Appendix Table A-4-5 (14) Average Monthly Wages of Drivers and Assistants 1/

M$/Month

Vehicle Type	Driver	Assistant
Medium Truck	500	300
Heavy Truck I	800	300
Heavy Truck II	1,000	300 x 2
Bus	700	300

1/ Including trip allowances and other fringe benefits.

Appendix Table A-4-5 (15) Insurance

M$/Year

Vehicle Type	With Tax	Without Tax
Car	355.9	284.7
Van/Pick-up	822.6	658.1
Medium Truck	1,236.0	988.8
Heavy Truck I	1,782.0	1,425.6
Heavy Truck II	3,960.0	3,168.0
Bus	1,100.0	880.0

Appendix Table A-4-5 (16) Road Taxes/Fees

Vehicle Type	Amount (M$/Year)
Car	149.0
Van/Pick-up	339.0
Medium Truck	470.0
Heavy Truck I	620.0
Heavy Truck II	1,050.0
Bus	450.0

Appendix Table A-4-5 (17) Vehicle Operating Cost

(M$/veh.km.)

Vehicle Type	(Taxes)	Level tangent				Gradient (1/2) 0 ∿ 3% (1/2) 3 ∿ 5%		
		Earth	Gravel	(1/2)Gravel (1/2)Paved	Paved	Gravel	(1/2)Gravel (1/2)Paved	Paved
Car	(WITH)	0.7625	0.4072	0.3478	0.2884	0.4276	0.3652	0.3028
	(WITHOUT)	0.5932	0.3068	0.2605	0.2142	0.3221	0.2735	0.2249
Truck 6ton	(WITH)	1.0501	0.7116	0.6171	0.5226	0.9002	0.7806	0.6611
	(WITHOUT)	0.8806	0.5992	0.5197	0.4401	0.7580	0.6574	0.5567
10ton	(WITH)	1.8541	1.2154	1.0334	0.8514	1.5375	1.3073	1.0770
	(WITHOUT)	1.5345	1.0068	0.8552	0.7035	1.2736	1.0818	0.8899
20ton	(WITH)	2.7836	1.6745	1.3872	1.0998	2.1182	1.7548	1.3912
	(WITHOUT)	2.3590	1.4240	1.1795	0.9350	1.8014	1.4921	1.1828
BUS	(WITH)	1.4111	0.8980	0.7518	0.6056	1.1360	0.9510	0.7661
	(WITHOUT)	1.1953	0.7663	0.6431	0.5198	0.9694	0.8135	0.6575

Appendix Table A-4-6 Estimate of Vessel Operating Costs

Appendix Table A-4-6 (1)	Operating Characteristics of Light Vessels
Appendix Table A-4-6 (2)	Operating Cost of Tug Boat
Appendix Table A-4-6 (3)	Operating Cost of Motor Vessels
Appendix Table A-4-6 (4)	Operating Cost of Barge
Appendix Table A-4-6 (5)	Operating Characteristics of Passenger Express Launch
Appendix Table A-4-6 (6)	Operating Cost of Passenger Express Launch
Appendix Table A-4-6 (7)	Operating Characteristics of Long Boats
Appendix Table A-4-6 (8)	Price of Hull
Appendix Table A-4-6 (9)	Price of Outboard Engine
Appendix Table A-4-6 (10)	Operating Cost of Long Boat with Outboard Engine
Appendix Table A-4-6 (11)	Cost of Log Rafting

Appendix Table A-4-6 (1) Operating Characteristics of Light Vessels

	Tug Boat				Barge (Tons)			Motor Vessel (Tons)		
	120HP	150HP	500HP	800HP	150	300	500	40	150	200
Loading Capacity	-	-	-	-	150	300	500	40	150	200
Ave. Operat. Speed(KPH)	10.0	10.0	12.0	12.0	8.0	8.0	8.0	11	12.5	13.5
Operating Hours/Day	10	10	10	10	14	14	14	10	24	24
Ave. Line Haul/Day(Km)	100	100	120	120	112	112	112	110	300	324
Operat. Days/Year	240	240	240	240	230	210	180	200	200	180
Operat. Km./Year	24,000	24,000	28,800	28,800	25,760	23,520	20,160	22,000	60,000	58,320
Life Years	15	15	20	20	20	22	25	15	22	25

Source: Interviews with Shipping Companies

Appendix Table A-4-6 (2) Operating Cost of Tug Boat

(M$/day)

Cost Item		120HP WITH	120HP WITHOUT	150HP WITH	150HP WITHOUT	500HP WITH	500HP WITHOUT	800HP WITH	800HP WITHOUT
1. Depreciation 1/	Engine:	22.92	15.83	41.67	29.17	58.33	40.83	83.33	58.33
	Hull:	20.83	17.70	55.56	47.22	75.00	63.75	114.58	97.40
2. Fuel 2/		96.60	94.20	128.80	125.60	193.20	188.40	241.50	235.50
3. Lubrication 3/		17.50	17.00	17.50	17.00	26.25	25.50	31.50	30.60
4. Maintenance 4/		41.67	35.42	62.50	53.12	125.00	106.25	166.67	141.67
5. Crew 5/		64.58	61.35	83.33	79.17	83.33	79.17	83.33	79.17
6. Stores 6/		6.25	5.94	6.25	5.94	9.17	8.71	10.00	9.50
7, Insurance 7/		5.42	4.24	12.50	10.00	20.83	16.83	31.25	25.31
8. Overhead 8/		27.58	25.17	40.81	36.72	59.11	52.94	76.22	67.75
Total/Day		303.35	276.85	448.92	403.94	650.22	582.38	838.38	745.23

1/ Price New, Engine:	55,000	38,000	100,000	70,000	140,000	98,000	200,000	140,000
Hull:	75,000	63,750	200,000	170,000	360,000	306,000	550,000	467,500
Life Years, Engine:	10 years		10 years		10 years		10 years	
Hull:	15 years		15 years		20 years		20 years	
2/ Fuel Consumption:	6 gallon/hr		8 gallon/hr		12 gallon/hr		15 gallon/hr	
Price of Fuel:	1.61/gal.	1.57/gal.	1.61/gal.	1.57/gal.	1.61/gal.	1.57/gal.	1.61/gal.	1.57/gal.
3/ Lubrication Consump:	0.02 gallon/mile		0.02 gallon/mile		0.025 gallon/mile		0.03 gallon/mile	
Price of Lubrit:	14.0/gal.	13.6/gal.	14.0/gal.	13.6/gal.	14.0/gal.	13.6/gal.	14.0/gal.	13.6/gal.
4/ Maintenance, Engine:	10,000/year	8,500/year	15,000/year	12,750/year	30,000/year	25,500/year	40,000/year	34,000/year
Hull:								
5/ Crew, Captain:	1 x 5,000		1 x 7,000		1 x 7,000		1 x 7,000	
Engineer:	-	15,500/year	1 x 6,000	20,000/year	1 x 6,000	20,000/year	1 x 6,000	20,000/year
Hands	3 x 3,500		2 x 3,500		2 x 3,500		2 x 3,500	
6/ Stores:	1,500/year		1,500/year		2,200/year		2,400/year	
7/ Insurance:	1% on value/day							
8/ Overhead	10% of total of 1/ through 7/							

Appendix Table A-4-6 (3) Operating Cost of Motor Vessels

(M$/day)

	40 ton		150 ton		200 ton	
	WITH	WITHOUT	WITH	WITHOUT	WITH	WITHOUT
1. Depreciation 1/	43.33	33.88	431.82	345.45	555.56	444.44
2. Fuel 2/	96.60	94.20	579.60	565.20	695.52	678.24
3. Lubrication 3/	20.01	19.43	56.00	54.40	67.20	65.28
4. Maintenance 4/	55.00	46.75	250.00	200.00	388.89	311.11
5. Crew 5/	77.50	73.63	150.00	135.00	183.33	164.70
6. Stores 6/	-	-	15.00	14.25	22.22	21.11
7. Insurance 7/	5.00	3.95	95.00	76.00	138.89	111.11
8. Overhead 8/	29.74	27.18	157.74	139.03	205.16	179.60
Total/Day	327.18	299.02	1,735.16	1,529.33	2,256.77	1,795.59

Source: Interviews with operators and dealers

1/	Price New:	100,000	79,000	1,900,000	1,520,000	2,500,000	2,000,000
	Life Years:			22 years (200 day/year)		25 years (180 day/year)	
2/	Fuel, Consump:	4.8 gallon/hr		15 gallon/hr		18 gallon/hr	
	Price of Fuel:	1.61/gal.	1.57/gal.	1.61/gal.	1.57/gal.	1.61/gal.	1.57/gal.
3/	Lubrication, Consump:	1/7 gallon/hr		1/6 gallon/hr		1/5 gallon/hr	
	Price of Lubricatn:	14.00/gal.	13.60/gal.	14.00/gal.	13.60/gal.	14.00/gal.	13.60/gal.
4/	Maintenance/Year:	11,000	9,350	50,000	40,000	70,000	56,000
5/	Crew, Captain:	1 x 5,000		1 x 8,000		1 x 8,000	
	Mate:	-	15,500/year	1 x 7,000	30,000/year	1 x 7,000	33,000/year
	Engineer:	-		1 x 6,000		1 x 6,000	
	Hands:	3 x 3,500		3 x 3,000		4 x 3,000	
6/	Stores:	-		3,000/year		4,000/year	
7/	Insurance:	1% on value/day					
8/	Overhead	10% of total of 1/ through 7/					

Appendix Table A-4-6 (4) Operating Cost of Barge

(M$/day)

	150 ton		300 ton		500 ton	
	WITH	WITHOUT	WITH	WITHOUT	WITH	WITHOUT
1. Depreciation 1/	55.00	41.30	90.04	67.53	136.22	102.22
2. Maintenance 2/	30.43	24.35	57.14	45.71	94.44	75.56
3. Crew 3/	69.57	62.61	109.52	98.57	166.67	150.00
4. Stores 4/	12.00	11.40	18.00	17.10	28.00	26.60
5. Insurance 5/	11.00	8.80	19.81	15.85	32.26	25.81
6. Overhead 6/	17.80	14.85	29.45	24.48	45.76	38.02
Total/Day	195.80	163.31	323.96	269.24	503.35	418.20

Source: Interviews with operators and dealers

1/ Price New:	253,000	190,000	416,000	312,000	613,000	460,000
Life Years:	20 years (230 days/year)		22 years (210 days/year)		25 years (180 days/year)	
2/ Maintenance/year:	7,000		12,000		17,000	
3/ Crew,						
Crane Operator:	1 x 9,000	16,000/year	1 x 9,000	23,000/year	1 x 9,000	30,000/year
Hands:	2 x 3,500		4 x 3,500		6 x 3,500	
4/ Stores:			1% on Value/day			
5/ Insurance:						
6/ Overhead:			10% of total of 1 through 5			

Appendix Table A-4-6 (5) Operating Characteristics of Passenger Express Launch

Distance;	104 kilometers K. Baram/Marudi	109 kilometers Marudi/L. Lama
Size of Hull	73' x 13.5'	n.a.
Loading Capacity (No. of Pass.)	120	70
Max. Cruising Speed (KPH)	38	30
Ave. Cruising Speed (KPH)	30	22
Operating Hours/Day	3.5	5.0
Operating Days/Year	365	304 1/
Annual Kilometrage	39,600	32,832
Life Years	20	16
Life Kilometrage	792,000	525,000
Life Years of Engine	10	6

Source: Interviews with operators and dealers

1/ 365 x 5/6

Appendix Table A-4-6 (6) Operating Cost of Passenger Express Launch

Cost Item		K.Baram - Marudi		Marudi - Long Lama	
		WITH	WITHOUT	WITH	WITHOUT
1. Depreciation, 1/	Engine:	43.84	27.40	38.38	24.00
	Hull:	19.18	16.30	22.62	19.22
2. Fuel 2/		289.80	261.00	193.20	174.00
3. Lubrication 3/		21.00	20.40	14.00	13.60
4. Maintenance, 4/	Engine:	27.40	23.29	19.74	16.78
	Hull:	5.48	4.66	4.28	3.64
5. Crew 5/:		54.25	48.82	51.32	46.18
6. Insurance 6/:		8.60	6.30	7.50	5.20
7. Overhead 7/:		46.96	40.82	35.10	30.26
Total/Day:		516.50	448.99	386.14	332.88

1/	Price New, Engine:	80,000 x 2	50,000 x 2	70,000 x 1	43,750 x 1
	Hull:	140,000	119,000	110,000	93,500
	Life Years, Engine:	10 years		6 years	
	Hull:	20 years		16 years	
2/	Fuel Consumption:	180 gallon/trip		120 gallon/trip	
	Price of Fuel:	1.61/gal.	1.57/gal/	1.61/gal.	1.57/gal.
3/	Lubrication Consump:	1.5 gallon/trip		1.0 gallon/trip	
	Price of Lubricatn:	14.00/gal.	13.60/gal.	14.00/gal.	13.60/gal.
4/	Maintenance, Engine:	10,000/year		6,000/year	
	Hull:	2,000/year		1,300/year	
5/	Crew, Captain:	7,200/year		7,200/year	
	Crew:	4,200/year x 3		4,200/year x 2	
6/	Insurance:	1% on value/day			
7/	Overhead:	10% of total of 1/ through 6/			

Appendix Table A-4-6 (7) Operating Characteristics of Long Boats

	Long Boat		
	67' x 4'	45' x 2.5'	20' x 2'/16' x 1.75'/ 14' x 1.5'
Loading Capacity (No. of Passengers)	15-18	6-8	2-3
Life Years	5	4	4
Ave. Operating Speed	11.6	11.6	8
Ave. Life Kilometrage	30,000	24,000	15,000
Engine Type	40HP x 1	25HP x 1	6 - 9HP
Life Years of Engine	(18,000)	2.5 (15,000)	2.0 (7,500)

Appendix Table A-4-6 (8)
Price of Hull

Boat Type	Price (M$) With Tax	Price (M$) Without Tax
67' x 4'	3,000	2,760
45' x 2.5'	1,800	1,656
16' x 1.75'	400	400

Appendix Table A-4-6 (9)
Price of Outboard Engine

Engine Type	Price (M$) With Tax	Price (M$) Without Tax
40 HP	2,500 (25%)	1,875
25 HP	1,450 (25%)	1,088
9 HP	1,100 (25%)	825
6 HP	1,000 (25%)	750

Appendix Table A-4-6 (10) Operating Cost of Long Boat with Outboard Engine 4/

		67' x 4'		45' x 2.5'		16' x 1.75'	
		WITH	WITHOUT	WITH	WITHOUT	WITH	WITHOUT
1. Depriciation 1/	Engine:	0.1389	0.1042	0.0967	0.0725	0.1333	0.1000
	Hull:	0.1000	0.0920	0.0750	0.0690	0.0267	0.0267
2. Fuel 2/		1.7457	1.5711	1.1638	1.0474	0.6750	0.6075
3. Maintenance 3/	Engine:	0.0750	0.0497	0.0435	0.0326	0.0300	0.0225
	Hull:	0.0900	0.0828	0.0540	0.0497	0.0120	0.0090
Total/km		2.1496	1.8998	1.4330	1.2712	0.8770	0.7657

Source: Interviews with local operators

1/ Price New, Engine:	2,500 (40HP)	1,875	1,450 (25HP)	1,088	1,000 (6HP)	750
Hull:	3,000	2,760	1,800	1,656	400	400
Life Years, Engine:	3.0 years		2.5 years		2.0 years	
Hull:	5.0 years		4.0 years		4.0 years	
2/ Fuel, Consumption:	4.5 gal./hr./11.6 km		3.0 gal./hr./11.6 km		1.2 gal./hr./8 km	
Price of Fuel:	4.5/gallon	4.05/gallon	4.5/gallon	4.05/gallon	4.5/gallon	4.05/gallon
3/ Maintenance:	3% of depreciable value/1000km for hull and engine					

4/ Operating characteristics of long boats are as follow:

particulars	67' x 4'	45' x 2.5'	20' x 2' 16' x 1.75' 14' x 1.5'
loading capacity (no. of passengers)	15-18	6-8	2-3
life years	5	4	4
ave. operating speed	11.6 km	11.6 km	8.0 km
ave. life kilometrage	30,000	24,000	15,000
engine type	40HP x 1	25HP x 1	6-9HP x 1
life years of engine	3.0 (18,000 kms)	2.5 (15,000 kms)	2.0 (7,500 kms)

Appendix Table A-4-6 (11) Cost of Log Rafting

1 Racket 100 logs
2 Rackets 200 logs

(1) Labour 6.5men x 8hrs/2rackets
M$4.0/hr
6.5 x 8.0 x 4.0 = $208/200 logs ---- $1.04/log

(2) Ropes; 8ft/10g x M$0.35/ft = M$2.8/log
$250(1 roll) = 720ft ---- $0.35/ft
M$2.8 x 1/2 times use = M$1.4/log

(3) Cable; 400ft/2rackets
400ft x M$5.50/ft = M$2,200/8 time life = M$275/200 logs

Tons	(350)	(700)	(1,400)	(2,800)	(3,500)
	100	200	400	800	1,000
No.logs(Rackets)	(1)	(2)	(4)	(8)	(10)
Labour	104	208	416	832	1,040
Ropes	140	280	560	1,120	1,400
Cable	138	275	413	689	827
Total	382	763	1,389	2,641	3,267
Inc. Overhead (20%)	458	916	1,667	3,169	3,920
Per log	4.58	4.58	4.17	3.96	3.92

1 H/T = 1.803m^3

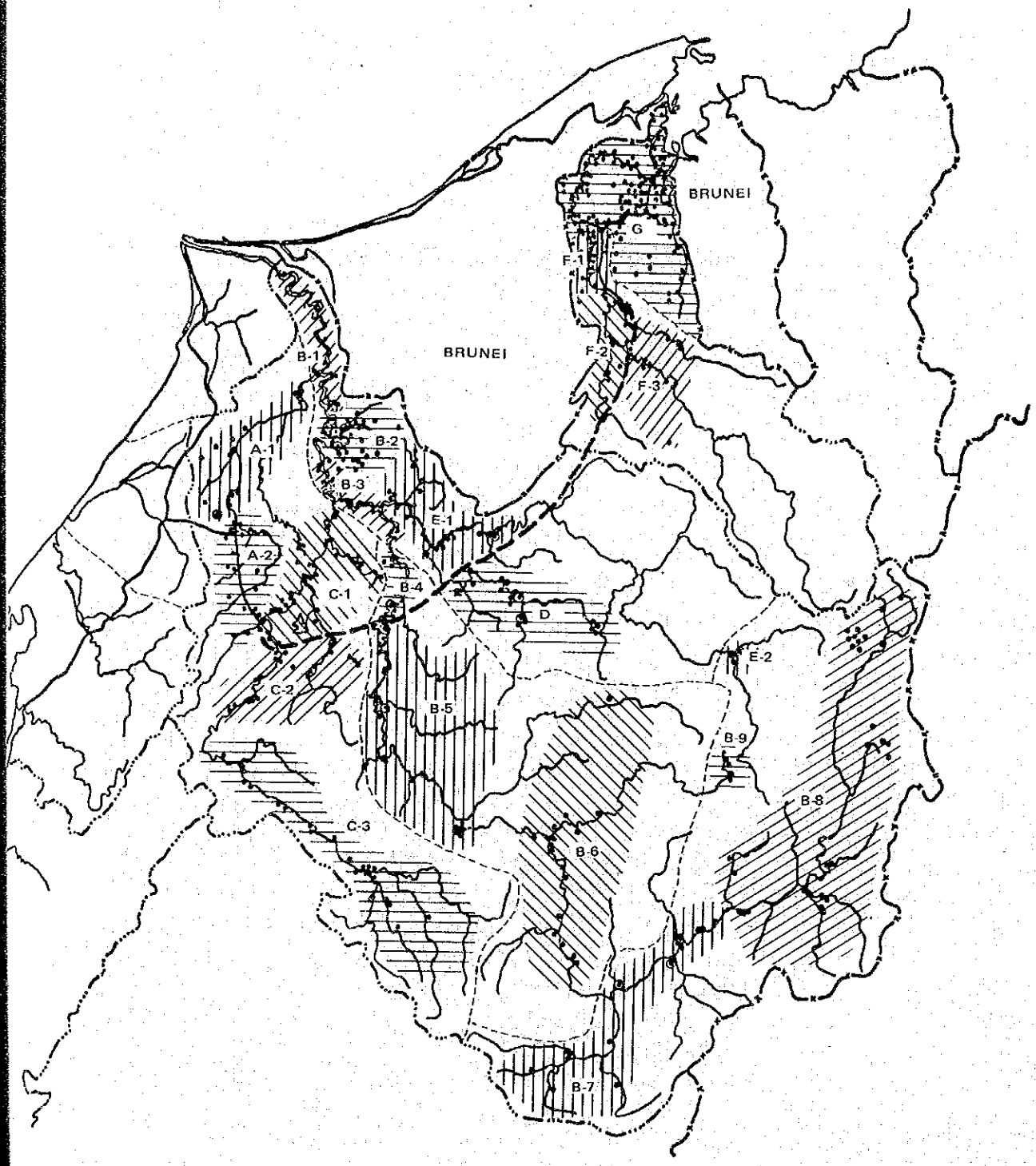
Appendix Table A-4-7 Population by Major River Basin

Area Code	Traffic Zone No.	1977	River Basin
A-1	5	2,900	
A-2	5	2,500	Sg. Bakong
Beluru	5	380	
C-1	6	4,100	
C-2	6	4,200	Sg. Tinjar
C-3	6	1,920	
B-1	7	1,000	
B-2	7	3,200	
B-3	7	1,700	
Marudi	7	5,000	
B-4	8	1,800	Bg. Baram
B-5	8	3,200	
B-6	9	2,600	
B-7	9	3,300	
B-8	9	2,400	
B-9	9	300	
Long Lama	8	1,500	
D	10	3,600	Sg. Apoh
E-1	10	2,500	Sg. Tutoh
E-2	10	100	
F-1	11	3,100	
F-2	11	2,300	Sg. Limbang
F-3	11	800	
G	12	18,000	Sg. Limbang

Appendix Table A-4-8 Estimated Future Population by Traffic Zone

Traffic Zone Code	Name	1977	1985	1995	2005
1.	Miri	50,700	72,100	106,500	153,100
2.	Bekenu	12,900	15,700	19,100	22,700
5.	Sg. Bakong	5,780	7,400	9,500	11,900
	Beluru	380	540	790	1,100
	Others	5,400	6,860	8,710	10,800
6.	Sg. Tinjar	10,220	12,800	16,400	20,500
7.	Lower Bg. Baram	10,900	13,000	15,800	18,400
	Marudi	5,000	5,700	6,600	7,300
	Others	5,900	7,300	9,200	11,100
8.	Bg. Baram Middle	6,500	8,000	9,900	12,100
	Long Lama	1,500	2,000	2,700	3,300
	Others	5,000	6,000	7,200	8,800
9.	Upper Bg. Baram	8,600	9,200	10,000	10,600
10.	Sg. Tutoh/Apoh	6,200	7,600	9,500	11,700
11.	N. Medamit	6,200	7,000	7,800	8,500
12.	Limbang	18,000	21,900	27,000	32,500
	TOTAL	136,000	174,700	231,500	302,000
3.	B. Niah	14,200	17,300	21,100	25,200
4.	Bintulu	18,200	28,800	51,100	90,600

Appendix Fig. A-4-1 Population Distribution by Major River Basin



Appendix Note A.4.1

Estimate of River Transport Demand in the Study Area

Appendix Note A.4.1 Estimate of River Transport Demand in the Study Area

(1) Estimate of Goods Traffic Demand by River

Goods movement to and from the Study Area consists mainly of exports of agricultural products, timber and stones while imports are general consumer goods, construction materials, fertilizer, animal feed and fuels. The goods movement which relate to the Project Road will be mainly those transported to and from the Baram District and partly of those to and from the Limbang District.

1) Estimate of Goods Requirement in the Baram and Limbang Districts

Most of the goods required for consumption in the Baram and Limbang Districts are those needing to be imported. In order therefore to estimate the amount of goods to these Districts the per capita consumption level of food, milled wheat, sugar, beverages, cement, iron and steel, fuels and other general goods was determined based on the available statistics and the results of the field survey as is shown in Appendix Table A . Appendix Table B shows the assumed consumption of animal feed and fertilizer usage in terms of per livestock head and per ha. respectively. Appendix Table A-4-2 shows the comparative figures of per capita consumption of major import items for Sarawak, Miri, Marudi and Limbang. Appendix Table C summarizes the estimated consumption of goods in the Baram and Limbang Districts.

Appendix Table A Estimated Per Capita Consumption by Commodity Item/Group for Baram and Limbang Districts 1/

kg/person

Commodity Group/ Item	Baram				Limbang			
	1977	1985	1995	2005	1977	1985	1995	2005
Food	40	46.9	57.1	69.6	40	46.9	57.1	69.6
Milled Wheat	5	5.9	7.1	8.7	7	8.2	10.0	12.2
Sugar	15	17.6	21.4	26.1	17	19.9	24.3	29.6
Beverages	5	5.9	7.1	8.7	6	7.0	8.6	10.4
Cement	40	54.7	81.0	119.9	70	95.8	141.8	209.9
Iron and Steel	15	20.5	30.4	45.0	17	23.3	34.4	51.0
Others	130	152.3	185.7	226.3	200	234.3	285.6	348.2
Fuel	210	266.0	357.5	480.5	180	228.0	306.4	411.8
Total	460	569.8	747.3	984.8	537	663.4	868.2	1,142.7

1/ Annual gorwth rate for commodity group/item is assumed as follows; 2% for food, milled wheat, sugar, beverages and others, 3% for fuel and 4% for cement and iron & steel.

Appendix Table B Estimated Per Head Animal Feed Requirements, and Per Hectare Fertilizer Requirements

	1977	1985	1995	2005	
Animal Feed (kg/head)	50	50	50	50	(Limbang)
	20	20	20	20	(Baram)
Fertilizer: (kg/ha)					
Paddy	n.a.	200	200	200	
Rubber	n.a.	165	165	165	
Pepper	n.a.	280	280	280	

Appendix Table C Summarizes the Estimated Amount of Import Goods Required in the Baram and Limbang Districts

tons

Commodity Group/Item	Baram 1977	Baram 1985	Baram 1995	Baram 2005	Limbang 1977	Limbang 1985	Limbang 1995	Limbang 2005
Food	1,928	2,720	4,060	5,930	968	1,535	1,987	2,854
Milled Wheat	241	342	505	741	169	237	348	500
Sugar	723	1,021	1,522	2,224	411	575	846	1,214
Beverages	241	342	505	741	145	202	299	426
Animal Feed 1/	189	221	270	329	261	306	373	454
Fertilizer	3,196	3,272	3,377	3,494	1,843	1,881	1,933	1,991
Cement	1,928	3,173	5,759	10,215	1,694	2,769	4,935	8,606
Iron and Steel	723	1,185	2,161	3,834	411	673	1,197	2,091
Petroleum Products	10,122	15,428	25,418	40,939	4,356	6,589	10,663	16,884
Miscellaneous Cargo	6,266	8,833	13,203	19,281	4,840	6,771	9,939	14,276
Total	25,557	36,537	56,780	87,728	15,098	21,358	32,520	49,296
Per Capita Consumption (tons)	530	630	799	1,030	624	739	934	1,202

1/ Annual growth rate of 2% throughout the years is assumed.

