4. Flood and Flood Mitigation

(1) Flooding Condition and Flood Damage

Flooding Zones

Flooding area by 2000 Flood around Phnom Penh, NR-1(C-1 and C-2) and NR-11 was very large with about 40 to 50 km width around Phnom Penh and about 20 km width around Neak Loueng. This large flooding area can be divided into three zones as follows: Zone 1: Mekong River Main Stream, Zone 2: Left Bank Side Flood Plain, and Zone 3: Right Bank Side Flood Plain (Colmatage Area). NR-1(C-1) is included in the Zone 3. NR-1 (C-2) and NR-11 are included in the Zone 2. Floodwater principally flows separately in these three zones, and Zone 1 and Zone 2 inter-connects around Neak Loueng (see Fig. S-4-1).

Furthermore, Zone 3 is composed of 3 Sub-zones. They are Sub-zone 3-1 with water from the Mekong River (eastern side), Sub-zone 3-2 with silent water (central part), and Sub-zone 3-3 with water from the Bassac River (western side). Based on the topography in the Zone 3 (Colmatage Area), potential discharge capacity of the Sub-zone 3-1 with water from the Mekong River was estimated at about 3,600 m^3/s.

Flooding Condition during 2000 Flood

Flooding conditions of 1996, 2000 and 2001 Floods were surveyed by questionnaire to people living along the NR-1(C-1), a part of NR-1(C-2), NR-11, NR-7, and NR-6 & 6A, which surround the Study Area.

Three overflows with depth of less than 0.5 meter occurred along NR-1(C-1) by 2000 Flood. Severe flood damage occurred along NR-1(C-2) and NR-11 by 2000 Flood. There are total 22 overflow places including breached sections along NR-1(C-2) from Neak Loueng East (distance about 9 km) and NR-11 from Neak Loueng East to Prey Veng (see Fig. S-4-2).

It was estimated that the maximum water level was almost same as the road top in 2/3 of the sections with three overflows occurring along NR-1(C-1) (see Fig. S-4-3). Inflow discharge from NR-1(C-1) to Colmatage Area (Zone 3) including two artificial Cut-offs and three new water gates which were under-constructed by Japan's Grant Aide in 2000, is estimated at 2,276 m^3/s. This is 63 % of the estimated potential discharge capacity (3,600 m^3/s) of the Sub-zone 3-1 with water from Mekong River in the Right Bank Flood Plain (Zone 3).

Flood Damage

The flood damage survey clarified that the flood damage composed of damage to houses, agriculture and others by 2000 Flood was almost the same as other floods. This means that flood damage of 2000 Flood was not increased by the two artificial Cut-offs of NR-1(C-1) made during 2000 Flood.

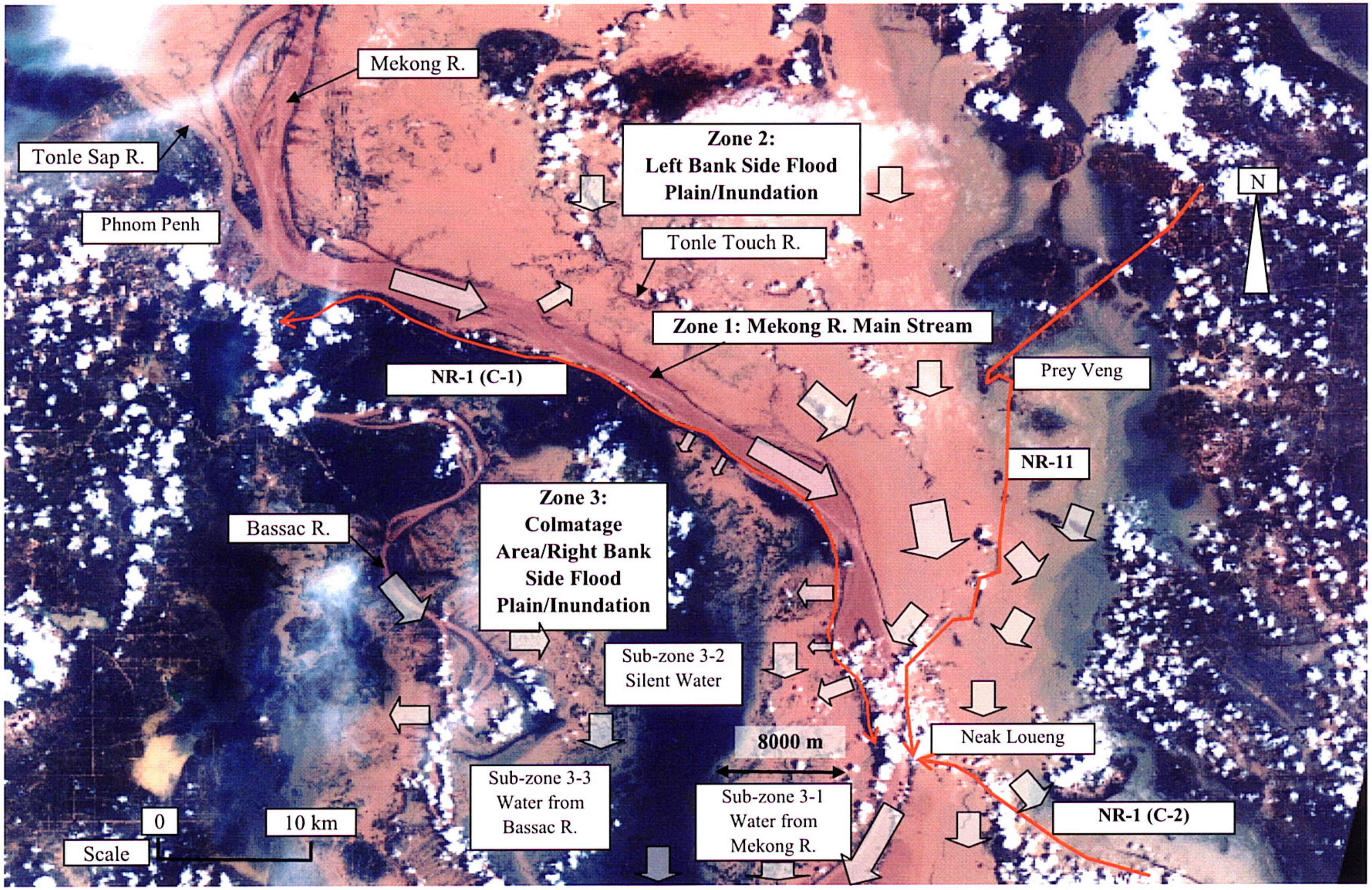


Fig. S-4-1 Flooding Condition of 2000 Flood (Landsat Image on Sep. 26, 2000)

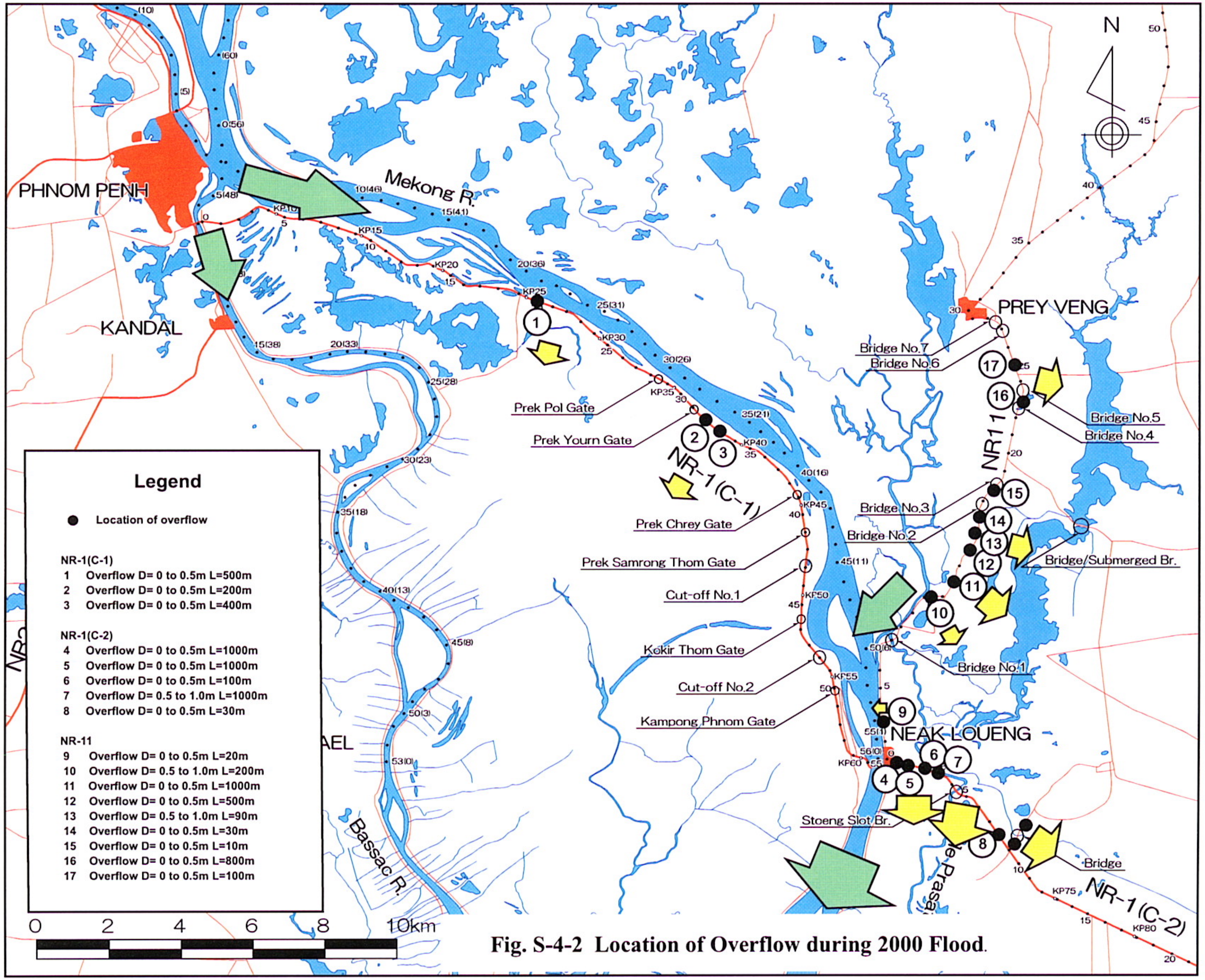


Fig. S-4-2 Location of Overflow during 2000 Flood

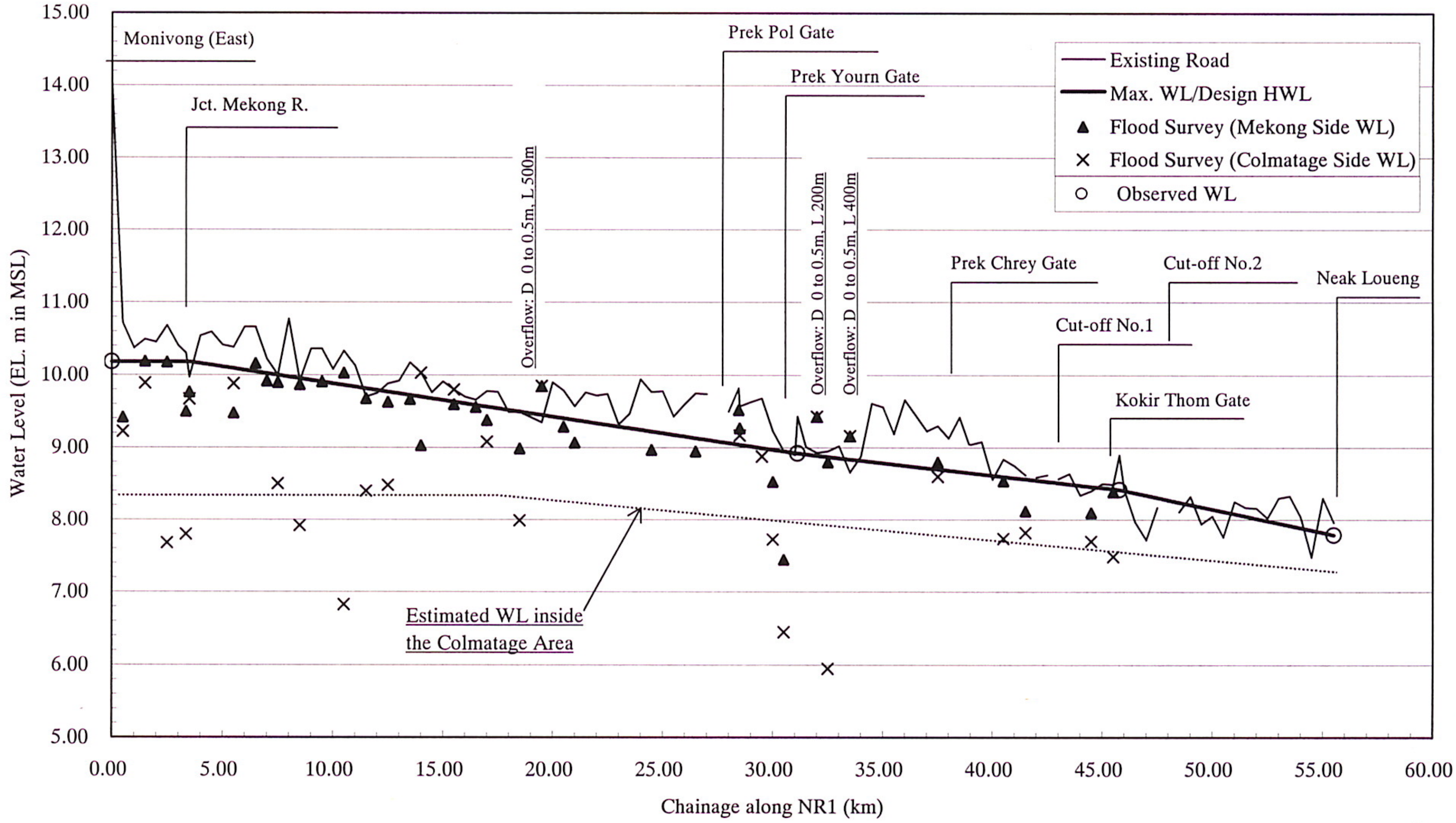


Fig. S-4-3 Estimated Maximum Water Level along NR-1(C-1) during 2000 Flood

(2) Hydraulic Simulation Model

In order to clarify the hydraulic effect by the two artificial Cut-offs along NR-1(C-1), unsteady hydraulic simulation model was developed by using MIKE11 software (see Fig. S-4-4). Effects of lowering the maximum water levels at Phnom Penh and Neak Loueng during 2000 Flood by the artificial Cut-offs were estimated at 9 cm and 14 cm respectively. This lowering of the flood water level at Phnom Penh and Neak Loueng was very important because these 2 towns seemed to be saved from flooding, but they would have been flooded if the water level was a little higher. Therefore, flood risks at Phnom Penh and Neak Loueng were still very high during 2000 Flood. Furthermore, effects of lowering the flood water level along NR-1(C-2) and NR-11 are estimated to be 13 to 14 cm, and decreasing flood discharge to NR-1(C-2) is estimated to be about 350 m^3/s. On the other hand, by the inflow from the two artificial cut-offs along NR-1(C-1), water level in the Colmatage Area was raised to 62 cm. However, this raising of water level did not increase flood damage in Colmatage Area.

