c. Gunung Nago left power plant

d. Gunung Nago right power plant.

Hydroelectric Power Generated

The irrigation water is used for electric power generation. According to the annual rainfall data at Tabing station, the year 1982 was the draughtest in recent 7 years since 1975. The flow duration of the irrigation canal in 1982 is adopted as an available water for power generation. The 75 day dependable discharge is assumed to be the maximum available water to estimate the maximum generator output.

Based on the canal profile and flow duration, the maximum output and annual production of electricity are estimated as shown in Table 11-1. The results are summarized as follow :

Item	L. Manis 1	L. Manis 2	G. Nago left	G. Nago right
Leading chan. length (m)	217	358	250	301
Penstock				
Length	21	20	10	13
Diameter (m)	0.50	0.50	0.85	0.90
Total head (m)	11.6	11.0	5.2	6.8
Max. output (kw)	105	97	128	194
Annual production (MWh)	385	357	462	640

11.3.3 Utilization of Electricity

Near the Limau Manis -1 and 2 plant sites Kel. Jawa Gadut having about 170 households exists. The village is not electrified yet. The village has a scheme to construct a diesel electric power plant within a frame of Bantuan Desa (Bangdes) Project for the year 1983/84 by Kotamadya Padang. The diesel plant will have capacity 15 kw and the scheduled budget is Rp. 1,400,000. In addition, the newly constructed PLTG Bandar Buat is located in about 4 km distance.

Kel. Pasar Baru which is located along Gunung Nago left irrigation canal has been already electrified.

Kp. Kuranji located near the Gunung Nago right power plant on the opposite side bank of Kel. Pasar Baru crossing the Kuranji river has around 1,500 households. The village is not electrified yet. According to the village office, there is no electrification scheme at present. However the village could be electrified by the PLN system, since the PLTG Bandar Buat is located only about 2 km apart.

Judging from the circumstances mentioned above, the mini-hydro-electric power projects in these sites are not deemed to be of higher priority at present. From the viewpoint of development of natural energy under the difficulty in acquisition of oil, the project might be taken up in future for electrification of agricultural works as well as village houses.

Table 1.1 (1) : Member List of Advisory Committee, Study Team and Counterpart Personnel

Advisory Committee

1.	Mr.	Youichiro Yano	Chairman of Committee
2.	Mr.	Toyotake Kawami	Advisor
3.	Mr.	Kouichi Yamamoto	Advisor
4.	Mr.	Kazunori Yoshioka	Advisor
5.	Mr.	Ryota Ono	Coordinator

Study Team

1.	Mr.	Hiroshi Ono	Team Leader/River Planner
2.	Mr.	Masao Matsumura	River Engineer
3.	Mr.	Toshio Terashima	Hydrologist
4.	Mr.	Tokio Imai	Surveying Güidance Engineer
5.	Dr.	Masahiko Oya	Geomorphologist
6.	Mr.	Masahiko Nakagami	Engineer for Geology & Soil-Mechanics
7.	Mr.	Noboru Jitsuhiro	Engineer for Water Resources Development
8.	Mr.	Ryosaku Nagata	Structure Engineer
9.	Mr.	Yoshiaki Ishizuka	Project Economist
10.	Mr.	Kazuhiko Takebayashi	Engineer for Urban Drainage
11.	Mr.	Takayuki Nobe	Construction Planner

Table 1.1 (2) Member List of Advisory Committee, Study Team and Counterpart Personnel.

Counterpart Personnel Group

1.	Mr. Mustafa Ibrahim BIE	Project Manager
2.	Drs. Joesni Raalin BIE	Project Manager
3.	Mr. Asnawi Marzuki MSc	Counterpart Coordinator
4.	Ir. Koesdayat	Team Leader/River Planner
5.	Ir. O.I. San	River Engineer
6.	Ir. Bambang Priyambodo	River Engineer
7.	Ir. Sutrisno	Hydrologist
8.	Mr. Herdy Pangow BE	Hydrologist
9.	Ir. Wagiono	Surveying Engineer
10.	Ir. Bambang Sulistiyono	Surveying Engineer
11.	Mr. Ishak BE	Geologist
12.	Ir. Agus Sutiyanto	Water Resources Engineer
13.	Mr. Hendarman BE	Water Resources Engineer
14.	Ir. Muryanto	Structure Engineer
15.	Ir. Irfan	Project Economist
16.	Ir. Sudarwanto	Project Economist
17.	Ir. D. Mujahit Hasbullah	Project Economist
18.	Mr. Rachyadi BE	Engineer for Urban Drainage
19.	Drs.Suchyar	Construction Planner

Table 3.1 Climatic Conditions

Item	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Rainfall (mm)													
Tabing	258	296	283	397	319	265	286	312	396	483	507	370	4,172
Gunung Nago	287	311	338	536	339	280	414	258	357	544	512	343	4,519
Max. temperature (°C)													
Tabing	30.5	30.6	30.6	30.6	30.7	30.7	30.3	30.2	30.0	30.1	29.9	30.1	30.4
Gunung Nago	31.8	31.8	31.9	31.8	32.4	32.0	31.5	31.6	31.8	31.6	32.4	32.1	31.9
Min. temperature (°C)													
Tabing	22.0	22.1	22.4	22.9	22.7	22.3	21.8	21.8	22.1	22.2	22.4	22.1	22.2
Gunung Nago	21.8	21.4	21.3	21.4	22.0	22.3	21.5	21.2	21.5	21.7	22.0	22.0	21.7
Mean temperature (°C)													
Tabing	26.0	25.9	26.2	26.3	26.4	26.1	25.7	25.6	25.5	25.7	25.7	25.8	25.9
Gunung Nago	27.4	27.1	27.1	27.0	27.3	27.2	26.9	26.6	26.5	26.7	26.9	27.4	27.0
Sunshine hour (%)													
Tabing	55	54	56	51	56	57	58	55	42	41	36	49	51
Gunung Nago	48	42	52	46	54	52	51	47	42	37	34	49	46
Relative humidity (%)													
Tabing	81	82	83	84	83	82	82	82	84	84	84	84	83
Gunung Nago	91	91	89	90	92	92	90	89	90	90	95	91	91
Wind speed (km/hr)													
Tabing	3.4	3.6	3.3	3.3	3.0	3.1	3.2	3.1	3.6	3.3	3.5	3.4	3.3
Gunung Nago	4.2	4.1	3.9	3.9	4.0	4.4	4.0	4.0	3.8	3.7	3.8	4.0	4.0
Evaporation (mm)													
Tabing	127	127	133	130	136	127	126	124	122	124	122	124	1,522
Gunung Nago /1	162	135	151	145	143	146	142	144	135	146	116	140	1,705

Source : Pusat Meteorologi dan Geofisika (1971 - 1982) and DPMA (1976 - 1982)

Note /1 : Data is from "Flood Warning Flood Forecasting " report prepared by P.T. WASKITA KARYA (1980/1981)

Table 3.2 Monthly Rainfall at Tabing Station

(Unit: mm)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1948	450	672	379	-	-	-	-	-	-	-	-	390	-
1949	-	321	313	334	165	120	88	239	439	398	-	-	-
1950	328	170	428	476	434	-	212	578	302	474	-	255	-
1951	319	336	-	364	282	253	201	292	368	-	597	546	-
1952	473	351	334	429	346	165	-	-	460	-	487	368	-
1953	248	236	389	302	151	258	421	233	390	653	492	538	4,311
1954	438	258	346	414	259	183	311	263	136	414	654	298	3,974
1955	189	327	389	520	448	196	252	304	424	379	294	553	4,275
1956	281	237	155	276	100	351	291	300	430	267	515	585	3,788
1957	208	249	494	429	258	290	398	281	-	325	312	642	-
1958	286	-	-	-	-	253	-	578	216	-	-	-	-
1959	173	178	405	-	233	-	-	177	-	668	586	418	-
1960	358	204	184	355	134	149	502	214	-	395	329	360	-
1961	-	-	152	121	-	426	77	84	-	-	-	158	-
1962	379	180	354	-	326	-	227	-	259	-	646	-	-
1963	-	38	96	174	369	110	376	-	-	-	-	562	-
1964	497	-	-	405	301	211	-	37	349	530	-	-	-
1965	-	-	467	252	-	96	71	-	397	-	434	-	-
1966	-	386	-	-	-	-	-	-	-	-	-	-	-
1967	-	-	137	373	-	170	260	94	-	-	613	-	-
1968	-	-	-	-	-	-	-	-	-	-	-	-	-
1969	-	-	-	-	-	414	192	-	304	745	643	646	-
1970	291	172	-	375	332	198	385	349	-	568	349	-	-
1971	263	200	356	241	182	360	169	514	392	331	426	705	4,139
1972	187	416	247	320	782	197	213	266	264	217	706	640	4,455
1973	212	215	395	390	235	445	389	277	435	293	388	411	4,085
1974	251	154	153	616	387	454	183	464	598	314	566	266	4,406
1975	272	333	170	373	256	126	288	319	290	311	166	315	3,219
1976	161	257	178	346	105	238	352	268	349	890	465	179	3,788
1977	358	297	108	295	446	192	152	147	257	476	741	434	3,903
1978	493	341	312	207	388	387	467	364	398	685	247	145	4,434
1979	240	329	238	525	280	307	352	224	516	416	696	190	4,313
1980	276	232	363	523	278	297	254	468	355	595	807	479	4,927
1981	185	313	220	557	295	99	461	177	611	891	512	311	4,632
1982	195	464	661	369	189	75	154	253	286	381	369	359	3,755
Ave.	297	281	301	370	295	242	275	288	369	484	502	414	4,118

Source : Pusat Meteorologi dan Geofisika

Table 3.3. Probable Rainfall Depths 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 : Gumber Method is used for the analysis

Table 3.4 Monthly Mean Daily Discharge

(Unit : m^3/s)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ave.
Lb. Begalung /1													
1972	-	-	-	-	-	-	6.6	8.8	8.3	-	15.0	16.8	-
1978	7.3	6.9	14.7	4.8	18.5	7.9	12.0	14.2	18.6	13.1	17.5	8.7	12.0
1979	9.5	16.6	7.0	21.4	9.0	11.4	13.1	11.6	16.8	9.5	27.0	9.5	13.5
1980	9.0	2.1	7.1	19.3	10.4	11.2	10.9	9.2	5.4	16.2	25.2	26.1	14.2
1981	8.3	7.1	5.5	23.4	15.3	13.3	18.9	5.1	27.0	40.7	25.7	17.7	17.3
Ave.	8.5	8.2	8.6	17.2	13.3	11.0	12.3	9.8	15.2	19.9	22.1	15.8	13.5
Gunung Nago /2													
1979	33.8	33.5	21.4	43.0	23.9	32.3	24.1	22.5	23.3	31.0	78.0	40.6	34.0
1980	21.9	-	17.8	38.6	25.2	23.6	24.9	22.4	9.0	34.0	-	-	-
1981	10.2	5.3	1.2	26.5	18.7	12.4	15.8	3.8	26.6	50.9	28.9	18.2	18.2
1982	3.5	5.6	30.0	22.9	19.2	0.6	0.0	0.0	0.5	2.4	8.9	18.9	9.4
Ave.	17.4	14.8	17.6	32.8	21.8	17.2	16.2	12.2	14.9	29.6	38.6	19.4	21.0
Lb. Minturun													
1979	-	-	-	-	5.5	9.6	10.7	9.5	11.3	11.9	34.4	18.4	-
1980	11.6	6.4	11.3	19.8	16.5	12.8	9.4	11.4	10.7	22.7	31.6	44.0	17.3
1981	13.2	10.6	8.1	20.0	16.8	12.1	14.4	8.8	16.1	32.7	24.6	15.3	16.1
1982	10.1	14.6	27.6	17.3	16.7	9.8	6.1	6.9	5.6	11.4	13.0	-	-
Ave.	11.6	10.5	15.7	19.0	13.9	11.1	10.2	9.1	10.9	19.7	25.9	25.9	15.3

Note /1 : Discharge at the downstream of the weir

/2 : Discharge overflowing the weir

Table 3.5 Carrying Capacity of Existing River Channel

Channel	Carrying Capacity (m^3/s)	
	Bankful	with 1.0 m freeboard
1. Arau River :		
Rivermouth - Jirak river	300 - 500	-
Jirak river - diversion weir	300 - 600	-
Flood relief channel	450 - 800	300 - 600
2. Kuranji river :		
Rivermouth - Nanggalo Br.	400 - 500	-
Nanggalo Br. - AWLR St. BK 3	300 - 600	-
Balimbing river :		
Kuranji r. - Laras r.	50 - 100	-
Laras r. - Kp. P.Ratus	50 - 100	-
3. Air Dingin river :		
Rivermouth - Koto Tuo weir	200 - 550	-

Table 3.6 Present Land Use in Objective Area for the Study

Kecamatan	Residencial area	Paddy field	Up-land crops area	Open land	River	Total
Padang Selatan	247	87	0	34	57	425
Padang Barat	667	0	0	0	11	678
Padang Utara	305	398	6	66	22	797
Padang Timur	501	243	7	5	20	776
Koto Tangah	227	910	150	1,804	98	3,189
Nanggalo	211	852	175	92	87	1,417
Kuranji	514	1,882	88	93	76	2,653
Pauh	98	550	8	4	22	682
Lbk. Kilangan	70	129	11	8	32	250
Lbk. Begalung	525	857	16	93	62	1,533
Total	3,365	5,908	461	2,199	487	12,420
%	27.1	47.6	3.7	17.7	3.9	100.0

Note : Open land includes areas of sea shore, fallaw area, wasted area, etc.

Source : 1/5,000 topographic map, 1/5,000 aerophoto in 1981, and information from local people.

Table 3.7 Summarized Flood Damages for Respective Return Periods

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 3.8 Present Water Balance

Month	Rain-fall at Tabing	Lb. Sarik		Gn. Nago		S. Guo		Lb. Minturun	
		Qr	Qa	Qr	Qa	Qr	Qa	Qr	Qa
	(mm/mon)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)
Jan.	193	1.23	3.58	3.26	6.05	0.74	0.55	2.40	5.13
Feb.	180	0.49	3.34	0.22	5.64	0	0.52	0	4.79
Mar.	155	0.49	2.88	0.22	4.86	0	0.45	0	4.12
Apr.	271	0.49	5.03	0.22	8.50	0	0.78	0	7.21
May	175	1.42	3.25	4.02	5.49	0.93	0.50	3.01	4.65
Jun.	126	1.59	2.34	4.69	3.95	1.09	0.36	3.53	3.35
Jul.	166	1.65	3.08	4.97	5.20	1.16	0.48	3.76	4.41
Aug.	177	1.21	3.29	3.15	5.55	0.71	0.51	2.32	4.71
Sep.	268	0.49	4.98	0.22	8.40	0	0.77	0	7.13
Oct.	314	1.14	5.83	2.87	9.84	0.65	0.90	2.10	8.35
Nov.	337	0.91	6.26	1.93	10.56	0.42	0.97	1.35	8.96
Dec.	259	1.24	4.81	3.29	8.12	0.75	0.74	2.43	6.89
D.A. (Km^2)			64		120		11		116
K-value			0.0273		0.0461		0.00422		0.0391

Notes

Qr : Water requirement

Qa : Available Water (= (Rainfall at Tabing) x K x 0.68)

K : Qa / (rainfall at Tabing)

Table 4.1 Past Budgets for Flood Control and Coast Protection Works

Year	Budget (Rp. 10^3)					
	Arau R.	Flood relief Channel	Kuranji R.	Air Dingin R.	Padang Coast	Total
1969 - 70	-	8,000	6,000	-	6,320	20,320
1970 - 71	4,500	13,500	2,500	-	-	20,500
1971 - 72	866	3,900	3,184	-	30,000	37,950
1972 - 73	1,583	11,531	-	5,902	35,000	54,016
1973 - 74	4,173	16,817	-	-	40,000	60,990
1974 - 75	-	6,025	3,510	-	40,000	49,535
1975 - 76	-	22,315	5,930	-	46,000	74,245
1976 - 77	-	14,898	9,601	4,000	45,000	73,499
1977 - 78	17,850	-	14,490	-	40,000	72,340
1978 - 79	19,108	-	20,000	-	50,000	89,308
1979 - 80	52,675	-	30,565	-	59,000	142,240
1980 - 81	12,338	107,678	29,889	-	69,992	219,897
1981 - 82	8,350	223,368	13,125	-	65,035	309,878
Total	121,443	428,032	138,994	9,902	526,347	1,224,718
1982 - 83	22,242	293,527	81,800	12,872	85,000	495,441

Table 5.1 Alternative Scheme for Arau River

Stretch	Scheme A-1	Scheme A-2	Scheme A-3
1. Middle Arau (new railway br. - Lbk Begalung weir	Bank protection only	Same as Scheme A-1	Same as Scheme A-1
2. Lower Arau (Lbk Begalung weir - river mouth)	Minor improvement	Improvement by diking system with bank protection	Improvement on intermediate scale between Scheme A-1 and A-2
3. Flood relief channel	Improvement as a main floodway for the whole strech by diking system with bank protection	Minor improvement	Improvement on intermediate scale between Scheme A-1 and A-2
4. Jirak river	Improvement by diking system	Same as Scheme A-1	Same as Scheme A-1
5. Lubuk Begalung weir	Reconstruction	Same as Scheme A-1	Same as Scheme A-1
6. Drainage facilities	Construction of outlet structures for drain and pumping station in low-lying area	Same as Scheme A-1	Sama as Scheme A-1

Table 5.2 Alternative Scheme for Kuranji River

Stretch	Scheme K-1	Scheme K-2
1. Middle Kuranji		
- Stretch between Gunung Nago weir & Kalawi br.	Bank protection only	Same as Scheme K-1
- Stretch between Kalawi br. & water supply intake	Improvement by diking system. Bank protection in some length	Same as Scheme K-1
2. Lower Kuranji (water supply intake - river mouth)	Improvement by continuous dike and dredging of lower channel. Bank protection in some length	Same as Scheme K-1, but proposed channel will be smaller than Scheme K-1 owing to effects of retarding basin.
3. Balimbing and Laras rivers	Improvement by diking system	Construction of Laras retarding basin
4. Drainage facilities	Similar facilities as Scheme A-1 for Arau river.	Same as Scheme K-1

Table 5.3 Alternative Scheme for Air Dingin River

Stretch	Scheme D-1	Scheme D-2
1. Middle Air Dingin	Bank protection only	Same as Scheme D-1
2. Lower Air Dingin	Improvement by diking system. Bank protection in some length.	Same as Scheme D-1, but proposed channel will be smaller than Scheme D-1 owing to effects of openning of river mouth.
3. River mouth	Existing sand spit is to be left it is. Back water effects due to obstruction by sand spit will be treated by hightening dike.	Existing sand spit is to be removed. Construction of training dike to maintain reiver mouth.
4. Drainage facilities	Similar facilities as Scheme A-1 for Arau river.	Same as Scheme D-1

Table 5.4 Design Discharge of Rivers in Indonesia

NO.	Name of River	Province	Catchment Area (km^2)	Design Flood (m^3/s)	Return Period (yr)
1.	Sungai Cimanuk	West Jawa	3,006	1,440	25
2.	Kali Serang	Central Jawa	937	900	25
3.	Sungai Citanduy	West Jawa	3,680	1,900	25
4.	Sungai Ular	North Sumatra	1,080	800	30
5.	Kali Pemali	Central Jawa	1,228	1,300	25
6.	Sungai Cipanas	West Jawa	220	385	25
7.	Bengawan Solo	Central/East Jawa	3,320	2,000	40
8.	Kali Madiun	East Jawa	2,400	2,300	40
9.	Sungai Wampu	North Sumatra	3,840	1,320	20
10.	Sungai Arakundo	Aceh	5,495	2,100	50
11.	Sungai Krueng Aceh	Aceh	1,775	1,960	50
12.	Kali Brantas	East Jawa	10,000	1,500	50
13.	Sungai Bah Bolon	North Sumatra	2,776	1,200	20
14.	Sungai Walanae	South Sulawesi	3,190	2,900	20
15.	Sungai Bila	South Sulawesi	1,368	1,900	20
16.	Sungai Jeneberang	South Sulawesi	729	3,700	50

Data Source : Directorate of Rivers, DGWRD.

Table 5.5 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
Triburary					
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 5.6 Length of Drainage Channel to be Improved and Proposed Capacity of Pumping Station

Drainage system	Drainage area (km^2)	Channel length to be improved (km)	Drainage	Capacity of pump (m^3/s)	Terminal	Remarks
Old urban area						
Jati	2.14	4.40	Gravity	-	Arau river	Including 574 m of diversion drain.
Palinggam	0.71	1.35	- do -	-	- do -	
Anak Jati	0.62	2.45	- do -	-	- do -	Including Kelenteng drain.
Olo-Nipah	1.40	5.75	- do -	-	- do -	
Kali Mati	0.21	0.95	Pump	1.0	- do -	Excluding Nipah area.
Damar	1.15	4.00	Gravity	-	Indonesian Ocean	
Ujung Gurun	1.62	5.05	Pump	5.0	Flood relief channel	
Sub-total	7.85	23.95	-	6.0		
New Urban area						
Purus	1.06	2.0	Pump	3.5	Flood relief channel	
Lolong	2.65	2.05	Gravity	-	Indonesian Ocean	
Ulak Karang	1.87	3.85	Pump	5.5	Kuranji river	
Lapai	1.42	3.70	Gravity	-	- do -	
Baung	1.82	2.50	Pump	5.5	- do -	
Penjalinan	1.10	1.45	Pump	3.0	Air Dingin river	
Tabing	12.08	3.50	Gravity	-	- do -	
Sub-total	21.46	19.05	-	17.5		
Total	29.41	43.00	-	23.5		

Table 5.7 Construction Cost for Proposed Comprehensive Plan

Item	Local currency (Rp. 10^6)	Foreign currency (US$ 10^3)	Eq. Total (Rp. 10^6)
I. Civil Works	16,074.4	36,874.7	51,843.1
Arau river	3,435.2	6,551.0	
Flood relief channel	5,762.2	11,993.0	
Kuranji river	5,107.4	13,338.5	
Air Dingin river	1,769.6	4,992.2	
II. Land Acquisition and House Compensation	2,390.4	-	2,390.4
Arau river	860.3	-	
Flood relief channel	577.2	-	
Kuranji river	683.8	-	
Air Dingin river	269.1	-	
III. Total (I + II)	18,464.8	36,874.7	54,233.5
IV. Engineering and Administration /1	2,769.8	5,531.3	8,135.2
V. Contingency /2	2,258.4	5,190.0	7,293.3
VI. Grand Total	23,493.0	47,596.0	69,662.0

Note : 1. Price level at the beginning of June '83 was applied

2. Conversion rate : US$ 1 = Rp. 970 = ¥ 240

3. The following lump sum costs were applied

for /1 15 % of the total costs of civil works, and land acquisition and house compensation

/2 10 % of the total costs of civil works, land acquisition and house compensation, and engineering and administration

Table 6.1 Objective River Stretches for Proposed Urgent Flood Control Works

River	Whole Stretch/1		Stretch for Main Works/2	
	Stretch	Length (km)	Stretch	Length (km)
1. Mainstream of Arau river	River mouth - bypass road Br.	8.5	Suspension Br.-confluence of Jirak river	1.9
2. Flood relief channel	River mouth - Lubuk Begalung weir	6.7	River mouth - Lubuk Begalung weir	6.7
3. Jirak river	Confluence to mainstream - railway Br.	2.5	Confluence to mainstream - railway Br.	2.5
4. Mainstream of Kuranji river	River mouth - Kalawi Br.	7.5	River mouth - Kalawi Br.	7.5
5. Balimbing river	Confluence to mainstream of Kuranji - Kp. Padjang	4.2	Confluence to mainstream of Kuranji - Kp. Padjang	4.2
6. Laras river	Confluence to Balimbing river - Kp. Blantikan	1.2	Confluence to Balimbing river - Kp. Blantikan	1.2
7. Air Dingin river	River mouth - Koto Tuo weir	5.2	River mouth - Koto Tuo weir	5.2

Remarks /1 : Whole stretch subject to improvement works including bank protection and ground sill works

/2 : Stretch subject to main works such as channel excavation and embankment works.

Table 6.2 Required Land Acquisition and House Compensation

Item	Unit	Quantity				Total
		Arau river	F.R.C.	Kuranji river	Air Dingin river	
I. River Channel Improvement Works						
Land I (residential area)	$10^3 m^2$	84.8	12.5	22.9	10.0	130.2
Land II (agricultural land & others)	"	46.8	83.5	606.3	190.0	926.6
House I (permanent house)	nos	-	-	-	-	-
House II (semi permanent house)	"	5	4	-	-	9
House III (small house)	"	52	17	58	13	140
House IV (temporary house)	"	33	21	34	7	95

Item	Unit	Quantity				Total
		Olo-Nipah	Ujung Guran	Purus	Ulak Karang	
II. Drainage Channel Improvement Works						
Land I (residential area)	$10^3 m^2$	4.0	37.0	9.0	2.0	52.0
Land II (agricultural land and others)	"	-	32.0	-	6.0	38.0
House I (permanent house)	nos	-	2	1	2	5
House II (semi permanent house)	"	-	4	2	-	6
House III (small house)	"	4	6	1	-	11
House IV (temporary house)	"	-	6	30	-	36

Note: House I ; Deluxe house which is constructed by concrete or brick structures with more than 100 m^2 of floor area in average.

House II ; Ordinary house which is constructed by concrete or brick structures with 60 m^2 of floor area in average.

House III ; Wooden house with 40 m^2 of floor area in average.

House IV ; Temporary house which is constructed by bamboo or nipah with 30 m^2 of floor area in average.

