13.1.5 Soil Erosion and Siltation

(1) Existing Soil Conditions

Soil conditions have been examined by Team's geologist in consideration of potential soil erosion or loss on the river bank.

Geological drilling results revealed that soil characteristics of the study area comprise a combination of Alluvium, Diluvium, Teritary, and Mesozoic formations; whereas the former two formations are not suitable for bridge foundations while the latter two are suitable for this purpose.

(2) Impact Assessment

The impact of soil erosion for embankment is conceptually assessed by the amount of soil loss, which is mainly related to various degrees of rainfall, vegetative cover, slope, and conservation practice. The amount of soil loss is generally estimated through application of the universal soil loss equation presented below.

$$A = R \times K \times LS \times C \times P$$

Where:
- A = amount of soil lost in tons per hectare
- R = rainfall erosion factor
- K = soil erodibility factor
- LS = slope factor, calculated from length and grade
- C = cover and management factor
- P = conservation practice factor

Due to its relatively flat terrain of the proposed bridge construction site and stiff characteristics of soil features, there would be no significant impacts of bridge construction on soil erosion or siltation.

(3) Mitigation Measures and Recommendations

Although no significant adverse impacts on soil erosion is expected, appropriate mitigation measures should be designed to head off any potential natural disasters. Concerning the prevention of soil erosion, as shown in the universal soil loss equation, minimizing the last three factors of LS, C and P are the main priorities, appropriate engineering design can contribute to satisfy these conditions. The most important measure is to establish ground cover caused by earthwork as soon as possible. The most likely and proper measures on this matter proposed and designed, include the provision of the embankment. In addition to the slope preventive measures, the provision of proper drainage system is also very effective means to reduce soil loss.

Besides engineering design to prevent soil erosion, R (rainfall erosion factor) in the equation is also worth considering. It is also important that proper construction work plan be drafted in due consideration of the known rainfall patterns to reduce the erosion, because it is well known that the R factor is the largest single term in the equation. Simply refraining from leaving bare soil exposed to strong rains will greatly limit potential problems. The recommendation to realize this ideal measure is very simple; major earthwork in concerned areas should be avoided during heavy rainy season. Although this measure is the simplest and most effective, it may not be practicable in many cases.

All the measures described above are desired to be instituted during construction. Additional measures are recommended which mainly relate to maintenance, contributing to P (conservation practice factor) in the equation. It is strongly recommended that the supervising agency designate responsible personal for maintaining the viability and effectiveness of the slope protection on the embankment.

13.1.6 Cultural/Historical Properties and Environmental Aesthetics

(1) Existing Conditions of Cultural/Historical Properties and Concept of Environmental Aesthetics

There are believed to be no important cultural/historical properties in the project affected areas. Only property of this category is a historical tower located near the river bank on the east side. The tower is believed to construct during French colonial era and is located about 150 meters from the center line of the planned bridge approach road.

Environmental aesthetics value is generally considered to be disturbed by the appearance of new structures, which may destroy the harmony of the existing scenery or simply shut it out. Areas to be considered typically include near temples and bridges, and areas with great land form changes. Differing from the other environmental parameters, this parameter cannot be numerically evaluated because an evaluation can only be made in a subjective manner.

(2) Impact Assessment

The historical tower close to the river bank will not be affected by the construction works as the distant between the monument and bridge approach road is more than 100 meters, far enough to have an impact.

Impacts of the introduction of a large bridge were evaluated by close investigation on the impacts on visual beauty near the bridge construction location. The result of evaluation revealed that the new bridge would harmonize with background scenery and there would be no significant visual beauty disruption caused by the appearance to the new bridge.

(3) Mitigation Measures and Recommendations

No mitigation measures are considered necessary as no significant negative impacts are expected.

13.1.7 Transportation Network

The analysis of impacts on transportation network in affected areas is based on the conducted traffic study, which is presented in Chapter 4 in this report. The focus of the analysis is probable traffic congestion caused by bridge opening.

(1) Existing Transportation Network

The traffic in the study area is currently carried by one major highway, Route 7 which is divided by the Mekong River, and urban type road networks on the west of the river and rural type one on the east of the river. All the roads converge on Route 7. With relatively low traffic volumes on the existing road systems on both sides of the river, no significant traffic congestion problems are observed at present.

(2) Impacts on Existing Transportation System

The planned bridge will connect currently divided Route 7 and contribute smooth traffic flow on Route 7. As the forecast traffic volume increase is relatively steady, no sharp increase in a certain section of the existing roads is expected, except for a roundabout on the west of the river. The roundabout is considered to accommodate the heaviest traffic in the study area and is also directly connected to the bridge approach road. It is anticipated that traffic volume at the roundabout will be increased and possibly cause traffic congestion.

(3) Mitigation Measures and Recommendations

Only anticipated traffic congestion might have developed at the roundabout as stated above. An appropriate measure to alleviate this potential problem is construction of overpass routing East-West. Although no overpass construction is proposed at this stage, it will need to be considered when congestion problem becomes obvious in the future; nevertheless, this problem will probably not be realized for quite some time.

13.2 Overall Environmental Impact Evaluation on the Project

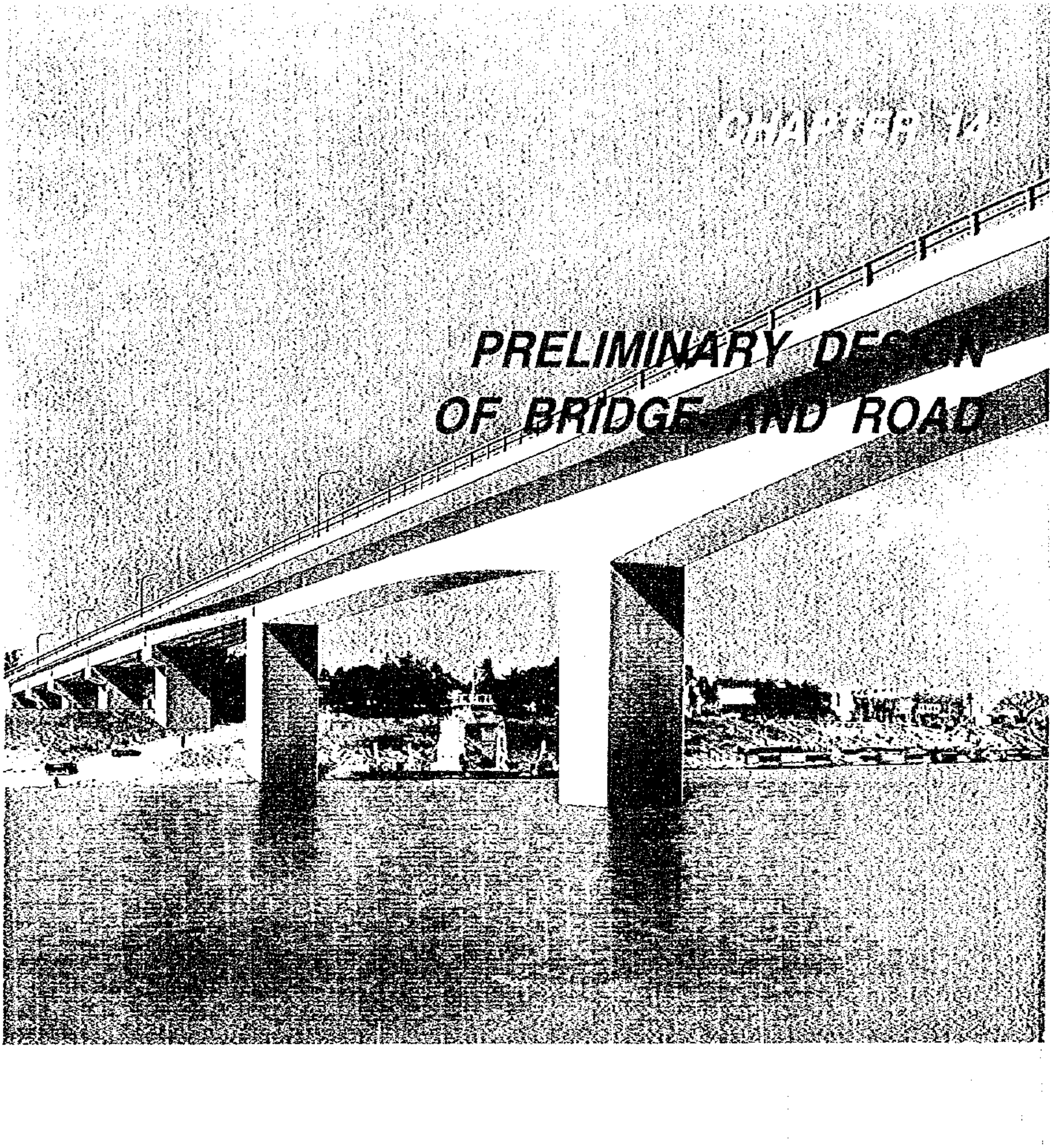
Existing conditions and predicted impacts on major environmental parameters are studied in depth, assessment of these impacts are made, and feasible mitigation measures and recommendations, as well as monitoring programs, are proposed.

It is studied from the entire analysis that the magnitude of adverse impact on the environment is mixed. Some environmental parameters will be affected to some extent, while others have minor impacts. For example, some areas on bridge approach roads need to be expropriated, causing human relocation problems, while impacts on the rest of parameters have been found minimal. All the environmental parameters will be adversely affected in some degree by the project implementation. However, adverse impacts on these environmental parameters can most likely be mitigated by the provision of proposed countermeasures and monitoring programs, and no serious environmental problems are expected in the future.

Consequently, overall environmental impact caused by this bridge construction project is evaluated to be minimal only if all the proposed mitigation measures and monitoring programs are properly implemented.

Apart from negative impact on the environment, on balance, it is expected that the new bridge will actually enhance economic development through the provision of smooth and time-saving transport systems. Economic evaluation of the project is also studied by the Team's economist concluding that the bridge construction project is economically viable (see Chapter 16). The economic viability and overall environmental impact discussed above will promise vital outcome from the project implementation.

As a final remark, it is proposed that mitigation measures during construction be clearly stated in construction contract and qualified environmental inspectors be hired to oversee implementation of the mitigation measures during construction. Reports on the mitigation measures should be prepared by inspectors and submitted to relevant agencies regularly.


CHAPTER 14
PRELIMINARY DESIGN
OF BRIDGE AND ROAD

CHAPTER 14. PRELIMINARY DESIGN OF THE BRIDGE AND ROAD

14.1 Design of the Bridge

14.1.1 General

The concept of preliminary bridge design was based on the functional requirements confirmed in the Interim Report (II) and discussed between the Study team and the Steering Committee on 20 December 1995. This chapter covers the preliminary bridge and approach road designs at a feasibility study level, which are required to define:

- basic design criteria and method;
- the total length of bridge and span length;
- the optimum technical solution for bridge (superstructure, substructure and foundation);
- the associated river training works; and
- the associated ancillary works.

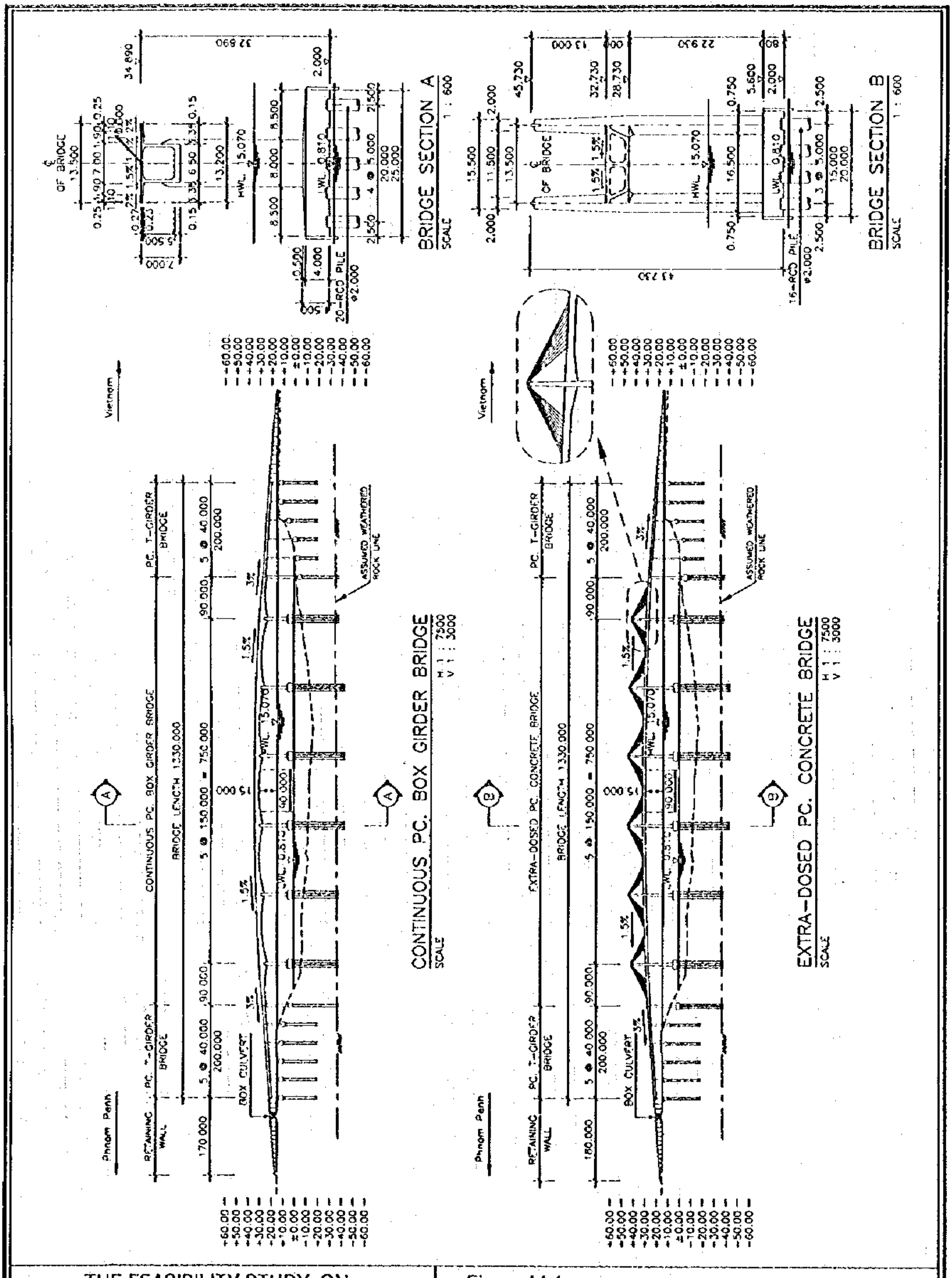
The above designs and related issues were studied in the following sections based on the output from the preceding detailed site surveys and discussions with officials.

14.1.2 Alternative Bridge Types

A comparison between concrete and steel bridge types was made in Chapter 7. It was evaluated that the prestressed concrete bridge type has the advantage of minimizing construction and maintenance costs, technology transfer for skilled workers, and efficient use of local materials. This section presents the comparison of two prestressed concrete bridge types: Continuous PC Box Girder Bridge and Extra-Dosed PC Bridge which are equally attractive for the span range of 100 - 170 m.

The two alternative bridge types as shown in Figure 14.1 have been compared on the basis of the following criteria:

- Construction period
- Technical aspect (feasibility)
- Actual experience of construction
- Maintenance requirement
- Construction cost
- Foreign and local components in the construction cost (impacts of construction on the local economy)
- Technology transfer



THE FEASIBILITY STUDY ON CONSTRUCTION OF THE MEKONG BRIDGE IN KINGDOM OF CAMBODIA	Figure 14.1 Alternative Bridge Types
	JAPAN INTERNATIONAL COOPERATION AGENCY

To select the most suitable bridge type, the above criteria are studied for both types. The evaluation results are summarized in Table 14.1. Both types are considered to be technically feasible, however the Study Team recommends that the Continuous PC Box Girder Bridge be selected for the following reasons:

(a) The Extra-Dosed PC Bridge type is considered to be more economical than the PC Box Girder or cable stayed bridge type in Japan, but has the disadvantage of requiring maintenance for cables and foreign technical assistance, which will push up the construction cost in Cambodia. In comprehensive cost comparison including maintenance cost, there is not apparent difference between both alternatives (Appendix 14.1).

(b) The PC Box Girder Bridge type is conventional method usually adopted for long span bridge. It is favorable from the viewpoints of technical transfer and maintenance. There are many actual experiences of construction of this bridge type in Bangladesh, Lao PDR, Kenya and other developing countries.

(c) While the PC Box Girder Bridge type is almost maintenance free, the Extra-Dosed PC Bridge requires technical know-how for effective inspection and maintenance for cables and expansion joints, and replacement of cables due to corrosion.

Table 14.1 Evaluation of Alternative Bridge Types

Item	PC Box Girder	Extra-Dosed Bridge
Construction Period	3.5 years	3.5 years
Technical Aspect	Conventional method and technically feasible	High-tech method but technically feasible
Actual Experience of Construction in Japan	Many bridges applied for long span	A few bridges but several applied in future
Maintenance Requirement	Almost maintenance free	Cables and cable sockets needed but possible to change cables
Construction Cost (Project Cost)	1.03 (1.00)	1.00 (1.00)
	Lowest cost because local materials and labour are available and cheap	Lowest cost in Japan but rather higher cost in Cambodia due to required technical assistance
Foreign and Local Components in Construction Cost	0.65 : 0.35 Local oriented bridge large impact on the local economy	0.67 : 0.33 Foreign oriented bridge
Technology Transfer	Basic technology transfer on PC bridge type	Advanced technical transfer on PC bridge field
Evaluation	◎	○

◎ : Very good

○ : Good

14.1.3 Span Arrangement by Selected Bridge Type

The construction of Continuous PC Box Girder Bridge is most likely limited to a maximum span of 170 m in view of structural stability and a minimum span of 120 m due to the navigation clearance (90 m x 15 m) in the Kompong Cham site. Based on the technical evaluation results, three alternative bridges with different span lengths have been studied as shown in Figure 14.2 and the optimal span lengths have been determined by comparing the construction cost.

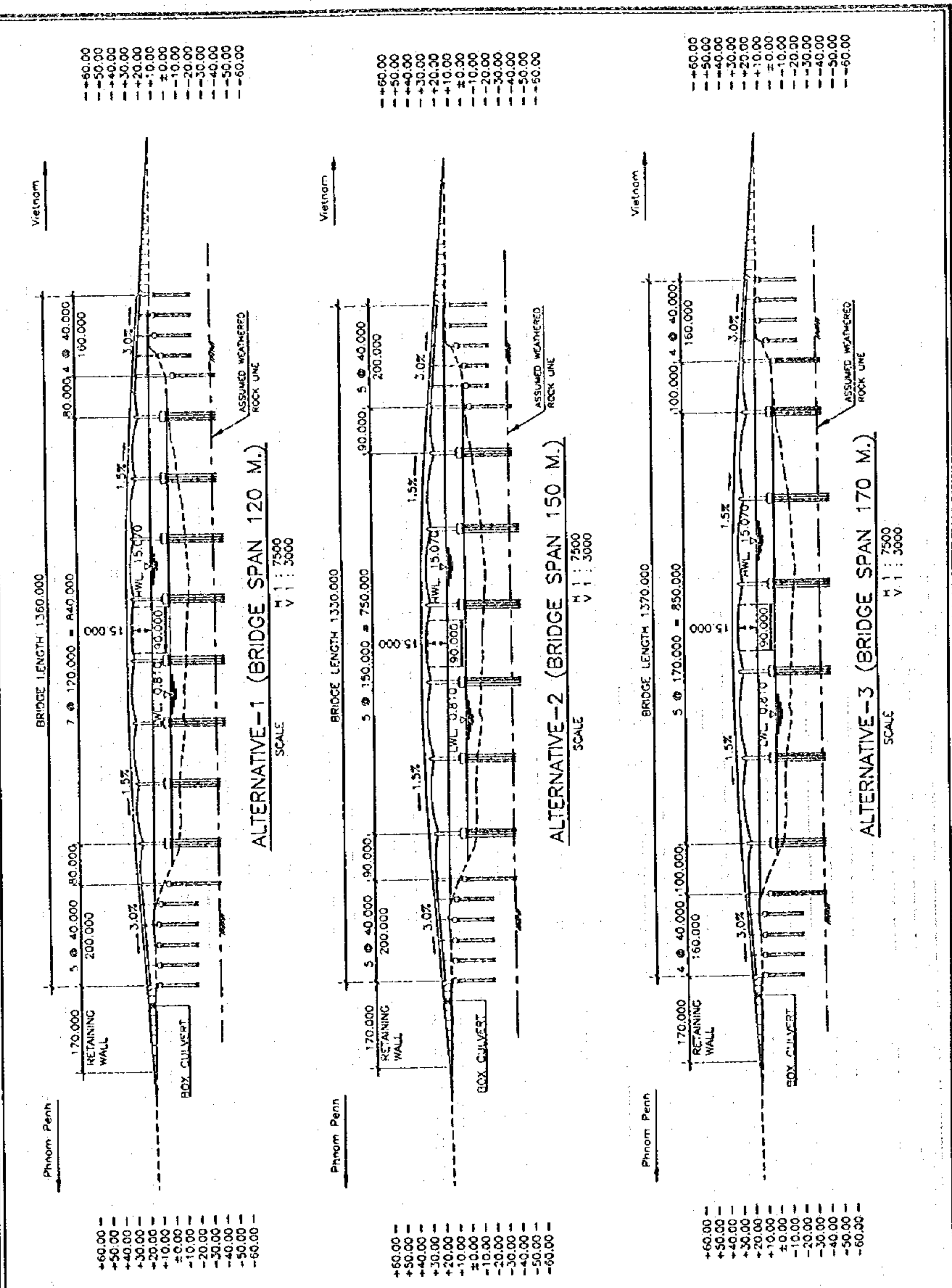
Alternative - 1: The superstructure consists of 9 spans of continuous PC box girder and 5 spans of PC T-girder on both approaches. The total bridge length is 1,360 m consisting of 1,000 m of main bridge and 360 m of approach bridge. Eight piers of the main bridge are supported by multi-column pile foundations in the river.