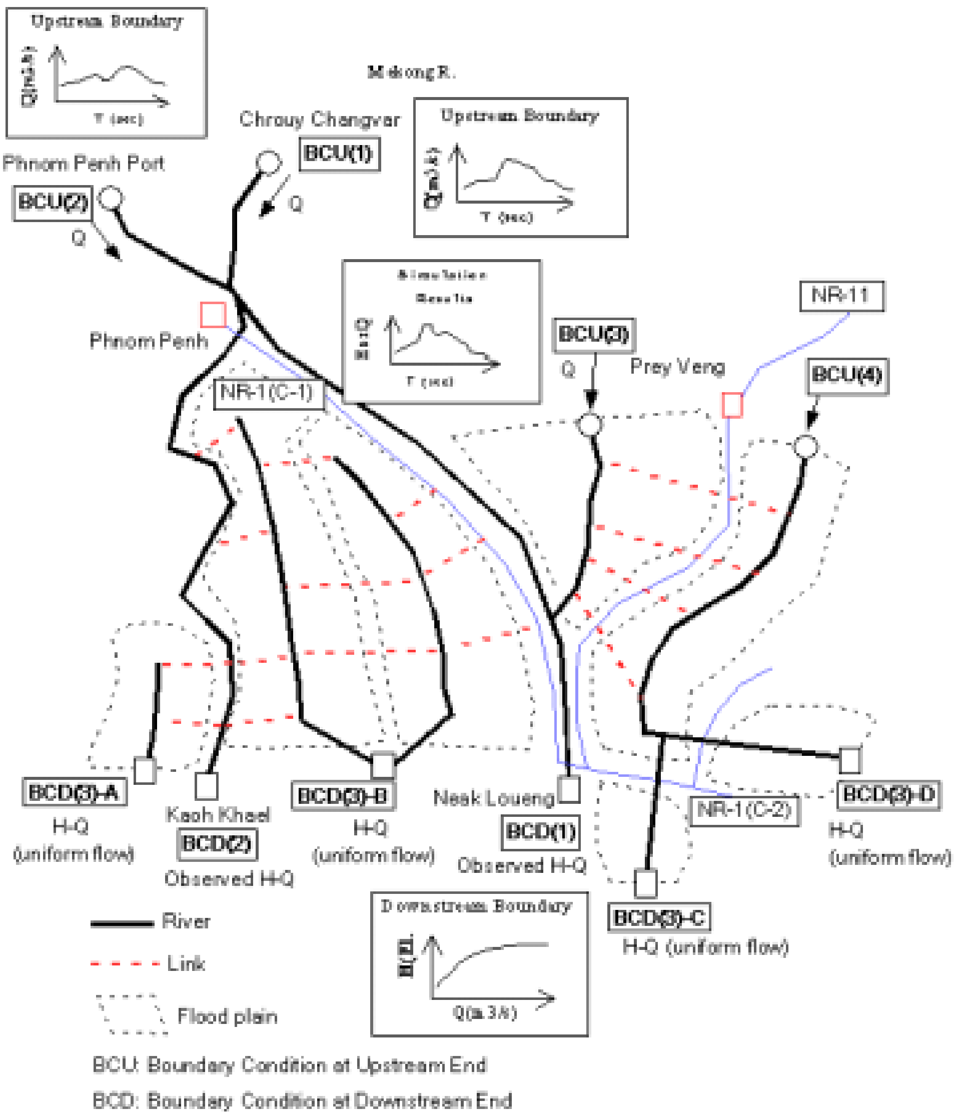


Fig. S-4-4 Model Structure of Hydraulic Simulation

(3) Flood Mitigation Plan

As a principle for constructing roads in a flood plain, the road should not be an obstacle to the flow of a flood. Based on this principle and the purpose of this project (which is to formulate an improvement plan for NR-1(C-1) to be all-weather road even during floods), the height of road embankments and openings along the NR-1(C-1) were planned.

1) Design Height for the Road Embankment

Since there is no clear historical trend of increasing flood water level along NR-1(C-1), it is sufficient to set the Design High Water Level (HWL) at the same elevation as the maximum water level of 2000 Flood. In order to maintain safety against wave height and possible floating debris, freeboard is considered above the HWL. HWL and freeboard for NR-1(C-1) are set as follows:

Design High Water Level (HWL): The maximum water level of 2000 Flood.

Freeboard: 0.50 meter for roads
1.00 meter for bridges and box culverts

2) Plan for Openings

Alternative Cases for Openings:

Based on the hydraulic effects by the openings for lowering the flood water level of the Mekong River, three alternative cases for openings are set as follows:

Alternative A: Keep existing inflow capacity (63 to 70% of Qo)
Alternative B: Increase inflow capacity (75 to 80% of Qo)
Alternative C: Minimum inflow capacity (14% of Qo)

Where, Qo is the potential discharge capacity of the Sub-zone 3-1 of water from the Mekong River (3,600 m^3/s) on the Right Bank Side Flood Plain (Zone 3).

Possible Sites for Openings:

Possible sites for openings (including bridges and culverts) were investigated. New openings can be studied between Km 20+000 to Neak Loueng. Along this stretch, openings can be installed at places where the number of houses to be affected by the flood from openings will be small and surrounding area is wide agricultural or vacant land. New openings cannot be installed between Km 0+000 to Km 20+000 because many houses exist and the land in the Colmatage side is used intensively for agriculture in this section. In total, the number of possible sites is 13: three sites for bridges, 10 sites for box culverts (with total length of 6,800 meters), and two sites for replacing existing pipe culverts.

Type of Openings:

Since flood flow about the order of 1,700 m^3/s to 1,800 m^3/s concentrates at the sites around Cut-off No.1 and Cut-off No.2, bridges are to be planned for these sites. In other places along NR-1(C-1), since flood flow is a kind of lateral flow, culverts (box culverts and pipe culverts) are to be distributed along the road.

Furthermore, based on the possibility of worsening the local scouring (including deep local scouring) by contraction flow with turbulence through the existing Cut-off No.1, it is necessary to burry the existing local scouring up to the surrounding ground elevation. Then, in order to keep existing inflow capacity (flow area) of the existing Cut-off No.1, install additional Cut-off No.1 at about 400 meters north, where ground elevation is the lowest around these places.

As the inflow to the existing Cut-off No.2 attacks the existing pier at a diagonal angle, it is planned to bury the existing Cut-off No.2 and shift it about 300 meters south, and install a new bridge where the ground elevation is the lowest around these places. By this shifting, reduction of the velocity of flood flow by dispersion in the inundation area in the Mekong Side can occur, and the angle of the inflow will be a right angle to the axis of bridges.

Selection of the Optimum Cases among the Alternative Cases:

Hydraulic effects of the alternative cases were studied by using the hydraulic simulation model. Among the Alternatives A, B, and C, Alternative C cannot be accepted because this case will worsen the flooding condition at Phnom Penh.

Alternative A cannot be recommended because the flood risk at Phnom Penh will still remain as high as it is at present.

Based on the hydraulic simulation, it was estimated that Alternative B could further lower the flood water level at Phnom Penh and Neak Loueng 2.0 to 3.5 cm below that of Alternative A. This 2.0 to 3.5 cm is very important to reduce flood risk including people's fear against the possibility of flooding. Furthermore, Alternative B can reduce flood discharge by 60 m^3/s for NR-1(C-2) more than Alternative A. There is no adverse impact to Colmatage Area by Alternative B as by Alternative A, and no adverse impacts to the Bassac River.

Therefore, Alternative B (ALT B-1) is the case to be proposed (see Table S-4-1 and Fig.S-4-5).

Table S-4-1 Proposed Openings along NR-1(C-1)

Opening	Length/Size	Place
Bridges	Total length: 232 m (Br-1: 66m, Br-2: 100m and Br-3: 66 m)	3 places
New Box Culverts with stop log slots	W 2.0 m x H 5.0 to 6.0 m x 2 cells	6 places
New Box Culverts without stop log slots	W 2.0 m x H 5.0 to 6.0 m x 2 cells	3 places
Improvement of Pipe Culverts	D 1.0 m x 1 no.	2 places
Improvement of Old Water Gates (by Box Culverts)	W 2.0 m x H5.6 m x 2 cells W 2.0 m x H5.8 m x 3 cells	2 places
JICA Water Gates	No change	4 places
Total		20 places

W: width, H: height and D: diameter

Note: Stop log slots are to be attached to the 6 box culverts for water use for agriculture.

(4) Protection against Erosion and Scouring

1) Protection for Embankment Slopes

Along NR-1(C-1), there are five places of total 3,800 meters where the road is facing the Mekong River and floodwater frequently attacks the embankment of NR-1(C-1). In these places, in order to protect embankment slopes on the Mekong Side against erosion by waves or flow, not only the ordinary slope protection by sod facing, but also revetment with wet masonry for the severest places between and Km 18+600 and 19+500 (900 meters) is proposed. For other four places, gentle embankment slope (1:3) with green belt by swamp trees along the Mekong Side of the road for total 2,700 meters is proposed (see Fig. S-4-6).

2) Protection for Bridges and Box Culverts

Protection for bridges and box culverts are necessary against erosion and local scouring by contraction flow with turbulence. The proposed protection for bridge is composed of revetment with wet masonry around abutments and bed protection by gabion mats and boulders. Inlets and outlets of box culverts are also proposed to be protected by revetment with wet masonry and gabion mats with boulders.

