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EXECUTIVE SUMMARY

GOVERNMENT OF MALAYSIA

STUDY ON KELANTAN RIVER BASIN-WIDE FLOOD MITIGATION

FINAL REPORT

EXECUTIVE SUMMARY

NOVEMBER, 1989

JAPAN INTERNATIONAL COOPERATION AGENCY

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5. Pre-feasibility Study on Combination Plan
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PREFACE

In response to a request from the Government of Malaysia, the Japanese Government decided to conduct a study on Kelantan River Basin-Wide Flood Mitigation and entrusted the study to Japan International Cooperation Agency (JICA).

JICA sent to Malaysia a survey team headed by Mr. Shigeo Ohnuma of Nippon Koei Co., Ltd, comprised of members from the Nippon Koei Co., Ltd and CTI Engineering Co., Ltd from April to December, 1988 and March to June, 1989.

The team held discussions with concerned officials of the Government of Malaysia, and conducted field surveys. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincerest appreciation to the officials concerned of the Government of Malaysia for their close cooperation extended to the team.

November, 1989

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

STUDY
ON
KELANTAN RIVER BASIN-WIDE FLOOD MITIGATION

November, 1989

Mr. Kensuke Yanagiya
President
Japan International
Cooperation Agency

Dear Sir,

LETTER OF TRANSMITTAL

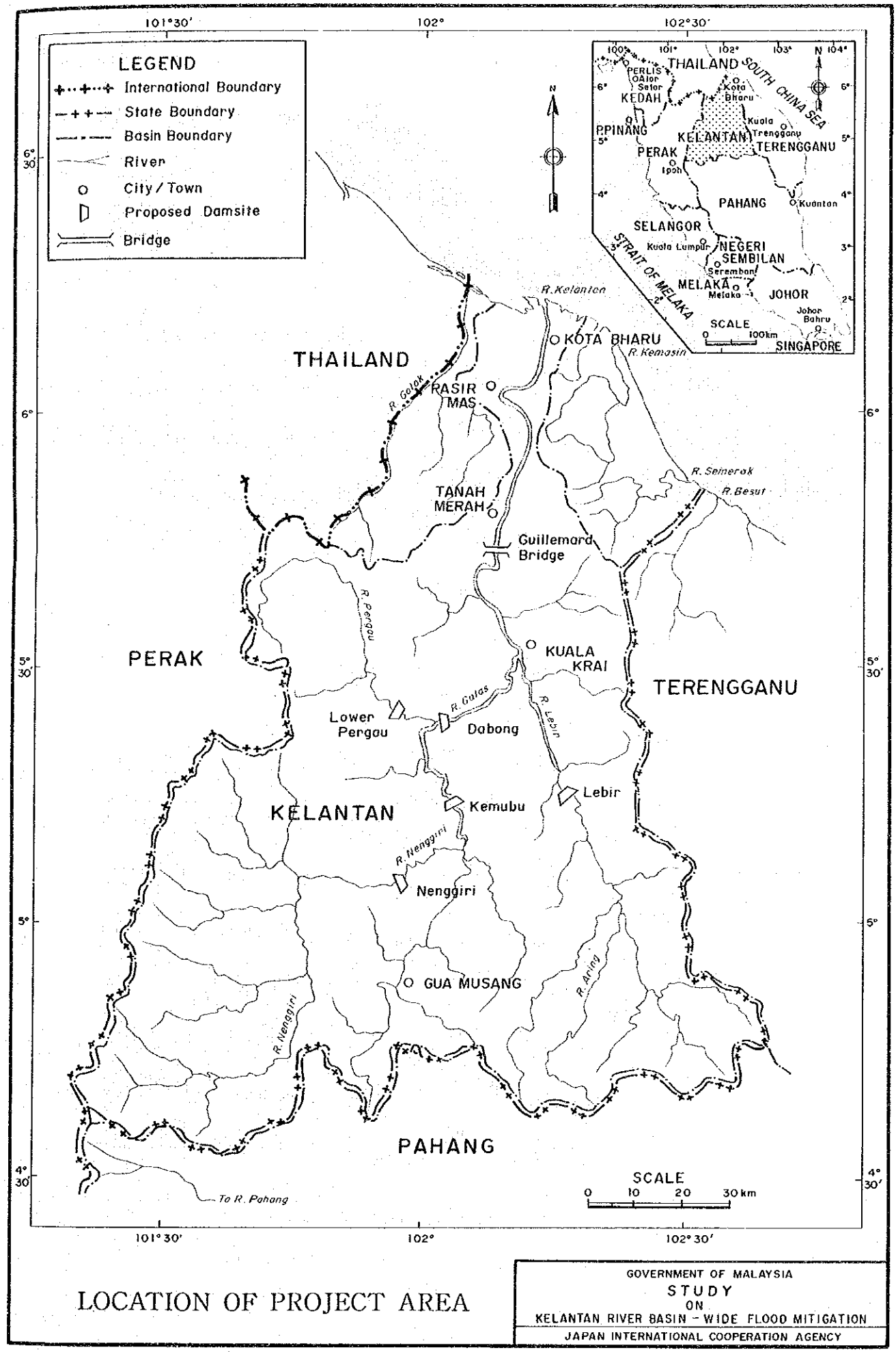
We have pleasure to submit herewith the Final Report for the Study on Kelantan River Basin-wide Flood Mitigation. The Study deals with the formulation of the flood mitigation master plan for the downstream reaches of the Kelantan River basin suffering from habitual flooding.

The Final Report consists of five parts. The Part I deals with the formulation of basin-wide flood mitigation plan on the Kelantan River. The Part II discusses the pre-feasibility studies for the Lebir and Kemubu dam schemes and the river improvement for the river stretches between Kuala Krai and the estuary selected in Part I. Parts III and IV discuss the 1988 Flood and geological investigation at Kemubu and Dabong damsites, respectively. Part V compiles the data of cross-sectional survey carried out between Kuala Krai and the estuary. This Executive Summary briefs the major outcomes in this study.

We would like to express our grateful acknowledgement to the personnel of your Agency, Advisory Committee, Ministry of Foreign Affairs, Ministry of Construction, and Embassy of Japan in Malaysia, and also to officials and individuals of the Government of Malaysia for their assistance and advice extended to the Study Team. We sincerely hope that the results of study would contribute to the flood mitigation and socio-economic development in the Kelantan River basin.

