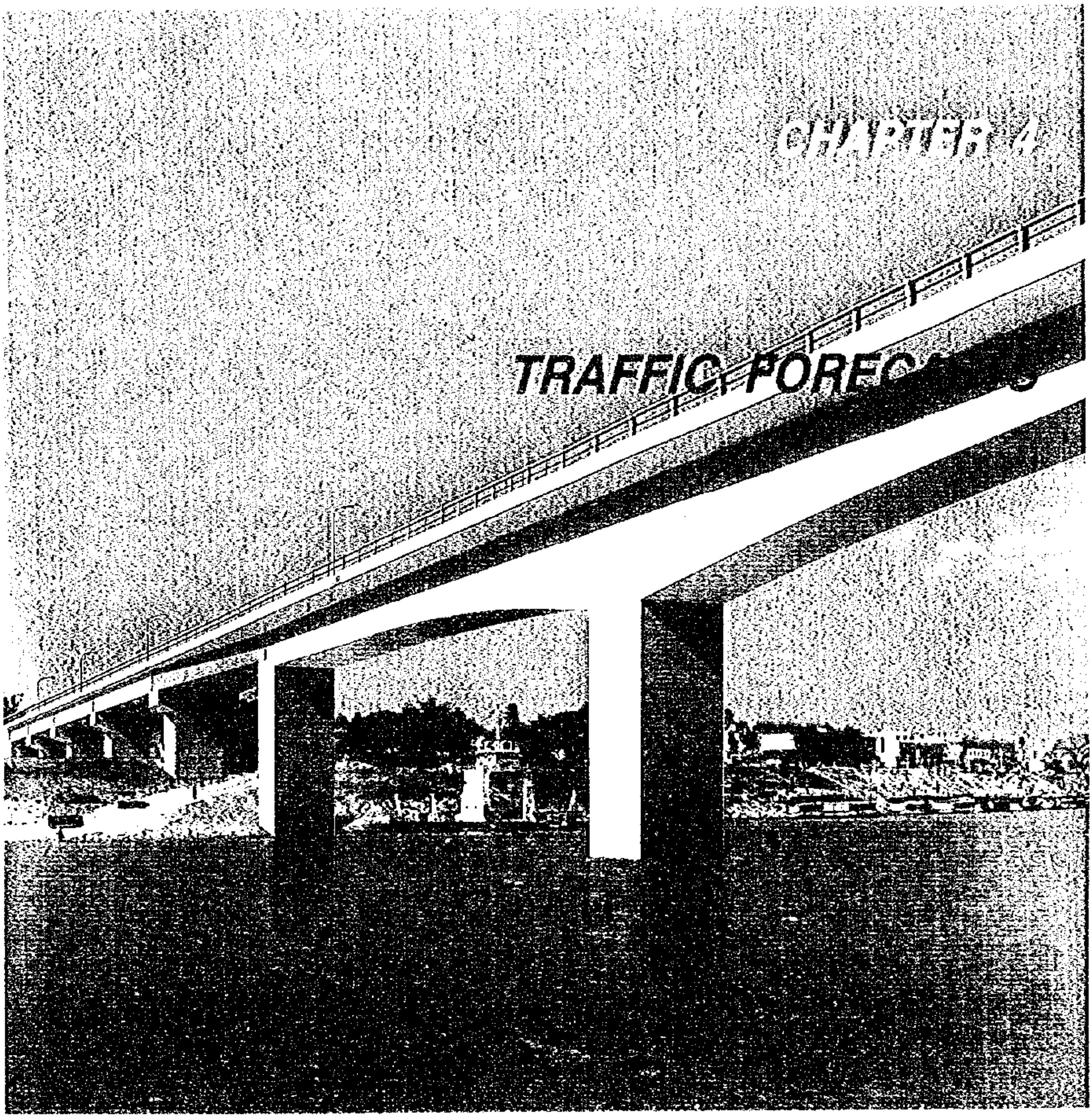
CHAPTER 4
TRAFFIC FOREC

CHAPTER 4 TRAFFIC FORECASTS

4.1 Traffic Study

This section summarizes the results of traffic count surveys, origin-destination interview surveys, and ferry waiting time surveys performed for this study. A brief description of river transport is also presented.

4.1.1 Road Traffic

(1) Data Sources

The most useful data source regarding road traffic is the Cambodia Transport Rehabilitation Study (TRS) sponsored by the Asian Development Bank. The Cambodia TRS was conducted in 1994, and it provides information pertaining to an origin-destination survey carried out at 6 sites in February and March 1994 (one of which was at the Neak Loeung Ferry), and 1993 traffic counts conducted by the MPWT at 40 sites throughout Cambodia as part of the JICA Chroy Chongvar Bridge Reconstruction Study. These data are compared to the traffic survey results of this study at the appropriate sections in this chapter.

(2) Existing Ferry Services

The two main ferries crossing the Mekong River are the Neak Loeung and Kompong Cham ferries owned and operated by the MPWT. The Neak Loeung Ferry operates three boats, the largest of which can accommodate about 30 cars and trucks or 180 tons. The medium-sized ferry can transport about 20 cars and trucks or 120 tons, and the smallest ferry can hold about 10 cars and trucks or 60 tons. During peak periods, all three boats are in operation; however, throughout most of the day only two boats are utilized.

The Kompong Cham Ferry operates two boats, the largest of which can accommodate about 10 cars and trucks or 60 tons, similar to the smallest of the three boats at Neak Loeung. The second boat is actually a barge pushed by a tugboat, and it can handle only about 5-6 cars and trucks or 40 tons.

The Neak Loeung and Kompong Cham ferries can easily accommodate heavy trucks, while the privately operated Svay Chrum and Prek Tamak ferries can only transport relatively light vehicles and a maximum of two sedans or pickups per boat. The Svay Chrum Ferry has three boats; however, usually only one is utilized throughout the day. The Prek Tamak Ferry operates two boats. The privately operated Kompong Cham Ferry has two boats, and it can only transport pedestrians, bicycles, and motorcycles. There are an additional 29 private ferries operating in Kandal and Kompong Cham provinces; however, these ferries are limited in capacity like the private Kompong Cham Ferry and are not capable of safely transporting vehicles other than bicycles and motorcycles.

(3) Traffic Volumes

Traffic counts were conducted for this study at 17 locations in the Study Area from 30 April to 14 May 1995, including the Neak Loeung Ferry, Svay Chrum Ferry, Prek Tamak Ferry, two Kompong Cham ferries (one private, one public), and Routes 1, 6A, 7, 11, 151, and 315; each location was surveyed for a seven day period, 12 hours per day (i.e., 06:00-18:00), with volumes recorded at hourly intervals for 13 different vehicle types. Three teams were employed: one based in Neak Loeung comprising ferry staff, one based in Phnom Penh consisting of MPWT staff, and a third based in Kompong Cham made up of staff from the Kompong Cham Provincial Department of Public Works. A total of 112 person-weeks (784 person-days) was required to conduct these traffic count (and simultaneous origin-destination interview) surveys.

The survey locations are shown in Figure 4.1, and traffic count results are summarized in terms of vehicular ADT and average daily PCUs in Figure 4.2. The highest vehicular traffic volumes were observed along Routes 1, 6A, and 7, with vehicular ADT volumes of 4,870, 5,440, and 4,420, respectively. Detailed traffic count results are presented in Appendix 4.1, and example survey forms are included in Appendix 4.5.

Traffic count results for the Neak Loeung, Svay Chrum, Prek Tamak, and Kompong Cham ferries are summarized in Figure 4.3 and presented in some detail in Table 4.1.[1] Traffic is highest at Neak Loeung, followed by Kompong Cham, Prek Tamak, and Svay Chum. From this table, it is clear that the majority of vehicular traffic crossing the Mekong River consists of non-motorized vehicles (NMVs) and motorcycles, with 25.2% and 58.8% vehicular traffic shares, respectively. By contrast, sedans, trucks, and minibuses/buses represent 6.4%, 1.9%, and 5.3% of the total vehicular river crossing volumes.

Table 4.2 compares traffic counts results between this study and MPWT counts conducted in 1993 (as reported in the Cambodia TRS) at four locations. The two survey points that are practically at the exact same site in both studies are Location No. 11 (Route 1, 20 km southeast of Phnom Penh) and Location No. 16 (Route 11, 5 km north of Neak Loeung); at both of these sites, traffic volumes of motorcycles, light vehicles, and heavy vehicles have increased. The most significant change between these two locations is a doubling in the number of motorcycles traveling on Route 11 between Neak Loeung and Prey Veng.

According to the other two locations shown in Table 4.2, traffic along Route 7 has increased significantly, probably the result of the rehabilitation of Route 6A. Route 11 north of Prey Veng appears to have experienced a drop in light and heavy vehicle traffic; however, this reduction may be the due to the Route 11 rehabilitation works, including the reconstruction of an impassable bridge,[2] being carried out at the time of the May 1995 survey.

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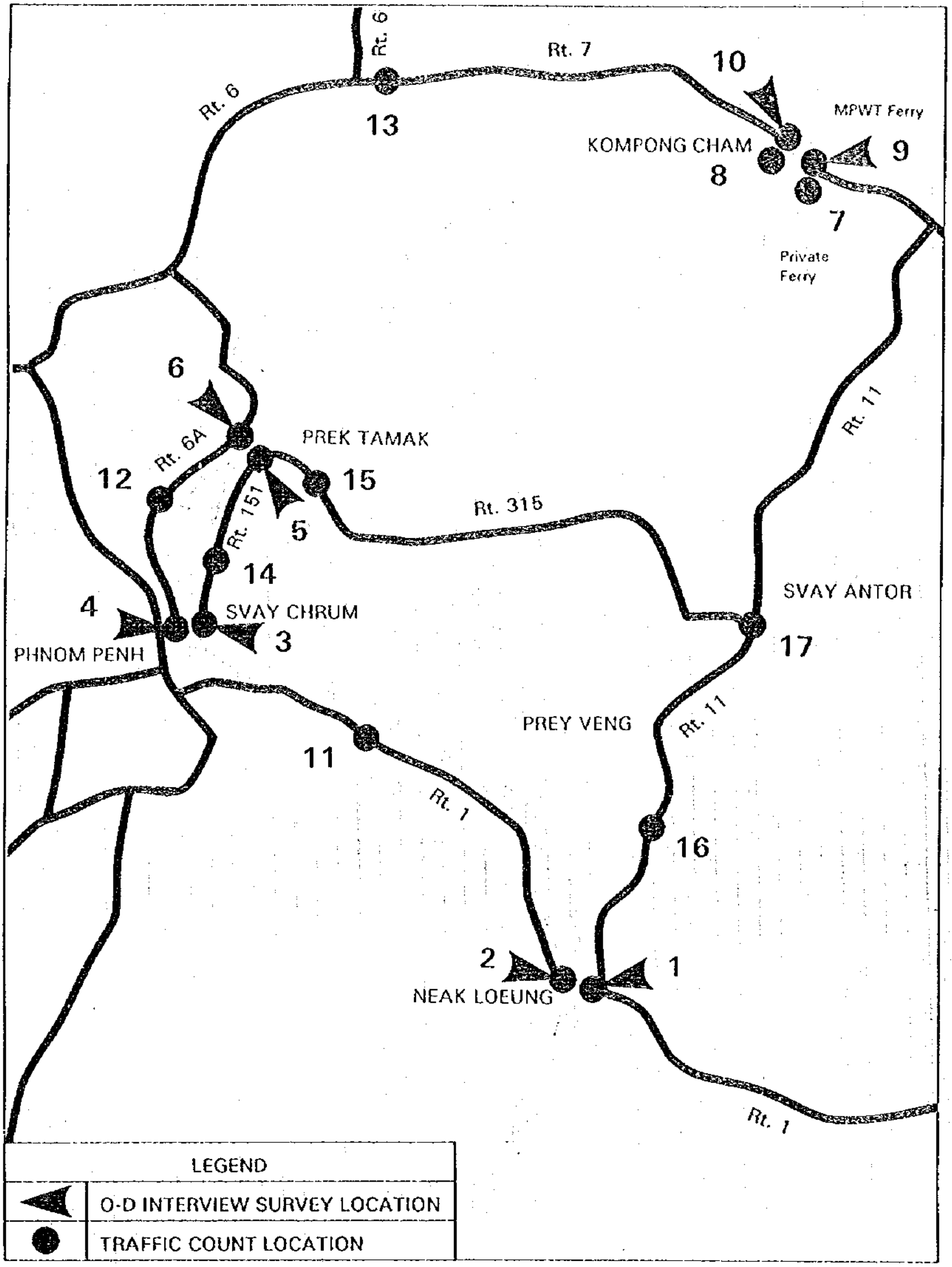
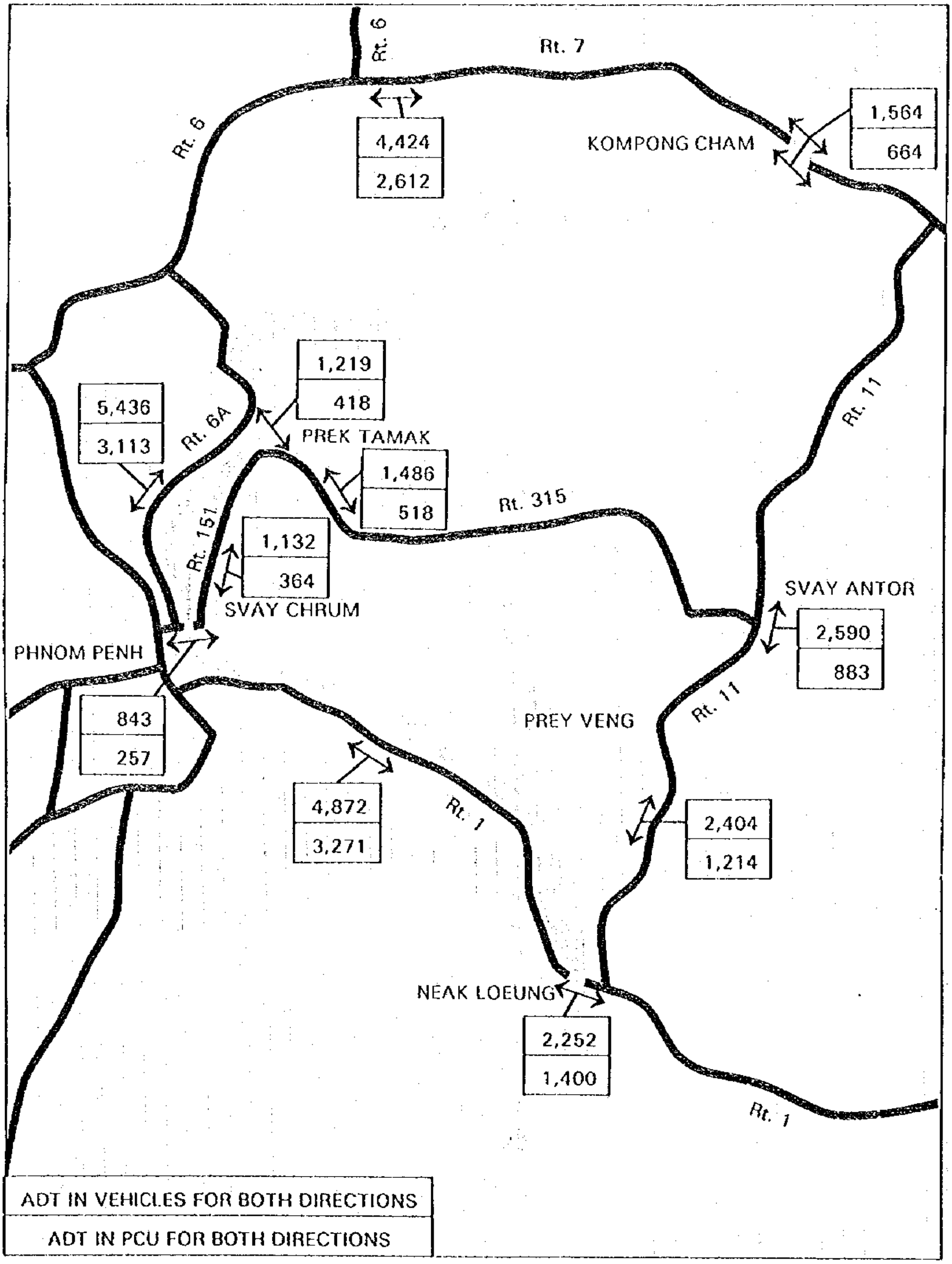
[1] Some volumes may differ slightly from those presented in the Progress Report of July 1995. After further review of the data input work performed in Cambodia, several data entry errors were discovered. These errors have been corrected, and the accurate figures are reflected in this report, including the attached Appendixes.

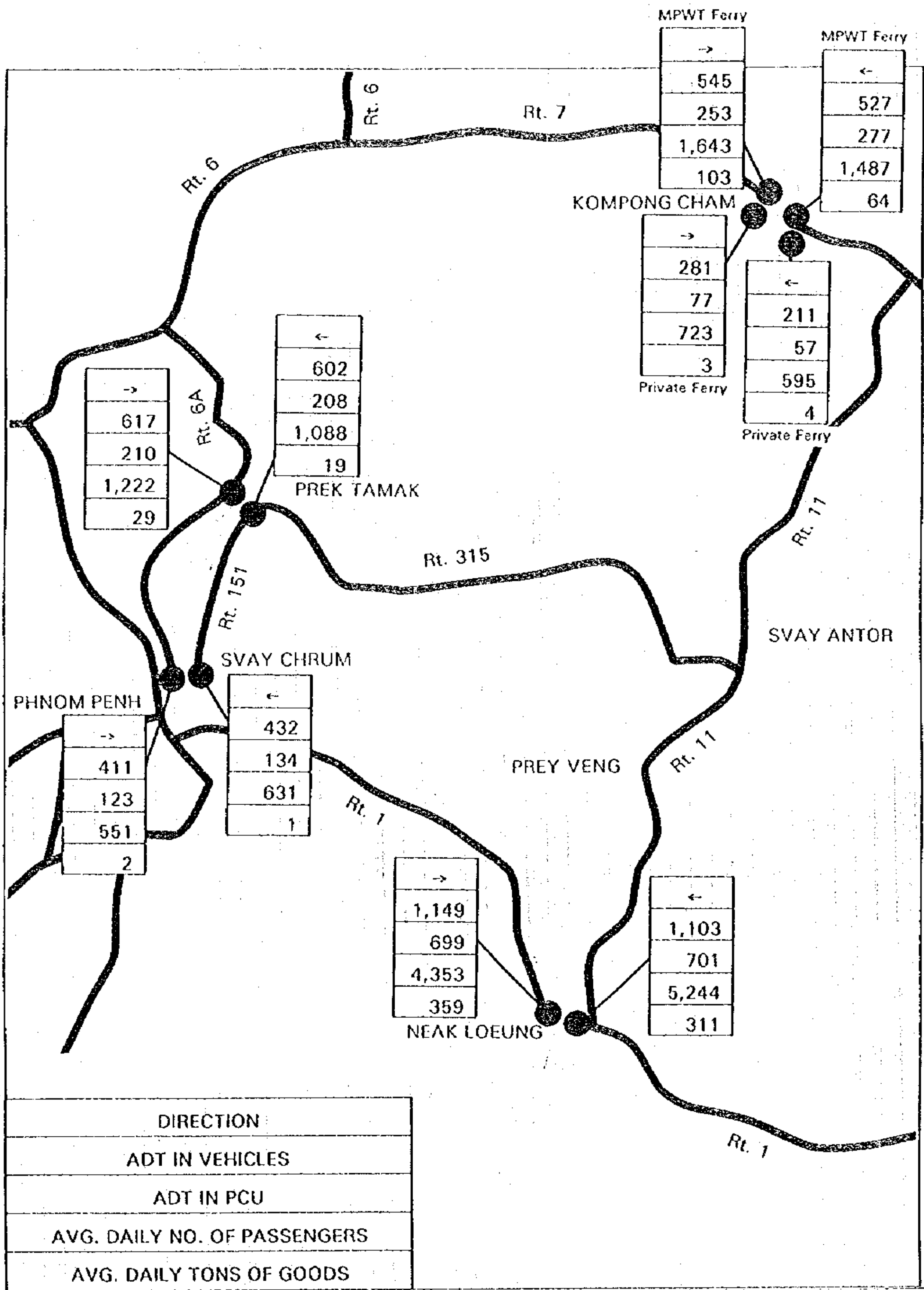
[2] A makeshift laterite diversion road (in very poor condition) was available to bypass this bridge.



THE FEASIBILITY STUDY ON CONSTRUCTION OF THE MEKONG BRIDGE IN KINGDOM OF CAMBODIA	Figure 4.1 Traffic Count and Origin-Destination Interview Survey Locations
	JAPAN INTERNATIONAL COOPERATION AGENCY



THE FEASIBILITY STUDY ON CONSTRUCTION OF THE MEKONG BRIDGE IN KINGDOM OF CAMBODIA	Figure 4.2 Results of Traffic Count Surveys, May 1995 (1)
	JAPAN INTERNATIONAL COOPERATION AGENCY



THE FEASIBILITY STUDY ON CONSTRUCTION OF THE MEKONG BRIDGE IN KINGDOM OF CAMBODIA	Figure 4.3 Results of Traffic Count Surveys, May 1995 (2)
	JAPAN INTERNATIONAL COOPERATION AGENCY

Table 4.1 Traffic Count Survey Results at the Four Mekong River Crossings, Daily Traffic (combined for both directions), May 1995

Travel Mode		Neak Loeung	Svay Chrum	Prek Tamak	Komp. Cham[1]	Total
Pedestrian or Passenger		8,199	11	181	2,747	11,138
Bicycle, Bicycle-with-Trailer, Cyclo		619	135	209	440	1,403
Animal Cart		31	9	15	26	81
Motorcycle		907	688	928	933	3,456
Motorcycle-with-Trailer		9	1	2	1	13
Sedan		285	6	29	59	379
Public Transport Pickup (Minibus)		203	-	11	35	249
Standard Bus		55	2	2	3	62
4WD, Standard Pickup		42	2	17	23	84
2-Axle Truck (Other Than Pickup)		30	-	7	12	49
3-Axle Truck		31	-	-	13	44
3+ Axle Truck		5	-	-	13	18
Military or Police Vehicle		36	-	-	6	42
Total No. of Vehicles		2,252	843	1,219	1,564	5,878
Total No. of MVs (excluding MCs)[2]		696	11	68	165	940
Total No. of PCUs	All vehicle types	1,400	257	418	664	2,739
	Excluding NMVs and MCs	969	12	81	265	1,326

Notes: [1]Includes both the Private and MPWT Kompong Cham ferries.
[2]MVs = motorized vehicles; MCs = motorcycles.

Table 4.2 Comparison of Traffic Count Results between this Study and MPWT Counts Conducted in 1993

Loc. No.	Description	May 1995 Traffic Count Survey Results			MPWT Oct. 1993 Traffic Count Survey Results		
		Vehicle Type			Vehicle Type		
		MC	Light	Heavy	MC	Light	Heavy
11	Route 1; 20 km SE of Phnom Penh	2376	1618	302	2330	1435	223
13	Route 7; 45 km W of Kompong Cham	1657	1219	196	1857	160	76
16	Route 11; 5 km N of Neak Loeung	1481	454	84	775	248	77
17	Route 11; 24 km N of Prey Veng	1142	95	44	1214	220	70

Table 4.3 compares traffic counts between this study and the Cambodia TRS at the Neak Loeung Ferry. Interestingly, the total number of motor vehicles including motorcycles has increased by 4.5%, while the total number of motor vehicles excluding motorcycles has decreased by 4.9%. Perhaps this observation reflects different travel characteristics between the seasons during which the traffic count surveys were undertaken (i.e., May 1995 vs. February/March 1994).

