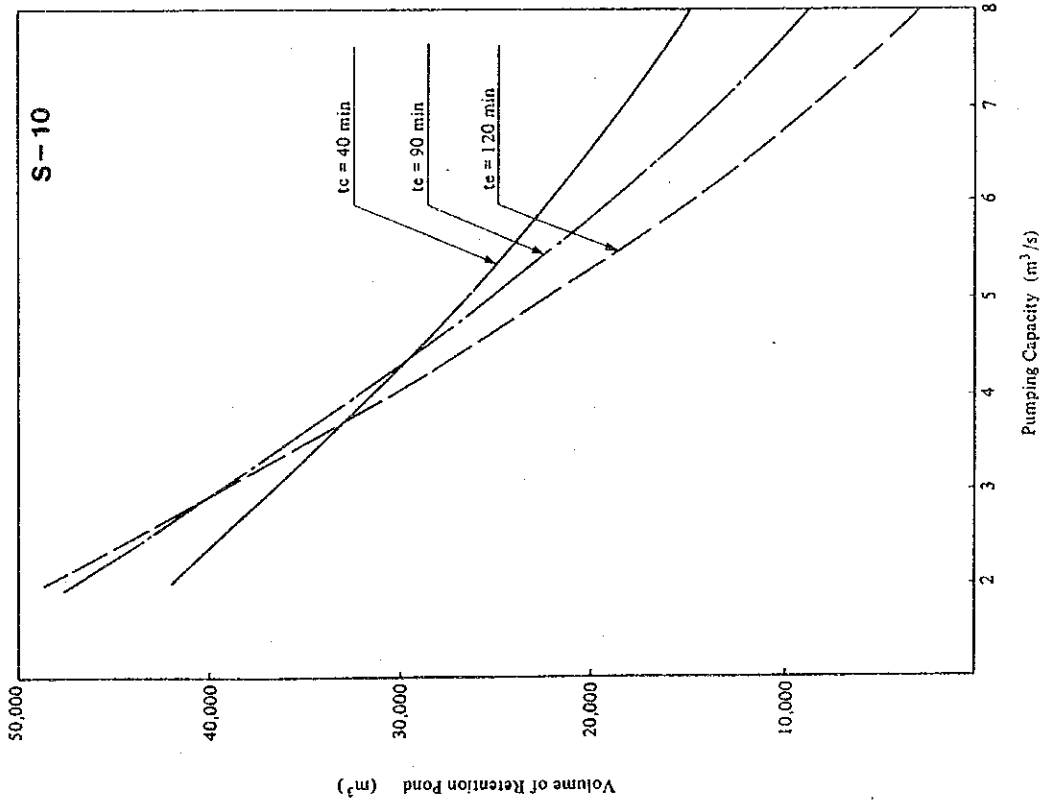


FIG. 9-5

RELATIONSHIP BETWEEN POND VOLUME AND PUMP CAPACITY

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND



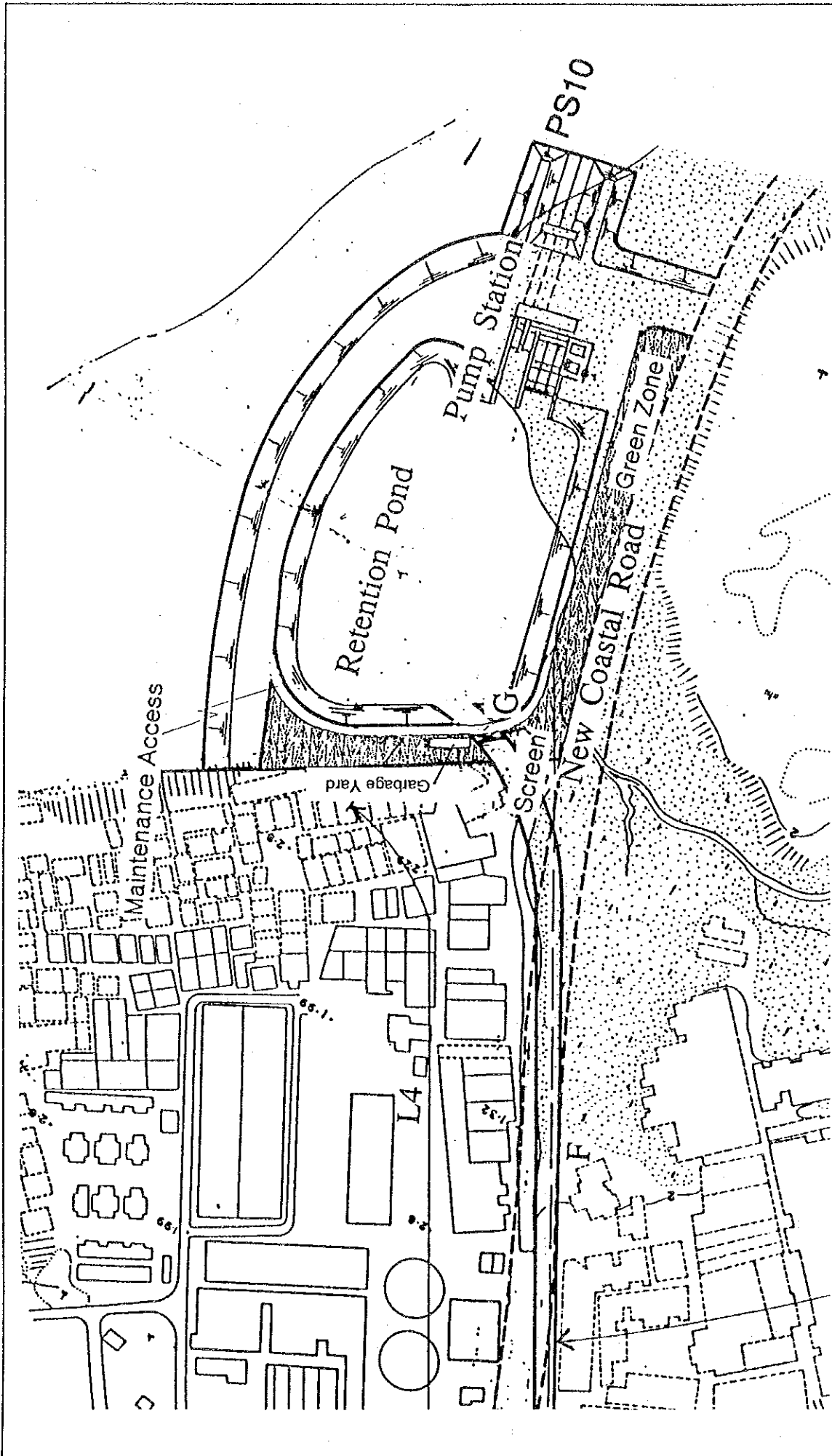


