SUPPORTING REPORT

PART-C

METEOROLOGY AND HYDROLOGY

THE STUDY ON FLOOD CONTROL FOR AMBON AND PASAHARI AREA
IN THE REPUBLIC OF INDONESIA
SUPPORTING REPORT
PART-C

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CHAPTER 1 CLIMATE

The climate in Indonesia can generally be described as marine tropical with high temperatures and much rain. Temperature variation is small and there is a rainy season from October to March and a dry season from April to September. The division of the rainy season and dry season is usually clear in the west region from Sumatra to Bali and in Irian Jaya, but the rainy season is shorter in much of the east region except for Irian Jaya. The weather conditions in the Ambon Study Area are outlined in Table-C.1.1. The average temperature and humidity are as high as 26.1 °C and 83 % respectively, indicating a hot and humid climate. Figure-C.1.1 characterizes the seasonal fluctuation of weather.

Table-C.1.1 Weather Conditions in Ambon Area (Pattimura Ambon Station)

Month/Year	Rainfall (mm)	Fine Weather Ratio (%)	Relative Humidity (%)	Maximum Temperature (°C)	Minimum Temperature (°C)	Average Temperature (°C)
January	135	54	79	31.5	23.8	26.8
February	100	60	78	31.6	23.8	27.1
March	152	65	80	31.2	23.6	26.8
April	179	63	84	30.7	23.6	26.6
May	396	54	87	29.7	23.6	26.1
June	556	38	88	28.6	23.2	25.3
July	511	37	86	27.8	22.7	24.8
August	367	42	85	27.7	22.7	24.8
September	284	62	85	28.7	22.7	25.2
October	113	71	83	29.9	23.1	26.1
November	74	77	81	31.3	23.6	27.1
December	124	59	81	31.5	23.7	26.9
Total/Average	3,000	57	83	30.0	23.4	26.1

Note : Figures are average values from 20 years between 1976-1995.

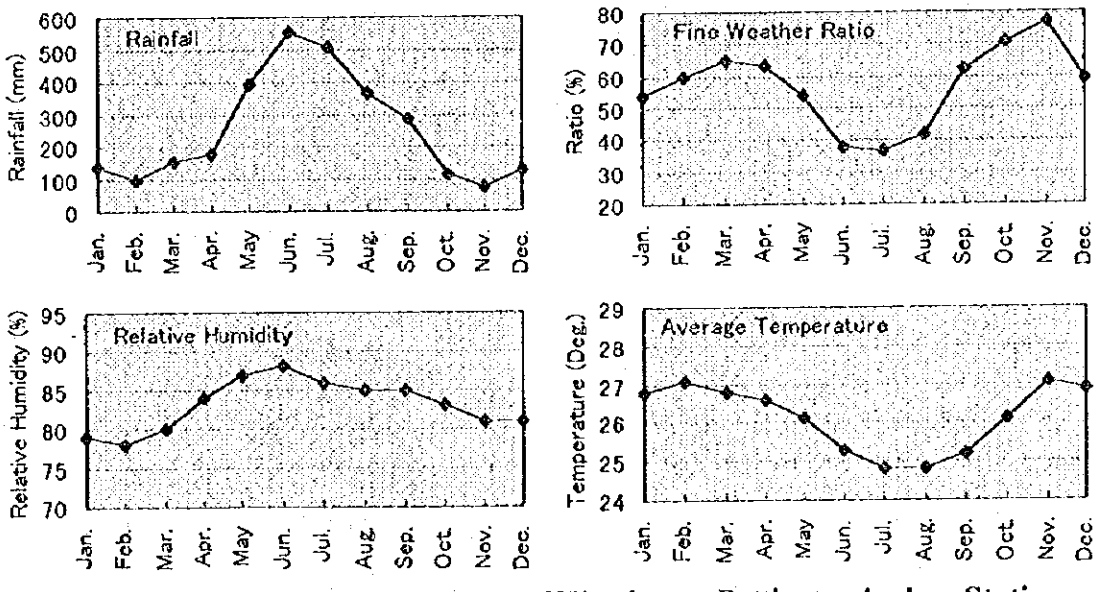


Figure-C.1.1 Seasonal Fluctuation of Weather at Pattimura Ambon Station

CHAPTER 2 NETWORK OF OBSERVATION STATIONS

2.1 Existing Observation Stations

Table-C.2.1 and Table-C.2.2 outline the meteorological (rainfall) stations and hydrological stations in Ambon Island. The location of these stations is shown in Figure-C.2.1. There are two meteorological (rainfall) stations in Ambon Island, namely Gunung Nona and Pattimura Ambon. There are five hydrological stations in Ambon island. Of these, three stations are located in the Study Area (Ruhu River, Tomu River, Batu Gajah River).

Table-C.2.1 Outline of Meteorological (Rainfall) Stations

Station Name	Elevation (EL.m)	Organization	Observation Item		Type of Gauge	Observation Period	
			Rainfall	Others		From	Operation
Gunung Nona	465	PUSLITBANG	O	-	A, O	1981	Operated
Pattimura Ambon (Ambon Airport)	10	BMG	O	O	A, O	1947	Operated

Note -
PUSLITBANG: Pusat Penelitian dan Pengenabangan Pengairan 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

Table-C.2.2 Outline of Hydrological Stations

Station Name (River Name)	Organization	Type of Gauge	Observation Period	
			From	Current Condition
Ruhu River	PU	Automatic Gauge Staff Gauge	1983	Closed Operated
Tomu River	PU	Staff Gauge	1994	Operated
Batu Gajah River	PU	Staff Gauge	1994	Operated
Tonahitu River	PU	Automatic Gauge	1985	Closed
Sikula River	PU	Automatic Gauge	1985	Operated

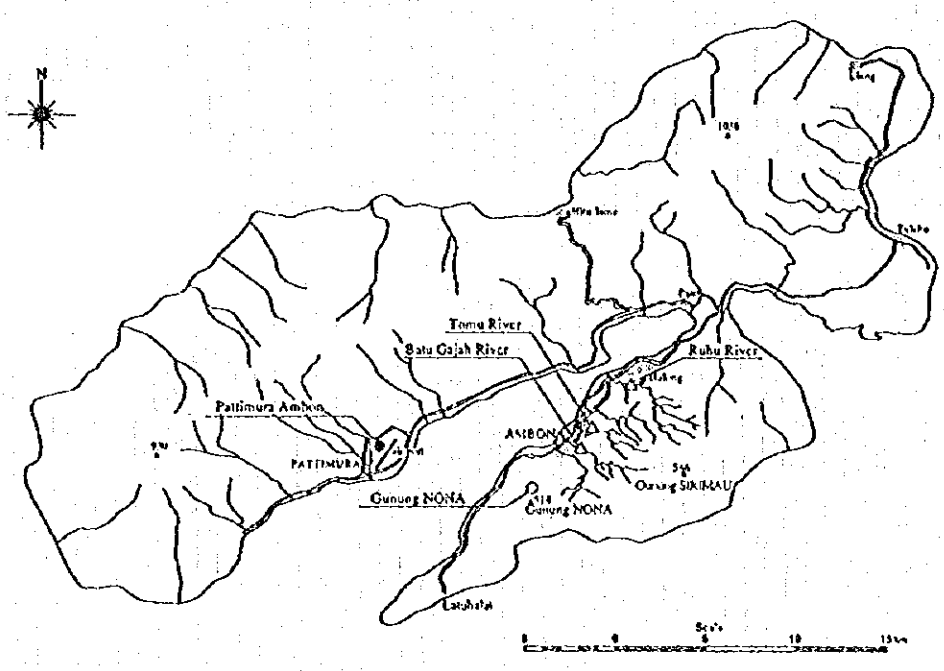


Figure-C.2.1 Location of Meteorological and Hydrological Stations

2.2 Condition of Existing Data

Table-C.2.3 and Table-C.2.4 show the condition of data recorded by the meteorological and hydrological stations. For the rainfall data in Ambon area, the station at Pattimura Ambon has kept better records: daily rainfall data for the past 25 years and hourly rainfall data for 14 years is available. The newer station at Gunung Nona only has daily rainfall data for a period of 5 months.

As for river water level records, there is very little available data. In Ambon area, the hydrological stations at Ruhu River, Tomu River, Batu Gajah River only have two years water level data. Regarding discharge measurement data, there are some data from four or five observation surveys conducted for the 5 target rivers in Ambon area. However, there are no flood data nor H-Q curves available.

Table-C.2.3 Condition of Existing Data at Meteorological Stations

Station Name	Distance from Study Area	Available Period of Existing Data		Suitability as Representative Station
		Daily Rainfall	Hourly Rainfall	
Pattimura Ambon	10 km	25 years	14 years	Suitable
Gunung Nona	Inside	5 months	-	Unsuitable

Table-C.2.4 Condition of Existing Data at Hydrological Stations

Station Name	Location	Available Period		H-Q Curve
		Daily Water Level	Flood Peak Discharge	
Ruhu	within study area	2 years	-	N.A.
Tomu	within study area	2 years	-	N.A.
Batu Gajah	within study area	2 years	-	N.A.
Tonahitu	outside of study Area	-	-	N.A.
Sikula	outside of study Area	2 years	-	N.A.

2.3 Organization of Meteorological and Hydrological Observation

Meteorological and hydrological stations are controlled by 2 institutions, PUSLITBANG [Research and Development Center of P.U.] and B.M.G.[Meteorological and Geophysical Agency]. These observatory organizations are shown in Figures-C.2.2 and C.2.3.

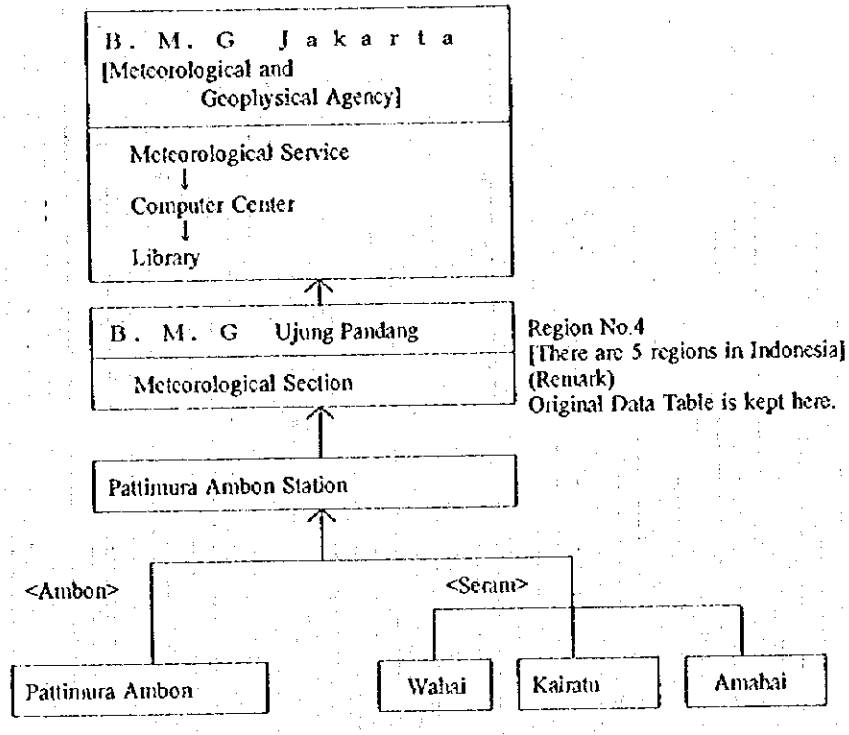


Figure-C.2.2 Observatory Organization of B.M.G

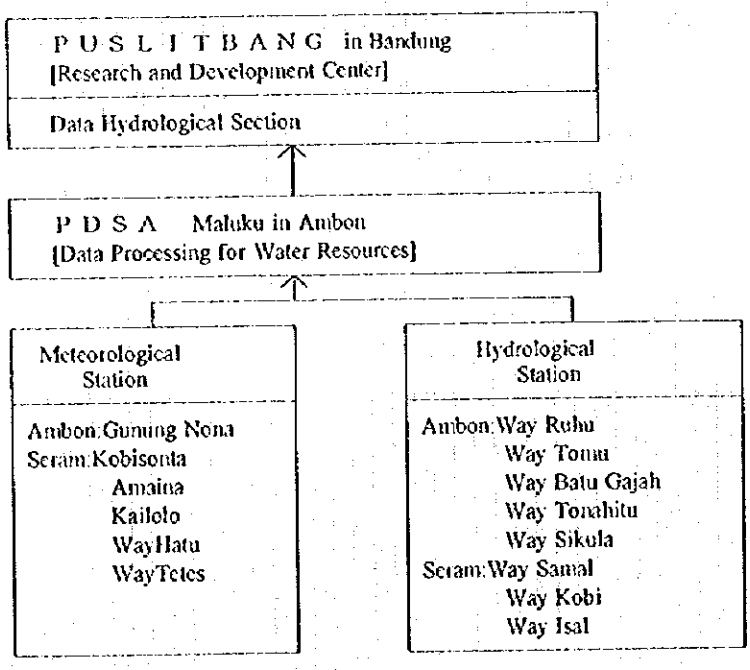


Figure-C.2.3 Observatory Organization of PUSLITBANG (PU)

CHAPTER 3 INSTALLATION OF OBSERVATION STATIONS

3.1 Observation Stations Installed by JICA Study Team

In order to verify meteorological and hydrological data in the target river basins, automatic rainfall recorders, automatic water level recorders and water level staff gauges have been installed as part of this Study. The following hydrometric observation stations were installed in the Ambon area by the Study Team :

- Automatic rainfall recorder (ARR) : 1 in Ambon
- Automatic water level recorder (AWLR) : 1 in Ambon
- Staff gauges : 5 in Ambon (1 on each river)

3.2 Location of Observation Stations

The locations of the observation stations installed by the Study Team in the Ambon area are shown in Figure-C.3.1 and the stations are listed in Table-C.3.1 below. The catchment areas at the location of each staff gauge and for each river basin are also indicated.

There were found to be three existing staff gauges on the Ruhu, Tomu and Batu Gajah rivers in the Ambon area. However, these existing staff gauges were made from wood and therefore it was decided to replace the old gauges with new steel staff gauges. The new gauges were installed in the same location as the existing gauges in order to ensure continuity of river water level data.