Table 4.3 Comparison of Traffic Counts at the Neak Loeung Ferry

Vehicle Type	May 1995 Traffic Count Survey Results	Cambodia TRS 1994 Traffic Count Survey Results
Motorcycle	907	802
Motorcycle-with-Trailer	9	6
Sedan	285	366
Minibus, 4WD, and Pickup	245	181
Standard Bus	55	88
2-Axle Truck	30	54
3-Axle Truck	31	32
3+ Axle Truck	5	5
Military or Police Vehicle	36	-
Total No. of MVs	1,603	1,534
Total No. of MVs (excluding MCs)	696	732
Total No. of MV PCUs	1,250	1,269

(4) Time Variations

Because traffic counts were recorded at hourly intervals, the traffic distribution by hour by vehicle type can be easily determined.[1] The peak period for westbound traffic at the Neak Loeung Ferry, for example, is 08:00-09:00 with a 14.7% share of vehicular ADT; the peak hour for eastbound traffic is also 08:00-09:00 with a 13.1% share of vehicular traffic. Interestingly, there is basically no afternoon/evening peak period at this location. The Svay Chrum Ferry has very pronounced peak periods in the morning for westbound traffic and in the afternoon for eastbound traffic; this pattern reflects the many commuter trips made at this location. The Prek Tamak and Kompong Cham (MPWT) ferries have relatively high morning peak hour volumes in both directions with flatter evening peaks.

(5) Vehicle Utilization

Vehicle utilization rates, determined from the origin-destination survey results, are shown in Table 4.4 for 10 different vehicle types at the Neak Loeung, Svay Chrum, Prek Tamak, and Kompong Cham (MPWT) ferry crossings. From this table, it is clear that most vehicles have relatively high person/passenger occupancy rates. Consider, for example, that the overall average occupancy is 1.5 persons for motorcycles, 4.5 for sedans, and 6.1 for four-wheel drives (4WDs) and standard pickups. Also, 3-axle and 3+ axle trucks at Neak Loeung tend to be heavily loaded with an average 8.6 and 17.4 tons of goods, respectively, significantly more than truck loads at Kompong Cham. The reason for this discrepancy appears to be that a significant number of empty trucks are hired in Kompong Cham; these empty trucks cross the Mekong River via the Kompong Cham MPWT ferry to the east side of the river where they are subsequently loaded with materials, which the trucks then haul to Svay Rieng and/or Phnom Penh via Route 11.

[1]These data are provided in tabular form in Appendix 4.1.

Table 4.4 Vehicle Utilization Results (from the Origin-Destination Survey), May 1995

Vehicle Type	Neak Loeung	Svay Chrum	Prek Tamak	Kompong Cham	Total
Bicycle, Bicycle-with-Trailer, Cyclo					
no. of observations	518	753	1,151	198	2,620
persons/vehicle	1	1.1	1	1.1	1.1
Animal Cart					
no. of observations	20	4	58	100	182
passengers/vehicle	0	0.5	0.7	0.6	0.5
load, tons/vehicle	0.2	0.1	0.2	0.5	0.4
Motorcycle					
no. of observations	2,232	4,574	5,593	1,751	14,150
/vehicle	1.4	1.4	1.6	1.8	1.5
Sedan					
no. of observations	1,609	59	237	466	2,371
persons/vehicle	4.5	3.6	4.1	4.9	4.5
Public Transport Pickup (Minibus)					
no. of observations	1	0	93	82	176
passengers/vehicle	-	-	12.4	9.5	11.1
Standard Bus					
no. of observations	137	0	14	9	160
passengers/vehicle	12.2	-	16.9	8.7	12.4
load, tons/vehicle	1.7	-	0.6	0.5	1.6
4WD, Standard Pickup					
no. of observations	471	0	15	327	813
persons/vehicle	6.3	-	8.4	5.6	6.1
load, tons/vehicle	0.7	-	1.2	0.6	0.7
2-Axle Truck (Other Than Pickup)					
no. of observations	120	0	1	79	200
passengers/vehicle	6.4	-	-	3	5.1
load, tons/vehicle	2.8	-	-	3.4	3
3-Axle Truck					
no. of observations	168	0	0	24	192
passengers/vehicle	2.3	-	-	1.7	2.2
load, tons/vehicle	8.6	-	-	2.6	7.8
3+ Axle Truck					
no. of observations	32	0	0	37	69
passengers/vehicle	1.5	-	-	2	1.8
load, tons/vehicle	17.4	-	-	2.4	9.3

Note: 1 Public Transport Pickups (Minibuses) at the Neak Loeung Ferry may have been miscoded by the surveyors as Standard Pickups.

2 The relatively low loaded shown for 3-axle and 3+ axles trucks at the Kompong Cham Ferry have been verified with an additional small-scale survey.

Table 4.5 compares vehicle utilization results between this study and the Cambodia TRS at the Neak Loeung Ferry. In all cases, the observed number of passengers and tons per vehicle by vehicle type are very similar between the two studies. From these data, it is evident that average truck loads for 3- and 3+ axle trucks have increased while their passenger occupancies have decreased.

Table 4.5 Comparison of Vehicle Utilization Results at the Neak Loeung Ferry

Vehicle Type	May 1995 O-D Survey Results	Cambodia TRS1994 O-D Survey Results
Motorcycle		
no. of observations	2,232	400
persons/vehicle	1.4	1.7
Sedan		
no. of observations	1,609	596
persons/vehicle	4.5	5.6
Standard Bus		
no. of observations	137	57
passengers/vehicle	12.2	11.4
4WD, Standard Pickup		
no. of observations	471	358
persons/vehicle	6.3	8.8
2-Axle Truck (Other Than Pickup)		
no. of observations	120	90
passengers/vehicle	6.4	7.2
load, tons/vehicle	2.8	3.4
3-Axle Truck		
no. of observations	168	65
passengers/vehicle	2.3	5.3
load, tons/vehicle	8.6	6
3+ Axle Truck		
no. of observations	32	13
passengers/vehicle	1.5	2.1
load, tons/vehicle	17.4	15.3

Another aspect of vehicle utilization is empty-truck ratio, which is presented for the three truck types at the Neak Loeung and Kompong Cham (MPWT) ferry crossings. According to this table, the empty-truck ratio is lowest at Neak Loeung for 3- and 3+ axle trucks and lowest at Kompong Cham for 2-axle trucks. The average Mekong River crossing empty-truck ratio was determined to be 29.7%, consistent with an assumed 30.0% empty-truck ratio (in a previous study) for Cambodia as a whole at this stage of its development.[1] (Table 4.6)

[1] i.e., PADECO Co., Ltd., *Promoting Subregional Cooperation Among Cambodia, The People's Republic of China, Lao PDR, Myanmar, Thailand and Viet Nam: Feasibility Study of the Ho Chi Minh-Phnom Penh-Bangkok Road Project*, Final Report - Main Text, April 1995, p. 3-27, which forecast a 30.0% empty-truck ratio for Cambodia for the period 1995-2000.

Table 4.6 Additional Truck Utilization Results (from the O-D Survey), May 1995

Vehicle Type	Neak Loeung	Svay Chrum	Prek Tamak	Kompong Cham	Total
2-Axle Truck (Other Than Pickup)					
no. of observations	120	0	1	79	200
empty truck ratio	33.60%	-	-	23.50%	29.30%
load, tons/loaded vehicle	4.1	-	-	4.4	4.3
3-Axle Truck					
no. of observations	168	0	0	24	192
empty truck ratio	20.40%	-	-	48.30%	24.90%
load, tons/loaded vehicle	10.2	-	-	5	9.6
3+ Axle Truck					
no. of observations	32	0	0	37	69
empty truck ratio	9.30%	-	-	68.90%	47.00%
load, tons/loaded vehicle	19.2	-	-	9.1	15.5
Total for all Trucks					
no. of observations	320	0	1	140	461
empty truck ratio	25.80%	-	-	36.90%	29.70%
load, tons/loaded vehicle	8.4	-	-	5	7.3

(6) Trip Purposes and Types of Commodities

The percentage shares of different vehicle trip purposes and types of commodities, also ascertained from the origin-destination survey results, are shown for NMVs, motorcycles, sedans, and 4WDs/pickups at the four main ferries in Tables 4.7 through 4.11. In nearly all cases, trips made for personal business reasons are those most frequently observed at the four locations, with shares ranging from 27% to 87%. At the Neak Loeung, Prek Tamak, and Kompong Cham ferries, a relatively high proportion of 4WDs/pickups function as shared taxis: 32%, 26%, and 33%, respectively. Out of the four ferries, commuting trips represent the highest proportion of total trips at the Svay Chrum Ferry.[1] Also, at the Svay Chrum and Prek Tamak ferries, a relatively high proportion of trips made by sedans were for family/social reasons, with shares of 27% and 22%, respectively.

[1] It was learned during the execution of the origin-destination surveys that a large number of civil servants live in the Svay Chrum area on the east bank of the Mekong River; 50% of all motorcycle trips and 21% of all sedan trips were commuting trips.

Table 4.7 Vehicular Trip Purposes Weighted by Trips per Week, Neak Loeung Ferry

Trip Purpose	Neak Loeung Ferry			
	NMV	Motorcycle	Sedan	4WD, Pickup
To/From Work	1%	6%	8%	7%
Employer's Business	3%	9%	4%	2%
Personal Business	56%	62%	64%	55%
Education/School/Training	19%	4%	5%	0%
Medical	10%	3%	1%	0%
Family/Social	4%	10%	6%	2%
Recreation/Leisure/Tourism	5%	5%	5%	2%
Shared Taxi	2%	1%	8%	32%
Total	100%	100%	100%	100%

Table 4.8 Vehicular Trip Purposes Weighted by Trips per Week, Svay Chrum Ferry

Trip Purpose	Svay Chrum Ferry			
	NMV	Motorcycle	Sedan	4WD, Pickup
To/From Work	22%	50%	21%	-
Employer's Business	2%	2%	8%	-
Personal Business	54%	36%	27%	-
Education/School/Training	19%	4%	6%	-
Medical	0%	0%	0%	-
Family/Social	3%	7%	27%	-
Recreation/Leisure/Tourism	0%	1%	11%	-
Shared Taxi	0%	0%	0%	-
Total	100%	100%	100%	-

Table 4.9 Vehicular Trip Purposes Weighted by Trips per Week, Prek Tamak Ferry

Trip Purpose	Prek Tamak Ferry			
	NMV	Motorcycle	Sedan	4WD, Pickup
To/From Work	1%	7%	18%	0%
Employer's Business	3%	2%	12%	6%
Personal Business	87%	68%	28%	52%
Education/School/Training	1%	2%	10%	13%
Medical	0%	1%	1%	0%
Family/Social	8%	19%	22%	0%
Recreation/Leisure/Tourism	0%	1%	7%	3%
Shared Taxi	0%	0%	2%	26%
Total	100%	100%	100%	100%

Table 4.10 Vehicular Trip Purposes Weighted by Trips per Week, Kompong Cham (MPWT) Ferry

Trip Purpose	Kompong Cham (MPWT) Ferry			
	NMV	Motorcycle	Sedan	4WD, Pickup
To/From Work	2%	10%	13%	19%
Employer's Business	0%	5%	1%	3%
Personal Business	84%	77%	36%	31%
Education/School/Training	4%	2%	2%	2%
Medical	1%	1%	0%	1%
Family/Social	7%	3%	5%	6%
Recreation/Leisure/Tourism	1%	1%	7%	4%
Shared Taxi	1%	1%	37%	33%
Total	100%	100%	100%	100%

Table 4.11 Vehicular Trip Purposes Weighted by Trips per Week, Average of the Four Ferry

Trip Purpose	Average of the Four Ferries			
	NMV	Motorcycle	Sedan	4WD, Pickup
To/From Work	8%	26%	10%	11%
Employer's Business	2%	3%	4%	2%
Personal Business	69%	55%	55%	47%
Education/School/Training	11%	3%	5%	1%
Medical	3%	1%	0%	1%
Family/Social	6%	11%	7%	3%
Recreation/Leisure/Tourism	1%	1%	5%	2%
Shared Taxi	1%	0%	14%	33%
Total	100%	100%	100%	100%

The percentage shares of different commodity types hauled by all vehicle classes at the four ferries are shown in Table 4.12. Manufactured goods and agricultural products are frequently transported at all four ferries, with shares of manufactured goods ranging from 19% to 26% and those for agricultural products ranging from 17% to 35%. Construction materials are also commonly observed at Neak Loeung (18%), while food/drinks are prevalent at Svay Chrum (31%) and Prek Tamak (29%). The Kompong Cham (MPWT) Ferry had the highest proportion of goods classified as other (22%).

Table 4.12 Commodity Types Weighted by Tonnage per Week for All Vehicles

Commodity Type	Neak Loeung Ferry	Svay Chrum Ferry	Prek Tamak Ferry	Kompong Cham Ferry	Average of the Four Ferries
Agricultural Products	17%	29%	35%	12%	17%
Logs/Lumber	4%	0%	1%	4%	4%
Food/Drinks	7%	31%	29%	19%	12%
Manufactured Goods	26%	21%	19%	21%	24%
Construction Materials	18%	7%	9%	10%	15%
Fuel/Chemicals	16%	4%	0%	12%	14%
Other	12%	7%	6%	22%	14%
Total	100%	100%	100%	100%	100%

(7) Origins and Destinations

As referred to earlier, a comprehensive origin-destination survey was conducted at the Neak Loeung, Svay Chrum, Prek Tamak, and Kompong Cham (MPWT) ferry locations in conjunction with the traffic count surveys for seven days, 12 hours per day, at each location (see Figure 4.1). This survey, therefore, covered the majority of transport crossing the Mekong River. Drivers of vehicles waiting to board ferries at both sides of the river were questioned regarding (1) trip origin, (2) trip destination, (3) time left origin, (4) expected arrival time at destination, (4) vehicle capacity in tons, (5) load in tons, (6) type of cargo, (7) trip purpose, and (8) average number of roundtrips per week. Surveyors also recorded the vehicle type, occupancy, and time of interview. Example survey forms are included in Appendix 4.5.

A total of 21,523 interviews were conducted (compared to 10,479 processed O-D interviews in the TRS study), making this survey the largest of its kind in at least 20 years. The number of interviews per site is shown in Table 4.13.[1]

[1]It is important to note that each driver was interviewed only once during the week (at only one side of the river); this procedure was followed (1) to ensure reliable results when expanding origin-destination survey responses by vehicle type according to the number of roundtrips per week and (2) to reduce the number of interviews that would need to be processed. Therefore, all drivers were screened prior to conducting an interview; if a driver had already been interviewed earlier in the week at either side of the river, he/she was not re-interviewed.

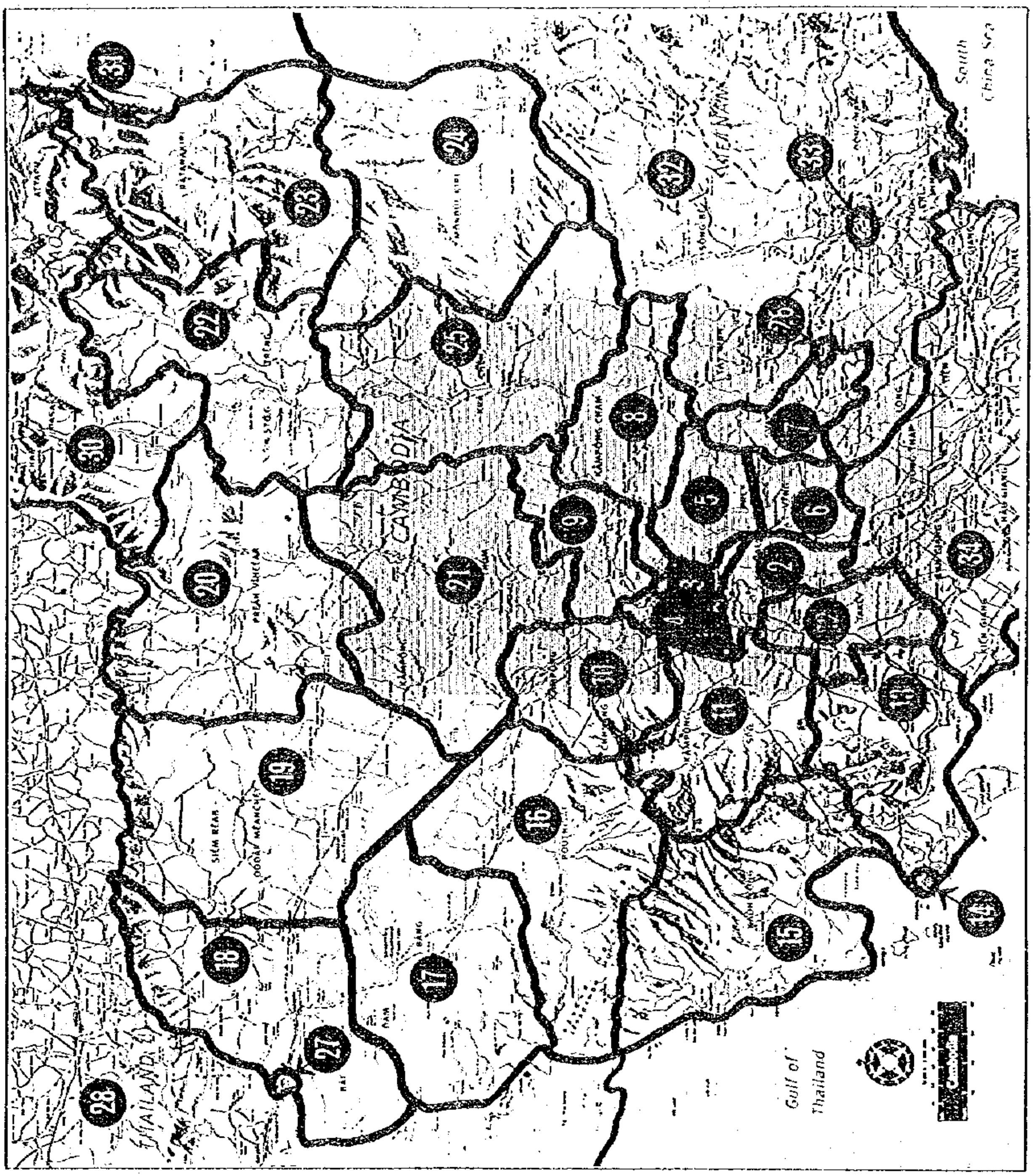
Table 4.13 Number of O-D Interviews per Location

Location		Processed Interviews	Percent
1.	E. Neak Loeung	2,959	
2.	W. Neak Loeung	2,463	
	Total	5,422	25.2%
3.	E. Svay Chrum	2,561	
4.	W. Svay Chrum	3,136	
	Total	5,697	26.5%
5.	E. Prek Tamak	3,220	
6.	W. Prek Tamak	4,081	
	Total	7,301	33.9%
9.	E. Kompong Cham	1,536	
10.	W. Kompong Cham	1,567	
	Total	3,103	14.4%
Grand Total		21,523	100.0%

A total of 34 zones were adopted, as shown in Figures 4.4 through 4.6; most zones correspond to provincial boundaries. For the purposes of this study, the provinces of Kandal and Kompong Cham were subdivided along the Mekong River; Kandal province was further divided into N.W. Kandal and S. Kandal at Phnom Penh. Prey Veng province was split into N. Prey Veng and S. Prey Veng to enable analysis of the potential diversion of trips between N. Prey Veng and Phnom Penh from the Neak Loeung Ferry to a possible bridge near Prek Tamak.[1] The cities of Sihanoukville, Ho Chi Minh City, and Bangkok were designated with exclusive zone numbers, as well as the border towns of Bavet/Moc Bai (Cambodia-Vietnamese border) and Poipet (Cambodian-Thai border). The resulting year 1995 Mekong River crossing matrices for average daily passenger transport and average daily tonnage transport are presented in Appendix 4.2[2] and summarized in Table 4.14. As expected, origin-destination combinations vary by vehicle type, with NMVs traveling relatively short distances, motorcycles making medium-distance trips, and other motor vehicles (e.g., sedans, trucks) traveling longer distances. Assuming all of the passengers and goods to/from Bavet/Moc Bai have destination/origin in Vietnam, the average number of passengers to/from Vietnam that cross the Mekong River in motor vehicles other than motorcycles represents 4.3% of the total number of passengers traversing the river.

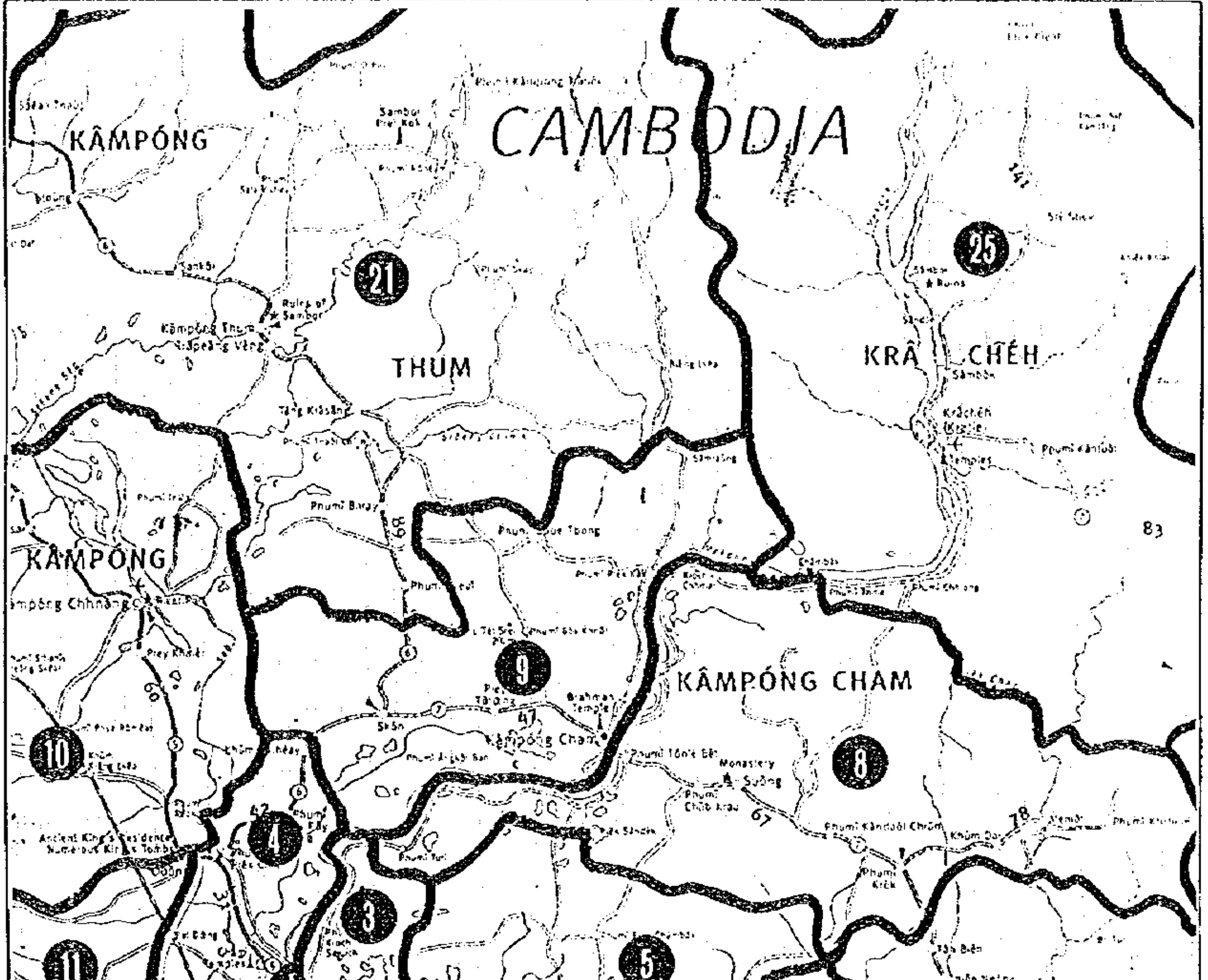
[2]A similar diversion of trips is also possible for trips between E. Kompong Cham and Phnom Penh.

