4-2 Traffic Demand in the Study Area

4-2-1 General

The current status of traffic in the Study Area was explained in Chapter 3 based on field investigation findings and the analysis of available data. Here, a more comprehensive analysis of passenger and cargo traffic and future traffic demand forecast will be made based on the field investigations findings, despite some areas where no road exists, where little information is available and much remains unknown.

The traffic demand level in an area is determined by many factors including its income, industrial and economic activity, transportation facility, and vehicle and vessel ownership levels. Of the various zonal economic indicators, the most reliable is population. The zonal populations have been estimated in Table 4-2 based on the sub-district population estimated in Chapter 2 and the 1977 statistics of community populations for each river basin shown in Appendix Table A-4-7 and Appendix Fig. A-4-1. Bintulu district population has been estimated with reference to the Bintulu Master Plan Study.

Table 4-2 Estimated Population by Traffic Zone

Traffic Zone	Name	1977	1985	1995	2005	Average Annual Growth Rate (%)		
						77–85	85–95	95–05
1	Miri	50,700	72,100	106,500	153,100	4.50	3.96	3.70
2	Bekenu	12,900	15,700	19,100	22,700	2.49	1.98	1.75
5	Sg. Bakong	5,780	7,400	9,500	11,900	3.14	2.51	2.27
6	Sg. Tinjar	10,220	12,800	16,400	20,500	2.85	2.51	2.26
7	Lower Bg. Baram	10,900	13,000	15,800	18,400	2.23	1.97	1.54
8	Bg. Baram Middle	6,500	8,000	9,900	12,100	2.63	2.13	2.03
9	Upper Bg. Baram	8,600	9,200	10,000	10,600	0.85	0.83	0.58
10	Sg. Tutoh/Apoh	6,200	7,600	9,500	11,700	2.60	2.23	2.11
11	N. Medamit	6,200	7,000	7,800	8,500	1.53	1.08	0.87
12	Limbang	18,000	21,900	27,000	32,500	2.49	2.10	1.88
Total	Study Area	136,000	174,700	231,500	302,000	3.18	2.84	2.69
3	B. Niah	14,200	17,300	21,100	25,200	2.50	2.00	1.79
4	Bintulu	18,200	28,800	51,100	90,600	5.90	5.90	5.89

4-2-2 Traffic Demand in Areas Along Existing Roads

(1) Miri Area

Miri area is served by the Miri-Bintulu trunk road and its feeder roads which connect local centers such as Bekenu, Niah/Batu Niah, and Beluru. The Project Road in this area branches out from the Miri-Bintulu road and extens to Beluru, and further, to Sg. Tinjar where traffic volume will be greatly influenced by development and social progress in this area.

The existing road network in Miri area was constructed between the early 1960s and the early 1970s. As agricultural and other roadside area development activities have made progress, the areal population has increased. The area is still undergoing steady development. In 1974, the development potentials of this area were outlined as the result of the Miri-Bintulu Regional Plan study. Oil palm-centered agricultural development and a deep-water port construction at Bintulu are the mainstay of the programmed development and investments currently being made in a more strategic manner under the leadership of the State Government. As for the detail effects of the road construction, see "Preliminary Impact Study on the Changes of Socio-economic Activity Level in the Miri Area Before and after the Road Construction" in Appendix Note A-10-1.

More changes will be caused in this area by Bintulu development (a deep-water port construction, key industry development in its hinterland, and urban development) and subsequent agricultural development, with its progress having impacts on the level and distribution pattern of traffic demands in this area. Although some delay is expected, the various development projects will be implemented basically as they were drawn, and, therefore, traffic demand increase will be substantial in this area. In fact, traffic volume has recently begun to increase at a fairly high rate, as seen in Chapter 3.

(2) Limbang Area

Unlike Miri area, Limbang area has a small population and is isolated from other parts of the State. It therefore has not enjoyed prominent

development investment, and, as a result, traffic has been light and increased little. Limbang Town (population 8,000) functions as the base to support a strong connection between this area and Brunei through socio-economic activities which take place via waterway. The road extending from Limbang Town to N. Medamit in the south, therefore, receives little direct influence from the exchange with Brunei. The shallow water limits the utilization of the port; entry into the port and mooring on a pier are impossible particularly during the "Landas" season. The airport accommodates only BN2's (capacity: 7 or 8 persons). The existing route via road to Miri is interrupted by a ferry boat connection, and, therefore, a direct and uninterrupted road access to Miri is a fervent desire of Limbang inhabitants. (Almost 100% of respondents indicated the need of the Project Road for some social or economic reason or other during the on-the-street interview survey conducted at the time of the 1978 field investigation.)

The most important of the factor bearing upon future traffic demand in Limbang area will be the Limbang Valley Development. Initial investigation started only in August 1978 and, therefore, it will be still some time before the development will commence. The factors for immediate consideration will be the areal expansion of Limbang township and the increase in its attraction and absorptive capacity due to the development of the town, as well as the rise of rural activities due to forest development. Particularly, the increased cash income opportunities for the inland inhabitants due to their participation in timber production has been reflected by increase in traffic between the inland area and Limbang Town.

4-2-3 Transportation Demands in River Basins in the Study Area

Waterway traffic demands in the currently roadless parts of the Study Area - that is, most of Baram area and a part of Limbang area - will be analyzed in this section.

(1) Cargo Transportation Demand

The existing cargo transportation demand in the river basins is basically for the shipping out of agricultural products, logs, and stones and for the inward delivery of consumer goods, construction materials, fertilizer, fuels, and so forth. The estimates

of these cargo transportation demands, explained in detail in Appendix Note A-4-1, are summarized below.

The outward shipment volume is obtained by deducting the in-area consumption volume from the total in-area production (present or future). Agricultural products other than rice (that is, pepper and rubber), logs, and crushed stone are practically all shipped out to Marudi or Miri, this amounted to an estimated 290,000 tons in 1977.

The inward delivery volume was only about 26,000 tons in 1977, consisting of a large variety of commodities including food, sugar, beverages, cement, steel products, fuels, fertilizer, feedstuff, and sundry goods. The transportation demands have been estimated based on zonal per capita consumption level of these commodities as estimated using the available statistics and the field investigation findings. The estimates are presented on Table 4-3.

These goods are transported via waterway, with occasional use of expensive helicopter and light aircraft (Cessna) transportation.

As for logs, floaters are rafted and sinkers (about 10% of total timber) are either combined with floaters or transported by barge. In either case, a tug boat is used for towing. Crushed stone, which is produced near Long Lama, is totally shipped by barge. The transportation of agricultural products is by long boats up to distribution centers in Marudi, Long Lama, and N. Medamit.

Incoming goods are carried by 50 to 150 ton motor vessels or express launches. Longboats must be used except for the sections between Miri and Marudi and between Marudi and Long Lama. Generally, daily consumer goods alone are not carried by longboat, but are transported together with passengers.

Table 4-3 Summary of Goods Transport Demands

000 tons

		Baram				Limbang			
		1977	1985	1995	2005	1977	1985	1995	2005
Imcoming	Total	25.6	36.5	56.8	87.7	15.1	21.4	32.5	49.3
	Fuel	10.1	15.4	25.4	40.9	4.4	6.6	10.7	16.9
	Cement, Iron	2.7	4.4	7.9	14.0	2.1	3.4	6.1	10.7
	Others	12.8	16.7	23.5	32.8	8.6	11.4	15.7	21.7
Outgoing	Total	290.8	375.9	518.9	699.6	1.7	1.4	1.4	1.5
	Paddy	3.7	3.2	2.8	2.0	1.7	1.4	1.4	1.5
	Agricultural Products	2.1	2.5	3.2	4.1	–	–	–	–
	Stones	135.0	167.8	228.6	310.9	–	–	–	–
	Timber	150.0	202.4	284.3	382.6	–	–	–	–

(2) Passenger Transportation Demand

The existing river passenger traffic demand, in terms of the number of trip-ends per 1,000 population, is high in Lower Baram and Baram Middle, where launch service is available as shown in Table 4-4.

Table 4-4 Level of Inter-zonal River Passenger Traffic Demand by Traffic Zone, 1978

Traffic Zone	Population	Trip-ends Per Day	Trip-ends/ 1,000 popu./Day
01 Miri	50,700	261	5.2
05 Bakong	5,780	22	3.8
06 Tinjar	10,220	29	12.8
07 Lower Baram (Marudi)	10,900	386	35.4
08 Baram Middle (Long Lama)	6,500	173	26.6
09 Upper Baram	8,600	73	8.5
10 Tutoh/Apoh	6,200	40	6.5

The recorded express launch utilization level, which is believed to provide a reliable base for estimating future river passenger traffic demand, has been rising at a fairly high rate. Although it is unlikely that the high rate will be sustained in the future, the recorded rise is largely attributable to the activation of timber production in Baram area. The growth rates indicated below have been estimated based on increases in inland inhabitant employment opportunities, their income, and their mobility due to increased by the timber production.

Table 4-5 Assumed Growth Rate of River Passenger Traffic in the Baram Area

	1974/75-1977/78	1978-1985	1985-1995	1995-2005
Express Launch	19.7	12.0	10.0	8.0
Longboat/Speed Boat	n.a.	10.0	8.0	6.0

Using the above growth rates, future river passenger traffic demand and distribution have been estimated as shown on Table 4-6 since it is likely that the effects of the timber production will cover the entire Baram basin, one growth rate has been applied to all parts of the basin.

Table 4-6 Distribution of Forecast River Passenger Traffic in the Baram Area, 1985 1/

	Sg. Bakong	Sg. Tinjar	Marudi	Long Lama	Upper Baram	Tutoh/ Apoh	Total
K. Baram (Miri)	10	14	6 (451)	0 (62)	6	22	58 (513)
	Sg. Bakong	4	20	6	0	4	44
		Sg. Tinjar	32	6	2	0	58
			Marudi	59 (150)	43 (22)	39 (7)	199 (630)
				Long Lama	72	0 (9)	143 (221)
					Upper Bg.Baram	0	123 (22)
						Sg.Tutoh /Apoh	65 (16)
							690 (1,402)

1/ Figures in parenthesis are those of passenger express launches

4-3 Transportation Cost Analysis

4-3-1 General

This section will analyze the transportation costs in the area "with" and "without" the Project Road. Transportation cost saving, which is one of the direct benefits of raod construction and improvement, is quantifiable and is the most important indicator of the benefits.

In parts of the Study Area where rivers are the only means of transportation, transportation cost is extremely high and transportation cost saving by road construction will be particularly large, which, in turn, will cause substantial changes in the area's traffic demand and traffic distribution pattern.

The following Appendices contain the data, assumptions and the estimates of transportation costs for types of vehicles and vessels used in the present analysis:

Motor Vehicle Operation Cost: Appendix Table A-4-5
Ship Transportation Cost : Appendix Table A-4-6

4-3-2 Passenger Transportation Cost

(1) Fare

The public transportation facilities existing in the Study Area are buses, taxicabs, MAS, and express launches. Their service frequency is low except on trunk routes and in major cities. Using the tariffs now in use, their fares per kilometer are compared as follows:

Table 4-7 Comparison of Transport Fares in the Study Area

Mode	Unit Fare (M$/km/passenger)
Bus	0.06
Taxi	0.28
Express Launch	0.08-0.09
Air	0.10

Source: Field Surveys

(2) Transportation Cost in Economic Cost

The economic costs of various modes of transportation are compared below (see Appendix Table A-4-5 and A-4-6 for details). The indicated high cost of express launch transportation is because express launches carry goods together with passengers and, therefore, the passenger fare load is reduced due to freight charge. While the transportation cost of express launch compares with that of passenger car, the cost of longboat is from two to four times that of passenger car-a proof of the high river transportation cost in the Study area. Comparison of travel time between modes of transportation reveals a greater disadvantage of the river mode for passenger transportation.

Table 4-8 Comparison of Average Unit Transport Costs (Economic) for Passengers

Type of Vehicle/Vessel		Per Veh. km.	Per Day	Ave. No. of Passengers (Capacity)	Unit Cost per Pass. km. (M$)	Average Travel Speed (km./hr.)
Passenger Car, 1/	Gravel:	0.3068	-	3.5 (4.0)	0.088	56
	Paved :	0.2142	-		0.061	80
Bus, 1/	Gravel:	0.7663	-	25.0 (44)	0.031	37
	Paved :	0.5198	-		0.021	48
Express Launch						
K. Baram-Marudi :		4.0817	448.99	51 (120)	0.080	30
Marudi-Long Lama:		3.0822	332.88	45 (70)	0.069	22
Long Boat						
67' x 4' (40HP)		1.8998	-	12 (15-18)	0.158	12
45' x 2.5' (25HP)		1.2712	-	6 (6-8)	0.212	12
16' x 1.75'(6HP)		0.7657	-	2 (2-3)	0.383	8

Source: JICA Survey Team.
1/ costs are those on level tangent roads.

(3) Analysis by Route

Comparative analysis of passenger movement using river and using road was made for distance, estimated travel time and estimated fares/transportation cost for the respective pairs of zones. Table 4-9 shows the characteristics of transport time and costs of river and road between traffic zones. As is shown in Table 4-10 the comparative ratio of time-distance and of cost for travel via the Project Road is distinctively superior to

Table 4-9 Characteristics of Competitive Transport Mode Between Major Zones for Passenger Movement

