CHAPTER 2 FLOOD ANALYSIS

2.1 Rainfall Analysis

2.1.1 Representative Rainfall Station and Basin Mean Rainfall

There are two meteorological (rainfall) stations in Ambon Island, namely Gunung Nona and Pattimura Ambon. Since Pattimura Ambon has both daily and hourly rainfall data for a long period and Gunung Nona has many missing data, Pattimura Ambon has been used as the representative rainfall station for daily rainfall, hourly rainfall and rainfall intensity analysis.

Table-I.2.1 Meteorological (Rainfall) Stations in Ambon

Station Name	Elevation (EL.m)	Organization	Available Period of Existing Data		Type of Gauge	Observation Period	
			Daily Rainfall	Hourly Rainfall		From	Operation
Gunung Nona	465	PUSLITBANG	5 month	-	A, O	1981	Operated
Pattimura Ambon (Ambon Airport)	10	BMG	25 years	14 years	A, O	1947	Operated

Note - PUSLITBANG: Pusat Penelitian dan Pengenabangan Pengairam in Bandung
- BMG : Badan Meteorologi dan Geofisika (Departmen Perhubungan)
- Others : Temperature, Relative Humidity, Sunshine Hours, Wind Speed, etc.
- A: Automatic Rainfall Gauge O : Ordinary Rainfall Gauge

The rainfall data to be used in the discharge analysis needs to be set with attention paid to the basin characteristics of each target river. In Ambon area, because the representative rainfall station of Pattimura Ambon is on the coast at a low altitude of EL. 10 m, care needs to be taken when applying its data to the upstream mountainous part of the target river basins. However, considering 1) the five target river basins have small catchment areas (6 - 16 km^2), and 2) the highest altitude of the river basins is lower than EL. 500 m, it is decided to use the rainfall data at Pattimura Ambon as the basin mean rainfall for the Ambon area since the difference is not considered significant.

2.1.2 Rainfall Probability Analysis

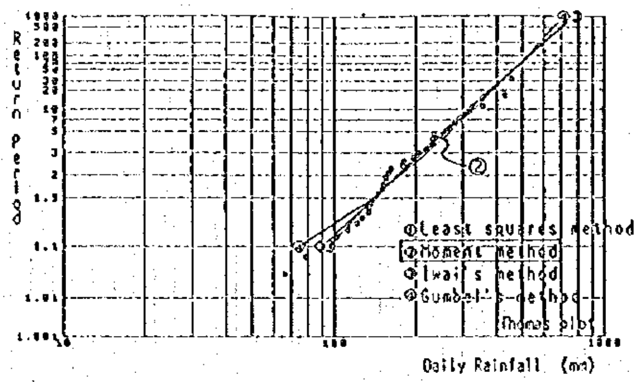
(1) Daily and Hourly Probable Rainfall

Table-I.2.2 and Figure-I.2.1 show the daily and hourly probable rainfall based on the annual maximum data of daily and hourly rainfall in representative rainfall station, namely Pattimura Ambon. Calculation was carried out using the Least Square Method, Moment Method, Iwai's Method and Gumbel's Method. Of these, the result from the Moment Method is adopted for probable rainfall in the study area because the result best fits the available data.

Table-I.2.2 Daily and Hourly Probable Rainfall [Pattimura Ambon]

Return Period (year)	2	3	5	10	20	30	50	100	200
Probable Daily Rainfall (mm)	171.8	212.1	259.5	321.9	384.6	421.9	469.9	537.0	606.7
Probable Hourly Rainfall (mm)	45.1	52.5	60.7	70.9	80.6	86.2	93.1	102.5	112.0

Note : - Calculated by Moment Method
- Annual Maximum Daily Rainfall Data of 32 years from 1959 to 1995
- Annual Maximum Hourly Rainfall Data of 14 years from 1959 to 1995



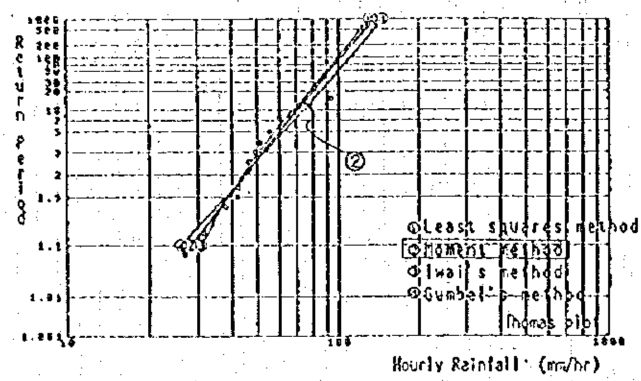


Figure-I.2.1 Plotting Positions of Daily and Hourly Probable Rainfall

(2) Rainfall Intensity Curve

The rainfall intensity curves/formula are set by the Talbot Formula using the probable daily rainfall and probable hourly rainfall of Pattimura Ambon. The calculation results are shown in Table-I.2.3.

Table-I.2.3 Probable Rainfall Depth (Pattimura Ambon)

Return Period	Talbot Constants a	Talbot Constants b	Probable Rainfall Depth (mm) 10 min	20 min	30 min	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	1 day
2	195.7	3.34	9	18	25	45	73	93	126	153	172
3	244.4	3.66	11	20	29	53	86	110	152	187	212
5	302.6	3.99	12	23	34	61	101	130	182	227	260
10	380.5	4.37	14	27	39	71	119	155	220	279	322
20	460.0	4.71	16	30	44	81	137	179	258	330	385
30	507.9	4.89	17	32	47	86	147	193	280	361	422
50	570.2	5.12	18	35	51	93	160	211	308	400	470
70	612.3	5.27	19	36	53	98	168	222	326	425	502
100	658.3	5.42	20	38	56	103	177	235	346	453	537
200	750.9	5.70	21	41	61	112	195	259	385	509	607

Note: Talbot Formula : $I_n = \dfrac{a}{(t+b)}$

I_n : Rainfall Intensity (mm/hr)
t : Rainfall Duration (hour) a, b : Constants

2.1.3 Flood Rainfall

The flood rainfall in the Study Areas are shown in Table-I.2.4. The maximum daily rainfall was recorded at 455 mm/day on August 28, 1988. Many of the flood rainfall have no hourly data, notably only two data out of the top 10 daily flood rainfalls. Of these flood rainfalls, hyetographs of the maximum floods with hourly rainfall data are shown in Figure-I.2.2. As can be seen from the figure, the hyetograph of this rainfall do not form smooth, mountain-shaped curves, but show many intermittent or sudden increases and decreases. This indicates that rainfall comes sporadically and locally in Ambon area.

Table-I.2.4 Flood Rainfall in Ambon [Pattimura Ambon]

Rank	Date (y/m/d)	Daily Rainfall		Maximum of Hourly Rainfall (mm/hour)	Ranking of Flood Hyetograph
		1 day (mm/day)	24 hours (mm/day)		
1	1988 / 08 / 28	455.0	-	-	
2	1984 / 06 / 22	430.7	-	-	
3	1964 / 09 / -	358.0	-	-	
4	1990 / 08 / 19	307.4	315.3	42.1	1
5	1963 / 06 / -	280.0	-	-	
6	1961 / 06 / -	267.0	-	-	
7	1989 / 06 / 22	233.0	-	-	
8	1981 / 07 / 25	231.9	-	-	
9	1996 / 08 / 22	230.3	230.3	28.0	2
10	1978 / 06 / 21	218.0	-	-	
11	1984 / 06 / 18	208.1	194.2	26.6	3
12	1987 / 02 / 09	203.0	-	-	
13	1978 / 07 / 20	197.0	-	-	
14	1990 / 06 / 06	196.4	190.0	43.7	4
15	1995 / 09 / 13	195.0	-	-	
16	1988 / 07 / 19	194.0	176.6	49.3	5
17	1984 / 07 / 02	189.6	-	-	
18	1954 / 06 / -	180.0	-	-	
19	1995 / 08 / 05	179.2	204.4	49.0	6
20	1955 / 09 / -	179.0	-	-	
21	1984 / 06 / 21	176.9	179.3	26.9	7
22	1995 / 08 / 04	170.2	-	-	
23	1988 / 07 / 09	166.0	-	-	
24	1959 / 05 / -	161.0	-	-	
25	1986 / 04 / 03	158.0	-	-	
26	1996 / 08 / 26	157.5	157.5	50.0	8
27	1966 / 06 / -	154.0	-	-	
28	1979 / 06 / 23	154.0	-	-	
29	1985 / 07 / 24	151.4	-	-	
30	1993 / 06 / 21	150.2	-	-	
31	1985 / 05 / 02	147.7	-	-	
32	1991 / 07 / 13	145.1	115.2	31.4	9
33	1988 / 07 / 18	144.0	144.1	40.4	10

Note: Above data were selected from the Pattimura Ambon data over 32 years [1959-1996].

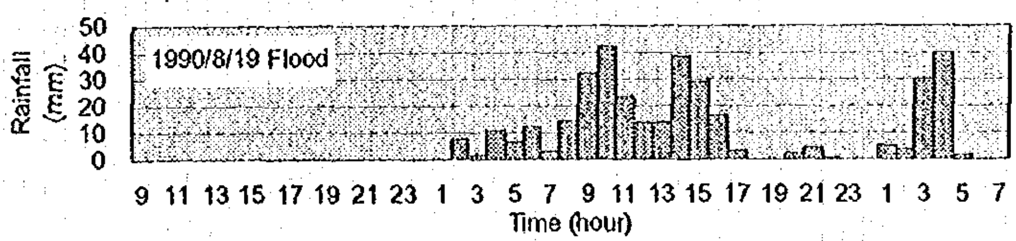


Figure-I.2.2 Hyetograph of Main Flood Rainfall in Ambon

2.2 Flood Runoff Analysis

2.2.1 Design Rainfall

(1) Flood Hyetograph

The top five flood rainfalls with daily and hourly data were selected as candidates for design rainfall, namely 1986/06/18, 1988/07/19, 1990/06/06, 1990/08/19 and 1996/08/22 flood. However, of these rainfall events, the big rainfalls that caused severe flood damage on 1984/06/22 and 1989/06/21, and another flood on 1988/08/28 are not included because there are no hourly rainfall data available. The hyetographs of the design rainfall candidates are presented in Figure-I.2.3.

(2) Probable Rainfall Depth and Enlarging Ratio

A period of one day is employed as the duration of design rainfall based on the following reasons :

- According to the hyetograph of the main rainfalls, the period of dominant rainfall leading to peak discharge is judged to be within 1 day.
- The basin catchment areas of five target rivers are relatively small with variation from 5 km^2 to 17 km^2 and freshet and depletion of flood water seem to be fast.

After the amount and duration of design rainfalls are given, the remaining two factors of time and aerial distributions shall be determined to form the design rainfall. In this report the time distributions are formed by enlarging or contracting several rainfall patterns, as they are, which occurred in the past, and such time distributions are adopted. Aerial distribution is not taken into account since the basin areas are small and only one location rainfall data is available. Enlarging ratios to design rainfall depth for the selected five rainfall are calculated by each rainfall and are shown in Table-I.2.5.

Table-I.2.5 Enlarging Ratio to Design Rainfall Depth

Flood Name	Actual Rainfall	Item	Return Period								
			2	5	10	20	30	50	70	100	200
Hourly Probable Rainfall (mm)			45	61	71	81	86	93	98	103	112
Daily Probable Rainfall (mm)			172	260	322	385	422	470	502	537	607
1984/06/18	194.2	Ratio	0.886	1.339	1.658	1.982	2.173	2.420	2.585	2.765	3.126
	26.6	MHR	23.6	35.6	44.1	52.7	57.8	64.4	68.8	73.6	83.1
1988/07/19	176.6	Ratio	0.974	1.472	1.823	2.180	2.390	2.661	2.843	3.041	3.437
	49.3	MHR	48.0	72.6	89.9	107.5	117.8	131.2	140.1	149.9	169.5
1990/06/06	214.2	Ratio	0.803	1.214	1.503	1.797	1.970	2.194	2.344	2.507	2.834
	43.7	MHR	35.1	53.0	65.7	78.5	86.1	95.9	102.4	109.6	123.8
1990/08/19	315.3	Ratio	0.546	0.825	1.021	1.221	1.338	1.491	1.592	1.703	1.925
	42.1	MHR	23.0	34.7	43.0	51.4	56.3	62.8	67.0	71.7	81.0
1996/08/22	230.3	Ratio	0.747	1.129	1.398	1.672	1.832	2.041	2.180	2.332	2.636
	28.0	MHR	20.9	31.6	39.1	46.8	51.3	57.1	61.0	65.3	73.8

Note:

Actual Rainfall : - Upper Column : Actual Daily Rainfall (mm/day)
- Lower Column : Actual Maximum Hourly Rainfall (mm/hour)

Item : - Ratio : Enlarging Ratio to Design Rainfall Depth
- MHR: : Maximum Hourly Rainfall Depth after Enlarging

