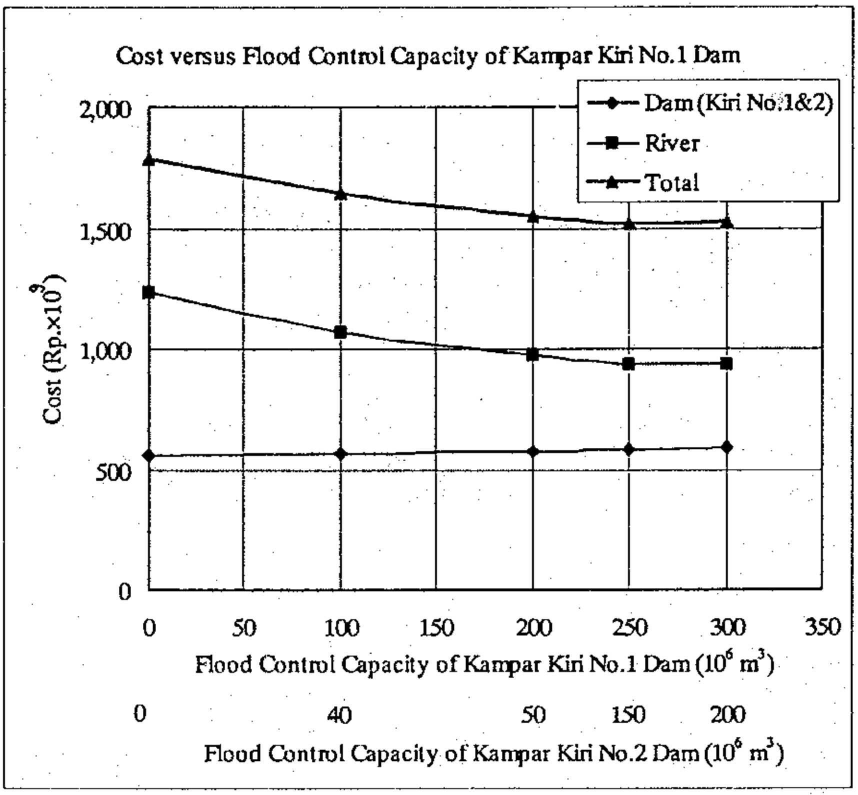
- Cost-crest level relations of Kampar Kiri No. 1 and No. 2 dams are as presented in SECTOR XII, DAM ENGINEERING. Design discharge - Improvement cost relation of improvement of the Kampar and Kampar Kiri rivers is as presented in Fig. XI.2.2.
- Cost of dam construction includes the cost of hydropower generation equipment.

The costs versus flood control capacities of Kampar Kiri No.1 Dam are plotted as below:



As shown in the above illustration, the total cost is minimum when Kampar Kiri No. 1 Dam has the flood control capacity of $250\times10^6m^3$ and Kampar Kiri No. 2 Dam has $150\times10^6m^3$. As shown by the study results, although both dams can physically provide more flood control capacity, the design discharge of 1,450 m^3/s at Lipat Kain is the minimum value because of the existence of a residual catchment area between the dams and Lipat Kain.

2.1.4 Optimum Plan

In accordance with the results of the cost comparison presented above, capacities have been provided to Kampar Kiri No. 1 and No. 2 dams and the major features of the optimum plan are as given below.

(1) Kampar Kiri No.1 Dam

Particulars	Description
Capacity Allocation	
Flood Control	$250\times10^6m^3$
Hydropower Generation	$646\times10^6m^3$
Dead Storage	$1,350\times10^6m^3$
Total	$2,246\times10^6m^3$
Water Level	
Surcharge Water Level	EL 128.5 m
Normal Water Level	EL 125.0 m
Low Water Level	EL 113.9 m
Flood Control	
Control Method	Non-gated control

(2) Kampar Kiri No. 2 Dam

Particulars	Description
Capacity Allocation	
Flood Control	$150\times10^6 m^3$
Hydropower Generation	$438\times10^6 m^3$
Dead Storage	$1,612\times10^6 m^3$
Total	$2,200\times10^6 m^3$
Water Level	
Surcharge Water Level	EL 136.9 m
Normal Water Level	EL 135.0 m
Low Water Level	EL 128.0 m
Flood Control	
Control Method	Non-gated control

(3) River Improvement Works

Particulars	Design Discharge (m^3/s)
Kampar Kiri River	
Lipat Kain	1,450
Kampar River	
Langgam - Kerinci	4,850
Kerinci - River Mouth	5,100

2.2 Optimization of Indragiri River Development Project

2.2.1 Basic Conditions and Planning Criteria

The basic conditions for the formulation of the Indragiri River Development Project are as described below.

(1) Purposes of the Project

The Indragiri River Development Project has the following purposes.

- Flood control of the middle and lower reaches of the Kuantan-Indragiri River;
- Irrigation water supply to Lubukjambi Irrigation Project; and,
- Hydropower generation at proposed dams.

(2) Proposed Dams

For the Project, three possible damsites were identified for both flood control and water resources development. The proposed dams are the Kuantan, Upper Sinamar and Sukam dams.

(3) Applicable Measures and Structures

To achieve the project purposes mentioned above, the following measures and structures are taken into consideration.

(a) Flood Control

- Kuantan Dam
- Upper Sinamar Dam
- Sukam Dam
- Indragiri River Improvement Works
- Gaung Floodway
- Indragiri Retarding Basin

Gaung Floodway was planned under the Sumatra Canalization Project and it is incorporated into the project with the capacity of 500 m^3/s as a given condition.

(b) Water Supply for Irrigation and Maintenance Flow

- Kuantan Dam
- Upper Sinamar Dam
- Sukam Dam
- Lubukjambi Intake Weir

(c) Hydropower Generation

- Kuantan Dam
- Upper Sinamar Dam
- Sukam Dam

(4) Design Scale for Flood Control

The design scale for flood control by phase and by area have been determined in SECTOR VI as follows:

Phase	Area	Design Scale (Return Period)
Final	Urban	50-year
	Rural	50-year
Initial	Urban	10-year
	Rural	5-year

(5) Standard Flood Discharge at Kuantan Dam

Standard flood discharges are set as below in accordance with the results of flood runoff analysis.

Design Scale	Standard Flood Discharge (m^3/s)
50-year Return Period	6,550
5-year Return Period	3,900

(6) Irrigation Water Requirements

Irrigation water requirements were calculated for 5-year return period through simulation for 12 years from 1981-92. Details are presented in SECTOR VIII, WATER RESOURCES DEVELOPMENT PLAN.

(7) Necessary Reservoir Capacity for Irrigation, River Maintenance Flow and Sedimentation

Necessary reservoir capacity for irrigation, river maintenance flow and sedimentation has been determined in SECTOR VIII, WATER RESOURCES DEVELOPMENT PLAN. The results are summarized in the table below.

Unit: $10^6 m^3$

Case	Kuantan Dam	Upper Sinamar Dam	Sukam Dam
No. 1	Irrigation: 213 Maintenance Flow: 117 Dead Storage: 425 Gross Storage: 755	---	---
No. 2	Irrigation: 145 Maintenance Flow: 117 Dead Storage: 425 Gross Storage: 687	Irrigation: 68 Maintenance Flow: 0 Dead Storage: 97 Gross Storage: 165	---
No. 3	Irrigation: 132 Maintenance Flow: 117 Dead Storage: 425 Gross Storage: 674	---	Irrigation: 203 Maintenance Flow: 0 Dead Storage: 27 Gross Storage: 230

(8) Flood Control Method

As discussed later, flood control capacity has not been given to the Upper Sinamar and Sukam dams. The flood control method for Kuantan Dam is accordingly discussed below.

The flood control method is broadly divided into gate controlled type and non-gated type. The gate controlled type is applied to Kuantan Dam to effectively utilize the reservoir capacity and to realize different capacity allocation for rainy and dry seasons in the Initial Phase.

(a) Control Method

Constant rate discharging method (refer to Fig. XI.2.3) was applied. In this method, inflow is discharged without control unless the inflow exceeds the control starting discharge. When the inflow exceeds the control starting discharge, outflow calculated by multiplying inflow by the constant rate is released. This is applied until the peak inflow hydrograph occurs. After the inflow peak, constant discharge is released unless a higher peak occurs.

(b) Control Starting Discharge

Control starting discharge is generally determined considering actual discharges during rainy season and flow capacity of the downstream channel. The monthly average discharge at Kuantan Dam in December, the month with the highest average discharge, is 328 m^3/s. If the control starting discharge is set close to this discharge, frequent operation is needed for minor floods. The flow capacity of the present channel of the Kuantan River is about 1,000 m^3/s. If the discharge exceeds this amount, inundation occurs. In due consideration of the above conditions, the control starting discharge for the flood control at Kuantan Dam is set at 500 m^3/s.

The relation between flood control capacity and maximum release is plotted in Fig. XI.2.4. This relationship was obtained by adopting various constant rates with control starting discharge of 500 m^3/s to the basic project flood of 50-year return period.

2.2.2 Alternative Cases

Parameter and variables for alternative cases have been identified by structure as summarized below. Alternative cases were prepared by the combination of dams to be developed, variation of surcharge water level (S.W.L.) and capacity allocation, as presented in Table XI.2.3.

(1) Kuantan Dam

The following conditions were considered to formulate alternative cases:

(a) Topographical Maximum S.W.L.

The topograhical maximum S.W.L. is set at EL 125.0 m.

(b) Alternative Cases of S.W.L.

Five alternative cases of S.W.L. have been studied. They are EL 125.0, EL 122.5, EL 120.0, EL 117.5 and EL 115.0 m.

(c) Allocation of Storage Capacity

Firstly, the capacity necessary for irrigation, river maintenance and sedimentation was allocated from the gross storage capacity. The remaining capacity was subsequently allocated to flood control and hydropower generation considering several combinations. These combinations include the allocation of all the remaining capacity to flood control or to hydropower generation.

(2) Upper Sinamar Dam

The following conditions were considered to formulate alternative cases:

(a) Allocation of Storage Capacity

Since the available reservoir capacity is relatively small at 68×10^6 m^3 compared to the catchment area, and the effect of the peak cut to flood control of the objective area is small. In the study on alternatives, reservoir capacity was used only for the irrigation water supply and hydropower was generated by water released for irrigation water supply.

(b) Normal Water Level

As discussed in SECTOR VIII, WATER RESOURCES DEVELOPMENT PLAN, the normal water level (N.W.L.) is set at EL 481.8 m.

(3) Sukam Dam

The following conditions were considered to formulate alternative cases:

(a) Allocation of Storage Capacity

The catchment area at Sukam damsite is 360 km^2 and this corresponds to only 5.6% of the entire catchment area of Kuantan Dam at 6,377 km^2. The effect of peak cut in the Sukam River is accordingly small. In the study on alternatives, reservoir capacity of Sukam Dam were used only for the irrigation water supply. Hydropower was generated by water released for irrigation water supply.

(a) Normal Water Level

As discussed in SECTOR VIII, WATER RESOURCES DEVELOPMENT PLAN, the normal water level (N.W.L.) is set at EL 216.0 m.

(4) River Improvement Works

Design discharge for river improvement in the downstream stretch has been calculated based on the flood control capacity of Kuantan Dam.

2.2.3 Cost and Benefit Comparison

Cost and benefits have been calculated and Net Present Value (B-C) and Benefit-Cost Ratio (B/C) were obtained accordingly. The calculation results are presented in Table XI.2.4 and the calculation procedure is as discussed below.

(1) Cost

(a) Dam

Applied is the dam crest elevation versus cost curve in SEXTOR XII, DAM ENGINEERING.

(b) River Improvement

The improvement cost for Kuantan-Indragiri River was calculated by stretch; namely the upper stretch (Lubukjambi-Peranap), middle stretch (Peranap-Japura), and lower stretch (Japura-River Mouth). The relation between cost and design discharge was plotted, as shown in Fig. XI.2.5.

(c) Hydropower Generation Facilities

Applied are the results presented in SECTOR XII, DAM ENGINEERING.

(2) Benefit

(a) Flood Control

Annual average damage reduction has been calculated at Rp. 165×10^9 (for details, refer to SECTOR XVI, ECONOMIC EVALUATION).

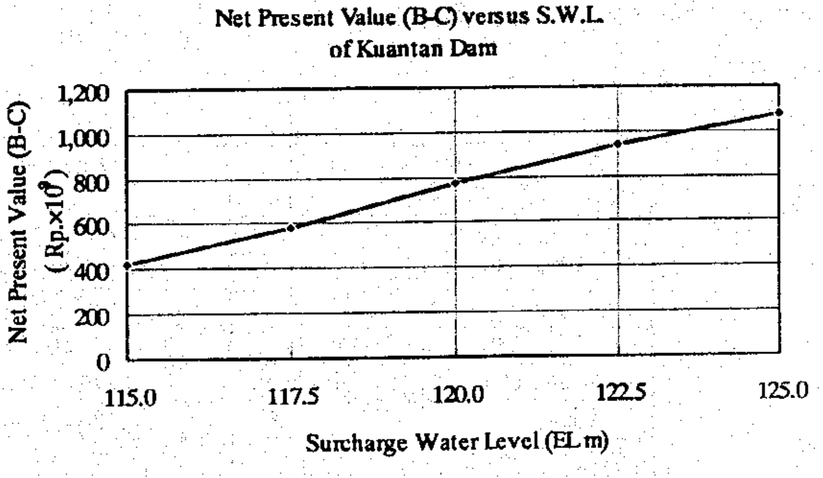
(b) Hydropower Generation

Values of 90% dependable power and annual generated energy for each case are as presented in Table XI.2.4. Annual benefit was calculated based on the following unit rates:

Particulars		Annual Benefit
kW Value	≤ 50 MW	Rp. 691,955/kW (US$318.14/kW × Rp. 2,175/US$)
	< 50 MW	Rp. 851,861/kW (US$391.66/kW × Rp. 2,175/US$)
kWh value		Rp. 38.715/kWh (US$0.0178/kWh × Rp. 2,175/US$)

(c) Net Present Value (B-C) and Benefit Cost Ratio (B/C)

Net Present Value (B-C) and Benefit Cost Ratio (B/C) were calculated accordingly, as shown in Table XI.2.4. Net Present Value (B-C), together with cost and benefit, was plotted against the flood control capacity of the Kuantan Dam for each case of surcharge water level (refer to Fig. XI.2.6). Alternative Case No. K-1-6 shows the highest Net Present Value. This case uses Kuantan Dam only with S.W.L. of EL 125.0 m and flood control and hydropower generation capacities of 400 and 945×10^6 m^3, respectively. The highest Net Present Value in each case of Surcharge Water Level was plotted as illustrated below.



2.2.4 Optimum Plan

As illustrated above, the Net Present Value is higher when the surcharge water level is higher. Consideration should be given, however, to the fact that transmigration areas Timpeh IV and V of West Sumatra Province are located in the southern part of the Kuantan Reservoir.

Timpeh IV and V are completely submerged if surcharge water level is set at EL 125 m. The following table shows the number of houses in the transmigration area to be submerged by the reservoir for three cases of surcharge water level.

Surcharge Water Level	Number of Houses to be Submerged		
	Timpeh IV	Timpeh V	Total
EL 115 m	0	0	0
EL 120 m	92	0	92
EL 125 m	147	378	525

From the engineering point of view, surcharge water level below EL 120.0 m, namely EL 117.5 m or EL 115.0 m, is less attractive especially when the effect of the initial phase of the project, namely the effect with only Kuantan Dam for flood control, is considered. Hence, the case having the surcharge water level of EL 120.0 m was finally selected.

An enlarged plot of B-C and B/C together with cost and benefit value in the case with surcharge water level of EL 120.0 m is shown in Fig. XI.2.7. As illustrated, the case with the flood control capacity of 400×10^6 m^3 gives the highest B-C and B/C. Hence, the case with the flood control capacity of 400×10^6m^3 at S.W.L. of EL 120.0 m was finally selected.

Major features of the Overall Development Plan for Indragiri River Development Project have been accordingly determined as below. Reservoir capacity allocation for the Kuantan Dam is presented in Fig. XI.2.8.

(1) Kuantan Dam

Particulars	Description
Capacity Allocation	
Flood Control	400×10^6 m^3
Hydropower Generation	415×10^6 m^3
Irrigation	117×10^6 m^3
River Maintenance Flow	213×10^6 m^3
Dead Storage (incl. sediment)	425×10^6 m^3
Total	$1{,}570\times10^6$ m^3
Water Level	
Surcharge Water Level	EL 120.0 m
Normal Water Level	EL 115.2 m
Low Water Level	EL 102.0 m
Flood Control	
Control Method	Constant rate discharging
Control Starting Discharge	500 m^3/s
Constant Rate	0.440

(2) River Improvement Works

Particulars	Description
Kuantan-Indragiri River	
Kuantan Dam - Peranap	3,200 m^3/s
Peranap - Japura	5,400 m^3/s
Japura - River Mouth *	5,050 m^3/s

* Indragiri Retarding Basin and Gaung Floodway are considered.

CHAPTER 3 FEASIBILITY STUDY

3.1 Optimization of Reservoir Allocation of Kuantan Dam for Initial Phase

Kuantan Dam is to be constructed in the initial phase of the Indragiri River Development Project at the scale determined in the Overall Development Plan. Presented in this chapter is the operation of Kuantan Dam for the period until the downstream river improvement is completed.

3.1.1 Basic Conditions

Each component of the Kuantan River Multipurpose Development Project was studied under the following conditions.

(1) Flood Control

In the initial phase, irrigation development is to be carried out in the left bank upstream area as mentioned in (2) Irrigation Development below. Accordingly, the irrigation development area is the objective flood control area in the initial phase. The design scale was set at 5-year return period because this area is a rural area.

