Fig. E-11 Location of Existing Bank Protection Works

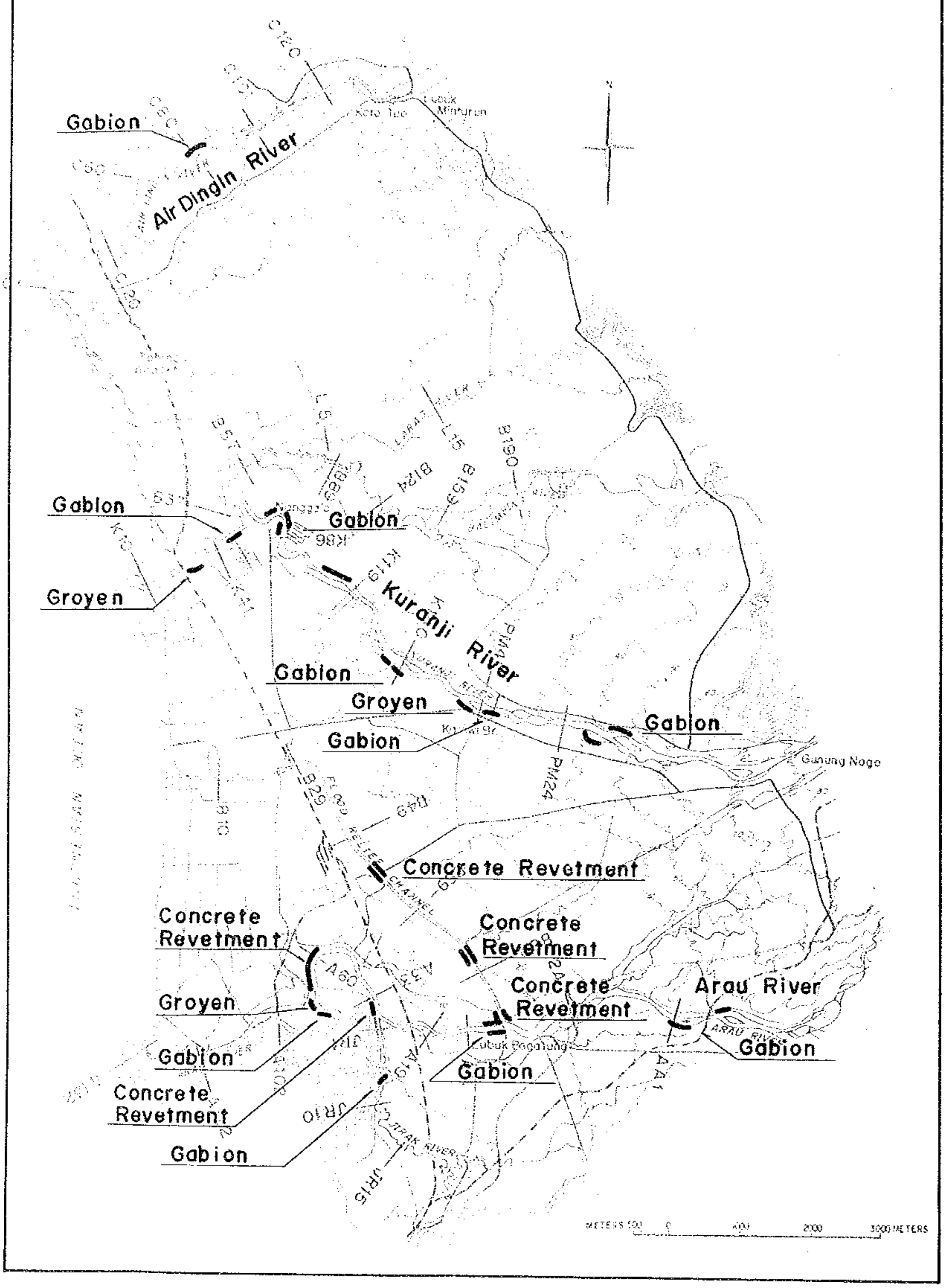
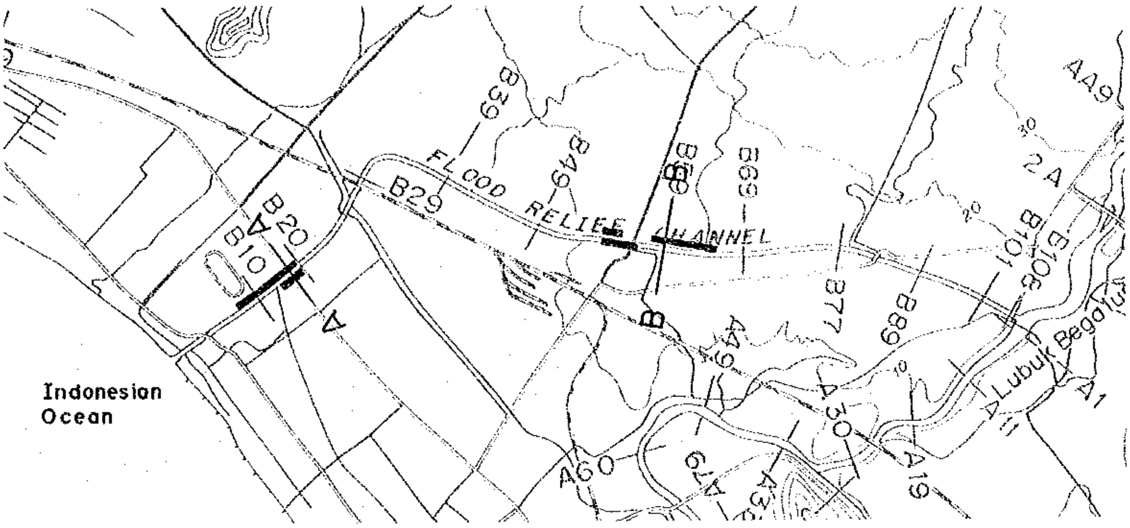
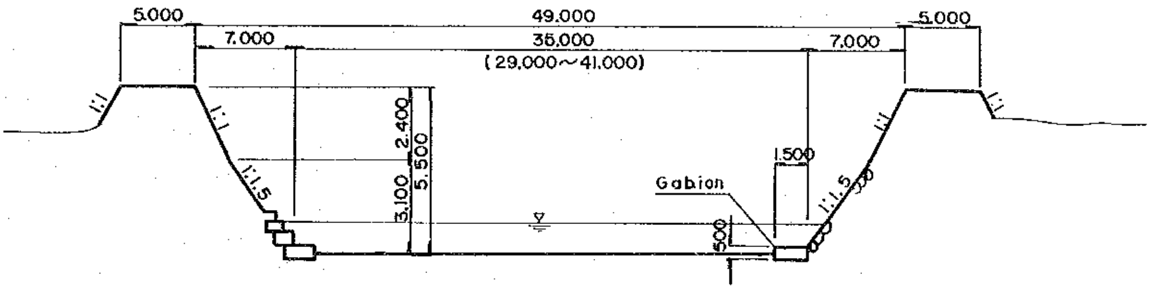


Fig. E-12 Typical Cross Section of Existing Dike (Flood Relief Channel)

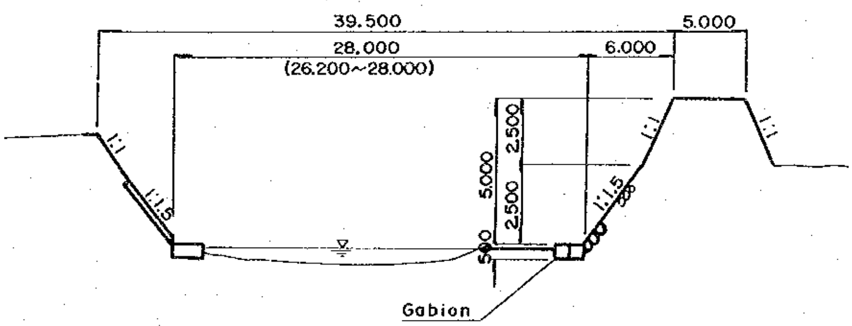
Location



A - A



B - B



APPENDIX F

FLOOD RUNOFF
AND
FLOODING MECHANISM

APPENDIX F

FLOOD RUNOFF AND FLOODING MECHANISM

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1. Flood Runoff

1.1 Methodology

1.1.1 General

According to the reports formerly conducted with regard to flood runoff of the Arau, Kuranji and Air Dingin rivers, both the unit graph method and the combined Melchior, De Weduwen and Thiessen methods were used. These estimates are reproduced in Table F-1. In this study, the storage function method is applied, since the method enables the estimation of runoff hydrographs from rainfall data in consideration of effect of flooding.

A runoff simulation model for calculation of a discharge hydrograph by use of the storage function method is, therefore, prepared. The flood runoff is analized on the basis of time-wise and aerial distribution of rainfall series observed in the past floods.

1.1.2 Runoff from Subbasin

A runoff from a subbasin is estimated as follows :

Equation for runoff from a subbasin :

$$S_1 = Kq_1^p \quad \text{(equation of storage)} \quad \cdots\cdots \quad (1.1)$$

$$r - q_1 = \frac{dS_1}{dt} \quad \text{(equation of continuity)} \quad \cdots\cdots \quad (1.2)$$

Where, S_1 : storage in a subbasin (mm)
r : effective rainfall (mm/hr)
q_1 : runoff from a subbasin (mm/hr)
K,p: storage coefficients

The factors such as a primary runoff percentage f_1 and saturation rainfall, R_{sa} are used for estimates of effective rainfall. The following assumptions are used in the calculation.

i) The runoff consists of a direct runoff and a base flow.

ii) The drainage area of subbasin is divided into the infiltration and primary runoff areas.

iii) In the infiltration area, the rainfall is infiltrated up to a saturation point, after that all rainfall becomes a direct runoff. The rainfall from the beginning to saturation point is called the saturation rainfall (R_{sa}).

iv) In the primary runoff area, all rainfall changes to a direct runoff, and a ratio of the primary runoff area to a drainage area is called the primary runoff percentage (f_1).

The runoff from the primary runoff area, q_1 is calculated by the following equation which is derived from Eqs. 1.1 and 1.2.

$$q_1(t) = 2 \left[r_{(t)} - \frac{K}{\Delta t} \{ q_1^p(t) - q_1^p(t-\Delta t) \} \right] - q_1(t-\Delta t) \quad \cdots\cdots\cdots (1.3)$$

Where Δt is time interval in calculation. In the calculation, the trial and error procedure is used. The runoff from the infiltration area, q_{sal}, is calculated by the following equation.

$$q_{sal} = 0, \quad (\Sigma r < R_{sa}) \quad \cdots\cdots\cdots (1.4)$$

$$q_{sal} = q_1, \quad (\Sigma r > R_{sa}) \quad \cdots\cdots\cdots (1.5)$$

Where Σr is a cumulative rainfall from the beginning.

The total discharge from a subbasin is calculated by use of the following equation.

$$\bar{Q} = \frac{1}{3.6} f_1 A q_1 + \frac{1}{3.6} (1 - f_1) A q_{sal} + Q_1 \quad \cdots\cdots\cdots (1.6)$$

$$Q(t) = \bar{Q}(t - T_1) \quad \cdots\cdots\cdots (1.7)$$

Where,
- Q : runoff from a subbasin (m^3/s)
- $\bar{Q}$: hypothetical runoff (m^3/s)
- q_1 : runoff from a primary area (mm/hr)
- q_{sal} : runoff from an infiltration area (mm/hr)
- f_1 : primary runoff percentage
- A : drainage area of subbasin (km^2)
- Q_1 : base flow (m^3/s)
- T_1 : lag-time (hr)

1.1.3 Channel Flow

The storage function of channel flow is estimated as follows :

Equation for the channel flow :

$$S_1 = K\,Q_1^p - T_1\,Q_1 \quad \text{(equation of storage)} \quad \ldots\ldots\ldots\ldots\ldots \quad (1.8)$$

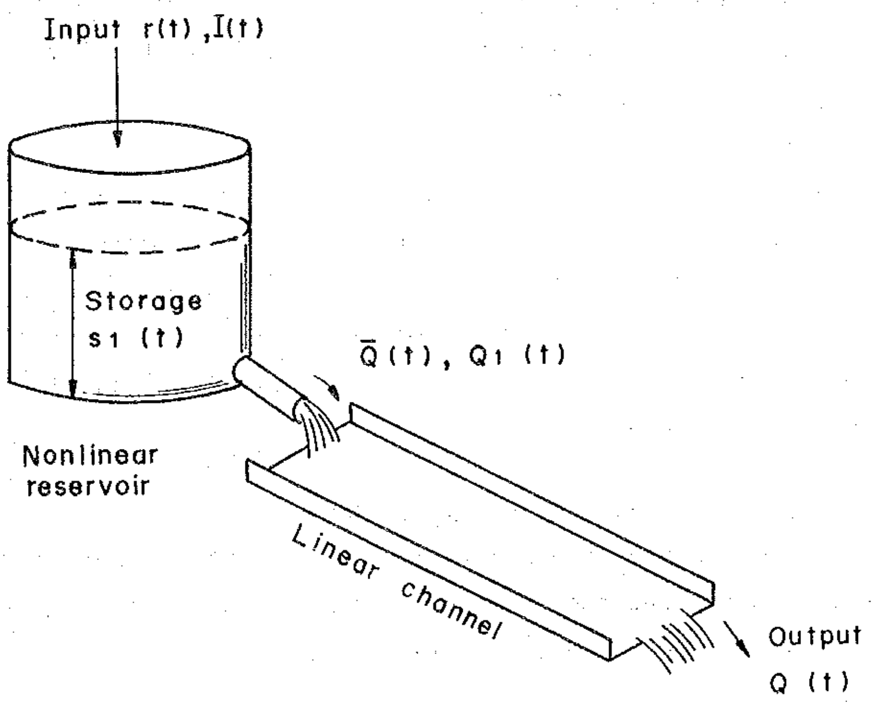
$$I - Q_1 = \frac{ds_1}{dt} \quad \text{(equation of continuity)} \quad \ldots\ldots\ldots\ldots \quad (1.9)$$

$$Q\,(t) = Q_1\,(t - T_1) \quad \text{(eq. of retarded runoff)} \quad \ldots\ldots\ldots \quad (1.10)$$

Where,
- S_1 : storage in channel (m^3/s)
- Q_1 : discharge at the middle point in the channel (m^3/s)
- I : inflow at the channel entrace (m^3/s)
- K,p : storage coefficients
- T_1 : lag-time
- Q : outflow at the channel exit (m^3/s)

The procedure of calculation is the same as that of runoff from a subbasin.

Basic model of the storage function method is shown below.



1.2 Runoff Simulation Model

1.2.1 Runoff System

The drainage area of the Arau, Kuranji and Air Dingin rivers is divided into 38 subbasins for runoff analysis as shown in Fig. F-1. The runoff system is explained by the runoff simulation model which is developed to estimate flood discharge as shown in Fig. F-2. The system incorporates 38 subbasins and 26 channels. When the subbasins receive much rainfall, a series of rainfall volume would be transferred to runoff discharge consisting of surface, subsurface and ground-water flows. The runoff discharge from each subbasin flows downwards through the channels and discharges to the Indonesian Ocean finally. A discharge hydrograph which is originated in a subbasin varies its form being influenced by both the storage effect of the channels and a discharge hydrograph from another subbasin to be combined.

1.2.2 Storage Function

The estimation of storage function is equivalent to that of storage coefficients such as K and p. The storage coefficient is estimated being applied to observed hourly and daily rainfall data and actual water level hydrographs recorded in stations during floods. The floods of April 1979, November 1980 and December 1982 are selected to examine the storage coefficients in consideration of their peak flood discharges, inundation areas suffered from the floods and availability of recorded hydrological data.

Isohyetal maps during the floods are used for calculation of average rainfall depths in each subbasin. For example, the isohyetal map of the 1980 flood which is made taking into consideration actual rainfall distribution in and out of the basin boundary is shown in Fig. F-3. The annual average rainfall distribution is also considered to complete the isohyetal map.

The estimated discharge hydrographs are compared with observed ones at check points to examine the availability of both the runoff simulation model and the storage function. The following gauging stations are selected as the check points.

River	Check Point
Arau	Lubuk Sarik
Flood relief channel	Lubuk Begalung
Kuranji	Gunung Nago
Kuranji	Kampung Melayu

The initial values of the storage coefficients were obtained from the formula of the Tone river basin/1 for mountainous area and the result of runoff model test by the Ministry of Construction, Japan/2 for plain area. After tentative calculations using trial and error procedure, the storage coefficients of the subbasins are estimated as shown in Table F-2. On the other hand, the storage function of the channels are estimated as shown in Table F-3 on the basis of channel conditions which are shown in Table F-4.

The estimated discharge hydrographs of the past floods are shown in Fig. F-4 with observed values. It shows that the estimated hydrographs are almost agreed with observed ones.

For the Air Dingin river, the storage coefficients are estimated referring to those of the Kuranji river, because there exists no rainfall station in the Air Dingin river basin and rating curve prepared for Lubuk Minturun station seems to be available within a range of low water flow only.

1.3 Rainfall Analysis

The characteristics of rainfall in the basins during floodtimes are described as follows :

a. Rainfall pattern observed at Tabing station shows that a series of rainfall which is collected in rain gauge is almost included within a 24 hours observation between 7 a.m. and 7 a.m. on the following day.

Note /1 : Report on the 18th technical symposium of Ministry of Construction, P. B-2.1, the Ministry of Construction, 1965

/2 : Technical Data Book (19-5), P.11, the Ministry of Construction, 1977

It is because storm rainfall occurs between late afternoon and early morning as shown in Fig. F-5.

b. A time of concentration is around 5 hours.

c. No rainfall period is usually long enough to the time of concentration. That implies a peak of discharge hydrograph is mainly influenced by a hyetograph which appeared a few hours ago.

On the other hand, situation of rainfall data is as follows :

a. Rainfall data is observed mostly on a daily-basis.

b. Since daily rainfall records from stations in the same day which are considered to bring about floods are so random, there exists not strong correlations among them. It seems that there is some difference in the way to observe the rainfall among the rainfall stations. It is very difficult to estimate the daily rainfall depth in basin average under the conditions above.

c. On the other hand, 2 day rainfall depth during floodtimes are distributed in the basin widely. Therefore, there are strong correlations among the stations. An application of data on the 2 day rainfall depth clears off the unreasonable values.

Taking into account the above information, it was decided that the probability analysis of rainfall depth is carried out with regard to 1 day rainfall depth while the correlation study is conducted by use of 2 day rainfall depth.

The probable 1 day rainfall depths at Tabing station were calculated by the Gumbel method, and are shown in Fig. F-6 and Table F-5 with the estimated probable 2 day rainfall depths.

The probable 1 day rainfall depths of the whole basin average are estimated through the correlation study with regard to 2 day records between Tabing and the whole basin as shown in Table F-6 and Fig. F-7. It shows that there exists a high correlation, that is, correlation coefficient is equal to 0.966. The estimated probable 1 day rainfall depth in the whole basin average is shown in Table F-7.

1.4 Flood Runoff Analysis

1.4.1 Probable Flood Discharge

The runoff hydrographs of probable flood discharge for the return periods of 5 yr., 10 yr., 25 yr., 50 yr. and 100 yr. are calculated on the basis of rainfall analysis and runoff study of the past floods. The hourly rainfall distribution for 2 days in the flood of November 1980 is selected as a typical rainfall pattern because it is recognized to be the biggest flood except 1972 flood, of which the hydrological data are not available, and the observation of water level has been carried out since then.

In calculation of flood runoff, the probable 1 day rainfalls are assumed to be in proportion to the typical rainfall pattern. The storage coefficients in the plain area are to be changed owing to land use conditions in the future as shown in Table F-8, while those in the mountainous area and channels are assumed not to be changed.

The probable flood discharges estimated at major sites are shown in Table F-9.

2. Flood Mechanism

2.1 Flooding Condition

2.1.1 Flooding Characteristics

The river basins are situated in the heavy rainfall zone by the monsoon and characterized by the topographic features of river channel with steep slope. Such heavy rainfall brings frequently about inundations in low lying areas of the basin.

Sumatra experiences two monsoons : the northwestern monsoon whose influence appears from October to April and the southwestern monsoon which affect the island from May to October. In West Sumatra, the main wet season occurs during the wet or northwestern monsoon period from October through December. In April and May, the secondary peak in rainfall appears associated with the change from the northwest to the southwest monsoon. In the Padang area, floods usually occur in November or December late in the wet season and April or May during the above transitional season from the northwest to the southwest monsoon.

As mentioned above, the three rivers of Arau, Kuranji and Air Dingin in question are characterized by steep slope and heavy rainfall.

Considering the duration and sharpness of flood peaks, it may be said that the above three rivers are so-called shotgunlike rivers. As soon as heavy rain falls in the mountain areas, the water stage rises rapidly in the lower reaches as well as in the middle reaches and the river water overtops the river banks exceeding the channel capacity. From such topographic and hydrological features of the rivers, the duration of flood is short, having about 5 hours. Moreover, the debouching of river water in flooding is frequently aggravated by high tides.

The flooding in the plain thus may be caused by the following factors :

a. Overbank flow of flood water of the river.
b. Insufficient capacity of the drainage system.
c. Backwater effect of flood water level in the river channel and tide level.

Regarding the urban area located between the Arau and the Kuranji rivers, intensive inundation seems to be caused by the combination of two or more of the above factors. Fig. F-8 shows flood prone area and typical flood flow directions.

2.1.2 Major Floods in the Past

According to the data on the past remarkable floods collected from DPU, West Sumatra and the information from local people during the field survey, the major floods in the past were the floods in May 1972, April 1979, November 1980, November 1981 and December 1982. The main features of the floods in terms of rainfall and inundated area are as follows :

Item	Unit	Flood				
		May 1972	Apr.1979	Nov.1980	Nov.1981	Dec.1982
2-day rainfall						
Tabing	mm	393	264	314	212	128
Gunung Nago	mm	-	298	301	-	-
Inundation area	ha	3,942	2,809	3,340	1,444	1,281

It is recognized that the both floods of May 1972 and Nov. 1980 were heavy from the above table.

2.2 Hydraulic Analysis by Simulation Model

2.2.1 Methodology for Analysis

The hydraulic analysis is made in order to grasp the characteristics of flooding and to estimate inundation area due to probable floods. The simulation is conducted for the probable floods with the model diagram after checking the model diagram with the past floods.

Simulation model consists of three components, i.e., flood runoff calculation from the sub-basin, channel flow calculation in the major channels and drainage calculation in the low lying areas of the urban area.

For each component, the following methods are applied.

a. Flood runoff calculation : results of flood runoff.

b. Channel flow calculation : unsteady flow equation.

c. Drainage calculation : equation of continuous using relations among elevation, area and storage volume.

Simulation model diagram is prepared based on the data on the existing river channel, topographic maps with a scale of 1/5,000, inundation maps due to the past remarkable floods and the results of field investigation. The prepared simulation model diagram is shown in Fig. F-10.

For the purpose of checking the model diagram thus prepared, simulation analysis is conducted using inundation maps on the past floods and the result of flood runoff calculation. The flood of Nov. 1980 is selected to simulate the model, considering the availability of hydrological data. Recorded tide levels in the time of flood of Nov. 1980 are also applied as the boundary condition at the rivermouth.

