CHAPTER 10 ENVIRONMENTAL CONDITIONS

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10.1 Outline of Environmental Conditions

In the course of Feasibility Study on Improvement of Cambodian National Road No.1, environmental study was made. The summary of environmental conditions is outlined below.

Meteorological conditions:

The climate of Cambodia is tropical monsoon type, with a rainy season, brought from the southwest monsoon, lasting from May through November; dry season is pronounced during the rest of the year. Annual precipitation varies across the country as follows: more than 3,000 mm in the western coastal region, between 1,800 and 3,000 mm east of the Mekong, and between 1,200 and 1,500 mm in the central plain. The annual average temperature is 28℃, with a maximum average 38℃in April, and a minimum average of 17℃ in January. There are some variations from year to year. The average annual precipitation is about 1,372 mm in 2001. The monthly average relative humidity do not vary thorough a year, keeping high value of about 75%. Kampong Cham has slightly higher relative humidity than Phnom Penh. The monthly maximum wind speed at Phnom Penh in summer time is higher than that in other seasons. Recent data on maximum and minimum of temperature (1996-2001) at the Pochentong observation station is shown in Appendix Table H-1 and the rainfall record of Kandal province is summarized in Table H-2.

Geographic and geological conditions:

Cambodia is situated in Southeast Asia between latitudes 10º and 15º North and longitudes 102º and 108º east. The country extends 580 km from East to West and 450 km from North to South. Topographically, the country is divided into two parts:

a) Central low-lying land (the central plain with a large part less than 10 meters in elevation) and the flat coastal areas.
b) Mountain ranges and high plateau surrounding the low-lying land.

The central plains surrounded by savanna, gradually changes into more forest and sparsely populated high lands and mountains. They form three quarters of the country, mainly consisting of the alluvial plains of the Mekong River and the Tonle Sap Basin which are the two dominant topographical features. National Road No 1 parallels the Mekong River, so the soil condition is quite similar to the Mekong Delta.

The mountain ranges and high plateau surrounding the plains consist of: the Elephant Mountains and the Cardamomes Mountains in the southwest and western regions, the Dangrek Mountain in the north adjoining the Korat plateau of Thailand and the Rattanak Kiri plateau and Chhloung high land in the east merging with the central high lands of Vietnam.

(1) Bio-geographic condition:

Cambodia is situated in the Indochinese subdivision of the Indo-Malayan Realm and comprises two bio-geographical provinces: Thai-Indochinese Rainforest and Thai-Indochinese Dry Forest.

(2) Biodiversity:

14 vegetation types, subdivided into 35 sub-types, are recognized in Cambodia. The natural vegetation includes evergreen lowland and mountain forest on the western slopes of the Cardamomes and Elephant Mountains, semi-evergreen forest in the northeast of Tonle Sap Lake with a mountain deciduous forest and hydrophilic communities in the north-east highlands.

The forest vegetation is variously dominated by the families dipterocarpeceae, Leguminosae, Lythraceae, Fagaceae and in some places Pinaceae or Podocarpaceae and possesses diverse flora with some areas featuring numerous endemic species. The Tonle Sap Lake is bordered by a flooded forest and along the coast there are some patches of mangrove forest. The total forested area is estimated at 11,262,100 ha. (62% of the country)

The relatively large extent and diversity of habitats maintain a wide array of fauna, even though, due to direct human persecution, some of the large mammals and birds face a drastic decrease in number. This fauna features a diversity of mammals including carnivores, primates, bears, elephants, rodents, pangolins, bats, deer, native wild cattle, and rhinoceros. There is probably more than 600 bird species. There is also an important diversity of fish species, with 215 currently listed.

With only a limited number of inventories conducted, Cambodian represents a tremendous opportunity to learn about unknown species, especially in the isolated rain forest of the Cardamomes Mountains. Fig. 10-1-1 shows an eco-regional map of Cambodia.

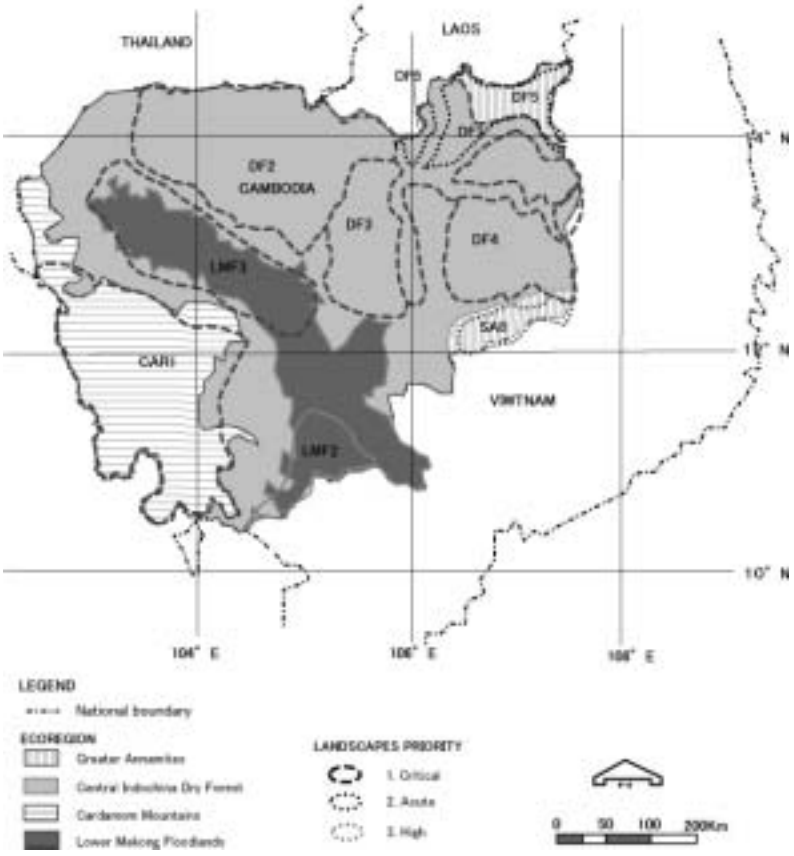


Fig. 10-1-1 Eco-regional Map of Cambodia

10.1.1 Objective of Environmental Study

This section gives the results of the Initial Environmental Impact Assessment (IEIA). It addresses impacts of Improvement of National Road No-1 (NR-1) in Cambodia and covers approximately 56 km of NR-1 from Monivong Bridge to Neak Loueng at the ferry point of the Mekong River. Fig. 10-1-2 shows the map of the Study area. Details and the scope of the Study were set out in the Minutes of Meeting between the Ministry of Public Works and Transportation and the JICA Study Team in May, 2002. The focus is on Social environmental impact, Natural environmental impact as well as pollution as discussed below.

1) Social environmental impact

Present social conditions that may be affected such as relocation of houses and resettlement issues are surveyed.

2). Natural environmental impact

The objective is to examine the existing environmental conditions along the project road and determine positive and negative effects during the short, medium and long term, including the construction period.

Parallel work has been carried out on data collection of laws, regulations and other existing relevant data.