Alternative - 2: The superstructure consists of 7 spans of continuous PC box girder and 5 spans of PC T-girder on both approaches. The total bridge length is 1,330 m consisting of 930 m of main bridge and 400 m of approach bridge. Six piers of the main bridge are supported by multi-column pile foundation in the river.

Alternative - 3: The superstructure consists of 7 spans of continuous PC box girder and 4 spans of PC T-girder on both approaches. The total bridge length is 1,370 m consisting of 1,050 m of main bridge and 320 m of approach bridge. Six piers of the main bridge are supported by multi-column pile foundation in the river.

The control points to estimate the bridge length are the navigation clearance, vertical clearance (4.0 m) of the box culvert on the Kompong Cham side and abutments on both sides. Elevations showing the layout of the three alternatives are presented in Figure 14.2.

Construction costs have been estimated for each alternative bridge, based on the same conditions presented in Chapter 10. The construction costs for the three cases, which should be accurate to within 10 - 15%, are shown in Table 14.2 and Figure 14.3. The construction period is assumed to be 42 months (3.5 years). The exchange rate is applied to be US$1.00 = 102.00 yen (November 1995 level).



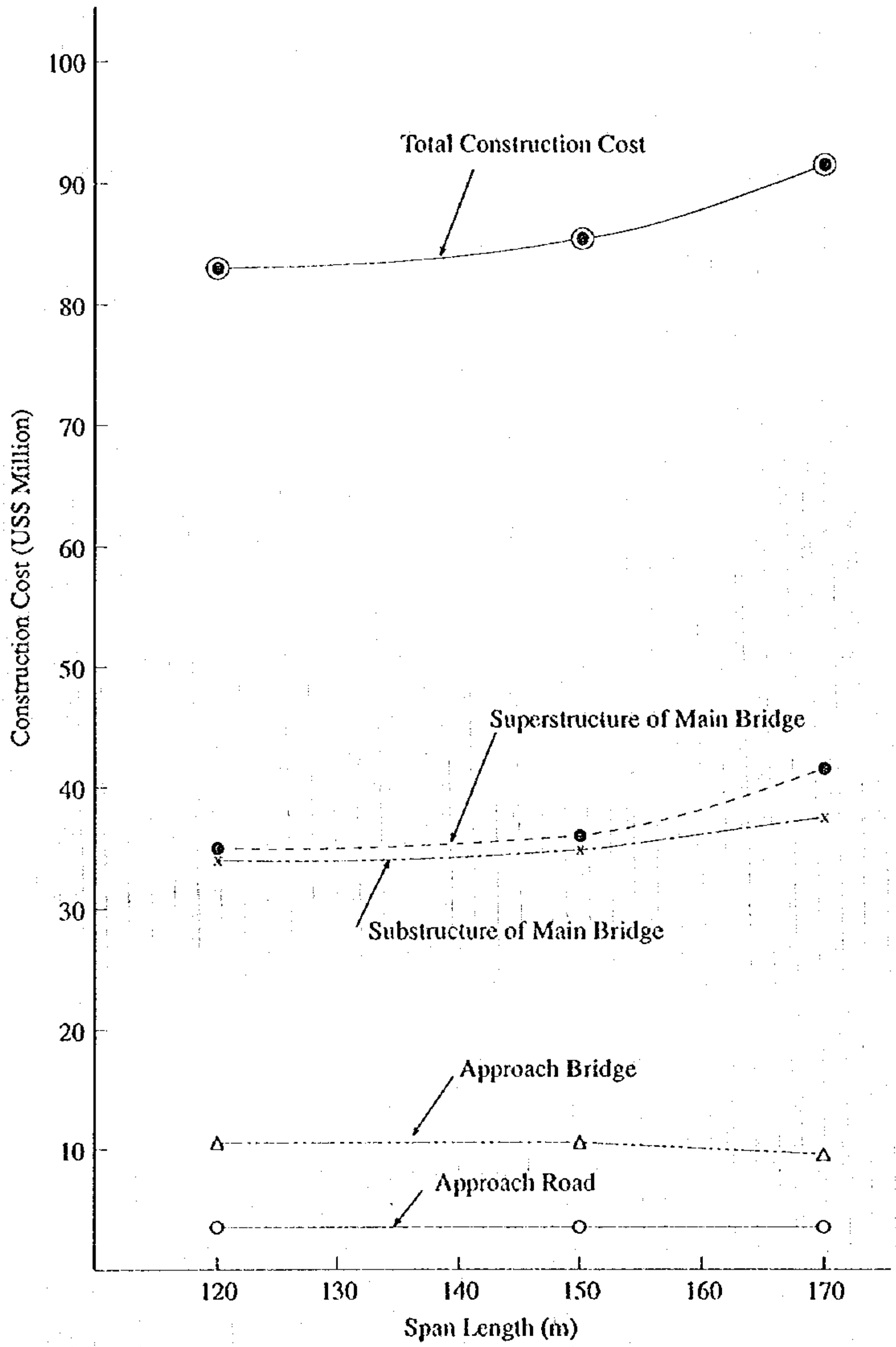
THE FEASIBILITY STUDY ON CONSTRUCTION OF THE MEKONG BRIDGE IN KINGDOM OF CAMBODIA	Figure 14.2 Span Arrangement by Selected Bridge Type
	JAPAN INTERNATIONAL COOPERATION AGENCY

Table 14.2 Comparison of Construction Cost

	Items	Estimated Costs (million US$)		
		Alternative - 1	Alternative - 2	Alternative - 3
(A)	Bridge			
	1) Main bridge			
	- Superstructure	29.00	30.08	34.55
	- Substructure	28.34	29.34	31.19
	2) Approach bridge			
	- Superstructure	5.43	5.61	5.25
	- Substructure	3.31	3.16	2.84
	3) Preparation works and others	13.22	13.64	14.77
	Sub-total	79.31	81.83	88.60
(B)	Approach Road			
	1) Embankment	1.92	1.92	1.92
	2) Pavement	0.45	0.45	0.45
	3) Road structures	0.80	0.80	0.80
	4) Preparation works and others	0.32	0.32	0.32
	Sub-total	3.49	3.49	3.49
(C)	Total Construction Cost	82.80	85.32	92.09
		(1.00)	(1.03)	(1.11)

Based on the result of cost comparison, it can be concluded that the most economical span length is about 120 m. To select the most cost effective solution, various alternative superstructure/substructure types and alternative materials were considered in Chapter 7 and in this chapter. The PC box girder superstructure with 120 m spans and wall-shaped pier substructure supported by multi-column pile foundation with large diameter concrete piles was adopted as the optimum bridge configuration.

The approach bridges for the various alternatives should be either of PC T-girder type or PC I-beam type. Consideration was given to the most appropriate construction method for each bridge type. The PC T-girder type with spans up to approximately 40 m, which could be erected by crawler cranes of large capacity, was selected for the approach bridges.



THE FEASIBILITY STUDY ON CONSTRUCTION OF THE MEKONG BRIDGE IN KINGDOM OF CAMBODIA	Figure 14.3 Construction Cost - Span Relation for the Bridge
	JAPAN INTERNATIONAL COOPERATION AGENCY

14.1.4 Design Criteria

In Cambodia, most bridges were designed by using various standards, such as French, AASHTO, Australian, Russian and Japanese standards. In this feasibility study for the Mekong Bridge, it was confirmed in the Minutes of Meeting on the Inception Report that the Japanese standards should be applied for the structure design. But based on the Cambodian natural conditions, the stipulations related to wind, temperature, earthquake etc. in the Japanese standards should be modified accordingly.

(1) Design Load

(a) Dead Load

The unit weights to be used for calculation of dead load will be as follows.

Material		Unit Weight (kgf/m3)
-	Steel, cast steel and forged steel	7,850
-	Cast iron	7,250
-	Reinforced concrete	2,500
-	Prestressed concrete	2,500
-	Concrete	2,350
-	Asphalt concrete pavement	2,300

In addition to the above materials, the following public utilities can be installed on the bridge in the future plan.

- Electric line 100 kg/m
- Telephone line 50 kg/m

It is necessary to estimate the unit weights equivalent to the capacity of the utilities.

(b) Live Load

Live load in the Japanese specification is introduced in the Technical Bulletin PUBLIC WORKS CONSTRUCTION VOL. 2 No. 1, Section 3 JAPANESE STANDARDS FOR HIGHWAY BRIDGE, published by the MINISTRY OF PUBLIC WORKS AND TRANSPORT, PUBLIC WORKS RESEARCH CENTRE, January, February 1995. But T-loading in the live load was revised from T-20 to T-25 in the latest specification published by the Japan Road Association in February 1994. It is recommended that T-25 be applied for the preliminary design in this feasibility study.

In this specification, the live load has different loading systems consisting of 1) live load for slab and floor system, and 2) live load for main girder. T-loading is applied to the live load for slab and floor system and L-loading is applied to the live load for main girder.

Figure 14.4 illustrates the type of T-loading and L-loading at transversal and longitudinal positions on the carriageway.

(c) Impact

Impact coefficient for superstructures is calculated by the following formula using the span length (L).

- Steel bridge : $i = 20/50 + L$
- PC bridge : $i = 20/50 + L$ applied to T-Loading
  $i = 10/25 + L$ applied to L-Loading

Impact is be applied to the sidewalk loading and main cables and stiffening girders of the suspension bridge.

(d) Current Water Pressure

Current water pressure is a horizontal dynamic load which acts on the vertically projected area of the pier under water level, and its magnitude is calculated by the following equation. The point of loading is 0.6 H from the river bed.

$$P = K \cdot V^2 \cdot A$$

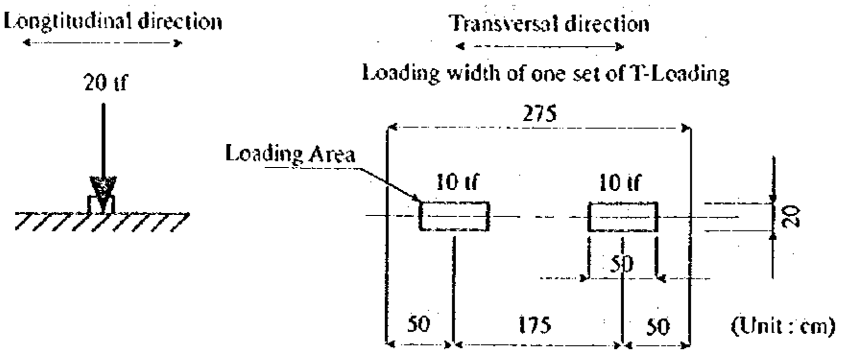
where,

P	:	Current water pressure (t)
K	:	Resistance coefficient of pier
V	:	Maximum current velocity (m/sec)
A	:	Vertically projected area of pier
H	:	Depth of water

According to records of flow velocity surveyed by the Study Team, the flow velocities near the Route 8-2 are 0.25m/sec, 0.75 m/sec and 1.65 m/sec in May, July and October respectively, while the maximum flow velocity estimated from the available discharge records is 2.53 m/sec. The Study Team recommends to adopt a maximum current velocity of 2.53 m/sec.

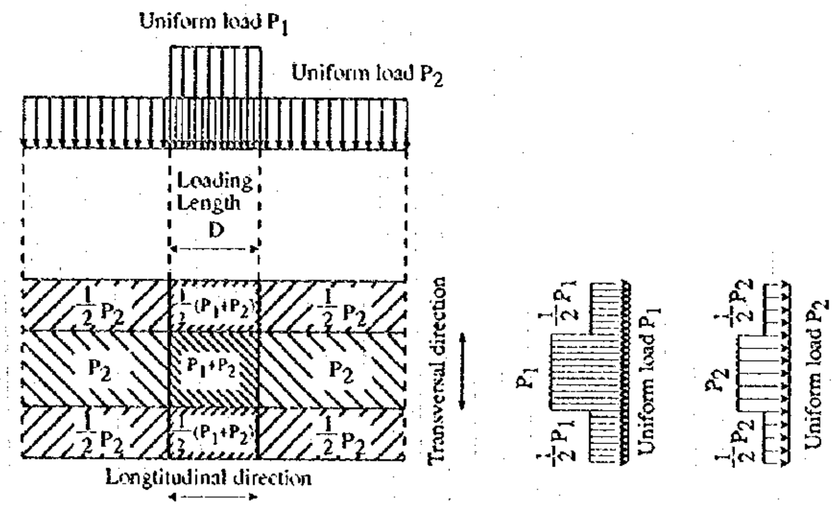
(c) Wind Load

The wind pressure on a bridge depends on the geographical location, local topography, height of the bridge above ground, and cross-section of the bridge. The design wind pressures are derived from the mean hourly wind speed (design wind speed). These wind speeds are appropriate to a height above the ground level of 10 m and a 50-year return period. The Study Team recommends to adopt a design wind speed of 30 m/sec based on the study of strongest winds records (1985 - 1995) in Kompong Cham as shown in Appendix 14.2.



Span Length Between Members L (m)	L ≦ 4	L > 4
Coefficient	1.0	$\frac{L}{32}+\frac{7}{8}$

T-Loading



Main Load (5.5 m in width)						Sub-load
Uniform Load P1			Uniform Load P2			
Loading Length (D (m)	Load (kgf/m2)		Load (kgf/m2)			
	For Bending Moment	For Shearing Force	L ≦ 80	80 < L ≦ 130	L > 130	
10	1,000	1,200	350	430 - L	300	50% of Main Load

L : Span Length (m)

L-Loading

THE FEASIBILITY STUDY ON CONSTRUCTION OF THE MEKONG BRIDGE IN KINGDOM OF CAMBODIA	Figure 14.4 T- loading and L - loading JAPAN INTERNATIONAL COOPERATION AGENCY

The design wind pressure (load) is estimated by the following formula:

$$P = 1/2 * D * V^2 * Cd * G$$

Where,

P	:	Design wind pressure (kgf/sq.m)
D	:	Air density (kgf. sec^2/m^4)
V	:	Design wind speed
Cd	:	Drag coefficient
G	:	Response coefficient of gust (1.90)

(f) Bridge Temperature

Effective bridge temperatures are derived from shade air temperature based on the data (1985 - 1995) collected in Kompong Cham (Appendix 14.3). The highest and lowest temperatures are 36.2°C and 20.4°C recorded in April 1990 and December 1988 respectively. According to these data, effective temperatures for the design of each type of bridge are considered to fluctuate within the following ranges:

Type of Bridge	Design Fluctuation of Temperature
Concrete Bridge	20°C ~ 40°C
Steel Bridge	15°C ~ 50°C

(g) Earthquake

It is considered that there is very little possibility of occurrence of earthquakes in Cambodia and their magnitude is relatively small. There seem to be no seismic activities in Cambodia and no records of earthquakes are available at the Ministry of Industry, Mines and Energy, Department of Geology and Mines. The location of epicenters of earthquakes in the world is presented in Appendix 14.4. Therefore, earthquake damage to the bridge can be ignored. A horizontal seismic coefficient of 0.05 is proposed to be adopted for design in this study, considering the horizontal stability of the structures.

(2) Design Method

For the preliminary design of the concrete and prestressed concrete bridge, the Japanese design method will be applied based on the 'SPECIFICATIONS FOR HIGHWAY BRIDGES, PART I and PART III' established by the Japan Road Association. The specifications determine an intermediate method of design between the allowable stress design and the ultimate strength design for the prestressed concrete bridge and allowable stress design for the concrete substructure of the bridge.

14.1.5 Study on Superstructure

(1) Type of Transverse

The transverse section suited to cantilever construction is box shape due to the construction procedure.

Two different shapes of the cross section can be designed as a function of the deck width of 13.5 m as shown in Figure 14.5. The single cell girder with two webs in conventionally sued and implies a saving approximately 3% in the volume of concrete in comparison with the two cell girder. In addition, it is sure that segment construction cycle should be redacted because construction procedure by traveling wagons is very simple.

The single cell girder is also expected to have sufficient rigidity for the girder in the transverse direction due to its closed section, while the rigidity for the two cell girder is smaller.

For the above-mentioned reasons, the single cell box girder was determined to be adopted in the subsequent design.

Girder depth at the pier is computed to be 6.5 m (1/18.5 of maximum span length) and 3.2 m (1/37.5 of maximum span length) at the center of span. Transition curve used for the girder depth change is adopted to be quadratic parabola curve between span center and end.

(2) Connecting Systems to Adjacent Cantilever Girders

In the cantilever construction method, connecting systems to adjacent cantilever girders are 1) system with hinged cantilevers, b) system with suspended span and c) system made structure continuous as shown in Figure 14.6. The consideration in connecting systems at the adjacent cantilever girder, was made to maximize the length of continuous box girders based on the following points.

a) Lower construction cost due to the saving of structure materials to be used for a continuous structure;

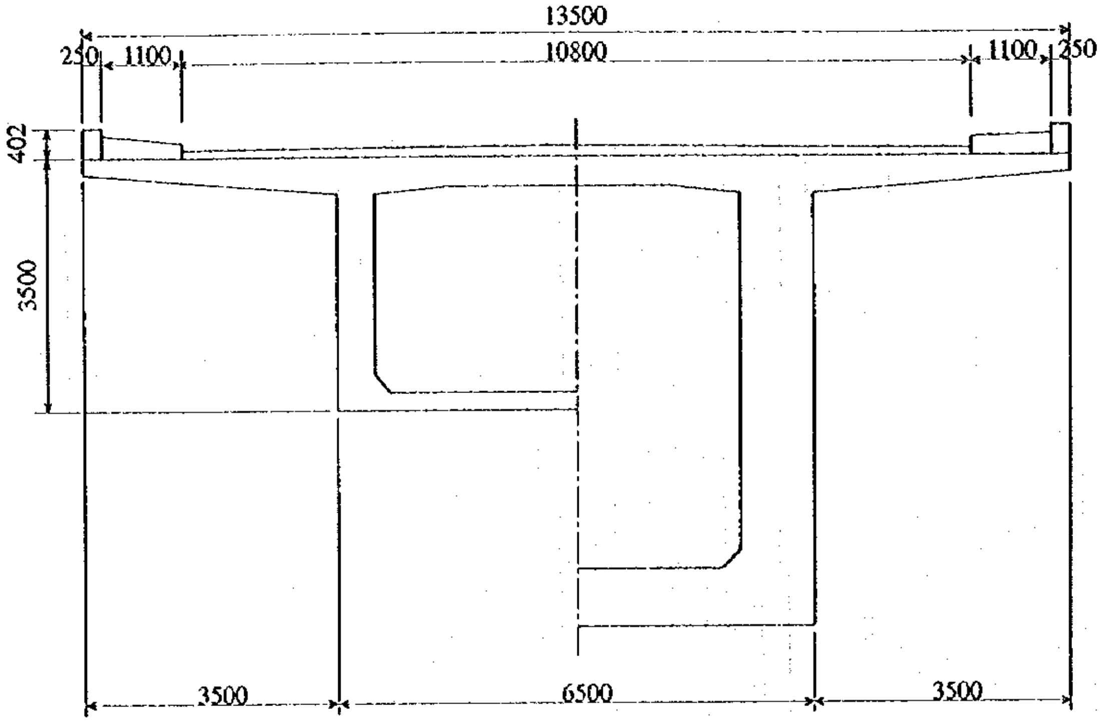
b) Higher structural stability;

c) Better roadway riding due to reduction of the expansion joints; and

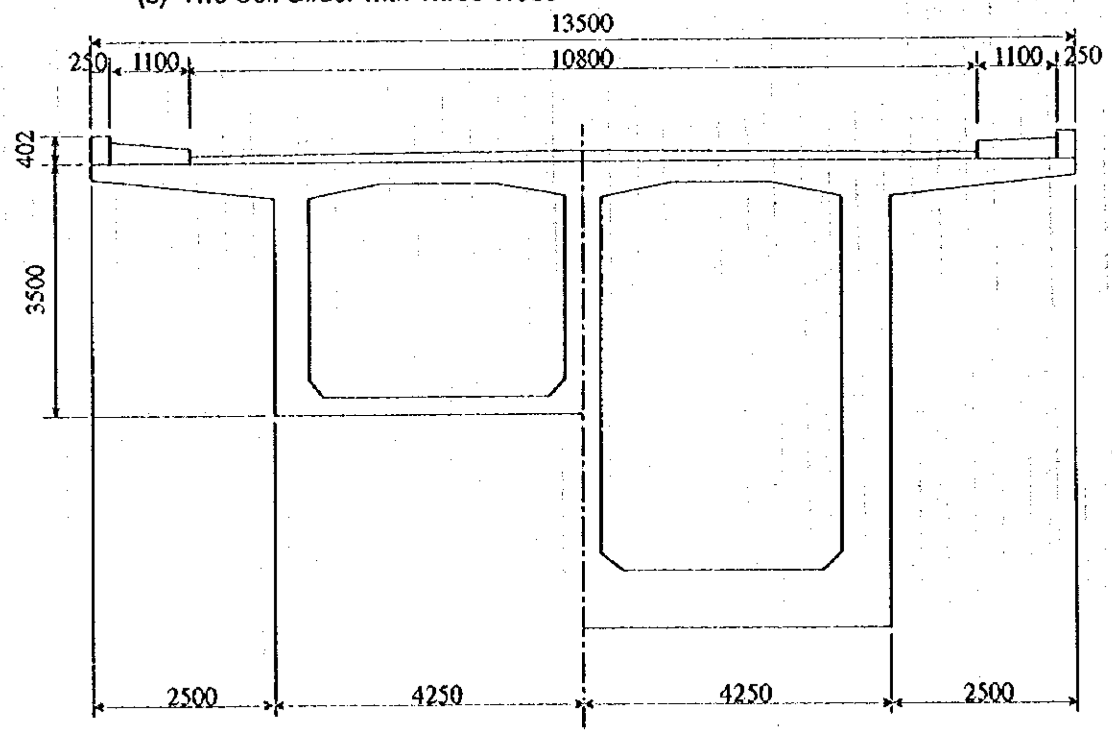
d) Less maintenance requirement due to reduction of expansion joints and bearings.