The formulas used for the analysis are presented below.
The equations for the channel flow are :

$$\frac{N}{g}\frac{\partial v}{\partial t} + \frac{a}{2g}\frac{\partial v^2}{\partial x} + \frac{\partial H}{\partial x} + \frac{n^2 v^2}{R^{4/3}} = 0 \quad \text{.................... (2.1)}$$

$$B_* \frac{\partial H}{\partial t} + \frac{\partial Q}{\partial x} = q \quad \text{.................................. (2.2)}$$

Where, t : time (sec)

x : distance between sections (m)

H : water level (m)

v : velocity (m/s)

Q : discharge (m^3/s)

R : hydraulic mean depth (m)

N , a : coefficients of velocity distribution

g : acceleration of gravity (m/s^2)

n : Manning's coefficient of roughness

B_* : river width (m)

q : inflow from tributaries per unit length of channel ($m^3/s/m$)

The equation for drainage in the low lying area is :

$$\frac{dv}{dt} = Q1 - (Q0 + QS) \quad \text{.................................. (2.3)}$$

Where, v : storage volume (m^3)

t : time (sec)

Q1 : inflow (m^3/s)

Q0 : Outflow to river channel (m^3/s)

QS : outflow to other basin (m^3/s)

For overflow on the road :

$$Q = h1 \cdot L \cdot m \cdot (2gh1)^{\frac{1}{2}} \quad \text{for } h0/h1 \leq 2/3$$
$$Q = h0 \cdot L \cdot m' \cdot (2g\,\Delta h)^{\frac{1}{2}} \quad \text{for } h0/h1 > 2/3 \quad \text{................ (2.4)}$$

Where, Q : overflow discharge (m^3/s)

L : width (m)

h1.h0 : water depth (m)

Δh : h1 - h0 (m)

m : constant (0.35)

m' : constant (0.91)

For side overflow :

$$Q = 2/3 \cdot m \cdot (2g)^{1/2} \cdot h^{3/2} \cdot L \quad \text{.......................... (2.5)}$$

Where, Q : discharge (m^3/s)

m : constant (0.55)

h : water depth (m)

L : width (m)

For channel flow :

$$Q = B\, h^{5/3} / n \cdot (H/L)^{1/2} \quad \text{................................ (2.6)}$$

Where, Q : discharge (m^3/s)

B : channel width (m)

h : water depth (m)

n : Manning's coefficient of roughness

H : difference of water levels between upper and lower sections (m)

L : distance between upper and lower sections (m)

2.2.2 Countercheck of Simulation Model

Hydraulic analysis was made to check the model diagram prepared using the data on the past flood of Nov. 1980. The calculation result is shown in Fig. F-11. According to the figure, it is recognized that the simulated inundation area almost coincides with the inundated area of the past flood of Nov. 1980.

2.2.3 Estimation of Probable Flooding Area

Using the simulation model, the probable flooding areas are estimated under the present channel conditions. The probable floods of 5-yr, 10-yr, 25-yr, 50-yr and 100-yr are selected to estimate the inundated area. In calculation, the time difference between the peaks of flood runoff and tide level is assumed to be zero.

The calculation results are shown in Fig. F-12. Table F-10 shows the maximum inundation depths and flooding duration in the inundated area.

Table F-1 Flood Runoff Discharge Estimated by Previous Studies

Item	Unit	Return Period (yr)							
		5	10	20	25	50	60	75	100
1. P.T. Indah Karya Report, 1973/1									
Arau River at Muara (A = 170 km²)									
Rainfall	mm	212	249	286	-	334	344	-	370
Discharge	m³/s	632	742	852	-	995	1025	-	1103
Kuranji River at Air Twar (A = 211 km²)									
Rainfall	mm	192	225	259	-	302	311	-	335
Discharge	m³/s	618	725	834	-	972	1001	-	1078
2. P.T. Indah Karya Report, 1974/2									
Arau River at Lubuk Begalung (A = 115 km²)									
Rainfall	mm	252	290	324	-	375	-	-	403
Discharge	m³/s	526	607	683	-	803	-	-	876
3. P.T. Waskita Karya Report, 1981/3									
Arau River									
Rainfall	mm	219	256	-	307	344	-	367	370
Discharge at Muara	m³/s	653	763	-	915	1025	-	1049	1103
at Lubuk Begalung	m³/s	488	571	-	685	767	-	818	825
Kuranji River									
Rainfall	mm	206	242	-	282	324	-	346	359
Discharge at Air Tawar	m³/s	663	779	-	931	1043	-	1114	1156
at Gunung Nago (A = 120 km²)	m³/s	360	424	-	506	567	-	606	628

Note, /1 : Method : combined Melchior, De Weduwen and Thiessen
Rainfall data : 1931 - 1960.

/2 : Method : Unit Hydrograph
Rainfall data : 1930 - 1941.

/3 : Method : Melchior
Rainfall data : 24 years before 1980.

Table F-2 Storage Coefficients of Subbasins under Existing Condition

Sub-basin NO.	Drainage Area (km^2)	Storage Coefficients K	P	f1	Lag-time (hr)
Arau River Basin	172.1				
101	31.7	59.08	0.303	0.5	0.58
102	32.2	64.70	0.282	0.5	0.22
103	8.9	62.79	0.288	0.5	0.0
104	31.5	60.07	0.299	0.5	0.44
105	11.7	82.68	0.600	0.5	0.0
106	9.1	58.78	0.303	0.5	0.03
107	4.6	63.38	0.286	0.5	0.0
108	4.6	56.15	0.600	0.5	0.0
109	4.3	47.18	0.361	0.5	0.0
110	10.3	138.12	0.600	0.5	0.0
111	3.4	73.00	0.600	0.5	0.0
112	3.1	88.44	0.600	0.5	0.0
113	1.3	42.00	0.600	0.5	0.0
114	2.4	13.20	0.600	0.5	0.0
115	5.1	73.67	0.600	0.5	0.0
116	2.4	19.92	0.600	0.5	0.0
117	2.5	21.67	0.600	0.5	0.0
118	3.0	65.01	0.281	0.5	0.0
Kuranji River Basin	211.9				
201	86.6	54.22	0.324	0.5	0.70
202	33.4	59.15	0.302	0.5	0.52
203	6.2	51.09	0.600	0.5	0.0
204	3.5	48.05	0.600	0.5	0.0
205	32.0	65.29	0.280	0.5	0.17
206	13.9	41.79	0.600	0.5	0.0
207	15.1	63.20	0.287	0.5	0.04
208	2.2	43.32	0.600	0.5	0.0
209	8.1	68.40	0.600	0.5	0.0
210	2.6	140.03	0.600	0.5	0.0
211	3.2	53.13	0.600	0.5	0.0
212	1.8	25.28	0.600	0.5	0.0
213	1.4	13.97	0.600	0.5	0.0
214	1.9	11.99	0.600	0.5	0.0
Air Dingin River Basin	133.5				
301	92.2	55.97	0.316	0.5	0.702
302	21.5	64.49	0.282	0.5	0.171
303	2.0	77.64	0.244	0.5	0.0
304	12.1	61.32	0.600	0.5	0.0
305	2.4	115.95	0.600	0.5	0.0
306	3.3	66.40	0.600	0.5	0.0
Total Area	517.5				

Table F-3(1) Discharge-storage Relation of Channels (Arau River)

(Unit ; m^3/s)

Channel NO. 101		Channel NO. 102		Channel NO. 103		Channel NO. 104		Channel NO. 105		Channel NO. 106		Channel NO. 107	
Q	S	Q	S	Q	S	Q	S	Q	S	Q	S	Q	S
4	1.8	2	1.0	3	2.8	3	5.2	7	17.2	3	3.9	1	2.8
52	9.2	23	4.9	48	14.2	49	26.1	98	86.4	45	20.0	18	13.9
161	18.3	69	9.8	150	28.3	153	52.2	310	173.1	144	40.0	56	27.8
491	36.7	203	19.6	458	56.7	472	104.4	976	345.8	451	80.0	173	55.6
927	55.0	374	29.4	867	85.0	900	156.7	1,902	518.9	873	120.0	334	83.3
				1,351	113.3			3,073	749.4	1,388	160.0	527	111.1
				1,894	141.7			4,615	980.0	1,983	200.0	747	138.9
				2,484	170.0			6,344	1,210.6	2,781	300.0	1,098	277.8
										3,768	400.0	1,577	416.7

Channel NO. 108		Channel NO. 109		Channel NO. 110		Channel NO. 111		Channel NO. 112		Channel NO. 113	
Q	S	Q	S	Q	S	Q	S	Q	S	Q	S
1	6.4	0.3	0.6	0.4	1.9	1.4	3.3	1.6	2.2	0.6	1.1
17	32.5	4.6	2.5	6.1	10.0	20.5	16.1	22.5	10.6	8.2	5.0
54	65.0	14	4.7	19	19.7	64	31.9	70	20.8	25	10.0
168	130.0	41	9.2	56	39.4	197	63.9	215	41.9	76	20.0
321	195.0	75	13.9	105	59.2	376	95.6	408	62.8	141	30.0
513	260.0	114	18.3	161	78.9	591	127.5	677	86.7	217	40.0
731	325.0	265	94.7	311	276.1	834	159.4	899	104.4	300	50.0
974	390.0	540	171.1	558	473.3	1,166	239.2	1,268	164.2	390	60.0
1,317	640.0	907	247.5	881	670.6	1,573	318.9	1,729	223.9	668	235.0
1,754	890.0	1,354	323.9	1,268	867.8			2,263	283.6	1,150	410.0
2,269	1,140.0									1,785	585.0

Note, Q ; discharge
S ; channel storage

Table F-3(2) Discharge-storage Relation of Channels (Kuranji River)

(Unit ; m^3/s)

Channel NO. 201		Channel NO. 202		Channel NO. 203		Channel NO. 204		Channel NO. 205	
Q	S	Q	S	Q	S	Q	S	Q	S
4	6.2	5	5.2	5	27.2	1	7.2	1	8.3
61	30.9	70	26.1	10	41.7	18	35.6	14	41.4
193	61.8	216	52.2	50	108.9	56	71.1	43	82.8
595	123.6	666	104.4	100	165.6	176	141.9	131	165.8
1,144	185.4	1,272	156.7	500	438.9	336	213.1	252	248.6
				1,000	669.4	536	283.9	551	973.9
				1,500	858.3	648	319.4	1,048	1,699.2
				2,000	1,041.7	1,084	911.1	1,703	2,424.4
						1,774	1,502.8	2,489	3,149.7
						2,646	2,094.4	3,395	3,875.0

Channel NO. 206		Channel NO. 207		Channel NO. 208		Channel NO. 209	
Q	S	Q	S	Q	S	Q	S
10	11.7	7	4.2	1	3.1	2	3.9
29	23.3	20	8.3	13	15.6	31	19.2
197	373.3	125	113.9	40	31.1	96	38.3
530	723.3	339	219.4	127	62.2	308	76.7
1,002	1,073.3	622	325.0	183	77.8	600	115.0
1,570	1,423,3	984	430.6	379	233.3	954	153.3
2,240	1,773.3	1,385	536.1	679	388.9	1,459	268.3
				1,063	544.4	2,098	383.3
				1,505	700.0		

Note, Q ; discharge

S ; channel storage

Table F-3(3) Discharge-storage Relation of Channels (Air Dingin River)

(Unit ; m^3/s)

Channel NO. 301		Channel NO. 302		Channel NO. 303		Channel NO. 304	
Q	S	Q	S	Q	S	Q	S
3	1.7	3	1.9	5	16.9	3	2.2
42	8.3	41	9.7	10	25.8	42	10.6
131	16.7	129	19.4	50	68.3	132	21.1
401	33.3	398	38.4	100	103.9	412	42.2
756	50.0	761	58.3	500	291.7	794	63.3
		1,205	77.8	1,000	530.6	1,023	73.9
		1,706	97.2	1,500	744.4	1,686	153.1
				2,000	958.3	2,593	232.2

Note, Q ; discharge
S ; channel storage

Table F-4 (1) Assumed Channel Condition (Arau River)

Channel No.	Length (km)	Slope	Low Water channel: Manning's n	Low Water channel: Depth (m)	Low Water channel: Width (m)	High Water Channel: Manning's n	High Water Channel: Width (m)	Lag-time (hr)
101	2.20	1/20	0.040	3.0	30	-	-	0.156
102	2.35	1/25	0.040	3.0	15	-	-	0.000
103	3.40	1/30	0.035	3.0	30	-	-	0.189
104	4.70	1/40	0.040	3.0	40	-	-	0.436
105	4.15	1/190	0.035	3.0	150	0.070	200	0.355
106	1.80	1/330	0.030	5.0	80	0.070	200	0.137
107	2.00	1/1,100	0.026	5.0	50	0.070	250	0.186
108	3.60	1/2,000	0.026	6.0	65	0.070	250	0.444
109	1.10	1/1,100	0.030	4.0	15	0.070	250	0.087
110	3.55	1/1,100	0.030	4.0	20	0.070	200	0.317
111	2.87	1/530	0.026	5.0	40	0.070	100	0.216
112	2.15	1/340	0.026	5.0	35	0.070	100	0.154
113	1.80	1/840	0.026	6.0	20	0.070	350	0.154

Table F-4 (2) Assumed Channel Condition (Kuranji River)

Channel No.	Length (km)	Slope	Low Water Channel: Manning's n	Low Water Channel: Depth (m)	Low Water Channel: Width (m)	High Water Channel: Manning's n	High Water Channel: Width (m)	Lag-time (hr)
201	4.45	1/40	0.040	3.0	50	-	-	0.454
202	4.70	1/20	0.040	3.0	40	-	-	0.354
203	8.34		0.040	3.0	150	0.070	200	0.816
	5.98	1/80						0.554
	2.36	1/290						0.262
204	4.26	1/1,200	0.030	4.5	60	0.070	500	0.473
205	7.46	1/910	0.030	3.0	40	0.070	350	0.987
206	4.20	1/870	0.030	2.0	10	0.070	300	0.389
207	1.90	1/1,000	0.030	2.0	8	0.070	200	0.176
208	2.24	1/2,100	0.026	2.5	50	0.070	250	0.287
209	1.38	1/1,500	0.026	4.0	100	0.070	300	0.131

Table F-4 (3) Assumed Channel Condition (Air Dingin River)

Channel No.	Length (km)	Slope	Low Water Channel: Manning's n	Low Water Channel: Depth (m)	Low Water Channel: Width (m)	High Water Channel: Manning's n	High Water Channel: Width (m)	Lag-time (hr)
301	2.00	1/30	0.040	3.0	30	-	-	0.145
302	1.40	1/90	0.040	3.0	50	-	-	0.097
303	7.73					0.070	200	0.599
	5.03	1/90	0.040	3.0	80			0.349
	2.70	1/630	0.030	2.5	70			0.250
304	0.95	1/530	0.026	3.5	80	0.070	300	0.088

Table F-5 Probable Rainfall Depth at Tabing Station

Return period (year)	Probable rainfall depth (mm)
1 day rainfall	
2	162.9
5	219.6
10	257.1
25	304.5
50	339.7
100	374.6
2 day rainfall	
2	196.1
5	256.5
10	296.5
25	347.0
50	384.5
100	421.7

Note : Gumbel Method is used for the analysis

Table F-6 2 Day Rainfall Depth at Tabing and in Basin Average

No	Date	2-Day Rainfall Depth (mm)	
		Tabing[/1]	Basin Average
1	1975 Dec. 20 - 21	157	114.1
2	1976 Oct. 5 - 6	184	149.0
3	1978 July 24 - 25	212	199.8
4	1979 Apr. 3 - 4	264	230.0
5	Apr. 30 - May 1	26	53.8
6	Sept.16 - 17	59	77.9
7	Nov. 26 - 27	239	208.8
8	1980 July 24 - 25	42	45.9
9	Nov. 22 - 23	314	260.9
10	1981 Apr. 4 - 5	118	117.9
11	Apr. 24 - 25	138	114.8
12	July 29 - 30	237	177.9
13	Oct. 14 - 15	270	215.4
14	Nov. 20 - 21	212	189.2
15	1982 Feb. 4 - 5	227	174.5
16	Apr. 21 - 22	100	98.6
17	May 18 - 19	45	62.9
18	Dec. 25 - 26	128	164.2

Source[/1] : Pusat Meteorologi dan Geofisika

Table F-7 Probable 1 Day Rainfall Depth in Basin Average

Return Period (year)	Probable 1 day rainfall depth (mm)
2	145.9
5	186.2
10	212.9
25	246.6
50	271.6
100	296.4

Note : The rainfall depth is estimated by the linear regression equation below.

$$Y = 0.711 x + 30.1$$

where Y : Probable 1 day rainfall depth in basin average

X : Probable 1 day rainfall depth at Tabing station

Table F-8 Storage Coefficients of Subbasins for Development Plan

Sub-basin No	Drainage Area (km^2)	Storage Coefficients K	P	f_1	Lag-time (hr)
Arau River Basin	172.1				
101	31.7	59.08	0.303	0.5	0.58
102	32.2	64.70	0.282	0.5	0.22
103	8.9	62.79	0.288	0.5	0.0
104	31.5	60.07	0.299	0.5	0.44
105	11.7	30.67	0.600	0.5	0.0
106	9.1	58.78	0.303	0.5	0.03
107	4.6	63.38	0.286	0.5	0.0
108	4.6	30.00	0.600	0.5	0.0
109	4.3	47.18	0.361	0.5	0.0
110	10.3	48.11	0.600	0.5	0.0
111	3.4	16.63	0.600	0.5	0.0
112	3.1	20.15	0.600	0.5	0.0
113	1.3	40.90	0.600	0.5	0.0
114	2.4	13.20	0.600	0.5	0.0
115	5.1	20.55	0.600	0.5	0.0
116	2.4	19.92	0.600	0.5	0.0
117	2.5	21.67	0.600	0.5	0.0
118	3.0	65.01	0.281	0.5	0.0
Kuranji River Basin	211.9				
201	86.6	54.22	0.324	0.5	0.70
202	33.4	59.15	0.302	0.5	0.52
203	6.2	45.23	0.600	0.5	0.0
204	3.5	48.05	0.600	0.5	0.0
205	32.0	65.29	0.280	0.5	0.17
206	13.9	34.23	0.600	0.5	0.0
207	15.1	63.20	0.287	0.5	0.04
208	2.2	35.87	0.600	0.5	0.0
209	8.1	68.40	0.600	0.5	0.0
210	2.6	111.59	0.600	0.5	0.0
211	3.2	38.94	0.600	0.5	0.0
212	1.8	25.28	0.600	0.5	0.0
213	1.4	13.97	0.600	0.5	0.0
214	1.9	11.99	0.600	0.5	0.0
Air Dingin River Basin	133.5				
301	92.2	55.97	0.316	0.5	0.702
302	21.5	64.49	0.282	0.5	0.171
303	2.0	77.64	0.244	0.5	0.0
304	12.1	42.84	0.600	0.5	0.0
305	2.4	103.07	0.600	0.5	0.0
306	3.3	66.40	0.600	0.5	0.0
Total Area	517.5				

Table F-9 Probable Flood Discharge at Major Sites

(Unit : m^3/s)

Location	Return Period (year)				
	5	10	25	50	100
Arau River					
Lb. Sarik	222	275	353	424	500
Kp. Baru	384	492	636	740	845
Lb. Begalung (before bifurcation)	427	531	671	773	902
After Confluence of Jirak R.	362	446	527	578	650
Rivermouth	399	482	585	660	724
Tributary					
Jirak R.	118	147	171	184	202
Flood Relief Channel					
Rivermouth	261	329	406	450	503
Kuranji River					
Gunung Nago	363	439	570	676	790
Kp. Melayu	377	453	574	675	774
After Confluence of Balimbing R.	639	768	926	1055	1169
Rivermouth	669	805	992	1131	1245
Tributary					
Balimbing R.	258	307	366	405	447
Laras R.	67	80	98	110	123
Air Dingin River					
Lb. Minturun	342	411	539	635	734
Rivermouth	386	464	560	653	758

Table F-10 Estimated Probable Maximum Inundation Depth and Duration

No/1	Sub-Basin	Return Period									
		100-yr.		50-yr.		25-yr.		10-yr.		5-yr.	
		H/2	T/3	H	T	H	T	H	T	H	T
Arau River Basin											
108	Jirak R. (Right)	1.50	25	1.15	24	0.95	23	0.80	22	0.70	22
109	Jirak R. (Left)	1.50	25	1.15	24	0.95	23	0.80	22	0.70	22
113	Lolong R. (Upstream)	1.00	22	1.00	21	0.90	20	0.75	19	0.50	17
114	Lolong, Purus R.	1.00	27	0.95	26	0.90	25	0.70	24	0.50	23
115	Jati Drainage	1.10	22	0.95	21	0.80	20	0.55	19	0.25	17
116	B. Purus Drainage	1.80	30	1.70	30	1.65	30	1.55	30	1.45	22
117	K. Mati, Olo II Drainage	1.10	30	1.05	30	0.95	30	0.80	30	0.70	22
Kuranji River Basin											
204	Kandis Area	1.15	16	1.00	15	0.90	14	0.80	13	0.50	11
210	S. Merah R.	1.90	22	1.75	21	1.65	20	1.40	19	1.20	18
211	Perupuk Area	1.40	25	1.20	24	1.00	23	0.80	22	0.50	19
212	Baung R.	1.50	24	1.40	24	1.00	24	0.60	23	0.15	22
213	Lapai R.	2.60	25	2.40	24	2.20	23	2.00	22	1.70	19
214	Ulak Karang R.	1.65	30	1.60	24	1.55	24	0.90	24	0.25	23
Air Dingin River Basin											
304	Tabing R.	1.70	12	1.50	11	1.30	10	0.80	8	0.25	5
305	Penjalinan Area	1.05	25	1.00	24	0.65	23	0.55	22	0.45	19

/1 Refer to Fig. F-1 in Appendix F.