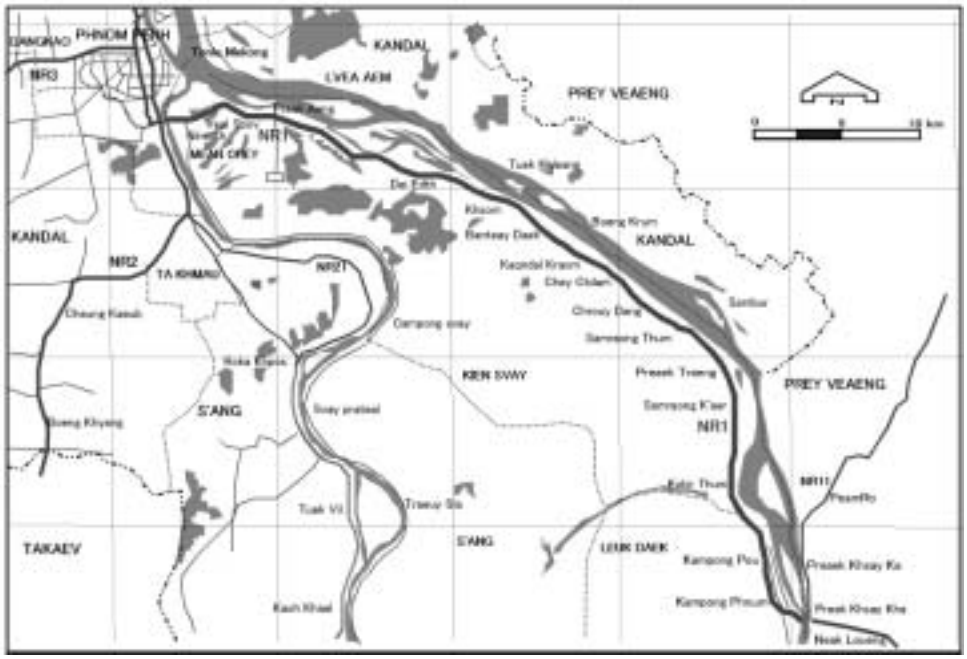


Fig. 10-1-2 Map of Study Area

10.1.2 Background of Environmental Conservation in Cambodia

Recently, the forests of the lower Mekong have received a great deal of attention for their biological diversity. In the eco-region, complex biodiversity is abundant: 12,000 to 15,000 species of plants, over 100 species or distinct sub-species of large mammals and over 750 birds are known to date. This diversity is spread throughout a rich variety of terrestrial habitats

including the dry coastal dune forests, major river systems and associated wetlands.

Despite the massive pressures on diversity in the forests of the lower Mekong from hunting and forest loss, the region still maintains the rich endemism of the Great Annamites, the herds of wild cattle in the Dry forests and the productive waters of the Mekong River and the Tonle Sap Basin.

It is only in the last 15 years that the true uniqueness of the Great Annamites biodiversity has begun to be recognized.

Central Indochina Dry Forests: Consisting of a mosaic of open dry forests, semi-evergreen forests and small ponds and seasonally wet grasslands, the central Indochina dry forests eco-region supports a host of species that require this variation in habitat.

Lower Mekong Flood lands: The Lower Mekong Flood lands are far from devoid of important taxa. Particularly they are around the Tonle Sap Lake and to some extent in the Mekong Delta.

Cardamones Mountains: The main biodiversity value of the Cardamones Mountains eco-region lies in the extent of virtually intact forest.

(1) The Protected Areas

The protected areas were established by the Royal Decree "Creation and Designation of Protected Areas" signed in 1993. This Royal Decree designated a total of 23 protected areas (covering 3,267,200 ha) divided into four categories: National Parks, Wildlife Sanctuaries, Protected (Cultural) Landscapes and Multiple-Use Area. These protected areas of wild land cover 18% of the Cambodian territory. The protected areas are shown in Fig. 10-1-3 and Table 10-1-1.

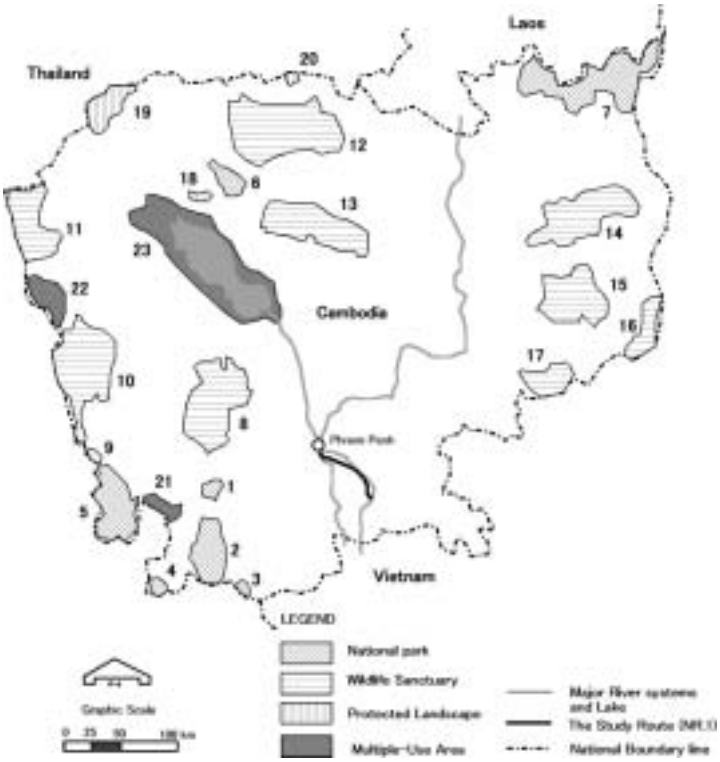


Fig. 10-1-3 Location of Protected Areas in the Kingdom of Cambodia

Table 10-1-1 Categories of Protected Areas in the Kingdom of Cambodia

Category		Area (ha)	Province
No.	Name		
National Parks		(736,250)	
1.	Kirirom	35,000	Koh Kong / Kampong Speu
2.	Phnom Bokor	140,000	Kampot
3.	Kep	5,000	Kampot
4.	Ream	15,000	Krong Preah Sihanouk
5.	Botum Sakor	171,250	Koh Kong
6.	Phnom Kulen	37,500	Siem Reap
7.	Virachy	332,500	Rattanak Kiri / Stung Treng
Wildlife Sanctuaries		(2,030,000)	
8.	Phnom Aoral	253,750	Koh Kong / Pursat / Kampong Chhnang
9.	Peam Krasob	23,750	Koh Kong
10.	Phnom Samkos	333,750	Koh Kong
11.	Roneam Daun Sam	178,750	Battambang
12.	Kulen Promptep	402,500	Siem Reap / Preah Vihear
13.	Bocung Per	242,500	Kampong Thom
14.	Lomphat	250,000	Rattanak Kiri / Mondul Kiri
15.	Phnom Prich	222,500	Mondul Kiri / Kratie
16.	Phnom Nam Lyr	47,500	Mondul Kiri
17.	Snuol	75,000	Kratie
Protected (Cultural) Landscape		(97,000)	
18.	Angkor	10,800	Siem Reap
19.	Somlot	81,200	Banteay Meanchey
20.	Tonle Sap	5,000	Preach Vihear
Multiplle-Use Area		(403,950)	
21.	Dang Peng	27,700	Koh Kong
22.	Somlot	60,000	Battambang
23.	Tonle Sap	316,250	Kampong Chhnang / Pursat / Battambang / Siem Reap / Kampong Thom

Source: Royal Decree, 'Creation and Designation of Protected Areas' 1 Nov. 1993

(2) Forest Reserve

The forest reserves constitute 3,875,100 ha and are primarily utilized for forest production. The designation of these areas reflects a long held concern for the importance of land use zoning and caters for the need to establish large reserves, especially for large “game animals”. However, the established system lacks representatives of several ecosystems in Cambodia. Table 10-1-2 and Fig. 10-1-4 show the Forest Reserve in Cambodia.

Table 10-1-2 Forest Reserve in Cambodia

Forest Classification	Area (km^2)	Area (%)
Evergreen forest	48,192	26.59%
Coniferous forest	83	0.05%
Deciduous forest	42,870	23.65%
Mixed forest	9,162	5.05%
Secondary forest	4,732	2.61%
Flooded mixed forest	2,572	1.42%
Flooded forest	3,570	1.97%
Mangrove forest	837	0.46%
Excluded forest	65,316	36.03%
Water bodies	3,925	2.17%
Total	181,259	100.00%

