SOCIO - ECONOMY

APPENDIX C

SOCIO ECONOMY

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. General

West Sumatra province has 8 Kabupaten and 6 Kotamadya with an area of 42,297 km^2 in 1981, the province had a population of 3,469,000[/1] giving a population density of 82/km^2.

Padang city is one of these Kotamadya, and is not only a central city of the province but also a center of commerical and economic activities. The city has Teluk Bayur port facing to the Indonesian Ocean, Muara port located at the estuary of the Arau river and Tabing Airport located in the northern part of the city.

Recently, a population of Padang city has increased owing to increase in the economic activities. Although the population growth ratio in old urban area is not so much, the ratio in the new urban area is about 8 % per year during the last ten years.

This APPENDIX C presents the results of the socio-economic survey on the present condition and the existing future development plans in Padang city.

2. Present Socio-economic Features

2.1 Land Use

According to the Report[/2], the land use of Padang city in 1981 was 14.5 % for urban area, 36.0 % for agricultural land and 49.5 % for forest as shown in Table C-1.

The present land use is surveyed in the plain area of the three basins of the Arau, Kuranji and Air Dingin rivers. The Plain area is bounded by (1) the footline of Mt. Padang and Mt. Kerambil from the estuary of the Arau river to Bandar Buat through Sudut, Koto Kecil and Bukit Putus on the south, (2) the road connected Bandar Buat and Lubuk Minturun on the east, (3) the road connected Lubuk Minturun and Tabing along the Air Dingin river on the north and (4) the Indonesian Ocean on the west.

/1 Sumatera Barat Dalam Angka, 1981.

/2 Rencana Induk Kota Padang 1983 - 2003, 1982.

For the land use survey, the topographic map of scale 1/5,000 surveyed in 1974 is used after modifying the map by new aerophotos taken in 1981. The land use in the plain area is shown in Fig. C.1.

The results of survey show that the land use of the plain area in 1981 was 27 % for residential area, 48 % for paddy field, and 25 % for other agricultural and open area including road, channel, etc. They are shown in Table C-2.

2.2 Population and Households

Padang city has 11 Kecamatan's (sub-districts) and an area of 646 km^2. In 1981, the city had a population of 494,000, which gave a population density of 765/km^2 /3. Therefore, the city accounts for about 14 % of the total population of West Sumatra province, while the city accounts for only 1.5 % of the total area of the province. This fact indicates the population density of the city is very high compared with those of other regions of the province.

The city has 11 sub-districts: Padang Selatan, Padang Barat, Padang Timur, Padang Utara, Koto Tangah, Nanggalo, Kuranji, Pauh, Lubuk Kirangan, Lubuk Begalung and Bungsu/Teluk Kabung, of which locations are shown in Fig. C-2.

Table C-3 shows the population of sub-districts in 1981. The population growth ratio of the city was about 3.4 % per year on the average during the last ten years, while that the old urban area (Padang Lama) comprizing Kecamatan Padang Selatan, Padang Barat and Padang Timur was about 2.3 % per year during the same period. On the other hand, the population growth ratios of the new urban area (Padang Baru) comprizing Kecamatan Padang Utara and Nanggalo which are located on the north of the old urban area were respectively 7.6 % and 9.7 % per year. These ratios are very high compared with those of other sub-districts.

The above mentioned fact indicates that the urban area of Padang city is rapidly expanding due to increase in population in the same

/3 Sumatera Barat Dalam Angka, 1981.

way of other principal cities in Indonesia.

In Indonesia, a population census was executed in 1980. The census showed that the households in the agricultural sector of West Sumatra province numbered 499,800, which were about 71 % of the total households of the province. On the other hand, those of Padang city were only 18 % of the total. The number of households in other sectors is not clarified.

2.3 Regional Economy

In 1980, the gross regional domestic production (GRDP) of West Sumatra province was counted to be 614 billion[/4] or Rp. 177,000 per capita, which composition is shown in Table C-4, while that of Padang city is not counted yet.

Padang city has various economic activities such as commerce, trading, industry and agriculture.

(1) Commerce and Trading

In 1981, Padang city possessed 2,900 firms concerned in commerce and trading, and 1,000 warehouses with about 136,000 m^2 in total space for handling the firms' goods. The exports in 1981 amounted to USD$ 89,840,000 while the imports in the same year was USD$ 15,322,000. This indicates that Padang city possessed valuable goods for export. The export amount of rubber accounts for about 35 % of the total export amount, timber 23 %, cassava 15 %, coffee 9 % and rattan 6 %.

On the other hand, the imports in 1981 were machinery, vehicles, paper and printing materials and metal goods. The amount of imported machinery and vehicles accounts for 30 % of the total import amount, paper and printing materials 26 % and metal goods 12 %.

Besides, domestic trading is also an important economic activity of Padang city. The goods are almost daily necessaries and traded through Teluk Bayur port between West Sumatra and other cities of Sumatra island and other islands of Indonesia.

/4 Pendapatan Regional Sumatra Barat, 1975 and 1980.

(2) Industry

Padang city possessed in 1981, 424 registered manufacturers concentrated in the urban area and its surrounding area. The major industries are rubber processing, food and drink production and textile, but the biggest one is cement production at Indarung of Kecamatan Lubuk Kilangan. As the output of cement exceeds the demand in construction materials of Padang city, it is exported not only to other cities of South Sumatra, Bengkulu and Lampung but also to Jakarta.

The commercial, trading and industrial activities of Padang city are shown in Table C-5.

(3) Agriculture

Main agricultural product is paddy. In 1981, about 58,300 tons of paddy were yielded from about 14,000 ha of harvested area. The average annual yield was 4.2 ton/ha.

Other agricultural products are maize, cassava, sweet potatoes, beans, fruits and vegitables. Among them, cassava and vegitables are produced surpassing others. In 1981, 3,400 tons of cassava were produced from 342 ha and 4,200 tons of vegetables from 716 ha.

Padang city has also plantations owned by small holders. The plantations mainly produce clove, coffee, rubber and nutmeg. In 1981, the yield and harvested area of clove were 240 tons and 1,550 ha, coconut 2,900 tons and 3,179 ha, coffee 31 tons and 110 ha, rubber 27 tons and 97 ha, and nutmeg 40 tons and 103 ha.

Table C-6 shows the agricultural production in Padang city including the above.

(4) Dairy Farming and Fishery

Production of cattle and buffalo meat is extensively carried on in Padang city. In 1981, the outputs were 317 tons and 620 tons respectively. Poultry farming is also important for egg production. In 1981, about 326,000 birds of local and foreign breeds were raised and 24,304,000 eggs were produced.

In 1981, the number of fishermen was about 4,700. The catch of fish was about 28 tons in fresh-water fishery and 5,705 tons in coastal fishery. The sales of coastal fishery amounted to Rp. 2,691,000,000. Table C-7 shows the production figures of dairy farming and fishery in 1981.

2.4 Regional Infrastructure

In 1980, Padang city had roads 621 km in total length consisting of state roads 43 km long, provincial roads 29 km long, district roads 160 km long, village roads 259 km long and hamlet paths 130 km long. The pavement ratio was however 40 % of the whole road network. Table C-8 shows length of roads and pavement ratio by sub-district.

In 1980, the total volume of supplied electricity was about 44,000 mkwh, and the total piped water consumption was 6 mcm. The breakdowns of them are shown in Table C-9.

Marine and air transportation are big elements of the activities of Padang city as the commercial and trading center of this region. Tabing Airport has daily jet services between Padang and Jakarta, Medan and Pakan Baru and fly to other countries is also easy through Jakarta and Medan. In 1981, the number of flights from and to the Airport amounted to 6,951 and the corresponding passengers numbered 280,083. Marine transportation is also flourishing. In 1981, passengers at Teluk Bayur port numbered 76,477 and loaded and unloaded goods amounted to 459,307,000 ton/yr and 280,743,000 ton/yr respectively. Muara port located at the estuary of the Arau river is also playing an important part for handling daily necessaries for inhibitants of Padang city. Table C-9 shows the conditions of infrastructures of Padang city in 1981.

3. Presentation of Development Plan of Padang City

3.1 Outline of Master Plan of Padang City

Padang city now has a city development plan named the Master Plan of Padang City (Rencana Induk Kota Padang 1983 - 2003) as one of local governmental projects under the Regional Development Program of whole Indonesia. The outline of the plan is described below.

(1) Objective Period of the Plan and Its Subject

The plan will be realized during a period for 20 years starting from 1983 to the year of 2003. For realization of the plan, a step-wise method is taken up consisting of 4 steps and 5 years each.

The study report on the plan introduces all the sub-projects under the plan and their budget sources which will perform during the first step from 1983 to the year of 1988. These sub-projects can briefly be classified into five categories such as (1) improvement of social infrastructures in the present urban area, (2) works for widening the existing road which runs along the foot of mountains in hinterlands, which will be an outside trunk road of Padang city, (3) land acquisition and commencing the construction works of new road connecting an existing road between Teluk Bayur and Lubuk Begalung, which is routing from Lubuk Begalung to the north of Tabing and will be an inside trunk road of the city, (4) improvement of port facilities of Teluk Bayur, and (5) improvement of facilities of Tabing Airport.

(2) Social Feature of Padang City in the Future

In the plan, a population in the year of 2003 is estimated at about 900,000 as shown in Table C-10 which is about twice of the population in 1981. The plan says that the number of population will be available to serve man-powers.

Accordingly, Padang city will have a leading role for developing potential powers of economy and industry as a commercial center of West Sumatra supported by those man-powers. In the year of 2003, the report say that the population density of 770/km^2 in 1981 will increase to 1,440/km^2, and number of household, 7 household/ha in 1981 in the plain area except the old urban area, will increase to 19 household/ha.

3.2 Future Land Use

For coping with the population growth as mentioned above, several works should be necessary such as land preparation for residence, improvement of social infrastructures, expansion of supply system of water and electricity, and giving working opportunities and so on.

For those needs, an intensional land use is planned taking account the urbanization of the plain area of Padang city. A wholesale land use change is planned in the future as shown in Fig. C-3 and Table C-11. For example, up to the year of 2003, present residential area of 11 % of the whole area of Padang city will be 16 %, and the present area for transportation of 1 % will be 5 % respectively.

On the other hand, on the land use in the plain area, most of the present agricultural area and open area will be changed to the residential area in the future. Only a little agricultural land will remain in the area of middle reaches of the Kuranji and Air Dingin rivers as shown in Fig. C-3. Fig. C-1 shows the land use as of 1991 based on the information obtained from Padang city and interview survey to several private developers.

3.3 Other Development Plan

(1) Toll Road

According to an information from Bina Marga, DPU, West Sumatra, a highway construction is planned in the route connected with the Bypass road at Lubuk Begalung and the existing road on the right bank of the Air Dingin river at the north of Tabing. The highway is one of the trunk roads included in the Master Plan of Padang city. The said highway is planned as a toll road with asphalt pavement of 7 m wide in two lanes and foot path of 2.5 m wide on both sides. The total length of the road is 17 km.

(2) Botanical garden

In the area located about 4 km upstream from Indarung of the Arau river basin as shown in Fig. C-4, a botanical garden is planned with the area of 240 ha in total. The planned area of the botanical garden is about 3 times large comparing with the area of 85 ha of Bogor Botanical Garden in West Jawa.

This plan of Botanical Garden has been studied by Andalas University since 1981, and is in final stage for making a basic idea at present. According to an information from the university, land acquisition will be started from 1984, but the detail scheme is not designed yet.

After completion, the botanical garden will have a role as an institutional center for forest conservation in West Sumatra and is expected to be a sightseeing and recreation place. Furthermore, a model forest scheme is planned by the university in the area located in the north of the botanical garden as an experiment plantation for seminar of students.

Table C-1 Land Use in Padang City

As of 1981, Unit: ha

Kecamatan	Residential area	Commercial area	Industrial area	Cultural area	Area for hospital, clinic, etc.	Religious area	Official area	Transportation area	Recreation area	Agricultural area and open land	Forest	Total
Padang Selatan	96.00	34.70	4.00	4.78	1.48	1.12	9.00	59.80	13.00	600.95	395.17	1,200
Padang Barat	285.40	90.00	3.10	8.38	1.90	1.02	56.00	56.16	7.60	167.44	-	677
Padang Utara	483.86	1.75	4.00	66.85	1.32	0.94	45.00	53.03	0.90	139.35	-	797
Padang Timur	280.00	0.90	7.50	21.75	9.10	1.28	32.00	42.50	1.35	365.62	-	762
Koto Tangah	3,958.00	1.40	28.00	0.95	1.02	2.68	18.00	566.92	10.00	3,556.00	7,642.03	15,785
Nanggalo	427.00	1.25	0.60	0.35	0.24	0.76	1.50	18.60	0.35	966.35	-	1,417
Kuranji	736.00	1.25	0.55	1.05	0.66	2.84	0.50	48.36	0.25	2,687.68	2,220.86	5,700
P a u h	215.00	0.75	0.50	21.40	0.45	1.24	0.50	22.20	0.20	8,208.55	6,229.21	14,700
Lb. Kilangan	96.00	0.55	209.60	1.05	0.72	0.84	0.50	27.36	25.00	897.83	7,420.55	8,680
Lb. Begalung	428.00	1.75	64.50	1.25	1.02	1.34	2.50	22.80	0.50	839.84	1,636.50	3,000
Bungus/Tl. Kabung	184.00	0.30	0.50	0.60	0.14	0.70	0.05	12.83	95.44	4,147.32	5,483.12	9,925
Total	7,189.26	134.60	322.85	128.41	18.05	14.76	165.55	930.56	154.59	22,576.93	31,027.44	62,663
%	11.50	0.21	0.52	0.20	0.03	0.03	0.26	1.48	0.25	36.03	49.49	100.00

Source : Rencana Induk Kota Padang 1983 - 2003 (Master Plan of the Padang city for 1983 - 2003), Pemerintah Kotamadya Daerah Tingkat II, Padang, 1982.

Table C-2 Land Use in Objective Area for the Study

As of 1981, Unit: ha

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, fallow area, wasted area, etc.

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

Table C-3 Area, Population & Households in Padang City

Kecamatan	Land area	Population (person)		Population Density (pers/km²)		Annual population growth ratio	Household	Number of persons per household
	(km^2)	1971	1981	1971	1981	(%)	(nos)	(pers/household)
Padang Selatan	12.20	45,848	57,410	3,758	4,706	2.3	10,020	5.7
Padang Barat	6.78	67,211	81,600	9,927	12,053	2.0	14,667	5.6
Padang Utara	7.97	23,369	48,622	2,932	6,101	7.6		5.6
Padang Timur	7.76	59,484	77,645	7,806	10,190	2.7	14,482	5.4
Koto Tangah	176.00	34,575	50,150	219	318	3.8	8,977	5.6
Nanggalo	14.17	10,612	26,108	749	1,842	9.7	4,675	5.6
Kuranji	57.00	38,718	48,546	679	852	2.3	9,120	5.3
Pauh	147.00	16,246	22,607	111	154	3.3	4,318	5.2
Lubuk Kilangan	86.50	14,293	22,717	165	262	4.7	3,939	5.8
Lubuk Begalung	30.00	30,438	45,861	1,015	1,529	4.2	7,852	5.8
Bungus/Tlk. Kabung	100.32	9,933	12,886	100	130	2.6	2,325	5.5
Total	645.70	350,727	494,152	560	765	3.4	89,061	5.5

Source : Padang Dalam Angka 1981, Kantor Statistik, Kotamadya Padang.

