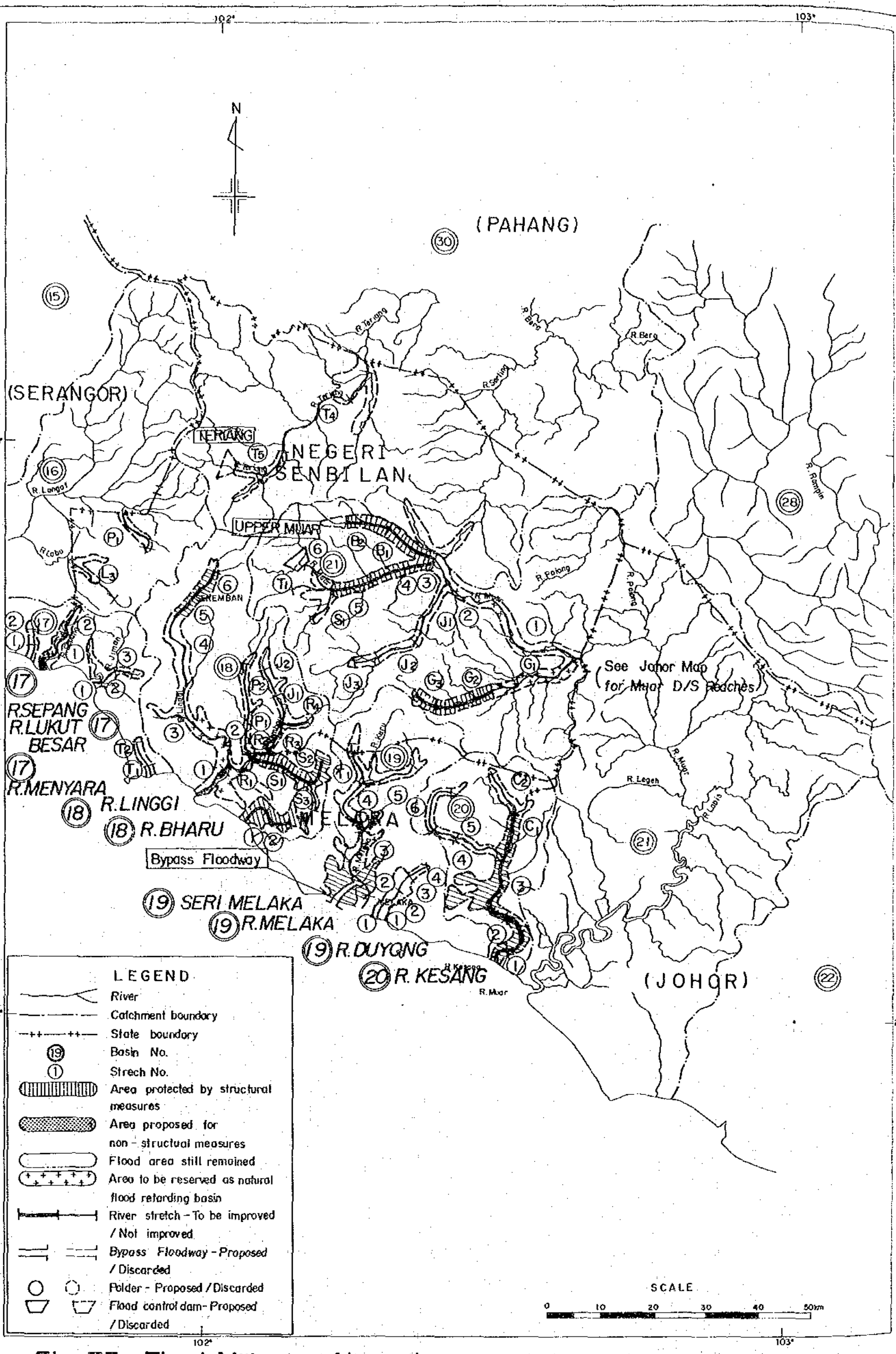

Fig. 73 Flood Mitigation Alternatives
Alt.F2- Melaka / N.Sembilan

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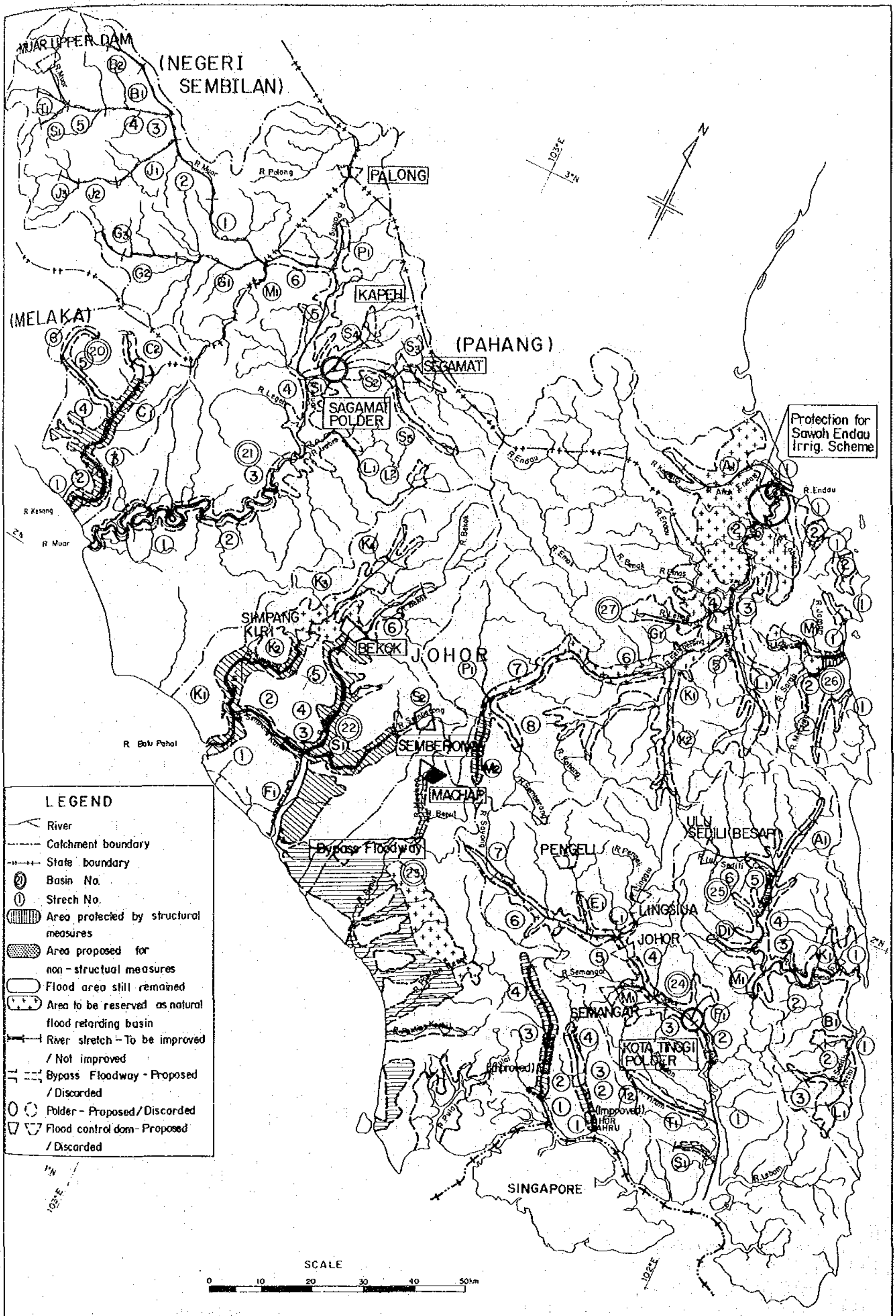

Fig. 74 Flood Mitigation Alternatives Alt.F2- Johor

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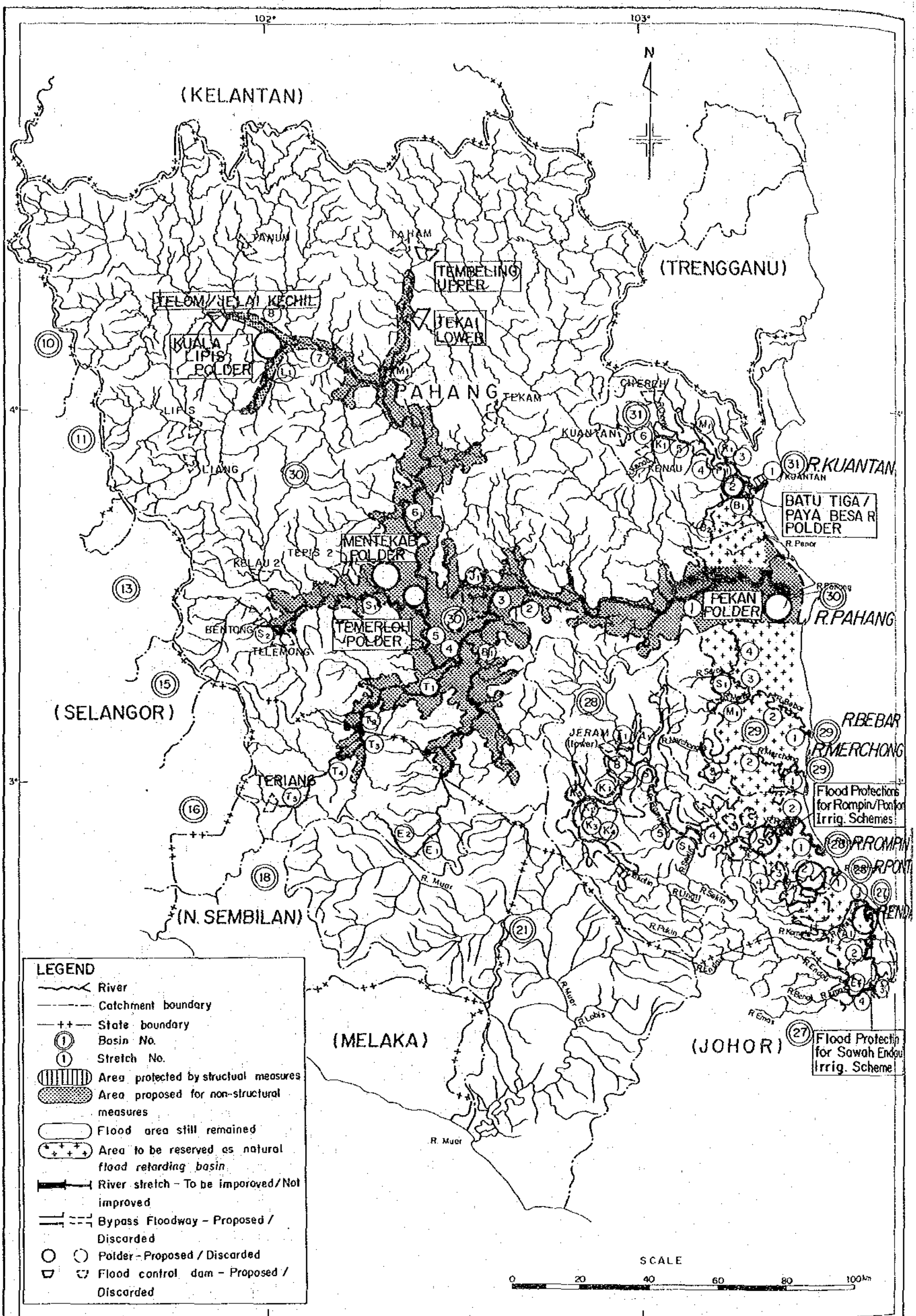

Fig. 75 Flood Mitigation Alternatives
Alt.F2- Pahang

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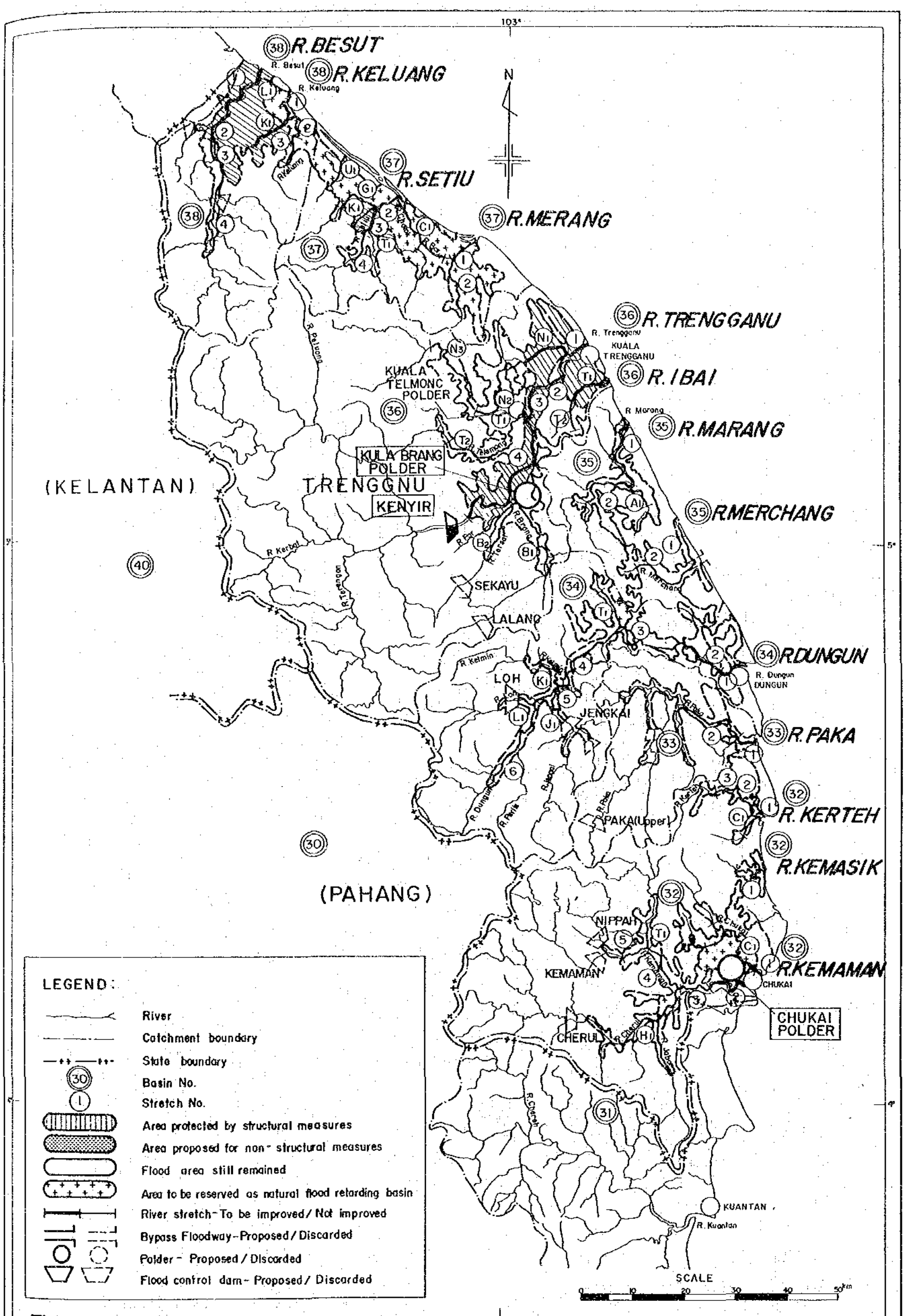