Source: Mekong Secretariat, Landsat Imagery, Thai Remote Sensing Center, 1992

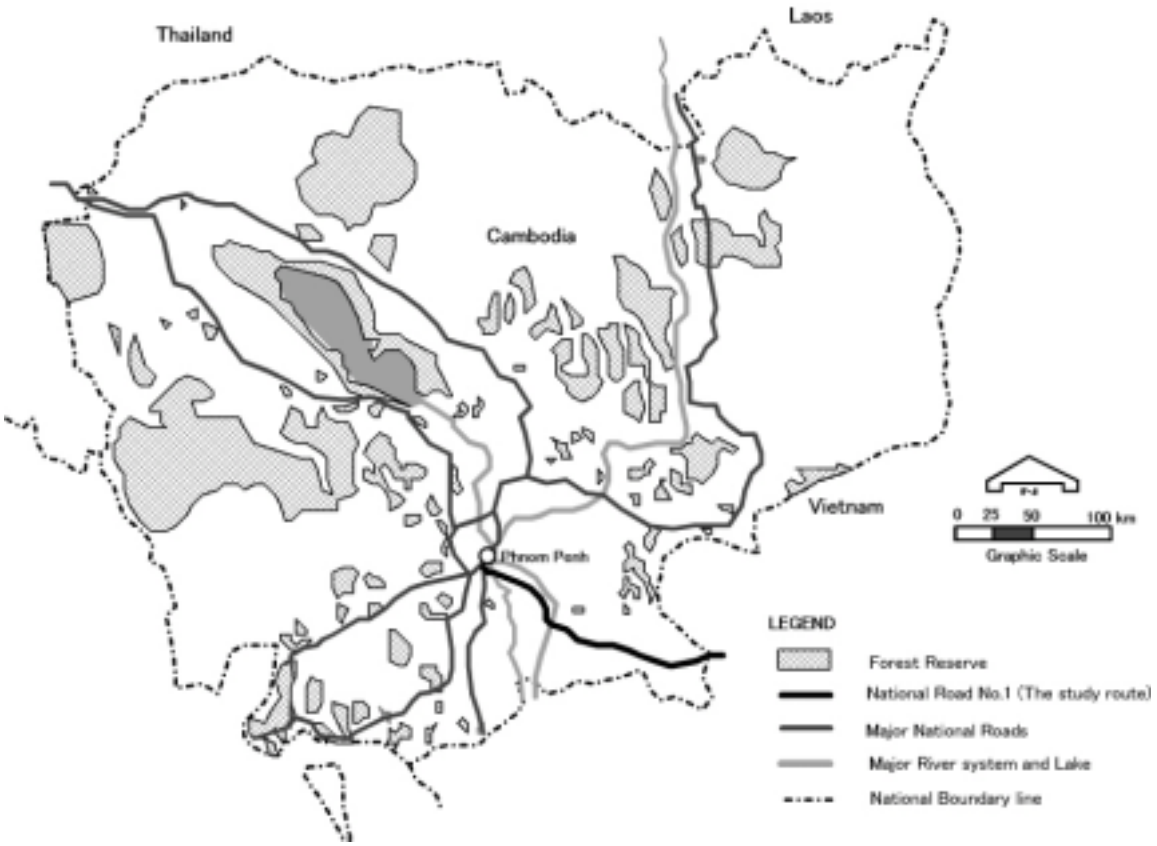


Fig. 10-1-4 Map of the Forest Reserve in the Kingdom of Cambodia

10.1.3 Outline of the Present Environment of the Study Area

The Study route of National Road No.1 (NR-1) runs for about 56 km from Monivong Bridge, Phnom Penh to Neak Loueng.

After leaving Phnom Penh the road traverses two Districts in the Province of Kandal. Fig. 10-1-2 in Section 10.1 shows the Study area.

The existing road traverses essentially rural areas except the first 3 km after Monivong bridge point and the ferry crossing at Neak Loueng, where agricultural land is interspersed with

roadside villages and towns. The road in the Monivong Bridge vicinity area has been developed as a busy commercial zone, and the Chbar Ampov market is also located there. NR-1 has 2 to 3 storey concrete-mortar buildings of shops and apartments for about 200 meters and this continues and is integrated with commercial activities.

The road from this point runs through flood land and is banked to rise up 3 to 6 meters. Buildings adjacent to the road are mostly built on concrete piles, and are typically single storey houses constructed of wooden floors and walls, and tilted roof. These serve both as shop and residence. Many storekeepers have extended their premises by encroaching onto the shoulder of the road by building wooden decks between the house and the road shoulder or sometimes mortaring part of the road shoulder.

The rising of the road on earth embankments in order to avoid flooding occurs throughout most of Kandal Province and house buildings take account of flood risk by raising houses on concrete piles. Building is very uniform, with virtually a standard design applied. This appears to reflect a preference for contract built houses, with very few rich people assuming responsibility for building their own homes. Poorer people do not have this option, but instead use natural materials to construct houses which are raised on wooden stilts.

Fig. 10-1-5 to 10-1-11 are sketches of present environmental conditions along the Study Route of NR-1.

Fig. 10-1-5 Commercial Area at Right Side of the NR-1 after Crossing Monivong Bridge

Fig. 10-1-6 NR-1 in Urban Area with Pagoda under Construction

Fig. 10-1-7 Typical Wooden House with Extended Deck at Low Laying Area at Right Side of NR-1

Fig. 10-1-8 Roadside Landscape near Tiger Beer Access Road

Fig. 10-1-9 Congested local Activities at Kokir Market Frontage at NR-1

Fig. 10-1-10 Typical Roadside Scenery with Village Bosquet and Settlement along NR-1

Fig. 10-1-11 Local Commercial Center at Neak Loueng near the End Point of the Study Route

10.2 Ordinances Related with the Environmental Impact Assessment

The Cambodia Ministry of Environment (MOE) was established in November 1993. The Law on Environmental Protection and Natural Resource Management (LEPNRM) was enacted in 1996.

The law contents are quite brief and deal mostly with overall powers of MOE. Specific details of policy and regulation are left to subsequent subordinate legislation (Sub-decrees and Prakas) some of which are now in process, covering environmental impact assessment, water pollution control, solid waste management, protected areas management, and regulation of insecticides.

The law provides opportunity for public participation in environmental protection matters, and mandates penalties for pollution and related offenses.

(1) Cambodian Land Legislation

The property rights system was introduced in 1884 during French colonization. After Cambodia gained independence from France in 1953, a Western-style land ownership system continued until 1975, when the Khmer Rouge seized power and eliminated all private property rights. Land ownership rights were reintroduced in 1989, following the failure of the Khmer Rouge regime in 1979 and ten years of unsuccessful collectivized production.

By 1989, Cambodia began reforming the entire economy towards a liberal economy and free-market system. In addition to implementing major economic reforms, the government took a further step and reintroduced private property rights in 1989.

According to Political Instruction No. 3, all land belongs to the State: “the land of the State of Cambodia is the property of the State”. At the same time, the ownership rights in force before 1975 were invalidated: “no one can claim the rights of ownership of land prior to 1979”. The Instruction also defined three categories of land, as follows:

- Land for Domicile: the provincial committee or municipality shall provide it for ownership.
- Cultivation land: Agricultural land is for production and exploitation. It is state land allocated for the farmers to manage and use for production and exploitation.

- Concession land: Greater than 5 hectares. Concession provides the right to occupy land for large-scale crop production, which will contribute, to the national economy.

(2) Current Land Legislation

Current land legislation is based on the new Land Law of August 2001 by the Ministry of Land and Management, Urban Planning and Construction. This supersedes any previous laws though several Articles as follows:

Article 4 describes that the right of ownership, recognized by article 44 of the Constitution, applies to all land and all buildings and constructions within the national territory in accordance with the conditions lay down by this statute. Goods are referred to as immovable goods.

Article 7 describes that the State does not recognize land property rights existing before 1979."

Current legislation recognizes Right of Occupation as a claim to ownership through Article 30 of the Land Law which states that "if any tentative possessor peacefully, honestly, publicly without ambiguity occupies land for five consecutive years and the land is free with no record in the enrollment register and does not belong to anybody, the tentative possessor shall become the owner."

(3) Land Acquisition

Government ownership of land is again defined in Article 10 of the Land Law as "The State is the owner of the immovable goods of the national territory enumerated in article 58 of the Constitution and of all property which is escheat or which has not been the subject of a due and proper private appropriation or which is not in the process of being appropriated pursuant to the provision of chapter 4 of this statute."

While Article 13 of the Land Law stipulates that the following property falls within the public domain of the State and public bodies:

- Property with a specific natural constitution, such as courses of navigable or floatable water, natural lakes, banks of navigable and floatable rivers and sea shores.
- Property, which is specially, developed for general use, such as quays of harbors, railways, stations and airports.
- Property, which is made available, either in its natural state or after development, to the public, such as roads, pathways, gardens and public parks.
- Property, which is allocated to render a service to the public, such as schools or educational institutions and administrative buildings.
- Property which is a natural resource protected by law.

