CHAPTER 4 FLOOD CONTROL PLAN

4.1 Basic Policy of Flood Control Plan

4.1.1 Principal Plan Conditions

(1) Targets of Flood Control Plan

The central area of Ambon city has suffered from river flooding 2 or 3 times a year, causing an inundation area of 36 ha and duration of 1-3 hours on average due to the flooding from the five target rivers. Also, large scale floods frequently attack the area. In recent years, big floods occurred in 1984, 1989 and 1996,and resulted in a wide inundation area of about 100 ha lasting 4-7 hours in the central part of the city. Therefore, urgent implementation of drastic measures are necessary to overcome this flood prone condition. To cope with this situation, the targets of this flood control plan are 1) to mitigate flood damage by structural and non-structural flood control measures, 2) to improve river environment condition through the implementation of flood control measures and 3) to propose a plan of water resources development for domestic use in Ambon city by designing multipurpose dams and reservoirs.

(2) Protected Area and Target Rivers

The protected area covered by this plan is the central part of Ambon city. This area, the possible flood prone area, includes the downstream parts of the basins for the five target rivers Ruhu, Batu Merah, Tomu, Batu Gajah and Batu Gantung. Each river flows down through V-shaped valleys to the flood plain (central part of Ambon city or this protected area). The most upstream part of this flood prone area is the outlet of each river valley. The protected area includes the most important parts of the city and forms the center of city functions such as commerce, culture, administration, etc.

(3) Project Target Year

The target year for planning is set at 2015, same as the Flood Control Master Plan. This target year is utilized to determine water demand and supply in the future. However water demand and supply in the next 15 years, i.e. until the year 2030, is also taken into account for the long term plan.

(4) Design Scale

The design scale of flood control plan is evaluated by the return period (recurrence interval) of the design flood. As a result of the following consideration, a design scale of 30 years is recommended for the flood control plan for Ambon central area.

Table-D.4.1 of "Flood Control Manual Volume II" provides a summary of return period criteria which have been used in the design of various flood control projects in Indonesia. In an area of Urban / Industrial Development like Ambon central city, the design flood return period varies 10 to 25 years in the short term, and 25 to 50 years in the long term. Also in this manual, recommended minimum design flood standard are presented in Table-D.4.2. For new projects like this project in Ambon, minimum design flood return periods of more than

10 years in the initial phase and more than 25 years in the final phase are recommended. As a comparison, the recently experienced severe floods in 1984 and 1989 are estimated to have a return period of approximately 10 years.

Table-D.4.1 Design Flood Return Period Used in Indonesia

Project Name	Location	Design Recurrence Interval (Years)					
		Agricultural Development		Rural Development		Urban/Industrial Development	
		Short Term	Long Term	Short Term	Long Term	Short Term	Long Term
Cimanuk and Cisanggarung River Basin Development Project	West Java	10 - 15	25 - 50	10 - 15	25 - 15	25 - 50	25 - 50
Citaduy River Basin Development	West Java	25	50	25	50	25	50
South Kedu Multipurpose Project	Central Java	5 - 15	15 - 20	15	20	15	20
Solo River Basin Development	Central Java	5 - 10	50	10	50	10 - 50	50
Brantas River Basin Development	East Java	10 - 25	50	25	50	25	50
Pemali Flood Control	Central Java	5	25	5	25	5	25
Jakarta Metropolitan Flood Control	West Java	25	100	-	100	-	100
Krueng Aceh Flood Control	Aceh	5	-	5	-	5	-
Lower Asahan River Flood Control	North Sumatra	25	-	25	-	25	-
Padang Urban Flood Control	West Sumatra	25	50	25	50	Varies	50
Jeneberang River Basin Development	South Sulawesi	Varies	50	25	50	25	50

Note.

1) Flood control project in Indonesia are often implemented in stages depending on the availability of funds. Accordingly, a lower level of flood protection is provided initially, but a higher level of protection is provided in the long term, after other works are implemented.
2) Area Division
   Agricultural Development : There is very little risk to life and potential economic loss is low.
   Rural Development : There is little risk to life and potential economic loss is significant.
   Urban/Industrial Development : There is considerable risk to life and potential economic loss is high.
3) Source : Flood Control Manual, Volume II, June 1993

Table-D.4.2 Recommended Minimum Return Period of Design Flood

Flood Conveyance System	Project Type(for River Flood Control Project) and Total Population (for Drainage System)	Initial Phase	Final Phase
River System	Emergency Project	5	10
	New Project	10	25
	Updating Project for rural and/or urban with P < 2,000,000	25	50
	Updating Project for urban with P > 2,000,000	25	100
Primary Drainage System (Catchment area > 500 ha)	Rural	2	5
	Urban P < 500,000	5	10
	Urban 500,000 < P < 2,000,000	5	15
	Urban P > 2,000,000	10	25

Notes :

1) Higher design flood standard should be applied if an economic analysis indicates that it is desirable or if flooding is a significant risk to human life.
2) P = Total Urban Population
3) Emergency Projects are developed without preliminary engineering and economic feasibility studies at sites where flooding is excessive and flooding problems present a significant risk to human life.
4) New Project include flood control projects where no previous flood projects have been developed or where Emergency Projects have been developed.
5) Updating Projects include rehabilitation projects and improvements to exiting project. Most River Basin Development Projects are considered to be updating projects.
6) Initial Phase is recommended for immediate use.
7) Final Phase is recommended for use in upgrading existing facility when the necessary funds become available.

4.1.2 Policy of Flood Control Measures

As essential information for preparation of flood control plan, the basin characteristics and conditions of the five (5) target rivers are summarized as follows:

- The catchment areas of the rivers are small: 6-8 km^2, in Batu Merah River, Tomu River and Batu Gajah River, and 17 km^2 in Ruhu River.
- The river slopes are rather gentle, 1/190-1/480 (EL.0-5m), 1/150-1/260 (EL.0-10m) in central city area, and are steep, 1/26-1/68 (EL.10-100m) in mid-stream and 1/10-1/22 in the upstream.
- Heavy rainfall hyetograph in Ambon is characterized as 2-3 hours continuation of peak rainfall of 30-50 mm/hr, two or three times of such peak rainfall over an interval of several hours. It is also characteristic in Ambon that daily rainfall of 100-200 mm continues for several days and causes flooding.
- Land slide frequently happens in steep slope areas at the time of heavy rain. The river beds seem to have been raised due to the excess sediment discharge. This sedimentation in river course decreases flow area and flow capacity.
- Residential houses are concentrated in the alluvial plain which forms the central city area. The new residential areas for expanding population spread to the suburbs. The upstream area of each target river is being developed for new residential zones.
- The river is indispensable environment factor for the inhabitants along the rivers. River water is utilized usually for cooking, washing and bathing. The river course provides a space for toilets and children's play grounds.
- For 28 % of Ambon's population, currently clean tap water is supplied by PDAM water supply network. However, by 2015, an increase in water supply of about 5,000 m^3/day will be required in the Study Area.

Based on the basin characteristics and river conditions mentioned above, the basic policy for flood control measures is set as follows :

- To fully attain the main target of plan (mitigation of flood damage), the Master Plan shall include structural measures and non-structural measures for flood control and sediment control.
- Also, in preparation of the Master Plan, plans for river environment conservation and water development for future domestic use through multipurpose dams are proposed.
- Structural flood control measures enable the design flood to flow safely into the sea without flooding, directly controlling flood flow in or along the river course. Structural measures include 1) river improvement work to increase flow capacity of river course and 2) dam and diversion channel to decrease flood peak discharge into the river course.
- Non-structural flood control measures are measures other than structural flood control measures to mitigate flood disasters, including various methods for flood runoff suppression, for flood proofing and for facilitation of flood control activities.
- To identify the most optimal structural measures plan for flood control, alternative plans are examined including river improvement work (large scale) with no other measure and river improvement work (small scale) with other measures (dam or diversion channel).

4.2 Plan and Design of Structural Flood Control Measures

In this chapter, 1) River Improvement, 2) Flood Control Dams, 3) Diversion Channels and 4) Check Dams shall be studied. As flood control measures for these works, the following measures are applied.

<River Improvement Work to Increase Flow Capacity>
The methods of increasing discharge capacity applied to the target area are as follows :

- Formation and excavation of river bed
- Heightening of dikes (flood wall)
- Concrete channel work
- Widening of river width

In view of the densely concentrated houses around the rivers and the resulting difficulty in purchasing land, the widening of river width should be carefully planned considering a large impact to the society. As a result, sectional expansion through excavation of river bed and heightening of flood walls, and concrete channel work must be the prioritized selection of river improvement works.

<Dams and Diversion Channels to Decrease Flood Peak Discharge>
The methods of decreasing flood peak discharge applied to the target area are to be flood control dams and diversion channels. Sites for retarding basin are not easy to find since there is no space in the city area and no suitable plain location in the mountain area. Flood control dams and diversion channels are planned in combination with river improvement works. Dam construction is effective as a flood control measure. Diversion channels should be selected at effective and efficient sites. Tunnel plans for diversion channel are recommended because of no requirement for land acquisition.

<Check Dams for Sediment Control>
Check dams should be taken into account where necessary in order to mitigate flooding caused by sedimentation in the river courses, and to minimize the reduction in the effective storage capacity of dams caused by the accumulation of sediment.

In addition to these structural flood control measures, landside drainage measures should also be taken into account. There are a number of drainage channels connected to the rivers from the built-up areas. According to the city drainage plan in 1993, side drains were recommended for the four rivers in the central city area. However implementation of these plans is proceeding only slowly. Therefore, in order to prevent / reduce reverse flows from the rivers into the city, 1) high water level of river should be kept low by excavating the river-bed, 2) adoption of flap gates, etc. should be considered which can be automatically closed when river water levels are high.

4.2.1 Design Criteria

The design for river improvement works, dams and reservoirs, diversion channels and check dams shall basically follow the "Flood Control Manual, Vol. III: Guidelines for Design and Implementation, Republic of Indonesia, Ministry of Public Works". Concerning items not specified in the Manual III, "Manual for River Works in Japan = Design, Ministry of Construction, Japan" shall be applied.

4.2.2 River Improvement

(1) Plan and Design Conditions

The proposed measures for river course improvement are follows:

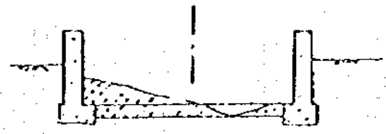
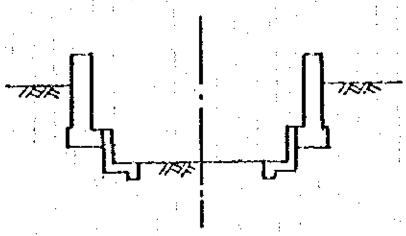
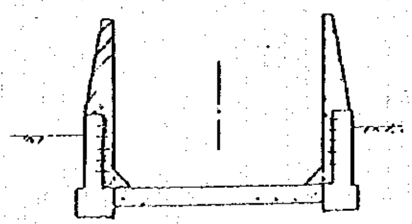
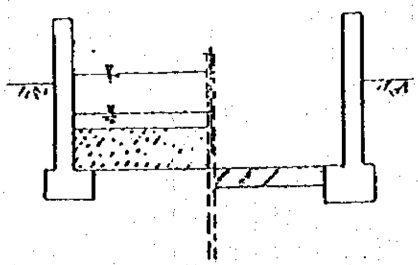
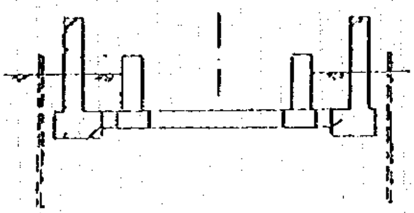
1) River-bed Formation
2) River-bed Excavation
3) Flood Wall Heightening
4) Concrete Channel Works
5) River Widening

The outline of these measures is shown in Table-D.4.3. The priority for adopting a measure is set according to the conditions of each river, taking into account social impact, economic efficiency, city drainage system and technical validity. Additional to these improvement measures, river bridge improvement is also employed to necessary sections. Bridges with piers in the river should be improved by excavation to increase clearance between the flood water level and the underside of the bridge.

Planning conditions of the river improvement works are set as follows:

1) River improvement plan for the design flood (30 year return period) is examined and other scale plans (5 year and 10 year return period) for combination plan with dam or diversion channel are also studied.
2) The range covered by the river improvement plan is from the most upstream flooded point of design flood discharge to the river mouth.
3) Current river alignment is not in principal changed.
4) Uniform flow calculation (Manning's Formula) is applied to each section which the improvement range is divided into so as to have nearly the same river width, according to the current river width. Manning's coefficient (n) is set as follows:
   - Current River : n=0.025
   - River after river-bed formation or excavation : n=0.020
   - River with concrete channel : n=0.015
5) As for the planning flood wall freeboard, 0.6 m (less than 200 m^3/sec) and 0.80 m (more than 200 m^3/sec and less than 500 m^3/sec) is employed, according to the design discharge.
6) The cross section is assumed to be rectangular after river-bed formation or excavation.
7) Excavation is assumed to be carried out with a river width of each divided section.

Table-D.4.3 Outline of River Improvement Works

Measures	Standard Cross Section	Outline of River Improvement Works
(1) River-bed Formation		- According to the current river-bed gradient, river-bed excavation is carried out until the level set based on the deepest river-bed. When excavating sediment (including rubbish and sludge) that has accumulated on the river-bed, the cross-sectional area of the river is increased and the roughness reduced. - In all the rivers, river-bed formation has to be done at first. - Flood wall reinforcing is not necessary.
(2) River-bed Excavation		- After river-bed formation, river-bed is excavated deeper and the cross-sectional area of the river is increased. - This measure makes flood water level lower so that landside water could be easy to flow into the river. However when excavating too deep, 1)estuary treatment becomes necessary and the cost becomes high, 2) river utilization by residents become difficult. - The maximum excavation depth is assumed to be less than about 1.0m.
(3) Flood wall Heightening		- First, partial flood wall heightening is employed inline with river-bed excavation. If flooding still cannot be controlled after carrying out river-bed excavation, the necessary cross-sectional area of the river is secured by flood wall heightening. - This measure is cheap and effective and land acquisition is not necessary. However flood water level becomes high so that landside water could not be flow into the river when flooding. - Then the heights of flood walls is to be less than current maximum flood wall height above ground level. Besides maximum flood wall height is to be less than 4 m as a general rule, because of structural limits (if the wall is more than 4 m, new construction of the wall is recommended).
(4) Concrete Channel		- In waterways where the design discharge capacity still cannot be flowed after executing the above 1), 2), 3) measures, concrete is lined on the river-bed. - By executing this, improvements in the coefficient of roughness and the tractive force of sediment can be expected. - However, river utilization would be limited.
(5) River Widening		- Neck points of narrow river section is improved in line with the above measures 1), 2), 3), 4), if the section is enough to be partially improved. - Narrow sections of rivers cannot help being widened after the above measures 1), 2), 3), 4), in order to secure the necessary cross-sectional area. - This measure is conditional upon first securing the land required for the widening and work execution. - When widening rivers, the existing flood walls are only removed after constructing the new flood walls.

(2) River Improvement for Ruhu River

< Current River Condition >

The river width, the longitudinal section (deepest river-bed elevation, left and right flood wall level, left and right side original ground level, OGL) and discharge capacity are as shown in Figure-D.4.1. Current river condition is summarized as follows:

- Catchment area at river mouth : 16.84 km^2
- Current river-bed gradient : 1/550
- River width : 12.0 to 45.0 m,
- Average river-bed elevation : EL. -0.4 m to EL. -0.9 m at the river mouth
  EL. 2.8 m at the most upstream (1'600)
- Flood wall height : 2.0-2.7 m (0'000-1'000)
  3.0-3.6 m (1'000-1'600)
- Discharge capacity : 110-150 m^3/sec (0'000-0'350)
  60 -100 m^3/sec (0'400-0'600)
  40 - 50 m^3/sec (0'650-0'950)
  50 -140 m^3/sec (1'000-1'350)
  130-200 m^3/sec (1'400-1'600)
- Bridges :

Location	0'047	0'059	0'074	1'018	1'359	1'554
Name	B1	B2	B3	B4	B5	B6
Under Level *	EL.2.55m	EL.1.70m	EL.3.50m	EL.4.08m	EL.4.71m	EL.5.51m
Bridge Pier	-	exist	-	exist	exist	-

* Under elevation of bridge beam (EL.m)

- Social Condition :
  One of reasons for the reduction of the cross-sectional area are sediment and rubbish in the river. It seems to be difficult to acquire land along the river, because there are inhabited houses near the flood walls in the middle reaches.

< Planning Condition >

Planning condition is summarized as follows:

- River improvement section : 0'000-1'600 (1600 m)
- Design discharge :

Return Period	5-year	10-year	30-year
0k000-1k600	170 m^3/sec	230 m^3/sec	320 m^3/sec

- Assumed current river width (before widening):

Distance	0'000-0'500	0'500-0'600	0'600-0'800	0'800-1'000	1'000-1'400	1'400-1'600
Width	28.0 m	12.0 m	17.0 m	14.0 m	17.0 m	14.0 m

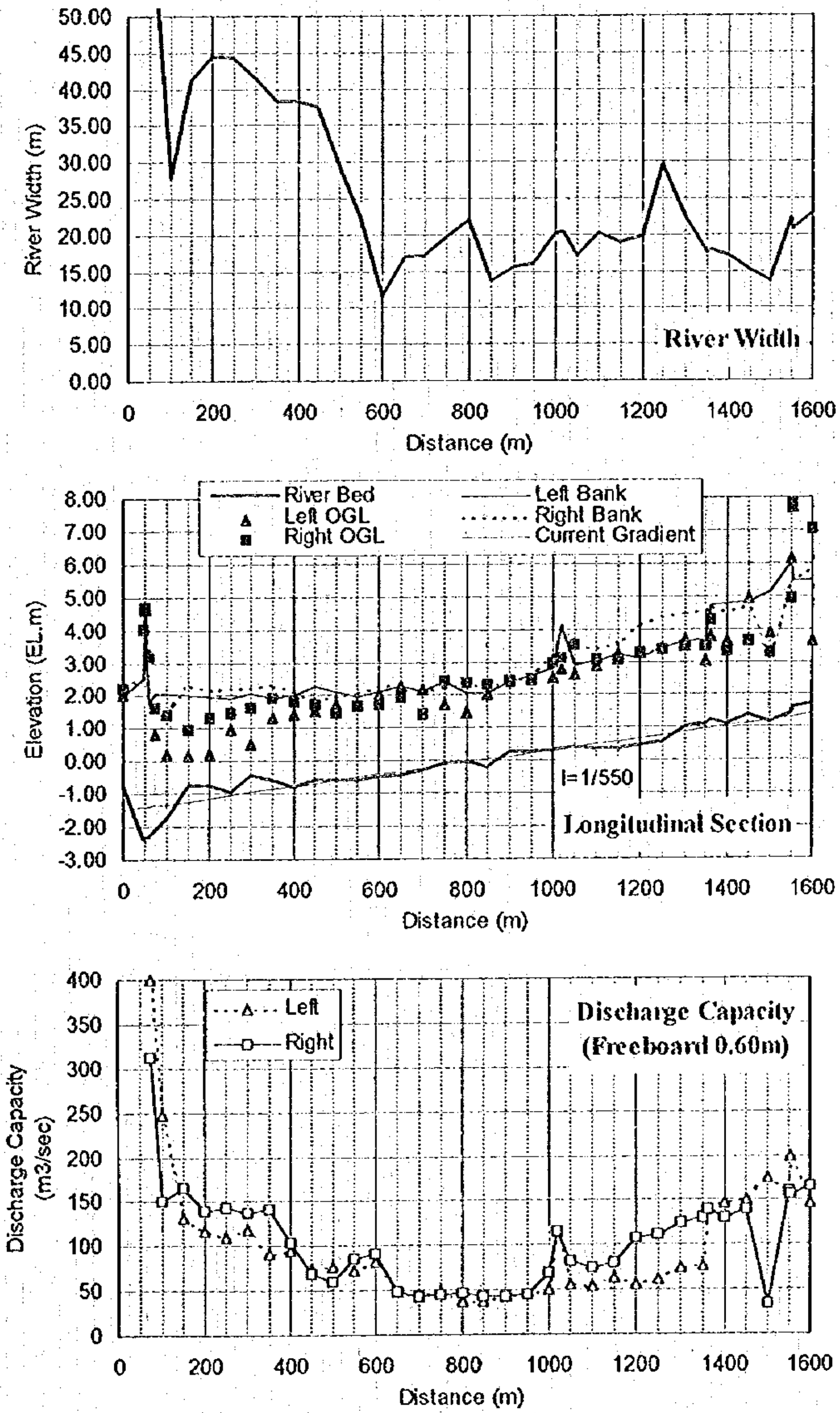


Figure-D.4.1 Current Condition of Ruhu River

< River Improvement Plan >

River improvement plans with 5, 10 and 30 year return period were studied and the components of the plan are described in Table-D.4.4.

