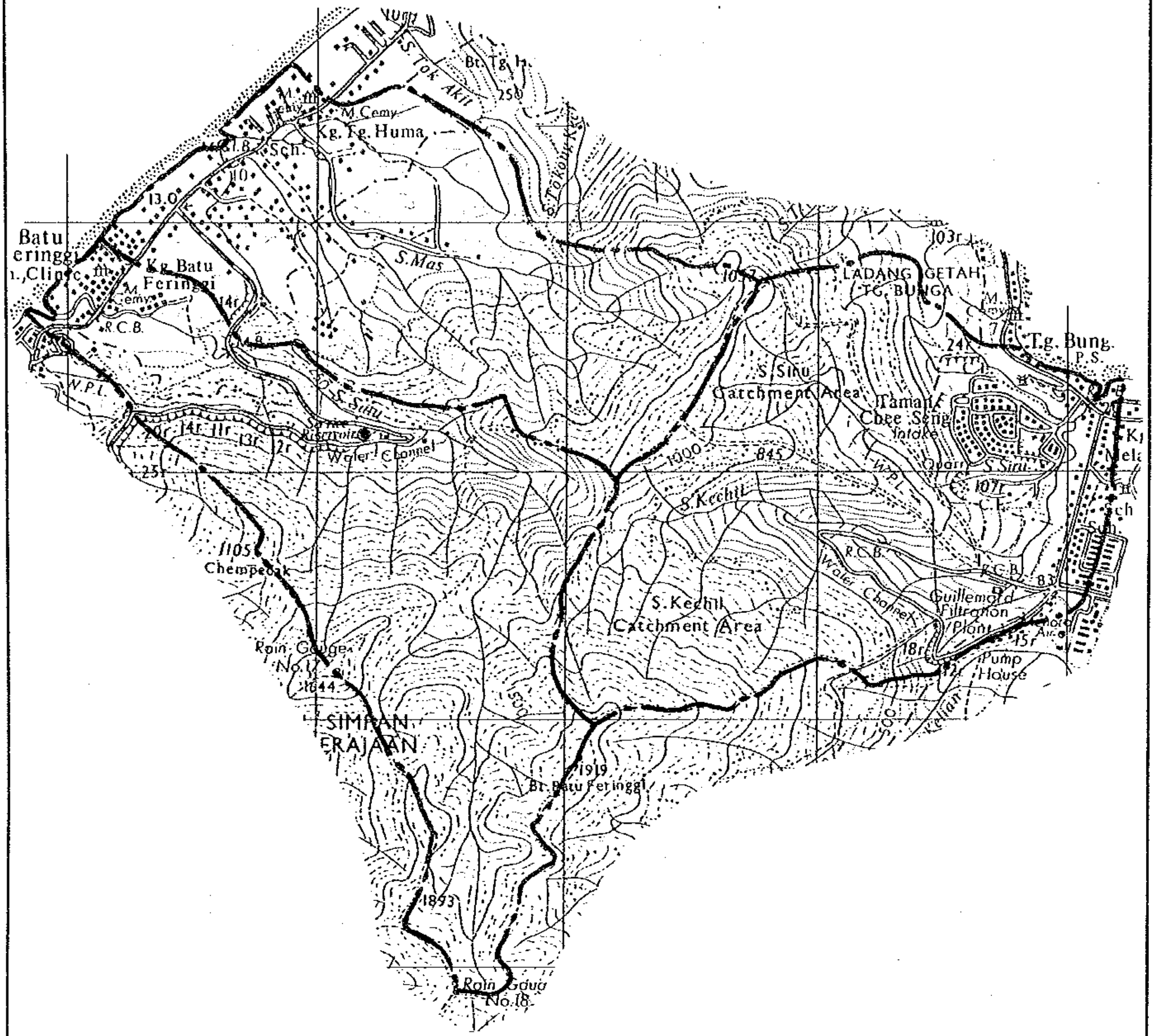
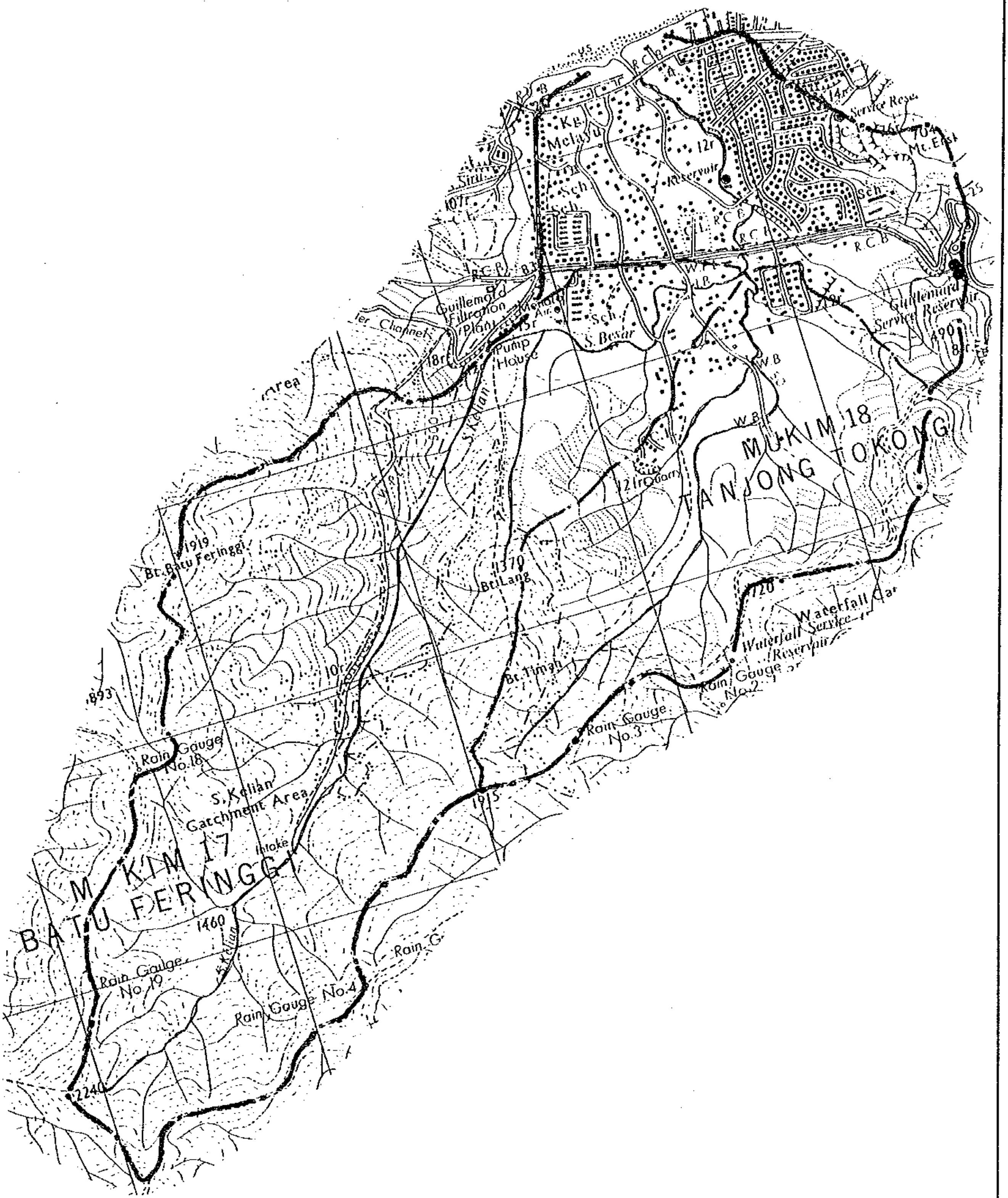


NO	RIVER NAME	: C.A	: Q-5	: Q-10	: Q-20	: Q-50	: Q-100
5	Sg.Satu	: 258 :	15 :	17 :	19 :	20 :	22

NO	RIVER NAME	: C.A	: Q-5	: Q-10	: Q-20	: Q-50	: Q-100
6	Sg.Mas	: 211 :	20 :	22 :	25 :	27 :	29

NO	RIVER NAME	: C.A	: Q-5	: Q-10	: Q-20	: Q-50	: Q-100
7	Sg.Kecil	: 275 :	19 :	21 :	23 :	26 :	27

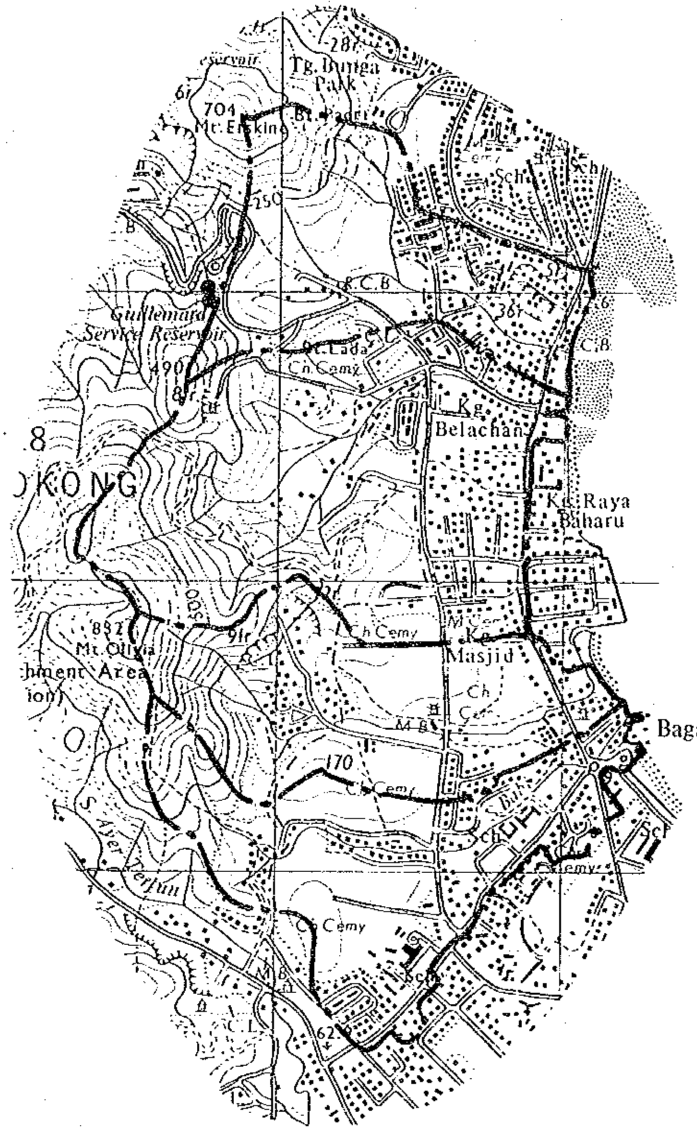
FIG. G-26 CATCHMENT OF SG. SATU, MAS AND KECIL



NO	RIVER NAME	C.A	Q-5	Q-10	Q-20	Q-50	Q-100
8	Sg.Kelian	904	33	37	40	44	47

FIG. G-27 CATCHMENT OF SG. KELIAN

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND



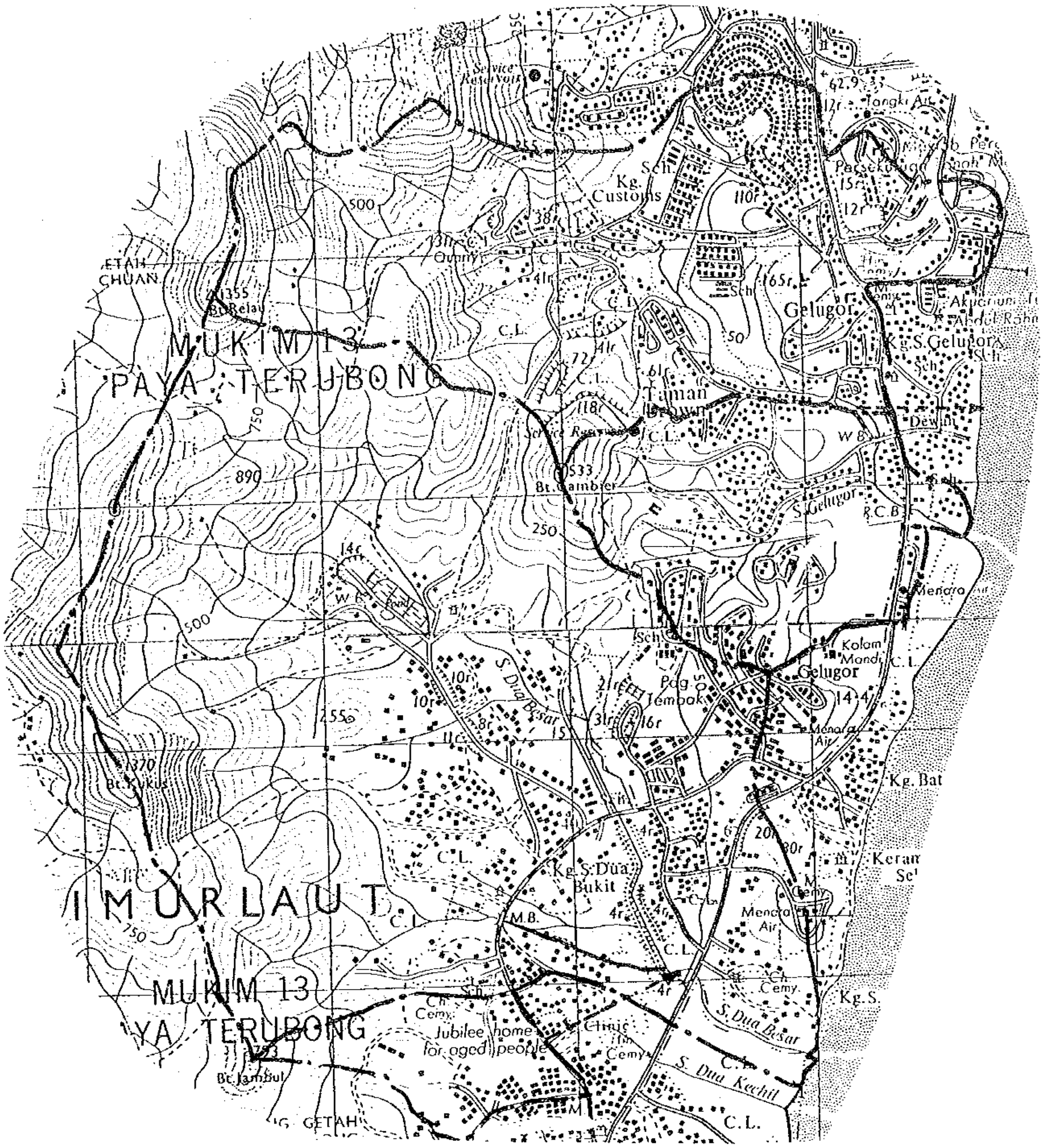
NO	RIVER NAME	C.A	Q-5	Q-10	Q-20	Q-50	Q-100
9	Sg.Balik Batu	80	14	15	17	18	20

NO	RIVER NAME	C.A	Q-5	Q-10	Q-20	Q-50	Q-100
10	Sg.Fettes	136	20	22	24	27	29

NO	RIVER NAME	C.A	Q-5	Q-10	Q-20	Q-50	Q-100
11	Sg.Bagan Jermal	83	9	10	11	13	14

NO	RIVER NAME	C.A	Q-5	Q-10	Q-20	Q-50	Q-100
12	Sg.Babi	84	9	10	11	12	13

FIG. G-28 CATCHMENT OF SG. BALIK BATU, FETTES, BAGAN JERMAL AND BABI

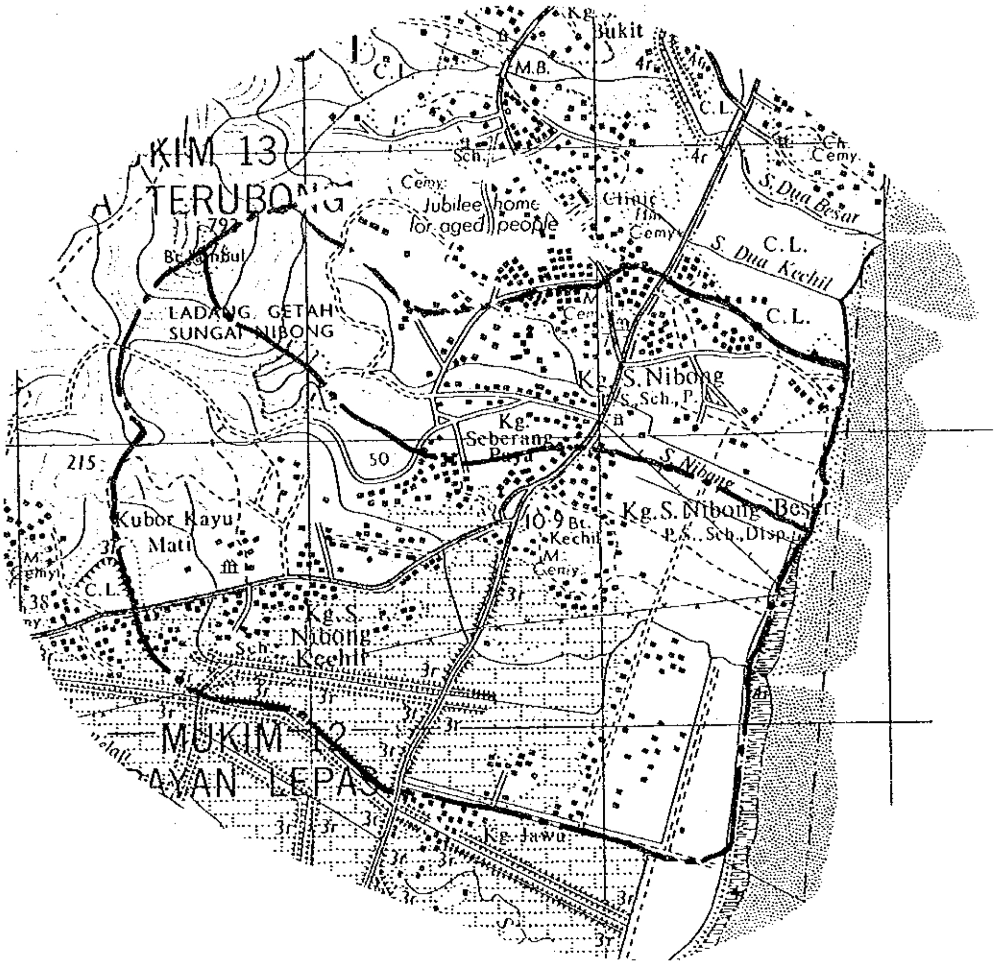


	RIVER NAME	C.A	Q-5	Q-10	Q-20	Q-50	Q-100
13	Sg. Gelugor (D)	314	22	24	27	29	31
	Sg. Gelugor (R)	125	19	20	22	25	27
		4.8	1	2	2	2	2

	RIVER NAME	C.A	Q-5	Q-10	Q-20	Q-50	Q-100
14	Sg.Dua Besar	672	41	46	50	55	59
	Sg. Kecil (D)	53	6	7	8	9	9

FIG. G-29 CATCHMENT OF SG. GELUGOR AND DUA BESAR

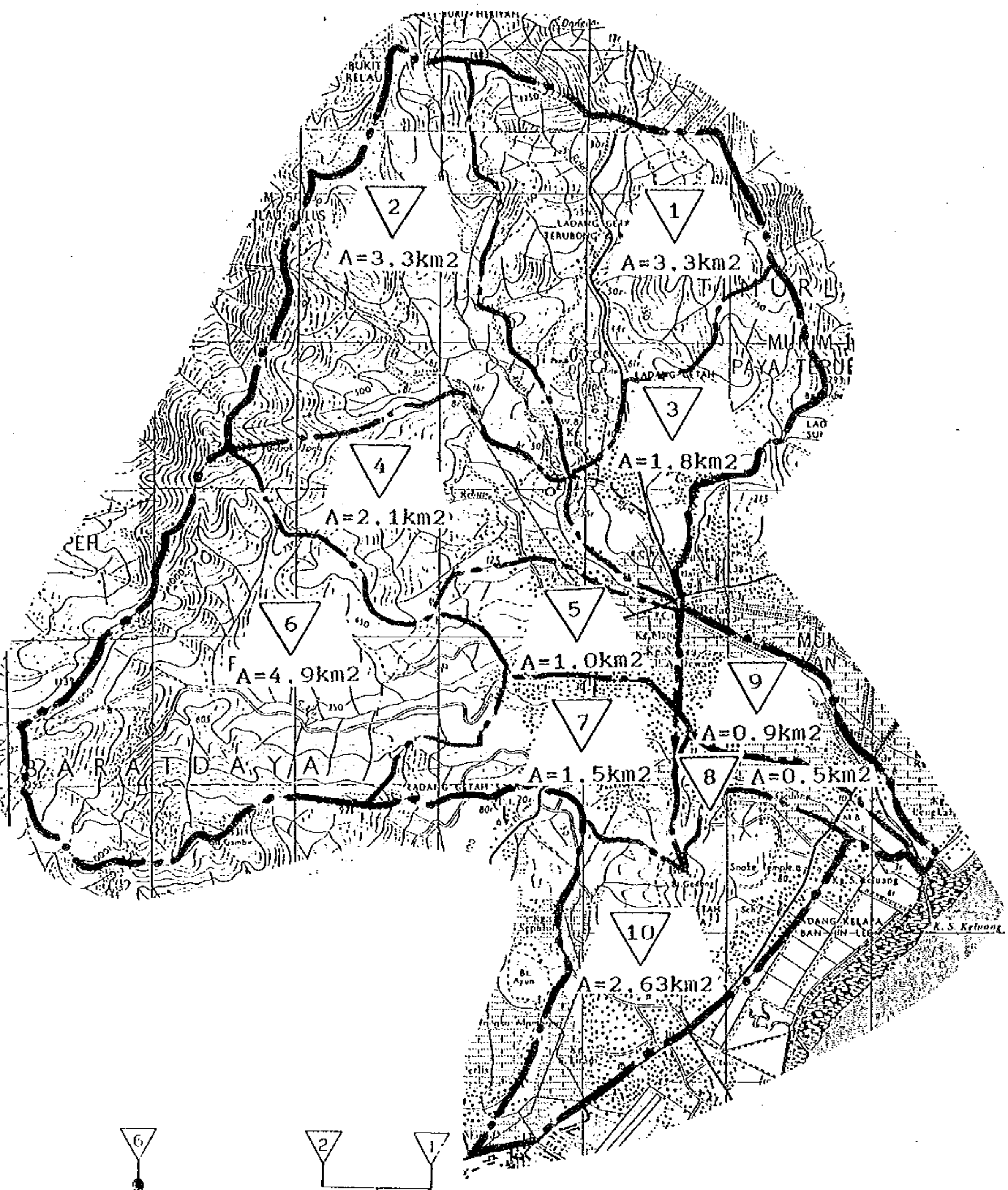
THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

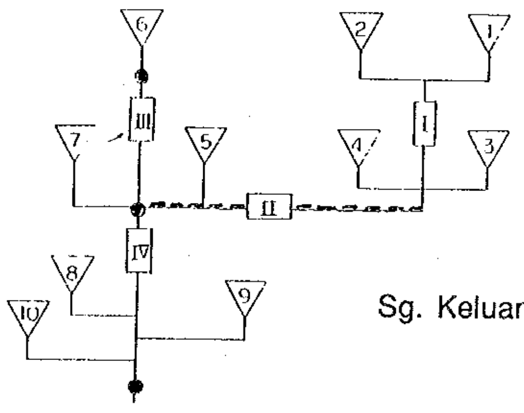


NO	RIVER NAME	: C.A	: Q-5	: Q-10	: Q-20	: Q-50	: Q-100
15	Sg.Nibong Besar	: 112 :	14 :	15 :	17 :	18 :	20

NO	RIVER NAME	: C.A	: Q-5	: Q-10	: Q-20	: Q-50	: Q-100
16	Sg.Nibong Kecil	: 277 :	32 :	35 :	38 :	42 :	45

FIG. G-30 CATCHMENT OF SG. NIBONG BESAR AND NIBONG KECIL

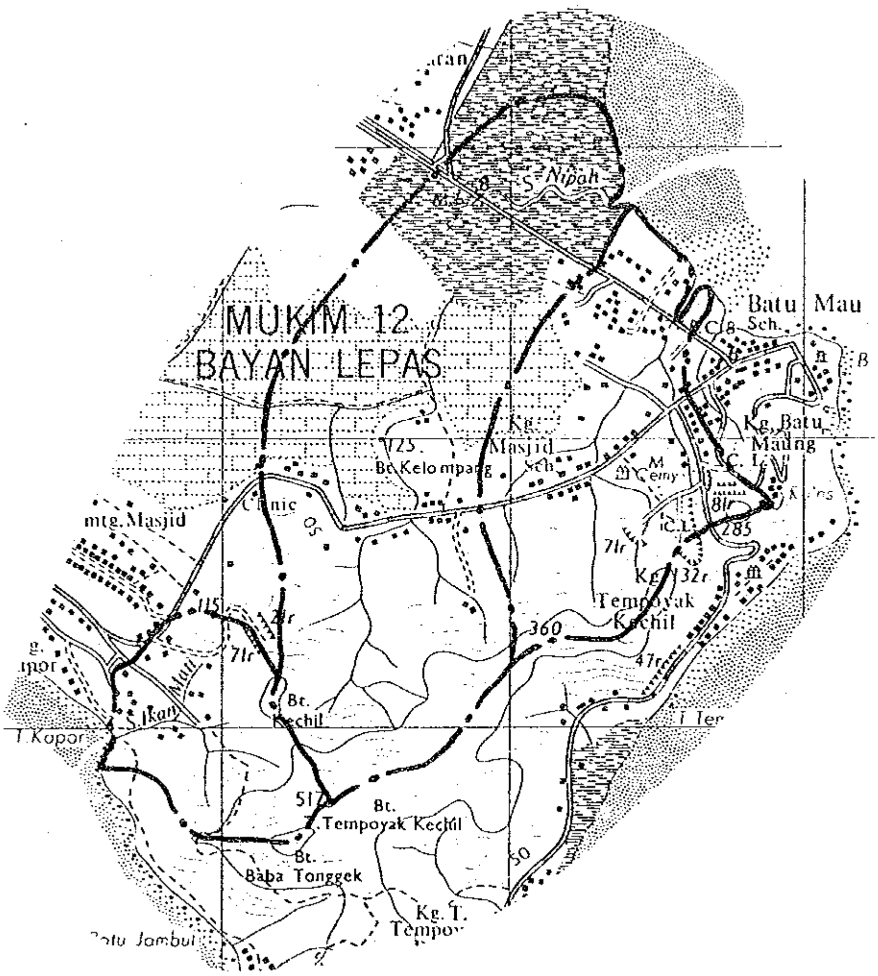




	Q-5	Q-10	Q-20	Q-50	Q-100
Sg. Keluang	28	45	73	125	150

FIG. G-31 CATCHMENT OF SG. KELUANG

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

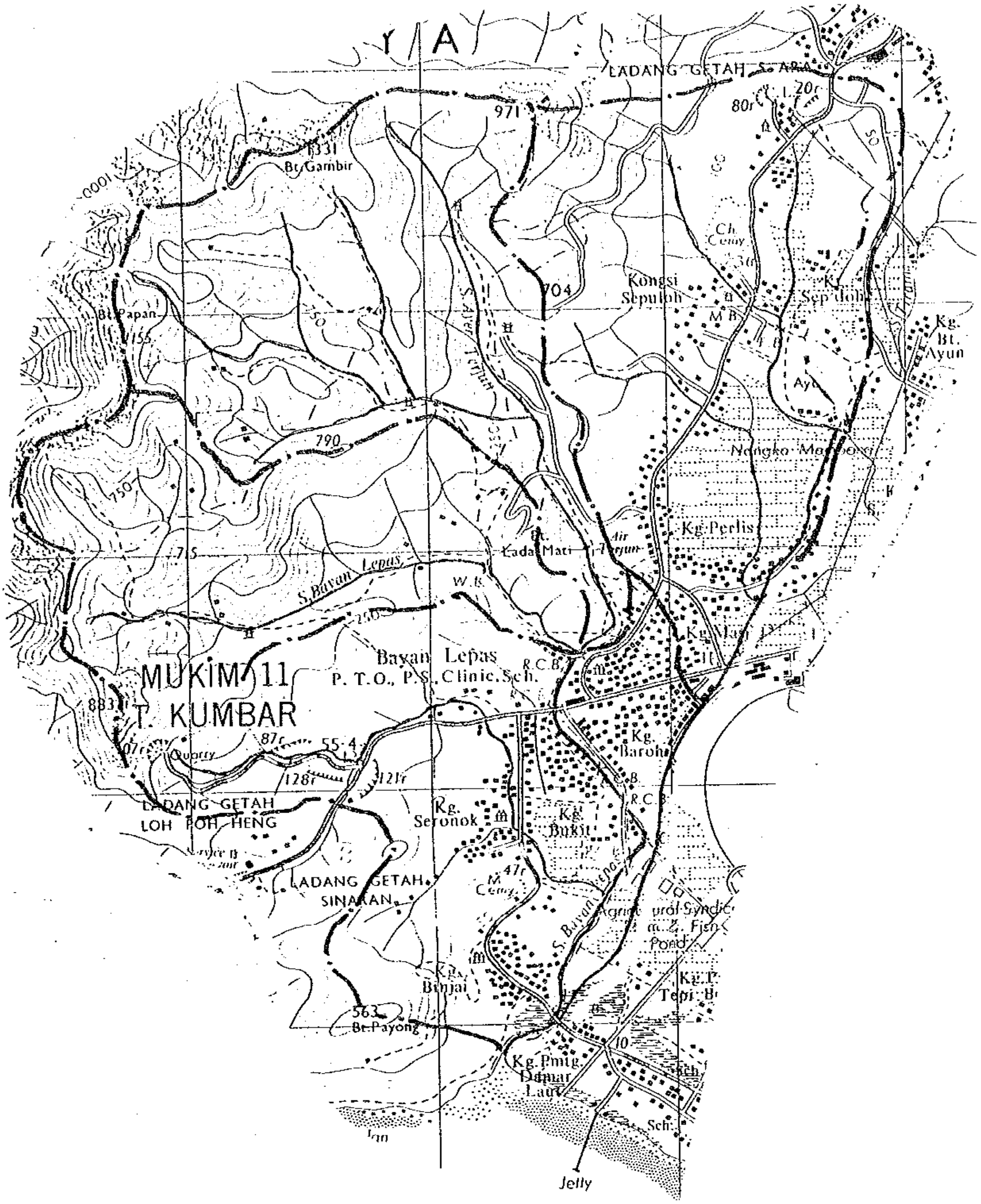


NO	RIVER NAME	: C.A	: Q-5	: Q-10	: Q-20	: Q-50	: Q-100
18	Sg.Nipah	: 169 :	17 :	18 :	20 :	22 :	24