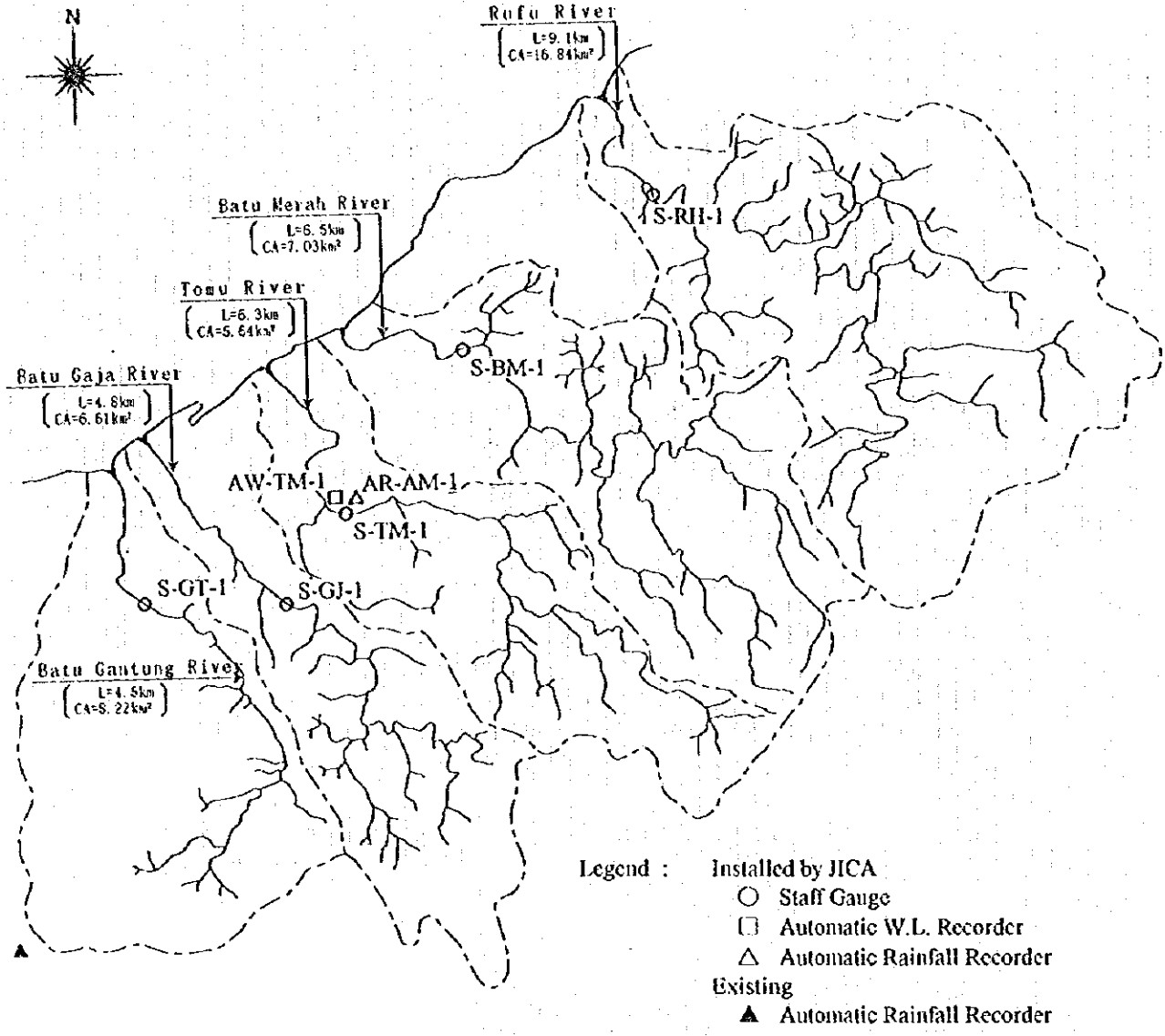
New staff gauges were also installed on Batu Merah and Batu Gantung rivers. The location of these gauges was agreed with P.U. and permission obtained from the head of each Desa for installation of the gauges. Installation of the gauges was completed during December 1996. Gauge readers have been appointed and the staff gauges were handed over to the responsibility of P.U. in early January 1997. Collection of daily water level data is now being carried out on all five target rivers in the Ambon area.

Table-C.3.1 Installed Observation Stations

Target Area	Item	Station Code	River or Basin	Catchment Area (km^2)	
				Station	Total
Ambon Area	Staff Gauge	S-RH-1	Ruhu River	14.91	16.84
		S-BM-1	Batu Merah River	6.14	7.03
		S-TM-1	Tomu River	3.99	5.64
		S-GJ-1	Batu Gajah River	4.92	6.61
		S-GT-1	Batu Gantung River	5.89	8.22
	AWLR	AW-TM-1	Tomu River	3.99	5.64
	ARR	AR-AM-1	Tomu River	-	5.64

In addition to the staff gauge at Tomu river, an automatic water level recorder (AWLR) has been installed adjacent to the staff gauge to monitor the hourly variation in river water level. This AWLR was also handed over to P.U. in January and collection of hourly water level data is in progress. P.U. staff are now responsible for the AWLR, including changing the recorder paper on a weekly basis.

The automatic rainfall recorder (ARR) for the Ambon area has been installed near to Tomu river, close to the location of the AWLR and staff gauge. The ARR was constructed on land belonging to the Army, adjacent to an existing fuel station. Installation was completed in December 1996 and responsibility for the ARR handed over to P.U. in early January 1997. Rainfall data is now being monitored (since the beginning of January) and P.U. staff are responsible for changing the recorder paper once per week.



Item	Station Code	River or Basin
Staff Gauge	S-RH-1	Ruhu River
	S-BM-1	Batu Merah River
	S-TM-1	Tomu River
	S-GJ-1	Batu Gajah River
	S-GT-1	Batu Gantung River
Automatic Water Level Recorder	AW-TM-1	Tomu River
Automatic Rainfall Recorder	AR-AM-1	Tomu River

Figure-C.3.1 Location of Observation Stations - Ambon Area

CHAPTER 4 CORRELATION ANALYSIS OF RAINFALL

Correlation analysis for daily rainfall was studied using the data from observation stations in Ambon Area, namely Pattimura Ambon by B.M.G and Tomu River installed by JICA last year. The date used in the analysis is daily rainfall data for 6 months (1996. January -- June). The result of calculation is shown in Table-C.4.1 and Figure-C.4.1. Data plotting for both Pattimura Ambon and Tomu River is scattered and correlation coefficient is low at 0.53. However, it can be seen that the correlation of the two is generally related as 1:1. Both stations are across Ambon Bay and the distance between both stations is as near as at about 10 km. Judging from the above, it follows that rainfall in Ambon area must be extremely regional.

Table-C.4.1 Results of Correlation Analysis of Rainfall in Ambon

X	Y	Correlation Formula	Correlation Coefficient	Calculation Term	Amount of Data
Pattimura Ambon	Tomu River	Y = 0.852 X	0.53	1997, JAN - JUN	172

Note: Daily Rainfall Data

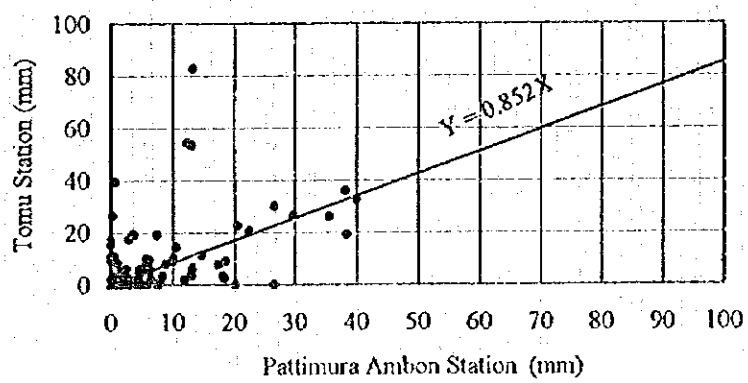


Figure-C.4.1 Results of Correlation Analysis of Rainfall in Ambon

CHAPTER 5 FLOW MEASUREMENT

Flow measurement has been carried out for the five rivers in the Ambon area using current meters provided by the Study Team. The discharge in each river was measured three times (with the exception of Batu Gantung) at the location of the existing and new staff gauges. Technology transfer was undertaken to explain river discharge measurement to Team counterparts and staff of the P.U. Hydrological Section who assisted in the river gauging activities.

River discharge was measured using the "velocity-area" method. Flow velocity was measured with a current meter at a number of positions across the river width and multiplied by the cross sectional area to give the total discharge. In the case of Batu Gantung, which has very low flow during the dry season, flow velocity was estimated using the "float" method. The time taken for a surface float to travel a known distance was measured - the average flow velocity is assumed to be equal to 0.7 times the measured surface velocity. The results of the river discharge measurement in the Ambon area are presented in Table-C.5.1 below.

Table-C.5.1 Results of Flow Measurement in Ambon Area

River	Date	Width (m)	No. of Verticals	Section Area (m^2)	Water Level (m)	Average Vel. (m/s)	Discharge Q (m^3/s)
RUHU	13/11/96	11.2	21	3.22	0.73	0.08	0.251
	12/12/96	11.2	21	2.54	0.71	0.08	0.207
	06/01/97	11.0	15	2.50	0.68	0.07	0.185
B.MERAH	10/12/96	6.7	16	0.85	0.18	0.32	0.272
	12/12/96	6.7	17	0.82	0.17	0.38	0.313
	06/01/97	6.8	15	0.85	0.16	0.34	0.288
TOMU	14/11/96	3.4	16	0.43	0.20	0.27	0.115
	11/12/96	3.4	16	0.35	0.19	0.20	0.072
	07/01/97	3.4	10	0.31	0.19	0.22	0.069
B.GAJAH	14/11/96	4.8	15	0.56	0.21	0.58	0.322
	11/12/96	4.8	22	0.42	0.20	0.50	0.260
	07/01/97	4.8	15	0.50	0.18	0.49	0.245
B.GANTUNG	10/12/96	2.0	Float	0.12	0.10	0.11	0.013
	08/01/97	1.5	Float	0.10	0.07	0.13	0.013

Although river discharge was measured three times during November, December and January, the water level and discharge volume in the Ambon rivers was low in all cases. In order to produce stage-discharge (H/Q) curves for the rivers, it is essential to observe water level and discharge data at higher flows. Further discharge measurement will be undertaken during the rainy season in the next phase of this Study.

CHAPTER 6 WATER LEVEL AND DISCHARGE ANALYSIS

6.1 H-Q Curve

Due to lack of discharge observation data, H-Q curves were obtained through calculations of uniform flow at the observation points. Firstly, the roughness coefficient of the river course was estimated as n = 0.030-0.050 during low-flow, taking account of the river condition. Three cases of H-Q curves were then obtained by means of uniform flow calculation. Secondly, by using the obtained curves, daily discharge corresponding to the daily average water level in an available period of 2 years (October 1994 to September 1996) was calculated. The correlation between the monthly run-off depth (mm) obtained and the monthly rainfall recorded at Pattimura Ambon was examined. As a result, a roughness coefficient of n = 0.030-0.040 proved to be unsuitable since the calculated monthly run-off depth exceeded the monthly rainfall. However with n = 0.050, the calculated run-off depth is approximately equal to the rainfall - refer to Figure-C.6.1. A roughness coefficient n = 0.050 is considered appropriate for the five target rivers during low water condition.

The H-Q curves were thus obtained by using the results of the uniform flow calculation with a roughness coefficient of n = 0.050. The H-Q curves for the three rivers are as follows:

- Ruhu River (S-RH-1) : $Q = 12.78 (H-0.5488)^2$
- Tomu River (S-TM-1) : $Q = 10.08 (H-0.05815)^2$
- Batu Gajah River (S-GJ-1) : $Q = 9.918 (H-0.0156)^2$: (H<0.3m)
  : $Q = 9.383 H - 2.0128$: (0.3m<H<0.5m)
  : $Q = 4.928 (H+0.2373)^2$: (H>0.5m)

Note: Q...Discharge(m^3/s), H...Water Level (m)

For Ruhu River and Tomu River one H-Q equation is sufficient, but for Batu Gajah River, three equations are developed for different ranges of water height, in order to improve the accuracy of the H-Q curves at the low water period. The H-Q curves for the three rivers are shown in Figure-C.6.2.

However, because the rainfall data are from the observation station in Pattimura Ambon which is about 10 km away from the Study Area and the correlation between the actual rainfall in the two area is still not clear, it may be necessary to modify the H-Q curves by using the rainfall observation data to be acquired from the station established by the JICA Study Team.

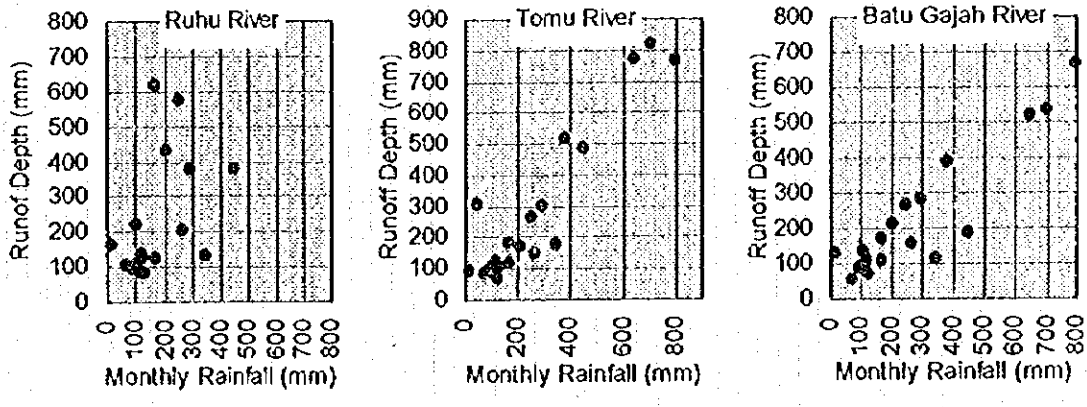
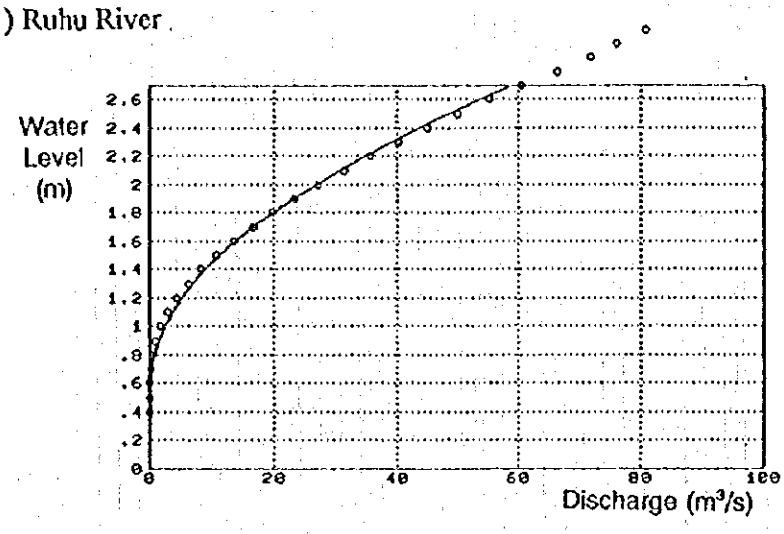
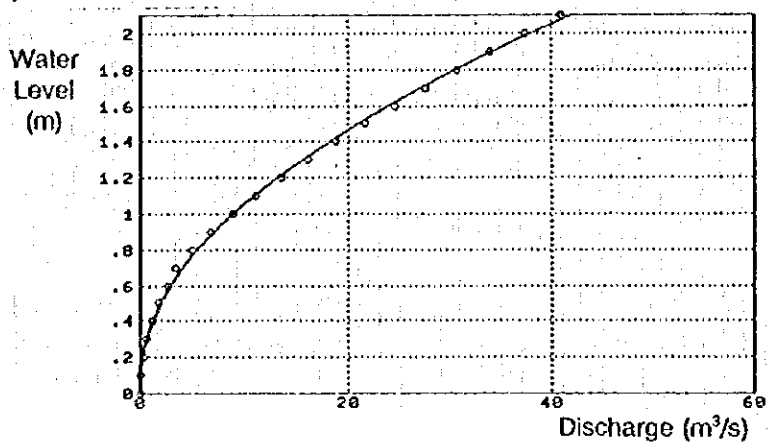


Figure-C.6.1 Study of Roughness Coefficient (n=0.050)

1) Ruhu River



2) Tomu River



3) Batu Gajah River

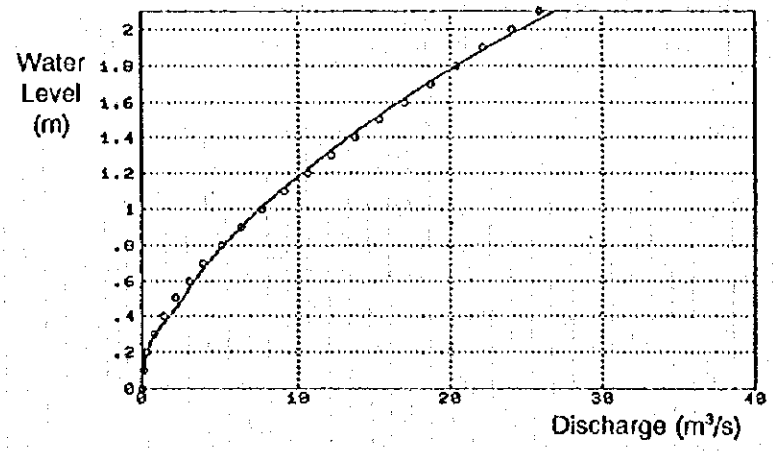


Figure-C.6.2 H-Q Curve for Rivers in Ambon

6.2 Flow Regime

Flow regime for the target rivers was obtained by reviewing the data of past 10 years. Since there are only two years' observation data (from October 1994 to September 1996) of daily average water level, those for the other 8 years were estimated by using the daily flow rate data and considering a proportional conversion factor of the annual rainfall. The flow regimes are shown in Table-C.6.1.