Traffic Zone Pair		RIVER												ROAD											
		Distance (km)				Average Travel Time (Hr)				Fare (M$/Passenger)				Distance (km)				Average Travel Time (hr)				Fare (M$/Passenger)			
		Road	Express	Long Boat	Total	Bus2/	Express	Long Boat	Total	Bus2/	Express	Long Boat	Total	Road	Express	Long Boat	Total	Bus2/	Express	Long Boat	Total	Bus2/	Express	Long Boat	Total
1. Miri	– 5. Sg. Bakong	25	75	52	25+127	0.78	2.50	3.47	6.75	1.50	6.75	12.48	20.73	69	–	–	69	2.16	–	–	2.16	4.14	–	–	4.14
	– 6. Sg. Tinjar	25	148	66	25+214	0.78	5.53	4.40	10.71	1.50	12.96	15.84	30.30	107	–	–	107	3.34	–	–	3.34	6.42	–	–	6.42
	– 7. Lower Baram (Marudi)	25	112	–	25+112	0.78	3.73	–	4.51	1.50	10.08	–	11.58	69	37	52	158	2.16	1.23	3.47	6.86	4.14	3.33	12.48	19.95
	– 8. Baram Middle (L/Lama)	25	220	–	25+220	0.78	9.13	–	9.91	1.50	18.72	–	20.22	132	–	–	132	4.13	–	–	4.13	7.92	–	–	7.92
	– 9. Upper Baram	25	220	123	25+343	0.78	9.13	8.20	18.11	1.50	18.72	29.52	49.74	132	–	132	255	4.13	–	8.20	12.33	7.92	–	29.52	37.44
	–10. Sg. Tutoh/Apoh	25	168	86	25+254	0.78	6.53	5.73	13.04	1.50	14.56	20.64	36.70	187	–	–	187	5.84	–	–	5.84	11.22	–	–	11.22
5. Sg. Bakong	– 6. Sg. Tinjar	–	73	118	191	–	3.03	7.87	10.90	–	6.21	28.32	34.53	38	–	–	38	1.19	–	–	1.19	2.28	–	–	2.28
	– 7. Marudi	–	37	52	89	–	1.23	3.47	4.70	–	3.33	12.48	15.81	63	108	–	171	1.97	5.40	–	7.37	3.78	8.64	–	12.42
	– 8. Long Lama	–	145	52	197	–	6.63	3.47	10.10	–	11.97	12.48	24.45	63	–	–	63	1.97	–	–	1.97	3.78	–	–	3.78
	– 9. Upper Baram	–	145	175	320	–	6.63	11.67	18.30	–	11.97	42.00	53.97	63	–	123	186	1.97	–	8.20	10.17	3.78	–	29.52	33.30
	–10. Sg. Tutoh/Apoh	–	93	138	231	–	4.03	9.20	13.23	–	7.81	33.12	40.93	118	–	–	118	3.69	–	–	3.69	7.08	–	–	7.08
6. Sg. Tinjar	– 7. Marudi	–	36	66	102	–	1.80	4.40	6.20	–	2.88	15.84	18.72	25	108	–	133	0.78	5.40	–	6.18	1.50	8.64	–	10.44
	– 8. Long Lama	–	72	66	138	–	3.60	4.40	8.00	–	5.76	15.84	21.60	25	–	–	25	0.78	–	–	0.78	1.50	–	–	1.50
	– 9. Upper Baram	–	72	189	261	–	3.60	12.60	16.20	–	5.76	45.36	51.12	25	–	123	148	0.78	–	8.20	8.98	1.50	–	29.52	31.20
	–10. Sg. Tutoh/Apoh	–	20	152	172	–	1.00	10.13	11.13	–	1.60	36.48	38.08	80	–	–	80	2.50	–	–	2.50	4.80	–	–	4.80
7. Marudi	– 8. Long Lama	–	108	–	108	–	5.40	–	5.40	–	8.64	–	8.64											–	
	– 9. Upper Baram	–	108	123	231	–	5.40	8.20	13.60	–	8.64	29.52	38.16												
	–10. Sg. Tutoh/Apoh	–	56	86	142	–	2.80	5.73	8.53	–	4.48	20.64	25.12	55	108	–	163	1.72	5.40	–	7.12	3.30	8.64	–	11.94
8. Long Lama	– 9. Upper Baram	–	–	123	123	–	–	8.20	8.20	–	–	29.52	29.52											–	
	–10. Sg. Tutoh/Apoh	–	52	86	138	–	2.60	5.73	8.33	–	4.16	20.64	24.80	55	–	–	55	1.72	–	–	1.72	3.30	–	29.52	3.30
9. Upper Baram	–10. Sg. Tutoh/Apoh	–	52	209	261	–	2.60	13.93	16.53	–	4.16	50.16	54.32	55	–	123	178	1.72	–	8.20	9.92	3.30	–		32.82

1/ Average travel speed and fares/costs were assumed as follows:

K. Baram – Narudi	:	30 Km/hr., M$0.09/Km/person
Marudi – L. Lama	:	20 Km/hr., M$0.08/Km/person
Long Boat	:	15 Km/hr., M$0.24/Km/person

2/ Between K. Baram and Miri by Bus
Average travel speed and bus fares were assumed as follows: 32 Km/hr., M$0.06/Km/person

use of the existing river route. It is therefore expected passenger traffic will be diverted to the Project Road from most of the internal areas.

Table 4-10 Comparative Ratio of Travel Time and Fare Between River and Road

	5. Bakong	6. Tinjar	7. Marudi	8. L/Lama	9. Upper Baram	10. Tutoh/ Apoh
1. Miri	3.13 / 5.01	3.20 / 4.71	0.65 / 0.58	2.39 / 2.59	1.47 / 1.34	2.23 / 3.29
	Bakong	9.18 / 15.14	0.64 / 1.24	5.13 / 6.56	1.80 / 1.63	2.64 / 4.02
		Tinjar	4.13-7.75 / 2.92-12.47	10.26 / 14.40	1.80 / 1.65	4.45 / 7.93
			Marudi	1.32 / 1.13	1.08 / 1.02	2.74-5.00 / 4.29-7.67
				L/Lama	-	4.84 / 7.52
					Upper Baram	1.67 / 1.66
						Tutoh/ Apoh

Upper: ratio of time ; River / Road

below: ratio of cost ; River / Road

4-3-3 Cargo Transportation Cost

(1) General

Cargo transportation cost varies with distance, cargo type, loading and unloading costs, and other conditions of transportation, but for the purpose of a rough inter-modal comparison, hauling costs have been estimated on Table 4-11 assuming average or standard operating conditions.

Table 4-11 shows that river transportation is in some cases more advantageous than road transportation. Long boat transportation, however, is far more expensive than road transportation (as was the case with passenger). Due to the fact that the year-round operation of motor vessels over 150 tons and barges and rafts towed by a tug boat is possible only in the main stream of the Baram River and the fact that rafting in its major tributaries is hindered by shallow water in dry season, the transportation cost which the entire area is bearing is very substantial. Particularly, the cost of consumer goods and agricultural products transportation by longboat is a direct expanse to many farmers.

Table 4-11 Comparison of Average Unit Transport Costs (Economic) for Goods 1/

Type of Vessel/Vehicle		Cost (M$) Per Veh. km.	Cost (M$) Per Day	Ave. Loading Tonnage	Unit Cost Per ton-km. (M$)	Average Veh./Vessel Speed (km./hr.)
Truck 6ton 2/	Gravel:	0.5992	-	6.0	0.100	43
	Paved :	0.4401	-		0.073	55
10ton 2/ 4/	Gravel:	1.0068	-	10.0	0.100	32
	Paved :	0.7035	-		0.070	45
20ton 2/ (T.Trailer)	Gravel:	1.4240	-	20.0	0.071	40
	Paved :	0.9350	-		0.047	52
Motor Vessel	40 ton:	-	299.0	32.0	0.085	11
	150 ton:	-	1,529.3	120.0	0.043	12.5
	200 ton:	-	1,975.6	160.0	0.038	12.5
Tug + Barges (500HP)(2x300ton)	:	-	1,120.9	480.0	0.020	8.0
Tug + Log Rafting 3/ (500HP)(400Logs)	:	-	-	800.0	0.015	3.5
Long Boat, 67' x 4'	=	1.8998	-	1.50	1.267	12
45' x 2.5'	=	1.2712	-	0.65	1.956	12
16' x 1.75'	=	0.7657	-	0.25	3.063	8

Source: JICA Survey Team
1/ costs are those based on average annual mileage and including hauleage only
2/ costs are those on level tangent roads
3/ based on the hauleage of 220 kms
4/ for log transport

(2) Comparison of Cargo Transportation Costs on Major Routes

As for cargo, tariffs are not clearly known, and, therefore, economic costs have been used for the comparison of inter-traffic zonal transportation cost "with" and "without" the Project Road. Time value has not been taken into direct consideration.

Long Lama - Miri:

Without the Project Road, the Baram River is the only channel of transportation on this section. From Long Lama to K. Baram is 220 kilometers via the River. Road is available for the distance of 25 kilometers between K. Baram and Miri Town. With the Project Road, this entire route will be reduced to a total distance of 132 kilometers. Major cargo are incoming general goods, construction materials, and fuels and outgoing agricultural products, timber, and crushed stone.

Tables 4-12 and 4-13 compare transportation costs of various types of cargo and indicate the following:

a) That the transportation cost of general cargo is 20% lower by 6-ton truck than by river transportation, and that difference in transportation time (about 4 hours by truck, 1 or 2 days by river) makes truck transportation more advantageous even on gravel road.

b) That River has an absolute advantage for the transportation of timber (logs) for export.

c) That, for the transportation of timber and crushed stone for consumption in Miri area, 20-ton trailers are competitive with barges, although trucks have some advantages over the river for gravel transportation.

Table 4-12 Comparison of Transportation Costs (Long Lama - Miri, General Cargo)

Section	Long Lama - Miri	
Commodity Type	General Cargo	
Mode	Road	vs. River
Vessel/Vehicle Type	6 ton Truck	40ton/150ton Motor Vessel
Distance (km.) Conditions	132 Paved Road, flat, partly rolling	River + Road (K. Baram - Miri) 220 + 25 Bg. Baram, flat paved road
Transportation Cost (M$/ton)	full road Line Haul: M$0.4401/km x 1.05 x 132km x 1/6 tons = M$10.16/ton Handling: M$3.5/ton Total M$13.66/ton Transport Cost on gravel road M$0.5992 x 1.05 x 132km x 1/6 tons + M$3.5/ton = M$17.34	40 ton Motor Vessel (full load) Line Haul, River: M$299.02 x 2 days (110km/day) x 1/40 tons = M$14.95/ton Line Haul, Road: M$0.440/km (6 ton truck) x 25km x 1/6 ton = M$1.83/ton Handling Cost: M$4.0 + M$3.5/2 = M$5.75/ton Total M$22.53/ton 150 ton Motor Vessel (80% load) Line Haul, River: M$1,529.33/day x $\frac{220km}{300km/day}$ x 1/150 tons x 1/0.8 = M$9.35/ton Line Haul, Road: M$1.83/ton Handling Cost : M$5.75/ton Total M$16.93/ton Average Transport Cost in use of fifty-fifty basis: (M$22.53 + M$16.93) x 1/2 = M$19.73/ton

Table 4-13 Comparison of Transportation Costs
(Long Lama - Miri, Log (Sinker)/Stones)

Section	Long Lama - Miri	
Commodity Type	Log (Sinker)/Stones	
Mode	Road vs.	River
Vessel/vehicle type	20 ton Truck - trailer	2 x 300ton Barge + 500HP Tug
Distance (km.) Condition	132 paved road, flat, partly rolling	River + Road (K. Baram - Miri) 220 + 25 Bg. Baram, flat Paved Road
Transportation Cost (M$/ton)	full load Line Haul: 0.9350 x 1.15 x 132km x 1/20 tons = M$7.10/ton Handling Cost:M$3.50/ton Total M$10.60/ton 80% load Total M$12.37	80% load Line Haul, River: (M$269.24 x 2 x 220km/112km + M$582.38 x 220km/120km) x 1/480 tons = M$4.43/ton Line Haul, Road: (Stones only, 6 ton Truck) M$1.83/ton Handling Cost, (Log): M$4.0/ton Handling Cost, (Stones): M$4.0/ton Total Log for Export: M$8.43/ton Stones and log: M$12.26 for local market

cf. Cost of log (floater) rafting: two rachets (400logs or 800tons) + 500HP Tug = rafting + tug + handling cost = M$4.58/log + (M$582.38 x 220 km x 1/120 km x 1/400logs) + M$4.0/log = M$5.63/ton

Long Lama - Bintulu

Transportation distance on this route is 230 kilometers by road and about 440 kilometers by river and sea. As shown by Table 4-14, waterway transportation cost is about 16% lower than that of 20-ton truck trailer. When goods are to be hauled beyond Bintulu by truck, additional stevedoring work will be required on the pier, which makes water transportation more advantageous.

On the other hand, when goods are to be processed in Bintulu area (an industrial estate planned for the port's hinterland), transportation of the goods by water transportation will require

trucking between the port and the factory, which reduces the difference in cost between road transportation and water transportation. In view of transportation time (about 5 or 6 hours by truck vs 3 or 4 days via waterway), large truck transportation appears to be advantageous.

Table 4-14 Comparison of Transportation Costs
(Long Lama - Bintulu, Log (Sinker), Sawn Timber)

Section	Long Lama - Bintulu	
Commodity Type	Log (Sinker), Sawn Timber	
Mode	Road vs.	River + Coastal Shipping
Vessel/Vehicle Type	20 ton truck-trailer	2 x 300 ton barges + 500HP Tug
Distance (km.)	230	River + Sea
Conditions	gradient 0-3%, paved road	200 + 220
Transportation Cost (M$/ton)	full load Line Haul: M$0.9350 x 1.10 x 230km x 1/20tons = M$11.83/ton Handling Cost: M$3.50/ton Total M$15.33/ton	80% load Line Haul: (M$269.24 x 2 x 440km/112km + M$582.38 x 440km/120km) x 1/600tons x 1/0.8 = M$8.85/ton Handling Cost: M$4.0/ton Total M$12.85/ton

Limbang - Miri:

Between Limbang and Miri, road distance is 285 kilometers and waterway distance is 210 kilometers; however, the waterway route entails road transportation for 25 kilometers between K. Baram and Miri. Road transportation cost even by 20-ton trailer as shown on Table 4-15 is about 17% higher than water transportation. Since use of the port in Limbang will entail an additional trucking cost of M$2 or (including handling cost), large truck transportation cost and water transportation cost are in proximity.

In view of transportation time differences and limited port utilization during "Landas" season, the introduction of large trucks will assure the benefits of road transportation.

Table 4-15 Comparison of Transportation Costs (Limbang - Miri, General Cargo)

Section	Limbang - Miri	
Commodity Type	General Cargo	
Mode	Road	vs. Coastal Shipping
Vessel/Vehicle Type	20 ton truck - trailer	200 ton Motor Vessel
Route: Distance (km.) Conditions	285 Paved road, flat but partly rolling	Sea + Road (K. Baram - Miri) 210 + 25 difficulties during "landas" season
Transportation Cost (M$/ton)	full load Line Haul: M$0.9350 x 1.1 x 285km x 1/20 tons = M$14.66/ton Handling Cost: M$3.50/ton Total M$18.16/ton Transport Cost by 6 ton Truck: M$25.45/ton	80% load Line Haul, Sea: M$1,975.59/day x 210km/324km x 1/200 tons x 1/0.8 = M$8.00/ton Line Haul, road (6 ton truck) = M$1.83/ton Handling Cost: M$5.75/ton Total M$15.58/ton

N. Medamit - Miri

Between N. Medamit (about 40 kilometers inland of Limbang) and Miri, large truck transportation already has some advantages over water transportation. This is because water transportation entails shore trucking and handling costs as pointed out in item 3) above. Although the transportation cost by 6-ton truck is still some 10% higher than water transportation cost, reduced travel time and refined service make road transportation competitive with water transportation.

Limbang - Bintulu:

Road transportation by 6-ton truck is not at all competitive with water transportation, but is fully competitive by 20-ton trailer when end-of-the route shore trucking in Limbang is considered.