/2 Maximum inundation depth above lower ground level (m)

/3 Duration of inundation on lower ground level (hr)

Fig. F-1 Sub-basins for Runoff Analysis

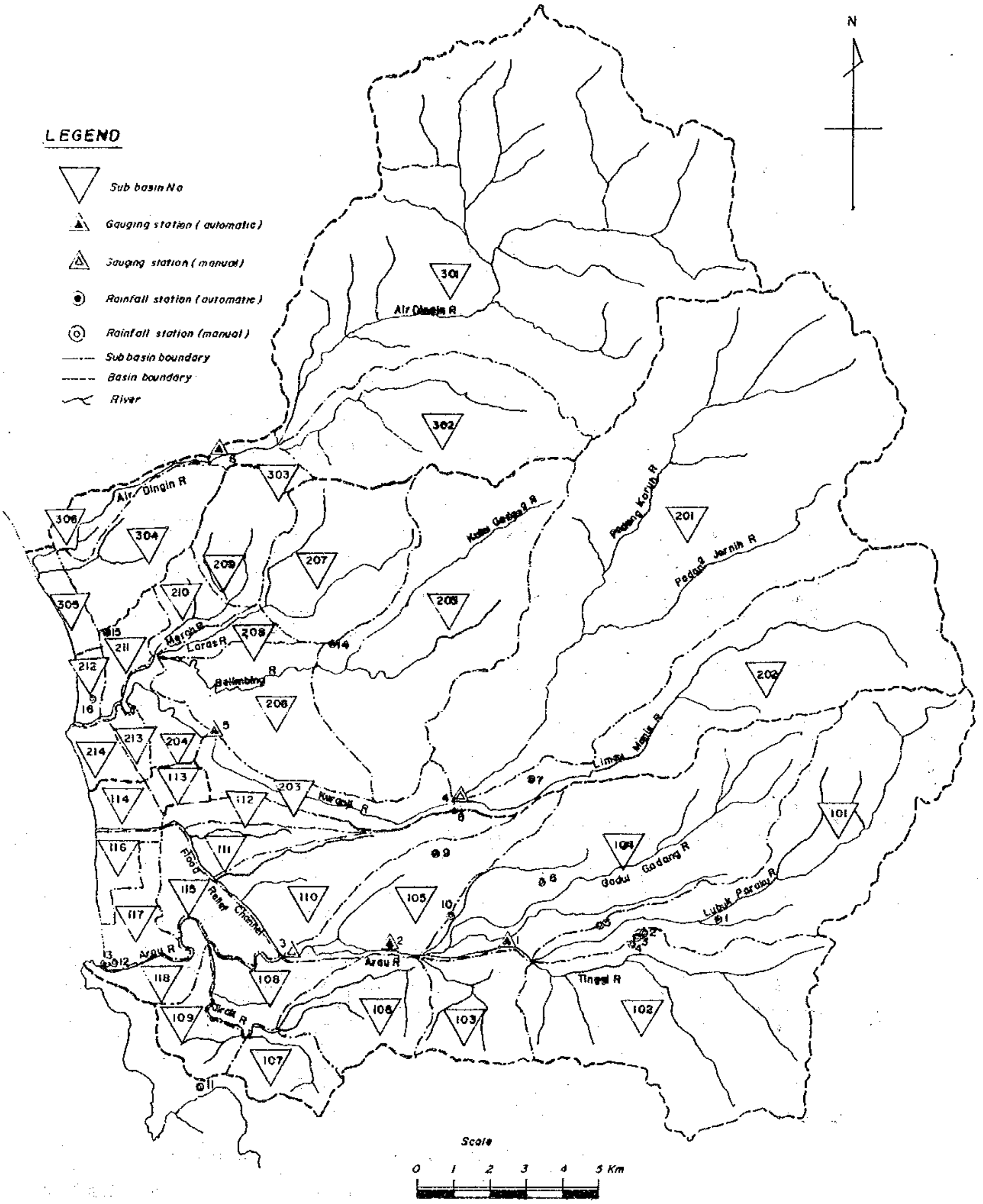
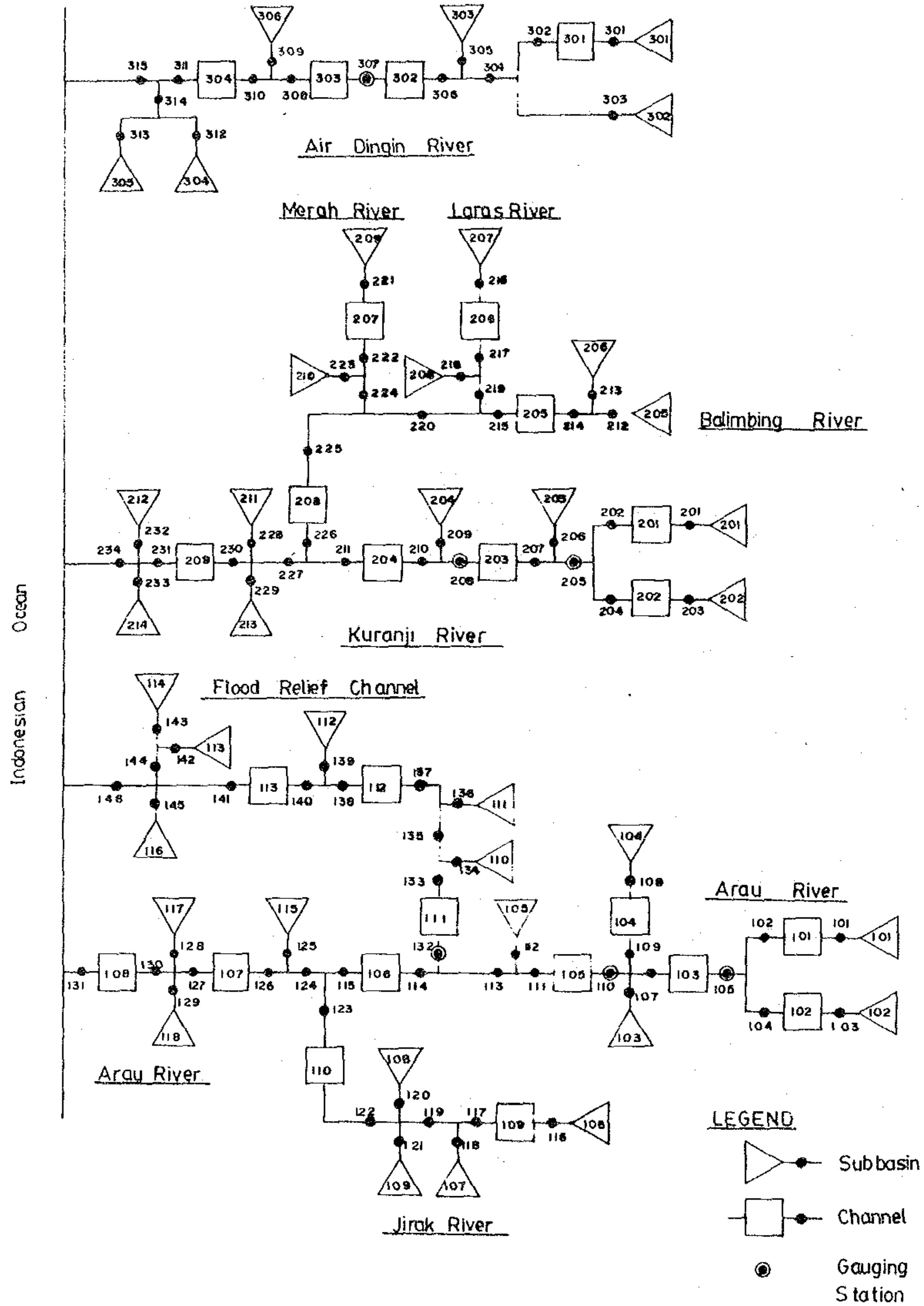


Fig. F-2 Runoff Simulation Model Diagram



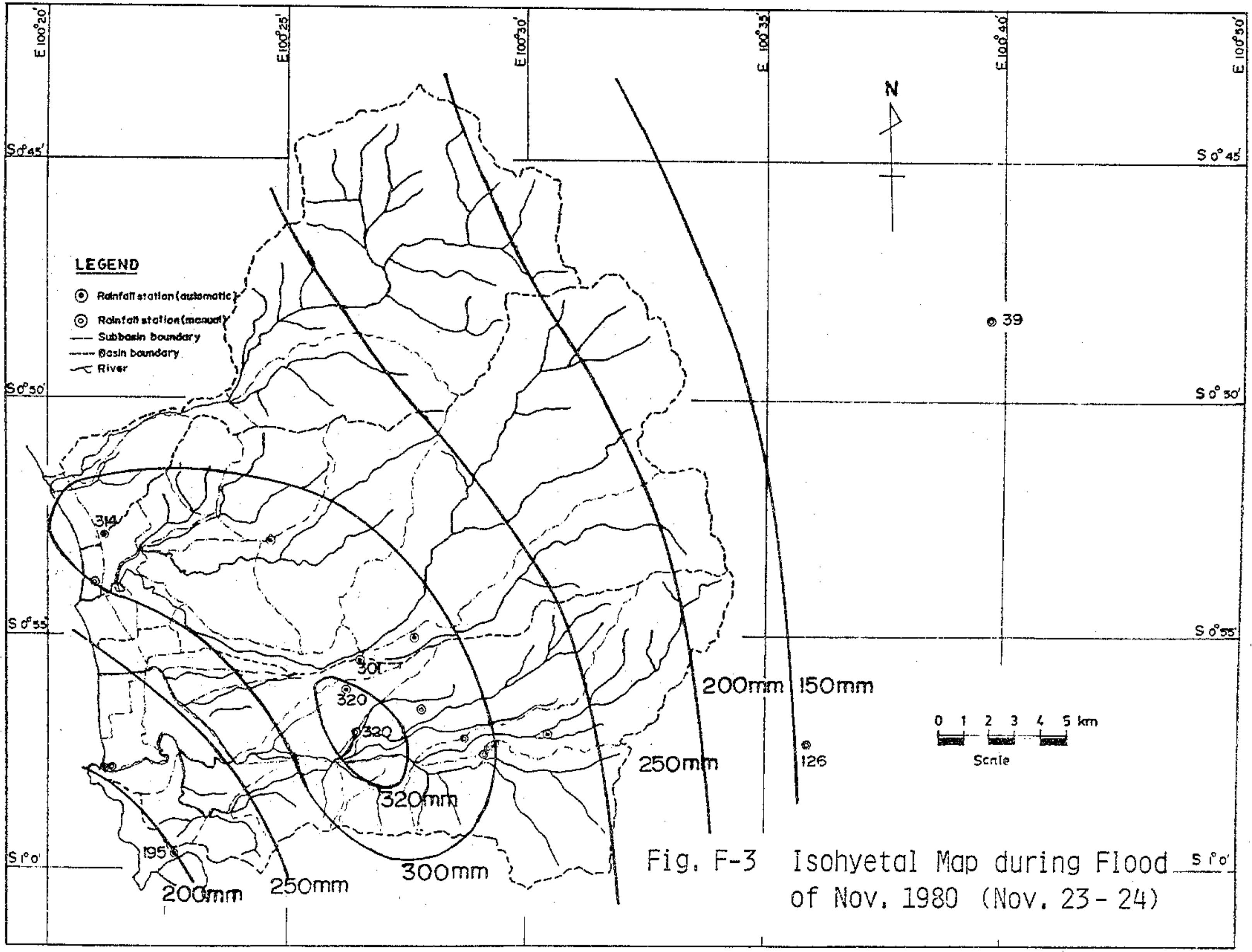
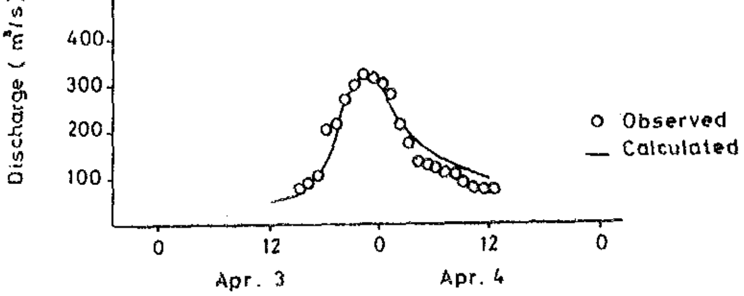


Fig. F-3 Isohyetal Map during Flood of Nov. 1980 (Nov. 23 - 24)

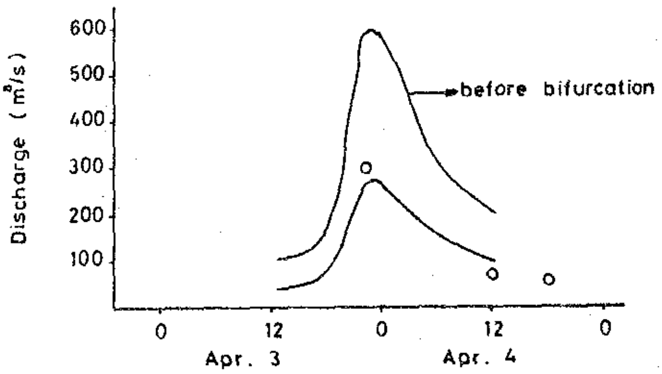
Fig. F-4(1) Discharge Hydrograph of Past Flood

April 1979 Flood

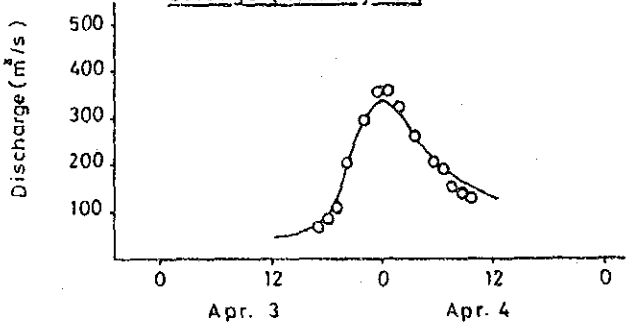
Lb. Sarik (Arau R.)



Lb. Begalung (Flood Relief Channel)