Table 7.1 Estimated Unit Construction Costs

Works	Unit	Unit Cost /1		
		Local C (Rp.)	Foreign C. (US$)	Eq. Total (Rp.)
Excavation				
I (high water channel)	m^3	499	1.50	1,954
II (major bed)	"	294	1.78	2,021
for rock	"	1,700	6.00	7,520
Dredging	"	801	3.54	4,235
Transportation	"	788	2.13	2,855
Embankment				
I (new levee)	m^3	425	1.51	1,889
II (strengthening)	"	456	1.07	1,494
Wet masonry revetment				
I (high water channel)	m^2	9,685	13.31	22,596
II (low water channel)	"	11,410	13.74	24,739
Dry masonry	"	7,453	9.32	16,494
Gabion	m^3	7,712	14.49	21,766
Riprap	m^3	13,709	10.83	24,215
Groin	"	7,712	14.49	21,766
Sod-facing	m^2	320	0.17	485
Drainage culvert				
I (1.5 x 1.5 x 1)	nos	15,200,100	22,726	37,244,320
II (2.0 x 2.5 x 1)	"	22,444,000	35,023	56,416,310
III (2.0 x 2.5 x 2)	"	32,120,000	49,665	80,295,050
Bridge (R.C)	m^2	173,730	274.82	440,306
(Metal)	m^2	201,352	543.82	728,858
Pier protection for existing bridge (riprap)	m^3	13,709	10.83	24,215
Drop structure	place	87,196,000	192,581	212,889,570
Groundsill works	m	474,462	424.91	886,620
Diversion weir				
Flood relief channel	l.s	317,914,110	508,496	811,155,230
Arau river (urgent)	"	246,874,420	229,963	469,938,530
Syphon	Place	31,263,100	45,067	79,978,090
Disposal of excess soil	m^3	176	0.81	963
Excavation of rock	"			
Pumping station				
I (3.5 m^3/s)	l.s	435,000,000	1,661,000	2,046,170,000
II (2.0 m^3/s)	"	359,000,000	1,401,000	1,717,970,000
Inspection road (gravel metaling)	m	2,422	3.03	5,362

Note /1 : US$ 1 = Rp. 970 = ¥ 240

Table 7.2 Construction Cost for Proposed Urgent Flood Control Project

	Item	Local currency (Rp.10^6)	Foreign currency (US$ 10^3)	Eq.Total (Rp.10^6)
I.	Civil Works	9,627.1	22,779.8	31,723.7
	Arau river	1,311.8	2,581.6	
	Flood relief channel	4,502.6	10,145.2	
	Kuranji river	2,982.7	7,937.9	
	Air Dingin river	830.0	2,115.1	
II.	Land Acquisition and House Compensation	1,819.9	-	1,819.9
	Arau river	489.4	-	
	Flood relief channel	577.2	-	
	Kuranji river	528.2	-	
	Air Dingin river	225.1	-	
III.	Total (I + II)	11,447.0	22,779.8	33,543.6
IV.	Administration /1	1,144.7	-	1,144.7
V.	Engineering /2	940.6	5,680.8	6,451.0
VI.	Contingency /3	1,353.7	2,846.4	4,114.7
VII.	Grand Total	14,886.0	31,307.0	45.254.0

Note : 1. Price level at the beginning of June '83 was applied

2. Conversion rate : US $ 1 = Rp. 970 = ¥ 240

3. The following lump sum costs were applied

for /1 10 % of the civil works cost

/2 10 % of the total local component of civil works, and land acquisition and house compensation

/3 10 % of the total costs of civil works, land acquisition and house compensation, and engineering and administration

4. Cost for civil works includes costs for preparatory works (8 % of direct civil works) and miscellaneous works (10 % of civil works). The cost for miscellaneous works includes cost for telemetering facilities to establish flood forecasting system in future.

Table 9.1 Economic Cost and Benefits Flow for Urgent Flood Control Project

Unit: Rp. 10^6

Year in order	Year	Economic cost				Benefit
		Construction cost	Replacement cost	O & M cost	Total	
1	1985/86	1,323	-	-	1,323	-
2	1986/87	1,234	-	-	1,234	-
3	1987/88	6,731	-	-	6,731	-
4	1988/89	9,672	-	-	9,672	-
5	1989/90	10,545	-	25	10,570	1,223
6	1990/91	10,545	-	75	10,620	3,669
7	1991/92	3,628	-	125	3,753	6,116
8	1992/93	-	-	150	150	7,339
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31	2015/16	-	-	150	150	7,339
32	2016/17	-	1,191	150	1,341	7,339
33	2017/18	-	1,191	150	1,341	7,339
34	2018/19	-	1,195	150	1,345	7,339
35	2019/20	-	-	150	150	7,339
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57	2041/42	-	-	150	150	7,339

Table 9.2 Required Fund for Proposed Urgent Flood Control Project

Description	L.C (Rp. 10^6)	F.C Required Loan Amount (US $ 10^3)	Total (Rp.10^6)
1. Land acquisition	1,819.9	-	1,819.9
2. Civil Works	9,627.1	22,779.8	31,723.5
(1) Arau river	1,311.8	2,581.6	3,816.0
(2) Flood relief Channel	4,502.6	10,145.2	14,343.4
(3) Kuranji river	2,982.7	7,937.9	10,682.5
(4) Air Dingin river	830.0	2,115.1	2,881.6
3. Administration	1,144.7	-	1,144.7
4. Engineering services	940.6	5,680.8	6,451.0
5. Total (1 to 4)	13,532.3	28,460.6	41,139.1
6. Physical contingency	1,353.3	2,846.3	4,114.2
7. Total (5 + 6)	14,885.6	31,306.9	45,253.3
8. Price contingency	17,600.0	12,441.2	29,668.0
9. Grand total	32,485.6	43,748.1	74,921.3

Remark : (1) Price escalation rate for F.C portion : 6 %

(2) Price escalation rate for L.C portion :15 %

(3) US $ 1 = Rp. 970.

Table 9.3 Disbursement Schedule of the Required Fund

(Unit: L.C. = Rp. 10^6; F.C. = US\$ 10^3)

DESCRIPTION	1985/86		1986/87		1987/88		1988/89		1989/90		1990/91		1991/92		TOTAL	
	L.C.	F.C.	L.C.	F.C.	L.C.	F.C.	L.C.	F.C.	L.C.	F.C.	L.C.	F.C.	L.C.	F.C.	L.C.	F.C.
1. Land acquisition	181.9	-	546.0	-	546.0	-	546.0	-	-	-	-	-	-	-	1,819.9	-
2. Civil Works	-	-	-	-	1,162.9	2,545.4	2,348.6	5,563.1	2,971.3	7,045.6	2,680.3	6,409.1	464.0	1,216.6	9,627.1	22,779.8
(1) Arau river	-	-	-	-	262.4	516.3	328.0	645.4	393.6	774.5	327.8	645.4	-	-	1,311.8	2,581.6
(2) Flood relief channel	-	-	-	-	900.5	2,029.1	1,125.7	2,536.3	1,350.8	3,043.6	1,125.6	2,536.2	-	-	4,502.6	10,145.2
(3) Kuranji river	-	-	-	-	-	-	894.9	2,381.4	894.9	2,381.4	894.9	2,381.4	298.0	793.7	2,982.7	7,937.9
(4) Air Dingin river	-	-	-	-	-	-	-	-	332.0	846.1	332.0	846.1	166.0	422.9	830.0	2,115.1
3. Administration	229.0	-	171.7	-	171.7	-	114.5	-	114.5	-	171.7	-	171.6	-	1,144.7	-
4. Engineering	265.1	1,530.2	66.2	382.5	121.9	753.7	121.9	753.6	121.9	753.6	121.9	753.6	121.7	753.6	940.6	5,680.8
5. Total (1 + 4)	676.0	1,530.2	783.9	382.5	2,002.5	3,299.1	3,131.0	6,316.7	3,207.7	7,799.2	2,973.9	7,162.7	757.3	1,970.2	13,532.3	28,460.6
6. Physical contingency	67.6	153.0	78.4	38.3	200.3	330.0	313.1	631.7	320.8	780.0	297.4	716.3	75.7	197.0	1,353.3	2,846.3
7. Total (5 + 6)	743.6	1,683.2	862.3	420.8	2,202.8	3,629.1	3,444.1	6,948.4	3,528.5	8,579.2	3,271.3	7,879.0	833.0	2,167.2	14,885.6	31,306.9
8. Price contingency	240.2	208.1	449.3	80.4	1,649.9	950.9	3,482.0	2,348.6	4,633.0	3,594.7	5,430.4	3,971.1	1,715.2	1,287.4	17,600.0	12,441.2
9. Grand Total	983.8	1,891.3	1,311.6	501.2	3,852.7	4,580.0	6,926.1	9,297.0	8,161.5	12,173.9	8,701.7	11,850.1	2,548.2	3,454.6	32,485.6	43,748.1

Note : 1. The price level of 1983 was applied to the estimation

2. The following were applied to the conversion rate

US\$ 1 = Rp. 970

3. The following were applied to the price contingency

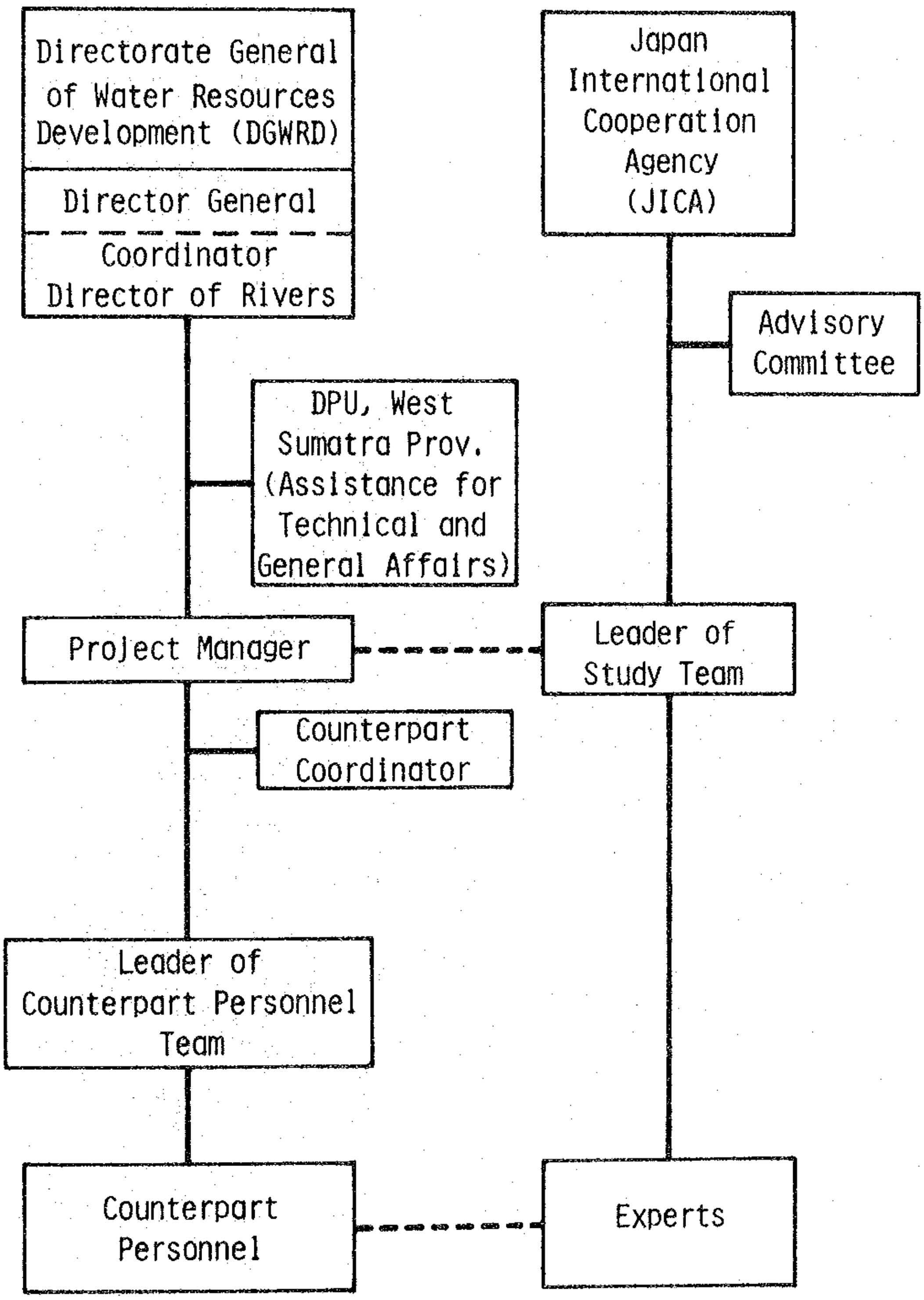
15 % for local currency

6 % for foreign currency

Table 11.1 Calculation of Annual Production of Electricity

Power plant		Discharge (m^3/s)	Duration (day)	head loss h1 (m)	head loss h2 (m)	head loss h3 (m)	Effect. head (m)	Output (kw)	Annual Product (MWh)	Total Annual Product (MWh/yr)
LIMAU MANIS -1										
Total head	: 11.6 m	0.75	75	0.22	0.74	0.10	10.54	58.1	105	
Leading chan. length	: 217 m	0.74	20	0.22	0.72	0.09	10.57	57.5	28	
Penstock length	: 21 m	0.67	85	0.22	0.59	0.08	10.71	52.7	108	
Penstock diameter	: 0.50 m	0.52	95	0.22	0.36	0.06	10.96	41.9	96	
		0.35	70	0.22	0.16	0.04	11.18	28.8	48	385
LIMAU MANIS -2										
Total head	: 11.0 m	0.75	75	0.36	0.71	0.11	9.82	54.1	97	
Leading chan. length	: 358 m	0.74	20	0.36	0.69	0.11	9.84	53.5	26	
Penstock length	: 20 m	0.67	85	0.36	0.56	0.09	9.99	49.2	100	
Penstock diameter	: 0.50 m	0.52	95	0.36	0.34	0.07	10.23	39.1	89	
		0.35	70	0.36	0.15	0.05	10.44	26.9	45	357
GUNUNG NAGO LEFT										
Total head	: 5.2 m	2.04	75	0.25	0.15	0.04	4.76	71.4	128	
Leading chan. length	: 250 m	2.04	20	0.25	0.15	0.04	4.76	71.4	34	
Penstock length	: 10 m	1.85	85	0.25	0.13	0.04	4.78	65.0	133	
Penstock diameter	: 0.85 m	1.39	95	0.25	0.07	0.03	4.85	49.6	113	
		0.89	70	0.25	0.03	0.03	4.89	32.0	54	462
GUNUNG NAGO RIGHT										
Total head	: 6.8 m	2.35	75	0.30	0.20	0.05	6.25	108.0	194	
Leading chan. length	: 301 m	2.35	20	0.30	0.20	0.05	6.25	108.0	52	
Penstock length	: 13 m	1.98	85	0.30	0.14	0.04	6.32	92.0	188	
Penstock diameter	: 0.90 m	1.30	95	0.30	0.06	0.04	6.41	61.2	140	
		0.83	70	0.30	0.02	0.03	6.45	39.3	66	640