Ruhu River has a relatively wide river width of about 17 m, compared with the other rivers' widths of less than 10 m. Moreover river widening is inevitable so that concrete channel work was not employed for the river improvement of Ruhu River. River excavation depth is employed at 1 m. As for the plan with 5-year return period, partial river widening of 300 m length is necessary. Wider and more drastic widening is inevitable for the plan with 10 and 30-year return period

Table-D.4.4 River Improvement Plan (Ruhu River)

Items			5-year	10-year	30-year
Plan Item	Design Discharge	Section	0'000-1'600	0'000-1'600	0'000-1'600
		Q (m^3/s)	170	230	320
	River-bed	Section	0'000-1'600	0'000-1'600	0'000-1'600
	: Gradient	-	1/550	1/550	1/550
	: Downstream Elevation	E (EL.m)	-2.50	-2.50	-2.50
	Standard Section	Section	0'000-1'600	0'000-1'600	0'000-1'600
	: Current River Width	Wc (m)	12.0-28.0	12.0-28.0	12.0-28.0
	: Planned River Width	Wp (m)	14.0-28.0	15.0-28.0	26.0-32.0
	: Water Height	Hw (m)	2.40-3.40	2.40-3.30	2.70-3.30
	: Dike Height	Hd (m)	3.00-4.00	3.20-4.10	3.50-4.10
Work Item	River-bed Formation	Section	0'000-1'600	0'000-1'600	0'000-1'600
		L (m)	1600	1600	1600
		V (m^3)	21000	21000	21000
	River-bed Excavation	Section	0'000-1'600	0'000-1'600	0'000-1'600
		D (m)	1.00	1.00	1.00
		L (m)	1600	1600	1600
		V (m^3)	32800	43000	54900
	Concrete Channel	Section	-	-	-
		L (m)	-	-	-
		A (m^2)	-	-	-
	Flood Wall Heightening	Section	0'650-1'550	0'520-1'530	0'400-1'550
		MnH (m)	3.50-4.00	3.50-4.00	3.50-4.00
	: Left	ΔH (m)	0.30	0.30	0.20-0.30
		L (m)	300	300	420
	: Right	ΔH (m)	0.20-0.60	0.20-0.60	0.20-0.60
		L (m)	350 (250)	350 (0)	500 (70)
	River Widening	Section	0'550-1'000	0'550-1'600	0'500-1'600
		ΔW (m)	3.0-5.0R	5.0-12.0R	12.0-20.0R
		L (m)	300	1100	1100
		A (m^2)	1500	10000	17000
	Bridge Improvement	Location	0'059-1'359	0'059-1'359	0'059-1'359
		Number	B2,B4,B5	B2,B4,B5	B2,B4,B5
Land Acquisition Areas		A (m^2)	1500	10000	17000
Resettlement Households		Number	40	147	147

Note

Q : Discharge (m^3/sec) E : Elevation (EL.m) W : Width (m) L : Length (m)
D : Depth (m) H : Height (m) MnH : Mean Height (m) ΔH : Mean Increase in Height (m)
ΔW : Widening Width (m) A : Area (m^2) V : Volume (m^3)
() : Flood wall heightening length without river widening length

(3) River Improvement for Batu Merah River

< Current River Condition >

The river width, the longitudinal section (deepest river-bed elevation, left and right flood wall level, left and right side original ground level, OGL) and discharge capacity are as shown in Figure-D.4.2. Current river condition is summarized as follows:

- Catchment area at river mouth : 7.03 km^2
- Current river-bed gradient : 1/320
- River width : 6.0 to 20.0 m,
- Average river-bed elevation : EL. -1.0 m at the river mouth
  EL. 3.9 m at the most upstream (1'600)
- Flood wall height : 1.8-2.3 m on average (2.7 m in maximum)
- Discharge capacity : more than 40 m^3/sec (0'000-0'250)
  20 -40 m^3/sec (0'300-0'500)
  13 - 25 m^3/sec (0'500-1'600)
- Bridges :

Location	0'009	0'116	0'377	0'386	0'686	0'993	1'535
Name	B1	B2	B3	B4	B5	B6	B7
Under Level *	2.55	1.73	3.00	2.56	3.67	5.35	7.30
Bridge Pier	-	-	-	exist	-	-	-

* Under elevation of bridge beam (EL.m)

- Social Condition : Batu Merah River is one of the rivers that flows through the central urban area of Ambon City. Accumulated sediment in the waterway has reduced the cross-sectional area of the river. Houses are densely concentrated around the flood walls along Batu Merah River and residents rely on the river for their water needs. As a result, these houses suffer damage whenever floods occur.
- Drainage : Drainage channels with small catchment area flow into the Batu Merah River and the largest of these is Alat River. This drainage channel is lined with concrete and serves to drain urban sewage. Alat River flows into Batu Merah River from its left side approximately 350 m upstream of the river mouth. This channel usually carries small amounts of domestic waste water. At flood times, rainfall water from urban area (landside water) flowing into the channel, causes the flow to increase and eventually leads to inundation.

< Planning Condition >

Planning condition is summarized as follows:

- River improvement section : 0'000-1'600 (1600 m)
- Design discharge :

Return Period	5-year	10-year	30-year
0k000-1k250	90 m^3/sec	110 m^3/sec	150 m^3/sec
1k250-1k600	80 m^3/sec	100 m^3/sec	130 m^3/sec

- Assumed river width (before widening) :

Distance	0'000-0'200	0'200-0'350	0'350-0'700	0'700-0'800	0'800-1'000	1'000-1'250	1'250-1'400	1'400-1'600
Width	20.0 m	16.0 m	8.50 m	6.5 m	10.0 m	7.0 m	7.0 m	6.0 m

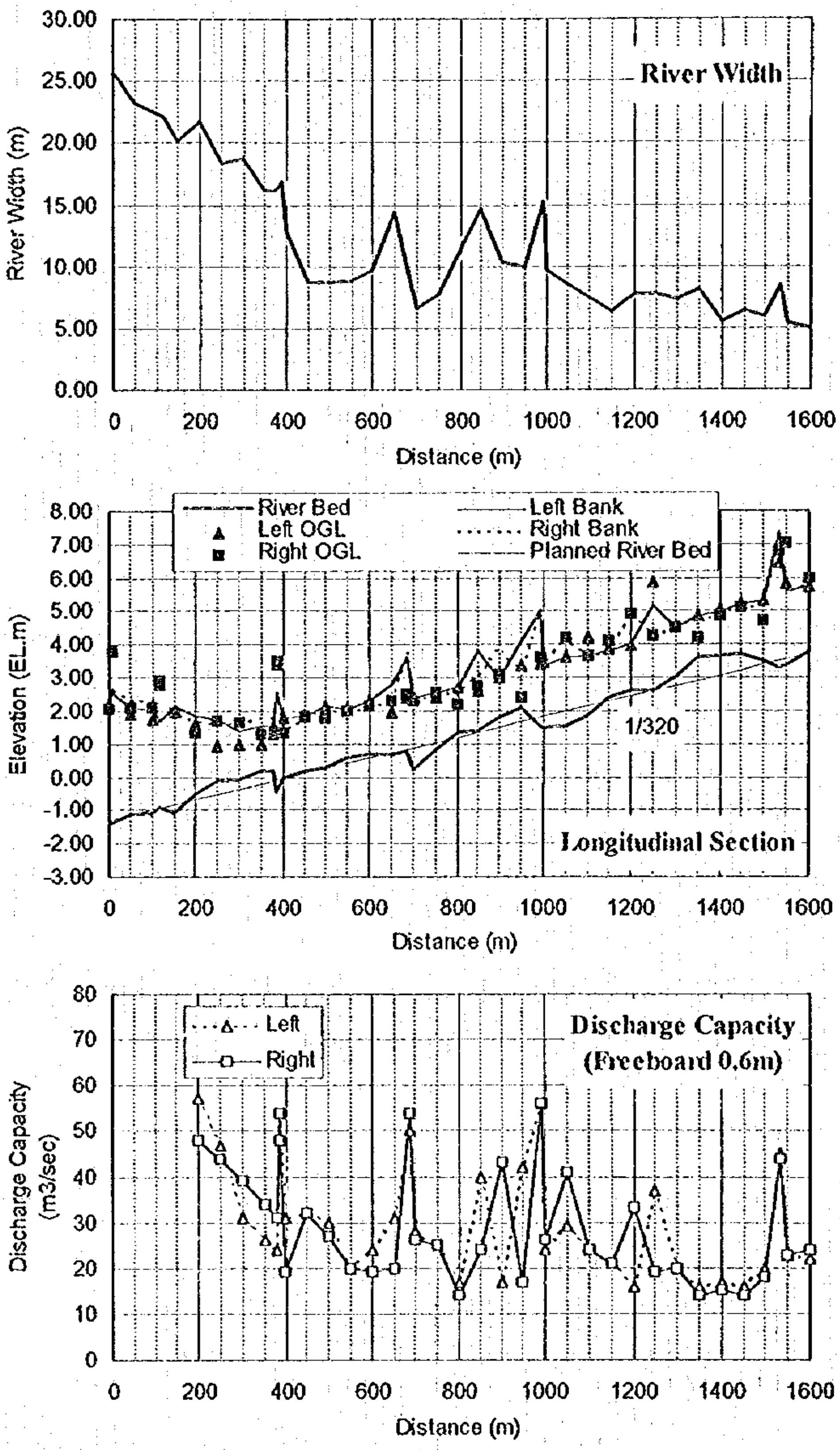


Figure-D.4.2 Current Condition of Batu Merah River

< River Improvement Plan >

River improvement plans with 5, 10 and 30 year return period were studied and the components of the plan are described in Table-D.4.5.

Batu Merah River has a slightly lower flood wall in height of 1.8-2.3 m, compared with the other rivers' wall height of 2.3-3.0 m at most sections. It results in low discharge capacity. Therefore, heightening of less than 1 m (less than 0.5 m if possible) was allowed to be employed for the planning. River excavation depth is employed at 1 m. As for the plan with 5-year return period, only limited section of 70 m is necessary to be widened. Wider and more drastic widening is inevitable for the plan with 10 and 30-year return period.

Table-D.4.5 River Improvement Plan (Batu Merah River)

Items			5-year	10-year	30-year
Plan Item	Design Discharge	Section	0'000-1'600	0'000-1'600	0'000-1'600
		Q (m^3/s)	90, 80	110, 100	150, 130
	River-bed	Section	0'000-1'600	0'000-1'600	0'000-1'600
	: Gradient	-	1/320	1/320	1/320
	: Downstream Elevation	E (EL.m)	-2.30	-2.30	-2.30
	Standard Section	Section	0'000-1'600	0'000-1'600	0'000-1'600
	: Current River Width	Wc (m)	6.0-20.0	6.0-20.0	6.0-20.0
	: Planned River Width	Wp (m)	6.0-20.0	6.0-20.0	8.0-20.0
	: Water Height	Hw (m)	2.00-3.10	2.00-3.10	2.00-3.10
	: Dike Height	Hd (m)	2.60-3.70	2.60-3.70	2.60-3.70
Work Item	River-bed Formation	Section	0'000-1'600	0'000-1'600	0'000-1'600
		L (m)	1600	1600	1600
		V (m^3)	6900	6900	6900
	River-bed Excavation	Section	0'000-1'600	0'000-1'600	0'000-1'600
		D (m)	1.00	1.00	1.00
		L (m)	1600	1600	1600
		V (m^3)	16500	19300	23500
	Concrete Channel	Section	0'400-1'600	0'400-1'600	0'200-1'600
		L (m)	1200	1200	1400
		A (m^2)	9500	11700	17400
	Flood Wall Heightening	Section	0'400-1'600	0'400-1'500	0'400-1'500
		MnH (m)	2.60-3.40	2.90	2.90
	: Left	ΔH (m)	0.20-0.60	0.20-0.40	0.20-0.40
		L (m)	1010	970	970
	: Right	ΔH (m)	0.30-0.60	0.10-0.70	0.10-0.70
		L (m)	1070 (1000)	800 (90)	800 (90)
	River Widening	Section	0'700-0'800	0'400-1'600	0'400-1'600
		ΔW (m)	2.0 R	1.5-3.5R	1.5-6.5
		L (m)	70	950	1200
		A (m^2)	350	4750	7750
	Bridge Improvement	Location	0'386	0'386	0'386
		Number	B4	B4	B4
Land Acquisition Areas		A (m^2)	350	4750	7750
Resettlement Households		Number	10	127	160

Note

Q : Discharge (m^3/sec) E : Elevation (EL.m) W : Width (m) L : Length (m)
D : Depth (m) H : Height (m) MnH : Mean Height (m) ΔH : Mean Increase in Height (m)
ΔW : Widening Width (m) A : Area (m^2) V : Volume (m^3)
() : Flood wall heightening length without river widening length

(4) River Improvement for Tomu River

< Current River Condition >

The river width, the longitudinal section (deepest river-bed elevation, left and right flood wall level, left and right side original ground level, OGL) and discharge capacity are as shown in Figure-D.4.3. Current river condition is summarized as follows:

- Catchment area at river mouth : 5.64 km^2
- Current river-bed gradient : 0k000-2'250 : /250, 2k250-2k700 :1/100
- River width : 7.0 to 15.0 m,
- Average river-bed elevation : EL. -0.5 m at the river mouth
  EL. 12.2 m at the most upstream (2'700)
- Flood wall height : 2.2-3.2 m on average (4.0 m in maximum)
- Discharge capacity : more than 70 m^3/sec (0'000-0'750)
  40 -60 m^3/sec (0'800-1'200)
  60 - 90 m^3/sec (1'200-1'500)
  20 - 30 m^3/sec (1'550-2'700)
  more than 100 m^3/sec (2'750-2'900)
- Bridges :

Location	0'008	0'309	0'347	0'460	1'033	1'404	1'750	1'823	2'007	2'308	2'645
Name	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
Under Level *	1.52	1.65	3.20	2.05	5.35	6.18	7.50	7.30	8.60	11.52	14.97
Bridge Pier	-	-	-	exist	exist	exist	-	-	-	-	-

* Under elevation of bridge beam (EL.m)

- Social Condition : Tomu River is one of the rivers that flows through the urban part of Ambon. Accumulated sediment and rubbish in the waterway have reduced the cross-sectional area of the river. As is the case with Batu Merah River, the dense concentration of houses along the flood walls mean that river widening works require much resettlement.
- Drainage : Drainage channels with small catchment area flow into Tomu River and the largest of these is Merdeka Drainage Channel, which flows into Tomu River from its left side approximately 400 m upstream of the river mouth. This drainage channel usually carries small amounts of domestic waste water, but rainfall water from urban area (landside water) flowing into the channel at flood times, causes the flow to increase and eventually leads to inundation.

< Planning Condition >

Planning condition is summarized as follows:

- River improvement section : 0'000-2'700 (2700 m)
- Design discharge :

Return Period	5-year	10-year	30-year
0k000-1k500	70 m^3/sec	90 m^3/sec	120 m^3/sec
1k500-2k700	50 m^3/sec	70 m^3/sec	90 m^3/sec

- Assumed river width (before widening) :

Distance	0'000-0'600	0'600-0'800	0'800-1'100	1'100-1'500	1'500-2'100	2'100-2'200	2'200-2'700
Width	15.0 m	8.0 m	8.0 m	15.0 m	8.0 m	8.0 m	7.0 m

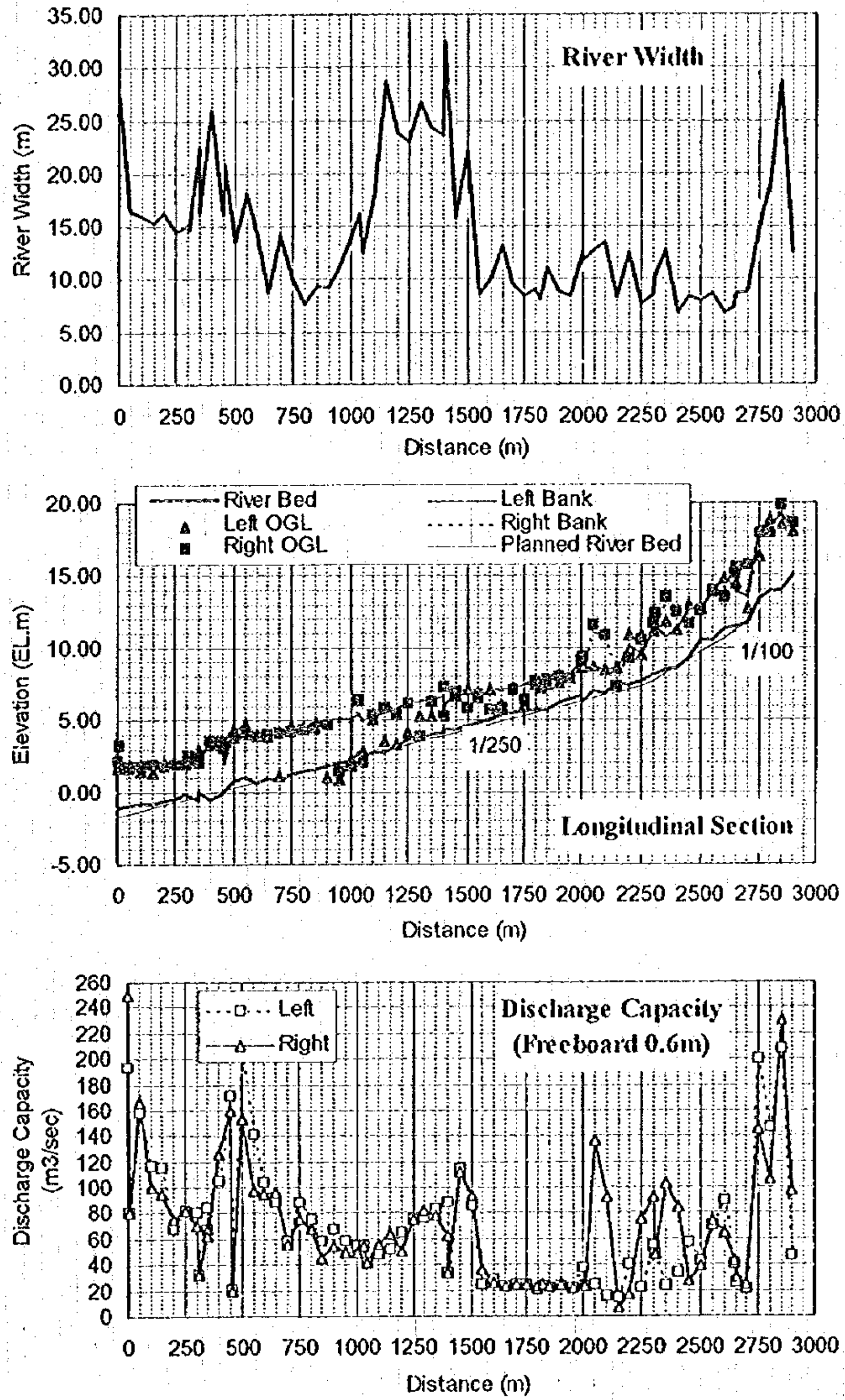


Figure-D.4.3 Current Condition of Tomu River

< River Improvement Plan >

River improvement plans with 5, 10 and 30 year return period were studied and the components of the plan are described in Table-D.4.6.

