GOVERNMENT OF MALAYSIA

NATIONAL WATER RESOURCES STUDY, MALAYSIA
PERLIS-KEDAH-PULAU PINANG
REGIONAL WATER RESOURCES STUDY
PART 1

VOL. 7
ANNEX
H. FLOOD MITIGATION PLAN

NATIONAL WATER RESOURCES STUDY, MALAYSIA
PERLIS-KEDAH-PULAU PINANG REGIONAL WATER RESOURCES STUDY
PART 1
Vol.7 ANNEX H.
FEB 84

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FEBRUARY 1984

JAPAN INTERNATIONAL COOPERATION AGENCY

NATIONAL WATER RESOURCES STUDY, MALAYSIA
PERLIS-KEDAH-PULAU PINANG
REGIONAL WATER RESOURCES STUDY
PART 1

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ABBREVIATIONS

(1) Organization/Plan

4MP	:	Fourth Malaysia Plan
DID (JPT)	:	Drainage and Irrigation Department
EPU	:	Economic Planning Unit
FELCRA	:	Federal Land Consolidation and Rehabilitation Authority
FELDA	:	Federal Land Development Authority
GSD	:	Geological Survey Department
JICA	:	Japan International Cooperation Agency
MADA	:	Muda Agricultural Development Authority
NEB (LIN)	:	National Electricity Board
NWRS	:	National Water Resources Study
PWD (JKR)	:	Public Works Department
RISDA	:	Rubber Industry Small-Holders Development Authority
WHO	:	World Health Organization

(2) Others

B	:	Benefit
BOD	:	Biochemical Oxygen Demand
C	:	Cost
COD	:	Chemical Oxygen Demand
D&I	:	Domestic and Industrial
dia.	:	Diameter
EIRR	:	Economic Internal Rate of Return
El.	:	Elevation Above Mean Sea Level
Eq.	:	Equation
Fig.	:	Figure
GDP	:	Gross Domestic Product
GNP	:	Gross National Product
H	:	Height, or Water Head
NHWL	:	Normal High Water Level
O&M	:	Operation and Maintenance
Q	:	Discharge
Ref.	:	Reference
SS	:	Suspended Solid

ABBREVIATIONS OF MEASUREMENT

Length

mm = millimeter
cm = centimeter
m = meter
km = kilometer
ft = foot
yd = yard

Area

cm^2 = square centimeter
m^2 = square meter
ha = hectare
km^2 = square kilometer

Volume

cm^3 = cubic centimeter
l = lit = liter
kl = kiloliter
m^3 = cubic meter
gal. = gallon

Weight

mg = milligram
g = gram
kg = kilogram
ton = metric ton
lb = pound

Time

s = second
min = minute
h = hour
d = day
y = year

Electrical Measures

V = Volt
A = Ampere
Hz = Hertz (cycle)
W = Watt
kW = Kilowatt
MW = Megawatt
GW = Gigawatt

Other Measures

% = percent
PS = horsepower
° = degree
' = minute
" = second
°C = degree in centigrade
10^3 = thousand
10^6 = million
10^9 = billion (milliard)

Derived Measures

m^3/s = cubic meter per second
cusec = cubic feet per second
mgd = million gallon per day
kWh = kilowatt hour
MWh = Megawatt hour
GWh = Gigawatt hour
kWh/y = kilowatt hour per year
kVA = kilovolt ampere
BTU = British thermal unit
psi = pound per square inch

Money

M$ = Malaysian ringgit
US$ = US dollar
¥ = Japanese Yen

CONVERSION FACTORS

	From Metric System	To Metric System
Length	1 cm = 0.394 inch	1 inch = 2.54 cm
	1 m = 3.28 ft = 1.094 yd	1 ft = 30.48 cm
	1 km = 0.621 mile	1 yd = 91.44 cm
		1 mile = 1.609 km
Area	1 cm^2 = 0.155 sq.in	1 sq.ft = 0.0929 m^2
	1 m^2 = 10.76 sq.ft	1 sq.yd = 0.835 m^2
	1 ha = 2.471 acres	1 acre = 0.4047 ha
	k km^2 = 0.386 sq.mile	1 sq.mile = 2.59 km^2
Volume	1 cm^3 = 0.0610 cu.in	1 cu.ft = 28.32 lit
	1 lit = 0.220 gal.(imp.)	1 cu.yd = 0.765 m^3
	1 kl = 6.29 barrels	1 gal.(imp.) = 4.55 lit
	1 m^3 = 35.3 cu.ft	1 gal.(US) = 3.79 lit
	10^6 m^3 = 811 acre-ft	1 acre-ft = 1,233.5 m^3
Weight	1 g = 0.0353 ounce	1 ounce = 28.35 g
	1 kg = 2.20 lb	1 lb = 0.4536 kg
	1 ton = 0.984 long ton	1 long ton = 1.016 ton
	= 1.102 short ton	1 short ton = 0.907 ton
Energy	1 kWh = 3,413 BTU	1 BTU = 0.293 Wh
Temperature	°C = (°F - 32)·5/9	°F = 1.8°C + 32
Derived Measures	1 m^3/s = 35.3 cusec	1 cusec = 0.0283 m^3/s
	1 kg/cm^2 = 14.2 psi	1 psi = 0.703 kg/cm^2
	1 ton/ha = 891 lb/acre	1 lb/acre = 1.12 kg/ha
	10^6 m^3 = 810.7 acre-ft	1 acre-ft = 1,233.5 m^3
	1 m^3/s = 19.0 mgd	1 mgd = 0.0526 m^3/s
Local Measures	1 lit = 0.220 gantang	1 gantang = 4.55 lit
	1 kg = 1.65 kati	1 kati = 0.606 kg
	1 ton = 16.5 pikul	1 pikul = 60.6 kg

ANNEX H

FLOOD MITIGATION PLAN

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1. INTRODUCTION

This ANNEX H presents the results of flood mitigation study including the updating of the estimated flood damage and overall flood mitigation plans which are studied by NWRS. It also includes a prefeasibility design of flood mitigation work in the lower reaches of the Muda river.

The study is mainly based on information collected and results of site visit in January to March, 1983. It is noted that river cross section survey was carried out for the 33 km long model river stretch in the Muda river as an undertaking by the Government of Malaysia.

2. PRESENT RIVER CONDITIONS

2.1 Studied River Basins

NWRS recommended to provide flood mitigation works for 5 rivers in the Region, the Perlis, Kedah, Muda, Perai and Pinang rivers. The total catchment area and population of the five major river basins is 9,980 km^2 and 2.1 million, respectively, corresponding to about 90% of the three States' total. The flood mitigation plan for these 5 river systems is herein further studied.

The river systems in the 5 major river basins are indicated in Table 1, and the features of the river basins are described hereunder.

(1) The Perlis river basin

The Perlis river basin is located in the State of Perlis with a catchment area of 790 km^2 and covers the State Capital of Kangar. Since the southern boundary is not clear in the flat plain, it is assumed that the basin boundary coincides with the State boundary.

The basin may be divided topographically into three regions, as follows:

- The flat plain area of the lower reaches in the southern part of the State, which is largely developed as a part of agricultural land of the Muda Irrigation Project, occupying about 70% of the total basin area;
- The undulating area of about 10% of the basin area, which gradually rises into limestone hills; and
- The mountainous area of about 20% of the basin area, which is mostly covered by dense jungle.

The Perlis river system is composed of five principal tributaries; the Temenggong, Kechor, Korok, Ngolong, Gial and Arau rivers as shown in Fig. 19. All the tributaries, except the Arau river, flow into the main stream just in and around the urban area of Kangar from the northern hilly area and the west. Since the completion of the Muda Irrigation in the southern half of the basin, the discharge of Arau river is partially diverted through the Arau canal.

In this basin, two flood control dams, Timah-Tasoh dam and Arau dam, are being considered.

(2) The Kedah river basin

Kedah river basin is located in the northern part of the State of Kedah and has several urban areas such as the State Capital of Alor Setar, Jitra and K. Nerang. It originates in the high mountain area which forms the borderline between the State of Perlis and Thailand in the northern and western edge of the basin, and has the biggest catchment area of 3,695 km^2 next to the Muda river basin in the State, occupying 40% of the

State's total area of 9,480 km^2. The middle basin is hilly. The lower basin extending from the coastline to some 10 to 16 km inland is extremely flat.

The Kedah river system has 3 major tributaries; the Pdg. Terap, Pauh and Pendang rivers as shown in Fig. 22. The Pdg. Terap river is the longest and has the largest catchment area among the tributaries (see Table 1). Its upper reaches has the high mountain area where the existing Pedu Dam is located.

(3) The Muda river basin

The Muda river basin stretches across the State of Kedah into the State of Pulau Pinang. The basin has the largest catchment area of 4,300 km^2, including Tembus river basin, among all the river basins in the Region.

The main stream originates in the north mountain area of the State of Kedah and flows down towards the south but changes its course towards the west coast below the confluence of the Muda river and the Ketil river. In the above-mentioned north mountain area, there is the Muda Dam of which stored water is conveyed into the Pedu Dam. There are also two proposed dam sites; Tawar-Muda and Beris.

In addition to the principal tributary of the Ketil river, there are tributaries of the Chepir and the Sedim rivers as shown in Fig. 21. The Ketil river has the largest subcatchment area in the basin of 884 km^2, including the catchment area of the secondary tributary of the Kupang river.

(4) The Perai river basin

The Perai basin stretches in the North and Central Districts of Province Wellesley, the peninuent area of Pulau Pinang, with a catchment area of 895 km^2.

The Kulim and Kereh rivers flow down from the west and the northwest, respectively, and meet the main stream of Perai river about 20 km upstream from the river mouth as shown in Fig. 22. There is the Perai barrage at the middle of the main stream. The river course above the barrage traverses in a swamp, while lower river stretch flows through the urban area of Butterworth. A part of the swamp area is being reclaimed in order to extend the urban area of Butterworth.

(5) The Pinang river basin

The Pinang river basin of 66 km^2 is located in the Pinang island and includes Pinang river whose downstream flows through the State Capital of Georgetown. The riverine area is quite urbanized, specially along the section of 2.4 km from the river mouth.

The Pinang river bifurcate into the Ayer Itam, Ayer Putich, Ayer Terjun and Jultong rivers. The Jultong river joins the Pinang river from the left in Georgetown. A culvert was constructed in 1976 in order to divert flood flow from the Jultong river to the sea.

2.2 River Channel Conditions

The information on the present river channel conditions were mainly collected by visiting the sites from January to March 1983. The existing channel widths and shapes at bottleneck sections are as shown in Table 2.

The flow capacity of existing river channels was calculated as shown in Table 3 based on the channel cross section and flood water surface slope which was estimated by use of flood water stage records in DID office. The calculation was carried out by means of Manning's formula of uniform flow with an assumed coefficient of roughness of 0.03.

The calculated flow discharge is compared with the catchment area as shown in Table 4. The specific discharge capacity ranges between 0.1 $m^3/s/km^2$ and 0.5 $m^3/s/km^2$. The relationship between the catchment area and discharge capacity is plotted on a logarithmic paper as shown in Fig. 1. A line showing the relationship between the catchment area and 2-year flood discharge prepared by NWRS is also shown in Fig. 3. It is clear that the existing river channels are hardly capable of even the discharge of a flood of 2 years in return period.

River channel and their riverine conditions are described as below.

(1) The Perlis river system

The Perlis river system, generally, has the smallest specific flow capacity among the 5 major rivers, as indicated in Fig. 1. Especially, the flow capacity in the lower reaches of Korok and Kechor rivers flowing from the north into Kangar urban area is less than 0.1 $m^3/s/km^2$. During a period of heavy rain, all the floods from the various tributaries are concentrated in the lowlying Kangar plain resulting in flooding Kangar urban area.

Downstream from Kangar, the channel meanders and the tidal effect is felt at Kangar urban area with the maximum stage fluctuation of about 2.5 m. The channel improvement in the downstream was planned against a 5-year return period flood and land acquisition of 10.9 km in length has been implemented after the 1982 flood. However, this improvement plan extends only up to the downstream of Kangar, and further implementation, including Kangar area, is anticipated to be virtually difficult due to the difficulty in land acquisition.

In the upper reaches, channel erosion is observed to a minor extent. Sedimentation is not a problem.

Most river channels have U-shape single cross sections but Arau canal is of a U-shaped double section. The channel is 30 m in width and 3 - 5 m in depth with a channel slope of 1/6,000 in the main stream of Perlis river. It is 10 m in width and 2 - 3 m in depth with a channel slope of 1/2,500 in the principal tributaries of Kerok and Kechor rivers.

(2) The Kedah river system

The river system has a specific flow capacity of around 0.15 $m^3/s/km^2$. There are several bottlenecks near K. Pai and K. Nerang along the Padang Terap river.

In the lower reaches of Kedah river which flows through Alor Setar, the channel has a U-shape single section of 100 m in width, 10 m in depth and 1/10,000 in channel slope and the stone pitching bank is observed. On the other hand, the Padang Terap river (the upper reaches of the Kedah river) has a V-shape single section of 30 m in width, 8 m in depth and 1/4,000 - 1/6,000 in channel slope.

As to sedimentation, no serious problem was observed in the middle and lower reaches except for some progressive silting in the estuary.

(3) The Muda river system

Bottlenecks were observed along the main tributary of the Ketil river, specially around the confluence of the Ketil river and the Kupang river.

Several bund lines continue along the downstream reaches of Muda river between the railway bridge and the Muda barrage. The width from the left bund to the right bund was observed to be 500 to 1,000 m and the height of bunds is about 6 m for the right bund and 3 m for the left bund. The riverside from the bund lines has some functions of a retarding basin.

In the lower reaches, the channel was observed to have a U-shape single section of a width of 80 - 100 m, a depth of 3 - 4 m and a channel slope of 1/6,000 - 1/7,000.

Some meanderings with localized erosions were observed in the lower and middle reaches.

(4) The Perai river system

The Kulim river has a U-shaped channel section of 10 m in width and 3 m in depth with a slope of 1/4,500. The Perai main stream has a U-shaped channel section but with varying sizes; the width is 60 - 100 m and the depth is 2 - 4 m. The slope is 1/7,000. The specific discharge capacity of the main stream is small compared with the Kulim and Kereh rivers. A swamp developed at the middle stretch of the Perai river has been partially reclaimed since the completion of the Perai barrage.

Mud deposit was observed in the lower reaches of Perai river, but this is not causing any problem.

(5) The Pinang river system

Most river channels in the Pinang river system have U-shape single sections and their riverine areas are thickly populated. The main stream of Pinang river, which flows down through the central Georgetown urban area, is estimated to have a flow capacity of about 20 m^3/s (0.3 $m^3/s/km^2$ in specific discharge) with a channel width of 10 m, a channel depth of 3 m and a channel slope of 1/8,000.

The principal tributaries, the Ayer Terjun and Ayer Itam rivers, have flow capacities of around 6 m^3/s and 15 m^3/s (0.5 $m^3/s/km^2$ and 0.4 $m^3/s/km^2$ in specific discharge), respectively, with channel widths of 5 - 7 m, channel depths of 2 - 3 m and channel slopes of 1/3,000 - 1/ 1/4,500.

In view of the dense housings in areas adjacent to river banks, channel improvement works is urgently needed. River improvement works though they have often been proposed, have not been implemented yet due to difficulty in land acquisition.

Erosions on the banks were observed from place to place. Sediment yield due to the urban development was observed. Although the sediment is not much, aggradation of river channel is anticipated due to the limited sediment-carrying capacity of the channel.

2.3 Existing River Structures

The existing river structures related to the flood mitigation were investigated by visiting the sites and interviewing the agencies which maintain the structures. Most of the facilities have the principal purpose of irrigation, except Perai barrage in Perai river basin and Jultong diversion in Pinang river basin, both of which are for drainage purposes.

Principal features of the major structures are tabulated in Table 5 and some of them are specially mentioned hereunder.

(1) Arau canal in Perlis river basin

The Arau canal in the southern part of Perlis river basin is an irrigation canal but it also has a function to divert a part of the flood discharge of Arau river (104 km^2) and the residual catchment area of the canal (68 km^2) into the sea directly. The maximum flow capacity of the canal is estimated to be about 20 m^3/s (Ref. Table 3).

(2) Pelubang barrage in Kedah river basin

The Pelubang barrage is located in the principal tributary, Pdg. Terap, and a part of the flood discharge from the upstream of the barrage can be diverted through the spillway of the barrage up to 1,000 cuft/s (about 28 m^3/s) directly into the sea.

(3) Perai barrage in Perai river basin

The Perai barrage protects Butterworth from flooding by retaining flood in the existing swamp, which is located upstream of the barrage. When flood is over and the river stage in the downstream reaches falls, the water retained by the barrage is released by opening its gates.

(4) Jultong diversion channel in Pinang river basin

A diversion channel was constructed at the lower reaches of Jultong river, a tributary of Pinang river, in 1976, in order to release about 80% of the flood discharge from Jultong river directly into the sea.

(5) Pedu and Muda dams in Kedah and Muda river basins

The Muda and Pedu dams have no specific flood control storage but some flood control effects can be expected from them. Water retained in the Muda dam is conveyed into the Pedu dam through a tunnel. Accordingly, any flood in the catchment area of the Muda dam are not discharged downstream of the Muda dam. The Pedu dam has a large storage capacity. This is suggestive that flood inflow into the Pedu dam is often retarded in a storage space between the reservoir water surface before the flood and reservoir high water surface.

2.4 Land Use

(1) Perlis river basin

The urban area of Kangar, the State Capital, is developed around the confluence of the Perlis river and its principal tributaries such as the Temenggong, Kechor, Korok, Repor and Gial rivers.

The southern half of the basin is mostly covered by paddy fields of the Muda Irrigation Project.

The middle reaches of the tributaries are cultivated for paddy and horticultural.

The undulating hilly land in the upper reaches of the tributaries are rubber farms and swamps. Uppermost mountains are covered by forest. Sugarcane plantations spread in the eastern area near the State of Kedah.

(2) The Kedah river basin

The coastal plain of the Kedah river basin is paddy field of the Muda Irrigation Project. Alor Setar, the capital of the State of Kedah is located at the confluence of the Pdg. Terap river and the Pendang river. Some swamp areas are also seen in the riverine, specially along the downstream of the Kedah river.

In the area, 10 to 40 km inland from the coastline, rubber plantations are developed, dotted with some horticultural lands and forest lands.

The upper mountain area bordering with Thailand is mostly covered with forest.

(3) The Muda river basin

The coastal plain of the Muda river for 20 km from the sea coast is mostly used for paddy cultivation.

Undulating land in the middle of the basin is largely developed for rubber plantation. Some horticultural lands and paddy fields exist in the riverine, especially along the Kupang river.

The upper basin area is covered by forest.

(4) The Perai river basin

Butterworth located in the coastal plain is expanding upstream.

The swamp located between the confluence of the Kulim river and the Kereh river and the Purai barrage is partly being reclaimed, and the surrounding area is used for paddy cultivation.

The upper basin area; the Kulim and Kereh river basin, is mostly covered by rubber farms.

(5) The Pinang river basin

Almost two-thirds of the Pinang river basin is occupied by the urban area of Georgetown, the State capital, and especially, the lower reaches are thickly populated. The upper basin area is mostly covered with forest.

3. FLOOD DAMAGE

3.1 Historical Flood Events

Historical flood events between 1963 and 1979 compiled by NWRS were reviewed and updated by incorporating new information in the Annual Flood Damage Report of DID, and the results of interview in the State DID and MADA and with private personnel. An outline of historical flood events is compiled in Table 6.

The rainfall pattern in the Region is dominated by the Southwest Monsoon from July to September, and the Northeast Monsoon from October to December.

(1) The Perlis river basin

Flood maps for the Perlis river basin were compiled based on the flood map prepared by the State DID, Annual Flood Damage Report, DID, and the results of interview with inhabitants.

The flood occurred in September 1976 was the worst flood brought about by the southwest monsoon (see Ref. 9). The north-south running tributaries such as the Temenggang, Kechor and Korok rivers inundated and Kangar was mostly flooded as shown in Fig. 2. The total flooded area is estimated to be 49.2 km^2. Flooding lasted for 3 - 4 days in the upper and middle stretches of rivers and for more than 7 days in the lower stretches including the Kangar plain. The depth of flooding was generally 0.5 - 1.5 m, but it was relatively deeper in the middle stretch of the tributaries.

The flood in July 1982 was another typical flood of southwest monsoon, though it was a little less serious than the flood in September 1976. The total flooded area was 35.4 km^2 as shown in Fig. 3. The duration of flooding was generally 3 - 4 days but it was more than 7 days in the Kangar plain. The flooding depth was generally 0.5 - 1.5 m but relatively deeper in the middle reaches of the rivers.

In the flood in September 1972, 6 km^2 of land was flooded for more than 7 days as shown in Fig. 4. The flooded area included the central area of Kangar and some other places. The flooding depth was 0.5 - 1.5 m but it was 1 - 2 m near the confluence of the Timah river and Tasoh river.

(2) The Kedah river basin

Not the flooded area map of individual flood event but flood prone area maps showing an envelop of flooded areas by past floods only were available for the Kedah river basin. Flooded area maps of 3 flood were compiled based on the information in DID Flood Damage Annual Report and the results of interview survey.

The flood occurred in December 1975 was the recorded maximum in the Kedah river basin. The Pdg. Terap river inundated for a river length of 12 km upstream of the Pelubang barrage, for a river length of 20 km upstream of the confluence of the Pdg. Terap river and the Pedu river and an area near Jitra as shown in Fig. 5. Total flooded area was 69.5 km^2. The duration of flooding was 3 - 4 days. The depth of flooding was more than 3 m upstream of the confluence of the Pdg. Terap river and the Pedu river, 2 - 3 m upstream of the Pelubang barrage and 1 - 2 m near Jitra. Kuala Nerang was seriously affected by a 3.3 m (11 ft) deep flooding lasting for 2 - 4 days.

In the event of the flood in November 1979, flooding lasted for 1 - 2 days with a depth of 1 - 2 m for a river length of 12 km upstream of the confluence of the Pdg. Terap river and the Pedu river including Kuala Nerang, 1 - 2 m at Kg. Pai and 0.5 - 1 m in the northern suburbs of Alor Setar as shown in Fig. 6. The total flooded area was 16.5 km^2.

The flood in October 1980 flooded Kuala Nerang for 1 - 2 days with a depth of 0.5 - 1 m as shown in Fig. 9. The flooded area was 0.7 km^2.

(3) The Muda river basin

Like in the case of the Kedah river basin, flood maps of individual floods in the Muda river basin were prepared based on the information in DID Flood Damage Annual Report and the results of interview survey.

The flood in December 1973 was caused by a heavy rainfall of 150 - 250 mm (6" - 10") of the northeast monsoon. The lower stretch of the Muda river and the middle stretch of the Ketil river entirely inundated as shown in Fig. 8. Total flooded area was 142.5 km^2. Flooding lasted 3 - 4 days with a depth of 1 - 2 m in the Muda river approximately between the confluence of the Muda river and the Chepir river, and in the Ketil river. Flooding in the Muda river below the confluence of the Muda river and the Ketil river lasted more than 7 days with a depth of 0.5 - 1 m. Many people had to evacuate.

The flood in November 1972 flooded 37.1 km^2 near the confluence of the Muda river and the Chepir river, at the confluence of the Ketil river and the Kupang river, at the confluence of the Muda river and the Ketil river and the coastal area below the railway bridge across the Muda river as shown in Fig. 9. The flooding of 1 - 2 m lasted for 5 - 7 days in Kuala Ketil.

The flood in October 1980 was less serious than that in November 1972. Total flooded area was 20.1 km^2 as shown in Fig. 10. Flooding in Kuala Ketil lasted 2 - 3 days with a depth of 0.5 - 1 m.

(4) The Perai river basin

A flood map of the flood in September 1971 was prepared for the Perai river based on the information in DID Flood Damage Annual Report and the results of interview survey. The flooded area by this flood was 17 km^2 below the confluence of the Kedah river and the Kulim river as shown in Fig. 11. The flooding lasted for 3 - 4 days with a depth of 0.5 - 1 m.

(5) The Pinang river basin

The flood in October 1980 in the Pinang river basin flooded 2 km^2 mostly in Georgetown for 1 - 2 days with a depth of 0.5 - 1 m.

The flooded area by the above-mentioned flood in each basin is classified by the duration and depth of flooding in Table 7.

3.2 Land Use and Population

The land use and population in the flooded area by the past floods was estimated under the socio-economic condition in 1982.

(1) Land use

The Land Use Map in 1974 prepared by DOA was updated to 1982 for the flooded area based on the information obtained during the present survey.

The land use in 1982 in the flooded area was estimated by river basin, by past flood, by the depth and duration of flooding as shown in Tables 8 to 12.

(2) Population

The population density in 1982 in the past flooded area was assumed by river basin and by urban/rural classification based on the results of the Socio-Economic Study.

The urban and rural population in 1982 within the flooded area was estimated by river basin by past flood as shown in Table 13.

(3) Number of households

The number of urban and rural households in 1982 in the flooded area was estimated by river basin by past flood as shown in Table 14, based on the estimated population in 1982 in the flooded area.

The average family size was assumed to be 4.8 persons in the State of Perlis, 5.2 persons in the State of Kedah and 5.7 persons in the State of Pulau Pinang, according to the 1970 Population and Housing Census, DOS.

3.3 Flood Damage by Past Flood

The flood damage by past floods was estimated assuming the land use and population in 1982. In other words, the estimated flood damage is what is expected if a recorded flood takes place in 1982.

3.3.1 Unit value of flood damage

(1) Production loss on paddy

The proportional extent of irrigated paddy and rainfed paddy in the flooded area was assumed by river basin as shown in Table 15, based on the results of the Irrigation Development Study.

The production value of irrigated paddy and rainfed paddy estimated by NWRS was updated as shown in Table 16, assuming an annual escalation rate of 10% for 1981 and 1982.

The flood damage on paddy was calculated by multiplying the net production value by the flood damage factor in Tables 17 and 18.

(2) Replanting cost of tree crops

The proportional extent of young trees less than 3 years old to total planted area was assumed to be 9% for rubber and oil palm, 6% for coconuts and 10% for other tree crops.

The replanting cost of tree crop arising from flood damage was calculated as a product of the replanting cost in Table 19 and the mortality ratio in Table 20/21.

(3) Production loss of tree crops

The flood damage on matured tree is disregarded except for rubber. The net production value of rubber was estimated to be M$3.3/kg. The production loss in rubber by flood is assumed to be 4.7 kg/ha per number of days of flooding.

(4) Production loss on horticulture

The net production value of horticulture estimated by NWRS was updated to M$3,510/ha, by assuming an annual escalation rate of 10% for 1981 and 1982. The production loss was calculated as the product of the net production value and the flood damage factor in Table 22.

(5) House/building damage

The unit value of house/building and related properties estimated by NWRS was updated as shown in Table 23, assuming an annual escalation rate of 10% for 1981 and 1982.

The flood damage was calculated as the product of the unit value and the flood damage factor in Table 24.

(6) Damage on public facilities and utilities

The flood damage on the road, railway, irrigation facilities, electricity facilities, telecommunication facilities, water supply facilities and other public facilities was assumed to be 30% of the damage on house/building and related properties.

(7) Indirect damage

Economic losses due to suspension of production, trade, transportation and communication, called the indirect damage were assumed to be 30% of the total value of the direct flood damage.

3.3.2 Flood damage under the socio-economic condition in 1982

The flood damage assuming the land use and population in 1982 was estimated for the past major floods as shown in Tables 25 and 26.

3.3.3 Flood damage under the socio-economic condition in 2000

The average annual growth rate of per capita GRP, urban population and rural population in the flooded area by river basin between 1982 and 2000 assumed in the Socio-Economic Study is summarized in Table 27, for the economic growth condition following 4MP and the lower economic growth condition.

The flood damage and affected population by the past major floods was estimated assuming the socio-economic condition in 2000 as shown in Table 28, following the two different assumptions of economic growth.

3.4 Probability of Exceedance of Past Floods

A curve showing the probability of exceedance of the annual maximum water level was constructed based on 11-year annual maxima of water levels at the Kangar hydrological station, in the Perlis river basin, as shown in Fig. 12.

A curve showing the probability of exceedance of the annual maximum 3-day basin rainfall was constructed based on a 20-year annual maxima of 3-day rainfall records at 4 rain gauges in the Kedah river basin as shown in Fig. 13.

A curve showing the probability of exceedance of the annual maximum discharge was constructed as shown in Fig. 14, based on an 18-year annual maxima of discharge records at the Jeniang hydrological station in the Muda river basin.

A curve showing the probability of exceedance of the annual maximum discharge was constructed as shown in Fig. 15, based on a 21-year annual maxima of discharge record at the Ara Kuda hydrological station.

The return period of the past major flood in each river basin was estimated as shown in Table 29, based on the above-mentioned relationships. For the Pinang river basin, the return period was assumed to be equal to that of the concurrent event in the Perai river basin.

3.5 Probable Flood Damage

According to the analysis described in 2.2, the return period of zero damage flood is estimated to be approximately 2 years.

The flood damage by the past major floods was estimated in Subsections 3.3.2 and 3.3.3 and the corresponding return period was estimated in Section 3.4. Consequently, the relationship between the return period and the flood damage could be established as shown in Fig. 16.

In the same way, the relationship between the return period and the flooded area and that between the return period and the affected population were established as shown in Figs. 19 and 18, respectively.