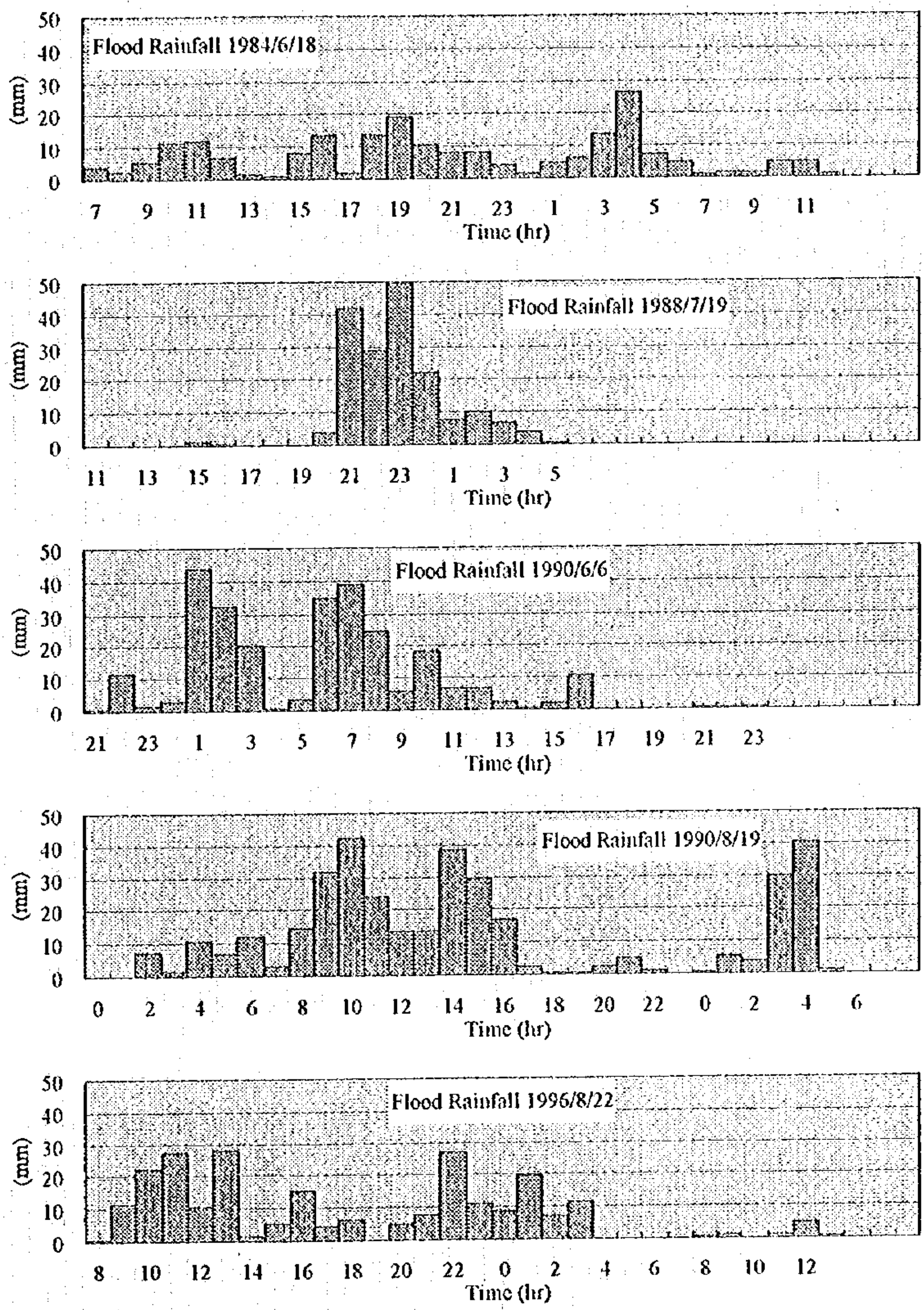


Figure-I.2.3 Actual Hyetograph of Selected Five Rainfalls

2.2.2 Flood Runoff Modeling

(1) Flood Runoff Model Used in the Study

In the Study *Storage Function Method* is employed for flood runoff analysis and the validity of the results - river discharges - are checked by *Rational Formula*.

Storage Function Method

In order to express the nonlinear characteristic of run-off phenomena, the storage function method can give the process of transformation from rainfall to run-off on the assumption that there is a one-to-one functional relation between the volume of storage and run-off. Calculations of the run-off from rainfall are carried out by using the volume of storage as medium function. By this method, a relationship can be established between the volume of storage (S) of a basin or river course and the discharge (Q) from it. This relationship is expressed as

$Sl = k \cdot Ql^{p}$ (k, p : Constants)

This equation is used then as a substitution for the solution of equation of motion. It indicates that run-off is proportional to the exponent of the volume of storage. This is equivalent to the consideration that the phenomena of rainfall and run-off are similar to the run-off from a notch in a container filled up with water.

Run-off calculations are performed by combining this equation of motion with the following equation of continuity:

$$\frac{dSl}{dt} = \frac{1}{3.6} f \cdot r_{ave} \cdot A - Ql$$

where, f : Inflow coefficient

r_{ave} : Average rainfall in a watershed (mm/hr)

A : Area of basin (km^2)

$Ql(t) = Q(t + Tl)$: Volume of run-off from the basin under the consideration of lag time (excluding base flow) (m^3/sec)

Sl : Apparent volume of storage in basin (m^3/sec·hr)

Tl : Lag time (hour)

The equation of continuity for the section of river course is given by

$$\frac{dS_1}{dt} = \sum_{j=1}^{n} f_j \cdot j_j - Q - Ql$$

where, I_j : Inflow from a basin, tributary or the upstream end of a river course to the river course being considered (m^3/sec)

f_j : Inflow coefficient

$Ql(t) = Q(t + Tl)$: Discharge at the downstream end of basin under the consideration of lag time (m^3/sec)

Sl : Apparent volume of storage of river course (m^3/sec·hr)

Tl : Lag time (hour)

Rational Formula

Maximum flood discharge is given by the following rational formula:

$$Q_p = \frac{1}{3.6} f \cdot R \cdot A$$

Where, Q_p : Maximum flood discharge (m³/sec)

f : Dimension-less runoff coefficient

R : Intensity of rainfall within the time of flood concentration (mm/hr)

T_p : Time of flood concentration

A : Catchment area (km²)

(2) River Basin Division

Each of the target river basins is divided into two or four sub-basins, taking into account the locations of staff gauges and main confluence. River basins division is drawn in Figure-I.2.4

(3) Establishment of Runoff Model

Based on the basin division, basin models for the five target rivers were established as shown in Figure-I.2.5.

Since flood discharge data of the five target rivers are not obtained, the overall storage function for river basin and river course is applied for the coefficient analysis. The coefficients of Storage Function is determined following empirical formula established in Japan and the results of the analysis are described in Table-I.2.6.

Empirical Formula Including Reserve Coefficient for River Basin

$$K = 43.4 \cdot C \cdot L1^{1/3} \cdot I1^{-1/3}$$

$$P = 1/3$$

$$Tl = 0.0470 \cdot L2 - 0.56 \qquad (L1 > 11.9km)$$

$$Tl = 0.0 \qquad (L1 \leq 11.9km)$$

Where,

C : Reserve Constant (Natural Basin : C=0.12, Urban Basin : C=0.012)

K, P : Coefficients of Storage Function

L1 : Length of main water course

I1 : Slope of main water course

Tl : Lag time (hour)

L2 : Length of water course from the farthest point in a catchment to the point

Empirical Formula (Tone River Runoff Analysis) for River Course

$$Sl = 1.67 \cdot Ks \cdot Ol^{0.6} - Tl \cdot Ol$$

$$K = 1.67 \cdot Ks = 0.185 \cdot L1 \cdot b^{0.4} \cdot I1^{-0.3} \cdot n^{0.6}$$

$$Tl = 0.00165 \cdot L1 \cdot I1^{-0.5}$$

Where,

Sl : Basin storage volume

Ol : Runoff volume

b : Mean river width (m)

n : Manning's roughness

Ks : Coefficient

Tl : Lag Time (hour)

Table-I.2.6 Basin Modeling

River	Basin Name	Catchment Area (km²)	Constant K	Constant P	River Course	River Length (m)	Constant K	Constant P
Ruhu	[1] Upper Basin	14.91	35	0.333	River A	2,270	1.2	0.6
	[2] Lower Basin	1.93	30	0.333	-	-	-	-
	Total	16.84	-	-	Total	2,270	-	-
Batu Merah	[1] Upper Basin	4.23	21	0.333	River A	2,240	0.6	0.6
	[2] Middle Basin	1.91	23	0.333	River B	1,270	0.6	0.6
	[3] Lower Basin	0.89	4	0.333	-	-	-	-
	Total	7.03	-	-	Total	3,510	-	-
Tomu	[1] Upper Basin	3.99	22	0.333	River A	1,960	0.8	0.6
	[2] Lower Basin	1.65	4	0.333	-	-	-	-
	Total	5.64	-	-	Total	1,960	-	-
Batu Gajah	[1] Upper Basin	4.92	23	0.333	River A	2,100	0.7	0.6
	[2] Lower Basin	1.05	4	0.333	-	-	-	-
	Total	5.97	-	-	Total	2,100	-	-
Batu Gantung	[1] Upper Basin1	5.89	21	0.333	River A	980	0.4	0.6
	[2] Lower Basin1	0.18	3	0.333	-	-	-	-
	[3] Upper Basin2	0.45	10	0.333	-	-	-	-
	[4] Lower Basin2	0.35	3	0.333	-	-	-	-
	Total	6.87	-	-	Total	980	-	-

Note. Lag time was disregarded because of very small value.

Table-I.2.7 shows the primary run-off rate, saturated run-off rate and saturation rainfall proposed by Kimura for all the rivers in Japan. Although these values are considerably scattered with flood even in the same basin, the values could be utilized in simplified runoff calculations for mountainous basins.

Table-I.2.7 f_1, f and R_{sa} for Rivers in Japan

Category \ Constant	Primary Runoff Rate f_1	Saturated runoff Rate f	Saturation Rainfall R_{sa} (mm)
Basin with non-Quaternary volcanic rocks	0.86 - 1.0	1.0	100 (0 - 200)
Basin with Quaternary volcanic rocks	0.65 (0.56 - 0.73)	1.0	300 (280 - 430)

As the geology of the target five river basins is mainly characterized by non-Quaternary volcanic rocks, the primary run-off rate, saturated runoff rate and saturation rainfall are adopted as follows:

- Primary Runoff Rate : 0.9
- Saturated Runoff Rate : 1.0
- Saturation Rainfall : 100 mm