Table C-4 Gross Regional Domestic Production of West Sumatra Province in 1980

Item	Gross Regional Domestic Production (Rp. Million)	(%)
1. Agriculture	241,509	39.32
a. Farm Food Crops	(125,670)	(20.46)
b. Farm Non Food Crops	(48,826)	(7.95)
c. Estate Crops	(204)	(0.03)
d. Livestock and Other Product	(35,939)	(5.85)
e. Forestry	(13,699)	(2.23)
f. Fishery	(17,172)	(2.80)
2. Mining and Quarrying	1,239	0.20
3. Manufacturing Industries	66,927	10.90
4. Construction	21,423	3.49
5. Electricity and Water Supply	1,403	0.23
6. Transport and Communication	46,606	7.60
7. Wholesale and Retail Trade	145,352	23.66
8. Bank and Other Financial Intermediaries	6,678	1.09
9. Ownership of Dwelling	16,623	2.72
10. Public Administration and Defence	53,763	8.76
11. Services	12,498	2.03
Total	614,021	100.00

Source : Pendapatan Regional Sumatera Barat, 1975 - 1980, prepared by Lembaga Penelitian Ekonomi Regional, Fakultas Ekonomi Universitas Andalas.

Table C-5 Activities of Commerce, Trading and Industry in Padang City

As of 1981

Description		Unit	Number, volume or weight
Commerce and Trading			
1. Number of Commerce and trading firms		firm	2,903
2. Space of warehouse		m^2	136,336
3. Export and import	: Export	US $ 1,000	89,840
	Import	"	15,322
4. Demestic trading			
Food	: Outgo	10^3 ton	114.0
	: Income	"	119.0
Daily necessaries	: Outgo	"	0.5
	Income	"	10.0
Agricultural products	: Outgo	"	83.6
	Income	"	52.3
Mining products	: Outgo	"	52.1
	Income	"	31.9
Construction materials	: Outgo	"	2.1
	Income	"	0.1
Metal and Chemical Industry			
1. Production			
Zinc and other metal products		ton	9,742
Fence and other metal goods		m	55,000
Bed and other metal furniture		pcs	134,000
Crumb rubber		ton	34,744
Soap and other chemical goods		10^3 pcs	9,070
2. Number of manufacturers			
Food and drink		firm	121
Textile		"	256
Leather		"	15
Chemical goods (inl. cement 1)		"	32

Scource : Padang Dalam Angka, 1981, prepared by Kantor Statistik, Padang

Table C-6 Agricultural Products

As of 1981

Kind of products	Harvested area (ha)	Yield (ton)
Ordinary farming area		
Paddy	13,969	58,316
Maize	69	103
Cassava	342	3,432
Sweet potatoes	30	221
Beans	164	130
Fruit	101	207
Vegetables	716	4,203
Plantation		
Clove	1,550	240
Coconut	3,179	2,887
Cinamun	30	1
Coffee	110	31
Rubber	97	27
Nutmeg	108	40
Red Pepper	6	1
Cashew nut	15	1

Source : Padang Dalam Angka 1981, Kantor Statistik, Padang.

Table C-7 Dairy Farming and Fishery in Padang City

As of 1981

Kind of products		Unit	Number or production
Dairy Farming			
Milk		Liter	53,301
Meat	: Cattle	kg	317,430
	Buffalo	"	620,320
	Horse	"	16,260
	Goat	"	5,350
	Pig	"	130,200
Livestock	: Cattle	head	6,062
	Buffalo	"	1,047
	Horse	"	744
	Goat	"	3,936
	Sheep	"	4,025
	Pig	"	986
	Foreign chicken	"	124,686
	National chicken	"	201,286
	Duck	"	10,728
Egg (chicken and duck)		10^3 pcs	24,304
Butchering	: Cattle	head	4,047
	Buffalo	"	4,390
	Horse	"	283
	Goat	"	568
	Pig	"	2,628
Fishery			
Fresh-water fishery		kg	28,055
Coastal fishery		kg	5,705,481
Fisherman		pers	4,664

Source : Padang Dalam Angka 1981, Kantor Statistik, Padang

Table C-8 Length of Roads in Padang City

As of 1980, Unit : km

Kecamatan	State road	Provincial road	District road	Village road	Hamlet path	Total	Pave't ratio (%)
Padang Selatan	-	7	12	7	17	43	53
Padang Barat	3	2	33	16	-	54	70
Padang Utara	6	6	12	32	10	66	42
Padang Timur	-	-	22	11	-	33	67
Koto Tangah	12	-	21	86	55	174	19
Nanggalo	-	-	6	10	15	31	16
Kuranji	-	-	22	50	8	80	36
Pauh	-	-	21	10	6	37	54
Lb. Kilangan	19	-	-	18	6	43	70
Lb. Begalung	3	10	11	9	5	38	50
Bungus/Teluk Gabung	-	4	-	10	8	22	18
Total	43	29	160	259	130	621	40

Source : Ringkasan Fakta dan Penjelasan Kotamadya Padang, 1982, Direktorat Tata Guna Tanah, Direktorat Jenderal Agraria, Department Dalam Negeri.

Table C - 9 Electricity, Water Supply and Transportation in Padang City

As of 1981

Description		Unit	Quantity	(%)
Electricity /1				
	Total supplied volume of electricity	kwh	44,078,304	(100 %)
	1) Household and others	"	25,508,961	(58 %)
	2) Business firm and industry	"	10,718,479	(24 %)
	3) Street lightings	"	1,084,623	(0 %)
	4) Offices	"	6,766,241	(15 %)
Water supply /1				
	Total piped water consumption	1,000 m^3	5,629	(100 %)
	1) Household	"	3,021	(54 %)
	2) Offices, social board, business firm/industry, hotel, and public supply	"	900	(16 %)
	3) Others	"	1,702	(30 %)
Transportation /2				
1. Tabing aiport	Number of passengers	person	280,083*	
	Number of flights	flight	6,951*	
2. Teluk Bayur port	Number of passengers	person	76,477	
	Loaded goods	1,000 tons	459,307	
	Unloaded goods	"	280,743	
3. Muara port	Loaded goods	1,000 tons	88,539	
	Unloaded goods	"	19,473	

Source : /1 Sumatra Barat Dalam Angka 1981, BAPPEDA dan Kantor Statistik, Suamtera Barat

/2 Padang Dalam Angka 1981, Kantor Statistik, Padang

Remarks : * Arrival and Departure

Table C-10 Population Projection
(1983 - 2003)

Year	Population
1983	520,432
1988	597,875
1993	685,346
1998	785,793
2003	901,138

Table C-11 Land Use

Land use	Year of 1981		Year of 2003	
	Area (km²)	%	Area (km²)	%
Housing	71.89	11.47	99.13	15.83
Commercial	1.35	0.21	2.00	0.32
Industrial	3.23	0.52	5.50	0.88
Educational	1.28	0.20	3.00	0.48
Health	0.18	0.03	1.00	0.16
Religious	0.15	0.02	1.00	0.16
Official	1.66	0.26	2.00	0.32
Transportation	9.31	1.48	30.00	4.79
Recreation	1.55	0.25	5.00	0.80
Agricultural & open land	225.77	36.03	169.70	27.09
Protected forest & hills	310.27	49.53	308.00	49.17
Total	626.63	100.00	626.63	100.00