Yours sincerely,

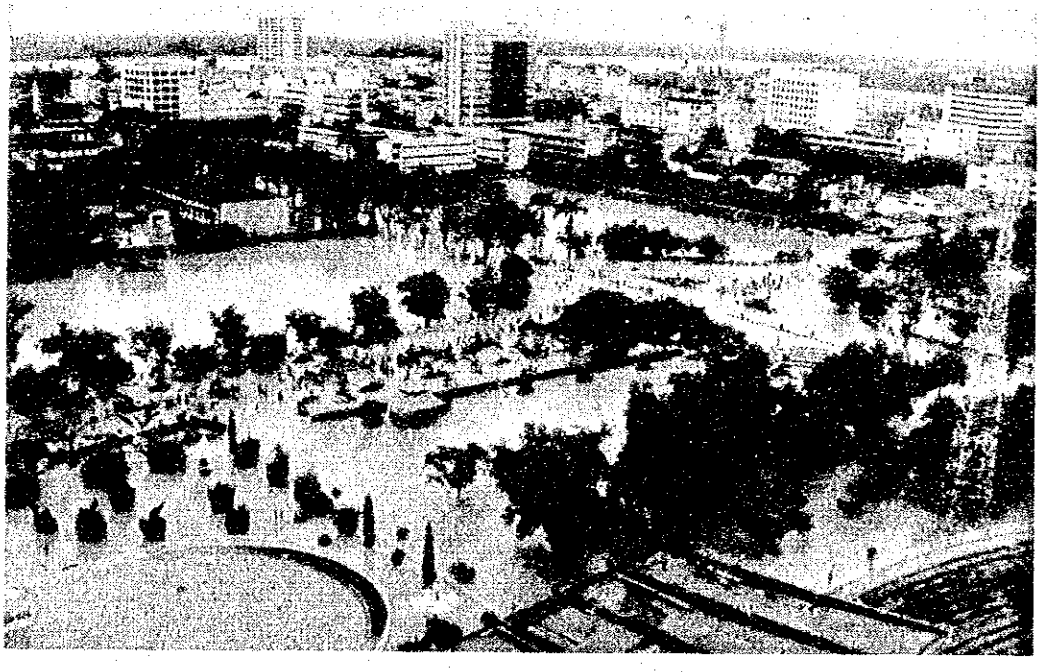
Shigeo Ohnuma
Team Leader



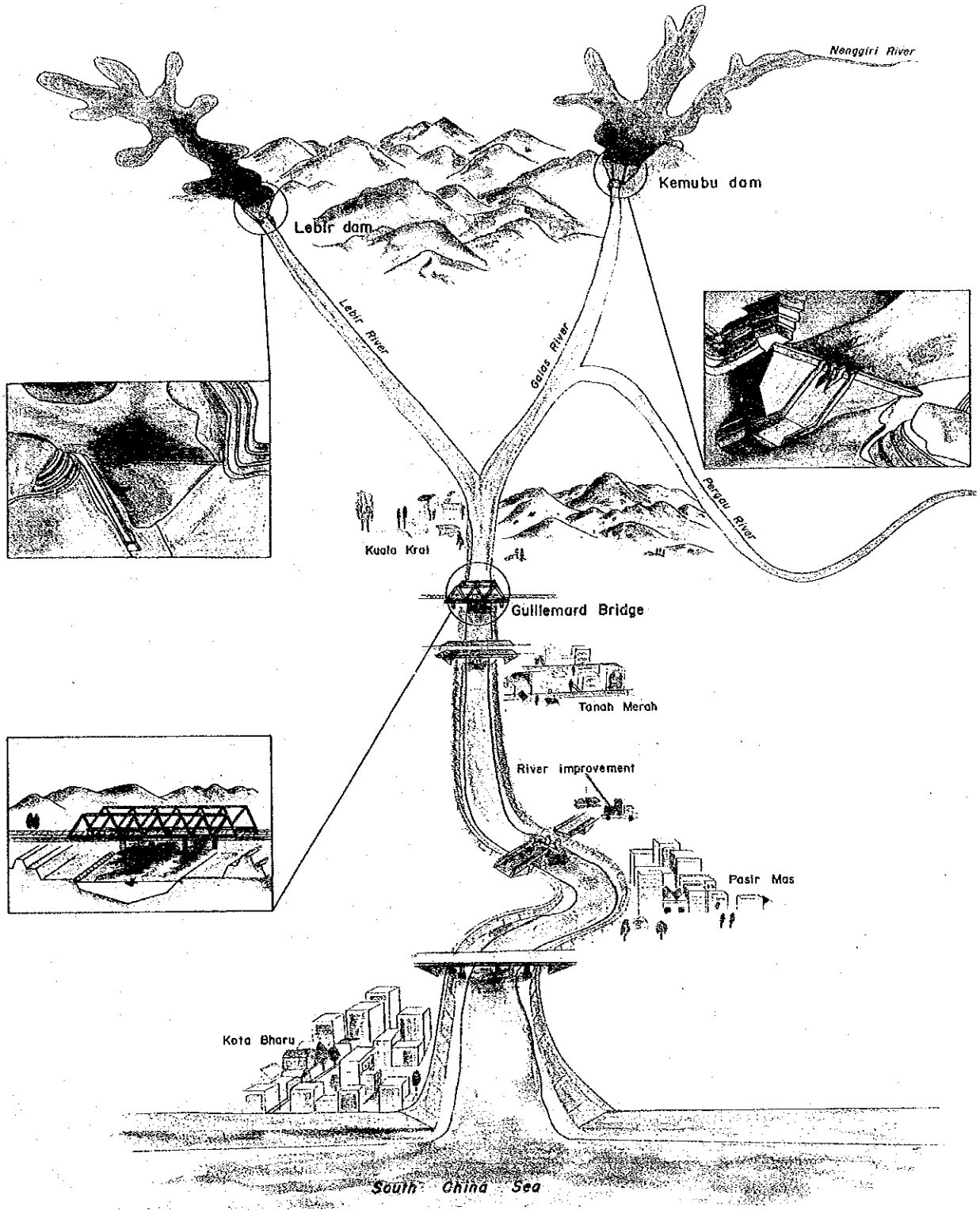
LOCATION OF PROJECT AREA

GOVERNMENT OF MALAYSIA
STUDY
ON
KELANTAN RIVER BASIN - WIDE FLOOD MITIGATION
JAPAN INTERNATIONAL COOPERATION AGENCY

Guillemard Bridge (November 26, 1988)



Kota Bharu Town (November 26, 1988)



Master Plan of the Kelantan River Flood Mitigation

EXECUTIVE SUMMARY

Background and objective of the study

1. The Kelantan River lying in the north-eastern part of Peninsular Malaysia brings enormous benefits to the people as a water source of water supply, irrigation, power generation and so on by its ample flow, but the people lived in the downstream reaches on the other hand suffer from habitual flooding with the frequency of almost once in two years. In recent years, 1967, 1983 and 1988 floods caused crucial damage to the vast plain extended in the downstream reaches of the Kelantan River.

2. Annually repeating floods of the Kelantan River bring not only extensive economic losses and human sufferings, but also the threat of floods contributes to such negative psychological attitudes that farmers tend to be reluctant to adopt modern agricultural technology, and industrialists would refrain from investing in flood-prone areas.

3. In this circumstance, the Government of Malaysia requested to the Government of Japan technical assistance to formulate a basin-wide flood mitigation plan of the Kelantan River. The study to formulate a basin-wide flood mitigation plan was commenced in April, 1988 under the cooperative work of Drainage and Irrigation Department (DID) and Japan International Cooperation Agency (JICA), the official agency responsible for the implementation of technical cooperation programmes of the Government of Japan.

4. The objectives of the study consist of the following:

(i) To formulate a basin-wide flood mitigation plan for the Kelantan River basin in the State of Kelantan, and

(ii) To perform pre-feasibility study for the major structures selected in the basin-wide flood mitigation plan.

In formulating the basin-wide flood mitigation plan for the Kelantan River basin, the study is approached by two ways; that is, one is to search the flood mitigation plan of the Kelantan River basin by giving the even weight between the flood mitigation plan and water resources development. The other way is to look for the flood mitigation plan placing high priority on itself. The selection of former or latter plan as the basin-wide flood mitigation plan for the Kelantan River basin is based on the comprehensive judgment taking into account the social impact, flood mitigation efficiency and budgetary constraint as well as project viability.

5. The Final Report consists of five parts. The Part I deals with the formulation of basin-wide flood mitigation plan on the Kelantan River. The Part II discusses the pre-feasibility studies for the Lebir and Kemubu dam schemes and the river improvement for the river stretches between Kuala Krai and the estuary selected in Part I. Parts III and IV discuss the 1988 Flood and geological investigation at Kemubu and Dabong damsites, respectively. Part V compiles the data of cross-sectional survey carried out between Kuala Krai and the estuary. This Executive Summary briefs the major outcomes in this study.

Project area

(1) The Kelantan River basin

6. The Kelantan River basin with a catchment area of 13,100 km^2 locates in the northeastern part of Peninsular Malaysia, occupying more than 85% of the Kelantan State (refer to Location Map). The basin is bounded by the State of Perak and Thailand on the west, by the State of Pahang on the south and by the State of Terengganu on the east. The northern part of the basin faces the South China Sea.

(2) Meteorology and Hydrology

7. The climate in the State of Kelantan is characterized by the seasonal monsoon. The north-east monsoon, which prevails mainly from October to December, brings heavy rainfall in the coastal plain. Around 50 percent of annual rainfall, which is about 2,700 mm, precipitates in the coastal plain on an average during these three months. This downpour in this period causes habitual flooding in the downstream areas of the Kelantan River, resulting in suffering from flood damage.

8. In the upstream river basin, however, there is no distinctive rainy season because of the rain shadow effect under the lee of coastal plain and the south-west monsoon which is generally less vigorous than the north-east monsoon prevailing from May to September.

9. The Kelantan River is generally characterized as the river with ample flow replenished by abundant rainfall of the basin. The mean flow of the Kelantan River is 540.6 m^3/sec at Guillemard Bridge, a stream gauge located just upstream of Tanah Merah, over the period of 1961 to 1984, which is equivalent to the annual runoff of 1,411.3 mm for the catchment area of 12,080 km^2.

10. The seasonal variation of flow shows the lowest level in April with an average of 282.2 m^3/sec, whilst the north-east monsoon occurred between November and December brings the highest rate of runoff with an average of 1,121.8 m^3/sec. The period of

July and August has slightly high flow of 315.0 m^3/sec.

(3) Geology

11. Most parts of the upstream reaches of the Kelantan River basin forming high mountainous ranges consist mainly of granites except for the southern part dominated by the Palaeozoic-Mesozoic rocks. These granites are massive and sound, shaping the steep mountain slopes with waterfalls and rapids.

12. The hilly area extended in the middle reaches consists mainly of the Permian and Triassic rocks, comprising phyllite, slate, shale, limestone, tuff, volcanics and metamorphic rocks. Due to metamorphism widely spread in the region, most of the Permian and Triassic rocks are deformed slightly to moderately. In general, the older rocks show a greater degree of metamorphism than the younger ones.

13. The downstream reaches are characterized by lower hilly area from Kuala Krai to Kg. Kemubu and flat alluvial plain area from Kg. Kemubu to the river mouth. The lower hilly area consists of Permian-Triassic sedimentary rocks and granites which have same geological conditions as the rocks distributed in the mid-stream reaches.

14. Flat alluvial plain area consists of alluvial deposits classified into marine deposits and fluviatile deposits, although it is not always possible to demarcate two types of deposits. The underlying bedrock consists mainly of the Permian sedimentary rocks and granites. The depth from the ground surface to the bedrocks is in 100 to 200 m at the estuary of the Kelantan River and gradually shallow towards the upstream area of the river.

(4) Socio-economy

15. The population of Kelantan is estimated at 1.09 million in 1988. District-wise, Kota Bharu District has the biggest population of 357,995, accounting for 32.8% or almost one third of the State population. Applying an average annual growth rate of 2.5% for population since 1980, the State population is forecasted to grow from 893.8 thousand in 1980 to 1,147.0 thousand in 1990, 1,468.3 thousand in 2000 and 1,879.5 thousand in 2010.

16. The Gross Domestic Product (GDP) of Kelantan is estimated at M$2,684.4 million at the market price in 1988, whilst M$78,458 million for the whole of Malaysia, resulting in the share of 3.4%. This ratio is much smaller than the populational ratio of 6.4% as well as the areal ratio of 4.5%. However, economy of Kelantan is forecasted to grow from M$2,684.4 in 1988 to M$9,816.8 million in 2010.

17. Supporting 70% of population, employing 50% of workforce, producing 30% of GDP and using 20% of land area, the agricultural sector plays and will continue to play a major role for the socio-economy of the State. Paddy, tobacco, rubber and oil palm are four major crops. Especially, paddy with annual production of 200,000 tons shares 13.5% of national paddy production with around 1.5 million tons a year.

(5) Flood frequency and past large floods

18. Present bankful flow capacity of the Kelantan River is 4,500 m^3/sec at Kota Bharu, 6,600 m^3/sec at Pasir Mas, 10,200 m^3/sec at Tanah Merah and 11,000 m^3/sec at Kuala Krai (refer to Fig. S.1). On the other hand, the frequency analysis of annual peak discharge at Guillemard Bridge shows peak discharge of 5,100 m^3/sec for 2-year flood, whilst 13,400 m^3/sec for 20-year flood and 16,300 m^3/sec for 50-year flood. The comparison of probable peak discharge and bankful flow capacity of the Kelantan River shows that inundation takes place with the frequency more than once in two years in the downstream reaches.

19. Among the floods occurred almost once in two years, 1967 and 1983 floods brought severe damage to the downstream reaches of the Kelantan River. The damage of 1967 flood spread over 300,000 ha (refer to Fig. S.2), 20% of the State area, and brought about M$30 million in total, whilst 1983 flood inundated about 60,700 ha, and caused the damage of around M$11.4 million. Furthermore, the flood with double peaks hit the downstream areas on November and December of 1988 when the study was being carried out, causing the evacuation of 36,800 people with 19 death toll and the damage of M$27 million.

20. To cope with habitual inundation mainly due to overtopping of flood water from the Kelantan River, DID has implemented flood mitigation works at several places, but limited to only local protection.

Water resources development in the basin

21. Water of the Kelantan River is at present used for irrigation, domestic and industrial water supply. Peak demand of irrigation water occurs in May/June, and the areas actually irrigated are limited within 60 to 70% of the total irrigable area due to available pumping capacity of 35 m^3/sec. On the other hand, an amount of 40 Mld is abstracted from the Kelantan River for the domestic and industrial water supply. Furthermore, an amount of 70 m^3/sec is estimated to be necessary as river maintenance flow to prevent from the salinity intrusion upto the Kota Bharu town area.

22. Water demand required for the Kelantan River will increase from 105.5 m^3/sec in 1985 to 161.1 m^3/sec in 2010; 6.5 m^3/sec for the domestic and industrial supply, 84.6 m^3/sec for the irrigation use and 70.0 m^3/sec for river maintenance.