For the above-mentioned reasons, 9 spans continuous PC box girder was adopted for the subsequent preliminary study.

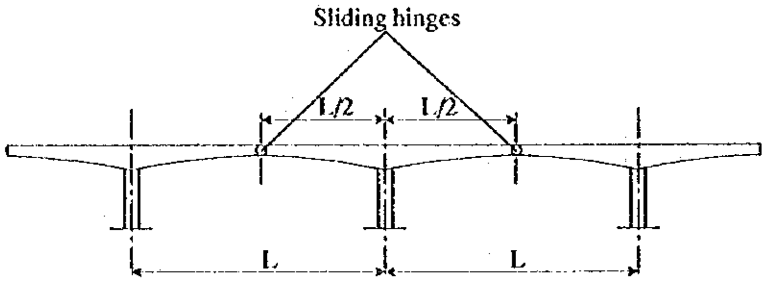
(a) Single Cell Girder with Two Webs



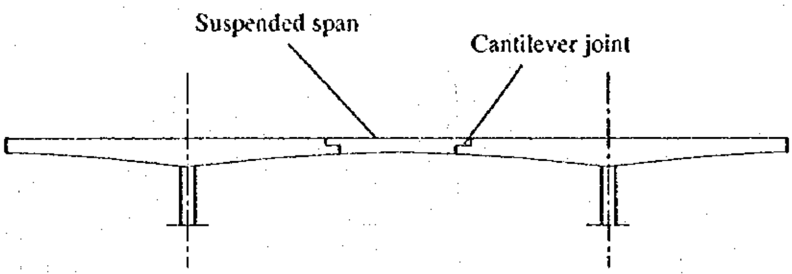
(b) Two Cell Girder with Three Webs



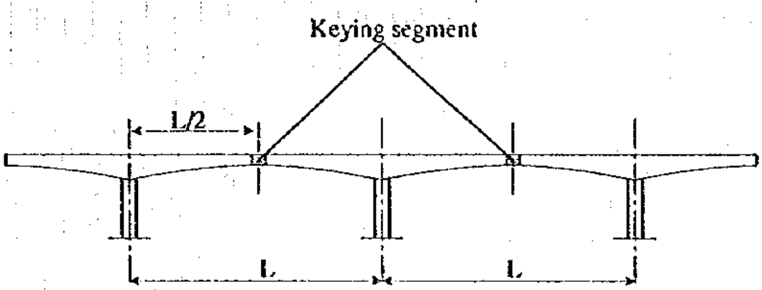
THE FEASIBILITY STUDY ON CONSTRUCTION OF THE MEKONG BRIDGE IN KINGDOM OF CAMBODIA	Figure 14.5 Alternative Cross-section for Main Bridge
	JAPAN INTERNATIONAL COOPERATION AGENCY



a) System with hinged cantilevers



b) Cantilever system with suspended span



c) System made structure continuous

THE FEASIBILITY STUDY ON CONSTRUCTION OF THE MEKONG BRIDGE IN KINGDOM OF CAMBODIA	Figure 14.6 Connecting System to Cantilever Girder JAPAN INTERNATIONAL COOPERATION AGNECY

For a long bridge with continuous multiple spans, the flexibility of piers is necessary to permit longitudinal expansion of the bridge without creating high bending moment at the piers.

(3) Approach Bridge

The structure for approach bridge is limited to three basic types; a) Simple span girder, b) Connecting girder and c) Continuous girder.

a) Simple Span Girder

The simple span girders are placed on two bearing. Expansion joints connect the girders to each other, which requires many expansion joints. Therefore, the simple span girder results in discomfort driving and also requires substantial maintenance.

b) Connecting Girder

Girders are placed on two bearing like the single girder, however, rebars connect adjacent girders and concrete fills the space between girders. The structure of the connecting girder is comparatively complex, but the number of expansion joints can be reduced.

c) Continuous Girder

The continuous type girder has no joints and gives comfortable driving. However, this structure is complex and costly because the prestressing cables are provided in the upper portion of the girders at the pier.

The connecting girder type with the cast-in-situ RC deck is proposed for the approach bridge in consideration of the following points:

- reduction of number of expansion joints due to a large number of queued piers with short span length
- minimum maintenance cost
- easier construction, especially considering the site conditions.

The girder type for the various alternatives should be either of PC T-girder type or PC I-girder type. Consideration was given to the most appropriate construction equipment for each bridge type. The PC T-girder type with spans up to approximately 40 m, which could be erected by 2 crawler cranes of 150 ton class, was selected for the approach bridges.

Appendix 14.5 shows the configuration of PC T-Girder.

14.1.3 Study on Substructure

(1) Piers for Main Bridge

Deep river scouring and big differences in water level between high and low water levels along the main bridge can result in the tops of the pier as much as 65 m above river bed level. Since the major horizontal loads are applied to the top of piers, the substructure will be required to have sufficient column strength and stability. The piers supporting the main structure are typically 6.5 m by approximately 2.5m in cross section above pile caps with rectangular end facing upstream and downstream.

For multispan bridge, the design is different according to whether the pier is simply supported or fixed at the pier. From viewpoint of geometrical characteristics of the site, the high and flexible piers provide between the girder and the piers which allow longitudinal movement of the girder (due to shrinkage, creep, thermal and moisture variations). This type of pier has the following advantages:

- it provides an efficient support for the deck under vertical loads, because of the twin supports;
- it has great horizontal flexibility (for longitudinal movements to the structure) - this resolves the problem of expansion in continuous structures;
- it provides an economic way to stabilize the balanced cantilevers during construction by simple temporary crossbracing of the diaphragms.

(2) Piers for Approach Bridge

Type of piers for approach bridge is determined to be a T-shaped pier on the spread footing with bearing piles, based on the following;

- to support tightly the superstructures on width to accommodate bridge bearings
- to minimize the area disturbed by piers and to keep sufficient space after construction
- to minimize concrete volume of the piers that imposed by economic considerations
- to harmonize type with piers of the main bridge.

The configuration of piers for the approach bridge is shown in Drawings in the Volume 4.

(3) Abutments

Abutments are the end supports and usually have the additional function of retaining embankment fill for the approach roads. The height of abutments was defined up to 10.0 meters considering the stability against overturning and sliding of the abutment. Such height is the most suitable type to be select the Inverted T-shaped abutment, which could be superior in construction aspects. The inverted T-shaped abutment in Kompong Cham side, the pilecaps will be embedded in the embankment sufficient compacted in order to minimize the height of abutment as shown in Figure 14.7.

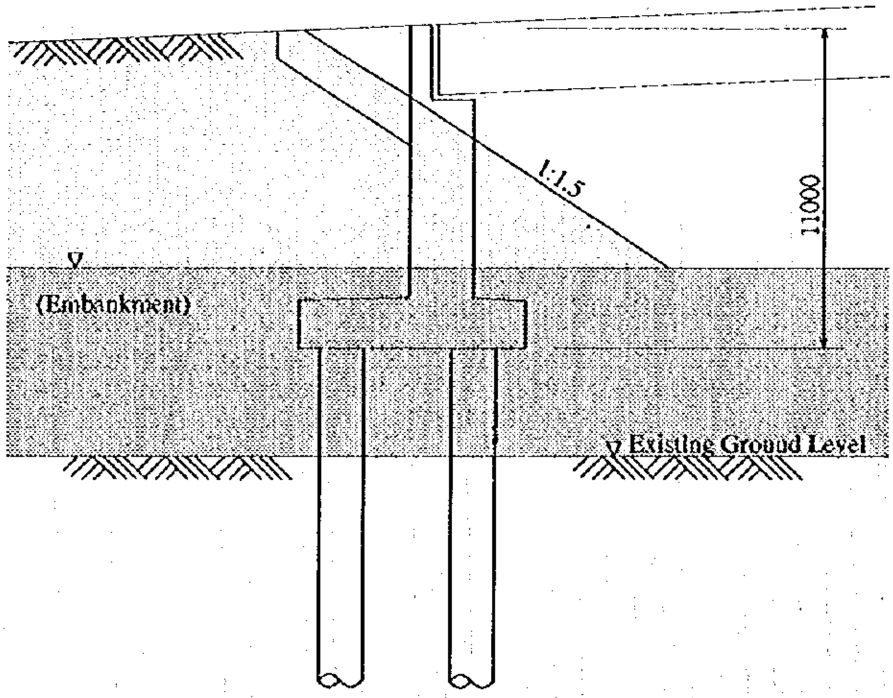


Figure 14.7 Longitudinal Profile at Abutment in Kompong Cham Side

14.1.7 Study on Foundation

(1) Type of Foundation

The multi-column pile foundation was selected in section 7.1.4 as the optimum foundation for the Mekong bridge. Having decided to use large diameter piles, it is desirable to use as few as possible to reduce the number of piles comparing with size of pile diameter in consideration of installation operations.

The Study Team has recommended cast-in-situ piles which install large steel cylinder piles for casing, drilling bored holes and then filling them with concrete. This is considered to be reliable for installing the pile tops into the bearing layer.

To install large diameter steel pipes with large scale floating driving equipment as used to build offshore oil installation would be considered for the rapid construction. But, the floating equipment is not commonly available in the world. The steel pipe piles are not considered suitable plan for the feasibility study for the Mekong Bridge.

The cast-in-place piles are bored by the reverse circulation drill equipment.

14.1.8 Local Scouring

(1) Estimation of Local Scouring

The following Larcy's empirical formula is provided for estimation of scoured depth of alluvial rivers.

$$dm = 0.47\ (Q/F)^{1/3}$$

$$D = C \times dm$$

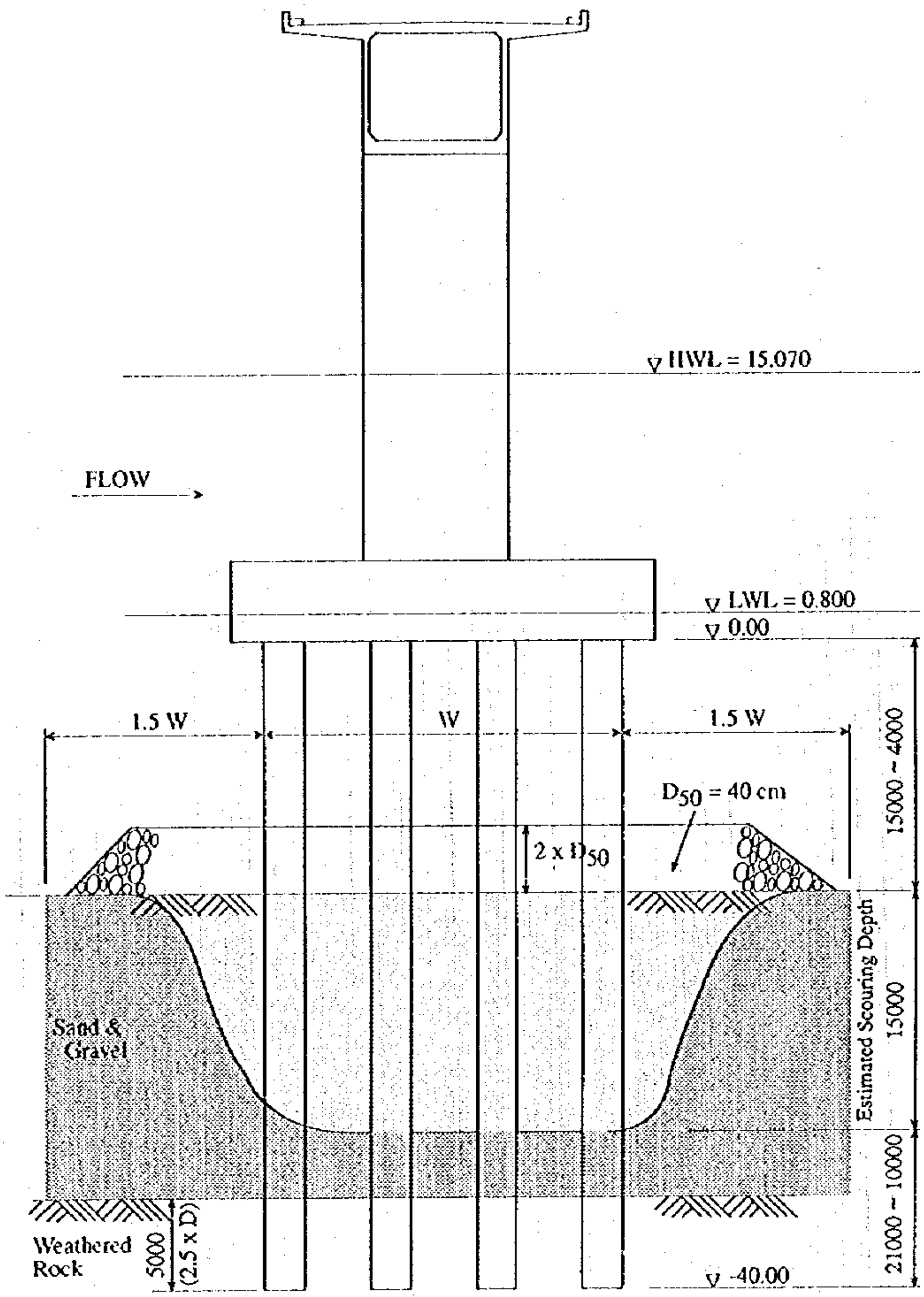
where,

dm	:	Mean Water Depth for Design Discharge, defined as wetted area divided by water surface width (m)
Q	:	Design discharge (m^3/sec)
f	:	Silt Coefficient
D	:	Maximum Scoured depth below Water Level Corresponding to Design Discharge (m)
C	:	Coefficient for Nose of Pier

The design discharge (Q) is given as the recorded maximum discharge at Kompong Cham gauging station, which is 57,000 m^3/sec in 1996. For this discharge, the corresponding mean water depth becomes 21.2 m at the proposed bridge site. The silt coefficient (f) is assumed at 1.0 according to the average grain size of the river bed material. The maximum scoured depth (D) is obtained by multiplying a coefficient of 2.0 for noses of piers to the mean water depth (dm) calculated by the above equation. The estimated maximum scoured depth is 36 m below the water surface. The scouring depth from the river bed is obtained at approximate 15.0 m which is the difference between the maximum scoured depth and the mean water depth for the design discharge.

(2) Measures for Local Scouring

Rip-rap apron is applied for protection of pier foundation as shown in Figure 14.8. The extent of rip-rap apron should cover a distance equal to 1.5 times the width of multi-column foundation from each edge. The average stone size is around 40 cm with a specific gravity of 2.65, taking the local flow velocity around foundation as 1.5 times the average flow velocity through the river channel. The thickness of rip-rap should be twice the average stone size.



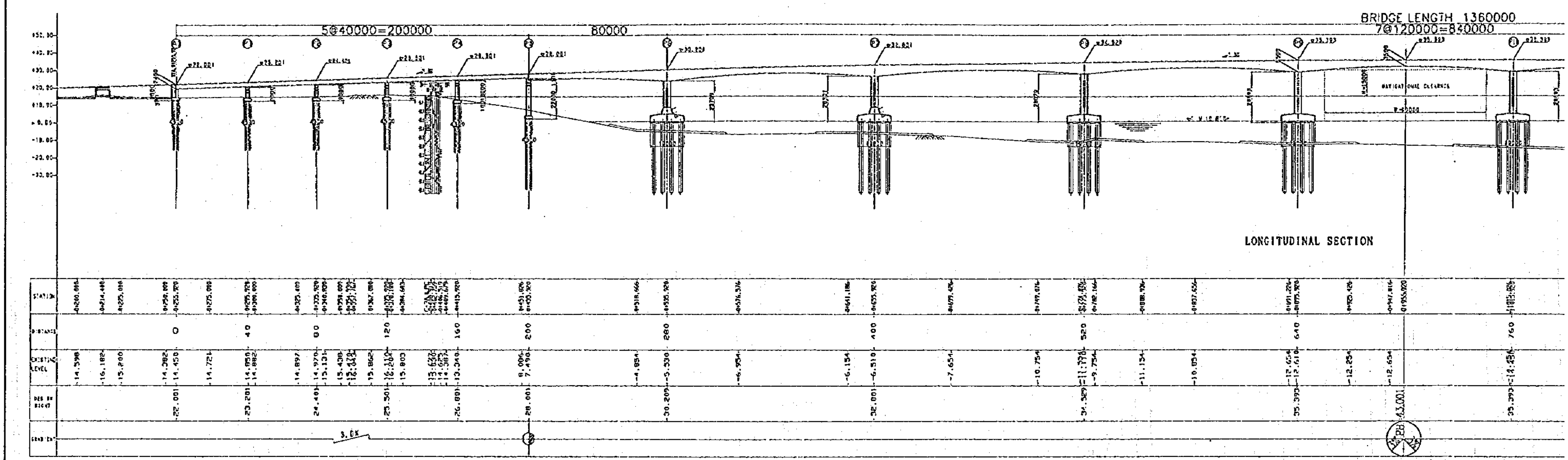
THE FEASIBILITY STUDY ON CONSTRUCTION OF THE MEKONG BRIDGE IN KINGDOM OF CAMBODIA	Figure 14.8 Local Scouring Depth and Measure
	JAPAN INTERNATIONAL COOPERATION AGENCY

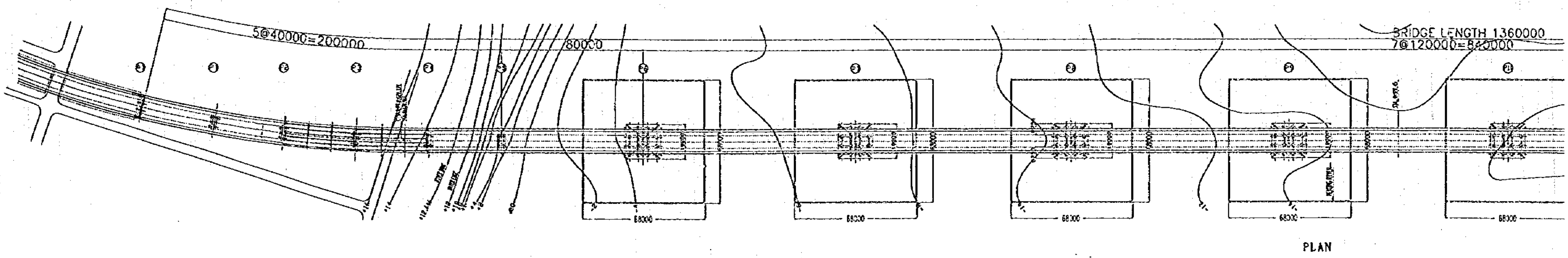
14.1.9 Ancillary Facilities for Bridge

Ancillary facilities for bridge consist of illumination system, handrail, drain pits, expansion joints, shoes and footpath. These facilities are basically the same requirement of the Chroy Changwar bridge but revised partially by the Study Team considering site conditions and technical aspects. The major ancillary facilities show in Appendix 14.6.

14.1.10 Configuration of the Proposed Bridge

As a result of the bridge engineering study, the proposed bridges consists of 9-span continuous PC Box Girder for the main bridge and PC T-connecting girder for both approach roads. A configuration of the bridge is shown in Figure 14.9.


