REPUBLIC OF INDONESIA
MINISTRY OF PUBLIC WORKS
DIRECTORATE GENERAL OF WATER RESOURCES DEVELOPMENT

STUDY REPORT
ON
PADANG AREA FLOOD CONTROL PROJECT

APPENDICES

DECEMBER 1983

JAPAN INTERNATIONAL COOPERATION AGENCY
TOKYO, JAPAN

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LIST OF APPENDICES

APPENDICES

TERMINOLOGY

Administrative districts

Kab. = Kabupaten	Regency
Kec. = Kecamatan	Subdistrict
Kodya = Kotamadya	City
Kel. = Kelurahan	Village (urban area)
Kp. = Kampung	Village (rural area)
Prop. = Propinsi	Province

Institutions

Balai Kota	City Hall
Bina Marga	Highway development
Cipta Karya	Housing, building and urban development
DGCK	Directorate General of Cipta Karya
DGWRD	Directorate General of Water Resources Development
DPMA = Direktorat Penyelidikan Masalah Air	Directorate of Research of Water Problems
DPU = Dinas Pekerjaan Umum	Public Works Service
DPUTL = Departemen Pekerjaan Umum dan Tenaga Listrik	Ministry of Public Works and Electricity
JICA	Japan International Cooperation Agency
PDAM = Perusahaan Daerah Air Minum	Water Enterprise of Padang Municipality
PLN = Perusahaan Listrik Negara	National Electric Corporation
Pusant Meteorologi dan Geofisika	Center of Meteorology and Geophysics

Natural objects

Bt. = Batang	River
Banjir Kanal	Flood relief channel or flood diversion channel
G. = Gunung	Mountain
S. = Sungai	River
Sawah	Paddy field or rice field

UNITS AND CONVERSION FACTORS

1) Length

mm = millimeter

cm = centimeter

m = meter

km = kilometer

2) Area

ha = hectare = $10^4 m^2$

km^2 = square kilometers = $10^6 m^2$

3) Volume

l, ltr = liter = 1,000 cm^3

m^3 = cubic meter

mcm = million cubic meter

4) Weight

mg = milligramme

g = gramme

kg = kilogramme

t, ton = metric ton = 1,000 kg

qwt = kwintal = quintal = 100 kg

5) Time

s, sec = second

min = minute

h, hr = hour

d = day

yr = year

6) Money

US$ = United States Dollar

Rp. = Rupiah

¥ = Japanese Yen

US$ = Rp 970 = ¥ 240

7) Others

MSL = Mean Sea level

kwh = kilowatt hour

mkwh = mega kilowatt hour

% = per cent

ppm = parts per million

HP = house power

°C = degree centigrade

°D = degree of hardness

10^3 = thousand

10^6 = million

10^9 = billion

HYDROLOGY

APPENDIX A

HYDROLOGY

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ANNEX

1. Rainfall

Rainfall observation in the Arau, Kuranji and Air Dingin river basins was commenced at Tabing station in 1921 by the Indonesian Air Force (AURI). In 1973, the management was transferred to the care of Pusat Meteorologi dan Geofisika. At present, the study area has 16 stations for daily observation, as shown in Fig. A-1. 10 of the stations belong to Pusat Meteorologi dan Geofisika. Among them Tabing station has the longest daily records as shown in Fig. A-2, although the records have been interrupted frequently. Also at Tabing, hourly rainfall has been observed since 1970. All of the stations managed by DPU have hourly observation records since they were installed.

Mean annual rainfall in the basins varies from 3,000 mm to 5,000 mm as shown in Fig. A-3. The most part of the basins receives more than 3,000 mm annual rainfall which is relatively higher compared with those in other regions out of the boundary. The recorded maximum daily rainfalls are 301 mm at Tabing and 353 mm at Bandar Buat stations.

The annual pattern of rainfall is a function of the monsoon circulations that Sumatra Island experiences and also the relative activity of trigger mechanisms. The northwest monsoon, that is, the wet monsoon which originates in the Pacific Ocean is dominant during the months from November to March. On the other hand, the southeast monsoon which affects the island from May to October is known as a dry monsoon since it originates in Australasia and develops overland. In addition, the intertropical convergence zone along which the weather is usually disturbed with frequent thunderstorms, is usually moving around the island between south in January and north in July. For the purpose of knowing actual annual pattern of rainfall, mean monthly rainfall at Tabing is arranged as shown in Table A-1. Annual pattern at Tabing station is also shown together with its maximum and minimum in Fig. A-4. It is seen that the basins receive much rainfall during the months from September to December being affected by the wet monsoon, while a slightly drier period is observed from May through August associated with the dry monsoon. In April the secondary rainfall peak is observed.

Annual maximum 1 day and 2 day rainfall depths at Tabing station are given in Table A-2 for the period from 1948 up to 1982. Using these data, probable 1 day and 2 day rainfall depths are calculated for 6 return periods consisting of 2 year, 5 year, 10 year, 25 year, 50 year and 100 year as shown in Fig. A-5. They are also shown in Table A-3.

2. Streamflow

2.1 Water Level Records

There are 10 gauging stations in the basins, as shown in Fig. A-6. Water level records at the stations are less than 10 years in period available, as shown in Fig. A-7, since most of the stations were installed recently except Lubuk Begalung station of the flood relief channel. Although the observation at Lubuk Begalung station started around 1959, most of records have been lost unfortunately. At present, 6 stations are managed by DPU while the remaining 4 stations installed by Indah Karya stopped their operations in less than a year. Among the 6 stations, 4 stations except Lubuk Begalung and Gunung Nago have automatic water level recorders. At Lubuk Begalung and Gunung Nago, water level is observed every 30 minutes during flood.

2.2 Discharge Rating Curve

DPU has carried out discharge measurement at major gauging stations since 1978. In 1981, Indah Karya prepared rating curves at 8 gauging stations by use of observed data including their own measurements. They are shown in Table A-4. In addition D.P.M.A. has also their own rating curves, although they are not in the form of equations.

Taking into consideration the above circumstances, discharge measurement was carried out by the Study Team at major stations shown in Table A-5 to provide rating curves with regard to Lubuk Minturun and Kampung Baru, and also to examine the existing ones by Indah Karya except for Kp. Tanjung Aur, Kp. Palinggam, Kp. Kalawi and Kp. Baru Nanggalo. Because the staff gauges at the above 4 stations were washed away by floods and daily water level was observed only for less than a year. In our judgement, the rating curves prepared by Indah Karya at

the stations of Lubuk Sarik, Lubuk Begalung and Kampung Melayu can only be serviceable to a narrow range of low water flow.
Therefore, with respect to these 3 rating curves, the Manning formula is used for extending the curves for the range of high water flow.
The rating curves for both Lubuk Minturun of the Air Dingin river and Kampung Baru of the Kuranji river are newly prepared by the Study Team.
The Manning formula is also applied to prepare the curves.

For Gunung Nago station, overflowing discharge from the weir is estimated by use of the following formula :

$$Q = C\ B\ H^{3/2}$$

where

Q : Discharge (m^3/s),
C : Coefficient (C = f (H)),
B : Width of weir (m),
H : Energy head at the top of weir (m).

The elevations of gage datums at major stations were surveyed by the Study Team during the study period. They are as follows :

Name of station	River	Elevation of gage datum (m, MSL)
Lubuk Begalung	Arau	11.548
Kampung Baru	Arau	28.843
Lubuk Sarik	Arau	91.768
Kampung Melayu	Kuranji	1.409
Gunung Nago	Kuranji	94.902
Lubuk Minturun	Air Dingin	47.592

The rating curves which are made or examined by the Study Team are shown in Fig. A-8.

2.3 Streamflow

Daily water level at Lubuk Begalung, Kampung Baru, Lubuk Sarik, Kampung Melayu, Gunung Nago and Lubuk Minturun stations are converted to daily discharge using rating curves. Daily discharge is also arranged to ten-day discharge at each station as shown in Table A-6. For the purpose of knowing annual flow pattern, monthly mean daily discharge at the stations are calculated and are shown in Table A-7 and Fig. A-9. It is recognized from the figures that the basins experience bigger discharge in April and the period from October through December. The biggest discharge appears in November, while the second flow peak is observed in April.

The data on water level from Kampung Baru seems to be unreliable in our judgement.

3. Tide

Tidal observation at Teluk Bayur located in lat. 1.0° S and long. 100.3° E was commenced at the beginning of the twentieth century by Dutch engineer. Although it was interrupted often, the observation has been continued. The records, however, are available only from 1975. Tide records form 1975 are tabulated in Table A-8 and also shown in Fig. A-10. They are summarized below.

Gage readings from Low Water Springs

HHL	MHHL	Mean sea level	MLLL	LLL
1.67 m	1.39 m	0.89 m	0.47 m	0.24 m

It is seen that the tide fluctuates ordinarily between 1.67 m and 0.24 m from low water springs which is taken as the datum of the gage.

It has been said that MSL situates 0.7 m above low water springs. On the other hand, the Study Team estimates that mean sea level in gage readings based on the tide level records is 1.01 m. Therefore the Study Team has investigated the cause of the difference. Finally it is concluded that the mean sea level is to be 0.89 m in gage readings, that is, 0.89 m above from low water springs. It is also found that gage readings of the mean sea level is almost the same as tbat of the MSL which is the datum of the elevation. The contents of the investigation are described in more detail in ANNEX of this APPENDIX.

4. Water Quality

According to the report of Padang Water Supply Project, Nov. 1982, the water quality of the Kuranji river at Kampung Malayu is suitable for municipal water supply as shown in Table A-9, while that of the Arau river was not recommended.

On the other hand, the report "Pekerjaan Survey Hidrometri dan Sedimentasi Sungai Batang Arau & Batang Kuranji di Propinsi Sumatera Barat" in 1981 presents that the water quality of both the Arau and Kuranji rivers is acceptable for irrigation usage as shown in Table A-10.

For the Kuranji river, data in terms of monthly mean on water quality which has been analyzed by the laboratory of Perusahaan Daerah Air Minum (P.D.A.M.) consists of more than 20 items. Among them, main components such as total hardness and organic materials are picked up. Seasonal fluctuation of water quality with regard to the main components is shown in Fig. A-11 for the period of January 1980 through December 1982. A component of bicarbonate shows a comparative wide range in parts per million. Components of ammonia, nitrite and manganese had been negative and iron is sometimes appears within the range of its tolerance level, although they are not shown.

5. Sediment

5.1 Sediment Discharge

5.1.1 Annual Sediment Discharge by Records

Sediment analysis has not been conducted so much in previous studies of the Arau, Kuranji and Air Dingin river basins. One of the analysis with the observed data can be seen in the report "Pekerjaan Survey Hidrometri dan Sedimentasi Sungai Batang Arau & Batang Kuranji di Propinsi Sumatera Barat" in 1981. On the basis of the observed data, relation curve between sediment and water discharges is made by the Study Team at the stations of Lubuk Sarik, Lubuk Begalung and Gunung Nago as shown in Fig. A-12.

Applying stream flow duration curve at each site, annual sediments at Lubuk Sarik, Lubuk Begalung and Gunung Nago are estimated as follows;

River	Site	Catchment Area (km^2)	Ave. Annual Sediment (t/yr.)	(t/km^2/yr.)
Arau	Lb. Sarik	64	84×10^3	1309
Flood relief channel	Lb. Begalung	-	138×10^3	-
Kuranji	G. Nago	120	173×10^3	1439

The Average annual sediment seems to be comparatively small in consideration of the fact that a big amount of annual rainfall depth is observed in the basins.

5.1.2 Sediment Transport Capacity of Channel

Grain size analysis is carried out along the main streams and their major tributaries in the middle and downstream reaches as shown in Fig. A-13. Table A-11 shows grain size distribution analyzed by the Study Team. Using the data on grain size distribution and the existing river channels, the relations between sediment and water discharges is calculated by use of sediment formula. In the present study sediment formulae of the Sato-Kikkawa-Ashida for bed load, Brown and Engelund-Hansen for total load are used to estimate the relations as shown in Table A-12. In the calculation, bed materials are divided into five groups depending on their sizes. The brief introduction of the sediment formulae mentioned above is as follows;

Sato-Kikkawa-Ashida formula

$$\frac{q_B}{U_* d_m} = \phi\, F\, (T_o/T_c) \cdot \frac{U_*^2}{(\frac{r_s}{r_w} - 1)\, g\, d_m} \quad \cdots\cdots (5.1)$$

Where, q_B : bed load per unit river width per unit time ($m^3/s/m$)

U_* : friction velocity (m/s)

d_m : mean diameter (m)

g : acceleration of gravity (9.8 m/s^2)

T_o : tractive force of flow (t/m^2)

T_c : critical tractive force (t/m^2)

F : function of T_o/T_c

r_s : unit weight of bed material (t/m^3)

r_w : unit weight of water (t/m^3)

Brown formula

$$\frac{q_T}{U_* dm} = 10 \left[\frac{U_*^2}{(\frac{r_s}{r_w} - 1) g dm} \right]^2 \quad \cdots\cdots (5.2)$$

Where, q_T : total load per unit river width per unit time ($m^3/s/m$)

Engelund-Hansen formula

$$q_T = 0.05\, r_s\, V^2 \sqrt{\frac{d_{50}}{g(\frac{r_s}{r_w} - 1)}} \left[\frac{T_o}{(r_s - 1) d_{50}} \right]^{3/2} \quad \cdots\cdots (5.3)$$

Where, q_T : total load per unit river width per unit time (t/s/m)

V : mean velocity (m/s)

d_{50}: grain size of 50 % of bed materials

For the purpose of knowing the distribution of sediment transport along channels, sediment transport capacity which corresponds to discharge carrying capacity is calculated using the relation between sediment and water discharges as shown in Fig. A-14. It gives an outline of sediment transport distribution that more amount of sediment appears in the middle reach compared with that in the downstream reach. For the Kuranji river, sediment volumes at the river mouth which are calculated by the formulae show comparatively much, because bed material occupied there is small in size.

5.2 Fluctuation of River Channel

5.2.1 Meandering

River courses show meanderings particularly in the middle and downstream reaches. Some of them are said to be still progressive so much at present, and traces of older river course can be seen in some places. The Study Team tried to find the fluctuation of river course extended over a long-term period up to the present by superimposition of the topographic maps in 1893 and 1974. The fluctuation for about 80 years is given in Fig. A-15. From the figure, the following are noticed.

It seems that the Arau river has not been changed so much because it takes almost the same river course as before except the upstream reaches of the bypass bridge. The flood relief channel also shows the same route.

As for the Kuranji river, it seems to be unstable in the upstream reaches of the water supply intake at Kampung Melayu. In addition the stretch between Nanggalo and the railway bridge is also changeable including its tributary, that is, the Balimbing river.

For the Air Dingin river, remarkable difference in its course is recognized in the stretch between the Koto Tuo intake and railway bridge. The river mouth also seems to have been moved so much during the 80 years.

5.2.2 Profile and Cross-section

For the purpose of knowing the fluctuation of river channels, the comparison of profiles and cross-sections surveyed in 1973, 1979, 1982 and 1983 are carried out. The location of those cross-sections are shown in Fig. A-16. The profiles and cross-sections are superimposed by use of fixed points such as banks and top of levees. Compared profiles and cross-sections are shown in Figs. A-17 and A-18 respectively. The following are noticed from the superimposition of them.

Arau river

The survey results conducted in 1982 and 1983 shows almost the same aspects except the downstream reaches from the suspension bridge. The result between the suspension bridge and confluence of the Jirak river in 1973 seems to be unreliable taking into account informations from interview survey and site inspection. Remarkable fluctuation can not be seen.

Flood relief channel

Except the downstream reaches between the first and third drop structures from the sea, remarkable fluctuation can not be found. The survey results in 1973 between the two drop structures are unreliable because river bed in this stretch is being kept by the drop structures from scoring. In the judgement by site inspection, river bed seems to have been risen to its possible highest point as a whole.

Kuranji river

Dominant fluctuation of the Kuranji river is not appeared. A stretch downstream from the Ulak Karang bridge seems to be deeper in water depth owing to dredging works by D.P.U. West Sumatra although the stretch is not covered by the superimposition of cross-sections in this study.

Regarding its tributary of the Balimbing river, river bed shows a slight lowering during 4 years from 1979 to 1983.

Air Dingin river

In the downstream reaches from Kampung Pulai, the Air Dingin river reveals a trend to be stable except near the river mouth. In the upstream reaches, however, it is recognized that the river bed is lowering because of exploitations of gravel and cobble stone.

5.3 Sedimentation at River Mouth

Sediment problem at river mouth is investigated on the basis of site inspection with an interview survey.

Arau river

According to the interview survey, low water depth had been decreased year by year until 1976 because of deposits from the upstream. This situation was improved by dredging works conducted in 1976, 1977 and 1982. Excluded deposits due to the dredging were calculated at about 70,000 m^3 using cross-sections in both years, while total dredged sediment from 1976 to 1982 is reported to be 180,000 m^3. On the contrary account of the difference of cross-sections in 1982 and 1983 shows that sediment of about 30,000 m^3 was deposited per annum. It is almost the same as estimated annual sediment inflow from mountainous area at Lubuk Sarik. Periodic dredging works will be required to maintain the quay.

Flood relief channel

The river mouth condition seems to be stable taking into account information at the site. It seems that most of sediments passing through the Lubuk Begalung weir are transported to the sea without sedimentation near the river mouth.

Kuranji river

River mouth of the Kuranji is always open. Condition near the river mouth seems to be unchangeable by coral reef which covers the river bed there. In addition sediment from the upstream is seemed to be small.

Air Dingin river

River course of the Air Dingin near the river mouth meanders so much. The location of river mouth has also been fluctuated in a range of 1 km. Such a condition seems to be caused by both comparatively small sediment from the upstream and remarkable littoral drift from the sea.

Table A-1 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 A-2 Annual Maximum Rainfall Depths at Tabing Station

Year	1 day rainfall		2 day rainfall	
	Date	Depth (mm)	Date	Depth (mm)
1948	-	-	Jan. 31 - Feb. 1	203
1949	Sept. 16	160	Sept. 15 - 16	168
1950	Aug. 17	259	Aug. 17 - 18	288
1951	Nov. 19	132	Feb. 15 - 16	144
			June 26 - 27	144
1952	Jan. 9	153	Apr. 5 - 6	179
1953	Dec. 24	159	Dec. 24 - 25	216
1954	Dec. 12	123	Nov. 2 - 3	181
1955	Sept. 21	192	May 11 - 12	236
1956	June 12	140	Dec. 8 - 9	222
1957	Mar. 5	223	Mar. 5 - 6	260
1958	Aug. 18	172	Aug. 17 - 18	203
1959	Mar. 9	130	Mar. 8 - 9	171
1960	July 8	163	July 18 - 19	185
1961	June 24	121	June 24 - 25	153
1962	Sept. 18	127	May 17 - 18	145
1963	July 15	100	Dec. 9 - 10	122
1964	Oct. 18	111	Jan. 3 - 4	157
1965	-	-	Mar. 25 - 26	125
1966	-	-	Feb. 5 - 6	129
1967	Nov. 29	169	Nov. 28 - 29	179
1968	-	-	-	-
1969	Oct. 18	301	Oct. 18 - 19	301
1970	Jan. 26	100	Oct. 26 - 27	167
	May 12	100		
1971	Aug. 16	144	Dec. 6 - 7	204
1972	May 6	280	May 6 - 7	393
1973	July 30	222	July 29 - 30	259
1974	June 22	131	June 21 - 22	208
1975	Dec. 21	142	Dec. 20 - 21	157
1976	Oct. 9	126	Oct. 5 - 6	184
1977	Jan. 16	144	Jan. 15 - 16	151
1978	Jan. 16	153	Oct. 24 - 25	215
1979	Apr. 3	234	Apr. 3 - 4	264
1980	Nov. 23	296	Nov. 22 - 23	314
1981	Sept. 10	180	Oct. 14 - 15	270
1982	Feb. 4	227	Feb. 3 - 4	227

Source : Pusat Meteorologi dan Geofisika.

Table A-3 Probable Rainfall Depths at Tabing Station

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

Note : Gumbel Method is used for the analysis.

Table A-4 Discharge Rating Curves prepared by Indah Karya

Station	Rating Curves
Kampung Lubuk Sarik	$Q = 7.340\ H^{3.533}$
Lubuk Begalung	$Q = 35.026\ H^{2.051}$
Kampung Tanjung Aur	$Q = 10.9293\ H^{2.222}$
Kampung Palinggam	$Q = 2.298\ H^{1.591}$
Kampung Gunung Nago	$Q = 149.554\ H^{1.309} + 4.477$
Kampung Kelawi	$Q = 43.8228\ H^{2.478}$
Kampung Melayu	$Q = 36.4754\ H^{1.903}$
Kampung Baru Nanggalo	$Q = 12.2180\ H^{2.420}$

Source : Pekerjaan Survey Hidrometri dan Sedimentasi Sungai Batang Arau & Batang Kuranji di Propinsi Sumatera Barat prepared by Indah Karya, 1981.

Table A-5 Discharge Measurement by Study Team

Station	Date	Gage Height (m)	Discharge (m^3/s)
Arau river			
Kp. Baru	Feb.21	0.72	6.4
Lb. Sarik	Feb.21	0.60	3.9
Flood relief channel			
Lb. Begalung	Feb.17	0.20	19.9
	Feb.21	0.04	7.1
Kuranji river			
Kp. Melayu	Feb.22	1.50	2.8
Gn. Nago	Feb.22	-0.10	3.3 /1
Air Dingin river			
Lb. Minturun	Feb.24	0.39	2.6

Note /1 : Discharge at the irrigation intake

Table A-6 (1) Ten Day Discharge

Station : Lb. Sarik (Unit : m^3/s)

Year	Period	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1976	1st	-	-	-	-	-	9.4	7.1	8.5	9.4	14.4	16.0	8.3
	2nd	-	-	-	-	-	5.8	14.7	9.7	6.8	40.7	-	11.1
	3rd	-	-	-	-	4.3	9.6	24.8	15.5	10.7	12.8	13.8	12.3
1977	1st	9.7	15.3	6.2	7.9	11.0	6.5	6.1	2.5	4.0	9.0	21.1	30.1
	2nd	12.2	17.8	7.4	8.0	12.0	11.6	10.6	4.8	4.8	9.0	25.6	14.4
	3rd	14.9	9.7	8.8	12.3	6.3	5.0	3.8	9.6	4.4	10.3	23.8	9.0
1978	1st	6.7	10.9	16.2	9.0	10.5	15.4	11.7	15.3	13.5	4.6	25.0	7.1
	2nd	10.9	9.3	19.6	10.2	13.6	8.7	10.1	9.9	5.5	7.8	21.0	11.8
	3rd	8.0	9.3	7.8	8.0	10.8	10.3	20.4	16.4	8.7	16.1	7.4	10.1
1979	1st	15.1	11.7	8.1	30.5	12.7	9.9	6.0	6.8	10.7	3.2	17.6	13.0
	2nd	8.1	14.5	4.3	7.1	3.6	9.7	6.5	3.2	11.1	6.6	17.3	5.7
	3rd	5.9	13.5	9.0	18.4	2.9	5.2	13.2	10.0	6.7	8.3	23.8	5.5
1980	1st	9.1	2.7	7.0	15.0	15.3	5.5	4.8	10.9	8.3	9.0	27.0	18.7
	2nd	6.4	2.0	5.7	17.1	8.5	3.7	7.2	5.9	6.7	11.3	14.3	15.2
	3rd	7.5	4.1	6.5	9.7	5.0	7.6	16.7	7.0	8.2	21.7	25.3	17.4
1981	1st	10.4	3.2	5.4	18.6	16.6	12.3	4.7	8.2	10.3	9.4	16.1	19.8
	2nd	3.3	4.7	3.7	7.8	8.9	8.1	8.2	4.4	15.6	39.6	9.5	9.9
	3rd	3.0	7.5	3.6	10.4	9.1	5.2	17.3	9.2	16.8	24.9	28.0	5.8
1982	1st	9.5	10.8	16.3	6.3	-	-	-	3.9	2.3	10.1	6.9	11.4
	2nd	6.3	11.2	11.1	7.7	-	-	-	4.6	4.7	9.4	5.3	7.5
	3rd	3.9	8.1	14.1	22.4	-	-	4.7	3.3	6.4	5.4	7.3	10.3

Table A-6 (2) Ten Day Discharge

Station : Kp. Baru (Unit : m^3/s)

Year	Period	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1981	1st	-	-	-	4.9	0.1	0.8	0.0	0.0	2.5	-	14.4	5.9
	2nd	-	-	-	0.1	0.0	0.1	0.0	0.0	7.3	49.0	3.4	2.4
	3rd	-	-	-	1.3	0.1	0.0	1.4	0.0	1.4	26.3	19.0	0.2
1982	1st	4.5	13.0	14.8	-	5.9	2.7	2.0	0.8	0.5	3.9	2.9	5.8
	2nd	2.8	2.2	7.7	-	6.9	1.7	1.5	1.9	1.9	3.7	2.0	3.3
	3rd	0.9	2.6	-	10.6	4.5	0.8	1.2	1.1	3.4	2.1	3.4	5.2

Note : Data on water level is unreliable

Table A-6 (3) Ten Day Discharge

Station : Lb. Begalung (Unit : m^3/s)

Year	Period	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1972	1st	-	-	-	-	-	-	5.1	7.8	7.4	-	9.3	10.5
	2nd	-	-	-	-	-	-	6.2	10.0	5.9	-	16.4	18.5
	3rd	-	-	-	-	-	-	8.2	8.6	11.6	-	19.2	21.1
1978	1st	6.6	9.5	16.1	6.0	8.3	10.5	7.4	19.8	16.6	5.0	24.9	5.3
	2nd	10.8	6.3	24.6	4.2	23.0	5.9	5.6	17.5	18.5	8.5	22.2	10.6
	3rd	4.7	4.2	4.5	4.2	23.8	7.4	22.0	6.0	20.7	24.5	4.1	10.2
1979	1st	18.4	12.2	9.1	30.4	22.6	16.6	7.7	13.3	22.6	3.0	24.7	19.6
	2nd	7.0	17.9	1.3	10.8	3.1	12.1	10.5	1.7	21.0	7.2	23.7	5.3
	3rd	3.8	20.4	10.4	23.1	1.5	5.5	20.2	19.0	6.7	17.5	32.5	4.2
1980	1st	10.0	1.1	4.1	25.6	17.7	23.6	2.3	15.7	10.0	12.0	26.2	20.5
	2nd	7.0	2.2	9.0	23.6	10.5	1.5	6.6	6.7	2.2	14.4	20.5	26.2
	3rd	10.0	3.1	8.2	8.7	3.7	8.6	22.8	5.5	4.2	21.6	29.0	31.1
1981	1st	22.1	1.1	10.7	37.6	11.9	23.5	6.2	10.9	14.4	16.4	20.4	33.6
	2nd	2.1	4.3	2.9	10.7	17.3	13.5	12.2	1.9	38.1	60.2	9.9	15.6
	3rd	1.5	18.1	3.2	21.8	16.8	3.0	36.4	2.8	28.4	45.6	45.2	5.1