[2]Note that these volumes have not been adjusted to account for the additional (small) ferries crossing the Mekong River at other locations. These additional ferries, however, are capable of transporting only passengers, bicycles, and motorcycles.

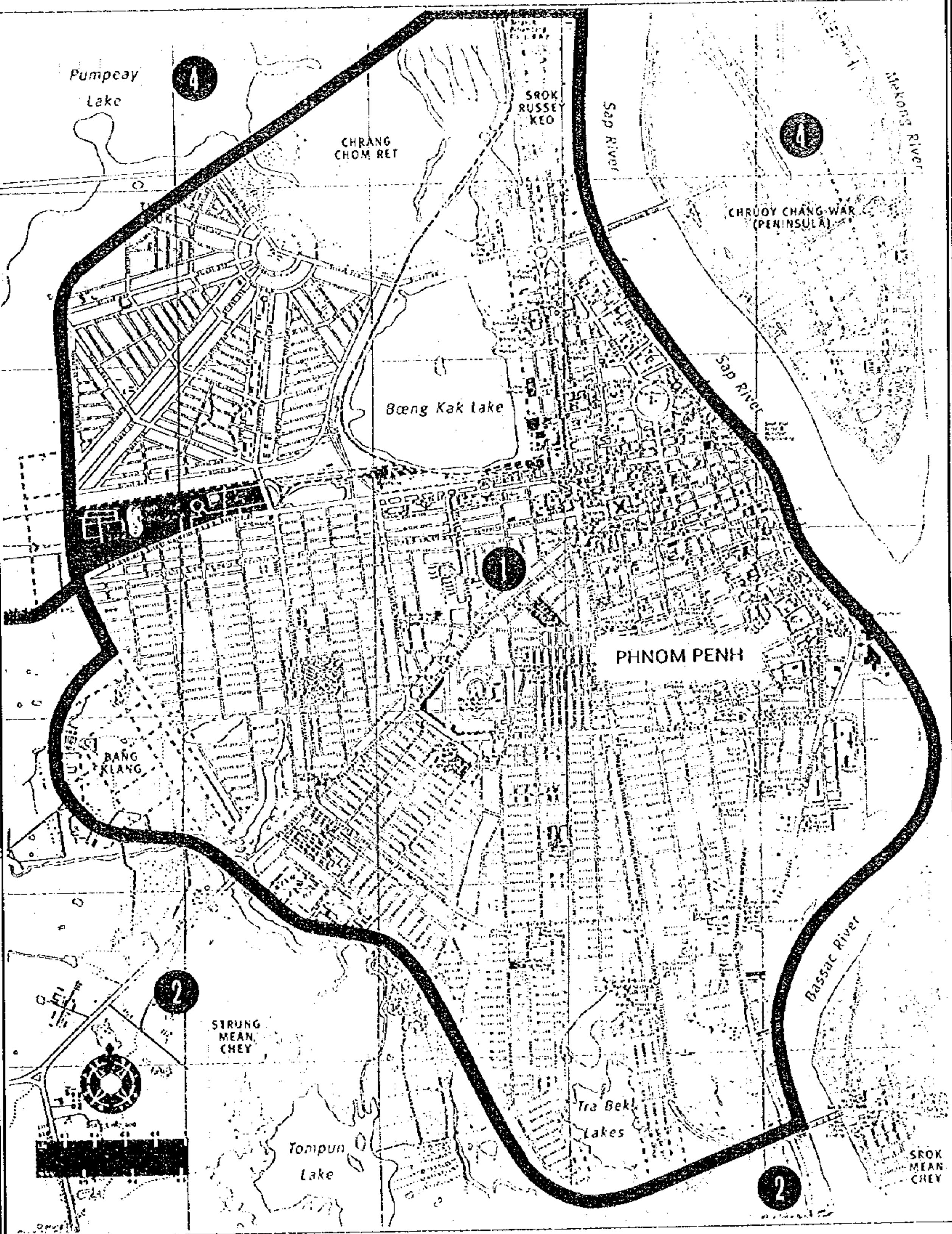


Shaded Portion Shown in More Detail in Figure 4.5

THE FEASIBILITY STUDY ON CONSTRUCTION OF THE MEKONG BRIDGE IN KINGDOM OF CAMBODIA	Figure 4.4 O - D Zone Map (1) JAPAN INTERNATIONAL COOPERATION AGENCY



THE FEASIBILITY STUDY ON CONSTRUCTION OF THE MEKONG BRIDGE IN KINGDOM OF CAMBODIA	Figure 4.5 O - D Zone Map (2)
	JAPAN INTERNATIONAL COOPERATION AGENCY



THE FEASIBILITY STUDY ON CONSTRUCTION OF THE MEKONG BRIDGE IN KINGDOM OF CAMBODIA	Figure 4.6	O - D Zone Map (3)
	JAPAN INTERNATIONAL COOPERATION AGENCY	

Table 4.14 Mekong River Crossing O-D Survey Results

Zone	Province	% of Avg. Daily Passengers (To/From)			% of Avg. Daily Tonnage	
		NMVs[1]	Motor-cycles	Other MVs[2]	From	To
1	Phnom Penh	5.5%	28.6%	44.9%	43.5%	29.8%
2	S. Kandal	20.8%	4.5%	0.6%	0.7%	1.9%
3	E. Kandal	11.8%	18.9%	3.8%	1.6%	3.1%
4	N.W. Kandal	7.4%	2.5%	0.3%	1.1%	0.5%
5	N. Prey Veng	13.1%	7.6%	4.3%	1.2%	9.7%
6	S. Prey Veng	6.7%	3.2%	14.6%	4.5%	3.9%
7	Svay Rieng	2.0%	3.4%	12.7%	7.9%	12.2%
8	E. Kompong Cham	16.3%	16.0%	11.0%	13.3%	13.9%
9	W. Kompong Cham	16.3%	14.2%	3.2%	9.0%	8.3%
10	Kompong Chhnang	-	-	0.1%	-	0.1%
11	Kompong Spoe	-	0.1%	0.1%	-	0.3%
14	Sihanoukville	-	-	0.1%	1.4%	-
21	Kompong Thom	-	-	0.1%	-	3.2%
26	Bavet/Moc Bai	-	1.0%	2.9%	15.4%	5.6%
27	Poipet	-	-	0.8%	-	-
32	S. Vietnam	-	-	0.4%	0.2%	4.5%
33	Ho Chi Minh City	-	-	0.2%	-	2.9%
Total		100.0%	100.0%	100.0%	100.0%	100.0%

Notes: [1]NMVs = non-motorized vehicles (i.e., bicycles, bicycles-with-trailers, cyclos, animal carts).
[2]Other MVs = other motorized vehicles (i.e., all motorized vehicle types except motorcycles; drivers of commercial vehicles not included).

Daily tonnage *from* Phnom Penh makes up 43.5% of the total cargo tonnage crossing the river by ferry, while that *from* Vietnam is 15.6%. Daily tonnage *to* Phnom Penh represents 29.8% of the total, while that *to* Vietnam is a surprisingly high 13.0%. Therefore, of the total cargo tonnage crossing the Mekong River by ferry, on average 36.7% has origin or destination in Phnom Penh and 14.3% has origin or destination in Vietnam. It is also of interest to note that the eastern half of Kompong Cham Province is a more significant generator/attractor of passenger trips and cargo tonnage than the western half, which contains the city of Kompong Cham.

4.1.2 Existing Ferry Operations

(1) Waiting and On-Board Times

During the carrying out of traffic count and O-D interview surveys, additional surveys were simultaneously conducted by the Study Team to determine the average passenger waiting and on-board times at the relevant ferries. The results are summarized in Table 4.15 and detailed in Appendix 4.3. As shown in the table, the MPWT Kompong Cham Ferry provides the slowest service among the major ferries in terms of total river crossing time. Interestingly, the Prek Tamak Ferry has the fastest service.

Table 4.15 Average Waiting and On-Board Times, May 1995

Ferry	Avg. Waiting Time (minutes)	Avg. Ferry Travel Time (minutes)	Avg. Unloading Time (minutes)	Total Time (minutes)
Neak Loeung	10	9	2	21
Svay Chrum	15	8	1	24
Prek Tamak	7	8	1	16
Kompong Cham (Private)	18	11	1	30
Kompong Cham (MPWT)	22	21	2	45

With the preceding information, it is possible to estimate the capacities of the respective ferries for this time of year (i.e., low water level) assuming they operate under relatively good, trouble-free conditions. The estimated capacities of the Neak Loeung, Svay Chrum, Prek Tamak, and Kompong Cham (MPWT) ferries are, respectively, 120, 12, 12, and 18 cars and trucks per hour for both directions. These figures highlight the severely limited capacities of all ferries except Neak Loeung (the private Kompong Cham Ferry cannot transport vehicles larger than motorcycles).

(2) Ferry Tariffs

Ferry tariffs or fares are provided in Table 4.16 and repeated in Appendix 4.4, which includes a table of fares in local currency. As shown, the fares charged by the two MPWT-operated ferries are significantly lower than those of the private ferries. The private Kompong Cham Ferry is able to charge higher fares than the MPWT ferry because it crosses the Mekong River in approximately half the time due to the lighter vessels utilized and lighter loads carried.

Fares for pedestrians range from US$ 0.04 at Neak Loeung to US$ 0.17 at both the Svay Chrum and Prek Tamak ferries. Motorcycle (plus rider) fares vary from US$ 0.13 to US$ 0.35, and those for sedans range from US$ 1.65 to US$ 3.48. Trucks are charged substantially higher fares, e.g., US$ 17.39 for 18-20 ton trucks at the MPWT Kompong Cham Ferry.

Table 4.16 Ferry Fares, 1994-95 (in US$)

Mode of Travel	Fare (US$)				
	Neak Loeung (MPWT)	Svay Chrum (Private)	Prek Tamak (Private)	Kompong Cham (Private)	Kompong Cham (MPWT)
Pedestrian	0.04	0.17[1]	0.09	0.17	0.09
Pedestrian with Handcart	0.26	-	0.17	-	0.09
Bicycle	0.09	0.26	0.13	0.17	0.13
Bicycle-with-Trailer	0.26	-	0.22	-	0.57
Cyclo	-	-	-	-	0.13
Animal Cart (empty)	0.09	1.09	1.30	-	0.22
Animal Cart (loaded)	0.09	1.09	1.74	-	0.22
Motorcycle	0.13	0.35[1]	0.17	0.35	0.22
Motorcycle-with-Trailer	1.22	1.09	0.26	-	2.26
Sedan	1.65	3.48	2.17	-	2.26
6-12 Seat Tourist Van (Minibus)	2.04	4.35	3.04	-	3.04
6-12 Seat Business Van (Minibus)	2.70	4.35	3.04	-	3.04
Light Truck, Pickup	2.70	4.35	3.04	-	3.04
13-20 Seat Vehicle (Bus); 5-Tons	4.00	-	-	-	3.83
21+ Seat Vehicle (Large Bus); 6-8 Tons	6.65	-	-	-	9.13
Gasoline Truck; 9-15 Tons (6,000 Liters)	10.57	-	-	-	9.13
Truck-with-Trailer; 11-16 Tons	-	-	-	-	13.04
3-Axle Vehicle; 16-18 Tons	13.26	-	-	-	-
Log-Carrying Truck; 18-20 Tons	16.52	-	-	-	17.39

Notes: [1]These rates are discounted by 50% for government employees Monday through Saturday.
[2]US$ 1.00 = 2,300 riel.

Source: This (unpublished) information was provided by the respective ferry operators during meetings with the Study Team in April and May 1995.

(3) Annual Revenues and Expenditures

Annual revenues and expenditures of the Neak Loeung and Kompong Cham (MPWT) ferries are summarized in Table 4.17 and detailed in Appendix 4.4. If converted to average daily revenues, the 1994 average daily income of the Neak Loeung Ferry was US$ 2,191, more than four times that of the Kompong Cham Ferry at US$ 472. Clearly, the Neak Loeung Ferry receives significantly higher patronage than the Kompong Cham Ferry, especially considering that the fares of the Neak Loeung Ferry tend to be lower than those of the Kompong Cham Ferry.

Table 4.17 Annual Revenues and Expenditures of MPWT Neak Loeung and Kompong Cham Ferries, 1994 (in US$)

Category	Neak Loeung Ferry	Kompong Cham Ferry
Total Revenues	799,794	172,349
Total Expenditures	461,348	131,772
Total Profit	338,446	40,577

Note: US $1.00 = 2,300 riel.

Sources: Neak Loeung Ferry Station and Kompong Cham Ferry Station, Department of Roads and Bridges, Ministry of Public Works and Transport.

The Svay Chrum, Prek Tamak, and (private) Kompong Cham ferries are operated by the private sector under contractual arrangements with the MPWT (see Table 4.18). The contract period for each private ferry is two years, after which open competitive bidding is repeated.[1]

Table 4.18 Contract Prices of the Svay Chrum, Prek Tamak, and Kompong Cham Private Ferries, 1994-95 (in US$)

Ferry	1994-95 Minimum Bid Price[1] (US$)	1994-95 High Bid Price[2] (US$)
Svay Chrum Ferry	8,695	54,955
Prek Tamak Ferry	3,480	63,045
Kompong Cham Ferry	30,435	73,870
Total	42,610	191,870

Notes: [1]The minimum bid price refers to the minimum bid level set by the Government when tendering ferry service operations to the private sector for the given years.
[2]The high bid price refers to the winning high bid (annual contract value to be paid to the Government) offered by the private sector.
[3]Note that the Kompong Cham Ferry shown above is different from the MPWT ferry of the same name.
[4]US$ 1.00 = 2,300 riel.

Sources: This (unpublished) information was provided by the Kandal Provincial Department of Public Works during a meeting with the Study Team on 5 May 1995 in Ta Khmad, Kandal Province, and by the Kompong Cham Provincial Department of Public Works during meetings with the Study Team on 6 and 16 May 1995 in Kompong Cham, Kompong Cham Province.

4.1.3 River Transport

(1) Services

On the route between Phnom Penh and Kompong Cham, ordinary boats and high-speed boats are operated. Ordinary boats transport both passengers and goods; However, they carry mainly goods and only a few passengers. There are 10 ordinary

[1]The contract prices of the private ferries in Kandal Province and Kompong Cham Province are provided in Appendix 4.4.

boats available. Each boat is operated at a rate of one trip per day for each direction, with a travel time of 9 hours upstream and 7 hours downstream. High-speed boats transport mainly passengers. There are two high-speed boats, each of which makes one round-trip per day with an average travel time of 130 minutes regardless of the direction of stream.

For river transport between Kompong Cham and Kratie, ordinary and high-speed boats are also operated. Twelve ordinary boats are available. Each boat makes one trip per day for each direction, with a travel time of 12 hours in the upstream direction and more than 12 hours in the downstream direction because of many inspections. One high-speed boat is operated with one round-trip per day and an average 150 minutes cruising time regardless of the direction of stream.

There are four ordinary boats and one high-speed boat available for services between Phnom Penh and Kratie.

No river transport service was observed downstream from Phnom Penh.

(2) Traffic Volume

Since the operations are private and no statistical data on river transport traffic volumes exists, estimates of traffic volumes depended on the compiled interview survey results at the Phnom Penh Port and MPWT offices.

The average number of passengers between Phnom Penh and Kompong Cham on ordinary boats was estimated to be about 30 passengers, and the average number of passengers on high-speed boats is 40 to 50 passengers while the capacity is 76 passengers. High-speed boats, which were recently granted operation rights, captured most river transport passengers. The average number of passengers between Kompong Cham and Kratie on ordinary boats was estimated t around 50 passengers per boat, and the average number of passengers on high-speed boats is about 80 passengers. Approximately 30-40% of passengers to/from Kratie are those between Kratie and Phnom Penh; these passengers transfer at Kompong Cham.

The main commodities carried upstream from Phnom Penh are timber, agricultural produce, and rock to Phnom Penh; and foodstuffs, household goods, and construction materials from Phnom Penh. The average occupancy is estimated at only some 20-30% of capacity. Boats with capacities of up to 150 tons can be used for far as Kratie, and between Kratie and Stung Treng 50 tons boats can be used without difficulty.

The Study team estimated the volumes of commercial goods for the routes (see Table 4.19).

Table 4.19 Traffic Volume by Waterway

Route	Passengers/year (total both direction)	Tons/year (total both direction)
Phnom Penh - Kompong Cham	150000	20000
Kompong Cham - Kratie	280000	37000
Phnom Penh - Kratie	100000	20000
Kratie - Stung Treng	7000	500

Source: Consultant's estimates

(3) Fares and Operating Cost

Fares considerably differ between the two types of service. The following fares by route and type were obtained through on-the-spot interview surveys.

Route	Types of Service	US$/passenger
Phnom Penh - Kompong Cham	High-speed boat	6.00
	Ordinary boat	2.40
Kompong Cham - Kratie	High-speed boat	9.00
	Ordinary boat	9.00

Cargo belonging to passengers are charged at a rate of US$0.60-1.20 per bag/parcel between Phnom Penh and Kompong Cham. Fares between Kompong Cham and Kratie include cargo charges; therefore, cargo belonging to passengers are not charged an extra fee for this section. However, high-speed boats have very little capacity for passenger cargo; consequently, most passengers with a significant amount of cargo take ordinary boats. Ordinary boats are able to charge the same fare as the high-speed boats because of their advantage in being able to carry large volumes of passenger-accompanied cargo.

Cargo transport fares by ordinary boat between Phnom Penh and Kompong Cham and between Kompong Cham and Kratie are US$1.60-4.00 and approximately US$4.00 per ton respectively.

The following average costs per ton-km for the main routes, with the current mix of boats with different sizes, were estimated based on the results of the TRS study.

Route	US$/ton-km
Phnom Penh - Kompong Cham	0.10
Phnom Penh - Kratie	0.07

4.2 Traffic Forecasts

4.2.1 Growth Parameters

(1) Patterns of Economic Development

(1.1) Basic Method of Forecasting

Usually two basic methods are used to forecast traffic and thereby estimate the future benefits of possible investments in transport infrastructure: extrapolation of observed trends or derivation of transport needs likely to occur by development of both the national and regional economy.

For traffic forecasts with a long-term horizon, trend extrapolation is not applicable in Cambodia, where political conflicts over the last 25 years have devastated the economy but large potential for development remains.

Prediction of the speed and direction of economic development over the next decade is not easy. However, forecasts based on economic development that incorporate careful analysis of development mechanisms of economies referring to those of other countries in East and Southeast Asia is preferred.

(1.2) Special Factors for Forecasting

Special factors making it difficult to predict economic development in Cambodia are as follows:

- Security Problems:

  Remaining land mines and bandit activities are serious constraints to the development of rural areas. The fact that the Government has less than full control of the country affects its development and some sectors of the economy.

- Financial Problems:

  Although efforts to increase Government revenues in almost all taxation fields were made, taxes are few and Government revenue is too low to finance even basic social services. In the infrastructure sector, project implementation is highly dependent on foreign assistance; these frail fiscal conditions incur uncertainty on economic development.

The rest of this section describes patterns of economic development applicable to Cambodia based on the experience in East and Southeast Asian countries with particular attention paid to the especial conditions in Cambodia.

(1.3) Population Growth

Empirically, demographic transition in a country falls into one of the following three stages:

i) Low population growth rate with high fertility rate and high mortality rate;

ii) High population growth rate with high fertility rate and low mortality rate; or

iii) Low population growth rate with low fertility rate and low mortality rate.

Generally the duration of the second stage depends on the manner of the fall in mortality rate owing mainly to both the prevention of epidemics and improved medical care. Transition to the third stage is due to changes in lifestyle brought about by a rise in income levels. Already it has been observed that some countries in East and Southeast Asia have proceeded to the third stage, as seen in Taiwan with a 1.2% population growth rate and in Thailand with a 1.3% population growth rate.

On the contrary, in Cambodia where the population growth rate was 2.6% in 1994 with a crude birth rate of 4.0% and a crude death rate of 1.5%, the current demographic situation remains at the second stage. The age dependency ratio (i.e., ratio of persons 0-14 years-old plus those 65 years-old-and-over to persons in the working-age-group defined as 15-64 years-old) reached an astonishingly high 93.2% in 1993. Consider, for example, that the age dependency ratio in developed countries is around 50-60%.

The probability of demographic transition in Cambodia to the third stage within a horizon of a few decades is deemed modest because of the existing poverty conditions and many obstacles to overcome.

(1.4) Economic Growth and Population

Regarding the relationship between economy and population, the following empirical evidence is well known. That is, "If a continuous intensive pressure of population expansion exists in a country, it is not an easy matter to get the average per capita income level out of the trap of the equilibrium condition of low income levels."

Generally, the economic development process of a country can be described as follows: "The process that a modern industrial sector with high productivity is established and fostered in the national economy where the traditional industrial sector, distressed by low productivity due to the labor surplus, is dominant and that the modern industrial sector play a more important role in the economic development by absorbing the labor surplus in the traditional industrial sector."

Population increases in a developing country are put into the traditional sector, usually the agricultural sector; however, agricultural production hardly rises in proportion to the labor input, and the increases in agricultural production diminish successively in general.

In Cambodia, the cultivable area has room for expansion. However, rapid increases by expansion of cultivated areas are not likely because of impediments created over the last two decades, such as land mines, devastated irrigation systems, and dilapidated roads. Although recent agricultural output levels show an increase, productivity is not comparable to that of neighboring countries. Increases in agricultural output by means of substitution of production elements and technical improvements cannot be anticipated due to the relatively large amount of surplus labor.

A significant issue regarding the economic development of a developing country is how to enhance the absorptive capacity of labor in the modern industrial sector.

(1.5) Industrialization

Two ways leading to industrialization are typically considered.

One method is industrialization through the export of primary products of the country, i.e., (1) export of primary products in the country that have relative advantages; (2) introduction of basic conditions for industrialization such as technology, materials, and half products procured by foreign currency obtained by the export of primary products; and (3) gradual realization of industrialization.