NO	RIVER NAME	: C.A	: Q-5	: Q-10	: Q-20	: Q-50	: Q-100
19	Sg.Kampung Masjid	: 84 :	14 :	15 :	16 :	18 :	20

NO	RIVER NAME	: C.A	: Q-5	: Q-10	: Q-20	: Q-50	: Q-100
20	Sg.Ikan Mati	: 38 :	9 :	10 :	11 :	12 :	13

FIG. G-32 CATCHMENT OF SG. NIPAH AND KAMPUNG MASJID AND IKAN MATI

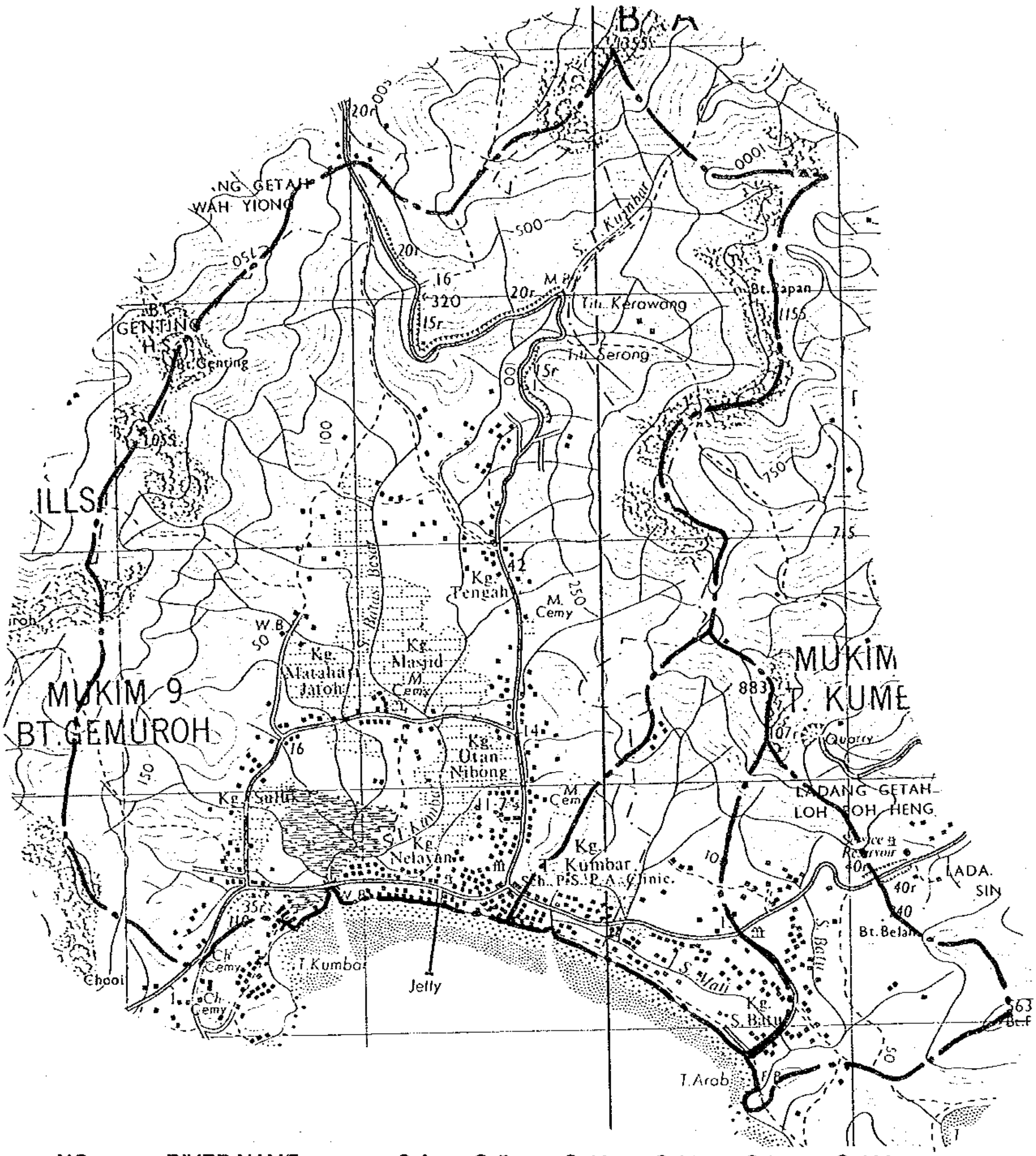


NO	RIVER NAME	C.A	Q-5	Q-10	Q-20	Q-50	Q-100
21	Sg.Bayan Lepas	704	30	34	37	40	43
	Sg.Tiram Diversion	283	22	24	27	29	31

FIG. G-33	CATCHMENT OF SG. BAYAN LEPAS AND TIRAM DIVERSION

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

JICA

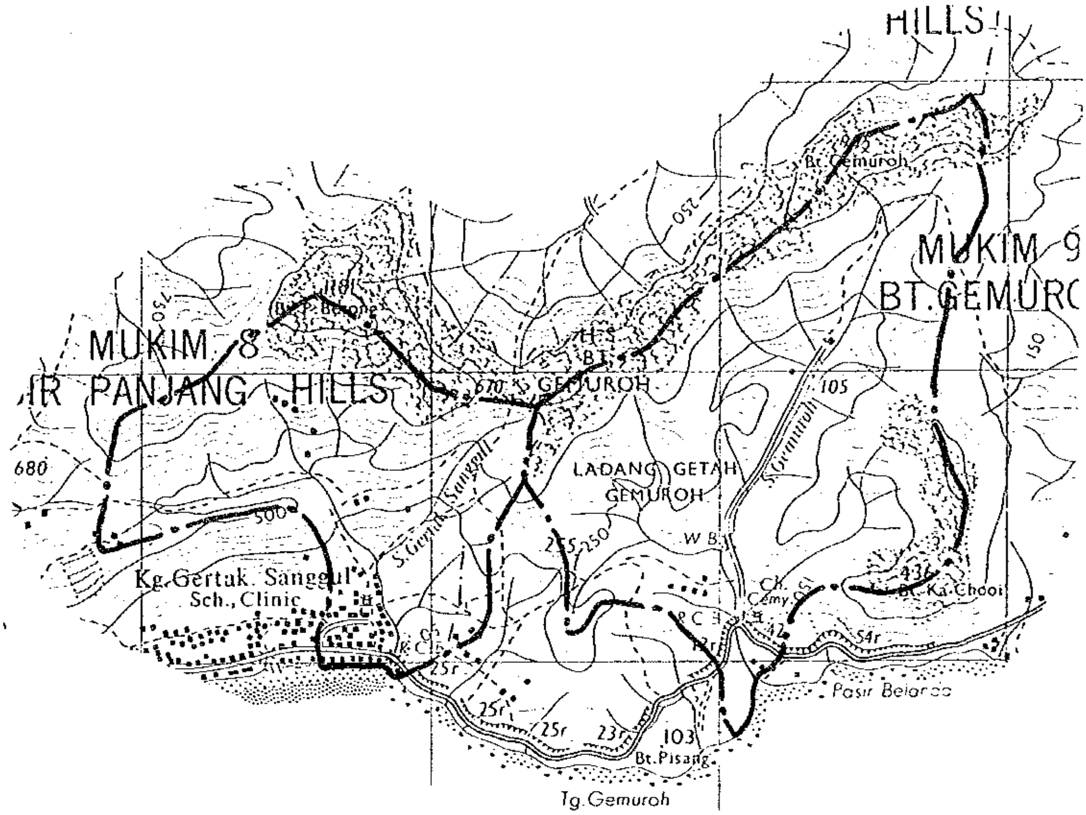


NO	RIVER NAME	: C.A	: Q-5	: Q-10	: Q-20	: Q-50	: Q-100
22	Sg.Batu	: 90 :	9 :	10 :	11 :	12 :	13

NO	RIVER NAME	: C.A	: Q-5	: Q-10	: Q-20	: Q-50	: Q-100
23	Sg.Mati	: 95 :	11 :	12 :	14 :	15 :	16

NO	RIVER NAME	: C.A	: Q-5	: Q-10	: Q-20	: Q-50	: Q-100
24	Sg.Teluk Kumbar	: 706 :	35 :	39 :	43 :	46 :	50

FIG. G-34 CATCHMENT OF SG. BATU, MATI AND TELUK KUMBAR



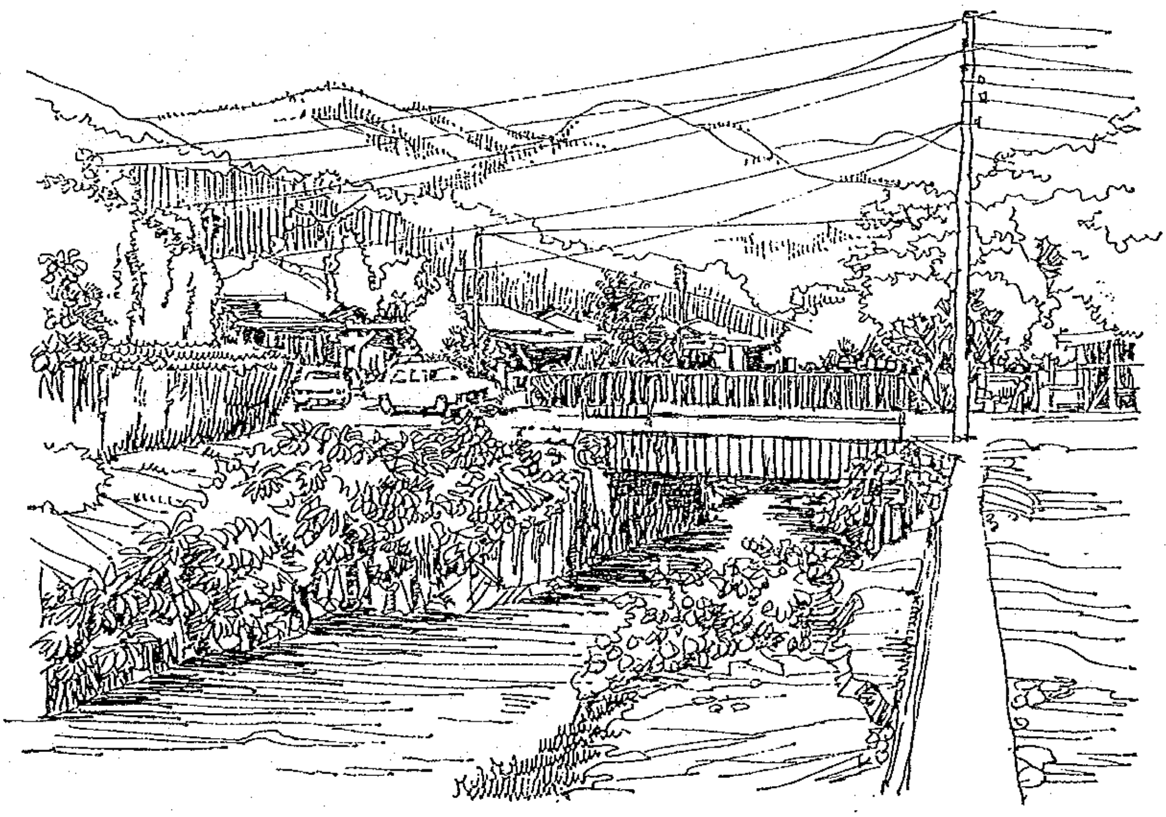
NO	RIVER NAME	: C.A	: Q-5	: Q-10	: Q-20	: Q-50	: Q-100
25	Sg.Gemuroh	: 191 :	16 :	17 :	19 :	21 :	22

NO	RIVER NAME	: C.A	: Q-5	: Q-10	: Q-20	: Q-50	: Q-100
26	Sg.Gertak Sanggul	: 103 :	11 :	12 :	14 :	15 :	16

FIG. G-35 CATCHMENT OF SG. GEMUROH AND GERTAK SANGGUL

APPENDIX H

FORMULATION OF FLOOD MITIGATION MASTER PLAN



APPENDIX H FORMULATION OF FLOOD MITIGATION MASTER PLAN

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1. INTRODUCTION

Flooding in the Sg. Pinang basin has occurred so far mainly in the centre of old Georgetown along the Sg. Pinang and along its tributaries, Sg. Dondang, Sg. Air Terjun, Sg. Air Itam and Sg. Jelutong.

After completion of Sg. Jelutong diversion channel, flooding in the mid-stream of Sg. Jelutong area has been mitigated ever since.

In other basins also, flooding has occurred mainly in the lower basins. However, due to recent intensive land development in the upper basin, especially in the hilly side, flooding now occurs even in the upper or middle basin, such as in the Sg. Dondang, Sg. Gelugor or Sg. Relau.

In addition, the role and responsibilities of the various Departments and Agencies in the planning, development and maintenance of flood mitigation and urban drainage works both within and outside the City of Georgetown are not clearly defined. This has led to confusion and duplication in the role and functions of various Agencies resulting in a decrease in efficiency and effectiveness on the planning, development and maintenance of flood mitigation and urban drainage works. To make matters worse, no effective coordination among DID or MPPP and the Agencies who jurisdict land development or human activities, such as cultivation, housing development, land reclamation, deforestation, and mining, has been done, resulting in erosion and siltation , frequent flooding and drainage problems.

In order to overcome these intricate problems, an overall flood mitigation and drainage plan for the whole basin of the Island was considered.

2. CAUSE OF FLOODING

In general, flooding is caused not only by unfavorable natural conditions but also by increase of storm water run-off due to development activities and problem of drainage facilities.

(1) Unfavorable natural conditions

- Monsoon rainfall and flash floods with high rainfall intensity.
- Topographical condition (mountainous areas) with leads to increased run-off.
- Tidal effect in the downstream reaches.

(2) Cause of flooding due to development and other human activates

- Increase of run-off coefficient of the basin due to rapid urbanization.
- Loss of natural potential retention pond due to filing up for housing development.
- Improvement of trunk drain or tributaries to an excessive level compared to the discharge capacity of downstream reaches.
- Flowing down of floating bamboos, branches and garbages in the river channel during floods.
- Construction of steep slope drainage system for housing development in hill areas.
- Sediment run-off into trunk drain or river due to soil erosion caused by land development.

(3) Problem of drain facilities

- Inadequate flow capacity of river channel or trunk drain.
- Insufficient clearance at bridge crossings.
- Lack of pumping facilities in lowlying areas located below high tide level.

Among these various factors, change in land use pattern has led to worsening of flooding conditions.

Furthermore in the future, backwater effect of the rivers in the eastern coastal areas is anticipated, resulting in worsening of drainage conditions.

3. CONCEIVABLE STRUCTURAL MEASURES

In order to establish the appropriate protective measures against flooding in Penang Island, the existing and future conditions of the rivers and basins shall be given careful consideration, as described in the following section.

- Topographic condition
- Problems of land acquisition
- Existing river and related structures
- Present and future land use pattern
- Land reclamation plan in the coastal area

In the Sg. Pinang basin, including its tributaries, almost all flat land has already been urbanized and in these areas land acquisition for widening of the river channel is extremely difficult. Hence, as conceivable alternative protective measures, river improvement by deepening, diversion channel, retention pond and flood control dam were considered.

In the northern coast of the Island, the rivers with rather large catchment, such as Sg. Teluk Bahang, Sg. Batu Ferringghi and Sg. Kelian, have 85% to 99% of their catchments in mountainous areas. Also the river stretches to be improved are short. Hence, river improvement will be the major protective measure.

In the east coast, the Sg. Keluang has a rather large catchment and long river stretches but there is no sufficient space for retention pond. For this basin, river improvement and diversion channel seem to be the appropriate protective measures.

Almost all rivers in the east coast which discharge into the South Channel should be extended at their river mouths due to land reclamation activities. This would result in rising of river stage making drainage of lowlying areas, including those reclaimed ones, rather difficult and vulnerable to flooding.

In the south coast, the Sg. Bayan Lepas and Sg. Teluk Kumbar are the main rivers. Large portions of their catchment areas are mountainous having no significant development potential. Hence river improvement seems to be the most suitable alternative.

The existing conditions, potential future developments and the conceivable structural measures for each river are briefed below.

3.1 Sg. Pinang

The Sg. Pinang system is composed of the 3.2 km long Sg. Pinang main stream and its main tributaries, Sg. Air Itam, Sg. Air Terjun, Sg. Dondang and Sg. Jelutong.

In this basin, the flooding problems have occurred mainly in old Georgetown area along the Sg. Pinang and also in the areas along the tributaries such as Sg. Air Itam and Sg. Jelutong.

After completion of Jelutong diversion channel, flooding problems of the area along the Sg. Jelutong have been mitigated. While, in the Sg. Dondang basin where intensive development is in progress, some lowlying areas have recently become areas of frequent flooding areas.

In the Sg. Pinang basin, two major flooding patterns are recognized.

The first is flooding due to over topping of river banks of the main river or tributary.

The second is flooding due to inner water especially in the lowlying area.

The inner water problems will be dealt with separately in APPENDIX I, with due consideration to the tidal effects in lowlying coastal area.

In order to mitigate flooding due to bank over-topping, the following measures will be considered for the main river and tributaries.

- For the Sg. Pinang, improvement by widening to maximum permissible extent and deepening will be considered.

- For the tributaries near the coast, e.g., Sg. Air Terjun, diversion channel or flood way to directly divert the discharge into the North Channel will be considered. The five alternatives of these diversion channels are shown in Fig.H-1 and Fig.H-2.

  Characteristics of each alternative are as follows;

Route No.1	Botanical Garden - Sg. Bagan Jermal Diversion Tunnel + Improvement of Sg.Bagan Jermal.
Route No.2	Botanical Garden - Sg. Babi. Diversion Tunnel + Improvement of Sg.Babi.
Route No.3	Diversion Channel under the Jalan Gottlieb and Jalan Bagan Jermal, and Improvement of Sg. Babi.
Route No.4	Diversion Channel under the Jalan Cantonment
Route No.5	Diversion Channel under the Jalan Residensi, Lebuh Raya Peel and Jalan Pangkor.
Route No.6	Diversion Channel from Sg. Air Itam to Route No.5 Channel.

These alternative routes are evaluated for their merits and demerits in Table H-1. Accordingly Route No.3 and Route No.5 were selected for detailed alternative study.

Regarding the diversion route from the Sg. Dondang or Sg. Air Item in the right side of the Sg. Pinang, the route connecting Sg. Dondang or Sg. Air Item with Sg. Jelutong And Sg. Mati was also considered.

These routes, however, were rejected because of extreme difficulty of land acquisition, insufficient gradient for the channel, and existence of lowlying area near the Sg. Mati.

The other alternatives of flood mitigation, the flood control dam and retention pond are described below.

i) Flood control dam

For Sg. Air Itam the possibility of raising Air Itam Dam was investigated to obtain some flood control storage. It is expected to raise this dam by about 3 meter in height in consideration to its topographical and geological conditions. The consequent maximum flood control capacity that could be attained is about 600,000 m^3, thereby reducing the run-off discharge at Jln. Jelutong Bridge by about 20 m^3/s. The spillway is a bell-mouth type massive concrete structure which could be raised. Even then, the flood control mechanism will only be natural without any gate, which is not an effective means of flood control. Furthermore, the catchment of this dam is only 5 km^2. Hence this dam alternative is not very useful.

As per the other tributaries of the Sg. Pinang system, the Sg. Air Putih and Sg. Air Terjun, the river catchment areas are very small and also the catchment area of dam could only be about 2 km^2, this dam catchment area is too small to obtain any useful flood control storage and hence this alternative was rejected.

ii) Retention pond

Dondang area of the Sg. Pinang basin is undergoing rapid development and frequently affected by flash floods.

Park lands proposed by the land use plan of MPPP were studied for their suitability as retention ponds to mitigate flooding in the Dondang area and as well in the downstream reaches of Sg. Air Itam and Sg. Pinang.

In addition, the existing race course ground in the vicinity of the left bank of Sg. Air Itam was also considered for retention pond. However, due to topographic condition, the pond must be of underground type.

This will be of very high construction cost with cumbersome maintenance requirements with respect to the removal of sediments and grits. Hence this underground pond alternative was rejected.

3.2 Sg. Teluk Awak

Change in land use pattern of the catchment area from forest area to park area is planned. And no significant increase in run-off is anticipated. However, the existing discharge capacity of the down stream stretches is inadequate, and hence river improvement works is deemed to be necessary.

3.3 Sg. Teluk Bahang

The prime structural measure is considered to be river improvements only, however retention pond also could be considered in the mid-stream stretches.

There exist two small dams for water supply in the upstream stretches. But no flood control storage is expected to be provided even when future increase in capacity is considered.

3.4 Sg. Batu Ferringghi

Though the catchment area is comparatively large, 89% is of mountainous terrains. No significant future change in land use is expected. River improvement in the short downstream stretches will be considered.

3.5 Sg. Satu

The land use of more than 80% of the catchment area will remain as natural forest even in future. River improvement for about 500 m length of downstream stretch will be considered.

3.6 Sg. Mas

About 50% of the catchment area is expected to be urbanized in future. The land development is anticipated to stretch up to the hilly area as well. River improvement for about 600 m river stretches will be considered.

3.7 Sg. Kecil

The catchment area is rather small and its land use is forest area of 70% and urbanized area of 30%. No significant change in future land use is expected. River improvement is the only conceivable alternative of flood mitigation because of its small catchment.

3.8 Sg. Kelian

About 30% of the catchment area has already been developed while the remaining 70% is to be preserved as natural forest reserve.

The developed area is composed of both the downstream flat-area and upstream hilly area. River improvement for the urbanized reaches will be considered.

3.9 Sg. Balik Batu

The catchment area is only $0.8km^2$, of which about 90% has already been developed for housing. River improvement works have already been accomplished. But about 70% of the improved river bed depth is already silted due to sediment run-off caused by land development activities in hilly area.

Hence mitigatory measures against sediment run-off (soil erosion) and progressing of sand bar formation due to literal drift in the river mouth are necessary.

3.10 Sg. Fettes

The future land use pattern of the catchment area is expected to consist of 70% in urbanized area. Especially the land development activities along the hilly slopes will cause severe soil erosion and sediment run-off to the river resulting in potential flooding problem due to sedimentation and rise in river channel bed.

The concrete pipes connecting the improved concrete channel at the river mouth, where the growth of mangroves on sand bar is abundant, have been broken.

It is recommended, as an urgent measure, to replace the closed concrete pipe with open channel section.

3.11 Sg. Bagan Jermal

About 40% of the catchment area consists of cemetery. No significant change in future land use is expected. Sediment run-off caused by housing development activities is recognized.

As conceivable structural measures of flood mitigation river improvements for the downstream stretches will be considered.

3.12 Sg. Babi

The catchment mainly consists of residential areas (housings) and cemetery. The flooding problem has been solved to a certain extent with the completion of river improvement works along the down stream stretches. For future increase in run-off, as well, river improvements for the upper stretches will be considered.

3.13 Sg.Gelugor

The lowlying area of the catchment remains inundated due to rapid and on-going land development activities at upstream hilly areas. In the downstream reaches, the concrete flood way to South Channel has already been completed. Both the existing and once improved channel portion at the middle stream stretches will be further improved for flood mitigation. The uppermost hilly areas undergoing rapid land development require urgent erosion control measures against sediment run-off.

3.14 Sg.Dua Besar

The urbanized area of the catchment is expected to increase to 65% with the development of hilly areas. The downstream stretch of Sg. Nibong Road, which is a meandering unlined channel, is planned to be straightened with concrete channel.

In the midstream stretches also there exist many concrete canalization plans prepared by housing developers. River improvements would be the basic flood mitigatory measures to be considered.

3.15 Sg. Nibong Besar

The river stretch at downstream of Sg. Nibong to concrete channel has already been improved. About 80% of the catchment area, a flat terrain, is expected to be developed in future. Accordingly, river improvement works are necessary for upper stretches as well. About 600 m of future extension of river channel at river mouth will be necessary to cater the planned land reclamation.

3.16 Sg. Nibong Kecil

Almost all the river channels along the industrial and housing areas have already been improved either to unlined or concrete channel sections. Any increase in future run-off will require re-inprovement of the river.

About 490m of future extension of river channel at river mouth will be necessary to cater the planned land reclamation.

3.17 Sg. Keluang

The Sg. Keluang river system consists of 1500m long Sg. Keluang main river and its tributaries, Sg. Relau and Sg. Ara. The total catchment area of the entire river system is 22 km2, of which about 77% is comprised of mountainous and hilly areas.

Future land development is expected to reach up to the hilly areas with urbanized areas comprising 40% of land use.

This catchment area is the most rapidly developed one among the east coast river basins and a very high increase in run-off is expected.

A diversion channel, connecting Sg. Relau to Sg. Ara, to protect the downstream reaches is planned by housing developer.

Sg. Keluang has already been improved to unlined channel and has sufficient river reserve.

To cope up with the development of upper reaches, river improvements will be considered.

In addition there exist mining and quarrying sites and on-going land development activities, especially in hilly areas of these upstream reaches. These lead to severe soil erosion and sediment run-off resulting in siltation and rise in river bed at downstream, a phenomenon already in progress.

Hence it is very necessary to institute suitable measures to control sediment run-off due to these activities.

The river channel of Sg. Keluang at river mouth will have to be extended 350 m in consideration to the on-going land reclamation activities.

3.18 Sg. Nipah

The future land use is expected to consist more than 80% of urbanized area. There exist vast tracts of flat terrains and only river improvement seems to be the protective measure against flooding.

At the estuary, the existing river channel will have to be extended to a distance of 500m because of the planned future land reclamation.

3.19 Sg. Kampung Masjid

The catchment area is only 0.84 km2. About 70% of the catchment will be urbanized in future. River improvements will be considered as the protective measure against flooding.

3.20 Sg. Ikan Mati

About 90% of the basin will be urbanized in future including hilly area. The river length is only a 500m, and river improvement works of deepening and widening will be considered.

3.21 Sg. Bayan Lepas

About 70% of the catchment remains, and also planned to be preserved, as mountainous forests. There exist some lowlying areas as well in the basin. River improvements for about 500m long downstream stretches will be carried out under the on-going Sg. Tiram Diversion Channel Project. As a protective measure for midstream stretches river improvement will be considered.

3.22 Sg. Batu and Sg. Mati

The catchment area of both these rivers are only about 0.9 km2. No significant change in future land use is expected in these basins. River improvements will be considered as the protective measure against flooding.

3.23 Sg. Teluk Kumbar

The catchment area of this river is comparatively large, but mostly consists of mountainous forests and agricultural lands. River improvements will be considered for the 1.7 km downstream reaches.

3.24 Sg. Gemuroh

The catchment area is almost entirely mountainous and only about 1% of the area is developed. No structural measures of flood mitigation is necessary.

3.25 Sg. Gertak Sanggul

The total length of river channel is only 300 m with enough discharge capacity. No significant change in land use pattern is expected in future. Flood mitigation measures are not necessary.

4. ESTABLISHMENT OF FLOOD PROTECTION LEVEL

The degree of protection with respect to flood mitigation is determined by the adoption of a suitable design storm return period.

In principle, the required design storm period should be decided based on the comparative study between the cost of investment and the resultant benefit. However owing to the difficulty in determining the basic data for analysis, and in order to eliminate regional discrepancies, usually the central government decides the standard degree of protection although these are subject to change along with economic growth of the country.

For Malaysia, according to the "National Water Resources Study, Malaysia" carried out by JICA in 1982, a design storm return period of 50-years is recommended when the flood damage exceeds M$ 20,000 per km of river reach and the population is more than 500 persons/km. However if loss of life is recorded then a 100 year return period is to be adopted.

Incidentally, the conceivable structural measures for the Sg. Pinang system is very much limited because of its topographic and land use conditions. River improvement works is essentially required as the major flood mitigatory measure, even with utmost use of the other measures of diversion channel and retention pond, and the scale of river improvements that would be possible will eventually dictate the degree of attainable flood protection level for the Sg. Pinang.

The relevant important rationale that necessitates river improvements as the major work component for attaining any considerable flood protection level for the Sg. Pinang are as follows:

- The existing discharge capacity of both the Sg. Pinang reaches at upstream of Jln. Jelutong Bridge and Sg. Air Itam are so low which corresponds to less than even 1.1-year return period, which self points out the requirement of river improvement works to attain any considerable flood protection level.

- The Sg. Pinang reaches at downstream of Jln. Jelutong Bridge has a maximum width of 46 m and will have a comparatively high discharge capacity of about 200 m^3/sec after deepening of river channel, which corresponds to a 30-year return period.

Finally, a flood protection level corresponding to 50-year return period was selected with due further consideration to the following.

It is possible to widen the following stretches of the Sg. Pinang, with due consideration to existing riverine land use, so that all their carrying capacities would correspond to a 50-year return period.

They are as follows:

- The stretches between Jln. Jelutong Bridge and Sg. Jelutong could be widened to 40 m to enhance its carrying capacity to about 210 m^3/sec.