23. Water deficit for domestic/industrial demand and river maintenance flow will occur once in about 20 years in 2010 in case without-dam scheme in the upper reaches, whilst the deficit will be almost offset with the development of either of Dabong, Lebir and Nenggiri dam schemes, which are identified in the Kelantan River basin as the promising schemes for the multi-purpose development (refer to Location Map). As for irrigation water demand, average annual deficit will be 12 m^3/sec in 2010 in the condition of "without dam", whilst less than 5 m^3/sec with the full development of either of above dam schemes.

24. Three dam schemes of Lebir, Dabong and Nenggiri are expected to generate huge hydropower as follows:

Dam	Normal High Water Level (El.m)	Required Storage Volume (MCM)	Dependable Capacity (MW)	Annual Generated Energy (GWh)
Lebir	65 - 90	460 - 1650	60 - 150	240 - 430
Dabong	54 - 67	410 - 1520	140 - 270	630 - 940
Nenggiri	135 - 160	250 - 550	170 - 280	580 - 790

25. The economic viability of those three dam schemes in water resources development including hydropower generation was assessed to be 6.0% for Lebir, 15.1% for Dabong and 17.4% for Nenggiri in terms of the economic internal rate of return.

Basic concept for the formulation of flood mitigation plans

26. The protection area from floods in this study is the vast plain area of the Kelantan River extended in the downstream reaches of Kuala Krai. Kota Bharu, Pasir Mas, Tanah Merah and Kuala Krai are four major urban areas developed in the flood-prone area of the Kelantan River. On the other hand, the rural areas are developed as agricultural lands of paddy, tobacco and so on with high production.

27. Flood Mitigation Master Plan of the Kelantan River is targeted for a 50-year flood, considering the development of the flood-prone area extended in the downstream reaches and habitual flooding.

28. Considering the present flow capacity of more or less 5,000 m^3/sec in the downstream reaches and large probable flood discharges, i.e. 13,400 m^3/sec in a 20-year flood and 16,300 m^3/sec in a 50-year flood, the flood mitigation by structural measure is contemplated by combining dam schemes and river improvement. Five dam schemes of Dabong, Kemubu, Nenggiri, Lower Pergau and Lebir are contemplated as a flood mitigation measure in the downstream reaches of the Kelantan River as well as water resources development.

29. Non-structural measures are also contemplated to reinforce the flood mitigation by structural measure. The following are conceived as the non-structural measures:

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

Formulation of flood mitigation plans with water resources development

30. Considering not only the flood mitigation effect of dams to the downstream reaches and flow capacity of the Kelantan River, but also the water resources development, following combination plans are contemplated:

Case	Combination of Structures
1	R/I only
2	Nenggiri + R/I
3	Kemubu + R/I
4	Dabong + R/I
5	Lebir + R/I
6	Lebir + Nenggiri + R/I
7	Lebir + Kemubu + R/I
8	Lebir + Dabong + R/I

It is noted that the Lower Pergau dam plus river improvement (R/I) was excluded due to almost nil effect of the Lower Pergau dam in flood peak reduction.

31. The optimization study for the Nenggiri, Dabong and Lebir dam schemes was performed with the objectives of power generation, irrigation water supply and flood mitigation. The Kemubu dam was studied as a single purpose of flood mitigation due to its small storage capacity and low water head. The Nenggiri dam scheme developed as a rockfill type was optimized with the crest elevation of 169 m, whilst the concrete gravity type with the crest elevation of 82 m and 80 m for Kemubu and Dabong respectively and the rockfill type with the crest elevation of 91.1 m for Lebir. On the other hand, comparative studies to select the suitable river improvement plan were carried out by combining levee construction, widening of river channel, river dredging and introduction of shortcutting. Consequently, the river improvement plan by means of levee construction, widening for remarkably narrowed river channel and reformation of river bed by dredging was selected.

32. Economic viability of eight conceivable flood mitigation plans proposed above was evaluated in terms of economic internal rate of return, EIRR, taking into account the water resources development. The Dabong plus river improvement gained the highest economic efficiency of 11.9% (refer to Table S.1). However, the development of the Dabong dam scheme causes great negative socio-economic impacts; 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 plantations.

Flood mitigation plan to minimize social impacts

33. Showing high economic efficiency, the multipurpose development of Dabong dam scheme requires a large scale relocation of houses, plantations and public facilities. The formulation of flood mitigation plan of the Kelantan River was therefore tried by giving high priority on itself and on minimization of social impacts. A flood protection level is targeted against a 50-year flood.

34. A notable concept in formulating the flood mitigation plan of the Kelantan River stressing on the minimization of social impacts is to control flood peak discharge to below 11,000 m^3/sec by the dams to be built in the upstream reaches based on the following reasons:

- A levee height will be within 5 m at a maximum point.
- Since the present flow capacity ranges from 4,500 m^3/sec at Kota Bharu in the downstream reaches to 11,000 m^3/sec in the upstream reaches of Guillemard Bridge, the design flood peak discharge of 11,000 m^3/sec is not considered to be heavy burden for levee construction, and levee with height lower than 5 m can be constructed even for the highest case.
- The relocation of existing and under-construction bridges should be avoided.
- The treatment of tributaries against backwater from the Kelantan River should be in the reasonable extent.
- Treatment of interior water should be in the reasonable range.
- Influence to the existing irrigation facilities should be minimized (for example, reconstruction of water intake facilities caused by the river bed deepening with a large scale).
- As intangible factors, the separation of local communities by levee should be avoided, and the change of micro-climate at local places should be minimized.

35. The site identification of flood mitigation dams was carried out stressing on the minimization of social impacts. A total of 15 potential sites was identified including the Dabong, Lower Pergau, Kemubu, Nenggiri and Lebir sites. The screening to find out the suitable damsites for flood mitigation eventually selected Dabong, Kemubu, Nenggiri and Lebir as promising schemes in terms of flood peak reduction.

36. A total of 48 alternative combination plans was prepared by combining above four dam schemes (refer to Table S.2). Mutual exclusiveness and three kinds of dam scale are taken into consideration in the preparation of combination plans. It is noted that the Kemubu and Nenggiri dam schemes are mutually exclusive in terms of flood mitigation, but both schemes, when the Nenggiri dam scheme is developed for hydropower generation, are compatible, judging from the relationship between the tailwater level of Nenggiri and the normal high water level, NHWL, of Kemubu.

37. Among 48 combination plans, only 15 combinations could meet the basic concept that flood peak discharge at Guillemard Bridge is to be controlled to below 11,000 m^3/sec by dams (refer to Table S.3).

38. Those 15 combination plans were grouped into two based on social impact, i.e. the number of households to be submerged in the reservoir as follows:

(a) Households to be submerged are 1,000 to 1,500

(b) Households to be submerged are 5,000 to 7,500.

39. The combination plans with the submerged households of more than 5,000 were discarded due to great social impact caused by the relocation of houses; that is, all the combinations including Dabong are eliminated (refer to Table S.3).

40. Only three combinations, Ks+Ll+R/I, Km+Ll+R/I and Kl+Ll+R/I, are grouped in (a), i.e. relatively small number of households to be submerged in the reservoir (1,000 to 1,500). The difference on the flood mitigation effect of Kemubu dam is little in Ks to Kl (refer to Table S.2). Thus, Kemubu with a small scale (Ks) is selected to minimize the social impact as follows:

Dam crest elevation	73.4 m
DFWL	71.4 m
SWL	
- 50-year flood	63.1 m
- 25-year flood	62.3 m
NHWL	55.0 m
Submerged houses, nos	1,000
Submerged plantation, ha	
- SWL (25-year flood)	430
- SWL (50-year flood)	450
- Dam crest elevation	970
Submerged forest, ha	
- SWL (25-year flood)	750
- SWL (50-year flood)	790
- Dam crest elevation	1,910

Note: Dam scheme K: Kemubu, L: Lebir
Dam scale l: maximum, m: medium, s: small

41. On the other hand, Lebir is selected to be optimal with a large scale. Considering the submergence of a large area by building Lebir with a large scale, a study to search the possibility to lower the dam was tried by keeping the almost same flood mitigation effect with large scale dam (Ll) as well as the possibility of water resources development. An ordinary overflow weir for flood mitigation was provided in the spillway to lower the dam by keeping the almost same flood mitigation effect with Ll. As a result, Ll' is proposed. Comparison of Ll and Ll' on the social impacts to be expected is tabulated below:

Items	Ll, m	Ll', m
Dam crest elevation	91.1	84.9
DFWL	87.6	81.4
SWL		
- 50-year flood	84.9	78.0
- 25-year flood	84.4	77.2
NHWL	80.0	70.0
Submerged houses, nos	165	156
Submerged plantation, ha		
- SWL (25-year flood)	12,200	8,300
- SWL (50-year flood)	12,450	8,700
- Dam Crest Elevation	17,130	12,450
Submerged forest, ha		
- SWL (25-year flood)	6,800	5,000
- SWL (50-year flood)	7,000	5,300
- Dam Crest Elevation	8,600	7,000
Peak discharge at Guillemard Bridge, cms		
- 50-year flood	10,720	10,650

Since Ll' makes possible to reduce social impacts by keeping the same flood mitigation effect with Ll, Ll' is recommended as the plan of Lebir scheme. Thus, the combination plan of Ks + Ll' + R/I is proposed as an optimal plan of flood mitigation in the Kelantan River basin.

42. The schemes to proceed in the pre-feasibility study stage are Lebir and Kemubu dam schemes and river improvement between Kuala Krai and the estuary. A conceptual feature of the master plan for the Kelantan River flood mitigation is sketched as given in Figure of the front page.

Implementation programme of the Kelantan River basin-wide flood mitigation plan

43. An implementation programme for the flood mitigation master plan of the Kelantan River basin carried out with Lebir and Kemubu dams and river improvement was prepared by taking into consideration the scale of construction cost (M$1,302 million), time period and so forth as given in Fig. S.3. Indeed, the implementation will be carried out for 20 years in the period of sixth to ninth Malaysia Plan.

44. The Lebir dam, which has greater flood mitigation effect than the Kemubu dam, will be built by the end of 1998, yielding substantial flood mitigation effect to all the river stretches between Kuala Krai and the estuary (refer to Fig. S.4). On the other hand, the completion of Kemubu dam in 2010 will raise the protection level by 50 years, the final target of protection.

45. The river improvement works of urban and rural areas will simultaneously be commenced at the beginning of 1993, however, the works for the urban area will be completed by year 2000, whilst 2010 for the rural area.

46. The fund requirement for the implementation of the Lebir and Kemubu dams and river improvement is disbursed based on the implementation schedule as given in Table S.4 and summarized as follows:

Unit: million M$

	Malaysia Plan			
	6th	7th	8th	9th
Required fund	387	430	130	356

Pre-feasibility study on the Lebir and Kemubu dam schemes and river improvement

(1) Preliminary design

Lebir dam scheme

47. The preliminary design for the Lebir dam scheme was carried out on a pre-feasibility study level as given in Figs. S.5 and S.6, and the main project features are summarized as follows:

Dam crest elevation	:	84.9 (91.1) m
SWL	:	78.0 (84.9) m
NHWL	:	70.0 (80.0) m
Flood control volume	:	860 million m^3
Type of dam	:	Rockfill centre core type
Embankment volume	:	4.9 million m^3
Construction cost	:	M$500 million.