G. Nago (Kuranji R.)



G. Nago

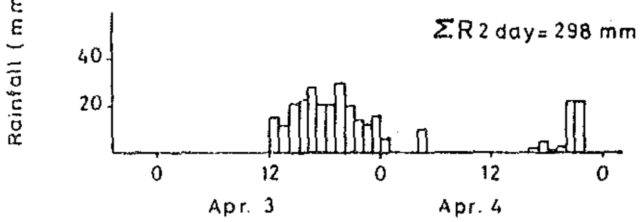


Fig.F-4(2) Discharge Hydrograph of Past Flood

November 1980 Flood

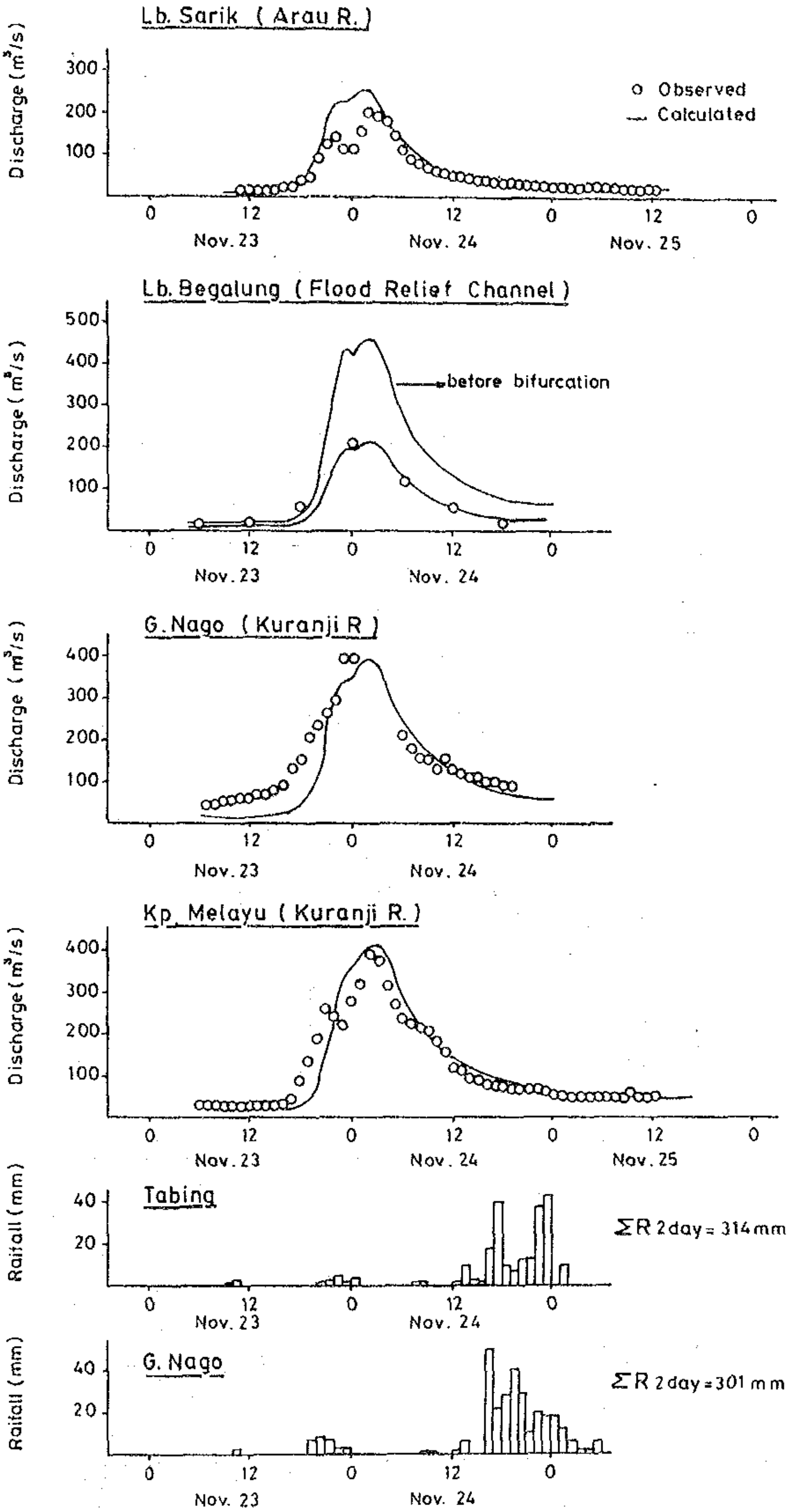


Fig.F-4(3) Discharge Hydrograph of Past Flood

December 1982 Flood

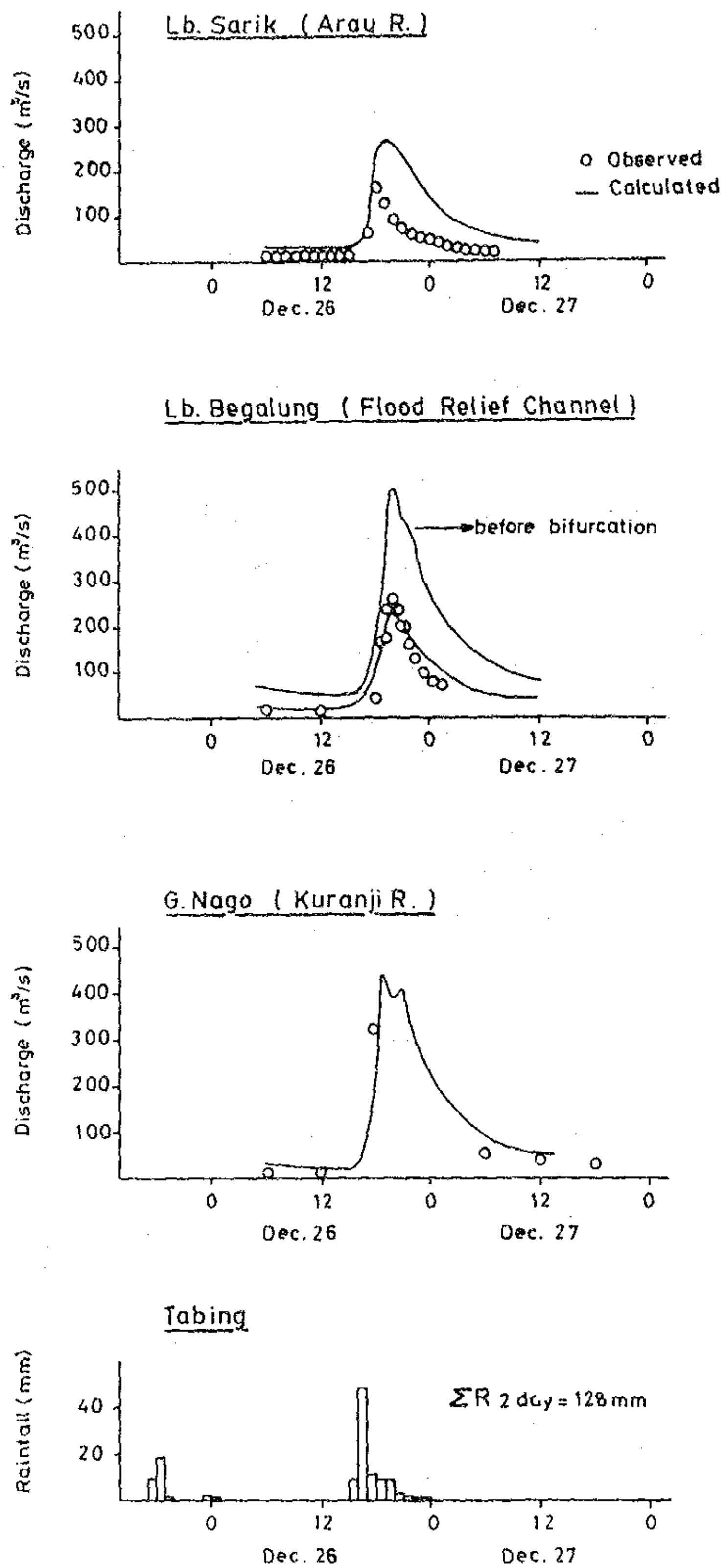


Fig. F-5 Typical Rainfall Pattern during Floods at Tabing

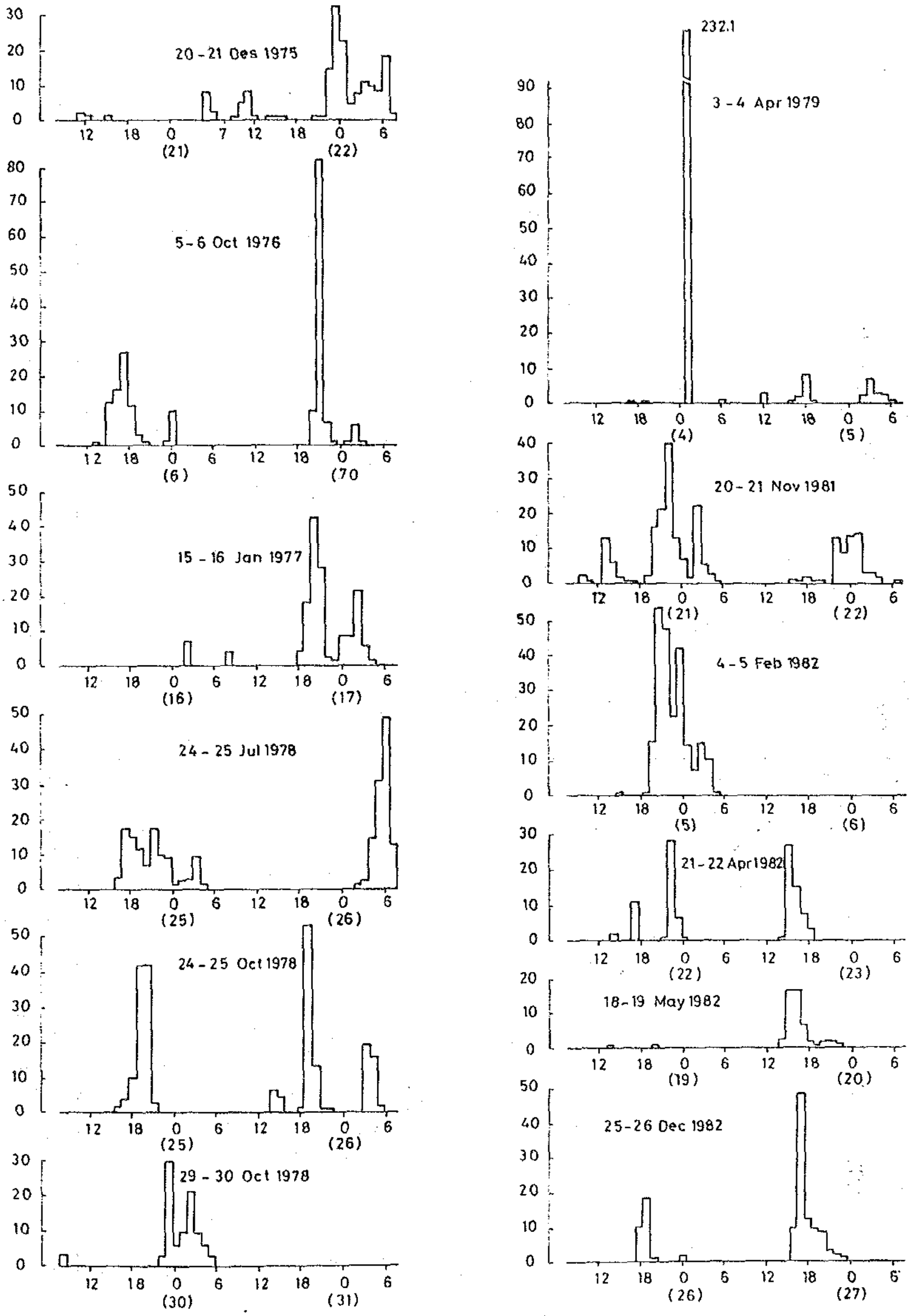
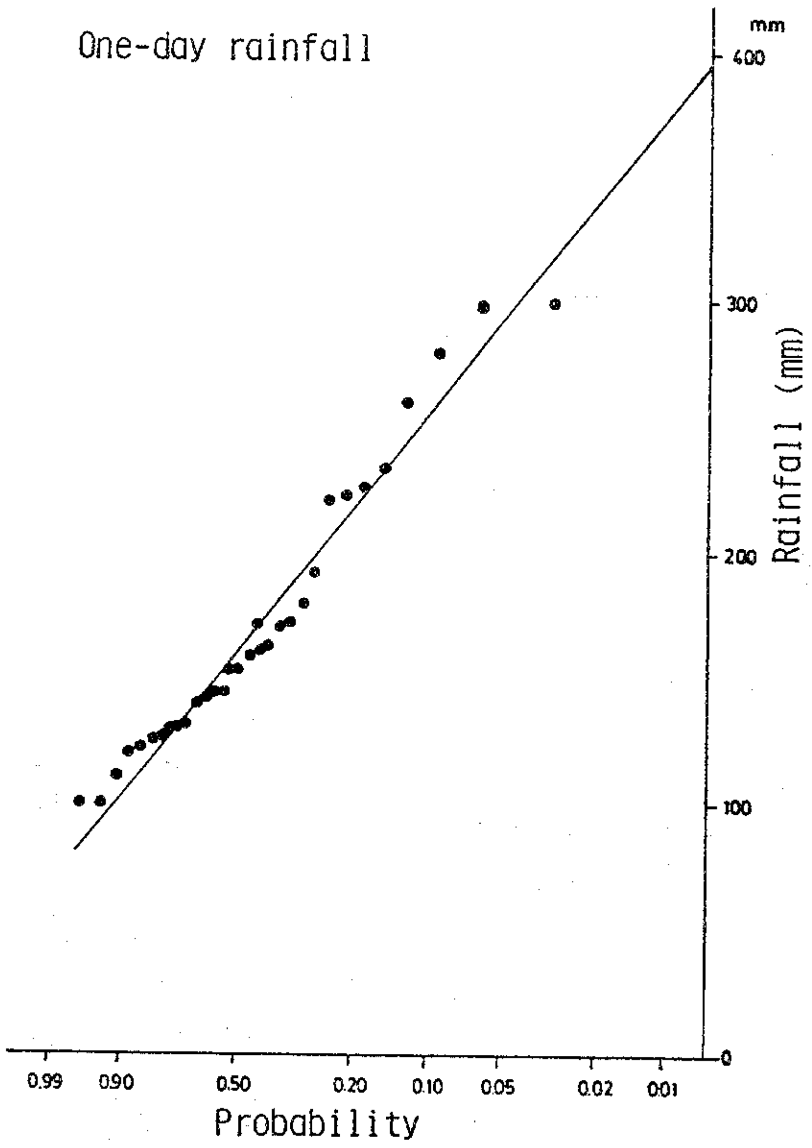
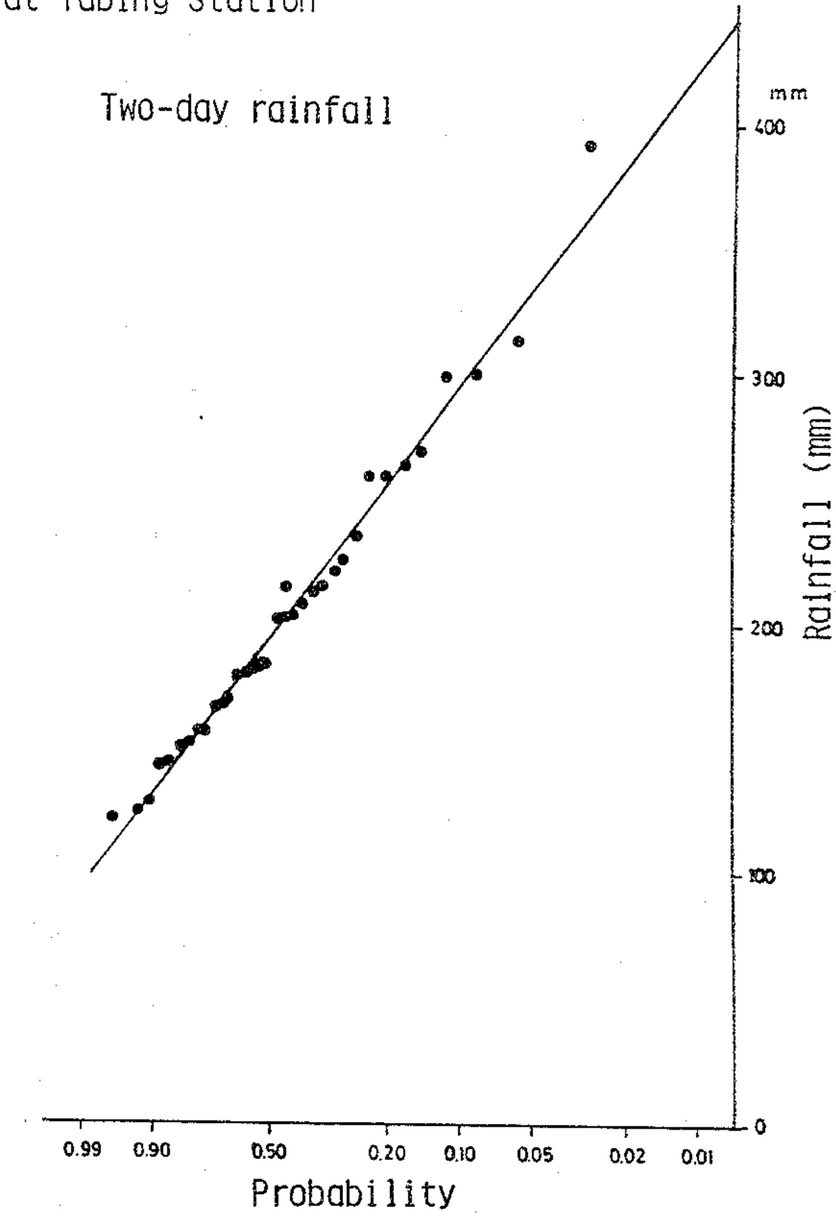


Fig. F-6 Probable Rainfall Depths at Tabing Station





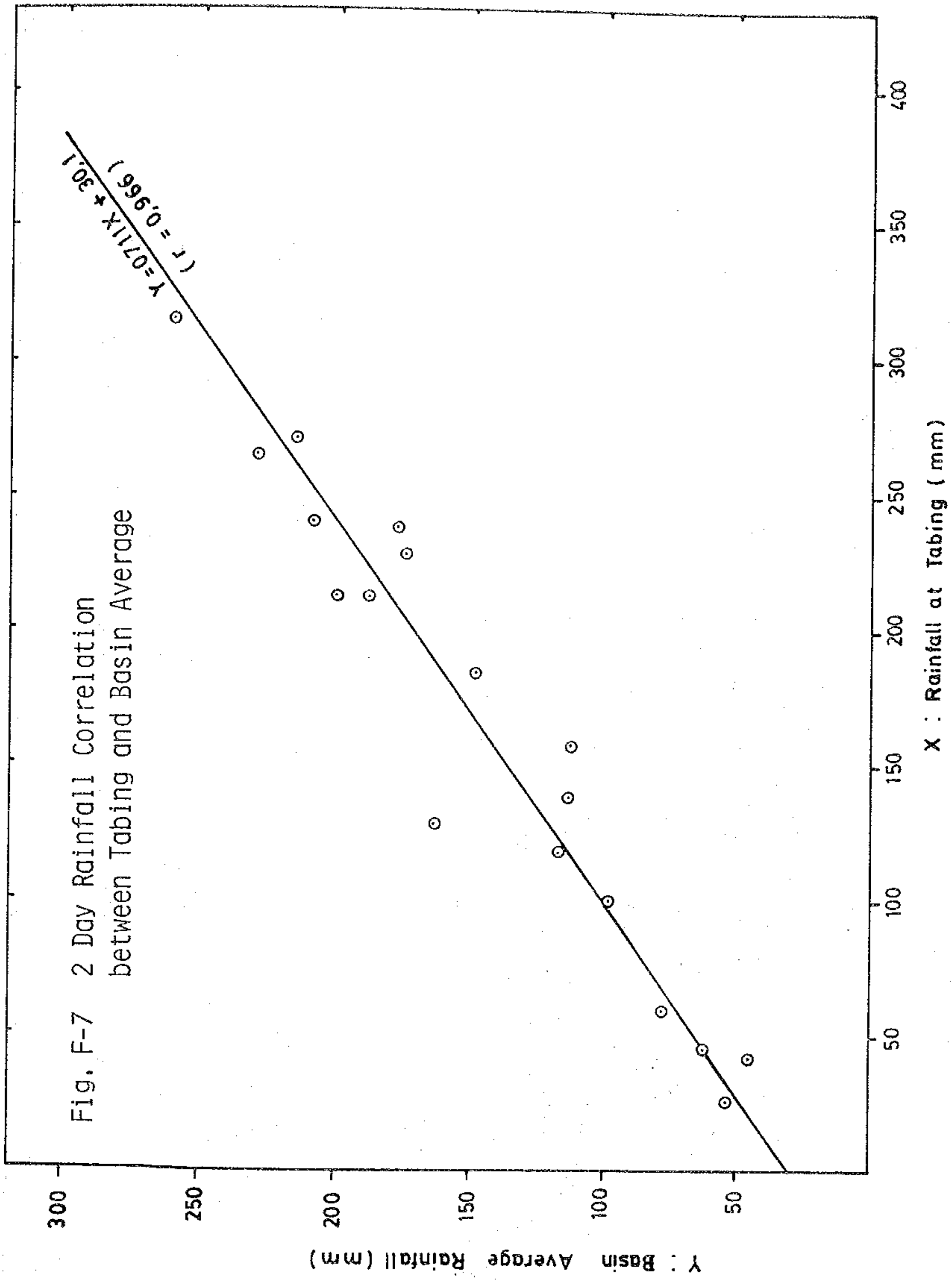


Fig. F-7 2 Day Rainfall Correlation between Tabing and Basin Average

Fig. F-8 Flood Prone Area and Typical Flood Flow Direction

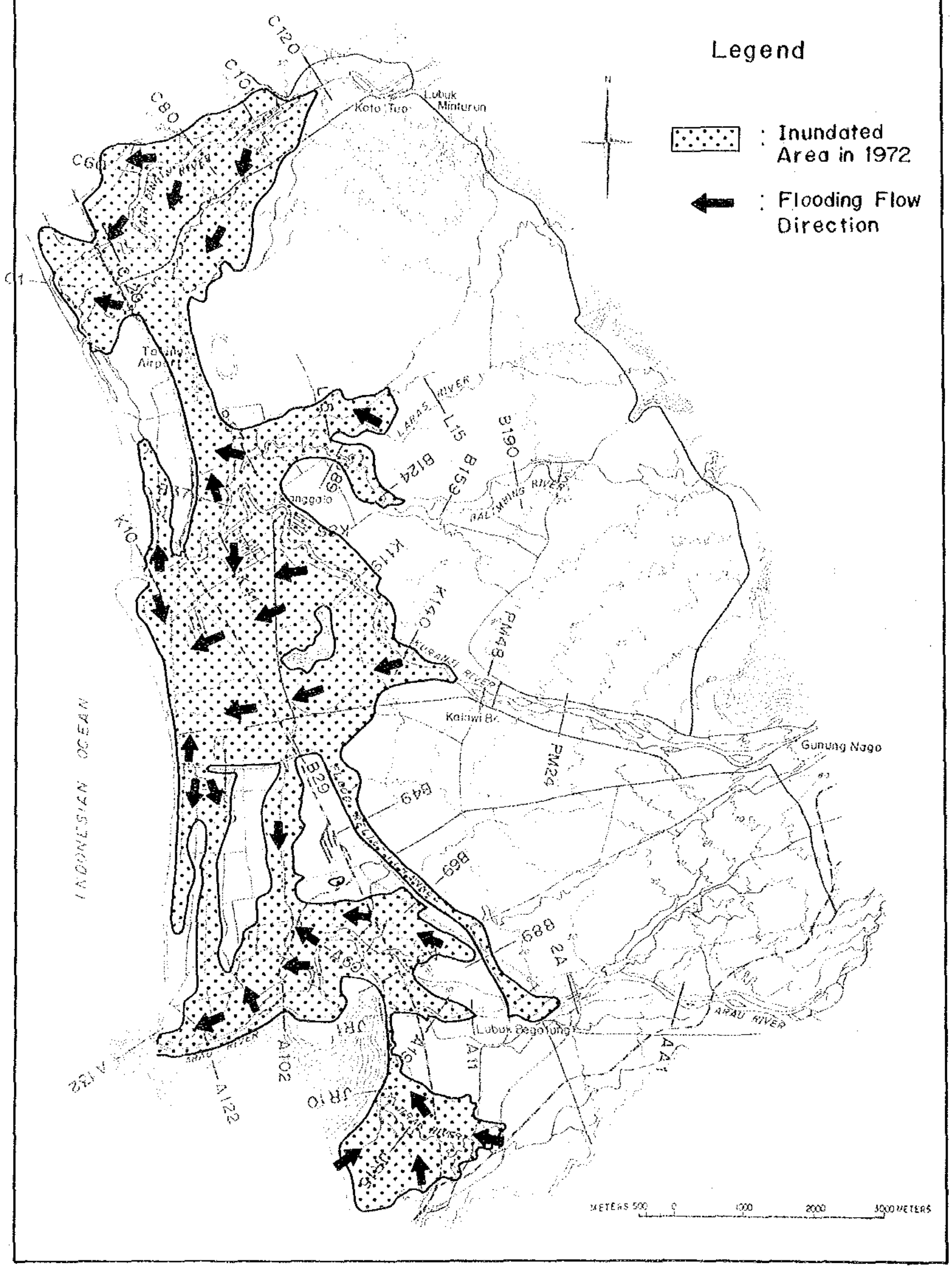
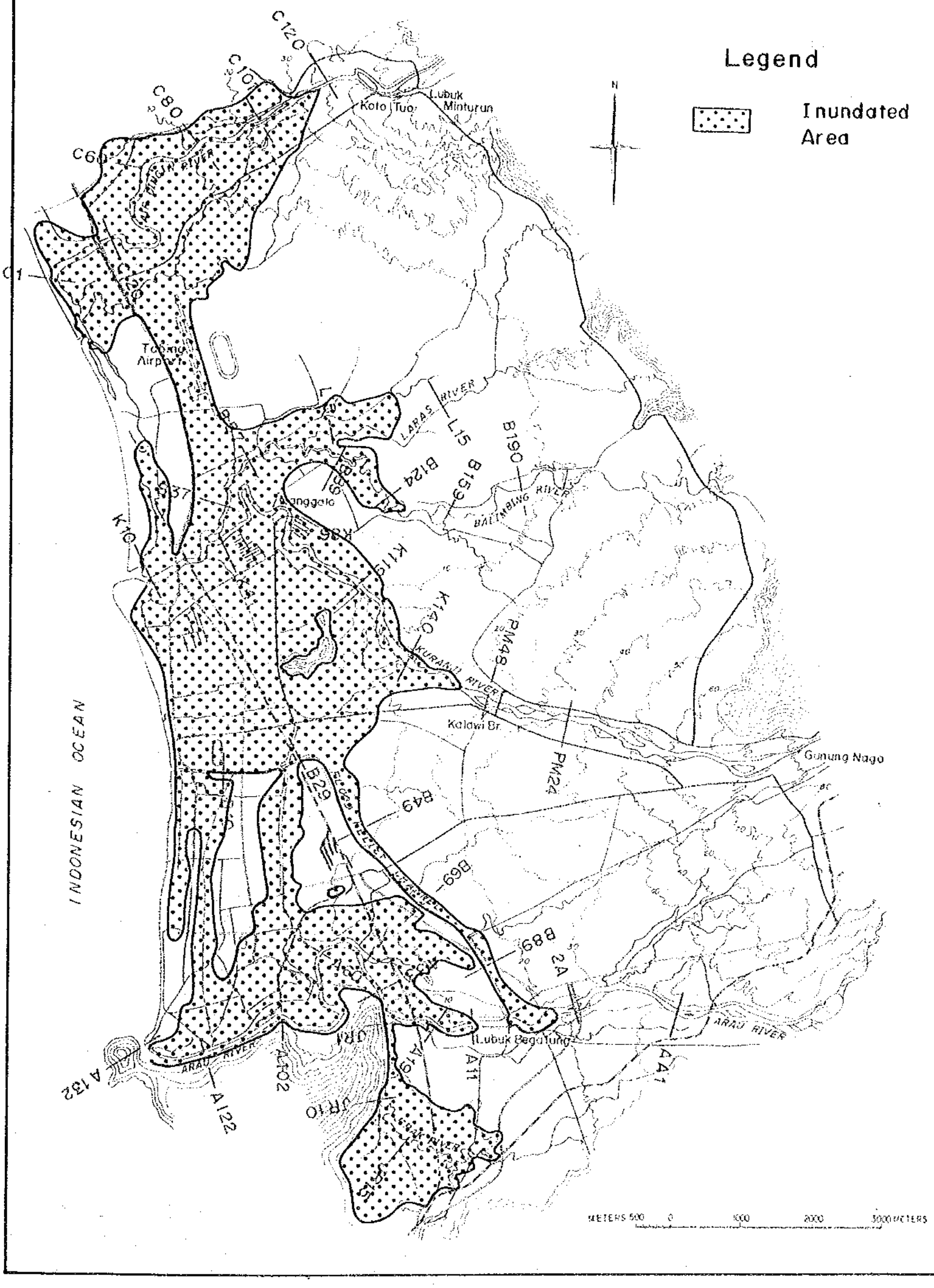


Fig. F-9(1) Inundated Area Caused by May 1972 Flood



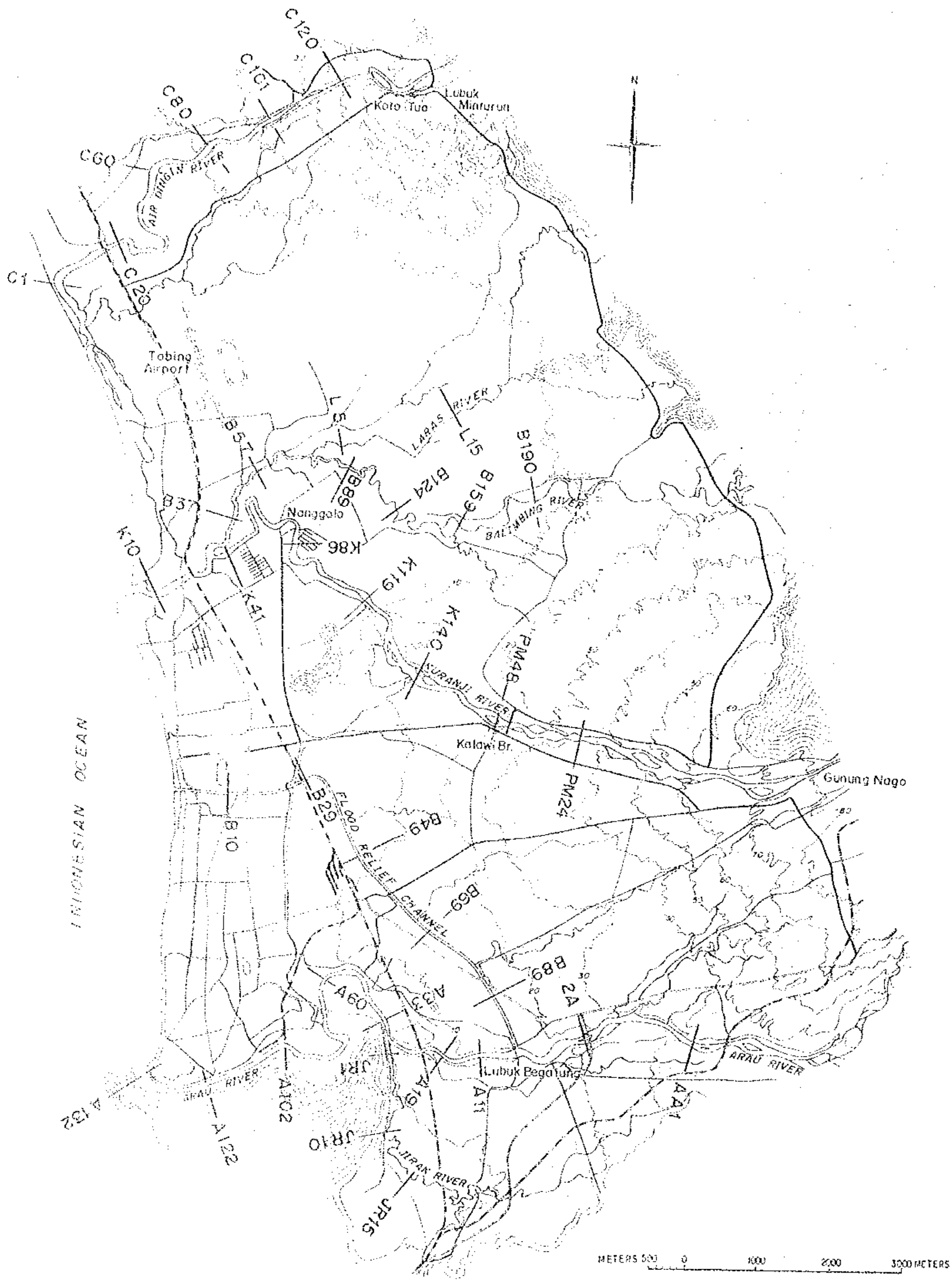

N
C120
C101
C80
C60
C1
C20
Koto Tuo
Lubuk Minturun
AIR DINGIN RIVER
Tabing Airport
L5
LARAS RIVER
L15
B57
B190
B88
B124
B153
BALIMBING RIVER
B37
Nanggalo
K86
K10
K41
K119
K140
PM48
KURANJI RIVER
Kalawi Br.
Gunung Nago
PM24
INDONESIAN OCEAN
B29
FLOOD RELIEF CHANNEL
B10
B49
B69
B89
2A
A60
A33
JR1
ARAU RIVER
A132
A122
A102
A19
A11
AA1
JR10
JIRAK RIVER
JR15
METERS 500 0 1000 2000 3000 METERS