Fig. 76 Flood Mitigation Alternatives
Alt.F2- Trengganu

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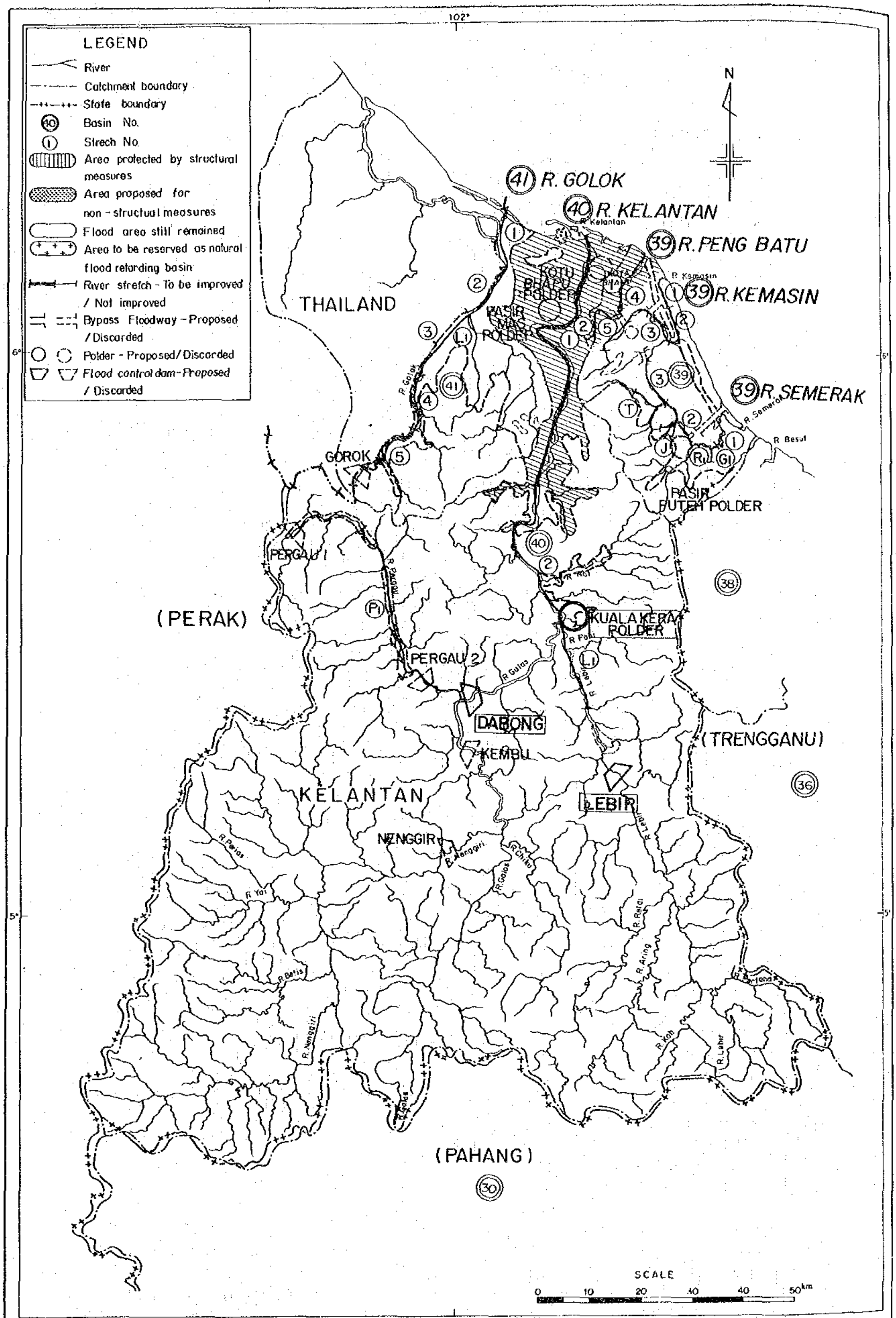

Fig. 77 Flood Mitigation Alternatives AltF2- Kelantan

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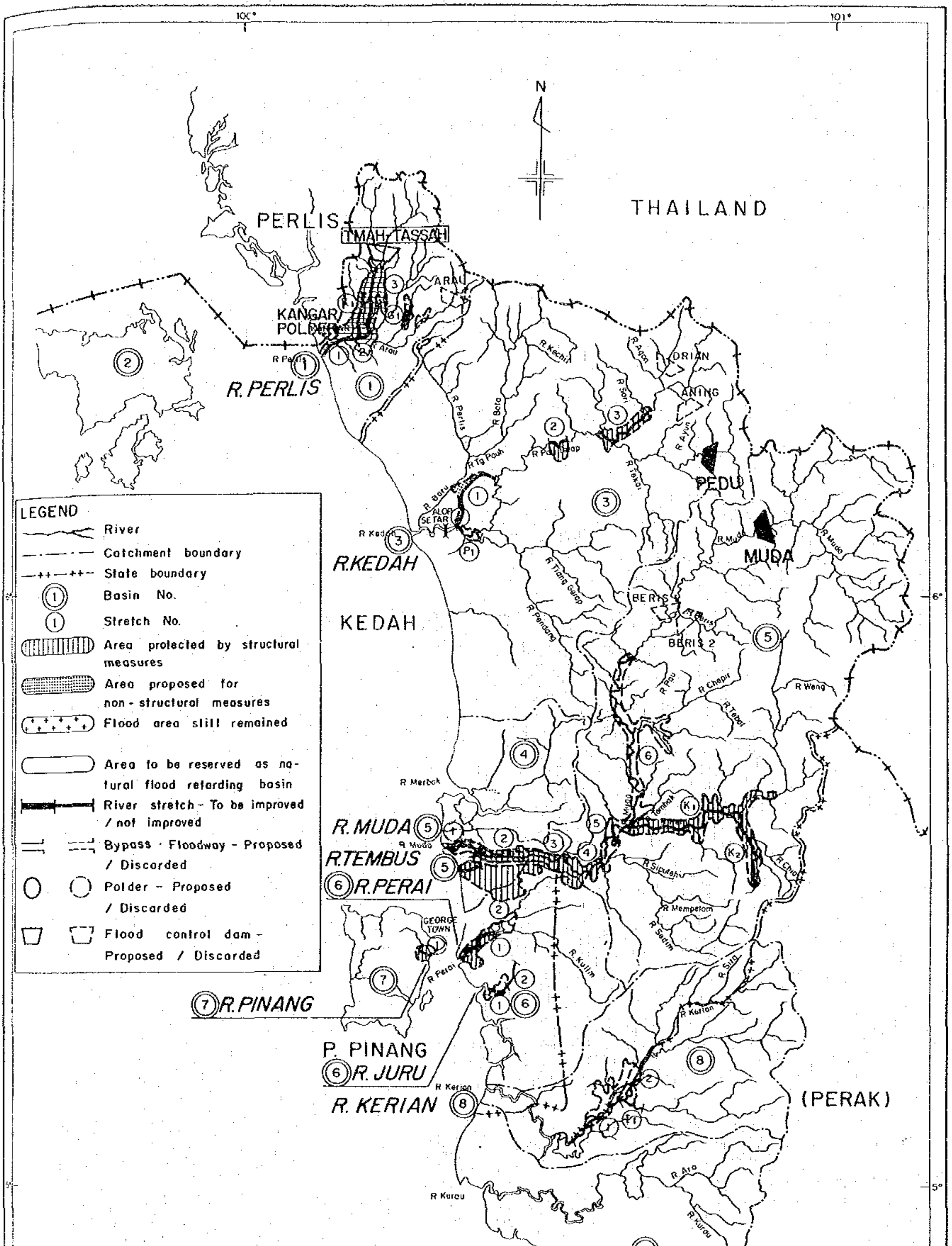

Fig. 78 Flood Mitigation Alternatives
Alt.F3- Perlis / Kedah / P.Pinang

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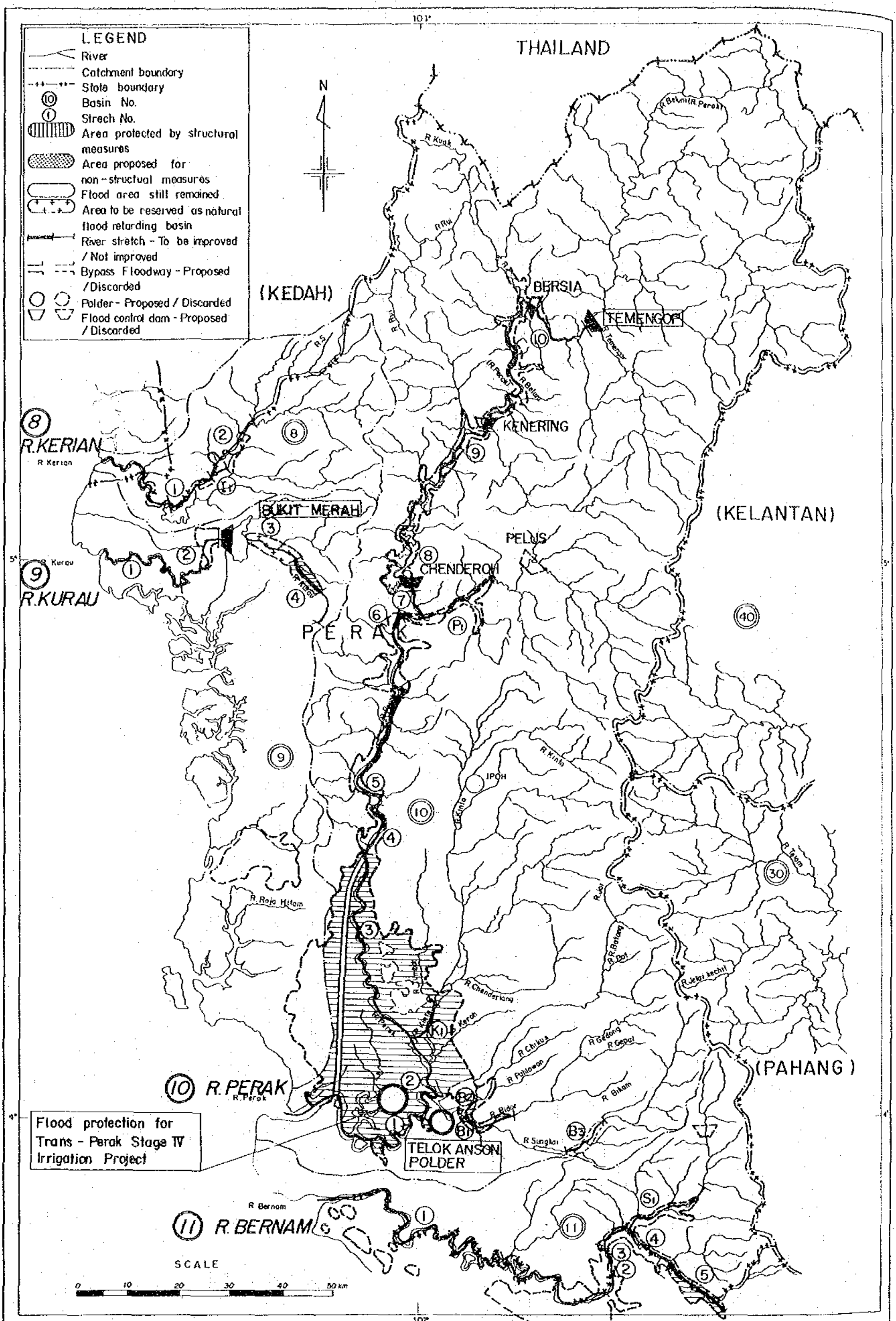

Fig. 79 Flood Mitigation Alternatives
Alt.F3 - Perak

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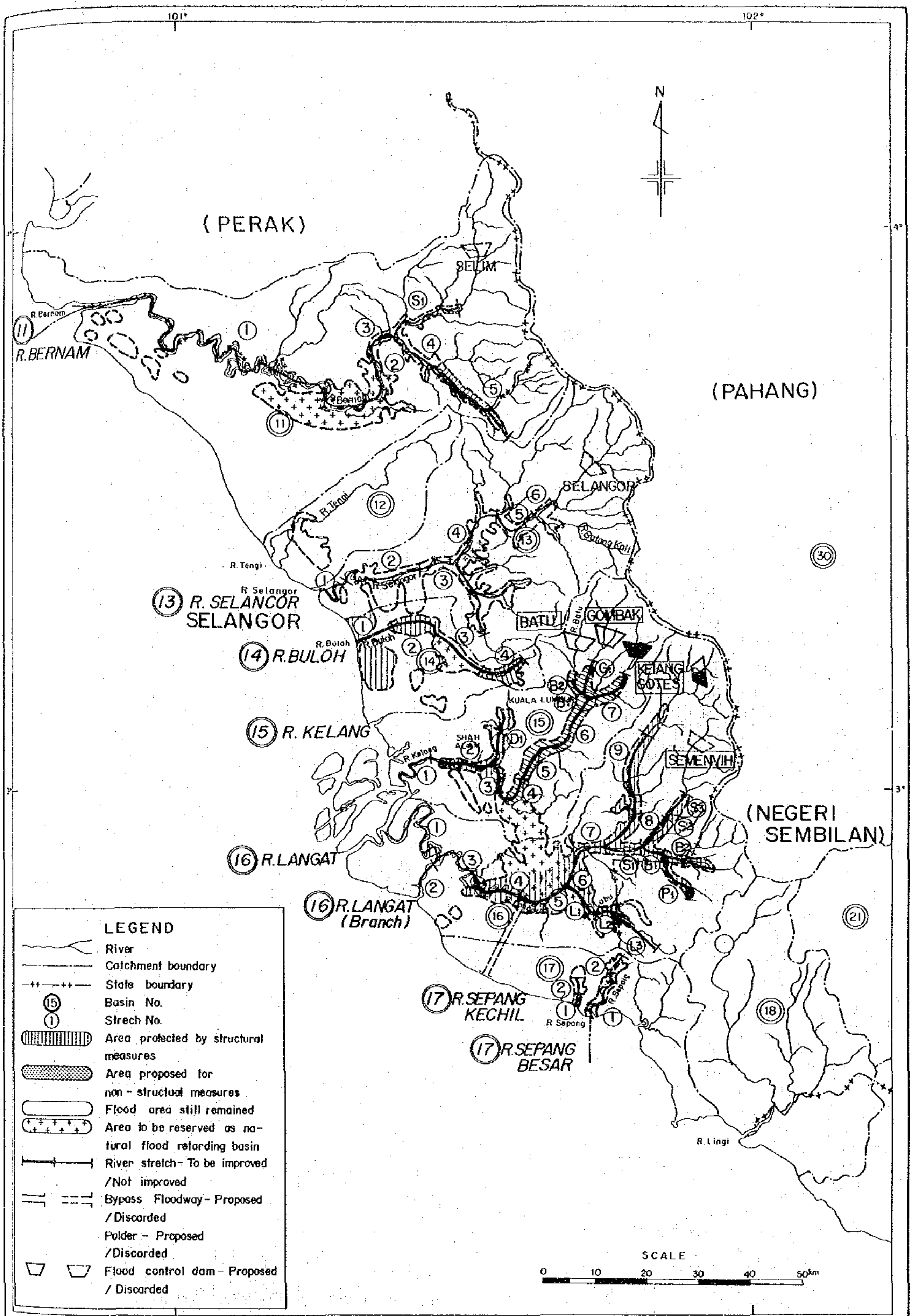

