Master Plan Study on Lower Asahan River Basin Development

Vol. 2
Flood Control Plan

Tables

Table 1.1 Member List of Advisory Committee and Study Team

JICA Advisory Committee		
1.	Dr. Kazuto Nakazawa	Chairman of Committee
2.	Mr. Masakuni Kawamata	Vice-chairman
3.	Mr. Hiroshi Miyai	Advisor
4.	Mr. Nobuo Ando	Advisor
5.	Mr. Akihiko Nunomura	Advisor
6.	Mr. Shuhei Seyama	Advisor
7.	Mr. Hitonori Ono	Coordinator
8.	Mr. Kazuo Nakagawa	Coordinator
JICA Study Team		
1.	Mr. Makoto Tsuda	Team Leader
2.	Mr. Hiroshi Ono	Deputy Leader/River Planner
3.	Mr. Yasuo Iwasaki	Water Resources Engr.
4.	Mr. Masao Matsumura	River Engr.
5.	Mr. Toshio Terashima	Hydrologist
6.	Mr. Tokio Imai	Survey Guidance Engr.
7.	Mr. Nobuhiko Uchiseto	Engr. for Geology & Soil-mechanics
8.	Mr. Kanetaka Gomi	Expert for Land use & Environment
9.	Mr. Fumihiko Furuichi	Regional Economist
10.	Mr. Kenjiro Onaka	Agriculture Engr.
11.	Mr. Syuichi Sato	Irrigation & Drainage Engr.
12.	Mr. Ryosaku Nagata	River Structure Engr.
13.	Mr. Masatomo Watanabe	Expert for Sediment
14.	Mr. Kazuhiko Takebayashi	Construction Planner
15.	Mr. Yoshiaki Ishizuka	Flood Control Economist

Table 1.2 List of Indonesian Counterpart Personnel

No.	Position	Name	Agency	Period
	Project Manager	Ir. J. Banjarnahor MSc.	DPU, North Sumatra	End of Oct. - date
	Deputy Project Manager	Ir. M.R. Sembiring	- do -	- do -
1.	Team Leader/River Planner	Ir. Rachman Syarief	CV. SECON	Dec.24, 1984 - May 29, 1985
2.	Water Resources Engr.	Ir. Alfred Purawidjaya	- do -	Jan. 7, 1985 - Mar.25, 1985
3.	Engr. for River & Sediment	Ir. Tani Winata	- do -	Jan.19, 1985 - Jun.28, 1985
4.	Hydrologist	Drs. Eko Harsono	- do -	Dec.24, 1984 - May 25, 1985
5.	Survey Guidance Engr.	Ir. Deddi Mulyadi	- do -	Dec.24, 1984 - Jul.29, 1985
6.	Expert for Land Use & Environment	Ir. Suhardi	- do -	Mar. 4, 1985 - Mar.25, 1985
7.	Expert for Economy & Agriculture	Ir. Priyo Budi Sayoko	- do -	Dec.24, 1985 - Mar.25, 1985 & Jul. 4, 1985 - Jul.25, 1985
8.	Engr. for Soil-Mechanics, Irrigation & Drainage	Ir. Trisna Sanjaya	- do -	Jan.26, 1985 - Mar.25, 1985 & May 18, 1985 - Jun.28, 1985
9.	River Structure Engr.	Ir. Andrianto Wijaya	- do -	Jan.26, 1985 - May 25, 1985
10.	Construction Planner	Ir. Dinas Sebayang	- do -	May 18, 1985 - Jun.13, 1985
11.	Temporary	Ir. Ibrahim	DPU, North Sumatra	End of Oct. - End of Nov.
12.	- do -	Drs. Sangap Tarigan	- do -	- do -

Table 4.1 Principal Features of Asahan No.3 Project

	Description	Feature
1.	Location	About 5 - 10 km downstream from Tangga Power station
2.	Reservoir area	
	- catchment area	4,010 km^2
	- Annual average discharge	129.3 m^3/s
	- Effective storage capacity	12 x 10^6 m^3
	- Resevoir surface area	2.4 km^2
	- HWL (FWL)	EL. 267.0 m
	- LWL	El. 262.0 m
	- Design flood	1,800 m^3/s
3.	Parhitean Dam	
	- Type	Center core type rock fill dam
	- Dam height	130 m
	- Crest length	390 m
	- Embankment volume	6,800,000 m^3
4.	Power Plant	
	- Gross head	177.0 m
	- Net head	171.0 m
	- Plant discharge	208.2 m^3/s
	- Installed capacity	300,000 KW = 75,000 KW x 4 units
	- Energy output	1,586 x 106 KWh/year

Source : Feasibility Report on the Asahan No.1 and No.3 Hydroelectric Power Development Project, Dec. 1982, JICA.

Table 4.2 Design Discharge and its Scale of Rivers in Indonesia

No.	Name of River	Province	Catchment Area (sq.km)	Design Flood (cms)	Specific Discharge (cms/sq.km)	Return Period (year)
1.	Cimanuk	West Java	3,006	1,440	0.48	25
2.	Serang	Central Java	937	900	0.96	25
3.	Citanduy	West Java	3,680	1,900	0.52	25
4.	U l a r	North Sumatra	1,080	800	0.74	30
5.	Pemali	Central Java	1,228	1,300	1.06	25
6.	Cipanas	West Java	220	385	1.75	25
7.	S o l o	Central/East	3,400	1,500	0.44	10 *1
		Java		2,000	0.59	40 *2
8.	Madiun	East Java	2,400	1,100	0.46	10 *1
				2,300	0.96	40 *2
9.	Wampu	North Sumatra	3,840	1,320	0.34	20
10.	Arakundo	A c e h	5,495	1,800	0.33	20
11.	Kring Aceh	A c e h	1,775	1,300	0.73	20
12.	Brantas	East Java	10.000	1,350	0.135	10 *1
				1,500	0.15	50 *2
13.	Bah Bolon	North Sumatra	2,776	1,220	0.44	20
14.	Walanae	South Sulawesi	3,190	2,900	0.91	20
15.	B i l a	South Sulawesi	1.368	1,900	1.39	20
16.	Jeneberang	South Sulawesi	729	3,700	5.08	50
17.	Ciujung	North Banten	1,850	1,100	0.59	10 *1
				1,600	0.86	50 *2
18.	Kuranji	West Sumatra	213	870	4.08	25 *1
				1,000	4.69	50 *2
19.	Air Dingin	West Sumatra	131	600	4.58	25 *1
				700	5.34	50 *2
20.	Marmoyo	East Java	290	230	0.79	20
21.	Surabaya	East Java	631	370	0.59	50

Note : *1 : 1st stage and/or urgent plan
*2 : 2nd stage and/or overall plan

Table 4.3 Water Quality Analysis of Rivers

PARAMETER		Unit	Sample Number											
			1	2	3	4	5	6	7	8	9	10	11	12
Chemist & Physics			(Bunut)		(Asahan)			(Silau)		(Kualuh)			(Natas)	(Kualuh)
Conductivity		micromhos/cm	92	84	84	104	108	52	50	35	31	42	35	33
pH			6.7	6.4	6.9	7.4	7.3	6.7	6.6	6.7	6.7	6.6	7.2	6,6
S.A.R.			0.148	0.152	0.146	0.142	0.149	0.237	0.234	0.276	0.269	0.214	0.262	0.268
Dissolved solid		mg/l	56	55	57	71	72	37	31	32	28	38	28	26
Suspendid solid		mg/l	68	26	46	82	102	14	42	38	42	22	34	28
Hardness		mg/l	16	15	27	34	36	9	10	9	10	8	15	7
K														
Potassium	(K)	meq/l	0.024	0.023	0.037	0.032	0.029	0.131	0.174	0.189	0.180	0.171	0.186	0.188
Sodium	(Na)	meq/l	0.134	0.134	0.136	0.139	0.142	0.283	0.291	0.215	0.290	0.296	0.228	0.231
Calcium	(Ca)	meq/l	0.22	0.18	0.36	0.40	0.44	0.16	0.12	0.14	0.18	0.14	0.20	0.14
Magnesium	(Mg)	meq/l	0.10	0.12	0.18	0.28	0.28	0.02	0.08	0.04	0.02	0.02	0.10	0.08
Iron	(Fe)	meq/l	0.36	0.09	0.09	0.02	0.06	0.03	0.04	0.06	0.01	0.03	0.0	0.01
Manganese	(Mn)	mg/l	0.16	0.09	0.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01
Nitrogen total		mg/l	0.18	0.22	0.11	0.12	0.11	0.21	0.28	0.31	0.34	0.36	0.22	0.34
A														
Chloride	(Cl)	meq/l	0.21	0.21	0.18	0.28	0.31	0.14	0.13	0.16	0.14	0.12	0.14	0.15
Sulphate	(SO4)	meq/l	0.08	0.08	0.13	0.17	0.19	0.11	0.08	0.15	0.13	0.11	0.13	0.13
Phosphate	(PO4)	meq/l	-	-	-	-	-	-	-	-	-	-	-	-
Bicarbonate	(HCO3)	meq/l	0.80	0.80	0.80	1.20	0.70	1.10	0.61	0.45	0.70	0.45	0.55	0.51
Carbonate	(CO3)	meq/l	0	0	0	0	0	0	0	0	0	0	0	0
Copper	(Cu)	mg/l	0	0	0	0	0	0	0	0	0	0	0	0
Cadmium	(Cd)	mg/l	0	0	0	0	0	0	0	0	0	0	0	0
Chromium	(Cr)	mg/l	0	0	0	0	0	0	0	0	0	0	0	0
Lead	(Pb)	mg/l	0	0	0	0	0	0	0	0	0	0	0	0
Zinc	(Zn)	mg/l	0	0	0	0	0	0	0	0	0	0	0	0
Phosphor	(P)	mg/l	0.08	0.08	0.07	0.07	0.06	0.11	0.12	0.07	0.07	0.06	0.11	0.10
Silicon	(Si)	mg/l	9.34	9.08	8.02	8.09	10.04	7.91	7.60	8.28	8.46	8.33	3.81	6.47

Note, -: No Analysis

Table 4.4 Principal Features of Proposed Long-term Flood Control Plan

Description	Unit	Bunut	Asahan/ Silau	Kualuh/ Kanopan
1. Stretch	km	33.7	84.2	46.3
2. Civil Works				
2.1 Embankment				
- length	km	67.4	99.7	80.3
- volume	cu m	1.20million	2.78million	2.22million
2.2 Excavation/dredging				
- length	km	26.7	60.5	-
- volume	cu m	1.45million	7.40million	2.20million
2.3 Bank protection				
(1) wet masonries				
- length	m	-	60	60
- volume	cu m	-	50	50
(2) crib	m	1,000	3,000	500
2.4 Reconstruction of structures				
(1) intake	place	-	5	1
(2) bridge	place	1	-	-
2.5 Construction of drainage culvert	place	1	19	17
3. Land acquisition/ Compensation				
3.1 Land	ha	153	375	475
3.2 House	nos.	12	844	111

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Figures

Fig.1.1 ITINERARY OF JICA TEAM MEMBERS AND COUNTERPARTS

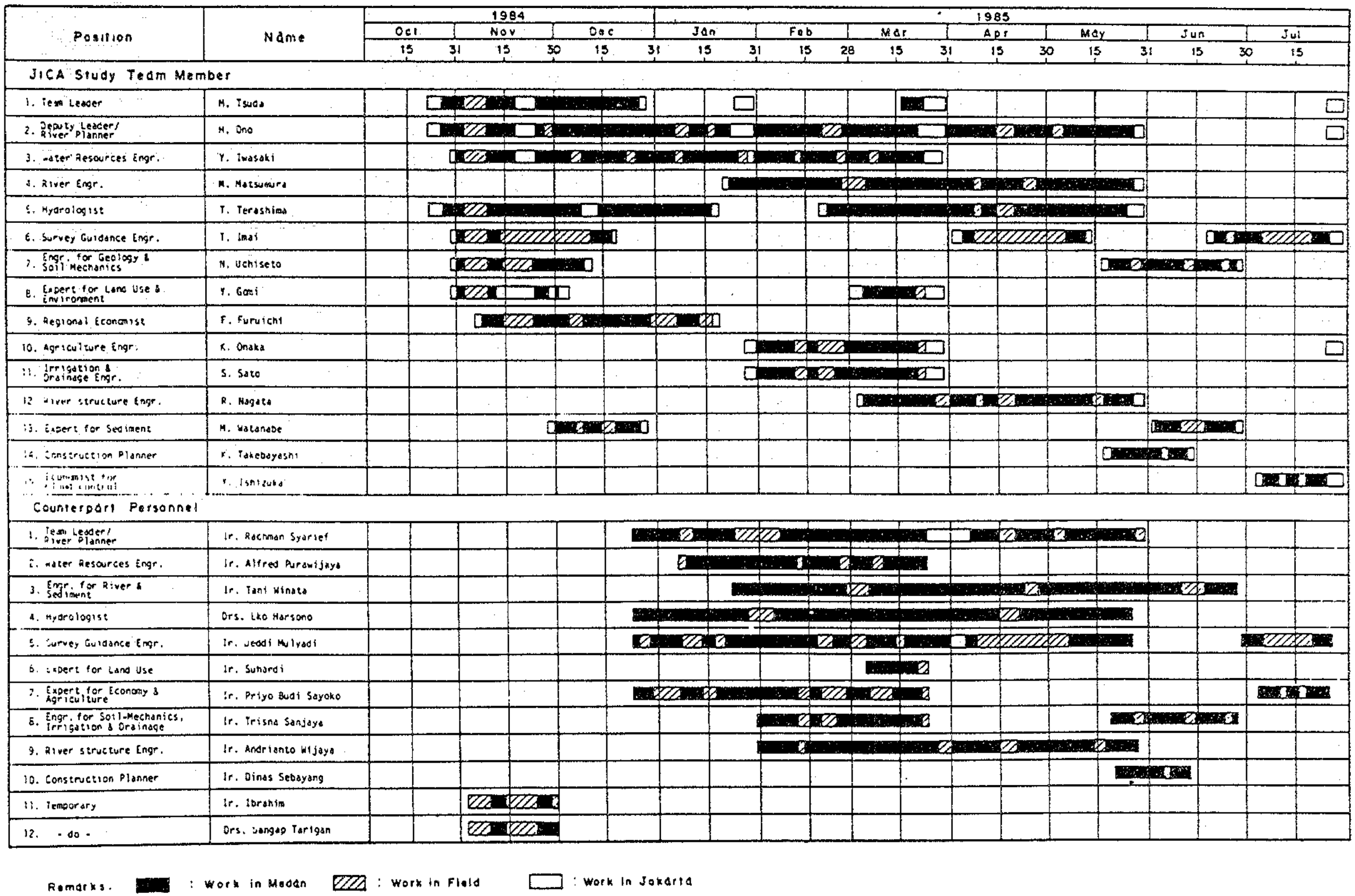


Fig. 3-1 MONTHLY RAINFALL PATTERN

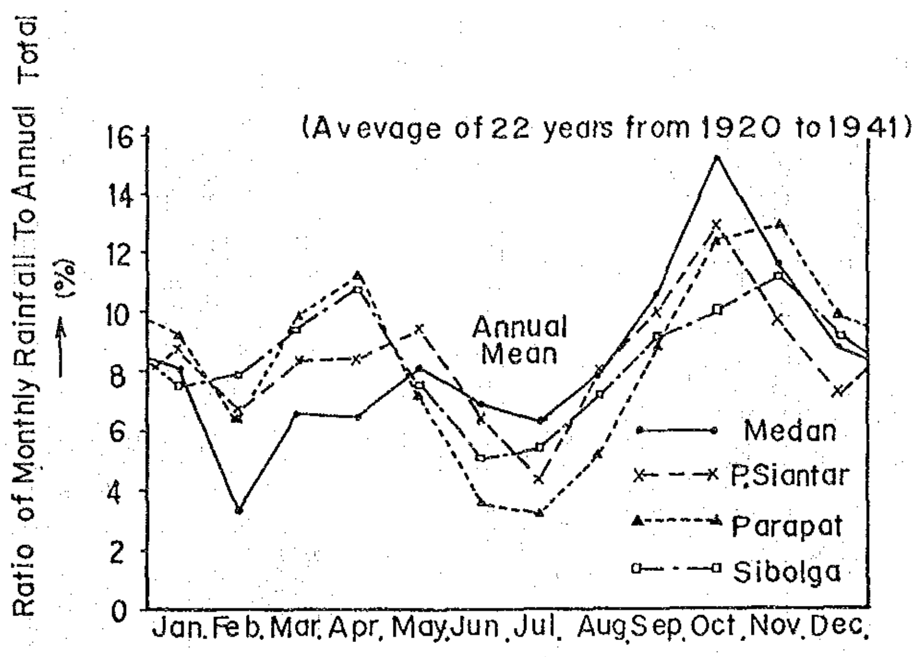


Fig. 3-2 SCHEMATIC TOPOGRAPHY AND GEOLOGY OF THE STUDY AREA

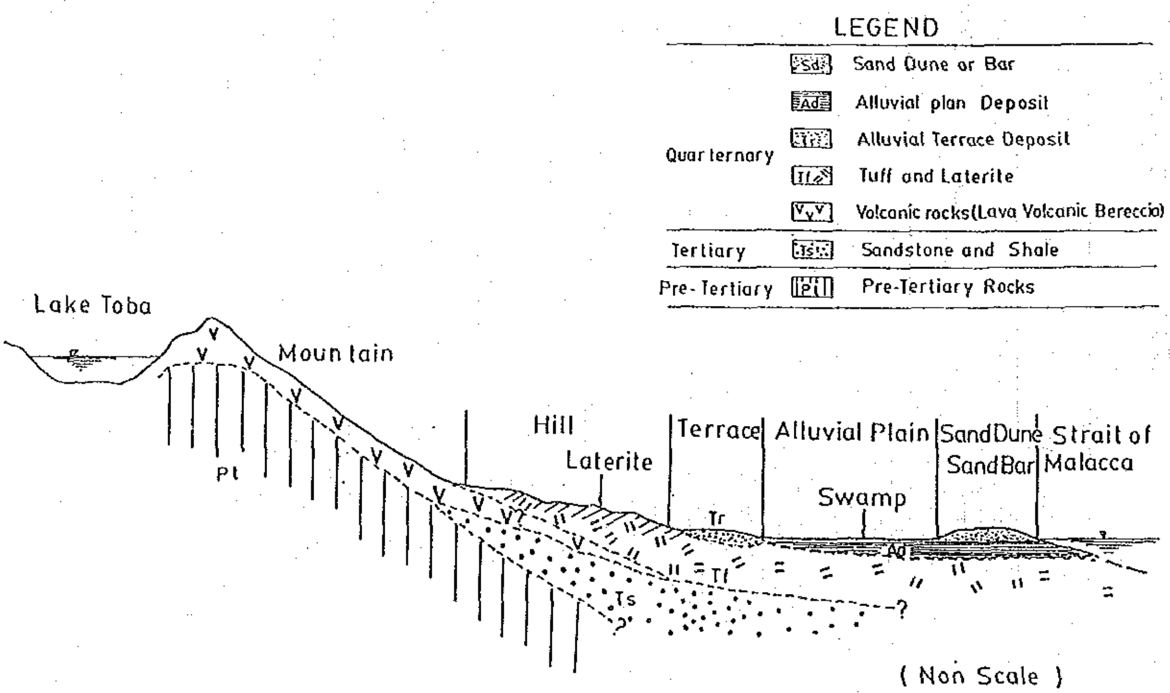
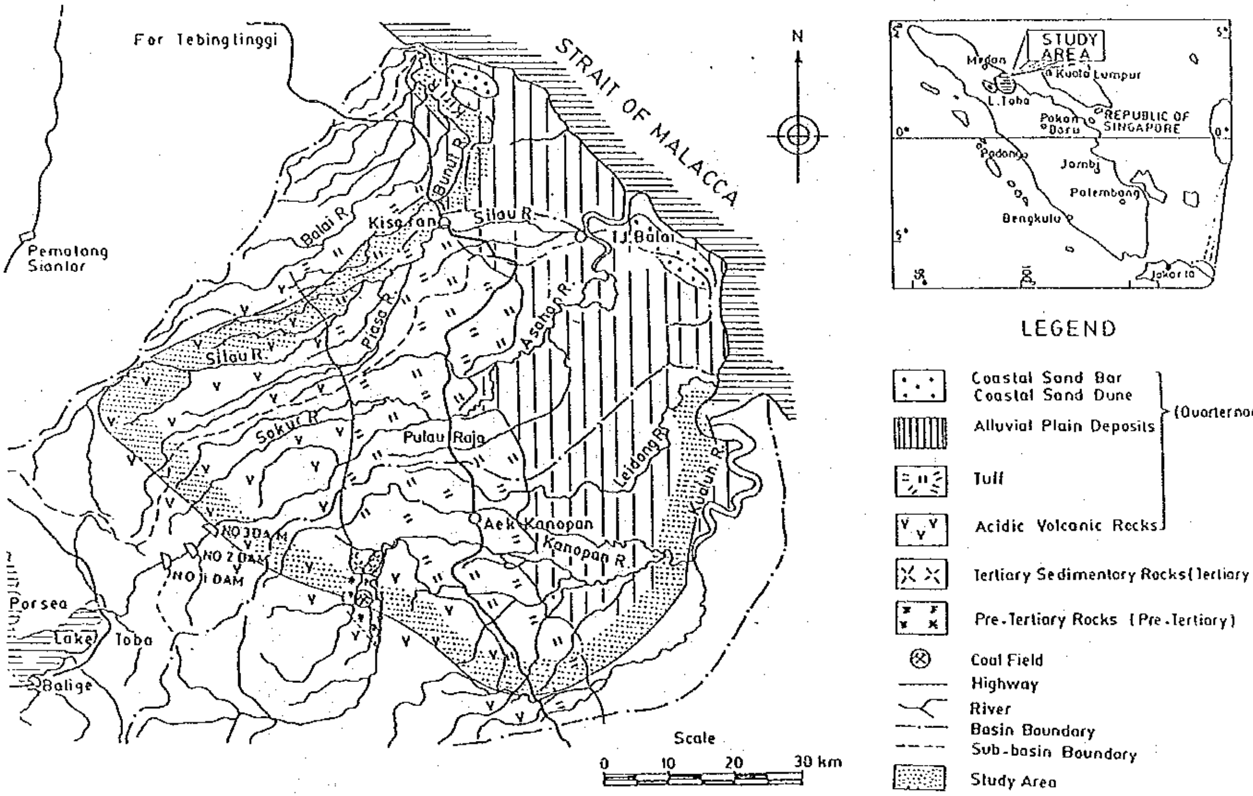
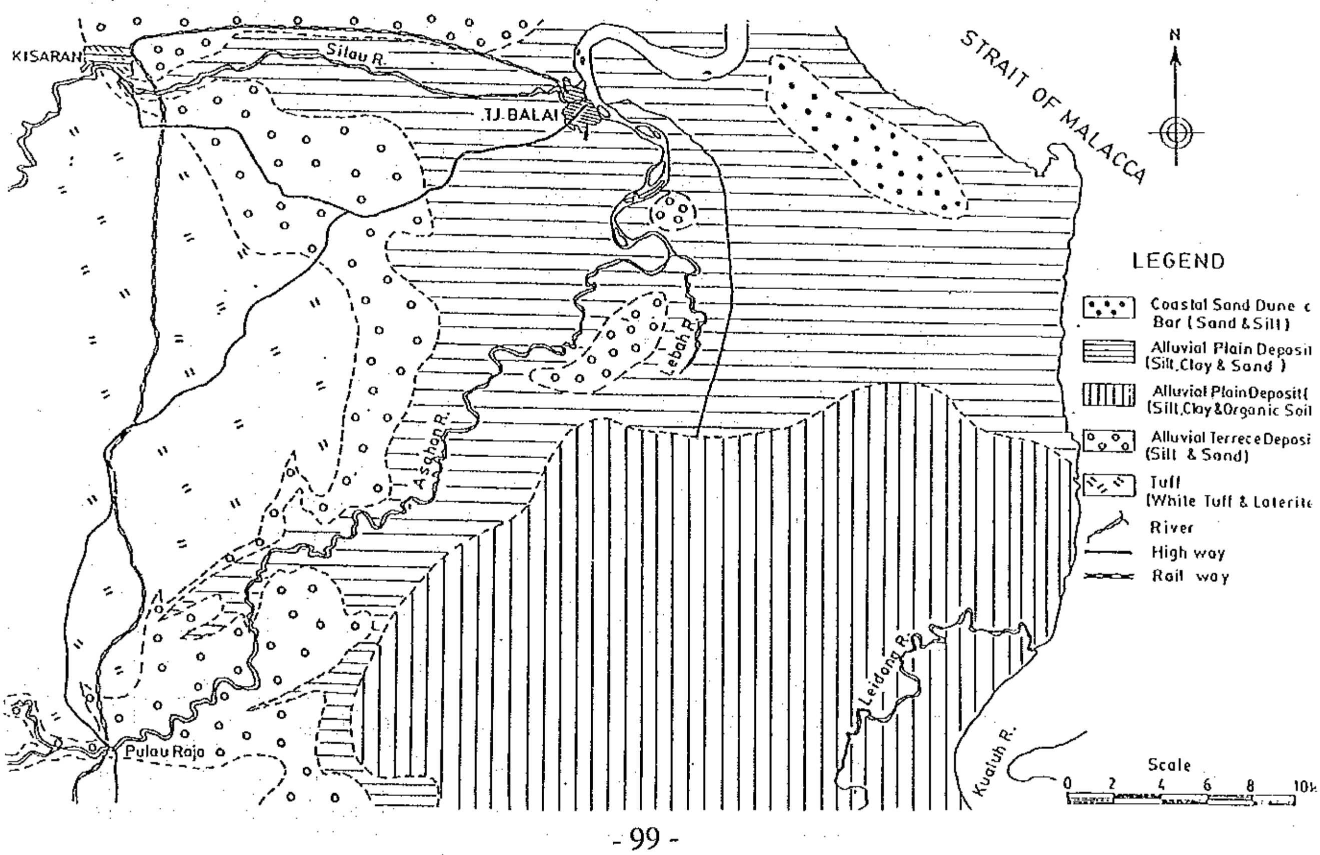


Fig. 3-3 GEOLOGICAL MAP OF THE STUDY AREA



GEOLOGICAL MAP OF THE LOWER ASAHAN AREA



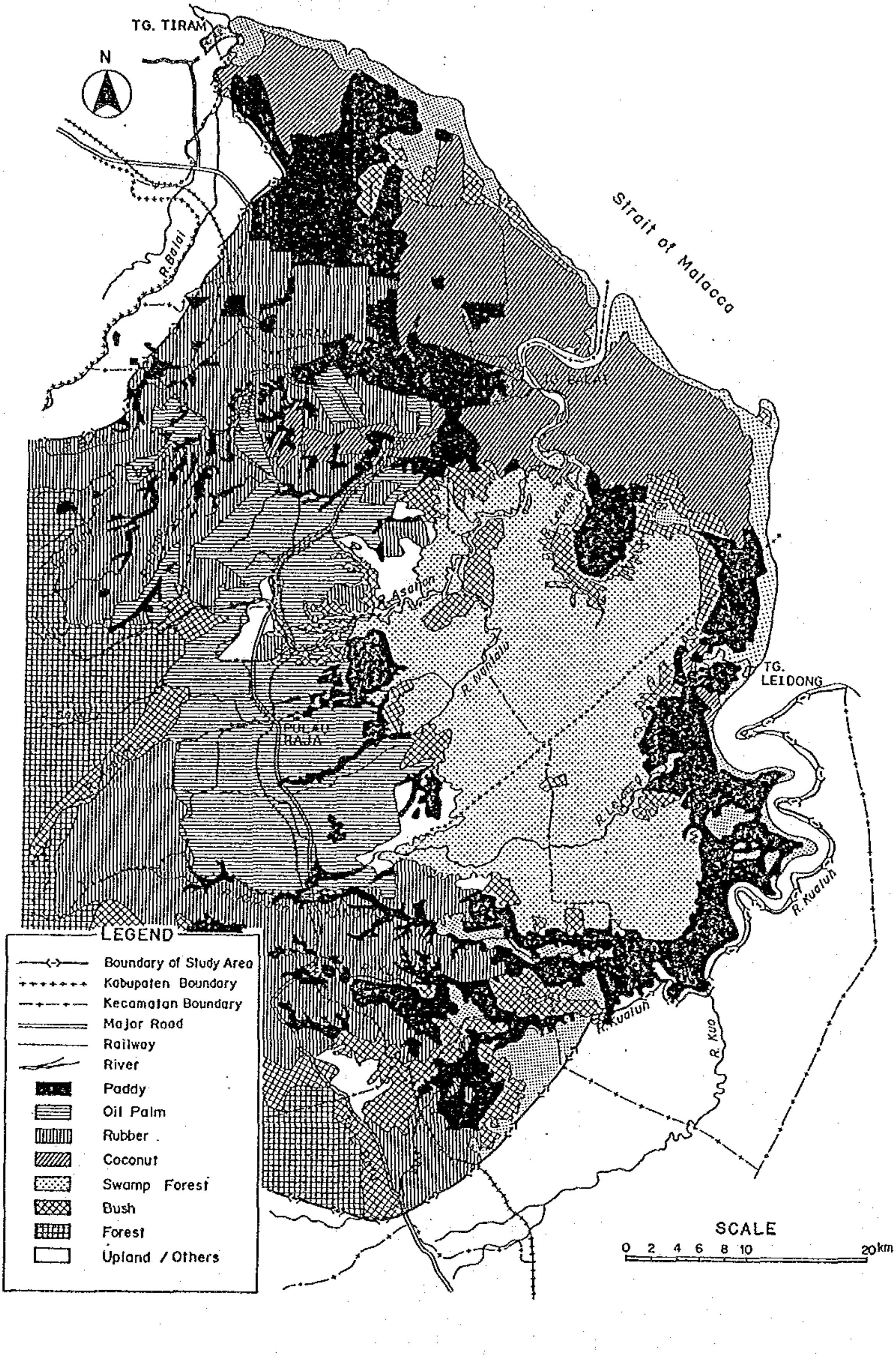


Fig. 3-4 PRESENT LAND USE

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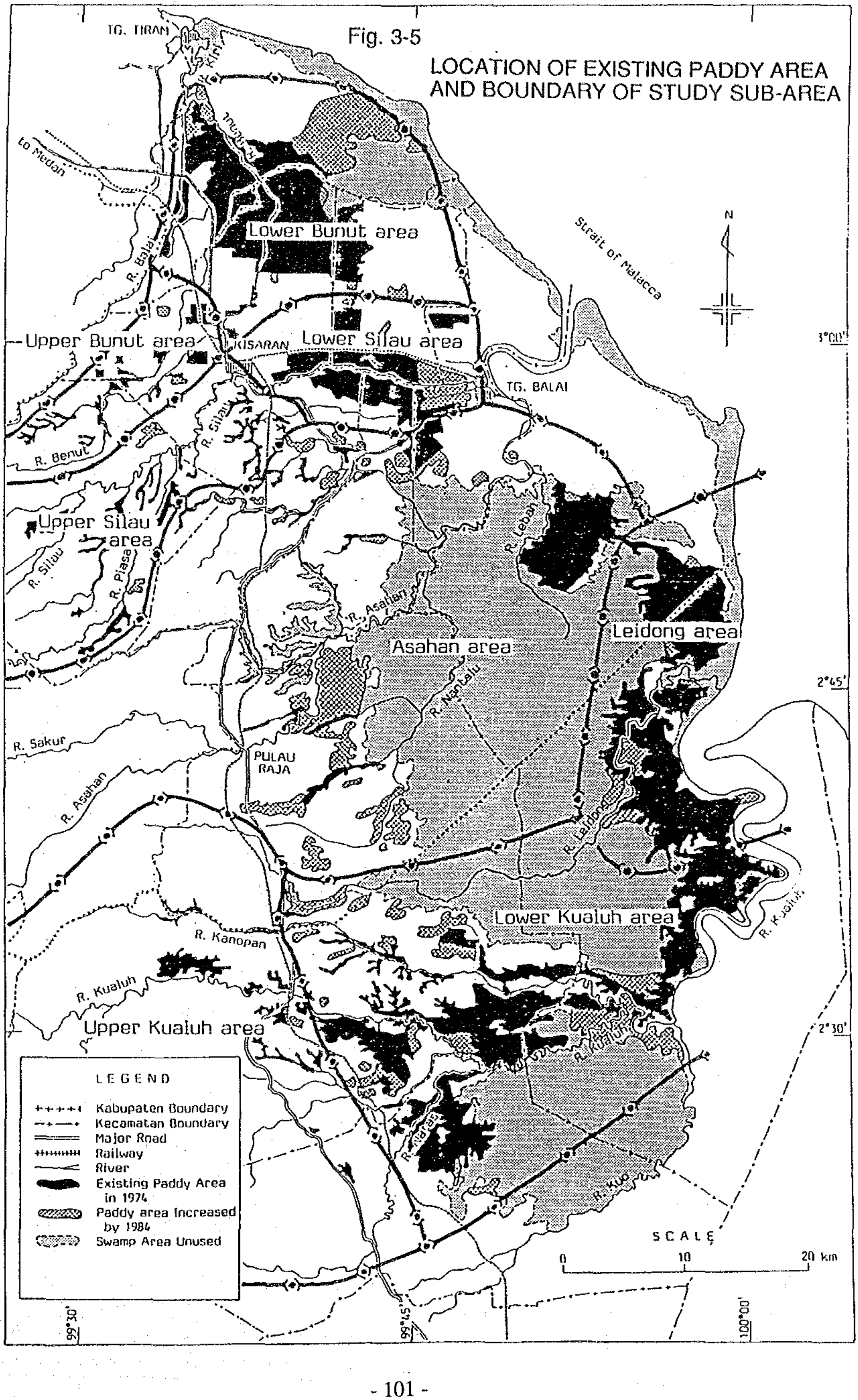
Fig. 3-5
LOCATION OF EXISTING PADDY AREA
AND BOUNDARY OF STUDY SUB-AREA
TG. TIRAN
To Medan
Strait of Malacca
N
Lower Bunut area
Upper Bunut area
KISARAN
Lower Silau area
TG. BALAI
R. Balai
R. Benut
R. Silau
Upper Silau area
R. Piasa
R. Leban
R. Asahan
Asahan area
Leidong area
R. Nantalu
R. Sakur
PULAU RAJA
R. Leidong
Lower Kualuh area
R. Kanopan
R. Kualuh
Upper Kualuh area
R. Kuo
3°00'
2°45'
2°30'
99°30'
99°45'
100°00'
LEGEND
Kabupaten Boundary
Kecamatan Boundary
Major Road
Railway
River
Existing Paddy Area in 1974
Paddy area Increased by 1984
Swamp Area Unused
SCALE
0
10
20 km