48. The Lebir dam scheme is planned to develop in two stages (refer to Fig. S.7). In the first stage, the dam with a smaller scale is built so as to keep the almost same flood mitigation effect taking advantage of the ordinary overflow weir of the spillway as the one in the second stage. The reservoir space below NHWL is used for augmenting irrigation water. The normal high water level (NHWL) is raised by 10 m from El. 70.0 m to El. 80.0 m in the second stage for ensuring the reservoir capacity for hydropower generation. The figures in parentheses on the above Table show the features in the second stage.

Kemubu dam scheme

49. The preliminary design for the Kemubu dam scheme was performed on a pre-feasibility study level as shown in Figs. S.8 and S.9. The main project features are summarized as follows:

Dam crest elevation	:	73.4 m
SWL	:	63.1 m
NHWL	:	55.0 m
Flood control volume	:	307 million m^3
Type of dam	:	concrete gravity
Concrete volume	:	150,000 m^3
Construction cost	:	M$226 million.

River improvement works

50. A pre-feasibility level design for the river improvement is carried out for the 100 km long river stretches between Kuala Krai and the estuary as depicted in Fig. S.10. The main features of river improvement are summarized as follows:

Total levee length	:	164 km
- Urban area	:	29 km
- Rural area	:	135 km
Embankment volume	:	13.2 million m^3
Average levee height	:	4 m
Construction cost	:	M$576 million
- Urban area	:	M$165 million
- Rural area	:	M$411 million.

(2) Construction plan and cost estimates

51. In order to implement the project work within the limited construction period, it is proposed to execute the project works by an international contract system. In consideration of the scale of the works and anticipated amount of construction cost, it is determined to execute the construction work by dividing into 4 packages, namely, construction of the Lebir dam project (Package 1), execution of river improvement works for urban areas such as Kota Bharu, Pasir Mas, and Tanah Merah (Package 2), construction of the Kemubu dam project (Package 3), and execution of river improvement works for the rural areas (Package 4). Construction works will be administrated by DID in association with an international engineering consulting firm.

52. The implementation period of 4 packages was studied considering site condition, magnitude of the works, identification of land acquisition, and financial balance to meet the Malaysia five-year plan as follows:

Package no.	Starting time	Scheduled completion time	Duration of construction period (year)
1	January 1993	December 1998	6
2	January 1993	December 2000	8
3	January 2007	December 2010	4
4	January 1993	December 2010	18

53. The financial cost for the flood mitigation plan was estimated as follows:

Unit:thousand M$

Cost items	F.C	L.C	Total
- Direct cost (Construction cost including preparatory works)	289,186	389,574	678,760
- Indirect cost (Land acquisition, administration and engineering service cost)	96,426	408,078	504,504
- Contingency (Physical contingency)	38,561	79,765	118,326
Total	424,173	877,417	1,301,590

Note ; (1) FC; Foreign currency. LC; Local currency.

(2) The cost for intake for power generation in Lebir dam is not included in this cost estimate (estimated direct cost for intake structure is M$22,523,000).

(3) Economic evaluation

54. The economic viability of the project is evaluated under the condition that all the project components, i.e. Lebir and Kemubu dams and river improvement are completed according to the proposed implementation programme. The benefit of flood mitigation increases according to the completion of project components. The increase of agricultural production by the Lebir dam is also counted as the project benefit, so that an EIRR value of 2.2% was gained.

55. Power generation by raising the dam height of the Lebir project in the second stage improved the project viability by 4.4% in EIRR. Furthermore, an addition of the Nenggiri hydropower project to the basin gained a higher EIRR value of 5.7% in the entire project viability.

56. A sensitivity test under no available relocation area of plantation was reckoned to be 0.8%. Another sensitivity test to give 1 m freeboard for levee gained the marginal improvement on economic viability, 2.5% from 2.2% of the original case with 2 m freeboard.

Non-structural measures

57. Non-structural measures such as flood zoning, restriction of

development and flood forecasting and warning system are normally applied to the flood-prone area where the structural measure cannot be economically viable or as a supplementary measure for structural measure. Since all the flood-prone areas in the downstream reaches of the Kelantan River are planned to be protected by such structural measures as dam and river improvement, an application of non-structural measures such as flood zoning and restriction of development is not contemplated in this study. Only the flood forecasting and warning system is considered to supplement or reinforce the structural measures. The result of the study on the existing flood forecasting and warning system states that prediction of flood runoff relies on six telemetered rain gauges. Since a higher density and well distributed telemetric outstations can further enhance the reliability of model prediction, 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 shall be installed at the dams to facilitate in the flood prediction.

Table S.1 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

Table S.2 Peak Discharge at Guillemard Bridge by the Combination of Dam Plan

No.	Combination	Peak Discharge at Guillemard Bridge (cms)
1	R/I only	17,420
2	Ds	13,602
3	Dm	12,334
4	Dl	11,079
5	Ls	16,257
6	Lm	15,265
7	Ll	13,213
8	Ns	16,890
9	Nm	16,550
10	Nl	16,229
11	Ks	15,802
12	Km	15,279
13	Kl	15,185
14	Ds + Ls	13,033
15	Dm + Ls	11,765
16	Dl + Ls	10,510
17	Ds + Lm	12,014
18	Dm + Lm	10,746
19	Dl + Lm	9,491
20	Ds + Ll	9,989
21	Dm + Ll	8,721
22	Dl + Ll	7,466
23	Ds + Ls + Ns	11,928
24	Ds + Lm + Ns	11,648
25	Ds + Ll + Ns	11,327
26	Ds + Ls + Nm	10,926
27	Ds + Lm + Nm	10,656
28	Ds + Ll + Nm	10,335
29	Ds + Ls + Nl	8,874
30	Ds + Lm + Nl	8,604
31	Ds + Ll + Nl	8,283
32	Ks + Ls	13,768
33	Km + Ls	13,245
34	Kl + Ls	13,151
35	Ks + Lm	12,776
36	Km + Lm	12,253
37	Kl + Lm	12,159
38	Ks + Ll	10,724
39	Km + Ll	10,201
40	Kl + Ll	10,107
41	Ns + Ls	15,736
42	Nm + Ls	15,466
43	Nl + Ls	15,145
44	Ns + Lm	14,744
45	Nm + Lm	14,474
46	Nl + Lm	14,153
47	Ns + Ll	12,692
48	Nm + Ll	12,422
49	Nl + Ll	12,101

Remarks ; Dam scheme D : Dabong N : Nenggiri
L : Lebir K : Kemubu
Dam scale l : maximum m : medium
s : minimum

Table 8.3 Combinations to Meet the Basic Concept on Peak Discharge at Guillemard Bridge

No.	Combination	Peak discharge at Guillemard Bridge, m^3/sec	Households to be submerged, nos
1	Dl + Ls	10,510	6,190
2	Dm + Lm	10,746	6,240
3	Dl + Lm	9,491	7,440
4	Ds + Ll	9,989	4,965
5	Dm + Ll	8,721	6,265
6	Dl + Ll	7,466	7,465
7	Ds + Ls + Nm	10,926	5,400
8	Ds + Lm + Nm	10,656	5,450
9	Ds + Ll + Nm	10,335	5,475
10	Ds + Ls + Nl	8,874	5,530
11	Ds + Lm + Nl	8,604	5,580
12	Ds + Ll + Nl	8,283	5,605
13	Ks + Ll	10,724	1,165
14	Km + Ll	10,201	1,365
15	Kl + Ll	10,107	1,460

Remarks : Dam scheme D : Dabong L : Lebir
K : Kemubu N : Nenggiri
Dam scale l : maximum m : medium s : minimum

Table S.4 Disbursement Schedule for the Flood Mitigation Plan of the Kelantan River Basin

Unit : Million M$

	Malaysia Plan																			
	6th					7th					8th						9th			
Schemes	'91	'92	'93	'94	'95	'96	'97	'98	'99	2000	'01	'02	'03	'04	'05	'06	'07	'08	'09	'10
1. River Improvement																				
1.1 Urban area			31.7	23.5	23.5	23.5	16.2	16.2	15.2	15.2										
1.2 Rural area			39.4	11.5	11.5	11.5	18.9	18.9	19.9	19.9	26.0	26.0	26.0	26.0	26.0	26.0	26.0	26.0	26.0	26.0
2. Dam Schemes																				
2.1 Lebir			117.3	57.5	71.7	84.7	112.0	57.5												
2.2 Kemubu																	69.6	51.2	52.7	52.0
Total			188.4	92.5	106.1	119.7	147.1	92.6	35.1	35.1	26.0	26.0	26.0	26.0	26.0	26.0	95.6	77.2	78.7	78.0
Total in each Malaysian Plan				387.0				429.6					130.0					355.6		