The second way is industrialization by substituting imported goods through a form of protectionism, i.e., (1) substitution of final products by production within the country based on the imported inputs, such as materials, intermediate products, and capital for the domestic market; (2) export of final products after production surpasses domestic demand; and (3) substitution of imported goods after the imported goods volume reaches the point of an efficient minimum domestic production scale.

Many developing countries adopted the second method as a strategy for industrialization. In other words, the way from downstream to upstream of the circuitous process of production was adopted as the general approach to industrialization. However, as is often the case, the substitution of some inputs for production did not follow the way mentioned above. It can almost be concluded that substitution of imported goods as inputs for production emerged due to the depletion of opportunities for substitution of imported final products and due to a crisis of foreign-exchange holdings.

This unexpected problem in industrialization by substitution of imported goods characterized as protectionism is usually considered as follows:

i) First, since the scale of the domestic ready market exploited by protectionism is usually small, opportunities for substitution of imported goods will diminish before long. Also, the industries substituting the imported goods can hardly metamorphose into export industries.

ii) Second, industrialization by substituting imported goods characterized as protectionism easily brings about the depletion of foreign-exchange reserves and forces industrialization by substitution of imported goods to occur in a more downstream field.

iii) Third, evidence shows that industrialization by substitution of imported goods has the tendency of intensive capitalization and low absorptive capacity of labor.

In the 1970s, most countries in Southeast Asia adopted the strategy to ease protectionism and systematize policies for promoting export industries. More specifically, the strategy was designed to promote particular production systems suitable for given conditions for production in developing countries, where the economy with excessive labor surplus is dominant, through the liberalization of import, exchange, and interest rates. The strategy was also designed to secure the relative advantages associated with foreign trade.

Depending on these strategies, the relative advantages of labor-intensive industries were identified in developing countries. Further successive policies for the promotion of exports were adopted, and international competitive power was further intensified.

However, it should be noted that the establishment of policies based on such strategies and the realization of export industries are the most important but difficult steps in the development of national economies. Especially in Cambodia, the uncertainties of security and finance complicate the problem.

(2) Consideration of Growth Parameters

(2.1) Population Growth

There is much uncertainty about the annual rate of population growth in Cambodia. Currently, it is estimated between 2.5 and 3.0% p.a. This figure is considerably high compared with 1.6% in Thailand (US$ 1,905 per capita nominal GDP, US$ 4,722 per capita ppp GDP) and 1.3% in Taiwan (US$ 9,805 per capita nominal GDP, US$ 9,830 per capita ppp GDP) in 1993.

As yet there is no Government policy on population. This situation may be due to a perception that the population is still small compared with neighboring countries and unoccupied land is still amply available. UN projections are 2.0% (medium case) and 2.4% (high) for the 1990s, and 1.4% (medium) and 1.7% (high) for 2000-2010 (*World Demographic Estimates and Projections, 1950-2025*, United Nations, 1988).

The population growth rate in urban areas is around 4% on average in countries in Southeast Asia. However, population concentration has already slowed in some megalopolises (e.g., Bangkok and its vicinity with 8.7 million inhabitants in 1992, Jakarta and its vicinity with 18.9 million inhabitants in 1993). The population of Phnom Penh and other urban areas fluctuates greatly according to season with many farmers seeking casual work in the large informal economy. The average population growth rate in Phnom Penh and Sihanoukville (formerly Kompong Som) was 6% from 1981 to 1993. The population growth rate in urban areas is assumed to be around 4% p.a.

Regarding population distribution, it can be considered that population will increase in the areas of three growth poles (Phnom Penh, Sihanoukville, and Siem Riep) and the anticipated growth corridor between Phnom Penh and Sihanoukville.

(2.2) GDP Growth

The average GDP growth rate during the period 1991-1993 was about 7% per year. The Government's target for the period 1994-1996 is 7-8% per year (*National Programme to Rehabilitate and Develop Cambodia*, 1994). Output growth in 1994 is estimated at 5% (as opposed to an initial projection of 7%), because of slower increases in agricultural production (rice in particular; as much as 300,000 tons of rice, 12% of production in 1993, may have been lost due to the combined effect of flooding and drought). By contrast, strong growth in construction and services has continued.

In the span of a decade, GDP growth rates in even those countries where remarkable development was achieved in East and Southeast Asia are about 8-9% on average. In Cambodia security problems and financial deficit for the investment in infrastructure and industry continue to suppress the country's economy.

However, in Cambodia even after solving the problems deterring rapid growth, a growth rate of 7-8% is not unrealistic. After initial rapid growth, deceleration to a slightly lower growth rate would be expected.

(2.3) Agriculture

In the agricultural sector, evidence in Southeast Asia shows that the growth rate of agricultural products is slightly higher than that of population. However it has the tendency of gradual decline. Also evidence shows that more market-oriented production such as rice, livestock, and vegetables has spread.

In Cambodia, agriculture grew at an average rate of 2% over 1991-1994 in monetary terms. In tonnage, output of livestock showed increases, outputs of crops fluctuated and has not shown evidence of increases. Agricultural output is significantly influenced from season to season by weather. Forestry accounts for 3-4% of GDP and is expected to remain at the existing production level with the reimposition of a ban on logging in May 1995.

Achieving self-sufficiency in rice is an immediate goal. However, the principal goals in the agricultural sector as presented by the Government are: (1) to ensure food security at both the national and household levels; (2) to produce surplus for export, not only of rice but also of other crops; (3) to expand rubber production for increased foreign exchange earnings; (4) to encourage the production of raw materials for local agro-industries; and (5) to improve the well-being and incomes of the rural population.

The growth rate of rice production is expected to be almost the same as the population growth rate or slightly higher. In contrast, the agricultural output level of products other than rice is expected to rise more rapidly in accordance with the relatively high domestic income-elasticity of demand for fruits and vegetables, removal of the current constraints on farm input supplies, and expansion of rubber exports.

With important natural resources and a relatively small population, Cambodia has high potential for agricultural development. Its physical potential lies primarily in the cultivated area that is concentrated in the alluvial basin around the Sap River and the Mekong River hydrographic network. Regionally, future prospects of rice production are expected to increase in proportion to the population growth rate except for some areas with security problems. The agricultural output level of other products is more sensitive to population increases. In Cambodia, agriculture grew at an average rate of 15% over 1991-1994 in monetary terms.

(2.4) Industry

The growth rate of the industrial sector surpassed not only that of GDP but also that of the service industry in Southeast Asia. Sometimes it showed a nearly 20% increase in production.

The prospects of each sub-sector comprising the industry sector are considered as follows:

The growth rate of mineral production is considered stable except in those areas where the mining of materials is a considerable part of construction activities. Leases have been granted to a number of foreign companies for offshore and inland exploitation of petroleum, oil, and lubricants (POL). If offshore drilling was successful, it would be necessary to assume the POL. However, POL production is currently nonexistent in Cambodia and there is great uncertainty regarding its probability of success and possible output levels; therefore, zero production was assumed in this study.

Present manufacturing industries dominant in Cambodia are characterized as light industries. They are food processing, beverages, cigarettes, textiles, garments, rubber processing, and the like. Presently industrial growth rates are high, but they are constrained by shortages in electricity supply and raw materials. For these reasons the present level of growth rates are initially expected for manufacturing in Cambodia; after the completion of rebuilding, higher growth rates are expected especially along the development corridor between Phnom Penh and Sihanoukville. Construction materials comprise mainly bricks, not cement or steel. Bricks are usually produced locally and are unlikely to enter international trade, whereas cement and steel may do so. Construction growth rates are taken to be above average because of the imperatives arising from the need to restore and extend the country's infrastructure.

In accordance with the above discussion, growth rates were established (Tables 4.20 through 4.22).

Table 4.20 Projected Average Annual Population Growth Rates

(%)

1995-1997	1997-2000	2000-2010	2010-2020
2.5	2.5	2.0	1.5

Source: JICA Study Team

Table 4.21 Projected GDP Growth Rates

(%)

1995-1997	1997-2000	2000-2010	2010-2020
7.0	8.0	8.0	7.0

Source: JICA Study Team

Table 4.22 Projected Growth Rates by Industrial Origin

(%)

	1995-1997	1997-2000	2000-2010	2010-2020
I. Plain Region				
Rice	4.0	4.0	4.0	3.0
Other Agricultural	6.0	10.0	10.0	8.5
Forest Products	0.0	0.0	0.0	0.0
Petroleum, Oil and Lubricants	0.0	0.0	0.0	0.0
Minerals	6.0	6.0	6.0	6.0
Construction Materials	10.0	10.0	11.0	10.0
Manufactured Products	11.0	11.0	12.0	11.0
II. Tonle Sap Lake Region				
Rice	2.5	2.5	2.0	2.0
Other Agricultural	6.0	10.0	10.0	8.5
Forest Products	0.0	0.0	0.0	0.0
Petroleum, Oil and Lubricants	0.0	0.0	0.0	0.0
Minerals	5.0	5.0	5.0	5.0
Construction Materials	5.0	5.0	7.0	5.0
Manufactured Products	6.0	6.0	8.0	6.0
III. Coastal Region				
Rice	2.5	2.5	2.0	2.0
Other Agricultural	6.0	10.0	10.0	8.5
Forest Products	0.0	0.0	0.0	0.0
Petroleum, Oil and Lubricants	0.0	0.0	0.0	0.0
Minerals	5.0	5.0	5.0	5.0
Construction Materials	6.0	10.0	11.0	10.0
Manufactured Products	6.0	6.0	12.0	11.0
IV. Plateau and Mountain Region				
Rice	2.0	2.0	1.5	1.5
Other Agricultural	6.0	10.0	10.0	8.5
Forest Products	0.0	0.0	0.0	0.0
Petroleum, Oil and Lubricants	0.0	0.0	0.0	0.0
Minerals	6.0	6.0	6.0	6.0
Construction Materials	5.0	5.0	5.0	5.0
Manufactured Products	6.0	6.0	8.0	6.0

Source: JICA Study Team

4.2.2 Future Traffic Demand

(1) Procedure of Traffic Demand Forecast

(1.1) Type of Traffic

Traffic forecasts were made for normal traffic, development traffic, traffic diverted from other roads or from other modes such as seaborne transport, and induced traffic. Domestic and international traffic were also considered separately. Additionally, passenger traffic and freight traffic were distinguished regarding the main characteristics of transport demand.

Average traffic volumes were individually forecast for different vehicle types. The methods of estimating the normal, development, diverted, and induced traffic are described in the sections that follow. The overall traffic forecast workflow is shown in Figure 4.7. Specifically, traffic growth rates were estimated for each vehicle type for each region in Cambodia.

(1.2) Vehicle Type

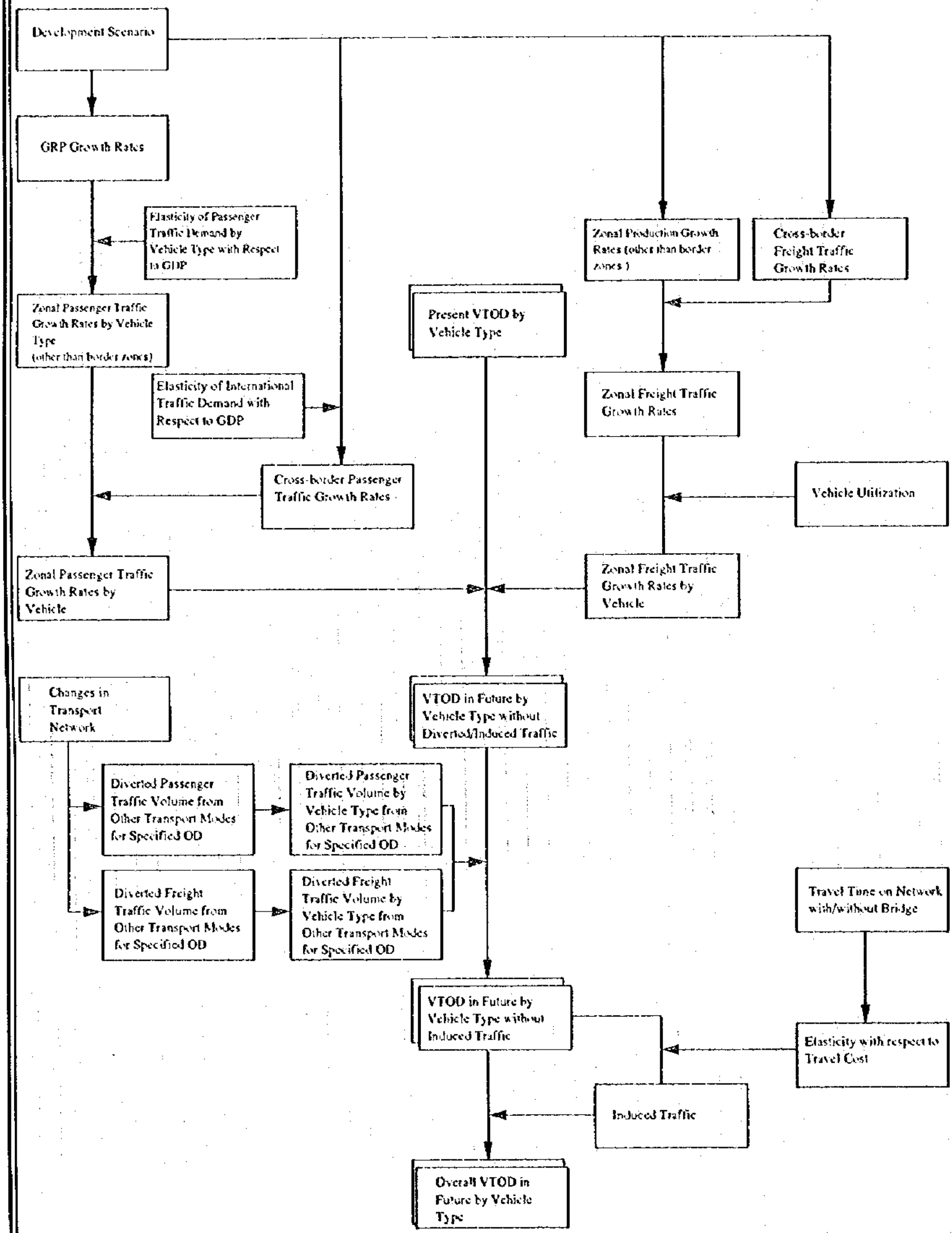
The vehicle types considered are the following:

- motorcycle (MC)
- passenger car (PC)
- light bus (LB)
- heavy bus (HB)
- light truck (LT)
- medium truck (MT)
- heavy truck (HT)

The first five types of vehicles are considered passenger transport vehicles, and the last two types are commodity transport vehicles. Motorcycles-with-trailers, which are commonly seen in Cambodia, are included in the motorcycle category. Passenger cars include only normal sedans or estate cars with typically 4-5 seats. Buses with less than 40 seats are classified into the light bus category in this study, although further subdivision may seem appropriate. Heavy bus is defined as a large bus having a capacity of more than 40 passengers. Light trucks include a multitude of different vehicle types, but most of which are regular pick-ups and 4WDs. Medium trucks are two-axle trucks with 6 wheels having load capacities around 6-8 tons. Heavy trucks are three-axle (or more) trucks with 10 wheels and most of which have a load capacity of 15 tons. Pedestrians and bicycles were not considered in this forecast because the benefits by reduction of time are assumed to be small.

(1.3) Forecast Year

Traffic demand forecasting was carried out for years 2001, 2011, and 2021 on the horizon of 20 years from the opening year (2001 or 2002).



THE FEASIBILITY STUDY ON CONSTRUCTION OF THE MEKONG BRIDGE IN KINGDOM OF CAMBODIA	Figure 4.7 Procedure of Traffic Demand Forecast
	JAPAN INTERNATIONAL COOPERATION AGENCY

(1.4) Zoning

Cambodia and adjacent countries were divided into same 34 traffic zones as in the origin-destination interview survey (see section 4.1.2 (7)).

(1.5) Forecast Procedure

The conceptual forecast procedures shown in the workflow diagram are the following:

- Development scenario of population, economy, and international trade in Cambodia are prepared for the initial base case;

- Normal and development traffic demand in the form of origin-destination (OD) matrices based on the estimated growth rates by zone and vehicle type are forecast for domestic passenger traffic, domestic freight traffic, international passenger traffic, and international freight traffic;

- Diverted traffic from other modes are then forecast for domestic passenger traffic, domestic freight traffic, international passenger traffic, and international freight traffic;

- Basic traffic matrices are forecast by summing the diverted traffic OD matrices and the normal and development traffic OD matrices;

- The reduction of travel time between cases with and without a Mekong River bridge are estimated, and induced traffic in the future is forecast by applying elasticities with respect to reduction of time to the basic traffic OD matrices;

- Future traffic matrices by vehicle type are constructed by adding the induced traffic OD matrices to the basic future traffic OD matrices; and

- Traffic volumes at bridge and ferry points are then forecast by assigning the traffic OD matrices in passenger car units (pcu) to the various networks (without bridge, with Neak Loeung Bridge, with Prek Tamak (Svay Chrum) Bridge, and with Kompong Cham Bridge).

(2) Intermodal Analysis of Traffic

Transport systems are rarely independent. Because different modes of transport often compete or complement each other, it is desirable to analyze the transport system including railways and waterways.

In general, the competing and complementing transport modes with respect to road traffic are sea, river, and railway. The cargo volume by air transport is negligible at present and in the foreseeable future due to the high cost.

At present, cargo transport between Thailand and Vietnam depends on transport by sea; however, it is likely that some cargo transport will divert from sea to land and pass through Cambodia after improvement of the appropriate roads and removal of certain obstacles (e.g., border-crossing restrictions for trucks).

Within Cambodia, diverted river traffic was considered in the section between Kompong Cham and northeastern Cambodia, where north-south transport depends heavily on the Mekong River because of security problems and severely damaged roads. Downstream of Phnom Penh, no significant river transport within Cambodia was observed.

A railway between Bangkok and Phnom Penh already exists and an extension to Ho Chi Minh City was proposed in the Economic Cooperation Programme of the Greater Mekong Subregion. However, the 48 km section of this railway between Sisophon (Cambodia) and Poipet (Thailand) is currently impassable due to internal strife. Although resumption of railway operations is expected in the not-so-distant future, this railway is not expected to have any significant influence on road traffic crossing the Mekong River because of its alignment. There is also great uncertainty regarding new railway construction between Phnom Penh and Ho Chi Minh City. Taking these factors into consideration, it was determined that railway transport should not be included in the road traffic forecast calculations.

Based on the above summary, modal shares between Thailand and Vietnam and between northern Cambodia and Kompong Cham (and, to some extent, Phnom Penh) were considered.

(2.1) Diversion from Sea to Road Transport

As referred to earlier, the likely change in modal split of border-crossing trade is the diversion from sea to road transport caused by road projects that improve accessibility between Thailand and Vietnam.

Table 4.23 and Figure 4.8 show the transport comparison by mode. The advantage of sea transport for long distances is clear, while railways and roads compete with each other for short- and medium-distance freight transport. Railway becomes more favorable as the transport distance increases. The choice of transport mode basically depends on the characteristics of the commodities being transported. Bulk commodities are normally transported by the cheapest mode, which is usually not the quickest.

Table 4.23 Comparison of Transport Costs in Cambodia, 1992

		Sea	Road	Railway
Transport Cost	(US$/ton-km)	0.027	0.084	0.042
Mooring Cost	(US$/ton)	0.39	-	-
Agent Cost	(US$/ton)	0.27	-	-
Port Charge (per day)	(US$/ton)	1.67	-	-
Transshipment Cost	(US$/ton)	14.00	-	14.00

Source: Ministry of Public Works and Transport, Cambodia
Phnom Penh Port Improvement Master plan Study, in cooperation with JICA, May 1993.

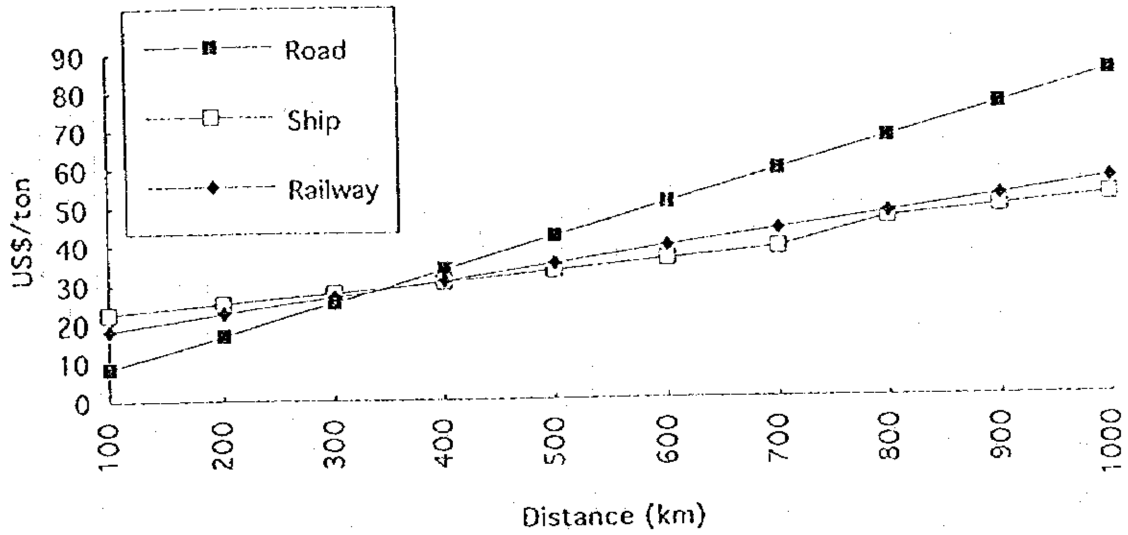


Figure 4.8 Transport Cost per Ton by Mode in Cambodia, 1992

Some portion of manufactured products with high value-added of cross-border seaborne freight between Thailand and Vietnam is assumed to be carried by land transport. Growth rates of international freight traffic were determined based on the estimated present international freight volume and export growth rates by country and commodity.

A moderate diversion rate of 10% was adopted in this study.

(2.2) Diversion from River to Road Transport

As for the international cargo transport between Cambodia and Laos or Vietnam, no reliable data are available. However, it can be reasonably assumed that international cargo transport between Cambodia and Laos by river is strictly limited by the Khong Falls on the Mekong River at the Cambodian-Lao border, and that the volumes are therefore negligible. Consequently, diversion from river to road transport between Cambodia and Laos PDR was not considered in this study.

The data on modal shares of river and road international cargo transport between Cambodia and Vietnam are also not available, although it is likely that each transport means has its own proper share corresponding to the characteristics of the commodities transported. In this study, the modal split between river and road for international cargo transport between Cambodia and Vietnam was assumed constant yet subject to the growth rates of international cargo transport demand.

As for transport within Cambodia, current transport demand between the area north of

Kompong Cham and Kompong Cham (and, to some extent, Phnom Penh) depends almost entirely on river transport because of the severely damaged roads north and east of Kompong Cham. Therefore, diversion from river to road transport is expected to occur if road conditions are improved. The present modal share of road transport demand between Kompong Cham and Phnom Penh is around 80-85%, as shown in Table 4.24. The diversion rate from river to road for transport demand between the area north of Kompong Cham and Kompong Cham (and Phnom Penh) was assumed to be 85% after the completion of required road improvements.

