5-3 Hydrology

5-3-1 Outline of the Basins

1) Rainfall

A year in East Malaysia is known to consist of the rainy seasons from October through January and from April through June, and the dry seasons from February to March and from July through September. In the project area, however, the rainfall is so heavy throughout the year that the difference between dry and rainy seasons is practically indistinguishable.

Fig. 5-9 shows the isohyet line chart for 1975, and Fig. 5-10 indicates the monthly rainfall at major rainfall stations both based on the 1975 edition of the Hydrological Year Book of Sarawak.

The yearly precipitation in the new road construction areas is 3,500 - 4,000 mm (140 - 160 inch).

2) Existing Conditions of Main Rivers

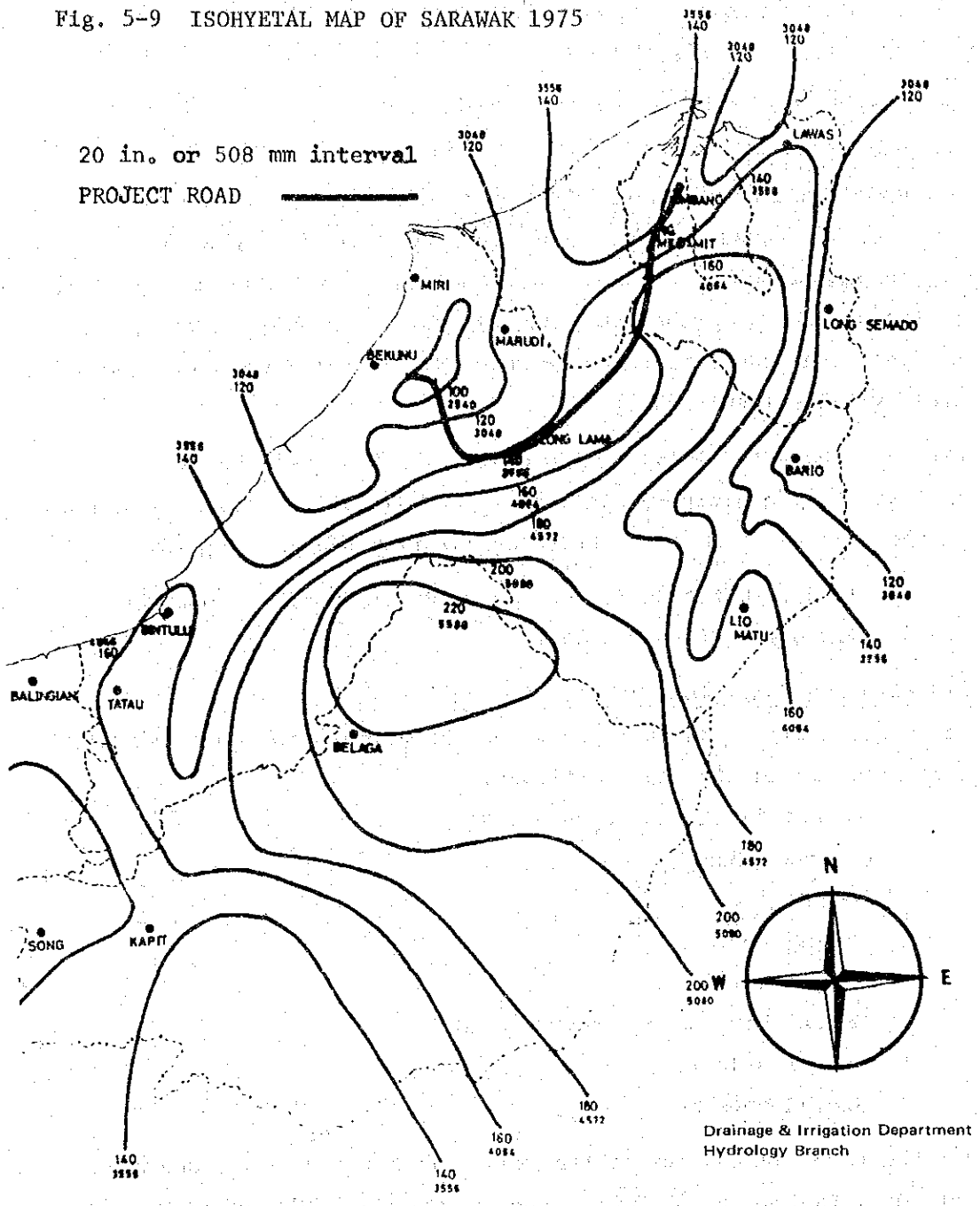
As shown in Fig. 5-11, a large number of rivers exist in the project area, including the followings:

- Batang Baram and tributaries:
  - ·Sungai Tinjar
  - ·Sungai Tru
  - ·Sungai Apoh
  - ·Sungai Tutoh
- Sungai Limbang and tributaries:
  - ·Sungai Medamit
  - ·Sungai Medalam.

All the river basins are so flat that the rivers meander and are not very stable. In addition, many rivers flood periodically. The location of roads should, therefore, be carefully selected taking into consideration such conditions which should be investigated properly.

Batang Baram in the vicinity of Long Lama is a large river having a width of 150 m, an upstream of 300 km length, and a catchment area area of 9,500 km^2.

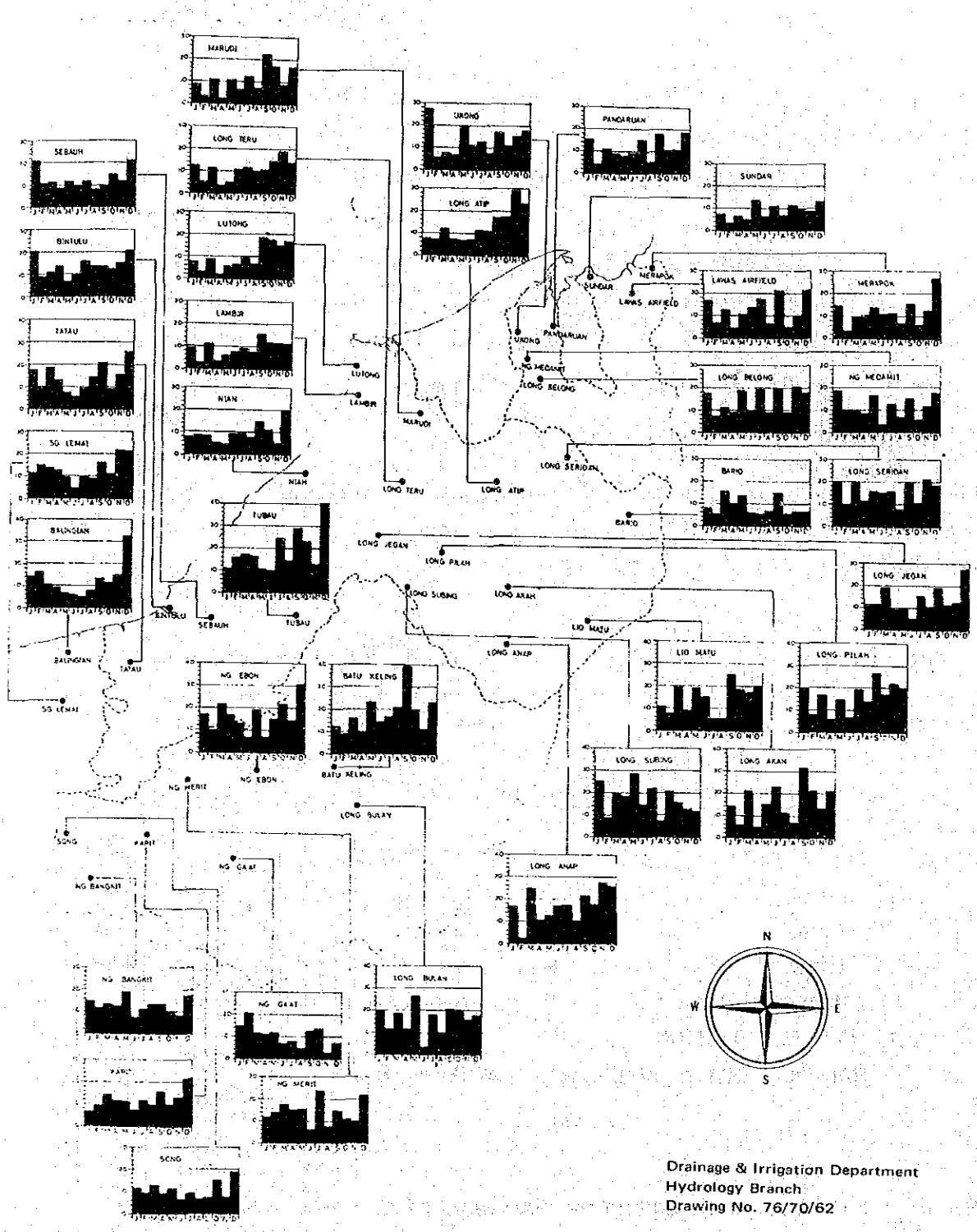
Fig. 5-9 ISOHYETAL MAP OF SARAWAK 1975



Transportation of lumber from the upper stream to the construction site area of the Batang Baram Bridge has not yet been done. This, however, will most likely happen in the future, and should, therefore, be taken into account in designing the bridge spans.

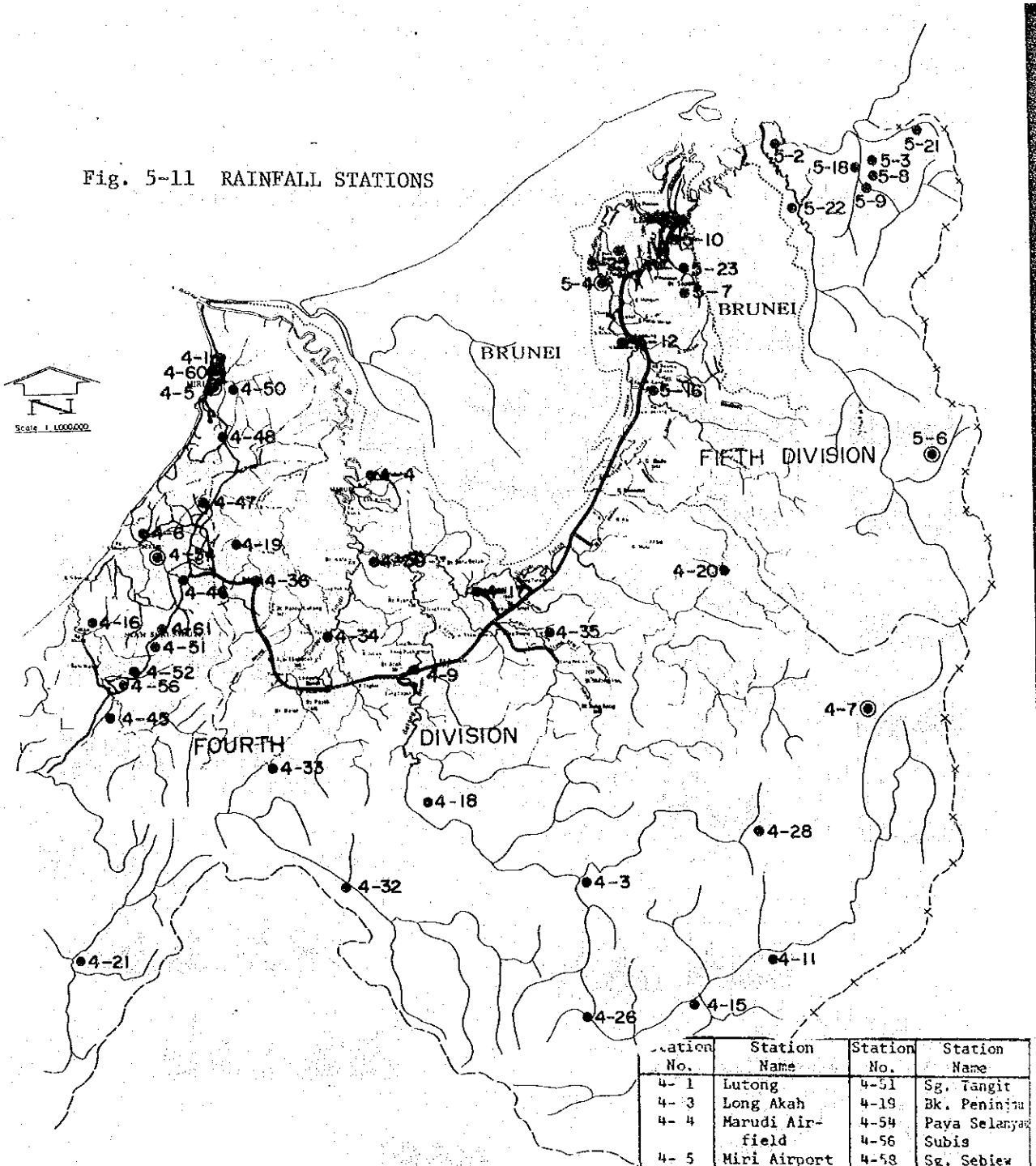
The second largest river next to Batang Baram in this area is Sugai Tutoh which, at the site of bridge construction, has exten-

Fig. 5-10 MONTHLY RAINFALL AT MAJOR RAINFALL STATIONS



Drainage & Irrigation Department
Hydrology Branch
Drawing No. 76/70/62

Fig. 5-11 RAINFALL STATIONS



Station No.	Station Name	Station No.	Station Name
4- 1	Lutong	4-51	Sg. Tangit
4- 3	Long Akah	4-19	Bk. Peninjau
4- 4	Marudi Air-field	4-54	Paya Selanyan
		4-56	Subis
4- 5	Miri Airport	4-58	Sg. Sebiew
4- 6	Bekenu Sibuti	4-59	Benawa
4- 7	Bario	4-60	D.I.D. Barrack
4- 9	Long Lama		
4-11	Lio Matu	4-61	Cattle Area
4-15	Long Moh	5- 2	Sundar
4-16	Niah	5- 3	Lawas Estate
4-17	Long Panai	5- 4	Ukong
4-18	Long Pilah	5- 6	Long Semadoh
4-20	Long Seridan	5- 7	Kubong
4-21	Tubau	5- 8	Lawas Reservior
4-23	Sebauh		
4-26	Long Anap	5- 9	Lawas Air-field
4-28	Long Leliang		
4-32	Long Subing	5-10	Limbang P/House
4-33	Long Jegan		
4-34	Long Teru	5-12	Ng. Medamit
4-35	Long Atip	5-16	Long Belong
4-36	Beluru	5-18	Lawas Depot
4-45	Sg. Niah	5-21	Merapok
4-46	Sg. Sibuti	5-22	Trusan
4-47	Sarawak Oil Palm	5-23	Pandaruan
		5-25	Lubai Tengah
4-48	Lambir		
4-50	Kpg. Wire-less		
4-52	Landang III		

LEGEND

PROJECT ROAD

RAINFALL STATION

RAINFALL WITH EVAPORATION STATION

Scurce : HYDROLOGICAL YEAR BOOK, SARAWAK 1975

sive river-bed sediments (gravel less than 20cm in diameter) so that neigher a vessel nor a raft except for the long boat can travel on it.