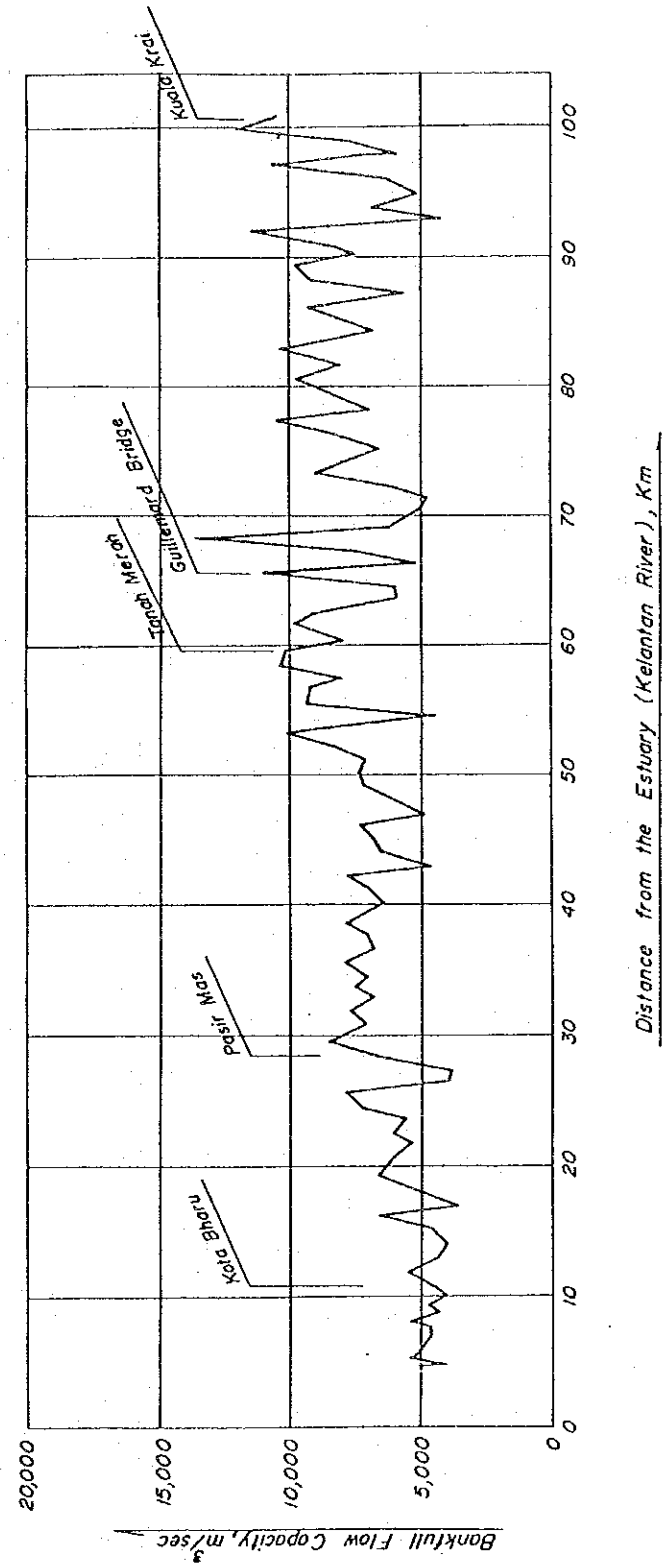


Fig. S.1

Bankful Flow Capacity of the Kelantan River

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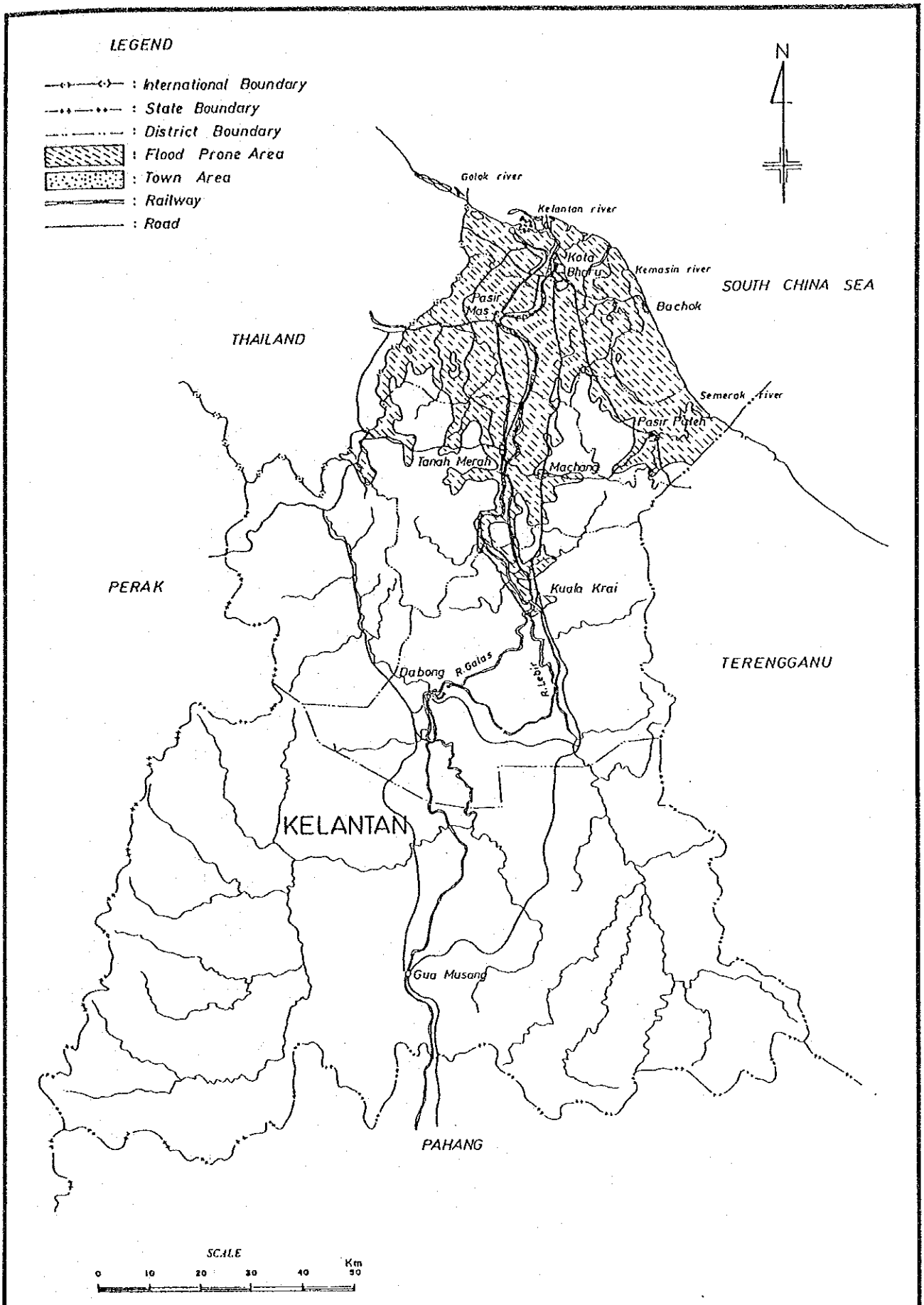

Fig. S.2

Flooded Area by January 1967 Flood

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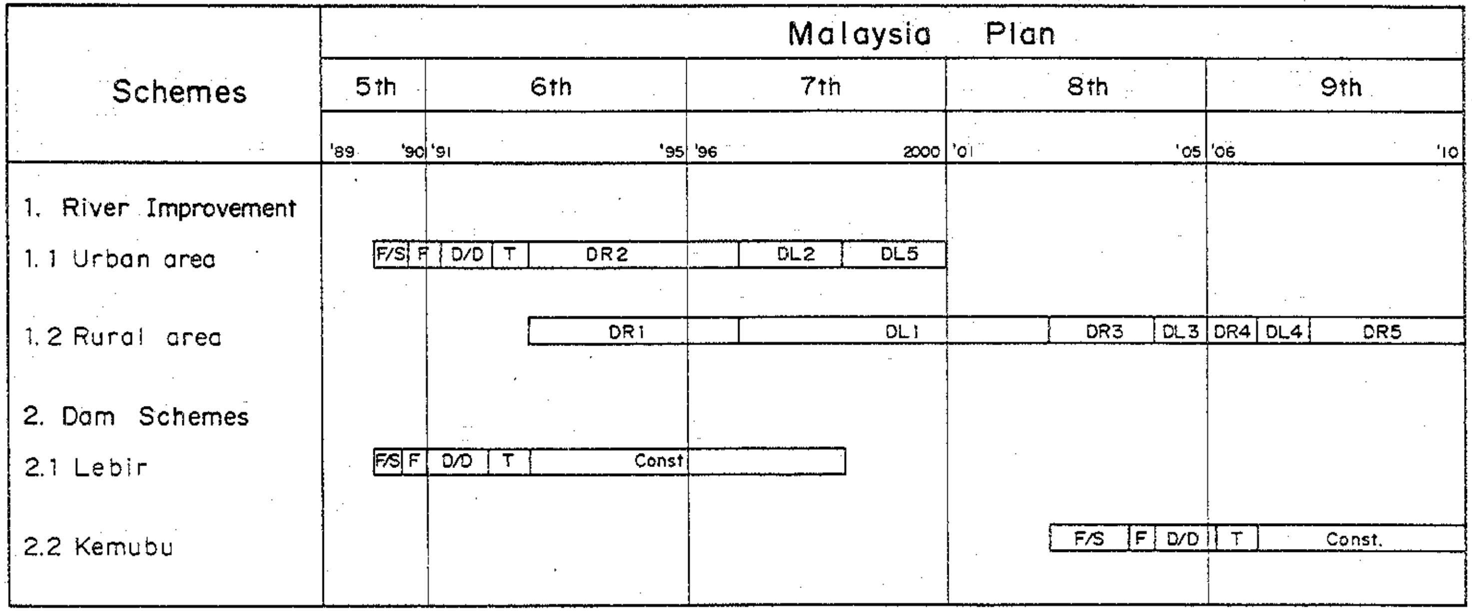

Notes : The feasibility study (F/S), detailed design (D/D) and financing (F) for all the river improvement works are carried out at the beginning of river improvement works for the urban area, whilst tender (T) is performed prior to the construction of each package. DR1, DL1 and so on denote the construction of respective river division.

Fig. S.3

Implementation Programme for the Flood Mitigation Plan of the Kelantan River Basin

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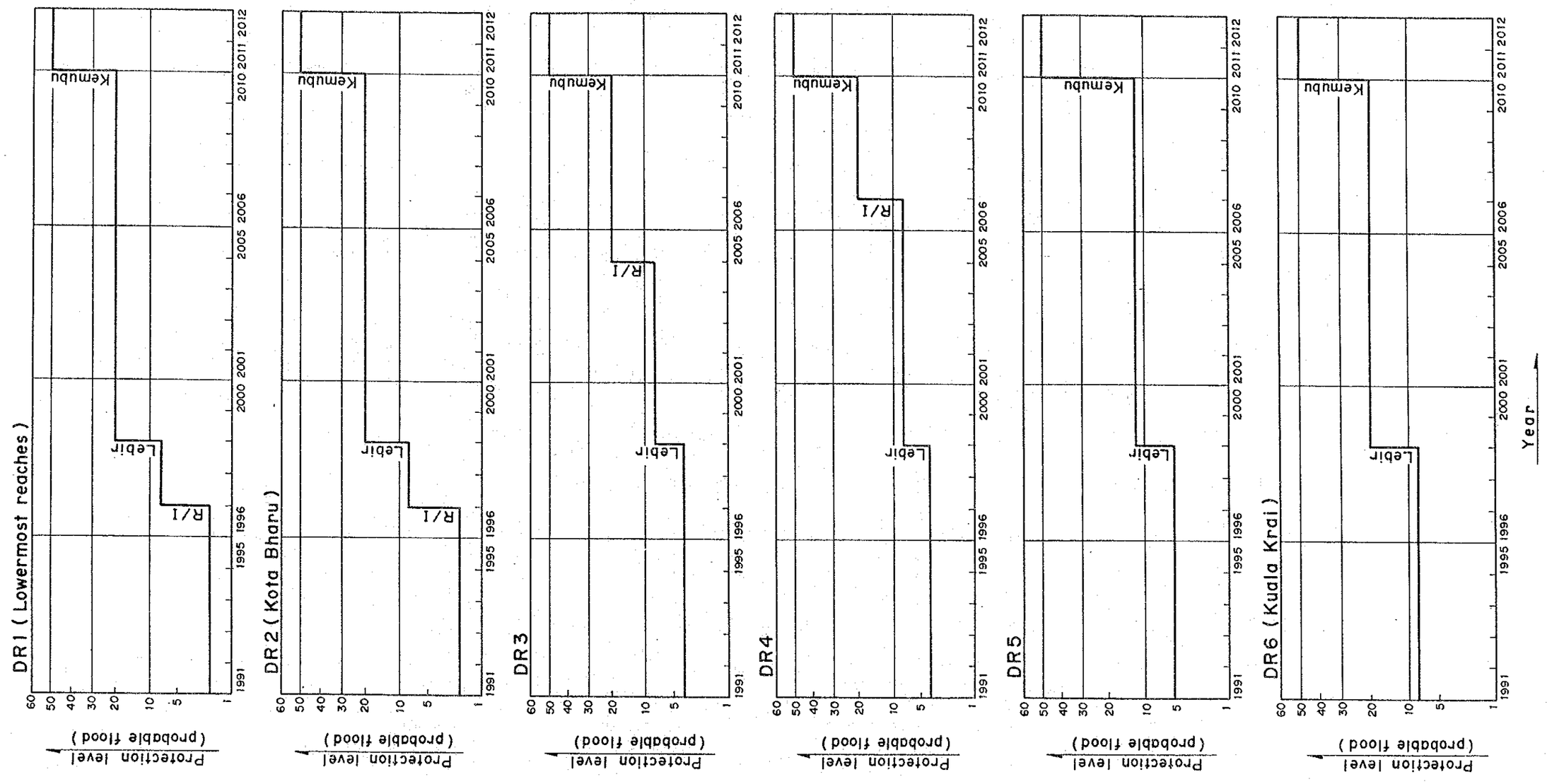

