the flood. The criteria for selection are referred to National Water Resources Study, Malaysia (Sectoral Report Vol.5, River Conditions) as follows:

(1) The riparian area with the annual flood damage less than M$20,000/km^2$ and population density of about 500 persons/km^2 is relieved from the flood with a 20-year return period.

(2) The riparian area with the annual flood damage more than M$20,000/km^2$ and population density more than 1,000 persons/km^2 is relieved from the flood with a 50-year return period.

The result of socio-economic studies indicates that the urban areas of Kota Bharu, Pasir Mas, Tanah Merah and Kuala Krai have the population density of more than 1,000 persons/km^2. Thus, the urban river stretches, i.e. KL 3, KL 5, KL 8, KL 9 (Temangan Lama and Bharu) and KL 12, are protected from a 50-year probable flood as priority protection areas.

On the other hand, remaining rural river stretches are protected from a 20-year probable flood according to the above criteria. However, it is desired to make one flood protection level in a river; that is, all the river stretches are protected from a 50-year probable flood. Considering the socio-economic importance and financial burden, the rural river stretches are initially protected from a 20-year probable flood, and their protection level will be brought up to a 50-year probable flood as an ultimate goal.

3.3 Conceivable Structural Measures

The following structural measures were contemplated for flood mitigation planning of the Kelantan River basin in view of river channel profile, inundation condition and basin topography:

- Widening of the river channel,
- Dredging for river bed excavation,
- Levee construction,
- Treatment of the river mouth, and
- Flood mitigation dams.

The details of these structural measures are explained as follows:

(1) River improvement including widening of the existing river channel, dredging and levee construction

The habitual flood prone areas are located in the plain area in the downstream reaches of the Kelantan River. It is contemplated that inundation in these river stretches is caused mainly due to insufficient flow capacity of the river channel. To increase flow capacity of the river channel, river improvement plans by combining the widening of the existing river channel, dredging and levee construction will be adopted in due consideration of river characteristics, hydraulic situation of the river channel and topography of the river stretches.

There is a big bent at Pasir Mas. It is considered to increase flow capacity of the river channel by introducing a short-cut way, which will be discussed as one of alternative measures for river improvement.

(2) Treatment of the river mouth

The river mouth of the Kelantan River is apt to be closed by sand dunes carried by the westward littoral current especially in the dry season. It may be considered that the flood water level in the vicinity of the river mouth is raised due to the closure of the river mouth. To cope with such situation, treatment of the river mouth by means of the jetty and arrangement of river channel will be contemplated by co-operating with the work carried out by the Marine Department and JKR.

(3) Flood mitigation dams

The southern part of the Kelantan River basin is occupied by mountainous zones, and therefore several flood mitigation dam plans have been contemplated. Among them, following dams are contemplated to be promising in taking into account water resources development and flood mitigation in the downstream reaches of the basin (refer to Appendix 2 of Annex VI):

(i) Dabong dam is located in the Galas River, about 132 km upstream from the river mouth or about 30 km upstream from the Lebir confluence. A catchment area is around 7,480 km^2.

(ii) Kemubu dam as a mutually exclusive alternative of the Dabong dam is situated in the Galas River at about 167 km upstream from the river mouth. A catchment area is about 5,630 km^2.

(iii) Nenggiri dam is located in the Nenggiri River at about 210 km upstream from the river mouth. A catchment area is about 3,690 km^2.

(iv) Lower Pergau dam as a mutually exclusive alternative of the Dabong dam is located in the Pergau River at about 10 km upstream from the Galas confluence. A catchment area is about 1,280 km^2.

(v) Lebir dam is situated in the Lebir River, at about 138 km upstream from the river mouth or about 36 km upstream from the Galas confluence. A catchment area is about 2,480 km^2.

For the flood mitigation in the downstream reaches of the basin, combinations of a dam or two dams selected from above five dams plus river improvement will be contemplated. Fig. VIII.3.2 shows the location of those five dams.

3.4 Criteria for Flood Mitigation Study

3.4.1 Establishment of flood mitigation level

It is contemplated to work out flood mitigation plans in the Kelantan River basin by stage-wise development, considering flood mitigation levels such as provisional stage and long term stage as a final target.

In application of structural measures, a high target level of protection as much as possible would be desirable to adopt for the safety of facilities for their long term stability and livelihood of the riparian people. However, a long term plan with the high target level needs a considerable amount of construction costs and a long term construction period. On the other hand, the flood mitigation master plan has tentatively been decided to formulate for condition in the year 2000. Considering these situations and socio-economic conditions in the basin area, a 20-year probable flood is applied as the design flood toward year 2000 to protect the rural riparian areas in the river stretches between Kuala Krai and about 2.5 km upstream from the river mouth, and a 50-year probable flood is adopted to protect urbanized riparian areas such as Kota Bharu, Pasir Mas, Tanah Merah and Kuala Krai.

In the long term stage as an ultimate goal, all the river stretches between Kuala Krai and about 2.5 km upstream from the river mouth will be protected from a 50-year probable flood. If the flood mitigation works to cope with a 50-year probable flood is completed, flood peak discharge with the same scale as that in 1967 can safely flow down without inundating all the riparian areas downstream from Kuala Krai.

3.4.2 Selection of suitable combination schemes

Present flow capacity of the river channel along the flood prone areas is more or less 5,000 m^3/sec which corresponds to the frequency of more than once in two years. Even if the river improvement works by means of widening of the existing river channel, dredging of the river bed and levee construction are executed, increase in the flow capacity will be around 3,000 m^3/sec to 4,000 m^3/sec. Since it is practically impossible to provide higher levee and larger widening of the river channel to discharge the design flood corresponding to a 50-year probable flood as an ultimate goal, combination plans of the flood mitigation dam and river improvement will have to be contemplated.

Once an optimum combination plan of the dam and river improvement scheme is determined to protect in the river stretches between Kuala Krai and 2.5 km upstream from the river mouth from a 50-year probable flood, a plan to protect rural river stretches from a 20-year probable flood will be worked out as a provisional stage.

For each combination scheme, probable peak discharges for the design flood will be determined at the selected points. Based on these probable flood discharges, dam and river improvement plans will be worked out and construction cost for the schemes will be estimated.

Since the dam scheme is worked out as multipurpose use including hydroelectric power generation, water supply for irrigation, municipal and industrial use and river maintenance, the suitable combination plans will be selected based on the concept that the combination to give the net benefit maximum is optimal. The net benefit is defined as the difference between the benefits resulting from flood mitigation and water resources development and all the costs necessary for the development of the schemes.

3.4.3 Flood mitigation by dam

The study on the flood mitigation by dam will be made under the following criteria;

(1) An optimum reservoir capacity is first of all searched for water resources development, i.e. hydropower generation, water supply for irrigation, M & I use and so on. Flood spaces for flood mitigation and safety of dam itself are allocated above the capacity for water resources development.

In case that the crest of dam determined from the above procedure is higher than the topographical maximum elevation to build a dam, flood spaces for flood mitigation and safety of dam itself are at first allocated below the topographical maximum elevation, and then the remaining reservoir capacity is used for water resources development. In case that no space is allocated for water resources development, the scheme is developed as a single purpose project of flood mitigation. It is noted for the determination of topographical maximum elevation that the geological condition at the site is also taken into account.

(2) The spillway comprises two sections; that is, an overflow weir to safely release PMF for dam itself and an ordinary overflow weir for flood mitigation. There are two ways to provide the ordinary overflow weir; that is, one is to provide the ordinary overflow weir under Normal High Water Level (NHWL) and to regulate water levels in dry and wet seasons by gates. Meanwhile, the other is to provide the ordinary overflow weir above NHWL without gates.

A reservoir simulation study in case of having the ordinary overflow weir under NHWL shows that water level lowered by the crest of ordinary overflow weir in wet seasons has high possibilities not to recover to NHWL in dry seasons, resulting in considerable losses of power generation (refer to Section 4.6 of Annex VI). Thus, the ordinary overflow weir is provided above NHWL. Furthermore, the suitable dimensions of it are searched by changing the peak-cut ratio (A routed peak outflow for the design flood/peak inflow of design flood).

(3) The dimension of the overflow weir for dam safety is determined under the condition that PMF is safely released by both ordinary overflow weir and overflow weir for dam safety. The crest of dam is decided by adding the freeboard to the flood water level for PMF.

(4) Probable flood discharges at the selected points for the respective outflows routed with the ordinary overflow weir are determined by flood routing study. Based on these probable floods, the river improvement scheme is worked out, and its construction cost is estimated. The optimum dimension of the ordinary overflow weir is determined by the least cost method by summing up the specific cost of dam for flood mitigation and cost of the river improvement scheme.

3.4.4 Flood mitigation by river improvement

Based on the probable flood peak discharges for the respective outflow from the ordinary overflow weir as stated in the foregoing, the river improvement scheme to protect the river stretches between Kuala Krai and about 2.5 km upstream from river mouth against a 50-year probable flood will be worked out under the following criteria:

(1) The flood water level to discharge the specified flood discharge should be lowered as much as possible.

(2) The widening of the river channel is only limited to remarkably narrow places.

(3) Since it is considered undesirable from the viewpoint of the stability of river bed to alter drastically the existing river bed slope, the dredging to arrange the river cross section should be contemplated.

(4) The levee with low height as much as possible should be contemplated to avoid the risk of water leakage through the levee structure for the flood with long duration and to drain easily the interior water.

Once an optimum combination plan of the dam and river improvement schemes is determined to protect the riparian areas between Kuala Krai and about 2.5 km upstream from river mouth from the 50-year probable flood, a stage development plan protecting from a 20-year probable flood will be worked out for the rural riparian area.

3.5 Flood Mitigation by Non-structural Measures

Considering the economic effectiveness, safety of inhabitants, social urgency and so on, non-structural measures should also be contemplated as a measure for the mitigation of flood damages in the flood prone area extended in the downstream reaches of the Kelantan River. The following are contemplated as the non-structural measures:

- Flood forecasting and warning system
- Flood zoning
- Legislation
- Others.

The flood forecasting and warning system has been introduced to the Kelantan River basin for making ease the evacuation from the threatened area, and the current problem for it was discussed in the preceding Section 2.5.

Flood zoning is to restrict the occupancy of high flood risk zone for mitigating the damages during floods. Legislation includes the restriction of development for the flood prone area, where structural measures cannot be economically justified, or will not be implemented over the foreseeable future.

Flood proofing, land use change and resettlement of population are counted as others of non-structural measures. Flood proofing is the actions taken by individuals or small groups within the flood plain to reduce flood damage to their property.

Land use change is the measure to reduce the potential damage to crops by apply of less damage-susceptible crops. Resettlement of population will be applied to the areas where the potential damage to property as well as loss of life in the flood prone area cannot be reduced by structural measures.

4. FORMULATION OF FLOOD MITIGATION PLANS

4.1 General

A 50-year probable flood is selected as the design flood of an ultimate goal to protect the entire riparian area in the river stretches between Kuala Krai and 2.5 km upstream of the river mouth, and then 20-year and 50-year probable floods are selected as the design flood to protect rural and urban riparian areas in the provisional stage, respectively.

The formulation of flood mitigation plans is carried out by two steps. Several promising combination plans are at first worked out for protecting the entire riparian area in the river stretches between Kuala Krai and 2.5 km upstream of the river mouth from a 50-year flood. A stage development plan for protecting the rural riparian areas from a 20-year flood is studied as a second step for the promising combination plans selected in the first step.

4.2 Flood Mitigation Effect by Dam

Five dam schemes (refer to Fig. VIII.3.2) as discussed in the preceding Section 3.3 are proposed not only for the flood mitigation in the downstream reaches of the Kelantan River, but also for hydropower generation, domestic and industrial water use, irrigation supply and so on.

To make combination plans for flood mitigation, flood mitigation effect by each dam was evaluated by incorporating it on the simulation model to predict flood peak discharges and hydrographs at the designated points (refer to Annex II, Hydrology). A 50-year probable flood is selected for the simulation, because the entire downstream reaches of the Kelantan River are protected from the 50-year probable flood as a final target.

The hydrological simulation model reveals that flood peak discharge with a recurrence interval of 50-year is some 16,400 m^3/sec under the natural condition, i.e. without structural measures, at Guillemard Bridge as shown in Table VIII.4.1. Fig. VIII.4.1 shows simulated discharges at respective points corresponding to a 50-year probable flood at Guillemard Bridge. In case that flood discharge inundated at the reaches between Kuala Krai and Guillemard Bridge (refer to Fig. VIII.2.6) is confined in the river channel only by river improvement (R/I), 50-year flood peak discharge increases by 17,400 m^3/sec.

In comparison with the present flow capacity of the Kelantan River (more or less 5,000 m^3/sec) and the flood peak discharge of 17,400 m^3/sec, the flood mitigation only by river improvement will not necessarily be a promising alternative for a 50-year probable flood. However, the alternative by river improvement only is kept as one of alternatives in selecting the most suitable combination plan for the flood mitigation of the Kelantan River.

The Nenggiri dam plus river improvement shows little flood peak reduction even by changing the peak cut ratio (= peak discharge from the spillway for flood mitigation/peak inflow) probably due to the fact that the catchment draining an area of 3,690 km^2 is located at the uppermost reaches with relatively little rainfall. Therefore, it is less advantageous to include the function of flood mitigation in the development objectives of the Nenggiri dam scheme. This fact is endorsed in comparison between Case 15 (Lebir + R/I) and 18 (Lebir + Nenggiri + R/I) of Table VIII.4.1 that flood peak discharge of 850 m^3/sec is only reduced by the addition of the Nenggiri dam scheme.

The Kemubu dam scheme is a mutually exclusive alternative with the Dabong dam scheme and will be developed as a single purpose project of flood mitigation. Flood peak discharge at Guillemard Bridge is about 13,900 m^3/sec in the highest peak-cut ratio (40%) of the Kemubu dam scheme plus river improvement (refer to Table VIII.4.1 and Fig. VIII.4.2). The relationship between inflow hydrograph to the Kemubu reservoir and outflow hydrograph from it is shown in Fig. VIII.4.3. Since the reduction of flood peak discharge by the Kemubu dam scheme is not so great due to a small reservoir scale, an addition of the Lebir dam scheme is also conceived for reducing the burden of flood mitigation to the river improvement as depicted in Case 21 to 23 of Table VIII.4.1.

The Lower Pergau dam plus river improvement shows less flood peak reduction probably due to the small catchment area and low reservoir efficiency. The topographical maximum elevation of building a dam is assumed to be El.72.0 m for assessing the flood mitigation effect of the Lower Pergau scheme. Since the topographical maximum elevation at the site for building a dam is informed to be much lower than El.72.0 m, the topographical survey to confirm the topography at the site was commenced, and then revealed that the topographical maximum elevation was El. 50 m at the site as shown in Fig. VIII.4.4. Therefore, the Lower Pergau dam scheme is excluded from the alternatives to mitigate floods in the downstream reaches of the Kelantan River.

The Lebir dam scheme plus river improvement shows considerable flood mitigation effect with flood peak discharge of about 12,500 m^3/sec at Guillemard Bridge (refer to Table VIII.4.1 and Fig. VIII.4.5). Thus, this Lebir dam scheme plus river improvement will be one of promising combination plans to protect the entire riparian area in the river stretches between Kuala Krai and 2.5 km upstream of the river mouth from a 50-year flood.

Flood peak discharge in the plan of the Dabong dam scheme plus river improvement greatly decreases by about 10,600 to 11,100 m^3/sec (refer to Table VIII.4.1 and Fig. VIII.4.6). Thus, this plan is also one of promising combination plans to protect the downstream reaches of the Kelantan River from a 50-year flood. The relationship between inflow hydrographs to the Dabong and Lebir reservoirs and outflow hydrographs from them is depicted in Fig. VIII.4.7.

Considering the flood mitigation effect of dams to the downstream reaches and flow capacity of the Kelantan River, following stage development plans are contemplated for each Combination plan (refer to Figs. VIII.4.8 to 4.15):

Case	Combination of structures	Stages	
		Provisional Stage	Final Stage
1	R/I only	R/I	R/I
2	Nenggiri + R/I	Nenggiri + R/I	R/I
3	Kemubu + R/I	Kemubu + R/I	R/I
4	Dabong + R/I	Dabong + R/I	R/I
5	Lebir + R/I	Lebir + R/I	R/I
6	Lebir + Nenggiri + R/I	Lebir + Nenggiri + R/I	R/I
7	Lebir + Kemubu + R/I	Lebir + Kemubu + R/I	R/I
8	Lebir + Dabong + R/I	Lebir + Dabong + R/I	R/I

Note: R/I means river improvement.

Combination plan 1, river improvement only, requires the river improvement works for the flood peak discharge of 14,400 m^3/sec in the rural riparian areas and 17,400 m^3/sec in the urban riparian areas as the provisional stage (Table VIII.4.1). River improvement works for the incremental discharge of 3,000 m^3/sec will be carried out in the rural riparian areas as the final stage.

Combination plans 2 to 5, which are the combination of a dam plus river improvement, need the construction of dam as well as river improvement to meet the protection requirement of urban and rural riparian areas set forth in the provisional stage. The protection level for the rural riparian areas will be raised from 20 to 50-year probable flood by river improvement as the final stage.

Simultaneous construction of two dams as well as river improvement is necessary for the provisional stage in Combination plans 6 to 8. Out of them, the river improvement of Combination plan 8 is only limited to the urban riparian areas in the provisional stage. The final stage to raise the protection level from 20 to 50-year probable flood in the rural riparian areas requires the river improvement for the incremental discharge of some 1,200 m^3/sec. It is noted in Table 4.1 that an overflow weir for flood mitigation is not provided to the spillway for the case with the lowest peak-cut ratio of each dam scheme; that is, the flood mitigation to the downstream reaches is only expected with the overflow weir for PMF.

4.3 Structural Plan for Dam

An optimization study for water resources development stressing on hydropower development was carried out for the

Nenggiri dam scheme, and then reckoned that the higher NHWL, the greater the net benefit gains (refer to Chapter 4, Annex VI, Review and Updating of Water Resources Development Plan). Thus, the crest of dam constructed as a rockfill type was at first fixed at El.169 m of topographical maximum elevation, and then the crest of spillway for PMF was determined at El.158.6, 158.8 and 159.5 m by coinciding with Surcharge Water Level (SWL), a water level routed a 50-year probable flood with the spillway for flood mitigation, for the peak-cut ratio of 100, 90 and 80%. In case of the peak-cut ratio of 76%, the spillway for the flood mitigation is not provided; that is, flood mitigation is expected with the spillway for PMF. MHWL for water resources development was finally determined at El.150.7, 152.9, 155.0 and 157.0 m by coinciding with the crest elevation of spillway for flood mitigation, which corresponds to the respective peak-cut ratio as shown in Table VIII.4.2. The spillway for the flood mitigation is a non-gated type. The width of 75 m adopted in the Feasibility Study of Nenggiri Dam Project is selected as the one of spillway for PMF.

The Kemubu dam scheme is developed as a single purpose of flood mitigation. The crest of dam was set at El.82.0 m by coinciding with the topographical maximum elevation, and then applying the same procedure used for the Nenggiri dam scheme, the crest of spillway for the flood mitigation was determined at El.53.0, 58.4, 63.0 and 65.7 m for the peak-cut ratios of 40, 30, 20 and 15%, respectively. The Kemubu dam will be built with a concrete gravity type considering topographic and geological favours at the site.

The Dabong dam scheme will be constructed with a concrete gravity type by availing the topographic and geological favours at the site. An optimization study for water resources development of the Dabong dam scheme (refer to Chapter 4, Annex VI) revealed that the higher NHWL, the greater the net benefit gains as did for the Nenggiri dam scheme. Thus, the crest of dam was at first fixed at El.80.0 m of topographical maximum elevation, and then NHWL was determined at El.62.4, 64.1, 65.6 and 66.7 m for the peak-cut ratios of 80, 70, 60 and 59.0% respectively by the routing calculation for PMF and a 50-year probable flood.

The optimization study for water resources development of the Lebir dam scheme (refer to Chapter 4, Annex VI) reckoned that the net benefit increases by lowering NHWL. However, the highest benefit-cost ratio and EIRR were gained by setting NHWL at El.80.0 m. In this situation, the crest of dam was at first set at El. 91.1 m of topographical maximum elevation, and then NHWL was computed at El. 76.3, 77.9, 79.3 and 80.0 m for the peak-cut ratios of 70, 60, 50 and 37% respectively by the routing calculation for PMF and 50-year probable flood. By seeking the high benefit-cost ratio and EIRR as much as possible, NHWL was determined at El. 76.3, 77.9, 79.3 and 80.0 m for the peak-cut ratios of 70, 60, 50 and 37%, respectively.

The Lebir dam will be constructed with a rockfill type, and then the spillway for PMF has the width of 150 m, which is selected in the Feasibility Study of Lebir project.

The construction costs of the Lebir, Dabong and Nenggiri dam schemes developed for hydropower generation and irrigated agriculture are estimated as discussed in Section 6.2 Construction Costs of Annex VI. The construction costs of those dam schemes including the Kemubu dam scheme are re-estimated for NHWL corresponding to the respective peak cut-ratios as shown in Table VIII. 4.3.

4.4 Structural Plan for River Improvement

4.4.1 Conditions for the structural plan of river improvement

For the flood mitigation in the downstream reaches of the Kelantan River basin, the several combinations of storage dams with river improvement works were contemplated as discussed in the preceding Section 4.2, Flood Mitigation Effect by Dam. Peak discharges for designing the alternative plan of river improvement works range from 5,000 m^3/sec up to 17,500 m^3/sec. The following conditions are adopted for the structural plan of river improvement:

(1) Predominant flow of the mesh-like channels near the estuary

The river mouth of the Kelantan forms mesh-like river channels, and a large scale sand dune is being developed at the debouchment of the river. River flow in the rainy season discharges mostly to the northern direction and partly to the western direction through the mesh-like river channels. The river mouth is apt to be closed in the dry season due to relatively low velocity of discharge from the main river.

It is planned in this study to protect the river stretch upstream of the mesh-like river channel by provision of level. The flood water level in the upstream stretch varies due to the flow condition of the mesh-like river channel. In order to study the treatment of the mesh-like channels, the relationship between the most predominant flow condition in the mesh-like river channels at flood time and flood water level in the upstream river channel was studied based on the data for tidal water level at Geting which is located at the river mouth of Golok, flood water level at Kota Bharu and flood discharge at Guillemard Bridge. The study was carried out by means of non-uniform flow calculation using the record of flood discharges occurred in November 1988.

It was clarified in this calibration study that the flood flows discharge dominantly through the Kelantan main stream and Suri channel near the coastal area as shown in Fig. VIII.4.16, and roughness coefficient of the river channel is 0.025.

It is considered to be suitable to straighten the river channel as far as possible from the viewpoint of stability and maintenance of river channel. Present dominant flow condition as shown in Fig. VIII.4.16 fits with the above requirement. Thus the river improvement plan was worked out under the condition that the mesh-like river channels to the direction of Tumpat are closed.

(2) Levee

The levee is basically constructed with an earth embankment type by the following reasons;

- It is easy to obtain a large amount of construction materials near the project site, resulting in the reduction of construction cost,

- It is rather easy to make the levee higher and wider in case that stage-wise development is considered, and

- Maintenance is easier than that for river channel.

The levee is constructed by securing the clearlance of 50 m wide from the bank of low-water channel at least.

Fig. VIII.4.17 shows the typical cross section of levee. The side slope of earth embankment is set at 1:3.0 taking into account the stability and the long duration of flood. To protect the toe of the levee from seepage water, toe drain is provided. While, the width of crest and height of freeboard are designed on the basis of the following design criteria:

Peak Discharge (cms)	Width of Crest (m)	Freeboard (m)
below 10,000	6.0	1.5
above 10,000	7.0	2.0

A special levee constructed with concrete is also taken into consideration at the places where land acquisition is not easy due to the urbanization developed by the river side such as Kota Bharu as shown in Fig. VIII.4.18.

(3) River structures

The construction of levee along the main river inevitably causes a problem of interior drainage, so that interior water must be drained by such structures as water gates and sluice valves. Some meandering portions of channel downstream from Pasir Mas are observed to be eroded. Revetment works will thus be needed for protecting them.

4.4.2 Comparative study of river improvement plan

The possible measures of river improvement for the downstream reaches of the Kelantan River are enumerated below:

(i) To confine flooding within the specified width by constructing the levee,

(ii) To increase the flow capacity of river channel by widening the river channel,

(iii) To increase the flow capacity of river channel by dredging the river bed, and

(iv) To increase the flow capacity of river channel by steepening water gradient by introducing short-cutting at the meandering portion.

The combination of the above measures was contemplated on the basis of the cross sections and longitudinal profile of the Kelantan River surveyed in this Study. As a result, the following four alternatives are taken up to determine the suitable river improvement plan;

(i) **Alternative-A**

A large scale levee is constructed along the main river without any improvement of river channel.

(ii) **Alternative-B**

A medium-sized levee is constructed along the main river. Additionally, the low-flow channel and remarkably narrowed river channel portion are reformed by dredging works.

(iii) **Alternative-C**

Low-flow channel is widened and reformed by dredging works with the average width of present river channel. Additionally, the small levee is constructed at the river banks with the low elevation.

(iv) **Alternative-D**

In addition to the most suitable plan selected among foregoing three alternatives, short-cutting is performed at a large meandering portion at Pasir Mas.