FIG. 9-6 GENERAL PLAN OF S-10 RETENTION POND

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND





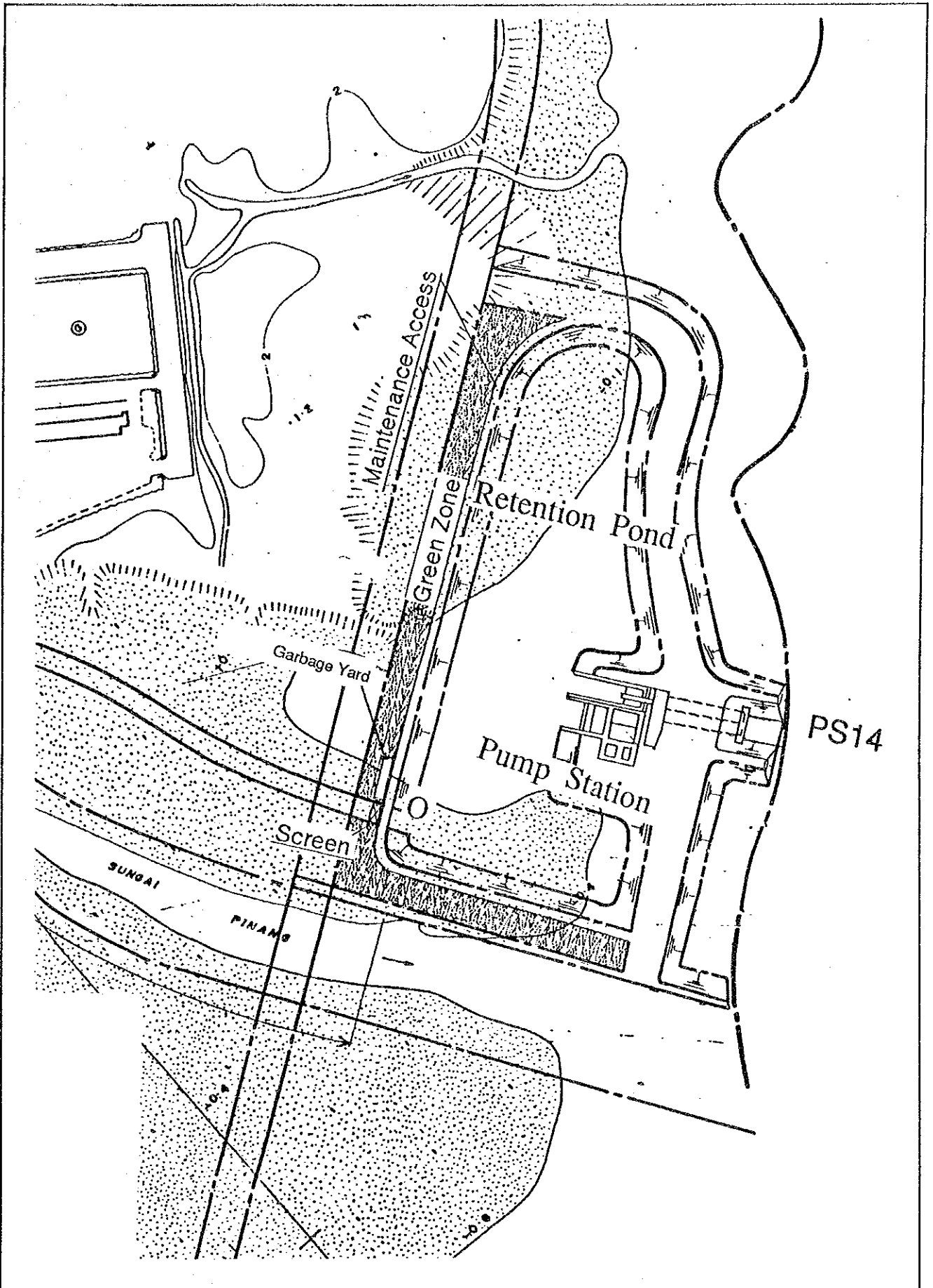
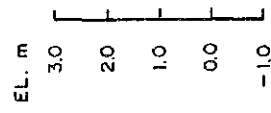
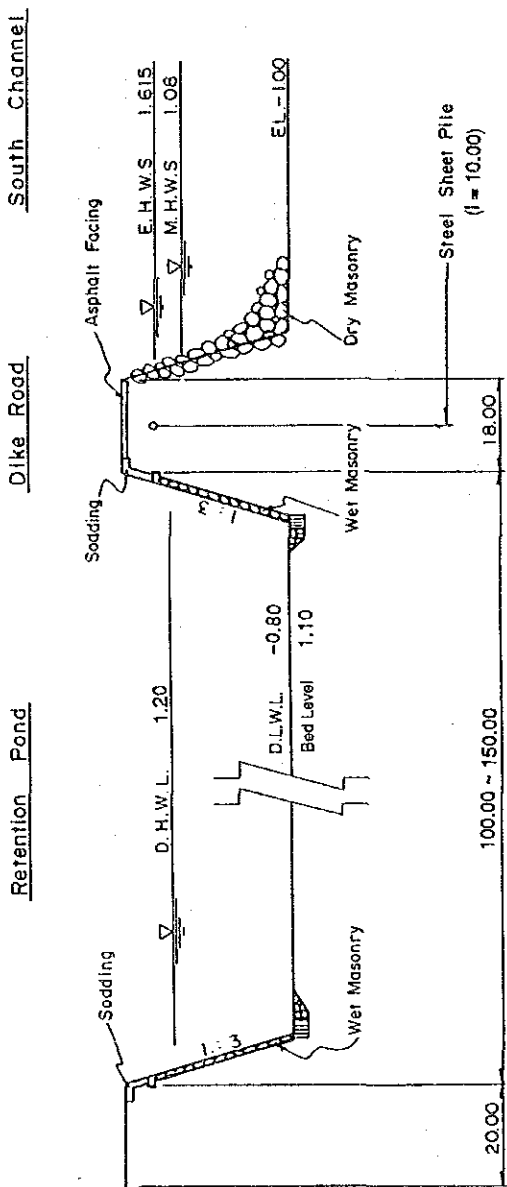