Article 44 of the Constitution of the Kingdom of Cambodia (1993) states that the government has "the right to confiscate properties from any person shall be exercised only in the public interest as provided for under law and shall require fair and just compensation in advance", while Article 20 maintains that "Nobody shall be forced to transfer his/her ownership, if forcing is not necessary in the public interest and (if) no proper and just indemnity has been paid to the owner."

However, the article 48 of the Land Law stipulates that "Property within the public domain of the State can in no case be the subject acquisitive possession. The situation of an occupant of the public domain of the State remains precarious and illegal if such occupation does not arise from contractual title or any authorization of the type expressly provided by law.

The illegal occupant must be requested to vacate the premises immediately. Such occupant incurs sanctions in accordance with article 259. The illegal occupant is not entitled to any indemnity for any works and improvements carried out on the land or the building.

In general, the Government of Cambodia possesses the Right of Way for National Roads of 25 meters from the center of road, and this provision was based on pre-1975 practices. However, according to the Prime Minister Declaration on 27 September 1999, the Right Of Way (ROW) of National Road Nos. 1, 4 and 5 is set 30 meters from the center of road in the rural areas. For the urban areas, this ROW varies (flexible), but is not less than 15 meters from the center of road.

Regarding land acquisition, the current procedure of land acquisition is described in the following section 10.5.

(4) Land Registration:

The right of private ownership was re-established in 1989 by allowing Cambodians to register their owner of land use and possession was granted which is as good as a title deed. Land registration today is conducted by the Land Cadastral Department, which is under the Ministry of Land Management, Urban Planning and Construction. The issuance of the title deed is a lengthy process and most respondents interviewed have applied for land title but have yet to receive any document other than the initial receipt. In the absence of other documentation, this is taken as title for land purchases and sales.

10.2.1 Law of Environmental Impact Assessment (EIA)

The Law on Environmental Protection and Natural Resource Management (LEPNRM) was enacted in 1996 as mentioned in above section 10.2. Initial Environmental Impact Assessment (IEIA) is always conducted on the objective project in the same manner of Environmental Impact Assessment (EIA) in accordance with provisions of LEPNRM. The necessity of EIA fully depends upon the judgment of MOE after MOE examines the IEIA report. Therefore, EIA may undertake additionally detailed survey and investigation on selected items in case that MOE should judge the necessity of EIA. It may interpret that EIA in this report expresses the general term of procedure specified in LEPNRM including IEIA.

Followings show major contents of the Law of Environmental Impact Assessment.

Article 6 and 7 in the chapter 3: EIA makes the provision that almost all projects, and private or public activities, will require EIA prior to approval, subject to criteria and procedures to be established by sub-decree pursuant to the law.

Article 6 describes that EIA shall be done on required projects and activities private or public, and shall be reviewed and evaluated by MOE before being submitted to the Royal Government

for decision. This assessment shall also be done for existing and in-process activities that have not yet been assessed for environmental impact.

The procedures of the environmental impact assessment shall be determined by sub-decree following the proposal of MOE. The nature and size of the proposed projects and activities and existing and in-process activities, both private and public that shall be subject to EIA that shall be determined by sub-decree following the proposal of MOE.

Article 7 describes that All Investment Project Applications and all projects proposed by the State shall have EIA as specified in article 6 of this law. MOE shall review and provide recommendations on EIA to the competent organization within the period determined in the Law on Investment of the Kingdom of Cambodia.

Also note that, the sub-decree for EIA processes (No. 72 ANRK.BK) was signed on August 11th 1999 by the Prime Minister.

Article 1 of this sub-decree has the objective to define EIA on required projects and activities of private or public sector which are being examined and evaluated by the MOE before being submitted to the Royal Government for decision. Also it defines the nature and size of the proposed activities together with the existing and on-going activities of both private and public sector to be assessed for Environmental Impact. Public participation is encouraged in EIA implementation in order to take ideas and suggestions into consideration for project approval.

Article 6 of the sub-decree prescribes that the Project's Owner shall provide the IEIA report first in case that EIA may be required as it is mentioned in the Annex of the sub-decree.

List of the projects that may require EIA has been issued in August 1999 by MOE. These include industrial, agriculture, tourism and infrastructure development. This Study belongs to the category of infrastructure project. The following 13 infrastructural activities and projects may require EIA in accordance with their size and capacity.

1) Urbanization development: Required for all sizes
2) Industrial zones: Required for all sizes
3) Construction of bridge-road: Required for capacity of 30 tons weight and more
4) Buildings: Required for height more than 12 meters or floors more than 8,000 m^2
5) Restaurants: Required for capacity of 500 seats and more
6) Hotels: Required for capacity of 60 rooms and more
7) Hotel adjacent to coastal area: Required for capacity of 40 rooms and more
8) National road construction: Required for length of 100 km and more
9) Railway construction: Required for all sizes
10) Port construction: Required for all sizes
11) Airport construction: Required for all sizes
12) Dredging: Required for size of 50,000 m^3 and more
13) Camping site: Required capacity of 200,000 people and more

Many ministries besides MOE have responsibilities for aspects of environmental management, through their mandates in public health (MOH), agricultural and forestry regulation (MAFF), industry policy (MIME), tourism (MOT), transportation and public infrastructure (MPWT) and the overall coordination of public and private investment (CDC). The government is making

efforts to develop appropriate coordination among these agencies for environmental management. One of the corollary objectives of the present project will be to facilitate the growth of that system, by encouraging environmentally responsible behavior on the part of urban construction legislation.

10.2.2 Legal Procedure of EIA and IEIA

EIA is managed by the Department of Environmental Impact Assessment and Review of the MOE. Fig. 10-2-1 shows organization chart of MOE and Fig.10-2-2 shows organization of Department of EIA and Review. The procedure chart on Environmental Impact Assessment (EIA) is shown in Fig. 10-2-3 and IEIA procedure on the Study Project is shown shortest flow line on the bottom in consequence of MOE approval letter to MPWT .