In the case of a 5-year return period project flood and flood control operation as determined for the Overall Development Plan is conducted, the peak discharge of 3,900 m^3/s is reduced to 2,000 m^3/s as shown in Fig. XI.3.1. Since the discharge of 2,000 m^3/s exceeds the flow capacity of the present channel of the Kuantan River along the irrigation development area, countermeasures are accordingly needed as discussed in Section 3.2.

(2) Irrigation Development

In the initial phase, the left bank upstream area of the Lubukjambi Irrigation System is to be developed. This area is on the left bank of the Kuantan River from Lubukjambi to Kampung Baru (near Cerenti). The reservoir capacity for water supply to this area is $4\times10^6 m^3$ only and the remaining capacity in the Overall Development Plan is allocated for other purposes (refer to Fig. XI.3.2).

(3) Hydropower Generation

In the initial phase, hydropower generation is considered to be subsidiary to flood control and irrigation development.

3.1.2 Study on Alternative Cases

The following two alternative cases have been studied and the optimum plan was selected.

Case 1	A part of the storage capacity for hydropower generation at Kuantan Dam is used for flood control during rainy season. The peak of a 5-year return period flood is reduced to the discharge of 1,000 m^3/s that will not cause damage to the objective flood control area, and no river improvement works are implemented.
Case 2	River improvement works are implemented in the Kuantan River. The design discharge is 2,000 m^3/s, the maximum release when a 5-year return period project flood occurs, and flood control operation as determined for the Overall Development Plan is conducted.

The study for the two alternative cases above is discussed more in detail below.

(1) Case 1

In the initial phase, a part of the storage capacity for hydropower generation at Kuantan Dam is used for flood control during rainy season. The rainy season period and flood control method were determined, and the reduction of hydropower benefit was subsequently calculated.

(a) Period of Rainy Season

In accordance with the daily average discharge records of the Kuantan River at Lubukkambacang for a 17-year period, discharges exceeding 1,500 m^3/s occurred in the six months period from October to March as shown in the table below. Accordingly, the rainy season considered for this area is the six months period from October to March.

Year	Month	Discharge (m^3/s)
1978	Dec.	2,150
1986	Jan.	3,950
1986	Mar.	2,700
1987	Oct.	2,050

Year	Month	Discharge (m^3/s)
1987	Nov.	1,650
1989	Jan.	3,200
1991	Dec.	1,875
1992	Dec.	2,375

(b) Flood Control Method

The present flow capacity of the Kuantan river channel in the stretch from Lubukkambacang to Kampung Baru (near Cerenti) is approximately 1,000 m^3/s. Accordingly, the flood control operation in the initial phase is to reduce the peak discharge of 3,900 m^3/s of 5-year return period to the maximum release of 1,000 m^3/s. The constant rate discharging method, the flood control method used in the Overall Plan, is adopted. As shown in Fig. XI.3.1, the necessary capacity and flood control features of Kuantan Dam are as given below.

Particulars	Value
Flood Control Capacity	$793 \times 10^6 m^3$
Control Starting Discharge	500 m^3/s
Constant Rate	0.147
Maximum Release	1,000 m^3/s

(c) Capacity Allocation and Water Level

In the initial phase, capacity allocation and water levels of Kuantan Dam are determined as tabulated below.

Unit: $10^6 m^3$

Capacity	Allocation	
	Dry Season (April-September)	Rainy Season (October-March)
Flood Control	400	793
Hydropower Generation	528	135
Irrigation	4	4
River Maintenance	213	213
Dead Storage	425	425
Gross Storage	1,570	1,570

Particulars	Water Level
Surcharge Water Level	EL 120.0 m
Normal Water Level	EL 115.2 m
Restricted Water Level in Rainy Season	EL 109.5 m
Low Water Level	EL 102.0 m

(d) Effect on Hydropower Generation

In the initial phase, a part of the storage capacity for hydropower generation at Kuantan Dam is used for flood control during rainy season. The output and generated energy calculated in SECTOR IX, HYDROPOWER DEVELOPMENT PLAN, are summarized below.

Particulars	Unit	Overall Plan	Initial Phase
Output (90% Dependable)	MW	103.6	94.4
Annual Generated Energy	GWh	657.0	583.4
Annual Benefit	Rp. 10^9	97.1	87.9

The reduction of annual benefit due to introduction of restricted water level during rainy season is accordingly calculated at Rp. 9.2 billion (Rp. 97.1 billion minus Rp. 87.9 billion).

The present value of the annual benefit has been calculated at Rp. 91.2×10^9 considering a capital recovery factor of 0.1009 (interest rate of 10% and project life of 50-year).

(2) Case 2

In Case 2, river improvement works are implemented in the Kuantan River to protect the objective flood control area. When a 5-year return period project flood occurs and flood control operation as determined for the Overall Development Plan is conducted, the maximum release is 2,000 m^3/s as stated before, and the design discharge for the river improvement is, accordingly, 2,000 m^3/s.

The cost of river improvement works for the Kuantan river stretch from Lubukkambacang to Kampung Baru (near Cerenti) was obtained from Fig. XI.2.4 considering the length of the stretch. Since the improvement cost for the stretch of Lubukjambi-Peranap with a length of 105.8 km is Rp. 400 billion, the cost for Lubukjambi-Kampung Baru with the length of 90.4 km is accordingly calculated at Rp. 342 billion.

3.1.3 Optimum Plan

From the study mentioned above, the present value of cost and benefit reduction were compared as shown in the table below. Accordingly, Case 1 is selected as the optimum plan. Capacity allocation for Kuantan Dam in the initial phase is as presented in Fig. XI.3.3.

Case No. / Explanation	Value
Case 1: (Reduction of Hydropower Generation Benefit)	Rp. 91.2×10^9
Case 2: (River Improvement Cost)	Rp. 342.0×10^9

3.2 Cost Allocation for Kuantan Dam

3.2.1 General

Kuantan Dam is a multipurpose structure for flood control, hydropower generation, irrigation water supply and river maintenance flow supply. It is to be constructed in the initial phase of the Kuantan Multipurpose Development Project. It is necessary to allocate the cost among these uses to fix the prices of power and to determine the contribution required of flood mitigation beneficiaries. Since flood control and river maintenance flow supply are considered to be under the jurisdiction of River , the purpose has been grouped as follows:

River	Flood control and river maintenance flow supply
Hydropower	Hydropower generation
Irrigation	Irrigation

In this section, the construction cost of the Kuantan Dam has been allocated to each purpose.

3.2.2 Method of Allocation

The most commonly applied allocation method is *the remaining-benefits and alternative justifiable-expenditure method.* This method is applied for the present Study. The outline of the method is as follows:

(1) Principles of Cost Allocation

- Cost for common use facilities is to be allocated to each purpose based on the determined allocation rate.
- Costs of facilities which are used exclusively for a single project function are to be borne by that function.

(2) Remaining-benefits and Alternative Justifiable-Expenditure Method

- Separable costs of costs for common use facilities for a single function are to be borne by that function.
- Joint costs (total cost less the sum of separable costs) are assumed to be distributed in accordance with the amount of remaining benefits. The remaining benefits are the difference between the lesser value of alternate single purpose cost or justifiable expenditure and the separable costs and exclusive-use facility costs.
- The allocation rate is the ratio of the total amount of the above two items to the total cost.

(3) Interest Rate and Project Life

Interest rate and project life have been set at 10% and 50 years, respectively.

3.2.3 Cost Allocation Calculation

The procedure of calculation is shown in Table XI.3.1 and summarized below.

(1) Capacity Allocation

The reservoir capacity allocation in the initial phase is as follows:

Unit: $10^6 m^3$

Capacity	Allocation	
	Dry Season (April-September)	Rainy Season (October-March)
Flood Control	400	793
Hydropower Generation	528	135
Irrigation	4	4
River Maintenance	213	213
Dead Storage	90	90
Sedimentation	335	335
Gross Storage	1,570	1,570

(2) Identification of Purpose

As stated previously, the purpose has been grouped as follows:

River	Flood control and river maintenance flow supply
Hydropower	Hydropower generation and dead storage
Irrigation	Irrigation

The reason of allocating dead storage capacity to hydropower generation is to maintain a higher reservoir water level for the benefit of hydropower generation.

(3) Alternate Single-purpose Cost

Alternate single-purpose costs have been calculated for the purposes of river and irrigation as follows:

(a) River

Necessary capacity is as follows:

Unit: $10^6 m^3$

Purpose	Capacity
Flood Control	793
River Maintenance Flow	213
Sedimentation	335
Total	1,341

The crest elevation of the alternate single-purpose dam with a capacity of $1,341 \times 10^6 m^3$ is obtained from dam crest elevation versus reservoir capacity curve presented in SECTOR XII, DAM ENGINEERING. It is EL 119.4 m. The construction cost is subsequently obtained at Rp. 253×10^9 through the dam crest elevation versus construction cost curve presented in the same sector report.

(b) Irrigation

Necessary capacity is as follows:

Unit: $10^6 m^3$

Purpose	Capacity
Irrigation	4
Sedimentation *	168
Total	172

* 50-year sedimentation is considered.

The crest elevation of EL 93.5 m and the construction cost of Rp. 180×10^9 have been obtained by the same procedure as the case for River above.

(4) Justifiable Expenditure

Justifiable expenditures have been calculated for the purposes of River, Hydropower and Irrigation as follows:

(a) River

Justifiable expenditure of the river consists of those for flood control and river maintenance flow supply. It is Rp. 512.9×10^9 (Rp. 300.9×10^9 + Rp. 212.0×10^9), as follows:

(i) Flood Control

Annual Benefit	Rp. 30.8×10^9
Annual Operation and Maintenance Cost (0.5% of Total Construction Cost)	Rp. 0.44×10^9
Capital Recovery Factor	0.1009
Justifiable Expenditure	Rp. 301×10^9

(ii) River Maintenance Flow

Justifiable expenditure of river maintenance flow has been calculated as the alternate cost. Necessary capacity is as follows:

Unit: $10^6 m^3$

Purpose	Capacity
River Maintenance Flow	213
Sedimentation	335
Total	548

The crest elevation of EL 106.7 m and the construction cost of Rp. 212×10^9 have been obtained.

(b) Hydropower Generation

Justifiable expenditure of hydropower generation has been calculated as follows:

90% Dependable Power	94.4 MW
Annual Generated Energy	583.4 GWh
Annual Benefit	Rp. 87.9×10^9
Annual O&M Cost	Rp. 0.44×10^9
Justifiable Expenditure	Rp. 867.2×10^9

(c) Irrigation

Justifiable expenditure of the irrigaiton has been calculated as follow (for detail, see Table XI.3.1):

Total Irrigation Area	5,234 ha
Annual Benefit	Rp. 8.22×10^9
Annual O&M cost	Rp. 0.44×10^9
Justifiable Expenditure	Rp. 77.1×10^9

(5) Separable Cost

Separable costs for a single function have been calculated as the total project cost less the estimated cost with that function omitted, as follows:

Unit: 10^9 Rp.

Purpose	Separable Cost
River	51.0
Hydropower	12.0
Irrigation	1.0

(6) Rate of Allocation

The rates of allocation have been accordingly determined as follows (for calculation detail, refer to Table XI.3.1):

Unit: %

Purpose	Rate of Allocation
River	35.2
Hydropower	58.4
Irrigation	6.4

TABLES

XI MULTIPURPOSE DEVELOPMENT PLAN

Table XI.2.1 ALTERNATIVE CASE FOR KAMPAR AND KAMPAR KIRI RIVER DEVELOPMENT PROJECT

	Reservoir Capacity				Design Discharge for River Improvement				
	Kiri No. 1		Kiri No. 2		Kiri No.1 - Lipat Kain	Kiri No.2 - Lipat Kain	Kampar Kiri	Langgam - Kerinci	Kerinci-River Mouth
Case	Purpose	Capacity	Purpose	Capacity	Design Q	Design Q	Design Q	Design Q	Design Q
		$10^6 m^3$		$10^6 m^3$	m^3/s	m^3/s	m^3/s	m^3/s	m^3/s
No. 1	F.C.	0	F.C.	0	1,630	1,240	3,100	6,800	7,050
	H.C.	646	H.C.	438					
	D.C.	1,350	D.C.	1,612					
	G.C.	1,996	G.C.	2,050					
No. 2	F.C.	100	F.C.	40	690	450	2,500	5,500	5,750
	H.C.	646	H.C.	438					
	D.C.	1,350	D.C.	1,612					
	G.C.	2,096	G.C.	2,090					
No. 3	F.C.	200	F.C.	50	450	370	1,700	5,050	5,300
	H.C.	646	H.C.	438					
	D.C.	1,350	D.C.	1,612					
	G.C.	2,196	G.C.	2,100					
No. 4	F.C.	250	F.C.	150	350	170	1,450	4,850	5,100
	H.C.	646	H.C.	438					
	D.C.	1,350	D.C.	1,612					
	G.C.	2,246	G.C.	2,200					
No. 5	F.C.	300	F.C.	200	250	80	1,450	4,850	5,100
	H.C.	646	H.C.	438					
	D.C.	1,350	D.C.	1,612					
	G.C.	2,296	G.C.	2,250					

Note:		
	F.C.:	Flood Control Capacity
	H.C.:	Hydropower Capacity
	D.C.:	Dead Storage Capacity
	G.C.:	Gross Storage Capacity

Table XI.2.2 COST CALCULATION BY DAM–RIVER IMPROVEMENT COMBINATION FOR KAMPAR AND KAMPAR KIRI RIVER DEVELOPMENT PROJECT

	Dam and Reservoir							River Improvement											
	Kiri No. 1			Kiri No. 2			Total Cost	Kiri No.1 – Lipat Kain		Kiri No.2 – Lipat Kain		Kampar Kiri		Langgam – Kerinci		Kerinci–River Mouth		Total Cost	Total Cost
Case	Purpose	Capacity	Cost	Purpose	Capacity	Cost		Design Q	Cost	Design Q	Cost	Design Q	Cost	Design Q	Cost	Design Q	Cost		
		$10^6 m^3$	10^9 Rp		$10^6 m^3$	10^9 Rp	10^9 Rp	m^3/s	10^9 Rp	m^3/s	10^9 Rp	m^3/s	10^9 Rp	m^3/s	10^9 Rp	m^3/s	10^9 Rp	10^9 Rp	10^9 Rp
No. 1	F.C.	0	–	F.C.	0		–	1,630	68	1,240	0	3,100	130	6,800	650	7,050	385		
	H.C.	646	–	H.C.	438		–												
	D.C.	1,350	–	D.C.	1,612		–												
	G.C.	1,996	373	G.C.	2,050	183	556		68		0		130		650		385	1,233	1,789
No. 2	F.C.	100	–	F.C.	40		–	690	18	450	0	2,500	115	5,500	601	5,750	340		
	H.C.	646	–	H.C.	438		–												
	D.C.	1,350	–	D.C.	1,612		–												
	G.C.	2,096	378	G.C.	2,090	192	570		18		0		115		601		340	1,074	1,644
No. 3	F.C.	200	–	F.C.	50		–	450	0	370	0	1,700	85	5,050	575	5,300	315		
	H.C.	646	–	H.C.	438		–												
	D.C.	1,350	–	D.C.	1,612		–												
	G.C.	2,196	384	G.C.	2,100	193	577		0		0		85		575		315	975	1,552
No. 4	F.C.	250	–	F.C.	150		–	350	0	170	0	1,450	72	4,850	563	5,100	302		
	H.C.	646	–	H.C.	438		–												
	D.C.	1,350	–	D.C.	1,612		–												
	G.C.	2,246	388	G.C.	2,200	196	584		0		0		72		563		302	937	1,521
No. 5	F.C.	300	–	F.C.	200		–	250	0	80	0	1,450	72	4,850	563	5,100	302		
	H.C.	646	–	H.C.	438		–												
	D.C.	1,350	–	D.C.	1,612		–												
	G.C.	2,296	391	G.C.	2,250	200	591		0		0		72		563		302	937	1,528

Note: F.C.: Flood Control Capacity
H.C.: Hydropower Capacity
D.C.: Dead Storage Capacity
G.C.: Gross Storage Capacity

