CHAPTER 9 PRELIMINARY COST ESTIMATE FOR THE CANDIDATE ROUTE

9.1 General

The preliminary cost estimate was determined according to estimates of construction cost, engineering service cost, land acquisition and compensation cost, contingency and maintenance cost. The objective of the cost estimate is to select the optimum route as one of several criteria among six (6) alternative routes. This chapter presents the construction plan envisaged at each alternative route and by bridge type, project cost estimates and total project costs comparing the six (6) alternative routes.

9.2 Preliminary Construction Plan

Basic conditions for a Preliminary construction plan were described in Appendix 9.1, which consists, (1) Procurement of Construction Materials, (2) Construction Equipment, (3) Transportation Plan, and (4) Working Conditions. This section presents preliminary bridge construction plans used to estimate construction costs for each alternative route.

9.2.1 Tentative Construction Schedule

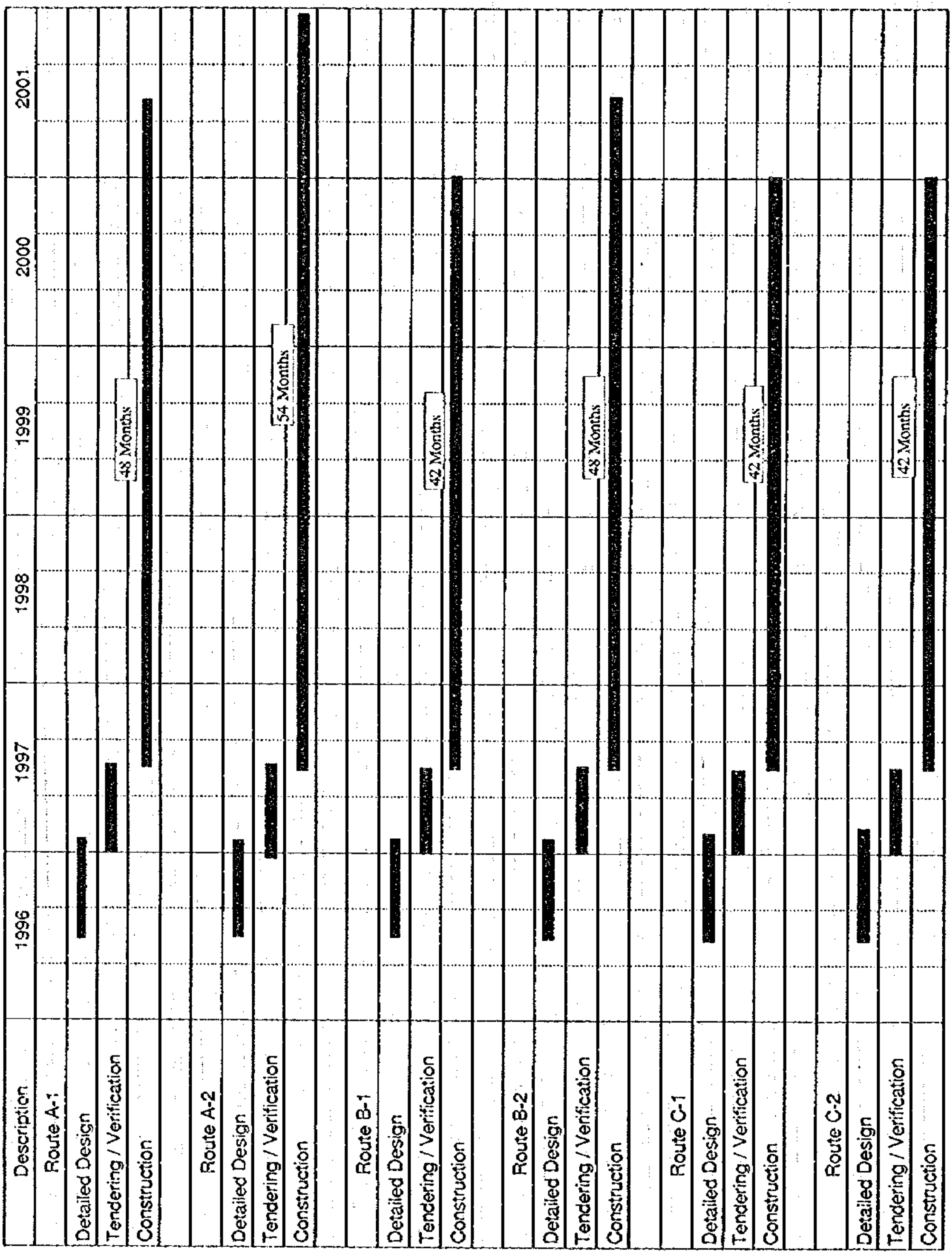
The total period for construction is expected to be 3.5 years (42 months) for alternative routes B-1, C-1 and C-2, 4 years (48 months) for routes A-1 and B-2, and 4.5 years (54 months) for routes A-2, respectively. A preliminary construction schedule for the alternative routes is shown in Figure 9.1.

9.2.2 Construction Facilities

Construction facilities, such as a concrete batching plant, a crushing and screening plant, a fabrication yard for precast prestressed concrete (PC) T-Girder, and stockyards for materials, would be developed near the selected bridge construction site. The area required for these construction facilities will be obtained along the river edges with embankments up to the high water levels for A route and B route. However, for C route it will be difficult to use the area in the city of Kompong Cham. It is considered that temporary quays would be constructed for loading and unloading construction materials and equipment directly or the construction sites.

9.2.3 Foundation and Substructure

For deep river water conditions, the multi-column pile foundation built according to the permanent casing construction method was preliminarily selected in section 9.2. Because it is not appropriate to construct a temporary staging area in the deep river from an economical viewpoint, a self-elevating platform (SEP) will be used for the staging of foundation works. The construction procedure for multi-column pile foundations is as follows:



THE FEASIBILITY STUDY ON CONSTRUCTION OF THE MEKONG BRIDGE IN KINGDOM OF CAMBODIA	Figure 9.1 Preliminary Construcion Schedule for Each Alternative
	JAPAN INTERNATIONAL COOPERATION AGENCY

(1) A steel casing is driven to a prescribed depth by a vibratory hammer on the self-elevated platform. Afforded protection from river currents and waves due to the casing, a shaft with a diameter of 2.0 m is then excavated with a reverse circulation drill. The reinforcing steel cage and shaft concrete are then placed in the inner casing.

(2) These first two steps are repeated until all of the concrete-filled steel columns for each respective pier are completed; subsequently, the supporting bridge frame or pier cap (consisting of beams, struts, wales, and forms) is assembled on the columns. Shaft and pier cap concrete are placed by a concrete batching plant located on a barge.

The construction period of the multi-column pile foundation is estimated at 6 months per pier (1 month for preparation, 3 months for column/pile construction, and 2 months for column/pile cap and pier construction), with each major pier consisting of at least 20 composite columns.

Concrete for the bridge foundation and substructure (pier and abutment) will be placed by a batching plant.

9.2.4 Superstructure

The three different types of superstructure for the main bridge, as considered in this study for the six alternative routes, are (1) suspension bridge, (2) PC cable-stayed bridge, and (3) continuous PC box girder bridge. Construction plans envisaged in this stage are described below:

(1) Suspension Bridge

Stiffening truss members for a suspension bridge are manufactured in Thailand and Singapore and could be transported to the site. Wires for the main cable are manufactured in factories, where they can be wound onto reels and shipped to the site. This wire is erected by using the air spinning method and banded into a parallel wire cable. Stiffening truss members can be erected at tower portions by a crawler crane. The stiffening truss is expanded toward the center by a traveler crane or some other erection machinery installed on the stiffening truss. The suspenders between the main cable and the stiffening truss are equally spaced and vertical.

Portal-type towers would be made of reinforced concrete to reduce construction costs. The towers must resist the forces imposed by the main cables in addition to the direct gravity and wind loads; therefore the concrete of which it is formed must be of high strength and the accuracy of construction must be precise. To maintain this accuracy, a slip form, which consists of a form lining, working platforms, jacks, climbing rods, and control equipment, is used for tower construction. The jacks pull the slip form continuously and gradually upward.

(2) Cable-Stayed Bridge

With a cable-staying arrangement, the harp layout is selected for the proposed PC cable-stayed bridge at A-1 route and A-2 route. This design reduces the risk of tower instability; it also involves simpler construction procedures.

The stay cables, which are necessary to protect against corrosion, are made of stranded prestressed cable threaded in polyethylene duct and grouted with urethane rubber. These cables are manufactured in factories in Japan, and the strands can be wound onto reels and transported to the site.

The girder of a cable-stayed bridge is divided into segments which can be precast at the fabrication yard during construction of the substructure components. Precasting segments has the following advantages:

- reduction of construction period;
- safe, controlled environment for pouring and setting of concrete (i.e., no adverse impacts due to weather or high-deck constraints); and
- simplicity of quality control (fewer required bridge specialists).

The lower part of the main tower is constructed prior to erection of the precast segments. The segments are transported onto the barge at the site and then lifted up and placed symmetrically and simultaneously by winches of mobile lifting equipment. The stay cable is placed at each successive segment of the girder and then tensioned. The upper part of the tower is constructed in parallel with erection of the girders, which are placed alternately from one cantilever to the next, to allow the concrete joints between the segments to harden.

(3) Continuous PC Box Girder Bridge

The pier head of this bridge type is constructed on bracket staging, which is supported by anchor bolts. Construction of the cantilever girder after completion of the pier head is carried out with two medium-sized travelers with a construction block of 3.0-4.0 m. Concrete for the girder is placed directly by a concrete pump connected to the batch plant on the barge. Because the concrete should set quickly and have high strength (to increase construction productivity and to ensure a durable structure), high-performance water-reducing admixtures or superplasticizers would be added to the concrete mixture. Concrete placing is carried symmetrically out within one day in order to reduce unbalanced forces acting on the incomplete structure.

The end girder at the abutment is constructed using post shoring, staging, and scaffolding, and it is connected with the cantilever girder by prestressing. The ends of the cantilever girders at the center of each span are then joined by a keying segment using a suspended shoring system. The continuity of both cantilever girders is ensured by prestressing cables tensioned after the hardening of concrete at the keying joint.

9.3 Project Cost Estimates

Project costs consist of construction costs, land acquisition and compensation costs, engineering service costs (i.e., detailed design and supervision costs), contingencies, and maintenance costs.

9.3.1 Construction Costs

The estimated overall costs of the bridges for the alternative routes were determined from the summation of preliminary quantities based on the drawings in Figures 7.1 to 7.9, and unit prices quoted from similar bridge projects.

Construction costs for the six alternative routes are shown in Table 9.1. Regarding routes B-1 and B-2, the estimated costs consist of bridge construction and major rehabilitation of a provincial road (Route 315). The construction costs estimated at this stage are assumed to be accurate to within 10-15%. The foreign currency exchange rate was applied to be US$ 1.00 = 94.64 Yen (August 1995 level); this rate was modified in Phase 2.

9.3.2 Engineering Service Costs

Engineering service costs consist of the detailed design and supervision works undertaken by consultants. In this stage, the engineering service cost for each alternative was assumed equal to 7% of the total construction cost.

9.3.3 Land Acquisition and Compensation Costs

Alternative routes for bridge and approach roads were proposed earlier in Chapter 7. For each alternative route, the Survey Team performed an interview survey concerning land acquisition and compensation costs in Kompong Cham and Kandal municipalities. A summary of the estimated total land acquisition and compensation costs for each alternative is presented in Table 9.2.

Table 9.2 Land Acquisition and Compensation Costs

Route	Land Acquisition and Compensation Cost (US$ million)
A-1 Route	0.05 /1
A-2 Route	0.05 /1
B-1 Route	0.15 /1
B-2 Route	0.15 /1
C-1 Route	0.20 /2
C-2 Route	1.59 /2

/1 : Costs assumed by the Study Team
/2 : Costs proposed by Kompong Cham Municipality

9.3.4 Contingencies

Contingencies are included to cover costs associated with the following uncertainties:

a) Changes in geological conditions and/or quantities, which may occur during preliminary design; and

b) Changes in economic conditions, such as foreign currency exchange rates.

Considering these factors, the contingency was assumed to be 10% of the combined costs for construction, engineering services, and land acquisition and compensation.

9.4 Maintenance Costs

The cost of maintaining the bridge and approach facilities depends on the type of structure constructed. Maintenance costs are preliminarily adopted as shown in Table 9.3.

Table 9.3 Maintenance Costs

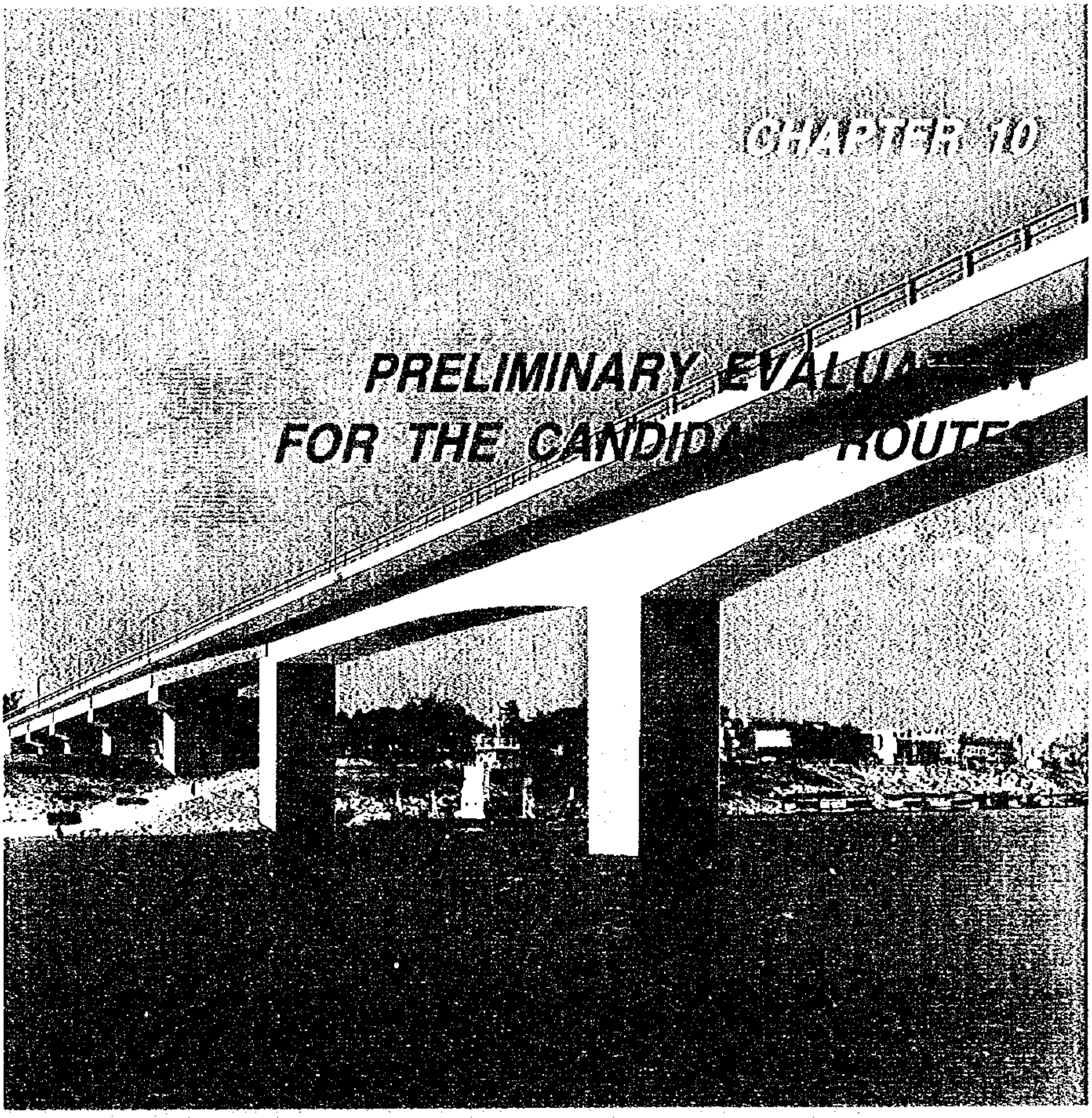
Item	Maintenance Interval	Maintenance Cost (US$)
1. Approach road and bank protection	Annual	500/km
2. Bridge and approach road overlays, and periodical bank protection	10 years	65,000/km
3. Repainting of bridge superstructure (steel)	10 years	240/ton

9.5 Total Project Costs

Total project costs, determined by summing the cost components presented above, are summarized in Table 9.4. Maintenance costs shown are those incurred over a 20-year period.