Fig. 1.1 Organization of Study



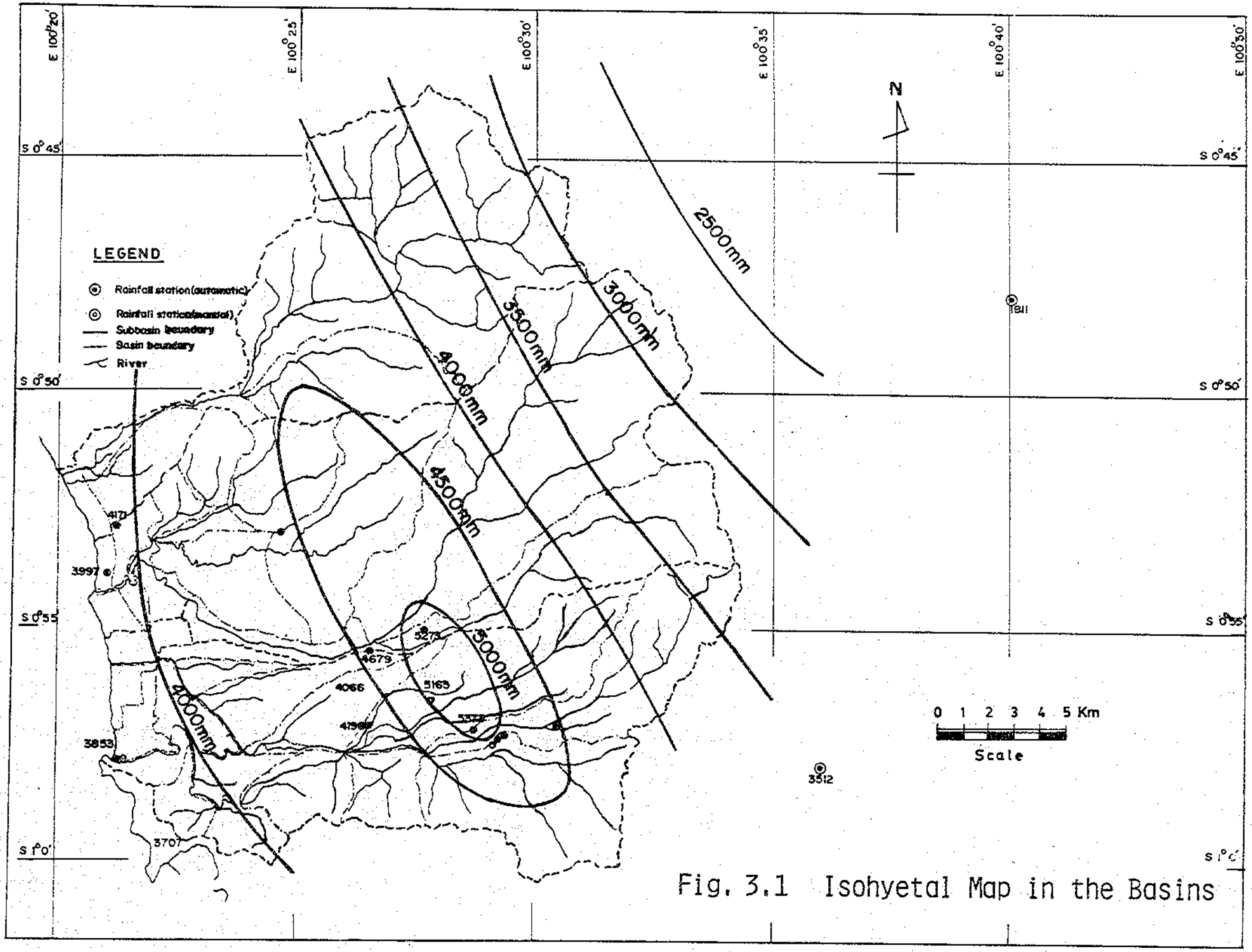


Fig. 3.1 Isohyetal Map in the Basins

Fig. 3.2 Monthly Rainfall at Tabing Station

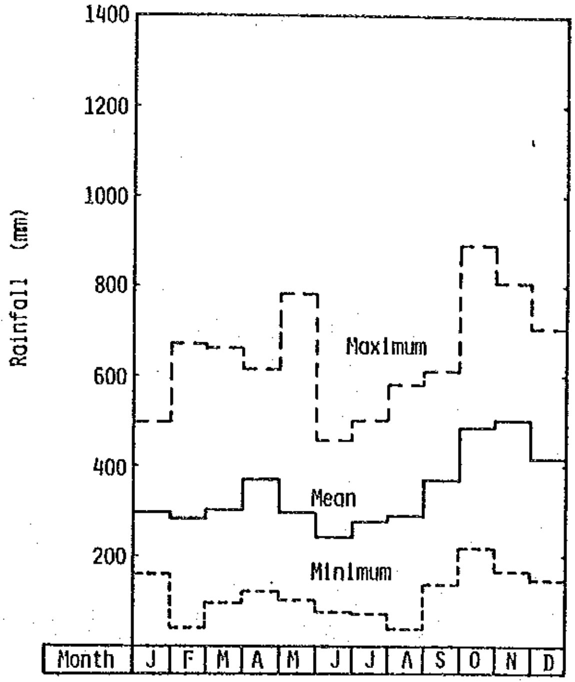


Fig. 3.3 Monthly Mean Daily Discharge

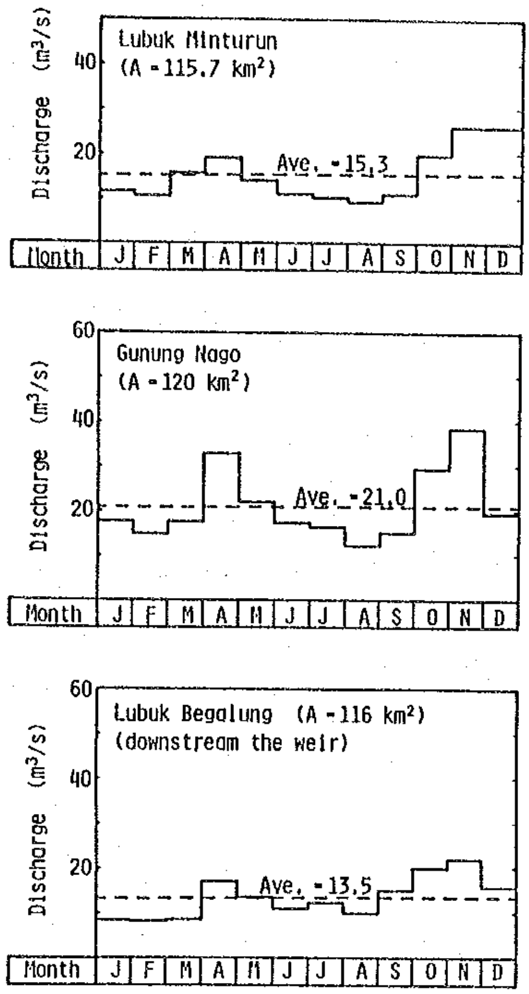


Fig. 3.4 River Basin

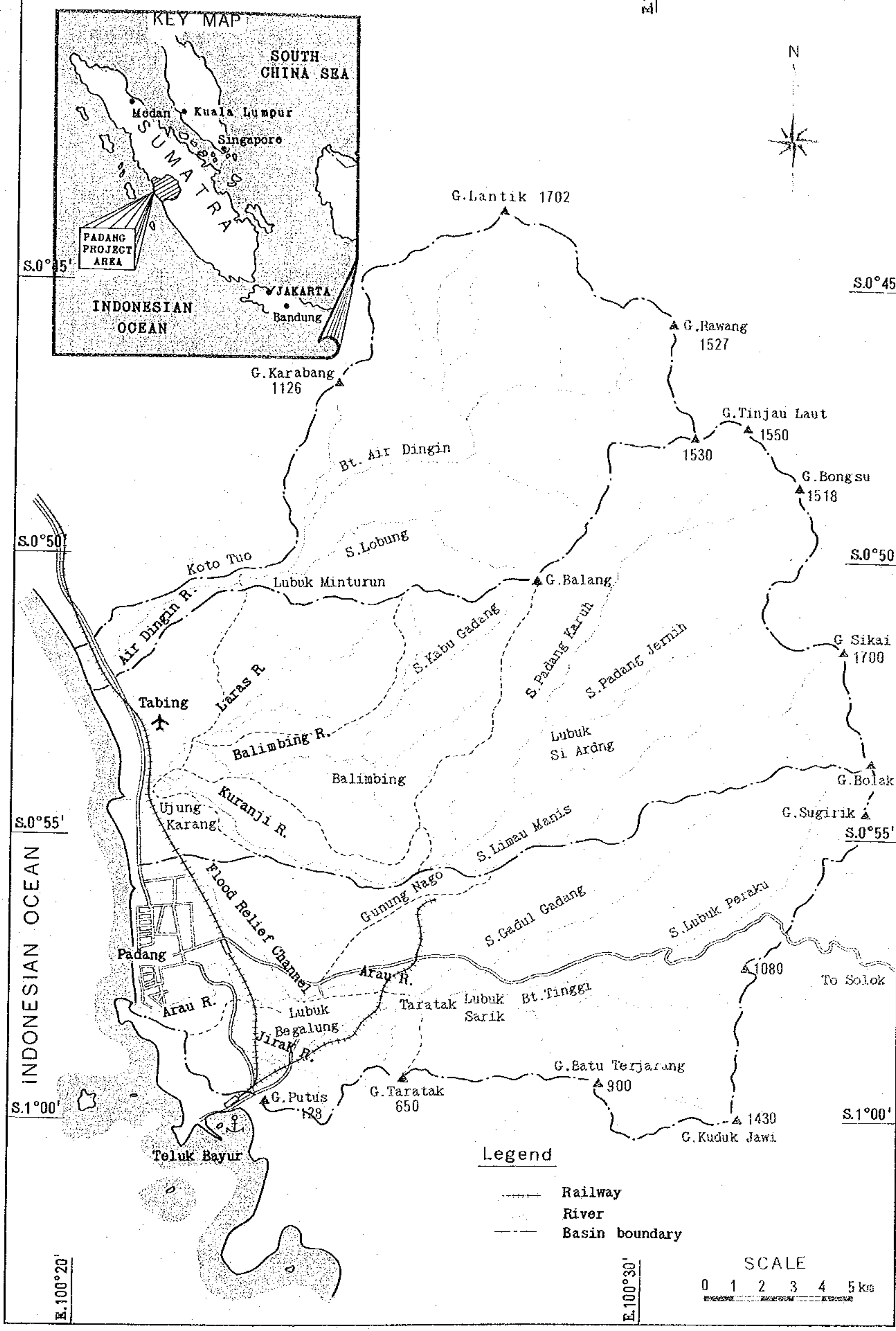


Fig. 3.5 Profile of Rivers

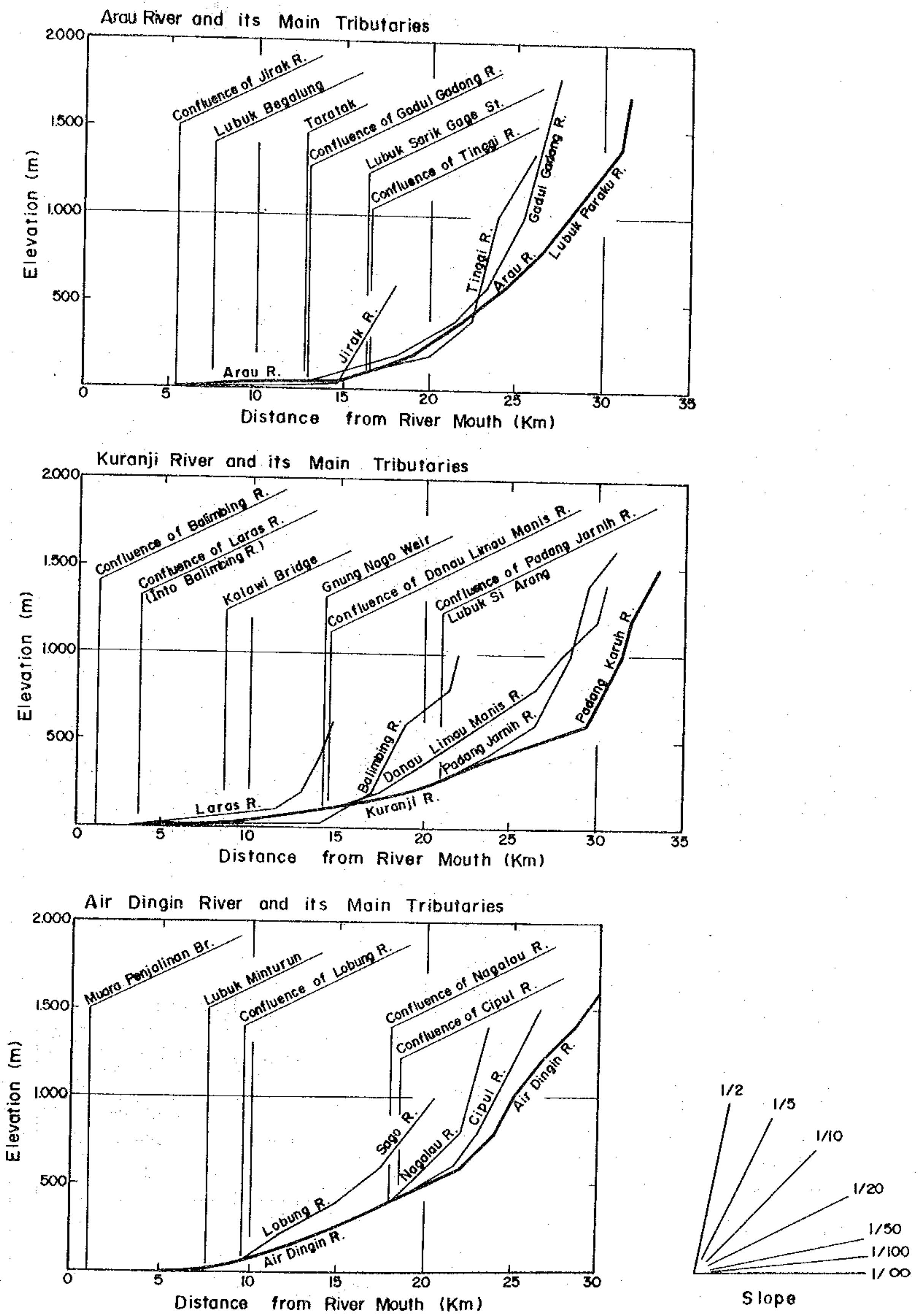
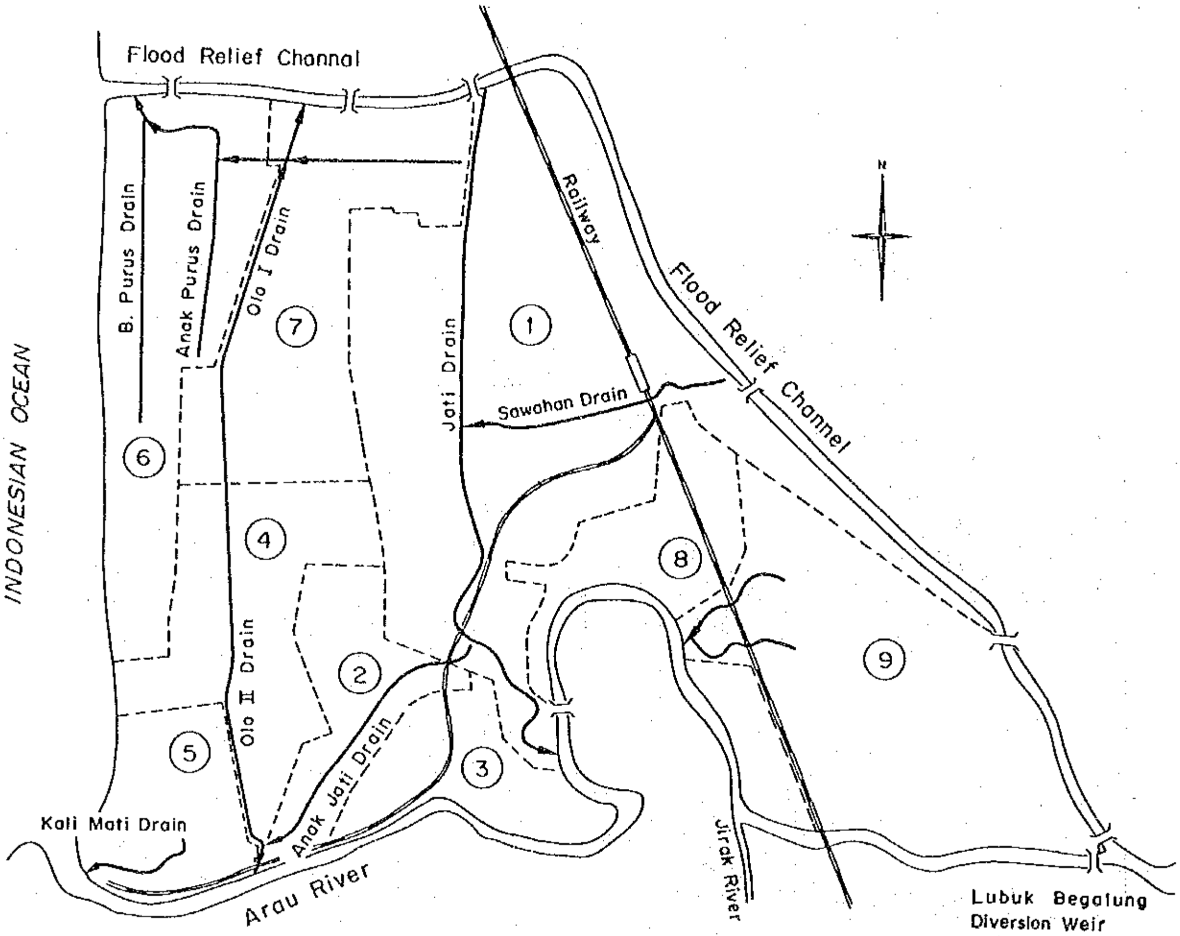
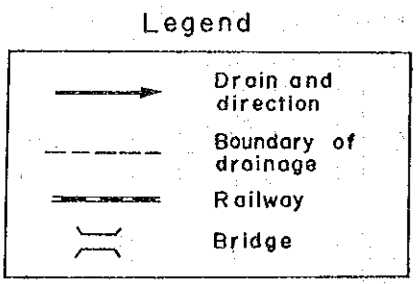


Fig 3.6 Existing Drainage System in Old Urban Area



	(ha)
1 Jati Drainage	:300
2 Anak Janti Drainage	: 50
3 Palinggam Hakim Drainage	: 50
4 Olo II Drainage	: 90
5 Kali Mati Drainage	: 55
6 B. Purus/Anak Purus Drainage	: 120
7 Olo I - Purus Kebun Drainage	: 120
8. Ganting/Parak Gadang Drainage	: 60
9 Aur Duri Drainage	: 150