Fig. 80 Flood Mitigation Alternatives Alt.F3 - Selangor

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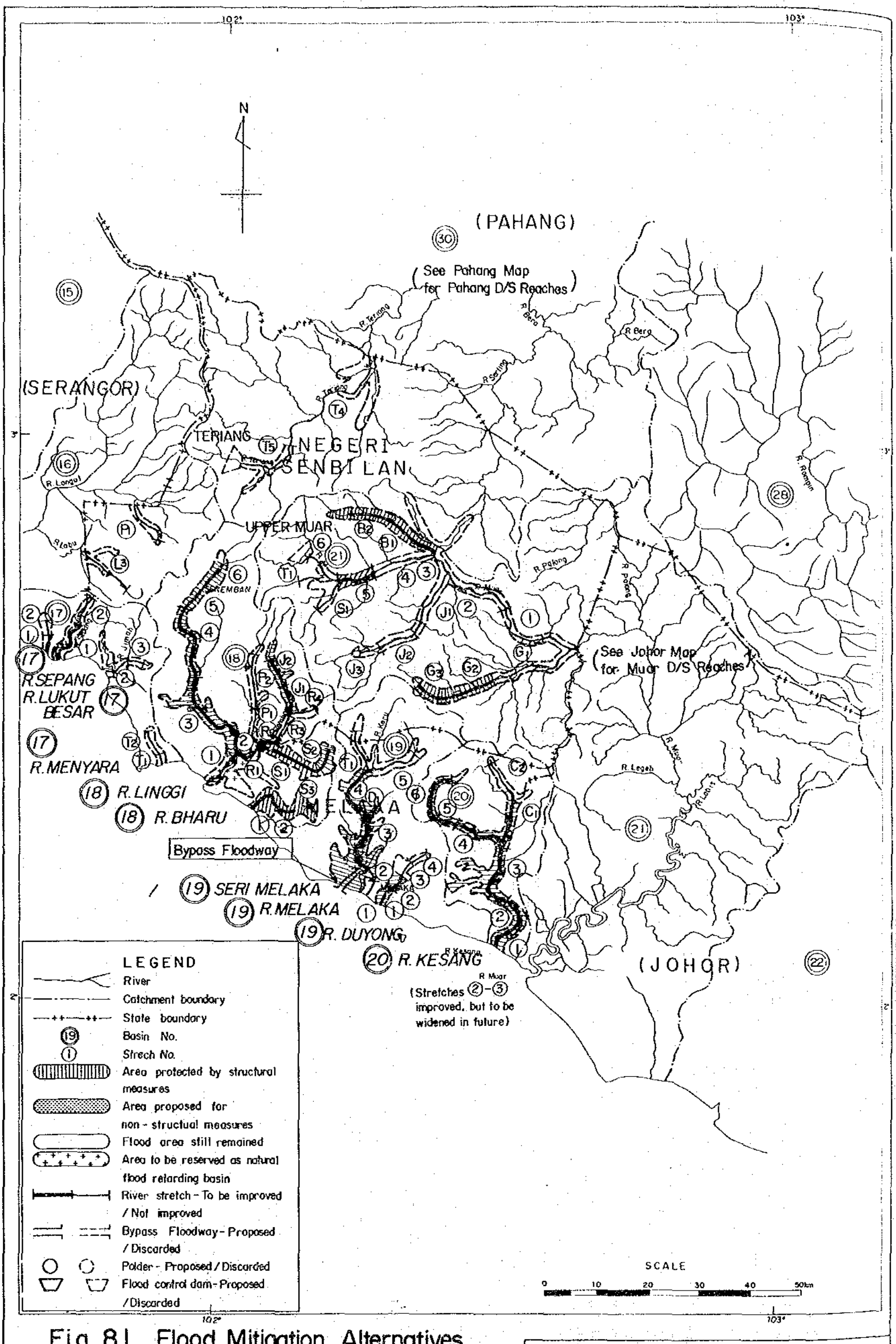

Fig. 81 Flood Mitigation Alternatives Alt.F3 - Melaka / N.Sembilan

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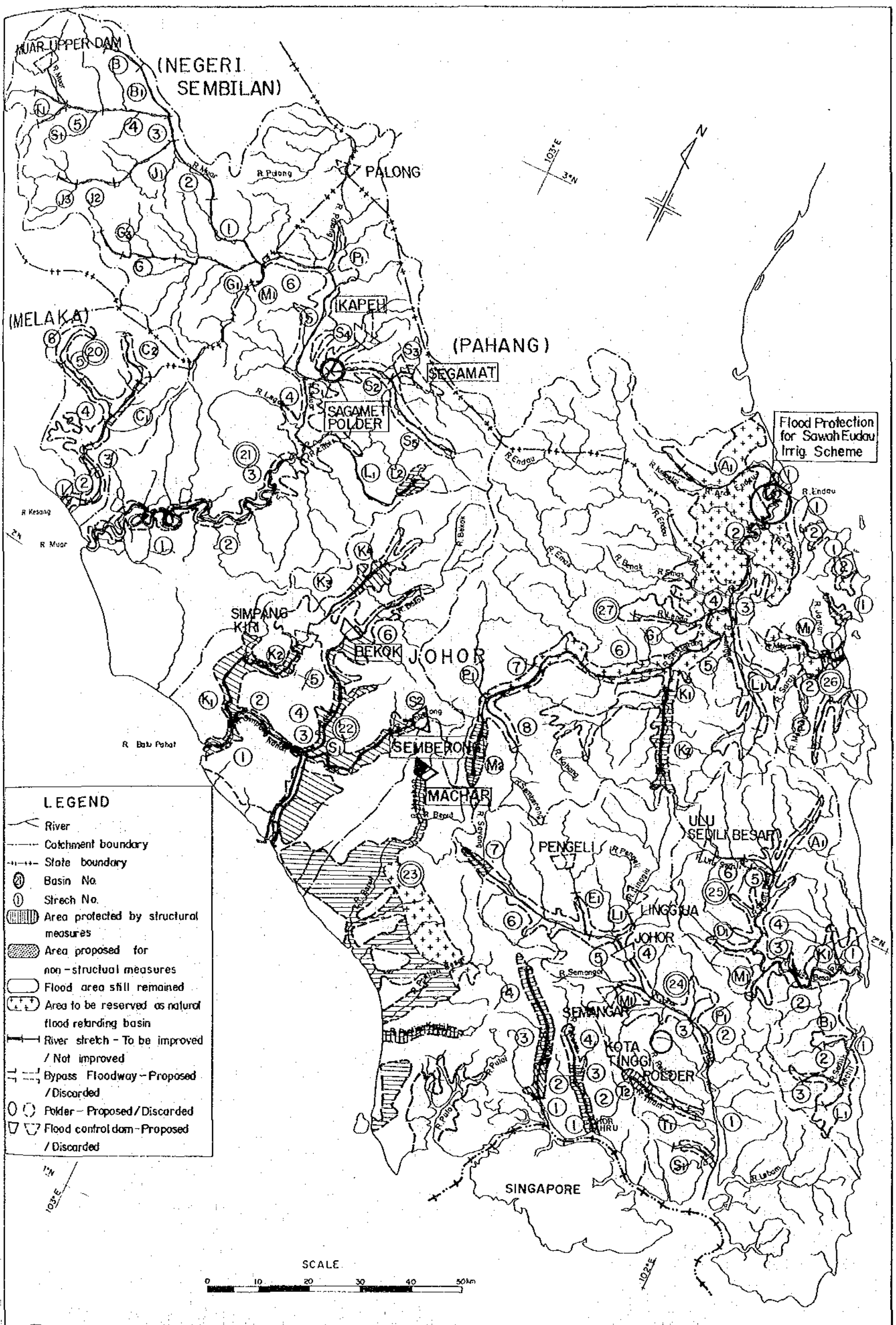

Fig. 82 Flood Mitigation Alternatives
Alt.F3- Johor

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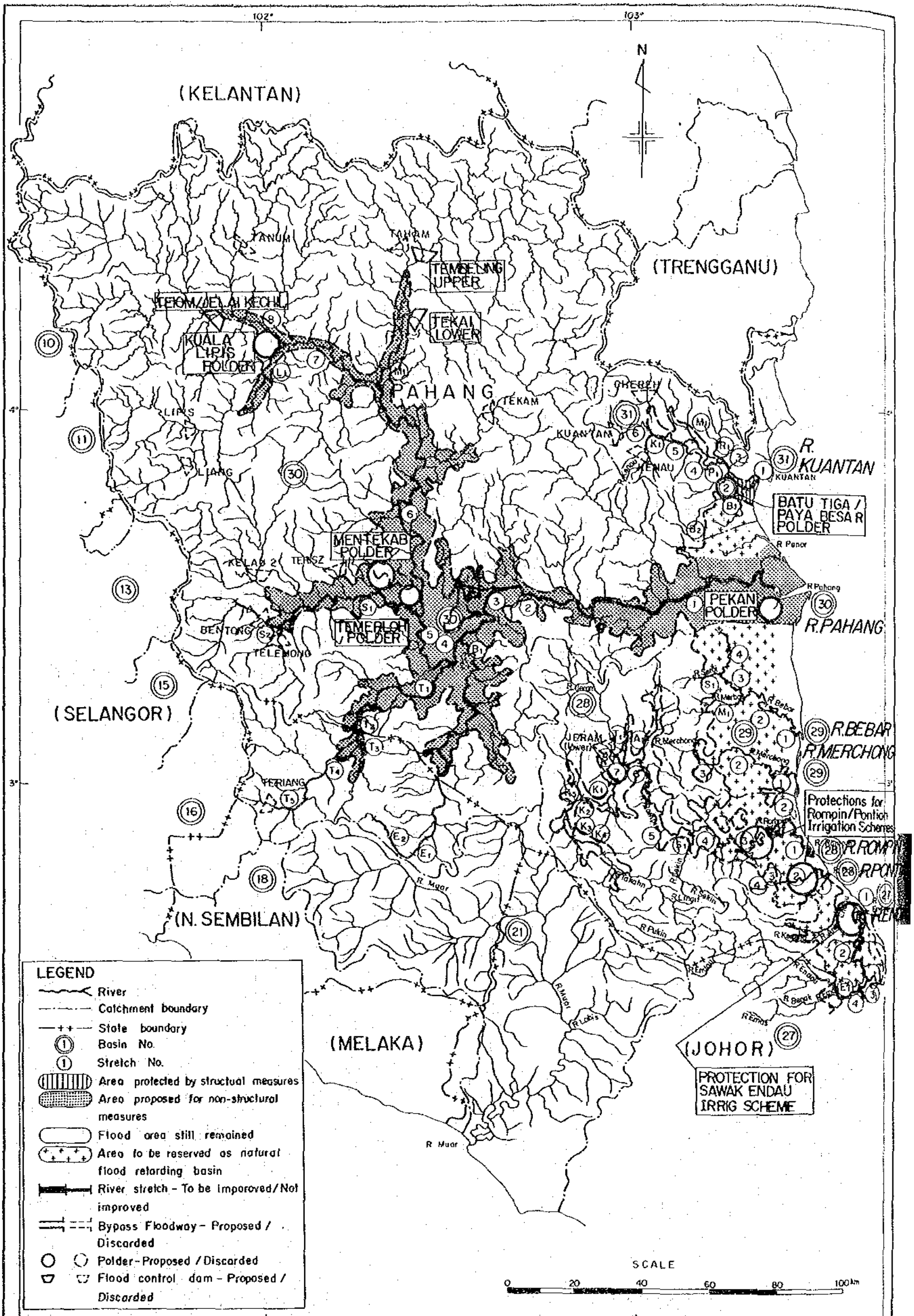

Fig. 83 Flood Mitigation Alternatives
Alt.F3- Pahang

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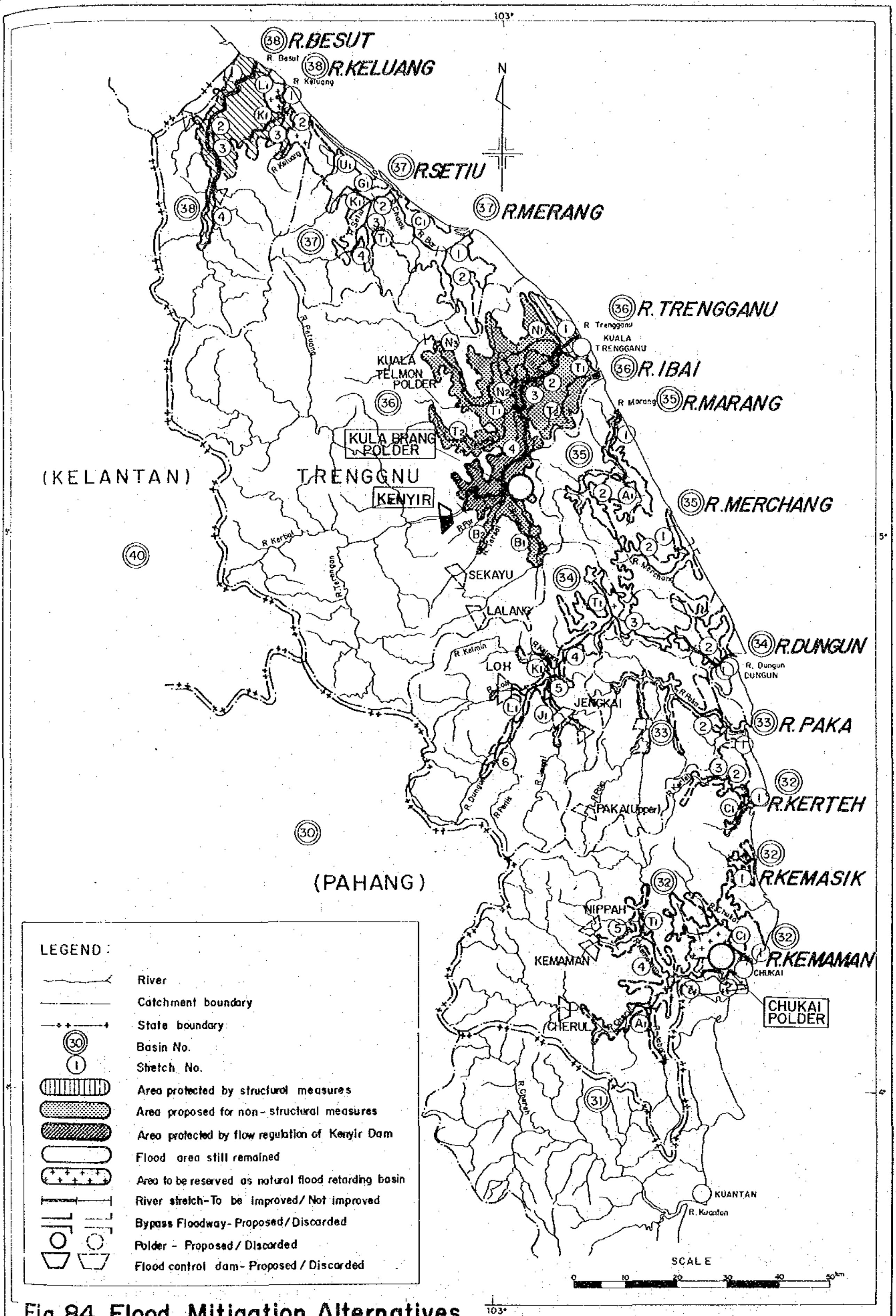