Table 9.4 Total Project Costs

Item	Project Cost (US$ million)					
	A-1 Route	A-2 Route	B-1 Route	B-2 Route	C-1 Route	C-2 Route
1) Construction Cost	109.87	121.18	90.72	142.53	98.84	87.02
2) Engineering Service Cost	7.70	8.64	6.35	9.97	6.92	6.67
3) Land Acquisition and Compensation Cost	0.05	0.05	1.10	0.10	0.20	1.59
4) Contingency	10.76	13.21	9.71	15.23	10.60	10.35
Subtotal	129.38	143.08	106.88	167.83	116.56	105.63
Ratio to C-2	1.22	1.35	1.01	1.59	1.10	1.00
5) Maintenance Cost	0.66	0.52	9.34	9.44	2.56	0.52
Total	130.04	143.60	116.22	177.27	119.21	106.15


CHAPTER 10
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CHAPTER 10 PRELIMINARY EVALUATION FOR THE CANDIDATE ROUTES

10.1 Economic Evaluation of Alternatives

10.1.1 Valuation of Benefits and Costs

As discussed in chapter 2, there are many indirect benefits that would arise from the Project, including accelerated industrial development and improvement of living conditions. The main quantifiable and direct benefits of the Project would be savings in waiting time related to freight and passenger traffic due to a bridge. Other than these benefits, savings in ferry operation costs in with bridge cases and additional ferry improvement costs in the without bridge case are considered as the benefits of Project. Decreases in vehicle operating costs (VOCs) accruing to the diversion caused by the Project are also estimated as benefits. As for costs, maintenance costs after completion of the bridge are also considered.

(1) Time Costs

(1.1) Passenger Time Costs

When estimating passenger time costs, results of the *Socio-Economic Survey in Cambodia (SESC)-1993/1994* were used, since the survey reported recent actual income and expenditure levels of households in Cambodia obtained from a household interview survey.

The survey sponsored by the ADB and UNDP was conducted jointly by the staff of the Strengthening Macro-Economic Management and Training Project and the National Institute of Statistics (NIS) under the Ministry of Planning. SESC was conducted in four rounds to capture seasonal effects. The sample size of each survey round was as follows:

Phnom Penh :	40 villages	approx. 400 households
Other Urban:	25 villages	approx. 250 households
Rural Area:	60 villages	approx. 600 households
Total:	125 villages	approx. 1,250 households

The survey covered 15 provinces.

The survey compiled demographic characteristics, housing characteristics, household expenditure, and household income data. Information relevant to this study is tabulated and shown in Table 10.1.

Table 10.1 Household Characteristics in Cambodia, 1993/1994

			Phnom Penh	Other Urban	Rural	Cambodia
1)	Average household size (a)	pers./ household	6.2	6.1	5.4	5.5
2)	Age dependency ratio (b)	%	73.8	84.0	96.8	93.2
	(% of 0-14 plus over 65 to 15-64)					
3)	Sectoral employment distribution (c)					
	Agriculture	%	12.2	30.3	86.5	77.8
	Industry	%	14.0	6.2	2.8	3.7
	Services	%	74.0	63.6	10.8	18.6
4)	Monthly average household expenditure (d)	Riel	882,465	637,989	240,292	308,760
		US$	357	258	97	125
5)	Monthly average household expenditure (e)	Riel	62,166	60,890	8,328	15,758
	on transport	US$	25	25	3	6
6)	Monthly average household income (f)	Riel	489,683	396,224	141,509	184,500
		US$	198	160	57	75
7)	Distribution of income by source (g)					
	Wages and salaries	US$	17.6	9.5	4.8	7.8
	Non-agricultural	US$	34.9	37.4	38.4	39.2
	Agricultural	US$	1.9	7.1	38.1	15.7
	Net rental value of owner occupied house	US$	33.0	39.8	5.3	15.4

Source: Socio-Economic Survey in Cambodia, National Institute of Statistics, Ministry of Planning and other funded by the ADB and UNDP, 1993/1994

Considering the composition of trip makers who would use the proposed bridges, averages of the three areas differentiated in the survey were used. Discrepancies between the reported monthly expenditures and monthly incomes were probably due to under-reporting of income. Expenditure figures were therefore used. Estimation of passenger time costs in 1993/1994 were derived according to the following steps:

i) Average income earners per household: (a)/((b)+1.0) = 3.2 pers./household

ii) Average monthly expenditure per trip maker: (d)/(A) = US$ 74

iii) Average per working hour expenditure per trip maker: (B)/160 = US$ 0.46 /hour

The data shown above indicate a high level of productive utilization of time. Assuming 20% non-productive time, the value of time for passengers in 1993/1994 is estimated as US$ 0.46 x 0.80 = US$ 0.37 /hour.

Assuming that the future increase of passenger time cost is in proportion to the future increase of GRP per capita, passenger time costs and passenger time costs by vehicle in the forecast years can be estimated (Tables 10.2 and 10.3).

Table 10.2 Projected per Capita GDP at 1995 Constant Prices

		1995	2001	2011	2021
GDP	US$ million	2,635	4,104	8,779	17,269
Population	1000s pers.	9,267	10,694	12,973	15,055
Per Capita GDP	US$/pers.	284	384	677	1147
Growth Rate of Per Capita GDP	US$/pers.	-	5.1%	5.8%	5.4%
Passenger Time Value	US$/pers.-hour	0.39	0.52	0.85	1.38

Source: GDP in 1995: Cambodian Authorities and World Bank Estimate, JICA Study Team

Table 10.3 Time Costs by Vehicle Type

(US$/veh. hour)

	MC	PC	LB	HB	LT	MT	HT
Average Occupancy in 2001 (pers./veh.)	1.5	5	10	20	5	2	2
Average Occupancy in 2011 & 2021 (pers./veh.)	1.5	4	10	20	4	2	2
2001 Passenger Time Cost 0.52 US$/pers.hour	0.78	2.60	5.20	10.40	2.60	1.04	1.04
2011 Passenger Time Cost 0.85 US$/pers.hour	1.28	3.40	8.50	17.00	3.40	1.70	1.70
2021 Passenger Time Cost 1.38 US$/pers.hour	2.07	5.52	13.80	27.60	5.52	2.76	2.76

Source: JICA Study Team

(1.2) Cargo Time Costs

For cargo, an average value per ton of US$ 520 was obtained from field surveys in this study (Table 10.4). Based on this average value, cargo time costs were valued by two different approaches. One is the approach applying an interest rate to cargo value. The prevailing interest rate is 18% for loans in foreign currency in Phnom Penh. Available loans for small operators would carry interest rates in the order of 20%. At a 20% interest rate and assuming a working time of some 160 hours per month, an inventory cost can be calculated by the following formula:

(US$ 520 x 0.20) / (12 months x160 hours/month) = US$ 0.054 /hour

The second method is the approach using turnover time of cargo. If the turnover time of cargo is assumed at one month and infinite demand is assumed, the value of cargo in one hour of transit could be calculated at US$ 3.25 (US$ 520/160 hours).

Table 10.4 Prices of Commodities on Trucks

Commodity	Average Price (US$/ton)	Percentage (%)
Agricultural Products	350	6.6
Logs & Timber	80	10.2
Foods/Drinks	870	10.2
Manufactured Goods	1300	25.6
Construction Materials	110	35.7
Fuel/Chemicals	330	0.7
Other	240	11.0
Total	520	100.0

Source: JICA Study Team survey

A true opportunity cost of cargo should fall somewhere in between the above two figures. For the purpose of this study, the average of two figures was used, i.e., US$ 1.65 per hour for cargo time cost. For the estimate of future cargo time costs, the cargo value was assumed to increase at an average rate of 5% per annum. Considering the average loading of each vehicle type, cargo time costs by vehicle type in the forecast years were estimated (Table 10.5).

Table 10.5 Cargo Costs by Loaded Vehicle

(US$/veh. hour)

		MC	PC	LB	HB	LT	MT	HT
Average Loading (tons/veh.)		-	-	-	-	1.0	4.5	11.5
	Value of Cargo in Transit							
2001	2.21 US$/ton.hour	-	-	-	-	2.21	9.95	25.42
2011	3.60 US$/ton.hour	-	-	-	-	3.60	16.20	41.40
2021	5.86 US$/ton.hour	-	-	-	-	5.86	26.37	67.39

Source: JICA Study Team

(2) Vehicle Operating Costs (VOCs)

Estimates of vehicle operating costs were carried out utilizing the VOC3 model, a subprogram of HDM-III.[1]

Motorcycles are not included in VOC3 program; therefore, the VOCs of motorcycles were initially determined by two methods: (1) by a labor-intensive, manual spread sheet method and (2) by the VOC3 model designating motorcycles in the "small" car category. According to the first method, motorcycle VOCs were estimated to be one-fourth those of passenger cars. After comparing these two methods and considering the amount of work that would be required to employ the first method throughout the analysis, the VOC3 method was adopted for calculating motorcycle VOCs.

[1]HDM-III was developed by the World Bank to make comparative cost estimates and economic evaluations of different construction and maintenance options including different time-staging strategies, either for a given road project on a specific alignment or for groups of links on an entire network.

The following eight vehicle types were adopted for VOC estimates:

- Motorcycle (MC): Honda Super Cub 90;
- Passenger Car (PC): Toyota Corona;
- Light Bus (LB): Toyota Coaster;
- Heavy Bus (HB): Fuso MP 218;
- Light Truck (LT): Toyota Hi-Lux;
- Medium Truck (MT): Mitsubishi FK 455 (70%) MAZ 8t (30%); and
- Heavy Truck (HT): Mitsubishi FV 415 (70%) KAMAZ 10t (30%).

Considering the existing vehicles observed in Cambodia, the specified vehicles initially seemed rather expensive. However, it is likely that new cars, trucks, and buses of Japanese or other makes will be more common than existing vehicles bought from the former Soviet Union; therefore, these vehicle types were specified.

The changes in the vehicle operating costs per vehicle-km are realistic over time; factors for passenger time costs and cargo time costs were adjusted to future VOCs as stated above. Details of VOC estimates are described in Appendix 13.1. Since VOCs vary in close relation to changes in travel speed or road roughness, the results of VOCs were estimated according to travel speed and international roughness index (IRI).[2]

The estimated results are shown in Table 10.6.

Table 10.6 Vehcle Operating Costs (VOCs)

VOCs in 2001 (US$/veh. 1,000 km)

	v=40km/h				v=60km/h			
	IRI				IRI			
	4	6	8	10	4	6	8	10
MC	60.2	63.0	66.5	70.9	50.7	53.6	57.3	62.0
PC	284.9	312.5	350.9	403.2	240.3	268.4	308.1	362.6
LB	491.9	511.9	536.8	568.1	405.2	427.3	456.6	494.9
HB	988.9	1029.7	1079.1	1139.6	822.0	867.1	925.5	1000.1
LT	239.2	262.4	285.2	308.5	208.9	233.3	258.2	284.4
MT	317.2	367.2	417.1	468.0	284.8	336.1	388.2	442.2
HT	539.0	609.4	681.1	755.1	487.3	560.0	635.5	714.7

[2] The IRI is a standardized roughness measurement related to those obtained by response-type road roughness measurement systems, with recommended units: meters per kilometer (m/km). The IRI is appropriate when a roughness measure is desired that relates to: overall vehicle operating cost, overall ride quality, dynamic wheel loads, and overall surface condition.

VOCs in 2011 (US$/veh. 1,000 km)

	v=40km/h				v=60km/h			
	IRI				IRI			
	4	6	8	10	4	6	8	10
MC	72.6	75.4	79.0	83.6	59.2	62.2	66.1	71.1
PC	317.9	345.5	384.1	436.8	262.4	290.8	330.9	386.3
LB	574.3	594.7	620.5	653.6	462.0	485.2	516.8	559.0
HB	1153.2	1194.8	1246.1	1310.1	934.2	981.6	1044.8	1127.5
LT	255.8	279.2	302.3	326.2	220.4	245.2	270.8	298.1
MT	333.7	384.0	434.4	486.0	296.3	348.1	401.2	456.5
HT	555.5	626.1	698.3	773.1	498.7	571.9	648.4	728.9

VOCs in 2021 (US$/veh. 1,000 km)

	v=40km/h				v=60km/h			
	IRI				IRI			
	4	6	8	10	4	6	8	10
MC	92.6	95.4	99.2	103.9	72.9	76.0	80.1	85.7
PC	370.8	398.6	437.5	490.7	297.9	326.7	367.7	424.6
LB	706.7	727.7	755.0	790.8	553.3	578.1	613.5	662.0
HB	1417.1	1460.0	1514.3	1584.0	1114.5	1165.5	1236.5	1332.0
LT	282.5	306.1	329.8	354.6	238.9	264.3	291.1	320.1
MT	360.4	411.0	462.1	514.9	314.8	367.4	422.0	479.4
HT	582.0	653.0	725.9	801.9	517.0	591.0	669.0	751.7

Source: JICA Study Team

(3) Ferry Operations and Improvement Costs

Survey results of ferry expenditures were used to determine ferry operation costs. Additional investment in ferries to cope with over-capacity traffic volumes can be diverted to the benefit of a bridge.

Information on itemized ferry improvement costs were derived from a ferry project funded by DANIDA and actual operation and administration costs at Neak Loeung surveyed in this study. Units costs of ferry improvement projects are estimated as follows:

- Ferry (with capacity of 30 vehicles): US$ 3.00 mil./boat
- Civil works (slipway and landing facilities): US$ 0.38 mil./ferry site
- Administration and operation: US$ 0.16 mil./boat-year

(4) Economic Project Costs

No data were available in existing reports regarding economic cost parameters. Therefore, the consultants performed various investigations and referred to other sources to determine appropriate conversion factors for economic cost estimates.

Regarding foreign exchange, in Cambodia the U.S. dollar trades freely in the parallel market, and this has caused problems inherent in a situation in which two currencies as well as gold circulate as media of exchange. The financial construction cost estimates were determined by domestic market surveys in Cambodia in U.S. dollars. Therefore, no shadow exchange rate was applied during the economic evaluation. The main tax laws applying to the present time were enacted in 1985; they decree the following four types of tax: import and export duties; turnover and profits taxes; business license tax; and excise tax. In a second major tax reform, which took place in 1991, the turnover and profits taxes were reorganized, and a property transfer tax was introduced in attempt to stem the rising State deficit. In 1994, presently utilized tax rates applied were enacted as shown in Appendix 10.2.

Because Cambodia imports nearly 100% of its construction materials and equipment, it is necessary to subtract the import duty component from these costs for economic evaluation. Import duties for mineral products range between 7-15%, chemical goods are 20%, machinery and equipment are 7-15%, depending on whether they are classified as necessities or luxuries. In addition, a 4% exercise duty is added to the value of all imports after the import duty has been charged. However, it should be considered that taxes are exempted to import goods which are input in foreign grant projects.

Following the devastation of the 1970s and the ensuing labor shortage in agriculture, so-called *krom samaki*, solidarity groups of small producers with a somewhat private nature, emerged. As Cambodia continued to shift from a centrally planned to a market-oriented economy throughout the 1980s, disengagement from communal agriculture evolved progressively. Therefore, no price distortion factor was considered necessary for unskilled labor costs in Cambodia.

Based on the discussion above, considerations about components of each works were made in determining an overall distortion factor to be applied to the total combined cost of labor, materials, and equipment. The tax portion of materials was assumed to account for about 5% for preparatory works, 6-10% for bridge works, and 2% for road works. Taxes on imported equipment were assumed to be exempt. Referring to standard distortion factors of other developing countries, a figure of 85% was adopted as the standard conversion factor in Cambodia.

Economic costs are shown in Table 10.7.

Table 10.7 Economic Costs of Project

(Unit: mil. US$)

Alternative	Economic Costs							
	Preparation Works	Bridge Works	Road Works	Engineering Cost	Land Acquisition/ Compensation	Contingency	Maintenance Cost	Total
A-1	17.42	85.65	2.93	7.70	0.00	10.00	0.56	124.26
A-2	19.25	95.86	1.67	8.64	0.00	11.04	0.44	136.90
B-1	12.20	48.07	28.74	6.35	0.00	8.26	7.94	111.56
B-2	18.41	67.08	54.52	9.97	0.00	12.97	8.04	170.99
C-1	15.51	74.99	3.72	6.92	0.17	9.01	2.18	112.49
C-2	13.67	68.31	3.02	6.67	1.35	8.10	0.44	101.56

Source: JICA Study Team

Note: Maintenance Costs were estimated for the period from the opening year to 2021

10.1.2 Economic Evaluation

(1) Evaluation Method

Although the main objective of economic evaluation is to ascertain information on the viability of alternatives, economic evaluation in this chapter also has the role to provide information on the relative supremacy of alternatives from an economic viewpoint. The detailed economic evaluation to obtain information on an effective combination of investments or effective operations of a bridge are to be carried out in the later steps of this study.

The economic evaluation pursued in this chapter assesses the feasibility of alternatives in the context of the Project entity rather than economic development of Cambodia. Therefore, the economic evaluation emphasizes quantifiable and direct benefits/costs in monetary terms.

The main quantifiable and direct benefits of the Project would be savings in waiting time related to freight and passenger traffic with a new bridge. Additionally, savings in ferry operating costs for with bridge cases and additional ferry improvement costs for the without bridge case are considered as the benefits of the Project. The decreases in vehicle operating costs accruing to the diversion caused by the Project are also estimated as a benefit. Maintenance costs (after completion of the bridge) are also considered in the economic evaluation.

(1.1) Present Ferry Operating Costs

Present ferry operating costs at the locations where the Mekong River Bridge may be constructed were considered as benefits of the Project.