FIG. 9-7

GENERAL PLAN OF S-18 RETENTION POND



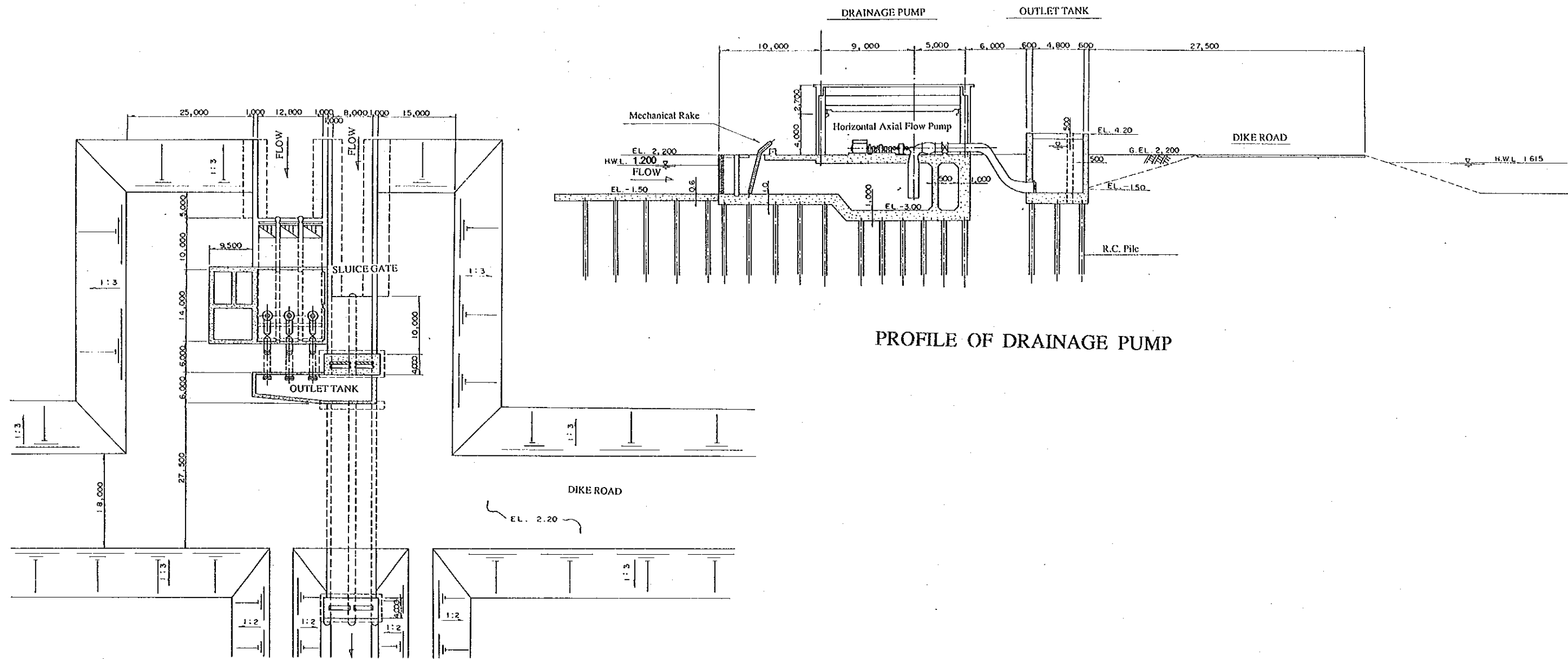
SCALE V 1 : 100  
H 1 : 1000

Typical Cross Section of Retention Pond

FIG. 9-8 TYPICAL CROSS SECTION OF RETENTION POND  
THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND







GENERAL PLAN SCALE 1:400

PROFILE OF DRAINAGE PUMP

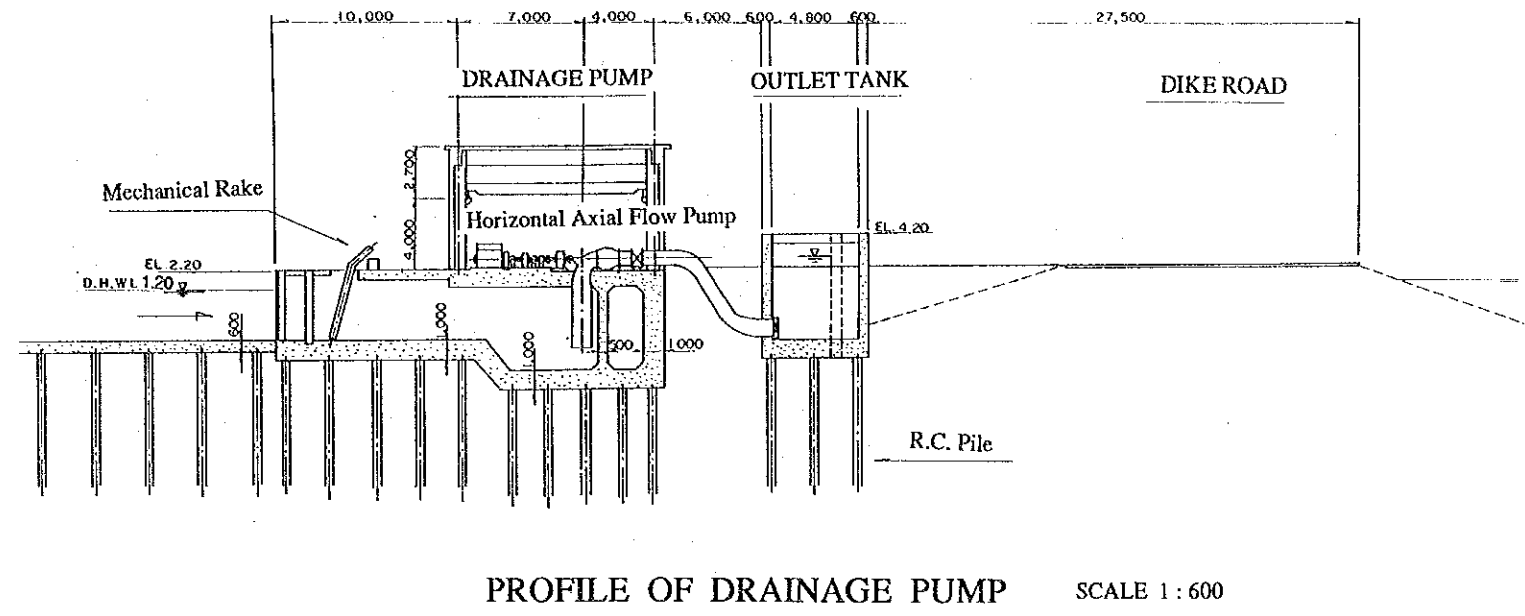
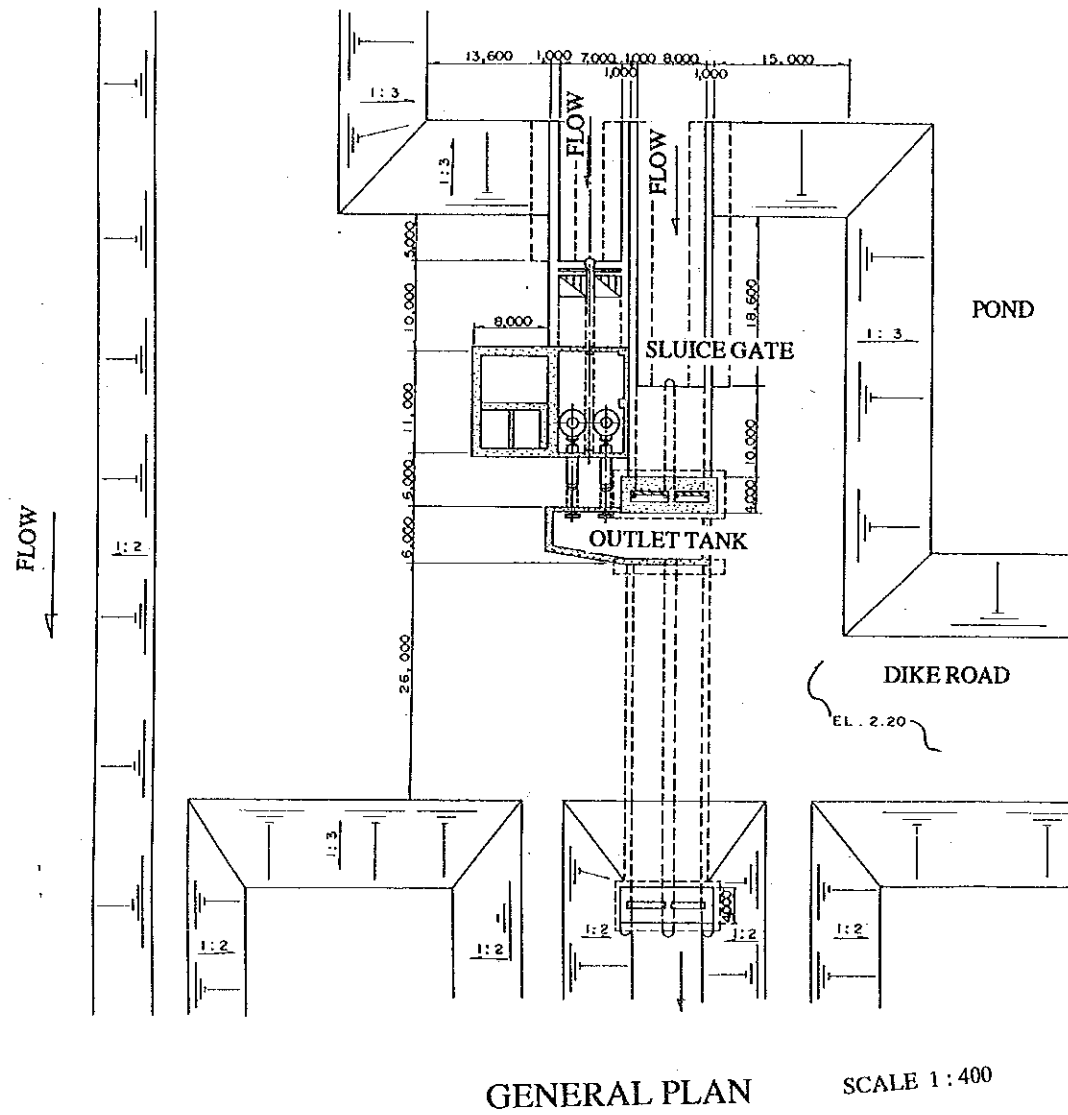
PROFILE OF SLUICE WAY