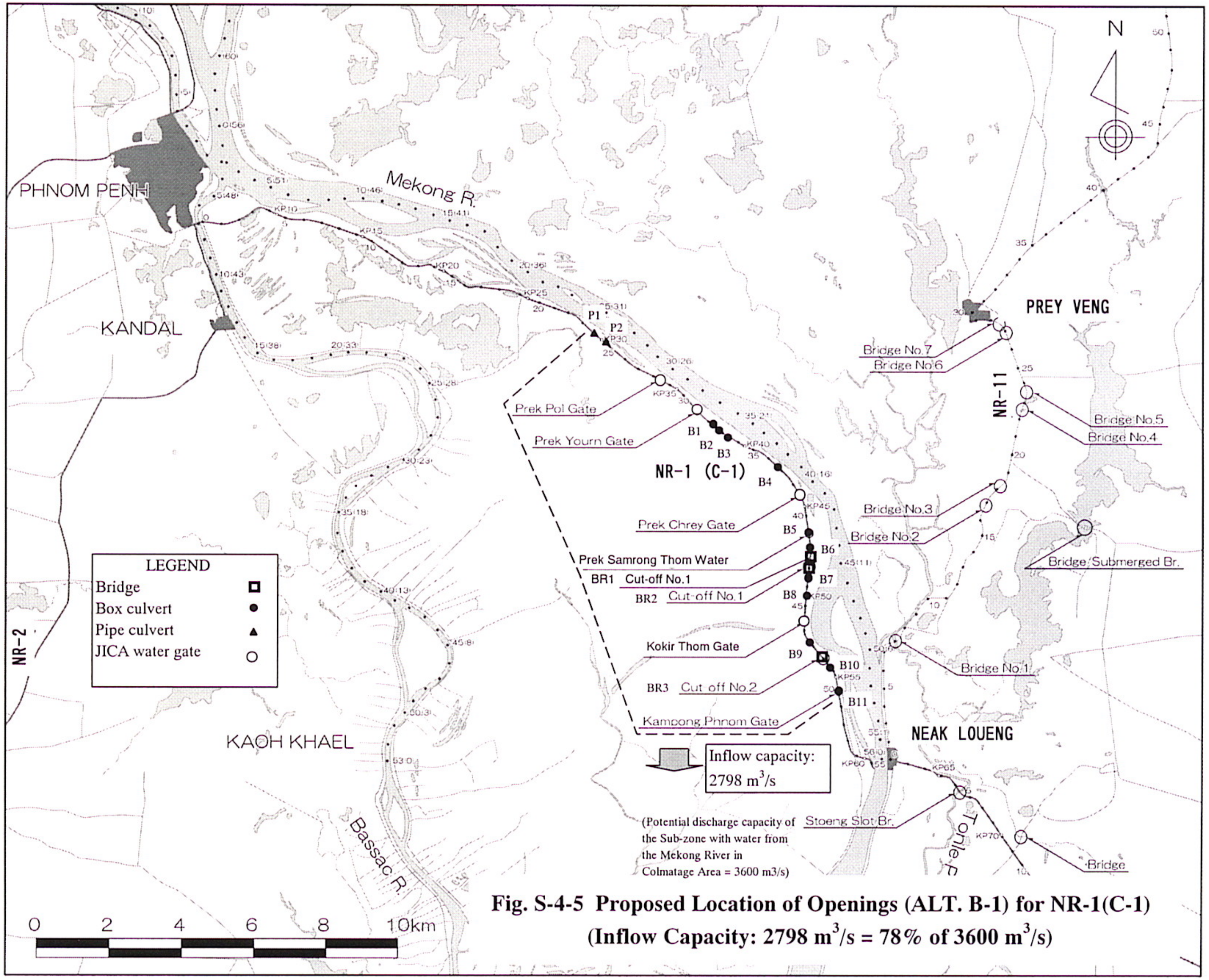
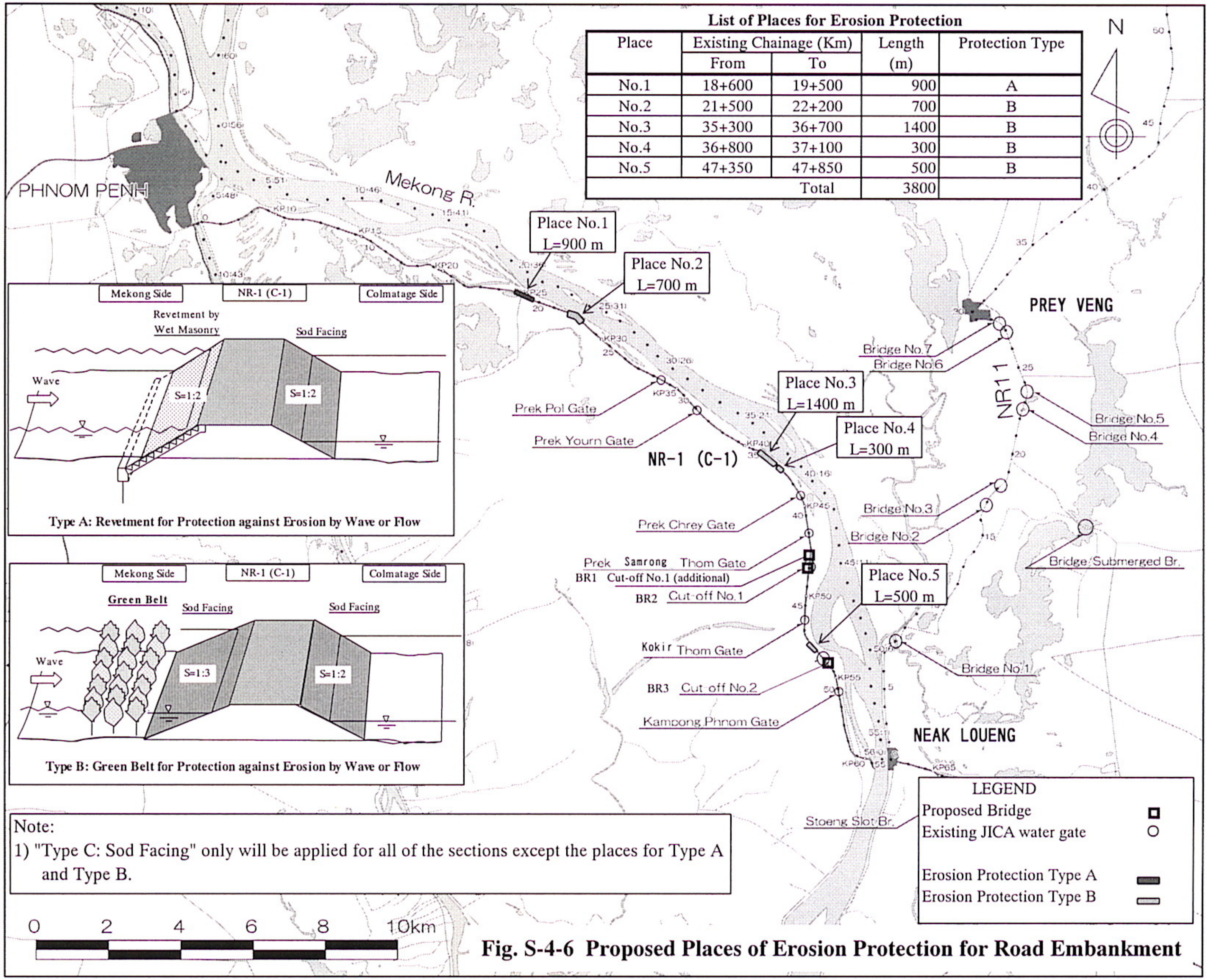


Fig. S-4-5 Proposed Location of Openings (ALT. B-1) for NR-1(C-1)

(Inflow Capacity: 2798 m^3/s = 78% of 3600 m^3/s)

List of Places for Erosion Protection

Place	Existing Chainage (Km)		Length (m)	Protection Type
	From	To		
No.1	18+600	19+500	900	A
No.2	21+500	22+200	700	B
No.3	35+300	36+700	1400	B
No.4	36+800	37+100	300	B
No.5	47+350	47+850	500	B
		Total	3800	



Note:
1) "Type C: Sod Facing" only will be applied for all of the sections except the places for Type A and Type B.

Fig. S-4-6 Proposed Places of Erosion Protection for Road Embankment

5. Road and Road Facility Plan

(1) Basic Concept and Design Criteria

1) Road and Road Facilities

In designing the road facilities, the following the basic concepts were adopted.

i) Since the Study Road (which is one of the most important national highways) is affected by flooding of Mekong River., the Study Road needs to be safe even during the flood season of Mekong River. Therefore, appropriate margin of road elevation should be secured against the flood water level.
ii) In addition, the road structure should be sufficiently resistant against the flood water with respect to erosion and seepage of water.
iii) The status of the Study Road as a part of Asian Highway Route A-1, connecting Thailand – Phnom Penh – Ho Chi Min City gives it additional importance.
iv) The alignment should be selected to minimize negative social impacts such as relocation. Although roadside land use of the Study Road is not dense except along a few urbanized sections, this policy should be always applied.
v) When a road is improved, vehicles tend to drive at a speed higher than that of before the improvement. Therefore, additional consideration should be given to traffic safety.

Geometric Design

In deciding the criteria for basic geometric design of the Study Road, the following design standards were referenced:

a) Cambodian Standard: Road Design Standard, 1999, Part 1: Geometric Design
b) Design Standard of Asian Highway
c) AASHTO Standard: A Policy on Geometric Design of Highways and Streets, 2001.
d) Road Structure Ordinance of Japan (RSOJ)

Considering such factors as type of terrain, roadside land use, expected actual traffic operation, characteristics of the traffic, as well as economy, the following criteria for geometric design are selected.

Table S-5-1 Criteria of Geometric Design

Design Elements	Unit	Recommended Value
Design Speed	km/h	80
Lane Width	m	3.50
Design Vehicle		WB-15
Minimum Radius of Horizontal Curve	m	280
Minimum Curve Length	m	(Desirable 70)
Minimum Transitional Curve Length	m	70
Minimum Radius of Curve for Omitting Transitional Curve	m	Absolute 380 Desirable 900
Stopping Sight Distance	m	115
Maximum Grade	%	4
Minimum Radius of Sag Curve	m	2000
Minimum Radius of Crest Curve	m	3000
Maximum Superelevation	%	6
Minimum Radius of Curve for Omitting Superelevation	m	2500
Crossfall: Traveled way & Paved Shoulder Unpaved Shoulder	%	3 4

Road Elevation

Selection of road elevation, with regard to the flood water level, is one of the key issues in the planning/designing of the Study Road. Three alternatives are considered for the selection of road elevation (embankment height).

s**Table S-5-2 Alternatives for Embankment Height**

Alternative	A	B	C
Embankment Height* (cm above HWL)	50	20	80

*Top of subgrade at the shoulder of slope

Considering such factors as required freeboard above flood water level, effect of water to performance of pavement structure and construction cost (earth work volume), Alternative A is selected.

Pavement

"AASHTO Guide for Design of Pavement Structures" (AASHTO Standard) was used as the basic criteria for pavement design. Also, other criteria, such as "Asphalt Pavement Manual" by Japan Road Association (JRO) were referenced.

In AASHTO Standard, required strength of a pavement structure, denoted as SN, is determined using the following equation:

$$\mathrm{Log}_{10} W_{18} = Z_R{*}S_0 + 9.36{*}\log_{10}(SN+1) - 0.20 + \frac{\mathrm{Log}_{10}\{\triangle PSI/(4.2-1.5)\}}{0.40 + 1094/(SN+1)^{5.19}} + 2.32{*}\log_{10} M_R - 8.07$$

Where;

W_{18} = predicted number of 18-kip equivalent single axle load applications

Z_R = standard normal deviate

S_0 = combined standard error of the traffic prediction and performance prediction

$\triangle PSI$ = difference between the initial design serviceability index, p_0, and the design terminal serviceability index, p_t

M_R = resilient modulus (psi) (of subgrade).

Fig. S-5-1 shows the flow for determining pavement strength.

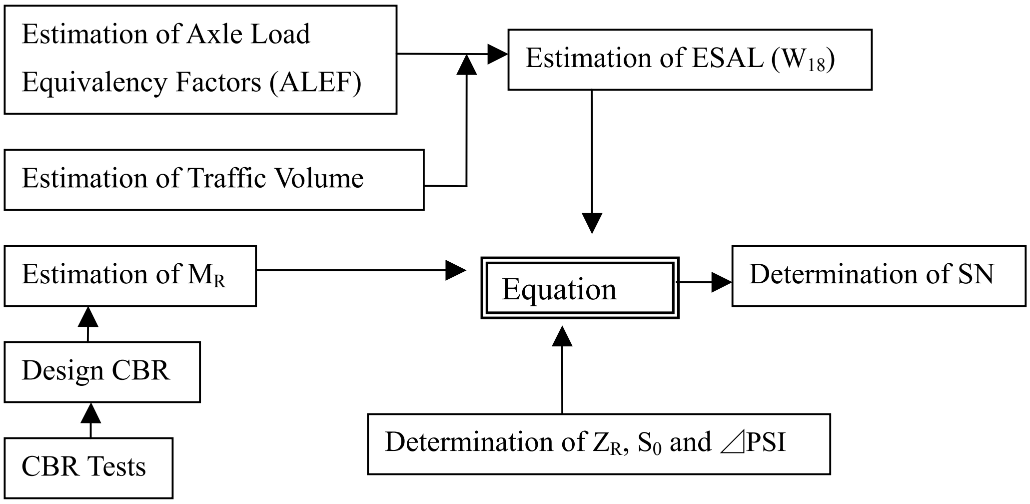


Fig. S-5-1 General Flow of Determining Pavement Strength

2) Opening Structures

Various Design Standards were applied to recent bridge/culvert construction projects by different donors, such as Cambodian, American (AASHTO), Australian, and Japanese etc. AASHTO and Japanese Standards are mainly applied to the project road, National Road No.1 (NR-1) C-1 section. Cambodian and other countries standards are referred for the preliminary design. NR-1 is also required to satisfy the Asian Highway standard as it is a part of Asian Highway A-1.

Applicable Design Standards for Structures are as follows:

- Standard Specifications for Highway Bridges: AASHTO, USA 1996
- Specifications for Highway Bridges: Japan Road Association, 1996, 2002
- Specifications of River Facilities: Japan River Association, 1998
- Bridge Design Standard: Ministry of Public Works and Transport, Cambodia 1999
- Road Design Standard: Ministry of Public Works and Transport, Cambodia 1999

The proposed typical cross sections on bridges and box culverts are shown below.

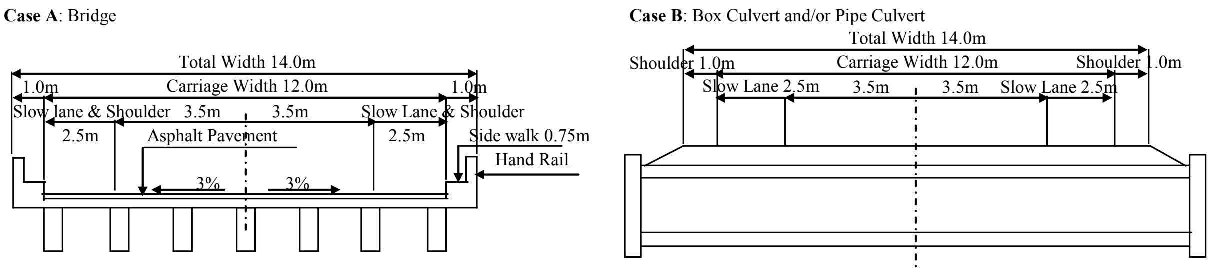


Fig. S-5-2 Proposed Typical Cross Sections of road on the Opening Structures

Items in table below are studied for setting the design conditions:

Table S-5-3 Items to Define the Design Conditions

Condition	Member	Items
Scale	Common	Topographical survey, Plan and longitudinal road alignment, Cross section
	Superstructures	HWL., Width of design riverbed and water surface, free board
	Substructures	Height of design riverbed, Embed depth of foundation, Protection
	Foundations	Bearing layer by geological survey
	Culverts	HWL., Width of design riverbed and water surface, Free board, Height of invert level, Thickness of Cover, Protection
Type	Bridge	Construction cost, period and method, Stability, Maintenance difficulty, Construction experience
	Culvert	Construction cost, period and method, Stability, Construction experience
	Protection	Wet masonry for slope protection, Gabion mat for riverbed

The design loads for structures are classified as shown below.

Table S-5-4 Classified Design Loads

Permanent Load		Transient Load	
1	Dead load and Superimposed Dead Load	8	Live Load
2	Earth Pressure	9	Footway and cycle truck live load
3	Shrinkage and Creep	10	Wind load
4	Differential Settlement	11	Earthquake load
5	Water Pressure	12	Erection load
6	Buoyancy	13	Impact load of floating debris and boat
7	Pre-stress Effects	14	Effects of Temperature Difference

Dead load intensity of main materials is shown below.