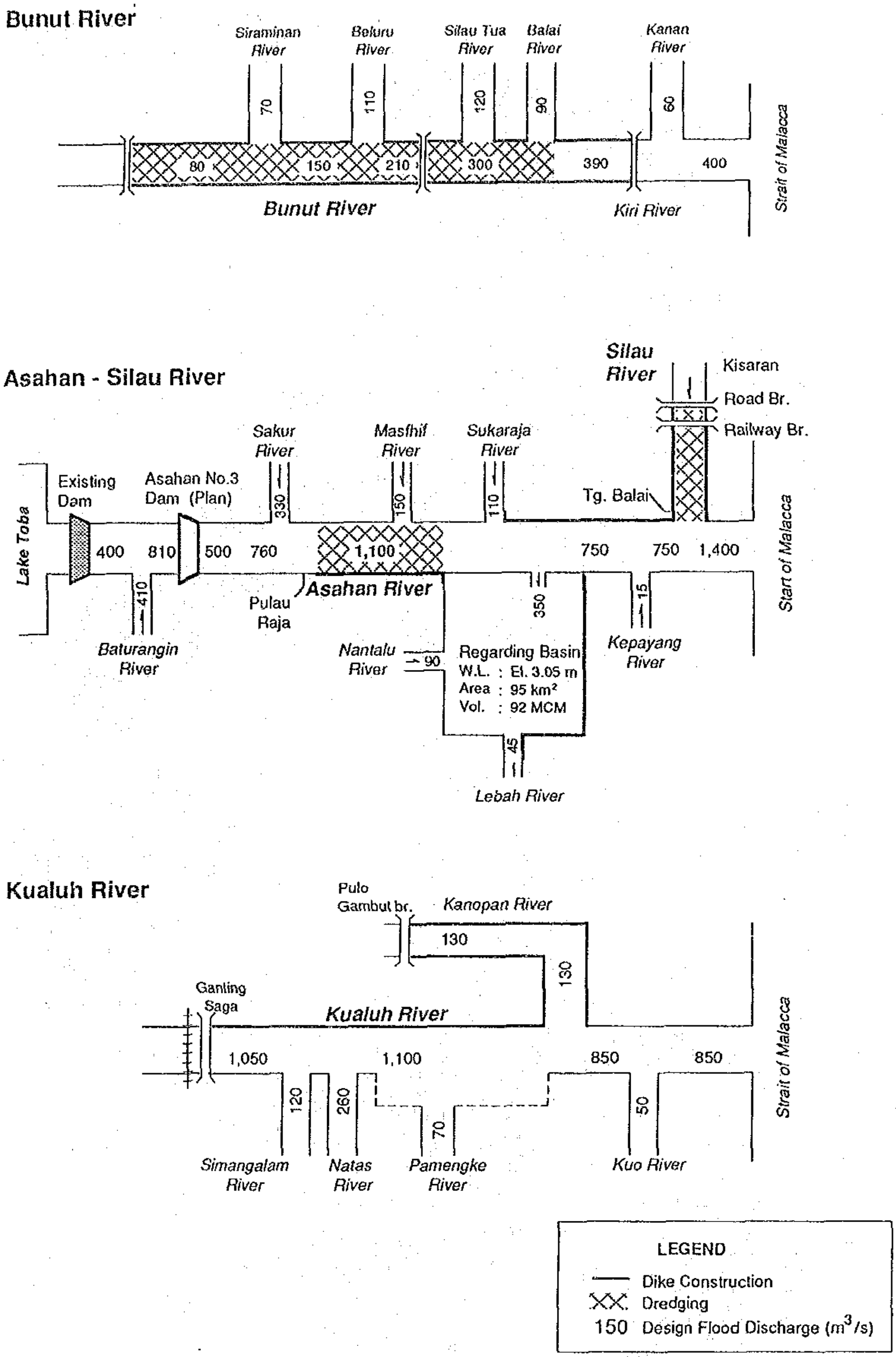

Fig. 4-1

FLOOD DISTRIBUTION PLAN
(Long-term Plan)

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LOWER ASAHAN RIVER BASIN DEVELOPMENT

Japan International Cooperation Agency

Fig. 5-1 CONSTRUCTION TIME SCHEDULE FOR URGENT FLOOD CONTROL PROJECT

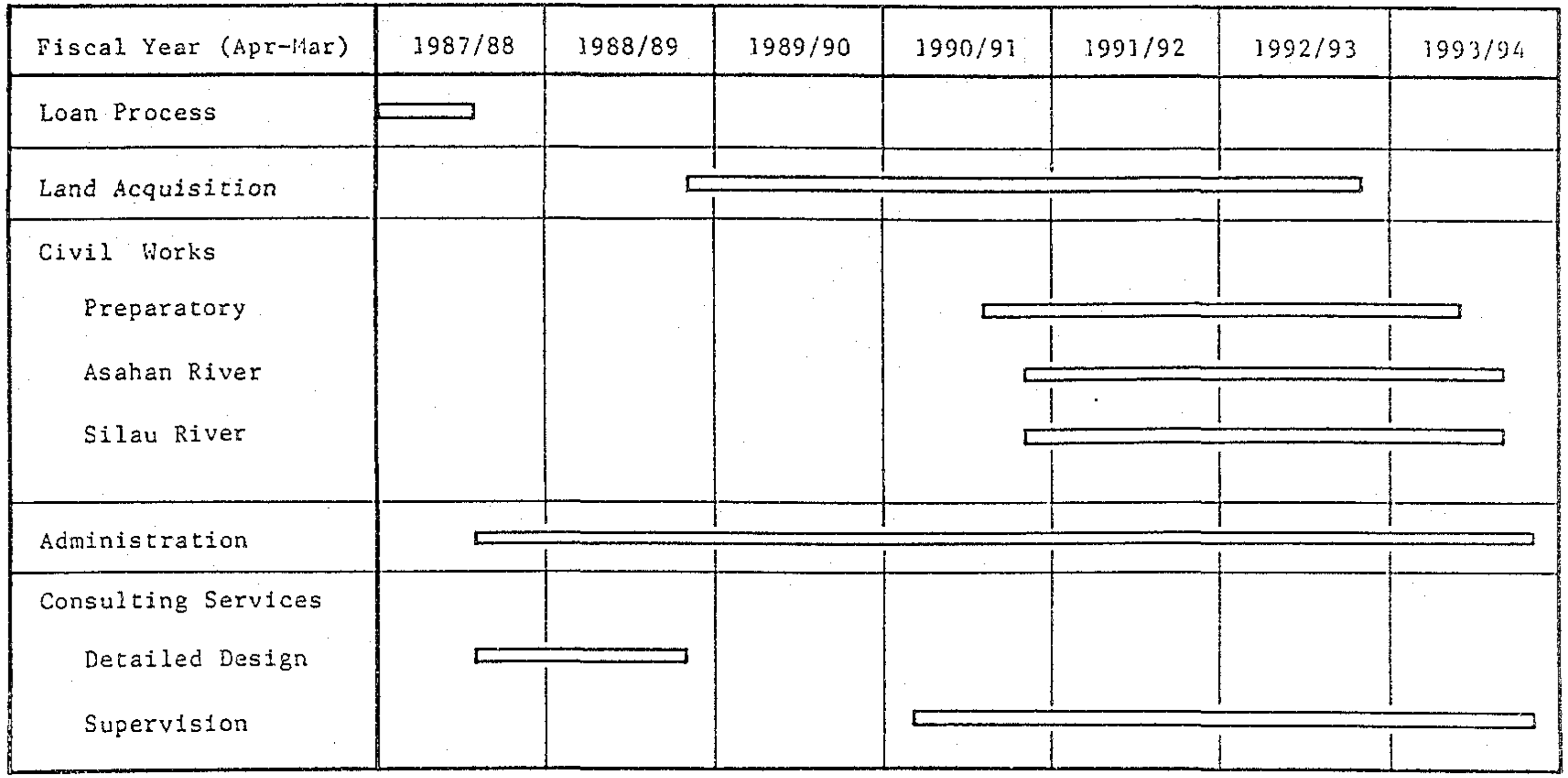
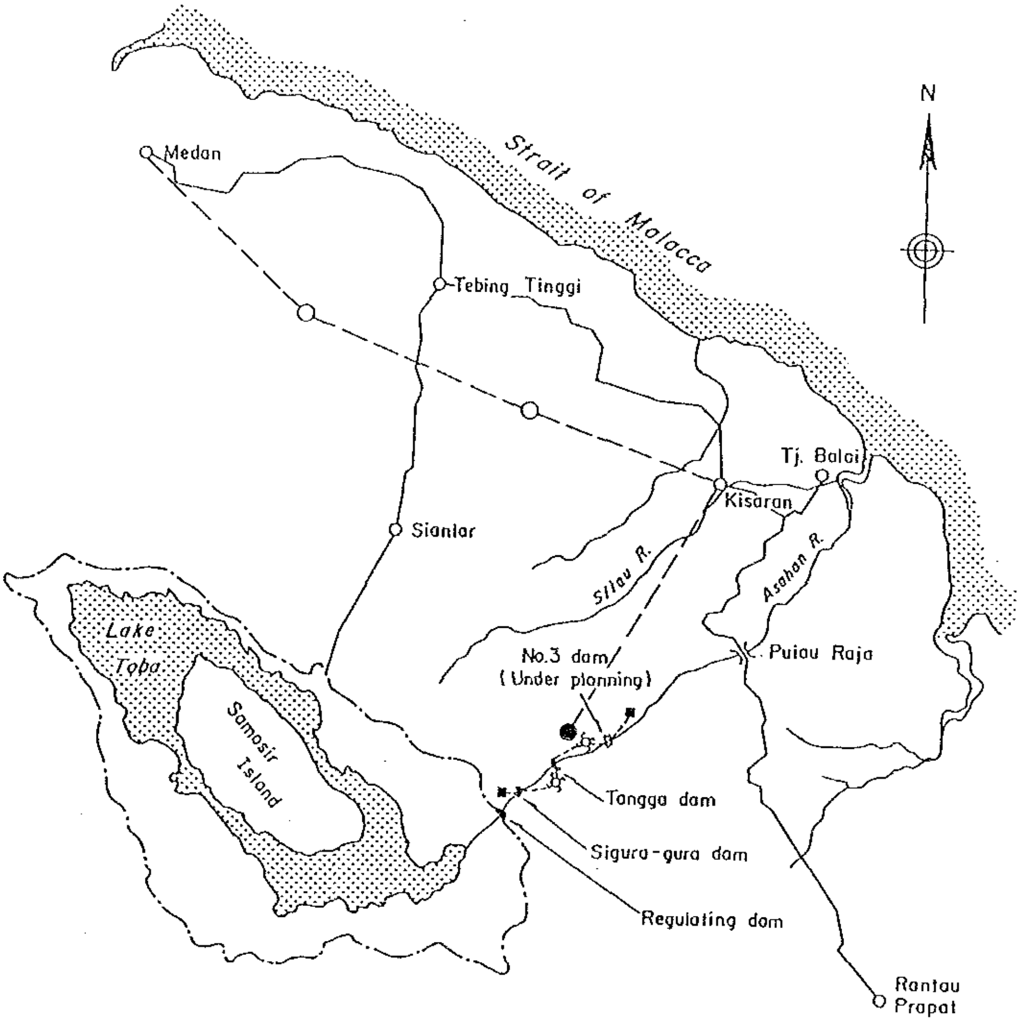


Fig. 5-2 PROPOSED FLOOD FORECASTING & WARNING SYSTEM



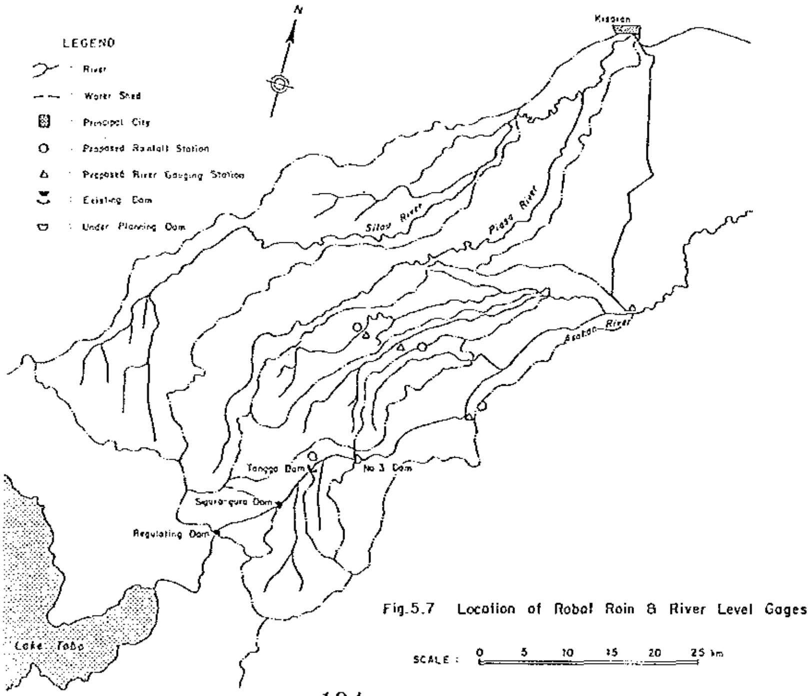


Fig.5.7 Location of Robot Rain & River Level Gages

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Appendix 2-A

Meteorology and Hydrology

Appendix 2-A

METEOROLOGY AND HYDROLOGY

TABLE OF CONTENTS

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LIST OF FIGURES

1. Climate

Climatic conditions in the basins were characterized using meteorological data such as temperatures, relative humidity, rainfall, sunshine hours, wind speed and evaporation in the stations of Sei Dadap in lower plane area and balige in mountainous area as shown in Table A-1. Not so much fluctuations except that for rainfall depths are recognized through a year. It seems that the basins have been experienced one or two peaks in rainfall depths. In rainy season which is appeared in September through December, the maximum rainfall depths are observed.

2. Rainfall

There are about 80 rainfall stations mostly established by PMG, RISPA and DPU as shown in Fig. A-1. All periods of available records at those stations are shown in Figs. A-2 and A-3. It shows that some of daily rainfall records were lost even though monthly records at the same period is still kept by them.

In order to know the local distribution of annual rainfall, an area-wise isohyetal map of annual mean rainfall depths covering the study area was prepared as shown in Fig. A-4. It explains general trend in the study area that rainfall depth increases gradually from coastal area of about 1,500 mm towards mountainous area near the Tangga dam of about 4,000 mm. It decreases in reverse to 1,500 mm through 2,000 mm around Lake Toba. Although it is recognized that the maximum value is recorded at the mountain slope of outside of Lake Toba, range of the heavy rainfall is still unknown because of thin observation net-work compared with that in the lower area. Local distribution of annual rainfall seems to be the same as that of heavy rainfall during flood times.

Typical annual rainfall pattern from 8 stations is shown in Fig. A-5. It gives longitudinal change of the pattern in the Asahan river basin from the coast facing the Strait of Malacca to the mountainous area near Lake Toba. It also shows that the basin receives much rainfall from September to December. Although the secondary peak appears in March through May, it is not so dominant near Lake Toba. On the other hand only one peak is observed in the coastal zone. The annual pattern of rainfall coincides with that of flood occurrence through a year.

Probable one day rainfall depths were calculated by the Gumbel method on the basis of the estimated annual maximum basin rainfall, which is shown in Table A-2, with regard to Pulau Raja, Kisaran, Tanjung Balai, Teluk Binjai and Tanjung Tiram stations. The results are shown in Table A-3 and Fig. A-6. The annual maximum two day rainfall is also shown in Table A-2 and Fig. A-6 for the reference.

3. Stream Flow

There are water level records from gaging stations in the Asahan, Silau and Kualuh rivers, and also lake Toba. Their locations are shown in Fig. A-7. At present 9 gaging stations are being operated by both DPU and INALUM on a hourly-basis except Kisaran station which still continue thrice-daily staff gage readings at every 7:a.m., 12:a.m. and 5:p.m. Existence of water level records is shown in Fig. A-8.

Collection of water level records at Pulau Raja, Kisaran and Pulo Dogom stations of the Asahan, Silau and Kualuh river basins were completed by the end of 1984. In addition discharge measurement was carried out by the Study Team at Pulau Raja from the end of January through the beginning of February 1985 to supplement the high water range of the discharge rating curve. The results are shown below:

Date	Water Level (Gauge Height) (m)	Discharge (cm)
Jan. 31 '85	2.73	202
Feb. 1 '85	2.58	230
Feb. 1 '85	2.52	212
Feb. 2 '85	2.28	201
Feb. 2 '85	2.20	171

Discharge rating curves at the stations were newly revised by use of both measurement records and hydraulic calculations based on river cross sections surveyed by DPU. The cross-sections of the said three stations during discharge measurement since 1980 were compared to examine their fluctuations at shown in Fig. A-9. It reveals that they have not suffered so much changes. The discharge rating curves are shown in Fig. A-10.

Daily water level records from the stations were converted to daily stream flows by use of the rating curves. The monthly mean discharges at those stations are shown in Table A-4 and Fig. A-11. Usually high water flow is observed in September through January or February, and also in May or June. In August in general, the discharge decreases to the minimum about a half of that in May or June.

Monthly mean discharge at Pulau Raja from residual area excluding upstream catchment area of Lake Toba was also estimated as shown in Table A-5, which was supplemented by use of correlation between discharges of the Silau river measured at Kisaran and the residual area are shown in Fig. A-12.

4. Tide

Records of tidal fluctuation at Kuala Tanjung and Bagan Asahan, which are located in 3° 22'N and 99°28'E, and 3°01'N and 99°52'E facing to the Strait of Malacca respectively, were collected by the Study Team until the end of 1984. The records demonstrate double day tide. They were arranged in Table A-6 and Fig. A-13 being summarized below:

(Unit: El. m)

Station	HHL	MHHL	MSL	MLLL	LLL
Kuala Tanjung	1.64	0.85	0.0	-0.86	-1.87
Bagan Asahan	2.25	1.17	0.0	-1.16	-1.75

where, HHL : Higher High Level
MHHL : Mean Higher High Level
MSL : Mean Sea Level
MLLL : Mean Lower Low Level
LLL : Lower Low Level

Table A.1 Climatic Conditions

(Unit : m3/s)

Item		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Max. Temperature (oC)														
Sei Dadap	('66-'83)	31.5	32.1	32.5	32.8	32.7	32.8	32.8	32.5	32.1	31.8	31.5	31.4	32.3
Balige	('73-'81)	24.8	25.2	25.1	26.0	26.2	25.8	25.5	25.0	25.0	25.0	24.8	24.7	25.1
Mean Temperature (oC)														
Sei Dadap	('66-'83)	25.7	26.0	26.3	26.7	26.8	26.8	26.5	26.3	26.2	26.2	26.2	26.0	26.4
Balige	('73-'82)	18.8	18.7	19.1	19.1	19.2	19.2	19.0	18.9	18.8	18.9	19.1	19.0	19.1
Min. Temperature (oC)														
Sei Dadap	('66-'83)	21.8	21.5	21.9	22.7	22.7	22.5	22.3	22.2	22.5	22.6	22.5	22.3	22.2
Balige	('75-'81)	15.1	15.1	15.3	15.7	16.0	15.6	15.6	15.3	15.3	16.3	16.1	15.8	15.4
Relative Humidity (%)														
Sei Dadap	('66-'83)	89	88	88	88	87	87	87	88	89	89	90	89	88
Balige	('73-'82)	85	85	86	86	84	84	84	83	84	85	85	85	85
Rainfall (mm)														
Sei Dadap	('66-'83)	72	53	87	111	129	113	140	145	229	225	175	139	1643
Balige	('73-'82)	108	140	123	159	139	120	119	71	126	182	206	187	1691
Sunshine Hours (%)														
Sei Dadap		-	-	-	-	-	-	-	-	-	-	-	-	-
Balige	('73-'75)	34	23	41	31	34	33	30	31	32	19	27	23	32
Wind Speed (m/sec)														
Sei Dadap	('79-'83)	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.3
Balige		-	-	-	-	-	-	-	-	-	-	-	-	-
Evaporation (mm)														
Sei Dadap	('79-'83)	102	104	109	111	112	111	115	115	108	105	90	99	1278
Balige		-	-	-	-	-	-	-	-	-	-	-	-	-

Table A.2 Annual Maximum Basin Average Rainfall (1/2)

(Unit: mm)

Year	1 day						2 day					
	P.Raja		Kisaran		T.Balai		P.Raja		Kisaran		T.Balai	
1963	Sep.28	50	Sep.28	47	Oct.17	24	Sep.28	53	Sep.28	76	Oct.18	33
1964	Jan.20	39	Sep.7	41	Sep.30	37	Mar.4	58	Jan.20	58	Oct.15	44
1965	Dec.17	50	Dec.6	54	Dec.6	32	Dec.17	56	Dec.6	76	Dec.6	37
1966	Nov.9	29	Mar.19	30	May 20	24	May 21	51	Oct.8	57	May 20	34
1967	Nov.10	38	Sep.22	33	Jun.19	33	Sep.22	68	Nov.30	50	Nov.30	41
1968	Aug.28	42	Jan.15	43	Jan.15	34	Oct.31	47	Jan.16	68	Jan.16	45
1969	Oct.14	86	Oct.14	50	Oct.14	39	Oct.15	102	Oct.14	8	Oct.14	54
1970	Oct.26	29	Oct.7	26	Oct.26	25	Oct.7	38	Oct.7	51	Oct.26	35
1971	Jun.22	36	Sep.20	28	Sep.20	22	Feb.23	71	Jan.5	54	Sep.20	41
1972	Oct.9	33	Sep.6	31	Sep.6	28	Sep.6	60	Sep.6	58	Sep.6	37
1973	Dec.1	66	Dec.1	77	Dec.26	42	Dec.27	122	Oct.21	84	Dec.27	60
1974	Sep.29	38	Sep.29	35	Jun.24	26	Dec.30	66	Jun.24	69	Dec.30	28
1975	May 21	50	Mar.22	38	Apr.21	30	Mar.22	61	Mar.22	62	Apr.22	35
1976	Feb.4	27	Feb.4	37	Jul.6	27	Feb.5	43	Sep.28	63	Sep.28	36
1977	Sep.30	49	Sep.30	59	Sep.30	37	Oct.2	73	Sep.30	74	Oct.1	48
1978	Dec.21	48	Dec.21	44	Oct.13	22	May 21	52	Dec.21	52	Oct.13	30
1979	Dec.12	37	Nov.19	21	Nov.12	28	Jun.12	41	Nov.14	40	Oct.18	31
1980	Nov.3	33	Mar.17	36	Aug.6	27	Aug.7	53	Dec.10	47	Aug.6	29
1981	Sep.7	44	Sep.10	34	Nov.17	32	Sep.7	61	Sep.11	61	Sep.11	38
1982	May 22	35	May 23	39	Aug.24	29	May 23	44	Nov.1	41	Oct.31	32
1983	Dec.18	36	Dec.18	47	Sep.9	23	Jun.18	51	Sep.10	78	Sep.10	28
1984	Dec.3	59	May 23	45	May 11	24	Jan.25	63	Sep.15	78	Feb.1	29

Table A.2 Annual Maximum Basin Average Rainfall (2/2)

(Unit: mm)

Year	1 day			
	T.Binjai (Kualuh R.)		T.Tiram (Kiri R.)	
1963	Dec.3	44	Sep.28	30
1964	May 14	45	Oct.14	22
1965	May 21	42	Dec.13	26
1966	Mar.21	44	Oct.3	22
1967	Sep.22	34	Oct.12	26
1968	Jul.20	21	Oct.29	26
1969	Oct.14	40	Oct.14	35
1970	Dec.25	32	Nov.5	15
1971	Feb.23	50	Sep.20	14
1972	Dec.4	29	Sep.6	19
1973	Oct.21	57	Dec.14	23
1974	Dec.29	38	Feb.4	28
1975	Sep.27	29	Dec.3	29
1976	Nov.3	26	Jul.6	30
1977	Feb.8	29	Oct.10	25
1978	Feb.14	27	Apr.16	30
1979	Sep.11	26	Jul.11	36
1980	Oct.5	30	Oct.10	35
1981	Nov.23	38	Oct.16	29
1982	Mar.29	34	Apr.28	25
1983	Sep.13	36	Sep.9	24
1984	Jan.23	38	Apr.8	39

Table A.3 Probable One Day Rainfall

(Unit: mm)

Return Period (yr)	P.Raja Asahan R.	Kisaran Silau R.	T.Balai Asahan R.	T.Binjai Kualuh R.	T.Tiram Kiri R.
100	103	91	51	64	46
50	92	82	47	60	43
30	84	76	44	56	40
25	80	73	43	55	39
15	72	66	41	52	37
10	66	61	38	49	35
5	54	51	34	44	32
2	37	37	28	36	27

Table A.4 Monthly Mean Discharge (1/2)

(Unit: m3/s)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
Station : Pulau Raja (Asahan R., 4486 km2)													
1977	-	-	-	137.0	150.5	142.8	123.5	119.2	111.3	168.7	190.4	200.0	-
1978	-	157.4	148.1	147.0	152.0	145.7	119.8	89.3	98.5	118.9	131.2	148.4	-
1979	118.0	99.9	191.1	114.4	97.7	127.6	92.1	79.5	101.1	123.0	182.0	180.6	117.3
1980	154.9	145.4	188.7	162.3	195.0	157.6	131.4	161.2	136.1	149.5	199.9	165.0	162.3
1981	190.2	-	-	-	-	-	-	-	149.9	144.9	163.8	108.1	-
1982	88.4	92.2	106.4	236.3	338.2	191.7	107.9	97.2	142.5	147.6	169.5	162.2	156.7
1983	149.3	105.9	89.0	75.7	87.2	94.3	113.9	102.7	136.8	139.2	118.1	161.2	114.4
1984	227.5	323.3	224.8	271.8	306.3	199.1	153.4	141.9	146.7	168.8	160.0	176.1	208.3
Ave.	154.7	154.0	141.4	163.5	190.0	151.2	120.3	113.0	127.9	145.1	164.4	162.7	151.8 (149.0)
Station : Kisaran (Sirau R., 1050 Km2)													
1973	61.0	44.7	63.5	85.9	60.3	68.3	-	-	77.9	80.3	71.9	194.2	-
1974	82.9	82.1	61.2	66.1	59.9	56.1	53.8	-	62.0	72.5	86.1	76.2	-
1975	74.7	67.6	63.8	100.3	84.1	56.9	54.3	44.3	83.7	84.6	94.6	89.1	74.8
1976	84.1	71.7	52.7	77.2	64.6	62.4	59.6	58.0	59.2	78.4	102.1	84.0	71.2
1977	62.0	52.6	45.6	46.3	50.2	49.6	33.7	42.9	55.7	121.8	94.6	81.8	61.4
1978	50.3	54.0	45.6	45.0	50.5	59.4	49.2	31.4	49.3	69.2	64.5	70.7	53.3
1979	52.7	44.9	38.7	61.6	45.0	59.4	43.1	34.5	53.2	59.7	96.4	69.5	54.9
1980	52.5	40.6	78.1	50.2	71.3	43.1	35.8	78.4	53.6	62.8	93.0	68.9	60.7
1981	72.7	59.7	41.8	51.7	85.5	47.6	46.7	36.3	79.1	81.7	73.7	48.9	60.5
1982	49.0	58.5	69.4	91.9	97.7	45.9	43.7	48.3	55.3	66.7	63.0	56.4	62.2
1983	46.4	35.9	40.0	28.7	46.1	41.8	47.1	43.4	74.8	88.4	49.8	82.9	52.1
1984	94.5	94.3	79.9	70.1	116.4	47.8	48.6	-	52.3	69.7	76.8	82.3	-
Ave.	65.2	58.9	56.7	64.6	69.3	53.2	46.9	46.4	63.0	78.0	80.5	83.7	61.2 (63.9)

Table A.4 Monthly Mean Discharge (2/2)

(Unit: m3/s)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
Station : Pulo Dogom (Kualuh R., 1116 km2)													
1979	-	-	-	-	-	-	-	-	-	-	-	65.1	-
1980	54.2	45.5	79.8	60.3	74.1	47.4	29.1	50.6	45.5	70.6	85.9	61.3	58.7
1981	94.9	68.3	34.1	56.8	80.5	50.8	48.7	27.0	76.0	81.3	69.4	47.1	61.2
1982	35.5	56.8	59.8	82.5	80.9	43.8	37.6	44.4	54.3	80.0	55.3	64.5	57.9
1983	56.4	36.4	30.9	22.1	37.0	41.2	51.4	31.5	83.8	76.3	57.3	105.6	52.5
1984	112.4	82.2	88.8	104.4	117.8	59.4	48.9	44.1	51.3	70.1	61.0	81.9	76.9
Ave.	70.6	57.8	58.7	65.2	78.1	48.5	43.1	39.5	62.2	75.7	65.8	70.9	61.4 (61.3)

Table A.5 Estimated Monthly Mean Discharge at Pulau Raja from Remaining Area Downstream of Siruar

(Unit : m3/s)