Note : Discharge at the downstream of the weir

Table A-6 (4) Ten Day Discharge

Station : Gunung Nago (Unit : m^3/s)

Year	Period	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1979	1st	41.0	39.9	21.4	71.2	44.5	39.1	23.5	7.5	30.5	-	62.5	62.3
	2nd	35.6	26.7	-	25.0	8.1	43.2	13.8	-	23.1	31.6	70.3	11.6
	3rd	25.6	36.5	23.5	32.7	8.2	9.7	34.0	38.0	10.6	30.5	101.4	16.8
1980	1st	12.6	-	19.5	33.4	41.6	32.5	-	69.5	13.3	31.2	-	-
	2nd	-	-	-	48.0	21.9	5.8	-	9.5	1.6	21.9	-	-
	3rd	35.6	7.5	17.0	34.3	9.0	-	27.9	4.7	11.1	47.6	-	-
1981	1st	26.5	0.0	3.2	42.5	14.3	24.8	2.7	11.7	9.5	21.7	24.3	42.9
	2nd	1.1	1.0	0.0	16.7	18.5	12.1	9.3	0.0	40.0	81.6	8.5	12.3
	3rd	3.8	16.5	0.2	20.5	23.0	0.4	33.6	0.0	30.3	49.6	53.8	1.3
1982	1st	3.7	0.9	35.5	8.4	27.8	1.7	0.0	0.0	0.0	3.9	11.6	28.5
	2nd	7.2	9.7	23.5	9.2	18.1	0.0	0.0	0.0	0.0	4.0	5.5	9.0
	3rd	0.0	6.4	30.9	51.2	11.6	0.0	0.0	0.0	1.4	0.0	9.0	19.1

Table A-6 (5) Ten Day Discharge

Station : Kp. Melayu (Unit : m^3/s)

Year	Period	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1978	1st	–	–	–	–	–	–	–	–	–	2.5	14.9	6.6
	2nd	–	–	–	–	–	–	–	–	–	8.6	13.8	9.6
	3rd	–	–	–	–	–	–	–	–	–	13.5	6.0	6.6
1979	1st	7.2	5.0	2.3	16.2	15.1	9.7	5.0	4.7	6.5	1.5	18.6	15.6
	2nd	4.7	4.8	1.1	5.6	3.0	10.3	3.1	2.1	6.9	7.9	20.2	4.6
	3rd	3.7	6.7	3.9	11.7	2.3	4.0	9.3	6.9	3.5	7.8	22.1	2.7
1980	1st	5.8	2.2	5.5	14.3	14.0	11.7	1.4	12.0	7.3	12.7	21.6	20.4
	2nd	2.8	1.8	2.6	21.9	7.0	1.8	2.5	5.7	4.6	10.6	12.6	17.4
	3rd	5.2	2.3	5.9	11.0	3.0	2.5	10.5	3.9	8.1	23.6	39.7	23.1
1981	1st	13.9	1.6	2.9	9.8	1.8	3.1	0.1	0.4	0.5	0.1	3.3	3.2
	2nd	3.3	1.4	1.6	3.9	1.7	1.1	0.2	0.0	3.1	9.4	0.2	0.0
	3rd	3.2	8.2	1.3	6.5	1.8	0.1	5.4	0.0	0.6	5.2	10.0	0.0

Table A-6 (6) Ten Day Discharge

Station : Lb. Minturun (Unit : m^3/s)

Year	Period	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1979	1st	-	-	-	-	-	7.9	8.6	9.6	13.4	4.3	26.8	35.0
	2nd	-	-	-	-	6.3	13.0	7.6	5.0	12.7	14.7	20.7	12.5
	3rd	-	-	-	-	5.0	7.8	15.4	13.7	7.7	16.2	63.0	8.7
1980	1st	11.8	7.0	11.1	18.0	29.8	24.6	5.2	13.9	12.1	17.8	35.5	25.0
	2nd	10.1	4.5	9.6	22.5	14.0	7.1	6.8	11.9	7.3	16.9	17.2	27.4
	3rd	13.0	8.0	13.0	18.7	9.6	7.5	15.7	6.2	12.8	32.3	42.2	74.8
1981	1st	18.1	8.7	9.9	27.2	14.6	16.8	7.0	14.2	11.6	17.4	20.5	25.1
	2nd	8.2	7.4	6.4	13.8	18.5	11.8	13.9	6.6	20.6	52.2	10.4	13.2
	3rd	11.9	17.8	8.1	19.7	17.3	7.7	21.6	6.4	16.5	29.0	42.9	8.2
1982	1st	13.4	14.9	35.1	13.1	19.4	13.7	6.0	5.3	5.2	13.2	13.6	-
	2nd	10.3	14.2	21.1	12.4	16.1	9.0	5.7	8.6	6.1	14.5	11.4	-
	3rd	6.9	14.8	26.7	26.2	14.9	6.6	6.5	6.8	5.5	6.9	-	-

Table A-7 (1) Monthly Mean Daily Discharge

(Unit : m^3/s)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ave.
Lb. Sarik													
1976	-	-	-	-	4.3	8.2	15.9	11.2	8.9	22.3	14.5	10.8	-
1977	12.5	14.6	7.5	8.4	10.5	7.7	6.7	5.5	4.4	9.4	23.4	18.0	10.7
1978	8.7	9.9	14.3	9.1	11.6	11.5	14.5	14.0	8.4	9.7	17.8	9.7	11.6
1979	9.6	13.2	7.2	18.7	6.3	8.3	8.7	6.9	9.5	6.1	19.6	8.0	10.2
1980	7.6	2.9	6.4	14.2	9.5	5.7	9.8	7.9	7.5	14.3	22.2	17.1	10.4
1981	5.5	5.0	4.2	12.3	11.4	8.6	10.3	7.4	14.2	24.6	17.9	11.6	11.1
1982	6.5	10.2	13.8	12.1	-	-	4.7	3.9	4.6	8.2	6.5	9.6	-
Ave.	8.4	9.3	8.9	12.5	8.9	8.3	10.1	8.1	8.2	13.5	17.4	12.1	10.5
Kp. Baru /1													
1981	-	-	-	2.1	0.1	0.3	0.5	0.0	4.4	36.5	13.8	2.4	-
1982	3.2	6.0	12.4	-	5.7	1.7	1.6	1.3	1.9	3.2	3.0	4.8	-
Ave.	3.2	6.0	12.4	2.1	2.9	1.0	1.1	0.7	3.2	19.9	8.4	3.6	5.4
Lb. Begalung /2													
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

Note /1 : Data on water level is unreliable

/2 : Discharge at the downstream of the weir

Table A-7 (2) Monthly Mean Daily Discharge

(Unit : m^3/s)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ave.
Gunung Nago /1													
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
Kp. Melayu													
1978	-	-	-	-	-	-	-	-	-	8.8	11.6	7.6	-
1979	5.2	5.4	2.5	11.2	6.7	8.0	5.9	4.6	5.7	5.8	20.3	7.5	7.4
1980	4.6	2.1	4.7	13.8	7.8	5.3	5.0	7.1	6.7	15.9	24.6	20.4	9.8
1981	6.7	3.4	1.9	7.0	1.8	1.4	2.0	0.1	1.5	3.6	4.3	1.1	2.9
Ave.	5.5	3.6	3.0	10.7	5.4	4.9	4.3	3.9	4.6	8.5	15.2	9.2	6.6
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	11.3	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 overflowing the weir.

Table A-8 (1) Gage Readings at Teluk Bayur

(Unit: cm)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
Higher High Level (HHL)													
1975	164	158	154	168	153	150	145	142	168	187	189	174	163
1976	138	158	153	168	146	148	146	152	181	193	-	173	160
1977	154	185	138	163	168	174	168	176	148	158	168	180	152
1978	148	158	146	158	188	169	168	162	146	167	164	170	162
1979	164	167	150	172	188	164	168	175	174	177	174	174	170
1980	168	168	152	181	182	171	183	172	176	188	179	188	176
1981	168	-	-	165	184	194	174	175	193	178	-	-	179
1982	-	-	168	180	169	-	175	168	167	163	181	-	171
Average	158	166	151	169	172	167	166	165	169	176	176	176	167
Mean Higher High Level (MHHL)													
1975	-	-	-	-	-	-	-	-	-	-	156	-	-
1976	-	-	-	-	-	-	-	-	-	-	-	-	-
1977	124	136	137	129	143	139	137	129	123	126	132	132	132
1978	126	125	131	218	156	139	137	137	124	135	138	131	134
1979	132	133	132	144	153	143	136	139	146	141	151	141	141
1980	136	130	130	140	150	153	149	139	138	152	152	154	143
1981	143	-	-	137	148	154	137	140	144	142	-	-	143
1982	-	-	144	148	141	-	144	140	142	141	147	-	143
Average	132	131	135	138	148	146	140	137	136	139	146	139	139
Mean Sea Level													
1975	-	-	-	-	-	-	-	-	-	-	99	-	-
1976	-	72	80	79	89	81	82	88	88	-	-	95	84
1977	79	83	75	80	92	86	87	81	78	79	83	84	82
1978	80	78	75	82	105	90	88	90	79	89	92	81	86
1979	78	82	80	94	102	89	90	92	96	95	96	93	90
1980	81	78	82	89	101	103	97	92	92	104	100	101	93
1981	88	-	-	98	104	101	96	91	93	89	-	-	95
1982	-	-	95	103	98	-	99	92	96	97	94	-	97
Average	81	79	81	89	99	92	91	89	89	92	94	91	89

Source : Port Administration of Teluk Bayur

Table A-8 (2) Gage Readings at Teluk Bayur

(Unit: cm)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
Mean Lower Low Level (MLLL)													
1975	-	-	-	-	-	-	-	-	-	-	52	-	-
1976	-	-	-	-	-	-	-	-	-	-	-	-	-
1977	36	36	37	35	48	43	43	39	37	36	42	46	40
1978	36	32	31	36	60	47	45	48	38	45	50	34	42
1979	33	37	38	50	59	47	48	50	55	52	57	46	48
1980	43	40	38	55	58	60	54	48	49	60	60	56	52
1981	44	-	-	52	59	56	55	48	52	53	-	-	52
1982	-	-	50	55	56	-	60	52	57	55	49	-	54
Average	38	36	39	47	57	51	51	47	48	50	52	45	47
Lower Low Level (LLL)													
1975	20	17	15	27	18	13	9	22	26	26	32	29	21
1976	3	14	12	31	24	27	33	20	34	-	-	25	22
1977	18	17	6	13	23	24	23	22	17	18	21	21	18
1978	14	16	12	23	34	30	24	25	15	24	29	22	22
1979	7	10	13	15	36	34	31	37	26	28	27	20	24
1980	10	13	13	28	35	48	38	28	29	38	33	36	29
1981	33	-	-	26	36	45	38	32	37	33	-	-	35
1982	-	-	33	43	17	-	44	31	35	39	15	-	32
Average	15	14	15	26	28	31	30	27	27	29	26	25	24

Source : Port Administration of Teluk Bayur

Note : HHL is the monthly maximum.

MHHL is monthly mean of the daily maximum.

Mean Sea level is monthly mean.

MLLL is monthly mean of the daily minimum.

LLL is the monthly minimum.

Table A-9 Water Quality of Kuranji River
(Kampung Melayu, November 1980)

Component	Unit	Mean	Standard deviation
Total hardness	° dH	4.08	± 0.85
Carbon dioxide (CO_2)	mg/l	7.00	± 1.45
Bicarbonate (HCO_3)	mg/l	25.9	± 5.6
Chloride (Cl)	mg/l	15.8	± 2.6
Permanganate demand	mg/l	5.7	± 3.3
Ammonia (NH_4^+)		neg	
Nitrite (NO_2^-)		neg	
Manganese (Mn)		neg	
Iron (Fe)	mg/l	neg - 0.2	
Sulfate ($SO_4^=$)	mg/l	36.2	± 8.3
Silicate (SiO_2)	mg/l	11.7	± 3.4

Source : Padang Water Supply Project Feasibility Study and Detailed Engineering (Feasibility Report, Part I)
Prepared by Lahmeyer International, November 1982.

Table A-10 Water Quality of Arau and Kuranji Rivers

Component	Unit	Classification			
		Arau river (Lb. Sarik)		Kuranji river (Kp. Melayu)	
DHL	Umho/cm	138	very good	210	very good
pH	-	8.3		7.2	good
Natrium (Na)	%	7.4	very good	27.0	good
Chloride (Cl^-)	mg/l	11.0	sufficient	5.5	good
Sulfate ($SO_4^=$)	mg/l	5.3	good	3.4	very good
Boron (B)	mg/l	-	very good	0.01	very good

Source : Laporan Utama Pekerjaan Survey Hidrometri dan Sedimentasi Sungai Batang Arau & Batang Kuranji di Propinsi Sumatera Barat prepared by P.T. Indah Karya, 1981.

Table A-11 (1) Test Results of River Bed and Sea Coast Materials

Sample No.	Percentage of Weight Passing through the seive (%)																
	Measure with a rule (mm)					Seive (mm)											
	1000	750	600	350	200	101.6	63.5	31.7	15.9	7.93	4.00	2.00	1.00	0.50	0.25	0.125	0.063
Jirak R.																	
R5							100	77.7	59.2	49.9	40.3	30.1	18.4	11.3	2.3	0.6	0.2
R6						100	93.2	63.2	45.2	32.3	23.8	17.8	8.9	3.1	0.8	0.4	0.2
Arau R.																	
R1							100	98.3	93.4	85.4	75.9	60.0	26.7	13.1	5.9	3.7	2.8
R25										100	99.5	97.5	95.5	92.5	32.4	3.2	0.5
R24					100	95.7	71.4	46.8	34.5	26.1	20.5	15.7	10.2	5.3	1.5	0.4	0.1
R4					100	86.6	65.5	43.4	31.6	24.6	17.6	11.4	5.9	3.0	1.1	0.4	0.2
R26					100	96.9	83.9	55.4	36.7	24.0	15.6	9.9	5.9	3.6	0.8	0.5	0.1
R2					100	94.8	89.0	62.3	43.8	34.8	27.1	21.8	17.8	11.4	2.8	0.7	0.2
R22 - 1						100	95.2	76.8	64.0	50.6	41.7	35.2	27.9	15.9	3.2	0.7	0.2
R22 - 2						100	73.8	26.2	22.4	20.6	18.1	14.9	10.8	5.9	1.8	0.7	0.2
R3	100	84.2	-	52.2	-	39.8	30.3	16.3	9.5	7.3	5.5	4.2	3.1	1.9	0.6	0.2	0.1
R34	100	61.8	-	55.1	-	42.0	32.0	17.2	10.0	7.7	5.8	4.4	3.3	2.0	0.6	0.2	0.1
Flood Relief C.																	
R7					100	98.9	92.0	62.4	45.6	34.6	27.1	21.7	15.0	6.1	2.0	0.9	0.4
R28												100	99.3	75.8	10.5	3.3	1.3
R29						100	82.0	45.2	23.0	15.0	11.9	10.4	9.4	6.8	1.3	0.6	0.3
R30						100	95.4	59.7	34.5	18.8	11.5	7.3	4.2	1.6	0.3	0.1	0
R23					100	98.2	81.7	47.7	29.7	17.2	10.8	7.3	5.4	4.2	1.5	0.9	0.2
R8					100	83.3	49.6	32.7	25.0	20.1	16.1	12.6	7.7	2.2	0.8	0.4	0.2
R21					100	98.1	88.4	60.3	43.3	27.5	19.8	15.5	12.1	6.6	1.8	0.5	0.2
Kuranji R.																	
R9											100	99.5	94.5	72.9	24.9	4.8	0.8
R32										100	99.4	98.5	94.0	58.1	9.0	1.5	0.6
R31 - L									100	99.3	97.8	97.1	96.4	89.0	16.3	2.2	0.7
R31 - C								100	96.5	89.9	77.3	64.7	45.5	13.6	2.5	1.0	0.5
R31 - R							100	97.9	88.9	78.1	64.7	52.3	39.0	13.2	2.6	0.7	0.3
R10								100	98.1	93.7	83.4	66.6	43.3	13.6	6.0	3.0	0.9
R27						100	99.4	80.1	52.9	34.4	24.2	18.0	13.5	7.5	1.1	0.2	0.1
R11								100	98.1	93.7	83.4	66.6	43.3	13.6	6.0	3.0	0.9
R12		100	86.3	79.4	-	71.1	56.7	36.1	26.4	19.9	15.3	11.8	8.3	4.4	1.5	0.6	0.2
R13	100	81.1	-	74.6	70.9	59.1	41.4	28.0	21.5	17.2	13.1	9.0	5.1	2.3	0.7	0.2	0.1
R35	95.2	76.0	-	42.2	40.1	33.4	23.4	15.9	12.2	9.7	7.4	5.1	2.9	1.3	0.4	0.1	0
Balimbing R.																	
R14								100	95.7	84.5	70.0	53.7	28.4	8.0	1.3	0.6	0.4
R20								100	99.8	86.4	71.2	57.4	40.8	20.8	7.3	3.0	1.2
R15						100	85.4	54.8	39.1	32.2	26.2	20.7	13.0	3.6	0.9	0.3	0.1
R16			100	98.1	-	88.7	72.1	49.7	31.8	23.9	18.7	14.8	10.3	4.7	1.5	0.6	0.3
Air Dingin R.																	
R17										100	97.7	92.7	70.5	27.5	9.2	2.4	0.9
R33						100	82.0	61.0	45.0	35.3	27.7	19.3	11.1	6.7	4.6	0.2	0
R18					100	96.5	80.9	58.6	44.6	34.3	25.6	18.8	12.3	6.3	2.0	0.8	0.3
R19			100	86.6	82.3	63.1	39.0	24.1	18.2	16.0	13.2	10.6	7.6	3.6	1.0	0.3	0.1
R36	100	78.0	-	53.0	50.4	38.6	23.9	14.7	11.1	9.8	8.1	6.5	4.7	2.2	0.6	0.2	0.1
R37	100	85.1	-	52.5	49.9	38.3	23.6	14.6	11.0	9.7	8.0	6.4	4.6	2.2	0.6	0.2	0.1
Sea Coast																	
S1										100	99.4	97.1	93.2	76.0	20.7	1.5	0.1
S2											100	99.9	99.3	90.4	38.8	3.8	0.1
S3												100	100	98.9	65.6	9.4	0.2
S4											100	99.8	98.4	82.1	35.6	3.8	0
S5											100	99.8	98.8	80.6	23.6	3.8	0.3
S6											100	99.9	99.1	80.4	22.3	1.4	0.2
S7											100	99.9	99.2	75.3	15.9	1.7	0.2
S8											100	99.9	98.4	86.7	31.1	7.8	0.1
S9											100	99.2	92.2	69.2	31.8	2.9	0.1
S10											100	99.9	99.0	85.4	36.7	3.6	0.1
S11												100	99.2	95.9	34.6	11.5	0.8

Note :

1. Sample No.R1 thru R20, R34 thru R37, and S1 thru S10 were sampled in Feb. and Mar., 1983.
2. Sample No.R21 thru R33 and S11 were sampled in July, 1983.

Table A-11 (2) Test Results of River Bed and Sea Coast Materials

Sample No.	Diameter (mm) Max.	60 %	30 %	10 %	Uc	Uc'	Wn	Gs	γ_t
Jirak R.									
R5	63.5	16.8	2.00	0.47	36	0.5	-	2.70	-
R6	101.6	29.0	6.60	1.05	28	1.4	3.7	2.69	2.11
Arau R.									
R1	63.5	2.0	1.08	0.39	5	1.5	11.4	2.64	1.64
R25	7.93	0.32	0.245	0.168	2	1.1	-	-	-
R24	200	48	11.2	0.91	53	2.9	-	-	-
R4	200	55	14.0	1.7	32	2.1	-	2.66	-
R26	200	36	11.0	2.0	18	1.7	-	-	-
R2	200	30	5.3	0.44	68	2.1	7.9	2.59	2.18
R22 - 1	101.6	13.0	1.15	0.39	33	0.3	-	-	-
R22 - 2	101.6	53	35	0.87	61	26.6	-	-	-
R3	1000	425	65	17	25	0.6	3.2	2.57	2.34
R34	1000	720	58	14	51	0.3	-	-	-
Flood Relief C.									
R7	200	29	5.2	0.62	47	1.5	7.2	2.65	2.18
R28	2.00	0.46	0.37	0.245	2	1.2	-	-	-
R29	101.6	42	20.5	2.0	21	5.0	-	-	-
R30	101.6	32	13.8	3.1	10	1.9	-	-	-
R23	200	43	16.2	3.6	12	1.7	-	-	-
R8	200	76	26.0	1.45	52	6.1	-	2.64	-
R21	200	30	9.2	0.72	42	3.9	-	-	-
Kuranji R.									
R9	4.00	0.42	0.27	0.14	3	1.2	33.3	2.64	1.78
R32	7.93	0.51	0.40	0.27	2	1.2	-	-	-
R31 - L	15.9	0.34	0.30	0.205	2	1.3	-	-	-
R31 - ℄	31.7	1.65	0.71	0.43	4	0.7	-	-	-
R31 - R	63.5	3.0	0.75	0.43	7	0.4	-	-	-
R10	31.7	1.60	0.75	0.40	4	0.9	16.0	2.65	1.84
R27	101.6	19	6.0	0.65	29	2.9	-	-	-
R11	31.7	1.60	0.75	0.40	4	0.9	16.0	2.65	1.84
R12	750	70	22	1.3	54	5.3	3.0	2.79	1.81
R13	1000	102	36	2.5	41	5.1	1.9	2.75	2.04
R35	1300	580	100	10.0	58	1.7	-	-	-
Balimbing R.									
R14	31.7	2.60	1.05	0.54	5	0.8	12.7	2.71	1.67
R20	31.7	2.30	0.69	0.30	8	0.7	-	2.73	-
R15	101.6	36.5	6.1	0.8	46	1.3	6.2	2.73	2.28
R16	600	45	14	1.0	45	4.4	5.4	2.72	2.09
Air Dingin R.									
R17	7.93	0.86	0.53	0.26	3	1.3	-	2.64	-
R33	101.6	30.0	5.0	0.80	38	1.0	-	-	-
R18	200	33.0	5.6	0.73	45	1.3	5.6	2.77	2.24
R19	600	110	43	1.7	65	9.9	1.7	2.75	2.21
R36	1000	470	87	11	43	1.5	-	-	-
R37	1000	450	87	11	41	1.5	-	-	-
Sea Coast									
S1	7.93	0.42	0.29	0.190	2	1.1	9.9	2.78	1.57
S2	4.00	0.32	0.225	0.155	2	1.0	8.7	2.75	1.79
S3	2.00	0.24	0.170	0.125	2	1.0	-	3.16	-
S4	4.00	0.36	0.23	0.155	2	0.9	3.7	3.11	1.78
S5	4.00	0.38	0.28	0.175	2	1.2	5.2	2.79	1.79
S6	4.00	0.38	0.28	0.190	2	1.1	10.6	2.73	1.55
S7	4.00	0.43	0.33	0.20	2	1.3	6.2	2.78	1.65
S8	4.00	0.355	0.245	0.165	2	1.0	11.8	2.73	1.57
S9	4.00	0.35	0.245	0.180	2	1.0	9.2	2.76	1.48
S10	4.00	0.425	0.240	0.165	3	0.8	16.2	2.74	1.79
S11	2.00	0.290	0.230	0.115	3	1.6	-	-	-

Note :

1. Sample S3 and S4 which show larger specific gravity include iron sands.
2. Uc ; Uniformity coefficient Gs ; Specific gravity
   Uc' ; Curvature coefficient γ_t ; Unit weight (g/cm^3)
   Wn ; Moisture content (%)

Table A-12 Estimated Relation between Sediment Discharge (QB) and Water Discharge (Q)

Code of site	Sato-Kikkawa-Ashida		Brown		Engelund-Hansen	
	a	b	a	b	a	b
Arau r.						
R 1	1.282×10^{-7}	1.835	8.436×10^{-8}	2.426	1.214×10^{-7}	2.523
R 4	2.162×10^{-6}	1.182	1.005×10^{-5}	1.289	1.508×10^{-5}	1.388
R 2	9.518×10^{-5}	1.020	1.048×10^{-3}	1.262	3.592×10^{-4}	1.434
R 3	5.486×10^{-6}	1.770	1.150×10^{-6}	2.000	4.584×10^{-7}	2.110
Jirak R.						
R 5	1.090×10^{-6}	1.697	2.993×10^{-6}	2.151	4.022×10^{-6}	2.064
Flood relief channel						
R 7	1.062×10^{-7}	1.658	1.846×10^{-7}	2.038	1.035×10^{-7}	2.216
R 8	2.287×10^{-6}	1.331	1.174×10^{-5}	1.567	6.240×10^{-6}	1.742
Kuranji R.						
R 9	1.419×10^{-9}	2.580	2.271×10^{-12}	4.322	2.918×10^{-12}	4.418
R 10	5.364×10^{-6}	1.263	3.643×10^{-6}	1.927	5.791×10^{-6}	1.950
R 11	5.797×10^{-6}	0.935	1.973×10^{-5}	1.091	7.621×10^{-6}	1.240
R 12	4.059×10^{-4}	0.811	4.857×10^{-3}	0.935	2.109×10^{-3}	1.116
R 13	3.987×10^{-4}	0.972	3.157×10^{-3}	1.185	7.410×10^{-4}	1.337
Balimbing R.						
R 14	5.464×10^{-9}	2.041	1.599×10^{-8}	2.097	2.260×10^{-8}	2.226
R 20	1.054×10^{-5}	1.019	2.561×10^{-5}	1.411	2.858×10^{-5}	1.544
R 15	2.286×10^{-6}	1.243	4.661×10^{-6}	1.633	2.222×10^{-6}	1.767
R 16	1.248×10^{-3}	0.547	1.561×10^{-2}	0.720	5.483×10^{-3}	0.752
Air Dingin R.						
R 17	8.215×10^{-11}	2.802	3.287×10^{-10}	2.892	1.424×10^{-10}	3.122
R 18	6.553×10^{-5}	0.649	2.545×10^{-4}	0.885	1.443×10^{-4}	0.941
R 19	2.224×10^{-5}	1.407	2.992×10^{-4}	1.546	5.950×10^{-5}	1.686