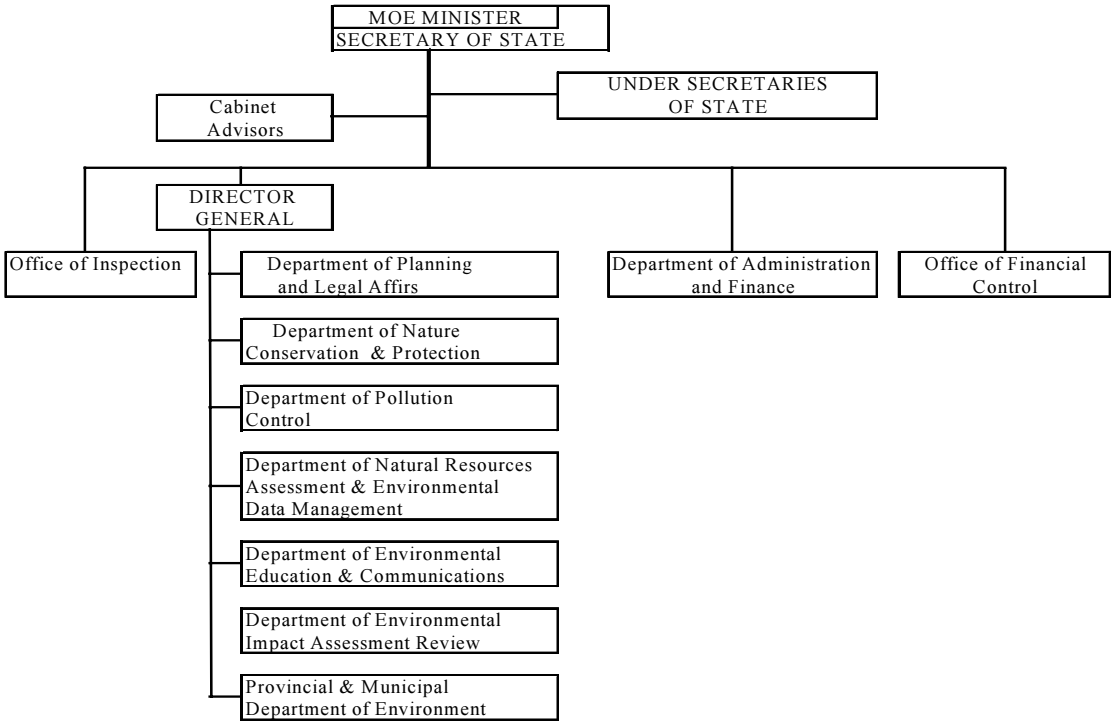


Fig. 10-2-1 Organization Chart of MOE

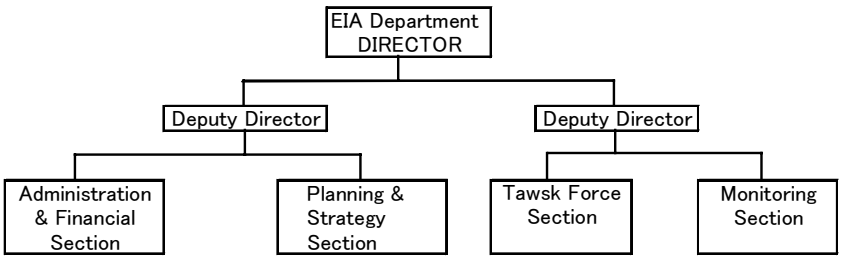
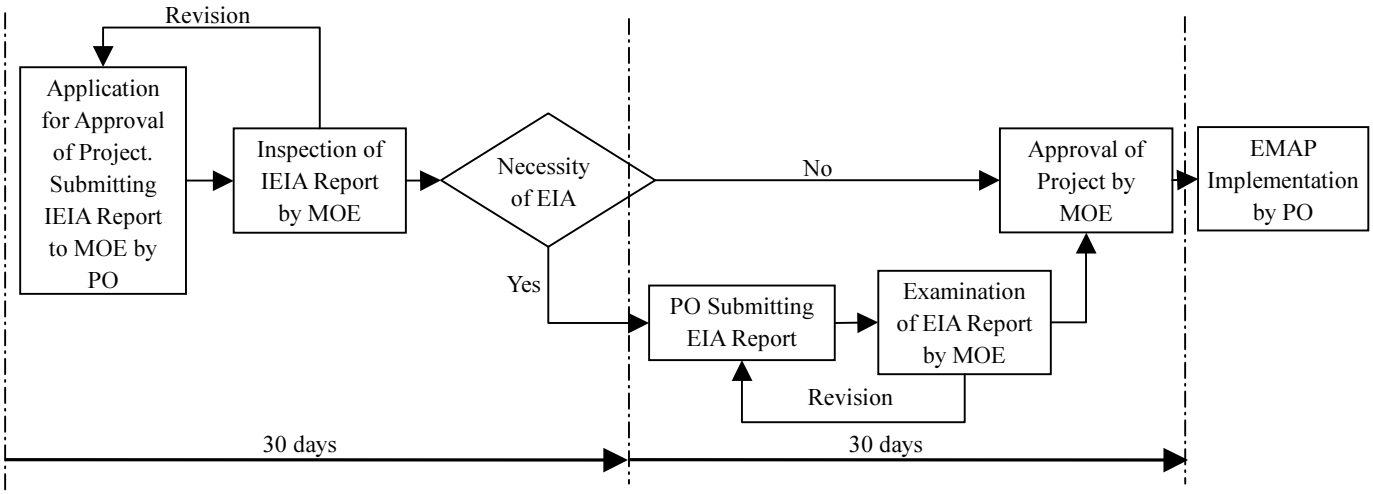


Fig. 10-2-2 Organization Chart of EIA Department of MOE



EIA: Environmental Impact Assessment, EMP: Environmental Management Action Plan
IEIA: Initial Environmental Management Plan MOE: Ministry of Environment PO: Project Owner,

Fig. 10-2-3 Flow Chart of EIA Procedure

It notes that the IEIA report on this project has been evaluated by MOE not to require EIA, and MOE has issued the approval letter to MPWT without EIA.

10.2.3 EIA Process with the Cambodian Law

Department of Environmental Impact Assessment prepared a guideline format for conducting EIA. This is based on a reference to Sub-decree on EIA Process, No.72 ANKR.BK dated 11th August 1999 and also a reference to Prakas (Declaration) on Guidelines for preparing EIA Report, No.49 BST.SSR Dated 9th March 2000.

Guideline for conducting Environmental Impact Assessment (EIA):

The Project's owner should prepare EIA Report to abide by this guideline; at least, EIA Report should be described as follows:

(1) Project Summary:

The project's owner should describe in short form with identification of project's goals and main objectives, methodologies, and key measures for reduction of environmental impacts in the EIA Report.

(2) Introduction:

a) Type, size, and location of the project
b) Background of the project's location
c) Within the framework of national and international laws and legislation standards.

(3) Purpose of the Project:

Project's owner should clearly explain about purpose of the project for present and future.

(4) Project Description:

a) Brief alternatives: size, location, timeframe (stages of project construction, project

operation, and project abandonment or closure) and sources of labor force.

b) The production process: sources and quantity of raw materials to be used and finished products.
c) Machinery requirement to run the project
d) Methodologies of waste disposals in order to determine any environmental impacts.
e) Description about the quantity and quality of solid and liquid waste to be disposed and discharged, sources of noise and vibration resulting from the process of this project (construction, operation) and the emission of dust particles into the atmosphere.
f) Project planning

(5) Description of Environmental Resources:

This part should describe all environmental resources needed such as:

a) Physical resources: Air (speed, quality, regime, climate,), Water (surface and ground-water quality, currents, and quality,), Land (Soil quality, relief, geology)
b) Ecological resources: Bio-diversity, Fauna, Flora and Forest, etc.
c) Socio-economical resources: Population and their settlement, Infrastructure, Land use, Public health and welfare and Condition of economic (livelihood, profession, and community)

(6) Public Participation:

All opinions given by the public in the EIA process should be addressed which can contribute to the decision making process. Public participation includes:

a) Local authorities and institutions involved, Opinion of public towards the development project

b) Consultation, Company interpretation

(7) Environmental Impact Analysis

All significant environmental impacts resulting from the project should be described in this part which includes:

a) Methodologies to identify the scope of the environmental impacts (by using the Matrix table)
b) Environmental impacts during project construction
c) Environmental impacts during project operation
d) Environmental impacts after the project abandonment or closure stage
e) The extent and kinds of significant accumulative environmental impact.

(8) Environmental Impact Mitigation Measures:

The environmental impacts stated above should be assessed by the project's owner in order to define specific environmental impact mitigation measures.

(9) Economical Analysis and the Environmental value:

In this part the project's owner should indicate the benefits of the project comparing the value or cost of local environmental damage.

(10) Environmental Management Plan:

The Environmental Management Plan is an important program implemented by the project's owner and other institutions involved. These plans include:

The Environmental Protection Measures in the stages of:

a) Project construction
b) Project implementation
c) Project abandonment or closure.

The Environmental Monitoring Program in the stages of:

a) Project construction
b) Project implementation
c) Project abandonment or closure.

(11) Institutional capacity:

In this part, the project's owner should demonstrate that he has institutional capacity to carry out the work associated with the execution of the EIA, and the implementation of the mitigation measures such as:

a) Organization structure
b) Budget / Schedule
c) Staff skills
d) Methodological tools and equipment

(12) Conclusion and Suggestion:

In this part the project's owner has to include assessment of environmental impacts both positive and negative aspects with full accountability and responsibility in the process of reporting EIA as well as addressing possible suggestions implicated in the project.

10.3 IEIA on the Study Route

10.3.1 Study Background

In June 2002, the JICA Study Team contracted a local consulting firm, the Khmer Consultant Engineering Corporation Ltd (KCEC) to conduct an IEIA and ISIA as part of the Study in accordance with the relevant laws and regulations in Cambodia and JICA Guideline. Although the resettlement issue is not included in EIA process of the law of Cambodia at present, the scope of work for KCEC to conduct IEIA and ISIA was set by the study team to add the following items to the standard process specified in the Cambodia law as described in 10.2.3:

1) Addition to (6) Public Participation:

c) Public information, explanatory of project scope and hearing include grievance at each district and commune level at the time of IRC sub-working group surveys.