The comparative study on these alternatives is carried out under the conditions that the flood peak discharge is 12,000m^3/sec.

Fig. VIII.4.19 shows the results of the comparative study. Based on this figure, the variation of flood water level, earthwork volume and required cost are enumerated as follows;

Item	Alt-A	Alt-B	Alt-C
1. Flood water level			
. Water level in Alt-B is almost same as that of Alt-A, but is several ten centimetres lower at narrow places due to dredging.			
. Water level in Alt-C is several ten centimetres to 1.5 metres lower than that of Alt-A and B.			
2. Work Quantity (mill. m^3)			
Dredging Work	-	2	58
Embankment for Levee	17	14	9
3. Cost of Earthwork (mill.M$)	138	118	400

The above results show that the flood water level for Alternative-C is lowered remarkably because of a huge amount of dredging work and widening of low water channel throughout all the 70 km long river stretches. Especially excavation volume near the river mouth occupies about 44% of the total volume. Consequently the required cost is about 4 times of Alternatives-A and B. Furthermore, Alternative-C is supposed to bring about the problem of difficulty of maintaining the design cross section of river channel and the intrusion of salt water during dry seasons.

The required cost for Alternative-B is almost same as that for Alternative-A. But the flood water level for Alternative-B is lower than that of Alternative-A. Thus, Alternative-B was selected as the suitable scheme in this study.

Besides, the combination of Alternatives B and D is studied to examine the effect of short-cutting (refer to Fig. VIII.4.20). In the flood water level for the discharge of 12,000 m3/sec, the volume of earthwork and its cost are also enumerated as follows:

Item	Alt-B	Alt-D
1. Flood water level		
Water level of Alt-D in the stretches of 40 km upstream from the short-cut portion is 3 m lower than that of Alt-B at most.		
2. Work Quantity (mill. m^3)		
Dredging Work	2	52
Embankment for Levee	14	8
3. Cost of Earthwork (mill.M$)	118	352

The above results show that Alternative-D, short-cutting of meandering portion at Pasir Mas, is not only a high cost measure, but also brings about the problems of spoiling excavated materials and of the reconstruction of existing irrigation distribution network. Besides, the river sand eroded in the short-cut channel is apt to deposit in the Kota Bharu river stretch. Considering these situations, Alternative-B is finally adopted as the optimum plan of river improvement measure.

4.4.3 Treatment of river mouth

A large scale sand dune is being developed at the river mouth of the Kelantan River because of a strong westward littoral current and relatively low velocity of discharge from the main river. The river mouth is apt to be closed by sand dunes in case that the low discharge continues in dry seasons. This phenomenon causes the inconvenience to navigational activities.

In order to examine flooding effect by the sand blockage at the river mouth, the relation between the flood water level and with-and-without sand blockage was studied by non-uniform flow calculation. Fig. VIII.4.21 shows the result of this study using the flood peak discharge of 11,100 m^3/sec. This figure shows that flood water level does not effectively go down only with the removal of sand dune at the river mouth. It would be required to dredge river bed upto several kilometres upstream from the estuary, when effective lowering of flood water level is expected. And, the dredging volume would be some million m^3 with a huge amount of annual maintenance cost. Accordingly, the river improvement plan in this study is carried out under the condition that the river mouth is remained as it is.

The river mouth in the Kelantan River always varies its location and causes the difficulties to navigational activities. In order to stabilize and maintain the river mouth and its direction and its upstream river channel, some measures including the provision of a jetty will be contemplated. However, the study on this river mouth treatment plan needs the solution for several technical problems such as the direction and length of the river mouth to be protected, the relation between erosion and scoring near the protected river mouth and littoral current and the relation among the river channel variation near river mouth, river discharge in the rainy and dry seasons and littoral current. To meet with these requirements, sufficient investigation is needed during a long term to obtain the following data;

- Tidal level and its wave height
- Topographic map of the river mouth and coast with a large scale
- Volume and direction of littoral drift sand
- Direction and velocity of surface wind velocity
- Grain size distribution of riverbed material
- Wind-blown sand.

Additionally, a hydraulic model test for the treatment of river mouth is one of useful methods to clarify the effect of the treatment works.

4.4.4 Urban drainage in Kota Bharu

Present drainage system in the town of Kota Bharu divides into three catchment areas; that is, south-west part of the town of Kota Bharu with a catchment area of 23.4 km^2, south-east part of the town of Kota Bharu with a catchment area of 12.5 km^2 and northern coastal plain of 74.9 km^2. The central part of Kota Bharu is located in the northern coastal plain area. Majority of sewage and runoff caused by localized storm is draind to the South China Sea through the Pengkalong Chepa River flowing from the downstream area of Kota Bharu to northeastern direction and Lubok Mulong River flowing from the upstream area of Kota Bharu to northern direction.

In order to clarify the relation between the inundation caused by overflow of flood from the Kelantan River and that due to intensively localized storm, the relation between the occurrance of relatively heavy rainfall in Kota Bharu and concurrent flood peak discharge at Guillemard Bridge was studied based on the rainfall record at Kota Bharu during the 1956-1986 period and water level record at Guillemard Bridge during the 1965-1986 period.

The 5-day rainfall more than 1,000 mm and concurrent flood peak discharge are estimated in Table II.5.5 in ANNEX II, HYDROLOGY, and they are summarized as follows:

Date	5-day rainfall (mm)	Flood peak (m^3/s)
1967, Jan.	1385	16,000
1981, Nov.	1123	2,028
1986, Dec.	1463	6,901

The flow capacity of river channel at Kota Bharu stretch has been estimated at around 5,000 m^3/sec. The Flood Report prepared by DID states that the town of Kota Bharu was not inundated during the intensively localized storm in 1981. The 5-day rainfall in November 1981 corresponds to about 15-year probability. This fact implies that the present drainage system has capacity to discharge the runoff with about 15-year return period, which is caused by intensively localized storm, and inundation in the town of Kota Bharu may scarcely occur unless the overtopping of flood from the Kelantan River takes place.

In order to further study the urban drainage in Kota Bharu, investigation and study on the existing drainage network and hydraulic conditions at the occurrence of intensively localized rainfall will be needed. These investigation and study should, however, be carried out after confirming sufficiently the inundation condition after the implementation of the proposed flood mitigation project.

4.4.5 Step-wise development plan

In case that river improvement is carried out with stage development as discussed in the preceding Section 4.2, the construction of levee will be executed in the following steps:

1) Provisional stage

- Continuous levees will be constructed on both banks to protect the rural riparian areas from a 20-year probable flood, i.e. river stretches of KL2, KL4, KL7, KL10 and KL11.

- A continuous levee will be constructed along the river to protect the urban riparian areas of Kota Bharu (KL3), Pasir Mas (KL5), Tanah Merah (KL8), Temangan Lama and Bharu (KL9) and Kuala Krai (KL12) from a 50-year probable flood.

2) Final stage

The levee in the rural riparian area will be made higher and wider to raise the protection level from a 20-year probable flood to a 50-year probable flood.

4.4.6 Relationship between the peak discharges and the construction cost of river improvement

The construction cost of river improvement was estimated assuming the five peak discharges at Guillemard Bridge; that is, 6,000, 9,000, 12,000, 15,000 and 18,000 m^3/sec.

The construction cost for the above river improvement as given in Fig. VIII.4.21 was estimated referring to the unit price in the similar projects in the basin.

4.5 Implementation Programme for Flood Mitigation Plans

4.5.1 Construction time schedule

The construction time shcedule for the conceivable eight flood mitigation plans was prepared under the following conditions and considering Malaysia Five-Year Development Plan;

(1) Construction period and disbursement:
- Seven years for the Dabong, Lebir and Nenggiri schemes with the disbursement of 0.05, 0.10, 0.25, 0.25, 0.20, 0.10 and 0.05,

- Three years for the Kemubu shceme with the disbursement of 0.20, 0.50 and 0.30.

(2) The construction period for river improvement is estimated

based on the embankment capacity of 2.0 million m^3 a year for levee, and the construction costs are uniformly disbursed.

(3) The construction of river improvement for the final stage is commenced immediately after the completion of the provisional stage.

(4) Consideration be given to disburse the annual construction fund evenly throughout the construction period.

(5) Prior to the implementation works, a series of pre-requisite works such as feasibility study, loan arrangement and detailed design are performed.

Fig. VIII.4.22 shows the construction time shcedule for eight conceivable flood mitigation plans prepared based on the foregoing conditions.

4.5.2 Annual disbursement schedule

Based on the foregoing construction time schedule, the annual disbursement schedule for eight conceivalbe flood mitigation plans and construction cost estimated in Table VIII.4.3, the annual disbursement schedule was prepared as shown in Table VIII.4.4.

4.6 Selection of Suitable Combination Plans

4.6.1 General

The benefits accrued from hydropower generation and irrigted agricultural development are discussed in Chapte 6, Economic Evaluation of Annex VI, whilst the benefits for flood mitigation are estimated in Annex V.

The construction costs for the development of dams and river improvement are estimated as discussed in the preceding Section 4.3 and 4.4. The economic viability of each combination plan is assessed by preparing the streams of those benefits and costs. The basic assumptions and conditions applied for the economic evaluation are given as follows:

(1) A project life is 50 years from the in-service date.

(2) Construction period and disbursement:
- Seven years for the Dabong, Lebir and Nenggiri schemes with the disbursement of 0.05, 0.10, 0.25, 0.25, 0.20, 0.10 and 0.05.

- Three years for the Kemubu shceme with the disbursement of 0.20, 0.50 and 0.30.

(3) The construction period for river improvement is estimated based on the embankment capacity of 2.0

million m^3 a year for levee, and the construction costs are uniformly disbursed.

(4) The construction of river improvement for the final stage is commenced immediately after the completion of the provisional stage.

(5) Economic cost is 85% of construction cost.

(6) The O&M costs of dams and river improvement are taken to be 0.5% of their direct construction costs. In case that hydropower generation is included as an objective of dam development, the O&M costs are assumed to be M$13 per KW.

(7) It is assumed that the river improvement works proceed from downstream to upstream stretches and benefit for flood mitigation by the river improvement in a certain river stretch accrues immediately after the completion of the river improvement work in this stretch.

4.6.2 Selection of suitable combination plan including water resources development

Based on the foregoing conditions and assumptions, economic evaluation by means of economic internal rate of return (EIRR) was made for the conceivable combination plans. The result is given in Table VIII.4.5, in which benefits for power generation, irrigation and flood mitigtion are counted.

The Dabong dam scheme shows the highest economic efficiency in terms of EIRR. Thus, the Dabong dam scheme is selected as the most promising plan for the water resources development of the Kelantan River basin and the flood mitigation in the downstream reaches of the Kelantan River.

It is noted there are negative socio-economic impacts for dam schemes as enumerated in Table IV 3.1 of ANNEX IV SOCIO ECONOMY. In this table, large constraints for dam construction are raised for Dabong. They are resettlement of about 7,400 houses with inhabitants of about 37,200, relocation of about 55 km long railway and 57 km long national highway and submergence of 11,000 ha wide rubber and oil palm plantation.

5. ENGINEERING STUDIES FOR RIVER IMPROVEMENT

5.1 General

As described in the preceding Section 4.6.2, the construction of Dabong dam with river improvement is the most conceivable scheme for the flood mitigation in the downstream area of the Kelantan River basin. The engineering studies of river improvement works for the above plan are presented hereinafter.

5.2 Engineering Studies for River Improvement

(1) Design discharge

Assuming the flood control effect of Dabong dam, the design discharge for river improvement works was estimated at 9,000 m^3/sec for the 20-year probable flood and 11,100 m3/sec for 50-year probable flood.

(2) River improvement plan

The river improvement work of Alternative-B was selected on the basis of the results of comparative study as described in the preceding Section 4.4.2. While, the structural plan consisting of earth and special levees was established by the design criteria as described in Section 4.4.1.

The design high water level and design river bed elevation along the Kelantan River are calculated as shown in Fig.VIII.5.1. While, the arrangement of levee is shown in Fig.VIII.5.2. The typical cross sections of river channel are also illustrated in Fig.VIII.5.3.

(3) Work quantity and construction cost

The scale of river improvement work and its quantity are enumerated as follows:

Protection area	:	from Kuala Krai to 2.5 km upstream from the river mouth
Design flood	:	11,100 m^3/sec at Guillemard Bridge
Length of levee	:	180 km (Levee for main and tributaries)
Height of levee	:	4.5 m on an average
Embankment volume of levee	:	15 million m^3

The construction cost for river improvement work was estimated as enumerated below:

(Unit:million M$)

Stage	Urban Area	Rural Area	Total
Provisional Stage	192	319	511
Final Stage	-	91	91
Total	192	410	602

6. RECOMMENDATION FOR NON-STRUCTURAL MEASURES

6.1 General

As discussed in the preceding Chapters, all the river stretches extended in the downstream reaches of the Kelantan River, flood prone area, are planned to be protected from a 50-year flood with the structural measures by combining flood mitigation dams and river improvement.

Non-structural measures such as flood zoning, restriction of development, land use change and resettlement of population are normally applied to the flood-prone areas where the structural measures cannot be economically viable or will not be implemented over the foreseeable future. Since the flood-prone areas in the downstream reaches of the Kelantan River will be protected with such structural measures as dams and river improvement in the foreseeable future, the application of non-structural measures such as flood zoning, restriction of development, land use change and resettlement of population is not conceived to be necessary for the flood-prone area in the downstream reaches of the Kelantan River.

Flood proofing of houses by means of elevated floor is commonly applied with individual basis in the flood-prone area of the Kelantan River. Considering the frequency of floods and time requirement for the dam construction and river improvement works, the construction of new houses with elevated floor is encouraged as one of measures for the flood mitigation in the Kelantan River basin. The guidance to construct new houses to the high elevation or newly protected areas is another measure for the flood mitigation in the Kelantan River basin.

There is no comprehensive flood mitigation plan by structural measures; that is, flood threat still remains even after the introduction of structural measures for flood mitigation. A flood forecasting and warning system will be introduced for mitigating the remaining flood threat as the reinforcement of the structural measures. Furthermore, flood mitigation by flood proofing requires the prediction of a coming flood for the advance preparation. In this sense, the introduction of flood forecasting and warning system is desired.

In fact, a flood forecasting and warning system was introduced for the entire Kelantan River basin in 1971, and was renewed in 1986 as discussed in the preceding Section 2.6, Existing Flood Forecasting and Warning System. Therefore, the improvement of existing flood forecasting and warning system is recommended as the non-structural measure for the flood mitigation in the Kelantan River basin.

6.2 Recommendation for Non-Structural Measures

A forecasting and warning system introduced in the Kelantan River basin consists of a real time water level and rainfall telemetric system. The Tank Model and the stage correlation techniques have been applied with much success over the years in forecasting the flood water levels which are then used in the release of flood warning to public. As explained in the preceding Section 2.5, the fact that inhabitants in the flood-prone areas evacuated to safe places when the warning of emergency level was issued shows that the flood forecasting and warning system in the Kelantan River basin functions well. Therefore, the current issue is to improve further reliability of flood prediction.

At present, the prediction of flood runoff relies on six telemetered rain gauges scattered over the 12,080 km^2 catchment area. Although the flood forecasting model used had predicted the flood discharges/levels quite well at Guillemard Bridge, the reliability of the model prediction can be further enhanced by having a higher density and well distributed telemetric outstations. Over the catchment area upon close inspection on the present telemetric network, it is recommended to install a new telemetered rainfall station in the Nenggiri River basin. In case that a dam or dams are built in the upper basin the existing flood forecasting model shall be modified, and additional combined telemetric rainfall and water level stations should be installed at the dams to facilitate in the flood prediction.

At present the flood forecasting and warning operation by the State DID in Kota Bharu is manned by State hydrological staff and backed-up by the Flood Forecasting Centre in DID Kuala Lumpur. In order to ease the data processing and decentralising the flood operation to the State DID, it is recommended to install micro-computer based link-up system to the existing telemetric terminal station at Kota Bharu. If the dams are built, new flood forecasting model would be required. Hence, training in the model development and its forecasting operation are required for the new system.

REFERENCES

1. The Kelantan River Basin Study, ENEX of New Zealand, 1977

2. National Water Resources Study, Malaysia, JICA, 1982

3. Nenggiri Dam Project, ELC, 1986

4. Lebir Dam Project (interim), JICA, 1988

5. Kota Bharu Flood Mitigation Scheme, Malaysia International Consultants Sdn. Bhd., 1983

6. Study for Master Plan of Fishing Complex at Kuala Besar, T. Shiozawa, Zamri Darus, et al.

Table VIII.2.1 Existing Bridges over the Kelantan River and Its Tributaries

No.	Name	Road/ Railway	River	Distance from the estuary	Dimensions, m Length	Width	Lowest El. of girder	Administration office	Year of Const- ruction	Remarks
1	Sultan Yahya Petra	Road	Kelantan	13	840.2	12.2	8.2	JKR	1963	
2	Pasir Mas	Road	Kelantan	28	633.0	12.5	15.3	JKR	1989	Under construction
3	Tanah Merah	Road	Kelantan	63	630.0	9.0	24.9	JKR	1987	
4	Guillemard	Railway	Kelantan	65	619.5	3.0	23.8	Railway Dept.	1924	
5	Manek Urai	Railway	Lebir	121	330.0	3.0	-	Railway Dept.	1928	TBM:El.117.751 m
6	Lalok	Road	Lebir	132	166.0	9.0	52.7	JKR	1982	
7	Kemubu	Railway	Galas	147	240.0	3.0	-	Railway Dept.	1930	TBM:El.142.670 m
8	Bertam	Railway	Nenggiri	174	210.0	3.0	66.7	Railway Dept.	1931	TBM:El.220.072 m

Table VIII.2.2 Existing Pumping Stations in the Kelantan River

No.	Name	Location from Pasir Mas	Left/right bank	Features: No. of pumps	Features: Capacity, cms	Features: Intake design level, m	Administration office	Year of Instal-lation	Remarks
1	Kemubu	18 km upstream	Right	5	10.8	5.4	KADA	1971	Extension up to 37.2 cms
2	Salor	4 km upstream	Right	2	1.7	2.4	KADA	1948	
3	Lemal	2 km upstream	Left	4	18.3	1.6	KADA	1963	
4	Pasir Mas	3 km upstream	Left	3	4.3	(1.9) 1/	KADA	1956	
5	Tanah Merah		Left	2	0.3		JKR	1984	Water supply
6	Pasir Mas		Left		0.3		JKR	1983	"

Note: 1/ A figure in the parentheses shows the low level.

Table VIII.4.1 Flood Mitigation Effect of Storage Dams

(Unit : cms)

Case	Scheme	Peak-cut ratio 1/		Peak discharge at Guillemard Bridge 20-year	50-year
1	Without structures 2/	-		13,437	16,369
2	R/I 3/ 4/	-		14,350	17,420
3	Nenggiri + R/I	100		13,367	16,175
4	- do -	90		13,394	16,206
5	- do -	80		13,435	16,254
6	- do -	76		13,456	16,299
7	Kemubu + R/I	40		11,609	13,936
8	- do -	30		11,689	14,136
9	- do -	20		12,118	14,719
10	- do -	15 5/		12,500	15,185
11	Lower Pergau + R/I	30		12,801	15,627
12	- do -	20		12,971	15,879
13	- do -	10		13,399	16,314
14	- do -	9 5/		13,433	16,348
15	Dabong + R/I	80		8,459	10,586
16	- do -	70		8,545	10,683
17	- do -	60		8,655	10,802
18	- do -	59 5/		8,988	11,079
19	Lebir + R/I	70		10,496	12,442
20	- do -	60		10,606	12,580
21	- do -	50		10,648	12,817
22	- do -	37 5/		10,661	13,213
23	Lebir + Nenggiri + R/I	70	100 6/	10,021	11,592
24	- do -	60	90	10,157	11,999
25	- do -	50	80	10,238	12,088
26	- do -	37	76	10,249	12,101
27	Lebir + Kemubu + R/I	70	15	8,841	10,680
28	- do -	60	20	8,665	10,453
29	- do -	50	30	8,459	10,083
30	- do -	37	40	8,543	10,107
31	Lebir + Dabong + R/I	70	80	4,936	6,066
32	- do -	60	70	5,224	6,429
33	- do -	50	60	5,486	6,745
34	- do -	37	59	6,000	7,466

Notes:

1/ Peak-cut ratio = Peak outflow from the spillway for flood mitigation/peak inflow

2/ Flood discharge in natural condition

3/ R/I means river improvement

4/ Inundated flow between Kuala Krai and Guillemard Bridge is confined in the river channel.

5/ An ordinary overflow weir for flood mitigation is not provided to the spillway for the case with the lowest peak-cut ratio of each dam scheme; that is, the flood mitigation to the downstream reaches is only expected with the overflow weir for PMF.

6/ The peak-cut ratio of the Lebir dam scheme is shown in the first column, while the second column for the Nenggiri dam scheme.

Table VIII.4.2 Principal Features of Spillway

Scheme	50-yr peak discharge, cms	Peak cut ratio %	Dam type	Dam Crest El. m	NHWL M	Spillway for flood mitigation, m: SWL 1/	Width (a)	Height	Spillway for PMF, M 1/: DFWL 1/	Width (b)
Nenggiri	4,668	100	Rockfill	169.0	150.7	158.6	-	7.9	166.0	75.0
	(1984)	90	Rockfill	169.0	152.9	158.8	17.0	5.9	166.0	75.0
		80	Rockfill	169.0	155.0	159.5	50.0	4.5	166.0	75.0
		76	Rockfill	169.0	157.0	-	-	-	166.0	75.0
Kemubu 2/	4,943	40	Concrete gravity	82.0	53.0	3/ 70.8	20.0	17.8	80.0	100.0
	(1983)	30	Concrete gravity	82.0	58.4	71.4	37.0	13.0	80.0	100.0
		20	Concrete gravity	82.0	63.0	72.5	70.0	9.5	80.0	100.0
		15	Concrete gravity	82.0	65.7	-	-	-	80.0	100.0
Dabong	8,431	80	Concrete gravity	80.0	62.4	73.1	25.0	10.7	78.0	100.0
	(1983)	70	Concrete gravity	80.0	64.1	73.7	45.0	9.6	78.0	100.0
		60	Concrete gravity	80.0	65.6	74.2	70.0	8.6	78.0	100.0
		59	Concrete gravity	80.0	66.7	-	-	-	78.0	100.0
Lebir	5,561	70	Rockfill	91.1	76.3	84.2	40.0	7.9	87.6	150.0
	(1983)	60	Rockfill	91.1	77.9	84.5	70.0	6.6	87.6	150.0
		50	Rockfill	91.1	79.3	84.7	120.0	5.4	87.6	150.0
		37	Rockfill	91.1	80.0	-	-	-	87.6	150.0

Notes: 1/ PMF; Probable Maximum Flood, NHWL; Normal High Water Level
SWL; Surcharge Water Level, DFWL; Design Flood Water Level

2/ The Kemubu project is developed as a single purpose project of flood mitigation.

3/ The crest elevation of spillway for flood mitigation.