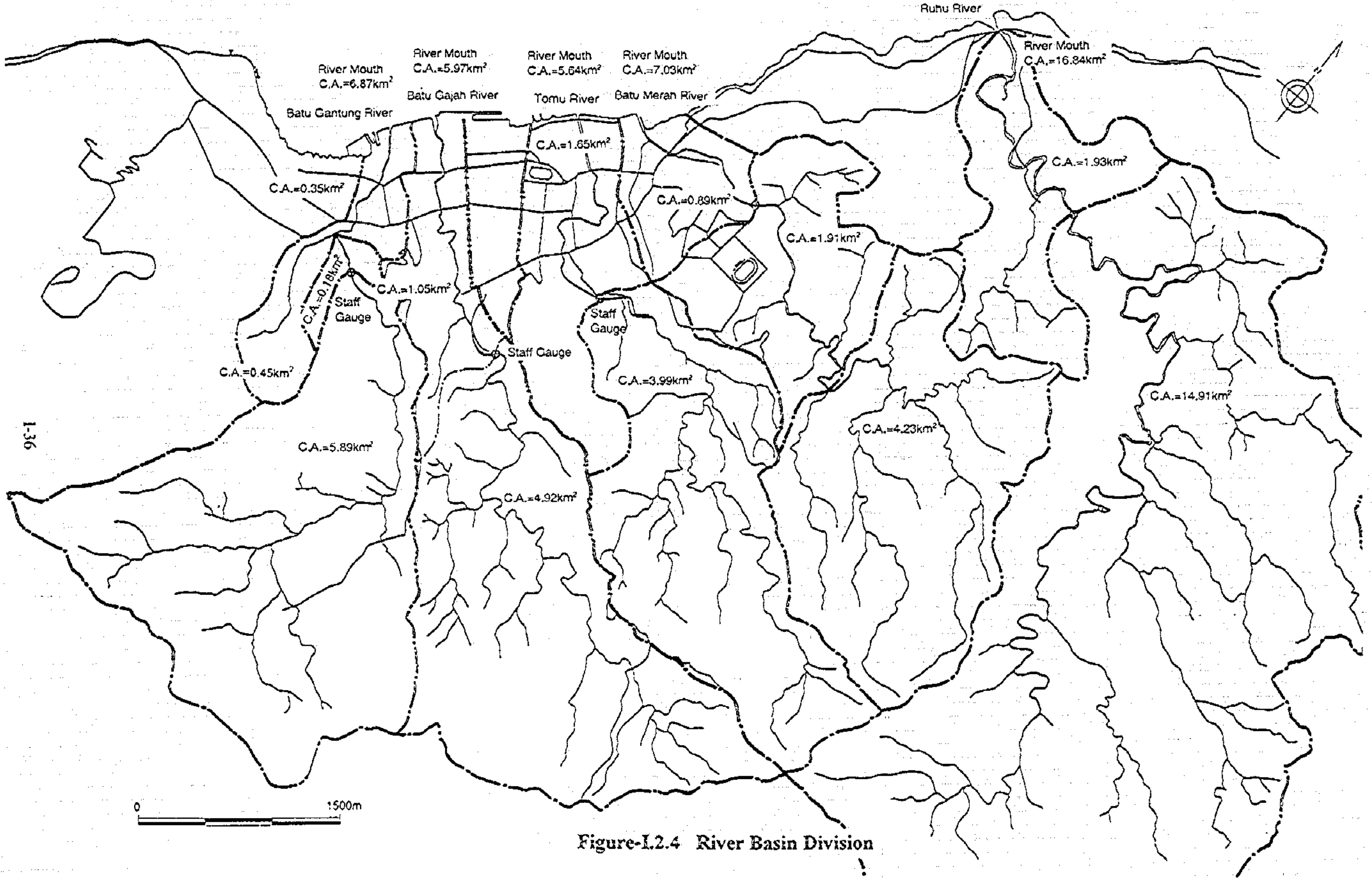


Figure-I.2.4 River Basin Division

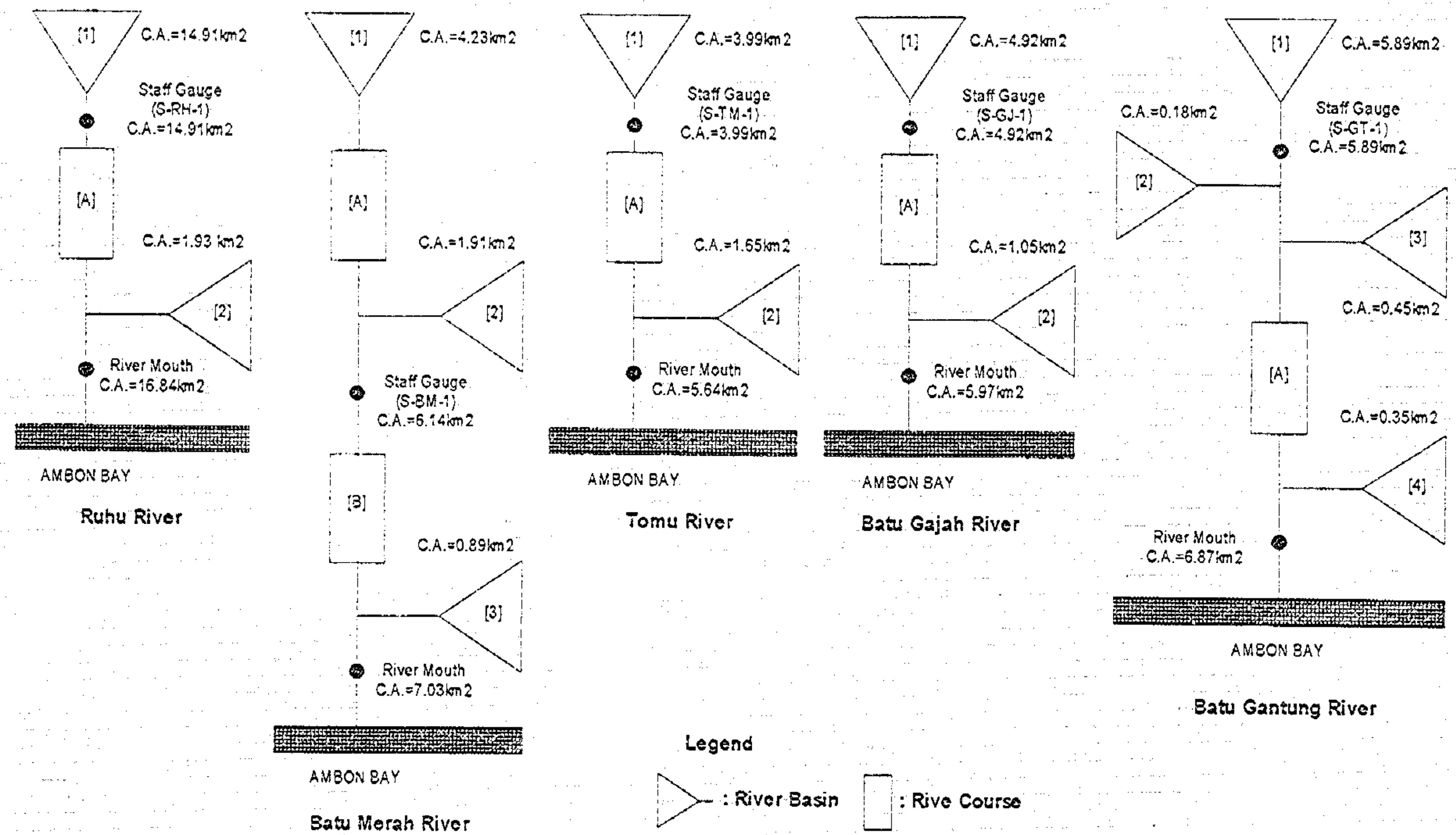


Figure-I.2.5 Basin Model

2.2.3 Flood Discharge

(1) Runoff Calculation

Using the runoff model established in the former section, flood discharge for each return period was calculated for five floods, namely, the floods of 1984/06/18, 1988/07/18, 1990/06/06, 1990/08/19 and 1996/08/22. Table-I.2.9 shows the calculated peak discharges. Figure-I.2.6 shows the different types of food hydrograph for Ruhu River with a 30-year return period.

(2) Peak Flood Discharge and Flood Hydrograph

Peak flood discharge for each return period is determined as shown in Table-I.2.8, employing 1990/06/06 flood with a "Cover Factor" of 80 %. The cover factor is defined as the degree how far the peak discharge of a selected hyetograph satisfies those of the hydrograph group. The following items have been taken in to consideration:

- The 1988/07/19 flood shows the maximum peak discharge. However the maximum hourly rainfalls after enlarging actual rainfall data is 1.4 to 1.9 times larger than probable hourly rainfalls. Then the 1988/07/19 flood hyetograph after enlarging is concluded to be too large as estimation of runoff.
- The peak discharges of 1984/06/18, 1990/08/19 and 1996/08/22 floods are nearly the same but smaller than the other.
- The second largest peak discharges is calculated with the 1990/06/06 flood. The maximum hourly rainfalls after enlarging actual rainfall data is within 0.8-1.1 times of probable hourly rainfalls of various return period.

The hydrograph of each river at river mouth with 5, 10, 30, 50-year return period is presented in Figure-I.2.7.

Table-I.2.8 Design Peak Discharge (Design Flood : 1990/06/06)

River	Reference Point	C.A. (km^2)	Item	Design Peak Discharge (m^3/sec) by Design Scale								
				2	5	10	20	30	50	70	100	200
Ruhu	S-RH-1	14.49	Q	79	150	200	251	281	319	345	373	429
			Specific-Q	5.5	10.4	13.8	17.3	19.4	22.0	23.8	25.7	29.6
	River Mouth	16.84	Q	90	168	223	280	314	358	387	418	482
			Specific-Q	5.3	10.0	13.2	16.6	18.6	21.3	23.0	24.8	28.6
Batu Merah	S-BM-1	6.14	Q	42	73	94	115	127	143	153	164	186
			Specific-Q	6.8	11.9	15.3	18.7	20.7	23.3	24.9	26.7	30.3
	River Mouth	7.03	Q	49	84	108	132	145	163	175	188	213
			Specific-Q	7.0	11.9	15.4	18.8	20.6	23.2	24.9	26.7	30.3
Tomu	S-TM-1	3.99	Q	28	48	61	75	83	93	99	107	121
			Specific-Q	7.0	12.0	15.3	18.8	20.8	23.3	24.8	26.8	30.3
	River Mouth	5.64	Q	41	69	87	106	117	131	141	151	172
			Specific-Q	7.3	12.2	15.4	18.8	20.7	23.2	25.0	26.8	30.5
Batu Gajah	S-GJ-1	4.92	Q	33	58	75	92	101	114	122	131	149
			Specific-Q	6.7	11.8	15.2	18.7	20.5	23.2	24.8	26.6	30.3
	River Mouth	5.97	Q	42	71	91	111	123	138	148	159	181
			Specific-Q	7.1	12.1	15.4	18.8	20.7	23.1	25.0	26.8	30.4
Batu Gantung	S-GT-1	5.89	Q	42	72	91	111	123	137	147	158	179
			Specific-Q	7.1	12.2	15.4	18.8	20.9	23.3	25.0	26.8	30.4
	River Mouth	6.87	Q	50	84	107	130	143	160	172	184	209
			Specific-Q	7.3	12.2	15.6	18.9	20.8	23.3	25.0	26.8	30.4

Note : Q : Discharge (m^3/sec)   Specific-Q : Specific Discharge ($m^3/sec/km^2$)

Table-I.2.9 Peak Discharge

River	Flood	Item	Peak Discharge (m^3/sec)								
			2	5	10	20	30	50	70	100	200
Ruhu	1984/6/18	S-RH-1	48	88	118	150	170	196	214	234	275
		R.Mouth	52	96	128	164	186	216	236	258	304
	1988/7/19	S-RH-1	91	202	288	377	428	492	534	579	667
		R.Mouth	103	223	320	420	478	551	599	650	750
	1990/6/6	S-RH-1	79	150	200	251	281	319	345	373	429
		R.Mouth	90	168	223	280	314	358	387	418	482
	1990/8/19	S-RH-1	51	92	119	147	162	185	206	229	275
		R.Mouth	58	103	135	166	183	206	229	254	307
	1996/8/22	S-RH-1	39	67	93	126	146	173	191	210	249
		R.Mouth	43	74	101	138	161	191	211	233	277
Batu Merah	1984/6/18	S-BM-1	25	45	60	76	85	97	105	114	132
		R.Mouth	30	53	69	87	98	111	120	131	151
	1988/7/19	S-BM-1	62	110	144	177	196	220	236	253	287
		R.Mouth	72	126	165	203	224	251	270	289	328
	1990/6/6	S-BM-1	42	73	94	115	127	143	153	164	186
		R.Mouth	49	84	108	132	145	163	175	188	213
	1990/8/19	S-BM-1	25	42	57	74	84	97	105	114	132
		R.Mouth	29	49	67	85	96	111	121	131	151
	1996/8/22	S-BM-1	21	38	51	66	74	85	83	101	116
		R.Mouth	24	45	60	76	85	98	106	115	133
Tomu	1984/6/18	S-TM-1	17	30	40	50	56	64	69	75	86
		R.Mouth	26	45	58	72	80	91	99	107	122
	1988/7/18	S-TM-1	40	72	94	115	128	143	153	164	186
		R.Mouth	61	103	134	164	181	202	217	232	264
	1990/6/6	S-TM-1	28	48	61	75	83	93	99	107	121
		R.Mouth	41	69	87	106	117	131	141	151	172
	1990/8/19	S-TM-1	16	28	38	48	55	63	69	75	86
		R.Mouth	24	41	56	70	79	91	98	106	122
	1996/8/22	S-TM-1	14	25	34	43	49	56	61	66	76
		R.Mouth	21	38	50	63	71	81	87	94	108
Batu Gajah	1984/6/18	S-GJ-1	20	36	48	60	68	77	84	91	105
		R.Mouth	26	45	59	74	83	94	102	110	127
	1988/7/18	S-GJ-1	49	87	115	141	157	176	188	202	229
		R.Mouth	61	107	140	172	190	213	229	245	278
	1990/6/6	S-GJ-1	33	58	75	92	101	114	122	131	149
		R.Mouth	42	71	91	111	123	138	148	159	181
	1990/8/19	S-GJ-1	20	33	45	58	66	77	84	91	105
		R.Mouth	24	41	57	72	81	94	102	111	128
	1996/8/22	S-GJ-1	16	31	41	52	59	68	74	80	93
		R.Mouth	21	38	51	65	73	83	90	98	113
Batu Gantung	1984/6/18	S-GT-1	24	45	60	75	84	95	103	111	128
		R.Mouth	31	54	71	88	98	112	121	130	150
	1988/7/18	S-GT-1	61	107	140	171	189	212	227	243	276
		R.Mouth	73	126	164	200	221	247	265	284	322
	1990/6/6	S-GT-1	42	72	91	111	123	137	147	158	179
		R.Mouth	50	84	107	130	143	160	172	184	209
	1990/8/19	S-GT-1	24	42	57	72	82	94	102	111	128
		R.Mouth	28	50	67	85	96	111	120	130	150
	1996/8/22	S-GT-1	21	38	51	65	73	84	91	98	113
		R.Mouth	26	46	60	76	86	98	106	115	132

Note S-RH-1 : Staff Gauge at Ruhu River S-BM-1 : Staff Gauge at Batu Merah River
S-TM-1 : Staff Gauge at Tomu River S-GJ-1 : Staff Gauge at Batu Gajah River
S-GT-1 : Staff Gauge at Batu Gantung River R.Mouth : River Mouth