Fig. 84 Flood Mitigation Alternatives
Alt.F3 - Trengganu

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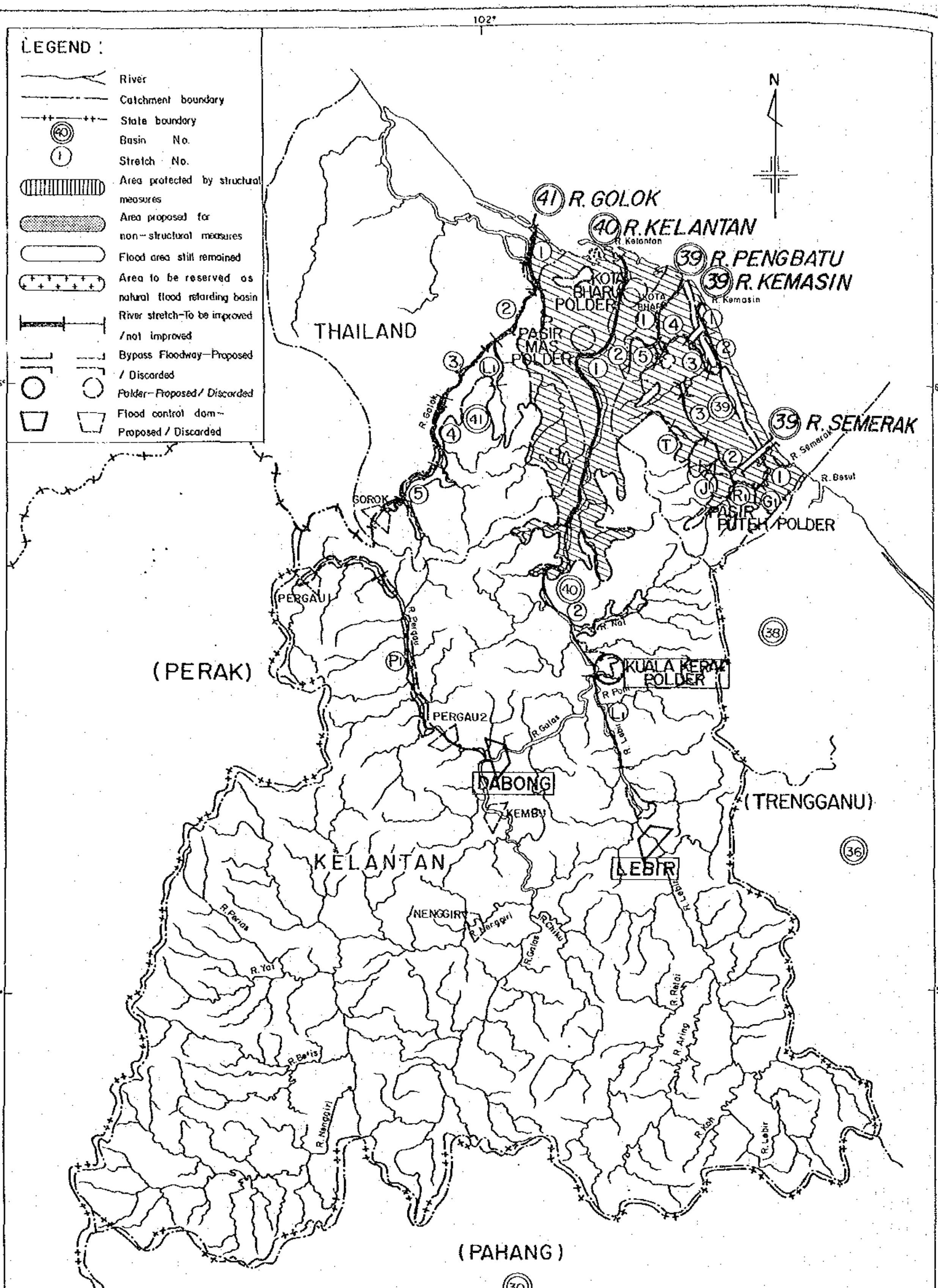

Fig. 85 Flood Mitigation Alternatives Alt.F3- Kelantan

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PART 2

SABAH AND SARAWAK

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1. INTRODUCTION

There are more than 50 river systems in Sabah and Sarawak. The rivers are used for many purposes such as inland navigation, transportation of timber logs and goods, irrigation, domestic water use and hydropower generation. While Floods occur almost every year and damage human life, agricultural crops, properties and public facilities. It is estimated that the flood prone area is 12,600 sq.km and 216,000 people live in the flood prone area at the year 1980 in Sabah and Sarawak. Flood damage potential will increase according to the population growth and GRP growth.

The objective of the river condition study is to make clear the constraints for the water use and related land use arising from the innundation, sedimentation and erosion of rivers. The results will be used for the water resources planning especially for flood control and mitigation plans.

The sectoral study comprises the following items:

(1) Review and observation of present river condition,
(2) Review of flood records and characteristics,
(3) Estimate of probable flood damage, and
(4) Formulation of flood mitigation plans, alternative study and selection of recommended plans.

Information was collected mainly from the state DID offices and also by visiting the field from August 1981 to July 1982. Chapter 2 gives the broad idea and background of Sabah and Sarawak, which are essential to grasp the project area. Chapter 3 describes the results of field investigation on which the alternative study and analysis are based. In Chapter 4, brief descriptions are given to the past flood events, flooding characteristics and existing flood control facilities. Studies in Chapter 5 are the estimation of probable damage for some 20 flooding rivers. Annual average damage is calculated by river basin.

Chapter 6, 7 and 8 deal with basic criteria and assumptions set out for plan formulation, cost estimate and benefit estimate, respectively. These criteria were applied uniformly to all the schemes studied, to aim at the comparison of the schemes on an equal basis. Chapter 9 discusses the flood mitigation plans, inclusive of structural and non-structural measures. Through the screening of various proposed measures, three alternative development plans have been formulated for each state. Chapter 10 describes the development schedule, budgetary and man-power requirements for the implementation of the three alternative development plans. The economic evaluation of the plans is also contained in this chapter.

Presented in Chapter 11 is the recommended development plan for each state, which was selected through a comparison among the proposed three alternative plans. Technical review of the recommended plan is discussed in the latter part of this chapter.

Data and reports used for the study and analysis are summarized at the end of the text as Reference.

Having been discussed by the goverment counterparts personnel, working groups and committees, the report was adjusted based on the comments made by the officials by the end of August 1982. Abrupt change is the recommended plan, which was formarly selected from an economical point of view but, presented herein, is selected from a social well-being point of view.

The study area is too large to outline the flood mitigation plans within a short period and insufficient data. Since the study is a master plan level, it might be not necessary to conclude the plans. The projects which are identified to be implemented will be refined in the feasibility study stage which followed by this study.

2. PROJECT AREA

2.1 Location

The States of Sabah and Sarawak are located at most northern and northern west part of Borneo between latitudes 1′ and 7′ 30" and longitude 109′ 30" and 119′. The area is surrounded by the South China Sea in its front, Kalimantan Indonesia in its back and Sulu Sea in its northwest front. Brunei is sandwiched by the two States. The land area in Sabah and Sarawak is 73.9 thousand and 124.4 thousand sq.km, respectively. Fig. 1 shows the location of Sabah and Sarawak.

The Crocker range, which runs close to and parallel to the coast, divides the Sabah state. Most of the rivers in the west coast of Sabah flash through the coastal plains, where most of major cities locate near the sea. On the other hand, rivers in the east coast debouch the wide flood plains at the middle reach of the rivers, which have the longer stretch than those in the west.

Several mountain ranges divide Sarawak from Indonesian territory. Major rivers in the northern and middle parts run criss-crossing and detouring through mountains and debouch to the wide flood plains.

Blessed with the geographical and climatological condition, the two States receive abundant rainfall throughout the year with less seasonal fluctuation. The annual rainfall is 2,570 mm in Sabah east, 2,900 mm in Sabah west, 3,250 mm in Sarawak north and 3,870 mm in Sarawak south respectively. Flood occurs usually in December and January.

2.2 Socio-economic Aspects

The total population in Sabah is around 1.1 million with population density of 13.6 persons/sq.km in 1980 (refer to Sectoral Report Socio-Economy). Around 600 thousand people reside in the West Coast Residency. The Districts of Kota Kinabalu and Labuan are moderately densely populated with more than 250 persons/sq.km. In Sarawak, total population is around 1.3 million with the density 10.4 persons/sq.km in 1980. Around 830 thousand people or two-thirds of the total population live in the First, Second and Third Divisions. The District of Kuching is the most densely populated district with 124 persons/sq.km. Districts in mountainous area are sparsely populated with the population density less than 10 persons/sq.km. Population and its density by district is as shown in Tables 1 and 2.

Sabah attained GRP of M$1,944 million in 1980 and M$1,771 in terms of per capita GRP, while in Sarawak GRP in 1980 was M$1,726 million and per capita GRP was M$1,313.

It is anticipated that the population would be 2.08 million for Sabah and 2.48 million for Sarawak in the year 2000, respectively. Per capita GRP would reach M$4,670 in 2000 with an average growth rate of 5.0% during the period from 1980 to 2000 for Sabah and M$4,191 in 2000 of 6.0% for Sarawak (refer to Sectoral Report Socio-Economy). These values are used as a basis of estimate of potential flood damage.

The States are further divided into administrative divisions and districts, which comprise 23 districts for Sabah and 25 for Sarawak.

2.3 River Basins

The States of Sabah and Sarawak were divided into a number of "Basins" in this Study for facilitating planning. The State of Sabah was divided into 26 Basins and the State of Sarawak was divided into 21 Basins. The Basin number, the name of Basin, the correlation to the administrative division, and the catchment area of each Basin are shown in Tables 3 to 5. The Basins in the States of Sabah and Sarawak are shown in Fig. 2. The administrative divisions of the States are shown in Fig. 3.

The Basins were delineated and their areas were measured on 1/500,000 contour maps based on the following criteria;

(1) Basin boundaries are watersheds,

(2) Each basin is a river basin or a group of river basins, and

(3) If either an international boundary or a state boundary crosses a river basin, it is a Basin boundary.

In most cases, the Basin boundary coincides with the administrative boundary of Residency, Division and/or District.

3. RESULTS OF FIELD INVESTIGATION

3.1 General

The field investigations on river conditions in the States of Sabah and Sarawak were carried out from October 5 to October 23 in 1981. Prior to the field investigation, the contour map study had been carried out. Available reports concerning river-related development and other relevant data had been scrutinized. The results of the field investigation as well as the findings from the contour maps and the land use maps will be used for the formulation of the most optimum plan for flood mitigation projects.

In order to attain the above objective, the field invetigations are directed towards;

(1) carrying out the actual field survey of rivers regarding river morphology, estuary condition, sediments, salt intrusion and flood problems,

(2) collection of data with regard to existing river structures,

(3) collection of lists of projects under construction or planning, which might affect the estimation of cost and benefit in formulating the flood mitigation project, and

(4) grasping the state policy on water resources development project by interviewing the agencies concerned.

3.2 River Profiles

Figs. 4 to 7 show the profile of major rivers. As the survey data are not available for most of the rivers, the figures were prepared based on the information contained in 1:50,000 maps. Although the accuracy is limited, particularly riverbed levels, these information could be used for subsequent planning study.

As is observed on the profiles, the river gradient in the middle to lower reaches is very flat for most of the rivers. This is one of the reasons for the floodings in these rivers.

3.3 River Conditions and Behaviour

With respect to river characteristics, data mainly on river morphology, estuary, sediment, salt water intrusion, water utilization condition and flood record have been collected for the use of formulating flood mitigation plans and water-related development in the area. The main features are described hereunder and also tabulated in Tables 6 to 46 for each river basin, respectively.

Bank erosions caused by meandering action of the river exist in the lower reach of almost all the rivers in Sabah and Sarawak. But the problems caused by the meandering action seemed not so serious in Sarawak with respect to direct damage to the properties nearby the rivers except the Baram river at Marudi town and the Sadong river at Simunjan town.

Simunjan town had to be shifted away from the river as the town was threatened by erosion. The meandering action and bank erosion or bank sliding are also accelerated by the tidal fluctuation, especially the tidal bore phenomena in the Lupar, Sadong and Samarahan rivers. While, in Sabah, houses, paddy fields and irrigation facilities along the river are in danger or were destroyed especially at Kota Marudu and along the Kadamaian, Papar and Pegalan rivers. These river banks are eroded during floods since the water contains a lot of gravel and boulders.

Sedimentation has not given rise to any problems so far. This is attributed to the fact that the catchments are covered with thick virgin forest. However, in the northern west part of Sabah, the sediment problems are anticipated in the future due to the deforestration and land development as well as the inherent nature of the rivers there.

Due to the predominant sea currents as well as the geographical shape of the west coast, the estuary problems such as river mouth clogging and sand bar are quite serious in Sabah and in northern Sarawak. The development of sand bars can be noted along the west coast of Sabah. The river mouths around the area are moving towards south due to the effect of tidal currents. In Miri port, river mouth dredging work is carried out every year. Flood situation is deteriorated by this action especially in rivers south of Kota Kinabalu. As the difference between high tide and low tide is so large in southern part of Sarawak, tractive forces in the receding stage of tide are probably big enough to sweep away the river bed deposits. Neither estuary clogging nor silting-up phenomena were found. Therefore, no estuary dredging work for navigation purpose has been executed.