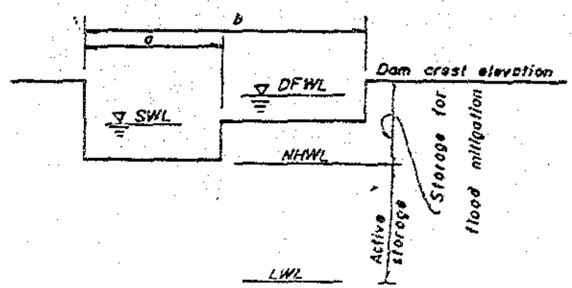

Table VIII.4.3 Cost of Combination Plans including Water Resources Development (1/2)

Combination	Peak cut ratio	Cost, million M$							
		Dam Project 1/				River improvement			Grand Total
		Dam	Power	Relocation	Total	R/I	Compensation	Total	
1. R/I only	-	-	-	-	-	751	132	883	883.0
2. Nenggiri + R/I	100	353.6	278.0	49.5	647.1	707	125	832	1,479.1
	90	353.6	284.5	49.5	653.6	708	125	833	1,486.6
	80	353.6	290.8	49.5	659.9	710	125	835	1,494.9
	76	353.6	297.0	49.5	666.1	713	126	839	1,505.1
3. Kemubu + R/I	40	84.9	-	54.7	139.6	626	111	737	876.6
	30	84.9	-	54.7	139.6	634	112	746	885.6
	20	84.9	-	54.7	139.6	655	116	771	910.6
	15	84.9	-	54.7	139.6	671	119	790	929.6
4. Dabong + R/I	80	94.2	410.1	270.9	775.2	481	85	566	1,341.2
	70	94.2	419.3	270.9	784.4	485	86	571	1,355.4
	60	94.2	427.0	270.9	792.1	499	88	587	1,379.1
	59	94.2	431.7	270.9	796.8	510	90	600	1,396.8
5. Lebir + R/I	70	291.9	184.7	190.1	666.7	570	101	671	1,337.7
	60	291.9	193.1	190.1	675.1	576	102	678	1,353.1
	50	291.9	202.0	190.1	684.0	586	103	689	1,373.0
	37	291.9	204.1	190.1	686.1	599	106	705	1,391.1
6. Lebir + Nenggiri + R/I	70 100	645.5	462.7	205.6	1,313.8	530	93	623	1,936.8
	60 90	645.5	477.6	205.6	1,328.7	555	98	653	1,981.7
	50 80	645.5	492.8	205.6	1,343.9	557	98	655	1,998.9
	37 76	645.5	501.1	205.6	1,352.2	558	98	656	2,008.2

Table VIII.4.3 Cost of Combination Plans including Water Resources Development (2/2)

Combination	Peak cut ratio		Cost, million M$							
			Dam Project 1/				River improvement			
			Dam	Power	Relocation	Total	R/I	Compensation	Total	Grand Total
7. Lebir + Kemubu + R/I	70	15	376.8	184.7	244.8	806.3	445	78	523	1,329.3
	60	20	376.8	193.1	244.8	814.7	450	80	530	1,344.7
	50	30	376.8	202.0	244.8	823.6	490	86	576	1,399.6
	37	40	376.8	204.1	244.8	825.7	521	92	613	1,438.7
8. Lebir + Dabong + R/I	70	80	386.1	594.8	461.0	1,441.9	156	28	184	1,625.9
	60	70	386.1	612.4	461.0	1,459.5	184	33	217	1,676.5
	50	60	386.1	629.0	461.0	1,476.1	210	37	247	1,723.1
	37	59	386.1	635.8	461.0	1,482.9	269	48	317	1,799.9

Note : 1/ The specific cost of flood mitigation is as follows:
M$ 132.0 million for Nenggiri
M$ 193.0 million for Dabong
M$ 191.0 million for Lebir

Table VIII.4.4 Annual Financial Cost of Combination Plan

(Unit : million M$)

Combination Plan	Malaysia Plan																			
	5 th		6 th					7 th					8 th					9 th		
	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	2000	'01	'02	'03	'04	'05	'06	'07	'08
1. R/I only						45.8	45.8	45.8	45.8	45.8	45.8	45.8	45.8	45.8	45.8	45.8	45.8	45.8	45.8	45.8
2. Nenggiri + R/I					33.5	124.5	225.1	225.1	191.5	124.5	90.9	57.4	57.4	57.4	57.4	57.4	57.4			
3. Kemubu + R/I						83.9	129.1	99.0	53.8	53.8	53.8	53.8	53.8	53.8	53.8	53.8	53.8			
4. Dabong + R/I						94.1	136.9	265.5	265.5	222.6	136.9	94.1	51.2	51.2						
5. Lebir + R/I					36.7	117.2	227.3	227.3	190.6	117.2	80.5	43.8	43.8	43.8	43.8	43.8	43.8			
6. Lebir + Nenggiri + R/I					36.7	125.9	236.0	236.0	199.3	125.9	122.7	119.6	220.2	220.2	186.6	67.1	33.5			
7. Lebir + Kemubu + R/I					36.7	115.2	225.3	225.3	188.6	115.2	78.5	71.9	117.1	87.0	41.8					
8. Lebir + Dabong + R/I					36.7	103.1	213.2	213.2	176.5	103.1	109.3	115.4	214.3	214.3	171.4	85.7	42.9			

Table VIII.4.5 Economic Comparison of Combination Plans

Case	Scheme	Peak-cut ratio, %		EIRR %
1.	R/I	-		5.34
2.	Nenggiri + R/I	100		9.91
3.	- do -	90		10.33
4.	- do -	80		10.53
5.	- do -	76		10.87
6.	Kemubu + R/I	40		4.44
7.	- do -	30		4.38
8.	- do -	20		4.22
9.	- do -	15		4.06
10.	Dabong + R/I	80		11.01
11.	- do -	70		11.31
12.	- do -	60		11.78
13.	- do -	59		11.93
14.	Lebir + R/I	70		6.11
15.	- do -	60		6.20
16.	- do -	50		6.29
17.	- do -	37		6.27
18.	Lebir + Nenggiri + R/I	70	100	9.24
19.	- do -	60	90	9.49
20.	- do -	50	80	9.66
21.	- do -	37	76	9.89
22.	Lebir + Kemubu + R/I	70	15	5.55
23.	- do -	60	20	6.06
24.	- do -	50	30	6.32
25.	- do -	37	40	6.34
26.	Lebir + Dabong + R/I	70	80	11.08
27.	- do -	60	70	11.19
28.	- do -	50	60	11.37
29.	- do -	37	59	11.19

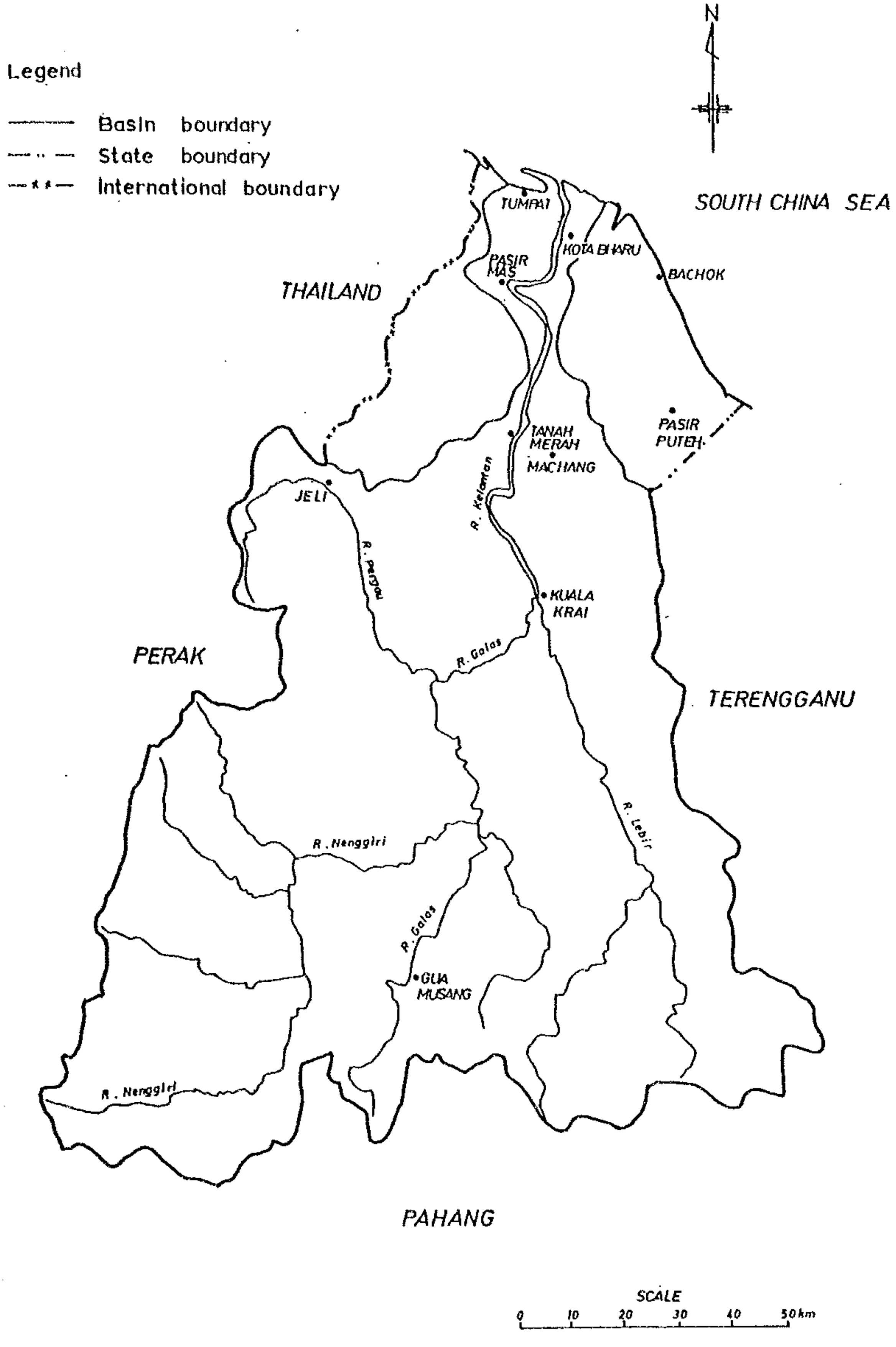

Fig.VIII.1.1

Kelantan River Basin

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STUDY
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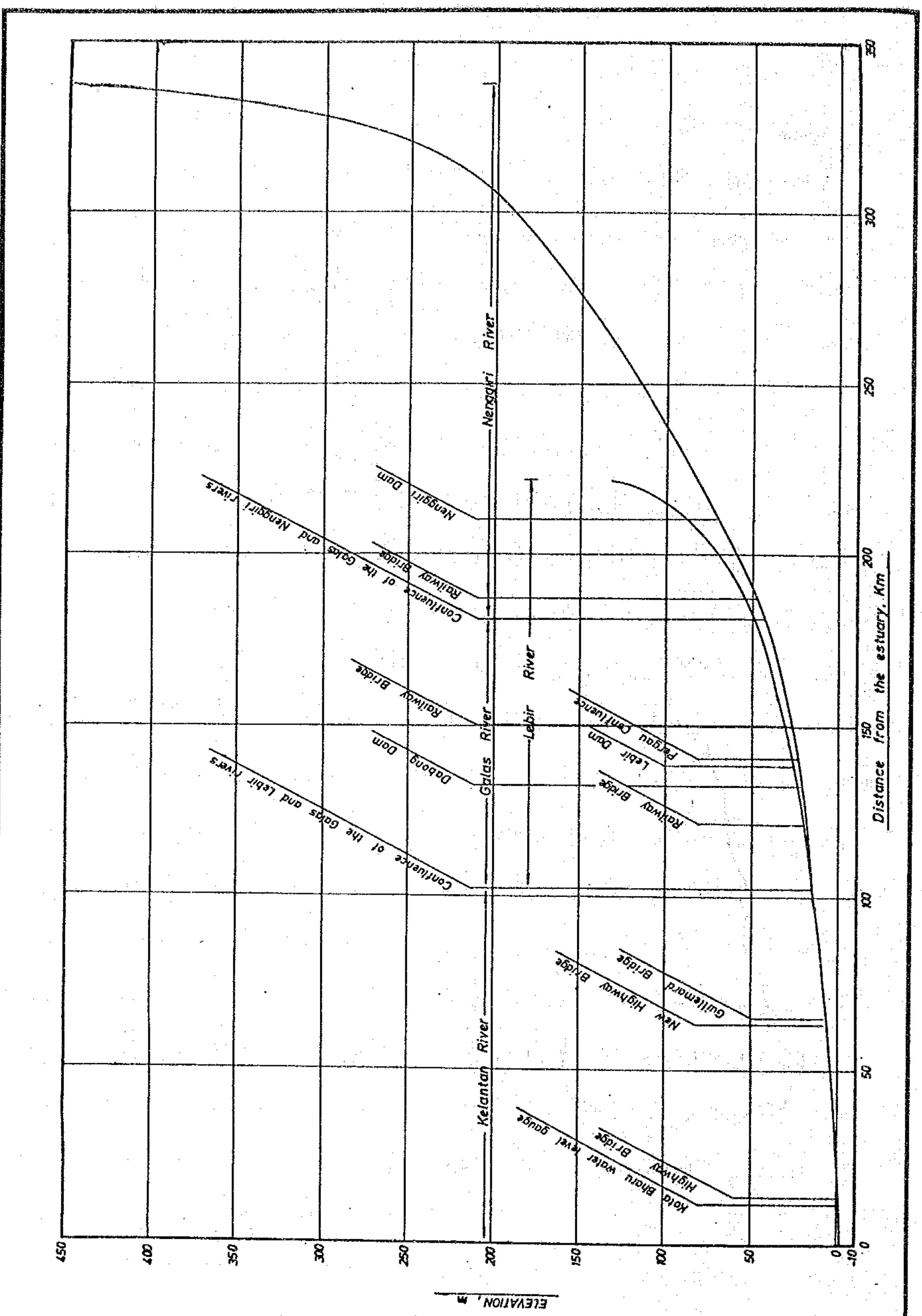

Fig.VIII.2.1

Longitudinal Profile of the Kelantan River System

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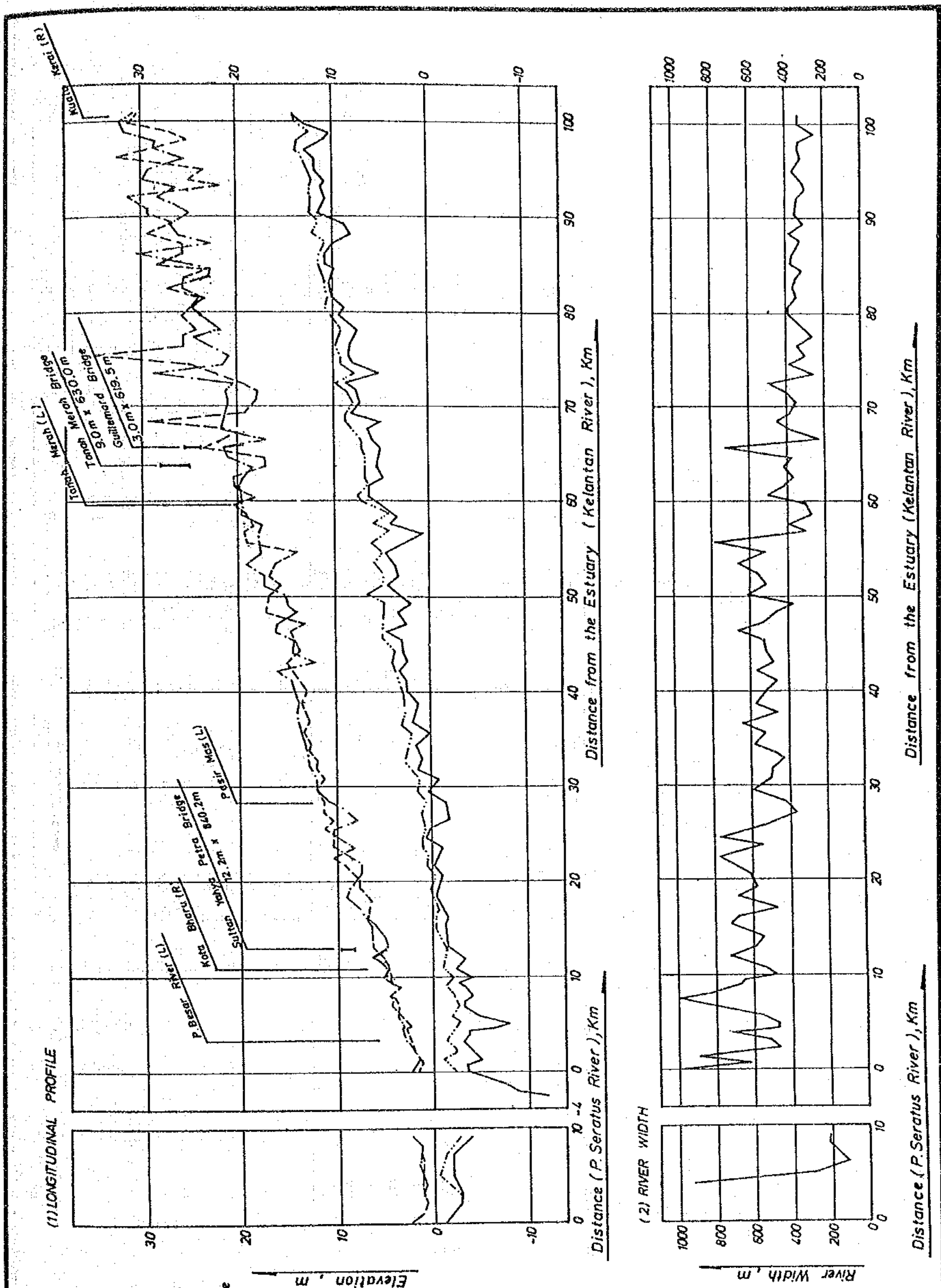

Fig.VIII.2.2

Characteristics of the Kelantan River

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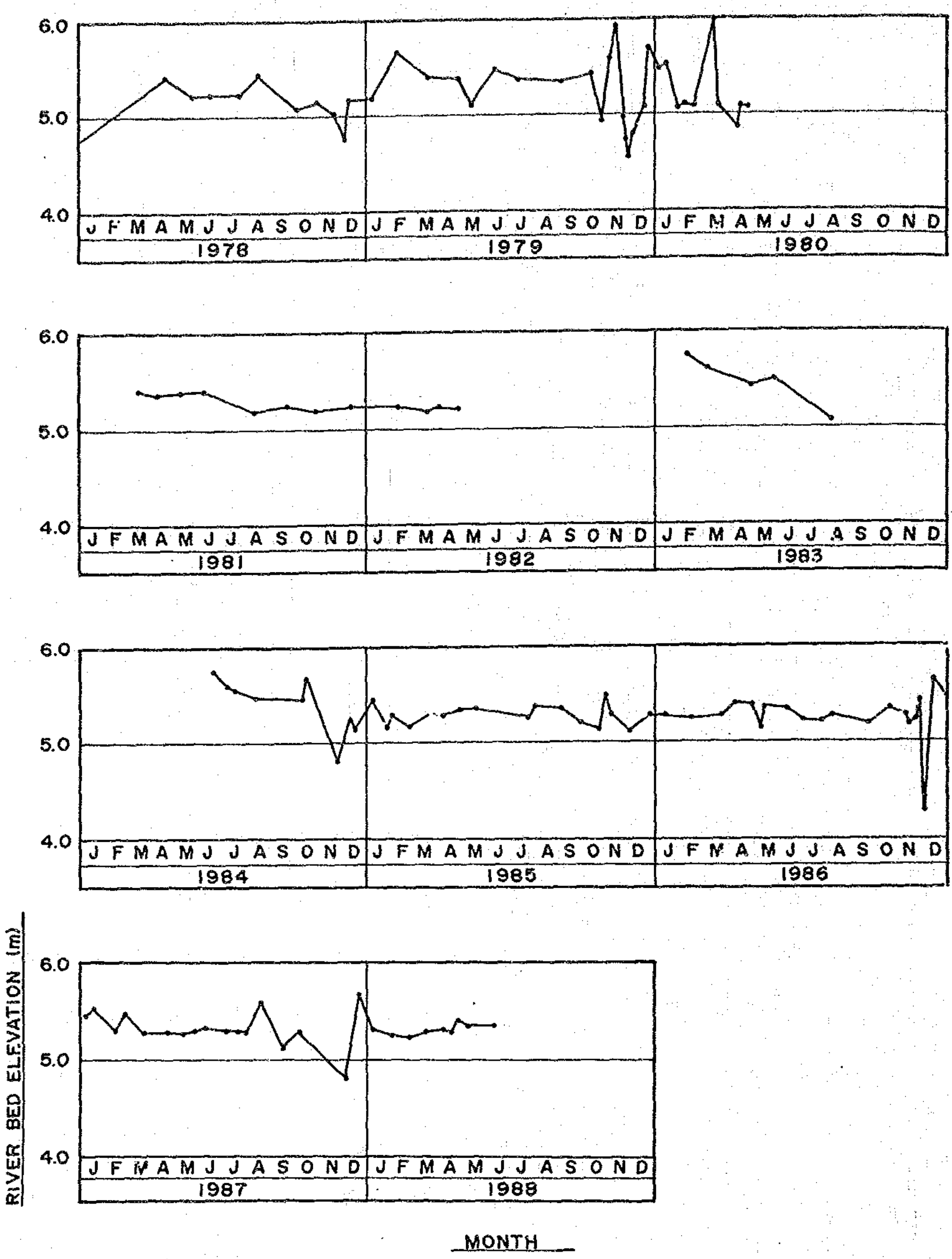

Fig.VIII.2.3

Variation of Lowest River Bed Elevation at Guillemard Bridge

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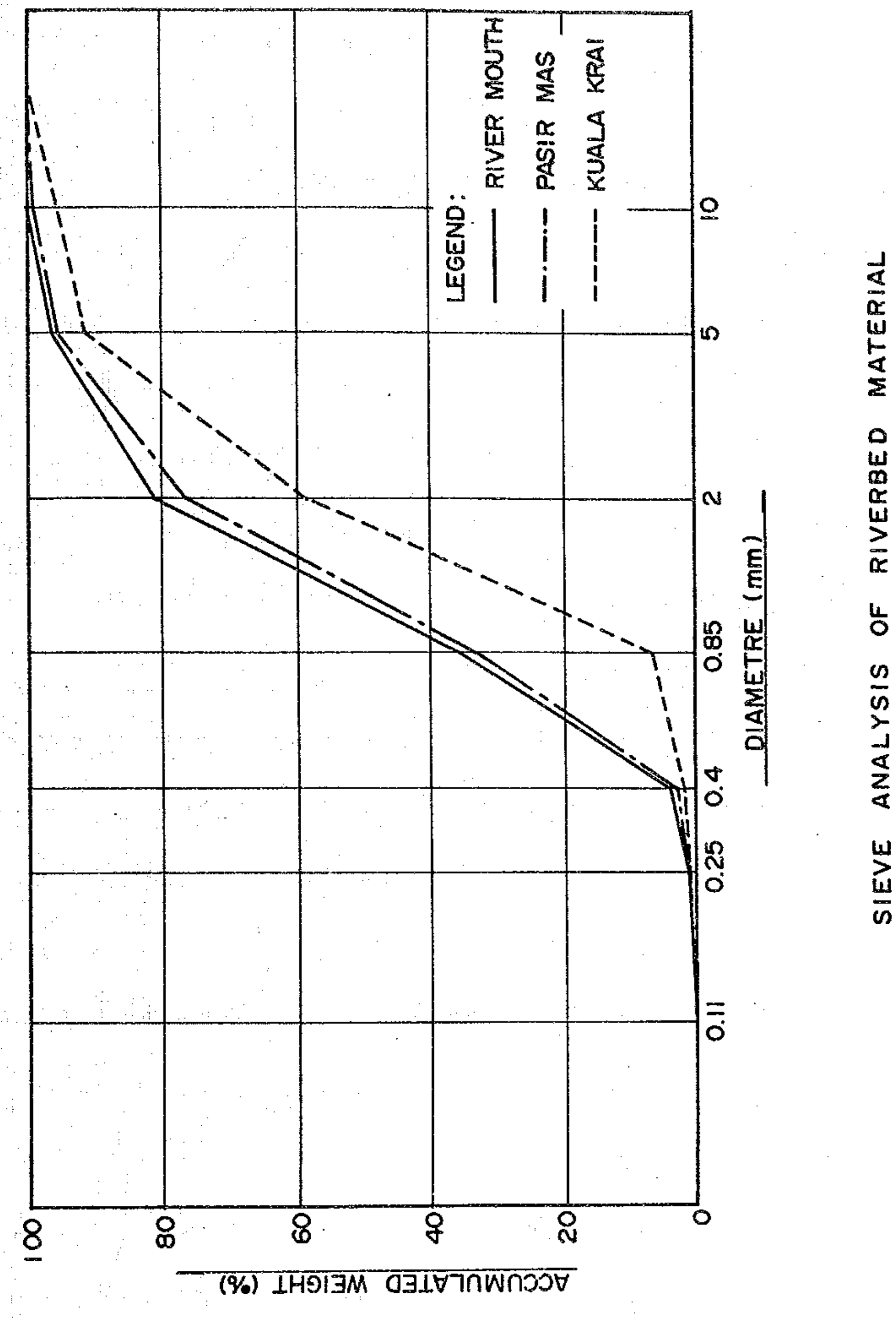

Fig.VIII.2.4

Sieve Analysis of River Bed Material

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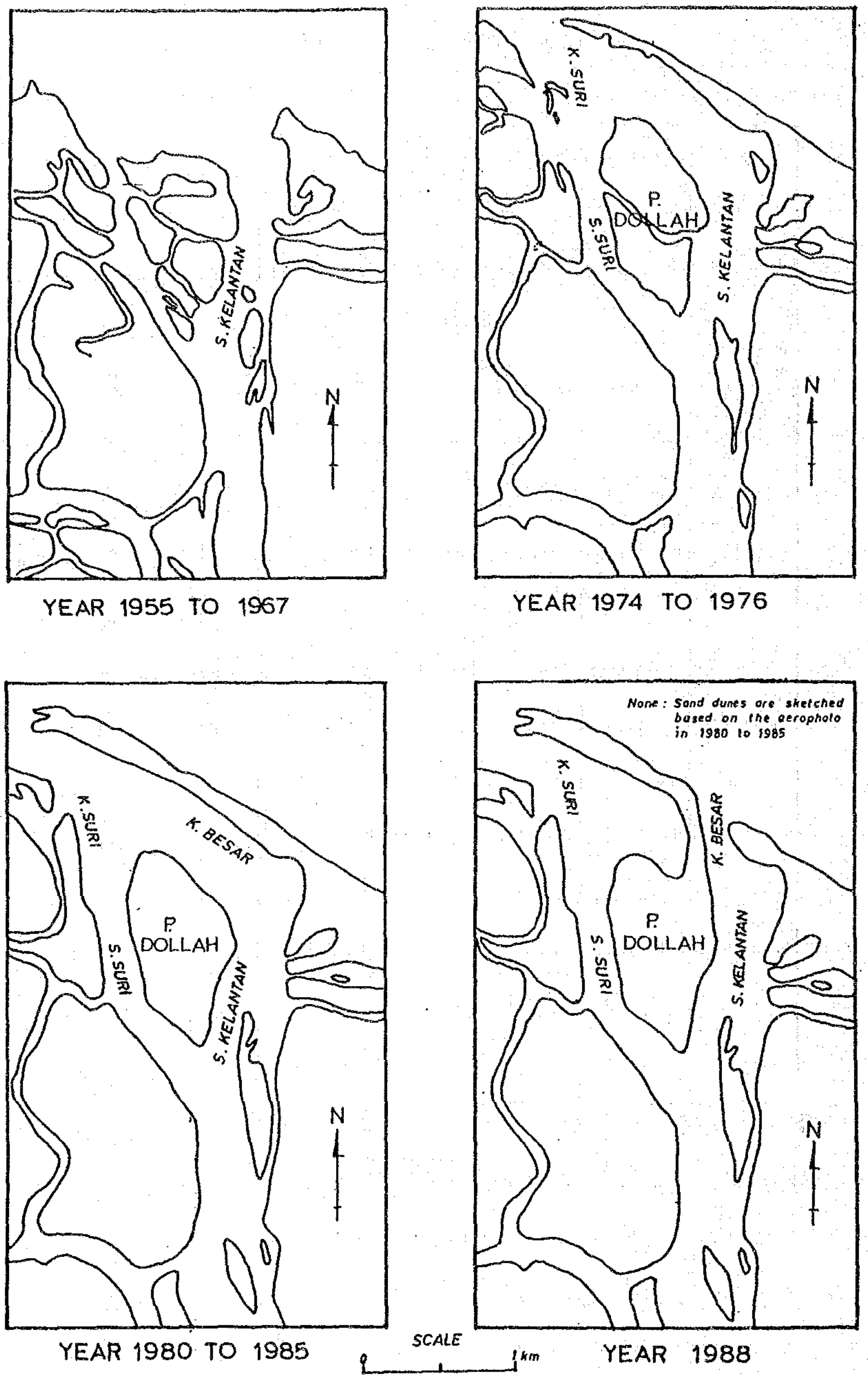