(1.2) Additional Ferry Investment in Without Bridge Case

Traffic forecast results show that, for the without bridge case under the condition of free-flow, traffic volumes will exceed ferry capacities in year 2011. For these cases, if additional investments in ferry improvements are not considered, passenger waiting times for ferries would grow enormously (and unrealistically) long and overinflated benefits of the Project would then be calculated. Consequently, additional ferry improvement investments were taken into account when estimating benefits of the bridge for these cases. The scale of ferry investments was assumed to be the provision of two ferry boats each with a capacity of 30 vehicles, and related facilities, administration, and operation. It is important to note that this without bridge case is significantly different from the literal "do nothing" base case typically applied in economic evaluations.

The timing of ferry improvement investments was determined such that the increased capacity would accommodate the future traffic demand at each ferry point when capacity levels are reached. As a result, no diverted traffic from one ferry point to another ferry point would occur in years 2001 or 2011, because the increased ferry capacities in these years would be sufficient to meet the demand. However, in 2021 the increased ferry capacity at Neak Loeung would not be able to meet the traffic demand; therefore, diversion of traffic from the Neak Loeung ferry to other ferries would emerge.

These additional ferry investments were considered as benefits of the Mekong River Bridge in the economic evaluation.

(1.3) Additional Ferry Investment Other Than the Bridge Location in With Bridge Case

Similar to the without bridge case, additional ferry investments were assumed at ferry points other than the bridge location for the with bridge cases. The timing of ferry improvement investments were assumed taking into account the year when traffic demand would exceed ferry capacity. The scale of ferry investments was assumed to be the provision of two ferry boats each with a capacity of 30 vehicles, and related facilities, administration, and operation. Consequently, the timing and scale of ferry investments at ferry points other than the bridge location were the same for both the with and without bridge cases. Therefore, the ferry capacities were basically applied to the future traffic demand; however, some changes in traffic flow were expected because of the travel time reduction with the bridge.

(1.4) Waiting Time Reduction at Bridge Locations

The reductions in travel time can be computed by traffic assignments for both the with and without bridge cases; however, the travel times at the bridge were externally assumed for traffic assignment. For the estimate of ferry waiting times for the without bridge cases, a simulation program was developed specially for this study.

The reductions in waiting time at the ferry points where the Mekong River Bridge may be constructed were considered as benefits of the Project.

(1.5) Change in Travel Distance

The change in travel distance caused by construction of the Mekong River Bridge was computed in the traffic assignment procedure. The VOCs estimated in this study include travel time costs; therefore, a change in time cost inherent to a change in travel distance can be estimated. For the estimate of changes in VOCs, unit VOCs (at 40 kilometers per hour as the average travel speed and a road roughness level of IRI 4) were externally applied to changes in VOCs between the with and without bridge cases.

The traffic assignment results showed that construction of a bridge at Prek Tamak would contribute to the curtailment of total travel distance compared to the without bridge case. These results also revealed that in 2021 construction of a bridge at Neak Loeung would contribute to the curtailment of total travel distance compared to the without bridge case, because traffic demand exceeded ferry capacity for the without bridge case and the excess traffic was required to detour to other ferries.

(1.6) Benefits in Intermediate Years

The benefits in intermediate years were estimated by interpolation between the years 2001, 2011, and 2021. The benefits after 2021 were linearly extrapolated based on the benefits in 2011 and 2021.

(1.7) Costs for Road Construction and Maintenance

As for costs, project costs of approach and access road improvements were included in total project costs. In the case of a Prek Tamak (Svay Chrum) bridge, the improvement cost of the access road, including maintenance cost, was estimated to be considerably high. However, these costs are added to the bridge cost to determine the total project cost. These road costs were included because improvement of the access road cannot be considered independent of the bridge project due to very poor existing road conditions that prevent many vehicles from passing through.

(1.8) Salvage Value

The salvage value of the Project was estimated to be 90% of the construction cost, and it was added as a negative cost in the last year of the evaluation period.

(1.9) Base Year

The beginning year of the Project was set as the base year for the economic evaluation.

(1.10) Evaluation Period

Because of the severe budgetary constraints in Cambodia, it is not likely that many large bridge Projects will be implemented in Cambodia. Therefore, the Project life in the economic evaluation should be long; a 30-year period after opening was assumed as the evaluation period.

(1.11) Evaluation Indicator

As evaluation indicators, the economic internal rates of return (EIRRs) were calculated for the evaluation period.

(2) Benefits

As an example, the benefits of travel time savings and VOCs for the scenario of a Neak Loeung bridge in year 2001 are illustrated below.

Table 10.8 Savings in Passenger Time Costs of Normal Traffic

	Unit Cost	Comp. Rate	Veh.	Time Reduction	Savings	
	(US$/veh.h)	(%)	(veh./day)	(min.)	(US$/day)	(US$ 1,000/year)
MC	0.78	-	1970	20	512	187
PC	2.60	46.9	548	20	475	173
LB	5.20	220	257	20	445	162
HB	10.40	5.3	62	20	214	78
LT	2.60	14.9	174	20	151	55
MT	1.04	4.9	57	20	20	7
HT	1.04	6.1	71	20	24	9
Total					1841	671

Table 10.9 Savings in Passenger Time Costs of Induced Traffic

	Unit Cost	Comp. Rate	Veh.	Time Reduction	Savings	
	(US$/veh.h)	(%)	(veh./day)	(min.)	(US$/day)	(US$ 1,000/year)
MC	0.78	-	524	20	68	25
PC	2.60	47.3	88	20	38	14
LB	5.20	32.3	60	20	52	19
HB	10.40	6.5	12	20	21	8
LT	2.60	12.4	23	20	10	4
MT	1.04	0.5	1	20	0	0
HT	1.04	1.1	2	20	0	0
Total					189	70

Benefits as changes in consumer surplus for induced traffic were estimated at half of that for normal traffic.

Table 10.10 Savings in Cargo Time Costs of Normal Traffic

	Unit Cost	Comp. Rate	Veh.	Time Reduction	Savings	
	(US$/veh.h)	(%)	(veh./day)	(min.)	(US$/day)	(US$ 1,000/year)
LT	2.21	14.9	174	20	128	47
MT	9.95	4.9	57	20	189	69
HT	25.42	6.1	71	20	602	220
Total					919	336

Table 10.11 Savings in Cargo Time Costs of Induced Traffic

	Unit Cost	Comp. Rate	Veh.	Time Reduction	Savings	
	(US$/veh.h)	(%)	(veh./day)	(min.)	(US$/day)	(US$ 1,000/year)
LT	2.21	12.4	23	20	8	3
MT	9.95	0.5	1	20	2	1
HT	25.42	1.1	2	20	8	3
Total					18	7

Benefits as changes in consumer surplus for induced traffic were estimated at half of that for normal traffic.

(2.1) Savings in VOCs

For the with Neak Loeung bridge case, compared to the without bridge case, computed total travel distances increase; therefore, the changes in VOCs caused by this expansion of travel distance were considered a negative benefit.

Table 10.12 Savings in VOCs

	Total Travel Distance (w/ Bridge)	Total Travel Distance (w/o Bridge)	Change in Travel Distance	Savings	
	(km/day)	(km/day)	(km/day)	(US$/day)	(US$ 1,000/year)
pcu.	239,301	238,719	582	171	62
MC	405,684	402,586	3098	179	65

Overall benefit by the bridge at Neak Loeung in 2001 was estimated at US$ 0.76 million per year.

The benefits of each bridge location in 2001, 2011, and 2021 were also estimated in the same manner. The time reduction due to the bridge was determined according to the relationship between traffic volume and ferry capacity (Table 10.13).

Table 10.13 Time Reduction due to Bridge Construction (min.)

Year	Neak Loeung	Prek Tamak	Kompong Cham
2001	20	19	43
2011	19	16	40
2021	20	18	38

Source: JICA Study Team

(3) Evaluation Results

The economic internal rates of return (EIRR) of the alternatives show values of around 6-10%. The Neak Loeung bridge project shows the highest EIRRs, followed by those of the Prek Tamak bridge project and Kompong Cham bridge project. One of the reasons for these relatively low EIRRs is the length of the project life, which was assumed to be 30 years in the economic evaluation.

Comparing the EIRRs of the two alternatives at each river-crossing point, the alternative with the lower project cost has a relative advantage and shows a higher EIRR. This observation is especially true in the case of Prek Tamak, since the two alternatives have significantly different project costs and therefore relatively large differences in EIRR.

The benefits in the case with a Neak Loeung bridge in 2021 were estimated to be large and consequently resulted in a higher EIRR. In the without bridge case, because of the assumption of the absolute ferry capacity limit, traffic diversion to the Prek Tamak ferry with the associated longer travel distance was forecast in the traffic assignment procedure, resulting in a large savings in VOC for the with Neak Loeung bridge case. If further ferry capacity improvements near the present Neak Loeung ferry are possible, this savings in VOC would substantially decrease due to the lower diversion of traffic to the Prek Tamak ferry. Consequently, the EIRRs of the with Neak Loeung bridge case would be lower. Moreover, although all international traffic between Cambodia and Vietnam by land are expected to utilize Route 1 in accordance with the present traffic pattern, if an international network between northeastern Cambodia and Vietnam and between Kompong Cham and Vietnam (via Route 72) is developed, the EIRRs of the Neak Loeung bridge project would decrease due to the decrease in international traffic using Route 1. On the contrary, given the international traffic utilizing Route 72 and 78 with Vietnam, it is likely that the transport demand for a Kompong Cham bridge would become high. Based on these considerations assuming a 3% increase in benefit stream for the with Kompong Cham bridge case, the EIRRs were estimated at 6.0% for the C-1 case and 6.5% for the C-2 case.

From an operational viewpoint, empirically 8-9 ferry boats at ferry sites with three landing facilities is the upper limit of the number of boats that can be safely utilized together. The ferries in such an operation should eventually be substituted by a bridge with any further increase in transport demand.

The results of transport demand analysis revealed that a large portion of transport demand at the Neak Loeung ferry would be compelled to detour and travel a longer distance before the year 2021 because of the ferry capacity constraint. It can be assumed that other ferry points will also require bridges with increased transport demand over time. In the long run, a bridge across the Mekong River will be necessary to cater transport demand although the intensification of ferry operations can meet the demand at present.

In conclusion, the economic evaluation revealed that the Project is not highly economical mainly due to the project cost, which is almost two-and-a-half or three times as much as that of the bridge over the Mekong River at the Lao-Thai border. However, the economic evaluation also implied that the EIRRs of each alternative are at appropriate levels for this bridge construction project.

Out of the bridge candidate sites, Neak Loeung showed some advantage; however, taking into account the above discussion, these relatively low EIRRs do not show absolute supremacy among alternatives (Table 10.14). Consequently, these EIRRs should not be strictly applied to single out one alternative.

Table 13.14 Results of Economic Evaluation

Indicator	Neak Loeung		Prek Tamak		Kompong Cham	
	A-1	A-2	B-1	B-2	C-1	C-2
EIRR	9.4%	8.9%	8.3%	6.4%	6.0%	6.5%

Source: JICA Study Team

10.2 Overall Evaluation of Alternatives

10.2.1 Initial Evaluation Criteria

The economic evaluation, as described in previous section 10.1, was necessarily limited to items readily quantifiable in terms of economic costs and benefits. In Cambodia such an approach in selecting an optimum bridge site is not sufficient under the circumstance in which many non-economic issues could be critical. Therefore, the following items were considered:

- Technical Difficulties of Construction Work;
- Maintenance Requirements;
- Environmental Impacts;
- Impacts of Construction Work on the Local Economy;
- Non-Economic Impacts on the Regional Economy;
- Level of Total Project Cost; and
- Economic Internal Rate of Return.

The following explains each of the above criteria.

(1) Technical Difficulties of Construction Work

Because of the extreme dearth of technical expertise and supporting materials and equipment in Cambodia, the type and degree of demand on them depending on alternative design must be carefully assessed in order to ensure successful construction of the Project. The assessment was made separately for the following:

(a) Superstructure: Depending on the selected type of superstructure, the degree of construction work difficulty was evaluated assuming that the entire erection work will be performed in Cambodia.

(b) Substructure: Considering site conditions, the degree of construction work difficulty was estimated for the selected types of foundation.

(c) Approach Road: As all of the planned approach roads of the alternatives pass through flooding areas, protection of slopes from erosion or installation of transverse structures is required to maintain the functions of the road in the rainy season. For this reason, the approach roads of each alternative were evaluated in terms of the degree of difficulty for constructing and maintaining them as a reliable part of the total road network.

(d) Construction Period: Due to the unpredictable behavior of the Mekong River, the construction period should be short. A long construction period may lead to a substantial cost increase, but such risks are not easily quantified.

(2) Maintenance Requirements

Whatever the financial source of the initial construction, maintenance of the bridge after its construction will have to be carried out by the Government of Cambodia. Considering the severely limited financial capacity and technical know-how of the Government, it is highly desirable to limit the types and amounts of maintenance to be as simple and least demanding as practicable.

(3) Environmental Impacts

The following items concerning environmental impacts were considered:

(a) Air and Noise Pollution: The magnitude of air and noise pollution was assessed for each alternative, with special attention to vulnerable pollutant receptors, such as local inhabitants, schools, hospitals, and temples near the bridge.

(b) Impacts on Water Quality and Aquatic Ecology: As construction work would affect water quality and aquatic ecology, these aspects were assessed for each alternative.

(c) Impacts on Cultural and Historical Heritage and Aesthetics: The Project may force changes in local cultural and historical heritage, such as temples and historical architecture, and the appearance of a new structure may disturb the aesthetics of the local landscape. These impacts were assessed for each alternative.

(d) Impacts on Human Settlements: Human resettlement requirements caused by the construction of each of the alternatives were assessed.

(4) Impacts of Construction Work on the Local Economy

(a) Impacts by Local Procurement of Materials: The extent of local procurement of materials was assessed for each of the alternatives.

(b) Technology Transfer: In the course of construction work, employed workers and technicians will acquire skills in various fields, which will later be used again in Cambodia to enhance its productivity. The extent of such technology transfer was assessed for each alternative.

(c) Employment Opportunity: The ability to create jobs in Cambodia varies depending on the types of construction. Each alternative was assessed with respect to its job creation ability.

(5) Non-Economic Impacts on the Regional Economy

As the functions of the Mekong River Bridge will be diverse, the effects of the bridge will be far-reaching but many are hard to quantify. Two categories of such effects were identified, one related to transport and the other to regional economy.

(a) Transport Effects

i) Improvement of Accessibility to Remote Areas: Improvement of accessibility to remote and isolated areas in particularly northeastern Cambodia is considered to have high social and political values.

ii) Reduction in Uncertainty and Risk: The Mekong River Bridge can assure uninterrupted traffic flow at ferry sites, where uncertainty and associated risks are substantial.

iii) Formation of an International Road Network: As stated earlier, formation of an international transport network has been promoted by regional conferences, recognizing its importance at this stage of development in the region. The New Asian Highway concept by ESCAP incorporates such an idea and the more recent Greater Mekong Subregional Economic Cooperation Programme identified a number of road projects for the particular purpose of promoting economic cooperation among countries in the region. The alternatives were evaluated as to whether or not they are located on the identified international network.

(b) Regional Development Effects

i) Control of Concentration of Population to the Capital: The Mekong River Bridge will allow the population in the surrounding areas to remain in the area and to make frequent trips to the capital rather than relocate to the capital.

ii) Agricultural Development: The increase in accessibility afforded by the Bridge will in turn improve the productivity of agriculture and expand the area of cultivation.

iii) Promotion of a Market-Oriented Economy: The improvement in accessibility to large economic centers in neighboring countries, such as Bangkok, Ho Chi Minh City, or Da Nang, will stimulate and promote the development of the Cambodian market-oriented economy. Each alternative was evaluated with respect to this aspect.

iv) Balanced Development of the Region: The increased accessibility of the east bank of the Mekong River will promote balanced development on both sides of the River.

(6) Level of Total Project Cost

As the available funds for the project will have some ceiling regardless of whether it is financed domestically or externally, the level of total project cost will be a decisive factor for actual implementation. A project with a cost above such a ceiling cannot be implemented regardless of the economic return.

(7) Economic Internal Rate of Return (EIRR)

Economic costs and benefits quantifiable in monetary terms were estimated, and an economic evaluation was carried out as shown earlier in this report. The economic internal rate of return (EIRR) is the most reliable measure of project feasibility.

10.2.2 Overall Evaluation

(1) Comprehensive Assessment of the Mekong River Bridge Alternatives

In this section, a comprehensive evaluation is carried out for the six alternatives with respect to the numerous criteria described previously in subsection 10.2.1. This evaluation is summarized in Table 10.15, which rates each alternative bridge location for each criterion with a mark of very good, good, fair, or bad. From this table, it is clear that the selection of one bridge location among the six is not an obvious choice. As a result, the following subsection presents the results of a final evaluation based on only the prime criteria.

(2) Recommended Route for the Mekong River Bridge

The assessment in subsection 10.2.2 (1) evaluated the six candidate bridge routes with respect to the numerous factors that can be considered for evaluation of the Project. However, this assessment, while comprehensive, does not pinpoint which among the six routes should be selected for construction of the first Mekong River Bridge in Cambodia.