Fig. S.4

Increase of Protection Level against Flood (1/2)

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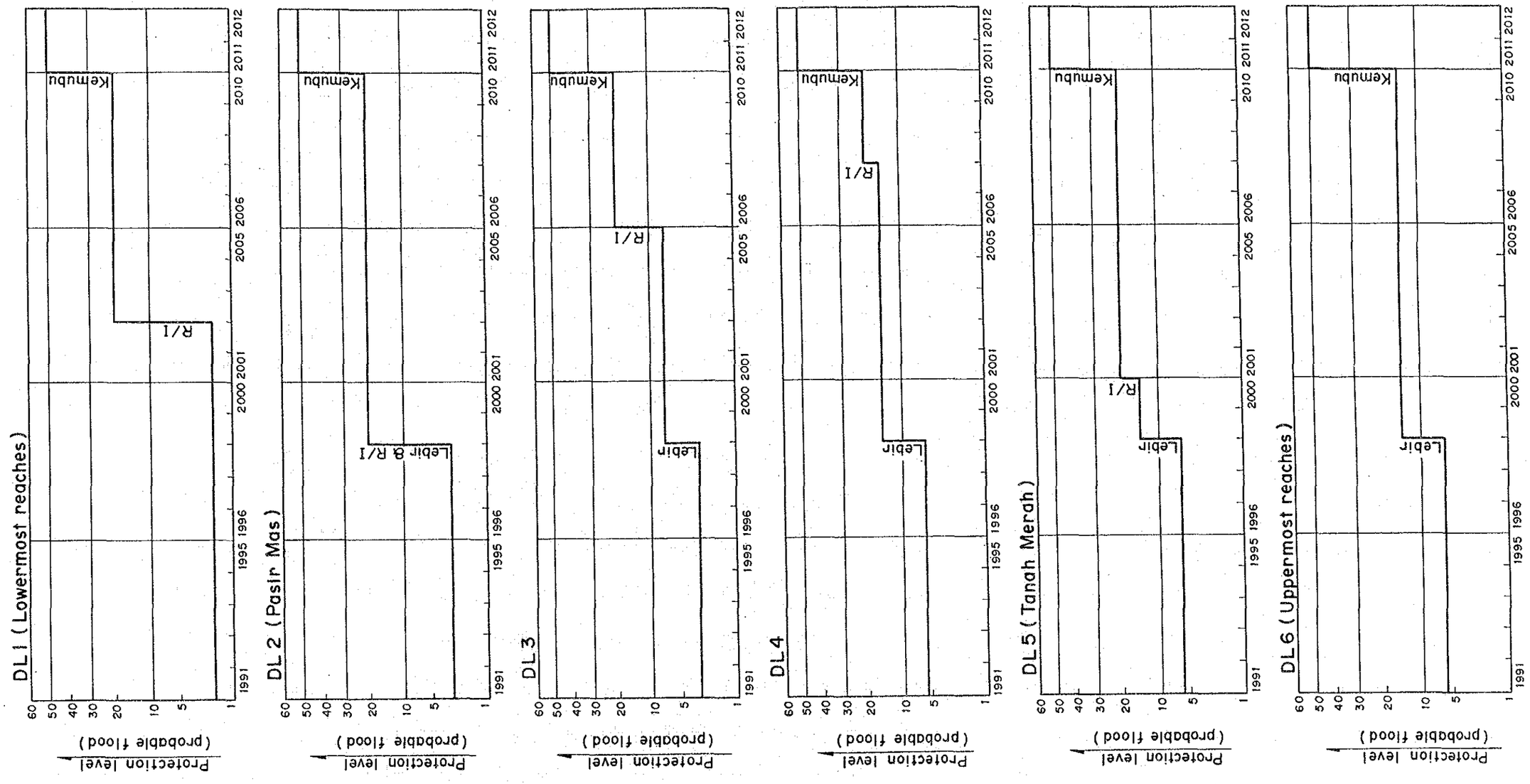

Fig. S.4

Increase of Protection Level against Flood (2/2)

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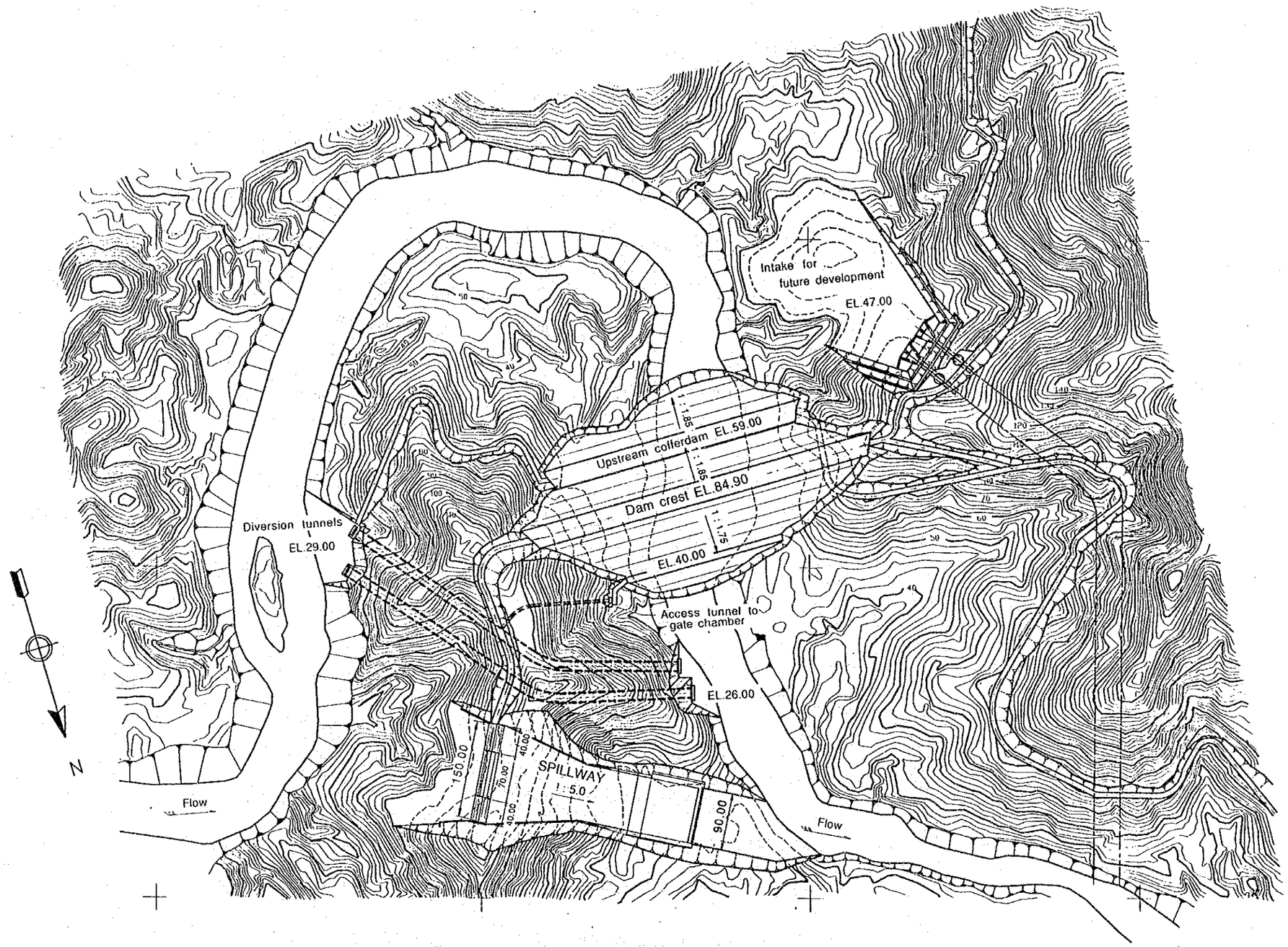