Table-C.6.1 Flow Regime

Year	Flow Regime (m^3/s)							Volume of Run-off (10^6m^3)	Depth of Run-off (mm)
	Mean	Maximum (1)	High (95)	Median (185)	Low (275)	Drought (355)	Minimum (365)		
Ruhu River									
1982	1.27	24.23	1.20	0.65	0.40	0.20	0.12	40.06	2,687
1983	2.03	38.86		1.04	0.63	0.32	0.19	64.23	4,308
1985	2.51	47.92	2.37	1.29	0.78	0.39	0.23	79.22	5,313
1986	1.41	27.01	1.34	0.73	0.44	0.22	0.13	44.65	2,995
1990	2.11	40.26	1.99	1.08	0.66	0.33	0.20	66.55	4,464
1991	1.36	26.05	1.29	0.70	0.43	0.21	0.13	43.06	2,888
1992	1.47	28.11	1.39	0.76	0.46	0.23	0.14	46.46	3,116
1993	1.16	22.22	1.10	0.60	0.36	0.18	0.11	36.74	2,464
1995	1.68	38.74	1.58	0.87	0.57	0.47	0.25	53.00	3,552
1996	2.74	45.71	2.60	1.40	0.81	0.22	0.16	86.60	5,811
Mean	1.77	33.91	1.65	0.91	0.55	0.28	0.16	56.06	3,760
Specific Q	11.90	227.44	11.08	6.11	3.72	1.86	1.10	-	-
Tomu River									
1982	0.24	2.85	0.34	0.10	0.09	0.08	0.05	7.55	1,891
1983	0.39	4.58	0.54	0.16	0.14	0.13	0.07	12.10	3,033
1985	0.48	5.65	0.67	0.20	0.17	0.16	0.09	14.92	3,740
1986	0.27	3.18	0.38	0.11	0.10	0.09	0.05	8.41	2,108
1990	0.40	4.74	0.56	0.17	0.14	0.13	0.08	12.54	3,142
1991	0.26	3.07	0.36	0.11	0.09	0.09	0.05	8.11	2,033
1992	0.28	3.31	0.39	0.12	0.10	0.09	0.05	8.75	2,194
1993	0.22	2.62	0.31	0.09	0.08	0.07	0.04	6.92	1,734
1995	0.42	6.65	0.59	0.15	0.15	0.15	0.03	13.10	3,285
1996	0.42	3.30	0.59	0.20	0.15	0.13	0.13	13.20	3,306
Mean	0.34	4.00	0.47	0.14	0.12	0.11	0.06	10.56	2,647
Specific Q	8.45	100.14	11.88	3.52	3.02	2.82	1.61	-	-
Batu Gajah River									
1982	0.28	3.59	0.30	0.15	0.09	0.07	0.00	8.67	1,757
1983	0.44	5.76	0.49	0.25	0.15	0.11	0.00	13.90	2,817
1985	0.54	7.10	0.60	0.31	0.19	0.14	0.00	17.14	3,475
1986	0.31	4.00	0.34	0.17	0.11	0.08	0.00	9.66	1,959
1990	0.46	5.97	0.51	0.26	0.16	0.11	0.00	14.40	2,919
1991	0.30	3.86	0.33	0.17	0.10	0.07	0.00	9.31	1,889
1992	0.32	4.17	0.35	0.18	0.11	0.08	0.00	10.05	2,038
1993	0.25	3.29	0.28	0.14	0.09	0.06	0.00	7.95	1,611
1995	0.38	6.15	0.37	0.24	0.18	0.15	0.00	11.90	2,409
1996	0.58	6.37	0.69	0.30	0.15	0.09	0.00	18.30	3,714
Mean	0.39	5.03	0.43	0.22	0.13	0.10	0.00	12.13	2,459
Specific Q	7.84	102.18	8.65	4.41	2.69	1.96	0.00	-	-

Notes :

- Rainfall data for the years 1984, 1987-1989 and 1994 are not available.
- Specific Q : Specific Discharge ($m^3/s/100km^2$)

CHAPTER 7 RAINFALL ANALYSIS

7.1 Representative Rainfall Station and Basin Mean Rainfall

7.1.1 Representative Rainfall Station

In the Ambon area, since the meteorological station at Pattimura Ambon has both daily and hourly rainfall data for a long period, it can be taken as a representative rainfall observation station for the Study Area. Pattimura Ambon has been used as the representative rainfall station for daily rainfall, hourly rainfall and rainfall intensity analysis.

7.1.2 Basin Mean Rainfall

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.

7.2 Probability Analysis

7.2.1 Daily and Hourly Probable Rainfall

Daily and hourly probable rainfall in Ambon area were calculated using annual maximum daily rainfall data for 32 years and annual maximum hourly rainfall data for 14 years from the representative rainfall station, namely Pattimura Ambon as shown in Table-C.7.1.

Table-C.7.1(1) Maximum Annual Daily Rainfall in Pattimura Ambon

No.	Date	Maximum Rainfall (mm/day)	No.	Date	Maximum Rainfall (mm/day)
1	1954/6/1	180.0	17	1981/7/25	231.9
2	1955/9/1	179.0	18	1982/6/7	140.0
3	1958/9/1	66.0	19	1983/7/5	134.8
4	1959/5/1	161.0	20	1984/6/22	430.7
5	1960/6/1	135.0	21	1985/7/24	151.4
6	1961/6/1	267.0	22	1986/4/3	158.0
7	1963/6/1	280.0	23	1987/2/9	203.0
8	1964/9/1	358.0	24	1988/8/28	455.0
9	1965/4/1	99.0	25	1989/6/22	233.0
10	1966/6/1	154.0	26	1990/8/19	307.4
11	1968/5/1	120.0	27	1991/7/13	145.1
12	1976/6/12	102.0	28	1992/7/18	125.6
13	1977/4/10	79.0	29	1993/6/21	150.2
14	1978/6/21	218.0	30	1994/4/14	133.0
15	1979/6/23	154.0	31	1995/9/13	195.0
16	1980/8/6	111.9	32	1996/8/22	230.3

Note: Total = 32 years

Table-C.7.1(2) Maximum Annual Hourly Rainfall in Pattimura Ambon

No.	Date	Maximum Rainfall (mm/hour)
1	1983/6/19 7:00	46.6
2	1984/5/31 8:00	46.6
3	1985/12/14 10:00	42.4
4	1986/7/16 17:00	34.0
5	1987/5/7 10:00	37.9
6	1988/5/7 19:00	55.5
7	1989/2/5 3:00	26.9
8	1990/6/6 8:00	51.0
9	1991/7/13 6:00	31.4
10	1992/11/28 14:00	43.8
11	1993/5/8 6:00	42.0
12	1994/4/14 10:00	60.0
13	1995/8/5 12:00	49.0
14	1996/7/26 9:00	94.0

Note: Total = 14 years

Table-C.7.3-4 and Figure-C.7.1-2 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 Ambon area as shown in Table-C.7.2 because the result best fits the available data. Using the daily probable rainfall, Maximum daily rainfall can be estimated by probability analysis. Maximum daily rainfall recorded at 455 mm/day on August 28, 1988 is estimated as about 1/50.

Table-C.7.2 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

Table-C.7.3 Calculation Results of Daily Probable Rainfall [Daily Rainfall in Pattimura Ambon]

Return Period (year)	Daily Probable Rainfall (mm/day)			
	Least Square	Moment	Iwai	Gumbel
1000	767.4	780.5	790.3	713.8
500	692.5	703.5	706.9	656.8
200	598.2	606.7	603.5	581.3
150	569.7	577.4	572.6	557.6
100	530.2	537.0	530.1	524.2
80	508.8	515.1	507.3	505.7
70	496.1	502.1	493.9	494.7
60	481.6	487.3	478.5	481.9
50	464.6	469.9	460.6	466.8
40	444.0	448.8	438.9	448.2
30	417.7	421.9	411.6	424.2
20	381.1	384.6	373.9	390.2
10	319.6	321.9	311.5	331.0
8	299.9	301.8	291.8	311.5
7	288.2	289.8	280.1	299.7
6	274.5	276.0	266.7	285.9
5	258.3	259.5	250.8	269.3
4	238.2	239.1	231.3	248.4
3	211.6	212.1	205.8	220.2
2	171.8	171.8	168.5	176.2

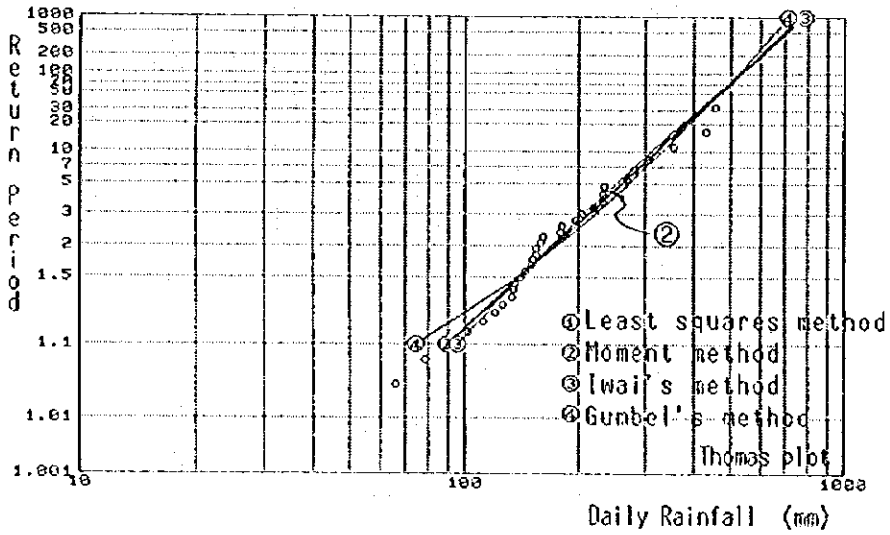


Figure-C.7.1 Plotting Positions of Daily Probable Rainfall [Daily Rainfall in Pattimura Ambon]

Table-C.7.4 Calculation Results of Hourly Probable Rainfall [Hourly Rainfall in Pattimura Ambon]

Return Period (year)	Hourly Probable Rainfall (mm/hour)			
	Least Square	Moment	Iwai	Gumbel
1000	129.0	134.3	139.4	146.3
500	120.0	124.6	127.4	135.6
200	108.3	112.0	112.4	121.4
150	104.6	108.1	107.8	116.9
100	99.5	102.5	101.5	110.6
80	96.6	99.5	98.1	107.1
70	94.9	97.7	96.1	105.0
60	93.0	95.6	93.7	102.6
50	90.7	93.1	91.0	99.8
40	87.8	90.1	87.7	96.3
30	84.1	86.2	83.5	91.8
20	78.9	80.6	77.7	85.3
10	69.7	70.9	67.8	74.2
8	66.7	67.7	64.6	70.5
7	64.8	65.7	62.7	68.3
6	62.7	63.5	60.5	65.7
5	60.0	60.7	57.9	62.6
4	56.7	57.2	54.7	58.6
3	52.2	52.5	50.4	53.3
2	45.1	45.1	44.0	45.0

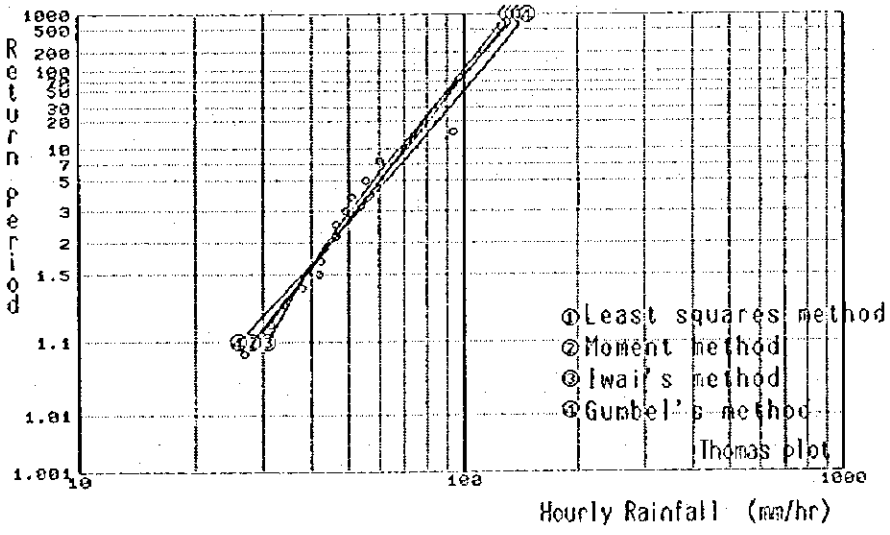


Figure-C.7.2 Plotting Positions of Hourly Probable Rainfall [Hourly Rainfall in Pattimura Ambon]

(2) Rainfall Intensity Curve

The rainfall intensity curves are calculated by the Talbot Formula using the probable daily rainfall and probable hourly rainfall for Ambon and Pasahari areas. Coefficients "a" and "b" in the Talbot Formula are calculated by the specific coefficient method. The calculation results are shown in Table-C.7.5 and Figure-C.7.3.