Table-10.15 OVERALL EVALUATION OF ALTERNATIVES OF THE MEKONG RIVER BRIDGE

			NEAK LOEUNG				PREK TAMAK					
General Information of Route	Bridge route crossing Mekong river			A - 1		A - 2		B - 1		B - 2		
	Width of river			1628m		848m		673m		934m		
	Depth of River			approximately 25m		approximately 25m		Approximately 30m		Approximately 24m		
	Existing Road to be connected			R-1		R-1		R-315		R-315		
	Vertical Navigational Clearance			37.5m		37.5m		15.0m		15.0m		
	Horizontal Navigational clearance			175.0m		175.0m		90.0m		90.0m		
Structural Aspects	Type of Structure			PC Cable Stayed Bridge(3span continuous 1 box girder)		PC Cable Stayed Bridge(3span continuous 1 box girder)		PC 5 Span Continuous 1 Box Bridge		PC 7 Span Continuous 1 Box Bridge		
	Bridge Length	Main Bridge		430.00m		430.00m		90+3@150+90=630.00m		90+5@150+90=930m		
		Approach Bridge		30@40+19@40=1960m		11@40+2@(60+150+100)+11@40=1540m		5@40+5@40=400m		5@40+6@40=440m		
		Total		2390m		1970m		1030m		1,370m		
	Bridge Width			13.50m		13.50m		13.50m		13.5m		
	Maximum Gradient			4.00%		4.00%		4.00%		4.00%		
Length of Approach Road				690+2,035=2,725m		980+1,100=2,080m		260+1,100=1,360m(and R-315=66.7km)		900+1180=2080m(and R-315=66.7km)		
Construction Works	Superstructure		△	Prestresed Concrete Cable Stayed Bridge	△	Prestressed Concrete cable Stayed Bridge	◎	Prestressed Concrete Box Bridge	◎	Prestressed Concrete Box Bridge	△	Sus
	Substructure		△	deep water depth	△	deep water depth	△	deep water depth	△	deep water depth	×	big
	Approach Road		○		○		×	R-315 runs across flooding area	×	R-315 runs across flooding area	△	
	Construction Period		○	48months	△	54months	○	42months	○	48months	○	
Maintenance Aspects			△	required Cable Stayed Bridge	△	required Cable Stayed Bridge	◎	not required special technical maintenance works	◎	not required special technical maintenance works	△	requ
Environmental Aspects	Air and Noise Pollution		○	Minor impacts caused by construction works and increased traffic volume	○	Minor impacts caused by construction works and increased traffic volume	◎	Although minor impacts caused by the increased traffic are anticipated, the number of pollution receptors are very small.	◎	Although minor impacts caused by the increased traffic are anticipated, the number of pollution receptors are very small.	○	Min wo
	Water Quality and Aquatic Ecology		○	Minor impacts caused by excavation of foundation	○	Minor impacts caused by excavation of foundation	○	Minor impacts caused by excavation of foundation	○	Minor impacts caused by excavation of foundation	○	Mi
	Cultural/Historical Properties and Environmental Aesthetics		△	Approach road close to school.	○	No significant impact	◎	No significant impact	◎	No significant impact	△	App on e
	Human Resettlement		○	Few houses and farms are scattered.	○	Few houses and farms are scattered.	○	Few houses are scattered.	○	Few houses are scattered.	△	Son
Traffic volume per day including bicycle and cycle				2305		2305		836		1276		
Influence by Construction Works	Economic impacts by locally procured materials		○	aggregate	○	aggregate	○	aggregate	○	aggregate	△	
	Technical Transfer		○	reinforcement worker/unskilled worker	○	reinforcement worker/unskilled worker	○	reinforcement worker/unskilled worker	○	reinforcement worker/unskilled worker	○	
	Employment Chance by Project		○		○		○		○		○	
Effects by Bridge	Effects on Traffic	Accessibility to Remote Areas	○	Improvement of accessibility to eastern bank	○	Improvement of accessibility to eastern bank	◎	Improvement of accessibility to eastern bank	◎	Improvement of accessibility to eastern bank	◎	Impr
		Travel Time Stability	◎		◎		◎		◎		◎	
		Saving in Ferry Operation Costs	◎		◎		○		○		◎	
		Travel Time	○		○		○		○		◎	Larg
		Savings in Travel Time Costs	◎	Large amount of travel time savings	◎	Large amount of travel time savings	◎	Large amount of travel time savings in rainy season	◎	Large amount of travel time savings in rainy season	◎	Larg
		International Network	◎	Network in GMS Economic Cooperation Program	◎	Network in GMS Economic Cooperation Program	△		△		◎	Netw
	Effects on Regional Development	Overpopulation in Capital	○		○		◎		◎		◎	
		Influenced Population	○		○		◎	Located near Phnom Penh	◎	Located near Phnom Penh	◎	Pop
		Agricultural/Resource Development	△		△		○	Agricultural development in the eastern bank	○	Agricultural development in the eastern bank	○	Pron
		Market Oriented Economy	◎	Formation of international trade corridor	◎	Formation of international trade corridor	○		○		○	Inter
		Balanced Regional Development	△		△		○	Promotion of Regional development in eastern bank	○	Promotion of Regional development in eastern bank	○	Regi
Total Project Cost(Million US$)				130.04		143.6		116.22(Bridge & Approach 77.41/R-315 38.81)		177.27(Bridge & Approach 105.23/R-315 72.04)		
Economic Evaluation (IRR)			○	9.40%	○	8.90%	○	8.30%	○	6.40%	△	
Overall Evaluation				○		△		○		×		

◎ : Very Good ○ : Good △ : Fair × : Bad

·ER BRIDGE

		NEAK LOEUNG		PREK TAMAK				KOMPONG CHAM		
		A - 2		B - 1		B - 2		C - 1		C - 2
		848m		673m		934m		547m		978m
		approximately 25m		Approximately 30m		Approximately 24m		approximately 55m		approximately 32m
		R-1		R-315		R-315		R-7		R-7
		37.5m		15.0m		15.0m		15.0m		15.0m
		175.0m		90.0m		90.0m		90.0m		90.0m
l box girder)		PC Cable Stayed Bridge(3span continuous 1 box girder)		PC 5 Span Continuous 1 Box Bridge		PC 7 Span Continuous 1 Box Bridge		Single Span Suspension Bridge		PC 7 Span Continuous 1 Box Bridge
		430.00m		90+3@150+90=630.00m		90+5@150+90=930m		500m		90+5@150+90=930m
		11@40+2@(80+150+100)+11@40=1540m		5@40+5@40=400m		5@40+6@40=440m		7@40..7@40=560m		5@40+5@40=400m
		1970m		1030m		1,370m		1,060m		1,330m
		13.50m		13.50m		13.5m		13.5m		13.5m
		4.00%		4.00%		4.00%		4.00%		4.00%
		980+1,100=2,080m		260+1,100=1,360m(and R-315=66.7km)		900+1180=2080m(and R-315=66.7km)		340+2,850=3,190m		500+2,150=2,650m
·d Bridge	△	Prestressed Concrete cable Stayed Bridge	◎	Prestressed Concrete Box Bridge	◎	Prestressed Concrete Box Bridge	△	Suspension Bridge(steel stiffened girder)	◎	Prestressed Concrete Box Bridge
	△	deep water depth	△	deep water depth	△	deep water depth	×	big difference of water level between dry & rainy season; high water current; deep water depth	△	big difference of water level between dry & rainy season; high water current
	○		×	R-315 runs across flooding area	×	R-315 runs across flooding area	△	East side is flooding area	△	East side is flooding area
	△	54months	○	42months	○	48months	○	42months	△	54months
lge	△	required Cable Stayed Bridge	◎	not required special technical maintenance works	◎	not required special technical maintenance works	△	required periodical repair t works for Suspension Bridge	◎	not required special technical maintenance works
tion works ne	○	Minor impacts caused by construction works and increased traffic volume	◎	Although minor impacts caused by the increased traffic are anticipated, the number of pollution receptors are very small.	◎	Although minor impacts caused by the increased traffic are anticipated, the number of pollution receptors are very small.	○	Minor impacts are anticipated due to construction works and increased traffic volume.	○	Minor impacts are anticipated due to construction works and increased traffic volume.
of foundation	○	Minor impacts caused by excavation of foundation	○	Minor impacts caused by excavation of foundation	○	Minor impacts caused by excavation of foundation	○	Minor impacts caused by excavation of foundation	○	Minor impacts caused by excavation of foundation
	○	No significant impact	◎	No significant impact	◎	No significant impact	△	Approach road close to temple and some impacts on environmental aesthetics	○	Some impacts on environmental aesthetics
	○	Few houses and farms are scattered.	○	Few houses are scattered.	○	Few houses are scattered.	△	Some houses are scattered.	△	Reliability developed commercial area
		2305		836		1276		1602		1602
	○	aggregate	○	aggregate	○	aggregate	△	aggregate	○	aggregate
worker	○	reinforcement worker/unskilled worker	○	reinforcement worker/unskilled worker	○	reinforcement worker/unskilled worker	○	reinforcement worker/unskilled worker	○	reinforcement worker/unskilled worker
	○		○		○		○		○	
m bank	○	Improvement of accessibility to eastern bank	◎	Improvement of accessibility to eastern bank	◎	Improvement of accessibility to eastern bank	◎	Improvement of accessibility to northeastern Cambodia	◎	Improvement of accessibility to northeastern Cambodia
	◎		◎		◎		◎		◎	
	◎		○		○		◎		◎	
	○		○		○		◎	Large reduction of river-crossing time	◎	Large reduction of river-crossing time
	◎	Large amount of travel time savings	◎	Large amount of travel time savings in rainy season	◎	Large amount of travel time savings in rainy season	◎	Large amount of travel time savings in rainy season	◎	Large amount of travel time savings in rainy season
ion Program	◎	Network in GMS Economic Cooperation Program	△		△		◎	Network in GMS Economic Cooperation Program	◎	Network in GMS Economic Cooperation Program
	○		◎		◎		◎		◎	
	○		◎	Located near Phnom Penh	◎	Located near Phnom Penh	◎	Populous area in Cambodia	◎	Populous area in Cambodia
	△		○	Agricultural development in the eastern bank	○	Agricultural development in the eastern bank	○	Promotion of development in northeastern Cambodi	○	Promotion of development in northeastern Cambodia
·dor	◎	Formation of international trade corridor	○		○		○	International trade corridor with Laos and Vietnam	○	International trade corridor with Laos and Vietnam
	△		○	Promotion of Regional development in eastern bank	○	Promotion of Regional development in eastern bank	○	Regional development in Northeastern Cambodia	○	Regional development in Northeastern Cambodia
		143.6		116.22(Bridge & Approach 77.41/R-315 38.81)		177.27(Bridge & Approach 105.23/R-315 72.04)		119.12		106.15
	○	8.90%	○	8.30%	○	6.40%	△	6.00%	○	6.50%
		△		○		×		△		◎

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This subsection, therefore, presents a synopsis of the critical factors that need to be considered (among the many presented earlier) for determining which among the six routes should be chosen as the site for the Mekong River Bridge.

(2.1) Critical Factors to be Considered

The Project, construction of the Mekong River Bridge, can be characterized as being of large scale and high cost, as well as displaying some international features. The specific conditions in Cambodia can characterized as a developing country in its infancy with uncertainty and constraints regarding its reconstruction.

These factors in combination yield the Project great significance with respect to the development of Cambodia in three areas:

i) Speed and Direction of Development

While there is no doubt that Cambodia will undergo reconstruction, the speed and direction of development in Cambodia over the next few decades depends primarily on political policies and attracted investment. Inevitably, a project of this magnitude, with a cost comparable to the total annual expenditure of the Ministry of Public Works and Transport, will increase the speed and influence the direction of development in Cambodia over the next few decades.

ii) International Economic Cooperation among Countries along the Mekong River

The Mekong River originates in the Tibetan Highlands, stretches southward 4,200 km to the South China Sea, and passes through Myanmar, Lao PDR, Thailand, Cambodia, and Viet Nam. Water resource development of the Mekong River is administered by the Mekong Committee, which is an intergovernmental regional organization. The New Asian Highway recently proposed by ESCAP and the international road projects in the Greater Mekong Subregional Economic Cooperation Programme have close relation to this Project. Therefore, the Project is internationally noted, and it is expected to display some characteristics of an international project in the Greater Mekong Subregion.

iii) Broad Indirect Effects

As mentioned earlier, the scale of the Project is large and its investment cost is very high. Because of these circumstances, the Project will have far-reaching effects that cannot be adequately quantified in terms of monetary amounts. Consider, for example, that the Project will promote industrial development, more effective national integration, and potentially a more equal distribution of income.

According to the above discussion, the evaluation of the Project and selection of the optimum route should not only consider Project cost and EIRR, but rather take a broad view in accordance with the important yet difficult-to-quantify aspects of the Project. Adopting this comprehensive point of view, the critical evaluation criteria for the Project were revised and their significance was reexamined.

(2.2) Final Evaluation

The aspects for evaluation considered most important are those affecting the probability of Project implementation. Clearly, the technical feasibility and economic feasibility of implementation are crucial for Project implementation. Because the technical feasibility (i.e., difficulties associated with construction work) is essentially reflected in the construction cost, the Project cost can be considered to encompass technical feasibility. Project EIRR is the prime measure of economic feasibility.

Other important aspects concern the capability of the selected bridge route to meet the wide-ranging objectives of the Project. With respect to this broad role of the Mekong River Bridge, the following three aspects are considered: (1) concordance with the national regional development strategy; (2) formation of an international network and promotion of an open-market economy; and (3) promotion of public welfare.

Other Project impacts, such as economic benefits derived from the procurement of local materials, transfer of technology, and expansion of job opportunities, are considered duplicative of the three above-mentioned criteria; therefore, they were not explicitly included as additional measures of effectiveness. While the three above-mentioned criteria share some overlap, the differences between and among them are readily distinguishable.

The last criterion selected as a crucial factor is environmental impact, which was discussed in detail in chapter 8.

The analysis of each criterion is summarized below.

i) Project Cost

Considering that the present MPWT annual budget is on the order of only US$ 50-60 million, the construction cost of the Mekong River Bridge is a critical issue. The Project cost should be minimized such that future repairs and maintenance of the bridge and approach roads can be carried out with minimum expenditure. According to this reasoning, the C-2 route with an estimated Project cost of approximately US$ 106 million is the most advantageous; the next least expensive alternative is B-1 (9.5% more costly), followed by C-1 (+12.2%), A-1 (+22.5%), A-2 (+35.3%), and B-2 (+67.0%).

ii) Economic Internal Rate of Return (EIRR)

EIRR is the rate of discount at which cost and benefit streams over 30 years are equalized (note that the project life is 100 years). As stated earlier, EIRR is often considered the main criterion of project feasibility because it reflects the economic benefits of the project as measured by quantifiable effects expressed in monetary terms. The EIRRs were 9.4% for A-1, 8.9% for A-2, 8.3% for B-1, 6.5% for C-2, 6.4% for B-2, and 6.0% for C-1, excluding the consideration of the economic loss to future traffic demand unrealized due to the lack of a bridge.

iii) Concordance with the National Regional Development Strategy

Although not explicitly stated in Government reports, regional development of northeastern Cambodia (i.e., the eastern portion of Kompong Cham Province and the entire provinces of Kratie, Stung Treng, Mondulkiri, and Ratanakiri) is undoubtedly tied to the regional development strategy of Cambodia. Northeastern Cambodia, although currently remote, isolated, and with a low population, has high development potential for mining and agriculture with abundant mineral resources and fertile soil. In the course of discussions with the MPWT, the role of the Mekong River Bridge in promoting the regional development of northeastern Cambodia was stressed. Kompong Cham is expected to function as the growth pole for the development of northeastern Cambodia; consequently, the C-1 and C-2 routes would reinforce this development potential and form a direct link to northeastern Cambodia. Therefore, C-1 and C-2 rank highest for this category, followed by B-1 and B-2, which would encourage agricultural development in the northeastern portion of Kandal Province and the northern portion of Prey Veng Province, and lastly A-1 and A-2.

iv) Formation of an International Network and Promotion of an Open-Market Economy

The Mekong River Bridge will indeed be expected to serve not only as an important domestic route, but also as a significant international link contributing to economic cooperation in the Greater Mekong Subregion.

Two types of international networks have been proposed by different authorities in Cambodia. One is the New Asian Highway proposed by ESCAP, and another is the international road projects in the Greater Mekong Subregional Economic Cooperation Programme. Routes A-1, A-2, C-1, and C-2 are located on these international networks and will improve transport between and among riparian countries along the Mekong River. The C-1 and C-2 routes are expected to provide a new international link with southern Laos (via Route 7) and central Viet Nam (via Route 78 from Stung Treng to Da Nang). Along the north-south international road between Phnom Penh and Kompong Cham, the Chroy Chang Va Bridge and Route

6A have already been rehabilitated by Japanese official development assistance. A bridge at C-1 or C-2 would constitute a logical progression of these improvements that strengthen the international network.