Table 4.24 Estimated Performance by Transport Means between Phnom Penh and Kompong Cham in 1995

Type	Transport Means	Tonnage (tons/year)	Modal Share (%)	Time Required (minutes)	Fare (US$/ton)	Remarks
Freight Traffic	Road	110,000	85%	150	30 (*9)	Chartered Truck * State Enterprise
	Ferry	20,000	15%	420 - 540	4	Slow boat

Type	Direction	Passengers (passengers/year)	Modal Share (%)	Time Required (minutes)	Fare (US$/passenger)	
Passenger Traffic	Road	650,000	81%	140	3	shared taxi
	Ferry	150,000	19%	420 - 540 (*130)	2.5 (*6)	* High-speed boat

Source: JICA Study Team

(3) Normal and Development Traffic

(3.1) Domestic Passenger Traffic Demand

Domestic passenger traffic demand was forecast by vehicle and region based on demand elasticity. According to the development scenario for Cambodia, future population and per capita income levels by region were established, and from these indices estimates of Gross Regional Product (GRP) were forecast.

Elasticity of vehicular traffic generation with respect to GRP was determined by vehicle type through an examination of elasticities empirically observed in Southeast Asian countries such as Thailand. Future zonal traffic growth rates were then determined by applying these elasticities to the GRP estimates. Future traffic OD matrices by vehicle type were subsequently forecast by applying the Fratar method to these zonal traffic growth rates to present (i.e., 1995) traffic OD matrices by vehicle type constructed from data obtained in the comprehensive traffic survey of this study.

Since there are no sufficient historical data in Cambodia to use for estimating vehicle-kilometer elasticities by vehicle type with respect to Gross Domestic Product (GDP), data in Thailand were used assuming that modal split trends in Southeast Asia are similar at comparable stages of development. The elasticities of passenger cars are more than 1.0, implying that their traffic growth rate is higher than that of GDP. However, one cannot assume that elasticity values will remain high in the long run because of the approaching saturation level of road traffic and vehicle ownership.

On the contrary, the elasticities of buses are consistently low, which implies that the growth rate of bus vehicle-kilometers cannot keep pace with the growth rate of GDP. Bus traffic volumes are dependent on public transport policy, unlike the situation for passenger cars. It is not evident that the future modal share between heavy buses and light buses will change. Therefore, the elasticities of heavy buses and light buses were set equal to each other for the forecast time period.

Although the elasticity of vehicle-kilometers is not conceptually equal to the elasticity of vehicle trips, the latter is substituted by the former in this study.

Future GRP estimates were derived from assumptions of future regional population and income levels. Given the future total population of Cambodia, which was estimated based on the assumed population growth rate, as a control total, the regional population growth rates were determined to reflect the changes in population distribution according to the development scenario and trends of present population increases (Table 4.25). Because no data on GRP were available in Cambodia, the GRP growth rates were estimated assuming that the growth rate of the total amount of income in each region is proportional to that of GRP. For the valuation of present regional income levels, the results of *Socio-Economic Survey in Cambodia-1993/1994* by ADB and UNDP were used. Future income levels by region were assumed according to the development scenario. Future GRP growth rates were determined based on future income levels of each region and population forecasts (Table 4.26).

Table 4.25 Projected Population Growth Rates by Region in Cambodia

Region	Avg. Annual Growth Rate (%)				
	1995 (Est.) (1,000 pers.)	1995-1997	1997-2000	2000-2010	2010-2020
Total	9267	2.5	2.5	2	1.5
I. Plain Region	5122	3.3	3.3	2.5	1.9
Phnom Penh	750	5	5	2.5	1.5
West Bank of the Mekong River	2389	3	3	2	2
East Bank of the Mekong River	1983	3	3	3	2
II. Tonle Sap Lake Region	2580	1.6	1.5	1.4	0.8
Siem Riep*	589	3	3	2.5	1.5
Other Provinces	1991	1.2	1.1	1	0.6
III. Coastal Region	650	1.7	1.6	1.5	1.1
Sihanoukville	116	4	4	3	2.5
Other Provinces	534	1.2	1.1	1	0.6
IV. Plateau and Mountain Region	915	1.2	1.1	1	0.6

Source: 1981; National Institute of Statistics, Ministry of Planning
1993; UNTAC's record the registered voters in 1993 (Ministry of Planning)

Note: *1; including 3,000 sq. km of Tonle Sap area.
*2; Banteay Meanchey was created in 1988 from 5 districts of Battambang and 3 districts of Siem Riep.
*3; Avg. annual population growth rates of Battambang and Siem Riep were estimated using total population of Battambang, Banteay Meanchey and Siem Riep.

Table 4.26 Economic Growth Rates by Region

Region		Whole Country	Plain Region				Tonle Sap Lake			Coastal			Plateau and Mountain
				Phnom Penh	West Bank of the Mekong River	East Bank of the Mekong River		Siem Riep	Other Provinces		Sihanouk-Ville	Other Provinces	
1995	Population (1,000pers.)	9267	5122	750	2389	1983	2580	589	1991	650	116	534	915
	Income Index	-	-	1.00	0.31	0.31	-	0.73	0.31	-	0.73	0.31	0.31
	GDP Share (%) (Est.)	100%	-	20.3%	20.1%	16.7%	28.4%	11.7%	16.7%	6.8%	2.3%	4.5%	7.7%
1997	Population (1,000pers.)	9736	5465	827	2534	2104	2663	625	2038	672	125	547	936
	Income Index	-	-	1.00	0.31	0.31	-	0.73	0.31	-	0.73	0.31	0.31
	GDP Share (%) (Est.)	100%	-	21.2%	20.1%	16.7%	27.9%	11.7%	16.2%	6.7%	2.3%	4.3%	7.4%
	GRP Growth Rate 1995-97	7%		9.2%	7.1%	7.1%	6.0%	7.1%	5.2%	6.2%	7.9%	5.2%	5.2%
2000	Population (1,000pers.)	10485	6026	957	2770	2299	2787	683	2104	705	141	564	967
	Income Index	-	-	1.00	0.31	0.31	-	0.73	0.31	-	0.73	0.31	0.31
	GDP Share (%) (Est.)	100%	-	22.5%	20.2%	16.7%	27.0%	11.7%	15.3%	6.5%	2.4%	4.1%	7.0%
	GRP Growth Rate 1997-2000	8%		10.2%	8.1%	8.1%	6.9%	8.1%	6.0%	7.2%	9.2%	6.0%	6.1%
2010	Population (1,000pers.)	12781	7691	1225	3376	3089	3204	874	2330	815	190	625	1071
	Income Index	-	-	1.00	0.40	0.40	-	0.73	0.40	-	0.73	0.40	0.40
	GDP Share (%) (Est.)	100%	-	19.8%	21.8%	19.9%	25.3%	10.3%	15.0%	6.3%	2.2%	4.0%	6.9%
	GRP Growth Rate 2000-10	8%		6.6%	8.8%	9.9%	7.3%	6.6%	7.8%	7.6%	7.2%	7.8%	7.8%
2020	Population (1,000pers.)	14833	9303	1422	4115	3766	3487	1014	2473	906	243	663	1136
	Income Index	-	-	1.00	0.50	0.50	-	0.75	0.50	-	0.75	0.50	0.50
	GDP Share (%) (Est.)	100%	-	16.8%	24.4%	22.3%	23.7%	9.0%	14.6%	6.1%	2.2%	3.9%	6.7%
	GRP Growth Rate 2010-20	7%	-	5.3%	8.2%	8.2%	6.3%	5.6%	6.7%	6.7%	6.6%	6.7%	6.7%

Source: Socio-Economic Survey in Cambodia-1993/1994 by ADB and UNDP

Note: The area West Bank of the Mekong River includes Takeo, and areas of Kandal and Kompong Cham on the west bank of the Mekong River.
The area East Bank of the Mekong River includes Svay Rieng, Prey Veng, and areas of Kandal and Kompong Cham on the east bank of the Mekong River.

The elasticities of vehicle trips with respect to GDP used for the traffic forecasts are shown in Table 4.27. For the forecast of future traffic, the elasticities of vehicle trips with respect to GDP were applied to GRP.

Table 4.27 Assumed Elasticity of Passenger Traffic Demand by Vehicle Type with Respect to GDP

Passenger Car and Light Truck	Light Buses	Heavy Buses	Motorcycle
1.5	0.7	0.7	1.2

Source: JICA Study Team

It can be seen that an explosive traffic increase will emerge after the opening of a new road or bridge. The rate of traffic increase on Route 6A after the opening of the Chroy Chang Va Bridge has been about 30% per year, which is almost the same growth rate as that of the number of registered vehicles in Cambodia. However, the rate of vehicular traffic increase on Route 6A will settle down after the first initial few years if the building activities along other national roads are considered. Nevertheless, if one compares an annual traffic growth rate of 10% to one of 30%, by year 2001 future traffic volumes in the 30% case would be 2.7 times higher than in the 10% case.

According to the empirically observed traffic explosion at the Chroy Chang Va Bridge, it is likely that the traffic volume at Prek Tamak (and Svay Chrum) where high latent development potential can be expected will increase faster than that forecast by the elasticity method. Therefore, the future traffic volume at Prek Tamak in the case with a Prek Tamak bridge was assumed to be 1.5 times larger than the initial forecast.

(3.2) Domestic Freight Traffic Demand

Domestic freight traffic demand was forecast by vehicle type and by region similar to the forecasting of domestic passenger traffic in this study. The growth rates of traffic demand were established based on regional production output levels. This approach represents a more direct method of forecasting freight traffic demand than other approaches, such as the utilization of elasticities with respect to the GRP or the manipulation of freight demand units by sectoral working population.

In this study, the empty-truck ratio was utilized to convert freight traffic demand into vehicle trips referring to the relationship between truck ownership and empty-truck ratios in other countries (Table 4.28 and 4.29). Changes in average loading were not considered.

Vehicular trips may grow at a rate of 1- 2% per annum in addition to freight volume growth resulting from an increase in the empty-truck ratio. The share of each truck type was assumed to be the same as the existing share within the forecast period.

Regarding regional production levels, seven commodity types were considered: rice, other agricultural products, forest products, POL (petroleum, oil, and lubricants), minerals, construction materials, and manufactured products.

Table 4.28 Empty-Truck Ratio

	Viet Nam	Cambodia	Thailand		
	1991	1993	1982 *1	1989	1990
Empty-Truck Ratio (%)	26.7	25.0	40.2	48.2	53.2
Truck per Thousand Inhabitants (Veh/thousand pers.)	1.4	0.9	3.6	5.1	5.7

Source: The toll Highway Development Study in the Kingdom of Thailand, Jul., 1991 Department of Highways, Ministry of Transport and Communications in cooperation with JICA;

Socialist Republic of Viet Nam, National Transportation Sector Review, Final Report volume II, Main report, prepared by BCEOM under contract with the United Nations Development Programme, 1992;

Road Development Study in the Northeastern Region, Department of Highways, Ministry of Transport and Communications, Thailand in cooperation with JICA;

Cambodia Transportation Rehabilitation Study, 1994, Ministry of Public Works and Transport in cooperation with SweRoad under Contract with Asian Development Bank; and

Road Transport Freight Volume Report 1989, Land Transport Department, Ministry of Transport and Communications, Thailand.

Note: *1 Pick-up trucks for freight use are exclusive.

Table 4.29 Assumed Empty-Truck Ratio

	Empty-Truck Raio (%)	
1995-2000	2000-2010	2010-2020
30.0	35.0	40.0

Source: JICA Study Team

The present output levels of agricultural products which include rice, agricultural products, and forest products were estimated based on the report "*Agricultural Development Option Review (FAO/UNDP, 1994)*" and Landsat Data. The production levels of construction materials and minerals were also derived from this report.[1]

Countrywide output of construction materials was apportioned to zones in direct correlation with population proportions, because brick-making is likely depend on population shifts and growth and bricks are typically produced close to where they are used.

As mentioned earlier, POL production is currently nonexistent in Cambodia. Although leases have been granted to a number of foreign companies for offshore and inland exploration, an assumption of zero production throughout the study period has been retained to avoid overestimating or speculating freight traffic growth due to uncertainties regarding the magnitude and location of POL production.

Food processing represents more than 50% of manufacturing, and it was therefore distributed in proportion to population. Also conversions from monetary values into

[1] *Regional Technical Assistance on Promoting Subregional Cooperation Among Cambodia, The People's Republic of China, Lao PDR, Myanmar, Thailand and Viet Nam - Subregional Transport Sector Study*, PADECO Co., Ltd., for the Asian Development Bank, 1994.

tons from the preceding report were used in this study.

Regional output levels by commodity type were estimated by applying the growth rates determined through the examination of preceding reports (Appendix 5.1).

Future traffic matrices by vehicle type were forecast by the Fratar method after applying these zonal traffic growth rates to present (i.e., 1995) OD matrices by vehicle type constructed from data obtained in the traffic survey of this study.

Similar to the domestic passenger traffic demand forecast, the future traffic volumes at Prek Tamak in year 2001 in the case with a Prek Tamak bridge were assumed to be 1.5 times higher than those forecast based on regional production levels.

(3.3) International Passenger Traffic Demand

International passenger traffic demand is related to the GDPs of origin and destination countries. Passenger traffic by road was forecast assuming that traffic grows 1.2 times faster than GDP, resulting in an average annual growth rate of 8.4% on the condition that GDP growth rates in Southeast Asian countries are around 7% per annum on average. The elasticity of international passenger traffic demand with respect to GDP seems reasonable in light of the experience of other developing countries.

The future modal share between air and road transport is assumed constant during the forecast period. Therefore, the growth rates of international passenger traffic by road were set equal to those of the total international passenger growth rates for the forecast period. The zoning system in this study was established to reflect this international traffic; future traffic matrices by vehicle type were forecast by the Fratar method after applying the zonal traffic growth rates to present (i.e., 1995) OD matrices by vehicle type.

(3.4) International Freight Traffic Demand

The principal basis for forecasting international freight movement between and among Southeast Asian countries was a comprehensive World Bank assessment of the dimensions of structural transformation during the process of development.[1]

According to this study, Cambodia and Lao PDR are classified as small, primary-sector-oriented countries, and Thailand and Vietnam are classified as large manufacturing-oriented countries. In accordance with these classifications, the study also provided clues for estimating export growth rates by commodity type. The main difficulty lies in data acquisition of international freight movement in tons; therefore, for the determination of present level international freight movement, the assets of the preceding study were utilized in this study (Table 4.30). For converting tonnage growth rates into vehicular growth rates, empty-truck ratios were considered in this study.

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[1] Moshe Syrquin and Hollis B. Chenery, *Patterns of Development, 1950 to 1983*, World Bank Discussion Paper No. 41, 1989.

Table 4.30 Growth Rates of International Freight

Country		Product	Freight Volume (tons)	Export Growth Rate (%)		
From	To		1995	1995-2000	2000-2010	2010-2020
Cambodia -->	Vietnam	Rice, Agriculture, and Forestry	213,798	6	5	5
		Petroleum, Oil, Lubricants, and Minerals	-	12	7	5
		Manufactures and Construction Materials	-	7.5	8	8.5
		Total (weighted)	213,798	0.4	0.4	0.7
Vietnam -->	Cambodia	Rice, Agriculture, and Forestry	12,979	4	5	6
		Petroleum, Oil, Lubricants, and Minerals	-	8	7	7
		Manufactures and Construction Materials	17,854	15	14	14
		Total (weighted)	30,833	10.9	11.9	13.0
Cambodia -->	Laos	Rice, Agriculture, and Forestry	8,427	6	5	5
		Petroleum, Oil, Lubricants, and Minerals	-	12	7	5
		Manufactures and Construction Materials	8,587	7.5	8	8.5
		Total (weighted)	17,014	6.8	6.7	7.2
Laos -->	Cambodia	Rice, Agriculture, and Forestry	3,371	6	5	5
		Petroleum, Oil, Lubricants, and Minerals	-	12	7	5
		Manufactures and Construction Materials	-	7.5	8	8.5
		Total (weighted)	3,371	6.0	5.0	5.0
Cambodia -->	Thailand	Rice, Agriculture, and Forestry	1,002,273	6	5	5
		Petroleum, Oil, Lubricants, and Minerals	-	12	7	5
		Manufactures and Construction Materials	3,435	7.5	8	8.5
		Total (weighted)	1,005,707	0.0	0.1	0.2
Thailand -->	Cambodia	Rice, Agriculture, and Forestry	57,298	6	6	6
		Petroleum, Oil, Lubricants, and Minerals	52,128	7	7	7
		Manufactures and Construction Materials	18,747	14	14	14
		Total (weighted)	128,174	7.7	8.4	9.5
Vietnam -->	Thailand	Rice, Agriculture, and Forestry	168,796	4	5	6
		Petroleum, Oil, Lubricants, and Minerals	133,602	8	7	7
		Manufactures and Construction Materials	5,857	15	14	14
		Total (weighted)	308,256	4.2	4.9	6.3
Thailand -->	Vietnam	Rice, Agriculture, and Forestry	37,184	6	6	6
		Petroleum, Oil, Lubricants, and Minerals	217,512	7	7	7
		Manufactures and Construction Materials	6,435	14	14	14
		Total (weighted)	261,131	7.1	7.2	7.5
Laos -->		Rice, Agriculture, and Forestry	48%	6	5	5
		Petroleum, Oil, Lubricants, and Minerals	8%	12	7	5
		Manufactures and Construction Materials	44%	7.5	8	8.5
		Total (weighted)	307,000	7.2	6.6	6.9
-->	Laos	Rice, Agriculture, and Forestry	2%	-	-	-
		Petroleum, Oil, Lubricants, and Minerals	50%	-	-	-
		Manufactures and Construction Materials	48%	-	-	-
		Total (weighted)	350,000	7	7	7

Source: After Moshe Syrquin and Hollis B. Chenery, Patterns of Development: 1950 to 1983, World Bank Discussion Paper No. 41, 1989, and PADECO Co., Ltd., Regional Technical Assistance on Promoting Subregional Cooperation Among Cambodia, The People's Republic of Chian, Lao PDR, Myanmar, Thailand and Viet Nam - Subregional Transport Sector Study, First Interim Report, for the Asian Development Bank, 1994

As with international passenger traffic demand, future traffic matrices by vehicle were forecast by the Fratar method after applying the zonal traffic growth rates to present (i.e., 1995) OD matrices by vehicle type.

(4) Diverted Traffic from Other Modes

(4.1) Domestic Passenger Traffic Demand

As stated earlier, transport between Phnom Penh and Kratie and between Kompong Cham and Kratie is likely to change mode from river to road. Two major problems concerning security and road conditions are assumed to be resolved in the future, and diversion from river to road is assumed to start taking effect in 2005; this assumption was derived from the proposed implementation program in *Cambodian Transport Rehabilitation Study*. The results of the traffic survey in this study were used for calculating present transport demand between these sections. The diversion rate was determined based on the comparison of estimated modal shares, which were derived from *Cambodian Transport Rehabilitation Study*, and the traffic survey in this study. Growth rates and modal shares by vehicle type were assumed to be the same as those for domestic normal and development passenger traffic. Future traffic matrices by vehicle type were forecast by the Fratar method applying the zonal traffic growth rates to the 2005 OD matrices.

(4.2) Domestic Freight Traffic Demand

Diverted domestic freight traffic demand was forecast by a method based on the same principles as for diverted domestic passenger traffic.

(4.3) International Passenger Traffic

As stated earlier, no international diverted traffic demand from transport means other than road was considered.

(4.4) International Freight Traffic

Provided that road conditions and custom procedures are improved and that the security problem is resolved in Cambodia, there is a possibility of traffic diversion of some commodities from sea to road between Thailand and Vietnam, especially between Bangkok and Ho Chi Minh City, the two of the largest economic centers in Southeast Asia separated by less than 900 km.

All existing international trade volumes between Thailand and Vietnam were assumed to be by sea transport. Although this assumption may overestimate sea transport volumes between Thailand and Vietnam, the actual volumes of land and air freight transport is negligible according to statistical reports.[1]

The diversion rate was determined by scrutinizing present composition rates of

[1] *Feasibility Study of the Ho Chi Minh-Phnom Penh-Bangkok Road Project*, PADECO Co., Ltd., for the Asian Development Bank, 1994.

commodities, which were estimated in the course of forecasting international normal freight traffic. Growth rates were assumed to be the same as those for international normal freight traffic. For conversion from tonnage growth rates into vehicular growth rates, empty-truck ratios were considered.

Future traffic matrices by vehicle type were forecast by the Fratar method after applying the zonal traffic growth rates to present (i.e., 1995) OD matrices by vehicle type.

(5) Induced Traffic

(5.1) Passenger Traffic Demand

Induced traffic arises either because a journey becomes more attractive by virtue of a reduction in cost or time or because of increased development that is brought about by the road investment. Induced traffic is difficult to forecast accurately and can be easily overestimated. Induced traffic is likely to be significant only in those cases where the road investment brings about a large reduction in transport costs. The Mekong Bridge project can be considered to fall under such an investment.

The common approach to forecasting induced traffic is to make use of information about demand elasticities. Evidence from several countries suggests a price elasticity range of -0.6 to -2.0 with an average of -1.0. In general, the elasticity of commodity-transport demand with respect to transport cost is much smaller than that of passenger transport demand and depends on the proportion of transport cost reflected in commodity prices.[1]

In this study, transport cost was substituted by travel time and the following steps were adopted for the estimate of induced passenger traffic: (1) first, the reductions in time due to the provision of a new bridge were estimated for each OD pair; (2) the changes in travel time between the with and without bridge cases were calculated and expressed as percentage changes (e.g., travel time reduction of 30% from zone 8 to zone 1); and (3) future induced traffic OD matrices by vehicle type were forecast by applying elasticities with respect to travel time to the traffic OD matrices by vehicle type. For passenger traffic, a value of -1.0 was adopted as the elasticity (i.e., a 10% decrease in travel time would result in a 10% increase in traffic volume).

(5.2) Freight Traffic Demand

Induced freight traffic demand was forecast by a method based on the same principles as for passenger traffic demand forecast. A value of -0.4 was adopted as the elasticity (i.e., a 10% decrease in travel time would result in a 4% increase in traffic volume).

4.2.3 Forecast Traffic

Traffic volumes at bridge and ferry points were forecast by assigning the traffic matrices in pcu to the networks.

[1] Transport Research Laboratory, *Overseas Road Notes 31*, 1993.

(1) Study Cases

Present river-crossing ferry capacity is designed to accommodate the present traffic demand; therefore, it is highly likely that future traffic demand at the ferry points will exceed ferry capacity. In such a case, if additional ferry improvement projects are not carried out, traffic diversion from ferry points to other river-crossing ferries or a bridge will take place. Future traffic volumes using a bridge are assumed to be influenced by the capacities of ferries at the other ferry sites (Table 4.31 and Figure 4.9). For the estimates of ferry waiting times in the without bridge case, a simulation program was developed expressly for this study.