Fig. C - 1 Land Use in 1981 and 1991

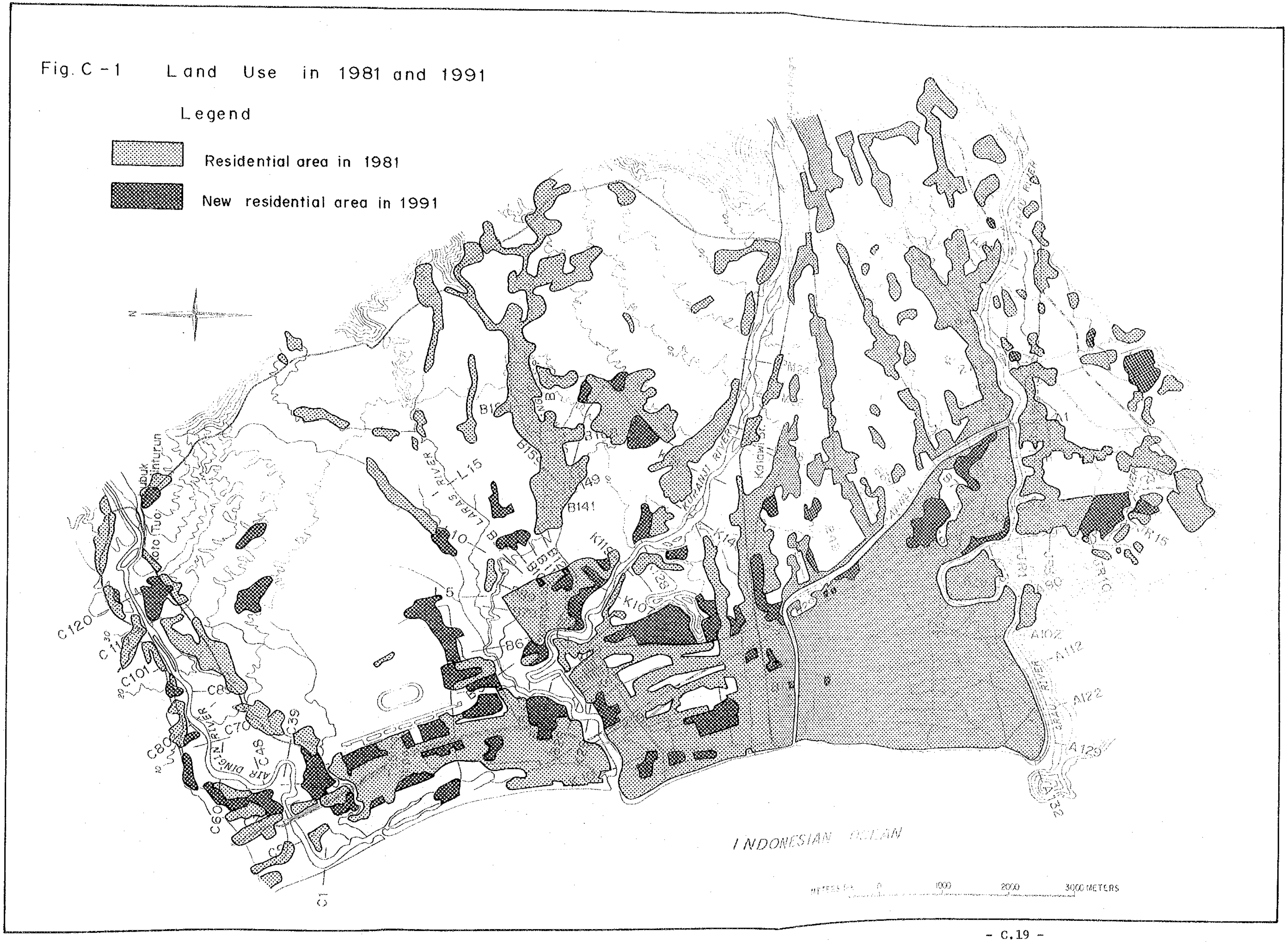


Fig. C - 2 Location of Kecamatan of Padang City

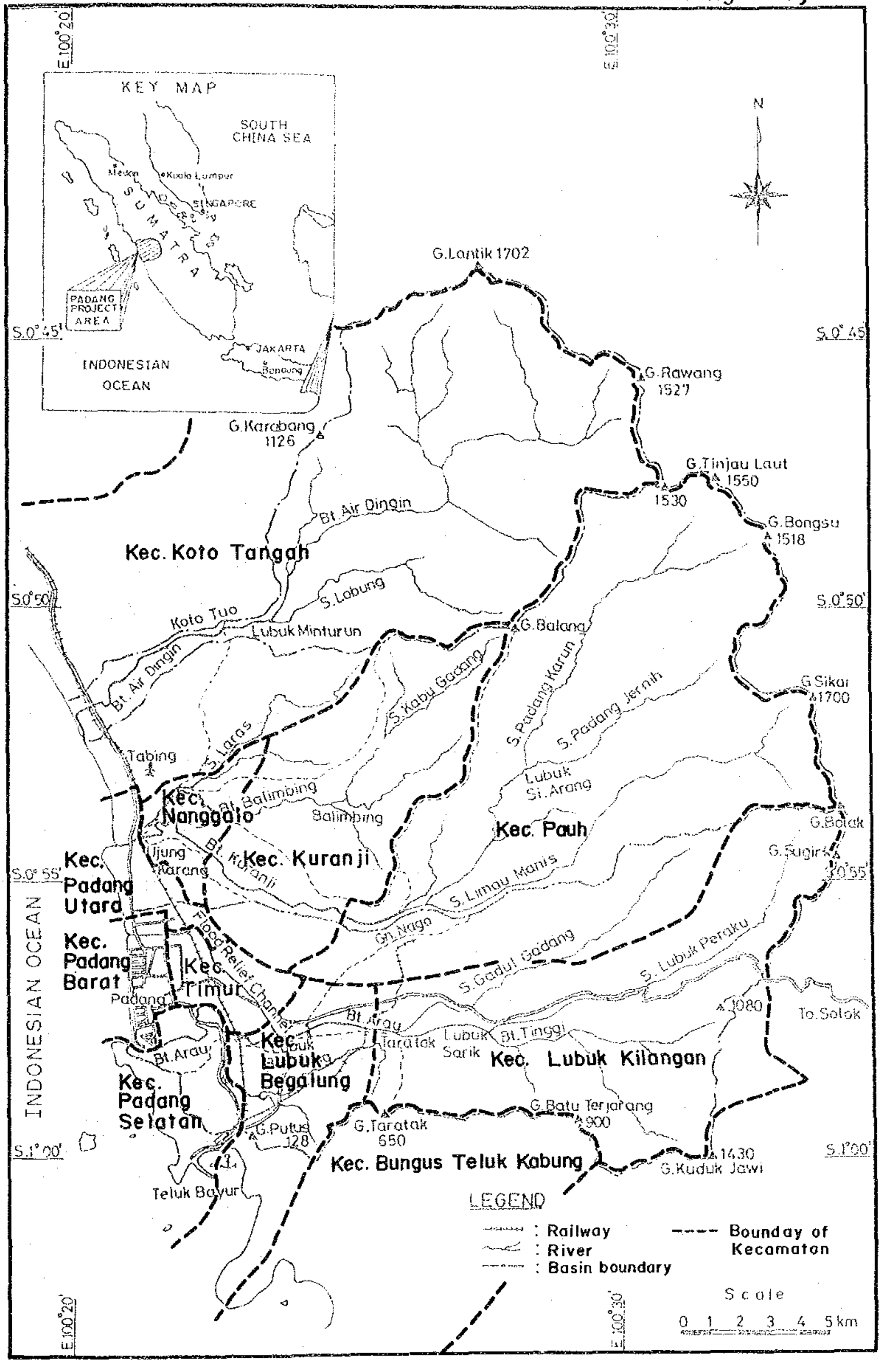
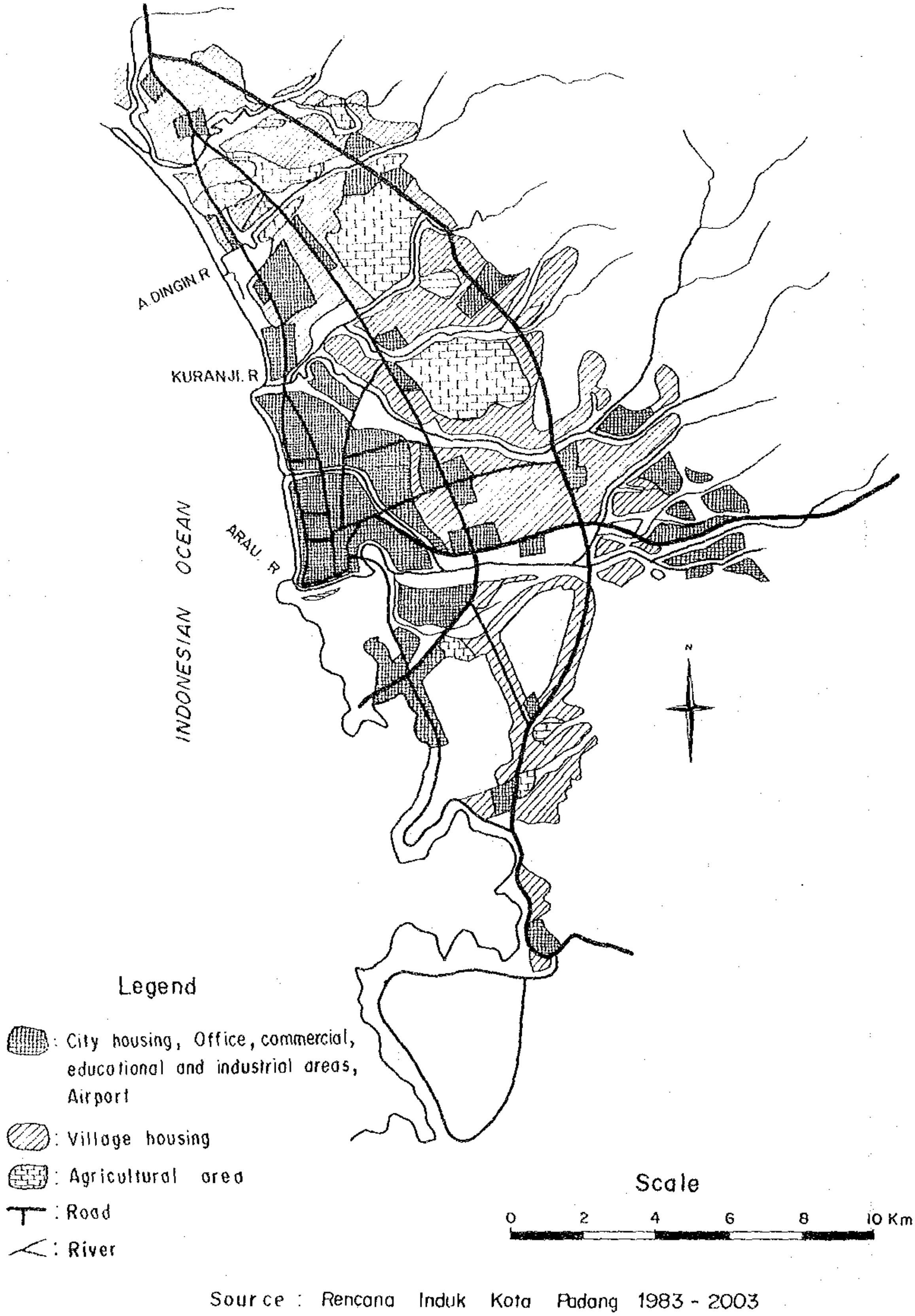
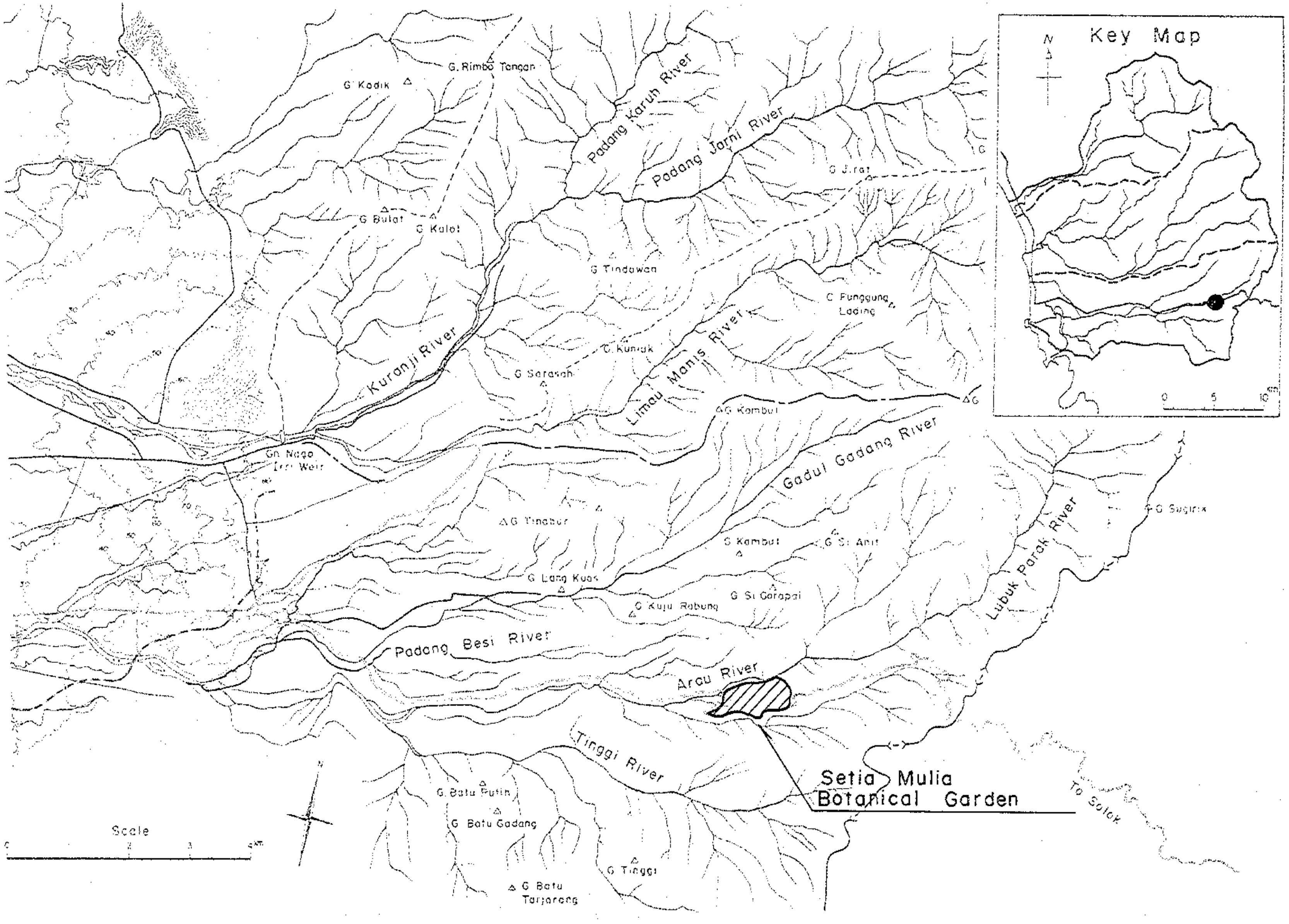


Fig. C-3 City Development of Padang in 2003



Source : Rencana Induk Kota Padang 1983 - 2003

Fig. C-4 Location of Setia Mulia Botanical Garden



APPENDIX D

FLUVIO - GEOMORPHOLOGY

APPENDIX D

FLUVIO-GEOMORPHOLOGY

TABLE OF CONTENTS

LIST OF FIGURES

1. General

When the development plan of the area is made, the planner must know the natural environment of the area in detail and he must pay attention to prevent natural disasters. The natural environment consists of topography, climate and hydrology. The relationship between topography, hydrology and human activity is close, because the topography was formed by the crustal movement and deposition or erosion by fluvial or marine action. This action appears as the destruction of the existing topography, for example, vertical faults or horizontal faults caused by earthquakes, land collapse caused by torrential rainfall and deposition of sand and gravel caused by flooding. These changes of the topography results in natural disasters for the people living there.

The geomorphology shows the history of the past natural disasters in the area. Therefore, if you classify the topography into various geomorphologic elements such as fan, natural levee etc., you can foretell disasters to be caused by the change of topography. If the development plan fits the natural development process of topography, natural disasters will not occur, but if the plan is not suitable for the natural development process of the topography, natural disasters will occur in the future.

According to the above mentioned reasons, the Study Team prepared a geomorphologic land classification map of the city of Padang and the surrounding area.

2. Geomorphological Survey Map

2.1 Purpose

A Geomorphological Survey Map of Padang City and Surrounding Area in West Sumatra Showing Classification of Flood Stricken Areas is a map such as to enable us to estimate not only the past floods but the future floods. The map may help in defining the type of flood which is the extent of areas to be submerged by floods, the duration of flood current, change of river course, possibility of erosion, deposits and other items.

Utilizing the geomorphologic land classification, it is possible to foretell the features of the flooding in each geomorphologic elements, for example, in the case of the alluvial fan, the velocity of the flood current is fast, period of inundation is short, change of river course is frequent and deposition and erosion are severe.

Furthermore, it is possible to estimate the features of flooding along the river courses by the combination of the geomorphological elements. If the river has big alluvial fan and big natural levees, the deposition of the rivers are active. In this case the ground elevation generally becomes higher toward the river channel. If the flood occurs, the flood water overflows toward the adjacent lowland. On the contrary, if the alluvial fan and natural levees are not developed well, the deposition of the river is not so active. In this case the ground elevation generally becomes lower toward the river channel. In flood time, flood water concentrates to the river channel from the surrounding areas. The former type of flood could be called as overflowing type and the latter as concentration type.

The geomorphologic land classification map shows not only the microtopography of the plain but also surface geology, soil condition and condition of underground water near the surface of the ground. Namely, the geomorphologic land classification map shows synthetically natural ground condition. For example the former research on the soil liquefaction due to earthquakes by use of the map gave the fact that there are a close relationship between location of the soil liquefaction and geomorphologic unit. As has been mentioned above, the field of the utilization of the map is broad.

2.2 Method

Before preparing the geomorphological map, the writer made a topographic base map on a scale of 1:20,000 utilizing a map of scale of 1:5,000. In preparing the geomorphological map the target area is firstly classified into major geomorphological elements by means of interpretation of aerial photographs such as steep slope, gentle slope on the mountain, pyroclastic flow, dissected-older fan, alluvial fan, natural levee, back-swamp, sandspits, abandoned river channel, coral reef and dry river bed. The aerophotographs scaled 1:15,000 are used. The initial map thus prepared is put into final form by checking the results of field surveys.

2.3 Description of Geomorphologic Elements

The area of the mountain and hill in the map is small. The mountains and hills are located along the upper reaches of the Arau, Kuranji and Air Dingin rivers and left bank of the Arau river. The mountains and hills consist of convex slope on the mountain ridge. Concave slopes are gentle on the mountain flank. The mountain slope is steep, but almost all the mountains are covered with dense secondary forest.

Pyroclastic flow terrace (or volcanic fan) is developed well along the Air Dingin river especially on the left bank. The pyroclastic flow has the shape of fan. The geometric factors of the fans of the Air Dingin and Kuranji are as follows :

	Unit	Air Dingin (Volcanic Fan)	Kuranji (Alluvial Fan)
Height of the apex	m	80	100
Height of the lower edge	m	10	10
Diameter	km	2.6	6.4
Slope		1/30	1/60

The fan is dissected radiately by long and narrow valley. The volcanic fan or pyroclastic flow is divided into two parts, upper part and lower part by steep slope belt. It is estimated that the deposition of the pyroclastic flow was done twice, namely, the lower part was formed firstly and upper part was deposited secondary.

There is none of such a volcanic fan on the right bank of the Air Dingin river but there are terraces. It is estimated that the volcanic fan was eroded out by the Air Dingin river and terrace was formed.

Alluvial fan is developed well along the Kuranji river remarkably, and small alluvial fan is developed along the lower reaches of the Air Dingin river and middle reaches of the Arau river but none in the lower reaches of the Arau river.

The eastern part of the fan of the Kuranji river is limited by the Arau river. The sketch of the outcrop (Fig. D-1) shows upper red soil layer, sand and gravel layer and reddish pyroclastic flow layer from the surface to the river bed. The Arau river and its tributary have dissected these three layers. Around the apex of the fan, the ground water exists about 7 to 10 m below the surface of the ground. Based on the observation at the outcrop and state of the ground water, it is estimated that the depth of the sand and gravel layer of the fan is shallow about 5 to 10 m.

The geomorphology of the fan consists of three geomorphological elements i.e, alluvial fan, slightly hilly area and narrow long dissected valley. Many slightly hilly areas are distributed radiately and almost of all villages on the fan are located on the slightly hilly area. It is estimated that the slightly hilly area is the remnants of the older fluvial fan or natural levee on the fan and the area is free from the flooding. The slightly hilly area and fluvial fan are 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, Baru Pulan Air and none lower reaches. The fan along the Air Dingin river is developed from the lower edge of the volcanic fan or pyroclastic flow to the coastal sand spits. There are many abandoned channels on the fan of the Air Dingin and Arau rivers.

Natural levee means slightly hilly area along the river course which was formed by sand transported from upper reaches in flood time. There are several natural levees in the areas from the lower edge of the fluvial fan of the Kuranji river to coastal sand spits and from the small canyon of the Arau river to the confluence point with the Jirak river. But the scale of the natural levee is small.

From coast to inland area, area with about 3 km width in the lower Kuranji and area with 1.6 km width in the lower Air Dingin are coastal plain. The area consists of slightly hilly sand spits and back marsh are located between these sand banks. The sand spits form more than 15 lines. The sand spits located along the coast consists of sand only. But the sand spits located 150 m from the coast are covered by humus soil layer with about 50 cm depth. Back swamps are covered by humus soil too. The sand spits located 1.6 km from the coast consist of clayish sand.

Big swampy area is located between the sand spits near Tabing air port and foot of the volcanic fan. The surface of the ground is covered by shrub and grass. The vegetation is seen on the peaty soil universally. But the results of the boring test of about 3 m depth shows that almost all part consists of soft reddish soil including the remains of vegetation and coastal sand sometimes. It is therefore estimated that the vegetation was disintegrated due to the high temperature and precipitation. Thus marshes are located not only between the Kuranji river and Air Dingin river but also in the eastern area from the Kuranji river.

Coral reef is developed at the river mouth of the Kuranji river. This is not alive but dead coral reef. Its surface is covered by sand, and the formation age is very old.

3. Geomorphological Development of Padang Plain

There is coral reef on the left bank of the river mouth of the Kuranji river. The formation age of the coral reef is seemed to the last interglacial age in the Würm Ice Age or post glacial age. At that time, the river mouth of the Kuranji was different in location from the present, because if the river mouth was located at present place, the growing of the coral reef was impossible due to the river water which has silt so much. It is therefore estimated that big lagoon was located in the back side of the coral reef at that time.

After that, pyroclastic flow flew down to the Padang plain due to the big volcanic eruption, and formed the basement of the fan of the Kuranji. The pyroclastic flow including angular gravels shows orange or reddish colour. The pyroclastic flow is seen at the several places in the fan, for example, at Baru Pulan Air of the Arau river and at

Kalawi of the Kuranji river.

After that, the pyroclastic flow was covered by sand and gravel layer with about 5 to 10 m thick and the fan was formed. The formation age of the fan is seemed to Würm Ice Age (18,000 years B.P.). At that time sea water level was lowered about 100 m than that at present due to the glacial eustasy.

Around 6,000 years B.P. sea water level was upheaved and reached 4 - 6 m higher than that of the present sea water level due to the change of climate. The some part of the fan and pyroclastic flow were eroded and the new fan was formed. After 6,000 years B.P. sand spits were formed. The line of sand spits were increased to sea side because of the lowering of the sea water level and deposition of sand.

Big marshes are located between the lower edge of the fan and sand spits. The biggest marsh was located at the inland side of the sand spits near the Tabing air port. The area was covered by vegetation. But peat bog layer was not formed due to the remarkable disintegration by the high temperature and precipitation. At present, there is soft reddish silt with about 3 m depth. Another back swamps were formed in the lowland among the sand spits.

After the formation of the sand spits, the sand spits were cut by the Kuranji and Air Dingin rivers. The location and direction of the lower reaches of the Kuranji river are related with fault line. The water of back-marshes were drained step by step and the area became land.

Fig. D-2 shows the model of the cross-section from the apex of the Kuranji to the coast. The formation process of the basin of the Air Dingin river and Arau river are different from that of the Kuranji. There are pyroclastic flow, fan and new alluvial fan in the middle reaches of the Arau river. The distribution is limited from the knick point to upper reaches. The features of the fluvial action of the three rivers will be discussed in the next chapter.