Note : $Q_B = aQ^b$

Q_B : m^3/s

Q : m^3/s

Fig. A - 1 Location of Rainfall Stations

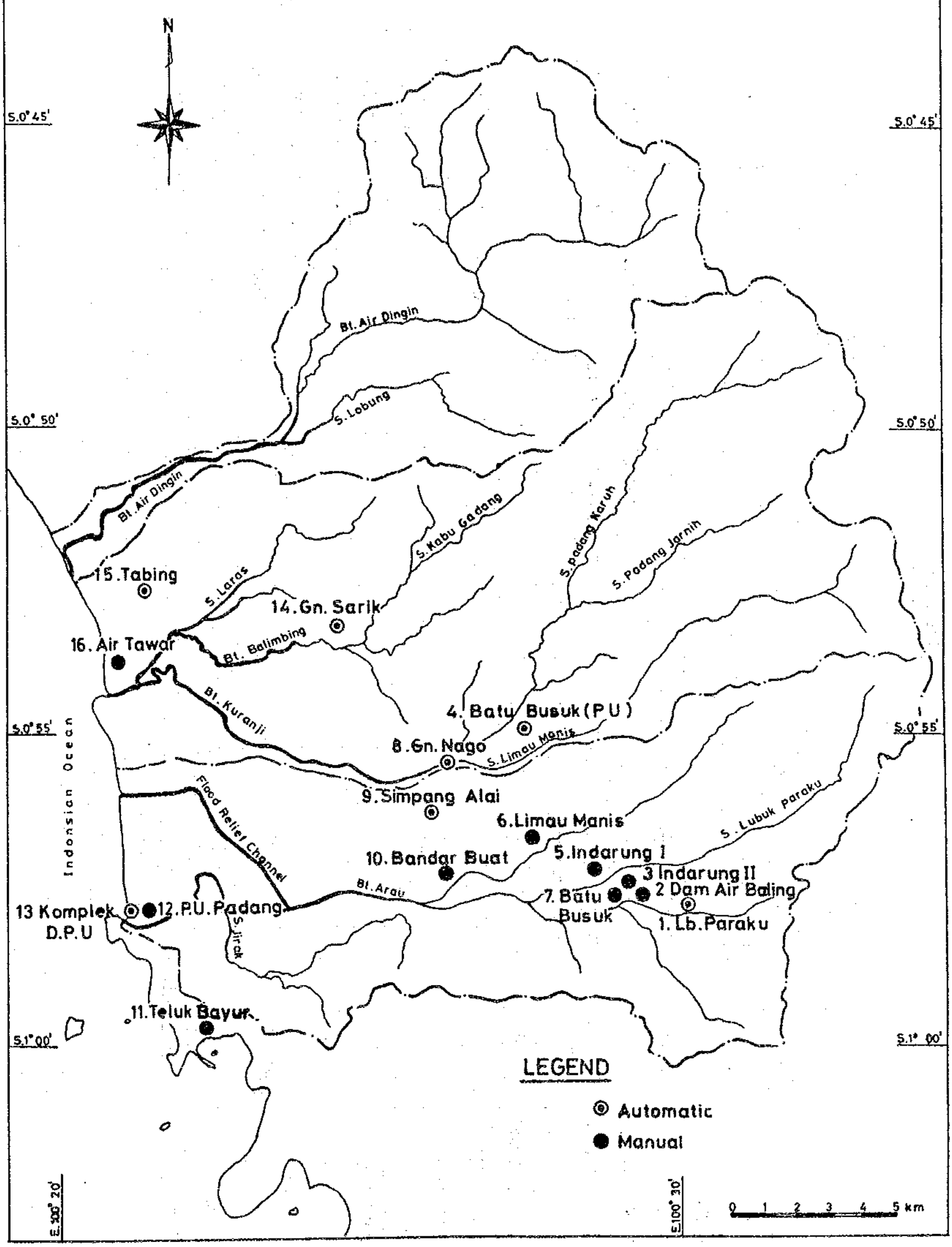
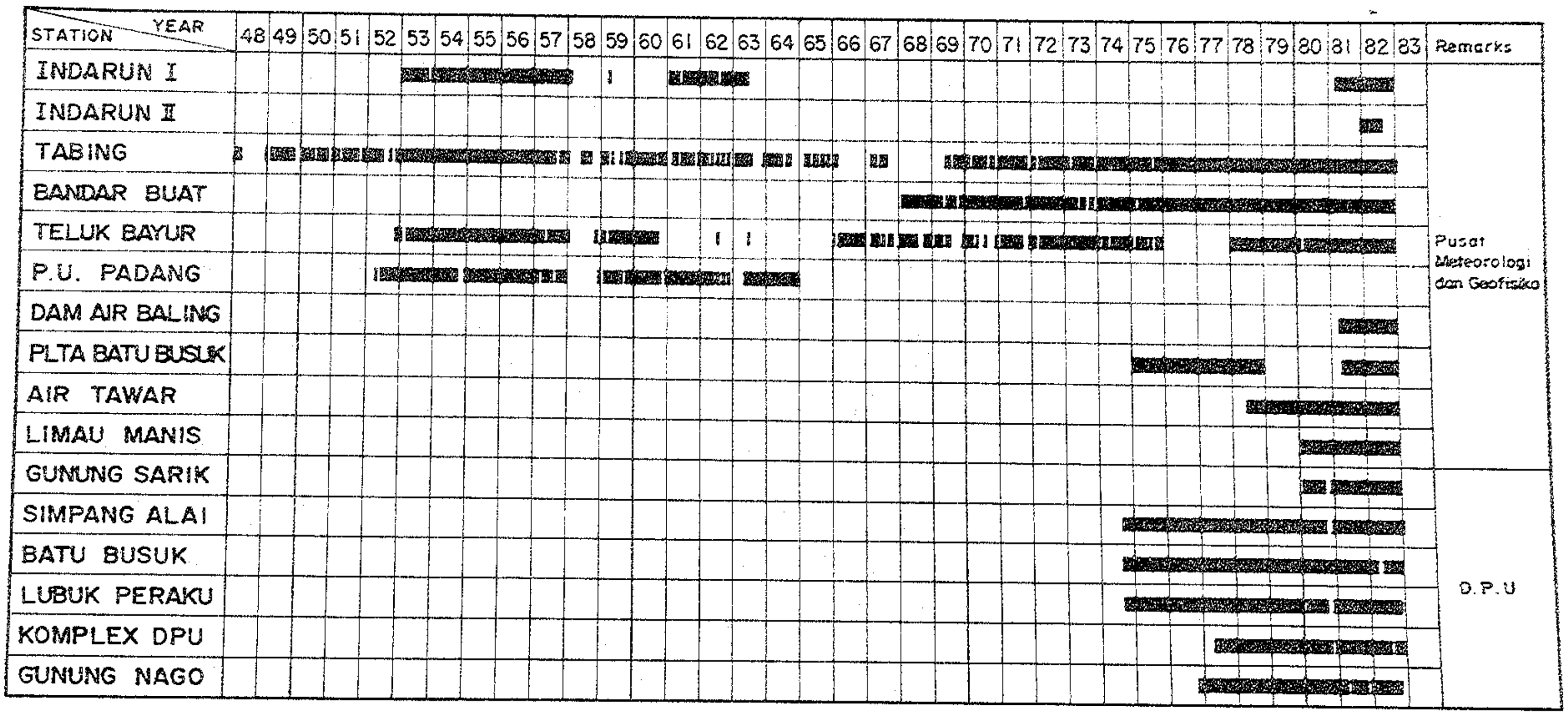


Fig. A-2 Available Daily Rainfall Records



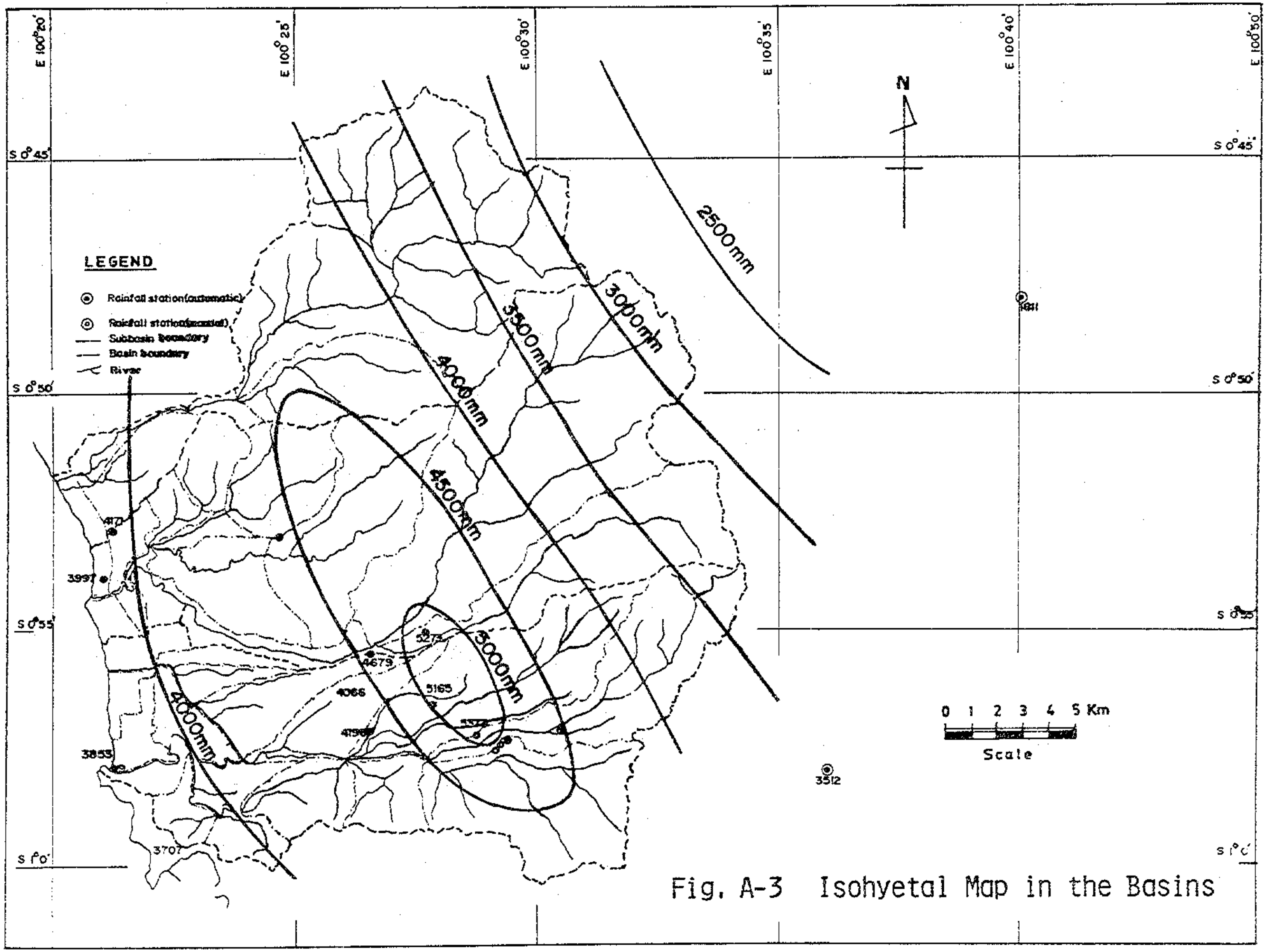


Fig. A-3 Isohyetal Map in the Basins

Fig. A-4 Monthly Rainfall at Tabing Station

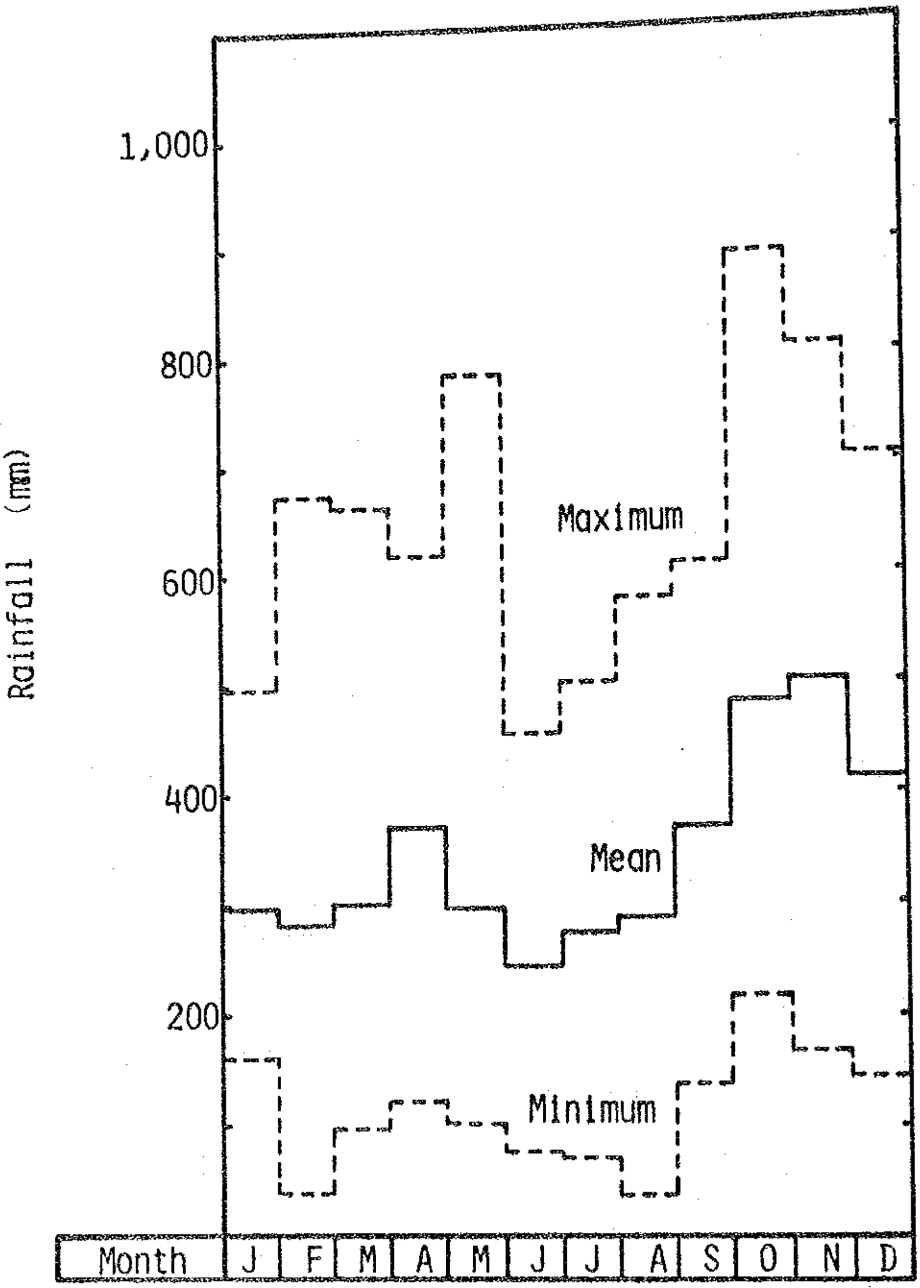
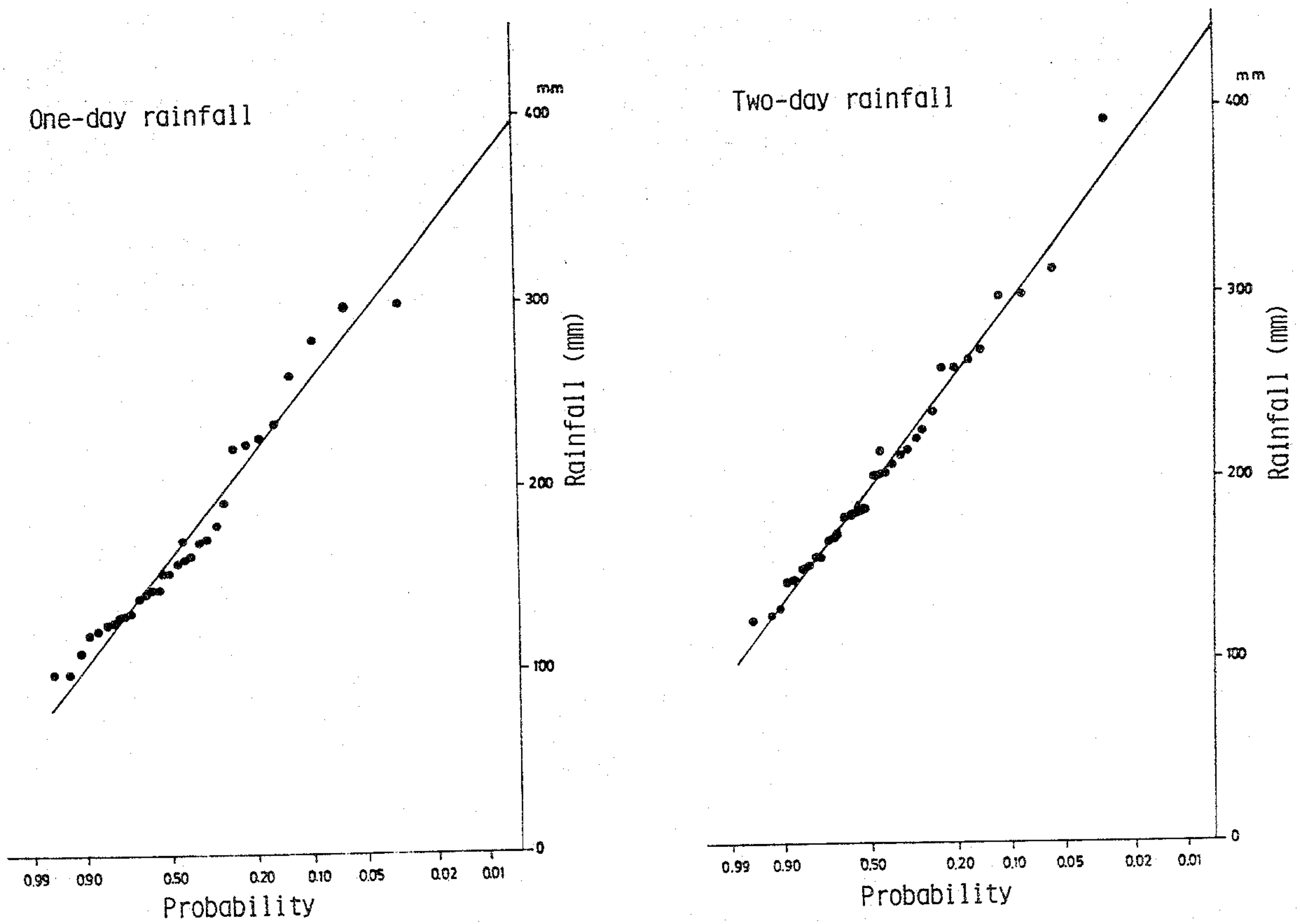


Fig. A-5 Probable Rainfall Depths at Tabing Station



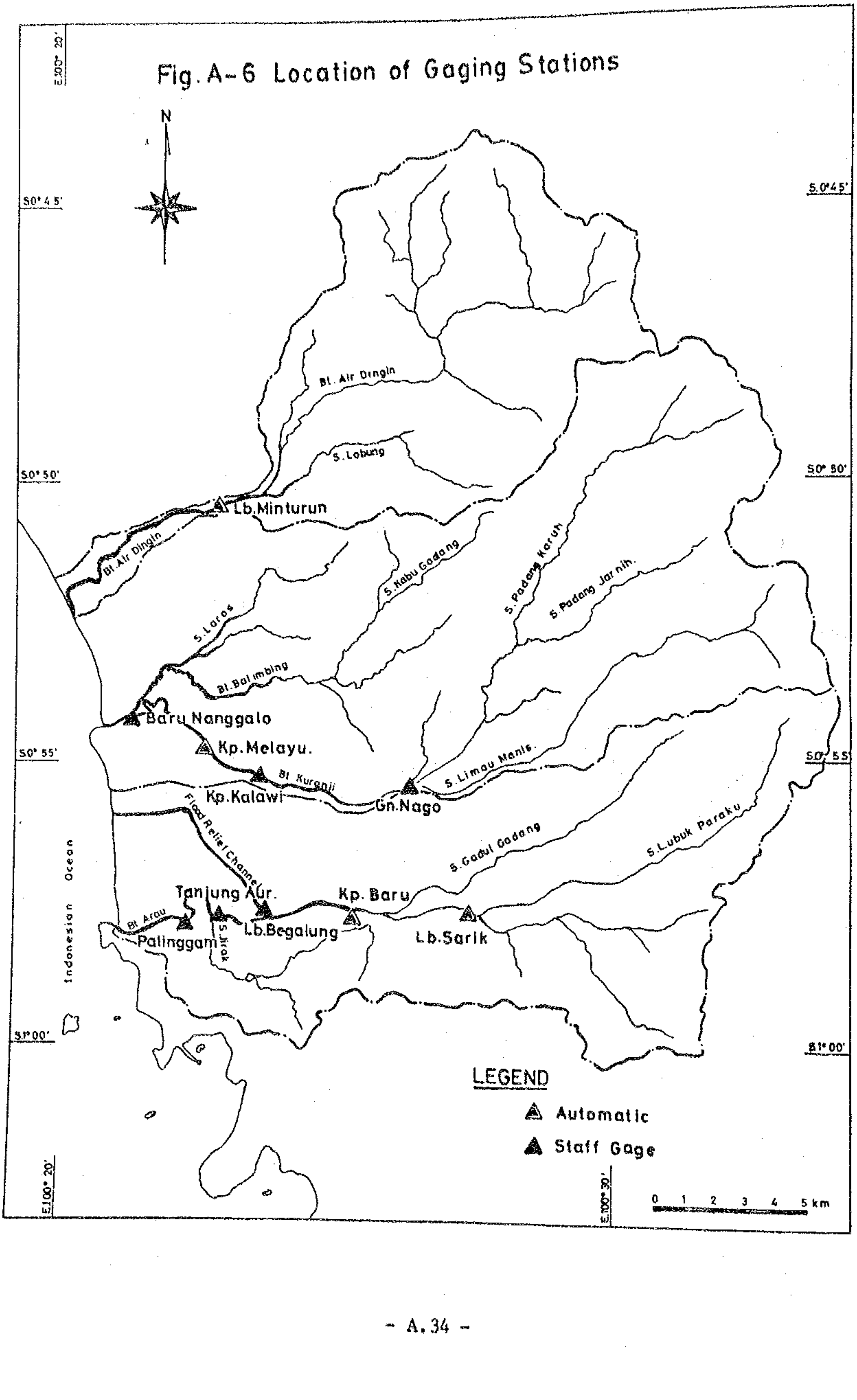
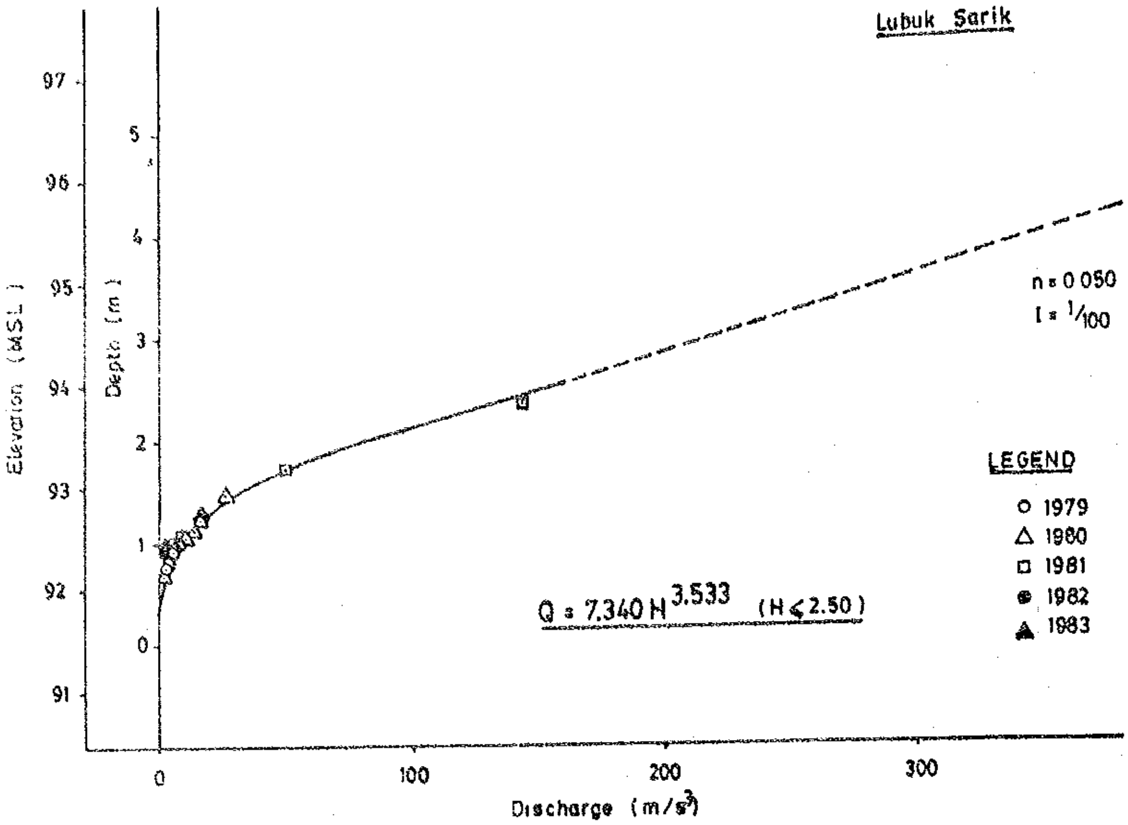


Fig. A-6 Location of Gaging Stations
N
S.0°45'
S.0°50'
S.0°55'
S.1°00'
E.100°20'
E.100°30'
Bt. Air Dingin
S. Lobung
Lb. Minturun
S. Kabu Gadang
S. Padang Karuh
S. Padang Jarnih.
S. Laras
Bt. Balimbing
Baru Nanggalo
Kp. Melayu.
Bt. Kuranji
S. Limau Manis.
Kp. Kalawi
Gn. Nago
Flood Relief Channel
S. Gadul Gadang
S. Lubuk Paraku
Tanjung Aur.
Kp. Baru
Bt. Arau
Palinggam
S. Jirak
Lb. Begalung
Lb. Sarik
Indonesian Ocean
LEGEND
Automatic
Staff Gage
0 1 2 3 4 5 km

Fig. A-7 Available Water Level Records

Station		Year 72	73	74	75	76	77	78	79	80	81	82	83	Remarks
AUTOMATIC														
I. Kuranji River														
1.1 Kampung Melayu	BK - 3													DPU-SUMBAR
II. Arau River														
2.1 Lubuk Sarik	BA - 1													DPU-SUMBAR
2.2 Kampung Baru	-													DPU-SUMBAR
III. Air Dingin River														
3.1 Lubuk Minturun	-													DPU-SUMBAR
STAFF GAUGE														
I. Kuranji River														
1.1 Gunung Nago	BK - 1													DPU-SUMBAR
1.2 Kampung Kalawi	BK - 2													PT. INDAH KARYA
1.3 Kp. Baru Nanggalo	BK - 4													PT. INDAH KARYA
II. Arau River														
2.1 Lubuk Sarik	BA - 2													DPU-SUMBAR
2.2 Kampung Tanjung Aur	BA - 3													PT. INDAH KARYA
2.3 Kampung Palinggam	BA - 4													PT. INDAH KARYA