Fig.VIII.2.5

Chronological Changes of the Estuary of the Kelantan River

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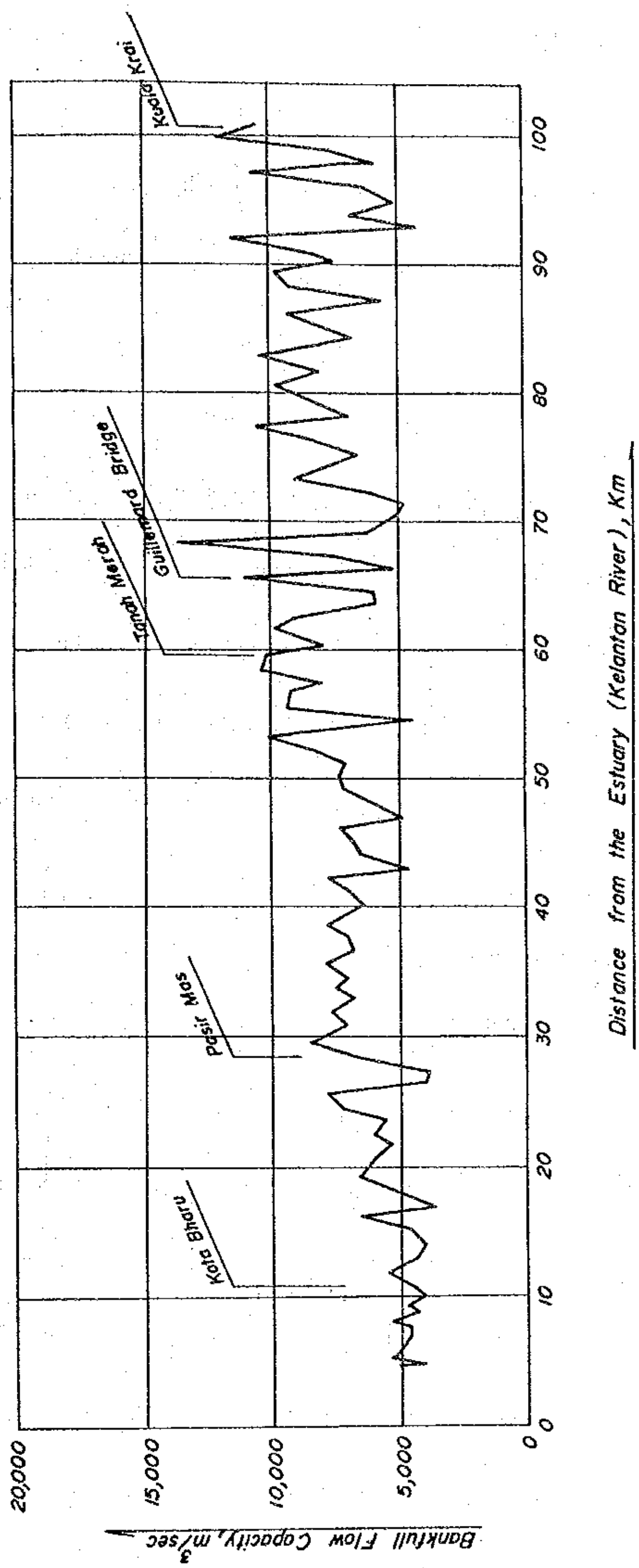

Fig.VIII.2.6

Bankful Flow Capacity of the Kelantan River

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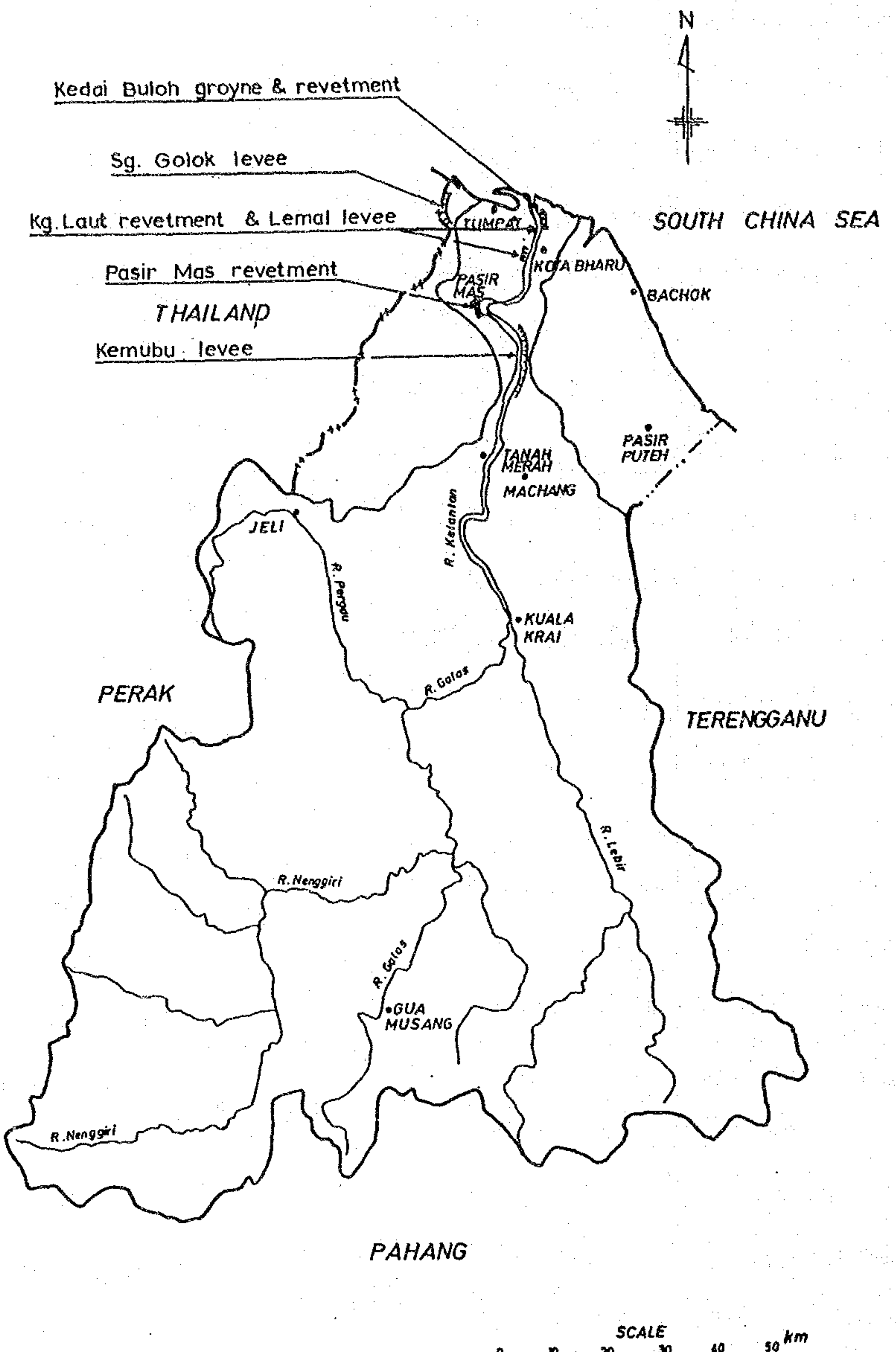

Fig.VIII.2.7

Existing Flood Mitigation Facilities

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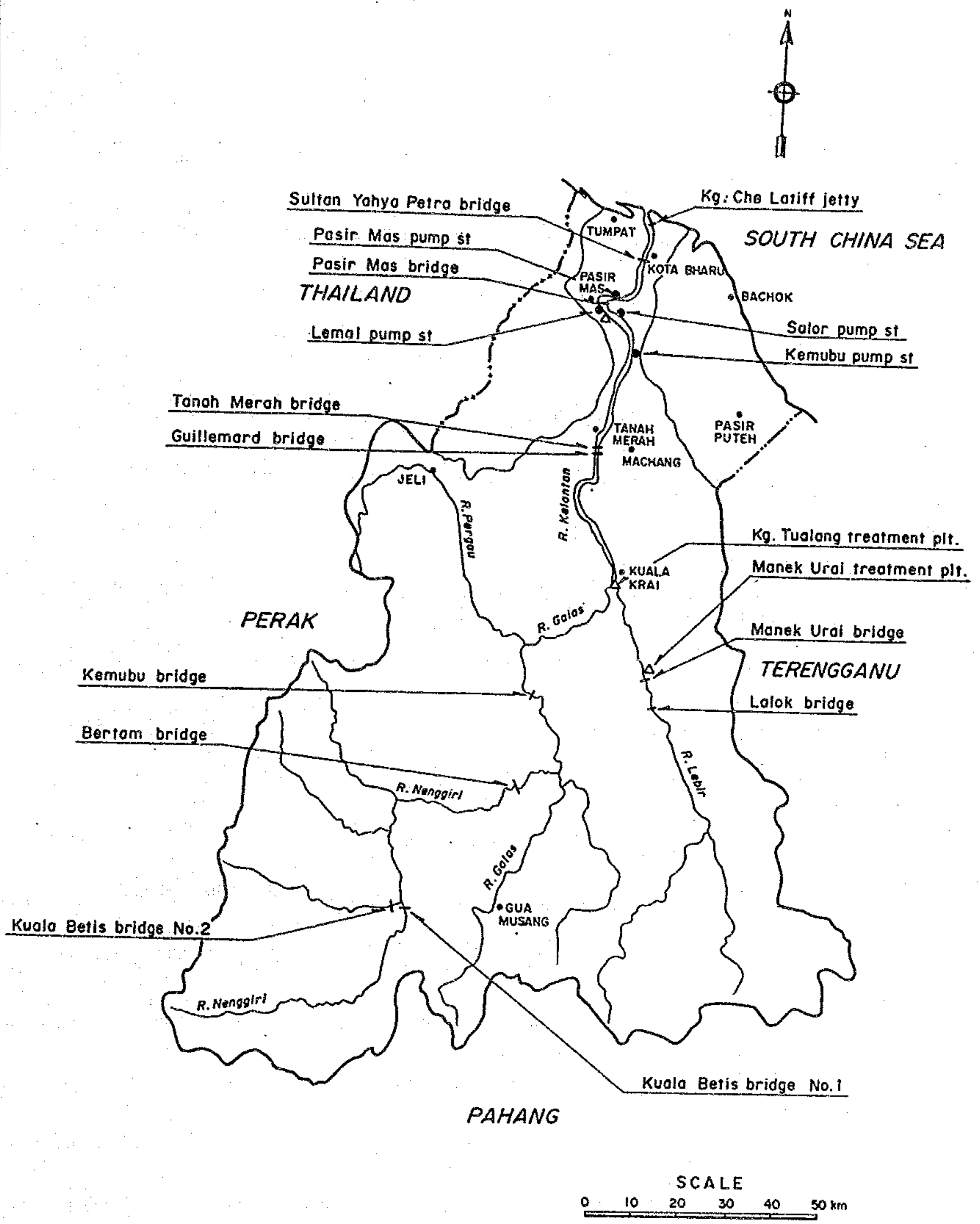

Fig.VIII.2.8

Existing Structures along the Kelantan River

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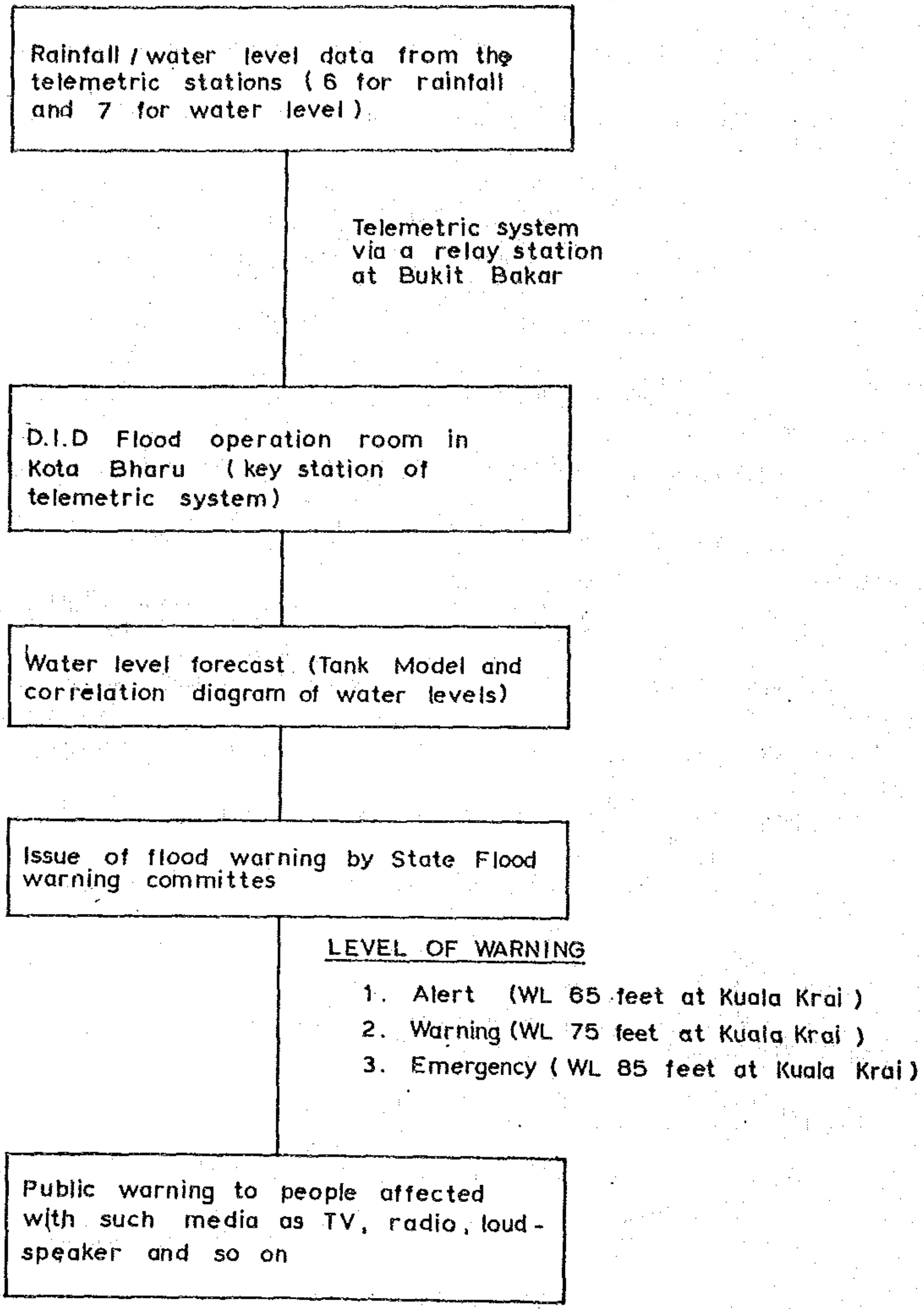

Fig.VIII.2.9

Flood Forecasting and Warning System in the Entire Kelantan River Basin

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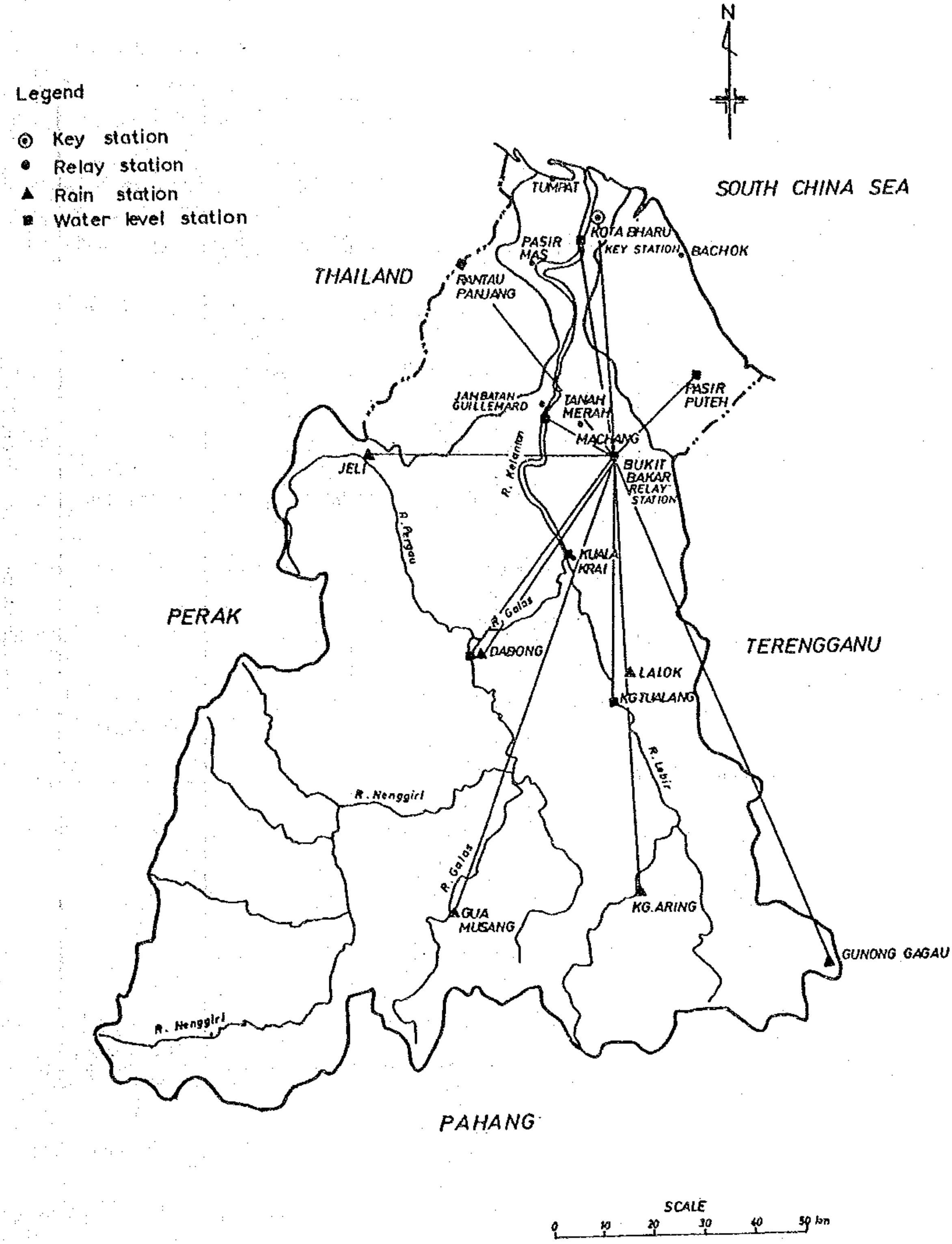

Fig.VIII.2.10

Telemetric System of Rainfall and Water Level Records in the Kelantan River Basin

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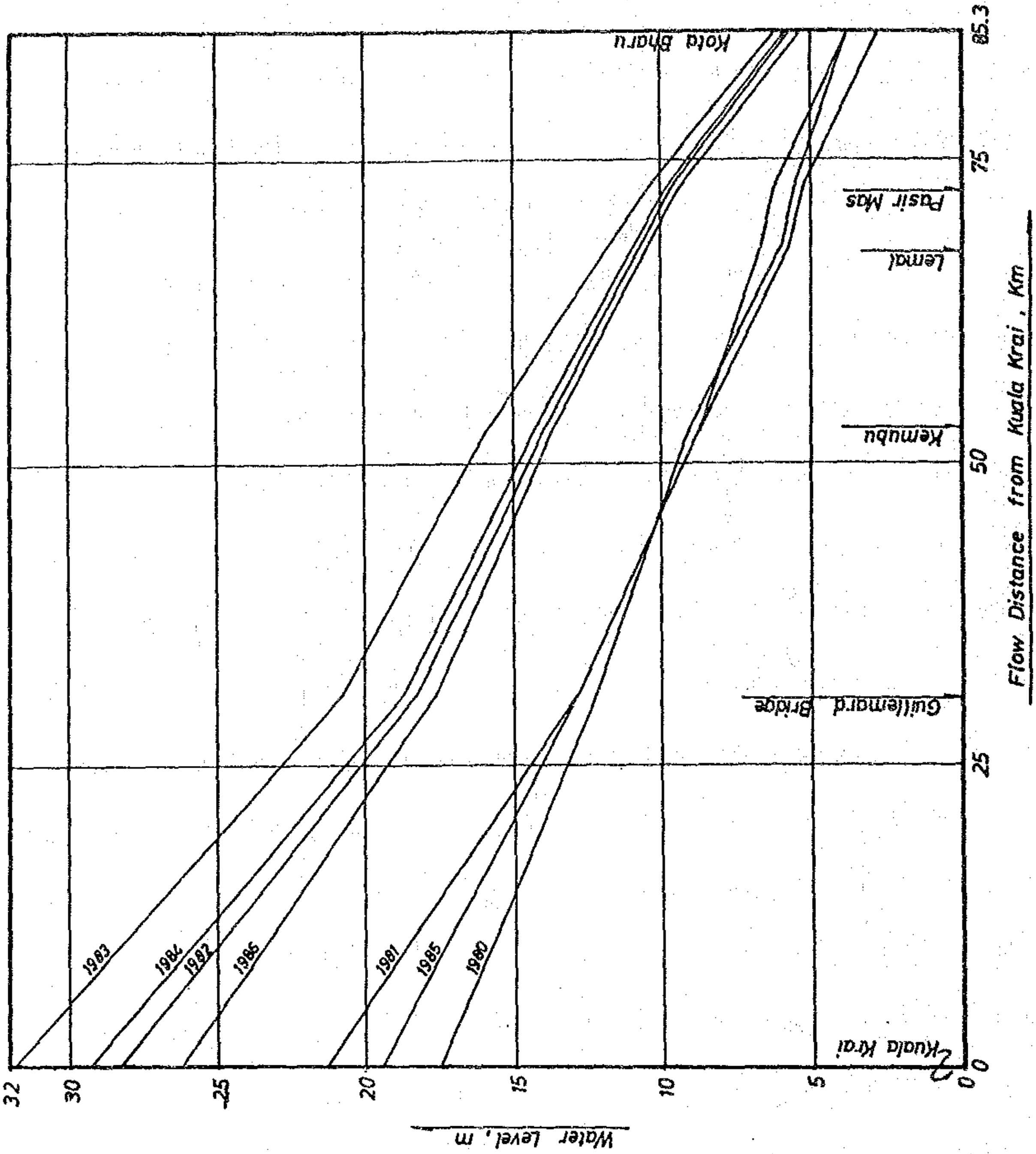