Most rivers in Sarawak are affected by the salt water intrusion. Of these, the Rajang river has its longest tidal reach of 200 km from the estuary to Kapit. No accurate information regarding salt water intrusion is available for the east coast of Sabah. Figs. 8 shows the tidal reach in Sarawak. The tidal reach is defined as the reach where the river flows from downstream to upstream from time to time according to the tidal effect. But the amount of salt varies from place to place. The water is taken for irrigation and domestic purpose even within the tidal reach.

The rivers are used for many purposes such as navigation, transportation of timber and goods, irrigation, domestic water use and hydropower generation. The transportation heavily relies on river water in Sarawak and east of Sabah. Most of the logs are hauled through rivers. In most cases in Sabah, water is pumped up from the rivers and used for irrigation. There are no records to indicate at which level the water would endanger the bottoms of ships and boats. Most vessels wait for the high tide to keep enough depth from the river bed. At one particular period, logging operations had to be stopped because of lack of water in the Kinabatangan river.

The most serious problem concerning rivers is flood. The flood of January,1981 is considered to be the most serious one in Sabah. The affected areas were Kinabatangan, Kota Marudu, Kota Belud, Papar, Tenom, and Beaufort in Sabah. Flood damage is mainly to agricultural products, irrigation facilities, roads and public facilities. Since houses in villages are mainly of stilt type, the damage to houses was more or less mitigated. Due to poor drainage system, some areas in major towns such as Kota Kinabalu, Sandakan and Tawau were inundated by flood waters for a short duration. While in Sarawak, the flood of January,1963 is deemed to be the most serious one. The affected areas included almost all the lowlands of Sarawak, in particular the flood plains along the Sarawak river in the First Division and along the Baram river in the Fourth Division. The flood caused by heavy rainfall and high tide lasted around one month. Past floods will be analysed in Chapter 4.

Owing to time constraint for field inspection and limited access to the sites, the Study could only achieve a general assessment of major problems inherent to the rivers.

3.4 Problems Associated with Rivers

The main problems associated with rivers are floods and bank erosion. Deforestration and its logging operations would increase the volume of flood. Unused logs left behind after the logging operations are swept down the rivers by floods, resulting in clogging in rivers and decreasing the flow area.

The river training work of the Maong river by means of short-cut, one of the tributaries of the Sarawak river, was reported to accrue the salt water intrusion.

4. FLOOD RECORDS AND EXISTING FACILITIES

4.1 Historical Flood Events

Tables 47 and 48 show the flood disasters recorded in Sabah and Sarawak during these several decades. Of those, the following flood events are the severest kind and should be noted:

Year of Occurrence	Extent of Flood
1963	Many parts of Sarawak experienced the most disastrous floods in recorded history during January and February. The flood caused by continuous rainfall stagnated in the areas for more than a week. The occurrence of king tides influenced the flood levels in the coastal and low-lying areas. Severely affected areas were the First and Fourth Divisions. The total number of person affected by floods were 35,600. Four persons lost their lives.
1967	Severe flood in northern and western parts of Sarawak. Affected areas were the Districts of Limbang, Miri and Bekenu in the north and the Districts of Kuching and Bau in the west.
1968	Severe flood in the Rajang, Lupar, Sadong and Sarawak river basins.
1971	Floods occurred over a large area of the middle and west parts of Sarawak. Affected areas were the Districts of Bekenu, Bintulu, Kuching and Bau.
1976	Severe flood at the Districts of Kinabatangan, Labuk and Beaufort in Sabah and at the Rajang river basin in Sarawak. Some deaths were reported in the Kinabatangan and Labuk river basins.
1979	Severe flood were recorded in Kota Kinabalu in Sabah, Baram and Miri in Sarawak. Estimated damage in Kota Kinabalu amounted to M$1 million.
1981	Most severe flood was experienced in the whole Sabah. In particular, the Districts of Kinabatangan, Beaufort and Tenom were heavily affected.

Of the above flood events, the 1963 and 1981 floods are of recent occurrence, for which records of flood behaviour and some damage have been made available. In the subsequent study, these two flood events are mainly evaluated to estimate the probable flood damage.

4.2 Flood Vulnerable Area

Shaded areas in Fig. 9 represent flood vulnerable areas which had been inundated during the past maximum floods. As the flood area in the east coast of Sabah is sparsely populated, no reliable data regarding flood area were made available in that region. But all the low-lying land in the downstream reaches are likely to be affected by the floods.

As shown in Fig. 9, floods occurred in most of the whole of the low land in Sabah and Sarawak. The areal pattern of flood occurrence is quite erratic and unpredictable year by year, depending on the course of monsoon flows. However, it shall be noted that severe floods often occurred simultaneously in terms of year at the Baram and Sarawak river basins.

4.3 Flood Characteristics

Flood type is generally classified into the following three types;

(1) Overbank flow due to insufficient channel capacity,

(2) Tidal effect and back water effect which cause floodings in the lower reaches and in the tributaries, respectively, and

(3) Inland flooding due to poor drainage.

Even in the case of flood due to overbank flow, the velocity of flood flow is in most cases less significant to the damages because of wide flooding area and flat gradient of the rivers. Flood water is turbid in most cases. Subsequent flood damage estimate will be made assuming these flooding condition, i.e. moderate to low flow velocity of the flood water and inundation by turbid water.

4.4 Seasonal Pattern of Flood Occurrences

Seasonal pattern of flood occurrence was examined based on records in the DID s flood reports. The results are shown on Fig. 10, which implies floods occur from December to January in most areas. In the Baram and Rajang river basins, floods occurred even in the dry season. No clear boundary was found out with regards to the month-time lag of flood occurrence.

Paddy growing stage coinciding with the main flood period is as follows.

Area	Flood season	Paddy growing stage
Sabah	Dec. to Jan.	Heading to ripening
Sarawak	Dec. to Jan.	Booting to heading

4.5 Flood Damage Records

Flood damage record is being collected by the related government departments and agencies. However, the survey and recording are not on the regular basis and the data are not available in a form of statistical records. DID s flood report is only a comprehensive flood record which was made available for the Study. It contains much useful technical information, but the damage records cover only partial fields due to the difficulty of damage data collection by a single agency.

Limited availability of the actual records prevented the Study Team from preparing a flood damage statistics.

4.6 Existing Flood Control and Warning Facilities

(1) Flood control facilities

There have been several facilities constructed such as in the Papar, the Talipok and Api-Api rivers in Sabah, but most of them are rather on ad-hoc basis. Perimeter bunds (ring polders) were constructed around low-lying farm lands to protect crops mainly in Sarawak. Farm villages in perimeter bunds are consequently protected from floods.

(2) Flood forecasting and warning facilities

Flood warning facility of siren system has been installed at Siniawan along the Sarawak river in 1976. The first flood warning level is set up 2 feet below the ground level. Around 500 people enjoy the benefit of the flood warning system.

Two flood forecasting and warning systems are to be installed in the Kinabatangan and the Sadong river basins in Sabah and Sarawak respectively. Both are under tendering stage as of August 1982.

5. ESTIMATE OF FLOOD DAMAGE

5.1 Method of Approach

The absence of flood damage statistical data has obliged the Study Team to carry out an elaborative work of flood damage estimate for each river basin. Among others, major difficulty was that no detailed topographic maps other than 1:50,000 maps were made available for most of the areas. Flood maps had to be prepared based on scarce contour information, 15 m (50 feet) intervals, contained in the 1:50,000 maps.

The flood damage consists of direct damage such as damage to properties and crops and indirect damage. In estimating the damage, proxy method had to be taken owing to the limited availability of data and records. The number of houses and the area of each land use category in the flood area are obtained by using the past flood maps, the contour maps and the land use maps. The flood damage then is estimated based on the data obtained therefrom multiplying values and damage factors which are the functions of flood depth and duration.

The flood damage obtained is co-related to the probability of exceedence through the flood discharge. An annual average damage is thereby postulated.

5.2 Preparation of Flood Maps

The flood maps were prepared principally by assuming the largest flood recorded in each basin during 17 years from 1963 to 1981, as far as the flood record is made available in the DID's flood reports. The flood events selected for each basin are shown in Tables 47 and 48.

The mapping was made based on the following data and information;

(1) Existing flood maps prepared by DID. They were particularly useful for mapping at places where flood level and ground height data are scarce,

(2) Information of spot flooding places (eg. villages, paddy schemes) recorded in the DID flood reports and surveyed by the Study Team, and

(3) Contour lines and spot ground heights shown on the 1:50,000 maps.

The areas are more or less undulated within the 50 feet contour. Flood depth varies from place to place, which might affect the accuracy of the study. It is recommended to carry out the precise survey in the feasibility stage.

Tables 49 to 57 summarize flood prone area by Basin. The total flood prone area is 13.7 million sq.km, which is as large as 7% of the total area of Sabah and Sarawak of 197 thousand sq.km.

5.3 Flood Area Statistics

(1) Land use areas

By superimposing the flood map on the latest-issued land use maps of 1970, land area in the flood area was measured for 11 classified land use categories. The results are shown by Basin in Tables 49 to 57. The total flood area is summarized below.

1.	Urban Area	55
2.	Mining	-
3.	Mixed Horticulture	124
4.	Rubber	744
5.	Oil Palm	79
6.	Coconuts	176
7.	Other tree crops	181
8.	Crop land	3,382
9.	Glassland	291
10.	Forest Land	3,455
11.	Swamp and Unused Land	5,215
	Total Flood Plain Area	13,702 sq.km

But the above figures do not always imply the area inundated, as is emphasized in the previous section that the areas are undulated within the 50 feet contour. It is necessary to multiply a factor, area damage factors, to obtain the number of people affected by floods. The area damage factors will be discussed in Section 5.5.

There may have been some changes in the land use and probably be under more intensive use since 1970 to the present in 1980. Flood damage estimate in this Study may have been slightly under estimated in that sense, since it is based on the 1970 land use date.

(2) Population in flood area

There are few data available for the number of people affected by the flood. Therefore, population in flood areas was estimated by multiplying population density in each land use category by areas in the flood prone area. Population in the district is available from the 1980 population and Housing Census of Malaysia. Urban population and area are obtained from SEPU in Sabah and SPU in Sarawak. For areas without data on its town population but marked as urban in the land use maps, the town population is assumed to be 10% of district population for Sabah and 5% for Sarawak respectively, applying the minimum urbanization ratio computed in both States. The urbanization ratio in Sabah and Sarawak is given in Table 58 and 59, respectively. The rural population is equivalent to the population in district less the urban population. By superimposing the land use map on the population map of Sarawak prepared by Department of Land and Surveys, Sarawak, people in rural area reside in (i) horticultural area, (ii) rubber,oilpalm and other permanent crops area and (iii) crop land area. It is impossible to assess how many people live in each category of land use. However, judging from the general tendency of living pattern and concentration of people near towns, it was assumed that one half of rural population reside in the above-mentioned category of horticulture area and one quarter of that in each latter two categories for Sabah. For Sarawak, it is assumed that population in horticulture area is equivalent to 30% of urban population. It is assumed that one-half of the rest of district population after deducting the said population in horticulture area resides in (i) rubber area and (ii) crop land, respectively. Population density in each land use category is shown in Tables 60 and 61.

The number of people in the flood area is obtained by multiplying the population density in each land use category by each land use area measured.

Population in flood areas was checked by counting the number of dots, (showing approximately 50 persons per dot), in the flood prone areas on the population maps of Sarawak. Population in flood area was updated to 1980, using the population growth rate from 1960 to 1980. As the transportation means still rely on the inland navigation in Sarawak and development of area is limited within the riverine areas which are often assaulted by floods, the population growth rate is assumed to be the same as the average rate of Sarawak. Table 62 shows the damaged population in the flood area by two methods for the sake of comparison.

(3) Number of households

The population and Housing Census of Malaysia 1980 is available, in which the number of households and living quarters is shown at state levels and at district levels, respectively. Since the difference between the number of households and that of living quarters is less than 3%, the number of living quarters, being regarded the same as that of households, is used for the estimation of the number of households in the flood areas. The number of living quarters in Sabah and Sarawak at the district level is shown in Tables 63 and 64. The number of persons per household is, therefore, obtained by dividing the population by the number of households in each district.

The number of households in the flood area was calculated by dividing the population in the flood area by the number of persons per household in that district.

(4) Wet paddy area

Crop land in the land use category is composed of wet paddy area and shifting cultivation area where hill paddy mainly is grown. The shifting cultivation area in the land use map does not mean that the land is used for cultivation. Most areas are, in fact, abandoned. Furthermore the shifting cultivation area are located in high altitudes where no flood water table reaches in general. Therefore, by applying the percentage of wet paddy over crop land of each district, the wet paddy area is obtained from crop land measured in the flood area. The flood damage to the hill paddy is deemed to be zero in this Study taking into account the altitudes and its value. Tables 65 and 66 show the percentage of wet paddy area in each district.

5.4 Flood Depths and Duration

As it was almost impossible to estimate the flooding depth on the 1:50,000 maps, the source of information available was only the records contained in the DID flood reports.

Inundation depths reported in the DID's reports are mostly those at people-resided or damage-recorded areas like villages and paddy areas. Average flood depth assessed in this Study, as shown in Tables 49 to 57, therefore, represents the depths in those people-resided/flood damageable lands, disregarding remote/unused lands (e.g. swamp land) where the depth record is usually not available and the damage value is nil.

5.5 Flood Damage Factors

Flood damage factors in this Study consist of two factors. One is an area damage factor which compensates the overestimation of damageable area being simply measured from the contour maps of 50 feet where the land is undulated and some parts are relieved from flood because of topography. The other is an ordinary damage factor which is derived from statistical and biological analysis.

(1) Crop damage factors

The crops are allotted to places where climate and soil conditions are preferable for their growth. In Sabah and Sarawak, the order of planting from low land to high altitudes is paddy, coconut, oil palm and rubber. It is generally agreed that most rubber plantations are relieved from flood damage because of thier altitudes. The area damage factors based on the field investigation and applied for the Study are as shown in Table 67, taking this crop arrangement along altitudes into account.

Ordinary damage factors were determined mostly by referring to the data and values analysed and recommended in the Phase II study. The adopted damage factors are shown in Tables 68 to 74 and Fig. 11.

Paddy;

- See Table 73 for damage factors. In determining the factors, plant height of local paddy varieties and the extent of damage of crops by seasons were duly considered as shown in Table 74.
- Flooded paddy area was classified into two categories, i.e. irrigated and rainfed, in proportion to the area ratio for each basin as shown in Tables 75 and 76.
- Area damage factor is assumed to be 1.0 since wet paddy field is in low-lyig land in most cases.