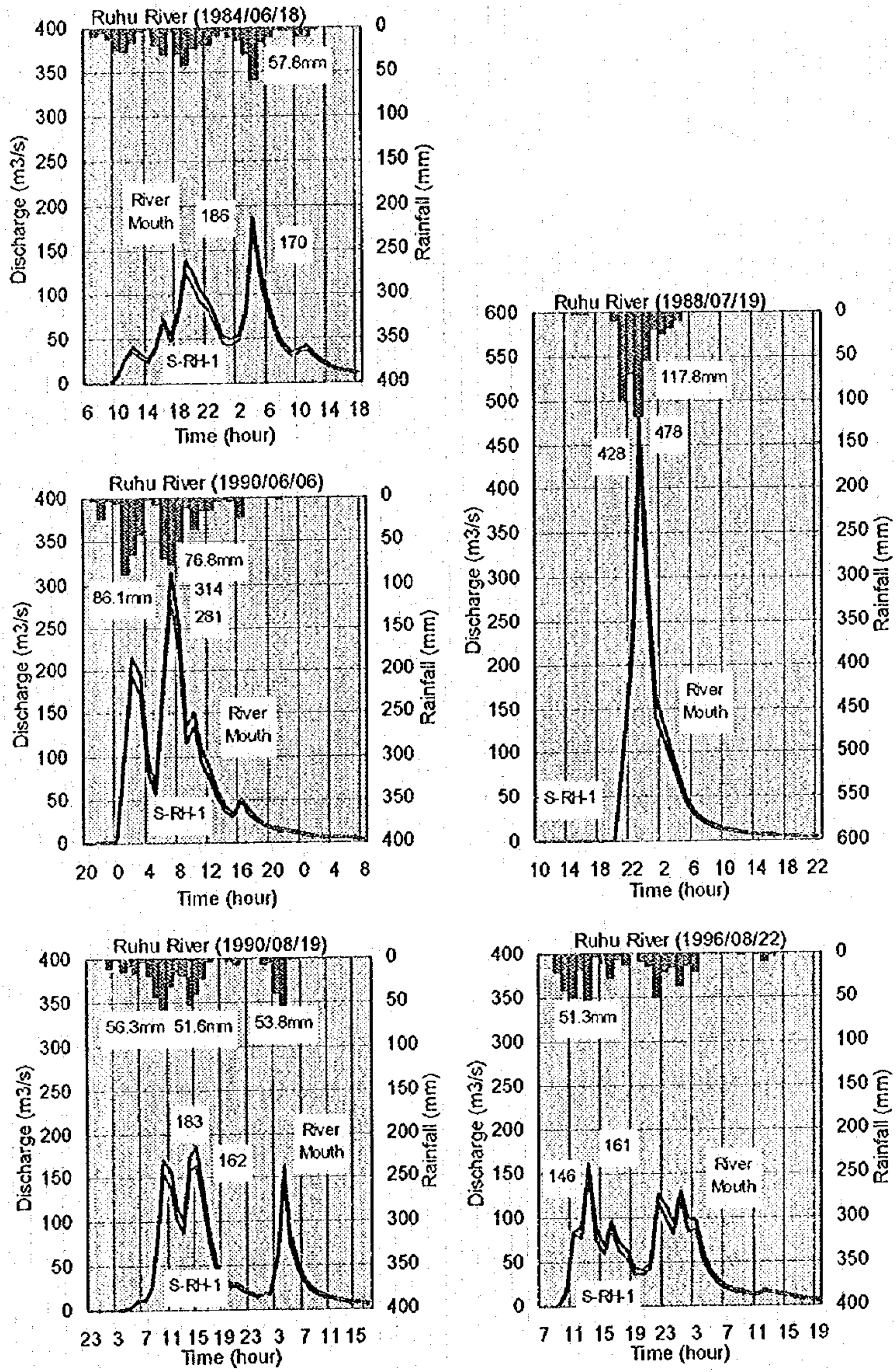


Figure-I.2.6 Flood Hydrograph of Ruhu River (Return Period 30 year)

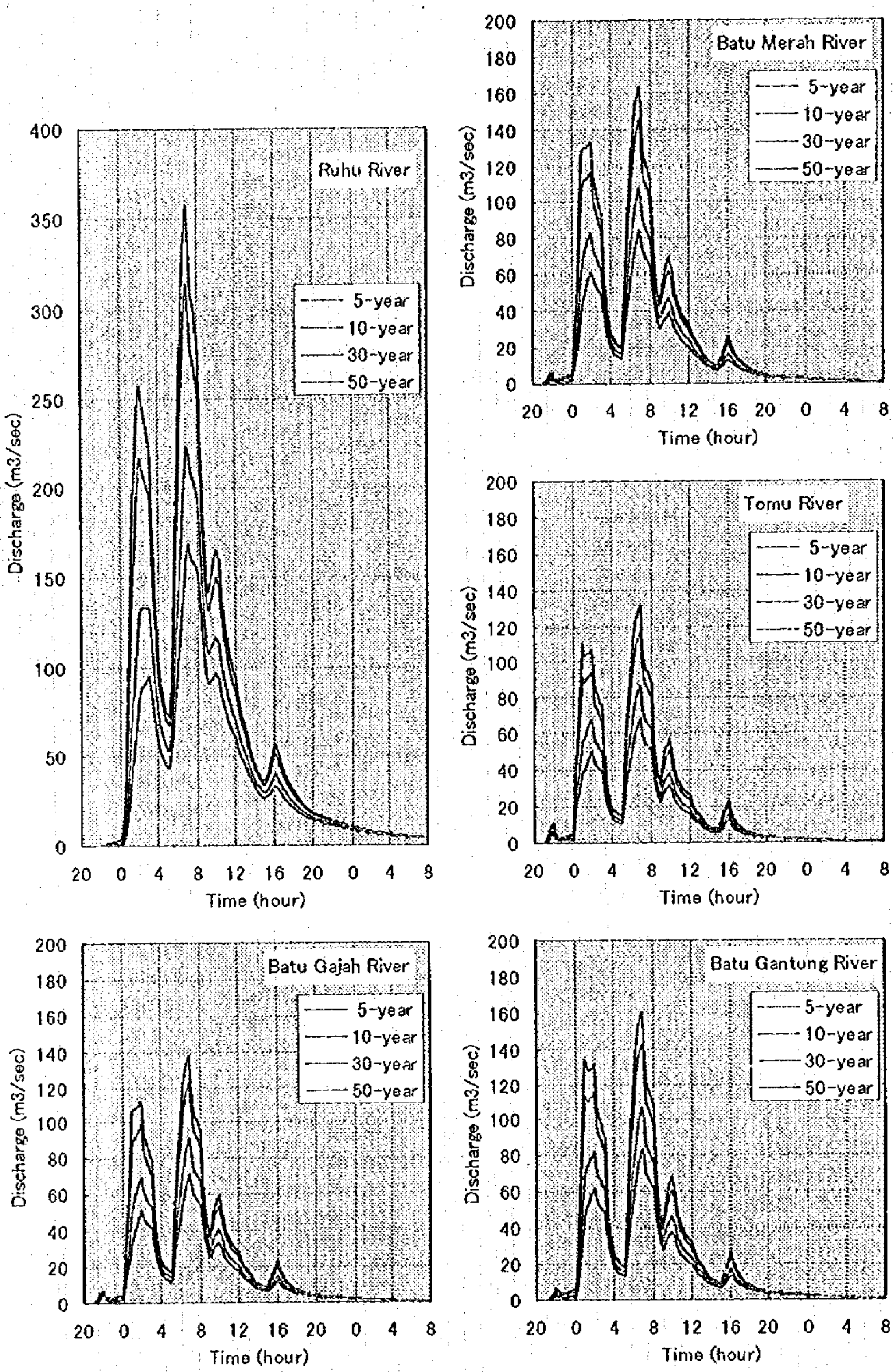


Figure-I.2.7 Design Flood Hydrograph (1990/06/06 Flood Type)

2.3 Flood Damage Analysis

2.3.1 Discharge Capacity of River Channels

Longitudinal and cross sectional river surveys for the five target rivers were carried out during this Study. The results of these surveys were used to assess the current discharge capacity of the rivers. This cross section data was compiled and the non-uniform flow calculation method was used to obtain stage discharge (H / Q) curves for every cross section over a range of flows up to a maximum of 250 m^3/sec (400 m^3/sec for Ruhu river). Manning's Roughness was assumed to be 0.025. The discharge capacity at each section was then estimated by comparing the left and right bank heights to the calculated stage discharge curves.

In addition, the discharge capacity was also calculated for the case when freeboard is considered - a value of 0.6 m was used in accordance with the "Manual for River Works in Japan" for design flood discharge of less than 200 m^3/sec. The calculation was repeated using the uniform flow method for both the 'No Freeboard' and '0.6m Freeboard' cases to provide a comparison and to identify any potential bottlenecks which might restrict river discharge capacity.

Based on this analysis, the discharge capacity of each river calculated by both methods is summarized in Table-I.2.10. The summary table gives the average and extreme values of minimum discharge capacity. Figure-I.2.8. shows the variation calculated discharge capacity at each cross section of the five target rivers in Ambon, in case of 'Non-uniform Flow' and '0.6m Freeboard' and

Table-I.2.10 Summary Result of Discharge Capacity

	Capacity (m^3/sec) - Non Uniform Flow				Capacity (m^3/sec) - Uniform Flow			
	No Freeboard		0.6m Freeboard		No Freeboard		0.6m Freeboard	
River Name	Average	Extreme	Average	Extreme	Average	Extreme	Average	Extreme
Ruhu River	60 - 80	50	40 -50	34	60 -80	44	40 - 60	30
Batu Merah River	30 - 40	24	20 - 30	15	20 - 30	17	15 - 25	9
Tomu River	40 - 50	22	20 - 30	10	40 - 50	21	20 - 30	8
Batu Gajah River	30 - 50	23	20 - 40	11	40 - 60	24	20 - 40	10
Batu Gantung River	40 - 60	36	20 - 40	20	50 -70	38	30 - 50	22

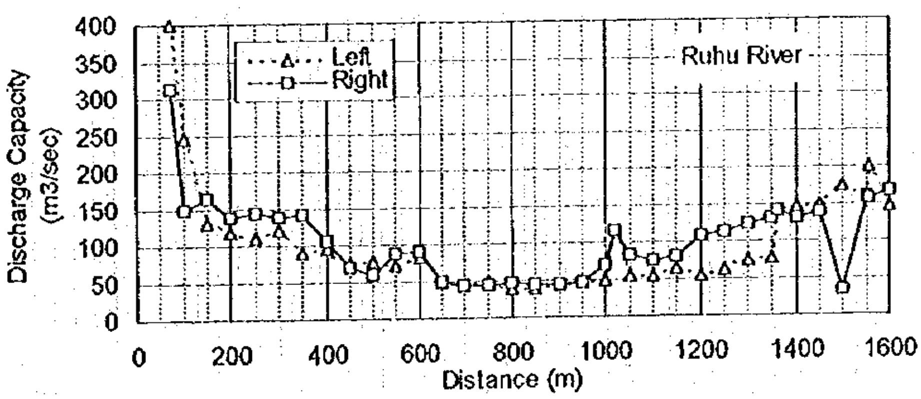


Figure-I.2.8(1) Discharge Capacity

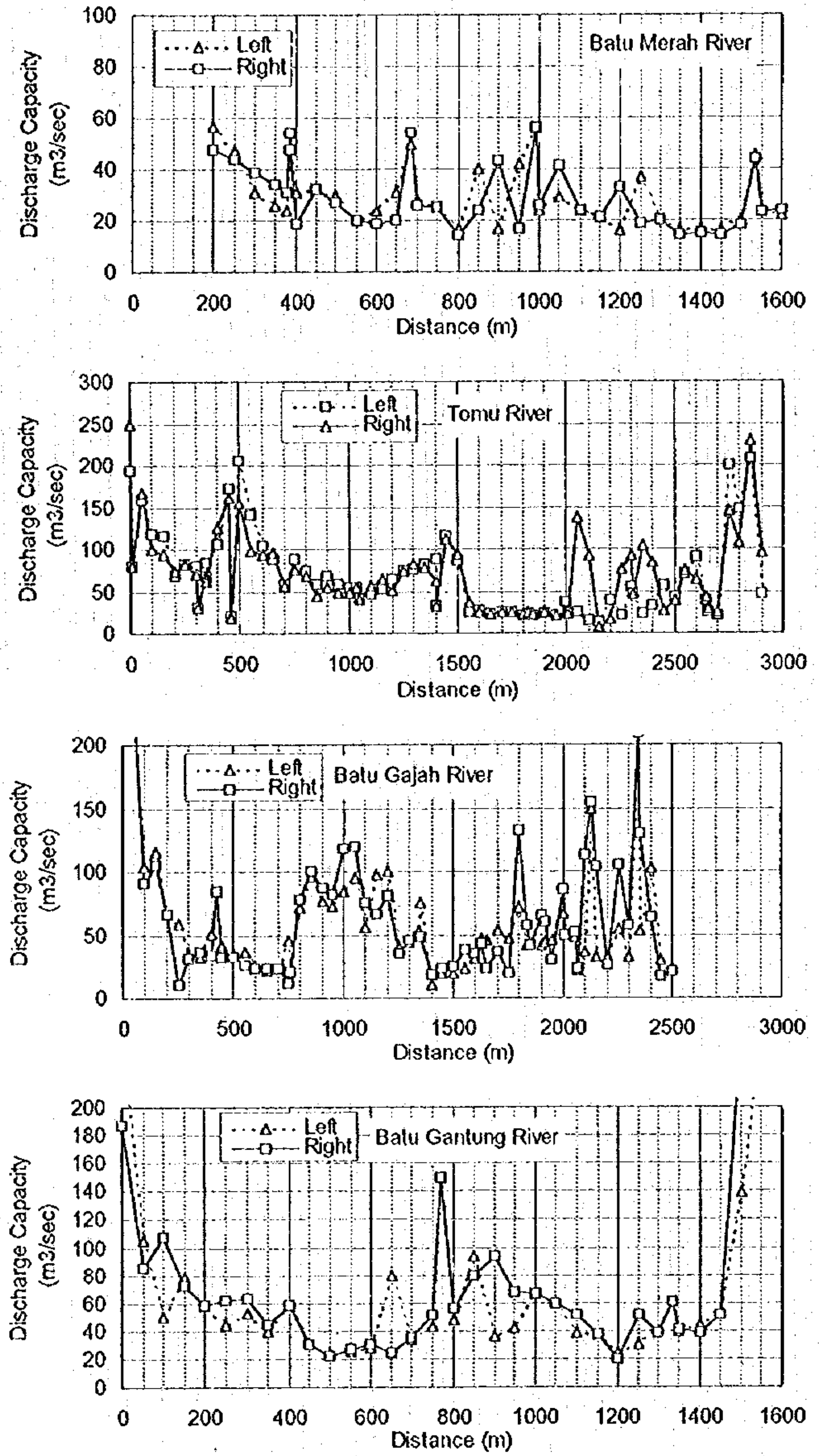


Figure-1.2.8(2) Discharge Capacity

2.3.2 Estimation of Flood Damage

(1) Methodology

It is necessary to estimate future flood damages in the "without project" case, in order to quantify the benefits of the "with project" case. There are two approaches, a combination of which is also possible for this analysis:

1) Examine the damage caused by past major floods, such as those which occurred in 1984, 1989, 1996 and annual flood, approximate their monetary value and estimate future damages.
2) Specify a potential flood area and its flood water level by examining the river discharge capacity and contours and apply a standard damage rate.