- The immediately upstream stretches between Sg. Jelutong and Sg. Air Terjun could be widened to 35 m to have a carrying capacity of 190 m^3/sec.

- The further upstream stretches between Sg. Air Terjun and Sg. Kecil could be widened to 30 m to have a carrying capacity of 160 m^3/sec.

Nevertheless reconstruction all the major bridges along these reaches of the Sg. Pinang is necessary, as the average width of a typical existing bridge is only 20 m, and the maximum average discharge capacity across bridge is only about 85 m^3/sec, which corresponds to a 10 year return period.

The distribution of the probable flood discharge with retention ponds and No.3 diversion channel are shown in Fig. H-3.

For all the other rivers other than the Sg. Pinang land acquisition for river improvement works are comparatively not very difficult. The catchment areas of these rivers are much small with much less developed areas in comparison to Sg. Pinang basin. Nevertheless, with due consideration to future developments and to be in compatible with the overall flood mitigation plan a 50-year return period was selected, universally.

5. FORMULATION OF MASTER PLAN

5.1 Planning Criteria For Flood Mitigation

5.1.1 Distribution of Design Flood Discharge

Fig.H-4 shows the distributions of the Design flood discharge of the Sg. Pinang system estimated based an the land use conditions in the year of 2010.

The river stretches having discharge capacities that are insufficient to carry a flood discharge of 50-year return period are as follows:

- The whole stretches of the Sg. Pinang
- The downstream stretches of Sg. Air Itam at its confluence with the Sg. Dondang
- Almost the whole stretches of the Sg. Dondang
- A portion of the mid and downstream stretches of the Sg. Air Terjun

In particular, the existing discharge capacity of the Sg. Pinang and Sg. Air Itam are extremely low. Hence, even with the flood mitigation measures of Air Terjun Diversion Channel and Dondang Retention Ponds, river improvement works will be necessary for these reaches.

In fact the Sg. Pinang reaches at downstream of the Jln. Jelutong bridge have comparatively rather wide cross sections. Still, these reaches will also require river improvement works of deepening as the discharge capacity is affected by tidal effects and extension of river mouth reaches due to land reclamation.

Fig.H-5 and H-6 show the design discharge distributions of the other important rivers, i.e. Sg. Keluang and Sg. Dua Besar. These rivers are of Grade A or Grade B.

5.1.2 Planning Criteria for Flood Mitigation Facilities

The following design criteria were adopted for planning the flood mitigation facilities with due consideration to the topographic and land use conditions, and effectiveness and safety of the structures.

1) River Improvement

- The river channel will be of single or double type trapezoidal sections.

- The double section will be adopted for the undeveloped reaches of large rivers having comparatively large catchment area.

- River reserve will be maintained conforming the standards of DID.

- The planned river channel will be, as far as possible, excavated water ways, and levees will be avoided in order to minimize the requirements of inner water drainage

- The design high water level at the river mouth will be the mean high water springs which is +1.08 m.

- A minimum freeboard of 0.6 m will be allowed at all river banks.

- All design cross section should have enough capacity to cater 100 year discharge below the bankfull level.

- All levee crest elevations shall be higher than a water stage of 1.60 m at the river mouth.

2) Diversion Channel

- The design discharge through a tunnel section will be 130% of the design flood discharge.

- The tunnel section will have a minimum clearance area of 15% of the area of flow corresponding to the design discharge.

3) Retention Pond

- Retention pond will be planned for multi-purpose use considering its effective use under normal conditions of no flooding.

5.2 Alternative Protective Measures

5.2.1 Alternative Measures

Six possible alternative protective measures of flood mitigation for the Sg. Pinang were considered for the selection of most suitable alternative.

For all the other rivers in Penang Island, excluding the Sg. Pinang system, river improvement works including diversion channels are the only conceivable structural mitigatory measures.

These alternatives are shown in Fig.H-7 and H-8. Except Alternative I, all other alternatives consist of a combination of several structural measures, and are capable of regulating the discharge in the main stream of the Sg. Pinang at Jln. Jelutong Bridge not to exceed the permissible maximum discharge of 210 m^3/s.

Alternative I consists of only river improvement by means of widening or deepening, hence will not exert any effects on river discharge.

Alternative V consists of the same protective measures of Alternative II and the Diversion channel No.5. In this case, the discharge at Jln. Jelutong bridge is 175 m^3/s.

The distribution of design flood discharge for each alternative is shown in Fig.H-9 and H-10.

The river improvement works of Sg. Jelutong is not included in the alternative comparison because it is same for all the alternatives.

1) Alternative I

The Alternative I consists of only river improvement of Sg. Pinang (3.15 km) and its tributaries, Sg. Air Itam (3.0 km), Sg. Jelutong (2.10 km), Sg Air Terjun (2.20 km) and Sg. Dondang (5.3 km). The total length of river improvement will be about 15.8 km.

2) Alternative II

The Alternative II consists of river improvement of Sg. Pinang and its tributaries, the Air Terjun No.3 Diversion Channel (Q=50 m^3/s) and Dondang Retention Ponds (V=300,000 m^3).

3) Alternative III

No.5 Diversion Channel was considered in Sg. Air Terjun as the alternative instead of the No.3 Diversion Channel. The discharge capacity of No.5 Diversion Channel is 80 m^3/sec and hence, Dondang Retention Ponds are not necessary.

The river improvement works, however, are necessary for Sg. Pinang and its tributaries.

4) Alternative IV

Enlargement and raising the top level of the existing Air Itam Dam by three (3) meters was considered as an alternative instead of Dondang Retention ponds.

River improvements and No.3 Diversion Channel are also necessary measures.

5) Alternative V

This alternative consists of river improvement of Sg. Pinang and its tributaries, No.3 Diversion Channel and No.5 Diversion Channel (45 m^3/s).

6) Alternative VI

This alternative consists of the same protective measures of Alternative V. However, No.5 Diversion Channel will cater to divert the discharge of about 45 m^3/s of the Sg. Air

Terjun and about 35 m^3/s of Sg. Air Itam. An additional diversion channel of 500 m in length between Sg. Air Itam and Sg. Air Terjun will be necessary.

These alternatives are summarized as follows:

Alternative	Sg. Pinang	Sg. Air Itam	Sg. Air Terjun	Sg.Dondang
I	R.Improvement	R.Improvement	R.Improvement	R.Improvement
II	ditto	ditto	No.3 Diversion R.Improvement	Retention Pond R.Improvement
III	ditto	ditto	No.5 Diversion R.Improvement	R.Improvement
IV	ditto	Air Itam Dam	No.3 Diversion R.Improvement	ditto R.Improvement
V	ditto	R.Improvement	No.3 & No.5 Diversion R.Improvement	Retention Pond R.Improvement
VI	ditto	ditto	No.3, 5 & 6 Diversion R.Improvement	ditto

5.2.2 Comparison of Alternatives

The cost of civil works, land acquisition, and compensation required were estimated for each alternative. The cost of civil works is calculated by multiplying the quantity of work by unit cost.

A tentative estimation of construction cost for all five alternatives is summarized below.

Unit: 1000 M$

Alternative	Civil Works	Land Acquisition	Total
Al-I	29,764	40,619	70,383
Al-II	34,376	32,276	66,652
Al-III	35,120	35,593	70,713
Al-IV	36,537	34,087	70,624
Al-V	40,890	30,032	70,922
Al-VI	45,432	27,915	73,347

It is to be noted that all these alterative schemes have the same flood protection level of 50-year return period.

Based on cost comparison it is evident that Alternative II (Al-II) is the most economic one.

In fact it is selected as the master plan alternative because it is evaluated to be the most optimum alternative with respect to technical and social aspects of the project implementation as well.

A brief merits and demerits of all alternatives are summarized below.

- Alternative I (Al-I) is the second most economical scheme as evident from the above cost comparison table. However, the scheme is expected to encounter much difficulties with respect land acquisition, housing relocation and compensation as the alternative involves long river improvement reaches.

- Alternative II (Al-II) as described above is selected as the master plan alternative. It is the most economical scheme and in addition the work components, the river improvements, Dondang Retention Ponds and No.3 route diversion channel are not expected to involve any significant social problems during implementation. The No.3 Diversion Channel will be constructed mostly under the existing roads and is of a small scale as it is located in the upper reaches of the tributary Sg. Air Terjun. Also it eliminates the requirement of river improvement works at downstream. The scheme involves virtually no land acquisition requirement.

- Alternative III (Al-III) differs from the above Alternative II mainly with respect to the diversion channel scheme. However it is only the fourth most economical scheme. The No.5 Diversion Channel is located at downstream Sg. Air Terjun. Hence not only it is of larger capacity in comparison to No.3 Diversion Channel but also requires river improvement of almost the whole reaches of Sg. Air Terjun. Also the construction of this diversion channel encounters much technical, social and environmental concerns and difficulties.

  They are;

  - The culvert is of 12 m wide and its construction would result in the destruction of many trees, and also during construction the whole road would become inaccessible along with separation of local communities, an important social problem.

  - The invert level of the culvert at outfall will be -2.00 m, which may result in siltation inside the culvert.

  - The channel may cause water quality deterioration of coastal waters of Gurney Drive, a famous tourist area, by discharging polluted river water.

- Alternative IV (Al-IV) would require further river improvement works along mid and downstream reaches of Sg. Dondang in comparison to Alternative II (Al-II).

Furthermore raising the level of Air Itam Dam would interfere with its prime function of water supply in addition to the high cost resulting from the requirement a temporary spillway during construction. Also it is extremely difficult to discharge flood water during construction.

- Alternative V (Al-V) consists of two sub alternatives, Al-V(1) and Al-V(2). These alternatives are the most expensive ones. In a addition, these consist of the No.5 Diversion Channel, resulting in all the demerits discussed under Alternative III (Al-III).

  Furthermore , in case of Alternative VI (Al-VI) the No.5 Diversion will discharge a 35 m^3/s of Sg. Air Itam to Gurney Drive, a famous tourist area. The deteriorated water quality of Sg. Air Itam may result in the coastal water quality deterioration as well, an important environmental concern.

A summary of comparison of alternatives is given in Table H-2.

5.3 Proposed Flood Mitigation Plan

5.3.1 Sg. Pinang

The proposed flood mitigation plan for the Sg. Pinang system show in Fig.H-15 consists of the following protective measures:

1) **River Improvement works along the reaches of Sg. Pinang and its tributaries with a total length of 19.8 km.**

Sg. Pinang	:	- Deepening and widening of river stretches of 3.15 km in length.
		- Construction of jetty of 710 m.
		- Reconstruction of seven (7) bridges including 2 wooden bridges.
Sg. Air Itam	:	- Deepening and widening of river channel of 3.0 km in length.
		- Reconstruction of three bridges
Sg. Air Terjun	:	- Deepening and widening of river channel of 2.20 km in length.
		- Reconstruction of nine bridges.
Sg. Dondang	:	- Deepening and widening of river channel of 5.3 km in length.
		- Reconstruction of 8 bridges.
Sg. Jelutong	:	- Deepening and widening of river channel of 2.1 km in length.
		- Reconstruction of 17 small brides

Figs.H-11 - H-15 show the proposed longitudinal profiles and cross sections of these river improvement stretches.

Fig.H-16 shows proposed plan of downstream reaches of the Sg. Pinang.

The characteristics of proposed river channel are shown in Table H-3.

2) Construction of Air Terjun Diversion Channel

The proposed diversion channel from Sg. Air Terjun to the North Channel will be constructed along Jln. Gottlieb and Jln. Jermal.

The largest cross section of this underground box culvert channel is 6.3 m x 2.76 m.

The proposed longitudinal profile and route of this diversion channel are shown in Fig.H-17 and Fig.H-18.

3) Construction of the Dondang Retention Ponds

In Master Plan stage, five (5) number retention ponds were selected in Dondang area using parks and open areas proposed by MPPP in the urban development plan.

These ponds have a total capacity of about 300,000 m^3.with effective water depth of 2 m.

The characteristics of these proposed diversion channel and retention ponds are shown in Table H-4.

5.3.2 Rivers Outside Georgetown

1) Sg. Keluang

a) Sg. Keluang

River improvement of 1.35 km will be executed including river course extension of 0.20 km along the planned new land reclamation areas.

b) Sg. Ara

River improvement of 2.21 km will be executed, including the reconstruction of one bridge.

c) Sg. Relau

River improvements of 1.64 km at upstream of diverting point of Sg. Relau. Reconstruction of one bridge.

d) Relau Diversion Channel

The diversion channel of 1.53 km connecting Sg. Relau with Sg. Ara will be constructed through the planned new development area. One new bridge will be constructed.

The proposed flood mitigation facilities for the whole river system is shown in Fig. H-19.

2) Sg. Dua Besar

River improvement of 3.25 km in length will be executed.

The extension of river course of 650 m due to future land reclamation at its estuary will also be executed.

3) The other rivers

The proposed flood mitigation facilities for the other rivers of grade B and C, are shown in Tables H-5 and H-6.

Total length of stretches to be improved will be 27.96 km. Number of bridges to be reconstructed is 39.

The longitudinal profiles and cross section of the river outside Georgetown are shown in Figs.H-20.

Figs.H-21 show the location of bridges to be reconstructed.

5.4 Recommendation for Non-Structural Measures

5.4.1 General

For formulating a flood mitigation plan, structural measures alone will not always achieve the objectives effectively. This is due to the fact that the cost of investment required for purely structural measures is enormous. Consequently, a comprehensive flood mitigation plan should always consist of both structural and non-structural measures.

In Penang Island, where rapid urbanization is expected to proliferate further, the following measures are recommended.

- Soil Erosion & Run-off Control.
- Removal of Floating Bamboos, branches and Garbages
- Formulation of Design Criteria for River and Related Structures.
- Instituting a Flood Warning System.

5.4.2 Soil Erosion and Run-off Control

There are many development activities in Penang Island which often involve the removal of top soil thereby leading to soil erosion and sediment run-off.

This problem is very acute in sloppy terrains with housing development, sand mining and agriculture.

These activities often cause not only natural environmental degradation but also sediment-related disasters.

Especially, land development activities in the Penang Hill, irrespective of its scale, is recommended to be strictly regulated by law.

During the course of such development activities, sediment transport with storm water run-off should be controlled at the source itself.

Storm water retention ponds will be very effective to control sediment run-off by flash floods. Hence it is recommended to formulate criteria for the installation of storm water retention ponds in accordance with the degree of land development activities when potential soil erosion is anticipated.

Such development activities should be executed abiding by Malaysian law "Earth Works By-Laws (1975)".

After the completion of the land development activities like housing, etc., some regressing and vegetation also be retrieved as an erosion control measure at source.

1) Consideration of Land Development in Steep Terrain

In Penang Island, there are many development activities such as housing development, sand mining and agriculture which are on-going or expected.

These land development activities, in general, bring about negative effects to their surroundings environment due to changes in the existing natural conditions.

Especially from the viewpoint of natural disaster prevention, the effects of land development will be carefully examined.

These problems are very acute in steep terrains. In Penang Island, especially on the mountain slope facing the east coast, at the foot of which densely built housing areas exist, it is strongly recommended to formulate the proper guidelines to control slope developments not only to preserve a natural heritage but also to prevent natural disaster.

The problems to be anticipated due to the steep land development activities are as follows:

- Decrease of potential water holding capability of the mountain.
- Increase of run-off coefficients.
- Decreased stability of steep terrain.
- Increase of soil erosion and sediment run-off resulting in a decrease in the flow capacity of river channel in its lower reaches.
- Decrease of time of concentration resulting in an increase in run-off discharge.
- Difficulty of installation of retention pond because of limited space.
- Danger of steep slope land collapse and land slide.

- Loss of natural beauty due to the appearance of bare land.

Among these problems, sediment run-off, increase of run-off discharge, and landslide/steep slope collapse could bring about serious damage to the downstream area.

Slope stability mainly depends on geology, the geological structure, slope gradient, and ground water conditions.

In developing steep terrain, these existing conditions shall be fully examined and proper countermeasures shall be taken.

The recent disaster including debris flow due to careless land development for resort area in Rio-De-Janeiro in Brazil, is an example of potential disasters which can be prevented by appropriate countermeasures.

5.4.3 Removal of Floating Bamboos, branches and Garbages

Most rivers in Penang Island have mountainous or hilly areas with natural forests in their upstream stretches.

During flooding, branches of trees, bamboos and other debris are carried down the river course which get entangled at river structures such as bridge piers and box culverts thereby disrupting discharge across them.

Hence removal of debris at regular interval and also after heavy rainfall or during flood discharge, is extremely necessary.

In order to prevent blockage effectively and prevent too much accumulation, it is recommended to institute the facilities for removal of such debris along upstream stretches.

Under normal flow conditions generally floating debris, mainly garbages, are only observed.

These do not cause any serious obstruction to river flow but is a source of environmental problem aesthetic nuisance.

For removing these normal debris of floating type screens in the form of manually operated plastic drums are recommended to be installed.

Incidentally, blockage of drains by garbages is already a serious problem in Georgetown.

It is very important to maintain the screens properly with periodic removal of garbages and other debris so that they will not become a source of river discharge disruption during flooding.

5.4.4 Formulation of Design Criteria for River and Related Structures

It is recommended to formulate design criteria for river and related structures such as bridges, gates, etc.

This is to ensure that such river and related structures do not hinder free flow under the conditions of flooding.

In the rivers in Penang Island, there exist many bridges which hinder free flow of flood discharge.

Recommended design criteria of bridge is shown as follows:

Bridge Design Criteria

Appendix D of "Urban Drainage Design Standards and Procedures for Peninsular Malaysia" prepared by DID presents some bridge design criteria. However, the description of basic conditions such as bridge openings, freeboard, location or direction of piers is very general.

In order to design bridge structures which have a minimum effect on river flow characteristics, more detailed criteria may be necessary.

Design criteria should be established by giving full consideration to hydraulic effects, consistent with good bridge design and economics.

The design criteria for bridge design adopted in Japan are as follows:

- Principle of structural plan of piers and abutments installed in the river reserve.

  1. The piers and abutments installed in the river reserve shall be planned for safety against river water action under design high water level conditions.

  2. The piers and abutments installed in the river reserve shall not hinder the flow of river water at the time of high water and shall not cause serious damage to the banks and other structures. Construction shall be properly planned to prevent river bed erosion.

- Abutments

  1. In rivers with a width of more than 50 m, or in the tidal stretch, the abutment shall not be installed within the sectional form of flow.

  2. In rivers with a width less than 50 m, with no tidal effect, the abutment shall not be installed within the river bank of river side.

  3. The river side face of the abutment shall be installed parallel to the bank alignment.

- Piers

  1. The horizontal cross section of the piers installed in the river channel shall be long and narrow, elliptical or similar if possible. The longer dimension of a pier shall be parallel to the direction of flow.

2. The foundation of the pier in a river channel, in principle, shall be installed at least 2 meter deep below the river bed.

- Span Length

1. The span length shall be equal to or greater than the values calculated by the following formula:

   $L = 20 + 0.005Q$ L = Span Length (m)

   Q = Design Discharge (m^3/s)

2. For a river which has a 2,000 m^3/s design discharge, in the above formula, a span length of 30 m or greater will be adopted.

3. The span length may be reduced to the following values if serious damage is not expected from the maintenance of the river.

   1) $Q < 500$ m^3/s and $B < 30$ m

      $L = 12.5$ m

   2) $Q < 500$ m^3/s $B > 30$ m

      $L = 15$ m

   3) 500 m^3/s $< Q <$ 2,000 m^3/s

      $L = 20$ m

      where L = Span length and

      B = River width

Bridge Clearances

The distance between the design flow water surface and the bottom of the bridge deck will vary from case to case and it is very difficult to decide on the criteria for the necessary clearance. However, the following freeboard criteria for levee design might be applicable to bridge clearance.

Design Discharge (m^3/s)	Freeboard (m)
$Q < 200$	0.6
$200 < Q < 500$	0.8
$500 < Q < 2,500$	1.0
$2,000 < Q < 5,000$	1.2
$5,000 < Q < 10,000$	1.5

10,000 < Q	2.0

These criteria may be recommended as one of the guidelines.

5.4.5 Instituting a Flood Warning System

It has already been pointed out that the catchment area of Sg. Pinang basin is only 46 km^2 and 78% of the basin is mountainous and hilly terrains.

Consequently, the time of concentration of run-off is very short. Therefore, instituting of the flood forecasting system is not practical.

The provision of a flood warning system is considerd to be most feasible proposal. It is observed that there is an existing automatic warning siren at the Sg. Pinang bank in the vicnity of Jalan Perak.

However, the existing solar power battery source of the siren is not effective after a long period of rainfall, thereby affecting the sound level of the siren.

In order to alleviate this problem, an alternative power source is recommended.

5.5 Institutional Framework for River and Basin Management

5.5.1 Proposed Institutional Reforms

It is evident from the foregone discussions that the existing framework of river and basin management and flood mitigation and drainage is rather unsatisfactory.

An institutional reform for the existing Comprehensive Flood Mitigation Committee is proposed below, clearly defining its functional authority and responsibility, so that its jurisdiction will encompass the overall watershed management of the whole island.

The specific responsibility of the committee shall include the following:

- To co-ordinate and integrate the various drainage plans and projects in the whole island.

- To regulate the various basin development plans and projects from the viewpoint of overall watershed management.

- To maintain the retarding areas in a predetermined mode to mitigate flooding.

- To formulate and update comprehensive flood mitigation plan encompassing the whole basin, to construct and upgrade the necessary flood mitigation facilities and to formulate and enforce the legal restrictions on basin development activities of run-off control.

- Preservation of water resources and water quality to enhance their beneficial use.

- Creation of a pleasant environment with overall improvement of flood mitigation and drainage and water resources management.

The comprehensive flood mitigation committee shall be comprised of members from the following organizations:

- SEPU
- DID
- Town and Country Planning Dept.
- PDC
- PWD
- MPPP
- Lands and Mines Dept.

DID shall be the secretariat of the committee.

Regarding the planning, design and construction of facilities of flood mitigation and drainage, the overall responsibility shall rest with EPU, with delegation of responsibility to DID, MPPP, PWD, and PDC.

With respect to the operation and maintenance of the flood mitigation and drainage facilities, the existing institutional arrangement involving DID, MPPP and PWD is satisfactory.

A flow chart illustrating conceptually the organization of flood mitigation and drainage and its various stages of cause-effect-mitigation relationship is shown in Fig.H-22.

5.5.2 Demarcation between Rivers and Trunk Drains for Purposes of Maintenance and Operation

The State Public Works Department and Municipal Council of Penang Island are responsible for the drainage systems outside the city limit of Georgetown and within the city limit of Georgetown, respectively. All natural streams and rivers on the Island are under the jurisdiction of the State Drainage and Irrigation Department.

Once a natural river is converted to a concrete channel, the maintenance and operation for this river will be under the jurisdiction of MPPP.

However, at present there is no clear definition for rivers and trunk drains, furthermore, there is no flood mitigation master plan for rivers.

Under this situation, it is almost impossible to carry out the proper management of rivers and drainage basins.

All 25 rivers selected for the Master Plan in this Study would have the capacity to safety discharge floods having a 50-year return period, despite their small catchment areas. This is because their catchment areas are expected to be highly developed in the near future.

However, regarding maintenance and operation, these rivers should be demarcated according to their major functions.

This demarcation is very important not only for flood mitigation or drainage but also for clarification of which agency is responsible for maintenance and operation of the facilities.

For demarcation of these rivers, in addition to topographic condition, land use and scale of catchment, the following conditions were considered:-

- Rivers with catchment areas less than 2 km^2 would be treated as drains.
- Portion of non-urbanized area in the future
- Portion of mountainous area.
- Natural base flow.
- Potential of river front or existing landscape.

A preliminary demarcation of rivers and drains is presented in Table H-7.

5.6 Implementation Program

Basically, the construction works for the comprehensive flood mitigation projects were contemplated to be divided to three phases with a total implementation period of eighteen (18) years taking into account the scale of investment, the extent of economic effectiveness and degree of urgency based on social requirement.

Fig.H-23 shows the implementation program for the 24 river systems in Penang Island.

Phase I

The urgent project (Phase I) was selected so as to realize a quick benefit of the flood mitigation project and to meet the urgent social requirement.

For the Sg. Pinang system, river improvement works of the Sg. Pinang and its tributaries, construction of Air Terjun Diversion Channel and Dondang Retention Ponds are contemplated as the urgent project works.

River improvement works for the downstream stretch of Sg. Gelugor, Sg. Dua Besar and Sg. Keluang and its tributaries, and the construction of Relau Diversion Channel are also included in this phase.

Phase II

In the Georgetown area, river improvement works of Sg. Air Terjun and upstream reaches of Sg. Dondang will be executed.

However, river improvement plan of these upstream reaches of Sg. Dondang should be reviewed considering the on-going housing project by PDC which is expected to fill up the existing ground and relocates completely the existing route of water way.

In addition Sg. Fettes, Sg. Bayan Lepas, Sg. Teluk Bahang, Sg. Teluk Awak, Sg. Mas and Sg. Nibong Kecil will be improved.

By the end of this phase, all river improvement works for the rivers of grade A and B will be completed.

Phase III

The remainder, 14 rivers which are less important, will be improved.

Since the program of land reclamation along the east cost of the Island is not clear, it is recommended to modify the implementation program of the rivers affected by land reclamation in the future accordingly.

5.7 Construction Cost of the Project

The construction cost of the project includes the costs of civil works, land acquisition, engineering service, administration, and contingency.

The cost required for civil works is calculated by multiplying work quantity by unit cost. The engineering and administration cost is assumed at 5% of the sum of those required for civil work cost and contingencies is assumed at 20% of the sum of the above costs.

The total project construction cost of Master Plan is estimated to be 260.7 million M$ in financial terms at 1990 price level. The cost breakdown of the financial construction cost is as follows:

(Unit : 10^3 M$)

Phase		Direct Cost Total	Indirect Cost	
Phase I	Sg. Pinang	27,670	107,780	135,450
	The others	8,770	31.460	40,230
Phase II	Sg. Pinang	4,998	15,508	20,506
	The others	11,036	14,974	26,010
Phase III	The others	15,730	22,795	38,525
			Total	260,721

5.8 Economic Evaluation of Master Plan

An economic evaluation aims at enlightening the magnitude of the economic feasibility of the 26 projects designed in the flood mitigation master plan in Penang Island.

5.8.1 Benefit of Flood Mitigation Project

The benefit of flood mitigation project is defined as the difference in the amount of damage potential "with the project" and "without the project." Since no specific flood mitigation project is scheduled at present by the relevant authorities, full scale of the flood damage potential in case of "without project" is set equivalent to the project benefit in this study.

For the Master Plan stage, the following direct damage potentials were considered as the benefit of flood mitigation project.

- direct damage
  1) general property damage
     - house damage potential
     - household assets damage potential
     - commercial assets damage potential
     - commercial stocks damage potential

  2) public property damage
     - flood damage of road
     - flood damage of bridge
     - flood damage of electric facilities
     - flood damage of telecommunication facilities
     - flood damage of school, hospital
     - flood damage of government building facilities

However, in the small catchments except the Sg. Pinang and Sg. keluang basins, only house and household damages were taken into account.

Number of the houses in the flood prone area is estimated based on the population density shown in the "Penang Island Structure Plan." In 1990, it shows that 5-year return flood inundates about 2,590 houses and 50-year return flood covers 35,300 houses, while in 2010, it is expected 5,610 houses will be inundated when Georgetown is suffered from 5-year return flood and 41,900 houses is damaged in case of 50-year return flood.

Flood damage ratios by water depth are set based on the data collected through the interview survey conducted by the Study Team.

Flood Damage Ratio

Water depth (cm)	House	Household Article	Commercial Assets	Commercial Stocks
$0<H<50$	0.004	0.058	0.052	0.127
$50\leq H<100$	0.030	0.096	0.121	0.276
$100\leq H<200$	0.068	0.135	0.161	0.379
$200\leq H<300$	0.112	0.136	0.208	0.479
$300\leq H$	0.170	0.687	0.243	0.562

Based on these damage ratios, the flood damage potential are estimated.

In this study, five (5) cases of return period of flood damage i.e. 5-year, 10-year, 30-year, 50-year, and 100-year return period of floods were estimated.

In the following space, the flood damage reduction attributable to the project for the Sg. Pinang Basin are shown.

(unit; million M$ 1989 Price)

Return Period	1990	2010
1.1-year	5.7	5.8
5-year	17.2	17.6
10-year	86.0	93.1
30-year	181.9	197.2
50-year	238.7	259.9

The average annual flood damage reduction is calculated by using the following equation:

$$D = \sum [(N_{m-1} - N_m) \times (L_{m-1} + L_m)/2]$$

where, D : Average annual damage reduction
N : Probability of floods
L : Damage potential corresponding to probability of floods
m : Ordinal number

In estimating the annual average damage, the 50-year return period is adopted as a maximum frequency because this return period corresponds to the design flood frequency of the master plan.

It is expected that flood mitigation project for the Sg. Pinang basin results in 25.0 million Malaysian dollar and 26.6 million Malaysian dollar of average annual damage reduction for 1990 and 2010 respectively (1989 price).

5.8.2 Economic Cost

Two categorization of the project cost were prepared in order to measure the investment efficiency of the actual flood mitigation project. Each project is evaluated based on two difference cost;

- Cost peculiar to flood mitigation works (excluding the cost for river reserve and land beautification

- Cost including the river reserve and land beautification

For the purpose of flood mitigation, first cost might be sufficient. However, some additional cost such as land acquisition for river reserve and land beautification are required to keep maintenance road and also to make the project more acceptable by the inhabitants, and to improve the amenity as well as to make the project more implementable in accordance with the Malaysian regulations.

5.8.3 Economic Evaluation

The economic evaluation of the project was made in terms of the economic internal rate of return (EIRR) based on the following assumptions:

- The financial project cost could be converted into economic cost by applying the conversion factors (=0.88).