Source: Inception Report on Padang DRIP, Dec. 1982

Fig. 3.7 Existing Drainage System in New Urban Area

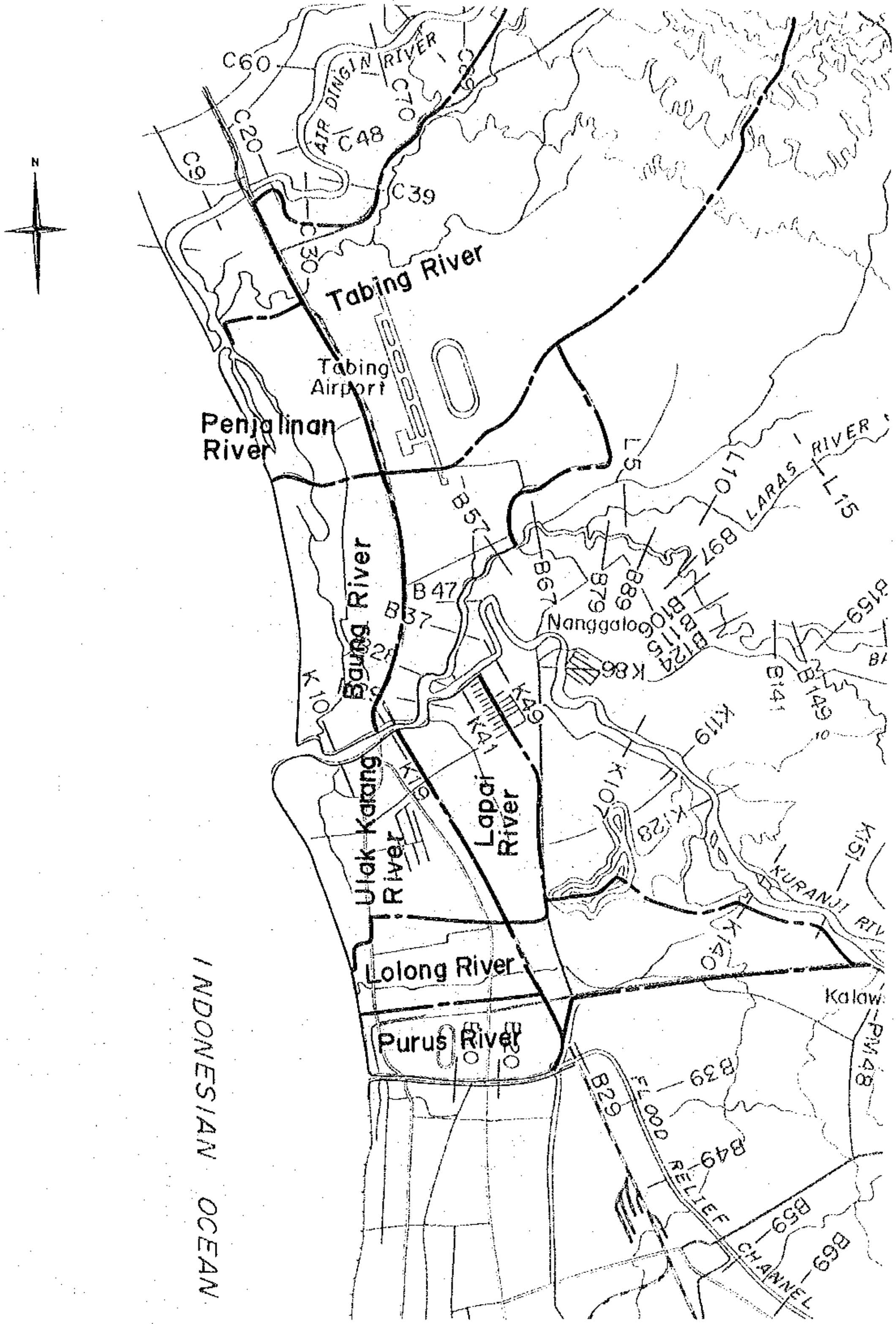


Fig. 3.8 Diversion Weir at Lubuk Begalung

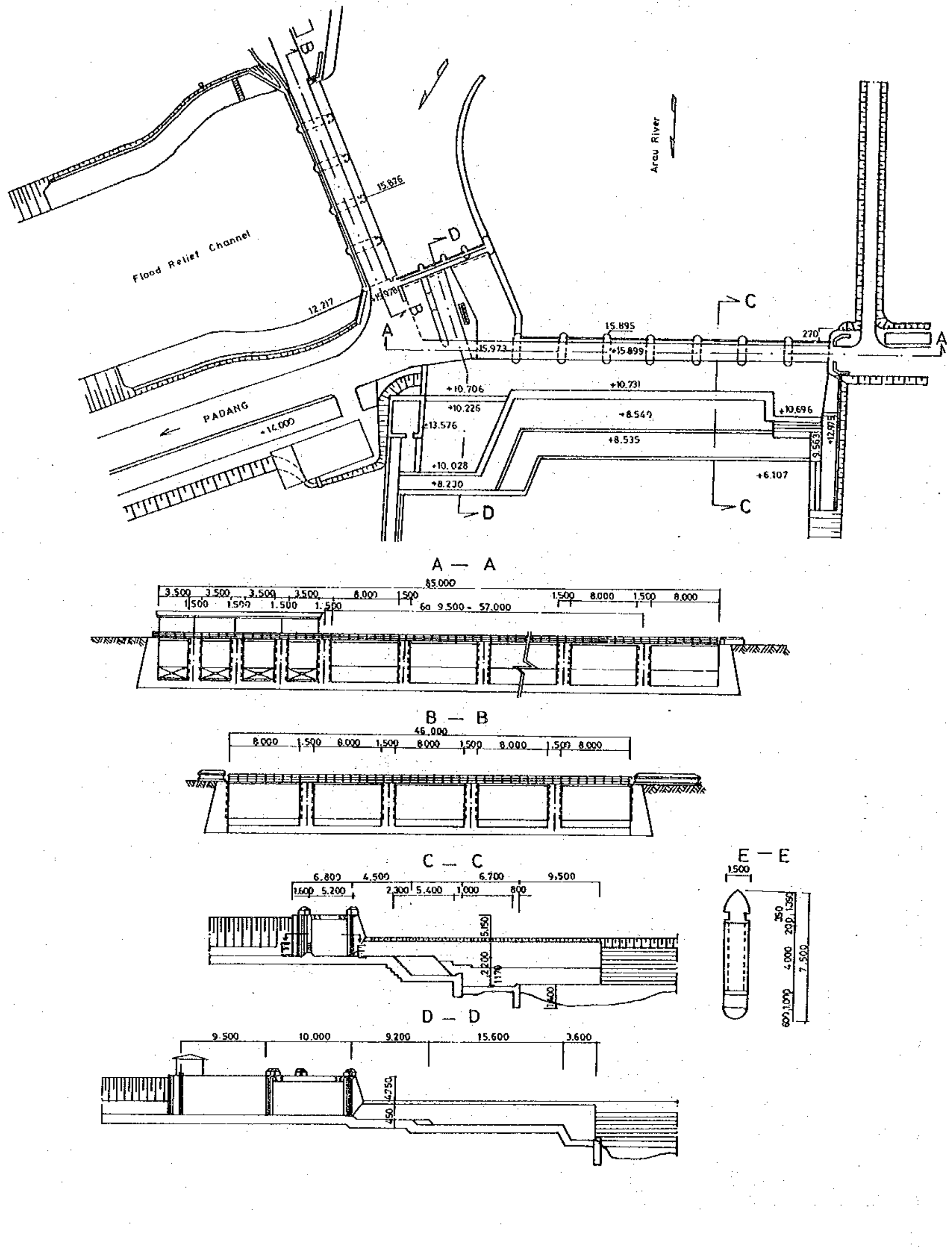


Fig. 3.9 Existing Groundsel at Downstream of Lubuk Begalung Weir

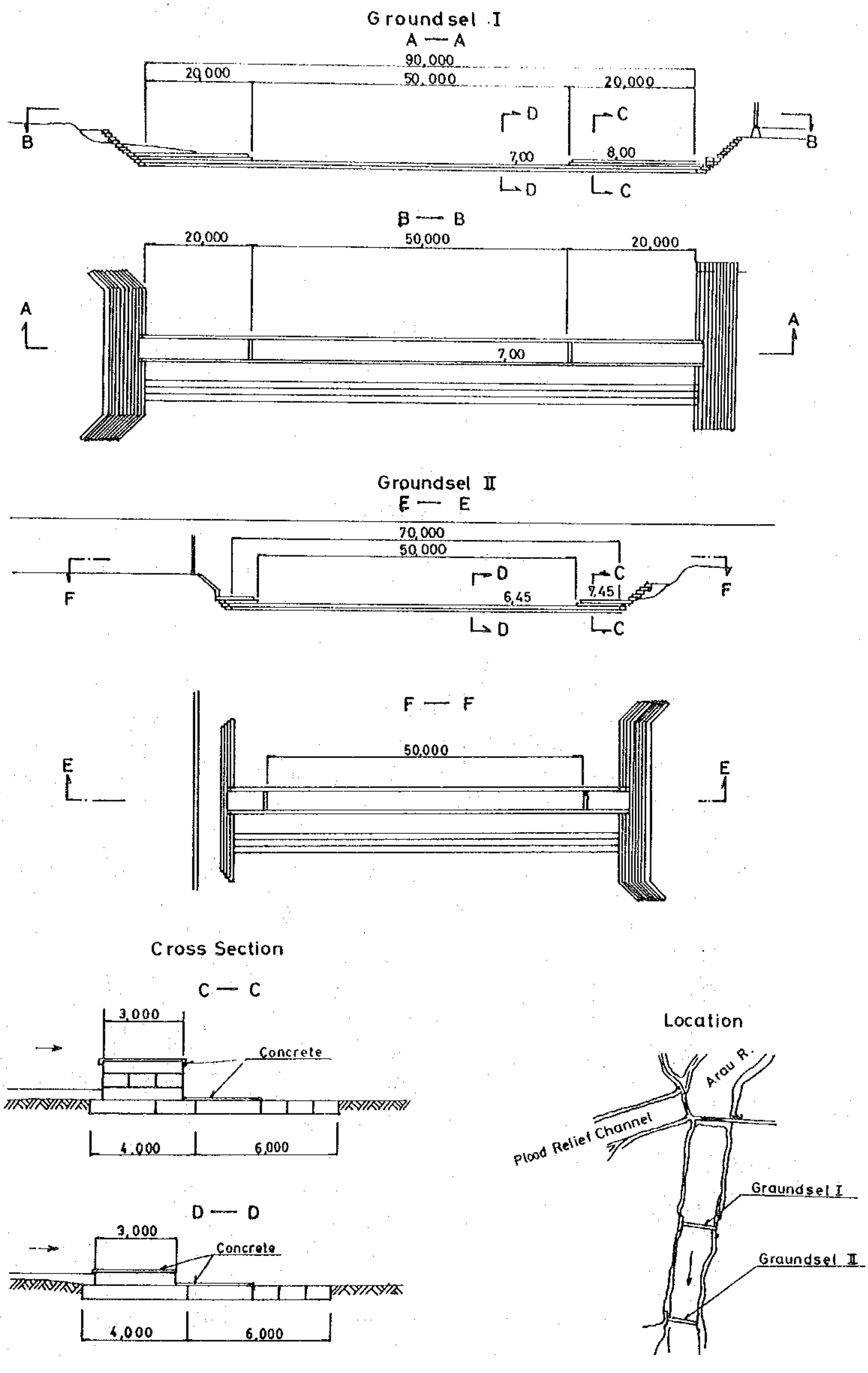


Fig. 3.10 Location of Existing Bank Protection Works

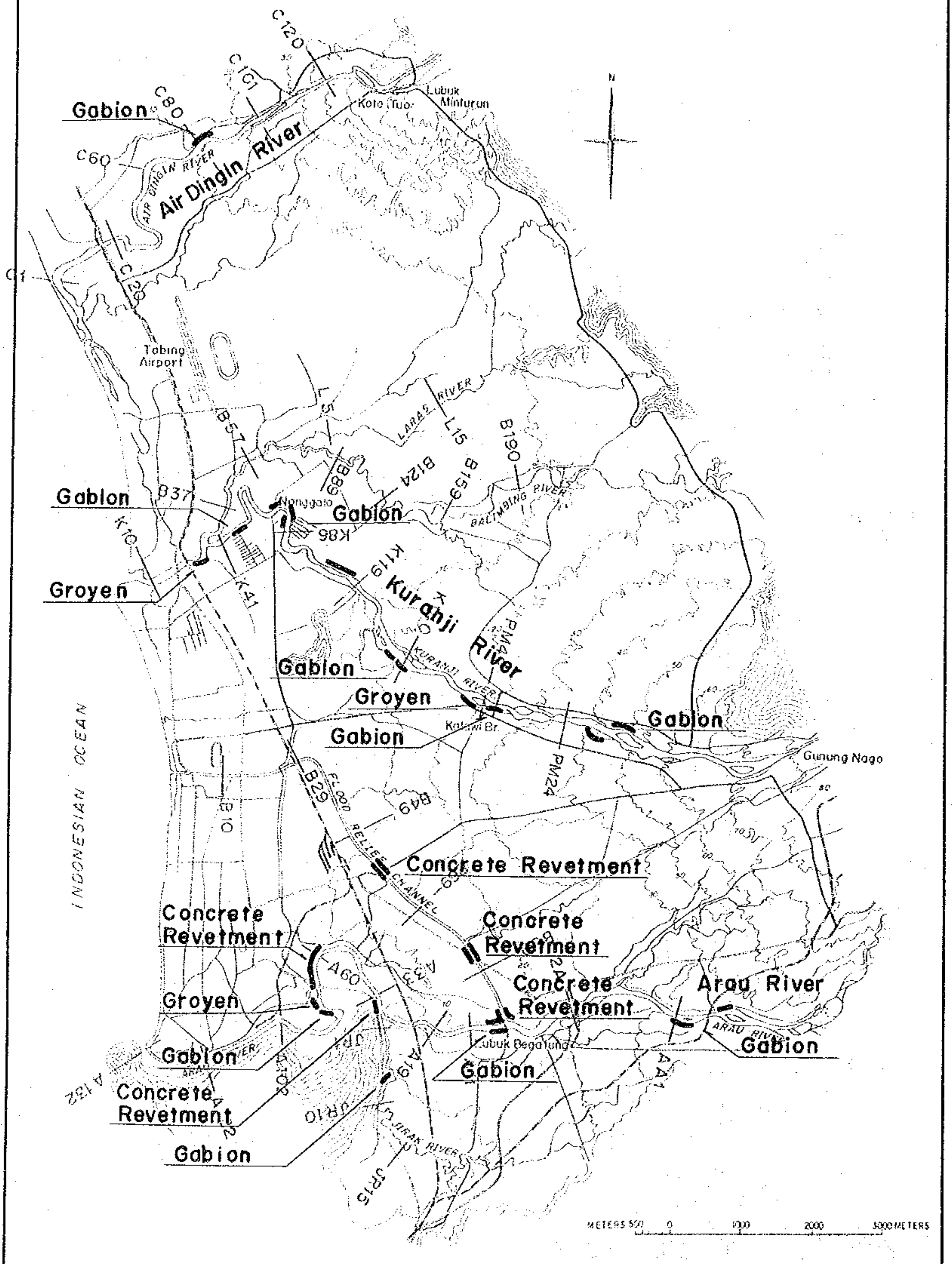


Fig. 3.11 Location of Existing Drainage Facilities

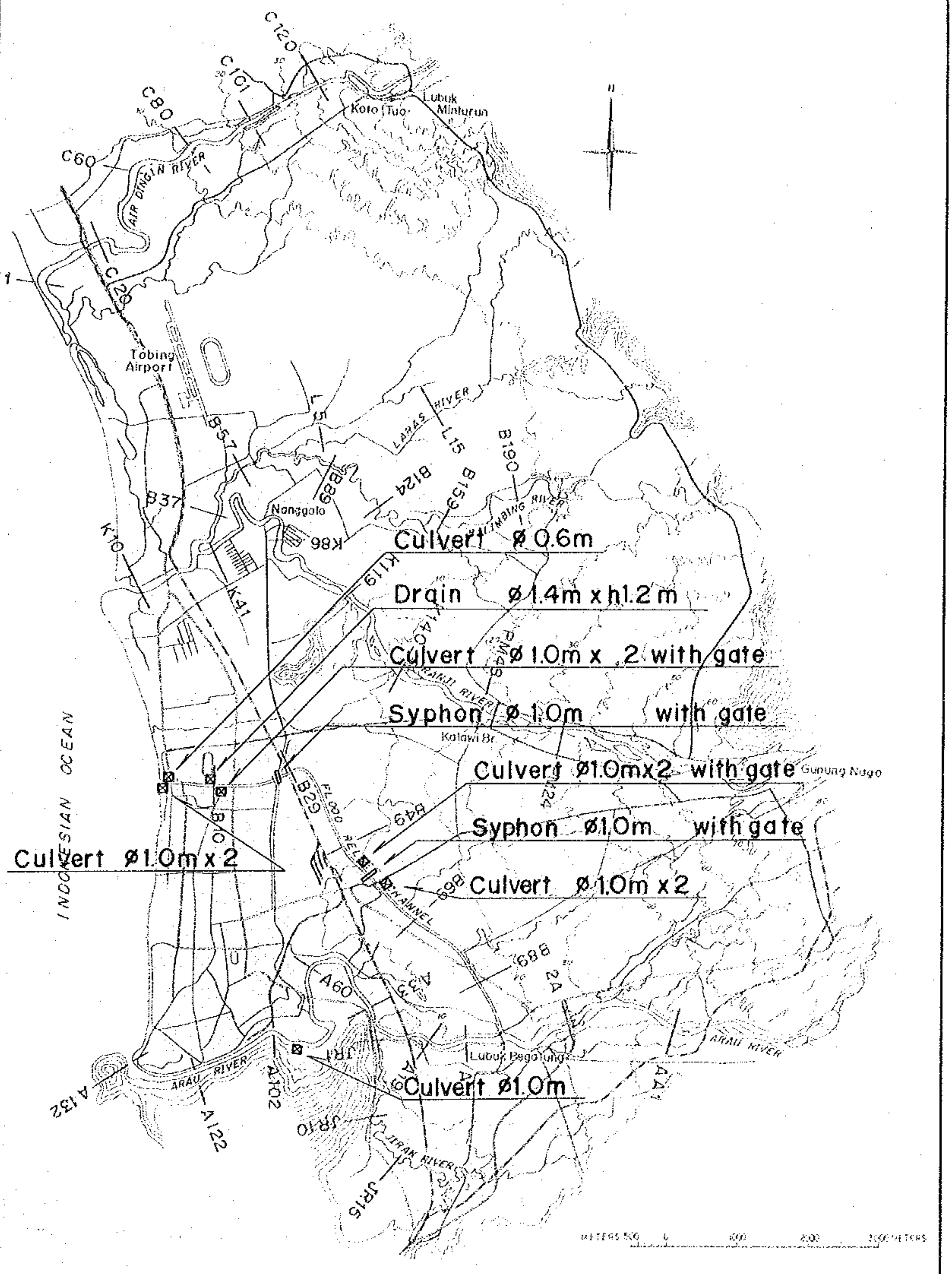


Fig. 3.12 Typical Flooding Flow Direction

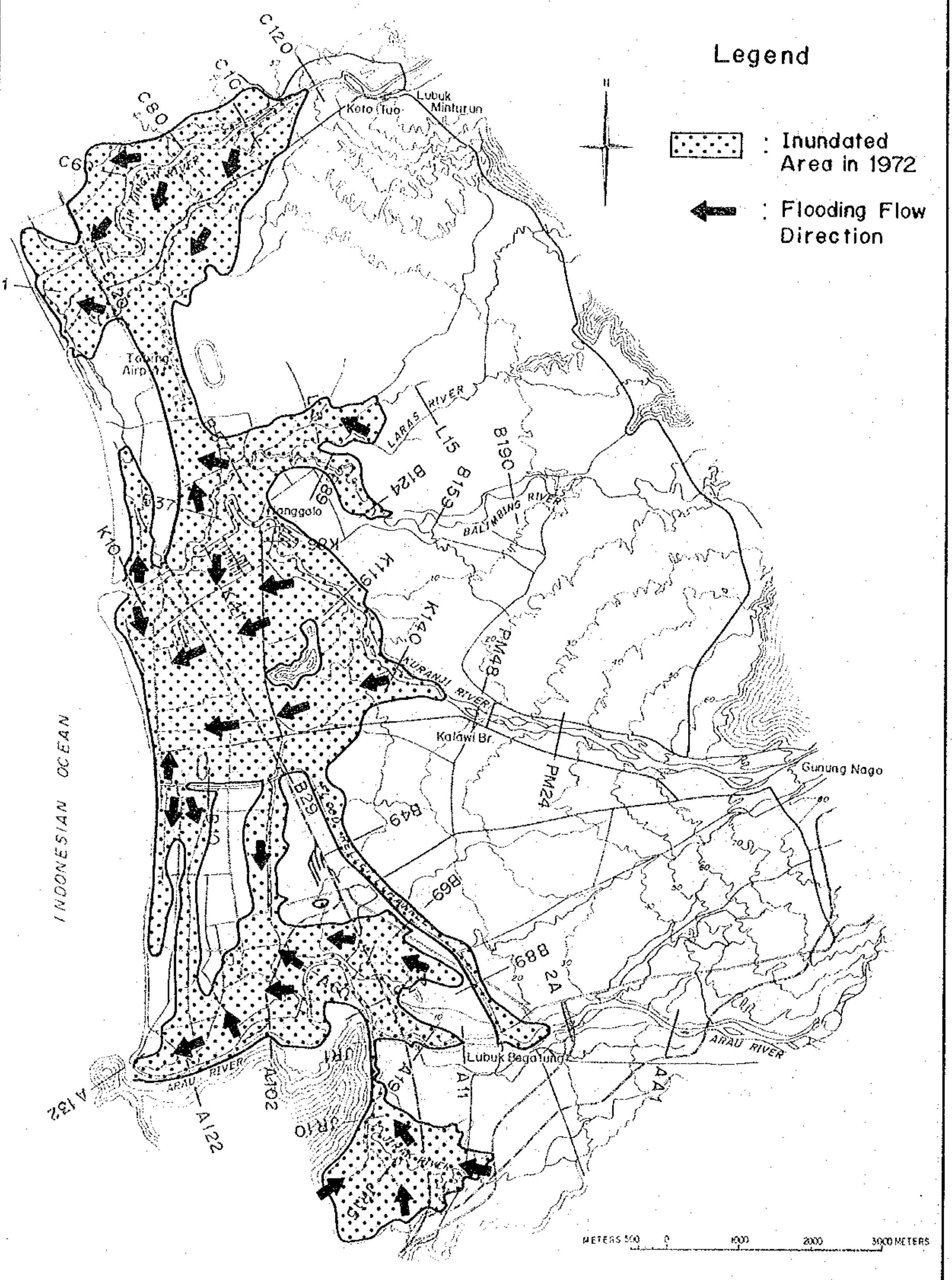


Fig.3.13 Present Land Use

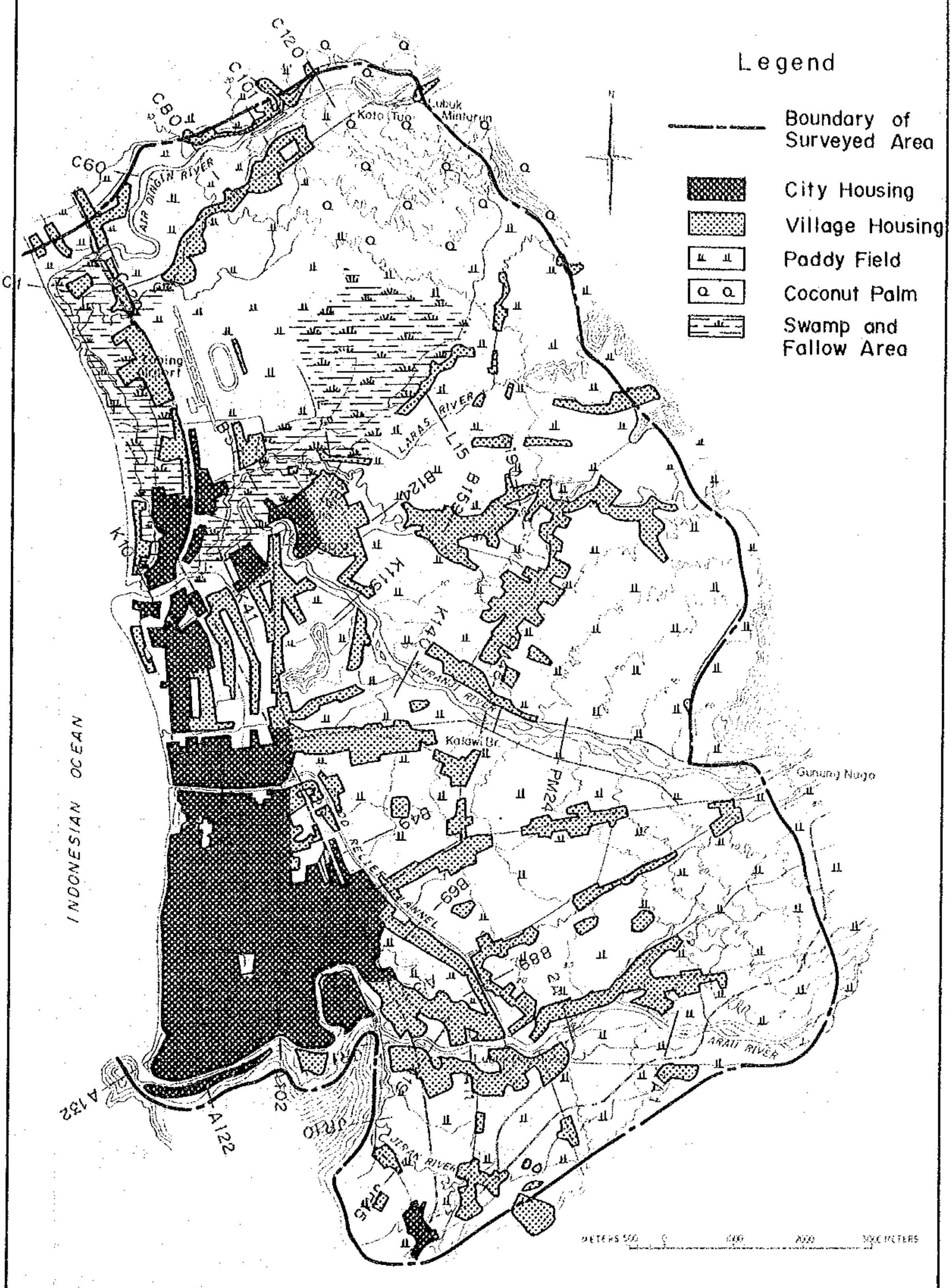


Fig 3.14 Schematic Geomorphologic Profile

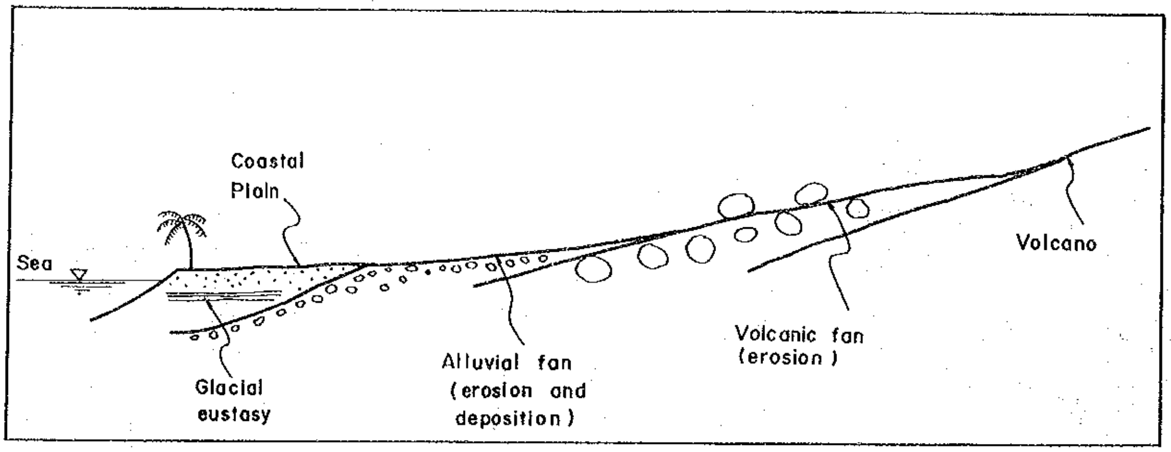


Fig 3.15 Features of Volcanic Fan around Kp. Baru

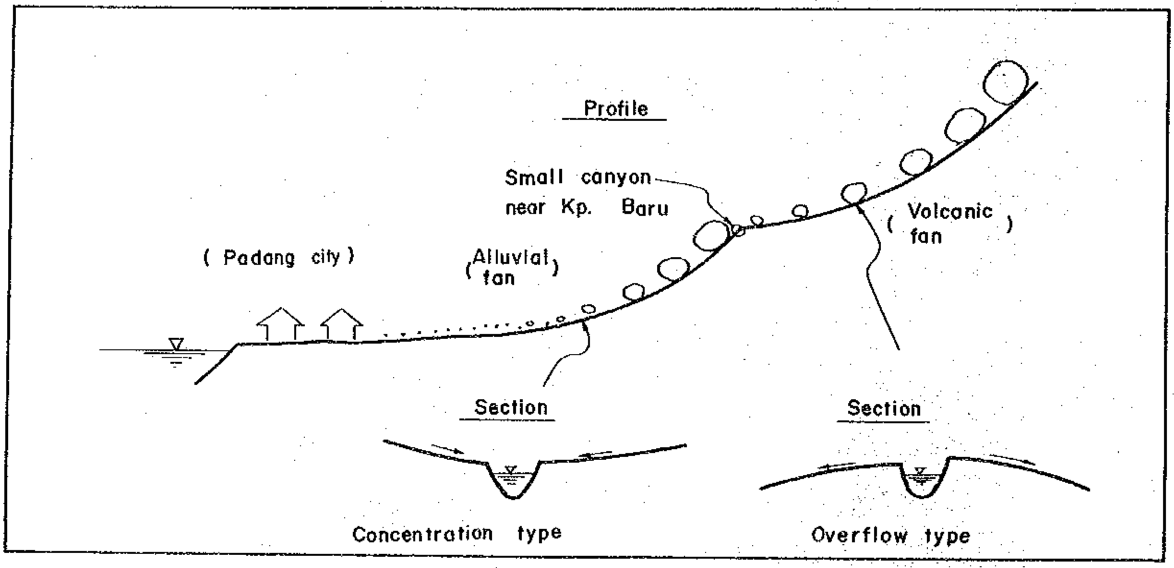


Fig 3.16 Schematic Profile of Coastal Plain

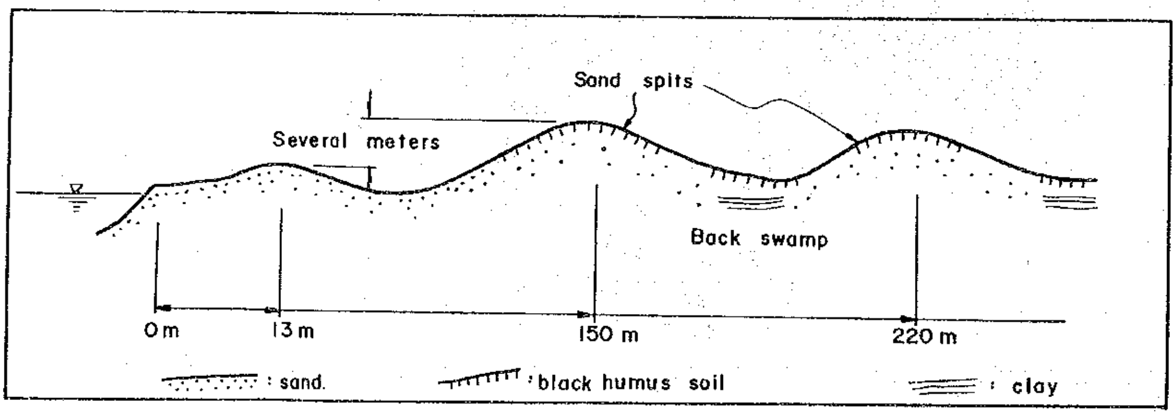


Fig. 3.17 Existing Irrigation Systems

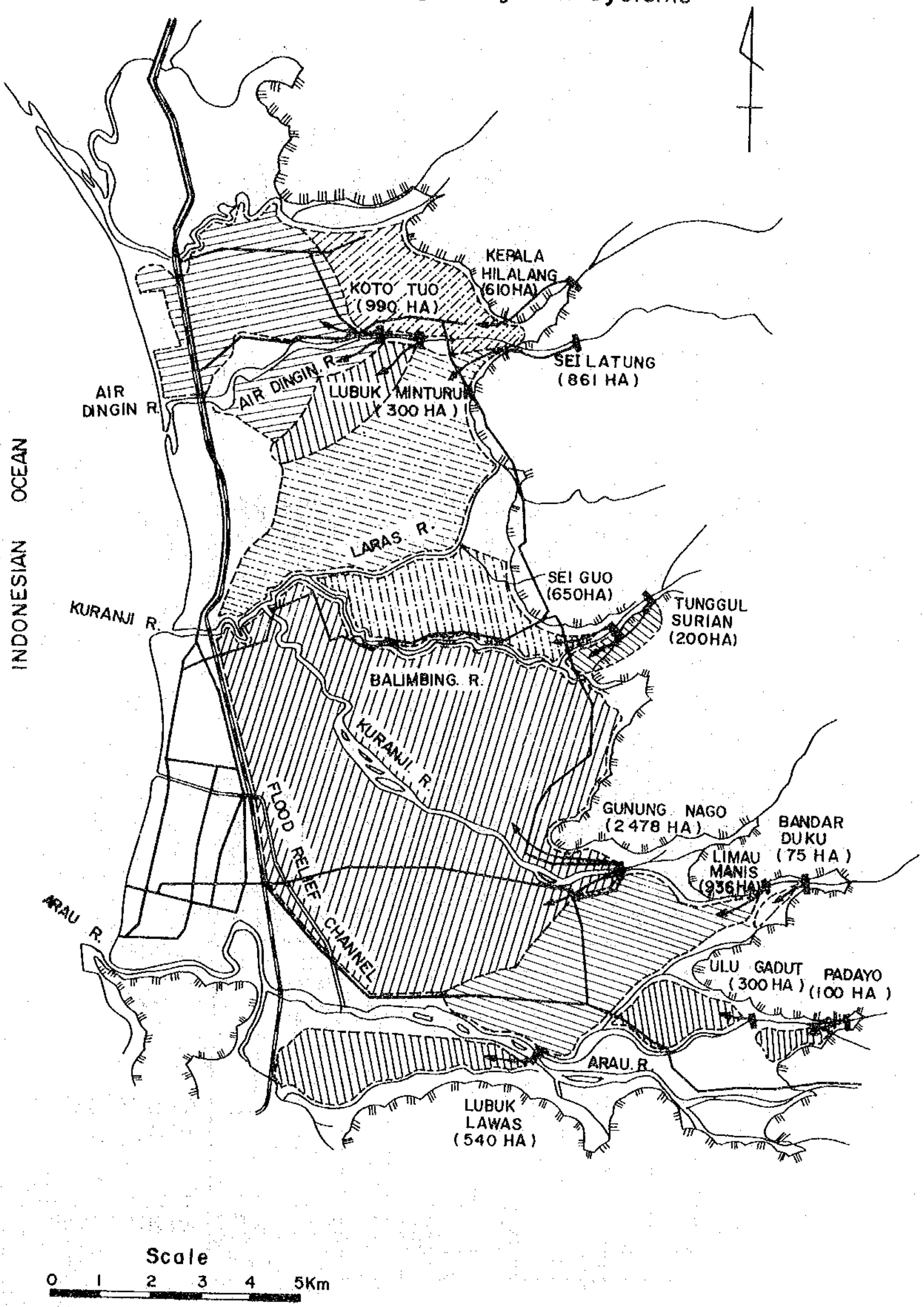


Fig. 3.18 Present Water Balance

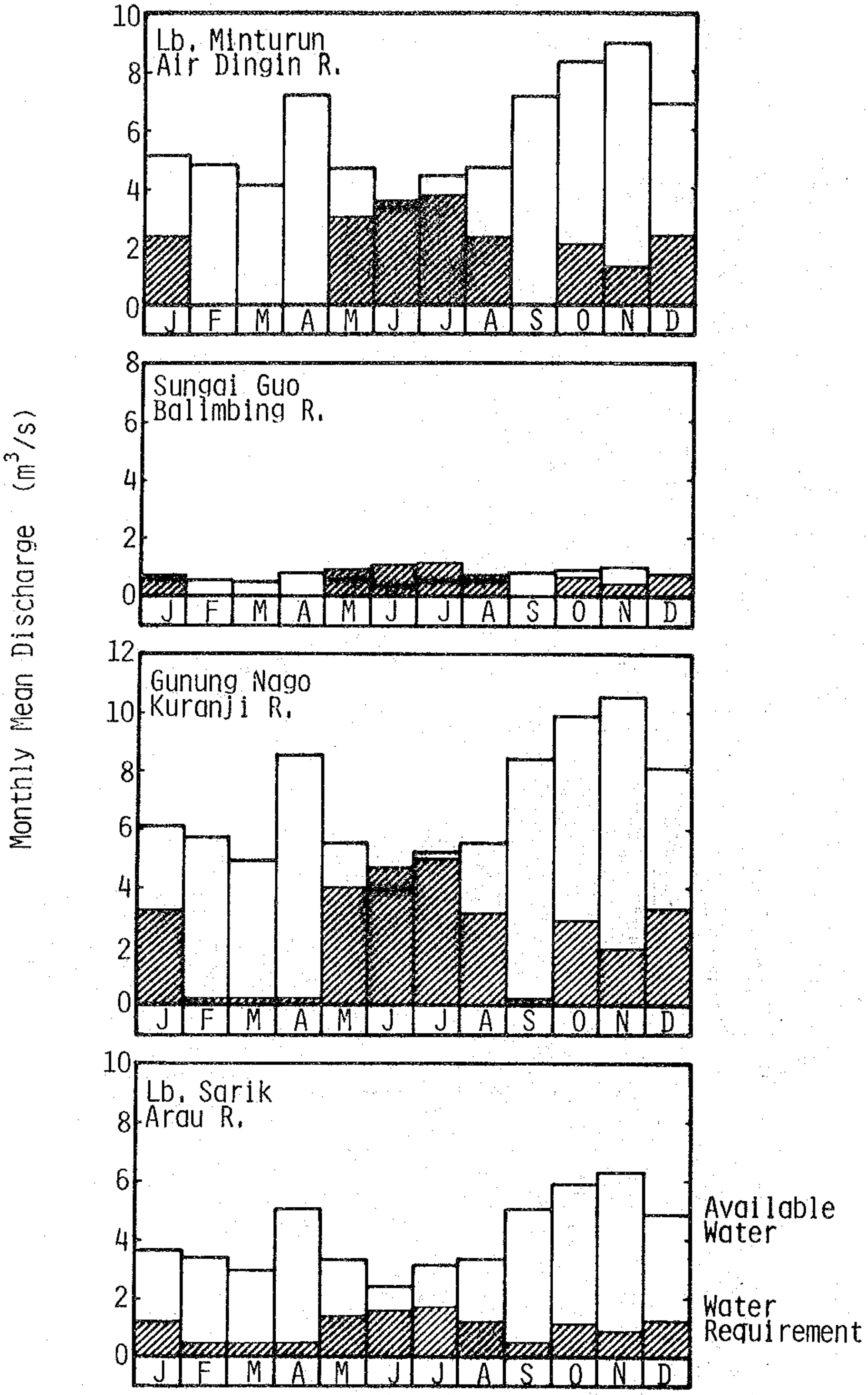
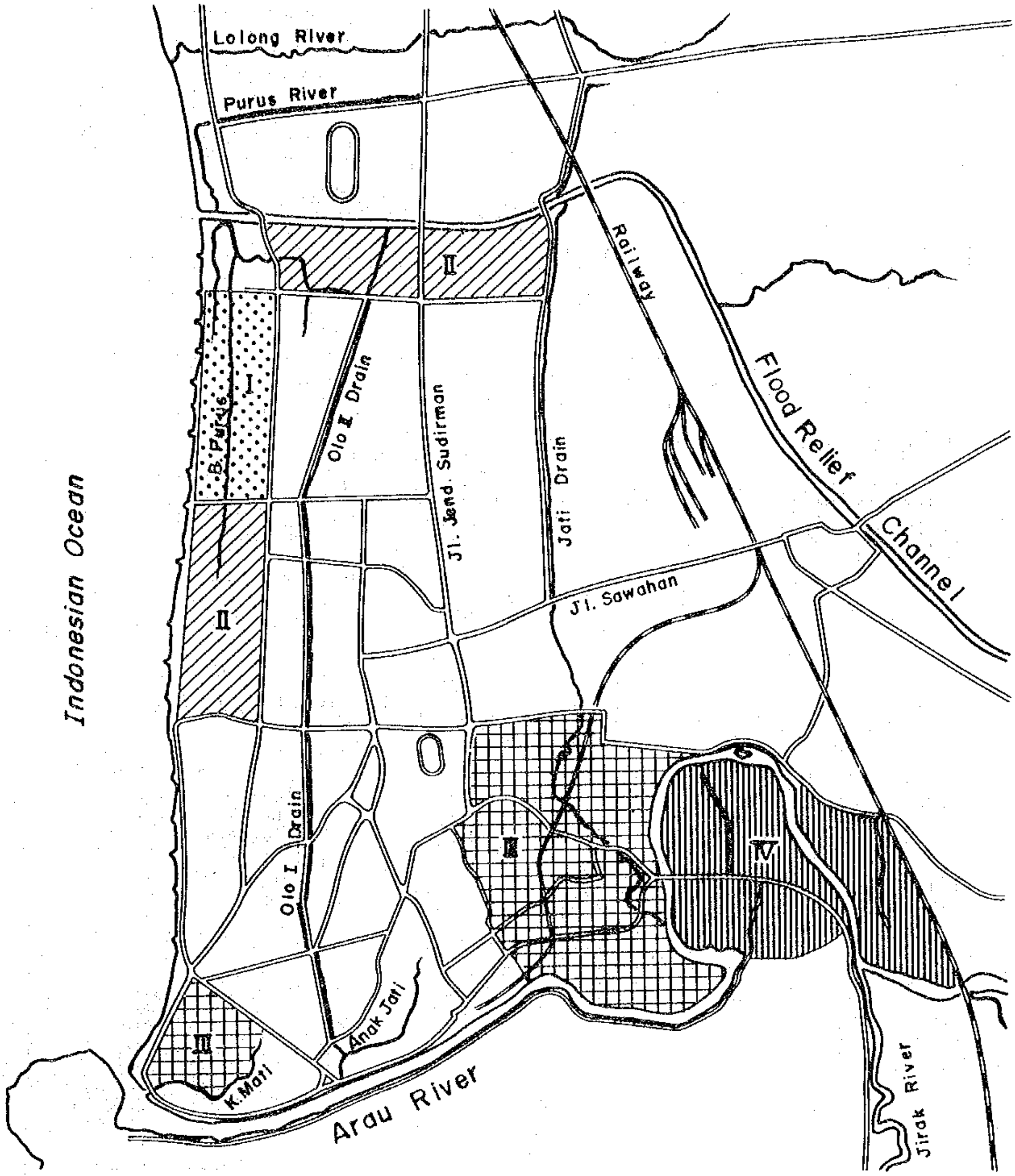


Fig. 4.1 Padang Kampung Improvement Program

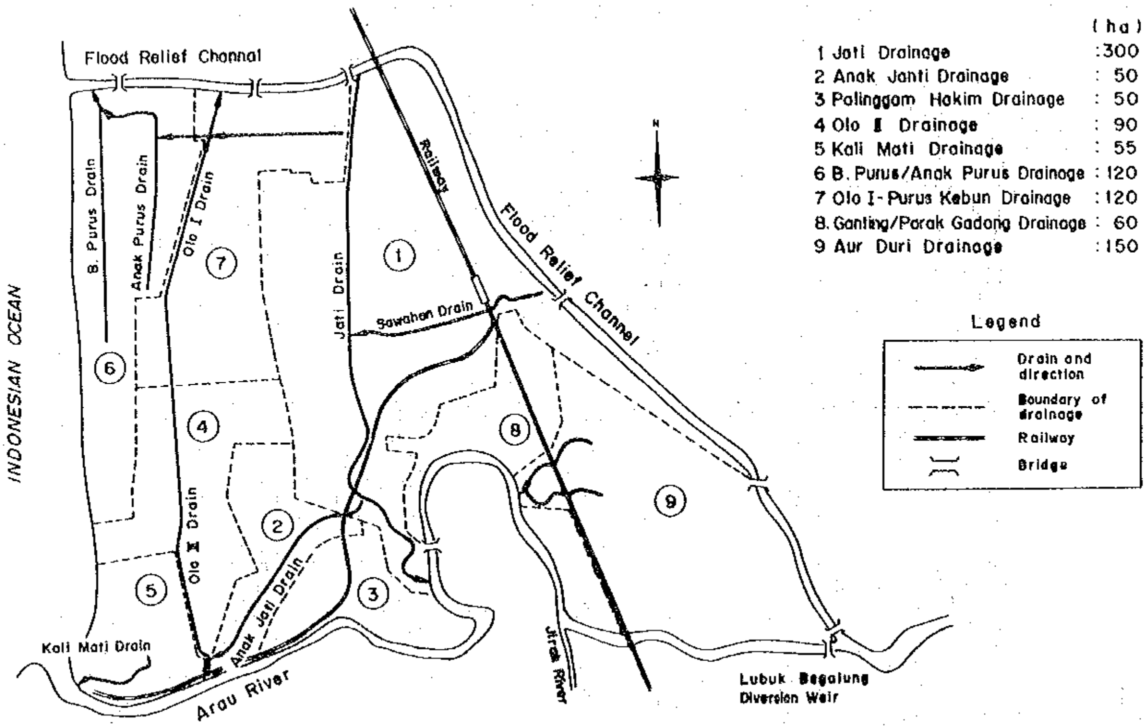


Legend

KIP Area Phase I
KIP Area Phase II
KIP Area Phase III
KIP Area Phase IV

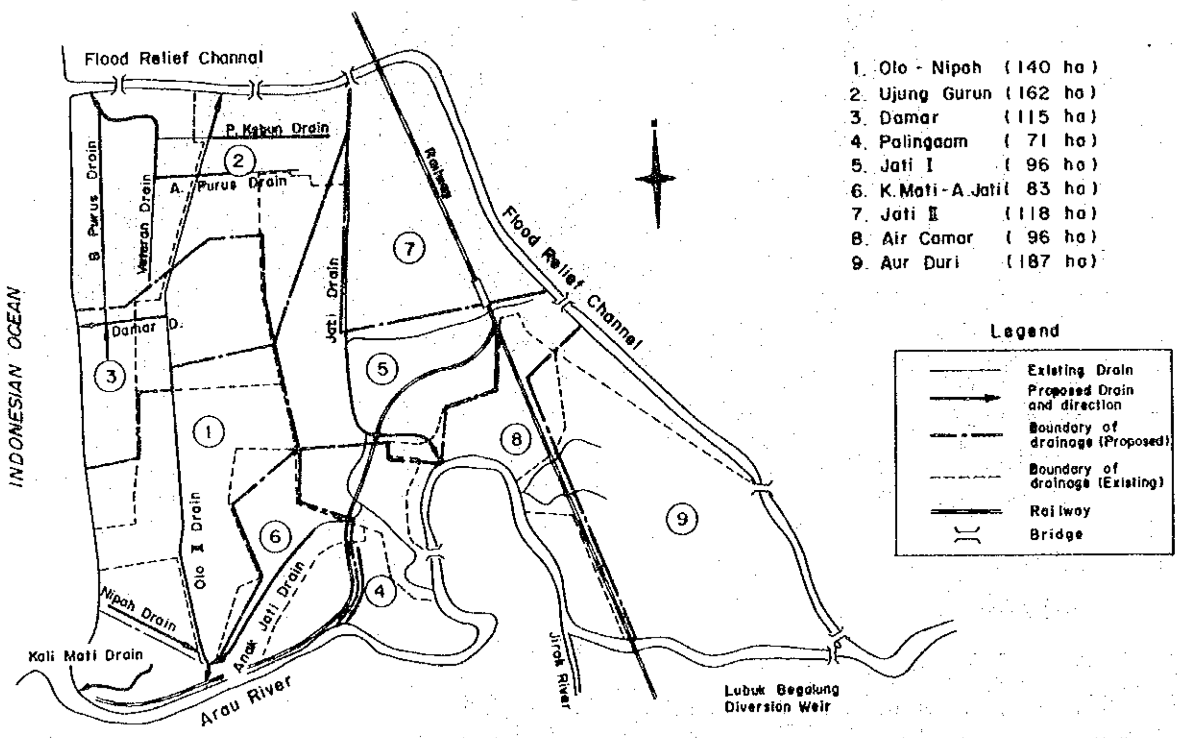
Source:
Padang KIP Feasibility Study 1980