SCALE 1:800

FIG. 9-9

PLAN, LONGITUDINAL AND CROSS SECTIONS OF S-10 PUMP STATION

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND



CASE - 1  
( $q = 1 \text{ m}^3/\text{sec}$ )  
SCALE 1 : 800

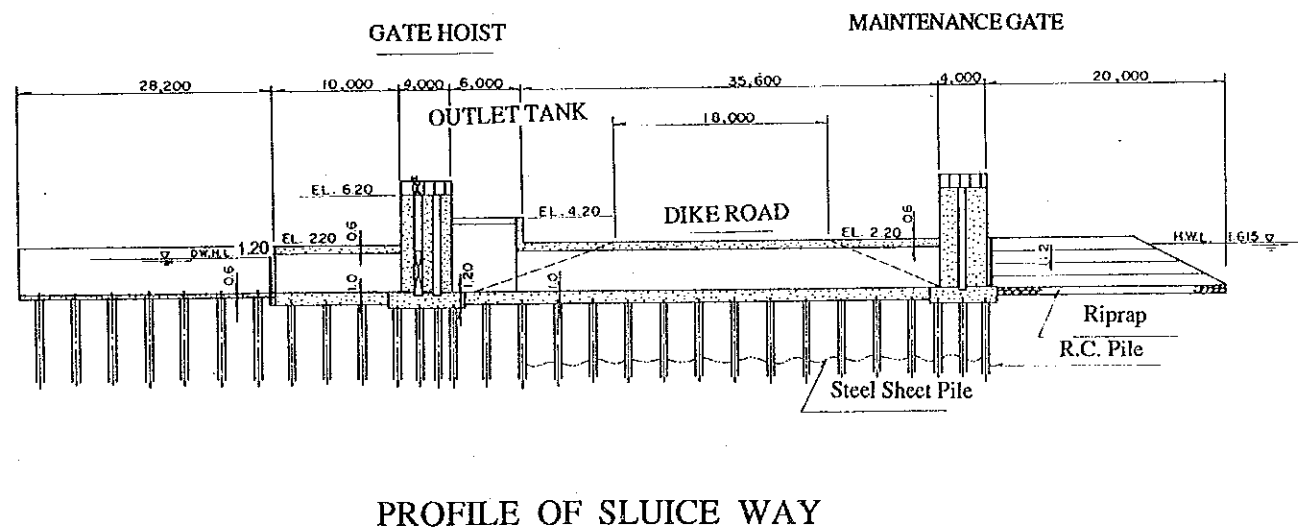


FIG. 9-10 PLAN, LONGITUDINAL AND CROSS SECTIONS OF S-18 PUMP STATION  
THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND



**Chapter 10**      **CONSTRUCTION PLAN AND COST ESTIMATE  
FOR URGENT PROJECT**





## CHAPTER 10 CONSTRUCTION PLAN AND COST ESTIMATE FOR URGENT PROJECTS

### 10.1 INTRODUCTION

The urgent projects for the construction stage (Phase I) have the following two schemes:

- i) Improvement of two major river systems (Sg. Pinang and Sg. Keluang), including some stretches of Sg. Gelugor and Sg. Dua Besar.
- ii) Improvement of three major drainage systems in Georgetown (S-10, S-18 and N-12 drainage basins).

The Five-year Construction Plan is adopted for executing these urgent projects.

### 10.2 CONSTRUCTION WORK FOR URGENT PROJECTS

The construction work for the Urgent Flood Mitigation and Drainage Projects consist mainly of excavation, embankment and bank protection for channel improvement, the construction of retention ponds, the construction of structures, such as concrete diversion channels, gates, culverts, bridges and drop structures, the construction of drainage pump stations, and the improvement of trunk drains.

The required major construction works are as follows:

- Improvement of Sg. Pinang (13.3 km), Sg. Keluang (5.25 km), downstream stretches (0.5 km and 2.1 km of the Sg. Gelugor and Sg. Dua Besar respectively).
- Construction of Air Terjun (1.74 km) and Relau (1.5 km) Diversion Channels.
- Construction of Dondang Retention Ponds at three (3) locations. They will have a total capacity of 8.4 ha.
- Construction of river related structures, mainly the renewal of existing bridges.
- Improvement of trunk drains N-12, S-10 and S-18 (about 4.5 km in total length).
- Construction of a retention pond (1.9 ha) and pumping station (6.0 m<sup>3</sup>/s) for the S-10 drainage area.

- Construction of a retention pond (2.4 ha) and pumping station (2.0 m<sup>3</sup>/s) for the S-18 drainage area.

### **10.3 CONSTRUCTION PLAN**

#### **10.3.1 Basic Considerations for Planning**

The construction plan for executing the projects is formulated by taking into account the following:

- a. The construction work is to be conducted in Penang Island and its central areas which are mainly international tourist resorts. Therefore, it is obliged that maintenance of environmental aspects, protection of existing public infrastructures and other relevant works will be required.
- b. Considering the degree of urgency and importance and the 6th Malaysia Plan (1991 - 1995), it is planned that the urgent project construction work is to be implemented within three (3) years starting at the beginning of 1993. Pre-construction works (detailed design, tendering, financial arrangement and others) are scheduled to be carried out within a two (2) year period (1991 to 1992).
- c. The river improvement and drainage works will proceed simultaneously and will be completed within a three (3) year period.
- d. Major work items for the river improvement include channel widening and deepening by excavation or dredging, revetment by wet masonry or concrete and levee embankment. Medium to small class equipment will be planned to be utilized considering the site conditions, such as urbanized area, the dense area of buildings, traffic and other restricted conditions. Excavated soil will be planned to be utilized effectively as material for the levee embankment, land reclamation of CDD 21, and others.
- e. A phased and rapid construction system will be applied for the Air Terjun Diversion Channel. Traffic, so far as practicable, will not be obstructed.

#### **10.3.2 Construction Schedule**

The proposed implementation schedule and construction time schedule for the urgent projects are given in Fig.10-1 and 10.2 respectively.

## **10.4 CONSTRUCTION COST FOR THE PROJECT**

### **10.4.1 Conditions and Assumptions for Cost Estimate**

The construction cost consists of these required for civil works, land acquisition and building compensation, engineering and administration costs, and contingencies.

The following conditions were applied for arriving at the financial cost estimate.

- The price level prevailing in August 1990 was applied. That was the time when the survey and investigation work was conducted at the site.
- The following foreign exchange rate was adopted for conversion purposes.

One (1) US\$ = M\$ 2.70 = Yen 140.0

#### **1) Composition of financial cost**

The financial cost of the urgent projects consists of the following items:

- Direct construction cost
- Land acquisition and building compensation cost
- Administration cost
- Engineering services cost for the detailed design including hydraulic model test and construction supervision.
- Physical and price contingencies

#### **2) Currency of estimate**

The estimated costs are indicated by the Malaysian Dollar both for the foreign currency portion and local currency portion.

#### **3) Disbursement of investment cost**

It is assumed that the investment cost will be disbursed according to the proposed implementation schedule starting at the detailed design stage.

### **10.4.2 Estimate of Construction Cost**

#### **1) Direct Construction Cost**

The direct construction cost for civil works is estimated by multiplying the unit cost of each work item by the corresponding work quantity. The unit cost of

respective work item consists of the cost for materials, labourers, equipment, and contractor's indirect costs for site expenses, overhead and profit. Required preparatory works such as access roads, construction roads, temporary buildings and others are estimated on a lump sum basis and are incorporated as the general items. The replacement costs for public utilities are estimated on a lump sum basis and treated as the provisional sum cost items incorporating the general items.

**2) Land Acquisition and Building Compensation Cost**

These costs are estimated based on the unit cost which were established by following the data obtained from the State Valuation Department. The costs are incorporated into the local currency component.

**3) Administrative Cost**

The cost for the project's administration, management and supervision for the implementation of the urgent projects was estimated in proportion to the direct construction cost. An allowance of about 5 % of the total direct construction cost was provided for the cost and incorporated in the local currency component.

**4) Engineering Services Cost**

The cost was also estimated in proportion to the direct construction cost to cover the detailed design, hydraulic model tests and construction supervision by consultants. The engineering services cost was estimated to be about 10% of the total direct construction cost and its 80% was incorporated into the foreign currency component and 20% into the local currency component.

**5) Contingencies**

Physical contingency

The physical contingency was provided to cope with the unpredictable physical conditions during implementation of the urgent projects amounting to approximately 15% of the total direct cost.

Price contingency

The price contingency was provided for the reflection of the inflational effect against the implementation of the urgent projects. The price contingency for the financial cost was estimated assuming the inflational rate to be 3% per annum for foreign currency and 3.2% for local currency portions by referring the inflational rate (3.2%) for the whole country of Malaysia in 1990.

### 10.4.3 Financial Cost of Urgent Projects

The financial cost for the urgent projects is summarized as follows.

Unit : Million M\$

Project	Amount (M\$)	Equivalent US\$
- Sg. Pinang System	135.5	(50.2)
- Sg. Keluang System	40.2	(14.9)
- Georgetown Drainage	37.9	(14.0)
<b>Total</b>	<b>213.6</b>	<b>(79.1)</b>

The breakdown of the financial cost for each urgent project is shown in Table 10-1 to 10-4.

### 10.4.4 Annual Disbursement Schedule

The annual disbursement of investment costs was allocated on the basis of the implementation schedule and is summarized as follows.