For the design of Sungai Tutoh Bridge, therefore, the passage of vessels and rafters does not need to be taken into consideration. On the other hand, protection of the bridge structures from driftwood during flood period must be considered, since this river is close to the mountainous jungle.

Sungai Medamit, Sungai Limbang and Sungai Medalam experience a rapid and extensive change in water level during a very short flood stage due to the fact that they are located very close to the mountainous area. Moreover, driftwood occurs in the rivers quite frequently so that many areas are extremely difficult to travel even by means of a long boat. For Sungai Medamit and Sungai Limbang which are also used in transporting single logs of standard lengths from the upper stream, the design of their spans and scour and impact protection means should be done with this use of the river taken into proper consideration.

The characteristics of basins at the location of bridge construction sites are given in Table 5-11.

Table 5-11 Characteristics of River Basins at Bridge Sites

No.	River Name	Station	Catchment area A(km^2)	River Length L(km)	Head H(m)	River Slope S
1	Tinjar	*1) STA 0	2,725	150.0	1,379	1/109
2	Tru	13 + 100	484	49.0	526	1/93
3	Baram	26 + 100	12,694	311.0	1,900	1/164
4	Temala	35 + 500	249	32.0	287	1/111
5	Apoh	51 + 500	1,006	56.0	708	1/79
6	Terawan	63 + 900	118	22.0	1,137	1/19
7	Tutoh	81 + 600	3,043	130.0	1,283	1/101
8	Mentawai	104 + 200	40	5.0	155	1/32
9	Medalam	114 + 100	255	25.0	1,866	1/13
10	Limbang	127 + 600	2,076	115.0	2,088	1/55
11	Medamit	136 + 100	351	59.0	1,845	1/32
12	Saliban	139 + 600	22	11.0	392	1/28
13	Lubang	*2) STA 1 + 900	7	2.6	294	1/9
14	Polub Merah	7 + 00	11	6.8	416	1/16
15	Mengari	12 + 600	10	2.5	20	1/125
16	Palas	19 + 300	10	5.4	293	1/18
17	Berleras	22 + 300	3	1.9	294	1/6
18	Lubai	23 + 700	175	32.0	480	1/67
19	Melaban	25 + 600	29	10.0	141	1/71
20	Bakol	28 + 200	5	1.8	112	1/16
21	Brangas	29 + 200	3	1.0	112	1/9
22	Berawan	31 + 100	30	11.0	141	1/78
23	China	35 + 200	6	2.3	21	1/110
24	Poyan	39 + 00	5	3.8	21	1/181

*1) Sg Tingar ∿ Ng. Medamit *2) Ng. Medamit ∿ Limbang

5-3-2 Rainfall Analysis

1) Rainfall Data

The distribution of rainfall stations within the project area is as shown in Fig. 5-11.

The annual isohyet line chart of the area and monthly rainfall at the individual rainfall stations are as illustrated in Fig. 5-9 and 5-10.

In order to compile the maximum annual daily rainfall, representative stations have been selected as listed in table 5-12, based on consideration of the availability of rainfall data, and the characteristics of distance from the project area.

The maximum annual daily rainfall for these representative rainfall stations are obtained in Table 5-13.

Table 5-12 A List of the Representative Rainfall Observation Station

No.	Station		River Basin	Type of Recorder
	Number	Name		
1	4-1	Lutong	Lutong	Std. G. & G.K(DAILY)
2	4-3	Lutong Akah	Baram	Std. G.
3	4-4	Marudi Airfield	Baram	Std. G. & G.K(DAILY)
4	4-5	Miri Airport	Miri	Std. G. & G.K(DAILY)
5	4-6	Bekenu Sibuti	Sibuti	Std. G.
6	4-7	Bario	Baram	Std. G. & G.K(DAILY)
7	4-9	Long Lama	Baram	G.K(WEEKLY)
8	4-11	Lio Matu	Baram	Std. G.
9	4-15	Long Moh	Baram	Std. G.
10	4-16	Niah	Niah	Std. G.
11	4-17	Long Panai	Baram	Std. G.
12	4-18	Long Pilah	Baram	Std. G.
13	4-20	Long Seridan	Baram	Std. G.
14	4-21	Tubau	Kemena	Std. G.
15	4-23	Sebauh	Kemena	Std. G.
16	4-26	Long Anap	Baram	Std. G.
17	4-28	Long Leliang	Baram	Std. G.
18	4-32	Long Subing	Baram	Std. G.
19	4-33	Long Jegan	Baram	Std. G.
20	4-35	Long Atip	Baram	Std. G.
21	4-45	Sg Niah	Niah	Std. G.
22	5-1	Limbang PWD	Limbang	G.K (DAILY)
23	5-4	Ukong	Limbang	Std. G. & G.K(DAILY)
24	5-7	Kubong	Pandaruan	Std. G. & G.K(DAILY)
25	5-10	Limbang	Limbang	Std. G.
26	5-12	Nanga Medamit	Limbang	Std. G. & G.K(DAILY)
27	5-16	Long Belong	Limbang	Std. G

Table 5-13 Maximum Annual Daily Rainfall

Year \ Station	4-1 Lutong	4-3 Long Akah	4-4 Marudi Airfield	4-5 Miri Airport	4-6 Bekenu Sibuti	4-7 Bario	4-9 Long Lama	4-11 Lio Matu	4-15 Long Moh	4-16 Niah	4-17 Long Panai	4-18 Long Pilah	4-20 Long Seridan	4-21 Tubau	4-23 Sebauh	4-26 Long Anap	4-28 Long Leliang	4-32 Long Subing	4-33 Long Jegan		4-35 Long Atip		4-45 Sg. Niah		5-1 Limbang pwd	5-4 Ukong	5-7 Kubong	5-10 Limbang	5-12. Nanga Medamit	5-16 Long Belong
1950		5.38	4.12	3.10																										
1951		6.30	2.53	7.70																										
1952	4.53	5.10	3.96	5.95																										
1953	5.82	6.54	3.20	4.10																										
1954	4.65	4.90	3.05	6.10																										
1955	4.95	6.59	3.28																											
1956	5.36	5.53	3.64	7.42				2.65																						
1957	5.45	6.78	3.04	5.76																										
1958	5.10	5.00		6.30			8.45																							
1959	6.10	6.93	5.56	9.15			4.28	3.33																						
1960	4.33	6.62	4.45	3.32																										
1961	7.91	4.35	4.58	7.41			4.59																							
1962	7.43	7.08	4.12	4.48																						4.75		8.40		
1963	13.80		27.06	11.97	10.65	2.17	5.47	1.65	4.00	12.60	7.40	5.12	3.85	3.62	3.50	4.76	3.87								5.92	3.84		5.50	4.42	
1964	3.02	7.00	6.04	3.09	3.63	1.47	4.21	3.69	3.74	3.95	4.91	30.41	3.14	3.62	5.89	4.18	2.78								4.24	5.11		4.96	4.85	10.1
1965	5.30	3.44	4.02	7.69	5.15	2.60	4.95	2.86	3.16	5.30	4.82	3.90	4.45	3.23	2.93	3.16	4.56	3.46	2.84		4.59				4.91	6.14		5.74	4.15	2.92
1966	6.01	4.43	4.25	4.62	10.55	2.40	9.00	3.20	4.50	3.00	7.92	4.65	3.60	3.75	3.62	3.60	3.54	3.30	5.50		9.35				4.15	7.50	3.24	4.85	5.22	
1967	6.23	5.80	4.80	6.52	5.77	3.83	5.98	2.98	4.46	2.11		4.45	8.05			3.96	4.65								4.88	6.20	6.45	6.39	5.30	
1968	3.74		4.23	4.37	6.82	6.74	4.80	5.35	8.05		17.90					4.90		3.96							7.90	7.89	5.43	8.68	6.70	
1969	7.78			6.41		3.00		3.35	5.74		4.02														3.21	4.02	3.56	4.90	3.80	
1970	7.37		3.20	5.10	5.10			4.12			4.46	4.68		10.03			4.17	11.05								5.16	6.33	5.79	4.50	
1971	6.53			5.26	11.00			3.31		7.49		5.36	4.79	17.61				12.25			5.09				3.00	5.20	4.73	3.84	4.15	4.03
1972	3.63	4.06	4.20	4.81	6.50	4.25		3.42	4.70	4.01	3.36	5.40	4.15	3.92		3.40		10.15	6.00		6.70				4.21	6.82	4.90	6.00	4.95	
1973	6.30	5.30	7.30	5.67	5.00	3.50		4.66		5.61		6.13	5.10	5.23					3.90		5.01				3.46	3.28	3.80	6.44	6.25	6.09
1974	7.98	5.66	3.15	4.10	3.43	2.25		4.75	3.00		6.13	5.05	4.16	3.98		4.90		7.39			6.12					5.47	4.40	4.93	5.40	7.25
1975	4.01	5.89	4.30	3.98		2.70		5.17		4.14		5.30	4.25	5.75	3.37	4.80		6.04	5.52		8.43					4.61	3.12	3.12	3.50	5.05
1976		4.22	5.00			3.75		4.80	5.15			5.43	4.57								4.65					3.52	8.22	5.52	4.92	5.20
1977		4.14	6.00			2.70		4.60	5.10		5.28	4.37	3.65			3.77		3.84			4.02				4.55	5.50	5.43		4.69	5.17

2) Probable Daily Rainfall

There are several methods of general use in calculating the probable daily rainfall, such as the Gumbel method, the Iwai method, the Thomas method, the Hazen method, and etc. The Thomas method which is of wider use in Malaysia is applied in this study.

The formular of the probability of excess in the Thomas method is as follows:

$$E = \frac{i}{N + 1}$$

where,

E = Probability of Excess

i = Order in the value of data

N = Number of data

The data from actual measurements and the Probability of Excess are given in the Appendix Fig. A-5-1 ∿ A-5-27. The Probable daily rainfall derived from these is as shown in Table 5-14, with this as a basis, and taking the importance of the area, as well as the rainfall quantity into considerations, the design return period is recommended to be 30 years.

Table 5-14 Probable Daily Rainfall

(mm)

Station		Return Period (years)		
Number	Name	10	30	50
4-1	Lutong	209	250	264
4-3	Long Akah	182	206	210
4-4	Marudi Airfield	176	210	228
4-5	Miri Airport	215	260	279
4-6	Bekenu Sibuti	316	420	470
4-7	Bario	132	168	182
4-9	Long Lama	170	194	206
4-11	Lio Matu	132	152	160
4-15	Long Moh	180	220	240
4-16	Niah	230	205	342
4-17	Long Panai	234	290	316
4-18	Long Pilah	160	172	180
4-20	Long Seridan	136	146	152
4-21	Tubau	148	168	176
4-23	Sebauh	100	106	109
4-26	Long Auap	130	142	150
4-28	Long Lellang	124	139	145
4-32	Long Subing	360	500	580
4-33	Long Jegan	190	230	250
4-35	Long Atip	225	270	295
4-45	Sg Nioh	128	170	191
5-1	Limbang PWD	174	208	224
5-4	Ukong	202	236	256
5-7	Kubong	196	240	260
5-10	Limbang	209	246	261
5-12	Nanga Medamit	168	175	182
5-16	Long Belong	254	325	370

5-3-3 Design High Water Discharge

1) Calculation

The Design High Water Discharge at the point of bridge construction is calculated by using the following Rational formula.

$$Q = \frac{1}{3.6} \cdot C.Ir.A.$$

Where,

Q = High Water Discharge (m^3/sec)

C = Coefficient of Run-off

Ir=Rainfall Intensity within the time of flood concentration (mm/hour)

A = Catchment Area (km^2)

2) Characteristics of Basin

a) Time of flood concentration.

The time of flood concentration is the time lag between the time of peak rainfall intensity and the time of peak discharge.

Although the use of observed data for the derivation of the time lag is more desirable, the following Kraven Formula is used in this study due to the deficiency of information.

$$T_I = \frac{L}{W}$$

Where,

T_I = The flow time of flood (hour)

L = The distance between the furthest point of constant riverbed within the basin, and the place of observation (km)

H = Head between the above points (km)

W = Propagation of flood wave obtained from Table 5-15. (m/sec)

Table 5-15 Propagation of Flood Wave

H/L	Over 1/100	1/100 - 1/200	Under 1/200
W (m/sec)	3.5	3.0	2.1

The time of flood concentration can be obtained by the use of the following formula, as shown in Table 5-16.

$$T = T_I + T_{II}$$

where,

T = Time of flood concentration

T_I = The flow time of flood (hour)

T_{II} = The inflow time from the furthest point in the basin into the river course. (Assumed here as 30 minutes)

Table 5-16 Concentration Time

No.	River Name	L(Km)	S	W(m/sec)	T_I(min)	T_{II}(min)	T(min)
1	Tinjar	150.0	1/109	3.0	833	30	863
2	Tru	49.0	1/93	3.5	233	"	263
3	Baram	311.0	1/164	3.0	1,728	"	1,758
4	Temala	32.0	1/111	3.0	178	"	208
5	Apoh	56.0	1/79	3.5	267	"	297
6	Terawon	22.0	1/19	3.5	104	"	134
7	Tuton	130.0	1/101	3.0	722	"	752
8	Mentawai	5.0	1/32	3.5	24	"	54
9	Medalam	25.0	1/13	3.5	119	"	149
10	Limbang	115.0	1/55	3.5	548	"	578
11	Medamit	59.0	1/32	3.5	281	"	311
12	Saliban	11.0	1/28	3.5	52	"	82
13	Lubang	2.6	1/9	3.5	12	"	42
14	Polub Merah	6.8	1/16	3.5	32	"	62
15	Mengari	2.5	1/125	3.0	14	"	44
16	Palas	5.4	1/18	3.5	26	"	56
17	Berleras	1.9	1/6	3.5	9	"	39
18	Lubai	32.0	1/67	3.5	152	"	182
19	Melaban	10.0	1/71	3.5	48	"	78
20	Bakol	1.8	1/16	3.5	9	"	39
21	Brangas	1.0	1/9	3.5	5	"	35
22	Berawan	11.0	1/78	3.5	52	"	82
23	China	2.3	1/110	3.0	13	"	43
24	Poyan	3.8	1/180	3.0	21	"	51

where, L: River length
S: River slope
W: Flow velocity

S = H/L

T_I : Flow time
T_{II}: Inflow time
T : Concentration time

3) Run-off Coefficient

The amount of run-off within a basin varies in accordance with the loss of rainfall which is determined by various factors such as landuse in the basin, conditions of land cover, etc.