- The total economic construction costs were distributed to each year of the construction period according to implementation program.

- The annual operation and maintenance costs are assumed to be 1.0% of economic construction cost.

- The project benefits are assumed to be realized 5 years after the beginning of the project implementation, in 1996.

- The opportunity cost of capital is 8.0%.

The results of this economic evaluation are shown in Table H-8.

Tables

TABLE H-1 COMPARISON OF ALTERNATIVE DIVERSION CHANNELS

Alternative NO.	Route	Catchment Area (km2)	Divert Discharge (m3/sec)	Design Discharge Capacity (m3/sec)	Bed Slope	Flow Velocity (m/s)	Length (m)	Present Conditions On/along the Route	Rough Estimate of Construction cost (million M$)	Construction Problems	Evaluation
1	Sg. Air Terjun (CH.4450) ↓ Mount Ersking Cemetery ↓ Sg. Bagan Jermal	6.23 Sg. Air Terjun + 0.83 Sg. Bagan Jermal	50	65 (Tunnel) 65 + 8 = 73 (Open-channel)	$\frac{1}{100}$ (Tunnel) $\frac{1}{200}$ ~ $\frac{1}{100}$ (Open-channel)	5.8 (Tunnel) 4.3 ~ 5.6 (Open-channel)	850 (Tunnel) + 1,100 (Open-channel)	Hills and river There are some houses (about 5 houses) on the both sides of lower reach of Sg. Bagan Jermal. (CH. 50 ~ 250)	7.84	- Construction works are comparatively difficult, because half of the diversion channel are tunnel type - In the lower reaches of Sg. Bagan Jermal, some houses and buildings will have to be relocated.	- The economical viability of the plan is not high.
2	Sg. Air Terjun (CH.4101) ↓ Mount Ersking Cemetery ↓ Sg.Babi	7.38 Sg. Air Terjun + 0.84 (Sg. Babi)	50 [60]	65 [78] (Tunnel) 65 + 8 = 73 [78] [86] (Open-channel)	$\frac{1}{100}$ (Tunnel) $\frac{1}{400}$ ~ $\frac{1}{100}$ (Open-channel)	5.8 (Tunnel) 3.2 ~ 5.7 (Open-channel)	290 (Tunnel) + 1,600 (Open-channel)	Hills and river There are some houses (about 20 houses) on the both sides of Sg. Babi CH. 50 ~ 250 CH. 450 ~ 500 CH. 750 ~ 1100 CH.1200 ~ 1300	5.10 [5.53]	- Construction works are easier than Alternative 1, because almost all reaches of the diversion channel are open - channel type. - Houses and buildings will have to be relocated, in some reaches of Sg. Babi.	- One of the best plans that have high economical/technical viability. - The major problem will be relocation of the houses and buildings along Sg. Babi.
3	Sg.Air Terjun (CH.3155) ↓ Jl.Gottlieb ↓ Jl.Bagan Jermal ↓ Sg.Babi	7.74	50 [63]	65 [82] (Culvert)	$\frac{1}{400}$ - $\frac{1}{100}$	3.4 - 5.7	1,493 (Culvert) + 65 (Culvert) + 150 (channel)	Roads Jl.Gottlieb Width = 8.7m Jl.Bagan Jermal Width = 7.4m and River	4.74 [5.14]	- Almost all reaches of the diversion channel are culvert type and are constructed under the existing roads. Therefore, construction work schedule will depend on whether the traffic is successfully controlled. - There are some buildings to be relocated, on the both sides of the mouth of Sg. Babi.	- The optimum plan - The major problem will be maintenance of the culvert.
4	Sg.Air Terjun (CH.1684) ↓ Jl.Brook ↓ Jl.Cantonment	10.09	50 [78]	65 [102] (Culvert)	$\frac{1}{500}$ - $\frac{1}{150}$	3.1 - 4.8	2,252 (Culvert)	Roads Jl.Brook Width = 8.8m Jl.Cantonment width = 9.1~16.8m	6.75 [9.30]	- There are some trees (13 big trees and 114 small trees) to be preserved, along the diversion route. All diversion channel is culvert type, and it will be difficult to excavate under the road taking into account of preservation of the trees.	- The economical viability of the plan is not high. - The major problem will be preservation of existing trees along the road
5	Jl.Residensi ↓ Leboh Raya Peel ↓ Jl.Pangkor	10.62	50 [83]	65 [108] (Culvert)	$\frac{1}{750}$	2.7	2,180 (Culvert)	Roads Jl.Residensi Width = 10~16m Leboh Raya Peel Width = 10m Jl.Pangkor width = 10m	7.54 [10.92]	- There are some trees (82 big trees and 47 small trees) to be preserved, along the diversion route. The riverbed elevation is 3.1m, and the slope of diversion channel is gentle. Therefore, the design culvert will be too wide to be constructed under the road taking into account of preservation of the trees.	- The economical viability of the plan is the lowest. - The major problem will be preservation of existing trees along the road.

* The figures in the boxes indicate the discharge capacity or construction cost, if 90% of the probable flood discharge of Sg. Air Terjun are diverted.

TABLE H-2 COMPARISON OF ALTERNATIVE PROTECTIVE MEASURES IN SG. PINANG BASIN

ALTERNATIVE	COMPONENTS OF ALTERNATIVE		COST FOR PROJECT (1000 M$)				EVALUATION			
			CIVIL WORKS	LAND ACQUISITION	HOUSE EVACUATION	TOTAL	DIFFICULTY OF IMPLEMENTATION	SOCIAL IMPACT	ENVIRONMENTAL IMPACT	OTHERS
AI-I	RIVER IMPROVEMENT	Qmax = 270 CMS	29.764	32,279	8,340	70,383	- No major difficulty.	- Land Acquistion almost impossible.	- No significant impact.	
	DIVERSION CHANNEL NO.3	-								
	DIVERSION CHANNEL NO.5	-								
	AIR ITAM DAM	-								
	RETENTION POND	-								
AI-II	RIVER IMPROVEMENT	Qmax = 210 CMS	24.847	26,536	5,740	66,652	- No major difficulty.	- Land acquisition difficult but possible.	- No significant impact.	
	DIVERSION CHANNEL NO.3	L=1.7 km. Q=50 CMS	4.740							
	DIVERSION CHANNEL NO.5	-								
	AIR ITAM DAM	-								
	RETENTION POND	V=300.000 CMS	4.789							
AI-III	RIVER IMPROVEMENT	Qmax = 200 CMS	27.580	29,573	6,020	70,713	- Insufficient space.	- Land acquisition difficult but possible. - Interference to residence accessibility.	- Land clearing involve major tree felling.	
	DIVERSION CHANNEL NO.3	-								
	DIVERSION CHANNEL NO.5	L=2.18 km. Q=80 CMS	7.540							
	AIR ITAM DAM	-								
	RETENTION POND	-								
AI-IV	RIVER IMPROVEMENT	Qmax = 200 CMS	25.966	28,067	6,020	70,624	- Construction of temporary spillway may be difficult.	- Land acquisition difficult but possible. - Decrease of water supply storage capacity.	- Slight impact due to increase inundation of reservoir.	- Inadequate technical information.
	DIVERSION CHANNEL NO.3	L=1.7 km. Q=50 CMS	4.740							
	DIVERSION CHANNEL NO.5	-								
	AIR ITAM DAM	V=600.000CMS	5.831							
	RETENTION POND	-								
AI-V	RIVER IMPROVEMENT	Qmax = 175 CMS	23.821	24,692	5,340	70,922	- Insufficient space.	- Interference to residence accessibility.	- Major tree felling.	- Siltation inside the channel.
	DIVERSION CHANNEL NO.3	Qmax = 50 CMS	4.740							
	DIVERSION CHANNEL NO.5	Qmax = 45 CMS	7.540							
	AIR ITAM DAM	-								
	RETENTION POND	V=300.000 CMS	4.789							
AI-VI	RIVER IMPROVEMENT	Qmax = 145 CMS	22.729	23,015	4,900	73,347	- Insufficient space.	- Interference to residence accessibility.	- Major tree felling - Deterioration of coastal water quality.	- Siltation inside the channel.
	DIVERSION CHANNEL NO.3	Qmax = 50 CMS	4.740							
	DIVERSION CHANNEL NO.5	Qmax = 80 CMS	13.174							
	AIR ITAM DAM	-								
	RETENTION POND	V=300.000 CMS	1.789							

CMS = m^3/s

TABLE H-3 CHARACTERISTICS OF PROPOSED RIVER CHANNEL IN SG. PINANG BASIN

BASIN NO.	NAME OF RIVER CATCHMENT (KM^2)	STRETCH (KM)	DESIGN DISCHARGE (M^3/S)	DESIGN REVETMENT SLOPE	DESIGN LONGITUDINAL SLOPE	WIDTH (M)	DEPTH (M)	VELOCITY (M/S)	DISCHARGE (M^3/S)	REMARKS
1	SG.PINANG 46.07 KM^2	-0.71 - 0.4	210.0	1 : 1	1 : 2000	44.3 - 44.5	3.3 - 3.4	1.76	219.3	TOTAL LENGTH (M) * 3155 (3865 : INCLUDE EXTENSION OF RIVER MOUTH)
		0.4 - 1.9	210.0	1 : 0.5	1 : 2000	40.3 - 44.3	3.2 - 3.3	1.76	210.8	
		1.9 - 3.1	195.0	1 : 1	1 : 950	30.4 - 40.3	3.1 - 3.2	2.42	195.8	
1-1	SG.JELTONG 1.69 KM^2	0.0 - 1.315	20.0	1 : 0.5	1 : 1070	4.7	2.5	1.52	20.3	* 2141
		1.315 - 2.105	6.0	1 : 0	1 : 1070	2.0	2.5	1.22	6.1	
1-2	SG.AIR TERJUN 10.76KM^2	0.0 - 2.400	45.0	1 : 1	1 : 500	11.3	2.5	2.41	45.7	4487
		3.093 - 4.644	70.0	1 : 1	1 : 250	11.8	2.5	3.5	70.0	* 2200
1-3	SG.AIR ITAM	0.0 - 1.0	160.0	1 : 1	1 : 800	25.4	3.0 - 3.1	2.5	160.5	3000
		1.1 - 2.6	145.0	1 : 1	1 : 800	23.6	3.0	2.5	145.0	
1-4	SG.DONDANG 11.33KM^2	0.0 - 1.547	60.0	1 : 1	1 : 600	14.0	2.5	2.4	60.6	* 5302
		1.547 - 3.732	60.0	1 : 1	1 : 680	10.2	2.5	3.0	60.0	
		3.732 - 6.094	45.0	1 : 1	1 : 190	8.9	2.5	3.5	45.6	

* Stretch to be improved in the Master Plan

TABLE H-4 PROPOSED DIVERSION CHANNEL AND RETENTION PONDS

Air Terjun Diversion Channel

Location	Design discharge (m^3/s)	Length (km)	Section H x B (m)	Slope	Remarks
Sg. Air Terjun to North Channel	65	1.7	2.76 x 6.3	$\frac{1}{200} \sim \frac{1}{250}$	

Dondang Retention Ponds

River	No.	Location (km)	Reservoir Surface (ha)	Capacity (m^3)	Remarks
Sg. Dondang	A	4.0	2.38	45,000	
	B	2.8	3.14	62,500	
	C	1.8	3.88	112,500	
	D	1.0	4.74	86,700	Tributary of Sg. Dondang
	E	1.5	1.27	23,700	Tributary of Sg. Dondang
Total			15.41	330,400	

TABLE H-5-1 CHARACTERISTICS OF PROPOSED RIVER CHANNEL IN THE BASINS OUTSIDE GEORGETOWN 1

BASIN NO.	NAME OF RIVER CATCHMENT (KM^2)	STRETCH (KM)	DESIGN DISCHARGE (M^3/S)	DESIGN REVETMENT SLOPE	DESIGN LONGITUDINAL SLOPE	WIDTH (M)	DEPTH (M)	VELOCITY (M/S)	DISCHARGE (M^3/S)	REMARKS
3	SG.TELUK BAHANG	0.0 - 1.8	52.0	1 : 2	1 : 530	18.3	2.0	2.19	52.1	TOTAL LENGTH (M)
	12.30 KM^2	1.8 - 2.35	52.0	1 : 2	1 : 440	17.5	2.0	2.37	52.6	(SHORT CUT)
		2.35 - 3.2	48.0	1 : 2	1 : 440	16.7	2.0	2.33	48.0	* 3130
		3.2 - 3.6	48.0	1 : 2	1 : 200	13.9	2.0	3.20	48.1	
10	SG.FETTES	-0.65 - 0.0	27.0	1 : 0	1 : 500	7.3	2.9 - 1.6	2.40	28.0	1900
	1.36 KM^2	0.0 - 0.09	27.0	1 : 0	1 : 300	6.0	1.6	2.97	28.5	* 600
		0.09 - 0.6	27.0	1 : 0	1 : 180	4.9	1.6	3.65	28.6	
		0.6 - 1.25	16.0	1 : 0	1 : 100	3.4	1.5	3.20	16.3	
13	SG.GELUGOR	0.0 - 0.65	25.0	1 : 1	1 : 450	8.7	1.7	2.10	25.0	* 2103
	4.07 KM^2	(Original River)	29.0	1 : 0	1 : 340	6.0	1.7 - 2.0	2.86	29.2	
		1.0 - 1.4	29.0	1 : 0	1 : 240	5.2	1.7	3.29	29.1	
		1.4 - 2.2	29.0	1 : 0	1 : 100	2.9	1.7	4.2	20.98	
		2.2 - 2.973								
14	SG.DUA BESAR	-0.65 - 0.808	55.0	1 : 1	1 : 1000	19.0	2.0	1.75	50.2	3950
	6.19 KM^2	0.808 - 1.8	30.0	1 : 1	1 : 390	9.6	2.0	2.38	30.4	* 3300
		1.8 - 2.9	27.0	1 : 1	1 : 200	7.7	2.0	3.02	27.2	
		2.9 - 3.3	7.0	1 : 0	1 : 100	1.5	1.5	3.15	7.1	
	SG.DUA BESAR R2	0.0 - 0.6	11.0	1 : 1	1 : 510	6.5	2.0	1.71	11.3	1400
		0.6 - 0.9	9.0	1 : 1	1 : 510	6.0	2.0	1.61	9.0	
		0.9 - 1.4	9.0	1 : 0	1 : 140	1.6	2.0	2.91	9.3	
17	SG.KELUANG	-0.20 - 1.05	125.0	1 : 2	1 : 1190	54.3	3.0	1.56	130.5	SG.KELUANG
	22.17 KM^2	1.05 - 2.20	110.0	1 : 2	1 : 1190	50.5	3.0	1.46	100.1	* 1740
		2.20 - 2.95	40.0	1 : 2	1 : 1190	26.2	2.5	3.16	101.3	SG.ARA
		2.95 - 3.41	40.0	1 : 2	1 : 450	22.4	1.8	1.70	40.1	* 1870
	SG.RELAU (UPPER STREAM)	2.41 - 4.045	65.0	1 : 1	1 : 360	14.9	2.0	2.79	65.3	SG.RELAU * 1635
	SG.RELAU (LOWER STREAM)	0.0 - 2.41	6.0	1 : 1	1 : 600	5.7	1.5	1.39	6.2	2410
21	SG.BAYAN LEPAS	0.0 - 1.10	69.0	1 : 1	1 : 900	26.2	1.7	1.75	69.2	2800
	7.04 KM^2	1.10 - 1.4	56.0	1 : 1	1 : 410	16.4	1.7	2.45	56.2	* 2400
		1.4 - 1.8	27.0	1 : 1	1 : 410	10.1	1.7	2.22	27.1	
		1.8 - 2.8	27.0	1 : 1	1 : 290	9.2	1.7	2.56	27.4	

TABLE H-5-2 CHARACTERISTICS OF PROPOSED RIVER CHANNEL IN THE BASINS OUTSIDE GEORGETOWN 2

BASIN NO.	NAME OF RIVER CATCHMENT (KM^2)	STRETCH (KM)	DESIGN DISCHARGE (M^3/S)	DESIGN REVETMENT SLOPE	DESIGN LONGITUDINAL SLOPE	WIDTH (M)	DEPTH (M)	VELOCITY (M/S)	DISCHARGE (M^3/S)	REMARKS
2	SG.TELUK AWAK 2.95 KM^2	0.0 - 1.4 1.4 - 2.1	21.0 21.0	1 : 1 1 : 1	1 : 470 1 : 370	10.2 9.5	1.5 1.5	1.96 2.17	22.1 22.2	TOTAL LENGTH (M) * 2100
4	SG.BATU FERRINGGHI 11.27 KM^2	0.0 - 0.9	53.0	1 : 1	1 : 450	11.2	3.0	2.67	56.0	* 400
5	SG.SATU 2.58 KM^2	0.0 - 1.176	20.0	1 : 1	1 : 300	8.9	1.5	2.37	22.0	* 500
6	SG.MAS 2.11 KM^2	0.0 - 1.778	27.0	1 : 1	1 : 200	9.1	1.5	2.92	28.1	* 600
7	SG.KECIL 2.75 KM^2	0.0 - 1.0	26.0	1 : 1	1 : 260	9.5	1.5	2.95	26.5	* 705
8	SG.KELIAN 9.04 KM^2	0.0 - 2.871	44.0	1 : 1	1 : 340	10.2	2.5	2.80	45.5	* 2811
9	SG.BALIK BATU 0.80 KM^2	0.0 - 0.5	18.0	1 : 0.5	1 : 200	5.7	1.7	2.84	20.5	* 500
11	SG.BAGAN JERMAL 0.83 KM^2	0.0 - 0.3	13.0	1 : 0.5	1 : 170	4.8	1.5	2.76	14.3	* 300
12	SG.BABI 0.84 KM^2	0.0 - 0.6 0.6 - 1.6	12.0 12.0	1 : 0.0 1 : 0.0	1 : 250 1 : 150	4.8 3.9	1.0 1.0	2.51 3.10	12.0 12.1	* 300 * 700
15	SG.NIBONG BESAR 1.50 KM^2	-0.6 - 1.2 1.2 - 1.65	25.0 25.0	1 : 0.3 1 : 0.3	1 : 600 1 : 300	7.48 5.88	1.7 1.7	2.26 3.0	25.4 25.5	* 600 * 450
16	SG.NIBONG KECIL 2.77 KM^2	-0.5 - 1.498	42.0	1 : 1	1 : 1960	18.1	2.2	1.30	42.1	* 900
18	SG.NIPAH 1.69 KM^2	-0.5 - 1.906	22.0	1 : 1	1 : 1600	10.5	2.5	1.31	22.2	* 1906
19	SG.KAMPUNG MASJID 0.84 KM^2	0.0 - 0.6	18.0	1 : 1	1 : 350	9.2	1.3	2.08	18.1	* 600
20	SG.IKAN MATI 0.38 KM^2	0.0 - 0.15	12.0	1 : 1	1 : 375	6.9	1.5	1.94	12.2	* 150
22	SG.BATU 0.90 KM^2	0.0 - 1.15	12.0	1 : 3.0	1 : 310	13.6	1.5	1.61	13.3	* 1000
23	SG.MATI 0.95 KM^2	0.0 - 1.037	25.0	1 : 3.0	1 : 265	13.8	1.5	1.77	15.1	* 800
24	SG.TELUK KUMBAR 7.06 KM^2	0.0 - 0.9 0.9 - 2.0 2.0 - 2.639	50.0 50.0 50.0	1 : 3.0 1 : 3.0 1 : 3.0	1 : 700 1 : 290 1 : 160	25.4 20.7 20.7	2.0 2.0 2.0	1.58 2.27	50.0 50.4	* 900 * 800
26	SG.GERTAK SANGGUL 1.03 KM^2	0.0 - 483.5	15.0	1 : 1	1 : 370	8.6	2.0 - 2.52	2.09	15.4	480

TABLE H-6-1 BRIDGES TO BE RECONSTRUCTED FOR MASTER PLAN

RIVER NAME	BRIDGE NO.	(m) CHAIN	EXISTING (m) SPAN LENGTH	EXISTING (m) WIDTH	EXISTING (m^2) AREA	PROPOSED (m) SPAN LENGTH	PROPOSED (m) WIDTH	PROPOSED (m^2) AREA
1-1 SG. PINANG	1	407	29	10.0	290.0	44.46	10.0	444.60
	2	904	20	6.0	120.0	40.45	6.0	242.70
	3	1,273	25	10.0	250.0	40.45	10.0	404.50
	4	2,122	18	15.0	270.0	30.40	15.0	456.00
	5	2,470	23	3.0	69.0	33.00	3.0	99.00
	6	2,928	12	3.0	39.0	33.00	3.0	99.00
	7	3,129	18	16.0	288.0	30.40	16.0	486.40
					1326.0			**2,232.00**
1-2 SG.AIR ITAM								
	1	1,062	13	30.0	390.0	25.40	30.0	762.00
	2	1,493	18	18.5	333.0	23.60	18.5	436.60
	3	2,471	21.8	9.5	207.1	23.60	9.5	224.20
					930.1			**1,422.80**
1-3 SG.AIR TERJUN								
	1	200	6.6	8.0	52.8	11.30	8.0	90.40
	2	530	6.6	8.0	52.8	11.30	8.0	90.40
	3	590	7.4	5.0	37.0	11.30	5.0	56.50
	4	790	10	6.0	60.0	11.30	6.0	67.80
	5	1,000	8	5.0	40.0	11.30	5.0	56.50
	6	3,490	5.4	9.0	48.6	11.80	9.0	106.20
	7	3,800	4.5x2x2	4.5	20.3	11.80	4.5	53.10
	8	4,380	7	2.0	14.0	11.80	2.0	23.60
	9	4,640	8.5	7.0	59.5	11.80	7.0	82.60
					385.0			627.10
1-4 SG.DONDANG								
	1	500	9	4.0	36.0	14.00	4.0	56.00
	2	527	9	5.0	45.0	14.00	5.0	70.00
	3	806	7	11.0	77.0	14.00	11.0	154.00
	4	1,400	6	3.0	18.0	16.00	3.0	48.00
	5	1,650	9	3.0	27.0	11.00	3.0	33.00
	6	1,880	7	5.0	35.0	10.20	5.0	51.00
	7	2,591	7.5	3.0	22.5	11.00	3.0	33.00
	8	2,865	9	3.0	27.0	11.00	3.0	33.00
					287.5			478.00

TABLE H-6-2 BRIDGES TO BE RECONSTRUCTED FOR MASTER PLAN

Sg. JELUTONG

NO.	CHR. (m)	EXISTING LENGTH (m)	WIDTH (m)	AREA (sq.m)	TYPE	PROPOSED LENGTH (m)	WIDTH (m)	AREA (sq.m)	TYPE
1	632	5.0	1.5	7.5	IRON	7.0	1.5	10.5	R.C. SLAB
2	1,509	5.0	1.5	7.5	WOOD	7.0	1.5	10.5	R.C. SLAB
3	1,554	5.0	1.5	7.5	WOOD	7.0	1.5	10.5	R.C. SLAB
4	1,583	5.0	1.5	7.5	IRON	7.0	1.5	10.5	R.C. SLAB
5	1,656	6.0	4.0	24	WOOD	7.0	4.0	28	R.C. SLAB
6	1,664	3.1	1.0	3.1	WOOD	8.0	1.0	8	R.C. SLAB
7	1,684	3.2	1.5	4.8	WOOD	5.0	1.5	7.5	R.C. SLAB
8	1,690	3.2	3.0	9.6	WOOD	5.0	3.0	15	R.C. SLAB
9	1,709	3.2	2.0	120	WOOD	5.0	2.0	10	R.C. SLAB
10	1,739	3.3	2.5	8.25	WOOD	5.0	2.5	12.5	R.C. SLAB
11	1,745	3.3	2.0	6.6	WOOD	5.0	2.0	10	R.C. SLAB
12	1,751	3.0	2.0	6	WOOD	5.0	2.0	10	R.C. SLAB
13	1,771	3.0	2.0	6	WOOD	5.0	2.0	10	R.C. SLAB
14	1,843	5.0	4.0	20	R.C.T-GIRDER	5.0	4.0	20	R.C. SLAB
15	1,854	4.0	4.0	16	R.C.T-GIRDER	7.0	4.0	28	R.C. SLAB
16	1,935	3.0	1.5	120	WOOD	6.0	1.5	9	R.C. SLAB
17	2,070	3.4	1.0	3.4	WOOD	5.0	1.0	5	R.C. SLAB

TABLE H-6-3 BRIDGES TO BE RECONSTRUCTED FOR MASTER PLAN

RIVER NAME	BRIDGE NO.	(m) CHAIN	EXISTING (m) SPAN LENGTH	EXISTING (m) WIDTH	EXISTING (m^2) AREA	PROPOSED (m) SPAN LENGTH	PROPOSED (m) WIDTH	PROPOSED (m^2) AREA
2. SG. TELUK AWAK								
	1	230	D1.x2	8.0	8.0	10.20	8.0	81.60
	2	510	3.1	8.0	24.8	10.20	8.0	81.60
	3	1,450	D1.5x2	3.5	5.3	9.50	3.5	33.25
					50.0			**196.45**
3. SG.TELUK BAHANG	1	280	17	6.0	102.0	18.30	6.0	109.80
					102.0			**109.80**
4. SG. BATU FERINGGI	1	210	7.7	4.0	30.8	11.20	4.0	44.80
					31.0			**45.00**
5. SG. SATU	1	300	8	6.0	48.0	8.90	6.0	53.40
					48.0			**54.00**
6. SG. MAS	No bridge to be re-built.							
7. SG. KECIL								
	1	100+16	8.8	6.0	52.8	9.50	6.0	57.00
	2	350+36	3	4.0	12.0	9.50	4.0	38.00
	3	700+28	5	4.0	20.0	9.50	4.0	38.00
					84.8			**133.00**
8. SG. KELIAN	1	620	8	10.3	82.4	10.20	10.3	105.06
	2	1,070	6	13.8	82.8	10.20	13.8	140.76
	3	1,720	5.8	3.2	18.6	10.20	3.2	32.64
	4	2,300	7.3	6.1	44.5	10.20	6.1	62.22
					183.8			**278.46**
9. SG. BALIK BATU	1	200	5.63	5.7	32.1	6.60	5.7	37.62
					33.0			**38.00**
10. SG. FETTES	No bridge to be re-built.							