Rubber;

- Mortality	Considered only for young rubber trees less than 3 years old. See Table 68 for mortality rates. No mortality for mature trees.
- Young trees	All trees are of matured type in the flood prone area in Sabah and Sarawak, so flood damage to this category is nil.

- Production loss — Production loss of rubber tree is the loss of rubber resin which cannot be tapped during flood,

$$P = 0.53 \times p \times D$$

where, P is the production loss of dry rubber, and p is the production loss rate, 4.0 kg/ha/day, assuming 600 kg/ha of annual production and 150 tapping days per annum. 0.53 is the proportion of matured rubber trees which yield rubber resin. D is the suspended days of tapping assuming that it can not be tapped for the period of one-half of flood duration.

Oil palm;

- Mortality — Only for young trees up to 3 years old. See Table 69 for mortality rates.

- Young trees — Flood damage to oil palm is limited within Padas and Limbang river basins. Oil palm areas in both river basins are full of matured type, so no mortality is accounted.

Coconut palms;

- Mortality — Only for young trees up to 3 years old. See Table 69 for mortality rates.

- Young trees — 6% of total planted area, assuming 2% replanting cycle.

- Area damage factor is 0.8.

Other tree crops;

- Damage factor was determined for cocoa trees which represent the crops within this category.

- Mortality — Only for young trees up to 3 years old. See Table 70 for mortality rates.

- Young trees — 10% of total planted area.

- Area damage Sector is 0.5.

Mixed horticulture:

- Damage factor of coconut palms is applied assuming that coconuts are planted around village houses.

(2) Livestock losses

Scarcity of actual damage records has obliged the Study Team to make use of the damage rates based on past records in the Peninsular Malaysia. Adopted loss rate is expressed per household affected by flood as shown in Fig. 12.

(3) Housing/properties losses

Not all the houses in the flood areas are affected by floods because of the topography. Houses in urban areas tend to locate at high places of flood-free because of the property. Houses in rural areas or villages are likely to locate in low-lying area because their activities are more or less related to agriculture. Houses affected by floods vary from place to place even in the same river basin. It is impossible to estimate these from the 1:50,000 maps. There is no record of houses affected by floods. Bearing this in mind, area damage factors to houses in each land use category, as shown in Table 67, are proposed to compromise and simplify the computation based on the field investigation.

Ordinary damage factors to this item vary according to flood depth since the dmages to housing and properties are the function of flood depth. The factors used in Japan were adopted. But the factors are modified taking into account that houses in villages are of stilt type assuming the floor of the houses is 0.9 m high above the ground level. The factors are shown in Table 72.

(4) Public facilities and utilities

This category includes the damage to roads, railways, irrigation facilities, electricity and telecommunication facilities, water supply works and other public facilities.

Information from 1:50,000 maps is not sufficient to estimate the damages in this category on a certain detailed basis. The damage was estimated to be 30% of building losses in both cases of public and private housings as a whole.

(5) Industrial facilities

This damage was not estimated in rural areas, in consideration that industrial facilities are in most cases located in urban areas.

Only for floods affecting some large urban areas or specific industrial areas, the estimate is made on a lump sum basis at 10% of the urban housing losses.Tawau (Basin No. 207 Tawau), Kota kinabalu (Basin No. 220 Putatan), Miri (Basin No. 231 Miri), Bintulu (Basin No. 236 Kemena), Sibu (Basin No. 241 Rajang) and Kuching (Basin No. 246 Sarawak) are regarded as industrial areas.

(6) Mining, grassland, forest and swamp

In view of minor or moderate damage potential in these areas, the damage was estimated to be nil.

(7) Indirect damage

The damage in this category involves the opportunity profits foregone brought by such economic activities as commercial transaction, industrial production, transportation and wages. The losses from interruption of utility services and cost for rescue and relief operation are included in this category.

The indirect damage can be usually estimated by multiplying a factor to direct damage. According to a survey conducted by US Corpos of Engineers in New England, the following rates were worked out:

Category of Damage	Indirect Loss/Direct Loss
Residential/Public	1.5
Agricultural	0.2
Highways	1.0

In this Study, a conservative rate of 30% is adopted, in consideration that the majority of damage comes from agricultural or related activities. Actual damage records studied in the Peninsular Malaysia also agree to this adopted rate, which is 32% to the direct damage based on the average of six flood events.

5.6 Value of Crops and Buildings

The following values of 1980 prices were used in the calculation of flood damages.

(1) Crop production values (refer to Sectoral Report Agriculture)

Paddy;
- Irrigated : M$1,130/ha in Sabah and M$1,060/ha in Sarawak
- Control drainage and rainfed: M$730/ha in Sabah (Rainfed) M$950/ha and M$620/ha in Sarawak

Rubber;
- Production loss, dry rubber : M$2.73/kg

Oil plam;
- replanting of young trees up to 2 years old : M$1,930/ha

Coconut;
- Replanting of young trees up to 2 years old : M$3,440/ha

Other crops;
- Replanting of young cocoa and coconut trees up to 2 years old : M$3,540/ha

Mixed horticulture;
- Replanting cost of coconut in in 75% of the area and production loss value of orchard in 25% of the area : M$2,900/ha

(2) Buildings/properties

Private housing;
- urban: M$7,500/household

- rural: M$3,000/household

Public buildings; M$2 million population (similar assumption to that made in Ref.22).

5.7 Estimate of Flood Damage

Damage for flood events selected for each Basin as described in Section 5.2 were then calculated based on loss quantities as explained in 5.3, damage factors as mentioned in 5.5 and crops/properties values as described in 5.6. The estimated damage amount is as shown in Table 49 to 57.

The estimated amount of damage represents the potential damage where the flood assaults the area under the present development conditions in 1980.

5.8 Annual Average Flood Damage

In flood mitigation project, the benefit is valued by the amount of damage accrued from flood hazard. The amount of flood damage varies according to the flood magnitude which is expressed in the probability of exceedence. Thus, it is necessary to estimate the annual average flood damage. The annual average damage is the amount of average damage suffered from flood per annum, or people would like to pay it annually for the flood mitigation measure to protect the area.

(1) Damage frequency curve

From the results of flood frequency analysis, the probability of exceedence of flood occurrence is correlated to these flood events and accordingly the return period is given to the flood events (refer to Sectoral Report Meteorology and Hydrology). The bankful discharge which no damage occurs could not be assessed due to insufficient river profile and lack of river cross sectional data. The non-damage discharge was selected referring to the chronological flood records as shown in Tables 47 to 48. The non-damage discharge is also correlated to the return period.

In most cases, only these two data are available for the estimation of flood damage frequency. The recorded flood discharge with the return period is valued by the flood damage expressed in terms of monetary value. The return period of non-damage discharge has the damage potential of zero. These two values are plotted on the semi-logarithm sheet.

In this case a smooth logarithm curve can be applied for the estimation of relation between the frequency and the damage. There is no levee along rivers so that the sudden change of the relationship does not take place. Two formulae would be conceived to generate the damage frequency curve.

$$F.D = a \times \ln (R.P) + b \quad (1)$$

$$F.D = \text{Square root } (a \times \ln (R.P) + b) \quad (2)$$

where, F.D : Flood Damage
R.P : Return Period

ln : Natural logarithm
a, b: Constant

Equation (1) is simple and easy to handle, but in most cases the tendency of damage frequency curve prefers Equation (2) as the increment of damage is large within the range of a probability of exceedence at higher percentage. The less the increment, the less the percentage of a probability of exceedence. Equation (2) gives the higher value of damage if the design level of probability is high (low return period). However, as the cost also includes certain amount of uncertainties, Equation (1) is adopted for conservative damage estimates. Nevertheless, the estimation of annual average damage derived in this way does not affect much the result.

Recurrence intervals of the selected flood events and non-flooding discharge are as shown in Tables 49 to 57. For river basins where hydrological records are not available or scarce, the recurrence probability of flood events was assumed to be similar to that in the neighbouring basins. The damage-frequency curves are shown on Figs. 13 to 16.

(2) Annual average flood damage

Annual average damage was then calculated on the basis of damage-frequency relationship worked out above.

An annual average damage is defined as the average amount of loss by flood and is also the area under the damage frequency curve and expressed as follows:

$$A.A.D = dD \times dP$$

where, A.A.D: Annual average damage
dD : Slice of damage corresponds to probability
$dD = D(Ql) - D(Ql + 1)$
dP : Slice of probability of exceedence
$dP = P(l) - P(l + 1)$

where the probability of exceedence is P(l) at Ql.

The results are presented by Basin in Tables 49 to 57 together with the estimated number of people in the flood susceptible area.

Annual average flood damage potential for Sabah and Sarawak is estimated to be M$12 million per annum. Approximately 216 thousand people are subjected to flood of varying probabilities.

6. PLANNING CRITERIA

This chapter describes the basic criteria and methodology of plan formulation study. The plan formulation is discussed in Chapter 9 hereinafter.

6.1 River Stretches and Design Flood

6.1.1 River stretches

To assess the viability of flood mitigation plans area by area, the flood area is divided into river stretches. The stretch division is made mainly in consideration of the distribution of flood areas, the layout of proposed flood protection schemes, the confluence of tributaries, and the land uses and damage potential of the areas.

6.1.2 Selection of design flood

(1) Design flood criteria

In planning the flood mitigation works, a primary requirement is to set out a hydrological design standard, i.e. hydrologic risk level allowed for the proposed plans. Reviewing the current local and overseas practices including the proposed criteria in the DID's Provisional Hydrological Procedure (Ref. 41), the following basic criteria have been assumed in this study:

Design Flood (frequency of interval in year)	Damage Potential	Population
100-year	Large (M$20 thousand /km over)	Casuality in past floods Densely populated (500 people/km over)
50-year	Large (M$20 thousand /km over)	Densely populated (500 people/km over)
20-year	Moderate (M$20 thousand /km under)	Sparsely populated (500 people/km under)

Remarks: 1) km-length of improved river stretch
2) Damage expressed in terms of average annual damage.
3) Quantitative criteria expressed in the table (M$/km, people/km) are only tentative classifications assumed in this study to select the design flood on an equal basis for all the rivers.

Based on the above criteria, the design flood is to be selected for each river stretch. A consideration is given so that a consistent design flood is to be selected over a certain number of stretches to avoid the excessive variation of design flood stretch by stretch.

Design flood for flow regulation by dams is selected to be 50-year flood. Even if the protection level of the downstream area is at 20-year flood, the flood control function of the dam is designed for 50-year flood to preserve a larger flood control capacity in dam with a view to coping with the possible grade-up of the flood protection level in the downstream area in future.

(2) Estimate of design flood discharge

The design flood discharge is estimated from the regional flood frequency curves shown on Figs. 17 and 18 (reproduced from Sectoral Report Meteorology and Hydrology). The curves are constructed as the max. envelope curve of flood events recorded at various rivers under varied flow-routing conditions. The largest values read on the envelope curve should represent flood runoff with a lesser effect of flow routing, and hence they could be regarded to represent flood discharge under a confined condition.

6.2 Structural Measures

Various alternative measures and their combinations are conceived for flood mitigation works. In this study, the following measures are mainly examined:

(a) Channel Improvement

This work is to increase the channel capacity by canalizing the river course and by bunding the river banks.

As to the cross-sectional improvement, composite-cross section is in principle proposed with a view to its favourable aspects of both hydraulic efficiency and channel stabilization. The channel section assumed is basically such that the present river channel is utilized as low-water channel, while the high-water channel is formed by river bunds constructed on the both banks.

In determining the sections, the following considerations were given:

- There were not enough time to investigate the rivers from estuary to the upstream fringe of flooded prone area. No river cross section is available. In this connection, the flow capacity of the rivers are assumed to be the maximum discharge of no-flood year in the historical records. The river cross section is obtained using the Manning formula. The ratio of width B and depth is fixed at 15 and the Mannings' n at 0.027. The present channel is used for the low-water channel.

- The width of high-water channel was selected in reference to the recommended width derived through experiences in Japan as shown in Table 77.

- The depth of high-water channel was then determined to pass the design flood discharge. Where required, a minor adjustment was made to balance the excavation and embankment volumes by slightly varying the high-water channel bed level.

Single-cross section is also assumed, but limitedly for the river stretches described below.

- comparatively small rivers with design flood of less than 200 cu.m/s

- stretches with a gradient steeper than 1/500

- river in urban areas densely populated.

In actual implementation, there may be in some places a difficulty of acquiring lands sufficient for constructing a composite-section channel. Further, in some rivers, the construction of an excavated channel with low levees may be recommended in order not to excessively raise the flood flow level. These details should be examined through further detailed survey for each river system.

The length of river improvement is measured on 1:50,000 maps. The longitudinal gradient of river flow is assumed by referring to the stage records of the past major flood events or by reading ground heights appeared on 1:50,000 maps.

(b) Bypass Floodway

This plan will be considered where there is a constraint of improving the existing river channel and where the short-cut of the channel is topographically possible.

The route of floodway was selected on the map. The cross section was decided with the aid of flow-profile computation when the design discharge run through two channels.

(c) Polder (Ring Bund)

This protection measure is conceived at the selected local areas where the damage potential is comparatively large. The work includes the construction of ring bund, drainage channels in the bunded area and drainage outlet facilities (e.g.pumping station).

The measure is applied to protect towns or villages where the population density is relatively large. The roads surrounding town is generally used for construction of ring bund.

(d) Flood Control Dam

Potential dams having a comparatively large catchment were examined on 1:50,000 maps. In planning the flood control dams, the following assumptions were made:

The required flood control storage is obtained from 5-day basin storm rainfall and design peak flood. River basins are classified and grouped according to the intensity of storm (refer to Sectoral Report Meteorology and Hydrology). The relation between 5-day storm rainfall and catchment area on each flood region is shown in Fig.19. The probability of flood occurrence used for the computation of effect of dam is assessed by 50-year flood for all dams. Flood inflow hydrograph is expressed in a polygon with 5-day duration. The hydrograph has a peak flood discharge at 24-hour on the time horizon and one more control point in the recession to coincide with the flood volume extracted from the amount of 5-day storm basin rainfall. The outflow discharge is regulated to be one-fourth of the inflow. Thus, the flood control storage is obtained by the inflow volumes less the outflow ones. The flood control storage is finally obtained by multiplying 1.2 by computed storage allowing inaccuracies of reservoir topography and flood hydrographs and mal-operation of gates.

- Flood routing effects at downstream point:
  K = Sq.root (1 - (1 - m2) x a/A)

  where, K : Flood reduction ratio at downstream point
  A : Catchment area of downstream point
  a : Catchment area of dam
  m2: Flood reduction ratio at damsite

If a group of dams is proposed, (1 - m2) x a in the above equation shall be deemed to be the sum of (1 - m2) x a for all the dams.