Table 5-17 is a list of the run-off coefficients used by the Japan Highway Public Corporation.

Table 5-17 Run-off Coefficient: C

Land Surface Condition	c.	Land Surface Condition	c.
Road surface and side slopes	0.9	Built urban area	0.7
Precipitous Mountainous area	0.8	Woods	0.3
Rolling mountainous area	0.7	Mountain area basin	0.8
Undulating hilly and forest areas	0.6	Flat stream basin	0.7
Flat fields	0.5	Large river basin with half of the area flat	0.6
Foundered paddy fields	0.8		

In view of the fact, that all river basins relevant to this project are of mountainous or rolling terrain covered with tropical jungles which will not likely be developed rapidly, and also that a run-off coefficient of C = 0.3 is adopted in the "Bridge Site Investigation Report" of the Sarawak D.I.D., the run-off coefficient to be adopted for the project area is assumed to be as follows:

	Run-off coefficient
for large rivers	0.3
small rivers	0.6

4) Rainfall Intensity within Time of Flood Concentration

The rainfall intensity for the flood concentration time should be based on the short time rainfall data and the use of rainfall intensity formula in general. However, due to the lack of information, only the daily rainfall data is given in this report.

The rainfall intensity within the time of concentration is calculated in this study from the following Mononobe's formula as in

Table 5-18.

$$Ir = \frac{R_{24}}{24} \left(\frac{24}{Tc}\right)^{2/3}$$

Where,

Ir = Rainfall Intensity within the Time of Concentration (mm/hour)

R_{24} = Daily Rainfall (mm/day)

Tc = Concentration Time

Table 5-18 Rainfall Intensity During Time of Concentration

No.	Name of River	R24 (mm/day)	Tc (hour)	Ir (mm/hour)	Rainfall Station
1	Tinjar	365	14.383	21.4	4-33, 4-32
2	Tru	201	4.383	26.0	4-18, 4-33
3	Baram	174	29.300	6.3	4-7, 4-11, 4-28, 4-9 4-15, 4-26, 4-3, 4-18
4	Temala	221	3.033	36.6	4-18, 4-35
5	Apoh	270	4.950	32.2	4-35
6	Terawan	270	2.233	54.8	4-35
7	Tutoh	158	12.533	10.2	4-20, 4-7
8	Mentawai	148	0.900	55.0	4-20
9	Medalam	205	2.483	38.8	5-16
10	Limbang	205	9.633	15.7	5-16
11	Medamit	205	5.183	23.7	5-16
12	Saliban	175	1.367	49.3	5-12
13	Lubang	175	0.700	76.9	5-12
14	Polub Merah	175	1.033	59.4	5-12
15	Mengari	175	0.733	74.6	5-12
16	Palas	175	0.933	63.5	5-12
17	Berleras	240	0.650	110.9	5-7
18	Lubai	207	3.033	34.2	5-7, 5-12
19	Melaban	240	1.300	69.9	5-7
20	Bakol	240	0.650	110.9	5-7
21	Brangas	240	0.583	119.2	5-7
22	Berawan	240	1.367	67.6	5-7
23	China	243	0.717	105.2	5-7, 5-10
24	Poyan	243	0.850	93.9	5-7, 5-10

where, R24: Daily Rainfall
Tc : Time of Concentration
Ir : Rainfall Intensity During Time of Concentration

5) High Water Discharge

The high water discharge has been calculated based on the previously stated Rational formula and the characteristics of the basins.

The design high water discharge is determined with a design return period of 30 years, the following are reasons for its determination.

(1) In the D.I.D. rule, the design return period of 30 years is always used for the design high water discharge for the design of bridges. This same rule applies in the Sarawak state.

(2) There is generally a difference between a mountainous area and an urban area. The pertinent planning area is regarded as a mountainous one based on its own characteristics.

(3) The design return period of 30 years includes almost every recorded flood as shown in the appendix Fig. A-5-1 through A-5-27.

Table 5-19 shows the design high water discharge at each location of bridge site.

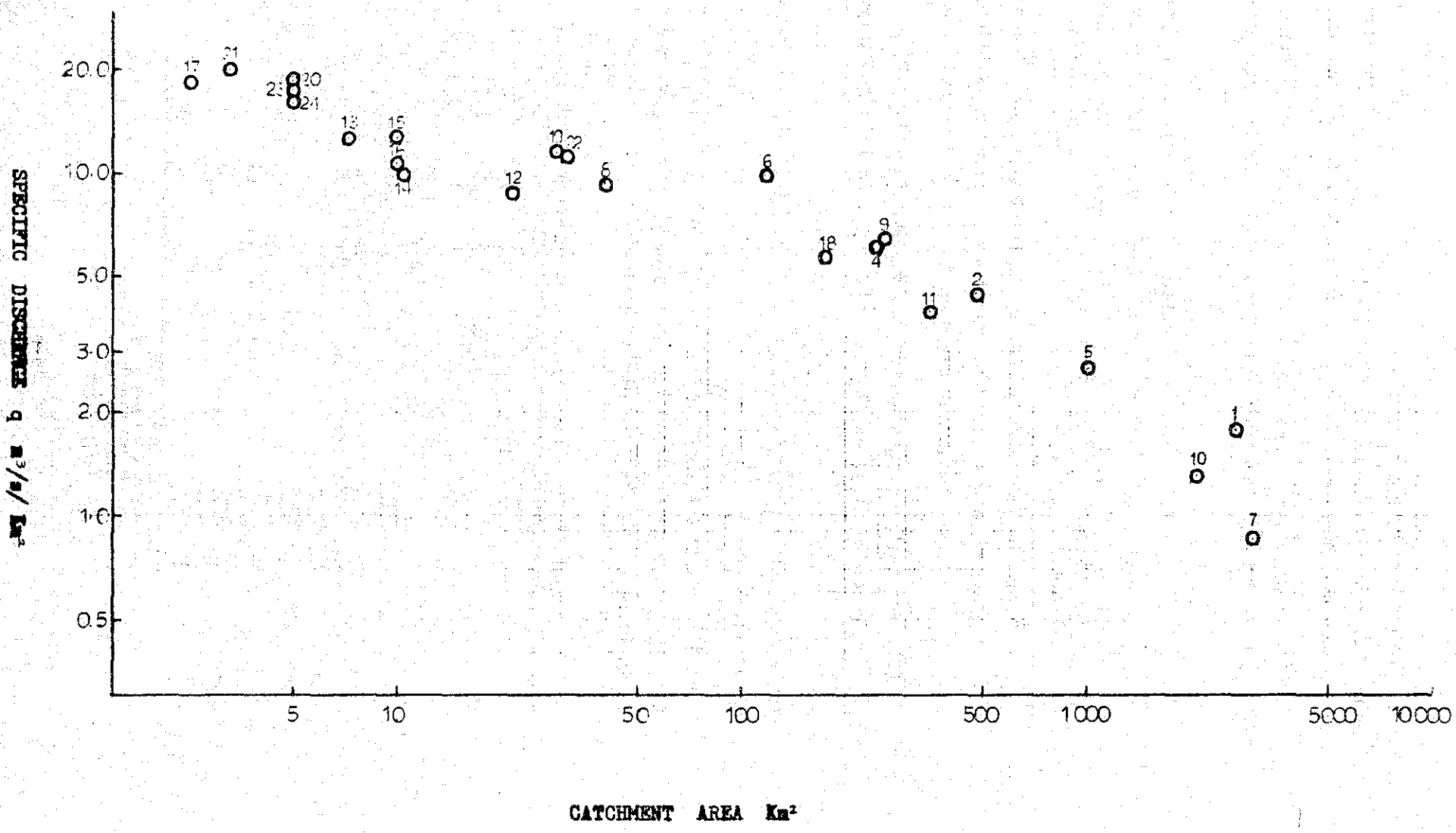
Fig. 5-12 shows the characteristics rendered appreciable by converting the above water discharge into specific discharge, and graphing it in relation to the Area of the basin.

Table 5-19 Calculation of Rain Water Discharge

No.	River Name	C	A(km^2)	Ir (mm/hour)	Q (m^3/sec)	q ($m^3/s/km^2$)
1	Tinjar	0.3	2,725	21.4	4,600	1.78
2	Tru	0.6	484	26.0	2,100	4.33
3	Baram	0.3	12,694	6.3	6,660	0.53
4	Temala	0.6	249	36.6	1,520	6.10
5	Apoh	0.3	1,005	32.2	2,700	2.68
6	Terawan	0.6	118	54.8	1,070	9.13
7	Tutoh	0.3	3,043	10.7	2,590	0.85
8	Mentawai	0.6	40	55.0	370	9.18
9	Medalam	"	255	38.8	1,650	6.47
10	Limbang	0.3	2,076	15.7	2,720	1.31
11	Medamit	0.6	351	23.7	1,380	3.95
12	Saliban	"	22	49.3	180	8.21
13	Lubang	"	7	76.9	90	12.78
14	Polub Merah	"	11	59.4	100	9.90
15	Mengari	"	10	74.6	120	12.00
16	Palas	"	10	63.5	110	10.60
17	Berleras	"	3	110.9	50	18.40
18	Lubai	"	175	34.2	1,000	5.70
19	Melaban	"	29	69.9	340	11.67
20	Bakol	"	5	110.9	100	18.52
21	Brangas	"	3	119.2	70	20.00
22	Berawan	"	30	67.6	340	11.28
23	China	"	6	105.2	110	17.50
24	Poyan	"	5	93.9	80	16.00

where, C : Run-off coefficient
A : Catchment area
Ir: Rainfall intensity
Q : Design water discharge
q : Specific discharge

Fig. 5-12 SPECIFIC DISCHARGE - CATCHMENT AREA



5-3-4 Design Cross Section

The design cross section at a bridge site is the cross section of clearance designed to allows the flow of the design high water discharge to pass safely through.

Determination of the cross section is usually made based on the following Manning's formula.

$$Q = A \cdot V$$

$$v = \frac{1}{n} \cdot I^{1/2} \cdot R^{2/3}$$

where,

Q = Discharge (m^3/s)

A = Cross sectional area of stream (m^2)

v = Velocity of flow (m/s)

R = Hydraulic mean depth (=A/P) (m)

P = Wetted perimeter (m)

n = Coefficient of roughness

I = Surface slope

Normally the surface slope, cross sectional characteristics etc. are determined by field investigation. In this study, however, since no such investigation result is yet available, the design flow speed is assumed, based on site observation with reference made also to the "Bridge Site Investigation Report" of the Sarawak D.I.D., as 3.0 m/sec.

Based on this assumption, the cross sectional area of the stream can be obtained from the following formula;

$$A = Q/v$$

The design cross section thus obtained for each river is given in Table 5-20.

With the design discharged and width of river further assumed as in Table 5-21, the clearance of bridge soffits are obtained as in Table 5-22.

Table 5-20 Required Discharge Area

No.	River Name	Discharge Q (m^3/sec)	Velocity V (m/sec)	Discharge Area A (m^2)
1	Tinjar	4,860	3.0	1,620
2	Tru	2,100	"	700
3	Baram	6,660	"	2,220
4	Temala	1,520	"	510
5	Apoh	2,700	"	900
6	Terawan	1,070	"	360
7	Tutoh	2,590	"	860
8	Mentawai	370	"	120
9	Medalam	1,650	"	550
10	Limbang	2,720	"	910
11	Medamit	1,380	"	460
12	Saliban	180	"	60
13	Lubang	90	"	30
14	Polub Merah	100	"	30
15	Mengari	120	"	40
16	Palas	110	"	40
17	Berleras	50	"	20
18	Lubai	1,000	"	330
19	Melaban	340	"	110
20	Bakol	100	"	30
21	Brangas	70	"	20
22	Berawan	340	"	110
23	China	110	"	40
24	Poyan	80	"	30

Table 5-21 Design Cross Section

No.	River Name	Discharge Area A(m^2)	Depth H(m)	Width B(m)	Clearance (m)
1	Tinjar	1,620	9.0	180	1.2
2	Tru	700	7.0	100	1.2
3	Baram	2,220	9.5	240	1.5
4	Temala	510	6.0	85	1.0
5	Apoh	900	7.5	120	1.2
6	Terawan	360	5.0	72	1.0
7	Tutoh	860	6.7	130	1.2
8	Mentawai	120	5.0	24	0.8
9	Medalam	550	6.0	92	1.0
10	Limbang	910	7.0	130	1.2
11	Medamit	460	6.0	77	1.0
12	Saliban	60	3.0	20	0.6
13	Lubang	30	2.0	15	0.6
14	Polub Merah	30	2.0	15	0.6
15	Mengari	40	2.0	20	0.6
16	Palas	40	2.0	20	0.6
17	Berleras	20	2.0	10	0.6
18	Lubai	330	5.0	66	1.0
19	Melaban	110	3.0	37	0.8
20	Bakol	30	2.0	15	0.6
21	Brangas	20	2.0	10	0.6
22	Berawan	110	3.0	37	0.8
23	China	40	2.0	20	0.6
24	Poyan	30	2.0	15	0.6

Table 5-22 Bridge Soffit Clearance Required

Design discharge (m^3/sec)	Clearance (m)
0 ∿ 200	0.6
200 ∿ 500	0.8
500 ∿ 2,000	1.0
2,000 ∿ 5,000	1.2
5,000 ∿ 10,000	1.5
10,000 ∿	2.0

5-3-5 Investigation of Bridge Site Conditions

Table 5-23 summarizes the results of investigation of the bridge site conditions on the main rivers.