Table XI.2.3 ALTERNATIVE CASE FOR INDRAGIRI RIVER DEVELOPMENT PROJECT

Case	Dam	S.W.L.	Storage Capacity						N.W.L.	Design Discharge		
			Gross	Flood Control	Hydropower	Irrigation	Maintenance Flow	Dead		Lubuk Jambi-Peranap	Peranap-Japura	Japura-Mouth
		EL.m	10^6 m^3	10^6 m^3	10^6 m^3	10^6 m^3	10^6 m^3	10^6 m^3	EL.m	m^3/s	m^3/s	m^3/s
K-1-1	Kuaman	125.0	2,100	1,345	0	117	213	425	108.8	1,260	4,570	4,180
K-1-2			2,100	1,200	145	117	213	425	111.4	1,520	4,670	4,290
K-1-3			2,100	1,000	345	117	213	425	114.2	1,910	4,840	4,470
K-1-4			2,100	816	529	117	213	425	116.7	2,280	4,990	4,620
K-1-5			2,100	600	745	117	213	425	119.3	2,720	5,180	4,820
K-1-6			2,100	400	945	117	213	425	121.3	3,160	5,360	5,010
K-1-7			2,100	200	1,145	117	213	425	123.2	4,420	5,890	5,570
K-1-8			2,100	0	1,345	117	213	425	125.0	6,550	6,780	6,500
K-2-1	Kuaman	122.5	1,820	1,065	0	117	213	425	108.8	1,780	4,780	4,400
K-2-2			1,820	1,000	65	117	213	425	110.0	1,910	4,840	4,470
K-2-3			1,820	816	249	117	213	425	112.9	2,280	4,990	4,620
K-2-4			1,820	600	465	117	213	425	115.8	2,720	5,180	4,820
K-2-5			1,820	400	665	117	213	425	118.3	3,160	5,360	5,010
K-2-6			1,820	200	865	117	213	425	120.6	4,420	5,890	5,570
K-2-7			1,820	0	1,065	117	213	425	122.5	6,550	6,780	6,500
K-3-1	Kuaman	120.0	1,570	815	0	117	213	425	108.8	2,280	4,990	4,620
K-3-2			1,570	600	215	117	213	425	112.4	2,720	5,180	4,820
K-3-3			1,570	400	415	117	213	425	115.2	3,160	5,360	5,010
K-3-4			1,570	200	615	117	213	425	117.8	4,420	5,890	5,570
K-3-5			1,570	0	815	117	213	425	120.0	6,550	6,780	6,500
K-4-1	Kuaman	117.5	1,350	595	0	117	213	425	108.7	2,740	5,190	4,830
K-4-2			1,350	400	195	117	213	425	112.1	3,160	5,360	5,010
K-4-3			1,350	200	395	117	213	425	114.8	4,420	5,890	5,570
K-4-4			1,350	0	595	117	213	425	117.5	6,550	6,780	6,500
K-5-1	Kuaman	115.0	1,160	405	0	117	213	425	108.8	3,160	5,360	5,010
K-5-2			1,160	200	205	117	213	425	112.3	4,420	5,890	5,570
K-5-3			1,160	0	405	117	213	425	115.0	6,550	6,780	6,500
K-Sn	Kuaman	120.0	1,570	468	415	49	213	425	107.8	3,000	5,290	4,940
	Up.Sinamar			0	0	68		93	481.8	–	–	–
K-Sk	Kuaman	120.0	1,570	481	415	36	213	425	107.5	2,980	5,290	4,940
	Sukam			0	0	203		19	216.0	–	–	–

Table XI.2.4 B-C AND B/C CALCULATION FOR ALTERNATIVE CASES OF INDRAGIRI RIVER DEVELOPMENT PROJECT

Case	Dam	S.W.L.	Reservoir Capacity			Cost (Construction Base Cost + Compensation)							Benefit				B-C	B/C
			Gross	Flood	Hydropower	Dam	River Improvement Lubuk Jambi-Peranap	River Improvement Peranap-Japura	River Improvement Japura-	River Improvement Total	Power Station	Total C	Flood Annual	Hydropower Annual	Total Annual	Present Value B		
		EL.m	10^6m^3	10^6m^3	10^6m^3 EL m *1	*2 10^9Rp	m^3/s *3 10^9Rp	m^3/s *3 10^9Rp	m^3/s *3 10^9Rp	10^9Rp	10^9Rp	10^9Rp	10^9Rp	MW GWh 10^9Rp	10^9Rp	10^9Rp	10^9Rp	
K-1-1	Kuantan	125.0	2,100	1,345	0 (WL.108.8m)	290	1,260 178.4	4,570 478.9	4,180 286.5	943.8	107	1,340.8	165.13	38.5 315.3 45.00	210.14	2,083.5	742.7	1.55
K-1-2	Kuantan		2,100	1,200	145 (WL.111.4m)	290	1,520 326.7	4,670 487.0	4,290 288.1	1,101.8	135	1,526.8	165.13	69.7 498.9 67.54	232.68	2,306.9	780.2	1.51
K-1-3	Kuantan		2,100	1,000	345 (WL.114.2m)	290	1,910 433.9	4,840 500.6	4,470 290.7	1,225.3	162	1,677.3	165.13	95.7 620.8 90.26	255.39	2,532.1	854.9	1.51
K-1-4	Kuantan		2,100	816	529 (WL.116.7m)	290	2,280 483.0	4,990 512.7	4,620 292.9	1,288.6	188	1,766.6	165.13	116.7 700.5 107.87	273.00	2,706.8	940.2	1.53
K-1-5	Kuantan		2,100	600	745 (WL.119.3m)	290	2,720 523.3	5,180 521.4	4,820 295.8	1,340.4	221	1,851.4	165.13	139.1 765.1 125.87	291.00	2,885.2	1,033.8	1.56
K-1-6	Kuantan		2,100	400	945 (WL.121.3m)	290	3,160 565.9	5,360 529.4	5,010 298.5	1,393.7	253	1,936.7	165.13	155.7 800.9 138.74	303.88	3,012.9	1,076.1	1.56
K-1-7	Kuantan		2,100	200	1,145 (WL.123.2m)	290	4,420 717.1	5,890 552.2	5,570 303.3	1,572.6	281	2,143.6	165.13	166.6 830.5 147.43	312.56	3,099.0	955.4	1.45
K-1-8	Kuantan		2,100	0	1,345 (WL.125.0m)	290	6,550 968.2	6,780 596.8	6,500 312.9	1,878.0	292	2,460.0	165.13	175.0 855.3 154.20	319.34	3,166.2	706.2	1.29
K-2-1	Kuantan	122.5	1,820	1,065	0 (WL.108.8m)	277	1,780 398.2	4,780 495.8	4,400 289.8	1,183.8	107	1,567.8	165.13	38.5 315.3 45.00	210.14	2,083.5	515.7	1.33
K-2-2	Kuantan		1,820	816	249 (WL.112.9m)	277	2,280 483.0	4,990 512.7	4,620 292.9	1,288.6	147	1,712.6	165.13	83.9 567.6 80.03	245.16	2,430.7	718.2	1.42
K-2-3	Kuantan		1,820	600	465 (WL.115.8m)	277	2,720 523.3	5,180 521.4	4,820 295.8	1,340.4	178	1,795.4	165.13	108.8 675.2 101.43	266.56	2,642.9	847.4	1.47
K-2-4	Kuantan		1,820	400	665 (WL.118.3m)	277	3,160 565.9	5,360 529.4	5,010 298.5	1,393.7	208	1,878.7	165.13	130.0 743.5 118.74	283.87	2,814.5	935.8	1.50
K-2-5	Kuantan		1,820	200	865 (WL.120.6m)	277	4,420 717.1	5,890 552.2	5,570 303.3	1,572.6	243	2,092.6	165.13	149.7 789.2 134.14	299.27	2,967.2	874.6	1.42
K-2-6	Kuantan		1,820	0	1,065 (WL.122.5m)	277	6,550 968.2	6,780 596.8	6,500 312.9	1,878.0	269	2,424.0	165.13	163.3 818.6 144.69	309.82	3,071.8	647.8	1.27
K-3-1	Kuantan	120.0	1,570	815	0 (WL.108.8m)	265	2,280 483.0	4,990 512.7	4,620 292.9	1,288.6	125	1,678.6	165.13	38.5 315.3 45.00	210.14	2,083.5	404.9	1.24
K-3-2	Kuantan		1,570	600	215 (WL.112.4m)	265	2,720 523.3	5,180 521.4	4,820 295.8	1,340.4	144	1,749.4	165.13	80.1 550.0 76.72	241.85	2,397.9	648.5	1.37
K-3-3	Kuantan		1,570	400	415 (WL.115.2m)	265	3,160 565.9	5,360 529.4	5,010 298.5	1,393.7	171	1,829.7	165.13	103.6 657.0 97.12	262.25	2,600.2	770.5	1.42
K-3-4	Kuantan		1,570	200	615 (WL.117.8m)	265	4,420 717.1	5,890 552.2	5,570 303.3	1,572.6	201	2,038.6	165.13	125.4 731.1 115.08	280.21	2,778.2	739.6	1.36
K-3-5	Kuantan		1,570	0	815 (WL.120.0m)	265	6,550 968.2	6,780 596.8	6,500 312.9	1,878.0	233	2,376.0	165.13	144.5 778.5 130.13	295.26	2,927.4	551.5	1.23
K-4-1	Kuantan	117.5	1,350	595	0 (WL.108.8m)	253	2,740 525.2	5,190 521.8	4,830 295.9	1,342.9	125	1,720.9	165.13	38.5 315.3 45.00	210.14	2,083.5	362.6	1.21
K-4-2	Kuantan		1,350	400	195 (WL.112.1m)	253	3,160 565.9	5,360 529.4	5,010 298.5	1,393.7	141	1,787.7	165.13	76.8 533.9 73.81	238.94	2,369.1	581.4	1.33
K-4-3	Kuantan		1,350	200	395 (WL.114.8m)	253	4,420 717.1	5,890 552.2	5,570 303.3	1,572.6	168	1,993.6	165.13	100.6 643.7 94.53	259.66	2,574.5	580.9	1.29
K-4-4	Kuantan		1,350	0	595 (WL.117.5m)	253	6,550 968.2	6,780 596.8	6,500 312.9	1,878.0	198	2,329.0	165.13	123.1 723.4 113.19	278.32	2,759.5	430.5	1.18
K-5-1	Kuantan	115.0	1,160	405	0 (WL.108.8m)	245	3,160 565.9	5,360 529.4	5,010 298.5	1,393.7	107	1,745.7	165.13	38.5 315.3 45.00	210.14	2,083.5	337.7	1.19
K-5-2	Kuantan		1,160	200	205 (WL.112.3m)	245	4,420 717.1	5,890 552.2	5,570 303.3	1,572.6	144	1,961.6	165.13	78.1 540.2 74.96	240.09	2,380.4	418.8	1.21
K-5-3	Kuantan		1,160	0	405 (WL.115.0m)	245	6,550 968.2	6,780 596.8	6,500 312.9	1,878.0	168	2,291.0	165.13	101.8 649.0 95.57	260.70	2,584.8	293.8	1.13
K-Sn	Kuantan	120.0	1,570	468	415 (WL.104.3m)	265	3,010 551.1	5,300 526.6	4,950 297.7	1,375.4	171	1,811.4	165.13	103.6 657.0 97.12	262.25	2,600.2		
	Up.Sinamar		165 Eff. 68	0	(WL. 481.8m)	508	-	-	-	0.0	76	584.0	-	13.3 120.1 15.98	15.98	158.4	363.2	1.15
K-Sk	Kuantan	120.0	1,570	481	415 (WL.105.9m)	265	2,980 548.2	5,290 526.2	4,940 297.6	1,372.0	171	1,808.0	165.13	103.6 657.0 97.12	262.25	2,600.2		
	Sukam		230 Eff. 203	0	(WL. 216.0m) 0	138	-	-	-	0.0	73	211.0	-	11.6 44.2 11.59	11.59	114.9	696.1	1.34

Note:

US$/kW (≥50MW):	318.14
US$/kW (<50MW):	391.66
US$/kWh:	0.0178
Rp./US$:	2,175
Present Worth of An Annuity Factor (Discount Rate:10%, Project Life:50-year):	9.9148

*1: (WL. m) is Normal Water Level

*2: Crest elevation is assumed by adding 2.0 m to S.W.L.

*3: Total cost is calculated by multiplying Direct Construction Cost by 1.3

Table XI.3.1(1/2) ALLOCATION OF CONSTRUCTION COST FOR KUANTAN DAM

Particulars		Unit	Purpose			Total
			River	Hydropower	Irrigation	
Required Reservoir Capacity		10^6 m^3	1,341	225	4	1,570
Multipurpose Cost						
Sedimentation Capacity		10^6 m^3	335			
Required Capacity		10^6 m^3	1,235			
Total capacity		10^6 m^3	1,570			
Dam Crest Elevation		EL m	122.0			
Construction Cost	(a)	Rp. 10^9	300.5			
Alternate Single Purpose Cost						
Sedimentation Capacity		10^6 m^3	335	-	168	
Required Capacity		10^6 m^3	1,006	-	4	
Total capacity		10^6 m^3	1,341	-	172	
Dam Crest		EL m	119.4	-	93.5	
Construction Cost	(b)	Rp. 10^9	286.9	-	204.1	
Justifiable Expenditure	(c)	Rp. 10^9	512.9	866.8	77.1	
Lesser value of (b) and (c)	(d)	Rp. 10^9	286.9	866.8	77.1	
Exclusive use facilities cost	(e)	Rp. 10^9	0.0	202.2	0.0	
(d)-(e)	(f)		286.9	664.6	77.1	
Separable Cost						
Sediment Capacity		10^6 m^3	335	335	335	
Other Purpose Capacity		10^6 m^3	229	1,010	1,231	
Total capacity		10^6 m^3	564	1,345	1,566	
Dam Crest		EL m	107.1	119.5	121.9	
Construction Cost	(g)	Rp. 10^9	242.7	286.9	299.4	
Separable Cost [(a)-(g)]	(h)	Rp. 10^9	57.8	13.6	1.1	72.6
Remaining Benefit [(f)-(h)]	(i)	Rp. 10^9	229.1	651.0	76.0	956
Ratio of Remaining Benefit	(j)	%	24.0	68.1	7.9	100.0
Allocated Joint Cost	(k)	Rp. 10^9	54.6	155.2	18.1	228 *1
Total Allocated Cost [(h)+(k)]		Rp. 10^9	112.4	168.8	19.2	300.5
Rate of Allocation		%	37.4	56.2	6.4	100.0

Note: *1 (Multipurpose Cost)-(Total of Separable Cost)

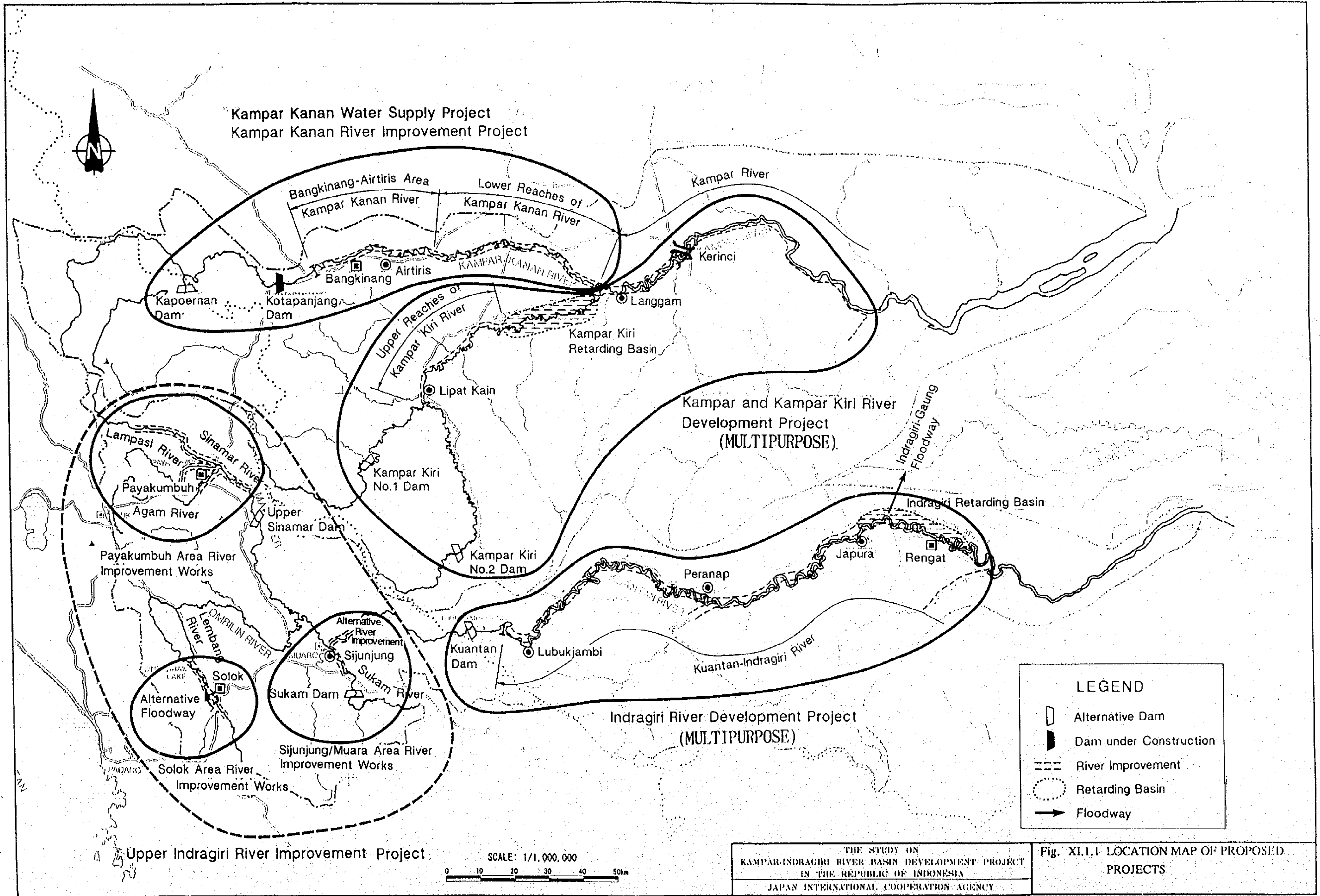
Table XI.3.1(2/2) ALLOCATION OF CONSTRUCTION COST FOR KUANTAN DAM