Fig. A-8(1) Discharge Rating Curves



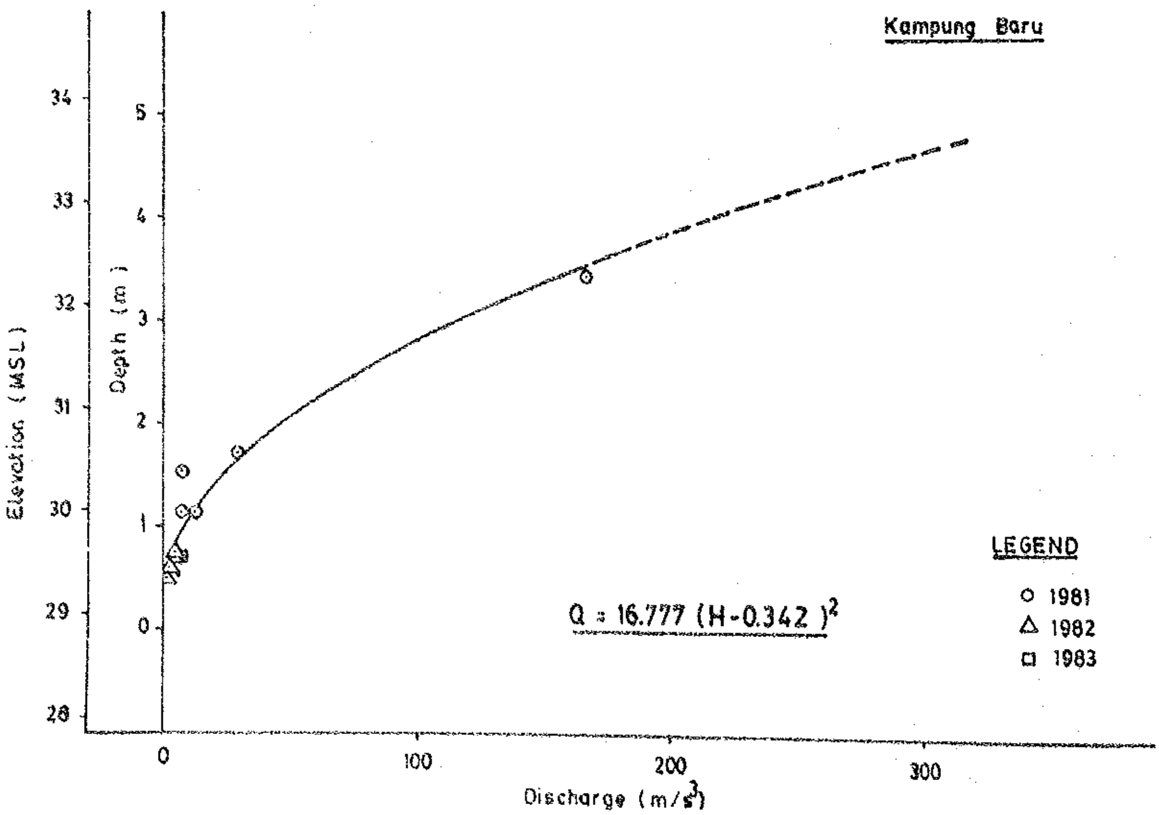
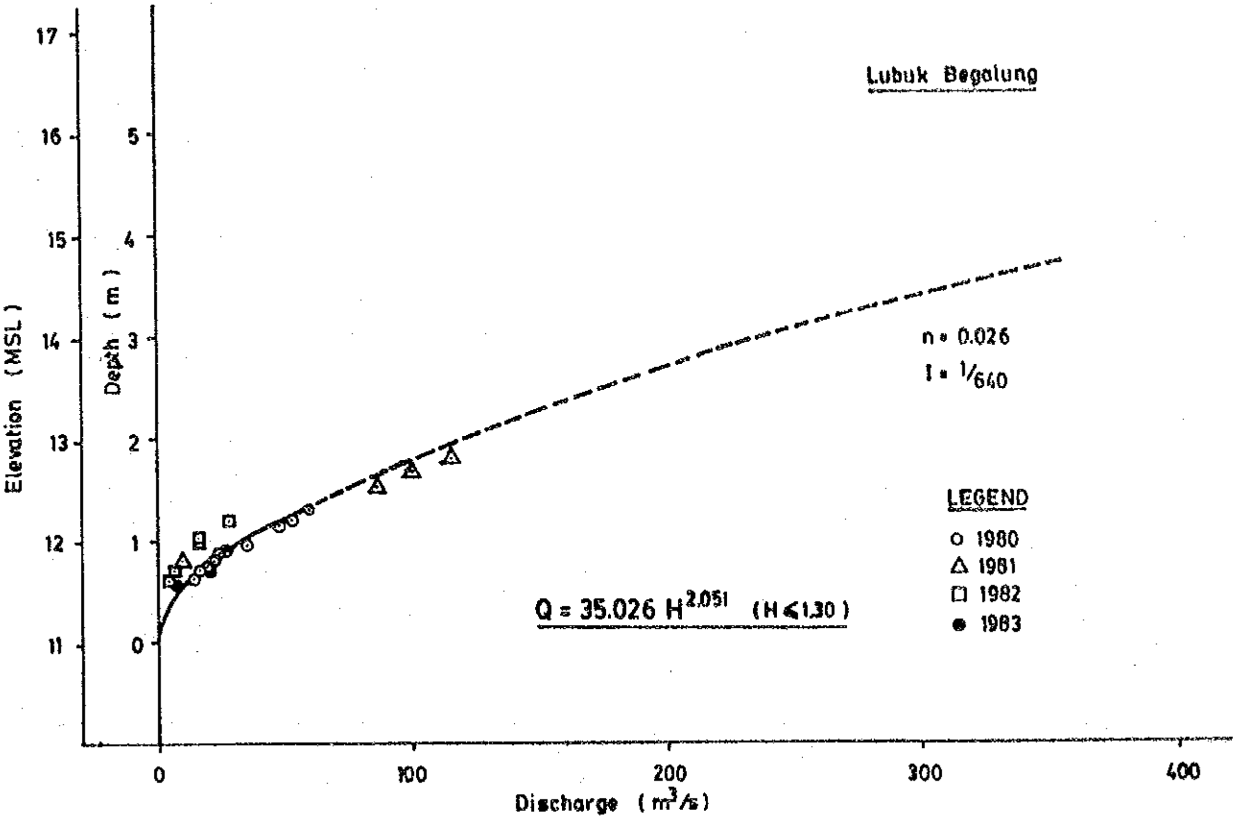


Fig. A-8(2) Discharge Rating Curves



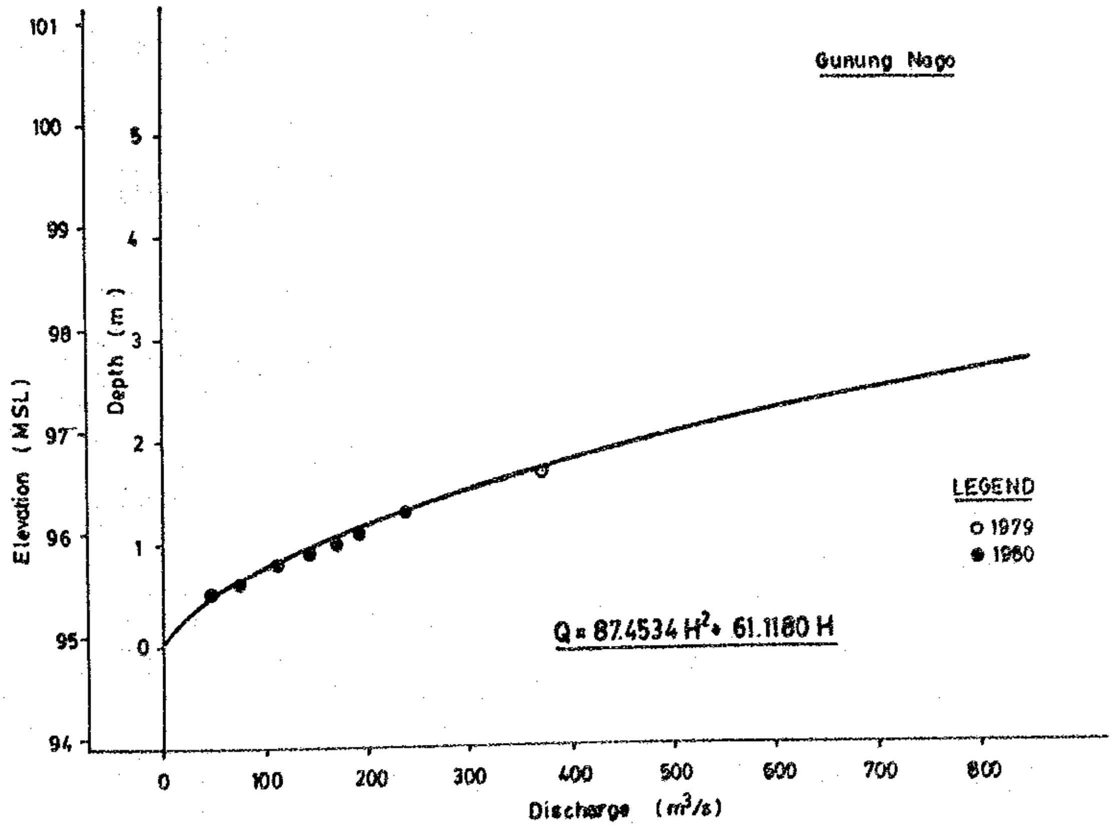
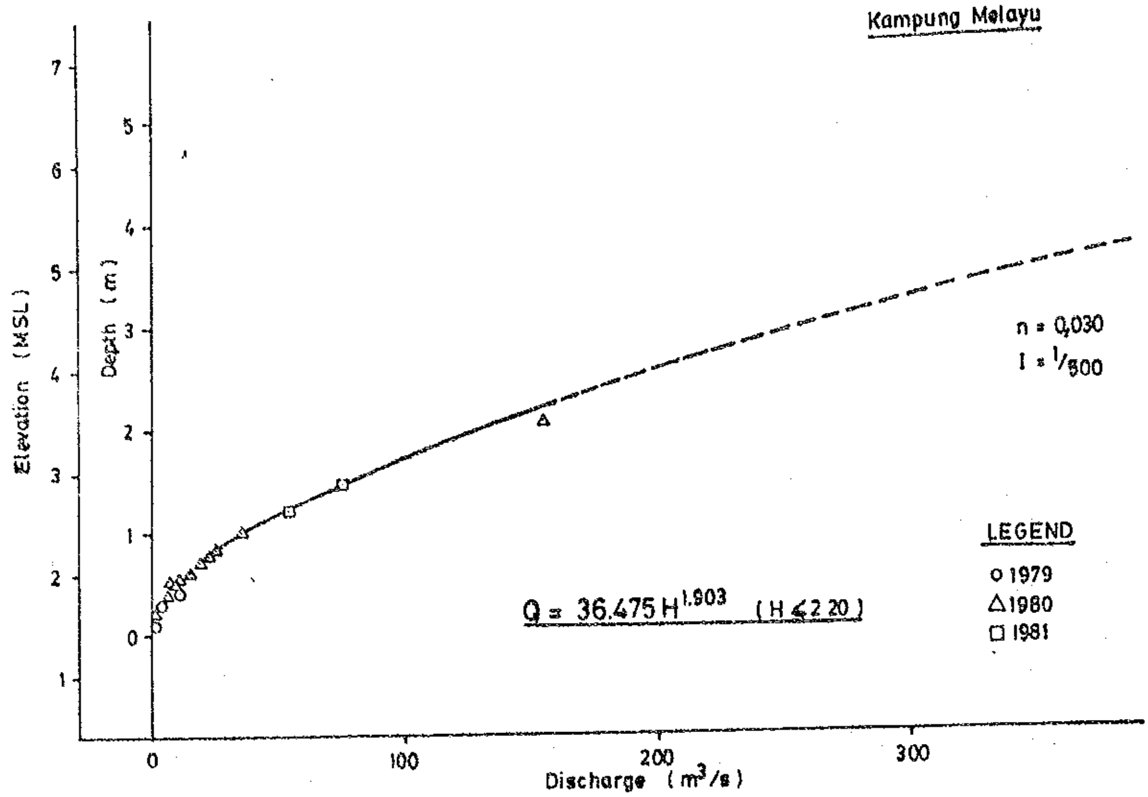


Fig. A-8(3) Discharge Rating Curves



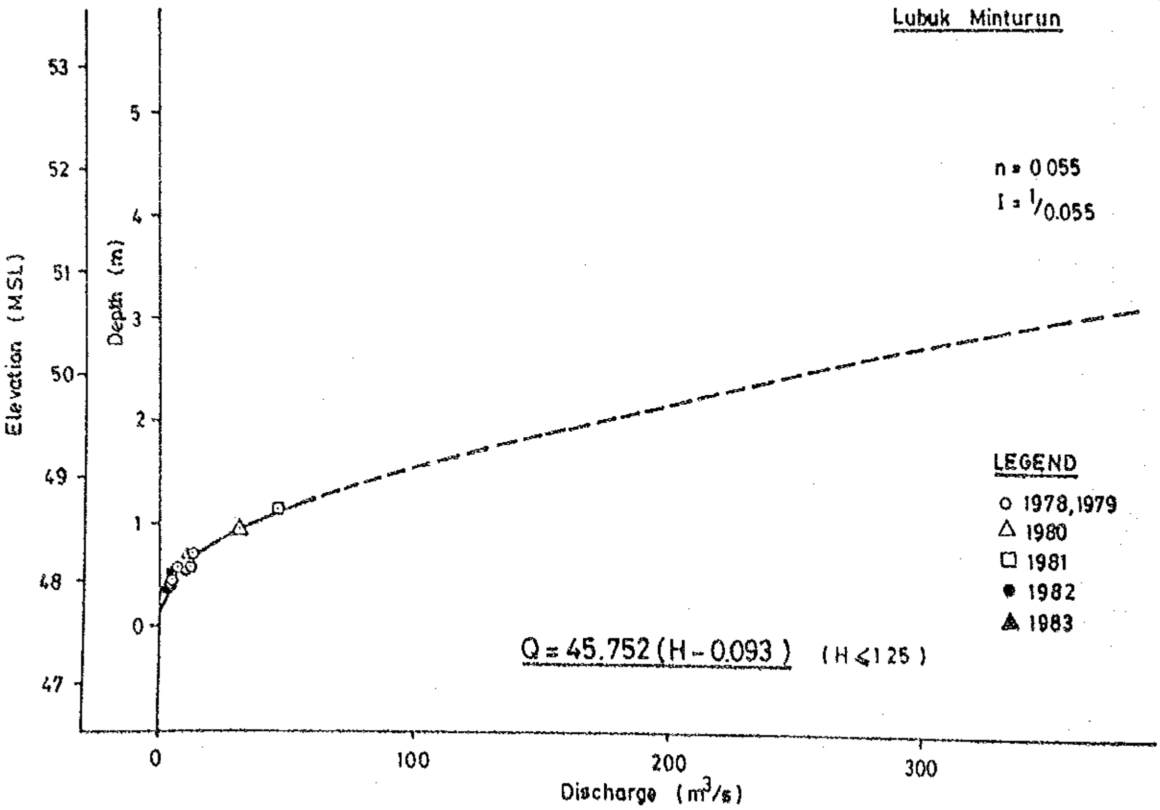


Fig. A-9 Monthly Mean Daily Discharge

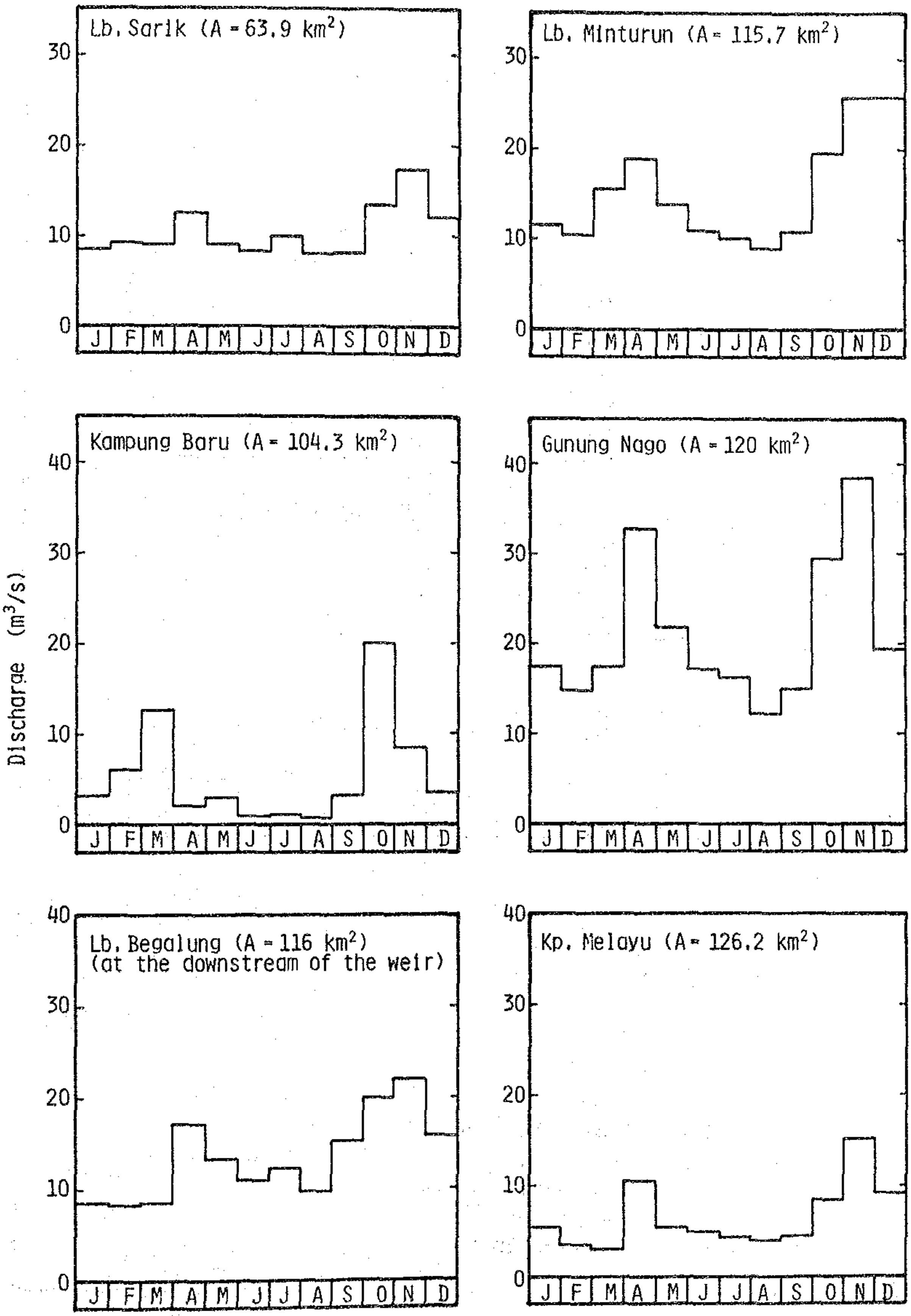
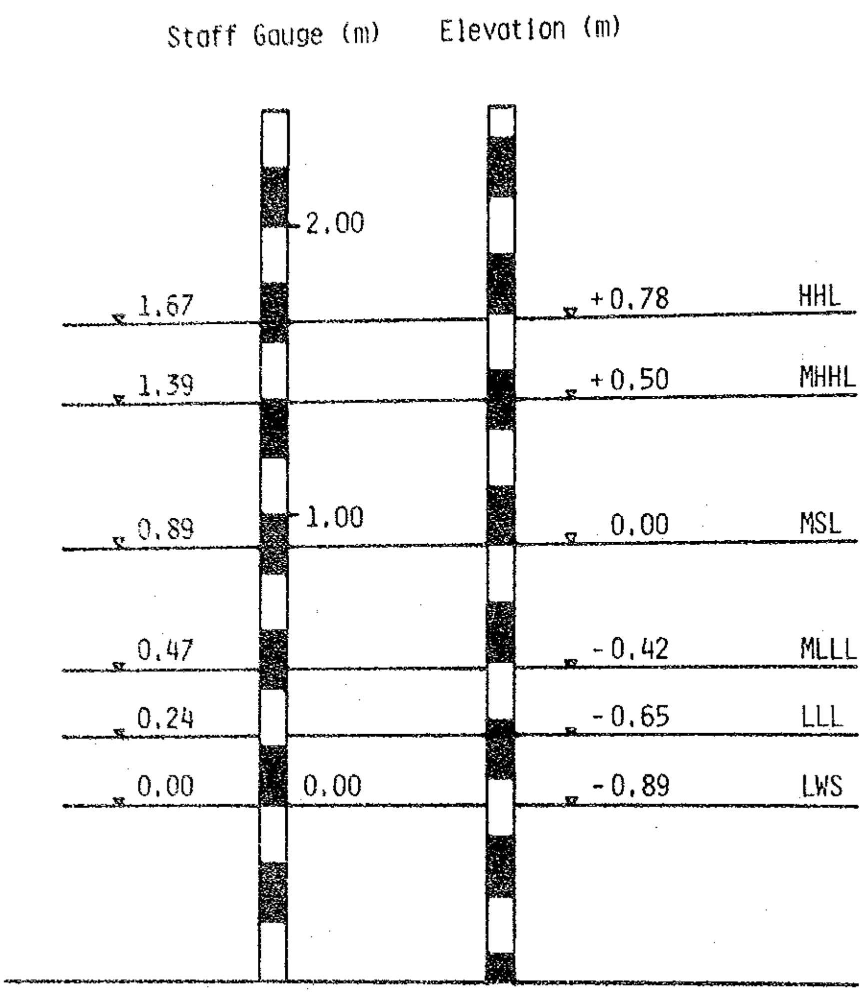
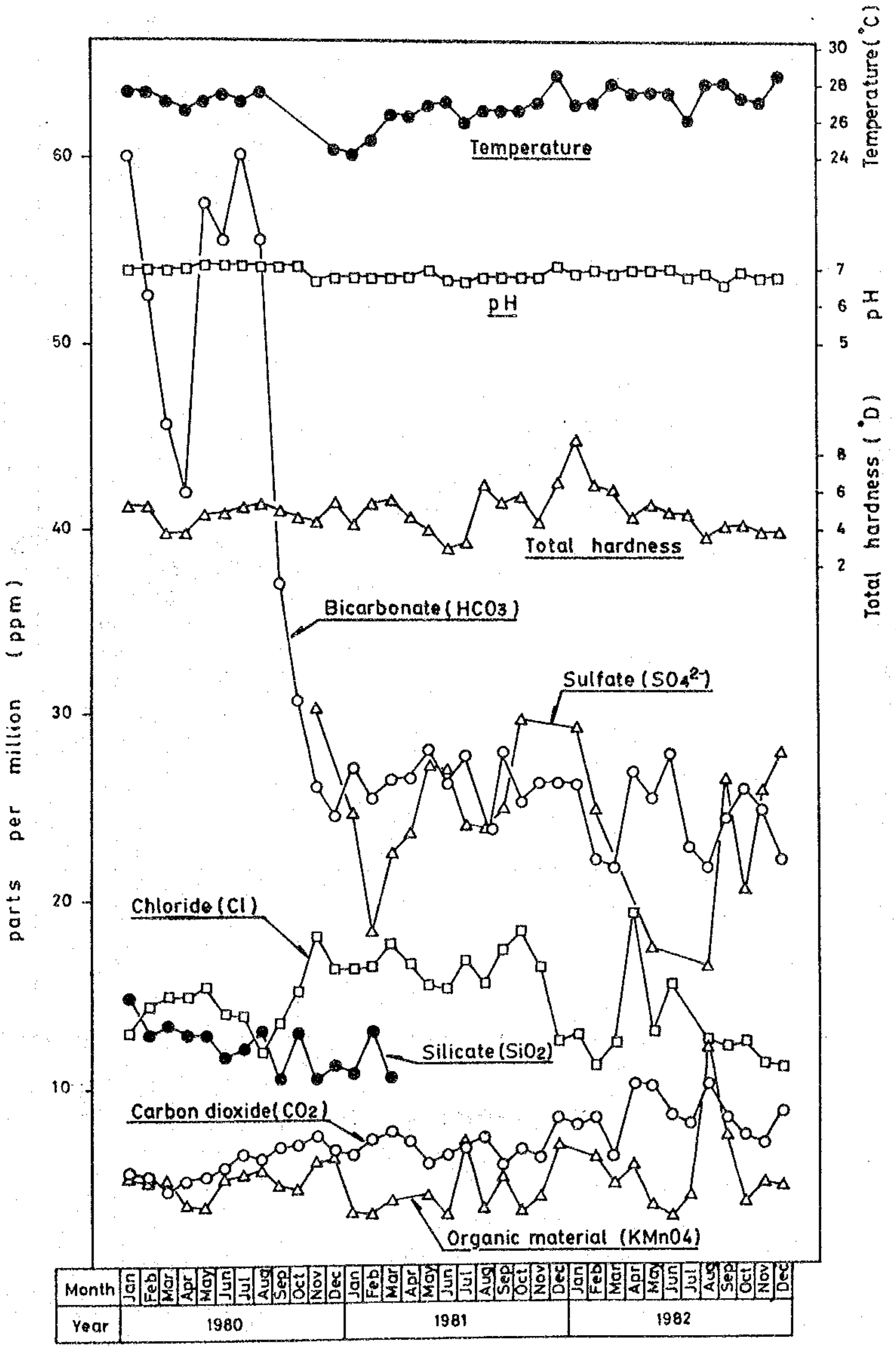


Fig. A-10 Tide Level at Teluk Bayur Harbour
(1975 - 1982)



HHL : Higher High Level
MHHL : Mean Higher High Level
MSL : Mean Sea Level
MLLL : Mean Lower Low Level
LLL : Lower Low Level
LWS : Low Water Spring