Table 5-23 Main River Survey Data

No.	Name of River	Station	Nearest Village	Description of Site			
				Width of River	Width of Flood	Stream	Existing Structure
1.	Sg. Salu	*1) STA 1 + 100	R. Peng Barat	9.0m	–	Muddy small stream	Wooden Br. ℓ = 12m b = 3.7
2.	Sg. Teman	24 + 100	R. Kodis	11.8m	50m	Muddy stream	Temporary Timber Bridge New Bridge under construction
3.	Sg. Bakong	36 + 800	R. Jampi	23.6m	–	Muddy stream Gravel on bed Driftwood	Temporary Timber Bridge New Bridge under construction
4.	Sg. Kelulit	45 + 400	–	11.8m	–	Muddy stream	Temporary Timber Bridge New Bridge being planned
5.	Sg. Bok	46 + 400	R. Pagan	26.0m	–	Muddy stream	Temporary New Bridge being planned
6.	Sg. Tinjar	54 + 700	Long Tulungan	93.0m	200m	Muddy stream	New Bridge being planned by Australian Colombo Plan
7.	Sg. Tru (Teru)	*2) STA 13 + 100	R. Ingkot	15.0m	45m	Muddy stream Meandering flow	–
8.	Batang Baram	26 + 100	Long Lama	150m	250m	Muddy stream	–
9.	Sg. Apoh	51 + 500	R. Akan Ajang	25.0m	75m	Muddy stream	–
10.	Sg. Tutoh	81 + 600	–	50.0m	–	Clear stream Gravel on bed	–
11.	Sg. Medalam	114 + 100	–	20.0m	–	Muddy stream Driftwood	–
12.	Sg. Limbang	127 + 600	R. Pakatom	70.0m	–	Muddy stream	–
13.	Sg. Medamit	136 + 100	R. Nanga Awang	15.0m	45m	Clear stream Gravel on bed	
14.	Sg. Lubang	*3) STA 1 + 900	Ng. Medamit	6.0m	400m	Muddy small stream	Steel Girder Br. Wooden Floor ℓ = 7.2 b = 3.7
15.	Sg. Polub Merah	7 + 100	Kpg. Lubok Lasas	6.0m	–	Gravel on bed Muddy stream	Steel Girder Br. Wooden Floor ℓ = 7.2 b = 3.7
16.	Sg. Mengari	12 + 600	Kpg. Tanjong Liman	6.0m		Muddy stream	Steel Girder Br. Wooden Floor ℓ = 7.2 b = 3.7
17.	Sg. Palas	19 + 300	–	3.5m	–	Gravel on bed small stream	Wooden Bridge ℓ = 3.9 b = 3.8
18.	Sg. Berleras	22 + 300	–	2.5m	–	Muddy very small stream	Wooden Bridge ℓ = 3.0m b = 3.7
19.	Sg. Lubai	23 + 700	–	33.0m	–	Muddy stream	Steel Girder Br. (3 spans) Wooden Floor ℓ = 35.2 b = 3.7
20.	Sg. Melaban	25 + 600	–	15.0m	–	Muddy stream	Steel Girder Br. Wooden Floor ℓ = 15.8 b = 3.7
21.	Sg. Bakol	28 + 200	Kpg. Bakol	10.0m	–	Bed Rock Gravel on bed	Steel Girder Br. Wooden Floor ℓ = 12.7 b = 3.8
22.	Sg. Brangas	29 + 200	Kpg. Bakol	9.0m	–	Muddy stream	Steel Girder Br. Wooden Floor ℓ = 9.9 b = 3.7
23.	Sg. Berawan	31 + 100	Kpg. Berawan	15.0m	–	Muddy stream	Steel Girder Br. Wooden Floor ℓ = 17.3 b = 3.7
24.	Sg. China	35 + 200	Limbang	6.0m	–	Muddy small stream	Wooden Br. ℓ = 9.0
25.	Sg. Poyan	39 + 00	Limbang	12.0m	–	Muddy stream	Temporary Bridge New Bridge under construction

*1) : Miri-Bintulu Rd. ∿ Sg. Tinjar
*2) : Sg. Tinjar ∿ Ng. Medamit
*3) : Ng. Medamit ∿ Limbang

5-4 Construction System

5-4-1 Local Constructing Industry

Table 5-24 shows the number of contractors registered with the Sarawak P.W.D. by type of classification.

Table 5-24 Number of Registered Local Contractors by Classification

Class	Head I	Head I	Head I	Contract price
A	5 (18)	12 (31)	2 (13)	100,000 -
B	2 (8)	4 (8)	1 (3)	100,000 - 2,000,000
BX	4 (6)	9 (20)	1 (2)	100,000 - 1,000,000
C	10 (19)	9 (24)	4 (10)	50,000 - 500,000
D	4 (21)	8 (35)	1 (10)	25,001 - 250,000
E	10 (19)	22 (42)	13 (20)	25,001 - 150,000
EX	20 (56)	50(248)	17 (30)	25,000 - 50,000
F	26 (62)	85 (66)	23 (44)	- 25,000

Where; Head I (Engineering Contractors)

For work in reinforced concrete, steel, masonary and timber bridges and culverts, framed buildings, wharves, jetties, sea and river walls, retaining walls, water supplies, service reservoirs, sewage works.

Head II (Building Contractors)

For work on framed and unframed buildings, building repairs, painting, sanitary and plumbing installation, domestic drainage, carpentry and joinery, water services, concrete drains works, including light timber and concrete piling, steel fencing and demolitions.

Head III (Road, Quarry and Earthwork Contractors)

For general earthwork, site clearing, levelling and drainage, road construction, river clearing and jungle felling, quarry operation.

Note: 1. West Malaysia & Overseas Contractors are involved.

2. ( ): Inclusive of Contractors registered on Limit-time basis.

3. Class depends on the Contract Price.

Source: Public Works Department List of Registered Contractors Head I, II & III Feb. 2975.

Those classified under "Head III" are the only local contractors qualified to contract a project of this type, and among the Head III contractors, those classified under class A are qualified to undertake contracts of over M$100,000 which further limits the number of available local contractors into two. Even if the contractors registered under limited-time basis (who are mainly West Malaysian and foreign contractors) were taken into account, the number would be only to 13.

Class A, B and BX consist mostly of contractors of engineering works, and very few for road construction. This is based on the fact that structural work under local P.W.D. are constructed by the registered contractors whereas earthwork and pavements are directly executed by P.W.D. personnel.

Since few pieces of construction machinery are owned by the registered contractors, such equipment is occasionally leased from the P.W.D. together with the mechanics.

5-4-2 Project Implementation System

In the case of large scale construction work which involves voluminous earthwork and the work should be executed by the use of heavy equipment, it is required that the executor involved has both sufficient equipment at his disposal, and sufficient technical capacity.

From this point of view, it is rather difficult to rely entirely on the local contracting industry for the implementation of this project, and therefore, consideration of different alternatives for the construction system is absolutely necessary.

Alternative 1: To follow the same customary practice in the implementation of P.W.D. projects.

In this case, structural work involved would be contracted to the local private sector and earthwork and pavements would be executed by the P.W.D.

personnel as usual, in the previously described system.

Alternative 2: To contract to foreign contractors by international tender.

In this case, the client would invite tenders from abroad and award the contract to the winner.

Alternative 3: To contract to Joint Ventures of foreign and local contractors

Considering the fact that the fleet of construction equipment owned by the local government has limited capacity as shown in Table 8-3, and that under the current situation it is already in full operation, it is not likely that P.W.D. can spare a substantial work force for the execution of a large scale construction project without a drastic reinforcement of both its equipment and personnel resources, which is obviously unfeasible. Besides, the execution of some large span bridges involved as structural works may be beyond the resources of local contractors, as far as technical know-how is concerned.

For these reasons, Alternative I is not recommended.

Alternative 2 is not recommended because it will not bring forth any merit to the local industry in spite of the heavy public investment.

Alternative 3 has the advantages both in the possibility of smooth and timely implementation of the vitally important project through the direct introduction of foreign technologies, and in providing the local contracting industry with opportunities to improve their technical capacity through working in close cooporation with advanced foreign contractors, which will in the long run, contribute to the economical development of the local society.

From the above points of view, it is recommended that Alternative 3 be adopted for the implementation of this project.

Chapter 6

DESIGN CRITERIA AND ALTERNATIVES

Chapter 6 DESIGN CRITERIA AND ALTERNATIVES

6.1 Introduction

The structure of the road must guarantee safety and a smooth flow of traffic by taking into consideration the topographical and geological features, climate and the estimated traffic conditions of the area where the construction of the road will take place.

A design standard is established as general guidelines to be followed in the design of a road so that it satisfies the above conditions.

Currently, at the Sarawak P.W.D., there is a trunk road standard and a feeder road standard which establishes design criteria for trunk roads and for feeder roads respectively. However, since there are insufficient desing criteria with regard to the topographical division, a new design criteria has been established for this project. The determination of technical and economical feasibility has been established for this project utilizing effective alternatives for the feasibility investigation and conducting a comparison from various angles.

6-2 Design Criteria for the Trunk Roads

6-2-1 General

In implementing this study project, the JICA Study Team has presented a new design criteria for trunk roads and this has been adopted. Prior to the adoption, the study team was requested to and did conduct a comparison based on the following three points:

i) Criteria recommended by the JICA Survey Team

ii) "Trunk Road Standard" of the Sarawak P.W.D.

iii) "Minimum Geometric Design Criteria for New Roads in Rural Area, Group 04" of Peninsular Malaysia P.W.D.

The scope of the comparison included the following aspects:

i) Comparison of the alternative criteria against requirements deduced from well established and internationally accepted theories.

ii) Comparison of costs required for construction in accordance with the alternative criteria.

Based on the results of this comparison, the recommended alternative standards have been adopted for the reasons outlined below. The details of this comparison are given in the Appendix Note A-6-1: Report for Study of Geometric Design Criteria".

1) The Sarawak Criteria is insufficient in that a topographical division in the design criteria is not established. The modern road design criteria in general, establishes topographical divisions with the cost and the protection of the natural environment taken into consideration. A supplement to the Sarawak Criteria must be made with regard to road construction in mountainous regions.

2) Since the difference in construction costs involved is relatively small between the use of the Peninsular standard and the recommended criteria, it is not justified to introduce the former which gives a lower road service standard.

3) Since the recommended criteria is almost the same as the existing local standard as far as the flat area portions are concerned, its adoption will not disturb the consistency of the road.

The details of the previous three alternative standards, the AASHO criteria and the Japanese road structure ordinance is listed in Table 6-1.

6-2-2 Geometric Design Criteria

As previously stated, the new geometric design criteria makes a topographical division between flat areas, rolling areas and mountainous areas. The values for the design speed, the road-bed and shoulder widths, the maximum gradient, the critical grade length, the sight distance, the minimum radius, the transition and vertical curves and the oblique grade have been determined for each area. An outline of the main items is listed below.

1) Design Speed

According to the Sarawak State Trunk Road Standard, no matter what the topographical feature is, the design speed is adopted at 80 km/hr (50 mph). With the recommended standard, to promote low cost and sufficient service, the areas have been divided into flat areas, rolling areas and mountainous areas and the design speeds have been established at 80 km/hr (50 mph), 64 km/hr (40 mph) and 48 km/hr (30 mph) respectively.

2) Cross-Section Design

The width of the lanes must be wide enough to accommodate vehicles passing or overtaking each other. According to AASHO, the ideal lane width for all roads is 12 ft. (3.66 m) and the Sarawak State Trunk Road Standard adopts this value as well. With the new standard, this value is also adopted and the width of the two lanes is established at 7.32 m (24 ft).

The shoulder widths of the flat areas and rolling areas are determined to be 3.05 m (10 ft) and for the mountainous areas, 1.22 m (4 ft) with both construction cost and service quality taken into consideration. For other aspects of the road cross section design the Sarawak State Trunk Road Standard is used.

3) Minimum Curve Radius

It is desirable to use the maximum curve radius according to the topographical features for the alignment. For determining the

Table 6-1 Comparison of Design Criteria

	Recommended Criteria			Sarawak Standard			Peninsular Standard			AASHO			Design Standard in Japan		
1. Terrain 2/	F	R	M	–			F	R	M	F	R	M	F	R	M
2. Design Speed	80 (50)	64 (40)	48km/H (30MPH)	64 (40)	48 (30)	40km/H (25mph) 1)	80 (50)	64 (40)	48km/H (30MPH)	80 (50)	64 (40)	48km/H (30MPH)	80	60	50km/H
3. Pavement Type		–			–			–			–			–	
4. Surface width (Pavement Width)	7.32m	(24)		7.	4.27m	(14)	6.71m		(22)	7.32 (24)	6.70 (22)	6.10m (20)	7.00	6.50	6.00m
5. Usable Shoulder	3.05 (10)	3.05 (10)	1.22m (4)	2.44 (8)	2.44 (8)	2.91m (3)	2.44 (8)	2.44 (8)	1.22m (4)	3.66 (12)	3.05 (10)	1.83m (6)	1.75	1.25	1.25m
6. Formation Width	13.42 (44)	13.42 (44)	9.76m (32)	9.15 (30)	9.15 (30)	8.53m (28)	12.81 (42)	12.81 (42)	10.37m (34)	14.64 (48)	12.81 (42)	9.76m (32)	10.5	9.0	8.5m
7. Central Reservation		–			–			–			–			–	
8. Reserve Width	61/46m	(200/150)		40/30m	(132/99)		40/30m	(132/100)		37/30m	(120/100)			–	
9. Maximum Gradient Normal / Absolute	3 / 4	5 / 6	6 / 8%	5	8	10%	4	6	9%	4	6	9%	4 / 7	5 / 8	6% / 9%
10. Critical Grade Length Against Absolute	336 (1,000)	183 (600)	122m (400)	183 (600)	122 (400)	122m (400)	336 (1,100)	183 (600)	122m (400)	336 (1,100)	183m (600)	–	400	300	300m
11. Stopping Sight Dist.–Min.	107 (350)	84 (275)	61m (200)	84 (275)	61 (200)	61m (200)	107 (350)	84 (275)	61m (200)	107 (350)	84 (275)	61m (200)	110	75	55m
12. Passing Sight Dist.–Min.	549 (1,800)	458 (1,500)	336m (1,100)	458 (1,500)	336 (1,100)	336m (1,100)	549 (1,800)	458 (1,500)	336m (1,100)	549 (1,800)	458 (1,500)	336m (1,100)	550	350	250m
13. Minimum Radius	305 (1,000)	220 (750)	153m (500)	214 (700)	153 (500)	100m (330)	214 (700)	131 (430)	70m (230)	214 (700)	131 (430)	70m (230)	280	150	100m
14. Transition Curves Min. L	73 (240)	64 (210)	55m (180)	64 (210)	55 (180)	55m (180)	73 (240)	64 (210)	55m (180)	46 (150)	38 (175)	31m (100)	70	50	40m
15. Widening	–	0.9 (3)	1.4m (4.5)	Accor 0.6 (2)	0.9 (3)	1.5m (5)	–	0.9 (3)	1.4m (4.5)		–		–	–	0.5m
16. Superelevation Max./Min.	1 : 10			1 : 12 (8.3%	1:10	(2.6%)	1 : 10			0.50	0.58	0.66	7/2	6/2	5/2%
17. Camber Cross Fall	1 : 38			1 : 38 (	1:30		1 : 40				2%			2%	
18. Vert Curves Crest Min. K	26 (85)	17 (55)	9m (28)	17 (55)	9 (28)	9m (28)	26 (85)	27 (55)	9m (28)	26 (85)	17 (55)	9m (28)	R=3,000	1,400	800m
Sag Min. K	23 (75)	17 (55)	11m (35)	17 (55)	11 (35)	9m (30)	23 (75)	17 (55)	11m (35)	23 (75)	17 (55)	11m (35)	R=2,000	1,000	700m
19. Oblique Grade	10	10.5	11.5%	10.5	11.5	11.5%		–			–		10.5	10.5	11.5%

value when the minimum curve radius is desired, the following items are taken into consideration:

a) Comfort Guarantee

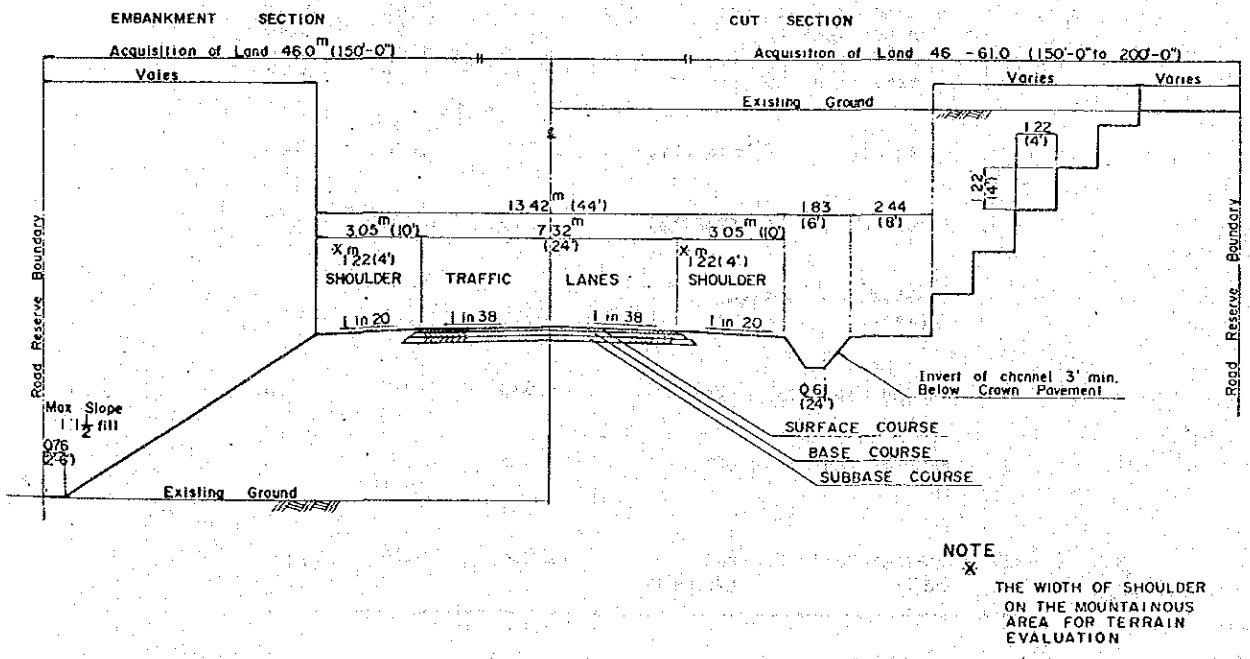
b) Useability. That is, the value must be applicable to most parts of the road.

With flat areas, the radius is the same as the value assigned by the trunk road standard which is 305 m (1,000 ft). For rolling areas the value is 229 m (750 ft) and for mountainous areas the radius is 153 m (500 ft).

4) Width of the Road Right of Way

With the recommended standard, the adopted width is the same as the width designated by the Truck Road Standard of 61 - 46 m (200 - 150 ft). But for the design, the standard width for flat areas and rolling areas must be a minimum of 61 m (200 ft) and for mountainous areas, a minimum of 46 m (150 ft). The typical cross-section is indicated in Fig. 6-1.

Fig. 6-1 TYPICAL CROSS SECTION OF TRUNK ROAD



5) Traffic Capacity

The traffic capacity is not included in the geometric design standard. The predicted traffic volume is indicated in Chapter 4 and the maximum volume is approximately 500 vpd. The traffic capacity here is calculated based on the methods of estimation for both the Japanese Road Structure Ordinance and AASHO. The results are shown in the table 6-2.

Table 6-2 Traffic Capacity

1. Terrain	F	R	M
2. Design Speed (km/hr)	80	64	48
3. Lane Width (m)	3.66	3.66	3.66
4. Lateral Clearance			
Left (m)	3.05	3.05	1.22
Right (m)	-	-	-
5. Heavy Vehicle			
Proportion of Heavy Vehicle (%)	20	22	36
Passenger Car Equivalent	2.9	3.9	4.0
6. Coefficient of Ajustment			
Lane Width	1.00	1.00	1.00
Lateral Clearance	1.00	1.00	0.96
Heavy Vehicle	0.72	0.61	0.48
Roadside Condition	1.00	1.00	1.00
Product of Coefficient	0.72	0.61	0.48
7. Basic Capacity (Veh/hr)	2,000	2,000	2,000
8. Possible Capacity (Veh/hr)	1,440	1,220	920
9. Ajustment of Design Level (%)	0.75	0.75	0.75
10. Design Capacity (Veh/hr)	1,030	915	690
11. Rate of Peak Hour (%) (K)	9	9	9
12. Average Daily Traffic (ADT) (Veh/day)	12,000	10,167	7,667

Note: F: Flat
R: Rolling
M: Mountainous

6) Maximum Grade and Critical Length

The maximum grade shall be determined from the ability of the vehicle to climb up-grade, which is indicated by the minimum tolerable speed, such as 100% for passenger car and 50% to 60% for commercial vehicle, corresponding to the design speed classification according to the type of topography.

The minimum tolerable speed is stipulated as that value where the reduction in speed, which is caused by the ability of vehicle to climb up-grade, does not disturb the operation of other vehicles.

The maximum grade is defined by two cases, i.e.: normal and absolute condition as follows.

Normal value

Normal value is a maximum grade on which the passenger car is able to climb at the design speed continuously and the commercial vehicle at the minimum tolerable speed. In this case, the grade is free from the critical length restriction.

Absolute value

Absolute value is a maximum grade with the restriction of the critical length. It is a particular length which the speed will be reduced to the minimum tolerable speed for the commercial vehicle and the design speed for the passenger car. It is assumed that each vehicle runs at the design speed at the beginning of the upgrade.

6-3 Design Criteria of the Feeder Roads

6-3-1 General

Although the design standard of the feeder roads connected to the trunk roads exists in the Sarawak State Feeder Road Standard, the design criteria is insufficient, particularly in that the design criteria is not given in accordance with topographical conditions at the site.

In the same way as with the establishment of a new geometric design criteria for the trunk roads, the new geometric design criteria of the feeder roads has been established. This one is based on the "Feeder Road Standard" of the Sarawak P.W.D., with reference to the "Minimum Geometric Design Criteria for New Roads in Rural Area, Group 02" of Peninsula Malaysia P.W.D.

The three standards are outlined in Table 6-3.

6-3-2 Geometric Design Criteria

As previously mentioned, with the new geometric design criteria, the topographical division is made between the flat areas, the rolling areas and the mountainous areas. The main points are summarized below.

1) Design Speed

According to the Sarawak State Feeder Road Standard, the design speed is 48 - 64 km/hr (30 - 40 mph) but to decrease the cost of construction and have sufficient service, topographical divisions must be made. The speed should be 64 km/hr (40 mph) for flat areas, 48 km/hr (30 mph) for rolling areas and 40 km/hr (25 mph) for mountainous areas.

2) Cross-Section Design

The width of the lanes are determined to be 4.27 m (14 ft) as designated by the feeder road standard, with the cost of construction and service taken into consideration. With flat areas and rolling areas, the shoulder widths are determined to be 2.44 m (3 ft) as with the feeder road standard. For the mountainous areas, the widths are determined to be 0.91 m (3 ft). The other dimensions are all in accordance with the feeder road standard.

Table 6-3 Comparison of Design Criteria

	Recommended			Sarawak		Peninsular (02)		
1. Terrain	F	R	M	–		F	R	M
2. Design Speed	64 (40)	48 (30)	40km/H (25mph)	48 ~ 64 km/H (30 ~ 40mph)		64 (40)	48 (30)	40 (25mph)
3. Pavement Type	–			–		–		
4. Surface Width (Pavement Width)	4.27m (14)			4.27m (14)		4.88m (16)		
5. Usable Shoulder	2.44 (8)	2.44 (8)	m 2.91 (3)	2.44m (8)		1.22 (4)	1.22 (4)	0.91m (3)
6. Formation Width	9.15 (30)	9.15 (30)	m 8.53 (28)	9.15m (30)		8.53m (28)		
7. Central Reservation	–			–		–		
8. Reserve Width	40/30m (132/99)			40/30m (132/99)		20m (66)	m 30 (100)	
9. Maximum Gradient Normal	5	6	8	5%		6	8	10%
Absolute	6	8	10	10%				
10. Critical Grade Length Against Absolute	183 (600)	122 (400)	122m (400)	–		Use Lay byes.		
11. Stopping Sight Dist. – Min.	84 (275)	61 (200)	61m (200)	–		84 (275)	61 (200)	61m (200)
12. Passing Sight Dist. – Min.	458 (1,500)	336 (1,100)	336m (1,100)	168m (550)		458 (1,500)	336 (1,100)	336m (1,100)
13. Minimum Radius	214 (700)	153 (500)	100m (330)	214m (700) 153m (500)		131 (430)	70 (230)	46m (150)
14. Transition Curves Min. L	64 (210)	55 (180)	55m (180)	–		64 (210)	55 (180)	55m (180)
15. Widening	0.6 (2)	0.9 (3)	1.5m (5)	According to P.W.D. Tables		0.6 (2)	0.9 (3)	1.5m (5)
16. Superelevation Max./Min.	1:10			1:12 (8.3%)/1:30 (3.3%)		1:10		
17. Camber Cross Fall	1:30			1:30 (3.3%)		1:30		
18. Vert.Curves Crest Min. K	17 (55)	9 (28)	9m (28)	–		17 (55)	9 (28)	9m (28)
Sag Min. K	17 (55)	11 (35)	9m (30)	–		17 (55)	11 (35)	9m (30)
19. Oblique Grade	10.5	11.5	11.5%	–		–		

Note: Figures in parenthesis are in feets.

F: Flat
R: Rolling
M: Mountainous

3) Minimum Curve Radius

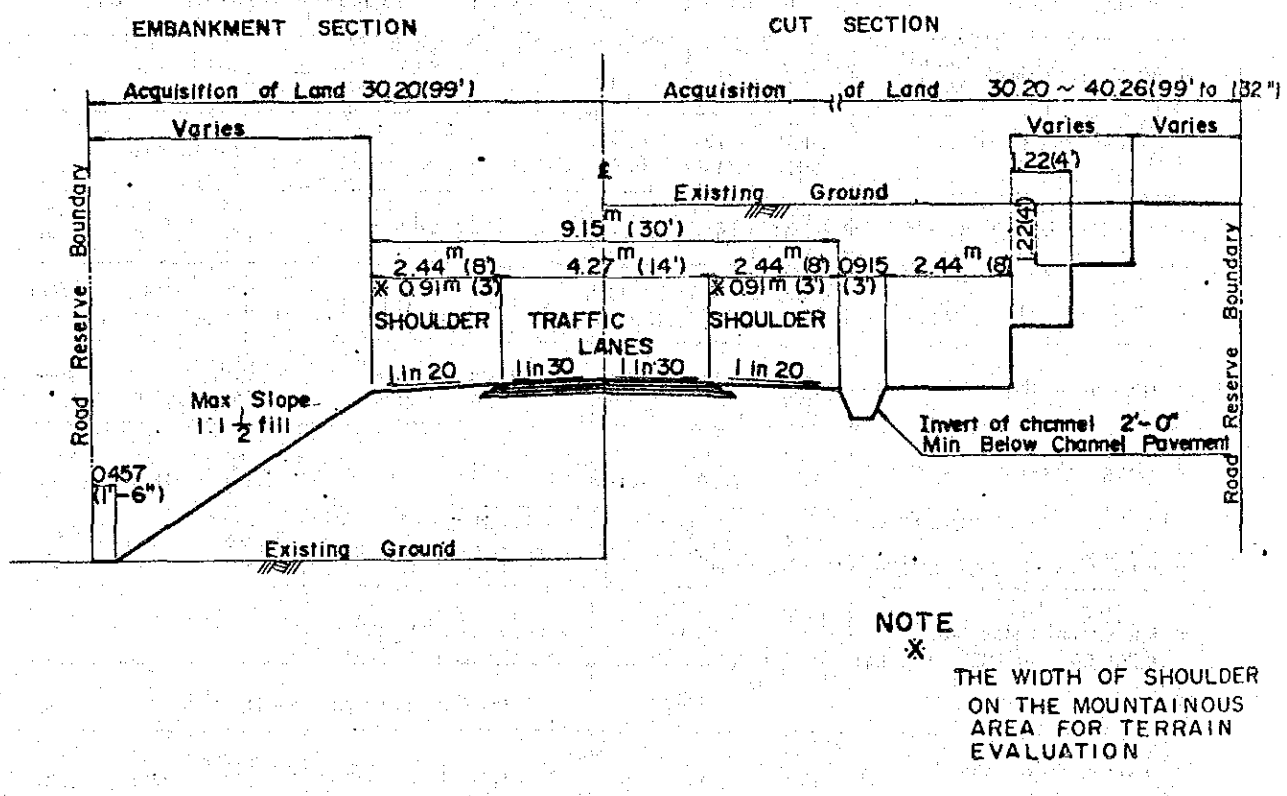
According to the feeder road standard, the radius is usually 214 m (700 ft) or an absolute 153 m (500 ft), but with the recommended standard, the radius for the flat areas is to be 214 m (700 ft), for the rolling areas 153 m (500 ft) and for mountainous areas 100 m (330 ft.).

The typical cross section of feeder road is indicated in Fig. 6-2.

4) Maximum Grade and Critical Length

The recommended standard is the same as the trunk road standard.

Fig. 6-2 TYPICAL CROSS SECTION OF FEEDER ROAD



6-4 Comparison of Trunk Road Designs

6-4-1 Comparison by Route

The trunk road in this project will be built from the end of the existing road of Beluru - Loagan Bunut within the 4th Division, passing through the only sub-center of this area of Long Lama and Gunong Mulu National Park, terminating at the end of the 5th Division road area of Ng. Medamit.

Prior to the preliminary design of the trunk roads, several alternatives of route location were prepared for selection with the 1:50,000 scale topographical map. Comparison between the two alternative routes within the Gunong and Mulu National Park was also made from the point of view of construction cost in order to determine the final route selection. These alternative routes are indicated in Fig. 6-3. In the selection of the routes, aside from the natural conditions, the following traffic and economical points were taken into consideration.

1) To pass through Long Lama as the development center of the Baram region.

2) To pass through the areas where there is a high potential agricultural development.

3) To allow the main communities as much access as possible to the feeder roads.

4) In the vicinity of the main rivers and the project road, it is advantageous to have a flat land or a place where a community can be developed in the future. This site must be above a certain minimum size.

5) Nature, natural resources and living organisms must be preserved.