2) Estimate of Outgoing Agricultural Products

Major agricultural products in the areas are rice, rubber and pepper. Nearly all the production of rubber and pepper is exported mainly via Miri, Marudi or Limbang and partly via Kuching. The surplus of rice in Baram District is transported to Miri.

Appendix Table D shows the estimated future deficit/surplus balance of rice in the Study Area. The surplus tonnage of Baram and Limbang Districts will be transported to the Miri area where a deficit of rice is expected to continue.

Appendix Table E shows the tonnage of rubber and pepper to be exported by export point. Export amount tonnage by port were determined with consideration to the present amount levels of the ports.

Appendix Table D Estimated Future Deficit/Surplus Balance of Rice in The Study Area

tons

		1977	1985	1995	2005
Miri 1/ :	Production	2,646	2,997	3,333	3,612
	Demand 2/	7,632	10,097	14,444	19,338
	Balance	Δ4,986	Δ7,100	Δ11,111	Δ15,726
Baram :	Production	10,013	11,162	12,265	13,517
	Demand 2/	7,712	8,700	10,665	12,354
	Balance	2,301	2,462	1,600	1,163
Limbang :	Production	4,777	5,304	5,812	6,563
	Demand 2/	3,751	4,191	5,046	5,740
	Balance	1,026	1,113	766	823
Study ARea :	Production	17,436	19,463	21,410	23,692
	Demand	19,095	22,988	30,155	37,432
	Balance	Δ1,659	Δ3,525	Δ8,745	Δ13,740

1/ Includes Miri and Sibuti sub-districts

2/ Per capita consumption is assumed as follows:

Miri : 120 kg. for 1977, 115 kg. for 1985 and 1995 and 110 kg. for 2005.

Baram : 160 kg. for 1977, 150 kg. for 1985 and 1995 and 145 kg. for 2005.

Limbang : 155 kg. for 1977, 145 kg. for 1985 and 1995 and 140 kg. for 2005.

Appendix Table E Production and Exports of Rubber and Pepper of Baram and Limbang Districts

tons

		Rubber				Pepper			
Area		1977	1985	1995	2005	1977	1985	1995	2005
Baram	Production :	2,500	2,929	3,571	4,353	565	744	1,050	1,480
	Export :								
	Marudi	750	879	1,071	1,306	170	223	315	444
	Miri	750	879	1,071	1,306	170	223	315	444
	Kuching	1,000	1,171	1,429	1,741	225	298	420	592
Limbang	Production :	1,750	2,050	2,499	3,047	85	435	613	865
	Export :								
	Limbang	788	923	1,125	1,371	60	305	429	606
	Kuching	962	1,127	1,374	1,676	25	130	184	259

3) Transport of Stones

At present stones are being produced in Batu Gadin near Long Lama. Current production is approximately 150,000 tons per year and nearly all are transported in 300 to 400 ton barges down to Marudi, Miri and Brunei.

Roughly 15,000 tons are utilized in Marudi, while the rest are transported mostly to the Miri areas and partly to Brunei. It has been confirmed that the reserves are large enough to supply stones for the next 20 years at the present production level and it is expected that even after this period stones will be readily available. Production and export of stones were estimated as shown in Appendix Table F .

Appendix Table F Production and Export of Stones from Batu Gading

000tons

	1978	1985	1995	2005
Production 1/ :	150	184.5	247.9	333.2
Export:				
Marudi 2/	15	16.6	19.3	22.4
Miri/Brunei	135	167.9	228.6	310.8

1/ Annual growth rate of 3% is assumed.

2/ Annual growth rate of 1.5% is assumed.

4) Transport of Timber

Of the whole timber production of the Baram District, the tonnage produced uprivers of the Project Road will be affected by the implementation of the Project Road as shown in Appendix Table G . Production of hill timber in the upriver areas of the Project Road is assumed to increase.

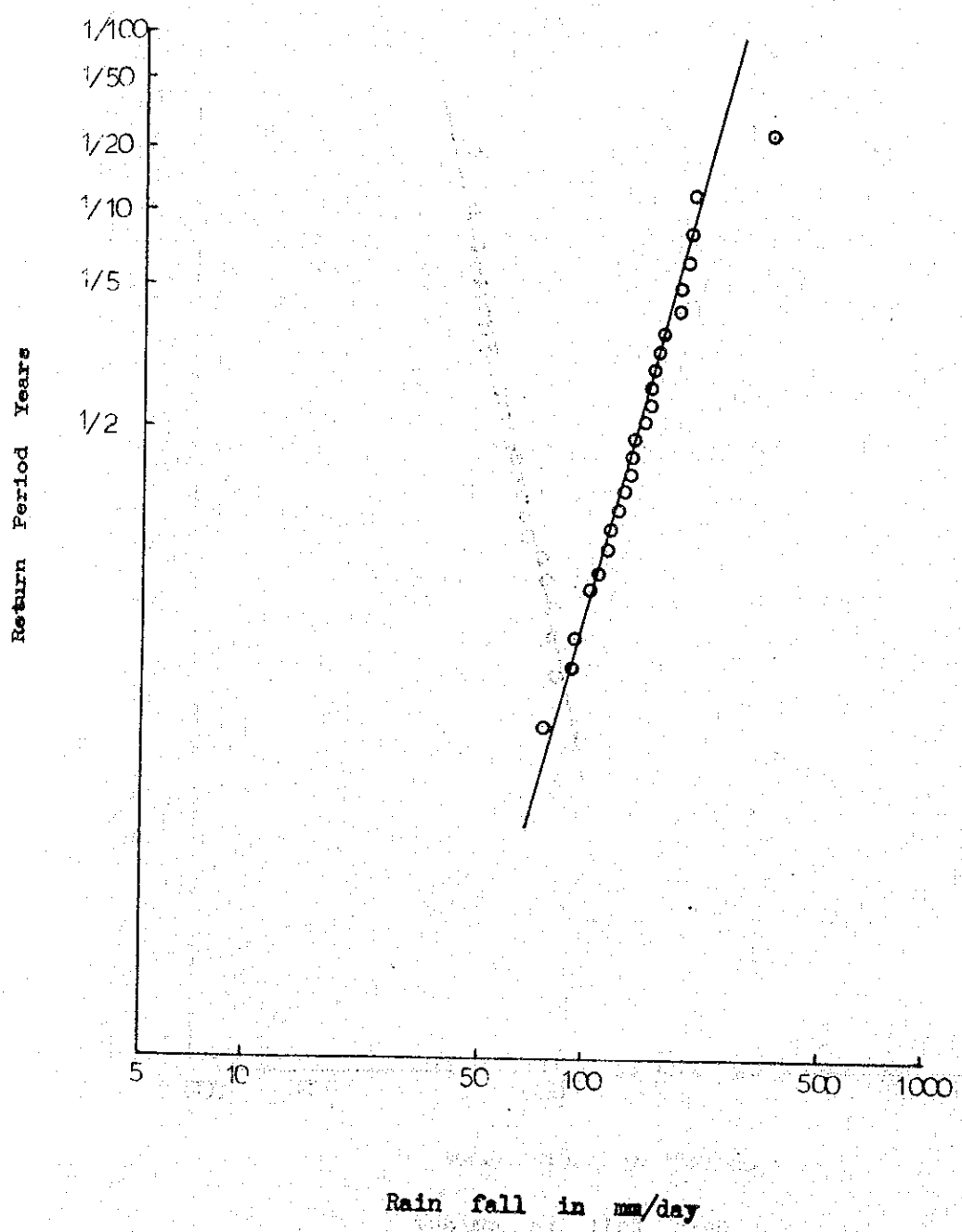
Appendix Table G Production and Export of Hill Timber of The Baram District

Area	1977	1985	1995	2005
				H/T
Whole of Baram	600	610	665	715
Area upriver of the Project Road	150	201	286	380
(% of whole of Baram)	(25)	(33)	(43)	(53)