Fig.VIII.2.11

Correlation Diagram of Water Level

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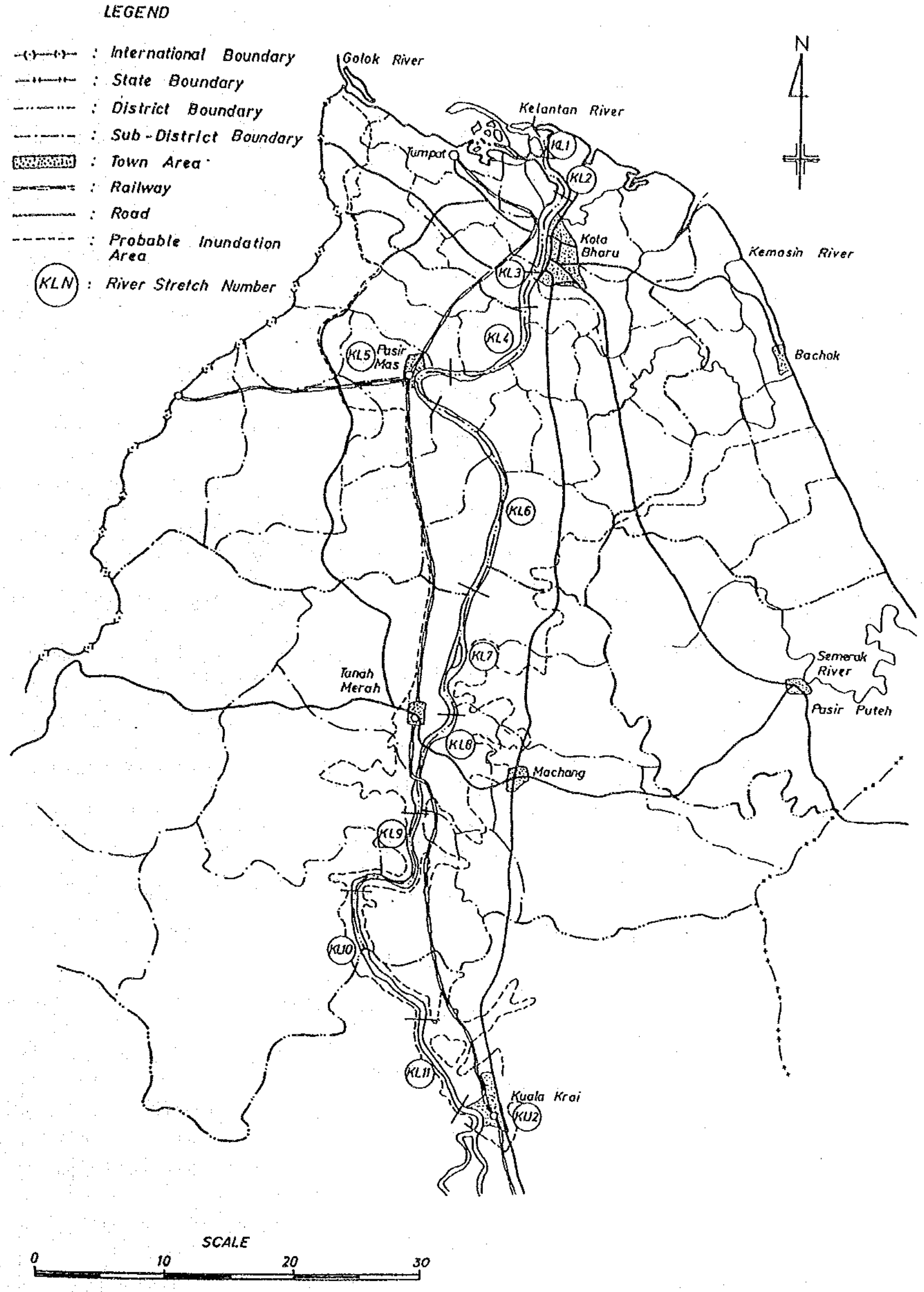

Fig.VIII.3.1

Division of River Stretches for Flood Analysis

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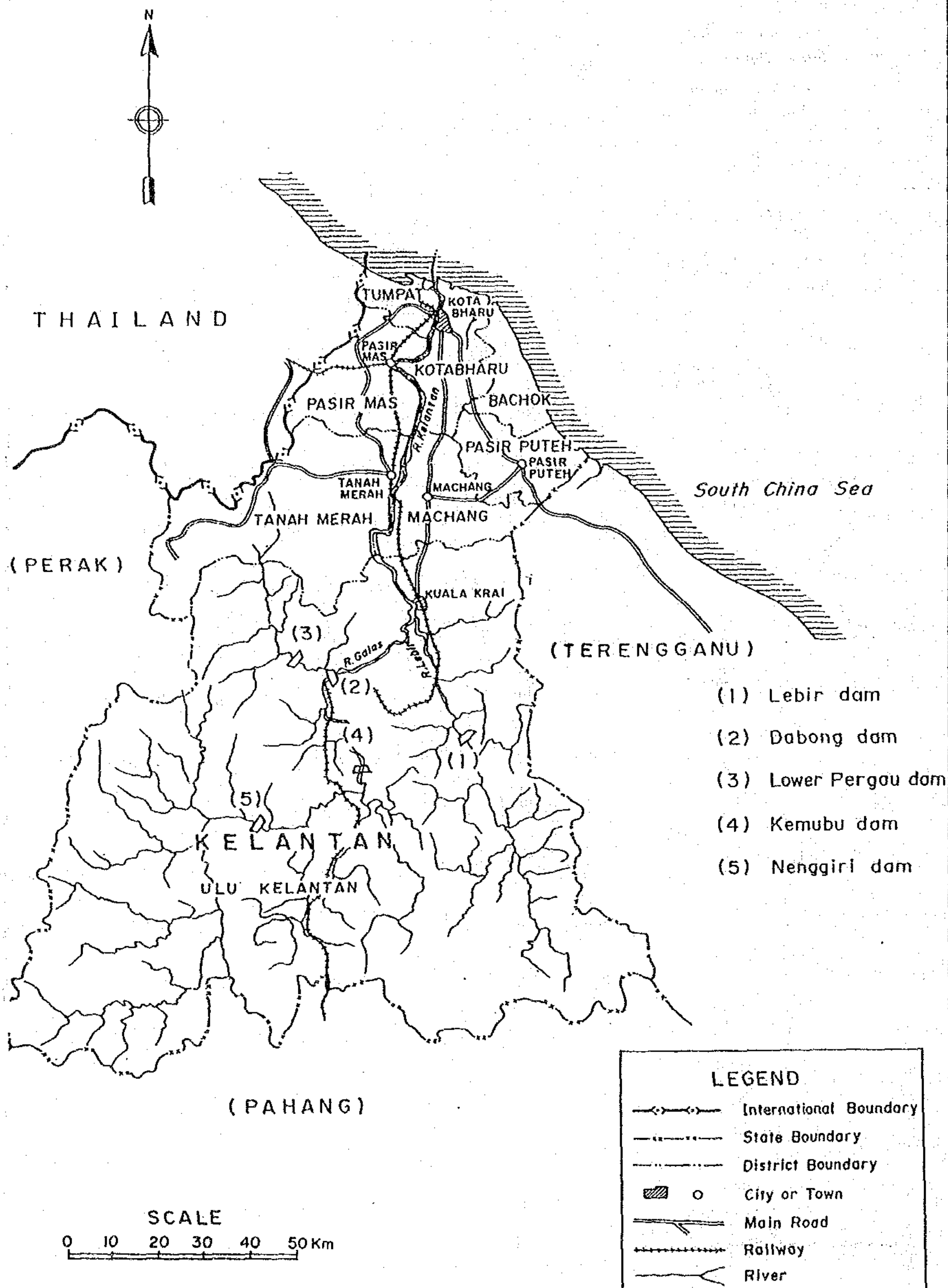

Fig.VIII.3.2

Location of Five Proposed Dam Schemes

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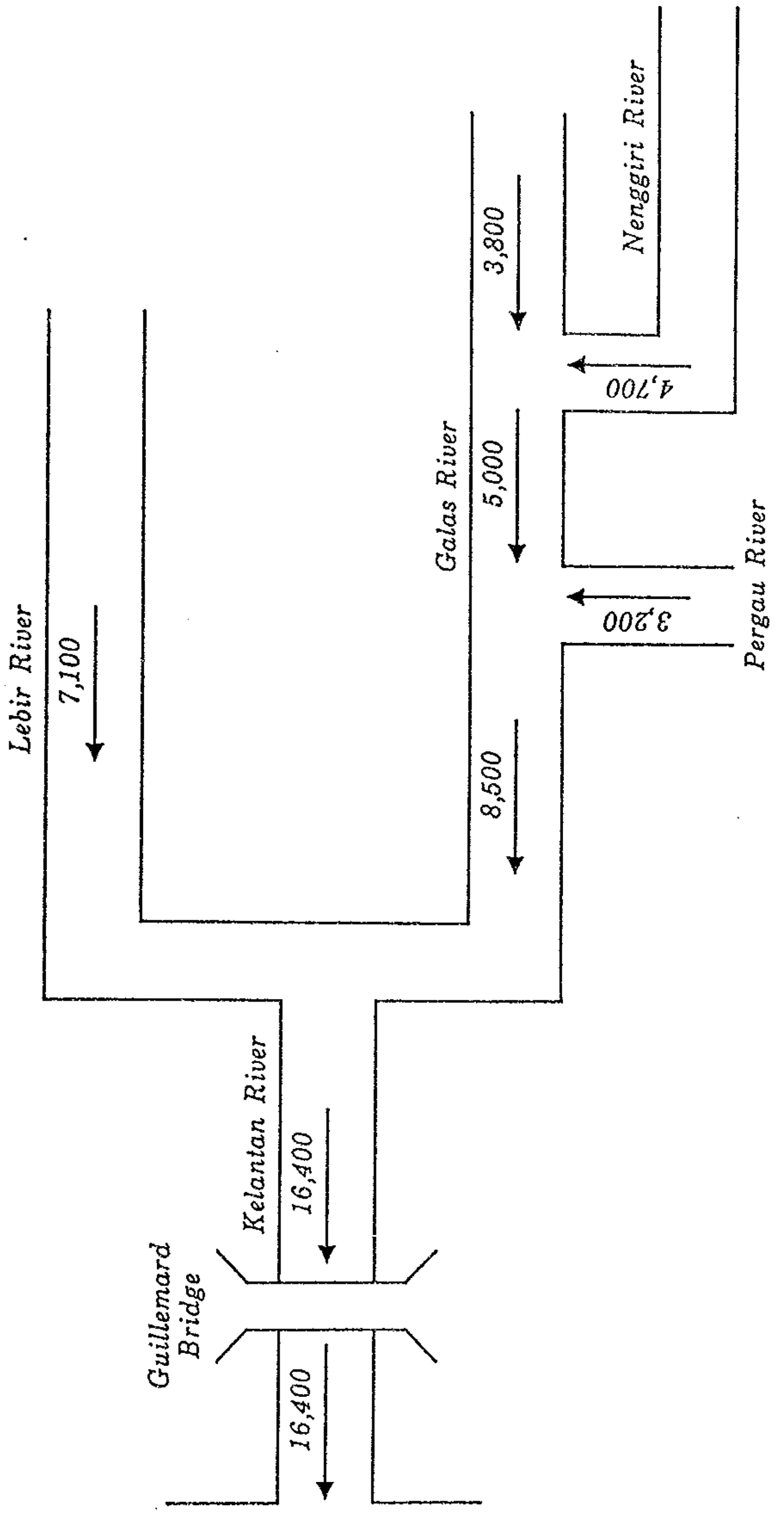

Fig.VIII.4.1

50-year Flood Peak Discharges under Natural Condition

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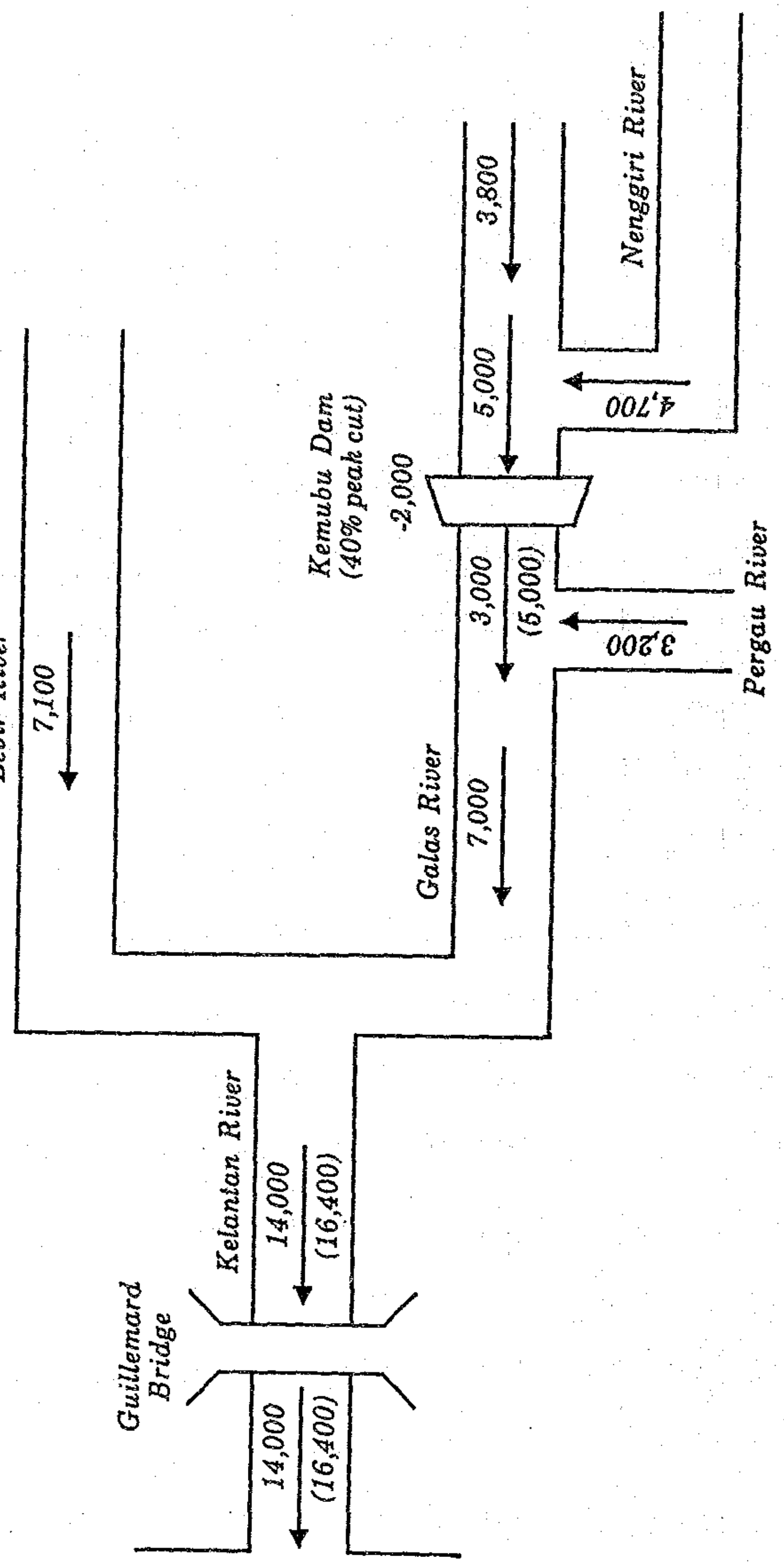

Fig.VIII.4.2

50-year Flood Peak Discharges
with Kemubu Dam Scheme

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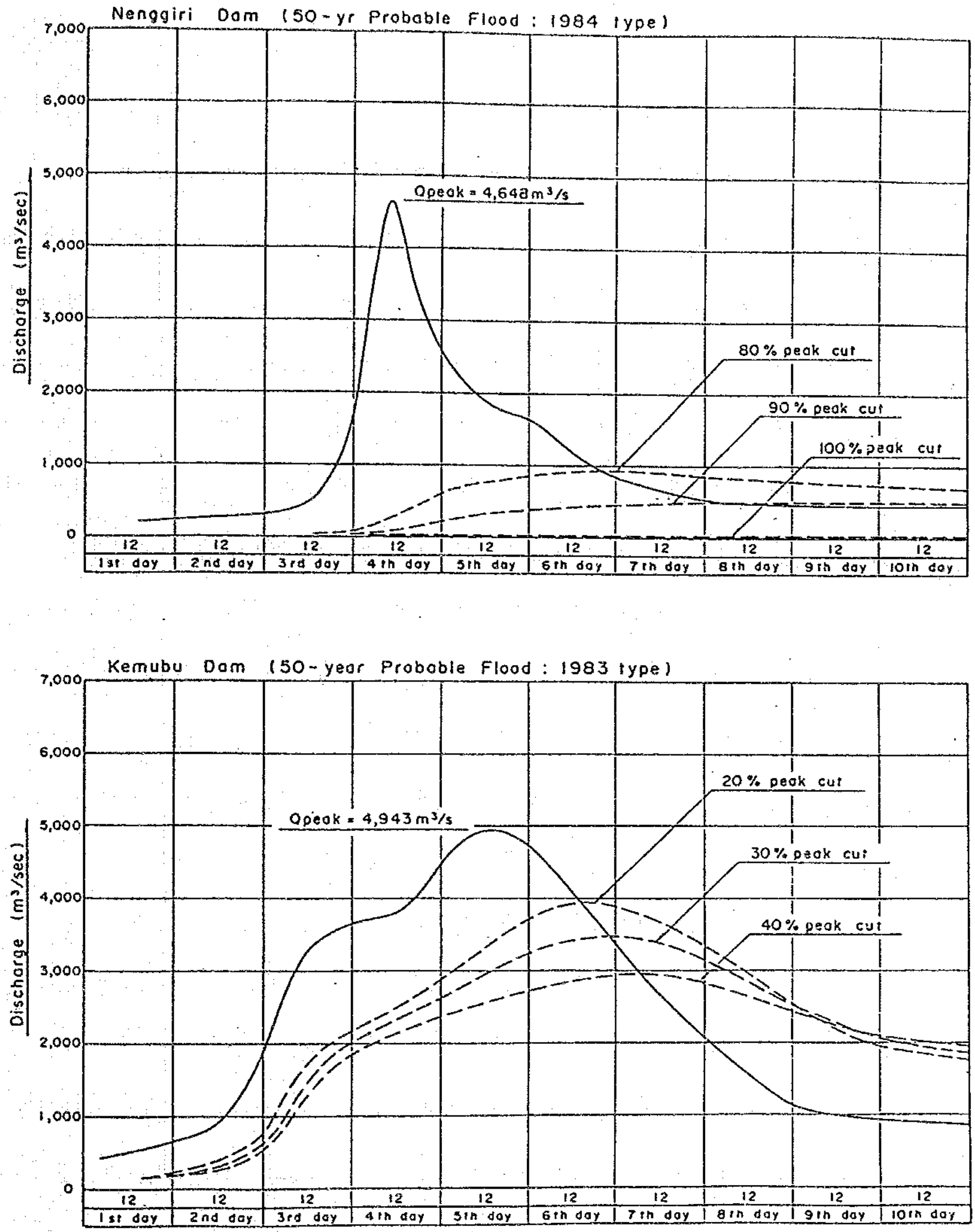

Fig.VIII.4.3

Flood Routing with Nenggiri and Kemubu Reservoirs

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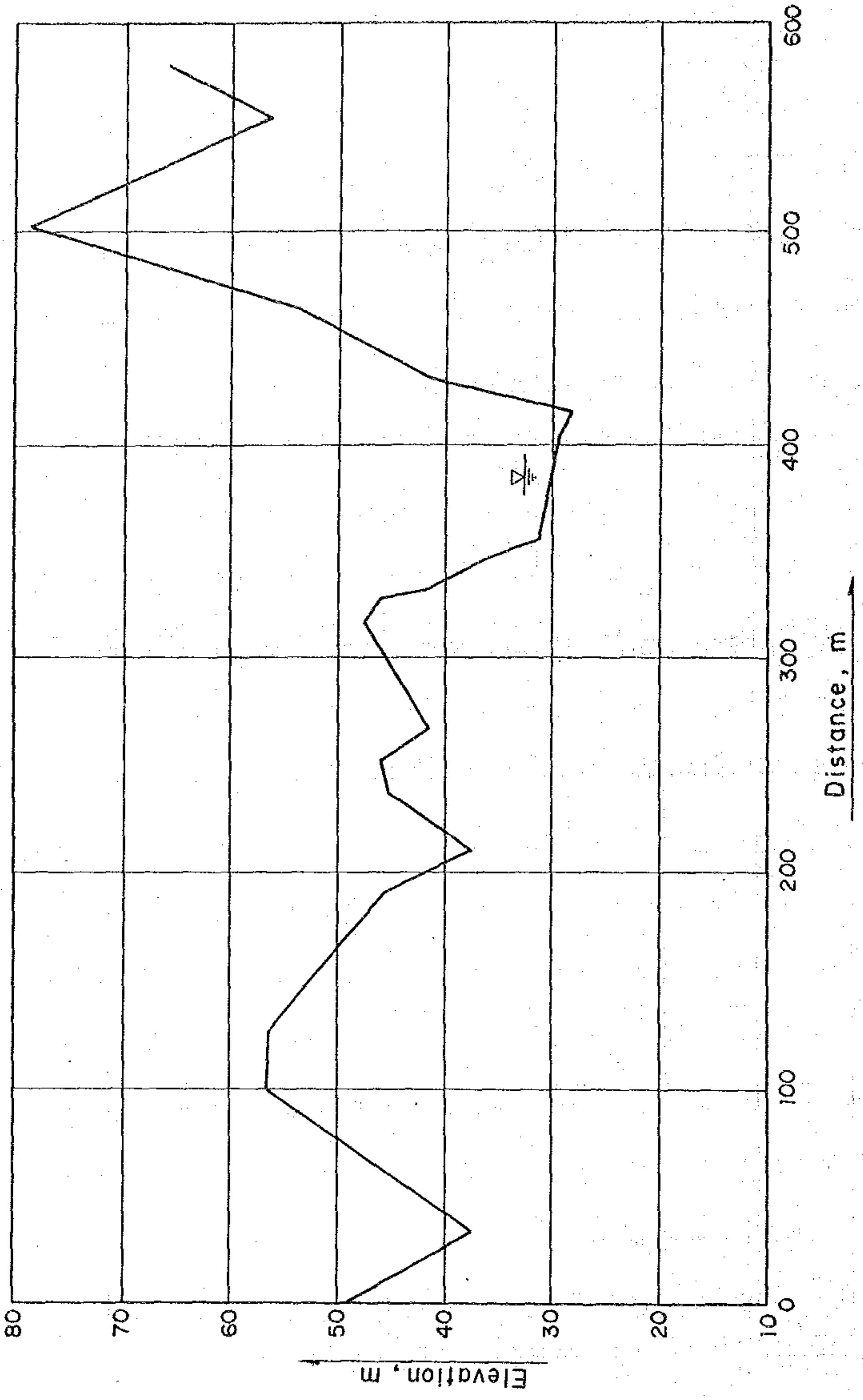

Fig.VIII.4.4

Cross Section at the Lower Pergau Damsite

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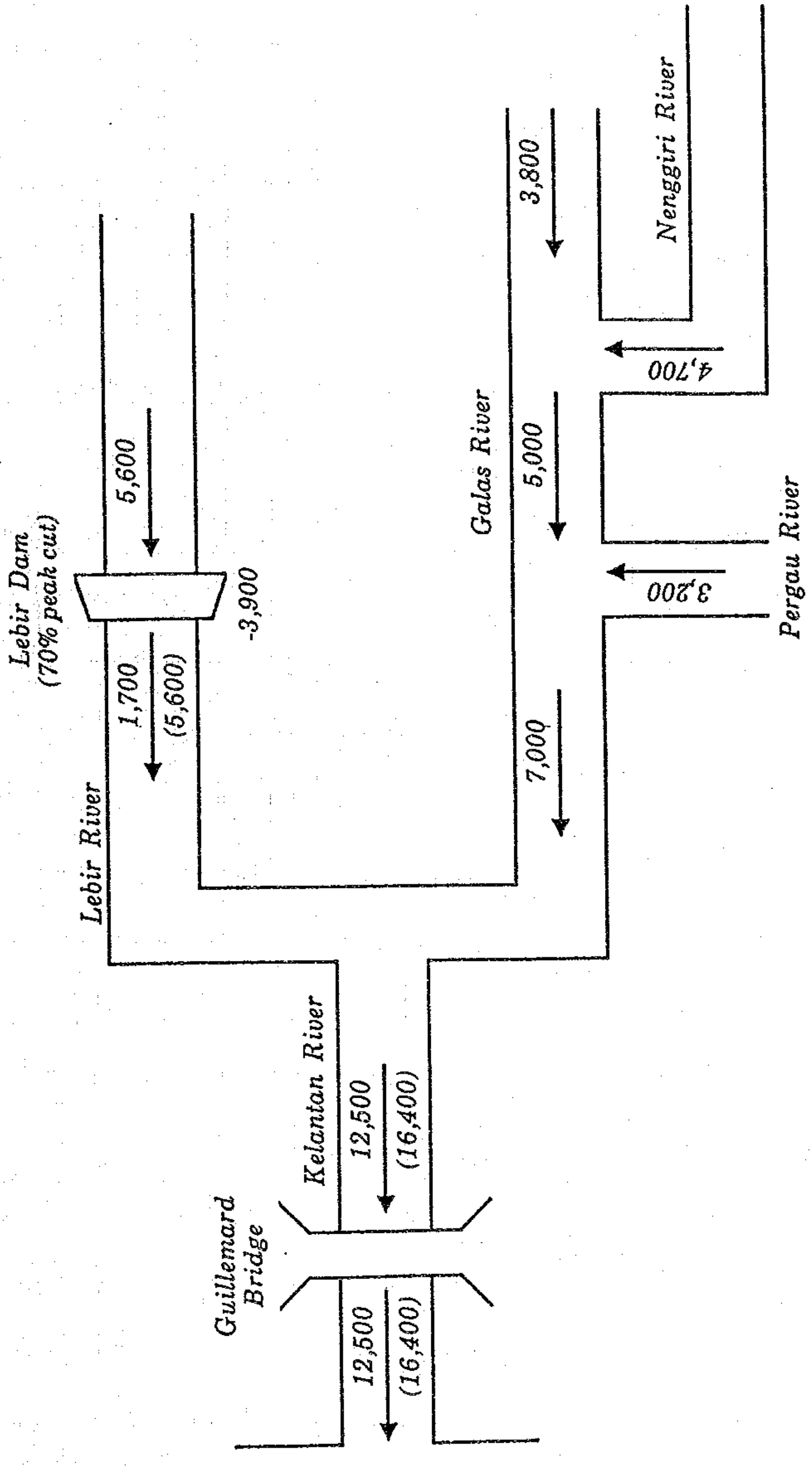