Improving accessibility to large economic centers in other countries, such as Bangkok, Ho Chi Minh City, or Da Nang, will stimulate and promote a market-oriented economy in Cambodia. Therefore, the formation of an international network with either routes A-1, A-2, C-1, or C-2 is expected to contribute to the promotion of an open-market economy. The B-1 and B-2 routes, on the other hand, are not envisaged to advance international traffic.

v) Promotion of Public Welfare

Although not easily measured in monetary terms, the impact of the Project on public welfare should be emphasized as an important indirect effect. Traffic accessibility to the remote and isolated areas located in northeastern Cambodia would remarkably improve medical and educational services, enhance security, and contribute to the stabilization of public welfare. Among the six alternatives, the C-1 and C-2 routes are relatively superior because of the vast area and population that would be influenced. The B-1 and B-2 routes would rank next since a bridge at either of these two locations would provide increased access to the area east of the Mekong River near Phnom Penh. The A-1 and A-2 routes are considered to have relatively little effect on public welfare.

vi) Environmental Impacts

The issue of environmental impacts with respect to Project implementation is also considered to be an important criterion. Among the six alternatives, only B-2 is regarded to have significant adverse environmental impacts (i.e., potential ruin to the vulnerable ecosystem of wetlands). Routes C-1 and C-2 have some adverse environmental impacts (e.g., human resettlement), while routes A-1, A-2, and B-1 are considered to have minor environmental impacts.

The issue of security with respect to Project implementation may also be considered an important criterion especial to Cambodia. It has been noted that there may be some security concerns at Kompong Cham. However, the magnitude of any potential risk cannot be reliably or reasonably ascertained at the present time; therefore, security was not included in the final evaluation.

(2.3) Final Recommendation

The above discussion carefully evaluates the technical feasibility, economic feasibility, important secondary benefits (under the circumstances at present and in the foreseeable future in Cambodia), and environmental impacts of the Project. After taking these critical factors into account, it can be concluded that the C-2 route has significant advantages over the other five alternatives in the following points:

i) Optimum Case under Budgetary Constraints

Considering the severe budgetary constraints of the Government of Cambodia, the C-2 route is the most reasonable alternative and will result in the lowest financial demand on the Government in terms of future repair and maintenance costs. Also, because the technical difficulties of construction work are fully incorporated into the Project cost estimates, selection of the C-2 route will minimize these complications.

ii) Broad Indirect Effects

As the EIRRs of all alternatives are relatively low, this criterion should not be strictly applied to single out a particular alternative. Other critical criteria that show significant differences between and among alternatives should be given appropriate emphasis.

From the viewpoint of broad indirect effects, which should be accorded proper significance for a project of this magnitude, the C2 route has the following advantages:

- construction of a bridge at the C-2 route will be in complete concordance with the national regional development strategy and enhance development of agricultural potential and natural resources in northeastern Cambodia;
- the C-2 route will form a vitally important link in the international network connecting Cambodia with Laos and Viet Nam and will contribute to strengthen the international network in the open-market economy; and
- the C-2 route will significantly improve accessibility to northeastern Cambodia and correspondingly bring substantial benefits to its population through improvements in medical and educational services, enhancements in security, and promotion of public welfare.

Therefore, based on this final evaluation of critical factors including due recognition of important indirect effects, the Study Team recommends that the C-2 route be selected for construction of the first Mekong River Bridge in Cambodia.

As a reference, a final evaluation matrix was prepared based on the above assessment of critical factors. This matrix, shown in Table 10.16, confirms the Study Team's findings.

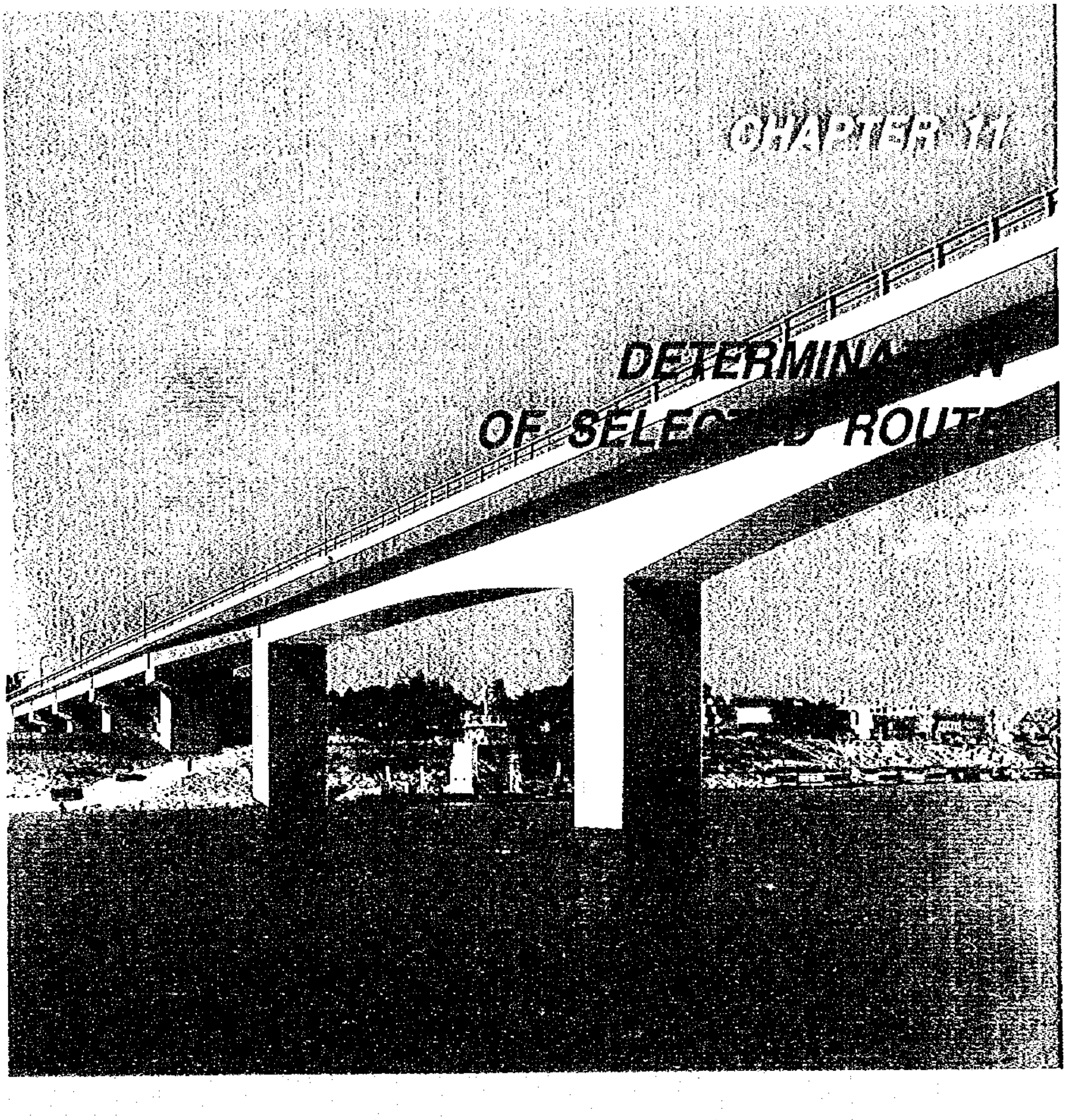
Table 10.16 Final Evaluation of Alternatives

	Weight	A-1 Ranking	A-1 Score	A-2 Ranking	A-2 Score	B-1 Ranking	B-1 Score	B-2 Ranking	B-2 Score	C-1 Ranking	C-1 Score	C-2 Ranking	C-2 Score
1. Project Cost	25%	3	0.08	3	0.08	2	0.13	3	0.08	2	0.13	1	0.25
2. EIRR	25%	1	0.25	1	0.25	2	0.13	3	0.08	3	0.08	3	0.08
3. Concordance with the National Regional Development Strategy	15%	3	0.05	3	0.05	2	0.08	2	0.08	1	0.15	1	0.15
4. Formation of an International Network and Promotion of an Open-Market Economy	15%	1	0.15	1	0.15	2	0.08	2	0.08	1	0.15	1	0.15
5. Promotion of Public Welfare	10%	3	0.03	3	0.03	2	0.05	2	0.05	1	0.10	1	0.10
6. Environmental Impact	10%	1	0.10	1	0.10	1	0.10	3	0.03	2	0.05	2	0.05
Total	100%	-	0.67	-	0.67	-	0.55	-	0.40	-	0.66	-	0.78

Source: JICA Study Team

Note: Score is calculated by the following formula:

Score = Weight x (1/Ranking), where ranking is either 1, 2 or 3; the highest score possible is 1.00.


CHAPTER 11
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CHAPTER11 DETERMINATION OF SELECTED ROUTE

11.1 General

The C-2 route was selected for the Mekong Bridge out of the six alternative routes proposed in the Interim Report (I). During the meeting between the Study Team and the Steering Committee on 5 October 1995, the Study Team expressed a preference for a slight shift of the alignment (approximately 300 m) downstream for the following reasons:

(a) Considering the severe budgetary constraints of the Government of Cambodia, land acquisition and compensation costs could be minimized.

(b) General scouring (i.e., lowering of the bed level) could occur along the original C-2 route.

(c) Construction of foundations in the deep river channel could be avoided.

It was agreed in the meeting that the Study Team will carry out detailed investigation of the bridge site near the C-2 route. The Study Team has selected a new route (C-3) approximately 300 m downstream as shown in Figure 11.1. The Study Area for the selected route is limited to the points between the roundabout (STA. 0 + 00) in Kompong Cham city and the connection to the existing Route 7 (STA. 3 + 595) on the east side.

This chapter presents the technical evaluation of the survey results to determine the most favorable route.

11.2 River Crossing Conditions

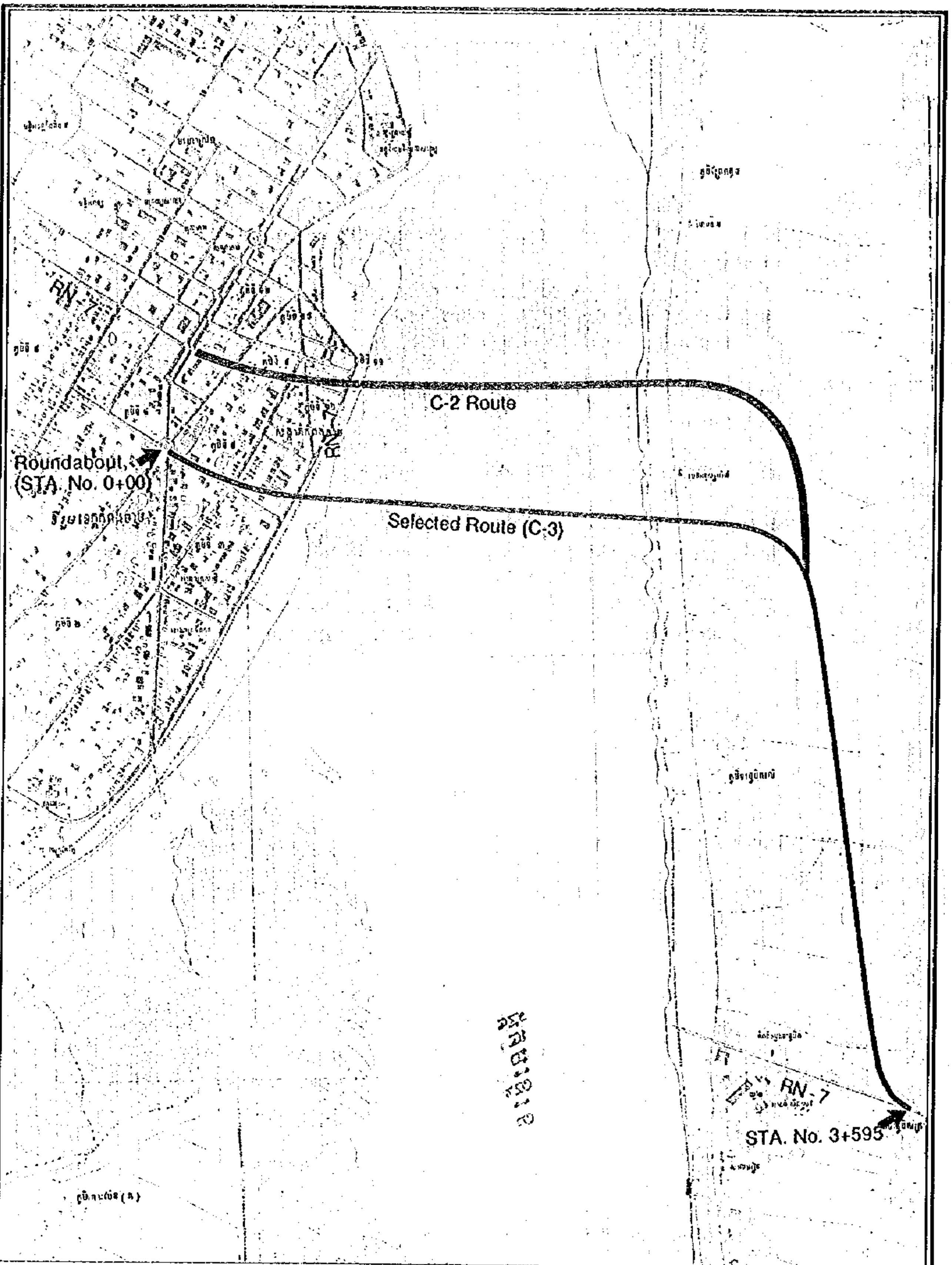
11.2.1 River Channel Conditions

(1) River Width

The river width is quite narrow at the Kompong Cham gauging station, becoming gradually wider downstream. The river width, defined as the distance between the top of river banks on both sides of the river, is 1,170 m at the proposed bridge site. It is narrowest, 820 m, at the Kompong Cham gauging station and 1,280 m at the C-2 route.

(2) Riverbed

The selected site is located in the vicinity of the turning point between riverbed scouring and deposition. General scouring is observed along the C-2 route, which is affected by the river flow through the narrowest section, while the riverbed level becomes gradually higher due to deposition in the lower reaches.



THE FEASIBILITY STUDY ON CONSTRUCTION OF THE MEKONG BRIDGE IN KINGDOM OF CAMBODIA	Figure 11.1 Selected Route of the Mekong Bridge
	JAPAN INTERNATIONAL COOPERATION AGENCY

General scouring is predicted to develop as a result of river bed changes. The lowest elevation of riverbed at the selected site is 16 m below mean sea level (MSL).

The upstream riverbed elevation is much lower, 47 m below MSL at the narrowest section and 26 m below MSL at the C-2 route, as shown in Figure 11.2.

(3) Water Level

The estimated probable high and low water levels at the proposed site are shown in Table 11.1. The west riverbank with an elevation of 16.2 m above MSL is high enough against the probable high water level. However, overbank flood may occur on the east riverbank with an elevation of 14.2 m above MSL, which is lower than the probable high water level with a 5-year return period. On the other hand, the top elevation of riverbank at the C-2 route is 15.7 m above MSL on both sides. Variation of the low water level in 5 years at the selected route, which will affect the construction of foundation, was estimated based on the existing data as shown in Appendix 11.1.

Table 11.1 Probable High and Low Water Levels at the Proposed Site

Water Level	Return Period (year)					
(MSL)	2	5	10	25	50	100
H.W.L.	13.62	14.25	14.54	14.81	14.97	15.10
L.W.L	0.98	0.82	0.73	0.66	-	-

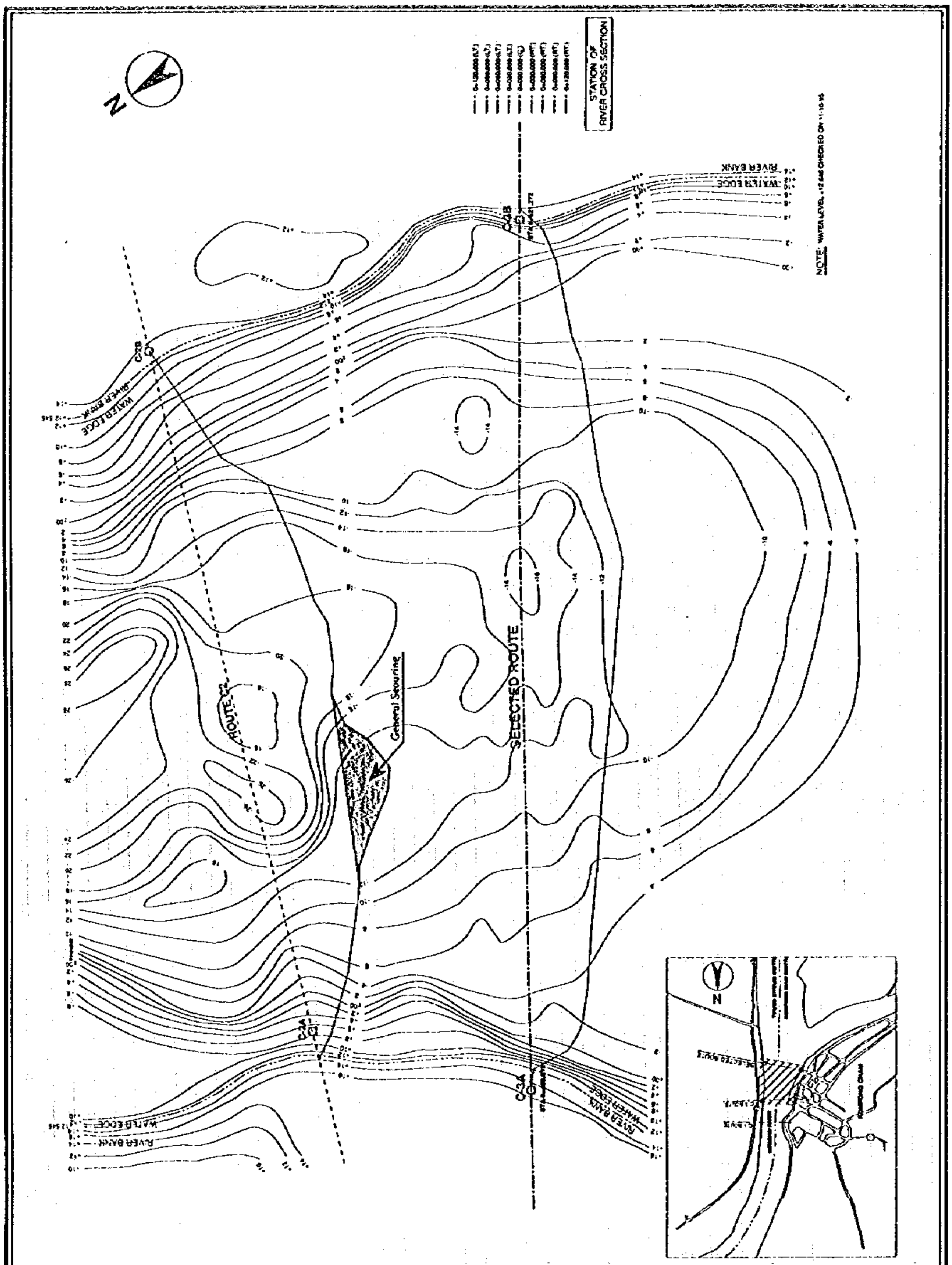
(4) Flow Velocity

The flow velocity was estimated based on the recorded maximum discharge at the Kompong Cham gauging station, which was 57,000 m^3/sec in 1966. The estimated flow velocity is 2.84 m/sec at the Kompong Cham gauging station, 2.53 m/sec at the C-2 site, and 2.37 m/sec at the selected route.