Breakdown of Capacity Allocation and Calculation of Justifiable Expenditure

Particulars	Unit	Value	
Catchment Area	km^2	7,453	
Capacity Allocation			
Flood Control (Rainy Season)	$10^6 m^3$	793	
Flood Control (Dry Season)	$10^6 m^3$	400	
Hydropower (Rainy Season)	$10^6 m^3$	135	
Hydropower (Dry Season)	$10^6 m^3$	528	
Irrigation	$10^6 m^3$	4	
River Maintenance	$10^6 m^3$	213	
Sedimentation	$10^6 m^3$	335	
Dead	$10^6 m^3$	90	
Sedimentation for 50-year	$10^6 m^3$	167.5	
Gross (Rainy Season)	$10^6 m^3$	1,570	
Gross (Dry Season)	$10^6 m^3$	1,570	
Dam Cost (Multipurpose Cost)	Rp. 10^9	265	
Basic Condition for Justifiable Expenditure Calculation			
Interest (i)		0.1	
Project Life (n)	Year	50	
$(1+i)^n$		117.39	
Capital Recovery Factor		0.1009	
Justifiable Expenditure for Flood Control			
Annual Benefit	Rp. 10^9	30.8	
Annual O&M Cost	Rp. 10^9	0.44	
Justifiable Expenditure	Rp. 10^9	300.9	
Justifiable Expenditure for River Maintenance Flow (Alternate Single Purpose Cost)			
Sediment Capacity	$10^6 m^3$	335	
Required Capacity	$10^6 m^3$	213	
Total capacity	$10^6 m^3$	548	
Dam Crest	EL m	106.7	
Construction Cost	Rp. 10^9	212	
Justifiable Expenditure	Rp. 10^9	212.0	
Justifiable Expenditure for Hydropower Generation			
90% Dependable Power	MW	94.4	
Annual Generated Energy	GWh	583.4	
kW value	US$/kW (>=50MW)	318.14	
kWh value	US$/kWh	0.0178	
Conversion Rate	Rp./US$	2,175	
Annual Benefit	Rp. 10^9	87.9	
Annual O&M Cost	Rp. 10^9	0.44	
Justifiable Expenditure	Rp. 10^9	866.8	
Justifiable Expenditure for Irrigation			Benefit Rate
Irrigation Area Existing 1	ha	1,670	0.3
Irrigation Area Existing 2	ha	376	0.6
Irrigation Area Existing 3	ha	2,096	1.0
Irrigation Area New	ha	5,234	1.0
Annual Unit Benefit	Rp.1000/ha	1,020.6	
Annual Benefit	Rp. 10^9	8.22	
Annual O&M Cost	Rp. 10^9	0.44	
Justifiable Expenditure	Rp. 10^9	77.1	

FIGURES

XI MULTIPURPOSE DEVELOPMENT PLAN



THE STUDY ON
KAMPAR-INDRAGIRI RIVER BASIN DEVELOPMENT PROJECT
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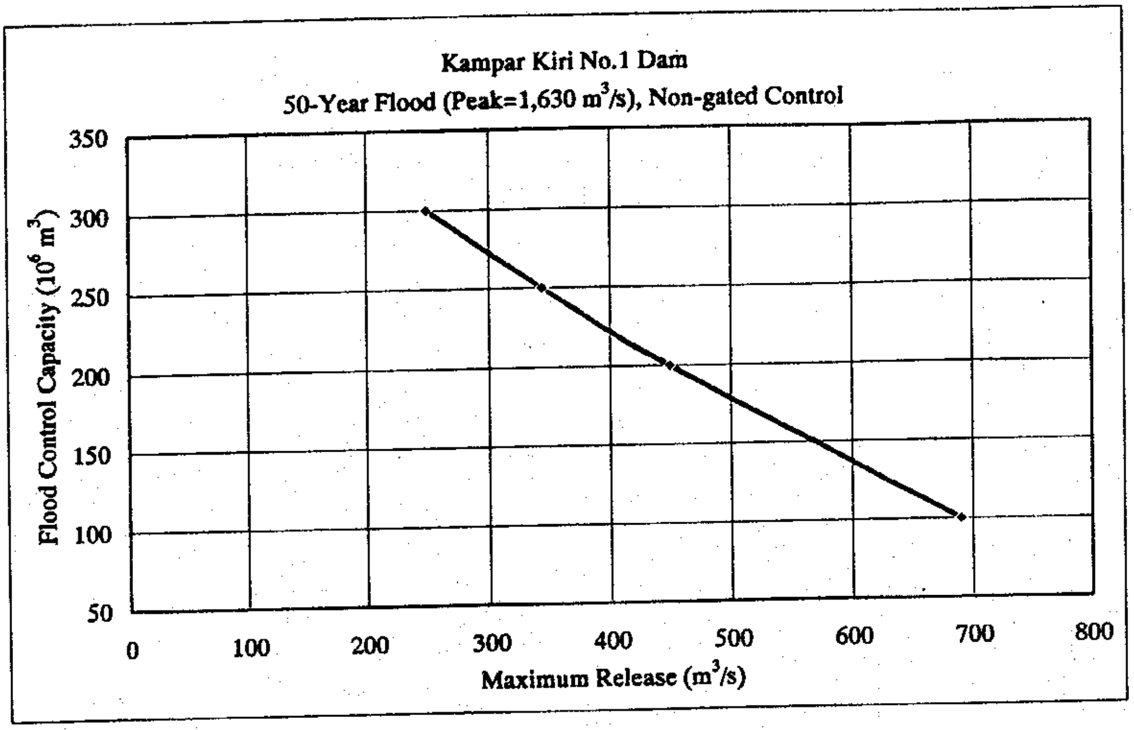
JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. XI.1.1 LOCATION MAP OF PROPOSED PROJECTS



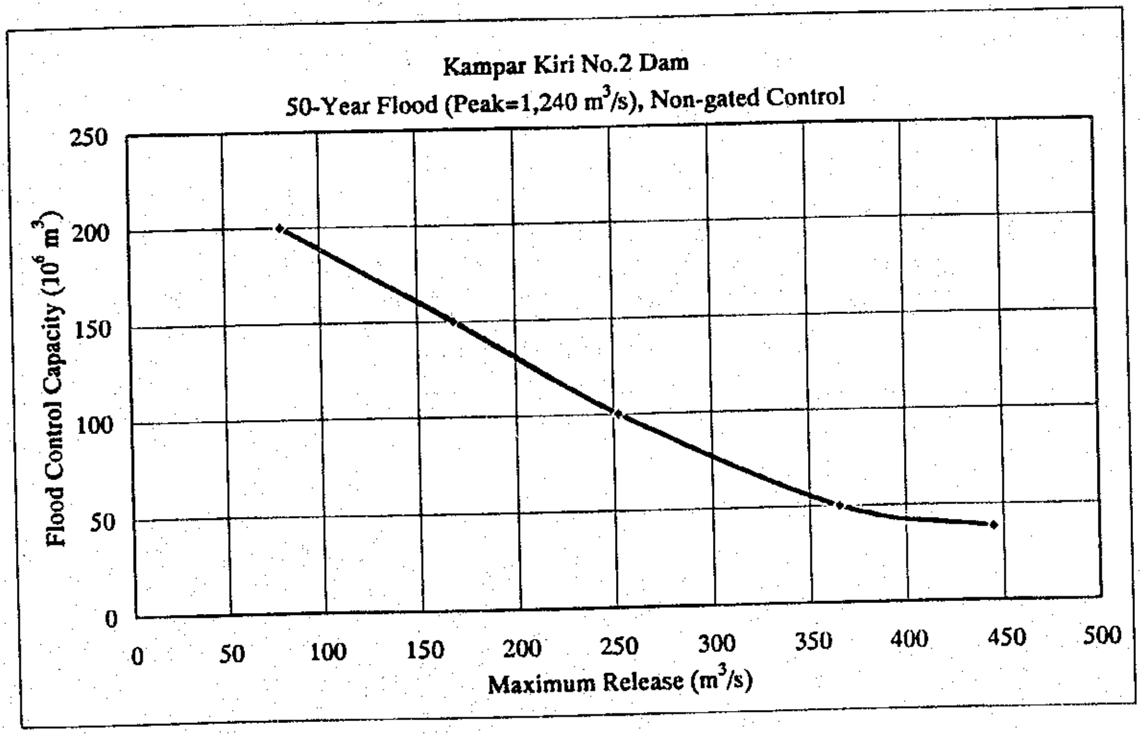


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Fig. XI.2.1 RELATION BETWEEN FLOOD CONTROL CAPACITY AND MAXIMUM RELEASE OF KAMPAR KIRI NO.1 AND NO.2 DAMS

Relation between Design Discharge and Improvement Cost
of Kampar Kiri - Kampar River

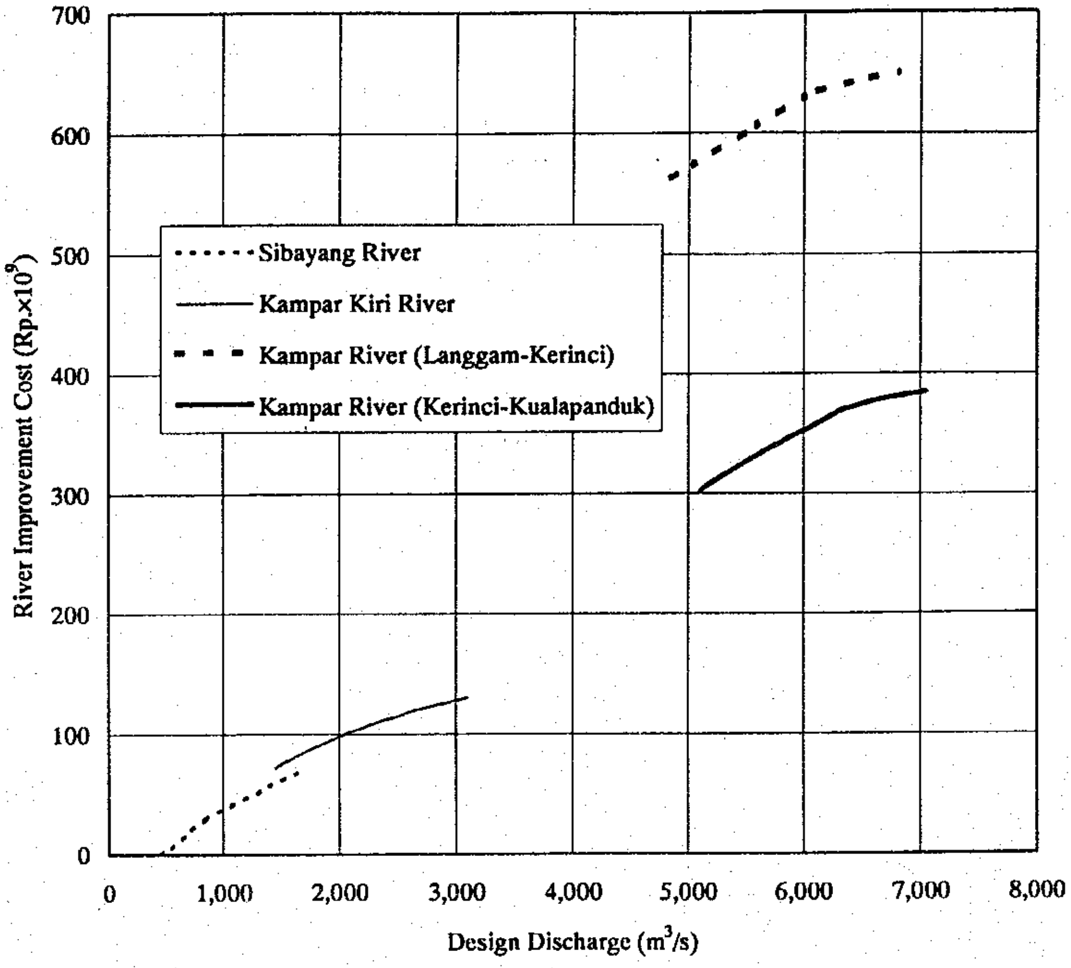
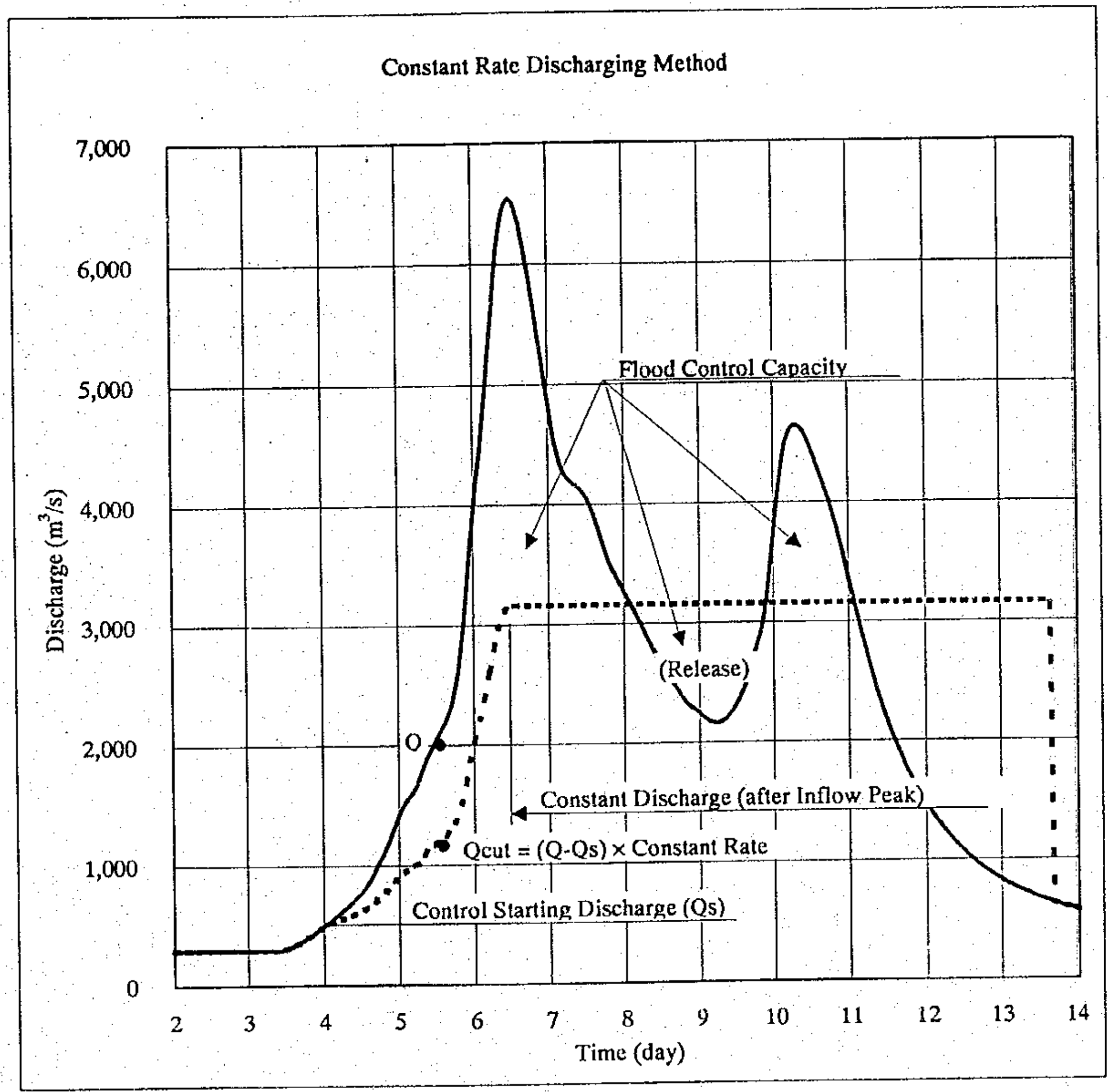
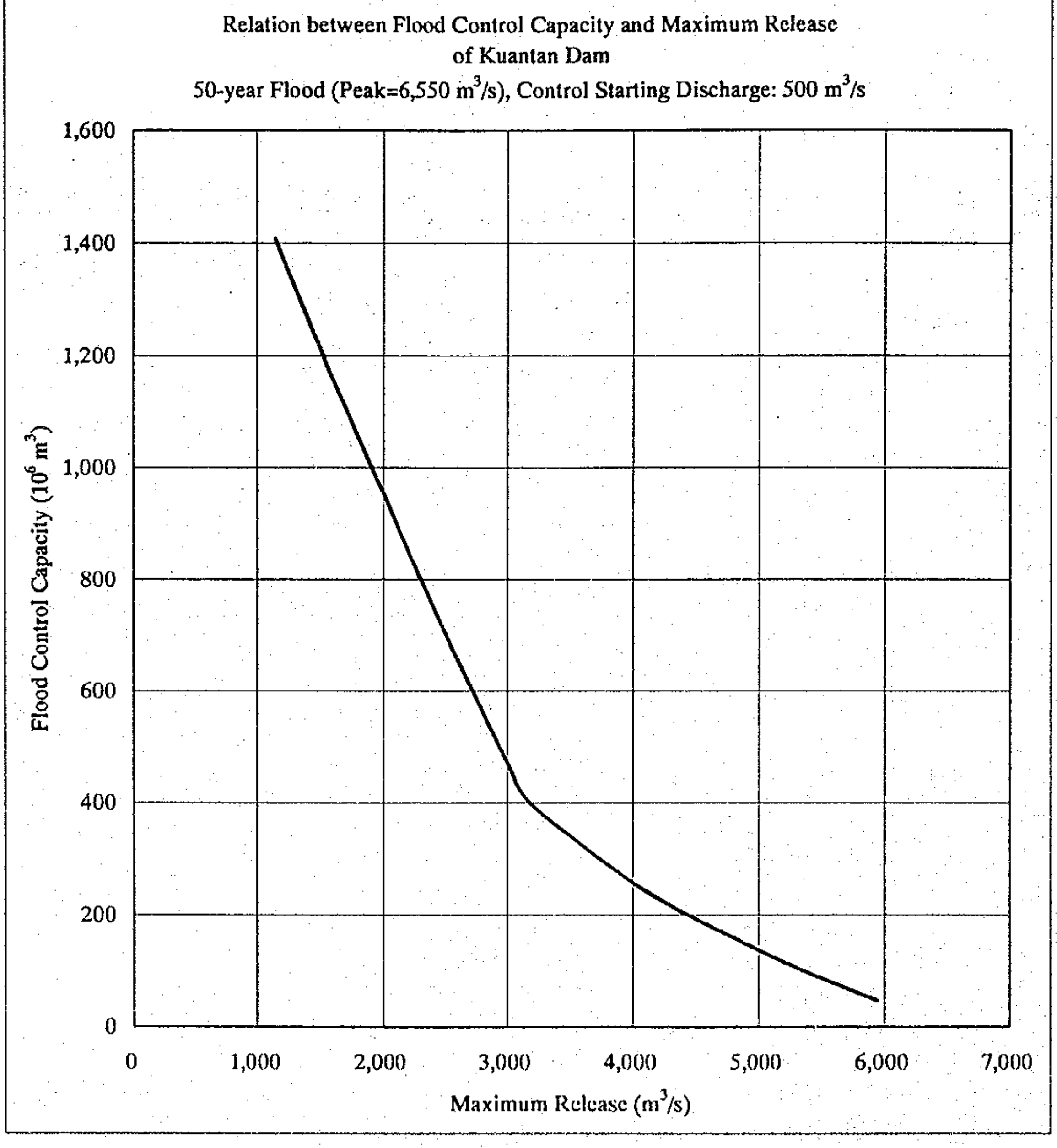