Fig. A-11 Seasonal Fluctuation of Water Quality
of Kuranji River



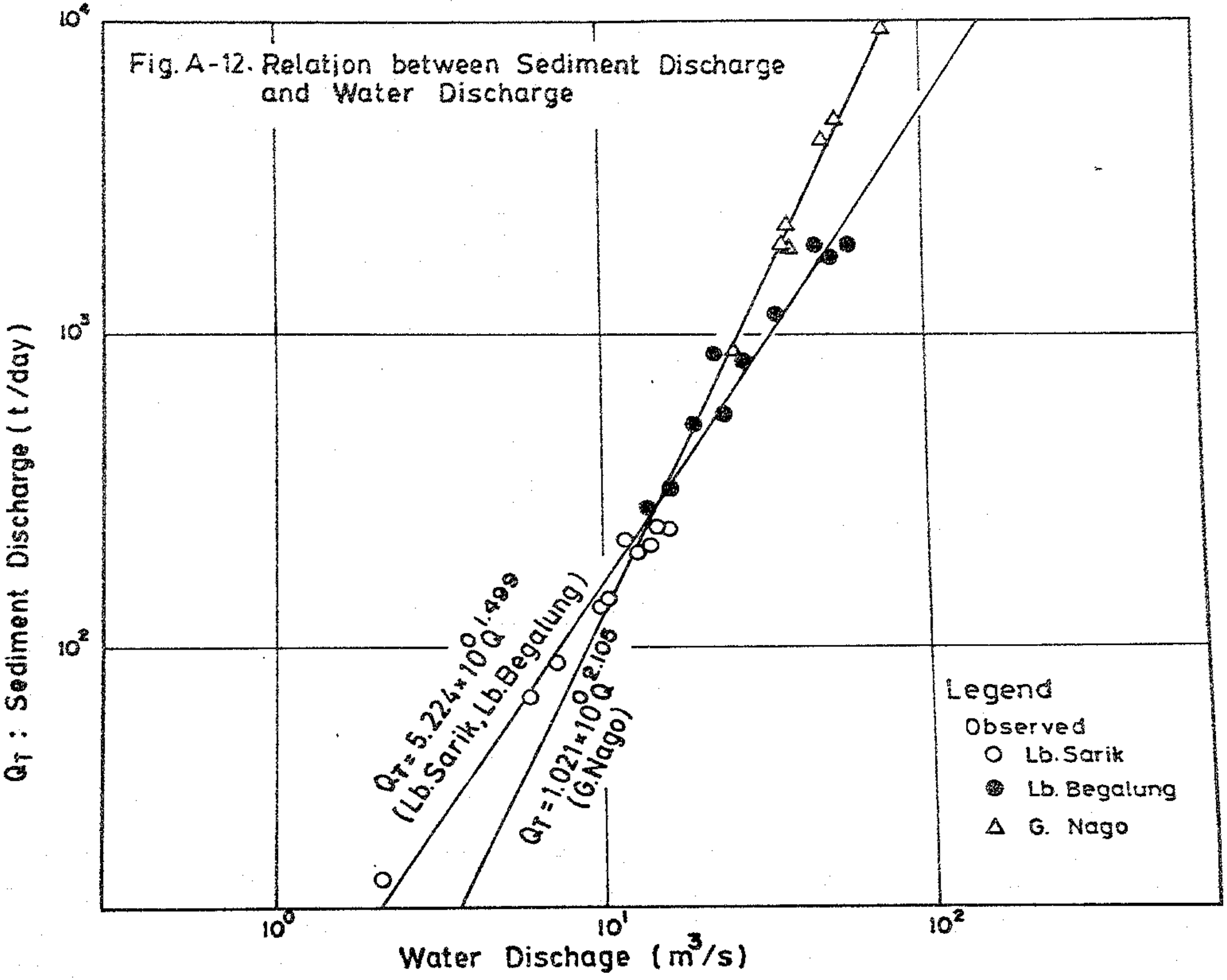


Fig. A-12. Relation between Sediment Discharge and Water Discharge

Fig. A-13 Sampling Location of Sea Coast and River Bed Materials

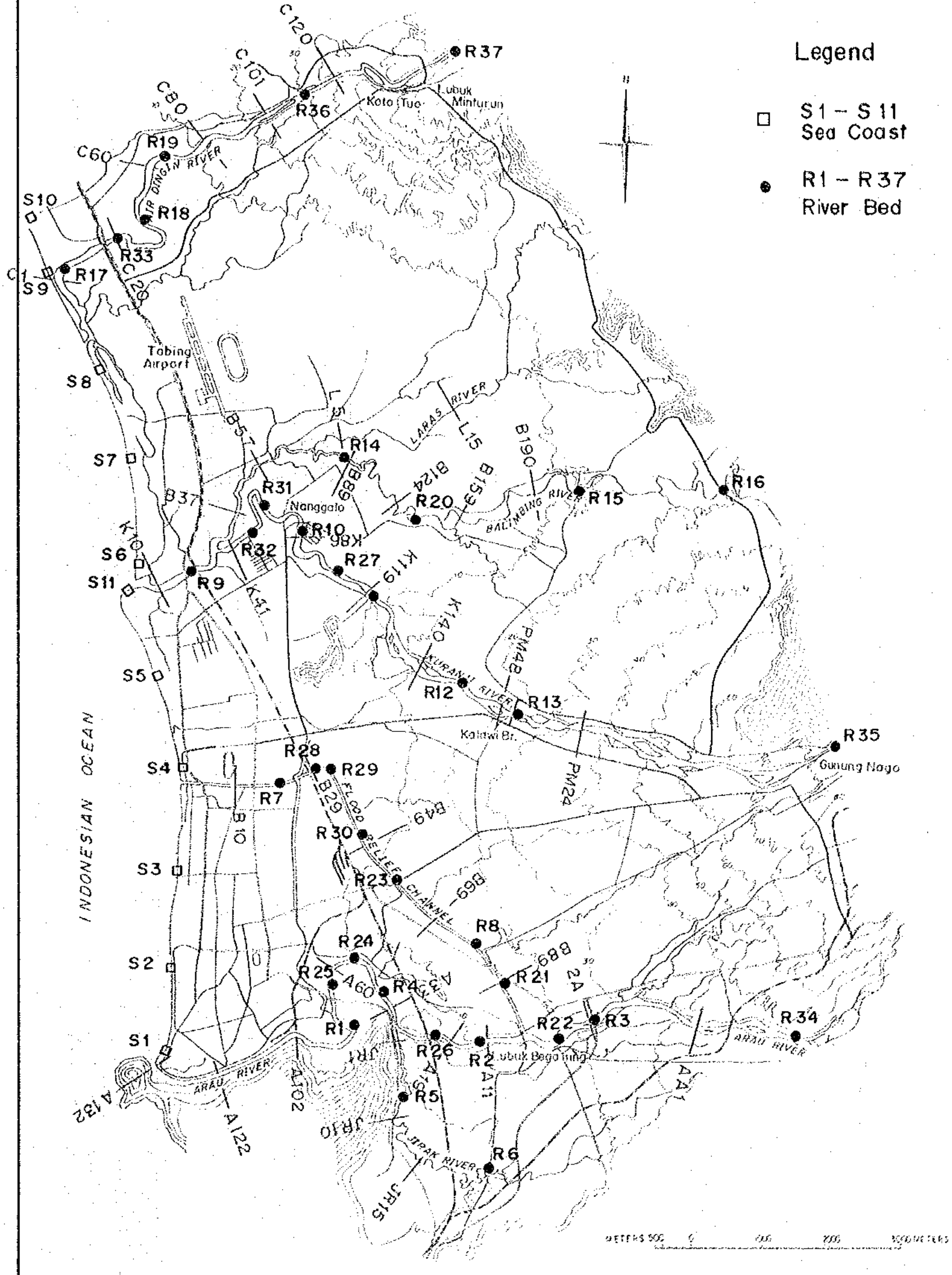


Fig. A-14 Sediment Transport Capacity of Channel

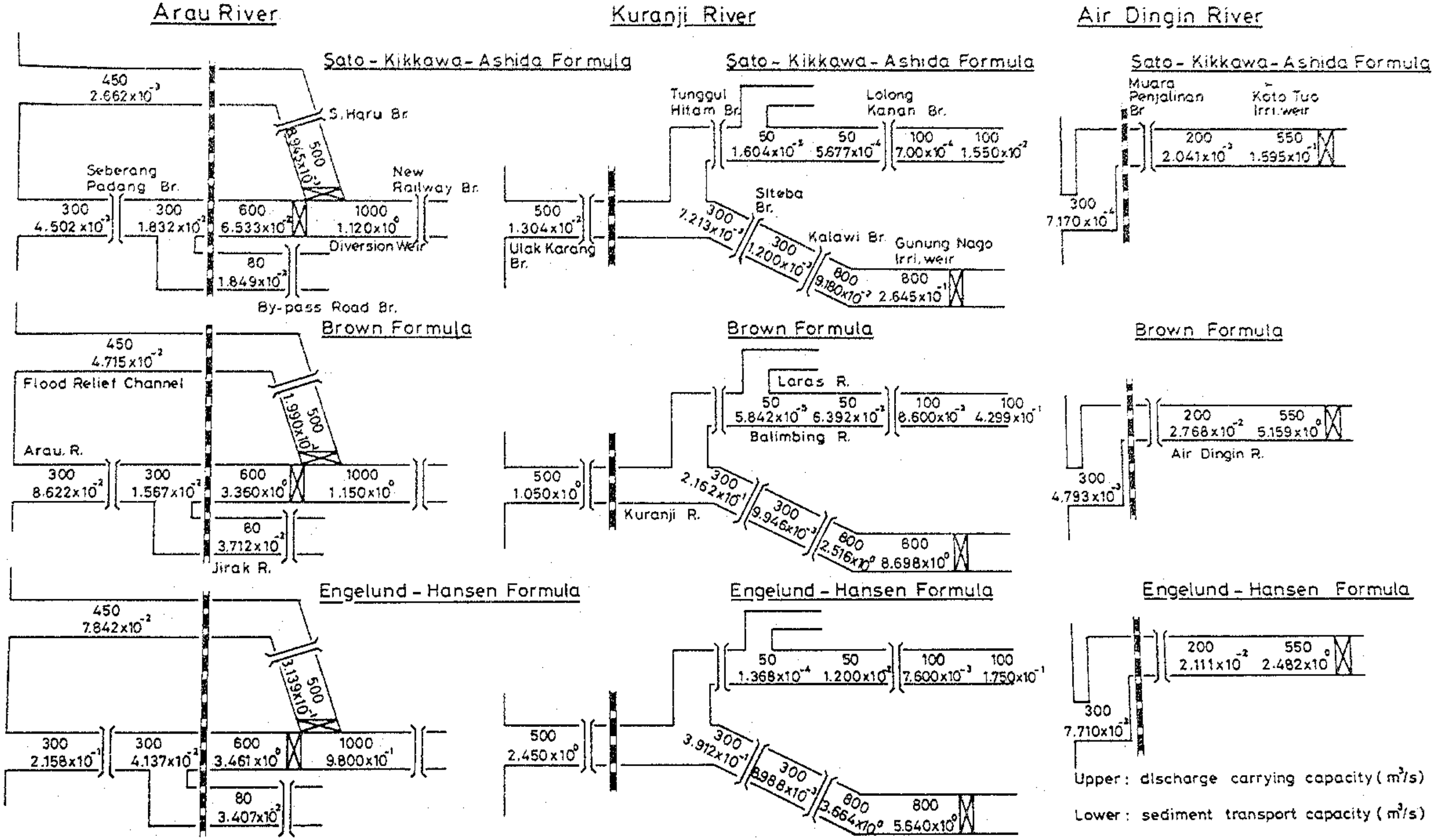


Fig. A-15 Fluctuation of River Course

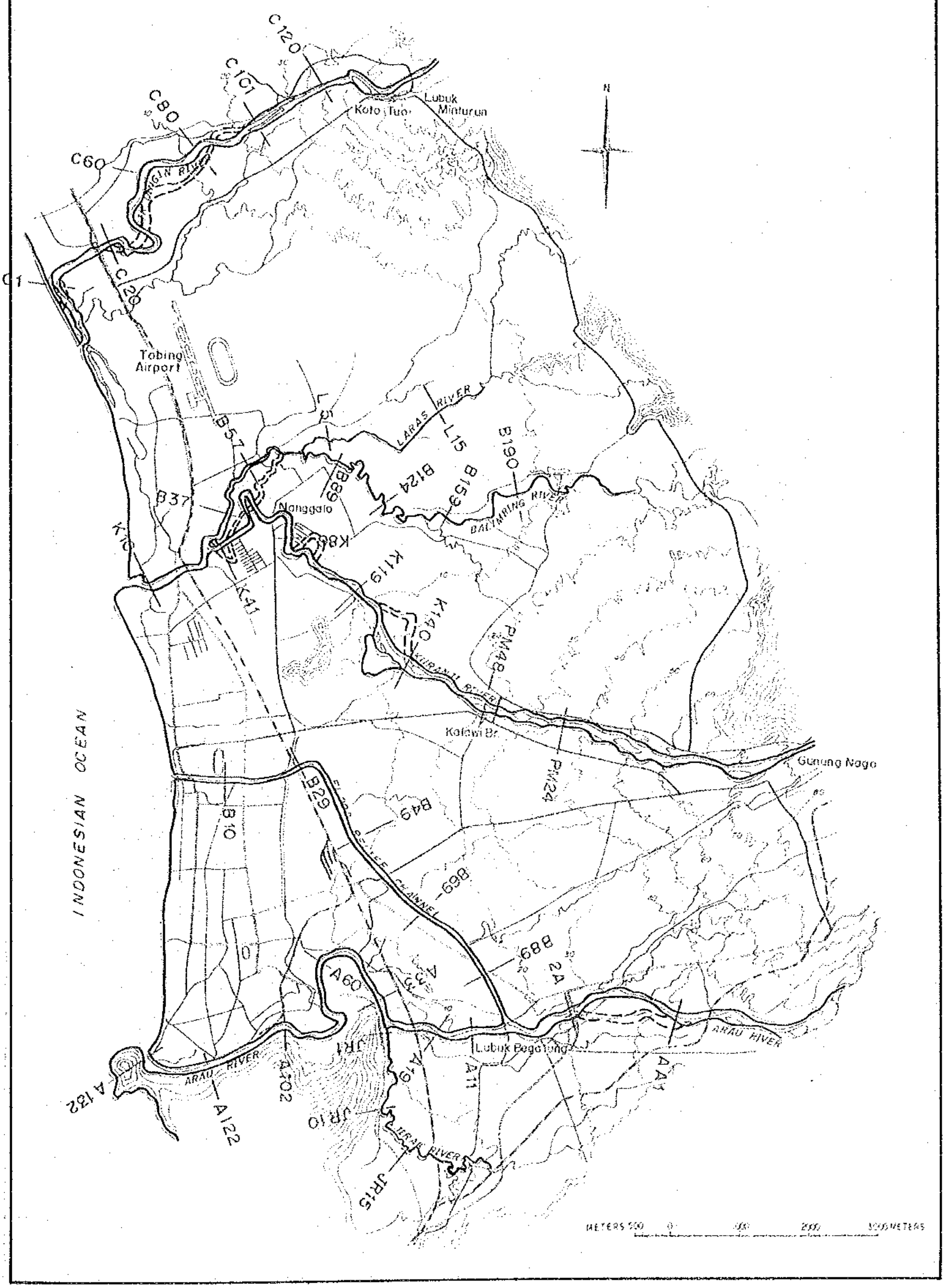


Fig. A-16 Location of Cross-section to be Compared

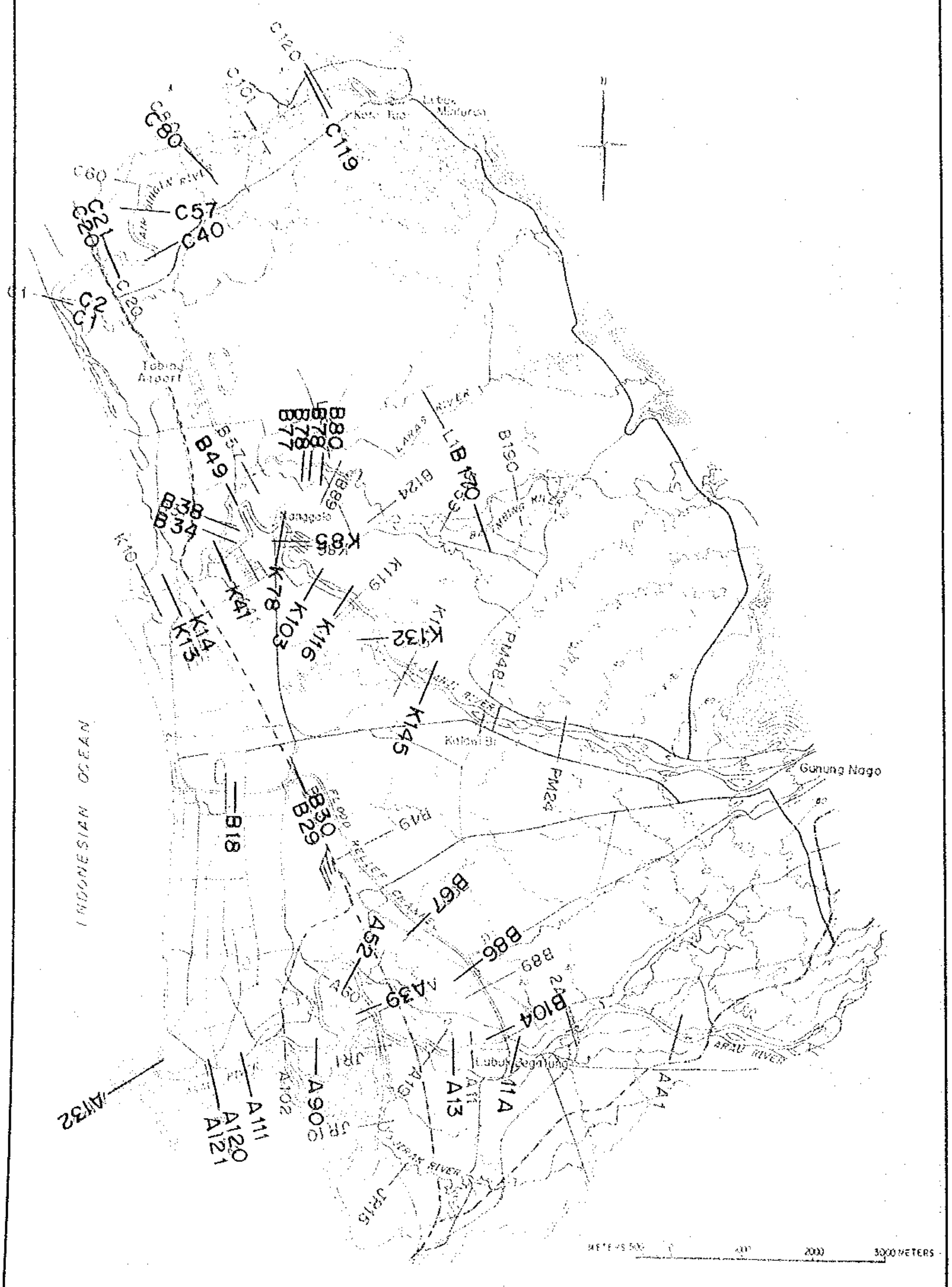


Fig. A-17(1). Fluctuation of River Profile

Arau River

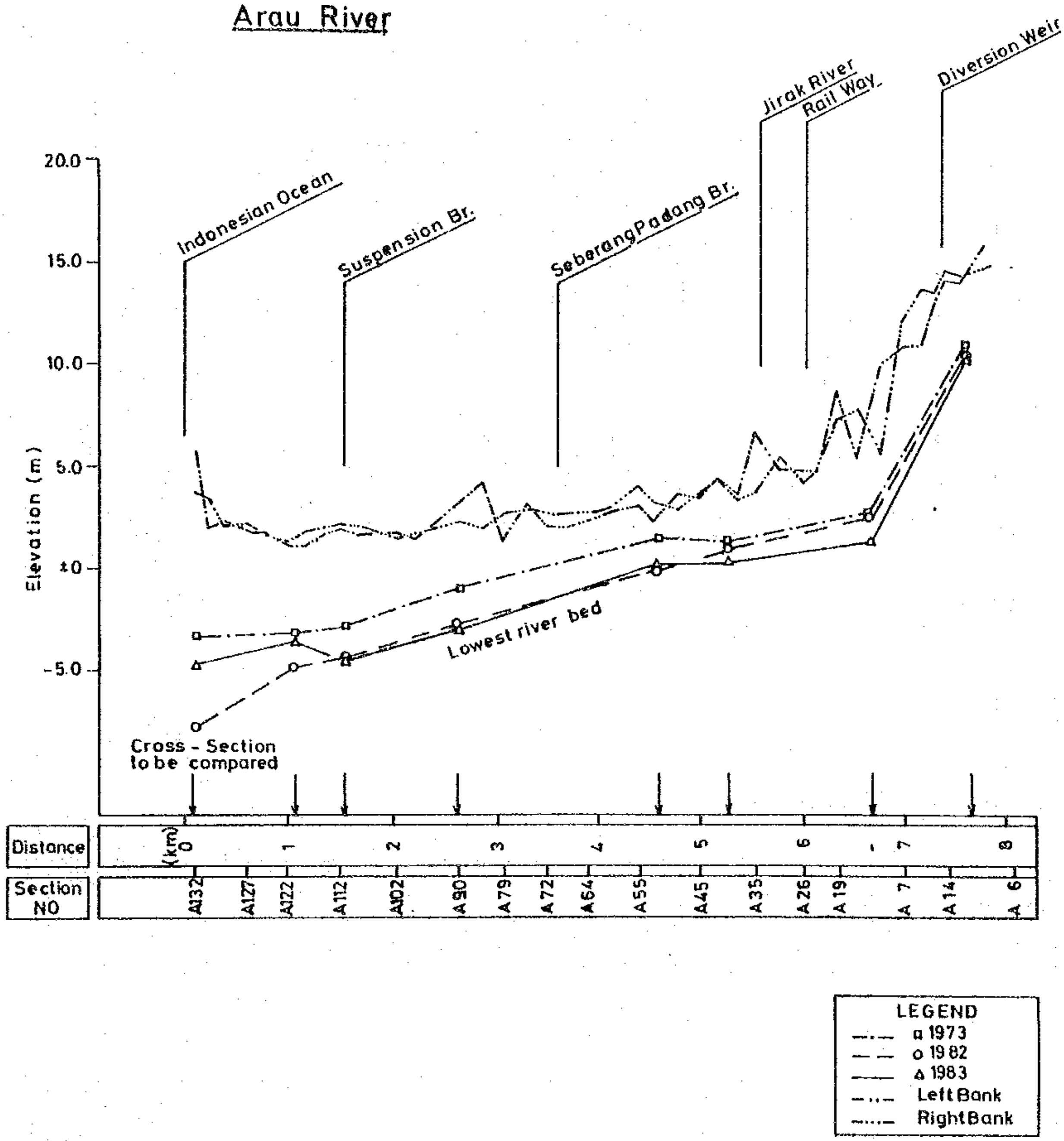


Fig. A-17(2). Fluctuation of River Profile

Flood Relief Channel

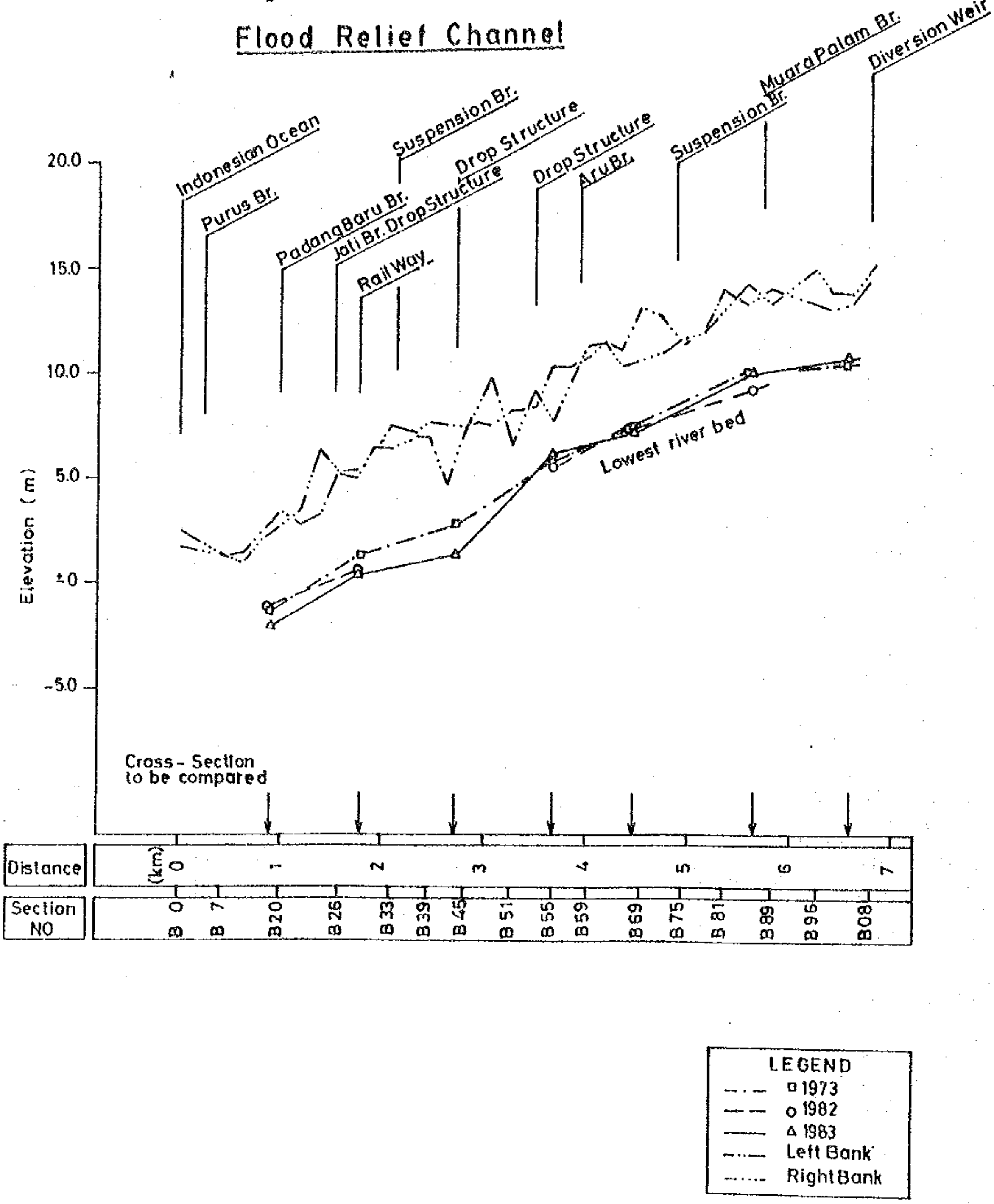


Fig.A-17(3).Fluctuation of River Profile

Kuranji River

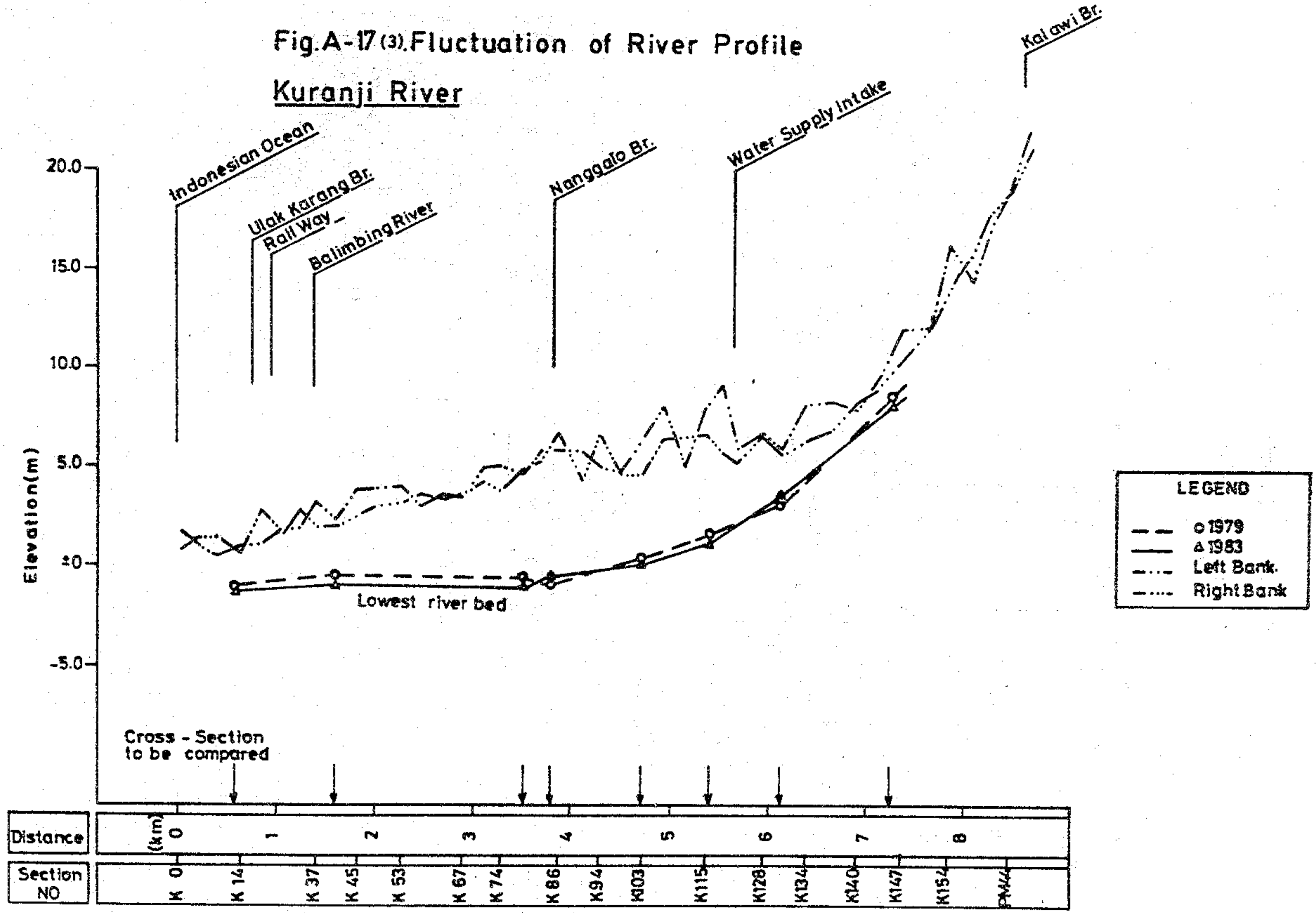


Fig.A-17(4) Fluctuation of River Profile

Balimbing River

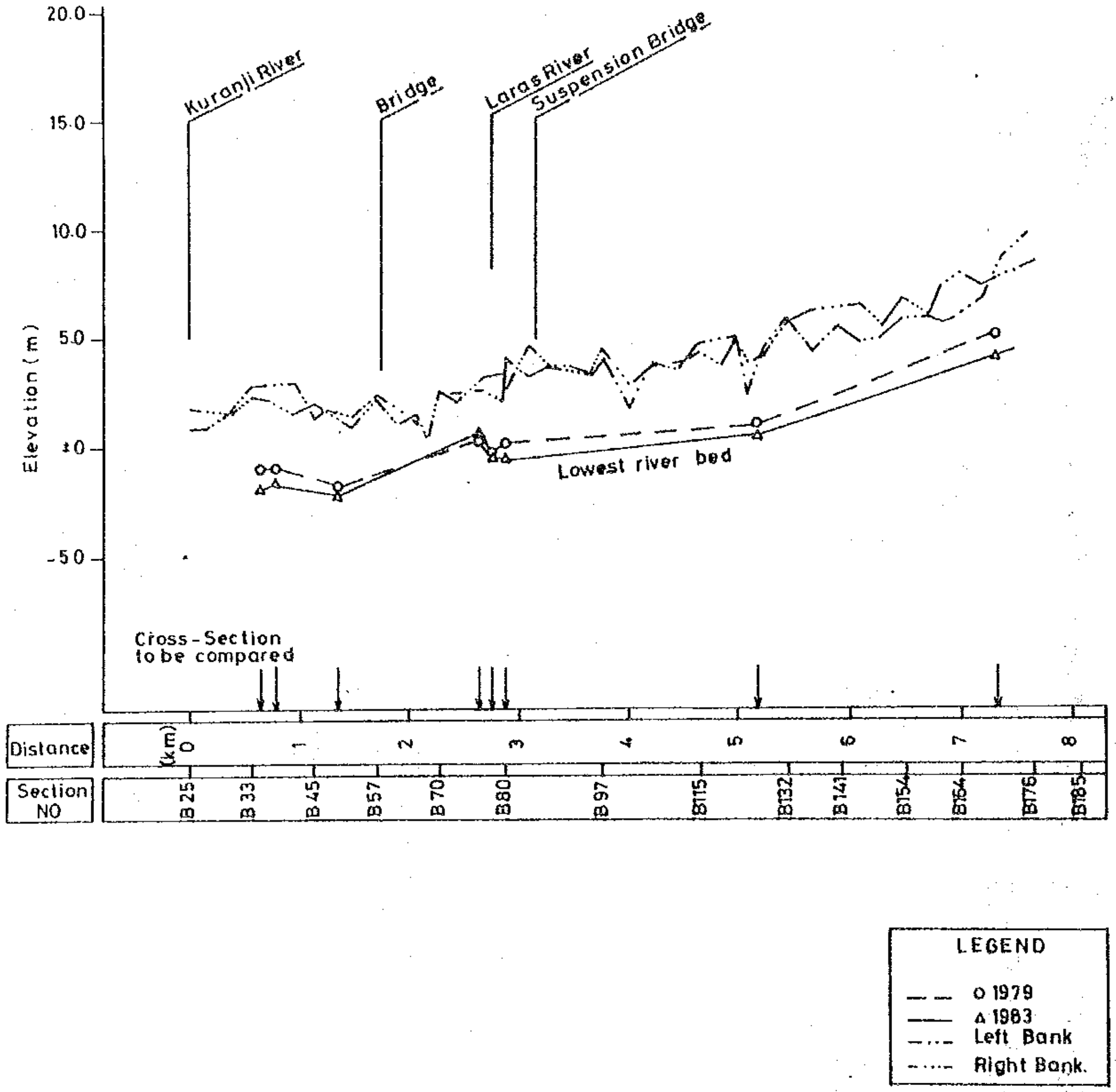


Fig. A-17 (5). Fluctuation of River Profile

Air Dingin River

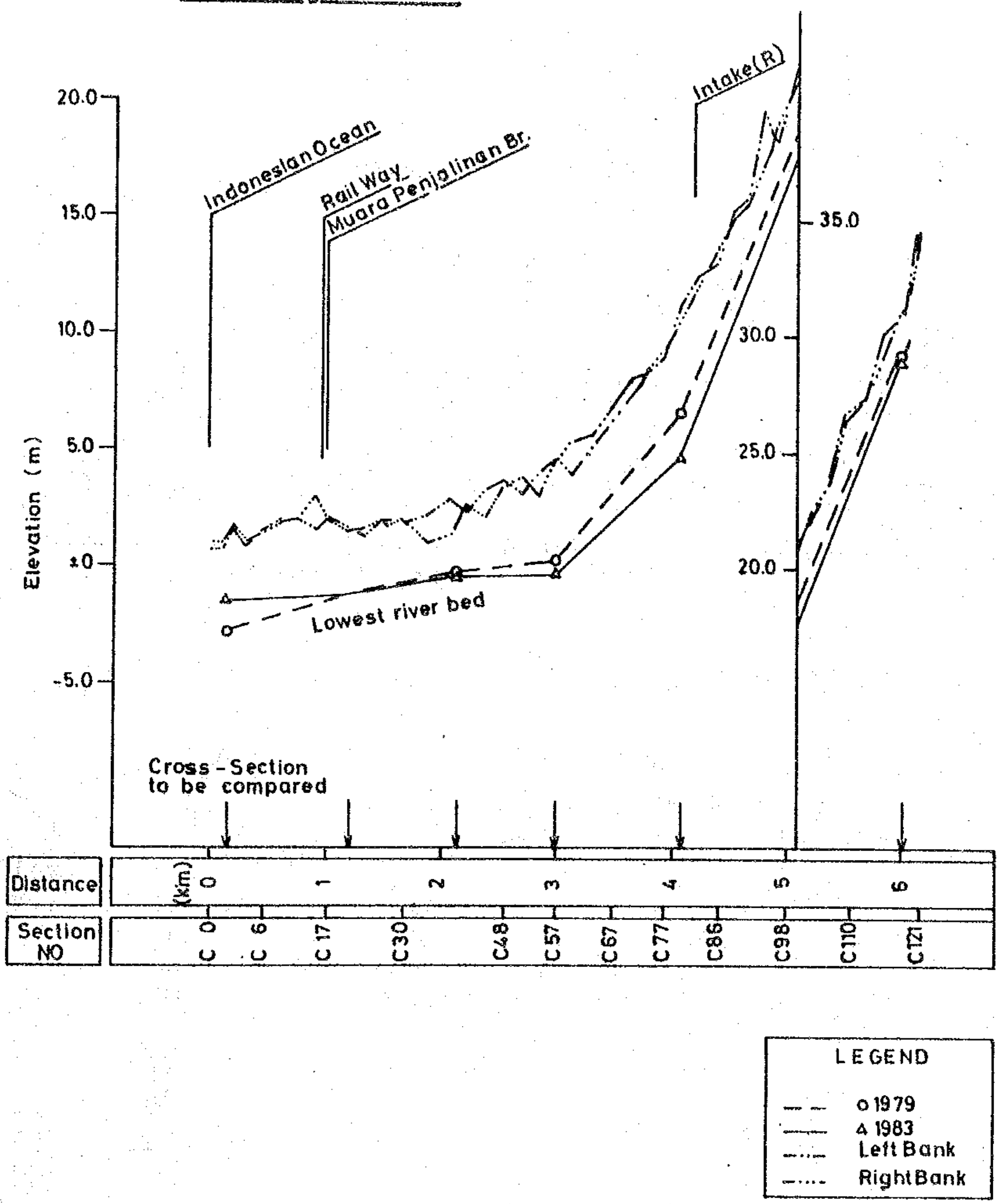


Fig.A-18(1) Fluctuation of River Cross-section

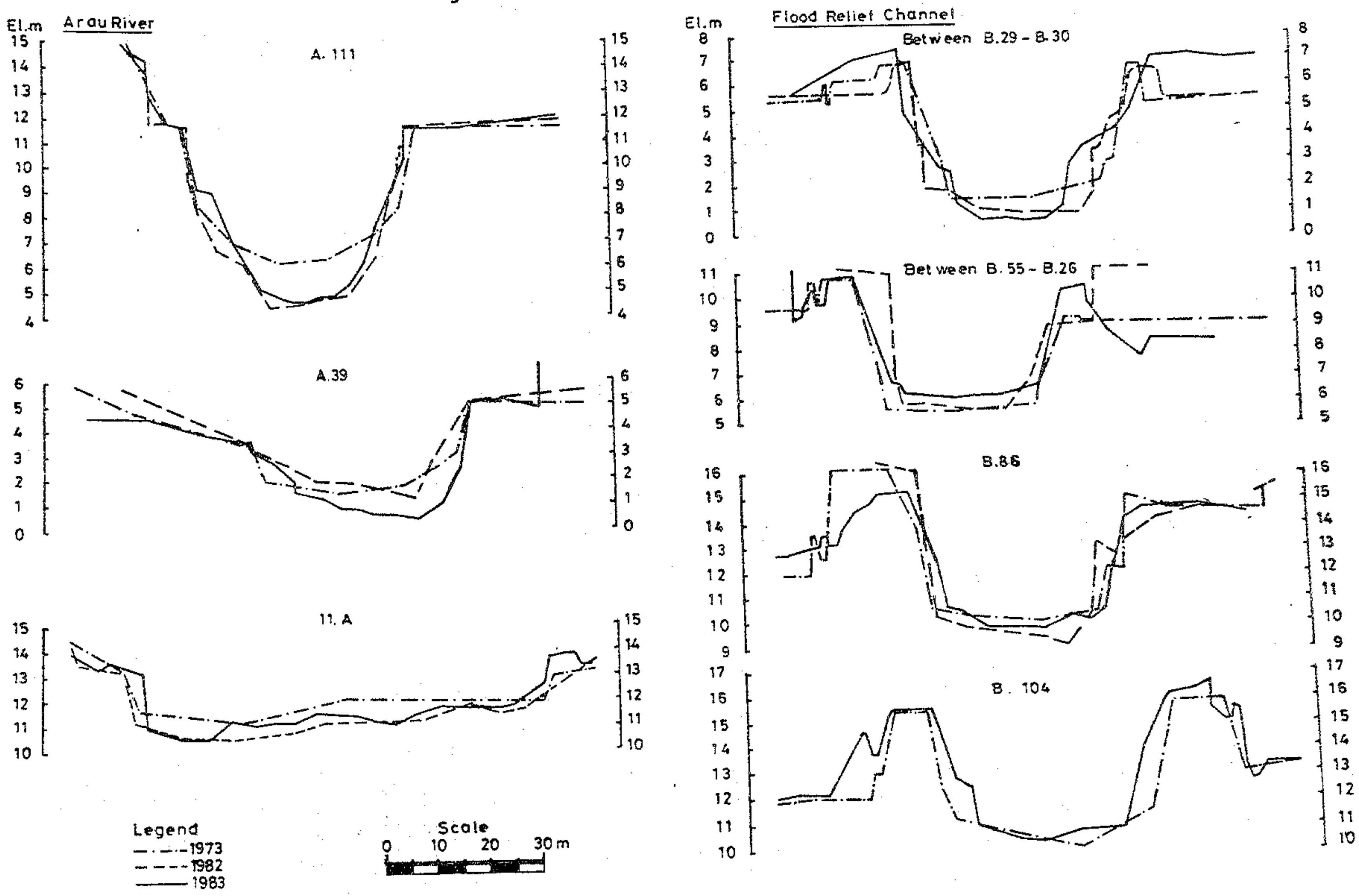
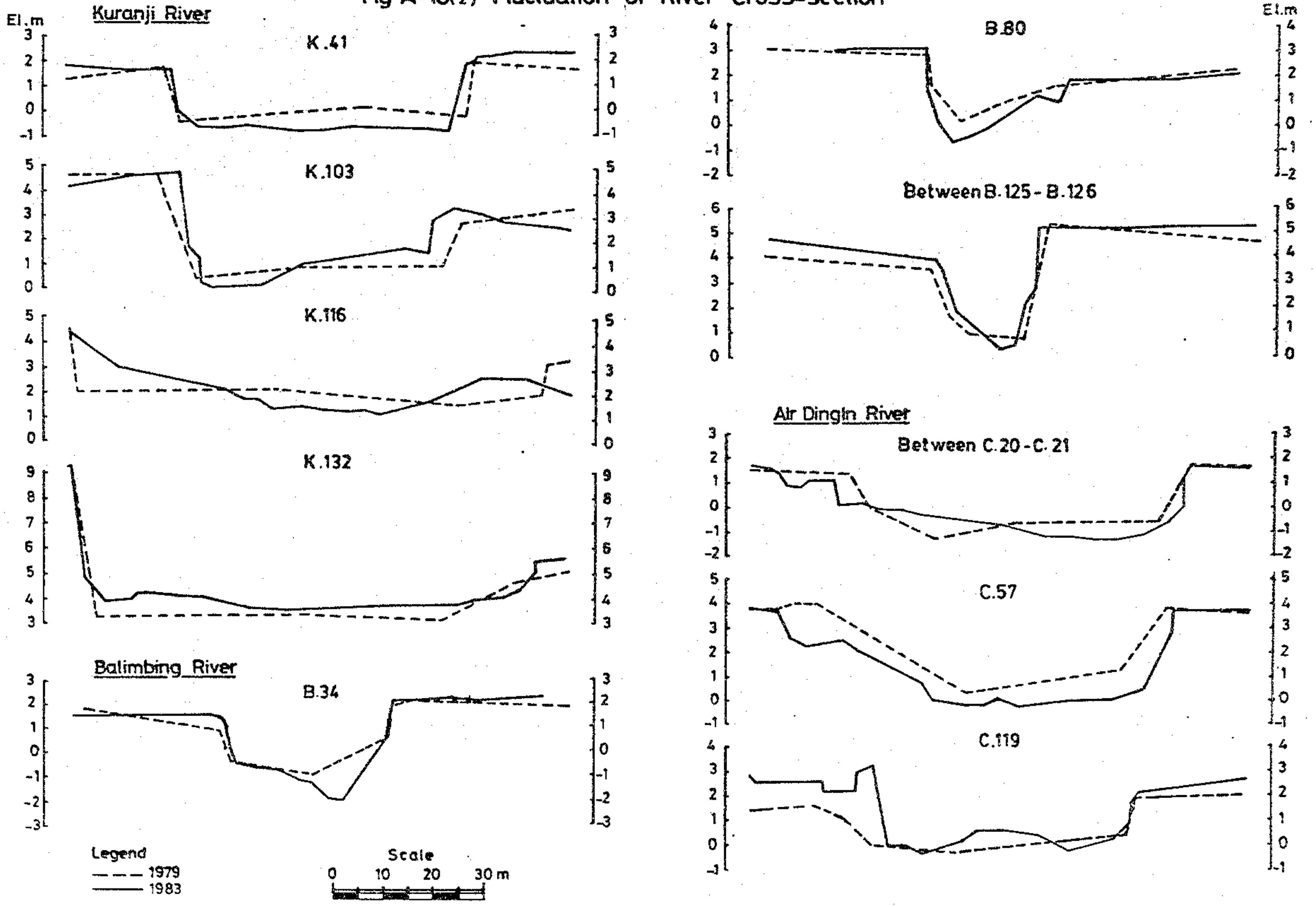


Fig A-18(2) Fluctuation of River Cross-section



INVESTIGATION RESULTS OF MEAN SEA LEVEL AT TELUK BAYUR

According to an information obtained from Mr. Daniel, Dinas Perencanaan, Teluk Bayur Harbor Authority, two bench marks were established by Dutch engineer around 1900. The elevation above MSL of the bench marks was surveyed at 3.6 m for BM 1 and 2.78 m for BM 2. At the same time, a tidal staff gage was also established near a small island in the harbor. During the period from 1942 to 1950, the staff gage was broken down and the data on tide level records were lost, but two bench marks have been kept in good condition. During the period from 1950 to 1960, a staff gage was installed again by the Indonesian, and the gage datum was tentatively adjusted to LWS which means 0.7 m below MSL. Although an automatic tidal recorder was installed in 1976, its gage datum has not been changed since 1976.

In March 1979, CV Kutamas tried to check the elevation of BM 2 for the ANai Project. According to their survey, the elevation of the bench marks above the gage datum was 4.416 m for BM 1 and 3.603 m for BM 2 which show that MSL is 0.816 m or 0.823 m above datum of tidal gage.

In February 1983, JICA study team for the Padang Area Flood Control Project tried to check the elevation of BM 2 for the purpose of clarifying relation between tridal gage and BM 2. The elevation of BM 2 was surveyed at 3.628 m above datum of the tidal gage. It shows that MSL is 0.848 m above the gage datum. The results of CV Kutamas and JICA study team show almost the same value.

On the other hand, MSL is estimated at 1.01 m by JICA stury team, based on the tidal level records from 1976 to 1982. There are three values of MSL, i.e, 0.7 m determined around 1950-1960, 0.823 m or 0.848 m surveyed by levelling and 1.01 m estimated from tidal level records.

JICA study team tried to inspect the staff of the tidal gage station, and the following fact is disclosed.

a. Datum of automatic recorder is being adjusted to 0.12 m below the datum of staff gage.

b. When the recorder installed in 1976 was replaced to new recorder in August 1982, the adjustment was not changed, because the bottom part of staff was broken and it could not be adjusted during the low tide.

In consideration of informations above, it is concluded that both survey results by levelling are almost in accord with that from tidal records. Therefore MSL is estimated at 0.89 m (1.01 m - 0.12 m = 0.89 m) in gage readings.

APPENDIX B

GEOLOGY

AND

SOIL - MECHANICS

APPENDIX B

GEOLOGY AND SOIL-MECHANICS

TABLE OF CONTENSTS

LIST OF TABLE

LIST OF FIGURES

1. Geology

The study area is roughly classified into plain and mountainous regions. The plain region is further classified into coastal plain, fluvial plain and volcanic fan. Fig. B-1 shows a model of topographical and geographical cross-section and Fig. B-2 shows a geological map of the study area.

1.1 Coastal Plain

The coastal plain is a flat region less than 10 m in elevation. This region faces the Indonesian Ocean and has undurated topography of 1 m or 2 m high. The unduration is formed with sand spits and back marshes developed in parallel with the coastal line. The coastal plain is a Quaternary alluvium which was formed by littoral deposits that were transported by the Arau, Kuranji and Air Dingin rivers. The region is characterised by geological features consisting of sandy strata mixed with gravel. But the surface layer is composed of brown cohesive soil.

1.2 Fluvial Plain

This is a fluvial plain formed by the Arau, Kuranji and Air Dingin rivers. The elevation of the plain ranges roughly from 80 m to 10 m on the Arau and Kuranji rivers, from 40 m to 10 m on the left side of the Air Dingin river, and from 60 m to 10 m on the right side of the Air Dingin river. This plain is characterised by a stratum mainly consisting of cobble stones of andesite mixed with sands and gravel. The size of the bed materials of the three rivers is approximately 0.5 m in the lower reaches and about 1.5 m in the upper reaches of the fluvial plain.

1.3 Volcanic Fan

This is a fan consisting of volcanic mud which was formed by the volcanic activity (pyroclastic flow) in the Quaternary Pleistocene epoch.

The elevation of the fan ranges from about 150 m to about 80 m on the Arau and Kuranji rivers and from 150 m to 40 m on the left side of the Air Dingin river. The fan consists of andesite and tuffbreccia.

1.4 Mountainous Region

The mountainous region in the study area is located approximately above 150 m in elevation. The region is characterised by geological features mainly consisting of volcanic rocks of the Tertiary period. Metamorphic rocks of the Pretertiary period are seen in Indarung located in the south-eastern part of the study area. The volcanic rocks consist of conglomerate, tuff, andesite and basalt. The metamorphic rocks consist of phyllite, quartzite and limestone.