Tomu River has relatively large discharge capacity compared with the other rivers' capacity. For the plan with 5-year return period, river-bed formation work is enough to secure the necessary cross sectional area. As for the plan with 10-year return period, river-bed excavation of 0.8 m in depth is employed. Concrete channel work was added in the plan with 30-year return period. In the section from 2k100 to 2k700, the discharge capacity with 5 - 10 years return period is secured by carrying out river-bed formation work.

Table-D.4.6 River Improvement Plan (Tomu River)

Items			5-year	10-year	30-year
Plan Item	Design Discharge	Section	0'000-2'700	0'000-2'700	0'000-2'700
		Q (m^3/s)	70, 50	90, 70	120, 90
	River-bed	Section	0'000-2'700	0'000-2'700	0'000-2'700
	: Gradient	-	1/250, 1/100	1/250, 1/100	1/250, 1/100
	: Downstream Elevation	E (EL.m)	-1.70	-2.50	-2.50
	Standard Section	Section	0'000-2'700	0'000-2'700	0'000-2'700
	: Current River Width	Wc (m)	7.0-15.0	7.0-15.0	7.0-15.0
	: Planned River Width	Wp (m)	7.0-15.0	7.0-15.0	7.0-15.0
	: Water Height	Hw (m)	1.40-2.50	1.60-3.30	1.60-2.70
	: Dike Height	Hd (m)	2.00-3.10	2.20-3.90	2.20-3.30
Work Item	River-bed Formation	Section	0'000-2'700	0'000-2'700	0'000-2'700
		L (m)	2700	2700	2700
		V (m^3)	26500	26500	26500
	River-bed Excavation	Section	-	0'000-2'100	0'000-2'100
		D (m)	-	0.80	0.80
		L (m)	-	2100	2100
		V (m^3)	-	19500	19500
	Concrete Channel	Section	-	-	0'600-2'700
		L (m)	-	-	2100
		A (m^2)	-	-	19300
	Flood Wall Heightening	Section	0'950-2'700	1'800-2'700	1'800-2'700
		MnH (m)	2.10-2.80	2.40-2.80	2.40-2.80
	: Left	ΔH (m)	0.10-0.30	0.10-0.40	0.10-0.40
		L (m)	770	130	130
	: Right	ΔH (m)	0.10-0.20	0.10	0.10
		L (m)	600	20	20
	River Widening	Section	-	-	-
		ΔW (m)	-	-	-
		L (m)	-	-	-
		A (m^2)	-	-	-
	Bridge Improvement	Location	0'460-2'007	0'460-1'882	0'460-1'822
		Number	B4, B7, B8, B9	B4-B8	B4, B5, B6, B8
Land Acquisition Areas		A (m^2)	-	-	-
Resettlement Households		Number	-	-	-

Note Q : Discharge (m^3/sec) E : Elevation (EL.m) W : Width (m) L : Length (m)
D : Depth (m) H : Height (m) MnH : Mean Height (m) ΔH : Mean Increase in Height (m)
ΔW : Widening Width (m) A : Area (m^2) V : Volume (m^3)
() : Flood wall heightening length without river widening length

(5) River Improvement for Batu Gajah River

< Current River Condition >

The river width, the longitudinal section (deepest river-bed elevation, left and right flood wall level, left and right side original ground level, OGL) and discharge capacity are as shown in Figure-D.4.4. Current river condition is summarized as follows:

- Catchment area at river mouth : 5.97 km^2
- Current river-bed gradient : 0k000-0'900 : 1/240, 0k900-2k200: 1/160
  2k200-2k600 : 1/65
- River width : 6.0 to 15.0 m,
- Average river-bed elevation : EL. -0.5 m at the river mouth
  EL. 20.2 m at the most upstream (2'600)
- Flood wall height : 2.3-2.8m (0'000-0'750),
  2.6-3.7m (0'800-1'350)
  1.2-1.4 m (1'400-1'600)
  about 1.5 m (1'800-2'600)
- Discharge capacity : more than 65 m^3/sec (0'000-0'200)
  10 - 35 m^3/sec (0'200-0'750)
  75 - 120 m^3/sec (0'800-1'200)
  20 - 50 m^3/sec (1'250-2'600)
- Bridges :

Location	0'424	0'744	0'750	1'344	1'629	1'835	1'919	2'007	2'070	2'130	2'344
Name	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
Under Level *	3.20	5.15	4.27	7.50	10.20	11.50	11.74	12.48	13.20	15.00	18.52
Bridge Pier	-	-	exist	-	exist	exist	-	-	-	-	-

* Under elevation of bridge beam (EL.m)

- Social Condition : Batu Gajah River practically runs through the center of the urban part of Ambon. The river course is almost straight. This river runs through a relatively high altitude area within the Ambon urban area. Accumulated sediment and rubbish in the channel have reduced the flow area of the river. The areas along the river in the downstream area are densely populated.
- Drainage : Drainage channels with small catchment area flow into the river and the largest one is Mesjid Drainage Channel, which flows into the river from its right side approximately 200 m upstream of the river mouth. These drainage channels carry domestic waste water rain water from urban area.

< Planning Condition >

Planning condition is summarized as follows:

- River improvement section : 0'000-2'600 (2600 m)
- Design discharge :

Return Period	5-year	10-year	30-year
0k000-2k100	80 m^3/sec	100 m^3/sec	130 m^3/sec
2k100-2k600	60 m^3/sec	80 m^3/sec	110 m^3/sec

- Assumed river width (before widening) :

Distance	0'000-0'200	0'200-0'500	0'500-1'250	1'250-1'950	1'950-2'200	2'200-2'600
Width	15.0 m	10.0 m	7.5 m	9.0 m	6.0 m	8.0 m

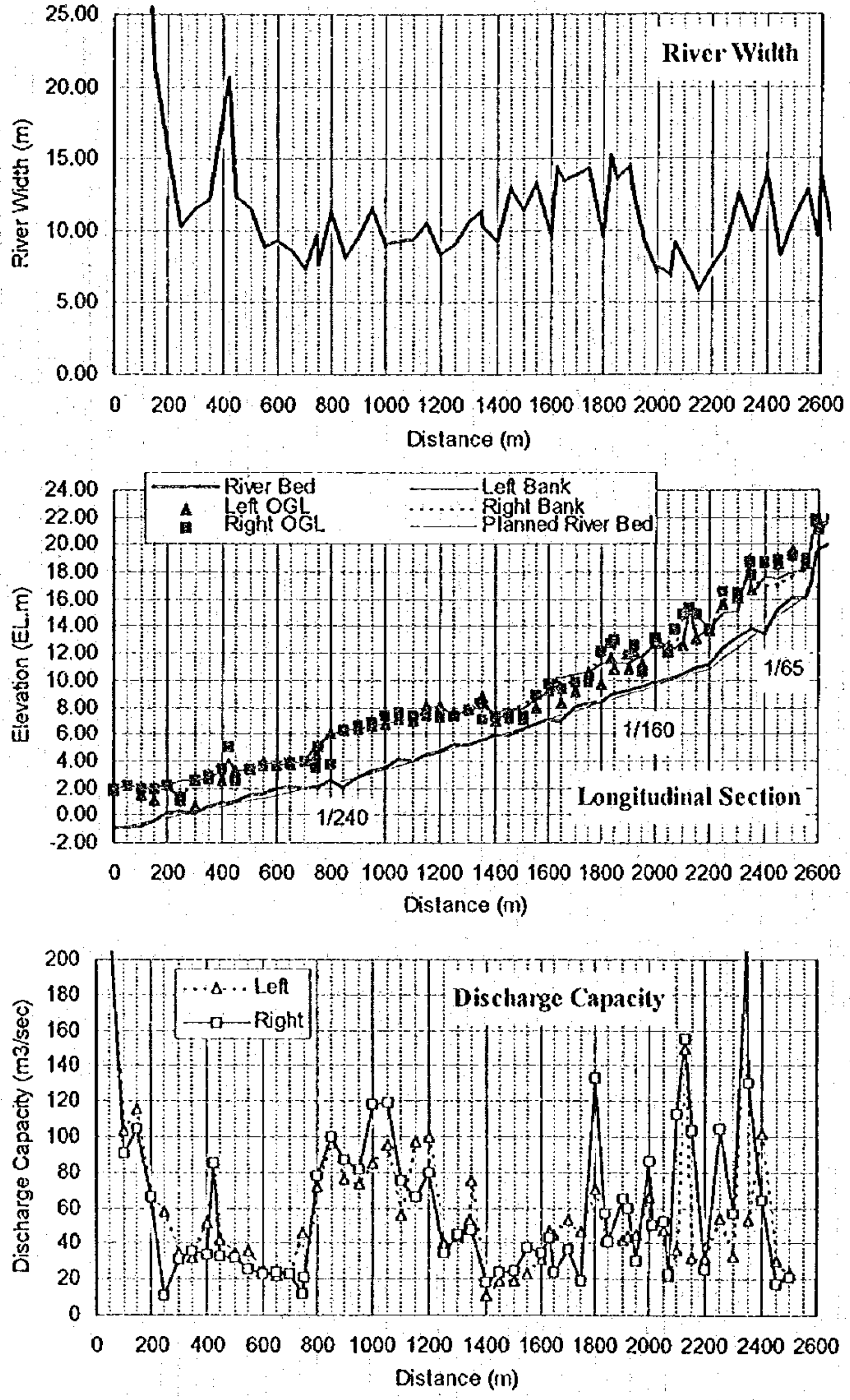


Figure-D.4.4 Current Condition of Batu Gajah River

<River Improvement Plan>

River improvement plans with 5, 10 and 30 year return period were studied and the components of the plan are described in Table-D.4.7.

River-bed excavation with 1.0 m depth from river mouth to 2k100 and partial flood wall heightening were employed as the plan with 5-year return period. Additional to this plan, concrete channel work from 0k200 to 0k900 is employed for the plan with 10-year return period. As for the plan with 30-year return period, drastic river widening is inevitable without long and high flood wall heightening. In the section from 2k100 to 2k600, the discharge capacity with 30-year return period is secured by carrying out river-bed formation work because of steep river gradient of 1/65.

Table-D.4.7 River Improvement Plan (Batu Gajah River)

Items			5-year	10-year	30-year
Plan Item	Design Discharge	Section	0'000-2'600	0'000-2'700	0'000-2'600
		Q (m^3/s)	80, 60	100, 80	130, 110
	River-bed	Section	0'000-2'600	0'000-2'600	0'000-2'600
	: Gradient	-	1/240,1/160,1/65	1/240,1/160,1/65	1/240,1/160,1/65
	: Downstream Elevation	E (EL.m)	-2.00	-2.00	-2.00
	Standard Section	Section	0'000-2'600	0'000-2'600	1'500-2'700
	: Current River Width	Wc (m)	6.0-15.0	6.0-15.0	6.0-15.0
	: Planned River Width	Wp (m)	6.0-15.0	6.0-15.0	8.0-15.0
	: Water Height	Hw (m)	1.3-2.70	1.60-3.20	1.90-2.80
	: Dike Height	Hd (m)	1.9-3.30	2.20-3.80	2.50-3.40
Work Item	River-bed Formation	Section	0'000-2'600	0'000-2'600	0'000-2'600
		L (m)	2600	2600	2600
		V (m^3)	30500	30500	30500
	River-bed Excavation	Section	0'000-2'100	0'000-2'100	0'000-2'100
		D (m)	1.00	1.00	1.00
		L (m)	2100	2100	2100
		V (m^3)	19000	19000	24400
	Concrete Channel	Section	-	0'200-0'900	0'200-2'100
		L (m)	-	700	1900
		A (m^2)	-	5600	18000
	Flood Wall Heightening	Section	0'200-1'450	0'700-1'600	0'200-2'600
		MnH (m)	2.50-3.20	2.80-3.80	2.50-2.90
	: Left	ΔH (m)	0.20-0.30	0.40	0.40
		L (m)	140	230	230
	: Right	ΔH (m)	0.20-0.40	0.20-0.40	0.20-0.40
		L (m)	150	150	230
	River Widening	Section	-	-	1'950-2'200
		ΔW (m)	-	-	1.5-3.0
		L (m)	-	-	1100
		A (m^2)	-	-	5500
	Bridge Improvement	Location	0'750-1'835	0'750-1'835	0'750-1'835
		Number	B3,B5,B6	B3,B5,B6	B3,B5,B6
Land Acquisition Areas		A (m^2)	-	-	5500
Resettlement Households		Number	-	-	147

Note Q : Discharge (m^3/sec) E : Elevation (EL.m) W : Width (m) L : Length (m)
D : Depth (m) H : Height (m) MnH : Mean Height (m) ΔH : Mean Increase in Height (m)
ΔW : Widening Width (m) A : Area (m^2) V : Volume (m^3)
() : Flood wall heightening length without river widening length

(6) River Improvement for Batu Gantung River

< Current River Condition >

The river width, the longitudinal section (deepest river-bed elevation, left and right flood wall level, left and right side original ground level, OGL) and discharge capacity are as shown in Figure-D.4.5. Current river condition is summarized as follows:

- Catchment area at river mouth : 6.87 km^2
- Current river-bed gradient : 0k000-0'950 : 1/230,
  0k950-1k450 : 1/160
- River width : 5.0 to 15.0 m,
- Average river-bed elevation : EL. -0.7 m at the river mouth
  EL. 6.9 m at the most upstream (1'450)
- Flood wall height : 2.6-3.4 m (0'000-1'450)
- Discharge capacity : more than 40 m^3/sec (0'000-0'400)
  20 - 40 m^3/sec (0'400-0'700)
  40 - 100 m^3/sec (0'700-1'150)
  20 - 60 m^3/sec (1'150-1'450)
  more than 140 m^3/sec (upstream of 1'500)
- Bridges :

Location	0'400	0'769	1'336	1'863	1'956	1'990
Name	B1	B2	B3	B4	B5	B6
Under Level *	3.85	7.00	8.59	48.85	51.72	52.35
Bridge Pier	exist	exist	-	-	-	-

* Under elevation of bridge beam (EL.m)

- Social Condition : Batu Gantung River runs to the south-east of the urban part of Ambon. Sediment and rubbish are accumulated in the river course. The areas along the river course are densely populated.
- Drainage : Drainage channels with small catchment area flow into Batu Gantung River and the largest one is Baabullah Drainage Channel, which flows into the from its right side approximately 200 m upstream of the river mouth. These drainage channels carries domestic waste water and rain water.

< Planning Condition >

Planning condition is summarized as follows:

- River improvement section : 0'000-1'450 (1400 m)
- Design discharge :

Return Period	5-year	10-year	30-year
0k000-0k950	90 m^3/sec	110 m^3/sec	150 m^3/sec
0k950-1k450	80 m^3/sec	100 m^3/sec	130 m^3/sec

- Assumed river width (before widening) :

Distance	0'000-0'100	0'100-0'250	0'250-0'500	0'500-0'850	0'850-0'950	0'950-1'150	1'150-1'450
Width	15.0 m	10.0 m	7.0 m	10.5 m	8.0 m	5.0 m	7.0 m

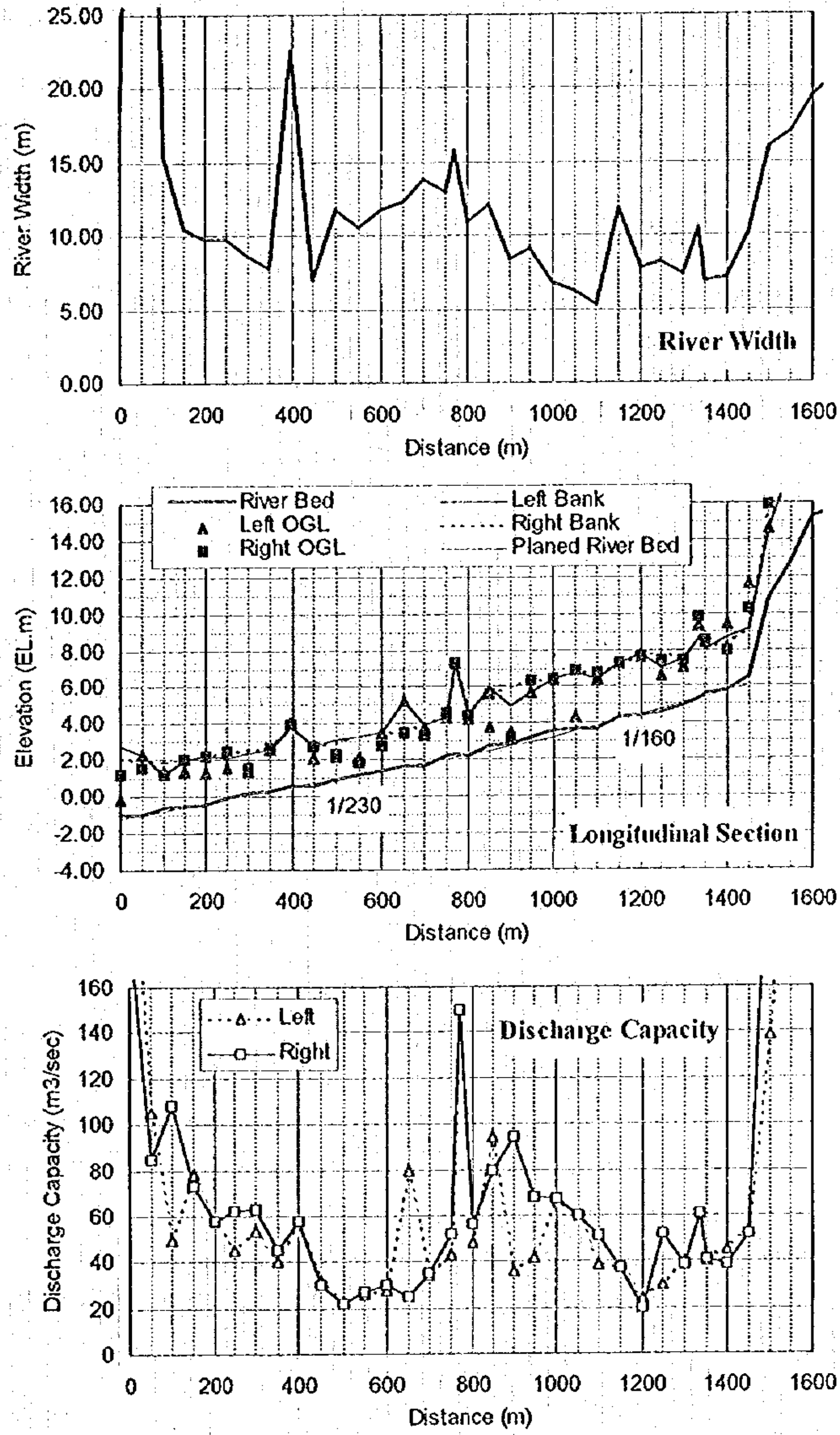


Figure-D.4.5 Current Condition of Batu Gantung River

< River Improvement Plan >

River improvement plans with 5, 10 and 30 year return period were studied and the components of the plan are described in Table-D.4.8.

River-bed excavation with 1.0 m depth of all sections and concrete channel work from 0k250 to 0k500 were employed as the plan with 5-year return period. For the plan with 10-year return period, concrete channel work from 0k500 to 1k150 was added but no river widening was planned for the both plans. As for the plan with 30-year return period, drastic river widening is inevitable without long and high flood wall heightening.