7.2.2 Flood Rainfall

The flood daily rainfall in the Study Areas are shown in Table-C.7.6. 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 ten (10) floods with hourly rainfall data are shown in Figure-C.7.4. As can be seen from Figure-C.7.4, the hyetographs of these 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-C.7.5 Probable Rainfall Intensity [Pattimura Ambon]

Return Period (year)		2	5	10	20	30	50	70	100	200
Rn(24)		171.8	259.5	321.9	384.6	421.9	469.9	502.1	537.0	606.7
Rn(1)		45.1	60.7	70.9	80.6	86.2	93.1	97.7	102.5	112.0
b		3.3	4.0	4.4	4.7	4.9	5.1	5.3	5.4	5.7
a		195.7	302.6	380.5	460.0	507.9	570.2	612.3	658.3	750.9
Rainfall	t= 0.2	55.3	72.3	83.3	93.7	99.7	107.1	112.0	117.1	127.2
Intensity	t= 0.5	51.0	67.5	78.2	88.3	94.2	101.4	106.2	111.2	121.0
In=a/(t+b)	t= 1	45.1	60.7	70.9	80.6	86.2	93.1	97.7	102.5	112.0
[mm/hr]	t= 2	36.7	50.6	59.8	68.6	73.7	80.0	84.3	88.7	97.5
t(hour)	t= 4	26.7	37.9	45.5	52.8	57.1	62.5	66.1	69.9	77.4
	t= 6	21.0	30.3	36.7	43.0	46.6	51.3	54.3	57.6	64.2
	t= 8	17.3	25.2	30.8	36.2	39.4	43.4	46.2	49.0	54.8
	t= 10	14.7	21.6	26.5	31.3	34.1	37.7	40.1	42.7	47.8
	t= 12	12.8	18.9	23.2	27.5	30.1	33.3	35.5	37.8	42.4
	t= 14	11.3	16.8	20.7	24.6	26.9	29.8	31.8	33.9	38.1
	t= 16	10.1	15.1	18.7	22.2	24.3	27.0	28.8	30.7	34.6
	t= 18	9.2	13.8	17.0	20.3	22.2	24.7	26.3	28.1	31.7
	t= 20	8.4	12.6	15.6	18.6	20.4	22.7	24.2	25.9	29.2
	t= 22	7.7	11.6	14.4	17.2	18.9	21.0	22.5	24.0	27.1
	t= 24	7.2	10.8	13.4	16.0	17.6	19.6	20.9	22.4	25.3

Note:
Probable rainfall intensity was calculated using probable daily and hourly rainfall, applying Talbot formula

[Talbot Formula]

In=a/(t+b) [mm/hr]

where, In : Probable rainfall intensity (mm/hr)
t : Rainfall Duration(hour)
a, b: Constant

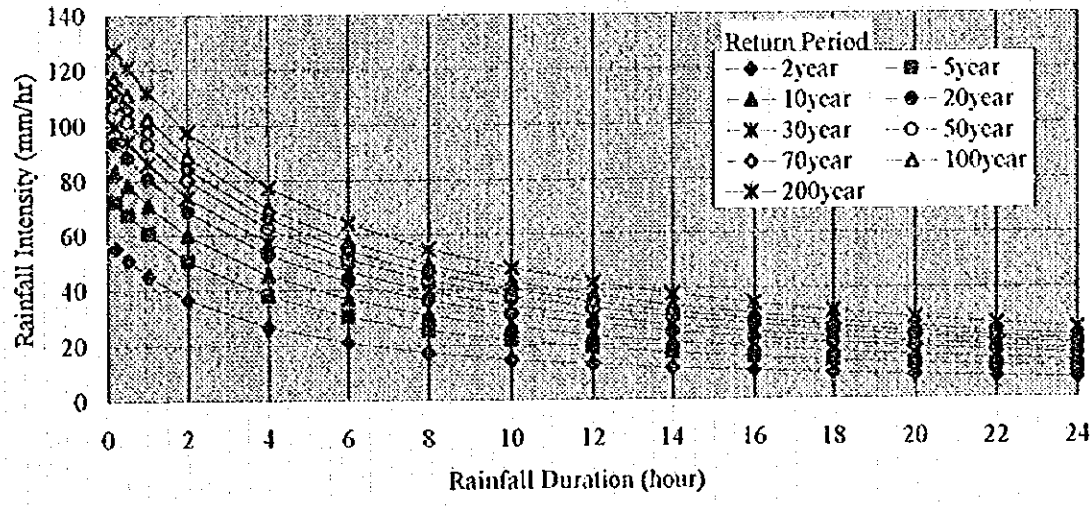


Figure-C.7.3 Probable Rainfall Intensity Curves [Pattimura Ambon]

Table-C.7.6 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].

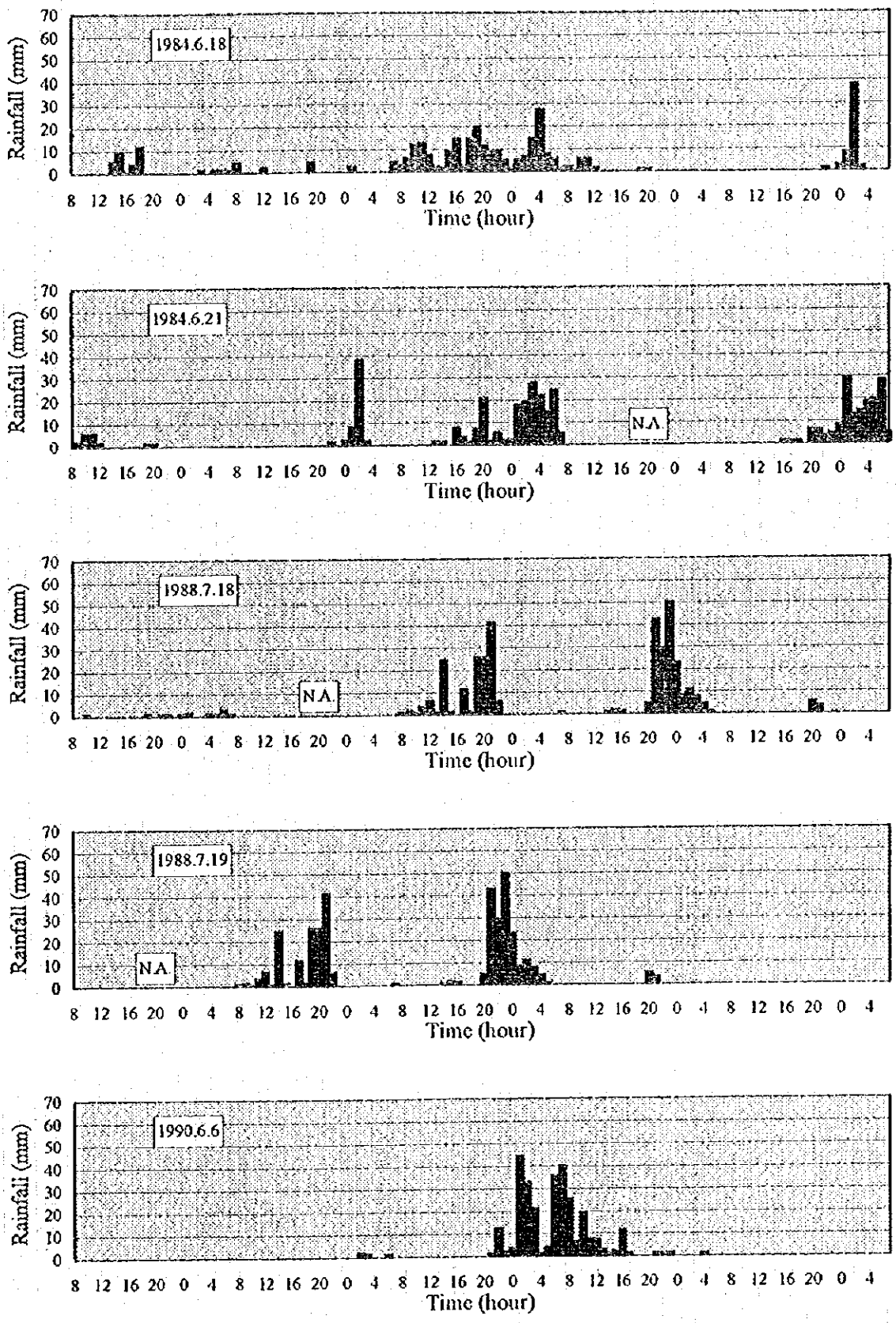


Figure-C.7.4(1) Hyetograph of Main Flood Rainfall in Ambon

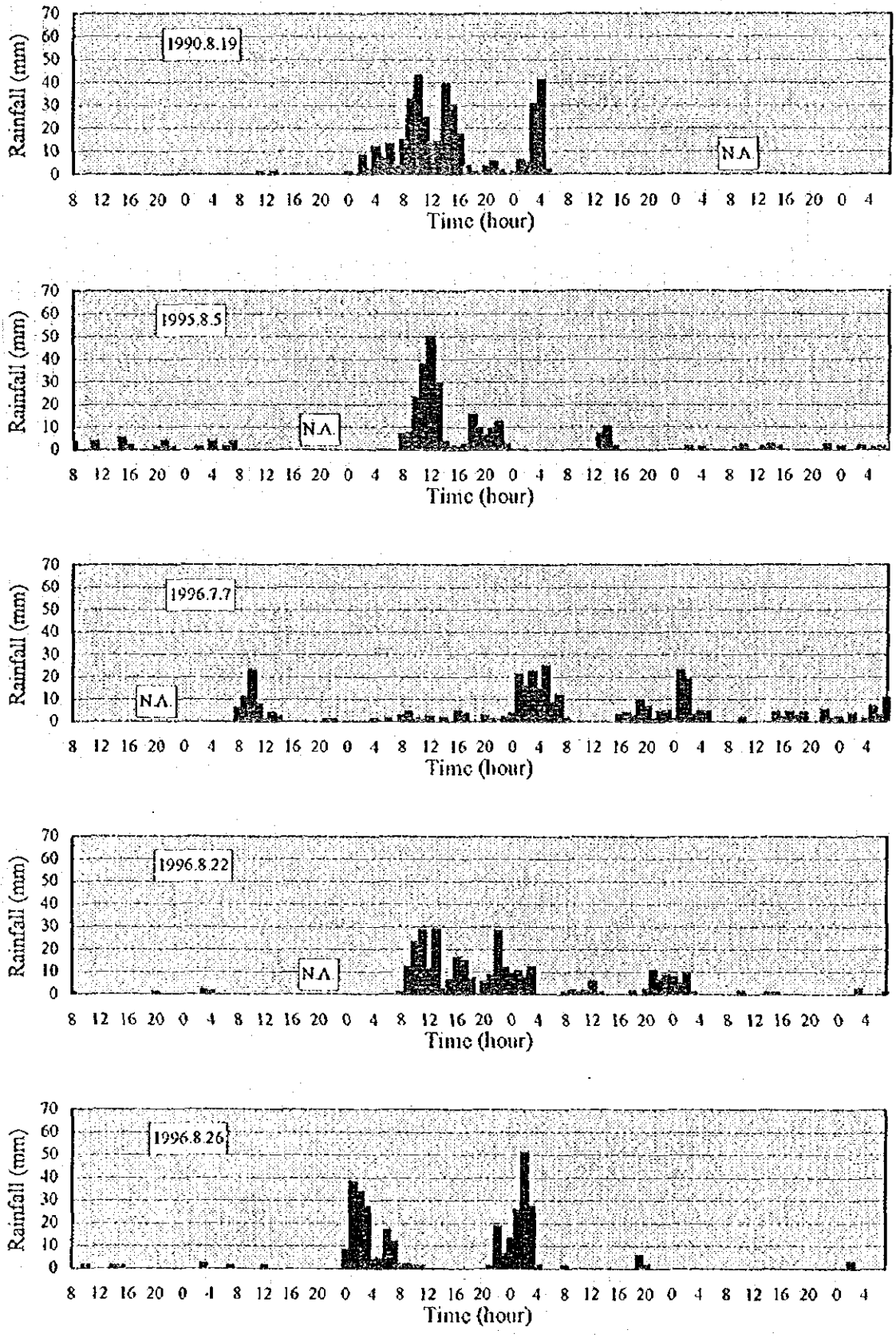


Figure-C.7.4(2) Hyetograph of Main Flood Rainfall in Ambon

SUPPORTING REPORT

PART-D

FLOOD CONTROL PLAN

THE STUDY ON FLOOD CONTROL FOR AMBON AND PASAHARI AREA
IN THE REPUBLIC OF INDONESIA
SUPPORTING REPORT
PART-D

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CHAPTER 1 DISCHARGE SYSTEMS FOR FLOOD WATER

1.1 River Systems

The Study area includes the basins of the five rivers named Ruhu River, Batu Merah River, Tomu River, Batu Gajah River and Batu Gantung River, from the north. The catchment areas and main river length were measured by the Study Team using the topographical map with scale of 1:5,000 and are stated in Table-D.1.1. The basin boundaries are illustrated in Figure-D.1.1.

Table-D.1.1 Catchment Area of Study River Basins

River Name	Catchment Area (km^2)	Length of Main Course (km)
Ruhu River	16.84	12.7
Batu Merah River	7.03	7.3
Tomu River	5.64	7.0
Batu Gajah River	5.97	6.7
Batu Gantung River	6.87	5.7

The longitudinal profiles of these five rivers are shown in Figure-D.1.2. The features of longitudinal slope by each river are presented in Table-D.1.2, dividing into downstream, mid-stream, and upstream sections. Features of the five target rivers are summarized as follows :

- Ruhu River, the most northerly of the target rivers and whose downstream and river mouth is away from the other rivers, has the largest basin and the most gentle river slope of the five rivers.
- Batu Merah River, Tomu River and Batu Gajah River, which are located in the center of the central city area, have similar features of basin area and slope. However, Batu Merah River has a slightly more gentle slope than the other two rivers.
- Batu Gantung River, which is located to the south of the target rivers, has the steepest slope of the five rivers. The big tributary which flows in at Desa Kudamati, with a catchment area of 1.8 km^2, seems not in fact to be a tributary. Although there is a water course to the upstream, it is not continuous to Batu Gantung River. Based on field reconnaissance, the upstream river water seems to infiltrate to groundwater near Desa Kudamati, but the condition at the time of flood has not yet identified.