(Catchment Area = 797 km2)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Average
1973	(56.4)	(44.1)	(58.3)	(75.2)	(55.9)	(62.0)	-	-	(69.2)	(71.0)	(64.7)	(157.0)	-
1974	(73.0)	(72.4)	(56.6)	(60.3)	(55.6)	(52.8)	(51.0)	-	(57.2)	(65.1)	(75.4)	(67.9)	-
1975	(66.8)	(61.4)	(58.6)	(86.1)	(73.9)	(53.4)	(51.4)	(43.8)	(73.6)	(74.3)	(81.8)	(77.7)	66.9
1976	(73.9)	(64.5)	(50.2)	(68.7)	(59.2)	(57.5)	(55.4)	(54.2)	(55.1)	(69.6)	(87.5)	(73.8)	64.1
1977	(57.2)	(50.1)	(44.8)	35.2	45.1	47.3	45.8	45.5	57.9	91.8	78.2	67.2	55.5
1978	(48.4)	55.8	48.7	45.1	47.1	53.9	41.7	23.6	37.1	45.5	61.9	75.2	48.7
1979	44.0	30.4	20.4	39.8	26.3	54.9	22.6	16.2	32.3	53.5	90.1	69.6	41.7
1980	47.9	41.5	72.1	44.8	76.0	45.0	33.6	63.4	44.9	56.9	103.6	64.7	57.9
1981	(65.3)	(55.5)	(42.0)	(49.4)	(75.0)	(46.3)	(45.6)	(37.8)	103.3	78.1	90.6	64.1	62.8
1982	47.4	53.2	59.4	63.3	87.4	54.5	50.5	44.9	47.9	71.3	44.5	53.3	56.5
1983	43.3	37.4	42.4	25.3	35.9	38.1	55.4	40.8	76.0	72.6	48.6	81.9	49.8
1984	98.2	83.5	80.6	85.5	94.8	76.7	55.9	44.2	52.5	75.0	68.8	72.5	74.0
Ave.	60.2	54.2	52.8	56.6	61.0	53.5	46.3	41.4	58.9	68.7	74.6	77.1	57.8 (58.8)

Note : Data with parenthesis are estimated by use of both observed discharge at Kisaran and regression curve shown below.

$$Q_{PR} - Q_{SI} = 0.755\, Q_{k} + 10.4$$

where ; Q_{PR} : discharge at Pulau Raja

Q_{SI} : discharge at Siruar

Q_{k} : discharge at Kisaran

Table A.6 Tide Level at Kuala Tanjung and Bagan Asahan

(Unit : cm above zero of tide gage)

	Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVE.	Max. or Min.
Kuala Tanjung															
HHL	1983	-	-	-	292	305	293	285	291	300	302	322	283		
	1984	285	291	302	309	315	292	296	309	321	305	-	-		321
MHHL	1983	-	-	-	233	245	271	228	238	242	249	256	231		
	1984	229	228	239	244	248	246	240	249	248	243	-	-	242	
MSL	1983	-	-	-	148	160	177	148	151	150	158	169	150		
	1984	149	144	150	156	163	160	156	161	164	166	-	-	157	
MLLL	1983	-	-	-	63	74	82	67	63	58	66	82	69		
	1984	69	60	61	67	77	73	72	72	79	89	-	-	71	
LLL	1983	-	-	-	10	18	26	-1	-22	-24	-7	24	-7		
	1984	-18	-30	-24	-4	24	15	2	-8	-11	19	-	-	-	-30
Bagan Asahan															
HHL	1983	-	-	-	-	-	-	-	-	-	-	-	390		
	1984	390	400	420	420	400	380	390	430	430	440	380	-		440
MHHL	1983	-	-	-	-	-	-	-	-	-	-	-	331		
	1984	329	328	332	338	330	329	336	340	336	335	321	-	332	
MSL	1983	-	-	-	-	-	-	-	-	-	-	-	213		
	1984	209	210	214	216	214	215	217	222	222	220	215	-	213	
MLLL	1983	-	-	-	-	-	-	-	-	-	-	-	95		
	1984	88	91	96	93	98	101	97	103	108	105	108	-	99	
LLL	1983	-	-	-	-	-	-	-	-	-	-	-	50		
	1984	40	40	40	40	50	50	50	40	40	40	40	-		40

Note ; HHl : Higher High Level
MHHL : Mean Higher High Level
MSL : Mean Sea Level
MLLL : Mean Lower Low Level
LLL : Lower Low Level

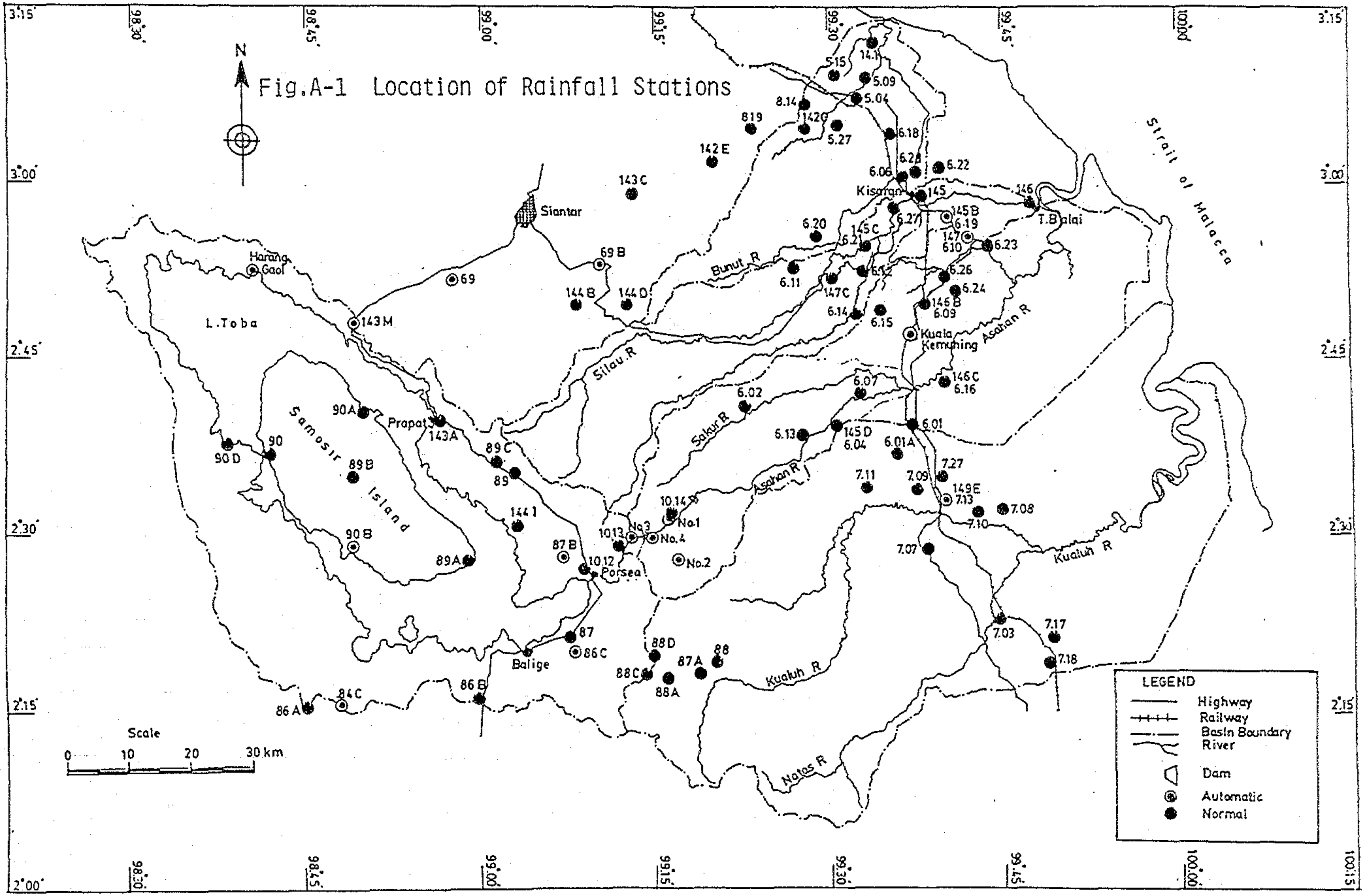


Fig.A-1 Location of Rainfall Stations

Fig.A-2 Monthly Rainfall Records (1/3)

	Station	Source	Type	Coordinates
	Harang Gaol	DPU	N	2 - 53N, 98 - 40E
			A	
69	Bahal Gajah	PMG	N	2 - 52N, 98 - 57E
143M	Gorbus	PMG	N	2 - 48N, 98 - 49E
			A	
90	Pangururan	PMG	N	2 - 37N, 98 - 42E
90A	Ambarita	PMG	N	2 - 40N, 98 - 50E
90D	Parmonangan	PMG	N	2 - 38N, 98 - 38E
90B	Palipi	PMG	N	2 - 29N, 98 - 49E
			A	
86A	Doloksanggul	PMG	N	2 - 15N, 98 - 45E
84B	Parmonangan	PMG	A	2 - 06N, 98 - 46E
84C	Hutaraja	PMG	N	2 - 15N, 98 - 48E
			A	
143A	Parapat	PMG	N	2 - 40N, 98 - 56E
89B	Runggonihuta	PMG	N	2 - 35N, 98 - 49E
89A	Onan Runggu	PMG	N	2 - 27N, 98 - 59E
86B	Pintu-Pintu	PMG	N	2 - 16N, 99 - 00E
89C	Aek Natolu	PMG	N	2 - 36N, 99 - 01E
89	Lumban Pea	PMG	N	2 - 35N, 99 - 03E
144 I	Kasinder	PMG	N	2 - 31N, 99 - 03E
87B	Porsea	PMG	N	2 - 28N, 99 - 07E
		DPU	A	2 - 27N, 99 - 10E
87	Balige	PMG	N	2 - 21N, 99 - 07E
86C	Sibarani	PMG	N	2 - 20N, 99 - 08E
			A	
10.12	Parparean	RISPA	N	2 - 27N, 99 - 09E
10.13	Simangkuk	RISPA	N	2 - 29N, 99 - 12E
10.14	Pintu Pohan	RISPA	N	2 - 31N, 99 - 16E
	INALUM NO.1	INALUM	A	2 - 31N, 99 - 16E
	INALUM NO.2	INALUM	A	2 - 28N, 99 - 17E
	INALUM NO.3	INALUM	A	2 - 30N, 99 - 13E
	INALUM NO.4	INALUM	A	2 - 30N, 99 - 15E

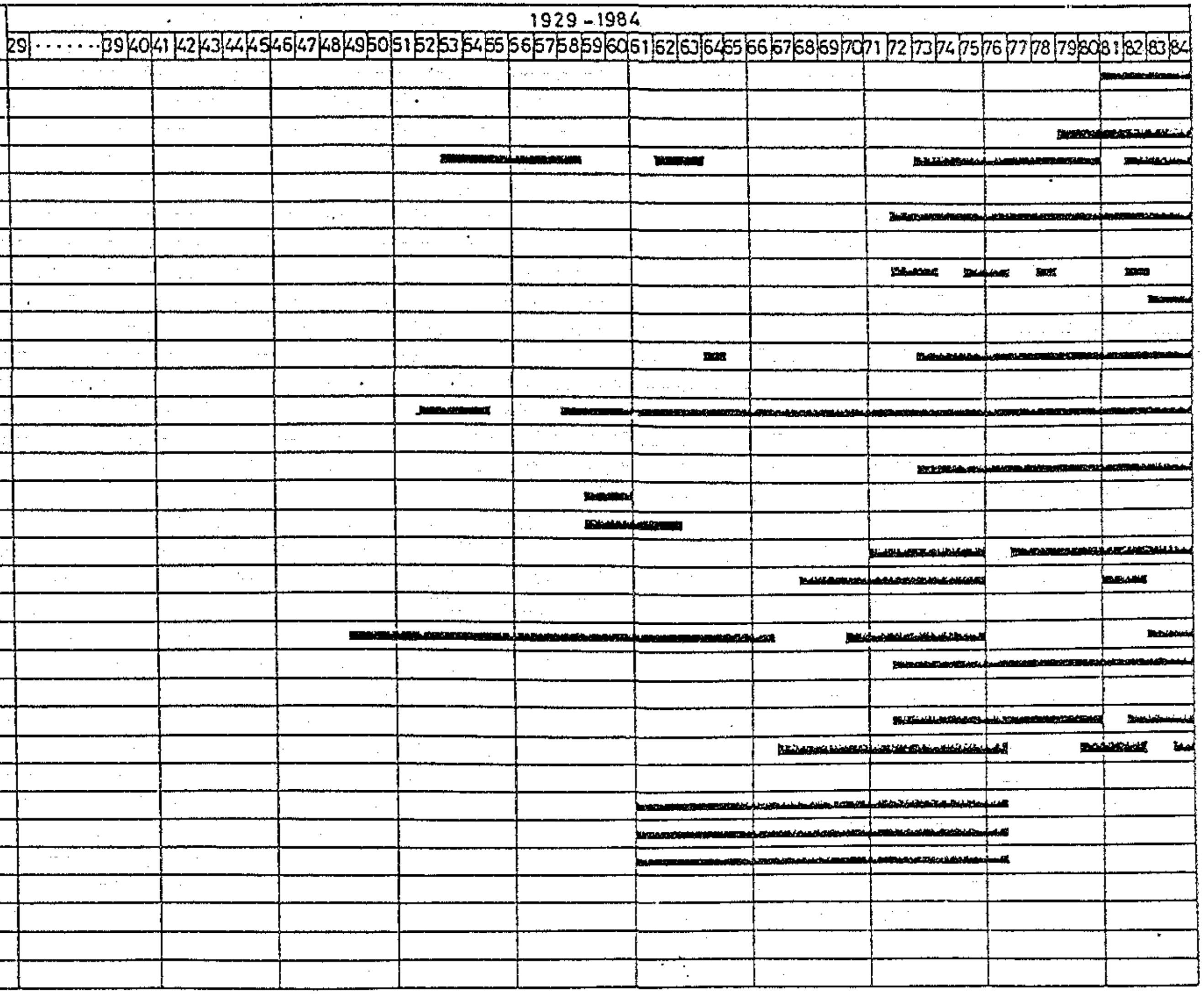


Fig.A-2 Monthly Rainfall Records (2/3)

	Station	Source	Type Coordinates
88C	Tongkonisalu	PMG	N 2-18N, 99-14E
88D	Matio	PMG	N 2-20N, 99-15E
88A	Sibosur	PMG	N 2-18N, 99-16E
87A	Nasa-UT	PMG	N 2-18N, 99-19E
88	Parsoburan	PMG	N 2-19N, 99-20E
143C	Bah Jambi	PMG	N 2-59N, 99-13E
69B	Sei Suka Deras	PMG	A 2-53N, 99-10E
144D	Tonduhan	PMG	N 2-50N, 99-13E
7.18	Panigaran	RISPA	N 2-19N, 99-49E
7.17	Padang Malabah	RISPA	N 2-21N, 99-49E
7.03	Aek Pamiengke	RISPA	N 2-23N, 99-44E
7.07	Damuli	RISPA	N 2-29N, 99-38E
7.08	Hanna	RISPA	N 2-32N, 99-45E
7.10	Labuhan Haji	RISPA	N 2-32N, 99-43E
7.27	Ledong Barat	RISPA	N 2-35N, 99-40E
149E 7.13	Membang Muda	PMG/RISPA	N 2-33N, 99-40E
			A
7.09	Kanopan Ulu	RISPA	N 2-34N, 99-38E
7.11	Londut	RISPA	N 2-35N, 99-33E
6 01A	Aek Loba Afd-2L	RISPA	N 2-37N, 99-36E
6.01	Aek Loba Empl	RISPA	N 2-39N, 99-37E
6 02	Aek Tarum	RISPA	N 2-41N, 99-23E
6.13	Padang Pulah	RISPA	N 2-39N, 99-28E
145D 6.04	Bandar Pulau Empl	PMG/RISPA	N 2-40N, 99-31E
6.07	Gunung Melayu	RISPA	N 2-42N, 99-33E
146C 6.16	Pulau Raja-1	PMG/RISPA	N 2-43N, 99-40E
6.20	Sei Kopas	RISPA	N 2-56N, 99-29E
6.11	Huta Padang	RISPA	N 2-53N, 99-27E
147C	Pulau Mandi	PMG/RISPA	N 2-52N, 99-30E
6.14	Piasa Ulu	RISPA	N 2-49N, 99-32E
6.15	Pulahan	RISPA	N 2-49N, 99-34E
145C 6.21	Sei Silau	PMG/RISPA	N 2-55N, 99-33E
6.12	Kuala Piasa	RISPA	N 2-53N, 99-33E

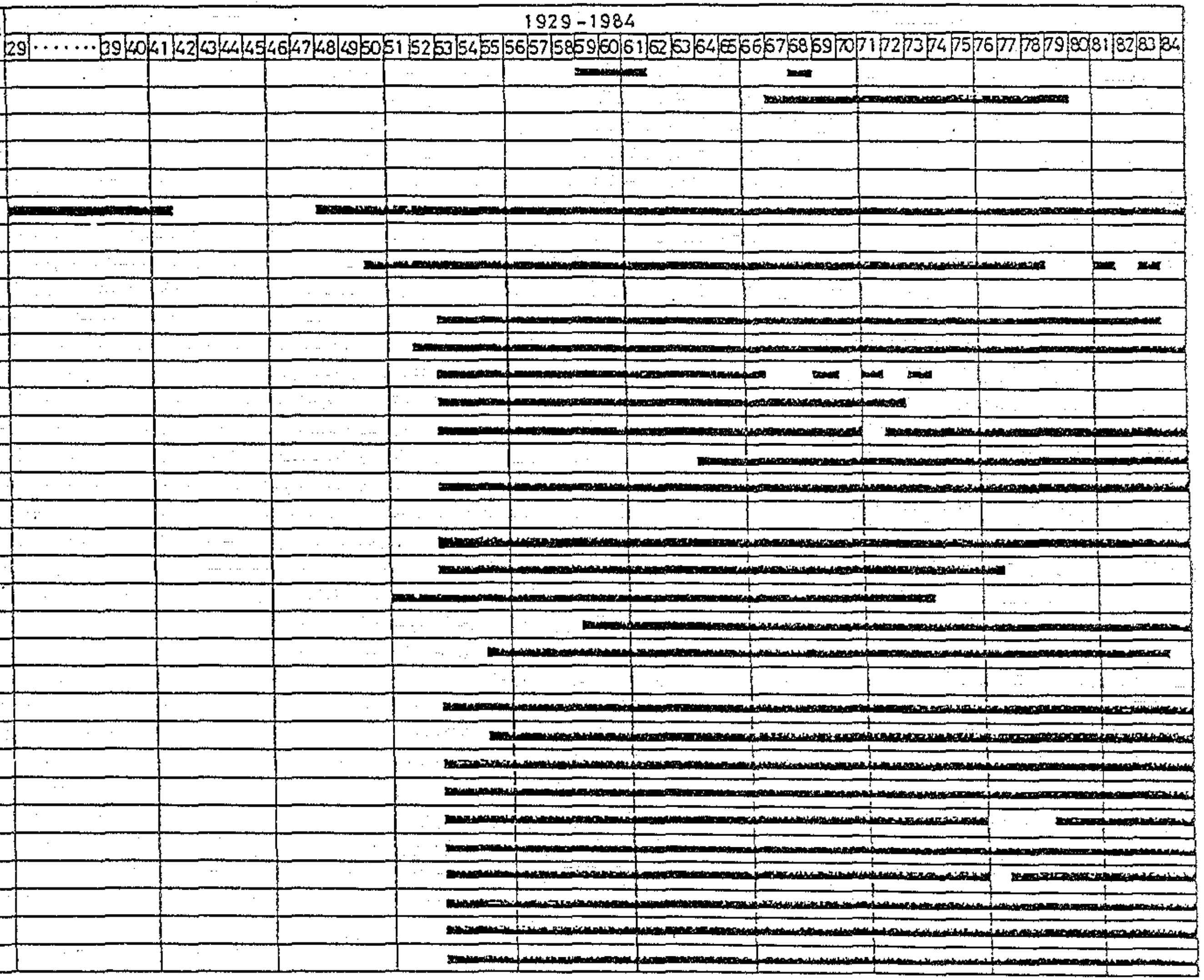


Fig.A-2 Monthly Rainfall Records (3/3)

Station			Source	Type	Coordinates
146B	6.09	Henglo	PMG/RISPA	N	2-50N, 99-38E
	6.24	Teluk Dalam	RISPA	N	2-51N, 99-41E
145		Kisaran	PMG	N	2-59N, 99-40E
145B	6.19	Sungai Dadap	PMG/RISPA	N	2-57N, 99-40E
				A	
144B		Bah Tangguia	PMG	N	2-50N, 99-08E
147	6.10	Hessa	PMG/RISPA	N	2-55N, 99-42E
				A	
	6.23	Sukaraja	RISPA	N	2-55N, 99-43E
	6.26	Teluk Manto	RISPA	N	2-52N, 99-40E
146		Tanjung Balai	PMG	N	2-58N, 99-48E
	6.27	Tanah Raja-2	RISPA	N	2-58N, 99-36E
	6.28	Sibogat	RISPA	N	3-01N, 99-37E
	6.06	Bunut	RISPA	N	3-01N, 99-36E
	6.22	Serbangan	RISPA	N	3-10N, 99-39E
	6.18	Sei Baleh-2	RISPA	N	3-04N, 99-35E
	5.27	Tinjowan Empl	RISPA	N	3-05N, 99-31E
142G		Dusun Ulu	PMG	N	3-05N, 99-28E
	8.19	Maligas A	RISPA	N	3-05N, 99-24E
		Kuala Kemuning	DPU	N	2-47N, 99-37E
				A	
142E		Mayang	PMG	N	3-02N, 99-20E
	5.15	Petatal	RISPA	N	3-10N, 99-31E
	5.09	Tanah Datar	RISPA	N	3-09N, 99-34E
	8.14	Dusun Ulu Empl	RISPA	N	3-07N, 99-28E
141		Labuhan Ruku	PMG	N	3-12N, 99-34E
	5.04	Lidah Tanah	RISPA	N	3-07N, 99-33E

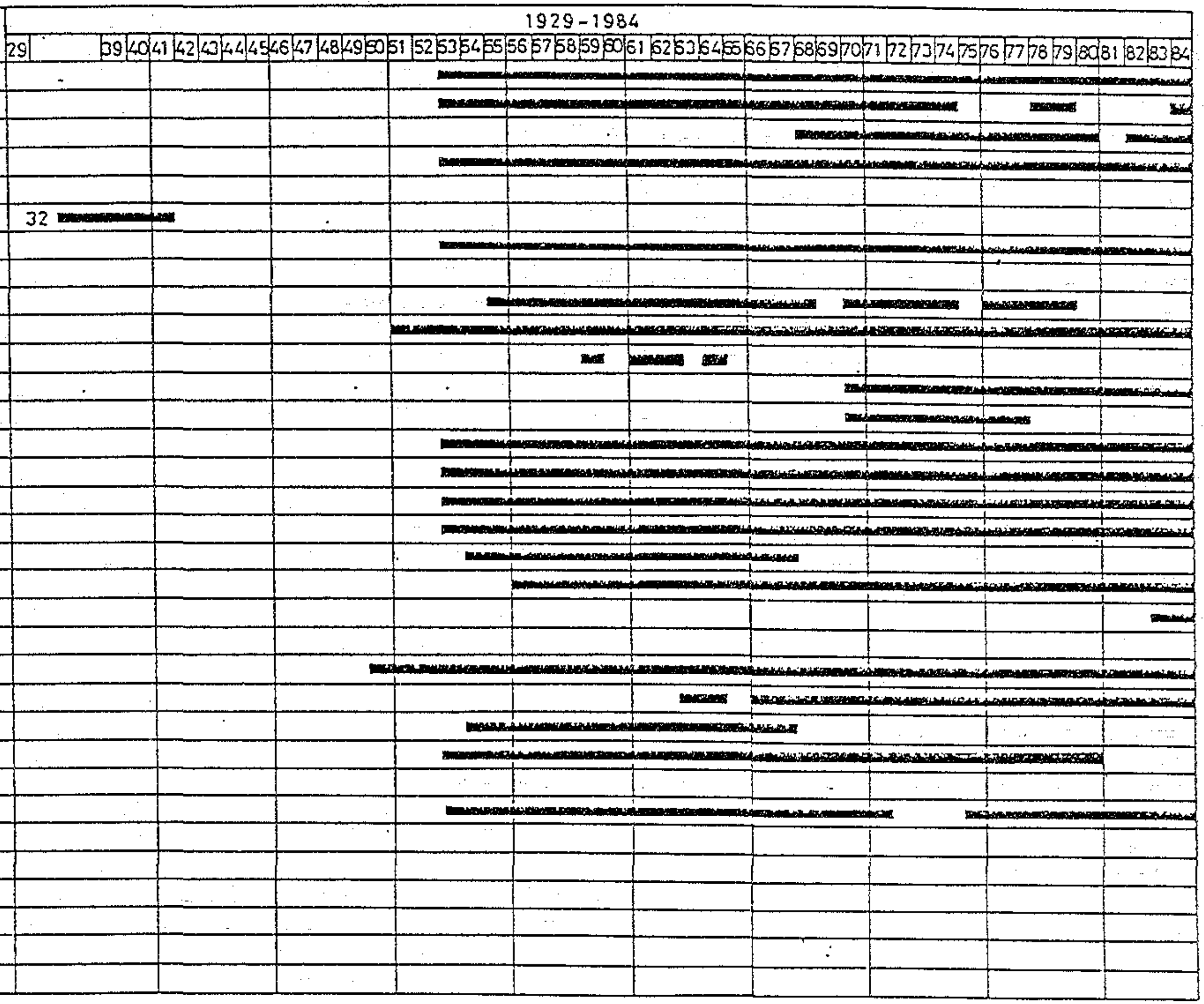


Fig.A-3 Daily Rainfall Records (1/3)

	Station	Source	Type	Coordinates
	Harang Gaol	DPU	N	2 - 53N, 98 - 40E
			A	
69	Bahal Gajah	PMG	N	2 - 52N, 98 - 57E
143M	Gorbus	PMG	N	2 - 48N, 98 - 49E
			A	
90	Pangururan	PMG	N	2 - 37N, 98 - 42E
90A	Ambarita	PMG	N	2 - 40N, 98 - 50E
90D	Parmonangan	PMG	N	2 - 38N, 98 - 38E
90B	Palipi	PMG	N,	2 - 29N, 98 - 49E
			A	
86A	Doloksanggul	PMG	N	2 - 15N, 98 - 45E
84B	Parmonangan	PMG	A,	2 - 06N, 98 - 46E
84C	Hutaraja	PMG	N,	2 - 15N, 98 - 48E
			A.	
143A	Parapat	PMG	N.	2 - 40N, 98 - 56E
89B	Runggonihuta	PMG	N	2 - 35N, 98 - 49E
89A	Onan Runggu	PMG	N.	2 - 27N, 98 - 59E
86B	Pintu-Pintu	PMG	N	2 - 16N, 99 - 00E
89C	Aek Natolo	PMG	N	2 - 36N, 99 - 01E
89	Lumban Pea	PMG	N	2 - 35N, 99 - 03E
144 I	Kasinder	PMG	N	2 - 31N, 99 - 03E
87B	Parsea	PMG	N	2 - 28N, 99 - 07E
		DPU	A	2 - 27N, 99 - 10E
87	Balige	PMG	N	2 - 21N, 99 - 07E
86C	Sibarani	PMG	N	2 - 20N, 99 - 08E
			A	
10.12	Parparean	RISPA	N	2 - 27N, 99 - 09E
10.13	Simangkuk	RISPA	N	2 - 29N, 99 - 12E
10.14	Pintu Pohan	RISPA	N	2 - 31N, 99 - 16E
	INALUM No.1	INALUM	A	2 - 31N, 99 - 16E
	INALUM No.2	INALUM	A	2 - 28N, 99 - 17E
	INALUM No.3	INALUM	A	2 - 30N, 99 - 13E
	INALUM No.4	INALUM	A	2 - 30N, 99 - 15E

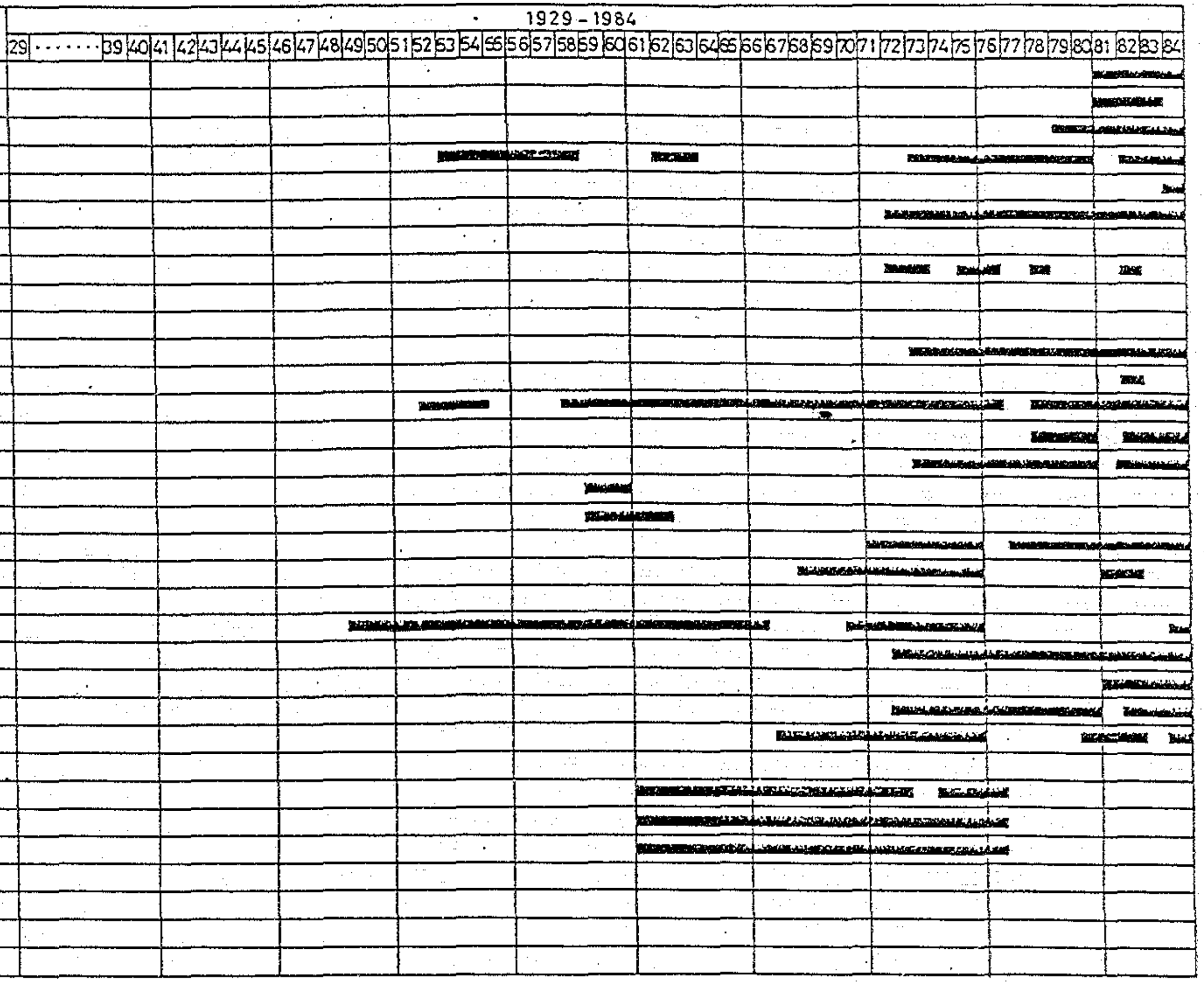


Fig.A-3 Daily Rainfall Records (2/3)

Station		Source	Type	Coordinates
88C	Tongkonisalu	PMG	N	2-18N, 99-14E
88D	Matio	PMG	N	2-20N, 99-15E
88A	Sibosur	PMG	N	2-18N, 99-16E
87A	Nasa-UT	PMG	N	2-18N, 99-19E
88	Parsoburan	PMG	N	2-19N, 99-20E
143C	Bah Jambi	PMG	N	2-59N, 99-13E
69B	Sei Suka Deras	PMG	A	2-53N, 99-10E
144D	Tonduhan	PMG	N	2-50N, 99-13E
7.18	Panigaran	RISPA	N	2-19N, 99-49E
7.17	Padang Malabah	RISPA	N	2-21N, 99-49E
7.03	Aek Pamiengke	RISPA	N	2-23N, 99-44E
7.07	Damuli	RISPA	N	2-29N, 99-38E
7.08	Hanna	RISPA	N	2-32N, 99-45E
7.10	Labuhan Haji	RISPA	N	2-32N, 99-43E
7.27	Ledong Barat	RISPA	N	2-35N, 99-40E
149E 7.13	Membang Muda	PMG/RISPA	N	2-33N, 99-40E
			A	
7.09	Kanopan Ulu	RISPA	N	2-34N, 99-38E
7.11	Londut	RISPA	N	2-35N, 99-33E
6.01A	Aek Loba Afd-2L	RISPA	N	2-37N, 99-36E
6.01	Aek Loba Empl	RISPA	N	2-39N, 99-37E
		PMG	A	
6.02	Aek Tarum	RISPA	N	2-41N, 99-23E
6.13	Padang Pulah	RISPA	N	2-39N, 99-28E
145D 6.04	Bandar Pulau Empl	PMG/RISPA	N	2-40N, 99-31E
6.07	Gunung Melayu	RISPA	N	2-42N, 99-33E
146C 6.16	Pulau Raja-1	PMG/RISPA	N	2-43N, 99-40E
6.20	Sei Kopas	RISPA	N	2-56N, 99-29E
6.11	Huta Padang	RISPA	N	2-53N, 99-27E
147C	Pulau Mandi	PMG/RISPA	N	2-52N, 99-30E
6.14	Piasa Ulu	RISPA	N	2-49N, 99-32E
6.15	Pulahan	RISPA	N	2-49N, 99-34E
145C 6.21	Sei Silau	PMG/RISPA	N	2-55N, 99-33E