Table 4-16 Comparison of Transportation Costs (N. Medamit - Miri, General Cargo)

Section	N. Medamit - Miri	
Commodity Type	General Cargo	
Mode	Road vs.	Coastal Shipping
Vessel/Vehicle Type	6 ton Truck 20 ton Truck - trailer	200 ton Motor Vessel + 6 ton truck
Route: Distance (km.) Conditions	244 Paved road, flat, partly rolling	Road + Sea + Road 4 + 210 + 25
Transportation Cost (M$/ton)	full load 20 ton truck trailer = M$16.05/ton 6ton truck: Line Haul: M$0.4401 x 1.05 x 244km x 1/6tons = M$18.79/ton Handling Cost: M$3.50/ton Total M$22.29/ton	80% load Line Haul, Sea: M$8.00/ton Line Haul, Road: M$0.4401 x (41 + 25)km x 1/6 tons = M$4.84/ton Handling Costs: M$4.00 + M$3.50 = M$7.50/ton Total M$20.34/ton

Table 4-17 Comparison of Transportation Costs (Limbang - Bintulu, General Cargo)

Section	Limbang - Bintulu	
Commodity Type	General Cargo	
Mode	Road vs.	Coastal Shipping
Vessel/Vehicle Type	20 ton Truck - trailer	200 ton Motor Vessel
Distance (km.) Conditions	355 paved road, flat, partly rolling	Sea 400
Transportation Cost (M$/ton)	full load Line Haul: M$0.9350 x 1.1 x 355km x 1/20tons = M$18.26/ton Handling Cost: M$3.50/ton Total M$21.76/ton Transport Cost by 6 ton Truck: M$30.84	80% load Line Haul: M$1,975.59/day x 400km/324km x 1/200tons x 1/0.8 = M$15.24/ton Handling Cost : M$4.0/ton Total M$19.24/ton

Based on the above findings, it is believed that the ton-kilometer transportation cost will be reduced as a result of road development (pavement) and that the use of larger vehicles and travel time, transportation safety, and assured delivery will make road transportation advantageous over water transportation. Water transportation, however, will continue to be generally advantageous in areas where barge or raft transportation is possible.

4-4 Traffic Forecast for the Study Area

4-4-1 Normal Traffic

The only sections of the Project Road which already exist are those which extend from the intersection of Miri - Bintulu road and Belulu road to part of the way to the Tinjar River via Beluru and the section between N. Medamit and Limbang.

Normal traffic in these sections of road has been forecast in Table 4-18 by applying appropriate yearly growth rates to the ADT in 1978 obtained through the field traffic survey and the census taken by the P.W.D. The yearly growth rates have been obtained based on the P.W.D. census findings (the past trend of traffic), increases in motor vehicle holdings in the area, and such economic indicators as the areal population, because in these sections, traffic level fluctuated largely in the past and the current level is very low. In making the forecast, the following considerations were made:

Generally high traffic increase rates have been recorded in Miri area, and it is expected that on the road extending from Miri - Bintulu road to Beluru, too, future increases will be fairly high in view of the roadside oil palm development and the completion of the road extension from Beluru to Sg. Tinjar. The construction of the section between Beluru and Sg. Tinjar will be completed in the near future, as the earthwork has already been finished up to Sg. Tinjar. The currently low traffic level of only about ten vehicles will rise rapidly upon the completion of this section. Other spur roads have shown that a traffic of 80 to 90 vehicle is generated within a very short period time after road completion. The roadside agricultural development potentials suggest a fairly high degree of eventual roadside development, and, therefore, ADT in 1985 has been estimated at 100 with high average growth rates for subsequent periods.

In Limbang area, traffic has remained at a very low level except in downtown Limbang. In recent years, however, traffic has tended to increase on the outskirts of downtown Limbang. Among other things, the high motor vehicle ownership growth rate in the 5th

Division (average annual increase of 17.2% during the 10 years from 1967 to 1977) and population increase rates in this area (2.3 to 3% per annum) fully support a future yearly traffic growth rate of 3.5% in N. Medamit - Ukong Junction - Bata Danau Junction section, which is closer to downtown Limbang. In view of the currently low absolute traffic level, it has been assumed that the traffic growth rates in these sections of road will not decline in the future. For the Kubong Junction - Limbang section, the future traffic growth rate has been estimated based on the past trends.

Table 4-18 Forecast of Normal Traffic (ADT) on the Existing Project Road Sections

Road Section	Length (kms.)	Base Year (1978)	1985	1995	2005	Average Annual Growth Rate (%) 1978-85	1985-95	1995-2005
Miri/Bintulu Rd. - Beluru	18.4	209	358	738	1,452	8.0	7.5	7.0
Beluru - Sg. Tinjar	36.3	10	100	196	368	1/	7.0	6.5
N. Medamit - Ukong Junc.	9.7	88	112	158	223	3.5	3.5	3.5
Ukong Junc. - Batu Donau Junc.	9.3	103	131	185	261	3.5	3.5	3.5
Batu Danau Junc. - Kubong Junc.	12.5	153	208	323	502	4.5	4.5	4.5
Kubong Junc. - Limbang	9.8	977	1,569	2,945	5,274	7.0	6.5	6.0

1/ ADT of 100 is assumed when this section is completed for the year 1985.

The distribution of motor vehicles has been estimated based on changes in the composition of traffic by the type of vehicle and by road section and on changes in the ownership of various types of vehicles. Table 4-19 shows the future composition ratios of various types of vehicles by road section, and Table 4-20 shows normal traffic forecast by type of vehicle by road section.

Table 4-19 Forecast of Vehicle Composition on the Existing Road Sections in the Study Area

Road Section	1985 Car/ Taxi	1985 Van/ Pick-up	1985 Truck	1985 Bus	1995, 2005 Car/ Taxi	1995, 2005 Van/ Pick-up	1995, 2005 Truck	1995, 2005 Bus
Miri/Bintulu Rd. - Beluru	35.0	10.0	52.0	3.0	50.0	10.0	35.0	5.0
Beluru - Sg. Tinjar	35.0	10.0	52.0	3.0	50.0	10.0	37.0	3.0
N. Medamit - Ukong Junc.	51.0	7.0	32.0	10.0	55.0	8.0	30.0	7.0
Ukong Junc. - Kubong Junc.	52.0	7.0	34.0	7.0	55.0	8.0	30.0	7.0
Kubong Junc. - Limbang	68.0	5.0	24.0	3.0	70.0	4.0	23.0	3.0

Table 4-20 Forecast of Traffic on the Existing Road Sections

Road Section	1985 Car/ Taxi	Van/ Pick-up	Truck	Bus	Total
Miri/Bintulu Rd. - Beluru	125	36	186	11	358
Beluru - Sg. Tinjar	35	10	52	3	100
N. Medamit - Ukong Junc.	57	8	36	11	112
Ukong Junc. - Batu Danau Junc.	67	9	45	10	131
Batu Danau Junc. - Kubong Junc.	108	15	70	15	208
Kubong Junc. - Limbang	1,067	78	377	47	1,569

Road Section	1995 Car/ Taxi	Van/ Pick-up	Truck	Bus	Total
Miri/Bintulu Rd. - Beluru	369	74	258	37	738
Beluru - Sg. Tinjar	98	20	72	6	196
N. Medamit - Ukong Junc.	87	13	47	11	158
Ukong Junc. - Batu Danau Junc.	102	15	55	13	185
Batu Danau Junc. - Kubong Junc.	178	26	97	22	323
Kubong Junc. - Limbang	2,062	118	677	88	2,945

Road Section	2005 Car/ Taxi	Van/ Pick-up	Truck	Bus	Total
Miri/Bintulu Rd. - Beluru	726	145	508	73	1,452
Beluru - Sg. Tinjar	184	37	136	11	368
N. Medamit - Ukong Junc.	123	18	67	15	223
Ukong Junc. - Batu Danau Junc.	144	21	78	18	261
Batu Danau Junc. - Kubong Junc.	276	40	151	35	502
Kubong Junc. - Limbang	3,692	211	1,213	158	5,274

4-4-2 Diverted Traffic

Completion of the Project Road will result in the diversion of waterway and air traffic to roads. However, that which will be diverted from air will be insignificant and, therefore, only that which will be diverted from river will be taken up here and divided into passenger traffic and cargo traffic for analysis.

(1) Diverted Passenger Traffic

As already seen in 4-3-2, the completion of the Project Road will have the greatest impact on river transportation among the existing modes of transportation. Of the rivers and roads currently available, the advantages of road over river has been established in most of areas, in terms of travel time and travel cost. Table 4-21 presents the modal split of traffic estimated based on the analysis made by competitive routes. It is expected that the existing river traffic for all OD pairs will be diverted to road except most of those related to Marudi. Of the future river passenger traffic which was previsouly shown on Table 4-6, that which will shift to road is shown in Table 4-22.

In view of the current modal split of passengers between bus and car, the future split has been estimated at 65% bus and 35% car, and average number of passengers of 25 per bus and 3 per car has been used for the conversion of the number of passengers to the volume of motor vehicle traffic.

Future traffic growth rates have been estimated at 9% per annum during the period of 1985 to 1995 and at 7% per annum during the period of 1995 to 2005, based on the river passenger traffic growth rates determined in 4-2-3.

Table 4-21 River Passenger Traffic Expected to Divert Into Project Road

River Traffic Between		Modal Split (%) River	Modal Split (%) Road	1985 Diverted Traffic (No. of Passengers) 5/	Remarks
01. Miri -	05	-	100	10	
	06	-	100	14	
	07	100	-	0	
	08	-	100	62 (62)	
	09	-	100	6	
	10	-	100	22	
05. Bakong -	06	-	100	4	
	07	100	-	0	
	08	-	100	6	
	09	-	100	-	
	10	-	100	4	
06. Tinjar -	07	30	70 1/	23	
	08	-	100	6	
	09	-	100	2	
	10	-	100	-	
07. Lower Baram - (Marudi)	08	30	70 2/	145 (105)	
	09	50	50 3/	33 (11)	09: Upper Baram
	10	30	70 4/	32 (5)	10: Tutoh/Apoh
08. Baram Middle - (Long Lama)	10	-	100	9 (9)	

1/ of which 80% was assumed to divert between Tinjar and Miri and 20% between Tinjar and Long Lama

2/ of which 100% was assumed to divert between Baram Middle and Miri

3/ same as in 2/

4/ of which 20% was assumed to divert between Tutoh/Apoh and Baram Middle and 80% between Tutoh/Apoh and Limbang

5/ Figures in parenthesis are the number of passengers diverted from express launches

Table 4-22 Forecast of Diverted Passenger Traffic

Road Section	No. of Passengers 1985	No. of Passengers 1995	No. of Passengers 2005	Vehicular Traffic 1985 Car	1985 Bus	1985 Total	1995 Car	1995 Bus	1995 Total	2005 Car	2005 Bus	2005 Total
Miri/Bintulu Rd. – Beluru	311	736	1,448	36	8	44	85	19	104	167	37	204
Beluru – Sg. Tinjar	315	746	1,467	37	8	45	88	19	107	173	37	210
Sg. Tinjar – Long Lama	292	691	1,359	34	8	42	80	19	99	157	37	194
Long Lama – Sg. Tutoh/Apoh	41	97	191	5	1	6	12	3	15	24	6	30
Sg. Tutoh/Apoh – N. Medamit	26	62	122	3	1	4	7	2	9	14	4	18
N. Medamit – Limbang	26	62	122	3	1	4	7	2	9	14	4	18

(2) Diverted Cargo Traffic

Of the incoming goods now brought in via Miri or Marudi, those which are delivered to Tinjar (Zone 6), Baram Middle (Zone 8), Upper Baram (Zone 9), and Tutoh/Apoh (Zone 10) are likely to shift onto the Project Road upon its completion. Likewise, the entire volume of outgoing agricultural products of these areas (Zones 6, 8, 9 and 10) will be diverted to the road. As far as logs for export are concerned, it is certain that the entire volume of timber transportation will continue to depend on the Baram River. It is quite possible, however, that the road completion will induce the construction of a sawmill near the sites of log production, in which case it is fairly likely that the log transportation to the mill and lumber transportation to local market in Miri area will be accomplished by trucks. The volume of timber traffic to be diverted from river to road has been estimated at 10% of the total. Tables 4-23 and 4-24 show the volume of goods to be diverted to the Project Road, upon completion, as estimated based on Table 4-3 and Appendix Note A-4-1.

Table 4-23 Diverted River Goods Traffic 000 tons

Type of Goods	1985	1995	2005
Incomming Goods:	20.0	31.1	48.5
Outgoing Goods:			
Agriculture Prodts.	3.4	3.6	3.7
Timber	20.2	28.4	38.3

Table 4-24 Diverted River Goods Traffic

Road Sections	1985		1995		2005	
	000tons	Veh./day	000tons	Veh./day	000tons	Veh./day
Miri/Bintulu Rd. – Beluru	24.7	23	36.7	34	55.4	51
Beluru – Sg. Tinjar	23.4	21	34.6	32	52.2	48
Sg. Tinjar – Long Lama	16.2	15	23.0	21	33.5	31
Long Lama – Sg. Tutoh/Apoh	4.3	4	6.7	6	10.6	10

4-5 Development Traffic Forecast

The development traffic whose generation is anticipated from the construction of the Project Road consists of the following:

1) That which will be generated as a result of agricultural development,

2) That which will be generated as a result of tourism development, and

3) That which will be generated as a result of the development of Long Lama into the sub-regional center.

1) Agricultural Development Traffic

Agricultural development traffic demand (trucks) has been estimated based on the agricultural production prediction in Table 2-17, Chapter 2, assuming that the entire volume of agricultural development production in Long Lama and Tutoh/Apoh will be shipped to Miri and that goods necessary for agricultural development will be brought in on return trips by the same trucks.

The Limbang Valley development of about 22,000 hectares is likely to generate a fair volume of traffic demand for the section between Limbang and N. Medamit. It is felt that the success of this development will largely depend, in addition to cultivation method, on the procurement of as many as about 20,000 families for labor, although it is not the purpose of this Study to determine the feasibility of the Limbang Valley development.

Provided that this development scheme is realized, it is assumed that passenger traffic which will result from the settlement of 60,000 to 80,000 people, the traffic of goods which will be required to support the needs of this population and the traffic which will result from the development of various industries, will be greater than the traffic demand for the yearly transportation of about 60,000 tons of rice. Even at today's level, a polulation of 80,000 would generate an inter-regional passenger traffic demand of roughly 2,400 trips per day. In view of the current population of Miri Town of about 50,000, the estimated 80,000 settlers in the

Limbang Valley, Miri - Limbang traffic demand will be substantial. In any event, the details of the Limbang Valley development will be clarified after the completion of the feasibility study which is presently being undertaken. At this stage, therefore, the completion in 1995 of the development of 22,000 hectares is assumed. Also, it is assumed that the volume of truck traffic demand for the transportation of products and the same volume of related small car traffic will be generated between N. Medamit and Limbang.

The agricultural development traffic forecast is presented in Table 4-25.

The forecast of tourism development traffic is nearly impossible at this stage. The Project Road completion and the accompanying organized tourism development in the northern part of Sarawak will produce sizeable traffic demand, but, because of elements of uncertainty in conditions of the forecast, 20,000 visitors to G. Mulu and 5,000 visitors to Baram have been estimated yearly (1990) for the purpose of this Study. The results of forecast are shown in Table 4-25.