TABLE H-6-4 BRIDGES TO BE RECONSTRUCTED FOR MASTER PLAN

RIVER NAME	BRIDGE NO.	(m) CHAIN	EXISTING (m) SPAN LENGTH	EXISTING (m) WIDTH	EXISTING (m^2) AREA	PROPOSED (m) SPAN LENGTH	PROPOSED (m) WIDTH	PROPOSED (m^2) AREA
11. SG. BAGAN JERMAL								
	1	150	1.6x1.1x2.0	19.0	30.4	4.80	19.0	91.20
					30.4			
12. SG.BABI								
	1	220	0.9x3	60.0	54.0	4.80	60.0	288.00
					54.0			**288.00**
13. SG. GELUGOR								
	1	850+7.5	11	10.0	110.0	11.40	10.0	114.00
	2	1150+40	7	11.0	77.0	9.90	11.0	108.90
	3	1800+19	7	2.0	14.0	8.50	2.0	17.00
					201.0			**239.90**
14. Sg. DUA BESAR	No bridge to be re-built.							
15. SG.NIBONG BESAR								
	1	830	4.5	25.0	112.5	7.48	25.0	187.00
	2	1,250	5	25.0	125.0	5.88	25.0	147.00
	3	1,400	1.9x1.85x1	82.0	155.8	5.88	82.0	482.16
	4	1,600	1.8x1.2x2	33.0	59.4	5.88	33.0	194.04
					452.7			**1,010.20**
16. SG. NIBONG KECHIL	No bridge to be re-built.							
17. Sg. Keluang	1	2,070	22	3.0	66.0	53.00	3.0	159.00
	2	3,143	16	3.0	48.0	27.00	3.0	81.00
18. SG. NIPAH								
	1	1,414	2.55	3.0	7.7	10.50	3.0	31.50
					8.0			**32.00**
19. SG. KAMPUNG MASJID								
	1	139	5.5	5.6	30.8	9.20	5.6	51.52
	2	438	2.4	4.0	9.6	9.20	4.0	36.80
					40.4			**88.32**
20. SG. IKAN MATI								
	1	44	1.5	3.5	5.3	6.90	3.5	24.15
	2	57	1	5.0	5.0	6.90	5.0	34.50
	3	101	3	3.0	9.0	6.90	3.0	20.70
					19.3			**79.35**

TABLE H-6-5 BRIDGES TO BE RECONSTRUCTED FOR MASTER PLAN

RIVER NAME	BRIDGE NO.	(m) CHAIN	EXISTING			PROPOSED		
			(m) SPAN LENGTH	(m) WIDTH	(m^2) AREA	(m) SPAN LENGTH	(m) WIDTH	(m^2) AREA
21. SG. BAYAN LEPAS	1	400	6	9.0	54.0	25.90	9.0	233.10
	2	1,250	5	4.5	22.5	16.00	4.5	72.00
	3	1,450	6	4.0	24.0	10.30	4.0	41.20
	4	2,060	4	9.5	38.0	9.40	9.5	89.30
					138.5			**435.60**
22. SG. BATU								
	1	411	6.3	1.5	9.5	13.60	1.5	20.40
					10.0			**21.00**
23. SG. MATI								
	1	272	5.08	2.2	10.9	13.80	2.2	29.67
	2	469	8.6	4.5	38.7	13.80	4.5	62.10
	3	666	3.75	2.2	8.3	13.80	2.2	30.36
					57.9			**122.13**
24. SG. TELOK KUMBER								
	1	87	13.5	5.5	74.3	25.40	5.5	139.70
	2	1,162	3.9	7.6	29.6	20.70	7.6	157.32
					103.9			**297.02**

TABLE H-7 DEMARCATION OF RIVER AND TRUNK DRAIN

CATCH-MENT NO.	NAME	CATCHMENT AREA (km2)	URBANIZED AREA (*) IN 2010 (%)	RIVER (R) OR DRAIN (D)		MOUNTAINOUS AREA (%)
1	Sg. Pinang	46.07	45	R		78
2	Sg.Teluk Awak	2.95	66	R		85
3	Sg. Teluk Bahang	12.30	32	R		89
4	Sg. Batu Ferringhi	11.27	6	R		99
5	Sg. Satu	2.58	18	R		92
6	Sg. Mas	2.11	77	R		63
7	Sg. Kecil	2.75	28	R		85
8	Sg. Kellan	9.04	30	R		85
9	Sg. Balik Batu	0.80	91	D		71
10	Sg. Fettes	1.36	80	D		67
11	Sg. Bagan Jermal	0.83	78	D		66
12	Sg. Babi	0.84	90	D	with Diversion	52
13	Sg. Gelugor	4.07	86	R		68
14	Sg. Dua Besar	6.19	93	R		54
15	Sg. Nibong Besar	1.50	90	D		19
16	Sg. Nibong Kecil	2.77	95	D		16
17	Sg. Keluang	22.17	44	R		71
18	Sg. Nipah	1.69	84	D		24
19	Sg. Kampung Masjid	0.84	84	D		39
20	Sg. Ikan Mati	0.38	92	D		53
21	Sg. Bayan Lepas	7.04	28	R		85
22	Sg. Batu	0.90	43	D		50
23	Sg. Mati	0.95	49	D		37
24	Sg. Teluk Kumbar	7.06	16	R		67
25	Sg. Gemuroh	1.91	1	R		100
26	Sg. Gertak Sanggul	1.03	9	R		83
27	Sg. Pulau Betong	11.04	6	R		40
28	Sg. Nipah	3.24	27	R		4
29	Sg. Burong	13.79	17	R		50
30	Sg. Kongsi	20.63	11	R		61
31	Sg. Pinang (D.B.D.)	19.99	8	R		72

Note: (*) Urbanized Area includes park, cemetry, and open land

TABLE H-8 SUMMARY OF ECONOMIC EVALUATION FOR ALL RIVERS IN STUDY AREA

No.	Name of River	Net Cost for the Flood Mitigation Works: Total Cost (mil. M$)	Total Benefit (mil. M$)	Balance (mil. M$)	EIRR (%)	Whole Cost including Land Acquisition for River Reserve and Land Beautification: Total Cost (mil. M$)	Total Benefit (mil. M$)	Balance (mil. M$)	EIRR (%)
1	Sg. Pinang					171.80	870.30	698.60	15.13
2	Sg. Teluk Awak	4.90	4.00	-0.90	0.00	6.13	4.00	-2.13	0.00
3	Sg. Teluk Bahang	8.03	8.83	0.80	0.43	9.39	8.83	-0.56	0.00
4	Sg. Batu Ferringghi	0.93	1.61	0.68	2.85	1.09	1.61	0.52	2.00
5	Sg. Satu	0.74	0.98	0.24	1.39	0.90	0.98	0.08	0.40
6	Sg. Mas	2.13	1.44	-0.69	0.00	2.59	1.44	-1.15	0.00
7	Sg. Kechil	1.98	1.48	-0.50	0.00	2.35	1.48	-0.87	0.00
8	Sg. Kellan	3.61	4.11	0.50	0.67	4.27	4.11	-0.16	0.00
9	Sg. Balik Batu	1.44	2.59	1.15	3.23	1.76	2.59	0.83	2.10
10	Sg. Fettes	1.97	4.64	2.67	3.88	2.41	4.64	2.23	2.93
11	Sg. Bagan Jermal	3.76	0.60	-3.16	0.00	4.44	0.60	-3.84	0.00
12	Sg. Babi	5.43	1.36	-4.07	0.00	6.46	1.36	-5.10	0.00
13	Sg. Gelugor	5.28	16.16	11.00	5.61	6.10	16.16	10.06	4.68
14	Sg. Dua Busar	7.00	13.70	6.70	0.00	7.70	13.70	5.90	0.00
15	Sg. Nibong Besar	3.60	12.10	8.50	5.60	4.21	12.10	7.89	4.81
16	Sg. Nibong Kechil		(no flood expected)						
17	Sg. Keluang					44.68	330.86	286.18	14.60
18	Sg. Nipah	21.29	11.69	-9.60	0.00	22.11	11.69	-10.42	0.00
19	Sg. Kampung Masjid	0.91	4.54	3.63	9.99	1.09	4.54	3.45	8.63
20	Sg. Ikan Mati	0.28	2.81	2.53	20.76	0.31	2.81	2.50	18.97
21	Sg. Bayan Lepas	3.79	14.46	10.67	6.38	4.55	14.46	9.91	5.46
22	Sg. Batu	3.52	2.62	-0.90	0.00	4.10	2.62	-1.48	0.00
23	Sg. Mati	1.71	2.59	0.88	2.41	1.98	2.59	0.61	1.53
24	Sg. Teluk Kumbar	6.32	12.72	6.40	4.58	7.19	12.72	5.53	3.70
25	Sg. Gemuroh		(no flood expected)						
26	Sg. Gertak Sanggul		(no flood expected)						

Figures

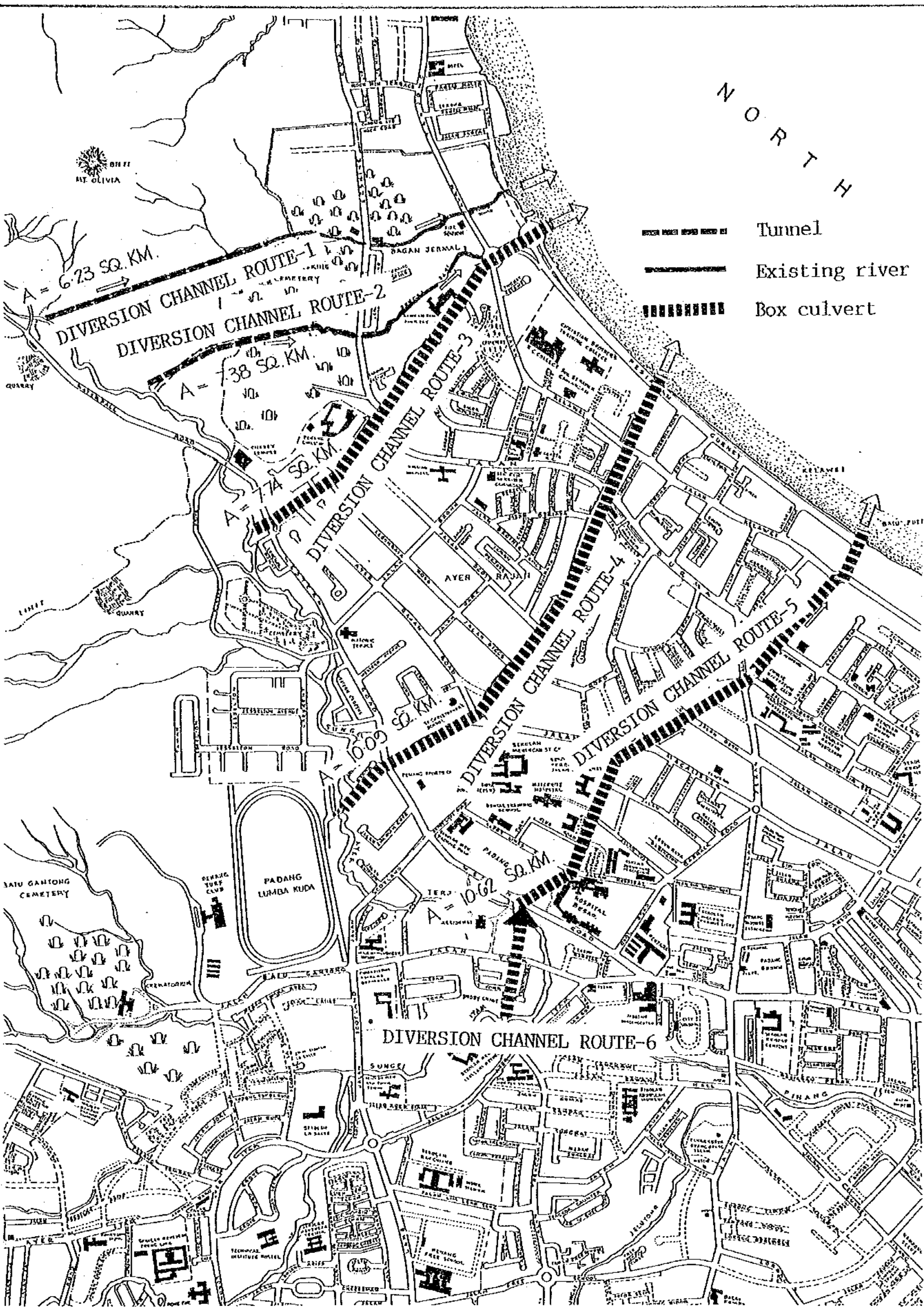
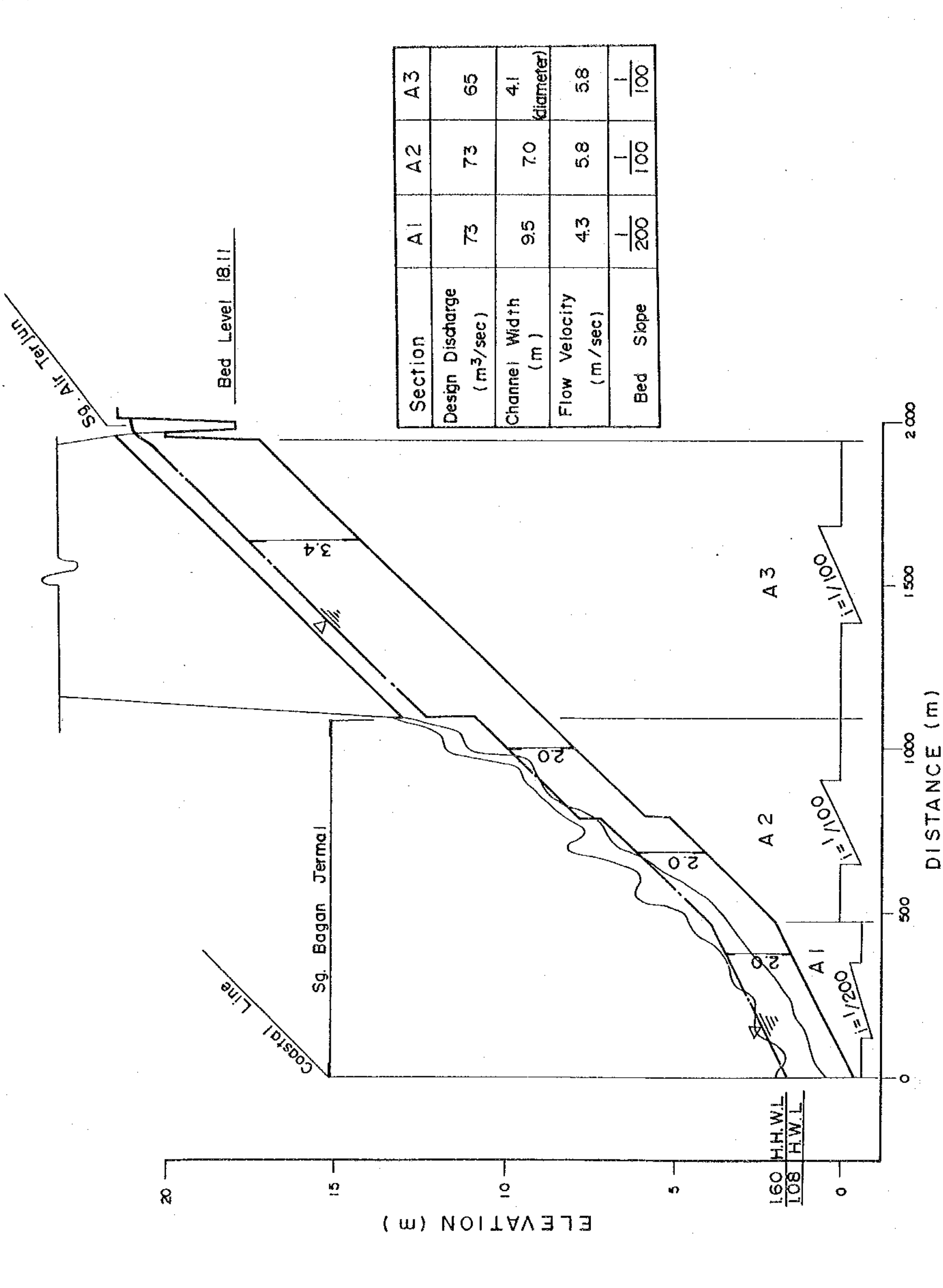


Fig. H-1 ALTERNATIVE DIVERSION ROUTES

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

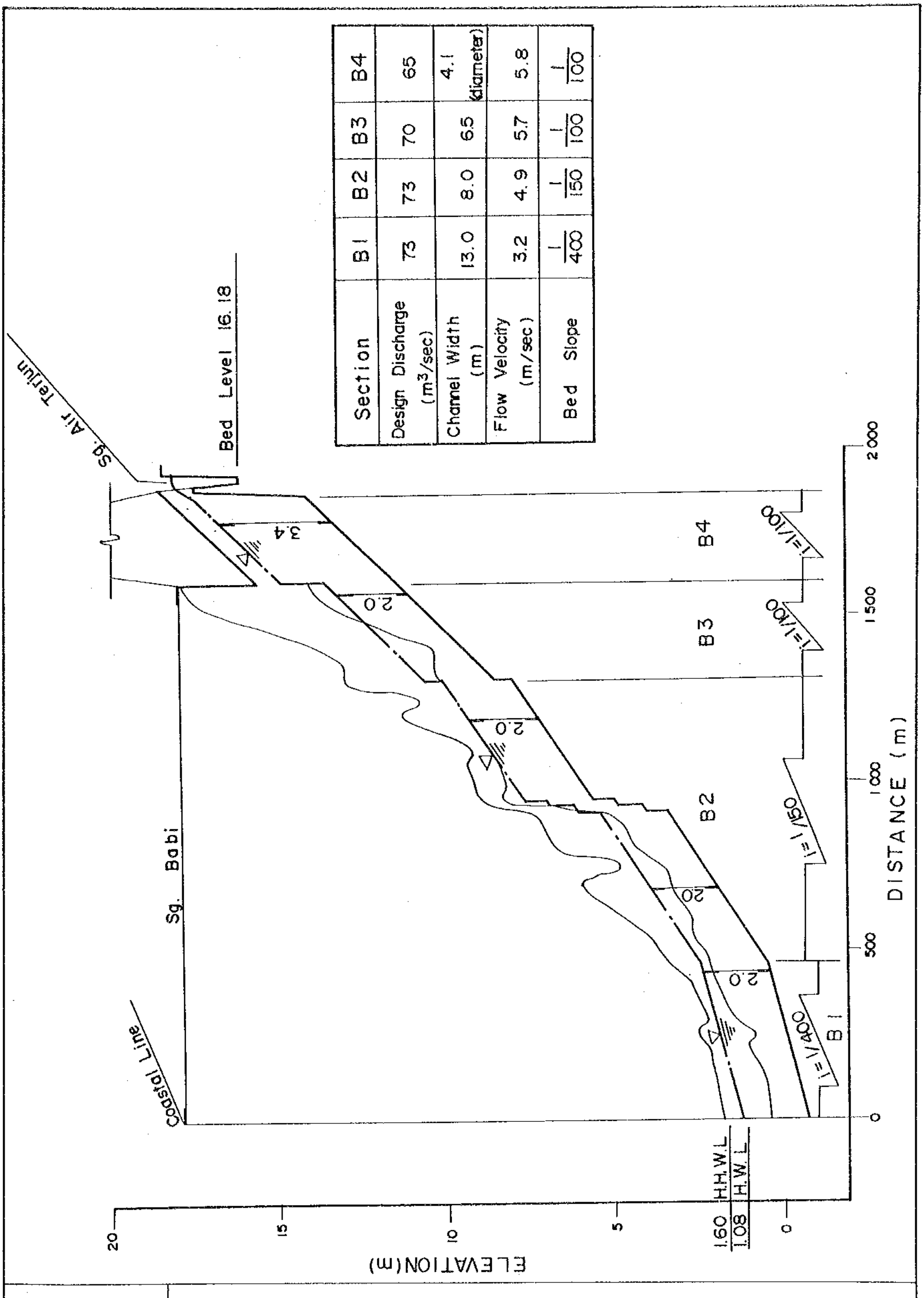


Section	A1	A2	A3
Design Discharge (m^3/sec)	73	73	65
Channel Width (m)	9.5	7.0	4.1 (diameter)
Flow Velocity (m/sec)	4.3	5.8	5.8
Bed Slope	1/200	1/100	1/100

FIG. H-2-1 LONGITUDINAL PROFILE OF DIVERSION CHANNEL ROUTE 1

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

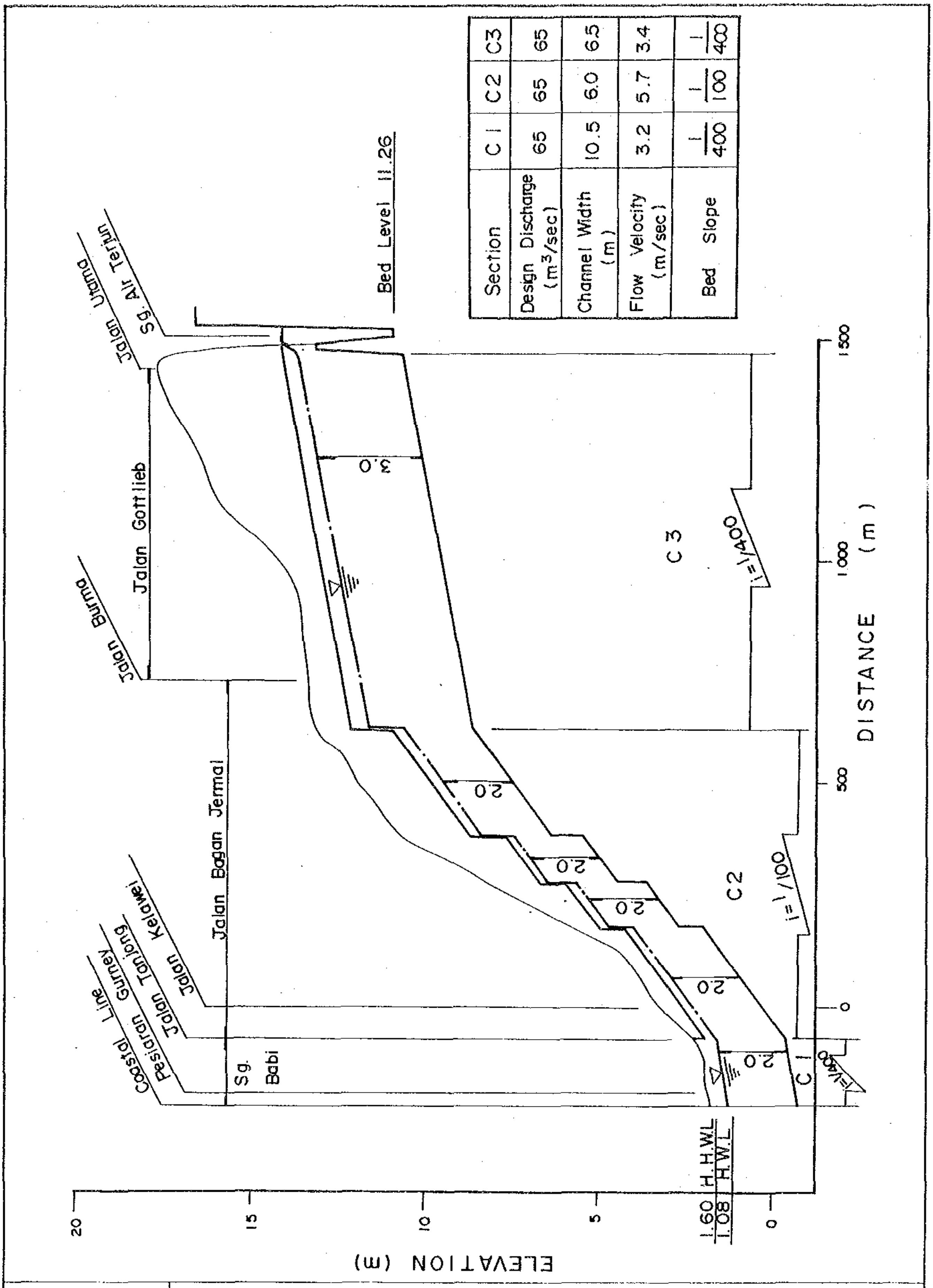
JICA



Section	B1	B2	B3	B4
Design Discharge (m^3/sec)	73	73	70	65
Channel Width (m)	13.0	8.0	6.5	4.1 (diameter)
Flow Velocity (m/sec)	3.2	4.9	5.7	5.8
Bed Slope	1/400	1/150	1/100	1/100

FIG. H-2-2 LONGITUDINAL PROFILE OF DIVERSION CHANNEL ROUTE 2

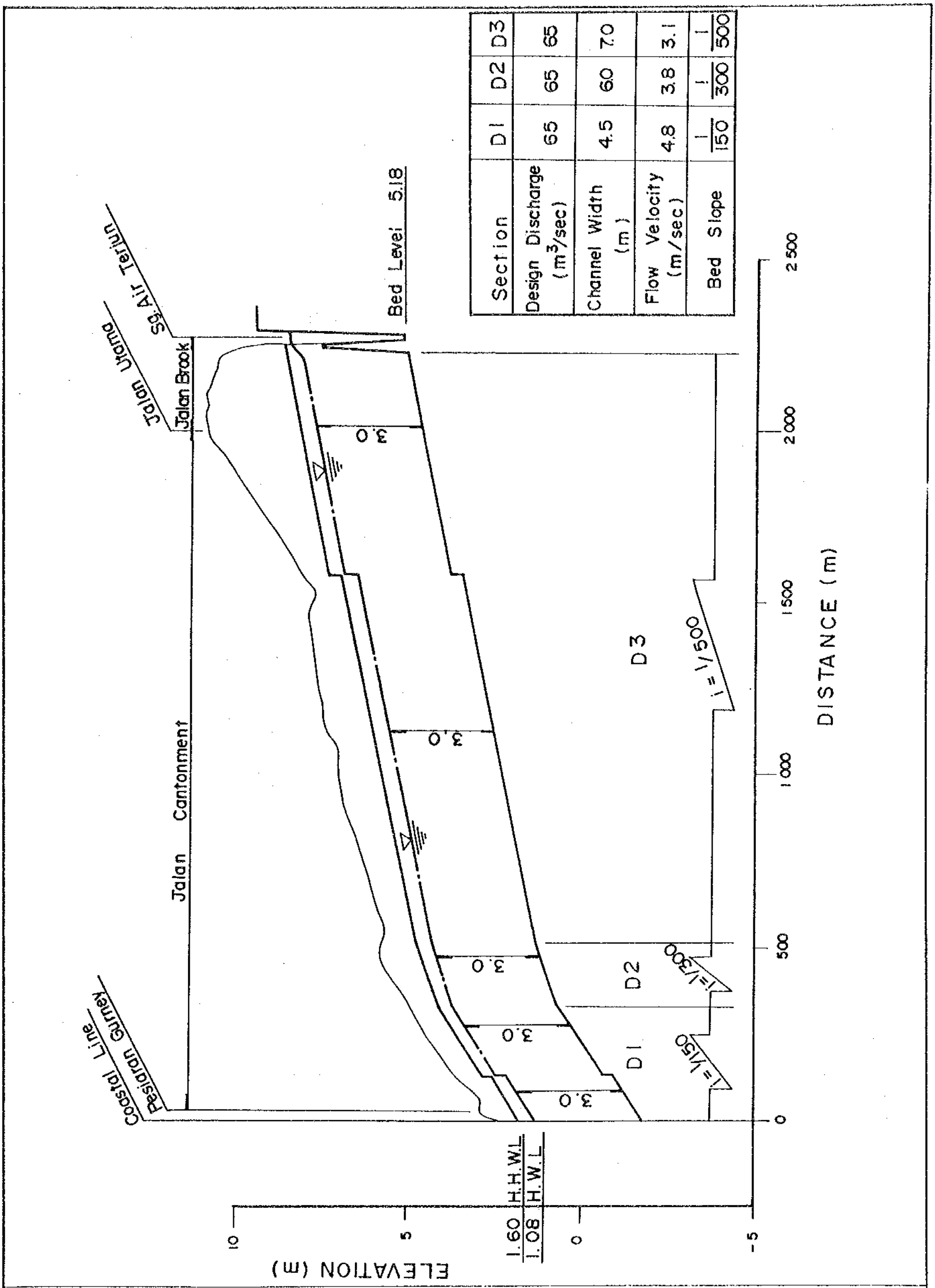
THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND



Section	C 1	C 2	C 3
Design Discharge (m^3/sec)	65	65	65
Channel Width (m)	10.5	6.0	6.5
Flow Velocity (m/sec)	3.2	5.7	3.4
Bed Slope	1/400	1/100	1/400

FIG. H-2-3 LONGITUDINAL PROFILE OF DIVERSION CHANNEL ROUTE 3

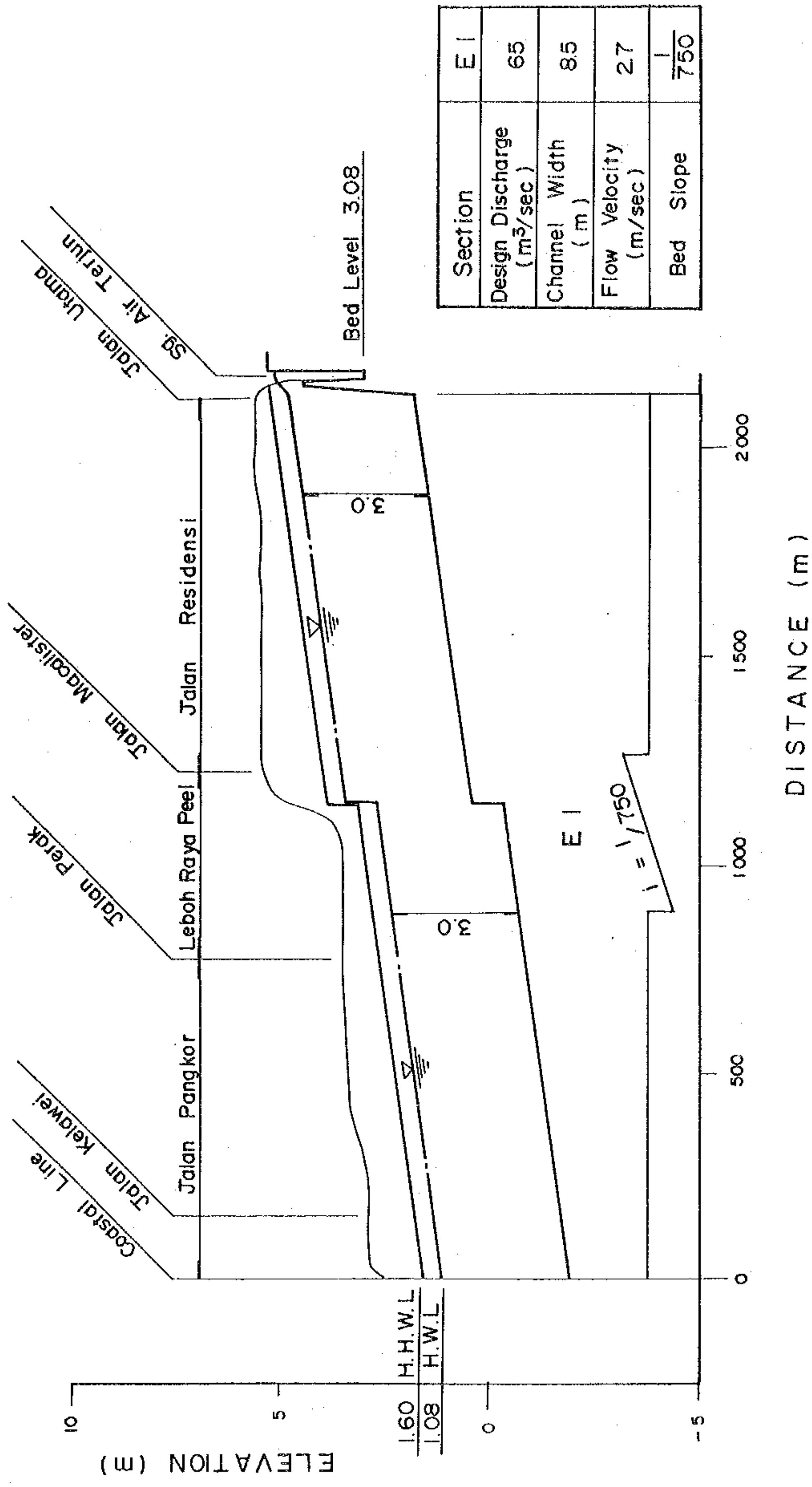
THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND



Section	D1	D2	D3
Design Discharge (m^3/sec)	65	65	65
Channel Width (m)	4.5	6.0	7.0
Flow Velocity (m/sec)	4.8	3.8	3.1
Bed Slope	1/150	1/300	1/500

FIG. H-2-4 LONGITUDINAL PROFILE OF DIVERSION CHANNEL ROUTE 4

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND



Section	E I
Design Discharge (m³/sec)	65
Channel Width (m)	8.5
Flow Velocity (m/sec)	2.7
Bed Slope	1/750