4. Comparison of Fluvial Action among Three Rivers

There are distinct regional differences in the fluvial action among the three rivers. From geomorphologic view point, the deposition by the Kuranji river is the biggest among the three rivers. Due to the push of the fan of the Kuranji river, the Arau river was narrowed near Baru Pulan Air. There are several knick points in the canyon. There are big differences in fluvial action between the upper reaches and lower reaches of the knick-point. Fig. D-3 shows the model of knick point and change of the gravel. The maximum diameter and roundness of the largest gravel in the upper part of the canyon are 85 cm and 6 respectively, but in the canyon the maximum diameter becomes about 210 cm and roundness becomes angular as 5. The river bed in the upper reaches of the canyon consists of andesite gravel and granite gravel. The ratio of two species is 1:10. But there is none granite gravel in the lower reaches. Furthermore, the river course of the upper reaches shows the braided stream. The above mentioned facts show that the deposition of the upper reaches of the knick point is big, but considerable part of the sand and gravel are 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 the both banks and stirred up from the river bed. Then the maximum diameter of the largest gravel increases. But the volume of sand and gravel which flow down to the lower reach is small. Namely, the deposition of the lower reaches of the Arau river is the smallest among the three rivers by the canyon. From fluvial geomorphologic view point, the state of flooding of the Arau river is moderate and the location of the Padang city is best among the three rivers.

In the case of the fan of the Kuranji river, there are many slightly hilly areas and many villages are located in the area. The area are estimated as the remnant of the older fan or natural levee on the fan and the area is free from the flooding. The fan of the Kuranji river is dissecting especially in the upper part, not only by the mainstream of the Kuranji but also small streams on the fan. Due to the erosion, the fan is becoming as dissected fan. There is no overflow from the mainstream to the adjacent area. Furthermore, the lowering of the river bed is accelerated by the Gunung Nago Weir.

There are several streams on the fan. Small deposition is seen at diversion point of the flood relief channel. The volume of the sand and gravels, which is transported by the small streams, is small. Because these gravels are not transported from the upper reaches of the Arau river but from the older fan.

In the case of the Air Dingin river, the erosion of the pyroclastic flow or volcanic fan and terrace are vivid. Due to the sand and gravel which are formed by the erosion, new alluvial fan has been formed between the volcanic fan (Pyroclastic flow) and sand spits. The shifting of the river course is frequent in the fan.

5. Geomorphological Features of Coast

5.1 General

Generally speaking, the coast line of the Padang shows the straight line except that the left banks of the Arau and Kuranji rivers just about 500 m and 300 m respectively out into open sea as small cape. The former is hard rock and the latter is coral reef. Other part is sand. The coast line is divided into several parts morphologically.

(1) Arau river - flood relief channel

The coast is protected by jetties and sea wall. The coast erosion in this stretch seems to be neutralized at present. Small deposition of sand is seen in the southern part of each jetty.

(2) Flood relief channel - coral reef

There are several concrete blocks which were used for jetty in former days between the flood relief channel and the Lotong river. The coast line seems to have been regressed from 1940 downward by the location of the concrete block and verbal information. The coast consists of sand almostly, but sometimes small gravel is seen. The gravel is not so flat as seen in the coast generally but round. The gravel is andesite. This fact shows that the gravel was transported from the Kuranji river. There is few sandy beaches between the flood relief channel and coral reef. There are many coconut palm trees, but some trees were died by salt damage. Fisherman living there said that the coast has been regressed about 20 m from 1940 downward. The death of the palm tree is related with the coastal erosion.

(3) Coral reef

The left bank of the river mouth of the Kuranji is slightly hilly area. The area consists of coral reef covered by sand. The coral reef is not alive but dead as has been mentioned in foregoing chapter. But new coral reef is growing in offshore of about 0.4 km from the coast. The fisherman is fishing at the coral. There was swampy area in land side of the coral reef covered by Nippa Palm. But 7 years downward the area was changed as artificially filled up field.

(4) Kuranji river - Air Dingin river

The coast line consists of sand. The width of the sandy coast is the biggest and about 300 m near the river mouth of the Kuranji. When compared the coast from the flood relief channel to the Kuranji river with that from the Kuranji river to the Air Dingin river the slope of the latter is gentler than that of the former and wave of the latter is moderate than that of the former.

(5) Air Dingin river - north

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

5.2 Geomorphological Consideration of Supply of Sand and its Movement

The sand of the coast is supplied from the river and transported by 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 from north to south, because the mouth of the Air Dingin river is winded to south and there is small gravels coming from the Kuranji river along the coast between flood relief channel and the Kuranji.

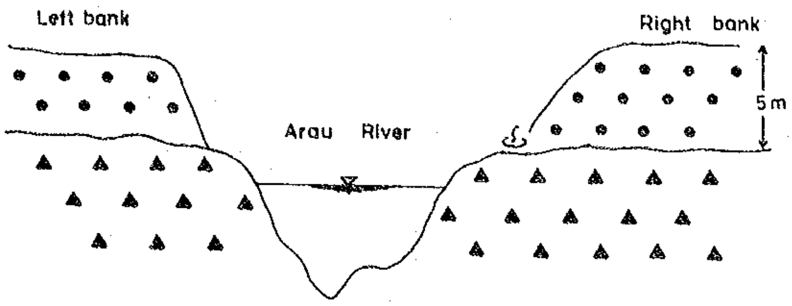
By the existance of the coral reef, the direction of the river mouth of the Kuranji is winded to north slightly. Therefore, after pouring of muddy river water to open sea, the muddy water is distributed from the mouth of the Kuranji to north. This phenomenon is confirmed not only by aerial photographs but also by the color of sea water. That is, the color of the sea water in the northern part of the Kuranji shows light brown color but light blue color in the south. Then the sand and silt which are transported by the Kuranji river are deposited in the northern coast from the river mouth mainly. The coast between the Kuranji and Air Dingin rivers shows depositional feature.

5.3 Geomorphological Consideration on Coastal Erosion

The erosion is predominant than deposition at the coast of the Padang plain except the coast between the Kuranji and Air Dingin rivers. One of the important reason of the coastal erosion is related with the supply of sand from three rivers. But as has been mentioned above the volume of the sand and gravel which are transported from the upper reaches of the three rivers are small. Main part of the sand and gravels are supplied from the existing fan and pyroclastic flow in the plain. The volume is estimated not so big. Especially, the volume of the sand and gravel which are transported by the Arau river is small. It seems that the coastal erosion between the Arau and Kuranji rivers is related with the features of the Arau river, especially existence of the knick point and the direction of the river mouth of the Kuranji river.

Furthermore, the artificial works such as construction of embankment and weir and exploitation of gravel give decrease in the flowdown of the sand and gravels. And a lot of sand and gravel are taken from the river bed for construction works and lowering of river bed is occurring now. It is therefore estimated that one of the important causes of the coastal erosion is related with the above mentioned natural conditions and artificial works.

Fig. D-1 Sketch of Outcrop near Kaboen along Arau River

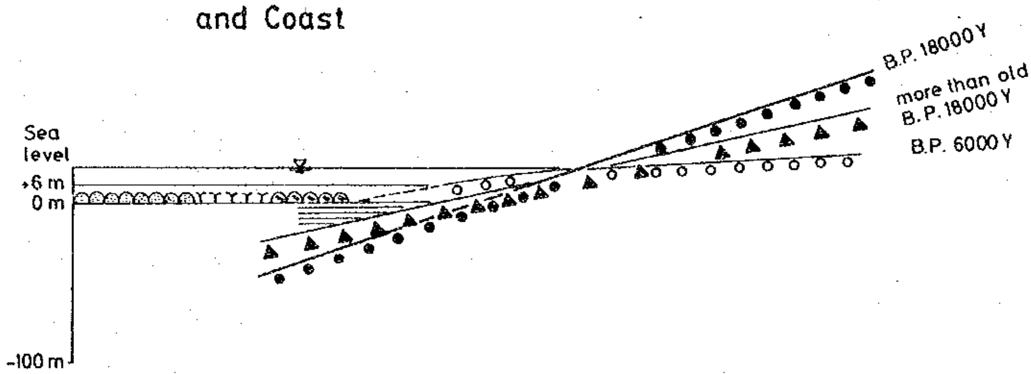


Pyroclastic flow surface was eroded

Sand and gravel layer of the older fan the layer is terraced of the left bank

Spring

Fig. D-2 Geomorphological Change between Apex of Kuranji River and Coast



Pyroclastic flow

Sand and gravel layer of older fan

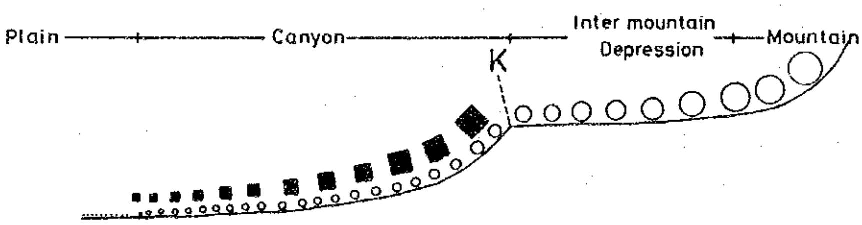
Sand and gravel layer of new fan (Alluvial fan)

Natural levee

Back swamp

Sand spits

Fig. D-3 Knick Point and Change of Gravel



K Knick point

Round gravel coming from the upper reach

Angular gravel supported from the both bank and river bed of the canyon

APPENDIX E

PRESENT CONDITIONS OF RIVERS

APPENDIX E

PRESENT CONDITIONS OF RIVERS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. Present Conditions of Rivers

1.1 River System

The study area contains the Arau, Kuranji and Air Dingin rivers which are located on the western slopes of the Barisan Mountains in West Sumatra Province, having catchment areas of 172 km^2, 213 km^2 and 131 km^2 respectively.

The three river basins and their profiles are shown in Figs. E-1 and E-2 respectively. The catchment areas at major points of the rivers are shown in Table E-1.

1.2 Characteristics of Rivers

Arau River

The Arau river originates in Mt. Bolak and flows down southwestwards on the western steep slopes of the mountain along deep and narrow valleys. At Lubuk Sarik, it joins the Tinggi river of about the same dimension. The main stream up to Lubuk Sarik is called the Lubuk Paraku river, and then the Arau river flows westwards and joins the Gadul Gadang river at Taratak. Downstream from Taratak, the topography changes from hill to plain.

At Lubuk Begalung, a flood relief channel is diverted from the main stream, installed with two diversion weirs. The diversion weir installed on the main river channel may be called the main-river weir and that installed on the flood relief channel may be called the flood-diversion weir. The reaches from Taratak to Lubuk Begalung have a bed slope of about 1/100 and are reportedly being lowered year by year. Downstream from the main-river weir, the slope of the main river channel decreases to 1/500.

At a point about 500 m downstream from the railway bridge, the Jirak river joins from the left. Afterwards, the mainstream flows down taking a meandering course through the urban area of Padang and empties into the Indonesian Ocean. Downstream from the railway bridge, the river bed slope decreases gradually toward the sea, from 1/600 to

1/2,000. In the estuary, there is a quay for small and middle class boats (50 - 100 ton), and warehouses exist on the right bank of the stretch between the river mouth and the suspension bridge (1.3 km from the mouth). According to information from the harbor authority of Teluk Bayur, maintenance dredgings of river channel were carried out, of which amount was about 100,000 m^3 in 1976 and 1977 and about 80,000 m^3 in 1982.

Flood Relief Channel

The flood relief channel was constructed in 1918, to divert a part of flood run off of the Arau river. The channel starts from the flood diversion weir at Lubuk Begalung and takes a route northwest. Then at Kampung Pinang Balik, it bends westward. The stream finally empties into the Indonesian Ocean.

The channel is 6.7 km long from Lubuk Begalung to the sea. Although it seems to have been built originally with a constant bed width, there is now some variation due to sedimentation, erosion and bank collapse. On the left bank, there is a road along the outside edge of the bank. The channel is said to have been designed to meet 240 m^3/s with a 2 m freeboard.

Three drop-structures were built in the middle reaches of the channel and drops the bed level by 4 m in total. The lower drop constructed under the Jati Bridge is still in a good condition despite its age. Immediately upstream of the structure, a syphon crosses the flood relief channel about 1 m under the channel bed. Other 2 drop structures are not in a very good condition. The middle drop-structure is a stepped gabion weir with concrete skin on the crest, but the central portion of the crest has collapsed resulting in uneven flow conditions. Gabion bank protection works are being executed downstream. The upper drop-structure is a concrete weir with a 1 m fall, but the central portion of the crest has also collapsed slightly.

In the stretch between the flood-diversion weir and the railway bridge, drainage channels are connected to the flood relief channel to drain excess water of paddy fields located between the Arau and Kuranji rivers. No outlet gates are equipped at present.

Rehabilitation works of the flood relief channel are being carried out by the provincial government from the upstream.

Kuranji River

The Kuranji river originates on the western slopes of Mt. Bongsu and flows southwestward along steep and narrow valleys. At Lubuk Si Arang, it joins the Padang Jarnih river. The main stream up to Lubuk Si Arang is called the Padang Karuh river. Afterwards, the Kuranji river flows down through a mountainous area and joins the Limau Manis river at Gunung Nago. Downstream from the confluence with the Limau Manis river, there is an irrigation weir constructed in 1973. At Gunung Nago, the topography changes from hill to plain. From Gunung Nago, the river flows westward meandering through the alluvial plain and joins the Balimbing river at Ujung Karang. The river-bed slope between the irrigation weir and the confluence with the Balimbing river gradually decreases from 1/100 to 1/1,000. Afterwards, the Kuranji river empties into the Indonesian Ocean.

The lower reaches of the river have remarkable meanderings with evidence of oxbows and old river channels. At the river mouth of the Kuranji, the water depth is shallow. A coral reef is seen on the bed at the river mouth. In the stretch between the river mouth and the Ulak Karang bridge, dredging works of river channel has been executed by DPU since 1982 in order to increase the carrying capacity of the channel.

The Balimbing river is one of the major tributaries of the Kuranji river. The river originates in Mt. Balang and flows down southwestward on the steep and narrow valleys. At Balimbing, it joins another tributary. The main stream up to this point is called the Kabu Gadang river. Downstream from Balimbing, the topography changes from hill to plain. Afterwards, the river flows westwards taking a meandering course through the alluvial plain and joins the Laras river at Kurao Gadung. Then, the river joins finally to the Kuranji river. The river bed slope from Balimbing to the confluence with the Kuranji river gradually decreases from 1/200 to 1/3,000. The low-lying area in the right bank of the Balimbing river functions as a natural retarding basin at present.

Air Dingin River

The Air Dingin river originates on the southern slopes of Mt. Lantik and flows southwestward along steep and narrow valleys. At 1.6 km upstream from a road bridge at Lubuk Minturun, the river joins the Labung river. At Koto Tuo downstream from the road bridge, there is an irrigation weir and the topography changes from hill to plain. Afterwards, the river flows westwards meandering through the alluvial plain and empties into the Indonesian Ocean. The river bed slope downstream from the irrigation weir gradually decreases from 1/50 to 1/1,000.

At the river mouth, a sand spit issues from the right bank and remarkably develops southward forming a very long beach. There is a very old topographic map which was drawn based on a survey made by the Topographic Bureau in Batavia in 1888. This map shows that the sand spit had ever extended far southward reaching the river-mouth of the Kuranji. At present, the long sand spit is cut at an in-between location creating an opening. The estuary inside the sand spit is being used as an anchorage for fisher boats.

Cross-sections and Longitudinal Profiles of River Channels

Available cross-sections of the river channels are collected and those are presented in Table E-2. In order to check the collected data and to obtain additional cross-sections, supplemental survey was made by the Study Team during the study periods of February, March, June and July 1983. Work items and quantity of the surveying made by the Study Team are listed in Table E-3.

Based on the surveyed cross-sections of river channel, the longitudinal profiles of the rivers are prepared as shown in Fig. E-3 to E-7 and the cross-sections are compiled in Data Book.