Table S-5-5 Dead Load Intensity

Category	Items	Unit	Value	Items	Unit	Value
Dead load	Aluminum alloy	kN/m^3	26.7	Sand – fine (dry)	kN/m^3	15.5-17.5
	Bituminous wearing surface, asphalt	kN/m^3	22.0	Sand – coarse (dry)	kN/m^3	18.0-19.5
				Sand (saturated)	kN/m^3	22.5
	Compacted earth filling	kN/m^3	16.0-19.0	Steel and other ferrous metals	kN/m^3	77.0
	Compacted gravel, road metal	kN/m^3	19.0-23.0			
	Concrete (light weight)	kN/m^3	12.3-19.6	Water, fresh	kN/m^3	9.8
	Concrete	kN/m^3	22.5-26.0	Water, salt	kN/m^3	10.0
	Masonry	kN/m^3	23.5			
Superimposed Dead load	Pavement	mm	50	Public utilities	kN/m	None
	Bridge parapet	kN/m^3	22.5-26.0	Others	kN/m	None
	Handrail	kN/m^3	22.5-26.0			

It is important to apply a live loading system which meets existing traffic conditions, derives sufficient durability of structures and avoids excessive design. It is also important to consider that the project road will be a part of National Road No.1 as well as Asian Highway A-1 (i.e., national and international trunk road networks).

It is recommended to apply the **live loading system of Japanese specification (TL-25, B-Live Load System)** for this project and reference American AASHTO (HL-93, HS20-44 System) and Cambodian Standards, Laws and Regulations. Japanese specification has the heaviest axel load (20 tons) among standards of four countries

(AASHTO, Cambodia, Ontario CANADA and Japan). It also covers "TT-43" former Japanese regulation of semi-trailer (total weight 43 tons). This total weight is also the heaviest among three standards (AASHTO, Cambodian and Japanese). The following are the applied standards for recent construction projects:

* Japanese Standard: Water gates on NR-1, 2002, by JICA, Japan's Grant Aid
* American AASHTO HS20-44: Structures on NR-1, C-2 section, 2002~, by ADB
* Japanese Standard: Bridges on NR-6A, 2001~, by JICA, Japan's Grant Aid

The table below shows essential specifications of main materials which are applied to the project structures.

Table S-5-6 Specifications of Materials

Concrete [σ ck: Concrete Compressive Strength (28 days)]			
PC girder	σ ck = 35N/mm^2	Abutment, Pier	σ ck = 21N/mm^2
RC girder	σ ck = 24N/mm^2	RC Pile (Cast-in-place)	σ ck = 30N/mm^2
RC Slab, Cross Beam	σ ck = 24N/mm^2	RC Pile (Precast)	σ ck = 30N/mm^2
Approach Slab	σ ck = 24N/mm^2	Box Culvert (Cast-in-place)	σ ck = 21N/mm^2
RC Handrail	σ ck = 21N/mm^2	Pipe Culvert (Precast)	σ ck = 30N/mm^2
Steel			
Reinforcing Steel	SD295, SD345 (Yield strength σ py >300N/mm^2)		
Pre-stressing Steel	T-12.7mm (Tensile load σ pt= 183kN), ϕ23mm (Yield strength σ py >930N/mm^2)		
Others			
Backfill Soil	Friction angle: ϕ=30°. Unit weight r=19 kN/m^3 (Sand)		

(2) Alternative Plans and Evaluation

The existing NR-1(C-1) has many vulnerable points such as low elevation against flood, poor capacity of road crossing structures, inadequate pavement structure and so forth. The following five alternative plans for achieving the target of road improvement "Provision of a Flood-free Road to an All-weather Standard" were examined. The main factors of the evaluation are Inflow Capacity, Pavement Structure and Cross-sectional configurations. The details of the study are as follows:

1) For the first step, ALT-Ia is the base case to find out the salient features of improvement plan for NR-1(C-1). ALT-Ia maintains the existing physical condition of NR-1 (C-1) as it is and the pavement structure is set as Double Bituminous Surface Treatment (DBST). The costs of earthwork and pavement are estimated to occupy 80% of construction cost, while structural cost will be 15%.

2) For the second step, the inflow capacity and location, and type of structure are examined for ALT-Ia (Q=2,200 m^3/s), ALT-IIa (Q=470 m^3/s) and ALT-IIIa (Q=2,700 m^3/s) to mitigate flood risk to maintain the function of NR-1 (C-1) as the trunk line. The increased inflow capacity of ALT-IIIa will contribute to mitigating flood risk along NR-1(C-1) including Phnom Penh and Neak Loueng with only around 6% of increase in construction cost. Accordingly, ALT- IIIa is selected and the opening structures are planned for it.

3) For the third step, the ALT-IIIab and ALT-IIIb are set based on ALT-IIIa to evaluate the Cross-sectional configurations. These alternatives have asphalt concrete pavement (AC) after the individual study and evaluation. ALT-IIIa has DBST and this pavement structure

will not satisfy the requirements of either national or international trunk line. Cambodian authorities will also have difficulties to maintain good condition of it considering the present situation of their maintenance system. Cross-sectional configurations are examined for ALT-IIIab (Km0~14:19m, Km14~56:14m) and ALT-IIIb (Km0~14:24m, Km14~56:14m) to compare cost and planning viewpoint. It was estimated that the increase of cost is only around 5% in ALT-IIIb from ALT-IIIab

The comprehensive evaluation reveals the superiority of ALT-IIIb quantitatively and qualitatively. The result is shown in Table S-5-7.

Table S-5-7 Comparison Study of Alternatives

Factor \ Alternatives*	Ia	IIa	IIIa	IIIab	IIIb
Inflow Capacity	2,200 m^3/s	470 m^3/s	2,700 m^3/s	2,700 m^3/s	2,700 m^3/s
Construction and Reconstruction of Opening Structures	Bridge 2 Pipe Culvert 2 Box Culvert 2	Bridge 0 Pipe Culvert 2 Box Culvert 2	Bridge 3 Pipe Culvert 2 Box Culvert 11	Bridge 3 Pipe Culvert 2 Box Culvert 11	Bridge 3 Pipe Culvert 2 Box Culvert 11
Cross Section (Hard Shoulder for Slow Moving Vehicles)	1.5m (Km 0.0~56.0)	1.5m (Km 0.0~56.0)	1.5m (Km 0.0~56.0)	2.5m (Km 0.0~14.0) 1.5m (Km 14.0~56.0)	2.5m (Km 0.0~56.0) Median** (Km 0.0~14.0)
Pavement Structure	DBST	DBST	DBST	AC	AC
Cost Index	1.00	0.85	1.06	1.19	1.24

* I: Inflow Capacity 2,200m^3/s、 II: Inflow Capacity 470m^3/s、 III: Inflow Capacity 2,700m^3/s
a: Hard Shoulder for Slow Moving Vehicles 1.5m、 b: Hard Shoulder for Slow Moving Vehicles 2.5m
** Median is space for future widening.

The description for each alternative is as follows:

ALT-Ia: Maintaining Existing Inflow Capacity
In this scheme, major physical conditions on NR-1(C-1) are kept as is. The inflow capacity maintains approximately 2,200 m^3/s at a peak period. The cross-sectional configuration is undivided 2-lane with 1.5 meters wide hard shoulder for slow moving vehicles over the whole stretch. The type of pavement is DBST as same as the existing pavement.

ALT-IIa: Decreasing Inflow Capacity by Closing of two Cut-offs
For the purpose of comparison, ALT-IIa is formulated on the basis of ALT-Ia. This plan has no bridge opening to close two cutoffs on NR-1, which is the same to the situation before the 2000 Flood. It enables to discharge of approximately 470 m^3/s at a peak period by four existing water gates and four culverts.

ALT-IIIa: Improvement on Flood Risk Mitigation
ALT-IIIa is formulated on the basis of ALT-Ia to mitigate flood risk along NR-1 including Phnom Penh and Neak Loueng by increasing the inflow capacity to approximately 2,700 m^3/s at a peak period by 3 bridges, 13 culverts and 4 existing water gates.

ALT-IIIab: Improvement with Minimum Requirement
For the purpose of comparison, ALT-IIIab is formulated on the basis of ALT-IIIa. This plan has 2.5 meters wide space for slow-moving vehicles up to Kokir Market where the percentage of slow-moving vehicles (such as motorcycles, moto-dops

and moto-remorks) are high enough to disturb steady traffic flow and to cause traffic accidents. Pavement structure is AC after the individual study and evaluation.

ALT-IIIb: Improvement on Traffic Function
ALT-IIIb is formulated on the basis of ALT-IIIab to secure steady traffic flow and to enhance traffic safety by providing 2.5 meters wide space for slow-moving vehicles over the whole stretch and to maintain space for future widening up to Kokir Market.

The superiority of ALT-IIIb is summarized as follows:

1) Expected roles and functions of NR-1 are to provide all-weather road to an international standard to connect between producing and consuming areas since NR-1 exists in the Plain Region where half of national population is concentrated on 14% of national land and production in agriculture as well as inland fishery is high. ALT-IIIb will be able to achieve such expected roles and functions to a considerable extent.
2) Proposed opening on NR-1(C-1) will contribute to mitigating flood risk along NR-1 including Phnom Penh and Neak Loueng. It is very sure that NR-1 will be more reliable traffic means as an arterial road in the local context and as a part of Asian Highway No. A-1 in the regional context.
3) ALT-IIIb has advantages such as space for slow-moving vehicles and future widening. The former aims to facilitate separating slow-moving vehicles from fast-moving and to secure traffic safety especially for approximately 1.5-meter wide moto-remorks. The latter involves providing additional lanes to cope with incremental traffic demand in future.
4) Such improvement works will increase construction cost slightly in a range of 5% against ALT-IIIa, and it will be acceptable provided that economic feasibility is confirmed in the succeeding study.

(3) Preliminary Design

1) Road and Pavement

Horizontal alignment

The following are considered as the basic policy for selecting the horizontal alignment:

i) Follow the existing alignment as much as appropriate
ii) Correct inadequacy of the existing alignment
iii) Correct places where the existing alignment does not meet the criteria

Vertical Alignment

Owing to the flat terrain, vertical alignment is generally gentle. Grades are less than 0.1% on usual embankment section. Relatively large grades of around 1% were used only on the approach sections of culverts and bridges.

Comparison of Criteria of Geometric Design Elements and Actually Used Values

Values of proposed criteria for geometric design elements and those actually used in the proposed alignments are compared in Table S-5-8.

Table S-5-8   Proposed Design Elements and Actually Used Values

Design Element		Proposed Value	Actually Used Value
Minimum Radius of Horizontal Curve	(m)	280	300
Minimum Curve Length	(m)	140 (Desirable)	142
Minimum Transitional Curve Length		Absolute: 44 Desirable: 70	72
Minimum Radius of Curve without Transitional Curve	(m)	Absolute: 380 Desirable: 900	495
Minimum Radius of Vertical Curve	(m)	Sag: 2000 Crest: 3000	Sag: 3200 Crest: 6200
Stopping Sight Distance	(m)	115	>115
Maximum Superelevation	(%)	6.0	4.0
Maximum Grade	(%)	4.0	1.6

Cross Section

Fig. S-5-3 shows an example of the typical cross section.

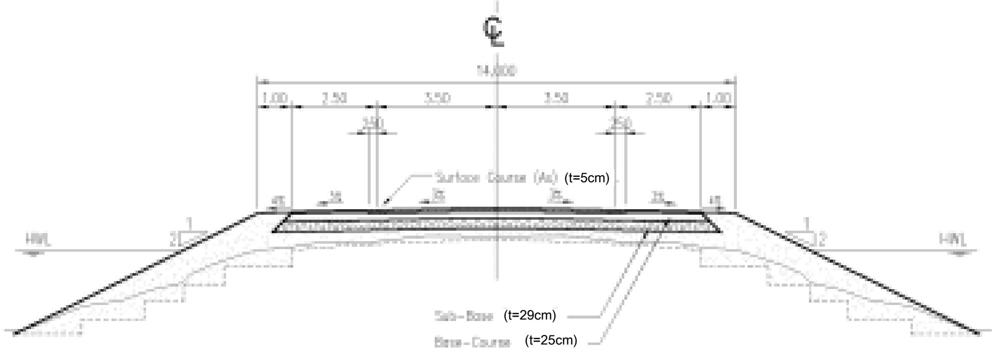


Fig. S-5-3   Typical Cross Section (Type E: Rural Section)

Soft Ground

Since the Study Road traverses alluvial land of Mekong River, existence of soft ground is suspected. Based on the result of geotechnical investigations, soft ground is not considered to cause serious problems with regard to both stability and settlement. However, it is necessary that additional soil investigations will be conducted in design stage.

Traffic Safety Measures and Control Facilities

To cope with the increased speed of vehicles after improvement and to secure safety, various safety measures including provision of road crossing structures, such as box culverts and pedestrian bridges, installment of traffic signals with other facilities (road markings, guard posts/rails, regulatory & warning signs, guide signs, and kilometer posts), and distribution of pamphlets to draw attention for traffic safety, are proposed. Figure S-5-4 shows an example of a box culvert used as a path for pedestrians and cattle.