Appendix Fig. A-5-1

PROBABLE MAXIMUM DAILY RAINFALL

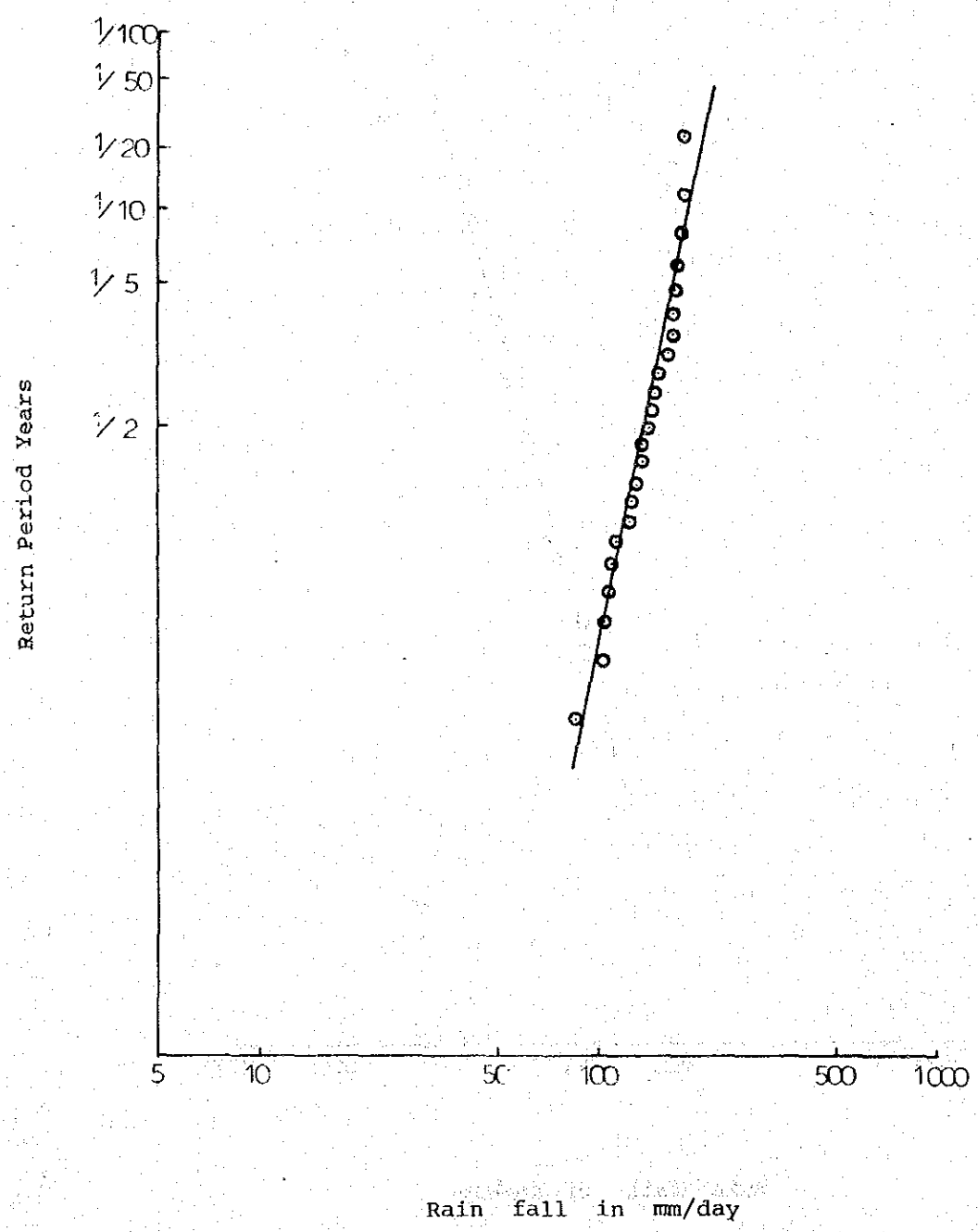
4 - 1 Lutong



Appendix Fig. A-5-2

PROBABLE MAXIMUM DAILY RAINFALL

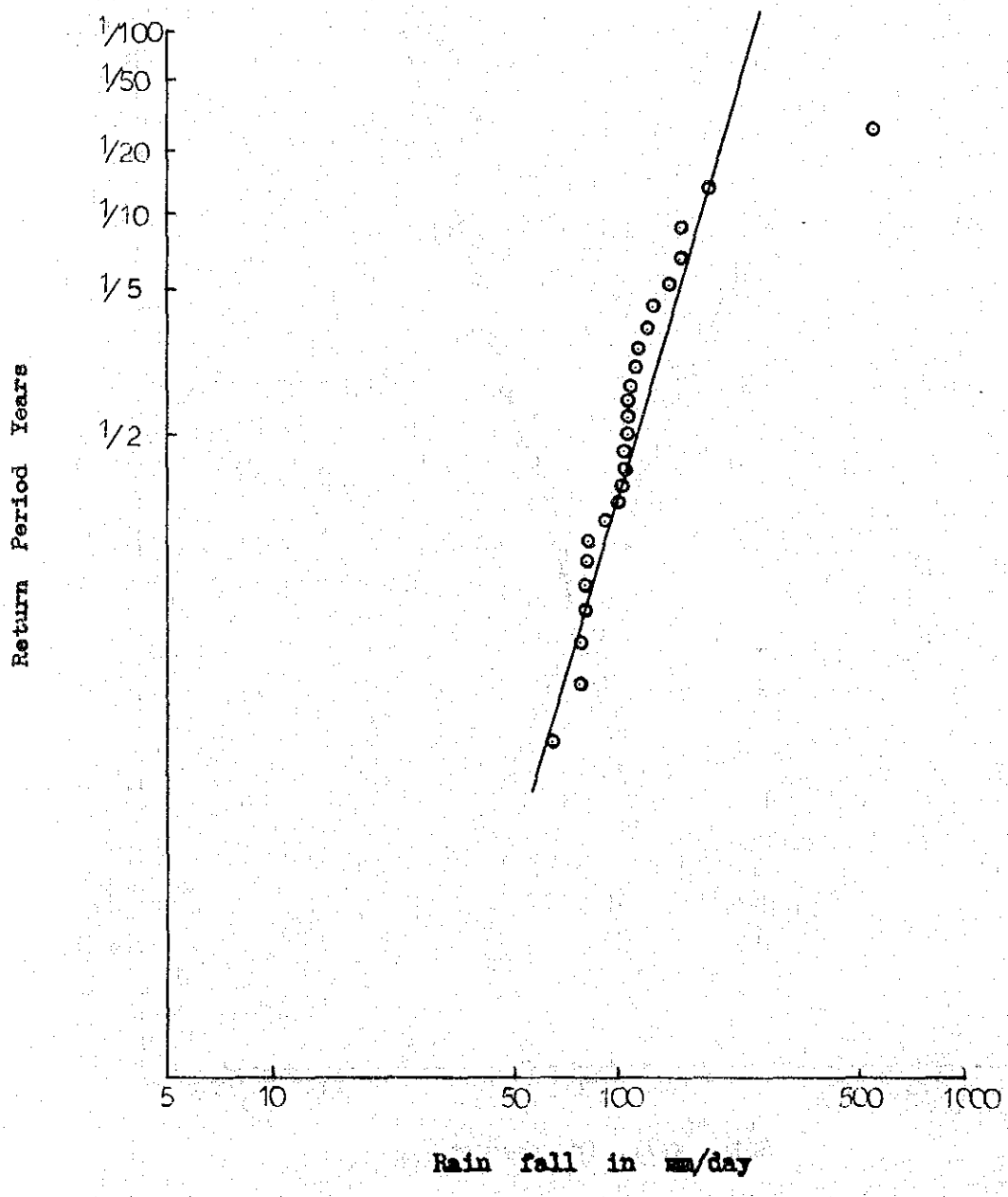
4 - 3 Long Akah



Appendix Fig. A-5-3

PROBABLE MAXIMUM DAILY RAINFALL

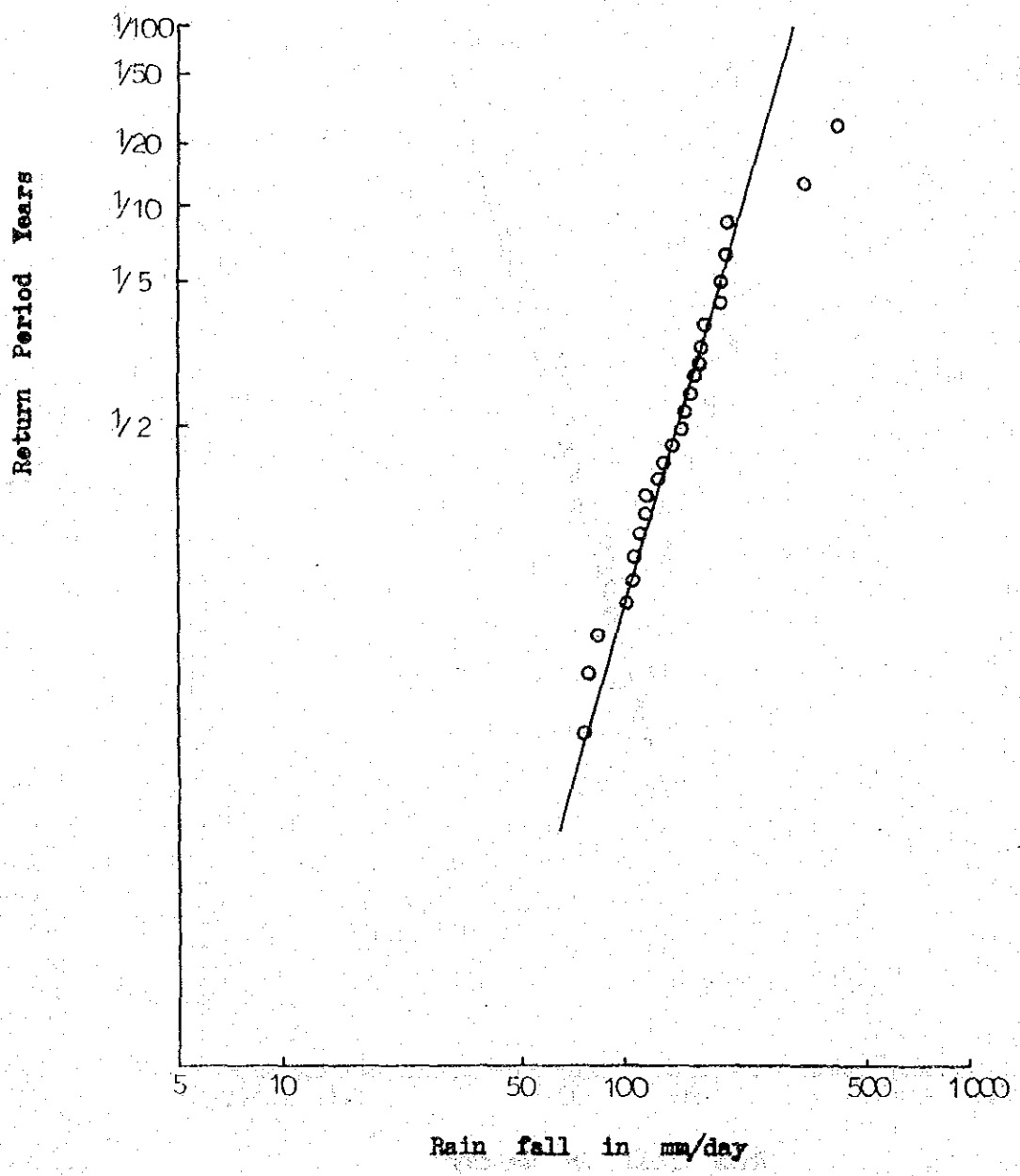
4 - 4 Marudi Aiffield



Appendix Fig. A-5-4

PROBABLE MAXIMUM DAILY RAINFALL

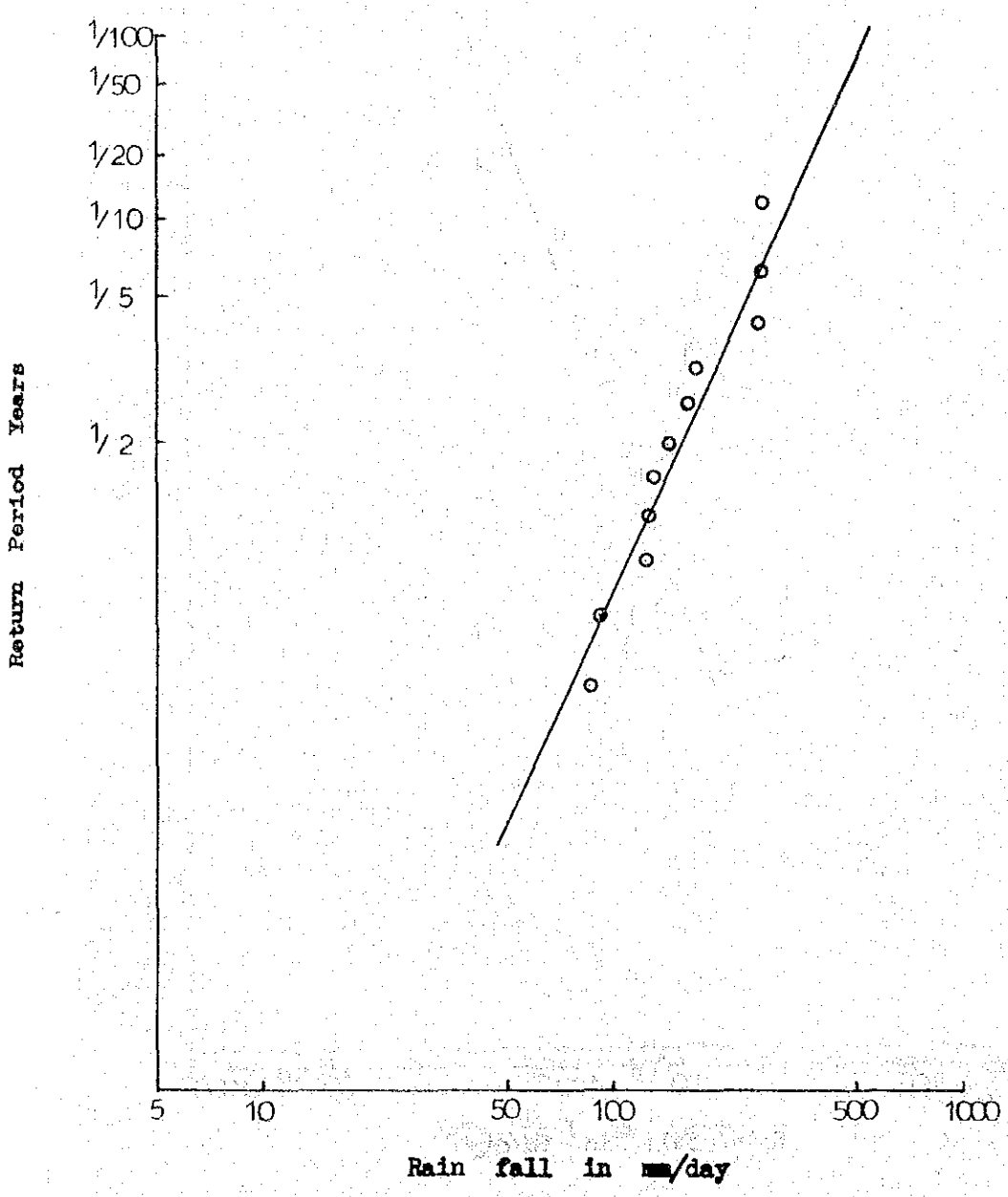
4 - 5 Miri Airport



Appendix Fig. A-5-5

PROBABLE MAXIMUM DAILY RAINFALL

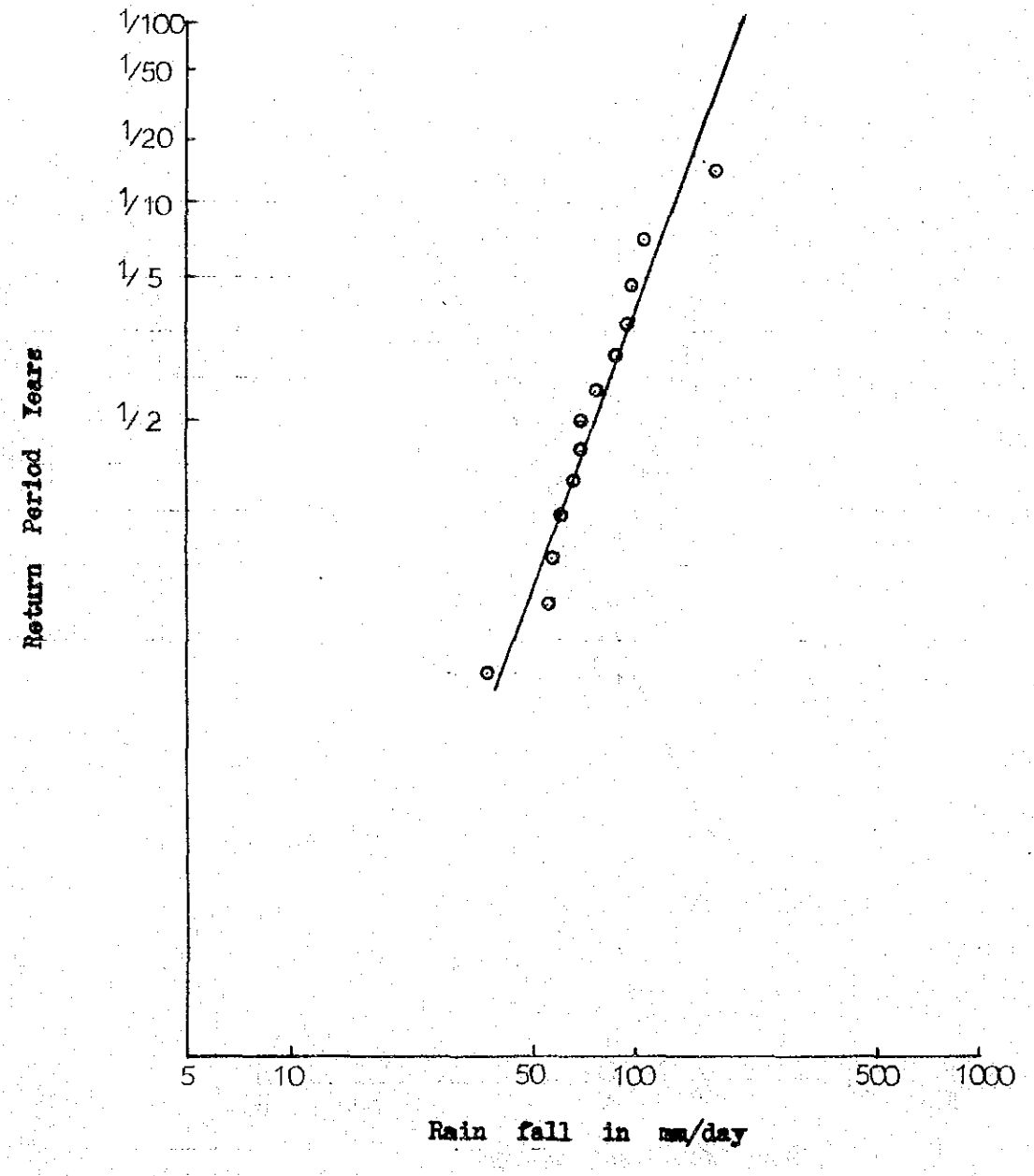
4 - 6 Bekenu Sibuti



Appendix Fig. A-5-6

PROBABLE MAXIMUM DAILY RAINFALL

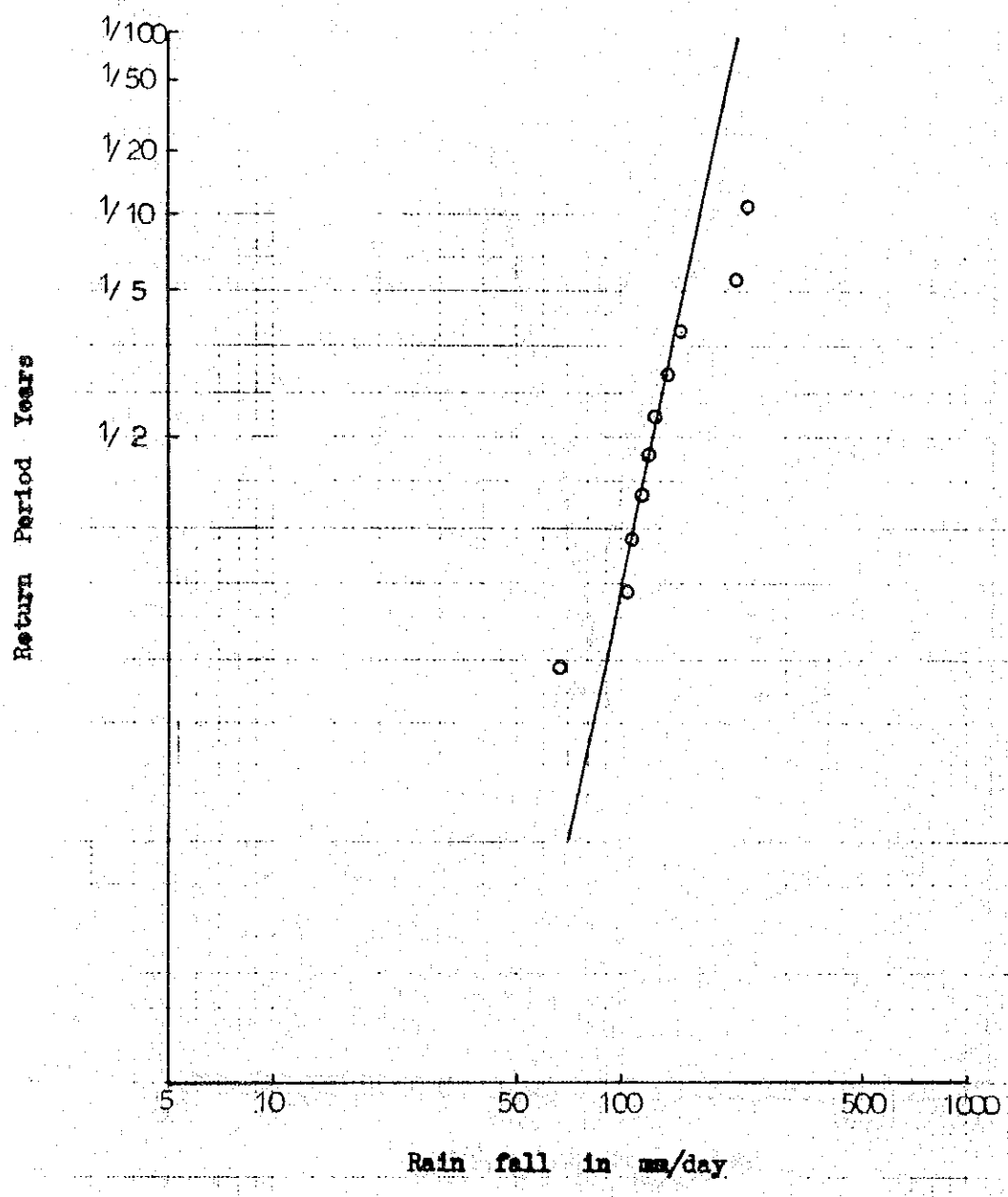
4 - 7 Bario



Appendix Fig. A-5-7

PROBABLE MAXIMUM DAILY RAINFALL

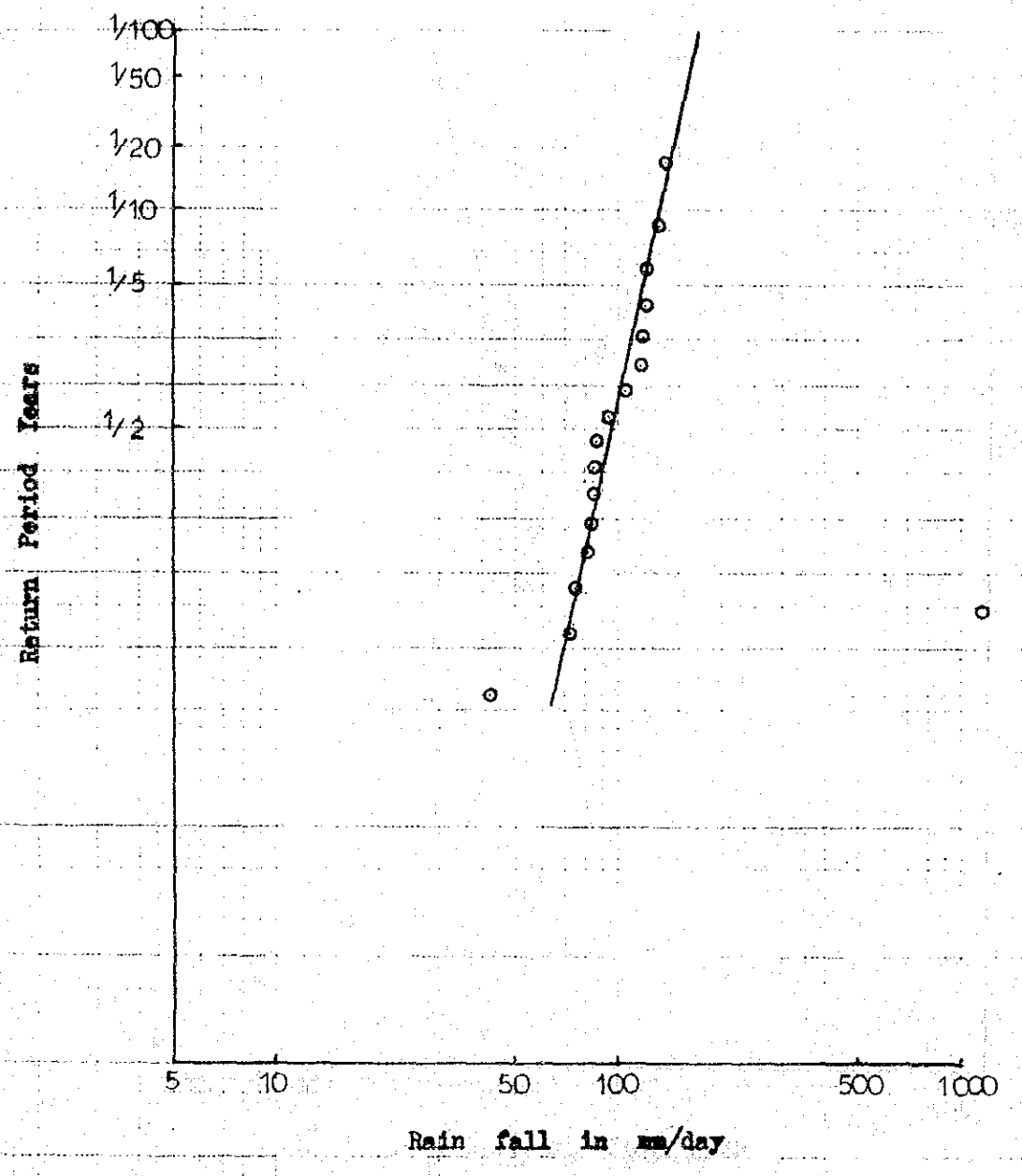
4 - 9 Long Lama



Appendix Fig. A-5-8

PROBABLE MAXIMUM DAILY RAINFALL

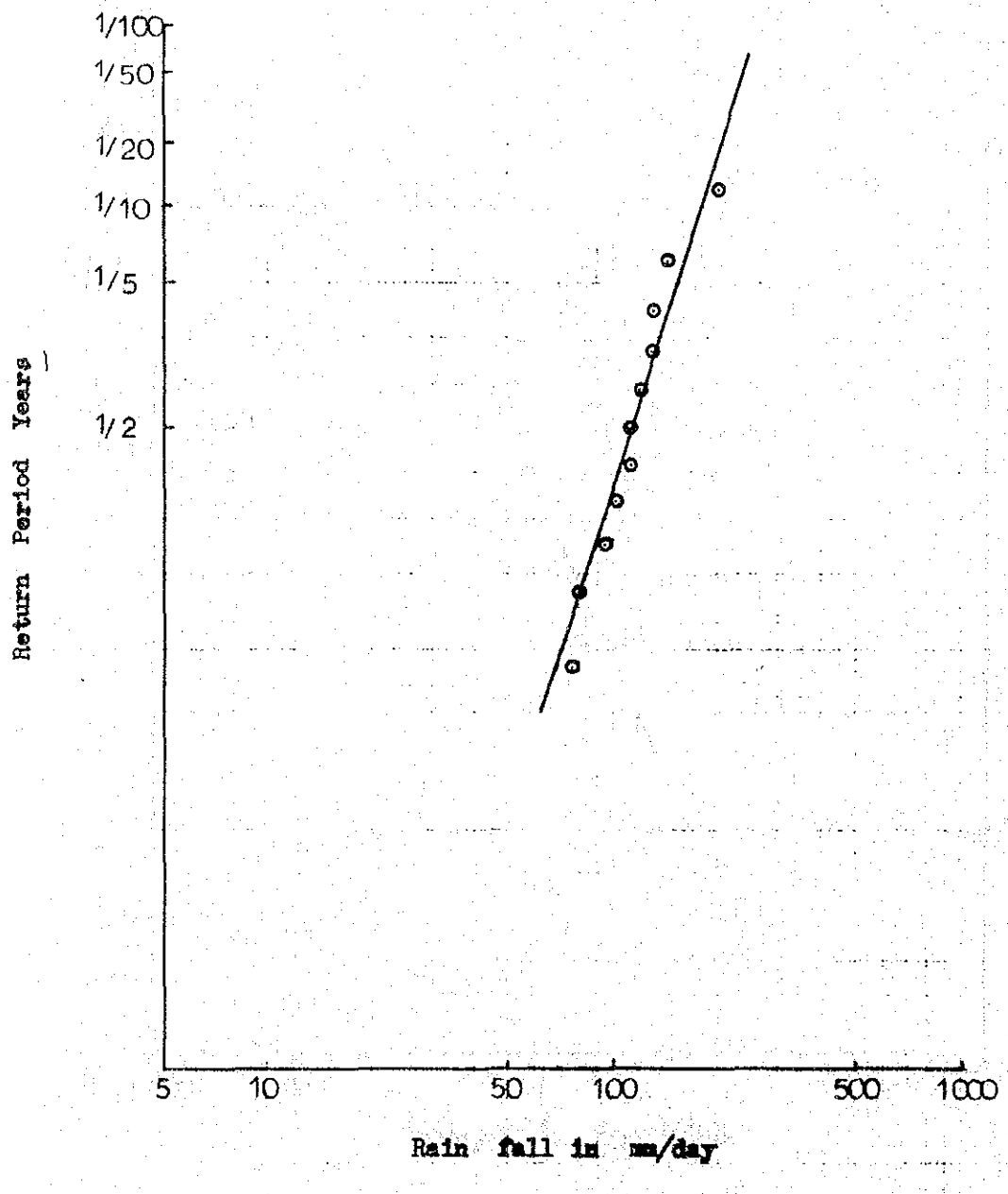
4 - 11 Lio Matu



Appendix Fig. A-5-9

PROBABLE MAXIMUM DAILY RAINFALL

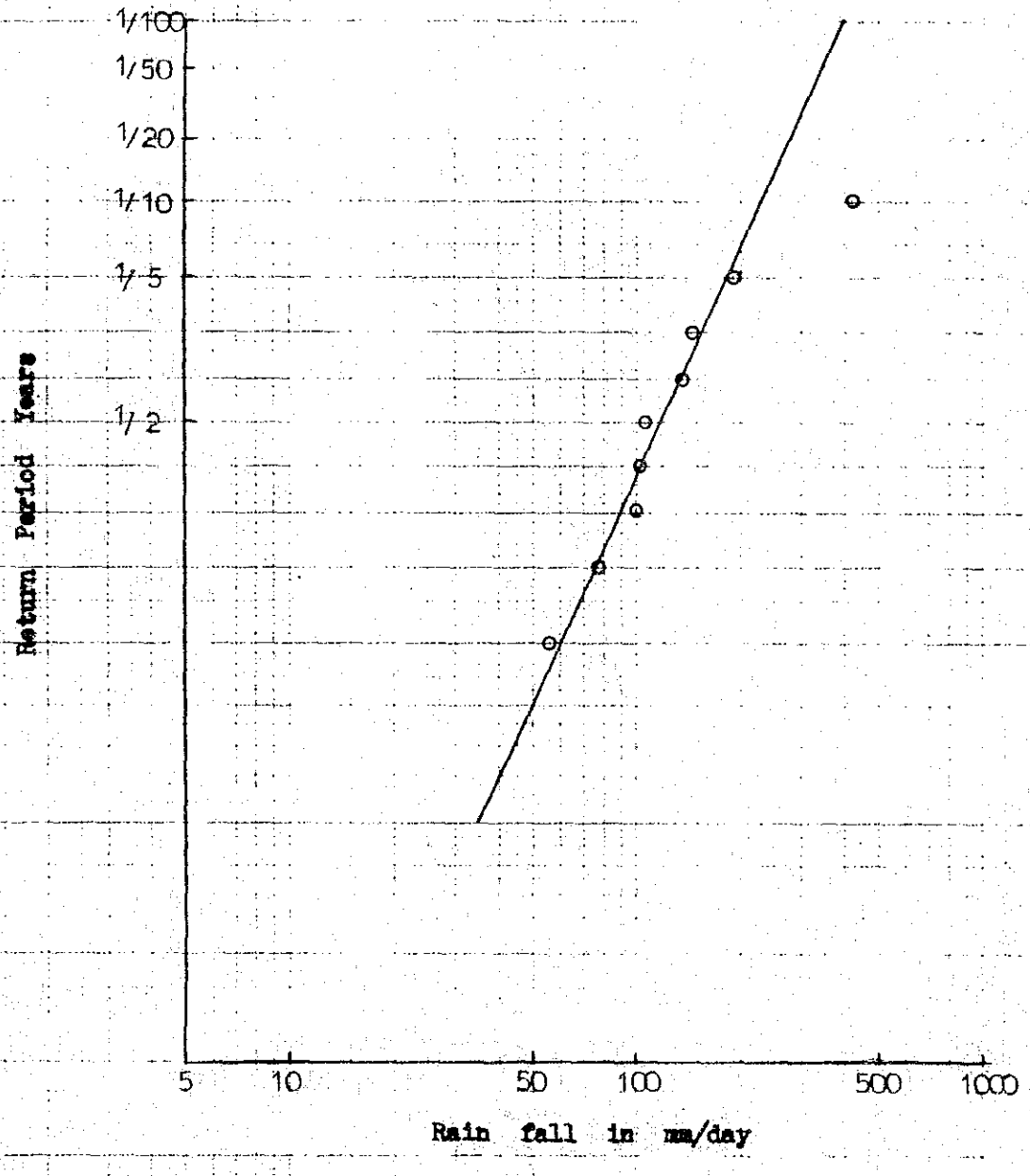
4 - 15 Long Moh



Appendix Fig. A-5-10

PROBABLE MAXIMUM DAILY RAINFALL

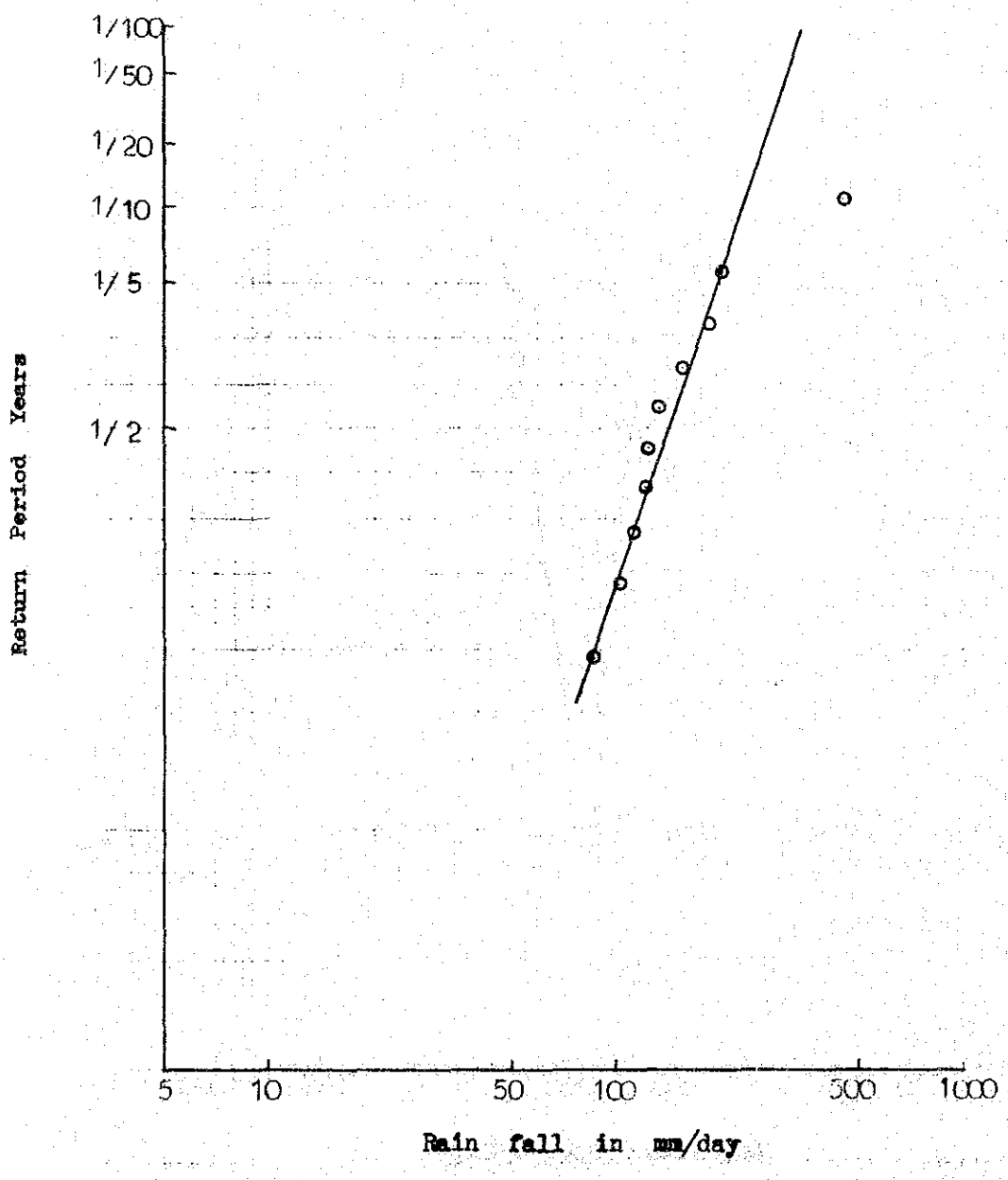
4 - 16 Niah



Appendix Fig. A-5-11

PROBABLE MAXIMUM DAILY RAINFALL

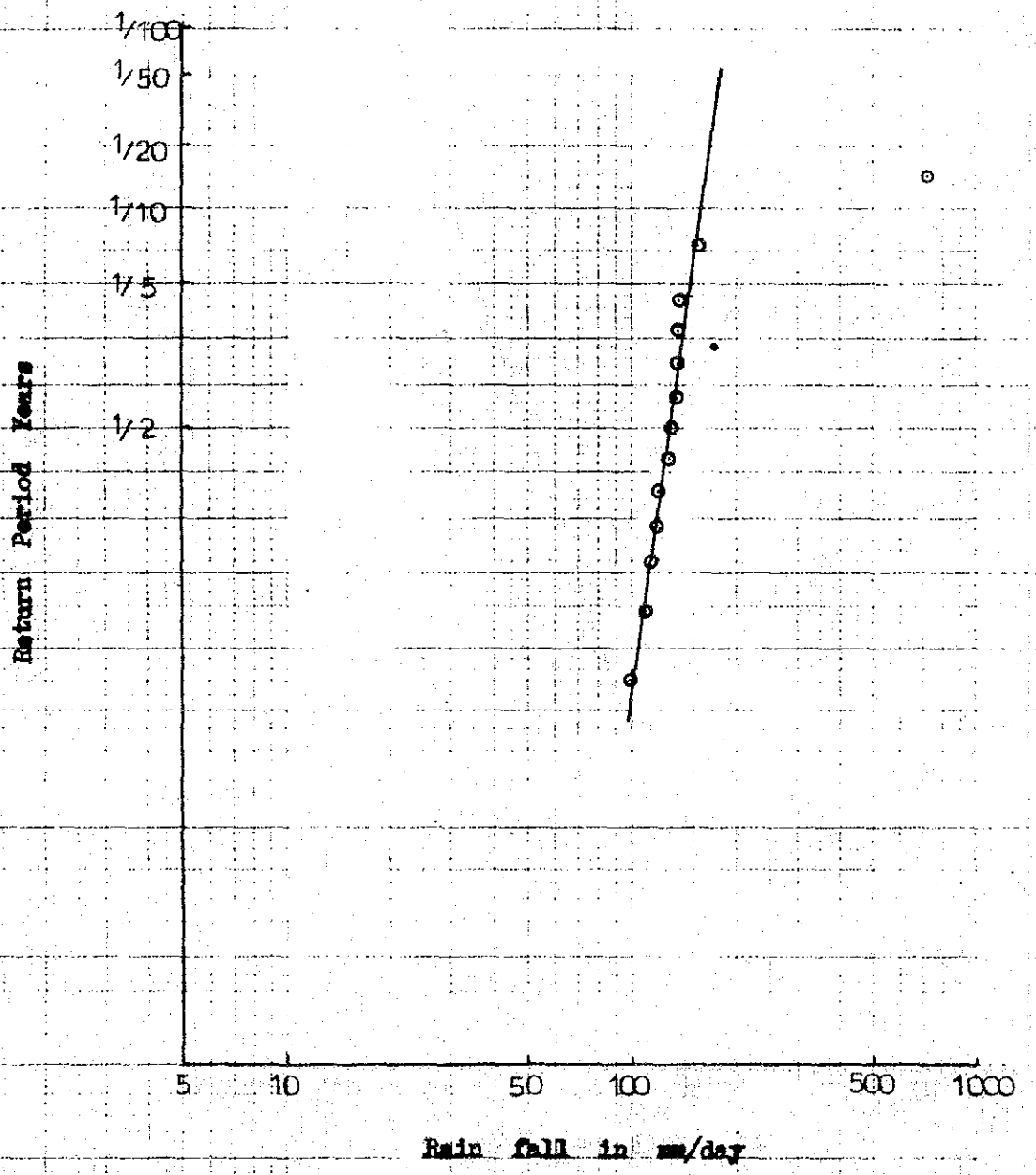
4 → 17 Long Panai



Appendix Fig. A-5-12

PROBABLE MAXIMUM DAILY RAINFALL

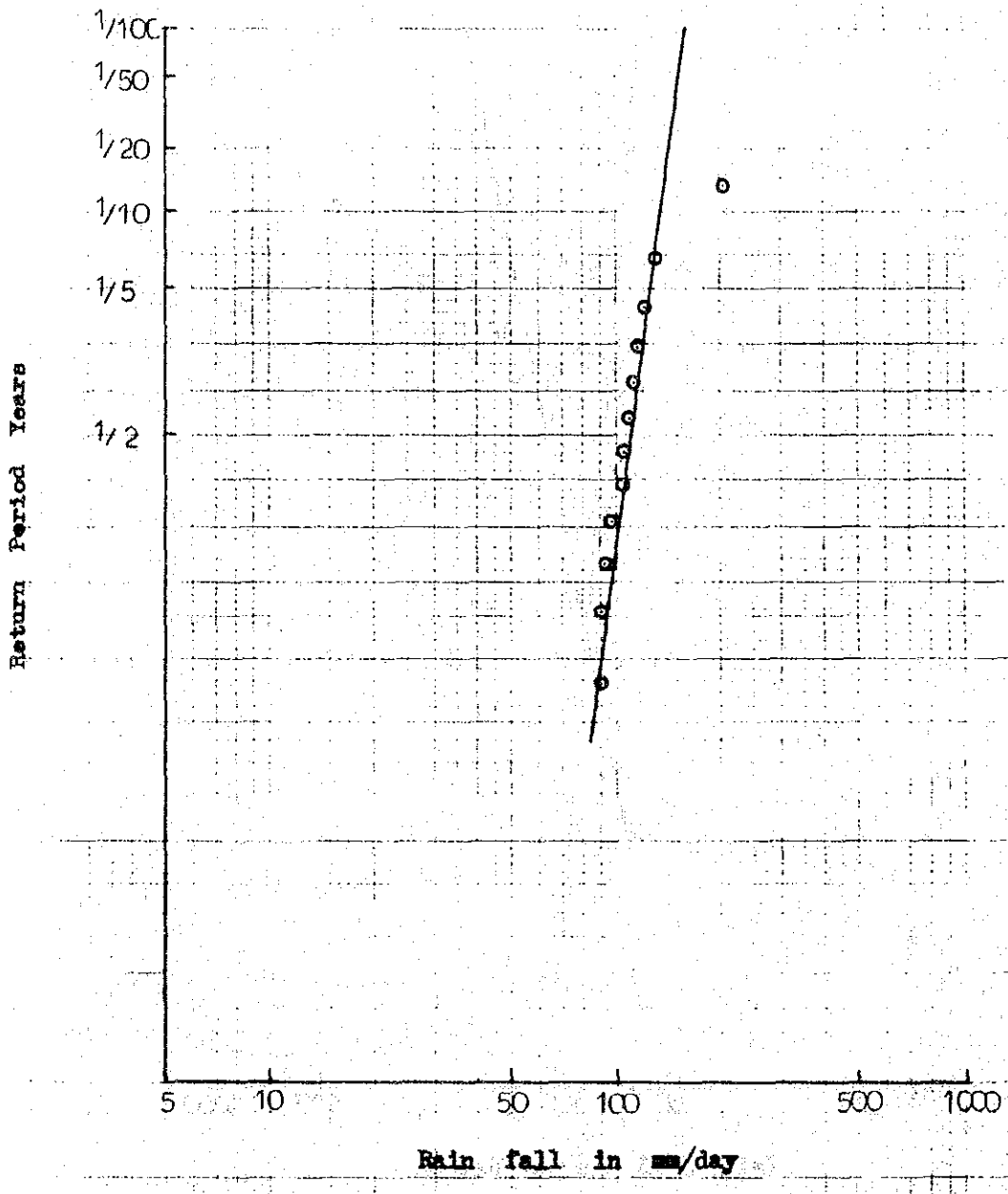
4 - 18 Long Pilah



Appendix Fig. A-5-13

PROBABLE MAXIMUM DAILY RAINFALL

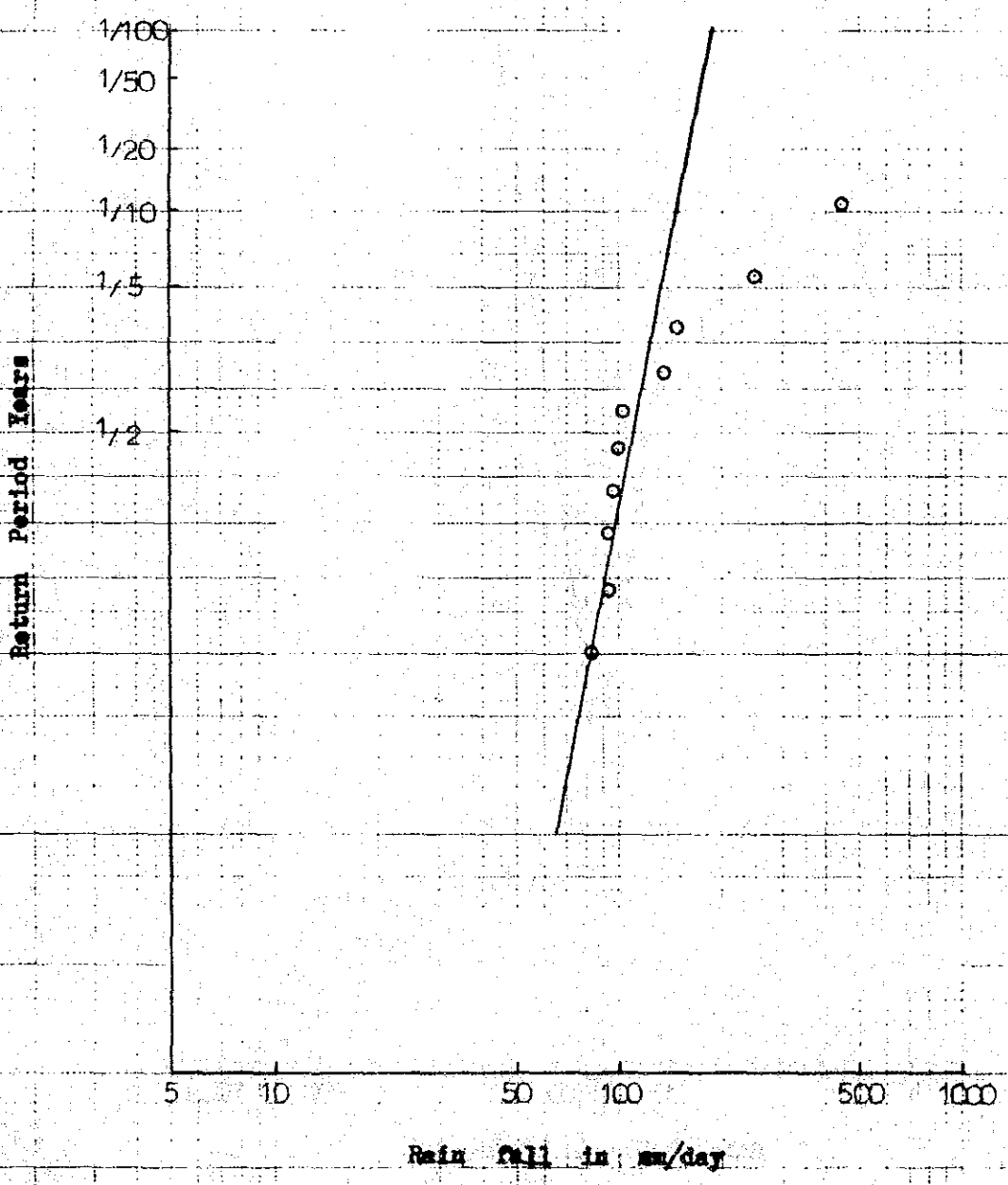
4 - 20 Long Seridan