The probable damage and affected population corresponding to the return periods of 5, 10, 20 and 50 years are estimated under the socioeconomic conditions in 1982 and 2000 assuming the economic growth following 4MP and lower economic growth as shown in Table 30.

4. ALTERNATIVE FLOOD MITIGATION PLANS

4.1 River Stretches

For the convenience of plan formulation, each river system was divided into several river stretches as shown in Figs. 19 to 22. A description of location, length and catchment area of each river stretch is shown in Table 31, and the width, depth and slope of typical channel section of each river stretch are summarized in Table 32.

4.2 Standard Project Flood Discharge

The rivers inundate a vast area when flood occurs and, accordingly, flood discharge is retarded on the travel. If flood flows down only within the river channel, the flood discharge will be larger than the recorded. The standard project flood discharge is herein defined as the flood discharge which will occur if a flood flows only within the river channel not inundating all the way.

The flood discharge in the rivers in the west coast was plotted for the return periods of 5, 10, 20 and 50 years against the catchment area as shown in Fig. 23, based on data in Ref. 1b. The envelops drawn on Fig. 23 were regarded as the relationship between the catchment area and the standard project flood discharge of specified return period.

By use of the above-mentioned relationship, the standard project flood discharge in each river stretch was estimated as shown in Table 33.

4.3 Alternative Setting

The flood mitigation measures considered are the channel improvement, bypass floodway, retarding basin and flood control dam.

The alternative plans are proposed in terms of structures provided and return period of design flood discharge.

4.3.1 Alternative plans without dam

(1) The Perlis river

The predominant problem area in the Perlis river basin is Kangar, where the Temenggang, Korok and Gial rivers flow in and the lower reaches of the Perlis river drains. Alternative 1 is the river improvement of various river stretches. Alternative 2 is the river improvement including the construction of a bypass floodway B1 for River Stretch P2 and another bypass floodway B2 to switch the flood discharge in River Stretch G1 into the sea. Gates are installed at the downstream end of River Stretch P3 to control discharge into River Stretch P2 and at the upstream end of River Stretch G1 to restrict flood discharge into River Stretch G1.

(2) The Kedah river

The problem area in the Kedah river basin is distributed along River Stretches K2 and K3 including Kuala Nerang. Alternative 1 is channel improvement.

(3) The Muda river

The problem area in the Muda river basin is mainly located along the Ketil river, especially at Kuala Ketil. Alternative 1 is channel improvement.

(4) The Perai river

The problem area in the Perai river is Butterworth along River Stretch P1. Alternative 1 is channel improvement of River Stretches P1 and P2. Alternative 2 is adjustment of existing swamp as a retarding basin R.

(5) The Pinang river

The problem area is Georgetown which develops along River Stretch P1. Alternative 1 is channel improvement.

The design discharges for the above-mentioned alternative plans are illustrated in Figs. 24 to 29.

4.3.2 Alternative plans with dam

The flood control dam is considered for the design flood of 50-year in return period. It is assumed that a flood control storage capacity is provided to the extent that 50-year flood discharge at the damsite can be reduced by 75%.

The reduction in flood discharge downstream of a dam was calculated by the following equation (Ref. 1c):

$$K = (1 - (1 - m^2) \times a/A)^{0.5} \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

where, K: Reduced flood discharge/Natural flood discharge at a specified point in the river

m: Outflow discharge/Inflow discharge at the damsite

a: Catchment area of the dam

A: Catchment area of the specified point

According to Eq. 1, the flood control effect of a dam having a catchment area of less than 10% of that at the problem area is insignificant, reducing flood flow at the problem area by only 5%. Table 34 lists potential dams identified by the Kedah/Perlis Water Resources Management Study, 1981. They were screened assuming that only a dam having a catchment area more than 10% of that at the problem area is effective. As a result, the Timah Tasoh, Arau and Ahning dams were found to be effective so far.

As the alternative plans for the Perlis river with the Timah Tasoh and Arau dams, two plans are proposed: Alternative 3 corresponding to Alternative 1 and Alternative 4 corresponding to Alternative 2.

For the Kedah river, a plan with the Ahning dam is proposed as Alternative 2.

The design flood discharges for the above-mentioned alternatives and illustrated in Figs. 30 and 31.

4.3.3 Alternative plans by design flood

The cost and benefit of each alternative plan are different by different design flood. An alternative plan for the design flood of a specific return period is labeled by the specified return period; for instance Alternative 1 for the design flood of 50 years in return period is named Alternative 1.50.

4.4 Design and Construction Cost Estimate

(1) River channel and bypass floodway

Typical cross section for the channel improvement and bypass floodway for varying design flood discharge is assumed as shown in Tables 35 and 36, in which symbols used are illustrated in Fig. 32.

The channel cross section in a River Stretch is not uniform under the existing condition. The required length of channel improvement is estimated as shown in Table 37, based on the results of field reconnaissance.

Number of new bridge required in relation to the channel improvement is estimated as shown in Table 38.

Assuming the unit costs for construction work and compensation as shown in Tables 39 and 40, the construction cost for the channel improvement is estimated as shown in Tables 41 and 42.

(2) Retarding basin

An analysis was made of the retarding effect of the existing swamp in relation to Alternative 2 of the Perai river.

The existing swamp extends for 8 km along River Stretch P2, which has a discharge capacity of 70 m^3/s. It can retain 9×10^6 m^3 of water in a depth of 1 m within the surface area of 9 km^2. The peripherical length of the swamp is estimated to be 12.5 km.

The recorded hydrograph of December 1980 flood at the Ara Kuda hydrological station in the Kulim river was adjusted to the design flood discharge in River Stretch P2 as shown in Fig. 33.

The volume between the existing river channel capacity of 70 m^3/s and the flood hydrograph is approximately the required storage capacity in the swamp to reduce the flood to 70 m^3/s. The required storage capacity and corresponding raising height of existing bund surrounding the swamp were calculated for varying design flood discharge as shown in Table 43. Consequently, the required work for Alternative 2 is heightening of the existing bund around the swamp. The design flood discharge is 70 m^3/s for all cases as shown in Fig. 28.

The construction cost of retarding basin is estimated as shown in Table 44.

(3) Dam

The flood control storage capacity of proposed dams and construction cost allocated to the flood mitigation purpose are estimated as shown in Table 45.

4.5 Flooded Area and Population by River Stretch

The flooded area in a River Stretch varies depending on the scale of flood. The annual average of flooded area is estimated to see how much flooded area is reduced by flood mitigation work.

The flood mitigation work can protect the land if the flood discharge is not more than the design flood discharge. It is not effective against the flood discharge larger than the design flood discharge. Consequently, certain annual average flooded area remains, even the flood mitigation work is provided.

The annual average flooded area is estimated for the condition without flood mitigation work and the conditions having flood mitigation work of design flood discharge of varying return period as shown in Table 46.

Using population data projected to 2000, the annual average of population protected is also estimated as shown in Table 47.

4.6 Annual Equivalents

Annual equivalents of flood damage with- and without-flood mitigation work are estimated as shown in Table 48, assuming the following conditions:

(1) Flood damage linearly increases between 1982 and 2000;

(2) Flood damage also linearly increases beyond 2000 but with a linear increase rate half as much as that between 1982 and 2000;

(3) Evaluation period is 50 years between 1991 and 2040; and

(4) Discount rate is 8%.

Table 49 shows the annual equivalent of economic benefit derived from the figures in Table 48.

Annual equivalent of cost of flood mitigation work is estimated as shown in Tables 50 and 51, assuming that the construction period is 5 years between 1986 and 1990 for the Kedah, Perai and Pinang rivers and 15 years between 1986 and 2000 for the Perlis and Muda rivers. OM cost is assumed to be 2% of construction cost for the channel improvement, bypass floodway and retarding basin and 0.5% of that for the dam.

4.7 Economic Comparison of Alternative Plans

The channel improvement in a river stretch is ineffective if the discharge capacity in the lower stretch is small. It is, therefore, assumed that the channel improvement in the lower river stretches should be provided before the improvement in the upper river stretch.

Improvement of lower stretch may reduce the flood damage in the upper stretch, but this effect is not taken into account herein.

Flood control dam/bypass floodway can benefit downstream river stretches by reducing flood discharge downstream. The share of damage reduction in downstream river stretches by dam/bypass floodway are estimated as shown in Table 52.

The cost of the flood control measures proposed for some river stretch may be larger than the benefit attributable to the measures. In this case, it is proposed to discard the measures, unless it is necessary for the channel improvement in upper river stretch.

With the above-mentioned conditions, the best combination of flood mitigation measures is selected for each alternative plan.

The cost of measures and benefit attributable to the measures of the best combination are listed in Tables 53 to 58.

The net economic benefit, benefit less cost, of alternative plans is summarized in Table 59.

4.8 Recommended Plans

The plan showing the largest net economic benefit under the condition of economic growth following 4MP is, in principle, recommended among the alternative plans for each river system.

Some of the recommended plans do not always maximize the net economic benefit if a lower economic growth is assumed. The lower economic growth involves a delayed buildup of economic benefit. In this connection, the recommended plan can attain the maximum benefit, even under the condition of lower economic growth, if the construction schedule is appropriately delayed.

The recommended plans are Alternative 4.50 for the Perlis river system, Alternative 1.10 for the Kedah river system, Alternative 1.10 for the Muda river system, Alternative 2.50 for the Perai river system and Alternative 1.50 for the Pinang river system, according to Table 59.

The principal feature of the recommended plans are summarized in Table 60 under the condition of the economic growth following 4MP and Table 61 under the condition of lower economic growth.

4.8.1 The Perlis river flood mitigation plan

The recommended flood mitigation work consists of the channel improvement of 23 km in length for River Stretches P, Tl, G2 and Al, two bypass floodways of 22 km in total length, and the Timah-Tasoh dam and the Arau dam as shown in Fig. 34. The design flood is 50-year flood.

The construction cost at 1982 constant price level is estimated to be M\$43 x 10^6 including M\$23.7 x 10^6 for the construction of channel improvement, and bypass floodways and M\$11.4 x 10^6 of dam construction cost allocated to the flood mitigation purpose and M\$7.9 x 10^6 of compensation cost.

Average annual flooded area of 8 km^2 in the river basin will be reduced by 3.4 km^2, or 43% if the recommended plan is fully implemented.

Under the condition of economic growth following 4MP, average annual flood damage in the river basin of M\$5.45 x 10^6 will be reduced by M\$4.20 x 10^6, or 77%. The value of EIRR is estimated to be 17.2%.

Average annual population affected by flood is projected to be 11,200 to 2000. It will be reduced by 7,800, or 70%.

Alternative 2.50 shows maximum net economic benefit under the condition of lower economic growth, but it involves larger construction cost for river improvement than Alternative 5.50, which is recommended under the condition of economic growth following 4MP. On the other hand, Alternative 5.50 is the second best plan under the condition of lower economic growth. It is the construction of the Timah-Tasoh dam only, which can be regarded as the first stage of the recommended plan, of which the other components may be implemented depending on the economic growth.

The construction cost of the Timah-Tasoh dam is estimated to be M$11.6 x 10^6 at 1982 constant price. The dam can affect River Stretches P1, P2 and P3. Under the condition of lower economic growth, the Timah-Tasoh dam will reduce M$2.77 x 10^6 of average annual flood damage by M$720,000, or 26%. The value of EIRR is estimated to be 8.2%.

The average annual flooded area of 8 km^2 in the river basin will be reduced by 1.4 km^2, or 18%. Average of annual population affected by flood projected to 2000 of 9,600 will be reduced by 2,800, or 29%.

In conclusion, the Timah-Tasoh dam should be constructed first and the other components of Alternative 5.50 should be implemented, in accordance with the economic growth.

4.8.2 The Kedah river flood mitigation plan

It is recommended to conduct the channel improvement of 18 km in length with a design flood of 10 years in return period as shown in Fig. 35. The construction cost at 1982 constant price level is estimated to be M$14.7 x 10^6 including the construction work of M$9.7 x 10^6 and the compensation of M$5.0 x 10^6.

Average annual flooded area of 7.5 km^2 in the river basin will be reduced by 1.4 km^2 or 19%.

Under the condition of economic growth following the assumption in 4 M.P., average annual flood damage of M$3.24 x 10^6 will be reduced by M$2.02 x 10^6 or 62%. The value of EIRR is estimated to be 14.1%. Annual average of people affected of 3,300 in 2000 will decrease by 1,600 or 48%.

Under the condition of lower economic growth, average annual flood damage of M$1.65 x 10^6 will be reduced by M$1.05 x 10^6 or 64%. The value of EIRR is estimated to be 9.3%. Average annual of people affected of 3,100 in 2000 will decrease by 1,500 or 48%.

4.8.3 The Muda river flood mitigation plan

The recommended plan for the Muda river is the channel improvement of 50 km in length with a design flood of 10 years in return period as shown in Fig. 36. The construction cost at 1982 constant rpice level is estimated to be M$40.4 x 10^6 including the construction work of M$36.4 x 10^6 and compensation cost of M$4 x 10^6.

Average annual flooded area of 16.2 km^2 in the river basin will be reduced by 3.2 km^2, or 20%.

Under the condition of economic gorwth following 4MP, average annual flood damage of M$6.57 x 10^6 will be reduced by M$3.12 x 10^6, or 47%. The value of EIRR is estimated to be 10.1%. Average annual population affected of 10,300 in 2000 will decrease by 6,200, or 61%.

Under the condition of lower economic growth, average annual flood damage of M$3.7 x 10^6 will reduce by M$1.91 x 10^6. The value of EIRR is estimated to be 8.1%. Average annual population affected of 10,000 in 2000 will decrease by 6,000, or 60%.

4.8.4 The Perai river flood mitigation plan

The recommended plan for the Perai river system is to provide a retarding basin by reforming the existing swamp as shown in Fig. 37. The construction cost at 1982 constant price level is estimated to be M$5.3 x 10^6 including M$0.8 x 10^6 of construction work and M$4.5 x 10^6 of compensation.

Average annual flooded area of 6.2 km^2 will be reduced by 4.9 km^2, or 79%.

Under the condition of economic growth following 4MP, average annual flood damage of M$1.6 x 10^6 will be reduced by M$1.54 x 10^6, or 96%. The value of EIRR is estimated to be 18.4%. Average annual population affected of 3,300 in 2000 will decrease by 2,600, or 79%.

Under the condition of lower economic growth, average annual flood damage of M$0.88 x 10^6 will be reduced by M$0.82 x 10^6, or 93%. The value of EIRR is estimated to be 12.9%. Average annual population affected of 2,500 in 2000 will decrease by 2,000, or 80%.

4.8.5 The Pinang river flood mitigation plan

The recommended plan for the Pinang river system is a channel improvement of 2.4 km in length with a design flood of 50 years in return period. The construction cost at 1982 constant price level is estimated to be M$38.6 x 10^6, including the construction work of M$3.7 x 10^6 and compensation of M$34.9 x 10^6.

Average annual flooded area of 1.1 km^2 will be reduced by 0.8 km^2, or 73%.

Under the condition of economic growth following 4MP, average annual flood damage of M$3.63 x 10^6 will be reduced by M$3.27 x 10^6, or 90%. The value of EIRR is calculated to be 12.5%. Average annual population affected of 5,400 in 2000 will decrease by 4,600, or 85%.

Under the condition of lower economic growth, average annual flood damage of M$2.17 x 10^6 will reduce by M$1.96 x 10^6, or 90%. The value of EIRR is low of 7.6%. Average annual population affected of 4,700 will decrease by 3,700, or 79%. Under these conditions, it will be difficult to justify the plan from the economic point of view, due to high compensation cost, but the implementation of this plan should be seriously considered from the viewpoint of social well-being; protection of large number of urban people.

The recommended plans as a whole can reduce average annual flood damage of M$20.49 x 10^6 in the 5 river basins by M$14.15 x 10^6, or 69%, and affected population of 33,700 in 2000 by 23,600, or 70% under the condition of economic growth following 4MP. Even under the condition of lower economic growth, average annual damage of M$11.17 x 10^6 will be reduced by M$6.46 x 10^6 and affected population of 29,200 in 2000 will decrease by 16,200, or 55%.

4.9 Implementation Schedule

The construction schedule is proposed as shown in Table 62 and the capital disbursement schedule is estimated as shown in Table 63.

5. PRE-FEASIBILITY DESIGN FOR MODEL RIVER STRETCH

5.1 The Model River Stretch

The flood mitigation aspect in the Perlis river basin is being studied in more detail under the Timah-Tasoh and Arau dams Study. Among the remaining Kedah, Muda, Perai and Pinang river flood mitigation plans, that for the Muda river is largest in scale. Hence, the Model study is carried out for the lower reaches of the Muda river.

The recommended flood mitigation scheme for Muda river basin is composed of the river channel improvements for the following river stretches:

- River Stretch No. M1 (the improvement length of 15 km from the Muda Barrage up to the Railway Bridge),
- River Stretch No. M2 (the improvement length of 20 km from the Railway Bridge up to Kg. K. Sedim),
- River Stretch No. M3 (the improvement length of 5 km in the section from Kg. K. Sedim to K. Ketil),
- River Stretch No. K1 (the improvement length of 5 km in the section from K. Ketil to the confluence of the Muda river and the Kupang river), and
- River Stretch No. K2 (the improvement length of 5 km along the Kupang river).

As described in the foregoing plan, the river channel work for the above-mentioned river stretches requires the construction period of 15 years from the year 1986 to the year 2000 covering the Fifth, Sixth and Seventh Malaysia Plan, because of the large work volume.

Among the above river stretches, the relatively high beneficial area of flood mitigation scheme is located around K. Ketil, and along Ketil and Kupand rivers which correspond to the areas along the stretches of M3, K1, and K2.

These areas are, however, located in the upper reaches of the Muda river, and any suitable flood reduction measures like flood control dam and retarding basin cannot be conceivable.

Therefore, the channel improvement downstream of the benefitted area as well as the benefitted upstream area itself are necessary for the flood mitigation of the Muda river. Further, in this case, the channel improvement of the downstream (Stretch No. M1 and M2) needs to take precedence to the channel improvement of the upstream (Stretch No. M3, K1 and K2) in the following points of view:

(a) The design flood in the upstream stretches (750 m^3/s) remarkably exceeds the existing flow capacity in the downstream stretches (400 m^3/s). Therefore, without the channel improvement of the downstream stretches, the channel improvement of the upstream stretches only cannot fulfill its flood mitigation effect; and

(b) If the channel improvement of the upstream stretches precedes that of downstream stretches, the lower reaches is anticipated to receive the worse flood damage rather than the present states.

Hence, the river stretches of the downstream (Stretch No. M1 and M2) should be improved in the first stage and, therefore, this Study takes up the stretches of M1 and M2 for the pre-feasibility design.

5.2 Pre-Feasibility Design

(1) Premises of design

This pre-feasibility design for the model river stretch is subject to the following premises:

(a) The design is done based on the field reconnaissance and the river channel survey which were conducted during this study term. The said survey included cross sectional survey at 26 sections which are indicated in Plate 1;

(b) As shown in Plate 1, the model river stretch extends from Muda Barrage up to Kg. K. Sedim (33.8 km in length), which corresponds to Muda river stretch numbered "M1" and "M2" in the aforesaid overall plan (Ref. Table 34); and

(c) In accordance with the recommended overall plan, the 10-year design flood was considered for this pre-feasibility design.

(2) Results of field reconnaissance and river channel survey

The field reconnaissance and river channel survey were conducted in early 1983 and the following matters were confirmed:

(a) The bankful flow capacity of the model river stretch was estimated at around 400 m^3/s on an average, ranging from 200 m^3/s to 600 m^3/s as shown in Fig. 38;

(b) The existing river channel has the following states:

- 100 - 150 m in width, about 5 m in depth, and 1/10,000 in slope in the sections from Muda Barrage (Section No. 1) up to 13 km upstream (Section No. 9);

- 60 - 100 m in width, about 7 m in depth, and 1/5,000 in slope between Section No. 9 and No. 26; and

(c) Six major intake facilities were confirmed along the model river stretch as shown in Plate 1.

(3) Longitudinal profile

Since neither serious erosion nor serious sedimentation was observed in the model river stretch, the existing riverbed slope was judged to be relatively stable, and the proposed river slope was determined in the manner of preserving the existing slope, except that a horizontal sedimentation is assumed between Section No. 1 and Section No. 9 at El. -0.9 m which is the overflow crest elevation of the Muda barrage.

(a) For the section from Muda barrage (Section No. 1) up to 10 km upstream (Section No. 9), the proposed riverbed is at El. -0.9 m.

(b) For the section between Section No. 9 and Section No. 26, the proposed riverbed slope is 1/5,000.

High Water Level (HWL) at the Muda barrage (Section No. 1) was estimated to be El. 3 m for 10-year design flood.

Plate 2 shows longitudinal profile, showing existing riverbed, existing bank lines, proposed riverbed, proposed HWL and the proposed dike top line.

(4) Cross section

There are several bunds along the model river stretch and they are effective to shut down water coming from outside of the river channel. This fact allows a flood water level above the original groundline, because no back swamp is expected. The cross section as shown in Plate 1 is proposed in the form of composite channel, where the low water channel size is adjusted to the size of the existing river channel in order to keep the existing water supply faculties operational and make less excavation volume.

Figures 40 and 41 show the proposed river cross sections according to the above-mentioned application of the aforesaid typical cross section.

(5) Alignment

The proposed alignment was designed paying attention to:

(a) the correction of track of the existing meandering river channel; and

(b) the avoidance of the proposed river channel course passing the following water intake facilities:

- Muda Pumping Intake (3 x 100 cusec and 1 x 200 cusec),
- Pekula Natural Flow Intake (3 x 45 cusec),
- Pinang Tunggal Pumping Intake (2 x 135 cusec),
- Sidam Kanan Natural Flow Intake (3 x 8 cusec), and
- Sidam Kiri Natural Flow Intake (3 x 12 cusec).

5.3 Pre-Feasibility Cost Estimation

The work items and their work volumes required for the river channel improvement of the model river stretch were estimated as below.

- Excavation Work : 1,736 x 10^3 m^3 of excavation volume
- Embankment Work : 1,652 x 10^3 m^3 of embankment volume
- Sod Facing : 1,208 x 10^3 m^2 of sod facing area
- Levee/Road Pavement: 270 x 10^3 m^2 of road pavement area corresponding to the total length of 67.5 km and the width of 4 m

The cost of construction was estimated based on the above work volume being multiplied by unit prices which were set up in the aforesaid regional master plan (Ref. Tables 39 and 40). Similarly, the estimated cost represents financial cost at 1982 price level, comprising direct construction cost, physical contingencies (30% of direct construction cost) and engineering cost (10% of the former two).

The compensation cost was separately estimated. This compensation cost was considered mainly to secure the high water channel portion of the proposed channel, which is located between the existing bunds and estimated at the low utility value. According to the field reconnaissance, the necessity of resettlement of housing was counted to be nil. Therefore, the compensation cost only for land acquisition was estimated based on the area of 440 ha. The compensation land consists of the rubber and oil palm land (23 ha), the paddy land (13 ha) and the forest land (404 ha), which were estimated based on 1:63,360 map.

The result of cost estimation is tabulated in Table 64, which indicates the total cost of M$27.87 x 10^6.

5.4 Pre-Feasibility Construction Schedule

The construction work of the project is scheduled for ten (10) years, commencing from the year 1986 under 5MP, including one (1) year for preparation and detailed engineering work.

The river improvement work consists of excavation, embankment, sod facing, etc. These works are assumed to be executed from downstream toward upstream along the river course in the stretch from the existing Muda barrage for about 34 km.

Of the above-mentioned works, the earthwork composed of excavation and embankment can be said to have the greatest work volume. Therefore, the critical path was determined by the progress of earthwork, and other works were scheduled in accordance with the earthwork schedule. Following this concept, the construction schedule for the model river stretch was prepared as shown in Fig. 39, where the annual work period was set up in 6 months of a dry season from January to June, since earthwork in a rainy season is difficult to undertake.

The distribution of annual work volume was considered mainly based on the availability of various kinds of heavy machinery for the earthwork. As shown in Plate 4, the earthwork volume in the first year of the construction period was made less than those of other years, considering the training period of operators.

The maximum annual volume of earthwork is extracted from Plate 4, as below.

- Underwater excavation: 88×10^3 m^3
- Land excavation : 173×10^3 m^3
- Embankment : 330×10^3 m^3

The number of heavy equipment required for the above earthwork was estimated through the following formula:

$$N = V/(W \times T)$$

where, N: Number of heavy equipment required for earthwork
V: Annual earthwork volume
W: Hourly work ability of heavy equipment
T: Total work hours of heavy equipment in a year
(= 7 hours/day x 6 months x 26 days = 1,092 hours)

As the results of the above estimation, the following heavy equipment are roughly anticipated (Ref. Table 66 for details):

- Back hoe for excavation and loading: 2 units
- Dump truck for transportation : 30 units
- Bulldozer for excavation : 9 units
- Wheel loader for loading : 9 units
- Bulldozer for spreading and compaction : 8 units

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TABLES

Table 1 CATCHMENT AREA OF EACH RIVER SYSTEM IN MAJOR RIVER BASINS

Name of River Basin	Name of River System	Catchment Area (km^2)	
Perlis	Gial (including Arau)	238	(Arau: 104)
	Korok, Baharn, etc.	271	
	Temenggong	87	
	Arau Canal	68	
	Perlis lower reaches	46	
	Others	80	
	Total	790	
Kedah	Pdg. Terap (upper from K. Nerang)	987	(Pedu: 533)
	Pdg. Terap (lower from K. Nerang)	849	
	Tajar and Pedang	812	
	Kedah lower reaches	412	
	Others	635	
	Total	3,695	
Muda	Muda (upper from Muda Dam)	984	
	Muda (Barrage - Muda Dam)	1,408	
	Ketil	884	
	Sedim	522	
	Others	502	
	Total	4,300	
Perai	Kereh	186	
	Kulim	177	
	Perai	87	
	Others	445	
	Total	895	
Pinang	Ayer Terjun	11	
	Ayer Itam and Dongdang	34	
	Pinang and Jultong	21	
	Total	66	

Table 2 EXISTING CHANNEL WIDTHS OF MAJOR RIVERS

Name of River	No.	Location: River System	Location: Specific Point	Distance from River Mouth (km)	Channel Width (m)	Shape of Cross Section
Perlis	1	Perlis	Kangar City	9 - 11	30 - 50	U-Shape Single Section
	2	Korok	—	9 - 19	10	U-Shape Single Section
	3	Arau Canal	—	11 - 16	4 (low) 14 (high)	U-Shape Double Section
	4	Arau	—	11 - 20	5	U-Shape Single Section
Kedah	1	Kedah	Alor Setar	13	110	U-Shape Single Section
	2	Pdg. Terap	Pelubang Barrage/1	37	60	V-Shape Single Section
	3	Pdg. Terap	K. Nerang	61	30	V-Shape Single Section
Muda	1	Muda	Muda Barrage/2	8	100	U-Shape Single Section
	2	Muda	State Border	25	80	U-Shape Single Section
	3	Ketil	K. Ketil	43	80	U-Shape Single Section
Perai	1	Perai	Perai Barrage/3	8	60	U-Shape Single Section
	2	Kulim	—	24	10	U-Shape Single Section
Pinang	1	Pinang	Georgetown	2	10	U-Shape Single Section
	2	Ayer Terjun	—	3	5	U-Shape Single Section
	3	Ayer Itam	—	3	7	U-Shape Single Section
	4	Jultong	Diversion Channel	0 - 2	6/4	Box Culvert

Remarks; /1, /2 and /3: Channel just upstream of the barrage
/4: Box Culvert with the size of 20' x 20'

Table 3 ESTIMATION OF EXISTING RIVER CHANNEL FLOW CAPACITY

Name of River	Location No./1	B (m)	H (m)	S (m)	A (m^2)	R (m)	I	Vmax (m/s)	Qmax (m^3/s)
Perlis	1	30.0	3.0	36.0	90.0	2.5	1/6,000	0.8	72.0
	2	10.0	2.0	14.0	20.0	1.4	1/1,800	1.0	20.0
	3	See Remarks/2		20.4	24.0	1.2	1/2,500	0.8	19.0
	4	5.0	2.5	10.0	12.5	1.3	1/2,500	0.8	10.0
Kedah	1	110.0	4.0	119.0	440.0	4.0	1/10,000	0.8	352.0
	2	60.0	6.0	61.2	180.0	2.9	1/4,500	1.0	180.0
	3	30.0	8.0	34.0	120.0	3.5	1/3,000	1.4	168.0
Muda	1	100.0	4.0	108.0	400.0	3.7	1/7,000	1.0	400.0
	2	80.0	4.0	88.0	320.0	3.6	1/6,200	1.0	320.0
	3	80.0	3.0	86.0	240.0	2.8	1/5,800	0.9	216.0
Perai	1	60.0	2.0	64.0	120.0	1.9	1/7,000	0.6	72.0
	2	10.0	3.0	16.0	30.0	1.9	1/4,500	0.8	24.0
Pinang	1	10.0	3.0	16.0	30.0	1.9	1/8,000	0.6	18.0
	2	5.0	2.0	9.0	10.0	1.1	1/3,300	0.6	6.0
	3	7.0	3.0	13.0	21.0	1.6	1/4,500	0.7	15.0

Remarks; /1: Ref. Location No. in Table 2

/2: Low water channel width and height = 4 and 3 m
High water channel width and height = 14 and 1 m
High water channel bank slope = 1:2

B = Channel Width; H = Effective Depth; S = Wetted Perimeter;
A = Cross Sectional Area of River; R = Hydraulic Mean Depth;
I = Water Surface Slope; Vmax = Maximum Water Velocity;
Qmax = River Flow Capacity