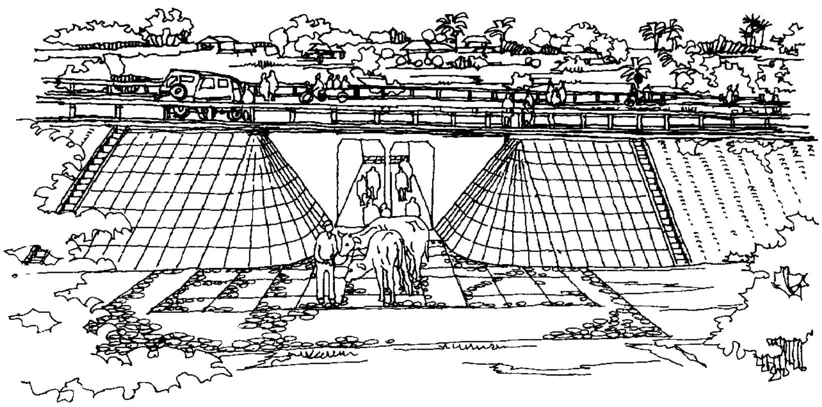


Fig. S-5-4 Example of Box Culvert Used as Crossing Facility

Road Related Facilities

To enhance the function of the Study Road as well as to contribute to traffic safety, the following facilities were proposed:

i) Moto-remork stops cum livestock refuge during flood
ii) Bus stop
iii) Pedestrian Bridge
iv) Weighing station
v) Approach Slopes for Local Road
vi) Road Station

Pavement Design

Pavement was designed following the procedures described in Subsection 5 (1) 1). Design CBR of 9 was used assuming improvement of subgrade by placing a selected material of 30 cm thickness. In estimating W_{18}, or 18-kips Single Axle Load Application, Axle Load Equivalency Factor (ALEF) of 1.89 was used for Heavy Vehicles. This figure was derived from the result of the Vehicle Weight Survey conducted in this Study. The most economical structure of pavements of pavement was selected depending on the traffic volume of each section. Fig. S-5-5 shows the structure of pavement for each section.

Section of Road	1	2	3	4	5
Station	Start -3.5	3.5 - 7	7- 14	14 - 36	36 - End
Pk (MPWT)	5.6 – 9.1	9.1 – 12.6	12.6 – 19.6	19.6 – 41.6	41.6 - End
Pavement Type	A	B	C	D	E

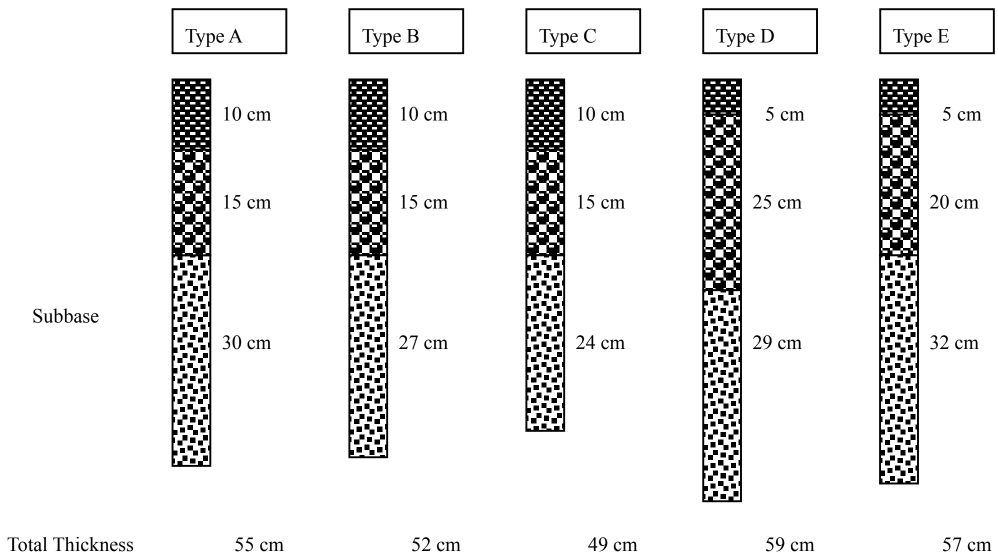


Fig. S-5-5 Recommended Pavement Structure

2) Opening Structures

Four types for opening structures are proposed as standards and listed in table below. Four types of bridges are compared to set the bridge type. The details are mentioned after the table. Hydraulic analysis was done to fix the width of box culvert (2.0 meters).

Table S-5-9 Standardized Type for Opening Structures

Type	No.	Scale	Considerations
Type A: Bridge	A-1	Length 50m = 2@25m	Super Structure: PC- I Girder (Splice Girder) Foundation: Pile Foundation estimated pile length 20-30m Bearing layer: depth 25-35m from ground level Protection: Wet masonry on slope, Gabion mat on riverbed
	A-2	Length 75m = 3@25m	
	A-3	Length 100m = 4@25m	
	A-4	Length 150m = 6@25m	
	A-5	(Length more than 150m)	
Type B: Box Culvert	B-1	1-Cell, 1@ 2.0*4.0-6.0m	Box Body: RC structure Foundation: RC pile square of 30cm, L=12m* Protection: Wet masonry on slope, Gabion mat on riverbed
	B-2	2-Cell, 2@ 2.0*4.0-6.0m	
	B-3	3-Cell, 3@ 2.0*4.0-6.0m	
Type C: Box Culvert with Water Gate	C-1	1-Cell, 1@ 2.0*4.0-6.0m	Box Body: RC structure, with simple gate system Foundation: RC pile square of 30cm, L =12m* Protection: Wet masonry on slope, Gabion mat on riverbed
	C-2	2-Cell, 2@ 2.0*4.0-6.0m	
	C-3	3-Cell, 3@2.0*4.0-6.0m	
Type D: Pipe Culvert	D-1	1-pipe ϕ 1.0m	Pipe Body: RC pre-cast. With concrete cover rounded Foundation: Spread

* Same length with Colmatage gates constructed by Japan's Grant Aide, NR-1 in 2002

<u>Bridge</u>

The following are the most applicable types for bridges. Each member was selected by comparing the characteristics which are in the table below with other types. The details are in the main report.

Super Structure: **Pre-stressed Concrete (PC) I-shaped Splice Girder,**
Span @25 meters [case 2]
Sub Structure: **Reinforced Concrete (RC) Reversed T Abutment,**
RC Elliptic Column Pier
Foundation: **Cast-in-place RC Pile, ϕ 1.0 meters L=20-25 meters**

The girder will be spliced on piers by RC concrete and PC cable (Crosswise) to make bridges surface continuous. It will secure easier maintenance and smooth run of the vehicles. The table below summarizes the characteristics and figure show the cross section of this bridge:

Table S-5-10 Characteristics of Evaluated Bridge

	Characteristics	Evaluation
1	Construction Cost	Lowest
2	Construction Period	Fairly Short: 17 months for all construction
3	Construction Method	Fairly Easy: Erection-girder, Girder 36.3t/no. Applied method to a few projects in Cambodia
4	Availability of Materials	Most materials are available except PC wire
5	Flow Obstruction Ratio	Fair: 5.4%, Span length is 25m, which is longer than minimum length (20m) by Japanese Standard
6	Maintenance	Few required, No Expansion Joint on Pier: Continuous Bridge Surface
7	Environment	No more than other types

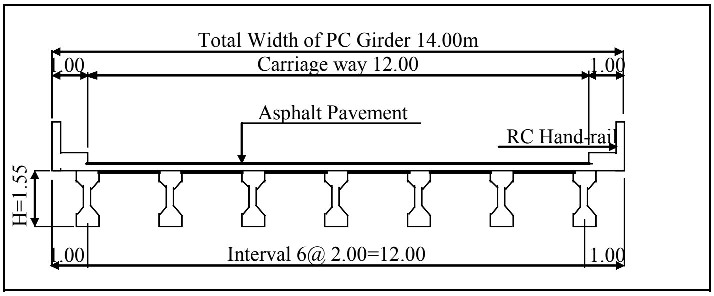


Fig. S-5-6 Typical Cross Section of PC Superstructure

For the cost estimation of bridges, four super structural types of large scale bridge (100-meter length) were compared as mentioned below.

Case-1: RC/PC Bridge- Span 6@ 16.7 meters
Case-2: PC Bridge- Span 4@ 25.0 meters
Case-3: PC Bridge- Span 3@ 33.3 meters
Case-4: Steel I Girder Bridge- Span 4@ 25.0 meters

<u>Culvert</u>

Pipe Culverts: Pre-cast RC pipe culverts shall be applied to this project. They should be covered with concrete lining to prevent water leakage. This type will only occupy a half of the cross section and secure the traffic flow during construction stage. It will also less impact the inhabitants nearby.

Box Culverts: RC type shall be applied to new construction and replacement of box culverts in this project. There will be two types: with and without water gates (stop logs). Foundation will be pre-cast RC piles with length approximately 12.0 meters (refer to the construction of Colmatage gates in NR-1 constructed in 2002)

Preliminary Design for Opening Structures

Location of proposed bridges and culverts are shown in the figure below.

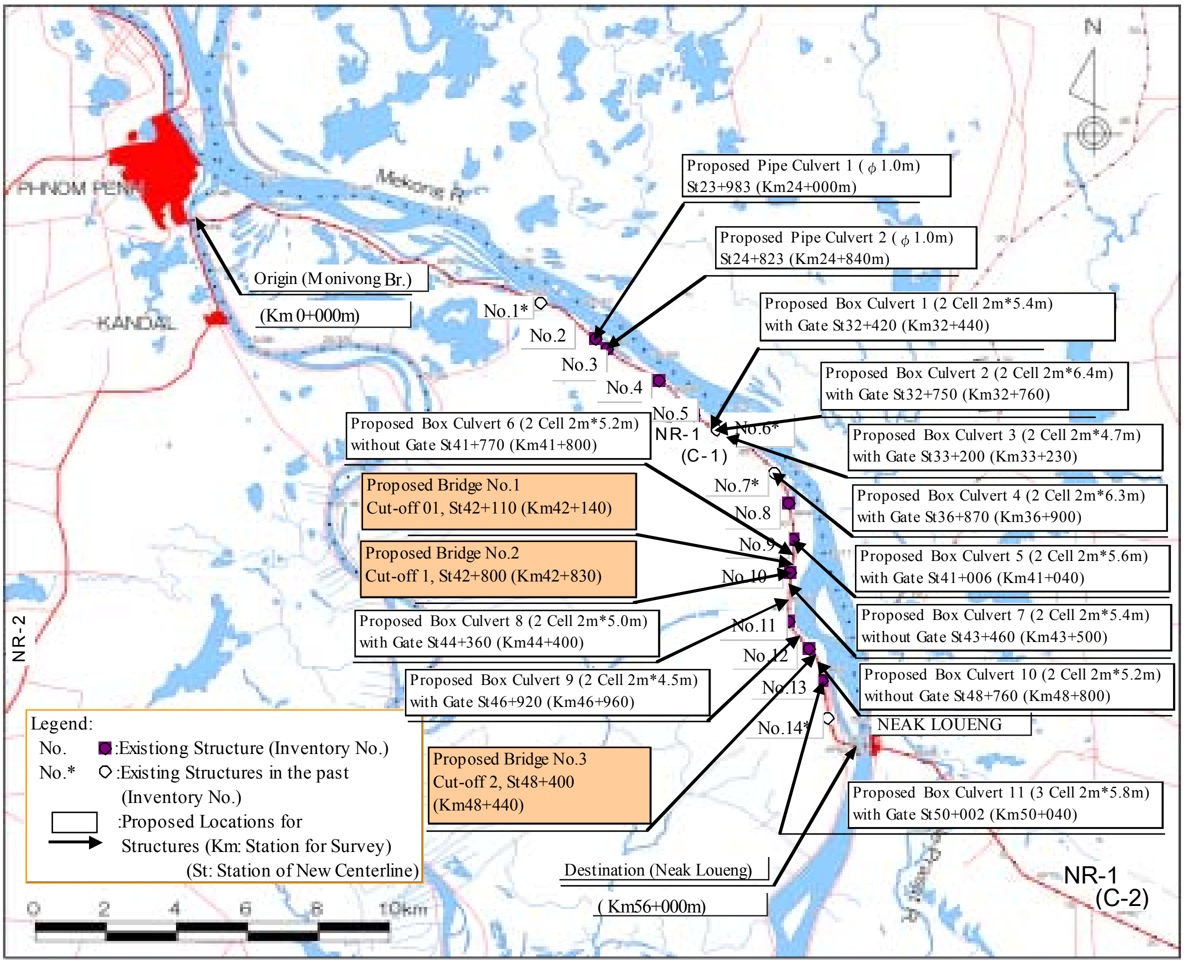


Fig. S-5-7 Location Map of Opening Structures for Preliminary Design

To set the elevation of road surface, free flow of bridges and box culverts is set as 1.0 meter. This is estimated as a sufficient height for the debris and boats of local inhabitants to pass through. Minimum cover of box culvert is 50 cm and 2.0 meters for pipe culverts in this design, considering the thickness of asphalt surface course and base course.

Wet masonry is proposed for the protection of slope and gabion mat for riverbed. Slope is set as 1:1.5 in front of abutment and 1:1 at inlet and outlet of culverts.

The location, dimension and type of proposed opening structures are determined based on field investigation, natural conditions and hydrological analysis. Details are shown in the table below. This figure also gives the detailed scale and type with station numbers based on the topographic survey and road alignment.

Table S-5-11 Outline of Proposed Opening Structures

- Bridges (PC I-shaped Splice Girder Bridges)

No.	No. on Location Map	St+	(Pk+)	Dimension	Remark
Br-1	9	St 42+ 110	(Pk 47+ 740)	L=66m (3 @ 22m, H=1.35m)	New Cut-off No.01
Br-2	10	St 42+ 800	(Pk 48+ 430)	L=100m(4 @ 25m, H=1.55m)	Cut-off No.1
Br-3	14	St 48+ 400	(Pk 54+ 040)	L=66m (3 @ 22m, H=1.35m)	New Cut-off No.02

- Box Culverts (RC with water gates)

No.	No. on Location Map	St+	(Pk+)	Dimension	Remark
BC1	3	St 32+ 420	(Pk 38+ 040)	2 Cell B2.0m*H5.4m	New Site
BC2	4	St 32+ 750	(Pk 38+ 360)	2 Cell B2.0m*H6.4m	Pipe culvert in the past.
BC3	5	St 33+ 200	(Pk 38+ 830)	2 Cell B2.0m*H4.7m	New Site
BC4	6	St 36+ 870	(Pk 42+ 500)	2 Cell B2.0m*H6.3m	Steel bridge in the past.
BC5	7	St 41+ 006	(Pk 46+ 640)	2 Cell B2.0m*H5.6m	Replace Prek Samrong W.G.
BC8	12	St 44+ 360	(Pk 50+ 000)	2 Cell B2.0m*H5.0m	New Site
BC9	13	St 46+ 920	(Pk 52+ 560)	2 Cell B2.0m*H4.5m	New Site
BC11	16	St 50+ 002	(Pk 55+ 640)	3 Cell B2.0m*H5.8m	Replace Kampong Phnom W.G.