Fig. F-9(3) Inundated Area Caused by Nov.1980 Flood

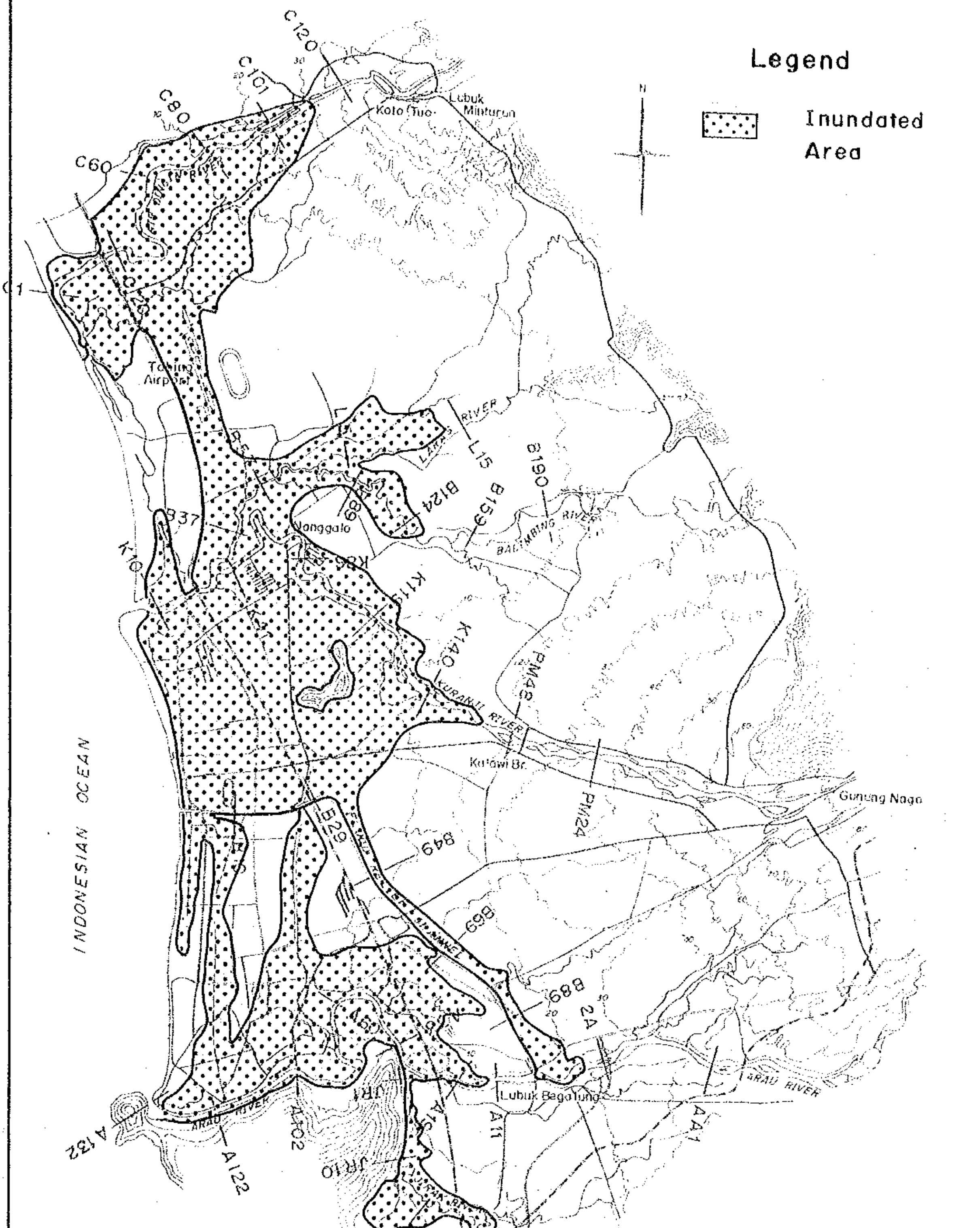


Fig. F-9(4) Inudated Area Caused by Nov. 1981 Flood

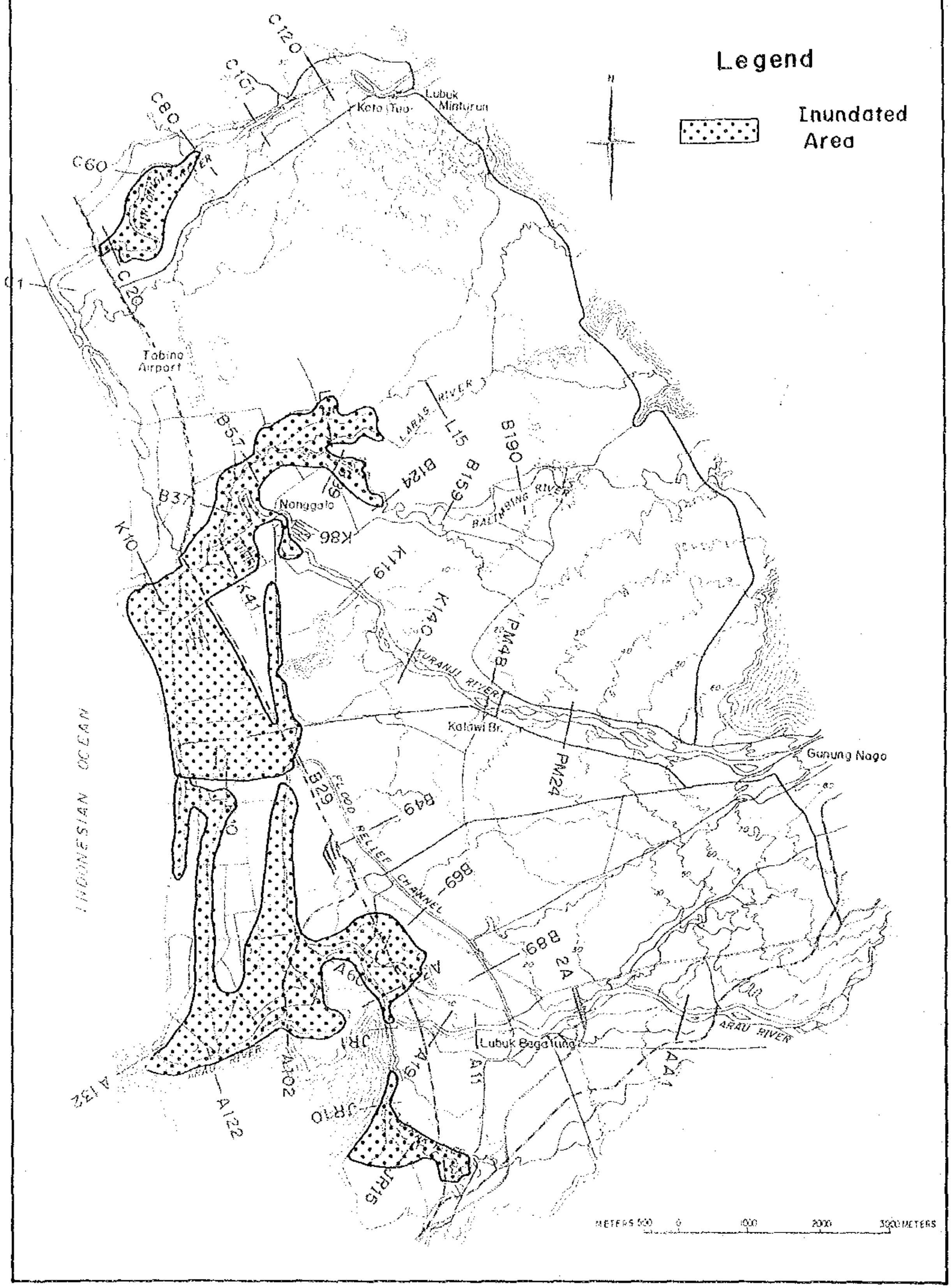


Fig. F-9(5) Inundated Area Caused by Dec. 1982 Flood

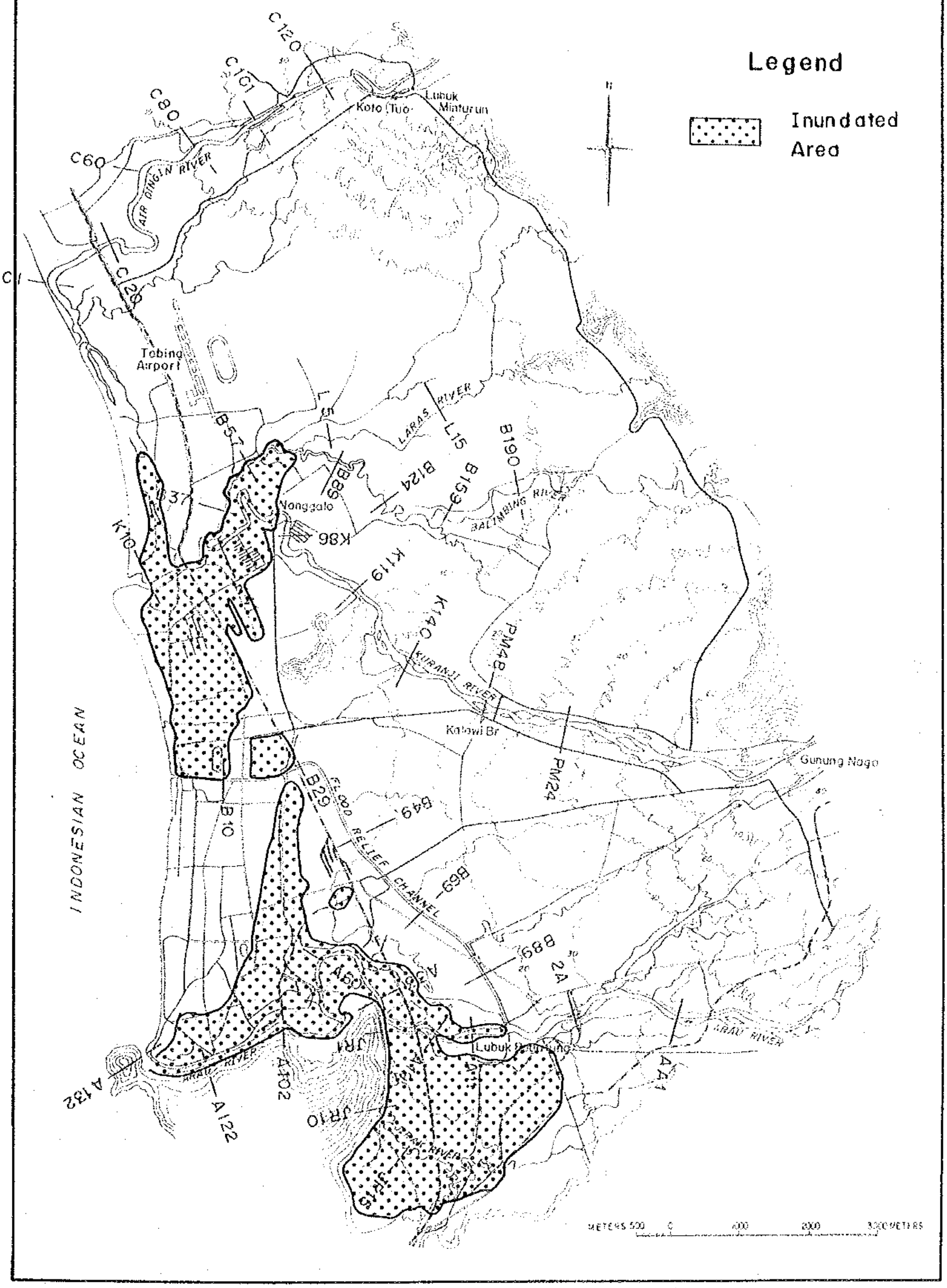


Fig. F-10 Simulation Model Diagram

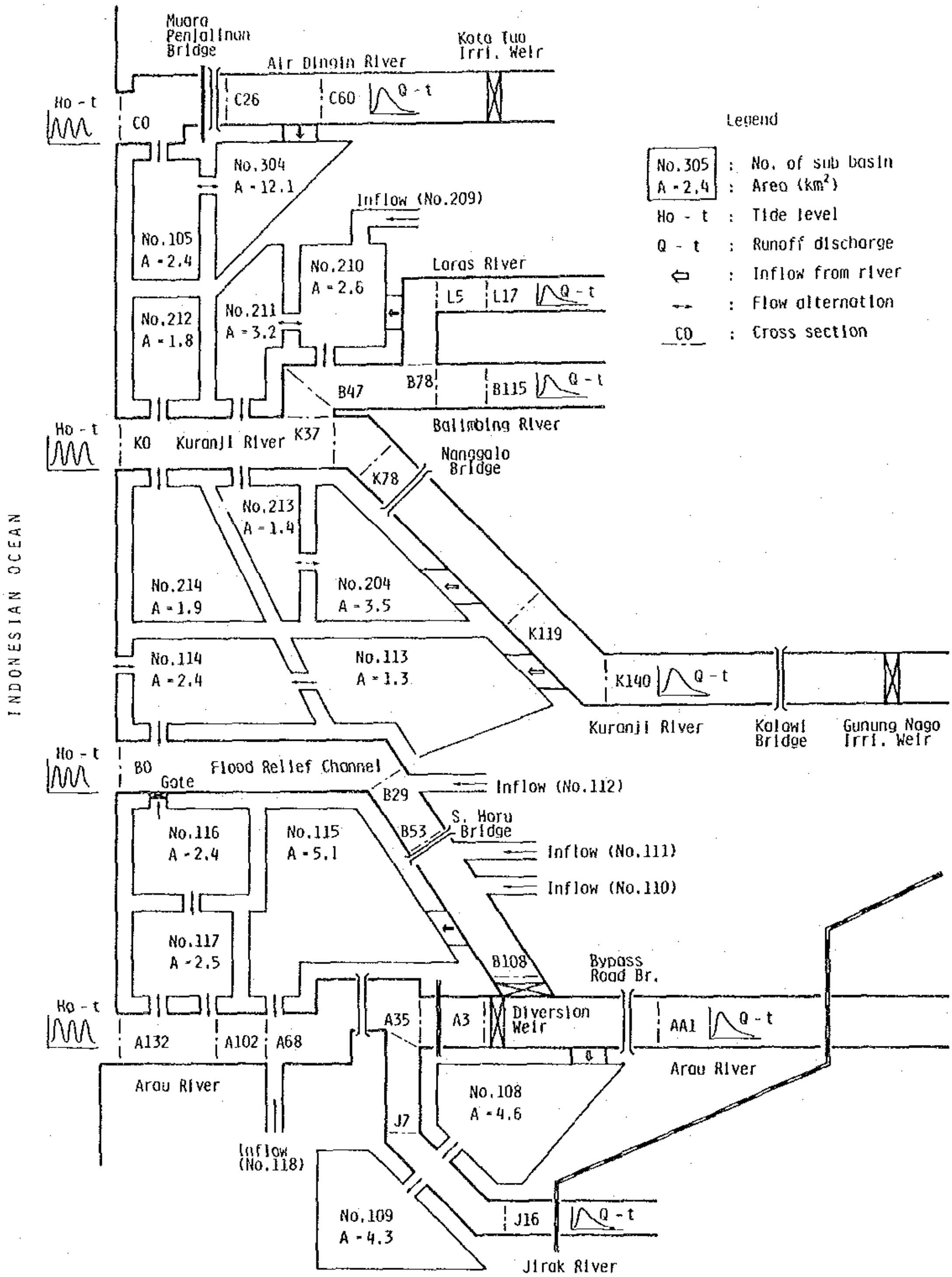


Fig. F-11 Simulated Inundation Area of Novmber 1980 Flood

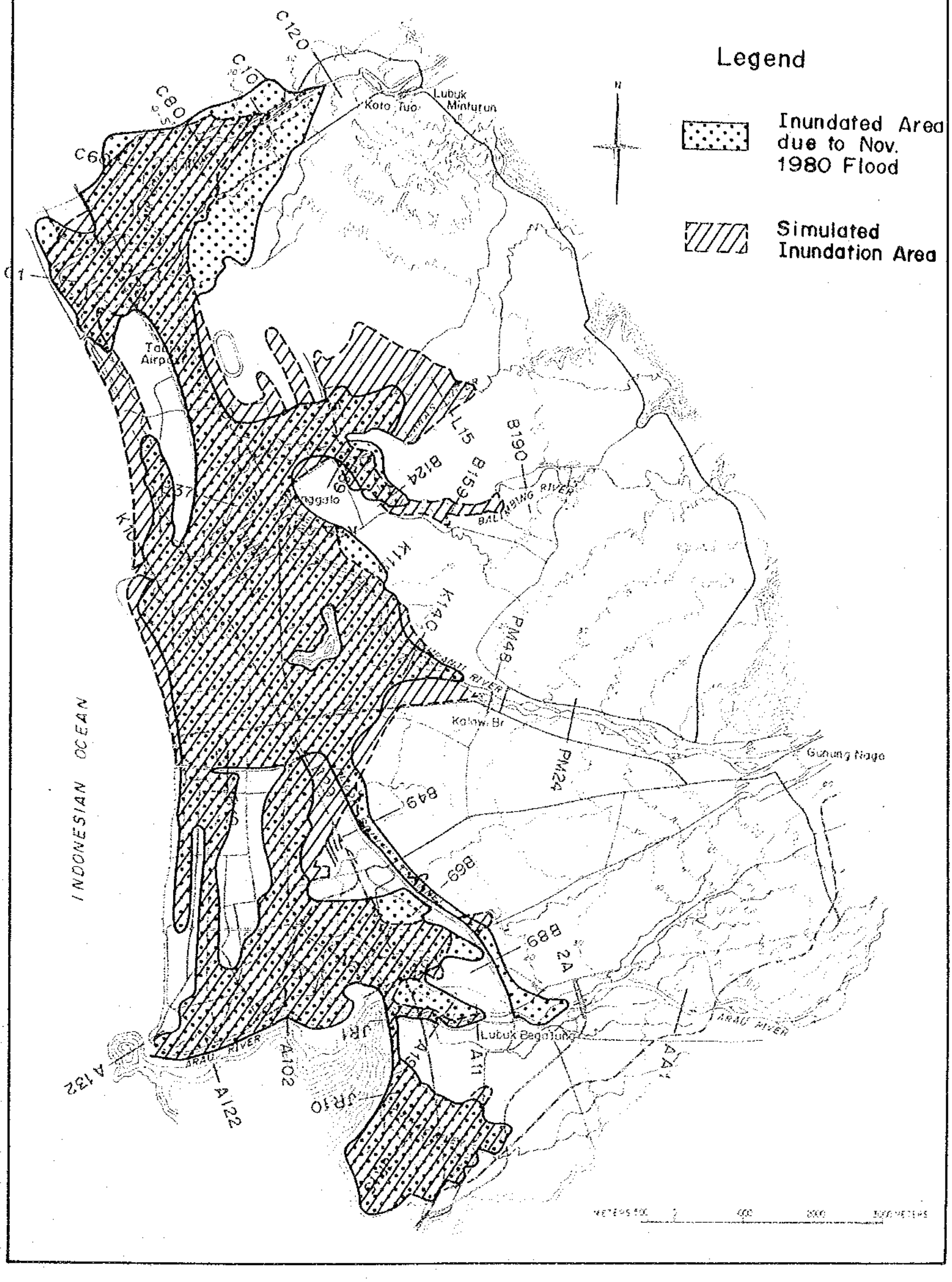


Fig. F - 12 (1) Probable Inundation Area (100-yr)

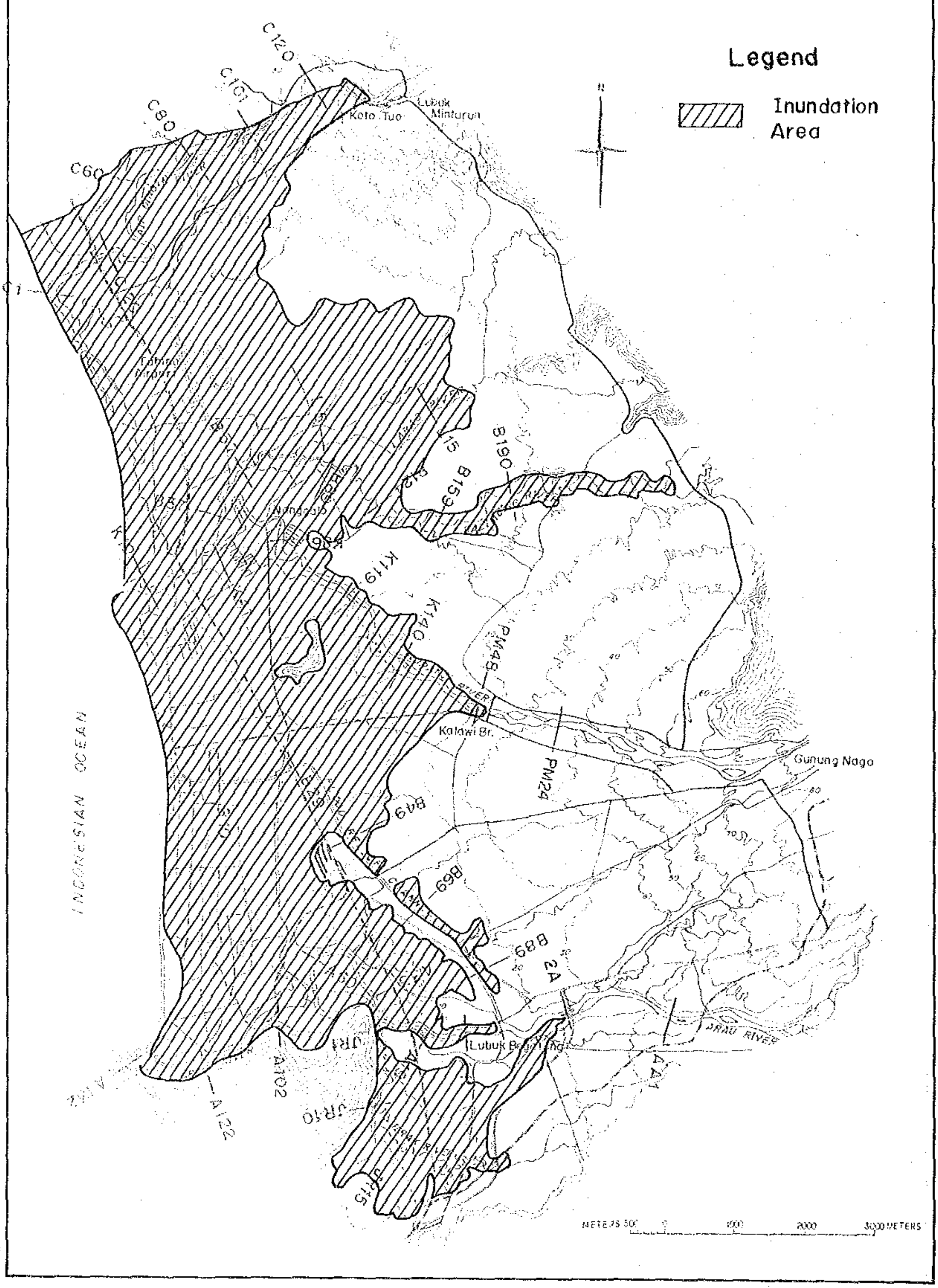


Fig. F-12(2) Probable Inundation Area (50-yr)