Fig. 4.2 Existing Drainage System in Old Urban Area



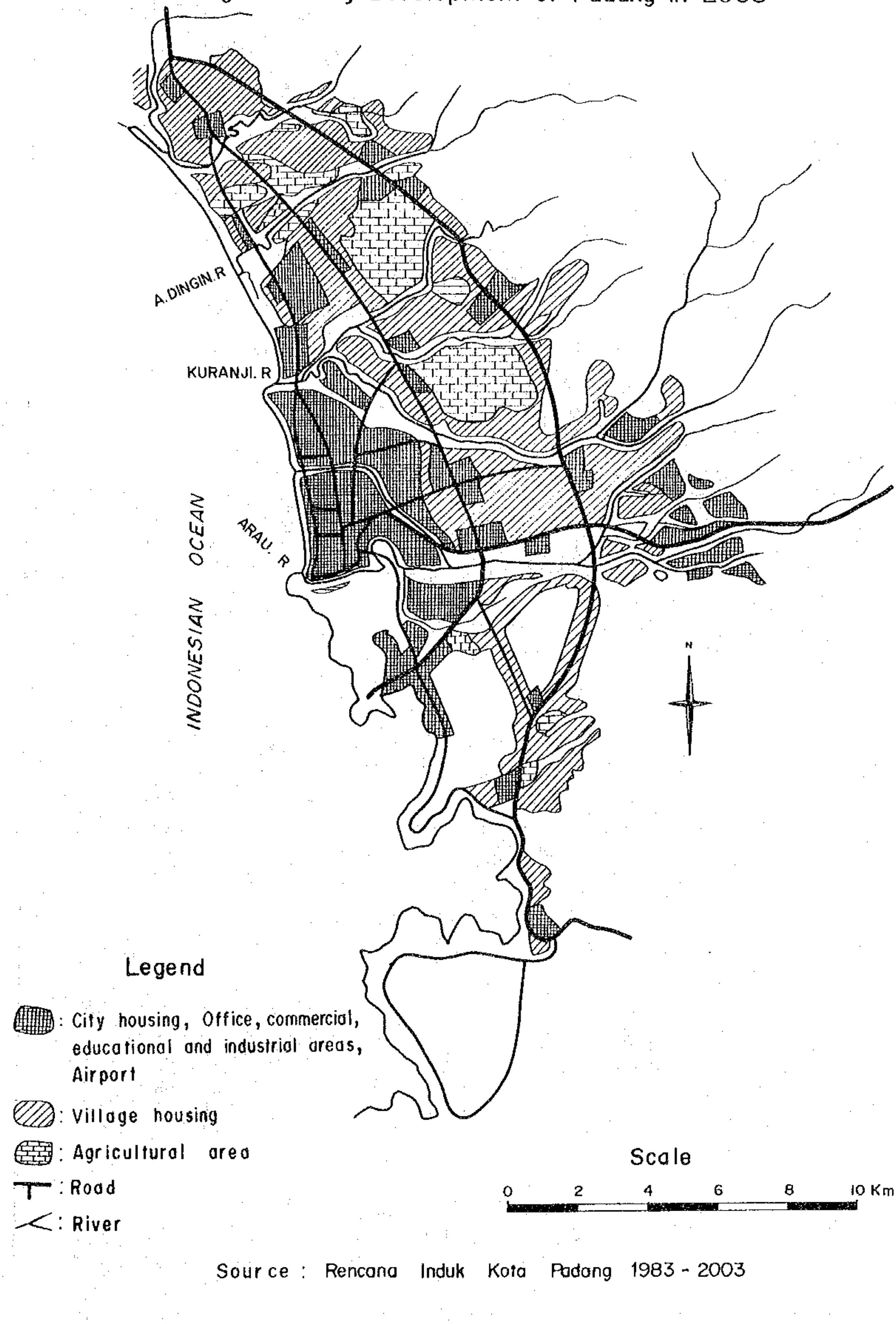
Source : Inception Report on Padang DRIP, Dec. 1982

Fig. 4.3 Proposed Drainage System in Old Urban Area



Source : Padang Drainage Improvement Project

Fig 4.4 City Development of Padang in 2003



Source : Rencana Induk Kota Padang 1983 - 2003

Fig. 5.1 Objective River Stretches for Comprehensive Flood Control and Drainage Plan

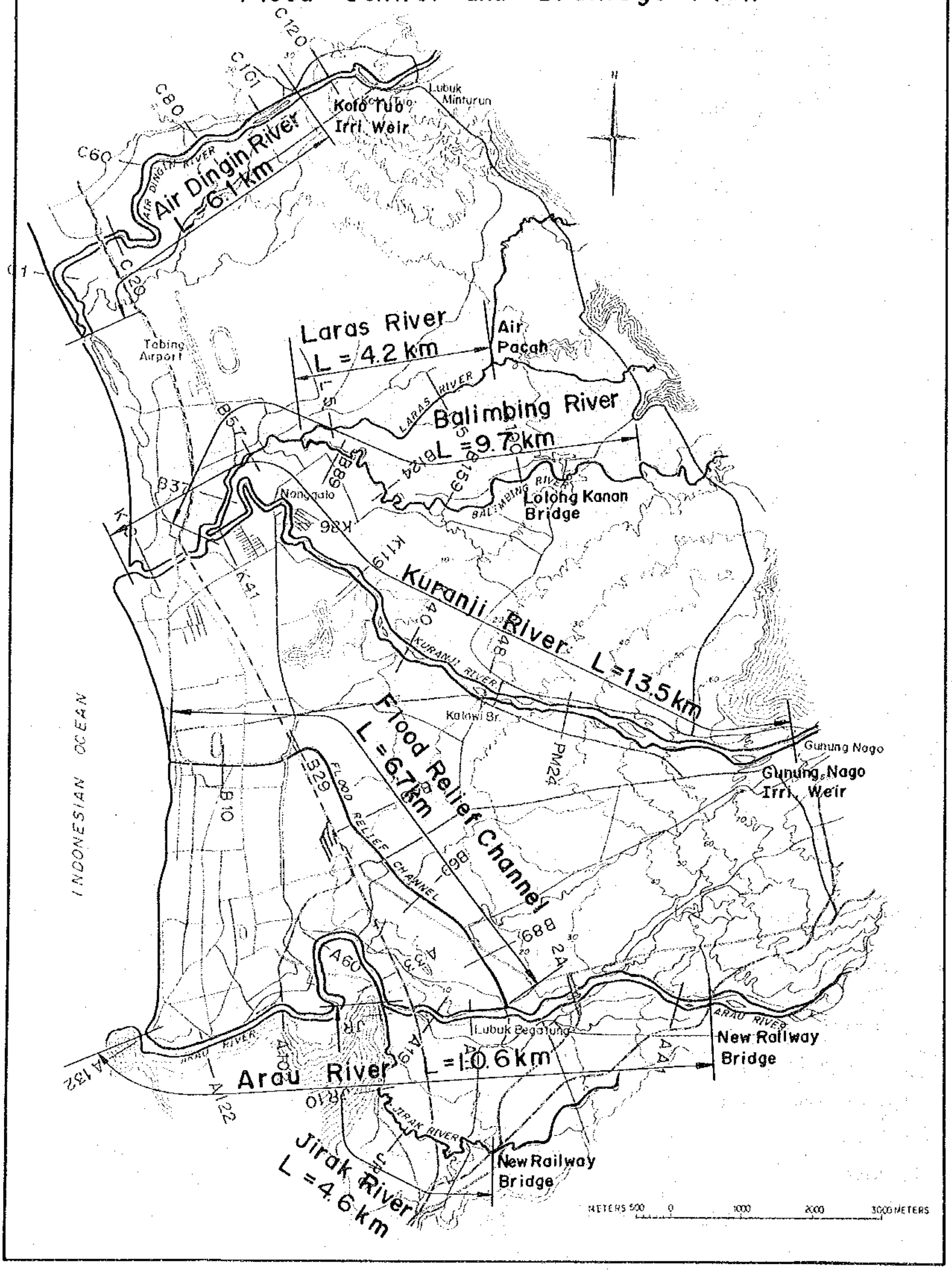


Fig. 5.2 Alternative Schemes for Comprehensive Flood Control and Drainage Plan

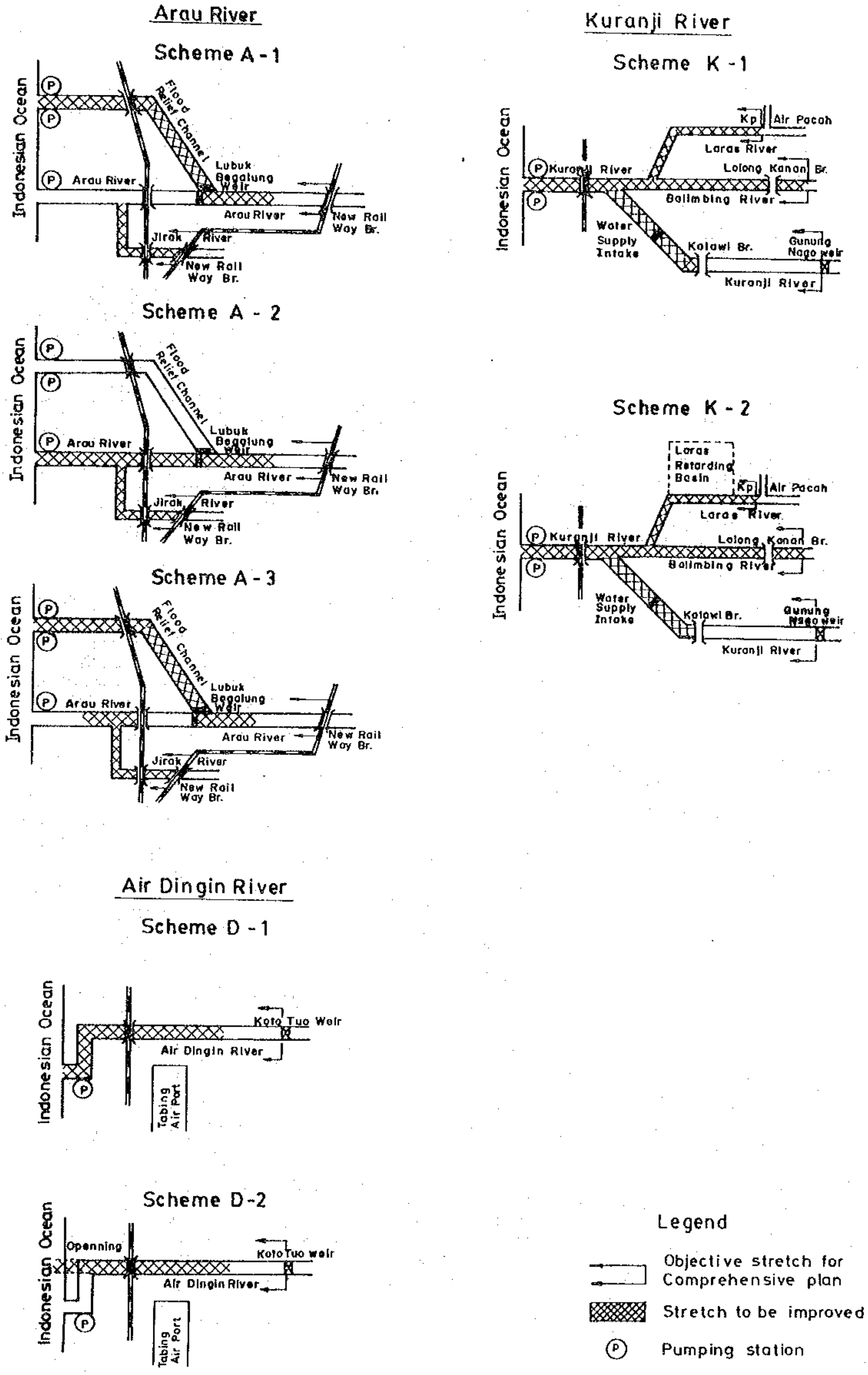


Fig. 5.3 Design Flood Discharge for Alternative Schemes

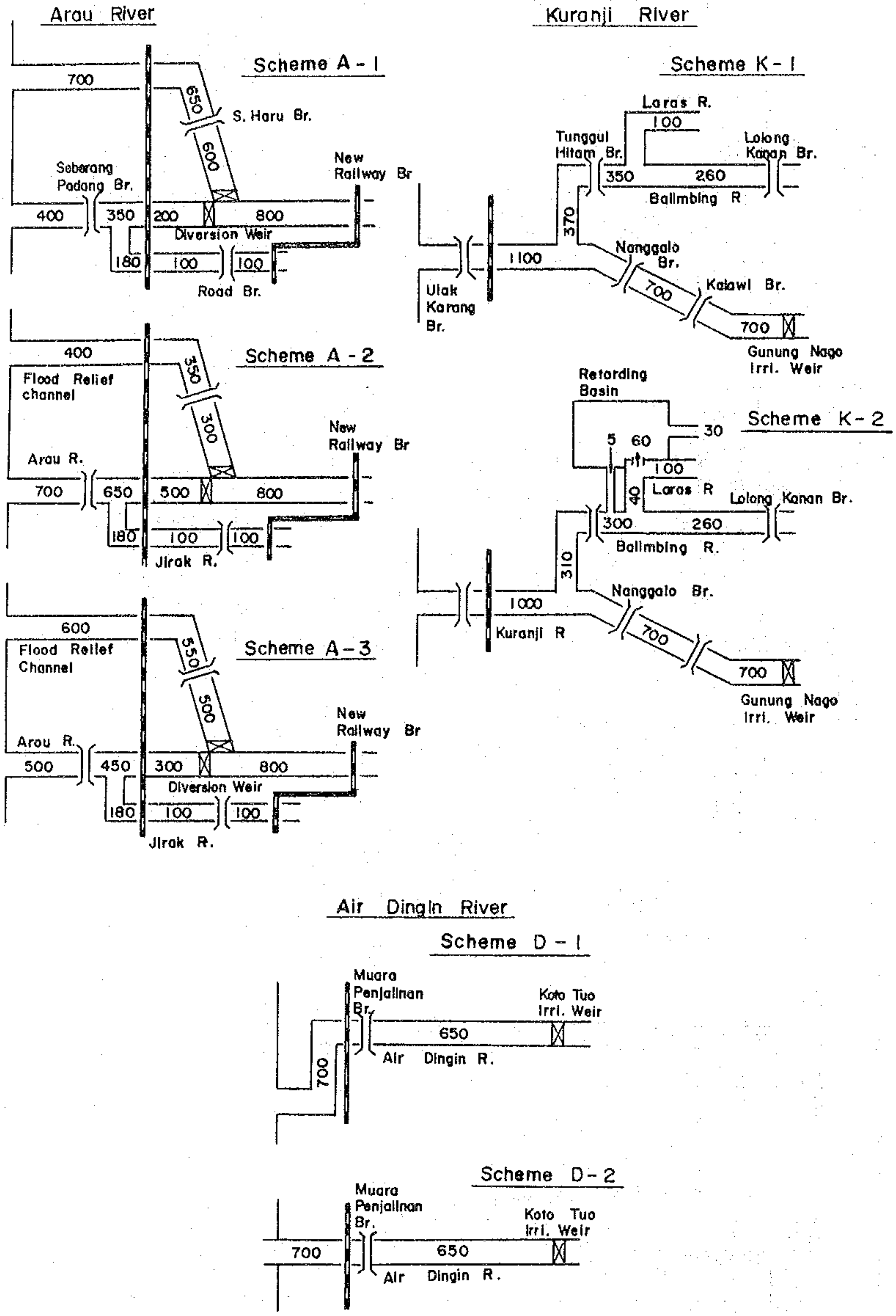


Fig. 5.4 Design Flood Discharge Distribution for Proposed Comprehensive Plan

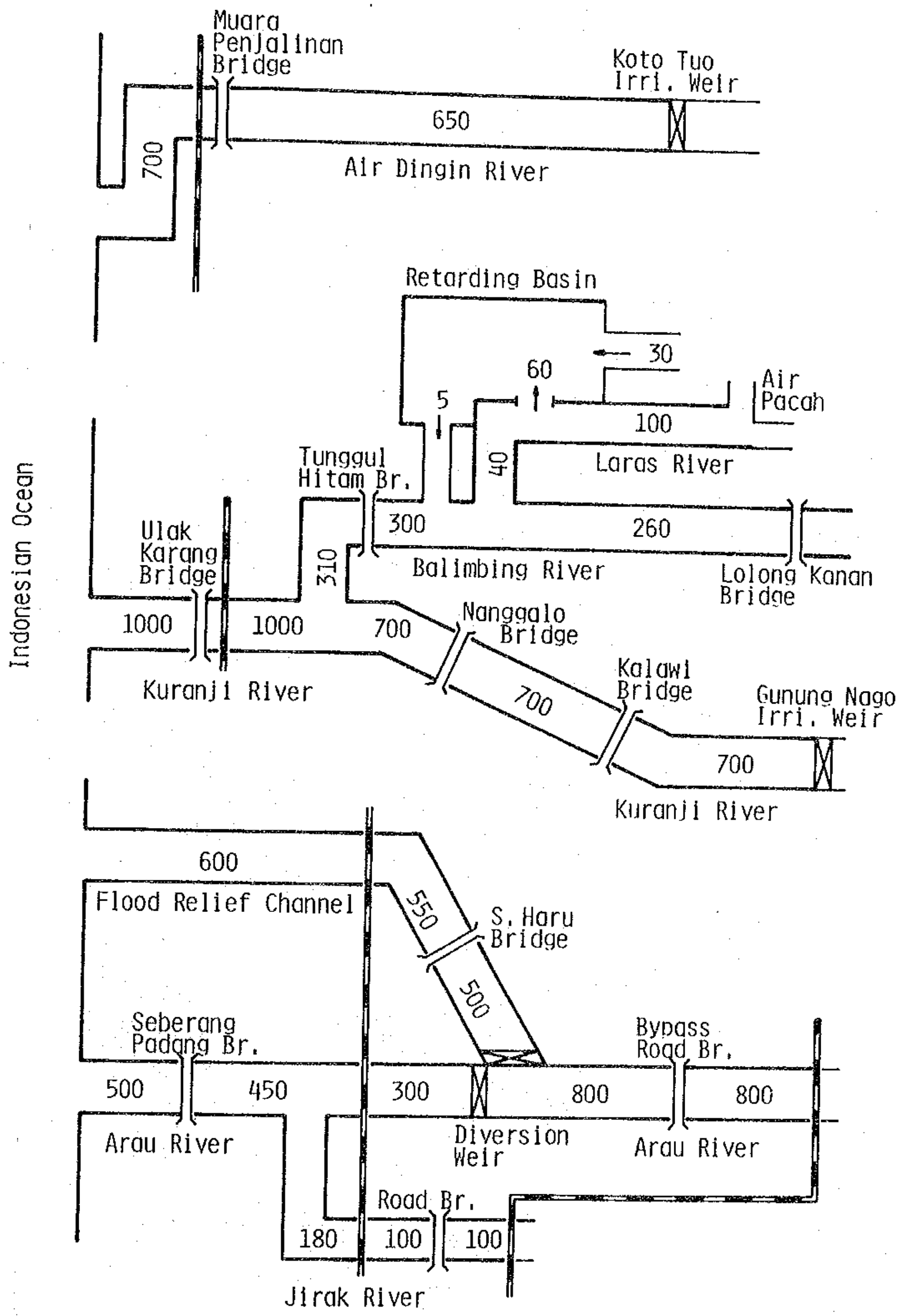


Fig. 5.5 Proposed Alignment of River Channel for Comprehensive Plan

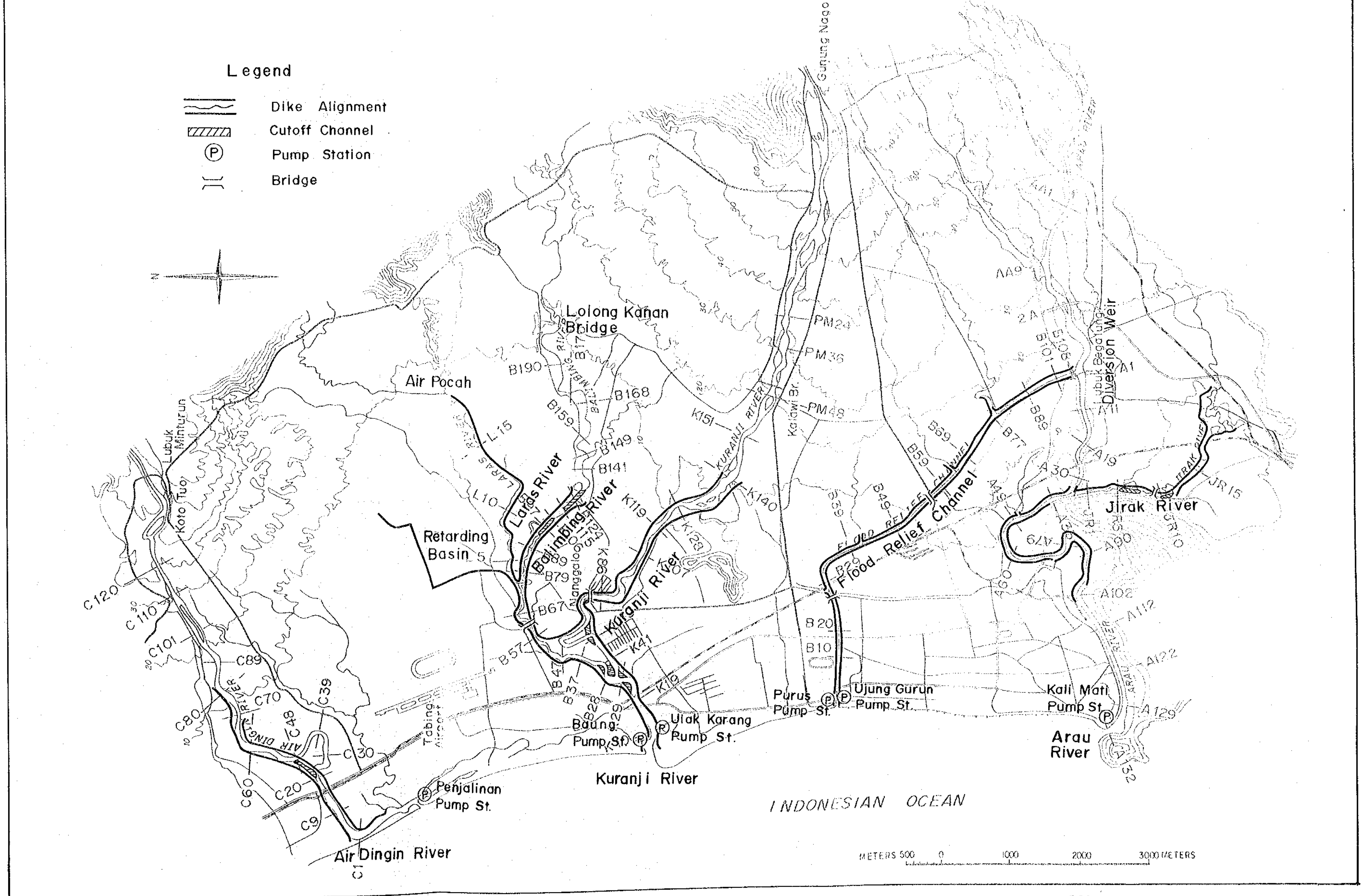


Fig. 5.6 Reconstruction of Lubuk Begalung Diversion Weir (Comprehensive Plan)