Both approaches have their own drawbacks. In the case of 1), most of the damage data for past floods have been lost and thus it is difficult to approximate the monetary value of the floods. With regard to 2), the flood pattern does not always coincide with land contours and there is no standard damage rate available in Indonesia. Since these two approaches can supplement each other, a combination of the two approaches was used for this study.

In this study, the flood damage analysis was carried out in the following manner:

1) Areas flooded and water levels for the past three major floods and annual floods were established through interviews and contour analysis
2) Damages from the above floods were estimated;
3) A "flood discharge - damage value" curve was drawn based on the results of above 2);
4) Yearly average of damage alleviation (yearly benefits of the project) was derived from probabilities of several water amount cases.

(2) Damage to General Assets (houses/buildings, household goods and industry inventories)

Several records on the total amount of damage to houses and buildings and the location of the inundated areas were found for the floods of 1984 and 1989. The damage was estimated by PU staff, who visited damaged houses and estimated the damage based on standard construction / material cost data collected by PU itself. However, since the breakdown of the data was lost, the accuracy of the data could not be confirmed. The damage to houses and buildings had to be re-estimated through interviews with residents and owners of businesses.

The exact damage to houses and buildings was, however, difficult to estimate, since peoples' memories of the floods had already faded, and in any case, flood damage to the structure of houses does not show immediately. After comparing the damage situation as ascertained from interviews with the standard damage rate used in Japan, the study team judged that it would be reasonable to apply the Japanese damage rate which is based on past experience in Japan. Table-I.2.11 shows the standard asset damage rate applicable in Japan.

Table-I.2.11 Standard Asset Damage Rate in Japan

Height of water above the floor		under 50 cm	50 cm to 99 cm	100 cm to 199 cm	200 cm to 299 cm	more than 300 cm	Remarks
Houses		12.4%	21.0%	30.8%	43.9%	57.2%	Group C
Household Articles		8.6%	19.1%	33.1%	49.9%	69.0%	
Office and Factory	Depreciable Assets	18.0%	31.4%	41.9%	53.9%	63.2%	
	Stock Assets	12.7%	27.6%	37.9%	47.9%	56.2%	

Source : Manual for River Works in Japan, Survey

Note :

- Floor height in Indonesia is usually very low and is set as 0 cm in this Study.
- Houses are grouped into A, B and C on the basis of ground gradient. Group C is categorized into the gradient of 1/500 and over.

The study team estimated the value of each type of general asset in all the flooded areas through a field investigation and made a zoning map based on this information. In addition, the data on the height of flood water was obtained through the interviews for the flood damage survey with around 200 residents in the study area.

Table-I.2.12 Value of General Assets

Code	Land Use Category	Value per Building (Rp million)	Value of Household Goods (Rp million)	Value of Depreciable / Stock Assets (Rp million)
A	Residential Area (Grade A)	14 (20)	4 (5)	-
B	Residential Area (Grade B)	8 (10)	2 (2.5)	-
C	Residential Area (Grade C)	4	1	-
D	Mix (Res. 90%+Home Ind. 10%)	8	2	6
E	Commercial Area (Grade A)	80	-	40
F	Commercial Area (Grade B)	40	-	30
G	Commercial Area (Grade C)	20	-	20
H	Large Industry Area	100	-	100
I	Medium Industry Area (Grade A)	50	-	50
J	Medium Industry Area (Grade B)	20	-	20
K	Public Facilities	70	20	-

(3) Damage to Infrastructure

Very limited data on the damage to infrastructure were obtained from organizations responsible for the construction and maintenance of infrastructure. Significant damage to roads and bridges was recorded outside the Central City, but damage within the Central City was not visible because the construction standard of roads and bridges is much higher there than outside the Central City. To estimate the damage to infrastructure that does not always appear immediately, the study team applied the Japanese standard damage rate. When the damage to assets is 100, the damage to roads and bridges can be estimated at 28.2, at 3.1 for telecommunications and at 2.3 for the electricity, totaling 33.4.

(4) Damage from Disruption of Businesses

It takes several days until normal commercial activities can resume after the occurrence of floods because:

1) people whose houses were damaged cannot go to work immediately since they have to repair and/or clean them; and/or
2) offices cannot function until they are cleaned/repaired.

With regard to 1), interviews with residents showed how many days it took them to clean/repair their houses. On average, 1.5 days were needed when the water level was less than 50cm, 2.5days when it was 50 to 99cm, and 3.5days when it was 100cm to 199cm, 4.5days when 200 to 299cm, and 5.5days when more than 300cm. The study team estimated the loss of GDP from 1) using the regional per capita GDP of Ambon City, Rp 3.0 million per year at 1996 prices. The loss of GDP for 2) may be estimated from sales data, but since there are no reliable sales data available in Ambon City, the study team applied the same proportion of GDP loss and damage to office buildings as that obtained in 1).

(5) Estimation of Past Flood Damage

The damage from the three past major floods and the annual flood are estimated and are shown in Table-I.2.13.

Table-I.2.13 Estimation of Past Flood Damage Unit : Rp. million

Flood	Item	Ruhu	Batu Merah	Tomu	Batu Gajah	Batu Gantung	Total
1984/06/22	No. of Houses	1,030	953	607	1,492	600	4,682
	Total General Assets	15,804	11,526	10,825	29,148	8,364	75,667
	General Assets Damage	2,711	2,407	2,251	5,607	1,674	14,650
	Infrastructure Damage	906	804	752	1,873	559	4,893
	Disruption of Businesses	268	349	180	598	217	1,612
	Total Damage	3,885	3,560	3,182	8,077	2,450	21,154
1989/06/22	No. of Houses	809	1,170	916	1,459	447	4,801
	Total General Assets	12,814	16,586	17,883	32,330	5,663	85,276
	General Assets Damage	2,387	3,897	3,667	6,443	964	17,358
	Infrastructure Damage	797	1,301	1,225	2,152	322	5,798
	Disruption of Businesses	313	483	348	886	124	2,154
	Total Damage	3,497	5,681	5,240	9,481	1,411	25,310
1996/08/22	No. of Houses	341	948	322	439	424	2474
	Total General Assets	5,488	11,344	5,028	6,298	5,448	33,605
	General Assets Damage	810	1,868	570	952	770	4,970
	Infrastructure Damage	271	624	190	318	257	1,660
	Disruption of Businesses	94	256	54	93	98	596
	Total Damage	1,175	2,748	815	1,364	1,125	7,226
Annual	No. of Houses	191	666	347	331	277	1812
	Total General Assets	2,208	9,640	4,603	5,250	2,490	23,651
	General Assets Damage	274	1,365	482	749	410	3,280
	Infrastructure Damage	92	456	161	250	137	1,095
	Disruption of Businesses	19	215	28	79	50	391
	Total Damage	384	2,036	671	1,079	596	4,766

Source : JICA Study Team

(6) Estimation of Assumed Flood Damage

Flood damage at probable discharge with 30-year and 100-year return period were estimated. In this case, assuming that all the flood discharge flows inside the river course, the river water level, namely flood water level, is calculated by using non-uniform flow calculation .Referring to the estimated flood water level, local topography of flooded area, the past flooded area and water depth, the flooded area and water depth with 30-year and 100-year return periods were studied. The flooded area and depth with 100-return period is presented in Figure-I.2.10.

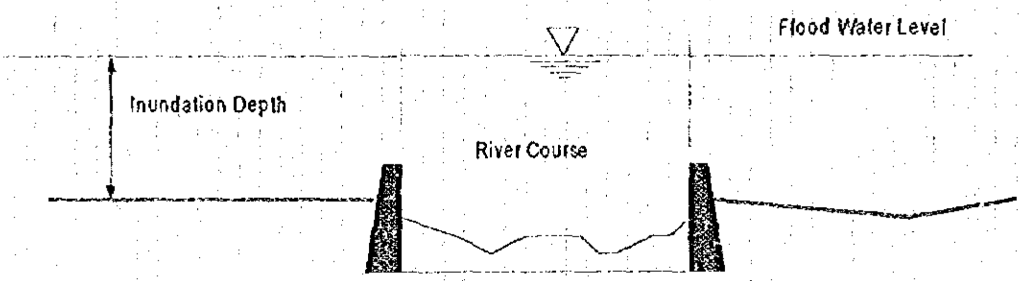


Figure-I.2.9 Assumption of Calculation of Flood Water Level

Table-I.2.14 Peak Discharge (m^3/sec)

Probability	Location	Ruhu	Batu Merah	Tomu	Batu Gajah	Batu Gantung
1/30	Staff Gauge	281	127	83	101	123
	River Mouth	314	145	117	137	143
1/50	Staff Gauge	319	143	93	114	137
	River Mouth	358	163	131	153	160
1/100	Staff Gauge	373	164	107	131	158
	River Mouth	418	188	151	177	184

Applying the same method of the past flood damage estimation, the flood damage with 30-year and 100-year return period were estimated and are shown in Table-I.2.15.

Table-I.2.15 Estimation of Flood Damage with 30-year and 100-year Return Period

Unit : Rp. million

Flood	Item	Ruhu	Batu Merah	Tomu	Batu Gajah	Batu Gantung	Total
Flood with 30-year Return Period	No. of Houses	1,557	2,993	2,664	2,382	1,608	11,124
	Total General Assets	23,672	71,269	52,903	78,180	23,090	249,114
	General Assets Damage	7,809	21,423	18,787	26,122	6,211	80,354
	Infrastructure Damage	2,608	7,155	6,275	8,725	2,075	26,838
	Disruption of Businesses	851	3,706	1,970	5,917	691	13,136
	Total Damage	11,269	32,285	27,033	40,764	8,977	120,328
Flood with 100-year Return Period	No. of Houses	1,731	3,521	3,220	2,692	1,945	13,109
	Total General Assets	26,291	89,701	64,610	93,780	28,101	302,483
	General Assets Damage	9,040	26,992	23,385	31,514	7,500	98,432
	Infrastructure Damage	3,019	9,015	7,811	10,526	2,505	32,876
	Disruption of Businesses	982	4,725	2,470	7,364	831	16,372
	Total Damage	13,042	40,732	33,666	49,403	10,836	147,680

Source : JICA Study Team

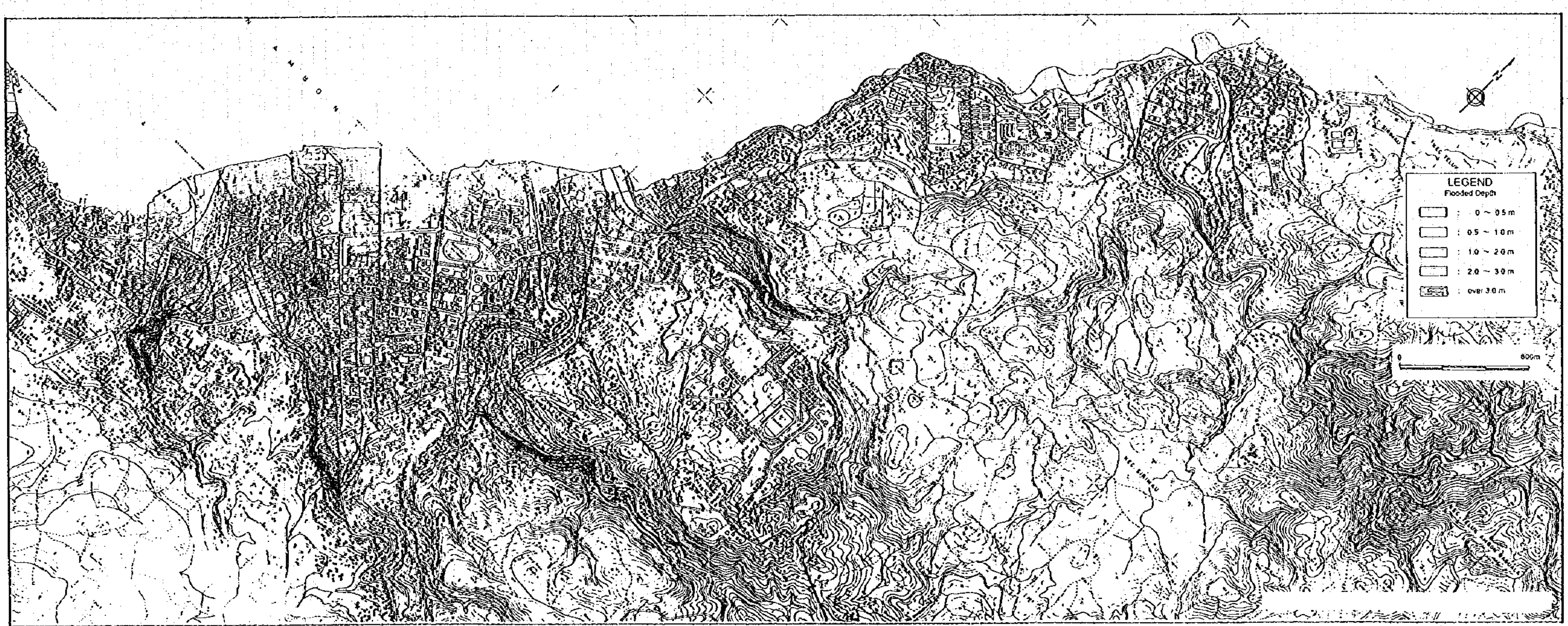


Figure-I.2.10 Estimated Flooded Depth and Area with 100-year Return Period

2.3.3 Flood Discharge - Damage Curve

(1) Probability Estimation of the Past Flood Discharge

The flood discharges of 1984/06/22, 1989/06/22 and 1996/08/22 floods were approximately estimated at the most upstream of the flooded area. The estimation method is similar to that of the assumed flood damage and is described as follows:

1) Based on the interviews of flood damage survey, the flooded water depth is obtained at the upstream cross section of the flooded area.
2) Assuming that all of flood discharge flows inside of the river course, flood discharge is calculated by using non-uniform flow calculation based on river water level, namely flood water level.