Table 4 RELATIONSHIP BETWEEN RIVER CHANNEL FLOW CAPACITY AND CATCHMENT AREA

Name of River	Location No./1	River Channel Flow Capacity (m^3/s)	Catchment Area (km^2)	Specific Discharge ($m^3/s/km^2$)
Perlis	1	72.0	596	0.12
	2	20.0	234	0.09
	3	19.0	220	0.06
	4	20.0	104	0.19
Kedah	1	352.0	2,648	0.13
	2	180.0	1,184	0.15
	3	168.0	987	0.17
Muda	1	400.0	3,099	0.13
	2	320.0	2,844	0.11
	3	144.0	884	0.16
Perai	1	72.0	414	0.17
	2	24.0	54	0.44
Pinang	1	18.0	66	0.27
	2	6.0	11	0.55
	3	15.0	34	0.44

Remarks; /1: Refer to Location No. of Table 2

Table 5 EXISTING RIVER FACILITIES

Name of River	Name of Facilities	Purpose	Structure
Kedah	1. Tidal Barrage	IR	Gate: 53' width x 7 gates Levee Crown Level: R.L. + 13'.50" Bed Level: R.L. - 12'.00"
	2. Pelubang Barrage	IR	
	- Main Barrage		Gate: 17'.70" width x 5 gates Bank Level: R.L. 17'.80" Bed Level: R.L. 7'.30"
	- Spillway		Bank Level: R.L. 32'.55" Bed Level: R.L. 9'.05"
	3. Pedu Dam	IR	Catchment Area: 171 km^2 Gross Storage Volume: 1,087 x 10^6 m^3 Active Storage Volume: 864 x 10^6 m^3
Muda	1. Muda Tidal Barrage	IR, WS	Gate: 40' width x 6 gates Max. Flood Release Capacity: 156 x 10^3 gal/s (709 m^3/s)
	2. Muda Dam	IR	Catchment Area: 984 km^2 Gross Storage Volume: 156 x 10^6 m^3 Active Storage Volume: 123 x 10^6 m^3
Perai	1. Perai Barrage	DR	Gate: 40' width x 4 gates Levee Crown Level: R.L. 6'.00" Bed Level: R.L. - 25'.00"
Pinang	1. Jultong Diversion	DR	Box Culvert (20' x 20')

Remarks; IR: Irrigation
WS: Water Supply
DR: Drainage

Table 6 ANNUAL FLOOD EVENTS

Year	Perlis	Kedah	Pulau Pinang
1963	Only minor flood affecting 1,000 acres of paddy	Flooding in scattered areas affecting 1,400 acres of paddy; 10 days	Flooding in central area causing damage to paddy nurseries in 30 acres
1964	Minor flooding with slight damage	Flooding for 19 days affecting 2,100 acres of paddy field	Georgetown flooded due to heavy rains. In P. Pinang, minor flooding for 3 days
1965	Minor flooding in 2 waves	Minor floods throughout the State, including Muda river	2 major floodings in Muda river. Loss to crops and livestocks: $40,000
1966	Minor flooding; no damage	Minor flooding in lowlying areas of North and South Kedah	Minor flooding in lowlying riverine area along Sg. Muda
1967	2 floods inundated Kangar town	Flooding in various areas, 2 - 5 days, no serious damage	No major floods except in low riverine areas along Sg. Muda
1968	No record	Minor floods, only slight damage to paddy	No memorable flood
1969	No memorable flood	Only minor floods with little damage	Minor flood in lowlying areas along Sg. Muda
1970	No memorable flood	Some floods in Central and South Kedah	Flooding in Wellesbey Province inundated 10,000 acres of lowlands
1971	No memorable flood	Moderate flood in Sg. Muda, Sg. Ketil, and Sg. Pdg. Terap. Muda Irrigation Scheme also inundated	Flooding in riverine area along Sg. Muda; paddy area in Sg. Tembus. Sg. Perai also flooded
1972	3 floods in Kangar area. Kangar town inundated	Flooding around K. Ketil and the confluence of Sg. Ketil and Sg. Kupang in the Muda river basin	Flooding in the lower reaches of Sg. Muda
1973	2 floods lasting 4 - 5 days; no damage recorded	Lowlying area along Sg. Muda, Pdg. Terap, and Ketil flooded	Severe flooding in the lowlying area of Sg. Muda
1974	No memorable flood	Minor flooding in lowlying land in Sg. Baru, Kota Setar	A localized flash flood in Sg. Air Terjun Area; no damage
1975	No memorable flood	Flooding in the most riverine along Padang Terap, specially in K. Nerang	Minor floods in riverine area along Sg. Muda
1976	Worst flood in 30 years. Flooding in Kangar town and in most tributaries	Few minor local floods in North Kedah. No report of damage	Flooding in riverine area of Georgetown, Butterworth and Muda irrigation area. Total damage: $550,000
1977	No memorable flood	Minor localized floods at Kuala Nalang, Pendang, Baling areas. No damage	Minor floods in riverine area of Georgetown, Bayan Baru, Butterworth. No major damage
1978	No memorable flood	Minor local flooding in Pendang district	Minor local flooding in P. Pinang Island, Butterworth. No damage
1979	No memorable flood	Local flooding in Padang Terap and Kota Setar districts	Minor local floodings in Georgetown, Butterworth and Bukit Mertajam areas
1980	No memorable flood	Flooding at the riverine areas of the Muda river basin affecting 1,352 houses	Severe flooding at the lowlying riverine areas of the Muda river basin due to the overflow affecting 434 houses and 400 acres of paddy field
1981	No memorable flood	No memorable flood	No memorable flood
1982	Flooding in various areas for 3 - 9 days, causing paddy field damage of M$102,500 and road inundation of total length of 13,847 m	No memorable flood	No memorable flood

Source; Ref. 1C

Table 7 FLOODED AREA BY DURATION BY DEPTH OF FLOODING

River Basin	Flood Event	Duration (Days)	Depth (m)	Area (km^2)
Perlis	Sep. 1976	3 - 4	0.5 - 1.5	17.7
		3 - 4	1.0 - 1.5	10.6
		More than 7	0.5 - 1.5	20.9
	Total			49.2
	Jul. 1982	3 - 4	0.5 - 1.5	7.6
		3 - 4	1.0 - 1.5	12.5
		More than 7	0.5 - 1.5	15.3
	Total			35.4
	Sep. 1972	More than 7	Less 0.5	0.5
		More than 7	0.5 - 1.0	3.0
		More than 7	1.0 - 1.5	0.7
		More than 7	1.0 - 2.0	1.8
	Total			6.0
Kedah	Dec. 1975	3 - 4	1.0 - 2.0	4.9
		3 - 4	2.0 - 3.0	24.4
		3 - 4	More than 3	40.2
	Total			69.5
	Nov. 1978	1 - 2	0.5 - 1.0	3.7
		1 - 2	1.0 - 2.0	12.8
	Total			16.5
	Oct. 1980	1 - 2	0.5 - 1.0	0.7
Muda	Dec. 1973	3 - 4	1.0 - 2.0	98.1
		More than 7	0.5 - 1.0	44.4
	Total			142.5
	Nov. 1972	1 - 2	1.0 - 2.0	10.9
		5 - 7	1.0 - 2.0	7.9
		More than 7	0.5 - 1.0	18.3
	Total			37.1
	Oct. 1980	1 - 2	0.5 - 1.0	2.4
		2 - 3	0.5 - 1.0	7.9
		More than 7	0.5 - 1.0	9.8
	Total			20.1
Perai	Nov. 1970	3 - 4	0.5 - 1.0	17.0
P. Pinang	Oct. 1980	1 - 2	0.5 - 1.0	2.0

Table 8 FLOOD AREA BY LAND USE (1/5)

	Perlis River - Sep. 1976 Flood			
Area No.	1	2	3	
Flood Depth (m)	0.5 - 1.5	1.0 - 1.5	0.5 - 1.5	
Flood Duration (days)	7	3 - 4	3 - 4	Total
Flood Area (km^2)				
- Urban Area	3.1	0	0	3.1
- Mining	0	0	0.9	0.9
- Mixed Horticulture	3.7	3.5	1.6	8.8
- Rubber	0	0	2.2	2.2
- Paddy	12.7	7.1	12.5	32.3
- Forest, Grassland, Swamp	1.4	0	0.5	1.9
Total	20.9	10.6	17.7	49.2

	Perlis River - Jul. 1982 Flood			
Area No.	1	2	3	
Flood Depth (m)	0.5 - 1.5	1.0 - 1.5	0.5 - 1.5	
Flood Duration (days)	More than 7	3 - 4	3 - 4	Total
Flood Area (km^2)				
- Urban Area	3.1	0	0	3.1
- Mining	0	0	0.3	0.3
- Mixed Horticulture	2.8	3.5	1.3	7.6
- Rubber	0	0	1.4	1.4
- Paddy	8.8	9.0	4.3	22.1
- Forest, Grassland, Swamp	0.6	0	0.3	0.9
Total	15.3	12.5	7.6	35.4

Table 9 FLOOD AREA BY LAND USE (2/5)

	Perlis River - Sep. 1972 Flood				
Area No.	1	2	3	4	
Flood Depth (m)	0.5	0.5 - 1.0	1.0 - 1.5	1.0 - 2.0	
Flood Duration (days)	7	7	7	7	Total
Flood Area (km²)					
- Urban Area	0	2.5	0.6	0	3.1
- Mixed Horticulture	0.1	0.1	0	0.7	0.9
- Rubber	0	0	0	0.1	0.1
- Paddy	0.4	0.4	0.1	1.0	1.9
Total	0.5	3.0	0.7	1.8	6.0

	Kedah River - Dec. 1975 Flood			
Area No.	1	2	3	
Flood Depth (m)	1.0 - 2.0	2.0 - 3.0	3	
Flood Duration (days)	3 - 4	3 - 4	3 - 4	Total
Flood Area (km²)				
- Urban Area	0	0	0.7	0.7
- Mixed Horticulture	0	0	2.0	2.0
- Rubber	0	7.3	0	7.3
- Paddy	2.5	0.5	3.2	6.2
- Mining	0	0	4.9	4.9
- Forest, Grassland, Swamp	0	4.3	9.8	14.1
Total	2.5	12.1	20.6	35.2

Table 10 FLOOD AREA BY LAND USE (3/5)

	Kedah River - Nov. 1979 Flood			
Area No.	1	2	3	
Flood Depth (m)	0.5 - 1.0	1.0 - 2.0	1.0 - 2.0	
Flood Duration (days)	1 - 2	1 - 2	1 - 2	Total
Flood Area (km^2)				
- Urban Area	0	0	0.7	0.7
- Mixed Horticulture	0	0	1.5	1.5
- Rubber	0	1.2	3.1	4.3
- Paddy	3.7	0	2.0	5.7
- Forest, Grassland, Swamp	0	0	4.3	4.3
Total	3.7	1.2	11.6	16.5

	Kedah River Oct. 1980 Flood	Muda River - Dec. 1973 Flood			
Area No.	1	1	2	3	
Flood Depth (m)	0.5 - 1.0	0.5 - 1.0	1.0 - 2.0	1.0 - 2.0	
Flood Duration (days)	1 - 2	7	3 - 4	3 - 4	Total
Flood Area (km^2)					
- Urban Area	0.7	0	0.7	0.3	1.0
- Mixed Horticulture	0	1.4	6.6	14.4	22.4
- Rubber	0	8.5	27.4	9.7	45.6
- Oil Palm	0	1.0	0	0	1.0
- Coconuts	0	1.0	0	0	1.0
- Paddy	0	8.2	22.3	10.0	60.5
- Forest, Grassland, Swamp	0	5.3	2.6	3.1	11.0
Total	0.7	44.4	59.6	38.5	142.5

Table 11 . LOOD AREA BY LAND USE (4/5)

	Muda River - Nov. 1972 Flood				
Area No.	1	2	3	4	
Flood Depth (m)	0.5 - 1.0	1.0 - 2.0	1.0 - 2.0	1.0 - 2.0	
Flood Duration (days)	7	5 - 7	1 - 2	1 - 2	Total
Flood Area (km^2)					
- Urban Area	0	0.7	0.3	0	1.0
- Mixed Horticulture	1.6	2.0	0	0	3.6
- Rubber	1.0	5.2	1.0	0	7.2
- Paddy	12.8	0	5.3	2.4	20.5
- Forest, Grassland, Swamp	2.9	0	0	2.0	4.9
Total	18.3	7.9	6.6	4.4	37.2

	Muda River - Oct. 1980 Flood			
Area No.	1	2	3	
Flood Depth (m)	0.5 - 1.0	0.5 - 1.0	0.5 - 1.0	
Flood Duration (days)	7	2 - 3	1 - 2	Total
Flood Area (km^2)				
- Urban Area	0	0.7	0.3	1.0
- Mixed Horticulture	0	1.5	0.6	2.1
- Rubber	0	5.7	0	5.7
- Paddy	6.3	0	1.5	7.8
- Forest, Grassland, Swamp	3.5	0	0	3.5
Total	9.8	7.9	2.4	20.1

Table 12 FLOOD AREA BY LAND USE (5/5)

	Perai Nov. 1970 Flood	Pinang Oct. 1970 Flood
Area No.	1	1
Flood Depth (m)	0.5 - 1.0	0.5 - 1.0
Flood Duration (days)	3 - 4	1 - 2
Flood Area (km^2)		
- Urban Area	1.2	2.0
- Coconuts	2.2	0
- Other Crops	0.8	0
- Paddy	0.4	0
- Forest, Grassland, Swamp	12.8	0
Total	17.4	2.0

Table 13 PRESENT POPULATION AFFECTED BY FLOOD (AS OF 1982)

River Basin	Flood Scale	Flood Area Urban (km^2)	Flood Area Rural (km^2)	Population Affected by Flood Urban (10^3 person)	Population Affected by Flood Rural (10^3 person)	Population Affected by Flood Total (10^3 person)
Perlis	Sep. 1976	3.1	8.8	11.8	18.5	30.3
	Jul. 1982	3.1	7.6	11.8	16.0	27.8
	Sep. 1972	3.1	0.9	11.8	1.9	13.7
Kedah	Dec. 1975	0.7	2.0	3.3	4.2	7.5
	Nov. 1979	0.7	1.5	3.3	3.2	6.5
	Oct. 1980	0.7	0	3.3	0	3.3
Muda	Dec. 1973	1.0	22.4	4.7	47.0	51.7
	Nov. 1972	1.0	3.6	4.7	7.6	12.3
	Oct. 1980	1.0	2.1	4.7	4.4	9.1
Perai	Nov. 1970	1.2	0	8.2	0	8.2
Pinang	Oct. 1980	2.0	0	13.6	0	13.6

Remarks; Figures show population in 1982 which were estimated assuming the following population density:

Perlis: Urban - 38 person/ha; Rural - 21 person/ha
Kedah : Urban - 47 person/ha; Rural - 21 person/ha
Muda : Urban - 47 person/ha; Rural - 21 person/ha
Perai : Urban - 68 person/ha; Rural - 40 person/ha
Pinang: Urban - 68 person/ha; Rural - 40 person/ha

Table 14 PRESENT NUMBER OF HOUSEHOLDS AFFECTED BY FLOOD (AS OF 1982)

River Basin	Flood Scale	Number of Households Affected by Flood Urban (10^3 nos.)	Rural (10^3 nos.)	Total (10^3 nos.)
Perlis	Sep. 1976	2.5	3.9	6.4
	Jul. 1982	2.5	3.3	5.8
	Sep. 1972	2.5	0.4	2.9
Kedah	Dec. 1975	0.6	0.8	1.4
	Nov. 1978	0.6	0.6	1.2
	Oct. 1980	0.6	0	0.6
Muda	Dec. 1973	0.9	9.0	9.9
	Nov. 1972	0.9	1.5	2.4
	Oct. 1980	0.9	0.8	1.7
Perai	Nov. 1970	1.4	0	1.4
Pinang	Oct. 1980	2.4	0	2.4

Table 15 PROPORTIONAL EXTENT OF IRRIGATED PADDY AND RAINFED PADDY AREA BY BASIN

Unit: %

	Perlis	Kedah	Muda	Perai	P. Pinang
Irrigated	45	80	37	87	75
Rainfed	55	20	63	13	25

Table 16 NET PRODUCTION VALUE OF PADDY BY STATE

Unit: M$/ha

	Perlis	Kedah	P. Pinang
Irrigated	1,540	1,340	1,430
Rainfed	1,210	1,100	1,220

Table 17 FLOOD DAMAGE FACTOR OF IRRIGATED PADDY BY DEPTH OF FLOODING

Unit: %

	Less than 0.5 m	0.5 - 0.9 m	More than 1 m
Lasting for 1 - 2 days	30	33	60
Lasting for 3 - 4 days	37	40	80
Lasting for 5 - 6 days	40	43	86
Lasting for more than 7 days	45	49	96

Source; Ref. 1C

Table 18 FLOOD DAMAGE FACTOR OF RAINFED PADDY BY DEPTH OF FLOODING

Unit: %

	Less than 0.5 m	0.5 - 0.9 m	More than 1 m
Lasting for 1 - 2 days	27	30	54
Lasting for 3 - 4 days	33	36	72
Lasting for 5 - 6 days	36	39	77
Lasting for more than 7 days	41	44	86

Source; Ref. 1C

Table 19 REPLANTING COST OF YOUNG TREE

Unit: M$/ha

	Rubber	Oil Palm	Coconuts	Others
Replanting cost	3,480	2,340	4,160	4,280

Table 20 MORTALITY RATIO OF YOUNG TREES BY DURATION OF FLOODING (1/2)

Unit: %

	7 Days	14 Days	21 Days	28 Days
Rubber	5	15	60	100
Oil palm/coconuts	10	20	70	100

Source; Refs. 2 & 1C

Table 21 MORTALITY RATIO OF YOUNG TREES BY DURATION OF FLOODING (2/2)

Unit: %

	4 Days	8 Days	12 Days	16 Days
Other tree crops	10	25	60	100

Source; Ref. 2

Table 22 FLOOD DAMAGE FACTOR OF MIXED HORTICULTURE BY DURATION OF FLOODING

Unit: %

	4 Days	8 Days	12 Days	16 Days	20 Days
Flood Damage Factor	10	25	50	75	100

Source; Ref. 5

Table 23 VALUE OF HOUSE/BUILDING AND RELATED PROPERTIES

		Value
Private house in urban area	:	M$9,080/household
Private house in rural area	:	M$3,630/household
Public building	:	M$200/population
Livestock	:	M$22/household

Table 24 FLOOD DAMAGE FACTOR OF HOUSE/BUILDING BY DEPTH OF FLOODING

Unit: %

	Less than 0.25 m	0.25 m -0.5 m	0.5 m -1.0 m	1.0 m -2.0 m	2.0 m -3.0 m	More than 3.0 m
Flood damage factor	3	5	7	11	15	22

Source; Ref. 10

Table 25 FLOOD DAMAGES BY PAST MAJOR FLOOD (1/2)
(ASSUMED YEAR OF ASSETS: 1982)

Item	Perlis			Kedah		
	Sep.'76	Jul.'82	Sep.'72	Dec.'75	Nov.'79	Oct.'80
1. Flood Damage Value (M10^3)						
1) Private Housing	2,178	2,062	1,446	1,213	813	372
2) Public Housing	507	465	238	269	170	55
3) Public Facilities & Utilities	806	758	505	445	295	128
4) Livestocks	65	52	29	16	14	7
5) Agricultural Crops						
- Paddy	3,593	2,461	209	631	308	-
- Others	516	422	79	113	17	-
6) Direct Damage Total	7,665	6,220	2,506	2,687	1,617	562
7) Indirect Damage Total	2,300	1,866	752	806	485	169
8) Grand Total	9,965	8,086	3,258	3,493	2,102	731
2. People to be Affected by Flood (10^3^)	30.3	27.8	13.7	7.5	6.5	3.3
3. Flood Area (km^2)	49.2	35.4	6.0	35.2	16.5	0.7

Table 26 FLOOD DAMAGES BY PAST MAJOR FLOOD (2/2)
(ASSUMED YEAR OF ASSETS: 1982)

Item	Muda			Perai	P. Pinang
	Dec.'73	Nov.'72	Oct.'80	Sep.'71	Oct.'80
1. Flood Damage Value (M10^3)					
1) Private Housing	4,646	1,295	576	929	1,548
2) Public Housing	1,426	291	129	136	227
3) Public Facilities & Utilities	1,822	476	211	320	533
4) Livestocks	123	26	17	18	29
5) Agricultural Crops					
- Paddy	4,957	1,353	449	21	-
- Others	1,099	323	107	9	-
6) Direct Damage Total	14,073	3,764	1,489	1,433	2,337
7) Indirect Damage Total	4,222	1,129	447	430	701
8) Grand Total	18,295	4,893	1,936	1,860	3,038
2. People to be Affected by Flood (10^3)	51.7	12.3	9.1	8.2	13.6
3. Flood Area (km^2)	142.5	37.2	20.1	17.4	2.0

Table 27 AVERAGE ANNUAL GROWTH RATE OF GRP AND POPULATION

Unit: %

River Basin	Perlis	Kedah	Muda	Perai	P. Pinang
Under the Economic Growth Following 4MP					
Per capita GRP	7.10	7.10	7.10	5.07	5.07
Urban population	3.70	2.20	4.70	0.60	0.30
Rural population	1.60	0.60	0.30	0	-
Under the Lower Economic Growth					
Per capita GRP	2.94	2.94	2.94	2.50	2.50
Urban population	2.20	0.70	3.60	-0.90	-1.10
Rural population	1.60	1.00	0.60	2.00	-

Table 28 FLOOD DAMAGES BY PAST MAJOR FLOOD (ASSUMED YEAR OF ASSETS: 2000)

			Economic Growth Following 4MP		Lower Economic Growth	
River Basin	Flood Even	Flood Area (km^2)	Flood Damage Value ($M\$10^6$)	People Affected by Flood (10^3 persons)	Flood Damage Value ($M\$10^6$)	People Affected by Flood (10^3 persons)
Perlis	Sep. 1976	49.2	23.2	46.1	15.1	41.5
	Jul. 1982	35.4	20.0	43.0	12.4	38.2
	Sep. 1972	6.0	10.4	25.0	5.3	19.8
Kedah	Dec. 1975	35.2	10.0	9.5	5.6	8.7
	Nov. 1979	16.5	6.4	8.4	3.4	7.5
	Oct. 1980	0.7	2.5	4.8	1.2	3.7
Muda	Dec. 1973	142.5	46.4	60.4	28.1	61.0
	Nov. 1972	37.2	12.3	18.8	7.5	17.3
	Oct. 1980	30.1	5.1	15.4	3.0	13.8
Perai	Sep. 1971	17.4	4.5	9.2	2.2	7.0
P. Pinang	Oct. 1980	2.0	7.4	14.5	4.7	11.1

Table 29 MAXIMUM FLOOD PARAMETER VERSUS ESTIMATED RETURN PERIOD OF PAST FLOODS

River Basin	Flood Event	Maximum Flood Parameter During the Flood	Return Period (year)
Perlis	Sep. 1976	Hmax (Kangar) = 3.15 m	20.0
	Jul. 1982	Hmax (Kangar) = 3.10 m	14.0
	Sep. 1972	Hmax (Kangar) = 2.83 m	5.0
Kedah	Dec. 1975	Rmax = 167.5 mm	12.5
	Nov. 1979	Rmax = 141.4 mm	4.5
	Oct. 1980	Rmax = 129.9 mm	2.6
Muda	Dec. 1973	Qmax (Jeniang) = 679 m^3/s	40.0
	Nov. 1972	Qmax (Jeniang) = 393 m^3/s	5.0
	Oct. 1980	Qmax (Jeniang) = 359 m^3/s	3.7
Perai	Nov. 1970	Qmax (Ara Kuda) = 57.6 m^3/s	8.4
P. Pinang	Oct. 1980	Qmax (Ara Kuda) = 53.1 m^3/s	6.7

Remarks; Hmax: The maximum water stage
Rmax: The maximum 3-day rainfall in the average of 4 stations (Ref. Fig. 15) during the flood
Qmax: The maximum discharge

Table 30 PROBABLE FLOOD DAMAGE

River Basin	Return Period (year)	Flooded Area (km^2)	1982 People Affected (10^3)	1982 Flood Damage ($M\$10^6/y$)	2000 Following 4MP People Affected (10^3)	2000 Following 4MP Flood Damage ($M\$10^6/y$)	2000 Lower Growth People Affected (10^3)	2000 Lower Growth Flood Damage ($M\$10^6/y$)
Perlis	5	6	13.7	3.3	25.0	10.4	19.8	5.3
	10	25	23.0	6.3	38.0	18.0	33.0	10.0
	20	49	30.3	9.9	46.1	23.2	41.5	15.1
	50	84	37.5	14.6	52.0	30.4	47.5	22.0
	Average	8.0	6.8	2.3	11.3	6.4	9.4	3.6
Kedah	5	8	6.6	2.4	8.5	6.3	7.6	3.6
	10	31	7.3	3.2	9.4	9.2	8.5	5.1
	20	43	7.7	3.7	9.7	11.6	9.0	6.6
	50	54	8.2	4.4	10.2	14.8	9.5	8.7
	Average	7.5	2.7	1.3	3.4	3.8	3.1	2.0
Muda	5	37	12.3	4.9	18.8	12.3	17.3	7.5
	10	72	25.0	9.4	33.0	24.0	32.0	14.5
	20	106	38.0	14.0	47.0	35.0	47.0	21.5
	50	134	56.5	20.0	65.0	50.0	66.0	30.5
	Average	21.3	7.6	3.3	10.3	8.3	10.0	5.0
Perai	5	11	5.2	1.1	6.0	2.9	4.6	1.5
	10	19	9.0	2.0	10.0	5.0	7.7	2.5
	20	28	12.6	2.8	14.4	7.2	11.0	3.5
	50	38	17.5	4.0	20.0	10.0	15.0	4.9
	Average	6.2	2.8	0.7	3.3	1.8	2.5	0.9
P. Pinang	5	2	9.2	2.2	10.0	5.7	9.0	3.6
	10	4	15.8	4.0	17.4	10.0	13.2	6.2
	20	5	22.2	5.8	25.0	14.1	19.0	8.8
	50	6	30.4	8.2	33.0	22.0	26.5	12.2
	Average	1.1	5.0	1.4	5.4	3.6	4.7	2.3

Table 31 RIVER STRETCHES DIVIDED FOR FLOOD MITIGATION PLAN

River Basin	River Stretch No.	River System	Location of River Stretch	River Stretch Length (km)	Catchment Area (km^2)
Perlis	P1	Perlis	K. Perlis - Kangar	10	596
	P2	Perlis	Kangar	3	509
	P3	Kechor	Upper stream from Kangar	27	234
	T1	Temenggong	Downstream of Temenggong	19	87
	G1	Gial	Downstream of Gial	5	238
	G2	Gial	Upper stream from junction of Arau river	18	116
	A1	Arau	Downstream of Arau	16	104
Kedah	K1	Pdg. Terap	Alor Setar - Pelubang barrage	36	1,836
	K2	Pdg. Terap	Pelubang barrage - K. Nerang	16	1,184
	K3	Pdg. Terap	Upper stream from K. Nerang	28	454
Muda	M1	Muda	Muda barrage - Railway bridge	15	4,000
	M2	Muda	Railway bridge - Kg. K. Sedim	20	4,000
	M3	Muda	Kg. K. Sedim - K. Ketil	16	3,276
	M4	Muda	Upper stream from K. Ketil	95	2,392
	K1	Ketil	K. Ketil - Kupang	35	884
	K2	Kupang	Downstream of Kupang	13	159
Perai	P1	Perai	Butterworth - Perai barrage	10	474
	P2	Perai	Upper stream from Perai	8	414
P. Pinang	P1	P. Pinang	River mouth	2.4	66

Table 32 SIZE OF EXISTING RIVER CHANNEL

River Basin	Stretch No.	Stretch Length (km)	Existing Channel Width (m)	Existing Channel Depth (m)	Existing Channel Bed Slope	Shape of Cross Section
Perlis	P1	10	30	3.0	1/6,000	U-Shape Single Section
	P2	3	30	3.0	1/6,000	U-Shape Single Section
	P3	17	10	2.0	1/1,800	U-Shape Single Section
	T1	5	5	2.5	1/2,500	U-Shape Single Section
	G1	5	5	2.0	1/2,500	U-Shape Single Section
	G2	4	5	2.5	1/2,500	U-Shape Single Section
	A1	4	5	2.5	1/2,500	U-Shape Single Section
Kedah	K1	15	110	4.0	1/10,000	U-Shape Single Section
	K2	10	60	6.0	1/4,500	V-Shape Single Section
	K3	10	30	8.0	1/3,000	V-Shape Single Section
Muda	M1	15	100	4.0	1/7,000	U-Shape Single Section
	M2	20	100	4.0	1/7,000	U-Shape Single Section
	M3	16	80	4.0	1/6,200	U-Shape Single Section
	M4	40	80	3.0	1/5,800	U-Shape Single Section
	K1	35	80	3.0	1/5,800	U-Shape Single Section
	K2	10	20	3.0	1/5,800	U-Shape Single Section
Perai	P1	10	60	3.0	1/7,000	U-Shape Single Section
	P2	8	30	2.0	1/4,500	U-Shape Single Section
P. Pinang	P1	2.4	10	3.0	1/8,000	U-Shape Single Section

Table 33 STANDARD PROJECT FLOOD

River Basin	River Stretch No.	Standard Project Flood (m^3/s) 5-Year	10-Year	20-Year	50-Year
Perlis	P1	210	250	290	340
	P2	190	230	260	310
	P3	100	120	150	170
	T1	50	56	70	90
	G1	110	120	150	180
	G2	60	70	90	110
	A1	56	60	80	100
Kedah	K1	500	600	650	740
	K2	360	440	500	550
	K3	170	200	240	280
Muda	M1	900	1,100	1,200	1,250
	M2	900	1,100	1,200	1,250
	M3	750	980	1,000	1,100
	M4	600	750	800	890
	K1	280	340	380	440
	K2	70	80	100	140
Perai	P1	180	210	250	290
	P2	160	190	220	260
P. Pinang	P1	42	45	60	75

Table 34 POTENTIAL DAM SITES BY PREVIOUS STUDIES

River Basin	River System	Name of Dam	Catchment Area (km^2)	Max. Storage Capacity (10^6 m^3)	Construction Cost/1 (M$$10^6$)	Proposed/2
Perlis	Korok	Timah Tasoh	150	38	29.5	FM, IR
	Gial	Buloh	13	-	-	FM
	Gial	Serai	10	-	-	FM
	Arau	Arau	50	39	29.2	FM, IR
Kedah	Bata	Tok Kassim	14	-	-	IR
	Bata	Badak-Temin	114	140	21.3	IR, HY
	Pdg. Terap	Sari	61	75	23.8	IR, HY
	Pdg. Terap	Agon	25	-	-	IR
	Pdg. Terap	Durian	75	90	25.5	IR, HY
	Pdg. Terap	Ahning	120	200	59.0	IR, HY
	Pdg. Terap	Ketil	19	-	-	IR
	Pdg. Terap	Kah Lng	18	-	-	IR
	Pedu	Ayan	16	-	-	IR
Muda	Muda	Tawar-Muda	135	130	37.9	IR, HY
	Muda	Sungei Ma	24	-	-	IR
	Muda	Beris	115	80	19.0	IR, HY
	Muda	Charok Sama Gajah	23	-	-	IR
	Muda	Kerik	20	-	-	IR
	Muda	Charok Kasai	10	-	-	IR
	Chepir	Weng	37	-	-	IR, HY
	Chepir	Legong	44	-	-	IR, HY
	Chepir	Charok Tebor	38	-	-	IR, HY
Perai	Kulim	Mengkuang	3.9	-	-	WS

Remarks; /1: The cost (except for the Arau and Ahning dams) was estimated by updating the 1980's price reported by "Kedah-Perlis Water Resources Management Study, 1981" to the price level with 8% escalation per annum, excluding the hydropower cost.
Figures for the Ahning dam are taken from Ref. 21.
The cost for Arau dam was estimated based on the 1980's price reported by the Sectoral Report of Vol. 16, "National Water Resources Study, Malaysia" with same procedure as the above.