Annual Disbursement Schedule for Financial Cost  
of Urgent Project

Unit : Million M\$

Year/Project	Sg. Pinang		Sg. Keluang		Drainage		Total		
	F.C.	L.C.	F.C.	L.C.	F.C.	L.C.	F.C.	L.C.	
1991		0.6	0.2		0.4		1.2		
	2.5	0.6	0.2		0.5		1.3		
1992		0.6	0.2		0.5		1.3		
	62.9	47.1	13.6		0.9		61.6		
1993		10.0	3.2		9.1		22.3		
	95.5	52.9	15.4		4.9		73.2		
1994		7.8	2.5		7.1		17.4		
	26.1	3.9	1.2		3.6		8.7		
1995		8.0	2.5		7.2		17.7		
	26.6	4.0	1.2		3.7		8.9		
		27.0	108.5	8.6	31.6	24.3	13.6	59.9	153.7
<b>Total</b>	<b>213.6</b>	<b>135.5</b>	<b>40.2</b>		<b>37.9</b>				

The annual disbursement schedule for each project is shown in Table L-6 in APPENDIX L.

#### 10.4.5 Operation and Maintenance Cost

The annual operation and maintenance (O & M) costs for the urgent projects were estimated for the said works as shown in Table L-13 in APPENDIX L. The O & M costs include the salary of operation and maintenance staffs, materials, labours and equipment costs for O & M works required for the project's facilities. Thus, the annual O & M cost for the urgent projects was estimated to be M\$ 0.3 million in total.

Unit : 1,000M\$

Category	O & M Costs
- Flood mitigation facilities ( rivers/retention ponds )	100
- Drainage facilities ( pumps/retention ponds )	200
Total	300

#### 10.4.6 Replacement Cost

Some of the project's facilities, especially mechanical and electrical equipment have, a shorter useful life than the concrete or earthing structures, and require replacement at a certain time during their project service life. The yearly replacement costs were estimated to be about M\$0.1 million for flood mitigation facilities every 20 years and about M\$3.0 million for drainage facilities.

## Tables





**TABLE 10 -1 SUMMARY OF FINANCIAL COST FOR THE URGENT PROJECTS**

Cost Items	(10 <sup>3</sup> M\$)		
	Costs		Amount
	F.C.	L.C.	
1. Direct Construction Cost	42,200	19,320	61,520
2. Land acquisition & house evacuation cost	-	98,490	98,490
3. Administration expenses<1	-	3,100	3,100
4. Engineering services cost<2	4,220	1,930	6,150
Sub total (1 - 4)	46,420	122,840	169,260
5. Contingency			
(1) Physical contingency<3	6,960	18,430	25,390
(2) Price contingency<4	6,380	12,620	19,000
Sub total	13,340	31,050	44,390
<b>Total (1 - 5)</b>	<b>59,760</b>	<b>153,890</b>	<b>213,650</b>

**Notes :**

- \* F.C. : Foreign currency component
- \* L.C. : Local currency component
- <1 : 5% of (1) approximately
- <2 : 10% of (1) approximately for detailed design and of direct cost and construction supervision
- <3 : 15% approximately of base cost(1 - 4)
- <4 : 3% for F.C. and 3.2% for L.C. per annum (1991 - 1995)

**TABLE 10 -2 SUMMARY OF FINANCIAL COST FOR THE URGENT PROJECT  
Sg.Pinang System**

Cost Items	(10 <sup>3</sup> M\$)		
	F.C.	L.C.	Amount
1. Direct Construction Cost	19,040	8,630	27,670
2. Land acquisition & house evacuation cost	-	75,950	75,950
3. Administration expenses<1	-	1,380	1,380
4. Engineering services cost<2	1,900	860	2,760
Sub total (1 - 4)	20,940	86,820	107,760
5. Contingency			
(1) Physical contingency<3	3,140	13,020	16,160
(2) Price contingency<4	2,880	8,650	11,530
Sub total	6,020	21,670	27,690
<b>Total (1 - 5)</b>	<b>26,960</b>	<b>108,490</b>	<b>135,450</b>

**Notes :**

- \* F.C. : Foreign currency component
- \* L.C. : Local currency component
- <1 : 5% of(1) approximately
- <2 : 10% of(1) approximately for detailed design and of direct cost and construction supervision including hydraulic model test
- <3 : 15% approximately of base cost(1 - 4)
- <4 : 3% for F.C. and 3.2% for L.C. per annum (1991 - 1995)
- <5 : Sg.Pinang System contains Sg.Pinang, Sg.Air Itam  
Sg. Dondang,Sg.Jelutong, Terjun Diversion

**TABLE 10 -3 | SUMMARY OF FINANCIAL COST FOR THE URGENT PROJECT  
SG.Keluang System**

Cost Items	(10 <sup>^3</sup> M\$)		
	F.C.	L.C.	Amount
1. Direct Construction Cost	6,070	2,700	8,770
2. Land acquisition & house evacuation cost	-	21,910	21,910
3. Administration expenses<1	-	440	440
4. Engineering services cost<2	610	270	880
Sub total (1 - 4)	6,680	25,320	32,000
5. Contingency			
(1) Physical contingency<3	1,000	3,800	4,800
(2) Price contingency<4	910	2,520	3,430
Sub total	1,910	6,320	8,230
<b>Total (1 - 5)</b>	<b>8,590</b>	<b>31,640</b>	<b>40,230</b>

**Notes :**

- \* F.C. : Foreign currency component
- \* L.C. : Local currency component
- <1 : 5% of (1) approximately
- <2 : 10% of (1) approximately for detailed design and of direct cost and construction supervision
- <3 : 15% approximately of base cost(1 - 4)
- <4 : 3% for F.C. and 3.2% for L.C. per annum (1991 - 1995)
- <5 : Sg.Keluang System contains Sg.Keluang, Sg.Ara Sg.Gelugor, Sg. Dua Besar

**TABLE 10 -4 SUMMARY OF FINANCIAL COST FOR THE URGENT PROJECT  
URBAN DRAINAGE WORKS**

Cost Items	(10 <sup>3</sup> M\$)		
	F.C.	L.C.	Amount
1. Direct Construction Cost	17,090	7,990	25,080
2. Land acquisition & house evacuation cost	-	630	630
3. Administration expenses<1	-	1,260	1,260
4. Engineering services cost<2	1,710	800	2,510
Sub total (1 - 4)	18,800	10,680	29,480
5. Contingency			
(1) Physical contingency<3	2,820	1,600	4,420
(2) Price contingency<4	2,600	1,440	4,040
Sub total	5,420	3,040	8,460
<b>Total (1 - 5)</b>	<b>24,220</b>	<b>13,720</b>	<b>37,940</b>