Fig.VIII.4.5

50-year Flood Peak Discharges with Lebir Dam Scheme

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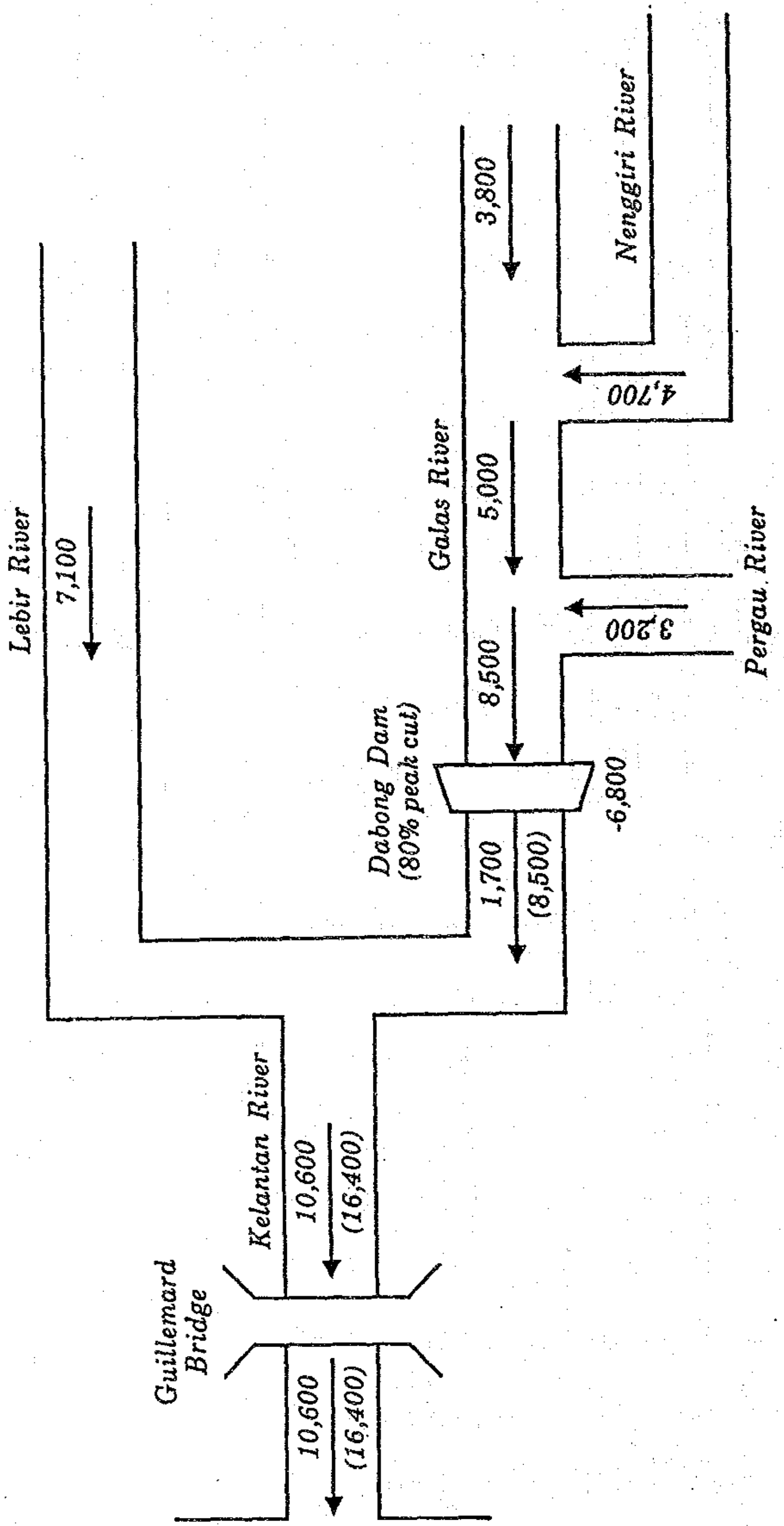

Fig.VIII.4.6

50-year Flood Peak Discharges with Dabong Dam Scheme

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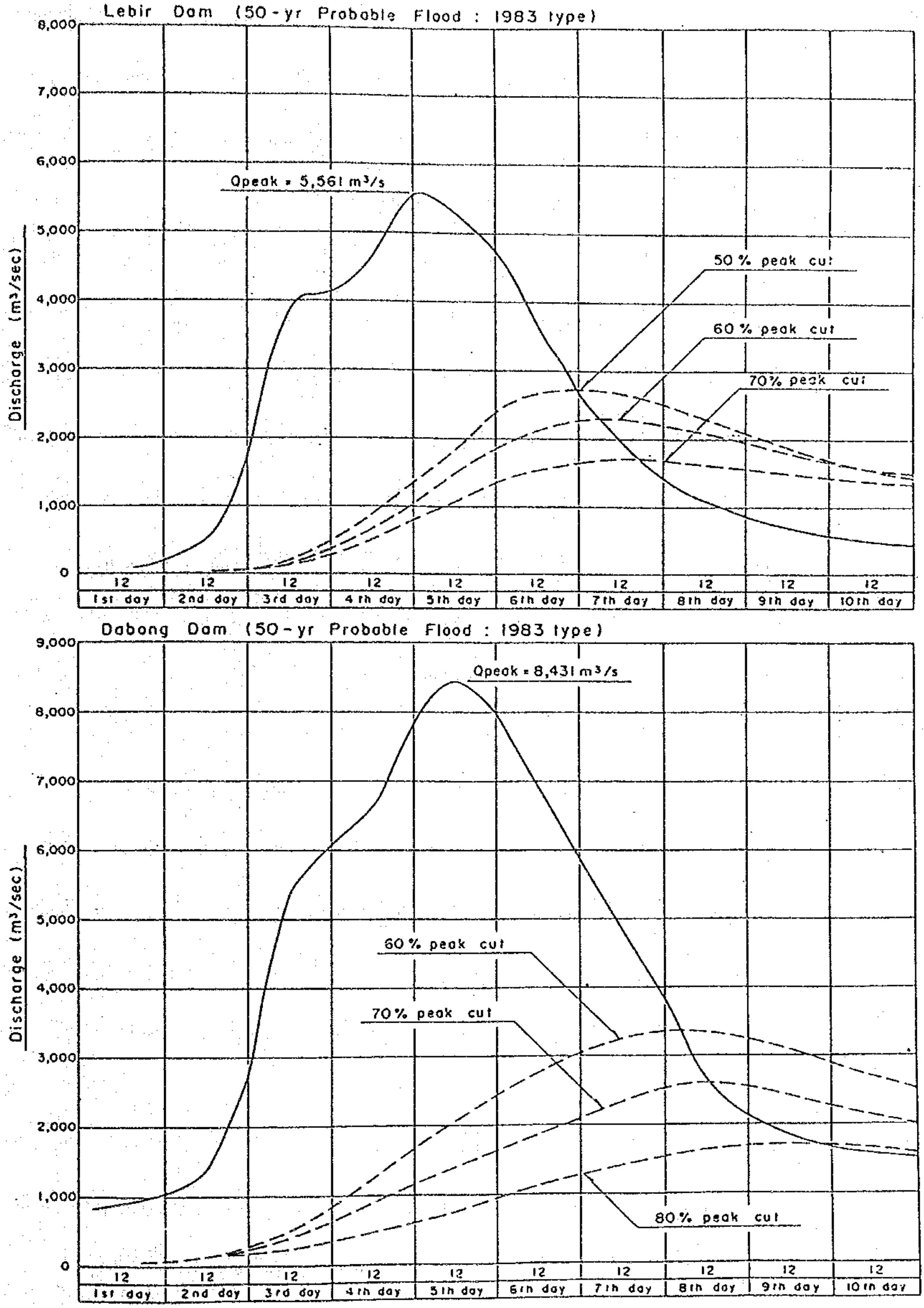

Fig.VIII.4.7

Flood Routing with Dabong and Lebir Reserviors

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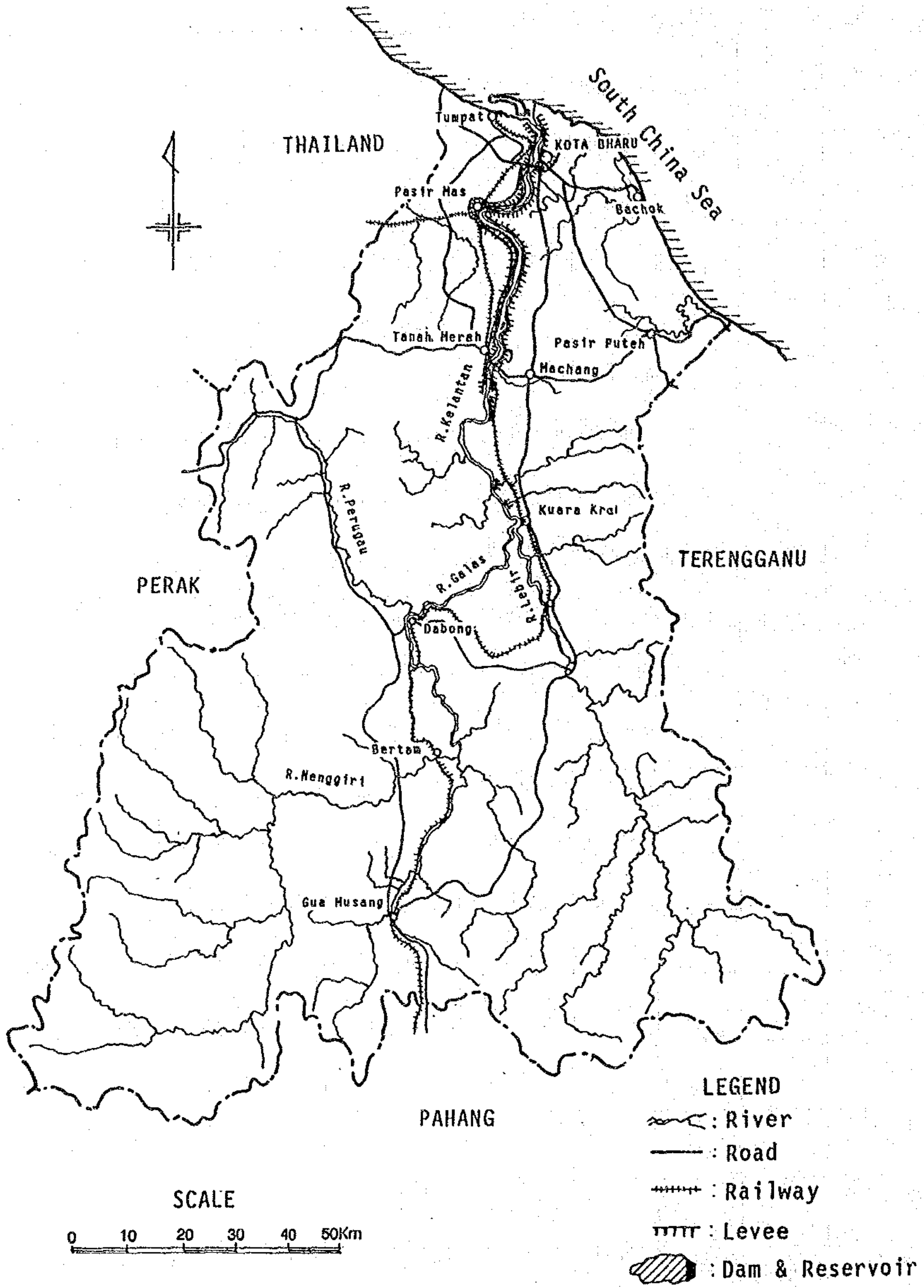

Fig.VIII.4.8

River Improvement Only

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JAPAN INTERNATIONAL COOPERATION AGENCY

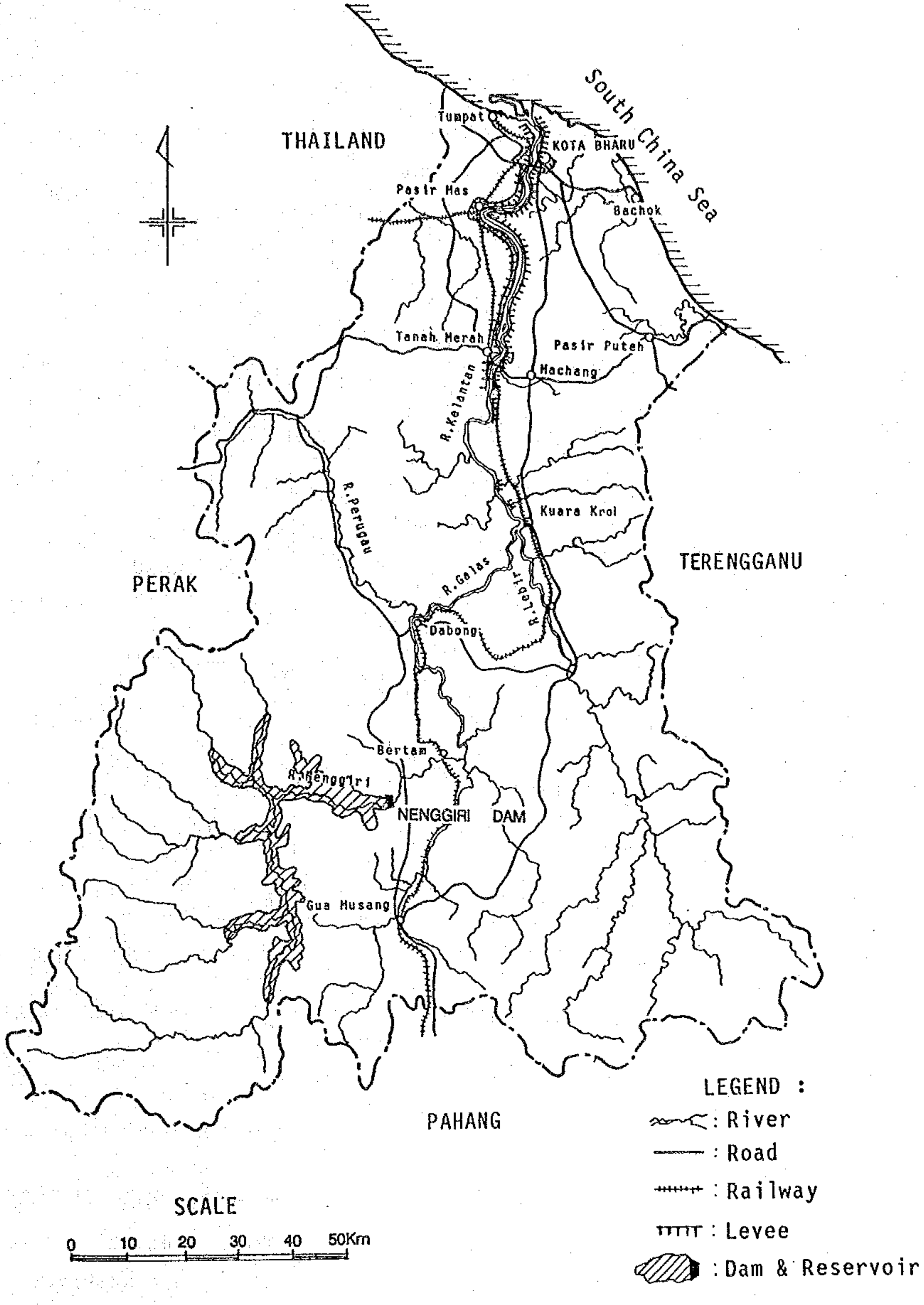

Fig.VIII.4.9

Nenggiri Dam + River Improvement

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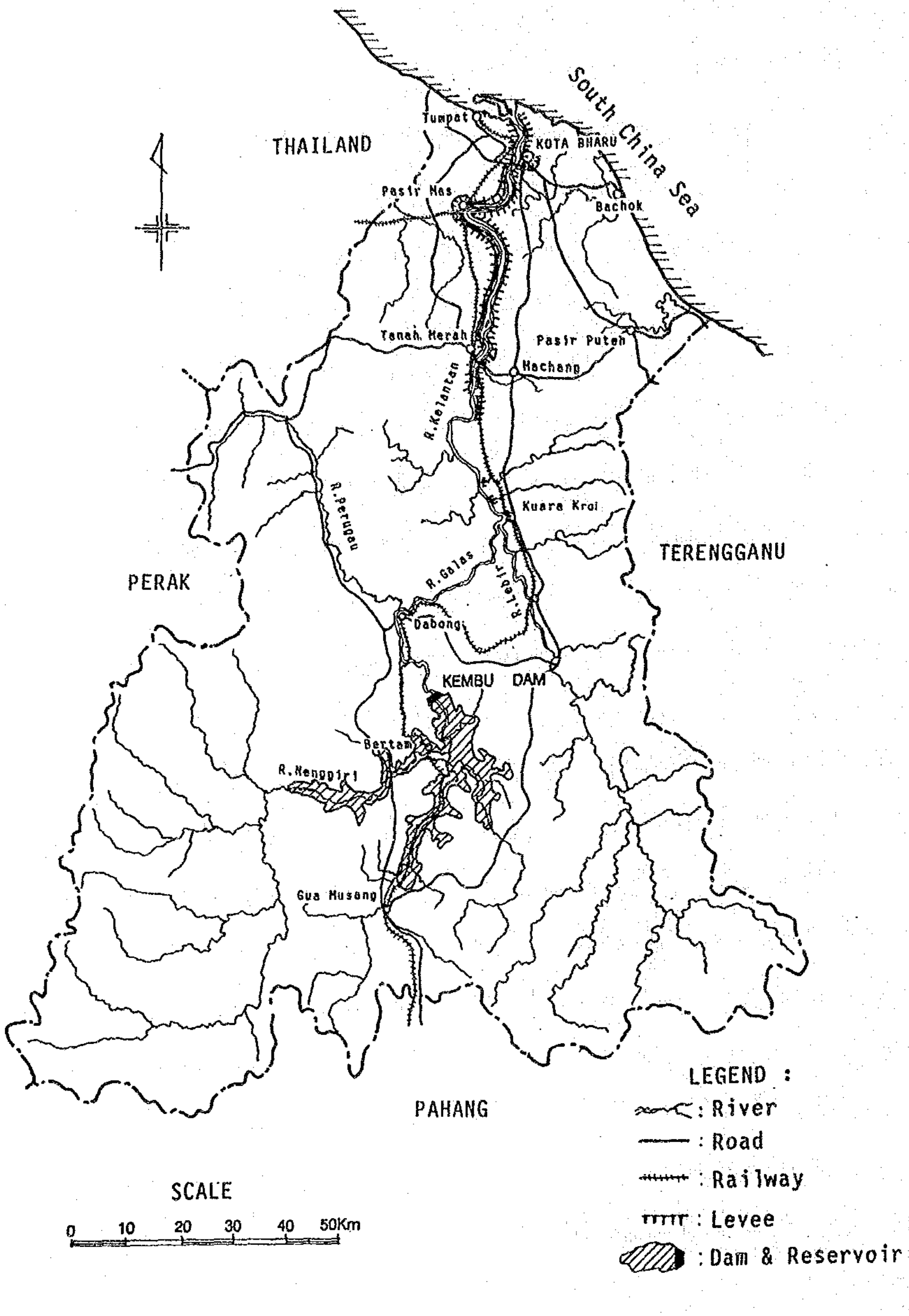

Fig.VIII.4.10

Kemubu Dam + River Improvement

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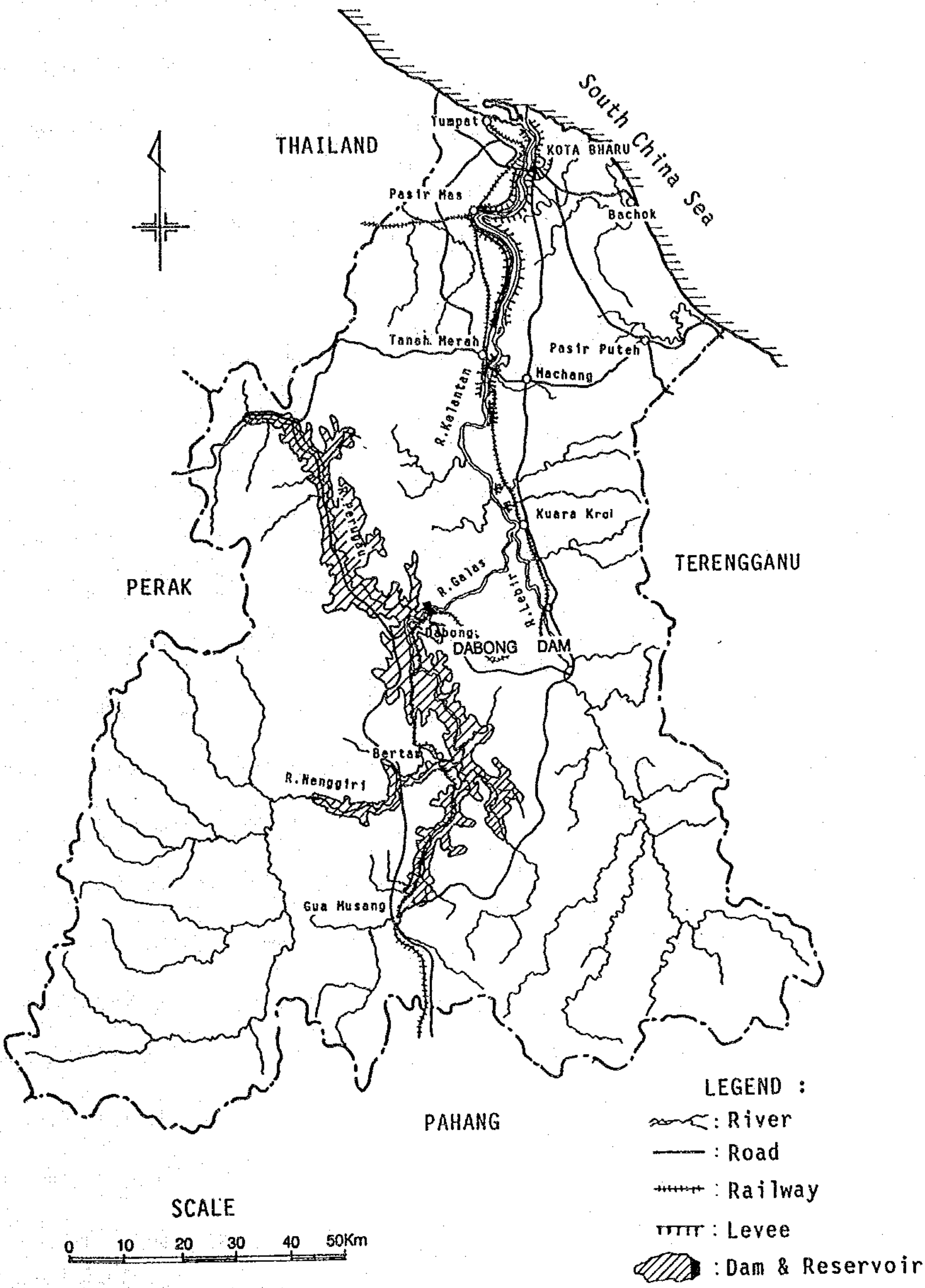