Table 4-25 Estimated Development Traffic due to Agricultural Development

Road Section	Type of Traffic	1990	1995	2005	Type of Vehicle
Miri – Long Lama	Agriculture	3	6	6	- 6 ton truck for transporting products
		3	6	6	- 100% of above for relevant goods traffic (6 ton truck)
		6	12	12	- 100% of goods traffic for passenger traffic (van/pickup)
Miri – Tutoh/Apoh	Agriculture	6	12	12	- 6 ton truck for goods traffic
		6	12	12	- Van/pickup for passenger traffic
N. Medamit – Limbang	Agriculture	20	60	60	- 6 ton truck for transporting products
		20	60	60	- 100% of above for relevant goods traffic (6 ton truck)
		40	120	120	- 100% of goods traffic for passenger traffic (van/pickup)
Tutoh/Apoh – Miri	G. Mulu 1/ 2/	11+3	18+5	47+13	- tourist traffic (car + mini-bus)
	Tourism	14	23	60	- related traffic (van/pickup)
Tutoh/Apoh – Limbang	G. Mulu 1/ 2/	7+2	11+3	29+8	- tourist traffic (car + mini-bus)
	Tourism	9	14	37	- related traffic (van/pickup)
Long Lama – Miri	Baram 1/ 2/	5+1	8+2	21+5	- tourist traffic (car + mini-bus)
	Tourism	6	10	26	- related traffic (van/pickup)

1/ 10% of annual growth rate was assumed from 1990 then after

2/ 50% by car with average three passengers and 50% by mini-bus with average 15 passengers were assumed

4-6 Estimate of Overall Passenger Traffic

4-6-1 Methodology

An entirely different method from that which has been discussed before will be used here for the forecast of overall passenger traffic to be generated upon the Project Road completion. The method takes note of passenger movement because it could be determined fairly accurately during the field traffic survey and population is the only relatively reliable regional economic indicator. The method is summarized below and the forecasting process is illustrated by the flow chart in Fig. 4-3.

(1) The OD, travel time, operation cost, cross-sectional traffic volume, and average number of passengers per vehicle (or vessel) of the existing road and river passenger traffic in the Study Area are first obtained.

(2) A traffic distribution model for Miri area is constructed from motor vehicle passenger traffic survey.

(3) The current average passenger travel cost in the Study Area is estimated for each traffic zone, and traffic demand curve is estimated based on generated/concentrated passenger traffic in each zone.

(4) The average travel cost is estimated for the future generation/concentration passenger traffic in each traffic zone upon the Project Road completion.

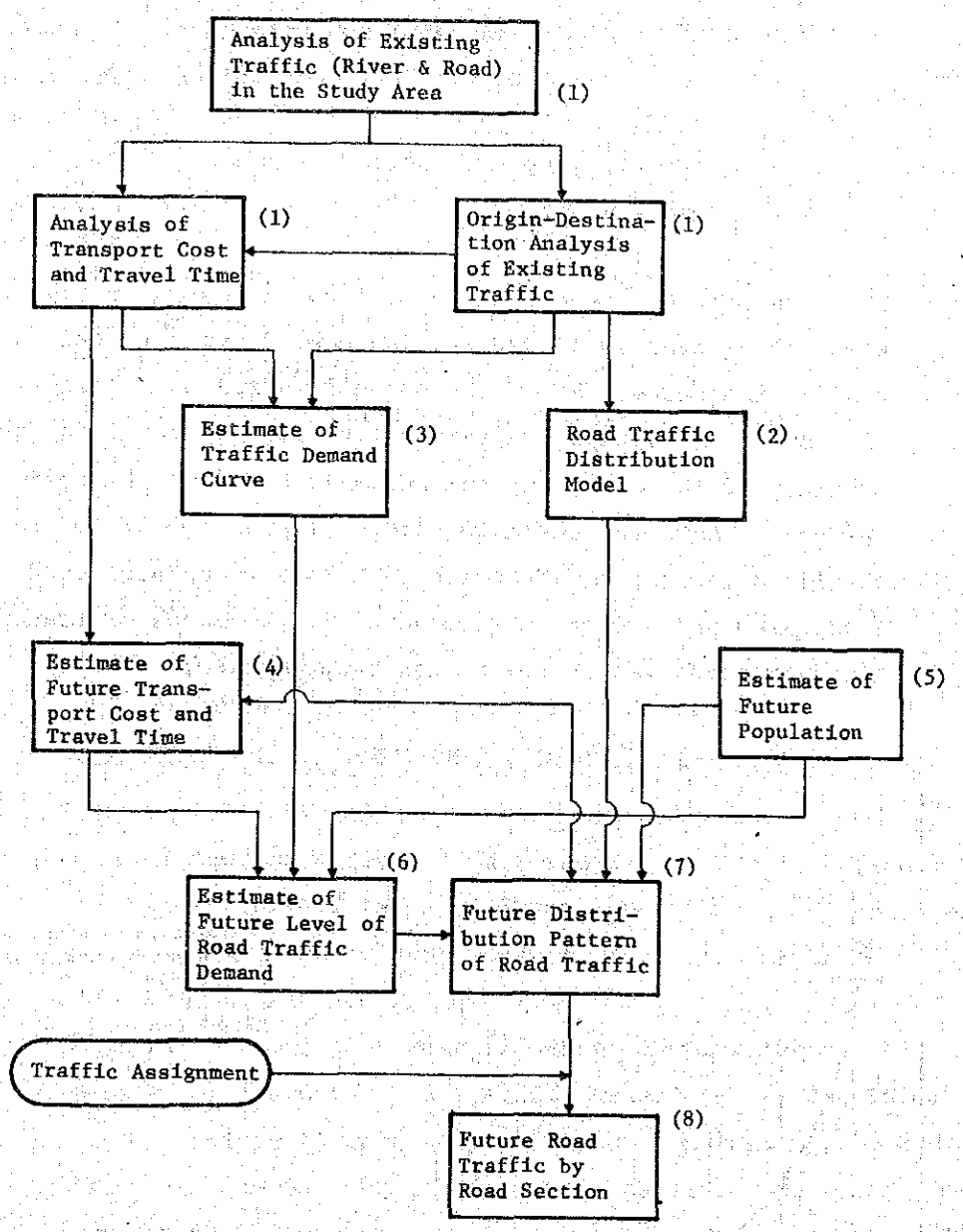
(5) Future population in the Study Area is estimated by traffic zone.

(6) Future generation/concentration passenger traffic is estimated for each traffic zone from (3), (4) and (5) above.

(7) Future passenger traffic distribution is forecast from (2), (4), (5) and (6) above.

(8) Based on (7) above and using the required travel time, traffic volume is forecast for each road section.

Fig. 4-3 FLOW CHART SHOWING METHOD OF ESTIMATING OVERALL ROAD PASSENGER TRAFFIC



4-6-2 Demand Forecast

1) Estimate of Traffic Demand Curve

The field surveys of river traffic as well as road traffic has revealed that the following equation describes the relationships the average travel cost per each trip-end and the generation/concentration traffic volume per population of 1,000 of a given traffic zone. Relevant values used for developping the equation are shown in Table 4-26.

$$Ti = \alpha \frac{1}{Ci^{\beta}}$$

Wherein, Ti = trip-ends per 1,000 population of Zone-i

Ci = average transport cost per trip-end of Zone-i

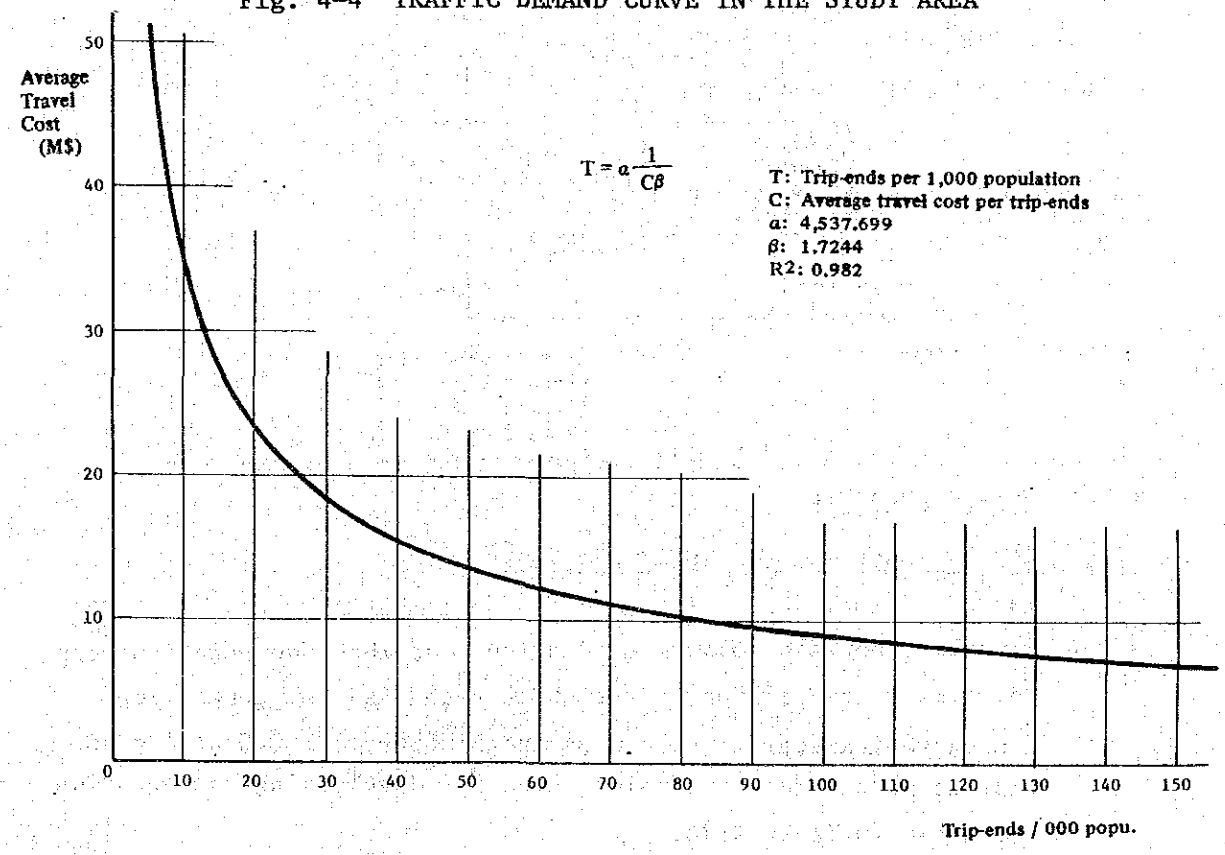
α = 4,537.699

β = 1.7244

R^2 = 0.982

This equation has been translated into the curve of Fig. 4-4, which shows that as transportation cost decreases, the volume of traffic increases. Since the curve is based on a limited number of samples and data whose reliability was not verified, the accuracy of the curve and the analysis based on the curve are not reliable. However, the methodological problems of forecast of traffic after the construction of a road in an area such as the Study Area where there exists no or little means of transportation justifies use of the method adopted here.

Fig. 4-4 TRAFFIC DEMAND CURVE IN THE STUDY AREA



2) Passenger Traffic Demand Forecast

Table 4-26 presents generation/concentration traffic volume for each traffic zone in 1985, estimated based on the traffic demand curve, an estimate of average future passenger travel cost, and future population. Of these, the most important factor was the estimate of average travel cost, which has been analyzed as follows:

- For river passengers in 1978, average travel cost per trip-end has been estimated using the fare rates of various means of transportation (or, in absence of a tariff, as in the case of longboats, estimates made in Section 4-3-3 were used).
- For motor vehicle passengers in 1978, who use a variety of means of transportation (cars, buses, vans, taxicabs, and even trucks), the average travel cost per trip-end has been estimated using 1.6 time the bus fare for simplicity and the actual passenger distribution pattern.
- For these reasons, it appears that a gap has resulted between the theoretical value and the estimated value of average travel cost per trip-end in Zones 01 to 05 where taxicab or other means of transportation whose fare is higher than that of bus must be used because of the low level of bus service. However, for Miri, the gap shrinks to an insignificant amount when allowance is made for traffic within Miri and for air traffic, which are not reflected in the number of trip-ends per 1,000 population. In the case of Zone 05, the gap is attributable to the facts that river transportation is still being heavily depended upon (traffic flow between Marudi and Zone 07 has been omitted from this analysis), that the road development has not yet fully taken effect, and that average travel cost is much higher than in other zones because the frequency of bus service is extremely low in this zone.
- In any event, it is obvious at this stage that a discrepancy between the theoretical value and the estimated value can result depending on zoning method and travel cost estimation method.

- For zones in which roads already exists, average travel cost upon the completion (assumed in 1985) of the road has been obtained by applying an estimated growth rate to an estimated current value. For other zones, average travel cost per trip-end has been estimated for each zone using 1.6 times of bus travel cost as average travel cost based on a an anticipated distribution pattern (using the distribution model shown in the next section). Actually, passenger distribution pattern and average travel cost will both change even in zones in which road already exists, but because little difference was indicated by a test, the 1978 estimate value was used.

- Zones which are believed practically free from the impact of the Project Road completion (Zones 07 and 09, and parts of Zones 06 and 10) have been either eliminated from analysis or necessary adjustment have been made. For Zone 01 (Miri) and Zone 12 (Limbang), necessary adjustment has been made after consideration of traffic with Brunei and of air traffic.

The 1985 generation/concentration traffic volume has been obtained by multiplying the estimated 1985 trip-ends per 1,000 population by zonal population.

Table 4-26 Estimated Passenger Traffic Demand, (With situation, 1985)

Traffic Zone	WITHOUT SITUATION			WITH SITUATION, 1985						
	1978 Trip-ends/ 1,000popu.	Average Travel Cost (M$/tripend) Theoretical value	Average Travel Cost (M$/tripend) Estimated Actual Value	Average Travel Cost (M$/ trip-end)	Estimated Trip-ends/ 1,000popu. (1978)	Adjustment Factor	Adjusted Trip-ends/ 1,000popu. (1978)	Growth Rate 4/ 1978-1985 (%/Year)	Estimated Trip-ends/ 1,000popu. (1985)	Estimated Trip-ends, 1985
01	54	13.06	8.23	8.23	120	x 0.45 1/	54	6.0	81	5,840
02	143	7.43	5.95	5.95	143	–	143	6.0	215	3,376
03	89	9.78	9.95	9.95	89	–	89	6.0	134	2,318
04	30	18.37	18.27	18.27	30	–	30	10.0	58	1,670
05	40	15.54	9.29	9.29	97	–	97	6.0	146	1,080
06	n.a.	n.a.	n.a.	11.40	68	x 0.70 2/	48	4.5	65	832
08	26.6	19.69	19.40	9.90	87	–	87	6.0	131	1,048
10	6.5	44.59	41.30	16.10	38	x 0.80 2/	31	4.5	42	319
11	43	14.91	n.a.	9.30	97	–	97	4.5	132	924
12	44	14.67	n.a.	10.30	81	x 0.50 3/	40	6.0	60	1.314

1/ the rest of inter-zonal traffic demand is currently met by road to and from Brunei and by air which are excluded.

2/ it was assumed 30 percent of the area will be little affected by Project Road.

3/ the rest of inter-zonal traffic demand is currently met by speed boat to and from Brunei and by air which are excluded.

4/ higher growth rate was assumed for the areas where either present growth rate is already high or planned development is expected.

4-6-3 Overall Passenger Traffic by Project Road Section

1) Passenger Traffic Distribution

The following gravity model was established for motor vehicle passenger OD pattern, based on the sample OD survey findings:

$$Tij = K \frac{(Pi \cdot Pj)^{\alpha}}{Dij^{\beta}}$$

Wherein Tij = Distribution traffic volume between zones i and j

Pi = Population of Zone i

Pj = Population of Zone j

Dij = Time distance between Zone i and j

K = 0.03295

α = 1.73253

β = 2.59915

R^2 = 0.8519

This equation, which relies on the sample OD survey taken in Miri, reflects relatively long trip samples such as Miri - Niah and Miri - Bintulu and is, therefore, believed to correspond to motor vehicle trip pattern in the Project Area. The zonal populations have already been shown. For time-distance between Zones in Table 4-2, operating speed was determined based on design speed and as shown in Appendix Table A-4-3. Based on the obtained distribution pattern, computation was done by the previously predicted trip-end for each Zone, and, thus, a future O-D table has been obtained as presented on Table 4-27.