BRIDGE LENGTH 1360000
5@40000=200000
80000
7@120000=840000
LONGITUDINAL SECTION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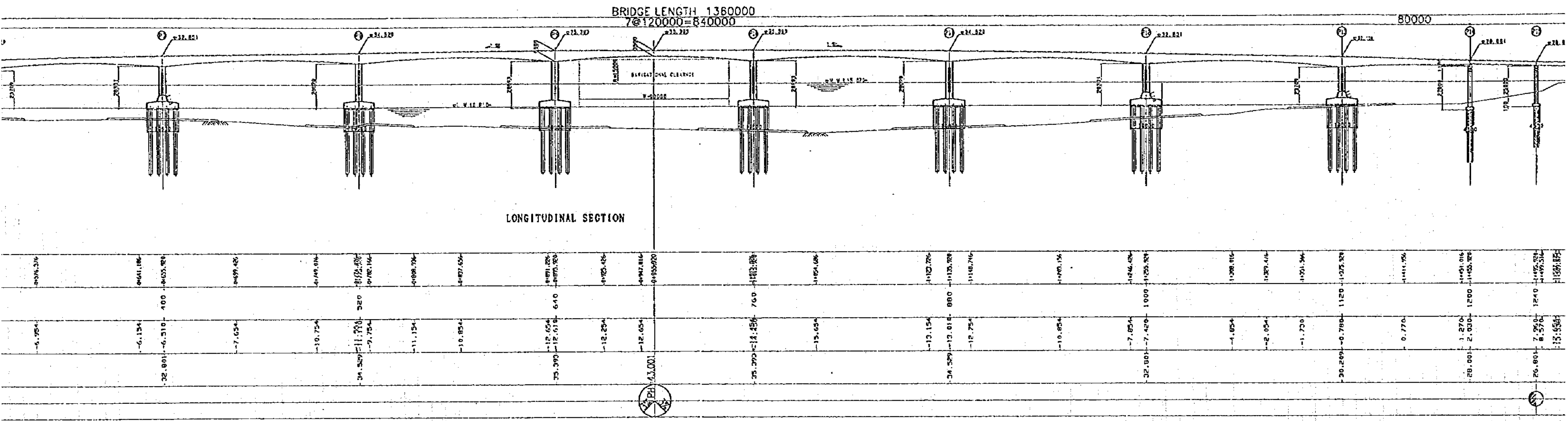
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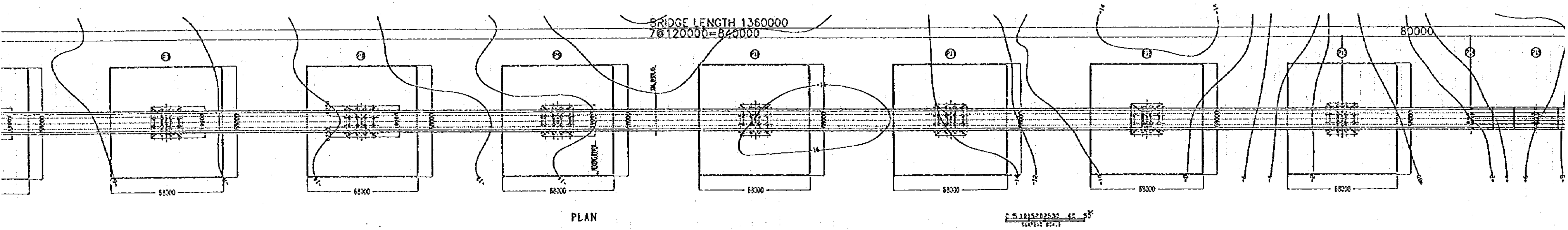
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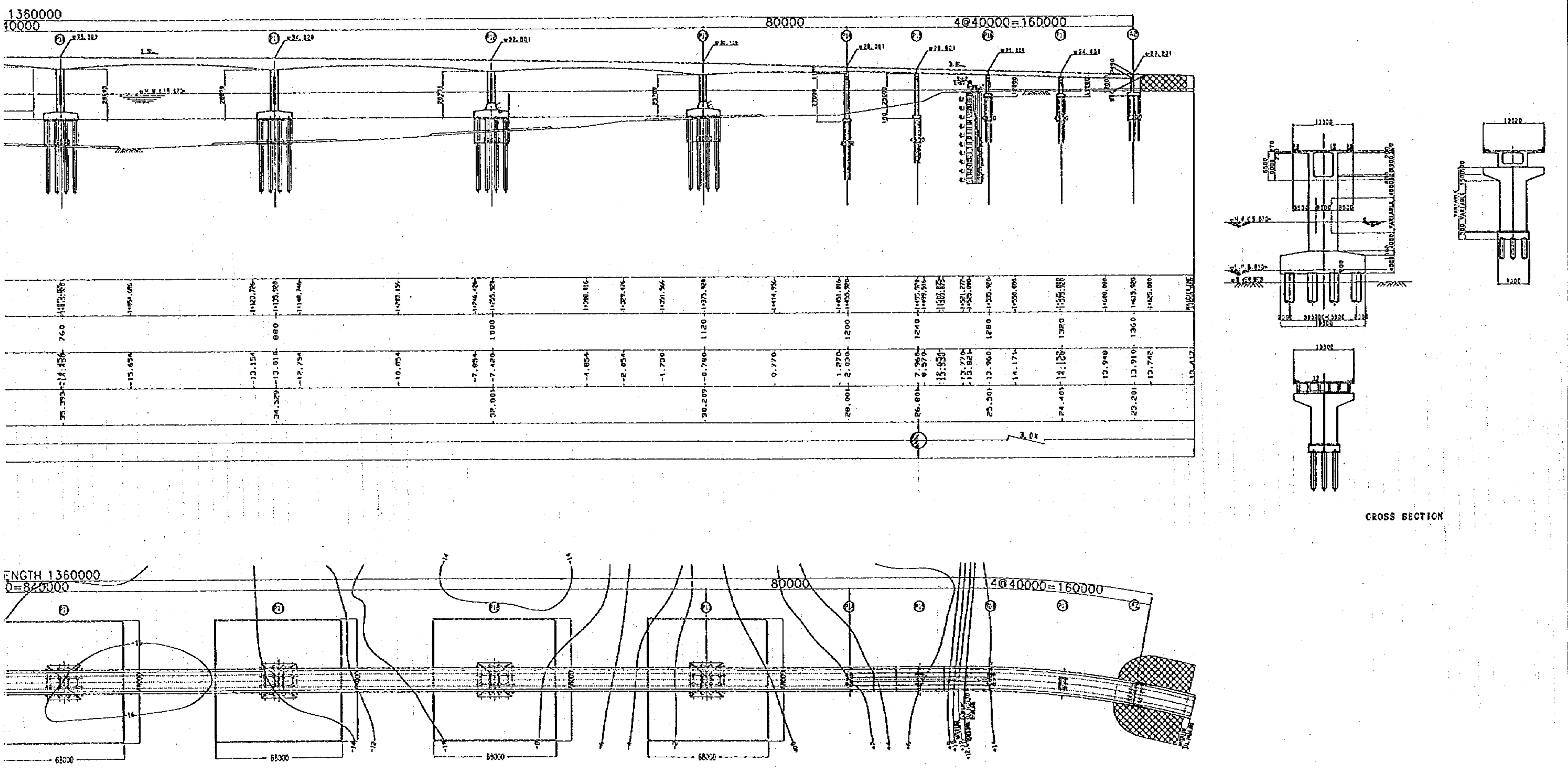


THE FEASIBILITY STUDY ON CONSTRUCTION OF THE MEKONG BRIDGE IN KINGDOM OF CAMBODIA

FIGURE 14.9

CONFIGURATION OF THE PROPOSED BRIDGE

JAPAN INTERNATIONAL COOPERATION AGENCY

14.1.11 Summary of Quantities for Bridge

The quantities of the bridge (substructure and superstructure) are calculated based on the preliminary design drawings and show in Table 14.3.

Table 14.3 Summary of Quantities for Bridge

Item	Description	Unit	Quantities
1.	MAIN BRIDGE		
1-1	Superstructure		
1-1-1	Concrete for PC Box Girder	m^3	13,730
1-1-2	Formwork for PC Box Girder	m^3	37,720
1-1-3	Reinforcing Bar for PC Box Girder	ton	1,647
1-1-4	PC Works		
(a)	Main Cable 12 T 15.2	ton	800
(b)	Lateral Cable 1T 21.8	ton	67
(c)	Vertical PC Bar, dia. 32 mm	ton	63
1-2	Foundation and Substructure		
1-2-1	Cast-Placed Conc. Pile 2.0 m dia.	m	5,120
1-2-2	Concrete for Pile Cap	m^3	12,550
1-2-3	Concrete for Pier Structure	m^3	4,350
1-2-4	Formwork for Pile Cap	m^2	5,320
1-2-5	Formwork for Pier Structure	m^2	4,570
1-2-6	Reinforcing Bar	ton	2,705
1-3	Bridge Ancillary Works		
1-3-1	Expansion Joint	m	27
1-3-2	Movable Shoes	No.	4
1-3-3	Footpath and Curb	m	2,000
1-3-4	Drain Pits	No.	134
1-3-5	Handrailing	m	2,000
1-3-6	Asphalt Surface	m^2	10,800
2.	APPROACH BRIDGE		
2-1	Superstructure		
2-1-1	PC T-Girder L = 40.0 m	No.	54
2-1-2	Erection of Girders	No.	54
2-1-3	Lateral Cable 1 T 21.8	ton	22
2-1-4	Concrete for Slab	m^3	570
2-1-5	Formwork for Slab	m^2	2,440
2-1-6	Reinforcing Bar for Slab	ton	34
2-2	Foundation and Substructure		
2-2-1	Cast-placed Conc. Pile 1.0 m dia.	m	2,080
2-2-2	Concrete for Pile Cap	m^3	760
2-2-3	Concrete for Pier Structure	m^3	2,260
2-2-4	Formwork for Pile Cap	m^2	400
2-2-5	Formwork for Pier and Abutment	m^2	300
2-2-6	Reinforcing Bar	ton	210
2-2-7	Structural Excavation & Backfill	m^3	1,400
2-3	Bridge Ancillary Work		
2-3-1	Expansion joint	m	27
2-3-2	Movable Shoes	No.	108
2-3-3	Footpath and Kerb	m	360
2-3-4	Handrailing	m	360
2-3-5	Asphalt Concrete Surface	m^2	3,890

14.2 Design of the Road

The proposed bridge site will require the construction of approach roads, at both ends, to connect the bridge to the existing road network. Relevant details relating to the site, including estimated preliminary lengths of the bridge and road approaches, and the main features within their immediate vicinities are summarized in Table 14.1 below.

The approach roads will be joined to the main bridge structure by viaducts which will be elevated curved structures with a minimum horizontal radius of 300 m. The horizontal curves along the main section of approach roads will have a minimum radius of 250 m, thus providing for a design speed of 90 km/h.

The approach roads are to be constructed at an elevation that is above the normal flood levels and will tie into the levels of the existing road network at either end. Adjacent to the bridge structure the roads will be constructed at a grade of 3%, to meet the road viaducts at an elevation that is some 7 to 8 m above the ground level. Refer to Appendix 14.7, for further details.

The minimum road elevations were based on the requirement that the top edge of subgrade (i.e., bottom edge of subbase course) should be at least 1 m above the floodwater level to protect the pavement layers from water infiltration.

Also, in order to minimize future accidents, the traffic accident prevention principles and measures detailed in subsection 7.2.4 were adopted for the selected site.

Table 14.4 Bridges and Road Approaches

Bridge and Road Approach[1]	Length (m)	Connects Bridge to:	Main Features of the Immediate Vicinity
Bridge (including viaducts)	1,330		
Western Approach	255	Street/Route 7	Houses, commercial bldgs
Eastern Approach	2,065	Route 7	Farmland, houses, swamps
Total	3,650		

Notes: [1]Road approach lengths include the curved sections that connect it to Route 7. Some road lengths differ from surveyed lengths due to office design modifications.

14.2.1 Preliminary Design of Approach Road - West Side

(1) Alignment and Road Details

(a) General

The western approach road is located along an existing street which is not in complete alignment with the proposed approach road, and is too narrow to accommodate the road reserve for the approach road, and the two service roads required to provide access to the adjacent properties. This will mean that the properties north of this street will need to be acquired and the houses on them demolished.

The preliminary design plan for approach road and associated road works is shown in Figures 14.10. The centerline of the approach road coincides with a proposed by-pass route (for Route 7) which will take traffic around the center of Kompong Cham.

The proposed works will also include improvements to a minor street which parallels the western approach and connects the proposed service road to the main road adjacent to the Mekong River.

(b) Approach Roads

As will also be noted the western approach road starts at a major intersection (6 streets) where some improvements will be required, as shown in Figure 14.10. The approach road will have a width of 13.50 m at the intersection, widening to 22.9 meters (to accommodate the tapers to the two service roads) at station 0+050 where, the approach road starts its climb to the viaduct and bridge, and, the two one way service roads, located either side of the approach road, nominally start.

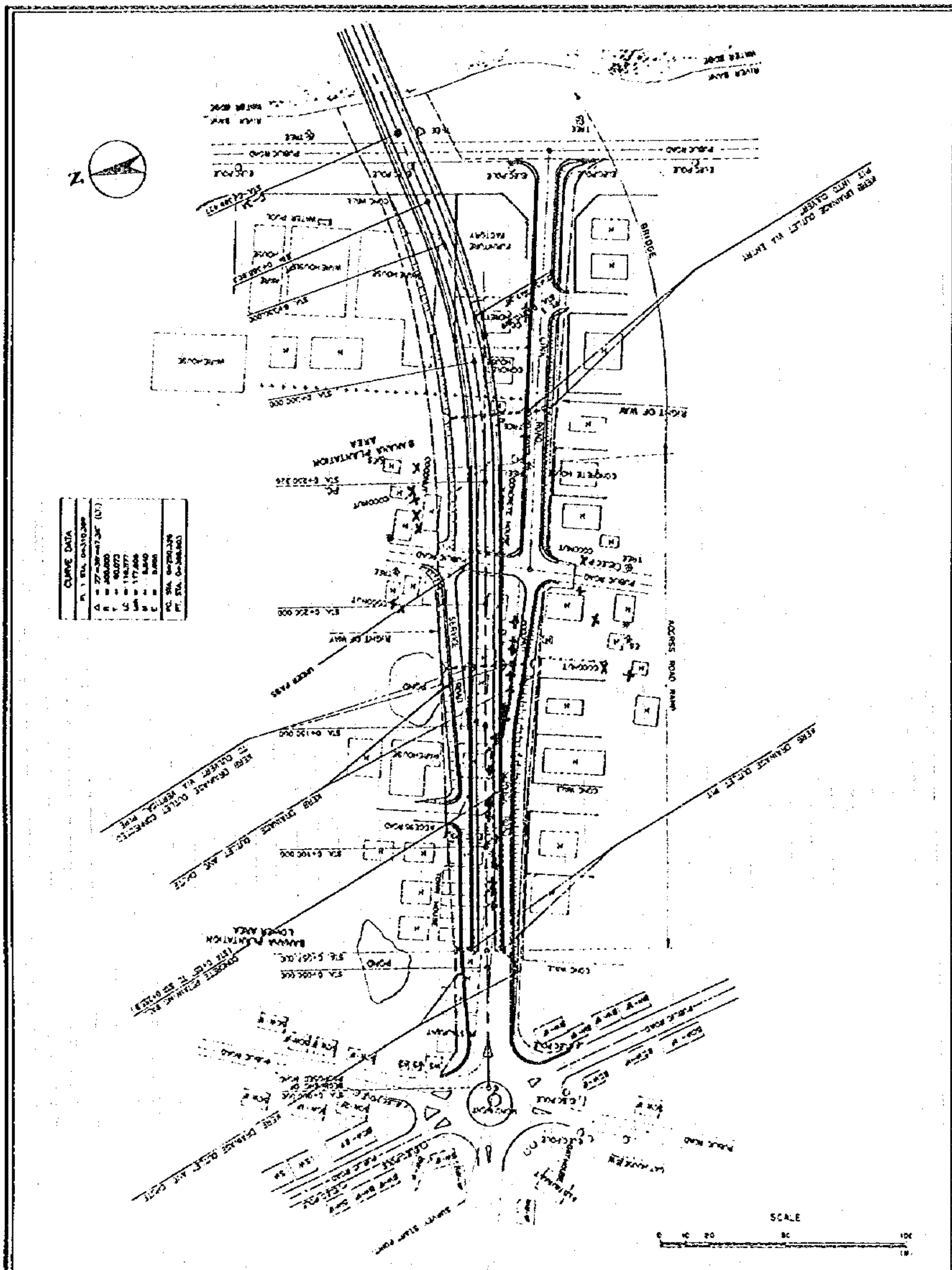
The approach road width includes two traffic lanes, with narrower lanes for slow traffic and sidewalks either side (this cross section continues across the bridge).

The improvements at the intersection will include a slight increase in road levels, required to both strengthen and shape the pavement at the intersection. The road will therefore start at a level of approximately 16.1 m, then descend at a slight grade (0.5%) for approximately 30 m at which point it will increase in level at a grade of 3%. This alignment will provide the height required to accommodate the vehicular underpass (box culvert) to be located at the cross street at station 0+215 , and achieve a level of 20.001 at the roads junction with the viaduct at station 0+255.92.

As the approach road is located at an elevated level for most of its length, along the existing street, and therefore blocking access to the existing houses, two service roads (each one way), one each side of the elevated approach road are to be provided. These will nominally be at a level of 15.8 m to 16.1 m, the difference being to allow surface drainage.

(c) Service Roads

These consist of two single lane one way streets, located either side of the approach road, that will provide access to the houses in the area and provide a link between the main streets at this point. As the existing street is at natural surface, and therefore subject to flooding, it is proposed that it be raised to the level of the adjoining main streets. The service road cross sections will consist of a 3.5 m traffic lane and a 1 m sidewalk. Appendix 14.8 shows the proposed cross section.



THE FEASIBILITY STUDY ON CONSTRUCTION OF THE MEKONG BRIDGE IN KINGDOM OF CAMBODIA	Figure 14.10 General Plan for Approach Road at Kompong Cham
	JAPAN INTERNATIONAL COOPERATION AGENCY

(d) Minor Link Road

The existing gravel road will be replaced by a new road that will be raised in height, to that of the adjoining streets, to provide flood free access for local traffic movements adjacent to the bridge. The road will be a two lane road consisting of two 3.5 meter traffic lanes flanked by 1.0 meter sidewalks.

(2) Embankment

It is proposed that ground level within the limits of the proposed works be raised to a level of approximately 15.5 m. This working platform will have a maximum width of approximately 25 m and have a maximum height of 1.6 m. It will accommodate the two service roads and the approach ramp (embankment) for the bridge.

The approach road embankment will then be constructed from this lower level works. It will be 13.5 m wide and be retained, for much of its length by a retailing wall of varying height (Note: the approach is a ramp that has a grade of 3%), starting at 0.5 m and rising to approximately 7.5 m at the viaduct abutment. The retaining wall has been provided to contain the embankment, thus minimizing the impact on the adjacent properties by reducing the width of right of way required to accommodate the proposed roadworks, as shown in Appendix 14.8.

Testing carried out to date on the geotechnical conditions (for the bridge abutment) at the site would indicate that much of the material found below the road consist of sands and gravels, with the upper 8 to 10 m consisting primarily of clays and silty clays, interspersed with fine sands. While there is the potential for settlement/consolidation, much of this will occur during the 3 year bridge construction. To encourage this it is proposed that the foundation area be compacted, using heavy compaction equipment, prior to the construction of the embankment, which will itself be constructed in the early months of construction contract.

The minimum embankment height adopted has been based on a combination of flood levels and the need to tie into the levels of existing streets, with the latter being the more significant for the western approach road.

(3) Intersections

(1) Station 0+ 0.0

It is proposed that the intersection consist of a roundabout with traffic splitter islands introduced to control traffic flows and to provide a refuge for pedestrians. It will also be necessary to both strengthen and, shape the surface of the pavement to ensure good surface drainage. This will be accomplished by the addition of a thick asphaltic concrete overlay, as a minimum. More significant work may become evident once more detailed investigations have been carried out during the design stage.

To accommodate the high percentage of non-motorised vehicles and motorcycles the circulating traffic lane width (normally 6.8 meters (to cater for an articulated truck) for a roundabout of the diameter proposed) has been set at 9 metres, well in excess of that required for a single circulating lane roundabout.

(2.) Station 0+215

This is essentially a normal intersection that will include the junction of the two service roads and the link road, with the present main road that passes under the western approach via an underpass (box culvert). The proposed works will include the underpass, reconstruction of the existing pavement within the intersection area, kerbing and sidewalks. Figure 14.3 shows the proposed layout.

(4) Pavements

(1) Design Traffic Load - Approach Road

The analysis of traffic data indicates that the design traffic load is 2.5 million ESE for the 20 year design period, 2001 to 2200. This is based on the commercial traffic volumes recorded in May 1995 and the growth figures reported in the Interim One Report. These are summarized in Table 14.5 and the accompanying text.