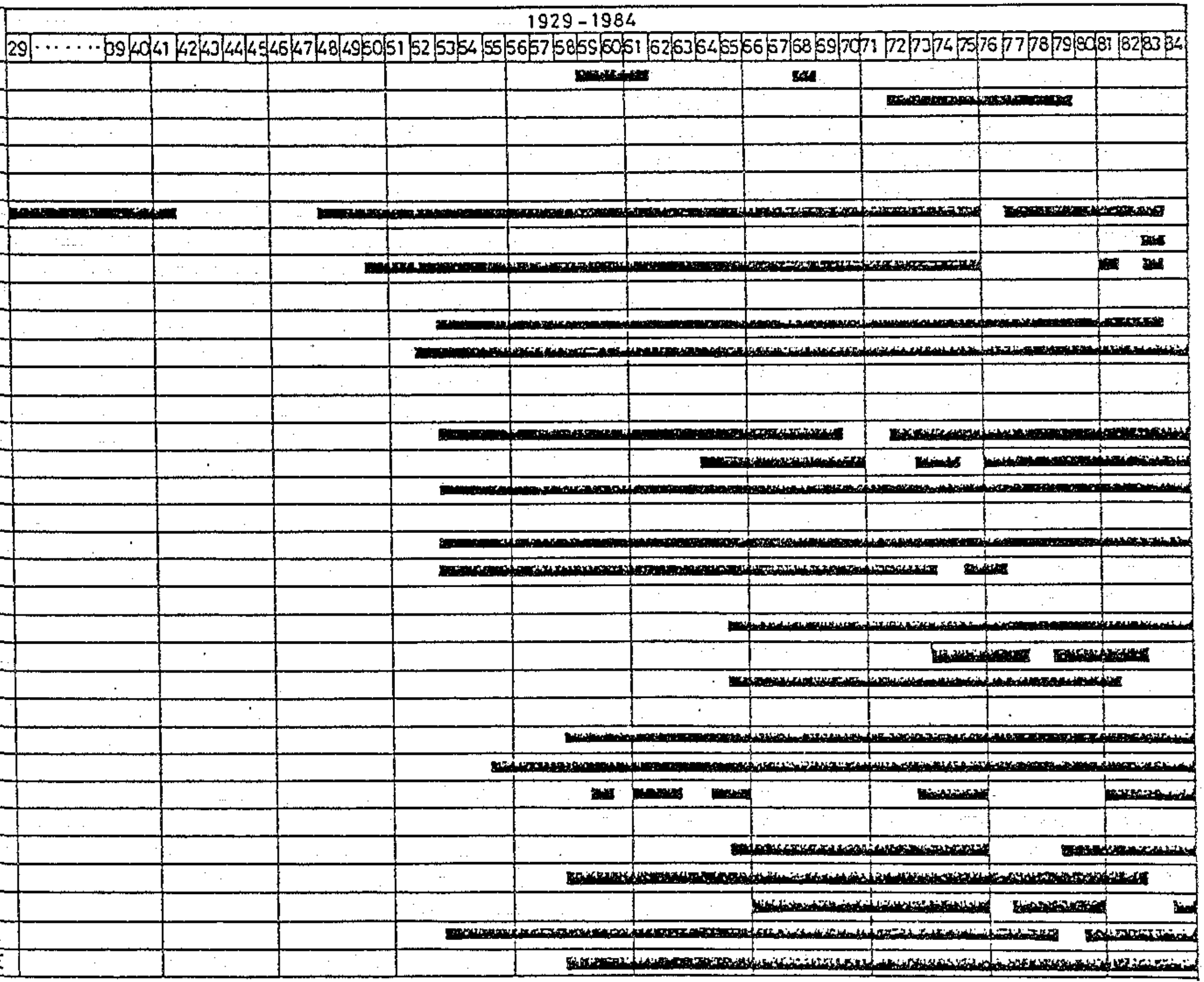


Fig.A-3 Daily Rainfall Records (3/3)

		Station	Source	Type	Coordinates
	6.12	Kuala Piasa	RISPA	N	2-53N, 99-33E
146B	6.09	Henglo	PMG/RISPA	N	2-50N, 99-38E
	6.24	Teluk Dalam	RISPA	N	2-51N, 99-41E
145		Kisaran	PMG	N	2-59N, 99-40E
145B	6.19	Sungai Dadap	PMG/RISPA	N	2-57N, 99-40E
				A	
144B		Bah Tanggula	PMG	N	2-50N, 99-08E
147	6.10	Hessa	PMG/RISPA	N	2-55N, 99-42E
				A	
	6.23	Sukaraja	RISPA	N	2-55N, 99-43E
	6.26	Teluk Manto	RISPA	N	2-52N, 99-40E
146		Tanjung Balai	PMG	N	2-58N, 99-48E
	6.27	Tanah Raja-2	RISPA	N	2-58N, 99-36E
	6.28	Sibogat	RISPA	N	2-01N, 99-37E
	6.06	Bunut	RISPA	N	2-01N, 99-36E
	6.22	Serbangan	RISPA	N	3-10N, 99-39E
	6.18	Sei Baleh	RISPA	N	3-04N, 99-35E
	5.27	Tinjowan Empl	RISPA	N	3-05N, 99-31E
142G		Dusun Ulu	PMG	N	3-05N, 99-28E
	8.19	Maligas A	RISPA	N	3-05N, 99-24E
		Kuala Kemuning	DPU	N	2-47N, 99-37E
				A	
142E		Mayang	PMG	N	3-02N, 99-20E
	5.15	Petatal	RISPA	N	3-10N, 99-31E
	5.09	Tanah Datar	RISPA	N	3-09N, 99-34E
	8.14	Dusun Ulu Empl	RISPA	N	3-07N, 99-28
141		Labuhan Ruku	PMG	N	3-12N, 99-34E
	5.04	Lidah Tanah	RISPA	N	3-07N, 99-33E

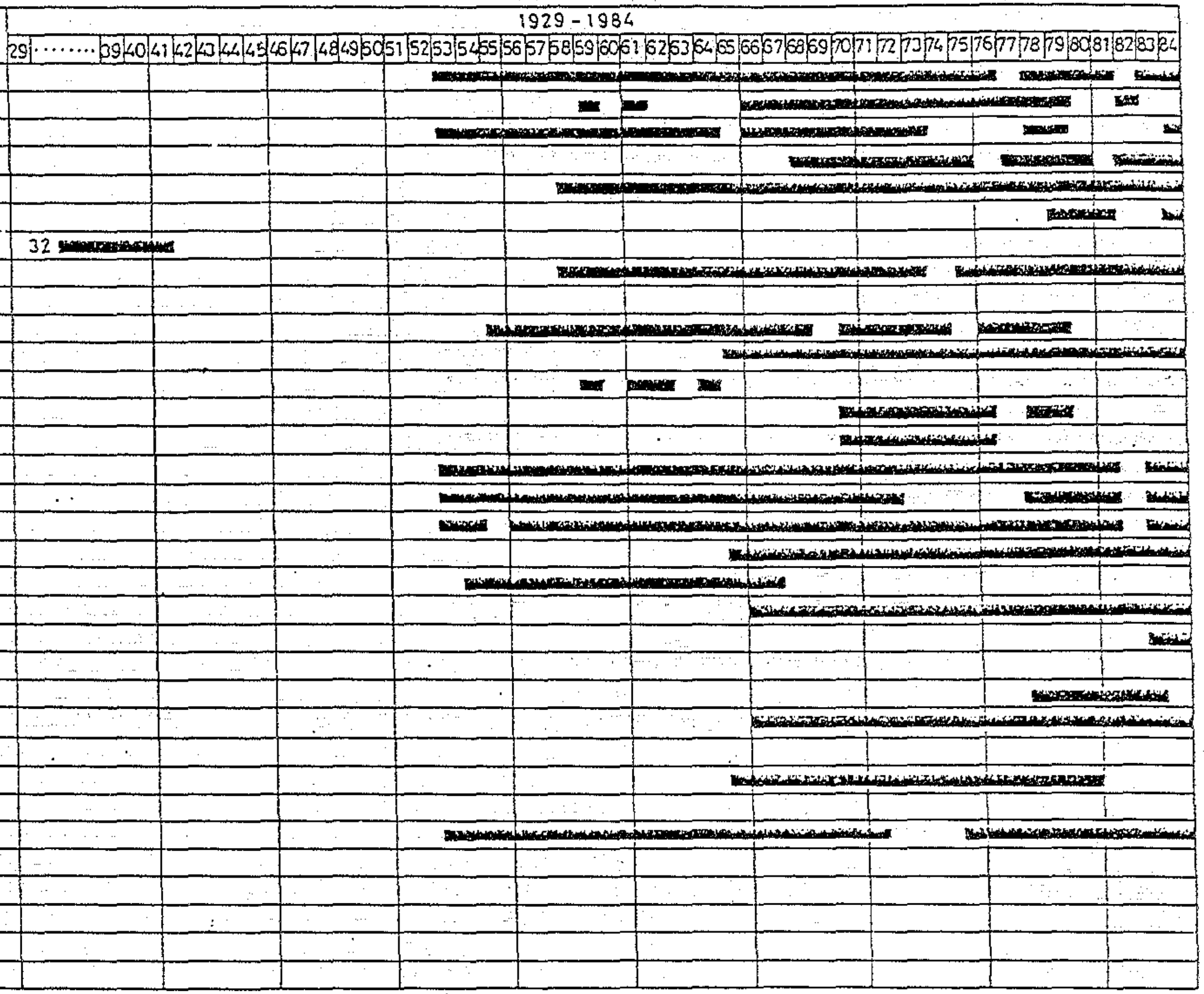


Fig.A-4 Isohyetal Map of Annual Rainfall

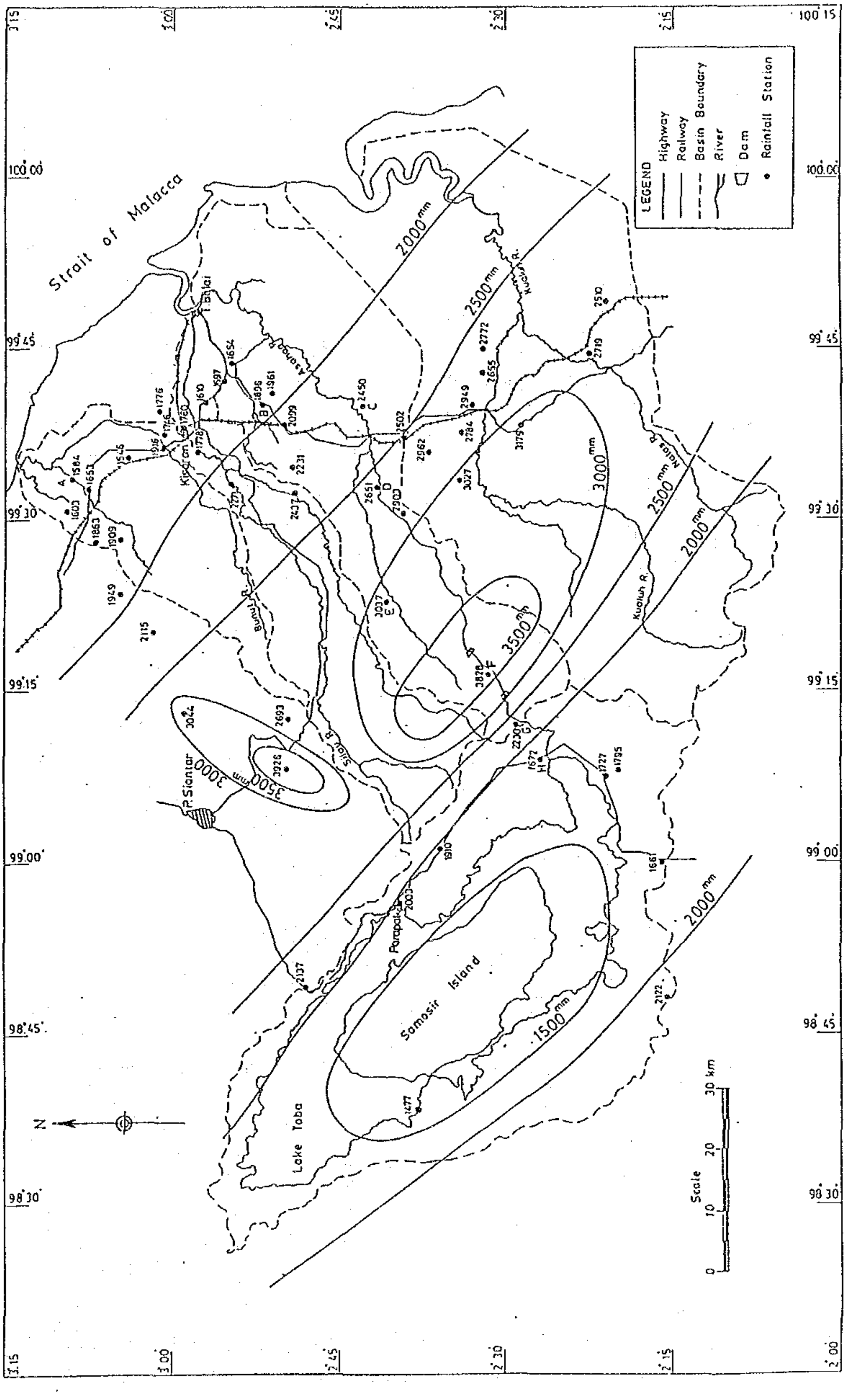
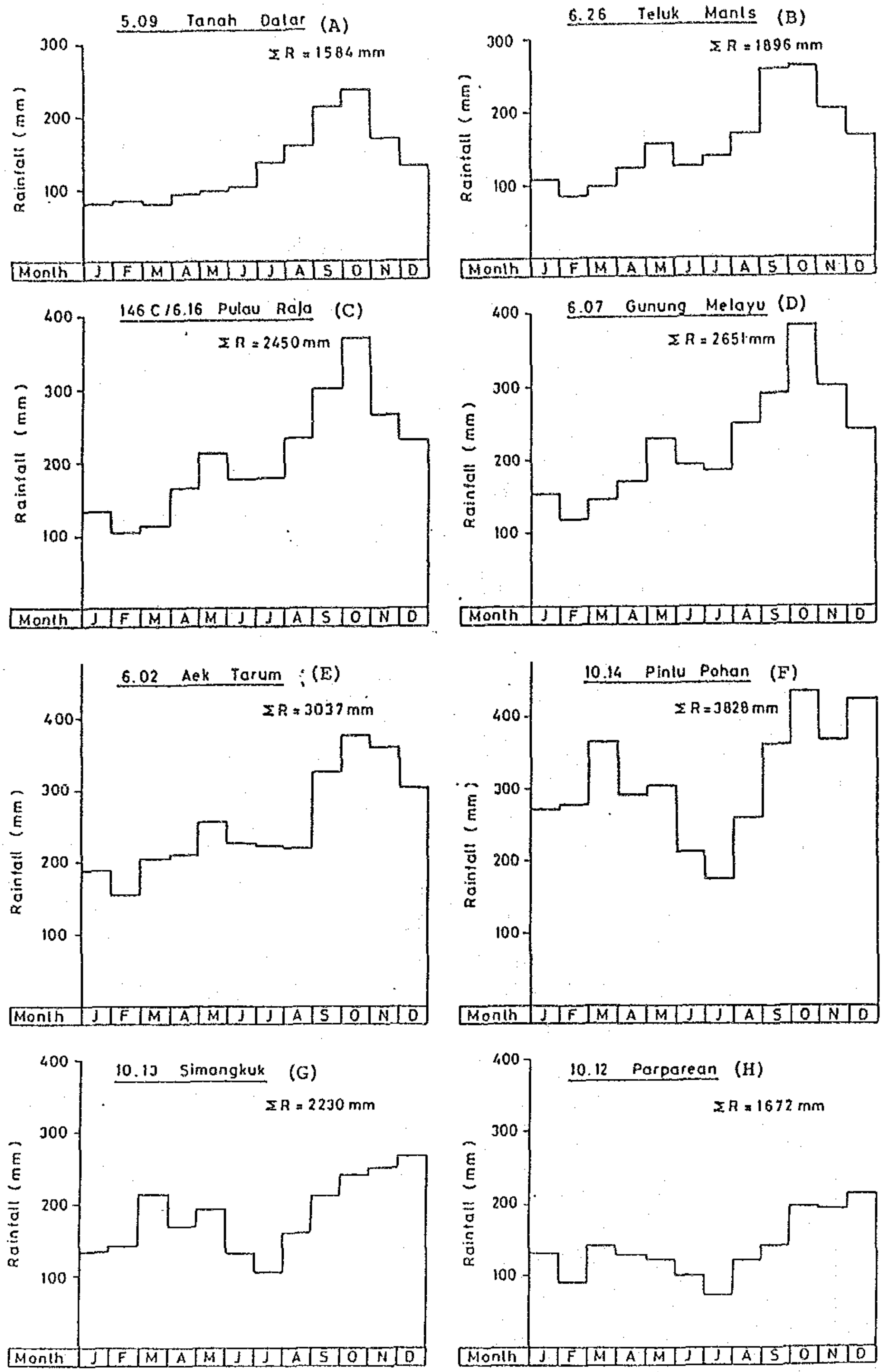


Fig.A-5 Typical Annual Rainfall Pattern



Note: Location of above stations is shown in isohyetal map (Fig.A.4)

Fig.A-6 Probability of 1-Day and 2-Day Rainfalls

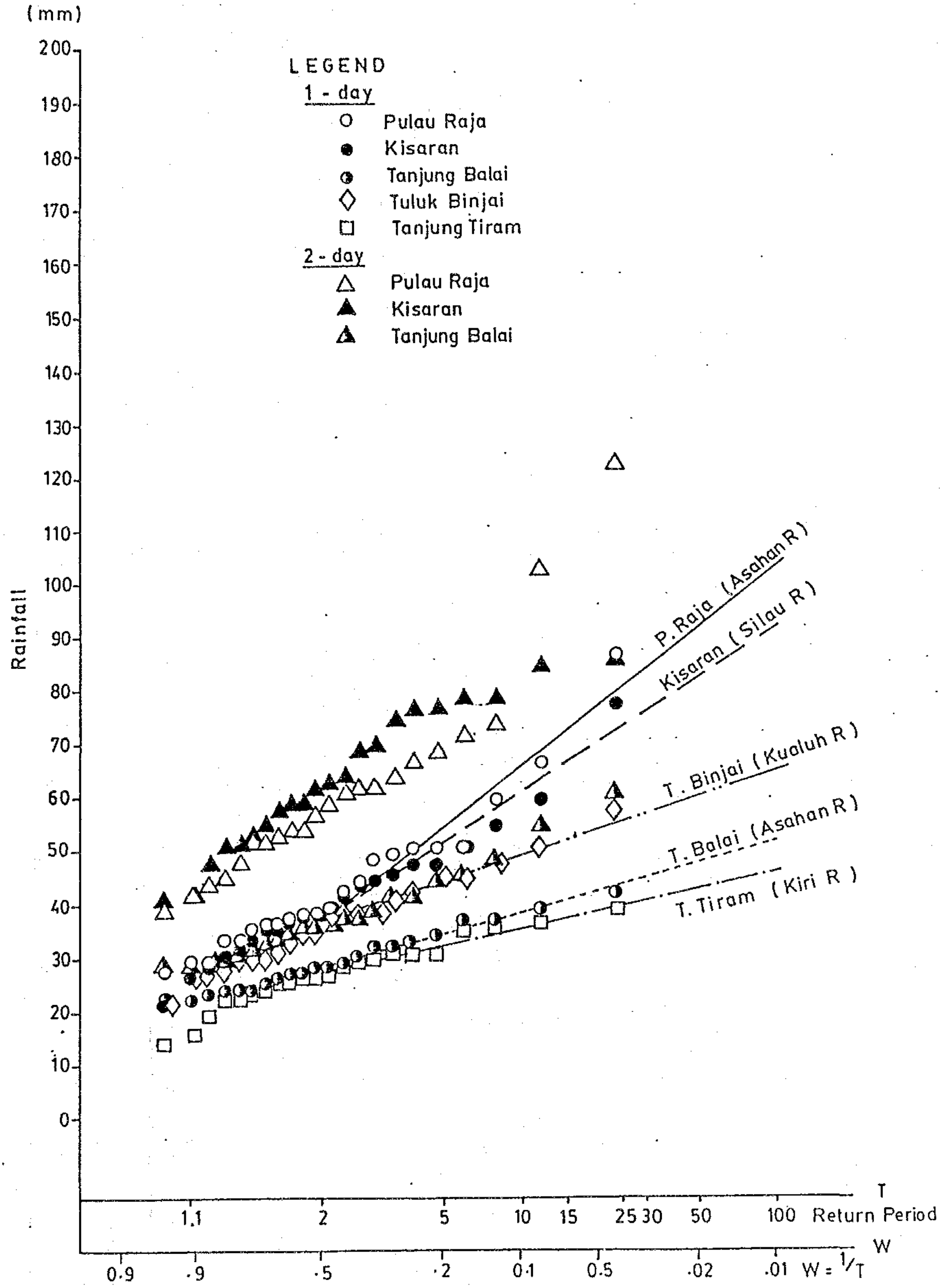


Fig.A-7 Location of Water Level Gaging Stations

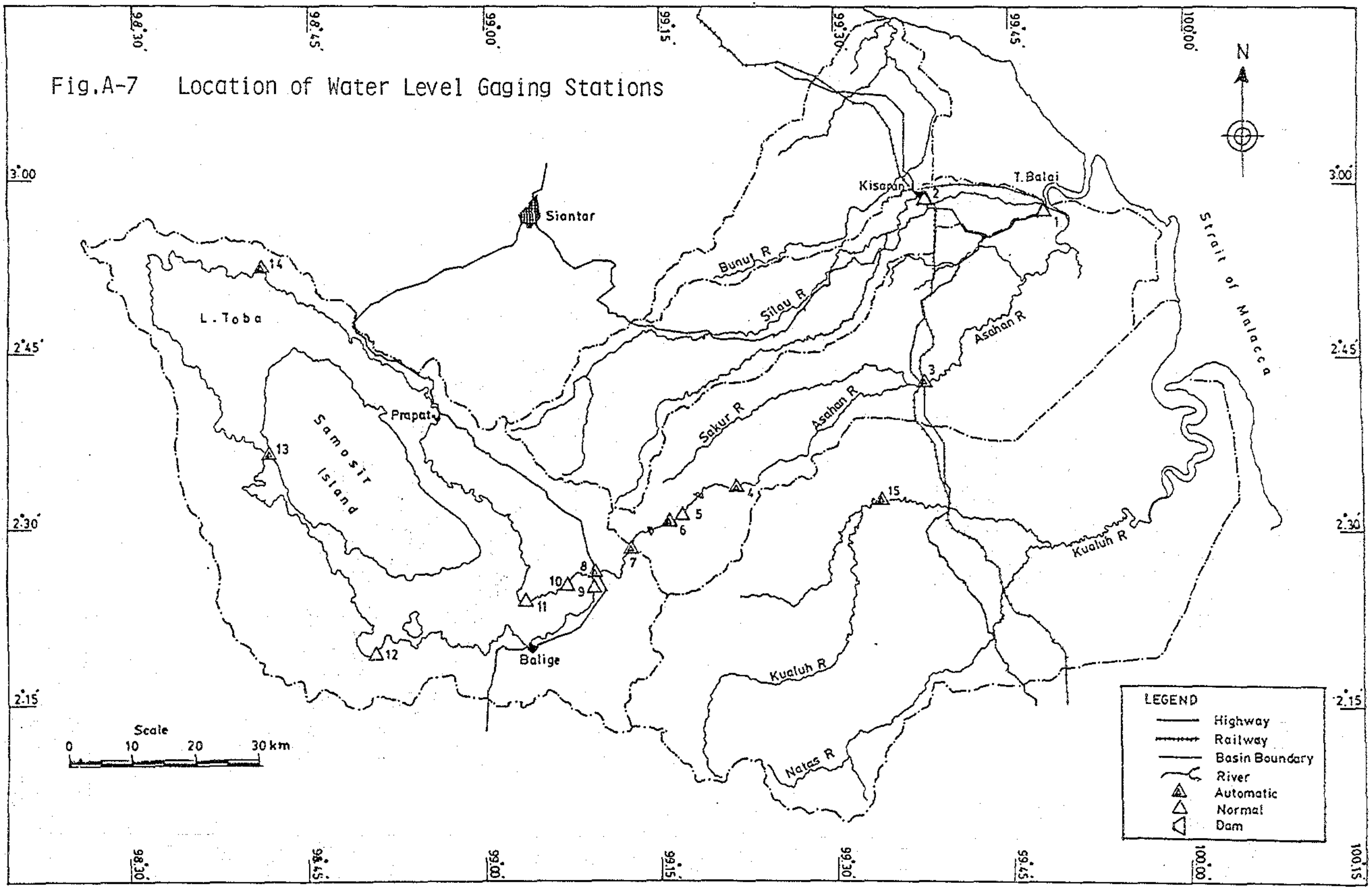


Fig.A-8 Water Level Records

	Station	Source	Type	Coordinates	Location
1	Tanjung Balai	DPU	N	2 - 58N, 99 - 48E	Silau R.
2	Kisaran	DPU	N	2 - 58N, 99 - 38E	Silau R.
3.	Pulau Raja	DPU	N A	2 - 34N, 99 - 38E	Asahan R.
4.	Hula Huli	INALUM	N A	2 - 34N, 99 - 21E	Asahan R.
5.	Siguragura	INALUM	N	2 - 31N, 99 - 17E	Asahan R.
6.	Simorea	INALUM	N A	2 - 31N, 99 - 16E	Asahan R.
7.	Siruar	INALUM	N A	2 - 28N, 99 - 12E	Asahan R.
8.	Porsea	INALUM DPU	N A	2 - 27N, 99 - 10E	Asahan R.
9.	Lingtong	INALUM	N	2 - 25N, 99 - 09E	L. Toba
10.	Djandi Matogu	INALUM	N	2 - 25N, 99 - 07E	L. Toba
11.	Lumban Butar Butar	INALUM	N	2 - 24N, 99 - 03E	L. Toba
12.	Simangulamper	INALUM	N	2 - 19N, 98 - 51E	L. Toba
13.	Pangururan	DPU	A	2 - 36N, 98 - 42E	L. TOba
14.	Harang Gaol	DPU	A	2 - 53N, 98 - 41E	L. Toba
15.	Pulo Dogom	DPU	A	2 - 32N, 99 - 34E	Kualuh R.

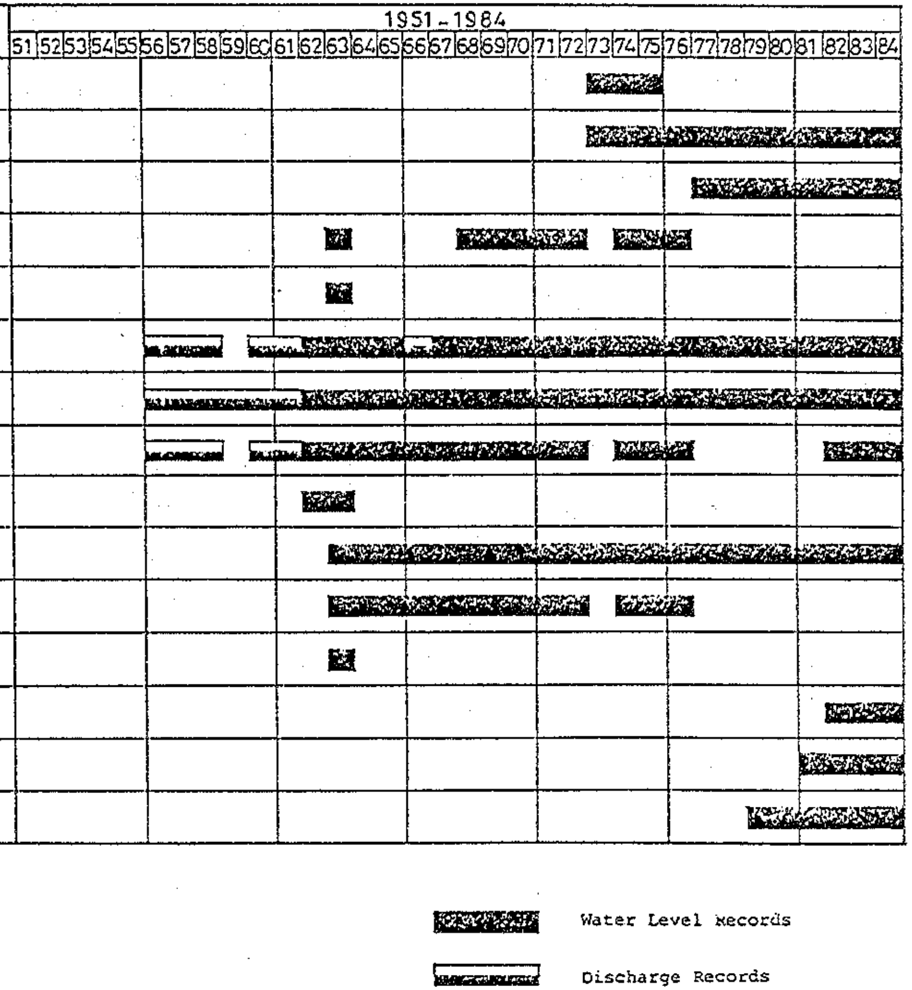


Fig.A-9 Cross-section at Gaging Stations

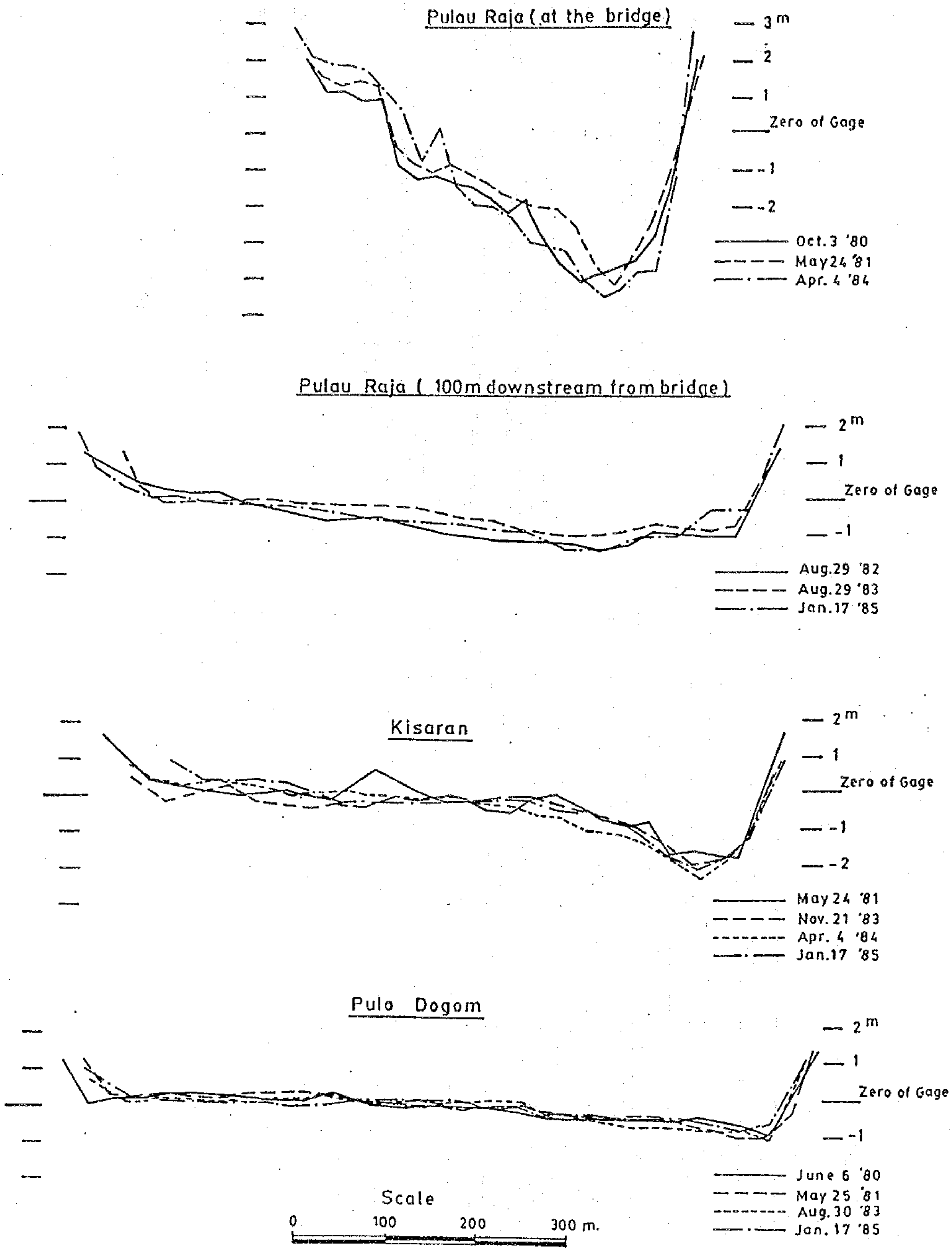


Fig.A-10 Discharge Rating Curve (1/3)