/2: FM = Flood Mitigation; IR = Irrigation; HY = Hydropower

Table 35 TYPICAL CROSS SECTION FOR DESIGN OF RIVER CHANNEL (1/2)

River Basin	River Stretch No.	Design Flood (m^3/s)	H (m)	B1 (m)	B2 (m)	B3 (m)	A (m)
Perlis	P1	340	4.0	78	90	96	336
		250	4.0	57	69	75	252
		170	4.0	38	50	56	176
	P2/B1/B2	310	4.0	71	83	89	308
		180	4.0	41	53	59	188
		60	4.0	12	24	30	72
	P3	170	3.5	26	37	42	109
		100	3.5	15	26	31	71
		60	3.5	8	19	24	46
	G1	180	4.0	25	38	44	128
		130	4.0	18	30	36	96
		100	4.0	13	25	31	76
	G2	110	3.0	26	35	41	92
		90	3.0	21	30	27	77
		60	3.0	14	23	20	56
	A1	100	3.0	23	33	39	86
		60	3.0	14	23	29	56
		40	3.0	9	18	24	41
	T1	90	3.0	21	30	36	77
		70	3.0	16	25	31	62
		50	3.0	11	20	26	47
Kedah	K1	740	5.0	151	166	174	793
		600	5.0	123	138	146	653
		450	5.0	92	107	113	498
	K2	550	5.0	75	90	98	413
		440	5.0	60	75	81	338
		320	5.0	43	58	64	253
	K3	280	4.0	45	57	63	204
		200	4.0	32	44	50	152
		120	4.0	18	30	36	96

Remarks; B1: Bypass floodway of P2
B2: Bypass floodway of G1

For dimension symbols, see Fig. 32.

Table 36 TYPICAL CROSS SECTION FOR DESIGN OF RIVER CHANNEL (2/2)

River Basin	River Stretch No.	Design Flood (m^3/s)	H (m)	B1 (m)	B2 (m)	B3 (m)	A (m)
Muda	M1, M3	1,250	5.0	214	229	237	1,108
		1,070	5.0	183	198	206	953
		870	5.0	149	164	172	783
	M3	1,100	5.0	177	192	200	923
		940	5.0	151	166	174	793
		720	5.0	116	131	139	618
	M4	890	4.5	165	180	188	777
		750	4.5	139	153	161	656
		570	4.5	106	120	128	507
	K1	440	4.0	99	111	117	420
		380	4.0	85	97	103	364
		280	4.0	63	75	81	276
	K2	140	3.5	39	50	56	156
		100	3.5	37	38	44	114
		70	3.5	18	29	35	82
Perai	P1	290	4.0	71	84	90	312
		250	4.0	62	74	80	272
		180	4.0	44	56	62	200
	P2	260	3.5	64	76	81	246
		220	3.5	54	65	70	207
		160	3.5	39	50	55	155
Pinang	P1	75	3.0	32	41	47	110
		60	3.0	25	34	40	89
		42	3.0	17	26	32	65

Remarks; For dimension symbols, see Fig. 32.

Table 37 REQUIRED LENGTH OF RIVER CHANNEL IMPROVEMENT AND BYPASS CHANNEL

Unit: km

River Basin	Alternative No.	River Stretch No.	10-Year Flood	20-Year Flood	50-Year Flood
Perlis	1, 3	P1	10	10	10
		P2	3	3	3
		P3	17	17	17
		G1	5	5	5
		G2	4	4	4
		A1	4	4	4
		T1	5	5	5
Perlis	2, 4	P1	10	10	10
		P2	-	-	-
		B1	6	6	6
		P3	15	15	15
		G1	-	-	-
		G2	4	4	4
		A1	4	4	4
		T1	5	5	5
		B2	16	16	16
Kedah	1, 2	K1	5	15	15
		K2	5	10	10
		K3	8	10	10
Muda	1	M1	15	15	15
		M2	20	20	20
		M3	5	16	16
		M4	20	40	40
		K1	5	35	35
		K2	5	10	10
Perai	1	P1	10	10	10
		P2	8	8	8
	2	P1 /1	-	-	-
		P2 /1	-	-	-
P. Pinang		P1	2.4	2.4	2.4

Remarks; /1: As to Alternative 2, the river channel improvement is not required.

Table 38 NEW BRIDGE REQUIRED BY RIVER CHANNEL IMPROVEMENT

River Basin	River Stretch No.	Number of Bridge	River Basin	River Stretch No.	Number of Bridge
Perlis	P1	1	Muda	M1	2
	P2	3		M2	1
	P3	4		M3	4
	G1	2		M4	1
	G2	0		K1	1
	A1	1		K2	0
	T1	1	Perai	P1	4
Kedah	K1	4		P2	1
	K2	2	Pinang	P1	6
	K3	1			
	P1	1			

Table 39 UNIT COST OF CONSTRUCTION FOR RIVER CHANNEL IMPROVEMENT

Item	Unit Cost	Source
Earth Works		
- Excavation	M$2.5/m^3	DID Quantity Surveyor
- Embankment	M$4.0/m^3	DID Quantity Surveyor
Sod Facing	M$2.7/m^2	Ref. 1C
Levee Road Pavement	M$8.6/m^2	Ref. 1c
Bridge	M$1,350/m^2	Ref. 10
Weir	M$20,000/m^2	Standard Price in Japan

Remarks; 1982's value

Table 40 UNIT COST OF COMPENSATION FOR RIVER CHANNEL IMPROVEMENT

Item	Unit	State					Source
		Perlis	Kedah	Muda	Perai	Pinang	
Paddy Land (Irrigated)	$M\$10^3$/ha	33	43	43	35	-	Ref. 8
Other Crop Land	$M\$10^3$/ha	26	29	29	34	-	Ref. 8
Forest Land	$M\$10^3$/ha	5	5	5	5	-	Ref. 1c
Residential Land (Urban)	$M\$10^3$/ha	861 (Kangar)	1,076 (Alor Setar)	-	2,153 (Butter-worth) 607 (Extention of Butter-worth)	2,578 (Pinang)	Ref. 8
Residential Land (Suburbs)	$M\$10^3$/ha	107	127	54	215	-	Ref. 8
House (Urban)	$M\$10^3$/House	59.9 (Kangar)	93.5 (Alor Setar) 62.2 (Jitra, K. Nerang)	-	61.7	114.0	Ref. 8
House (Suburbs)	$M\$10^3$/House	20.0	20.0	20.0	20.0	-	Ref. 1c

Remarks; 1982's value

Table 41 CONSTRUCTION COST FOR CHANNEL IMPROVEMENT WITHOUT DAM

Unit: M$10^6

River Stretch	10-Year Flood Con-struction	10-Year Flood Compen-sation	10-Year Flood Total	20-Year Flood Con-struction	20-Year Flood Compen-sation	20-Year Flood Total	50-Year Flood Con-struction	50-Year Flood Compen-sation	50-Year Flood Total
Perlis Alternative 1: Without Bypass Floodway									
P1	7.1	0.7	7.8	9.4	0.8	10.2	9.9	1.0	10.9
P2	3.8	15.9	19.7	4.6	18.8	23.4	4.8	23.4	28.2
P3	8.2	1.3	9.5	8.4	1.4	9.8	10.8	1.5	12.3
T1	1.7	0.3	2.0	2.0	0.3	2.3	2.2	0.4	2.6
G1	2.7	0.3	3.0	3.1	0.4	3.5	3.9	0.5	4.4
G2	1.3	0.2	1.5	1.4	0.3	1.7	2.0	0.5	2.5
A1	1.4	0.3	1.7	1.6	0.4	2.0	2.3	0.4	2.7
Perlis Alternative 2: With Bypass Floodways									
P1	5.6	0.5	6.1	7.1	0.6	7.7	8.6	0.7	9.3
P2	-	-	-	-	-	-	-	-	-
B	4.7	0.7	5.4	5.7	1.0	6.7	9.2	4.3	13.5
P3	8.2	1.3	9.5	8.4	1.4	9.8	10.8	1.5	12.3
T1	1.7	0.3	2.0	2.0	0.3	2.3	2.2	0.4	2.6
G1	-	-	-	-	-	-	-	-	-
G2	1.3	0.2	1.5	1.4	0.3	1.7	2.0	0.5	2.5
A1	1.4	0.3	1.7	1.6	0.4	2.0	2.3	0.4	2.7
C	6.6	1.1	7.7	9.6	1.3	10.9	12.2	1.6	13.8
Kedah									
K1	2.3	4.6	6.9	23.2	5.9	29.1	28.7	8.1	36.8
K2	4.3	0.1	4.4	10.7	0.2	10.9	12.4	0.3	12.7
K3	3.1	0.3	3.4	5.2	0.3	5.5	6.0	0.4	6.4
Muda									
M1	9.3	2.1	11.4	28.3	3.4	31.7	30.1	5.0	35.1
M2	15.3	1.2	16.5	30.2	2.6	32.8	33.1	4.2	37.3
M3	6.5	0.4	6.9	21.9	1.9	23.8	28.2	2.2	30.4
M4	29.7	3.5	33.2	34.0	3.9	37.9	47.3	4.5	51.8
K1	1.1	0.2	1.3	10.5	0.6	11.1	17.8	0.9	18.7
K2	0.8	0.1	0.9	2.0	0.4	2.4	3.2	0.9	4.1
Perai Alternative 1: Without Retarding Basin									
P1	6.8	8.4	15.2	7.9	17.3	25.2	9.6	26.0	35.6
P2	5.4	0.1	5.5	5.9	0.2	6.1	7.1	0.2	7.3
Pinang									
P1	2.5	22.1	24.6	2.9	28.5	31.4	3.7	34.9	38.6

Remarks; No channel improvement is provided for Perai Alternative 2: with retarding basin.

Table 42 CONSTRUCTION COST FOR CHANNEL IMPROVEMENT WITH DAM

Unit: $M\$10^6$

Alternative	Stretch	Construction	Compensation	Total
Perlis Alternative 3: With Timah-Tasoh & Arau without bypass floodway	P1	9.2	0.8	10.0
	P2	0.5	17.9	18.4
	P3	8.7	1.0	9.7
	T1	2.2	0.4	2.6
	G1	2.7	0.4	3.1
	G2	2.0	0.5	2.5
	A1	1.2	0.3	1.5
Perlis Alternative 4: With Timah-Tasoh & Arau with bypass floodway	P1	6.1	0.5	6.6
	P2	-	-	-
	B1	2.8	0.8	3.6
	P3	8.7	1.0	9.7
	T1	2.2	0.4	2.6
	G1	-	-	-
	G2	2.0	0.5	2.5
	A1	1.1	0.4	1.5
	B2	9.5	1.4	10.9
Kedah with Badak-Temin, Sari, Durian & Ahning	K1	24.4	6.4	30.8
	K2	10.0	0.2	10.2
	K3	3.8	0.3	4.1
Kedah with Badak-Temin	K1	24.7	7.6	32.3
	K2	12.4	0.3	12.7
	K3	6.0	0.4	6.4
Kedah with Sari, Durian & Ahning	K1	25.9	6.9	32.8
	K2	10.0	0.2	10.2
	K3	3.8	0.3	4.1

Table 43 STORAGE VOLUME OF RETARDING BASIN REQUIRED

Return Period (Year)	Design Flood Discharge (m^3/s)	Required Storage Volume of Retarding Basin (10^6 m^3)	Required Raising Height of Existing Band (m)
10	190	10.2	0.1
20	220	14.6	0.6
50	260	20.0	1.2

Table 44 CONSTRUCTION COST OF RETARDING BASIN

Return Period (Year)	Required Raising Height of Existing Band (m)	Required Banking Volume (10^3 m^3)	Construction Cost (M$$10^3$)	Compensation (M$$10^3$)	Total Cost (M$$10^3$)
10	0.1	36.0	206	4,500	4,706
20	0.6	61.5	352	4,500	4,852
50	1.2	141.0	806	4,500	5,306

Table 45 CONSTRUCTION COST OF DAM ALLOCATED FOR FLOOD MITIGATION

River Basin	Dam Name	Catchment Area (km^2)	Flood Storage (10^6 m^3)	Allocated Construction Cost (M$$10^6$)		
				Construction	Compensation	Total
Perlis	Timah-Tasoh	150	15	8.8	2.8	11.6
	Arau	50	5	2.6	1.1	3.7
	Total	200	20	11.4	3.9	15.3
Kedah	Ahning	120	12	1.7	0.2	1.9

Table 46 ANNUAL AVERAGE OF FLOODED AREA

Unit: km^2

River System	River Stretch	Without Development	With Development 10-year	20-year	50-year
Perlis	P1	1.0	0.7	0.4	0.3
	P2	1.1	0.8	0.4	0.3
	P3	3.8	3.3	2.8	2.2
	T1	0.6	0.6	0.4	0.4
	G1	0.8	0.6	0.4	0.2
	G2	0.3	0.3	0.2	0.2
	A1	0.4	0.3	0.3	0.2
Kedah	K1	1.0	0.8	0.7	0.6
	K2	2.1	1.6	1.4	1.0
	K3	4.4	3.7	3.3	2.9
Muda	M1	2.6	1.4	0.8	0.4
	M2	3.0	1.6	0.9	0.4
	M3	3.2	1.7	1.0	0.5
	M4	5.1	4.3	4.0	3.7
	K1	6.2	3.3	1.9	0.9
	K2	1.2	0.7	0.5	0.4
Perai	P1	2.0	1.1	0.8	0.4
	P2	4.2	0.5	1.6	0.9
P. Pinang	P1	1.1	0.7	0.4	0.3

Table 47 ANNUAL AVERAGE OF POPULATION AFFECTED

Unit: 10^3

River System	River Stretch	Without Development	With Development		
			10-Year	20-Year	50-Year
Perlis	P1	1.0 (0.9)	0.4 (0.4)	0.2 (0.2)	0.1 (0.1)
	P2	6.3 (5.3)	2.6 (2.4)	1.4 (1.3)	0.6 (0.6)
	P3	3.0 (2.5)	2.1 (1.8)	1.9 (1.6)	1.7 (1.4)
	T1	0.3 (0.3)	0.2 (0.2)	0.2 (0.2)	0.2 (0.2)
	G1	0.3 (0.3)	0.1 (0.1)	0.1 (0.1)	0.0 (0.0)
	G2	0.1 (0.1)	0.1 (0.1)	0.1 (0.1)	0.1 (0.1)
	A1	0.2 (0.2)	0.1 (0.1)	0.1 (0.1)	0.1 (0.1)
Kedah	K1	0.2 (0.2)	0.1 (0.1)	0.1 (0.1)	0.1 (0.1)
	K2	0.7 (0.7)	0.6 (0.6)	0.5 (0.5)	0.4 (0.4)
	K3	2.4 (2.2)	1.0 (0.9)	0.4 (0.4)	0.1 (0.1)
Muda	M1	0.5 (0.5)	0.3 (0.3)	0.2 (0.2)	0.1 (0.1)
	M2	0.7 (0.7)	0.4 (0.4)	0.2 (0.2)	0.1 (0.1)
	M3	3.7 (3.6)	1.9 (1.9)	1.2 (1.2)	0.5 (0.5)
	M4	2.8 (2.7)	2.4 (2.3)	2.4 (2.3)	2.2 (2.1)
	K1	1.9 (1.8)	1.0 (1.0)	0.6 (0.6)	0.3 (0.3)
	K2	0.7 (0.7)	0.4 (0.4)	0.3 (0.3)	0.2 (0.2)
Perai	P1	1.2 (0.9)	0.7 (0.5)	0.4 (0.3)	0.3 (0.2)
	P2	2.1 (1.6)	1.2 (0.8)	0.8 (0.6)	0.4 (0.3)
P. Pinang	P1	5.4 (4.7)	3.0 (2.4)	2.0 (1.6)	1.2 (1.0)

Remarks; 2000 population projected following 4MP. Figures between parentheses are 2000 population projected assuming the lower economic growth.

Table 48 ANNUAL EQUIVALENT OF FLOOD DAMAGE BY RIVER STRETCH

Unit: M$$10^6$/y

River System	River Stretch	Without Development	With Development 10-Year	20-Year	50-Year
Perlis	P1	0.34 (0.17)	0.11 (0.06)	0.08 (0.04)	0.04 (0.02)
	P2	2.33 (1.43)	0.78 (0.47)	0.57 (0.36)	0.21 (0.13)
	P3	0.67 (0.41)	0.31 (0.22)	0.25 (0.17)	0.23 (0.14)
	T1	0.73 (0.37)	0.51 (0.25)	0.44 (0.23)	0.39 (0.20)
	G1	0.56 (0.18)	0.29 (0.10)	0.20 (0.08)	0.13 (0.06)
	G2	0.44 (0.12)	0.23 (0.06)	0.16 (0.05)	0.10 (0.04)
	A1	0.38 (0.09)	0.16 (0.03)	0.09 (0.02)	0.03 (0.01)
Kedah	K1	0.46 (0.22)	0.18 (0.08)	0.15 (0.06)	0.11 (0.05)
	K2	0.78 (0.40)	0.29 (0.14)	0.25 (0.14)	0.19 (0.10)
	K3	2.00 (1.03)	0.75 (0.38)	0.63 (0.33)	0.48 (0.25)
Muda	M1	0.44 (0.25)	0.16 (0.10)	0.08 (0.05)	0.02 (0.01)
	M2	0.57 (0.32)	0.21 (0.13)	0.11 (0.07)	0.03 (0.02)
	M3	1.81 (1.03)	0.77 (0.39)	0.52 (0.29)	0.28 (0.16)
	M4	1.43 (0.77)	1.28 (0.69)	1.25 (0.67)	1.21 (0.65)
	K1	1.72 (0.98)	0.67 (0.33)	0.41 (0.22)	0.18 (0.10)
	K2	0.60 (0.35)	0.21 (0.07)	0.11 (0.06)	0.04 (0.02)
Perai	P1	0.42 (0.23)	0.15 (0.08)	0.08 (0.05)	0.02 (0.02)
	P2	1.18 (0.65)	0.39 (0.23)	0.20 (0.12)	0.04 (0.04)
P. Pinang	P1	3.63 (2.17)	1.53 (0.83)	0.95 (0.49)	0.36 (0.21)

Remarks; Flood damages projected following 4MP. Figures between parenthesis are flood damages projected assuming the lower economic growth.

Table 49 ANNUAL EQUIVALENT OF ECONOMIC BENEFIT BY RIVER STRETCH

Unit: M$$10^6$/y

River System	River Stretch	10-Year	20-Year	50-Year
Perlis	P1	0.23 (0.11)	0.26 (0.13)	0.30 (0.15)
	P2	1.55 (0.96)	1.76 (1.07)	2.12 (1.30)
	P3	0.36 (0.19)	0.42 (0.24)	0.44 (0.27)
	T1	0.22 (0.12)	0.29 (0.14)	0.34 (0.17)
	G1	0.27 (0.08)	0.36 (0.10)	0.43 (0.12)
	G2	0.21 (0.06)	0.28 (0.07)	0.34 (0.08)
	A1	0.22 (0.06)	0.29 (0.07)	0.35 (0.08)
Kedah	K1	0.28 (0.14)	0.31 (0.16)	0.35 (0.17)
	K2	0.49 (0.26)	0.53 (0.26)	0.59 (0.30)
	K3	1.25 (0.65)	1.37 (0.70)	1.52 (0.78)
Muda	M1	0.28 (0.15)	0.36 (0.20)	0.42 (0.24)
	M2	0.36 (0.19)	0.46 (0.25)	0.54 (0.30)
	M3	1.04 (0.64)	1.29 (0.74)	1.53 (0.87)
	M4	0.15 (0.08)	0.18 (0.10)	0.22 (0.12)
	K1	1.05 (0.65)	1.31 (0.76)	1.54 (0.88)
	K2	0.39 (0.28)	0.49 (0.29)	0.56 (0.33)
Perai	P1	0.27 (0.15)	0.34 (0.18)	0.40 (0.21)
	P2	0.79 (0.42)	0.98 (0.53)	1.14 (0.61)
P. Pinang	P1	2.10 (1.34)	2.68 (1.68)	3.27 (1.96)

Remarks; Annual equivalents projected following 4MP. Figures between parenthesis are annual equivalents projected assuming the lower economic growth.

Table 50 ANNUAL EQUIVALENT OF COST WITHOUT DAM

Unit: M$10^6/y

Alternative	Stretch	10-Year Flood	20-Year Flood	50-Year Flood
Perlis Alternative 1: Without bypass floodway	P1	0.39	0.56	0.60
	P2	0.99	1.28	1.55
	P3	0.48	0.54	0.67
	T1	0.10	0.12	0.14
	G1	0.15	0.19	0.24
	G2	0.08	0.10	0.14
	A1	0.09	0.11	0.15
Perlis Alternative 2: With bypass floodway	P1	0.31	0.42	0.51
	P2	-	-	-
	B1	0.27	0.37	0.74
	P3	0.48	0.54	0.67
	T1	0.10	0.12	0.14
	G1	-	-	-
	G2	0.08	0.10	0.14
	A1	0.09	0.11	0.15
	B2	0.39	0.59	0.76
Kedah Alternative 1	K1	0.45	1.60	2.02
	K2	0.29	0.60	0.70
	K3	0.22	0.30	0.35
Muda Alternative 1	M1	0.53	1.48	1.64
	M2	0.77	1.53	1.74
	M3	0.32	1.11	1.42
	M4	1.55	1.77	2.42
	K1	0.06	0.52	0.87
	K2	0.06	0.11	0.19
Perai Alternative 1: Without Retarding Basin	P1	1.15	1.91	2.69
	P2	0.42	0.46	0.55
Perai Alternative 2: With Retarding Basin	P1	-	-	-
	P2*	0.36	0.37	0.40
P. Pinang	P1	1.86	2.38	2.92

Remarks; *: Retarding basin

Table 51 ANNUAL EQUIVALENT OF COST WITH DAM

Unit: M$$10^6$/y

Alternative	Stretch	
Perlis Alternative 3: With Timah-Tasoh & Arau without bypass floodway	P1	0.55
	P2	1.01
	P3	0.53
	T1	0.14
	G1	0.17
	G2	0.14
	A1	0.08
	D1	0.64
	D2	0.20
Perlis Alternative 4: With Timah-Tasoh & Arau with bypass floodway	P1	0.36
	P2	-
	B1	0.20
	P3	0.53
	T1	0.14
	G1	-
	G2	0.14
	A1	0.08
	B2	0.60
	D1	0.64
	D2	0.20
Kedah Alternative 2: With Ahning dam	K1	1.95
	K2	0.63
	K3	0.29
	D3	0.11

Table 52 ESTIMATED SHARE OF ECONOMIC BENEFIT BY BYPASS FLOODWAYS, RETARDING BASIN AND DAMS

Persis River System

Unit: %

River Stretch Where Benefit Accrue	P1	P2	P3	A1
C ; Enlarged Arau canal	30	42		
D1; Timah-Tasoh dam	40	40	50	
D2; Arau dam				70

Kedah River System

River Stretch Where Benefit Accrue	K1	K2	K3
D3; Ahning dams	3	8	20

Perai River System

River Stretch Where Benefit Accrue	P1	P2
R ; Retarding basin	100	100

Table 53 ESTIMATED ANNUAL EQUIVALENTS OF ECONOMIC COST AND BENEFIT OF BEST COMBINATION OF FLOOD MITIGATION MEASURES IN EACH ALTERNATIVE PLAN FOR PERLIS RIVER SYSTEM (1/2)

Unit: $M\$10^6/y$

10-Year Design Flood

		Following 4MP				Lower Growth			
		Alternative 1.10		Alternative 2.10		Alternative 1.10		Alternative 2.10	
	Measures	Cost	Benefit	Cost	Benefit	Cost	Benefit	Cost	Benefit
P1:	Improvement	0.39	0.23	0.31	0.16	0.39	0.11	0.31	0.08
P2:	Improvement	0.99	1.55	-	-	-	-		
B1:	Bypass for P2	-	-	0.27	0.90	-	-	0.27	0.56
P3:	Improvement	-	-	-	-	-	-		
T1:	Improvement	0.10	0.22	0.10	0.22	0.10	0.12	0.10	0.12
G1:	Improvement	0.15	0.27	-	-	-	-		
G2:	Improvement	0.08	0.21	0.08	0.21	-	-		
A1:	Improvement	0.09	0.22	0.09	0.22	-	-		
B2:	Bypass for G1	-	-	0.39	0.99	-	-	0.39	0.43
	Total	1.80	2.70	1.24	2.70	0.49	0.23	1.24	1.19
	B - C	0.90		1.46		0.08		-0.05	

20-Year Design Flood

		Following 4MP				Lower Growth			
		Alternative 1.20		Alternative 2.20		Alternative 1.20		Alternative 2.20	
	Measures	Cost	Benefit	Cost	Benefit	Cost	Benefit	Cost	Benefit
P1:	Improvement	0.56	0.26	0.42	0.18	0.56	0.13	0.42	0.09
P2:	Improvement	1.28	1.76	-	-	1.28	1.07	-	-
B1:	Bypass for P2	-	-	0.37	-	-	-	0.37	0.62
P3:	Improvement	-	-	-	-	-	-	-	-
T1:	Improvement	0.12	0.29	0.12	0.29	0.12	0.14	0.12	0.14
G1:	Improvement	0.19	0.36	-	-	-	-	-	-
G2:	Improvement	0.10	0.28	0.10	0.28	-	-	-	-
A1:	Improvement	0.11	0.29	0.11	0.29	-	-	-	-
B2:	Bypass for G1	-	-	0.59	1.18	-	-	0.59	0.59
	Total	2.36	3.24	1.71	3.24	1.84	1.34	1.50	1.44
	B - C	0.88		1.53		0.50		-0.06	

Table 54 ESTIMATED ANNUAL EQUIVALENTS OF ECONOMIC COST AND BENEFIT OF BEST COMBINATION OF FLOOD MITIGATION MEASURES IN EACH ALTERNATIVE PLAN FOR PERLIS RIVER SYSTEM (2/2)