Table 4.31 Estimated Ferry Waiting Time

Ferry Site	Traffic Volume (both directions) (pcu./12h)	Average Waiting Time (min.)	Max. Waiting Time (12 hours/day)
Neak Loeung	1,400	5.0	10.0
	1,600	5.0	10.0
- Ferry Operation Level in 2001	1,800	5.7	15.0
ferry 1; 30 vehicle capacity	2,000	6.0	15.0
ferry 2; 20 vehicle capacity	2,200	8.8	25.0
ferry 3; 10 vehicle capacity	2,400	11.7	35.0
ferry 4 (new); 30 vehicle capacity	2,600	18.3	40.0
- Average Headway 10 min.	2,800	29.9	55.0
	3,000	61.7	75.0
	3,200	Out of Ferry Capacity	
Svay Chrum & Prek Tamak	200	7.5	15.0
	220	7.5	15.0
- Ferry Operation Level in 2001	240	8.8	30.0
ferry 1; 2 vehicle capacity	260	9.5	30.0
ferry 2; 2 vehicle capacity	280	10.3	30.0
ferry 3; 2 vehicle capacity	300	17.4	45.0
ferry 4; 2 vehicle capacity	320	18.4	45.0
- Average Headway 15 min.	340	19.5	45.0
	360	55.2	90.0
	380	58.2	90.0
	400	Out of Ferry Capacity	
Kompong Cham	600	10.0	20.0
	650	10.0	20.0
- Ferry Operation Level in 2001	700	11.4	30.0
ferry 1; 10 vehicle capacity	750	12.0	30.0
ferry 2; 6 vehicle capacity	800	12.1	30.0
ferry 3 (new); 30 vehicle capacity	850	13.3	30.0
- Average Headway 20 min.	900	20.9	50.0
	950	24.4	50.0
	1,000	28.1	70.0
	1,050	49.3	70.0
	1,100	61.9	70.0
	1,150	77.6	90.0
	1,200	Out of Ferry Capacity	

Source: JICA Study Team

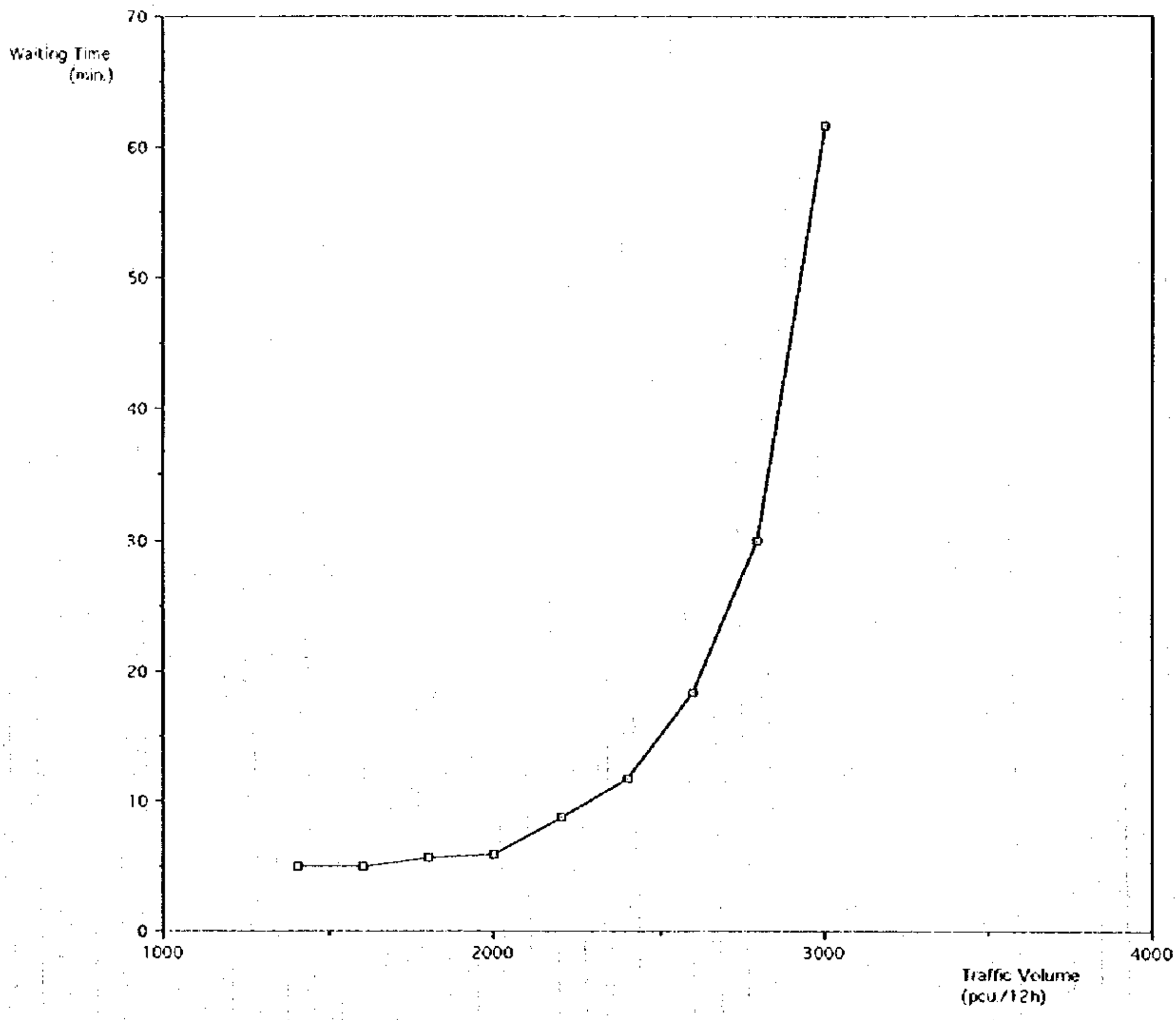


Figure 4.9 Estimated Ferry Waiting Time at Neak Loeung

In this chapter, emphasis was placed on the economic analysis of cases with and without a bridge rather than forecasting future traffic volumes on the bridge in accordance with the changes in ferry capacities. The study cases were established to ensure that the estimated project benefits were made clear by comparing with and without bridge cases.

From this point-of-view, four study cases were established: without bridge case, with Neak Loeung Bridge case, with Prek Tamak (Svay Chrum) Bridge case, and with Kompong Cham Bridge case for the years 2001, 2011, and 2021 on the following conditions:

(1.1) Without Bridge Case

If no additional ferry investments are made, the present ferry services cannot accommodate future river-crossing traffic demand. In this case, the passenger waiting times for ferries will grow enormously long and some of the traffic will divert to other river-crossing points. Eventually, the total river-crossing traffic demand within Cambodia will exceed the total capacity of three main ferry points (i.e., Neak Loeung, Prek Tamak, and Kompong Cham). To avoid an unrealistic increase in waiting times or the unsolvable problem of some traffic remaining overnight or queuing for days at ferry points, ferry improvement projects that can accommodate the latent traffic demand at each ferry point were assumed. Free flow of traffic, which means no ferry capacity constraints, was assumed at the river-crossing ferry sites in the traffic assignment procedure. At Neak Loeung, a safe ferry operation level with 8 or 9 ferry boats operating simultaneously and three landing facilities were assumed; therefore, the ferry capacity at Neak Loeung for the traffic assignment was assumed to have a ferry capacity limit equal to double that of the year 2001 level. The ferry capacities at the year 2001 level at Neak Loeung and Kompong Cham were determined including the approved ferry improvement project by DANIDA. The normal traffic OD matrix in pcu derived from the OD matrices by vehicle type and the normal traffic MC OD matrix were assigned separately during the traffic assignment procedure in this case.

(1.2) With Bridge Cases

Corresponding to the without bridge case, in the with bridge cases the capacities of river-crossing ferries were assumed to accommodate the latent transport demand at each ferry point. Therefore, additional investments for ferry capacity improvement are assumed to occur at the same time as for the without bridge case. Free flow of traffic, which means no ferry capacity constraints, was assumed at the river-crossing ferry points in the traffic assignment procedure. During the assignment, traffic capacity constraints at the bridge were considered; however, the travel time of the bridge link was set constant.

Some of the river-crossing traffic demand will change their route choice during traffic assignment because of the change in network conditions between the with and without bridge cases.

The normal and induced OD matrices in pcu derived from the OD matrices by vehicle type and the normal and induced traffic MC OD matrices were used in these cases. Traffic assignments were carried out for the OD matrix in pcu, and for the MC OD matrix (Table 4.32).

(2) Traffic Forecast Results

Traffic volumes at the bridge and ferry points in each case were forecast by assigning the traffic matrices in pcu to the networks. For the convenience in operation, OD matrices by vehicle type in each forecast year were converted into a matrix in pcu (except for MC). Traffic assignments were separately carried out for MC OD matrices and OD matrices in pcu, because MC were assumed to move in a different manner from other motorized vehicles and have lesser capacity-restraining characteristics.

Table 4.32 Traffic Assignment Cases for Economic Evaluation

Wuithout Bridge Case (2001, 2011, 2021)

Network	- free-flow at ferry points excluding the case for 2021.	
	(In 2021 ferry capacity constranit at Neak Loeung of the double level of that in 2001 is assumed.)	
	(Travel time was considered at ferry point.)	
VTOD	assignment(1)	- Normal Traffic (incl. Development and Diverted Traffic) by Vehicle type excluding MC
	assignment(2)	- Normal Traffic (incl. Development and Diverted Traffic) for MC

With Neak Loeung Bridge Case (2001, 2011, 2021)

Network	- free-flow at ferry points other than Neak Loeung	
	(Travel time and no ferry capacity constraint were considered at ferry point.)	
	(Travel time was considered at ferry point.)	
VTOD	assignment(1)	- Normal Traffic (incl. Development and Diverted Traffic) by Vehicle type excluding MC
		- Induced (incl. Development and Diverted Traffic) by Vehicle type excluding MC
	assignment(2)	- Normal Traffic (incl. Development and Diverted Traffic) for MC
		- Induced (incl. Development and Diverted Traffic) for MC

With Prek Tamak (Svay Chrum) Bridge Case (2001, 2011, 2021)

Network	- free-flow at ferry points excluding the case for 2021.	
	(In 2021 ferry capacity constranit at Neak Loeung of the double level of that in 2001 is considered.)	
	(Travel time was considered at ferry point.)	
VTOD	assignment(1)	- Normal Traffic (incl. Development and Diverted Traffic) by Vehicle type excluding MC
		- Induced (incl. Development and Diverted Traffic) by Vehicle type excluding MC'
	assignment(2)	- Normal Traffic (incl. Development and Diverted Traffic) for MC
		- Induced (incl. Development and Diverted Traffic) for MC

With Kompong Cham Bridge Case (2001, 2011, 2021)

Network	- free-flow at ferry points excluding the case for 2021.	
	(In 2021 ferry capacity constranit at Neak Loeung of the doublo level of that in 2001 is considered.)	
	(Travel time was considered at ferry point.)	
VTOD	assignment(1)	- Normal Traffic (incl. Development and Diverted Traffic) by Vehicle type excluding MC
		- Induced (incl. Development and Diverted Traffic) by Vehicle type excluding MC
	assignment(2)	- Normal Traffic (incl. Development and Diverted Traffic) for MC
		- Induced (incl. Development and Diverted Traffic) for MC

Note: It can be considered that additional costs of ferry capacity improvement in without Bridge case for vehicle overflowing at ferry points are benefit of Bridge.

VOCs related to change in travel distance caused by ferry capacity constraint and reduction of travel time by bridge is considered as benefit of Bridge.

Benefit = Additional costs of ferry capacity improvement (without bridge case)

+ Reduction of passenger/Cargo time costs by the Bridge
+ Savings in ferry operation costs (with bridge case)
+ Vehicle operating costs related to change in travel distance

The MINUTP software was utilized for handling OD matrices, performing Fratar calculations, and computing the traffic assignments. MINUTP is a suite of computer programs that provide the capability to perform the usual functions of traditional transport planning with regard to trip generation, distribution, network assignment, etc.

The highest traffic volume was forecast at Neak Loeung; the traffic volume in pcu at Neak Loeung in the case of a Neak Loeung Bridge was forecast around 1,800 pcu/day in 2001, 4,700 pcu/day in 2011, and 11,400 pcu/day in 2021. The Prek Tamak (Svay Chrum) Bridge case and Kompong Cham Bridge case follow with similar magnitudes of traffic volume. Note that the 1995 traffic volumes for the Neak Loeung, Prek Tamak, and Kompong Cham ferries crossings in terms of pcv/day (not including NMVs and MCs) were 970, 80 and 260, respectively.

It can be seen that latent traffic demand at each ferry point will exceed year 2001 ferry capacity by 2011. The results of the traffic assignments are shown in Tables 4.33 through 4.35.

Table 4.33 Traffic Assignment Results for Year 2001 at the Three River Crossings

Description	Neak Loeung River Crossing	Prek Tamak River Crossing	Kompong Cham River Crossing
Normal Traffic in pcu. (not incl. MC) (pcu./day)			
1. No Bridge Senario	1,540	120	480
2. Bridge at Neak Loeung	1,560	110	480
3. Bridge at Prek Tamak	1,340	910	190
4. Bridge at Kompong Cham	1,540	120	480
Induced Traffic in pcu. (not incl. MC) (pcu./day)			
1. No Bridge Senario	-	-	-
2. Bridge at Neak Loeung	230	0	0
3. Bridge at Prek Tamak	0	170	0
4. Bridge at Kompong Cham	0	0	130
Normal Traffic for MC (veh./day)			
1. No Bridge Senario	1,910	2,460	1,770
2. Bridge at Neak Loeung	1,970	2,400	1,770
3. Bridge at Prek Tamak	950	5,510	1,510
4. Bridge at Kompong Cham	1,910	2,460	1,770
Induced Traffic for MC (veh./day)			
1. No Bridge Senario	-	-	-
2. Bridge at Neak Loeung	520	0	0
3. Bridge at Prek Tamak	0	1,900	0
4. Bridge at Kompong Cham	0	0	990

Source: JICA Study Team

Note: Normal Traffic figures also include those for Development and Diverted Traffic

Table 4.34 Traffic Assignment Results for Year 2011 at the Three River Crossings

Description		Neak Loeung River Crossing	Prek Tamak River Crossing	Kompong Cham River Crossing
Normal Traffic in pcu. (not incl. MC) (pcu./day)				
1.	No Bridge Senario	4,110	390	1,890
2.	Bridge at Neak Loeung	4,150	340	1,890
3.	Bridge at Prek Tamak	3,510	1,930	940
4.	Bridge at Kompong Cham	4,100	390	1,890
Induced Traffic in pcu. (not incl. MC) (pcu./day)				
1.	No Bridge Senario	-	-	-
2.	Bridge at Neak Loeung	580	0	0
3.	Bridge at Prek Tamak	0	350	0
4.	Bridge at Kompong Cham	0	0	410
Normal Traffic for MC (veh./day)				
1.	No Bridge Senario	4,920	6,520	4,980
2.	Bridge at Neak Loeung	5,120	6,330	4,980
3.	Bridge at Prek Tamak	2,430	9,500	4,490
4.	Bridge at Kompong Cham	4,920	6,520	4,980
Induced Traffic for MC (veh./day)				
1.	No Bridge Senario	-	-	-
2.	Bridge at Neak Loeung	1,360	0	0
3.	Bridge at Prek Tamak	0	3,330	0
4.	Bridge at Kompong Cham	0	0	2,780

Source: JICA Study Team

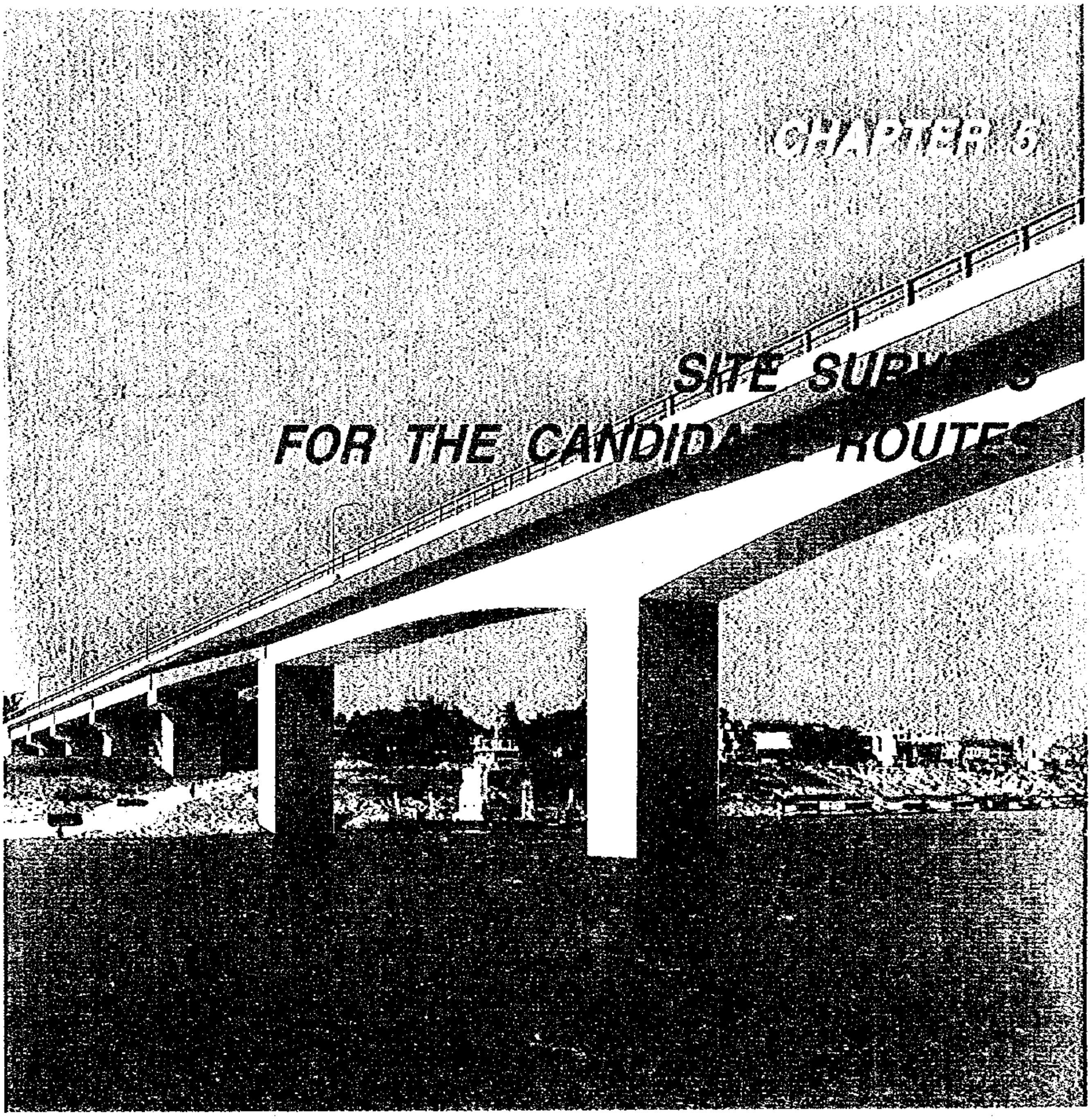
Note: Normal Traffic figures also include those for Development and Diverted Traffic

Table 4.35 Traffic Assignment Results for Year 2021 at the Three River Crossings

	Neak Loeung River Crossing	Prek Tamak River Crossing	Kompong Cham River Crossing
Normal Traffic in pcu. (not incl. MC) (pcu./day)			
1. No Bridge Senario	6,340	4,610	4,900
2. Bridge at Neak Loeung	10,010	930	4,900
3. Bridge at Prek Tamak	6,190	6,760	2,890
4. Bridge at Kompong Cham	6,300	4,460	5,080
Induced Traffic in pcu. (not incl. MC) (pcu./day)			
1. No Bridge Senario	-	-	-
2. Bridge at Neak Loeung	1,390	0	0
3. Bridge at Prek Tamak	0	940	0
4. Bridge at Kompong Cham	0	0	1,140
Normal Traffic for MC (veh./day)			
1. No Bridge Senario	4,920	6,520	4,980
2. Bridge at Neak Loeung	5,120	6,330	4,980
3. Bridge at Prek Tamak	2,430	9,500	4,490
4. Bridge at Kompong Cham	4,920	6,520	4,980
Induced Traffic for MC (veh./day)			
1. No Bridge Senario	-	-	-
2. Bridge at Neak Loeung	1,360	0	0
3. Bridge at Prek Tamak	0	3,330	0
4. Bridge at Kompong Cham	0	0	2,780

Source: JICA Study Team

Note: Normal Traffic figures also include those for Development and Diverted Traffic


CHAPTER 5
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CHAPTER 5 SITE SURVEY FOR THE CANDIDATE ROUTES

The site surveys performed at each of the alternative bridge sites, originally identified, consisted of topographic and bathymetric surveys and geological investigations. These are discussed below.

5.1 Topographic and Bathymetric Surveys

The detailed topographic and bathymetric field surveys of the six alternative bridge crossings and topographic surveys of all road approaches were performed during the period from 21 April 1995 to 10 June 1995.

5.1.1 Topographic Surveys

Topographic surveys included setting up bridge centerlines, setting up centerlines of approach roads, taking cross-sections at 50 m intervals, for a width of 100 m from either side of the centerline (i.e., a 200 m band), and noting the surrounding topography, structures, roads, and other features. Temporary bench marks made of concrete were also established.

Topographic surveys for bridges (overland portion) and approach roads were carried out over the following approximate lengths:

Neak Loeung A-1 Site	4,300 m
Neak Loeung A-2 Site	3,200 m
Prek Tamak B-1 Site	2,900 m
Prek Tamak (Svay Chrum) B-2 Site	2,500 m
Kompong Cham C-1 Site	1,500 m(*)
Kompong Cham C-2 Site	3,100 m

(*) Up to the point where the eastern approach road alignments of C-1 and C-2 coincide

The following survey drawings were produced:

- Alignment and topography plans at a scale of 1:1,000, showing the centerline of surveyed bridge and approach roads; layout of existing roads, including centerline, edges of roadway and width; structures and other obstructions (such as buildings, walls, fences, electric poles, telephone poles, lamp posts, trees, etc.); location and type of above ground services; location of river edges; location of ponds, swamps, canals, and streams; and other topographic data.

- Cross-sections at scales of 1:1,000 horizontal and 1:100 vertical.

- Plans and ground profiles of bridges at scales of 1:2,500 horizontal and 1:1,000 vertical, showing existing ground levels, river depths, and water levels.

- Plans and profiles of approach roads at scales of 1:2,500 horizontal and 1:1,000 vertical, showing existing ground levels and estimated design levels.

- Existing topographic maps at scales of 1:50,000 and 1:250,000 covering the entire study area, and aerial photographs at a scale of 1:10,000 (enlarged from original prints of 1:25,000), covering all bridge sites, approach roads, Route 315, Route 151, and the area between Routes 151 and 315, were procured and studied. Photomosaic maps of Routes 151 and 315 were prepared.

5.1.2 Bathymetric Surveys

Bathymetric surveys consisted of several river cross sections at each site taken by echo sounding in the river and by normal land surveying between the water line and the river bank.

The following river cross-sections were taken at each site:

Neak Loeung A-1 Site	7 sections, about 900 m wide
Neak Loeung A-2 Site	7 sections, about 950 m wide
Prek Tamak B-1 Site	7 sections, about 750 m wide
Prek Tamak (Svay Chrum) B-2 Site	7 sections, about 1,000 m wide
Kompong Cham C-1 Site	7 sections, about 700 m wide
Kompong Cham C-2 Site	7 sections, about 1,000 m wide

The following bathymetric drawings were produced:

River cross-sections at scales of 1 :2,000 horizontal and 1:750 vertical.