Table-D.4.8 River Improvement Plan (Batu Gantung River)

Items			5-year	10-year	30-year
Plan Item	Design Discharge	Section	0'000-1'450	0'000-1'450	0'000-1'450
		Q (m^3/s)	90, 80	110, 100	150, 130
	River-bed	Section	0'000-1'450	0'000-1'450	0'000-1'450
	: Gradient	-	1/230, 1/160	1/230, 1/160	1/230, 1/160
	: Downstream Elevation	E (EL.m)	-2.20	-2.20	-2.20
	Standard Section	Section	0'000-1'450	0'000-1'450	0'000-1'450
	: Current River Width	Wc (m)	5.0-15.0	5.0-15.0	5.0-15.0
	: Planned River Width	Wp (m)	5.0-15.0	5.0-15.0	7.0-15.0
	: Water Height	Hw (m)	2.10-3.30	2.00-3.10	2.40-3.00
	: Dike Height	Hd (m)	2.70-3.90	2.60-3.70	3.00-3.60
Work Item	River-bed Formation	Section	0'000-1'450	0'000-1'450	0'000-1'450
		L (m)	1450	1450	1450
		V (m^3)	3600	3600	3600
	River-bed Excavation	Section	0'000-1'450	0'000-1'450	0'000-1'450
		D (m)	1.00	1.00	1.00
		L (m)	1450	1450	1450
		V (m^3)	17700	17700	20000
	Concrete Channel	Section	0'150-0'950	0'150-1'450	0'150-1'450
		L (m)	250	900	1300
		A (m^2)	1900	7400	12600
	Flood Wall Heightening	Section	1'050-1'150	0'400-0'150	-
		MnH (m)	3.90	3.30	-
	: Left	ΔH (m)	0.30	0.30	-
		L (m)	50	100	-
	: Right	ΔH (m)	-	0.40	-
		L (m)	-	100	-
	River Widening	Section	-	-	0'250-1'150
		ΔW (m)	-	-	0.5-3.5(L)
		L (m)	-	-	550
		A (m^2)	-	-	2750
	Bridge Improvement	Location	0'400-0'769	0'400-0'769	0'400-0'769
		Number	B1,B2	B1,B2	B1,B2
Land Acquisition Areas		A (m^2)	-	-	2750
Resettlement Households		Number	-	-	73

Note

Q : Discharge (m^3/sec) E : Elevation (EL.m) W : Width (m) L : Length (m)
D : Depth (m) H : Height (m) MnH : Mean Height (m) ΔH : Mean Increase in Height (m)
ΔW : Widening Width (m) A : Area (m^2) V : Volume (m^3)
() : Flood wall heightening length without river widening length

4.2.3 Dam and Reservoir

(1) Selection of Dam Site

The 13 locations of candidate dam sites were selected on the five rivers in hilly areas as shown in Figure-D.4.6, on the basis of topographical and geological considerations. From the economic and social view points, each dam site was evaluated as shown in Table-D.4.9, comparing such factors as dam volume, reservoir area and compensation items (houses and public facilities). The most appropriate dam site for each river is selected below, taking into account the following considerations.

Ruhu River

The dam volume of RH-1 is less than half that of RH-2, but the reservoir area of RH-1 is 1.5 times larger than RH-2. Since the catchment area is nearly same and no houses and inhabitants are found there, the economically advantageous dam site RH-1 is selected for Ruhu River.

Batu Merah River

The dam volumes of BM-2 and 3 are smaller, about half that of BM-1, but the reservoir area of BM-1 and BM-2 are nearly the same and slightly smaller than BM-3. There are more than 50 houses in the submerged area of BM-1, and more than 150 houses for BM-2 and BM-3. Although there are many houses, BM-2 is selected for Batu Merah River because of economical advantages.

Tomu River

The dam volume of TM-3 is smallest, followed by TM-1 and TM-2, although these are nearly the same. The reservoir areas of all the dam sites are also not so different from each other. Although the catchment area is smallest, 2.71 km^2, dam site TM-1 is selected for Tomu River, since no houses are located in the submerged area.

Batu Gajah River

The dam volume of GJ-2 and 3 are more than half of GJ-1, and the reservoir areas of GJ-2 and 3 are smaller than GJ-1. The dam sites of GJ2 and GJ-3 have nearly same condition of dam volume and reservoir area. Therefore, since GJ-2 has fewer houses in the submerged area, dam site GJ-2 is selected for Batu Gajah River.

Batu Gantung River

The dam volume of GT-1 is smaller than GT-2, but the reservoir area of GT-1 is larger than GT-2. Since the social impacts of the dams is nearly the same as each other, the economically advantageous dam site GT-1 is selected for Batu Gantung River.

Table-D.4.9 Comparison of Candidate Dam Sites

River System	Dam No.	Catchment Area (km2)	Dam and Water Level Specification (Storage Volume = 1,000,000m3)			Social Condition
Ruhu	RH-1 (*)	14.49	Dam Base Elevation	(m)	20.0	No houses and inhabitants
			Dam Height	(m)	34.3	
			Dam Volume	(1000 m^3)	172.0	
			Reservoir Area	(1000 m^2)	196.3	
	RH-2	14.71	Dam Base Elevation	(m)	7.0	No houses and inhabitants
			Dam Height	(m)	44.8	
			Dam Volume	(1000 m^3)	397.0	
			Reservoir Area	(1000 m^2)	125.8	
Merah	BM-1	3.46	Dam Base Elevation	(m)	17.0	More than 50 houses located along the river, a church, a school and a paved primary road will fall under the water if the depth of the reservoir is over 20m.
			Dam Height	(m)	26.5	
			Dam Volume	(1000 m^3)	233.0	
			Reservoir Area	(1000 m^2)	200.0	
	BM-2 (*)	4.97	Dam Base Elevation	(m)	4.0	More than 150 houses, a mosque and a paved primary road will fall under the water, if the depth of the dam is more than 25m.
			Dam Height	(m)	25.1	
			Dam Volume	(1000 m^3)	112.0	
			Reservoir Area	(1000 m^2)	201.8	
	BM-3	5.21	Dam Base Elevation	(m)	2.0	Similar to the case of BM2
			Dam Height	(m)	27.1	
			Dam Volume	(1000 m^3)	115.0	
			Reservoir Area	(1000 m^2)	220.9	
Tomu	TM-1 (*)	2.71	Dam Base Elevation	(m)	33.0	No houses and inhabitants
			Dam Height	(m)	28.4	
			Dam Volume	(1000 m^3)	212.0	
			Reservoir Area	(1000 m^2)	141.8	
	TM-2	3.45	Dam Base Elevation	(m)	11.0	Around 19 houses, a church and a paved primary road will need to be relocated
			Dam Height	(m)	34.9	
			Dam Volume	(1000 m^3)	226.0	
			Reservoir Area	(1000 m^2)	167.5	
	TM-3	3.51	Dam Base Elevation	(m)	7.0	20 to 40 houses (out of the 70 houses of the community) will fall under the water.
			Dam Height	(m)	34.1	
			Dam Volume	(1000 m^3)	206.0	
			Reservoir Area	(1000 m^2)	145.1	
Gajah	GJ-1	2.93	Dam Base Elevation	(m)	68.0	No houses and inhabitants
			Dam Height	(m)	47.2	
			Dam Volume	(1000 m^3)	732.0	
			Reservoir Area	(1000 m^2)	146.0	
	GJ-2 (*)	4.37	Dam Base Elevation	(m)	38.0	Around 18 houses will fall under the water. No public facilities are found in the reservoir area.
			Dam Height	(m)	35.9	
			Dam Volume	(1000 m^3)	339.0	
			Reservoir Area	(1000 m^2)	118.2	
	GJ-3	4.69	Dam Base Elevation	(m)	22.0	20 to 40 houses (out of the 70 houses of the community) will fall under the water.
			Dam Height	(m)	40.2	
			Dam Volume	(1000 m^3)	330.0	
			Reservoir Area	(1000 m^2)	124.5	
Gantung	GT-1 (*)	4.76	Dam Base Elevation	(m)	65.0	A public health center and a paved primary road which connects the village in the mountain and the downtown will have to be relocated if the depth of the reservoir is 25m.
			Dam Height	(m)	38.4	
			Dam Volume	(1000 m^3)	229.0	
			Reservoir Area	(1000 m^2)	112.5	
	GT-2	5.43	Dam Base Elevation	(m)	49.0	No houses will fall under the water except for the public health center to be relocated. A water trunk line installed by PDAM will have to relocated.
			Dam Height	(m)	43.9	
			Dam Volume	(1000 m^3)	342.0	
			Reservoir Area	(1000 m^2)	96.5	

Note

1) The study is based on 1:5,000 topographical maps.
2) *: most promising dam site for each river system

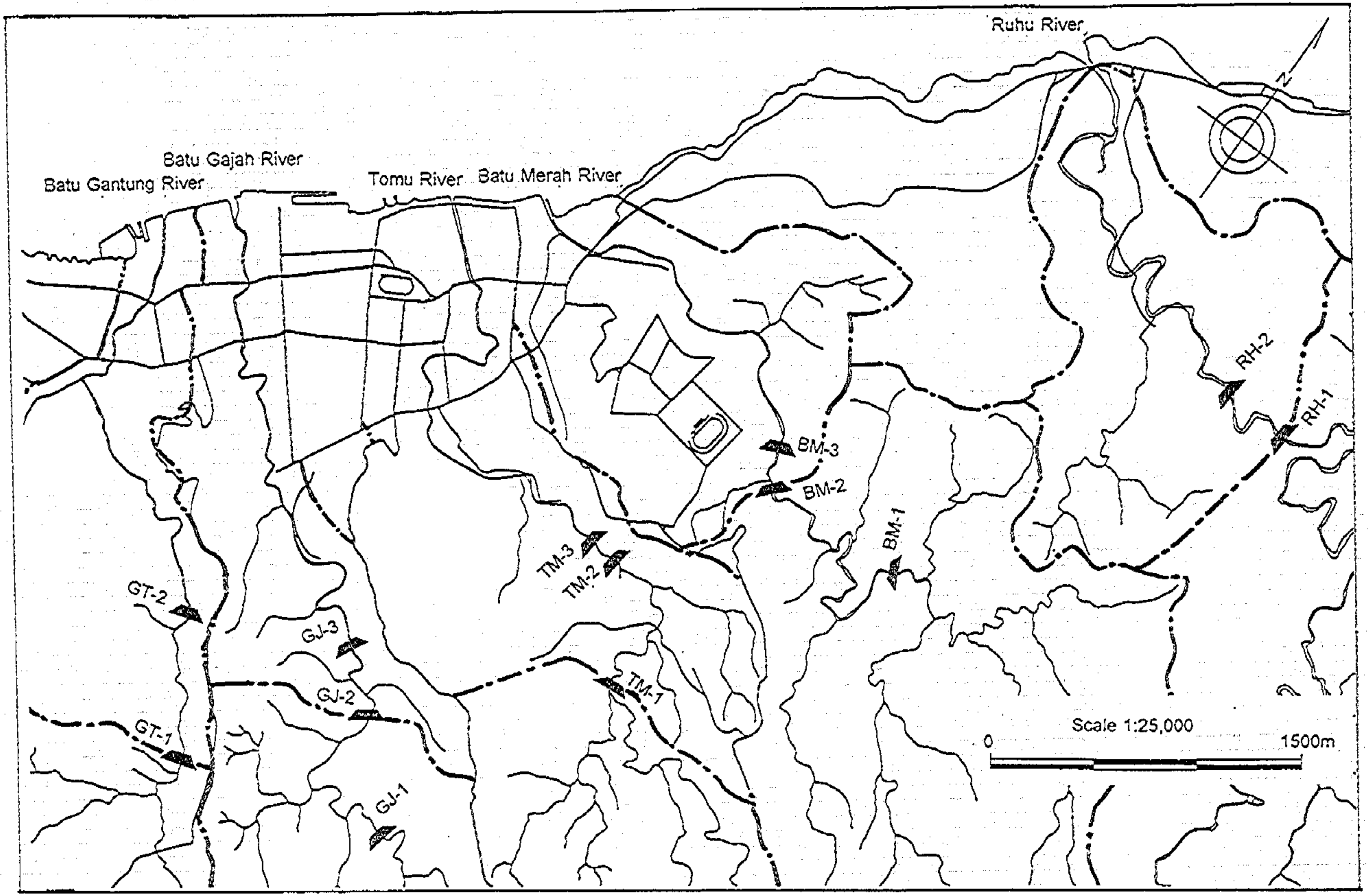


Figure-D.4.6 Locations of Candidate Dam Sites

(2) Specific Sediment Yield to the dams

Factors affecting sedimentation in dam reservoirs include catchment area, geology, topography, flora, rainfall, discharge in the river basin, and characteristics of the dam storage capacity. At present, there is no method that can definitely relate the above factors and dam sedimentation volume; however, there are some methods proposed based on experience or statistics. In this section, the sediment capacity of Batu Gajah Dam and Batu Gantung Dam were set using Kira's method based on experience and using examples of proposed sediment capacity of existing dams in Indonesia.

(a) Calculation by Kira's Method

From investigation of 36 dam reservoirs constructed in Japan, Kira proposed the following formula for assumption of dam sedimentation volume, taking account of dam storage capacity.

$$q_s = (\gamma_s/100)\, C / F * 10^6$$

$$\gamma_s = 0.00012\, \phi^{0.868}$$

$$\phi = R_f / (C/F)$$

qs :Dam Specific Sediment Volume ($m^3/km^2/year$)

γ_s :Ratio of Mean Annual Sedimentation (%)

R_f :Undulation [Height of top of river basin from dam site] (m)

C :Storage Capacity (m^3)

F :Catchment Area (m^2)

Using the above formula, specific sedimentation volume for both Batu Gajah Dam and Batu Gantung Dam are calculated as shown in Table-D.4.10.

Table-D.4.10 Calculation Results of Specific Sediment Volume by Kira's Method

Item	Batu Gajah Dam	Batu Gantung Dam
(1) Dam Basement Elevation	40 m	65 m
(2) Top Elevation of Dam Basin	480 m	520 m
(3) = (2) - (1) : R_f	440 m	455 m
(4) Gross Storage Capacity : C (m^3)	1,532,000	1,337,000
(5) Catchment Area : F (m^2)	$4.27*10^6$	$4.76*10^6$
(6) C / F	0.35878	0.28088
(7) ϕ	1,226.378	1,619.909
(8) γ s	0.0575582	0.0732857
(9) Specific Sediment Volume ($m^3/km^2/year$)	207	206

(b) Examples of Proposed Sediment Capacity of Large Dams in Indonesia

Table-D.4.11 indicates examples of the proposed sediment capacity of existing dams in Indonesia located in similar geological formations (Cretaceou-Jurassic Ultra Basic Rocks, Coral Limestone, Tertiary Volcanic Rocks) as the Ambon Area and with small catchment areas (less than 20 km^2). Figure- indicates the relationship between catchment area and proposed specific sediment capacity of the existing dams mentioned above. From this figure, it can be seen that proposed specific sediment capacity of the dams is mostly under 400 $m^3/km^2/year$.

Table-D.4.11 Examples of Proposed Sediment Capacity of Large Dams in Indonesia

No.	Dam Name	River Name	Location	Catchment Area C.A.(km2)	Dam Height (m)	Sediment Volume (1000m3)	Specific Sediment (m3/km2)
1	Greneng	S.Gowak	Jawa Tengah	4.99	11.7	393	788
2	Lodan Wetan		Jawa Tengah	11.66	26.5	450	386
3	Gunung Rowo	S.Gunungrowo	Jawa Tengah	10.45	20.5	160	153
4	Nawangan	Bengawan Solo	Jawa Tengah	2.67	25.0	93	348
5	Song Putri	Bengawan Solo	Jawa Tengah	2.67	32.0	65	243
6	Plumbon	Bengawan Solo	Jawa Tengah	7.20	28.8	510	708
7	Ketro	Bengawan Solo	Jawa Timur	5.00	15.0	100	200
8	Batu Bokah	S.Batu Bokah	NTB	3.62	21.2	1	3
9	Ncera	S.Condo	Lombok	6.60	16.0	35	53
10	Lamenta	S.Lamenta	Lombok	4.60	16.0	33	72
						Average	295

Note: 1) Source: Large Dams in Indonesia (1995)
2) Dams are located in similar geological formations as the Ambon Area and with catchment area under 20km².
3) Specific Sediment is calculated as 100 years term.

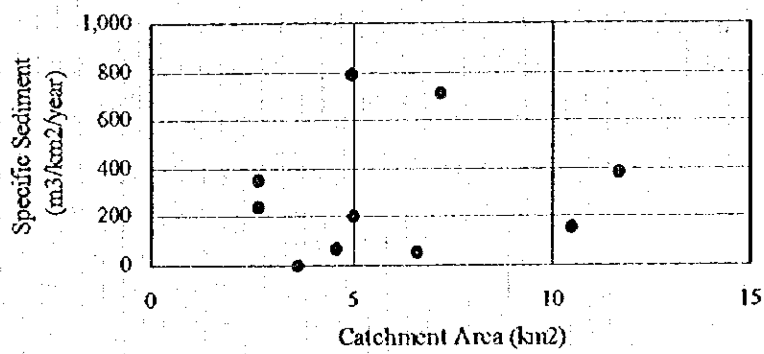


Figure-D.4.7 Relationship between Catchment Area and Proposed Specific Sediment

(c) Proposed Sediment Capacity

Table-D.4.12 shows the results given by the above 2 methods. The proposed specific sediment capacity of existing dams (mostly under 400 $m^3/km^2/year$) is generally twice that given by Kira's method (200 $m^3/km^2/year$). Therefore proposed sediment capacity of both Batu Gajah Dam and Batu Gantung Dam was set using specific sediment capacity of 400 $m^3/km^2/year$ as shown in Table-D.4.12, taking account of examples of existing dams in Indonesia.

Table-D.4.12 Proposed Sediment Capacity of Batu Gajah Dam and Batu Gantung Dam

Dam		Batu Gajah Dam	Batu Gantung Dam
Catchment Area (km^2)		4.27	4.76
Specific Sediment ($m^3/km^2/year$)	Kira's Method	207	206
	Examples in Indonesia	Approximately Under 400	
	Proposed Specific Sediment	400	400
Proposed Sediment Capacity (m^3)		170,800 ≒171,000	190,400 ≒191,000

(3) Flood Regulation by Dam and Reservoir

Flood Regulation System

The most reliable and effective method shall be applied for flood regulation system by dams. There are the four methods, namely 1) Natural Control Method, 2) Constant Discharging Method, 3) Constant Rate Control Method, and 4) Constant Rate and Discharging Method. In view of the small basin area (less than 20 km^2) and ease of operation and maintenance in this case, the Natural Control Method has been adopted as the flood regulation system for all the planned dams. Spillways are gate-less type, i.e. not fitted with gates for flood control.

Flood Regulation Calculation and Dam Plan

The design scale of flood control plan for all the rivers is set at 30-year return period. The design flood hydrograph is the flood pattern of June 6, 1990. The flood control dam for each river is planned based on the following conditions: 1) Case-1 : river course is improved with 5-year return period design scale, 2) Case-2 : river course is improved with 10-year return period design scale.

Then the design flood discharge before and after regulation at the river mouth and the dam is presented in Table-D.4.13. To regulate the discharge Qb to Qa at the river mouth, flood regulation calculation was carried out by changing the size of spillway size.

Table-D.4.13 Design Flood Discharge Before/After Regulation by Dam

Unit: m^3/s

Items	Return Period	Ruhu RH-1	Merah BM-2	Tomu TM-1	Gajah BG-2	Gantung BG-1
Design Discharge (Qd) at Dam site	30-year	273	103	57	90	99
Design discharge before regulation (Qb) at Reference point	30-year	314	145	117	123	143
Design discharge after regulation (Qa) at Reference point	5-year	170	90	70	80	90
	10-year	230	110	90	100	110

Note: Reference point is set at river mouth.