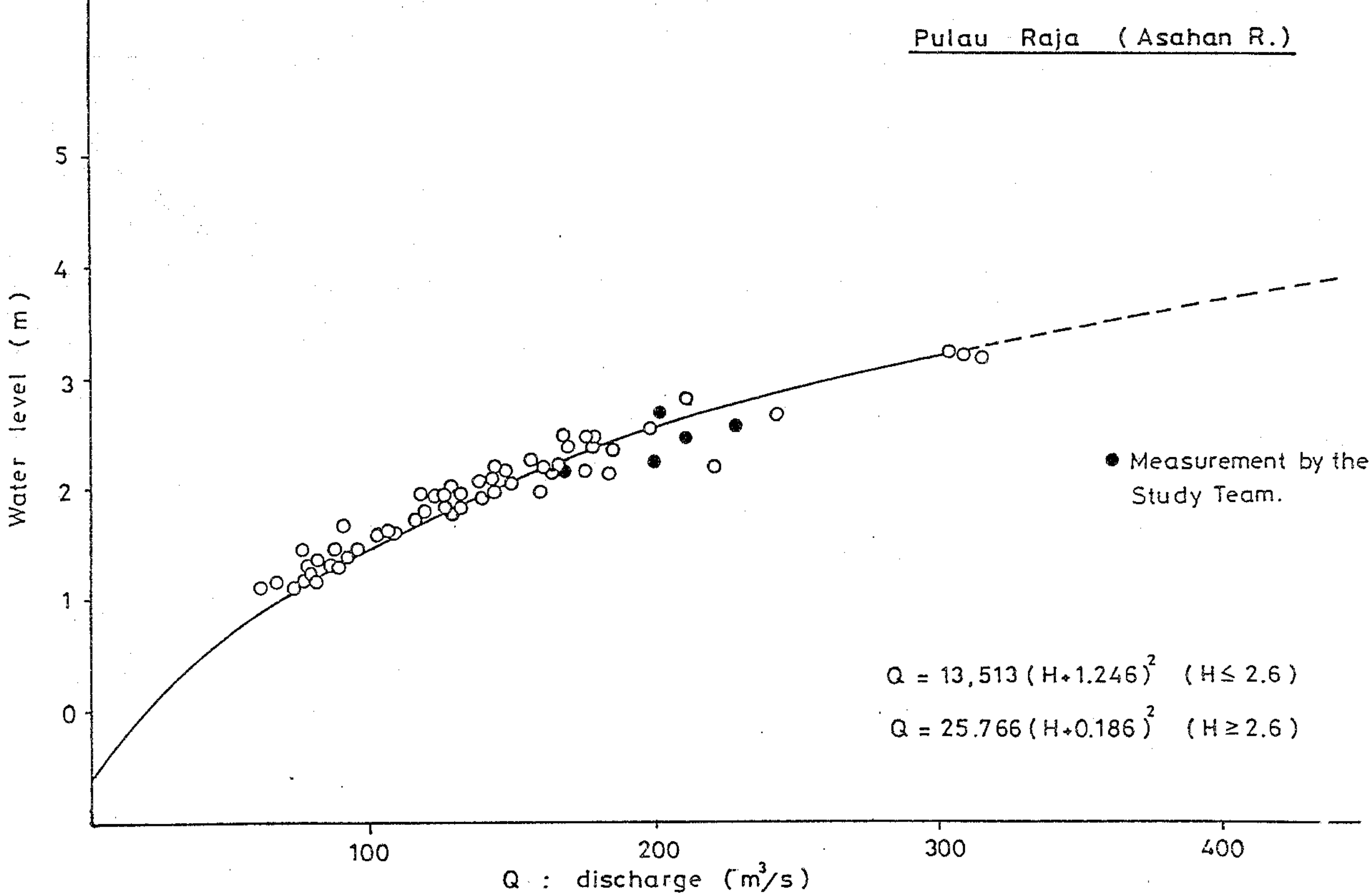


Fig.A-10 Discharge Rating Curve (2/3)

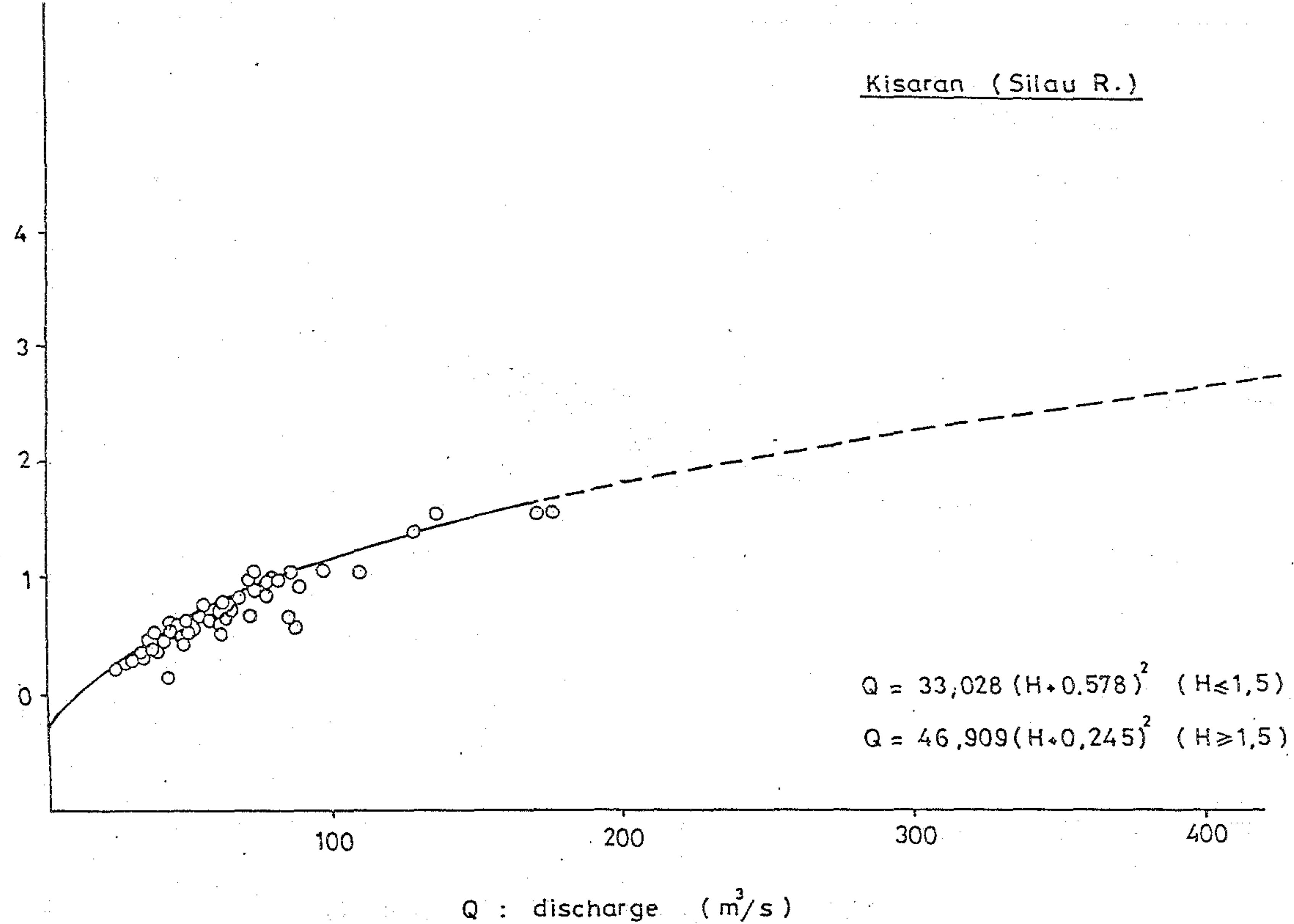


Fig.A-10 Discharge Rating Curve (3/3)

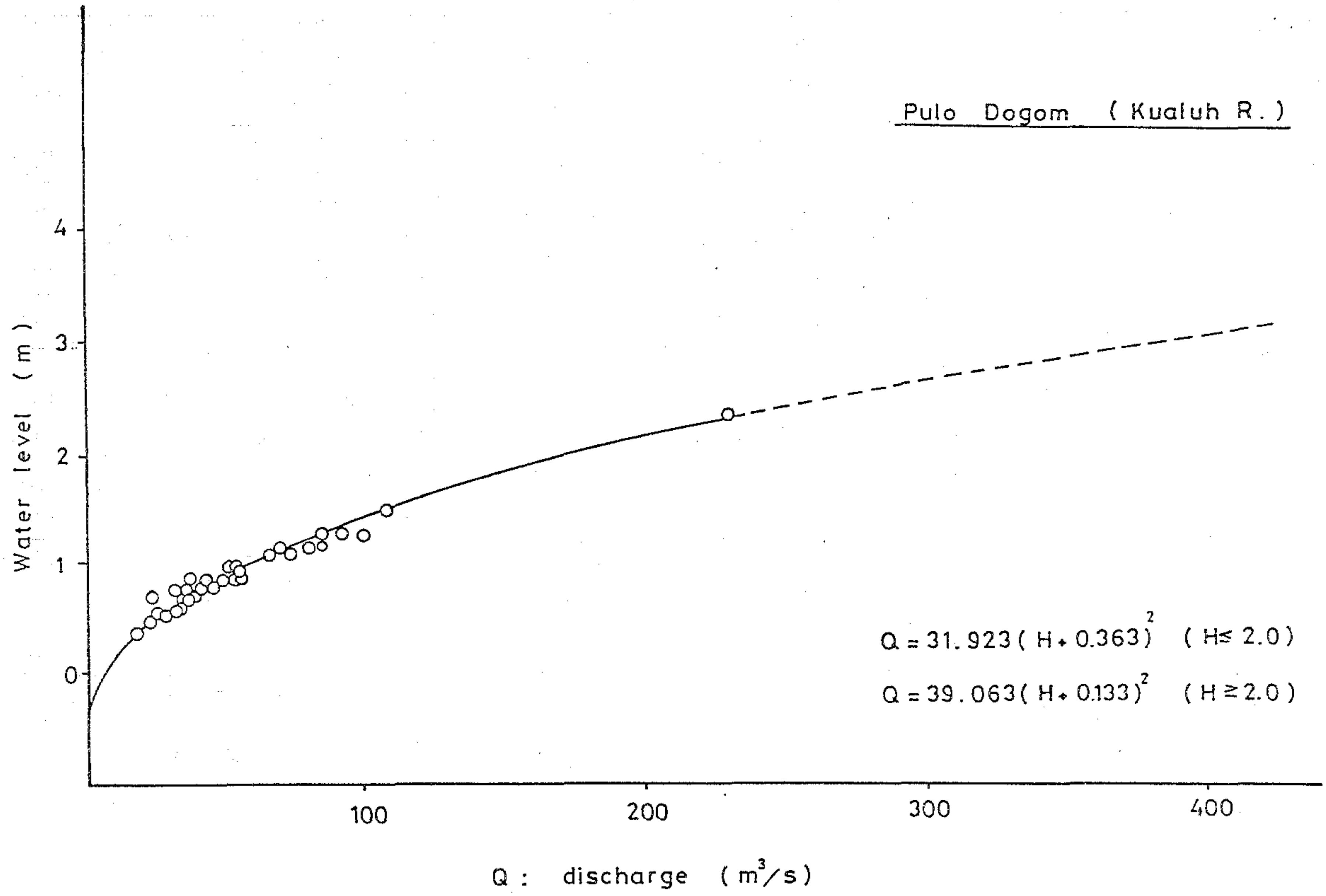
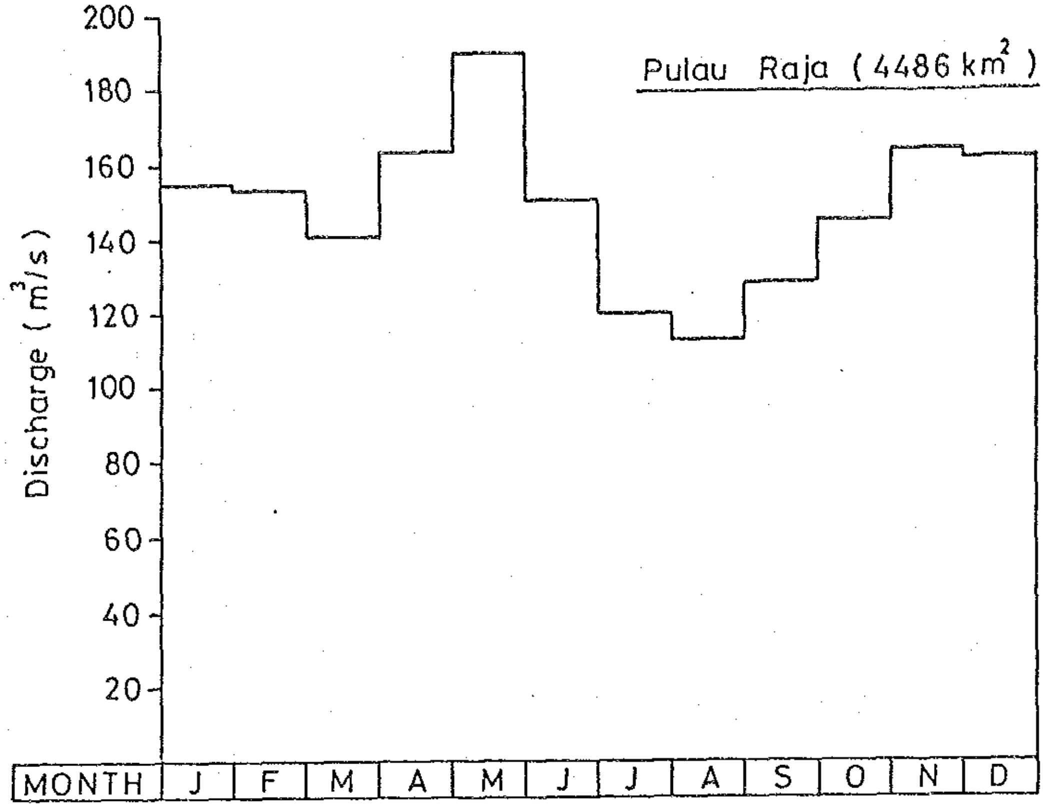
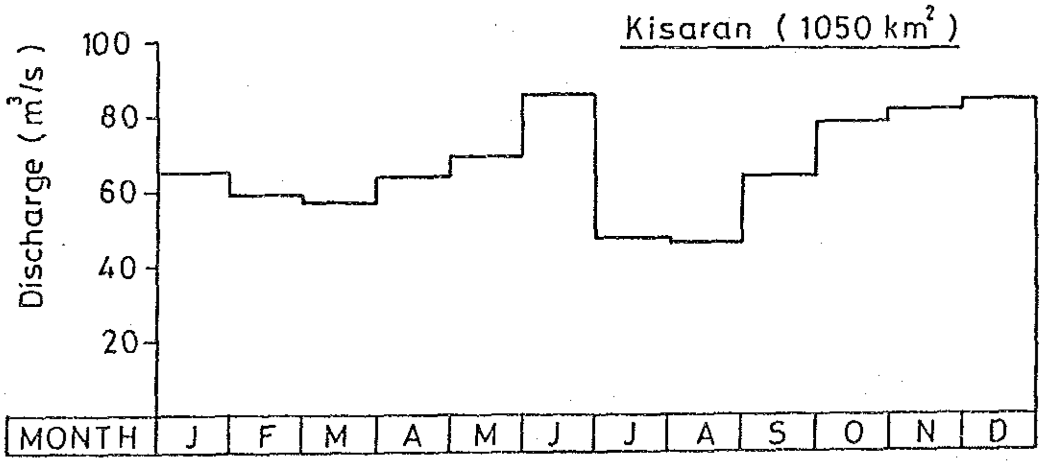


Fig.A-11 Monthly Mean Discharge





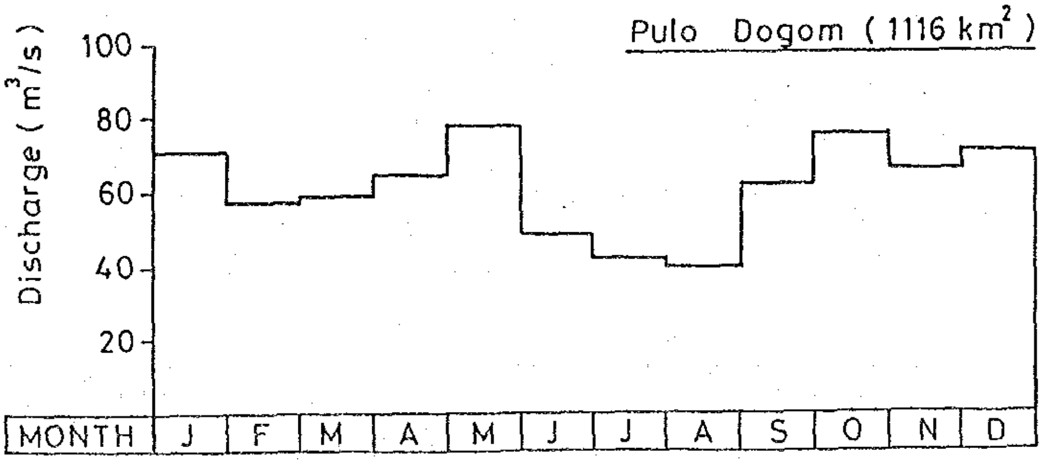


Fig.A-12 Correlation of Monthly Mean Discharge between Kisaran and Residual Area of Pulau Raja

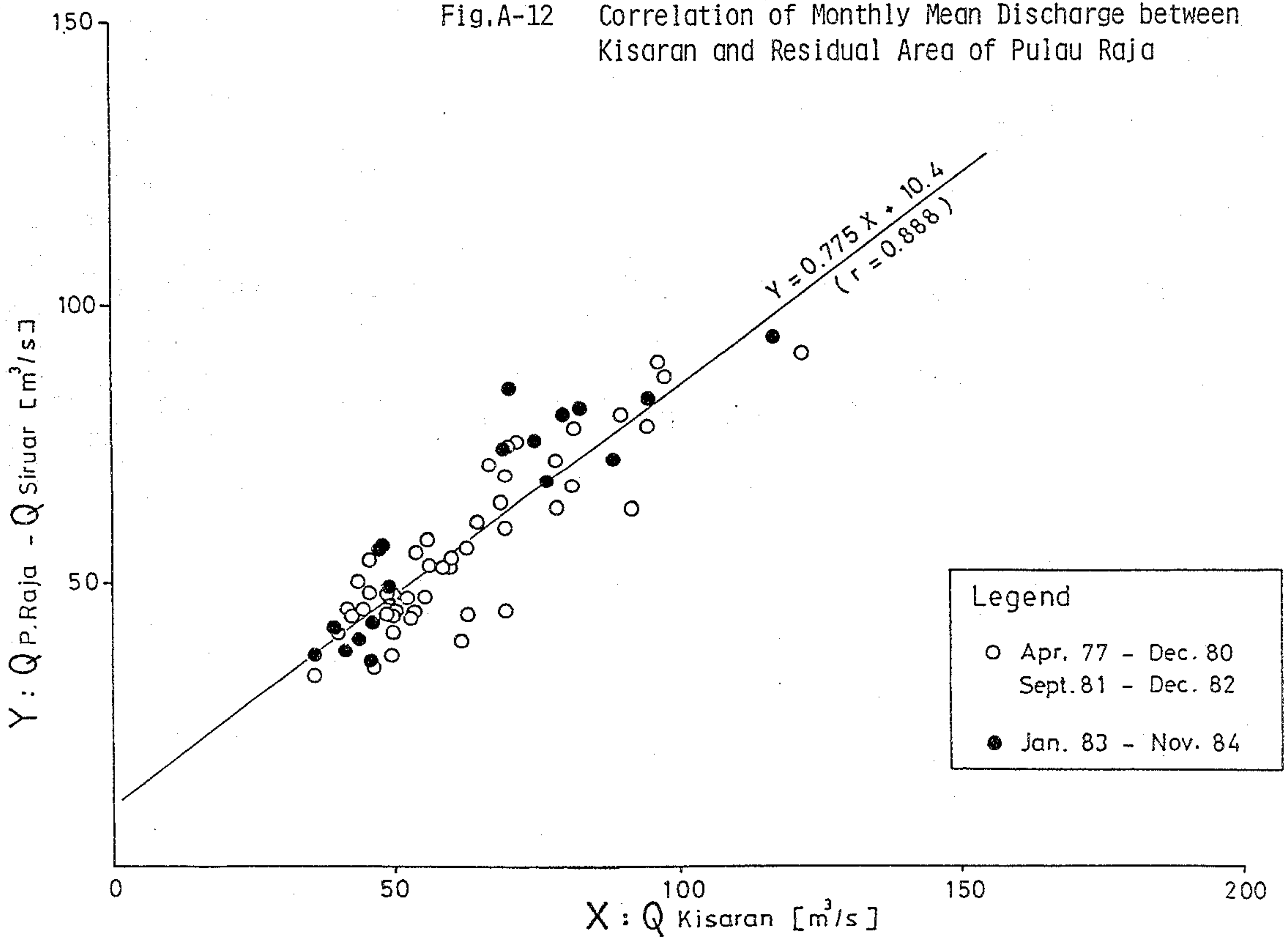
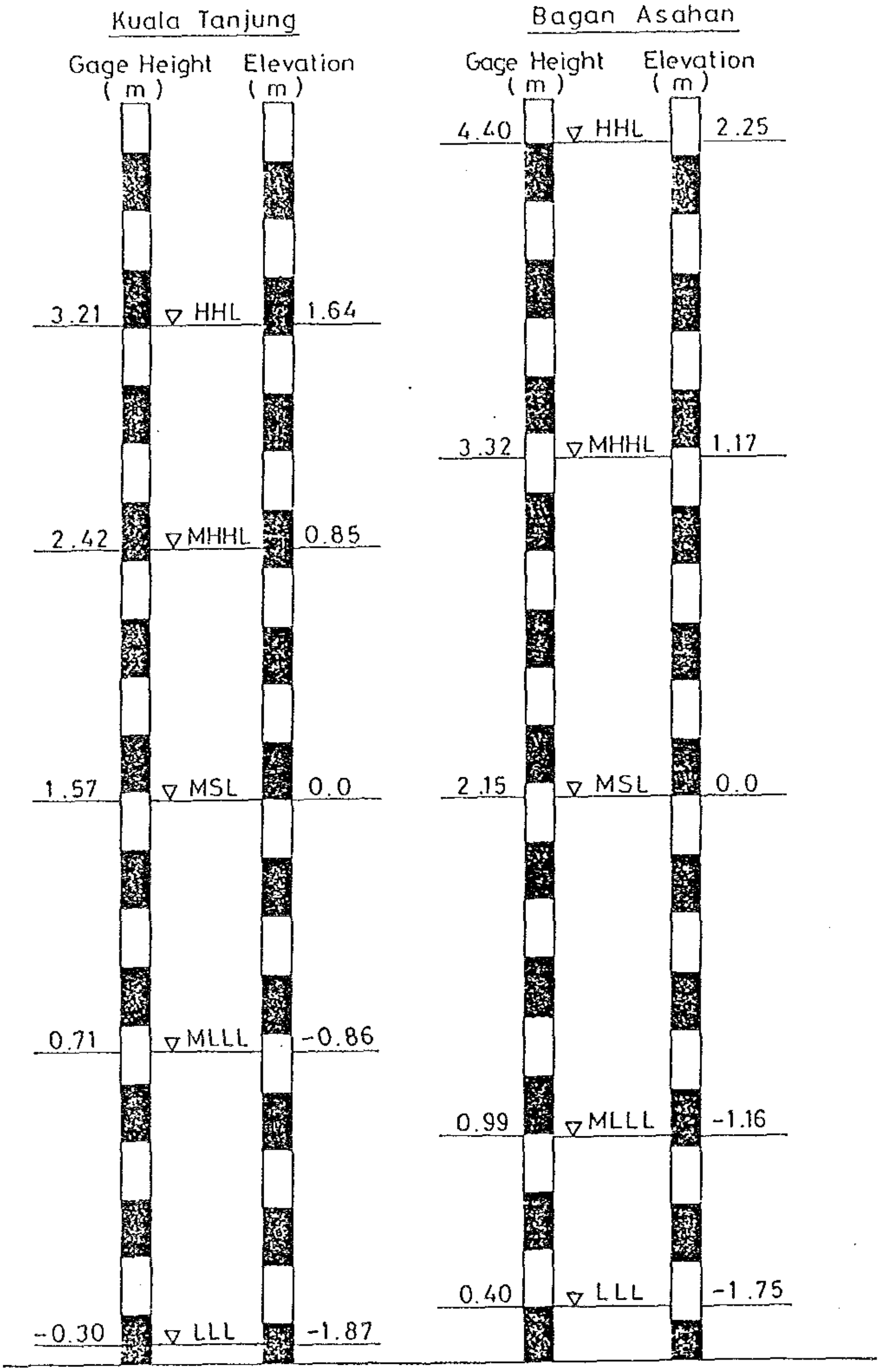


Fig.A-13 Tide Diagram



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

Master Plan Study on Lower Asahan River Basin Development

Vol. 2
Flood Control Plan

Appendix 2-B

Soil Mechanics

Appendix 2-B

SOIL MECHANICS

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1. Soil Mechanical Surveys Made

Soil mechanical survey for the study has been carried out in the following three stages:

- 1st Stage: JICA Geotechnical Engineer assigned from October 29 to December 12, 1984 has made field reconnaissance, collection and review of the available geotechnical data, establishment of detailed survey program and preparation of report on his findings and studies as mentioned in Progress Report I.

- 2nd Stage: Actual field investigations and laboratory tests were carried out by C.V. SECON, a consulting firm in Bandung under the contract with DGWRD from February 1985 in accordance with the scope of works and technical specifications recommended in the Progress Report I.

  The scope of geotechnical surveys and tests consists of the following four work items:

  (1) Soil mechanical tests on 40 samples taken from river bed materials (25 from Asahan river and 15 from Silau river).

  (2) Dutch cone penetration tests, augering and soil mechanical tests at 16 places.

  (3) Soil mechanical tests on 9 samples consisting of natural soils and soil samples mixed with river bed materials.

  (4) Soil mechanical tests on 36 samples taken from the existing dikes along Asahan and Silau rivers.

  The C.V. SECON was scheduled to complete the above works and to submit a final report to JICA Study Team by the end of May 1985. As a matter of fact C.V. SECON submitted to JICA Study Team in Medan a part of the survey and test results on May 4, 1985 and informed that the final report be submitted on June 1, 1985.

Therefore JICA despatched the same Geotechnical Engineer to the site from May 17 to June 30 for review, analyses and engineering judgement.

- 3rd Stage: JICA Geotechnical Engineer reviewed and analyzed the test results submitted by C.V. SECON and found that the results of Dutch cone penetration tests had been satisfactorily carried out and useful, but other soil tests had been not. On June 11, he received the second data sheets of soil tests but still in question. So he visited Bandung and discussed with C.V. SECON about those questions. C.V. SECON agreed to carry out re-test on all the soil samples and inform the results to JICA Survey Team in Medan as soon as possible. JICA Geotechnical Engineer received the third data sheets in Jakarta on June 28, 1985 and returned to Tokyo. According to C.V. SECON, the remaining test results will be submitted as soon as possible.

In the third stage period the following information was obtained in addition to the data collected during the first stage:

Final Report, Pekerjaan Penyelidikan Geologi Teknik dan Mekanika Tanah di Asahan (1985, P.T. Esconsoil Ensan, Medan).

This report mentions the results of the following surveys and tests:

(a) Dutch cone penetration tests at 108 places along the Asahan river and the Silau river (depth of 20 m).

(b) Hand augering at the same 108 places to take soil samples to the depth of 5 m.

(c) Test pit at 15 places in scale 1.0 m x 1.0 m x 4.0 m.

(d) Soil mechanical tests on 85 samples taken from the hand augering and test pit.

However, the final report of C.V. SECON are not submitted by the end of September 1985. All the findings and analysis on geotechnical data are mentioned in Chapter 4, "Geotechnical Recommendations".

2. Soil Foundation for Embankment

DGWRD has carried out numerous soil investigations for the several river planning projects including Lower Asahan River Basin Development along the Asahan and Silau rivers as shown in Fig. B-1. The details are stated in Ref. T12 to T16 attached to the end of this Supporting Report Vol. I.

In order to clarify the general foundation condition for this study, main soil properties are summarized from the above references as follows:

(1) Soil profile

Soil profile along the Silau, Asahan and Kepayang (a small tributary of Asahan joining near Tg. Balai) rivers are made based on field classification by a lot of auger borings as shown in Figs. B-2 to B-4. Details on the Silau and Asahan rivers are shown Tables B-1 to B-2. Stratigraphy of the soil layer is summarized as shown below:

Stratigraphy of Soil Layer along the Silau River

Layer	Thickness (m)	Composition
Top soil	0.5 - 1.0	Clay, organic soil
Silt	0 - 2.5	Silt interbedded with thin sand and clayey layers.
Upper clay	0.5 - 5.5	Clay
Lower clay	more than 3	Clay with little sand interbedded with thin silt layers.

Stratigraphy of Soil Layer along the Asahan River

Layer	Thickness (m)	Composition
Top soil	0.5	Organic soil, clay
Clay	1 - 3.5	Clay
Fine-coarse sand	0.5 - 5.0	Sandy clay, sand, sand with gravel
Silty clay	0.5 - 5.0	Clay, silt
Silt	more than 1.5	Silt, sandy silt

Stratigraphy of Soil Layer along the Kepayang River

Layer	Thickness	Composition
Top soil	0.5	Organic soil, peat
Silt clay	2.5 - 3.0	Silty clay interbedded clay
Clay	1.0 - 2.0	Clay
Sandy clay	more than 0.5	Sandy clay

The upper part (0 to 2.5 m) of soil foundation along the Silau river between Kisaran and Tg. Balai consists of silty soil except top soil and the lower part is composed of clayey soil.

On the other hand the soil foundation along the Asahan river is complicated in structure, but generally divided into five layers; namely top soil, clay, fine-coarse sand, silty clay and silt layers.

The one along the Kepayang river is simple in structure and divided into four layers, namely top soil, silty clay interbedded clay layers, clay an sandy clay layers.

(2) Cone penetration test results

The Dutch cone penetration tests carried out along the Asahan, Silau and Kepayang rivers are illustrated in Figs. B-4 through B-6 showing the strength of cone penetration resistance Those profiles suggest the existence of five layers having different resistances, among which the top layer is weakest less than 10 kg/cm^2 of resistance corresponding to about 3 in N-value in the standard penetration test.