FIG. H-2-5 LONGITUDINAL PROFILE OF DIVERSION CHANNEL ROUTE 5

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

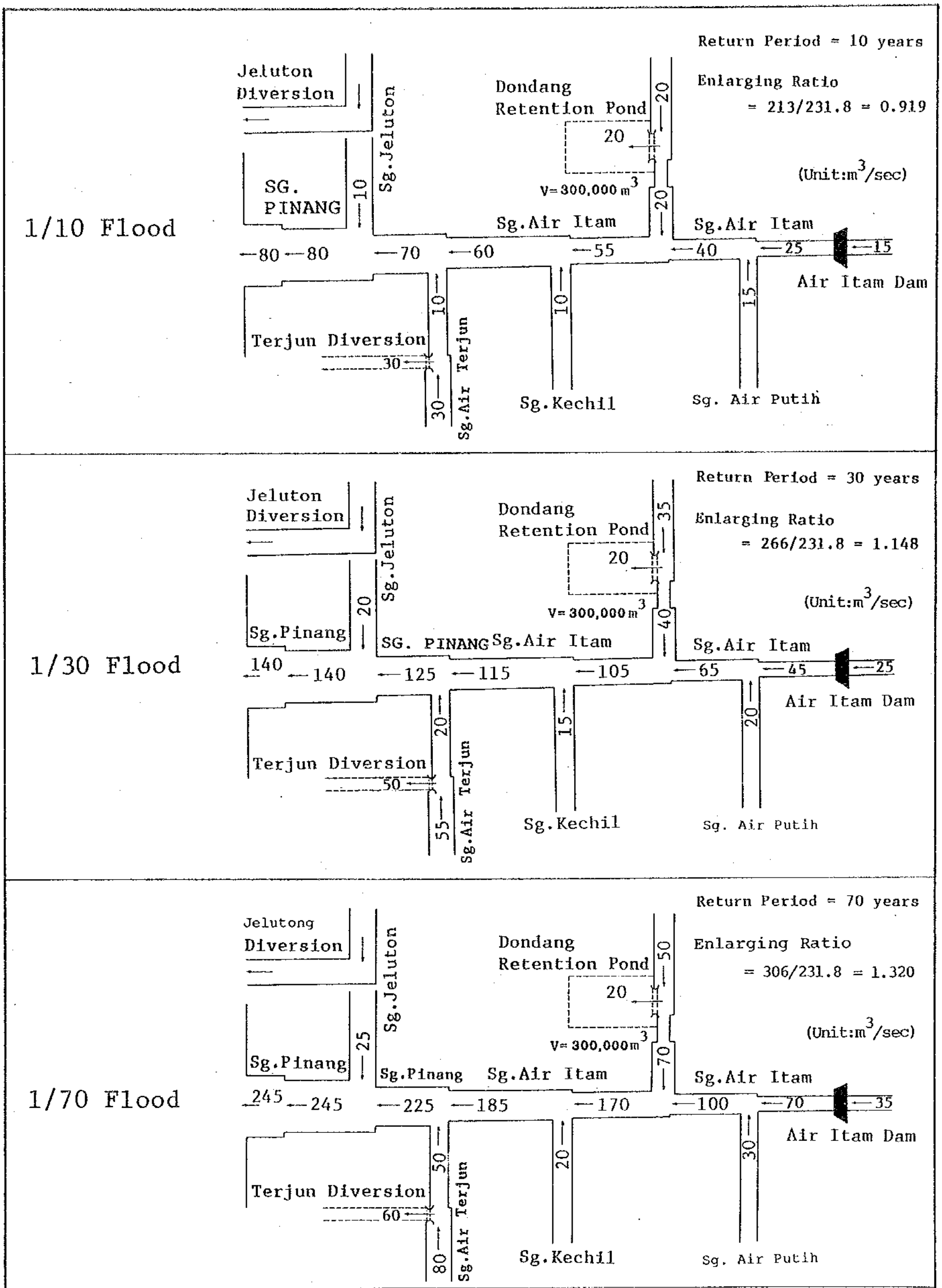


FIG. H-3 DISTRIBUTION OF PROBABLE FLOOD DISCHARGE

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

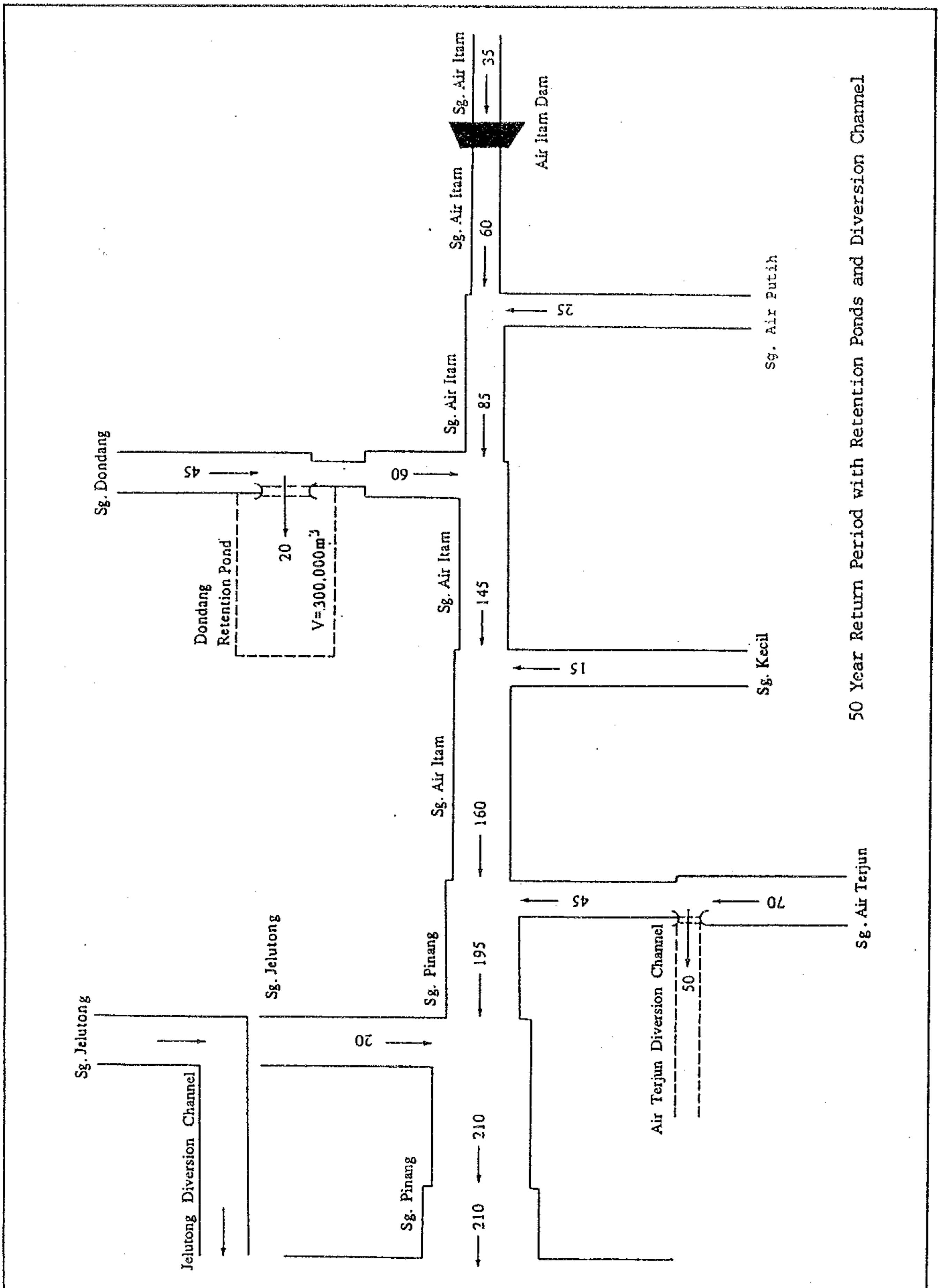
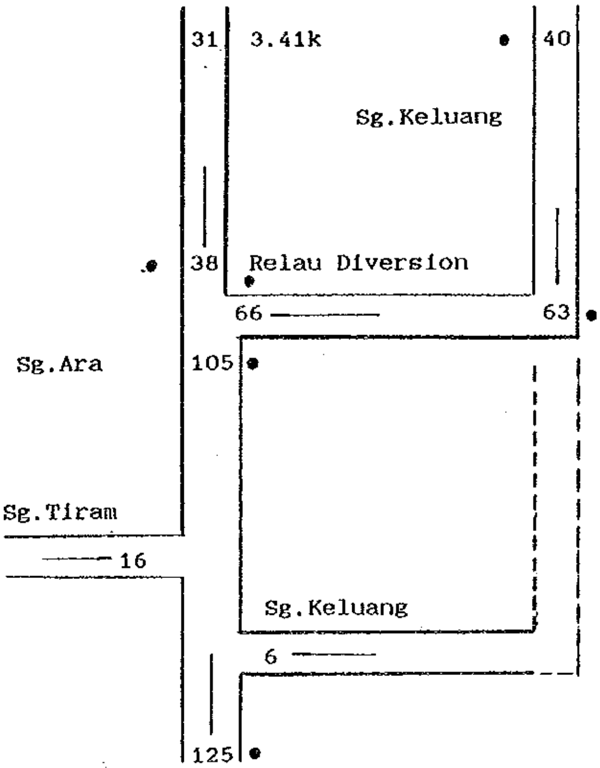


FIG. H-4	DESIGN FLOOD DISCHARGE DISTRIBUTION OF SG. PINANG SYSTEM

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

	CALCULATION POINT					Unit: (M^3/S)
TIME	1	2	3	4	5	6
1. 18	2.	5.	6.	4.	10.	15.
	3.	6.	7.	5.	12.	16.
	5.	8.	8.	6.	14.	19.
	8.	12.	10.	8.	17.	22.
	11.	16.	13.	10.	23.	26.
	16.	23.	17.	13.	30.	31.
1. 19	21.	31.	24.	17.	41.	39.
	24.	37.	31.	21.	53.	48.
	27.	43.	39.	25.	64.	60.
	30.	48.	46.	29.	75.	74.
	33.	53.	53.	32.	85.	88.
	37.	58.	59.	35.	94.	101.
1. 20	40.	63.	65.	38.	103.	112.
	36.	61.	66.	38.	105.	121.
	34.	57.	65.	37.	102.	125.
	32.	53.	62.	35.	97.	124.
	30.	50.	58.	34.	92.	120.
	28.	47.	55.	32.	87.	115.
1. 21	27.	45.	52.	30.	83.	109.
	24.	41.	49.	28.	77.	103.
	22.	38.	46.	26.	72.	97.
	20.	35.	42.	24.	66.	91.
	19.	32.	39.	22.	61.	85.
	17.	30.	36.	21.	57.	79.
1. 22	16.	27.	34.	19.	53.	74.
	18.	29.	33.	19.	52.	70.
	21.	32.	33.	20.	54.	68.
	23.	35.	36.	21.	57.	69.
	25.	39.	39.	23.	62.	71.
	28.	42.	42.	25.	67.	75.
1. 23	30.	46.	46.	26.	73.	81.
	30.	47.	49.	28.	77.	86.
	30.	48.	51.	28.	79.	91.
	30.	48.	52.	29.	81.	95.
	30.	48.	53.	29.	82.	98.
	31.	49.	53.	29.	82.	99.



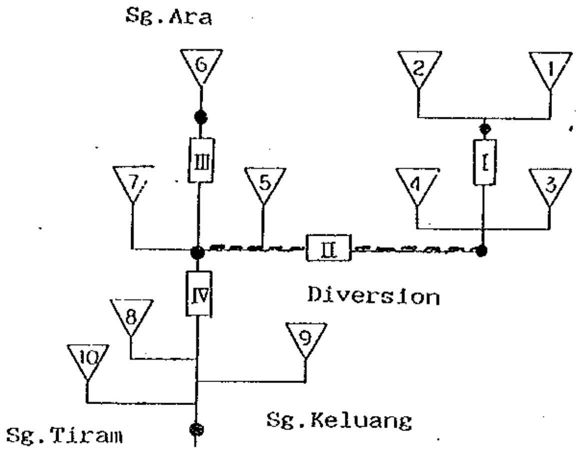


FIG. H-5	DESIGN FLOOD DISCHARGE DISTRIBUTION OF SG. KELUANG

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

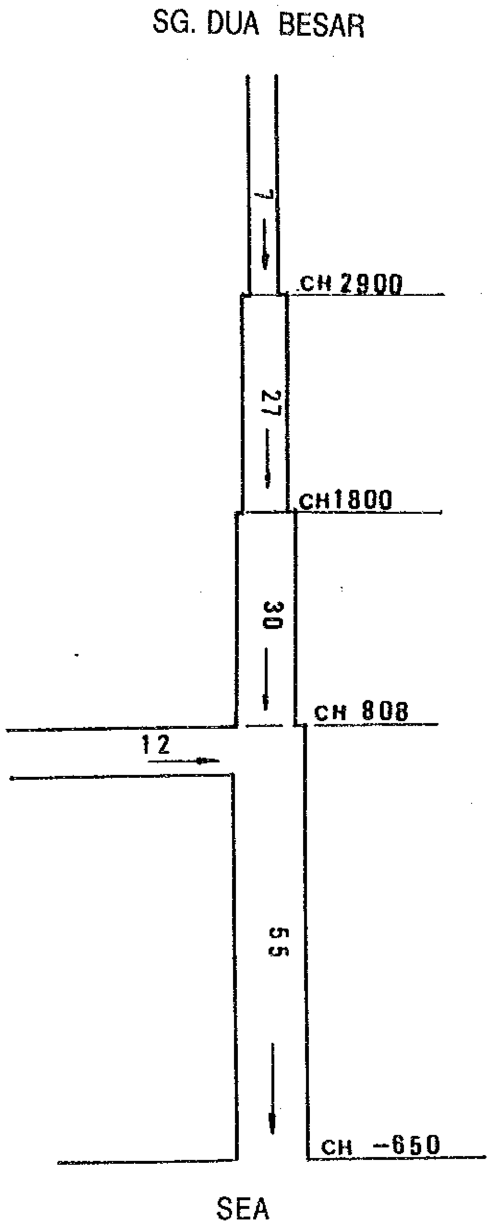


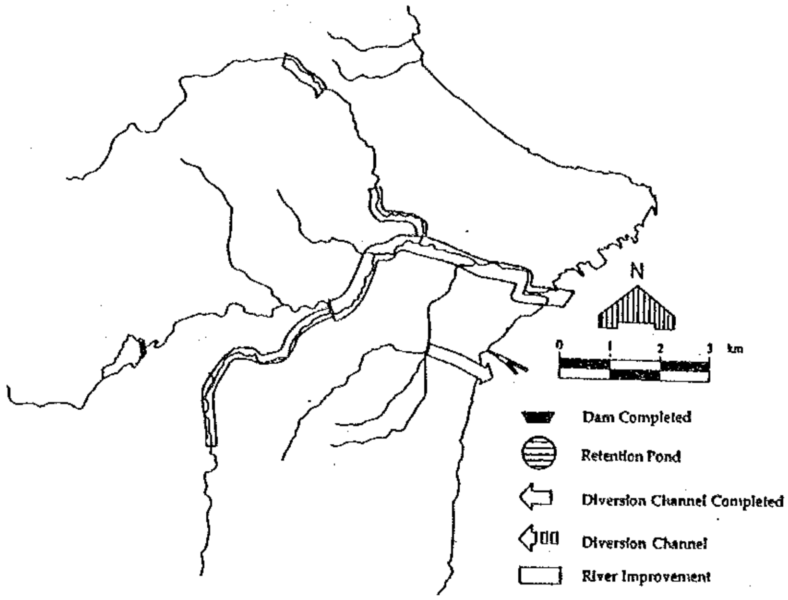
FIG. H-6 DESIGN FLOOD DISCHARGE DISTRIBUTION OF SG. DUA BESAR

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

JICA

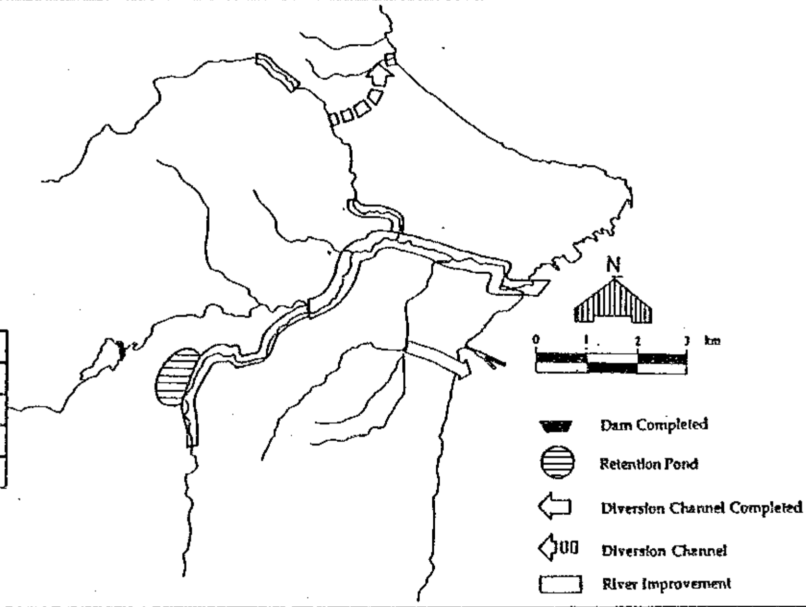
Alternative I

RIVER IMPROVEMENT	Qmax = 270 CMS
DIVERSION CHANNEL NO.3	-
DIVERSION CHANNEL NO.5	-
AIR ITAM DAM	-
RETENTION POND	-



Alternative II

RIVER IMPROVEMENT	Qmax = 210 CMS
DIVERSION CHANNEL NO.3	L=1.7 km, Q=50 CMS
DIVERSION CHANNEL NO.5	-
AIR ITAM DAM	-
RETENTION POND	V=300,000 CMS



Alternative III

RIVER IMPROVEMENT	Qmax = 200 CMS
DIVERSION CHANNEL NO.3	-
DIVERSION CHANNEL NO.5	L=2.18 km, Q=80 CMS
AIR ITAM DAM	-
RETENTION POND	-

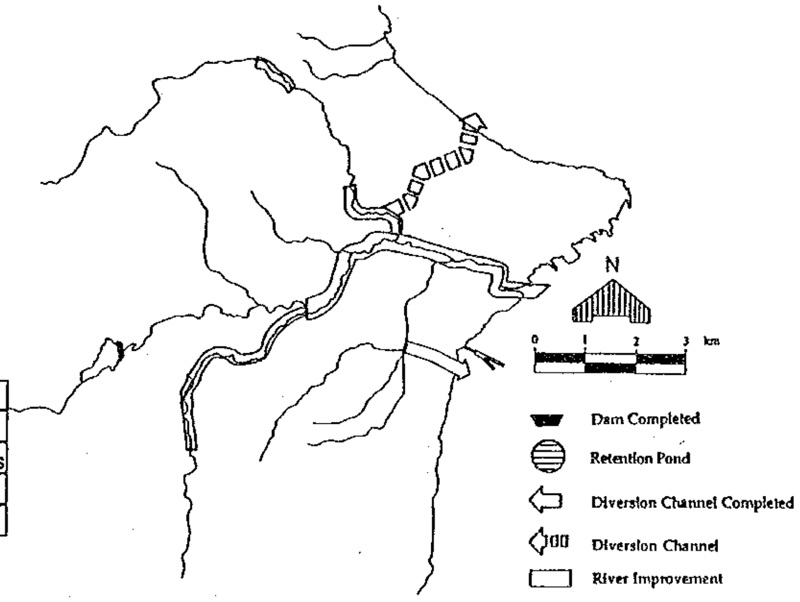
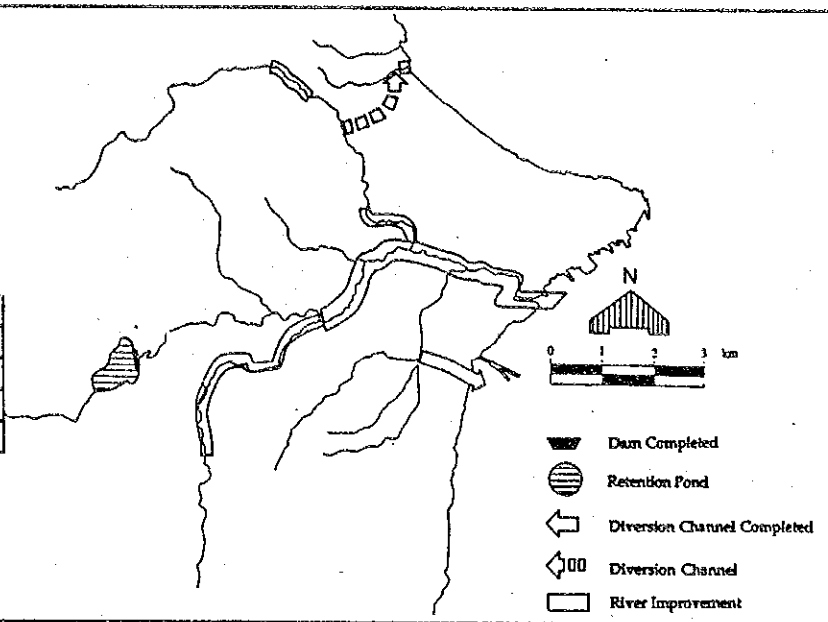


FIG. H-7 **ALTERNATIVE PROTECTIVE MEASURES FOR SG. PINANG SYSTEM AL-I, AL-II, AL-III**

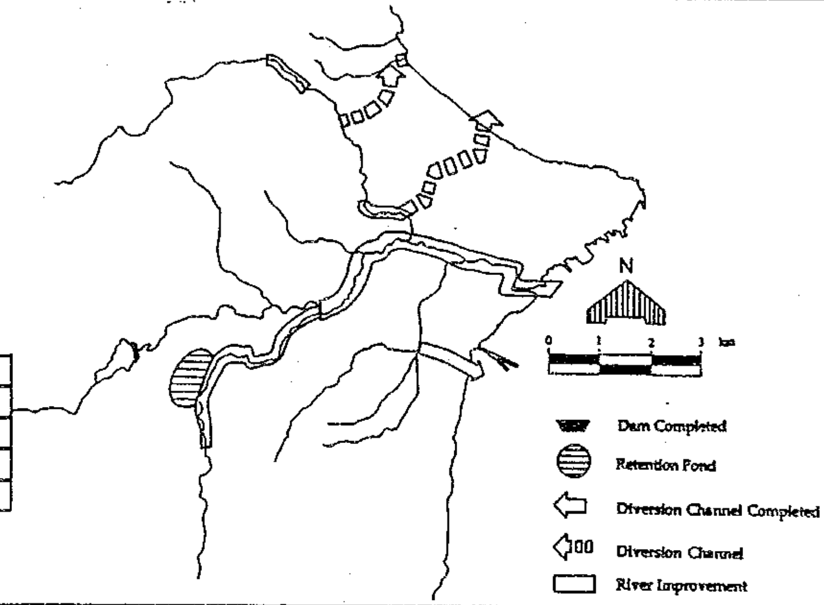
Alternative IV

RIVER IMPROVEMENT	Qmax = 200 CMS
DIVERSION CHANNEL NO.3	L=1.7 km, Q=50 CMS
DIVERSION CHANNEL NO.5	-
AIR ITAM DAM	V=600,000CMS
RETENTION POND	-



Alternative V

RIVER IMPROVEMENT	Qmax = 175 CMS
DIVERSION CHANNEL NO.3	Qmax = 50 CMS
DIVERSION CHANNEL NO.5	Qmax = 45 CMS
AIR ITAM DAM	-
RETENTION POND	V=300,000 CMS



Alternative VI

RIVER IMPROVEMENT	Qmax = 145 CMS
DIVERSION CHANNEL NO.3	Qmax = 50 CMS
DIVERSION CHANNEL NO.5	Qmax = 80 CMS
AIR ITAM DAM	-
RETENTION POND	V=300,000 CMS