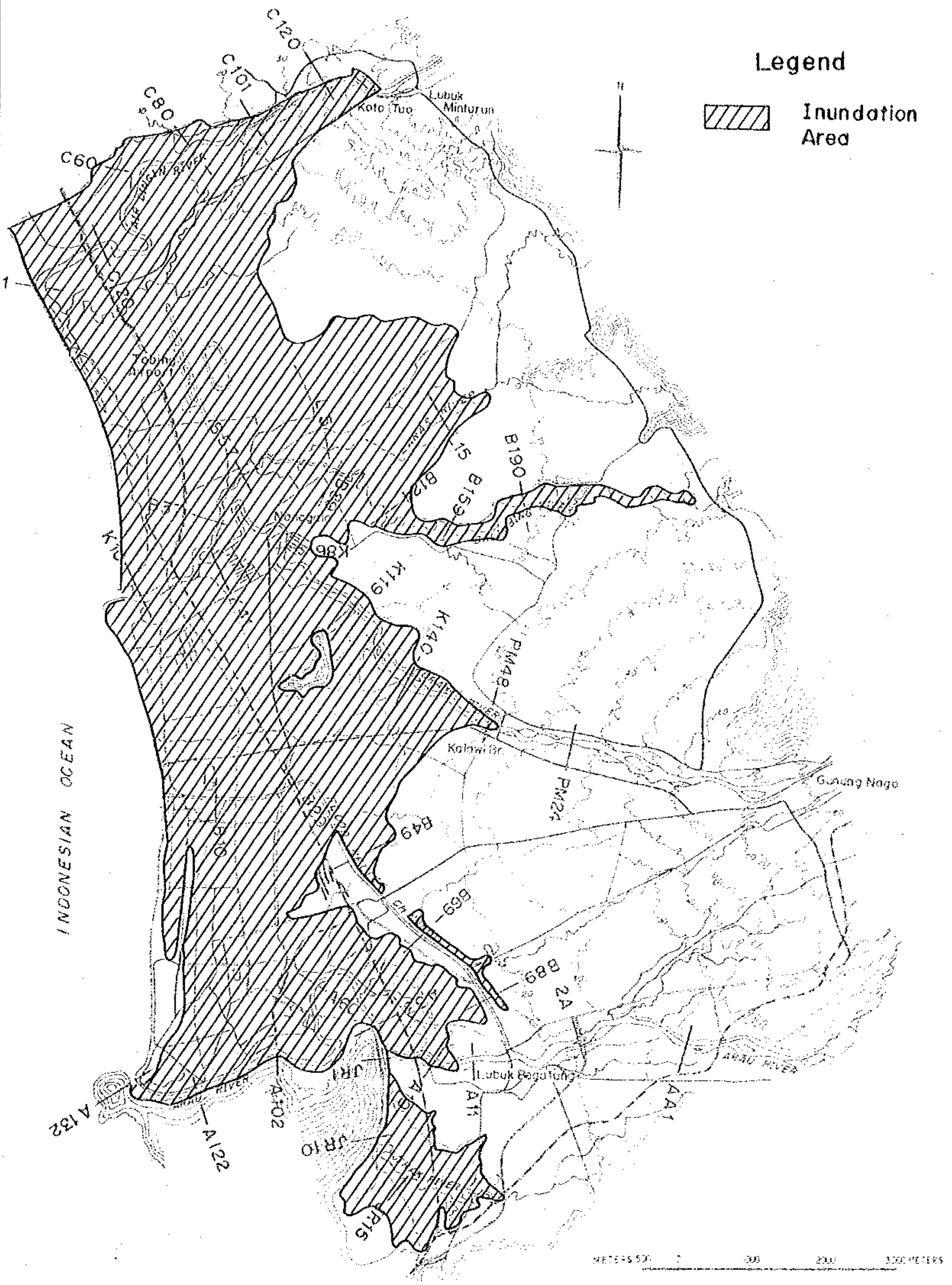


Fig. F-12 (3) Probable Inundation Area (25-yr)

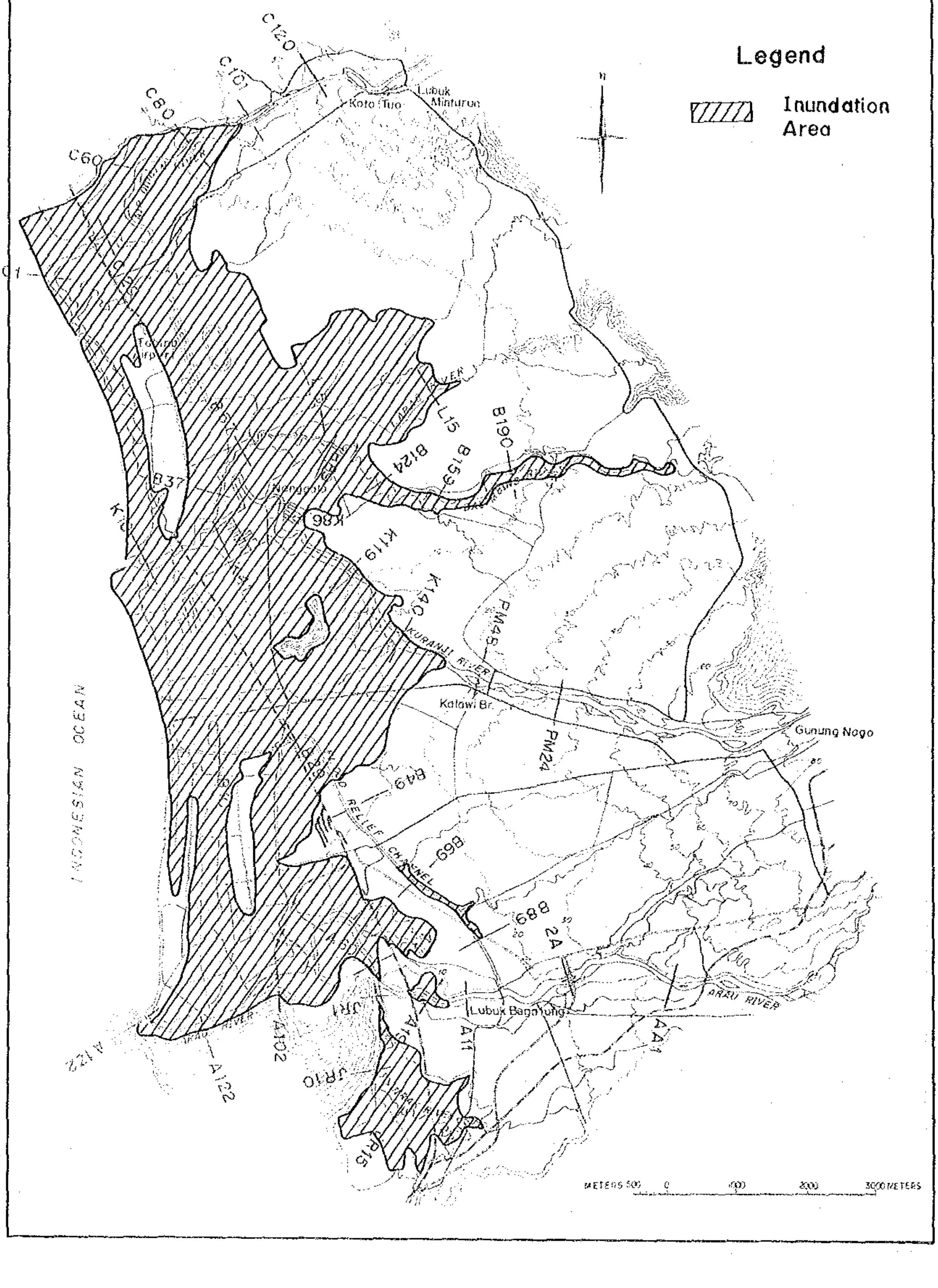


Fig. F-12(4) Probable Inundation Area (10-yr)

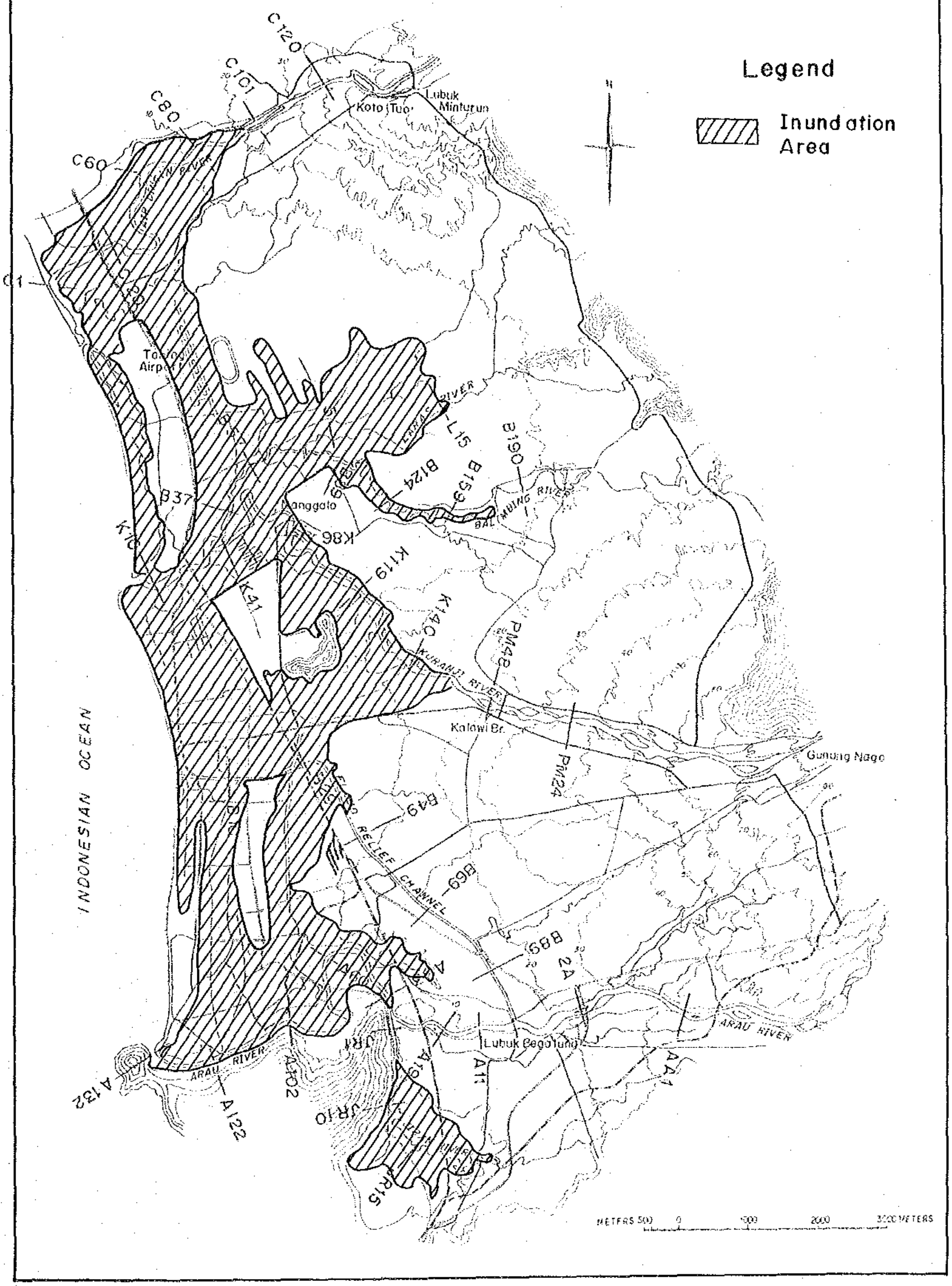
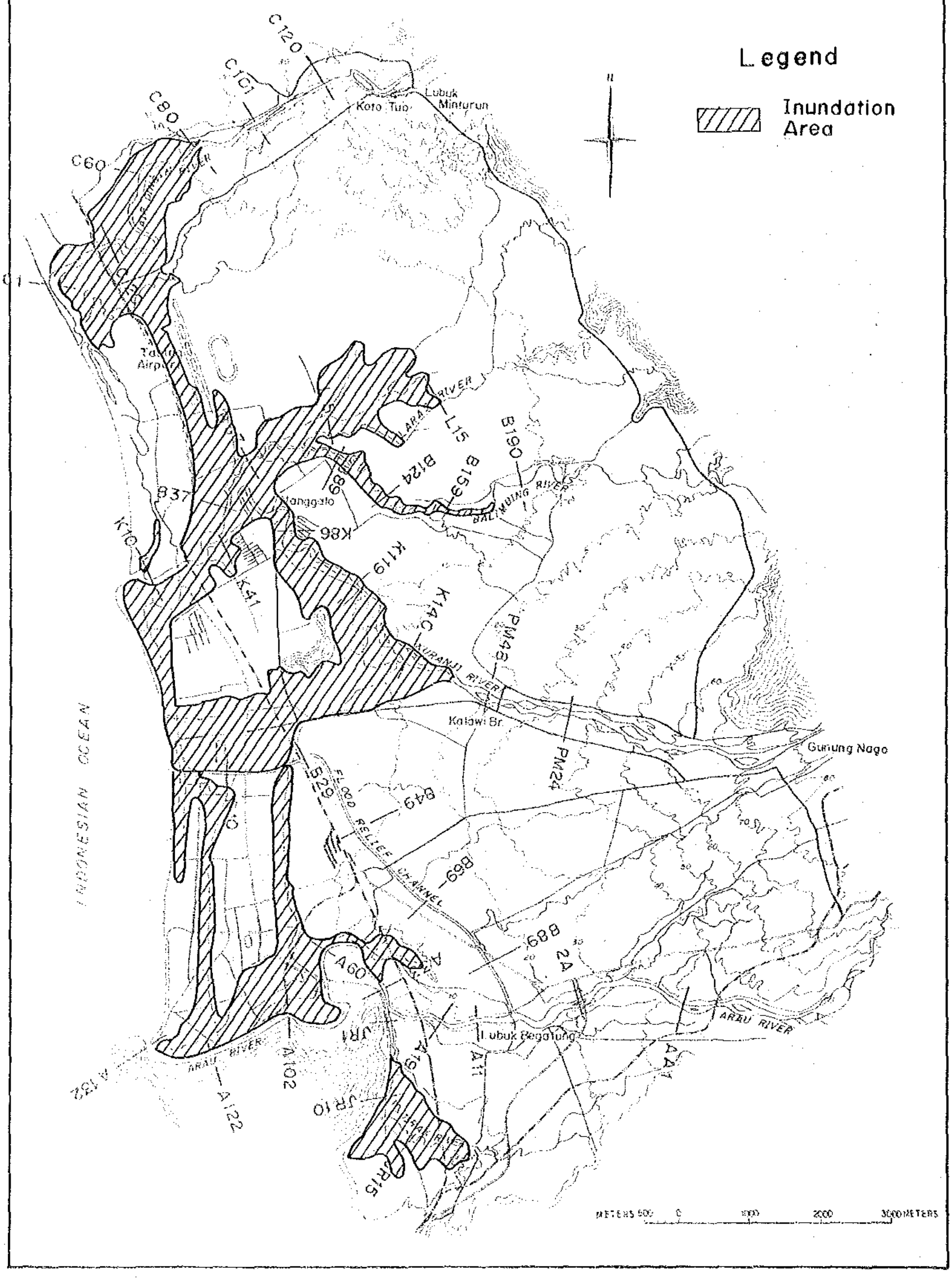


Fig. F-12(5) Probable Inundation Area (5-yr)



APPENDIX G

FLOOD DAMAGE

APPENDIX G

FLOOD DAMAGE

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1. Methodology

1.1 General

The flooding area is located in the middle and lower basins of the Arau, Kuranji and Air Dingin rivers which flow through Padang city. The Flooding area is composed of the old and new urban areas and their surrounding areas.

Flood damages are estimated, in principle, from properties in the flooding area multiplied by the damage ratio depending on the flooding conditions. The damages are estimated for the respective properties such as house and household effects, shops and warehouses, agricultural crops, public facilities and others.

The flooding conditions such as area, depth and duration of flooding or inundation are obtained based on the calculation results by the flood simulation model in APPENDIX F.

All the monetary values are expressed by the economic prices as of the beginning of June 1983. The conversion rates of foreign and local currencies are assumed at US$ 1 = ¥ 240 = Rp. 970.

The methods adopted to the estimation of damages for respective properties are discussed further in the following sections.

1.2 Damages to Houses and Household Effects

House

The house includes residence and farm house. The unit value of the house is estimated as:

$$V_h = A_f \times C_{con} \times R_{dep}$$

$$= 85\ m^2 \times Rp.43,750/m^2 \times 0.64 = Rp.2,440,000 \text{ for residence.}$$

$$= 44\ m^2 \times Rp.32,250/m^2 \times 0.70 = Rp.990,000 \text{ for farm house.}$$

Where, V_h : unit value of house,

A_f : average floor area of a house, estimated based on data[/1] from Kecamatan office. A weighted mean floor areas of temporary, ordinary, semi-parmanent and parmanent houses are applied to estimate the area of ordinary and farm houses,

C_{con}: unit area construction cost of house based on data published from Padang city[/2], and

R_{dep}: depreciation rate of house. The rate for appraisal of fixed assets used in Japan is applied because local data are not obtainable.

The rates of damage to house are shown in Table G-1 applying standards in Japan.

Household Effects

The values of total household effects of residence and farm house are estimated as :

$$V_{he} = Q_{he} \times P \times R_{dep}$$

= Rp.730,000/house for residence,
= Rp.500,000/house for farm house.

Where, V_{he} : value of household effects per house,

Q_{he} : standard quantity of household effects of each house based on the information from Kantor Perdagangan Padang (Commercial Office of Padang city) and Kecamatan office[/3],

P : unit price based on consumer price surveyed by Kantor Statistik Padang (Statistic Office of Padang city), and

R_{dep}: depreciation rate of household effects (= 70 %). The rate for appraisal of fixed assets used in Japan is applied since local data are not obtainable.

/1 Daftar Pertanyaan, Kecamatan Padang Timur, 1982.

/2 Perobahan Taksiran Harga Bangunan, 1982.

/3 Kecamatan Padang Timur.

In estimating the value of household effects, the average life time and period of use are assumed to be 6 years and 2 years, respectively. Vertical distribution of household effects used for the estimation is shown in Table G-1.

The rates of damage to household effects are shown in Table G-1 applying the standards in Japan.

1.3 Damages to Shops and Warehouses

Building

In the similar manner as unit value of house, the unit values of shop building (V_s) and warehouse (V_w) are estimated as follows:

V_s = 65 m^2 × Rp.58,250/m^2 × 0.77 = Rp.3,030,000 for shop building,

V_w = 136 m^2 × Rp.70,000/m^2 × 0.77 = Rp.8,000,000 for warehouse.

The floor area of shop buildings is assumed as an average of those of residence and farm house since they include kiosks. The average floor area of warehouses is estimated based on the data from the Commerical Office of Padang city.

The rates of damage to shop buildings and warehouses are shown in the said Table G-1.

Stored Goods

The values of stored goods in a shop and a warehouse are estimated as follows :

$$V_s = (Q_{pin} + Q_{lin} - Q_{pout} - Q_{lout}) \times S_s \times P/N_s$$

$$= \text{Rp. } 3{,}960{,}000/\text{shop},$$

$$V_w = (Q_{pin} + Q_{lin} + Q_{pout} + Q_{lout}) \times S_w \times P/N_w$$

$$= \text{Rp. } 10{,}300{,}000/\text{warehouse}.$$

Where, V_s, V_w : values of stored goods in a shop and a warehouse respectively,

Q_{pin}, Q_{pour} : average monthly import goods and export goods for inter-local and international trade at Teluk Bayur and Muara ports, respectively. Records in 1982[/4] collected at Teluk Bayur and Muara port authorities were used. Only the goods which may have relation with shops and warehouses on their distribution routes were taken into account,

Q_{lin}, Q_{lout} : average monthly goods to be carried into and carried out from Padang city respectively, by land transportation. Records in 1982[/5] collected at Land Traffic and Transportation Authority of West Sumatra are used,

S_s, S_w : period of storage in shop and warehouse. Based on the information from the Commercial Office of Padang city, S_s is assumed at 3 months and S_w at 0.3 month,

P : unit price of stored goods estimated based on consumer price surveyed by the Statistic Office of Padang city, and

N_s, N_w : total number of shops and warehouses respectively, in Padang city.

The vertical distribution of stored goods in shops and warehouses used for the damage estimation is shown in the said Table G-1. The damage rates of the stored goods are shown in the said Table G-1.

The appraisement of properties consisting residence, shop, warehouse, farm house and their household effects or stored goods as results of calculation mentioned above in Section 1.2 and 1.3 are shown in Table G-1.

/4 Kunjungan Kapal dan Cargo Flow serta Penumpang Turun Naik Melalui Pelabuhan Teluk Bayur, 1982.

/5 Jumlah Angkutan Barang Keluar/Masuk Dati I Sumatera Barat, 1982.

1.4 Damages to Agricultural Crops

According to Padang Dalam Angka (Statistical Yearbook of Padang), the farm land of upland crops is far small, less than 1 % of the total flood prone area. The flood damages to upland crops are negligible. Therefore, only the paddy is taken account in estimating the agricultural flood damages.

The flood damages of paddy are estimated as follows:

$$D_p = A_p \times Y_p \times P \times R_y$$

Where,
- D_p : flood damages of paddy,
- A_p : inundated area of paddy field
- Y_p : unit yield rate of paddy per ha (= 4.2 ton/ha) based on the Statistical Yearbook of Padang.
- P : unit price of paddy, and
- R_y : yield reduction rate of paddy due to flood.

Unit Price of Paddy

Based on the paddy price predicted by the World Bank (IBRD), the farm gate price of paddy (dry stalked paddy) at Padang is estimated as shown in Table G-2. The unit price of the paddy is estimated at Rp.338/kg.

Cropping Pattern and Flood Season

The double cropping is performed in Padang area, i.e., the first crop from transplanting in November to harvesting in the middle of April, and the second crop from the middle of May to August.

On the other side, the area has two flood seasons around November and April which happen to be at the beginning of tillering stage and ripening stage of paddy.

Yield Reduction Rate

In consideration of growing stage of paddy in flood season, the following yield reduction rates for different flooding condition are assumed based on the data[6] developed in Japan.

Yield reduction rate (%)			
Sedimentation or erosion	Inundation depth (m)		
	0 to 0.3	0.3 to 0.5	Over 0.5
100	4	6	10

1.5 Damages to Public Facilities

Flood damages to river facilities, roads and bridges are as follows according to DPU, West Sumatra, and Padang city.