Table 4-27 Estimated Distribution of Passenger Traffic in the Study Area - with Situation, 1985

(No. of Trips)

	02 Bekenu	03 Niah	04 Bintulu	05 Bakong	06 Tinjar	08 Baram Middle	10 Tutoh/ Apoh	11 N. Medamit	12 Limbang	Total
01 Miri	2,628	1,221	814	565	171	247	53	14	147	5,860
02		283	124	215	37	45	8	2	20	3,362
03			562	128	36	45	10	3	27	2,315
04				44	24	37	12	4	45	1,666
05					67	44	5	1	9	1,078
06						486	14	2	16	853
08							81	8	53	1,046
10								26	108	317
11									875	935
12										1,300

2) Vehicular Traffic by Road Section

Future traffic on the Project Road by section, shown in Table 4-28, has been obtained by distributing the value of Table 4-27 in the same manner as diverted traffic was distributed. A passenger split of 65% bus (average passenger, 25) and 35% car (average passenger, 3) was used.

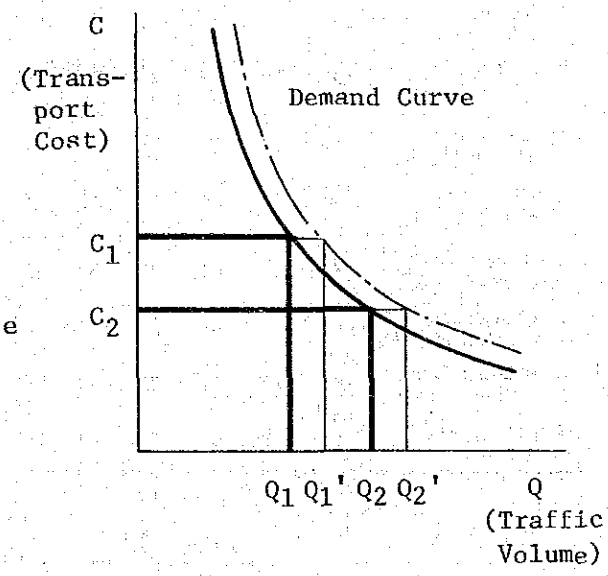
Table 4-28 Estimated Future Passenger Traffic on Project Road Sections - 1985

Road Section	Car	Bus	Total
1. Miri/Bintulu Road - Beluru	226	50	460
2. Beluru - Sg. Tinjar	130	29	265
3. Sg. Tinjar - Long Lama	151	34	308
4. Long Lama - Sg. Tutoh/Apoh	62	14	127
5. Sg. Tutoh/Apoh - N. Medamit	57	13	117
6. N. Medamit - Limbang	152	34	310

4-7 Forecast of Induced Traffic

1) Definition of Induced Traffic

Induced traffic can be defined as the traffic which will be generated due to the reduction of transport cost even if the traffic generating potentials are constant. As is shown in the Figure below, cost reduction from C_1 to C_2 results in an increase of traffic Q_1 to Q_2. Thus $Q_2 - Q_1$ represents induced traffic volume.



Development traffic can be defined in the Figure as the traffic which will be generated due to the shift in the demand curve because traffic generating potentials will increase due to development. Thus $Q_1' - Q_1$ represents development traffic volume.

As the traffic volume forecasted in section 4.6 is the total passenger traffic or Q_2', the induced traffic can be calculated by deducting Q_1 (or normal and diverted traffic volume) and $Q_1' - Q_1$ ($\doteqdot Q_2' - Q_2$ or development traffic from Q_2'.)

2) Estimate of Induced Traffic

Induced passenger traffic volume by Project Road Section, therefore, was calculated by deducting the sectional passenger traffic volume of normal, diverted and development from that of the total shown in Table 4-27.

Traffic has so far been only passenger traffic. Truck traffic has been estimated assuming a 60% ratio of bus and car traffic to the total traffic and a 1:5 ratio between van/pickup and medium truck.

Table 4-29 shows the results of the estimates.

Table 4-29 Forecast of Induced Traffic by Project Road Section

Road Section	1985					1995					2005				
	Car/ Taxi	Van/ P.up	Truck	Bus	Sub-Total	Car/ Taxi	Van/ P.up	Truck	Bus	Sub-Total	Car/ Taxi	Van/ P.up	Truck	Bus	Sub-Total
1. Miri/Bintulu Rd. – Beluru	57	9	48	29	143	112	19	94	57	282	201	34	168	102	505
2. Beluru – Sg. Tinjar	50	7	37	16	110	98	14	72	31	215	176	26	129	56	387
3. Sg. Tinjar – Long Lama	109	15	74	24	222	214	29	145	47	435	384	52	261	85	782
4. Long Lama – Tutoh/Apoh	51	7	34	11	103	100	13	68	22	203	180	24	122	39	365
5. Tutoh/Apoh – N. Medamit	50	7	34	11	102	98	13	67	22	200	176	24	119	39	358
6. N. Medamit – Ukong Junc.	88	12	61	21	182	173	24	119	41	357	310	43	213	74	640
7. Ukong Junc. – B. Danau Junc.	88	12	61	21	182	173	24	119	41	357	310	43	213	74	640
8. B. Danau Junc. – Kubong Junc.	88	12	61	21	182	173	24	119	41	357	310	43	213	74	640
9. Kubong Junc. – Limbang	88	12	61	21	182	173	24	119	41	357	310	43	213	74	640

4-8 Summary of Forecast Traffic

Table 4-30 summarizes the forecast of traffic volume on the Project Road sections for the years of 1985, 1995 and 2005. Although the level of ADT varies considerably by section, most of the sections have an ADT of 300 to 600 in 1985, while the Long Lama - N. Medamit section has a volume of only 115 to 130 in 1985. Some 10 kms (or 6.2 miles) of the section near Limbang Town will have an ADT as high as 1,800 in 1985. The annual growth rate of ADT will be 7 to 8.6 percent for 10 years after 1985 and 4 to 6.7 percent for the subsequent 10 years.

Table 4-30 Summary of Forecast Traffic Volume on the Project Road Sections (ADT)

Road Section	1985	1995	2005	Average Annual Growth Rate (%) 1985-95	1995-2005
Miri/Bintulu Rd. – Beluru	600	1,272	2,432	7.8	6.7
Beluru – Sg. Tinjar	307	664	1,233	8.0	6.4
Sg. Tinjar – Long Lama	311	669	1,227	8.0	6.3
Long Lama – Tutoh/Apoh	133	294	549	8.3	6.4
Tutoh/Apoh – N. Medamit	115	237	450	7.5	6.6
N. Medamit – Ukong Junc.	347	792	1,195	8.6	4.2
Ukong Junc. – B. Danau Junc.	366	819	1,223	8.4	4.1
B. Danau Junc. – Kubong Junc.	443	957	1,464	8.0	4.3
Kubong Junc. – Limbang	1,804	3,579	6,236	7.1	5.7

Table 4-31 and 4-32 show the forecast of traffic volume on the Project Road Sections by traffic type and by vehicle type respectively.

Table 4-31 Summary of Forecast Traffic Volume by Traffic Type by Project Road Section

Road Section	1985					1995					2005				
	Normal	Diverted	Development	Induced	Total	Normal	Diverted	Development	Induced	Total	Normal	Diverted	Development	Induced	Total
1. Miri/Bintulu Rd. – Beluru	358	67	32	143	600	738	138	114	282	1,272	1,452	255	220	505	2,432
2. Beluru – Sg. Tinjar	100	66	33	110	307	196	139	114	215	664	368	258	220	387	1,233
3. Sg. Tinjar – Long Lama	–	57	32	222	311	–	120	114	435	669	–	225	220	782	1,227
4. Long Lama – Tutoh/Apoh	–	10	21	103	133	–	21	70	203	294	–	40	144	365	549
5. Tutoh/Apoh – N. Medamit	–	4	10	102	115	–	9	28	200	237	–	18	74	358	450
6. N. Medamit – Ukong Junc.	112	4	50	182	347	158	9	268	357	792	223	18	314	640	1,195
7. Ukong Junc. – B. Danau Junc.	131	4	46	182	366	185	9	259	357	819	261	18	296	640	1,223
8. B. Danau Junc. – Kubong Junc.	208	4	46	182	443	323	9	259	357	957	502	18	296	640	1,464
9. Kubong Junc. – Limbang	1,569	4	46	182	1,804	2,945	9	259	357	3,579	5,274	18	296	640	6,236

Table 4-32 Summary of Forecast Traffic by Vehicle Type by Project Road Section

Road Section	1985					1995					2005				
	Car/Taxi	Van/P.up	Truck	Bus	Total	Car/Taxi	Van/P.up	Truck	Bus	Total	Car/Taxi	Van/P.up	Truck	Bus	Total
1. Miri/Bintulu Rd. – Beluru	226	61	263	50	600	592	150	410	120	1,272	1,162	289	751	230	2,432
2. Beluru – Sg. Tinjar	130	33	116	29	307	310	91	200	63	664	601	173	337	122	1,233
3. Sg. Tinjar – Long Lama	151	31	95	34	311	320	86	190	73	669	609	162	316	140	1,227
4. Long Lama – Tutoh/Apoh	62	17	41	14	133	130	48	86	30	294	251	96	144	58	549
5. Tutoh/Apoh – N. Medamit	57	12	34	13	115	116	27	67	27	237	219	61	119	51	450
6. N. Medamit – Ukong Junc.	152	45	117	34	347	278	171	286	57	792	476	218	400	101	1,195
7. Ukong Junc. – B. Danau Junc.	159	46	126	32	366	286	173	294	57	819	483	221	411	100	1,223
8. B. Danau Junc. – Kubong Junc.	200	52	151	37	443	362	184	336	66	957	615	240	484	117	1,464
9. Kubong Junc. – Limbang	1,159	115	458	69	1,804	2,246	276	916	132	3,579	4,031	411	1,546	240	6,236

Chapter 5

TECHNICAL STUDY AND ANALYSIS

Chapter 5 TECHNICAL STUDY AND ANALYSIS

5-1 Geological Analysis

5-1-1 Outlines

1) Geology

Northern Borneo is composed mainly of geologically young sedimentary rocks of Tertiary and Upper Cretaceous age as shown in Table 5-1 and Fig. 5-1.

Table 5-1 Percentage Distribution of Rock Groups in Northern Borneo

Rock Group	Sarawak	Brunei	Sabah	Total
Quaternary	15%	38%	14%	15%
Tertiary & Upper Cretaceous	78	62	74	76
Precretaceous	3	-	-	2
Igneous	4	-	12	7

The Tertiary and Upper Cretaceous rocks consist mainly of fine grained sandstone alternating with clays or shales. The Quaternary deposits are alluvial and largely derived from the older sedimentary rocks.

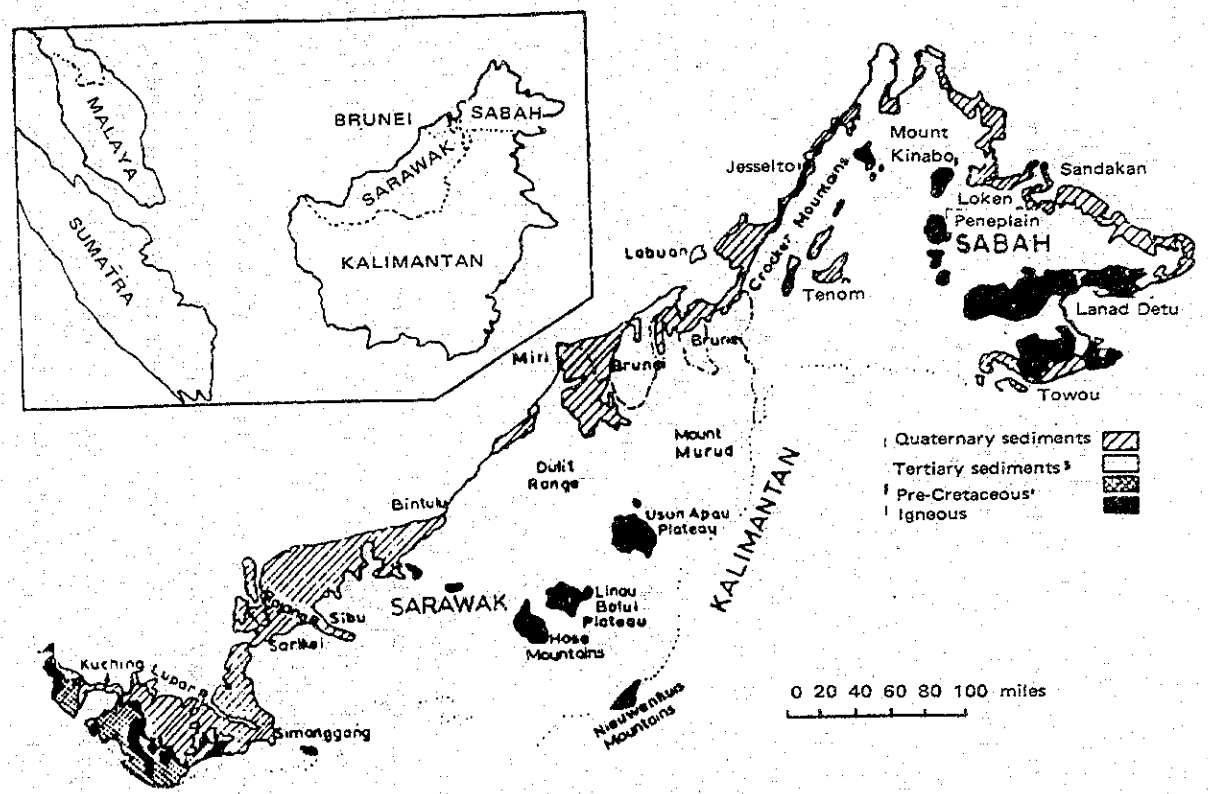
The project area consists mainly of the alluvial Quaternary deposits and the Tertiary sedimentary rocks such as shale, sandstone and lignite, but portionally, Precretaceous Limestone as shown in Fig. 5-2.

The Tertiary sedimentary rocks are unsuitable for use as aggregate materials, because they are not well cemented. The gravel contained in the alluvial Quaternary deposits can be used for the purpose.