Fig.VIII.4.11

Dabong Dam + River Improvement

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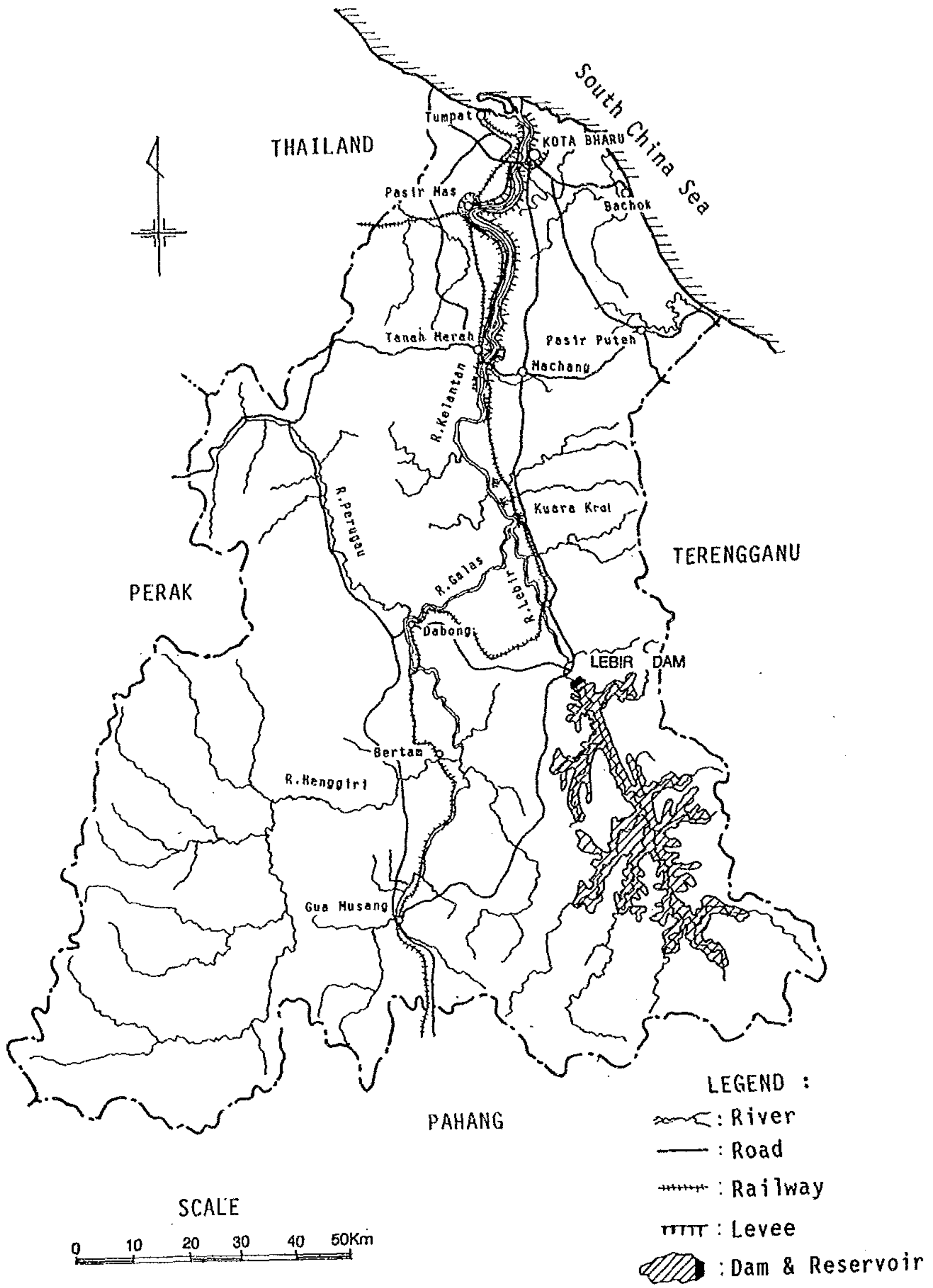

Fig.VIII.4.12

Lebir Dam + River Improvement

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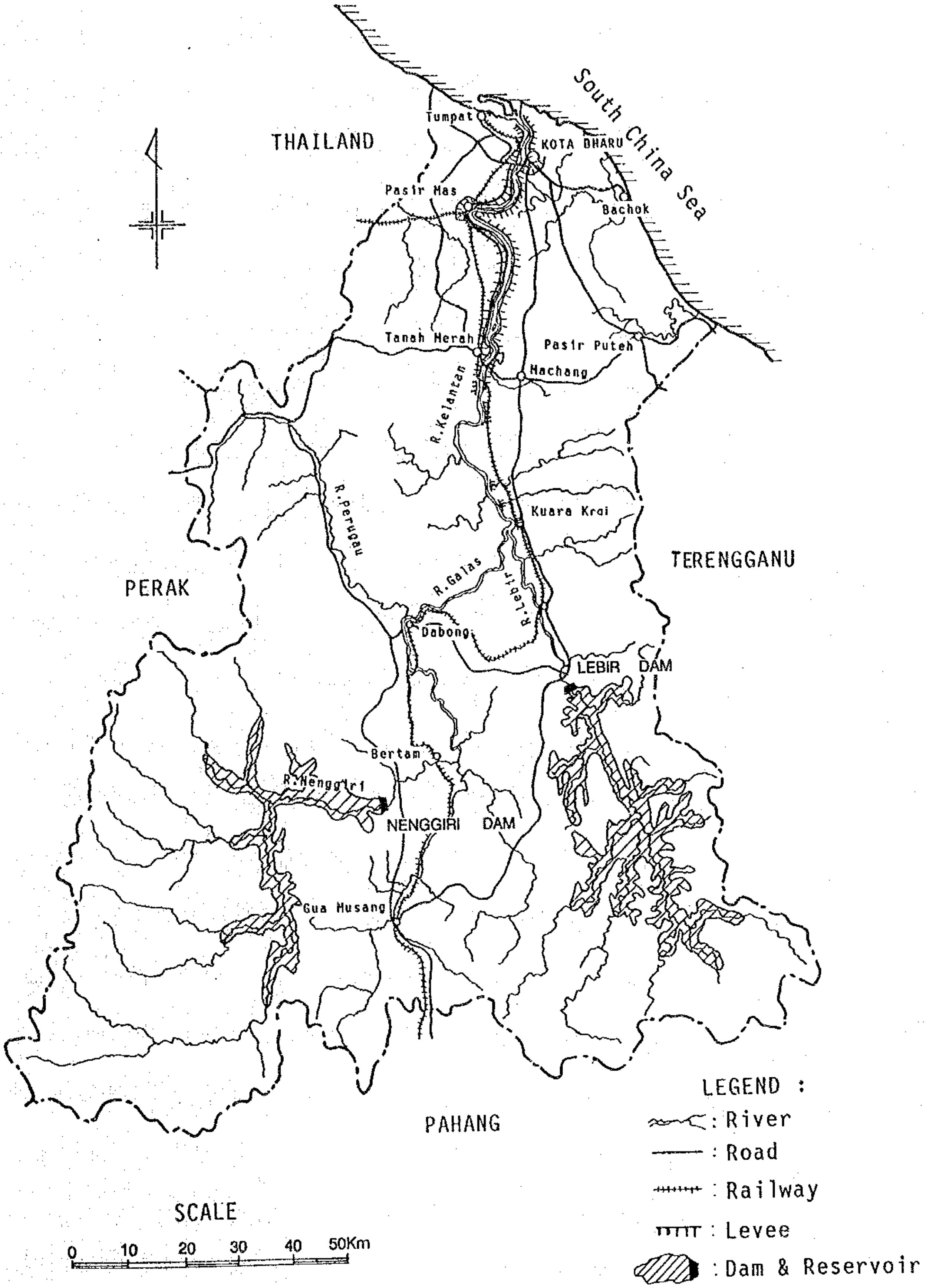

Fig.VIII.4.13

Lebir Dam + Nenggiri Dam + River Improvement

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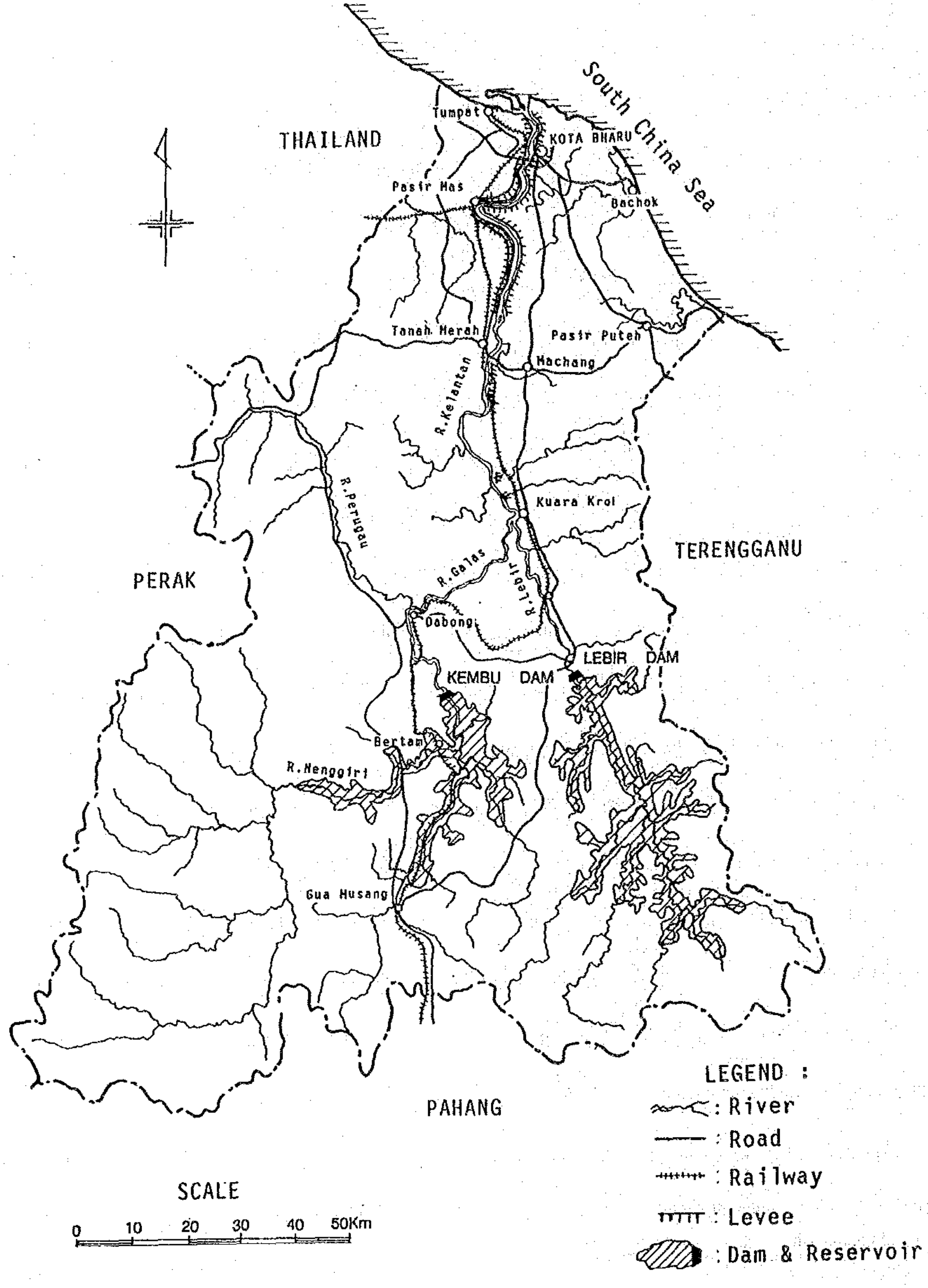

Fig.VIII.4.14

Lebir Dam + Kemubu Dam
+ River Improvement

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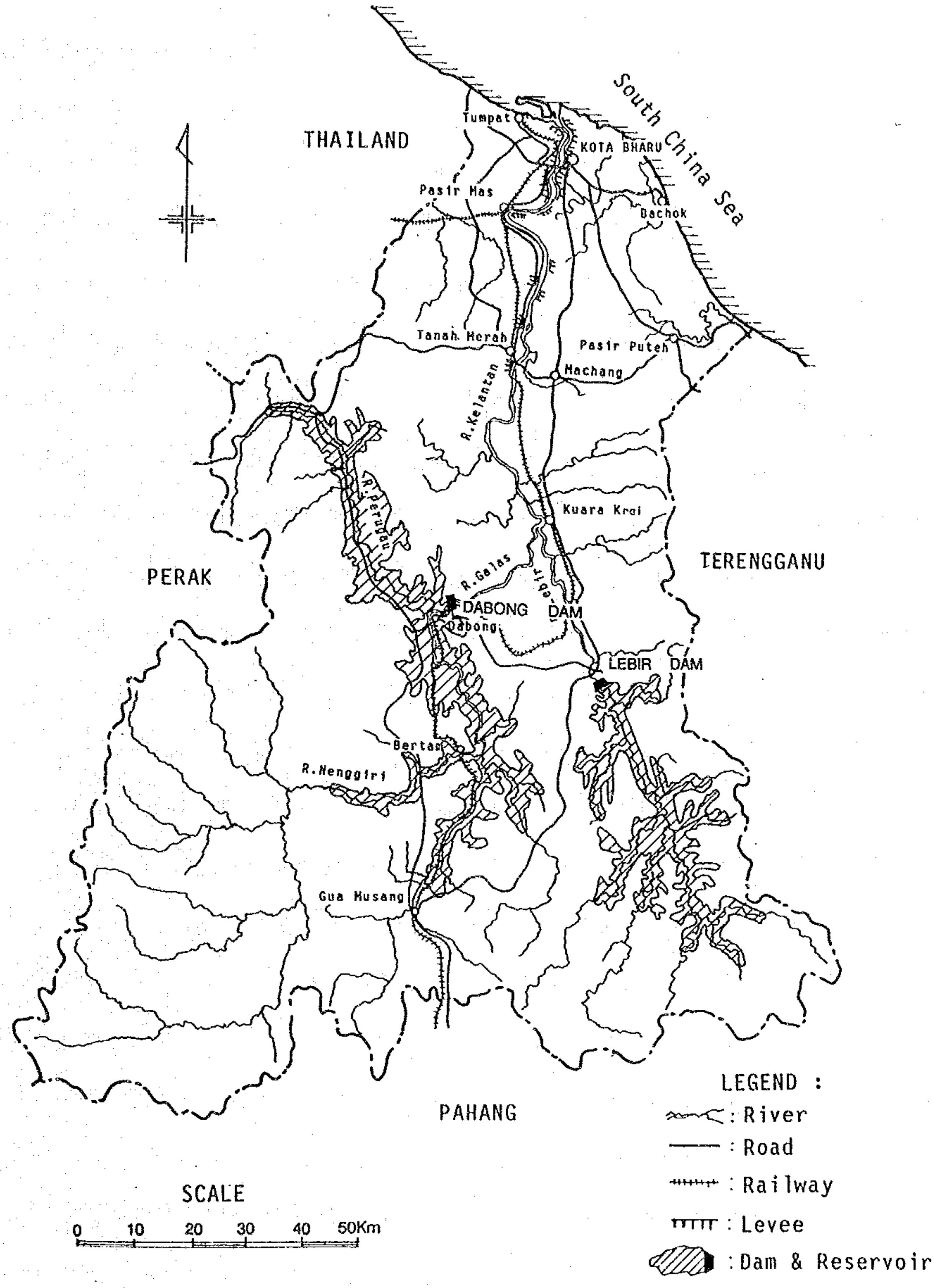

Fig.VIII.4.15

Lebir Dam + Dabong Dam + River Improvement

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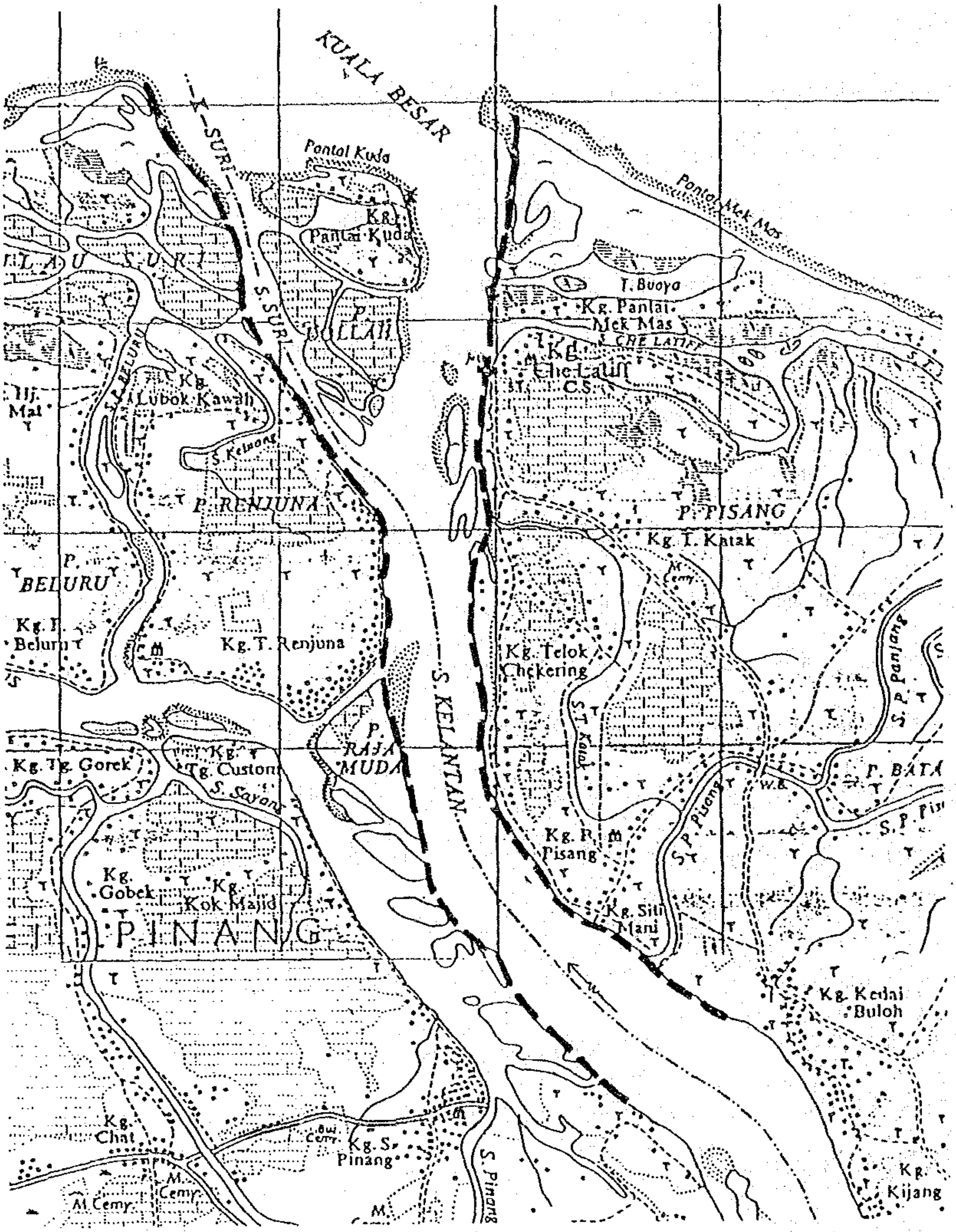

— — — — :BOUNDARY OF PREDOMINANT FLOW AT THE FLOOD TIME

Fig.VIII.4.16

Predominant Flow Condition
For the Flood Time

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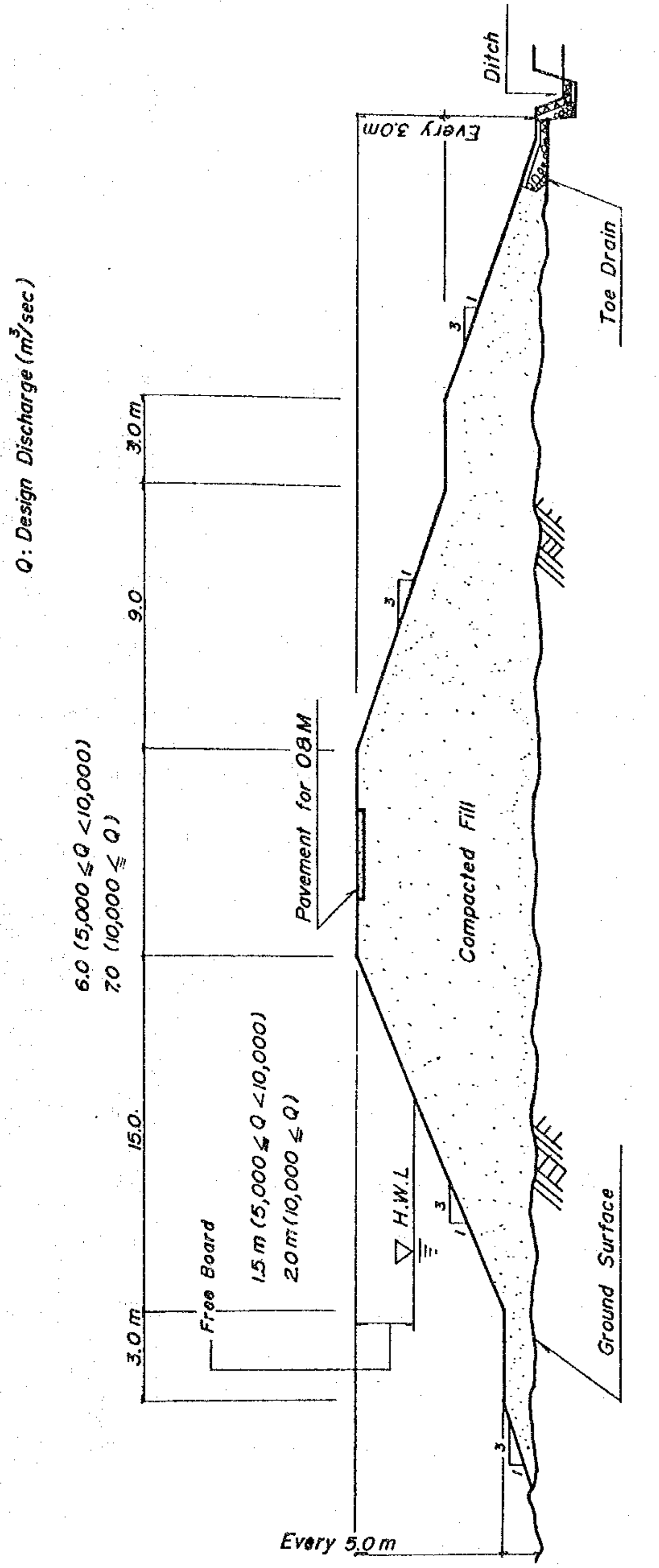

Fig.VIII.4.17

Typical Levee (Earth Embankment)

GOVERNMENT OF MALAYSIA STUDY ON KELANTAN RIVER BASIN - WIDE FLOOD MITIGATION
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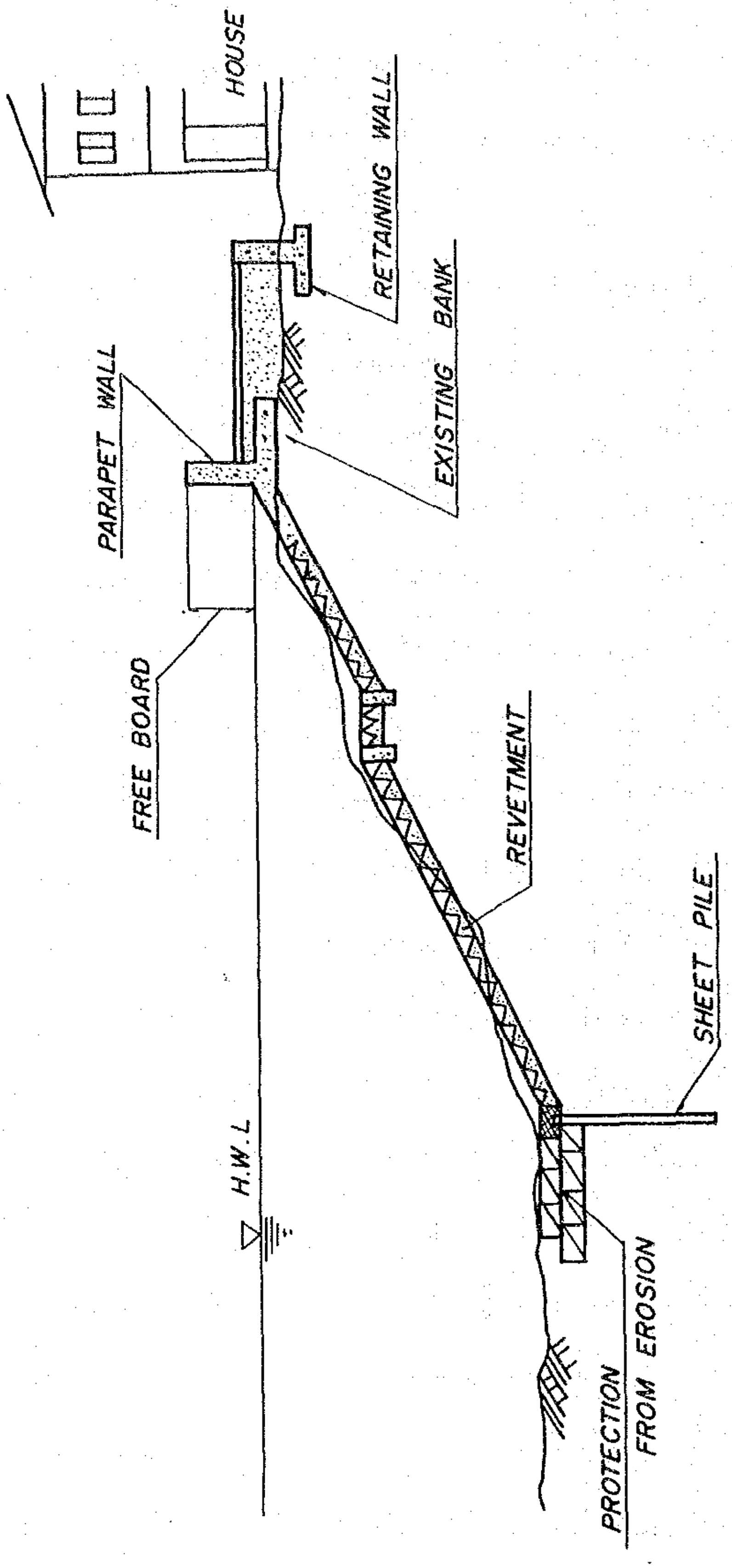