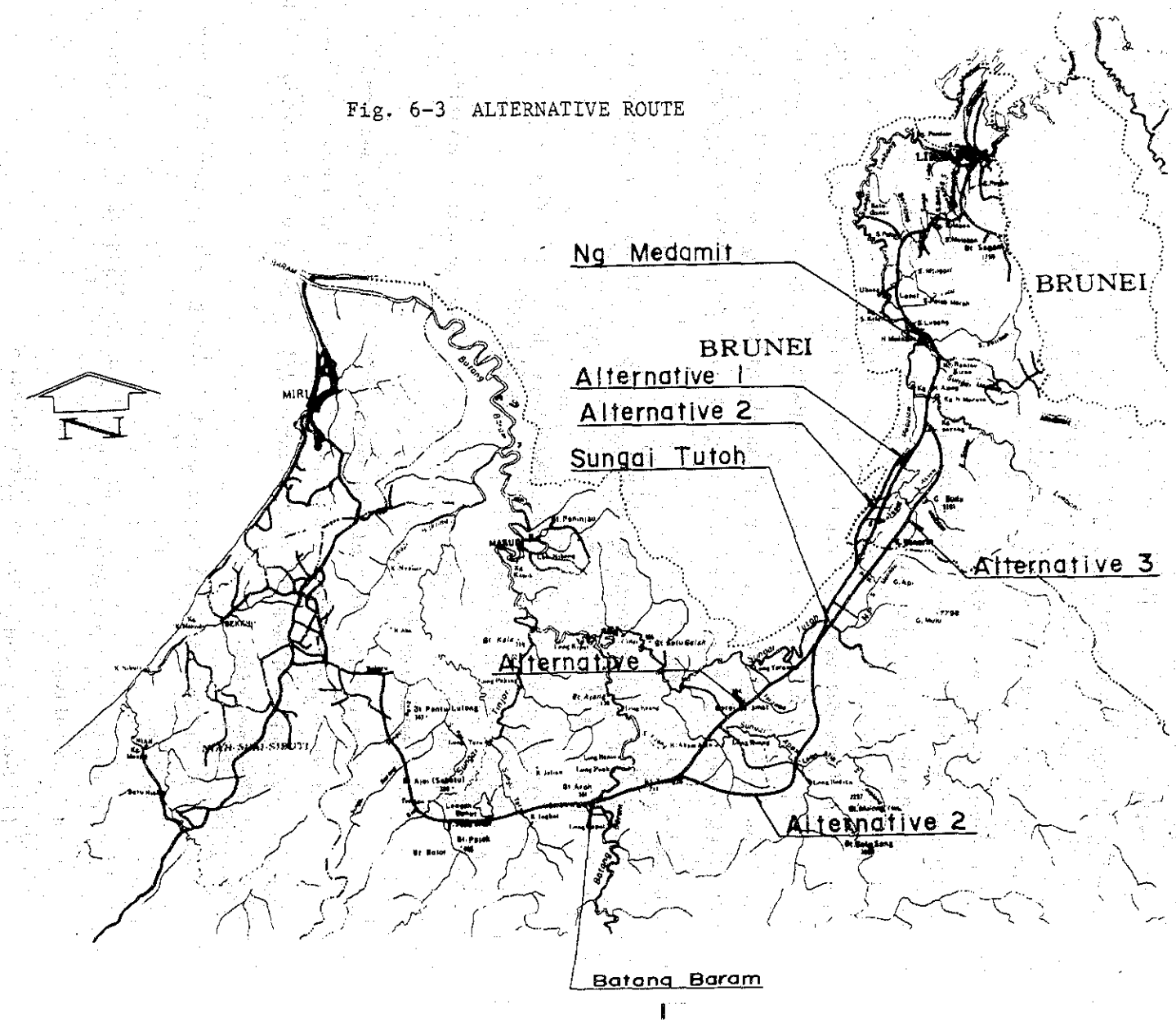
The outline of the compared routes and the results of the study are as follows:

1) Batang Baram ∿ Sungai Tutoh Section

a) Alternative 1

Starting from Long Lama, bypassing the swamp areas, the route

Fig. 6-3 ALTERNATIVE ROUTE



crosses the Sg. Apoh in the vicinity of the villages of R. Akam Ajan and Long Buang. Again bypassing the swamp areas along the meandering Sg. Apoh, it passes the vicinity of Long Terawan, the route finally reaches the crossing point of Sg. Tutoh where the geological features become stabilized and the width of the river becomes narrower.

b) Alternative 2

The route bypasses the swamp areas along Sg. Bemong and Sg. Lahai from Long Lama, coming close to the village of Long Apoh, going along the Melana forest reserve and proceeding northward, arrives at the location of the crossing of the Sg. Tutoh.

Alternative 1 has been selected for the following reasons based on a comparison between Long Atip and R. Akam Ajang on the basis of the potential for development and in technical skills required.

1) With regard to the potential for regional development, R. Akam Ajang has shown a steady increase in population of 2.6% per year whereas at Long Atip, the population distribution has shown a decrease over the years. The route indicated in the first alternative shows a higher potential for the development of the region.

2) By a technical comparison, the route indicated in the alternative 2 is 10 km longer than the alternative 1. The earthwork volume would therefore be greater, also.

(2) Sungai Tutoh ∿ Ng. Medamit Section

a) Alternative 1

This route starts from Sg. Tutoh and goes northward through an area of rolling and mountainous terrain including the saddle between the skyline mountains on the east and the precipitous Brunei borderline on the west, and ends at Ng. Medamit. In the future, this route will be a convenient means of connection to the Gunong Mulu National Park.

b) Alternative 2

This is the route starting from Sg. Tutoh, going up north along the border to reach Ng. Medamit. There is some uncertainty about crossing an un-defined portion of the Brunei-Sarawak borderline.

c) Alternative 3

This route starts from Sg. Tutoh and goes through the basin of Sg. Assam and Sg. Mentakong which are located between the precipitous mountain range of Gunong Mulu and Gunong Apo and the skyline of the Brunei borderline. It ends at Ng. Medamit.

The route suggested in alternative 3 suffers yearly from flood due to the heavy rainfall of 2,500 - 3,000 mm per year which is typical of the tropical rain forest region. Also the Gunong Mulu Study Team has pointed out that this region has a high scientific value and road construction might destroy the environment.

Therefore, the alternative 3 has been ruled out for social and economic reasons as well as technical reasons, and alternatives 1 and 2 have been investigated further.

The layout plans and profiles are shown in Appendix Fig. A-6-1 ∿ A-6-5.

The comparison of the alternatives 1 and 2 is shown in Table 6-4 ∿ 6-6.

Table 6-4 Comparison of Alignment

		Alternative 1	Alternative 2
i.	Length of Route	27.4 km	28.4 km
ii.	Terrain	Rolling/mountainous	Rolling/mountainous
iii.	Min. Radius	1,500 m	1,000 m
iv.	Max. Gradient	6%	6%
v.	Length of Bridge	340 m	280 m
vi.	Nos. of Culvert		
	Box Culvert	14	14
	Pipe Culvert	65	67

Table 6-5 Comparison of Work Quantity

		Alternative 1	Alternative 2
i.	Clearing/Grubbing	495,940 m^2	651,360 m^2
ii.	Excavation/Embankment		
	Cut. Soil	65,000 m^3	856,675 m^3
	Soft - Rock	-	225,825 m^3
	Hard - Rock	-	56,400 m^3
	Embankment	45,000 m^3	533,030 m^3
iii.	Pavement		
	Subgrade preparation	200,600 m^3	207,900 m^2
	Sub-Base/Base Course	40,100 m^3	41,600 m^3
	Bituminous Primecoat/Surface	200,600 m^2	207,900 m^2
iv.	Bridges		
	Short-Span	1,190.4 m^2	892.8 m^2
	Intermediate-Span	992 m^2	992 m^2
	Long-Span	-	-
v.	Drainage Structure		
	Box-Culvert		
	2.0 x 2.0	72 m	72 m
	3.0 x 2.0	72 m	72 m
	3.0 x 3.0	72 m	72 m
	Pipe-Culvert		
	ϕ 900 m/m	924 m	966 m
	ϕ 1,500 m/m	672 m	672 m
vi.	Guard Rail	14,800 m	17,650 m
vii.	Marking	54,800 m	56,800 m
viii.	Traffic Sings	3 ech	3 ech

Table 6-6 Comparison of Construction Cost
(Unit: 1,000 MS)

		Alternative 1	Alternative 2
i.	Construction Cost (a)	15,224	28,813
	Clearing/Grubbing	2,400	3,167
	Excavation/Embankment	671	13,329
	Pavement	6,632	6,877
	Bridges	4,487	3,910
	Drainage Structures	289	294
	Guard Rail	977	1,165
	Marking	66	69
	Traffic Signs	2	2
ii.	Contingencies (b) (a x 10%)	1,553	2,882
iii.	Survey and Administration Fees (c) (a + b x 10%)	1,708	3,170
iv.	Total Construction Cost (a + b + c)	18,785	34,869

From the results of the technical and economical comparison, alternative 1 has been determined to be the better one and has been chosen as the alternative which will be recommended.

6-4-2 Comparison by Construction Method

1) Introduction

It is not preferable from the economic point of view to implement improvement and new construction simultaneously on the entire project, since it will require a huge capital cost, large numbers of construction machinery and plant, and a large labor force.

It is recommended to establish a plan of staged construction, and maximize the effect of the initial investment, taking into

consideration factors such as physical conditions, priorities for regional development and construction techniques.

A study of staged construction has been carried out both on the constructed section and the cross section component for the roads.

As for the construction section of a proposed road, the priority of construction shall be determined in accordance with the technical and economic priorities and role of a trunk road.

2) Establishment of Construction Section

In order to complete the proposed road economically and in as short a period of time as is possible, it is necessary to divide the project into a number of sections. For the division, the following factors will be taken into account.

- -- The physical conditions of the region.
- -- The economic and financial factors.
- -- The scale of construction, construction items and period of construction.
- -- The experiences and capabilities of the construction contractors.

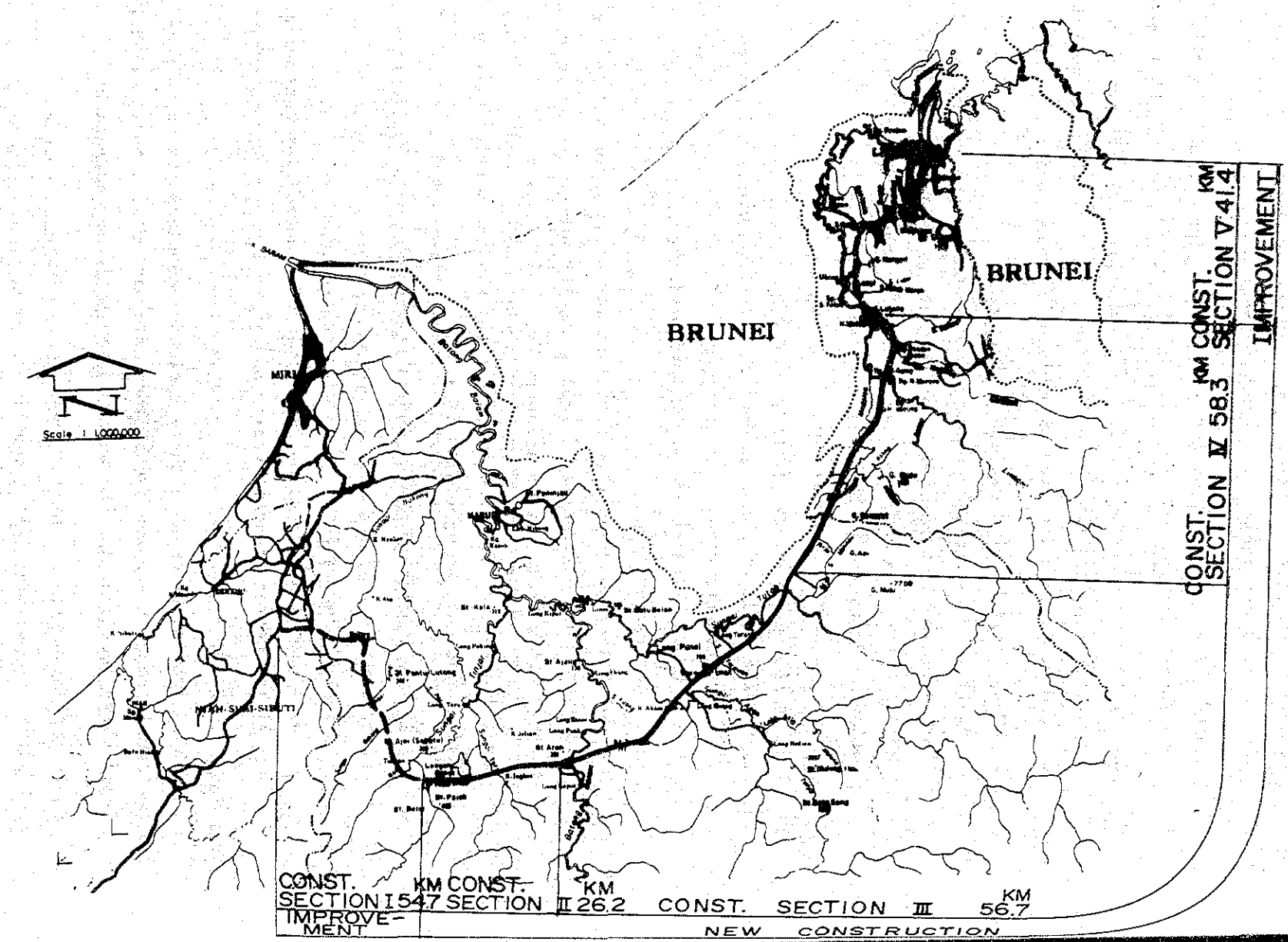
The determination of section divisions may be an important factor related to the construction period since the proposed road runs through the terrain with a large river.

The following factors also influence the way the section will be divided and must be carefully studied.

1) Application of the amount of new construction and improvement.
2) Execution by local or foreign contractors.
3) Regional distribution and supply of construction materials.
4) The method of construction and scale for staged construction.

Taking into consideration these various conditions, the construction sections have been established as shown in Fig. 6-4. An outline of these sections will be stated in the following paragraphs.

Fig. 6-4 MAP OF CONSTRUCTION SECTION



3) Outline of the Construction Sections

a) Construction Section I (L = 54.7 km - 11.2 mile)
This section refers to the 18.4 km route starting from the Miri-Bintulu road where this trunk road deviates (34 miles from Miri) to the point 1 km before Beluru (this will be called the Beluru junction) and the 36.3 km route starting from the Beluru junction up to Sg. Tinjar.

The first 18.4 km of this section was built in 1969 to feeder road standards according to the Sarawak State Design Standard. The quantity of work takes into consideration the upgrading of the standard for a trunk road, the conversion of the wooden bridge into a permanent bridge and the pavement of roads. The 1 km section between the Beluru junction and Beluru has been excluded from project scope since it is a branch lane from the main road.