2) Addition to (10) Environmental Management Plan:

The Resettlement Action Plan in the stages of:

a) IRC sub-working group survey for affected houses and households
b) Compensation for Project Affected Persons (PAPs)
c) Resettlement and Procedure for avoiding difficulties and frictions

The IEIA report was prepared by MPWT in assistance with the JICA study team and the local consultant KCEC. KCEC organized three parties of survey team with 15 numbers of researchers and assistants under the tow professional representatives of the firm. KCEC team made survey in corporate with JICA study team. In the IEIA report recommendation on environmental conservation measures, management and control were made together with outline cost estimate for environmental mitigation measures and expected impacts caused by the improvement of NR-1 were evaluated.

MPWT submitted the IEIA report to MOE, and the Department of Environmental Impact Assessment Review and Monitoring of MOE evaluated the IEIA report. After the review of the report, MOE issued an approval letter on the project to MPWT in mid of November.

10.3.2 General description of the Study Area

The Study Route of National Road No.1 (NR-1) runs about 56 km from Phnom Penh to Neak Loueng. After leaving Phnom Penh, the road traverses two Districts in the Province of Kandal as shown in Fig. 10-3-1.

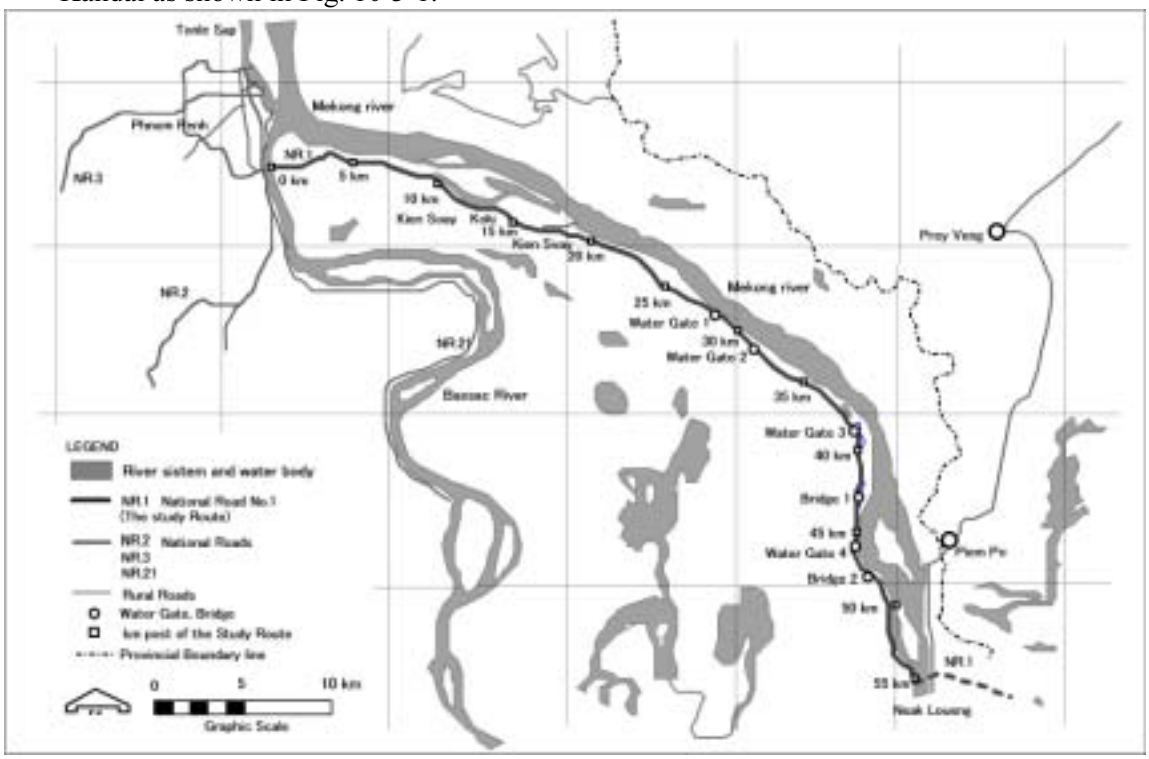


Fig. 10-3-1 Study Route of NR-1

Development along the existing road is essentially rural, with agricultural land being

interspersed with roadside villages and towns. Only two distinct urban sectors are found and these are the first 3 km after the Monivong Bridge and the ferry crossing at Neak Loueng. The road is the subject to heavy commercial development from Monivong Bridge to the end of border of Phnom Penh city 5 km after Monivong Bridge. The Chbar Ampov market is located by the bridge and is a major transshipment point for goods coming from south-east Cambodia and from Vietnam.

NR-1 at this point is flanked by 2 or 3 storey concrete-mortar shops and apartments for about 200 meters and this continues to be the focus of intensive commercial activities with virtually a continuous facade of local shops on each side for 3 km. The road at this point runs through flood land and is banked to a height of between 3 to 6 meters. Buildings adjacent to the road have almost all been built on mortar stilts, and are typically single storey dwellings constructed of wooden floors and walls and tilted roof. These serve both as shop and residence, with the family cooking and sleeping in the back. Many storekeepers have extended their premises by encroaching onto the shoulder of the road by building wooden decks between the dwelling and the road shoulder or by cementing part of the shoulder.

The road between Phnom Penh and the ferry at Neak Loueng measures 56 kms.

The rising of the road on earth embankments in order to avoid flooding occurs throughout much of Kandal Province and house building takes account of flood risk by raising dwellings on stilts. Buildings are remarkably uniform, with virtually a standard design being used. This appears to reflect a preference for contract built houses, which very few wealthier people assuming responsibility for building their own homes but instead hiring specialist teams. Poorer people do not have this option but instead use natural materials to construct houses which are raised on wooden stilts.

10.3.3 Study Objectives and Method

The Study area covers an area along NR-1, Monivong Bridge to Neak Loueng section and the vicinity areas that are presumed to be affected by the project. The objective of this assessment was to evaluate the expected impact which might be caused by the road widening and improvement. The major study items are as follows:

1) Social Environmental conditions
2) Natural Environmental conditions
3) Current Status of Air and Water Pollution and noise level

IEIA analysis has been made in accordance with the relevant laws and regulations of the MOE which states that large scale development project is subjected to IEIA firstly and to EIA later. Major work items of the Study are:

1) The collection of the basic data on social environment, natural environment, current status of air and water pollution, noise, and resettlement.
2) The interpretation and validation of the data.
3) The analysis of different schemes for Initial Environmental Impact Assessment (IEIA) and Initial Social Impact Assessment (ISIA). ISIA includes hearing survey for project affected persons on status of households, vocations and income levels. Also includes counting project affected houses, structures and assets.

4) Conclusion and recommendation of a solution as well as subsequent work for the implementation of the project.

Methods:

For the social environmental survey, resettlement questionnaire has been prepared and field surveyors have been selected to take part in this study. The survey area is predetermined to be a "Right of Way" of 30 meters on each side of the road from the centerline along NR-1. All households within this corridor were surveyed. A range of questions were made about the households and an assessment of the value of property such as houses, fences and trees was carried out.

The survey teams investigated one household every 100 meters. Within this 100 meters section, surveyors also determined the number of households (on both sides of the road) and estimated the cost of everything that could be compensated. Survey team pursued sampling at every 100 meters interval and total of potentially affected households was precisely determined. This sampling survey was used in rural areas.

In urban areas, households were surveyed at 50 meters interval using the same method. The urban areas were identified along NR-1 as Kokir, Prek Aeng, Neak Loueng and Chbar Ampov, which were at 0.4, 0.5, 0.9 and 2.0 km, respectively.

10.3.4 Social Environment

This Section sets out the contents of the study, and various findings as follows:

(1) Administrative Superintendence of the Local Districts and Areas

There are two dense populated places along the road from Monivong Bridge to Neak Loueng. First is the Chbar Ampov market which is adjacent to Monivong Bridge. This market is used for vegetable wholesalers and retailers, as well as for distribution of imported food. The second is Kien Svay district town. This town consists of local market called Kokir, where villagers can sell their products, especially fruits and food. In addition, there are three urban areas: namely, Kandal Leu, Kandal Kraom and Prek Ta Kaev villages.