In the first screening process of evaluating the flood control function of dams, the dams having a flood routing effect of less than 5% (i.e. K > 0.95) at downstream damage centers are discarded at the beginning of the study. Dams having K value of less than 0.95 are examined in further detail.

If the dam is planned for multipurpose, the storage for consumptive uses and hydropower is secured above the sediment capacity. Flood control space is secured above the consumptive use storage. If the dam is planned only for flood control purpose, the flood control storag is added above the sediment storage.

Sediment yield of 200 cu.m/sq.km/year will be stored in the bottom of reservoir.

6.3 Non-structural Measures

Three measures were conceived for the non-structural measure of flood mitigation alternative. These are a restriction of development, a resettlement plan and a flood proofing. A delineation may be made according to the actual flood record and the topographical condition for the purpose of zoning in each area in the flood prone area. The measure would be adopted on a spot basis or along the river depending on the flood depth rather than a stretch basis.

Detailed examination of these measures requires an extensive volume of study, which seems to be beyond the capability of this study. In this study, a very preliminary evaluation is attempted to compare the merits of the following non-structural measures:

(a) Restriction of development

In the flooding areas where structural improvement measure is economically not justified, the following administrative controls could be enforced to suppress the future increase of damage potential in the area:

- flood area zoning and restriction of development
- public education
- flood risk mapping

This measure may be considered in a flood area where the damage potential is comparatively large.

(b) Resettlement plan

A more positive measure is to reduce the damage potential in the present flood prone area by resettling the people to higher land.

This plan is conceived for flood area having the following characteristics:

- paddy lands, but of small to medium scale, where the structural measure will not be justified.

- less population reasonable for resettlement

- severe flood condition with casuality

(c) Flood proofing

This measure comprises the structural change of buildings, elimination of opening, reorganization of spacing, higher structural elevation, and/or local ring dyke around buildings.

It is expected that, with the provision of this measure, most of the damages to buildings and properties can be reduced.

This protective measure will be conceived for flooding areas having the following characteristics:

- less populated at scattered places

- crop damages are not significant

- less severe flood condition, e.g. shallow inundation depth and low flow velocity

6.4 Flood Forecasting and Warning System

A certain portion of the damages to properties as well as the casuality could be reduced if the flood warning is given in due advance (say 24 hrs) and the effective evacuation is succeeded.

As the improving and upgrading measures, the installation of telemetric forecasting systems is proposed for the river basins where the following are expected:

- at least 24 hrs advanced warning attainable with telemetric system installation

- more than 5,000 beneficiaries in the warning disseminated area in the year 2000.

6.5 Other River Behaviour Problems

6.5.1 Estuary silting

In view of the absence of the detailed study data and the complicate nature of this problem, any proposal under this study seems premature.

6.5.2 Erosion control

No specific projects are proposed for this purpose, assuming that the minor erosions at local places will be remedied by channel improvement proposed for flood mitigation works or by routine river maintenance projects for which the cost is separately estimated in 7.4 (3).

6.5.3 Sediment removal

Maintenance dredging will be needed to remove riverbed sediment for the rivers identified. Cost thereof is to be included in the routine river maintenance projects.

6.5.4 Salt water intrusion

The water is taken for the domestic use at upstream of the tidal reach. The river water is not used for irrigation scheme in the tidal reach. Judging from the demand for water and the cost, the river water in the tidal reach will not be utilized by the year 2000. No specific projects are proposed.

7. COST FUNCTIONS AND ESTIMATE

7.1 Structural Measures

Basically, cost of the works was estimated based on quantities mostly measured on maps being multiplied by unit prices predetermined for each proposed work. The estimated cost represents financial cost at 1980 price level, comprising construction cost, engineering cost (10% of construction cost),and physical contingencies (30% of the former two and land procurement cost). Land procurement and resettlement costs are estimated separately.

Cost functions and prices assumed in the estimate are described hereinbelow.

(1) Channel improvement

a. Length of improvement:

- measured on 1:50,000 maps.In principle, the length is measured along the present river course, in a manner to envelop small meanders, but to short-cut excessive meanders.

b. Flow gradient

- determined based on flood stage records in the past flood events to be supplemented by contour information appeared on 1:50,000 maps.

c. Cost per km:

- ref. to Table 78 for channel improvement cost.

- Based on the typical river channel cross section obtained in 6.2, the construction cost of river channel improvement were estimated for several cases using the unit prices shown in Table 78. The cost were further interpolated according to the design flood discharge and the longitudinal gradient and shown in Table 78.

(2) Bypass flood way

a. Channel cross section:

- a single cross section is adopted.

b. Length of floodway:

- measured on 1:50,000 maps.In principle, straight channel route is selected.

c. Flow gradient:

- determined in a similar manner to (1) above. Outlet water level at the sea is selected at EL. 0.0 msl.

d. Cost per km:

- the construction cost per km was estimated based on computed floodway cross section using the unit prices used for channel improvement. The cost table was prepared according to the design capacity and the gradient as shown in Table 79.

(3) Polder

a. Layout and length of bund:

- the town is bunded using the existing road network around town. The length of bund is measured on 1:50,000 maps.

b. Height of bund:

- estimated based on information of average inundation depth in the past flood event. Basically, a freeboard of 1 m high is added.

c. Drainage works:

- drainage area is measured on 1:50,000 maps. Drainage requirement by pumping is assumed to be 1.2 cu.m/s per sq.km of drainage area.

d. Cost functions and prices:

- cost functions comprise the following:
  - construction of bunds
  - internal drainage facilities in bunded area
  - pumping facilities at drainage outlet

- unit prices used for the estimation are shown in Table 80.

(4) Flood control dam

a. Flood control storage:

- required flood control capacity is calculated for each proposed dam in a manner described in 6.2 (d).

b. Incremental dam volume:

- in case of multipurpose dams, incremental dam volume required for flood control is estimated principally based on dam height-volume curve.

$$V = \{(H22 - H12)/H12\} \times V1$$

where, V : incremental dam volume
H1 : height of dam without flood control
H2 : height of dam with flood control
V1 : volume of dam without flood control

- in case of flood control single-purpose dam, the dam volume is calculated independently based on the estimated sediment volume, flood storage volume, reservoir capacity curve and dam volume curve.

c. Cost for flood control storage

- if the previous cost estimate (at least of feasibility study grade) exists, the previous estimate is updated to the 1980 price level and the cost for flood control is calculated in the following manners:

$$C = V \times Co/Vo$$

where, C : cost for flood control
V : incremental dam volume due to flood control
Co : updated cost of dam proposed in the previous study
Vo : volume of dam proposed in the previous study

The above implies that the cost for flood control is represented simply by the incremental cost due to flood control. No further detailed cost allocation was attempted in this study.

- for dams where no previous estimate exists, the unit prices per cu.m of dam volume are applied. See table 81 for the estimated unit prices.

(5) Land procurement and resettlement

Since the study is of master plan level and it is not the purpose of the study to count the exact cost of land procurement. The construction cost derived herein would be used as a preliminary judgement of the project and it should be refined in the feasibility stage. The same thing can be said to the resettlement described below. The estimate was made on a broad sence so as to grasp the cost incurred for the project and evaluate the adverse effect of the project.

a. Land area:

- Expropriated land area is estimated by multiplying the length of structures (channel, polder dyke) by newly required widths for structures. The land use categories of expropriated area are assumed to be the proportional to that of flood prone area.

b. Resettlement requirement:

- Number of people to be removed by structural measure is obtained by multiplying the expropriated area of each land use category by the population density described in Sec. 5.3.

c. Prices of land and resettlement:

Property market report 1979 was used for the estimation of land cost. The land is classified into urban, rural and agricultural areas and further devided according to the nearness to a big town and crop category. The values are shown in Table 82.

7.2 Non-structural Measures

As described in 6.3, the study only aims at very approximate evaluation of the non-structural measures. The cost estimate herein is based on the following bold assumptions:

(1) Restriction of development

a. Expenditures for land management office:

- this cost covers salaries for the personnels of the management office, buildings, equipment, and all other expenditures related to land use management.

- once the land use control is enforced, this expenditure occurs continuously throughout the subsequent period.

- ref. to Table 83 for the assumed price.

b. Cost for flood risk mapping:

- this cost covers aero-photo surveys and mapping for production of 1:5,000 to 1:2,500 maps.

- the cost will be disbursed during the first 5 years.

- ref. to Table 83 for the estimated price.

(2) Land use change and resettlement plan

a. Resettlement cost:

- this cost comprises (i) the cost for resettlement of people and (ii) the cost of new lands to be supplied to people at the resettled area. It is assumed 30 families can be accommodated in 1 ha. Public buildings and facilities are included.

- ref. to Table 83 for the estimated prices.

(3) Flood proofing

- various measures are conceived, but the cost assumed herein is the subsidy to household for rebuilding of the house or for construction of a local ring dyke around the house.

- ref. to Table 83 for the estimated price.

7.3 Flood Forecasting and Warning system

The cost estimate is based on unit prices predetermined for each type of telemetric stations, to be multiplied by the number of stations proposed for each of the river basins.

Table 84 shows the unit prices by type of the telemetric station.

7.4 Operation and Maintenance Costs

In order mainly to simplify the cost stream calculation, annual operation and maintenance (O&M) costs are expressed in percentage to the initial cost. Table 85 shows the rates of O$M costs for the proposed structural works, together with the estimated service life of the structures.

Replacement of structures/equipment is scheduled at the end of the service life assumed above.

8. BENEFIT ESTIMATE

8.1 Structural Measures

The benefit of the flood mitigation project accrues from the reduction of flood damages and the benefit due to land enhancement effects. Thus, the benefit is the difference of flood damage without-project and with-project. The damage potentials would increase according to the population and per-Capita GRP growths. The damage potential of 50 years on the time horizon are to be compared with the cost of flood mitigation project. For the economic evaluation, costs and benefits are assessed by economic values.

(1) Estimate of present flood damage (1980 year condition)

For the economic comparison, the values of crop are assessed by the border price for paddy. Other crops are valued taking into accounts the opportunity costs. It is difficult to assess the economic value of those other than agricultural crops. The economic values for these are regarded as the same as the ones described in Chapter 5.

The method of flood damage estimates are shown in Chapter 5, but the flood damage potentials are obtained by each stretch to test the viability of the mitigation project by each stretch.

(2) Estimate of future damage potentials (2000 year conditions)

Flood damage potential will increase in future due to more intensive use of land resources and the incremental value of assets and properties. To estimate the future damage, the following basic assumptions are made:

Crop damages:

- higher damage potential due to increased crop yield per area. As for paddy, it is assumed the paddy area in the flood prone area is to be proportionally increased according to the expansion plan of paddy area estimated by DID. If a new irrigation scheme is planned by DID in the flood prone area, the damage potential to the scheme is also taken into account. The value of paddy is the one in flood-free area assuming that the incremental of yield owes to flood mitigation measures.

- It is assumed that the number of houses will increase according to the population growth, and properties and its quantities according to the per-capita GRP growth. Hence the damage potential to houses and properties is assumed to augment according to the GRP growth rate. Damage potentials to public building, public facilities and utilities will be also increased accordng to the GRP growth.

Population:

- The population increase in the flood prone area is deemed to be the same as that in the Division in Sabah & Sarawak since the means of transportation still rely on rivers. The affected population in the year 2000 is estimated applying the population growth rate of the division.

Housing and properties incl. livestocks:

- increment of properties value and quantities per household at a rate of GRP growth.

(3) Land enhancement type benefit

Agricultural production in the flood-affected areas is normally less than that in the flood-free lands. Once the flood mitigation project is implemented, however, the production of the areas tends to increase to a level comparable to that of the flood-free area.

The implementation of flood mitigation project may also increase the value of urban lands. New housing scheme or industry project would be introduced. However it is uncertain and not possible to predict at which place these scheme are allotted. For conservative estimate, this land enhancement type benefit was not included in the benefit estimate of this study.

(4) Growth of damage potential

As described above, the flood damage potential is estimated for both the present (1980) and future (2000) year conditions. In the evaluation of the projects in 10.4, it is assumed that the damage potential will increase linearly from 1980 to 2000, and thereafter further increase at a half rate of GRP growth.

8.2 Non-structural Measures

The estimation of these benefit is only attainable through an indepth study with the collection of supporting data and the examination of various alternatives. Without such detailed data, an attempt was made to estimate the benefits based on very rough assumptions described below.

(1) Restriction of development

(Conditions without the restriction of development)

- population will increase at a rate of population growth in the district.

- Additional agricultural lands will be developed and private/public facilities expanded at an equal rate with the population growth, i.e. the damage potential in the flood area will increase in proportionate to the GRP growth.

(Conditions with the restriction of development)

- Due to the enforcement of the restriction of development, the damage potential will increase only by a rate of per-Capita GRP growth. This is because a part of population increase could not be controlled even if zoned.

(Benefit)

- The benefit is deemed to be the difference in the damage potentials of the above 2 cases. The benefit stream of 50 years is discounted to the first year at a rate of 8%.

(2) Land use change and resettlement plan

- Reduced damage to buildings/properties:

  $B = Y (H + G)$

  where, H : annual damage to housing/properties - 1980 year

  G : annual damage to public buildings - 1980 year

  Y : a multiplication factor to include public facilities damage and indirect damage (= 1.69)

The population and the properties will increase according to the growth. Hence the 50 years damage reduction can be generated and this is counted as the would-have benefit of the restriction of development.

(3) Flood proofing

- Reduced damages to housings/properties

  $B = H$

  where, H : damage to housing/properties
- Reduction in public facilities damage and indirect damage is not counted.
- Benefit stream of 50 years is computed using the same manner as (2) above.

8.3 Flood Forecasting and Warning System

Due to lack of data and actual practice in Sabah & Sarawak, no benefit can be outlined. Therefore the benefit is assumed the same as the cost.

8.4 Other Project Benefits

No specific attempt was made to estimate the benefit from other improvement works such as river dredging and routine river maintenance works, in consideration that these works are more or less requisite to meet the public requirement and are to be evaluated from social well-being viewpoint.

9. FLOOD MITIGATION PLANS

9.1 Design Flood by River Stretch

Following the criteria set out in 6.1, design flood was determined for each of 109 river stretches of 38 flooding rivers.

9.2 Flood Mitigation Benefit by River Stretch

Tables 86 to 93 show the estimated benefit by river stretch, which will accrue once the area is protected from flood inundation. The damage reduction is expressed as average annual damage less residual damage at the given protection level.

The expressed amount in the tables is deemed to be flood mitigation benefit from structural measures. The benefit due to non-structural measures is to be estimated separately in a manner described in 8.2.