Judging from the river channel conditions, the selected site is more favorable for the bridge construction in general, except overbank flood on the east riverbank. Necessary flood clearance and height should, therefore, be provided on the approach embankment on the east riverbank.

11.2.2 Bearing Layer for Foundation

Owing to the active scouring nature of the river and the shallow depth of diluvium sand and gravel deposits in the riverbed, these deposit layers cannot support the foundation of the main bridge. Therefore, the main bridge section over the river will be founded on the weathered Mesozoic sandstone layer, which lies about 40 m below MSL along the



THE FEASIBILITY STUDY ON CONSTRUCTION OF THE MEKONG BRIDGE IN KINGDOM OF CAMBODIA	Figure 11.2 Contour Lines and Cross Sections in the River of Alternative Routes
	JAPAN INTERNATIONAL COOPERATION AGENCY

selected route and has a compressive strength of approximately 40 kg/cm^2. The piles can be designed to carry load by both shaft friction and end bearing and can be extended into the weathered rock to form a socketted length up to 5 times the pile diameter, considering the rock conditions and depth of sand and gravel deposits in the river bed.

11.3 Road Network

Further consideration about the network formation is necessary for the determination of the optimum route.

Since traffic on the Mekong Bridge consists of two types, through traffic and traffic related to Kompong Cham, the bridge should form a best network together with other roads for this traffic. Two typical types of network formation are considered to cope with this mingled traffic, one stressing the function of a bypass road in the future for through traffic with due consideration of transaction of traffic related to Kompong Cham, and the other stressing the function of a rather urban trunk road for urban traffic.

The former types of network is more recommendable for the following reasons: First, with the increase of traffic in the long run, mingled traffic in the urbanized area might cause the problems of decrease in the average travel speed and traffic congestion; therefore, to avoid those problems, a road with considerably large through traffic should be located far from the urbanized area. Second, because the land demand for establishment of new industries such as agro-industry or commerce is expected to arise along the route concurrently with the improvement of Route 7, a road alignment in the area which has available land for development is advantageous.

With the above concept, the following basic conditions for selection of the optimum route are assumed from the viewpoint of network formation. First, smooth connection of roads on Route 7 on both sides of the Mekong River should be assured. Second, the route should be so aligned as to form a new bypass way and allow land development along it in the future. Third, because traffic related to Kompong Cham should also be secured, the route should not be far from the present urban area.

Taking all the above into consideration, the new route connected to the existing road, 300 m downstream of the proposed C-2 route, is most recommendable.

11.4 Connection with Existing Roads and Constraints

The proposed bridge will improve traffic flows on Route 7 which is currently constrained by the ferry crossing at Kompong Cham. Route 7 itself originates at Skun where it intersects Route 6, and continues in the easterly direction to Kompong Cham, over a distance of 45 km. Beyond the ferry crossing the route runs east up to the junction with

Route 11, then changes to the northerly direction to Laos, branching off to Viet Nam at the Cambodian town of Krek.

The alignment of the approach roads is planned as follows:

(1) Western Approach

The western approach road will be located in Kompong Cham city and much of its length will be aligned along an existing small street, up to an intersection that is already relatively busy, catering primarily for light and non-motorized traffic. The proposed alignment will require the removal of some houses and acquisition of land along the existing street for its construction.

It is intended that in the short term traffic from the bridge will move in the northerly direction from the above intersection to Route 7 in Kompong Cham. In the longer term, the traffic will proceed directly ahead through the intersection, in the westerly direction, via a bypass road (Route 7) which will take traffic to the western outskirts of Kompong Cham without passing through the main business district and residential areas. The importance of the present intersection in ensuring smooth traffic flows is therefore significant and means that it should be improved. This will take the form of a roundabout and traffic islands to direct traffic flows.

It will also be necessary to improve the small street in the immediate area of the western approach road that will be affected by the proposed roadworks, in order to insure that local traffic flow is not overly constrained. This will include the improvements of one street, the relocation of a second and the provision of a vehicular underpass for one of the cross streets.

(2) Eastern Approach

The eastern approach will pass essentially through open country and therefore has few constraints. Flooding has the greatest impact on the road, and has determined the minimum level to be adopted for the road on the eastern side of the Mekong river.

11.5 Social Impacts

Upon the preliminary selection of C-2 as the optimum route of the bridge, a detailed site survey was undertaken in order to reaffirm a possible alternative route near C-2. Particular attention was given to the issues of human resettlement and compensation to those affected. The detailed field investigation has revealed that there is a better location (C-3 Route), which has less significant social impacts caused by the construction of the approach roads. The new location is about 300 meters downstream of C-2. As previously identified, some relatively developed commercial structures, e.g. rice distributors, are located in C-2 and the area is considered to serve an economic hub and play an important community function as a place of public assembly in Kompong

Cham. Besides the personal impacts of dislocation of households, particularly those holding remarkable commercial activities, social impacts include interpersonal impacts that may arise from the removal of these activities and persons engaging in the activities. On the other hand, houses are sparsely located and no significant commercial activities are observed along the selected route (C-3).

It was also revealed that land prices in the selected route are lower than those in C-2. This makes land acquisition and provision of compensation easier than in the case of C-2.

Accordingly, the selected route has advantages in the aspects of social impacts, considering the smaller number of households to be removed, no impact on commercial activities or community cohesion, and lower land acquisition and compensation costs.

11.6 Existing Ferry Facilities and Navigation

The selected route will cross over the existing ferry ramp and the area involved in the upgrading project of ferry landing facilities proposed by DANIDA*1. This project is scheduled to be implemented in 1997. Therefore, The Cambodian Government has started to coordinate both projects: construction of the Mekong Bridge and upgrading of ferry landing facilities. The main consideration for future development of the ferry system is whether to retain the existing ferry ramp and facilities or to move all of them to a new location (e.g., Prek Tamak).

During construction of the bridge, the existing ferry ramp should be moved from time to time. The Study Team proposes that the ferry ramp be shifted 1 km downstream to the old ferry ramp site during the rainy season, and 300 m upstream to a temporary site during the dry season, considering the availability of enough water depth to allow the ferry vessels to reach the ramp.

*1 In 1991 the Mekong Secretariat identified the need to upgrade ferry facilities at four important river crossings. Denmark through Danish Development Assistance (DANIDA), stressed such a need and dispatched a consultant to prepare the design and tender documents in 1994. The Government of Cambodia through MPWT, applied via the Mekong Secretariat to DANIDA for funds of the project implementation, which is now in the stage of conclusion and verification of the contract.

11.7 Description of the Selected Route

11.7.1 Horizontal and Vertical Alignment

The proposed bridge will require the construction of approach roads to connect the bridge to Route 7 at both ends. On the west bank this will be achieved by connection to the road network in Kompong Cham, which will also need to be modified to accommodate the proposed approach road. On the east bank the connection will be made by providing a simple curve which will direct Route 7 to the eastern approach via a connecting road that is approximately 2 km in length. An intersection will be provided to ensure access to the village where the present ferry terminal is located on the east bank.

The proposed alignment is relatively simple with only 3 horizontal curves along the 3.5 km long approach roads and bridge. Two of the curves are on the immediate approach to the main bridge section. These curves will have a minimum radius of 200 meters ensuring that speeds of 80 kph can be easily maintained. The vertical alignment is also very simple, because it is flat, over the majority of the approach road length. Only the final approach sections to the bridge itself will have a proposed grade of 3%.

11.7.2 Proposed Right of Way

The required right of way will have a nominal width of 40 m (20 meters on each side of the centerline), except the western approach (in Kompong Cham), the high embankment section of the eastern approach and the connection with Route 7, where the width of the right-of-way will need to be increased to as much as 70 meters over short lengths.

The greatest impact of the proposed roadworks will be felt on the western approach where a number of houses and other buildings will need to be demolished to provide the required width. To ensure that this impact would be minimized it was decided to, firstly, shift the road alignment to the north so that properties on only one side of the alignment will be affected and, secondly, construct retaining walls for the main approach embankment which confine the width it occupies at ground level to that of the road formation.

11.7.3 Land Acquisition and Compensation

Based on the above study of the right of way, the Study Team performed an interview survey concerning land acquisition and compensation costs in Kompong Cham municipalities. The costs were preliminarily estimated at 1.0 million US dollars, which are substantially lower than those in the case of the C-2 Route (1.59 million US dollars).

The construction of the bridge and approach roads will involve no disruption to the existing utilities such as power supply, water supply and waste disposal. However, construction of service roads and concrete box culverts will be required for maintaining existing traffic and drainage which will be affected by the embankment of approach roads.


CHAPTER 12
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CHAPTER 12 SITE SURVEYS FOR THE SELECTED ROUTE

12.1 General

Site surveys, which consist of topographic and bathymetric surveys, geological investigation and flow velocity survey were performed along the selected route at Kompong Cham with following objectives:

- to propose an alignment of the approach road and associated road works, and the right of way

- to plan the land acquisition and resettlement program

- to confirm the bearing layer for foundation piles

- to examine the river channel condition and estimate the depth of local scouring

- to prepare basic criteria for bridge design from a geographic and hydraulic viewpoint

The site surveys of the bridge crossing and approach roads were carried out between 10 October and 9 November 1995.

12.2 Topographic and Bathymetric Surveys

Detailed topographic and bathymetric field surveys of the bridge crossings and road approaches were performed between the 10 October 1995 to 30 October 1995.

12.2.1 Topographic Surveys

Topographic surveys included setting out the bridge and approach road centerlines, taking cross-sections at 50 m intervals (25 m on curves) for a width of 30 to 100 m, either side of the centerline (i.e., a 60 to 150 m band), and recording the surrounding topography, structures, roads, and other features.

Topographic surveys for bridge (overland portion) and approach roads were carried out for a length of approximately 3,700 meters. A plane table survey was also carried out on the west bank alignment to establish the position of the streets and houses along the proposed alignment. This latter survey included the intersection at which the bridge approach road connects to the existing road system in Kompong Cham.

The following survey drawings were produced:

- Alignment and topography plans at a scale of 1:1,000, showing the centerline of the 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, type, and size of 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 the bridge site 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 preliminary design levels.

12.2.2 Bathymetric Surveys

Bathymetric surveys consisted of 9 river cross sections, at the selected site including echo sounding in the river and normal land surveying between the water line and the river bank. Each cross section was of the order of 1,000 m in width.

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.

12.2.3 General Topography and Bathymetry at Bridge Site

The terrain at the 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 elevation at the site is -16 m at the deepest location. These and other features of the river crossing and the approach roads are summarized in Tables 12.1 below.

The low ground beyond the higher banks which flank the river are subject to flooding in most years. This will need to be taken into account in the final design, to ensure that the impact of the road embankment, on the drainage patterns, is minimised.

Table 12.1 Kompong Cham Site (C3) Features

River Crossing	
Width	890 m
Bottom Elevation	-16.0 m
West Bank Edge Elevation	16.1 m
East Bank Edge Elevation	13.9 m
Western Approach Route	
Length (excluding intersection)	255.92 m
Highest Ground Elevation	15.9 m
Lowest Ground Elevation	14.1 m

Vicinity - The western approach route lies within the city of Kompong Cham, intersecting several streets (refer to Figure 14.2).

Eastern Approach Route	
Length	2,065 m
Highest Ground Elevation	14.2 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 14.2). 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.

12.3 Geological Survey

12.3.1 Outline of Geology around the City of Kompong Cham

The study area for the selected route is between the ferry ramp of Kompong Cham and a line 100 m downstream of the monument in Tonle Bet Leu village located on the west bank of the Mekong River. Although the elevation of Kompong Cham city ranges from 10 to 30 meters above sea level, the elevation of the study area ranges from 10 to 15 m.

Geological conditions in the city of Kompong Cham are a little different from the Neak Loeung and Prek Tamak areas, as can be seen in Figure 12.1 which shows the Major Geotectonic and Morphotectonic Units of Cambodia. According to this map, the Neak Loeung and Prek Tamak areas are located on the Tonle Sap - Mekong Plains, while the Kompong Cham area is located adjacent to the south boundary of the South-East Volcanic Belt. Figure 12.1 also reveals that although sedimentary rocks are in the majority in the former unit, volcanic rocks are in the majority in the later unit. Therefore volcanic rocks begin to appear north of the study area.

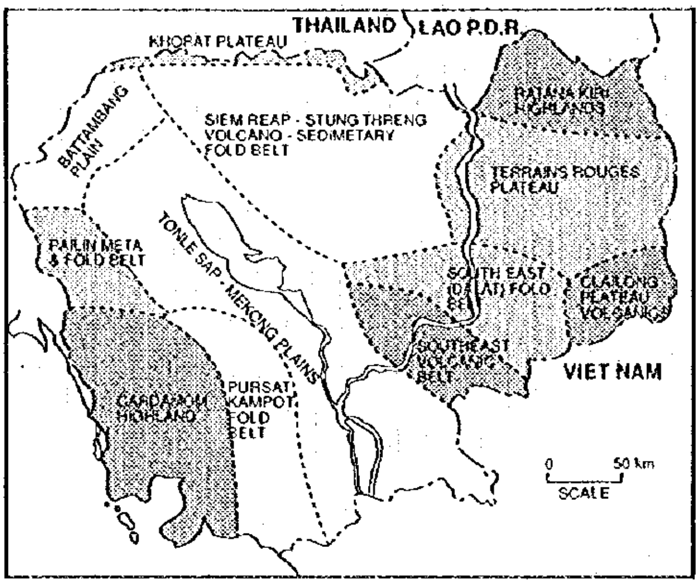


Figure 12.1 Major Geotectonic and Morphotectonic Units of Cambodia

The Study Team executed six drillings along and in the Mekong River around the city of Kompong Cham. BHC-1 and BHC-3 were carried out in the first site survey, while BH-1 to BH-5 were performed in the detailed geological survey as shown in Figure 12.2. These encountered six distinct formations in the study area. These formations and the geological sequence are shown in Table 12.2.

Table 12.2 Geological Formation for Bridge Foundation

Geological age	Formation	Description	Suitability for Foundation
Holocene	Alluvium	Clay (Ac), sand (As)	Not suitable
Pleistocene	Diluvium	Clay (Dc), sands (Ds)	Not suitable
Tertiary	Basaltic lava	Basaltic rocks (Tb)	Suitable
Mesozoic	Consolidated sand	Dense sand (Ms).	Suitable
Mesozoic	Mudstone	Hard clay (Mc) .	Suitable
Mesozoic	Rhyolite	Weathered Ryolite (Mr)	Suitable

Alluvium deposit of Holocene and Basaltic lava of the Tertiary cover the Kompong Cham area. Basaltic lava is distributed north of the line connecting the Weather Bureau of Kompong Cham with the Phum Vatt Angkor Krau in Kompong Cham City. Basalt lava generally covers the area above the 20 m contour while Alluvium deposit covers the area of lower than 15 m in elevation.

The characteristics of the six formations listed in Table 12.1 are as follows:

Alluvium deposits -- consist mainly of sand, gravel, silt and clay. These deposits form a river terrace and active flood plain including buried channels along the Mekong River. The results of drilling show that this formation can be divided into sand (As) and clay layers (Ac).