The route existing 9.7 km from the Beluru junction is built under the feeder road standard and the remaining section is built under the trunk road standard. All the bridges are permanent bridges and the pavement is a gravel pavement.

The section of 4 km from the left bank of the Sg. Tinjar has been under construction since 1975 under the MRCU.10 and is planned to be completed in 1980.

The quantity of work takes into consideration the upgrading of the standard of the 9.7 km road section and pavement construction. The bridge that will be built under the Colombo Plan on the Sg. Tinjar will be approximately 100 m long. Investigations have been completed by Australia and the bridge is now being designed and is planned to be built soon.

b) Construction Section II (L = 26.2 km - 16.3 mile)
This is the newly constructed 26.2 km route that begins from the right bank of Sg. Tinjar, through the south side of Lake Loagan Bunut, crossing Sg. Tru and ending at the right bank of the Batang Baram.

c) Construction Section III (L = 56.7 km - 35.2 mile)
This route begins at the right bank of Batang Baram, passing through the northern section of Long Lama, eastbound along Batang Baram and crossing Sg. Apoh and Sg. Terawan by-passing Long Terawan 10 km to the southeast of it, crossing Sg. Tutoh ending at the junction of NP Base Camp. Both Sg. Apoh and Sg. Tutoh of this area are not suitable as waterways for the transportation of heavy machinery. For this reason, there is a need for constructing a road extending to approximately two kilometers around the vicinity of Long Terawan.

d) Construction Section IV (L = 58.3 km - 36.2 mile)
This is the newly constructed 58.3 km section starting from the junction of NP Base Camp, passing through the border of the 4th Division and the 5th Division, crossing the Sg. Medalam and connecting to the existing road at the right bank of Sg. Limbang. Ng. Medamit is on the left bank of Sg. Limbang and a lumber camp is on the right bank. This section goes through the Gunong Mulu National Park area which is predicted to develop into an area for tourism. Currently a forest road from Sg. Tutoh exists and makes the transportation of equipment and materials possible.

e) Construction Section V (L = 41.4 km - 25.7 mile)
This is the existing road section from the right bank of Sg. Limbang to the center of Limbang. The main road has been built under the feeder road standard before 1966 and except for the asphalt pavement in Limbang, the pavement is gravel.

The quantity of work takes into consideration the upgrading of the standard for a trunk road, the rebuilding of bridges and pavement construction.

4) Stage Construction Method

There is an evident order of priority for construction in the two sections of existing roads to be improved: that is, Miri/Bintulu Road to Beluru, Beluru and Sg. Tinjar and the section between Ng. Medamit and Limbang, and also the new sections to be constructed which connect to the above two sections.

Namely, if we lay stress on the factor of regional development, the priority shall be given to all improvement sections and the new construction section to Long Lama which is a sub-center of the 4th Division, and the top priority shall be on the new construction section which starts at Sg. Tinjar, passing Batang Baram and ends at Long Lama.

[A] Cross-Section

From the viewpoint of the cross section component for the roads the following stage construction is proposed.

a) In the first stage of construction, only one lane of roadway (lane of 3.66 m and 2 shoulder of 3.05 m in width), gravel pavement, and one lane of bridge and other structure are to be executed. Then in the second stage of construction, they are to be expanded to a two-lane standard.

b) In the first stage, the road is two-lane to be paved by gravel for public use and in the second stage, it is gradually to be improved to asphalt pavement.

c) In the first stage, the bridge is to be executed as a permanent bridge of one lane and it will be improved to two-lanes in the future.

Alternative a) was proposed in the interim report, but due to the strong request by Sarawak state, the expansion to a two-lane standard will be conducted at an early stage.

Regarding Alternative c), the design of a single lane bridge with a long span structure can be a problem from the structural point of view. Even with a short span structure, it can be extremely difficult with regard to the substructure design. Therefore, in the initial stage, a two-lane bridge will be constructed. As a result, the pavement construction of Alternative b) will be the only one that will be implemented. For the pavement structure which has been discussed in Chapter 7, the following have been considered as the alternatives.

i) Gravel pavement
ii) Bituminous surface dressing
iii) Bituminous pavement

Bituminous pavement for the vicinity of Limbang where the estimated traffic volume is heavy will be executed in one stage. But with the other areas, items i) or ii) will be executed in the beginning. Bituminous surfacing will be executed later when the cummulative equivalent number of standard (8.2t) axles exceeds 500,000.

[B] Priority of Implementation in regard to the Construction Sections

The construction section of the proposed road is classified into the following.

-- The improvement section of existing road: Miri-Bintulu Rd. ∿ Beluru ∿ Sg. Tinjar. Ng. Medamit ∿ Limbang
-- The new construction section:
Sg. Tinjar ∿ Long Lama ∿ Ng. Medamit

The priority of construction is to be determined subject to the physical conditions (Tropical rainy and dry seasons, discharge of river, etc.), the existence of development areas, the magnitude of work involved and construction difficulty for the section.

The improvement section of existing road of Miri-Bintulu Rd. ∿ Beluru is a two-lane road paved by the gravel.
It has been open for public use since 1969, and the population along its route and the traffic volume tends to increase annually. Therefore, the improvement of the section will contribute to the socio-economic development of the area.

As for the section of Ng. Medamit ∿ Limbang, which has been open for public use from 1966, the effect of the improvement will be large considering the growth in traffic volume.

For the new construction section, the priority of construction shall be determined subject to the magnitude of work and construction difficulty and the following regional development

factors:

1) Long Lama as a center of regional community
2) Development of tourism based on Gunong Mulu National Park
3) Regional agricultural and forestry development.

The construction of section of Sg. Tinjar ∿ Long Lama shall be given a priority, since there are various potentials for development such as Long Lama as a sub-center of the area, the land dotted along the section for the agriculture and the tropical jungle for forestry.

Gunong Mulu National Park, which has one of the largest stalactite caves in the world, will be gradually developed as a tourism spot through the scientific research and conservation for flora and fauna following the socio-economic development of the area.

Based on the above considerations, the priority of construction for the new road sections is determined as follows:

Priority Order	Section	Length (km)
1.	Sg. Tinjar ∿ Long Lama	26.2
2.	Long Lama ∿ Sg. Tutoh ∿ Junction of NP Base Camp	56.7
3.	Junction of NP Base Camp ∿ Ng. Medamit	58.3

6-5 Comparison of the Major Structures

A comparison of the methods of crossing the Batang Baram, the largest river in the project area has been made.

There are two alternative methods which can be considered for crossing the Batang Baram:

1) by bridge
2) by ferry

The following is a consideration of the two alternatives.

6-5-1 The Bridge Alternative for Batang Baram

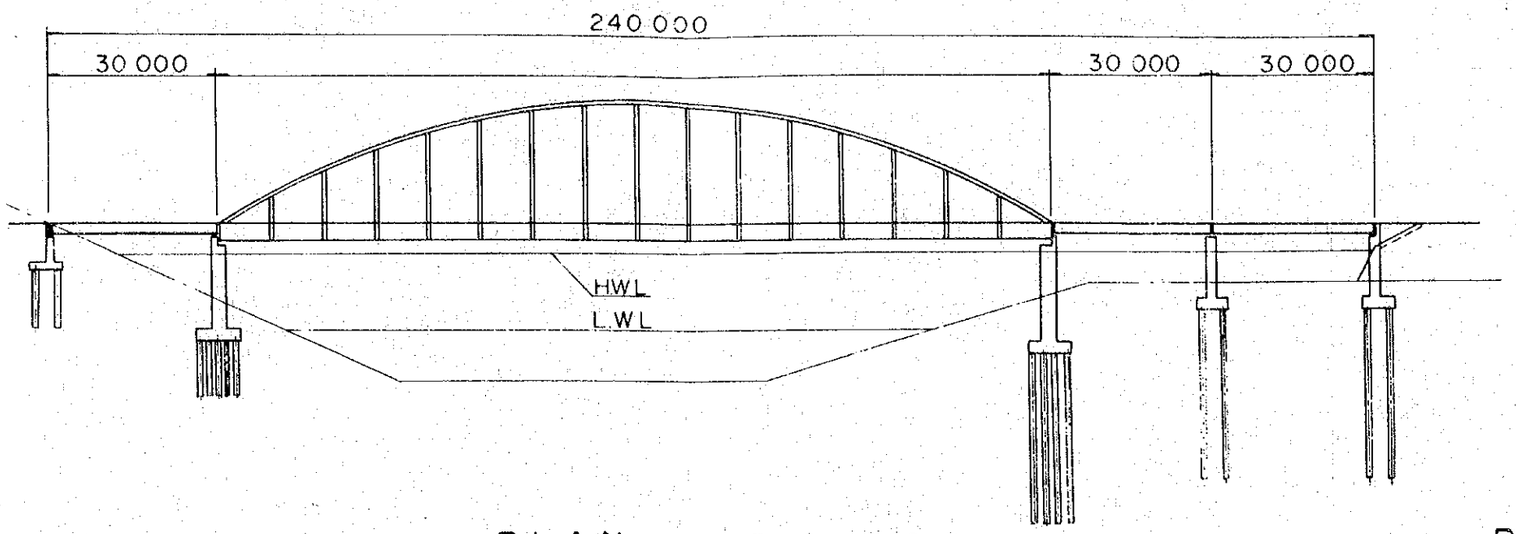
Batang Baram has a very high rate of flow throughout the year, and from K. Baram, the mouth of the river to Long Lama, it is possible for a 400 ton vessel to enter. Everyday, a passenger ship with a capacity of seating 60 - 80 people is operated on the river. At the present moment, lumber is not transported to the upper stream from Long Lama, but it is predicted that this will be developed in the future.

Taking into consideration the navigation of the ships and rafts, it is proposed that the low flow zone should be crossed with a Langer girder of 150 m span without building a center bridge pier. The bridge length should be 240 m, with the side spans of 30 m span PC composite beams, on the left bank side and two spans on the right. The length of the bridge has been determined from the flood volume in Chapter 5.

The foundation is based on the results of bore hole investigation conducted in Phase II. Reinforced concrete piles have been chosen for the left side bank and steel pipe piles are chosen for the right side bank. Fig. 6-5 shows the general view of the Batan Baram bridge. The quantity of the construction has been shown in Table 6-7 and the construction cost is shown in Table 6-8.

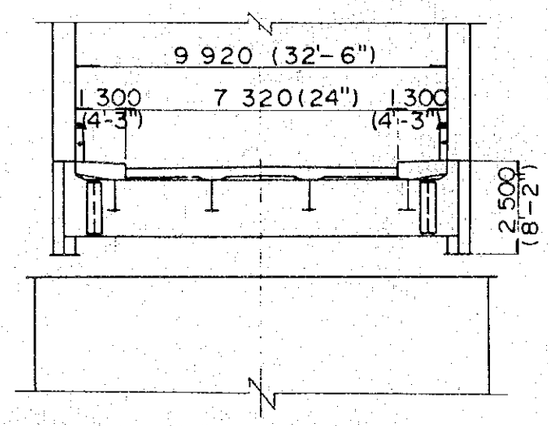
Fig 6-5 GENERAL VIEW OF BATANG BARAM BRIDGE

ELEVATION SCALE 1 : 500

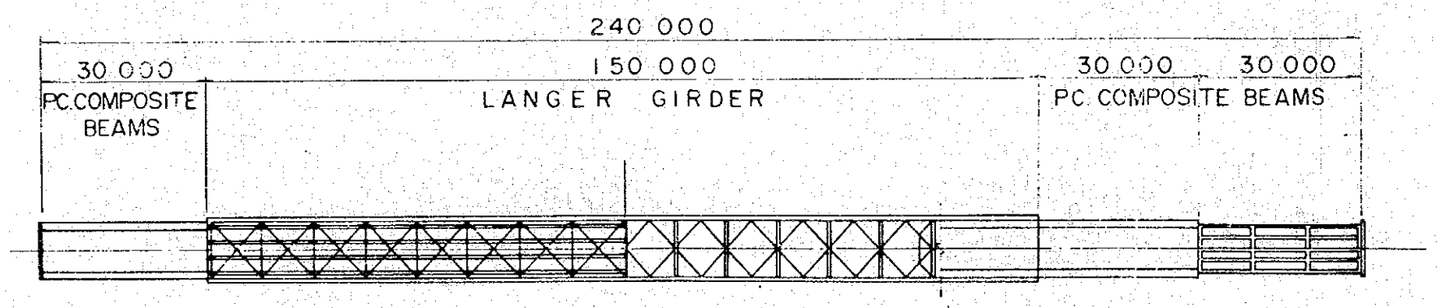


LANGER GIRDER SECTION

SCALE 1 : 150

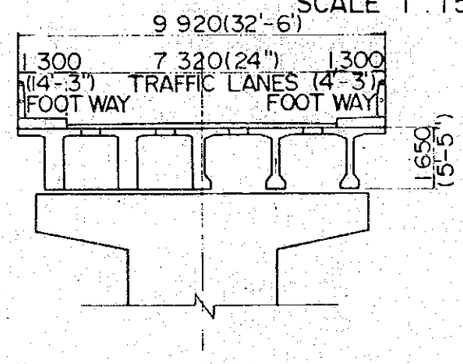


PLAN SCALE 1 1 000



PRESTRESSED CONCRETE COMPOSITE BEAMS SECTION

SCALE 1 : 150



NOTE

1. SUPERSTRUCTURE TYPE IS OF LANGER GIRDER AND PRESTRESSED CONCRETE COMPOSITE BEAM.
2. ALL SIZES AND NUMBERS OF SUPERSTRUCTURE, SUBSTRUCTURE, AND FOUNDATION PILES ARE PRELIMINARY.
3. DIMENSIONS ARE IN MILLMETERS.

Table 6-7 Quantity of Work

	Items	Unit	Langer Girder	P.C. Beam	Total
Super-structure	Steel beams	ton	768.9		768.9
	Concrete	m^3	357	396	753
	Formwork	m^2	1,488	2,550	4,038
	Reinforcement	ton	71.4	33.3	104.7
	Pavement	m^2	1,488	828	2,316
	P.C. Wire	ton		18.3	18.3
Sub-structure	Concrete	m^3	572	720	1,292
	Formwork	m^2	800	795	1,595
	Reinforcement	ton	25.8	43.2	69.0
	Excavation	m^3	1,600	2,430	4,030
	R.C. Piles □500	m	350	160	510
	Steel pipe pile ϕ600	m	720	960	1,680

Table 6-8 Gross Breakdown of Estimated Construction Cost

Items		Quantities		Cost (M$)	
		Unit	Quantity	Unit cost	Cost
Super-Structure	Steel beams	ton	768.9	3,445.41	2,649,000
	Concrete	m^3	753	180.847	136,000
	Formwork	m^2	4,038	12.249	49,000
	Reinforcement	ton	104.7	1,318.5	138,000
	Pavement	m^2	2,316	80.998	188,000
	P.C. Wire	ton	18.3	3,432.87	63,000
	Subtotal				3,223,000
Sub-Structure	Concrete	m^3	1,292	166.988	216,000
	Formwork	m^2	1,595	12.249	20,000
	Reinforcement	ton	69.0	1,318.5	91,000
	Excavation	m^3	4,030	7,079	29,000
	Piles RC□500	m	510	116,466	59,000
	Steel pipes ϕ600	m	1,680	137.3	231,000
	Subtotal				646,000
	Total				3,869,000

Note: Taxes are excluded from the above table

The maintenance cost for the bridge will be as follows according to Table 8-13 of Chapter 8.