(Rp.10^6)

Year	Damages at current price			Damages [9] at present price
	Damages to [7] river facilities	Damages to [8] road & bridges	Total	
1972	118.00	1.66	119.66	776.00
1973	20.99	0.54	21.53	107.00
1974	9.53	0.81	10.34	42.00
1975	28.24	0.86	29.10	114.00
1976	24.51	1.19	25.70	97.00
1977	32.34	3.37	35.71	128.00
1978	39.31	1.59	40.90	135.00
1979	100.00	3.88	103.88	259.00
1980	225.39	4.76	230.15	353.00
1981	200.00	7.00	207.00	285.00
1982	150.86	7.58	158.44	206.00
Average				216.00

/6 Rate of Decrease in Yield of Submerged Paddy, by Agricultural Experiment Station of the Ministry of Agriculture and Forestry, Japan.

/7 Proyek Perbaikan dan Pengamanan Sungai Daerah TK I, Sumatera Barat, P.U., Sumatera Barat.

/8 Rehabilitasi, Peningkatan dan Pemeliharaan Jalan di Kotamadya Padang, P.U., Kotamadya Padang.

/9 Using the conversion rate of construction materials reported in Indikator Economi, Biro Pusat Statistik, Jakarta.

These damages correspond to 8.4 % of total flood damage of house and household effects, and agricultural crops. Taking into account of other damages to such agricultural facilities as intake, irrigation and drainage canals, total damages to public facilities are assumed at 10 % of total damages to house and household effects and agricultural crops.

1.6 Other Damages

The amount corresponding to 10 % is assumed that of the total direct flood damages for the losses due to interruption of smooth traffic and other economic activities in the urban area.

2. Flood Damages in Present Situation

2.1 Probable Flood Damages

The land in the objective area has rapidly been developed for residential area year by year. If a project is implemented for flood control in this area, it seems to be necessary 7 and/or 8 years as a period for project implementation. Therefore, probable flood damages are estimated for obtaining basic data in estimation of project benefits for the situation of the year 1991 adding to the present condition based on the situation as of 1981.

For the situation of the year 1991, a developing conditions of land are assumed on the basis of informations obtained from the Padang city office, the office of National Housing Program (PERUMNAS) of the Ministry of Domestic Affairs in Padang and several private developers in Padang who have the actual Development plans at the present time. The floods of 2, 5, 10, 25 and 100-year return periods are taken up for the studies.

For the estimation of amount of damages, the objective flooding area is divided into eight blocks as shown in Fig. G-1, in consideration of cases for conceibable alternatives :

a. Arau river system
   - Block 1 : Arau mainstream and flood relief channel
   - Block 2 : Jirak river

- Block 3 : Interior water area

b. Kuranji river system
   - Block 4 : Kuranji mainstream
   - Block 5 : Balimbing and Laras rivers
   - Block 6 : Interior water area

c. Air Dingin river system
   - Block 7 : Air Dingin river
   - Block 8 : Interior water area

The flood damages are estimated for every return periods and for every blocks.

Flooding Area and Paddy Field

According to the results of flood simulation analysis in APPENDIX F, flooding area and paddy field in it as of 1981 and 1991 are shown in Tables G-3 and G-4. In preparing the table, land areas are measured for every block, land use, range of inundation depth using the flooding maps prepared by flood simulation analysis and aerial photoes taken in 1981 by each river system, site reconnaissance, and collected data and informations from several authorities and/or agencies mentioned at the beginning of this Section.

Number of Buildings Submerged

The number of buildings in the flooding area is counted on the aerial photoes taken in 1981. Then, the buildings are classified into residence, shop, warehouse and farm house by the composition rate of them in respective Kecamatan. The rates as shown in Table G-5 are derived based on data collected from the Commercial Office of Padang city and 1980 census report of the city. The unit damages per house/building are calculated as shown in Table G-6. Number of buildings submerged are calculated as shown in Table G-7 for each Kecamatan, Table G-8 for respective return periods, and Table G-9 for depth of inundation.

For estimation of number of houses in flooding area as of 1991, a rate of 28 houses per ha is applied for the housing area which will be developed naturally up to the year 1991, based on the information for on-going housing projects obtained from the Agrarian Office, City Planning Office, past population tendencies and present density of houses as of 1981. as shown in Fig. G-2.

The number of submerged buildings as of 1991 is estimated as shown Table G-10.

Probable Flood Damages

Table G-11 and 12 show the calculation of flood damages for respective return periods, kinds of properties and blocks of basins as of 1981 and 1991 respectively. The flood damages, thus, estimated are summarized in Table G-13 and 14. The total flood damages for respective return periods under the conditions of the year 1981 and 1991 are as follows :

Return Period (year)	Flood damages (Rp. 10^6)							
	Arau river system		Kuranji river system		Air Dingin river system		Total	
	1981	1991	1981	1991	1981	1991	1981	1991
2	920	920	570	700	240	260	1,730	1,870
5	9,510	10,400	1,750	2,160	360	630	11,620	13,190
10	16,110	16,570	3,520	4,460	710	1,060	20,340	22,090
25	22,800	23,610	4,790	5,920	1,690	2,850	29,270	32,370
50	23,590	24,560	5,490	6,560	3,070	3,080	32,160	34,200
100	25,000	26,050	6,220	7,260	3,160	3,700	34,380	37,020

2.2 Annual Average Flood Damages

The annual average flood damages are estimated as a cumulus of flood damage segments derived from probable flood damages multiplied by the corresponding probability of occurrence, from non-damageable runoff up to 100-year probable flood.

The calculation of annual average flood damages are shown in Table G-15 and 16. The results are as follows :

(Rp. 10^6/year)

River system/Block		Annual average flood damages 1981	1991
a. Arau river system			
- Block 1 : Arau mainstream and flood relief channel	:	2,400	2,630
- Block 2 : Jirak river	:	70	80
- Block 3 : Interior water area	:	2,480	2,510
- Sub-total	:	4,950	5,220
b. Kuranji river system			
- Block 4 : Kuranji mainstream	:	510	680
- Block 5 : Balimbing and Laras rivers	:	290	390
- Block 6 : Interior water area	:	370	380
- Sub-total	:	1,170	1,450
c. Air Dingin river system			
- Block 7 : Air Dingin river	:	330	460
- Block 8 : Interior area	:	30	30
- Sub-total	:	360	490
d. Total	:	6,480	7,160

Table G-1 Basic Rates for Estimation of Damages

A. Rate of Damage to House and Building Submerged

Water level above floor (m)	Rate of damage
0 - 0.49	0.037
0.50 - 0.99	0.064
1.00 - 1.49	0.099
1.50 - 1.99	0.137
2.00 - 2.49	0.179

Source : Ministry of Construction, Japan.

B. Rate of Appraisement of Household Effects and Stored Goods by Height above Floor Level (Unit : %)

Kind of houses	Height above floor level (m)					
	0 - 0.5	0 - 1.0	0 - 1.5	0 - 2.0	0 - 2.5	0 - 3.0
Residence	56	79	89	94	99	100
Shop and warehouse	38	63	77	88	96	99
Form house	65	90	95	98	100	100

Source : Ministry of Construction, Japan.

C. Rates of Damages to Properties Submerged (Except Houses/Buildings)

Kind of properties	Rate of damage to submerged goods
(A) Household effects of residence and farm house	0.690
(B) Stored goods of shops and warehouse	0.597

Source : Ministry of Construction, Japan.

D. Appraisement of House or Building and Househod Effects or Stored Goods (Unit : Rp. 10^6)

Kind of house	Appraisement		
	House/Building	Household effects/ stored goods	Total
Residence	2,440	730	3,170
Shop	3,030	3,960	6,960
Warehouse	8,000	10,300	18,300
Farm house	990	500	1,490

Table G-2 Calculation of Economic Farm Gate Price of Paddy

Unit : Rp./ton

1. International Market Price of Milled Rice, FOB-Bangkok, Thai 5 % broken, US$ 662/1	642,140
2. Quality Discount at 20 %	513,700
3. External Transportation Cost (Bangkok - Teluk Bayur)	+)36,000
4. Port Handling Charge and Storing Cost (Including cost of sack)	+)16,100
5. Price of Milled Rice at Ex-DOLOG (at Teluk Bayur)	565,800
6. Inland Transportation Cost (Teluk Bayur - Padang, Rp.82/ton x 1.5 x 14 km)	-) 2,000
7. Milling Charge	-)30,700
8. Local Storage Loss (5%)	-)28,300
9. Price of Milled Rice at Ex-Mill Gate	504,800
10. Conversion to Price of Dry Stalked Paddy (68 %)	343,300
11. Handling and Transportation Cost (farm gate to mill)	-) 5,100
12. Economic Farm Gate Price of Dry Stalked Paddy	338,200 (338,000)

Source : Price Prospects for Major Primary Commodities, IBRD, 1981 (Forecasted price of milled rice in 1990 is made based on 1982 constant dollars converted from 1980 constant dollars: US$ 575 x 1.151 = US$ 662).

/1 Conversion rate : US$ 1 = Rp. 970.

Table G-3 Inundated Area for Respective Return Periods in 1981

Unit : ha

River		Return period											
		2 - yr		5 - yr		10 - yr		25 - yr		50 - yr		100 - yr	
		Whole area	Paddy area	Whole area	Paddy area	Whole area	Paddy area	Whole area	Paddy area	Whole area	Paddy area	Whole area	Paddy area
Arau river system	Arau main-stream	0	0	100	0	220	10	270	20	340	30	380	130
	Flood relief channel	0	0	40	0	110	10	140	30	170	40	170	60
	Jirak river	0	0	60	40	90	60	160	80	200	100	280	110
	Interior water area	360	10	400	10	440	10	500	10	570	10	590	10
	Sub-total	360	10	600	50	910	90	1,170	140	1,420	180	1,700	310
Kuranji river system	Kuranji main-stream	50	10	410	240	580	250	720	290	770	310	820	330
	Balimbing river	120	20	230	40	300	50	410	70	460	80	490	80
	Laras river	210	70	250	90	400	150	540	210	690	280	830	340
	Interior water area	80	0	90	0	110	0	110	0	110	0	110	0
	Sub-total	460	100	980	370	1,390	450	1,780	570	2,030	670	2,250	750
Air Dingin river system	Air Dingin river	170	100	250	170	280	200	310	220	410	260	420	270
	Interior water area	50	0	180	70	240	70	260	80	280	80	300	90
	Sub-total	220	100	430	240	520	270	570	300	690	340	720	360
Grand total		820	210	2,010	660	2,820	810	3,520	1,010	4,140	1,190	4,670	1,420

Note : Inundated area caused by flood due to mainstream and interior water are classified into an area of mainstream and an interior water area.

Table G-4 Inundated Area for Respective Return Periods in 1991

Unit : ha

River		Return period											
		2 - yr		5 - yr		10 - yr		25 - yr		50 - yr		100 - yr	
		Whole area	Paddy area	Whole area	Paddy area	Whole area	Paddy area	Whole area	Paddy area	Whole area	Paddy area	Whole area	Paddy area
Arau river system	Arau mainstream	0	0	100	0	220	10	270	10	340	20	380	120
	Flood relief channel	0	0	40	0	110	10	140	30	170	40	170	60
	Jirak river	0	0	60	20	90	30	160	50	200	70	280	80
	Interior water area	360	0	400	0	440	0	500	0	570	0	590	0
	Sub-total	360	0	600	20	910	50	1,170	90	1,420	130	1,700	260
Kuranji river system	Kuranji mainstream	50	10	410	200	580	200	720	230	770	240	820	260
	Balimbing river	120	20	230	40	300	30	410	40	460	50	490	50
	Laras river	210	60	250	70	400	130	540	190	690	250	830	310
	Interior water area	80	0	90	0	110	0	110	0	110	0	110	0
	Sub-total	460	90	980	310	1,390	360	1,780	460	2,030	540	2,250	620
Air Dingin river system	Air Dingin river	170	100	250	150	280	180	310	190	410	220	420	230
	Interior water area	50	0	180	70	240	70	260	80	280	80	300	90
	Sub-total	220	100	430	220	520	250	570	270	690	300	720	320
Grand total		820	190	2,010	550	2,820	660	3,520	820	4,140	970	4,670	1,200

Note : Inundated area caused by flood due to mainstream and interior water are classified into an area of mainstream and an interior water area.

Table G-5 Distribution Ratio of Buildings in Each Kecamatan

(as of 1981)

	Residence	Shop	Ware house	Farm house	Total
1. Padang Selatan	87 %	6 %	1 %	6 %	100 %
2. Padang Barat	84	13	3	0	100
3. Padang Utara	94	4	1	1	100
4. Padang Timur	91	5	1	3	100
5. Koto Tangah	49	8	2	41	100
6. Naggalo	85	3	1	11	100
7. Kuranji	59	4	1	36	100
8. Lubuk Begalung	84	2	0	14	100

Source : Dinas Tata Kota, Kotamadya Padang.

Table G-6 Unit Damages per House/Building
(Price : at the beginning of June 1983)

(Unit: Rp.10^3)

Kecamatan	Depth of inundation	Residence Bldg	Residence Prpts	Shop Bldg	Shop Goods	Warehouse Bldg	Warehouse Goods	Farm house Bldg	Farm house Prpts
Padang Selatan	0.20-0.69(m)	112	244	10	54	4	23	3	14
	0.70-1.19	153	345	13	89	6	39	4	19
	1.20-1.69	231	388	18	109	9	47	6	20
	1.70-2.19	231	410	18	125	9	54	6	20
	2.20-2.69	322	432	28	136	12	59	9	21
	sediment/erosion	1,669	537	143	190	63	82	47	25
Padang Barat	0.20-0.69(m)	108	236	21	117	13	70	0	0
	0.70-1.19	148	333	28	194	17	116	0	0
	1.20-1.69	223	375	39	237	26	142	0	0
	1.70-2.19	223	396	39	270	26	162	0	0
	2.20-2.69	312	417	60	295	36	177	0	0
	sediment/erosion	1,611	518	310	411	189	247	0	0
Padang Utara	0.20-0.69(m)	121	264	6	36	4	23	1	2
	0.70-1.19	165	372	9	60	6	39	1	3
	1.20-1.69	250	419	12	73	9	47	1	3
	1.70-2.19	250	443	12	83	9	54	1	3
	2.20-2.69	349	467	18	91	12	59	2	3
	sediment/erosion	1,803	580	95	127	63	82	8	4
Padang Timur	0.20-0.69(m)	185	256	13	45	7	23	2	7
	0.70-1.19	279	360	19	74	10	39	4	9
	1.20-1.69	393	406	27	91	14	47	5	10
	1.70-2.19	393	429	27	104	14	54	5	10
	2.20-2.69	591	452	40	113	21	59	8	10
	sediment/erosion	1,745	561	119	156	63	82	23	13
Koto Tangah	0.20-0.69(m)	99	138	20	72	13	47	34	93
	0.70-1.19	150	194	31	119	20	78	51	128
	1.20-1.69	212	219	43	146	28	95	72	135
	1.70-2.19	212	231	43	166	28	108	72	139
	2.20-2.69	318	244	64	182	43	118	108	142
	sediment/erosion	940	302	191	253	126	165	319	173
Nanggalo	0.20-0.69(m)	110	239	5	27	4	23	6	25
	0.70-1.19	150	337	7	45	6	39	8	34
	1.20-1.69	226	379	9	55	9	47	12	36
	1.70-2.19	226	400	9	62	9	54	12	37
	2.20-2.69	315	422	14	68	12	59	17	38
	sediment/erosion	1,630	524	71	95	63	82	86	47
Kuranji	0.20-0.69 (m)	182	166	15	36	10	23	45	81
	0.70-1.19	302	234	25	60	17	39	75	113
	1.20-1.69	444	263	37	73	25	47	110	119
	1.70-2.19	444	278	37	83	25	54	110	122
	2.20-2.69	632	293	53	91	35	59	157	125
	sediment/erosion	1,132	364	95	127	63	82	280	152
Lbk. Begalung	0.20-0.69(m)	108	236	3	18	0	0	7	32
	0.70-1.19	148	333	4	30	0	0	10	44
	1.20-1.69	223	375	6	36	0	0	15	46
	1.70-2.19	223	396	6	42	0	0	15	48
	2.20-2.69	312	417	9	45	0	0	21	49
	sediment/erosion	1,611	518	48	63	0	0	109	59

Table G-7 Number of Buildings Submerged in Each Kecamatan

River	Return period	Padang Selatan	Padang Barat	Padang Utara	Padang Timur	Koto Tangah	Nang-golo	Kuranji	Lubuk Begalung
Arau river	2 - yr	0	0	0	0	0	0	0	0
system :	5 - yr	0	5,150	180	40	0	0	0	0
Block 1/Arau	10 - yr	1,650	6,440	390	90	0	0	0	0
main stream	25 - yr	1,650	6,566	560	220	0	0	0	30
and flood	50 - yr	1,650	7,900	560	270	0	0	0	150
relief channel	100 - yr	1,650	8,240	570	330	0	0	0	440
Block 2/	2 - yr	0	0	0	0	0	0	0	0
Jirak river	5 - yr	0	0	0	0	0	0	0	210
	10 - yr	0	0	0	0	0	0	0	400
	25 - yr	0	0	0	0	0	0	0	430
	50 - yr	0	0	0	0	0	0	0	430
	100 - yr	0	0	0	0	0	0	0	430
Block 3/	2 - yr	0	1,220	160	0	0	0	0	0
Interior	5 - yr	0	6,480	250	0	0	0	0	0
water area	10 - yr	0	8,125	400	100	0	0	0	0
	25 - yr	0	8,640	420	170	0	0	0	0
	50 - yr	0	8,700	490	190	0	0	0	0
	100 - yr	0	9,250	770	240	0	0	0	0
Kuranji river	2 - yr	0	0	180	0	0	70	0	0
system :	5 - yr	0	0	770	0	0	290	10	0
Block 4/	10 - yr	0	0	1,580	0	0	1,160	40	0
Kuranji main	25 - yr	0	0	2,420	0	0	1,390	150	0
stream	50 - yr	0	0	2,710	0	0	1,390	240	0
	100 - yr	0	0	2,850	0	0	1,390	340	0
Block 5/	2 - yr	0	0	0	0	150	20	10	0
Balimbing	5 - yr	0	0	0	0	410	40	110	0
and Laras	10 - yr	0	0	0	0	610	40	160	0
rivers	25 - yr	0	0	0	0	700	420	260	0
	50 - yr	0	0	0	0	940	750	310	0
	100 - yr	0	0	0	0	1,210	1,130	310	0
Block 6/	2 - yr	0	0	580	0	0	0	0	0
Interior	5 - yr	0	0	1,120	0	0	0	0	0
water area	10 - yr	0	0	1,310	0	0	0	0	0
	25 - yr	0	0	1,750	0	0	0	0	0
	50 - yr	0	0	1,750	0	0	0	0	0
	100 - yr	0	0	1,760	0	0	0	0	0
Air Dingin	2 - yr	0	0	0	0	320	0	0	0
river system :	5 - yr	0	0	0	0	500	0	0	0
Block 7/	10 - yr	0	0	0	0	810	0	0	0
Air Dingin	25 - yr	0	0	0	0	940	0	0	0
river	50 - yr	0	0	0	0	1,420	0	0	0
	100 - yr	0	0	0	0	1,500	0	0	0
Block 8/	2 - yr	0	0	0	0	50	0	0	0
Interior	5 - yr	0	0	0	0	50	0	0	0
water area	10 - yr	0	0	0	0	50	0	0	0
	25 - yr	0	0	0	0	50	0	0	0
	50 - yr	0	0	0	0	50	0	0	0
	100 - yr	0	0	0	0	50	0	0	0

Table G-8 Number of Buildings Submerged for Respective Return Periods

Unit : number

River	Kind of buildings	Return period					
		2 - yr	5 - yr	10 - yr	25 - yr	50 - yr	100 - yr
Arau river system : Block 1/ Main stream (Incl. F.R.C)	Residence	0	4,570	7,260	7,620	8,790	9,140
	Shop	0	610	1,010	1,070	1,220	1,260
	Warehouse	0	170	230	240	280	280
	Farm house	0	20	70	70	90	110
	Sub-total	0	5,370	8,570	9,000	10,380	10,790
Block 2/ Jirak river	Residence	0	180	340	390	390	390
	Shop	0	0	0	10	10	10
	Warehouse	0	0	0	0	0	0
	Farm house	0	30	60	60	60	60
	Sub-total	0	210	400	460	460	460
Block 3/ Interior water area	Residence	1,170	5,700	7,700	7,820	9,130	9,540
	Shop	160	780	1,070	1,090	1,280	1,320
	Warehouse	40	180	240	250	290	290
	Farm house	10	70	70	70	80	110
	Sub-total	1,380	6,730	9,080	9,230	10,780	11,260
Total		1,380	12,310	18,050	18,690	21,620	22,510
Kuranji river system Block 4/ Main stream	Residence	220	900	2,330	3,290	3,580	3,760
	Shop	10	40	130	160	170	180
	Warehouse	0	10	30	40	50	50
	Farm house	20	120	290	470	540	590
	Sub-total	250	1,070	2,780	3,960	4,340	4,580
Block 5/ Balimbing and Laras rivers	Residence	150	470	690	1,140	1,640	2,170
	Shop	10	20	30	60	80	100
	Warehouse	0	10	10	20	20	40
	Farm house	20	60	80	160	260	340
	Sub-total	180	560	810	1,380	2,000	2,650
Block 6/ Interior water area	Residence	500	950	1,210	1,450	1,450	1,450
	Shop	20	40	60	60	60	60
	Warehouse	10	10	10	30	30	30
	Farm house	50	120	160	210	210	210
	Sub-total	580	1,120	1,440	1,750	1,750	1,750
Total		1,010	2,750	5,030	7,090	8,090	8,980
Air Dingin river system : Block 7/ Main stream	Residence	150	240	370	480	720	760
	Shop	30	40	60	70	110	110
	Warehouse	10	10	20	20	30	30
	Farm house	130	210	340	370	560	600
	Sub-total	320	500	810	940	1,420	1,500
Block 8/ Interior water area	Residence	20	20	20	20	20	20
	Shop	10	10	10	10	10	10
	Warehouse	0	0	0	0	0	0
	Farm house	20	20	20	20	20	20
	Sub-total	50	50	50	50	50	50
Total		370	550	860	990	1,470	1,550
Grand total		2,760	15,610	23,940	26,770	31,180	33,040

Table G-9 Number of Buildings Submerged by Depth of Inundation

(Unit : number)