Appendix Fig. A-5-14

PROBABLE MAXIMUM DAILY RAINFALL

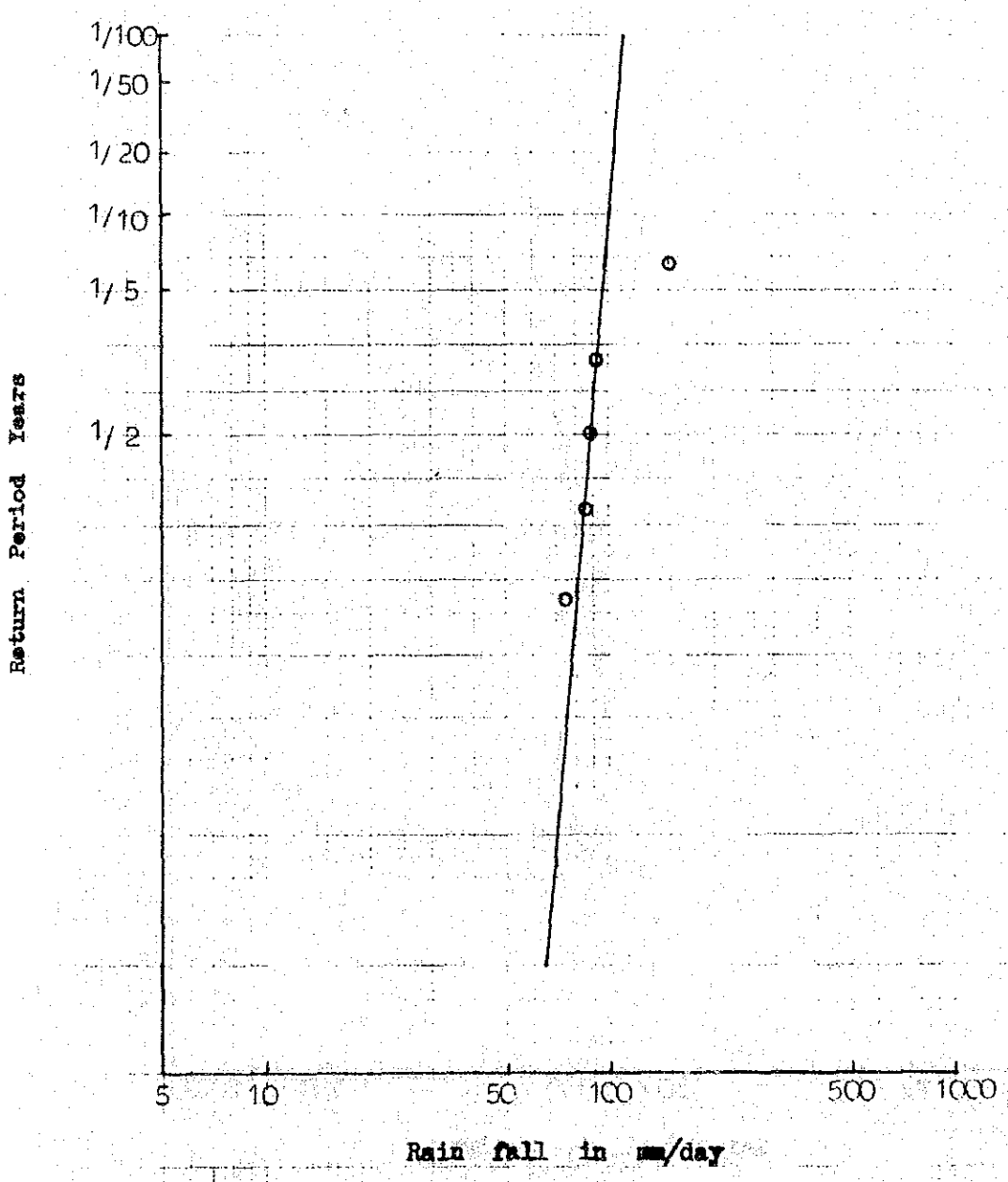
4 - 21 Tuban



Appendix Fig. A-5-15

PROBABLE MAXIMUM DAILY RAINFALL

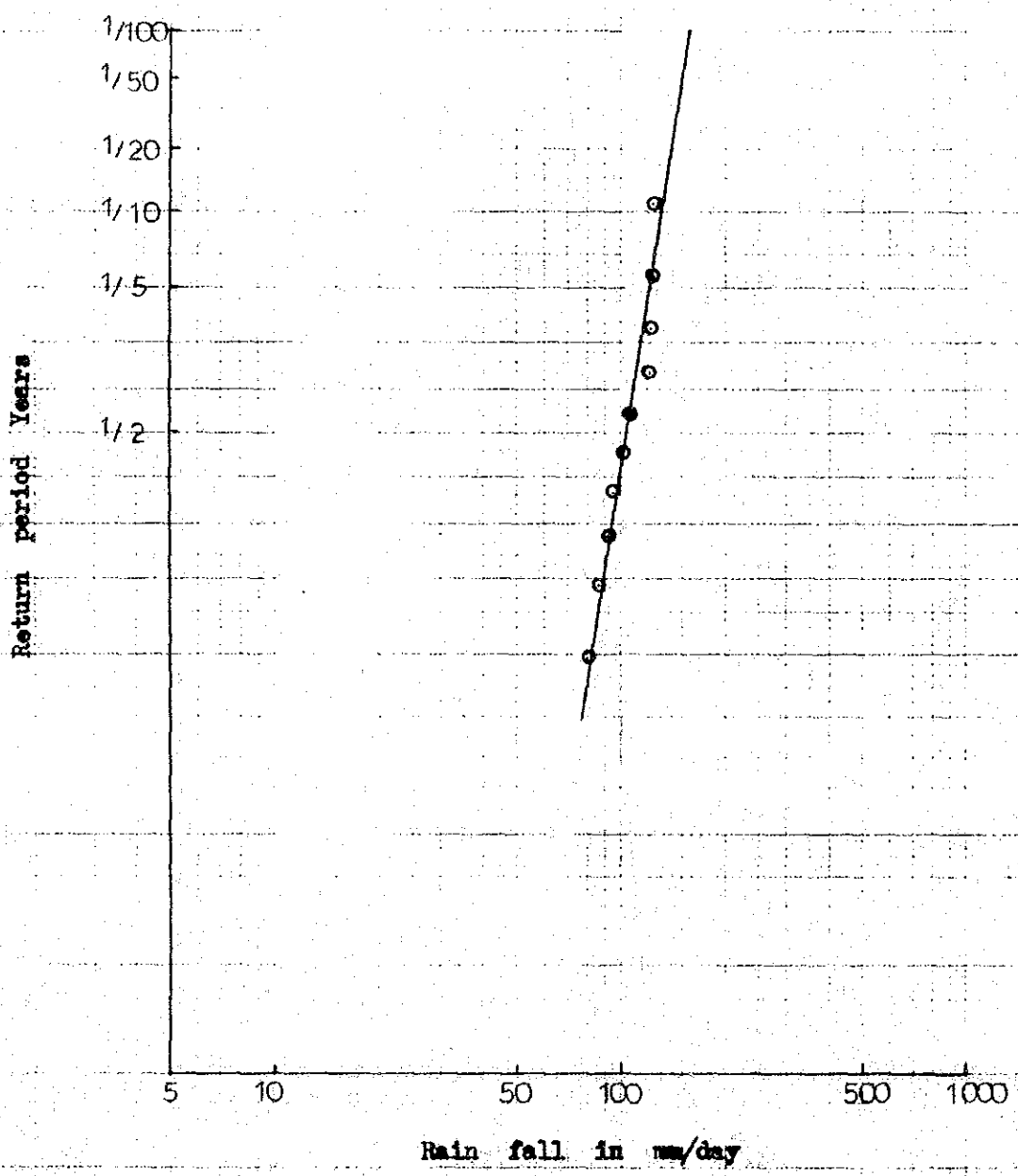
4 - 23 Sebauh



Appendix Fig. A-5-16

PROBABLE MAXIMUM DAILY RAINFALL

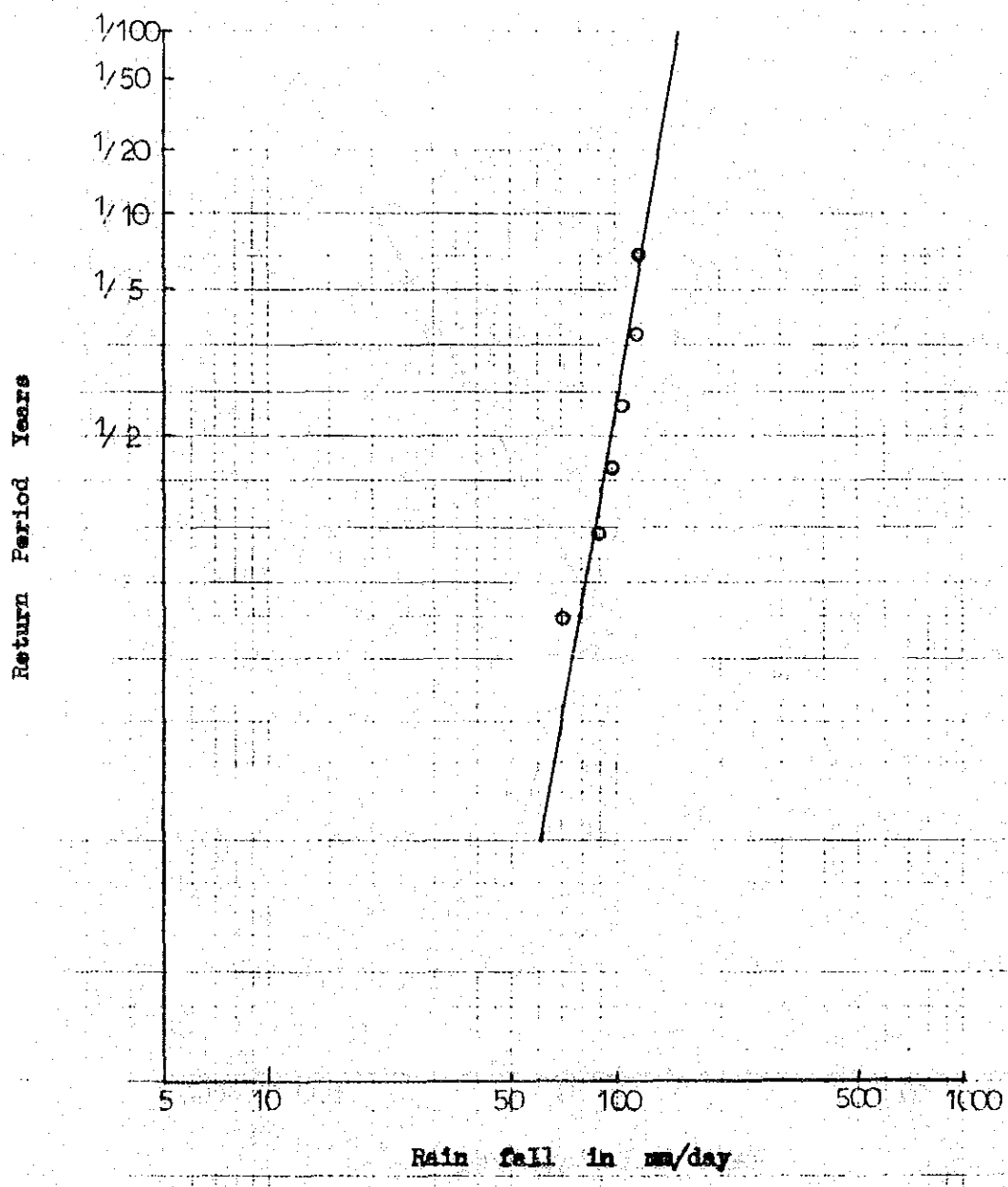
4 - 26 Long Anap



Appendix Fig. A-5-17

PROBABLE MAXIMUM DAILY RAINFALL

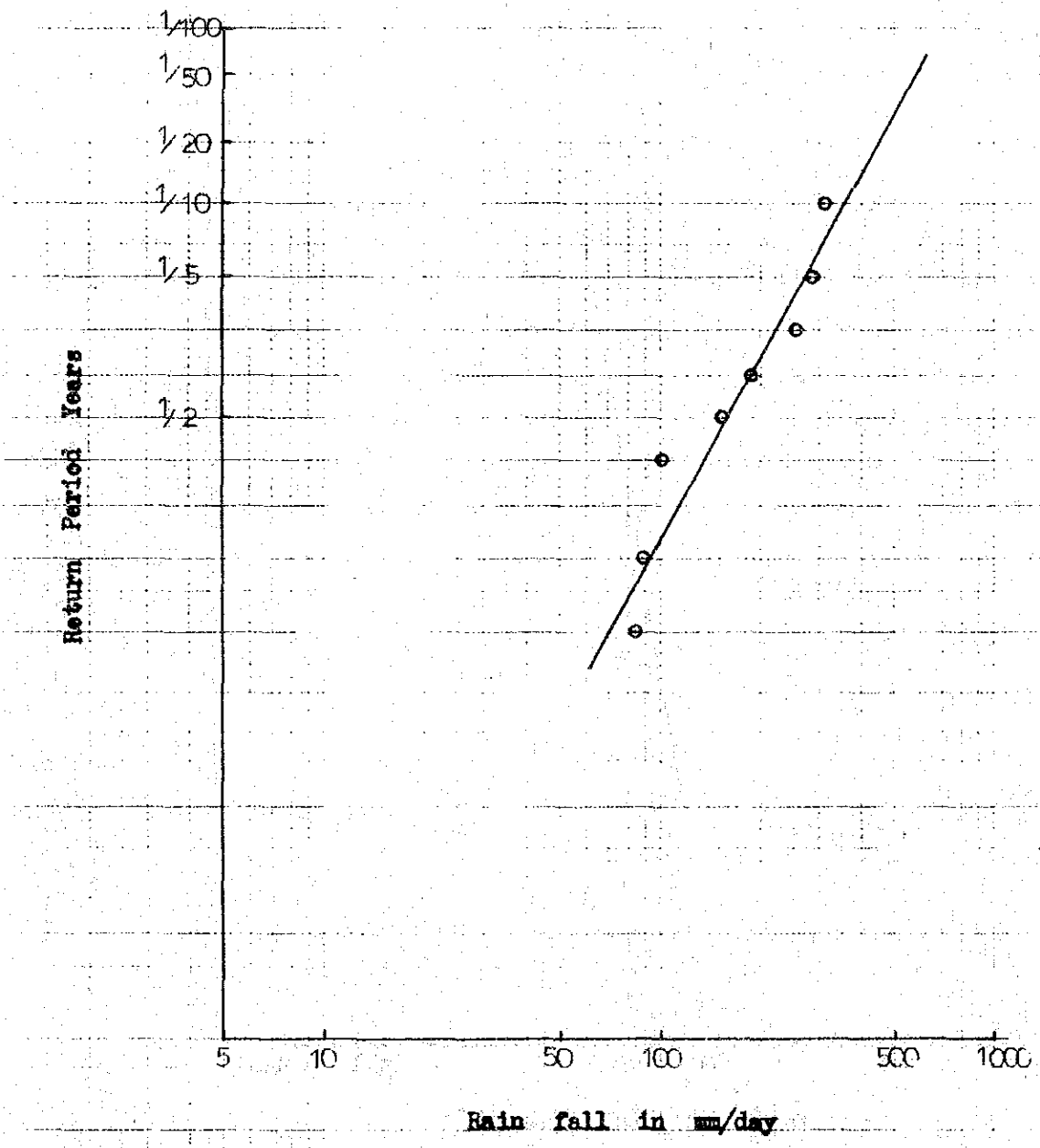
4 - 28 Long Leliang



Appendix Fig. A-5-18

PROBABLE MAXIMUM DAILY RAINFALL

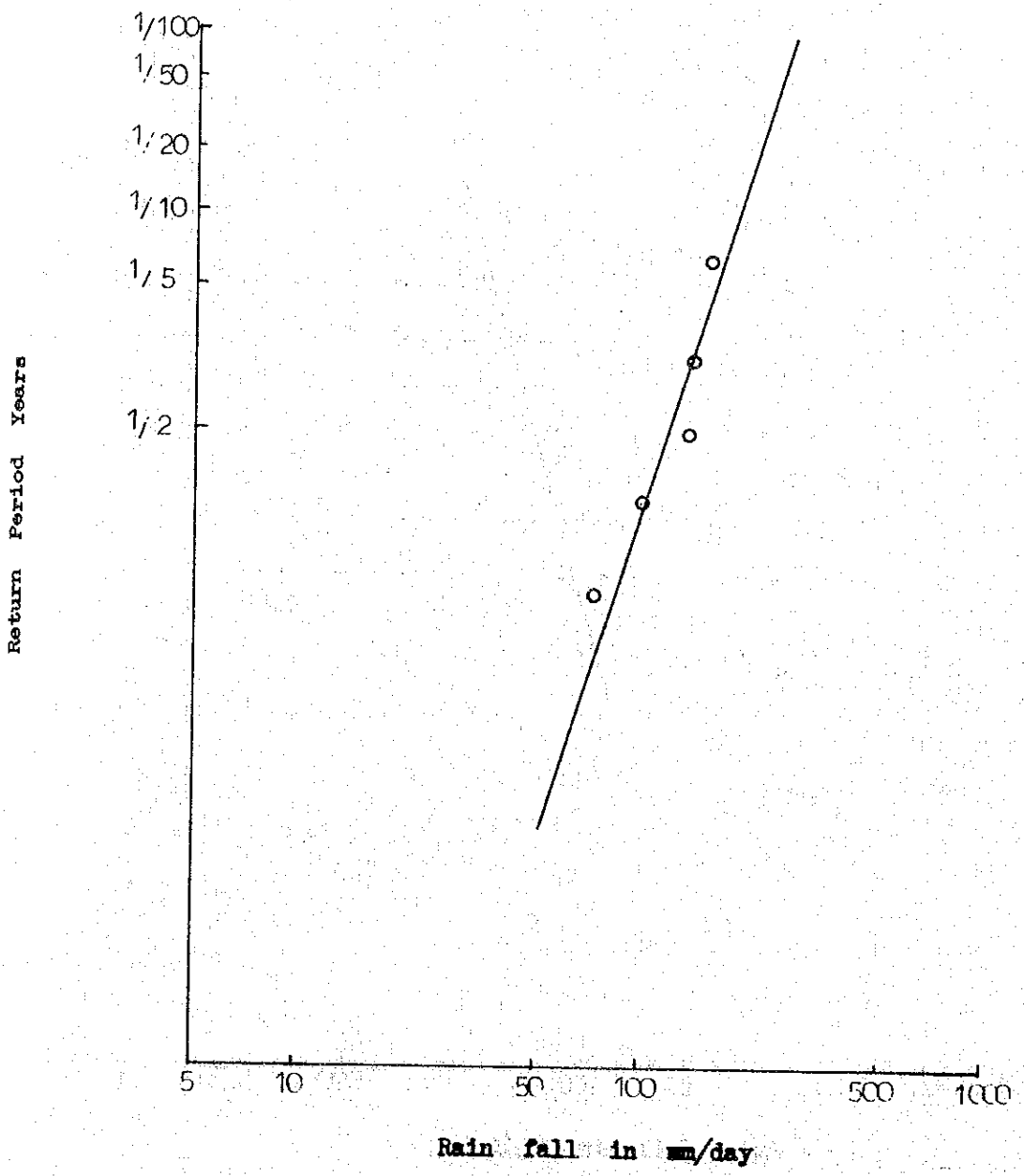
4 - 32 Long Subing



Appendix Fig. A-5-19

PROBABLE MAXIMUM DAILY RAINFALL

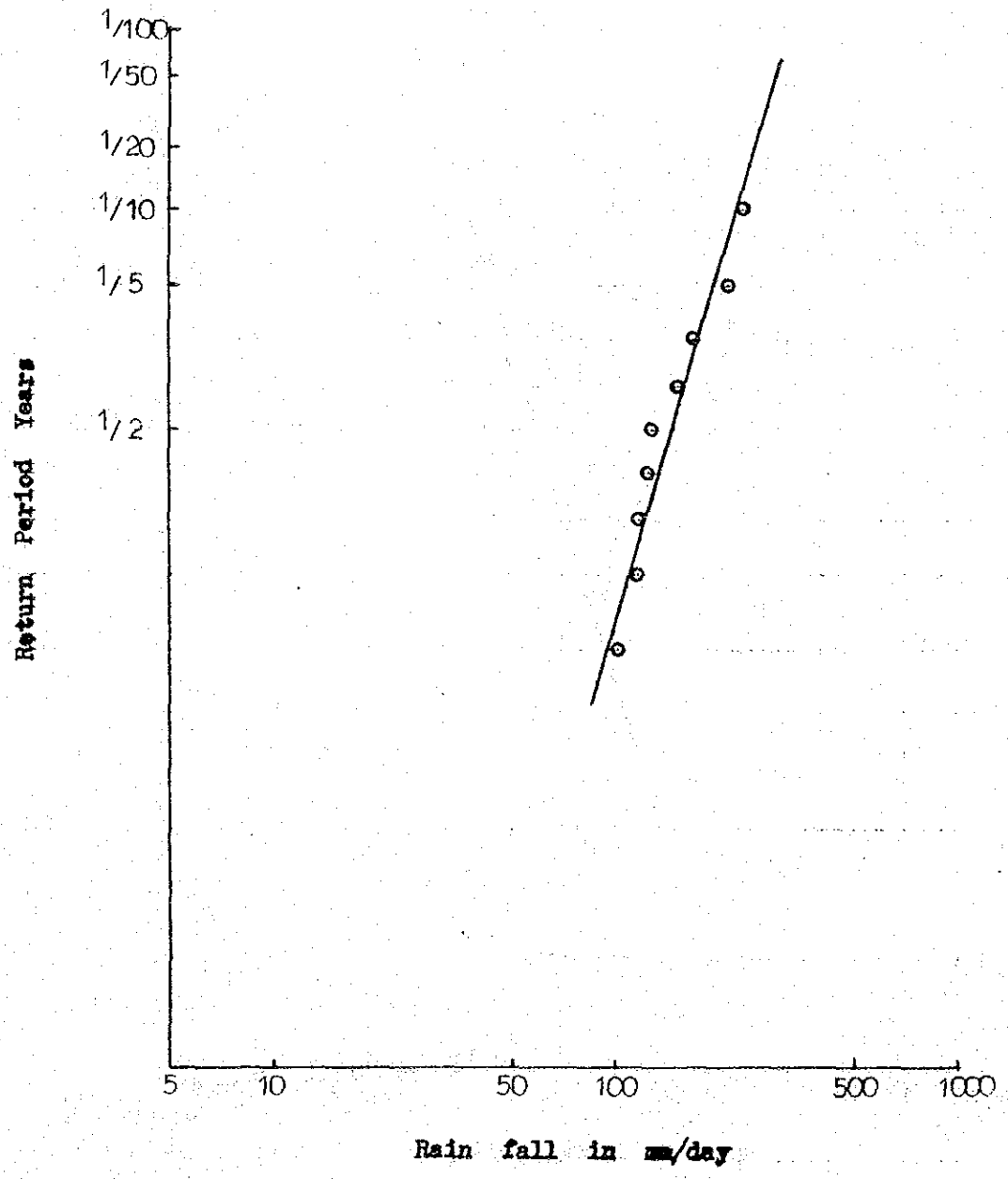
4 - 33 Long Japan



Appendix Fig. A-5-20

PROBABLE MAXIMUM DAILY RAINFALL

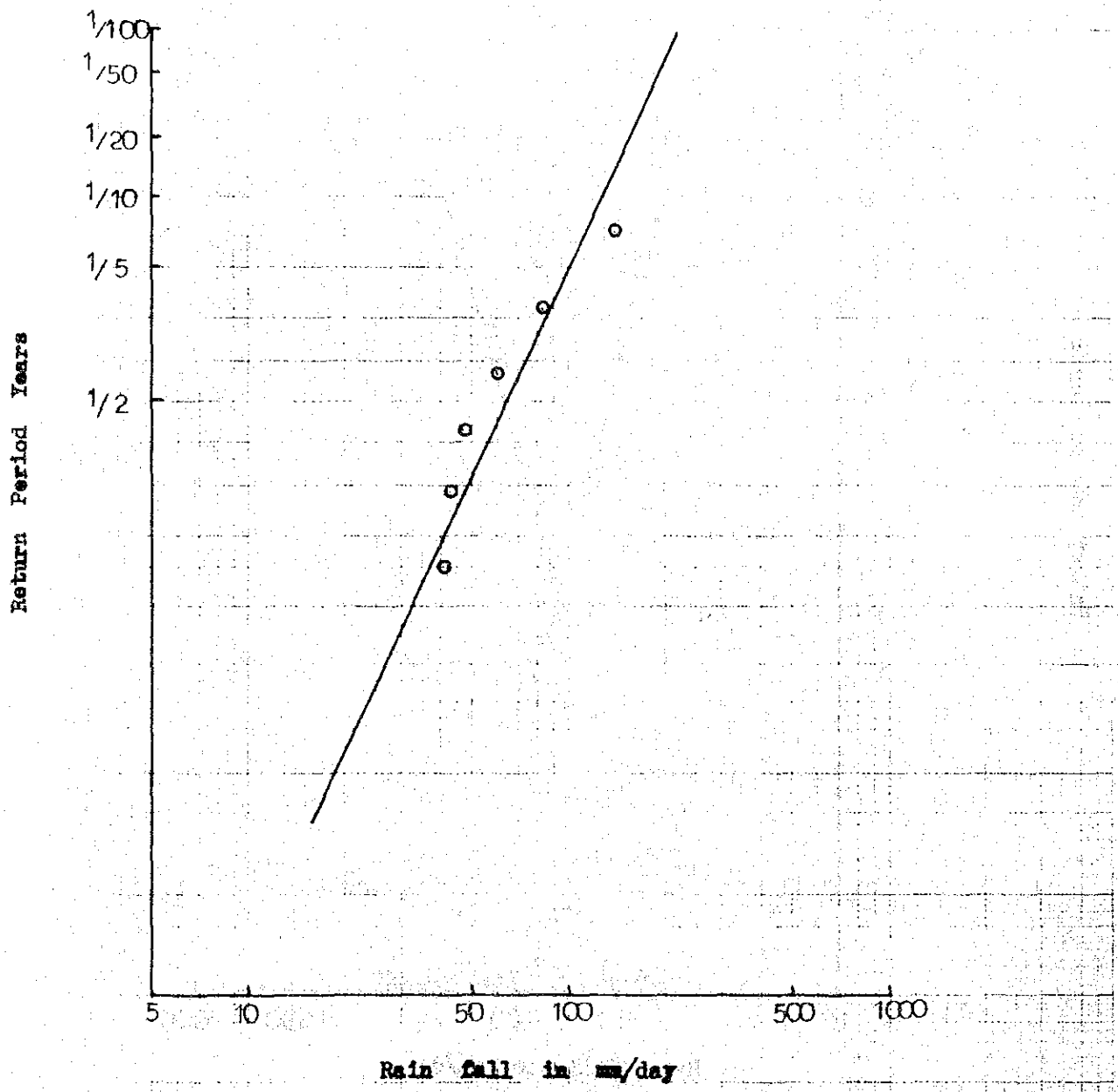
4 - 35 Long Atip



Appendix Fig. A-5-21

PROBABLE MAXIMUM DAILY RAINFALL

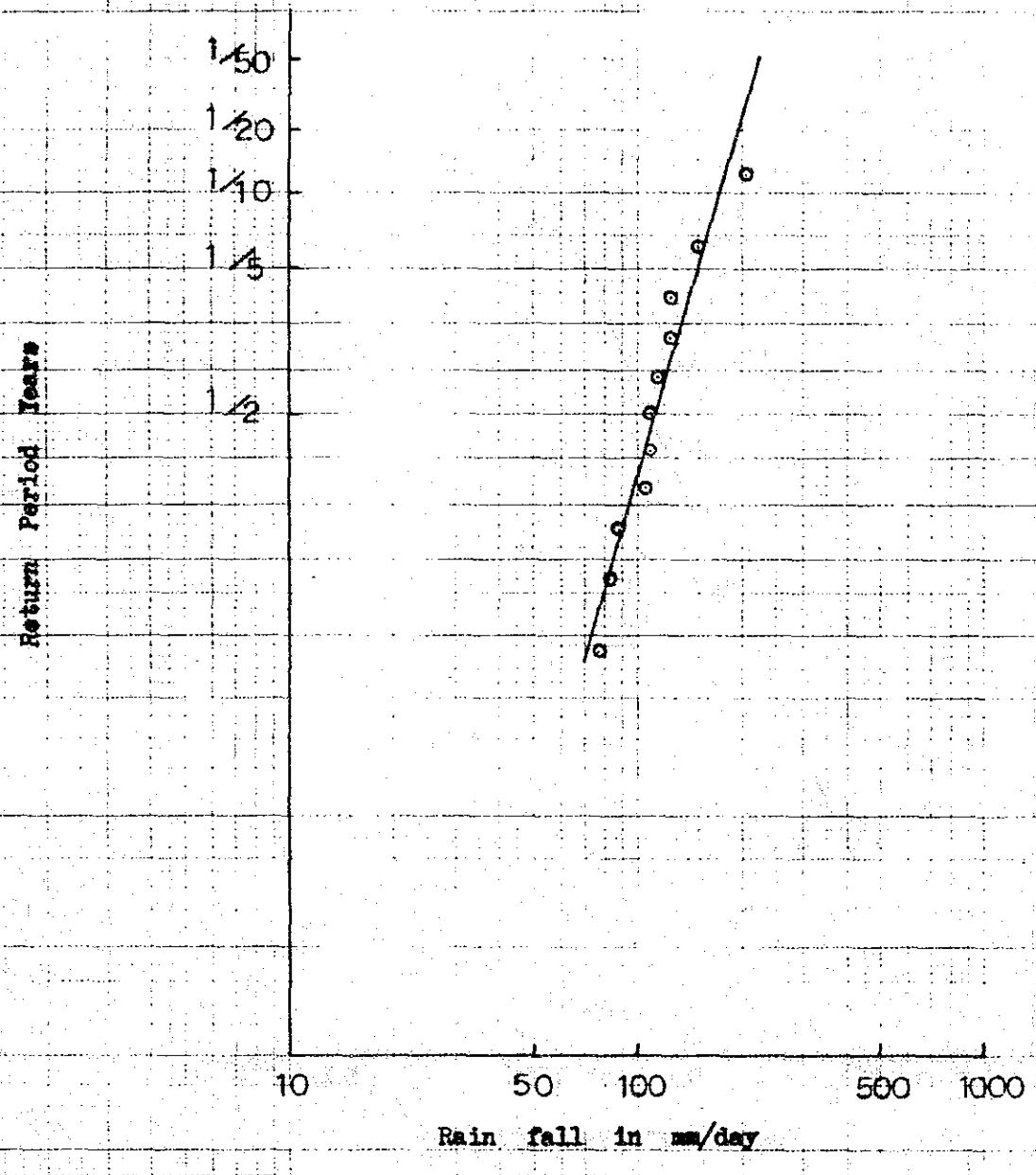
4 - 45 Sg. Niah



Appendix Fig. A-5-22

PROBABLE MAXIMUM DAILY RAINFALL

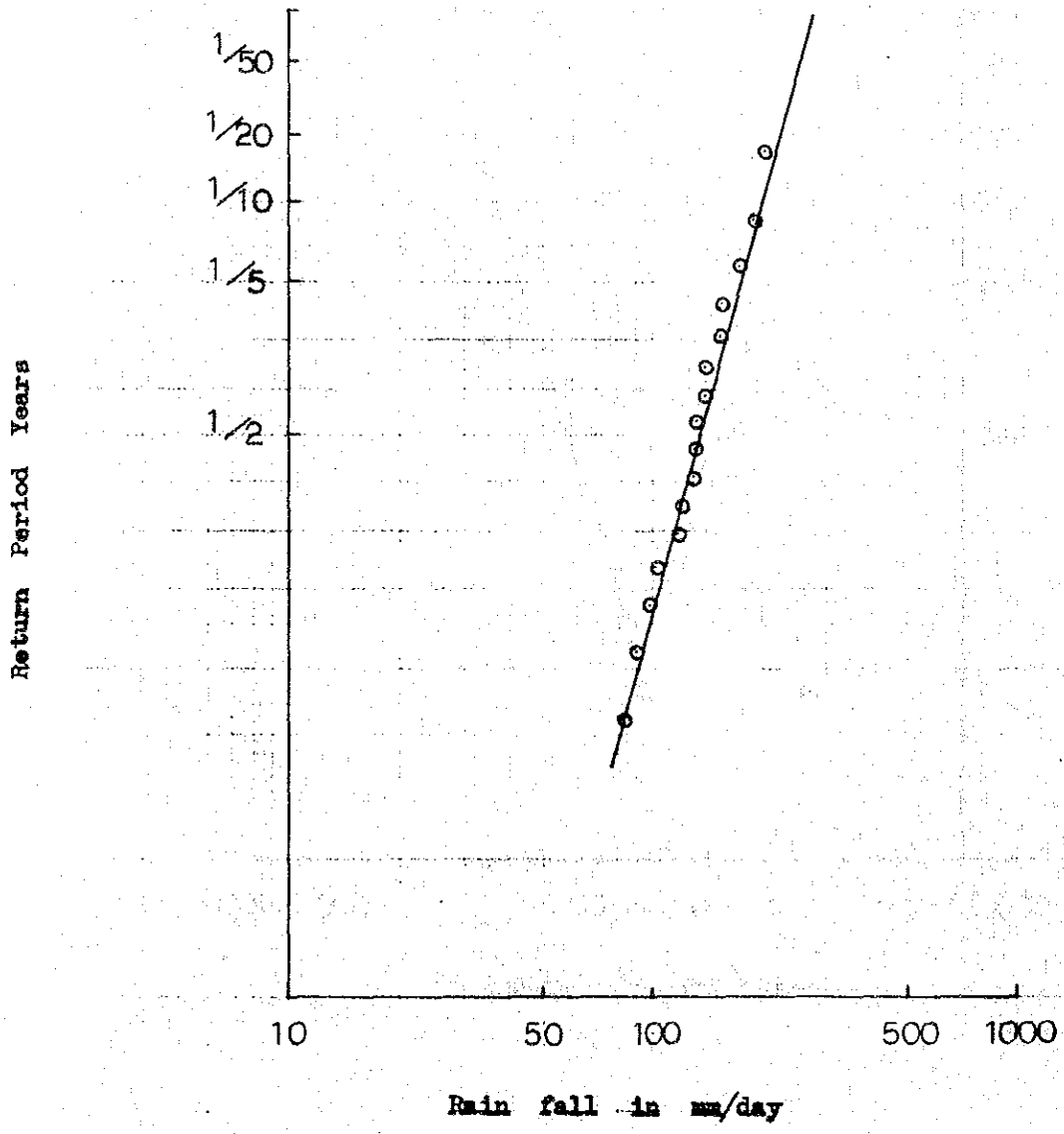
5 - 1 Limbang



Appendix Fig. A-5-23

PROBABLE MAXIMUM DAILY RAINFALL

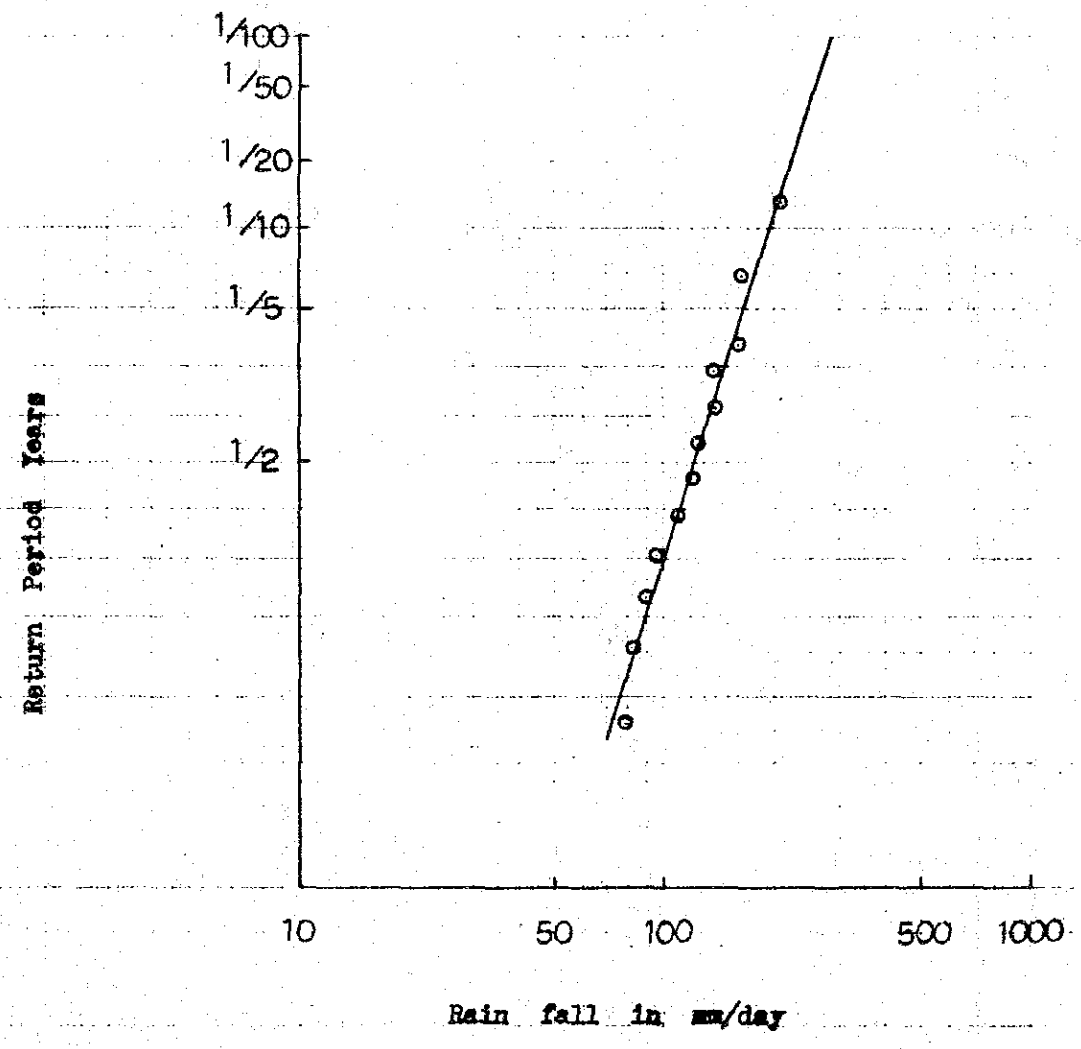
5 - 4 Ukong



Appendix Fig. A-5-24

PROBABLE MAXIMUM DAILY RAINFALL

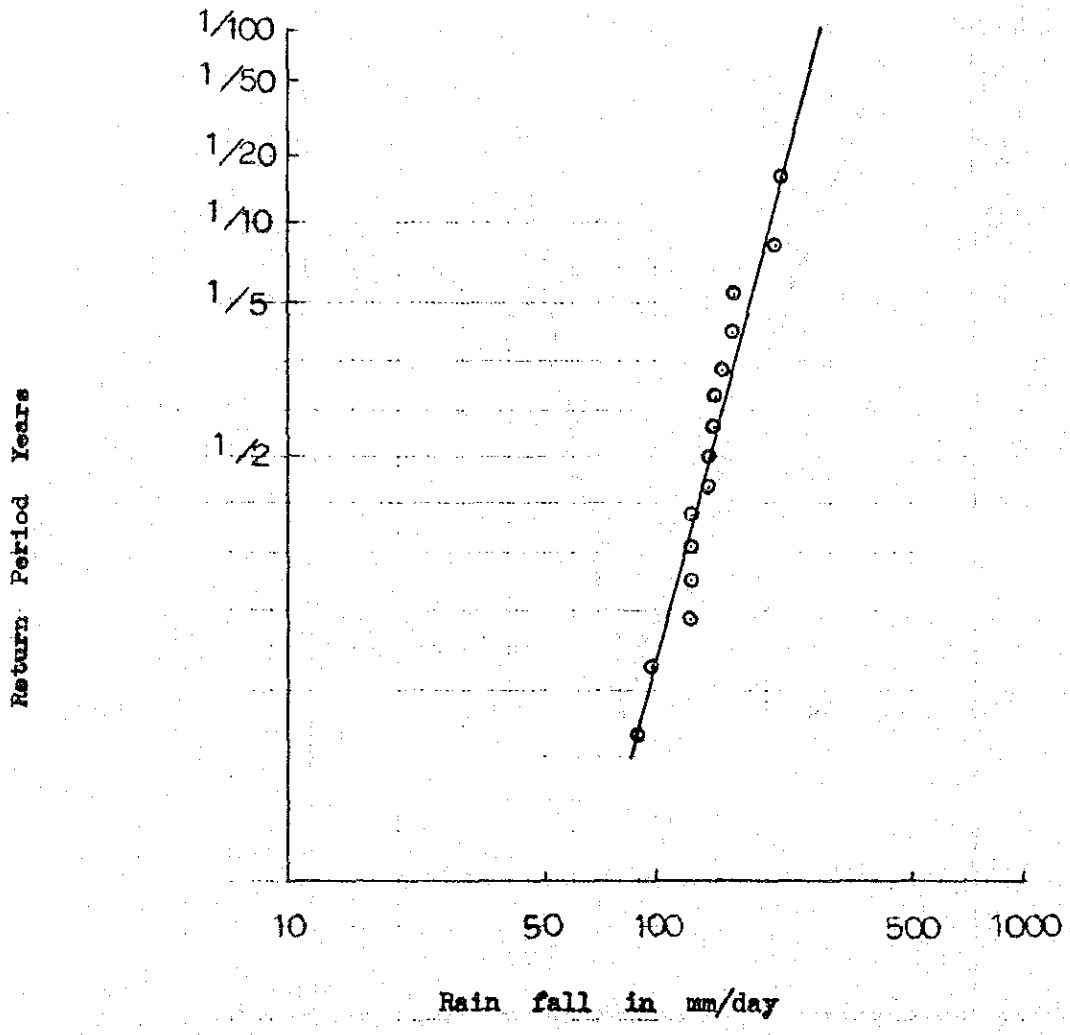
5 - 7 Kubong



Appendix Fig. A-5-25

PROBABLE MAXIMUM DAILY RAINFALL

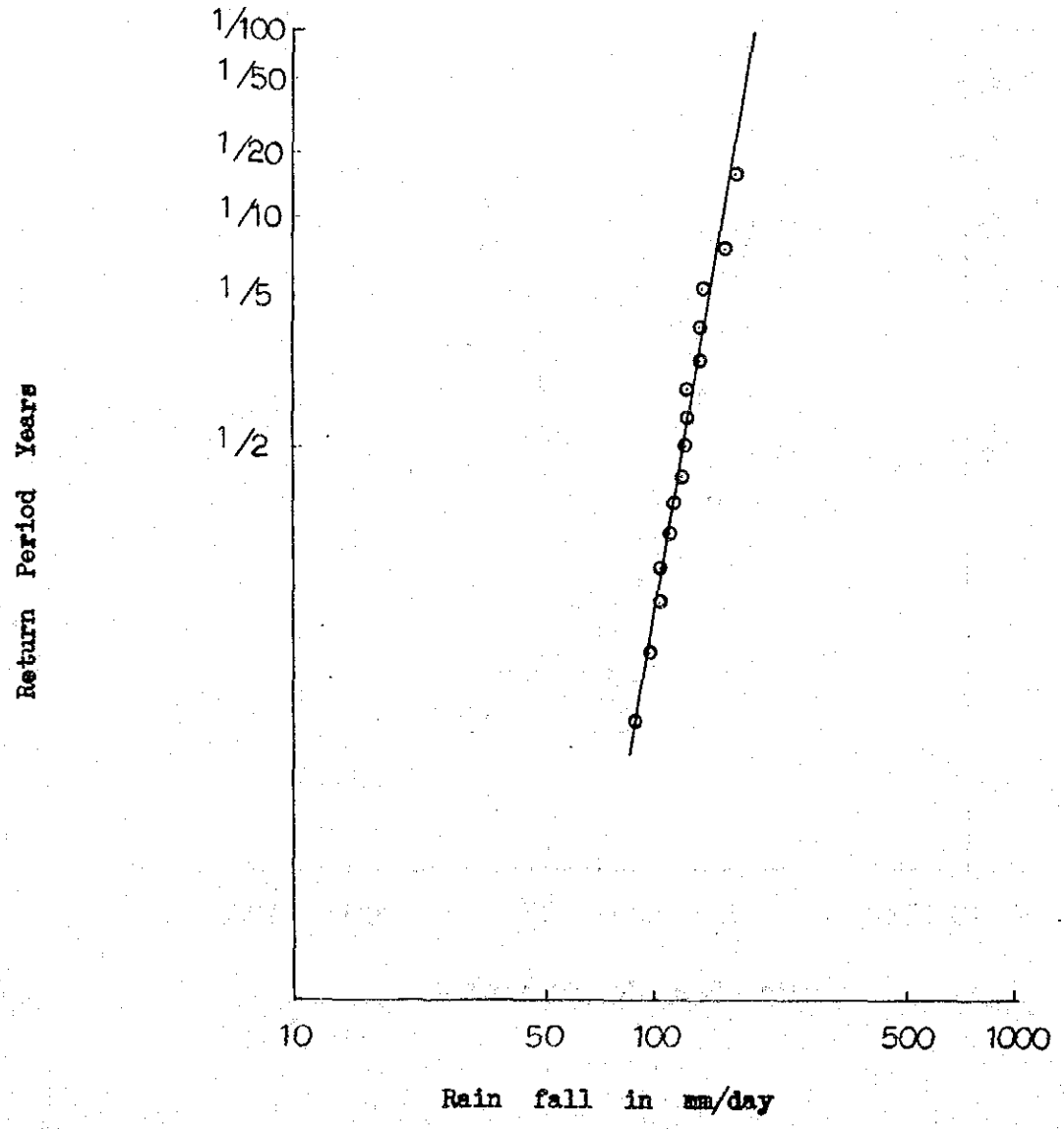
5 - 10 Limbang



Appendix Fig. A-5-26

PROBABLE MAXIMUM DAILY RAINFALL

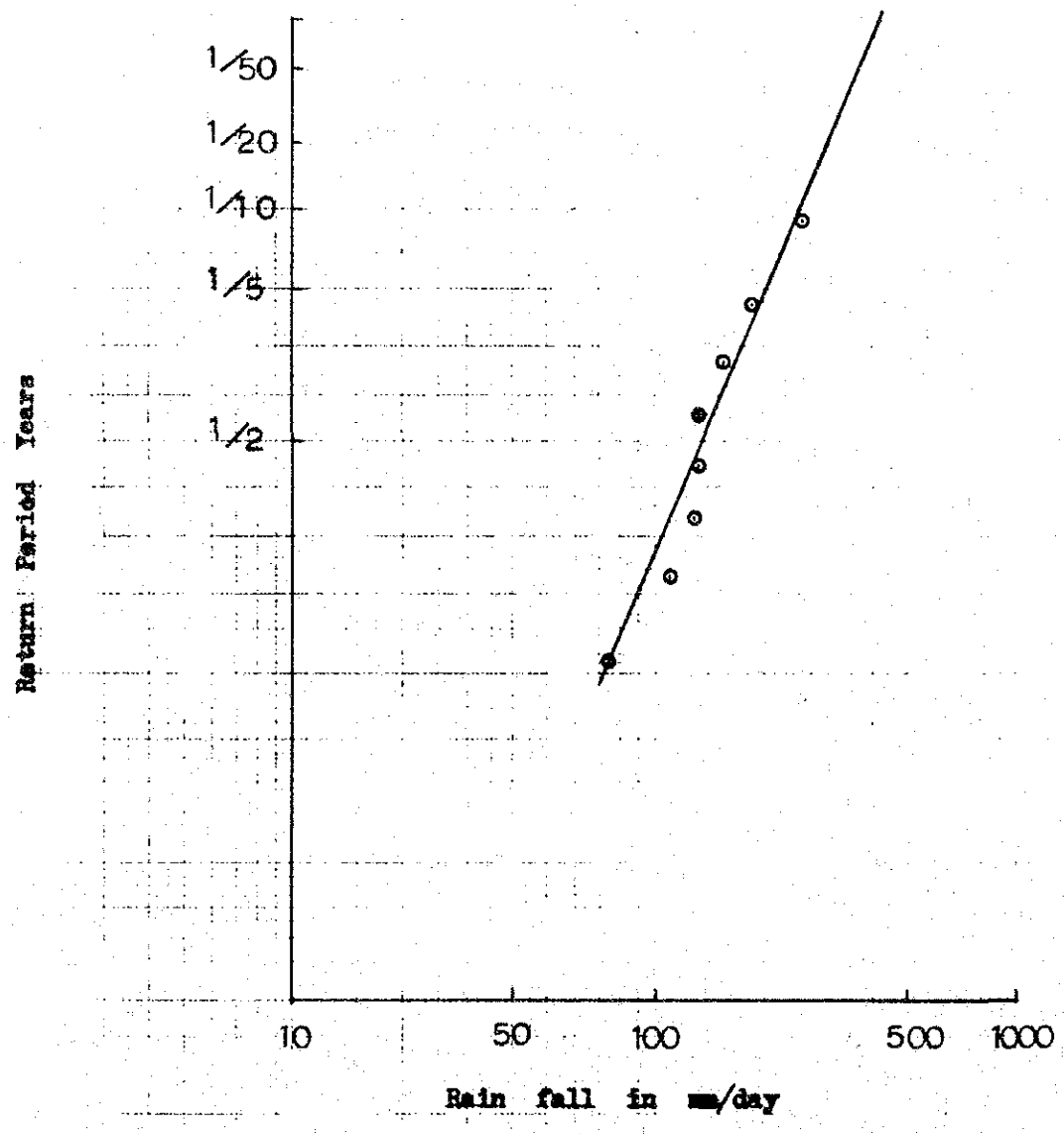
5 - 12 Nanga Medamit



Appendix Fig. A-5-27

PROBABLE MAXIMUM DAILY RAINFALL

5 - 16 Long Belong



Appendix Note A-6-1

Report on Study of Geometric Design Criteria for the Project Road

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CHAPTER 1 GENERAL OUTLINE

This is the second report for "The Feasibility Study of Beluru/Long Lama/Limbang Trunk Road Construction Project" following the "Interim Report" submitted in December 1978.

In the "Interim Report" the JICA Survey Team recommended a new set of design criteria prepared for the purpose of the above project, based on the existing Sarawak "Trunk Road Standard" and the Peninsular Malaysian "Minimum Geometric Design Criteria for New Roads in Rural Areas", making due reference also to similar standards used in other parts of the world.

Various opinions regarding these recommended criteria were raised by the authorities concerned. Some pointed out that they fell below the existing local standard whereas others maintained that they were excessive by the Peninsular Malaysian Standard, considering the volume of traffic involved.

It was then requested that the JICA Survey Team should make a review of the design standards and identify their points of argument in assessing the existing criteria.

This report is prepared in response to the above request. It covers the technical and cost comparisons of the criteria in question, and the thoughts behind the introduction of the new design criteria which include among others the following major points of consideration.