Fig.XI.2.2 RELATION BETWEEN DESIGN DISCHARGE AND IMPROVEMENT COST OF KAMPAR AND KAMPAR KIRI RIVERS



THE STUDY ON KAMPAR-INDRAGIRI RIVER BASIN DEVELOPMENT PROJECT IN THE REPUBLIC OF INDONESIA JAPAN INTERNATIONAL COOPERATION AGENCY	Fig.XI.2.3 CONSTANT RATE DISCHARGING METHOD



THE STUDY ON KAMPAR-INDRAGIRI RIVER BASIN DEVELOPMENT PROJECT IN THE REPUBLIC OF INDONESIA	**Fig.XI.2.4** RELATION BETWEEN FLOOD CONTROL CAPACITY AND MAXIMUM RELEASE OF KUANTAN DAM
JAPAN INTERNATIONAL COOPERATION AGENCY	

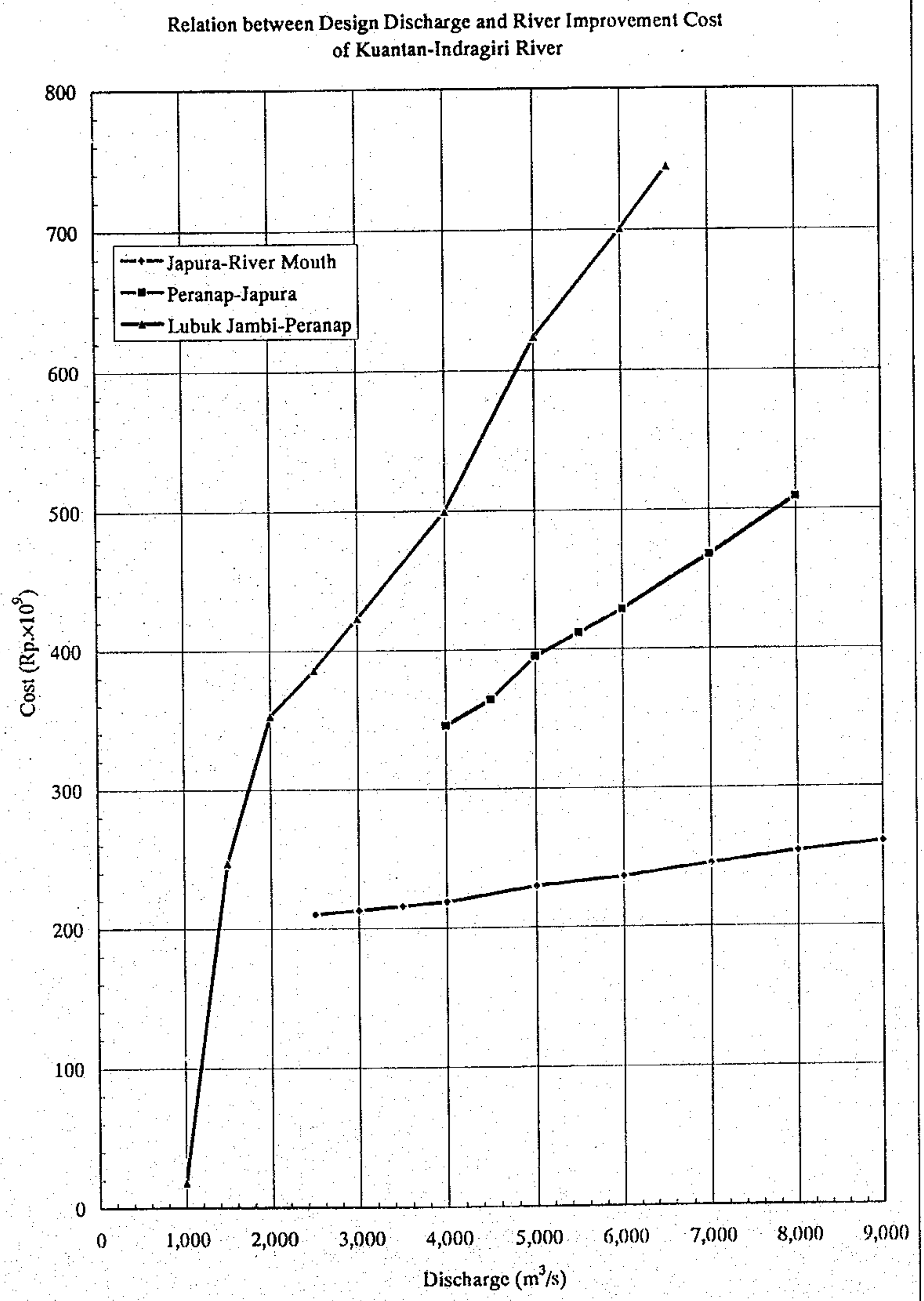


Fig. XI.2.5 RELATION BETWEEN DESIGN DISCHARGE AND RIVER IMPROVEMENT COST OF KUANTAN-INDRAGIRI RIVER

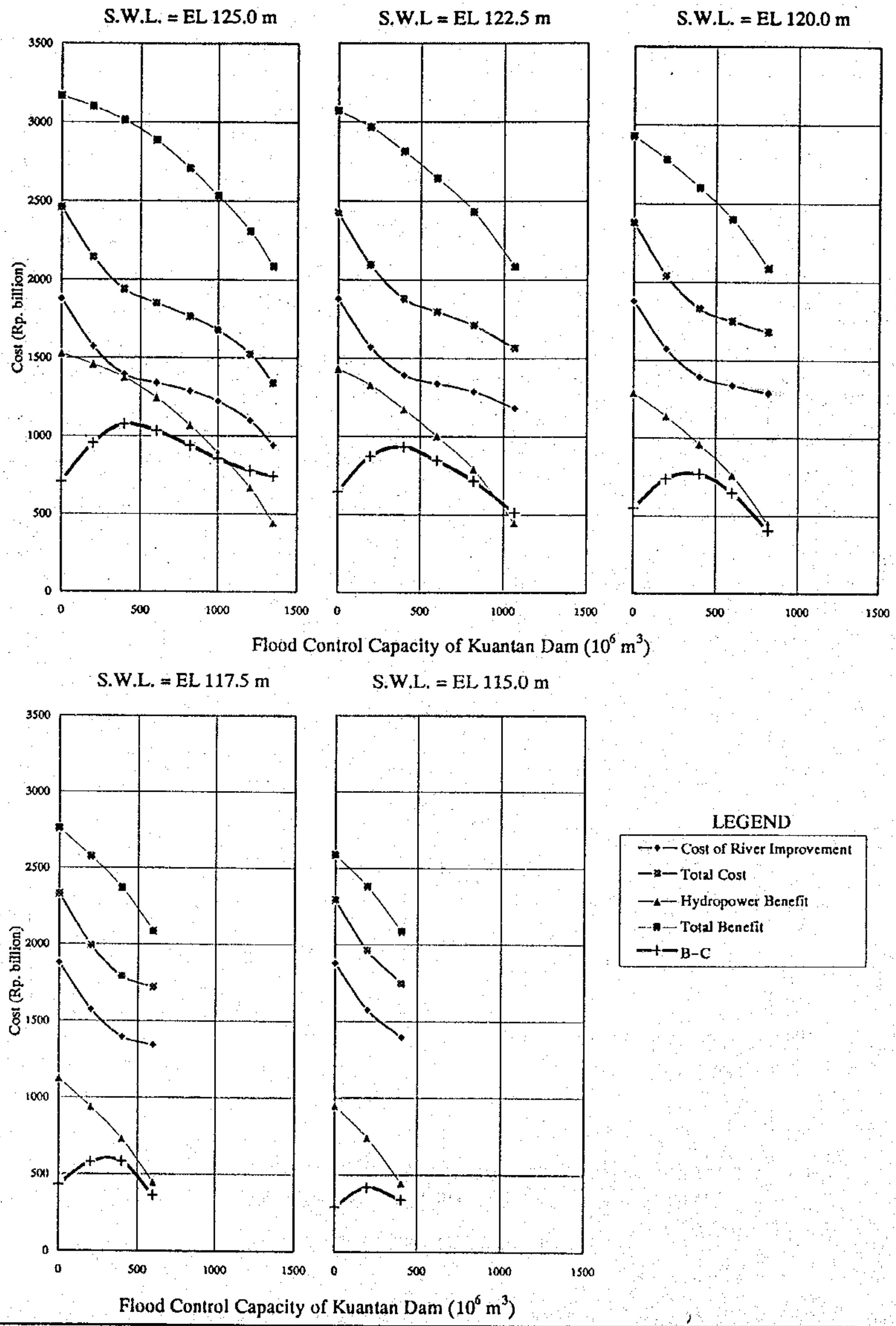


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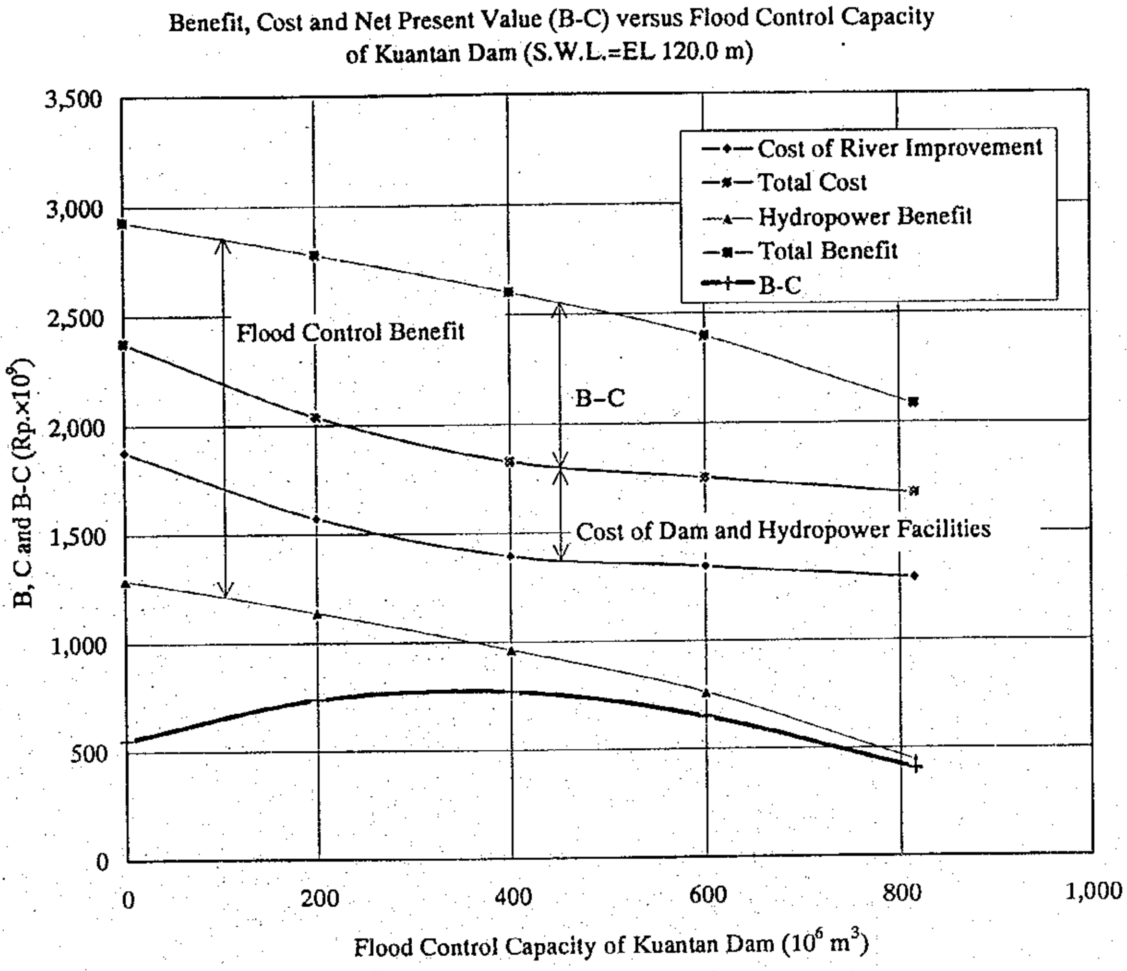
Fig.XI.2.6 NET PRESENT VALUE (B-C) PLOT FOR VARIOUS SURCHARGE WATER LEVELS OF KUANTAN DAM



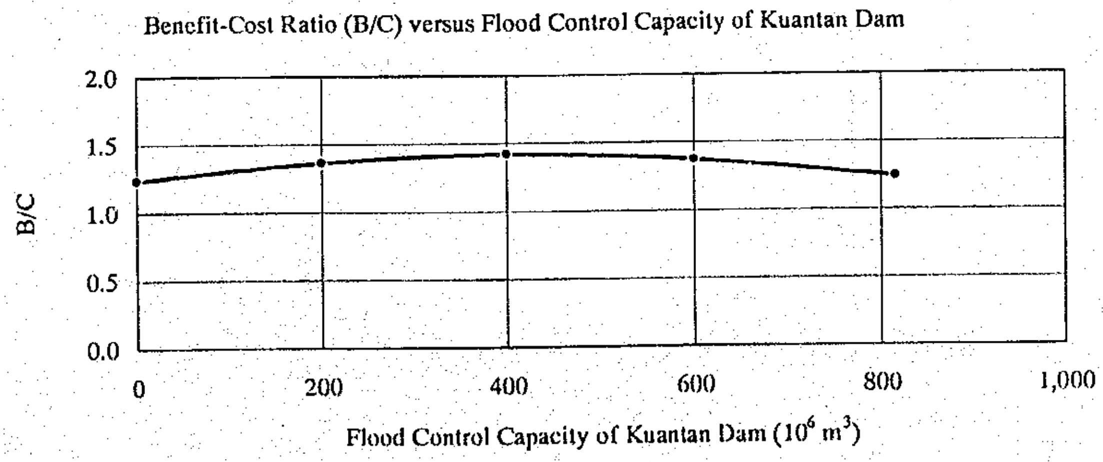


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Fig.XI.2.7 NET PRESENT VALUE (B-C) AND BENEFIT COST RATIO (B/C) PLOT FOR PROPOSED SURCHARGE WATER LEVEL OF KUANTAN DAM