2) Soil

Only two sections of the project road, Miri/Bintulu Road ∿ Sg. Tinjar (54.7 km) and Limbang ∿ Sg. Limbang (41.4 km) are accessible by automobile. The remainder of the intermediate section of 141.2km (88 mile) in length, was investigated either from a helicopter or a long boat. For this reason, it was very difficult to obtain

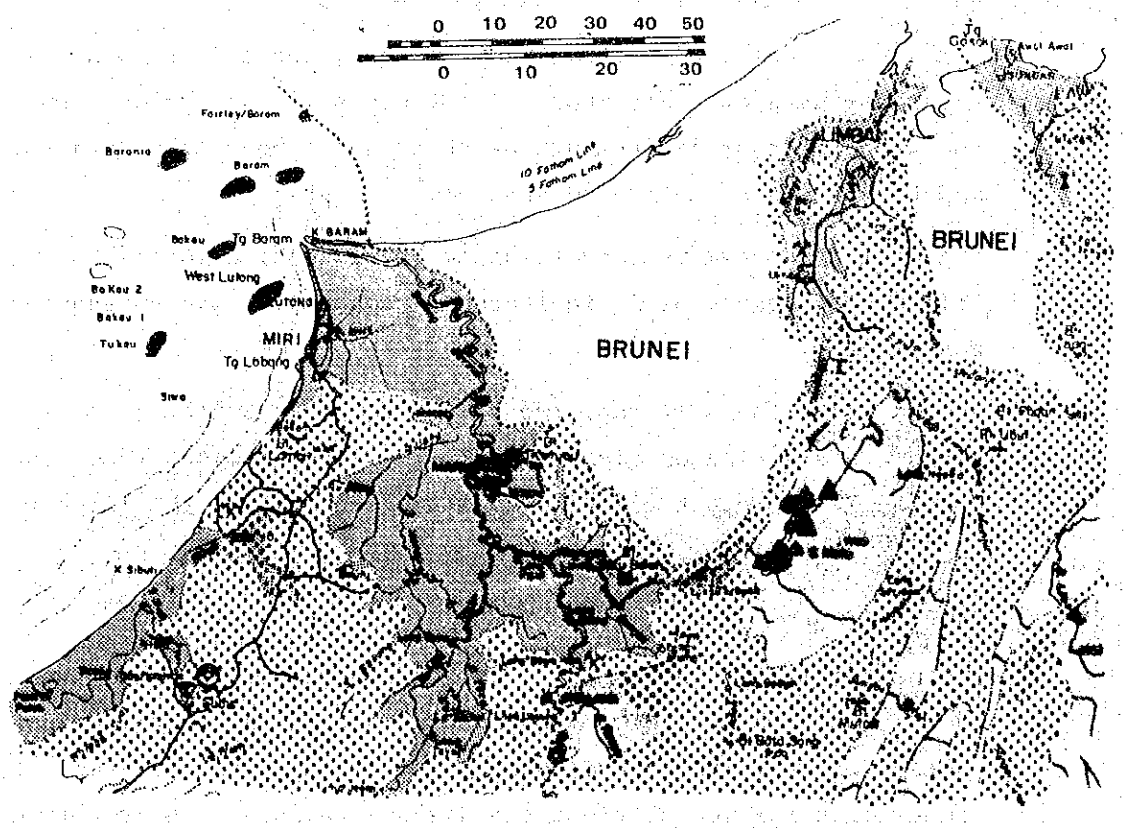
Fig. 5-1 SKETCH MAP SHOWING OF NORTHERN BORNEO



Source: Road Making Materials in Northern Borneo

R R L Road Research Technical Paper No.68

Fig. 5-2 MINERAL RESOURCES MAP



GEOLOGY

- Pleistocene and recent sediment
- Neogene sedimentary rocks (including some late Palaeogene rocks in North Sarawak)
- Palaeogene sedimentary rocks (including some early Neogene rocks, and late Cretaceous rocks in West Sarawak)

	FIELD			WELL	SEEPAGE
	In Production	Potential	Abandoned	Significant hydrocarbon indications	
OIL					
NATURAL GAS				Oil and Gas	
COAL					Occurrence
	Deposit with Proven Reserves		Deposit Worked		Occurrence
PHOSPHATE					
GLASS SAND					
DOLOMITE					
SAND AND GRAVEL					
LIMESTONE					
QUARRY	Operating		Abandoned		

Source: Mineral Resources Map of Sarawak, Malaysia, First edition, 1976

detailed soil information within the limited period available for field investigation.

The lack of detailed information, however, was offset to a certain extent by data obtained from a 1:500,000 soil map produced by the Department of Agriculture based on auger bore hole data to a depth of 1.2 m below ground surface.

The soil is classified according to "A Classification of Sarawak Soils", Department of Agriculture, Sarawak, 1966 and subsequent amendment.

According to the soil map, red yellow Podzolic Soils and peat soils are distributed along almost all of the project road, and Grey Soil and recent alluvial soil are found along the large rivers.

The peat soils are generally most troublesome in road construction work.

The peat soil is fibrous and rich in organic matter. It usually consists of 50% of organic components, and has a natural moisture content of over 300%. When used as a fill material, it tends to cause consolidation settlement and slope failure, and is therefore difficult to handle. When such a soil is involved, the cost of earthwork construction increases considerably.

In view of this, location of the road in this project has been made in such a way that traversing over peat soil area is avoided as much as possible. Fig. 5-3 illustrates the distribution of area topped with over three meters depth of poor soil which consists of 35% or more of organic matter.

In order to obtain scientific information on the soil conditions at the project site, and the quality of available fill and roadbed materials, laboratory tests on soil samples have been conducted both for Phase I and Phase II of this study.

Fig. 5-4 illustrates the distribution of bore holes from which soil was sampled, 8 in Phase I and 3 in Phase II.

Fig. 5-3 MAP OF SWAMP AREA

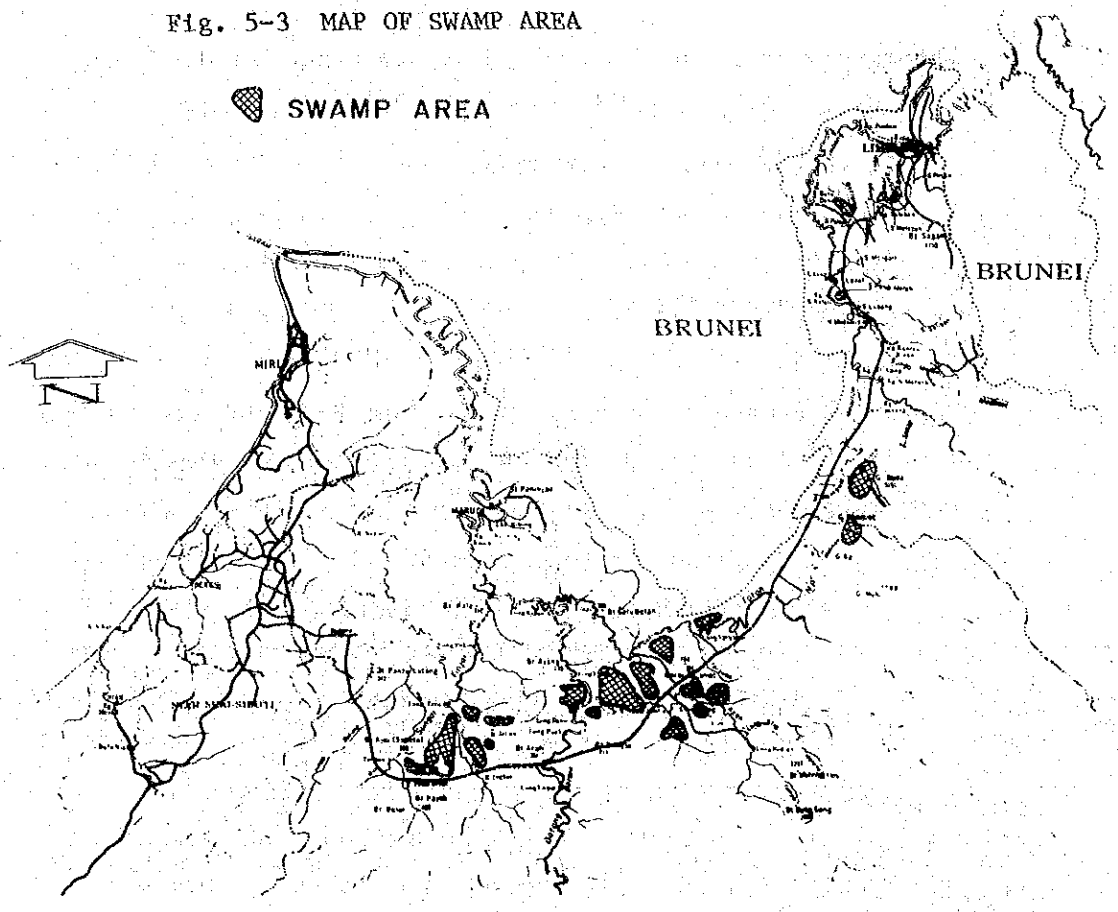
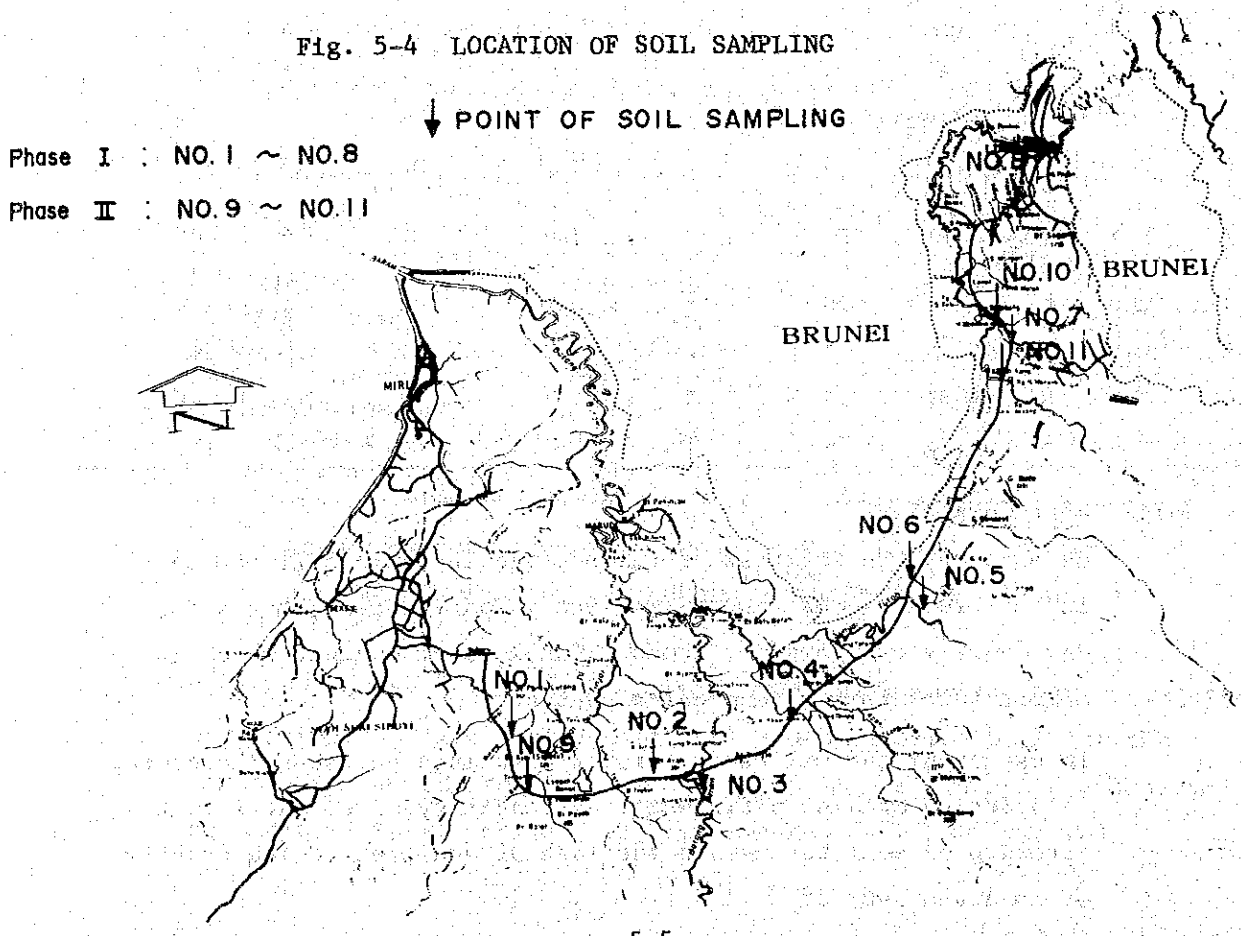


Fig. 5-4 LOCATION OF SOIL SAMPLING



Laboratory tests were performed by the Central Material Laboratory of P.W.D.. These tests included the following items:

1. Natural moisture content
2. Grain-size Analysis
3. Compaction
4. Atterberg limits
5. CBR

Table 5-2 presents the results obtained from the above tests, and Table 7-13 shows the design CBR value determined on the basis of this information.

Table 5-2 Summary of Soil Test Results

Sample Spot	Natural Moisture Content %	Soil Type	Atterberg Limits			Specific Gravity	Compaction			C.B.R.
			Liquid Limit %	Plastic Limit %	Plasticity Index %		Optimum Moisture Content %	Max. Dry Density g/cm³	Max. Dry Density lb/ft³	
1	23.5	CI	38	23	15	2.65	13	1.87	117	3
2	32.0	OI & MI to CI	47	30	17	2.65	14	1.81	113	3
3	28.5	CI	44	22	22	2.63	14	1.82	114	3
4	33.5	CI	43	24	19	2.64	17	1.78	111	7
5	9.0		--- N.P. ---			2.65	-	-	-	-
6	39.0	CI to OI & MI	42	25	17	2.65	18	1.76	110	4
7	35.5	OH & MH to CH	67	34	33	2.64	21	1.63	102	4
8	29.0	CH	56	28	28	2.67	16	1.81	113	2
9	33.0	MI & OI	40	29	11	2.62	19	1.62	101	5
10	19.0	MI & OI	39	28	11	2.66	17	1.65	103	2
11	28.0	ML & OL	31	24	7	2.63	16	1.80	112	16

5-1-2 Earthwork Plan

As shown by the soil test results given in Table 5-2, the soil in the project area ranges from Sandy loam to clay, has a max. dry density of 1.6 g/m³, and a natural water content which is almost twice the optimum water content.

In executing the earthwork, proper care must be taken, therefore, in order to obtain sufficient trafficability, i.e. sufficient strength of soil to sustain the load of equipment which travels or is drawn over it.

Since rainfall is abundant in the project area, proper drainage of storm water is also important because it has a strong effect on the operation rate of the equipment.

Since the planned road will be constructed on voluminous cut to embankment, the earthwork cost involved in this project is high. In order to cut down the construction cost and time requirements, the earthwork should basically be executed by means of heavy equipment.

1) Embankment

Embankment fill can become unstable due to several factors such as susceptibility to the influence of water, causing settlement and slope failure. It is therefore important that the fill material selected and the method of work be carefully chosen before executing the embankment fill construction.

The annual rainfall in the project area amounts to 3,500 ∿ 4,000 mm, or 140 ∿ 160 inch. In selecting the earthwork equipment, its trafficability under such climate conditions should be carefully considered. Special requirements for the execution of large scale earthwork under such conditions should also be studied.

Table 5-3 Types of Earthwork Equipment, Suitable Distance of Transport and Cone Index Required

Equipment	Suitable distance of soil transport	Cone index (kg/cm^2) qc
Bulldozer	Under 100 m	2 ∿ 7
Scraperdozer	50 ∿ 500 m	4 ∿ 6
Tractor Scraper	70 ∿ 500 m	7
Motor Scraper	200 ∿ 2,000 m	10
Shovel-type Excavater and Dump truck	Over 70m	12

Note: Cone index required for the operation of bulldozer and scraperdozer varies according to the type of machine.