Table 14.5 Commercial Traffic Volumes (both directions combined)

Traffic Type	Standard Bus	2 Axle Truck	3 Axle Truck	3+ Axle truck
Normal Traffic (1995)	3	12	13	13
Induced Traffic (2001)	4	3	3	3

Annual traffic growth percentages for the 4 vehicle types in the above table were 3.3, 11.9, 10.1 and 10.1 percent respectively (2001 to 2020). The same growth rates were adopted for the period 1995 to 2000.

ESA (equivalent axle load) for the four vehicle types were 1.0, 1.6, 2.8 and 4.0 respectively. These figures were based on the 1994 Cambodian Transport Rehabilitation Study, and other relevant studies in the region.

(2) Subgrade Condition

While no specific testing was carried out during this study, experience with the sandy material found along the alignment would indicate that the material would have a minimum soaked CBR (Californian Bearing Ratio) of at least 5% and average of 8%. Care in winning the material and/or mixing the upper layers with a laterite (select subgrade) would ensure the higher figure.

These subgrade CBR estimates assume that a free draining pavement cross section is to be used, as shown in Appendix 14.9.

(3) Pavement Thickness - Approach Road

Pavement design was based on the AUSROADS design manual for the design traffic load (2.5 million) ESA) and subgrade conditions detailed above. The resulting pavement thickness for a subgrade strength of 8% is as shown in Table 14.6 below (bold figures). Pavement thickness for a CBR 5% subgrade material is also shown, for comparison.

Table 14.6 Pavement Layers and Thickness

Pavement Layer	CBR 5%	**CBR 8%**
AC Surfacing	50	**50**
Base	175	**175**
Subbase	200	**150**

Appendix 14.9 illustrates the proposed pavement cross-section.

(4) Pavement Materials

While laterites, which are suitable as a subbase, are known to be readily available in close proximity to the bridge site (within 25 km on the west bank and, within 15 km on the east bank), the same cannot be said for the materials required for the upper layers, namely the surfacing and base layer. The layers require crushed products which, while available, are located some 70 to 100 km to the south.

It may therefore be necessary to establish a project crushing facility to produce the required materials from sources reported to be located in the Kompong Cham area, including hard rock sources and river gravel, located within 40 and 5 kilometers respectively, from the bridge site.

An asphalt mixing plant will also need to be established at the site to produce the surfacing required for the road surface and bridge deck.

(5) Pavements for Minor Roadworks

These works include the two service roads, the link road and the roundabout. All except the roundabout will carry only minor traffic and will therefore only require relatively thin pavements. As AC surfacing is proposed for the bridge deck and the approach road it is proposed that this also be adopted for the minor works, although of a lesser thickness (30mm).

The adopted base and subbase thickness for the service and link road is 125 mm and 150 mm respectively. This was based on a subgrade CBR of 8% and a traffic load of 0.5 million ESA.

While the pavement at the roundabout will need to cater for significantly more traffic, the existence of a reasonable pavement and the need to control levels means that a AC overlay of 150 mm (average) has been assumed at this time. More detailed investigations will be required during the design stage to establish the actual pavement needs at the intersection.

(5) Drainage

The proposed road works will cut across the main drainage path, which is from south to north and retained between the north/south main roads which parallel the river at this location. Culverts are required under the approach and service road embankments at two locations, namely Station's 0+057 (under each service road), 0+195, 0+265 (under the link road and first span of the bridge).

Road surface drainage is catered for by kerbs with openings located at specific locations to carry the water under the adjacent sidewalks, via concrete drainage chutes, to natural surface. Kerb side water also discharges directly into culvert pipes, via entry pits structures, at a number iof locations.

(6) Guard Rails

Guard rails will need to be provided on both sides of the road for the full length of the approach embankment (a length of approximately 200m).

(7) Construction Considerations

The construction of the working platform, referred to above, will need to preceded by the removal of saturated materials found in a number of locations, but principally adjacent to the intersection at station 0+0.00. It is important that this construction is carried out during the dry season to ensure ready access for the removal of unsuitable materials.

14.2.2 Preliminary Design of Approach Road - East Side

(1) Alignment

The road alignment is both flat and straight having only one vertical and two horizontal curves in the 2 kilometers of road located on the eastern side of the river. The horizontal curves are located at either end of the road where they are associated with the final approach to the bridge (300 m radius) and connection with Route 7 (250 m radius). The vertical curve is located at the final approach to the bridge where a grade of 3% has been adopted.

The road level for all, but the last rising grade, is 16.4 m, placing the road surface level some 1.4 m above the 50 year flood level recorded at the site.

The eastern approach road will have a width of 13.50 m within 200 m of the viaduct edge, and thereafter be reduced in width, over a length of 50 m, to 9.5 m. Refer to Figure 14.11.

(2) Embankment

The embankment will be of conventional construction with batters of 2 to 1. These will be protected from erosion, for the full length of the embankment, by a grass covering which will be established as part of the construction. The first 30 meters of the embankment, where it is likely to exposed to higher water velocities during periods of flood will be protected by a concrete facing.

Testing carried out on the geotechnical conditions (for the bridge abutment) indicate that much of the material found below the road consists of sands and gravels, with the upper 3 to 7 m being silts and silty clays. While there is the potential for settlement/consolidation, much of this will occur during the 3 years of bridge construction. To encourage this it is proposed that the foundation area be compacted, using heavy compaction equipment, prior to the construction of the embankment, which will itself be constructed in the early months of construction contract.

Additional testing should be carried out during the final design stage to establish the stability and settlement characteristics of the approach road embankments and their foundations.

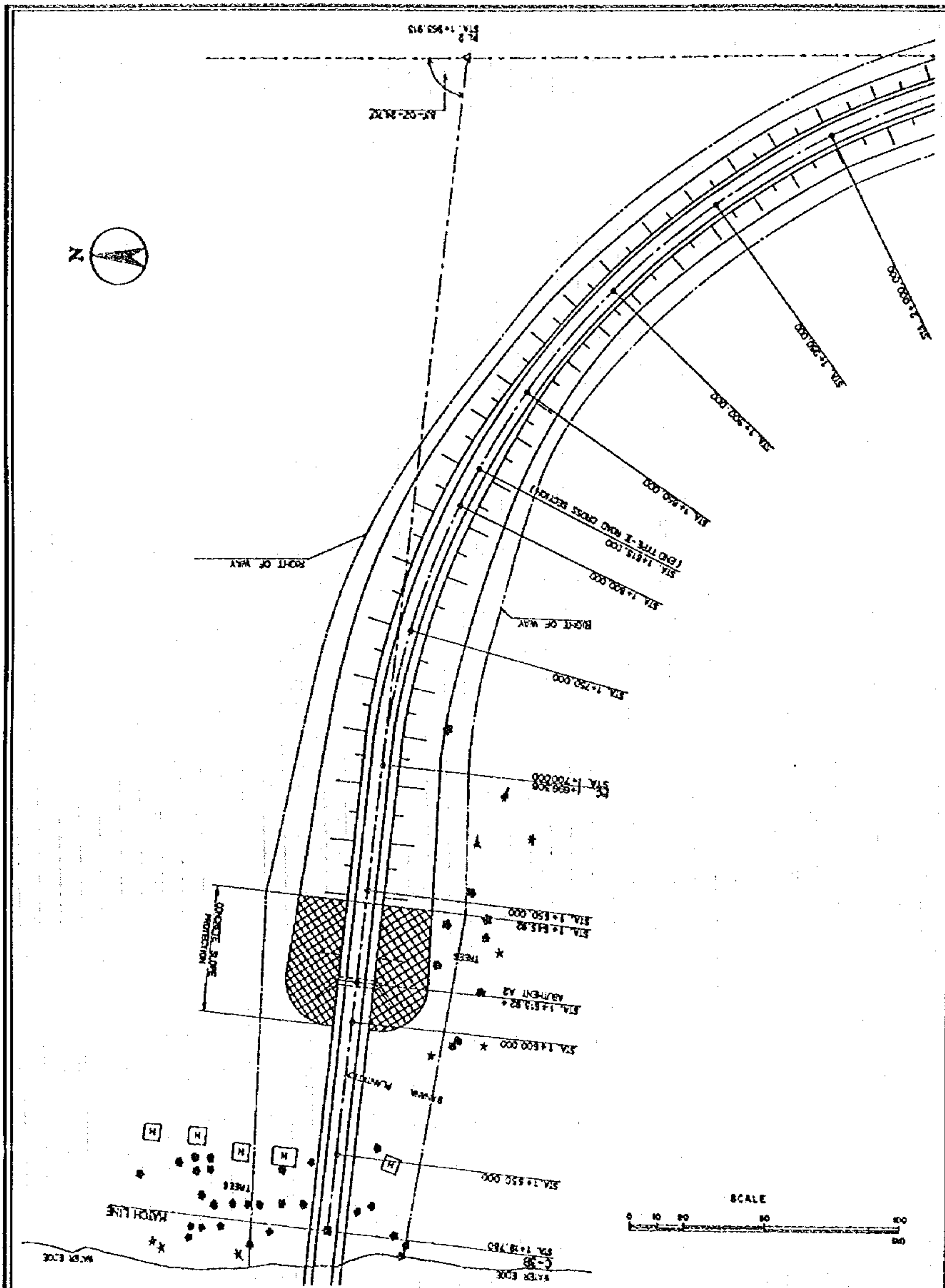
(3) Intersections

The "Y" intersection proposed earlier in the study was reassessed and modified to that shown in Figure 14.12. The new layout recognizes that the new alignment for Route 7, and therefore the passage of all the through traffic, will be via the bridge. The road connection to the village and east bank ferry terminal will therefore be of less importance, negating the need for the western leg of the "Y" intersection previously proposed.

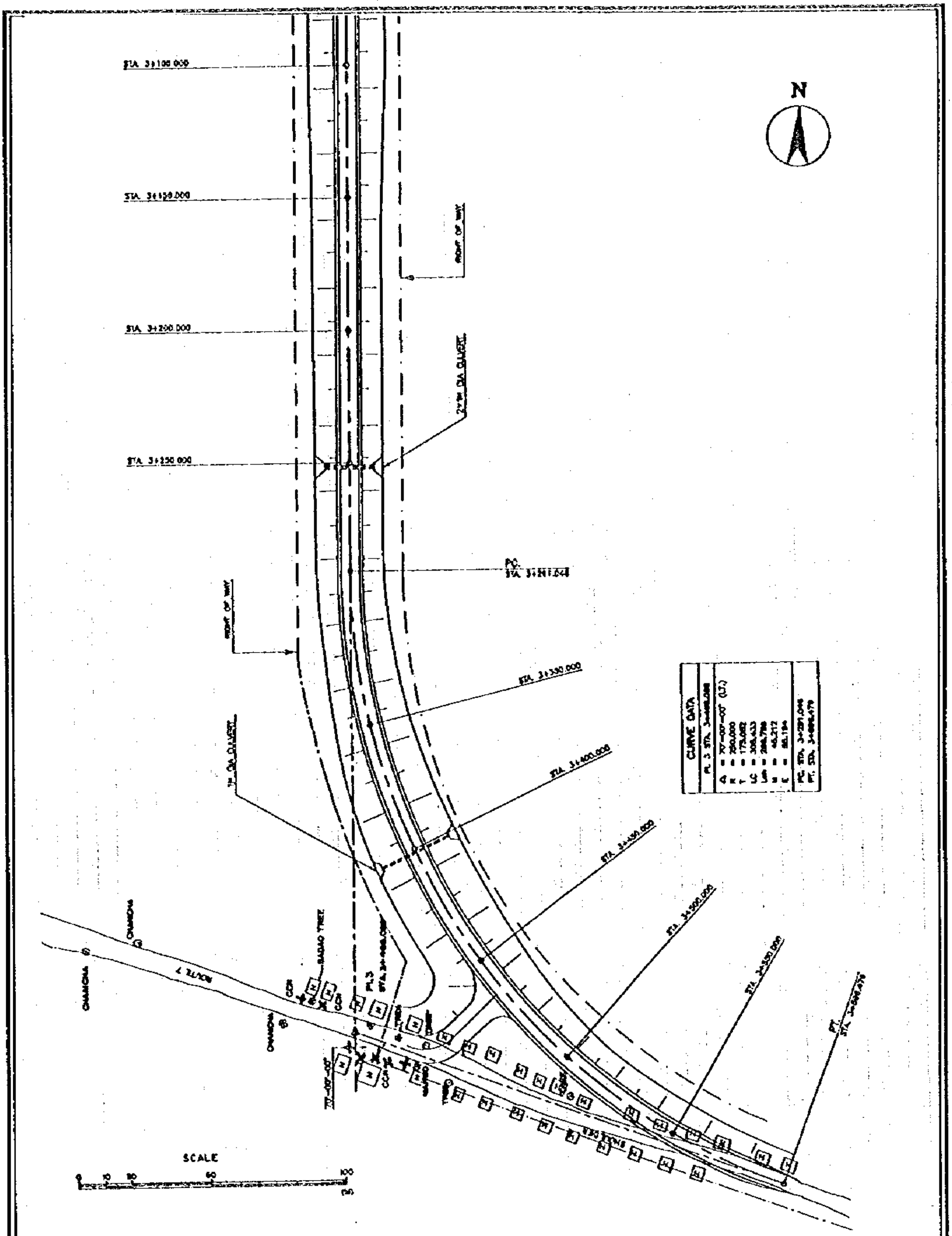
A simple "Tee" intersection is now proposed to connect this village.

(4) Pavements

The pavement needs and details are the same as those proposed for the western approach. Refer to 14.2.1 (4) for details of the proposed pavement.



THE FEASIBILITY STUDY ON CONSTRUCTION OF THE MEKONG BRIDGE IN KINGDOM OF CAMBODIA	Figure 14.11 General Plan for Approach Road on the East Bank JAPAN INTERNATIONAL COOPERATION AGENCY



THE FEASIBILITY STUDY ON CONSTRUCTION OF THE MEKONG BRIDGE IN KINGDOM OF CAMBODIA	Figure 14.12 General Plan of Junction on the East Bank
	JAPAN INTERNATIONAL COOPERATION AGENCY

(5) Drainage

The flood waters found along the eastern approach road are caused by the Mekong river overtopping its banks to the northeast, as well as immediately adjacent to the bridge site. It is therefore necessary to cater for floodwater flows from both directions, as the approach road while generally located along a slight ridge, cuts across the two separate drainage paths, one south to north and the second, east to west. These paths became evident as flood waters receded in the last weeks of the second phase of the study.

While the full drainage pattern could not be fully defined, it is evident that culverts will be required in at least 6 locations, 4 of which will provide for localized depressions while two sites will cater for larger areas and will therefore require multiple cell culverts. Open drains will also need to constructed adjacent to the base of the road embankments, to connect smaller depressions to these culvert sites.

The bridge identified in the Interim One Report while seen as not being necessary, as floodwaters appear to rise on both sides of the proposed approach road, should not be fully discounted at this point, given that it was not possible to fully define the drainage patterns on the east bank.

(6) Guard Rails

Most current road standards require the provision of guardrails when the height of embankment is greater than 2 meters and the batter slope is steeper than 3 to 1. The western approach embankment will have a height of 5 to 7 meters and 2 to 1 slopes and would in most instances warrant the provision of guardrail for the full length of the approach road. A guardrail has therefore been proposed for the full length of the eastern approach road.

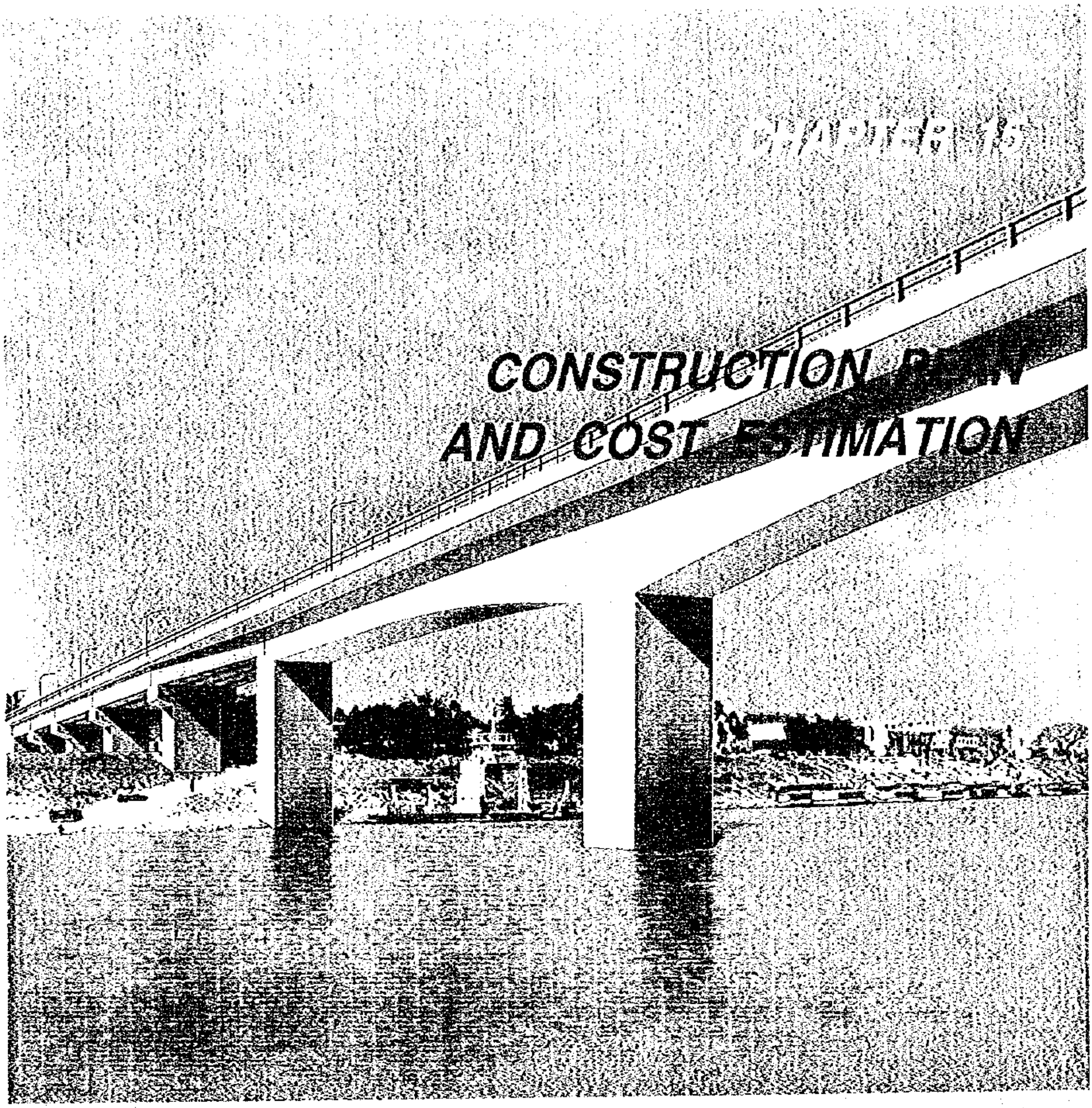
(7) Construction Considerations

The alignment crosses low lying land in a number of locations. It is understood that a number of these could be minor swamps where it will be necessary to remove some of the organic matter before and/or during the constructing the embankment. A task that would be more easily achieved, if carried out during the dry season.

The limited testing carried out todate indicates that the upper layers are relatively ***loose.*** This will mean that the foundation for the embankment will need to be compacted, after clearing, using heavy compaction rollers (vibrating or impact).

14.2.3 Summary of Quantities for Approach Road

Item	Description	Unit	Quantities
1.	Embankment and Pavement		
1.1	Clearing	m^2	96,900
1.2	Embankment	m^3	254,100
1.3	Sub-base Course	m^3	4,400
1.4	Base Course	m^3	4,840
1.5	Asphalt Concrete Pavement	m^2	29,800
1.6	Slope Protection (Sodding)	m^2	47,100
1.7	Slope Protection (Concrete)	m^2	2,470
1.8	Road Pavement	m^2	1,380
2.	Road Structure		
2.1	Guard Rail	m	4,400
2.2	Sidewalk and Curb	m	1,500
2.3	Pipe Culvert	m	310
2.4	Box Culvert	No.	1
2.5	Retaining Wall	m	360


CHAPTER 15
CONSTRUCTION PLAN
AND COST ESTIMATION

CHAPTER 15 CONSTRUCTION PLAN AND COST ESTIMATION

15.1 Construction Plan

15.1.1 General

Construction planning for the Mekong Bridge is based on the optimum scale of the selected bridge established in Chapter 14. It is assumed that construction works will be undertaken by an international contractor based on the probable construction methods and equipment, which are summarized in section 15.1.6. Planning concerning construction schedule, procurement of materials and equipment, construction facilities, and working conditions also are prepared.

15.1.2 Construction Schedule

The construction schedule for the selected bridge works has been developed from the planning of individual activities and construction methods detailed in section 15.1.6.

The total period of construction is planned to be 3.5 years (42 months) considering the following conditions and assumptions:

a) The mobilization would be carried out in October of the first year before the river subsides in November and December so that the foundation works could be commenced and substantially completed during the low water level.