2. Soil-mechanics

2.1 Available Data

The machine boring was conducted at Lubuk Bugalung weir by DGWRD in December, 1982. Boring results at 3 holes of which depth is 15 m each are available at the weir. Other soil mechanics data are also collected from DPU, West Sumatra. These are investigation results for building and bridge construction projects in Padang city. The list and location of the collected data are shown in Table B-1 and Fig. B-3.

In addition to the foundation investigation mentioned above, investigation was conducted by DPU for the Padang Area Flood Control Project during the period from April to May in 1983. The additional investigation consists of 5 machine borings and 20 Dutch cone tests mainly at the proposed structure sites for pumping stations, bridges and drainage sluices, 10 test pits on river banks for borrow pit for levee, and soil tests for sampled materials. The list of the additional investigation is shown in Table B-2 and its location in the said Fig. B-3.

2.2 Outline of Soil-mechanics Conditions

On the basis of the results of the foundation investigation and site reconnaissance, soil-mechanics conditions of the study area such as soil profile, foundation for structures, soil for embankment and workability of construction equipment are outlined in the succeeding sections.

2.2.1 Soil Profile

By use of foundation investigation results as available, soil profiles are prepared at the sections shown below. The locations of sections are shown in Fig. B-3 and their soil profiles are shown in Fig. B-4.

Section	Location
I. West to east section	
A - A'	Along the Arau river
B - B'	In old Padang city
C - C'	Along flood relief channel
D - D'	Along the Kuranji river
E - E'	Along the Balimbing river
F - F'	In back marsh behind the Tabing air port
G - G'	Along the Air Dingin river
II. North to south section	
H - H'	Along the coastline

The section H - H' shows the soil profile along the coastline in the north to south direction. The profile is characterized by 3 distinct layers, i.e., sandy soil, cohesive soil, and sand and gravel layers from the ground surface. The principal features of these soil layers are shown in Table B-3.

The section A - A' thru G - G' show the profiles from sea coast to inland in the west to east direction. As seen in section A- A' and

C - C', the cohesive soil layer (2nd layer) becomes thinner toward east and seems to end around the boundary of coastal plain and fluvial plain.

2.2.2 Bearing Capacity as Structure Foundation

The physical and soil mechanics tests are conducted using the disturbed and undisturbed samples obtained by the machine boring. The results of soil tests are shown in Table B-5. Among these results the values obtained by soil mechanics tests are deemed to be unreliable. This may come from difficulty in sampling of undisturbed soil.

As a whole, the ground in the fluvial plain higher than 10 m, MSL is composed of sand and gravel layers and enough bearing capacity with N-value more than 30. The ground in the coastal plain lower than 10 m, MSL has around 15 m thick cohesive soil layer with medium to hard consistency under the surface sand layer of 10 to 15 m in thickness with loose to medium relative density.

For the Padang Area Flood Control Project, structures such as pumping stations, bridges, drainage sluices and dikes are to be proposed. With regard to the foundation treatment for these structures in the coastal plain, two measures are conceivable in general, i.e., foundation on the surface sand layer (1st layer) with pile groupe if necessary and foundation on the sand and gravel layer (3rd layer) under the cohesive layer (2nd layer) with piles. In the case of latter measure, the structure may be subject to settlement due to consolidation. The following foundation treatments measures are recommendable for designing these structures, although the depth until the sand and gravel layer under the cohesive soil layer should be confirmed at each proposed structure site.

a. Pile foundation borne by the 3rd layer for the big and heavy structures such as pumping stations and bridges.

b. Group pile foundation borne by the 1st layer for the drainage sluice.

c. Foundation directly on the 1st layer for dikes.

Some descriptions on the boring results at each site are given below :

a. Lubuk Begalung site : The boring depth is 15 m. The ground is sand and gravel with N-value more than 50 from surface to the bottom.

b. B1 site for proposed pumping station : The 3rd layer is found at the depth of 29 m from the surface. Foundation piles are desirable to be borne by the 3rd layer. Since the site is located at the foot of Mt. Padang, the depth of the 3rd layer may changeable by sites.

c. B2 site for proposed pumping station : The depth of the 3rd layer is more than 30 m. The depth of the 3rd layer is not confirmed yet by the boring. Foundation piles are desirable to be borne by the 3rd layer.

d. B3 site for proposed bridge : Since this site is located on the upper limb of coastal plain, the cohesive soil layer is not found. The foundation of bridge can be borne by the sand and gravel layer. Considering from its location, cohesive soil layer might be found by another boring. Further investigation may be needed around the site.

e. B4 site for proposed pump station : The 3rd layer is found at the depth of 27 m from the surface under the 13 m thick sand layer and 14 m thick cohesive soil layer. Foundation piles are desirable to be borne by the 3rd layer.

f. B5 site for proposed bridge : The cohesive soil layer is found under the 15 m thick sand layer. The 3rd layer is not found within the boring depth of 20 m.

Design data on the foundations of bridges are collected from Bina Marga, DPU West Sumatra, and shown in Table B-4. These will also be referred to design of structure foundation for the Project.