Design of Dam and Reservoir

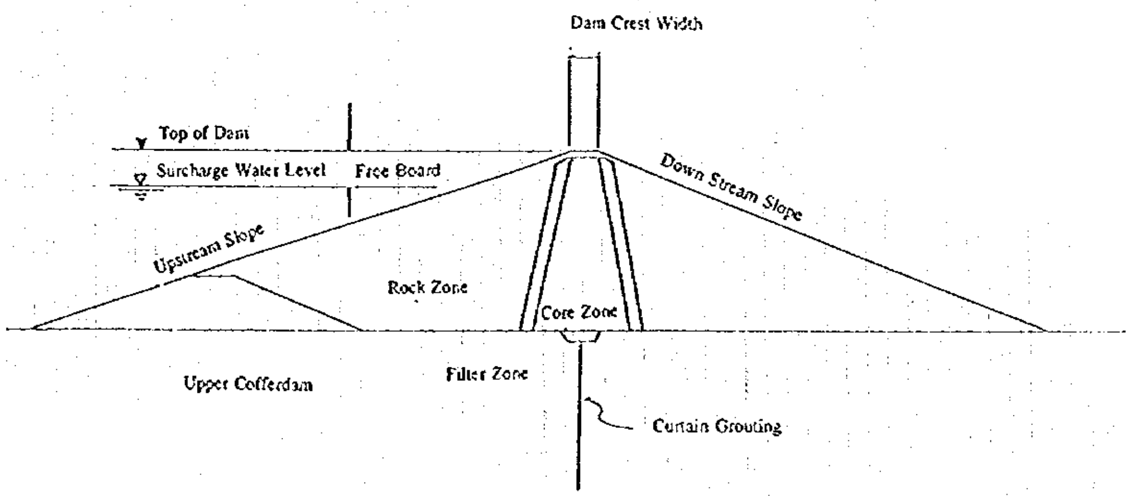
The dam is designed as Fill-Type dam considering the geological condition at the dam site. The design slopes of dam are 1:3.0 (for upstream slope) and 1:2.5 (for downstream slope). The design freeboard and dam crest width are 4.0 m and 5.0 m respectively.

The reservoir capacity comprises the volume for flood control, for reservoir sedimentation and for development of river maintenance flow. The flood control volume shall include 20 % contingency of the calculated necessary volume. The reservoir sedimentation volume is capable of storing 100 years sediment discharge. The design specific sediment discharge is 400 km^3/year/km^2. To obtain the volume for development of river maintenance flow, it is assumed that maintenance discharge is 2 m^3/sec/100km^2 based on the average drought discharge. The volume is calculated as follows: Volume = 2 m^3/sec/100km^2 x [Catchment Area] x 86400 sec x 10 days x 100 km^2. The design results are shown in Table-D.4.14.

Table-D.4.14 Specifications of Dams and Reservoirs

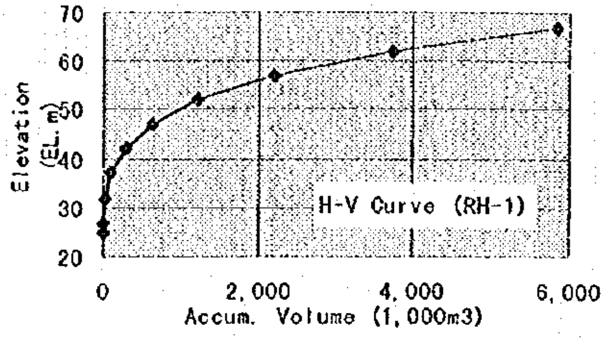
Items		Ruhu		Batu Merah		Tomu		Batu Gajah		Batu Gantung	
		RH-1		BM-2		TM-1		GJ-2		GT-1	
Design Scale of River		1/5	1/10	1/5	1/10	1/5	1/10	1/5	1/10	1/5	1/10
Catchment Area (km^2)		14.49		4.97		2.71		4.37		4.76	
Unregulated peak discharge (m^3/sec)	Dam	273		103		57		90		99	
(30-year return period)	River Mouth	314		145		117		123		143	
Outflow at peak inflow (m^3/sec)	Dam	125	167	47	69	9	28	46	67	46	66
Regulated peak discharge	Dam	138	197	51	77	10	30	51	70	50	71
(m^3/sec)	River Mouth	170	230	90	110	70	90	80	100	90	110
Cut discharge (m^3/sec)	Dam	148	106	56	34	48	29	44	23	53	33
	River Mouth	144	84	55	35	47	27	43	23	53	33
Sediment Capacity (1000 m^3)		580		199		109		175		191	
River Maintenance Capacity (1000 m^3)		251		86		47		76		83	
Flood Storage Capacity (1000 m^3)		2,272	1,528	869	536	1,047	399	574	357	725	425
Effective Storage Capacity (1000 m^3)		2,523	1,779	955	622	1,094	446	650	433	808	508
Total Storage Capacity (1000 m^3)		3,103	2,359	1,154	821	1,203	555	825	608	999	699
Low Water Level (EL.m)		46.4		17.8		45.4		57.2		86.4	
Normal Water Level (EL.m)		48.8		19.6		46.4		59.4		88.4	
Surcharge Water Level (EL.m)		60.0	57.6	27.0	25.1	59.2	52.8	68.0	65.3	99.5	96.0
Dam Top Elevation (m)		64.0	61.6	31.0	29.1	63.2	56.8	72.0	69.3	103.5	100.0
Dam Base Elevation (m)		23.0		6.0		34.0		38.0		66.0	
Freeboard (m)		4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Dam Height (m)		41.0	38.6	25.0	23.1	29.2	22.8	34.0	31.8	37.5	34.0
Dam Crest Length (m)		103.0	98.0	134.0	126.0	183.0	164.0	220.0	209.0	145.0	132.0
Dam Foundation Length (m)		10.0	10.0	24.0	24.0	70.0	70.0	70.0	70.0	20.0	20.0
Conduit	Width (m)	3.7	5.3	2.5	4.3	1.0	2.0	2.4	3.5	2.2	3.0
	Height (m)	3.7	5.3	2.5	4.3	0.8	2.0	2.4	3.5	2.2	3.0
Upstream Slope		1:3.0	1:3.0	1:3.0	1:3.0	1:3.0	1:3.0	1:3.0	1:3.0	1:3.0	1:3.0
Downstream Slope		1:2.5	1:2.5	1:2.5	1:2.5	1:2.5	1:2.5	1:2.5	1:2.5	1:2.5	1:2.5
Dam Top Width (m)		5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Dam Volume (1000 m^3)		201	172	115	94	271	159	406	335	228	174
Land Acquisition Area (1000m^2)		411	346	236	202	155	108	108	93	113	95
Resettlement Household (number)		-	-	150	150	-	-	20	20	-	-

Typical Cross Section of Dam



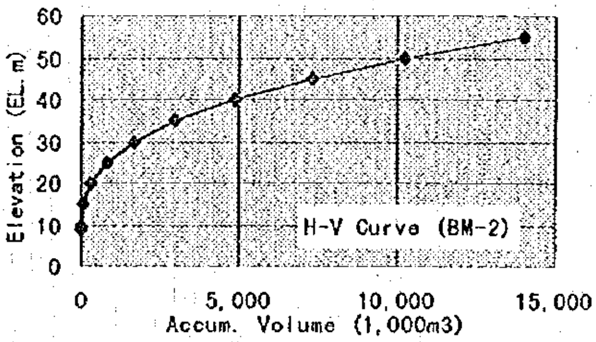
Dam Site :RH-1 (Ruhu River)

Elevation (EL.m)	Hight (m)	Area (m2)	Volume (1,000m3)	Accum.Vol. (1,000m3)
25	0	0	0.00	0.0
27	2	770	0.77	0.8
32	5	5,745	16.29	17.1
37	5	29,693	88.60	105.7
42	5	48,787	196.20	301.9
47	5	80,208	322.49	624.3
52	5	150,545	576.88	1,201.2
57	5	250,031	1,001.44	2,202.7
62	5	354,595	1,511.57	3,714.2
67	5	495,084	2,124.20	5,838.4



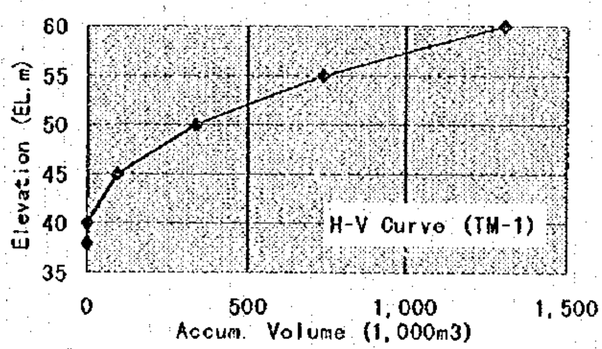
Dam Site :BM-2 (Batu Merah River)

Elevation (EL.m)	Hight (m)	Area (m2)	Volume (1,000m3)	Accum.Vol. (1,000m3)
9	0	0	0.00	0.0
10	1	1,776	0.89	0.9
15	5	24,404	65.45	66.3
20	5	71,662	240.17	306.5
25	5	129,525	502.97	809.5
30	5	217,620	867.86	1,677.3
35	5	308,711	1,315.83	2,993.2
40	5	432,139	1,852.13	4,845.3
45	5	538,988	2,427.82	7,273.1
50	5	662,453	3,003.60	10,276.7
55	5	822,964	3,713.54	13,990.2



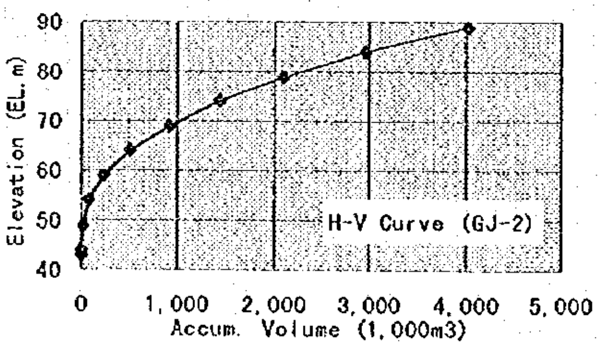
Dam Site :TM-1 (Tomu River)

Elevation (EL.m)	Hight (m)	Area (m2)	Volume (1,000m3)	Accum.Vol. (1,000m3)
38	0	0	0.00	0.0
40	2	1,806	1.81	1.8
45	5	34,174	89.95	91.8
50	5	63,982	245.39	337.1
55	5	94,800	396.96	734.1
60	5	131,526	565.82	1,299.9



Dam Site :GJ-2 (Batu Gajah River)

Elevation (EL.m)	Hight (m)	Area (m2)	Volume (1,000m3)	Accum.Vol. (1,000m3)
43	0	0	0.00	0.0
44	1	153	0.08	0.1
49	5	4,909	12.66	12.7
54	5	20,936	64.61	77.3
59	5	41,710	156.62	234.0
64	5	67,585	273.24	507.2
69	5	91,890	398.69	905.9
74	5	118,137	525.07	1,431.0
79	5	150,676	672.03	2,103.0
84	5	193,492	860.42	2,963.4
89	5	234,678	1,070.43	4,033.8



Dam Site :GT-1 (Batu Gantung River)

Elevation (EL.m)	Hight (m)	Area (m2)	Volume (1,000m3)	Accum.Vol. (1,000m3)
70	0	0	0.00	0.0
71	1	530	0.27	0.3
76	5	5,472	15.01	15.3
81	5	13,264	46.84	62.1
86	5	31,347	111.53	173.6
91	5	54,474	214.55	388.2
96	5	72,095	316.42	704.6
101	5	100,409	431.26	1,135.9
106	5	125,612	565.05	1,700.9
111	5	198,700	810.78	2,511.7
116	5	243,174	1,104.69	3,616.4
121	5	326,794	1,424.92	5,041.3

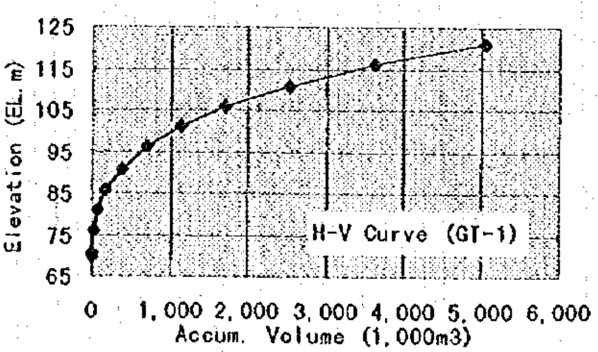


Figure-D.4.8 Water Height and Volume of Dam Reservoir

4.2.4 Diversion Channel

(1) Design Conditions

To reduce the discharge into the downstream reaches, the diversion channel plan is studied. Of the five target river systems, diversion channel system is only applicable to three rivers (Ruhu, Batu Merah and Tomu) due to the topographical conditions of the rivers. For the other two rivers (Batu Gajah and Batu Gantung), the diversion channel is not practical.

The objective of a diversion channel is to transport the flood discharge which is in excess of channel capacity. Diversion plans are examined regarding two cases of river course improvement, namely 5 and 10-year return period design scale. In the case of diversion tunnel, the tunnel is designed as follows:

- Design Discharge Capacity : 130 % of allocated discharge
- Tunnel Section Area : Flow section: 85%, Non-flow section: 15%
- Shape of Tunnel Section : Standard Horseshoe Shape
- Roughness of Tunnel : 1.5 x 0.010 (Concrete lining) = 0.023

(2) Designed Diversion Channel

The diversion channels for the three river systems are planned and designed as follows. Specifications of each diversion channel are summarized in Table-D.4.15 and Figure-D.4.9.

<Ruhu River>

The diversion channel is diverted from 1k100 to 0k500 to avoid the large river meander and narrow water course. The diversion was planned as a fully open channel (length = 290 m) and the gradient of the channel will be approximately 1/270 which is significantly steeper than the original river-bed gradient of 1/550. The river upstream of the diversion channel inlet is necessary to be improved with a design scale of 30-year return period.

<Batu Merah River>

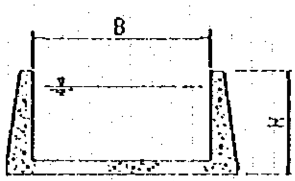
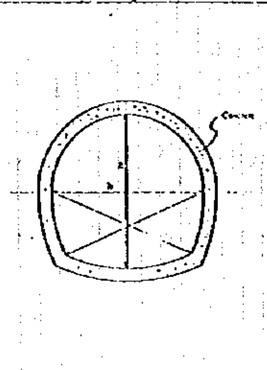
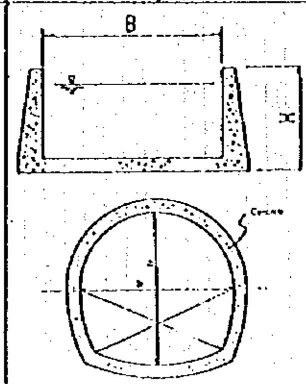
The diversion channel was planned as a tunnel (length = 1,200 m) diverted from 1k600 directly to Ambon Bay about 800 m north from the river mouth of Batu Merah River. The location of the inlet was determined as the most upstream point to which river section improvement is necessary. The gradient of the channel is shallow at 1/440, because the river-bed elevation at the diversion inlet is low.

Potential drawbacks are that the tunnel cross-sectional area becomes large due to the small gradient between the diversion inlet and the outlet (sea), and that the tunnel discharge capacity is largely affected by fluctuations in the sea water level. As the gradient of the diversion tunnel is small at 1/440, high precision is required in tunnel construction work. In terms of social conditions, the land acquisition area is small because of no open channel section.

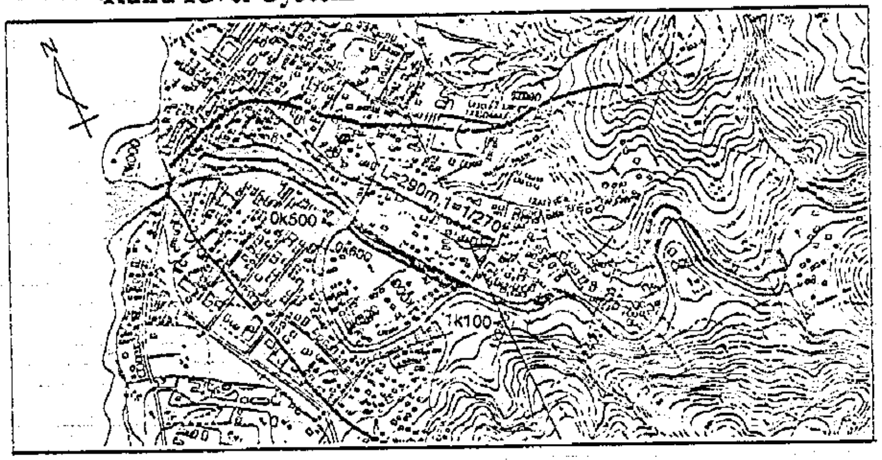
<Tomu River>

The diversion was diverted from 2k700 to 0k800. The location of the inlet was determined as the most upstream point to which river section improvement is necessary. The diversion was planned as a 900 m long tunnel with an open channel of length 250 m. The gradient of the channel will be approximately 1/110. The downstream from 0k800 at the outlet will have relatively large discharge capacity after the river-bed excavation. Large cross section is not necessary because relatively steep gradient can be applied to the diversion. In terms of social conditions, land acquisition and resettlement is needed because 250 m of the diversion before the outlet is an open channel.

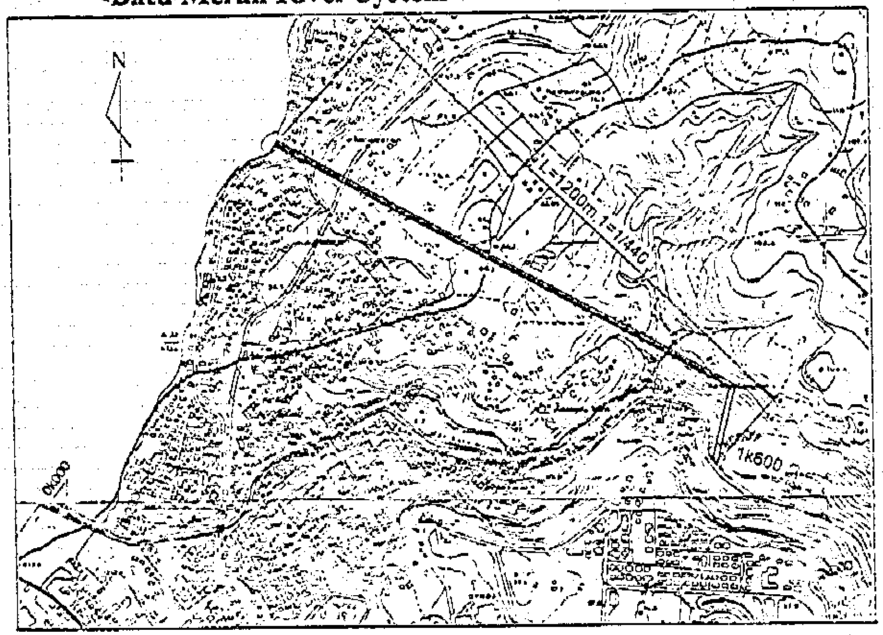
Table-D.4.15 Specifications of Diversion Channels

Items	Ruhu River		Batu Merah River		Tomu River	
	DIV-RH1	DIV-RH2	DIV-BM1	DIV-BM2	DIV-TM1	DIV-TM2
General Description	Partial (5year) River Course Improvement with Diversion Channel	Partial (10year) River Course Improvement with Diversion Channel	Partial (5year) River Course Improvement with Diversion Channel	Partial (10year) River Course Improvement with Diversion Channel	Partial (5year) River Course Improvement with Diversion Channel	Partial (10year) River Course Improvement with Diversion Channel
Design Discharge	150 m3/sec	90 m3/sec	60 m3/sec	40 m3/sec	50 m3/sec	30 m3/sec
<Inlet>						
Location	1k100	1k100	1k600	1k600	2k700	2k700
River-bed Level	EL. -0.50 m	EL. -0.50 m	EL. 2.70 m	EL. 2.70 m	EL. 11.70 m	EL. 11.70 m
High Water Level	EL. 2.31 m	EL. 2.20 m	EL. 5.50 m	EL. 5.50 m	EL. 13.20 m	EL. 13.50 m
<Outlet>						
Location	0k500	0k500	850 m north from River Mouth	850 m north from River Mouth	0k800	0k800
River-bed Level	EL. -1.59 m	EL. -1.59 m	EL. 0.00 m	EL. 0.00 m	EL. 1.50 m	EL. 0.70 m
High Water Level	EL. 1.41 m	EL. 1.41 m	EL. 0.80 m	EL. 0.80 m	EL. 3.70 m	EL. 3.40 m
Total Length - Tunnel - Open Channel	290 m - 290 m	290 m - 290 m	1,200 m 1,200 m -	1,200 m 1,200 m -	1,150 m 900 m 250 m	1,150 m 900 m 250 m
Gradient	1/270	1/270	1/440	1/440	1/110	1/110
Land Acquisition	1,540 m^2	1,540 m^2	1,200 m^2	1,200 m^2	2,476 m^2	2,476 m^2
Resettle Household	30	30	-	-	34	34
Size of Tunnel and Channel	Open Channel B x H = 7.0m x 3.5m	Open Channel B x H = 6.0m x 3.2m	Tunnel D = 5.8m A = 25.4 m^2	Tunnel D = 5.1m A = 19.7 m^2	Open Channel B x H = 4.0m x 2.6m Tunnel D = 4.2m A = 13.3 m^2	Open Channel B x H = 3.5m x 2.2m Tunnel D = 3.5m A = 9.3 m^2
Typical Cross Section						