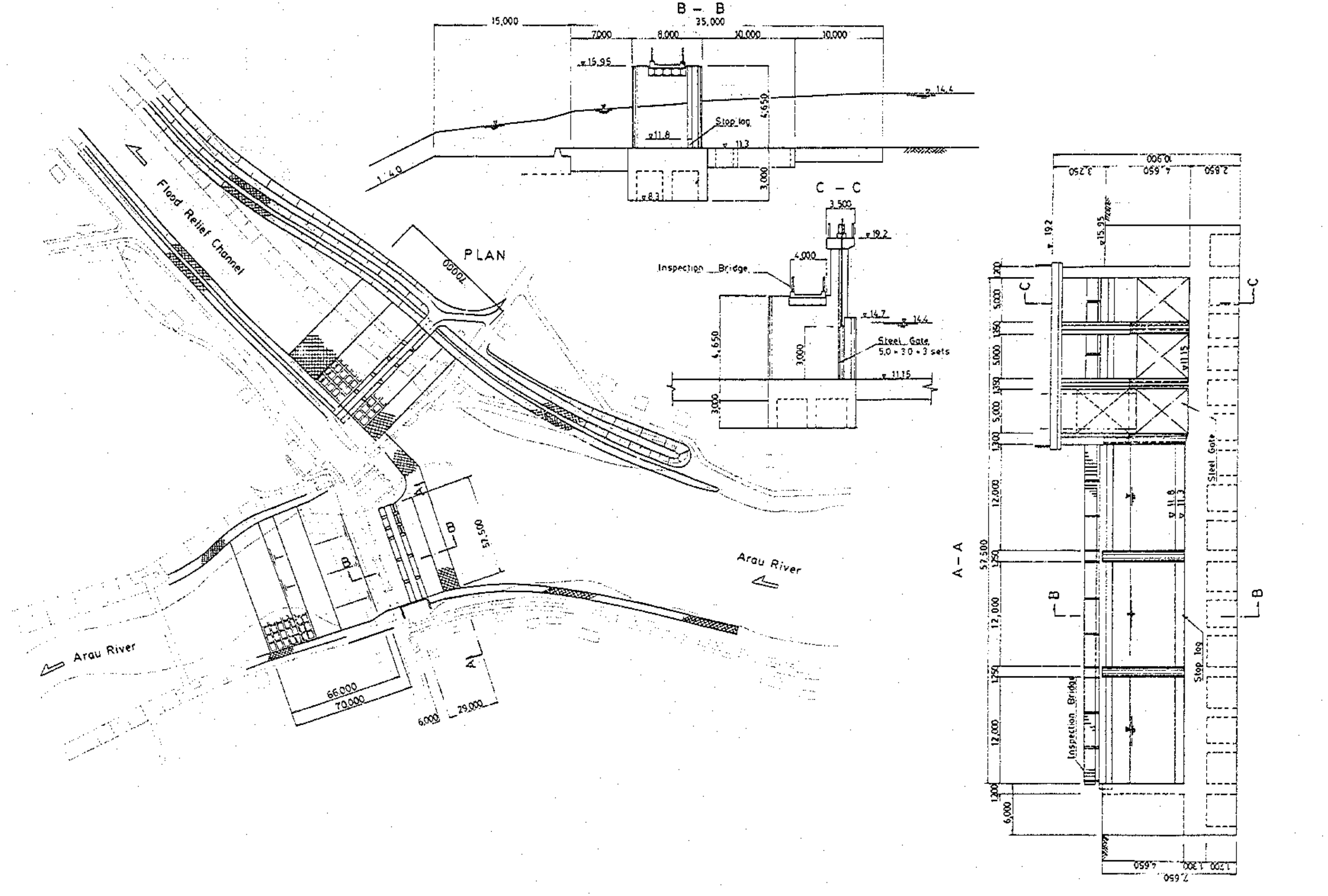


Fig. 6.1 Flood Discharge Distribution
for Urgent Flood Control Project

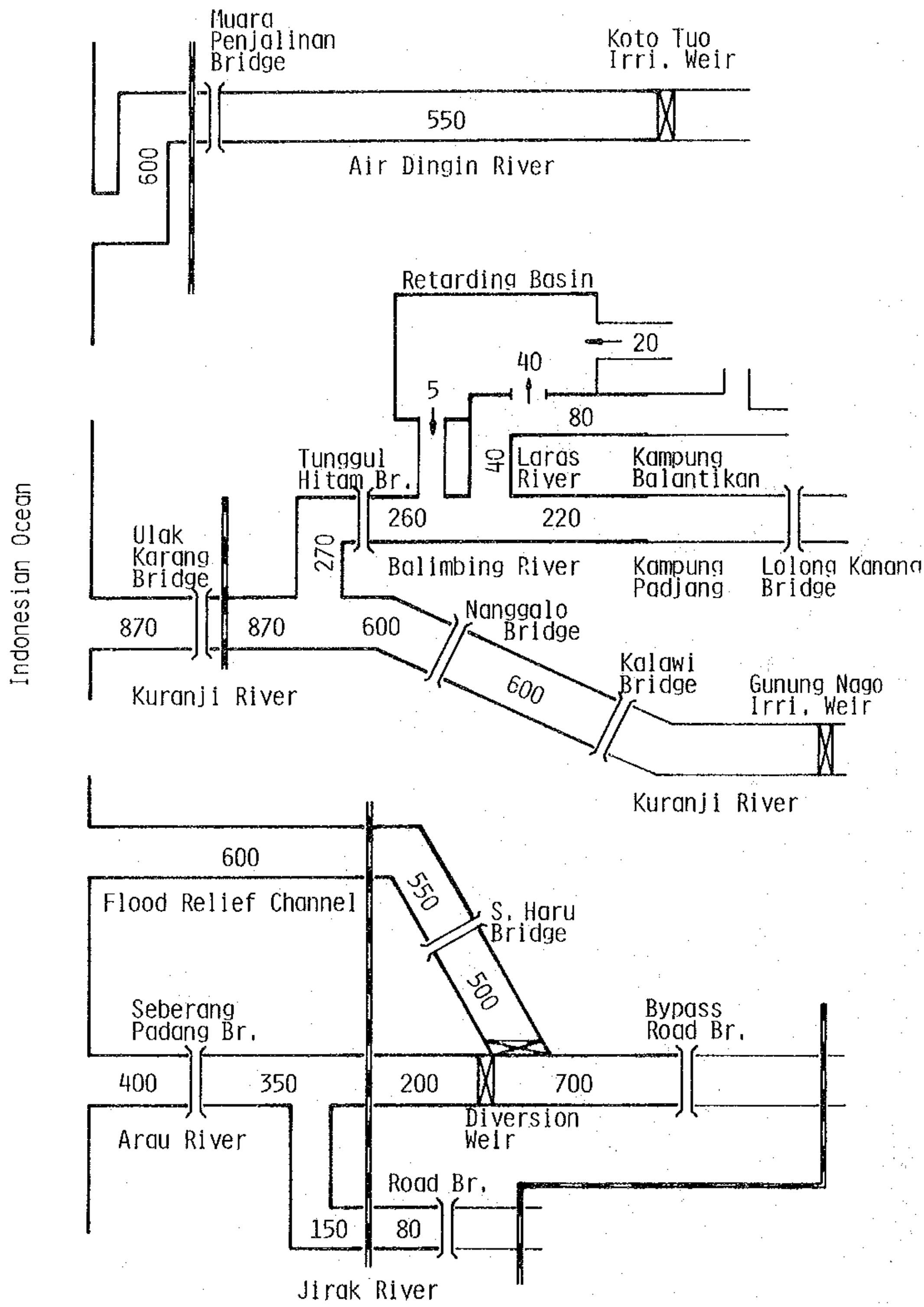


Fig. 6.2 Proposed Alignment of River Channel for Urgent Flood Control Project

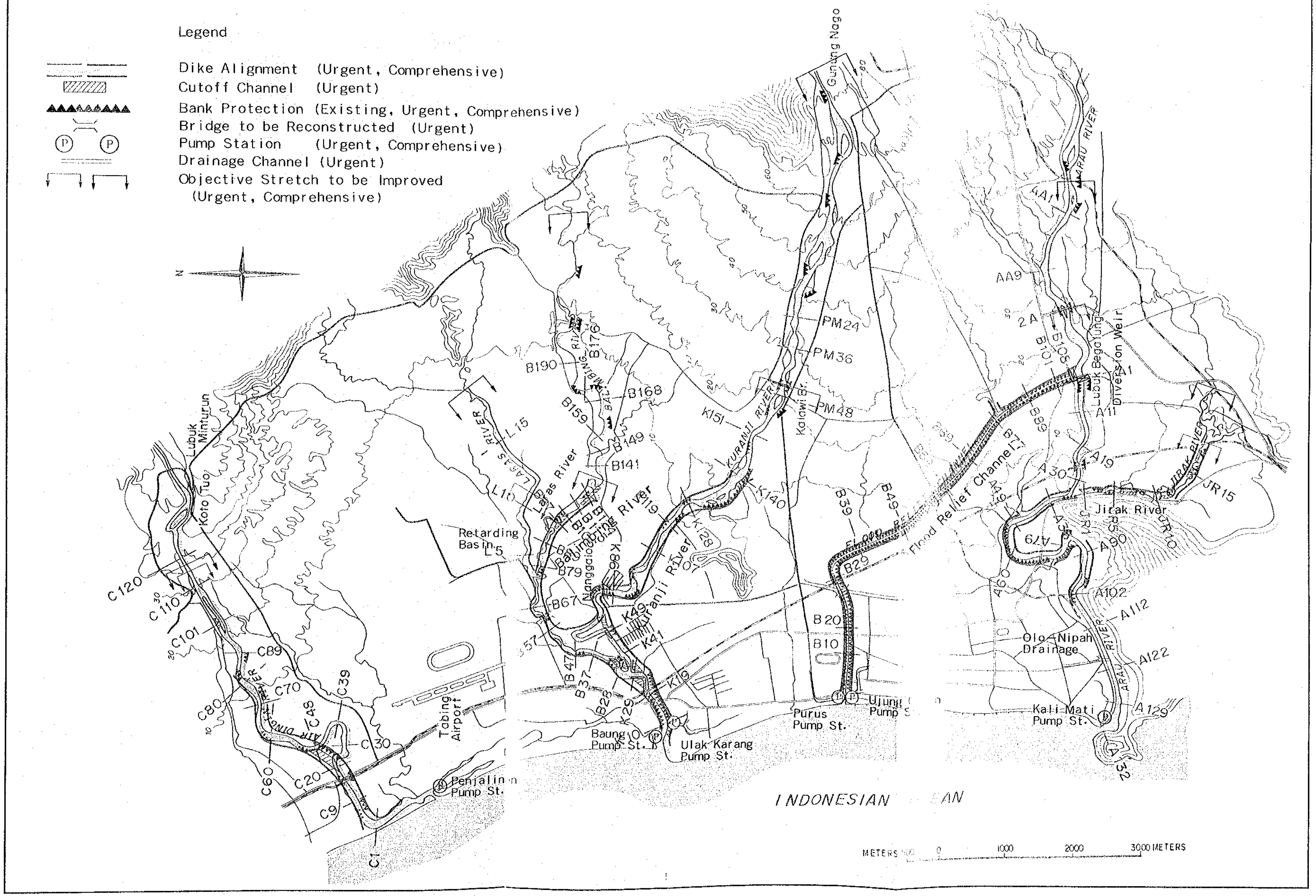


Fig. 6.3 Lubuk Begalung Weir to be Reconstructed by Urgent Flood Control Project

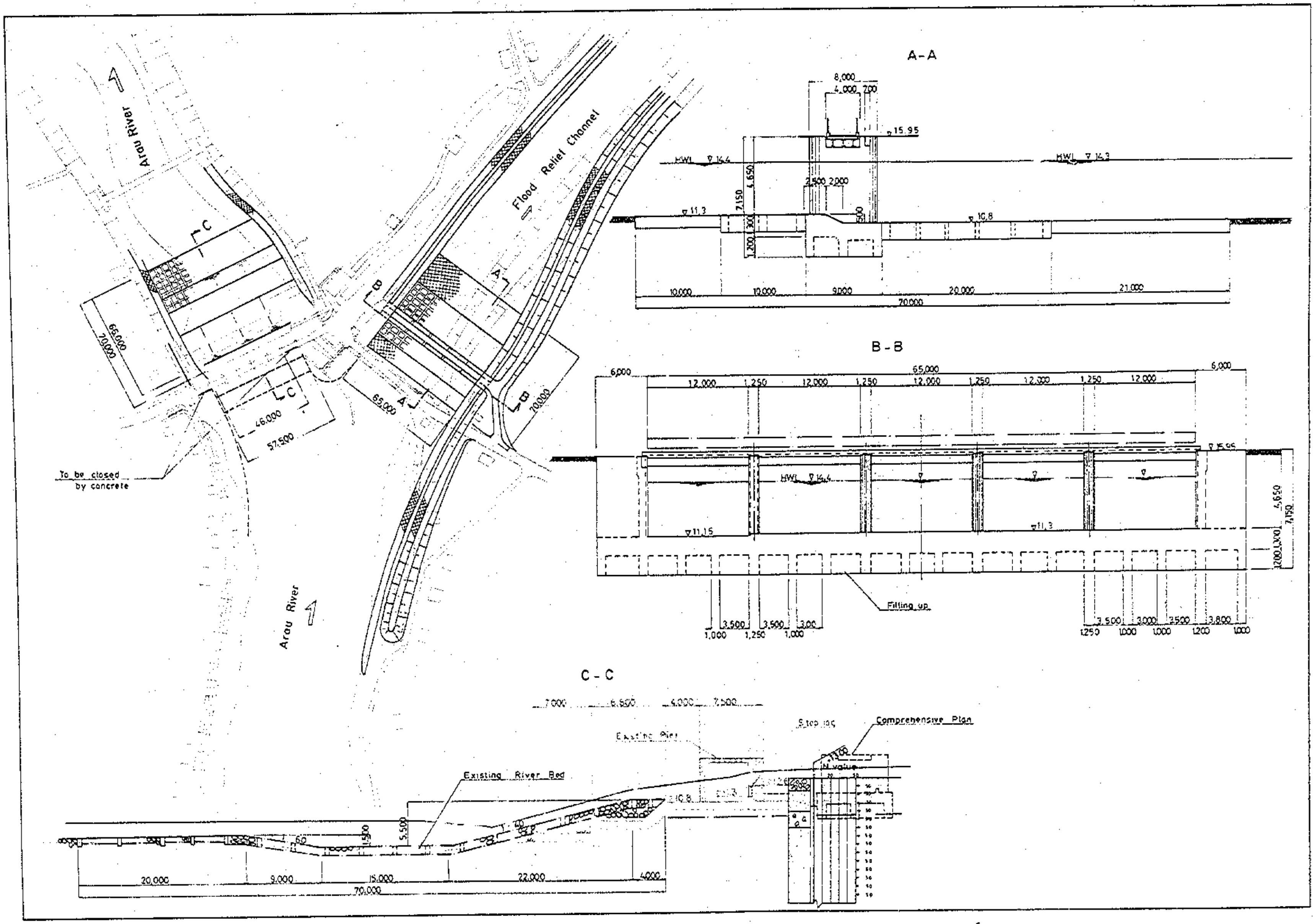


Fig. 6.4 Proposed Layout of Urban Drainage

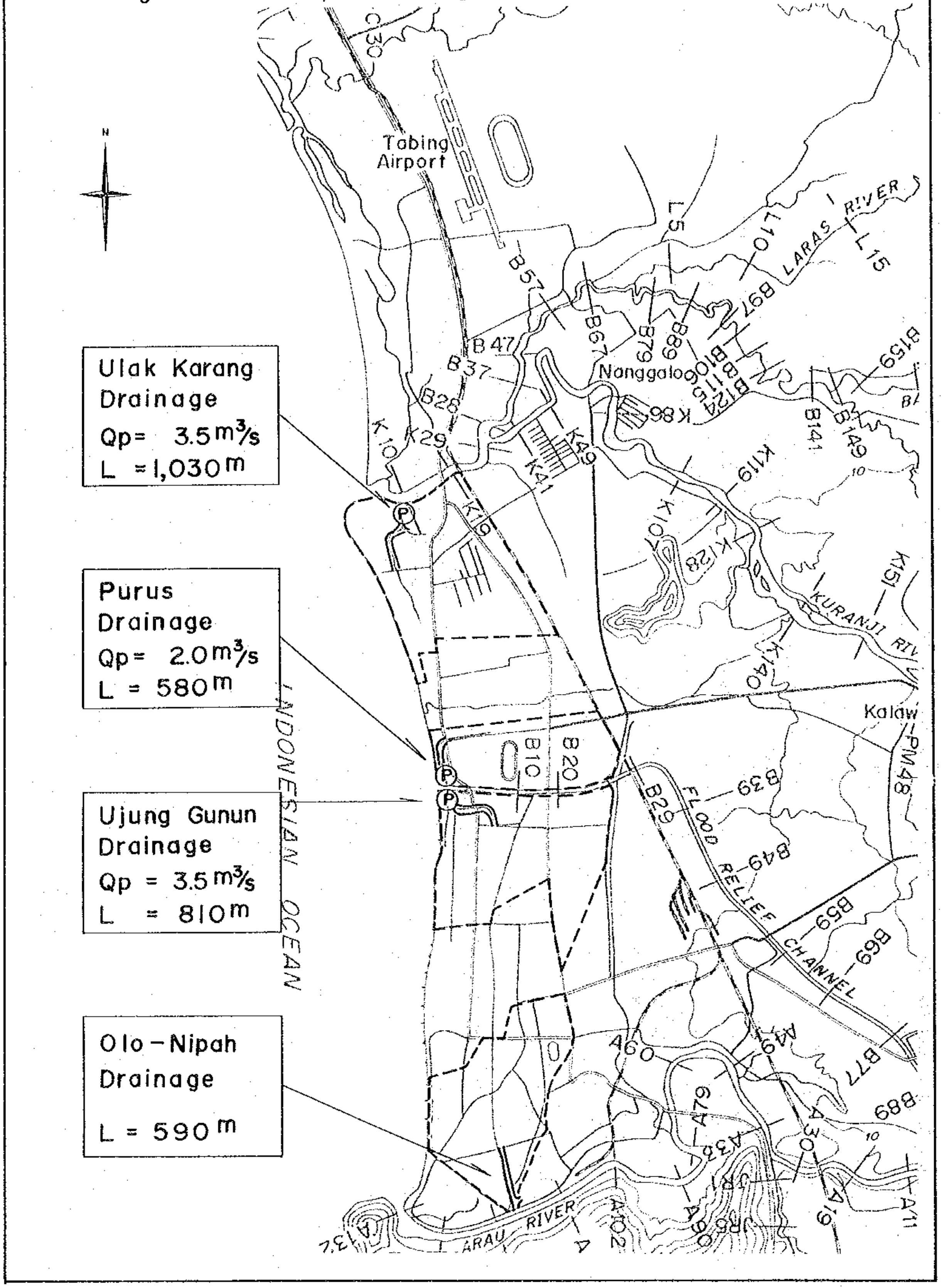


Fig. 7.1 Construction Time Schedule

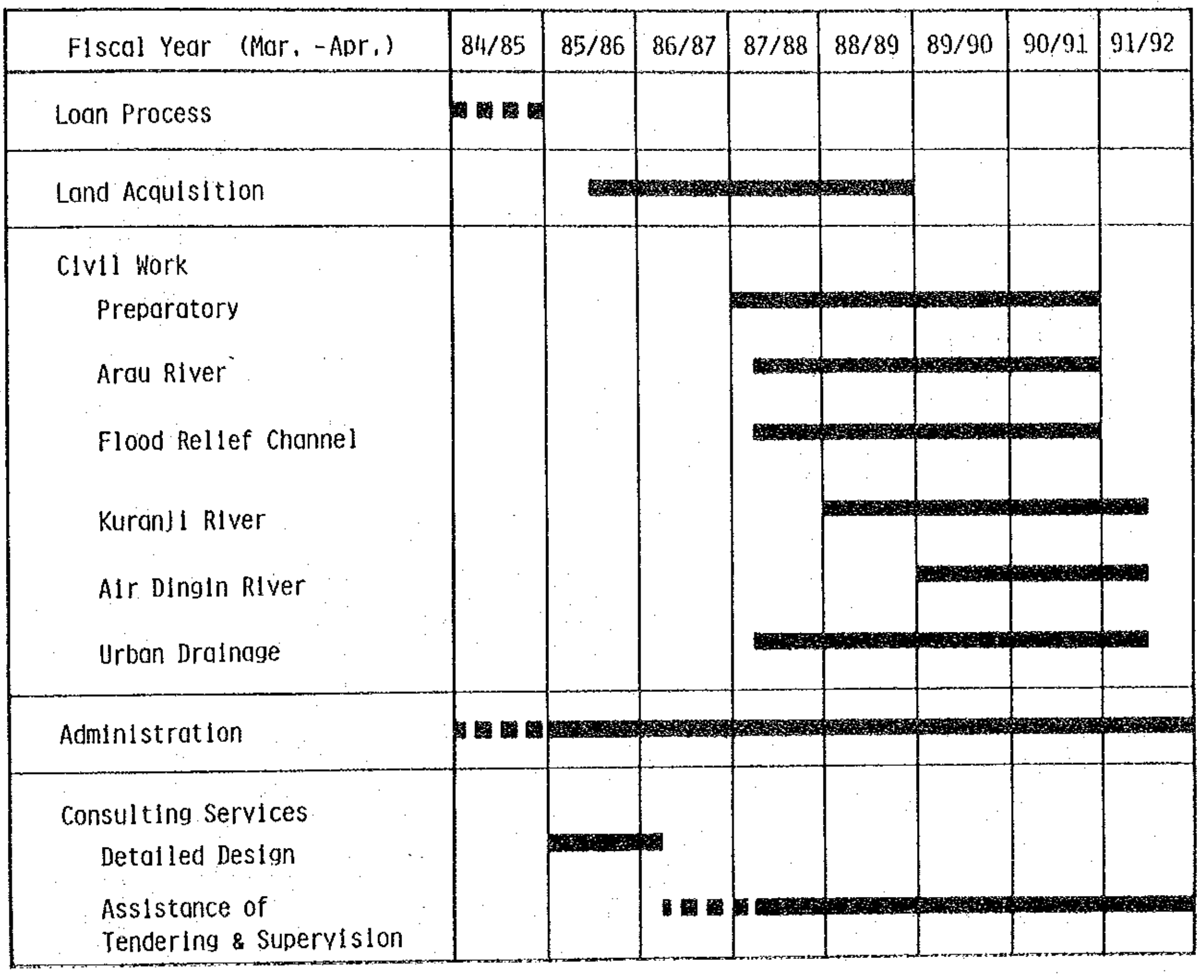


Fig. 8.1 Present Organization Chart for Flood Control Works

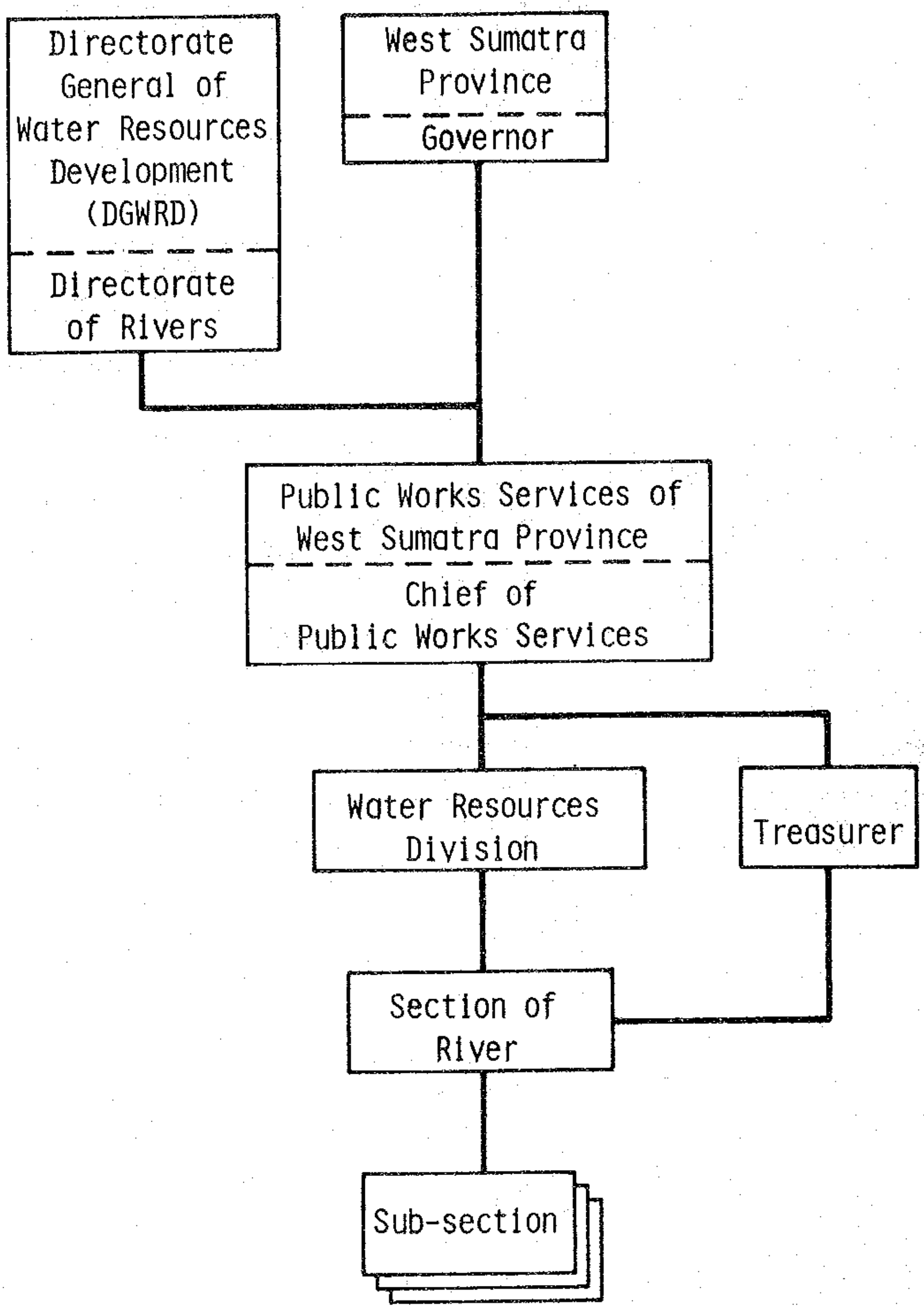


Fig. 8.2 Organization Chart for Implementation of the Project (Construction Stage)

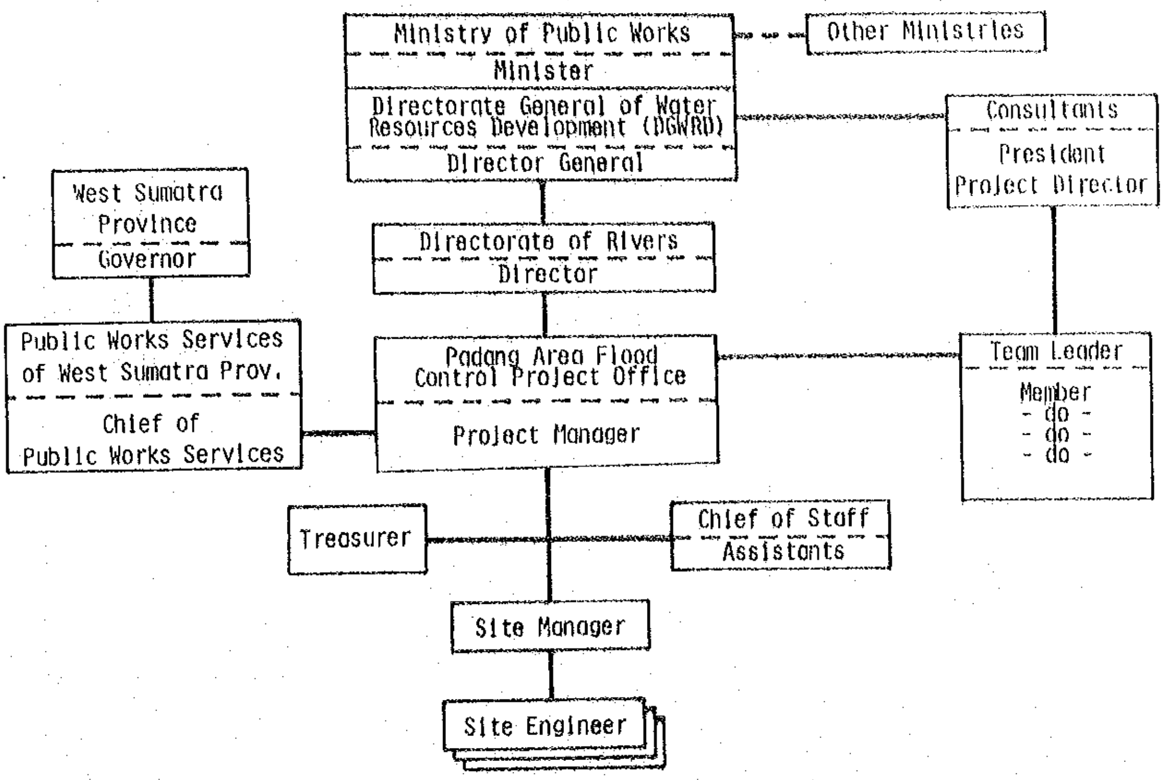


Fig. 8.3 Organization Chart for Administration, Operation and Maintenance after Completion of the Project (Operation & Maintenance Stage)