Diluvium formation -- lies under the Alluvium formation. Diluvium formation also comprises clay, sand and gravel. The results of drilling show that this formation is unconsolidated or semiconsolidated and can be divided into sand layers (Ds), clay layers (Dc), and gravel layers (Dg).

Tertiary formation -- comprises jointed basaltic lava (Tb) bearing olivine. This can be observed on the right side of the Mekong River, around the Weather Bureau. Basalt is estimated to have a compressive strength of more than 100 kg per cm^2 and an internal friction angle of about 40 degrees.

Mesozoic formation - drilling results show that the Mesozoic formation lies below the Diluvium formation and can be divided into a consolidated sand layer (Ms), a weathered mudstone layer (Mc) and weathered ryolite layer (Mr).

12.3.2 Geological Condition of Selected Route

The JICA Team excuted two drillings on both sides of the Mekong River along the selected route: BH-1 was located on the east of the Mekong River, BH-2 was at the opposite side. These drilling logs and the geological profile are shown in Figure 12.2 and the data in Appendix 12.1 to Appendix 12.7.

The results of two drillings are very similar in geological sequence. The geology can be described as composed of Alluvium deposit, Diluvium sediment, with the Mesozoic formation as the base rock.

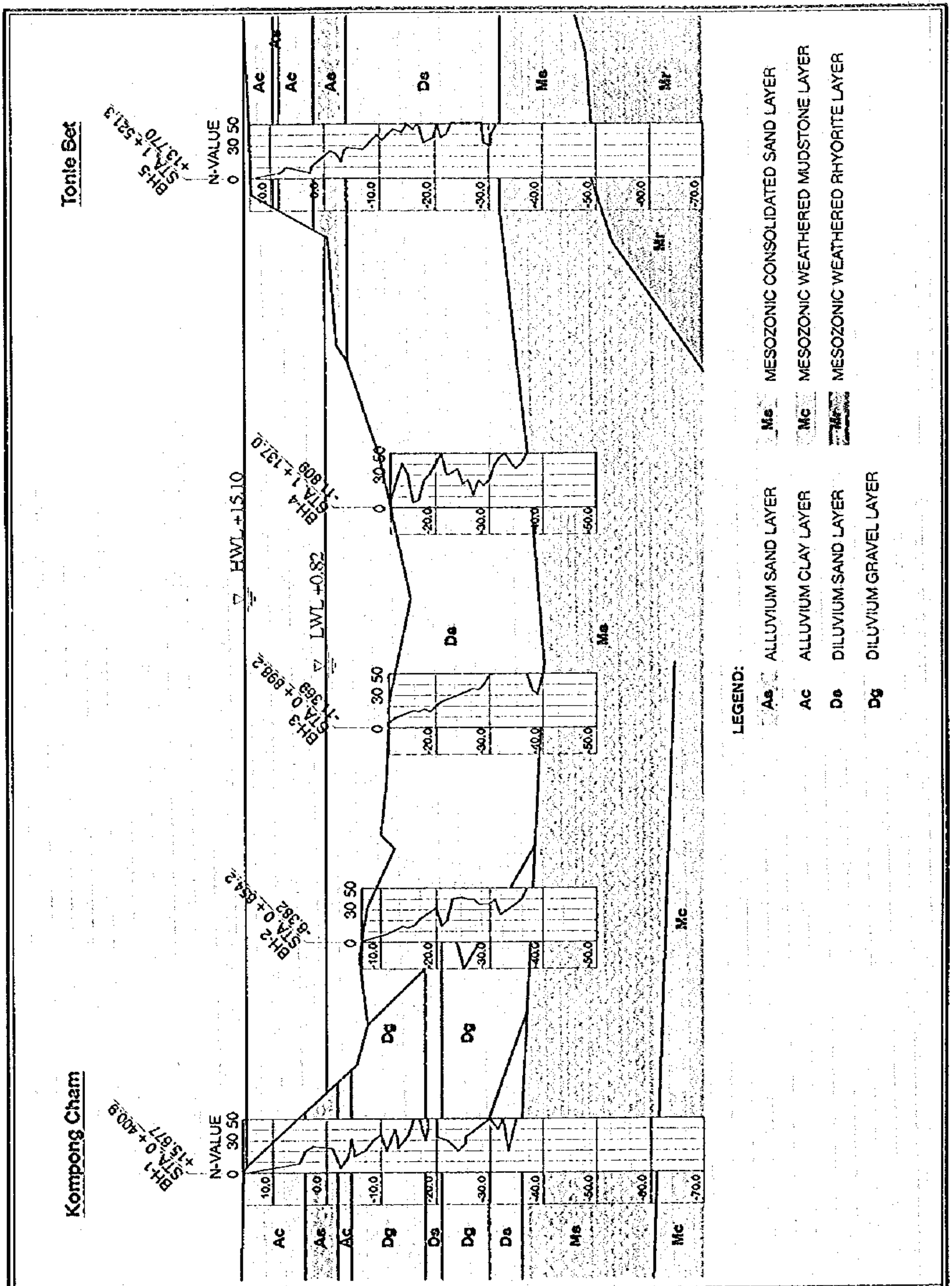
Alluvium deposit that consists of both sand (As) and clay layers (Ac) can be observed on the ground surface. The sand layer (As) consists of fine to medium sand which is gray to brown in color. The clay layer (Ac) consists of silty clay that is brown to blackish brown in color. These layers (Ac) lie with a continuity in the Alluvium deposit. The thickness of this deposit is estimated to be about 20 meters. N-value is below 10. This deposit is not suitable for the bridge foundation.

The Diluvium sediment which underlies the Alluvium deposit comprises sand layers (Ds) and gravel layers (Dg). The sand layers (Ds) consist of fine to coarse grain sand which is gray to brown in color. Gravel layers (Dg) comprise sandy gravel to gravel which are pale gray to grayish brown in color and contain quarts, chert and sometimes basalt fragment. These layers are estimated to lie lenticularly and discontinually in the Diluvium sediment. Clay layer (Dc) was not recognized in the two drillings. The thickness of the Diluvium sediment is about 30 meters with an N-value ranging from 20 to 40 based on Standard Penetration Test. The Diluvium sediment is therefore considered not suitable for the foundation of big structures due both to the heterogeneity of consolidation and the low N-value.

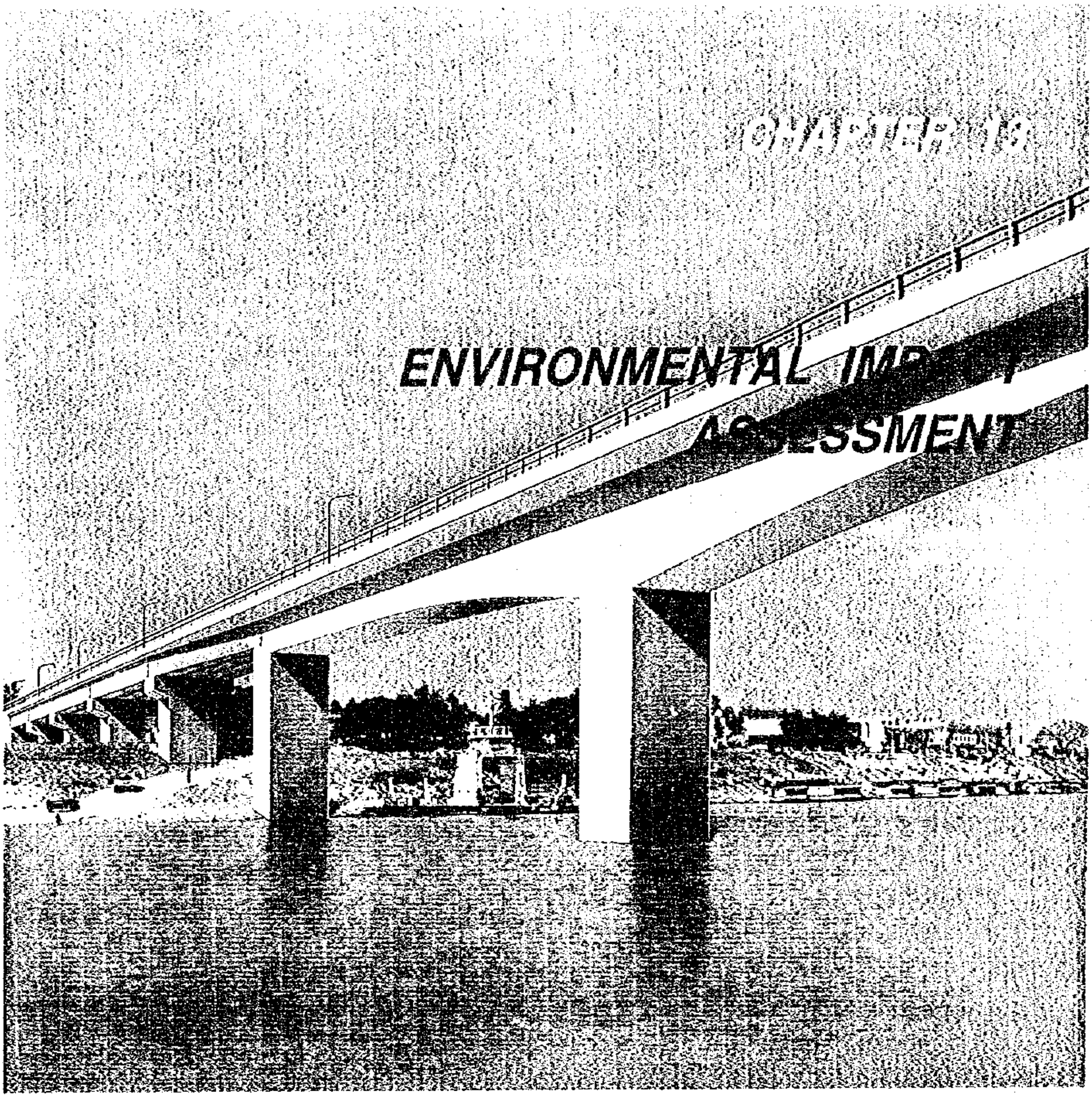
Mesozoic formations are distributed below the Diluvium sediment. These formations are formed by a consolidated sand layer (Ms), weathered mudstone layer (Mc) and weathered rhyolite layer (Mr). The cores of the consolidated sand layer (Ms) indicate a very dense fine to coarse sand which is sometimes interbeded with gravel which is pale gray to yellowish brown in color. This layer lies continually in the Mesozoic sediment.

The thickness of this layer ranges from 17 to 26 meters. The samples of weathered mudstone layer (Mc) show this layer comprises hard clay with pale brown color. The distribution of this layer is limited to the right side of the Mekong River where the thickness is more than 10 meters. The cores of the weathered rhyolite layer (Mr) indicate a very dense, homogeneous weathered rhyolite with grayish green to grayish blue color. The distribution of weathered rhyolite layer (Mr) is limited to the left side of the Mekong River. The thickness of the weathered mudstone layer (Mc) is more than 15 meters.

Mesozoic formations with an N-value of over 50 are estimated to have a compressive strength is about 40 kg per cm^2 and a cohesion of about 10~30 kg per cm^2. These formations are suitable for the bridge foundation.



THE FEASIBILITY STUDY ON CONSTRUCTION OF THE MEKONG BRIDGE IN KINGDOM OF CAMBODIA	Figure 12.2 Geological Profile for the Selected Route JAPAN INTERNATIONAL COOPERATION AGENCY


CHAPTER 13
ENVIRONMENTAL IMPACT
ASSESSMENT

CHAPTER 13 ENVIRONMENTAL IMPACT ASSESSMENT (EIA)

13.1 Present Environmental Conditions, Impact Assessment, Mitigation Measures, Monitoring Programs and Recommendations

As the impacts of bridge construction on the environment are generally considered minor if it is compared to large-sized infrastructure developments, e.g., road, railway, and dam, a full-scale impact assessment still needs to be undertaken in order to minimize or even eliminate the adverse impacts caused by the project implementation.

The major environmental parameters which would be adversely affected by the project include air and noise pollution, water quality and aquatic ecology, and human resettlement. Impacts on other concerned parameters, soil erosion and siltation, cultural/historical properties and environmental aesthetics, and transportation system, are also briefly presented.

13.1.1 Air Quality

The assessment of air quality impacts caused by the project implementation involves monitoring existing air quality to obtain baseline information, and air quality modeling to predict future pollutant levels. The modeling results are then compared to the ambient air quality standards set by the Japanese Government and the Thai Government.[1]

(1) Existing Ambient Air Quality

Existing air quality was monitored at a total of six locations near the selected bridge construction location. The pollutant monitored was limited to oxides of nitrogen (NOx) due to the unavailability of the equipment measuring other air pollutants. A conventional filter budge method was used for the measurement and the sampling period was 24 hours for respective measuring points.

The results of the monitoring revealed that the levels of NOx were well below the set standards of both the Japanese and Thai Governments, 290 micrograms per cubic meter (ug/m^3) and 320 ug/m^3, respectively. The results of the measuring are shown in Table 13.1 below.

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[1] As no environmental standards for air quality and noise levels are yet set in Cambodia, the Japanese standards are applied to the impact assessment. The standards set by the Thai government are also referred as example of a practice of neighboring countries of Cambodia.

Table 13.1 Existing Air Quality near Proposed Bridge Construction Sites

(Unit: ppm)

	A	B	C	D	E
NOx Level	18	12	14	20	3

Note: Following points were selected for noise level monitoring:
A: Major road facing the Mekong River under bridge approach road
B: Alley under bridge approach road
C: Major road under bridge approach road
D: Traffic circle at the end of bridge approach road
E: East of the Mekong River

(2) Air Quality Modeling and Impact Assessment

Future air quality was predicted in terms of NO_2 using an emission database and mathematical model. Emission factors were calculated by adapting the United States Mobile 4 model, which was compiled by the United States Environmental Protection Agency in 1985 for four levels of emission control technologies, namely from Tech I (no emission control) to Tech IV (three-way catalytic converter). The Thailand Development Research Institute Foundation (TDRI), one of leading think tanks in Thailand, developed a database taking into account of fleet mix between Tech II and Tech VI, as well as improved fuel quality since 1993, and the database is used for calculating the emission factors for various types of motor vehicles and pollutants. The calculated emission factors of NOx are presented below.

(Unit:g/km)

Average Speed (km/hour)	24	32	60	100
Private Car (gasoline)	1.9	2.0	2.1	3.8
Pickup Truck (diesel)	1.4	1.2	1.2	2.4
Heavy Vehicle (diesel)	19.0	17.0	17.0	18.0

It should be noted here that oxides of nitrogen (NOx) are not the same as Nitrogen Dioxide (NO_2), but consist of mostly Nitric Oxide (NO) which is not a pollutant of concern because it is harmless for human being. Therefore, the comparison of modeled results to the set standards cannot be made directly.

The average concentrations from a continuous infinite cross-wind line source were calculated by the modified Sutton Formula, with an assumption that the angle of the wind to the road is between 45 and 90 degrees, which is presented below.

$$C = 0.8Q(\exp(-(z+h)^2/(2S_z^2))+(\exp(-(z+h)^2/(2S_z^2)))/(Sz)u$$

Where:
C = pollutant concentration (mg/cubic meter)
Q = emission (mg/m/sec)
z = height of receptor (m)
Sz = dispersion coefficient (m)
u = average wind speed (m/sec)

h = height of road from the ground level (m)

For using the formula, an initial dispersion of two meters added to Sz was applied. For the preparation of the concentration contours, a grid of 10 by 10 meters was prepared for each selected grid point, in which the concentrations were calculated and the contours were drawn. The diversion coefficient (Sz) for vertical direction was calculated according to Slade (1968) for stability class B as the power function $0.53\ X^{0.73}$ (where X is the distance downwind from a source of pollutant), which is a good estimator taking into account the initial plume turbulence due to traffic effects when released. The estimated values are based on instantaneous release, as the nature of the plume is like that, and calculated as follows:

at 10 meters: Sz = 2.84 meters	at 20 meters: Sz = 4.72 meters
at 30 meters: Sz = 6.35 meters	at 40 meters: Sz = 7.83 meters

The wind direction related to Q (emission) in the formula was assumed to be at 90 degrees to the road. If the angle is less than 90 degrees, a factor of Q/sin@ is applied instead of Q, where @ is the wind angle. It is also assumed that the general wind direction in the project areas is northeast to southwest during winter (November to March) and southeast to northeast during the rest of the season. it is expected that the East-West bridge route will be exposed to about 45 degree winds. In the case of 45 degree winds, the concentration profile would have to be multiplied by a factor of 1.414. Considering relatively stable meteorological conditions in the project influenced areas, a wind speed (cross-wind flow) with one meter per second is assumed and applied for all the model runs.

For calculating pollutant concentrations, background levels of the pollutants were not taken into account, because the results of monitoring existing pollutant concentrations are so low that it was determined to ignore the background concentrations for the model running.

The results of the modeling indicate that predicted NOx levels at the edge of roads never exceed 50 ug/m^3 and the concentration levels are low enough to meet the respective set standards of NO_2 with 290 ug/m^3 (Japanese) and 320 ug/m^3 (Thai).