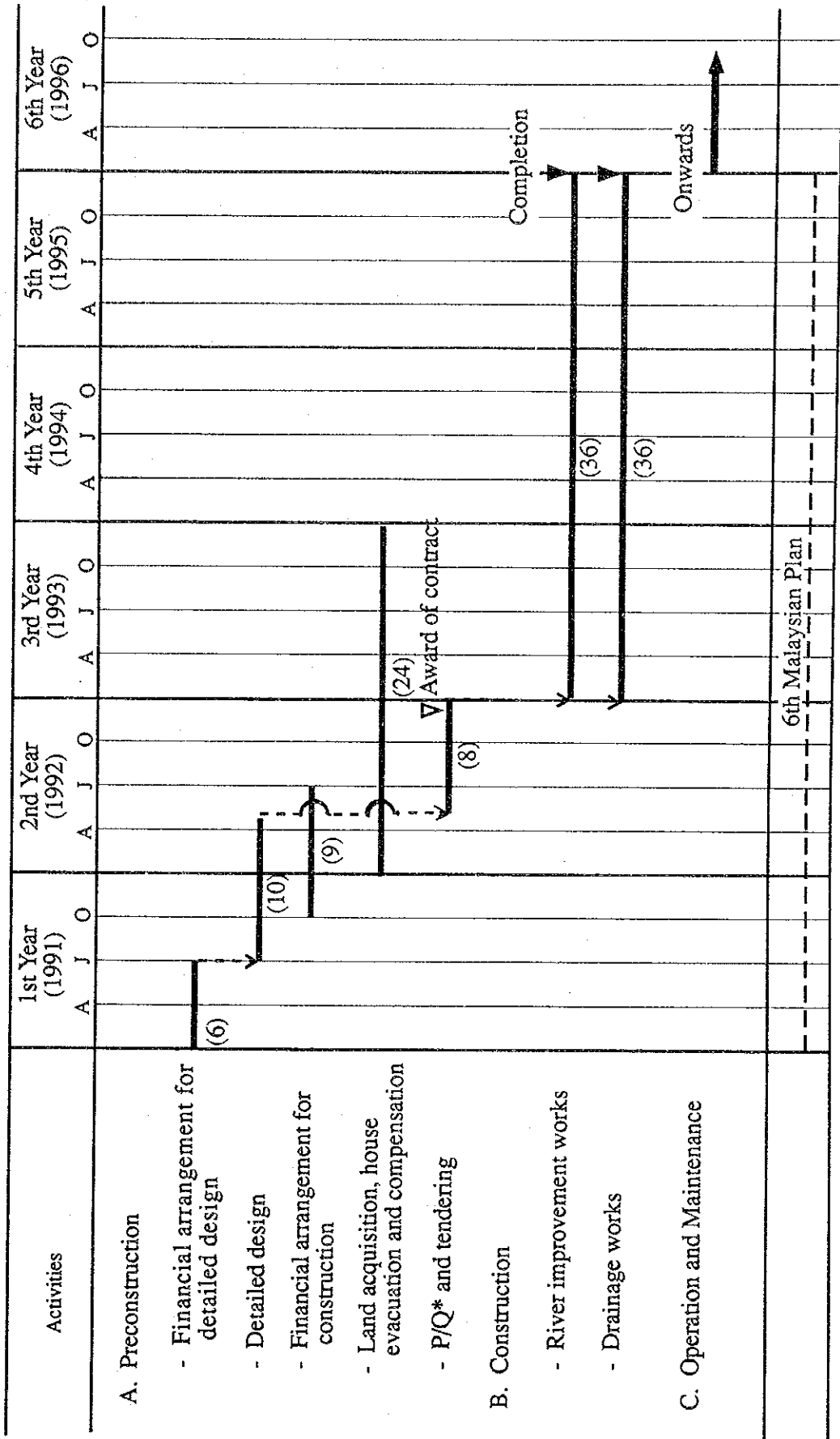
Notes :

- \* F.C. : Foreign currency component
- \* L.C. : Local currency component
- <1 : 5% of(1) approximately
- <2 : 10% of(1) approximately for detailed design and of direct cost and construction supervision
- <3 : 15% approximately of base cost(1 - 4)
- <4 : 3% for F.C. and 3.2% for L.C. per annum (1991 - 1995)

## Figures



FIG. 10-1 IMPLEMENTATION SCHEDULE FOR THE URGENT PROJECTS



\* Prequalification of tender

Fig. 10-2 CONSTRUCTION TIME SCHEDULE FOR THE URGENT PROJECTS

Work Items	Unit	Q'ty	1st Year (1993)			2nd Year (1994)			3rd Year (1995)		
			4	7	10	4	7	10	4	7	10
<b>A. River improvement works</b>											
<b>1. Sg. Pinang system</b>											
(1) Pinang river, channel works , related structures	km -	3.15 L.S	[Bar from 4 to 10]			[Bar from 4 to 7]					
(2) Jelutong river, channel works , related structures	km -	2.14 L.S							[Bar from 4 to 10]		
(3) Air Itam river, channel works , related structures	km -	3.00 L.S				[Bar from 4 to 7]					
(4) Dondang river, channel works , retention ponds , related structures	km places -	4.32 3 L.S				[Bar from 4 to 10]			[Bar from 4 to 7]		
(5) A. Terjun diversion channel, culvert	km	1.74	[Bar from 4 to 10]								
<b>2. Sg. Keluang system</b>											
(1) Keluang river, channel works , related structures	km -	3.38 L.S							[Bar from 4 to 7]		
(2) Ara river, channel works , related structures	km -	1.87 L.S							[Bar from 7 to 10]		
(3) Relau diversion channel works	km	1.53							[Bar from 4 to 10]		
3. Sg. Gelugor	km	0.50							[Bar from 4 to 10]		
4. Sg. Dua Besar	km	2.10							[Bar from 4 to 10]		
<b>B. Drainage improvement works</b>											
<b>1. N-12 drainage system</b>											
(1) Trunk drains	-	L.S	[Bar from 4 to 10]								
<b>2. S-10 drainage system</b>											
(1) Trunk drains	-	L.S	[Bar from 7 to 10]			[Bar from 4 to 7]					
(2) Retention pond	Place	1	[Bar from 4 to 7]			[Bar from 7 to 10]					
(3) Pumping station	Place	1	[Bar from 4 to 7]			[Bar from 7 to 10]					
(4) Outlet channel	Lin.m					[Bar from 4 to 7]					
<b>3. S-18 drainage system</b>											
(1) Trunk drains	-	L.S				[Bar from 4 to 7]			[Bar from 7 to 10]		
(2) Retention pond	Place	1				[Bar from 4 to 7]			[Bar from 7 to 10]		
(3) Pumping station	Place	1				[Bar from 4 to 7]			[Bar from 7 to 10]		
(4) Outlet channel	lin.m								[Bar from 7 to 10]		
			4	7	10	4	7	10	4	7	10
			1st Year (1993)			2nd Year (1994)			3rd Year (1995)		



**Chapter 11 OPERATION AND MAINTENANCE PLAN FOR  
URGENT PROJECT S**



**CHAPTER 11      OPERATION AND MAINTENANCE PLAN  
FOR URGENT PROJECTS**

**11.1 PRESENT STATUS OF OPERATION AND MAINTENANCE OF  
THE EXISTING FLOOD MITIGATION AND DRAINAGE  
FACILITIES**

The activities of operation and maintenance (O/M) for the existing major facilities of flood mitigation and drainage are as follows:

Flood Mitigation

- a) Periodical dredging in Sg. Pinang and other rivers.
- b) Periodical removal of floating debris by screening.
- c) Clearing of river banks and leveling of maintenance road surface.
- d) O/M of flood forecasting and warning system.

Drainage

- a) Periodical removal of sediments and floating debris by screening.
- b) Maintenance of flap gates.
- c) Removal of floating debris in Prangin Pump Station
- d) O/M of Prangin Pump Station. (S-10 Drain)

These activities are conducted mainly by State DID and MPPP. However, due to budget constraints and the ambiguousness of the demarcation of river stretches among the agencies concerned, these flood control and drainage activities are still at a rather unsatisfactory level. Among these facilities, Prangin Pumping Station especially, has a problem of O/M. The present status of this pump station is summarized in Table N-1 in APPENDIX-N.

**11.2 REQUIRED OPERATION AND MAINTENANCE WORKS**

In the urgent projects, several new facilities for flood mitigation are to be constructed. They are the Dondang retention ponds, the diversion channels, water gates, tidal gates and pumping station. Hence, to ensure the expected beneficial effects of both the existing and proposed flood mitigation and drainage facilities, the following O/M works are strongly recommended to be undertaken by the relevant agencies:

River Channel

- a) Periodical dredging
- b) Removal of floating debris
- c) Clearing of river banks and leveling of maintenance road surface.

### Retention Ponds

- d) O/M of outlet gates in the Dondang retention ponds
- e) Desilting of the retention ponds when necessary
- f) Clearing and removal of garbage after flooding

### Pumping Stations and Retention Ponds

- g) O/M of pumps in S-10 and S-18 pump stations
- h) O/M of tidal gates in S-10 and S-18 retention ponds
- i) Removal of floating debris by screening
- j) Periodical dredging of the retention ponds when necessary

Operation and Maintenance of these flood control and drainage facilities require the provision of the following equipment:

- a) Trucks for garbage transportation: 2 each
- b) Supervision vehicles: 2 each

## **11.3 OPERATION AND MAINTENANCE OF GATES AND PUMPING STATIONS**

### **11.3.1 Pumping Stations in the S-10 and S-18 Areas**

The tidal gates at the S-10 and S-18 retention ponds will be constructed to protect the inland against high tides.

These gates are kept open under normal circumstances. When the tidal level is expected to rise beyond an elevation of 1.2 m, the operation of the tidal gates is necessary.