Fig.VIII.4.18

Special Levee

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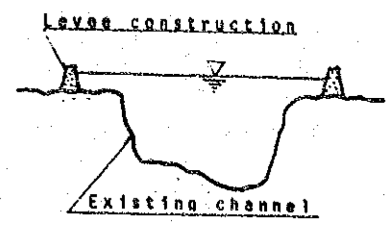
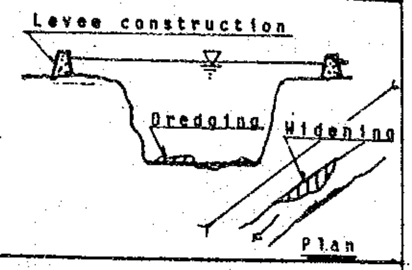
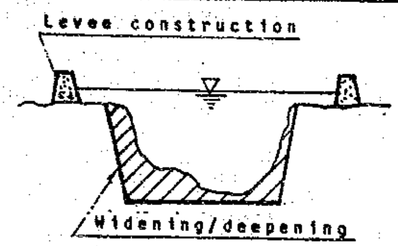
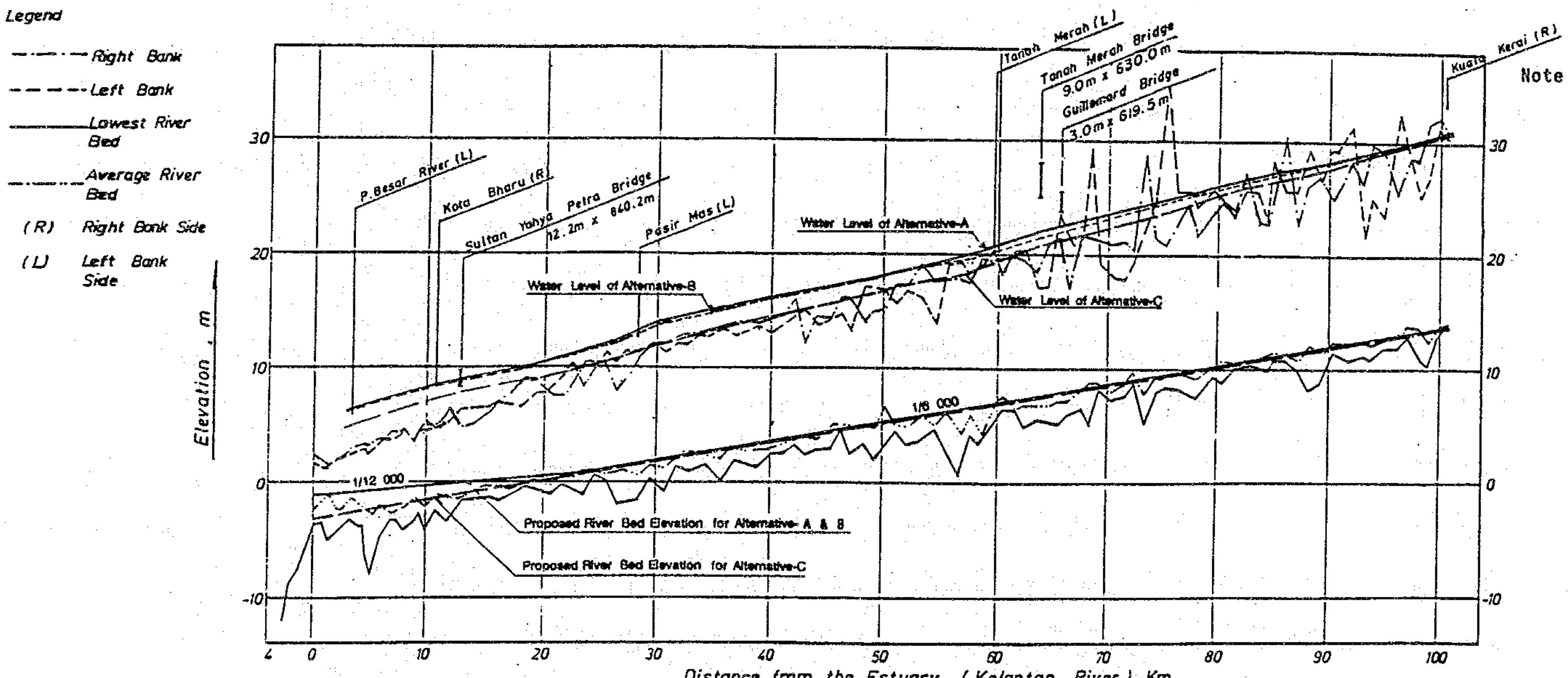
Alternative	Structural Measure	Explanation	Sketch of Measure	Water Level	Earthwork Volume & their Cost	Remarks
A	Levee construction only.	To confine the flood within the certain width.		. Water level in Alt-A is almost same as that of Alt-B, but is several ten centimetres lower at narrow places due to dredging. . Water level in Alt-C is several ten centimetres to 1.5 metres lower than that of Alt-A and B.	(1) Embankment volume for levee = 17 million m^3 (2) Cost = 138 million M$	
B	Levee construction + Widening of the existing channel at the remarkable narrow places + Dredging for arrangement of the channel cross-section.	To confine the flood within the certain width and to lower the flood water level by the excavation of narrow channel portions.			(1) Excavation volume = 2 million m^3 (2) Embankment volume for levee = 14 million m^3 (3) Cost = 118 million M$	(1) Low water level compared with Alternative-A (2) Lowest cost among three Alternatives
C	Levee construction + Widening and deepening of existing channel on a large scale (especially deepening of channel downstream of Kota Bharu).	To lower flood water level remarkably and to confine the flood within the certain width.			(1) Excavation volume = 58 million m^3 (2) Embankment volume for levee = 9 million m^3 (3) Cost = 400 million M$	(1) Lowest water level among three Alternatives (2) Highest cost among three Alternatives (3) Difficulty of maintenance of proposed cross-section of channel at river mouth (4) Problem of moving-upward of salty water



LONGITUDINAL PROFILE

Note : Alternative-C was studied on the following conditions ;

- Proposed riverbed slope of 1/6,000 from rivermouth to Kuala Krai
- Channel widening of 600 m (rivermouth to 24 km), 500 m (24 km to 55 km) and 300 m (55km to 72 km).

Fig.VIII.4.19

River Improvement Plans A to C

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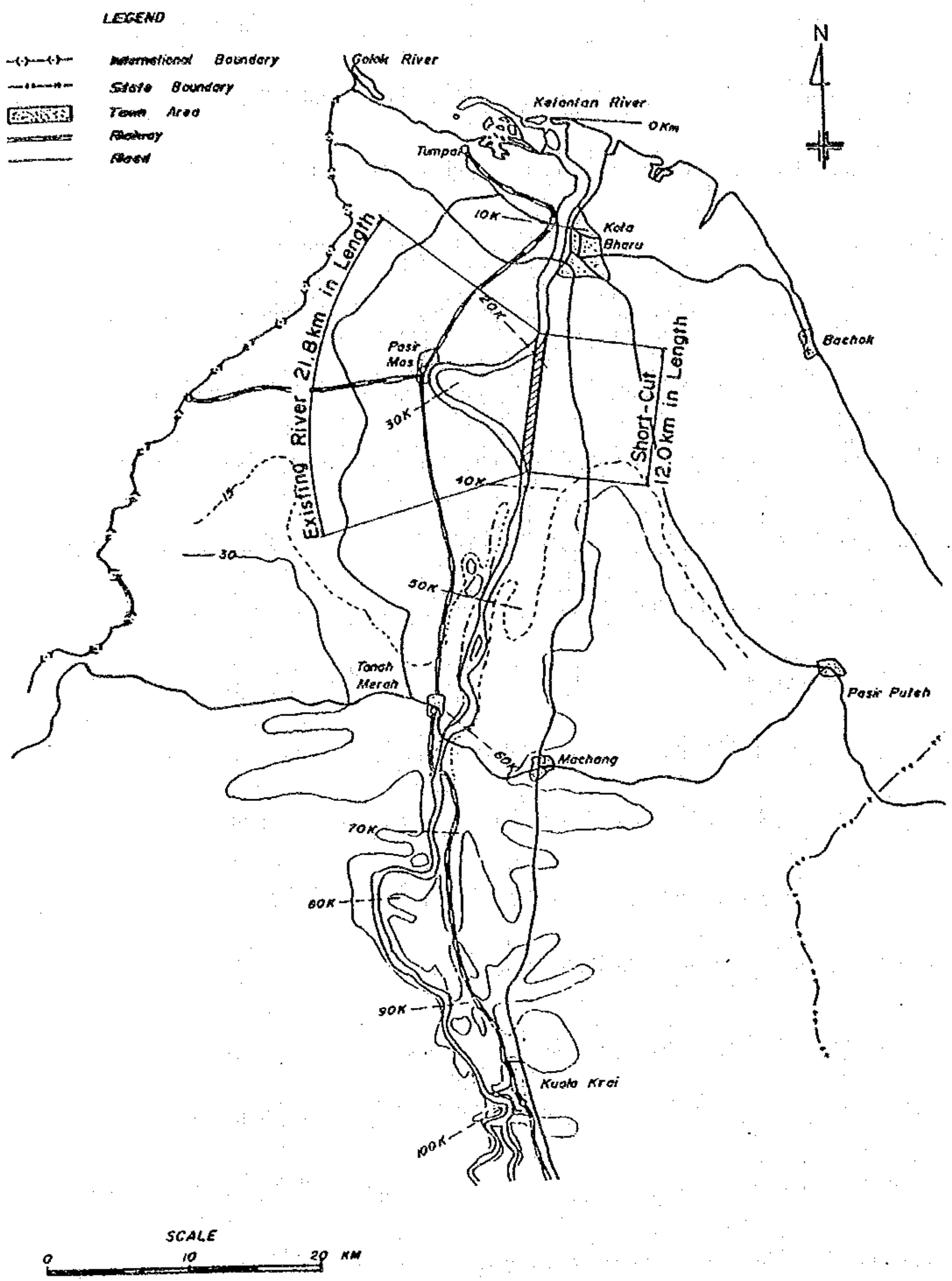
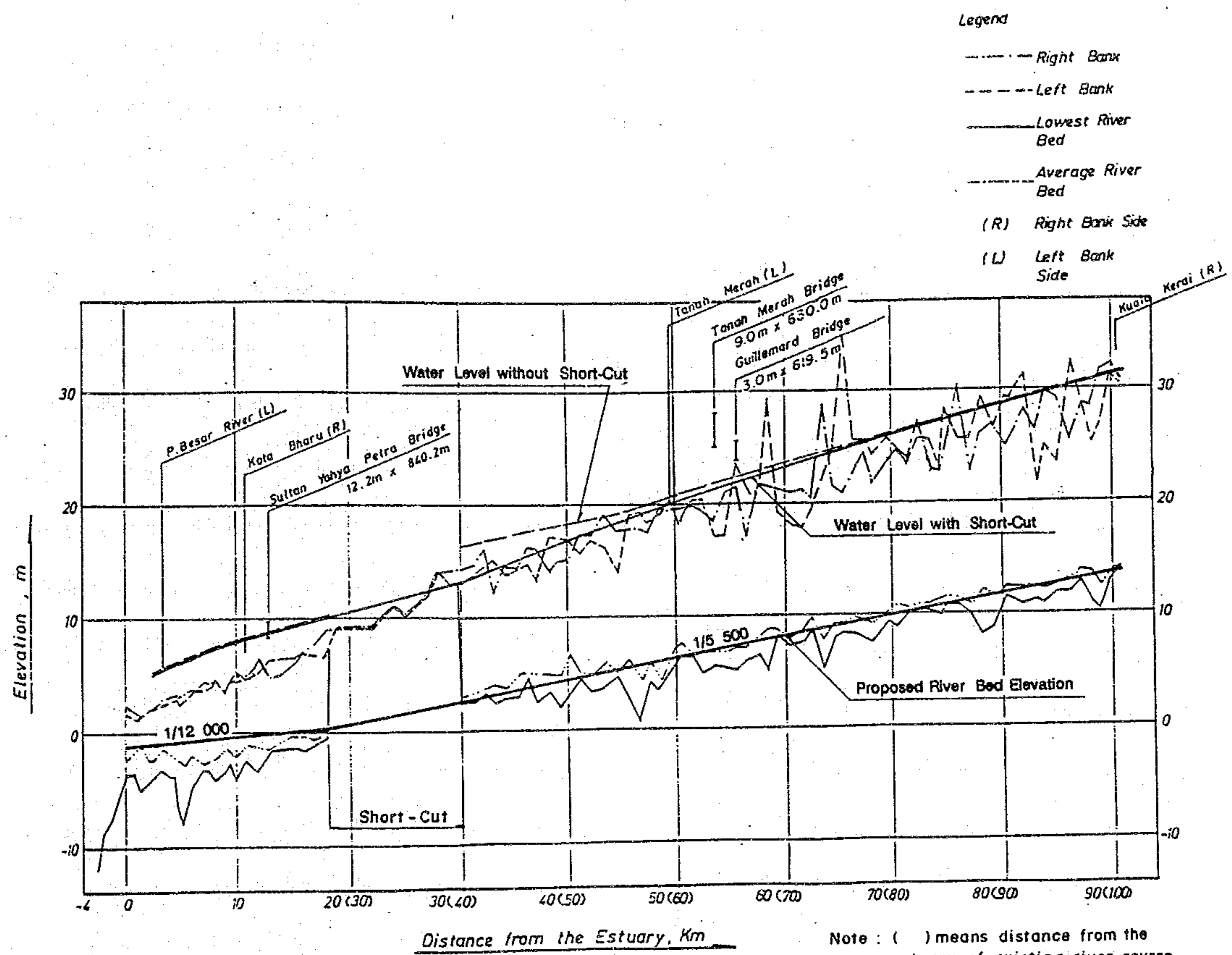


LOCATION OF SHORT-CUT



Note : ( ) means distance from the estuary of existing river course

LONGITUDINAL PROFILE

Fig.VIII.4.20

River Improvement Plan D
(short-cut)

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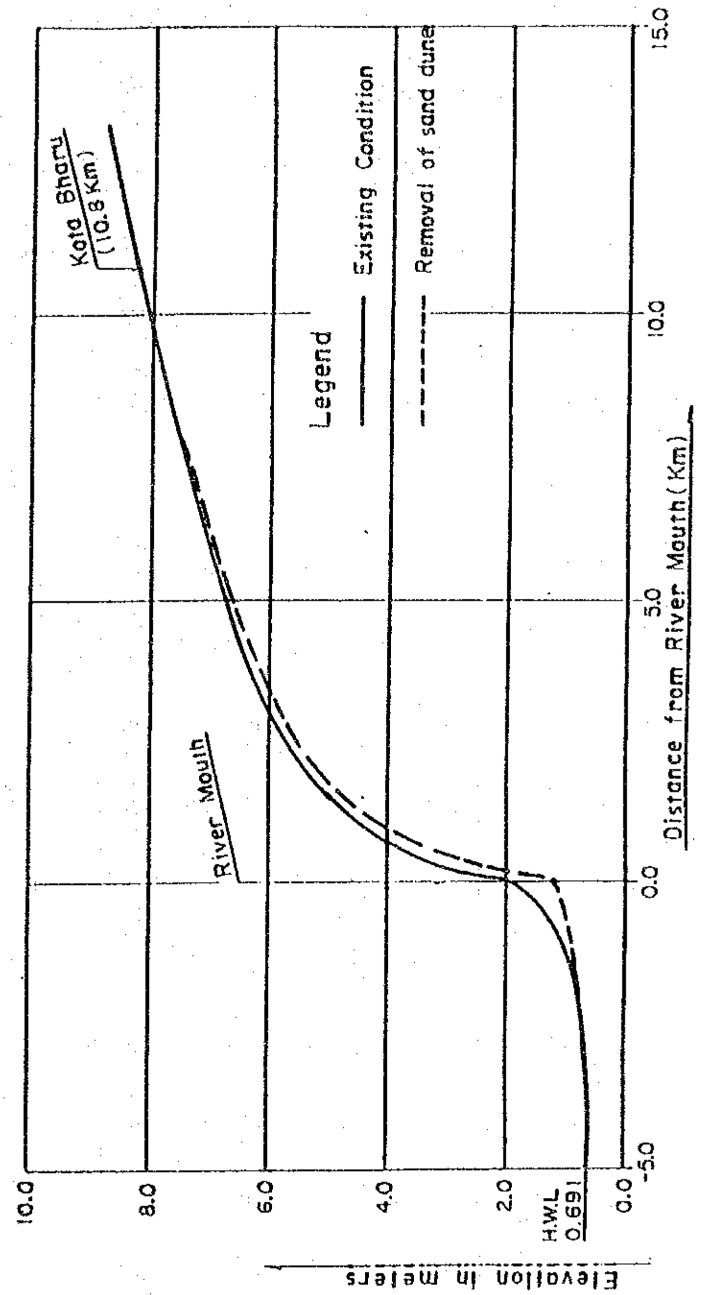
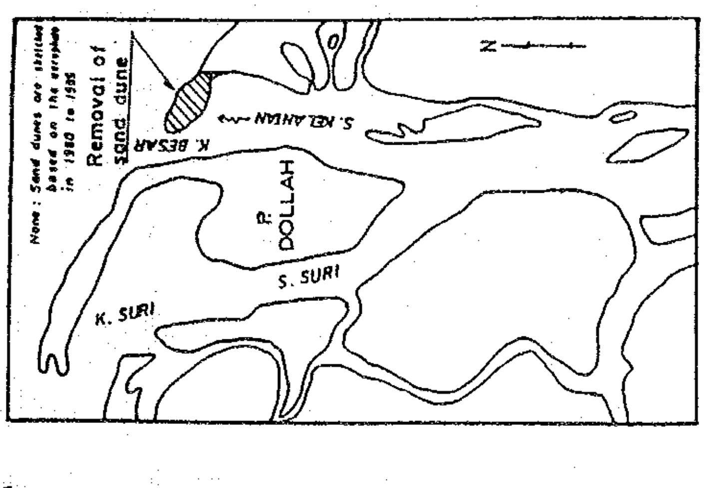


LONGITUDINAL PROFILE



PLAN

Fig.VIII.4.21

Longitudinal Profile of Water Level for the Treatment of River Mouth

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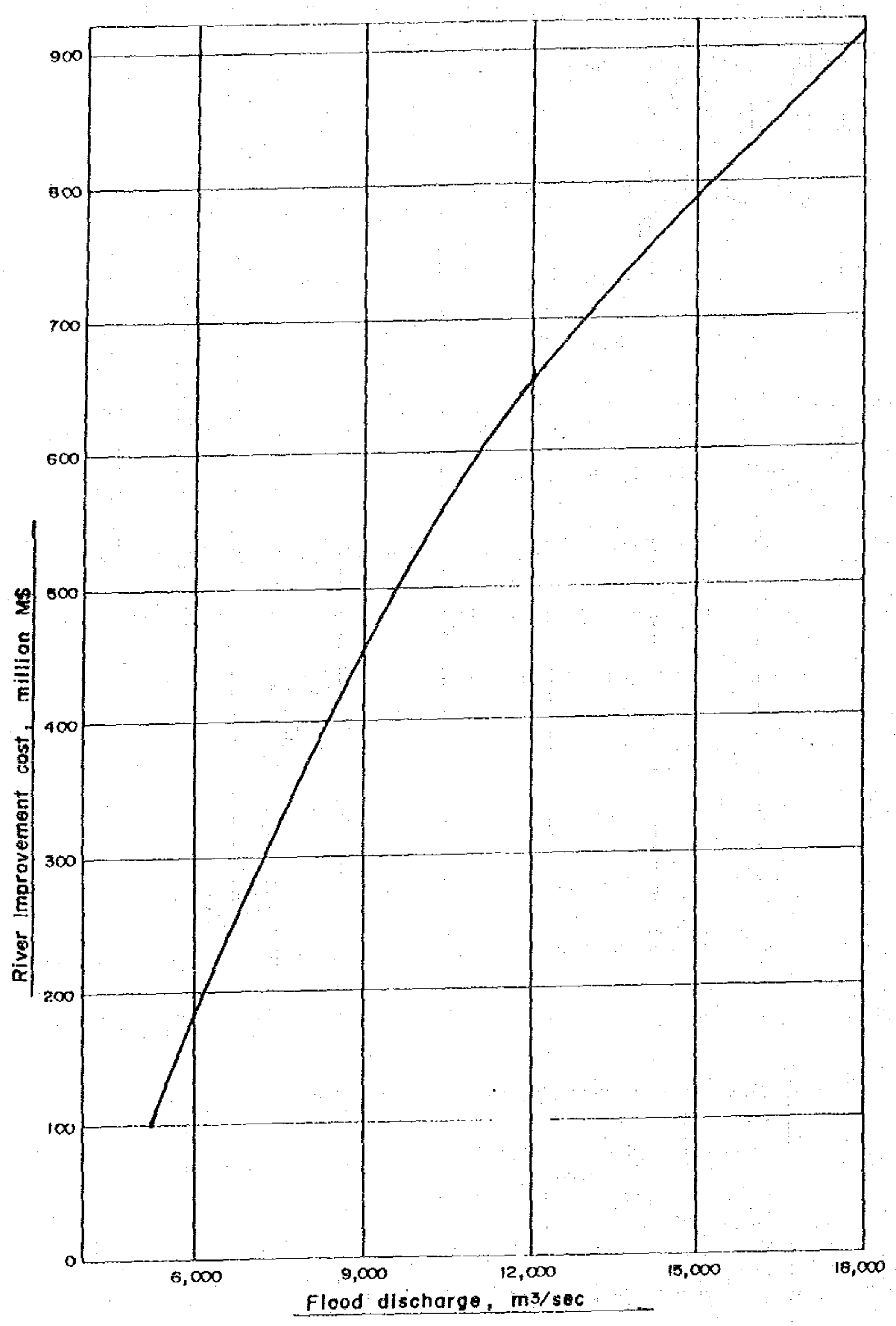

Fig.VIII.4.22

Relationship between Discharge and River Improvement Cost

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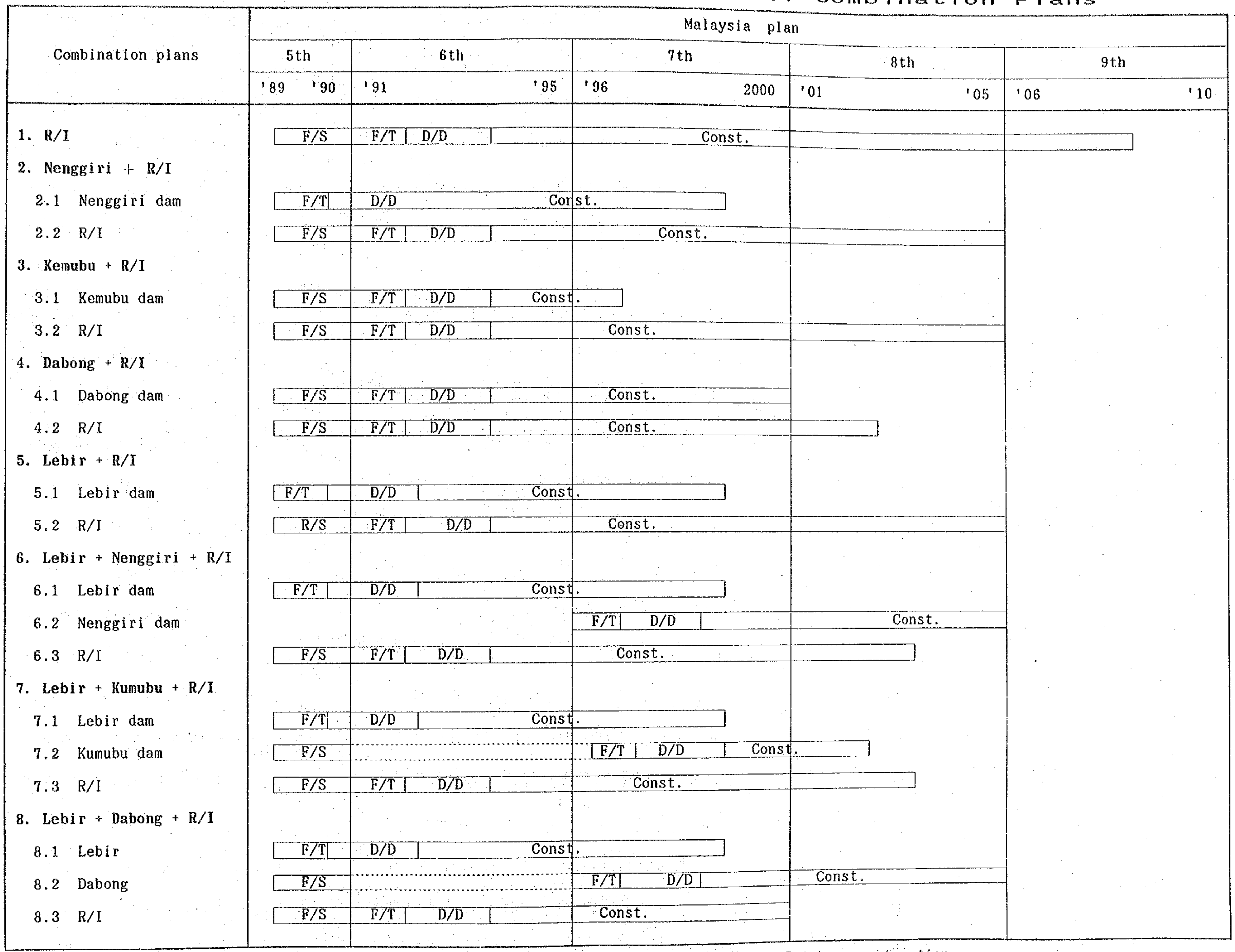
Implementation Programme of Combination Plans



Notes : F/S; feasibility study, F/T; financing and tendering, D/D ; detailed design, Const.; construction

Fig.VIII.4.23

Implementation Programme of Combination Plans

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