1.3 Exploitation of Sands and Gravel on River-bed

A lot of sand and gravel on the river-bed of the Arau, Kuranji and Air Dingin rivers is being exploited, especially exploitation of cobble stones is remarkable in the middle reaches of the said rivers. Those sand, gravel and cobble strones are used as construction materials for roads, buildings and so on. The sites of the exploitations are as follows:

a. Arau river : a stretch between Lubuk Begalung weir and the bypass-road bridge.

b. Kuranji river : a stretch between the Melayu municipal intake and the Gunung Nago weir.

c. Air Dingin river : a stretch between Kampung Pulai and the Koto Tuo head works.

Since the data on exploitation of sands, gravel and cobble stones are not available, the present and past exploitation volumes are roughly estimated as shown in Table E-4, on the basis of field inspection and interview survey. It is estimated that about 110,000 m^3/yr of sand, gravel and cobble stones are being exploited at present in the Arau, Kuranji and Air Dingin rivers.

With regard to the large-scale exploitation in the past, about 120,000 m^3 of gravel and cobble stones were taken from the Arau river for construction of the bypass road during the period from 1977 to 1979, and about 70,000 m^3 of gravel and cobble stones were also taken from the Air Dingin river for construction of the Katib Sulaiman road in 1978 and 1979.

1.4 Carrying Capacity of River Channels

Carrying capacity of the existing channels is estimated with regard to the Arau, flood relief channel, Kuranji, Balimbing and Air Dingin rivers, based on calculation by the non-uniform flow method. In the calculations, the Manning's coefficients of roughness shown in Table E-5 are adopted considering the conditions of river channels.

The estimated carrying capacities are shown in Table E-6. They are summarized below.

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

2. Flood Control Facilities

2.1 Flood Diversion Facilities at Lubuk Begalung

For the purpose of diverting the flood water of the Arau river a flood relief channel was constructed in 1918 branching from the river at Lubuk Begalung which is located at about 7.5 km upstream from the river mouth of the Arau. To secure the function of diversion, the flood diversion weir was constructed across the flood relief channel and the main river weir across the main river at the same time with the construction of the flood relief channel.

2.1.1 Present Conditions of Weirs

The main river weir is about 65 m in total width and consists of 7 openings and 4 sand flush gates, which are shown in Fig. E-8. Except an opening located at the left of the weir, the remaining 6 openings are equipped with stoplogs. These stoplog gates seem to be difficult to control in time of flood, because the stoplogs are too heavy to lift up and no lifting equipment is installed. In fact, it is reported that the stoplogs have not been moved these 10 years. At present, the river bed upstream from the weir has been raised up to the crest of stoplogs due to deposition of sand and gravel.

The 4 sand flush gates are respectively equipped with a wooden gate leaf, 3.5 m in width and 1.6 m in depth, fitted with dual rising spindles. The gate leaves were replaced with new ones in 1982.

The steel girders of the main river weir have been corroded extremely and surface concrete of upper part of the piers is off in places. But the floor slabs are not much abraded. The river bed immediately downstream of the main river weir is remarkably lowered due to scouring. The downstream apron of the weir was repaired in 1979 since the middle part of the apron was broken. At the same time as the repairing, ground sills composed of cribs and gabions were constructed at two places about 100 m and 300 m downstream from the weir. Fig. E-9 shows them.

2.1.2 Hydraulic Model Test for Discharge Diversion Ratio

For the purpose of knowing the diversion ratio of discharge of the Arau river, the Directorate of Rivers, DGWRD executed a hydraulic model test at the Bengawan Solo River Laboratory, Surakarta in 1982.

According to the Report on Experiment of Hydraulic Model Test for Lubuk Begalung diversion weir of the Arau river, 1982, a fixed-bed hydraulic model was built on the scale of 1 : 35. Cross sections and longitudinal profiles of the prototype were surveyed by the laboratory staff in April 1982 with regard to the stretches necessary for the model test. The roughness of the model was adjusted assuming that those of the prototype were as follows.

Channel stretch	Roughness
1. Arau river	
Upstream of weir	0.035
Downstream of weir	0.030
2. Flood relief channel	0.026

The tests were carried out with regard to 12 cases of different conditions of weirs, comprizing the existing condition and modified conditions of the weirs. Out of them, Table E-7 shows the measured diversion ratios with respect to a case of combination of 7 discharges and 2 conditions of sand-flush gates, opened and closed. By use of the values of diversion ratio given in the table, discharges after diversion under the existing condition are calculated with regard to two discharges of 500 m^3/s and 700 m^3/s before diversion. The result is shown below.

Discharge before diversion (m^3/s)	Main river		F. relief channel	
	Discharge (m^3/s)	Ratio (%)	(m^3/s)	Ratio (%)
1. All sand-flush gates closed				
500	293	59	207	41
700	427	61	273	39
2. All sand-flush gates opened				
500	329	66	171	34
700	444	63	256	37

2.1.3 Stability of Main River Weir

About 65 years have past since the weir was constructed. It is generally considered that the concrete material used for the weir is chemically neutralized and weakened. However, the weir is judged to be still structurally strong enough, for the dimensions of weir body and piers are deemed bigger than the up-to-date design values and few damages are found on the slab concrete of the inspection bridge which was probably constructed at the same time with the weir.

Therefore, the stability is examined for overturning, sliding and bearing capacity of the weir body with pier. No design drawing nor information on structures of foundation is available. The following conditions are assumed for the stability examination :

a. Foundation without piles is assumed since the foundation ground is covered with 1.5 m thick gravel layer above the 10 m thick sand layer (n-value more than 50) according to the geological survey results.

b. Dimensions of floor slab are assumed as follows :

- Thickness : 1 m

- Length along flow direction : 7.5 m same with the length of the pier.

- Width : two cases are assumed

  Footing -1 : 3.5 m taking 1 m wide floor slab on both sides of pier (width 1.5 m)

  Footing -2 : 9.5 m taking 4 m wide floor slab until the center of the weir spanning on both side of the pier.

c. Crest elevation of stop logs : two cases of the existing and heightened stop logs are considered. The water level corresponding to discharge 700 m^3/s before diversion is taken into account.

Cases	Stop log crest (m,MSL)	Water level (m,MSL)
Existing	12.6	14.4
Heightened	13.3	15.2

d. Assumed unit weight :

- Reinforced concrete slab for inspection bridge : 2.5 t/m^3

- Pier and floor slab concrete : 2.3 t/m^3
- Stop log : 1.1 t/m^3

e. Formulas and criteria applied :

Safety against overturning :

$$e = \frac{M}{W} - \frac{L}{2} \leqq \frac{L}{6} \text{ : within middle thirds}$$

Safety against sliding :

$$F = \frac{W \cdot \tan (2/3)\ \phi}{H} \geqq 1.5$$

Safety against bearing capacity :

$$q = \frac{W}{L.B} \left(1 \pm \frac{6e}{L} \right) \leqq q_a = 30\ t/m^2$$

Where

M : Total rotaling moment (t.m)

W : Resultant vertical force (t/m^2)

H : Resultant horizontal force (t/m^2)

L : Length of floor slab (= 7.5m)

B : Width of floor slab (= 3.5 m or 9.5 m)

ϕ : Internal friction angle of gravel (= 35 degrees)

q_a : Allowable bearing capacity of ground (30 t/m^3 is assumed considering the surveyed n-value more than 50)

e : Eccentricity (m), safety factor against overturning

F : Safety factor against sliding

q : Bearing capacity (t/m^2)

The load and acting force for the pier in case 2 are shown in Fig. E-10.

According to the method and assumptions mentioned above, safety factors of the main river weir are thus calculated as follows :

Item	Allowable value	Case 1	Case 2	Case 3	Case 4
Stop log	-	Ex.	Ex.	Hi.	Hi.
Floor slab width (m)	-	3.5	9.5	3.5	9.5
Overturning (e : m)	1.25	0.25	0.30	0.53	0.59
Sliding (F)	1.5	2.31	1.53	1.75	0.81
Bearing cap. (t/m^2)	30	9.0	5.0	10.7	6.0

Ex., Hi. : Existing and heightened stop-log crest

From the above table, it is preliminarily concluded that the main river weir is stable against overturning, sliding and bearing capacity. However, safety factor for sliding is less than the allowable value when the water level is raised by stop-log crest heightening.

2.2 Bank Protection Works

Gabion works are widely used for bank protection (bronjong). Fig. E-11 presents the locations of the existing bank protection works in the rivers. In the flood relief channel, gabion is employed as foot protection works as well as slope protection.

2.3 River Dikes

Diking system of earth dikes exists only on the both banks of the flood relief channel. Fig. E-12 shows the standard dike section. In the flood relief channel, the widening of the channel width and bank protection works are presently being carried out. Major dimensions of dike section to be improved are as follows.

a. Top width of dike crown : 5 m

b. Average slope : 1/1.0 to 1/1.5

The other rivers have no dike except small dikes locally constructed.

2.4 Bridges, Syphon and Others

There are many bridges crossing the rivers, especially in the lower reaches of the Arau, Kuranji and Air Dingin rivers. Major dimensions of the bridges are listed in Table E-8.

The two units of syphon and three units of aqueduct cross under or over the flood relief channel. The syphons are located just downstream of the Jati and Andarass bridges with the purpose to supply originally the irrigation water and now the flashing water to urban drainage canals. The aqueducts were constructed to supply irrigation water into the paddy field which exists on the left bank of the flood relief channel.

Table E-1 Catchment Area of Arau, Kuranji and Air Dingin Rivers

River	Tributary	Point	Catchment Area (km^2)
Arau	Main stream	Lubuk Sarik	64
		Lubuk Begalung	116
	Jirak river	Confluence to Main stream	23
	Area between Arau River and Flood Relief Channel		12
	Area between Flood Relief Channel and Kuranji River	Railway Bridge	17
		River mouth	21
	River mouth		172
Kuranji	Main stream	Gunung Nago	120
		Confluence of Balimbing River	130
	Laras River	Confluence to Balimbing River	17
	Drainage channel	Confluence to Balimbing River	11
	Balimbing River	Confluence of Laras River	63
		Confluence of Drainage channel	74
		Confluence to Kuranji River	74
	Area between River mouth and Confluence of Balimbing River	Railway Bridge	5
		River mouth	9
	River mouth		213
Air Dingin	Main stream	Lubuk Minturun	116
		Railway Bridge	119
	River mouth		131

Table E-2 (1) Collected River Surveying Results (1st Phase)

River name	Surveying items	Extent From	Extent to	Sheets	Scale	Year	Company name
Arau R.	Plan	River mouth	2.90 Km Upstream of Lubuk Begalung weir	6	1/2000	1973	P.T. INDAH KARYA
"	Longitudinal Profile	"	"	8	V=1/200 H=1/2000	"	"
"	Cross-section	"	"	21	V=1/200 H=1/200	"	"
Flood relief channel	Plan	River mouth	Lubuk Begalung weir	4	1/2000	1973	"
"	Longitudinal Profile	"	"	5	V=1/200 H=1/2000	"	"
"	Cross-section	"	"	13	V=1/200 H=1/200	"	"
Balimbing R.	Plan	River mouth	4 Km upstream of Buah Manggis bridge	8	1/2000	1979	P.T. ARGA BUMI RAYA
"	Longitudinal Profile	"	"	5	V=1/200 H=1/2000	"	"
"	Cross-section	"	"	50	V=1/200 H=1/200	"	"
Kuranji R.	Plan	Confluence of Balimbing river	1 Km downstream of Kuranji Kalawi bridge	3	1/2000	1979	"
"	Longitudinal Profile	"	"	2	V=1/200 H=1/2000	"	"
"	Cross-section	"	"	19	V=1/200 H=1/200	"	"
Air Dingin R.	Plan	River mouth	1.7 Km upstream of Lubuk Minturun bridge	6	1/2000	1979	"
"	Longitudinal Profile	"	"	4	V=1/200 H=1/2000	"	"
"	Cross-section	"	"	38	V=1/200 H=1/200	"	"
Arau R.	Plan	River mouth	Bypass bridge	14	1/1000	1982	PERSERO P.T. VIRAMA KARYA
"	Longitudinal Profile	"	"	14	V=1/200 H=1/2000	"	"
"	Cross-section	"	"	33	V=1/100 H=1/200	"	"
Flood relief channel	Plan	River mouth	Lubuk Begalung weir	12	1/1000	1982	"
"	Longitudinal Profile	"	"	12	V=1/200 H=1/2000	"	"
"	Cross-section	"	"	25	V=1/100 H=1/200	"	"
Kuranji R.	Plan	River mouth	Gunung Nago bridge	26	1/1000	1982	"
"	Longitudinal Profile	"	"	26	V=1/200 H=1/2000	"	"
"	Cross-section	"	"	93	V=1/100 H=1/200	"	"

Table E-2(2) Collected River Surveying Results (2nd phase)

River name	Surveying Items	Extent/Sites		Sheets	Scale	Year	Company name
		From	to				
Arau R.	Plan	River mouth	1.2 Km Upstream of railway bridge	8	1/2000	1983	CV. SURYA KENCANA
"	Longitudinal Profile	"	"	5	V=1/200 H=1/2000	"	"
"	Cross-section	"	"	67	V=1/200 H=1/200	"	"
Flood relief channel	Plan	River mouth	Lubuk Pegalung weir	5	1/2000	1983	"
"	Longitudinal Profile	"	"	3	V=1/200 H=1/2000	"	"
"	Cross-section	"	"	35	V=1/200 H=1/200	"	"
Arau R. Kuranji R. Air Dingin R. Flood relief channel	Cross-section		at bridge	4	V=1/200 H=1/200	1983	"
Arau R. Kuranji R. Flood relief channel	Plan		at drainage facility	9	1/200	1983	"

Table E-3 Work Item and Quantity of River Surveying

Surveying item	Object river/site	Kind of work	Work quantity	
			1st phase	2nd pahse
River				
1. Control survey	- Whole study area	- Selection of control points and leveling	65 km	-
2. Cross section and profile surveying of river channels	- Laras and Jirak rivers	- Longitudinal profile	6.6 km	3.0 km
		- Cross section	35 sections	18 sections
	- Arau, Kuranji, Balimbing, Air Dingin and flood relief channel	- Check survey of elevation	4 km	6.5 km
		- Check survey of cross section	21 sections	37 sections
	- Others	- Longitudinal profile	-	3.5 km
		- Cross section	-	26 sections
	- Retarding basin	- Longitudinal profile	-	21 km
	- Check dam	- Longitudinal profile	-	1.2 km
		- Cross section	-	4 sections
	- Irrigation canals	- Longitudinal profile	-	4.6 km
		- Cross section	-	20 sections
3. Installation of sub-bench marks	- Stream gauging stations, river-crossing structures, and other major facilities	- Selection of sub-bench marks	58 sites	-
		- Leveling	6.3 km	-
Urban area				
1. Cross section and profile surveying of river channels	-River in urban area	- Longitudinal profile	20 km	2.8 km
		- Cross section	40 sections	11 sections
2. Profile surveying of urban area	- Urban area	- Longitudinal profile	-	45 km
3. Planimetric surveying	- Terminal drainage facilities	- Traversing	-	4 places
		- Planimetric surveying	-	30,000 m^2

Table E-4 Estimated Exploitation Volume of Sand, Gravel and Cobble Stones on River-bed