The thickness of this weak top layer along Asahan river ranges from 2 to 6 m except the lower reaches, 17 km upstream from Tanjung Balai. In this lower reaches the depth of weak layer deepens more than 15 m. If embankment is required in those reaches special foundation treatment, such as replacement of foundation soils by sandy materials, etc. will be required.

The thickness of the weak top layer along Silau river ranges from 1 to 5 m between Kisaran and Air Joman. It deepens up to 10 m at Tanjung Balai.

The same weak layer along Kepayang river lies almost horizontally in depths from 4 to 8 m. For the design of embankment a sufficient height shall be added against the post-embankment settlement of those foundations with proper drainage facilities.

3. Soil Materials for Embankment

The numerous soil mechanical tests carried out on soil samples along Asahan and Silau rivers so far are clarified into the following properties of soils. Some general engineering considerations are stated in the last part of this Paragraph.

(1) Gradation

Gradation curves of soil samples along the Silau river are shown in Fig. B-7. These are well graded in general. Coefficients of uniformity (Cu = D60/D10) of almost whole samples are greater than 10 and coefficients of curvature ($Cc = D30^2/D10$) greater than 1.

Gradation curves of samples along the Asahan river are shown in Fig. B-8. These also indicate the same tendency as the Silau river except sandy silt.

Triangular classification charts for soil samples along the Silau and Asahan rivers are shown in Figs. B-9 and B-10. Both charts suggest that soil foundation belongs to fine-grained soil (F) and sandy fine-grained soil, partially sand with fine-grained soil.

(2) Soil consistency

The physical properties of most fine-grained soils and particularly clayey soils are greatly affected by water content.

Plasticity charts for the soils along the Asahan river and the Silau river are shown in Fig. B-11.

In case of the Silau river, most samples are plotted near the "A" line, and liquid limits (W_L) are greater than 50%, belonging to CH, MH and OH in the Unified Soil Classification System. It suggests that soil foundation consists of (1) high plasticity and inorganic clay, (2) inorganic silt and (3) medium to high plasticity and organic clay.

Samples taken from the Asahan river are plotted widely above and below the "A" line and liquid limits range from 40 to 110%, belonging to CH, CL, OL, ML and MH. It suggests that soil foundation is composed of (1) low to high plasticity and inorganic clay, (2) low plasticity and organic silty clay and (3) inorganic silt.

Consistency index (Ic) and liquidity index (I_L) are as listed below.

Consistency Index and Liquidity Index

River	Consistency Index (Ic)	Liquidity Index (I_L)
Silau*1	(-) 0.5 - 0.7	0.3 - 1.5
Asahan*2	(-) 0.2 - 0.7	0.1 - 2.3

Source: *1: Ref. T12
*2: Ref. T13

(3) Specific gravity (Gs)

Specific gravity of soils along the Silau river ranges from 2.50 to 2.75, the one along the Asahan river from 2.45 to 2.75 as shown in Fig. B-12. In case of Asahan river, more than half of samples indicate less than 2.60, suggesting to contain some organic matters.

(4) Moisture content (Wn)

Natural moisture content of soils along the Silau river is as high as 30 to 60% between Kisaran and Air Joman and 40 to 80% between Air Joman and Tg. Balai as shown in Fig. B-13. This figure shows that the lower reaches, the higher natural moisture content. Fig. B-14 shows moisture content of soils along the Asahan river is as high as 20 to 100% in general and it has the same tendency as in the Silau river.

(5) Dry density (d) and natural wet density (t)

Dry density of soils along the Silau river ranges from 0.9 to 1.3 g/cm^3 as shown in Fig. B-12. Dry density of soils along the Asahan river ranges from 0.6 to 1.2 g/cm^3. The one along the Asahan river is slightly less than the one along the Silau river, suggesting a little higher content of clayey soil.

Natural wet density of soils along the Silau river ranges from 1.6 to 1.8 g/cm^3 and those along Asahan river range from 1.4 to 1.6 g/cm^3.

(6) Void ratio (e) and degree of saturation (Sr)

Void ratio of soils along the Silau river is as high as 0.8 to 1.6 and the one along the Asahan is 1.0 to 4.0. Degree of saturation along the Silau river and the Asahan river ranges from 60 to 100%.

(7) Permeability

Permeability coefficient ranges mostly in order of 10^{-6} to 10^{-7} cm/sec as the soils along Asahan and Silau rivers are mostly clayey or silty. A few soil samples taken from thin sandy layers show the coefficient of 10^{-3} cm/sec. When those fine sand is mixed for the embankment materials with clayey soils, it is expected to increase the compactability to get rather higher dry and wet density. When a proper mechanical compaction is made during embankment no problem is anticipated as for the permeability.

(8) Internal friction angle, cohesion and shear strength

Triaxial compression tests (unconfined and undrained) and direct shear tests showed that most of soils have very low internal friction angle of less than 8 degrees. Cohesion ranges 0.15 to 0.35 kg/cm^2. Shear strength distributes in a wide range between 0.1 to 0.7 kg/cm^2 but mostly in very low range less than 0.4 kg/cm^2.

(9) Optimum moisture content for compaction

The standard compaction tests showed the range of optimum moisture content of 22 to 26% and the dry density range of 1.3 to 1.6 g/cm^3 under the optimum moisture content.

This means that it is required to dry the natural soil materials before embankment.

(10) River bed materials

River bed materials consist mainly of fine to coarse sand. Mean particle size along the Asahan river ranges from 0.2 mm to 1.0 mm, it has the tendency to decrease from upstream to downstream. In case of the Silau river, the one ranges from 0.4 mm to 1.3 mm and it shows the same tendency as the Asahan river, as shown in Fig. B-7 to b-8.

4. Geotechnical Recommendations

As all the above soil tests clarified, the soil materials in this area are characterized to have very high content of silty or clayey materials with high natural water content. It naturally causes very low dry density after compaction under the high natural water content.

Sufficient drying operation is required before embankment as much as possible to make the water content nearer to the optimum range of 22 to 26%. Even so the dry density obtained after proper mechanical compaction in the field may range between 1.4 and 1.6 g/cm^3.

The internal friction angle is also very small. Therefore those soil properties shall be fully considered in design of embankment, such as gentler slopes of both sides for stability.

The foundation soils also have the nearly same properties, implying that fairly big settlement will be caused by consolidation after embankment. It is strongly recommended to design sufficient extra embankment against the settlement with enough drainage facilities along the embankment. When very weak soil foundation is encountered such part shall be replaced by sandy materials as required.

LIST OF REFERENCES AND DATA

T1 Topography Map in 1979 with scale of 1/50,000; Topography Bureau of Army

T2 Topography Map in 1985 with scale of 1/20,000; JICA

T3 Aero Photograph in March-April 1984 with scale of 1/10,000; P.T. EXSA InternationL

T4 Aero Photograph in October-December 1984 with scale of 1/20,000; JICA

T5 River Profiles and Cross-sections of Silau River in 1981; P.T. Nusantara Survey

T6 River Profiles and Cross-section of Asahan River 1982; P.T. Yaramaya & P.T. Esconsoil

T7 River Profiles and Cross-sections of Asahan and Silau River in 1985; JICA and C.V. SECON

T8 General Geological Maps (1/5,000,000 covering the whole Indonesia and 1/1,000,000 covering Sumatra Island)

T9 Project Completion Report Vol. I, Asahan Hydroelectric and Aluminium Project (March, 1984 by P.T. Indonesia Asahan Aluminium, Section 2.5 Geology)

T10 False Colour Composite Image (1/250,000) processed from Landsat data taken on April 29, 1977 by the Remote Sensing Project Office, Center for Data Processing and Mapping (PUSDATA) of Ministry of Public Works

T11 Report of Feasibility Study on the North Sumatra Transmission Line Project (May 1980, JICA, Section 5.3 Geology)

T12 - (1/2) Laporan Utama, Perencanaan Pengamanan Banjir Sei Silau, Propinsi Sumatera Utara (April/1981, P.T. Nusantara Survey Bandung)

- (2/2) Lampiran, Hasil Penyelidikan Mekanika Tanah Perencanaan Pengamanan Banjir Sei Silau, Propinsi sumatera Utara (April 1981, P.T. Nusantara Survey Bandung)

T13 - (1/2) Laporan Penyelidikan Mekanika Tanah dan Hasil Penelitian Laboratorium, Project Perencanaan Pengamanan Banjir Sungai Asahan, Kabupaten Asahan, Propinsi Sumatera Utara (November 1983, I.T.B. Bandung)

- (2/2) Laporan Mekanika Tanah, Proyek Perencanaan Pengamanan Banjir Sungai Asahan, Kabupaten Asahan, Propinsi Sumatera Utara (July 1983, I.T.B. Bandung)

T14 Final Report, Pekerjaan Penyelidikan Geoteknik dan Mekanika Tanah untuk Rencana Bendung, Waduk, Saluran Induk Irigasi dan Tanggul Utama Sei Asahan (September 1984, P.T. Esconsoil Ensan, Medan)

T15 Final Report, Pekerjaan Penyelidikan Geoteknik dan Mekanika Tanah di Asahan (1985, P.T. Esconsoil Ensan, Medan)

T16 Data Survai dan Test Laboratorium Mekanika Tanah Perencanaan Pengembangan Sumber* Sumber Air Daerah Aliran Sungai Asahan Hilir Sumatera Utara (C.V. SECON June 1985)

Table B-1 Main Soil Property of Silau River (1/3)

Location	Bank	Identification of soil natural condition						
		Sample description	Classification Unified	Moisture content W%	Specific gravity Gs gr/cm³	Unit weight n t/m³	Dry density d t/m³	Void ratio e.
I	Right	Sandy clay clay + a little sand	CH MH	38.01 102.39 (56.07)	2.553 2.629 (2.594)	1.73 1.80 (11.77)	1.28 1.44 (1.35)	0.83 1.03 (0.93)
	Left	Sandy clay	CH CL CM	40.27 57.78 (50.00)	2.541 2.763 (2.610)	1.62 1.68 (1.65)	1.04 1.35 (1.65)	0.90 1.61 (1.19)
II	Right	Clay Sand	CH SM	26.91 48.02 (36.53)	2.528 2.739 (2.632)	1.55 1.84 (1.71)	1.05 1.49 (1.28)	0.84 1.41 (1.09)
	Left	Sand	SM	23.43 56.79 (42,68)	2.606 2.736 (2.699)	1.63 1.83 (1.72)	1.16 1.45 (1.34)	0.80 1.35 (1.34)
III	Right	Clay Clay + Sand	MH	64.23 80.24 (72.24)	2.564 2.715 (2.640)	1.58 1.65 (1.62)	0.96 1.33 (1.15)	1.67 1.04 (1.36)
	Left	Clay	MH	58.36 95.47 (76.92)	2.546 2.570 (2.558)	1.62 1.67 (1.65)	1.02 1.35 (1.19)	1.50 0.90 (1.20)
IV	Right	Clay	CH MH	70.91 86.00 (78.46)	2.627 2.539 (2.583)	1.56 1.47 (1.52)	0.91 0.79 (0.25)	1.89 2.21 (2.05)
	Left	Clay Clay + Sand	MH CH	68.23 108.31 (94.56)	2.603 2.738 (2.690)	1.60 1.73 (1.66)	0.95 1.39 (1.22)	1.88 0.96 (1.28)

Source : Report of NUSANTARA 1981

Location I : Kp. Tinggi Raja

II : (right) Jemb. K.A. Kp. Setang
: (left) Jemb. K.A. Kp. Mutiara

III : Kp. Tasik Malaya

IV : Tanjung Balai

Table B-1 Main Soil Property of Silau River (2/3)

Location	Bank	Atterberg limit			Sieve analysis		Strength	
							Direct shear	
		LL	PL	PI	% finer 0.074 m	% finer 2.000 mm	Ø (°)	C Kg/cm²
I	Right	51.55	24.37	27.18	93.40	-	23°00'	0.29
		64.85	32.09	39.93	96.65	100	25°30'	0.23
		(58.11)	(28.02)	(31.59)	(95.16)	-	-	-
	Left	46.15	23.60	22.55	79.30	-	21°30'	0.16
		75.10	35.81	40.10	96.40	100	27°00'	0.11
		(1.23)	(60.89)	(31.35)	(29.54)	-	-	-
II	Right	68.75	32.44	36.31	-	-	-	-
		53.45	24.71	28.74	97.70	100	6°00'	0.20
		(61.10)	(28.58)	(32.53)	11.80	-	50°30'	0.19
		-	NP	-	(60.26	-	-	-
	Left	32.75	22.44	10.31	28.30	-	-	-
		-	NP	-	58.35	100	-	-
		-	-	-	(44.09)	-	-	-
III	Right	109.10	47.61	61.49	95.50	-	5°00'	0.69
		91.90	40.60	51.30	80.00	100	-	-
		(100.5)	44.11	56.10	87.75	-	-	-
	Left	67.90	38.48	33.42	92.70	-	6°00'	0.06
		87.75	40.74	47.01	80.50	-	-	-
		(77.83)	(37.61)	(40.22)	(86.60)	100	-	-
IV	Right	70.50	30.38	40.12	90.05	-	6°30'	0.08
		81.30	38.86	42.44	97.30	100	5°45'	0.09
		(75.90)	(34.62)	(41.28)	(96.68)	-	-	-
	Left	111.0	49.10	61.90	70.50	-	7°30'	0.10
		128.75	52.79	77.68	96.70	100	-	-
		(122.40)	(50.55)	(71.85)	(85.97)	-	-	-

Table B-1 Main Soil Property of Silau River (3/3)

Location	Bank	Strength				Proctor compaction		
		Unconfined Compression		Triaxial		Optimum Moisture content	Maximum dry density	
		Natural Kg/cm²	Remolded Kg/cm²	ø (°)	C (Kg/cm²)	W.opt.(%)	d max.(gr/cm³)	Wn%
I	Right	1.76	1.41	19°30'	0.30	24.27	1.39	102.39
		0.94	0.51	21°30'	0.26	22.52	1.41	44.44
		-	-	-	-	-	-	-
	Left	0.35	0.19	21°30'	0.25	24.31	1.35	45.29
		0.50	0.30	24°30'	0.18	22.39	1.32	40.27
		-	-	-	-	-	-	-
II	Right	0.42	0.29	7°00'	0.22	23.14	1.49	26.91
		0.45	0.31	8°00'	0.20	26.31	1.42	28.52
		-	-	-	-	-	-	-
	Left	-	-	-	-	25.23	1.39	56.79
		-	-	-	-	26.41	1.45	49.63
		-	-	-	-	-	-	-
III	Right	0.46	0.28	9°00'	0.12	-	-	-
		-	-	-	-	24.30	1.33	80.24
		-	-	-	-	-	-	-
	Left	0.34	0.17	7°00'	0.15	-	-	-
		-	-	-	-	23.44	1.35	95.47
		-	-	-	-	-	-	-
IV	Right	0.40	0.20	6°36'	0.16	-	-	-
		0.38	0.40	8°30'	0.15	-	-	-
		-	-	-	-	-	-	-
	Left	0.27	0.18	8°00'	0.18	-	-	-
		-	-	-	-	26.33	1.31	107.13
		-	-	-	-	24.41	1.39	108.31

Table B-2 Main Soil Property of Asahan River (1/3)

Boring No	Depth	Identification of soil: Sample description	Identification of soil: CU	Natural condition: Moisture content W%	Natural condition: Specific gravity Gs(gr/cm³)	Natural condition: Unit weight (gr/cm²)	Natural condition: Dry density (gr/cm³)	Natural condition: Void ratio e
BT-1	2.00-2.40		MM	55.54	2.59	1.60	1.03	1.52
BT-5	2.80-3.20		ML	46.17	2.55	1.54	1.05	1.42
BT-10	2.00-2.40		SM	59.71	2.46	1.51	0.95	1.46
BT-11	2.00-2.40		ML	68.35	2.66	1.56	0.92	1.86
BT-15	2.00-2.40		MH	58.52	2.53	1.41	0.89	1.84
BT-18	1.60-2.00		MH	51.70	2.62	1.56	1.04	1.55
BT-20	2.00-2.40		MH	76.29	2.44	1.52	0.84	1.87
BT-24	1.60-2.00		MH	86.46	2.57	1.46	0.78	2.28
BT-25	1.60-2.00		MH	71.67	2.72	1.46	0.85	2.20
BT-30	1.40-1.80		ML	55.98	2.66	1.52	0.98	1.73
BT-33	1.20-1.60		MH	86.45	2.62	1.43	0.77	2.42
BT-35	1.60-2.00		MH	48.91	2.62	1.55	1.04	1.52
BT-38	1.60-2.00		ML	51.54	2.73	1.52	1.00	1.72
BT-40	1.00-1.40		SM	64.47	2.76	1.52	0.90	1.99
BT-44	1.60-2.00		MH	123.93	2.59	1.38	0.61	3.20
BT-45	1.40-1.80		MH	104.62	2.54	1.42	0.69	2.66
BT-50	1.80-2.20		MH	146.90	2.66	1.33	0.54	3.94
TP. 8	SU(US)1.25		SP	26.49	2.58	1.80	1.42	0.81
TP.18	SU(US)1.50		SW	44.51	2.62	1.60	1.11	1.37
TP.28	SU(US)1.25		SW	29.78	2.74	1.45	1.11	1.45
TP.38	SU(US)1.25		SM	30.72	2.68	1.79	1.37	0.96
TP.48	SU(US)1.00		SW	34.38	2.60	1.63	1.21	1.14
TP-2	BU(US) 1.50		-	30.57	2.63	1.61	1.24	1.13
TP-3	BU(US) 1.50		SP	22.09	2.71	1.77	1.45	0.87
TP-2	SBI(US)1.00		SP	57.20	2.67	1.50	0.96	1.80
TP-3	SBI(US)1.00		SM	50.25	2.60	1.58	1.06	1.47
TP-3	SBII(US)2.00		SM	55.33	2.63	1.56	1.00	1.62
TP-4	SBII(US)1.50		SM	49.59	2.64	1.57	1.05	1.51

Source : Report of ESCONSOIL, 1984

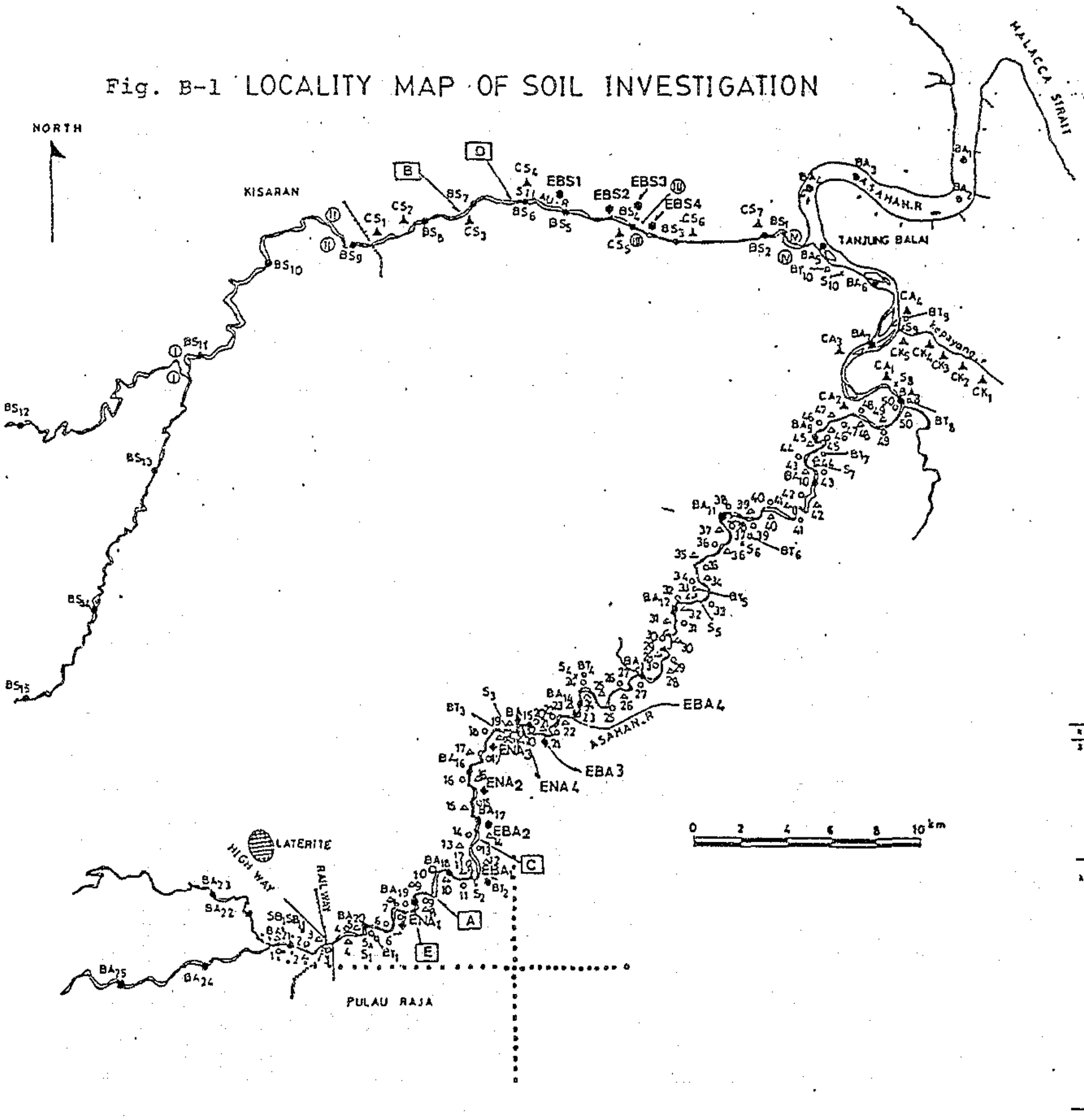
Table B-2 Main Soil Property of Asahan River (2/3)

Boring No.	Depth	Atterberg limit LL	PL	PI	Sieve analysis % finer 0.074 mm	Strength: Unconfined compression qu (kg/cm²)	St	Triaxial Total c (kg/cm²)	Triaxial ø (°)
BT-1	2.00-2.40	53.20	43.56	9.64	85.68	0.14	1.62	0.06	3.5°
BT-5	2.80-3.20	41.80	34.97	6.83	75.96	0.15	1.42	0.55	16°30'
BT-10	2.00-2.40	39.60	37.62	1.98	36.24	-	-	0.10	8°
BT-11	2.00-2.40	46.90	39.75	7.15	57.65	-	-	0.08	4°
BT-15	2.00-2.40	63.50	44.73	18.77	56.71	-	-	0.08	2°
BT-18	1.60-2.00	52.80	37.95	14.85	95.09	-	-	0.08	5°
BT-20	2.00-2.40	61.50	48.27	13.27	69.03	-	-	0.08	5°
BT-24	1.60-2.00	60.50	48.12	12.38	79.40	-	-	0.06	4°
BT-25	1.60-2.00	57.05	45.38	11.67	73.38	-	-	0.10	4°
BT-30	1.40-1.80	44.04	35.59	8.65	84.64	-	-	0.08	2°
BT-33	1.20-1.60	68.00	54.24	13.76	85.69	-	-	0.10	4°
BT-35	1.60-2.00	51.00	38.79	12.21	73.03	-	-	0.27	4°
BT-38	1.60-2.00	45.00	36.12	8.88	57.42	-	-	0.15	4°
BT-40	1.00-1.40	48.25	35.57	12.68	39.21	-	-	0.19	7°
BT-44	1.60-2.00	77.20	62.29	14.91	62.92	-	-	0.06	35°
BT-45	1.40-1.80	60.80	50.93	9.87	73.07	-	-	0.06	3°
BT-50	1.80-2.20	83.20	74.91	8.29	79.32	-	-	0.04	3°
TP. 8	SU(US)1.25	-	-	-	1.56	-	-	-	-
TP.18	SU(US)1.50	-	-	-	5.72	-	-	-	-
TP.28	SU(US)1.25	-	-	-	9.57	-	-	-	-
TP.38	SU(US)1.25	-	-	-	22.81	-	-	-	-
TP.48	SU(US)1.00	-	-	-	2.41	-	-	-	-
TP-2	BU(US) 1.50	-	-	-	-	-	-	-	-
TP-3	BU(US) 1.50	-	-	-	8.19	-	-	-	-
TP-2	SBI(US)1.00	-	-	-	7.29	-	-	0.21	3°30'
TP-3	SBI(US)1.00	-	-	-	76.30	-	-	0.04	5°
TP-3	SBII(US)2.00	-	-	-	53.15	-	-	0.12	5°30'
TP-4	SBII(US)1.50	-	-	-	63.72	-	-	0.06	2°

Table B-2 Main Soil Property of Asahan River (3/3)

Boring No.	Depth	Strength Effective Ce (kg/cm²)	Strength Effective Øe (°)	Consolidation Compression index Cc	Proctor Compaction W opt (%)	Proctor Compaction d (gr/cm³)	Remarks
BT-1	2.00-2.40	0.06	5°	0.85	-	-	
BT-5	2.80-3.20	0.45	25°	0.63	-	-	BT.1(I.T.B)
BT-10	2.00-2.40	0.08	14°	0.66	-	-	
BT-11	2.00-2.40	0.08	7°	0.46	-	-	BT.2(I.T.B)
BT-15	2.00-2.40	0.07	5°	0.60	-	-	
BT-18	1.60-2.00	0.08	7°30'	0.50	-	-	BT.3(I.T.B)
BT-20	2.00-2.40	0.06	9°	0.55	-	-	
BT-24	1.60-2.00	0.06	6°	1.21	-	-	BT.4(I.T.B)
BT-25	1.60-2.00	0.10	6°	0.54	-	-	
BT-30	1.40-1.80	0.06	4°30'	0.68	-	-	
BT-33	1.20-1.60	0.10	7°	0.50	-	-	BT.5(I.T.B)
BT-35	1.60-2.00	0.24	6°	1.00	-	-	
BT-38	1.60-2.00	0.14	7°	0.47	-	-	BT.6(I.T.B)
BT-40	1.00-1.40	0.18	10°	0.18	-	-	
BT-44	1.60-2.00	0.06	6°	1.68	-	-	BT.7(I.T.B)
BT-45	1.40-1.80	0.06	6°	0.61	-	-	
BT-50	1.80-2.20	0.04	4°30'	1.25	-	-	BT.8(I.T.B)
TP. 8 SU(US)	1.25	-	-	-	15.70	1.736	
TP.18 SU(US)	1.50	-	-	-	26.00	1.491	
TP.28 SU(US)	1.25	-	-	-	25.60	1.532	
TP.38 SU(US)	1.25	-	-	-	23.20	1.524	
TP.48 SU(US)	1.00	-	-	-	24.60	1.502	
TP-2 BU(US)	1.50	-	-	-	21.70	1.554	
TP-3 BU(US)	1.50	-	-	-	20.70	1.620	
TP-2 SBI(US)	1.00	0.19	7°	-	23.80	1.562	
TP-3 SBI(US)	1.00	0.04	10°	-	24.20	1.581	
TP-3SBII(US)	2.00	0.11	9°	-	23.80	1.518	
TP-4SBII(US)	1.50	0.06	4°	-	-	-	

Fig. B-1 LOCALITY MAP OF SOIL INVESTIGATION



LEGEND

▲ : DUTCH CONE PENETRATION TEST (C.P.T.)
- CA-1-4 ----- ASAHAN RIVER
- CK-1-5 ----- KEPAYANG [illegible] RIVER
- CS-1-7 ----- SILAU RIVER
- △ 1-50 ----- ASAHAN RIVER

○ : HAND AUGER BORING (H.A.B.)
- I - IV ----- SILAU RIVER
- 1 - 50 ----- ASAHAN RIVER

● : MACHINE BORING (M.B)
- 1 - 5

■ : Test Pit (P.T)
- 1 - 50
- SB1 - SB11

◉ : GRADING ANALYSIS OF RIVER BED MATERIAL (RBM)
- BA-1-25 ----- ASAHAN RIVER
- BS-1-15 ----- SILAU RIVER

◆ ● : SOIL TESTS ON ACTUAL EMBANKMENT MATERIALS (E.T)
- ENA ----- NORMAL (NOT BROKEN) POINT OF EXISTING DIKE IN ASAHAN RIVER.
- EBA ----- BROKEN POINT OF EXISTING DIKE IN ASAHAN RIVER.
- EBS ----- BROKEN POINT OF EXISTING DIKE IN SILAU RIVER.