The estimated discharges and probability of the past floods are shown in Table-I.2.16, which includes the estimation of flood occurrence probability based on the rainfall data. The flood occurrence probability should be the same for all river basins because the Study Area is small and the river basins are close to each other. Based on the estimation of flood discharges, flood occurrence probability of each flood is estimated below:

Flood	Probability
1984/06/22	about 1/10
1989/06/22	about 1/10
1996/08/22	about 1/3

In this Study, therefore, the probable discharges with above probability are adopted as the estimated flood discharge of each flood and are shown in Table-I.2.17.

Table-I.2.16 Preliminary Estimation of Past Flood Discharges

Item	Rivers	1984/06/22 Flood		1989/06/22 Flood		1996/08/22 Flood	
		Figure	Probability	Figure	Probability	Figure	Probability
Daily Rainfall (mm/day)		430.7	1/33	233.0	1/3.6	230.7	1/3.4
Hourly Rainfall (mm/hr)		-	-	(66.7)	(1/7.4)	28.0	under 1/2
Discharge (m^3/sec)	Ruhu at R.M.	178	1/6	211	1/9	159	1/5
	Batu Merah at S.G.	103	1/14	103	1/14	78	1/7
	Tomu at S.G.	57	1/8	75	1/20	39	1/3
	Batu Gajah at R.M.	102	1/10	102	1/10	42	under1/2
	Batu Gantung at R.M.	97	1/8	82	1/5	69	1/3

Notes R.M. : River Mouth, S.G. : Staff Gauge

Table-I.2.17 Estimation of Return Period and Discharge of Past Floods

Item	Rivers	Location	1984/06/22 Flood	1989/06/22 Flood	1996/08/22 Flood
Return Period (year)			10	10	3
Discharge (m^3/sec)	Ruhu	Staff Gauge	200	200	108
		River Mouth	223	223	123
	Batu Merah	Staff Gauge	94	94	56
		River Mouth	108	108	64
	Tomu	Staff Gauge	61	61	37
		River Mouth	87	87	54
	Batu Gajah	Staff Gauge	75	75	44
		River Mouth	102	102	62
	Batu Gantung	Staff Gauge	91	91	55
		River Mouth	107	107	66

(2) Flood Discharge - Damage Value Curve

Based on the above flood damage study, relationship between flood discharge and flood damage value is estimated, taking into account of the following :

- The flood discharge with no damage is assumed as the discharge capacity of each river.
- Damaged flood occurred 2-3 times a year in all five rivers.
- The flood of 1996/08/22 was estimated to be 3-year return period.
- The floods of 1984/06/22 and 1989/06/22 were estimated to be nearly the same scale and equivalent to the 10-year return period.
- Flood damage of 30-year and 100-year return period were estimated by the Study Team.

Therefore the Study Team employed the estimation method shown in Table-I.2.18 to the flood discharge - damage curves.

Table-I.2.18 Estimation Method

Return Period	Discharge	Damage
0.3-year *	Discharge capacity	No damage
0.4-year *	Annual flood discharge	Actual annual flood damage
3-year	Discharge with 3-year return period	Actual flood damage on 1996/08/22
10-year	Discharge with 3-year return period	Larger value of Actual flood damages on 1984/06/22 and 1989/06/22
30-year	Discharge with 30-year return period	Estimated flood damage with 100-year return period
100-year	Discharge with 100-year return period	Estimated flood damage with 100-year return period

Note. * Derived from the fact that damaged flood occurred 2-3 times a year in all five rivers

The relationship between flood discharge and damage value is shown in Table-I.2.19 and Figure-I.2.11 for each river.

Table-I.2.19 Relationship between Flood Discharge and Damage Value

Ruhu River			Batu Merah River			Tomu River		
Return Period	Discharge (m^3/sec)	Damage (Rp. Mil.)	Return Period	Discharge (m^3/sec)	Damage (Rp. Mil.)	Return Period	Discharge (m^3/sec)	Damage (Rp. Mil.)
0.3-year	50	0	0.3-year	20	0	0.3-year	30	0
0.4-year	70	384	0.4-year	35	2,036	0.4-year	35	671
3-year	123	1,175	3-year	64	2,748	3-year	54	815
10-year	223	3,885	10-year	108	5,681	10-year	87	5,240
30-year	314	11,269	30-year	145	32,285	30-year	117	27,033
100-year	418	13,042	100-year	188	40,732	100-year	151	33,666
Batu Gajah River			**Batu Gantung River**			**Total**		
Return Period	Discharge (m^3/sec)	Damage (Rp. Mil.)	Return Period	Discharge (m^3/sec)	Damage (Rp. Mil.)	Return Period	Discharge (m^3/sec)	Damage (Rp. Mil.)
0.3-year	30	0	0.3-year	30	0	0.3-year	-	0
0.4-year	40	1,079	0.4-year	45	596	0.4-year	-	4,766
3-year	62	1,364	3-year	66	1,125	3-year	-	7,226
10-year	102	9,481	10-year	107	2,450	10-year	-	26,737
30-year	137	40,764	30-year	143	8,977	30-year		120,328
100-year	177	49,403	100-year	184	10,836	100-year	-	147,680

Source : JICA Study Team

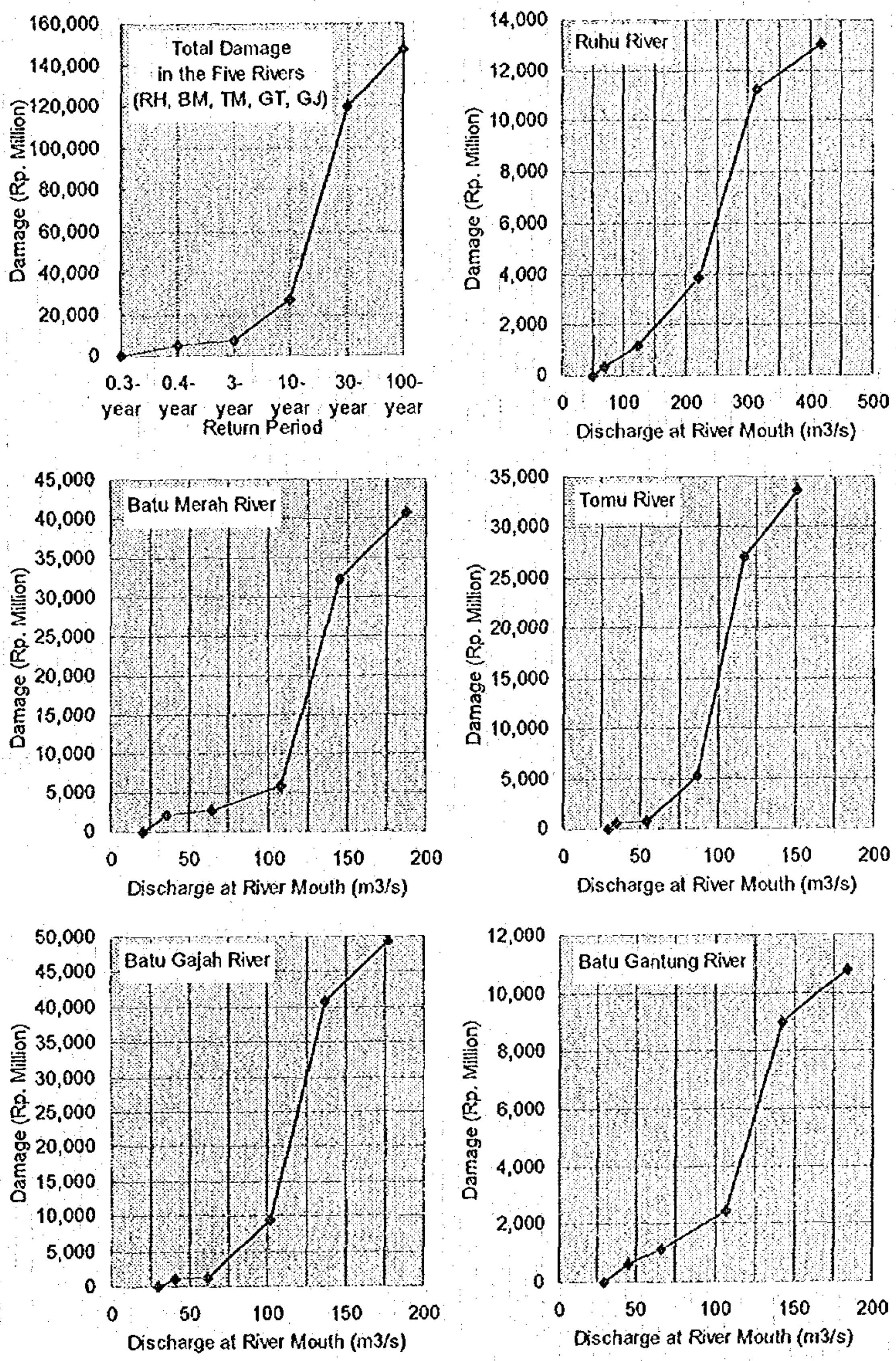


Figure-I.2.11 Flood Discharge / Flood Scale - Damage Value Curve

CHAPTER 3 FLOOD CONTROL MASTER PLAN

3.1 Basic Policy of Flood Control Plan

3.1.1 Principal Plan Conditions

(1) Targets of Flood Control Master 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. 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 a design scale of 30 years is adopted for the flood control plan for Ambon central area as a result of the following consideration:

"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-I.3.1. 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-I.3.1 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.

3.1.2 Policy of Flood Control Measures

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

1) **Structural Measures and Non-structural Measures** : To fully achieve the main target of the plan (mitigation of flood damage), the Master Plan shall include structural measures and non-structural measures for flood control and sediment control.
2) **Water Development and River Environment Conservation** : In preparation of the Master Plan, plans for river environment conservation and water development for future domestic use through multipurpose dams are proposed.
3) **Structural Measures [River Improvement, Dams and Diversions]** : 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 the river course and 2) dams and diversion channels to decrease the flood peak discharge into the river course.
4) **Non-structural Measures [Flood Mitigation]** : Non-structural flood control measures are measures other than structural flood control measures to mitigate flood disasters and include various methods for flood runoff suppression, for flood proofing and for facilitation of flood control activities.
5) **Alternative Plans and Optimum Measures** : To identify the optimum structural measures plan for flood control, alternative plans are examined including river improvement work (large scale) with no other measures and river improvement work (small scale) in combination with other measures (dams or diversion channels).

3.2 *Structural Flood Control Measures*

3.2.1 Study of Flood Control Measures

In this section, 1) River Improvement, 2) Flood Control Dams, 3) Diversion Channels and 4) Check Dams will be studied. For each work, following measures were adopted as flood control measures for these works.

River Improvement to Increase Flow Capacity
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.
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.

(1) River Improvement

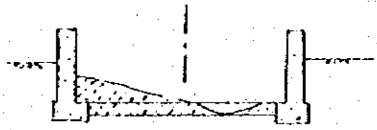
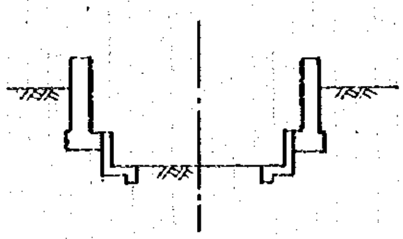
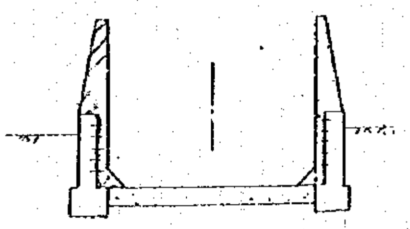
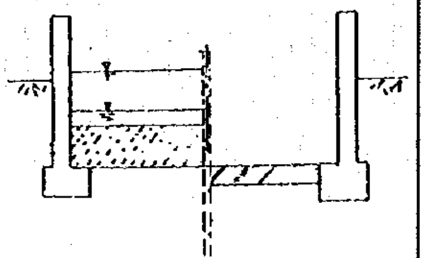
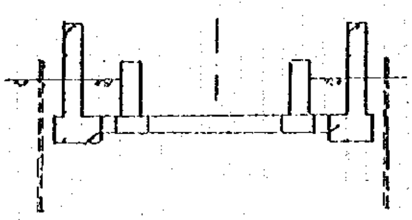
(a) Plan and Design Conditions

The proposed measures for river improvement are 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-I.3.2. 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 might be improved.

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) 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 at n=0.025 for current condition, n=0.020 for river after river-bed formation or excavation and n=0.015 for concrete channel.
3) 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.
4) The cross section is assumed to be rectangular after river-bed formation or excavation.
5) Excavation is assumed to be carried out with a river width of each divided section.

Table-I.3.2 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.