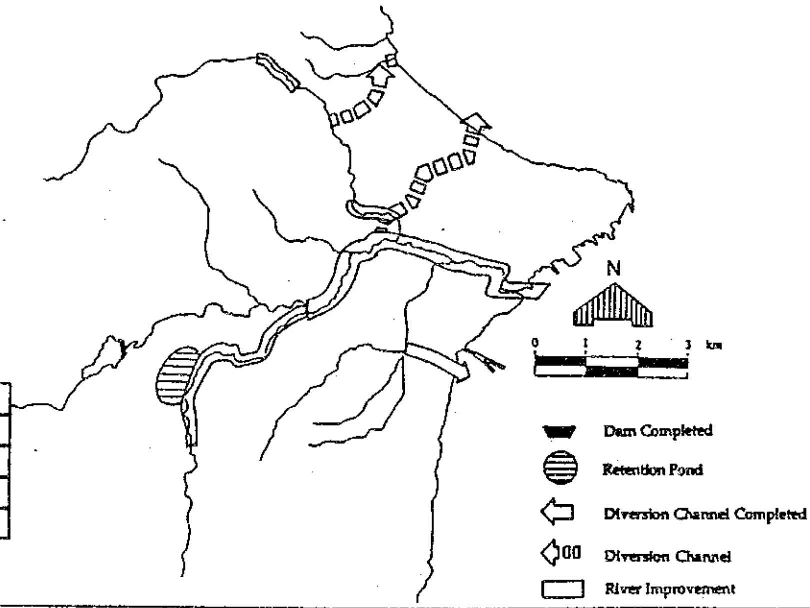


FIG. H-8 **ALTERNATIVE PROTECTIVE MEASURES FOR SG. PINANG SYSTEM AL-IV, AL-V, AL-VI**

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

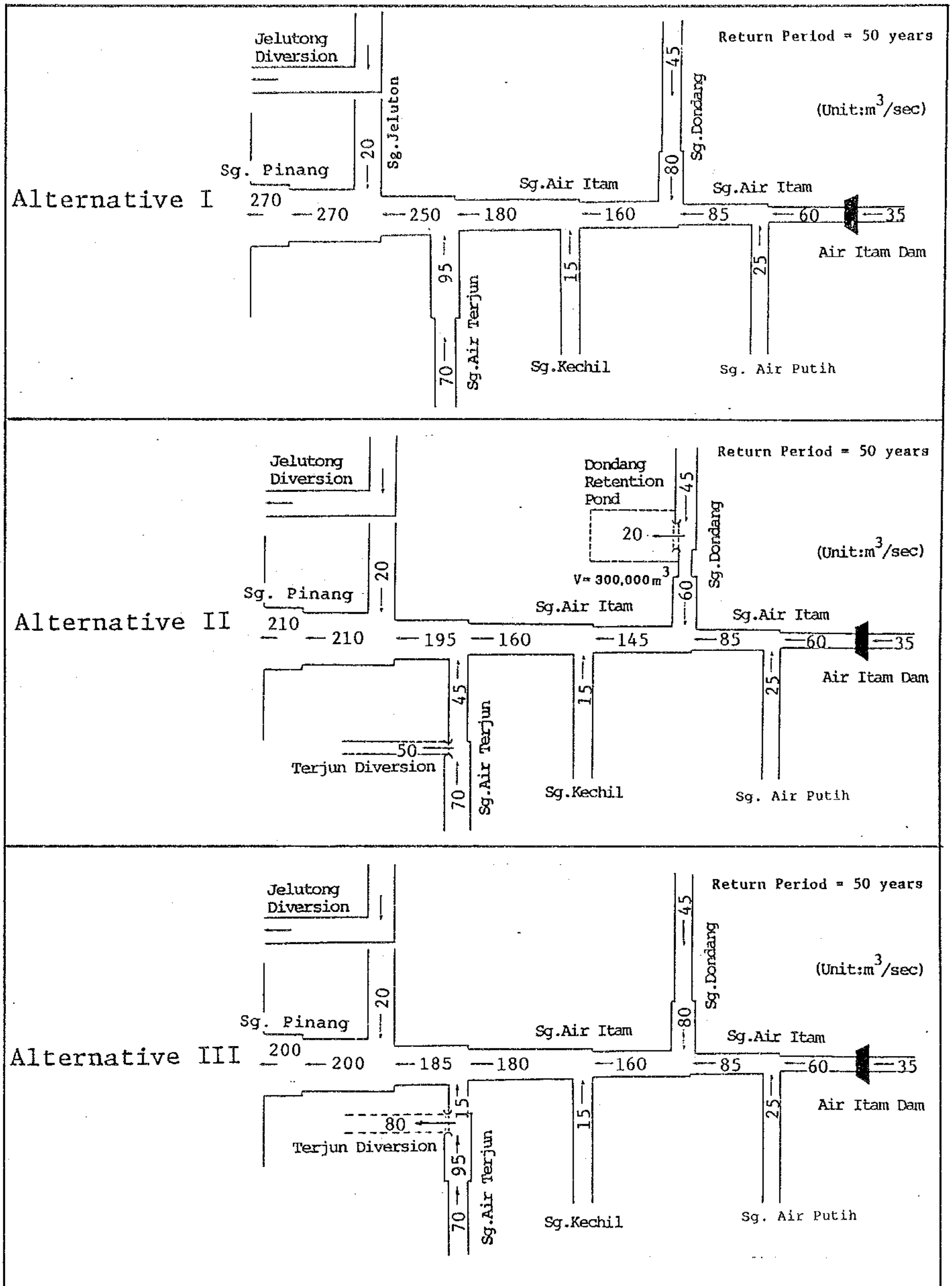


FIG. H-9 **FLOOD DISCHARGE DISTRIBUTION FOR ALTERNATIVES AL-I, AL-II, AL-III**

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

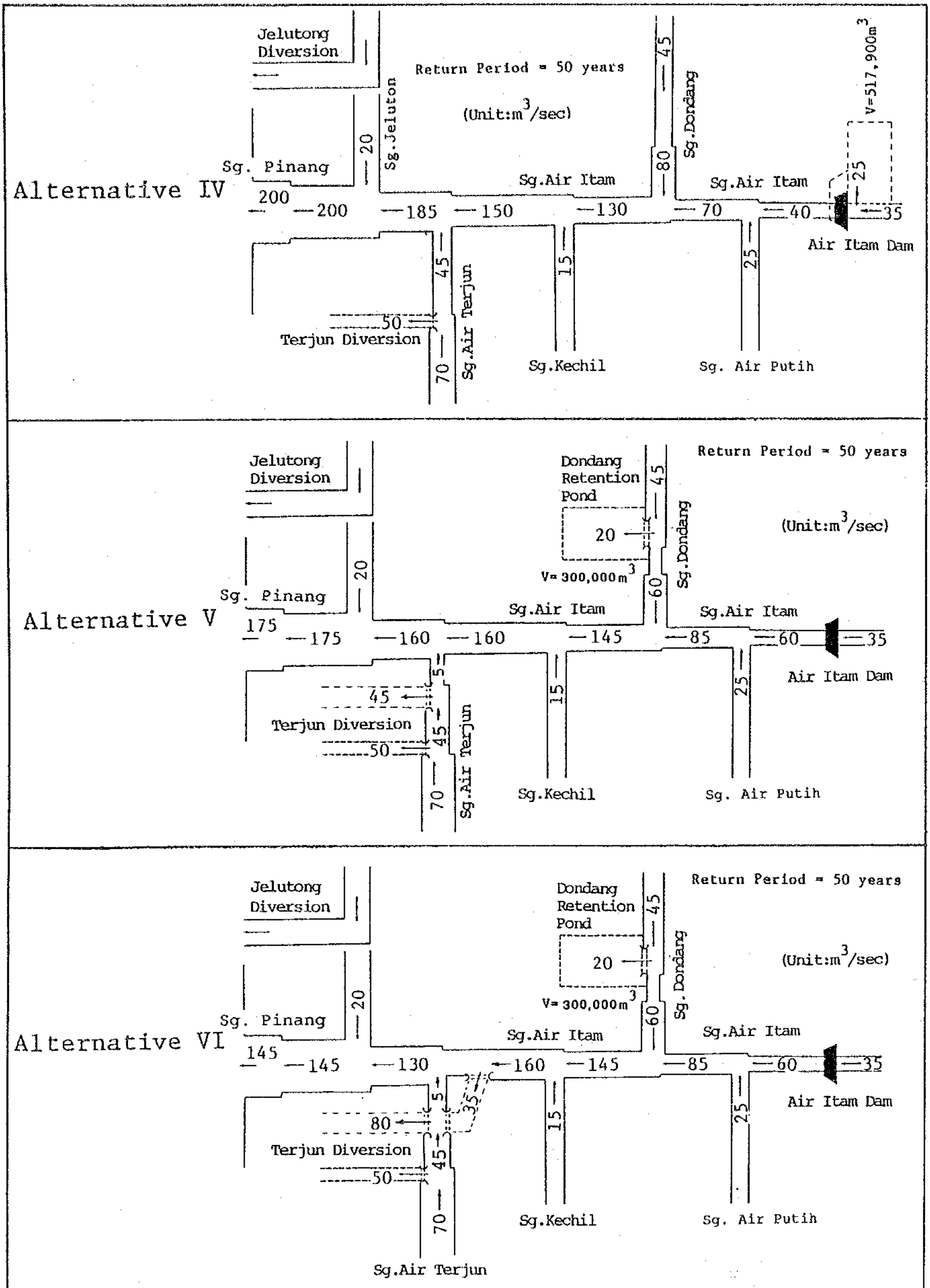
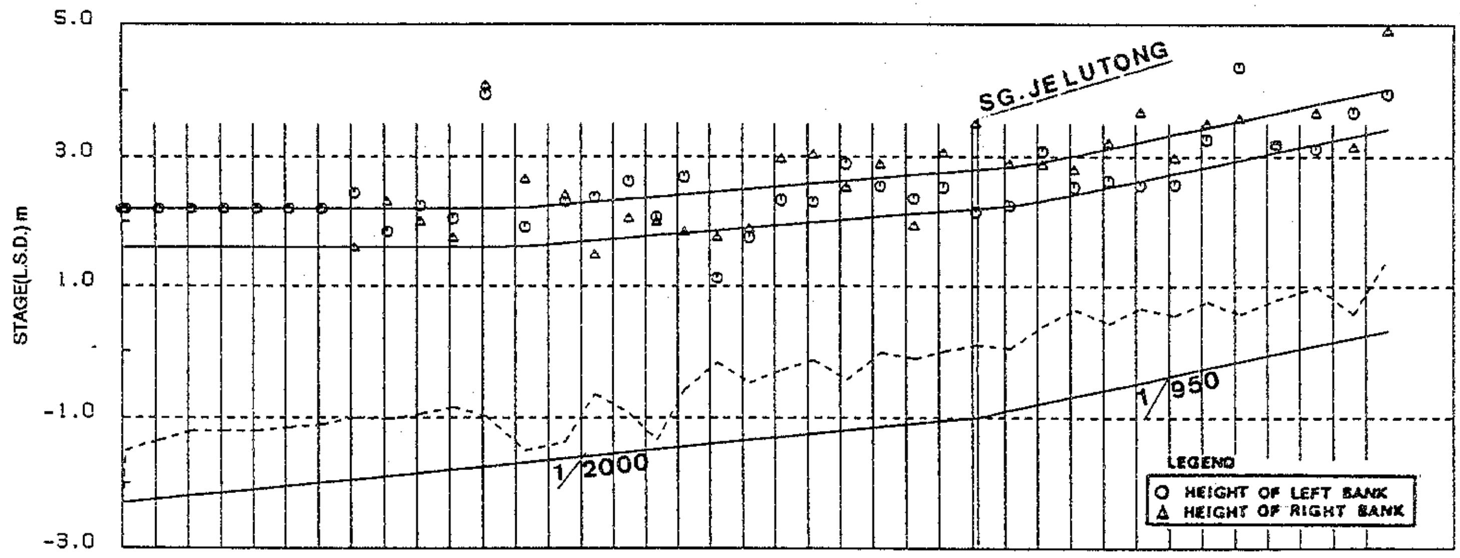


FIG H-10	FLOOD DISCHARGE DISTRIBUTION FOR ALTERNATIVES AL-IV, AL-V, AL-VI

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

JICA



CHAINAGE	DISTANCE	PROPOSED BANK LEVEL	DESIGN H.W.L.	PROPOSED BED LEVEL
-710.0	0.0	2.200	1.600	-2.30
-700.0	10.0	2.200	1.600	-2.285
-600.000	100.000	2.200	1.600	-2.245
-500.000	100.000	2.200	1.600	-2.195
-400.000	100.000	2.200	1.600	-2.145
-300.000	100.000	2.200	1.600	-2.095
-200.000	100.000	2.200	1.600	-2.045
-100.000	100.000	2.200	1.600	-1.995
0.000	100.000	2.200	1.600	-1.945
100.000	100.000	2.200	1.600	-1.895
200.000	100.000	2.200	1.600	-1.845
300.000	100.000	2.200	1.600	-1.795
400.000	100.000	2.200	1.600	-1.745
500.000	119.000	2.207	1.607	-1.686
600.000	122.000	2.259	1.659	-1.625
700.000	92.000	2.299	1.699	-1.579
800.000	105.000	2.344	1.744	-1.526
900.000	87.000	2.382	1.782	-1.483
1000.000	86.000	2.419	1.819	-1.440
1100.000	101.000	2.462	1.862	-1.389
1200.000	99.000	2.504	1.904	-1.340
1300.000	99.000	2.547	1.947	-1.290
1400.000	98.000	2.589	1.989	-1.241
1500.000	100.000	2.632	2.032	-1.191
1600.000	105.000	2.678	2.078	-1.139
1700.000	102.000	2.721	2.121	-1.088
1800.000	89.000	2.759	2.159	-1.043
1900.000	98.000	2.801	2.201	-0.994
2000.000	102.000	2.845	2.245	-0.887
2100.000	102.000	2.921	2.321	-0.779
2200.000	98.000	3.024	2.424	-0.676
2300.000	102.000	3.131	2.531	-0.569
2400.000	97.000	3.233	2.633	-0.467
2500.000	105.000	3.344	2.744	-0.356
2600.000	98.000	3.447	2.847	-0.253
2700.000	99.000	3.551	2.951	-0.149
2800.000	113.000	3.670	3.070	-0.030
2900.000	121.000	3.798	3.198	0.098
3000.000	114.000	3.918	3.318	0.218
3100.000	102.000	4.025	3.425	0.325

Q = 210 m³/s (chainage -710.0 to 1900.000)

Q = 195 m³/s (chainage 1900.000 to 3100.000)

FIG. H-11-1 LONGITUDINAL PROFILE OF SG. PINANG

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

JICA

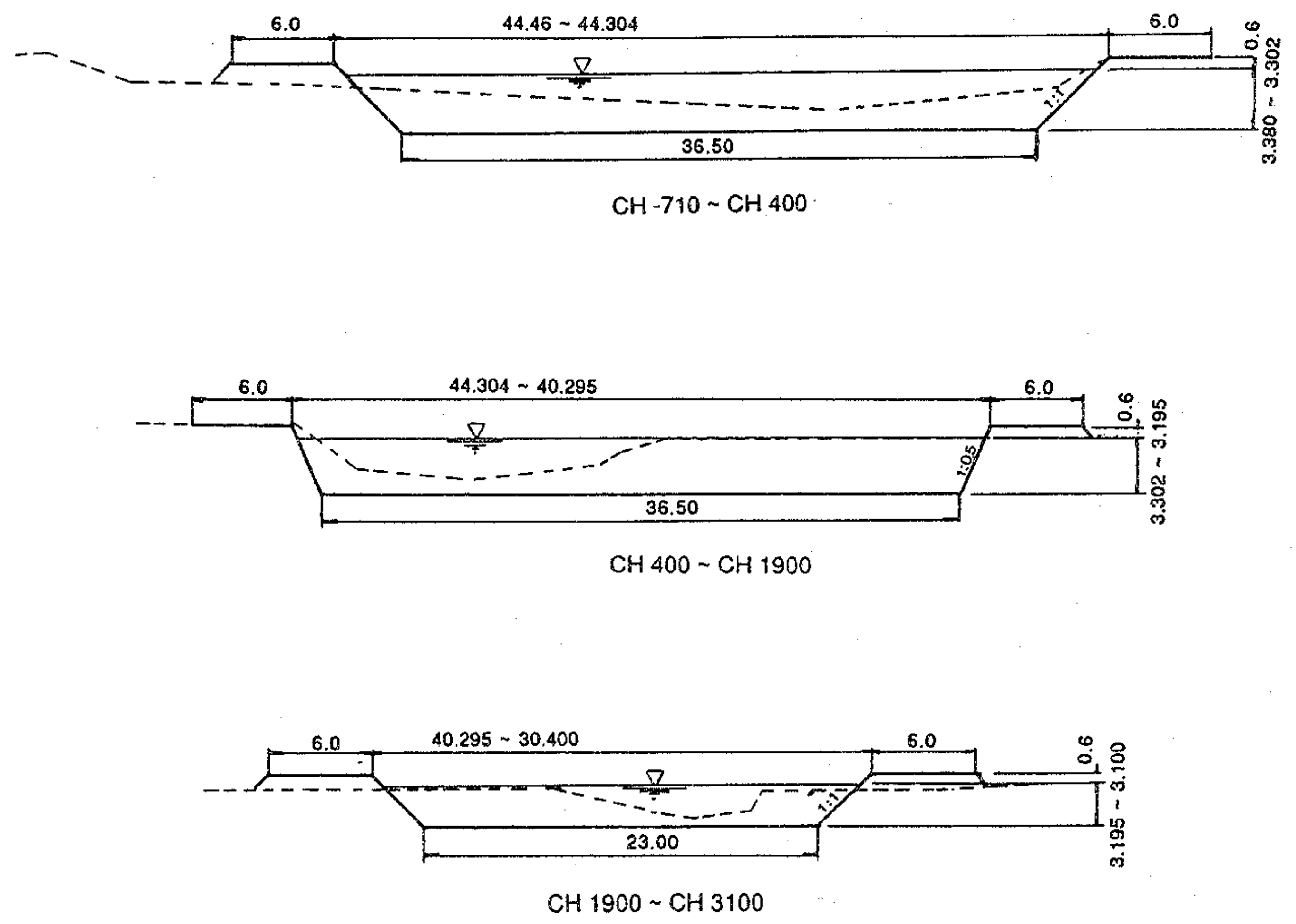
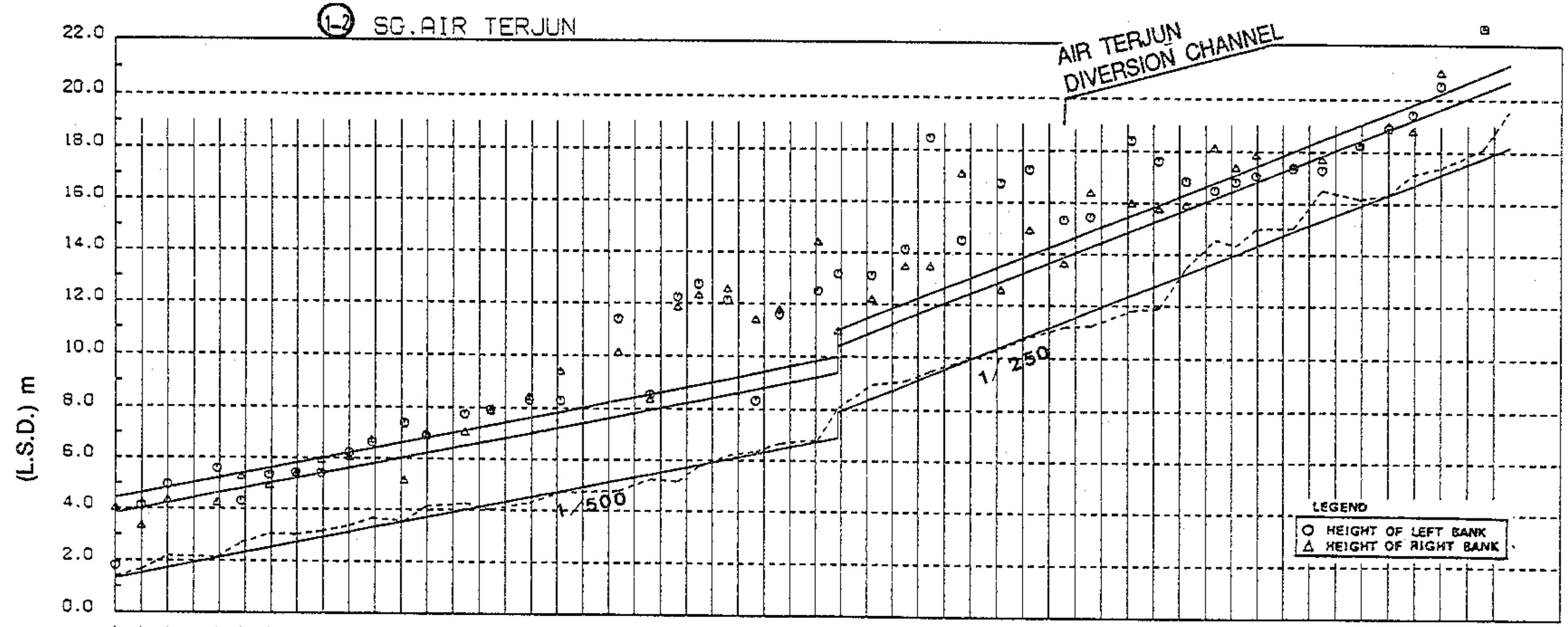


FIG. H-11-2	PROPOSED CROSS SECTIONS OF SG. PINANG
THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND	



CHAINAGE	DISTANCE	PROPOSED BANK LEVEL	DESIGN H.W.L.	PROPOSED BED LEVEL
0.000	0.000	4.025 4.425	3.425 3.825	0.325 1.325
103.000	99.000	4.623	4.023	1.523
195.000	100.000	4.823	4.223	1.723
291.000	191.000	5.205	4.605	2.105
400.000	93.000	5.391	4.791	2.291
500.000	108.000	5.607	5.007	2.507
600.000	103.000	5.813	5.213	2.713
700.000	98.000	6.009	5.409	2.909
814.000	108.000	6.225	5.625	3.125
902.000	86.000	6.397	5.797	3.297
1005.000	125.000	6.647	6.047	3.547
1060.000	84.000	6.815	6.215	3.715
1200.000	149.000	7.113	6.513	4.013
1299.000	99.000	7.311	6.711	4.211
1396.000	147.000	7.605	7.005	4.505
1513.000	123.000	7.851	7.251	4.751
1608.000	224.000	8.299	7.699	5.199
1700.000	122.000	8.543	7.943	5.443
1809.000	105.000	8.753	8.153	5.653
1915.000	82.000	8.917	8.317	5.817
2009.000	112.000	9.141	8.541	6.041
2090.000	109.000	9.359	8.759	6.259
2198.000	92.000	9.543	8.943	6.443
2306.000	150.000	9.843	9.243	6.743
2400.000	78.000	8.889 10.888	8.308 10.388	6.889 7.888
2544.000	132.000	11.527	10.927	8.427
2608.000	130.000	12.047	11.447	8.947
2700.000	97.000	12.435	11.835	9.335
2800.000	119.000	12.911	12.311	9.811
2911.000	150.000	13.511	12.911	10.411
3000.000	111.000	13.955	13.355	10.855
3093.000	130.000	14.475	13.875	11.375
3200.000	102.000	14.883	14.283	11.783
3300.000	158.000	15.515	14.915	12.416
3387.000	104.000	15.931	15.331	12.831
3500.000	104.000	16.347	15.747	13.247
3599.000	111.000	16.791	16.191	13.691
3699.000	81.000	17.115	16.515	14.015
3805.000	78.000	17.431	16.831	14.331
3900.000	143.000	18.003	17.403	14.903
4013.000	111.000	18.447	17.847	15.347
4101.000	143.000	19.019	18.419	15.919
4199.000	109.000	19.455	18.855	16.355
4300.000	90.000	19.815	19.215	16.715
4400.000	106.000	20.239	19.639	17.139
4492.000	162.000	20.887	20.287	17.787
4644.000	97.000	21.275	20.675	18.175

Q = 45 m³/s (CHAINAGE 0.000 – 3093.000)

Q = 70 m³/s (CHAINAGE 3093.000 – 4644.000)

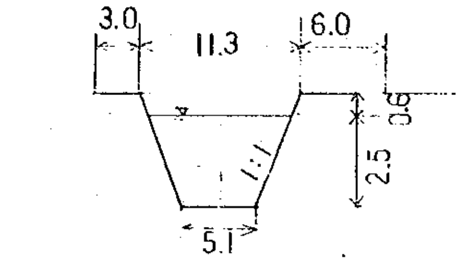
FIG. H-12-1 LONGITUDINAL PROFILE OF SG. AIR TERJUN

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

JICA

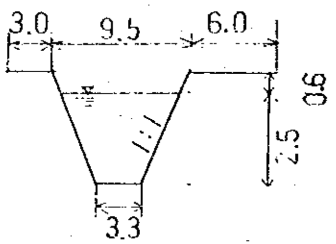
(1-2) SG. AIR TERJUN

CH 0.0 – CH 2400



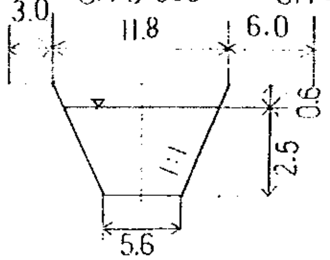
N	I/I	H	A	B	R	RR	V	Q	BB	QK
.025	500.000	2.500	19.000	10.100	1.561	1.346	2.407	45.738	5.100	45.000

CH 2400 — CH 3 093



N	I/I	H	A	B	R	RR	V	Q	BB	QK
.025	250.000	2.500	14.500	8.300	1.398	1.250	3.163	45.866	3.300	45.000

CH 3 093 — CH 4 644

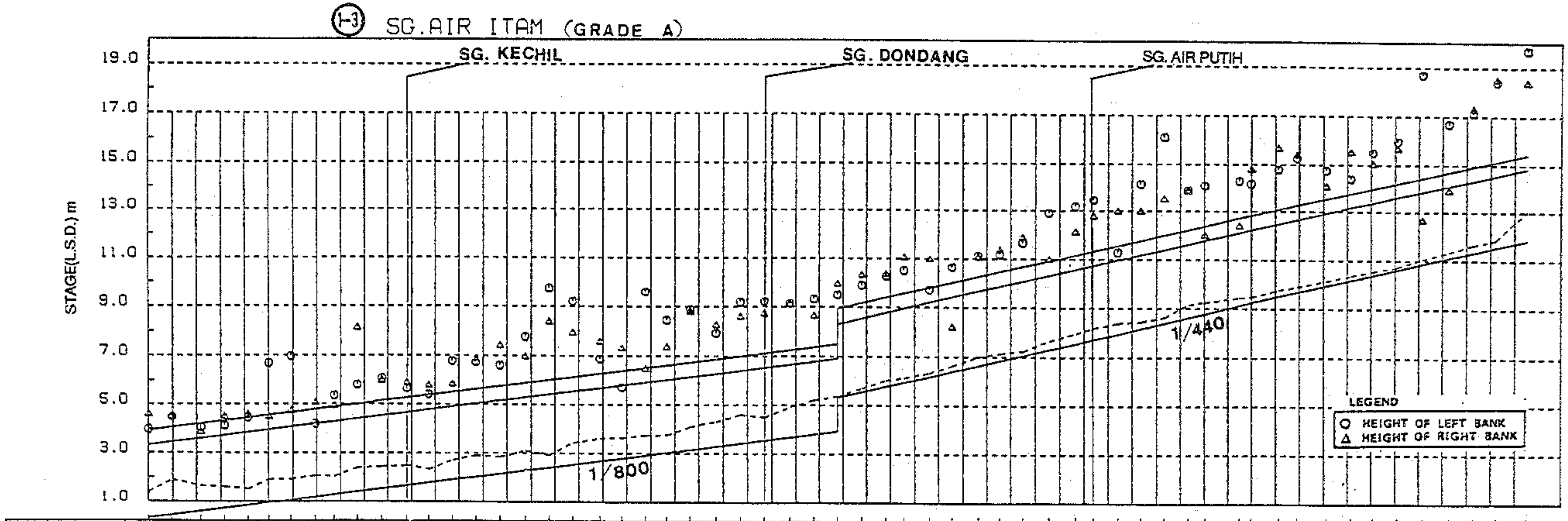


SCALE 1/200 (vertical), 1/500 (horizontal)

N	I/I	H	A	B	R	RR	V	Q	BB	QK
.025	250.000	2.500	20.250	10.600	1.598	1.367	3.458	70.026	5.600	70.000

FIG. H-12-2 PROPOSED CROSS SECTIONS OF SG. AIR TERJUN

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND



CHAINAGE	DISTANCE	PROPOSED BANK LEVEL	DESIGN H.W.L.	PROPOSED BED LEVEL
0.000	0.000	3.925	3.325	0.325
100.000	97.000	4.046	3.446	0.446
200.000	120.500	4.197	3.597	0.597
300.000	99.500	4.321	3.721	0.721
400.000	97.000	4.449	3.842	0.842
500.000	87.000	4.551	3.951	0.951
600.000	91.000	4.665	4.065	1.065
700.000	102.000	4.793	4.193	1.182
800.000	80.000	4.892	4.293	1.293
900.000	96.000	5.012	4.412	1.413
1000.000	105.000	5.144	4.544	1.544
1100.000	105.000	5.275	4.675	1.675
1200.000	92.000	5.390	4.790	1.790
1300.000	99.000	5.514	4.914	1.914
1400.000	97.000	5.635	5.035	2.035
1500.000	102.000	5.763	5.163	2.163
1600.000	106.000	5.895	5.295	2.295
1700.000	98.000	6.017	5.418	2.418
1800.000	100.000	6.142	5.543	2.543
1900.000	113.000	6.284	5.684	2.684
2000.000	91.000	6.398	5.797	2.797
2100.000	100.000	6.623	5.822	2.822
2200.000	88.000	6.632	6.032	3.032
2300.000	97.000	6.754	6.154	3.154
2400.000	107.000	6.887	6.287	3.287
2500.000	100.000	7.012	6.412	3.412
2600.000	100.000	7.137	6.637	3.637
2700.000	105.000	7.269	6.669	3.669
2800.000	101.000	7.395	6.795	3.795
2900.000	100.000	7.520 / 8.920	6.820 / 8.320	3.820 / 5.320
3000.000	102.000	9.152	8.552	5.552
3100.000	103.000	9.386	8.786	5.786
3200.000	75.000	9.556	8.956	5.956
3300.000	105.000	9.795	9.195	6.195
3400.000	84.000	10.009	9.409	6.409
3500.000	109.000	10.256	9.656	6.656
3600.000	89.000	10.458	9.859	6.859
3700.000	95.000	10.675	10.075	7.075
3800.000	107.000	10.918	10.318	7.318
3900.000	109.000	11.165	10.665	7.665
4000.000	75.000	11.336	10.736	7.736
4100.000	101.000	11.565	10.965	7.965
4200.000	96.000	11.784	11.184	8.184
4300.000	97.000	12.004	11.404	8.404
4400.000	99.000	12.229	11.629	8.629
4500.000	70.000	12.388	11.788	8.788
4650.000	146.000	12.720	12.120	9.120
4700.000	50.000	12.834	12.234	9.234
4800.000	116.000	13.095	12.495	9.495
4900.000	77.000	13.270	12.670	9.670
5000.000	121.000	13.545	12.945	9.945
5100.000	104.000	13.781	13.181	10.181
5200.000	91.000	13.988	13.388	10.388
5300.000	104.000	14.226	13.626	10.626
5400.000	104.000	14.461	13.861	10.861
5500.000	112.000	14.715	14.115	11.115
5600.000	99.000	14.940	14.340	11.340
5700.000	98.000	15.163	14.563	11.563
5829.000	126.000	16.450	14.850	11.850

Q=160 m³/s (0.000 – 1100.000); Q=145 m³/s (1100.000 – 2600.000); Q= 85 m³/s (2600.000 – 4000.000); Q=60 m³/s (4000.000 – 5829.000)

FIG. H-13-1 LONGITUDINAL PROFILE OF SG. AIR ITAM

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

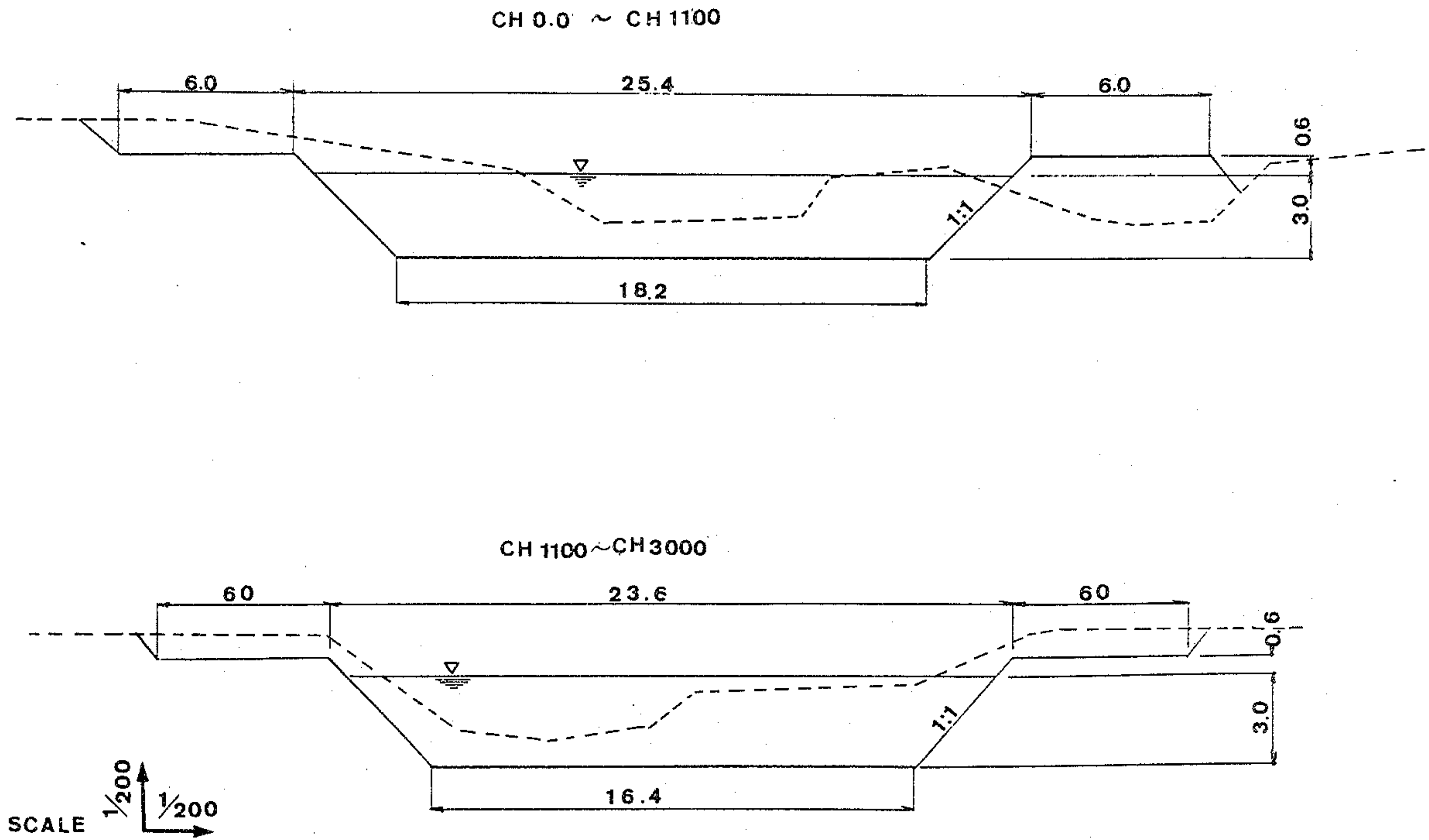
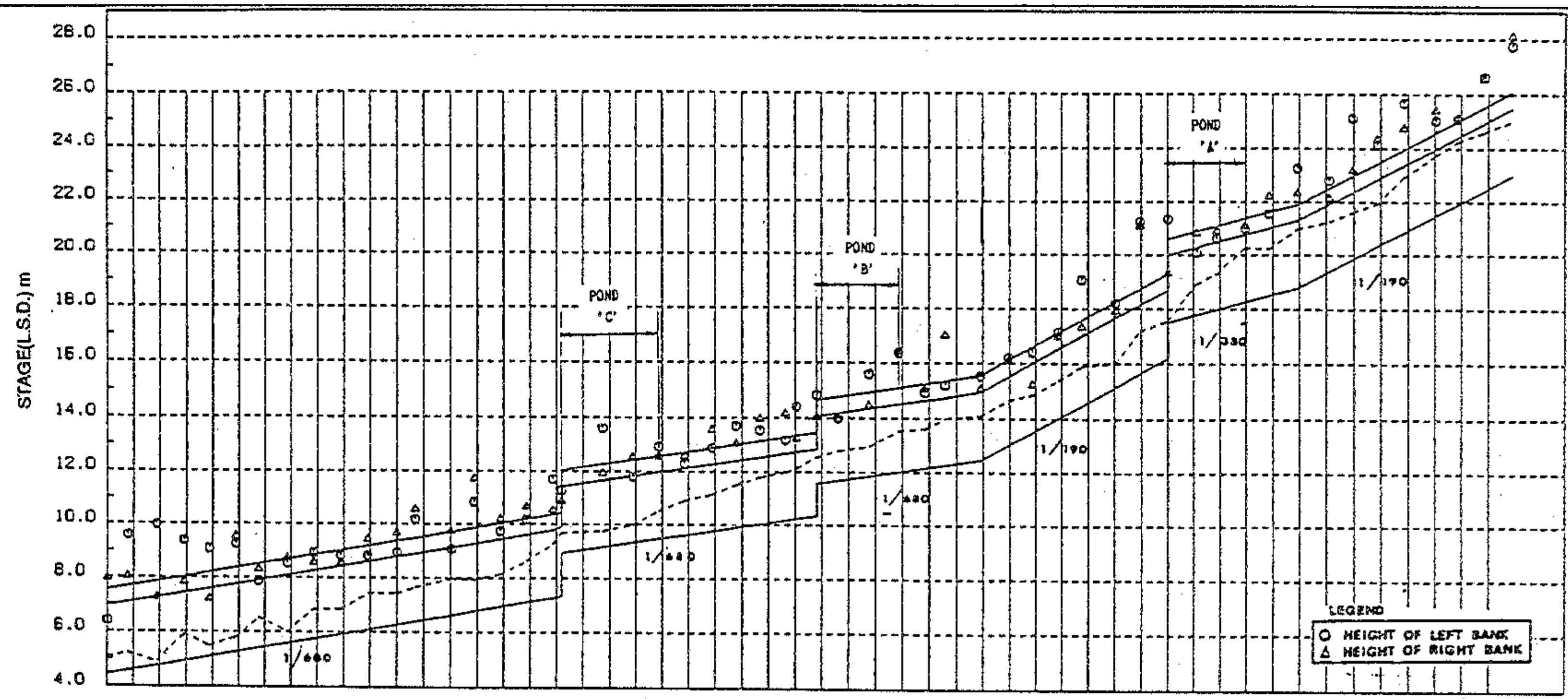