Unit: M$$10^6$/y

50-Year Design Flood

		Following 4MP									
		Alternative 1.50		Alternative 2.50		Alternative 3.50		Alternative 4.50		Alternative 5.50	
	Measures	Cost	Benefit	Cost	Benefit	Cost	Benefit	Cost	Benefit	Cost	Benefit
P1:	Improvement	0.60	0.30	0.51	0.21	0.55	0.18	0.36	0.09	-	-
P2:	Improvement	1.55	2.12	-	-	1.01	1.27	-	-	-	-
B1:	Bypass for P2	-	-	0.74	1.23	-	-	0.20	0.38	-	-
P3:	Improvement	-	-	-	-	-	-	-	-	-	-
T1:	Improvement	0.14	0.34	0.14	0.34	0.14	0.34	0.14	0.34	-	-
G1:	Improvement	0.24	0.43	-	-	0.17	0.43	-	-	-	-
G2:	Improvement	0.14	0.34	0.14	0.34	0.14	0.34	0.14	0.34	-	-
A1:	Improvement	0.15	0.35	0.15	0.35	0.08	0.20	0.08	0.20	-	-
B2:	Bypass for G1	-	-	0.76	1.41	-	-	0.60	1.41	-	-
D1:	Timah-Tasoh	-	-	-	-	0.64	1.19	0.64	1.19	0.64	1.19
D2:	Arau	-	-	-	-	0.20	0.25	0.20	0.25	-	-
	Total	2.82	3.88	2.44	3.88	2.93	4.20	2.36	3.77	0.64	1.19
	B - C	1.06		1.44		1.27		1.74		0.55	

		Lower Growth									
		Alternative 1.50		Alternative 2.50		Alternative 3.50		Alternative 4.50		Alternative 5.50	
	Measures	Cost	Benefit	Cost	Benefit	Cost	Benefit	Cost	Benefit	Cost	Benefit
P1:	Improvement	0.60	0.15	0.60	0.05	0.36	0.09	0.36	0.05	-	-
P2:	Improvement	-	-	-	-	-	-	-	-	-	-
B1:	Bypass for P2	-	-	0.74	0.75	-	-	0.20	0.23	-	-
P3:	Improvement	-	-	-	-	-	-	-	-	-	-
T1:	Improvement	0.14	0.17	0.14	0.17	0.14	0.17	0.14	0.17	-	-
G1:	Improvement	-	-	-	-	-	-	-	-	-	-
G2:	Improvement	-	-	-	-	-	-	-	-	-	-
A1:	Improvement	-	-	-	-	-	-	-	-	-	-
B2:	Bypass for G1	-	-	0.76	0.77	-	-	0.60	0.71	-	-
D1:	Timah-Tasoh	-	-	-	-	0.64	0.72	0.64	0.72	0.64	0.72
D2:	Arau	-	-	-	-	-	-	-	-	-	-
	Total	0.74	0.32	1.64	1.74	1.14	0.98	1.94	1.92	0.64	0.72
	B - C	-0.42		0.10		-0.16		-0.02		0.08	

Table 55 ANNUAL EQUIVALENTS OF ECONOMIC COST AND BENEFIT OF BEST COMBINATION OF FLOOD MITIGATION MEASURES IN EACH ALTERNATIVE PLAN FOR THE KEDAH RIVER SYSTEM

Unit: M$$10^6$/y

		10-Year Design Flood				20-Year Design Flood			
		Following 4MP		Lower Growth		Following 4MP		Lower Growth	
		Alternative 1.10		Alternative 1.10		Alternative 1.20		Alternative 1.20	
	Measures	Cost	Benefit	Cost	Benefit	Cost	Benefit	Cost	Benefit
K1:	Improvement	0.45	0.28	0.45	0.14	1.60	0.31	1.60	0.16
K2:	Improvement	0.29	0.49	0.29	0.26	0.60	0.53	0.60	0.26
K3:	Improvement	0.22	1.25	0.22	0.65	0.30	1.37	0.30	0.76
	Total	0.96	2.02	0.96	1.05	2.50	2.21	2.50	1.18
	B - C	1.06		0.09		-0.29		-1.32	

		50-Year Design Flood							
		Following 4MP				Lower Growth			
		Alternative 1.50		Alternative 2.50		Alternative 1.50		Alternative 2.50	
	Measures	Cost	Benefit	Cost	Benefit	Cost	Benefit	Cost	Benefit
K1:	Improvement	2.02	0.35	-	-	2.02	0.17	-	-
K2:	Improvement	0.70	0.59	-	-	0.70	0.30	-	-
K3:	Improvement	0.35	1.52	-	-	0.35	0.78	-	-
D3:	Ahning dam	-	-	0.11	0.26	-	-	0.11	0.13
	Total	3.07	2.46	0.11	0.26	3.07	1.25	0.11	0.13
	B - C	-0.61		0.15		-1.82		0.02	

Table 56 ANNUAL EQUIVALENTS OF ECONOMIC COST AND BENEFIT OF BEST COMBINATION OF FLOOD MITIGATION MEASURES IN EACH ALTERNATIVE PLAN FOR THE MUDA RIVER SYSTEM

Unit: M$$10^6$/y

Measures		10-Year Design Flood				20-Year Design Flood			
		Following 4MP Alternative 1.10		Lower Growth Alternative 1.10		Following 4MP Alternative 1.20		Lower Growth Alternative 1.20	
		Cost	Benefit	Cost	Benefit	Cost	Benefit	Cost	Benefit
M1:	Improvement	0.53	0.28	0.53	0.15	1.48	0.36	1.48	0.20
M2:	Improvement	0.77	0.36	0.77	0.19	1.53	0.46	-	-
M3:	Improvement	0.32	1.04	0.32	0.64	1.11	1.29	-	-
M4:	Improvement	-	-	-	-	-	-	-	-
K1:	Improvement	0.06	1.05	0.06	0.65	0.52	1.31	-	-
K2:	Improvement	0.06	0.39	0.06	0.28	0.11	0.49	-	-
	Total	1.74	3.12	1.74	1.91	4.75	3.91	1.48	0.20
	B - C	1.38		0.17		-0.84		-1.28	

Measures		50-Year Design Flood			
		Following 4MP Alternative 1.50		Lower Growth Alternative 1.50	
		Cost	Benefit	Cost	Benefit
M1:	Improvement	1.64	0.42	1.64	0.24
M2:	Improvement	-	-	-	-
M3:	Improvement	-	-	-	-
M4:	Improvement	-	-	-	-
K1:	Improvement	-	-	-	-
K2:	Improvement	-	-	-	-
	Total	1.64	0.42	1.64	0.24
	B - C	-1.22		-1.40	

Table 57 ANNUAL EQUIVALENTS OF ECONOMIC COST AND BENEFIT OF BEST COMBINATION OF FLOOD MITIGATION MEASURES IN EACH ALTERNATIVE PLAN FOR THE PERAI RIVER SYSTEM

Unit: M$$10^6$/y

10-Year Design Flood

Measures		Following 4MP				Lower Growth			
		Alternative 1.10		Alternative 2.10		Alternative 1.10		Alternative 2.10	
		Cost	Benefit	Cost	Benefit	Cost	Benefit	Cost	Benefit
P1:	Improvement	1.15	0.34	-	-	1.15	0.18	-	-
P2:	Improvement	0.42	0.98	-	-	0.42	0.53	-	-
R :	Retarding Basin	-	-	0.36	1.06	-	-	0.36	0.57
	Total	1.57	1.32	0.36	1.06	1.57	0.71	0.36	0.57
	B - C	-0.25		0.70		-1.66		0.21	

20-Year Design Flood

Measures		Following 4MP				Lower Growth			
		Alternative 1.20		Alternative 2.20		Alternative 1.20		Alternative 2.20	
		Cost	Benefit	Cost	Benefit	Cost	Benefit	Cost	Benefit
P1:	Improvement	1.91	0.34	-	-	1.91	0.18	-	-
P2:	Improvement	0.46	0.98	-	-	0.46	0.53	-	-
R :	Retarding Basin	-	-	0.37	1.32	-	-	0.37	0.71
	Total	2.37	1.32	0.37	1.32	2.37	0.71	0.37	0.71
	B - C	-1.05		0.95		-1.66		0.34	

50-Year Design Flood

Measures		Following 4MP				Lower Growth			
		Alternative 1.50		Alternative 2.50		Alternative 1.50		Alternative 2.50	
		Cost	Benefit	Cost	Benefit	Cost	Benefit	Cost	Benefit
P1:	Improvement	2.69	0.40	-	-	2.69	0.21	-	-
P2:	Improvement	0.55	1.14	-	-	0.55	0.61	-	-
R :	Retarding Basin	-	-	0.40	1.54	-	-	0.40	0.82
	Total	3.24	1.54	0.40	1.54	3.24	0.82	0.40	0.82
	B - C	-1.70		1.14		-2.42		0.42	

Table 58 ANNUAL EQUIVALENTS OF ECONOMIC COST AND BENEFIT OF BEST COMBINATION OF FLOOD MITIGATION MEASURES IN EACH ALTERNATIVE PLAN FOR THE P. PINANG RIVER SYSTEM

Unit: M$$10^6$/y

10-Year Design Flood

Measures	Following 4MP Alternative 1.10 Cost	Following 4MP Alternative 1.10 Benefit	Lower Growth Alternative 1.10 Cost	Lower Growth Alternative 1.10 Benefit
P1: Improvement	1.86	2.10	1.86	1.34
B - C	0.24		-0.52	

20-Year Design Flood

Measures	Following 4MP Alternative 1.20 Cost	Following 4MP Alternative 1.20 Benefit	Lower Growth Alternative 1.20 Cost	Lower Growth Alternative 1.20 Benefit
P1: Improvement	2.38	2.68	2.38	2.68
B - C	0.30		-0.70	

50-Year Design Flood

Measures	Following 4MP Alternative 1.50 Cost	Following 4MP Alternative 1.50 Benefit	Lower Growth Alternative 1.50 Cost	Lower Growth Alternative 1.50 Benefit
P1: Improvement	2.92	3.27	2.92	1.96
B - C	0.35		-0.96	

Table 59 SUMMARY OF NET ECONOMIC BENEFIT BY ALTERNATIVE PLAN

Unit: M$$10^6$/y

River	Alternative	Following 4MP	Lower Growth
Perlis	1.10	0.90	0.08
	2.10	1.46	-0.05
	1.20	0.88	0.05
	2.20	1.53	-0.06
	1.50	1.06	-0.42
	2.50	1.44	0.10
	3.50	1.27	-0.16
	4.50	1.84	-0.02
	5.50	0.55	0.08
Kedah	1.10	1.06	0.09
	1.20	-0.29	-1.32
	1.50	-0.61	-1.82
	2.50	0.15	0.02
Muda	1.10	1.38	0.17
	1.20	-0.84	-1.28
	1.50	-1.22	-1.40
Perai	1.10	-0.25	-1.66
	2.10	0.70	0.21
	1.20	-1.05	-1.66
	2.20	0.95	0.34
	1.50	-1.70	-2.42
	2.50	1.14	0.42
P. Pinang	1.10	0.24	-0.52
	1.20	0.30	-0.70
	1.50	0.35	-0.96

Table 60 PRINCIPAL FEATURE OF RECOMMENDED PLANS UNDER THE ECONOMIC GROWTH FOLLOWING 4MP

River System		Perlis	Kedah	Muda	Perai	P.Pinang
1. Alternative		4.50	1.10	1.10	2.50	1.50
2. Flood Mitigation Measures						
2.1 Channel improvement	(km)	45*	18	50	-	2.4
2.2 Dam	(10^6 m^3)	20	-	-	-	-
2.3 Retarding basin	(10^6 m^3)	-	-	-	20	-
3. Construction Cost						
3.1 Channel improvement	(M$$10^6$)	23.7	9.7	33.0	-	3.7
3.2 Dam	(M$$10^6$)	11.4	-	-	-	-
3.3 Retarding basin	(M$$10^6$)	-	-	-	0.8	-
3.4 Compensation	(M$$10^6$)	7.9	5.0	4.0	4.5	34.9
Total	(M$$10^6$)	43.0	14.7	37.0	5.3	38.6
4. Economic Effect						
4.1 Flood damage without development	(M$$10^6$/y)	5.45	3.24	6.57	1.60	3.63
4.2 Damage reduction	(M$$10^6$/y)	4.20	2.02	3.12	1.54	3.27
4.3 4.2/4.1	(%)	77	62	47	96	90
4.4 Net economic benefit	(M$$10^6$/y)	1.84	1.06	1.38	1.14	0.35
4.5 EIRR	(%)	17.2	14.1	11.1	18.4	12.5
5. Average Annual Flooded Area						
5.1 Without development	(km^2)	8.0	7.5	16.2	6.2	1.1
5.2 Reduction	(km^2)	3.4	1.4	3.2	4.9	0.8
5.3 5.2/5.1	(%)	43	19	20	79	73
6. Average Annual Population Affected (2000)						
6.1 Without project	(10^3)	11.2	3.3	10.3	3.3	5.4
6.2 Reduction	(10^3)	7.8	1.6	6.7	2.6	4.6
6.3 6.2/6.1	(%)	70	48	61	79	85

Remarks; *: Including bypass floodways

Table 61 PRINCIPAL FEATURE OF RECOMMENDED PLANS UNDER LOWER ECONOMIC GROWTH

River System		Perlis	Kedah	Muda	Perai	P.Pinang
1. Alternative		5.50	1.10	1.10	2.50	1.50
2. Flood Mitigation Measures						
2.1 Channel improvement	(km)	-	18	50	-	2.4
2.2 Dam	(10^6 m^3)	15	-	-	-	-
2.3 Retarding basin	(10^6 m^3)	-	-	-	20	-
3. Construction Cost						
3.1 Channel improvement	(M$$10^6$)	-	9.7	33.0	-	3.7
3.2 Dam	(M$$10^6$)	8.8	-	-	-	-
3.3 Retarding basin	(M$$10^6$)	-	-	-	0.8	-
3.4 Compensation	(M$$10^6$)	2.8	5.0	4.0	4.5	34.9
Total	(M$$10^6$)	11.6	14.7	37.0	5.3	38.6
4. Economic Effect						
4.1 Flood damage without development	(M$$10^6$/y)	2.77	1.65	3.70	0.88	2.17
4.2 Damage reduction	(M$$10^6$/y)	0.72	1.05	1.91	0.82	1.96
4.3 4.2/4.1	(%)	26	64	52	93	90
4.4 Net economic benefit	(M$$10^6$/y)	0.08	0.09	0.17	0.42	-0.96
4.5 EIRR	(%)	8.2	9.3	9.3	12.9	7.6
5. Average Annual Flooded Area						
5.1 Without development	(km^2)	8.0	7.5	16.2	6.2	1.1
5.2 Reduction	(km^2)	1.4	1.4	3.2	4.9	0.8
5.3 5.2/5.1	(%)	18	19	20	79	73
6. Average Annual Population Affected (2000)						
6.1 Without development	(10^3)	9.6	3.1	10.0	2.5	4.7
6.2 Reduction	(10^3)	2.8	1.5	6.0	2.0	3.7
6.3 6.2/6.1	(%)	29	48	60	80	79

Table 62 CONSTRUCTION SCHEDULE

	5MP	6MP	7MP
High Growth Case			
Perlis	D1	P1, T1, C	D2, G2, A1, B
Kedah	K1	K2	K3
Muda	M1	M2	M3, K1, K2
Perai	R		
P. Pinang			D1
Low Growth Case			
Perlis	D1		
Kedah		K1, K2	K3
Muda	M1	M2	M3, K1, K2
Perai	R		
P. Pinang			D1

Table 63 DISBURSEMENT SCHEDULE

Unit: $M\$10^6$

	5MP	6MP	7MP
High Growth Case			
Perlis	11.6	20.1	11.3
Kedah	6.9	4.4	3.4
Muda	14.8	16.5	9.1
Perai	5.3		
P. Pinang			38.6
Total	38.6	41.0	62.4
Low Growth Case			
Perlis	11.6		
Kedah		11.3	3.4
Muda	14.8	16.5	9.1
Perai	5.3		
P. Pinang			38.6
Total	31.7	27.8	51.1

Table 64 COST OF RIVER CHANNEL IMPROVEMENT FOR MODEL RIVER STRETCH IN MUDA RIVER BASIN

Work Item		Unit Cost	Volume	Amount
I.	Construction			
(1)	Excavation	M$2.5/$m^3$	1,740 x 10^3 m^3	M$4,350 x 10^3
(2)	Embankment	M$4.0/$m^3$	1,650 x 10^3 m^3	6,600 x 10^3
(3)	Sod Facing	M$2.7/$m^2$	1,210 x 10^3 m^3	3,270 x 10^3
(4)	Levee/Road Pavement	M$8.6/$m^2$	270 x 10^3 m^3	2,320 x 10^3
	Total			M$16,540 x 10^3
II.	Compensation			
(1)	Rubber/Oil Palm Land	M$29 x 10^3/ha	23 ha	M$670 x 10^3
(2)	Paddy Land	M$43 x 10^3/ha	13 ha	560 x 10^3
(3)	Forest Land	M$5 x 10^3/ha	404 ha	2,020 x 10^3
	Total			M$3,250 x 10^3
III.	Engineering Service (10% of I)			M$1,650 x 10^3
IV.	Physical Contingencies (30% of I, II & III)			M$6,430 x 10^3
	Grand Total			M$27,870 x 10^3

Table 65 REQUIRED NUMBER OF MAJOR CONSTRUCTION EQUIPMENT FOR RIVER CHANNEL IMPROVEMENT OF MODEL RIVER STRETCH

Equipment Item	Underwater Excavation	Land Excavation	Embankment	Total
Back Hoe (for Excavation & Loading)	40 m^3/h 2 units	-	-	2 units 2 units
Dump Truck (for Transportation)	20 m^3/h 4 units	20 m^3/h 9 units	20 m^3/h 17 units	30 units
Bulldozer (for Excavation)	-	40 m^3/h 4 units	70 m^3/h 5 units	9 units
Wheel Loader (for Loading)	-	80 m^3/h 2 units	50 m^3/h 7 units	9 units
Bulldozer (for Spreading & Compaction)	-	-	40 m^3/h 8 units	8 units

Remarks; Upper Line: Hourly work ability
Lower Line: Number of equipment

FIGURES

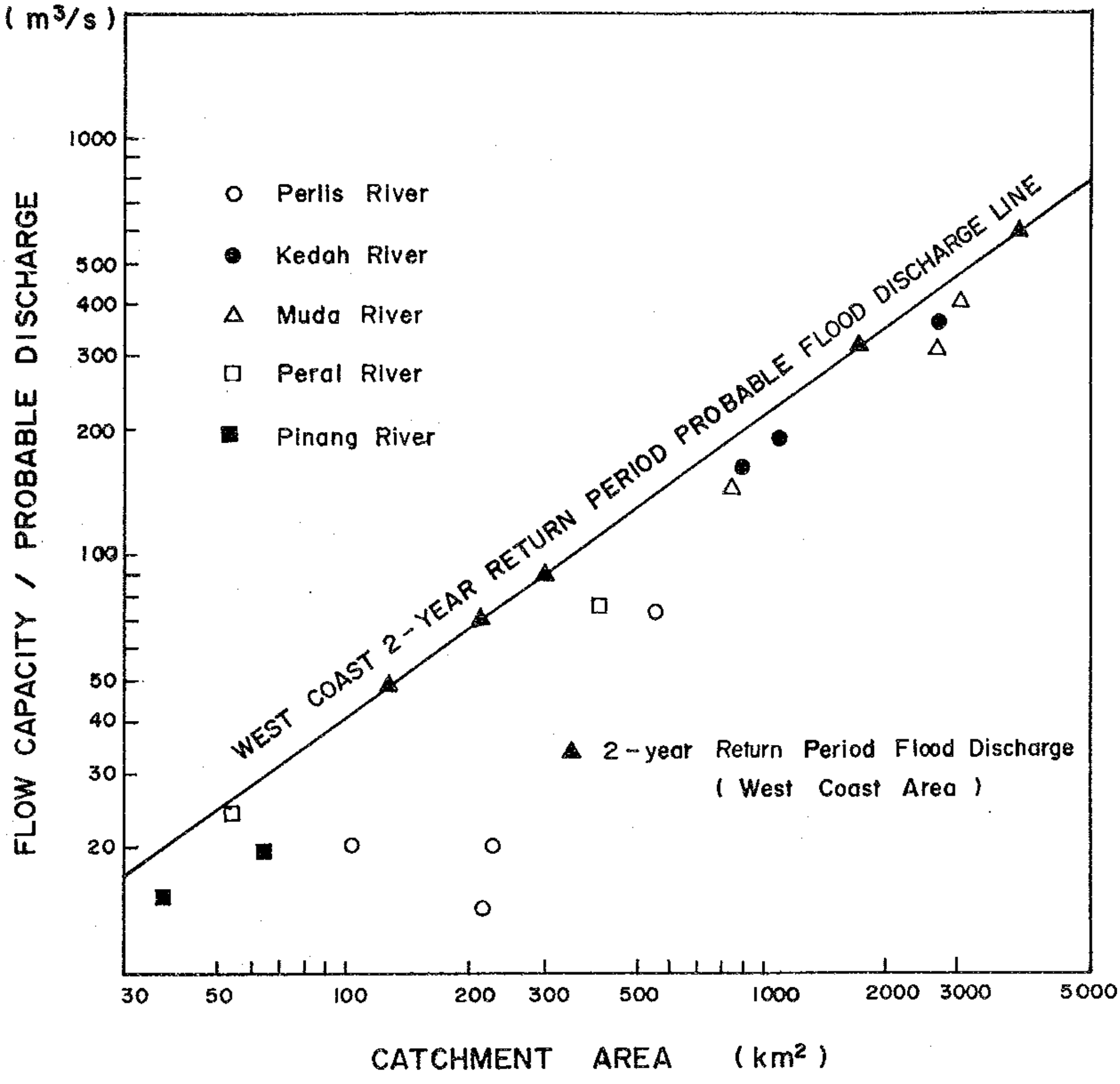

Fig. 1 Flow Capacity Versus Catchment Area

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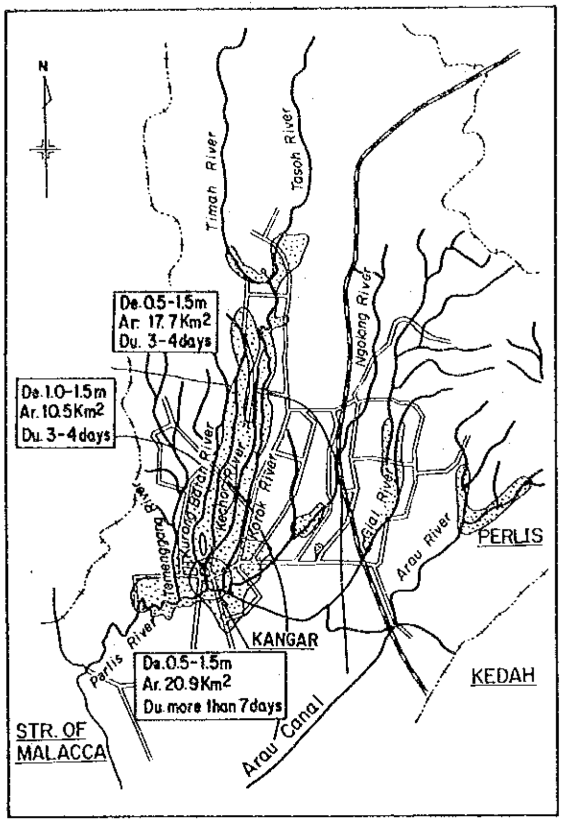

Fig. 2 Flood Map - Perlis River
Sep. 1976 Flood

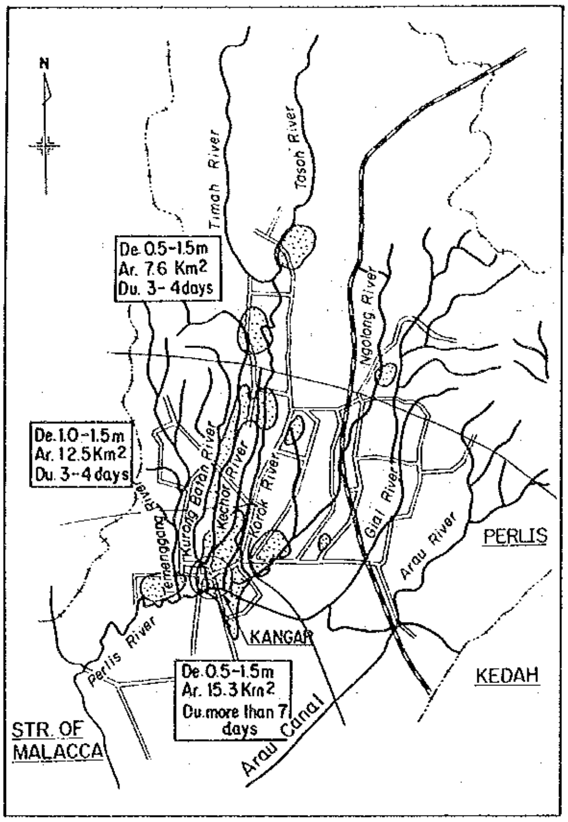

Fig. 3 Flood Map - Perlis River
Jul. 1982 Flood

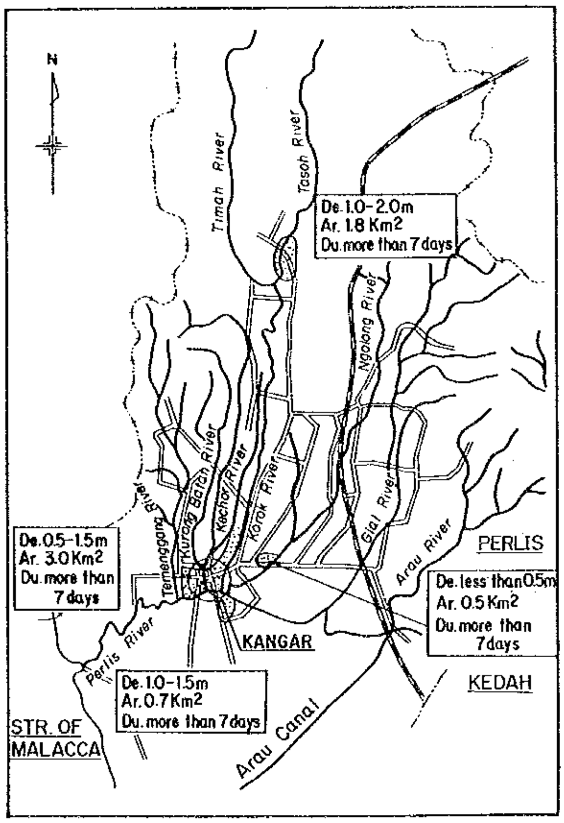

Fig. 4 Flood Map - Perlis River
Sep. 1972 Flood

LEGEND

- Flood Area
- Basin Boundary
- River Line
- Road Line
- Railway Line
- Urban Area
- De. Flood Depth
- Ar. Flood Area
- Du. Flood Duration
- Boundary line Indicating different depth and duration of flooding

0 5 10 km

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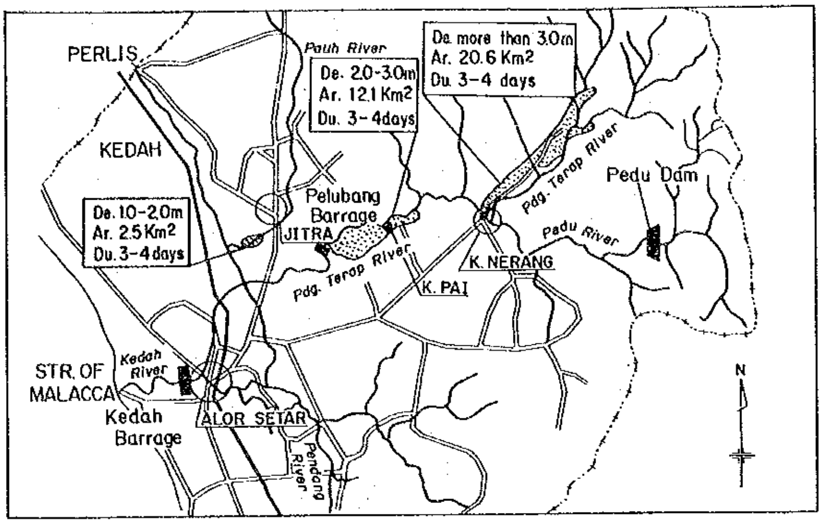
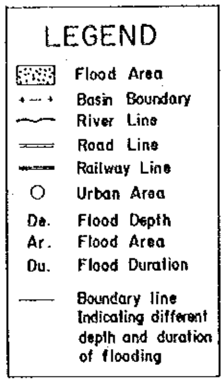
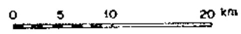