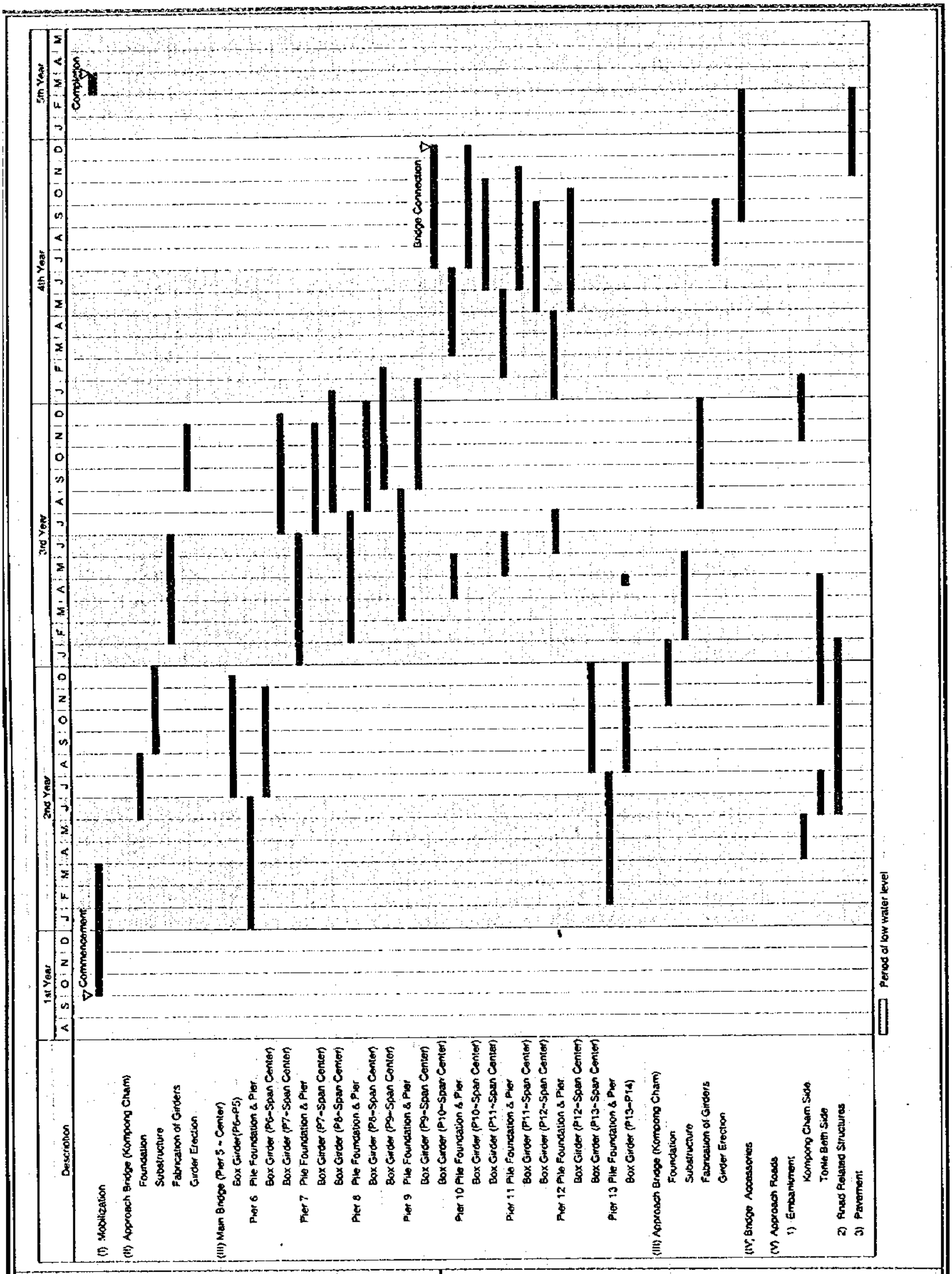
b) Foundation works for the main bridge would commence January in the first year, and be completed within two (2) dry seasons. Therefore, 4 piers (Foundations and substructure under W.L 15.00 m) out of 8 piers in the river would be constructed in each year.

c) Construction of the PC box girder would be carried out all year round in parallel with construction of the PC T-girder bridge.

d) The superstructure would be completed by the end of December of the forth year. Circle time of a segment for main box girder is approximately estimated at 8 days.

e) Construction of the approach road would commence in the 2nd dry season and be completed in February of the fifty year.

According to above conditions and assumptions, the construction time schedule is illustrated in Figure 15.1



THE FEASIBILITY STUDY ON CONSTRUCTION OF THE MEKONG BRIDGE IN KINGDOM OF CAMBODIA	Figure 15.1 Construction Time Schedule for the Proposed Bridge
	JAPAN INTERNATIONAL COOPERATION AGENCY

15.1.3 Procurement of Materials and Equipment

(1) Local Materials

(a) Coarse Aggregate

Rocks for coarse aggregate can be obtained from the quarry site located at Preset, approximately 40 km west of the Kompong Cham bridge site.

River gravel is excavated near Kratie (100 km north of Kompong Cham) in the dry season. Generally, this in-situ material is a mixture of gravel and sand. Boulder is also obtained and used extensively for concrete after a crushing. The river gravel could be transported by barge along the Mekong River to the construction sites and used for concrete for the bridge. However, the transportation route from Kompong Cham to Kratie is now restricted due to security.

(b) Fine Aggregate for Concrete

River sand can also be obtained from a sand bar near Kompong Cham, just downstream from the proposed bridge construction site (C-2 Route). The sand contains a large quantity of fine sand. Consequently, it is necessary to mix this sand with coarse sand based on mechanical analysis. Fine aggregate can be produced by the crushing plant, at the same quarry as that for the coarse aggregate at Preset. However, the quantity produced from the existing crushing plant is small; therefore, a large capacity rod mill is required for the bridge project.

(c) Aggregate for Pavement

Aggregate for pavement can be obtained from the same quarry site of coarse aggregate for the west side approach road and the quarry site at Ba Phnom 100 km south of Kompong Cham for the east side approach road.

(d) Embankment Soil

Embankment soil for the approach road to the bridge can be obtained from borrow areas in the vicinity of the bridge construction site. Lateritic soil is applicable for the sub-grade. Roadside borrow material along Route 7, which is sandy and silty soil, could be used for embankment fill, however sandy type may be susceptible to erosion. At low areas and swampy areas, clay soil may dominate and this soil is considered unsuitable for embankment fill.

(2) Imported Materials

A local cement factory supplies portland cement at Kompot for the local market, but it cannot handle the increased demand. Most cement is imported from Thailand. Reinforcing bar (round bar, deformed bar and steel bar) and bitumen which are not produced in Cambodia, can be imported from Thailand. Bridge materials such as PC tendon, and its anchor and bridge accessories such as bridge bearings, expansion joints etc. could be imported from Thailand. Steel pipes for casing pipes (ø2.00 m) can be imported from Japan considering the difficulty of procurement in neighboring countries..

(3) Construction Equipment

There are twelve (12) contractors registered in Cambodia. Several contractors have light equipment for road works and are undertaking road improvement projects. But the amount of equipment is limited and the equipment is rather old. These contractors have very little experience, if any, for bridge projects; therefore they do not have appropriate bridge construction equipment. For construction of the Mekong River Bridge, large -scale equipment such as a Crawler crane, Wagon for bridge girder, Vibro- hammer, Pile-hammer, Floating crane, Self-elevating-platform, Concrete plant on barge, and many barges and Tug-boats would like be required. These heavy equipment could be transported from Singapore, Thailand, and Japan. If a suspension bridge or cable stayed bridge is selected, special equipment could be brought from Japan.

(4) Transportation Plan

Imported materials and equipment are transported from Thailand, Singapore, and Japan via the Mekong River from Vietnam to the Phnom Penh port ,which is the international port on the Mekong River in Cambodia, and which has been rehabilitated. The Phnom Penh port has two(2) quays of approx. 150m and ported 6,000 ton ship. Track crane of 45t class will be equipped for loading and unloading. The access road from the port to the sites is available for inland transportation. During the Mekong River Bridge construction, it is considered that temporary quays would be constructed for loading and unloading directly on the construction sites.

15.1.4 Construction Facilities

Construction facilities required for construction of the Mekong bridge would be a concrete batching plant, a crushing plant, fabrication yards for precast PC T-girders, offices, warehouses, motor pool, stock piles and camp yards. These facilities would be developed on construction yards of both river sides, accessed to the river front with movable jetties. On the west side, the governmental land could be prepared for the construction yard-1 in which offices, motor pool and warehouses are developed. The areas on the east side are subject to inundation during the flood season, to expedite the installation of the various construction facilities, extensive embankment (Up to level 15.00) will be required for construction yard-2 in which, crushing plant, fabrication yards for precast PC T-girders, stock piles and labour camps.

15.1.5 Working Conditions

(1) Workable Days

Monthly workable days can be estimated through an analysis of past rainfall records in Phnom Penh. Total workable days throughout an average year are 275 days for bridge works and 260 days for road works. A detailed breakdown of monthly workable days is shown in Appendix 15.1.

(2) Technical Level and Skilled Labor

The proposed Mekong Bridge, which would be the largest bridge in Cambodia, would require the application of sophisticated bridge construction methods. However, the technical level in Cambodia does not meet the international standard technical level. Therefore, it is envisaged that foreign contractors will be selected by the international tender. Skilled laborers are very limited in number, and have little experience concerning bridge construction. It will be necessary for sufficient foreign experts, such as crane operators and foremen to be involved such that they can supervise and train local skilled laborers.

(3) Working Hour

Typical working hours in Cambodia are 8:00 ~ 17: 00 with 2 hours for lunch time. Consequently, the actual working day consists of 7 hours. Night work may be required for foundation works , which can only be executed in the dry season.

(4) Water Level

Based on the high and low water level record at Kompong Cham, the variation of the water level is illustrated in Appendix 15.2 The following conditions are assumed on the construction of the main bridge.

a) Foundation works could be carried out under 5.0 m MSL. Workable period will be 5 months (Jan ~ May) ~ 7 months (Dec ~ Jun) considering variation. Therefore, it is proposed that piling works be commenced in the middle of December and completed in the middle of May.

b) The highest water level is 14.77 MSL recorded in September 1991. It is assumed that level of the temporary bridge and camp yard be constructed at 15.00 MSL.

c) Variation from the highest to the lowest water throughout the year is assumed at 14.00 m and water depth between 16.0 m and 30.0 m at the deepest river bed.

15.1.6 Construction Method

(1) Foundation and Substructure

The substructure of the Mekong bridge has 8 piers in the river which are supported by multi-column pile foundation, 9 piers and 2 abutments in the inundated area. Construction sequence of the multi-column pile foundation is illustrated in Figures 15.2 and 15.3. Construction materials and equipment are transported by barges between piers and construction yards. Concrete is mixed by a batching plant on barge and placed by concrete pump with a long boom tug-boat.

(2) Superstructure

The construction of the main bridge consists of 4 phases from the view point of construction methods; 1) Pier top blocks, 2) Cantilever girder blocks, 3) Key segment at center and 4) End girder blocks. The construction sequences of the main bridge are illustrated in Figure 15.4. Four sets (8 numbers) of traveling wargens are required for 16 months.

The erection of T-girder for approach bridge is carried out by 2 number of 150 ton crawler crane.

15.2 Cost Estimate

15.2.1 General

Project cost estimate consists of construction cost, detailed design and supervision cost, non-eligible costs (land acquisition and compensation cost, taxes and duties, and MPWT's administration cost), and contingencies. The basic system of the project cost estimate is shown in Figure 15.5, considering the following assumptions.

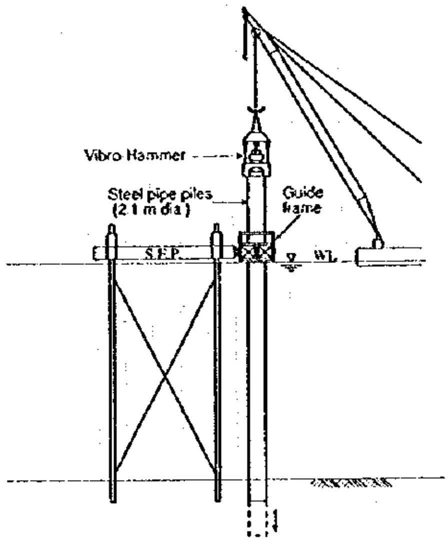
a) Cost estimate is made at the price level as of the end of February 1996.

b) The foreign currency exchange rates are assumed to be;

US$1.0 = Yen 104.85 = Bs 25.19

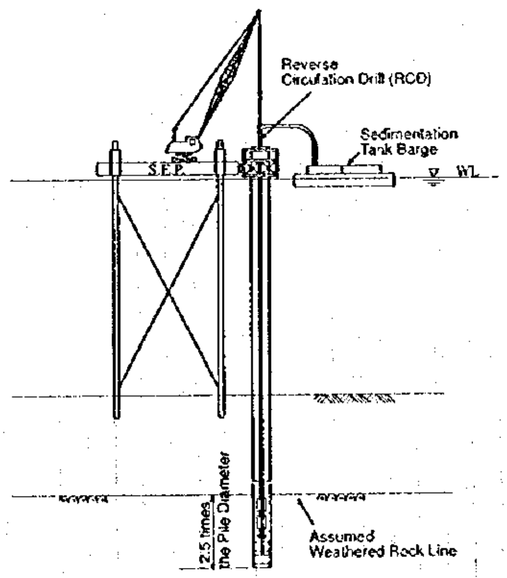
c) Materials and equipment, which cannot be procured in Cambodia, and basically imported from Thailand, except special materials and equipment for large scale bridge.

d) It is assumed that the project is undertaken by a International Contractor selected in a competitive tender under the supervision of a Japanese consultant.



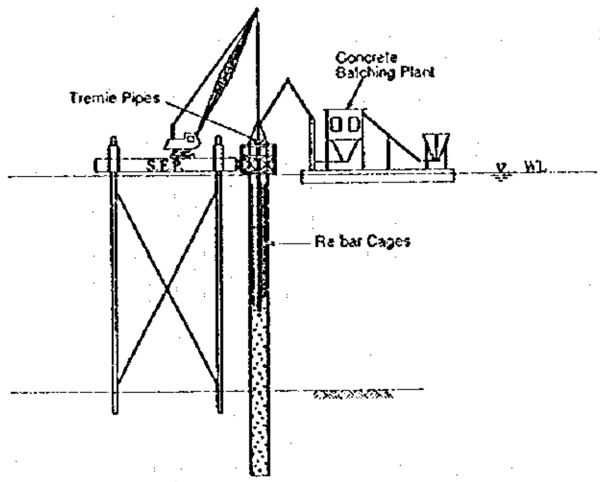
Step - 1: Driving Steel Pipe Pile

Self-elevating Platform (SEP) is set at the exact position and steel pipe piles are driven by vibro-hammer through guide frame attached to SEP.



Step - 2: Drilling by Reverse Circulation Drill (RCD)

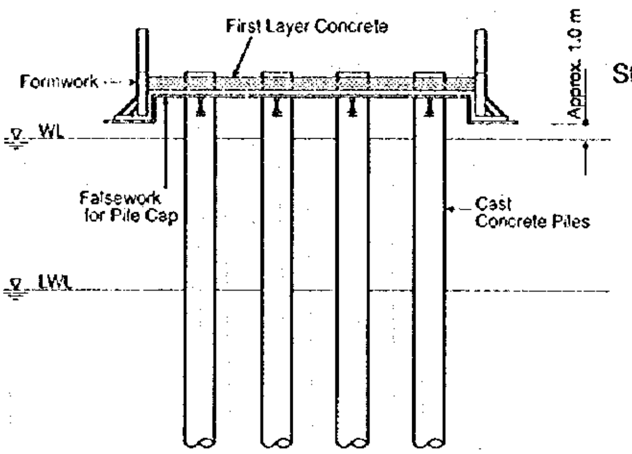
Bore holes having the 2.0 m dia. are made in the steel pipe piles and drilled down to weathered rock to form a socket length up to 2.5 times the pile diameter.



Step - 3: Concrete Placing for Piles

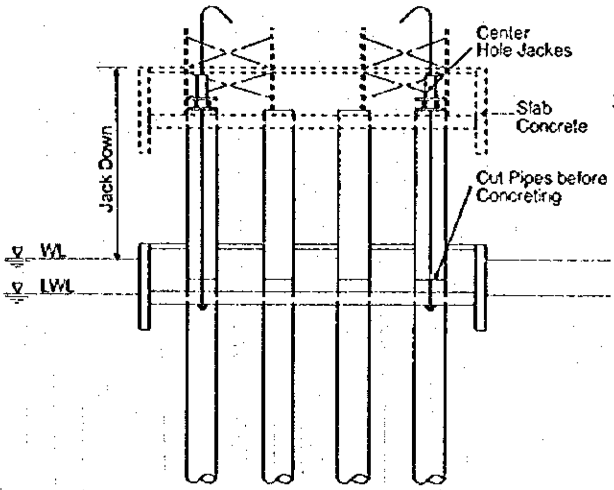
After slime at the borehole tip is removed, the required concrete volume for one pile is placed with tremie pipes by the large capacity of concrete batching plant.

THE FEASIBILITY STUDY ON CONSTRUCTION OF THE MEKONG BRIDGE IN KINGDOM OF CAMBODIA	Figure 15.2 Construction Method of Foundation Piles
	JAPAN INTERNATIONAL COOPERATION AGENCY



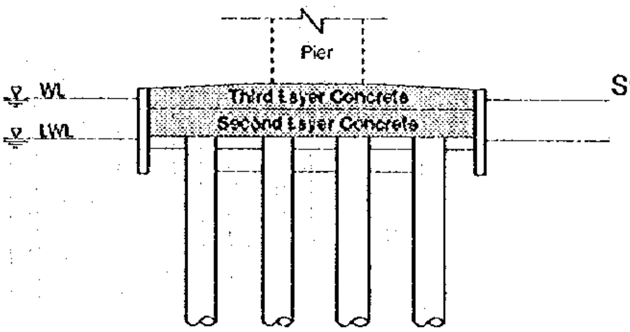
Step - 1: Setting Falsework for Pile Cap

Falsework for pile cap is set above water level and slab concrete (First Layer) of 1.0 m is placed. Side formworks are set before jacking down slab concrete of pile cap.



Step - 2: Jack Down Slab Concrete

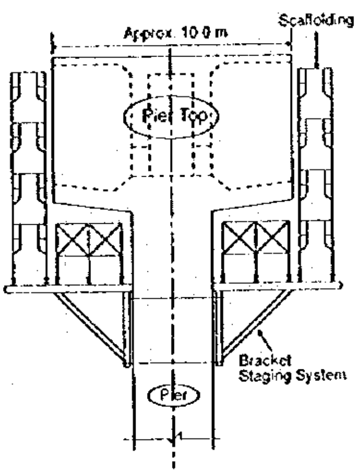
When water level is down near the low water level the slab concrete is jacked down up to 0.00 m MLS by center hole jacks. Projecting pipes are cut before placing the second layer concrete.

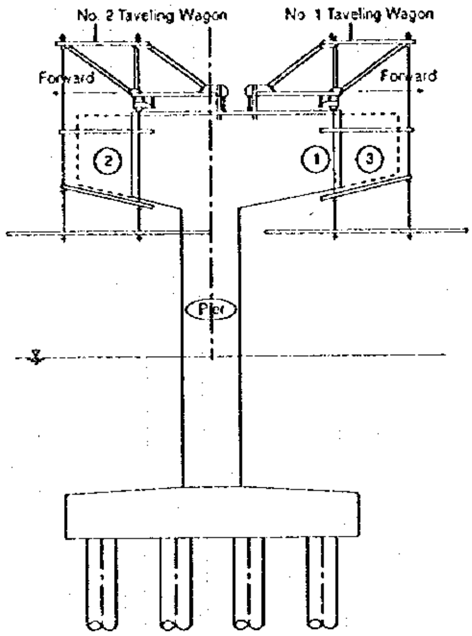


Step - 3: Concrete Placing for Pile Cap

Concrete for pile cap is placed in two times (Second and third layer concrete) after dewatering inside of formwork. Sequentially, pier under 15.0m MSL is constructed within dry season.