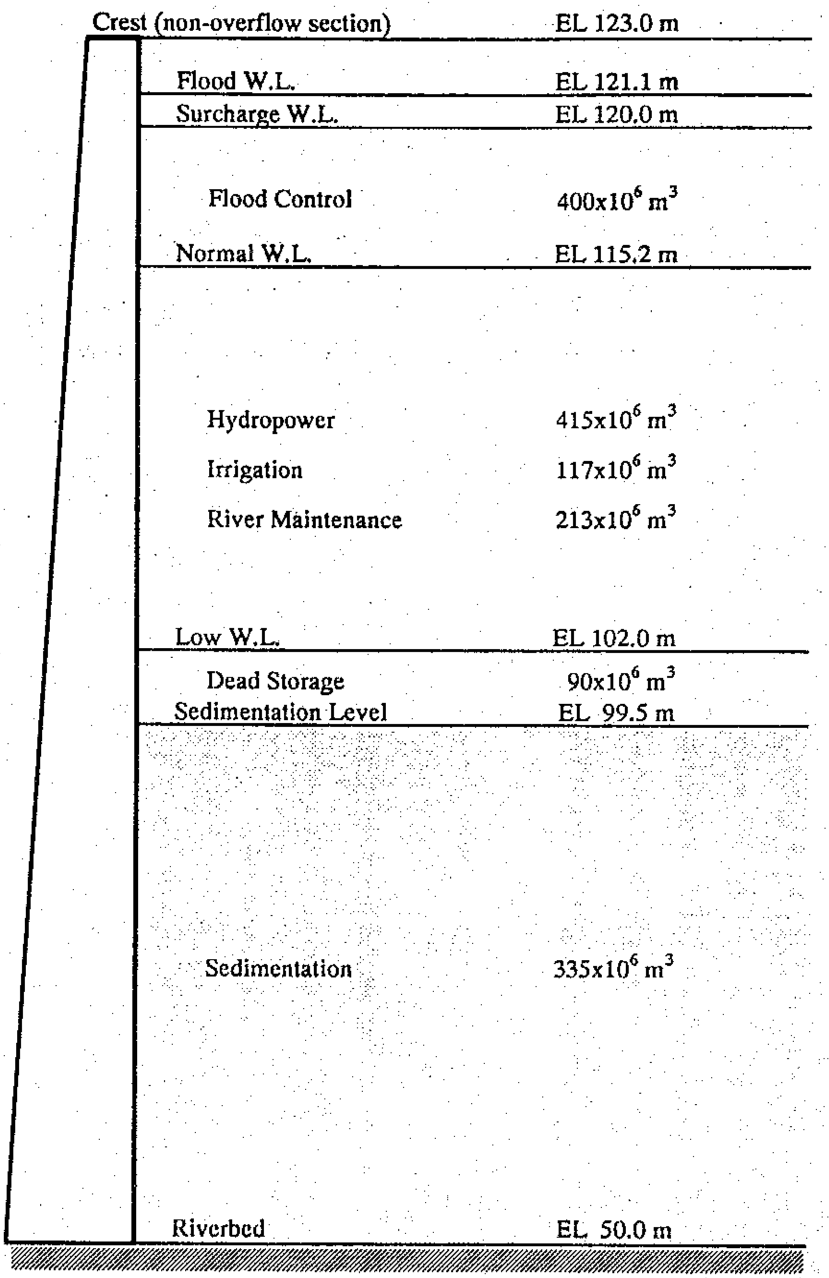
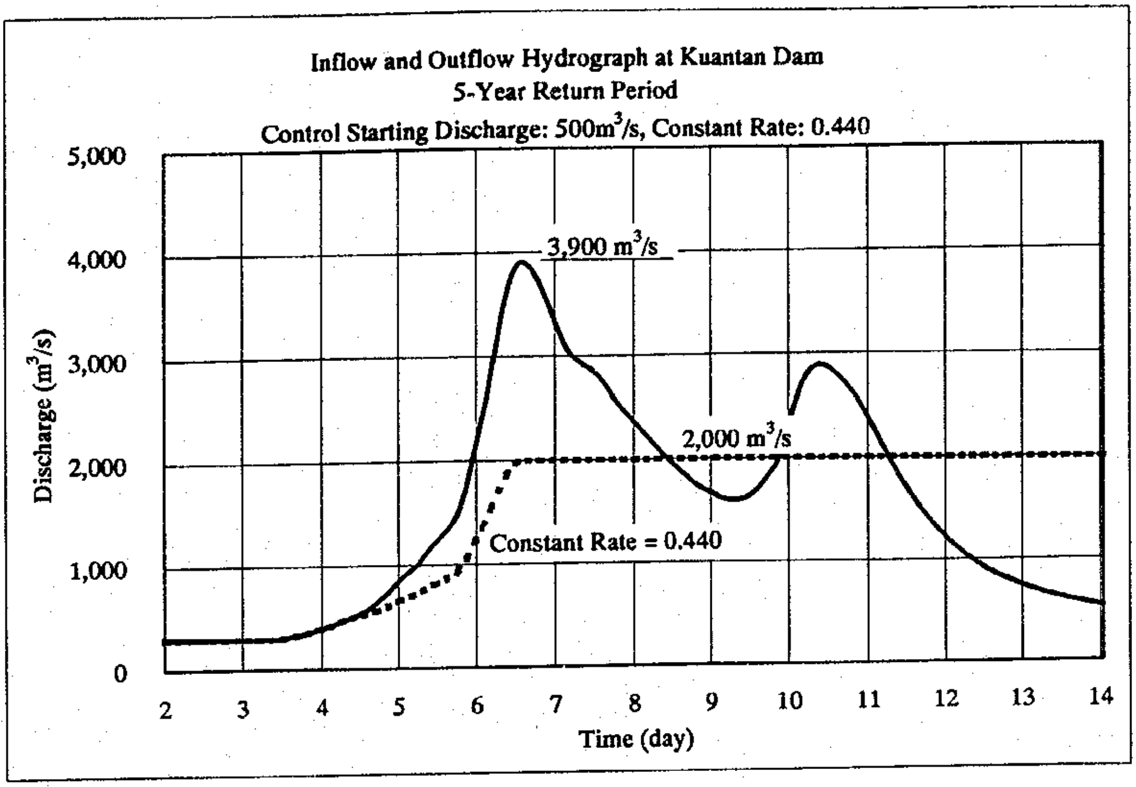


Fig. XI.2.8 RESERVOIR CAPACITY ALLOCATION OF KUANTAN DAM FOR OVERALL PLAN


Inflow and Outflow Hydrograph at Kuantan Dam
5-Year Return Period
Control Starting Discharge: 500m³/s, Constant Rate: 0.440

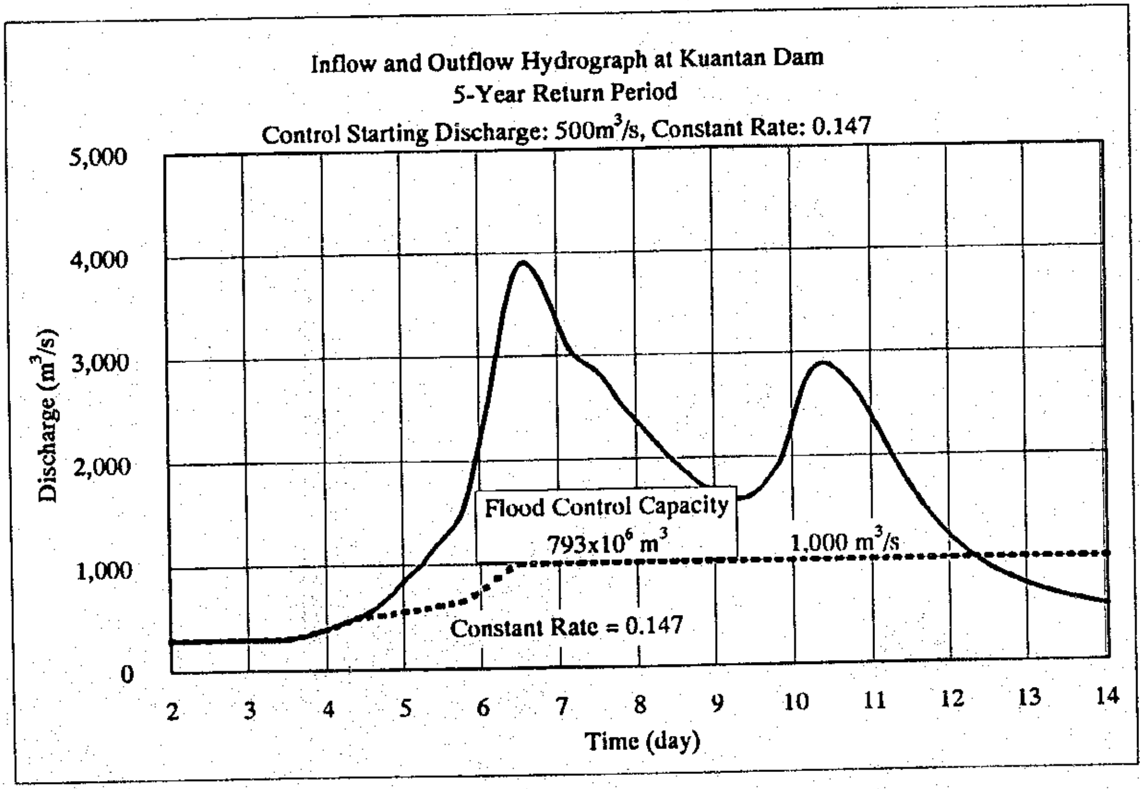

Inflow and Outflow Hydrograph at Kuantan Dam
5-Year Return Period
Control Starting Discharge: 500m³/s, Constant Rate: 0.147

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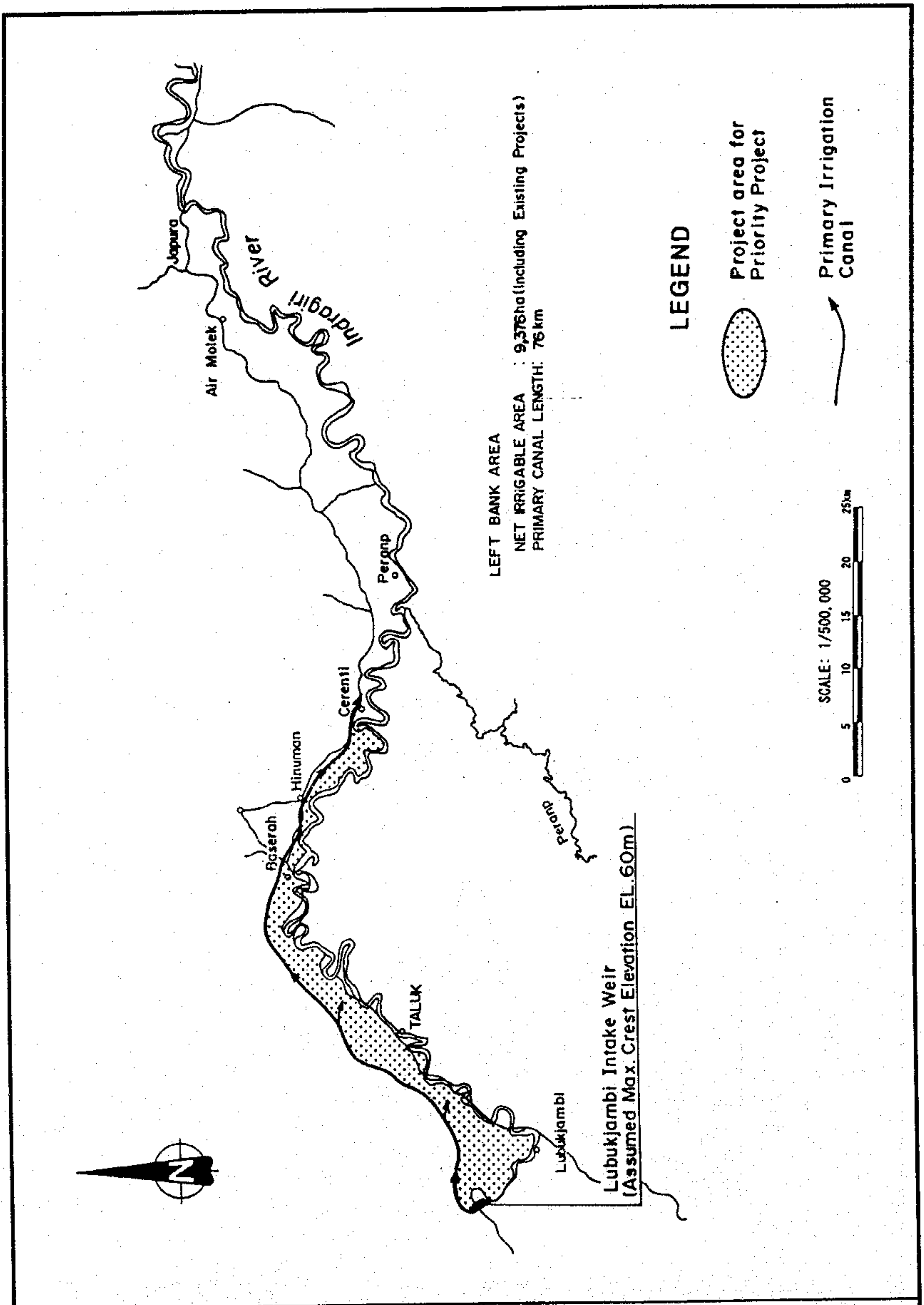
Fig.XI.3.1 CONTROL OF 5-YEAR RETURN PERIOD FLOOD BY KUANTAN DAM IN INITIAL PHASE



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KAMPAR-INDRAGIRI RIVER BASIN DEVELOPMENT PROJECT
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Fig.XI.3.2 LOCATION OF PRIORITY PROJECT FOR LUBUKJAMBI IRRIGATION DEVELOPMENT PROJECT

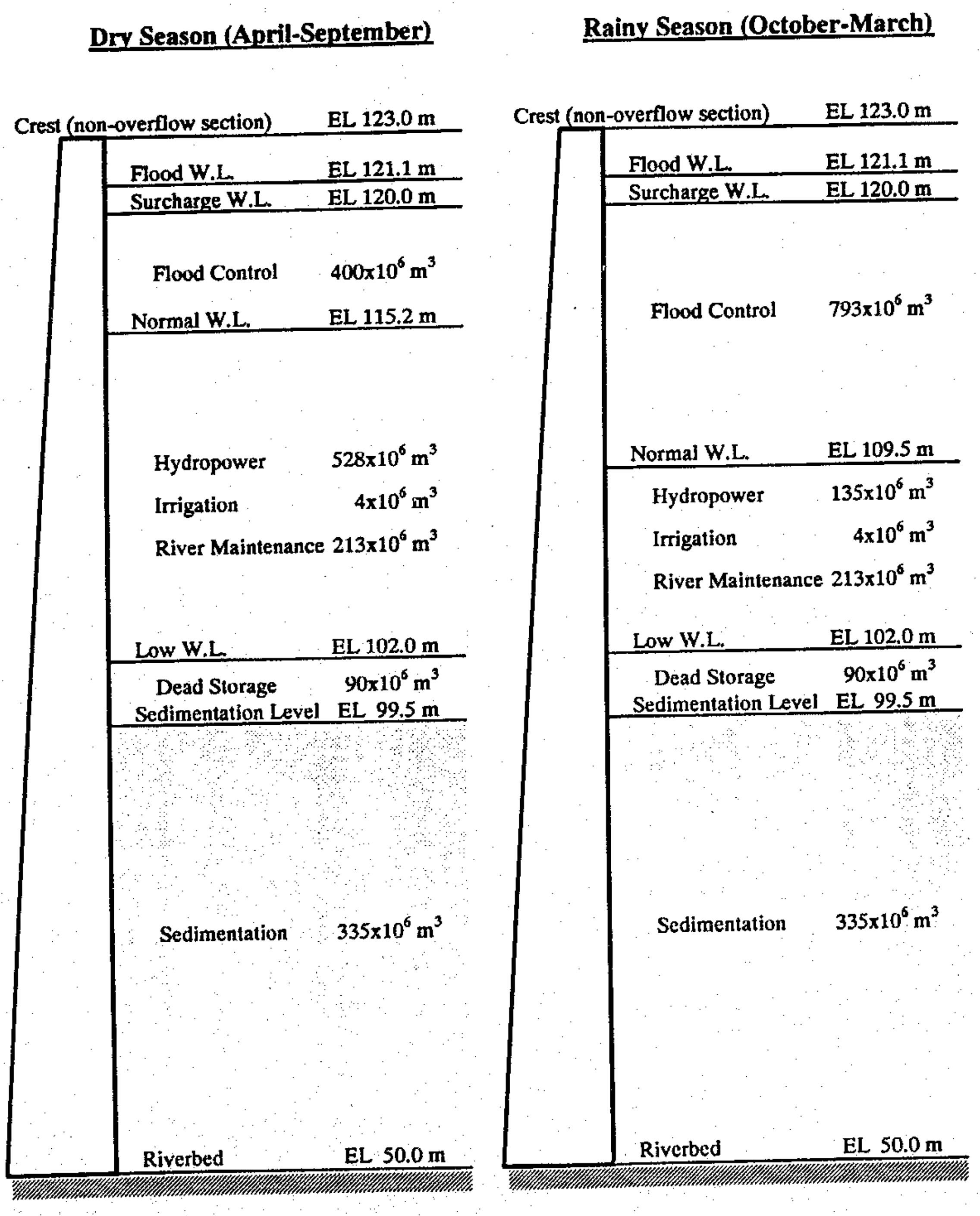

Fig. XI.3.3 RESERVOIR CAPACITY ALLOCATION OF KUANTAN DAM FOR INITIAL PHASE

XII DAM ENGINEERING

SECTOR XII
DAM ENGINEERING

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CHAPTER 1 SELECTION OF POSSIBLE DAMSITE FOR OVERALL DEVELOPMENT PLAN

1.1 Candidate Damsite

1.1.1 Selection of Candidate Damsite

PLN conducted a prefeasibility study on hydropower development in the Kampar, Indragiri and Rokan river basins from 1979 to 1983 and identified 11 promising damsites; five in the Kampar river basin, four in the Kuantan river basin and two in the Rokan river basin. Among them, nine damsites in the Kampar and Indragiri river basins are situated in the present study area.

Aside from the previous PLN study, an overall review of the promising damsites was carried out in this study and one additional damsite was identified in the Sukam river basin in the Indragiri river system. Therefore, the candidate dams for the Overall Development Plan study comes to 10 in total for the 10 dams listed below. Their locations are as shown in Fig. XII.1.1.

(1) Kampar River Basin
  - (a) Kapoernan Dam
  - (b) Mahat Dam
  - (c) Kototengah Dam
  - (d) Kampar Kiri No. 1 Dam
  - (e) Kampar Kiri No. 2 Dam

(2) Indragiri River Basin
  - (a) Upper Sinamar Dam
  - (b) Lower Sinamar Dam
  - (c) Sukam Dam
  - (d) Upper Kuantan Dam
  - (e) Kuantan Dam

1.1.2 Physical Condition of Candidate Damsite

The maximum water level and reservoir capacity of the candidate damsites selected were studied on topographic maps with the scale of 1/50,000 and contour line of 25 m interval. Then, five damsites for the Kampar Kiri No. 1, Kampar Kiri No. 2, Upper Sinamar, Sukam and Kuantan dams, respectively, were further studied on topographic maps with scale of 1/10,000 and contour line of 2 to 10 m interval.

The reservoir areas of these 10 candidate damsites are shown in Fig. XII.1.2. The axis of each dam is as shown in Fig. XII.1.3. The elevation-area-storage capacity curves of reservoirs are as shown in Fig. XII.1.4, and potential reservoir capacities of the dams are given in Table XII.1.1.