2.2.3 Embankment Materials

According to the site reconnaissance and bed material sampling, the river bed materials in the reaches shown below are applicable to embankment materials of dikes. The bed materials for other reaches may not always be applied to the dike because of its coarse size.

a. Arau river up to about 4 km upstream from river mouth

b. Flood relief channel up to about 1 km upstream from river mouth

c. Main Kuranji river up to about 4 km upstream from river mouth

d. Balimbing river up to about 6 km from the confluence of the main Kuranji

e. Air Dingin river up to about 1 km upstream from river mouth

Soil survey by the test pits is carried out on the river banks in the coastal plain in order to find the borrow pit for embankment materials. The depth of the test pits is 2.5 m to 3 m. The soil logs of test pits are shown in Fig. B-5.

Physical soil test is conducted for the disturbed samples taken from the test pits. The results of the soil test are compiled in Data Book. The grading curves and soil classification are shown in Figs. B-6 and B-7. The compaction test is also carried out and the results are shown in Fig. B-8.

The survey by the test pit suggests that the river bank materials up to 3 m depth in the coastal plain are clay, silt, sand, gravel and their mixture, and are suitable for embankment materials for dikes.

2.2.4 Workability of Construction Equipment

Judging from the soil and foundation investigation, ordinary construction equipment is workable in the study area except for the back marsh area behind the Tabing air port.

In the back marsh area, the ground is poor showing qc = 0 at least 2 m depth. The earth works by swamp type equipment or manpower may be necessary. The construction method in the back marsh area should be decided based on the further foundation investigation by cone penetration tests, auger boring at several sites and phisical soil test of soils obtained by the boring.

Table B - 1 Existing Data on Foundation Investigation

No.	Location	Survey Item		Data Source
1.	KANTOR BANK DAGANG NEGARA	Hand auger boring Sounding Soil test	2 places 3 " 	Laboratorium penyelidikan tanah/jalan
2.	BANGUNAN BAGIAN LUBUK BEGALUNG	Machine boring Sounding Soil test	3 places 5 " 	P.T. Geovisi Nusantara
3.	KANTOR BANK PEMBANGUNAN DAERAH	Machine boring Hand auger boring Sounding Soil test	2 places 3 " 5 " 	Laboratorium penyelidikan tanah/jalan
4.	KANTOR BANK DAGANG NEGARA	Machine boring Soil test	2 places 	"
5.	KANTOR PERUSAHAAN AIR MINUM	Hand auger boring Sounding Soil test	2 places 4 " 	"
6.	KANTOR LIAJR	Hand auger boring Sounding Soil test	2 places 4 " 	"
7.	KANTOR DEPARTEMEN AGAMA	Hand auger boring Sounding Soil test	2 places 2 " 	"
8.	KANTOR BKKBN	Hand auger boring Sounding Soil test	1 place 3 places 	"
9.	PROYEK JEMBATAN RIAU - SUMBAR (Kuranji R.)	Soil profile	1 sheet	Dinas Jembatan
10.	JEMBATAN NANGGALO	Hand auger boring Sounding Soil test	2 places 4 " 	Laboratorium penyelidikan tanah/jalan
11.	JEMBATAN TABING	Sounding	2 places	"
12.	PROYEK JEMBATAN RIAU/SUMBAR (Air Dingin R.)	Soil profile	2 sheets	Dinas Jembatan

Table B - 2 Additional Soil Investigation

Item of investigation	Quantity	Remarks
1. Machine boring 30 m × 3 sites = 90 m 20 m × 2 sites = 40 m	5 sites (130 m)	Site NO B1 thru B5 with starndard penetration test
2. Dutch cone test	20 sites	Site NO D1 thru D20
3. Test pit	11 sites	Site NO P1 thru P11 incl. 1 site by Study Team
4. Soil test		
a. Physical and soil mechanics tests for undisturbed samples obtained by boring	5 samples	
b. Physical test for disturbed samples obtained by boring	13 samples	
c. Physical test and compaction test for samples obtained from test pit	10 samples	

Notes

1. Physical test includes tests for moisture content, specific gravity, liquid limit and plastic limit, grain size, and wet density
2. Soil mechanics test includes unconfined compression test, triaxial compression test, and consolidation test

Table B - 3 Principal Features of Soil Layers along Costline

Soil layer	Thickness	Classification of soil	N-value	Estimated soil factor/1			Remarks
				γ_t	c	ϕ	
1st layer	abt.10-15 m	Sandy soil	5 - 20	1.85	0	28	Alluvium
2nd layer	abt. 15 m	Cohesive Soil	5 - 15	1.70	0.35	0	Alluvium
3rd Layer	-	Gravel and Sand	More than 30	2.00	0	40	Diluvium

/1 γ_t : Wet density (g/cm^3), c : cohesion (kg/cm^2),
ϕ : Internal friction (degree)

Table B - 4 Foundations of Bridges Constructed Recently

Location	Name of Br.	Diameter of Pile	Length	Material	Remarks
1. Arau River	Seberang Padang Br.	ϕ508	15.5 - 21.7 m	Steel	
2. "	By-pass Br.	-	-	-	Spread foundation
3. Flood Relief Channel	Purus Br.	ϕ508	36.0	Steel	
4. "	Padang Br.	400 × 400	36.0	R.C.	
5. "	Marapalam Br.	ϕ3,000	6.0	R.C.Well	
6. Kuranji River	Ulak Karang Br.	400 × 400	24.0	R.C.Pile	
7. "	Nanggalo Br.	ϕ2,000	6.0	R.C.Well	
8. Air Dingin River	Muara Panjalinan	ϕ508	21.0	Steel	

Source : Information from Bina Marga

Fig. B-1 Geomorphologic and Geological Cross - Section

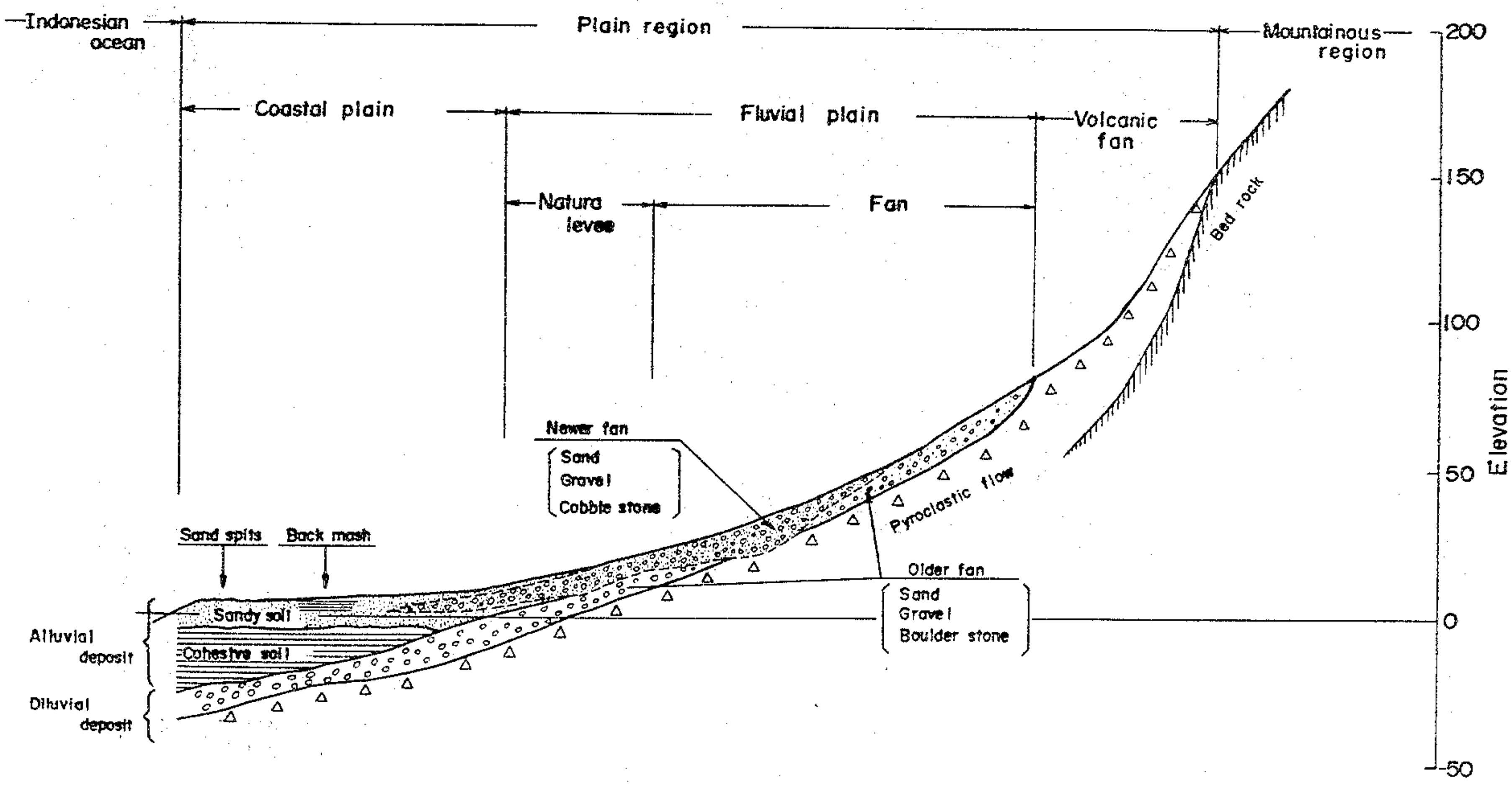
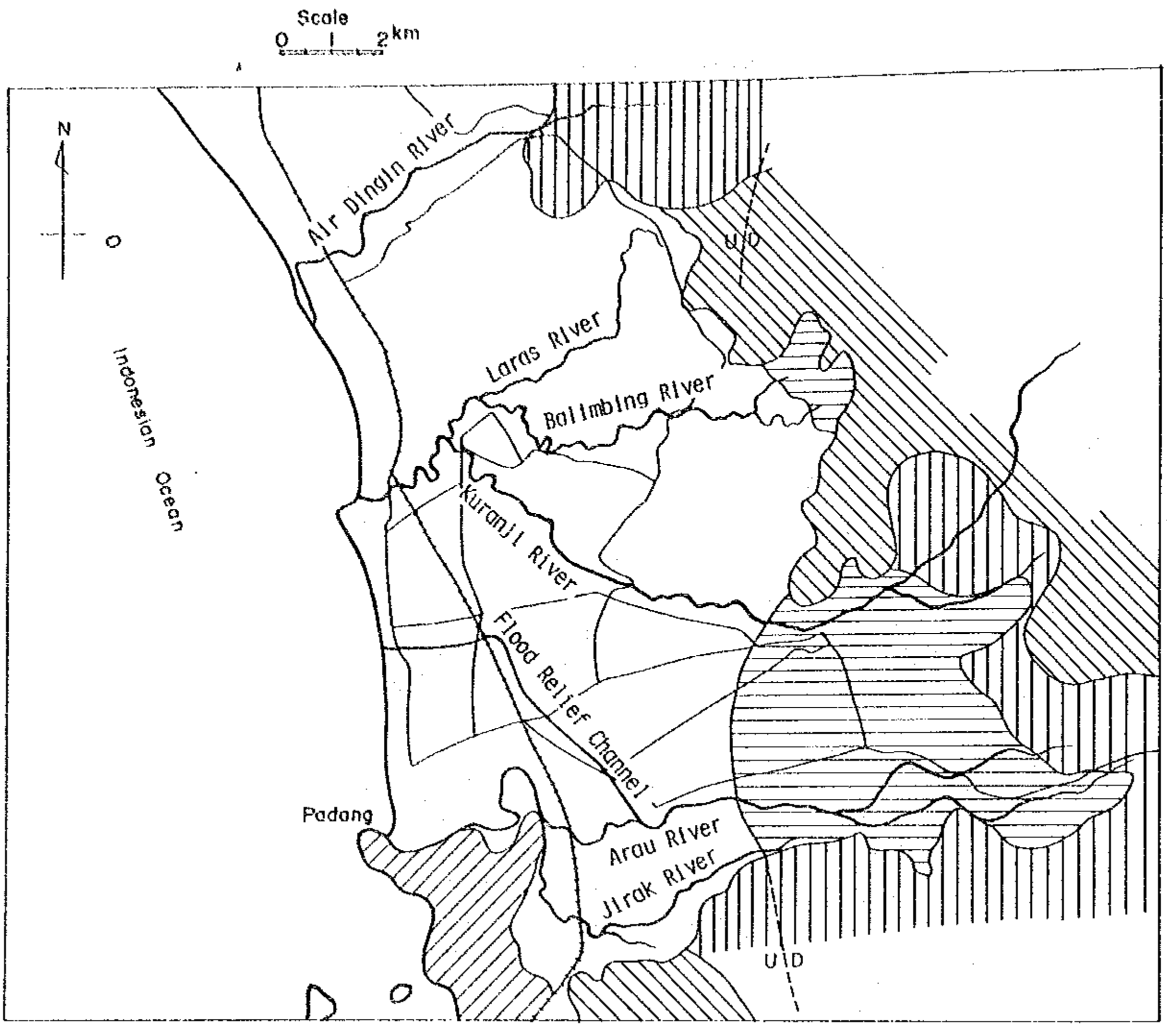
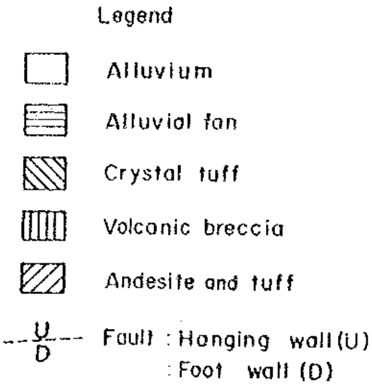


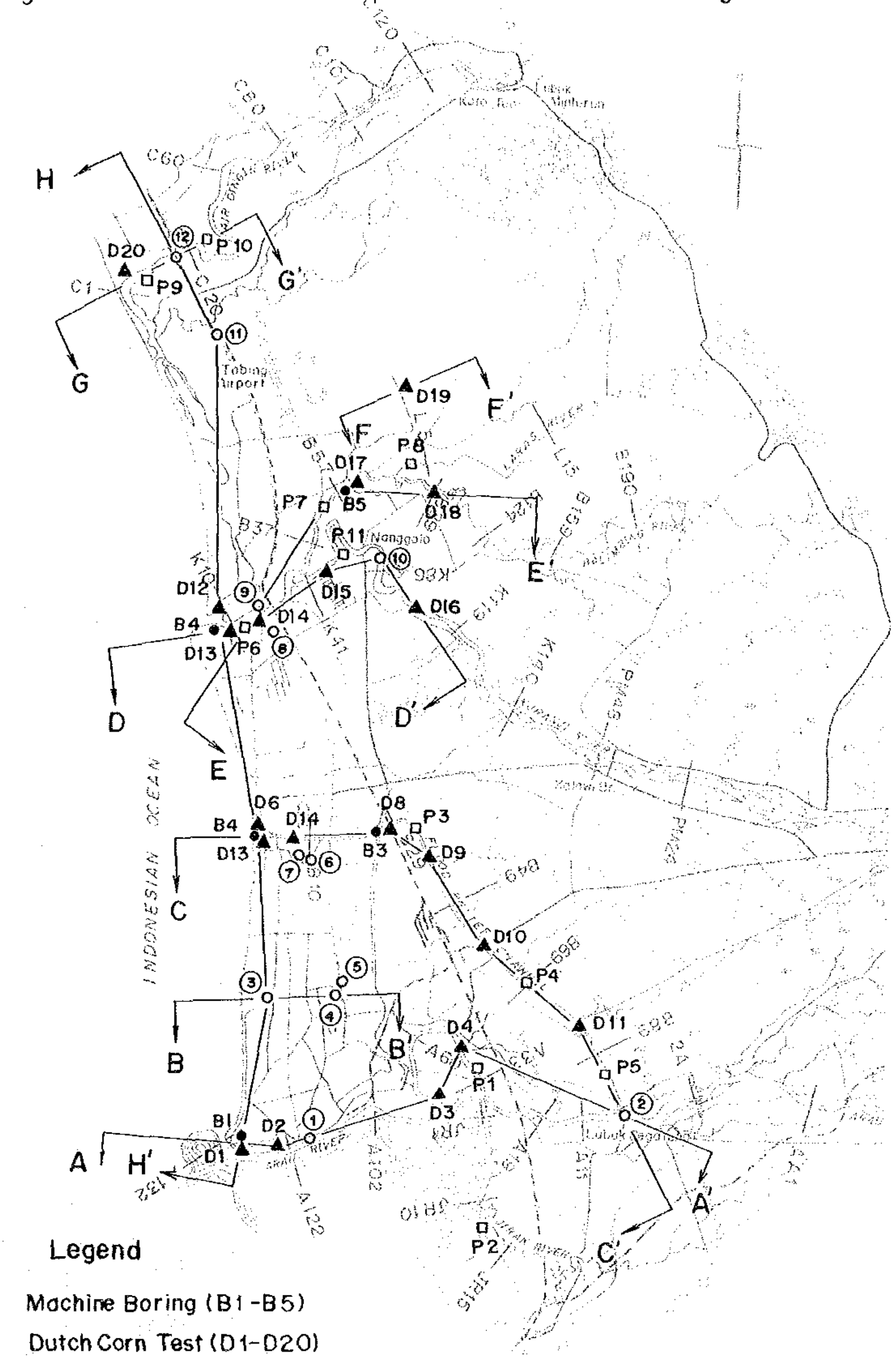
Fig. B-2 Geological Map





SOURCE: LAPORAN
PENYELIDIKAN GEOLOGI TEKNIK
DAN MEKANIKA TANAH
PENGENDALIAN BANJIR
KOTA PADANG PROPINSI SUMATRA
BARAT, DPU, May 1983

Fig. B-3 Location of Data on Foundation Investigation



Legend

- ● Machine Boring (B1-B5)
- ▲ Dutch Corn Test (D1-D20)
- □ Borrow Pit (P1-P11)
- ○ Data from Other Projects (① - ⑫)
- A—A' Section of Soil Profile (A-H) in Fig.B-4

Fig. B-4(1) Soile Profile

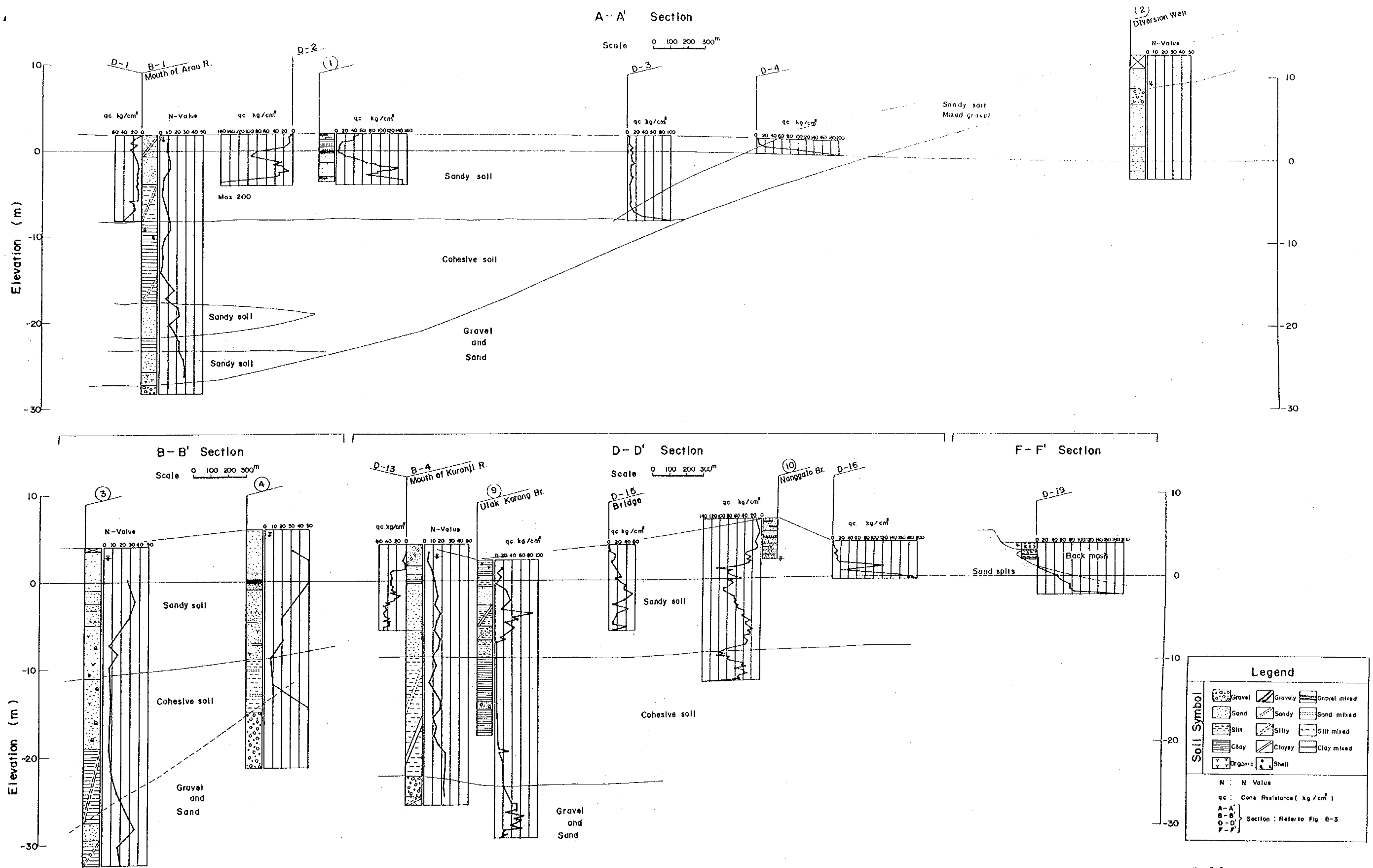


Fig. B-4(2) Soil Profile

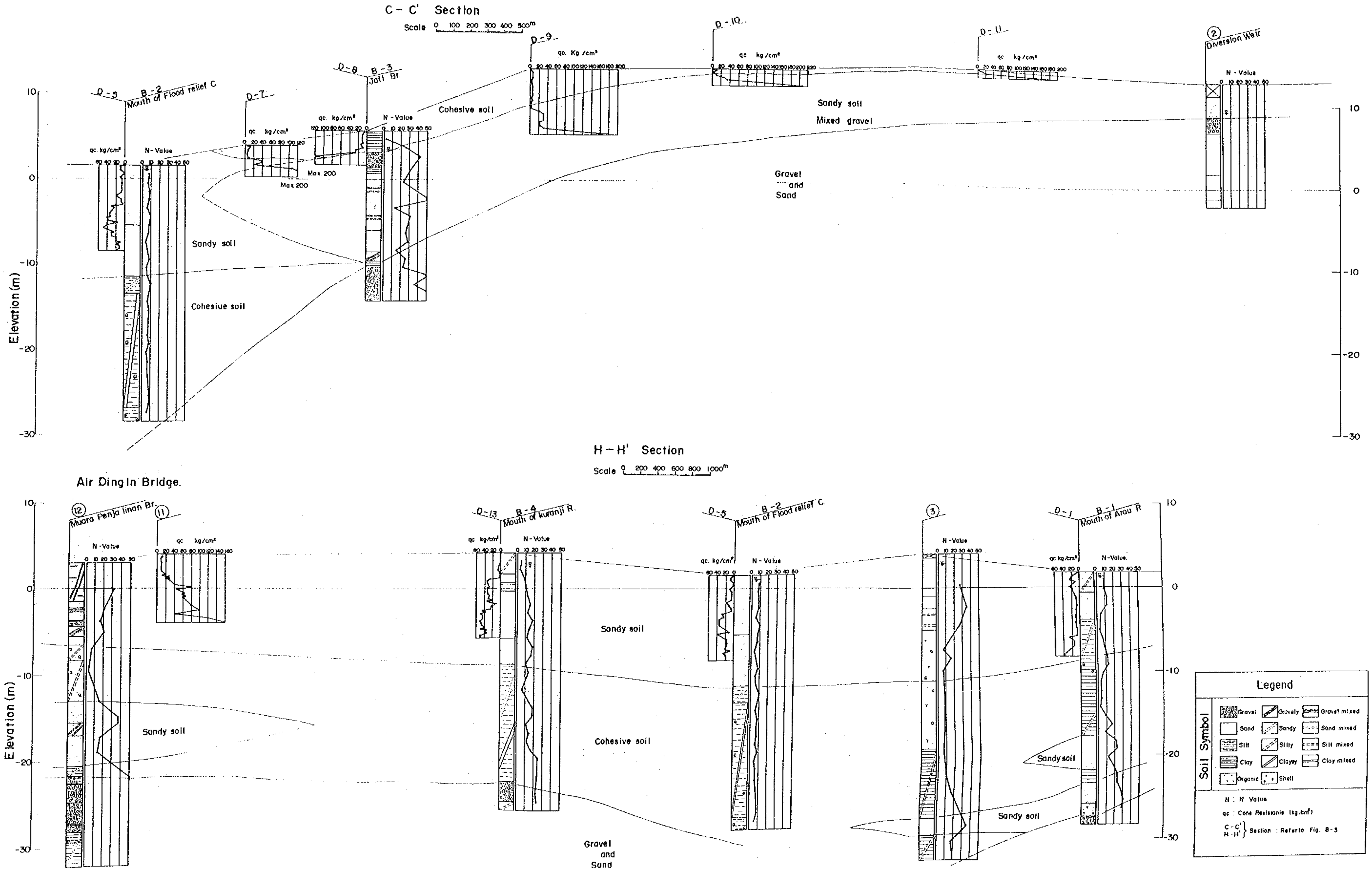
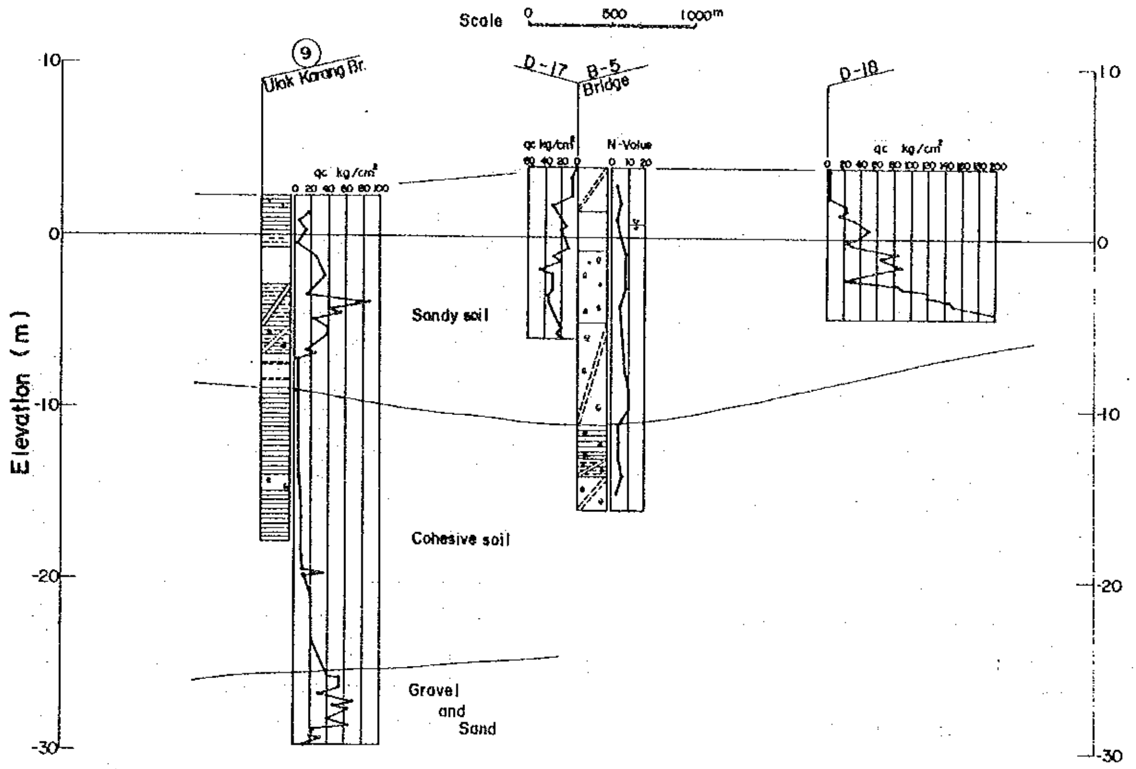