- Introduction of the new design criteria in place of the existing Sarawak Standard is desirable in order to avoid excessive destruction of nature which inevitably occurs if roadworks in the mountainous and rolling areas were to be constructed to the same standard as roads located in flat areas, and is also justifiable from economy point of view.
- The use of the new criteria in stead of the existing Peninsular standard is desirable since construction costs

involved are not so much different as to justify changing of the whole standard which disturbs the consistency of roadwork standard in the context of the existing local network system.

CHAPTER 2 INTRODUCTION

2.1 Subject Matter

This report deals with the comparison of the following sets of design criteria for the purpose of finalizing the choice to be made for the Beluru/Long Lama/Limbang Trunk Road Construction Project.

i) Criteria recommended by the JICA Survey Team
ii) "Trunk Road Standard" of Sarawak P.W.D.
iii) "Minimum Geometric Design Criteria for New Roads in Rural Areas, Group 04" of Peninsular Malaysia P.W.D.

It covers the following aspects:

i) Comparison of the alternative criteria both mutually and against requirements deduced from well established and internationally accepted theories.
ii) Comparison of costs required to construct in accordance with the alternative criteria.

2.2 Outline of the Criteria Compared

The Sarawak "Trunk Road Standard" which was devised to promote socioeconomical effects of road developments in the context of local conditions prevailed at the time of its publication, is featured by the prevalence of design criteria which fit best road developments in flat areas. In view of the increasing need of road construction in inland areas where mountainous and rolling terrains prevail, supplementation of this standard has become an essential requirement in particular by providing additional criteria for areas of such terrains, as is commonly seen in modern road design criteria of other parts of the world.

Other aspects of necessary reinforcement for the purpose of maintaining the quality of all roadworks above technically desirable standards include the stipulation of required sight distances, transition curves, vertical curves, etc.

The Peninsular Malaysian "Minimum Design Criteria for New Roads in Rural Areas" is closely similar to the AASHO standard of "A Policy on Geometric Design of Rural Highways". It consists of 6 groups of criteria, classified by traffic volume, out of which "Group 04" has been chosen here as the alternative for comparison with the recommended Sarawak Standard and criteria, from the following points of view.

i) "Group-04" is meant for roads carrying traffic 400 ~ 750 vpd (ADT two-way) of traffic volume, and therefore complies with the forecast traffic volume in the year 2002 for this project, which is approximately 500 vpd at maximum.

ii) The requirements of "Group 04" is relatively close to the existing local standard particularly in comparison with "Group 03" which is far from being compatible with it.

A summary of the criteria studied in this report is given in the following table.

Table - 1

		Recommended			Sarawak		Peninsular		
1	TERRAIN	F	R	M	-		F	R	M
2	DESIGN SPEED	80 (50)	64 (40)	48 km/H (30 MPH)	80 km/H	(50 MPH)	80 (50)	64 (40)	48 km/H (30 MPH)
3	PAVEMENT TYPE		-		-			-	
4	SURFACE WIDTH (PAVEMENT WIDTH)	7.32m	(24)		7.32 m	(24)	6.71 m	(22)	
5	USABLE SHOULDER	3.05 (10)	3.05 (10)	1.22 m (4)	3.05	(10)	2.44 (8)	2.44 (8)	1.22 m (4)
6	FORMATION WIDTH	13.42 (44)	13.42 (44)	9.76 m (32)	13.42	(44)	12.81 (42)	12.81 (42)	10.37 m (34)
7	CENTRAL RESERVATION		-		-			-	
8	RESERVE WIDTH	61/46 m		(290/150)	61/46 m	(200/150)	40/30 m	(132/100)	
9	MAXIMUM GRADIENT NORMAL ABSOLUTE	4	6	8%	5% 8%		4	6	9%
10	CRITICAL GRADE LENGTH	336 (1,100)	183 (600)	122 m (400)	-		336 (1,100)	183 (600)	122 m (400)
11	STOPPING SIGHT DIST. - MIN.	107 (350)	84 (275)	61 m (200)	-		107 (350)	84 (275)	61 m (200)
12	PASSING SIGHT DIST. - MIN.	549 (1,800)	458 (1,500)	336 m (1,100)	-		549 (1,800)	458 (1,500)	336 m (1,100)
13	MINIMUM RADIUS NORMAL ABSOLUTE	305 (1,000)	229 (750)	153 m (500)	305 m 228 m	(1,000 750)	214 (700)	131 (430)	70 m (230)
14	TRANSITION CURVES MIN. L	73 (240)	64 (210)	55 m (180)	-		73 (240)	64 (210)	55 m (180)
15	WIDENING	-	0.9 (3)	1.4 m (4.5)	According to M.O.T. Tables		-	0.9 (3)	1.4 m (4.5)
16	SUPERELEVATION MAX./MIN.		1 : 10		1:12 (8.3%)/1:38 (2.6%)			1 : 10	
17	CAMBER CROSS FAIL		1 : 38		1:38 (2.6%)			1 : 40	
18	VERT CURVES CREST MIN. K	26 (85)	17 (55)	9 m (28)	-		26 (85)	17 (55)	9 m (28)
	SAG MIN. K	23 (75)	17 (55)	11 m (35)	-		23 (75)	17 (55)	11 m (35)
19	OBLIQUE GRADE	10	10.5	11.5%	-			-	

Note: The figures in parenthesis show the values in feets.

CHAPTER 3 TECHNICAL COMPARISON

3.1 Traffic Capacity

The possible capacities and the design traffic capacities calculated on the basis of the alternative criteria are as shown in table - 2 . Bases of the calculations are as follows.

i) Percentage of heavy vehicle

The traffic in the survey area features in high percentage of heavy vehicle as in the followings (see Interim Report-Dec. '78).

Flat area	20%
Rolling area	22%
Mountainous area	36%

ii) Passenger car equivalent of heavy vehicle

The passenger car equivalents of heavy vehicle on 2-lane roads, based on assumed gradients and critical grade lengths, are as follows.

Flat area	2.9
Rolling area	3.9
Mountainous area	4.0

iii) Adjustment by lane width

Assuming the marginal lane width not affecting the traffic capacity to be 3.5 m, coefficients of adjustment for traffic capacity of smaller widths are determined as follows.

Lane width (m)	Coefficient of adjustment
3.50	1.00
3.25	0.94
3.00	0.85
2.75	0.77

iv) Adjustment by lateral clearance

The marginal lateral clearance not affecting traffic capacity on a 2-lane road is assumed as 1.75 m. For cases of smaller lateral clearance, the following coefficients of adjustment are applied.

Lateral clearance (m)	Coefficient of adjustment
1.75	1.00
1.50	0.98
1.25	0.96
1.00	0.93
0.75	0.91

v) Adjustment for heavy behicle

The coefficient of adjustment for heavy vehicle is calculated by applying the following formula.

$$\gamma_r = \frac{100}{100-Pr + Er \cdot Pr}$$

Where, γ_r = coefficient of adjustment for heavy vehicle

Pr = percentage of heavy vehicle

Er = passenger car equivalent of heavy vehicle

vi) Adjustment by roadside condition

Coefficients of adjustment applied in accordance with roadside conditions are as follows.

Degree of urbanization	Coefficient of adjustment
Rural area	1.0 - 0.9
Semi-urban area	0.9 - 0.8
Urban area	0.8 - 0.7

vii) Possible traffic capacity

The possible traffic capacities are calculated by multiplying the basic traffic capacities (2,000 vph)

with the above coefficients of adjustment.

$$C = C_B \times \gamma_L \times \gamma c \times \gamma_r \times \gamma_I$$

Where C = possible traffic capacity

C_B = basic traffic capacity (2,000 vph)

γ_L = coefficient of adjustment by lane width

γc = coefficient of adjustment by lateral clearance

γ_I = coefficient of adjustment by roadside condition

viii) Design level and adjustment of design level

The design level is divided into 3 classes with a view to maintain the traffic condition above a required level in the target year. Adjustment of each design level is made by applying the following coefficients respectively.

Design level	Coefficient for adjustment of design level
1	0.75
2	0.85
3	1.00

ix) Design traffic capacity

The design traffic capacity is calculated by applying the following formula.

$$C.D. = C \cdot ADL$$

Where C.D, = design traffic capacity (vph)

C = possible traffic capacity (vph)

ADL = coefficient of adjustment of design level

x) Average daily traffic

The average daily traffic (ADT) is calculated by applying the following formula.

$$ADT = \frac{100}{K} \cdot C.D$$

Where ADT = average daily traffic (vpd)
C.D = design traffic capacity (vph)
K = ratio of 30th hourly traffic volume against ADT (assumed as 9%)

The value of ADT for the alternative criteria thus obtained are as follows:

Criteria	ADT (vpd)
Recommended	12,000 ~ 7,600
Sarawak	9,500
Peninsular	11,000 ~ 7,100

The forecast future traffic volume on the proposed road is approximately 500 vpd at maximum in the year 2002.

3.2 Design Requirements

i) Width of usable shoulder

Road shoulders in the project area function as sidewalks for pedestrians and emergency parking spaces for troubled vehicles. Taking this into consideration together with the high percentage of heavy vehicle (20-36%) here, usable shoulder widths should be made as wide as possible so far as economically reasonable.

The widths of usable shoulders required by the alternative criteria together with AASHO and Japanese standards are as follows.

Standard	Terrain	Shoulder width (m)
Recommended	Flat	3.05
	Rolling	3.05
	Mountainous	1.22

Table-2 Traffic Capacity

	Recommended			Sarawak	Peninsular		
1. Terrain	F	R	M		F	R	M
2. Design speed (kph)	80	64	48	80	80	64	48
3. Lane width (m)	3.66	3.66	3.66	3.66	3.36	3.36	3.36
4. Lateral clearance Left (m)	3.05	3.05	1.22	3.05	2.44	2.44	1.22
Right (m)	-	-	-	-	-	-	-
5. Heavy vehicle Pct. of heavy vehicle (%)	20	22	36	30	20	22	36
Passenger car equivalent	2.9	3.9	4.0	3.5	2.9	3.9	4.0
6. Coefficient of adjustment Lane width	1.00	1.00	1.00	1.00	0.94	0.94	0.94
Lateral clearance	1,00	1.00	0.96	1.00	1.00	1.00	0.96
Heavy vehicle	0.72	0.61	0.48	0.57	0.72	0.61	0.48
Roadside condition	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Product of coefficient	0.72	0.61	0.46	0.57	0.68	0.57	0.43
7. Basic capacity (kph)	2,000	2,000	2,000	2,000	2,000	2,000	2,000
8. Possible capacity (vph)	1,440	1,220	920	1,140	1,360	1,140	860
9. Adjustment of design level (%)	0.75	0.75	0.75	0.75	0.75	0.75	0.75
10. Design capacity(kph)	1,080	915	690	855	1,020	855	645
11. Rate of peak hours (K) (%)	9	9	9	9	9	9	9
12. Average daily traffic (ADT) (kpd)	12,000	10,167	7,667	9,500	11,333	9,500	7,167

Standard	Terrain	Shoulder width (m)
Sarawak		3.05
Peninsular	Flat	2.44
	Rolling	2.44
	Mountainous	1.22
AASHO	Flat	3.66
	Rolling	3.05
	Mountainous	1.83
Ministry of Construction, Japan	Flat	1.75
	Rolling	1.25
	Mountainous	1.25

In our recommendation, the larger figure between the Sarawak and the Peninsular Standards has been chosen for flat and rolling areas and the smaller for the mountainous areas from the traffic demand and economy points of view.

ii) Maximum gradient, critical grade length and length of vertical curve

Maximum grade

Maximum grades are recommended as follows by topographical condition, taking the uniformity of traffic into consideration.

Flat area	4%
Rolling area	6%
Mountainous area	8%

A flater gradient of 8% in comparison with the tolerable slope of 9% is adopted as the maximum gradient for mountainous areas, taking into consideration the high percentage of heavy vehicle.

Critical grade length

For critical gradient lengths which is not specified in the Sarawak Standard, the criteria in the Peninsular Standard is adopted.

Length of vertical curve

Vertical curves are used at changing points of vertical gradients to smooth away the undesirable impact of an abrupt change of momentum, and to secure the required sight distance. It is calculated in several aspects by the use of the following formulae.

a. The length required to alleviate the momentum impact

$$L = \frac{V^2 |I_1 - I_2|}{395} \quad \ldots\ldots \text{ (applied to both crests and sags)}$$

Where L = length of vertical curve (m)

V = design speed (kph)

$|I_1 - I_2|$ = absolute value of the difference of vertical gradients (%)

b. The length required to secure sight distance

$$L = \frac{D^2 |I_1 - I_2|}{426} \quad \ldots\ldots \text{ (applied to crests only)}$$

Where D = sight distance (m)

c. The length required to secure sight distance using head lights at night

$$L = \frac{D^2 |I_1 - I_2|}{122 + 3.5D} \quad \ldots\ldots \text{ (applied to sags only)}$$

Vertical curve lengths required at crests are calculated as follows.

	Recommended			Sarawak	Peninsular (m)		
	F	R	M		F	R	M
$L = \frac{V^2 \lvert I_1 - I_2 \rvert}{395}$	16.2A	10.4A	5.8A	16.2A	16.2A	10.4A	5.8A
$L = \frac{D^2 \lvert I_1 - I_2 \rvert}{426}$	26.9A	16.6A	8.7A	-	26.9A	16.6A	8.7A

Where $A = \lvert I_1 - I_2 \rvert$

Vertical curve lengths required at sags are calculated as follows.

	Recommended			Sarawak	Peninsular (m)		
	F	R	M		F	R	M
$L = \frac{V^2 \lvert I_1 - I_2 \rvert}{395}$	16.2A	10.4A	5.8A	16.2A	16.2A	10.4A	5.8A
$L = \frac{D^2 \lvert I_1 - I_2 \rvert}{122+3.5D}$	23.1A	17.0A	11.1A	-	23.1A	17.0A	11.1A

In comparison to the above requirements, the design criteria in the standards under comparison are as follows.

	Recommended			Sarawak	Peninsular (m)		
	F	R	M		F	R	M
at Crest	26A	17A	9A	-	26A	17A	9A
at Sag	23A	17A	11A	-	23A	17A	11A

iii) Stopping and passing sight distances

The sight distance is one of the main factors which determine the safety and comfort of roads, as are lane width, alignment, gradient and etc.

a. Stopping sight distance

A stopping sight distance is the distance that a vehicle traverses after the applying of brake, until it comes to a complete stop. It varies depending on the initial speed, the coefficient of friction between tires and roadway, and the reaction time of the driver. It is calculated by applying the following formular.

$$D = 0.694V + 0.00394 \frac{V^2}{f}$$

Where D = stopping distance (m)
V = running speed (kph)
f = coefficient of frcition between tires and roadway

The coefficient of friction f varies in relation to the conditions of tires, road surface and braking operation. Its experimental values are as follows.

Design speed	Running speed	f
80 kph	68 kph	0.31
64 "	58 "	0.33
48 "	43 "	0.35

The required sight distances computed based on the above provisions and those in the design criteria are as follows.

	Recommended			Sarawak	Peninsular		
	F	R	M		F	R	M
computed requirement	105.96	80.41	50.65	105.96	105.96	80.41	50 65
design criteria	107	84	61	-	107	84	61

b. Passing sight distance

The required passing sight distance D is calculated by summing up the 4 components d_1, d_2, d_3 and d_4 which are determined respectively as in the followings:

$$D = d_1 + d_2 + d_3 + d_4$$

d_1 ..... the distance traversed by the passing vehicle between the instance acceleration is applied for the purpose of passing, and the instance it enters opposite lane. It is calculated from the following formula.

$$d_1 = \frac{V_0}{3.6} \cdot t_1 + \frac{1}{2} a \cdot t_1^2$$

where V_0 = Speed of passed vehicle (kph)

a = Average acceleration (m/sec^2)

t_1 = Acceleration Time (sec)

d_2 ..... the distance traversed by the passing vehicle on the opposite lane during passing operation.

$$d_2 = \frac{1}{3.6} V \cdot t_2$$

where V = speed of passing vehicle (kph)

t_2 = time for passing: 9.3~10.4 sec

d_3 ..... the distance between the passing vehicle and the nearest on-coming vehicle on the opposite lane at the end of passing operation.

$d_3 = 30 \sim 100$ m (assumed based on survey data)

d_4 ..... the distance travelled by the nearest on-coming vehicle on the opposite lane during passing operation.

$$d_4 = \frac{2}{3} \cdot d_2 = \frac{2}{3} \cdot \frac{1}{3.6} \cdot V \cdot t_2$$

The required passing sight distances thus obtained for all design criteria under comparison are as in table-3.

Table-3

	Recommended			Sarawak	Peninsular		
	F	R	M		F	R	M
Initial speed of passing vehicle/speed of opposing vehicle	80	64	48	80	80	64	48
Speed of passed vehicle	60	48	36	60	60	48	36
Average rate of acceleration	0.65	0.63	0.62	0.65	0.65	0.63	0.62
Acceleration time	4.2	3.7	3.4	4.2	4.2	3.7	3.4
d_1	81.5	53.6	37.6	81.5	81.5	53.6	37.6
Duration of passing vehicle occupying opposite lane	10.4	9.5	9.0	10.4	10.4	9.5	9.9
d_2	231.1	168.9	120.0	231.1	231.1	168.0	120.0
d_3	60	44	28	60	60	44	28
$d_4 = \frac{1}{3} \cdot d_2$	115.6	84.5	60.0	115.6	115.6	84.5	60.0
$D = d_1+d_2+d_3+d_4$	488.2	351.0	245.6	488.2	458.2	351.0	245.6
Requirement specified in criteria	549	458	366		549	458	366

iv) Minimum curve radius

The minimum Curve Radius are determined by applying the following formula, substituted with marginal safe values of vehicle speed, superelevation and side friction factor.

$$R = \frac{V^2}{127(i+f)}$$

Where: R = curve radius (m)
V = vehicle speed (kph)
i = rate of roadway superelevation
f = side friction factor

Making reference to AASHO and the Japanese Standard, the side friction factor (f) is determined here as follows:

Design speed (kph)	80	60	50
Side friction factor f	0.12	0.13	0.14

The required minimum curve radius based on the formula and side friction factors above, and those in the design criteria under comparison are as follows.

		Calculated (m)	Design criteria (m)
Recommended	Flat	229	305
	Rolling	140	229
	Mountainous	76	153
Sarawak		345 ~ 248	305 ~ 228
Peninsular	Flat	229	214
	Rolling	120	131
	Mountainous	76	70

Design criteria in the Sarawak and Peninsular standards in this regard fall below the above computed requirement, and therefore require to be revised so as to prevent accidents caused by lateral sliding.

v) Length of transition curve

A transition curve is employed to provide drivers with a natural easy-to-follow path at the entrance or exit of a circular curve, or to provide a convenient desirable arrangement for superelevation runoff, or to facilitate the transition in width where the pavement section is widened around a circular curve. The length of it is determined by the use of the following formula.

a. Curve length required from steering operation point of view.

$$L = v \cdot t = \frac{V}{3.6} t \quad \text{..... formula (1)}$$

Where: L = length of transition curve (m)
v = vehicle speed (m/sec)
t = travelling time on the transition curve (sec)
V = design speed (kph)

b. Curve length required from rate of centrifugal acceleration point of view

$$L = \left(\frac{V}{3.6}\right)^3 / P.R \quad \text{..... formula (2)}$$

Where: P = rate of increase of centrifugal acceleration (0.5 m/sec)
R = curve radius (m)

The required lengths of transition curves computed from the above formulae, and those in the design criteria under comparison are as follows:

	Recommended (m)			Sarawak (m)	Peninsular (m)		
	F	R	M		F	R	M
From formula (1)	67	53	40	89	67	53	40
From formula (2)	72	49	31	72	103	86	68
Design criteria	73	64	55	-	73	64	55

The design criteria in the Peninsular standard is seen to fall under the computed requirement.

vi) Oblique grade

An oblique grade is the result of the combination of horizontal alignment and profile, and is greater than both the head and cross falls it composes of. A vehicle travelling on a sloped curve tends to recline, slip and experience load displacement in the direction of the oblique grade, which therefore requires to be limited within a certain extent so as to contain the above undesirable effect within an appropriately safe limit. The maximum tolerable oblique grade at decling slopes is calculated by the use of the following formula.

$$S = \sqrt{i^2 + j^2}$$

Where: i = cross fall (%)

j = longitudinal gradient (%); and

$$j = j_{max} - \frac{(V/3.6)^2}{gR} i$$

V = vehicle speed (kph)

R = minimum curve radius (m)

g = 9.8 m/sec^2

The tolerable oblique grades thus obtained for the respective standard under comparison and those specified in the design criteria are as follows:

		Calculated (%)	Design criteria (%)
Recommended	Flat	10.3	10
	Rolling	11.0	10.5
	Mountainous	11.8	11.5
Sarawak		10.3	-
Peninsular	Flat	10.3	-
	Rolling	10.6	-
	Mountainous	11.9	-

These figures indicate that combination of the maximum allowable gradient with the minimum allowable curvature radius falls below the tolerable limit and should therefore be avoided whichever of the standards under comparison is concerned.

CHAPTER 4 COST COMPARISON

4.1 Method of Study

i) Topographical conditions

Construction costs vary strikingly in accordance with physical conditions of the area involved. Consideration in this aspect is therefore important here.

For the purpose of this study, the areas involved are grossly classified into the following two types.

- Type 1 : Flat and rolling areas .... from Sg. Tenjah to Sg. Tutoh and from Sg. Medalam to Ng. Medamit.
- Type 2 : Mountainous area ..... from Sg. Tutoh to Sg. Medalam via Mulu National Park.

ii) Route locations

a. Flat and rolling areas

The differences in the elements of road alignment within flat and rolling areas, between route locations based on the different design criteria under comparison are comparatively small. These two topography types are therefore included in one classification here for the sake of convenience. The recommended route for these portions in our Interim Report is taken as the common basis of cost comparison.

The lengths of roads within these areas are as follows:

- Sg. Tenjah ~ Sg. Tutoh	79.0 km
- Sg. Medalam ~ Ng. Medamit	22.0 km
Total	101.0 km

b. Mountainous area

The road section starting from the crossing at Sg. Tutoh, traversing the Mulu National Park area and the ridgeline along the boundary between 4th and 5th Div's, ending at Sg. Medalam is regarded as mountainous area road. Utilizing new topographical maps of 1 : 10,000 scale, tentative route design based on the respective criteria in question are produced, and used as the basis of cost comparison.

The total length of each route thus obtained is as follows:

- Recommended 34.6 km
- Sarawak 34.0 km
- Peninsular 35.0 km

4.2 Cost Estimation and Comparison

i) Work items and estimate of quantity

a. Work items

Quantity estimations here are made in accordance with the breakdown list of work items adopted in the Interim Report.

b. Quantity of works

- Clearing and grubbing

The area of development is classified by existing landuse into forest, agriculture and rubber plantation areas, and estimated assuming both the depth of excavation and the height of embankment to be 3 m in average.

- Excavation and embankment

Earthwork volumes are computed based on the estimated average sectional area of each alternative developed from the typical cross

sections illustrated in Fig. 1.2. In computing the sectional areas, the existing terrains are classified into 4 groups, namely of 10, 20, 30% slopes and level area. Excavated materials are assumed to compose of 80% of soil, 15% of soft rock and 5% of hard rock.

Where the volume of excavation is less than that of embankment, the imbalance will assumably be covered by borrowed soil.

- Drainage structure

Box culverts and pipe culverts are allocated in accordance with judgements based on the topological map.

- Bridge

Number of bridges are estimated in 3 categories by span, namely that of short, middle and long span ones, in accordance with terrains of their location. Smaller widths are assumed for bridges along the route located as per the Peninsular Standard.

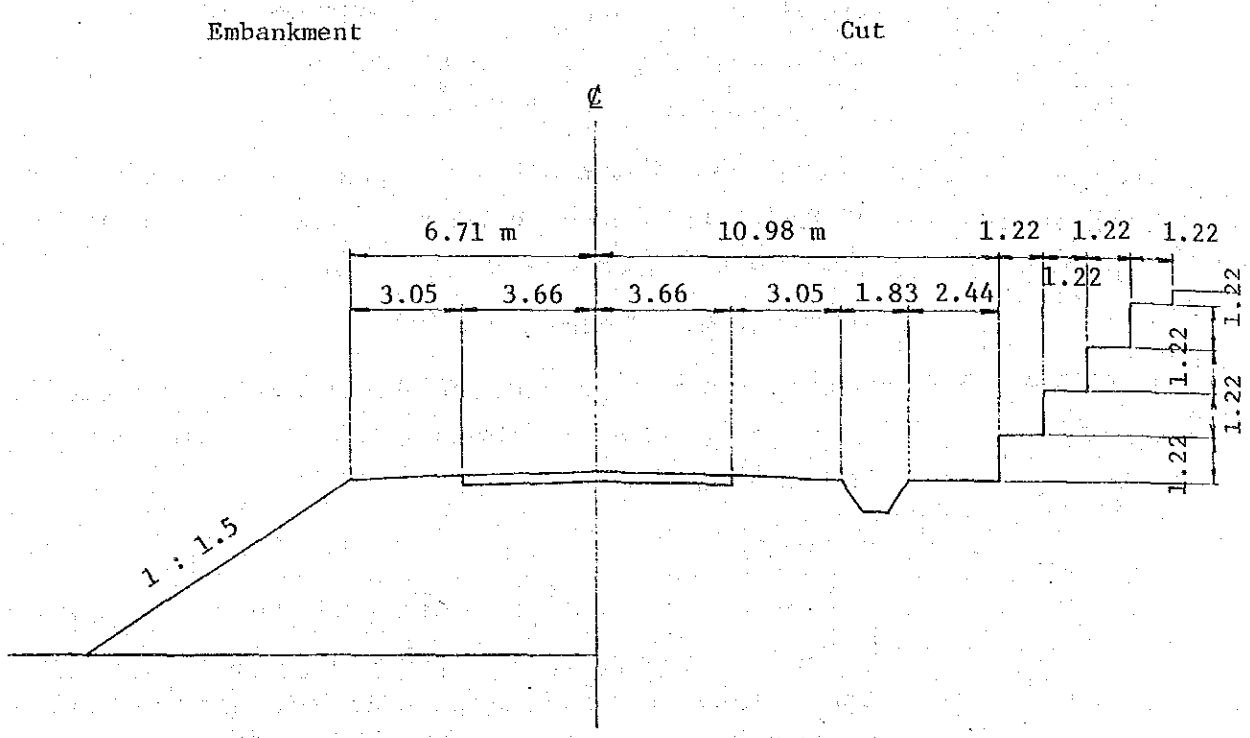
- Pavement

For the purpose of construction cost comparison, a common pavement structure is tentatively designed, such that only the differences in average width of pavement are reflected in the estimated cost differences.

The quantity of work per unit length of road by work item is as listed in the following.