(b) **Ruhu River Improvement**

< Current River Condition >

The longitudinal section (deepest river-bed elevation, left and right flood wall level, left and right side original ground level, OGL) is shown in Figure-I.3.1. 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)

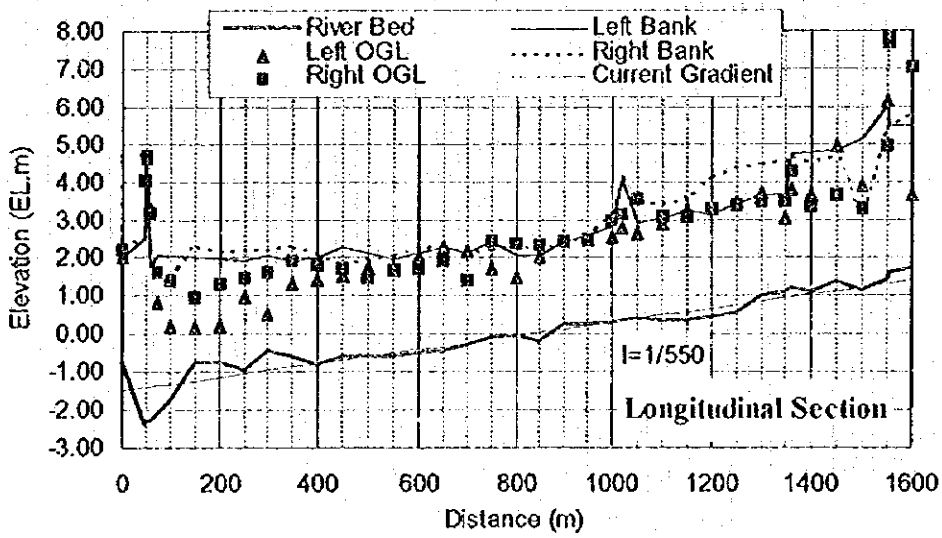


Figure-I.3.1 Longitudinal Section of Ruhu River

< 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

< 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-I.3.3.

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-I.3.3 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

(c) Batu Merah River Improvement

< Current River Condition >

The longitudinal section (deepest river-bed elevation, left and right flood wall level, left and right side original ground level, OGL) is shown in Figure-I.3.2. 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)

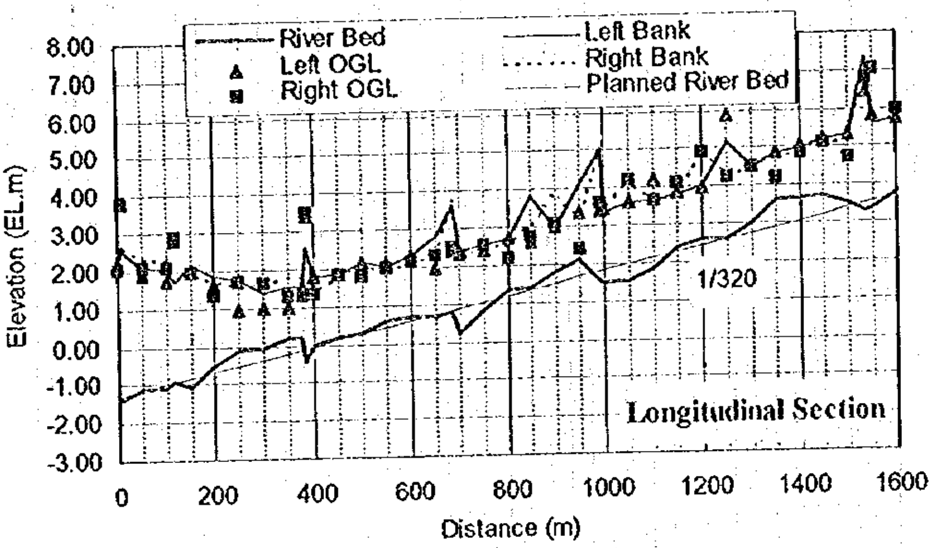


Figure-I.3.2 Longitudinal Section of Batu Merah River

< 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

< 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-I.3.4.

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-I.3.4 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

(d) Tomu River Improvement

< 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-I.3.3. 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)

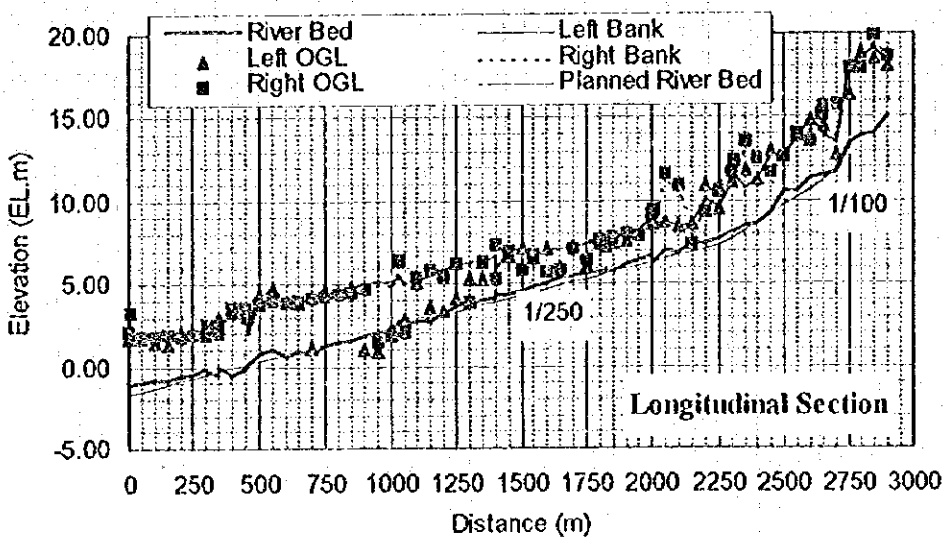


Figure-I.3.3 Longitudinal Section of Tomu River

< 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

< 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-I.3.5.

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-I.3.5 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

(e) Batu Gajah River Improvement

< 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-I.3.4. 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)

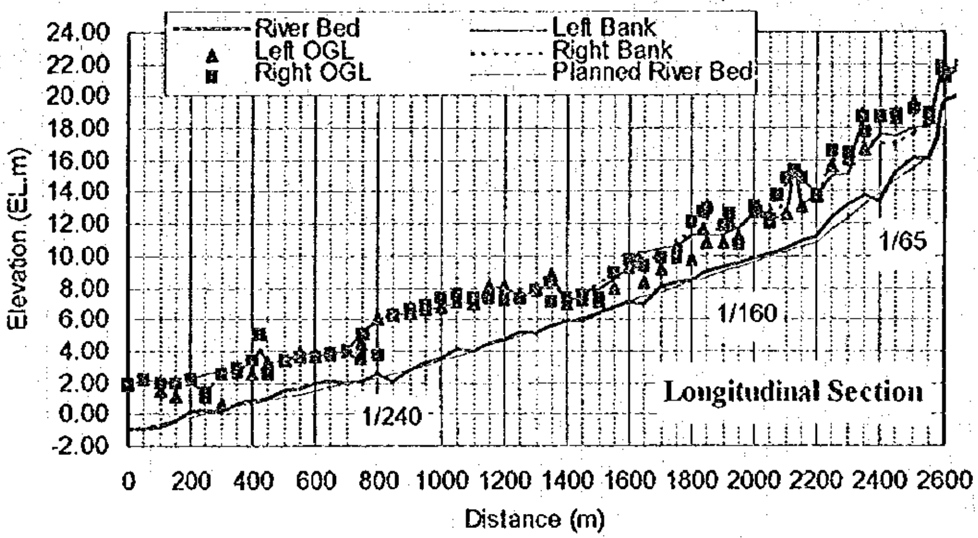


Figure-I.3.4 Longitudinal Section of Batu Gajah River

< 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

<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-I.3.6.

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-I.3.6 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

(f) Batu Gantung River Improvement

< 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-I.3.5. 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)

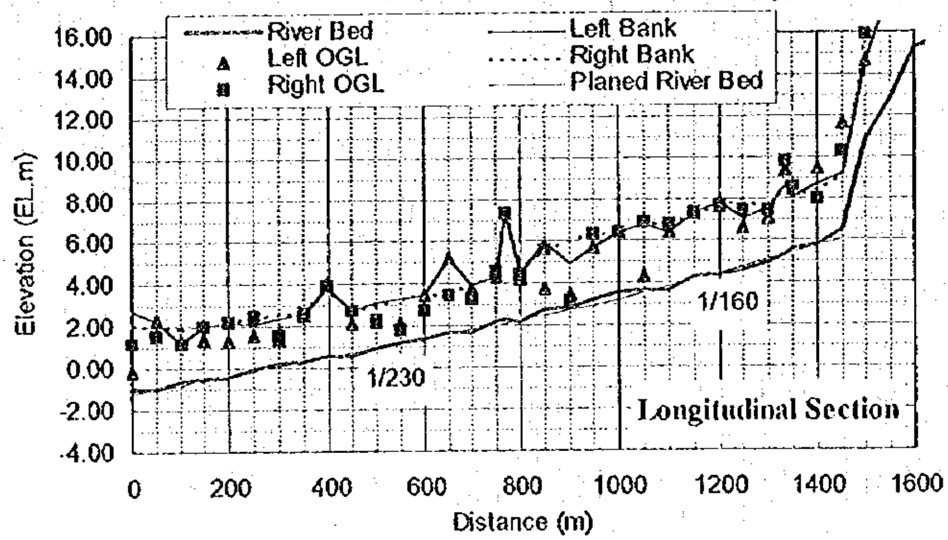


Figure-I.3.5 Longitudinal Section of Batu Gantung River

< 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

< **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-I.3.7.

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-I.3.7 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

(2) Dam and Reservoir

(a) Selection of Dam Site

The 13 locations of candidate dam sites were selected on the five rivers in hilly areas as shown in Figure-I.3.6, on the basis of topographical and geological considerations. From the economic and social view points, each dam site was evaluated as shown in Table-I.3.8, 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.

<u>Ruhu River</u>

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.

<u>Batu Merah River</u>

The dam volumes of BM-2 and 3 are smaller, about half that of BM-1, but the reservoir area M-1 and BM-2 are nearly the same and slightly smaller than BM-3. There are more than [illegible] 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.

<u>Tomu River</u>

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.

<u>Batu Gajah River</u>

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.

<u>Batu Gantung River</u>

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-I.3.8 Comparison of Candidate Dam Sites

River System	Dam No.	Catchment Area (km^2)	Dam Specification (Storage Volume = 1,000,000m^3)			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	
Ganlung	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

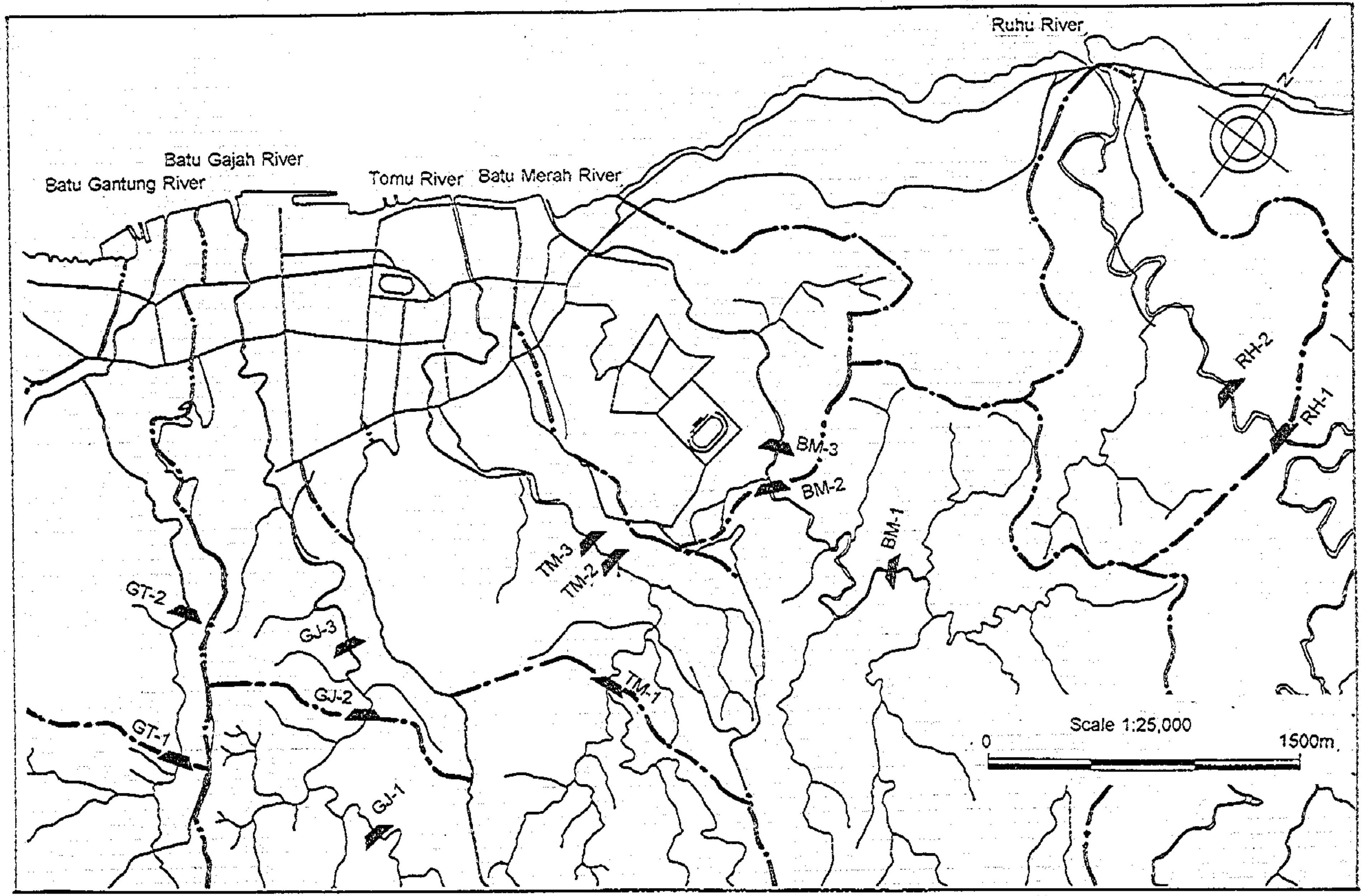


Figure-I.3.6 Locations of Candidate Dam Sites

(b) 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-I.3.9. 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-I.3.9 Design Flood Discharge Before/After Regulation by Dam

Unit: m^3/s

Design Discharge Item	Case	Ruhu	Batu Merah	Tomu	Batu Gajah	Batu Gantung
		RH-1	BM-2	TM-1	BG-2	BG-1
Dam : Design Discharge (Qd)	-	273	103	57	90	99
Reference Point : before regulation (Qb)	-	314	145	117	123	143
Reference Point : after regulation (Qa)	Case-1	170	90	70	80	90
	Case-2	230	110	90	100	110

Note: Reference point is set at river mouth.
Case-1 : river course is improved with 5-year return period design scale.
Case-2 : river course is improved with 10-year return period design scale.