River bed contour plans at 1:2,000 scale, showing contour lines every 2 m, and edges of river bank and water line.

5.1.3 General Topography and Bathymetry at Bridge Sites

The terrain at each site is generally flat, with slopes averaging less than one percent. Elevations are normally higher at the edge of river banks, with the difference between bank edge and lowest inland levels being a few meters. River bottom elevations range from -21 m to -26 m, except at the Kompong Cham C-1 site where river bottom elevation is -46 m. Features of river crossings and approach routes at each site are summarized in Tables 5.1 through 5.6.

5.1.4 General Topography of Connecting Roads

Connecting roads are those linking the approaches to Prek Tamak sites B-1 and B-2 with Route 11. For B-1, the connecting road would be Route 315. For B-2, the connecting road would consist of about 7.5 km of Route 151, from Svay Chrum to Taval; 10 km of a new road, from Taval to Thmei; and 48 km of Route 315, from Thmei to Route 11 at Svay Antor.

The 60 km length of Route 315 (starting at km 0 in Prek Tamak) crosses flat terrain, ranging in elevation between 8 m and 12 m, except for a 3 km long section between km 3 to km 6 where the elevation is lower.

Table 5.1 Neak Loeung A-1 Site Features

River Crossing

Width - Main Channel	575 m
- Secondary Channel	255 m
- Island	815 m
Bottom Elevation (Main Channel)	-22.0 m
West Bank Edge Elevation	7.7 m
East Bank Edge Elevation	8.0 m

Western Approach Route

Length	755 m
Highest Ground Elevation	7.7 m
Lowest Ground Elevation	4.8 m

Vicinity - The approach route runs in a westward direction from the western edge of the secondary channel to its junction with Route 1 (see Figure 3.2). It intersects two local earth roads which run parallel to the river. The first road is situated near the river, and the second about 400 m inland. There are houses alongside both local roads with farmland in between them.

Easter Approach Route

Length	2,940 m
Highest Ground Elevation	8.0 m
Lowest Ground Elevation	2.9 m

Vicinity - The approach route runs eastward from the eastern edge of the main channel, intersecting Route 11, and then turns southward to its junction with Route 1 (see Figure 3.2). It intersects several small access roads. There are houses alongside Route 11, the access roads, and Route 1. A temple is situated near the junction with Route 11. The route crosses an area of bushland and several ponds subject to severe flooding.

Table 5.2 Neak Loeung A-2 Site Features

River Crossing

Width	880m
Bottom Elevation	-21.0 m
West Bank Edge Elevation	7.0 m
East Bank Edge Elevation	8.0 m

Western Approach Route

Length	1,550 m
Highest Ground Elevation	7.0 m
Lowest Ground Elevation	5.8 m

Vicinity - The approach route runs in a north-westward direction from the edge of the river to its junction with Route 1 (see Figure 3.2). It intersects one local earth road and one access road situated near the river. There are houses alongside the local and access roads and Route 1 with farmland in between.

Eastern Approach Route

Length	1,670 m
Highest Ground Elevation	8.0 m
Lowest Ground Elevation	5.5 m

Vicinity - The approach route runs north-eastward from the river's edge to its junction with Route 1 (see Figure 3.2). It intersects a local road situated alongside the river and several small access roads. There is a small clinic near the intersection with the local road, and houses alongside Route 1 and the local and access roads. Most of the surrounding area is farmland.

Table 5.3 Prek Tamak B-1 Site Features

River Crossing

Width	700 m
Bottom Elevation	-26.0 m
West Bank Edge Elevation	8.5 m
East Bank Edge Elevation	10.5 m

Western Approach Route

Length	400 m
Highest Ground Elevation	10.6 m
Lowest Ground Elevation	7.6 m

Vicinity - The approach route runs in a north-westward direction from the river to its junction with Route 6A (see Figure 3.3). It intersects one local earth road and one access road situated near the river. There are houses alongside the local and access roads and Route 6A with farmland in between.

Eastern Approach Route

Length	1,235 m
Highest Ground Elevation	1 0.5 m
Lowest Ground Elevation	7.6 m

Vicinity - The approach route runs south-eastward from the river to its junction with Route 315 (see Figure 3.3). It intersects two local roads, one situated alongside the river and the other (Route 151) about 200 m inland. There are houses along the local roads and Route 315, and a temple near the junction of the approach road and Route 315. Most of the surrounding area is farmland.

Table 5.4 Prek Tamak (Svay Chrum) B-2 Site Features

River Crossing

Width	970 m
Bottom Elevation	-21.0 m
West Bank Edge Elevation	9.8 m
East Bank Edge Elevation	9.2 m

Western Approach Route

Length	1,150 m
Highest Ground Elevation	9.8 m
Lowest Ground Elevation	4.0 m

Vicinity- The approach route runs in a westward direction from the river to its junction with Route 6A (see Figure 3.3). It intersects one local earth road situated near the river and several access roads. There are houses alongside the local and access roads and Route 6A. The area between river and Route 6A consists of farmland, bushland, and ponds and is subjected to severe flooding.

Eastern Approach Route

Length	1,380 m
Highest Ground Elevation	9.6 m
Lowest Ground Elevation	4.3 m

Vicinity - The approach route runs north-eastward from the river to its junction with Route 151 (see Figure 3.3). It intersects two local roads situated parallel to the river and crosses a swamp about 200 m wide. There are houses along Route 151 and the other local roads. Most of the surrounding land is bush land and swamps subject to flooding.

The first 7.5 km section of the B2 connecting road (on Route 151) is generally on flat terrain above 10 m in elevation. The 10 km section from Taval to Thmei crosses several swamps and low-lying areas subject to severe flooding. Over the next 48 km the road coincides with Route 315, ranging in elevation between 8 m and 12 m.

Table 5.5 Kompong Cham C-1 Site Features

River Crossing

Width	580 m
Bottom Elevation	-46.0 m
West Bank Edge Elevation	16.1 m
East Bank Edge Elevation	11.5 m

Western Approach Route

Length	650 m
Highest Ground Elevation	16.9 m
Lowest Ground Elevation	12.3 m

Vicinity - The western approach route lies within the city of Kompong Cham, intersecting several streets (see Figure 3.4).

Eastern Approach Route

Length	3,070 m
Highest Ground Elevation	13.5 m
Lowest Ground Elevation	9.0 m

Vicinity - The approach route first runs eastward from the river past its junction with a local road situated alongside the river. It then turns southward to its junction with Route 7 (see Figure 3.4). It intersects some access roads near Route 7. There are houses alongside Route 7 and the various local and access roads. Most of the surrounding area consists of farmland and bushland subject to flooding.

Table 5.6 Kompong Cham C-2 Site Features

River Crossing

Width	890 m
Bottom Elevation	-26.0 m
West Bank Edge Elevation	15.1 m
East Bank Edge Elevation	13.9 m

Western Approach Route

Length	720 m
Highest Ground Elevation	15.9 m
Lowest Ground Elevation	14.5 m

Vicinity - The western approach route lies within the city of Kompong Cham, intersecting several streets (see Figure 3.4).

Eastern Approach Route

Length	2,370 m
Highest Ground Elevation	14.6 m
Lowest Ground Elevation	9.7 m

Vicinity - The approach route first runs eastward from the river past its junction with a local road situated alongside the river. It then turns southward to its junction with Route 7 (see Figure 3.4). It intersects some access roads near Route 7. There are houses alongside Route 7 and the various local and access roads. Most of the surrounding area consists of farmland and bushland that is subject to flooding.

5.2 Geological Survey

5.2.1 Outline of Geology in the Study Area

The study area includes Neak Loeung, Prek Tamak, and Kompong Cham on the Central Plain in Cambodia. The elevation of the study area ranges from 10 to 30 m above sea level. Alluvium deposit formed by the Mekong River widely covers this area. Other formations are not observable on the ground surface except at the right-hand side (i.e., west bank) of the Kompong Cham site.

Geological drilling results show that the geology of the study area comprises Alluvium formation, Diluvium formation, Tertiary formation, and Mesozoic formation. Except for tertiary formation, these formations are each divided into the sand layer and clay layer.

The first formation is Alluvium formation of Holocene and Recent. This formation mainly consists of sand, gravel, silt, and clay, widely covering the study area. These deposits form river terraces and active flood plains, including buried channels along the Mekong River. The drilling results show that this layer can be divided into a sand layer (As) and a clay layer (Ac). The N-value of this formation is below 10; therefore, this formation is not suitable for bridge foundations.

The second formation is Diluvium formation of Pleistocene. This formation lies under the Alluvium formation. This formation is comprised of a clay layer and a sand layer. The drilling results show that these layers are unconsolidated or semiconsolidated and can be divided into a sand layer (Ds) and a clay layer (Dc). The N-value of this formation ranges from 20 to 40. This formation is not suitable for foundations of large structures due to the heterogeneity of consolidation and the N-value.

The third formation is Tertiary formation. This formation comprises basaltic lava (Tb). Basaltic lava bearing olivine with joints can be observed at the right-hand side of the Mekong River at the Kompong Cham site. The distribution area of this formation is limited to the Kompong Cham site in the study area. As it is estimated that the compressive strength of this basalt rock is more than 100 kg/cm2 and the internal friction angle is about 40 degrees, this formation is suitable for bridge foundations.

The last formation is Mesozoic formation. Drilling results show that Mesozoic formation lies beneath the Diluvium formation and can be divided into a weathered sandstone layer (Ms) and a hard clay layer (Mc). This formation is distributed from the Neak Loeung site to the Kompong Cham site. As the strength of this formation is estimated to have a compressive strength of about 40kg/cm2 and the cohesion is about 10-30 kg/cm2, this formation is sufficient for bridge foundations.

This geological sequence is shown in Table 5.7.

Table 5.7 Geological Formation for Bridge Foundation

Geological Age	Formation	Description	Suitability for Foundation
Holocene	Alluvium	Clay (Ac), Sand (As)	Not suitable
Pleistocene	Diluvium	Clay (Ds), Sand (Ds)	Not suitable
Tertiary	Basaltic Lava	Basaltic Rocks (Tb)	Suitable
Mesozoic	Sandstone	Hard Clay (Mc)	Suitable
		Weathered Ss (Ms)	Suitable

5.2.2 Geological Site Conditions

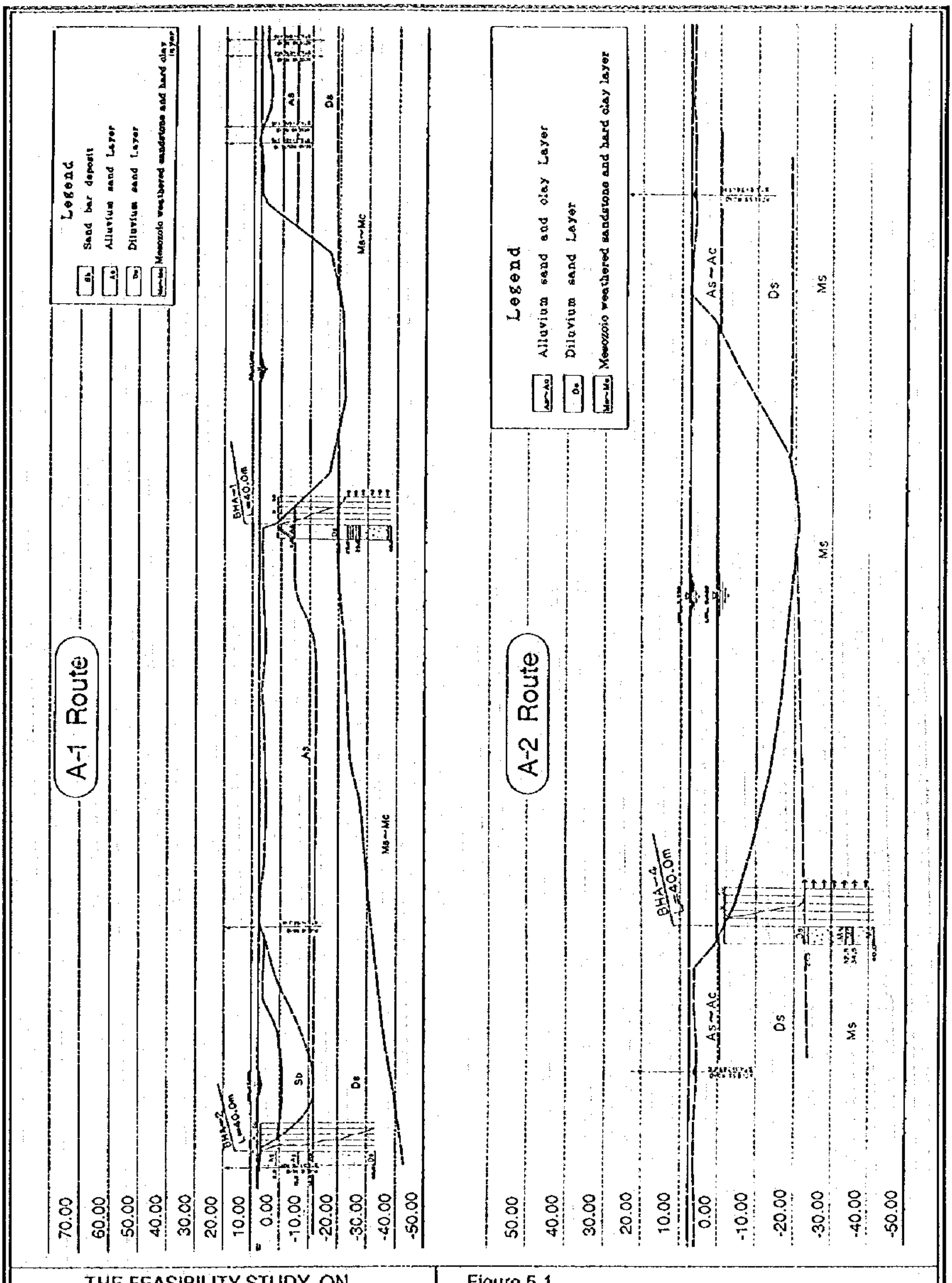
(1) Neak Loeung Site

At the Neak Loeung site the Study Team performed geological drilling tests along the A-1 and A-2 routes, as shown in the Appendix 5. The geology can be described as Alluvium deposit (As), Diluvium sediment (Ds), and Mesozoic Sandstone (Ms) as the base rock along the A1 route. Alluvium deposit (As) composed of sand is observed on the ground surface. The thickness of this deposit is estimated at about 10-15 m. Diluvium sediment lies beneath the Alluvium deposit (As). Diluvium sediment (Ds) also comprises sand. Some drilling results show that the N-value of this sediment, according to the Standard Penetration Test, ranges from 10 to 40. The thickness of this layer is greater than 15 m. The Mesozoic sandstone formation is distributed below the Diluvium sediment. This formation is formed by a hard clay layer and a weathered sandstone layer. The hard clay layer is partly situated lenticularly.

The geology can be also described by Alluvium deposit (As), Diluvium sediment (Ds), and Mesozoic Sandstone (Ms) as the base rock along the A-2 route. The thickness of the Alluvium deposit (As) is estimated at about 10 m from the ground surface. The Diluvium sediment (Ds) lies underneath the Alluvium deposit (As). Some drilling results show that the N-value of this sediment, according to the Standard Penetration Test, ranges from 10 to 40. The thickness of this layer is about 20 m. The Mesozoic sandstone formation is distributed below the Diluvium sediment. This formation is formed by a hard clay layer and a weathered sandstone layer. Therefore, the foundation for the bridge would be 30m below the ground surface. The geological profile along the A-2 route is shown in Figure 5.1.

(2) Prek Tamak Site

At the Prek Tamak site, the Study Team performed geological drilling tests along the B-1 and B-2 routes, as shown in the Appendix. The geological conditions along both routes at the Prek Tamak Site are generally similar to those of the Neak Loeung site. Along the B-1 and B-2 routes, the thickness of Alluvium deposit (As~Ac) is estimated at about 10-15 m below the ground surface. The Diluvium sediment (Ds) lies below the Alluvium deposit (As ~Ac). Some drilling results



THE FEASIBILITY STUDY ON CONSTRUCTION OF THE MEKONG BRIDGE IN KINGDOM OF CAMBODIA	Figure 5.1 Geological Profile at Neak Loeung (A-1 and A-2 Routes)
	JAPAN INTERNATIONAL COOPERATION AGENCY

show that the N-value of this sediment ranges from 10 to 40. The Mesozoic sandstone layer (Ms), which is suitable for bridge foundation, is below the Diluvium sediment. The top surface line of the Mesozoic sandstone layer (Ms) is uneven due to past scouring of the old Mekong River. The geological profiles along the B-1 and B-2 routes are shown in Figures 5.2, respectively.

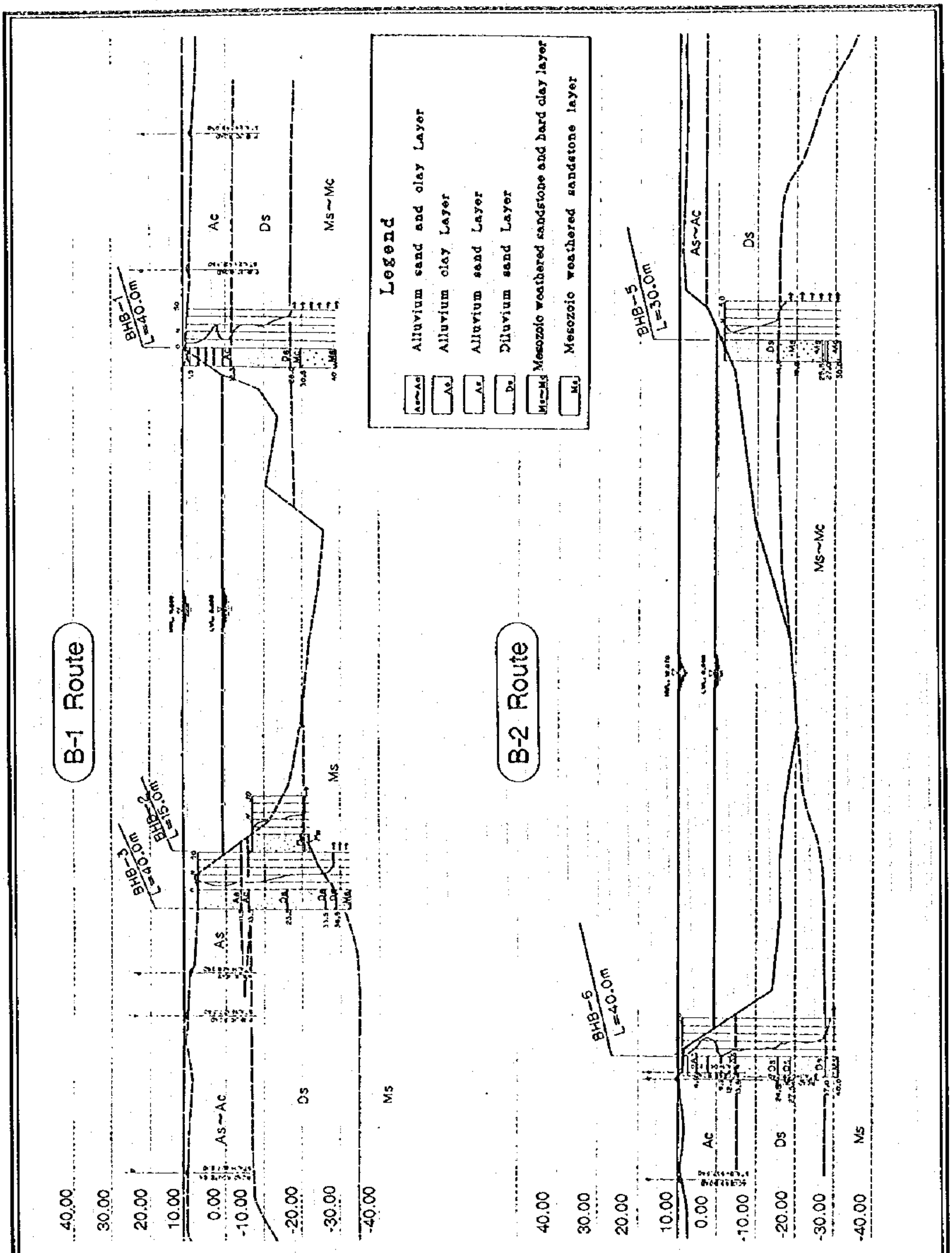
(3) Kompong Cham Site

At the Kompong Cham site, the Study Team performed geological drilling tests along the C-1 and C-2 routes, as shown in the Appendix. At the Kompong Cham site, the geological conditions are different between the C-1 and C-2 routes.

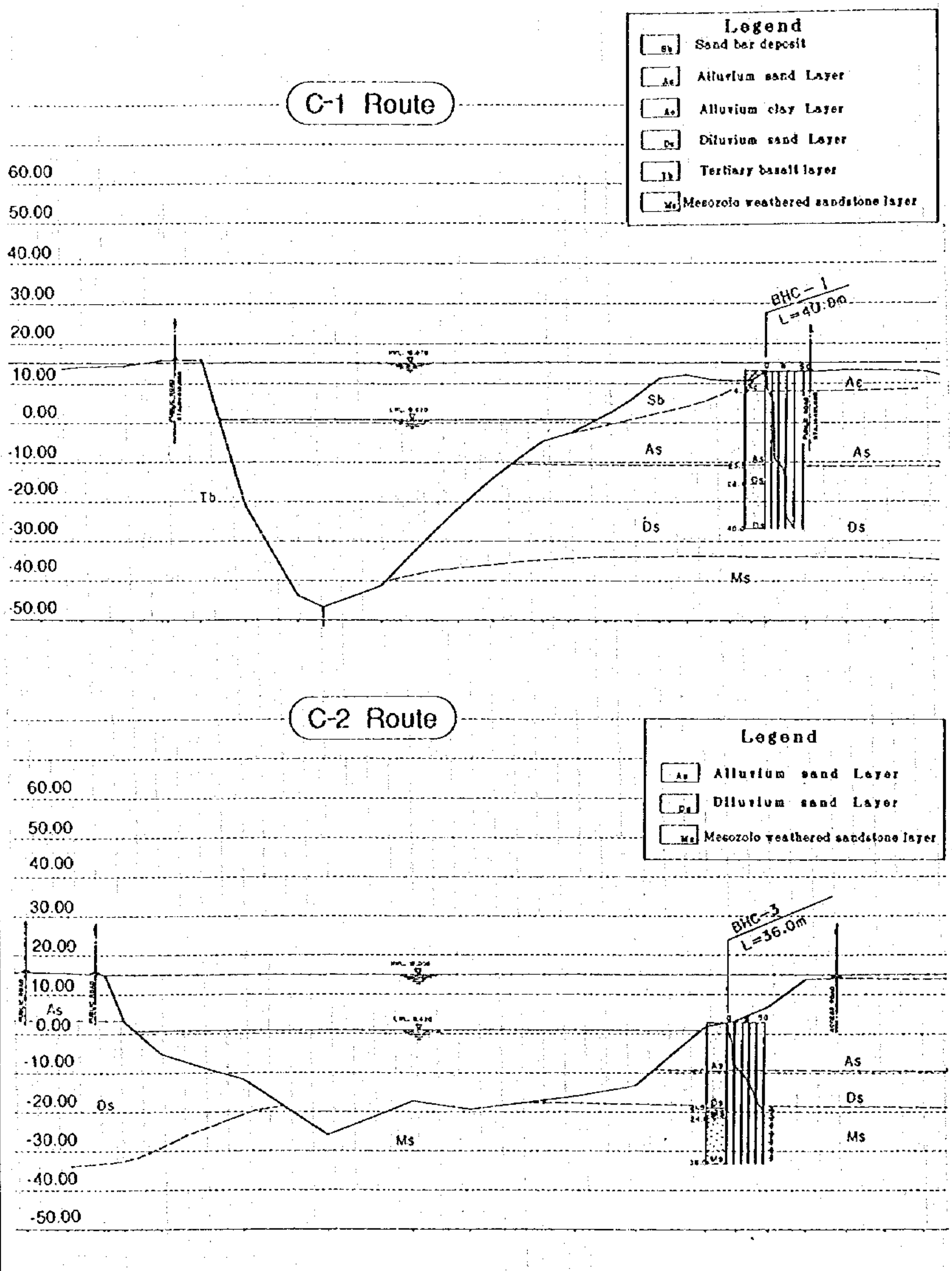
On the right-hand side of Mekong River (i.e., west bank), Basaltic lava (Tb) can be observed on the ground surface along the C-1 route. This lava (Tb) with several joints comprises hard basalt rocks of Late Tertiary Era. The steep slope of the western river bank demonstrates that the outcrops of this lava are on that slope. This lava (Tb) is suitable for bridge foundation.