Fig.-1 TYPICAL CROSS-SECTION BY RECOMMENDED CRITERIA AND SARAWAK STANDARD

Flat/Rolling Area



Mountainous Area

(by Recommended Criteria)

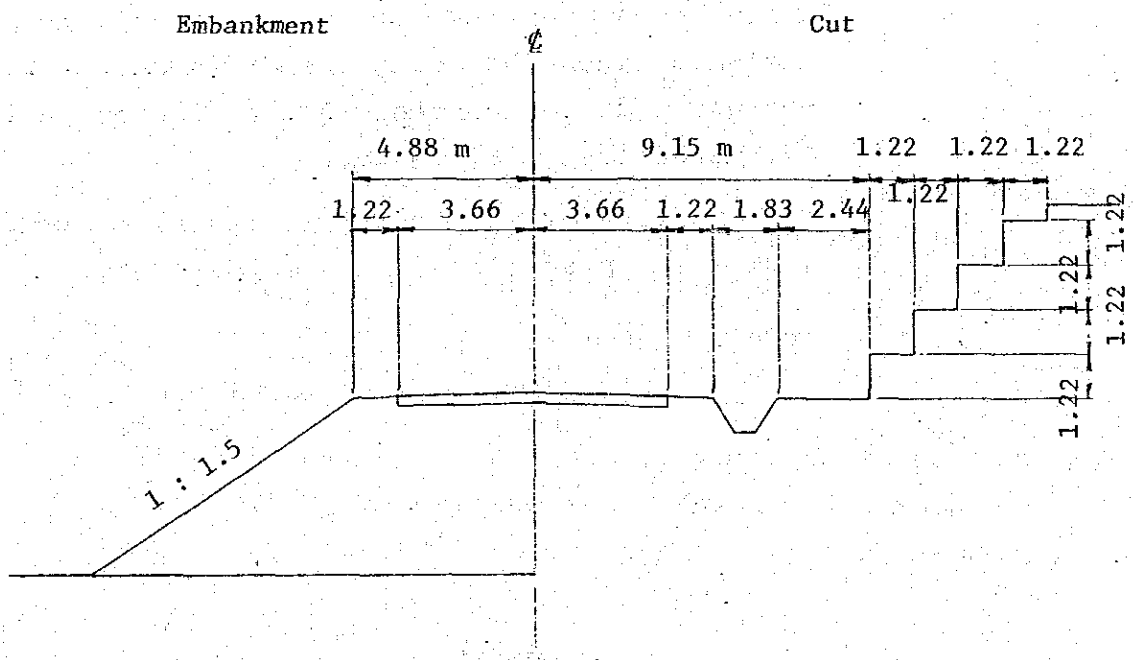
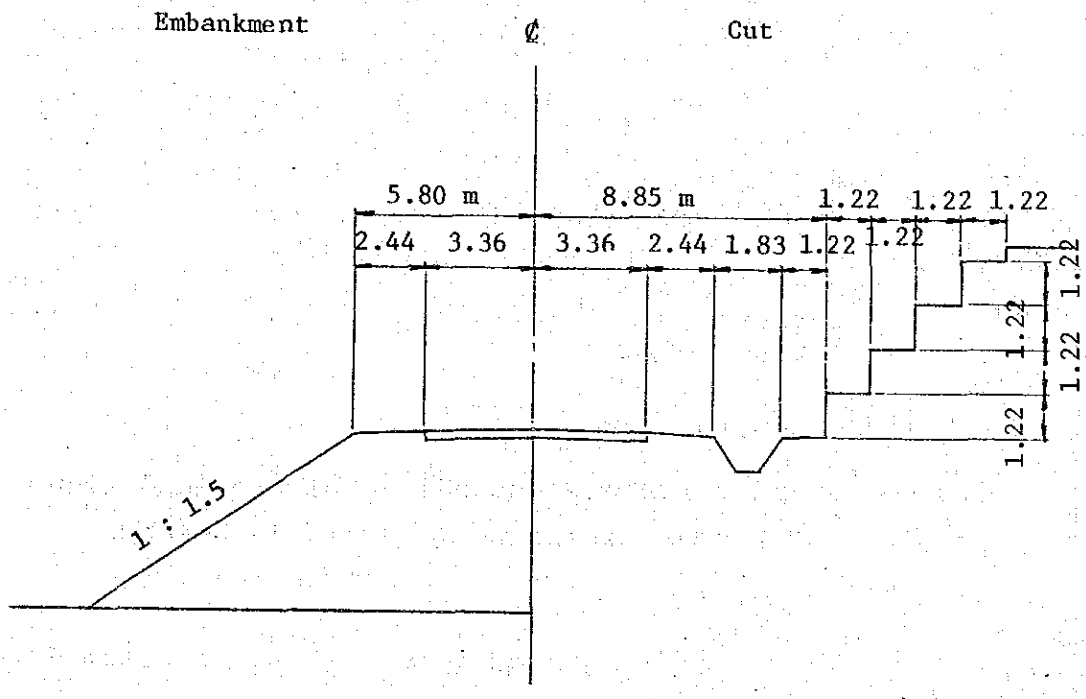
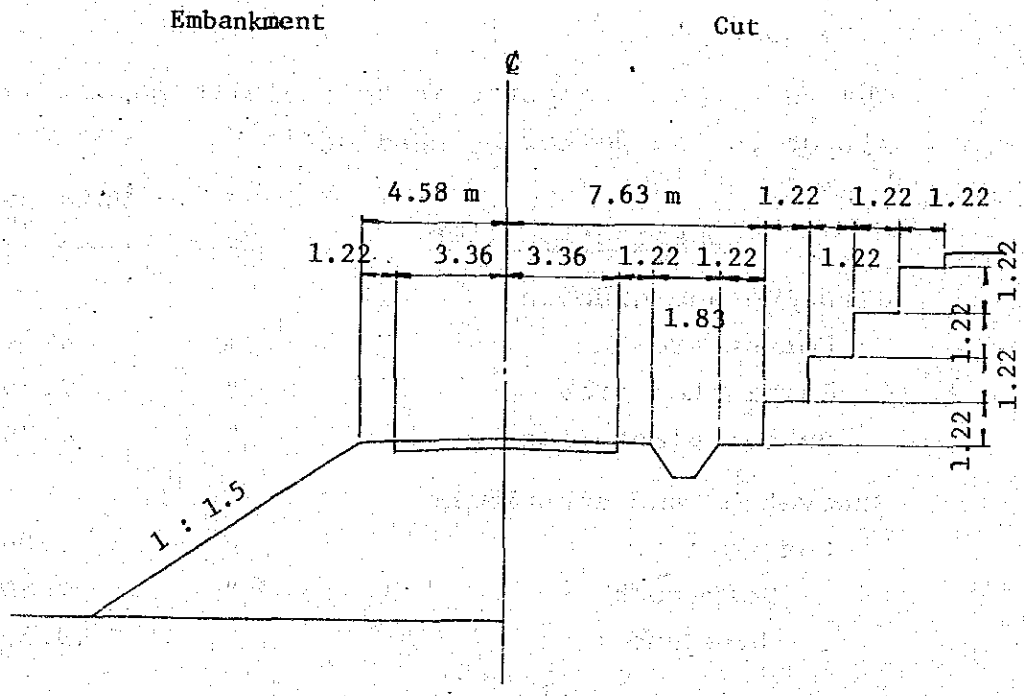


Fig.-2 TYPICAL CROSS-SECTION BY PENINSULAR STANDARD

Flat/Rolling Area



Mountainous Area



	Recommended	Sarawak	Peninsular
Subgrade preparation (m^2/m)	7.32	7.32	6.71
Subbase course (m^2/m)	2.19	2.19	2.01
Base course (m^3/m)	1.09	1.09	1.01
Bituminous prime coat (m^2/m)	7.32	7.32	6.71
Bituminous surface course (m^2/m)	7.32	7.32	6.71

- Guard rail

Guard rails are assumed to be provided along cut slopes exceeding 4 meters in height.

- Marking

The total length of road marking is assumed to be twice that of the road.

- Traffic sign

Traffic sign is assumed to be installed at 10 km intervals.

ii) Unit cost

The unit costs computed in the Interim Report as listed in the followings are applied.

Construction item	Unit	Unit cost (MS)
Cleaning and grubbing		
Forest area	m^2	4.84
Cultivated area	"	0.75
Rubber plantation	"	0.30
Excavation and embankment		
Cut soil	m^3	5.00
Soft rock	"	7.50
Hard rock	"	59.50

Construction item	Unit	Unit cost (MS)
Borrow for filling	m^3	7.59
Removal of top soil	"	2.86
Drainage structure		
Box culvert 2.0 x 2.0	m	185.00
" 3.0 x 2.0	"	235.00
" 3.0 x 3.0	"	317.00
Pipe culvert ø 900	"	109.90
ø1,500	"	200.15
Bridge		
Short span	m^2	1,940.00
Middle span	"	2,195.00
Long span	"	2,262.00
Pavement		
Subgrade preparation	m^2	0.41
Sub-base course	"	44.31
Base course	m^3	46.43
Bituminous primecoat	m^2	0.66
Bituminous surface course	"	13.85
Guard rail	m	66.00
Marking	m	1.20
Traffic sign		
Traffic sign	piece	560.00
Millage post	"	91.00

iii) Comparison of construction cost

The estimated construction costs are listed in detailed breakdowns by criteria and by terrain in Table 5, and 6 are summarized in the following table.

Table-4

(Unit of const. cost: 1,000M$)

Alternative	Mountainous area			Flat/Rolling area			Total		
	Length	Const.cost		Length	Const.cost		Length	Const. cost	
		Cost	Ratio		Cost	Ratio		Cost	Ratio
Recommended criteria	km 34.6	28,685	1.00	km 101.0	96,778	1.00	km 135.6	125,463	1.00
Sarawak criteria	km 34.0	33,153	1.16	km 101.0	96,778	1.00	km 135.0	129,931	1.04
Peninsular criteria	km 35.0	26,360	0.92	km 101.0	90,168	0.93	km 136.0	116,528	0.93

The differences between the alternatives in construction cost for the mountainous area portion are considerably large. With the cost of construction based on the recommended criteria taken as 1.0, the index of the other alternatives area 1.16 for the Sarawak standard and 0.92 for the Peninsular counterpart. The difference between the Sarawak and the Peninsular alternatives amounts to 0.24.

Such differences mainly constitute of the differences in the volume of earthworks involved and that in the width of pavement. The differences in earthwork volume which is particularly decisively large, is obviously the result of the obsence of separated

design criteria for area of mountainous terrain in the Sarawak Standard.

For the flat and rolling area portion, the construction cost indice taking that of the recommended criteria as 1.00 are 1.00 and 0.93 for the Sarawak and Peninsular Standards respectively.

The relatively small differences here constitute mainly of the following elements.

- Difference in earthwork requirements in relation to road width
- Difference in quantity of bridge works
- Difference in pavement width

The relative indices of the total construction cost with that by the recommended criteria taken as 1.00 are 1.04 for the Sarawak Standard, and 0.93 for the Peninsular Standard.

Table-5 ESTIMATE OF CONSTRUCTION COST FOR MOUNTAINOUS AREA

UNIT: M$

Construction items	Unit		Recommended criteria		Sarawak criteria		Peninsular criteria	
	Unit	Unit cost	Quantities	Cost	Quantities	Cost	Quantities	Cost
Clearing & grubbing		M$						
Forest area	m^2	4.84	525,880	2,545,260	646,000	3,126,640	514,500	2,490,180
Excavation & embankment								
Cut Soil	m^3	5.00	1,406,413	7,032,065	1,804,404	9,022,020	1,278,557	6,392,785
Soft rock	"	7.50	263,702	1,977,765	338,326	2,537,445	239,730	1,797,975
Hard rock	"	59.50	87,900	5,230,050	112,775	6,710,113	79,910	4,754,645
Drainage structures								
Box culvert 3 x 3	m	317.00	33	10,461	38	12,046	32	10,144
" 2 x 2	"	185.00	417	77,145	468	85,470	392	72,520
Pipe culvert ϕ 1,500	"	200.15	262	52,440	262	52,440	246	49,237
ϕ 900	"	109.90	100	10,990	38	4,177	100	10,990
Bridges								
Middle span	m^2	2,195.00	694.4	1,524,208	694.4	1,524,208	578.9	1,270,689
Short span	"	1,940.00	347.2	673,568	347.2	673,568	289.5	561,533
Pavement								
Sub-grade preparation	m^2	0.41	253,199	103,812	248,880	102,040	234,850	96,289
Sub-base course	"	44.31	75,752	3,356,576	74,460	3,299,323	70,350	3,117,209
Base course	m^3	46.43	37,703	1,750,551	37,060	1,720,696	35,350	1,641,301
Bituminous prim-coat	m^2	0.66	253,199	167,112	253,272	167,160	234,850	155,001
Bituminous surface course	"	13.85	253,199	3,506,807	253,272	3,507,818	234,850	3,252,673
Guard rail	m	66.00	8,800	580,800	7,940	524,040	9,100	600,600
Marking	"	1.20	69,380	83,256	68,000	81,600	70,000	84,000
Traffic sign								
Traffic sign	Piece	560.00	3	1,680	3	1,680	4	2,240
Mailage post	"	91.00	3	273	3	273	4	364
TOTAL COST			28,684,819		33,152,757		26,360,375	

Table-6 ESTIMATE OF CONSTRUCTION COST FOR FLAT/ROLLING AREA

UNIT: M$

Construction items	Unit		Recommended criteria		Sarawak criteria		Peninsular criteria	
	Unit	Unit cost	Quantities	Cost	Quantities	Cost	Quantities	Cost
Clearing & grubbing								
Forest area	m^2	4.84	1,919,000	9,287,960	1,919,000	9,287,960	1,823,050	8,823,562
Cultivated area	"	0.75	666,600	499,950	666,600	499,950	600,000	450,000
Rubber plantation	"	3.30	30,300	99,990	30,300	99,990	27,000	89,100
Excavation & embankment								
Cut Soil	m^3	5.00	2,224,950	11,124,750	2,224,950	11,124,750	2,113,700	10,568,500
Soft rock	"	7.50	153,850	1,153,875	153,850	1,153,875	146,158	1,096,185
Hard rock	"	59.50	38,500	2,290,750	38,500	2,290,750	36,575	2,176,213
Borrow for fill	"	7.59	1,430,665	10,858,748	1,430,665	10,858,748	1,359,132	10,315,812
Removal of top soil	"	2.89	95,160	275,012	95,160	275,012	90,402	261,262
Drainage structures								
Box culvart 2 x 2	m	185.00	250	46,250	250	46,250	235	43,475
" 3 x 2	"	235.00	250	58,750	250	58,750	235	55,225
" 3 x 3	"	317.00	250	79,250	250	79,250	235	74,495
Pipe culvert φ 900	"	109.90	3,900	428,610	3,900	428,610	3,666	402,894
φ1,500	"	200.15	2,800	560,420	2,800	560,420	2,632	526,795
Bridges								
Short span	m^2	1,940.00	7,490	14,530,600	7,490	14,530,600	6,616	12,835,040
Middle span	"	2,195.00	4,370	9,592,150	4,370	9,592,150	4,135	9,076,325
Long span	"	2,262.00	2,600	5,881,200	2,600	5,881,200	2,481	5,463,162
Pavement								
Subgrade preparation	m^2	0.41	739,320	303,121	739,320	303,121	677,710	277,861
Sub-base course	"	44.31	221,190	9,800,929	221,190	9,800,929	203,010	8,995,373
Base course	m^3	46.43	110,090	5,111,479	110,090	5,111,479	102,010	4,736,324
Bituminous prim-coat	m^2	0.66	739,320	487,952	739,320	487,952	677,710	444,289
Bituminous surface course	"	13.85	739,320	10,239,582	739,320	10,239,582	677,710	9,386,284

UNIT: M$

Construction items	Unit		Recommended criteria		Sarawak criteria		Peninsular criteria	
	Unit	Unit cost	Quantities	Cost	Quantities	Cost	Quantities	Cost
Guard rail	m	66.00	57,850	3,818,100	57,850	3,818,100	57,850	3,818,100
Marking	m	1.20	202,000	242,400	202,000	242,400	202,000	242,400
Traffic sign								
Traffic sign	Piece	560.00	10	5,600	10	5,600	10	5,600
Mailage post	"	91.00	10	910	10	910	10	910
TOTAL COST			96,778,338		96,778,338		90,168,186	

CHAPTER 5 GENERAL ASSESSMENT AND CONCLUSION

The technical and cost comparisons made in the previous chapters are in summary as follows.

i) Design Traffic Capacity against the forecast traffic volume of 500 vpd (ADT two-way) in the year 2002

	Design Traffic Capacity (vpd)
Recommended	12,000 ~ 7,600
Sarawak	9,500
Peninsular	11,000 ~ 7,100

ii) Quantified Requirements

	Recommended	Sarawak	Peninsular
Verticle curve length at crest	A	-	A
at sag	A	-	A
Stopping sight distance	A	-	A
Passing sight distance	A	-	A
Minimum curve radius	A	B	B
Transition curve	A	-	B
Oblique grade	A	-	-

Where A Equivalent to or above the computed safety requirement

B Below the computed safety requirement

\- Not specified in the criteria

iii) Construction Cost (Total length of roadwork: Approximately 135 km)

	(Total length: 135 km)		(Mountainous area: 35 km)	
	Cost	Index	Cost	Index
Recommended	M$ 125 million	1.00	M$ 29 mil	1.00
Sarawak	M$ 130 million	1.04	M$ 33 mil	1.16
Peninsular	M$ 117 million	0.93	M$ 26 mil	0.92

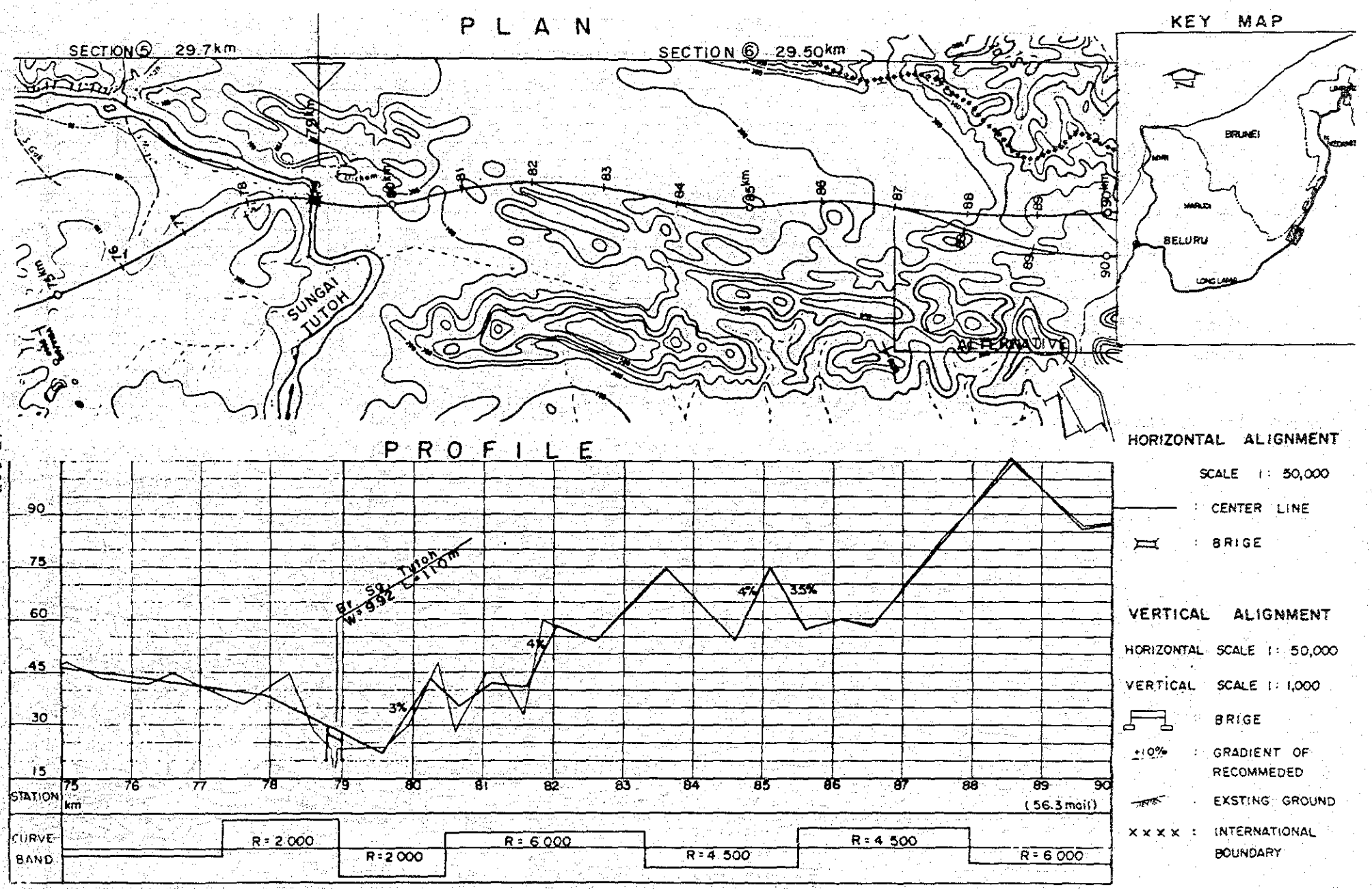
As stated in the introduction, the Sarawak Standard is featured by the absence of separated design criteria for areas of mountainous and rolling terrains, and the absence of stipulations for the requirements of some design elements, such as curve lengths, sight distances and etc., which are important safety factors for roadway performance. While supplementation of additional design criteria of the latter category is necessary so that qualities of all roadways can be maintained above the desirable standard, introduction of new criteria of the former category is even more important as the lack of such criteria itself inevitably demands all roadways in areas of mountainous and rolling terrains to be constructed to the same standard as in flat area, which is not only costly in pecuniary aspect as discussed in the last chapter, but also in the unquantifiable aspects related to destruction of nature which should be confined to the extent of absolute necessity.

From the above points of view it is justifiable that consideration be made to replace the existing Sarawak Standard by either the Peninsular Standard or the recommended criteria which is basically a modification of the existing local one.

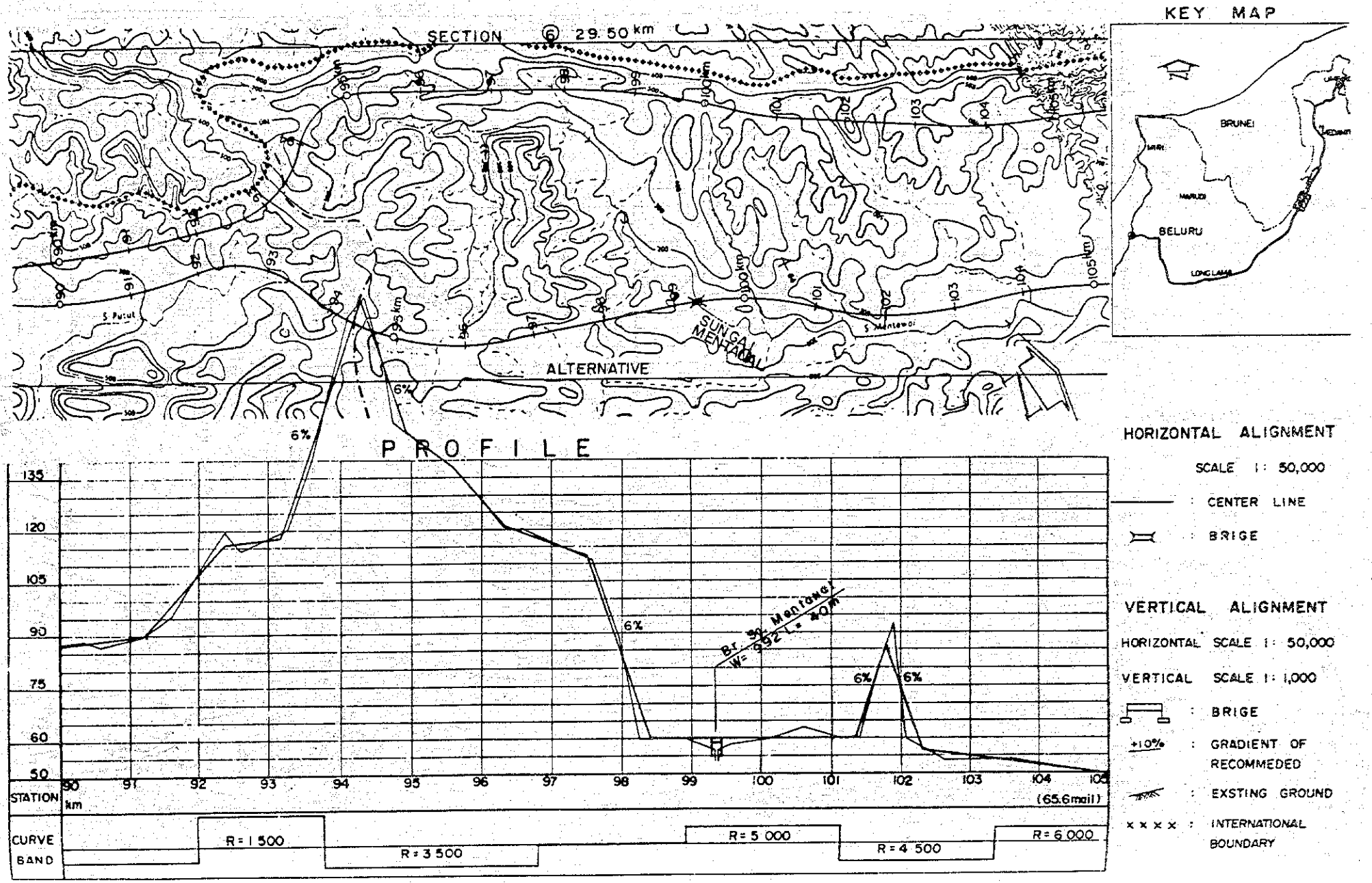
However, as the difference in construction costs involved in relatively small between the use of the Peninsular standard and the recommended criteria, it is not justifiable to introduce the former in stead of the latter which are almost the same as the existing local standard as far as the flat area portions are concerned, taking into consideration the importance of consistency in roadway standard within the same network system, which will inevitably be disturbed by switching of the whole Standard.

It is therefore advisable that the recommended standard be adopted for this construction project, and if possible, as a base of revision for the existing standard to be implemented in future constructions.