Exploitation site	Unit	Volume	Remarks
Exploitation Volume at present/1			
1. Arau River			
- Lubuk Begalung Weir Bypass-Road Br.	m^3/yr	16,000	13trucks × $4m^3$ × 300days
- Upstream of Bypass-Road Br.	"	3,500	3 × 4 × 300
- Sub-total	"	19,500	
2. Kuranji River			
- Melayu Weir - Kelawi Br.	m^3/yr	42,000	35trucks × $4m^3$ × 300days
- Kelawi Br. - G. Nago Weir	"	36,000	30 × 4 × 300
- Upstream of G. Nago Weir	"	1,000	1 × 4 × 300
- Sub-total	"	79,000	
3. Air Dingin River			
- Kp. Dulai (1.5 km - 2 km)	m^3/yr	8,000	5-10trucks × $4m^3$ × 300days
- Kp. Dulai (3.4 km) - Koto Tuo Head Works	"	500	1 × 4 × 100
- Sub-total	"	8,500	
4. Total	m^3/yr	107,000	
Exploitation Volume in the past			
1. Arau River			
- Lubuk Begalung Weir By-pass-Road Br.	m^3	120,000/2	for Bypass-road construction, exploitation in 1977 and 1979
2. Kuranji River			
- Near Kelawi Br.	m^3/yr	36,000	exploitation in 1980 and 1982
- Near Kelawi Br.	"	6,000	exploitation in 1970 and 1980
- Melayu Weir - 2 km upstream	m^3/yr	10,000	by P.T. Sarana Andalas from 1978 to 1982
3. Air Dingin River			
- Kp. Dulai	m^3	70,000/2	for Katib Sulaiman road construction, exploitation in 1978 and 1979
- Kp. Dulai	m^3	14,000/2	by Bina Marga for Asphalt Mixing Center, up to April 1983

Source /1 : Estimated by field inspection and interview survey

/2 : Information collected from Bina Marga, West Sumatera Province

Table E-5 Manning's Roughness Coefficients Adopted for Calculation of Carrying Capacity under Existing Condition of Channel

Channel Stretch	Manning's n
1. Arau River	
Rivermouth - Jirak River	0.026
Jirak River - Diversion Weir	0.030
Diversion Weir - Bypass-Road Br.	0.035
2. Flood Relief Channel	
Rivermouth - Diversion Weir	0.026
3. Kuranji River	
Rivermouth - Road Br. at Kp. Nanggalo	0.026
Road Br. at Nanggalo - AWLR Station No. BK-3	0.030
AWLR Station No. BK-3 - Kalawi	0.040
4. Balimbing River	
Kuranji R. - Suspension Br.	0.026
Suspension Br. - Lolong Kanan Br.	0.030
5. Air Dingin River	
Rivermouth - Tributary (1.4 km from rivermouth)	0.026
Tributary - 2.2 km from rivermouth	0.030
2.2 km - 3.2 km from rivermouth	0.035
3.2 km from rivermouth - Koto Tuo Weir	0.040

Table E-6(1) Estimated Carrying Capacity of Existing Channel

Channel Stretch	Carrying Capacity (m^3/s)	
	Bankful	With freeboard 1.0 m
1. Arau River		
Rivermouth - Suspeneion Br.	500	-
Suspension Br. - Jirak River - 0.5 km	300	-
Jirak River - 0.5 km - Rail way + 0.5 km	300	-
Rail Way + 0.5 km - Diversion Weir	more than 600	-
Diversion Weir - By-pass Br.	800	-
By-pass - Gauging St.	more than 1,000	-
Jirak River	80	-
2. Flood Relief Channel		
Rivermouth - Padang Baru Br. + 0.2 km	600 - 700	400 - 500
Padang Baru Br. + 0.2 km - Drop Structure (2.8 km from river mouth)	450 - 500	350 - 400
Drop Structure (2.8 km from river mouth) - Muara Palam Br.	700 - 800	500 - 600
Muara Palam Br. - Diversion Weir	500 - 600	300 - 400
3. Kuranji River		
Rivermouth - Balimbing River	500	-
Balimbing River - Nanggalo Br.	400	-
Nanggalo Br. - Water Supply Intake	300	-
Water Supply Intake - Water Supply Intake + 1.3 km	300	-
Water Supply Intake + 1.3 km - Kalawi Br.	600	-
Kalawi Br. - Gunung Nago	more than 800	-

Table E-6(2) Estimated Carrying Capacity of Existing Channel

Channel Stretch	Carrying Caapcity (m^3/s)	
	Bankful	With freeboard 1.0 m
4. Balimbing River		
Kuranji River - Laras River	50	-
Laras River - Laras River + 3.2 km	50 - 100	-
Laras River - Lolong Kanan Br. + 3.2 km	50 - 100	-
Lolong Kanan Br. - Lolong Kanan Br. + 2.2 km	100	-
Laras River	10	-
5. Air Dingin River		
Rivermouth - Muara Penjalinan Br.	300	-
Muara Penjalinan Br. - 3.5 km up from Rivermouth	200	-
3.5 km up from - Koto Tuo Weir Rivermouth	550	-

Remarks : In calculation of carrying capacity, the following river surveying results are used.

Surveyed results in 1982 : Arau river, Flood relief channel, and Kuranji river.

Surveyed results in 1979 : Balimbing river and Air Dingin river.

Table E-7 Diversion Ratio at Lubuk Begalung Diversion Facilities under Existing Condition Obtained by Hydraulic Model Test

Discharge before Diversion (m^3/s)	Mainriver		Relief Channel	
	Discharge (m^3/s)	Ratio (%)	Discharge (m^3/s)	Ratio (%)
1. <u>All sand-flush gates opened</u>				
100	47	47	53	53
200	112	56	88	44
300	178	59	122	41
400	242	61	158	40
500	329	66	171	34
600	278	63	222	37
700	444	63	256	37
2. <u>All sand-flush gate closed</u>				
100	36	36	64	64
200	91	45	109	55
300	157	52	143	48
400	223	56	177	44
500	293	59	207	41
600	358	60	242	40
700	427	61	273	39

Source : Report on Experiment of Hydraulic Model Test for Lubuk Begalung Diversion Weir of the Arau River, West Sumatra, in 1982 by Bengawan Solo River Laboratory, Surakarta.

Table E-8 Major Dimensions of Existing Bridges

Unit : m

Name	Dimension Length	Width	Height	Date	Elevation	Type
1. Arau River						
1. Suspension	41.0	1.5	0.2	-	2.6	Suspension
2. Water pipe	27.0 × 2	φ600		1964	4.6	Pipe beam
3. Seberang Pdg./1	10 × 2 + 50	9.0	1.0	1982	6.8	Truss
4. Railway	105.0	5.5	0.7	-	10.3	Tied arch
5. Road br.	(8.0 × 8)	4.0	0.55	1920	15.3	Plate girder
6. By-pass	35.8 × 3	10.0	2.3	1980	22.1	P.C. simple
2. Flood Relief Channel						
1. Purus/2	56.3	9.4	1.3	1983	4.6	Truss
2. Padang Baru	35.8	16.8	2.25	1980	6.0	P.C. simple
3. Jati	15.6 × 2	4.5	0.7	1920	6.7	Plate girder
4. Water pipe	33.0	φ600		1964	-	Pipe beam
5. Railway	44.1	4.0	0.7	-	7.2	
6. (Parak Kopi)	40.0	1.1	0.25	-	7.8	Suspension
7. Aru/4	9.1 × 3	4.1	0.5	1920	11.5	Plate girder
8. (Kubu)	39.3	1.0	0.25	1945	15.5	Suspension
9. Muara Palam/3	42.0	7.0	2.4	1981	17.4	Concrete simple
10. Road br./4	(8.0 × 5)	4.0	0.55	1920	15.9	Plate girder
3. Kuranji River						
1. Ulak Karang	30.9 × 33	10.0	1.9	1974	5.4	P.C. simple
2. Railway	42.5 × 2	4.0	0.9		4.3	Tied arch
3. Nanggalo	50.8	9.0	1.3	1982	7.4	Truss
4. Kelawi	69.7	4.1	1.0	1970	24.3	Truss
5. Gu. Nago	10.2+15.7×3	3.5	0.5	-	-	Plate girder
6. (Sapih)	23.0	4.0	0.5	1960	3.5	Plate girder
7. Kurao	-	-	-	1960	5.0	Suspension
4. Air Dingin						
1. Railway	43.0 × 2	3.8	0.7	1976	4.5	Tied arch
2. Muara Penjalinan	30.8 × 3	10.5	1.7	1976	5.4	P.C. simple

/1 : Seberang Padang old .... L = 55.9, B = 5.3

/2 : Purus B .... L = 47.2, B = 6.0

/3 : Muara Palam/4 .... L = 34.1, B = 4.2

/4 : With Irrigation Channel (Steel made)

Fig. E-1 River Basin

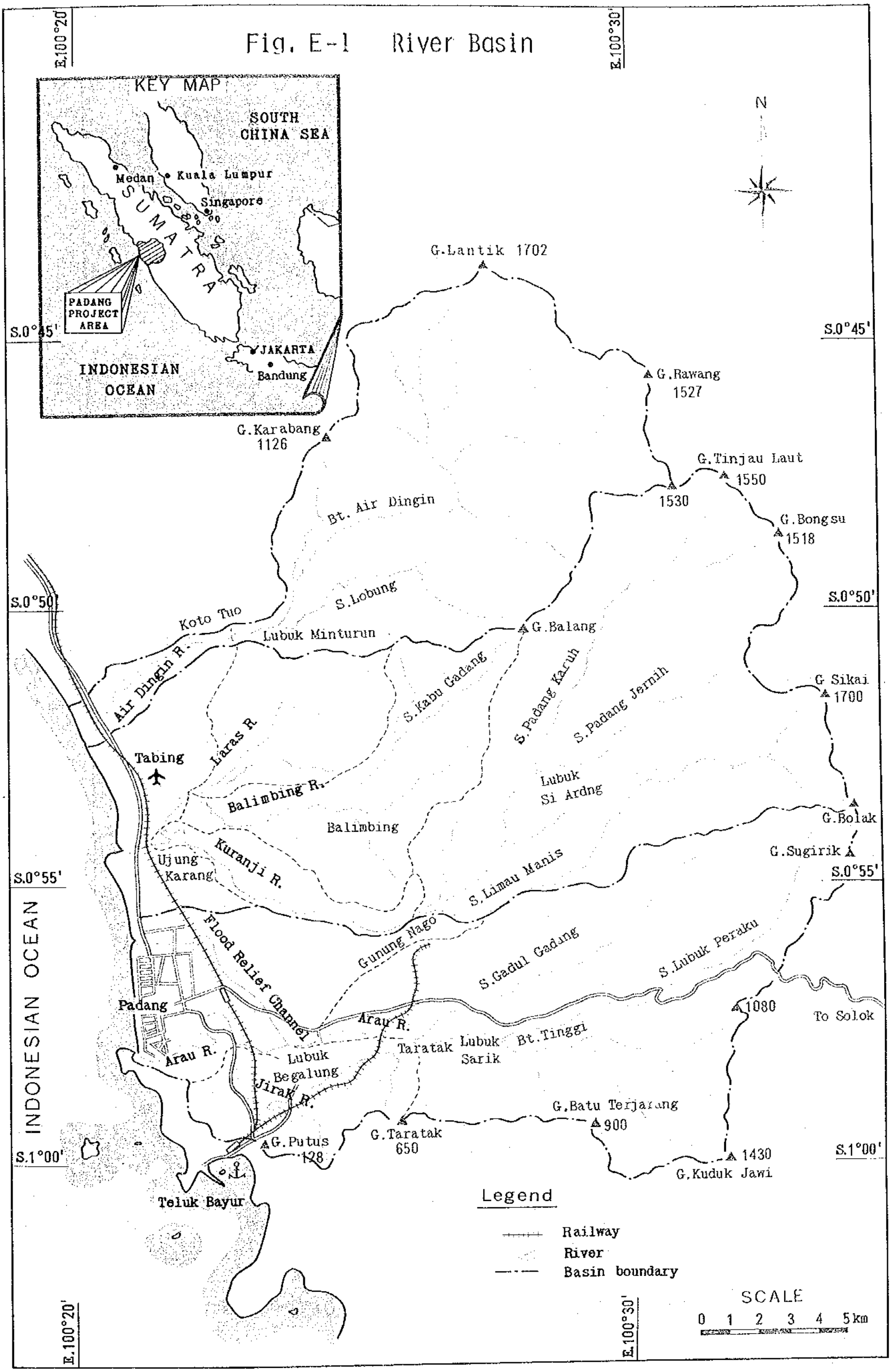
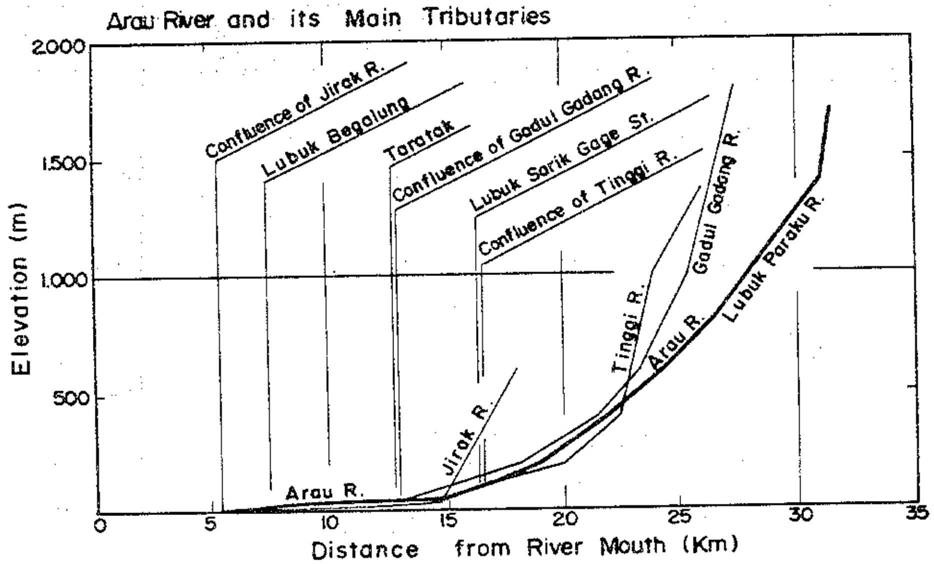
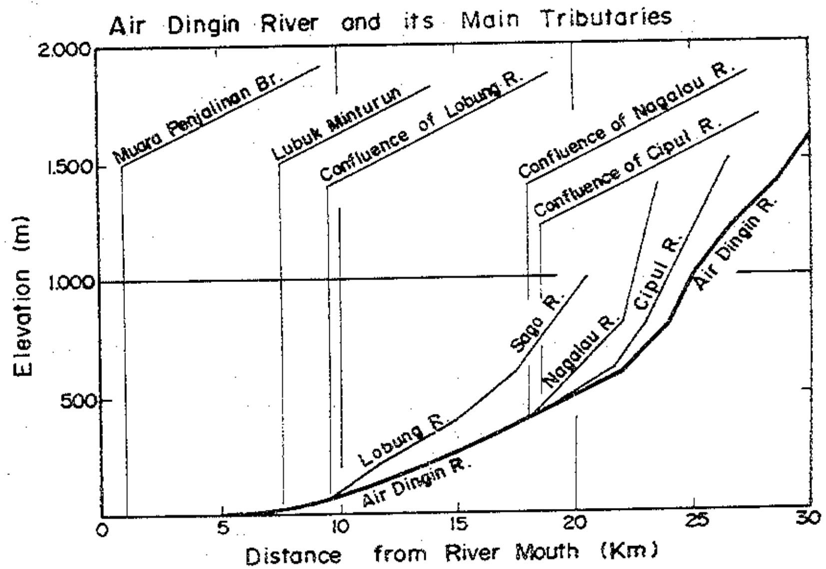
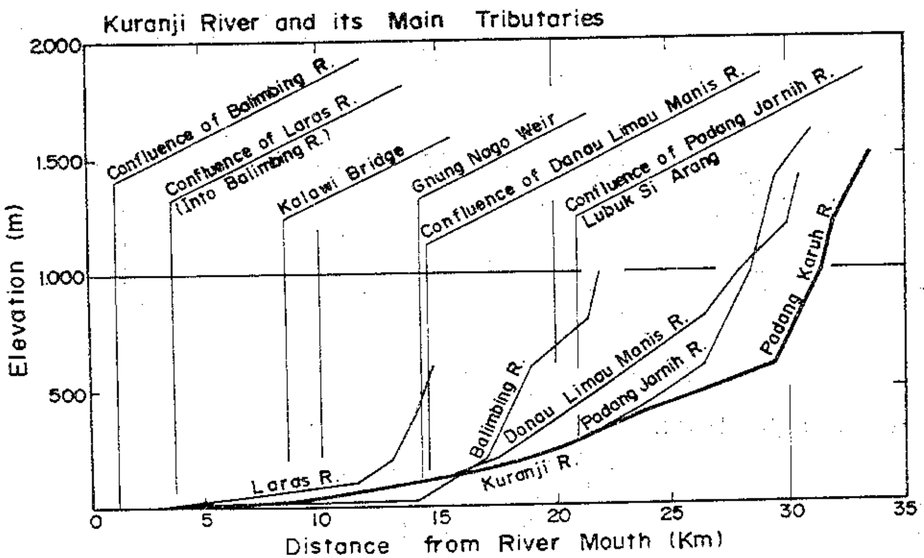