Table-D.1.2 Features of Longitudinal Slope

River	Downstream		Mid-stream	Upstream
	EL. 0 - 5 m	EL. 0 -10 m	EL. 10 - 100 m	EL. 100 - 200 m
Ruhu	1/480	1/260	1/68	1/22
Batu Merah	1/370	1/230	1/39	1/10
Tomu	1/250	1/160	1/29	1/12
Batu Gajah	1/260	1/210	1/32	1/11
Batu Gantung	1/190	1/150	1/26	1/14

Source : JICA Study Team

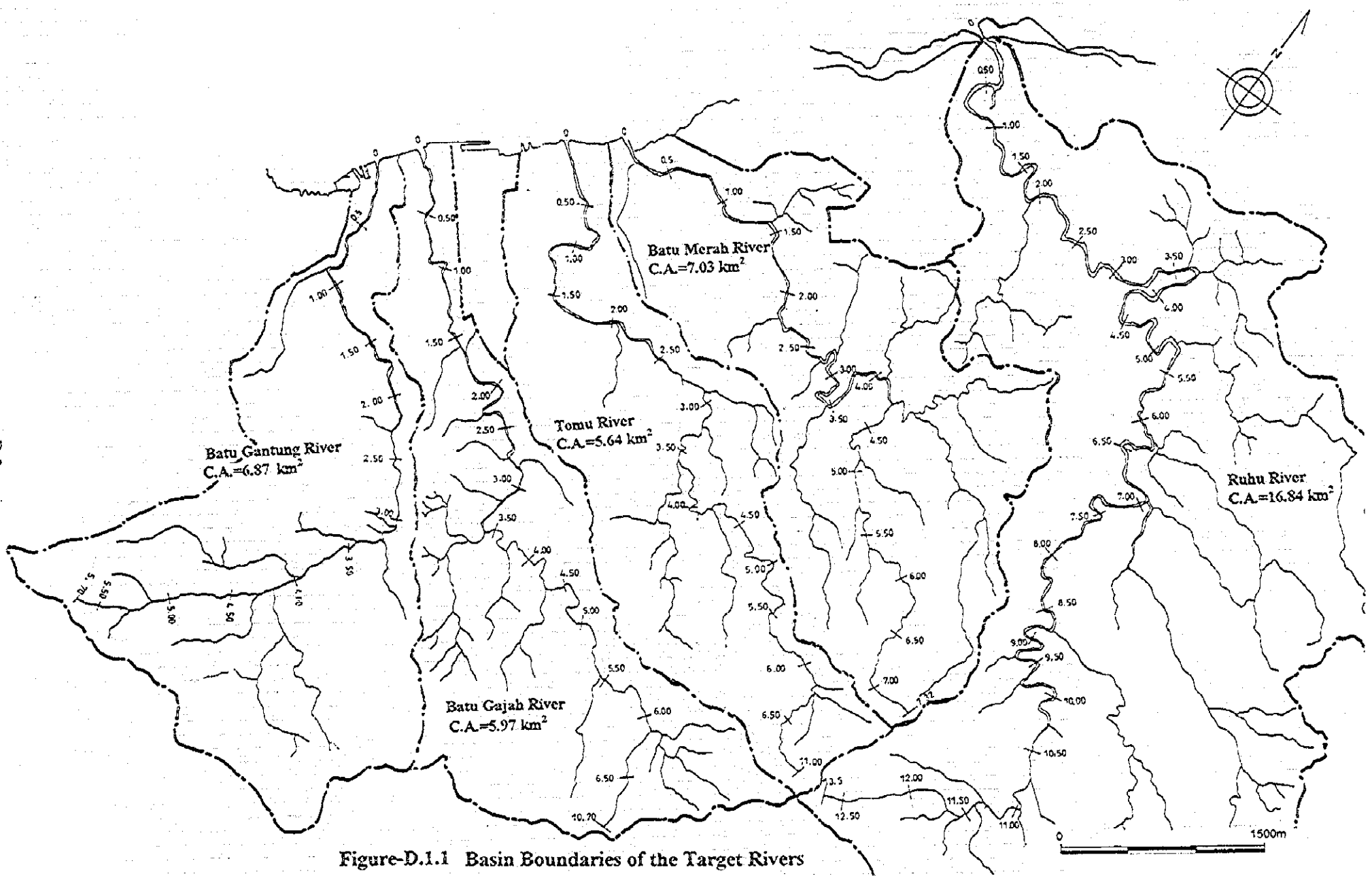


Figure-D.1.1 Basin Boundaries of the Target Rivers

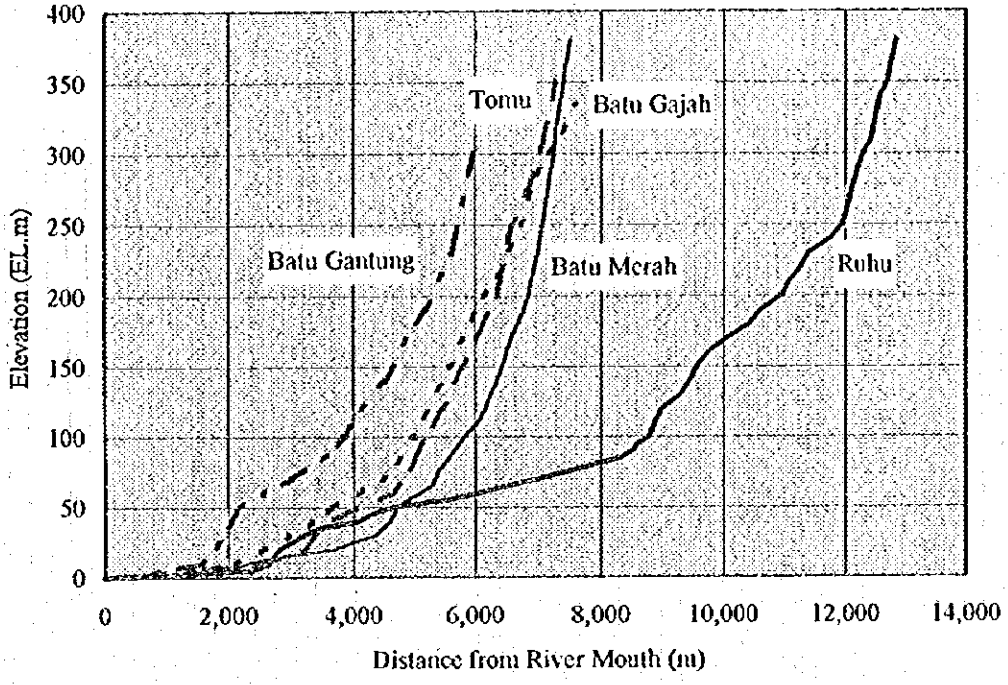


Figure-D.1.2 Longitudinal Section of the Target Rivers

1.2 Urban Drainage Systems

1.2.1 Current Situation

There are four rivers and two primary drainage channels running through the central Ambon City as shown in Figure-D.1.3. The four rivers, i.e. Batu Merah, Tomu, Batu Gajah and Batu Gantung Rivers have mountainous upstream area, but the two drainage channels, namely Alat and Titar Rivers are urban rivers with no flow from the mountain area. There are also three main secondary drainage channels, namely Merdeka, Mesjid and Baabullah channels, as well as numerous smaller drainage channels. The condition of these urban rivers and main drainage channels are described in the following paragraphs.

(1) Alat River

Alat River is an urban river that runs through the central city area between Batu Merah River and Tomu River before merging with Batu Merah River near the river mouth. The channel has a concrete lined structure of width typically between 2.5 and 3.5 meters and depth 1.5m. The river usually discharges domestic waste water from residential area. However when it rains, storm water from road sides and smaller drainage channels flows into the river and fills the channel to capacity. Since large amounts of garbage are often dumped into the channel from the surrounding area, the river discharge capacity has dropped and inundation frequently occurs. There is also a problem with sedimentation and deposits of sand and other debris are evident.

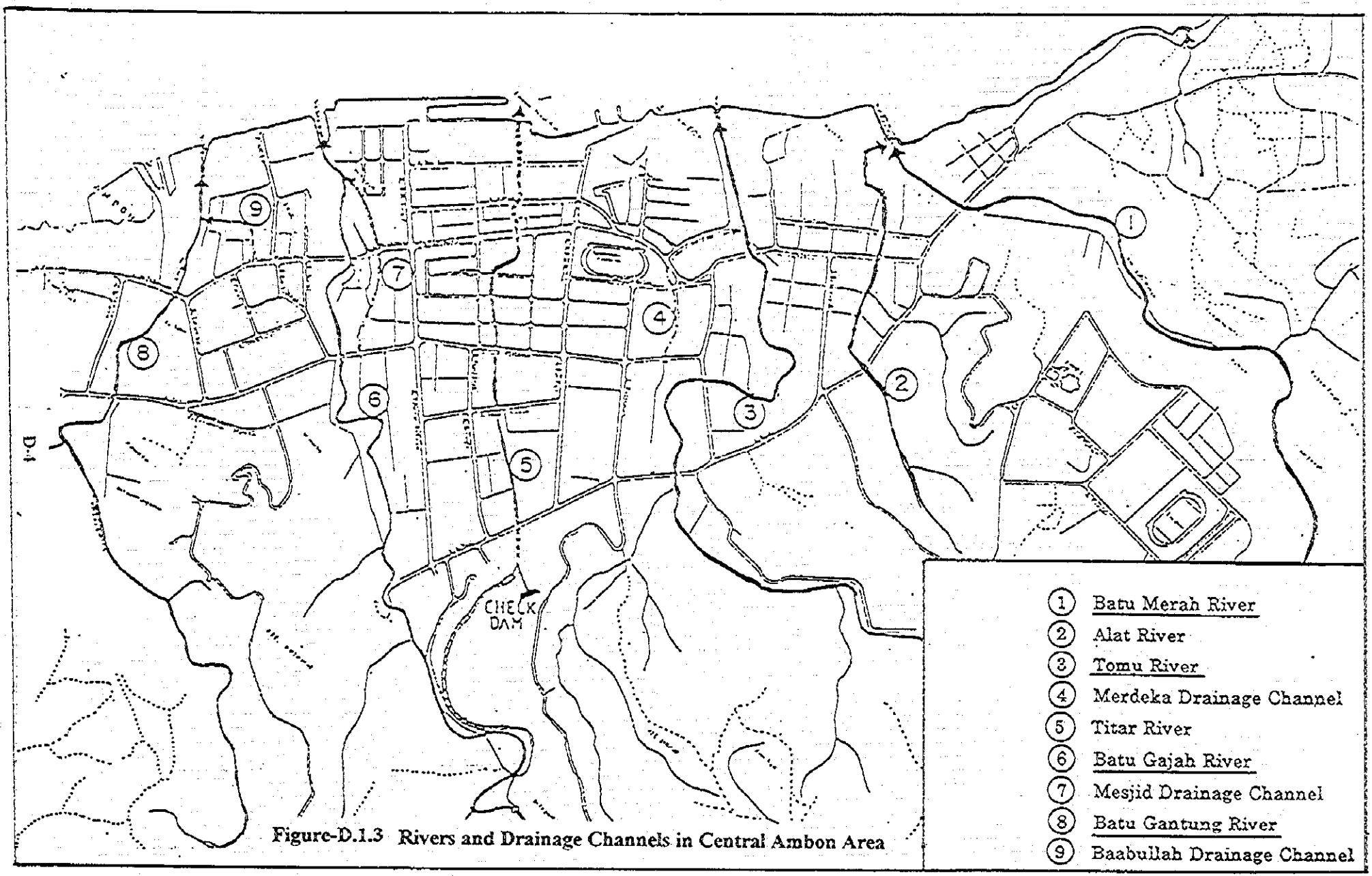


Figure-D.1.3 Rivers and Drainage Channels in Central Ambon Area

(2) Titar River

Titar River is an urban river of length 1500 m, that runs through the central city area between Tomu River and Batu Gajah River and discharges directly into Ambon Bay. Titar River receives sewage and storm water from many smaller drainage channels. Similar to Alat River, it is a concrete channel of width 2.5 to 3.5 m and depth 1.0 to 1.5 m, with its final 350 m constructed as a culvert through the downtown area before discharging to the sea. Due to the accumulation of garbage discarded from the surrounding houses, the river discharge capacity has dropped and inundation frequently occurs. The condition is worse in the culvert section. Titar River is connected to Batu Gajah River by a channel from the check dam on Batu Gajah. This channel was intended to function as means of flushing Titar River to prevent the build up of sediment and sewage deposits. However, the intake at the Batu Gajah check dam no longer functions and the channel has become blocked in places.

(3) Other Main Drainage Channels

In addition to the above two rivers, three main drainage channels receive domestic sewage and storm water from the central city area. Merdeka channel is nearly 600 m in length and flows between Tomu and Titar Rivers before merging with Tomu River. Mesjid channel flows between Batu Gajah and Titar Rivers and merges with Batu Gantung River. Mesjid channel is 500m long, about half of which is in culvert. There is a serious problem of sediment and rubbish deposits in the channel, as well as a bottleneck beneath the mosque where the building's foundations obstruct the channel. Baabullah channel flows between Batu Gajah and Batu Gantung Rivers before merging with Batu Gantung River. The total length of the channel is 300m, part of which is in culvert.

Figure-D.1.4 outlines schematically the urban drainage system in central Ambon City. Many small drainage channels in the central city are connected with Titar River. However, the discharge capacity of Titar River is very low due to dumping of garbage as described above. In order to prevent flood inundation from Titar River, as well as from the other urban rivers and channels, regular cleaning and maintenance of drainage channels is recommended to keep discharge capacities as high as possible.

1.2.2 Planned Improvements

According to the 1993 Final Report of the Technical Planning and Outline Plan for Urban Drainage in Ambon undertaken on behalf of Cipta Karya, the main problems with the existing urban drainage system, leading to localized flooding in the central city area, include :

- river water level being higher than the level in the secondary and tertiary drainage channels, due either to heavy rain or high tides.
- dumping of garbage in the drainage channels.
- sedimentation and build of up sand and other deposits.
- poor levels of operation and maintenance, with no evidence of cleaning or dredging of the drainage channels, probably due to limited funding.
- high growth rate in urban housing, often of an illegal temporary nature.
- poor structural condition of the channels.
- bottlenecks caused by the construction of building foundations, bridge piers, etc.

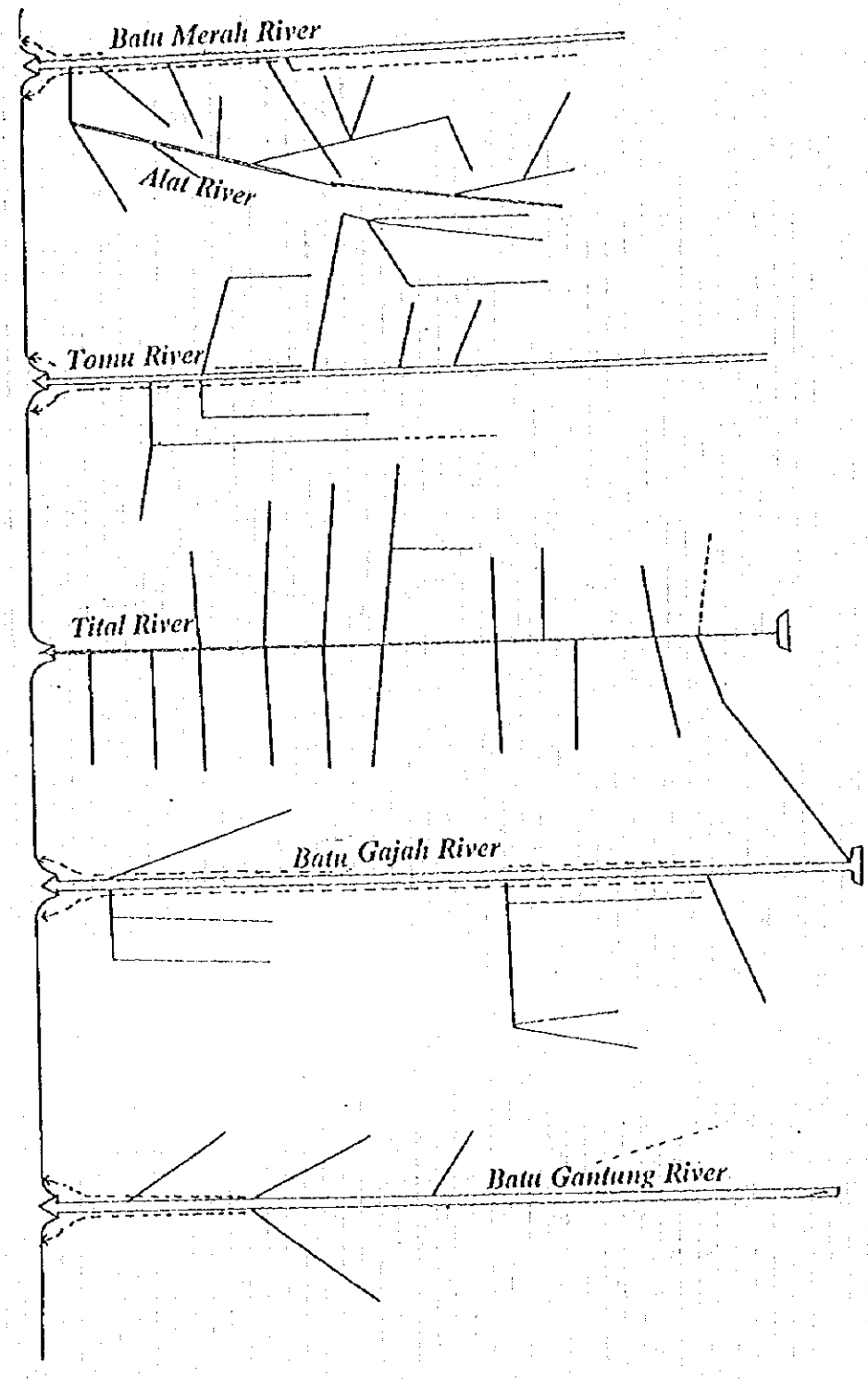


Figure-D.1.4 Schematic of Drainage System in Central Ambon Area

The Report recommendations are described below and Figure-D.1.5 shows the proposed improvements to the urban drainage system in the central Ambon area.