Based on the data in Table 5-3 which indicates the Cone Index required and the appropriate distance of soil transportation work for the reasonable use of each type of equipment, the earthwork machines to be employed in the project are recommended to be as follows:

Distance of conveyance	Conveyor
Short distance	Bulldozer
Medium distance	Bulldozer with tractor scraper
Long distance	Shovel type excavater with dump truck

Proper control of work performance is an essential requirement in order to obtain sufficient strength of the embankment. The following are examples of acceptable parameters for earthwork control.

(1) Dry density

Proportion of the dry density of the compacted soil to the maximum dry density of the standard compaction test is determined and used as a parameter.

(2) Degree of saturation or air void ratio

Proportion of the air to the water which occupy the voids in the filled material is used for controlling the compaction of cohesive soil.

(3) Characteristics of material strength

Indicaters of the characteristics of strength and deformation of the compacted soil, such as the result of penetration test, the field CBR value, the deflection under proof-rolling etc. are used as parameters in earthwork control.

Since this project covers a site of approximately 240 km in length, a variety of soil conditions will most likely be involved. An appropriate method of fill work control should therefore be selected case by case in accordance with the site conditions encountered.

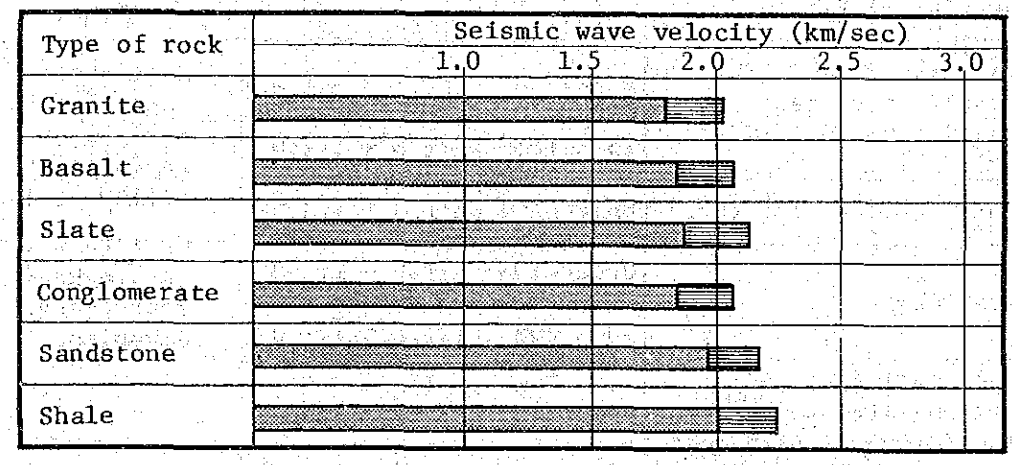
2) Cut

Cut area refers to the excavated area between the existing ground level and the subgrade. The cut areas in this project consist mostly of soft rock, according to the monthly reports of a neighbouring road construction project (Beluru-Long Teru Road Project by MRCU-10, 1975, 1978) having a similar topographical feature, and "Soil map of Malaysia, Timor 1968". The seismic wave velocity tests were conducted in phase II of the study at three locations along

the Miri-Bintulu Road. The average of velocities obtained from the above test was 1,000m/sec.

Based on geological consideration, the use of a 32 ton bulldozer and ripper method is recommended for the execution of earthwork for cut areas in this project. The scope of application of a 32 ton bulldozer in ripper excavation is shown in Fig. 5-5.

Fig. 5-5 Scope of Application of a 32 ton Bulldozer in Ripper Excavation



--- Bulldozer applicable in ripper method

--- Bulldozer applied in other methods

Source: "Road Construction Earthwork Handbook", Japanese Road Association

3) Side Slope Construction

The maximum gradient for side slopes currently accepted by the Sarawak P.W.D. is as follows:

(1)	For fill area:	1:1.5
(2)	For cut area:	Stepped side slope W=1.22 m, H=1.22 m

In this project, side slopes for fill area should be constructed in accordance with the above criteria, taking the following factors into consideration:

- The local climate condition which is characterized by heavy precipitation
- Quality of the fill material

- Height of the fill embankment

Table 5-4 presents the standard gradient of side slopes in Japan in relation to the fill material and height of fill. The practice of construction stepped side slopes is well suited for the local rainy climate and should also be followed in this project.

Table 5-4 Standard Side Slope Gradient for Various Materials and Depths of Fill

Material of Fill	Depth of Fill	Standard Gradient	Remark
Well graded sand (SW), gravel/mix of sand and gravel (GM) (GC) (GW) (GP)	Under 5m	1:1.5 ∿ 1:1.8	° Data apply to cases where the foundation soil is strong and free from the possibility of inundation. ° Classifications given in brackets are representative examples.
	5 ∿ 15m	1:1.8 ∿ 1:2.0	
Poorly graded sand (SP)	Under 10m	1:1.8 ∿ 1:2.0	
Rock Debris	Under 10m	1:1.5 ∿ 1:1.8	
	10 ∿ 20m	1:1.8 ∿ 1:2.0	
Sandy Soil (SM) (SC) hard cohesive soil, hard clay (diluvial hard cohesive soil, clay, Kanto-loam, etc.)	Under 5m	1:1.5 ∿ 1:1.8	
	5 ∿ 10m	1:1.8 ∿ 1:2.0	
Soft cohesive soil (VH)	Under 5m	1:1.8 ∿ 1:2.0	

Inspections of the side slopes were made as part of the reconnaissance study of the existing Miri-Bintulu Road, conducted in March 1979. During these inspections, it was observed that the conditions of natural vegetation on the side slopes varied extensively depending on the terrain and the quality of soil, and that there were cases of erosion of the side slopes where the vegetation is poor.

It is recommended, therefore, that a study be made regarding the proper technique for side slope protection.

5-1-3 Subsurface Exploration for Bridge Foundation

Subsurface explorations which include the following items have been conducted at the locations indicated in Table 5-5 and Fig. 5-6 for the design of bridge foundations.

Field work

Standard Mackintosh Probe Test

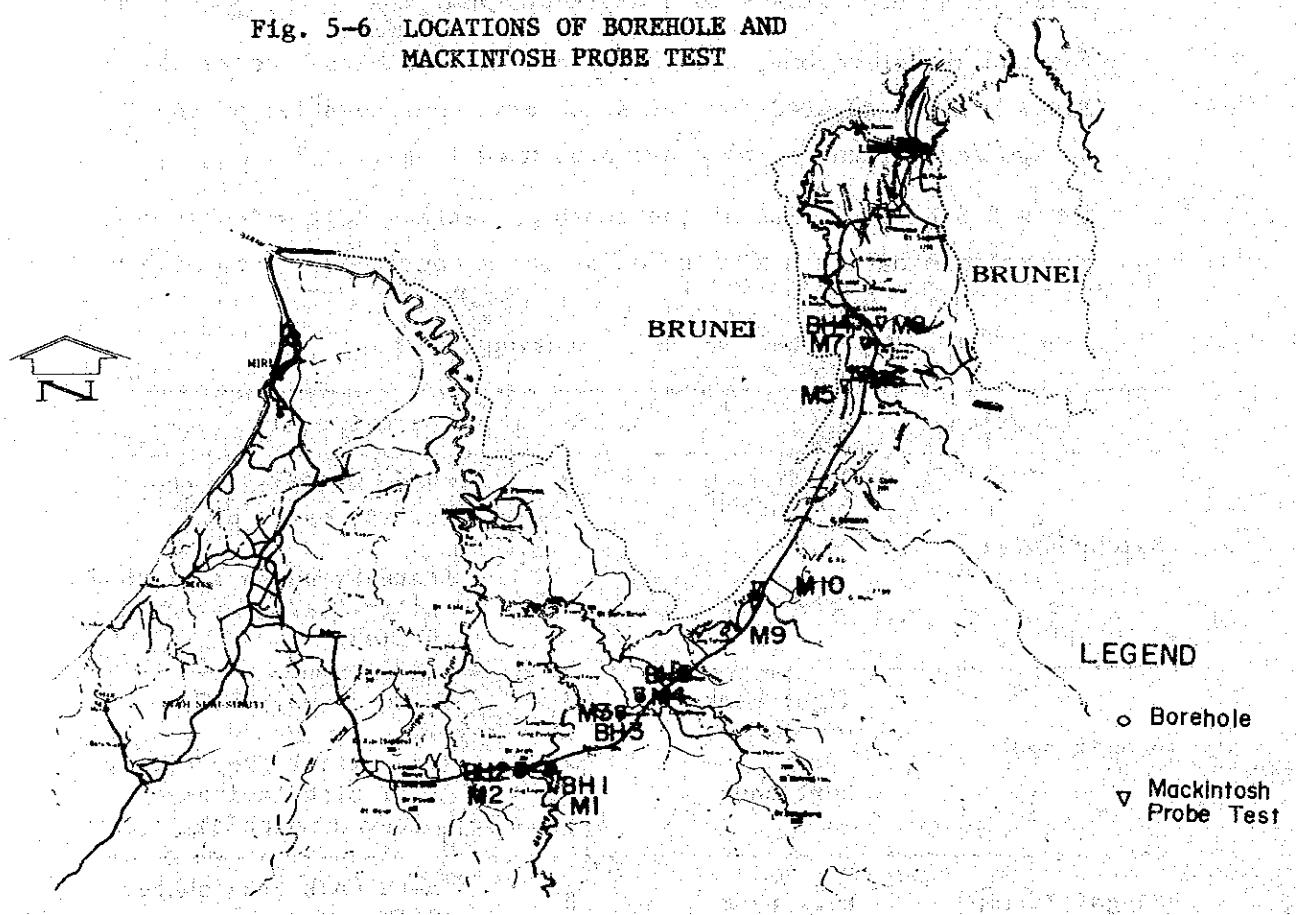
Machine Boring

Standard Penetration Test with Split-Barrel Sampling

Table 5-5 Locations of Subsurface Exploration for Bridge Foundations

Location		Number	
		Standard Mackingtosh Probe Test	Machine Boring and SPT
Batang	Baram	2	2
Sungai	Apoh	2	2
Sungai	Tutoh	2	-
Sungai	Medamit	2	1
Sungai	Limbang	2	-
Total		10	5

Fig. 5-6 LOCATIONS OF BOREHOLE AND MACKINTOSH PROBE TEST



Laboratory testing

Specific gravity

In-situ moisture content

grain-size enalysis

Atterberg limits

The Standard Mackintosh Probe Test is widely practiced in Malaysia. Such a test, however, does not seem to yield reliable results. The Mackintosh Probe Test, Machine Borings and Standard Penetration Test were all conducted at Batang Baram. The results of the Mackintosh Probe Test revealed the existence of a sufficiently strong bearing stratum at 6 m depth with a bearing capacity of 43.7 t/m^2, which was obtained from the blow numbers of above 100.

The test bore holes, in contrast, indicated that the soil at 6 m depth is a very soft grey sandy, clayey silt having an N value of 2. The bearing stratum, in fact, is a very stiff dark grey clayey, sandy silt which exists to a depth of 29 m.

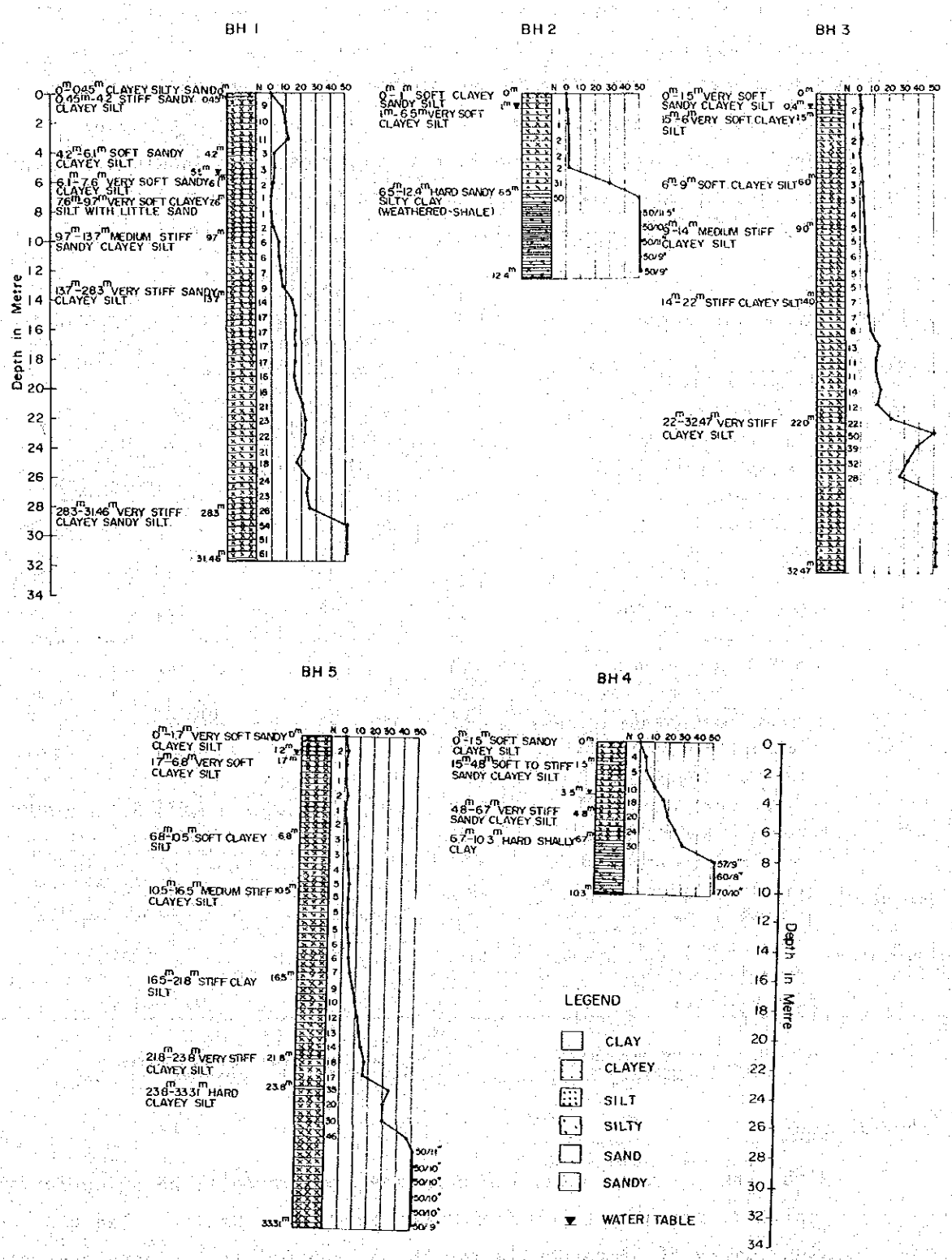
For the above reasons, bore hole data and Standard Penetration Tests will be adopted for the structural consideration of the bridge foundations. These are presented in Fig. 5-7.

Table 5-6 gives a list of the depth of bearing soil which is defined here as one having a N value of 50 for a continuous depth of 5 m.