Fig. 8.5

General Plan of Lebir Dam

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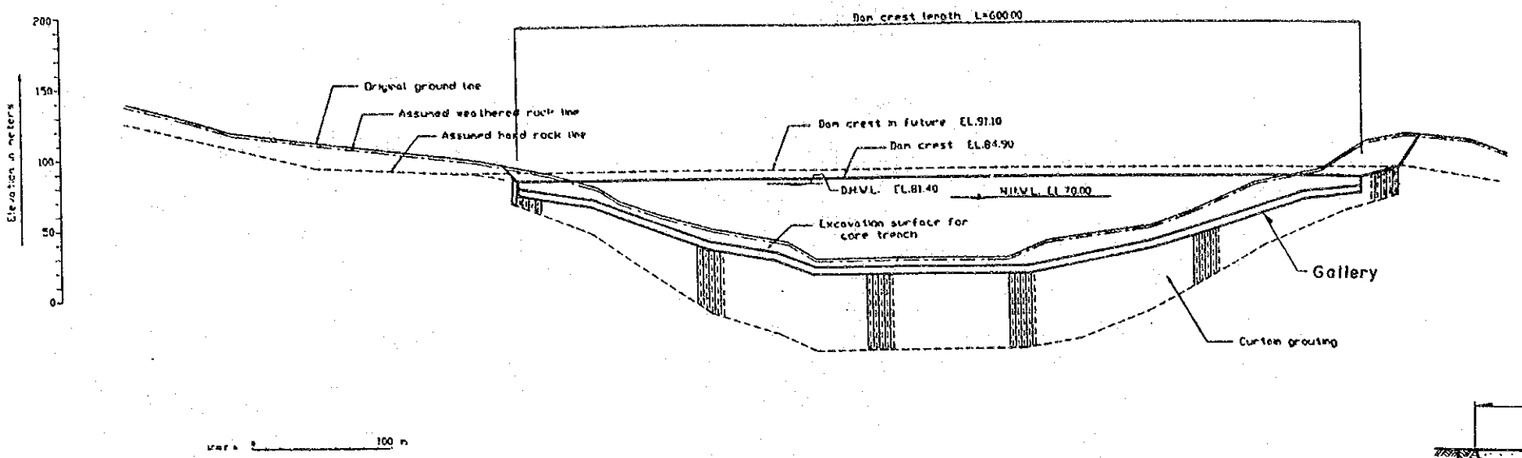
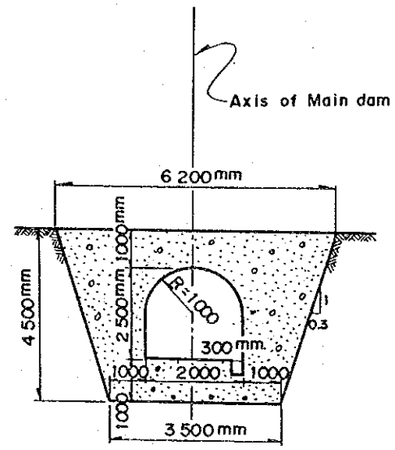
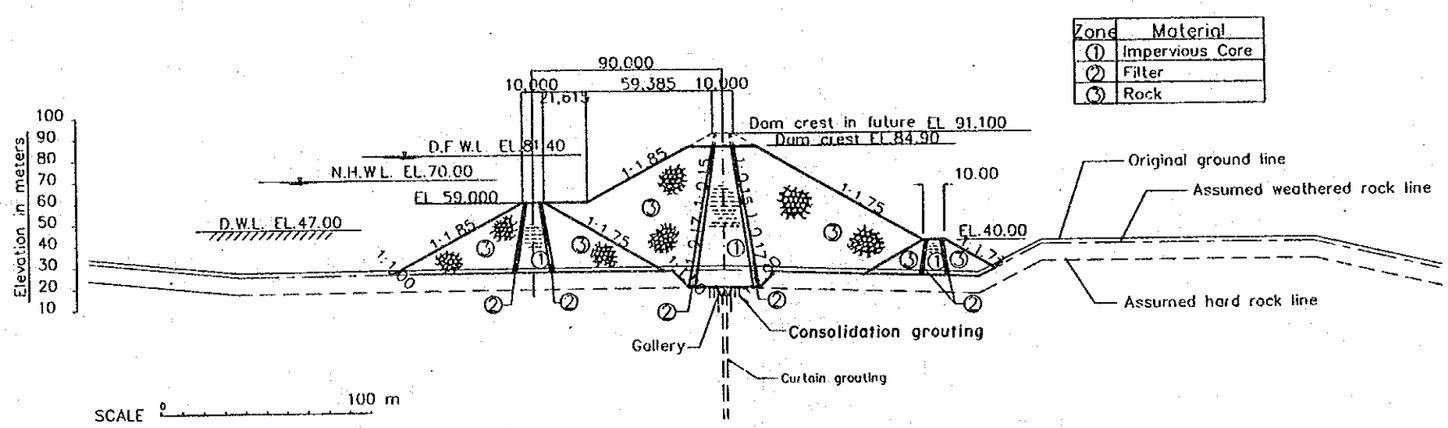


PROFILE OF LEBIR DAM



TYPICAL CROSS SECTION OF GALLERY



TYPICAL CROSS SECTION OF MAIN DAM

Fig. 8.6

Profile and Typical Cross Section of Lebir Dam

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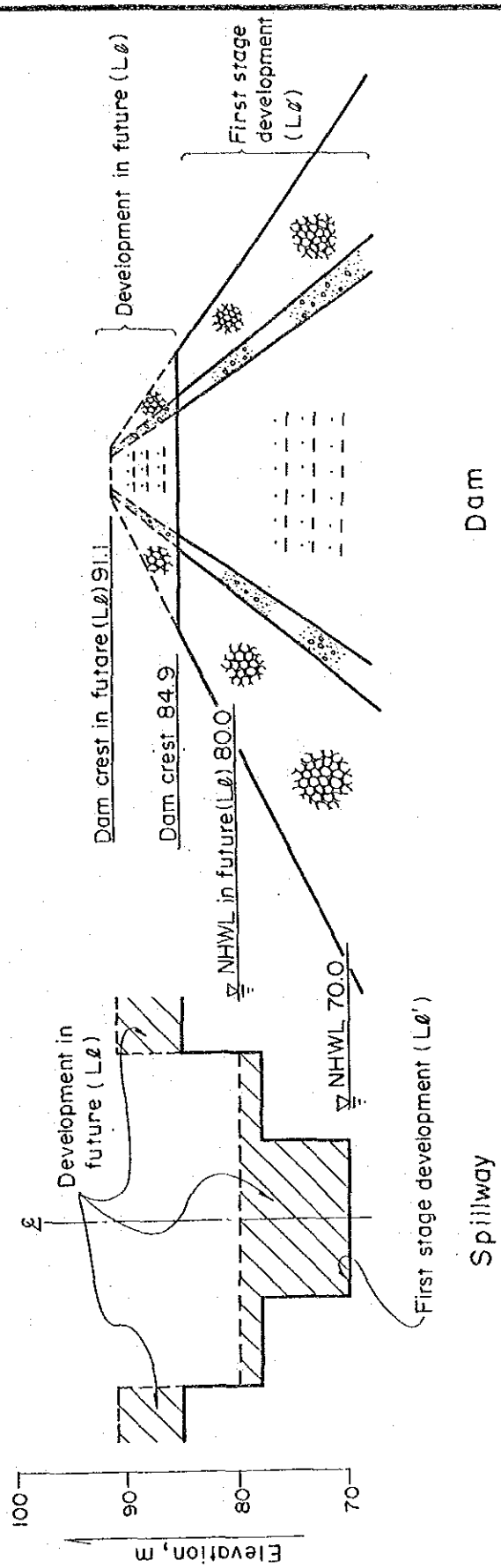

Fig. 8.7

Stage Development Plan of Lebir Dam

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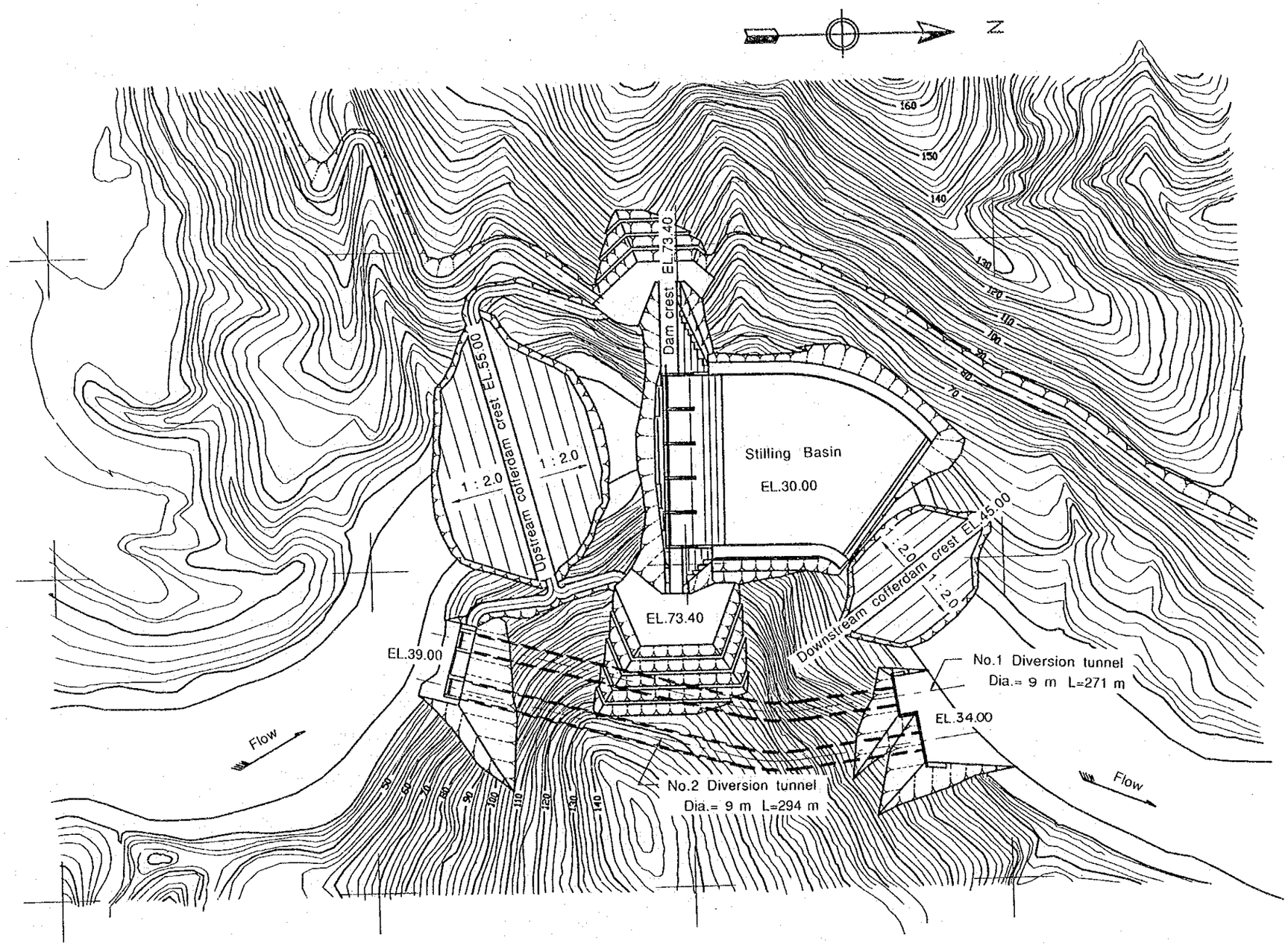