(1) Side Drains

Side drains are proposed for both the left and right sides of the four main rivers, Batu Merah, Tomu, Batu Gajah and Batu Gantung, from the point where runoff from the smaller side drainage channels is unable to flow into the main river to the river mouth. The side drains would collect the storm water run off and domestic sewage from the central city area and discharge directly to the sea. The main obstacles in constructing side drains are land acquisition and demolition of buildings on the route of the proposed drains. The report recommends construction of closed culverts or underground drains, with temporary relocation of residents and demolition of housing during the construction period.

(2) Alat River

Channel improvement and widening of the road culverts for Alat River are proposed. In particular, renovation of the channel and widening of a culvert to 3.5 m wide by 0.6 m deep are recommended for Alat River near to its confluence with Batu Merah, an area prone to localized flooding.

(3) Titar River

The renovation and improvement of Titar river is given highest priority in the Ambon Urban Drainage Plan, in particular, the reconstruction and renovation of the flushing duct which connects Titar River to the existing check dam on Batu Gajah. At the downstream of Titar River, discharge capacity needs to be increased by the construction of a second culvert, 2.0 m wide by 1.25 m high and of length 350 m. Dredging and maintenance of Titar River is also emphasized because of the low channel gradient and the limited discharge capacity.

(4) Other Main Drainage Channels

Baabullah Culvert. It is proposed to change the route of the existing Baabullah Channel to flow directly into Ambon Bay, rather than connecting to Batu Gantung. The new route would be constructed as a closed culvert of width 1.5 m and depth 1.1 m, running along existing streets and having a removable concrete plate cover and access manholes for maintenance.

In addition to the improvements described above, the lining of two existing natural drainage channels is proposed; namely for Kali Mati, a tributary of Tomu River, and for Air Mata Cina, a tributary of Batu Gajah River. For Kali Mati, the report recommends lining the channel with masonry over a length of 1 km and a typical section of 3.5 m wide by 1.0 m deep.

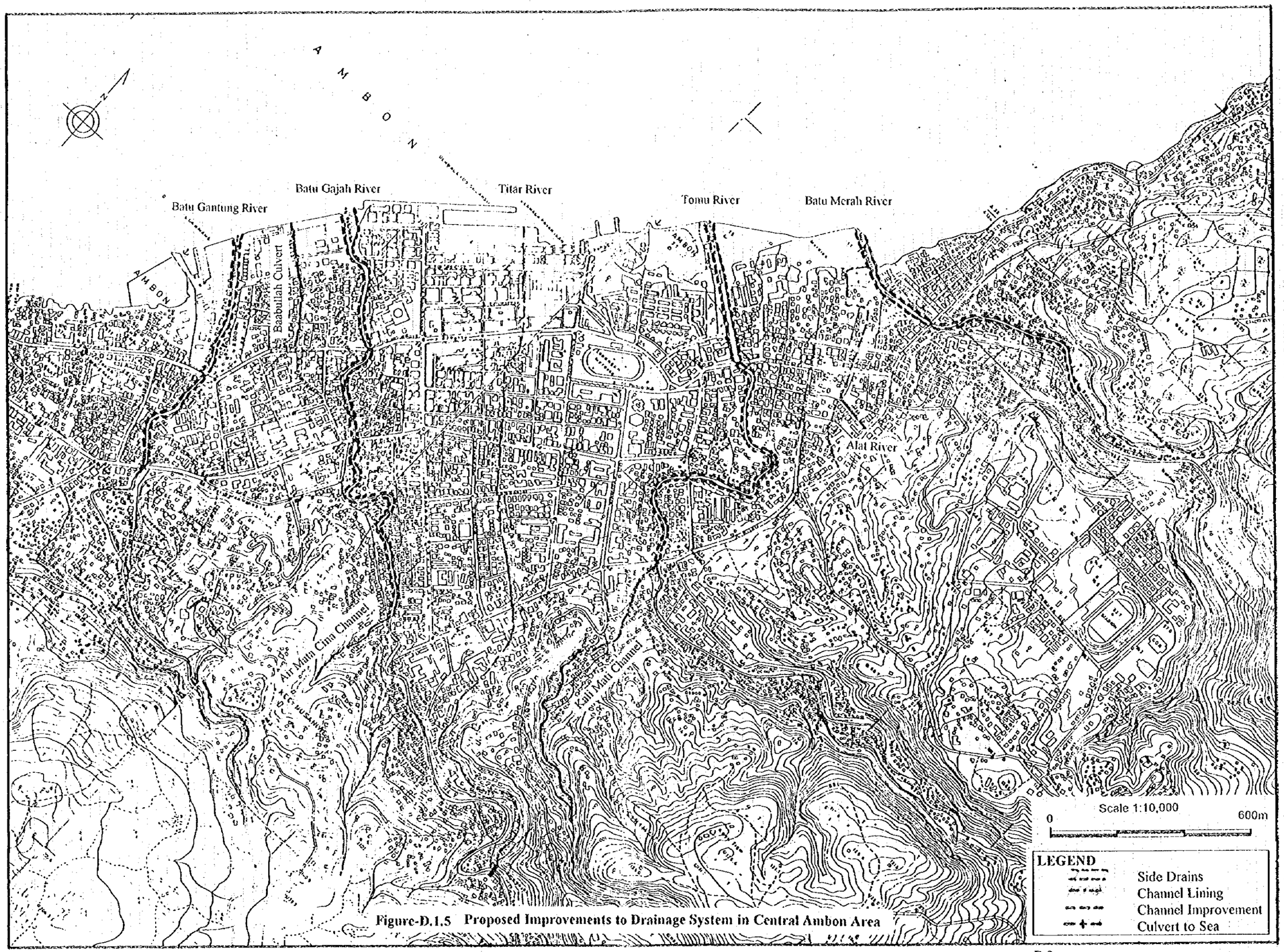


Figure-D.1.5 Proposed Improvements to Drainage System in Central Ambon Area

1.3 Current Discharge Capacity of Rivers

Longitudinal and cross sectional river surveys for the five target rivers were carried out during Phase I of this Study as described in Supporting Report Part-J. The results of these surveys were used to assess the current discharge capacity of the rivers. The river cross sections were surveyed every 50 m over a length of between 1.6 km (Ruhu & Batu Merah) and 2.9 km (Tomu & Batu Gajah). 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). 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-D.1.3 and shown in more detail in Table-D.1.4. The summary table gives the average and extreme values of minimum discharge capacity. Figure-D.1.6. shows the variation in river width and calculated discharge capacity at each cross section of the five target rivers in Ambon.

Table-D.1.3 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	43	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

Table-D.1.4(1) Discharge Capacity - Ruhu River

RUHU RIVER				Discharge Capacity (m3/sec)							
		Bank Height		NON UNIFORM FLOW				UNIFORM FLOW			
Section	Distance	(m)		No Freeboard		0.6m Freeboard		No Freeboard		0.6m Freeboard	
No.	(km)	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Ruh01+	0.000	2.02	2.20	400	400	350	350	400	400	350	350
Ruh03+	0.100	2.07	1.46	365	245	247	150	216	144	146	88
Ruh05+	0.200	1.96	2.15	185	209	118	139	250	288	159	192
Ruh07+	0.300	2.08	2.23	193	212	120	138	216	244	134	159
Ruh09+	0.400	2.04	2.13	170	182	95	105	186	200	104	115
Ruh11+	0.500	2.10	1.96	162	140	77	60	156	138	74	59
Ruh13+	0.600	2.12	2.27	127	139	81	91	62	70	40	46
Ruh15+	0.700	2.14	2.13	66	66	43	43	88	88	57	57
Ruh17+	0.800	2.05	2.37	58	73	38	47	60	86	39	55
Ruh19+	0.900	2.41	2.40	69	69	43	43	77	77	48	48
Ruh21+	1.000	2.83	3.19	80	99	50	68	115	144	72	99
Ruh23+	1.100	3.01	3.42	85	106	54	75	112	145	71	103
Ruh25+	1.200	3.14	4.12	87	145	55	108	100	184	63	137
Ruh27+	1.300	3.64	4.49	110	162	75	124	124	208	85	159
Ruh29+	1.400	4.80	4.55	190	172	147	130	169	150	131	113
Ruh31+	1.500	5.16	3.06	231	50	175	34	158	44	120	30
Ruh33+	1.600	5.51	5.77	192	212	147	166	200	233	153	182

Table-D.1.4(2) Discharge Capacity - Batu Merah River

BATU MERAH RIVER				Discharge Capacity (m3/sec)							
		Bank Height		NON UNIFORM FLOW				UNIFORM FLOW			
Section	Distance	(m)		No Freeboard		0.6m Freeboard		No Freeboard		0.6m Freeboard	
No.	(km)	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Mer01+	0.000	2.29	2.28	250	250	200	200	250	250	200	200
Mer03+	0.100	2.06	2.32	250	250	200	200	230	250	200	200
Mer05+	0.200	1.82	1.68	107	95	57	48	123	108	66	55
Mer07+	0.300	1.41	1.65	56	75	31	39	43	58	24	30
Mer09+	0.400	1.81	1.33	46	35	31	19	44	24	30	13
Mer11+	0.500	2.14	2.04	44	42	30	27	36	32	25	21
Mer13+	0.600	2.31	2.11	37	33	24	19	33	26	21	15
Mer15+	0.700	2.40	2.25	40	37	28	26	36	32	25	22
Mer17+	0.800	2.69	2.54	30	27	17	14	38	31	22	16
Mer19+	0.900	2.97	3.86	34	63	17	43	22	54	11	37
Mer21+	1.000	3.37	3.45	36	37	24	26	33	37	22	26
Mer23+	1.100	3.66	3.65	34	34	24	24	27	27	19	19
Mer25+	1.200	4.01	4.92	27	45	16	33	21	46	12	34
Mer27+	1.300	4.51	4.54	32	32	20	20	22	22	14	14
Mer29+	1.400	4.96	4.86	31	29	17	15	17	17	9	9
Mer31+	1.500	5.31	5.19	27	25	20	18	23	20	17	14
Mer33+	1.600	5.72	5.82	31	33	22	24	23	25	16	18

Table-D.1.4(3) Discharge Capacity - Tomu River

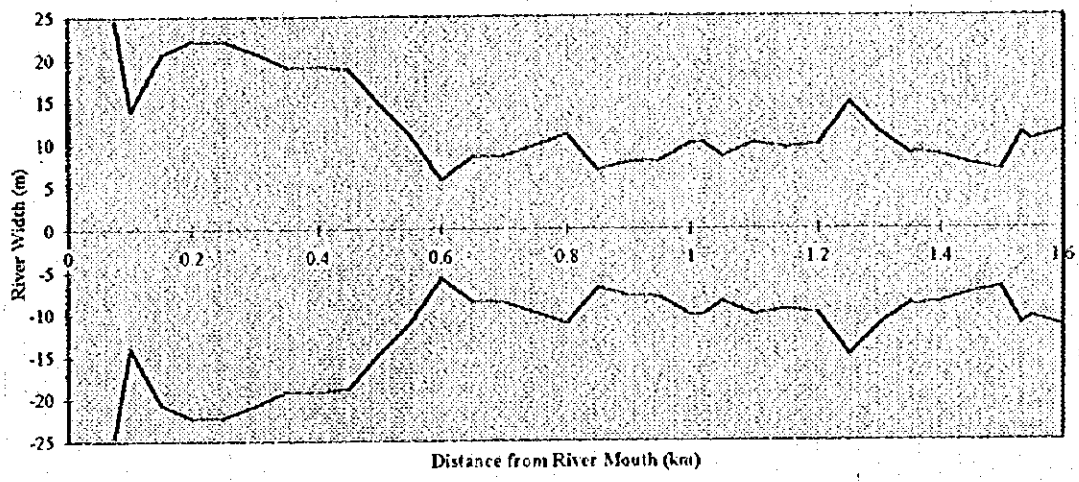
TOMU RIVER				Discharge Capacity (m3/sec)							
				NON UNIFORM FLOW				UNIFORM FLOW			
Section	Distance	Bank Height (m)		No Freeboard		0.6m Freeboard		No Freeboard		0.6m Freeboard	
No.	(km)	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Tom01+	0.000	1.82	2.82	250	250	194	250	248	300	192	300
Tom03+	0.100	2.09	1.91	176	157	117	100	179	163	119	104
Tom05+	0.200	1.87	1.96	113	120	68	75	138	145	83	91
Tom07+	0.300	2.29	2.15	128	117	80	70	131	120	82	72
Tom09+	0.400	3.25	3.56	144	168	105	126	285	300	208	225
Tom11+	0.500	4.32	3.81	250	217	206	154	215	171	177	121
Tom13+	0.600	4.00	3.87	150	140	104	95	176	164	122	111
Tom15+	0.700	4.24	4.15	84	80	59	56	152	145	107	102
Tom17+	0.800	4.44	4.35	117	111	75	68	80	75	51	46
Tom19+	0.900	5.04	4.70	91	78	68	54	100	85	75	59
Tom21+	1.000	5.15	4.92	75	67	54	50	135	117	97	87
Tom23+	1.100	5.30	5.54	70	79	48	56	143	170	98	121
Tom25+	1.200	5.88	5.51	87	73	65	51	214	162	160	113
Tom27+	1.300	6.29	6.41	101	106	77	82	218	238	166	184
Tom29+	1.400	6.62	6.11	115	93	89	62	188	120	145	80
Tom31+	1.500	7.08	7.18	126	132	86	94	133	145	91	103
Tom33+	1.600	7.09	7.01	48	46	28	26	62	58	36	33
Tom35+	1.700	7.17	7.15	48	48	25	25	42	42	22	22
Tom37+	1.800	7.48	7.65	38	44	21	24	43	52	24	28
Tom39+	1.900	7.97	7.99	47	47	24	25	40	40	20	21
Tom41+	2.000	9.08	8.60	60	42	38	24	95	68	60	39
Tom43+	2.100	8.47	10.65	23	120	15	92	38	180	25	138
Tom45+	2.200	10.12	9.11	61	27	40	17	96	40	63	25
Tom47+	2.300	11.12	11.91	82	131	55	92	90	142	60	100
Tom49+	2.400	11.23	12.46	54	117	34	84	57	117	36	84
Tom51+	2.500	12.70	12.61	72	68	43	39	79	75	47	43
Tom53+	2.600	14.76	14.20	123	92	90	65	125	95	91	67
Tom55+	2.700	13.58	13.86	34	42	21	25	57	75	35	45
Tom57+	2.800	18.51	17.95	195	150	147	107	300	300	226	214
Tom59+	2.900	18.01	18.42	120	150	47	97	137	181	54	117