SOIL TEST OF POSSIBLE IMPROVEMENT OF MATERIALS, MIXED WITH LATERITE.
- ----- SAMPLING LOCALITY OF LATERITE

A : Soil Mechanical Tests on Soil Samples Mixed with River Bed Materials
- A - E ..... Sampling Locality of Laterite

River	Report	Item	Quantity
Silau	P.T. NUSANTARA (1981)	H.A.B.	: I-IV (Left & Right)
		E.T	: I-IV (Left & Right)
	C.V. SECON (1985)	C.P.T	: CS1 - CS7
		H.A.B & E.T	: CS1 - CS7 EBS1 - EBS4
		R.B.M	: BS1 - BS15
Asahan	[illegible] (1983)	H.A.B	: BT.1 - BT10
		E.T	: BT.1 - BT10
		C.P.T	: S1 - S10
	P.T ESCONSOIL (1984)	H.A.B	: 01 - 050
		C.P.T	: 01 - 50
		E.T	: 01 - 050
			41 - 450
		M.B	: 1 - 5
		T.P	: 1 - 50
	C.V. SECON (1985)	C.P.T	: CA1 - CA4, CK1 - CK5
		E.T	: CA1 - CA4 CK1 - CK5
		R.B.M	: BA1 - BA25

Fig. B-2 Soil Profile along Silau River

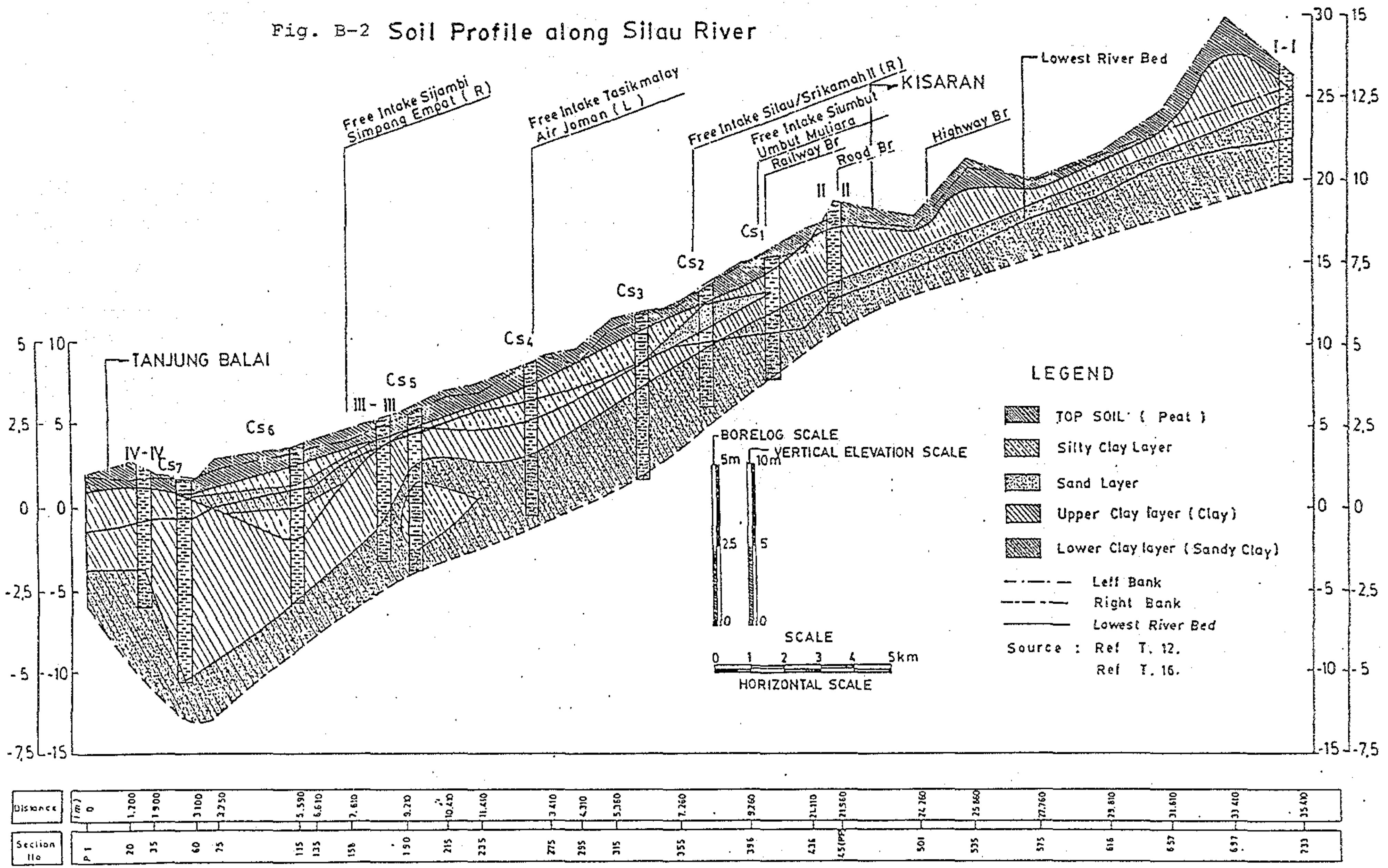


Fig. B-3 SOIL Profile along Asahan River

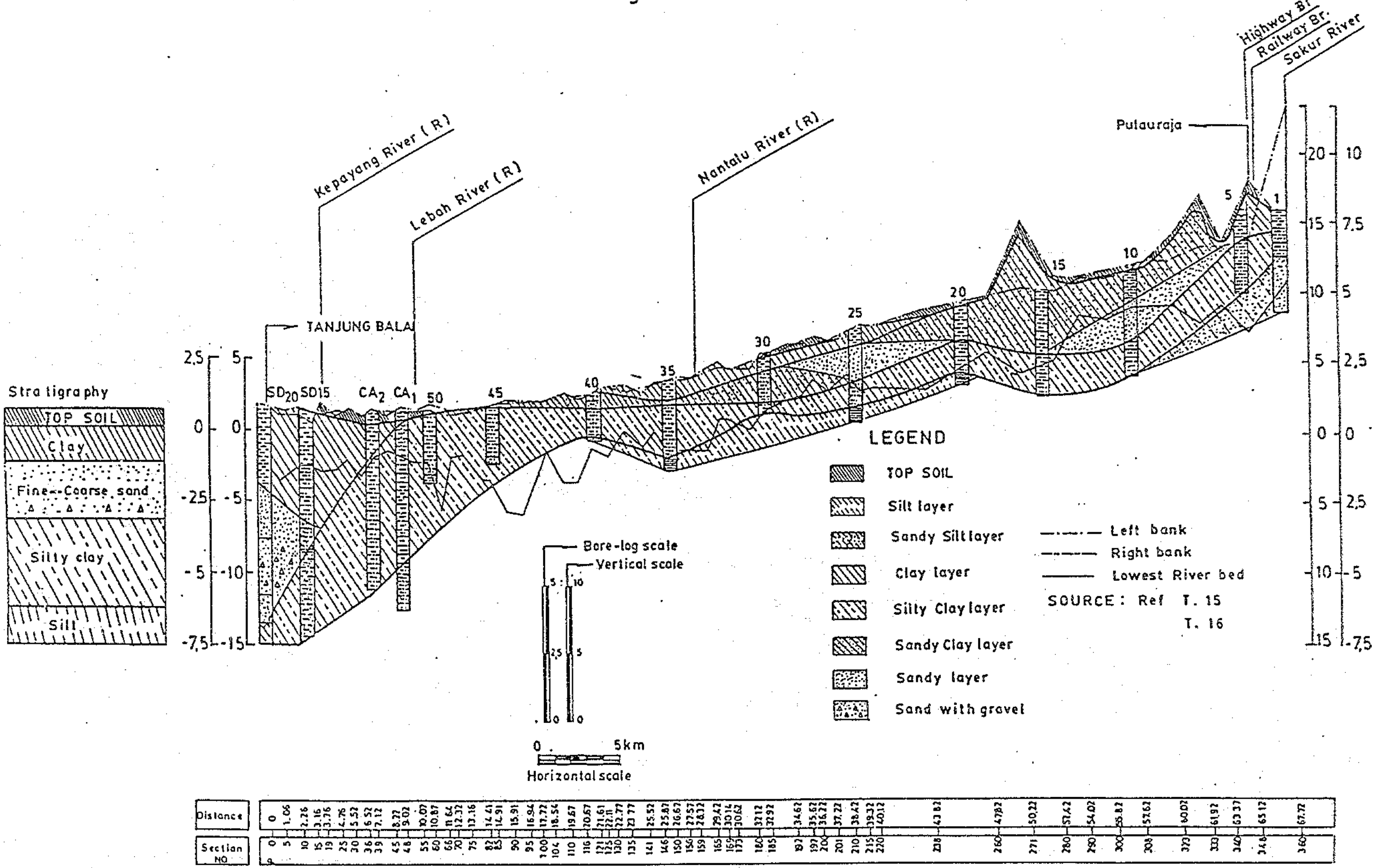
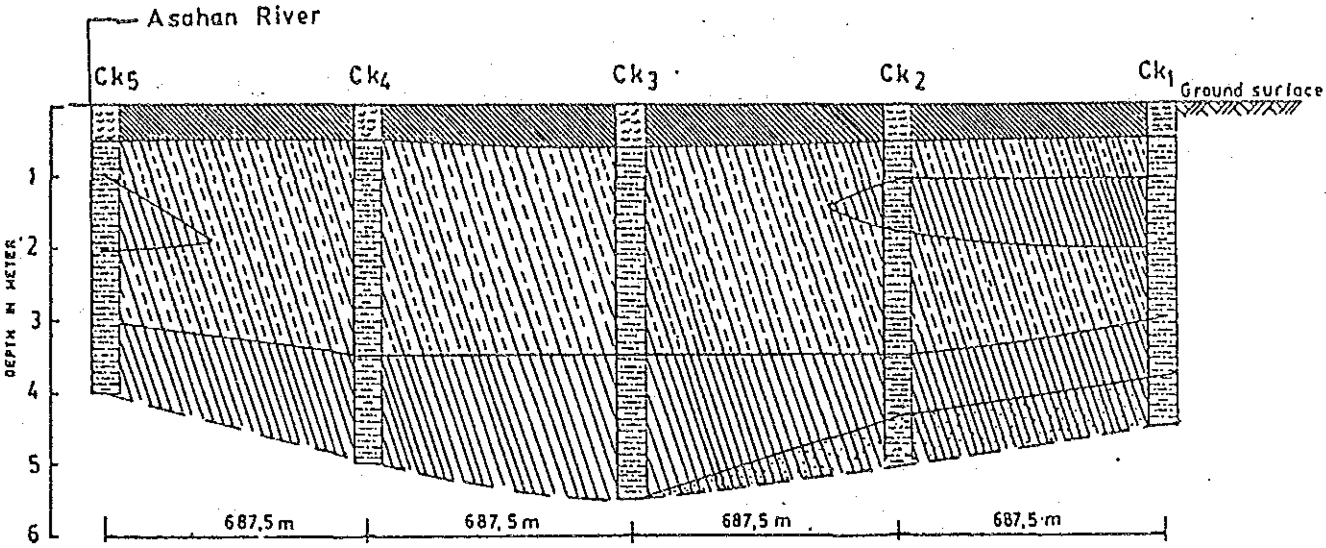


Fig. B-4 Soil Profile and Cone Resistance Profile along the Kepayang River

SOIL Profile along Kepayang River

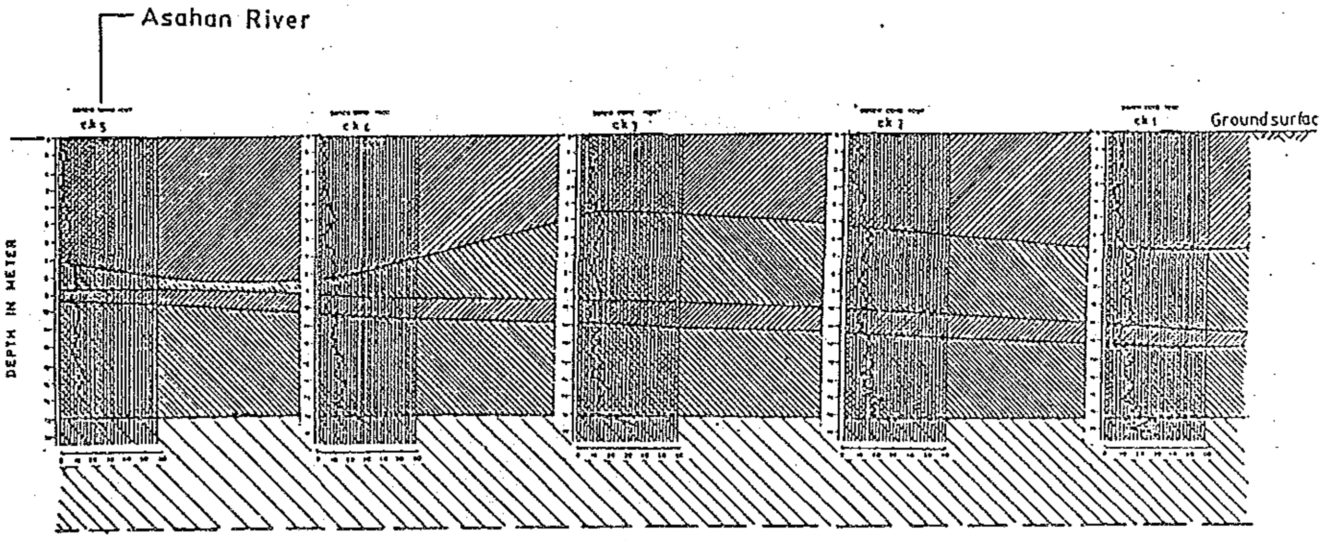


Legend

- TOP SOIL (Peat)
- Silty Clay layer
- Clay layer
- Sandy Clay layer

SOURCE : Ref. T. 16

Cone resistance along Kepayang River.



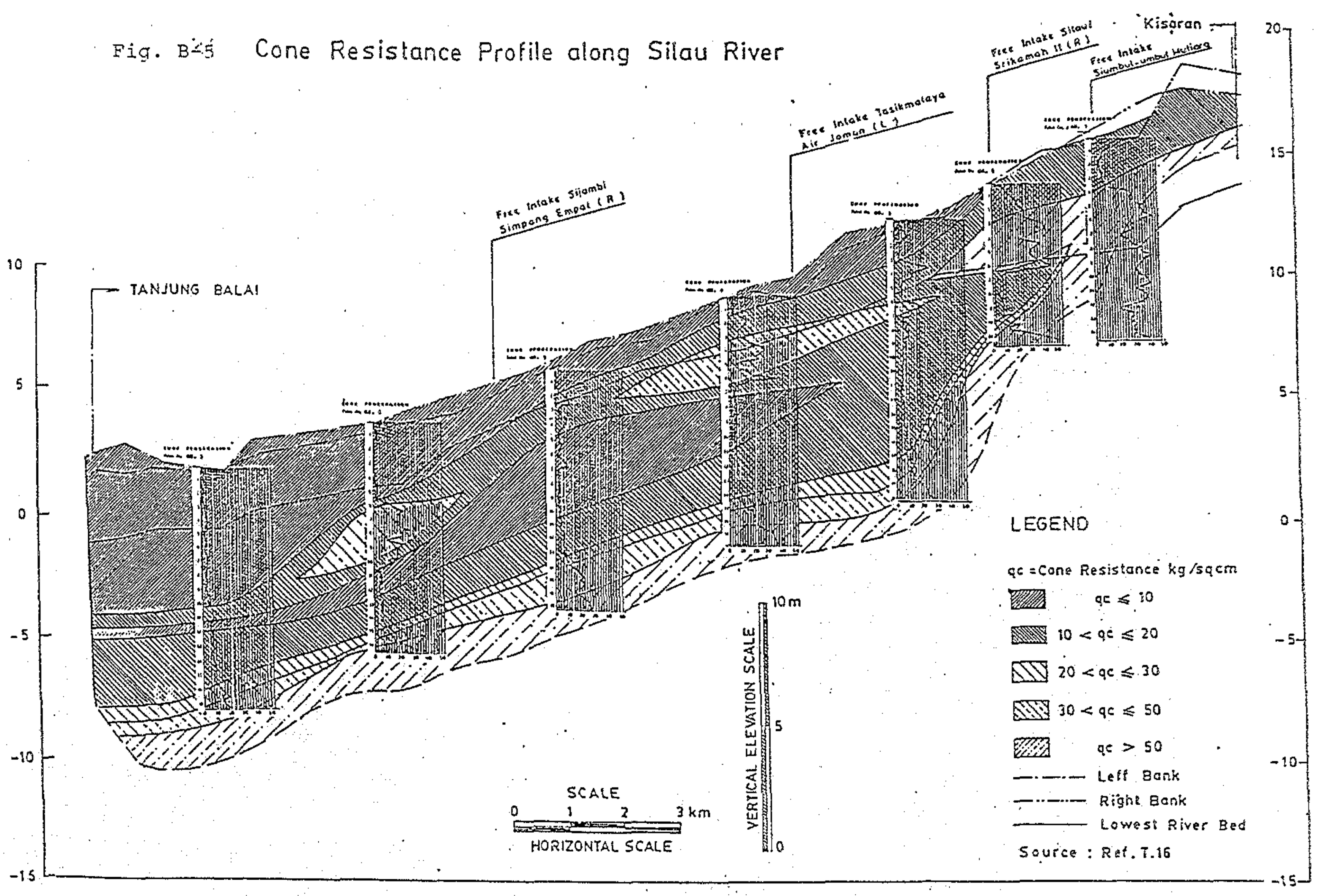
Legend

qc = Cone Resistance kg/sq cm

- qc < 10
- 10 < qc < 20
- 20 < qc ≤ 30

SOURCE : Ref T. 16

Fig. B-5 Cone Resistance Profile along Silau River



Distance (m)	0	1,200	1,900	3,100	3,750	5,590	6,610	7,610	9,210	10,410	11,410	13,410	14,310	15,360	17,260	19,280	21,110	21,360
Section No	P1	20	35	60	75	115	135	158	190	215	235	275	295	315	355	396	436	45(PP)

Fig. B-6 Cone Resistance Profile along Asahan River

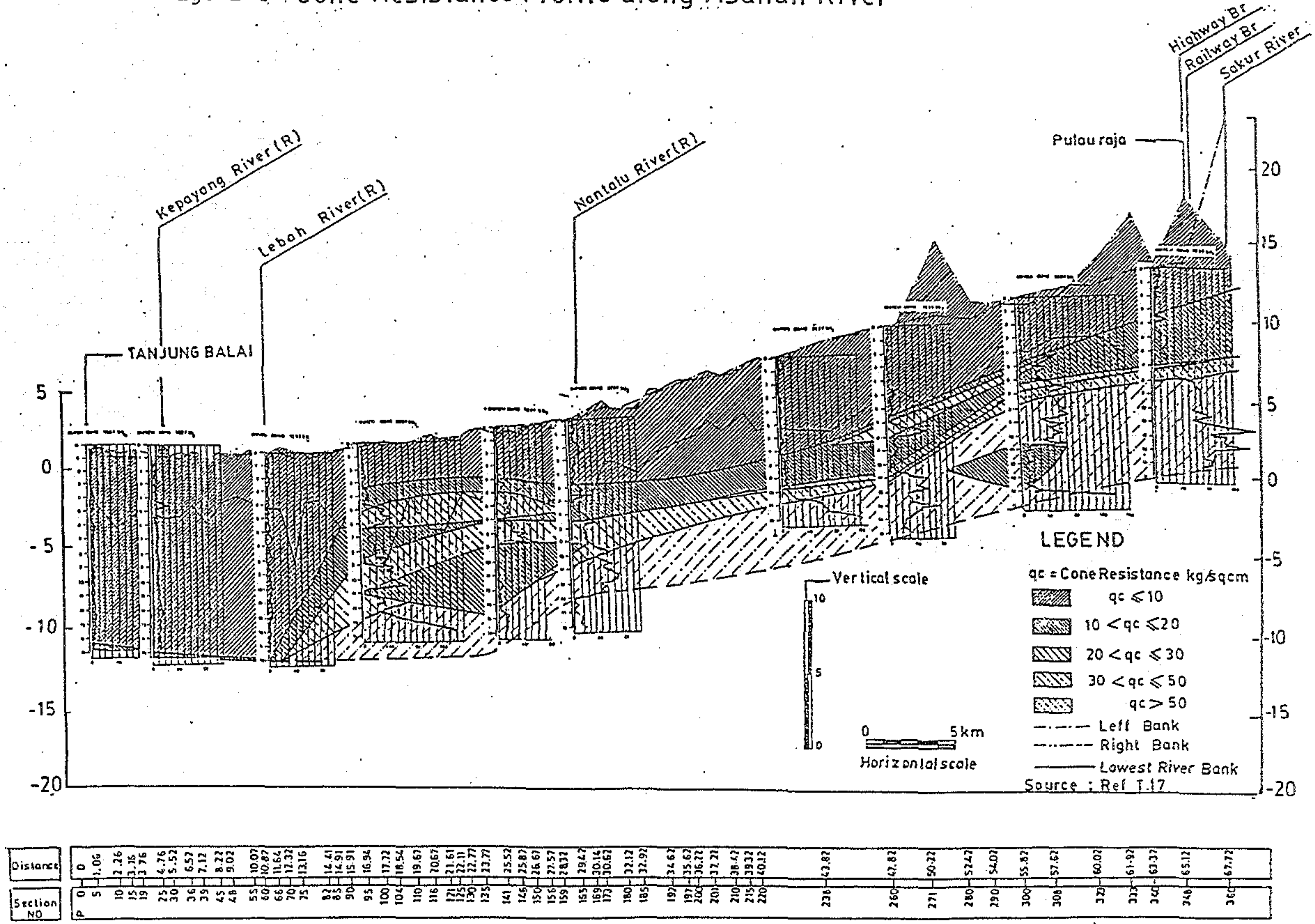
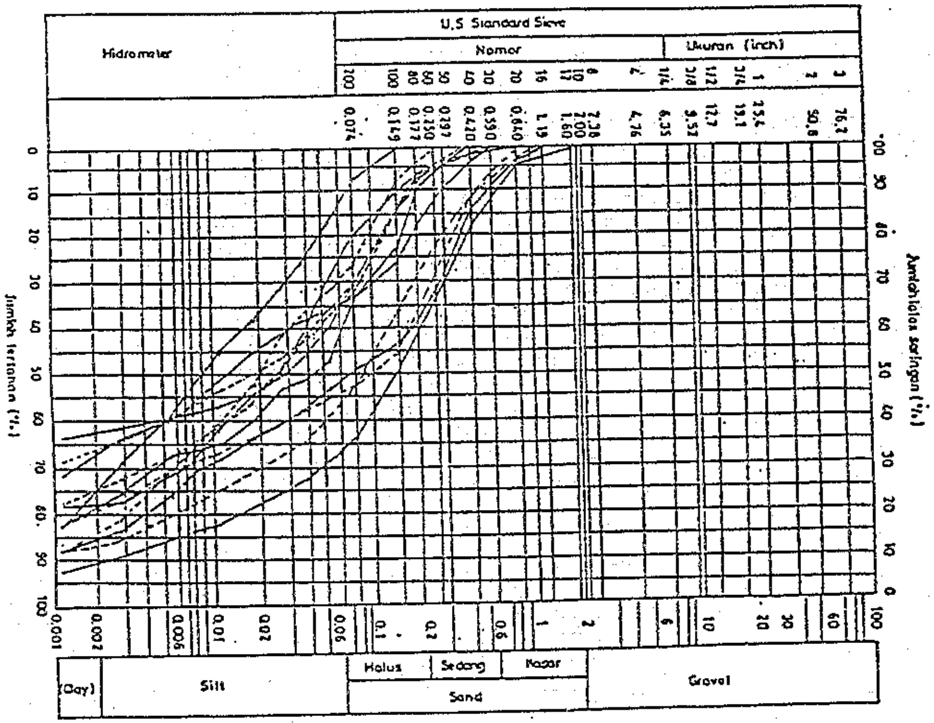


Fig.B-7 Gradation Curves of Soils along Silau River

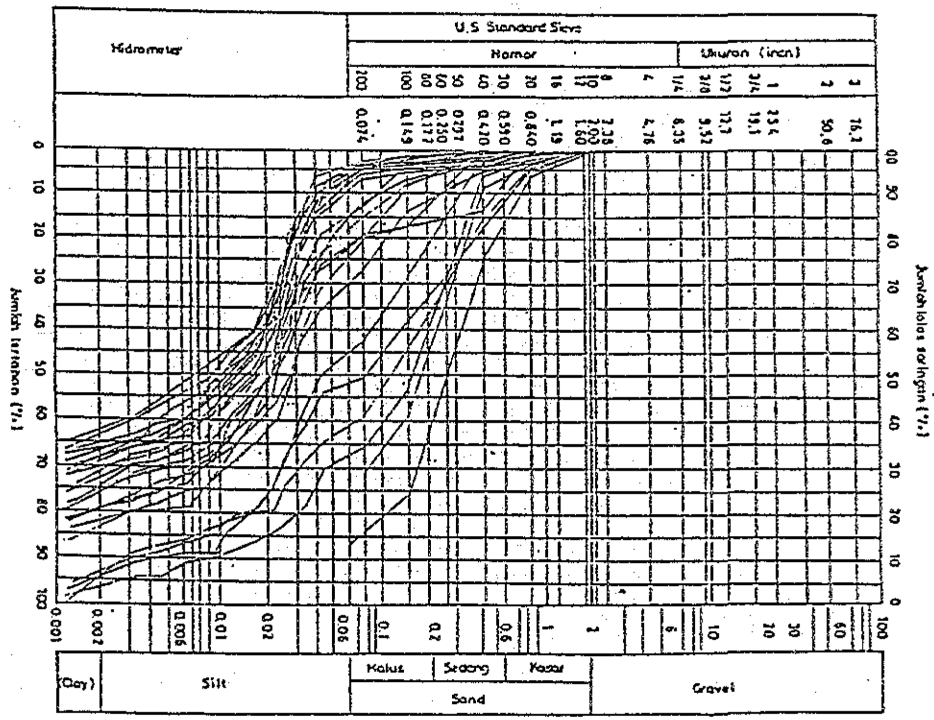
(1) Gradation Curves between
Jati Sari*1 and T. Balai (I - IV)



Source : Ref. T. 12

*1 : Village Name about 10 km upstream from Kisaran

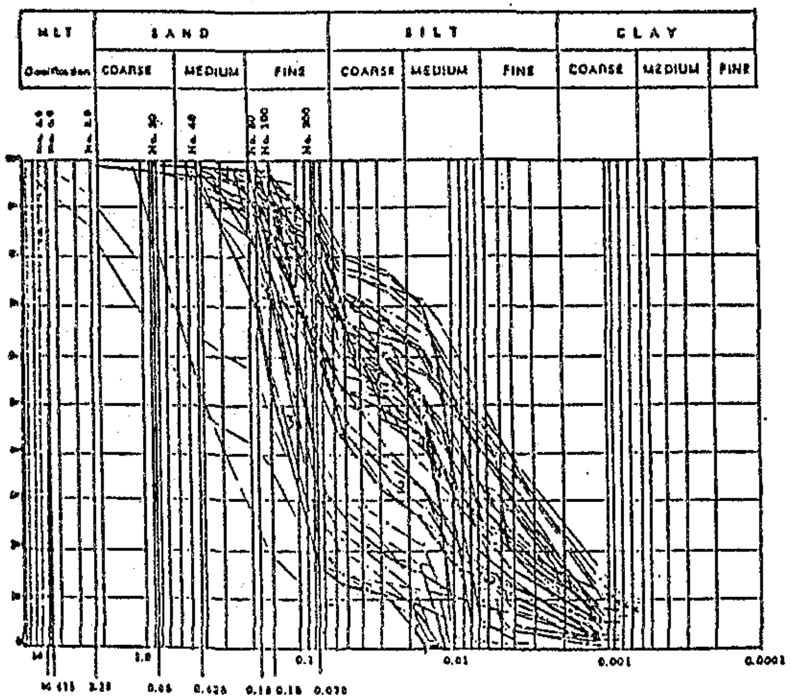
(2) Gradation Curves between
Kisaran and T. Balai (CS1 - CS7)



Source : Ref. T. 16

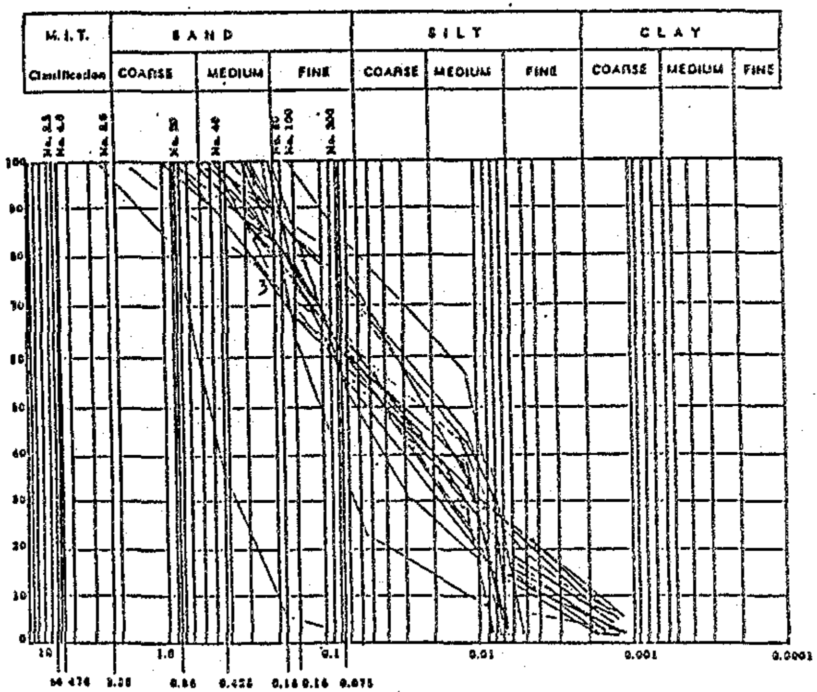
Fig. B-8 Gradation Curves of Soils along Asahan River

(1) Gradation Curves between Pulau Raja and Lebah River in Asahan River



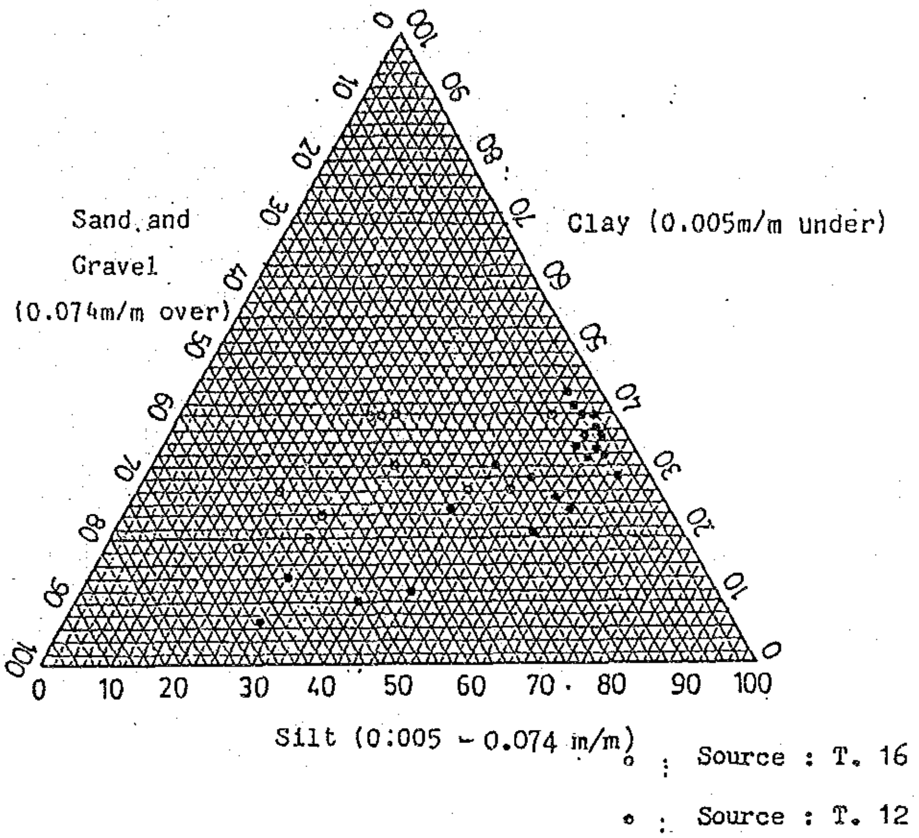
Source : Ref. T. 14

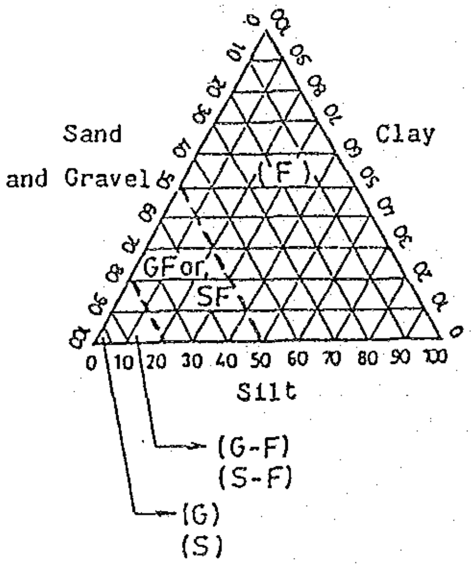
(2) Gradation Curves between Lebah River and Tanjung Balai in Asahan River



Source : Ref. T. 15

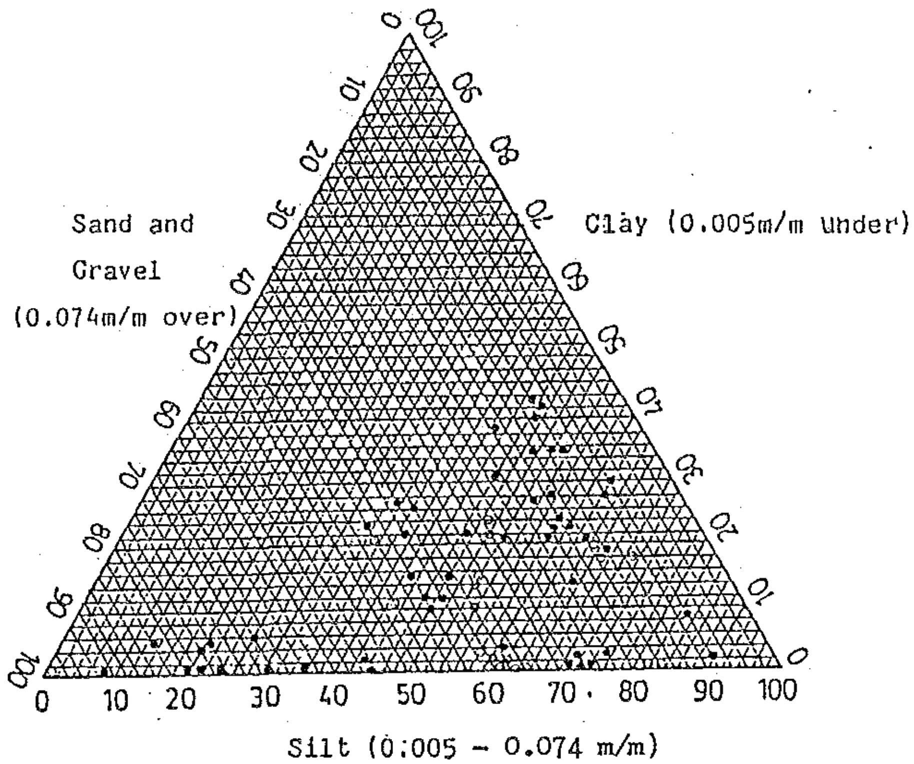
Fig. B-9 Triangular Classification Chart of Soils along Silau River





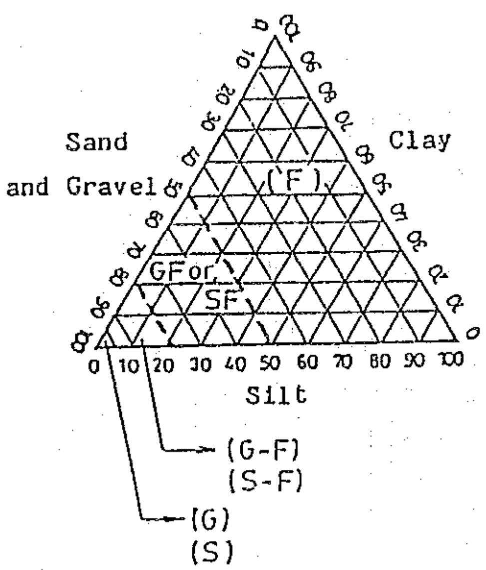
(F) : Fine-grained Soil
(SF) : Sandy Fine-grained Soil
(GF) : Gravely Fine-grained Soil
(S-F) : Sand with Fine-grained Soil
(G-F) : Gravel with Fine-grained Soil
(S) : Sand
(G) : Gravel

Fig.B-10 Triangular Classification Chart of Soils along Asahan River



Source : Ref. T. 14

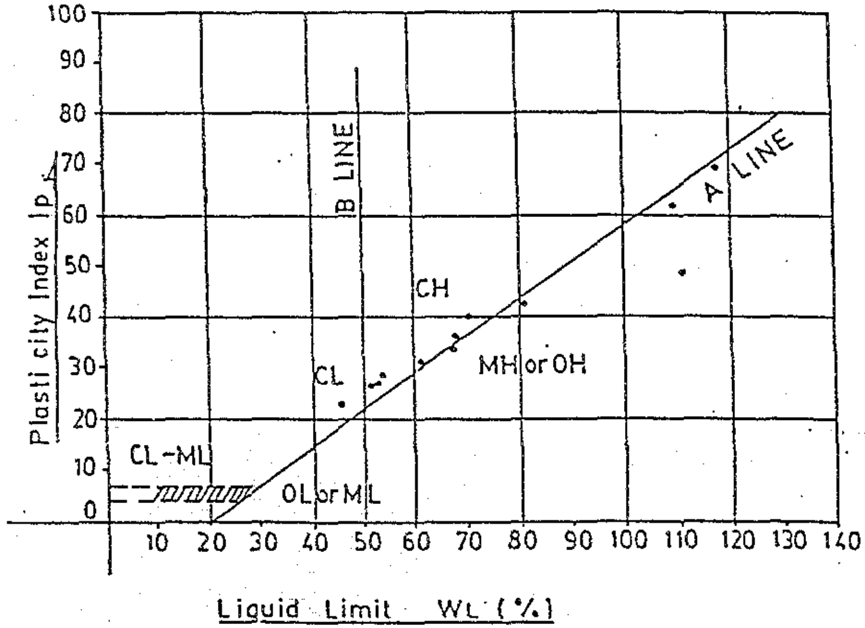
Source : Ref. T. 13



(F) : Fine-grained Soil
(SF) : Sandy Fine-grained Soil
(GF) : Gravely Fine-grained Soil
(S-F) : Sand with Fine-grained Soil
(G-F) : Gravel with Fine-grained Soil
(S) : Sand
(G) : Gravel

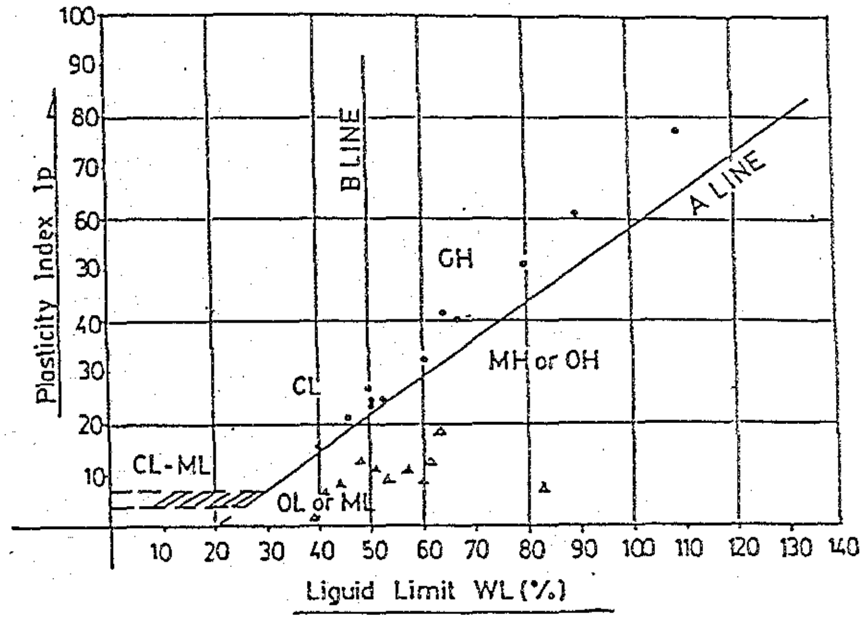
Fig. B-11　Plasticity Charts of Soils along Silau and Asahan Rivers

Silau River



Source : Ref. T. 12.