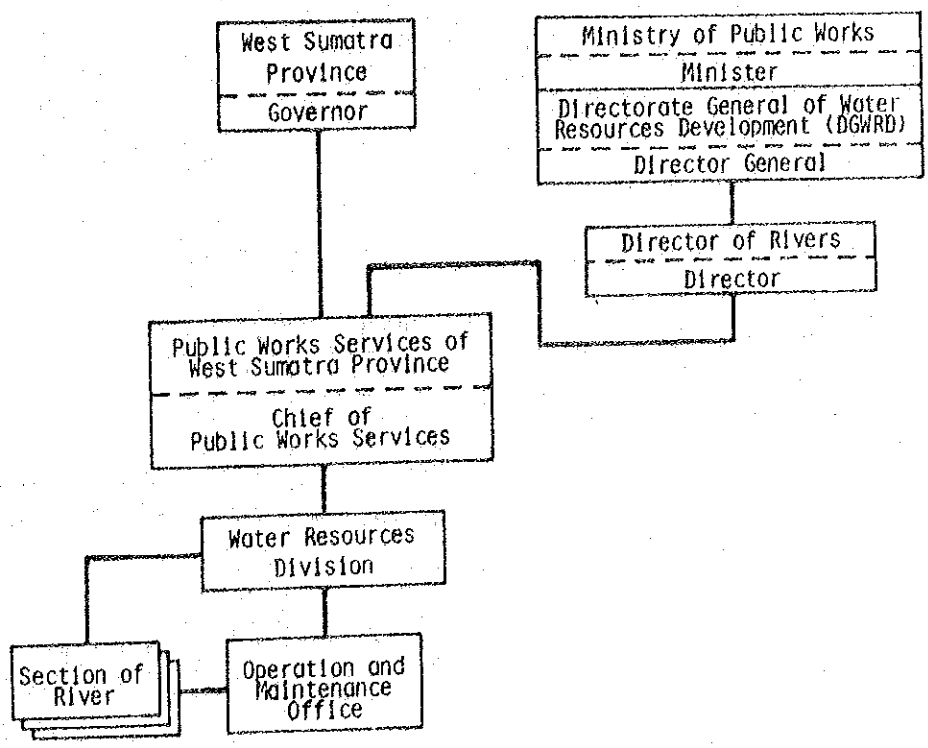


Fig. 9.1 Sensitivity of IRR of Urgent Flood Control Project

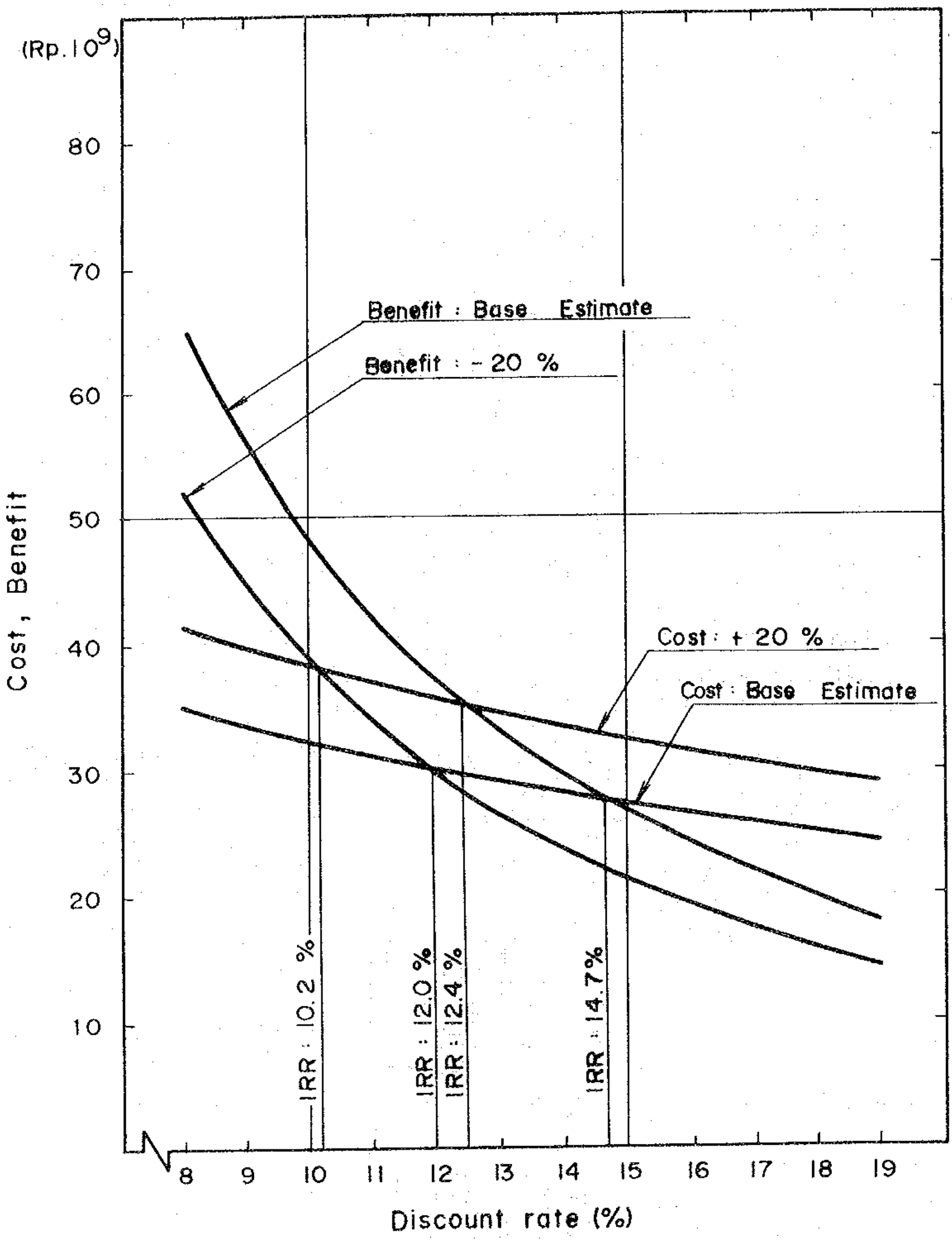
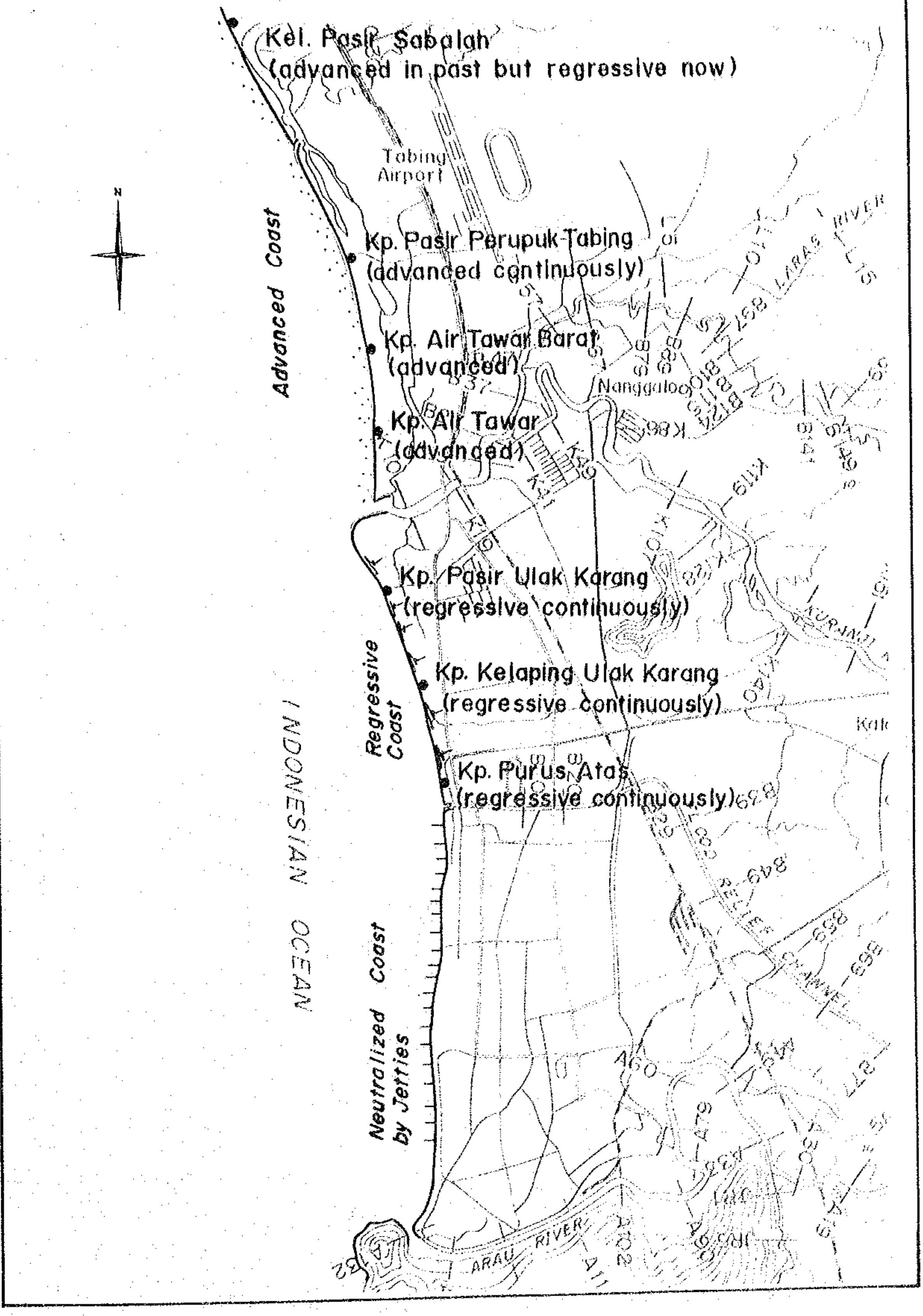


Fig. 10.1 Condition of Padang Coast



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A GEOMORPHOLOGICAL SURVEY MAP OF PADANG CITY AND SURROUNDING AREA IN WEST SUMATRA SHOWING CLASSIFICATION OF FLOOD STRICKEN AREAS

1983

ISSUED BY JAPAN INTERNATIONAL COOPERATION AGENCY,
TOKYO, JAPAN

A GEOMORPHOLOGICAL SURVEY MAP OF PADANG CITY AND SURROUNDING AREA IN WEST SUMATRA SHOWING CLASSIFICATION OF FLOOD STRICKEN AREAS

1. Necessity of Geomorphologic Land Classification in Development Plan of Area

When the development plan of the area is made, the planner must know the natural environments of the area in detail. The natural environments consists of geomorphology, climate, hydrology, etc. The relationships between geomorphology, hydrology and human activities are close. For example in mountainous regions, the topography was formed by the upheaval ground movement and changed its feature by erosional action caused by torrential rainfall, etc. The change of topography results in natural disasters for the people living there. The geomorphology shows the history of the natural disasters in the area in the past. If the plan is suitable for the natural development process of the topography, natural disasters will not occur; but if the plan is not suitable, natural disasters will occur.

2. A Geomorphological Survey Map of River Basins Showing Classification of Flood Stricken Areas

After World War II Japan was facing the twin problems of food shortage and flood hazards. The staple food of the Japanese is rice, which is mainly grown in the alluvial plains devastated by frequent floods caused by typhoons. Hence, the knowledge of the topography of the alluvial plains became necessary not only to increase rice yield but to minimize flood damage. Fortunately, the Japanese geographers took great interest in the study of alluvial plains which was greatly facilitated by the availability of aerial photographs. This gave birth to the geomorphological survey maps of the river basins which were not only used for controlling floods and erecting embankments but also for proposing land use, bridge sites, etc.

A geomorphological survey map of river basins enables us not only to estimate the nature and extent of past floods but to predict their future trends as well with regard to the extent of the area submerged, the length of time in which an area would be under water, depth of the standing water, direction of flood current, changes of the river course, possibility of erosion, deposition and numerous other details. The reasons why such a survey map helps in indicating the flood types are that the relief features of a plain and its sand and gravel deposits have been formed by repeated floods. Consequently, the micro-topography of the plain and its sand and gravel accumulation well preserve traces of past floods.

Geomorphological features such as terrace, valley plain, alluvial fan, natural levee, back-swamp, delta, etc., influence the extent and nature of flooding. For example on the alluvial fan erosion and deposition of sands and gravels are common, changes of river channel are frequent, flood waters drain off quickly, on the natural levee depositions are mostly of sand, flood waters drain off well; but in a back-swamp and delta the water is generally deep and remains stationary for a long time leaving a thick mantle of silt and clay.

This clearly exhibits that by classifying the geomorphological configuration of areas which subject to frequent flooding one can define not only the types of past floods but their future trends as well.

As has been mentioned above, theoretically, we can predict the state of flooding utilizing the Geomorphological Survey Map of the River Basin Showing the Classification of Flood

Stricken Areas. But the phenomena of the natural environment are complicated.

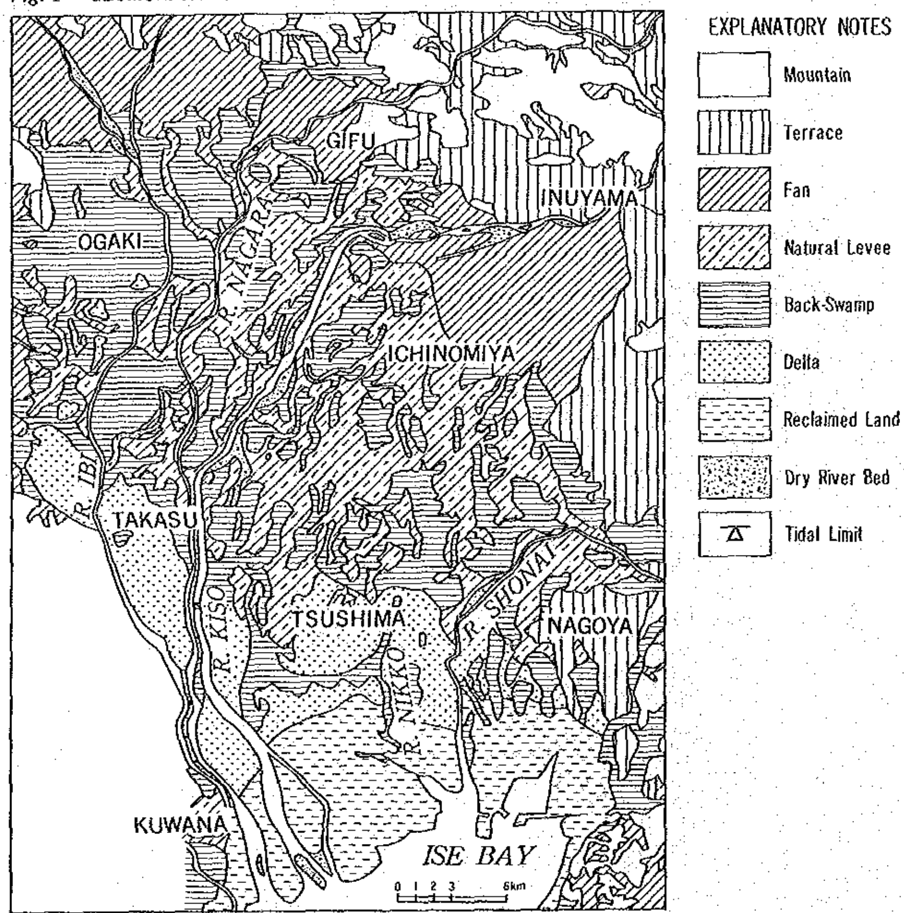
Incidentally, the Isewan Typhoon proved the accuracy of such a Geomorphological Survey Map of the River Basin Showing the Classification of Flood Stricken Areas. The southern part of the Nobi Plain (Nagoya City is located in the plain) was devastated by the high tide caused by the Isewan Typhoon, in 1959.

As a result of the disaster striking the city of Nagoya and its vicinity some 5200 persons were drowned and about 530,000 million yen (about $ 1.472.000.000) worth of property was lost.

The high tide attacked the area four years after the preparation of "A Geomorphological Survey Map". Then the high tide proved to be a test of such maps on the largest scale and of the greatest value. It was found that actual flooding was almost exactly the same as predicted in the map with respect to the area of submersion and depth and duration of inundation.

Fig. 1 shows the Geomorphological Survey Map of the Kiso River Basin (Nobi Plain). There are fans formed by the Kiso, Nagara and Ibi Rivers in the northern part of the Nobi Plain. We see three or four distinct natural levees from the fan to the city of Nagoya and Tsushima. These natural levees show the ancient main course and branch courses of the

Fig. 1 GEOMORPHOLOGICAL LAND CLASSIFICATION MAP OF THE NOBI PLAIN



by M. OYA(1957)

Kiso River before the 15th century. Back-swamps occupy the spaces between natural levees.

We see the delta from the natural levee to the south, the reclaimed land constructed since the 16th century along the coast of Ise Bay and the artificial fields filled in along the circumference of Nagoya Port. The ground level of the delta is almost in accord with sea level, and the area of ground in the Nobi Plain below sea level covered 185,4Km^2 in 1959.

We could notice the close relationship between the high tide and topography in many cases. Especially, the area of inundation was just the same as the area of the delta. The extremity of the influx was seen at the boundary of the delta, i,e, the line connecting the city of Nagoya with Tsushima.

The routes of high tide and flood-type were decided by the land-forms. The forecast of the state of flooding in the alluvial plain was possible on the basins of the relationship between the high tide caused by the Ise Bay Typhoon and land-forms in the Nobi Plain.

After preparation of the Geomorphological Survey Map of the Nobi Plain Showing the Classification of Flood Stricken Areas, not only of many important plains in Japan but also of the Vientiane Plain along the Mekong River and the Branmaputra-Jamuna, Ganges Plain in Bangladesh were also provided respectively.

3. A Geomorphological Survey Map of Padang City and the Surrounding Area in West Sumatra Showing Classification of Flood Stricken Areas

The writer (Dr. Masahiko OYA) participated in the study team on the flood control works of the Padang Area Flood Control Project organized by the Japan International Cooperation Agency. He subsequently made the geomorphological Survey Map Showing Classification of Flood Stricken Areas in the city of Padang, which is located in West Sumatra.

(Method)

Before preparing the geomorphological map, the writer made a topographic base map on a scale of 1:20,000 utilizing a map on a scale of 1:5,000.

In preparing the geomorphological map, the target area was first classified by major geomorphological elements such as steep slopes and gentle slopes on the mountains, pyroclastic flow, fan, alluvial fan, natural levee, back-swamp, sand-spits, abandoned river channels, coral reef and dry river bed utilizing aerial photographs.

It is convenient to use a photographic scale which is slightly larger than that of the projected map.

At this time the writer used photographs whose scale was 1:15,000. The initial map thus prepared was put into final form checking the results of field surveys of the area.

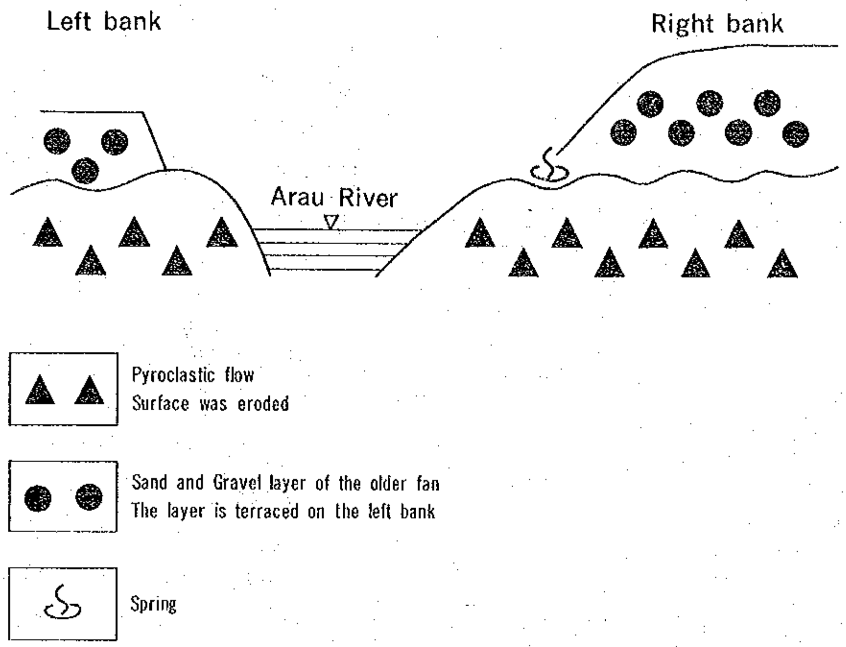
(Description of the geomorphological elements)

The area of the *mountains and hills* in the map is small. The mountains and hills consist of convex on the mountain ridge, concave slopes and gentle slopes on the mountain flanks, and steep slopes.

There are many steep slopes in the mountains along the Air Dingin River, but there are few land collapses. Almost all the mountains are covered by dense secondary forests.

The fluvial fan is remarkably well developed along the Kuranji River. Small fluvial fans are developed along the lower reaches of the Air Dingin River and middle reaches of the Arau River but none in the lower reaches.

Fig. 2 SKETCH OF THE OUTCROP NEAR KABOEN ALONG THE ARAU RIVER



The east most part of the fan of the Kuranji River is limited by the Arau River. The sketch of the outcrop (Fig. 2) shows the upper red soil layer, the brown sand and gravel layer and the reddish pyroclastic flow layer from the surface to the river bed. The Arau River and its tributary have dissected these three layers. And around the apex of the fan, ground water is located about 7 to 10m below the surface of the ground. Based on observation at the outcrop and the state of the ground water the writer estimated that the depth of the sand and gravel layer of the fan is shallow, about 5 to 10m.

The geomorphology of the fan consists of three geomorphological elements, i,e, 1) fan 2) slightly hilly area 3) alluvial fan and 4) narrow and long dissected valley.

Many slightly hilly areas are distributed radiately. And almost all villages on the fan are located in the area. The writer estimated that the slightly hilly area is natural levee on the fan or a remenant of the older fluvial fan. The area is free from flooding. The fan is dissected by the stream especially in the upper part of the fan.

The fan of the Arau River is small. The fan is developed in the upper reaches from the small canyon at Barupuiauan but none is developed in the lower reachs.

In the case of the Air Dingin River, the older fan is covered by pyroclastic flow. The alluvial fan is developed from the older fan to the coastal sand spits.

Pyroclastic Flow is well developed along the Air Dingin River especially on the right bank. The pyroclastic flow has the shape of the fan. The pyroclastic flow is dissected by long and narrow valley.

Another pyroclastic flow is seen on the river bottom and on both banks along the Air Dingin River and Arau River.

Terrace is developed along the Air Dingin River. The writer estimated that the pyroclastic flow and older fan were eroded and terraced.

Natural Levee means the slightly hilly area along the river course consisting of sand which was deposited in flood times.

There are several natural levees between the lower edges of the fluvial fans and the coastal sand spits. But these natural levees are small.

Back-swamp or delta is developed between the coastal sand spits and the lower edges of the fan. A big swampy area is located between the sand spits near the airport and the lower edge of the pyroclastic flow and the natural levee along the Laras River. The surface of the ground is covered with shrub and grass. The vegetation is universally seen in the peaty area. But the results of the boring test to a depth of about 3m, shows that almost all parts consist of soft reddish soil including the remains of vegetation and sometimes sand. (Fig. 3). The writer estimated that the vegetation disintegrated due to the high temperature and a lot of rainfall.

Back-swamps between sand spits (Interbarnal slough) are located along the coast. The drainage in the area is bad because sand-spits are developed along the sea-coast. The back-swamps located along the Baung River are the biggest. But recently the drainage has slightly improved due to river improvement.

Coral Reefs are developed at the river mouth of the Kuranji River. This is not alive but dead coral reef. Except along the sea-shore, the surface is covered by sand.

4. Geomorphological Development of the Padang Plain

Fig. 4 is a model of a geomorphological cross-section of the Padang Plain from the apex of the Kuranji River to the sea-coast.

Pyroclastic flows came down to the Padang Plain due to big volcanic eruptions, and formed the base of the fan of the Kuranji. Pyroclastic flows are seen at several places in the fan, for example, at Barupuiauan along the Arau River and or Kalawi along the Kuranji River.

Later, the pyroclastic flow was covered by sand and gravel layers about 5 to 10m thick and formed the fan. The formation age of the fan is not yet decided, but the age is estimated as the Würm Ice Age. At that time the sea water level was about 100m (about 18,000 years B.P.) lowered than that at present due to glacial eustasy.

Due to the change of climate 4000 to 6000 years B.P. the sea water level rose and reached 4 to 6m higher than that at present. The lower part of the fan was covered by marine deposits.

After that sand spits were formed. The line of sand spits increased along the sea side because of the lowering of the sea water level. Lagoons were formed at the inland side of the sand spits. During this time, coral reefs developed. At that time there was no river mouth of Kuranji at the present place.

The sand spits were cut by the Kuranji River partly because of the lowering of the sea water level and partly because of the horizontal crustal movement. The writer recognized that along the horizontal fault line near the river mouth of the Kuranji. Due to the crustal movement the Kuranji River formed the new channel at the present place and the coral reefs were killed by muddy water. The writer could see that the quality of the coral reef was changed by muddy river water.

New pyroclastic flow down along the Air Dingin River.

The fan and the pyroclastic flows have been eroded, and a new alluvial fan has been formed.

Fig. 3 GEOLOGICAL RECORD OF BORE HOLE IN THE BACK-SWAMP IS LOCATED AT THE NORTHERN PART OF AIRPORT

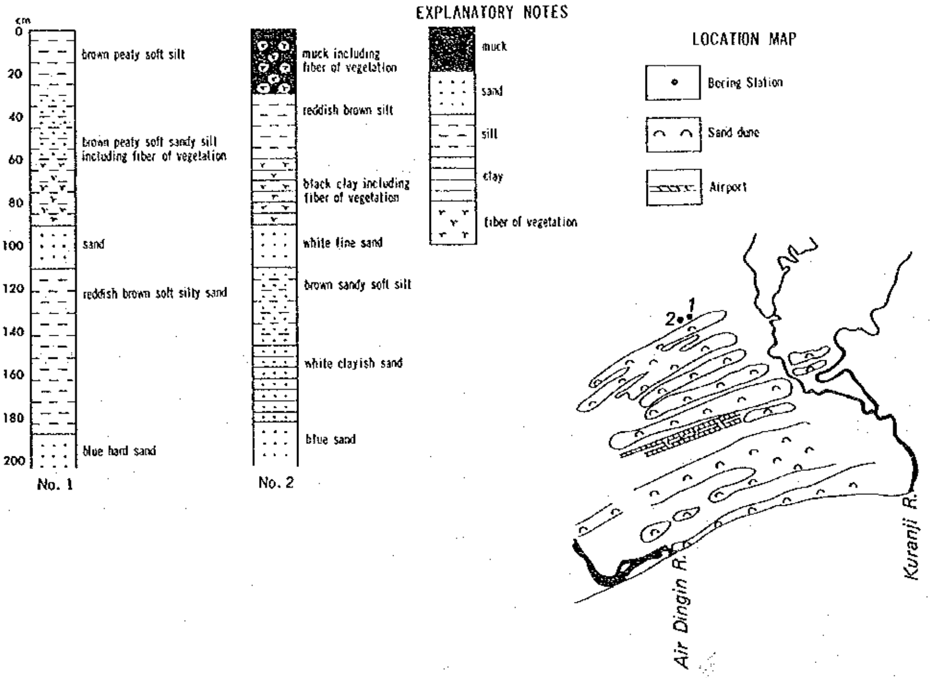
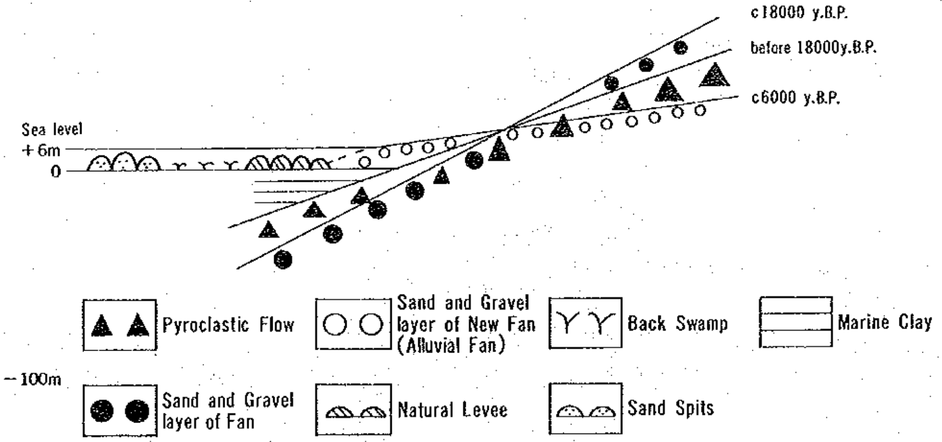


Fig. 4 GEOMORPHOLOGICAL CHANGE BETWEEN THE APEX OF THE KURANJI RIVER TO THE COAST



There is no fan along the left bank of the Arau River. The area of deposition by the Arau River is limited by big deposition of the Kuranji River. The small canyon with knick-points along the Arau River was formed by the deposition of the Kuranji River.