- Box Culverts (RC without water gates)

No.	No. on Location Map	St+	(Pk+)	Dimension	Remark
BC6	8	St 41+ 770	(Pk 47+ 400)	2 Cell B2.0m*H5.2m	New Site
BC7	11	St 43+ 460	(Pk 49+ 100)	2 Cell B2.0m*H5.4m	New Site
BC10	15	St 48+ 760	(Pk 54+ 400)	2 Cell B2.0m*H5.2m	New Site

- Pipe Culverts (RC Precast)

No.	No. on Location Map	St+	(Pk+)	Dimension	Remark
Pipe1	1	St 23+ 983	(Pk 29+ 600)	D=1.0m	Replace Pipe Culvert
Pipe2	2	St 24+ 823	(Pk 30+ 440)	D=1.0m	Replace Pipe Culvert

Maintenance Method of structures

The inspection works of the existing structures are important to improve their serviceability effectively with less cost.

The appropriate evaluation and immediate/effective improvement/rehabilitation of the existing bridges will extend the public serviceability and their life span.

3) Construction Schedule

Planning of procurement

The materials and equipment which are used for construction is to be procured from Phnom Penh city, but subgrade, sub-base-course, base course and aggregate are to be procured from outside of Phnom Penh where the hauling cost is the lowest.

Construction schedule

Construction of this project is divided broadly into the two categories of road and structures (box culverts, pipe culverts and bridges).

Construction time schedule is prepared based on quantity of works and selected construction method considering the following conditions in the project area:

- Earth works: six months from November to April
- Asphalt pavement works: throughout the year.
- Sub structure works under HWL: six months from November to April.

The construction schedule of each is mentioned as follows:

Table S-5-12 Construction Schedule for Culvert Construction

Year	1								
Work \ Month	1	2	3	4	5	6	7	8	9
Preparation Work					(4.5 Months for Box)				
Detour Road					(3.0 Months for Pipe)				
Box-Piling									
Culvert Placing									
Rebetment Work									
Insidental Work									

Table S-5-13 Construction Schedule for Bridge Construction

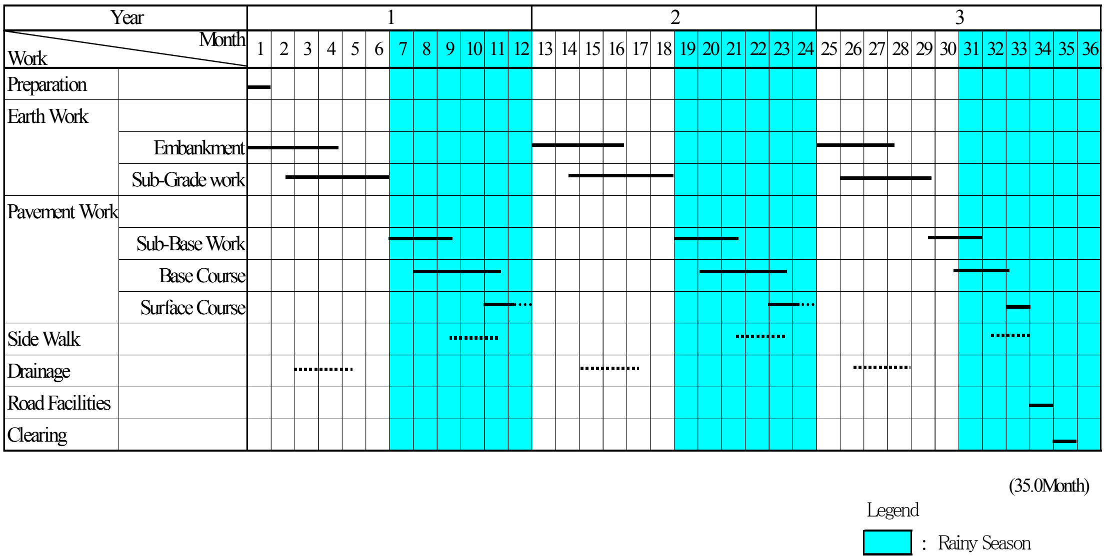
Year	1												2						
Work \ Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Preparation Work																			
Detour Road																			
Casting of Girder																			
Sub-Structure																			
Abutment 1																			
Foundation Work																			
Structure Work																			
Pier 1																			
Foundation Work																			
Structure Work																			
Pier 2																			
Foundation Work																			
Structure Work																			
Pier 3																			
Foundation Work																			
Structure Work																			
Abutment 2																			
Foundation Work																			
Structure Work																			
Super Structure																			
Election																			
Slab																			
Rebetment Work																			
River Bed Work																			
Subsidiary Work																			
Demolitin of detour																			
Cleaing																			

(18.5Month)

Legend

: Rainy Season

Table S-5-14 Construction Schedule for Road Construction



6. Project Implementation Plan

(1) Road Improvement Plan

The road improvement plan aims to secure the flow of traffic of NR-1 throughout the year and to avert flood damage. The improvement plan also aims to achieve an international standard for NR-1 as a part of Asian National Highway A-1. The following components are proposed to improve the project road for both long-term and short-term improvement:

1) Improvement of vertical alignment (higher than 2000 Flood level plus 50 cm) and pavement thickness
2) New construction of asphalt concrete pavement whose structure consists of roadbed embankment including subgrade, sub-base course, base course and surface course
3) Provision of space for slow-moving vehicles
4) Provision of sidewalk and drainage together with street lighting up to the intersection to Tiger beer factory
5) Provision of space for future widening up to Kokir Market
6) Improvement of existing intersection to Tiger beer factory by channelization with traffic signal
7) Existing two temporary bridges replaced by new pre-stressed concrete bridge with protection against erosion and local scouring
8) Existing two pipe culverts replaced by new pipe culvert with protection against erosion
9) Existing two water gates replaced by new box culvert with protection against erosion
10) Construction of one new pre-stressed concrete bridge with protection against erosion and local scouring
11) Construction of nine new box culverts with protection against erosion
12) Protection of slope surface of road embankment: 900-meter long revetment and 2,900-meter long green belt
13) Traffic safety measures by installing road markings, guard posts and rails, regulatory &

warning signs, guide signs, kilometer posts and traffic signal at intersections

14) Road related facilities such as moto-remork stops cum livestock refuge during flood, bus stops, pedestrian bridges, weighbridge station, approach slopes for local road and Road Station
15) Provision of space for toll plaza and administration office, if necessary

(2) Construction Planning

Construction planning should be made based on quantities of each main construction work item and selection of construction methods for site conditions. Quantities of main construction works are summarized as follows:

Table S-6-1 Quantities of Major Construction Works

Classification	Item	Unit	Quantity
Earth Work	Excavation	m^3	1,564,852
	Removal of existing pavement	m^2	333,000
	Embankment work	m^3	1,259,102
	Subgrade work	m^3	396,400
	Trimming work of Slope	m^2	743,064
	Embankment Material*	m^3	1,259,102
	Subgrade Material*	m^3	296,500
Pavement Work	Sub-Base	m^2	769,980
	Base Course	m^2	827,620
	Surface course (As)	m^2	695,000
Structure Work (Bridge Construction)	L=66.0m (3@22m) Width=14m	m^2	924
	L=100.0m (4@25m) Width=14m	m^2	1,400
	L=66.0m (3@22m) Width=14m	m^2	924

Construction time schedule is prepared based on quantity of works and selected construction method. 36 months of construction period are estimated to attain optimum investment schedule.

(3) Implementation Time Schedule

For the purpose of economic analysis, project implementation time schedule is prepared as shown in Table S-6-2.

Table S-6-2 Project Implementation Time

		2003										2004												2005		2006		2007	
																								Term		Term		Term	
		M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	1st	2nd	1st	2nd	1st	2nd
1)	Basic Design	═	═	═	═	═	═	═	═	═																			
2)	Detailed Design/ Preparation of tender Documents										═	═	═	═	═														
3)	Pre-qualification of Contractors															═	═												
4)	Tender Notice																★												
5)	Tendering/ Tender Evaluation																	═	═										
6)	Signing of Contract																			★									
7)	Construction																				═	═	═	═	═	═	═	═	═
8)	Completion of Work																												★

7. Project Cost

Construction Cost

The construction cost consists of direct cost and indirect cost. The direct cost is estimated based on surveyed market prices, indirect cost is estimated to multiplying direct cost by a percentage. The percentage of indirect cost to direct cost is shown in Table S-7-1.

Table S-7-1 Percentage of indirect cost to direct cost

Items	Indirect Percent of Direct cost
Temporary facility cost	4% (Approx)
Field expenses	17% (Approx)
Over head	10% (Approx)

Consultancy Cost

The consultancy cost for detailed engineering service account for 4% of direct cost; the construction supervision service is estimated at 6% of direct cost in this study.

Compensation Cost

The estimated compensation cost consists of items for House & Shop, Fence, Tree, Plantation and Allowance.

Relocation Cost for Utilities

The relocation cost is estimated for utilities which are necessary to relocate the telegraph poles along project site and optical cable underground.

Survey and demolition Cost for UXO

Survey and demolition of UXO will not be carried out along the route. It has already been carried out in the past and involves the safety of inhabitants.

Cost on Environmental Measurement

The cost on environmental measurement is estimated in IEIA which was studied in this study. It is mainly the cost of environmental monitoring program, resettlement action plan and environmental management action plan.

Project cost

The project cost consists of construction cost, consultancy cost, compensation cost, relocation cost for utility, and Cost of Environmental Measurement. The project cost is mentioned in Table S-7-2.

Table S-7-2 Project Cost Unit: US$

Item	Financial Cost	Local Cost	Foreign Cost	Tax
1. Construction Cost				
1) Direct Cost				
Earth Work	7,194,800	4,611,300	2,160,170	423,330
Pavement Work	13,074,450	8,195,100	3,838,850	1,040,500
Structure Work	6,858,200	4,397,800	2,060,020	400,380
Drainage Work	386,200	243,200	113,800	29,200
Road Facility Work	1,646,000	965,300	452,250	228,450
Temporary Work	331,300	217,600	101,900	11,800
Sub Total	29,490,950	18,630,300	8,726,990	2,133,660
2) Indirect Cost				
Temporary Facility Cost	1,179,638	745,212	349,080	85,346
Field Expenses	5,013,462	3,167,151	1,483,588	362,722
Overhead	2,654,186	1,676,727	785,429	192,029
Sub Total	8,847,285	5,589,090	2,618,097	640,098
Total	38,338,235	24,219,390	11,345,087	2,773,758
2.Consultant Fee				
Detailed Engineering	1,179,638	745,212	349,080	85,346
Construction Supervision	1,769,457	1,117,818	523,619	128,020
Total	2,949,095	1,863,030	872,699	213,366
3.Compensation Cost	1,395,322	1,268,474	0	126,847
4.Relocation Cost for Utility	655,097	595,543	0	59,554
5.Survey and demolition Cost for UXO	0	0	0	0
6.Cost on Environmental Measurement	69,810	63,464	0	6,346
Ground Total	**43,408,000**	**28,010,000**	**12,218,000**	**3,180,000**

8. Proposed Road Operation and Maintenance Plan

(1) Present Financial Situation

In the present budgetary system, the operation expenditure is categorized into construction and maintenance even though the indicators are that the majority of the maintenance funds probably will be spent on emergencies by provincial level and leave very little for conventional maintenance activities.

The budgets of 2000 and 2001 suddenly increased about 10 billion Riel because the road maintenance fund of 10 billion Riel equivalent to 2.5 million US$ was added annually. The budget for 2002 is planned as 16,180 million Riel including the road maintenance fund of 10.5 billion Riel.

The road maintenance budget comes from "Fund for Repair and Maintaining of Road (FRMR)" which transferred to the direct management of the Prime Minister and MEF in May 2002. The fund will be used for routine and periodic maintenance and repair of the national, provincial and other roads under the management and responsibility of MPWT and other ministries. Therefore, MPWT should request to MEF for allocation of budget for road maintenance and planning, technical standard and financing objectives from the fiscal year of 2003.

In addition to the above-mentioned administrative change, MPWT through MEF officially requested to the Government of Japan in July 2002 for approval of utilization of the counterpart fund of non-project grant aid 1996 for the project “Road Maintenance Catch-up Program”.

(2) Road Maintenance Practices

MPWT is responsible for maintenance of 12,156 km of roads. Its source of funds for road maintenance is the revenue accrued from fuel taxes and vehicle registrations.

The following jurisdictions are set forth for NR-1(C-1) Section (Phnom Penh to Neak Loueng) under current road maintenance system in the study area:

i) NR-1(C-1) Section from the beginning point to Veal Sbov, L= 3.5 km is under jurisdiction of DPWT of Phnom Penh Municipality.
ii) NR-1(C-1) Section from Veal Sbov to Neak Loueng, L= 52.5 km is under jurisdiction of DPWT of Kandal province.
iii) Emergency flood rehabilitation project under PMU-I maintains NR-1(C-1) Section.

The basic concept of the road maintenance system and its organization is that MPWT manages the overall maintenance program and annual activities of national and provincial roads, and provincial DPWT executes them.