River	Depth of inundation	2 - yr	5 - yr	10 - yr	25 - yr	50 - yr	100 - yr
Arau river system : Block 1/ Main stream (Incl. F.R.C)	0.20 - 0.69(m)	0	3,120	3,900	2,620	3,180	3,600
	0.70 - 1.19	0	1,260	2,800	4,160	4,310	3,890
	1.20 - 1.69	0	990	1,870	2,220	160	0
	more than 1.70	0	0	0	0	2,570	2,810
	sediment/erosion	0	0	0	0	160	490
	Total	0	5,370	8,570	9,000	10,380	10,790
Block 2/ Jirak river	0.20 - 0.69(m)	0	10	10	70	70	70
	0.70 - 1.19	0	200	390	390	390	390
	1.20 - 1.69	0	0	0	0	0	0
	more than 1.70	0	0	0	0	0	0
	sediment/erosion	0	0	0	0	0	0
	Total	0	210	400	460	460	460
Block 3/ Interior water area	0.20 - 0.69(m)	1,380	5,120	6,850	2,510	3,370	3,690
	0.70 - 1.19	0	1,270	1,870	6,360	7,050	7,210
	1.20 - 1.69	0	340	360	360	0	0
	more than 1.70	0	0	0	0	360	360
	sediment/erosion	1,380	6,730	9,080	9,230	10,780	11,260
Kuranji river system : Block 4/ Kuranji main stream	0.20 - 0.69(m)	250	990	970	1,320	1,570	1,770
	0.70 - 1.19	0	0	1,700	2,000	2,020	2,020
	1.20 - 1.69	0	30	30	500	580	580
	more than 1.70	0	50	80	60	60	60
	sediment/erosion	0	0	0	80	110	150
	Total	250	1,070	2,780	3,960	4,340	4,580
Block 5/ Balimbing and Laras rivers	0.20 - 0.69(m)	180	390	560	750	970	1,150
	0.70 - 1.19	0	0	80	420	650	1,110
	1.20 - 1.69	0	120	120	120	170	180
	more than 1.70	0	50	50	0	120	120
	sediment/erosion	0	0	0	90	90	90
	Total	180	560	810	1,380	2,000	2,650
Block 6/ Interior water area	0.20 - 0.69(m)	580	1,120	1,310	1,350	1,350	1,360
	0.70 - 1.19	0	0	130	80	0	0
	1.20 - 1.69	0	0	0	320	400	400
	more than 1.70	0	0	0	0	0	0
	sediment/erosion	0	0	0	0	0	0
	Total	580	1,120	1,440	1,750	1,750	1,750
Air Dingin river system : Block 7/ Air Dingin	0.20 - 0.69(m)	320	500	660	580	480	550
	0.70 - 1.19	0	0	0	0	170	180
	1.20 - 1.69	0	0	0	0	0	0
	more than 1.70	0	0	150	0	0	0
	sediment/erosion	0	0	0	360	770	770
	Total	320	500	810	940	1,420	1,500
Block 8/ Interior water area	0.20 - 0.69(m)	50	50	0	0	0	0
	0.70 - 1.19	0	0	50	0	0	0
	1.20 - 1.69	0	0	0	50	50	50
	more than 1.70	0	0	0	0	0	0
	sediment/erosion	0	0	0	0	0	0
	Total	50	50	50	50	50	50

Table G-10 Number of Houses/Buildings Submerged for Respective Return Period in 1991

Unit : number

River	Kind of buildings	Return period					
		2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
Arau river system	Residence	1,170	12,140	17,490	20,940	21,250	22,660
	Shop	160	1,450	2,330	2,780	2,810	2,950
	Warehouse	40	320	520	640	640	670
	Farm house	10	60	140	140	160	230
	Sub-total	1,380	13,970	20,480	24,500	24,860	26,510
Kuranji river system	Residence	1,100	3,000	5,820	6,860	7,410	8,060
	Shop	50	140	260	300	320	350
	Warehouse	20	40	80	90	100	110
	Farm house	70	240	400	560	680	820
	Sub-total	1,240	3,420	6,560	7,810	8,510	9,340
Air Dingin river system	Residence	210	690	860	980	1,040	1,250
	Shop	30	80	110	120	120	150
	Warehouse	10	20	30	30	30	40
	Farm house	150	200	330	280	310	400
	Sub-total	400	990	1,330	1,410	1,500	1,840
Total		3,020	9,220	28,370	33,720	34,870	37,690

(1/4)

Table G-11(1) Flood Damages for Respective Return Periods in 1981

Unit ; Rp.10^6

River/block	Item	Return period					
		2 - yr	5 - yr	10 - yr	25 - yr	50 - yr	100 - yr
Arau river system							
1. Block 1 : Arau mainstream and flood relief channel	House & others	0	3,610	6,995	11,501	11,722	12,330
	Agricultural products	0	0	2	6	45	177
	Sub-total	0	3,610	6,997	11,507	11,767	12,507
	Public facilities	0	361	700	1,151	1,177	1,251
	Direct damage	0	3,971	7,697	12,658	12,944	13,758
	Indirect damage	0	397	770	1,266	1,294	1,376
	Total	0	4,368	8,467	13,924	14,238	15,134
2. Block 2 : Jirak river	House & others	0	117	226	253	254	255
	Agricultural products	0	4	5	6	7	9
	Sub-total	0	121	231	259	261	264
	Public facilities	0	12	23	26	26	26
	Direct damage	0	133	254	285	287	290
	Indirect damage	0	13	25	28	29	29
	Total	0	146	279	313	316	319

Table G-11(2) Flood Damages for Respective Return Periods in 1981

(2/4)

Unit ; $Rp.10^6$

River/block	Item	Return period					
		2 - yr	5 - yr	10 - yr	25 - yr	50 - yr	100 - yr
3. Block 3 : Interior water area	House & others	761	4,124	6,087	7,073	7,468	7,885
	Agricultural products	1	1	1	1	1	1
	Sub-total	762	4,125	6,088	7,074	7,469	7,886
	Public facilities	76	413	609	707	747	789
	Direct damage	838	4,538	6,697	7,781	8,216	8,675
	Indirect damage	84	454	670	778	822	867
	Total	922	4,992	7,367	8,559	9,038	9,542
Kuranji river system							
1. Block 4 : Kuranji main-stream	House & others	111	519	1,645	2,082	2,283	2,461
	Agricultural products	1	21	22	84	72	83
	Sub-total	112	540	1,667	2,166	2,355	2,544
	Public facilities	11	54	167	217	236	254
	Direct damage	123	594	1,834	2,383	2,591	2,798
	Indirect damage	12	59	183	238	259	280
	Total	135	653	2,017	2,621	2,850	3,078

Table G-11(3) Flood Damages for Respective Return Periods in 1981

(3/4) Unit ; Rp.10^6

River/block	Item	Return period					
		2 - yr	5 - yr	10 - yr	25 - yr	50 - yr	100 - yr
2. Block 5 : Balimbing and Laras rivers	House & others	90	360	537	997	1,384	1,790
	Agricultural products	11	18	23	45	49	55
	Sub-total	101	398	560	1,042	1,433	1,845
	Public facilities	10	40	56	104	143	185
	Direct damage	111	438	616	1,146	1,576	2,030
	Indirect damage	11	44	62	115	158	203
	Total	122	482	678	1,261	1,734	2,233
3. Block 6 : Interior water area	House & others	261	510	681	746	750	753
	Agricultural products	0	0	0	0	0	0
	Sub-total	261	510	681	746	750	753
	Public facilities	26	51	68	75	75	75
	Direct damage	287	561	749	821	825	828
	Indirect damage	29	56	75	82	83	83
	Total	316	617	824	903	908	911

Table G-11(4) Flood Damages for Respective Return Periods in 1981

(4/4) Unit ; $Rp.10^6$

River/block	Item	Return period					
		2 - yr	5 - yr	10 - yr	25 - yr	50 - yr	100 - yr
Air Dingin river system							
1. Block 7 : Air Dingin river	House & others	166	257	526	1,176	2,267	2,329
	Agricultural products	6	10	21	167	218	231
	Sub-total	172	267	547	1,343	2,485	2,560
	Public facilities	17	27	55	134	249	256
	Direct damage	189	294	602	1,477	2,734	2,816
	Indirect damage	19	29	60	148	273	282
	Total	208	323	662	1,625	3,007	3,098
2. Block 8 : Interior water area	House & others	26	26	28	47	48	48
	Agricultural products	0	4	5	5	5	5
	Sub-total	26	30	43	52	53	53
	Public facilities	3	3	4	5	5	5
	Direct damage	29	33	47	57	58	58
	Indirect damage	3	3	5	6	6	6
	Total	32	36	52	63	64	64

Note : House & others consist residences, shops, warehouses, farm houses and their household effects or stored goods.

Table G-12(1) Flood Damages for Respective Return Periods in 1991

(1/4) Unit ; $Rp.10^6$

River/block	Item	Return period					
		2 - yr	5 - yr	10 - yr	25 - yr	50 - yr	100 - yr
Arau river system							
1. Block 1 : Arau main-stream and flood relief channel	House & others	0	4,235	7,322	12,115	12,460	13,137
	Agricultural products	0	0	2	5	39	168
	Sub-total	0	4,235	7,324	12,120	12,499	13,305
	Public facilities	0	424	732	1,212	1,250	1,330
	Direct damage	0	4,659	8,056	13,332	13,749	14,635
	Indirect damage	0	466	806	1,333	1,375	1,464
	Total	0	5,125	8,862	14,665	15,124	16,099
2. Block 2 : Jirak river	House & others	0	137	237	261	262	262
	Agricultural products	0	0	2	3	4	7
	Sub-total	0	137	239	264	266	269
	Public facilities	0	14	24	26	27	27
	Direct damage	0	151	263	290	293	296
	Indirect damage	0	15	26	29	29	30
	Total	0	166	289	319	322	326

Table G-12(2) Flood Damages for Respective Return Periods in 1991

(2/4) Unit ; Rp.10^6

River/block	Item	Return period					
		2 - yr	5 - yr	10 - yr	25 - yr	50 - yr	100 - yr
3. Block 3 : Interior water area	House & others	762	4,225	6,128	7,126	7,535	7,958
	Agricultural products	0	0	0	0	0	0
	Sub-total	762	4,225	6,128	7,126	7,535	7,958
	Public facilities	76	423	613	713	754	796
	Direct damage	838	4,648	6,741	7,839	8,289	8,754
	Indirect damage	84	465	674	784	829	875
	Total	922	5,113	7,415	8,623	9,118	9,629
Kuranji river system							
1. Block 4 : Kuranji main-stream	House & others	166	716	2,231	2,720	2,749	2,781
	Agricultural products	1	18	18	67	56	65
	Sub-total	167	734	2,249	2,787	2,805	2,846
	Public facilities	17	73	225	279	280	285
	Direct damage	184	807	2,474	3,066	3,085	3,131
	Indirect damage	18	81	247	307	309	313
	Total	202	888	2,721	3,373	3,394	3,444

Table G-12(3) Flood Damages for Respective Return Periods in 1991

(3/4) Unit ; $Rp.10^6$

River/block	Item	Return period					
		2 - yr	5 - yr	10 - yr	25 - yr	50 - yr	100 - yr
2. Block 5 : Balimbing and Laras rivers	House & others	135	524	728	1,316	1,821	2,349
	Agricultural products	7	10	18	34	36	42
	Sub-total	142	534	746	1,350	1,857	2,391
	Public facilities	14	53	75	135	186	239
	Direct damage	156	587	821	1,485	2,043	2,630
	Indirect damage	16	59	82	149	204	263
	Total	172	646	903	1,634	2,247	2,893
3. Block 6 : Interior water area	House & others	265	515	688	754	758	760
	Agricultural products	0	0	0	0	0	0
	Sub-total	265	515	688	754	758	760
	Public facilities	27	52	69	75	76	76
	Direct damage	292	567	757	829	834	836
	Indirect damage	29	57	76	83	83	84
	Total	321	624	833	912	917	920

Table G-12(4) Flood Damages for Respective Return Periods in 1991

(4/4) Unit ; Rp.10^6

River/block	Item	Return period					
		2 - yr	5 - yr	10 - yr	25 - yr	50 - yr	100 - yr
Air Dingin river system							
1. Block 7 : Air Dingin river	House & others	179	481	816	2,157	2,305	2,810
	Agricultural products	6	9	19	144	184	197
	Sub-total	185	490	835	2,301	2,489	3,007
	Public facilities	19	49	84	230	249	301
	Direct damage	204	539	919	2,531	2,738	3,308
	Indirect damage	20	54	92	253	274	331
	Total	224	593	1,011	2,784	3,012	3,639
2. Block 8 : Interior water area	House & others	26	26	38	48	49	49
	Agricultural products	0	4	5	5	5	5
	Sub-total	26	30	43	53	54	54
	Public facilities	3	3	4	5	5	5
	Direct damage	29	33	47	58	59	59
	Indirect damage	3	3	5	6	6	6
	Total	32	36	52	64	65	65

Note : House & others consist residences, shops, warehouses, farm houses and their household effects or stored goods.

Table G-13 Summarized Flood Damages for Respective Return Periods in 1981

Unit : Rp.10^6

River	Item	Return period					
		2 - yr	5 - yr	10 - yr	25 - yr	50 - yr	100 - yr
Arau river system	House & others	761	7,851	13,308	18,827	19,444	20,470
	Agricultural products	1	5	8	13	53	187
	Sub-total	762	7,856	13,316	18,840	19,497	20,657
	Public facilities	76	786	1,332	1,884	1,950	2,066
	Direct damage	838	8,642	14,648	20,724	21,447	22,723
	Indirect damage	84	864	1,465	2,072	2,145	2,272
	Total	922	9,506	16,113	22,796	23,592	24,995
Kuranji river system	House & others	462	1,409	2,863	3,825	4,417	5,004
	Agricultural products	12	39	45	129	121	138
	Sub-total	474	1,448	2,908	3,954	4,538	5,142
	Public facilities	47	145	291	396	454	514
	Direct damage	521	1,593	3,199	4,350	4,992	5,656
	Indirect damage	52	159	320	435	500	566
	Total	573	1,752	3,519	4,785	5,492	6,222
Air Dingin river system	House & others	192	283	564	1,223	2,315	2,377
	Agricultural products	6	14	26	172	223	236
	Sub-total	198	297	590	1,395	2,538	2,613
	Public facilities	20	30	59	140	254	261
	Direct damage	218	327	649	1,535	2,792	2,874
	Indirect damage	22	33	65	153	279	287
	Total	240	360	714	1,688	3,071	3,161
Total	House & others	1,415	9,543	16,735	23,875	26,176	27,851
	Agricutural products	19	58	79	314	397	561
	Sub-total	1,434	9,601	16,814	24,189	26,573	28,412
	Public facilities	143	961	1,682	242	2,658	2,841
	Direct damage	1,577	10,562	18,496	26,609	29,231	31,253
	Indirect damage	158	1,056	1,850	2,660	2,924	3,125
	Total	1,735	11,618	20,346	29,269	32,155	34,378

Table G-14 Summarized Flood Damages for Respective Return Periods in 1991

Unit : Rp.10^6

River	Item	Return period					
		2 - yr	5 - yr	10 - yr	25 - yr	50 - yr	100 - yr
Arau river system	House & others	762	8,597	13,687	19,502	20,257	21,359
	Agricultural products	0	0	4	8	43	175
	Sub-total	762	8,597	13,691	19,510	20,300	21,532
	Public facilities	76	861	1,369	1,951	2,031	2,153
	Direct damage	838	9,458	15,060	21,461	22,331	23,685
	Indirect damage	84	946	1,506	2,146	2,233	2,369
	Total	922	10,404	16,566	23,607	24,564	26,054
Kuranji river system	House & others	566	1,755	3,647	4,790	5,328	5,890
	Agricultural products	8	28	36	101	92	107
	Sub-total	574	1,783	3,683	4,891	5,420	5,997
	Public facilities	58	178	369	489	542	600
	Direct damage	632	1,961	4,052	5,380	5,962	6,597
	Indirect damage	63	197	405	539	596	660
	Total	695	2,158	4,457	5,919	6,558	7,257
Air Dingin river system	House & others	205	507	854	2,205	2,354	2,859
	Agricultural products	6	13	24	149	189	202
	Sub-total	211	520	878	2,354	2,543	3,061
	Public facilities	22	52	88	235	254	306
	Direct damage	233	572	966	2,589	2,797	3,367
	Indirect damage	23	57	97	259	280	337
	Total	256	629	1,063	2,848	3,077	3,704
Total	House & others	1,533	10,859	18,188	26,497	27,939	30,106
	Agricultural products	14	41	64	258	324	484
	Sub-total	1,547	10,900	18,252	26,755	28,263	30,590
	Public facilities	156	1,091	1,826	2,675	2,827	3,059
	Direct damage	1,703	11,991	20,078	29,430	31,090	33,649
	Indirect damage	170	1,200	2,008	2,944	3,109	3,366
	Total	1,873	13,191	22,086	32,374	34,199	37,015

Table G-15 Annual Average Flood Damages in 1981

River	Return period (year)	Exceedance	Difference of exceedance	Damage (Rp.10^6)		Annual damage (Rp.10^6)	
				Amount	Mean	Segment	Cumulative
Arau river system	1	1.000	-	0	-	-	0
	2	0.500	0.500	922	461	231	231
	5	0.200	0.300	9,506	5,214	1,564	1,795
	10	0.100	0.100	16,113	12,810	1,281	3,076
	25	0.040	0.060	22,796	19,455	1,167	4,243
	50	0.020	0.020	23,592	23,194	464	4,707
	100	0.010	0.010	24,995	24,294	243	4,950
Kuranji river system	1	1.000	-	0	-	-	-
	2	0.500	0.500	573	287	144	144
	5	0.200	0.300	1,752	1,163	349	493
	10	0.100	0.100	3,519	2,634	263	756
	25	0.040	0.060	4,785	4,152	249	1,005
	50	0.020	0.020	5,492	5,139	103	1,108
	100	0.010	0.010	6,222	5,857	59	1,167
Air Dingin river system	1	1.000	-	0	-	-	0
	2	0.500	0.500	240	120	60	60
	5	0.200	0.300	360	300	90	150
	10	0.100	0.100	714	537	54	204
	25	0.040	0.060	1,688	1,201	72	276
	50	0.020	0.020	3,071	2,380	48	324
	100	0.010	0.010	3,161	3,116	31	355

Table G-16 Annual Average Flood Damages in 1991

River	Return period (year)	Exceedance	Difference of exceedance	Damage ($Rp.10^6$)		Annual damage ($Rp.10^6$)	
				Amount	Mean	Segment	Cumulative
Arau river system	1	1.000	-	0	-	-	0
	2	0.500	0.500	922	461	231	231
	5	0.200	0.300	10,404	5,663	1,699	1,930
	10	0.100	0.100	16,566	13,485	1,349	3,279
	25	0.040	0.060	23,607	20,037	1,205	4,484
	50	0.020	0.020	24,564	24,036	482	4,966
	100	0.010	0.010	26,054	25,309	253	5,219
Kuranji river system	1	1.000	-	0	-	-	0
	2	0.500	0.500	659	348	174	174
	5	0.200	0.300	2,158	1,427	428	602
	10	0.100	0.100	4,457	3,308	331	933
	25	0.040	0.060	5,919	5,188	311	1,244
	50	0.020	0.020	6,558	6,239	125	1,369
	100	0.010	0.010	7,257	6,908	69	1,438
Air Dingin river system	1	1.000	-	0	-	-	0
	2	0.500	0.500	256	128	64	64
	5	0.200	0.300	629	443	133	197
	10	0.100	0.100	1,063	846	85	282
	25	0.040	0.060	2,848	1,956	117	399
	50	0.020	0.020	3,077	2,963	59	458
	100	0.010	0.010	3,704	3,391	34	492

Fig. G-1 Inundation Area Classified by Flooding Causes (for 100-yr Flood)

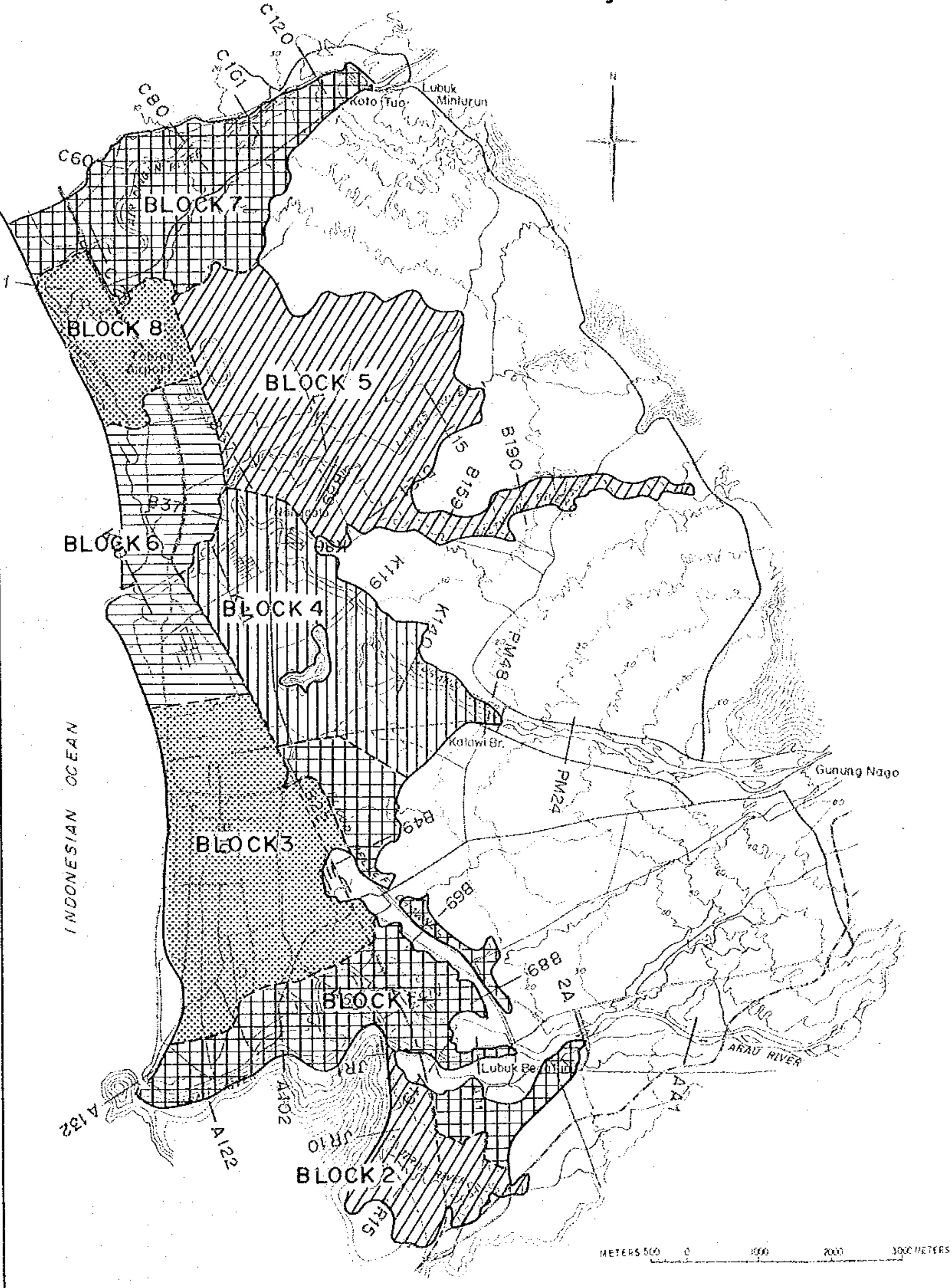

Fig. G-2 Housing Density in Flooding Area