(2) Local Community and population

There are three districts located along the Study area of NR-1. Those are Mean Chey, Kien Svay and Leuk Daek districts. In terms of number of communes, Kien Svay district was the largest one. In nine communes of Kien Svay district, there were 28,535 households; this equals to 148,358 inhabitants including 70,930 males and 77,428 females. In three communes of Mean Chey district, there were 27,443 households that equal to 157,112 inhabitants including 74,500 males and 82,612 females. In two communes of Leuk Daek district, there were 9,811 households that equal to 52,976 inhabitants including 25,487 males and 27,489 females.

From Monivong Bridge to Neak Loueng, the road runs across 14 communes and 42 villages. Of these, eight villages are in the three communes of Mean Chey district, 29 villages are in the 9 communes of Kien Svay district and 5 villages are in the 2 communes of Leuk Daek district. Numbers of households and population of the Study area along

NR-1 for each District and Commune are shown in the Table H-3 in Appendix.

(3) Economic activities and conditions

1) Income distribution of local peoples along the Study route.

The Socio-Economic survey reports that rural areas have the highest levels of poverty (43%), with 39% of the total population of Cambodia living below the poverty line. In 1998 the per capita income was estimated at US$ 280. The highest poverty rates were reported among farmers (46%). More than three quarters of the poor were lived in households headed by farmers. Poverty rates fell with level of schooling and were lower among female-headed households (35%) and higher among male-headed households (40%).

The Cambodia Poverty Assessment (1999) concludes "the poor will benefit most from policies that improve the functioning of the markets, including those for agricultural commodities, inputs and rural credit. Earnings and income from the household head as well as contributions from other family member contributions determine key sources of livelihood, for the poor. The household head is usually the most important member linked to employment characteristics of the household. The following Table 10-3-1 shows the monthly mean income for each of the income quintiles of the interviewed households along the Study route.

Table 10-3-1 Average Monthly and Annual Income by Sex of Head of Households by Quintile

Quintile (Each 20%)	Monthly mean Average income		Annual mean average for males & female heads of households		Male head of household mean annual income (middle)		Female head of household annual income (middle)	
	Riels	US$	Riels	US$	Riels	US$	Riels	US$
Lowest quintile	27,808	7	333,704	85	324,432	83	357,638	92
					(320,000)	(82)	(380,000)	(97)
Second quintile	71,681	18	860,167	220	869,092	223	832,113	213
					(865,000)	(221)	(805,000)	(206)
Third quintile	124,099	39	1,489,792	382	1,490,396	382	1,487,299	381
					(1,465,000)	(377)	(1,460,000)	(374)
Four quintile	201,480	52	2,417,770	620	2,416,093	620	2,426,253	622
					(2,362,500)	(606)	(2,441,500)	(626)
Highest quintile	606,124	155	7,273,486	1,865	6,896,445	1,768	9,226,178	2,366
					(4,668,000)	(1,197)	(5,270,000)	(1,351)
Mean (middle)	208,494	53	2,501,922	641	2,399,292	615	2,865,896	734

The above table reveals that females in the lowest quintile earn slightly more than males per month while on average they earn more in the top quintile. However female head of households have a higher proportion (about 50%) concentrated in the lowest two quintiles proportionate to men.

2) Social employment structure and monthly income level

891 respondents in the resettlement survey consist of 358 male (40.2%) and 382 female (42.9%), and the remained of 151 (17.0%) had no information on the distinction of sex. Among 740 samples of male and female, monthly average income level is analyzed in

nine categories of occupational group as shown in Table 10-3-2.

Table 10-3-2 Income Level of Occupational Groups

No.	Occupation head of household	Monthly mean average income			
		Male		Female	
		(Riels)	eqv. (US$)	(Riels)	eqv. (US$)
1	Government Officials	503,884	126.3	180,760	45.3
2	Professional	462,683	116.0	290,513	72.8
3	Business	279,711	70.1	750,303	188.0
4	Private employee	728,812	182.7	102,269	25.6
5	Farmer, Fisherman	154,190	38.6	145,378	36.4
6	NGO or International Organization	172,448	43.2	211,974	53.1
7	Labor or unskilled worker	251,431	63.0	196,304	49.2
8	Retired/Pensioner	298,639	74.8	83,750	21.0
9	Others	291,122	73.0	225,822	56.6

Note: Exchange rate of 1US$=3,990Riels is adopted for reference.

3) Occupational situation of the local peoples

Agricultural sector is the major group sharing local population, the second occupation group was government officials (7.3%), with 8.6% male heads of households and only 3% of female heads of households reportedly government officials. The next important occupational sector was "businessman" which constituted 4% female and 3.5% male heads of households. Laborers and unskilled workers were evenly spread across males and females at 3%. A very small number, 1% reported as professional with twice as many females than males in this category. Less than one percent reported as retired or pensioners. However, all 891 respondents interviewed in the resettlement survey falls into various occupational groups as shown in Table 10-3-3.

Table 10-3-3 Occupation of All Interviewed 891 Respondents

No.	Occupation	No. of person	%
1	Farmer	195	21.89
2	Police man	32	3.59
3	Small business	172	19.30
4	Government staff	65	7.30
5	Student	28	3.14
6	Repair (Motor or Bicycle)	20	2.24
7	Home keeper	98	11.00

No.	Occupation	No. of person	%
8	Enterprise	36	4.04
9	Laborer	26	2.92
10	Retired	15	1.68
11	Motor Taxi	14	1.57
12	Fisherman	2	0.22
13	Driver	4	0.45
14	No information	184	20.65
Total		891	100.00

(4) Public Facilities distribution

The Study area has public facilities such as schools, hospitals and electric sub-stations. There is water supply distribution system already installed 1 km from Monivong Bridge which is supplied by Water Supply Authority; however, some areas have private water supply and most people use water from the wells or rivers and lakes. For electricity, they use battery or other sources. Meanwhile optical fiber communication system has being

installed in the vicinity area around Monivong Bridge. Main public facilities at different points are given in Table 10-3-4.

Table 10-3-4 Main institutional public facilities at different point of Km

No.	Facility	Km	Remarks
1	Market	0+100	Chbar Anpov
2	Market	6+000	Prek Aeng
3	Hospital	9+900	Khbal Kaoh
4	Market	13+600	Kokir
5	Hospital	13+900	Bang Aek Srok Kien Svay

(5) Land Use of the Study area

The land use pattern in the area is mostly used for agricultural activity including cultivation areas and rice field. Some of the land is used for other purposes such as factories/enterprises, livestock farm and petrol stations. Fig.10-3-2 shows the land use pattern in the Study area.