Meeting the increasing requirement for service of the road system is critical to the country’s economic development. The Government gives highest priority to arterial road improvement. Roads are largely deteriorated and they require both paving and improvement of vertical alignment to cope with floods. Moreover, many bridges, which also play an important role as a part of the road system, remain in serious condition and deteriorated due to lack of repair and maintenance and recent increase of heavy traffic. Accordingly, damaged bridges become traffic bottlenecks, jeopardize road safety, and hinder the smooth flow of road transportation.

Both legal entities of DPWT and PMU have similar problems as follows:

i) Shortage of road and bridge construction equipment and machinery
ii) Shortage of local engineers qualified in managing and supervising the operation of road and bridge construction equipment and machinery
iii) Lack of skilled construction equipment operators, mechanics, and electricians
iv) Lack of repair facilities and tools
v) Lack of managerial capability and research ability

In order to strengthen road maintenance capability and to cope with incremental demand brought about by the governmental policy of road improvement, it is necessary to enhance funding availability and to remedy institutional weakness.

It is expected that the proposed Road Maintenance Management Organization (RMMO) as the executing body of “Road Maintenance Catch-up Program” will undertake actual practice in a pilot model to train operators, mechanics and managers, and that such trained people with new skills will eventually contribute to deliver effective construction equipment and to strengthen the road maintenance system.

(3) Increase of Road Maintenance Fund

The total project cost is US$ 43.4 million (equivalent to 168 billion Riels), including costs of resettlement and utility relocation. This is obviously a heavy financial burden to the Government, compared with local funds for capital investment of 511.4 billion Riels in 2002. Moreover, upon the completion of the project, routine maintenance will require 66.5 million Riels every year according to the average National Road's maintenance unit cost of 1.2 million Riels/km. In addition, periodic maintenance will require approximately 6.3 billion Riels every 10 years.

Therefore, in order to secure the annual funds required for road maintenance, it is necessary to increase the road maintenance fund by strengthening road user cost recovery practices and to draw up a long-term strategy for cost recovery from road users.

The following measures are envisaged to ensure financing mechanism for road maintenance that are indispensable to strengthen road maintenance capability and to cope with incremental demand brought about by the governmental policy of road improvement:

1) To appropriate necessary funds from "Fund for Repair and Maintenance of Road (FRMR) to MPWT
2) To follow up on Road Maintenance Catch-up Program officially requested to Japan
3) To realize the concept "Fee-for-Service" to contribute to increasing the road maintenance fund such as:
   - To examine possibility to surcharge additional toll to heavy vehicles at Neak Loueng ferry
   - To build a toll plaza together with weighbridge station and administration office in case of shortage of funds.

9. Project Evaluation

This section summarizes the economic, financial and environmental evaluations of the project.

(1) Economic Evaluation

The economic evaluation indicates whether the investment to the project road is worth implementing or not from the national economic point of view.

Economic Cost

The economic cost of the project is estimated by conversion of the estimated financial cost.

Table S-9-1 Estimation of Project Cost

		Financial Cost	Economic Cost
1	Construction Cost	38,338	32,933
2	Land Acquisition Cost	1,396	974
3	Utility Relocation Cost	655	457
4	Engineering Fee	2,949	2,491
5	Environmental Cost	70	49
Total Cost		43,408	36,904

Unit: US$ '000

The maintenance cost is defined as difference between the maintenance cost in cases of without project and with project. The average maintenance cost for National Roads in 2002 is estimated as about US$ 300/km to maintain the minimum passable condition. This cost represents the maintenance cost of without project. The maintenance cost for the project road is estimated as US$ 1,530/km. This is a cost to keep the road surface smooth and in good condition after implementation of the asphalt concrete pavement. Therefore, US$ 1,230/km becomes the maintenance cost in this evaluation.

Benefits

There are various benefits derived from the project, of which the following tangible benefits are taken into account in the study:

- Saving in travel time cost (time saving)
- Saving in vehicle operation cost (VOC saving)

The time saving and VOC saving are estimated on the basis of the forecast traffic demand on the project road and unit time cost and unit vehicle operating cost, respectively.

Table S-9-2 Estimation of Time Saving and VOC Saving

	Saving in Time Cost	Saving in VOC		
		Saving in Fixed Cost	Saving in VOC Cost	Total Saving in VOC
2005	606,424	330,505	2,688,948	3,019,454
2010	1,044,896	483,057	3,672,314	4,155,370
2015	1,745,169	648,042	4,618,931	5,266,974

Unit: US$

1) Benefit – Cost Analysis

Based on the above mentioned benefits and cost estimations, the economic analysis of the project is made. Table S-9-3 shows the results of benefit - cost analysis of the project. The results show that a net present value (NPV) of US$ 3.9 million and B/C ratio of 1.14 over the 20 year life of the project, using a discount rate of 12%. The economic internal rate of return (EIRR) is computed at 13.3%.

Table S-9-3 Results of Benefit Cost Analysis

	NPV ('000US$)	B/C Ratio	EIRR
Indicators	3,115	1.106	13.3%

Notes: 1) Project life of the project is 20 years
2) Discount Rate is 12%

2) Sensitivity Analysis

The sensitivity of the project to various economic parameters is analyzed, especially in the following cases:

- Employment of lower economic growth scenario (from 6% to 4% per annum)
- Increase of project Cost by 20% or decrease of benefit by 20%
- Reduction of saving in travel time cost by 50% or no growth of unit time value in future.

The project is economically justified even by employment of lower economic growth scenario as shown in Table S-9-4.

Table S-9-4 Results of Sensitivity Analysis of Alternative Economic Growth Rate

	EIRR
Base Case (Medium Growth Rate)	13.3%
High GDP Growth Rate	15.3%
Low Economic Growth Rate	11.3%

Notes: 1) Project life of the project is 20 years
2) Discount Rate is 12%

As for the increasing project cost and/or decreasing benefit, the project is justified to the degree shown by the yellow cells in Table S-9-5

Table S-9-5 Sensitivity Analysis regarding Cost and Benefit

		Benefit				
		20% Down	10% Down	Base case	10% Up	20% Up
Construction cost	20% Up	8.4%	9.8%	11.0%	12.0%	13.3%
	10% Up	9.4%	10.8%	12.1%	13.3%	14.4%
	Base Case	10.5%	11.9%	13.3%	14.6%	15.8%
	10% Down	11.8%	13.3%	14.7%	16.0%	17.3%
	20% Down	13.3%	14.9%	16.4%	17.8%	19.1%

Note: Project life of the project is assumed to be 20 years

Regarding to the reduction of saving in travel time cost and/or no growth of unit time value in future, the results of sensitivity to the project are shown in Table S-9-6. The results show that the project can be mostly justified from economical viewpoint.

Table S-9-6 Sensitivity Analysis regarding Time Value

	EIRR
Base Case	13.3%
Reduction of Travel Time Cost to 50%	11.7%
Reduction of Travel Time Cost to 0	9.9%
No Growth of Unit Time Value	12.2%

Notes: 1) Project life of the project is assumed to be 20 years
2) Discount Rate is 12%

Conclusions from Economic Point of View

As analyzed above, implementation of the project road is justified since the economic indicators of most cases are higher than the cut-off level which can be considered as 12% EIRR.

(2) Financial Evaluation

The financial capability of the Government is examined to indicate whether the budget can be provided to implement the project smoothly. In order to estimate financial capability, the capital investment funds and local funds are estimated.

Capital Investment Funds

Table S-9-7 shows the forecast capital investment funds and local funds estimated from GDP and Government budget. Capital investment funds in the following four years from 2003 to 2006 will make available about 7,900 billion Riels or US$ 2,000 million.

Table S-9-7 Projected Capital Investment Funds and Local Funds Unit: Billion Riels

	Local Fund for Capital Investment	Capital Investment Funds	Percentage
2001	325.0	1,025.0	31.7%
2002	511.4	1,704.7	30.0%
2003	542.1	1,807.0	30.0%
2004	574.6	1,915.4	30.0%
2005	609.1	2,030.3	30.0%
2006	645.6	2,152.1	30.0%
2007	684.4	2,281.2	30.0%

Sources: 1) Figure in Cambodia Statistical Yearbook, 2001
2) Other figures are estimated by JICA Study Team

The capital investment budget during 2003 – 2007 will be provided for US$ 1,996 million as mentioned in section 16.2.1 in main report. Taking into account that the road sector share of capital investment budget is 16%, the capital investment budget for road sector will make available US$ 319 million. Since the capital investment requirement between 2003 and 2007 is US$ 145 million for on-going projects and US$ 425.5 million for high priority projects, the funds are expected to be provided for on-going projects including the project road. However, high priority projects may not be implemented due to shortage of available funds.

Table S-9-8 Comparison between Capital Investment Budget Availability and Requirements

Capital Investment Budget for 2003 to 2007	US$ million	1,996.0
Share of Road Sector	%	16
Capital Investment Budget for Road Sector for 2003 to 2006	US$ million	319.4
Necessary Fund to implement the On –Going Projects	US$ million	145.3
Necessary Fund to implement the High Priority Projects	US$ million	425.5
Balance	US$ million	- 251.4

As conclusion of the financial analysis, the implementation of the project road of the National Road No. 1 from Phnom Penh to Neak Loueng (identified as the on-going project group in the PIP) will be able to be provided with the necessary funds.

(3) Environmental Evaluation

1) Natural Environmental Impact

i) Impact on hydraulic conditions

- Negative impacts

The construction of bridges and culverts will affect the direction of water flow and its volume in the Colmatage area.

- Positive impacts

The selection of bridges and culverts is carefully examined to reduce the flood risk not only along NR-1(C-1) but also Phnom Penh and Neak Loueng. The inflow floodwater will bring benefits of inland fishery and supplying fertile soil to the Colmatage area.

- Mitigation measures for negative impacts

The location of bridges and culverts is carefully selected to minimize adverse impacts to the existing land use. During construction, attention should be paid to local people who utilize the land adjacent to bridges and culverts.

ii) Impact on geological conditions

- Negative impacts

Once the topsoil is excavated and slope is exposed at potentially erosive places such as some critical sections with high filling and deep cutting along the roadside, erosion will easily occur. It may cause loss of fertile topsoil if borrow pits and stockpiles of materials are located in arable lands. The movement of heavy vehicles for construction works will affect soil and vegetation easily along and nearby the project site.

- Positive impacts

Possible natural erosion will be retarded by well-designed prevention and preservation measures because floodwater is guided and proper protection is constructed where the velocity will be high.

After NR-1(C-1) is improved, all the vehicles will pass along the paved road without any dust and fertile topsoil will be properly preserved.

- Mitigation measures for negative impacts

Arable lands should not be used as earth borrowing or storage sites whenever possible. The topsoil should be kept and refilled after excavation to minimize the impact on productive lands, if any.

It may be necessary to construct new access roads to quarry and borrow sites, and place them through agricultural lands. These temporary roads will be made along existing farm tracks in order to avoid losses to agricultural lands.

During construction, the contractor should pay attention to the prevention of excessive damage/compunction to arable lands on condition that the provision of protection work will be stipulated in the conditions of contract and specifications.

iii) Impact on flora and fauna

- Negative impacts

  Clearing and grubbing for site development will lose many trees. If construction workers are not controlled properly they easily behave to cause excessive damage to natural resources and wild animals. Stream and channel crossings during the dry season may be obstructed and altered by construction activities, and these may affect aquatic fish in the flood season.

- Positive impacts

  The inflow floodwater to the Colmatage area will enable improvement to natural conditions for flora and fauna.

- Mitigation measures for negative impacts.

  During construction, the contractor should pay attention to the prevention of excessive damage to natural resources and wild animals on condition that the provision of prevention will be stipulated in the conditions of contract and specifications.

2) Social Environmental Impact

i) Impact on compensation issues

- Negative impacts

  1,805 households will be resettled and their properties will be affected due to evacuation of project-affected persons (PAPs).

  Public utilities such as drinking water pipe, power and telecommunication cables will be relocated due to widening of pavement.

- Positive impacts

  No positive impacts are expected.

- Mitigation measures for negative impacts

  The Government has adopted a policy to compensate the people whose interests are affected by the project. PAPs will get the financial support not for land but for their buildings, agricultural crops and trees in case of improvement of an existing road.

ii) Impact on traffic issues

- Negative impacts

  Public nuisances such as interruption, detour and traffic congestion that will take place during construction are some of the major negative impacts. It is also predicted that high speed movement of heavy vehicles for construction will cause traffic problems such as hampering smooth and safe traffic flow around construction areas.

- Positive impacts

  By improving NR-1(C-1) as a flood-free road to an all-weather standard, road users enjoy benefits such as being assured of road transport throughout the year, securing traffic safety and conserving the environment.

- Mitigation measures for negative impacts.

  Proper traffic control measures should be taken to relieve the congestion through better coordination between the contractor, the Provincial Transportation Department, and the police department. Speed of construction vehicles should be controlled through road safety education, and enforcement (including fines) should be imposed to drivers not complying with traffic rule and regulation.

  Provide adequate signs, barriers and flag persons for traffic control. Also communicate to the public through radio, TV, and newspaper announcements regarding the scope and timeframe of projects.

iii) Impact on sanitary issues

- Negative impacts

  The formation of standing water on construction sites in tropical areas often leads to the spread of insect-borne diseases such as malaria, dengue fever and schistosomisis if adequate sanitation and adequate health care are not provided in settled areas; this is especially anticipated for construction workers at their camps.

- Positive impacts

  Roadside drainage and sidewalks will be installed in urban areas. Such improvement to NR-1(C-1) will contribute to preventing standing water along the road.

- Mitigation measures for negative impacts

  There must be a vigorous program by the constructor to avoid such standing water. Proper information should be given to the local people and construction workers about the dangers of water-borne diseases in standing water and how to prevent them.

iv) Impact on HIV/AIDS issues

- Negative impacts

  Prostitution and illicit drugs are factors to the rapid spread of HIV/AIDS directly or indirectly. Migrant workers such as equipment operators and laborers may become infection carriers of HIV.