Asahan River



Source : Ref. T. 13.
Ref. T. 14.

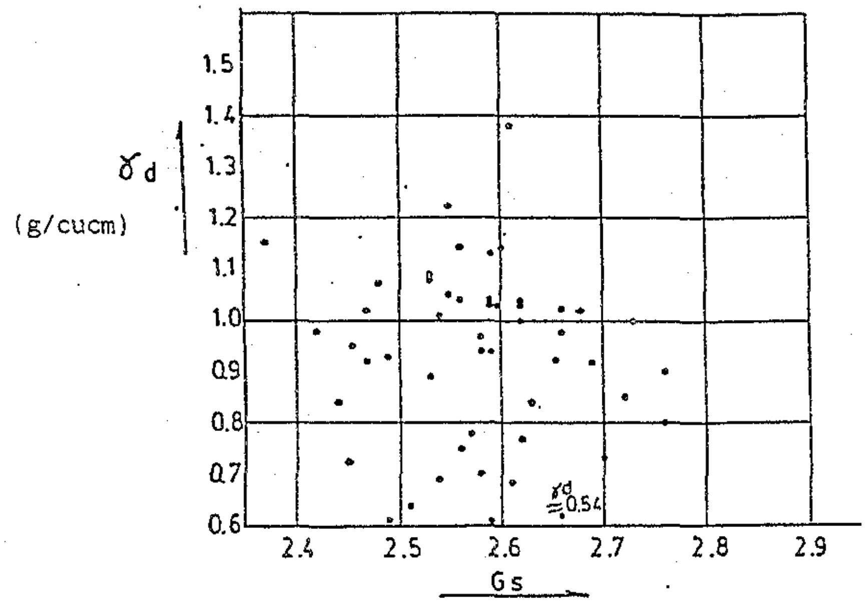
Sampling Depth

• : 2,0 - 2,5 m.
• : 5,5 ~ 6,0 m
Data From I.T.B 1983

▲ : 1,4 ~ 2,0 m.
△ : 2,0 - 2,4 m.
Data From ESCONSOIL 1984

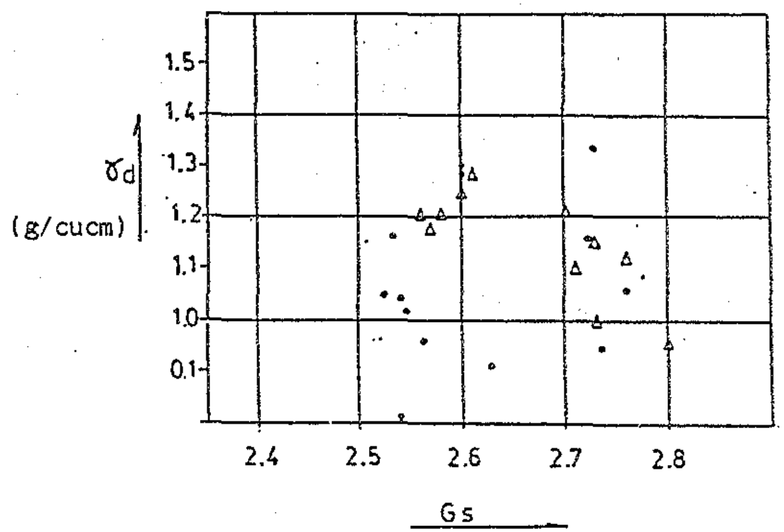
Fig. B-12 Correlation of Specific Gravity and Dry Density of Soils along Silau and Asahan Rivers

Asahan River



Souce : Ref. T. 14

Silau River



Souce : Ref. T. 12

Ref. T. 16

Fig. B-13 Moisture Content of Soils along Silau River between Kisaran and Tg. Balai

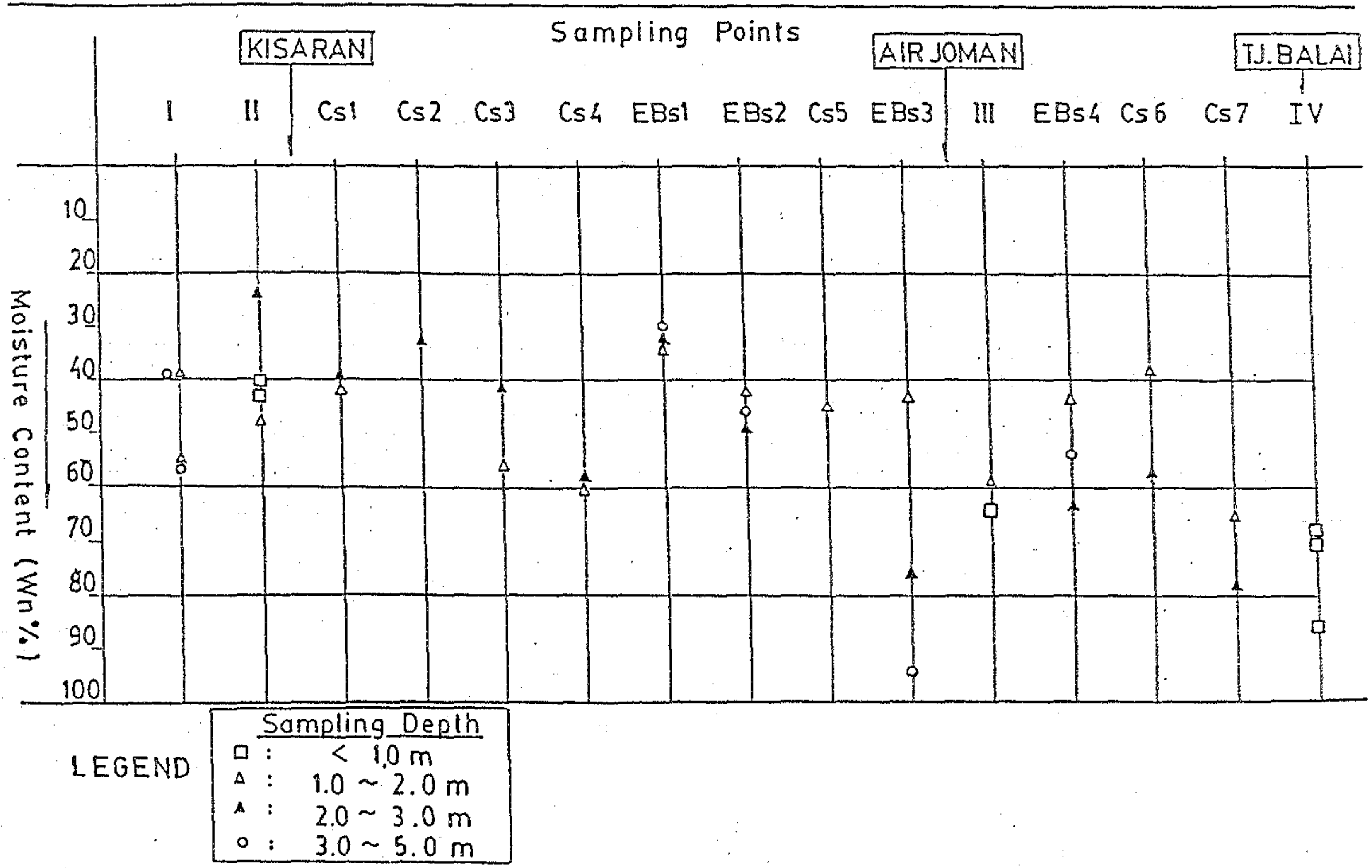
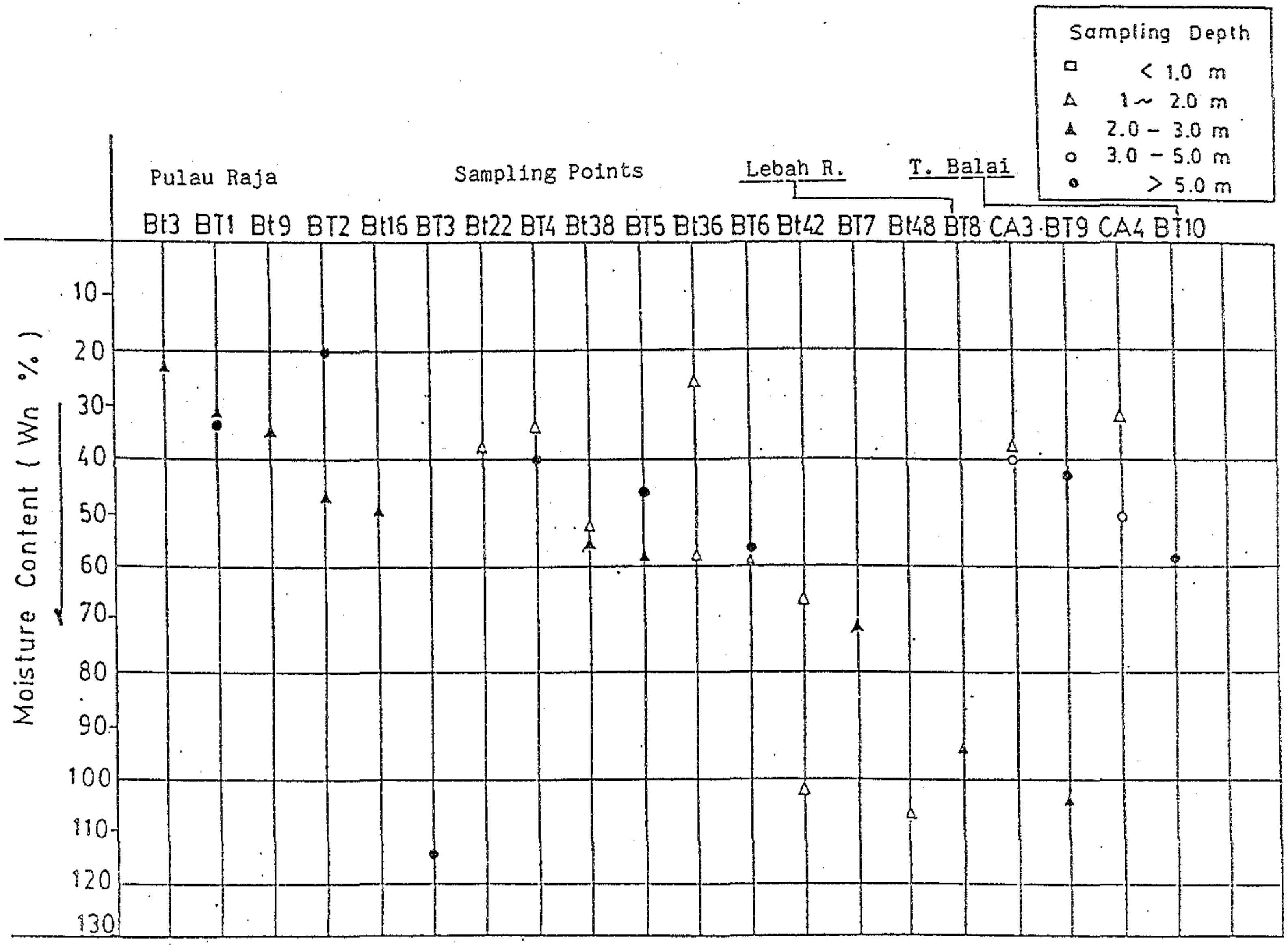


Fig. B-14 Moisture Content of Soils along Asahan River between Pulau Raja and Tg. Balai



Appendix 2-C

Socio-economy

Appendix 2-C

SOCIO-ECONOMY

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1. Socio-Economic Conditions

1.1 National Background

Indonesia is an archipelago of 13,667 islands stretching along the equator for 5,110 km from Northwest Sumatra to Irian Jaya on its southeastern border. Its total land area is 1.9 million km^2, but its total surface area including the seas within its boundaries is over 4.8 million km^2. Of the numerous islands, Sumatra is the second largest island after Kalimantan and covers an area of 473,606 km^2.

As of 1983, total population of Indonesia is estimated at around 158 million. Annual growth rate of population is about 2.38% from 1971 through 1983. It is projected however that the annual population growth rate will be lowered to 1.9% in 1995-2000. The population projection in the Statistical Yearbook of Indonesia shows that the population of the country in the year 2000 would reach more than 222.7 million.

The distribution of population and natural resources among islands is very uneven. The island of Java, covering only 7% of the total land area, sustains almost 62% of the total population (population density in 1980: 690 persons/km^2), whereas the island of Sumatra, covering 24.7% of the total area, accommodates 19% of the total population with the density of 59 persons/km^2. However, the ratio of the population in Java to the total population shows a tendency to decrease gradually owning to transmigration programs implemented by the Government and accounted for 2% during the period from 1971 to 1983, while the population growth of Sumatra was 3.4% in the same period including the increase by transmigration.

The population of 10 years and over of age was 104.4 million in 1980. Among them, the labor force is 51.6 million corresponding to 49.4% of the population of 10 years and over of age.

Indonesia is basically an agricultural country but being gradually industrialized. The employed population of 28.8 million, 55.8% of the labor force, are still working in the agricultural sector such as agriculture, forestry, stockbreeding and fishery. The GDP share of agricultural sector to the whole industry has a tendency to decrease from 32.8% in 1978 to 29.8% in 1982. Accordingly, it is observed that the shares of manufacturing and service sectors are increasing, as shown in Table C-2.

Such a change in industrial structure is reflecting on the issue of regional and urban development. Urbanization in Indonesia has been accelerating. Between 1971 and 1980, the rural-urban migration accounted for slightly more than half of the 9.6 million increase in Indonesia's urban population. During the same period, the urban population increased by 4% per annum compared with 2.6% during the period of 1961-1971.

At this pace, Indonesia's urban population will be more than double from its 1980 level of 33 million to 72 million by 2000. One of the most important features of Indonesia's development is that rural-urban differences within regions might be greater than differences among regions. Due to population pressure, 4.3 million Indonesians or 16% of the natural increase in population resettled permanently in provinces outside those of their birth between 1971 and 1980. Approximately 1.7 million people (or about 40%) moved from Java to outer islands in the same period. Of these, 1 million were resettled through the official transmigration program.

Owing to the remarkable achievements of Repelita I, II and III, the proportion of the population living in poverty declined from 57% to 40% between 1970 and 1980. The reduction in poverty was conspicuous in the outer islands, where poverty incidence reduced from 43% to 28%. Nevertheless, there still exists outstanding theme to redistribute incomes and alleviate regional socio-economic disparities.

The economy of Indonesia performed well during the decade to 1981, as shown below:

GDP Growth of Indonesia

(% per annum at 1973 constant prices)

1970-79 Average	1980	1981	1982	1983	1981-83 Average
7.6	9.9	7.9	2.3	4.0	4.7

Source: World Bank Report

GDP expanded at an average annual rate of & 7.8% in this sustained growth period. But, the overall economic growth was slowed down since 1981, mainly due to deterioration in the terms of trade by the economic ressesion all over the world.

In 1982, the GDP growth at constant prices recorded the lowest growth rate of 2.3% over past 15 years. Real exports declined by 14% due to weaking in demand for the major primary exports, such as petroleum and its products, wood, rubber, coffee, tin ore, etc. On the supply side, the impetus for growth from the agriculture sector weakened in 1982 due to a severe drought. Table C-2 shows the export and import of major commodities in Indonesia from 1978/79 to 1982/83. Indonesia GDP per capita is estimated at US$560 in 1983 and expected to exceed US$600 in 1984 at current prices.

The agricultural sector which accounts for a half or more of total employment is the mainstay of the national economy and has been given the high priority within the public sector investment program. However, rice, the most important staple food, is continuously imported at about 1.4 million tons per year on the average during the past 10 years (See Table C-3). Rice production for 1982 is estimated to be 23.2 million tons, about 4% above the 1981 level (22.3 million tons), although it increased by an average annual rate of 9.7% during the period of 1979-1982.

Under such circumstances, the production is expected to grow at an average rate of over 3.5% for attaining to food self-sufficiency, alleviating balance of payments pressures, and improving income, employment and nutrition levels, etc.

In Indonesia, the Forth Five Year Development Plan (Repelita IV, 1984/85 - 1988/89) is now under execution. The Repelita IV is based on the following directives:

1) To raise the standards of living, intellectual abilities and general welfare of the people and lay strong foundations for subsequent stages of the nation's development,

2) To establish the foundation which will serve as an effective basis for future sustained development, and to create an environment that provides every incentive and opportunity for all concerned to participate and perform, fully and harmoniously, in the national development effort,

3) To continue to give priority to economic development with emphasis on agricultural self-sufficiency in food, and on industries; at the same time to give more attention to social development and the development of other non-economic fields,

4) To continue to be based on the "Trilogi Pembangunan" or the Development Trilogy, namely, equity, a sufficiently high rate of economic growth, and a sound and dynamic national stability.

The indications are that the strategy under Repelita IV remains fundamentally unchanged from the one under Repelita III (1979/80 - 1983/84) of placing greater emphasis on equitable development. While the priority of Repelita IV is still on economic development, greater emphasis is given to human resource development comprising education, health,manpower, clean-water supply, nutrition, housing and human settlement, as represented in sectoral percentage breakdown of development budget (See Table C-4).

In Repelita IV, the average growth rate is expected to be approximately 5% per annum, comprising 3% in agriculture, 2.4% in mining, 9.5% in manufacturing, 5% in construction, 5.2% in transportation and communication and 5% in other sectors. With the planned rate of growth, agriculture is expected to be able to support the efforts to consolidate a sustainable food self-sufficiency for the country as well as to accelerate the industrial and export development.

The total government development budget for the entire Repelita IV period amounts to Rp. 78,609.5 billion, while that of the first year of 1984/85 is Rp. 10,459.3 billion. The allocations are based on the national priority stated in the Guidelines of State Policy with emphasis on equity, health, education and social overhead capital.

The transmission program is implemented in line with the national policy to alleviate regional social disparities. In Repelita IV, the Government attaches high priority to an increase in the rate of transmigration and aims to resettle 750,000 families of about 3.6 million people from Java to the islands of Sumatra, Kalimantan, etc.

1.2 History of Sumatra Island

Colored by the historical vicissitude, Sumatra represents a tremendous diversity in terms of culture (tribe, language, customs, etc.), economic structure and so on. This diversity posses considerable challenges for the Government. In this context, it is becoming important to explore the old to be able to understand the new, i.e. the trends in conjunction with macro socio-economic development.

Historical background of Sumatra and its pre-colonial economy can be sketched as outlined hereunder, based on the studies: E. M. Loeb, "Sumatra - Its History and People" edited by Oxford in Asia Paperbacks and A. Reid, "The Pre-Colonial Economy of Indonesia", Australian National University.

(1) Historical background

Unfortunately, the history of Sumatra has no uniformity in the interpretation of original sources.

Sriwijaya in the Palembang river valley in Sumatra was colonized by Hindus at an early date. The first Hindu Kingdom mentioned in Sumatra was that of Malayu (Malay Land) in Jambi in 644 A.D. A short time afterwards, the Kingdom of Sriwijaya gained a foothold on the Malay Peninsula and came into close contact with Java.

The first use of the name Sumatra occurred in 1017. As the power of Sriwijaya weakened, the Javanese influence on Sumatra increased until the name Malayu stood for the entire island.

In 1281, the Islam Kingdoms began to form on Sumatra's north coast. At about this time (1292), Macro Polo, the first European visited Sumatra, traveling there and found eight small kingdoms. But, the small states had not yet been converted according to the commentaries of his travel book. In 1377, Sriwijaya was definitely conquered by Java.

The European history of Sumatra consists of the struggle between the English and the Dutch for the possession of the island. This struggle resulted in the victory of the Dutch. In 1824, the treaty was signed between the two nations to insure the possessions of the British on the main land and the possessions of the Dutch on the island.

(2) Pre-colonial economy

Indonesians have grown crops for exports for many centuries. Rice was always the largest items of maritime trade. The large commercial cities such as Aceh and Banten were fed primarily by imported rice of Java, and saw little need to plant rice their own hinterlands until the Dutch introduced tactics of naval blockade in the mid-17th century. In addition to rice, salt and dried or pickled fish were always traded from coastal to interior regions and frequented also over long distances.

In the 15th to 17th centuries, the major boom crop was pepper. Pepper cultivation appears to have been introduced to Sumatra from India only about 1400. Other cash crops were similarly taken up whenever a demand presented. Tobacco was extensively growth in almost every suitable area by the end of the 18th century. As to coffee, it is estimated that Indonesia produced about a quarter of the world's needs in the mid-19th century.

In the meantime, Indonesia small holders began to produce rubber, copra, coffee, and most recently cloves, etc., long before the era of modern capitalist penetration. Thus, the successful agricultural entrepreneurs who accumulated the capital as well as modern capitalists in the 20th century, promoted the flow of immigrants to their frontier areas.

1.3 Regional Socio-Economy

The North Sumatra Province covers an area of 71,680 km^2, occupying 15% of the total area of Sumatra Island. Administratively, North Sumatra Province is divided into 11 Kabupatens (Regencies) and 6 Kotamadyas (Municipalities); 198 Kecamantans (Sub-Districts); and 5,643 Desas (Villages).

Based on the 1980 census and population projection, the population of the North Sumatra Province in 1983 is estimated at around 9 million, corresponding to 29% of the total population of Sumatra Island and its population density is about 127 persons/km^2. The population growth rate was 2.5% per annum during the period of 1980-1983. This growth rate is lower by 0.1% than that during the period of 1971-1980. Based on the forecast of future population, the North Sumatra Province is expected to reach a population of some 13.7 million in 2000 with the average annual growth rate of 2.5% being equivalent to the rate for the period of 1980-1983.

The population of 10 years and over of age in the Province was 5.74 million in 1980 comprising 2.85 million of male and 2.89 million of female, and it corresponds to 63.9% of the total population. The labor force was 2.9 million in 1982, corresponding to 50.5% of the population of 10 years and over of age.

The percentage of employee active population in the Province was 99% of the total labor force in 1982 and the percentage of persons employed in agricultural sector was 60.6%, followed by 13.7% for commerce, 10.6% for services, 9.5% for others and 5.6% for industry. The percentage of persons employed in the agricultural sector to those in all the industry sectors decreased from 67.9% in 1980 to 60.6% in 1982. A gradual decrease in the share of agricultural sector seems to be the recent trend in Indonesia. In 1983, the number of farm-households in the Province was 974,000, accounting for 73.5% of the total number of households.

The Gross Regional Domestic Product (Non mining GRDP) of North Sumatra Province increased from Rp. 621.3 billion in 1975 to Rp. 1,055.3 billion in 1981 at 1975 constant prices (See Table C-5). This shows the average real growth rate of 9.2% per annum. GRDP on the North Sumatra Province accounts for 6% of Indoneisa's GDP. Assuming that GDP per capita index of the whole country is 100, that of the Province quotes 105.8 at the 1979 current prices, as figured in Table C-6. This indicates that North Sumatra Province is the middle developed one among 27 provinces of the country, but the index of 105.8 is fairly below that of 164.7 on the whole Sumatra.

The share in GRDP by main sector (at 1975 constant prices) in 1982 was 41.3% for agriculture, 0.2% for mining and quarrying, 7.1% for manufacturing industries, 4.5% for construction, 11.9% for transportation and communication and 35.0% for trade, financing and other services. The share of agricultural sector reduced by 3.7% during the period from 1975 to 1982. Most of commodities exported from North Sumatra Province are composed of estate and plantation products such as palm oil, rubber, palm kernel, latex, copra chips, etc., as shown in Table C-7.

The per capita income of the Province in 1982 was Rp. 324,055 at the current prices and Rp. 130,805 at the 1975 constant prices. The average growth rate of the per capita income was 6.5% per annum during the period from 1975 to 1982. This growth rate is higher than 4.0% for the whole Indonesia.

1.4 Socio-Economy of Study Area

1.4.1 Study Area

The study area is located at about 160 km south-east of Medan, capital of the North Sumatra Province. The study area consists of two (2) Kabupatens and one (1) Kotamadya; greater parts of Kab. Asahan, some parts of Kab. Labuhan Batu and Whole Kotamadya Tanjung Balai. It covers about 6,000 km^2 or 8.4% of the gross area of the North Sumatra Province.

Catchment areas of the four (4) rivers: Bunut, Silau, Asahan and Kualuh comprise a part of other Kabupatens in their upper basin. However, the study area for socio-economy is limited to 13 Kecamatans in Kab. Asahan, 3 Kecamatans in Kab. Labuhan Batu and the whole Kotamadya Tanjung Balai, judging from the objectives of regional economic study in the present master plan (See Table C-8).

The study areas covers 13 Kecamatans among 17 in Kab. Asahan and its area accounts for 86% of the total areas of Kabupaten Asahan (4,681 km^2). The city of Kisaran is the administrative center (Ibu Kota) of Kabupaten Asahan. Kabupaten Labuhan Batu within the study area covers 2,085 km^2, corresponding to 22% of the total area. This Kabupaten is administrated by Ibu Kota of Rantau Prapat. Kotamadya Tanjung Balai surrounded by Kabupaten Asahan is treated as an autonomous municipality with the total area of 1.9 km^2. Each Kecamatan and Kotamadya has several Desa as an administrative substructure. Number of Desas in the study area is 199 in total including 155 in Asahan, 40 in Labuhan Batu and 4 in Tanjung Balai.

1.4.2 Population

Population census in Indonesia were carried out in the years 1961, 1971 and 1980 after the independence. Populations in last thirteen (13) years (1971-1983) are given in Table C-9, summarizing them for the whole Indonesia, Sumatra island, North Sumatra Province, two Kabupatens of Asahan and Labuhan Batu and one Kotamadya of Tanjung Balai, and the areas of these Kabupatens and Kotamadya within the study area.

In 1983, the study area supports the population of some 798,900 consisting of 603,400 in Asahan, 152,700 in Labuhan Batu and 42,800 in Tanjung Balai (See Table C-10). The population in the study area is about 9% of the total of the Province. Average population per household in the area is estimated at 5.3 and this size is slightly higher than those of Sumatra island (5.2) and national average (4.9), but lower than that of the Province (5.4) as shown in Table C-11.

Population in the study area is unevenly distributed due to its topography and dense in the northeastern coastal part and coarse in the southwestern mountain area. Distribution of population in the study area is as follows:

1) Majority of the population is concentrated in municipalities along the provincial and local roads from Tebing Tinggi to Rantau Prapat and from Kisaran to Tanjung Balai.

2) Many fishermen's families are found along the rivers and coastal areas.

3) In southeastern part of the study area covered with swamps, number of inhabitants is very few.

The population density in the study area was about 130 persons/km^2 in 1983. This figure is higher than those in the Province (119) and the whole of Sumatra island (59).

The population density in Kabupaten Asahan in 1983 was 149 persons/km^2, that in Kabupaten Labuhan Batu 73 persons/km^2 and 22,500 persons/km^2 in Kotamadya Tanjung Balai, as shown in Table 2.13. These figures indicate the accelerated urbanization in the study area, especially in two cities: Tanjung Balai and Kisaran.

Table C-12 shows population distribution ratio between urban and rural areas. The population in the urban area was 15.3% in the whole Kabupatens/Kotamadya and 17.2% in the study area in 1980. These percentages are fairly below the national average of 22.4%. In North Sumatra Provinces, this figure is about 26%, owing to the existence of big city of Medan.

In connection with the urbanization which has a centripetal force to attract population, it is noticed that the annual population growth rate of neighboring regions has attendancy to decrease in recent years. The average growth rate in the study area was only 1.2% per annum during the period from 1980 to 1983, implying outflow of population to outside. This percentage is fairly small compared with 2.5% of the Province, 3.3% of Sumatra and 2.3% of the country (See Table C-9).

Table C-13 shows the population by age and sex groups in the study area, North Sumatra Province and Indonesia. In the study area, the population under 15 years of age accounts for 46.3% of the total, i.e. the average age is low compared with those of North Sumatra Province (45.1%) and Indonesia (40.8%). It means many new labor force will require much more job opportunities in near future.