Fig. E-2 Profile of Rivers







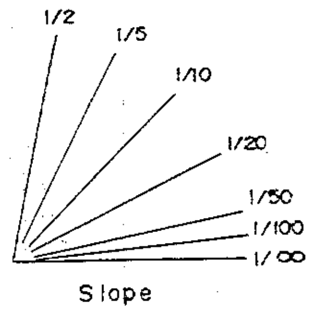


Fig. E - 3(1) Existing Profile of Arau River

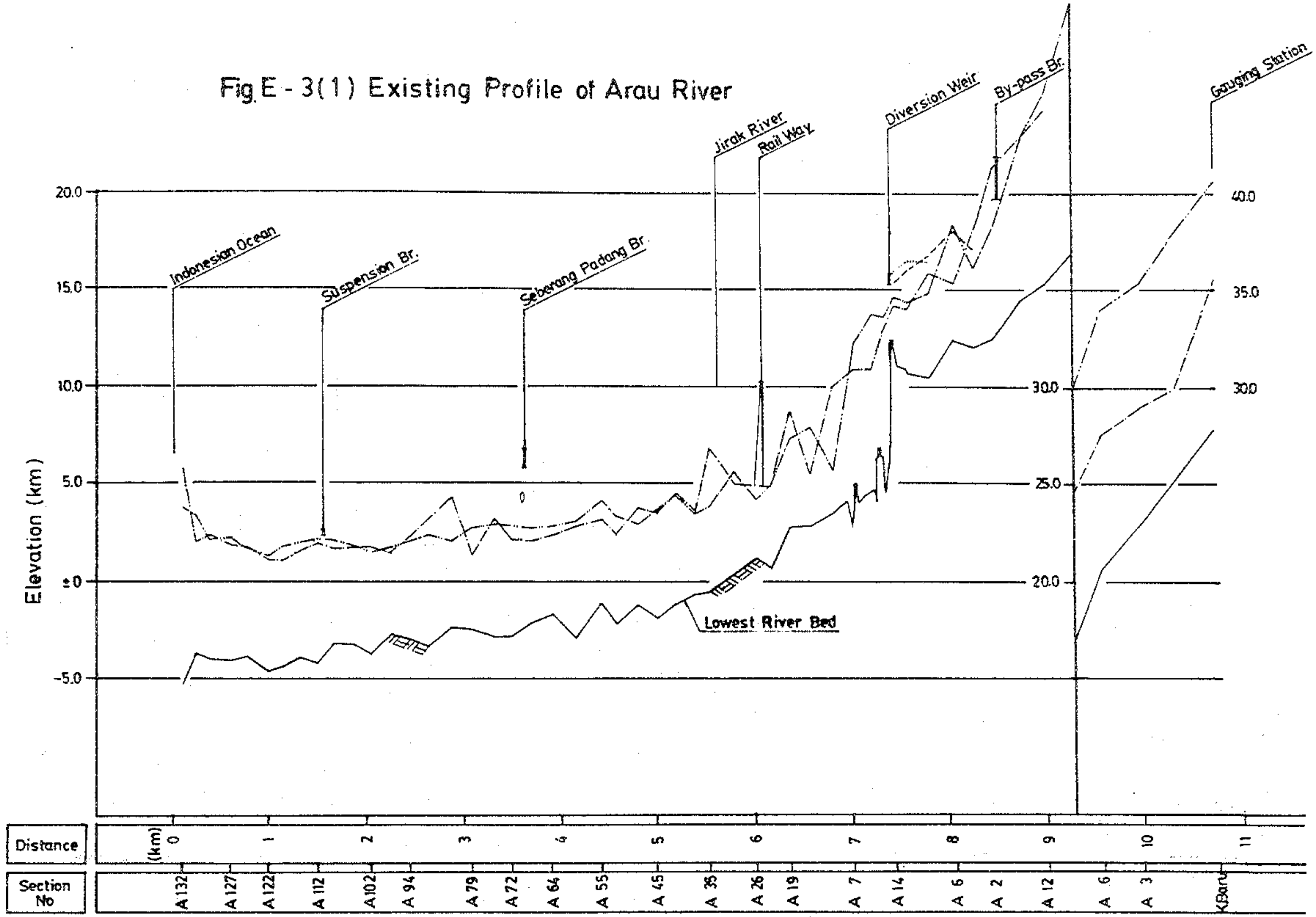


Fig. E-3(2) Existing Profile of Jirak River

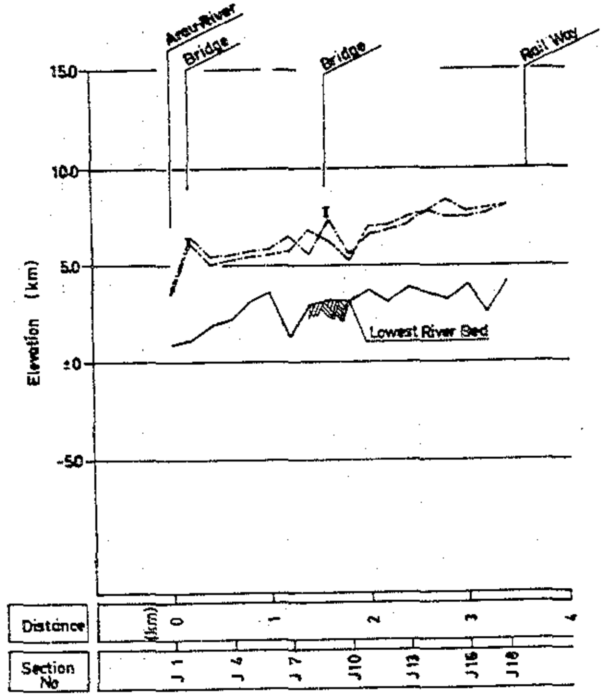


Fig. E-4 Existing Profile of Flood Relief Channel

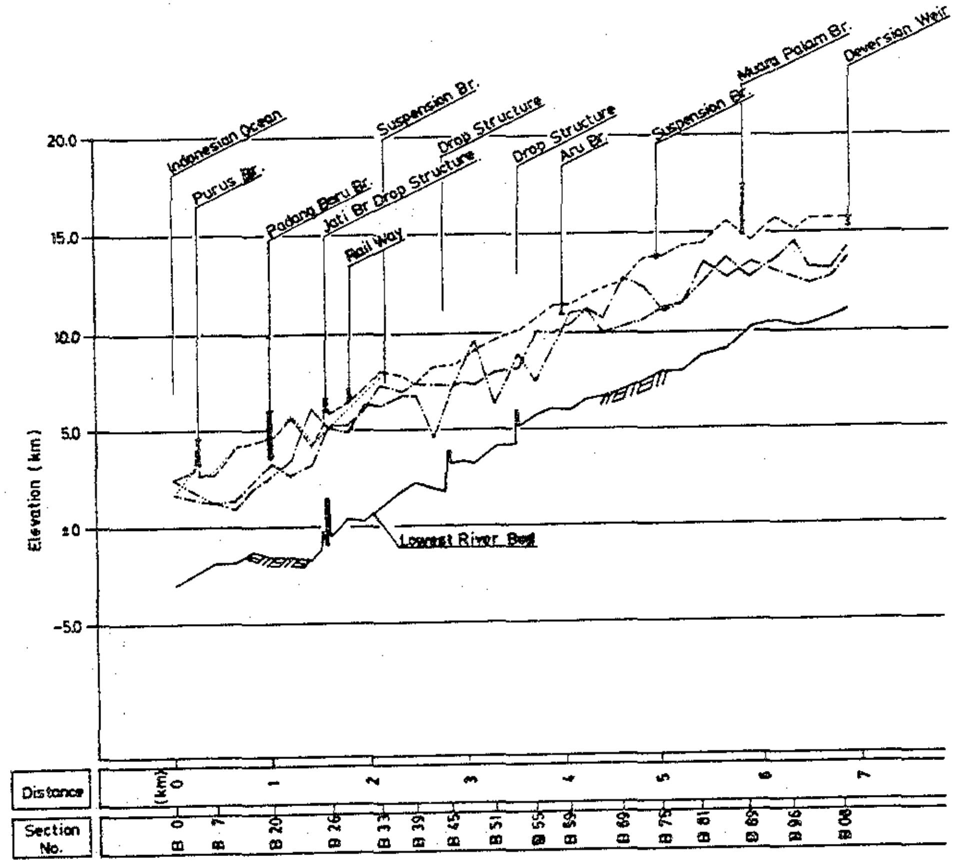


Fig. E-5 Existing Profile of Kuranji River

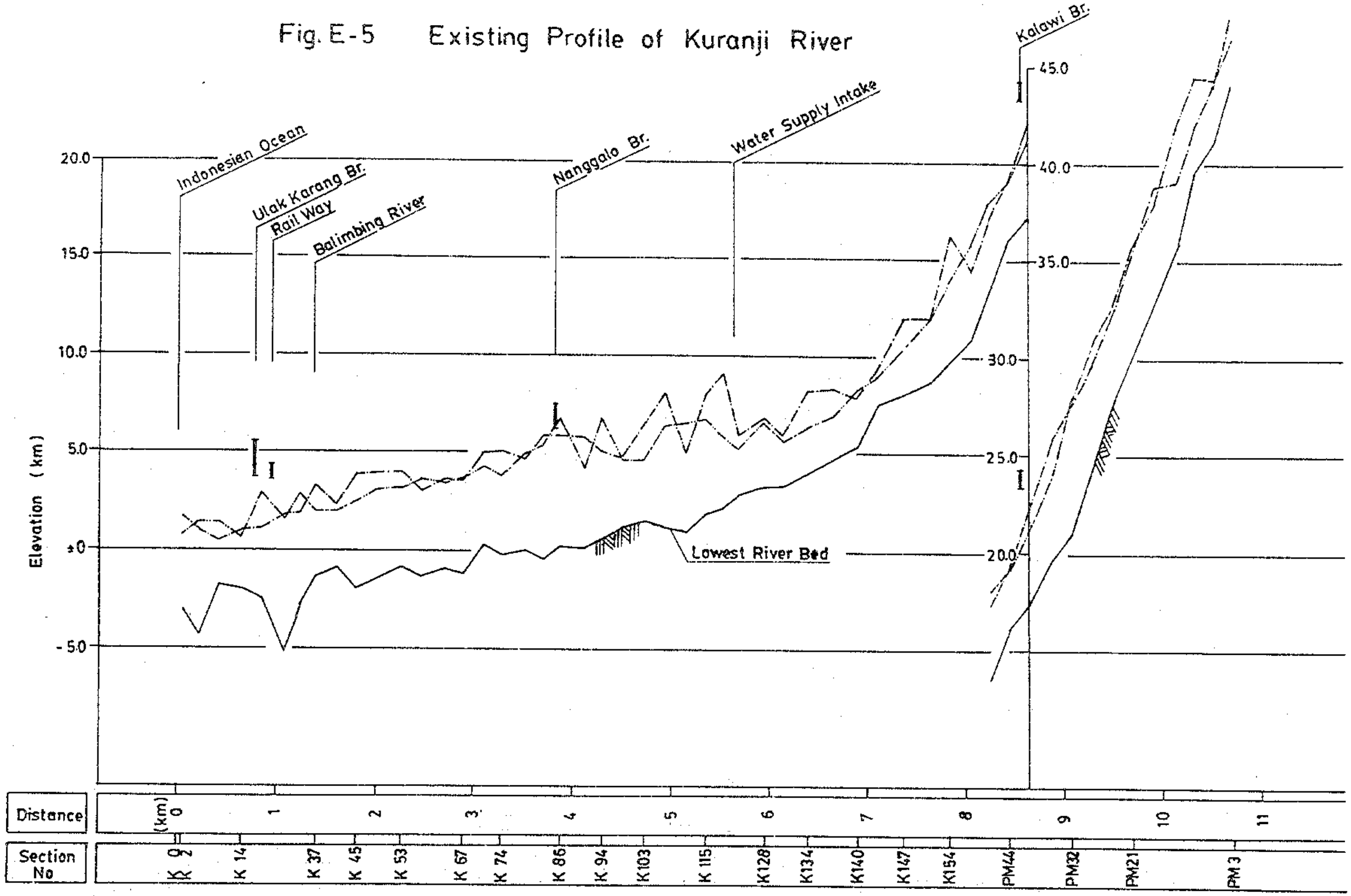


Fig.E-6(1) Existing Profile of Balimbing River

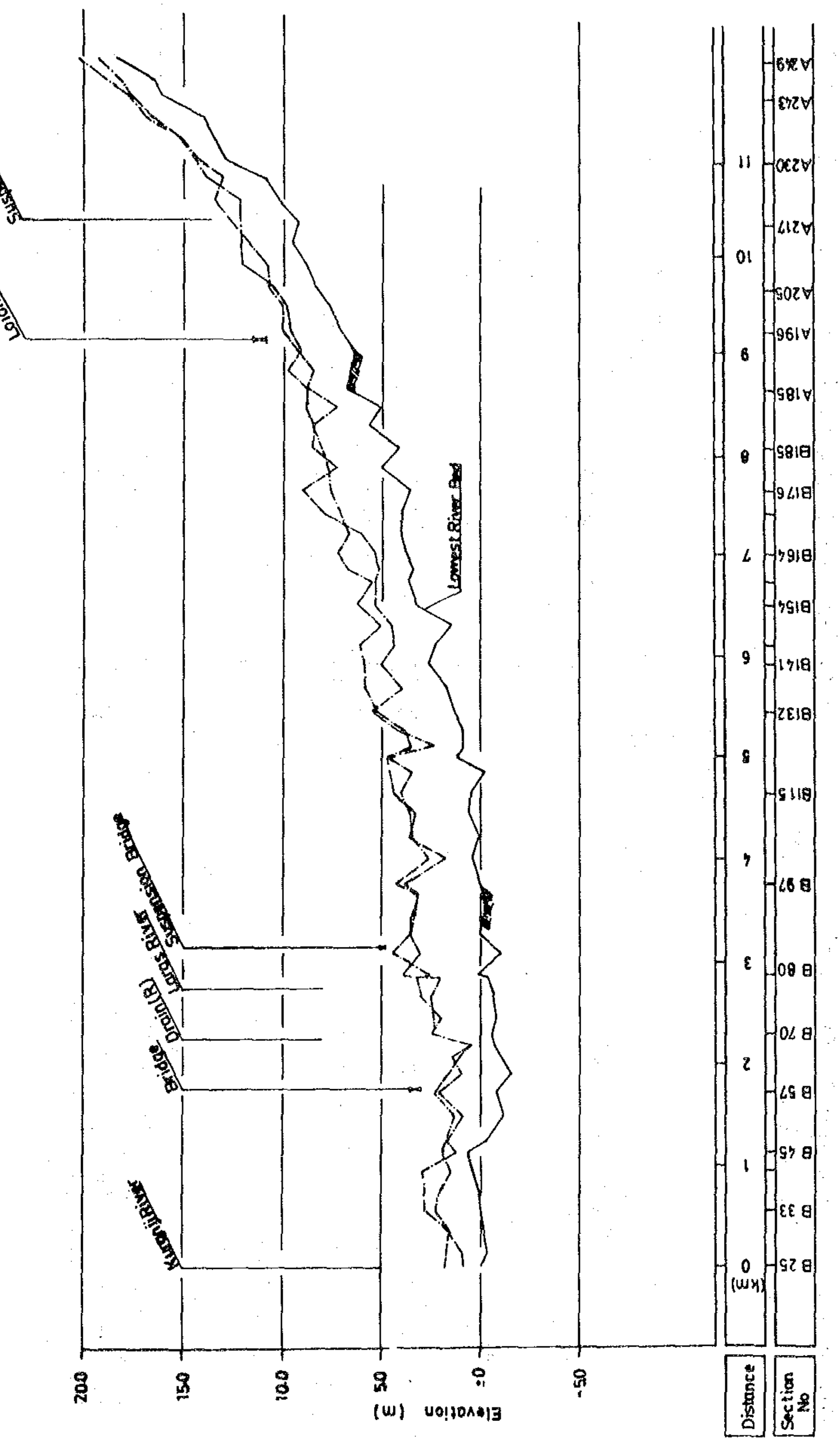


Fig. E-6 (2) Existing Profile of Laras River

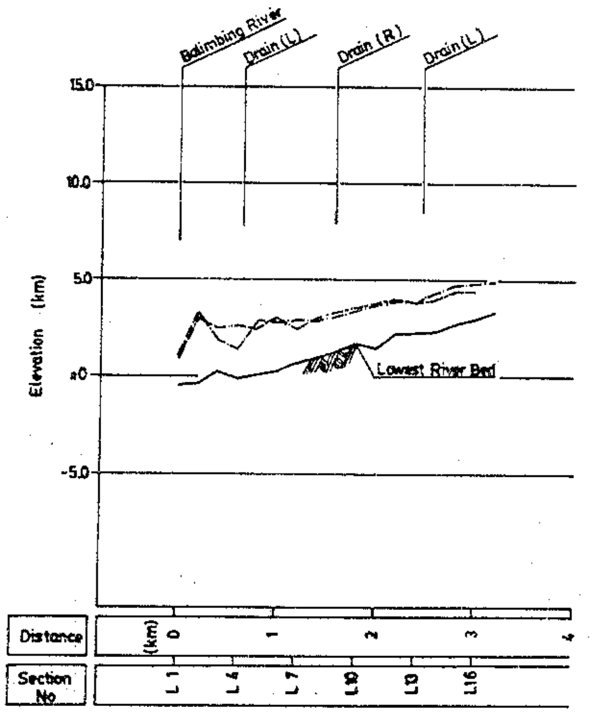


Fig. E-7 Existing Profile of Air Dingin River

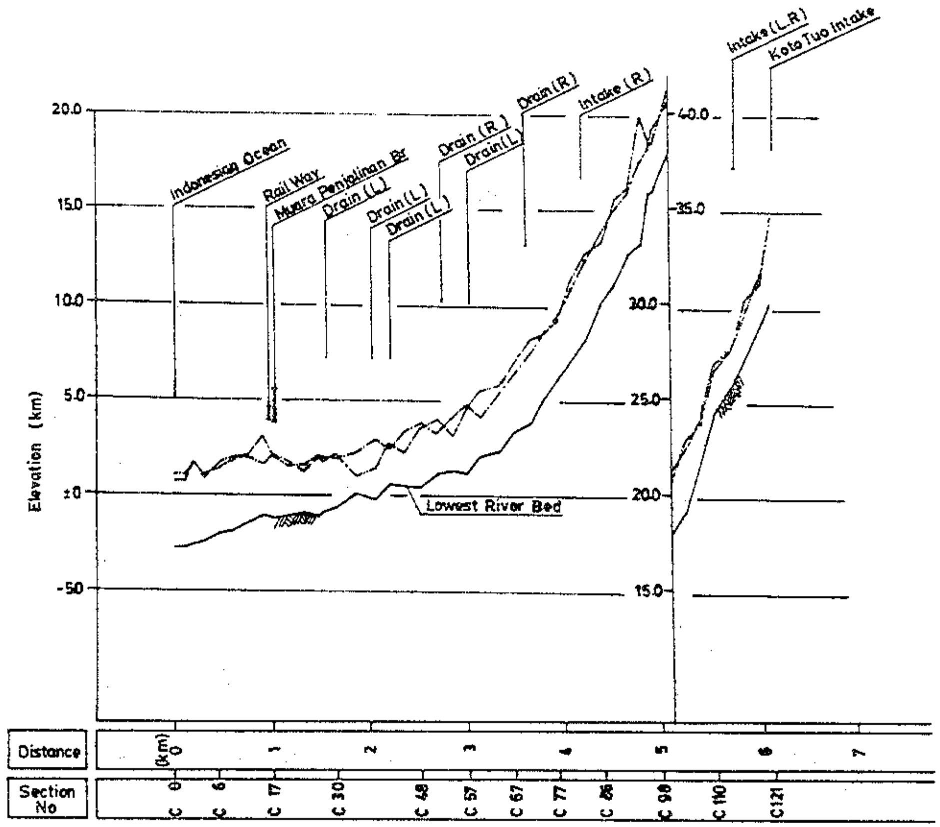


Fig. E-8 Diversion Weir at Lubuk Begalung

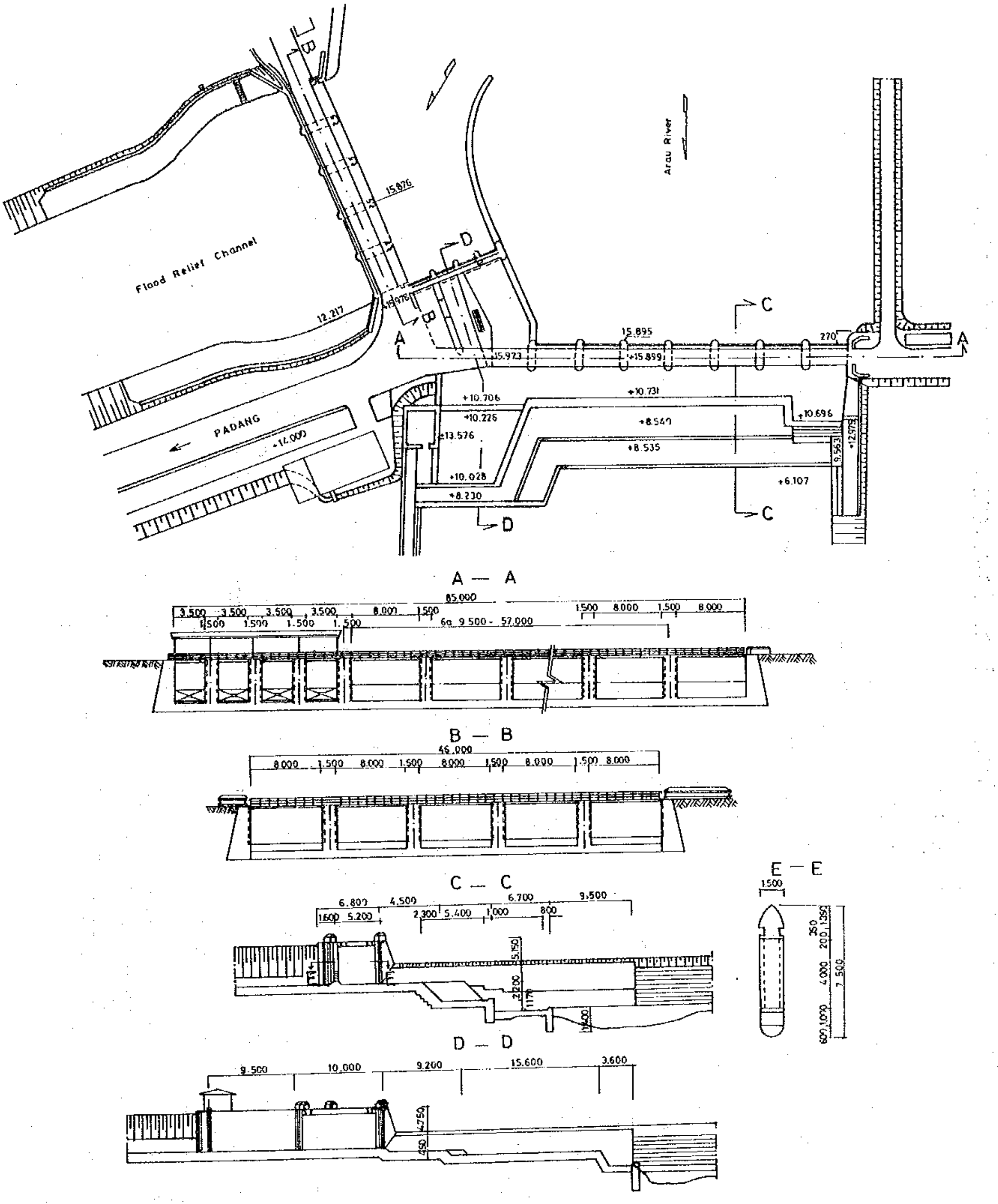