GENERAL PLAN

Fig. S.8

General Plan of Kemubu Dam

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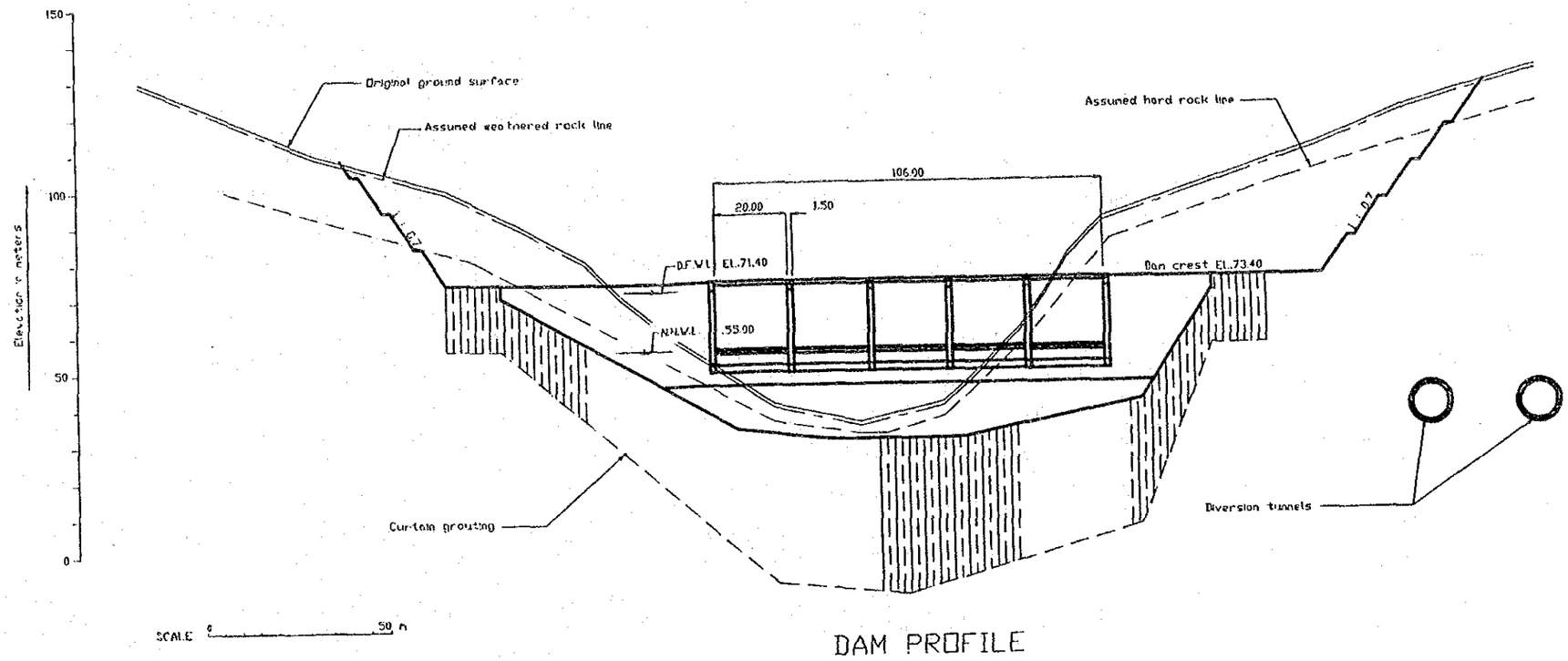
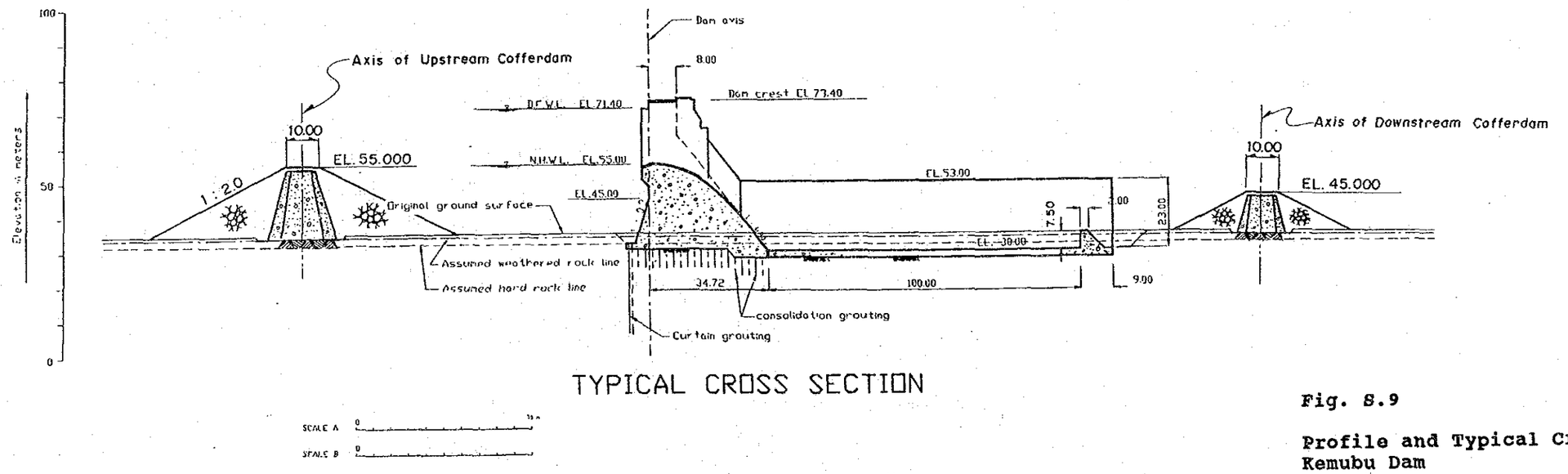


DAM PROFILE



TYPICAL CROSS SECTION

Fig. S.9

Profile and Typical Cross Section of Kemubu Dam

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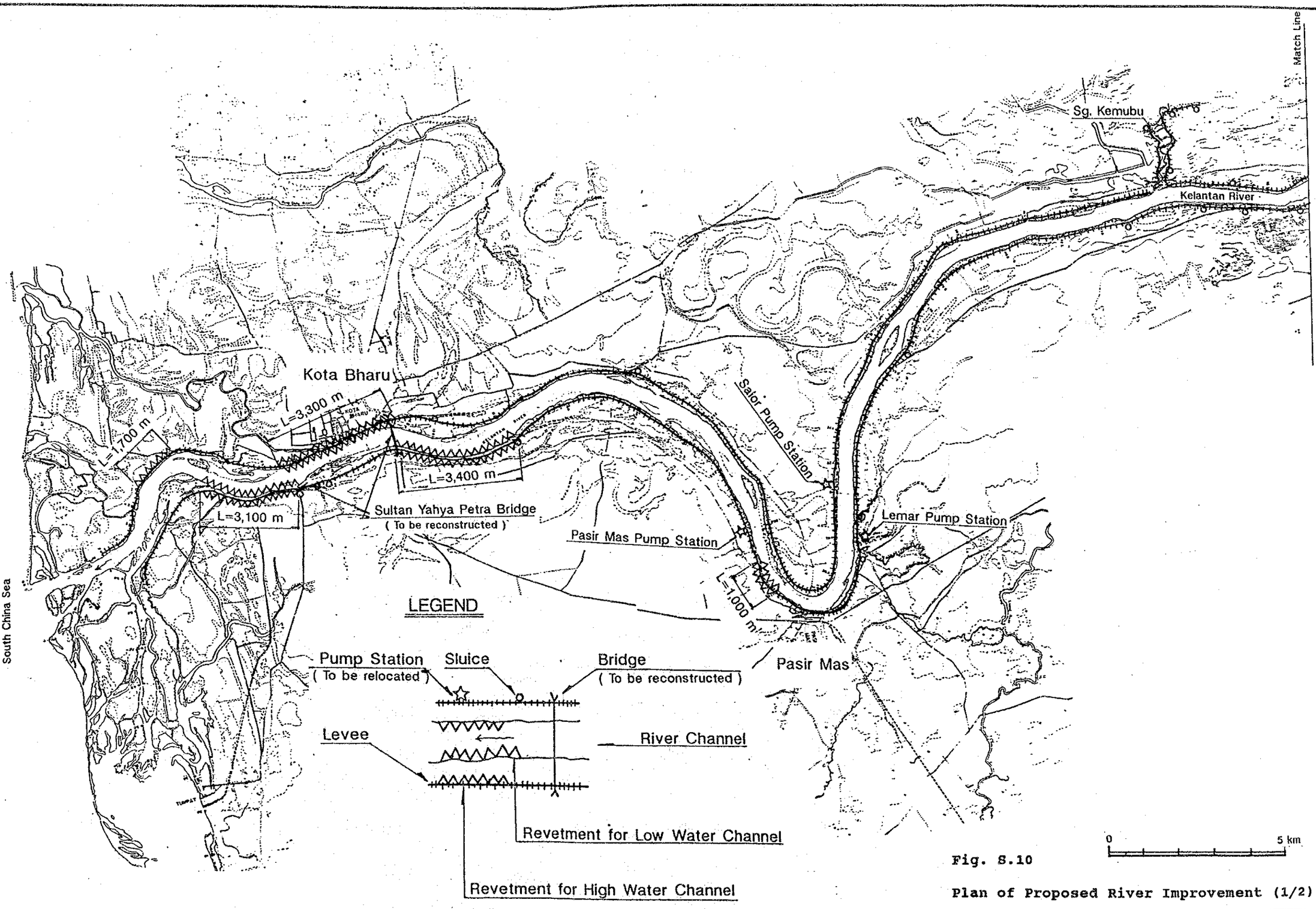

Fig. S.10

Plan of Proposed River Improvement (1/2)

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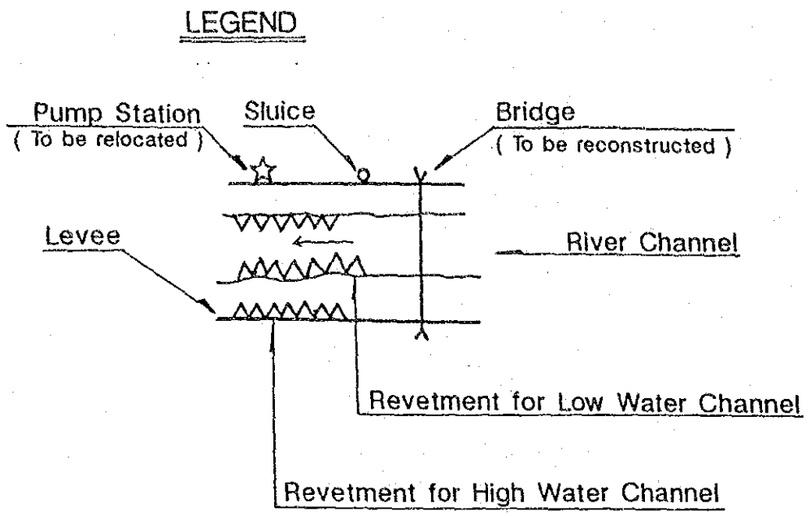

Fig. S10

Plan of Proposed River Improvement (2/2)

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