Table 5-6 Depth of Bearing Stratum

Location		Depth (m)	Description
Batang Baram	Right bank	29	Very stiff dark grey clayey sandy SILT
	Left bank	7	Hard brownish grey sandy silty CLAY (weathered shale)
Sungai Apoh	Right bank	28	Hard clayey SILT
	Left bank	27	Very stiff grey clayey SILT with laminated decayed material
Sungai Medamit	Left bank	8	Hard dark gray shaley CLAY

Fig. 5-7 SOIL PROFIL



5-2 Construction Materials

Since the rocks existing around the project area are geologically young, it is difficult to obtain aggregate of good quality. The quarry sites in the project area are shown in Fig. 5-8. The existing quarries and other potential sources of aggregates in and around the project site produce lime stone or gravel. These types of material are suitable for use in the road pavement, judging from the test results, which was conducted by the P.W.D. conforming to the requirements of British Standards, as shown in Table 5-7.

Table 5-7 Physical Properties of Local Aggregates in Sarawak

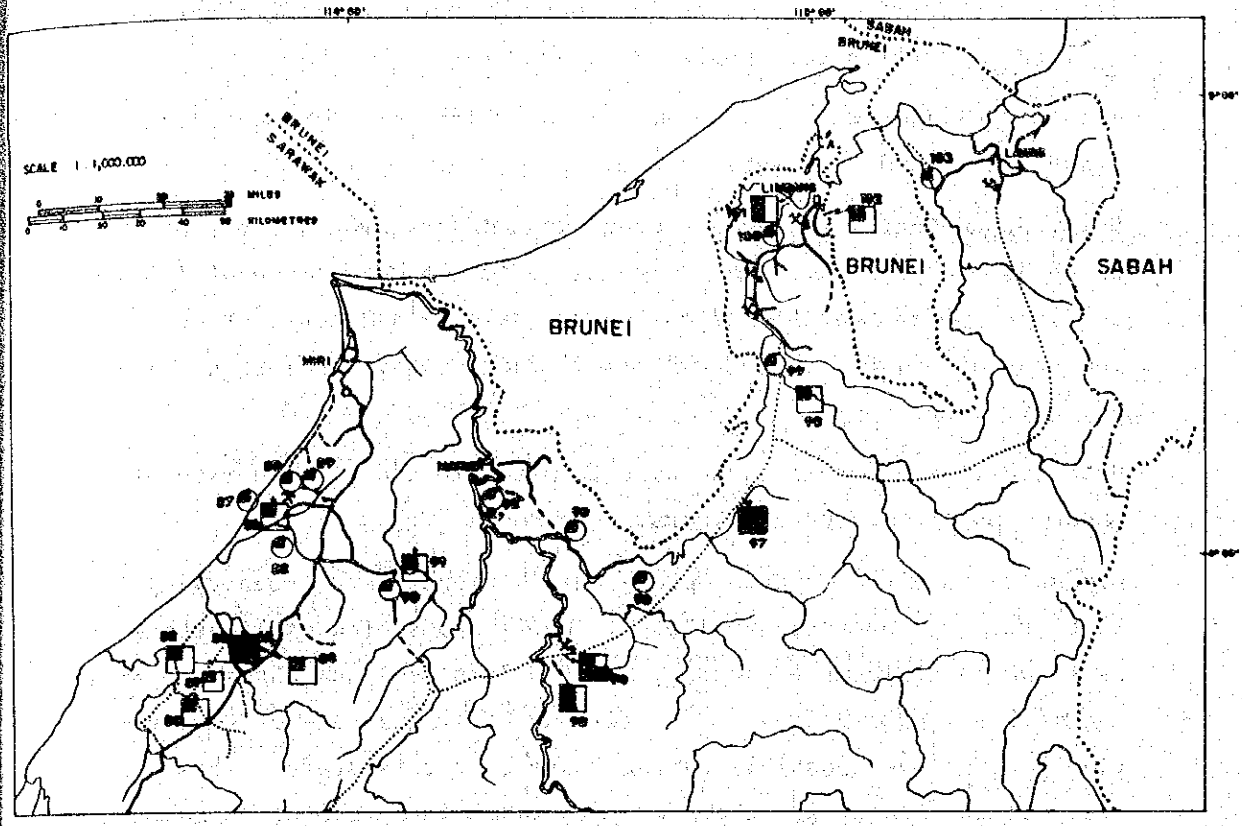
Division	Quarry Site	A.I.V.	Mod. A.I.V.	A.C.V.	L.A. Abrasion	S.G.	Water Absorption	Government or Private
1st	Stabar Quarry	23%	24%	22%	18%	2.50	1.9%	Government
"	Sinibong Quarry	17	18	19	-	2.65	2.8	Government
"	M38 Kuching/Serian	12	14	16	14	2.72	0.48	Government
2nd	Sebuyan Quarry	30	-	27	35	2.70	0.4	Government
"	Abok Quarry	17	26	19	20	2.68	1.6	Government
"	Lachau Quarry	18	19	19	18	2.66	1.25	Government
"	Marup Quarry	25	29	22	24	2.68	1.0	Government
"	Kalambi Quarry	25	29	22	24	2.68	0.5	Government
4th	M22 Bintulu/Miri Road	21	25	18	18	2.67	1.2	Government
"	Batu Niah	27	29	26	29	2.65	2.31	Government
"	Batu Gading	24	-	25	-	2.68	0.6	Private
5th	Ukong Gravel	31	33	30	-	2.43	1.4	Government
"	Lubai Tengah Gravel	43	46	40	-	2.62	1.7	Government
"	Berawan/Nanga Medamit Gravel	30	32	28	-	2.64	1.23	Government
"	Lawas/Damit Gravel	32	33	27	49	2.65	2.34	Government
"	Bukit Kubang Gravel	48	50	39	83	2.54	1.8	Government
"	Pandaruan Gravel	36	42	-	-	2.65	2.04	Government
Suitability for Construction	for concreting aggregate	max.45	-	-	-	-	-	
	for structural concrete	max.30	-	-	-	-	-	
	for road stone	-	max.40	-	-	-	-	
	for road surfacing	-	-	max.35	-	-	max.2	
	for road construction	-	-	-	max.50	-	-	
	for road bases	-	-	-	-	-	max.4	

Note: 1) A.I.V. – Aggregate Impact Value
2) Mod. A.I.V. – Modified Aggregate Impact Value
3) A.C.V. – Aggregate Crushing Value
4) L.A. Abrasion – Los Angeles Abrasion
5) S.G. – Specific Gravity

5-2-1 Quarry

Within the project area, two quarries are currently being operated activity, one at Batu Niah and the other, Batu Gading. The Batu Niah quarry of limestone is run by the P.W.D. It produces a crusher run of 75 mm (3 inches) in maximum size at the rate of 10,000 ∿

Fig. 5-8 QUARRY SITES OF THE PROJECT AREA



Rock Type	Quality	Quantity
Limestone	Average	Million Cubic Yards
Gravel & Limestone	Poor	>10
		5 - 10
		1 - 5
		<1

Average - means rock may be suitable for use in road base course and surfacing, and as concrete aggregates and blockstones for load bearing structural uses in minor engineering works.

Poor - means rock may be suitable for use as road fill, in road sub-base course and possibly base course.

Existing Quarry Sites

Government Quarries

(4th Div.)

✱ 7 Marudi Quarry
✱ 1 Niah Quarry (M.65 M/8 Rd.)

(5th Div.)

✱ 6 Lawas/Damit Rd. (M.5-1/2) River Gravel
✱ 3 Lubai Tengah
✱ 4 Ukong Quarry
✱ 5 M.15 Berawan/Nanga Medamit Rd.

Private Quarries

(4th Div.)

✱ 2 Holly Stone Quarry
84 Kong Thai Sawhill

Potential Quarry Sites

80. Sungai Kurong, Niah
81. Sungai Lembong, Suai Area
82. Sungai Semilau, Yong Choon Jin Quarry Niah
83. Gunung Subis (National Park)
84. Kong Thai Sawmill (Miri) Sdn. Bhd.
85. Bulak Setap, Sibuti
86. Trusan Limestone, Miri
87. Tanjong Batu, Miri
88. Seraya Limestone, Miri
89. Kedulit Sandstone, Miri
90. Beluru Sandstone
91. Beluru Limestone
92. Lubok Nibong, Marudi
93. Bukit Betok, Marudi
94. Bukit Besungai, Marudi
95. Tutoh Valley
96. Temasok, Limbang
97. Melinau Limestone, Limbang
98. Selidong and Keramit Limestone, Limbang
99. Middle Limbang Valley
100. Tempas Hill, Limbang
101. Bukit Gadong Laul, Limbang
102. Panduran, Limbang
103. Trusan River, Limbang

Note: ✱ Existing Quarry
+ Abandoned Quarry
* Indicates Possible Use of Rock

16,000 ton/month, and is expected to be able to maintain the current rate of production for another 20 years.

The Batu Grading quarry is operated by two private firms, Holly Stone Quarry and Sharikat Betoh Quarry.

Holly Stone Quarry produces eleven types of aggregate sizes, of which 300 mm size (12 inches) is the maximum, at the rate of 120,000 ton/year, while Sharikat Betoh Quarry deals with 3 types of one at the rate of 30,000 ton/year, 25 mm (1 inch) being the largest size of their product.

Both quarries are said to be able to maintain the current rate of production for another 20 years.

Limestone is also found in Gunong Mulu National Park. Quarrying in this area is, however, prohibited. While deposition of limestone is known in Selidong & Karamit, Bukit Gadons Laul and Pandaruan area, a complete investigation for confirming their quantity of reservation has not been possible during Phase I of this study. These areas at the moment are therefore not taken into account as sources of aggregate supply for this project.

5-2-2 Gravel

Gravel is distributed in a formation of terrace or river-bed Sediment.

1) Terrace Sediment

The Terrace Sediment was formed in the Quarternary, and is distributed as shown in Fig. 5-8. There are 3 gravel pits operating on Limbang side, at Lubai Tengah, Ukong Quarry and M15 Berawan Nanga Medamit Rd. respectively. Although it has been confirmed in the Phase II investigation that the reserves at the Ukong Pit have almost been exhausted, a new source of gravel has been discovered near Ukong by the Limbang P.W.d., and production can begin at assuming that compensation problems are settled with the inhabitants of the area. Based on a field reconnaissance, this area has been assumed to be the source of gravel supply for the plans of this project.

Gravel produced from all the above pits can be used as sub-base material, without sieving, and with the exception of that of Lubai

Tengah, can also be used for surfacing courses.

Gravel is anticipated to be available for this project also from Temasok and Middle Limbang Valley, as a terrace sediment. This source must still be investigated.

2) River-bed Sediment

Rivers in the project area are generally gentley flowing, thus favoring the deposition of gravel in them. Rivers which can be considered as producers of gravel include Sungai Tutoh, Sungai Melinau, Sungai Medaiam, and Sungai Limbang, all of which are close to the mountain sides.

As a result of material tests in the Phase II study, it was found that Sungai Tutoh and Sungai Limbang are qualified to be gravel suppliers for this project, both qualitatively and quantitatively. They have been considered in the material supply plan for this project. The estimated quantity of reserves of gravel on these rivers are as follows:

Sungai Tutoh	900,000 m^3
Sungai Limbang	200,000 m^3

5-2-3 Aggregate Supply and Use

The quantity of aggregate required for this project amounts to approximately 1 million m^3, including sub-base material, surfacing material and concrete aggregates.

Most of this requirement will be acquired from the products from Batu Niah, Batu Gading and near Ukong.

For the construction sites near the border of the 4th and 5th Divisions, aggregates will be supplied from Sungai Tutoh as these sites are located far away from Ukong and Batu Gading from which smooth delivery of large quantities of aggregates would be difficult due to the climate and topographical conditions.

Other methods to be considered for supplying the construction sites on Limbang end include procurement from Kuching. This is not practical, however, taking into consideration the cost of transportation required to cover the distance of 700 km between Kuching and Limbang, and also the large quantity required, which cannot be

easily catered, even though the market price of aggregate is cheap in Kuching, (being around M$ 6 ∿ 11 per m^3).

Table 5-8 shows the prices of aggregates and places of production around the border of 4th and 5th Divisions.

Table 5-8 Price of Aggregates by Source (per $1m^3$)

Source	Distance * transported (km)	Net Unit Price (M$)	Transport Cost (M$)	Aggregate Price (M$)
Batu Gading	60	22.1	12.0	34.1
Kuching	780	8.5	48.6	57.1
Sg. Tutoh	16	13.0	3.2	16.2

Fig. 5-8 and Table 5-7 presents the quality and quantity of aggregate reserves for each place of production.

As shown in Table 5-9, the quality of gravel from Sungai Tutoh and Sungai Limbang satisfies the usable requirement for road pavement and concrete aggregates, according to the test results of the P.W.D. Central Material Laboratory.

Table 5-9 Aggregate Tests on River Gravel

Items	Sg. Tutoh	Sg. Limbang	Suitability for Construction		
			Concrete Structure	Surface Course	Base Course
Los Angeles abrasion value (%)	24	28	-	Max. 50	Max. 50
Water absorption (%)	1.3	1.5	-	Max. 2.0	Max. 4.0
Aggregate impact value (%)	19	24	Max. 30	Max. 40	Max. 40

Table 5-10 shows a recommended scheme for material supply from each place of production with respect to construction site delivery and proposed use.

Table 5-10 Supply, Allocation and Use of Aggregate

Quarry	Construction Section Supplied		Use	Estimated Quantity Required (1,000m³)
Batu Niah	1, 2	Miri-Bintulu Road ∿ Beluru ∿ Sg. Tinjar	Base Course	201
Batu Gading	3, 4	Sg. Tinjar ∿ B. Baram ∿ Sg. Apoh ∿ Sg. Tutoh	Base course Surface course Concrete structure	236
Sg. Tutoh	5, 6	Sg. Tutoh ∿ Sg. Medalam	Base course Surface course Concrete structure	280
Near Ukong and Sg.Limbang	7, 8	Sg.Medalam ∿ Ng.Medamit ∿ Ukong ∿ Limbang	Base course Surface course Concrete structure	282

* Note: "Distance Transported" indicates the distance between the source of aggregate and the construction site at the border of the 4th and 5th Divisions.

The construction site of Miri-Bintulu Road ∿ Beluru ∿ Sungai Tinjar are to be supplied from Batu Gading for surfacing courses and structural concrete aggregates, since the aggregate from Batu Niah is not suitable for such purposes.

For the production of aggregates at the quarry, the use of a crusher plant of 150 ton per hour capacity is recommended. Crushed aggregate should be regularly produced, stored and always ready to be transported to the construction site.

For the excavation of gravel at Sungai Tutoh, and Sungai Limbang the following alternatives means should be considered.

a) Dragline
b) Bulldozer
c) Dredger

Of the above three alternatives, a) and b) have the advantages of easy access to the site, and having a low cost. However, these

are not suitable in this case because of their small capacity which cannot comply with the large demand of the project.

As for the remaining alternative c), even though it has the disadvantage of being more costly to procure, and provides difficult access to the site, its capability of continuous operation and capacity of production justify the preference of it over the others.

It is therefore recommended that a dredger be installed for gravel excavation at Sungai Tutoh and Sungai Limbang.