THE FEASIBILITY STUDY ON CONSTRUCTION OF THE MEKONG BRIDGE IN KINGDOM OF CAMBODIA	Figure 15.3 Construction Method of Pile Cap
	JAPAN INTERNATIONAL COOPERATION AGENCY



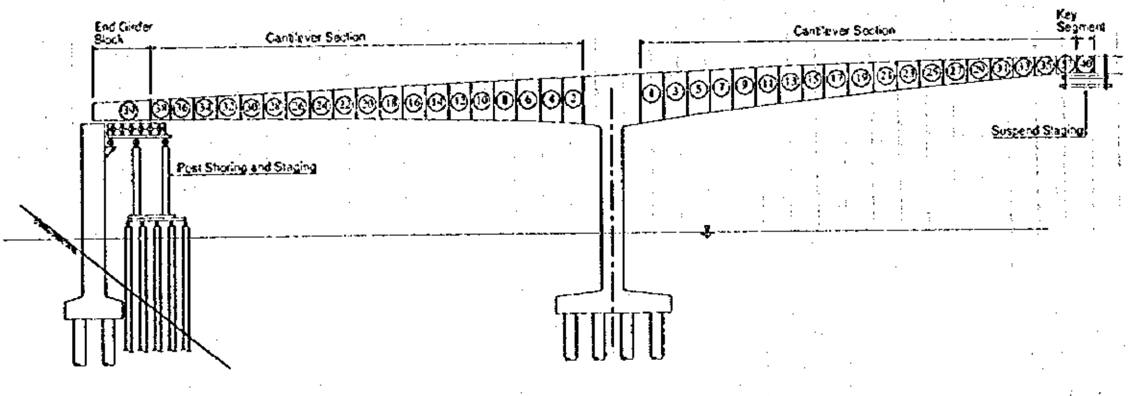


Step - 1: Pier Top

Top portions of the pier, called the pier top, are concreted on blacket staging which are anchored to pier. It can be used as the starting platform for the traveling wagons.

Step - 2: Setting and Movement of Traveling Wagons

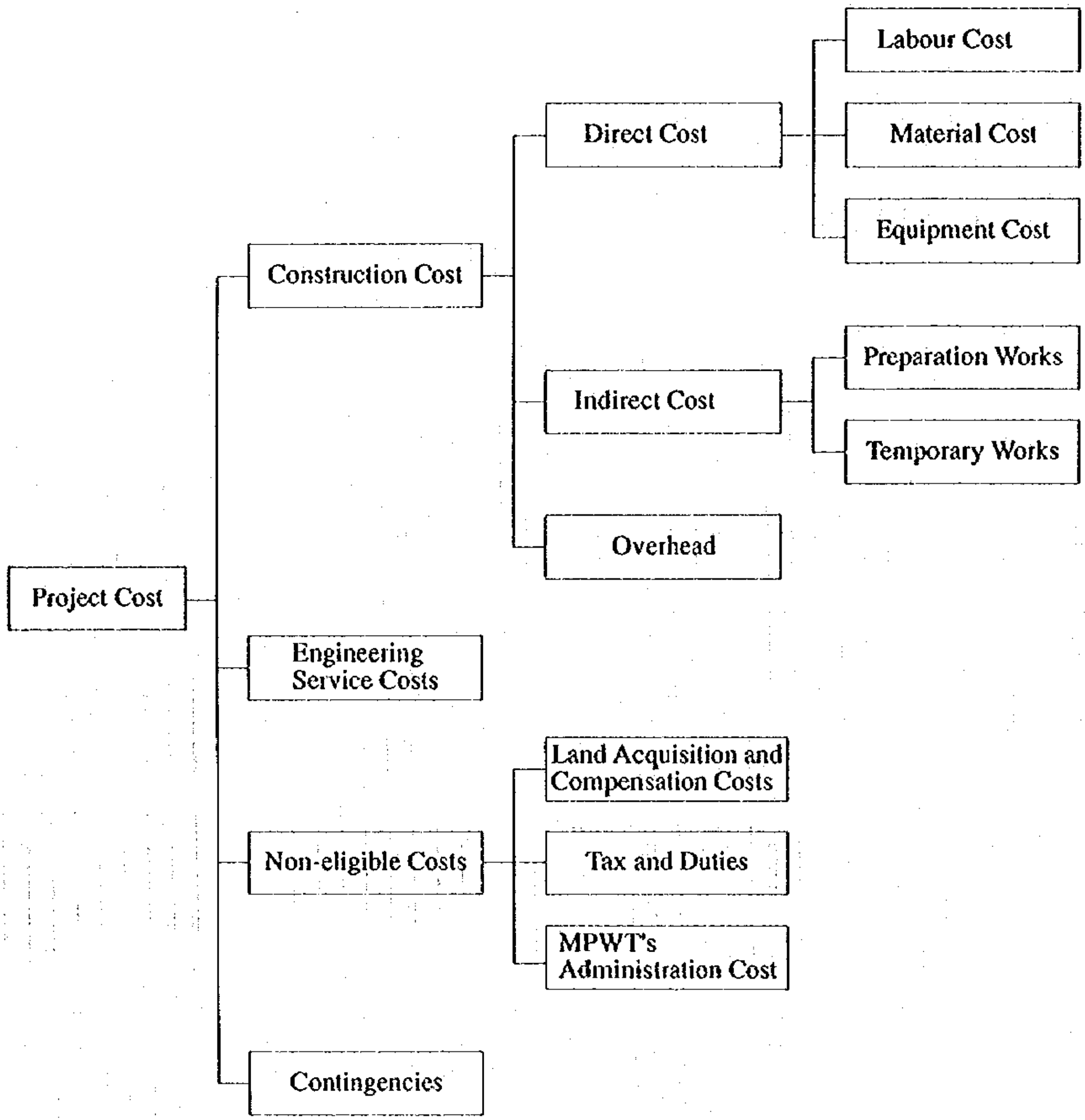
Two traveling wagons are placed side by side on the top of pier, then forming, re-bar installation, and concreting are performed on the first block of the box girder. After prestressing the block, the wagons travel forward.



Step - 3: Cantilever Method of End Girder Block and Key Segment for Continuous Structure

The main girder is constructed with cantilever method with two wagons moving simultaneously. The 15 subsequent blocks are alternately constructed on each side by the same solution as Step - 2. The end of the cantilever girders at abutments and at the center of each span (key segments) are constructed by using post shoring and staging, and a suspending staging which will be concreted and prestressed on the suspend shoring system when establishing continuity.

THE FEASIBILITY STUDY ON CONSTRUCTION OF THE MEKONG BRIDGE IN KINGDOM OF CAMBODIA	Figure 15.4 Construction Method of Superstructure JAPAN INTERNATIONAL COOPERATION AGENCY



THE FEASIBILITY STUDY ON CONSTRUCTION OF THE MEKONG BRIDGE IN KINGDOM OF CAMBODIA	Figure 15.5 Basic System of Project Cost Estimation
	JAPAN INTERNATIONAL COOPERATION AGENCY

15.2.2 Construction Cost

Construction cost was prepared for the optimum bridge at the selected route in Kompong Cham, based on the unit prices developed in this section and work quantities estimated in Chapter 14. The unit prices were adjusted with the factors reflecting the geometrical conditions, variations of water level and speed between dry and rainy seasons, and construction plans presented in Section 15.1.

Construction cost consists of direct cost, indirect cost and overhead as described below:

(1) Direct Cost

Direct cost consists of labour, material and equipment costs for each work items. Labour are recruited in Cambodia and supervised and trained by foreign experts. The labour costs per day were surveyed by interview from the contractors who now undertake the bridge and road projects, and listed in Appendix 15.3.

Equipment cost are estimated based on the depreciation rate considering the workable days per year at the site estimated in Appendix 15.1. Life year, depreciation ratio, Maintenance ratio and Management ratio for each equipment apply for the Japanese standard. The equipment cost per hour was estimated according to the above conditions and listed in Appendix. 15.4.

Materials, that are not produced locally or are of insufficient quality are conceivable imported from Thailand or Japan. The unit prices given are the market prices in Thailand and Japan. Transportation costs to the site and import taxes and duties in Cambodia are not included in the unit prices, and are estimated separately. The unit prices of principal construction materials are shown in Appendix 15.5.

(2) Indirect Cost

Indirect cost consists of preparation works and temporary works. The estimated cost of the preparatory works can be obtained from a summation of development of camp years including reclamation and roads in the site, provision of the site facilities for contractor and Resident Engineer's staff and transportation cost. The cost of temporary works will include construction of temporary jetties, coffer dams and access roads to the site.

(3) Overhead

Overhead consists of costs of contractor's supervision, general overhead and profit of headquarters, and insurance including indemnification of the principal against property damage and public risk. The overhead is assumed as 25% of direct cost.

15.2.3 Engineering Service Costs

Engineering service costs consist of the detailed design and supervision costs undertaken by a Japanese consultant. The engineering service costs were assumed equal to 7% of the total construction cost.

15.2.4 Non-eligible Cost

Non-eligible financing cost consists of land acquisition cost, taxes and duties and MPWT's administration cost which are provided by the Cambodian Government.

(1) Land Acquisition and Compensation Cost

The proposed right-of-way based on the space required for the bridge, approach road and intersection (roundabout) is proposed in the preliminary design. Based on the right-of-way, a meeting was held in the office of Kompong Cham Province under the chairman of the Governor of Kompong Cham on 22 December 1995.

West Shore (Kompong Cham town side)

Fifty-three families in which 40 houses with land, 1 commercial warehouse, 1 restaurant and 6 plots without house are affected. It was confirmed that the land acquisition cost is approximately US$26.4 per m^2 and the compensation cost ranges from US$60 to US$120 per m^2 depending on the house condition. The land acquisition and compensation cost for Kompong Cham side are estimated and shown in Table 15.1.

Table 15.1 Land Acquisition and Compensation Cost (Kompong Cham side)

Description	Areas (m^2)	Cost (US$)
Land Acquisition	14,900	393,700
Compensation	6,540	546,600
Total	21,440	939,600

East Shore (Tonle Bet side)

Seventy-two families in which 27 houses with land are affected. It was confirmed that the land acquisition cost ranges from US$0.25 to US$2.0 per m^2 and the compensation cost is approximately US$30 per m^2. The land acquisition and compensation cost for Tonle Bet side are estimated and shown in Table 15.2.

Table 15.2 Land Acquisition and Compensation Cost (Tonle Bet side)

Description	Areas (m^2)	Cost (US$)
Land Acquisition	77,000	42,300
Compensation	1,250	37,400
Total	78,250	79,700

Total land acquisition cost and compensation cost are estimated at US$1,020,000 approximately.

(2) Taxes and Duties

Import taxes of construction materials and equipment are levied on the CIF (Cost, Insurance & Freight) prices when the materials and equipment are imported to Cambodia, provided always that the materials and equipment be sent back from Cambodia after completion of the project, the taxes are excepted. Tax ratios of the construction materials and equipment are listed in Appendix 10.1.

(3) MPWT's Administration Cost

The MPWT will provide staffs who have the responsibility for the coordination of various national input and the management of the project as the Client. It is assumed that the MPWT's administration cost be 4 percent of the engineering service cost in this stage.

15.2.5 Contingencies

This cost estimate is prepared on information available from the Feasibility study stage. It is assumed that bridge construction commence about two years hence. Consequently, allowance must be made for such unknown factors as:

a) Economic changes (exchange rate, inflation etc.) in Cambodia, Thailand and Japan.

b) Changes in geological condition in the river and work quantities which may occur during the detailed design stage.

c) Changes in assumptions regarding the proposed quarry and borrow areas and procurement of materials and equipment.

From an assessment of the above factors involved, the contingency is assumed to be a maximum of 10% of the construction cost.

15.2.6 Total Project Cost

Total project cost was estimated by the procedure described in the previous sub-sections 15.2.2 to 15.2.5. The total project cost is estimated at US$79,678,000 (US$51,003,000 for foreign portion and US$28,675,000 for local portion) and summarized in Table 15.3. The breakdown of the construction cost is detailed in Appendix 15.6.

Table 15.3 Summary of the Project Cost

NO.	WORK ITEM	FOREIGN (US$)	LOCAL (US$)	TOTAL (US$)
1)	CONSTRUCTION COST			
A)	Preparation Works	9,519,000	1,406,000	10,925,000
B)	Temporary Works	2,097,000	174,000	2,271,000
C)	Main Bridge	26,734,000	15,160,000	41,894,000
D)	Approach Bridge	2,292,000	2,145,000	4,437,000
E)	Approach Road	2,023,000	1,647,000	3,670,000
F)	Ancillary works	668,000	933,000	1,601,000
	TOTAL (1)	43,333,000	21,465,000	64,798,000
2)	ENGINEERING FEE	3,033,000	1,503,000	4,536,000
3)	NON-ELIGIBLE COST			
3.1	Land Acquisition and Compensation Cost		1,020,000	1,020,000
3.2	Taxes and Duties		1,899,000	1,899,000
3.4	Administration Cost of MPWT		181,000	181,000
	TOTAL (3)		3,100,000	3,100,000
4)	CONTINGENCIES	4,637,000	2,607,000	7,244,000
5)	PROJECT COST (1+2+3+4)	51,003,000	28,675,000	79,678,000

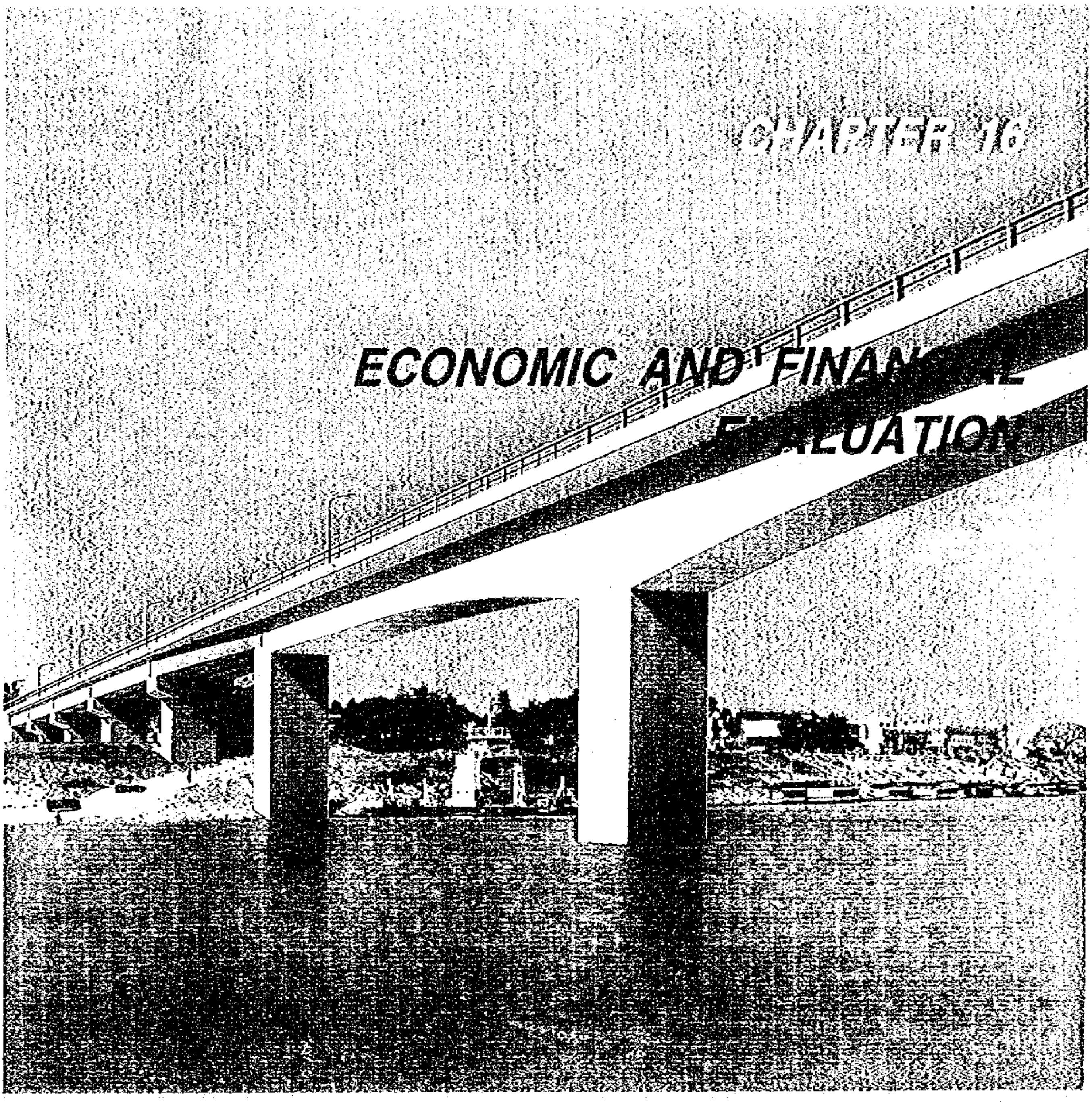
15.2.7 Maintenance Cost

Although continuous PC Box Girder Bridge is almost free of maintenance over the anticipated life of the structure, the minimum maintenance is required. Its maintenance items and interval are preliminary adopted as shown in Table 15.4.

Table 15.4 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

Total maintenance cost for 20 years was roughly estimated at US$957,000 as shown in Appendix 15.7.


CHAPTER 16
ECONOMIC AND

CHAPTER 16 ECONOMIC AND FINANCIAL EVALUATION

16.1 Economic Evaluation

16.1.1 Introduction

The principal objective of the Project is to address infrastructural constraints and promote equitable economic growth in Cambodia. A major step in achieving this objective is to construct a bridge across the Mekong River, thereby providing reduced transport costs and an impetus for economic growth. Secondary objectives include enhancing the development of the agricultural and industrial base in eastern Cambodia and improving the earning prospects of residents in the areas affected by the Project. In addition, the bridge will link the eastern and western sections of Cambodia divided by the Mekong, which has been a major goal for decades.

16.1.2 Economic Evaluation

The economic analysis has been conducted on the basis of a "with" and "without" comparison. The economic benefits of the Project have been quantified in terms of time cost savings afforded to passengers and freight that now cross the Mekong by ferry, and vehicle operating cost (VOC) savings in terms of reduced vehicle-kilometers traveled and avoidance of ferry fares by vehicles that now cross the Mekong by ferry.

The evaluation method utilized in this chapter is somewhat different from the preliminary evaluation employed in Chapter 10. The objective of the preliminary economic evaluation was to provide a criterion for the purpose of selecting the most desirable route among the three alternatives. During the preliminary evaluation, the focus was appropriately centered not on the absolute magnitude of economic benefits, but rather on the relative magnitude of economic desirability for each respective alternative. Consequently, it was preferable to limit the components subject to benefit quantification to those that could be measured with a fair level of certainty. In this chapter, however, the purpose of the economic evaluation is to determine whether investment in the Project will produce economic benefits in excess of the minimum amount obtainable by investing in other projects. The magnitude of the total economic benefit is the issue here. Therefore, an attempt was made to estimate the minimum level of development benefits that can be expected by the Project.

The economic benefit stream was carried out for a 30-year planning horizon. The benefits in intermediate years were estimated by interpolation between the years 2001, 2011, and 2021. Benefits in years 2022-2031 were set equal to those in 2021, as traffic volumes in these years cannot be forecast with any confidence. Because the bridge is expected to be opened to traffic in April 2002, the benefits initially calculated for 2001 were set equal to zero and those calculated for 2002 were multiplied by a factor of 0.75.

All costs and benefits in the economic analysis have been stated in terms of February 1996 United States dollars (US$1.00 = Yen 104.85 = Riel 2,300). Taxes and duties were excluded from the economic analysis because they are transfer payments, which do not increase or decrease the availability of real resources to the rest of the economy. These items may, however, affect the distribution of financial costs and benefits between the

Project entity and other entities; therefore they are included in the financial evaluation presented in section 16.2.

Other than the deduction of taxes and duties, it was conservatively assumed that no conversion factor should be applied to the capital or maintenance costs of the Project. As noted earlier in section 10.1, no shadow exchange rate is required and no price distortion factor is considered necessary for unskilled labor costs. Although the preliminary economic evaluation of candidate routes, presented earlier, adopted a standard conversion factor of 0.85, this assumption was based on the less detailed cost information available at the time. With the known amount of taxes and duties of the Project, the application of this factor was appropriately dropped.

16.1.3 Economic Benefits and Costs

(1) Time Cost Savings

Time costs savings were calculated for passengers and freight by vehicle type. Unit costs expressed in US$ per vehicle-hour by vehicle type and time savings in minutes due to the Project were presented earlier in section 10.1. Consistent with standard practice, the benefits as changes in consumer surplus for induced traffic were valued at half of that for normal traffic. The time cost savings for both passengers and freight were then estimated to be US$0.9 million in 2002, US$5.4 million in 2011, and US$17.2 million in 2021.

(2) Vehicle Operating Cost Savings

Vehicle operating cost savings were determined by vehicle type in terms of reduced vehicle-kilometers traveled and avoidance of ferry fares. Again, the benefits as changes in consumer surplus for induced traffic were valued at half of that for normal traffic. Fares at the Kompong Cham ferry are US$0.22 per MC, US$2.26 per PC, US$3.83 per LB, US$9.13 per HB, US$3.04 per LT, US$9.13 per MT, and US$13.04 per HT, as presented in Appendix 4.4. These fares were converted to economic prices using a factor of 0.975 to account for tax payments made by the ferry operator in the amount of 2.5 per cent of total revenues (i.e., business taxes, so-called other taxes, and profit-related taxes); the State finance report of the Kompong Cham ferry operated by the Ministry of Public Works and Transport is also shown in Appendix 4.4. The VOC savings for reduced vehicle-kilometers traveled and avoidance of ferry fares were then estimated to be US$0.7 million in 2002, US$2.8 million in 2011, and US$6.2 million in 2021.