On the left side of the river, the geological conditions can be described by Sandbar deposit (Sb), Alluvium deposit (As), Diluvium sediment (Ds), and Mesozoic Sandstone layer (Ds) as the base rock. Although the drilling did not reach the Mesozoic Sandstone layer (Ds), the top surface of the Mesozoic Sandstone layer (Ds) is expected to lie about 50 m below the ground surface.

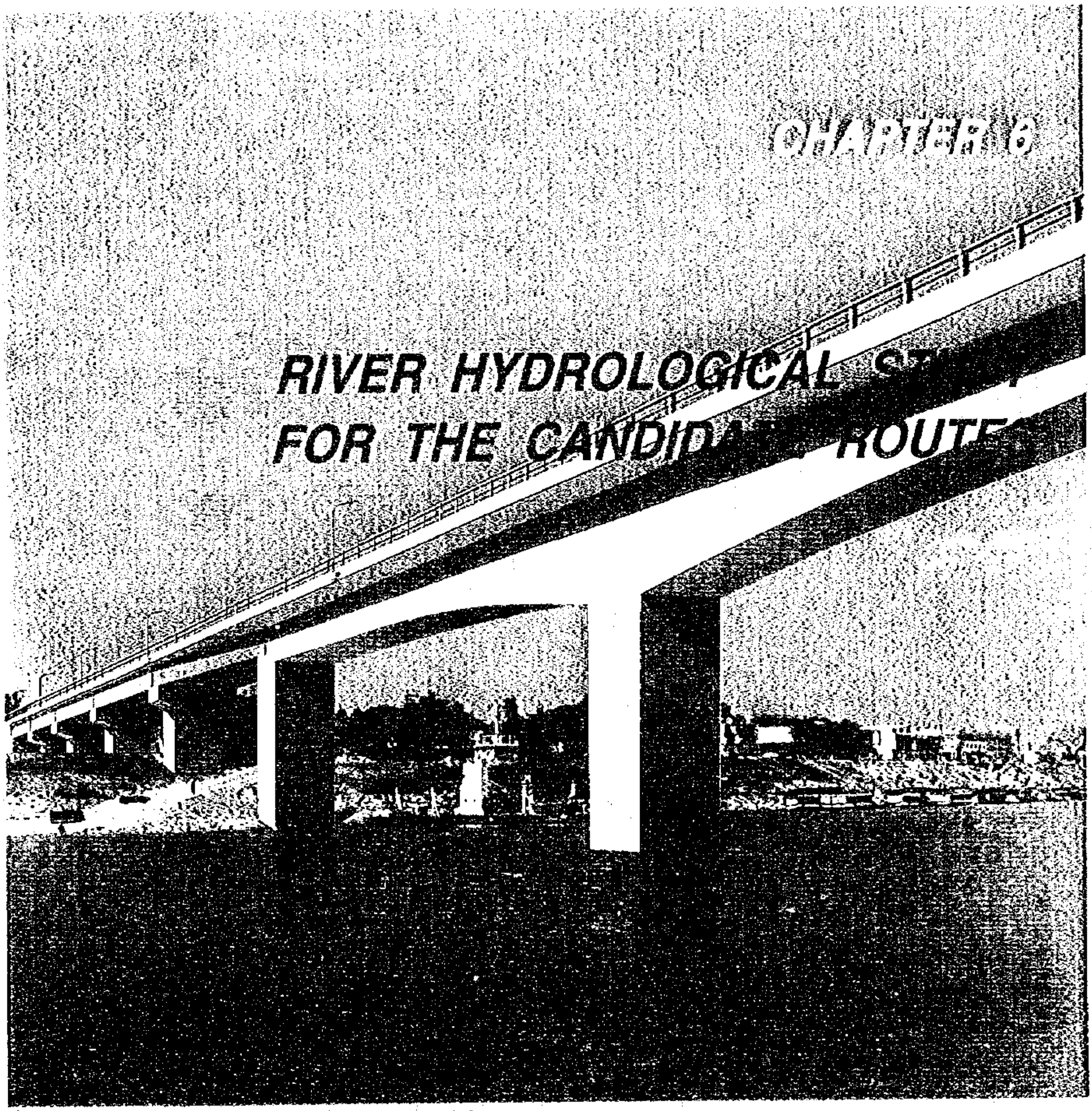
Basaltic lava (Tb) is not observed on the right-hand side of the Mekong River along the C-2 route. The geology along the C-2 route can be described by Alluvium deposit (As), Diluvium sediment (Ds), and Mesozoic Sandstone (Ms) as the base rock. The thickness of Alluvium deposit (As) is 10~20 m from the ground surface. The Diluvium sediment (Ds) lies underneath the Alluvium deposit. Some drilling results show that the N-value of this sediment, according to the Standard Penetration Test, ranges from 10 to 40; the thickness of the layer is greater than 10 m. The Mesozoic sandstone formation (Ms) as base rock is distributed below the Diluvium sediment. This formation (Ms) comprises a weathered sandstone layer. Although the Mesozoic sandstone formation (Ms) was confirmed by the drilling tests in the river, the top surface of the base rock on the right-hand side along the C-2 route is estimated to be about 50 m below the ground surface due to the scouring of the old Mekong River. The geological profile along the C-2 route is shown in Figure 5.3.



THE FEASIBILITY STUDY ON CONSTRUCTION OF THE MEKONG BRIDGE IN KINGDOM OF CAMBODIA	Figure 5.2 Geological Profile at Prek Tamak (B-1 and B-2 Routes)
	JAPAN INTERNATIONAL COOPERATION AGENCY



THE FEASIBILITY STUDY ON CONSTRUCTION OF THE MEKONG BRIDGE IN KINGDOM OF CAMBODIA	Figure 5.3 Geological Profile at Kompong Cham (C-1 and C-2 Routes)
	JAPAN INTERNATIONAL COOPERATION AGENCY


CHAPTER 6
RIVER HYDROLOGICAL
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CHAPTER 6 RIVER HYDROLOGICAL STUDY

6.1 Climate and Hydrology

6.1.1 General Features of the Mekong River

The Mekong River originates in the Tibetan Highlands with an elevation of some 5,000 m above sea level. The river flows down through the countries of Myanmar, Laos, Thailand, Cambodia and Vietnam, and then finally runs into the South China Sea at the south end of the Indo-Chinese Peninsula. The catchment area of the Mekong River is 795,000 km2, and the length of the water course is 4,200 km. Location map of the Mekong River basin is show in Figure 6.1.

Around the Tibetan Highlands, the Mekong River runs parallel with the Yangtze River and the Salween River forming deep gorges. From its origin to the Golden Triangle, which is the area around the borders of Myanmar, Thailand, and Laos, the river has a rather steep slope of around 1/400 on average. The river slope becomes gradually gentle after the Golden Triangle. The average river slope is around 1/2,500 from the Golden Triangle to Vientiane. Downstream from Vientiane, the river runs almost north to south along the border of Thailand and Laos and then into Cambodia. The river slope is gentle in general except around the Khone Falls. The average river slope is 1/8,500 from Vientiane to Phnom Penh.

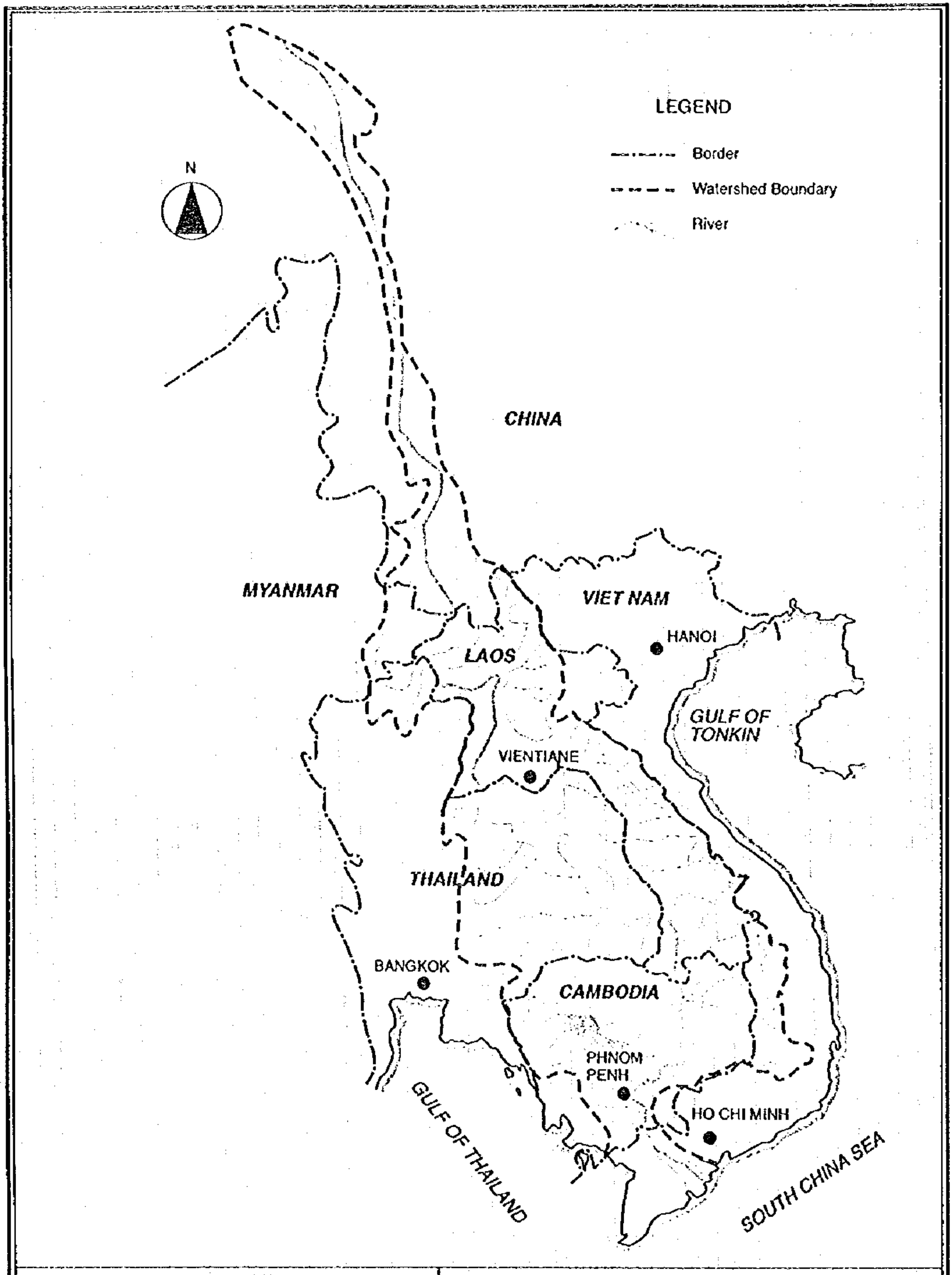
At Phnom Penh, the Mekong River joins with the Sap River. During the flood season, the water flow of the Sap River is reversed by the flood water of the Mekong River and flows into the Great Lake (i.e., Lake Tonle Sap), which is located 100 km upstream from the confluence. The Great Lake is functioning as natural retardation storage in the Mekong River basin. The flood prone area spreads widely over the low-lying plain downstream of Kompong Cham in Cambodia to around Vinh Long and Can Tho in Vietnam.

The Mekong River splits into two branches, the mainstream and the Bassac River, at Phnom Penh. These rivers form the Mekong Delta at the furthest downstream section, and finally pour into the South China Sea.

6.1.2 Climate

(1) General

The Climate in Cambodia is classified as 'Tropical Monsoon' with definite wet and dry seasons affected by the direction of the monsoon. The south-west monsoon prevails in the wet season from May to October. This monsoon brings warm, moist air from the Indian Ocean and provides rainfall to Cambodia before passing the mountains along the Vietnamese border. On the other hand, the north-east monsoon with dry, cold air dominates in the dry season from November to April. Table 6.1 and Figure 6.2 show the summary of climatological records at Phnom Penh.



THE FEASIBILITY STUDY ON CONSTRUCTION OF THE MEKONG BRIDGE IN KINGDOM OF CAMBODIA	Figure 6.1 Location Map of Mekong River Basin
	JAPAN INTERNATIONAL COOPERATION AGENCY

Table 6.1 Climatological Record at Phnom Penh (Pochentong)

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual
Rain (mm)	3	2	23	71	113	116	163	168	283	222	110	4	1,278
No. of Rainy Days	(1)	(0)	(2)	(6)	(13)	(15)	(19)	(19)	(22)	(19)	(9)	(1)	(125)
Temperature (°C)													
Average Max.	31.0	32.7	34.2	35.0	34.0	33.0	32.1	32.1	31.2	30.6	30.2	30.0	32.2
Mean	26.0	27.5	28.9	29.6	28.6	28.1	27.5	27.6	27.2	27.1	26.7	25.6	27.5
Average Min.	21.4	22.3	23.7	24.7	24.6	24.6	24.3	24.6	24.5	24.3	23.4	21.8	23.7
Evaporation (mm)	177	198	260	225	184	179	179	167	142	145	150	176	2,182
Relative Humidity (%)	71	69	69	72	80	80	82	82	84	86	79	75	77

Source : Meteorology and Hydrology Department of Ministry of Agriculture

(2) Rainfall

Average annual rainfall in Cambodia varies from 1,500 mm or less in the central plain, from 1,500 to 2,500 mm in the surrounding mountains, and from 2,500 to 3,000 mm or more in the south-west coastal area. The monthly variation of rainfall at Phnom Penh shows that the peak of the rainy season takes place in September, and the rainfall during the wet season (from May to October) amounts to 83% of the annual rainfall. In the dry season, rainfall is scarcely observed especially from December to March.

(3) Air Temperature

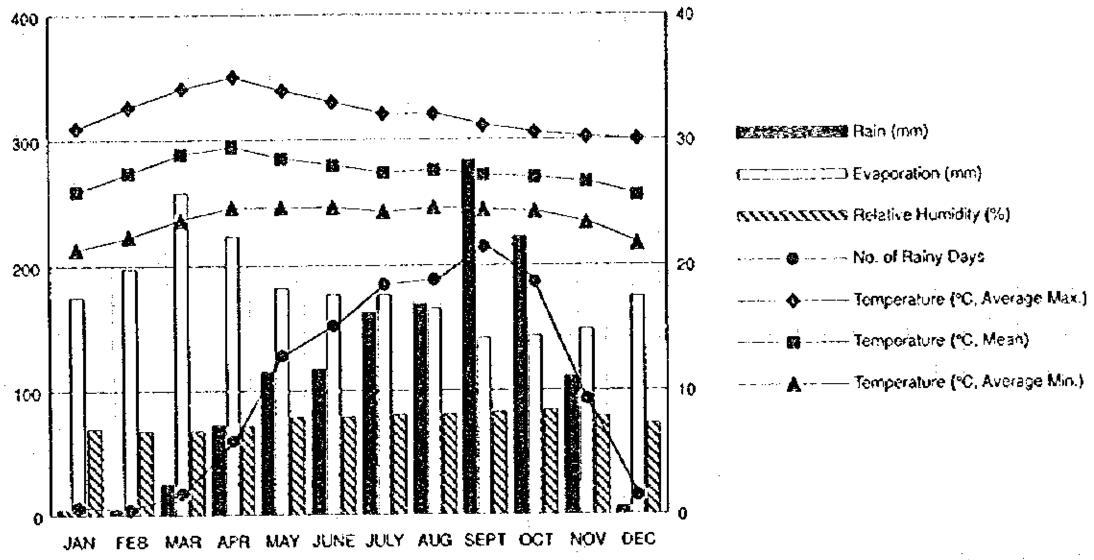
Air temperature becomes highest in April and lowest in December. In Phnom Penh, the average air temperature by month ranges from 35°C to 30°C for the daily maximum, from 30°C to 25°C for the daily mean, and from 25°C to 21°C for the daily minimum. The recorded absolute maximum and minimum air temperatures are 40.5°C and 13.3°C, respectively.

(4) Relative Humidity

The annual mean relative humidity is 77% in Phnom Penh. Variation of the average monthly relative humidity shows that the highest (86%) takes place in October and the lowest (69%) is observed in February/March.

(5) Evaporation

The annual evaporation at Phnom Penh is some 2,200 mm on average, which amounts to 170% of the annual rainfall. The average monthly evaporation rate becomes highest in March and lowest in September and exceeds the monthly rainfall except in August, September, and October.



Source : Meteorology and Hydrology Department of Ministry of Agriculture

Figure 6.2 Climatological Record at Phnom Penh (Pochentong)

6.1.3 Hydrology

(1) Gauging Stations

In Cambodia, hydrological observations of river stage were initiated around the end of the 19th century, and discharge measurements were carried out in the 1960s. The observations were discontinued in the early 1970s due to security conditions and restarted around 1980.

River stage is recorded as gauge height, and each gauging station has a different elevation of gauge zero. In the lower Mekong basin, elevation of gauge zero is indicated by height from the mean sea level of Hatien datum. Hydrological records including gauge height at discharge on a daily basis were obtained for the gauging stations listed in Table 6.2.

Table 6.2 Hydrological Gauging Station

Name	River	Latitude	Longitude	Distance from Sea (km)	Gauge Zero (EL. m)
Kratie	Mekong	12° 28.6' N	106° 00.9' E	545	-1.08
Kompong Cham	Mekong	11° 59.7' N	105° 27.9' E	410	-0.93
Phnom Penh	Mekong	11° 35' 00" N	104° 56' 33" E	332	-1.08
Neak Loeung	Mekong	11° 15' 37" N	105° 17' 13" E	277	-0.33
Phnom Penh	Bassac	11° 33.7' N	104° 55.9' E	325	-1.02
Tan Chau /1	Mekong	10° 48.2' N	105° 14.6 E	220	0.00

Source : National Mekong Committee
Note /1 : Gauging station in Vietnam

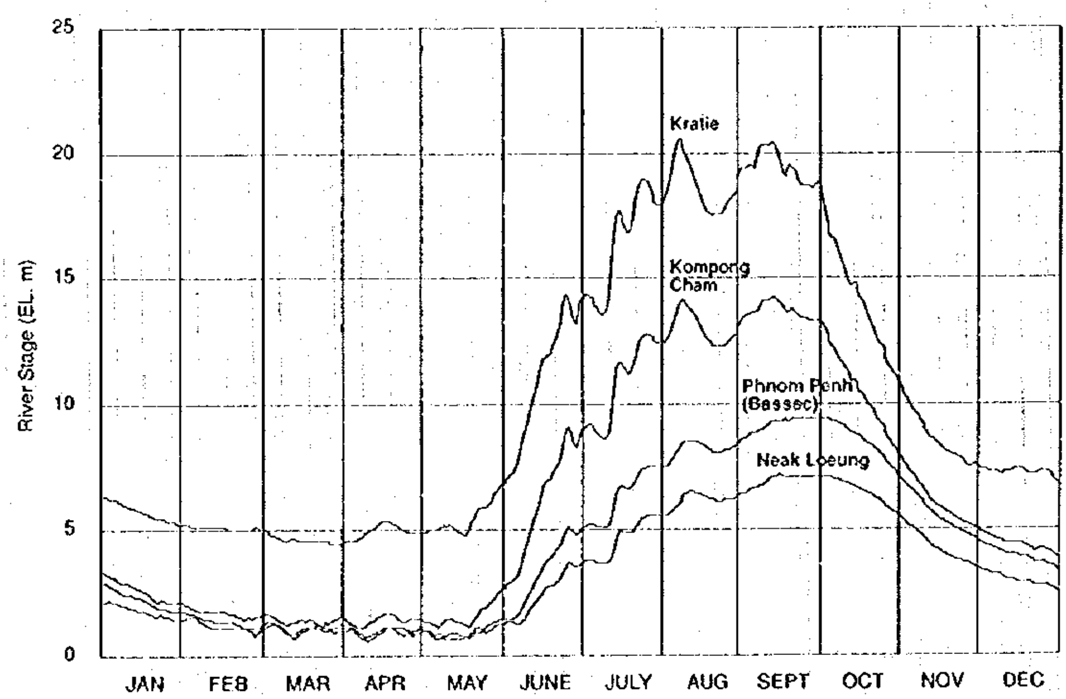
(2) Water Level and Discharge

The water level hydrographs at Kratie, Kompong cham Phnom Penh (Bassac) and Neak Loeung in 1994 are presened in Figure 6.4. The water level of the Mekong River becomes lowest in April at the end of the dry season. From the beginning of the wet season, the water level gradually increases and reaches its highest levels in September/October. The average difference between the highest and lowest water level is around 12 m at Kompong Cham, 9 m at Phnom Penh, and 7 m at Neak Loeung. Table 6.3 presents the recorded highest and lowest water level at the gauging stations along the Mekong River.

Table 6.3 Recorded Highest and Lowest Water Levels

	Maximum		Minimum	
Station	Gauge Height (m)	Elevation (EL. m)	Gauge Height (m)	Elevation (EL. m)
Kratie	23.02 (1984)	21.94	4.67 (1960)	3.59
Kompong Cham	15.82 (1939)	14.89	1.74 (1963)	0.81
Phnom Penh	11.08 (1961)	10.00	1.22 (1960)	0.14
Neak Loeung	7.93 (1966)	7.60	-	-

Source : National Mekong Committee, Meteorology and Hydrology Department of Ministry of Agriculture



Source : National Mekong Committee, Meteorology and Hydrology Department of Ministry of Agriculture

Figure 6.3 Water Level Hydrographs in 1994

The average discharge at Kratie with a catchment area of 646,000 km^2 is 13,970 m^3/sec (1924 - 68) which is equivalent to an annual runoff volume of 440 x 10^9 m^3 or an annual runoff depth of 682 mm. The annual maximum and minimum discharge at Kratie are 52,000 m^3/sec and 1,750 m^3/sec on average, respectively. The ratio of the maximum discharge to the minimum discharge is