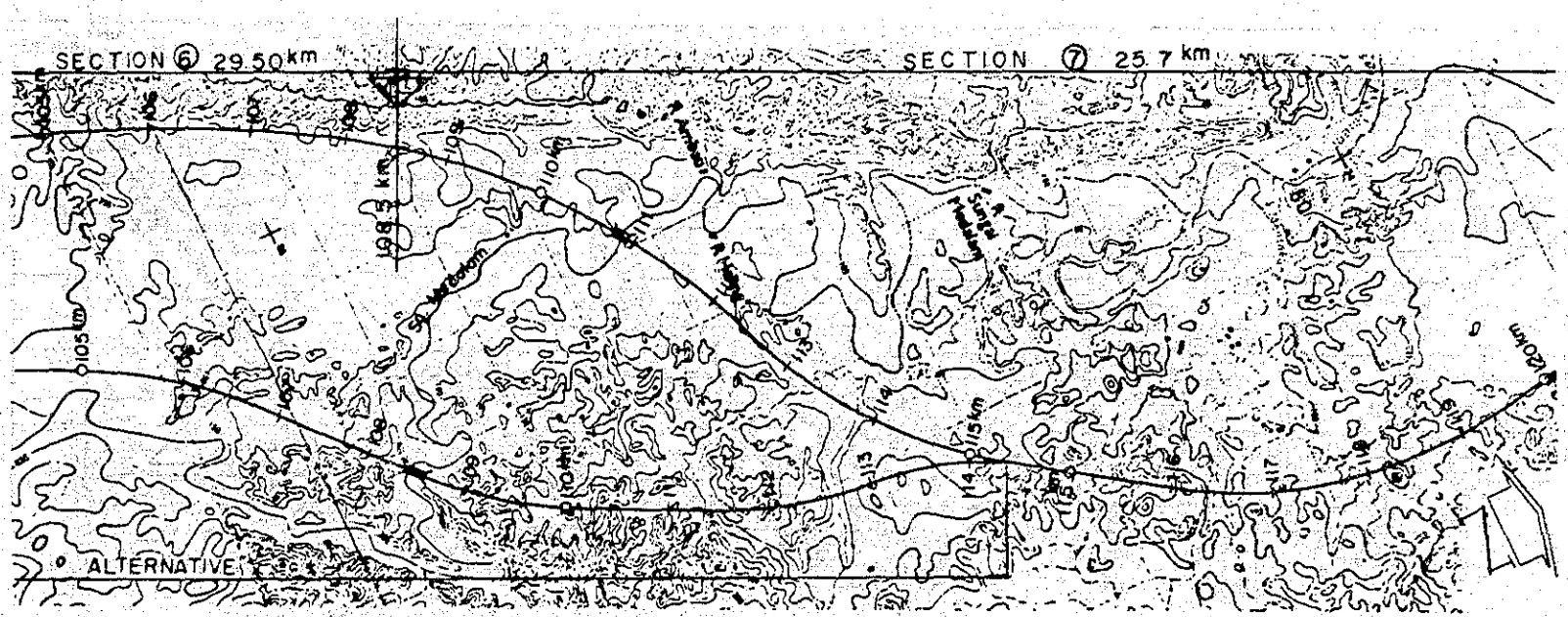
Appendix Fig. A-6-1 PLAN AND PROFILE (1)

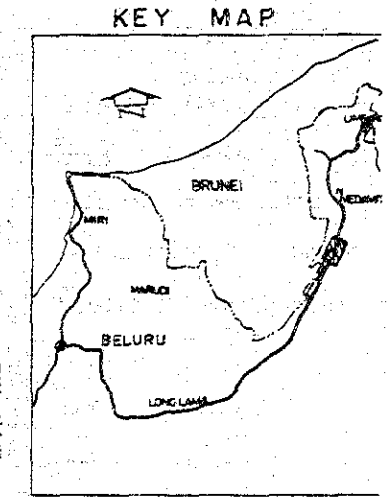


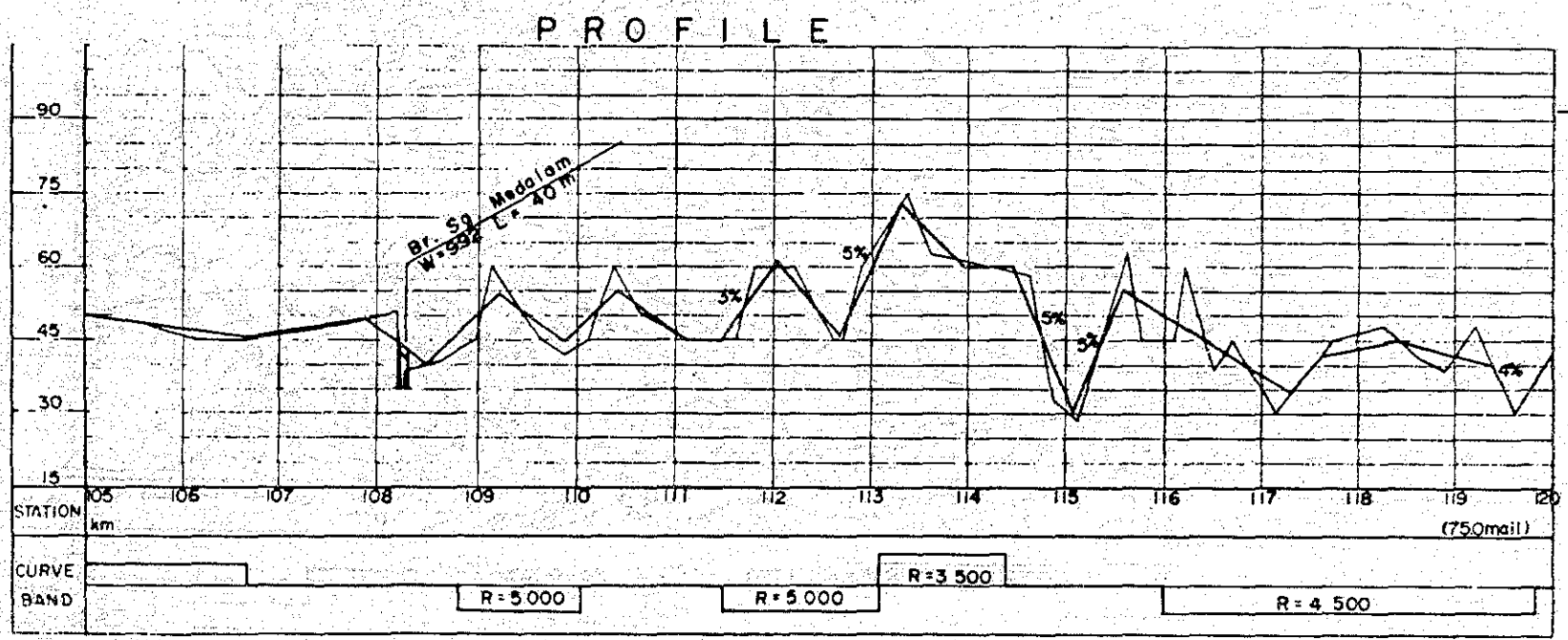
Appendix Fig. A-6-2 PLAN AND PROFILE (2)



Appendix Fig. A-6-3 PLAN AND PROFILE (3)







HORIZONTAL ALIGNMENT

SCALE 1 : 50,000

CENTER LINE

BRIGE

VERTICAL ALIGNMENT

HORIZONTAL SCALE 1 : 50,000

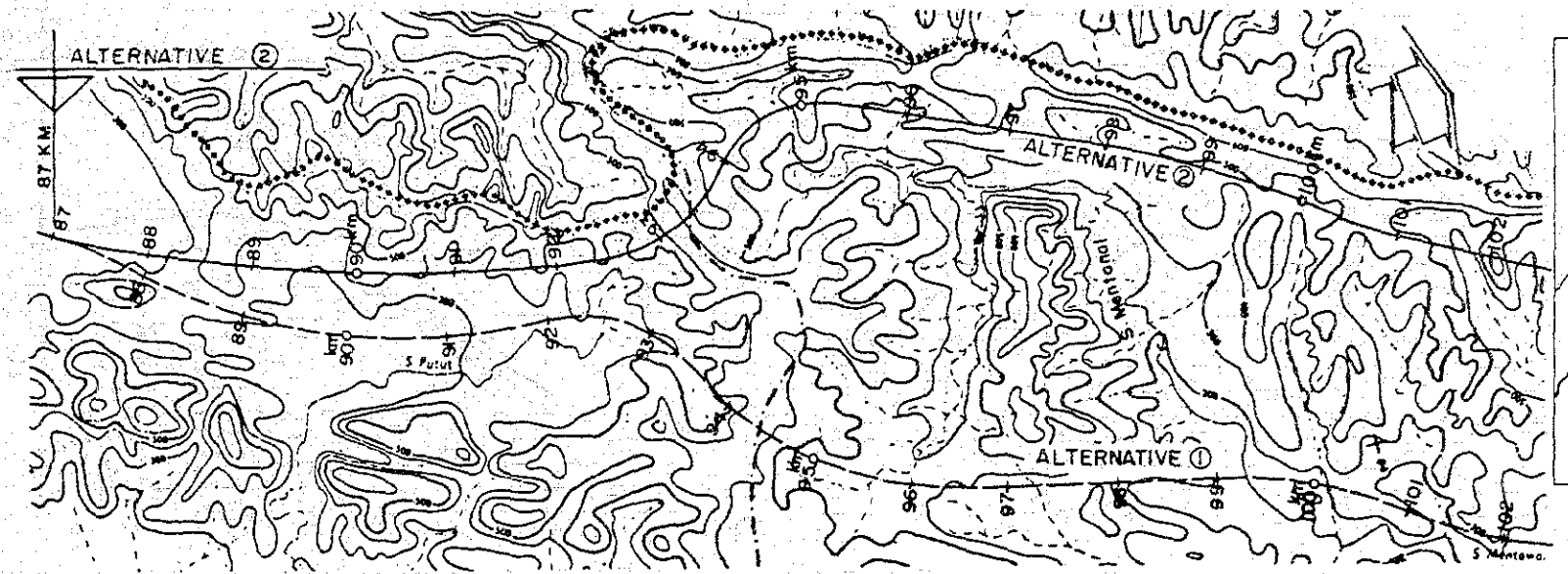
VERTICAL SCALE 1 : 1,000

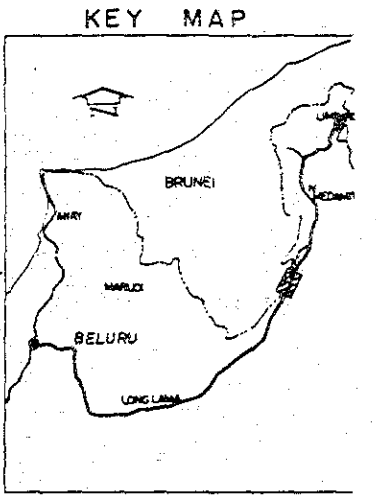
BRIGE

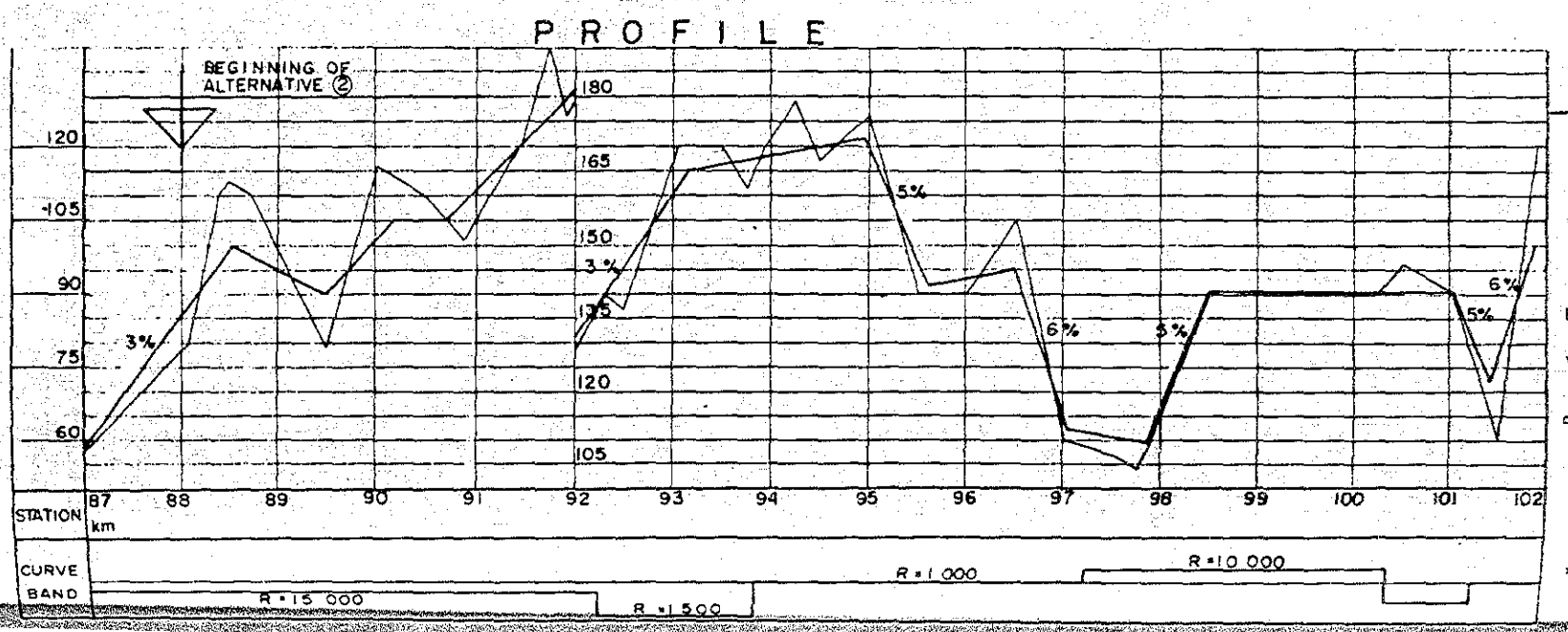
±10% : GRADIENT OF RECOMMEDED

EXSTING GROUND

Appendix Fig.A-6-4 PLAN AND PROFILE (4)







HORIZONTAL ALIGNMENT

SCALE 1 : 50,000

: CENTER LINE

: BRIGE

VERTICAL ALIGNMENT

HORIZONTAL SCALE 1 : 50,000

VERTICAL SCALE 1 : 1,000

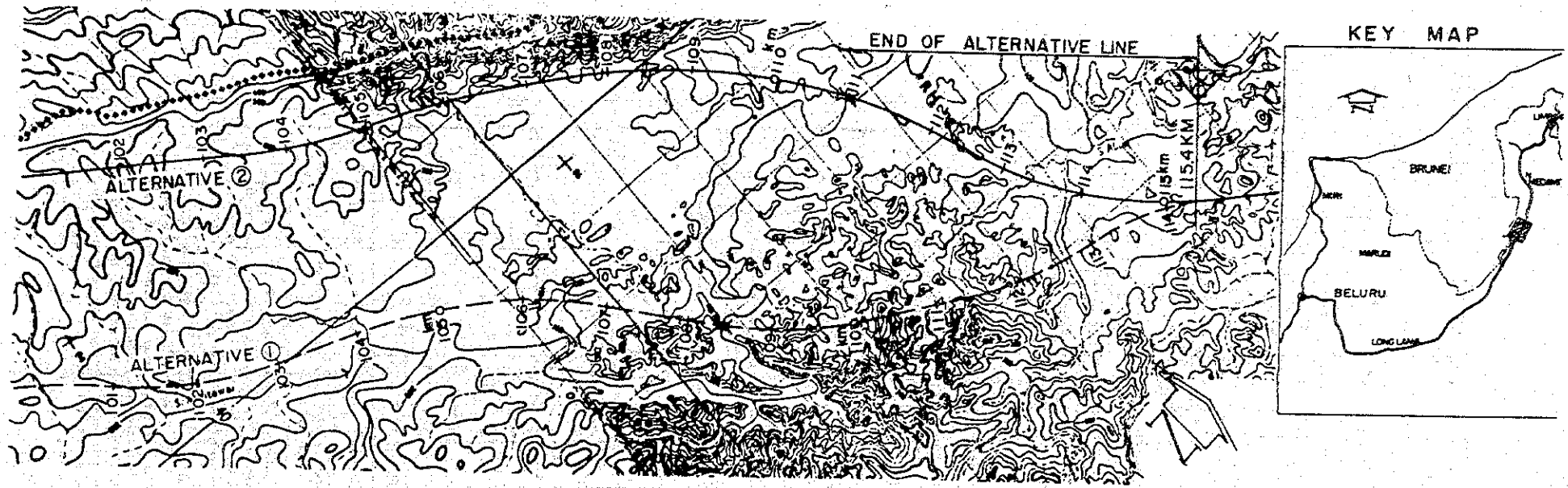
: BRIGE

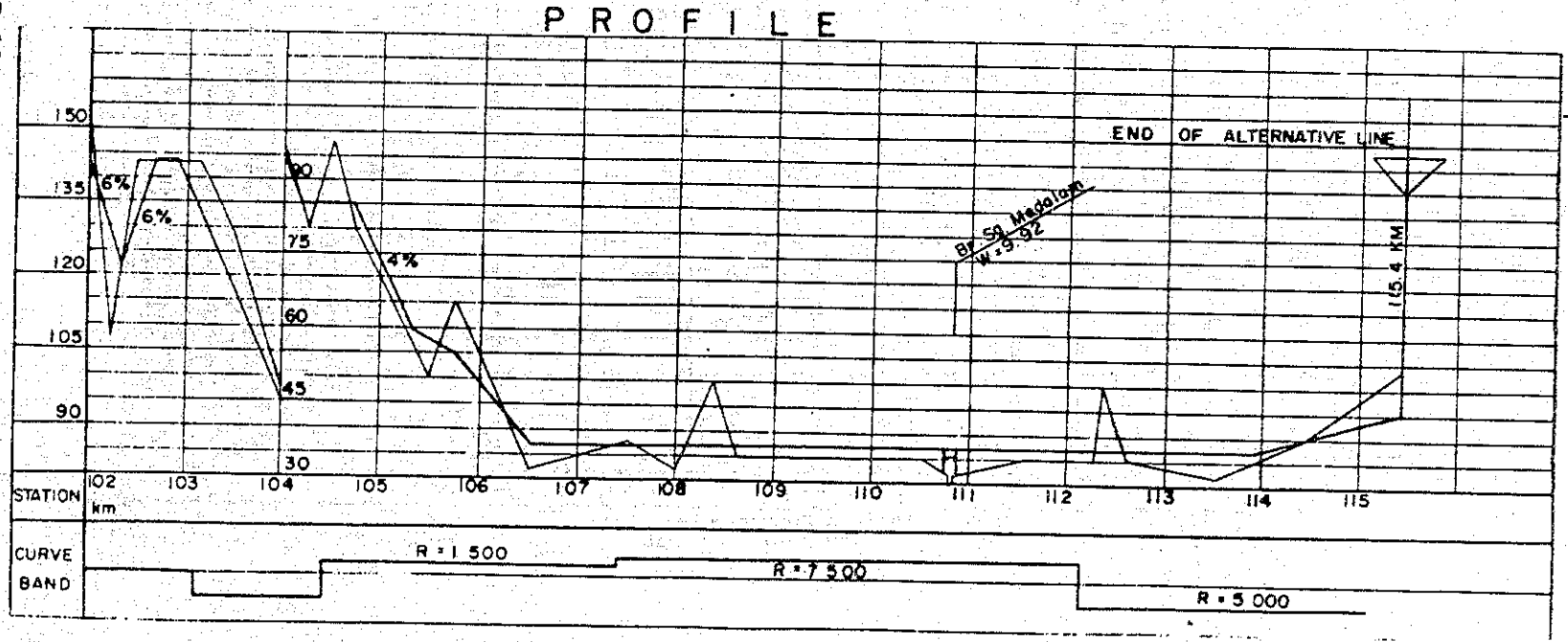
+1.0% : GRADIENT OF RECOMMEDED

: EXSTING GROUND

× × × × × : INTERNATIONAL BOUNDARY

Appendix Fig. A-6-5 PLAN AND PROFILE (5)





HORIZONTAL ALIGNMENT

SCALE 1 : 50,000

: CENTER LINE

: BRIGE

VERTICAL ALIGNMENT

HORIZONTAL SCALE 1 : 50,000

VERTICAL SCALE 1 : 1,000

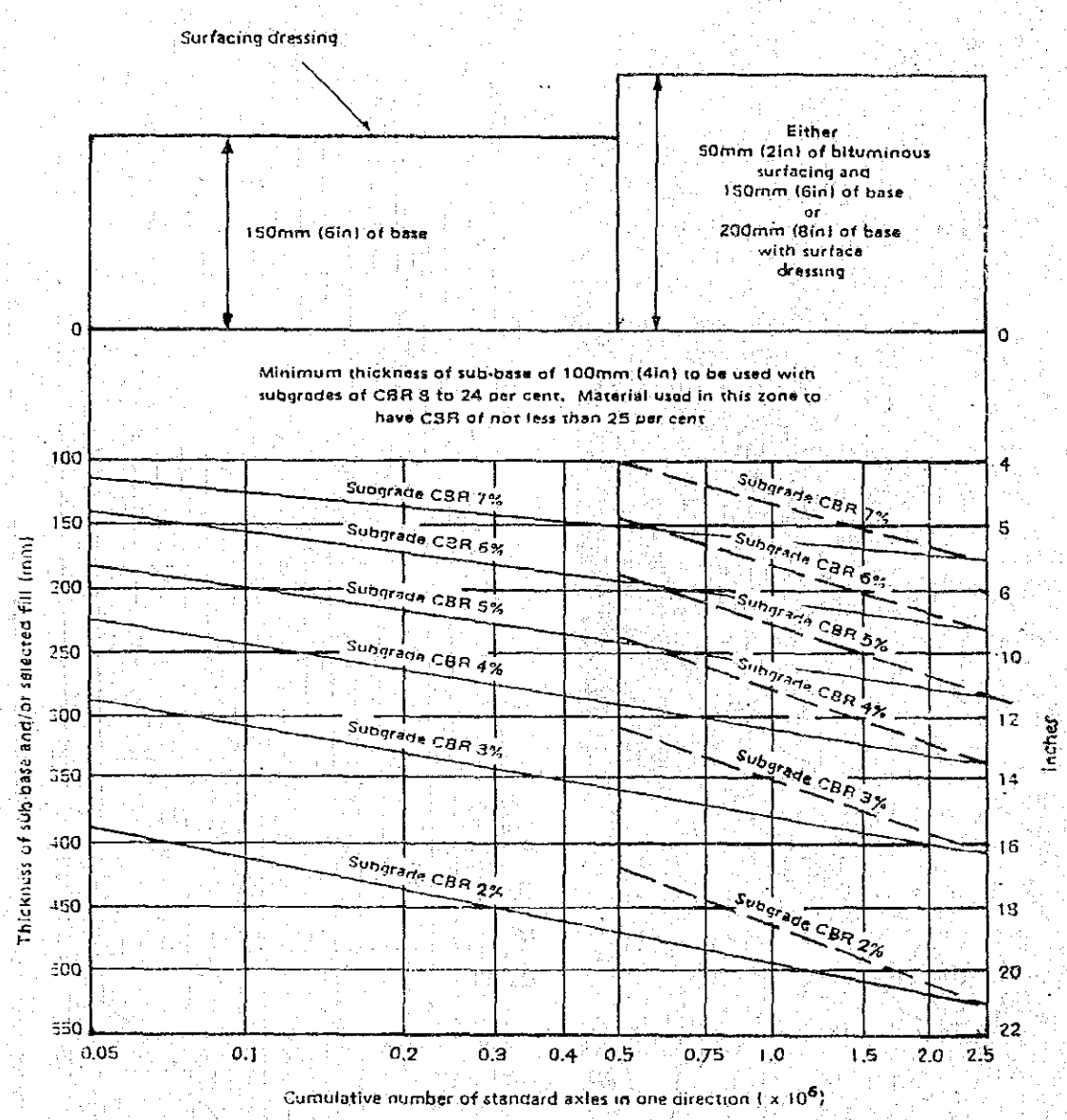
: BRIGE

+10% : GRADIENT OF RECOMMEDED

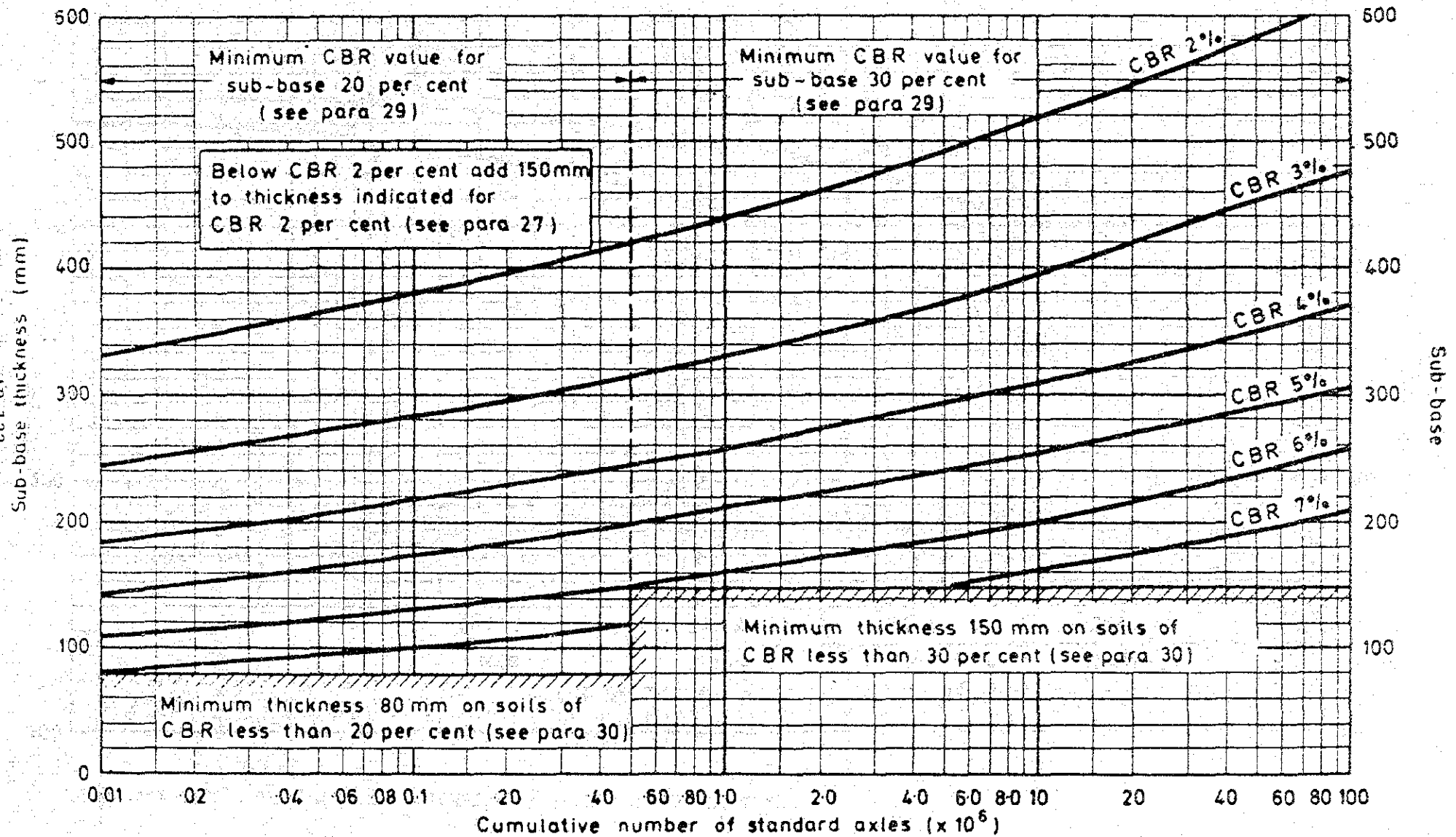
: EXSTING GROUND

x x x x x : INTERNATIONAL BOUNDARY

APPENDIX
Fig A-7-1
PAVEMENT DESIGH CHART FOR FLEXIBLE PAVEMENTS



If it is desired to provide at the time of construction a pavement capable of carrying more than 0.5 million standard axles, the designer may choose either a 150mm (6in) base with a 50mm (2in) bituminous surfacing or a 200mm (8in) base with a double surface dressing. For both of these alternatives, the recommended sub-base thickness is indicated by the broken line.

Alternatively, a base 150mm (6in) thick with a double surface dressing may be laid initially and the thickness increased when 0.5 million standard axles have been carried. The extra thickness may consist of 50mm (2in) of bituminous surfacing or at least 75mm (3in) of crushed stone with a double surface dressing. The largest aggregate size in the crushed stone must not exceed 10mm (¼in) and the old surface must be prepared by scarifying to a depth of 50mm (2in). For this stage construction procedure, the recommended thickness of sub-base is indicated by the solid line.

Appendix Fig. A-7-2 THICKNESS OF SUB-BASE