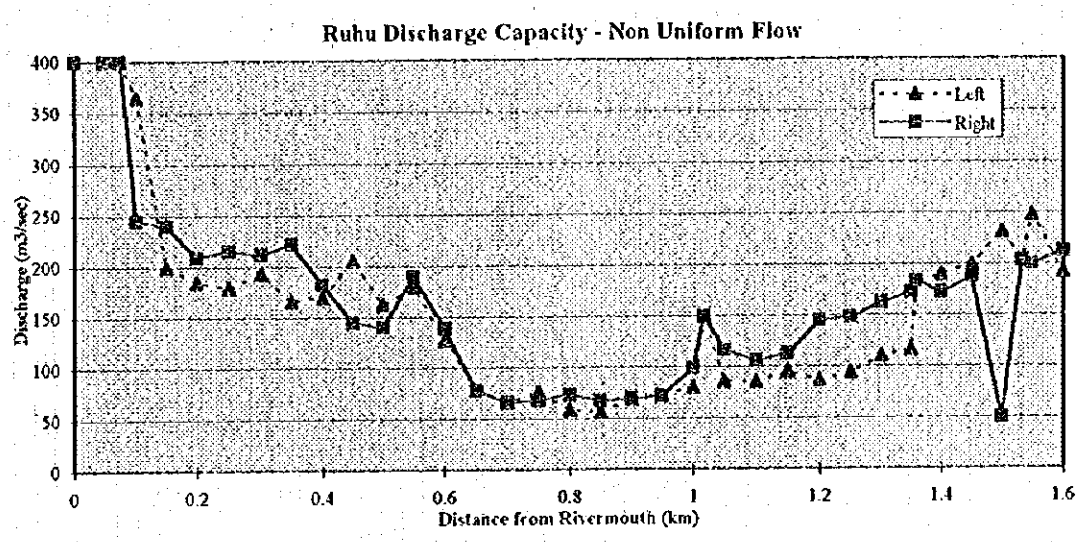
Table-D.1.4(4) Discharge Capacity - Batu Gajah River

BATU GAJAH RIVER				Discharge Capacity (m3/sec)							
				NON UNIFORM FLOW				UNIFORM FLOW			
Section	Distance	Bank Height (m)		No Freeboard		0.6m Freeboard		No Freeboard		0.6m Freeboard	
No.	(km)	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Gaj01+	0.000	1.87	1.90	250	250	250	250	250	250	250	250
Gaj03+	0.100	2.05	1.95	200	182	104	91	250	250	130	125
Gaj05+	0.200	2.17	2.18	121	121	66	66	100	100	55	55
Gaj07+	0.300	2.64	2.56	61	57	35	31	75	70	43	38
Gaj09+	0.400	3.45	3.00	77	57	51	34	152	107	101	64
Gaj11+	0.500	3.43	3.38	67	65	35	32	50	48	26	24
Gaj13+	0.600	3.76	3.67	45	42	25	23	50	48	28	26
Gaj15+	0.700	3.99	3.98	45	45	23	23	38	38	19	19
Gaj17+	0.800	6.03	6.21	94	101	72	78	160	174	123	134
Gaj19+	0.900	6.36	6.60	103	114	76	87	131	146	97	111
Gaj21+	1.000	6.70	7.37	114	146	85	118	121	163	90	132
Gaj23+	1.100	6.96	7.36	87	110	56	75	100	125	64	85
Gaj25+	1.200	8.07	7.72	140	116	100	80	120	100	86	69
Gaj27+	1.300	7.85	7.88	67	67	44	45	100	100	66	67
Gaj29+	1.400	7.03	7.32	25	38	11	18	25	37	11	18
Gaj31+	1.500	7.97	8.24	41	54	19	25	41	57	19	26
Gaj33+	1.600	9.21	9.29	61	66	31	35	55	58	28	31
Gaj35+	1.700	10.45	10.07	78	62	53	37	123	88	84	53
Gaj37+	1.800	11.24	12.16	110	179	71	133	100	160	65	119
Gaj39+	1.900	11.31	11.85	67	91	42	65	88	140	55	100
Gaj41+	2.000	12.68	13.09	96	120	66	86	79	96	54	69
Gaj43+	2.100	12.85	14.87	57	140	37	113	62	163	40	132
Gaj45+	2.200	13.84	13.64	47	42	32	26	102	92	69	57
Gaj47+	2.300	15.13	15.70	58	77	33	57	105	175	60	130
Gaj49+	2.400	17.65	17.01	150	100	102	64	236	154	160	99
Gaj51+	2.500	17.95	17.78	49	41	24	21	72	61	35	31

Table-D.1.4(5) Discharge Capacity - Batu Gantung River

BATU GANTUNG RIVER				Discharge Capacity (m3/sec)							
				NON UNIFORM FLOW				UNIFORM FLOW			
Section	Distance	Bank Height (m)		No Freeboard		0.6m Freeboard		No Freeboard		0.6m Freeboard	
No.	(km)	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Gan01+	0.000	2.76	2.16	250	250	250	187	250	231	250	173
Gan03+	0.100	1.25	1.98	96	169	50	108	81	143	42	91
Gan05+	0.200	2.19	2.20	96	96	58	58	87	87	53	53
Gan07+	0.300	2.42	2.61	86	97	53	63	64	73	39	47
Gn9B1+	0.400	3.85	3.84	78	78	58	58	250	250	186	186
Gan11+	0.500	3.12	3.03	37	35	23	22	83	77	52	48
Gan13+	0.600	3.48	3.57	45	47	28	30	71	77	44	49
Gan15+	0.700	3.94	3.99	54	56	34	35	88	93	55	58
Gan17+	0.800	4.53	4.69	78	83	48	56	81	92	50	62
Gan19+	0.900	4.95	6.08	64	133	36	94	58	117	33	83
Gan21+	1.000	6.44	6.42	96	96	67	67	80	80	56	56
Gan23+	1.100	6.42	6.78	60	74	39	51	48	57	31	39
Gan25+	1.200	7.78	7.63	65	60	24	20	111	105	41	35
Gan27+	1.300	7.50	7.46	58	58	40	39	63	63	43	42
Gan29+	1.400	8.67	8.41	70	60	45	39	77	67	50	44
Gan31+	1.500	14.59	15.90	200	250	139	250	200	250	139	250
Gan33+	1.600	19.53	19.73	250	250	250	250	250	250	250	250
Gan35+	1.700	30.02	30.70	250	250	250	250	250	250	250	250
Gan37+	1.800	45.54	45.00	250	250	250	250	250	250	250	250
Gan39+	1.900	49.14	50.00	69	104	45	80	120	200	78	154
Gan41+	2.000	53.52	53.52	70	70	53	53	210	210	159	159





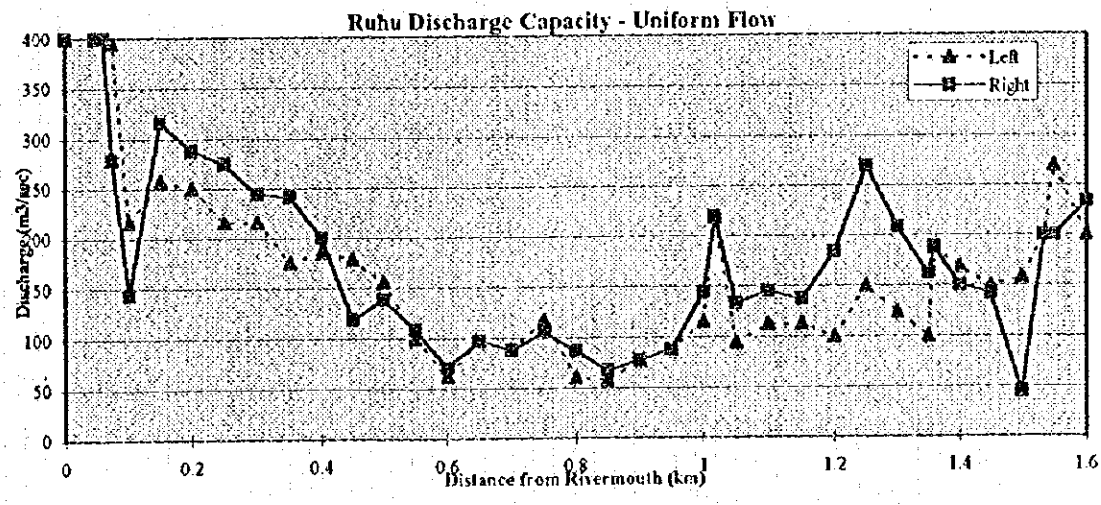
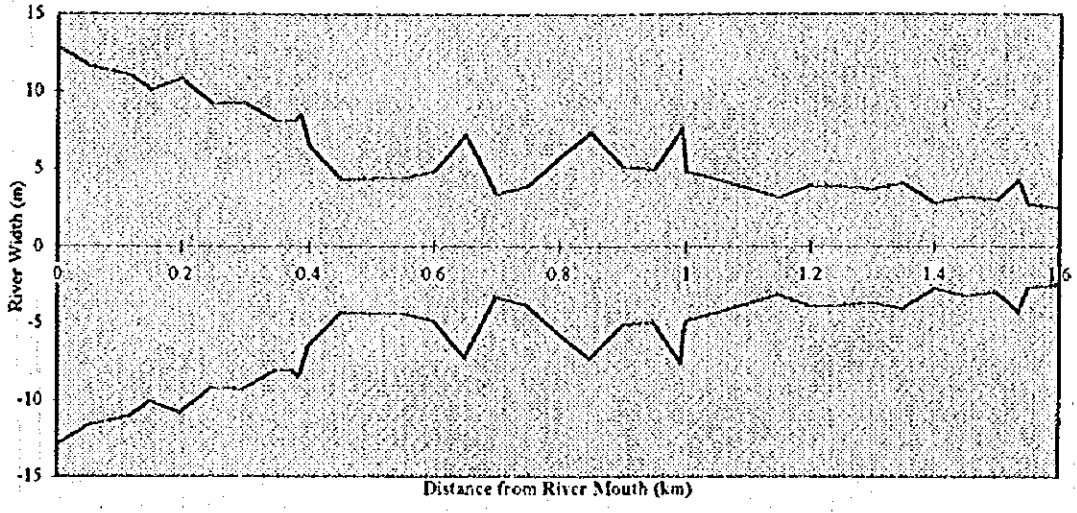
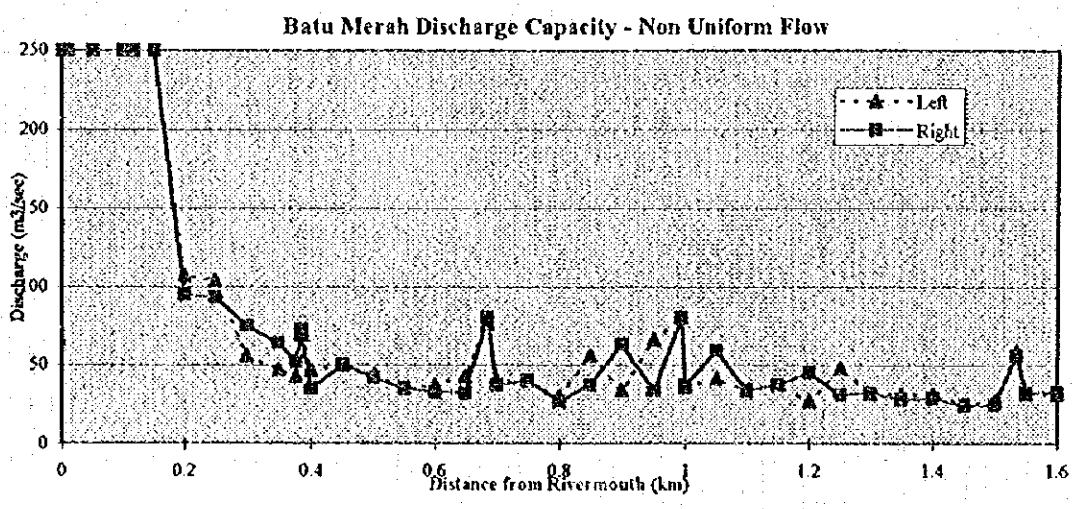


Figure-D.1.6(1) River Width and Discharge Capacity - Ruhu River





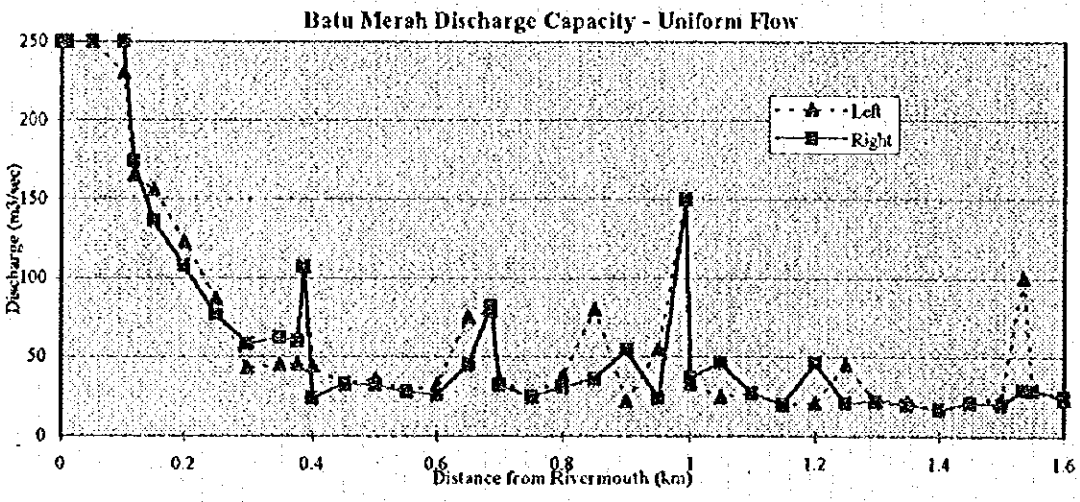
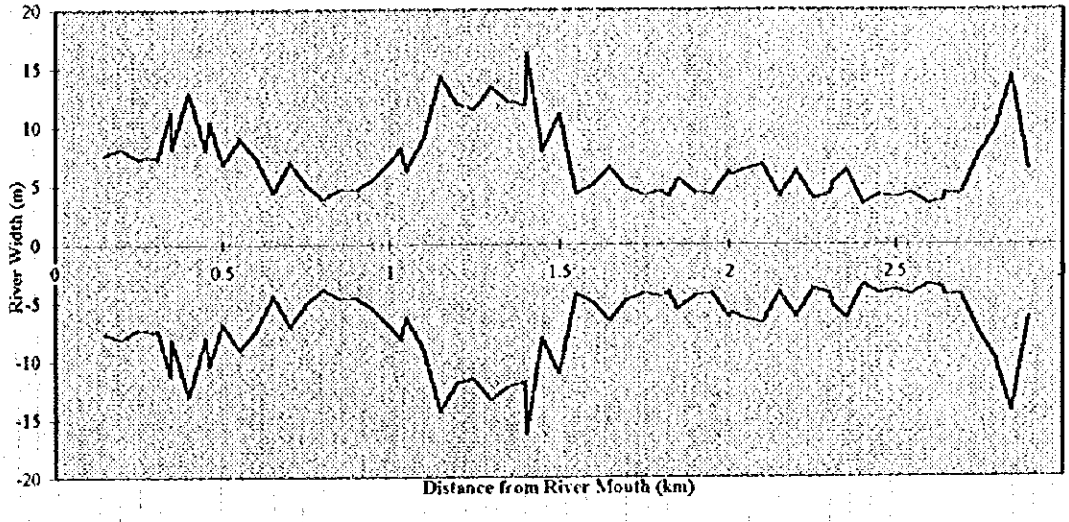
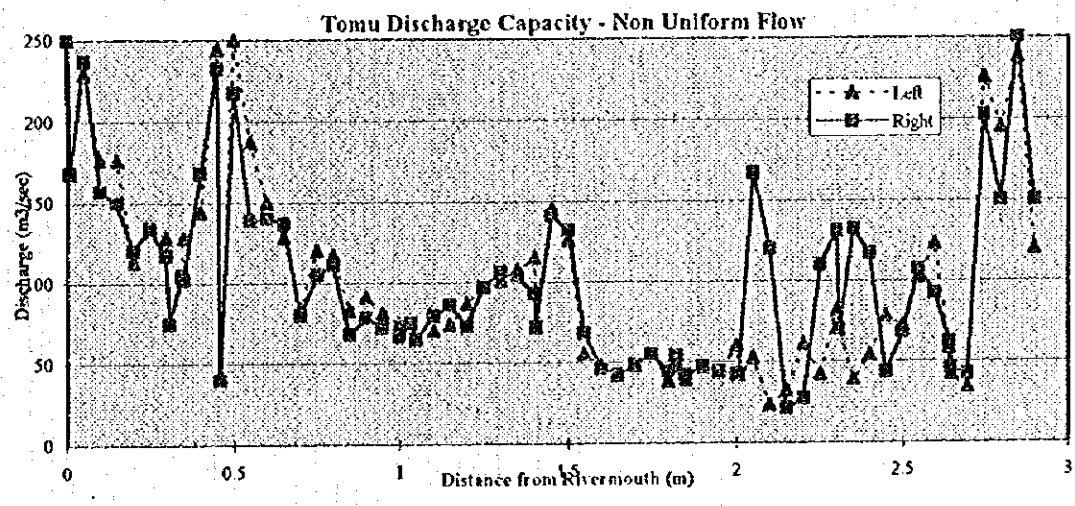