Fig. E-9 Existing Groundsel at Downstream of Lubuk Begalung Weir

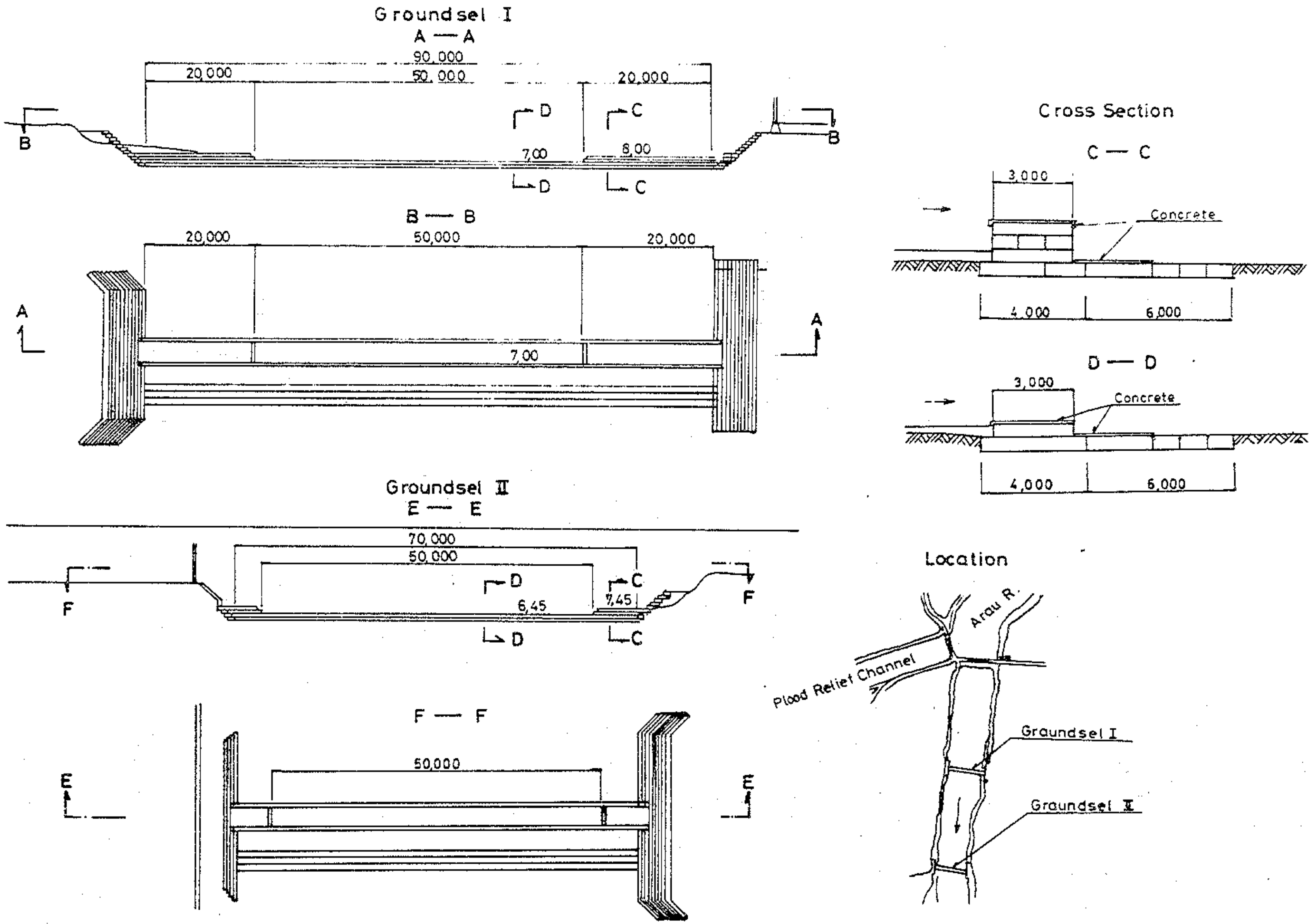
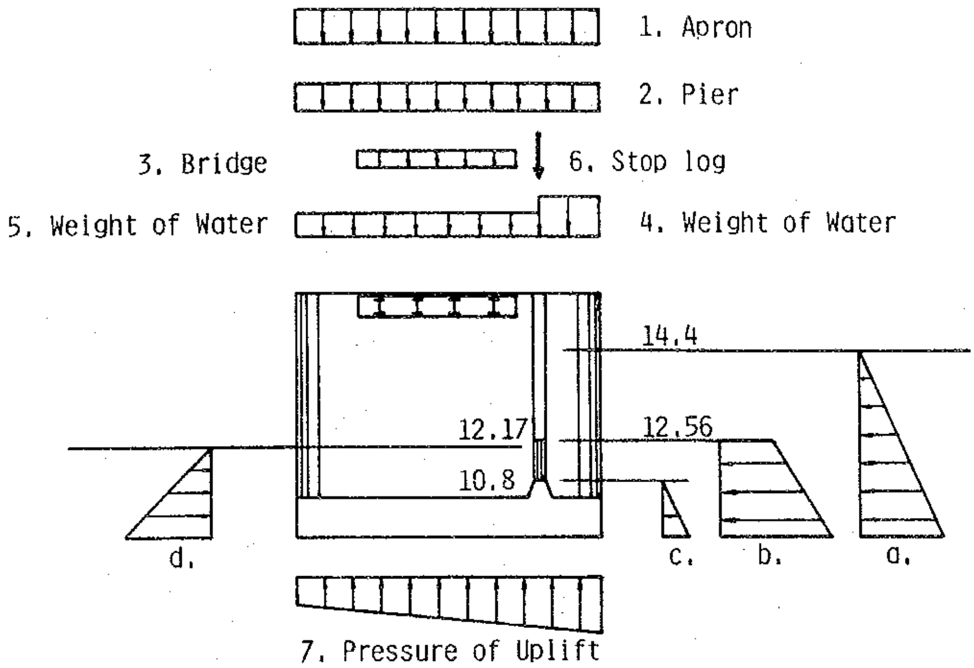


Fig. E-10 Stability Analysis of Pier of Lubuk Begalung Weir

Loading



Acting Force for the Pier

Vertical Component (W)

Item	Value (ton)
1. Apron	164
2. Pier	129
3. Bridge	16
4. Weight of Water	43
5. Weight of Water	66
6. Stop log	3
7. Pressure of Uplift	-243
Total	W = 175

Horizontal Component (H)

Item	Value (ton)
a. Water Pressure for Pier	16
b. Water Pressure for Stop log	71
c. Earth Pressure	3
d. Water Pressure of downstream	-27
Total	H = 63

Safety Factor for Sliding of the Pier

$$F = \frac{W \tan(2/3)\phi}{H} = \frac{175 \times 0.577}{63} = 1.60 > 1.5 = F_{min}$$

where, ϕ : internal friction angle of foundation (= 45°)