Fig. 5 Flood Map - Kedah River Dec. 1975 Flood





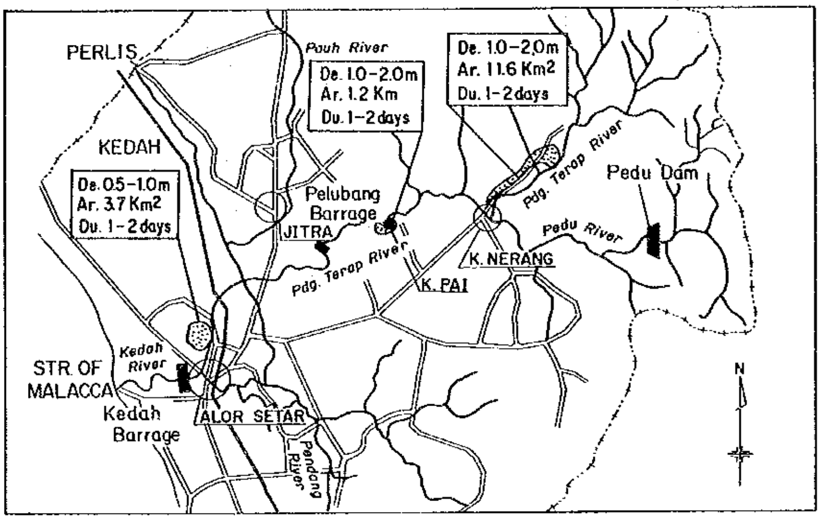


Fig. 6 Flood Map - Kedah River Nov. 1979 Flood

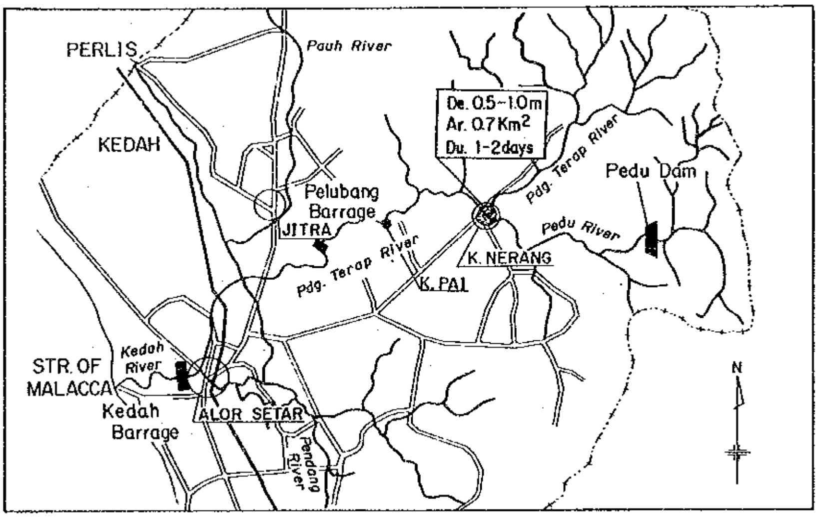


Fig. 7 Flood Map - Kedah River Oct. 1980 Flood

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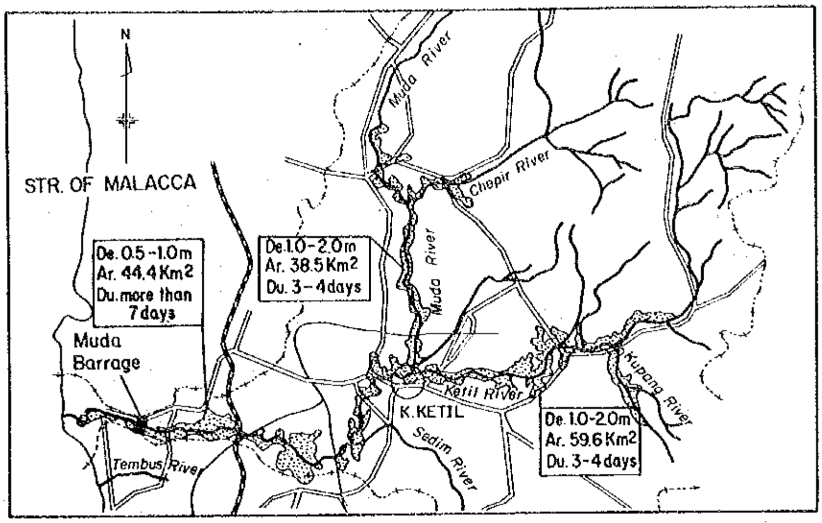
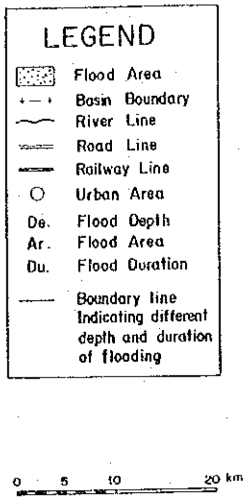


Fig. 8 Flood Map - Muda River Dec. 1973 Flood



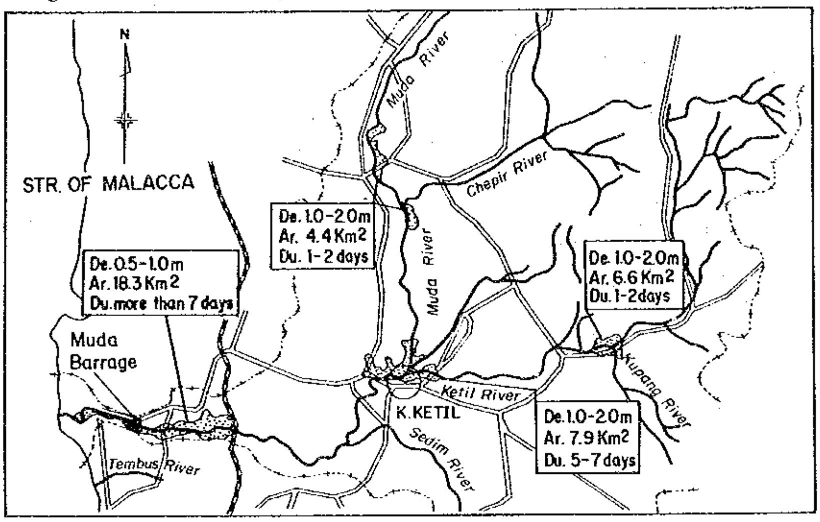


Fig. 9 Flood Map - Muda River Nov. 1972 Flood

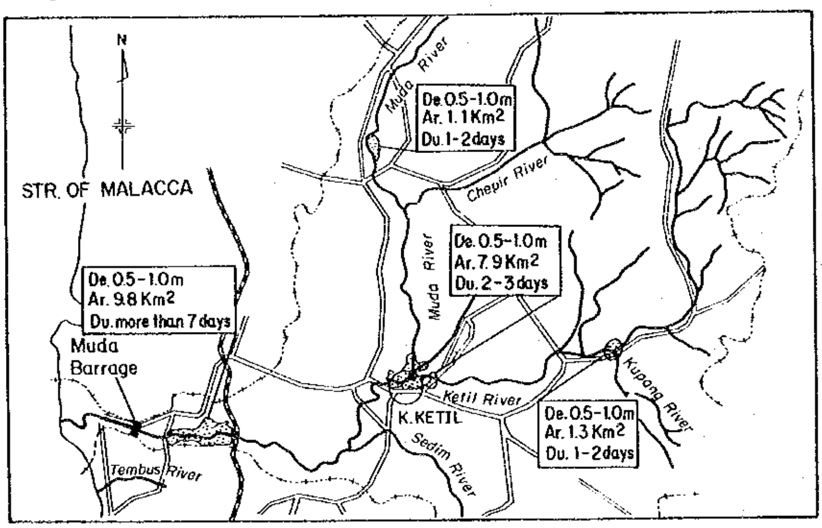


Fig. 10 Flood Map - Muda River Oct. 1980 Flood

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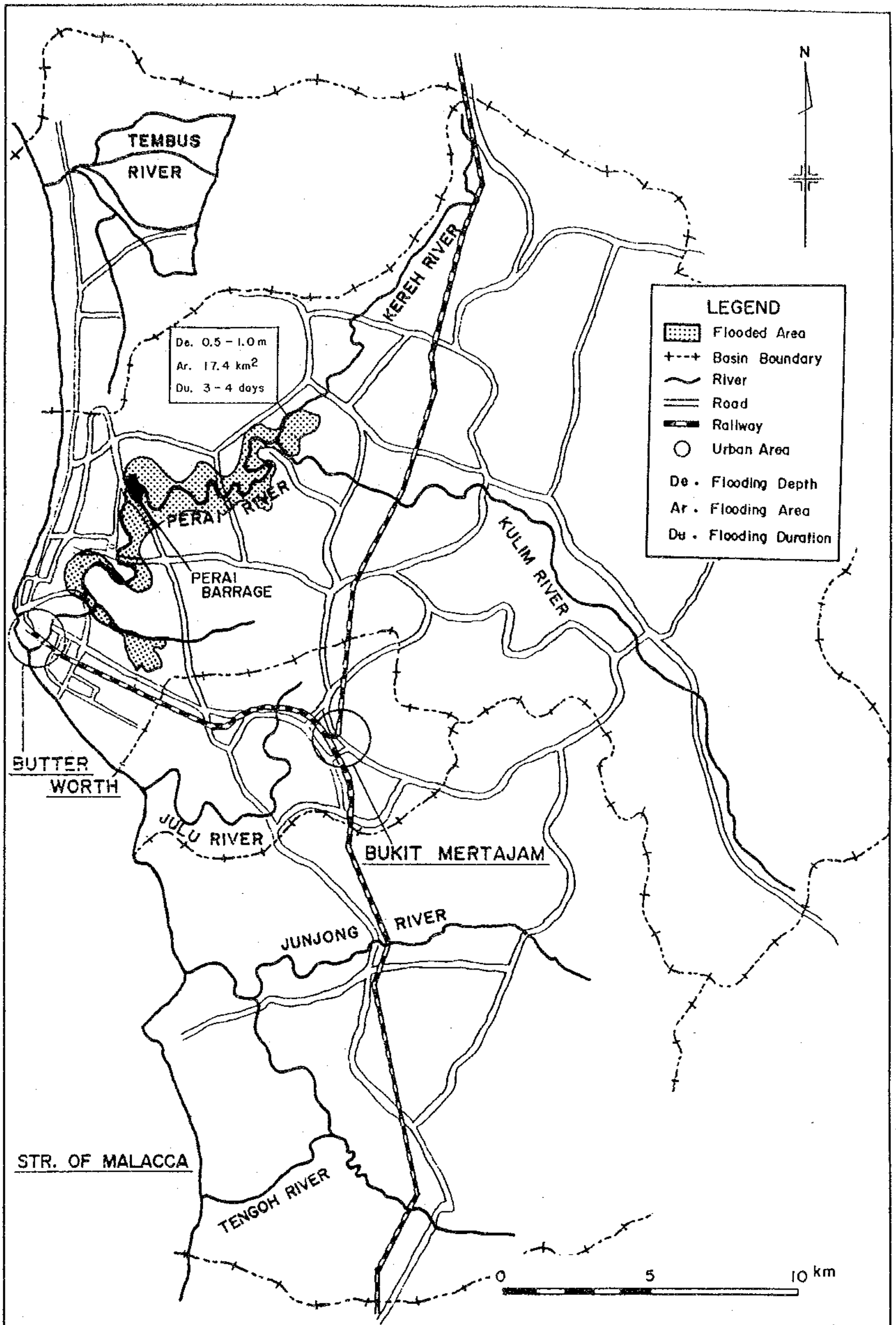

Fig. 11 Flood Map - Perai River
Sep. 1971 Flood

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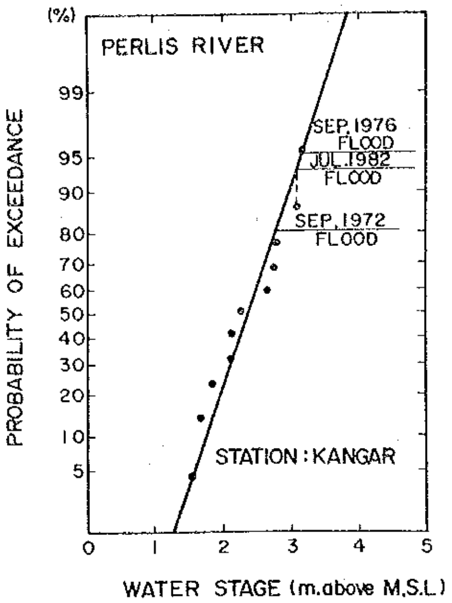

Fig. 12 Water Stage Frequency Curve

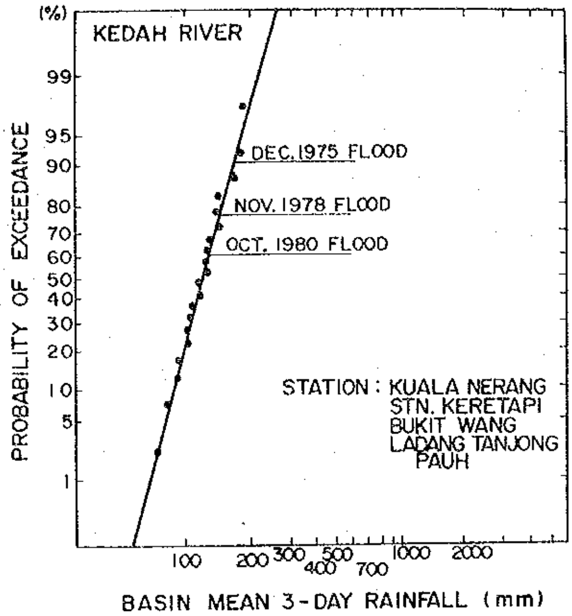

Fig. 13 Basin Mean 3-Day Rainfall Frequency Curve

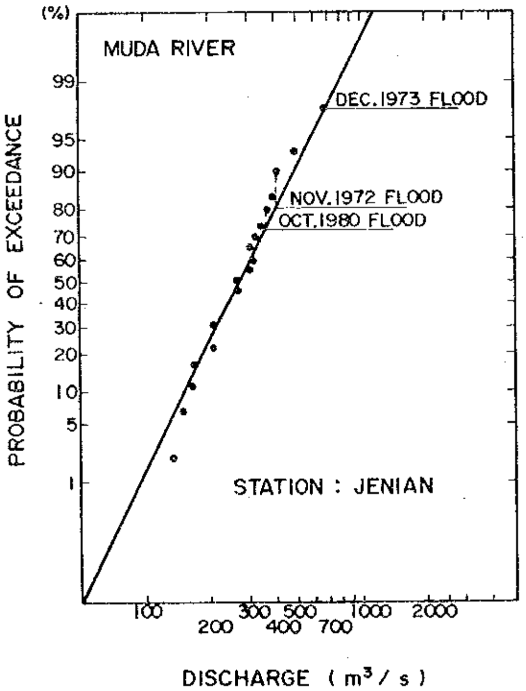

Fig. 14 Flood Discharge Frequency Curve

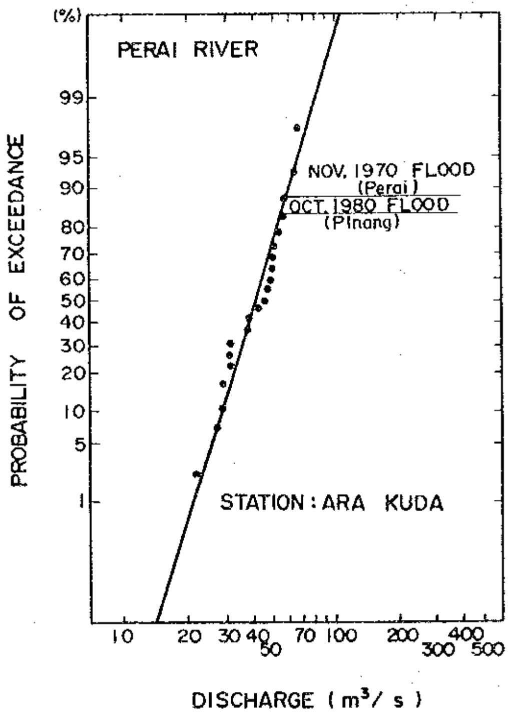

Fig. 15 Flood Discharge Frequency Curve

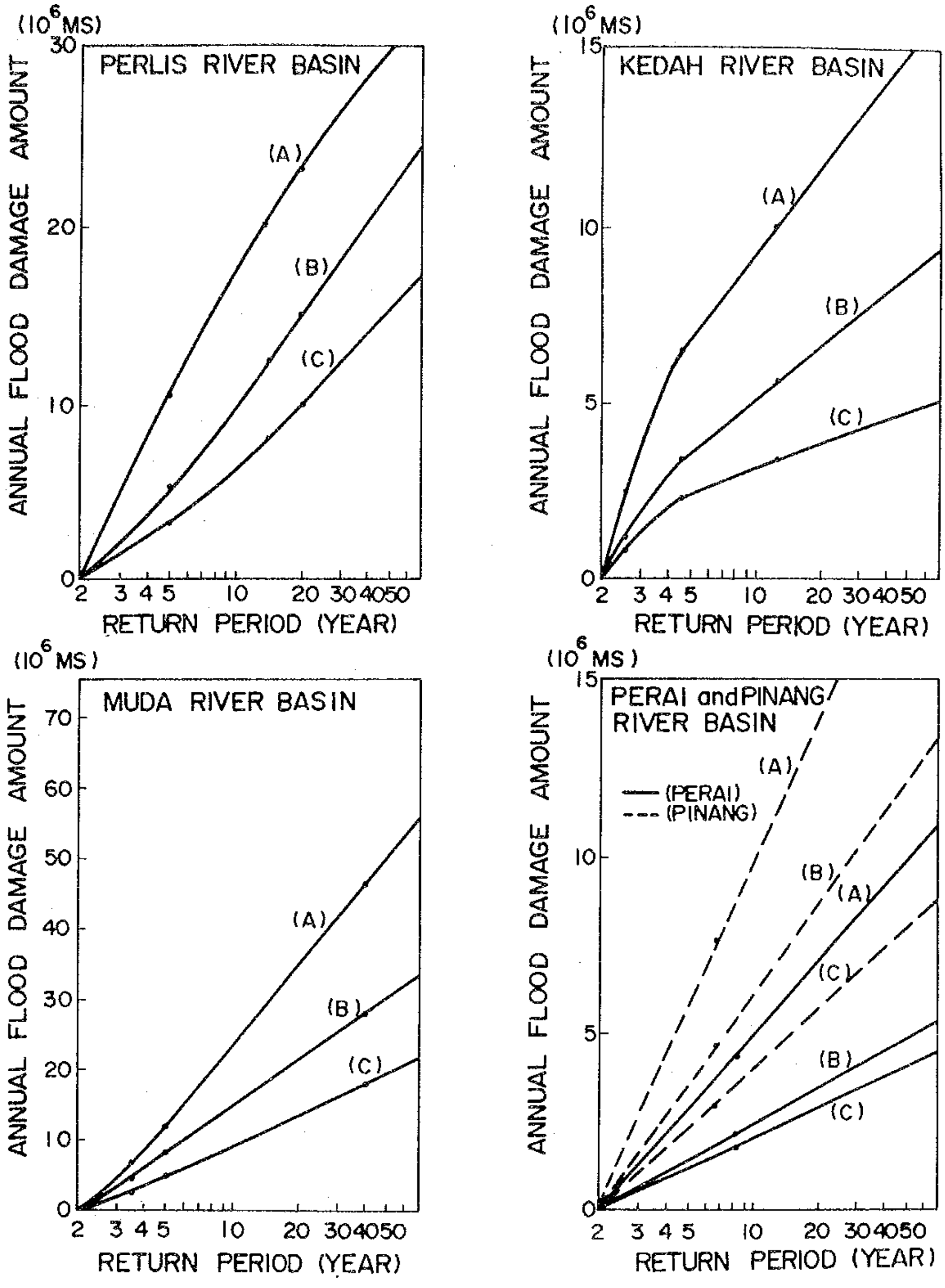

Fig. 16 Flood Damage Amount Frequency Curve

LEGEND

CURVE (A) : FUTURE DAMAGE IN 2000 IN THE ASSUMPTION OF 4MP'S ECONOMIC GROWTH

CURVE (B) : FUTURE DAMAGE IN 2000 IN THE ASSUMPTION OF LOWER ECONOMIC GROWTH

CURVE (C) : PRESENT DAMAGE AS OF 1982

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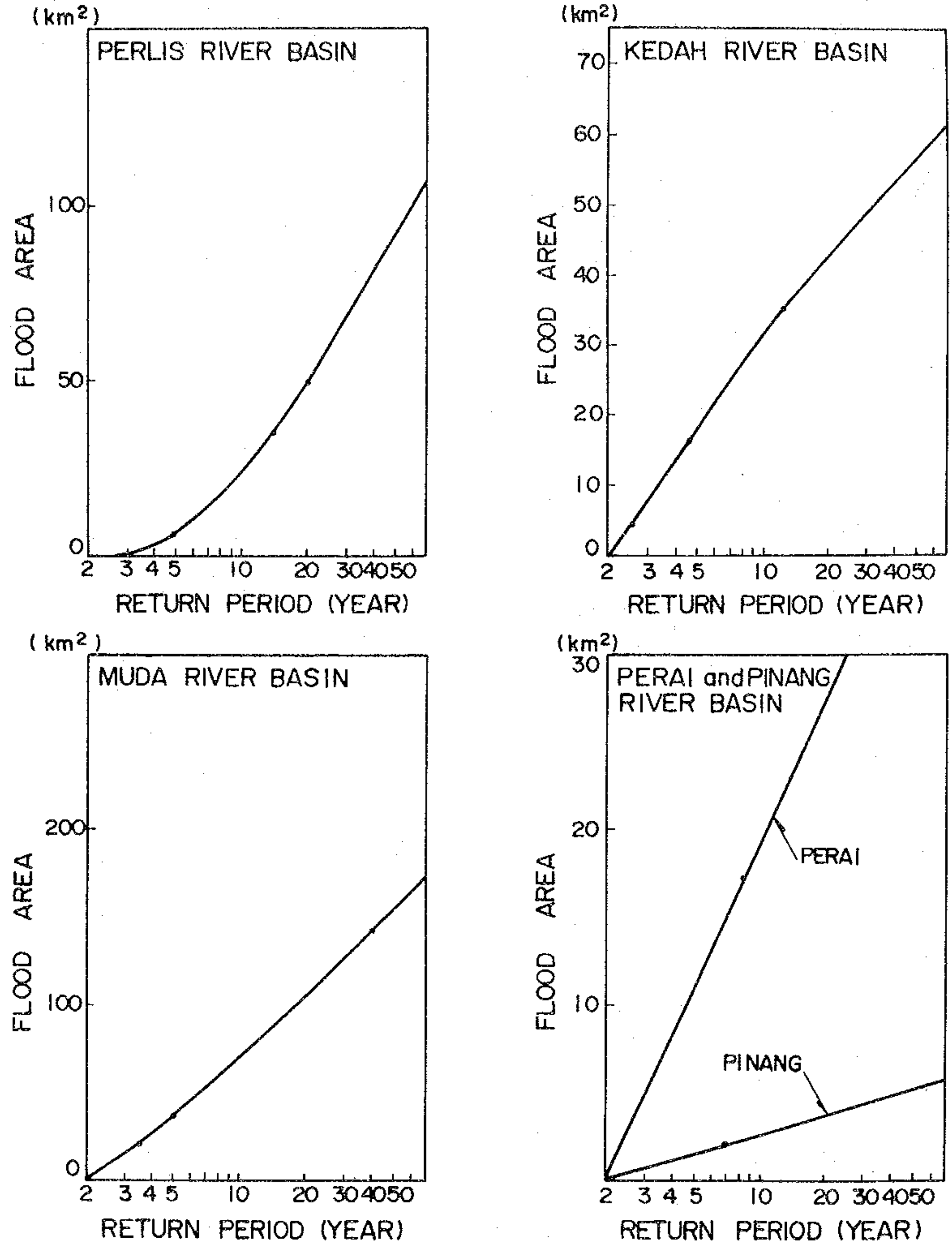

Fig. 17 Flood Area Frequency Curve

LEGEND

CURVE (A) : FUTURE DAMAGE IN 2000 IN THE ASSUMPTION OF 4MP'S ECONOMIC GROWTH

CURVE (B) : FUTURE DAMAGE IN 2000 IN THE ASSUMPTION OF LOWER ECONOMIC GROWTH

CURVE (C) : PRESENT DAMAGE AS OF 1982

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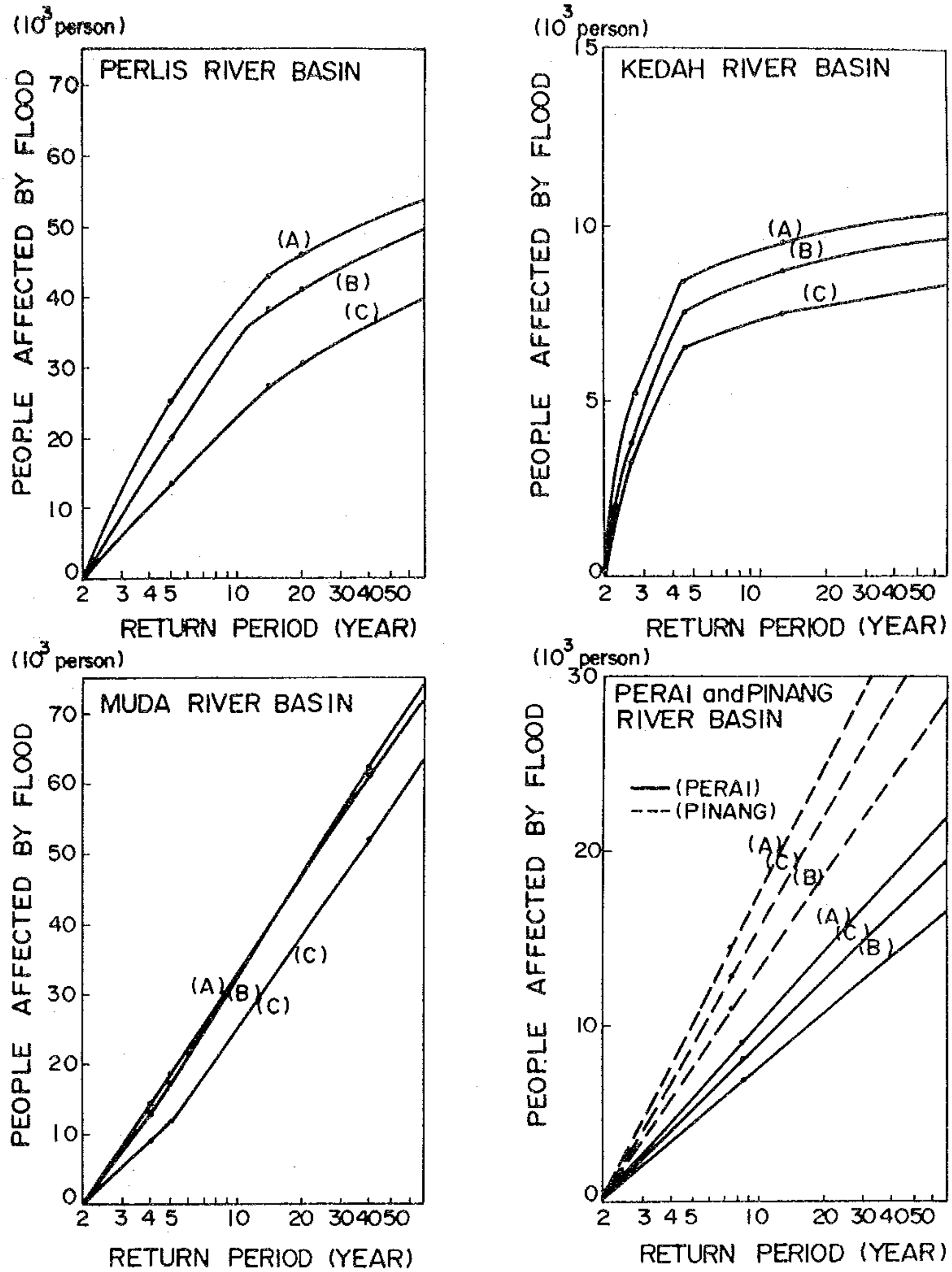

Fig. 18 People Affected by Flood Frequency Curve

LEGEND

CURVE (A) : FUTURE DAMAGE IN 2000 IN THE ASSUMPTION OF 4MP'S ECONOMIC GROWTH

CURVE (B) : FUTURE DAMAGE IN 2000 IN THE ASSUMPTION OF LOWER ECONOMIC GROWTH

CURVE (C) : PRESENT DAMAGE AS OF 1982

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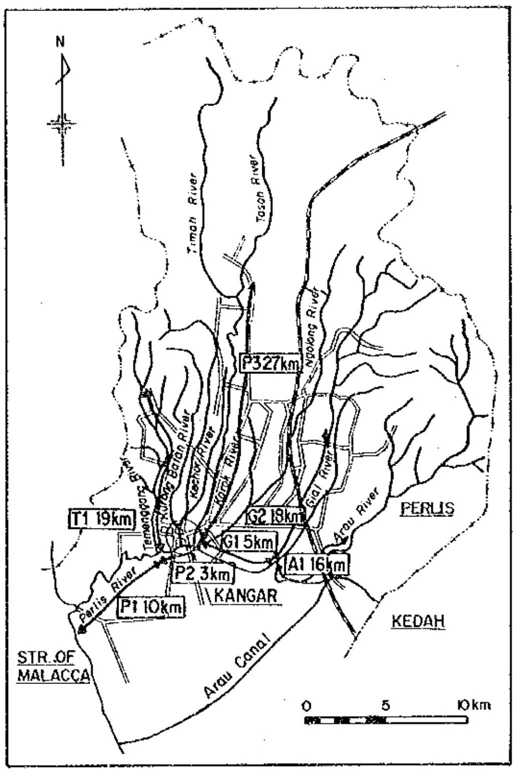

Fig. 19 River Stretches Divided for Flood Mitigation Plan (1/4) - Perlis River Basin -