The maximum water levels were determined taking topographic and social conditions into account. The maximum water level of the Kapoernan Dam is limited by the Muara Takus, an old and very precious Buddhist temple located upstream of the dam, while that of the Upper Kuantan Dam is limited by the large towns of Muara and Sijunjung upstream of the dam.

The maximum water levels of the Kototengah and Upper Kuantan dams are limited to EL 240.0 m and EL 150.0 m, respectively, due to topographic conditions. The reservoir capacities of these dams are small and no effective storage can be secured against 100-year sediment deposit.

The Mahat damsite with riverbed elevation of EL 63.5 m will be submerged in the reservoir of the Kotapanjang Dam which is presently under construction with a high water level of EL 85.0 m.

The Lower Sinamar damsite has geological problems at the foundation due to the existence of limestone near the proposed dam axis and serious water leakage is expected.

1.2 Possible Damsite

1.2.1 Criteria for Selection

The present study aims at establishing the Overall Development Plan of flood control and water supply for irrigation, domestic use, hydropower, industry, inland fishery, etc. To meet this objective, dams at the possible damsites were selected from among the candidate damsites based on the following criteria, referring to the results of field reconnaissance, related reports and topographic maps.

- Dams for flood control purposes should have a catchment area of more than 30% of the catchment area at the reference point. considering the effects of dam.
- Dams to be proposed should have a catchment area of at least 400 km^2 and an effective storage capacity of more than 100×10^6 m^3 considering economic feasibility.
- Dams with geological problems at the foundation should be eliminated.

1.2.2 Selection of Possible Damsite

The dams at candidate damsites were evaluated in accordance with the selection criteria mentioned above. From among the 10 candidate damsites, the following six dams were selected as possible dams subject to further study.

(1) Kapoernan Dam
(2) Kampar Kiri No. 1 Dam
(3) Kampar Kiri No. 2 Dam
(4) Upper Sinamar Dam
(5) Sukam Dam

(6) Kuantan Dam

On the other hand, the remaining four dams were eliminated due to the reasons mentioned before.

(1) Mahat Dam: Existence of Buddhist Temple in the reservoir area.
(2) Kototengah Dam: No effective storagecapacity.
(3) Lower Sinamar Damsite: Limestone foundation.
(4) Upper Kuantan Damsite: No effective storage capacity.

Geological conditions of the six possible damsites are described in SECTOR IV, GEOLOGY AND SOIL MECHANICS. The physical conditions of the six possible damsites are summarized in Table XII.1.2.

1.3 Comparison between a Single Large Dam and Several Small Dams

In the previous section, a dam with a rather large storage capacity is considered as a means of efficient and economical flood control and water resources development. However, a large dam naturally has greater environmental and social impacts than small dams. To reduce the impacts, the construction of several small dams may become an alternative.

As studied in subsequent sectors, the Kuantan Dam on the Indragiri River is a promising dam as a priority project for the flood control and water supply plans. This dam is large and has a gross storage capacity of 1,570 × $10^6 m^3$ or an effective storage capacity of 1,145 × $10^6 m^3$. To compensate for this large dam, many small dams shall have to be constructed and this will be very costly.

For instance, the gross storage capacity of a standard scale small dam with a height of 10 m on a river channel with a width of 100 m and riverbed slope of 1/500 in a hilly area comes to 2.5 × 10^6 m^3. To have the storage capacity equal to the Kuantan Dam, about 550 small dams are required. On the other hand, the gross storage capacity of a small weir with a height of 4 m on a river channel with a width of 200 m and riverbed slope of 1/5,000 in the lower stretch comes to 8.0 × 10^6 m^3, and 120 weirs are required.

The construction of a lot of small dams is therefore unrealistic and very costly although the scale of small dams is sufficiently small. Furthermore, flood control by small dams is operationally difficult because the complete combined operation of all dams is required due to small storage capacities and flood protection may have to be made by a complete dike system. A single large dam is accordingly recommended in the present study since the required storage is large enough to fulfill the envisaged function of the dam. Small dams are to be considered locally depending on water demand.

CHAPTER 2 STRUCTURAL LAYOUT PLAN OF POSSIBLE DAMS FOR OVERALL DEVELOPMENT PLAN

2.1 General

To estimate the cost of possible dams selected, the structural layout plan of each dam is prepared. Criteria for the structural layout plan are established, referring to guidelines, standards and criteria for dam design in Indonesia and Japan. These are modified to some extent, taking local conditions and practices applied to the existing dams and auxiliary facilities into account.

The dams subject to structural layout planning are as follows:

(1) Kapoeman Dam
(2) Kampar Kiri No. 1 Dam
(3) Kampar Kiri No. 2 Dam
(4) Upper Sinamar Dam
(5) Sukam Dam
(6) Kuantan Dam

2.2 Criteria for Structural Layout Plan

2.2.1 Selection of Dam Type

Two types, concrete gravity dam and rockfill dam with a center core, were adopted. Type selection for each dam is made based on the following considerations.

- Topographical and geological conditions at damsite;
- Availability of construction materials in and around the damsite; and
- Construction cost.

Upstream and downstream slopes of dam are empirically determined as follows.

- Concrete Gravity Dam : 1 : 0.15 (upstream); 1 : 0.8 (downstream)
- Rockfill Dam : 1 : 2.3 (upstream); 1 : 1.8 (downstream)

Based on the above, dam type of the six possible dams are determined as below:

Name of Dam	Dam Type
Kapoeman Dam	Concrete gravity type
Kampar Kiri No. 1 Dam	Rockfill type
Kampar Kiri No. 2 Dam	Concrete gravity type
Upper Sinamar Dam	Rockfill type
Sukam Dam	Concrete gravity type
Kuantan Dam	Concrete gravity type

2.2.2 Discharge Facilities

For discharge facilities, the following criteria are applied:

Diversion Tunnel

(1) Number of Tunnel Lanes

Dam Type	No. of Lanes
Concrete Dam	1 lane in principle
Rockfill Dam	2 lanes in principle

Circular section tunnel shall be adopted, and invert elevations of inlet and outlet of the tunnel shall be set at the same elevation as the existing riverbed.

(2) Type of Cofferdam

Main Dam	Cofferdam
Concrete Type	Concrete gravity type
Rockfill Type	Rockfill type with center core

Spillway

(1) Ordinary Spillway

Ordinary spillway shall be provided to regulate outflow discharge for the flood control of up to a 50-year return period flood.

(2) Emergency Spillway

Emergency spillway shall be provided to discharge extraordinary floods of more than 50-year return period flood for ensuring dam safety.

River Outlet

River outlet shall be provided to discharge water for normal flow such as river maintenance flow, irrigation water, domestic water, etc.

2.2.3 Design Discharge

Scale of design discharges for discharge facilities are set as follows:

(1) Diversion Tunnel

Dam Type	Design Scale
Concrete Dam	2-year return period flood
Rockfill Dam	20-year return period flood

(2) Emergency Spillway

Dam Type	Design Scale
Concrete Dam	1,000-year return period flood
Rockfill Dam	Probable maximum flood (PMF)

(3) River Outlet

The design discharge cover river maintenance flow and water supply discharges. The design discharges determined are given in Table XII.2.1.

2.2.4 Design Water Level

Design water levels of reservoirs are defined as follows:

(1) Design Flood Water Level (FWL)

Maximum water level, during dam design flood flowing out through both emergency and ordinary spillways considering reservoir retardation effects.

(2) Surcharge Water Level (SWL)

Maximum water level corresponding to maximum storage volume to be allocated for flood control.

(3) Normal Water Level (NWL)

Maximum water level corresponding to maximum storage volume to be allocated for water utilization such as water supply and power generation.

(4) Low Water Level (LWL)

Water level corresponding to dead storage volume consisting of sediment plus dead water.

Sediment volume shall be calculated assuming the following specific sedimentation volumes and 100-year sedimentation.

River Basin	Specific Sediment Volume
Kampar River Basin	500 $m^3/km^2/yr$
Kuantan River Basin (Sinamar River)	585 $m^3/km^2/yr$
Kuantan River Basin (Kuantan and Sukam Rivers)	525 $m^3/km^2/yr$

The sediment capacity of each dam is given in Table XII.1.1.

2.2.5 Dam Crest Elevation and Width

Dam Crest Elevation

Dam crest elevations shall be determined as the highest among the following cases:

(1) Concrete Gravity Dam

(a) Design flood water level (FWL) + 1.0 m ((freeboard) + 1.0 m (additional height due to spillway bridge construction, if necessary).

(b) Normal water level (NWL) + 2.0 m (freeboard) + 1.0 m (additional height due to spillway bridge construction, if necessary).

(c) Surcharge water level (SWL) + 2.0 m (freeboard) + 1.0 m (additional height due to spillway bridge construction, if necessary).

(2) Rockfill Dam

(a) Design flood water level (FWL) + 2.0 m (freeboard) + 1.0 m (additional height for road construction).

(b) Normal water level (NWL) + 3.0 m (freeboard) + 1.0 m (additional height for road construction).

(c) Surcharge water level (SWL) + 3.0 m (freeboard) + 1.0 m (additional height for road construction).

In the Overall Development Plan study, the dam crest elevation is simply taken as NWL + 5 m, considering the above conditions.

Dam Crest Width

Crest width of dams is determined as follows, considering the required width during construction and after completion.

Concrete Dam	5 m
Rockfill Dam	8 m

2.3 Structural Layout Plan

To estimate the cost of possible dams for the comparative study on the Overall Development Plan formulated, layout plans are prepared based on the criteria mentioned in the Section 2.2.

Fig. XII.2.1 shows the typical structural layout plans of the possible dams. Their main features are tentatively given below, subject to change through further study.

Name of Dam	Dam Type	Dam Height (m)	Crest Length (m)	Gross Storage Capacity (10^6m^3)	Effective Storage Capacity (10^6m^3)
Kapoernan	Concrete Gravity	34.5	197.0	140	84
Kampar Kiri No. 1	Rockfill	103.0	495.0	2,300	902
Kampar Kiri No. 2	Concrete Gravity	95.0	385.0	2,250	579
Upper Sinamar	Rockfill	132.5	650.0	165	68
Sukam	Concrete Gravity	66.5	330.0	230	203
Kuantan	Concrete Gravity	73.0	294.0	1,570	1,145

2.4 Cost Estimate

Based on the layout plans prepared, the construction cost of each layout plan is estimated under the conditions without hydropower plan and with hydropower plan applying unit costs presented in SECTOR XV, PROJECT COST ESTIMATE.

The costs estimated are given in Fig. XII.2.2 in the form of curve by the different dam height or installed capacity.

CHAPTER 3 PRELIMINARY DESIGN OF KUANTAN DAM AT FEASIBILITY STUDY

3.1 Principal Features of Design

This chapter describes the preliminary design concept and principal features of the main structures of the Kuantan Dam which is selected as a priority project. The design is made at the feasibility study level.

Through the optimization study of dam scale described in SECTOR XI, MULTIPURPOSE DEVELOPMENT PLAN, the principal features of the Kuantan Dam have been determined as follows:

Surcharge Water Level (SWL)	EL 120.00 m
Normal Water Level (NWL)	EL 115.20 m
Low Water Level (LWL)	EL 102.00 m
Effective Storage for Water Supply	$745 \times 10^6 m^3$
Total Installed Capacity	114 MW
Maximum Turbine Discharge	270 m^3/sec

Fig. XII.3.1 shows the reservoir area of the Kuantan Dam.

3.2 Preliminary Design

3.2.1 Design Conditions

The basic design conditions are as follows:

(1) Design Flood Discharge

Diversion Scheme	1,510 m^3/sec (2-year probable flood)
Dam and Spillway	10,050 m^3/sec (1,000-year probable flood)
Spillway Energy Dissipator	7,360 m^3/sec (100-year probable flood)
River Outlet	100 m^3/sec

(2) Design Values

Seismic Coefficient	0.12
Period of Seismic Wave	1.0 sec
Wind Velocity	30 m/sec
Fetch	2,100 m
Unit Weight of Mass Concrete	2.30 ton/m^3
Unit Weight of Silted Deposit in the Air	1.80 ton/m^3
Porosity (n) of Silted Deposit	0.40
Allowable Bearing Capacity of Rock Foundation	40 kg/cm^2
Shearing Strength of Bedrock	15 kg/cm^2
Internal Friction of Bedrock	35 degrees

3.2.2 Main Dam

Dam Axis

Taking the geological and topographic conditions into consideration, three alternatives of dam axis; namely, upstream dam axis, middle dam axis and downstream dam axis, are set as given in Fig. XII.3.1, based on the topographic maps with scale of 1/5,000.

The three alternatives were compared mainly according to cost and geological conditions under the following conditions:

Dam Type	Concrete gravity
Dam Crest Elevation	EL 128.5 m
Upstream Dam Design Slope	1 : 0.15
Downstream Dam Design Slope	1 : 0.80
Spillway and Powerhouse Sizes	Same for all alternatives
Hard Rock Line	5 m deep from original ground surface
Generating Equipment and Metal Works	Same for all alternatives

Based on the above conditions, the work quantity of major works at the respective dam axis was estimated, as follows:

Item No.	Items of Work	Unit	Upstream Dam Axis	Middle Dam Axis	Downstream Dam Axis
1	Access Road	m	20,900	20,000	18,800
2	Diversion Tunnel Length	m	450	500	530
3	Upstream Cofferdam Crest Length	m	135	130	155
4	Main Dam				
	Crest Length	m	1,000	320	320
	Excavation	m^3	57,000	63,000	62,000
	Dam Concrete	m^3	374,000	416,000	398,000
5	Spillway and Powerhouse				
	Excavation	m^3	545,000	355,000	656,000

The cost of the three alternatives were estimated, as follows:

Unit: 10^6 Rp

Item No.	Items of Work	Upstream Dam Axis	Middle Dam Axis	Downstream Dam Axis
1	Access Road	8,400	8,000	7,500
2	Diversion Tunnel	24,900	27,400	29,100
3	Cofferdam	6,500	6,300	7,200
4	Main Dam and Spillway	91,600	96,700	96,900
5	Powerhouse and Tailrace	25,800	24,800	26,400
	Total	157,200 (100.0%)	163,200 (103.8%)	167,100 (106.3%)

According to the above table, the upstream dam axis is the most economical, although the difference among the three alternatives is comparatively small.

However, a shale zone appears at the upstream dam axis as shown in Fig. XII.3.2 according to the investigation by PLN, which is rather weathered and not suitable for foundation of any type of dam on the mainstream with a big catchment area. Dam construction in the shale zone should be avoided. Moreover, a rockfill dam plan is abandoned from the viewpoint of safety, because the proposed Kuantan Dam is situated on the mainstream of the Indragiri River and has a large catchment area of 6,377 km^2 excluding the Singakarak lake basin.

Considering geological conditions and cost, the middle dam axis is finally selected in view of the following reasons:

- Geological condition of the upstream axis is considered to be worst among the three alternatives because of the existence of a shale zone in the riverbed and left abutment. A shale zone does not appear at the middle and downstream axes and concrete gravity dam can be constructed at such locations.
- Since both the upstream and downstream axes have steep slopes for abutments, excavation of slope for the construction of powerhouse will reach nearly 100 m in height assuming an average slope cut of 1 : 1.0, and it is difficult or costly to maintain stability at such a high slope. The slope cut at the middle axis will be around 30 m in maximum height.
- The middle dam axis is the second lowest cost alternative among the three alternatives, but cost difference between the upstream and middle axes is as small as Rp. 6 billion, which corresponds to 3.8% of the cost of the upstream axis.
- At the middle axis, there is a gentle sloped area downstream from the axis on the right abutment. It will be convenient to accommodate construction facilities at this area and also to keep work space.

Dam Type

The topography and geology at the proposed damsite will allow the construction of either concrete gravity dam or rockfill type dam. However, a rockfill dam plan is abandoned from the viewpoint of safety because the proposed Kuantan Dam is situated on the mainstream of the Indragiri River and has a large catchment area of 6,377 km^2 excluding the Singkarak lake basin, as mentioned before, and a large design flood discharge of 10,050 m^3/sec.

Dam Crest Elevation

The proposed reservoir has SWL at EL 120.00 m and NWL at EL 115.20 m. The flood water level (FWL) was estimated as EL 121.08 m by flood routing, as shown in Fig. XII.3.2, assuming retarding effect of the reservoir for the 1,000-year probable flood, which is explained in Subsection 3.2.4. The dam crest elevation should be designed to be safe against the flood discharge, water waves by wind or earthquake and other allowances. The crest elevation of the concrete gravity dam having spillway gates is determined to be the maximum among the following three cases:

- Case 1 : $H_n + h_w + h_e + 0.5$ (if $h_w + h_e < 1.5$, $H_n + 2.0$)
- Case 2 : $H_s + h_w + h_e/2 + 0.5$ (if $h_w + h/2 < 1.5$, $H_s + 2.0$)
- Case 3 : $H_d + h_w + 0.5$ (if $h_w < 0.5$, $H_d + 1.0$)

where;

H_n : normal water level (EL 115.20 m)
H_s : surcharge water level (EL 120.00 m)
H_d : design flood water level (EL 121.08 m)
h_w : wind wave runup (m)
h_e : wave runup due to earthquake (m)

The values of h_w and h_e were calculated at 1.13 m and 0.48 m, respectively, employing wind velocity of 30 m/sec, fetch of 2,100 m, earthquake coefficient of 0.12 and period of seismic wave of 1.0 sec.

Accordingly, the required dam crest elevation for each case is given as below:

Case 1	EL 117.32 m
Case 2	EL 122.00 m
Case 3	EL 122.71 m

Since the highest elevation among the three cases is EL 122.71 m, the dam crest elevation is determined at EL 123.00 m with some allowance.