These gates shall be closed when the sea water level is about -0.8 m and remain closed until the tidal level peaks beyond 1.2 m and shall be opened when the level recedes below 1.2 m. In general, under no rainfall conditions, the pumps will not be operated because the retention pond has sufficient capacity to keep the water level low enough, even when normal dry weather flow enters the pond.

However, under rainfall conditions, once the runoff entering the pond exceeds a certain amount, the pumps will be operated.

The general guideline for operation of tidal gate and drainage pump is as follows:

- i) Basic conditions
  - Design High Water Level of the Pond; + 1.20m
  - Design Low Water Level; - 0.80m

- Effective Depth of the Pond; 2.00m
- Lowest ground level in the catchment; + 1.40m
- Design discharge of trunk drain; S-10 1.85m<sup>3</sup>/s  
S-18 15.0m<sup>3</sup>/s
- Pump Capacity; S-10 6m<sup>3</sup>/s  
S-18 2m<sup>3</sup>/s
- Storage Capacity of Retention Pond; S-10 22,000m<sup>3</sup>  
S-18 56,000m<sup>3</sup>

ii) Operation of tidal gate

- Closing of gate; when the tidal level rises beyond an elevation of 1.20m.
- Timing of closing; when the tidal level lowers below an elevation of - 0.80m (D.L.W.L. of the pond).
- Duration of closing; 6 - 7 hours.
- Timing of opening; when the tide level falls below an elevation of + 1.20m.

iii) Operation of Pump

The pump will be operated only when the floods in coincidence with high tide occurs.

- Timing of operation; when the rising speed of water level goes beyond 30 cm/h, or when the inflow to the pond increases beyond the design pump capacity.
- Duration of continuous operation; Maximum 6 -7 h.

These conditions should be examined in more details in the further stage.

### 11.3.2 Retention Ponds in Dondang Area

At the outlet of each retention pond, a flap gate and a sluice gate will be installed.

The flap gate will be used to release the inner water in the retention pond. The sluice gate will discharge water stored in the pond for flood mitigation of Sg. Dondang.

Under normal flooding conditions, only the discharge from the retention pond area will be released automatically through the flap gate.

When the scale of floods of Sg. Dondang exceeds the 30-year return period, discharge of Sg. Dondang enters into the retention pond overflowing the weir.

The release of water stored in the retention pond has to be regulated so that the river discharge will not exceed the allowable design discharge at each point near the outlet of each pond.

#### **11.4 REQUIRED ORGANIZATION FOR CONSTRUCTION, OPERATION AND MAINTENANCE**

The required organization for the construction of the proposed Urgent Flood Mitigation and Drainage Works is shown in Fig. 11-1.

Fig. 11-2 shows the required operation and maintenance organization.

Such an organization is recommended to be established by reorganizing the existing organizational structures of SDID and MPPP.

Moreover, the retention ponds in the Dondang area are planned for multipurpose usage. Works related to these ponds are to be coordinated between SDID and MPPP.

## Tables





Fig. 11-1 ORGANIZATION CHART FOR CONSTRUCTION OF THE URGENT PROJECTS BY DID

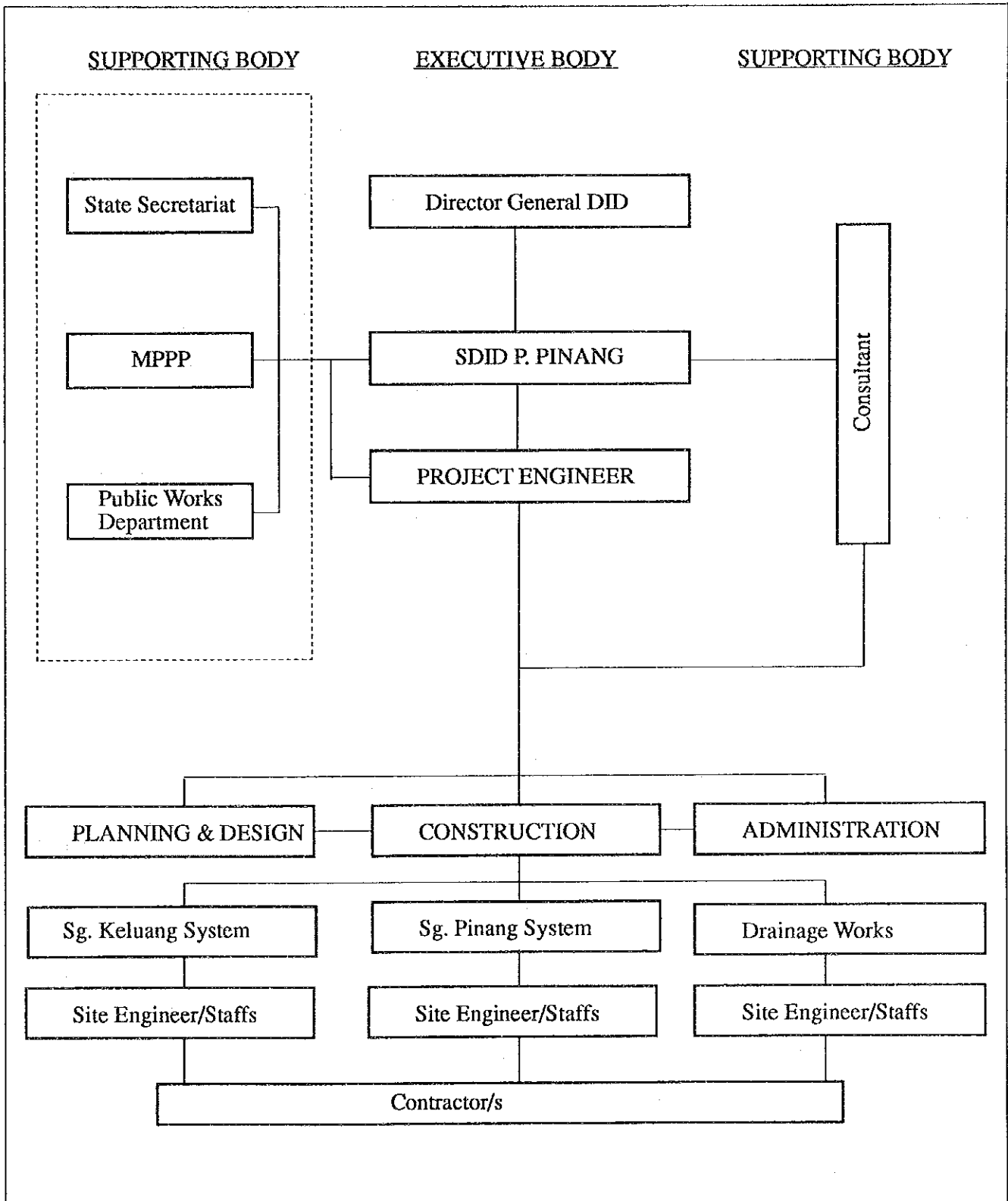
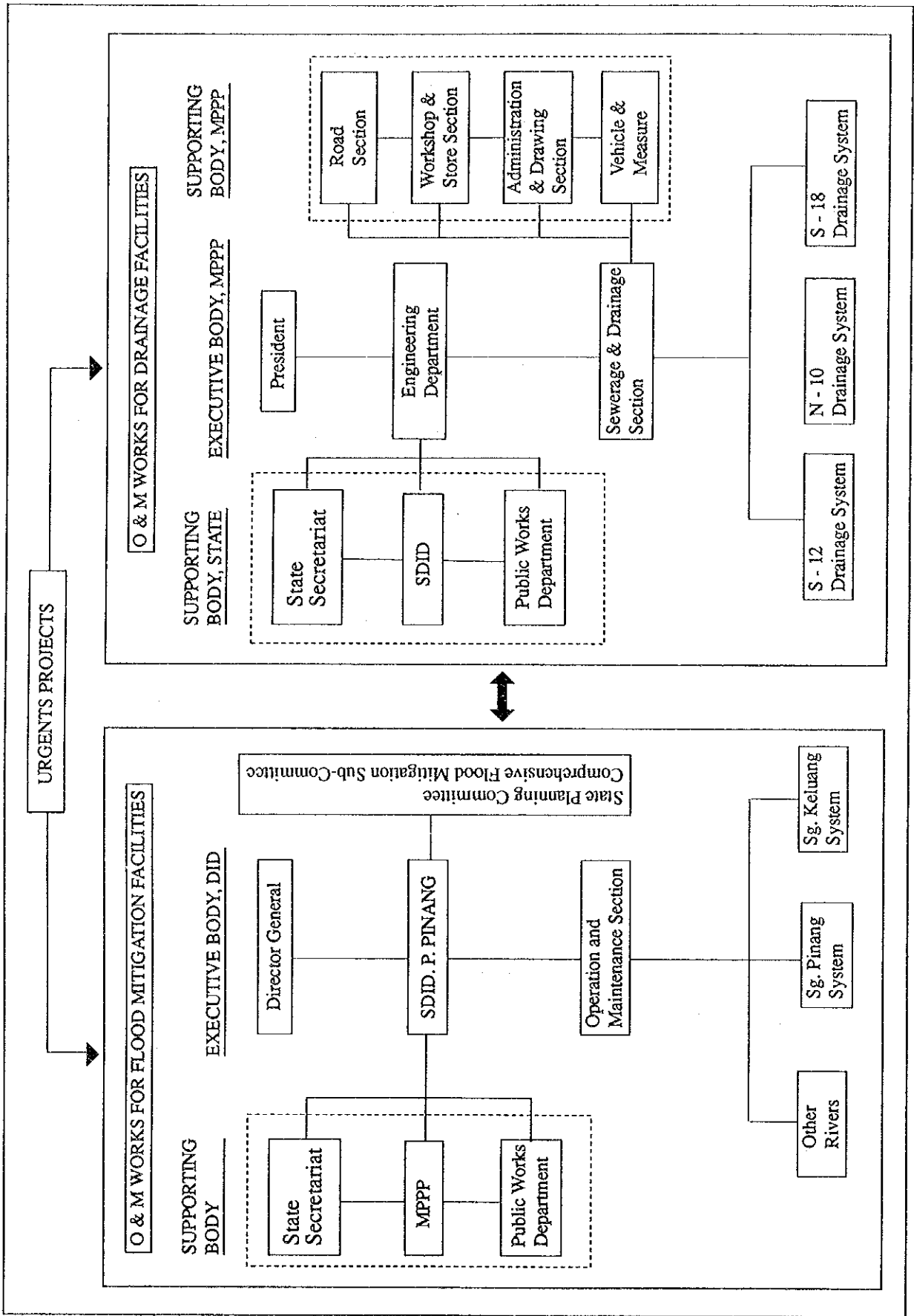