- Positive impacts

  Since the project will contribute to stimulating economic and social development by improving communication and reducing poverty, education and dissemination of prevention information will be used to prevent the spread of HIV/AIDS.

- Mitigation measures for negative impacts

  Through education programs and management of migrant workers as well as local people on health care, needed information will become public knowledge in vicinity areas.

Provision of education and control for HIV/AIDS infections for workers should be taken. It is necessary for contractors to fund HIV prevention strategy and program in their activities as a pre-condition of approval of construction project. During construction, the contractor should pay attention to the prevention of HIV/AIDS on condition that the provision of prevention will be stipulated in the conditions of contract and specifications.

3) Impact on Pollution

i) Impact on air and dust pollution

- Negative impacts

Emission gas and dust will be generated from vehicles, equipment and machinery for construction during construction, especially hauling vehicles and mixing/crushing plants.

- Positive impacts

Conserving environment is expected to ensure smooth traffic throughout the year by improving a flood-free road to an all-weather standard.

- Mitigation measures for negative impacts

Vehicles and machinery are to be regularly maintained so that emissions conform to national standards. Water should be sprayed during the construction period in any mixing area where dry materials are handled and/or crushed. Temporary access roads to quarry and borrow pits must be included in the dust suppression program. Vehicles delivering materials to and from the construction sites should be covered to avoid spills.

ii) Impact on water pollution

- Negative impacts

Entering bitumen as well as fuel/lubricants into either running or dry stream beds may cause water quality degradation when proper management is not conducted.

Construction materials generally contain fine particles, and it is apt to drain into watercourses nearby construction sites to cause water pollution. The wastewater from the campsite and yard may also cause water pollution entering directly into water bodies and irrigation systems if justifiable measures are not taken.

- Positive impacts

Nil

- Mitigation measures for negative impacts

Earth and aggregate materials should be stored in an enclosure such that sediment-laden water does not drain into watercourses. Wastewater should be treated properly if it is necessary to dispose.

Bitumen storage and mixing areas must be properly handled. Any petroleum products used in the preparation of the bitumen mixture must also be carefully managed to avoid spills and contamination of the local water body. Spills of oil products into a water body from construction vehicles and machines shall be controlled and managed properly.

Vehicle maintenance and refueling should be conducted within construction camps that are designed to prevent lubricants and fuels from spilling. Waste petroleum products must be collected, stored and taken to the approved disposal sites. All justifiable measures should be taken to treat the wastewater properly before disposing them to watercourse.

iii) Impact on noise and odor pollution

- Negative impacts

Noise and odor pollution will be generated from vehicles, equipment and machinery for construction during construction, especially hauling vehicles and mixing/crushing plants. Asphalt mixing plant will be noisy with some odor and a risk of fire. Aggregate crushing plants may generate noise. Construction activity with vehicles and machines may produce permissible noise level if sensitive areas such as hospitals and schools are located nearby.

- Positive impacts

Conserving environment is expected to ensure smooth traffic throughout the year by improving to a flood-free road to an all-weather standard.

- Mitigation measures for negative impacts

Hauling vehicles and mixing/crushing plants will be enforced to prevent excess of acceptable noise and odor standards. Machinery and vehicles should be maintained properly to minimize noise.

During construction, the contractor should pay attention to the prevention of noise and odor pollution on condition that the provision of prevention will be stipulated in the conditions of contract and specifications.

iv) Impact on waste disposal issues

- Negative impacts

Considerable materials will be disposed of from existing road. Such disposal will bring adverse environmental impacts to the surrounding.

- Positive impacts

Nil

- Mitigation measures for negative impacts

All construction materials should be attempted to be reused, recycled or properly disposed of. This will become particularly important at the many small public works sites. All worn out parts, equipment and empty containers also Bailey bridge parts must be removed from the site to a proper storage location designated and shuld be attempted to be reused.

Sufficient disposal measures will be taken in the construction camps (i.e., provision of garbage bins and sanitation facilities). Solid waste and garbage will be collected in bins and disposed of daily, according to a brief and basic waste management plan prepared by the contractor.

(4) Overall Evaluation

1) Technical Feasibility

Technical risks of the project have been minimized to the extent possible by having a technical design based on various engineering site surveys, full-scaled natural condition surveys and social/environmental surveys. Such technical design and associated cost estimates are based on results from a series of meetings with MPWT counterparts, presentations/workshops and individual discussions with the agencies concerned. Emphasis was given to the selection of alternative plans where flood mitigation measures were carefully examined not to adversely induce aspects of environmental and social impacts. Accordingly, the technical feasibility for the project is confirmed from all aspects.

2) Environmental and Social Impact

The IEIA was conducted in accordance with the environmental rules and regulations of Cambodia as well as environmental guidelines of JICA, and it concluded that there are neither substantial nor irreversible adverse environmental and social impacts arising from the Project. No adverse social impact is expected because the project only involves the improvement of existing roads and no additionally land acquisition for road right-of-way is required.

In the course of the Study, the activities designed to identify and predict the impact on the biogeographically environment and other matters was prepared based on the MOE's comments on IEIA. MPWT as the executing agency for the project has submitted the final report of IEIA to MOE, and due procedure was carried out in November 2002. MOE has issued an approval letter to the project.

Therefore, the environmental justification for the project is confirmed officially.

3) Economic Feasibility

The major quantifiable benefits accruing from the project are mainly savings of transport cost and time for existing and future traffic in the eastern part of the country, especially between Phnom Penh and Neak Loueng. The economic analysis includes such benefits comprised from generated and induced traffic that are forecast in the future socio-economic framework. The annual traffic growth rate in the planning period is forecast to be 5.8% as a whole. The base EIRR for the project is 13.3%, with various growth scenarios giving results that range from 11.3% to 15.3%.

Therefore, high priority should be given to the implementation of the project because the project will promote economic and social development and there is expectation of a sufficient economic return. The project will also contribute to reduce poverty in the Plain Region through increased employment opportunities both during and after construction, accelerated agricultural and inland fishery development induced by lower transport costs and improved accessibility of goods and people to markets.

10. Conclusion and Recommendations

(1) Conclusion

1) Justification of the Project

The project will realize the strategic transport axis in East-south Asia as a part of Asian Highway No. A-1 by improvement of major arterial roads to an all-weather international standard.

The significant benefits of the project are summarized as the enhancement of traffic safety and environmental conservation by well-designed paved road, the integration of producing and consuming centers in terms of regional context, and the reduction of transport cost to provide better market accessibility for more competition toward low prices and to increase job opportunities for the local poor especially in the development corridor between Phnom Penh and Neak Loueng. It is also anticipated that local people will have better access to social facilities including schools, Pagodas and other public facilities.

The project will also stimulate the development of the Asian Highway No. A-1 and induce incremental demand of domestic cargo as well as international trade to Vietnam.

Such transformation will accrue considerable degrees of both direct and indirect benefits in the Plain Region, especially by relieving transport constraints such as traffic bottlenecks by temporary bridges and traffic accident, and strengthening social and cultural links between settled areas in the country.

2) Implementation of the Project

i) It is recommended that the improvement of National road No. 1 C-1 Section (Phnom Penh - Neak Loueng L=56 km) be given the highest priority in the Second Socio-Economic Development Plan (SEDP-2) due to its necessity and urgency. The project is located in the surroundings of urbanized and settled area and sufficient economic return is anticipated due to the higher traffic volumes.

ii) Two openings exist on NR-1(C-1), which have been built artificially to prevent Phnom Penh from submergence during 2000 Flood, and temporary bridges crossing openings become serious traffic bottleneck because of one-lane width and load limit control. Well-designed bridges and culverts in the project will contribute to decreasing the floodwater level along NR-1(C-1) and at Phnom Penh, and accordingly flood risk will be reduced not only for NR-1(C-1) and Phnom Penh but also along NR-1(C-2) and NR-11 if 2000 Flood level should reoccur. By the inflow of floodwater to the Colmatage area through the proposed openings, the water level inside the Colmatage area will slightly increase. However, no adverse impacts will affect agriculture in the Colmatage or the Bassac River. Therefore, it is recommended that the project be given the highest priority due to high feasibility.

iii) The pavement condition on NR-1(C-1) is so deteriorated that it is hard to maintain normal traffic function throughout the year and to secure traffic safety as well. Since the road structure is highly vulnerable to flood and floodwater, road users incur high transport costs even though the road maintenance might be carried out in the usual way. The proposed road improvement plan consists of appropriate flood mitigation measures, flood-free embankment level and strong as well as durable pavement structure. Accordingly it is technically feasible to cope with flood, floodwater and incremental demand of traffic and maintenance.

iv) The proposed plan will not require acquisition of land but evacuation of dwellers within Road Right-of-Way (ROW). According to prevailing procedure, 1,805 houses are located within tentative ROW of 30 meters, and they should move outside the tentative ROW. Since the permanent ROW is designated as 60 meters, it is socially feasible to vacate the land by a due procedure taken as the fair and just compensation to make Project Affected Persons (PAPs) resettled voluntarily outside the ROW.

Accordingly, it may be concluded that the institutional and administrative arrangement for project implementation should be taken without interruption.

(2) Recommendations

The following recommendations are made for the implementation of the project:

1) Appropriation of Funds for Project Implementation

The development fund for the project will cover direct and indirect costs.

The former consists of construction cost and consultant fee. It is recommended that the Government request a donor country to assist funding them, using bilateral ODA or a loan from a multi-lateral lending agency so as to alleviate the financial burden to the Government.

The later consists of compensation for resettlement and utility relocation, and the Government should appropriate the necessary funds for them in a timely manner.

2) Evacuation of Road Right-of-Way for the Project

It is necessary to evacuate PAPs from 30-meter wide ROW and to relocate utilities such as electricity and communication cables to proper locations before the construction works commence. These resettlement and relocation works require due and time-consuming procedures. Accordingly, it is recommended that such procedures should be taken in a timely manner to secure the necessary space for construction work.

3) Control of Development along NR-1(C-1)

The required funds for compensation will be appropriated on the basis of the cost estimate that will be carried out at the design stage. However, many activities such as installation of utilities, construction of houses/buildings and land reclamation might occur during the pre-construction period unless otherwise controlled, and they will also affect the budget.

It is recommended that any development within and along NR-1(C-1) should be effectively controlled to prevent indiscriminate activities and to facilitate the realization of project.

4) Maintenance of Detour Road at Cut-off No. 1 and No.2

Two temporary bridges at Cut-off No.1 and No.2 will be used until the construction work commences. Since it takes more than two years to start the construction work, it is necessary for MPWT to maintain detour roads and bridges properly.

Furthermore, a new detour road with temporary bridge should be constructed at Cut-off No.1 because a new bridge will be built at the same location.

5) Control of Over-loaded Trucks

It is very sure that pavements and bridge structures suffer damage from over-loaded trucks, and it is more serious for the temporary bridges at Cut-off No.1 and No.2. It is recommended that action be taken immediately so that a weighbridge station at Cut-off No.2 be built to control over-loaded trucks.

6) Ensuring Financing Mechanism for Road Maintenance

The following measures are recommended to ensure financing mechanism for road maintenance since it is indispensable to strengthen road maintenance capability and to cope with incremental demand brought about by the governmental policy of road improvement:

i) To appropriate necessary fund from "Fund for Repair and Maintenance of Road (FRMR) to MPWT
ii) To follow up Road Maintenance Catch-up Program officially requested to Japan
iii) To realize the concept "Fee-for-Service" to contribute to increasing the road maintenance funds such as:
   - To examine possibility to surcharge additional toll to heavy vehicles at Neak Loueng ferry
   - To build a toll plaza together with weighbridge station and administration office in case of shortage of funds

7) Improvement of Outlet Channel of Colmatage Water Gates

Outlet channels of Colmatage water gates constructed by Japan's grant aid are eroded partially by strong current. Not only for the function for agricultural water use but also the existing water gates along NR-1(C-1) have the function to mitigate flood. In order to utilize this flood mitigation function, it is recommended to improve the existing outlet channels including bank protection against erosion.

The existing water gates and channels along the left bank of the Bassac River also have function to mitigate flood. However, many channels have no gate or no function because the structures of existing gates are deteriorated and damaged. Therefore, in order to utilize the function of flood mitigation and water use fully, it is also recommended to improve the Colmatage water gates and channels along the left bank of the Bassac River.

8) Countermeasure against the Bank Erosion of the Mekong River

It is recommended to conduct observation of the bank erosion every year, and provide some countermeasure beforehand, so that the bank erosion will not become a really serious problem to NR-1(C-1).

9) Study on Bridge over the Mekong River at Neak Loueng

Since the project will realize the strategic transportation axis in East-south Asia as a part of Asian Highway No. A-1 by improvement of National Road No.1 to an all-weather international standard, it is indispensable to avoid interruption.

It is necessary to deliberate a scheme for bridge crossings since considerable numbers of travelers are always exposed to risk and inconvenience. Therefore, it is recommended that a study on bridges over the Mekong River at Neak Loueng should be conducted.

10) Comprehensive Study on Improvement of Chbar Ampov Intersection

Congested Chbar Ampov Intersection is one of major traffic bottlenecks on National Road No. 1 C-1 together with Neak Loueng Ferry and Kokir Market. Accordingly, it is desirable to improve it simultaneously if NR-1 C-1 is improved to a flood-free road to an all-weather standard. However, physical constraints such as close location to the bridge, steep slope, staggered shape and lack of land availability in the vicinity are so severe and complicated that it is difficult to solve the problems only by an engineering design without the construction of 2nd Monivong Bridge.

It is recommended that the in-depth investigations and more comprehensive study covering Chbar Ampov Market, Kbal Ntal Intersection and its surroundings in Mean Chey District of Phnom Penh Municipality should be conducted for the improvement plan at Chbar Ampov Intersection.

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