Typical Cross Section

The proposed typical cross section of the dam is shown in Fig. XII.3.4. The principal dimensions are as follows:

Crest Elevation	EL 123.00 m
Crest Width	5.0 m
Upstream Slope	
Below EL 100m	0.25
Above EL 100 m	vertical
Downstream Slope	0.85

These dimensions were determined by conventional 2-dimensional stability analysis. The allowable safety factors are as follows:

- SF (safety factor) shall not be less than 4.0.
- Eccentricity shall be less than 12.4 m.
- Reaction shall be less than 400 ton/m^2.

Item	Condition		
	at Completion	Normal	at SWL
Sliding (SF)	42.90 (o.k.)	4.01 (o.k.)	4.24 (o.k.)
Eccentricity	8.0 m (o.k.)	5.1 m (o.k.)	6.5 m (o.k.)
Bearing Capacity	131.3 ton/m^2 (o.k.)	101.3 ton/m^2(o.k.)	109.2 ton/m^2(o.k.)

Foundation Treatment

In the geological assessment, no serious defect was found at the proposed damsite. However, considering the type and height of the dam, careful attention should be paid to the foundation treatment.

The foundation of the concrete gravity dam is normally excavated to the firm rock surface to obtain sufficient strength and imperviousness of the foundation. In this design, the following grouting works are planned.

Consolidation Grout (for dam foundation)	4 m grid and 5 m in depth
Curtain Grout	1 m interval in 1 row and 20 m to 50 m in depth

3.2.3 River Diversion

Design Conditions

Diversion tunnels and cofferdams are provided to divert riverflow during the period of construction of the main dam as shown in Fig. XII.3.4. The diversion tunnels are arranged on the right abutment side considering the topographic and geological conditions at the damsite.

Two lanes of diversion tunnels are provided to cope with the rather large design flood and river closure sequence.

A 2-year probable flood with a peak discharge of 1,510 m^3/sec is adopted as the design flood discharge for the diversion scheme without the effect of flood retarding in the river channel. The downstream outlet water level is estimated at EL 66.5 m assuming uniform flow. In designing the diversion tunnel, the maximum velocity is limited to less than 15 m/sec for the tunnels lined with reinforced concrete to prevent scouring of the lining concrete.

River Diversion Scheme

Since the upstream cofferdam is set apart from the main dam in case of a concrete gravity dam, the optimum diversion scheme is selected to minimize the total construction cost of the upstream cofferdam and the diversion tunnels.

The comparison study was made assuming the different diameters of diversion tunnel. Type of the cofferdam is concrete gravity. Freeboard is taken as 1.0 m to the water level for the design discharge. The result of the study is as below.

Particulars	Case 1	Case 2	Case 3
Diameter of Tunnel (2 lanes)	8.3 m	8.8 m	9.3 m
Height of Cofferdam	31.9 m	26.9 m	23.2 m
Cost of Cofferdam (10^9 Rp)	16.1	18.0	20.0
Cost of Tunnel (10^9 Rp)	7.7	5.0	3.5
Total Cost (10^9 Rp)	23.8	23.0	23.5

Based on the above results, the diameter of 8.8 m is selected as the cheapest combination. The required crest elevation of the cofferdam is set at EL 79.00 m (26.90 m in height). The flow velocity of the diversion tunnel at the design discharge is 12.4 m/sec.

3.2.4 Spillway

Design Conditions

The spillway is designed to be an over-flow type with gates in the central part of the main dam as shown in Fig. XII.3.4. A stilling basin type energy dissipator is adopted from the viewpoint of reliable energy dissipation because the powerhouse locates beside the spillway.

The spillway is designed to discharge a 1,000-year probable flood with a peak discharge of 10,050 m^3/sec, taking the retarding effect of the reservoir into account. However, the energy dissipator is designed for a 100-year probable flood with a peak discharge of 7,360 m^3/sec.

Optimization of Spillway Width

The width of a spillway overflow crest is related with the dam crest elevation. A smaller width for spillway requires a higher dam crest elevation. A comparative study was therefore made to determine the least cost width. The crest elevation of the spillway is set at EL 106.5 m for the flood control purpose which has to discharge 500 m^3/sec at water level EL 109.5 m. The required dam crest elevation is given by flood routing for 1,000-year probable flood. The results of the study are summarized below.

Particulars	Case 1	Case 2	Case 3	Case 4
Spillway Width (m)	40	50	60	70
Dam Crest Elevation (EL m)	126.94	126.25	126.08	126.08
Construction Cost (10^9 Rp)				
Dam and Spillway	107.4	105.3	104.4	104.0
Spillway Gate	9.6	10.9	12.8	14.9
Total	117.0	116.2	117.2	118.9

Though the least cost width is 50 m, this width is not enough to discharge the aforesaid 500 m^3/s for flood control at the water level of EL. 109.5 m. The width of the spillway is therefore set at 60 m to meet the above condition.

Fig. XII.3.3 shows the result of flood routing for the width of 60 m. The maximum outflow from the spillway comes to 6,970 m^3/sec against the inflow peak of 10,050 m^3/sec and the reservoir water level (FWL) reaches EL 121.08 m.

Stilling Basin

The stilling basin is designed to cope with a 100-year probable flood as mentioned above. The dimension of the stilling basin is 69 m wide × 115 m long × 26 m deep. The apron is set at EL 53.00 m and the elevation of top of sidewall is EL 79.00 m.

3.2.5 Waterway

Design Conditions

The waterway for power generation is arranged on the right side of dam body to secure suitable location for powerhouse as shown in Fig. XII.3.4. The waterway is composed of an intake, a penstock line and tailrace. The design discharge of waterway is 270 m^3/sec.

Intake

The intake is divided into three to cope with the penstock line. Fan-shaped weir is provided in the inlet portion to prevent sediment and air entrance. The elevation of inlet center is EL 95.0 m. Intake gate of roller gate type is installed infront of each intake. The dimension of gate is 5 m wide × 5 m high × 3 units. Trashrack with fixed screen is also installed infront of each intake to prevent entrainment of flowing logs into the penstock lines. The dimension of trashrack is 23 m high × 7 m wide × 3 units.

Penstock Line

The penstock consists of 3 lines of steel pipes connecting the intake and turbine. The diameter of penstock is determined to be 4.2 m, assuming economic flow velocity of 5 m/sec against turbine discharge of 270 m^3/sec. The penstock is set at EL 95.0 m at inlet and EL 53.0 m at outlet for turbine. The length of penstock line is 105 m.

3.2.6 Power Station

The power station is located immediately downstream from the main dam on the right riverbank, taking the topographic conditions into account as shown in Fig. XII.3.4. The power station consists of powerhouse, tailrace and outdoor switchyard. The powerhouse accommodates three units of generating equipment.

Turbine and Generator

A vertical shaft Kaplan type of turbine is selected from Fig. XII.3.6 applying one unit output of 38 MW and net head of 50.7 m. The generator is designed to be 3-phase AC synchronous type and have a capacity of 38 MW of output and 45 MVA of capacity, assuming the power factor of 0.85. The centerline of turbine is set at EL 53.0 m.

Powerhouse and Tailrace

An open-type powerhouse is adopted taking the topographic conditions into account. The powerhouse has a dimension of 29 m wide × 58 m long to accommodate three units of turbines and generators. The ground floor is set at EL 79.0 m.

The tail water level is EL 59.0 m for the maximum turbine discharge of 270 m^3/s. The tailrace is designed to be a trapezoidal shaped channel with bottom width of 55 m and the channel bed is set at EL 55 m. The draft tube is set at EL 53 m.

Outdoor Switchyard

The outdoor switchyard of 3-phase single bus type is situated between main dam and powerhouse at ground elevation of EL 79 m. The dimension of the switchyard is 30 m wide × 60 m long. The switchyard accommodates the main switchgear equipment.

The Kuantan Power Station is planned to be connected to the planned Telukkuantan Substation with transmission line.

3.2.7 River Outlet

A square conduit type of river outlet is provided in the main dam body, under the rightmost spillway pier. The dimension of the river outlet is 2.3 m wide × 2.3 m high. It is set at EL 80.0 m to discharge 100 m^3/s against LWL of EL 102.0 m. The river outlet is equipped with a high pressure type slide gate.

3.2.8 Transmission Line and Substation

A substation is planned in the town of Telukkuantan according to the PLN's plan, as shown in Fig. IX.5.1 in SECTOR IX, HYDROPOWER DEVELOPMENT PLAN. The Kuantan Power Station is therefore planned to be connected to the Telukkuantan Substation by transmission line.

The transmission line has a capacity of 150 kV. The distance from the power station to Telukkuantan Substation is about 30 km.

3.2.9 Main Features of Kuantan Dam Project

The design drawings are shown in Fig. XII.3.4. The main features of the Project are as follows:

Reservoir	
Gross Storage Capacity	$1{,}570\times10^6$ m^3
Effective Storage Capacity	$1{,}145\times10^6$ m^3
Flood Water Level (FWL)	EL. 121.08 m
Surcharge Water Level (SWL)	EL. 120.00 m
Normal Water Level (NWL)	EL. 115.20 m
Low Water Level (LWL)	EL. 102.00 m
Sediment Level	EL. 99.50 m
Effective Depth	18.0 m
Surface Area at SWL	91.5 km^2
Catchment Area	6,377 km^2 (excl. Singkarak Lake basin)
Annual Average Inflow	210.1 m^3/s

Dam	
Type	Concrete Gravity
Dam Crest Elevation	EL 123.00 m
Height	73.0 m
Freeboard	1.9 m
Crest Length × Crest Width	294.0 m × 5.0 m
Non-overflow Crest Elevation	EL 123.00 m
Overflow Crest Elevation	EL 106.50 m
Overflow	
Depth	14.6 m
Length	69 m (15 m × 4 gates + 3 m × 3 piers)
Volume of Dam	339,100 m^3
Base Width	74.55 m
Slope	
Upstream Face	Vertical (above EL 100 m) 1 : 0.25 (below EL 100 m)
Downstream Face	1 : 0.85

Spillway	
Type	Gated type
Discharge Capacity	6,970 m^3/s
Gate Type and Dimension	Roller Gate; 14.5 m (H) × 15.0 m (W) × 4-unit

Diversion Works	
Diversion Tunnel	
Number	2 lanes
Length	460 m (No. 1) and 510 m (No. 2)
Inner Diameter	8.8 m
Total Design Capacity	1,510 m^3/s

Intake	
Type	Submerged on Upstream Face
Elevation of Intake	95.0 m
Gate Type and Dimension	Roller Gate; 5.0 m (H) × 5.0 m (W) × 3-unit
Screen	23 m (H) × 7 m (W) × 3-unit

Penstock	
Type	Partly embedded, encased in dam body
Dimension	4.2 m (Dia.) × 105 m (L) × 3-line

Power Station	
Type	On Ground
Dimension	58 m (L) × 29 m (W) ×53 m (H)

Tailrace	
Type	Open Channel
Length	52 m
Gradient	1 : 2.0
Section	Trapezoidal
Gate Type	Roller Gate; 6.0 m (H) × 6.0 m (W) × 1-unit

River Outlet	
Type	Conduit
Dimension	2.3 m (H) × 2.3 m (W) × 1-unit
Gate Type	Slide Gate; 2.3 m (H) × 2.3 m (W) × 1-unit

Capacity of Power Plant	
Maximum Output	114,000 kW (38,000 kW× 3-unit)
Maximum Turbine Discharge	270 m^3/s
Effective Head	50.7 m
Annual Ave. Generated Energy	657 GWh

Turbine	
Type	Vertical Shaft, Kaplan
Installed Capacity	40.0 MW × 3-unit
Effective Head	50.7 m
No. of Revolutions	214 rpm

Generator	
Type	3-Phase AC, Synchronous
Capacity	46,000 kVA × 3-unit
Voltage / Frequency	11 kV / 50 Hz

Main Transformer	
Type	3-Phase ONAF Outdoor Type
Capacity	45,000 kVA × 3-unit
Voltage	11/150 kV

Transmission Line from Kuantan P/S to Telukkuantan S/S (Planned)	
Length	30 km
Phase	3-Phase System
Voltage	150 kV
No. of Circuits	Double

Substation	
Location	Telukkuantan
Type	3-Phase, Outdoor, Single Bus
Voltage	150/20 kV

Switchyard	
Location	Right Bank of Damsite
Type	3-Phase, Outdoor
No. of Bays	5 Bays (3 for G/E and 2 for T/L)
Voltage	150/11 kV

TABLES

XII DAM ENGINEERING

Table XII.1.1 POTENTIAL RESERVOIR CAPACITIES OF CANDIDATE DAMSITES

Dam	Catchment Area (km^2)	Annual Runoff (10^6m^3)	Possible Max. WL (EL.m)	Gross Storage Capacity (***) (10^6m^3)	Sediment Capacity (*) (10^6m^3)	Effective Storage Capacity (10^6m^3)
1. Kapoernan	650	1,164	125.00	139	33	107
2. Mahat	993	1,747	100.00	295	50	245
3. Kototengah	660	1,183	240.00	15	33	0
4. Kampar Kiri No.1	1,187	1,908	130.00	2,348	59	2,289
5. Kampar Kiri No.2	552	858	150.00	3,189	28	3,161
6. Upper Sinamar	1,580	2,031	485.00	197	93	104
7. Lower Sinamar	1,796	2,308	485.00	1,350	106	1,244
8. Sukam	360	583	240.00	693	19	674
9. Upper Kuantan (**)	5,816	8,493	150.00	272	305	0
10. Kuantan (**)	6,377	9,183	125.00	2,100	335	1,765
Total	19,971	29,458		10,598	1,060	9,589

Note : * Sediment volume is calculated assuming the following specific sediment volume and sedimentation period of 100 years:

- Kampar river system : $500m^3/km^2/yr$,
- Kuantan river system (Sinamar river) : $585m^3/km^2/yr$ and
- Kuantan river system (Kuantan and Sukam rivers) : $525m^3/km^2/yr$

** excluding Singkarak lake basin (1,076 km^2)

*** Storage capacities show topographically maximum volume.

Scales of topographic maps used for the study are as follows:

1/10,000 for Kampar Kiri No.1, Kampar Kiri No.2, Upper Sinamar, Sukam and Kuantan dams

1/50,000 for other dams

Table XII.1.2 PHYSICAL CONDITIONS OF POSSIBLE DAMSITES

Damsite Item	Kapoernan	Kampar Kiri No.1	Kampar Kiri No.2
1. River System	Kapurnangadang River	Sibayang River	Singingi River
2. Location	about 4.5km upstream of the confluence with the Kampar Kanan River	about 2km upstream of Tanjungbalit	about 9km upstream of Muaralembu
Latitude and Longitude	100°35'29"(E) 00°16'30"(N)	101°04'00"(E) 00°11'18"(S)	101°17'50"(E) 00°25'06"(S)
3. Catchment Area (km^2)	650	1,187	552
4. Site Topography	0.2 km wide valley between long hills with a steep slope in the foot zone and a flat top zone, and about1/360 river-bed grade	0.45 km wide valley bordered by a steep slope on the left and a low hill (150 m) on the right side, and about 1/1,820 river-bed grade	narrow, V-shaped valley, 0.35 km wide, bordered by steep slopes, and about 1/2,200 river-bed grade
5. Foundation Geology	Miocene conglomeratic sandstone and siltstone moderatly hard to weak	Alternance of mudstone/shale and sandstone/quartzite, Permo-Carboniferous	Quartzite or sandstone with possible shale intercallations, Permo-Carboniferous
6. Proposed Dam Type	Concrete gravity dam	Rockfill dam	Concrete gravity dam

Damsite Item	Upper Sinamar	Sukam	Kuantan
1. River System	Sinamar River	Sukam River	Kuantan River
2. Location	about 3km downstream of the confluence with the Batiksarik River	about 5km upstream of the crossing point of the Sukam River and the Trans Sumatra highway	about 10.5km upstream of Lumbukkambacang
Latitude and Longitude	100°46'18"(E) 00°19'00"(S)	101°01'08"(E) 00°46'47"(S)	101°19'34"(E) 00°36'48"(S)
3. Catchment Area (km^2)	1,580	360	6,377 (*)
4. Site Topography	0.5 km wide valley bordered by a hill with flat top on the right and a mountain with gentle slope on the left side, and about 1/70 river-bed grade	0.25km wide canyon with 35 m high, vertical walls and a gentle upper slope on the left side, and about 1/120 river-bed grade	narrow, V-shaped valley, 0.3 km wide, bordered by steep slopes, and about 1/700 river-bed grade
5. Foundation Geology	Alternance of black shale and quartzite, Permo-Carboniferous	Sandstone, hard on the lower slopes and possibly marl on the upper slopes, Oligocene	Hard quartzite on the lower slope with possible mudstone intercalations on the upper slope, Permo-Carboniferous
6. Proposed Dam Type	Rockfill dam	Concrete gravity dam	Concrete gravity dam

Note : * excluding Singkarak lake basin (1,076 km^2)

Table XII.2.1 DESIGN DISCHARGES FOR POSSIBLE DAMS

Facilities	Dam	Design Discharge (m^3/sec)
Diversion Tunnel	Kapoernan	560
	Kampar Kiri No. 1	1,150
	Kampar Kiri No. 2	500
	Upper Sinamar	1,310
	Sukam	400
	Kuantan	1,510
Spillway	Kapoernan	2,180
	Kampar Kiri No. 1	7,270
	Kampar Kiri No. 2	1,990
	Upper Sinamar	1,760
	Sukam	8,380
	Kuantan	10,050
River Outlet	Kapoernan	-
	Kampar Kiri No. 1	15
	Kampar Kiri No. 2	10
	Upper Sinamar	15
	Sukam	5
	Kuantan	100