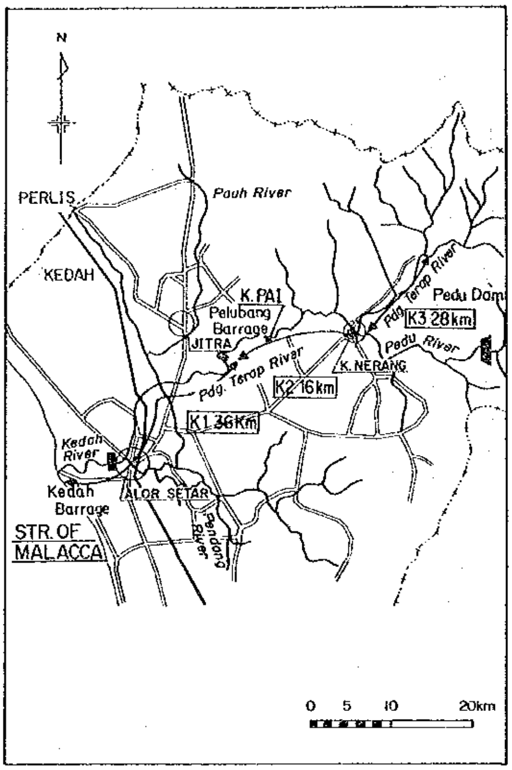

Fig. 20 River Stretches Divided for Flood Mitigation Plan (2/4) - Kedah River Basin -

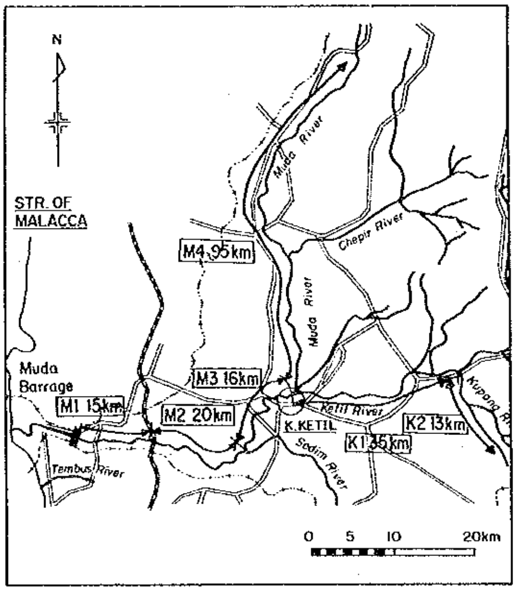

Fig. 21 River Stretches Divided for Flood Mitigation Plan (3/4) - Muda River Basin -

LEGEND

- River Line
- Basin Boundary
- Road Line
- River Stretch
- P1 10km River Stretch No. and Its Length
- Barrage

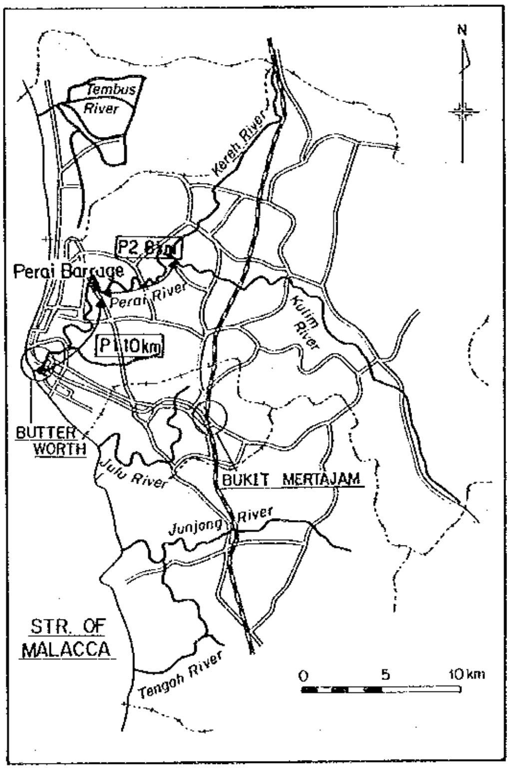

Fig. 22 River Stretches Divided for Flood Mitigation Plan (4/4) - Perai River Basin -

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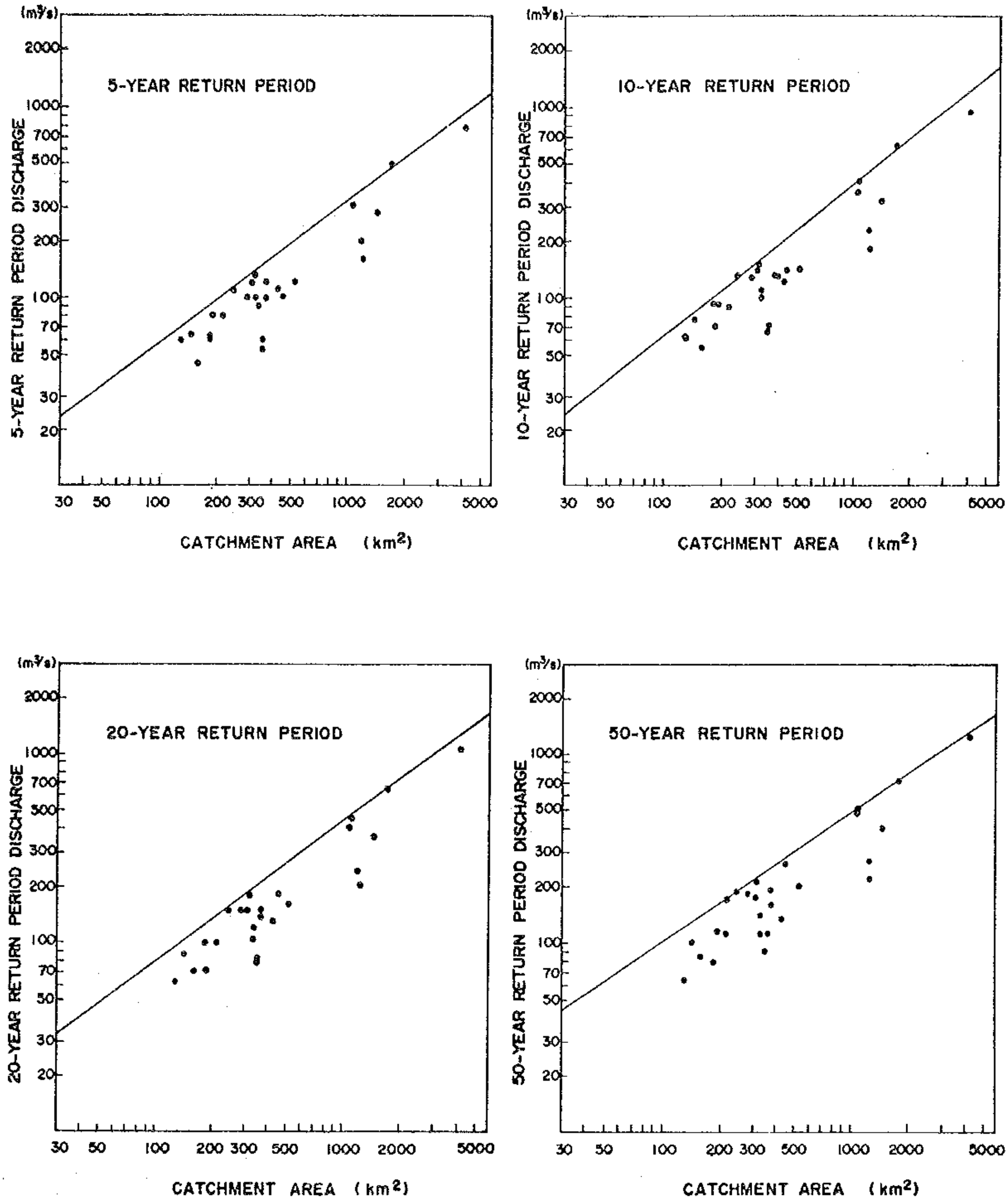

Fig. 23 Relationship Between Catchment Area and Peak Discharge by Return Period in West Coast River

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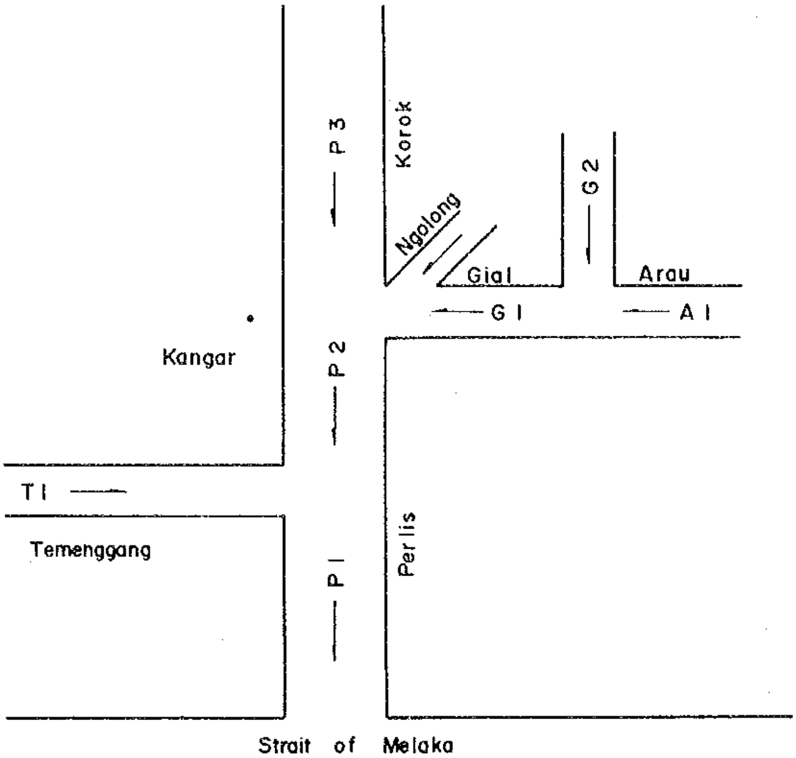
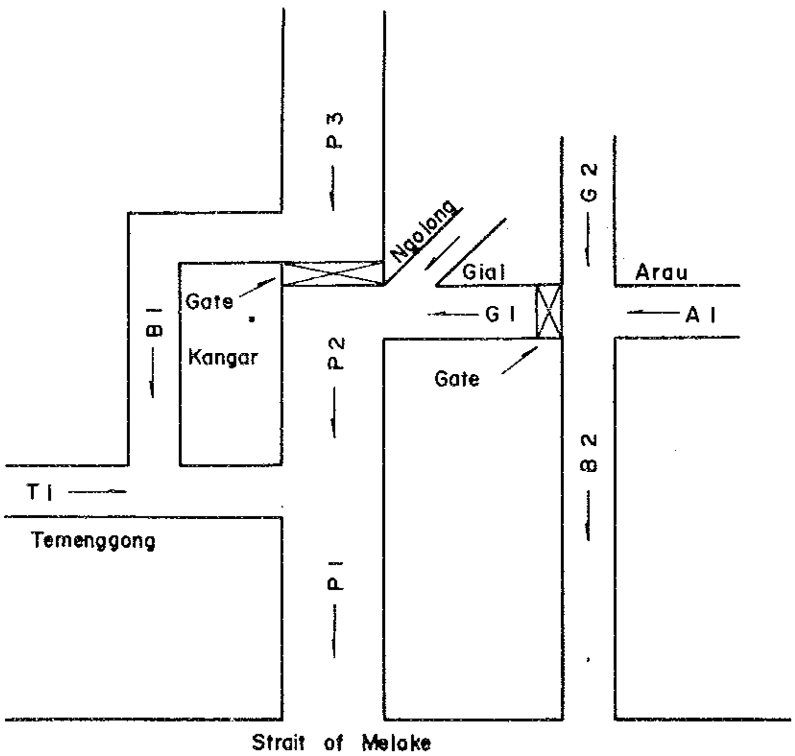


Alternative 1 : Without Bypass Floodway

Design Flood Discharge (m^3/s)

	10 - y	20 - y	50 - y
P 1	250	290	340
P 2	230	260	310
P 3	120	150	170
T 1	56	70	90
G 1	120	150	180
G 2	70	90	110
A 1	60	80	100



Alternative 2 : With Bypass Floodways

Design Flood Discharge (m^3/s)

	10 - y	20 - y	50 - y
P 1	190	230	270
P 2	30	60	70
B	120	150	170
P 3	120	150	170
T 1	56	70	90
G 1	—	—	—
G 2	70	90	110
A 1	60	80	100
B 2	120	150	180

Fig. 24 Design Flood Discharge Without Dam - Perlis

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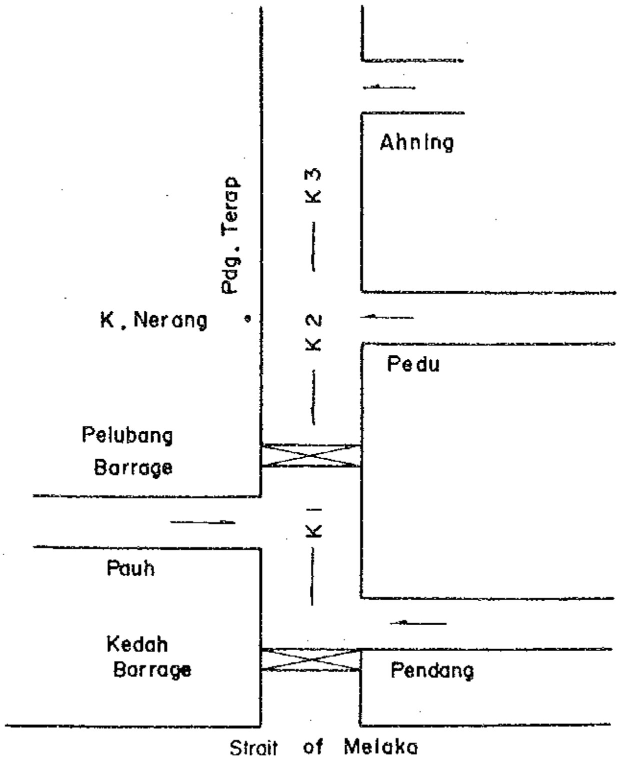
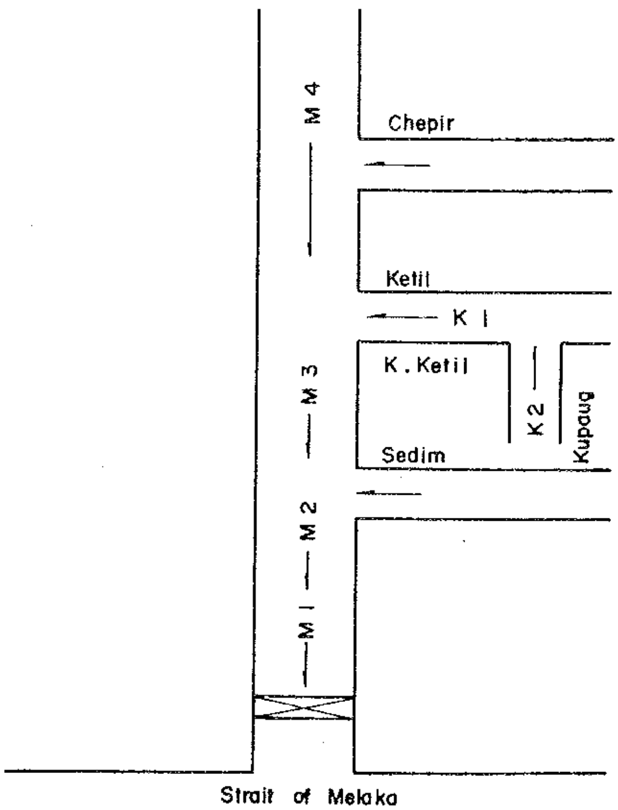


Design Flood Discharge (m^3/s)

	10 - y	20 - y	50 - y
K 1	600	650	740
K 2	440	500	550
K 3	200	240	280

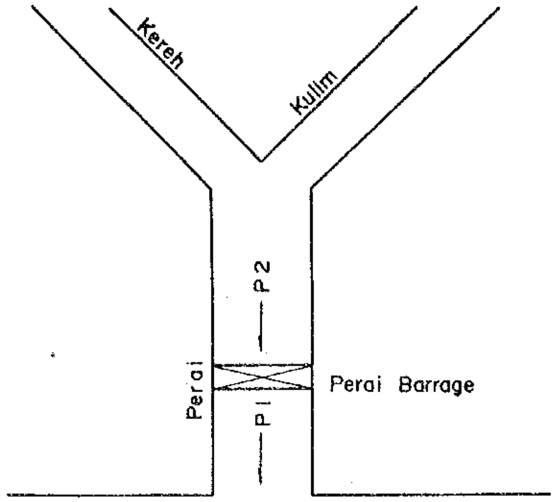
Fig. 25 Design Flood Discharge for Alternative 1: Without Dam - Kedah



Design Flood Discharge (m^3/s)

	10 - y	20 - y	50 - y
M 1	1 100	1 200	1 250
M 2	1 100	1 200	1 250
M 3	980	1 000	1 100
M 4	750	800	890
K 1	340	380	440
K 2	80	100	140

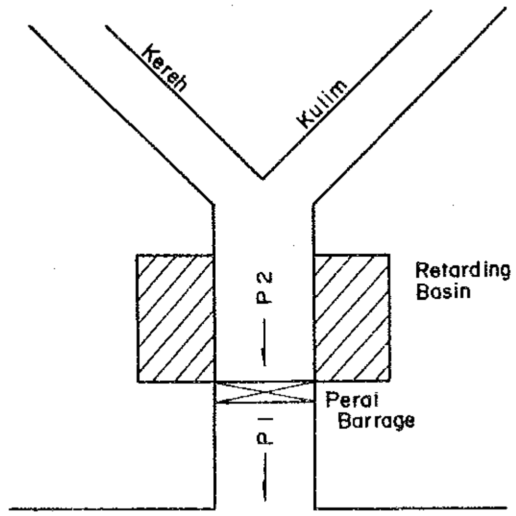
Fig. 26 Design Flood Discharge for Alternative 1 - Muda



Design Flood Discharge (m^3/s)

	10 - y	20 - y	50 - y
P 1	210	250	290
P 2	190	220	260

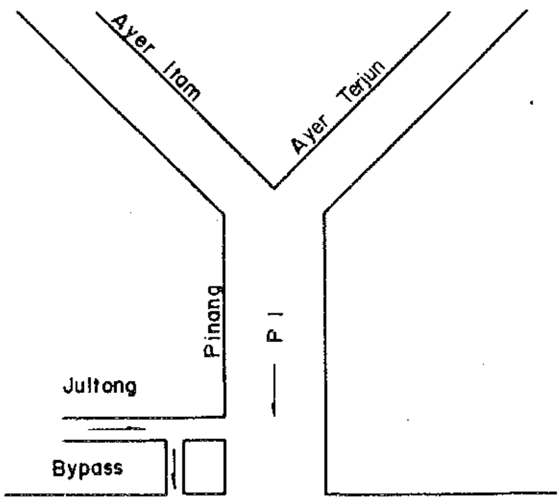
Fig. 27 Design Flood Discharge for Alternative 1: Without Retarding Basin - Perai



Design Flood Discharge (m^3/s)

	10 - y	20 - y	50 - y
P 1	70	70	70
P 2	70	70	70

Fig. 28 Design Flood Discharge for Alternative 2: With Retarding Basin - Perai



Design Flood Discharge (m^3/s)

	10 - y	20 - y	50 - y
P 1	45	60	75

Fig. 29 Design Flood Discharge for Alternative 1 - Pinang

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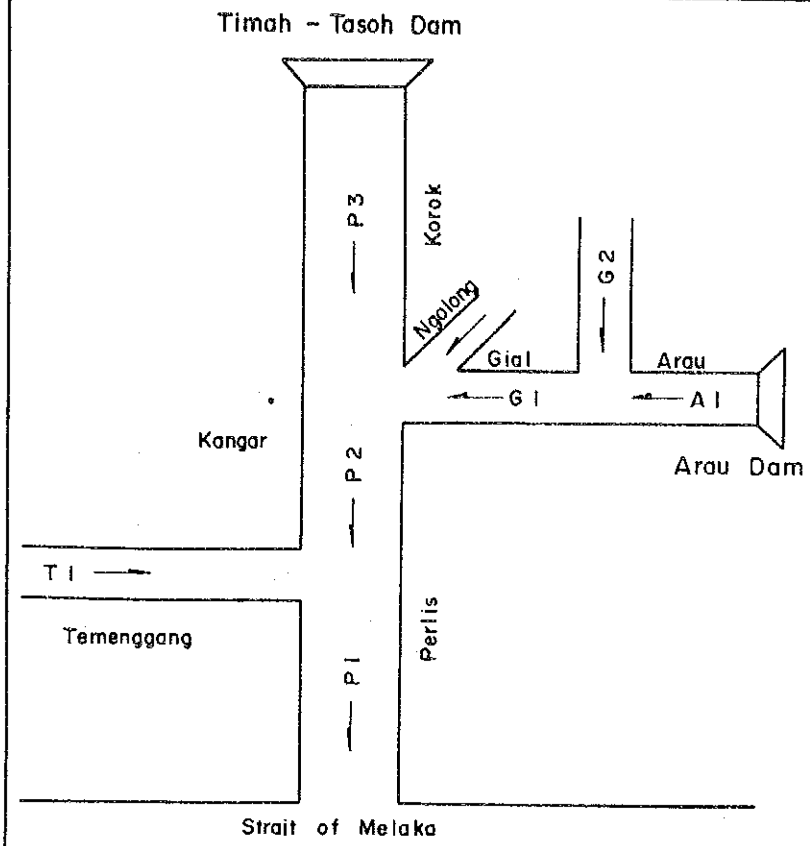
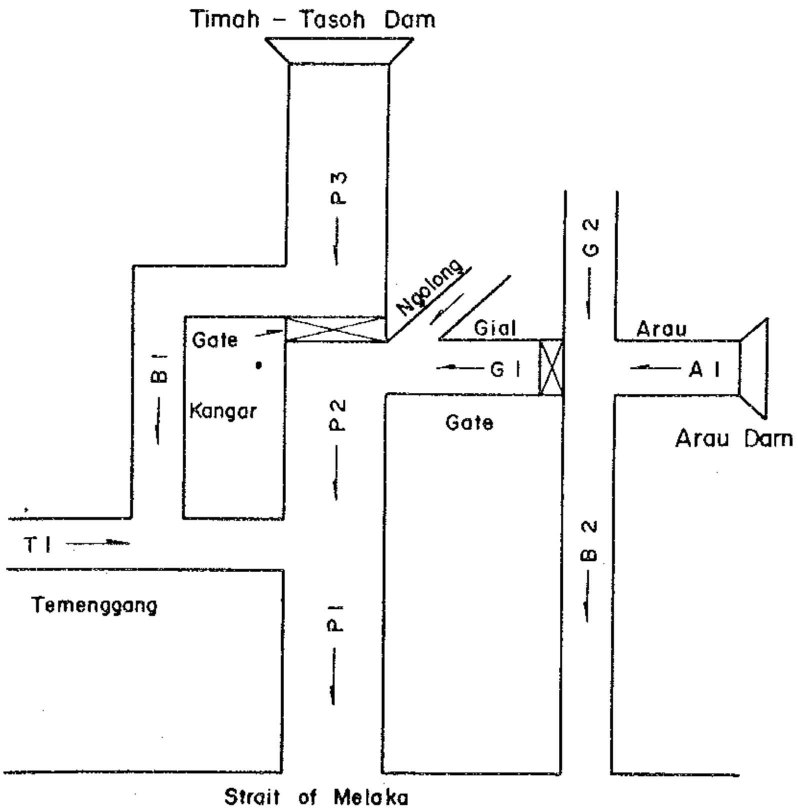


Alternative 3 : Without Bypass Floodway

Design Flood Discharge (m^3 / s)

	Timah - Tasoh + Arau
P I	280
P 2	250
P 3	100
T I	90
G I	160
G 2	110
A I	75



Alternative 4 : With Bypass Floodways

Design Flood Discharge (m^3 / s)

	Timah - Tasoh + Arau
P I	210
P 2	70
B I	100
P 3	100
T I	90
G I	—
G 2	110
A I	75
B 2	160

Fig. 30 Design Flood Discharge With Dam - Perlis

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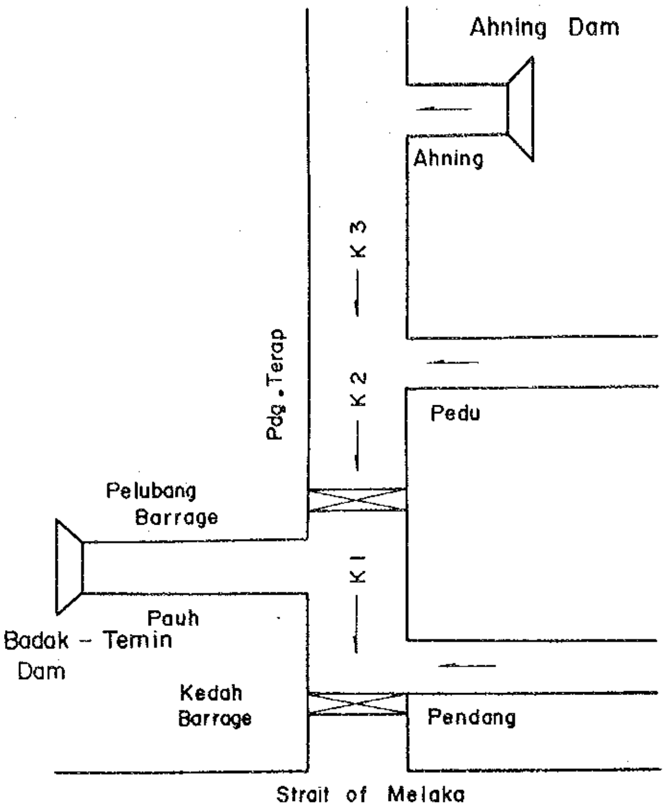
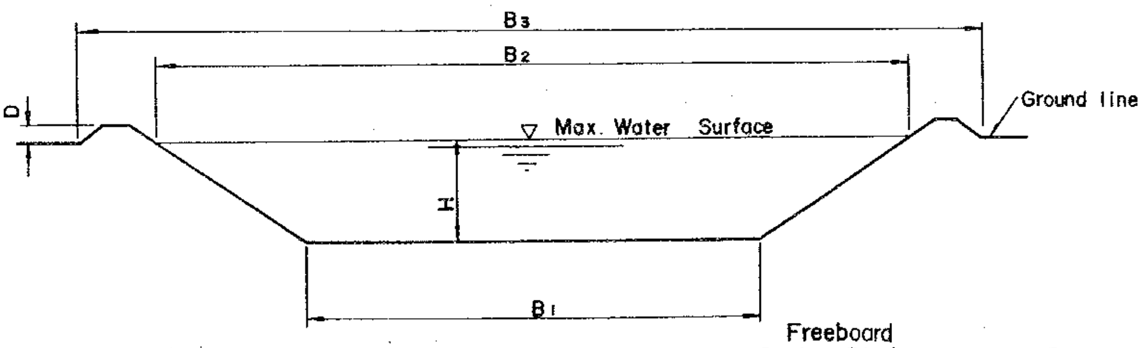


Design Flood Discharge (m^3/s)

	Ahning
K 1	730
K 2	520
K 3	260

Fig. 31 Design Flood Discharge for Alternative 2:
With Dam - Kedah



Freeboard

Design Discharge (m^3/s)	D (m)
300	0.7
500	0.8
1.000	1.0
2.000	1.0

Fig. 32 Definition Sketch of Channel Cross Section

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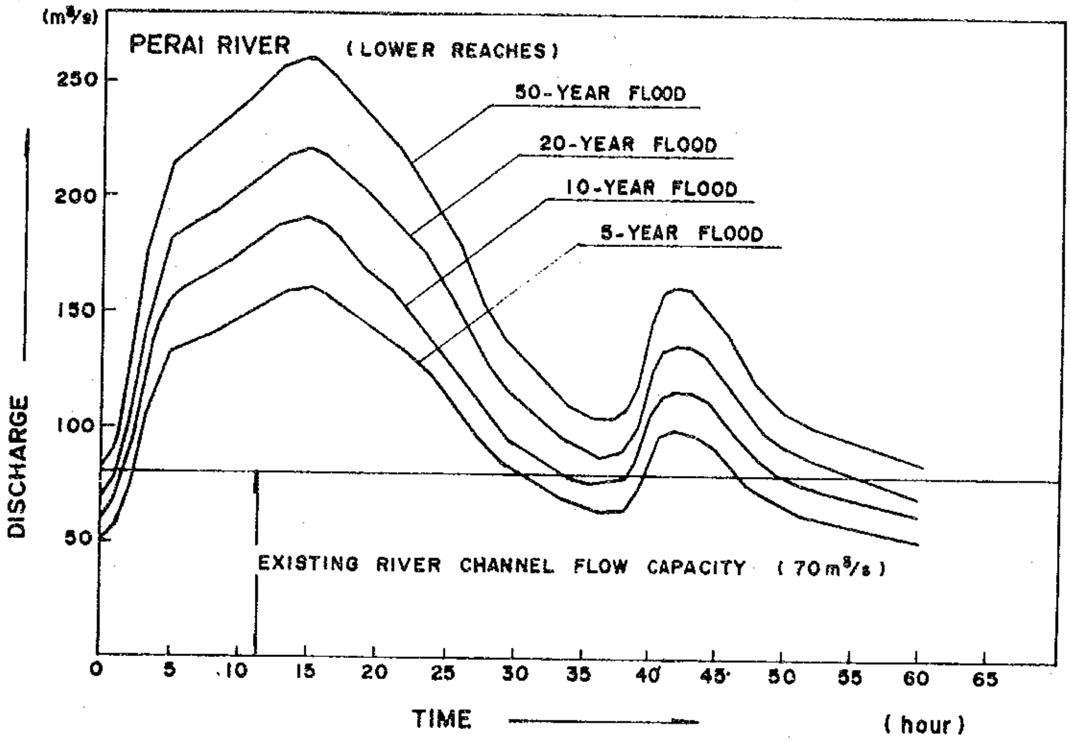