<Ruhu River System>



<Batu Merah River System>



<Tomu River System>

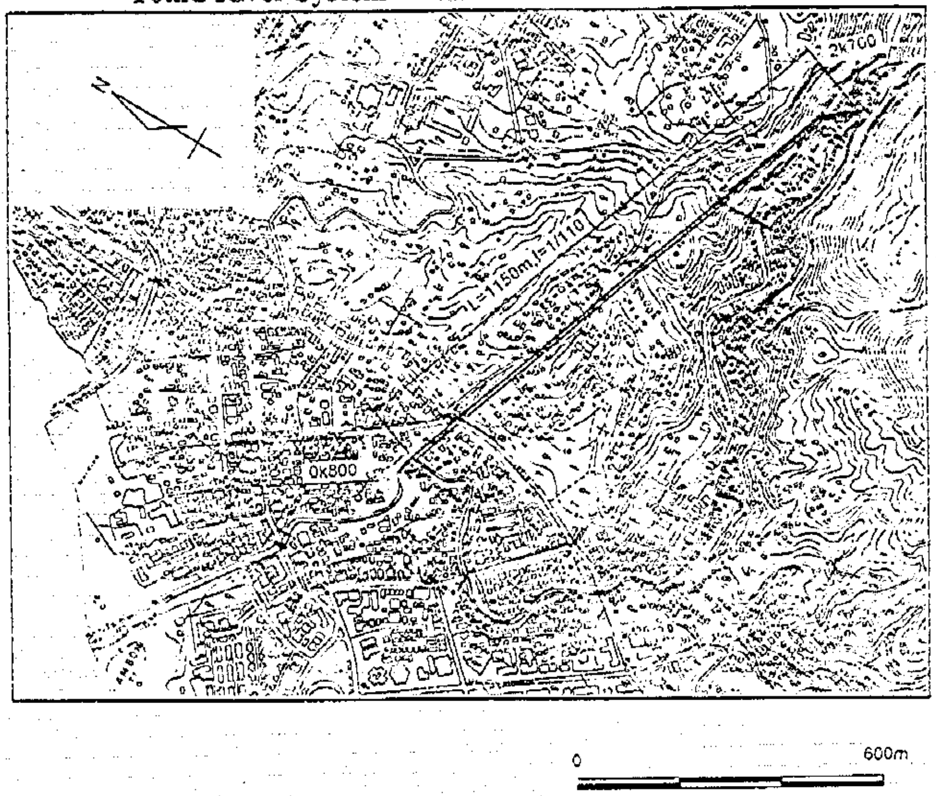


Figure-D.4.9 Diversion Channel Plans

4.2.5 Check Dam

(1) Basic Policy

The five target rivers in the Ambon Study Area produce a lot of sediment which is washed into the river courses and eventually into Ambon Bay. These sediments accumulate in the river channels, reducing the discharge capacity and eventually contributing to the problem of flooding. Data concerning sediment concentration during times of flooding have yet to be collected. However, the rivers contain muddy water even at normal times (especially Batu Merah River) and so much sedimentation can be seen in all the rivers that it is considered that sediment runoff is extreme. Consequently, on four of the five target rivers (with the exception of Batu Merah River where a check dam is already in place), the necessity for check dams is studied in the following sections. The objective of the check dams is to retain most of the sediment and ensure the smooth transportation of remaining sediment to the sea, preventing accumulation of deposits in the river course.

(2) Proposed Sediment Production Yield

In principle, the proposed sediment production is estimated using investigation data of land erosion and slope collapse in the target basin (depth and area of erosion, volume of slope collapse, etc.). Such data has not yet been obtained for the study area, therefore the proposed sediment production yield was set based on the annual amount of sediment suggested by Akitani that indicates the general standard of surface erosion for each land classification (refer to Table-D.4.16).

Regarding the Ambon study area, collapse of land slopes is frequently reported during the rainy season. Also, the upstream area is going to be developed according to the increase in population. Since the circumstances of land erosion are not yet known, proposed sediment production was set at 10mm/year (10,000m^3/km^2/year) as the annual surface erosion, assuming that the Ambon study area can be considered as bare land.

Table-D.4.16 Annual Amount of Surface Erosion (Akitani)

Land Classification	Annual Amount of Surface Erosion (mm/year)
Torrent Land	100-10
Bare Land	10-1
Agriculture Land	1-0.1
Grass, Forest	0.1-0.01

Source : Manual for River Works in Japan

(3) Proposed Sediment Discharge and Proposed Allowable Sediment Discharge

Proposed sediment discharge should be set as the lower value of the proposed sediment production yield and the sediment transportation capacity of the upstream river course. Proposed allowable sediment discharge should be set as the sediment transportation capacity of the downstream river course.

The sediment transportation capacity of the upstream and downstream river courses was calculated for each river as follows.

- The constituent elements of sediment discharge were assumed to be the three elements of bed load, suspended load and wash load.
- Sediment amounts were calculated as annual average values. Regarding bed load and suspended load, the Ashida and Michiue method, well known from river bed fluctuation analysis and dam sedimentation analysis in Japan, was used. Wash load was assumed to be equal to the combined amount of bed load and suspended load, based on the results obtained from studies of rivers in Japan.
- Representative cross sections for use in calculation were set for both upstream and downstream of the river basins.
- The flood discharge was obtained by extending the designed flood hydrograph of June 6, 1990 according to the scale of flood probability.
- Regarding sediment grain size distribution, average distributions were used for each river based on the findings of the river bed material survey.
- Annual average amount of sediment was obtained by summing the amount of sediment per flood calculated for each scale of flood probability, taking the frequency of flood occurrence into account, multiplied by the frequency.

(a) Proposed Sediment Discharge

Since the sediment transportation capacity of the upstream river course was considerably more than proposed sediment production yield, as indicated in Table-D.4.17, the proposed sediment discharge was set as the value of the proposed sediment production yield. In addition, the constituent element ratio of the proposed sediment discharge was determined from the calculation result of the sediment transportation capacity of the upstream river course.

Table-D.4.17 Proposed Sediment Discharge

Item	Unit	Ruhu	Tomu	Batu Gajah	Batu Gantung	Remark
Sediment Discharge in Upstream	m^3/year	804,000	110,000	134,000	140,000	
Designed Sediment Production	m^3/year (m^3/km^2/year)	149,100 (10,000)	39,900 (10,000)	49,200 (10,000)	60,700 (10,000)	Proposed Sediment Discharge

(b) Proposed Allowable Sediment Discharge

Proposed allowable sediment discharge was set as the value of the sediment transportation capacity of the downstream river course, as shown in Table-D.4.18.

Table-D.4.18 Proposed Allowable Sediment Discharge

Item	Unit	Ruhu	Tomu	Batu Gajah	Batu Gantung	Remark
Sediment Discharge in Downstream	m^3/year	272,000	76,000	112,000	116,000	Proposed Allowable Sediment Discharge

(4) Check Dam Plan

The comparison between proposed sediment discharge and proposed allowable sediment discharge for each river is indicated in Table-D.4.19. From the table it can be seen that the sediment transportation capacity of each river seems to be sufficient to handle the total amount of sediment discharge from upstream. However, in terms of sediment constitution breakdown, it can be seen that there is insufficient capacity to transport the bed load. Consequently, since there is a possibility that some of the bed load carried from upstream to downstream may accumulate in the downstream river courses, it is necessary to cut the flow of bed load in order to prevent sedimentation and resultant flooding.

Table-D.4.19 Comparison between Sediment Discharge and Allowable Sediment Discharge

River	Sediment Flow					Proposed Sediment Capacity
	Item *1	Bed Load	Suspended Load	Wash Load	Total	
		($1000m^3/y$)	($1000m^3/y$)	($1000m^3/y$)	($1000m^3/y$)	(m^3) *2
Ruhu	(1) Outflow	5.01	69.54	74.55	149.10	
	(2) River Capacity	1.00	135.00	136.00	272.00	
	Balance : (2) - (1)	-4.01	65.46	61.45	122.90	40,000
Tomu	(1) Outflow	4.72	15.23	19.95	39.90	
	(2) River Capacity	1.00	37.00	38.00	76.00	
	Balance : (2) - (1)	-3.72	21.77	18.05	36.10	37,000
Batu Gajah	(1) Outflow	4.04	20.56	24.60	49.20	
	(2) River Capacity	3.00	53.00	56.00	112.00	
	Balance : (2) - (1)	-1.04	32.44	31.40	62.80	10,000
Batu Gantung	(1) Outflow	5.64	24.71	30.35	60.70	
	(2) River Capacity	2.00	56.00	58.00	116.00	
	Balance : (2) - (1)	-3.64	31.29	27.65	55.30	36,000

Notes:
*1 (1) Outflow : Proposed sediment discharge
(2) River Capacity : Proposed allowable sediment discharge
*2 Check Dam Capacity was designed as 10 years storage volume based on bed load flow shortfall.

Consequently, it is necessary to construct check dams on four of the five target rivers excluding Batu Merah River where a check dam is already in place. In planning the check dams, the check dam capacity was designed to enable storage of bed load sediment accumulated over 10 years on the assumption that excavation or dredging of sediment in each check dam would be executed every ten years. Dam sites were selected at upstream narrow valley sections to avoid any impact on inhabited homes. The specifications of each dam are as indicated in Table-D.4.20.

Table-D.4.20 Outline of Check Dams

River	Location	Basement Elevation EL.(m)	Dam Height (m)	Dam Length (m)	Sediment Capacity (m^3)	Dam Volume (m^3)	Land Acquisition (m^2)
Ruhu	RH-1	EL.40m	10 m	50 m	40,000	2,500	33,000
Tomu	TM-1	EL.45m	7 m	110 m	37,000	2,700	30,000
Batu Gajah	Upstream of GJ-2	EL.70m	8 m	80 m	10,000	2,600	16,000
Batu Gantung	Upstream of GT-1	EL.100m	11 m	40 m	36,000	2,400	6,000

Note. Resettlement households are nothing for all the check dams

4.3 Alternative Flood Control Plans

4.3.1 Flood Control Plans for Ruhu River

The following five alternative flood control plans for the Ruhu river system are studied and proposed. Refer to Table-D.4.21, Figure-D.4.10 and Figure-D.4.11.

1) Alternative FCP-RH1: River Improvement (30)
Full size river course improvement (scale: 30 year return period), not including dam and diversion channel

2) Alternative FCP-RH2: River Improvement (5) + Dam
Partial river course improvement (scale: 5 year return period) to decrease land acquisition and resettlement, combined with flood control dam

3) Alternative FCP-RH3: River Improvement (10) + Dam
Partial river course improvement (scale: 10 year return period) to decrease land acquisition and resettlement, combined with flood control dam

4) Alternative FCP-RH4: River Improvement (5) + Diversion Channel
Partial river course improvement (scale: 5 year return period) to decrease land acquisition and resettlement, combined with diversion channel (open channel)

5) Alternative FCP-RH5: River Improvement (10) + Diversion Channel
Partial river course improvement (scale: 10 year return period) to decrease land acquisition and resettlement, combined with diversion channel (open channel)

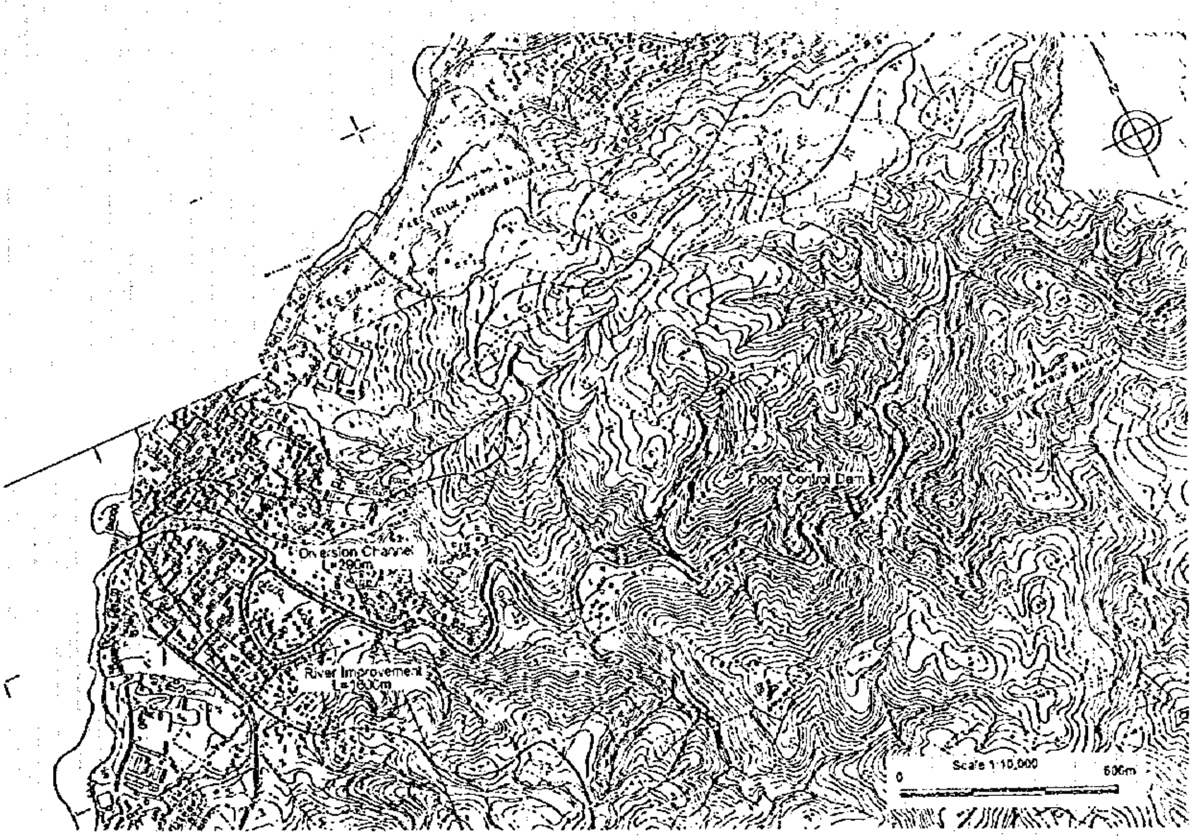


Figure-D.4.10 Location of Components of Alternative Plan (Ruhu River)

Table-D.4.21 Alternatives of Flood Control Plan for Ruhu River

Item		FCP-RH1	FCP-RH2	FCP-RH3	FCP-RH4	FCP-RH5
Total Compensation						
- Land Acquisition	A (m^2)	50,000	445,500	389,000	44,440	44,540
- Resettlement	Household	147	40	147	150	177
River Improvement Plan						
Improvement Scale (Return Period)		30-year	5-year	10-year	5-year	10-year
River-bed Formation	Section	0'000-1'600	0'000-1'600	0'000-1'600	0'000-1'600	0'000-1'600
	L (m)	1600	1600	1600	1600	1600
	V (m^3)	21,000	21,000	21,000	21,000	21,000
River-bed Excavation	Section	0'000-1'600	0'000-1'600	0'000-1'600	0'000-1'600	0'000-1'600
	D (m)	1.00	1.00	1.00	1.00	1.00
	L (m)	1,600	1,600	1,600	1,600	1,600
	V (m^3)	54,900	32,800	43,000	44,100	49,100
Concrete Channel	Section	-	-	-	-	-
	L (m)	-	-	-	-	-
	A (m^2)	-	-	-	-	-
Flood Wall Heightening	Section	0'400-1'550	0'650-1'550	0'520-1'530	0'400-1'550	0'400-1'550
	MnH (m)	3.50-4.00	3.50-4.00	3.50-4.00	3.50-4.00	3.50-4.00
: Left	ΔH (m)	0.20-0.30	0.30	0.30	0.10-0.30	0.20-0.30
	L (m)	420	300	300	480	420
: Right	ΔH (m)	0.20-0.60	0.20-0.60	0.20-0.60	0.20-0.60	0.20-0.60
	L (m)	500 (70)	350 (250)	350 (0)	500 (170)	500 (70)
River Widening	Section	0'500-1'600	0'550-1'000	0'550-1'600	0'550-1'600	0'500-1'600
	ΔW (m)	12.0-20.0R	3.0-5.0R	5.0-12.0R	3.0-15.0R	5.0-12.0R
	L (m)	1,100	300	1,100	900	1,100
	A (m^2)	17,000	1,500	10,000	9,900	10,000
Bridge Improvement	Location	0'059-1'359	0'059-1'359	0'059-1'359	0'059-1'359	0'059-1'359
	Number	B2,B4,B5	B2,B4,B5	B2,B4,B5	B2,B4,B5	B2,B4,B5
Groundsill Work	Location	-	-	-	-	-
	H (m)	-	-	-	-	-
- Land Acquisition	A (m^2)	17,000	1,500	10,000	9,900	10,000
- Resettlement	Household	147	40	147	120	147
Flood Control Dam						
- Dam Type	-	-	Rock Fill	Rock Fill	-	-
- Dam Height	H (m)	-	41.0	38.6	-	-
- Dam Length	L (m)	-	103.0	98.0	-	-
- Dam Volume	V (m^3)	-	201,000	172,000	-	-
- Land Acquisition	A (m^2)	-	411,000	346,000	-	-
- Resettlement	Household	-	-	-	-	-
Diversion Channel						
- Type	-	-	-	-	Open	Open
- Length	L (m)	-	-	-	290	290
- Standard Section	W (m)	-	-	-	7.0	6.0
	H (m)	-	-	-	3.5	3.2
- Land Acquisition	A (m^2)	-	-	-	1,540	1,540
- Resettlement	Household	-	-	-	30	30
Check Dam						
- Dam Height	H (m)	15	15	15	15	15
- Dam Length	L (m)	50	50	50	50	50
- Dam Volume	V (m^3)	2,500	2,500	2,500	2,500	2,500
- Land Acquisition	A (m^2)	33,000	33,000	33,000	33,000	33,000
- Resettlement	Household	-	-	-	-	-

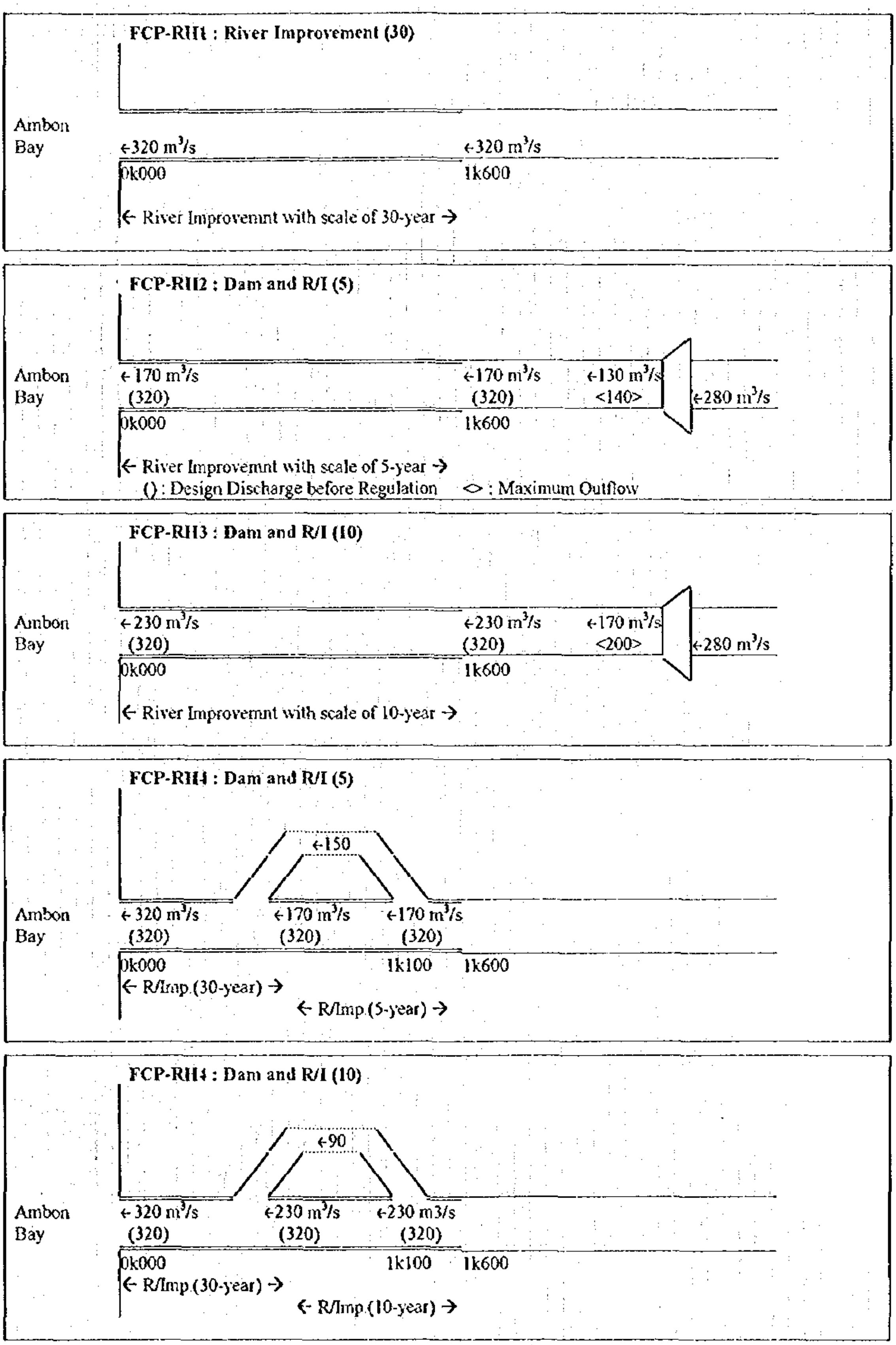


Figure-D.4.11 Distribution of Flood Discharge (Ruhu River)

4.3.2 Flood Control Plans for Batu Merah River

The following five alternative flood control plans for the Batu Merah river system are studied and proposed. Refer to Table-D.4.22, Figure-D.4.12 and Figure-D.4.13.