Fig. H-13-2	PROPOSED CROSS SECTIONS OF SG. AIR ITAM

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND



CHAINAGE	PROPOSED BED LEVEL	DESIGN H.W.L.	PROPOSED BANK LEVEL	DISTANCE
0.014	4.442	6.942	7.542	13.000
0.092	4.572	7.072	7.672	78.000
0.203	4.757	7.257	7.857	111.000
0.335	4.928	7.428	8.028	103.000
0.435	5.087	7.587	8.187	95.000
0.527	5.253	7.753	8.353	100.000
0.620	5.402	7.902	8.502	89.000
0.757	5.585	8.085	8.685	110.000
0.852	5.752	8.252	8.852	100.000
1.059	5.922	8.422	9.022	102.000
1.160	6.093	8.593	9.193	103.000
1.266	6.277	8.777	9.377	110.000
1.413	6.390	8.890	9.490	68.000
1.547	6.612	9.112	9.712	133.000
1.698	6.775	9.275	9.657	85.000
1.731	6.940	9.440	10.040	99.000
1.827	7.107	9.607	10.207	100.000
1.932 / 1.967	7.272 / 7.328 / 8.828	9.772 / 9.882 / 11.428	10.372 / 10.428 / 12.028	93.000 / 34.000
2.159	9.157	11.657	12.257	155.000
2.233	9.323	11.823	12.423	113.000
2.302	9.470	11.970	12.570	100.000
2.400	9.613	12.113	12.713	97.000
2.649	9.764	12.264	12.864	103.000
2.636	9.897	12.397	12.997	90.000
2.736	10.029	12.523	13.129	90.000
2.825 / 2.917	10.172 / 10.233	12.672 / 12.733	13.272 / 13.333	97.000 / 42.000
3.033	10.343 / 11.883	12.843 / 14.063	13.443 / 14.663	78.000
3.173	11.681	14.181	14.781	80.000
3.289	11.850	14.350	14.950	115.000
3.415	12.013	14.513	15.113	111.000
3.509	12.153	14.653	15.253	95.000
3.595	12.263	14.763	15.363	76.000
3.732	12.459	14.959	15.559	133.000
3.841	13.022	15.522	16.122	107.000
3.963	13.496	15.996	16.596	90.000
4.013	14.022	16.522	17.122	100.000
4.215	14.485	16.985	17.585	89.000
4.356	15.164	17.664	18.264	129.000
4.449	15.653	18.153	18.753	93.000
4.559	16.208 / 17.881	18.708 / 20.881	19.308 / 20.881	108.000
4.660	17.768	20.288	20.888	109.000
4.736	17.990	20.490	21.090	77.000
4.854	18.277	20.777	21.377	109.000
5.002	18.512	21.012	21.612	69.000
5.155	18.796	21.296	21.896	109.000
5.294	19.406	21.906	22.506	116.000
5.387	19.659	22.559	22.959	95.000
5.514	20.338	22.838	23.438	91.000
5.617	20.864	23.364	23.964	100.000
5.702	21.485	23.985	24.585	110.000
5.883	21.917	24.417	25.017	82.000
5.993	22.443	24.943	25.543	100.000
6.094	22.980	25.480	26.080	102.000

FIG. H-14-1 LONGITUDINAL PROFILE OF SG. DONDANG

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

JICA

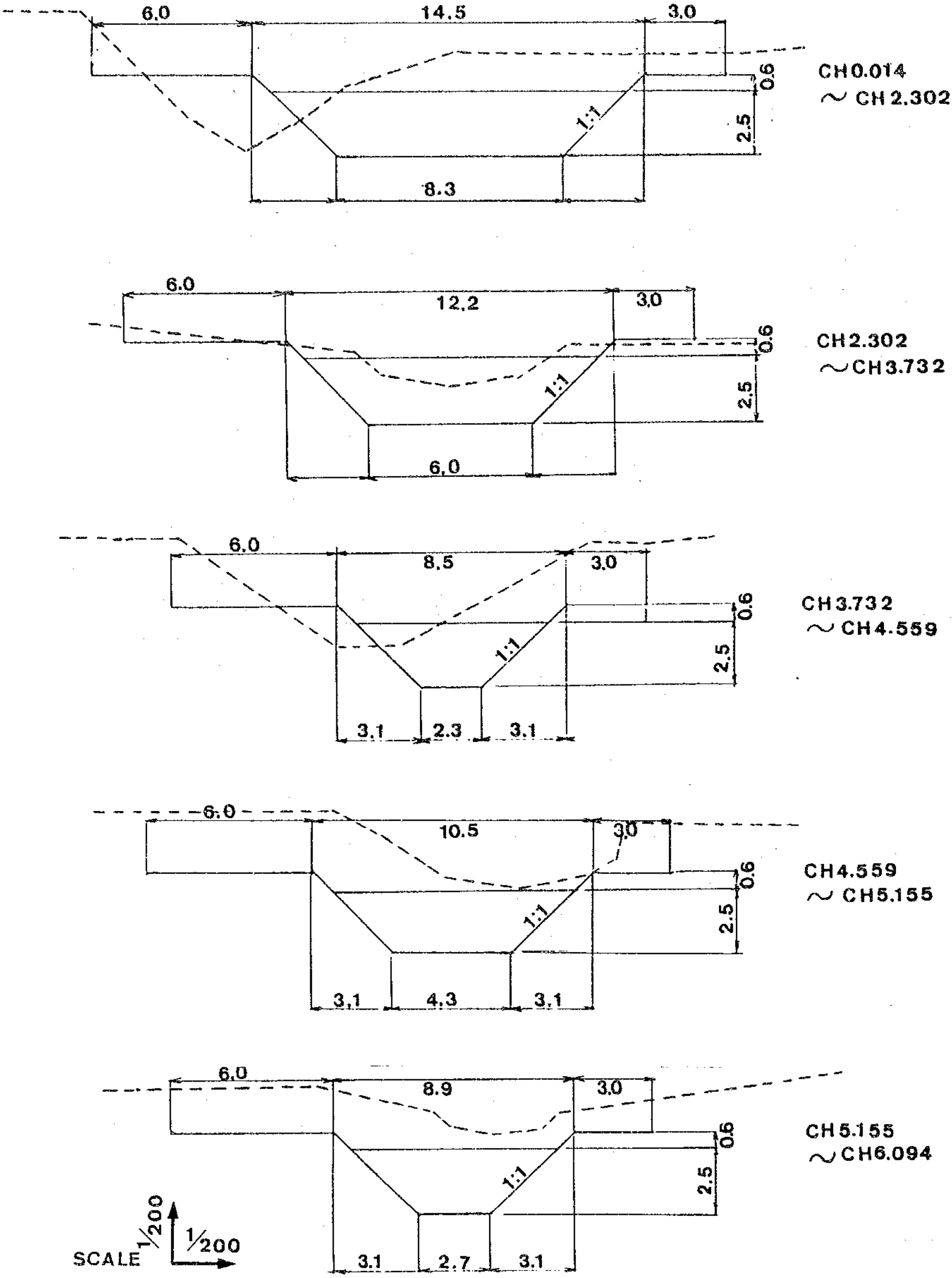
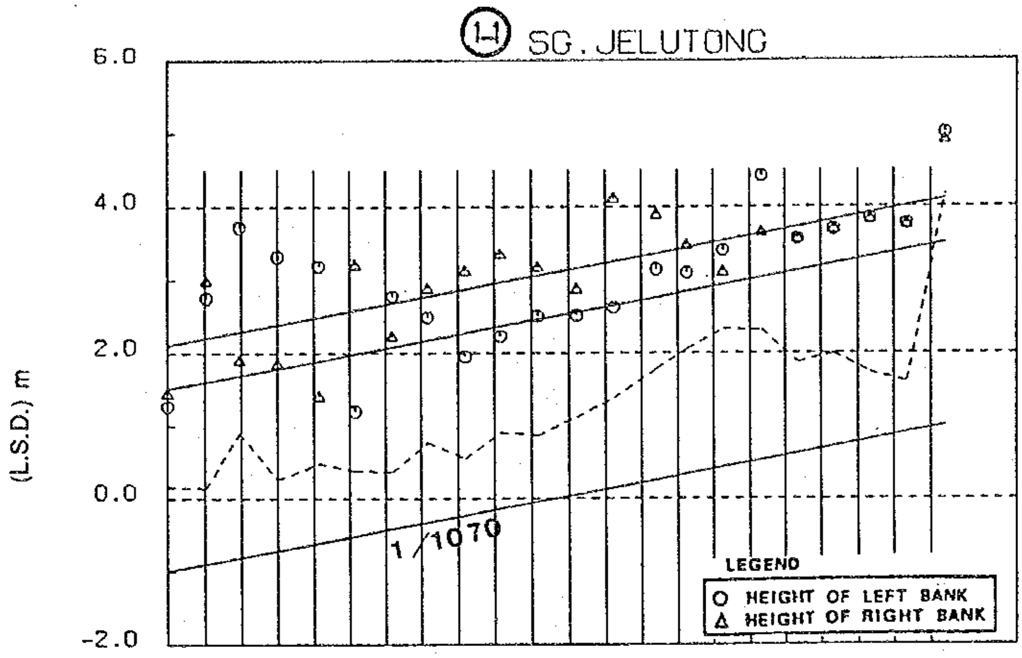


FIG. H-14-2	PROPOSED CROSS SECTIONS OF SG. DONDANG

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

JICA



BED LEVEL	-0.994	-0.896	-0.812	-0.713	-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.	1.506	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 m³/s (CHAINAGE 0.000 – 1315.000)

Q = 6 m³/s (CHAINAGE 1315.000 – 2105.000)

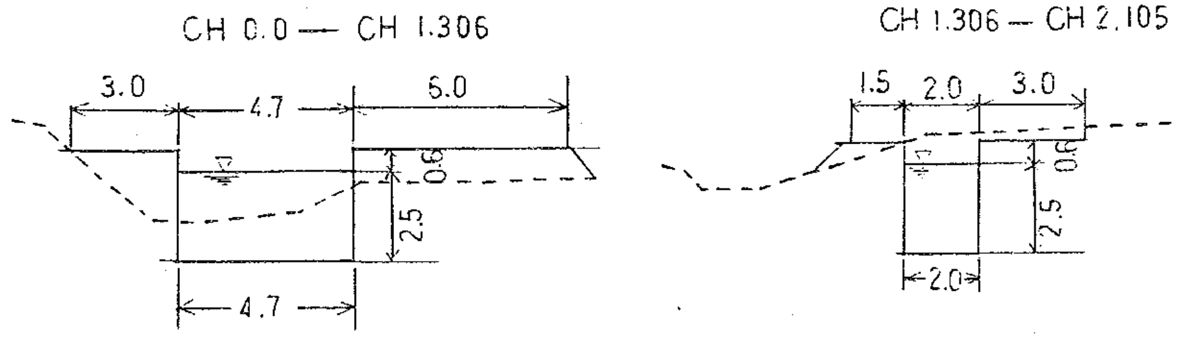


FIG. H-15 PROPOSED LONGITUDINAL PROFILE AND CROSS SECTION OF SG. JELUTONG

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

JICA

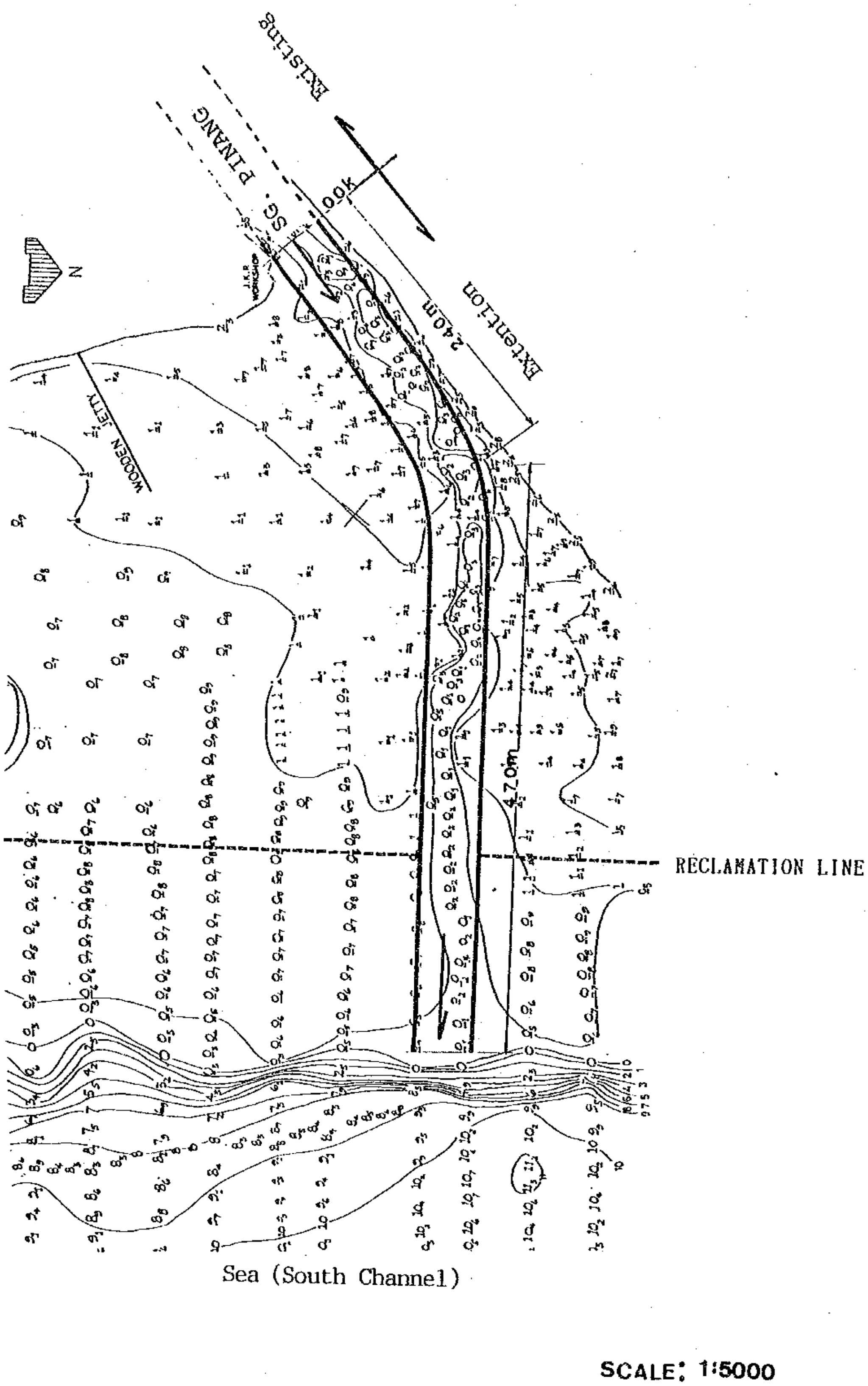
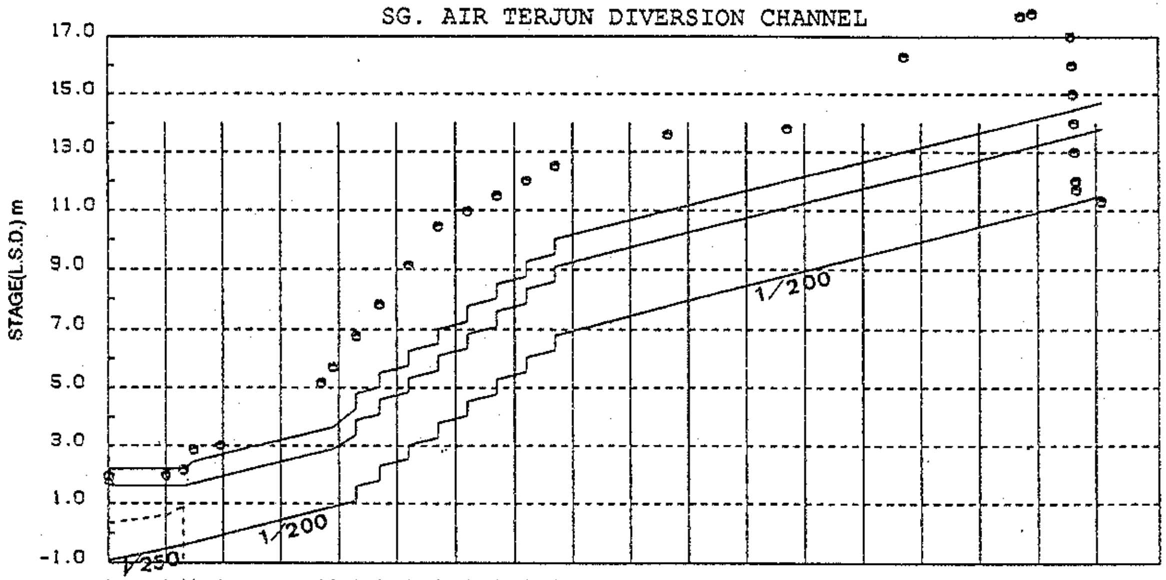


FIG. H-16	PROPOSED PLAN OF DOWNSTREAM REACHES OF SG. PINANG

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND



PROPOSED COPING LEVEL	2.200	2.200	2.200	2.450	2.685	3.560	3.660	4.820	5.820	6.270	6.820	7.270	8.820	8.270	10.820	10.990	12.020	13.020	14.020	14.120	14.720
PROPOSED H.W.L.	1.600	1.600	1.600	1.690	1.925	2.800	2.900	3.800	4.600	5.950	6.400	6.650	7.600	8.650	9.600	10.070	11.100	12.100	13.100	13.200	13.800
PROPOSED INVERT LEVEL	-0.920	-0.520	-0.400	-0.310	-0.075	0.800	0.900	1.500	2.800	3.850	3.800	4.850	5.800	6.650	6.800	7.770	8.800	9.800	10.800	10.900	11.500
EXISTING GROUND LEVEL	1.940	1.980	2.150	2.860	3.010	5.180	5.710	6.760	7.810	9.130	10.440	10.960	11.480	12.000	12.520	13.600	13.800	16.300	17.670	17.750	11.300
DISTANCE	0.000	100.000	30.000	18.000	47.000	175.000	20.000	40.000	40.000	50.000	50.000	50.000	50.000	50.000	50.000	194.000	206.000	200.000	200.000	20.000	44.000
CHAINAGE	0.000	100.000	160.000	178.000	225.000	400.000	420.000	460.000	500.000	550.000	600.000	650.000	700.000	750.000	800.000	994.000	1200.000	1400.000	1600.000	1620.000	1740.000

FIG. H-17 PROPOSED LONGITUDINAL PROFILE OF AIR TERJUN DIVERSION CHANNEL

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

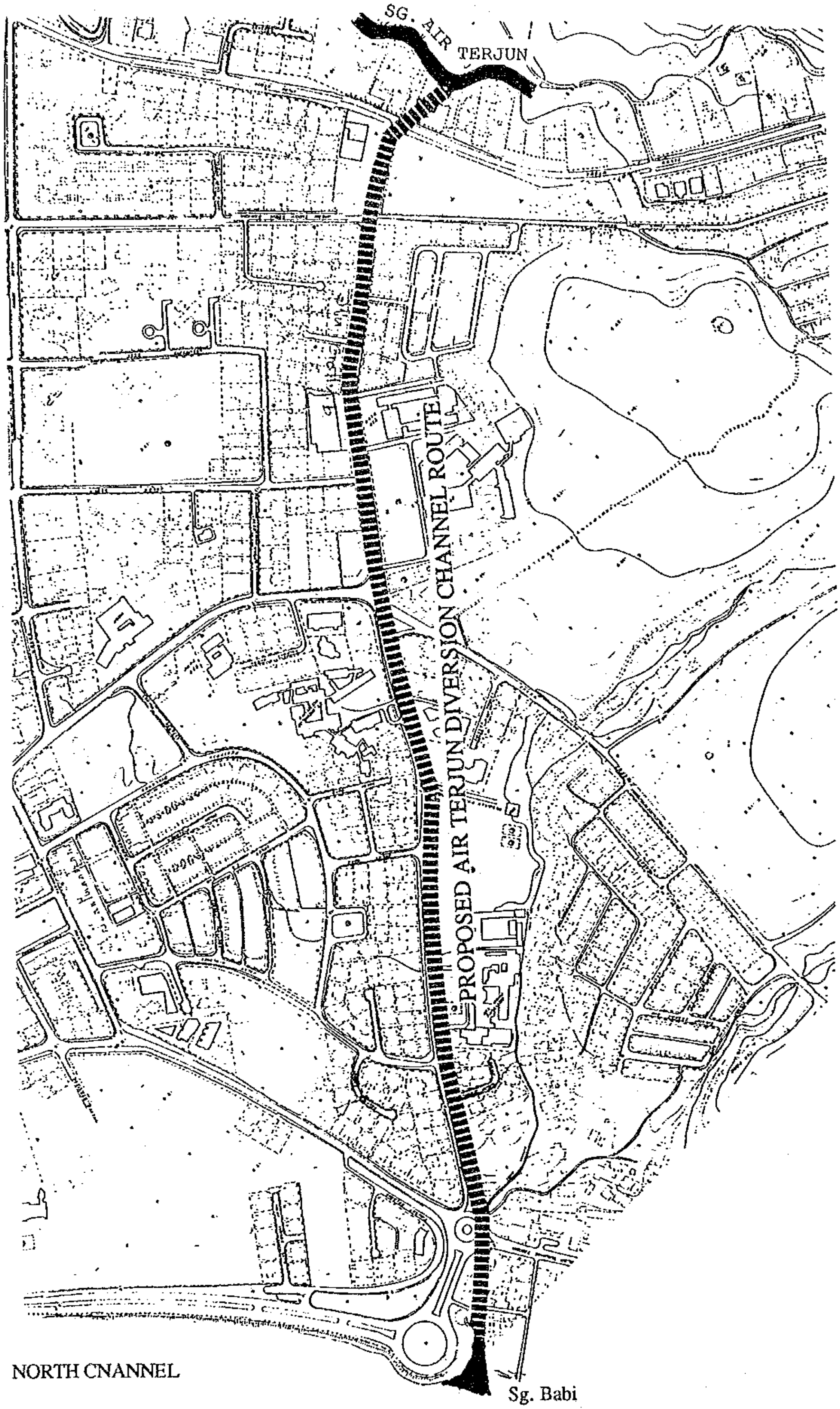


Fig. H-18	PLAN OF PROPOSED AIR TERJUN DIVERSION CHANNEL ROUTE

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

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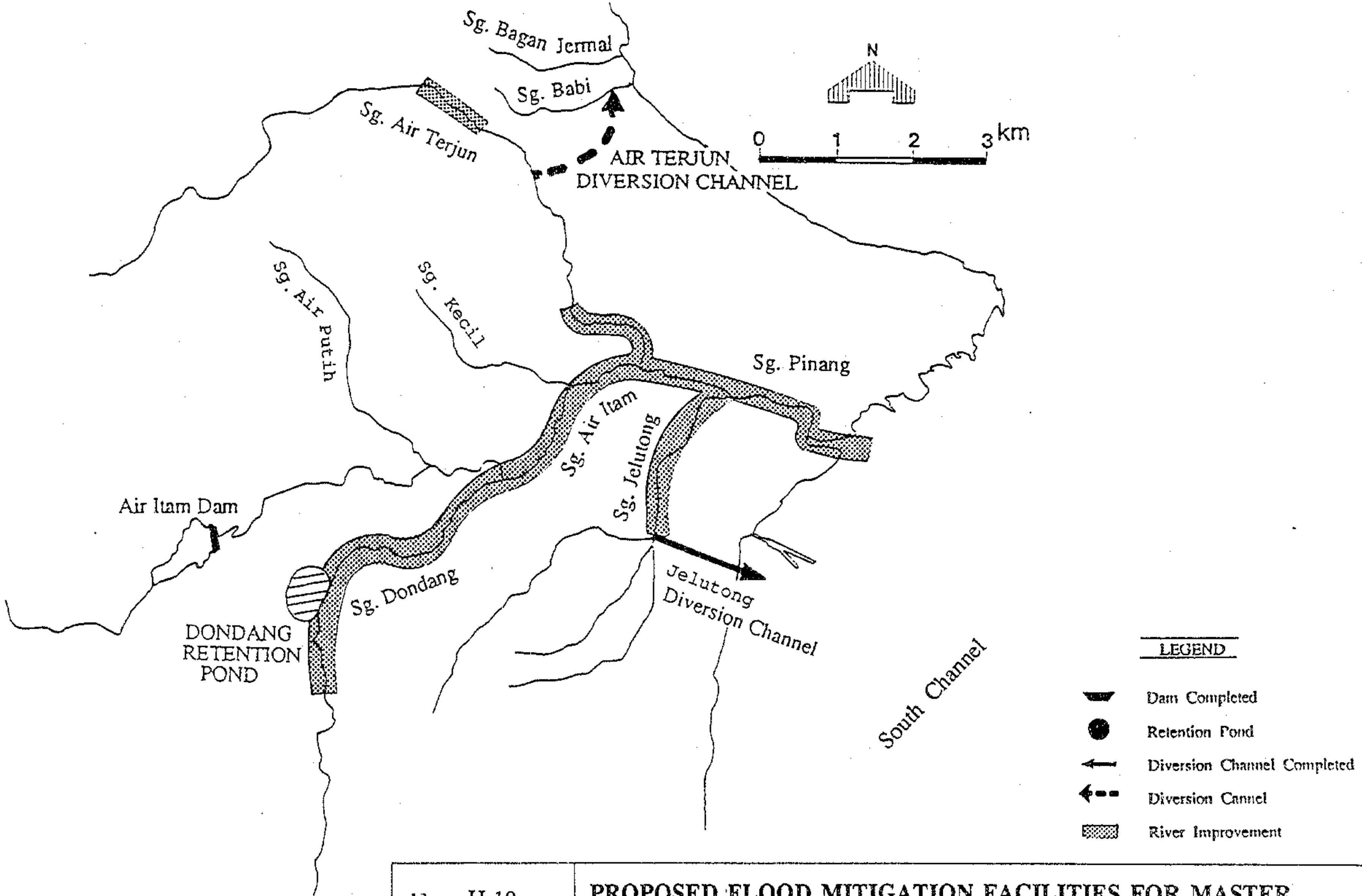

FIG. H-19	PROPOSED FLOOD MITIGATION FACILITIES FOR MASTER PLAN OF SG. PINANG SYSTEM

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

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