Fig. 11-2 ORGANIZATION CHART FOR OPERATION & MAINTENANCE WORKS BY DID & MPPP



**Chapter 12 ENVIRONMENTAL ASPECTS**



## CHAPTER 12 ENVIRONMENTAL ASPECTS

### 12.1 ENVIRONMENTAL FEATURES OF THE OBJECTIVE FEASIBILITY STUDY AREA

Regarding the environmental and landscape conditions of the objective riverside areas, they are in relatively bad shape as a result of water pollution, solid waste, natural grown sedges and vegetation on the banks. More frequent maintenance and care for the river reserves is highly expected, especially at focal points. Yet, it is recognized that a great potential for improving the landscape exists.

#### 12.1.1 Sg. Pinang Area for River Improvement

All the river stretches of the improvement objectives, except Sg. Air Terjun, are heavily polluted. At this moment the rivers are not suitable for any meaningful beneficial uses.

The vegetation along the river in the upstream areas is shaded by wayside trees. However, the areas near the estuary and downstream are, to a great extent, exposed to the sun.

#### 12.1.2 Sg. Dondang Retention Ponds and Park Areas

The three retention ponds will be constructed at the mid reaches of Sg. Dondang. The recent water quality survey conducted indicated the river water to be heavily polluted by organic matter.

The major waste being discharged into the river include raw and semi-treated domestic sewage and pig wastes. The poor water quality of Sg. Dondang has rendered it unsuitable for any meaningful beneficial usage.

In these areas, dense and diverse riparian vegetation is growing. Common grasses, palms, shrubs and bamboo inhabit the river banks. Waste and decaying organic matter can be seen along the river banks in the vicinity of the retention ponds. Housing development activities have caused odours and the deposition of eroded sediment.

A dense canopy of bamboo covers the river. Because of water pollution, there are but very few fish in the river.

#### 12.1.3 Diversion Channel Route Area

In the vicinity where the proposed diversion channel is to divert into Jln. Gottlieb, there is a rather flat area having lush vegetation, such as grass, palm and banana trees, bamboo thickets, and tall wayside trees at its

riparian fringe. Fish fauna in this area includes species of the common guppy and others.

The area of the proposed diversion channel at Jln. Gottlieb is where most of the commercial activities take place (shops, hotels and hawkers). Hawker activities are increasing along the Jln. Gottlieb; their principal activities are primarily conducted at night. The area along Jln. Bagan Jermal is mostly for residential and institutional use.

A small portion of the diversion channel will be at Sg. Babi's downstream area. This is a relatively flat area. Kampong-style residential houses and some representative villages are situated along the river banks.

#### **12.1.4 Area of Sg. Ara and Sg. Keluang**

The objective area of Sg. Ara and Sg. Keluang is approximately 3.8 km in length from the new reclamation area at the estuary to a part of the upper reach of the river. Downstream of the river itself is undergoing reclamation work by PDC. In this area there is an airfield and an industrial zone. Wide expanded river reserve may have a high potential for establishing river front greenery landscape.

At the mid to upper stream, residential areas, government reserved areas, and Kampong-type residential areas are allocated with relatively low density along the widely expanded river reserve.

Most of the river banks are definitely wide enough to have gentle slopes and a good view of the amicable riverside scenery. At the upper reaches of the river, the banks become narrow and steep and are covered with bamboo thickets, trees and shrubs.

#### **12.1.5 Area of Retention Ponds for Urban Drainage**

The proposed area for the retention ponds for urban drainage is located at the reclamation area adjacent to the low cost high-rise residential development area near the Sg. Pinang estuary. The area is unused open space with flat expanded land facing the sea. This area is to be a part of the CDD 21 reclamation project area.

The proposed site is a muddy area near the shore. Patches of green and blue-green algal mats can be seen on the mud-flats along with garbage and other solid wastes. This matter has either been flushed out by the river flow or deposited by tidal affects.

Some aquaculture activities are presently ongoing near the coastal waters south of the proposed retention ponds.

Around of this area, high-rise housing flats are located in the reclamation land to the west of the

retention ponds site. Dense squatter settlements are located a short distance northwest of the proposed ponds site.

## **12.2 ENVIRONMENTAL APPROACH TO FLOOD MITIGATION**

In this section, two conceptual approaches to mitigate flooding are proposed in conjunction with the flood mitigation and drainage study. One approach is to use some future park areas and open spaces as retention ponds into which the flood waters can be temporarily diverted. The other approach is to provide diversion channel to divert the flood water directly into the sea.

### **12.2.1 Retention Ponds and Multi-use Park Environment**

Within the three future park areas, flood regulating functions (retention ponds) are to be formulated. The flood water is diverted into these temporary pond areas. The retention ponds may occasionally be combined as a temporary pond and only filled with diverted water at critical hours during floods having more than a 30-year return period, so that normally these are no water impounded in this portion of the pond areas.

The major portions of the retention pond areas are provided as spaces for diversified recreational activities. These retention pond areas are to be landscaped and used for multi-use recreational purposes.

Fig.12-1, Fig.12-2 show the temporary retention ponds and the sunken water front parks system at Sg. Dondang.

### **12.2.2 Retention Ponds of Urban Drainage**

Two retention pond sites for urban drainage mitigation may be allocated near the estuary of Sg. Pinang in Georgetown's coastal reclamation zone. Each of these ponds has an area of 2 ha. In this vicinity there is a forested green belt for screening and preventing odour problems. The retention ponds face the sea allowing adequate ventilation.

Fig.12-3 shows a retention pond for urban drainage at the Sg. Pinang estuary.

### **12.2.3 Diversion Channel**

The channel reserve area shall be provided with neat bank slopes and landscaped plantings on the flat tops of the berms. Or, in the case of limited reserve width, revetments and nearby riverside space should be provided with solid landscaping. Along the channel, some access ways to the waterfront for maintenance purposes and pedestrian use may be necessary.

A box culvert type of diversion channel shall be provided under the existing road area when there is not