1) Alternative FCP-BM1: River Improvement (30)
Full size river course improvement (scale: 30 year return period), not including dam and diversion channel

2) Alternative FCP-BM2: River Improvement (5) + Dam
Partial river course improvement (scale: 5 year return period) to decrease land acquisition and resettlement, combined with flood control dam

3) Alternative FCP-BM3: River Improvement (10) + Dam
Partial river course improvement (scale: 10 year return period) to decrease land acquisition and resettlement, combined with flood control dam

4) Alternative FCP-BM4: River Improvement (5) + Diversion Channel
Partial river course improvement (scale: 5 year return period) to decrease land acquisition and resettlement, combined with diversion channel (open tunnel)

5) Alternative FCP-BM5: River Improvement (10) + Diversion Channel
Partial river course improvement (scale: 10 year return period) to decrease land acquisition and resettlement, combined with diversion channel (open tunnel)

Figure-D.4.12 Location of Components of Alternative Plan (Batu Merah River)

Table-D.4.22 Alternatives of Flood Control Plan for Batu Merah River

Item		FCP-BM1	FCP-BM2	FCP-BM3	FCP-BM4	FCP-BM5
Total Compensation						
- Land Acquisition	A (m^2)	7,750	236,350	206,750	1,550	5,950
- Resettlement	Household	160	160	277	10	127
River Improvement Plan						
Improvement Scale (Return Period)		30-year	5-year	10-year	5-year	10-year
River-bed Formation	Section	0'000-1'600	0'000-1'600	0'000-1'600	0'000-1'600	0'000-1'600
	L (m)	1600	1600	1600	1600	1600
	V (m^3)	6,900	6,900	6,900	6,900	6,900
River-bed Excavation	Section	0'000-1'600	0'000-1'600	0'000-1'600	0'000-1'600	0'000-1'600
	D (m)	1.00	1.00	1.00	1.00	1.00
	L (m)	1,600	1,600	1,600	1,600	1,600
	V (m^3)	23,500	16,500	19,300	16,500	19,300
Concrete Channel	Section	0'200-1'600	0'400-1'600	0'400-1'600	0'400-1'600	0'400-1'600
	L (m)	1,400	1,200	1,200	1,200	1,200
	A (m^2)	17,400	9,500	11,700	9,500	11,700
Flood Wall Heightening	Section	0'400-1'500	0'400-1'600	0'400-1'500	0'400-1'600	0'400-1'500
	MnH (m)	2.90	2.60-3.40	2.90	2.60-3.40	2.90
: Left	ΔH (m)	0.20-0.40	0.20-0.60	0.20-0.40	0.20-0.60	0.20-0.40
	L (m)	970	1010	970	1010	970
: Right	ΔH (m)	0.10-0.70	0.30-0.60	0.10-0.70	0.30-0.60	0.10-0.70
	L (m)	800 (90)	1070 (1000)	800 (90)	1070 (1000)	800 (90)
River Widening	Section	0'400-1'600	0'700-0'800	0'400-1'600	0'700-0'800	0'400-1'600
	ΔW (m)	1.5-6.5	2.0 R	1.5-3.5R	2.0 R	1.5-3.5R
	L (m)	1,200	70	950	70	950
	A (m^2)	7,750	350	4,750	350	4,750
Bridge Improvement	Location	0'386	0'386	0'386	0'386	0'386
	Number	B4	B4	B4	B4	B4
Groundsill Work	Location	-	-	-	-	-
	H (m)	-	-	-	-	-
- Land Acquisition	A (m^2)	7,750	350	4,750	350	4,750
- Resettlement	Household	160	10	127	10	127
Flood Control Dam						
- Dam Type	-	-	Rock Fill	Rock Fill	-	-
- Dam Height	H (m)	-	25.0	23.1	-	-
- Dam Length	L (m)	-	134.0	126.0	-	-
- Dam Volume	V (m^3)	-	115,000	94,000	-	-
- Land Acquisition	A (m^2)	-	236,000	202,000	-	-
- Resettlement	Household	-	150	150	-	-
Diversion Channel						
- Type	-	-	-	-	Tunnel	Tunnel
- Length	L (m)	-	-	-	1,200	1,200
- Standard Section	D (m)	-	-	-	5.8	5.1
	A (m^2)	-	-	-	25.4	19.7
- Land Acquisition	A (m^2)	-	-	-	1,200	1,200
- Resettlement	Household	-	-	-	-	-
Check Dam						
- Dam Height	H (m)	-	-	-	-	-
- Dam Length	L (m)	-	-	-	-	-
- Dam Volume	V (m^3)	-	-	-	-	-
- Land Acquisition	A (m^2)	-	-	-	-	-
- Resettlement	Household	-	-	-	-	-

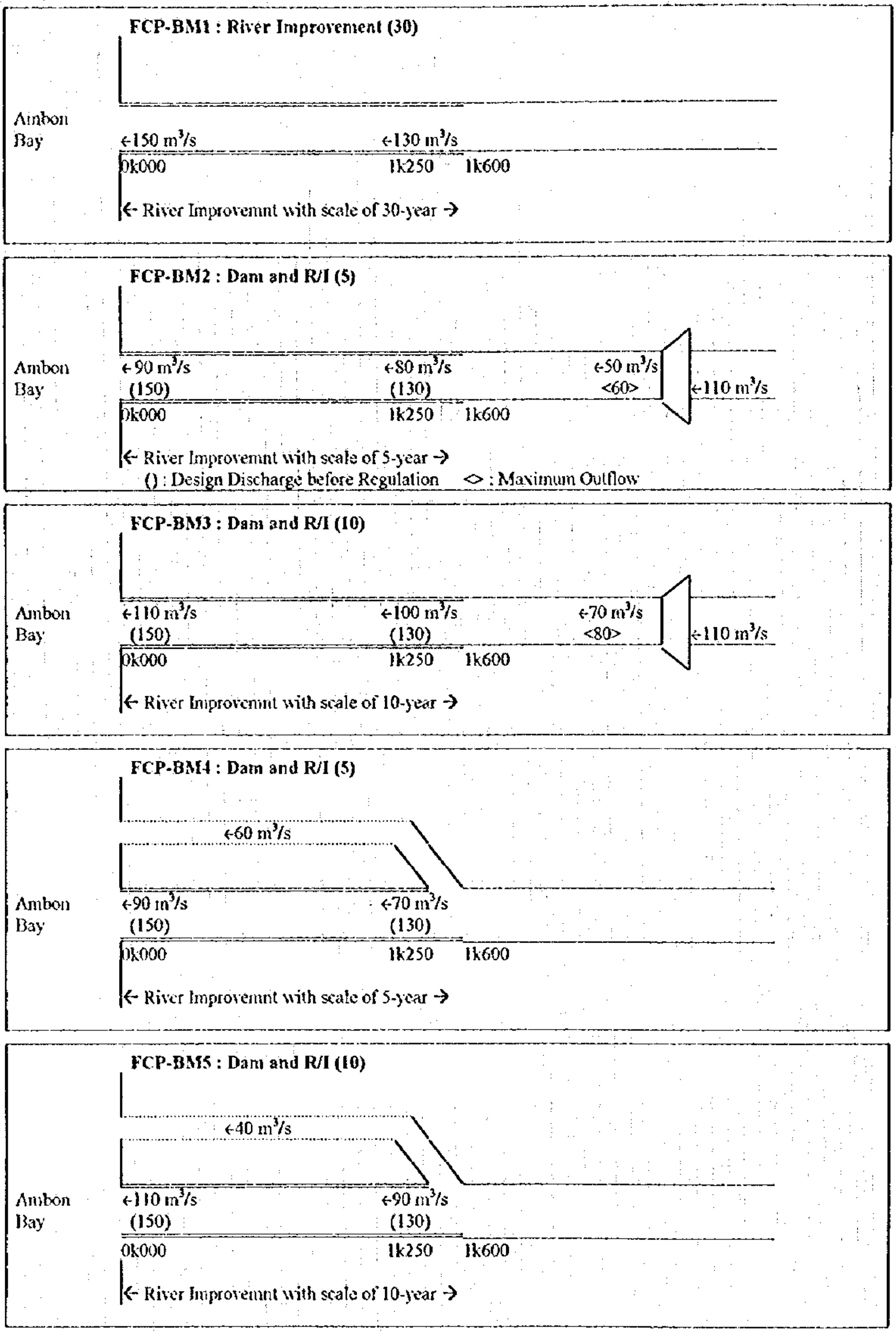


Figure-D.4.13 Distribution of Flood Discharge (Batu Merah River)

4.3.3 Flood Control Plans for Tomu River

The following five alternative flood control plans for the Tomu river system are studied and proposed. Refer to Table-D.4.23, Figure-D.4.14 and Figure-D.4.15.

1) Alternative FCP-TM1: River Improvement (30)
Full size river course improvement (scale: 30 year return period), not including dam and diversion channel

2) Alternative FCP-TM2: River Improvement (5) + Dam
Partial river course improvement (scale: 5 year return period) to decrease land acquisition and resettlement, combined with flood control dam

3) Alternative FCP-TM3: River Improvement (10) + Dam
Partial river course improvement (scale: 10 year return period) to decrease land acquisition and resettlement, combined with flood control dam

4) Alternative FCP-TM4: River Improvement (5) + Diversion Channel
Partial river course improvement (scale: 5 year return period) to decrease land acquisition and resettlement, combined with diversion channel (open tunnel/channel)

5) Alternative FCP-TM5: River Improvement (10) + Diversion Channel
Partial river course improvement (scale: 10 year return period) to decrease land acquisition and resettlement, combined with diversion channel (open tunnel/channel)

Figure-D.4.14 Location of Components of Alternative Plan (Tomu River)

Table-D.4.23 Alternatives of Flood Control Plan for Tomu River

Item		FCP-TM1	FCP-TM2	FCP-TM3	FCP-TM4	FCP-TM5
Total Compensation						
- Land Acquisition	A (m^2)	30,000	185,000	138,000	32,480	32,360
- Resettlement	Household	-	-	-	34	34
River Improvement Plan						
Improvement Scale (Return Period)		30-year	5-year	10-year	5-year	10-year
River-bed Formation	Section	0'000-2'700	0'000-2'700	0'000-2'700	0'000-2'700	0'000-2'700
	L (m)	2700	2700	2700	2700	2700
	V (m^3)	26500	26500	26500	26500	26500
River-bed Excavation	Section	0'000-2'100	-	0'000-2'100	0'000-0'800	0'000-2'100
	D (m)	0.80	-	0.80	0.80	0.80
	L (m)	2,100	-	2,100	800	2,100
	V (m^3)	19,500	-	19,500	8,300	19,500
Concrete Channel	Section	0'600-2'700	-	-	0'600-0'800	0'600-0'800
	L (m)	2,100	-	-	200	200
	A (m^2)	19,300	-	-	1,800	1,800
Flood Wall Heightening	Section	1'800-2'700	0'950-2'700	1'800-2'700	0'950-2'700	1'800-2'700
	MnH (m)	2.40-2.80	2.10-2.80	2.40-2.80	2.10-2.80	2.40-2.80
: Left	ΔH (m)	0.10-0.40	0.10-0.30	0.10-0.40	0.10-0.30	0.10-0.40
	L (m)	130	770	130	770	130
: Right	ΔH (m)	0.10	0.10-0.20	0.10	0.10-0.20	0.10
	L (m)	20	600	20	600	20
River Widening	Section	-	-	-	-	-
	ΔW (m)	-	-	-	-	-
	L (m)	-	-	-	-	-
	A (m^2)	-	-	-	-	-
Bridge Improvement	Location	0'460-1'822	0'460-2'007	0'460-1'882	0'460-2'007	0'460-1'822
	Number	B4-B6, B8	B4, B7-B9	B4-B8	B4, B7-B9	B4-B6, B8
Groundsill Work	Location	-	-	-	0'800	-
	H (m)	-	-	-	0.80	-
- Land Acquisition	A (m^2)	-	-	-	-	-
- Resettlement	Household	-	-	-	-	-
Flood Control Dam						
- Dam Type	-	-	Rock Fill	Rock Fill	-	-
- Dam Height	H (m)	-	29.2	22.8	-	-
- Dam Length	L (m)	-	183.0	164.0	-	-
- Dam Volume	V (m^3)	-	271,000	159,000	-	-
- Land Acquisition	A (m^2)	-	155,000	108,000	-	-
- Resettlement	Household	-	-	-	-	-
Diversion Channel						
- Type	-	-	-	-	Open, Tunnel	Open, Tunnel
- Length	L (m)	-	-	-	900, 250	900, 250
- Standard Section	W, D (m)	-	-	-	4.0, 4.2	3.5, 3.5
	H (m)	-	-	-	2.6	2.2
- Land Acquisition	A (m^2)	-	-	-	2,480	2,360
- Resettlement	Household	-	-	-	34	34
Check Dam						
- Dam Height	H (m)	15	15	15	15	15
- Dam Length	L (m)	140	140	140	140	140
- Dam Volume	V (m^3)	7,000	7,000	7,000	7,000	7,000
- Land Acquisition	A (m^2)	30,000	30,000	30,000	30,000	30,000
- Resettlement	Household	-	-	-	-	-

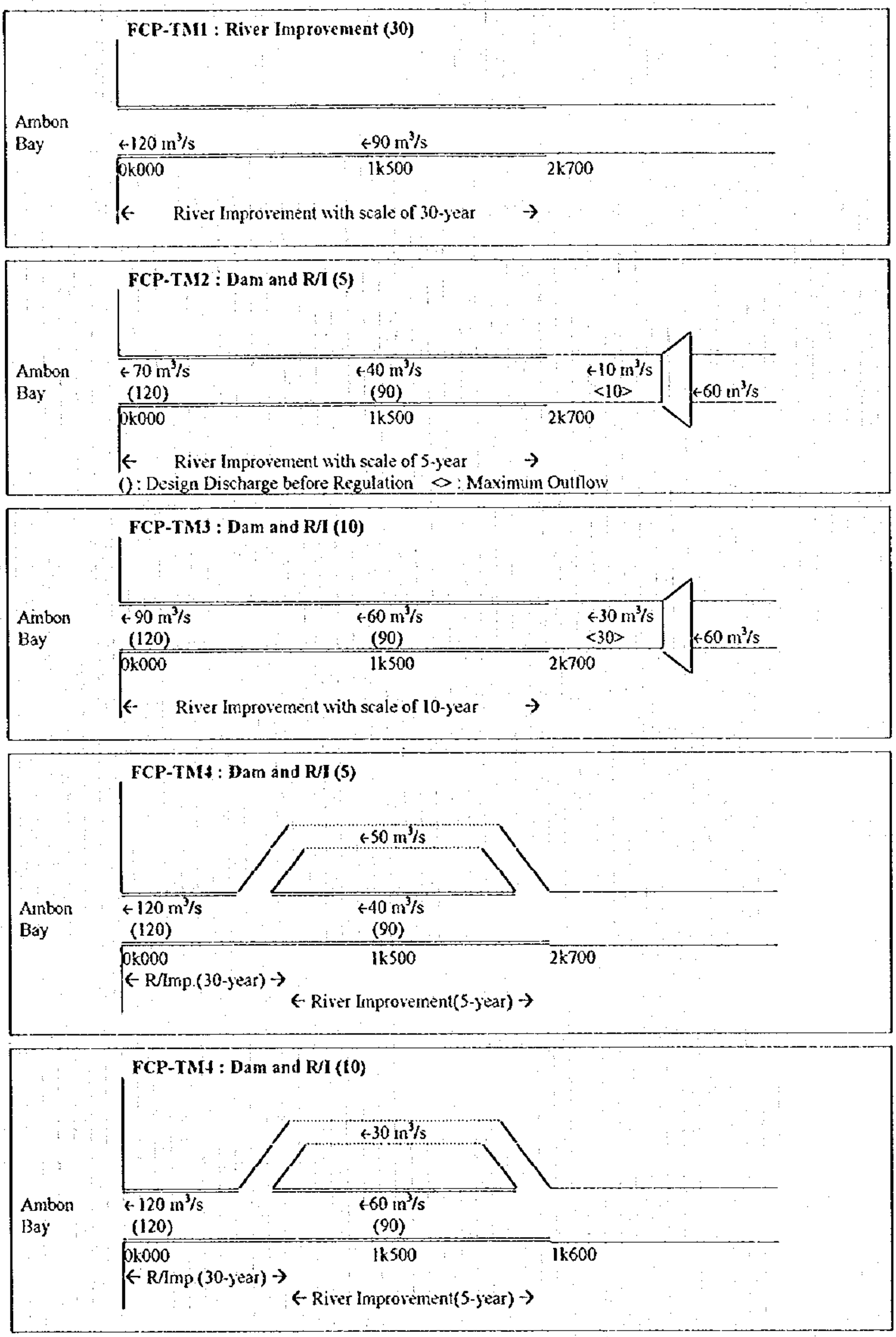


Figure-D.4.15 Distribution of Flood Discharge (Tomu River)

4.3.4 Flood Control Plans for Batu Gajah River

The following three alternative flood control plans for the Batu Gajah river system are studied and proposed. Refer to Table-D.4.24, Figure-D.4.16 and Figure-D.4.17.