Fig.B-4(3)Soil Profile

E - E' Section



G - G' Section

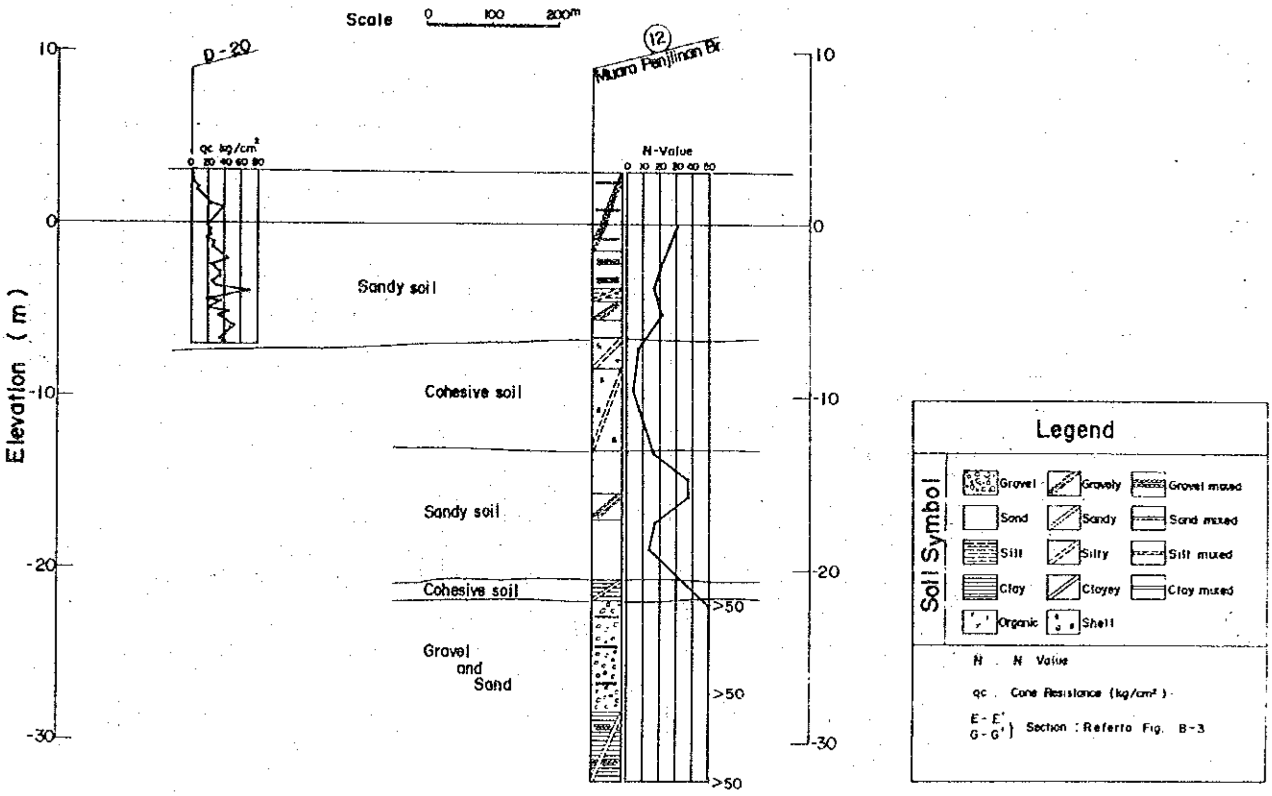
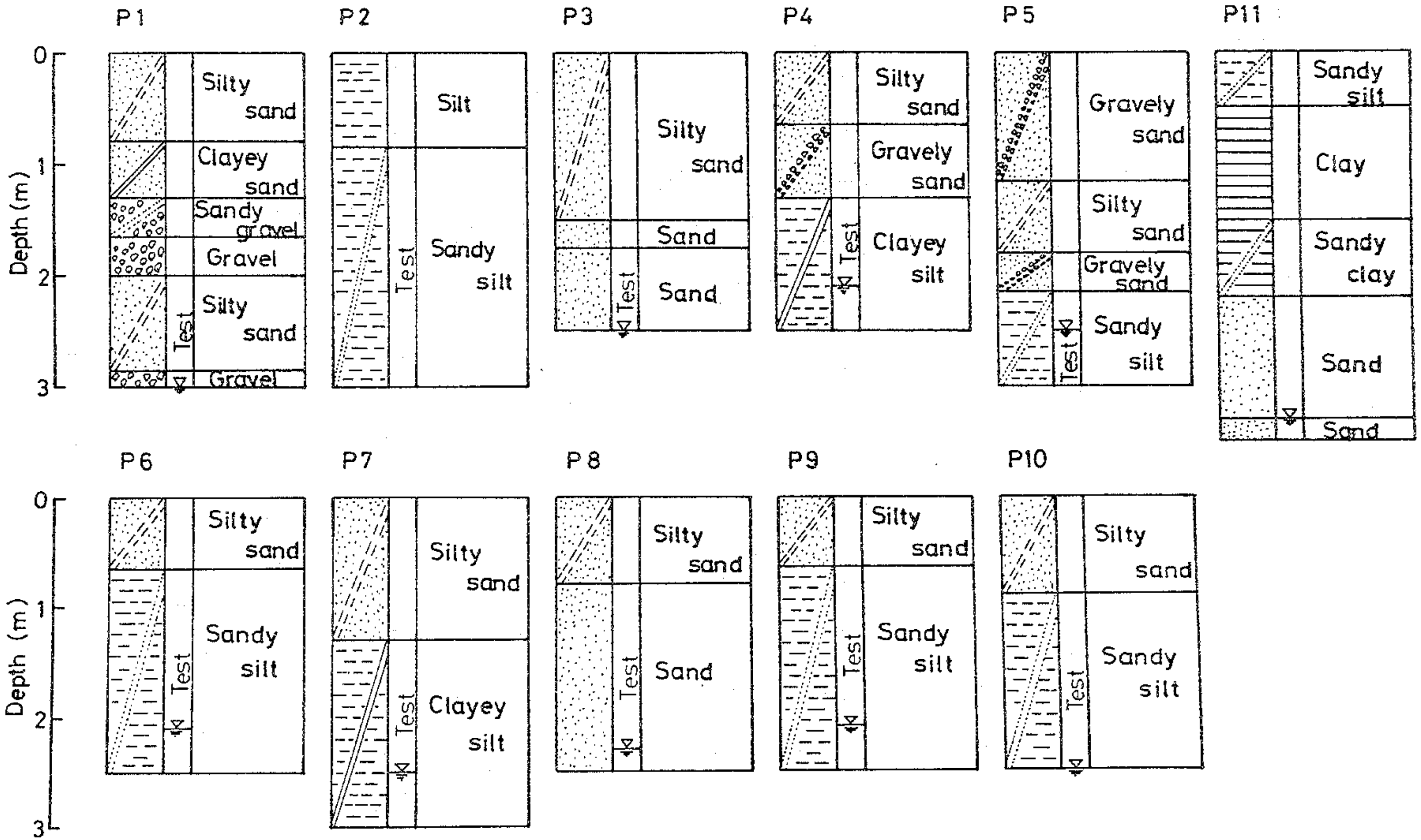
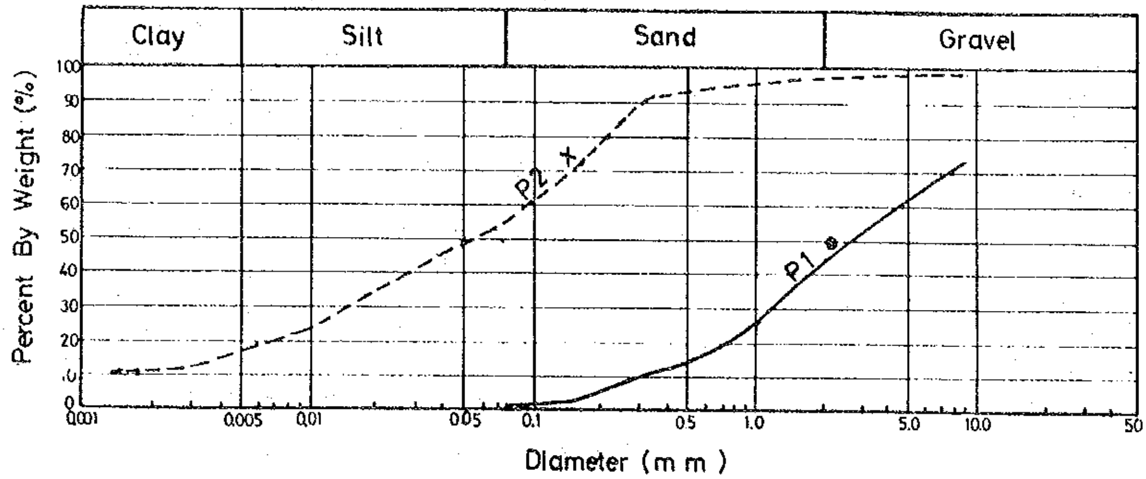


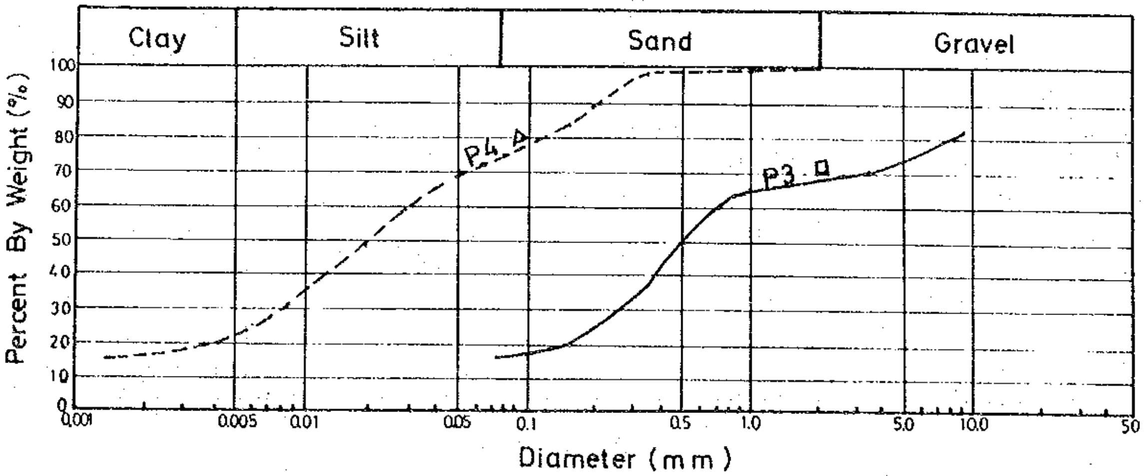
Fig. B-5 Log of Test Pit



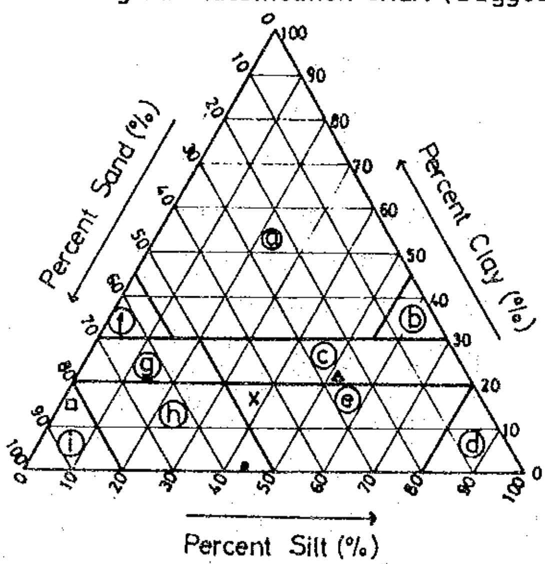
Note : Location of borrow pit is shown in Fig. B-3.

Fig. B-6 (1)   Grain Size Accumulation Curve





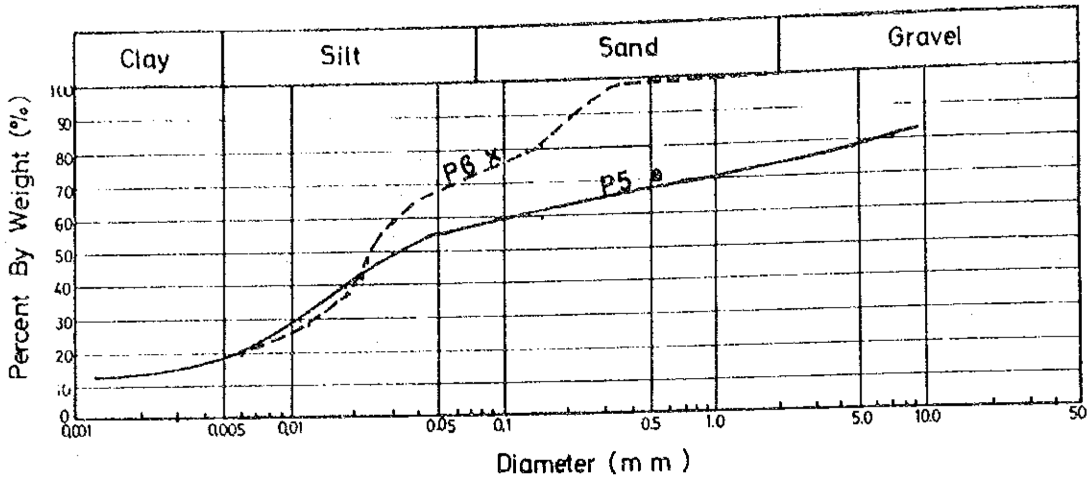
Triangular Classification Chart (Suggestion by JIS.)

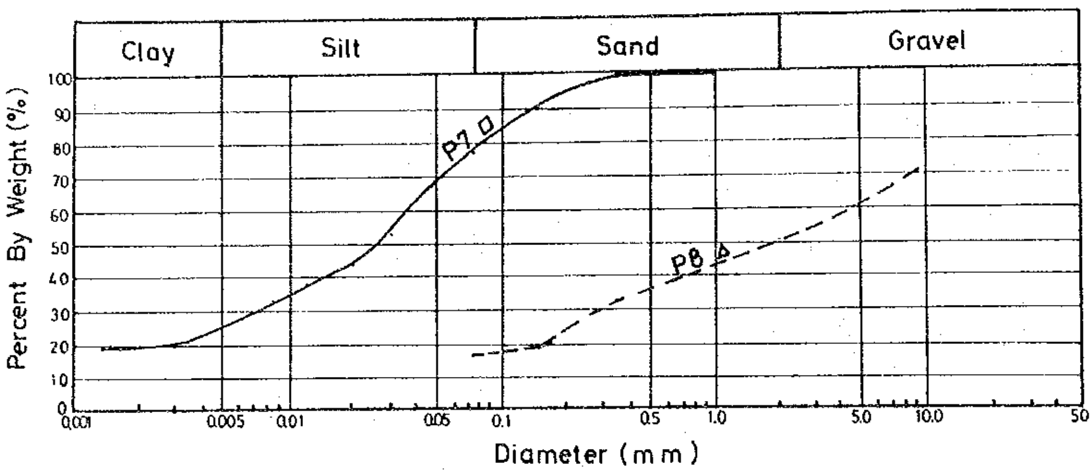


- ⓐ Clay
- ⓑ Silty clay
- ⓒ Clayey silt Δ
- ⓓ Silt
- ⓔ Sandy silt x
- ⓕ Sandy clay
- ⓖ Clayey sand
- ⓗ Silty sand •
- ⓘ Sand □

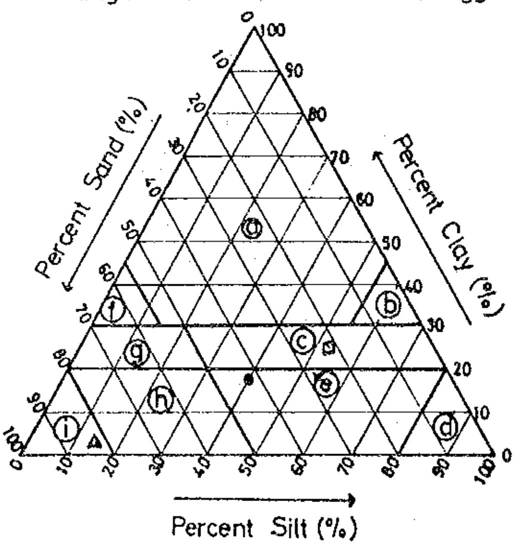
Location of sample is shown in Fig. B-3.

Fig. B-6 (2) Grain Size Accumulation Curve





Triangular Classification Chart (Suggestion by JIS.)



ⓐ Clay

ⓑ Silty clay

ⓒ Clayey silt ◻

ⓓ Silt

ⓔ Sandy silt • x

ⓕ Sandy clay

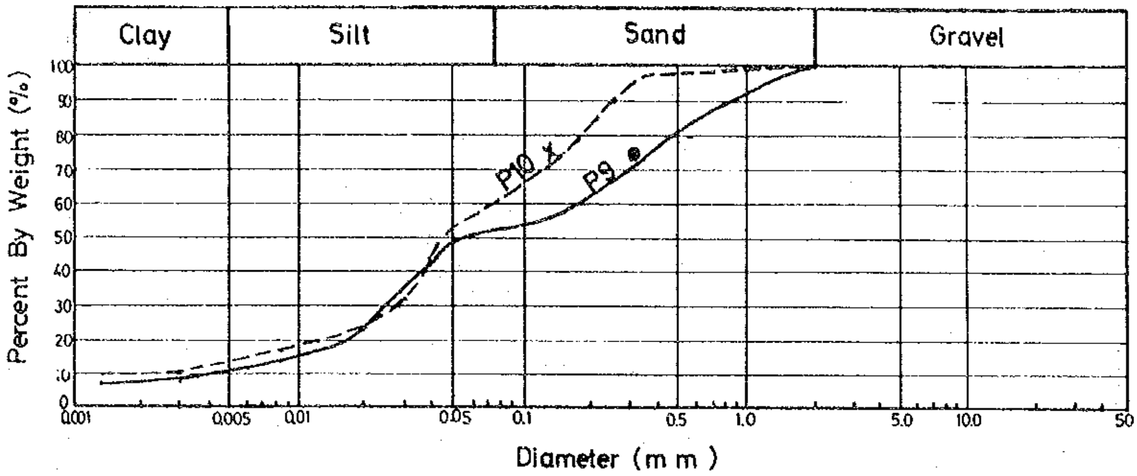
ⓖ Clayey sand

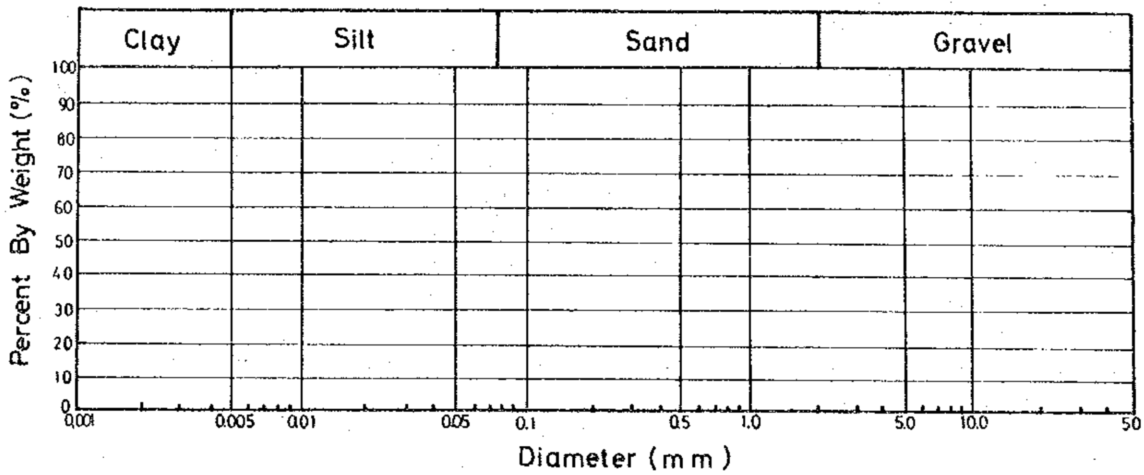
ⓗ Silty sand

ⓘ Sand ▲

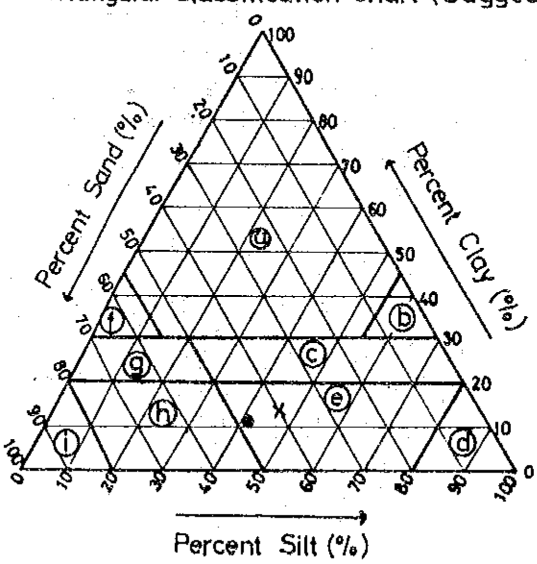
Location of sample is shown in Fig. B-3.

Fig. B-6 (3) Grain Size Accumulation Curve





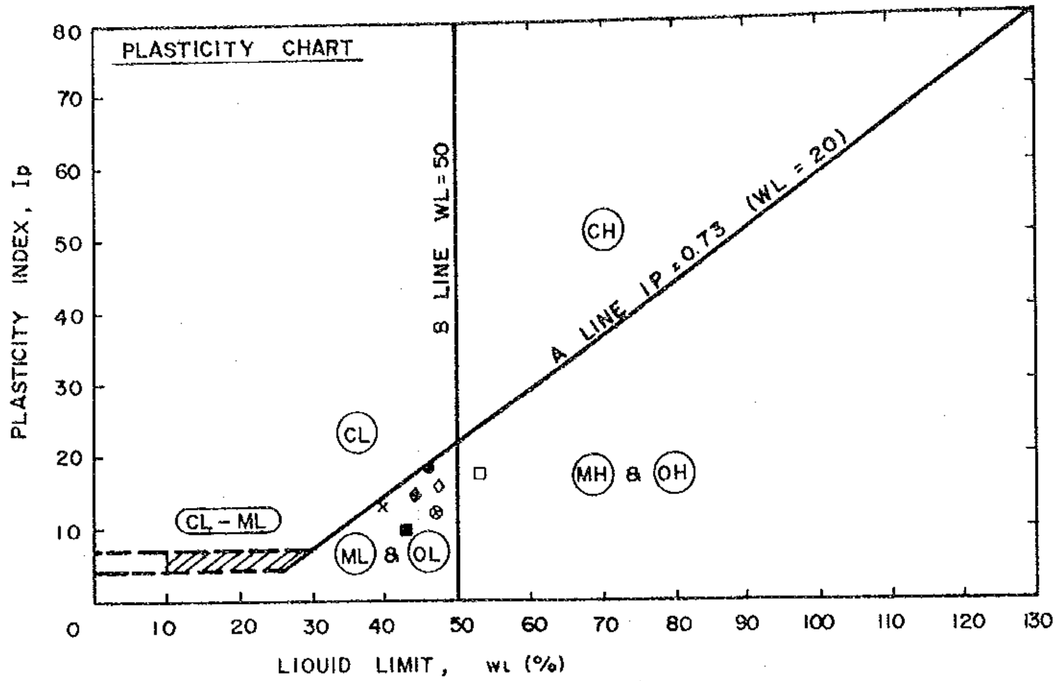
Triangular Classification Chart (Suggestion by JIS.)



ⓐ Clay
ⓑ Silty clay
ⓒ Clayey silt
ⓓ Silt
ⓔ Sandy silt ● x
ⓕ Sandy clay
ⓖ Clayey sand
ⓗ Silty sand
ⓘ Sand

Location of sample is shown in Fig. B-3.

Fig B-7 Classification of Soil



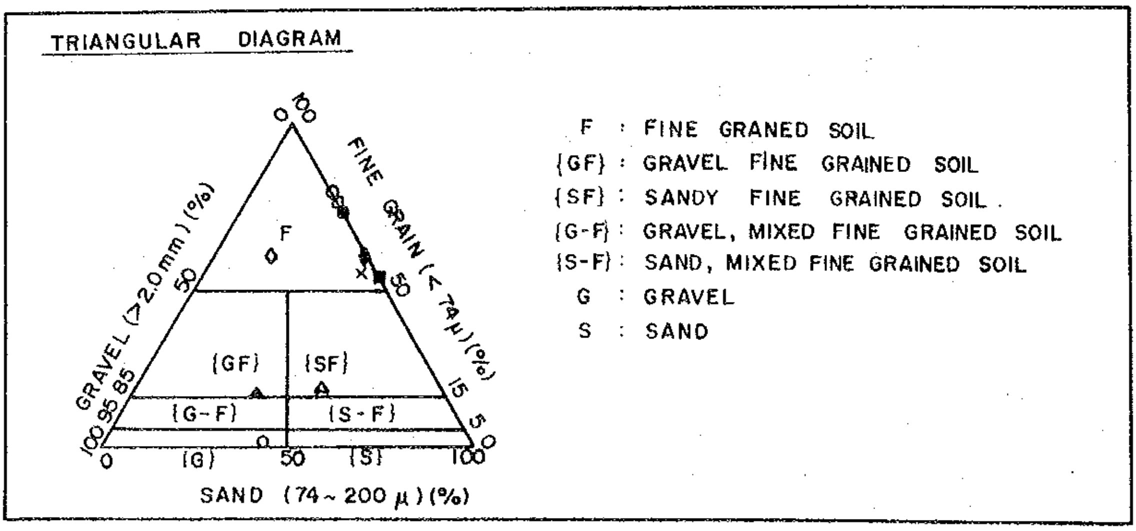


Fig. B - 8 Compaction Test