Fig. 33 Flood Hydrograph

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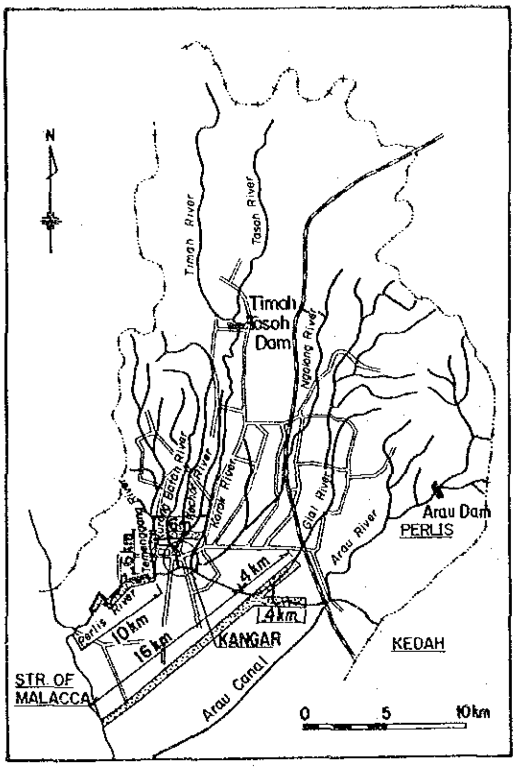


Fig. 34 Recommended Flood Mitigation Plan (1/4) - Perlis

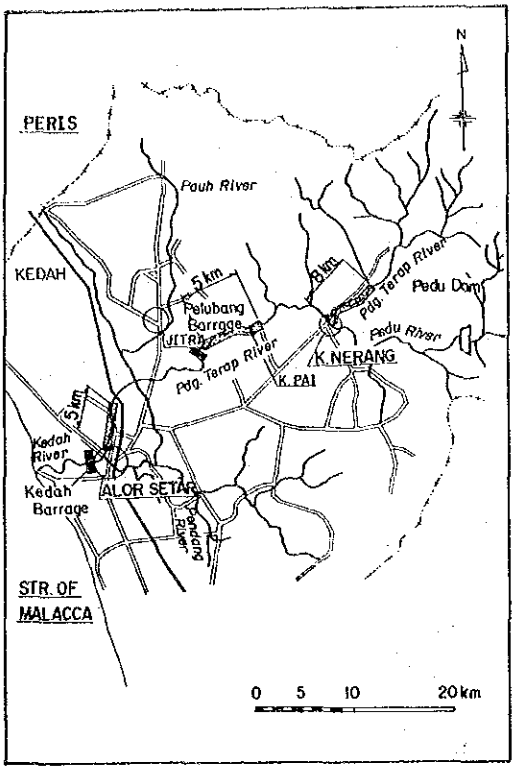


Fig. 35 Recommended Flood Mitigation Plan (2/4) - Kedah

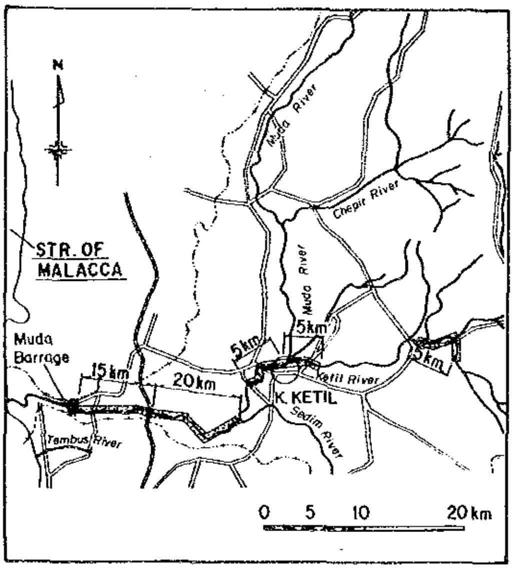


Fig. 36 Recommended Flood Mitigation Plan (3/4) - Muda

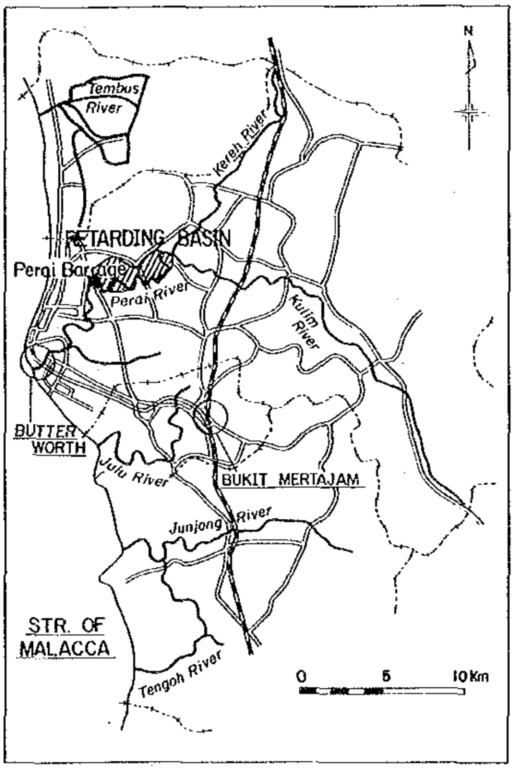
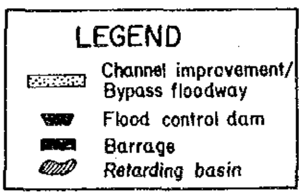


Fig. 37 Recommended Flood Mitigation Plan (4/4) - Perai



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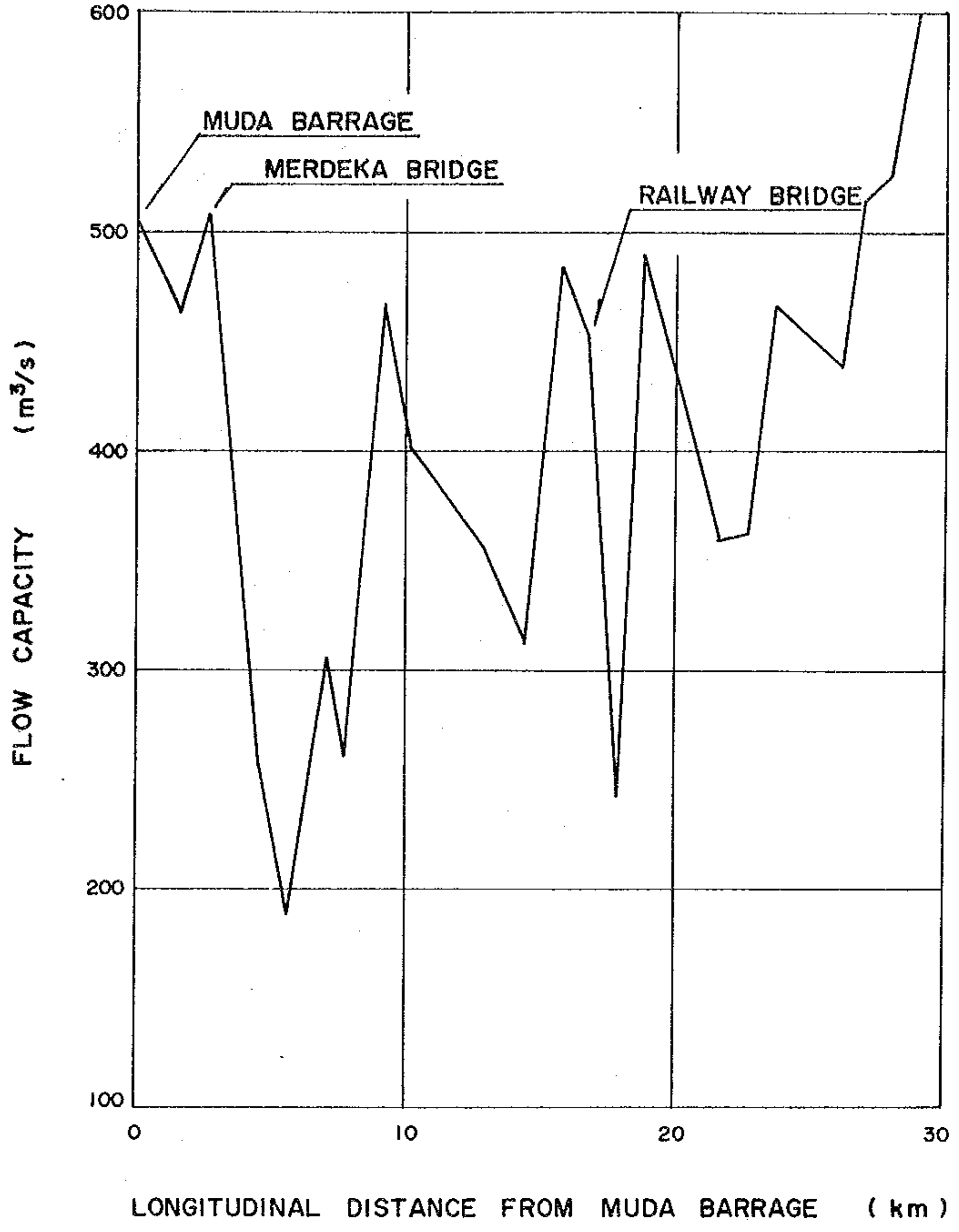

Fig. 38 Present Flow Capacity of Downstream of Muda River

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Unit: 10^3 m^3
10^3 m^2

WORK ITEM	1st Year	2nd Year	3rd Year	4th Year	5th Year	6th Year	7th Year	8th Year	9th Year	10th Year
PREPARATION	■	■								
DETAILED ENGINEERING	■	■	■	■	■	■	■	■	■	■
UNDER WATER EXCAVATION		x 10^3 m^3 29 ■	88 ■	88 ■	88 ■	59 ■	59 ■	59 ■	59 ■	59 ■
LAND EXCAVATION		x 10^3 m^3 58 ■	173 ■	173 ■	173 ■	115 ■	115 ■	115 ■	115 ■	115 ■
EMBANKMENT		x 10^3 m^3 110 ■	330 ■	330 ■	330 ■	220 ■	220 ■	220 ■	220 ■	220 ■
SOD FACING		x 10^3 m^2 60 ■	181 ■	181 ■	181 ■	121 ■	121 ■	121 ■	121 ■	121 ■
LEVEE/ROAD PAVEMENT		x 10^3 m^2 14 ■	41 ■	41 ■	41 ■	27 ■	27 ■	27 ■	27 ■	27 ■

ACCOMPLISHED IMPROVEMENT LENGTH (CUMULATION)		km 0.7	km 4.0	km 5.5	km 7.5	km 10.0	km 14.0	km 18.0	km 27.0	km 34.0

LEGEND:

146 x 10^3 m^3 — WORK VOLUME

■ — WORK PERIOD

Fig. 39 Construction Schedule of River Channel Improvement for Model Stretch of Muda River

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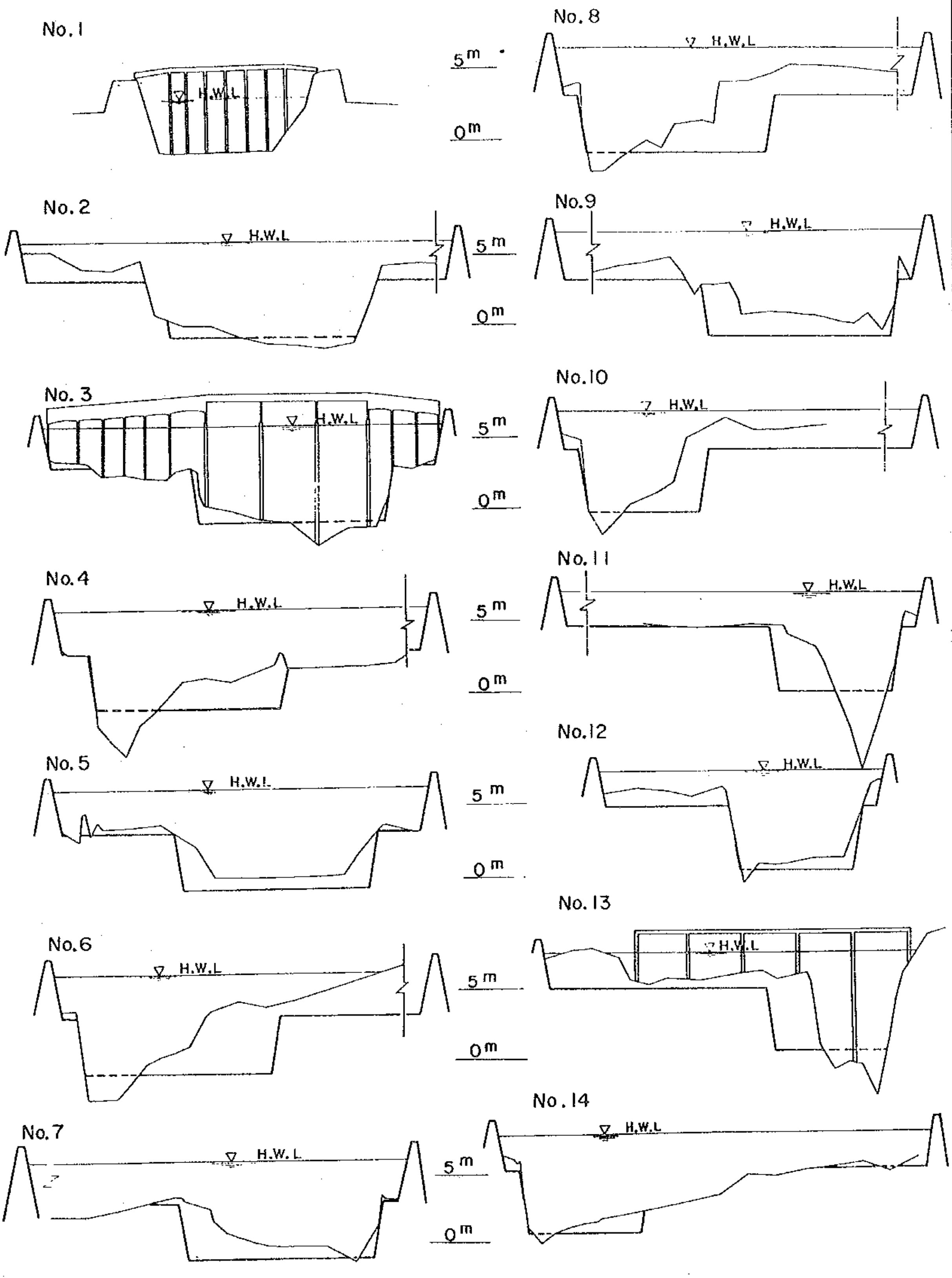

SCALE : VERTICAL 1/400

HORIZONTAL 1/4000

Fig. 40 Proposed Cross Section for Model River Stretch of Muda River (1/2)

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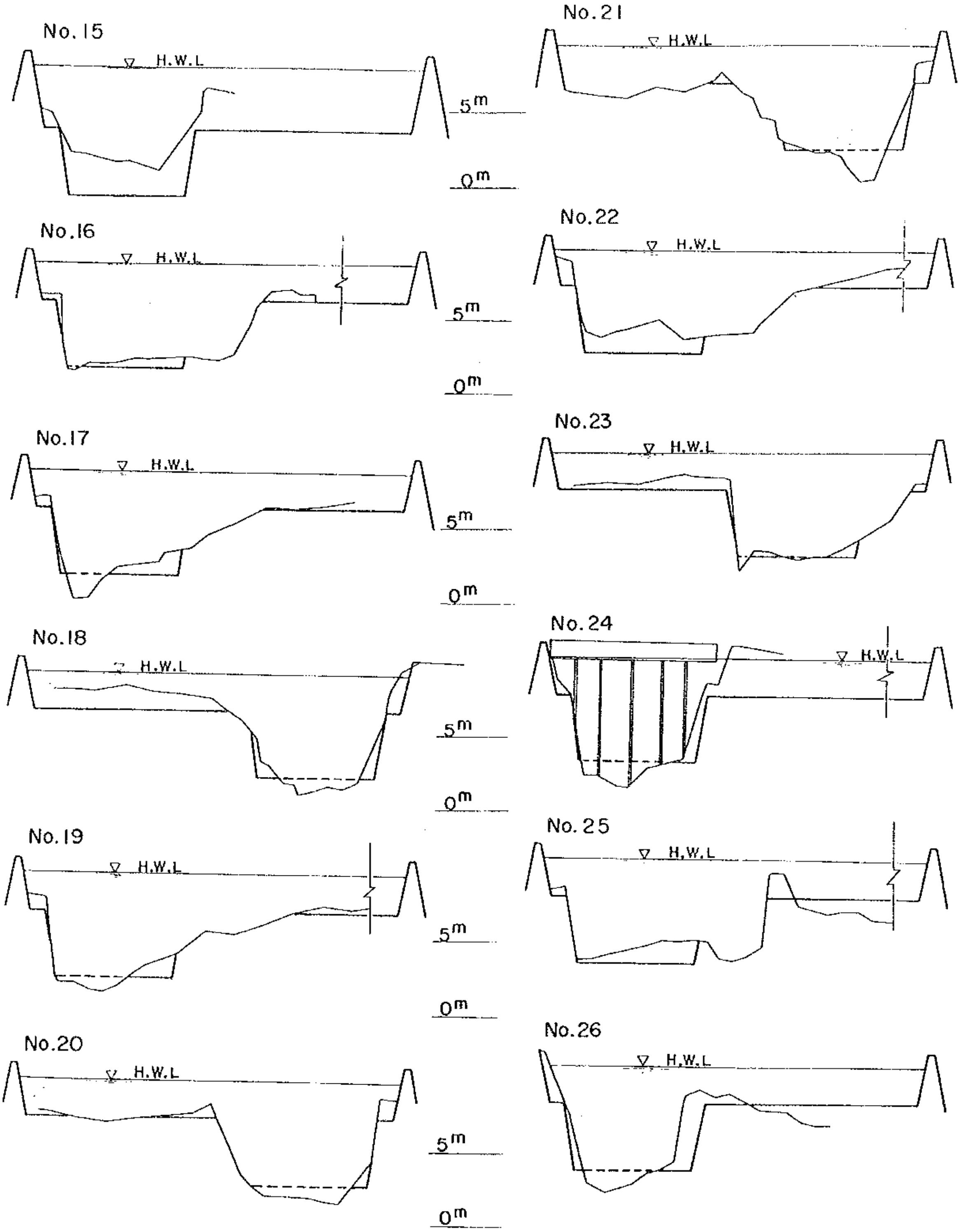

SCALE : VERTICAL 1/400

HORIZONTAL 1/4000

Fig. 41 Proposed Cross Section for Model River Stretch of Muda River (2/2)

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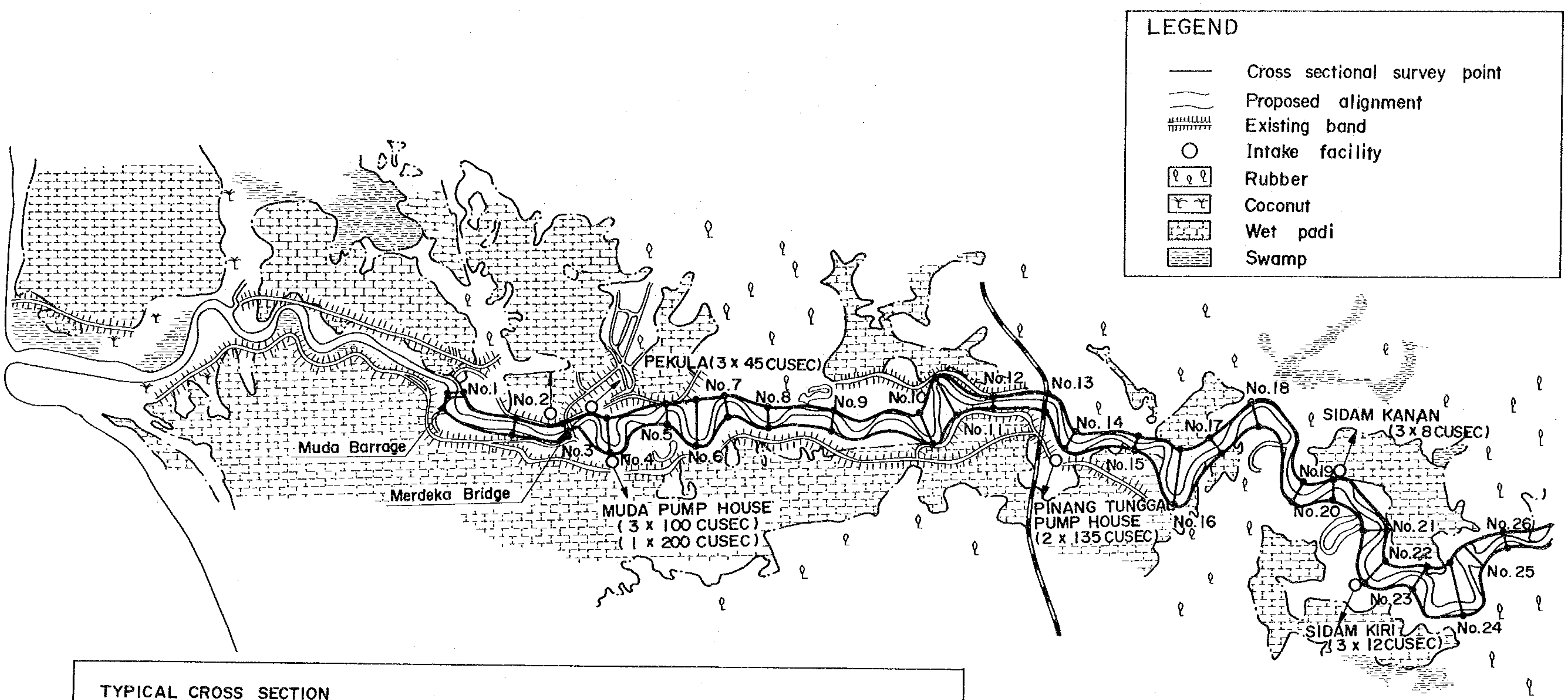
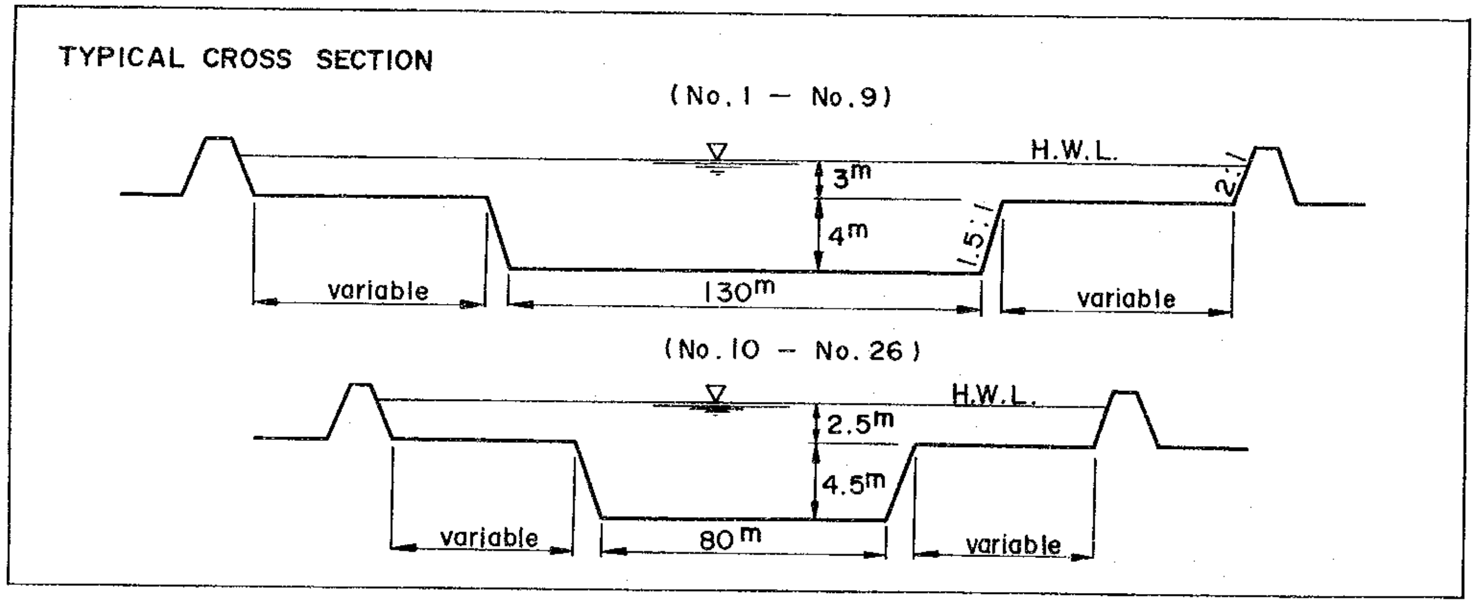
PLATES





Plan of River Channel Improvement for Model Stretch of Muda River

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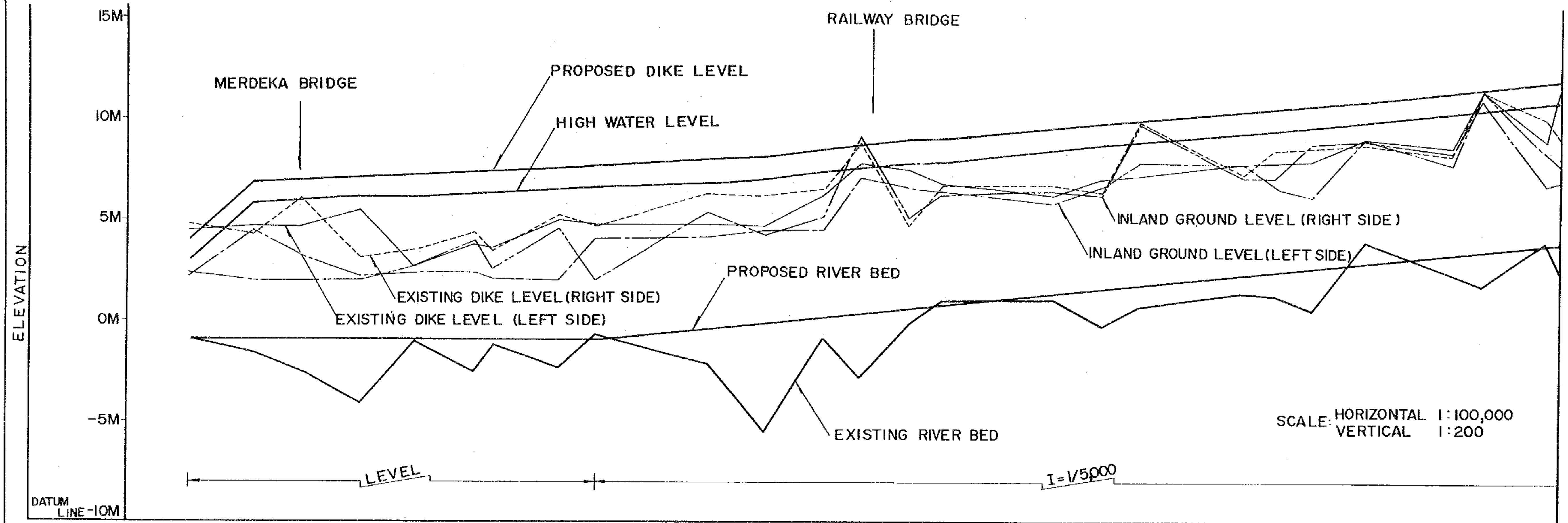
PLATE NO. 2



STATION POINT NO.	PROPOSED RIVER BED (M)	PROPOSED H.W.L (M)	PROPOSED DIKE (M)	EXISTING RIVER BED (M)	INCREASE DISTANCE (M)	INTERVAL DISTANCE (M)
1	-0.9	3.0	4.0	-0.9	0.00	0.00
2	-0.9	5.9	4.4	-1.6	1580	1580
3	-0.9	6.0	4.7	-2.5	2781	1201
4	-0.9	6.1	5.0	-4.1	4212	1431
5	-0.9	6.2	5.3	-1.0	5524	1312
6	-0.9	6.3	5.7	-2.5	7039	1515
7	-0.9	6.3	5.8	-1.2	7479	440
8	-0.9	6.4	6.1	-2.3	9058	1579
9	-0.9	6.5	6.4	-0.7	9982	924
10	-0.4	6.8	7.0	-2.1	12726	2744
11	-0.1	7.0	7.3	-5.5	14139	1413
12	0.2	7.3	7.6	-0.8	15557	1418
13	0.4	7.5	7.8	-2.8	16476	919
14	0.6	7.7	8.0	-0.1	17649	1173
15	0.8	7.8	8.2	1.0	18486	837
16	1.9	8.4	8.7	1.1	21157	2671
17	1.6	8.6	9.0	-0.3	22389	1232
18	1.8	8.8	9.2	0.7	23331	942
19	2.3	9.3	9.7	1.4	25934	2603
20	2.4	9.4	9.8	1.3	26663	729
21	2.6	9.6	10.0	0.5	27612	949
22	2.9	9.9	10.3	3.9	28950	1338
23	3.3	10.3	10.7	2.3	31063	2113
24	3.5	10.5	10.9	1.8	31790	727
25	3.8	10.8	11.2	4.0	33399	1609
26	3.9	10.9	11.3	2.4	33768	369

Proposed Longitudinal Profile for Model River Stretch of Muda River

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