1) Alternative FCP-GJ1: River Improvement (30)
Full size river course improvement (scale: 30 year return period), not including dam and diversion channel
2) Alternative FCP-GJ2: River Improvement (5) + Dam
Partial river course improvement (scale: 5 year return period) to decrease land acquisition and resettlement, combined with flood control dam
3) Alternative FCP-GJ3: River Improvement (10) + Dam
Partial river course improvement (scale: 10 year return period) to decrease land acquisition and resettlement, combined with flood control dam

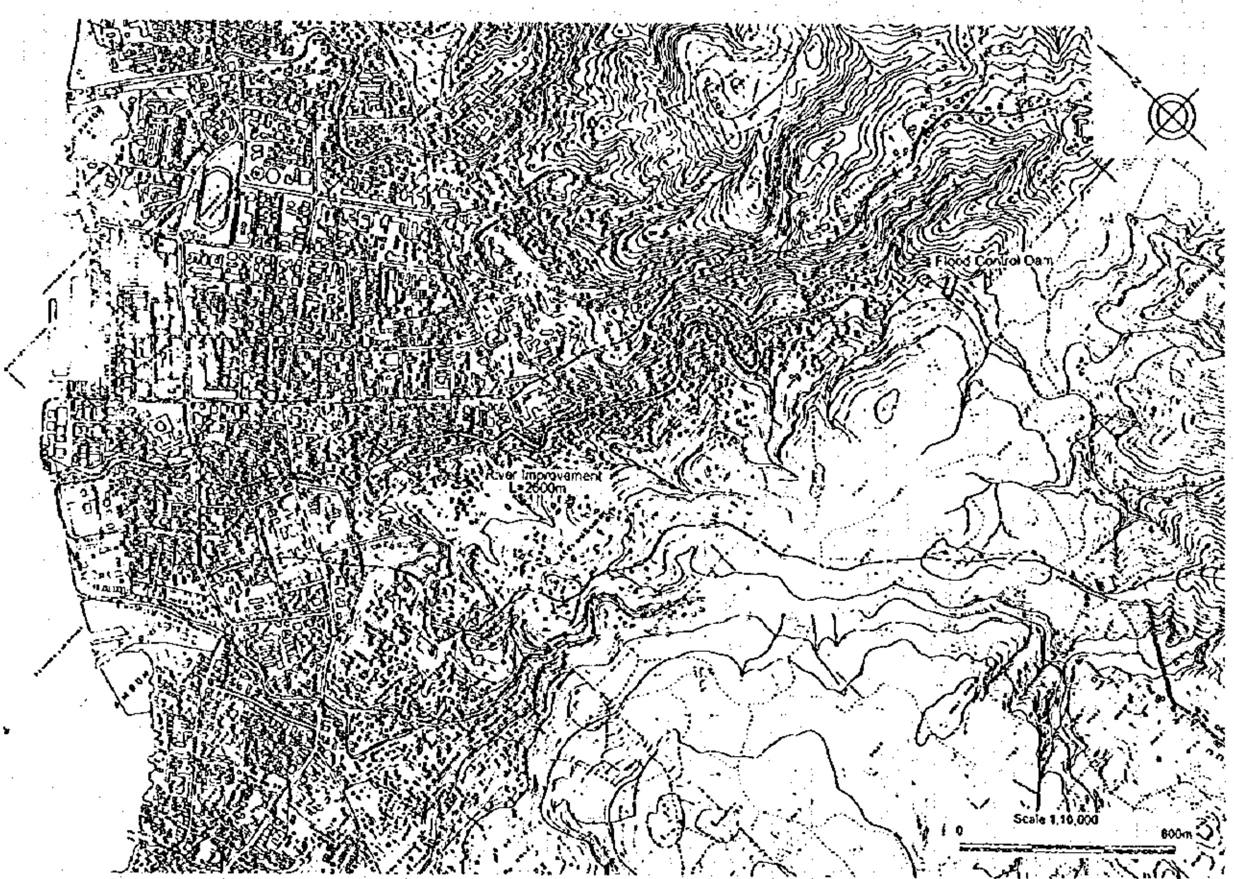


Figure-D.4.16 Location of Components of Alternative Plan (Batu Gajah River)

Table-D.4.24 Alternatives of Flood Control Plan for Batu Gajah River

Item		FCP-GJ1	FCP-GJ2	FCP-GJ3
Total Compensation				
- Land Acquisition	A (m^2)	21,500	124,000	109,000
- Resettlement	Household	147	20	20
River Improvement Plan				
Improvement Scale (Return Period)		30-year	5-year	10-year
River-bed Formation	Section	0'000-2'600	0'000-2'600	0'000-2'600
	L (m)	2,600	2,600	2,600
	V (m^3)	30,500	30,500	30,500
River-bed Excavation	Section	0'000-2'100	0'000-2'100	0'000-2'100
	D (m)	1.00	1.00	1.00
	L (m)	2,100	2,100	2,100
	V (m^3)	24,400	19,000	19,000
Concrete Channel	Section	0'200-2'100	-	0'200-0'900
	L (m)	1,900	-	700
	A (m^2)	18,000	-	5,600
Flood Wall Heightening	Section	0'200-2'600	0'200-1'450	0'700-1'600
	MnH (m)	2.50-2.90	2.50-3.20	2.80-3.80
: Left	ΔH (m)	0.40	0.20-0.30	0.40
	L (m)	230	140	230
: Right	ΔH (m)	0.20-0.40	0.20-0.40	0.20-0.40
	L (m)	230	150	150
River Widening	Section	1'950-2'200	-	-
	ΔW (m)	1.5-3.0	-	-
	L (m)	1,100	-	-
	A (m^2)	5,500	-	-
Bridge Improvement	Location	0'750-1'835	0'750-1'835	0'750-1'835
	Number	B3,B5,B6	B3,B5,B6	B3,B5,B6
Groundsill Work	Location	-	-	-
	H (m)	-	-	-
- Land Acquisition	A (m^2)	5,500	-	-
- Resettlement	Household	147	-	-
Flood Control Dam				
- Dam Type	-	-	Rock Fill	Rock Fill
- Dam Height	H (m)	-	34.0	31.8
- Dam Length	L (m)	-	220.0	209.0
- Dam Volume	V (m^3)	-	406,000	335,000
- Land Acquisition	A (m^2)	-	108,000	93,000
- Resettlement	Household	-	20	20
Diversion Channel				
- Type	-	-	-	-
- Length	L (m)	-	-	-
- Standard Section	W (m)	-	-	-
	H (m)	-	-	-
- Land Acquisition	A (m^2)	-	-	-
- Resettlement	Household	-	-	-
Check Dam				
- Dam Height	H (m)	15	15	15
- Dam Length	L (m)	95	95	95
- Dam Volume	V (m^3)	4,800	4,800	4,800
- Land Acquisition	A (m^2)	16,000	16,000	16,000
- Resettlement	Household	-	-	-

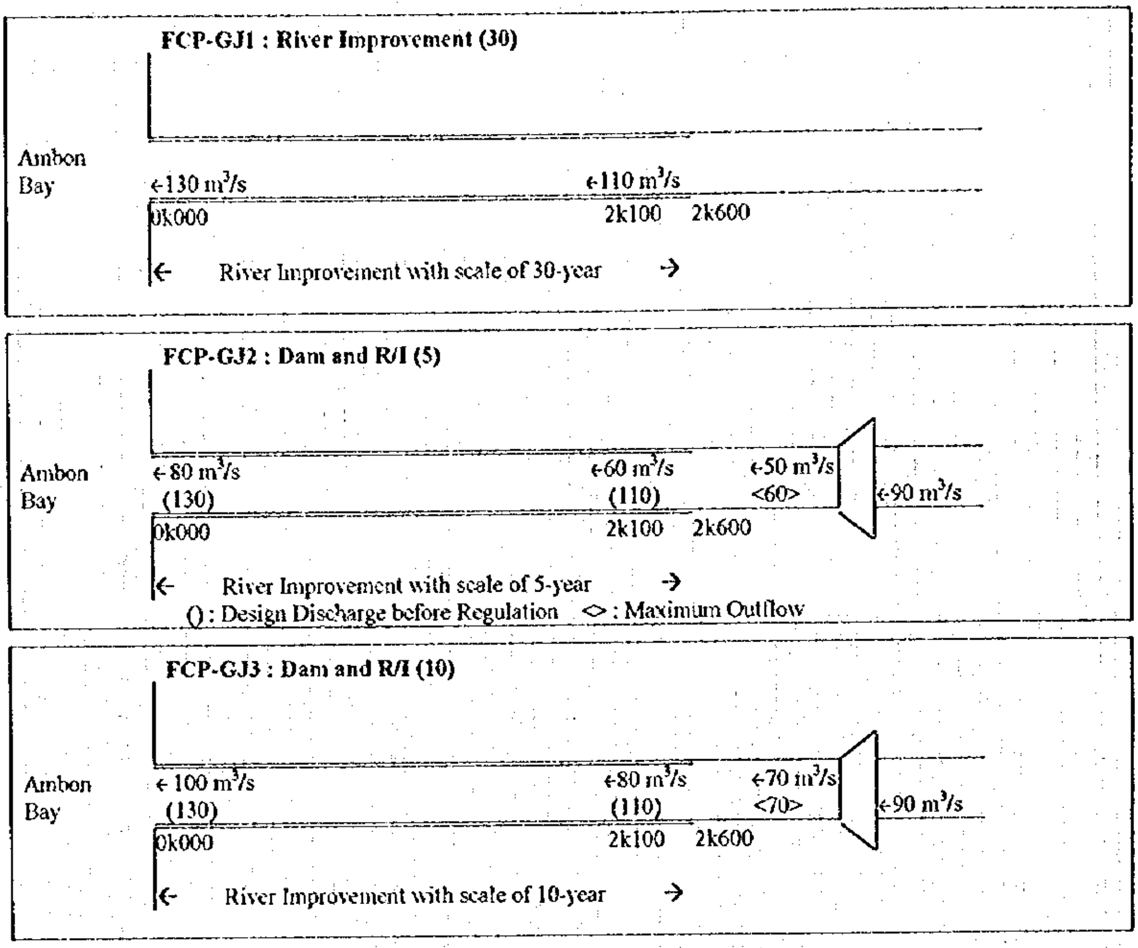


Figure-D.4.17 Distribution of Flood Discharge (Batu Gajah River)

4.3.5 Flood Control Plans for Batu Gantung River

The following three alternative flood control plans for the Batu Gantung river system are studied and proposed. Refer to Table-D.4.25, Figure-D.4.18 and Figure-D.4.19.

1) Alternative FCP-GT1: River Improvement (30)
Full size river course improvement (scale: 30 year return period), not including dam and diversion channel

2) Alternative FCP-GT2: River Improvement (5) + Dam
Partial river course improvement (scale: 5 year return period) to decrease land acquisition and resettlement, combined with flood control dam

3) Alternative FCP-GT3: River Improvement (10) + Dam
Partial river course improvement (scale: 10 year return period) to decrease land acquisition and resettlement, combined with flood control dam

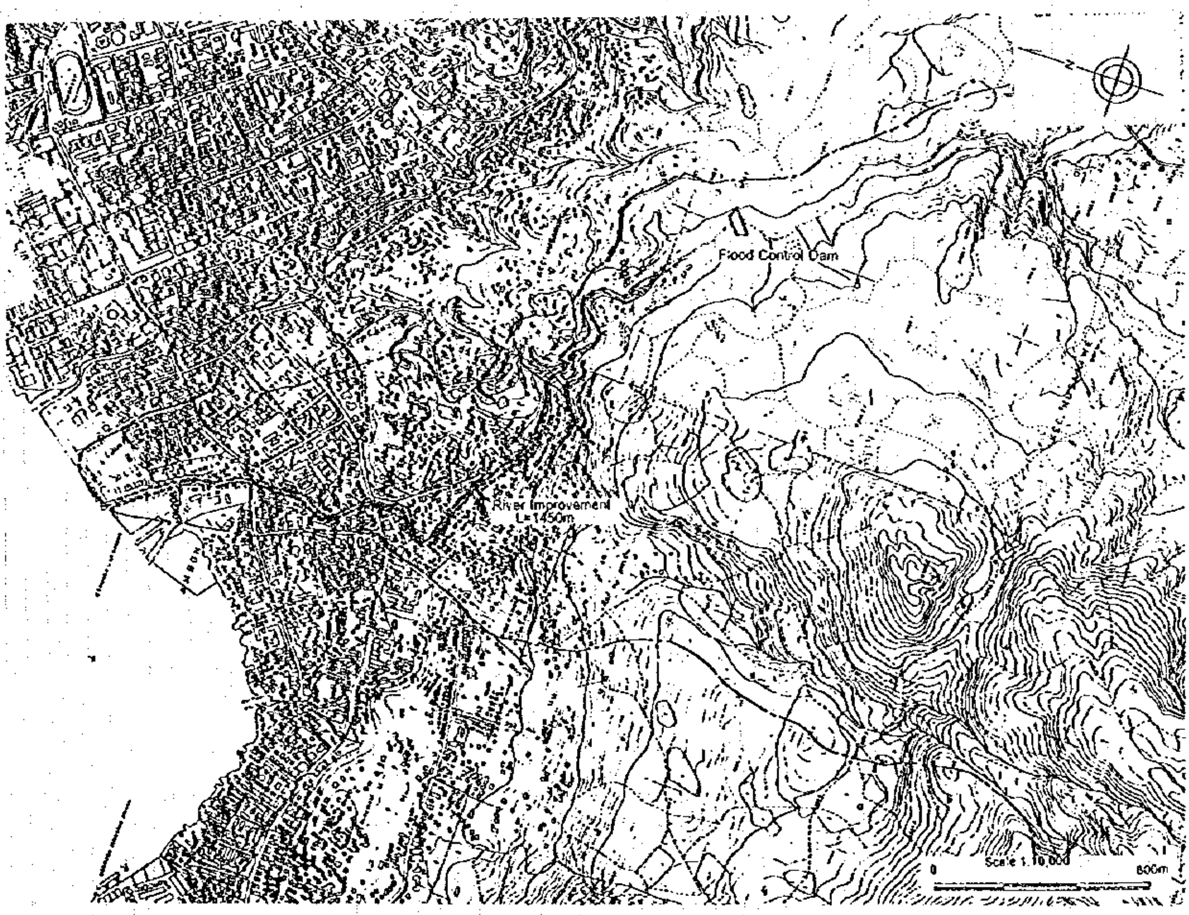


Figure-D.4.18 Location of Components of Alternative Plan (Batu Gantung River)

Table-D.4.25 Alternatives of Flood Control Plan for Batu Gantung River

Item		FCP-GT1	FCP-GT2	FCP-GT3
Total Compensation				
- Land Acquisition	A (m^2)	10,750	137,000	101,000
- Resettlement	Household	127	-	-
River Improvement Plan				
Improvement Scale (Return Period)		30-year	5-year	10-year
River-bed Formation	Section	0'000-1'450	0'000-1'450	0'000-1'450
	L (m)	1,450	1,450	1,450
	V (m^3)	3600	3600	3600
River-bed Excavation	Section	0'000-1'450	0'000-1'450	0'000-1'450
	D (m)	1.00	1.00	1.00
	L (m)	1,450	1,450	1,450
	V (m^3)	20,000	17,700	17,700
Concrete Channel	Section	0'150-1'450	0'250-0'500	0'250-1'150
	L (m)	1,300	250	900
	A (m^2)	12,600	1,900	7,400
Flood Wall Heightening	Section	-	1'050-1'150	0'400-0'550
	MnH (m)	-	3.90	3.30
: Left	ΔH (m)	-	0.30	0.30
	L (m)	-	50	100
: Right	ΔH (m)	-	-	0.40
	L (m)	-	-	100
River Widening	Section	0'250-1'150	-	-
	ΔW (m)	0.5-3.5(L)	-	-
	L (m)	550	-	-
	A (m^2)	2,750	-	-
Bridge Improvement	Location	0'400-0'769	0'400-0'769	0'400-0'769
	Number	B1,B2	B1,B2	B1,B2
Groundsill Work	Location	-	-	-
	H (m)	-	-	-
- Land Acquisition	A (m^2)	2,750	-	-
- Resettlement	Household	73	-	-
Flood Control Dam				
- Dam Type	-	-	Rock Fill	Rock Fill
- Dam Height	H (m)	-	37.5	34.0
- Dam Length	L (m)	-	145.0	132.0
- Dam Volume	V (m^3)	-	228,000	174,000
- Land Acquisition	A (m^2)	-	113,000	95,000
- Resettlement	Household	-	-	-
Diversion Channel				
- Type	-	-	-	-
- Length	L (m)	-	-	-
- Standard Section	W (m)	-	-	-
	H (m)	-	-	-
- Land Acquisition	A (m^2)	-	-	-
- Resettlement	Household	-	-	-
Check Dam				
- Dam Height	H (m)	15	15	15
- Dam Length	L (m)	50	50	50
- Dam Volume	V (m^3)	2,500	2,500	2,500
- Land Acquisition	A (m^2)	6,000	6,000	6,000
- Resettlement	Household	-	-	-

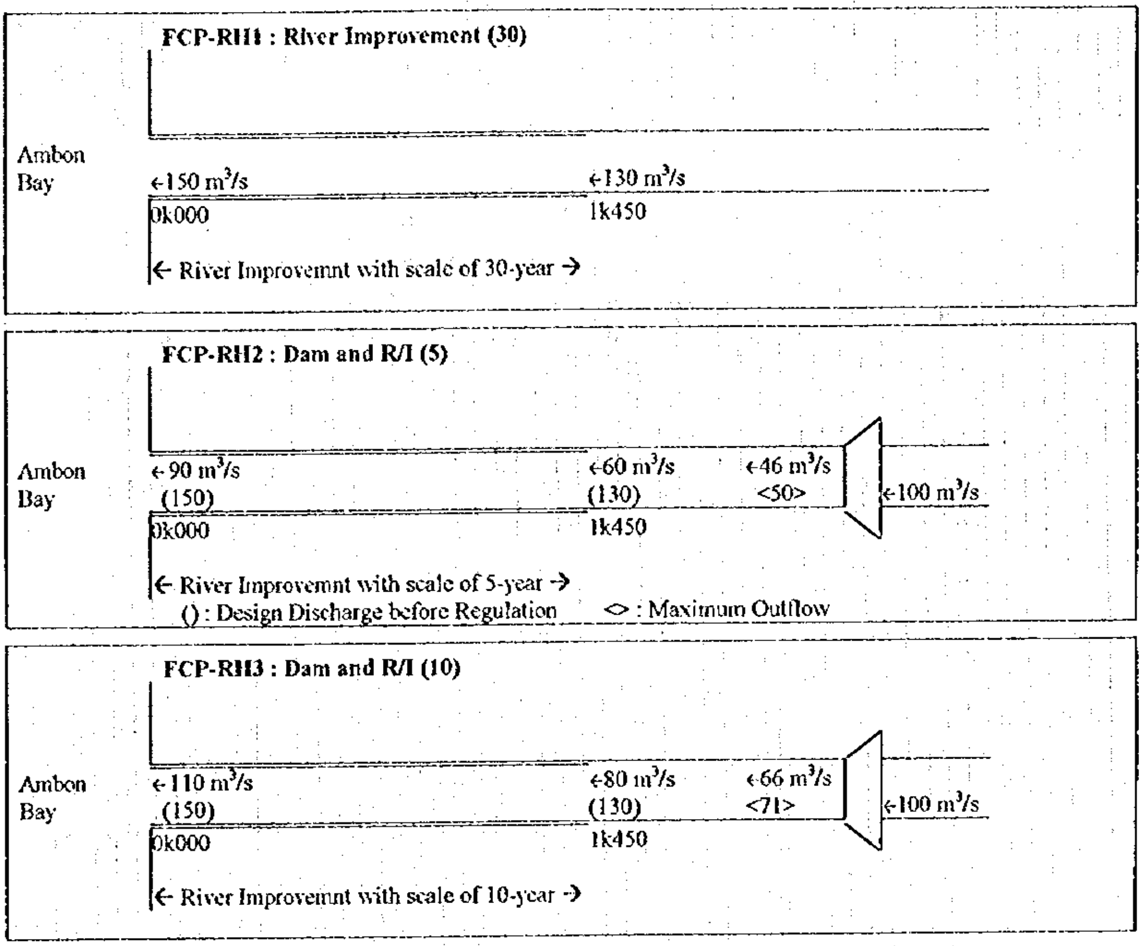


Figure-D.4.19 Distribution of Flood Discharge (Batu Gantung River)