Figure-D.1.6(2) River Width and Discharge Capacity - Batu Merah River





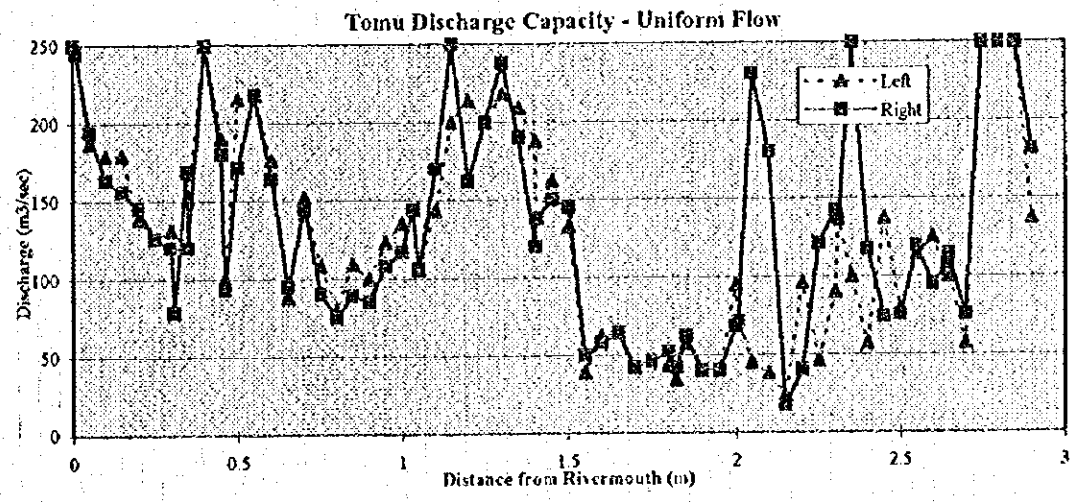
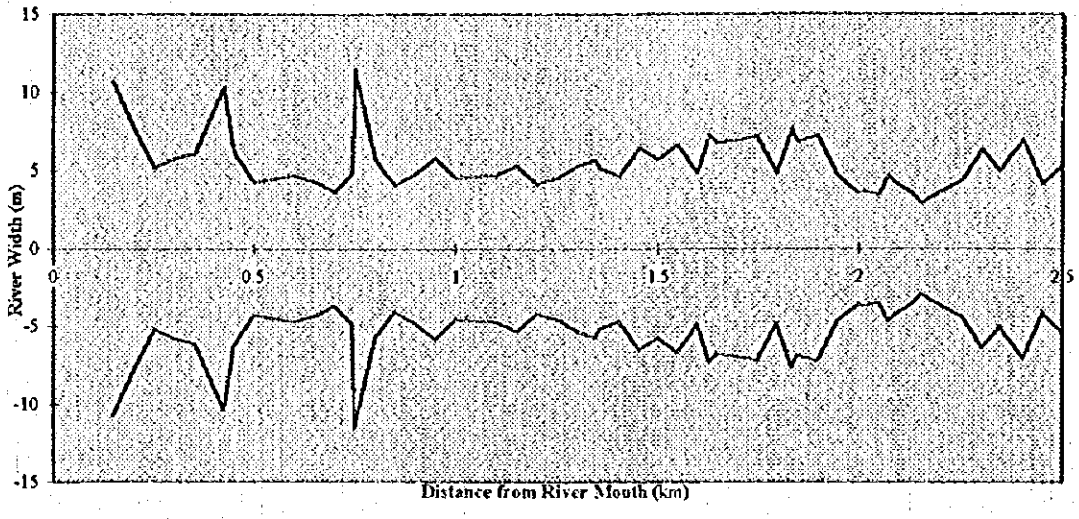
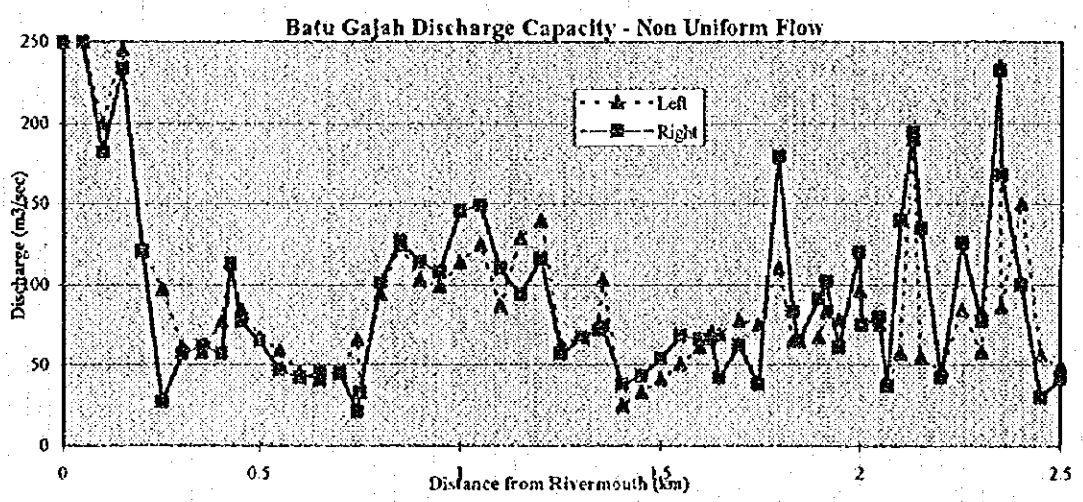


Figure-D.1.6(3) River Width and Discharge Capacity - Tomu River





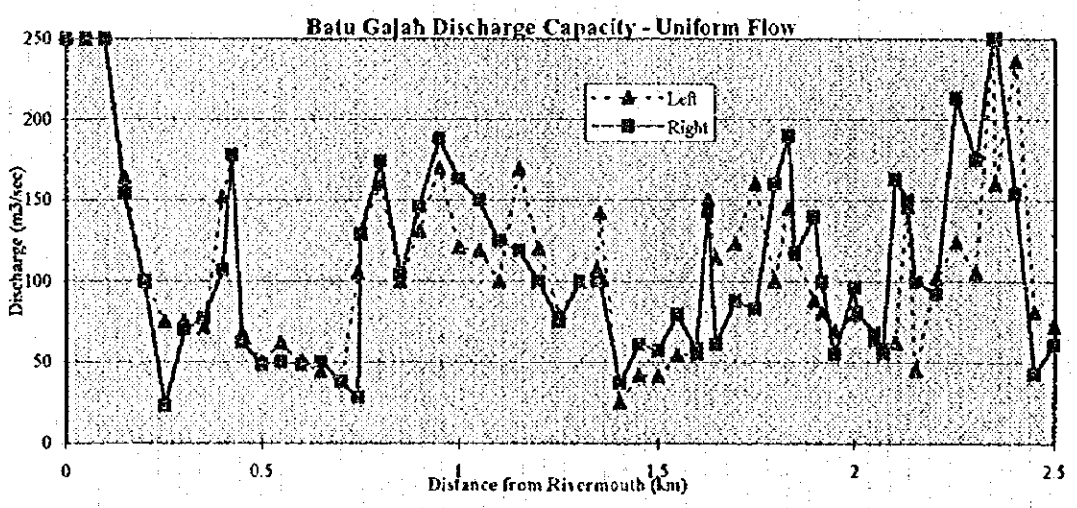
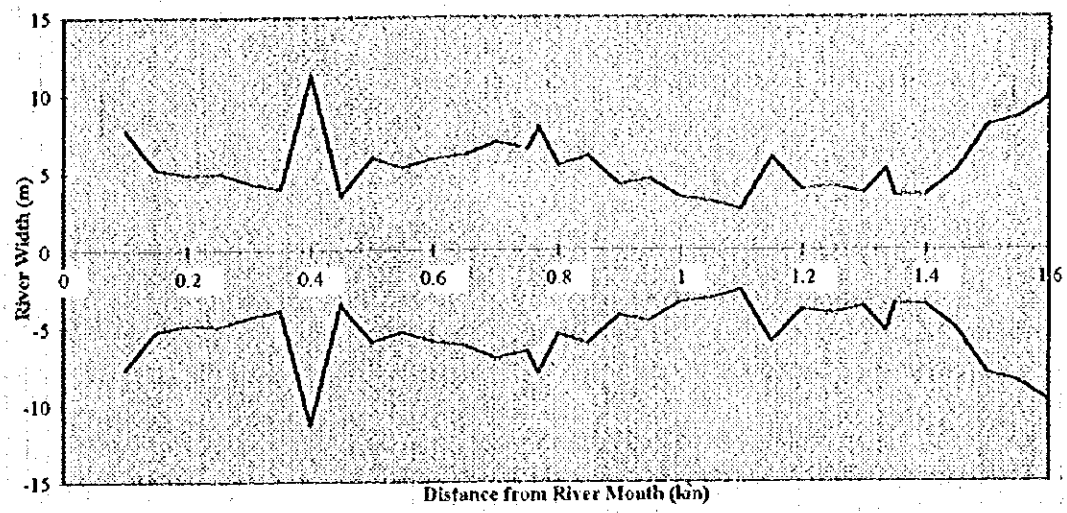
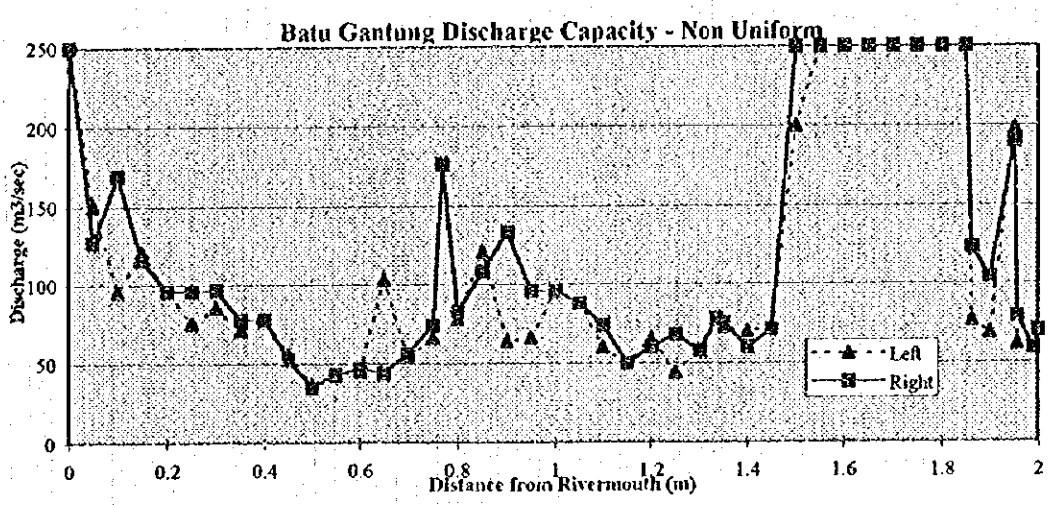


Figure-D.1.6(4) River Width and Discharge Capacity - Batu Gajah River





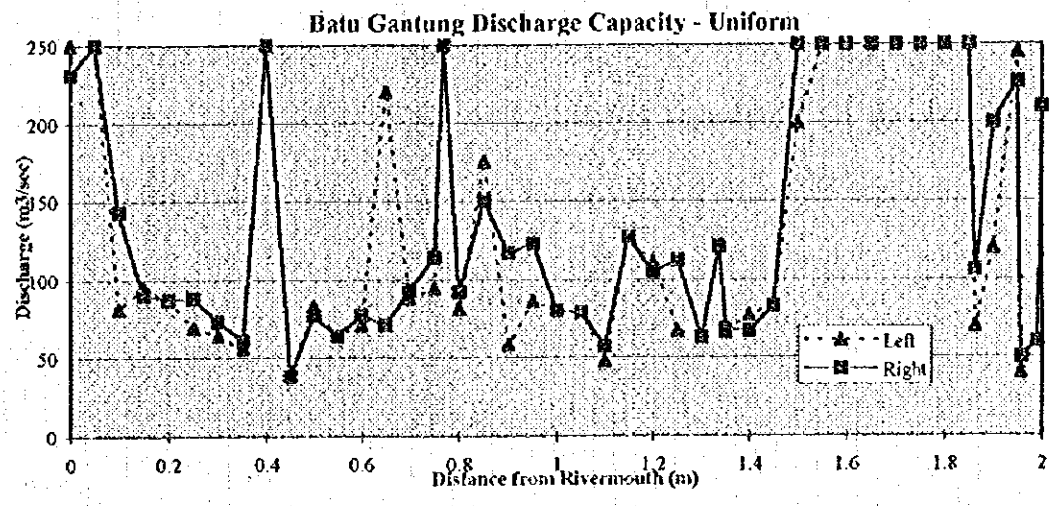


Figure-D.1.6(5) River Width and Discharge Capacity - Batu Gantung River