<Design of Dam and Reservoir>

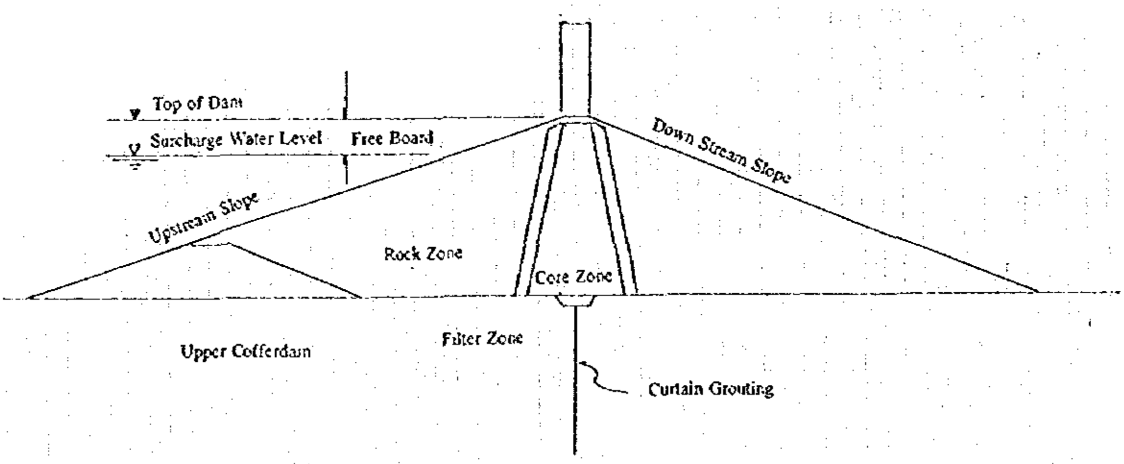
The dam is designed as Fill-Type dam considering the geological condition at the dam site. The design slopes of dam are 1:3.0 (for upstream slope) and 1:2.5 (for downstream slope). The design freeboard and dam crest width are 4.0 m and 5.0 m respectively.

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-I.3.10.

Table-I.3.10 Specifications of Dams and Reservoirs

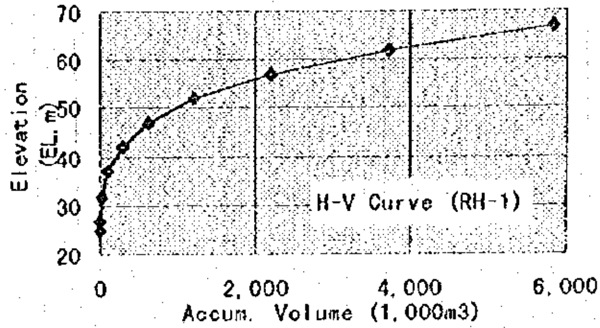
Items		Ruhu		Batu Merah		Tomu		Batu Gajah		Batu Gantung	
		RH-1		BM-2		TM-1		GJ-2		GT-1	
Design Scale of River		1/5	1/10	1/5	1/10	1/5	1/10	1/5	1/10	1/5	1/10
Catchment Area (km²)		14.49		4.97		2.71		4.37		4.76	
Unregulated peak discharge (m³/sec) (30-year return period)	Dam	273		103		57		90		99	
	River Mouth	314		145		117		123		143	
Outflow at peak inflow (m³/sec)	Dam	125	167	47	69	9	28	46	67	46	66
Regulated peak discharge (m³/sec)	Dam	138	197	51	77	10	30	51	70	50	71
	River Mouth	170	230	90	110	70	90	80	100	90	110
Cut discharge (m³/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 m³)		580		199		109		175		191	
River Maintenance Capacity (1000 m³)		251		86		47		76		83	
Flood Storage Capacity (1000 m³)		2,272	1,528	869	536	1,047	399	574	357	725	425
Effective Storage Capacity (1000 m³)		2,523	1,779	955	622	1,094	446	650	433	808	508
Total Storage Capacity (1000 m³)		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	31.3	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 m³)		201	172	115	94	271	159	406	335	228	174
Land Acquisition Area (1000m²)		411	346	236	202	155	108	108	93	113	95
Resettlement Houschold (number)		-	-	150	150	-	-	20	20	-	-

Typical Cross Section of Dam



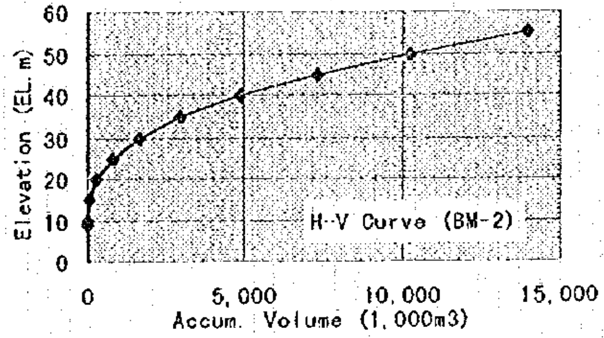
Dam Site : RH-1 (Ruhu River)

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



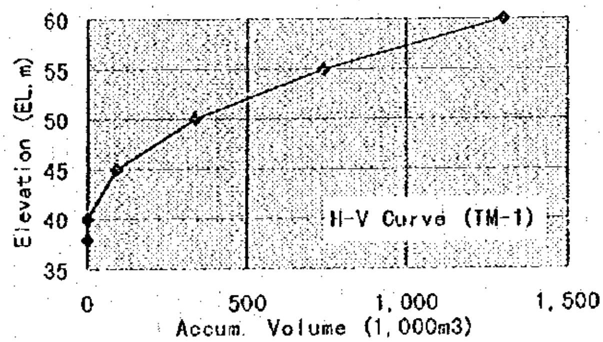
Dam Site : BM-2 (Batu Merah River)

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



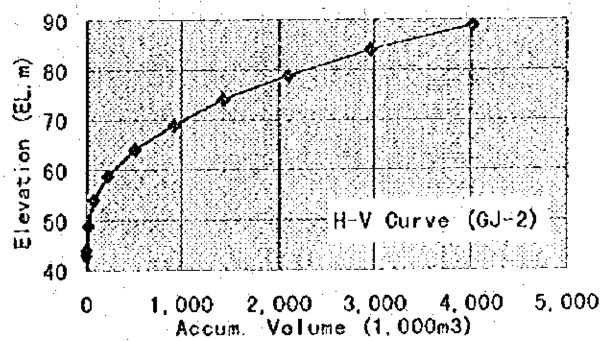
Dam Site : TM-1 (Tomu River)

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

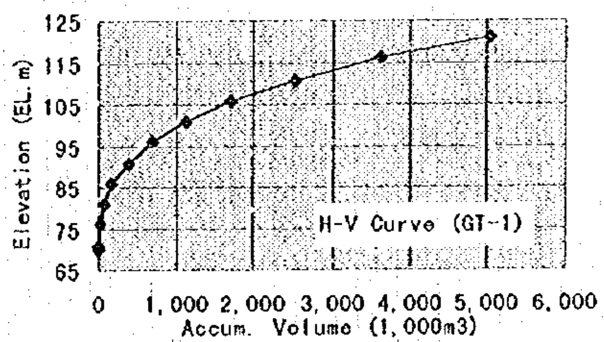


Figure-I.3.7 Water Height and Volume of Dam Reservoir

(3) Diversion Channel

(a) 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

(b) 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-I.3.11 and Figure-I.3.8.

<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>

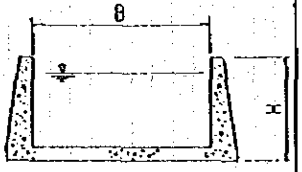
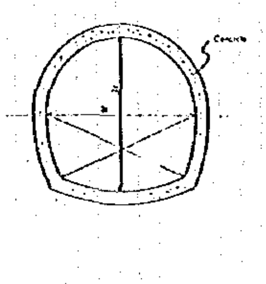
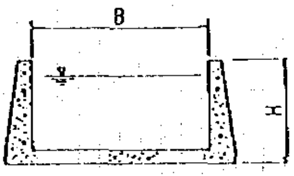
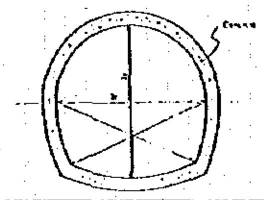
The diversion channel was planned as a tunnel (length = 1,200 m) diverted from 1k600 directly to Ambon Bay about 800 m north from the river mouth of Batu Merah River. The location of the inlet was determined as the most upstream point to which river section improvement is necessary. The gradient of the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

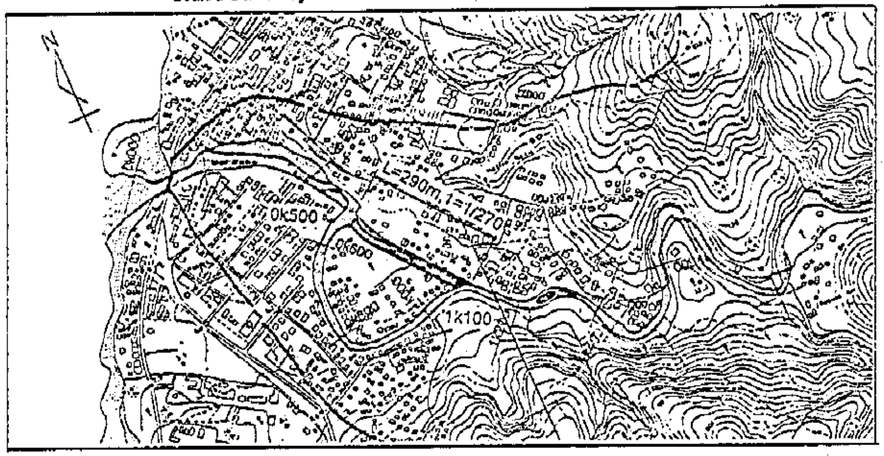
<Tomu River>

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.

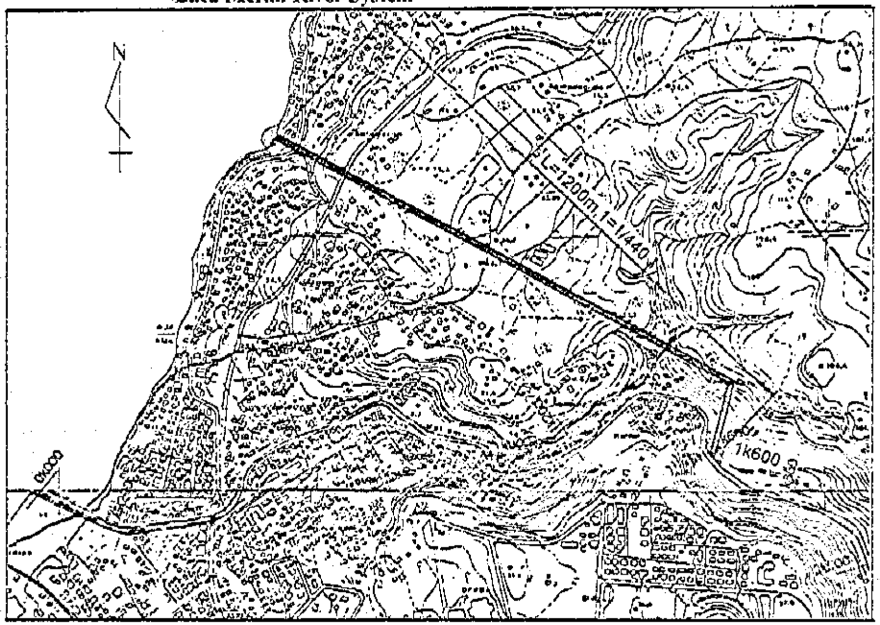
Table-I.3.11 Specifications of Diversion Channels

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 m^3/sec	90 m^3/sec	60 m^3/sec	40 m^3/sec	50 m^3/sec	30 m^3/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	<u>Open Channel</u> B x H = 7.0m x 3.5m	<u>Open Channel</u> B x H = 6.0m x 3.2m	<u>Tunnel</u> D = 5.8m A = 25.4 m^2	<u>Tunnel</u> D = 5.1m A = 19.7 m^2	<u>Open Channel</u> B x H = 4.0m x 2.6m <u>Tunnel</u> D = 4.2m A = 13.3 m^2	<u>Open Channel</u> B x H = 3.5m x 2.2m <u>Tunnel</u> D = 3.5m A = 9.3 m^2
Typical Cross Section					 	

<Ruhu River System>



<Batu Merah River System>



<Tomu River System>

Figure-I.3.8 Diversion Channel Plans

(3) Check Dam

(a) 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.

(b) 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-I.3.12).

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-I.3.12 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-I.3.13, 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-I.3.13 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-I.3.14.

Table-I.3.14 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-I.3.15. 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-I.3.15 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-I.3.16.

Table-I.3.16 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: No resettlement households are required for any of the check dams.