The features of the fluvial action of the three rivers will be discussed in the next chapter.

5. Comparative Study of the Fluvial Action of the Three Rivers —Arau, Kuranji and Air Dingin

There are distinct regional differences in the fluvial action of the three rivers of the Arau, Kuranji and Air Dingin.

Due to the push of the fan of the Kuranji River, the Arau River was narrowed near Barupiauan. There are several knick-points in the canyon. At these points stream flow is rapids (Fig. 5). There are big differences in fluvial action between the upper reaches and the lower reaches of the knick-points. The maximum diameter of the largest gravel is 85cm with a roundness of 6 in the upper part of the canyon, while the gravel becomes bigger in the canyon, about 210cm, and angular with a roundness of 5 (Fig. 6).

The river bed in the upper reaches of the canyon consists of andesite and granitic gravel. The ratio of the two species is 10:1. But there is no granitic gravel in the lower reaches. There is no granitic rock in the upper reaches of the Kuranji River. Furthermore, the river course of the upper reaches shows a braided stream. When we have a flood the flood waters overflow from the mainstream to the adjacent areas. The above mentioned facts show that the deposition of the upper reaches of the knick-points is big, but a considerable part of the sand and gravel is stopped by the knick-point in the canyon, and only smaller gravel is allowed to flow down via the knick-point. At the canyon big gravel is poured from both banks and stirred up from the river bed. Then the maximum diameter of the largest gravel is increased. But the volume of sand and gravel which flows down to the lower reaches is small (Fig. 7)

A topographic cross-section of the lower reach shows that the nearer to the river the land is, the lower it becomes. When we have a flood, flood water concentrates in the surrounding area to the mainstream. From a fluvial geomorphologic view point, in the case of the lower reaches of the Arau River, the state of flooding is moderate and deposition is the smallest among the three rivers. Therefore the location of Padang City is good.

In the case of the fan of the Kuranji River, there are many slightly hilly areas and many villages. The area is estimated as the natural levee on the fan or remenant of the fan, and the area is free from flooding. The fan of the Kuranji River is dissected especially in the upper part not only by the mainstream of the Kuranji but also by small streams on the fan. Furthermore, the lowering of river bed due to the existance of the Gunung Nago Weir and also excavation of the sand and gravel for construction work is recognized.

There are several streams on the fan. A small deposition is seen at the confluence point with the Flood Relief Channel. The volume of the sand and gravel which is transported by the small streams is small, because the sand and gravel is not transported from the upper reaches of the Kuranji River but from the fan.

In the case of the Air Dingin River, the erosion of the pyroclastic flow terrace and the fan is vivid. Due to the sand and gravel produced by erosion, a new alluvial fan has been formed between the pyroclastic flow and the sand-spits. A shifting of the river course is frequent in the alluvial fan.

Fig. 5 SKETCH OF THE KNICK-POINT AT BARUPIAUAN, ARAU RIVER

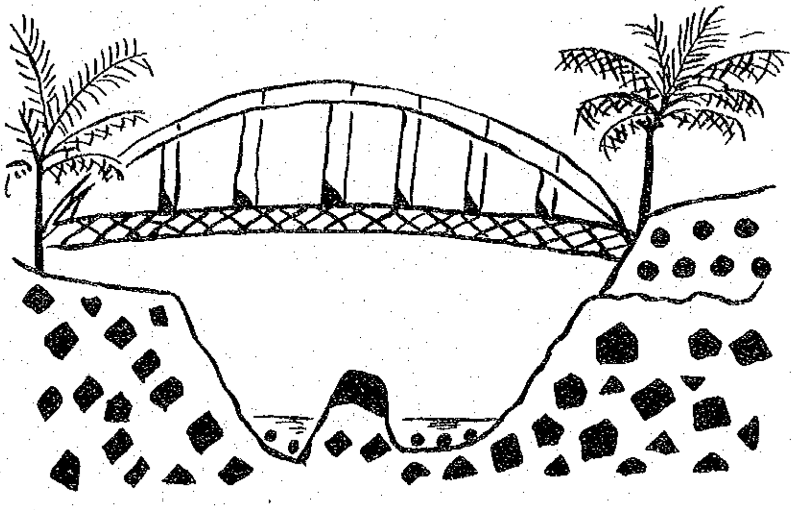
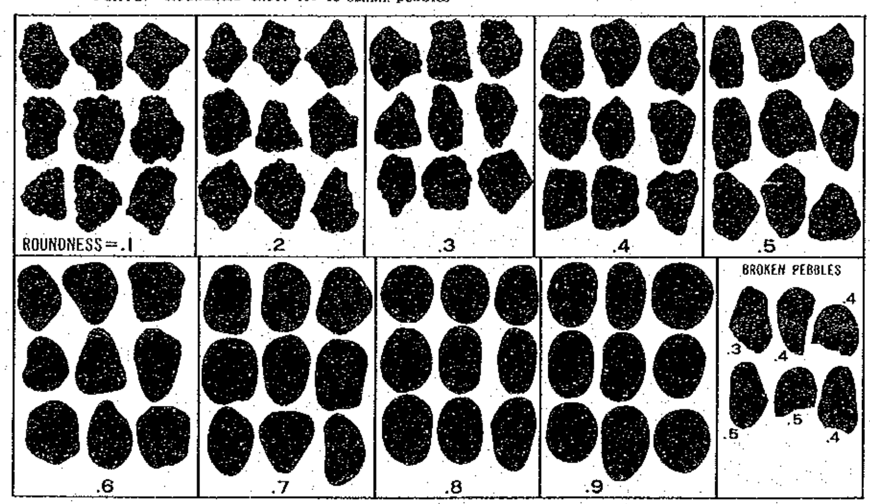


Fig. 6 PEBBLE IMAGES FOR VISUAL ROUNDNESS

PLATE: —Roundness chart for 16-32mm. pebbles

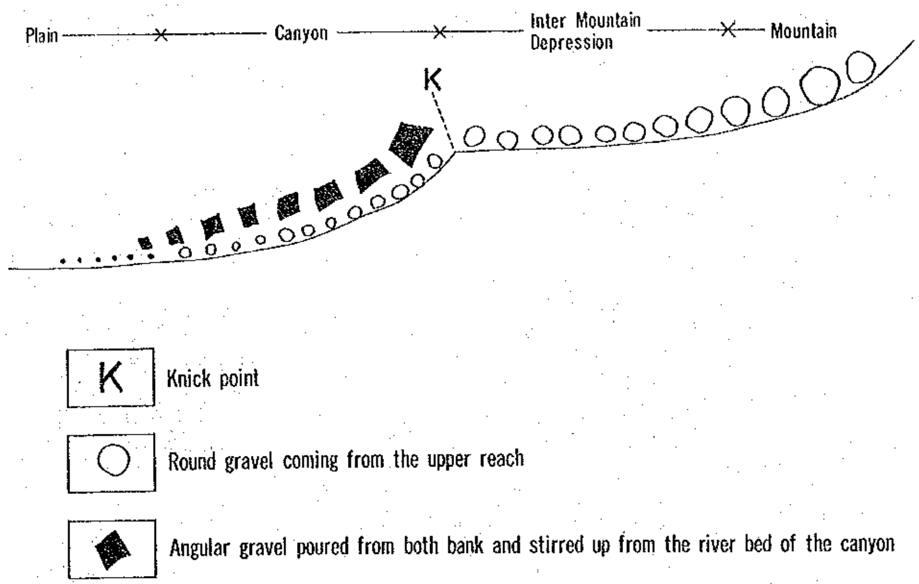


by Krumbein

6. Geomorphological Features of the Coast

Generally speaking, the coast line of the Padang Plain shows a straight line. But the left bank of the Arau River juts out about 500m, and the left bank of the Kuranji River also juts out about 300m into the open sea as a small cape. The former consists of hard rock and the latter, coral reef. Other parts of the coast line are straight or slightly curved and consists of sand.

Fig. 7 KNICK POINT AND CHANGE OF THE GRAVEL



Division of the Coast

The coastline is divided into several parts morphologically.

1) Arau River – Flood Relief Channel

The Area is surrounded by coastal embankments, and there are more than 30 jetties. They have been constructed since 1969. People living there said that the coastal line has retreated about 25m since 1969 to the present. Small depositions are seen at the southern part of each jetty.

2) Flood Relief Channel

There are several concrete blocks which were used for jetties in former days between the Flood Relief Channel and the Lolong River. The coast line is estimated to have retreated about 10m downward since 1940 from the location of the concrete blocks according to the story of the people living there.

The coast consists of sand almost entirely, but sometimes small gravel is seen. The gravel is not as flat as that seen in the coast generally but round. The gravel is andesite. This shows that the gravel was transported from the Kuranji River.

The slope of the coast is steep and, the height of the waves looks high. People living there said that high waves overflow the sand spits and flow down to the drainage canal which is located behind the sand spits. The houses located between the sand spits and the drainage canal are submerged 2 to 4 times in one year.

There are few sandy beaches between the Flood Relief Channel and the coral reef. There are many coconut palm trees, but some trees have died due to salt damage. Fisherman living there said that the coast have retreated about 20m since 1940 downward. The death of the palm tree is also related to coastal erosion.

3) Coral Reef

The left bank of the river mouth of the Kuranji is a sligthly hilly area. The area consists of coral reef and cover sand. The coral reef is not alive but a dead coral reef as has mentioned in the foregoing chapter. But a new coral reef is growing about 0,4km offshore. Fisherman are fishing the coral reef here.

There were swampy areas on the inland side of the coral reef covered by Nippa Palm. But during this past seven years the area has been changed as artificially filled-up fields.

4) Kuranji River – Air Dingin River

The coastline consists of sand. The width of the sandy coast is the biggest, about 300m, near the river mounth. If we compare the coast with the coast between the Flood Relief Channel and the Lolong River, the slope of the former is more gentle than that of the latter and the waves of the former are more moderate than that of the latter.

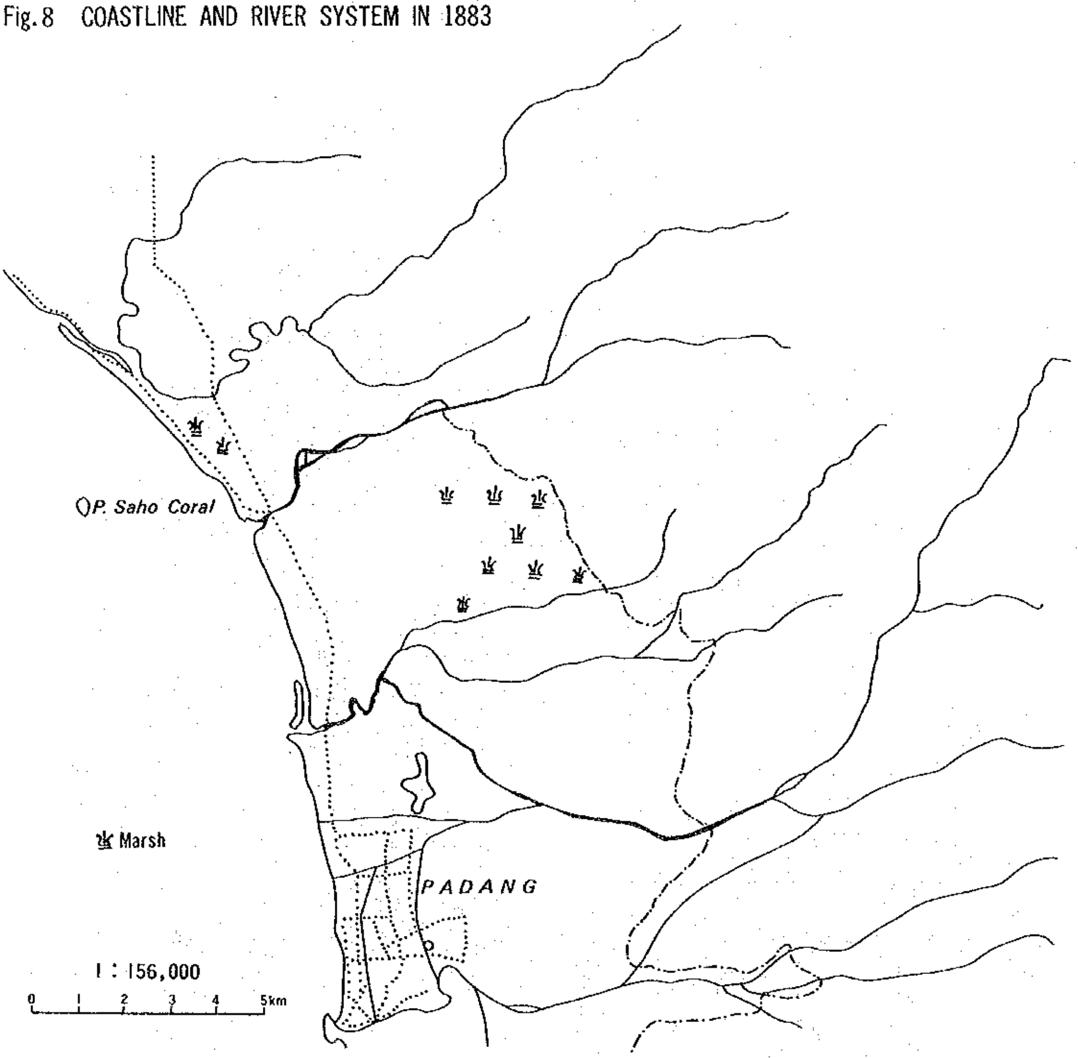
The writer found a map which was prepared by Van Eeen Ge deelte Van in 1883. The map shows that there was a sand bank at the right bank of the river mouth of the Kuranji River. At present, there is a narrow long back-marsh along the Baung River (Fig. 8). The sand bank in 1883 has grown and formed the present sandy beach and back marsh along the Baung River. By comparison of the map of 1883 with the present condition, the writer was able to recognize that coast has advanced about 200m.

People living there said that the coastline had retreated before 1967, but after that the coast has expanded and recovered about 13m.

5) Air Dingin River to North

The coast is sandy beach. There are many cusps along the coast. This shows that erosion is more predominant than deposition.

Fig. 8　COASTLINE AND RIVER SYSTEM IN 1883



Van Eeen Ge deelte Van Sumatra's West Kust 1883 AMSTERDAM

7. Geomorphological Consideration of the Supply of Sand and its Movement Coastal Erosion

The sand of the coast is supplied from the rivers, transported by the littoral current and washed ashore by waves.

The width of the sandy beach is the biggest at the river mouth of the Kuranji. As has been mentioned above, the deposition by the Kuranji River is the biggest among the three rivers.

The main direction of the littoral current is estimated to be from north to south, Because the mouth of the Air Dingin River is winded to the south and there are small gravels coming from the Kuranji River between the Kuranji River and the Flood Relief Channel, in addition the deposition is seen at the southern side of each jetty.

Based on the map of 1883, we know that the Air Dingin River pours to the Indonesia Ocean with right angle. But the map of 1893 shows that the mouth of the Air Dingin River was winded to the south and joined with the mouth of the Kuranji River. The change has occurred due to the big deposition along the seacoast from the river mouth of the Kuranji to the North. After that the river mouth of the Air Dingin returned to the north and reached the present site.

Due to the coral reef the direction of the river mouth is winded slightly to the north. Therefore, after the pouring of the muddy river water into the open sea, the muddy water is dispersed from the mouth of the Kuranji River to the north. The writer made sure of the above-mentioned phenomenon not only by aerial photographs but by the color of the sea water. Namely, the color of the sea water in the northern part of the Kuranji shows a light brown color while a light blue color is recognized in the south. Live coral reefs located offshore from the river mouth of the Kuranji are situated in the blue-color sea. This shows that the sand and silt which were transported by the Kuranji River were mainly deposited on the northern coast from the river mouth.

Erosion is more predominant than deposition along the coast of the Padang Plain except for the coast between the Kuranji and Air Dingin Rivers.

One of the important reasons for the coastal erosion is related to the supply of sand coming from the three rivers. But as has been mentioned above the volume of sand and gravel which is transported from the upper reaches of the three rivers is not so big. The major part of the sand and gravel was supported by the bank erosion of the pyroclastic flow, the fan and natural levee in the plain. The volume is estimated not to be so big. Especially, the volume of the sand and gravel which is transported by the Arau River is small. And the direction of the river mouth of the Kuranji is winded to north by the existence of the coral reef.

Furthermore, weirs, dams and riverside embankments were constructed. These artificial works obstruct the flow of the sand and gravel which has been taken for construction work and a lowering of the river bed has occurred in recent years.

The writer estimated that the causes of coastal erosion are related to the above-mentioned natural conditions of the river and coast as well as artificial works.

8. Utilization of the Map

1) The map is useful to foretell the types of flooding in each geomorphological element. For example, in the case of the fan, deposition is big and change of river course is frequent while the water drains off well.

2) By a combination of geomorphological elements, you can estimate whether erosion is predominant or deposition is predominant in each river, and the type of flooding, i,e, overflowing or concentration type. For example, if you compare the Arau, Kuranji Rivers with regard to deposition, deposition of the Kuranji is bigger than that of the Arau River. Furthermore, you can estimate the causes of coastal erosion or deposition.

3) You can estimate where stable places or unstable places are by the map. For example, the river course in the alluvial fan is unstable, but that in a delta or natural levee is relatively stable. Utilizing the map, you can select a bridge site.

4) You can estimate the geomorphological formation process from the map.

5) There are close relationships between the state of the soil and the ground water situated near the ground surface.

6) You can use the map for city planning and land use. For example, coastal sand spits and natural levee areas are safe from flooding but back-swamps and deltas are dangerous.

7) There are close relationships between the area of liquefaction caused by earthquakes and geomorphology. You can estimate the areas in which liquefaction might occur. According to the experience in Japan, the lower part of the sand dunes and natural levees is a dangerous place.

(The map and the paper are written by Dr. Masahiko OYA)

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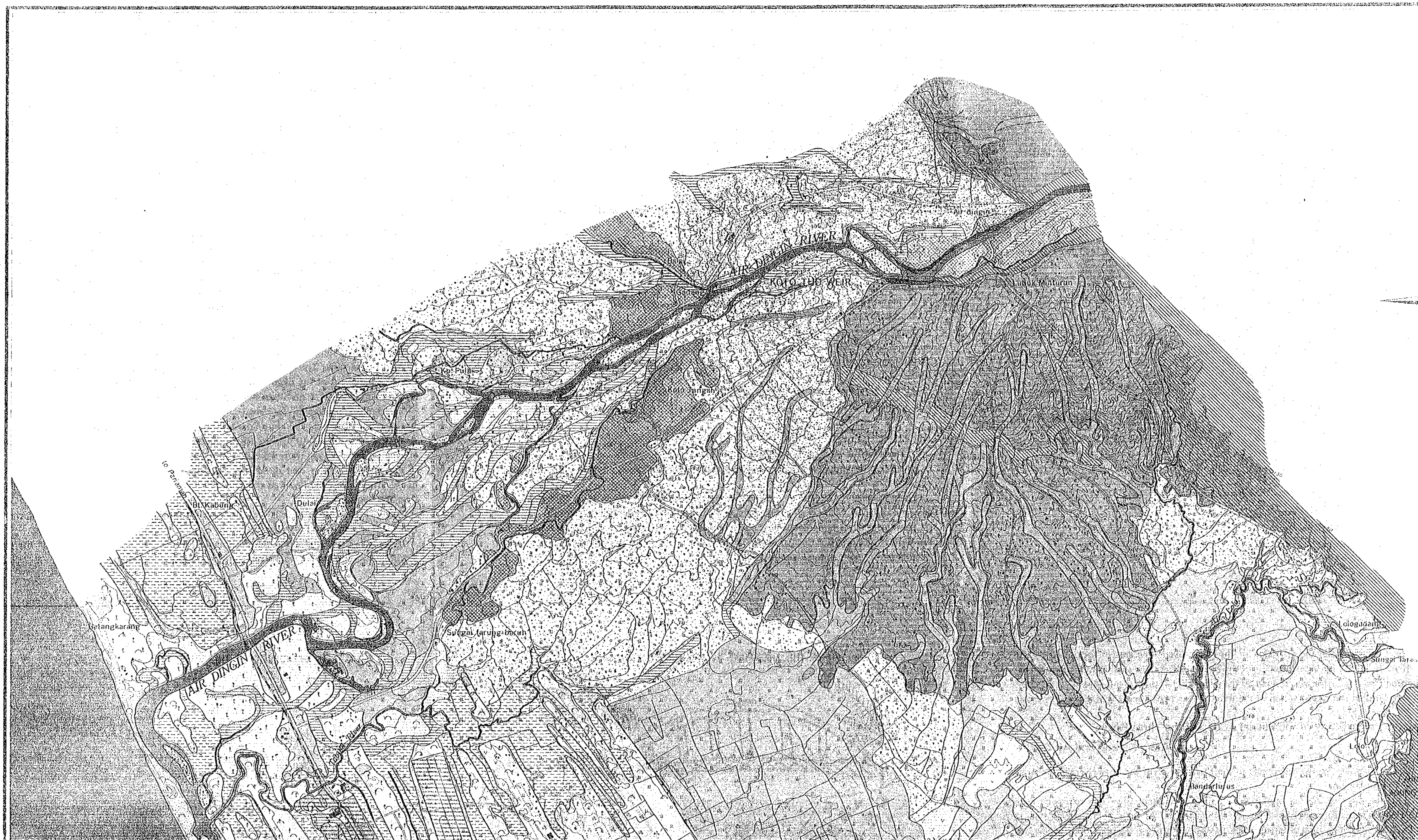
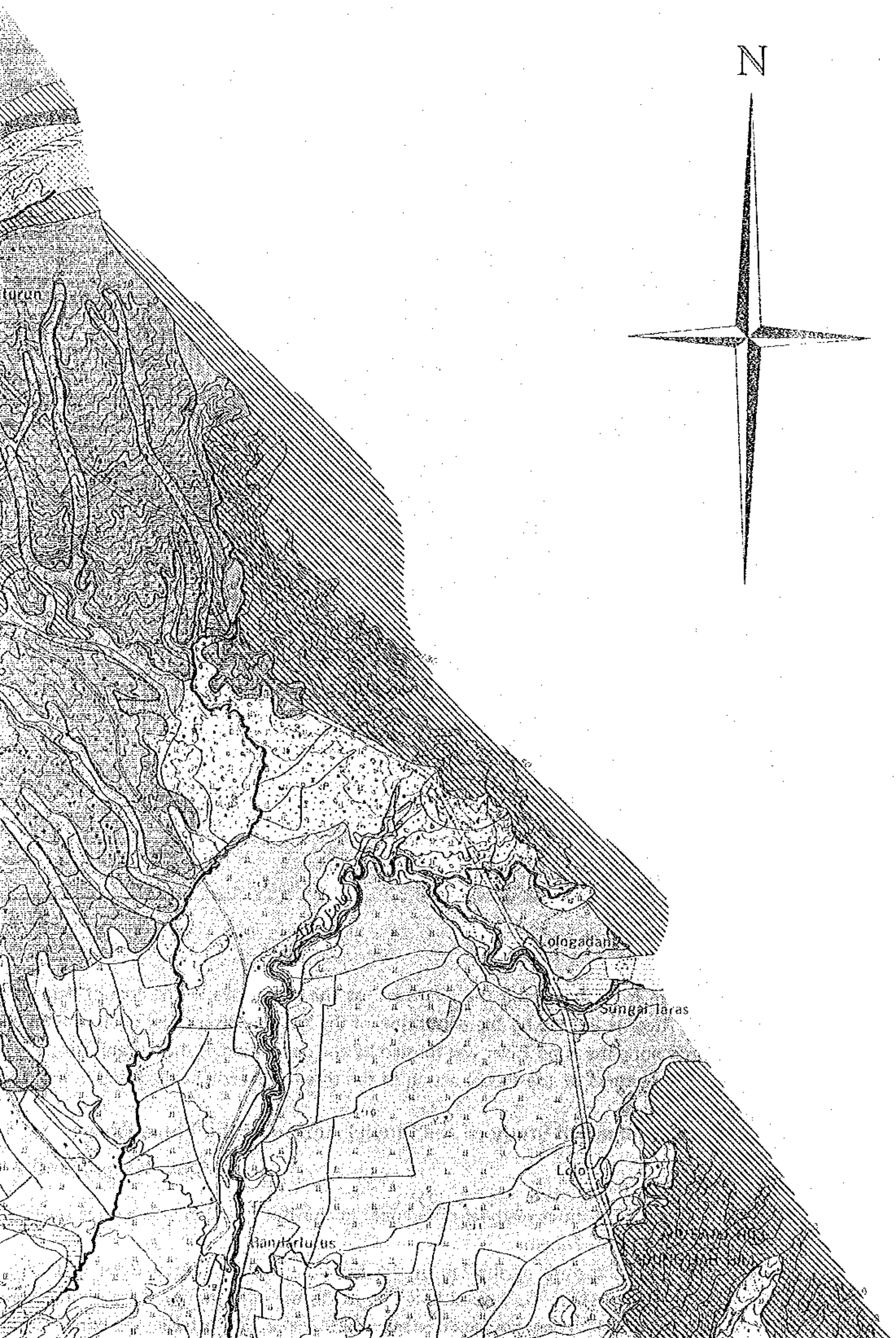
A GEOMORPHOLOGICAL SURVEY MAP OF PADANG CITY AND SU
SHOWING CLASSIFICATION OF FLOOD ST



OF PADANG CITY AND SURROUNDING AREA IN WEST SUMATRA
SIFICATION OF FLOOD STRICKEN AREAS



EXPLANATORY NOTES

- BOUNDARY OF TOPOGRAPHY
- CLIFF
- STEEP SLOPE
- CONVEX SLOPE ON THE MOUNTAIN RIDGE
- GENTLE SLOPE ON THE MOUNTAIN FLANK
- CONCAVE SLOPE ON THE MOUNTAIN FLANK
- PYROCLASTIC FLOW TERRACE OR VOLCANIC FAN (NEVER SUBMERGED AT FLOOD TIME)
- TERRACE (NEVER SUBMERGED AT FLOOD TIME)
- SLIGHTLY HILLY AREA (NATURAL LEVEE) ON THE FAN (THE AREA IS SAFETY FROM THE FLOODING)
- FAN (THIS PART GETS SUBMERGED IN AN EXTRAORDINARY FLOOD TIME, BUT THE WATER DRAINS OFF WELL)
- ALLUVIAL FAN (IN FLOOD TIME, THE EROSION, DEPOSIT, CHANGE OF WATER COURSE ARE SEEN, THE WATER DRAINS OFF WELL)
- VALLEY PLAIN (IN FLOOD TIME, WHEN SUBMERGED, VELOCITY OF THE FLOOD CURRENT IS FAST AND WATER DRAINS OFF WELL)
- NATURAL LEVEE (THIS PART GETS SUBMERGED IN AN EXTRAORDINARY FLOOD TIME, BUT THE WATER DRAINS OFF WELL)
- BACK SWAMP (THIS PART IS LONG SUBMERGED IN FLOOD TIME)
- BACK SWAMP (PEATY) (THIS PART GETS SUBMERGED AT TORRENTIAL RAINFALL)
- ARTIFICIALLY FILLED UP FIELD (THIS PART GETS SUBMERGED IN AN EXTRAORDINARY FLOOD TIME, BUT THE WATER DRINS OFF WELL)