Because this economic evaluation includes benefits due to the avoidance of ferry fares, the savings in avoidance of ferry operating and improvement costs were excluded. Fare revenues at Kompong Cham are sufficient to cover all operating and some improvement costs; therefore, including both benefits would represent a form of double counting. Although this approach differs from that of the preliminary economic evaluation, which included ferry operating and improvement cost savings and excluded ferry fare savings, both methods are valid.

The method used in the preliminary evaluation only looked at the changes in physical resource utilization, whereas the method used in the final evaluation looked at the changes in final consumption as the aggregate of consumption by individual consumers. The final consumption of the Cambodian economy obviously includes the amount spent obtaining the ferry service. Although the former method is conservative in that the economic value of the ferry service is excluded except for the value of physical input to produce the service, it was considered suitable for evaluating alternatives as it produces itemized benefit figures. The latter method measures the change in aggregate economic value as appears in the final GDP calculation. Therefore, the latter method was adopted for the final analysis for the purpose of showing the magnitude of real changes in the economy.

(3) Total Costs

Total costs include (i) the capital investment expenditures excluding taxes and duties disbursed over the five-year construction program period of 1998-2002, as shown in Appendix 15.10 (total cost of US$77.8 million); (ii) periodic bridge and approach road maintenance and repair costs incurred in 2011 and 2021, as shown in Appendix 15.9, and estimated for 2031; and (iii) annual bridge and approach road maintenance and repair costs of approximately US$1,800 per year.

In addition, the residual value of assets was calculated as 40 per cent of the total economic capital cost and included (as a benefit) in capital costs for 2031. Although large in magnitude, this benefit occurs at the end of the economic evaluation period and therefore has a minimal impact on the economic viability of the project.

16.1.4 Economic Internal Rate of Return

According to the economic benefits and costs determined through the techniques described above, the EIRR was estimated to be 9.5 per cent; Table 16.1 summarizes the analysis, including the distribution of benefits and costs by year.

Table 16.1 Economic Internal Rate of Return (EIRR) Derivation

(US$ million)

Year	Capital Costs	Maintenance Costs	Time Cost Savings Passenger	Time Cost Savings Freight	VOC Savings	Net Benefits
1998	-7.6					-7.6
1999	-19.3					-19.3
2000	-25.8					-25.8
2001	-20.4					-20.4
2002	-4.7	-0.0	0.7	0.2	0.7	-3.1
2003		-0.0	1.1	0.4	1.0	2.5
2004		-0.0	1.3	0.5	1.1	2.9
2005		-0.0	1.5	0.6	1.3	3.3
2006		-0.0	1.7	0.7	1.5	3.9
2007		-0.0	2.0	0.8	1.7	4.5
2008		-0.0	2.3	1.0	1.9	5.2
2009		-0.0	2.7	1.2	2.2	6.1
2010		-0.0	3.1	1.5	2.4	7.1
2011		-0.4	3.6	1.8	2.8	7.8
2012		-0.0	4.0	2.1	3.0	9.1
2013		-0.0	4.4	2.4	3.2	10.1
2014		-0.0	4.9	2.8	3.5	11.1
2015		-0.0	5.4	3.2	3.8	12.4
2016		-0.0	5.9	3.7	4.1	13.7
2017		-0.0	6.5	4.3	4.5	15.2
2018		-0.0	7.2	4.9	4.9	16.9
2019		-0.0	7.9	5.7	5.3	18.8
2020		-0.0	8.7	6.6	5.7	21.0
2021		-0.5	9.6	7.6	6.2	22.9
2022		-0.0	9.6	7.6	6.2	23.4
2023		-0.0	9.6	7.6	6.2	23.4
2024		-0.0	9.6	7.6	6.2	23.4
2025		-0.0	9.6	7.6	6.2	23.4
2026		-0.0	9.6	7.6	6.2	23.4
2027		-0.0	9.6	7.6	6.2	23.4
2028		-0.0	9.6	7.6	6.2	23.4
2029		-0.0	9.6	7.6	6.2	23.4
2030		-0.0	9.6	7.6	6.2	23.4
2031	31.1	-0.6	9.6	7.6	6.2	53.9
		EIRR	9.5%			

Note: 1. Annual bridge and approach road maintenance costs were included in the evaluation; however, because the magnitude of these costs is relatively low, they appear as 0.0 in the printout.

2. The residual value of assets, included in capital costs for 2031, was calculated as 40 per cent of the total economic capital costs.

16.1.5 Sensitivity Analysis

A sensitivity analysis was undertaken to assess the economic internal rate of return under the following conditions: (i) investment costs increasing 10 per cent, (ii) all benefits being reduced 15 per cent, and (iii) both costs increasing 10 per cent and benefits being reduced 15 per cent. The results are as follows:

Sensitivity Condition	EIRR
Costs Increased by 10%	8.9%
Benefits Reduced by 15%	8.5%
Costs Increased by 10% and Benefits Reduced by 15%	8.0%

The results of the sensitivity analysis indicate that the EIRR in the worst case scenario is 8.0 per cent. The 9.5 per cent EIRR in the base case was determined via an analytical approach that adopted conservative cost and benefit figures as input data.

Although the bridge proposal appears to have a marginal economic return on investment, it is important to restate that the construction of a Mekong Bridge at Kompong Cham will not only reduce transport costs, but will also serve as a catalyst for economic growth, especially on the east bank of the Mekong. In the preliminary evaluation presented in Chapter 10, the bridge at Kompong Cham (i.e., C-2) scored highest among the six alternative routes in part because of its concordance with the national regional development strategy and promotion of public welfare.

Certainly, quantitative economic analysis results are only one of a number of criteria that must be considered. National strategies should also be weighed, along with environmental and social impacts. The following section, therefore, discusses important (non-quantified) development benefits of the Project.

16.1.6 Non-Quantified Development Benefits

In order to properly attribute development benefits (i.e., an increase in economic growth) to the Project, three basic conditions must be met. The most important one is that the economic development would not have taken place without the Project. It must also be true that the resources used in the new development would otherwise have remained unused or have been used less productively. Moreover, it is essential that the economic activity stimulated does not replace activity that otherwise would have taken place. In the case of the Project, these three conditions are clearly met.

As discussed in Chapter 2, the potential for expanding agricultural and industrial production in this region is very high. Agricultural products that could be cultivated on a significantly larger scale include rubber, rice, timber, maize, soybean, mungbean, cassava, sweet potato, tobacco, groundnut, cotton, coffee, and cashew. Minerals that are present in the area, but unknown in quantity, include base metals, bauxite, gold, iron, and coal/lignite; industrial and construction materials are also known to be present.

Where a transport facility leads to increased output and the aforementioned conditions are met, it is desirable to determine the net value of this additional output as the measure of economic benefit. (The net value of output and savings in vehicle operating costs for generated or induced traffic are, of course, not additive.) In many situations, however, the transport improvement is not the only new investment needed to achieve the increased production. This situation raises the problem of allocating the benefit (i.e., the increased production) among the transport improvement (i.e., the Project) and other investments.

Ideally, the net value of the additional output expected for each of the 18 above-listed agricultural and mineral products as well as for industrial and construction materials would be calculated, the additional investment required to produce these new yields would be calculated, and the benefits attributable to the Project would be allocated accordingly. However, in the case of Cambodia--and the East Bank Region of the Mekong in particular--there is no source of reliable data on potential agricultural and mineral production levels. Any attempt to predict in detail specific agricultural and mineral production levels would therefore be highly speculative and subject to an unsatisfactory margin of error, thereby rendering the determination of development benefits meaningless.

In addition, the bridge will certainly induce an increase in value-added of various sectors of the economy other than agriculture and minerals, such as commerce and industry. However, quantification of these components is also extremely difficult given the level of usable data.

Although it was not considered possible to forecast the magnitude of development benefits with any confidence, they will most likely be significant, as detailed above. In light of these potentially large development benefits and the base EIRR of 9.5 per cent (which does not include development benefits), it is believed that the Project is economically viable.

16.2 Financial Evaluation

16.2.1 Government Finance

Estimated government revenues and expenditures for the years 1989 through 1993 and budget for the year 1994 are shown in Table 16.2. In 1994 the government planned to get a total revenue of 460 billion Cambodian Riel (200 million US dollars) and to spend 898 billion Cambodian Riel (390 million US dollars), a 57% increase in revenue and a 48% increase in expenditure over 1993. These increases in current monetary terms however hardly kept up with inflation, which was estimated at 140% for 1990, 200% for 1991, 75% for 1992, and 114% for 1993. In terms of 1990 constant prices, both revenue and expenditure have actually declined since 1990. The 1994 budget represents only 73% of the 1990 level in revenue and 66% in expenditure.

The government fiscal position remains extremely weak as the tax regime and collection system have not been prepared in line with the changing economic structure. Although some progress has been made in recent years, it will take some time for the position to significantly improve. Public revenue in 1994 was estimated at 7% of GDP, whereas public expenditure at 15%.Therefore, at present, foreign bilateral and multilateral aid accounts for about 40% of the national budget. The government will have to continue relying on foreign aid for some time to come.

Table 16.3 shows the balance of payments and Table 16.4 shows overall external financing requirements as estimated by the World Bank.

Table 16.2 Government Revenues and Expenditures[1]

(Billion Riel)

	1989	1990	1991	Estimate 1992	Estimate 1993	Budget 1994
Revenue[2]	15.3	23.3	58.8	156.1	290.1	460.0
Tax revenue	6.2	13.3	31.1	109.7	234.1	342.2
Non-tax revenue	9.2	10.0	27.8	46.3	56.0	117.9
Expenditure[2]	21.9	50.2	104.2	245.7	608.4	898.2
Total current expenditure	18.5	43.3	99.0	238.6	373.2	584.6
Contingency allowance	0.0	0.0	0.0	0.0	0.0	18.0
Capital	3.5	6.9	5.2	7.1	235.2	295.6
Current deficit on cash basis	-3.1	-20.0	-15.4	-107.2	-76.1	-109.8
Current deficit on accounts basis	-3.1	-20.0	-40.2	-82.5	-83.1	-124.6
Overall deficit on cash basis	-6.6	-26.9	-20.6	-114.3	-311.3	-423.4
Overall deficit on accounts basis	-6.6	-26.9	-45.3	-89.6	-318.3	438.2
Financing (net)	6.6	26.9	45.3	89.6	318.3	423.4
Foreign	2.0	7.2	6.1	1.5	239.1	429.6
Domestic	4.6	19.7	39.2	88.1	79.2	-6.2
Bank	4.6	19.7	14.5	112.8	30.7	11.8
Arrears[3]	0.0	0.0	24.7	-24.7	7.0	0.0
Private sector	0.0	0.0	0.0	0.0	41.5	-18.0

Source: Ministry of Finance; Asian Development Bank estimates/Country profile, Cambodia 1995 - 96, EIU

Note: 1 The Government budget does not incorporate debt-service payment on arrears to bilateral official creditor.

2 Revenue and expenditure entries are on an actual basis

3 Mostly arrears in salaries of civil servants

Table 16.3 Summary of Balance of Payments, 1991-95

	1991	1992	1993	1994 Est.	1995 a/ Proj.
			(in millions of US dollars)		
Trade Balance	-32.5	-86.2	-184.8	-291.4	-389.7
Total Exports	212.5	264.5	219.1	302.7	240.7
Exports	67.3	51.3	37.7	135.7	82.1
Re-exports	145.2	213.2	181.4	167.0	158.7
Total Imports	245.0	350.7	403.9	594.1	630.5
Of which Retained Imports	99.8	137.5	222.5	427.1	471.8
Services Balance	1.3	27.6	44.3	5.2	17.3
Private Transfers	3.5	9.0	3.5	9.0	16.0
Current Account Balance (excluding official transfers)	-27.7	-49.6	-137.0	-277.2	-356.4
Official Transfers	2.5	5.0	95.7	102.6	104.2
Current Account Balance (including official transfer)	-25.2	-44.6	-41.3	-174.6	-252.2
Capital Account	25.2	38.0	79.7	212.2	207.4
Overall Balance	-10.0	-6.6	38.4	37.5	-44.9
Gross Official Reserves					
In Millions of US Dollars	-	29.9	70.7	115.0	146.0
In Months of Retained Imports	-	2.6	2.0	2.1	2.5
			(In percent of GDP)		
Trade Balance	-1.7	-4.3	-8.2	-12.5	-14.8
Current Account Balance (excluding official transfers)	-1.5	-2.5	-6.1	-11.8	-13.5
Memorandum Item: Nominal GDP (in millions of US$)	1,900	2,002	2,245	2,340	2,635

a/ ESAF framework

Source: IMF estimates based on data provided by the Cambodian authorities

Table 16.4 External Financing Requirements, 1993-95

(in million of US Dollars)

	1993	1994 Est.	1995 Proj.
Use of Foreign Exchange	297.2	560.8	821.0
of which:			
Import (retained)	225.5	427.1	471.8
Clearance of Arrears a/	-	-14.5	225.0
Sources of Foreign Exchange	187.8	377.1	345.7
Exports	37.7	135.7	82.1
Service Receipts	72.0	72.5	94.5
Private Transfers	3.5	9.0	16.0
Private Capital Flows	74.6	159.9	153.1
Financing Requirements	109.5	183.7	475.4
External Financing Requirements	109.5	183.7	475.4
Development Assistance	100.8	163.7	167.4
Commodity/Budget Aid	24.2	68.9	47.0
Project Aid	76.6	94.8	120.4
IMF Disbursements	8.7	20.0	40.8
Debt Rescheduling			239.2
Financing Gap b/			28.0

a/ Does not include claims by former CMEA countries estimated at Rub 840 million

b/ Assumed to be filled through additional financing flows

Source: IMF and World Bank estimates based on data provided by the Cambodian authorities.

According to the World Bank, the balance of payment situation would be fairly stable for the mid-term outlook. Exports would grow by 20% per year due largely to rubber exports and non-traditional export, whereas imports would increase in dollar terms by 10% per year. The external current account deficit would decrease after 1994 peak of 13.5% of GDP.

As illustrated in Table 16.4, official development assistance is essential although private capital inflows are expected to take up increasing share of net external capital inflow. Prospects for foreign financial assistance are not unfavorable. Cambodia has benefitted from the rescheduling of its external debt in 1995, and external debt relative to GDP is projected to stabilize at just below 25%.

16.2.2 Investment in Road Sector

During the years of 1991 to 1993 virtually no investment was made in the road sector. In 1994, an amount close to half a percentage of GDP was expended in the road sector. This percentage is expected to slip back to an estimated 0.3% in 1995, a exremely low level. Table 16.5 shows the situation.

Table 16.5 Road Sector Investment

billion Riel

Year	Nominal GDP	National Budget	Road Expenditure	Road % of GDP
1991	1,336	104.2	0.64	0.05
1992	2,508	245.8	0.73	0.03
1993	5,546	610.0	1.13	0.02
1994(Est.)	6,048	895.1	28.37	0.47
1995(Proj.)	7,647	1,055.3	22.51	0.29

Source: Office of Finance, MPWT. World Bank, Cambodia: Rehabilitation Program, Feb. 1995

The Socio-Economic Rehabilitation Plan 1994-1995, which was adopted by the National Assembly, stipulated the allocation of 165.6 billion riel for public works of roads, ports, airports, telecommunications and post offices for the year. No breakdown of the amount is available, but the majority is considered to be spent in the road sector. No source of funds for the amount has yet to be identified.

To date, the most comprehensive plan for the road sector rehabilitation and development is contained in the Cambodia Transport Rehabilitation Study carried out as a Technical Assistance by the Asian Development Bank. The Study estimated US$40 million for emergency road rehabilitation and an additional US$10 million for bridges to be implemented in the period of 1995-1999. This program amounts to about US$10 million per year. For reconstruction, the Study assumed US$50 million will be available from various donor agencies during the period. In all, the Study assumed US$20 million per year would be available for the road sector, or 50 billion riel, a substantial increase over levels achieved in the last two years.

The possibility of financing road sector investment with the government's own funds is remote as 40% of the national budget relies on foreign grants and loans.

16.2.3 Financial Plan for the Subject Project

Table 16.6 shows the required disbursements for each year of implementation.

As shown in Table 16.6, a total of US$51.0 million in foreign currency will be required, while the rest of the project cost US$28.7 million should be paid in domestic currency. Estimated year by year disbursements are US$7.3 million in 1998, US$19.9 million in 1999, US$26.1 million in 2000, US$20.8 million in 2001, and US$4.7 million in 2002. These figures can be compared with the total national budget of US$460 million in 1995 and the total MPWT budget of US$12.2 million for 1994 and estimated US$9.8 million for 1995.

Table 16.7 shows an example financing plan under favorable loan conditions including a foreign loan applied to the foreign currency portion with a grace period of 7 years, interest rate of 1.5% and 20 year payback period, and a domestic loan applicable to the local currency portion with an interest rate of 14% and 20 year payback period.

Table 16.6 Project Disbursement Schedule

(Unit: US$)

No.	Description	1998 FC	1998 LC	1999 FC	1999 LC	2000 FC	2000 LC	2001 FC	2001 LC	2002 FC	2002 LC	Total FC	Total LC
1)	Construction Works	3,855,900	535,600	11,104,750	5,468,300	14,074,300	8,138,250	11,286,400	6,312,250	3,011,650	1,010,600	43,333,000	21,465,000
2)	Engineering Cost	909,900	450,900	606,600	300,600	758,250	375,750	606,600	300,600	151,650	75,150	3,033,000	1,503,000
3)	Non-Eligible Cost	0	1,074,300	0	36,200	0	45,250	0	63,200	0	9,050	0	1,228,000
	3.1 Land Acquisition and Compensation Cost		1,020,000									0	1,020,000
	3.2 Taxes and Duties		569,700		569,700		379,800		379,800		0		1,899,000
	3.3 Administration Cost of MPWT		54,300		36,200		45,250		63,200		9,050	0	208,000
4)	Contingency	476,580	263,050	1,171,135	637,480	1,483,255	893,905	1,189,300	702,885	316,330	109,480	4,636,600	2,606,800
	Total	5,242,000	2,894,000	12,882,000	7,012,000	16,316,000	9,833,000	13,082,300	7,732,000	3,480,000	1,204,000	51,003,000	28,675,000
		8,136,000		19,894,000		26,149,000		20,814,000		4,684,000		79,678,000	

Table 16.7 Example Financing Plan

(US$million)

Year	Borrowing		Interest	Repayment		Total	MPWT	
	F.C.	L.C.	F.C.	F.C.	L.C.	Financial	Budget	%
1998	5.24	2.89	0.08	0.0	0.43	0.51	12.0	4.3
1999	12.88	7.01	0.27	0.0	1.48	1.75	12.8	13.7
2000	16.32	9.83	0.52	0.0	2.94	3.46	13.7	25.1
2001	13.08	7.73	0.71	0.0	4.10	4.81	14.8	32.5
2002	3.48	1.20	0.77	0.0	4.28	5.54	16.0	34.6
2003			0.77	0.0	4.28	5.54	17.3	32.0
2004			0.77	0.0	4.28	5.54	18.7	29.6
2005				2.95	4.28	7.23	20.2	35.8
2006				2.95	4.28	7.23	21.8	33.2
2007				2.95	4.28	7.23	23.6	30.6
2008				2.95	4.28	7.23	25.4	28.5
2009				2.95	4.28	7.23	27.5	26.3
2010				2.95	4.28	7.23	29.7	24.3
2011				2.95	4.28	7.23	31.8	22.7
2012				2.95	4.28	7.23	34.0	21.3
2013				2.95	4.28	7.23	36.4	19.9
2014				2.95	4.28	7.23	38.9	18.6
2015				2.95	4.28	7.23	41.6	17.4
2016				2.95	4.28	7.23	44.5	16.2
2017				2.95	4.28	7.23	47.7	15.1
2018				2.95	3.85	6.80	51.0	13.3
2019				2.95	2.80	5.75	54.6	10.5
2020				2.95	1.33	4.28	58.4	7.3
2021				2.95	0.18	3.13	62.5	5.0
2022				2.95	0.0	2.95	66.8	4.4
2021				2.95	0.0	2.95	71.5	4.1
2022				2.95	0.0	2.95	76.5	3.9
2023				2.95	0.0	2.95	81.9	3.6
2024				2.95	0.0	2.95	87.6	3.4

A heavy financial burden will fall on MPWT relative to its likely budget level. Table 16.8 also shows the MPWT budget level by year as calculated by expanding the 1995 budget by applying the GDP growth rates previously assumed. From 2001 through 2008 almost one third of the MPWT budget will have to be devoted to servicing loans. Well over 10% of the budget will have to be spent every year for debt service for the next 10 years. Even if the government can borrow 75% of the total project cost at very favorable concessional terms as assumed above, debt service would be more than 20% of the entire MPWT budget from 2001 through 2011. This is clearly an untenable situation as far as the MPWT's budgetary allocation is concerned.

It is also clear however that the project in itself is economically well justifiable as shown in the preceding Section 16.1. It is therefore strongly recommended that external financing without debt service obligation be sought for the implementation of this project.