9.3 Plan Formulation

Also following the basic criteria described in 6.2 and 6.3, flood mitigation plan was formulated for both the structural and non-structural measures. The total number of plans studied is as follows:

Structural measures:	
- Channel improvement	109 stretches
- Bypass floodway	3 locations
- Polder	3 locations
- Flood control dam	107 dams
Non-structural measures:	109 stretches

For all the plans stated above, cost (C) and benefit (B) were estimated based on the prices and methods described in the foregoing chapter 7 and 8. The cost used for the economic analysis is defined as 80% of financial cost which includes transfer payments and salvage value. Furthermore, the cost-benefit relation is worked out in terms of (B-C) for comparison of the plans. Annual cost and benefit are calculated on the premises of 50-year evaluation horizon and 8% discount rate. For the sake of comparison, the project economic cost is set at 1980 and the benefit stream starts from 1981 onward, as if all the projects were implemented in 1980.

9.3.1 Structural Measures

(1) Channel improvement

Tables 86 to 93 show the outline and cost-benefit features of the river channel improvement proposed for all the 415 stretches.

(2) Bypass floodway

Table 94 describes flood bypass plans examined in this study.

(3) Polder

Polder plan was mainly considered for protection of urban areas as shown in Table 95.

(4) Flood control dam

Firstly, flood flow reduction effect by dam at downstream points was examined as evaluated. Dams having only a lesser extent of flood reduction effect at the downstream points (less than 5% i.e. K > 0.95. Ref. 6.1.3 (d)) were ruled out from further study. Table 96 and 97 show the principal features of flood control dams examined.

For dams passed through from the above screening, flood control storage volume and cost for the storage were estimated.

The viability of flood control dams was assessed in a manner to compare the total cost of dam and reduced channel improvement work with the benefits in the stretches downstream from the dam. In case that a group of dams is proposed, the best combination of the dams leading to a least total cost requirement (dams + downstream channel improvement) was selected for each river basin. Annual cost of dam is distributed and added to that of river improvement in proportion to the annual cost difference of channel improvement between without dam and with dam.

Tables 98 to 102 show the flood control dam plans finally selected, together with the plans of associated channel improvement.

9.3.2 Non-structural measures

By applying cost functions and benefit estimate formulae described in 7.2 and 8.2, cost and benefit of 3 conceived non-structural plans were estimated for all the stretches, irrespective of whether the plans are applicable to the area from techno-sociological viewpoint.

Of the plans, resettlement plan will not be applicable in the areas where damages to paddy and people do not occur, and the flood proofing plan is also not applicable in the non-populated flood areas, respectively.

The estimated cost and benefit by stretch are not reproduced in this report, but only the computed B - C values presented in Tables 103 to 105.

9.4 Formulation of Development Alternatives

9.4.1 Alternatives setting criteria

As a function of formulating the national water resources and use alternatives, three alternatives for flood mitigation development are proposed. Alternative F1 is the implementation of proposed measures to protect 90% of population in the flood prone area. Alternative F2 is the implementation of measures for 50% of population in the potential inundated area, and Alternative F3 is the implementation of only economically viable measures. The plans have been formulated for each state.

The strategies and alternatives setting criteria are as follows:

Alternative	Strategy and Target	Criteria for Formulation of Plans
F1: Total development alternative	Elimination of most part of flood hazards. Excepting very sparsely populated area, 90% of population in flood prone area to be relieved from flood hazard	Combination of least-costly structural measures. Improvement area/stretch to be selected in the order of damage potential and population thereat.
F2: Social well-being emphasized alternative	More than 50% of population presently in flood prone area to be relieved from flood hazard.	Combination of structural and non-structural measures. Improvement area/stretch to be selected in the order of population thereat.
F3: Economic-efficiency emphasized alternative	Implementation of only economically viable projects.	Combination of structural and non-structural measures assessed to have a positive B - C value.

9.4.2 Selection of alternatives

Following the alternatives setting criteria proposed in 9.4.1 above, the 3 alternatives are then formulated for each state through comparison of flood mitigation measures produced in 9.3 above. Tables 103 to 105 summarize the damage potential (in terms of average annual damage in 2000 year condition) and population (in 2000) of each stretch and the annual equivalent (B - C) values of various measures for ease of comparison. As a result, the measures shown on the right-most column of the tables are selected for inclusion in the 3 development alternatives.

The selection of the measures is done by the following process.

Among several structural measures, a measure which gives relatively higher annualized net benefit is selected for the alternative F1. Stretches are added up until the number of people protected attains 90% of that in flood prone area. Channel improvement is generally selected for the measure of the alternative F1 for its character of the work. Stretches are incorporated until the number of people protected exceeds 50% of that in flood prone area for the alternative F2 among structural and non-structural measures. Stretches which gives the positive net benefit are selected for the measure of the alternative F3. For all alternatives, adjustment is made for the consistency of measures for the adjacent stretches.

The selected alternatives are summarized in Tables 103 to 105, together with showing the estimated B-C. The location of the proposed projects is shown in Figs. 20 to 25 by alternative selected for each state.

9.5 Flood Forecasting and Warning System

The installation of telemetric system is proposed for 16 river basins as indicated in Tables 106 and 107.

Notwithstanding the benefit-cost estimated in the tables, this study recommends that all the proposed systems are to be implemented, as a part of social well-being program until the year 2000. The system will be requisite irrespective of whether other structural or non-structural measures are implemented simultaneously.

10. SCHEDULES AND EVALUATION

10.1 Development Schedule

Development schedule of the flood mitigation alternatives has been prepared in consideration of the following:

- all the projects conceived in the alternatives are to be implemented towards the year 2000.

- for 4MP period, only the projects authorized in 4MP will be implemented. Other proposed projects are scheduled in 5MP period onward (1986 onward).

- the implementation period of a project is assumed basically to be 5 years. In case the annual expenditure exceeds M$ 20 million , the period is extended to 10 or 15 years.

- projects accorded higher returns will be implemented at earlier period, to be followed by the next-evaluated projects. The scheduling is made to distribute the expenditures almost equally throughout a period from 1986 to 2000 or slightly increasingly in the latter period.

10.2 Budgetary Schedule

Basing on the development schedules formulated in 10.1 above, budget requirement in the succeeding 5-year plan periods is estimated as shown in Tables 108 to 113. Annual disbursement schedule is estimated to be 10, 20, 30, 25, and 15% of the project cost within 5 years. The budget for 4 MP period is excluded and not shown since it is pre-requisite.

The budget requirement estimated in the tables includes the budgets for flood forecasting/warning system. See Tables 106 and 107 for the estimated cost of those works, respectively.

10.3 Man-power Schedule

Man-power requirement is estimated by assuming a typical work force requirement by the size of the projects which is expressed in terms of project capital cost as shown in Table 114. Additional man-power requirement for each of the flood mitigation alternatives F1 to F3 is shown in Table 115 and 116.

It is presumed that the flood forecasting/warning systems and routine river maintenance works could be managed basically by the present number of DID staff.

10.4 Economic Evaluation of Alternatives

To assess the economic viability of the flood mitigation alternatives F1 to F3, economic evaluation was made based on the following criteria:

Cost stream:

- Project is allotted according to the criteria stipulated in 10.1.

- Disbursement schedule is as per estimated in 10.2 above.

- Economic cost is assumed approximately to be 80% of financial cost. Cost for flood forecasting system is excluded in the evaluation.

Benefit stream:

- Damage potential (or damage reduction by flood control project) increases linearly from 1980 to 2000, at a rate of GRP growth thereafter. The benefit stream starts just after one year of the project completion.

Evaluation horizon: 50 years

Economic viability of the alternatives is compared in terms of economic internal rate of return. The result is presented in Tables 117 and 118.

The tables also show the assessments on social well-being account items.

11. RECOMMENDED PLAN

11.1 Selection of Recommended Plan

Through the studies in 10 above, the three flood mitigation alternatives are evaluated as summarized below.

Item	Alternative F1	F2	F3
Sabah			
- EIRR (%)	2.6	7.1	13.4
- Damage reduction (M$ million) /1	2.6	3.5	1.0
- No. of people relieved (thousand)	172.2	76.9	42.1
- Reduced flood area (thousand sq.km)	848	403	81
- Budget burden /2 (M$ million)	286.9	114.1	21.1
- Additional man-power requirement	170	60	20
Sarawak			
- EIRR (%)	NA	5.7	20.7
- Damage reduction (M$ million) /1	10.9	7.7	2.0
- No. of people relieved (thousand)	262.2	116.8	34.3
- Reduced flood area (thousand sq.km)	4,379	1,412	547
- Budget burden /2 (M$ million)	4,542.0	518.7	21.1
- Additional man-power requirement	740	200	20

Remarks: /1 Average annual damage reduction for 50 years project life.
/2 Budget from 5MP - 7MP

Recommendations from the above comparison are as follows:

(1) Alt. F1 will be the most desirable with a view to the attainable reductions in flood damages, Nos. of flood victims and flood-affected land resources. However, a critical constraint is the heavy budgetary burden, which seems almost beyond a limit of budgetary capability at least up to year 2000. Employment of additional staff is also a major constraint to the selection of this alternative.

(2) Alt.F2 and F3 are seemed to be both acceptable with regards to the budget and people protected by the projects.

(3) Alt.F3 is to select the projects whose EIRR is more than 8%. Consequently the projects are concentrated on relatively populated and developed states. The projects for the states less populated would be left behind.

(4) Since 50% of the population of each state will be protected, Alt.F2 would be prefererable from regional and social well-being points of view.

(5) Alt.F2 attains a reduction of about 43% of the potential flood damage, relieves 194,000 people or 53% of the total victims from flood hazards in the year 2000 condition and protect 13% of flood prone area. These attainments seem to be acceptable as a minimum target towards the year 2000.

(6) As a conclusion, the flood mitigation plan is formulated in a minimum scale, that is, hereby recommended is the implementation of Alt. F2.

As a results, no previllage of priority is resulted in among populated states and less populated states. With regards to the land enhancement benefit, it is counted by other sector where a concrete development plan or irrigation project plan are set up. No benefit can be assessed where the plan is not foreseen yet in this Study.

Besides the budget for the recommended flood mitigation projects, and the costs for flood forecasting system, are also to be preserved in the public fund requirement for 5 to 7MP periods.

11.2 Description of Recommended Plans

The recommended plan for flood mitigation is summarized in Table 119 and 120.

Tawau river flood mitigation project

Tawau, populated by 50,000, is located at the estuary of the Tawau river. The town is often flooded, because the river, stretching for 9 km in the town, is not capable of discharging flood. For example, a flash flood in January, 1981 flooded 18 sq.km and affected 6,000 people, mostly within the town. The recommended flood mitigation plan consists of the excavation of a bypass floodway of 3 km in length and improvement of existing river channel of 9 km in length. Although incorporation of flood control storage was preliminarily discarded in the proposed Tawau dam, it should be further studied in the stage of feasibility study.

Bandau plain flood mitigation project

The Langkon, Bongan, Kota Marudu and Tandek rivers run through the Bandau plain where several villages are located. A flood associated with high tide in January, 1981 inundated 109 sq.km including Langkon and Kota Marudu towns. A budget has been allocated under 4MP for the flood mitigation in the Bandau plain. The recommended flood mitigation plan is river channel improvement of 56 km in length in order to protect Bandau plain.

Kadamaian river channel improvement project

The flood of January, 1981 affected the low-lying area of Kota Belud town and the irrigation scheme. A comparatively large scale irrigation scheme is carried out and will be expanded in the flood prone area. The banks were eroded in several places by floods. The recommended flood mitigation plan is the river channel improvement of 16 km in length in the most downstream stretch.

Putatan river channel improvement project

The Moyog river distributes into small channels of small discharge capacity in the south of Kota Kinabalu. The major distributary is the Putatan river causing drainage problem in the surrounding area. The Putatan river inundated 7 sq.km and affected 7,000 people in a flood in 1974. The recommended flood mitigation plan is river channel improvement of 12 km in length in the town area.

Limbang flood mitigation dam project

The Limbang valley project has beeen proposed for agricultural development of 20,000 ha including 8,600 ha of paddy irrigation in the lower Limbang valley. The major constraint of the development is flood problem. The Limbang flood mitigation dam is proposed at just upstream of the Limbang valley project area. The storage capacity of 450 million cu.m can reduce flood discharge to a non-damage flow in the downstream river channel, and also power generation will be made possible. Since the project is for irrigation purpose, the project cost is included in the irrigation sector of this study.

Miri river flood mitigation project

The Miri river inundated 674 sq.km in January, 1963. Miri town located near the estuary of the Miri river is an industrial town of 55,000 in population at present. The flood damage must be large if the same flood occurs under the present condition. The recommended flood mitigation plan is the construction of a bypass flood-way of 5 km in length at just upstream of Luton, which is located 2 km to the north of Miri.

Construction of ring bund at Niah

The construction of ring bund including bank protection work is recommended for Niah of 900 in population.

Kemena river channel improvement plan

The river channel improvement is recommended for a 30 km stretch in length of the Kemena river to protect 17,000 people in the flood prone area in Bintulu.

Matu river channel improvement plan

The Matu river flooded 226 sq.km in 1963 affecting 7,000 people. The recommended plan is the river channel improvement of 21 km.

Sarawak river flood mitigation plan

The recommended plan includes the Bengoh flood mitigation dam in the Sarawak river and channel improvement of 142 km in the Sarawak and Samarahan rivers to protect 62,000 people in the flood prone area. The dam can be developed as a multipurpose project with water supply scheme. The superiority on technical and economic points of view is preliminarily given to the Bengoh dam over the Giam dam, however, the latter shall be examined in the feasibility stage.

Flood forecasting and warning system

The flood forecasting and warning systems are proposed for 7 river basins in Sabah and 9 for Sarawak by the year 2000. Of these, the system in Bongan (Basin 217), Papar (221), Baram (230) and Sarawak (246) are recommended to be installed in 5MP period.

12. PLAN IN CASE OF LOWER ECONOMIC GROWTH

12.1 Assumed GDP Growth Rate

The recommended plan in the foregoing chapter is bssed on an assumption that the growth rate of GDP is 7.7% in 1980 to 1985, 8.4% in 1985 to 1990, and 7.5% in 1990 to 2000, in accordance with 4MP and OPP.

For reference, a plan under a lower economic growth was prepared, assuming that Malaysia's economy might be affected by a long-lasting world-wide economic depression. The growth rate of GDP assumed was 7% in 1980 to 1985, 6% in 1985 to 1990, and 5% in 1990 to 2000.

12.2 Parameters Predominantly Related to GDP Per Capita

The parameters dominated by GDP per capita are the urbanization ratio and value of flood damage. These parameters under the condition of lower economic growth were estimated assuming a functional relationships with GDP per capita. Higher population growth rate is adopted in rural area and lower in urban than 4MP and OPP estimate.

12.3 Development Plan

The recommended flood mitigation plan under the condition of low economic growth does not change except the Kadamaian river channel improvement plan.

12.4 Beneficial and Adverse Effects

The beneficial and advers.e effects of the flood mitigation plan in the case of lower economic growth are summarized in the main report.

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