		Maintenance Fee 1000 M$
Langer girder		30.75
PC beam	3.6 x 0.09	= 0.32
Indirect cost	(30.75 + 0.32) x 0.1 =	3.11
	TOTAL	34.18

6-5-2 The Ferry Alternative for Batang Baram

1) Ferry Boats

The estimated traffic volume of vehicles that cross the Batang Baram as mentioned in Chapter 4 is as follows:

	Car/taxi	Van/P.up	Truck	Bus	Total
1985	151	31	95	34	311
1995	320	86	190	73	669
2005	609	162	316	140	1,227

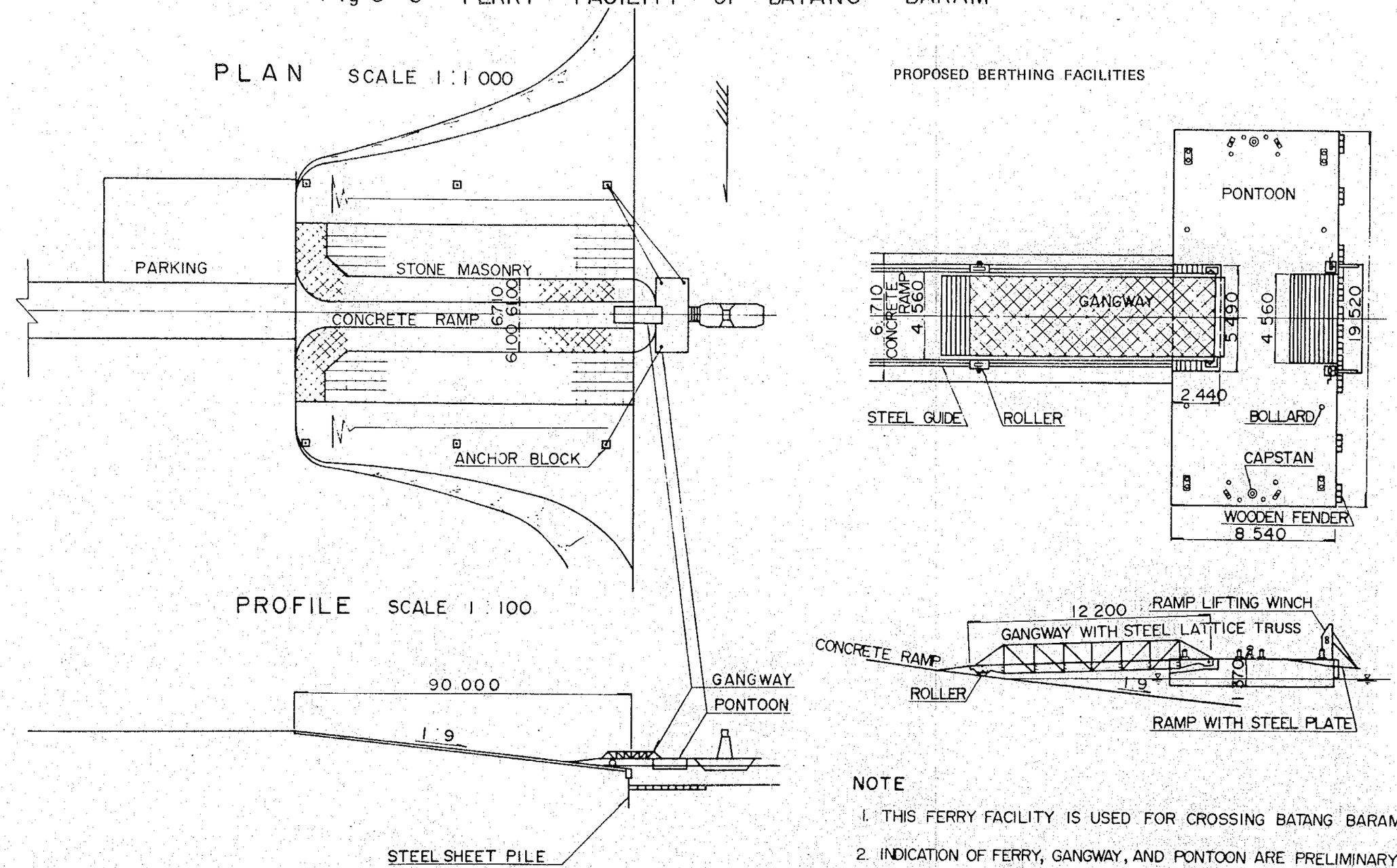
In the beginning, the crossing will be done with only one ferry boat in operation. As the capacity begins to show an insufficiency, vessels will be added. The ferries are to be operated for 10 hours per day. One round trip will take about 20 minutes. The capacity of the ferry boats in the beginning will be 5 passenger vehicles and three trucks. The maximum number of vehicles to be transported in a day will be: 8 vehicles x 2 x 60/20 x 10 = 480 vehicles.

2) Ferry Facilities

The variation in the water level at the crossing location is usually about 10 m. A schematic design of facilities that will be able to cope with this variation is shown in Fig. 6-6.

This design is meant for the use of two ferry boats. An expansion will be required when there are three ferry boats to be accommodated.

Fig 6-6 FERRY FACILITY OF BATANG BARAM



NOTE

1. THIS FERRY FACILITY IS USED FOR CROSSING BATANG BARAM.
2. INDICATION OF FERRY, GANGWAY, AND PONTOON ARE PRELIMINARY.
3. DIMENSIONS ARE IN MILLIMETERS.

3) Costs of Construction and Maintenance

i) Construction Cost

The following is an estimate of the cost of constructing a ferry boat and its facilities:

Ferry boat (3 trucks + 5 cars)	M$ 442 x 10^3
Pontoon (2) (18m x 9m x 1.35m)	338 x 10^3
Gangway (2) (L=12.2m)	65 x 10^3
Land facility (2 sites) (L=90m)	491 x 10^3
TOTAL	M$1,336 x 10^3

ii) Maintenance Cost

Table 6-9 shows the breakdown of the average yearly cost for maintenance.

Table 6-9 Cost of Ferry Maintenance

(1000 M$)

Items \ No. of operating ferries	1	2	3
Labor cost	64.0	128.0	192.0
Fuel	14.0	28.0	42.0
Routine Maintenance costs	6.0	12.0	18.0
Periodic repairs	42.0	84.0	126.0
Rent for a ferry during a 3-week repair period	42.0	-	-
Facilities maintenance and cost	3.0	4.5	6.0
Total	171.0	256.5	389.0

6-5-3 Comparison between the Batang Baram Bridge Alternative and Ferry Alternative

The expenses for constructing and maintaining a bridge and a ferry boat are listed in Table 6-10. An economical evaluation has been made in Chapter 10.

Table 6-10 Comparison between the Batang Baram Bridge and Ferry Alternatives

(1000 M$)

Items	Bridge	Ferry Boat and Facilities		
		Number of ferry boats 1	Number of ferry boats 2	Number of ferry boats 3
Construction cost	5,030	1,336	1,778	2,220
Maintenance cost	34	171	257	384

6-6 Establishment of Alternatives

Based on the considerations so far discussed, on the outlines of geometric design, route location, structural design and construction plan, the most effective alternatives to be studied with respect to feasibility of project implementation will be determined as a combination of the alternatives of pavement structures, major structures, and staging of construction, as follows:

Alternatives for pavement structure:

1. Gravel pavement
2. Bituminous surface dressing
3. Bituminous pavement

Alternatives for major structure (crossing facility on Batang Baram)

1. Bridge
2. Ferry

Alternatives for construction staging:

1. Simple stage construction
2. 2 stage construction
3. 3 stage construction

A total of 18 alternatives are listed above (3 x 2 x 3 = 18) to be compared in order to determine the final selection of a construction scheme.

A comparative study of the cost aspects will be discussed in Chapter 8, and an economical analysis will be made in Chapter 10.

Chapter 7

IMPROVEMENT PLAN AND PRELIMINARY DESIGN

Chapter 7 IMPROVEMENT PLAN AND PRELIMINARY DESIGN

7-1 Outline

The road proposed for this project is a trunk road approximately 237 km long diverging from Miri-Bintulu Road reaching Limbang via Beluru, Long Lama, and connecting to the Gunong Mulu National Park Area. It consists partially of road improvement and partially of new construction. For the sections a, between the juncation of Miri-Bintulu Road and Sg. Tinjar, and b, from Ng. Medamit to Limbang which total approximately 96 km, the existing roads will be improved and used.

The intermediate section of approximately 141 km between Sg. Tinjar and Ng. Medamit will be newly constructed.

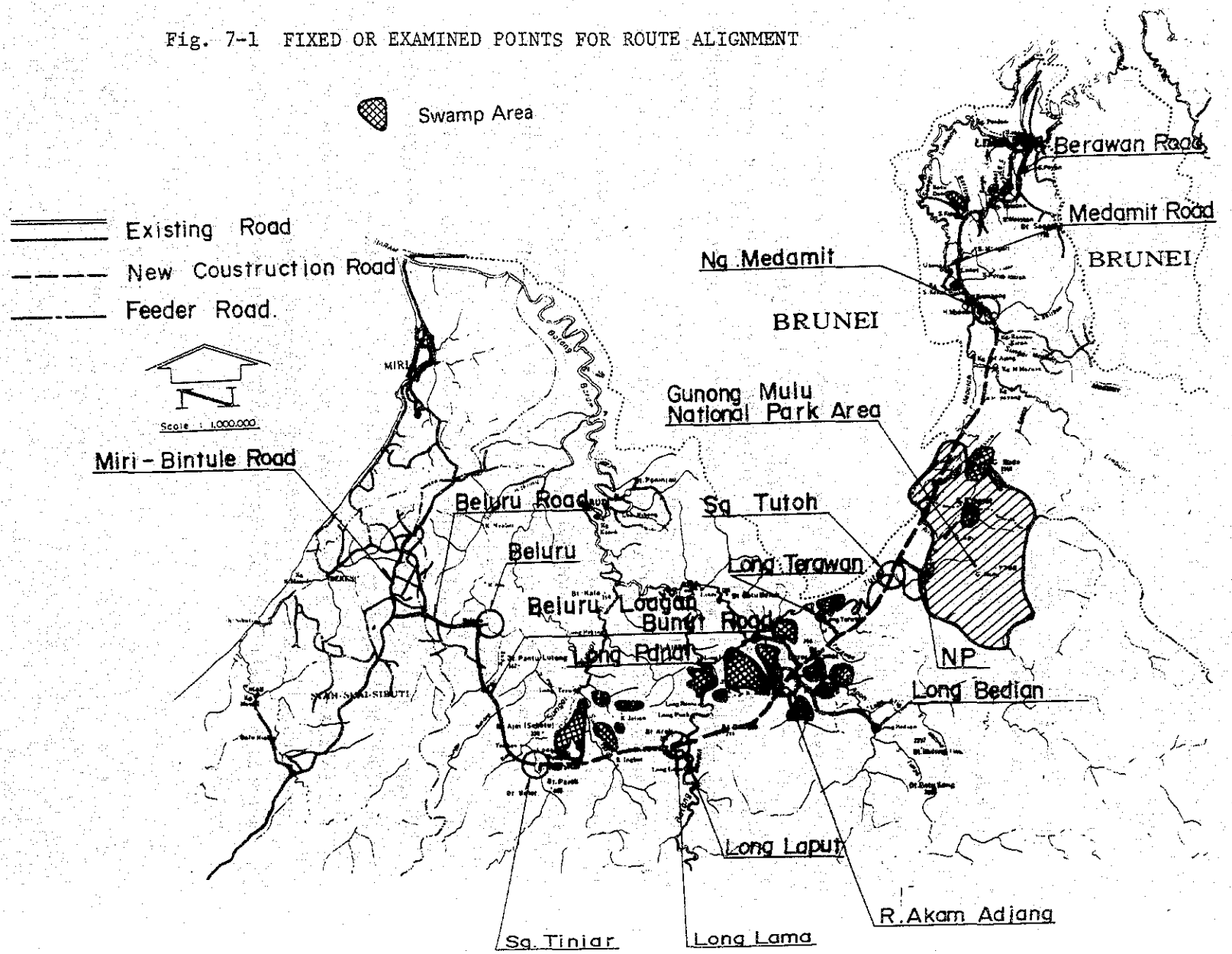
The existing roads involved are constructed mostly on feeder road standards, paved with gravel. The existing bridges along these roads are single lane ones constructed either of timber or steel beams with timber slabs. For the purpose of upgrading their standard to that of a trunk road, a preliminary design has been drawn up for necessary changes of alignment and width.

For the new road section, preliminary route selection was first made based on 1:50,000 topographical maps. A preliminary design was then prepared using 1:10,000 topographical maps developed from aerial photographs.

For the feeder roads branching out from the trunk roads, preliminary design which includes mainly route locations was accomplished using 1:50,000 topographical maps, as illustrated in Fig. 7-1.

The location, length and type of bridges (the main structures on these routes), has been determined. Pavement design was drawn up according to the British Standard based on forecast future traffic volume.

Fig. 7-1 FIXED OR EXAMINED POINTS FOR ROUTE ALIGNMENT



Design sections are established as shown in Table 7-1.

Table 7-1 Design Sections

Design Section	Station	Description
1	*1) STA 0 ∿ 18 + 400	Miri-Bintulu road ∿ Beluru
2	18 + 400 ∿ 54 + 700	Beluru ∿ Sg. Tinjar
3	*2) STA 0 ∿ 26 + 200	Sg. Tinjar ∿ Batang Baram
4	26 + 200 ∿ 51 + 600	Batang Baram ∿ Sg. Apoh
5	51 + 600 ∿ 81 + 600	Sg. Apoh ∿ Sg. Tutoh
6	81 + 600 ∿ 114 + 100	Sg. Tutoh ∿ Sg. Medalam
7	114 + 100 ∿ 141 + 200	Sg. Medalam ∿ Ng. Medamit
8	*3) STA 0 ∿ 41 + 400	Ng. Medamit ∿ Limbang

Note: *1) and *2) are road improvement sections

*3) is a new road section