(3) Mitigation Measures and Monitoring Program

Although no significant air pollution problems are anticipated, it is proposed that mitigation measures be taken into consideration to minimize air quality deterioration during both construction and operation stages. Feasible mitigation measures for both stages of the project implementation follow.

During the construction stage, water and chemical sprinkling would be an efficient means to alleviate dust impacts on roadside residents. Additional proposed measures to minimize air quality decline include; locating a concrete mixing sites at isolated sites, enclosure of material stockpiles, storage of bulk construction materials in closed silos with appropriate dust preventing filters, shrouding the aperture for dry mix batching, and confining working vehicles to designated routes only.

Ambient air quality monitoring is desired to be carried out in order to prevent any unforeseen negative impacts during both stages of the project implementation. It is recommended that during construction monitoring the dust levels measured by Total Suspended Particles (TSP) concentrations, which is the major disturbing matter for inhabitants, be performed near the construction sites where inhabitants are nearby. The selection of the monitoring points depend on the stage of the construction, but it is wise to be suggested at this time that the same stations as air quality monitoring were conducted be the monitoring points of dust levels during construction. The monitoring at each point should be at least 3-day continuous with an appropriate interval. During operation, in addition to TSP, monitoring Carbon Monoxide (CO) should be carried out at the same sites at least every five years. All the monitored results have to be sent to the supervising agencies, i.e., the Ministry of Public Works and Transport and the Ministry of Environment.

13.1.2 Noise

The assessment of noise impacts caused by the project implementation involves monitoring existing noise levels to obtain baseline information, and noise level modeling to predict future noise levels. The modeling results are then compared to the noise level standards set by the Japanese and Thai governments.

(1) Existing Noise Level

The implementation of the project in both construction and operation stages will cause an increase in noise level near construction sites and along bridge approach roads. Noise levels associated with earthworks in construction stage and increased traffic volume in operational stage will be increased near construction sites and approach roads. Back ground noise levels were measured for four days at five monitoring locations, four on the west of the river and one on the east of the river. Monitored noise levels are shown in Table 13.2 below.

Table 13.2 Existing Noise Levels near Proposed Bridge Construction Sites

(Unit: dB)

Date	A	B	C	D	E
October 20, 1995	64	58	55	68	42
October 25, 1995	65	55	55	65	41
October 26, 1995	67	54	60	67	41
October 27, 1995	65	55	61	67	40

Note: Following points were selected for noise level monitoring:
A: Major road facing the Mekong River under bridge approach road
B: Alley under bridge approach road
C: Major road under bridge approach road
D: Traffic circle at the end of bridge approach road
E: East of the Mekong River

It is found from the results of monitoring that noise levels measured on the east of the river is nil as there are only four households near the construction site and the road condition along the river is so poor that it is unable to accommodate motor vehicles. On the west of the river nearby city center of Kompong Cham, however, noise levels are mixed. At points A and D, noise levels are relatively high because motorists keep sounding their horns. This indiscriminate horning manner is considered to increase about 10 decibel if it is compared to the noise levels without horning. At points B and C, traffic volumes are lower than those of A and D and not many motorists are driving their vehicles with indiscriminate horning, resulting in relatively low noise levels.

(2) Noise Level Modeling and Impact Assessment

The prediction of the noise levels was performed with the general highway noise model, developed by the United States Federal Highway Administration (FHWA). The computational sequences for the model is as follows:

a) Reference energy mean emission levels are obtained from "National Reference Energy Mean Emission Levels as a Function of Speed" (FHWA, 1978). The term is L_0E_i and varies for each class of vehicle, i.

b) A flow adjustment term is added to the number of vehicles per hour (Ni), reference distance (D_0), speed (Si), and time (T), in this case 1 hour. The term is $+10\log(N_iD_0)/(SiT)$.

c) A distance adjustment, $10\log(D_0/D)^{(1+a)}$, is added, where D is the actual distance; D_0 is 15 meters and "a" is site parameter.

d) A finite roadway adjustment term can be used for the case of road segments at bends.

e) A shielding adjustment term can be added according to specific sites such as earth berms and barriers.

The predicted noise levels are obtained from the summation of the calculated results of a) to e), the resultant levels are the 1-hour equivalent sound level ($Leq_{(h)}$). In order to get 24-hour equivalent sound level ($Leq_{(24)}$), the average of a series of levels was calculated. In general, the $Leq_{(24)}$ is 2-4 dB less than the peak $Leq_{(h)}$ because of the general traffic pattern, which is heavy during daytime and light during nighttime.

The primary information needed for the model running are traffic volume and vehicle running speed, by fleet breakdown. Traffic volumes for passenger cars (PC) and motorcycles (MC) in years of 2001, 2011 and 2021 are forecast by team's traffic engineer and these information are summarized in Table 13.3 below.

Table 13.3 Traffic Volume Forecasts near Bridge in 2001, 2011 and 2021

Year	(km/h)	PC	MC
2001	60	480	1,770
2011	60	1,890	4,980
2021	60	5,080	4,980

Note: PC=passenger car, MC=motorcycle

Similar to the case of air quality modeling, the background noise, which is generally the range from 50 to 60 dB for $Leq_{(24)}$, was not considered significant since the addition of such low levels would not affect the noise generated by vehicle running significantly, and was therefore not included in the modeling input.

The predicted noise levels were calculated to be the range between 45 and 65 dB.

The Office of Environmental Policy and Planning (OEPP) of Thailand sets standards for 24-hour equivalent sound level ($Leq_{(24)}$) to be 70 dB. If the predicted noise levels exceed the standard value, the mitigation measures are to be considered. It is worth to note here that the FHWA $Leq_{(h)}$ recommends 57 dB for parks and historical places, 67 dB for picnic and recreation areas, and 72 dB for developed areas. Japan's Environmental Agency also stipulates the daytime and nighttime noise standards for the three types of land uses, sensitive areas, residential areas, and mixture of residential and commercial areas. The set standards for these areas are 45 dB (daytime) and 35 dB (nighttime) for sensitive areas, 60 dB (daytime) and 50 dB (nighttime) for residential areas, and 60 dB (daytime) and 50 dB (nighttime) for the mixture of residential and commercial areas. These criteria, applied in the United States and Japan, will also be used for sensitive areas for this study, as no such standards currently exist in Cambodia.

In summary, the modeling results indicate that there are no significant incremental increase in noise levels due to the predicted traffic volumes in specified year.

It may also need to be mentioned about the noise generated during construction stage. Noise disturbance during construction is shorter than one during operation; however, its magnitude is considered much higher than one caused during operation. Typical construction equipment used for bridge construction and noise levels caused by the equipment, including mitigation measures, are described in Appendix 13-1.

(3) Mitigation Measures and Monitoring Program

As it is found that traffic volume increase induced by the opening of the bridge even in year 2021 is relatively low level, incremental noise level increase is considered minimal and, therefore, no mitigation measures are considered necessary during the operational phase.

However, temporary sharp increases in noise levels during the construction phase are anticipated and mitigation measures on respective construction equipment should be taken into consideration.

Concerning the monitoring program, during the operation phase of the project, no noise monitoring is considered necessary; while monitoring during the construction is recommended to ensure the minimization of the noise impacts to local inhabitants disturbed by the construction.

13.1.3 Water Resources and Aquatic Ecology

The Mekong River is a typical example of lotic resources having its characteristics of running freshwater systems. Although the level of water contamination is considered minor in the portion of Cambodia, with its characteristics of international river, originated in the People's Republic of China and passed through other upstream riparian counties, Thailand, Myanmar and Lao PDR, the discharge of organic materials flowing from the upstream may adversely affect the water quality in the downstream, low concentration of dissolved oxygen, which is a critical factor for the survival of aquatic resources. As the introduced organic matter flows downstream, it is subject not only to decomposition but also to sedimentation. If the watercourse is long enough and has sufficient water velocity, running water could purify the introduced organic matter through the self-purification process. However, if organic matter is released to the river along its length, either through unregulated point source releases., e.g., sewerage sewers, enriched surface runoff, or agricultural water, (though this is not a likely case of the Mekong River), a *polysaprobic zone* (poly = many kinds of; saprobic = pertaining to decay) would extend farther downstream and possibly contaminate the water quality near the bridge construction site of Kompong Cham. Therefore, it is worth measuring the existing water quality for the study.

Another aspect of possible water quality deterioration that should be given particular attention in impact assessment is actual construction activities. These activities include earthmoving works near the river bank and waterworks in water body. The impacts caused by these activities typically include an increased volume of sedimentation and temporary diversions of streams near river banks caused by earthworks and water quality deterioration caused by oil discharge from machinery maintenance and excrement discharge from construction camps.

(1) Existing Water Quality and Aquatic Resources[2]

Water was sampled at the center of the river. Seven parameters, Chemical Oxygen Demand (COD), Suspended Solid (SS), Dissolved Oxygen (DO), Nitrates, Fecal Coliform, pH, and Water Temperature, were tested by the Pasture Institute in Phnom Penh. The results of testing are shown in Table 13.4. It can be understood from the table that water quality is relatively good; good habitual situations for freshwater fish.

[2] Reference was made to *the Fisheries and Integrated Mekong River Basin Development; Terminal Report of the Mekong Basinwide Fishery Study* prepared by the University of Michigan, School of Natural Resources and Environment, 1976.

Table 13.4 Existing Water Quality

COD mg/l	SS mg/l	DO mg/l	Nitrates mg/l	Coliform MPN/100ml	pH	Temp. Celsius
1.2	25.2	8.5	0.78	1,500	7.8	28.5

Fish resources inhabiting the Mekong River near Kompong Cham were identified by the interviews with local fishermen and local fishing techniques were also identified, using lift nets, drift nets, purse seine nets, push nets, set nets, gill nets, traps nets, and conical set nets. The results of the interviews revealed that fish commonly caught in the study area's water body include families of anchovy, carp, catfish, snakehead, and eel. Technical names of these fish species are presented in Appendix 13.2.

(2) Impact Assessment

During construction, water bodies close to the bridge piers will need to be temporarily diverted and in some cases temporarily dammed, and existing useful water drainage patterns may be altered. This could result in irregular and interrupted down stream flow and drainage, affecting local water users. Bridge construction, particularly if a new bridge were constructed over the major rivers, would have some impact on aquatic ecology; the principal sources of water quality deterioration affecting aquatic ecology are water stream alteration and sedimentation changes from earthworks associated with the bridge piers and approaches, grease and oil discharges from machinery maintenance, and fecal contamination from construction camps.

During operation, only concerned adverse impacts on water quality is water runoff from the pavement surface of the bridge.

(3) Mitigation Measures and Recommendations

During construction, locating machinery maintenance areas and construction camps away from the river is an efficient means of preventing water quality deterioration caused by bridge construction activities. In order to reduce the chance of oil spills from construction equipment and fecal contamination from construction camps, it is recommended that the supervising agency be designated the sites for these areas and provide adequate facilities to deal with the activities. Concerning the prevention of pollutants runoff from the pavement surface, there are no very effective mitigation measures except for maintaining designed drainage system effectively. Adequate monitoring of the function of the drainage system of the bridge is recommended.

13.1.4 Socio-economics and Human Resettlement

Bridge construction will require the expropriation of residential land, necessitating relocation of affected inhabitants.

(1) Existing Socio-economic and Inhabiting Conditions

Existing socio-economic conditions around the selected bridge construction location were examined by a series of interviews with local inhabitants and probable involuntary human resettlement situations were investigated by the field survey. Collected data were utilized as a basic information on the analysis.

Although newly proposed bridge construction location is carefully selected, it still causes some impacts on local inhabitants who will need to be removed, mainly due to bridge approach road construction. There would be some 30 houses likely to be removed, about 20 on the west side of the river and about 10 on the east side of the river. On the west side, most houses affected will be caused by construction of bridge approach road, while on the east side, caused by the construction of an interchange connecting an approach road and existing Route 7. It is worth noted here that responsible agency on this matter is not the Ministry of Public Works and Transport, but Kompong Cham authority. A discussion between the Study Team and Kompong Cham officials, headed by the Deputy Governor, was made in November 1995, and it was confirmed that the local authority will take appropriate actions in order not to make anybody worse off. An appropriate resettlement program drafted by the Study Team is described in the following section.

A total of 111 households were interviewed. Interviewed households were randomly selected and the interview was conducted based on a prepared questionnaire, asking for household structure, occupation, employment status, education background, land ownership, and attitudes towards the project. The results of the surveys are summarized in Table 13.5.

Table 13.5 Results of Socio-Economic Survey

Average size of household	6.8 persons
Monthly household income	US$886(Average) US$200 (Median) US$50 (Mode)
Land price (per m^3)	US$236(Average) US$137 (Median) US$568 (Mode)
Per cent own land	98 %
Education background	4% (Elementary) 45% (Secondary) 51% (Higher)
Attitude towards project	99 per cent in favor

The results of survey indicate that in this relatively developed area most of household heads are engaged in government services or private merchandise, some cases both, and their monthly incomes generally fall into the range between US$50 and US$200. Some households earn more than US$5,000 per month, which pushes up average income to be US$886. Most of the lands in which houses are built are owned by local inhabitants. The land price is gradually increasing lately and the current estimated land prices range between US$9 and US$833 per square meter.[3] As the survey was conducted in the center part of Kompong Cham, mode of land price resulted US$568 (6 samples). Local inhabitants in the area have generally good education background, more than 95 per cent having secondary or higher schooling. It was ascertained from the Interviews that people are quite positive to the project implementation. The investigation revealed that the overall reaction to the project is very positive, more than 99 per cent of interviewed persons were in favor of the bridge and expected increased employment opportunities as construction workers, more convenience of quick river crossing, and overall economic development in the regions. Some respondents stressed that appropriate compensation should be provided to those affected, including resettlement plans and mitigation measures on bridge construction and operation.

(2) Impact Assessment

Induced socio-economic impacts typically include population increase, changes in employment opportunity, and land price changes. Some area-wide population increase are expected mainly caused by improved traffic flow in the influenced area. Bridge construction may not significantly affect employment opportunity of local inhabitants as most of them are found to have their jobs in government agencies or commercial entities. Land prices changes are also expected although no specific land price-increasing factors directly induced by the bridge operation is determined.

Concerning the impacts on land expropriation, i.e., human resettlement, adverse impacts on the relocating local inhabitants can be offset by the provision of appropriate countermeasures. The interview survey with local inhabitants has revealed that majority of the inhabitants agree to move to relocated places only if they are given at least same level of living standards.

(3) Mitigation Measures and Recommendations

Viable mitigation measures to minimize negative induced socio-economic impacts include the control on changes in land use. In order to prevent unfavorable land value hike, new commercial and industrial development in likely affected areas must be strictly controlled. Therefore, it is recommended that relevant agencies prepare appropriate land use planning, in line with bridge operation/management program.

Realignment, bypassing the affected areas as much as possible, would be the first measure to be considered to alleviate land expropriation impact, related to human relocation problem. If this measure is not viable, appropriate compensation measures should be taken place; the measures should include provision of sufficient fund or substitution housing in proper locations to keep at least same level of living standards

[3] It should be noted that land prices shown in the above table include the cost of land itself and structures, houses and/or commercial buildings, on the land. It was understood from the interviews with officials that land prices are greatly dependent upon the value of building structures and contribution of land to "the land price" is relatively minor. It should be further noted that the land prices shown in the table are values estimated by those interviewed as land pricing system has yet established in Cambodia.

for relocated inhabitants. Resettlement plan is drafted by the Study Team and the plan is described below.

(1) The initial design stage makes a detailed investigation of the area of land required and the number of houses to be removed according to the bridge construction.

(2) Based on these estimates the requiring body prepares an acquisition budget using compensation values currently enforced in Kompong Cham province about compensation unit price of requisition land, pulling down and removing houses. The detailed engineering design of the project is then used to check the accuracy of the preliminary estimates.

(3) The requiring body then officially presents the land offices in Kompong Cham with detailed plans, detailing the location and amount of land and number of houses required. The Prefectural land offices together with the county's (or city's) land offices then take responsibility for verifying the land and house requirement plans and calculating the compensation values.

(4) The requiring body then deposits the agreed compensation payment with the relevant land office within ten days. Thereafter the requiring body together with the local land administration officials begins the legal enforcement process. This begins with informing those affected of the loss of their lands or houses. Then, with local consent and information, the local authority is required to plan and build new houses and allocate new or existing land before making the site available.

(5) After this time the construction unit, working together with the local land authority, assists people to move to their new sites. This is followed by the demolition of structures and site clearance some two months before project construction begins.

In any case the resettlement plan should specify alternative resettlement sites. This kind of plan should be studied in depth well-before actual construction starts. The information provided in the resettlement plan for the new sites should encompass host population, resource use pattern, social infrastructure, inventory of fauna and flora, and assessment of public health conditions.

It is also recommended that a public hearing be held at proper timing. The hearing is desired to be organized by relevant agencies and to be based on integrity and goodwill. The purpose of the hearing is to solve conflicts between an executing agency and inhabitants. Hence, the hearing has to provide a whole picture of the project, both pros and cons, with inhabitants, and the agency acquires better understand of inhabitants' concern. A successful public hearing is considered important step for smooth implementation of the project. Since adverse impacts of this bridge project are considered relatively small, holding an appropriate public hearing on proper timing is strongly recommended.