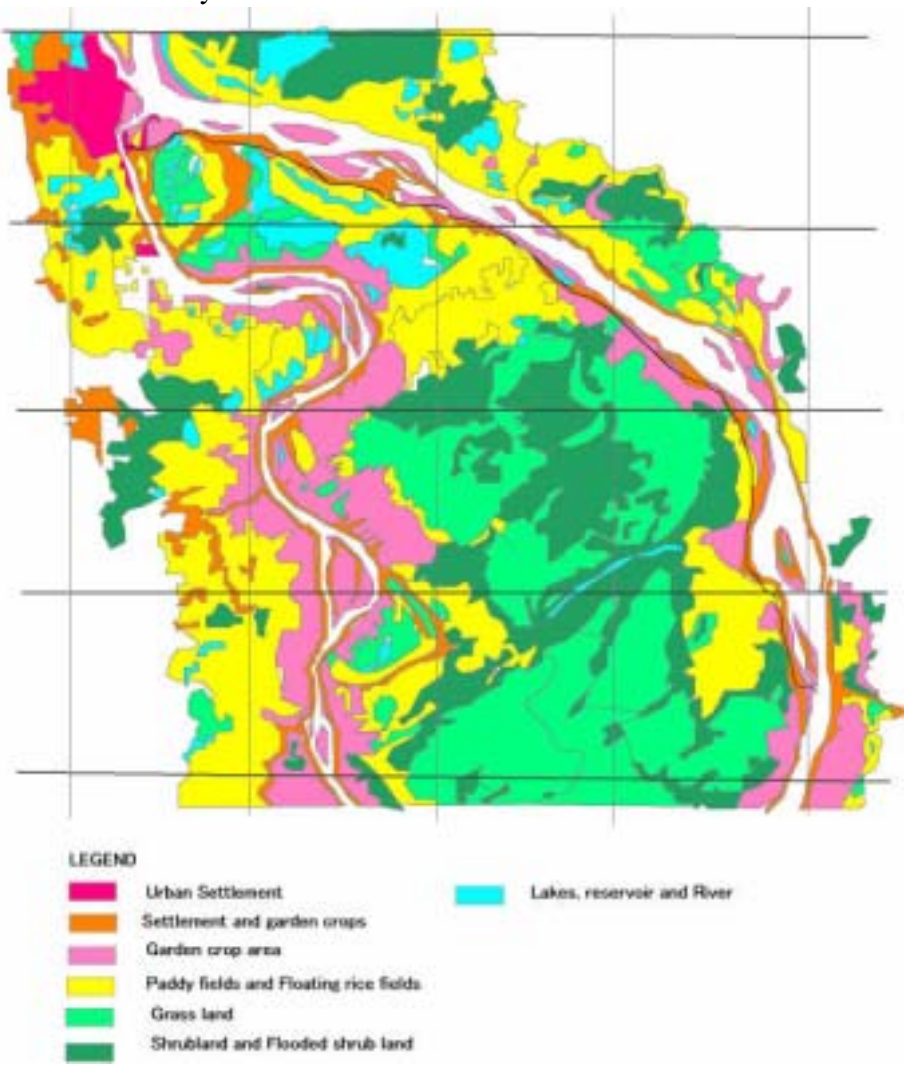


Fig. 10-3-2 Landuse Pattern in the Study Area

1) Land use and current use of road side area.

As majority of villagers are farmers who grow fruit trees and vegetable and rice, the land use pattern in those three villages of the Study area is mainly used for agricultural use.

Beside this, the land is also used for other purposes such as factories and enterprises, livestock farm and petroleum stations.

Regarding the land use of the road side area, actually the land belongs to the right of way (ROW) occupied by settlers. Current use of road side area was analyzed and identified through the interview with settlers. Among the 891 samples, quite high portions (98%) of case settlers use the roadside area as detailed in Table 10-3-5. Also quite few of them (1.7%) have property right within the ROW.

Table 10-3-5 Current Use of the Road Side Area and Use of Land with Property Right

Use of the roadside area	No. of sample	%
in Use	827	92.82
Not used	12	1.35
Temporally use	52	5.84
Total	891	100.00

ROW or having property right	No. of sample	%
Use of land within ROW	754	84.62
Having Property right in ROW	15	1.68
No information	122	13.69
Total	891	100.00

Generally land use of those settlements is categorized into eight types, mostly residential use with fruit tree planting as shown in Table 10-3-6.

Table 10-3-6 Land Use Type of the Household

No.	Land use type	No. of sample	%
1	Rice	2	0.22
2	Kitchen garden vegetable & plant	15	1.68
3	Vegetables for sell	4	0.45
4	Fruit tree	286 (465)	20.09
5	Fishery / Lotus plant	0	0.00
6	Bus station / Storage	6	0.67
7	Residence	607	68.13
8	Small Store	78	8.75
Total		891	100.00
No.	Other use of land	No. of sample	%
1	Fence	90	10.10
2	House	10	1.12
3	Well	2	0.22
4	Shop	15	1.68
5	Kitchen garden	2	0.22
6	No information	772	86.64
Total		891	100.00

Note: Figure in ( ) shows actual case together with residential use.

(6) Historical Monuments, Ruins, cultural assets and religious facilities

The Study area generally consists of residential villages and agricultural area, and there is not any historical ruins related to Angkorean and pre-Angkorean era registered in the Study area; nor there any historical temple or monument registered. There is a lot of Buddhist temples located along the road. Those temples are not affected by the road improvement project due to the extension of the road's boundary; however, some of their fences will be affected. Main cultural assets and religious facilities along the Study Route are shown in Table 10-3-7.

Table 10-3-7 Main Cultural Assets and Religious Facilities at Different Point of Km

No.	Facility	Km Point	Remarks
1	Pagoda	1+200	Nirouth Rangsey
2	Pagoda	3+900	Chheu Teal Khpos
3	Primary School	6+100	Prek Aeng
4	Pagoda	8+100	Muchheum Voan
5	Pagoda	9+000	Cham Pha
6	Pagoda	9+100	Chan Rangsey
7	Primary School	10+300	Yok Bat
8	Pagoda	10+500	Kien Svay Khnong
9	Pagoda	11+200	Chitaram
10	Pagoda	12+200	Kien Svay Krau
11	School	12+200	Rasmey Sammaky
12	Pagoda	14+300	Vanntamul
13	Pagoda	15+200	Slakaet
14	School	15+200	Slakaet
15	Pagoda	16+300	Sutharam
16	Pagoda	17+650	Dei Edth
17	School	17+700	Chey Voramann Ramon 7
18	Pagoda	18+700	Enn Prum Broey
19	School	20+500	Sdau Kanlaeng
20	School	35+100	Hun Sen Samrong Thum
21	Pagoda	39+600	Dei Dosh
22	Pagoda	49+200	Kampong Phnom
23	School	54+900	Kampong Chamlang

(7) Human Interest

1) Peoples interest on the road improvement project

One of the most interested topics of the NR-1 improvement project for local peoples are either their assets are affected or not and how they are thinking on the project. Through the interview process for these issues, following data were collected and analyzed as shown in Table 10-3-8. Among the 891 respondents, most of them are affirmative opinion for the NR-1 improvement project and 4.9% of them are considered to be having negative opinion.

Table 10-3-8 Peoples Interest on the Road Improvement Project

No.	People's interest on the project	No. of sample	%
	Affirmative opinions		
1	Never confuse if needed	189	21.2
2	Need some compensation, If house is affected	301	33.8
3	Affect some part of the house	58	6.5
4	Affect some part of land	45	5.1
5	Will discuses if house is affected or remove	7	0.8
6	Project is needed for prevent traffic accident	6	0.7
7	No body stay in the house	51	5.7
8	No house and land for live	67	7.5
9	Un-used land for affected area	10	1.1
10	Affected all of the house	22	2.5
11	It will be happy for improvement	17	1.9
12	No information & comment	74	8.3
	Negative opinions		
13	No need for widen the road	8	0.9
14	Not response or unhappy for improvement	36	4.0
Total		891	100.0

2) Status of house ownership and year of construction

Regarding the status of house and building, ownership and year of construction of the

house and buildings were analyzed with compensation objective. By law, houses and buildings which built before the year of 1996, are to be given right of property for the settlers. Interviews with the settlers were conducted from Monivong Bridge to 6.9 km point for collecting information on the status of tendency. Table 10-3-9 shows the status of ownership portion of house and building, Table 10-3-10 provides year of construction by four building structure types, Table 10-3-11 shows year of construction by three building usage types and Table 10-3-12 classifies year of construction by the status of ownership.

Table 10-3-9 Status of House Ownership

No.	Status of house ownership	No. of sample	%
1	Owners	677	75.98
2	Tenant	24	2.69
3	No information	188	21.10
Total		891	100.0

Table 10-3-10 Year of Construction by Type of Building

No.	Year of construction	Wooden	Concrete	Bamboo	Others	Total
1	Before 1996	103	9	0	1	113
2	After 1996	22	3	2	0	27
Total		125	12	2	1	140

Table 10-3-11 Year of Construction by Use of Building Status

No.	Year of construction	House	Shop	Others	Total
1	Before 1996	94	14	4	112
2	After 1996	23	5	0	28
Total		117	19	4	140

Table 10-3-12 Year of Construction by Building Tenure

No.	Year of construction	Rent	Ownership	No Ownership	Total
1	Before 1996	5	105	0	110
2	After 1996	2	24	4	30
Total		7	129	4	140

3) Infections of insect borne diseases

The Study area as same as in most area of Cambodia, there is a common fear of spread of insect-borne diseases such as malaria, dengue fever and schistosomisis when adequate sanitation, waste disposal and adequate health care are not provided in the settled area, especially it is anticipated for construction workers at their camps.

4) HIV /AIDS as a specific health problem

Also recently, since the population mobility, poverty, and illicit drug use in Cambodia are factors contribute directly or indirectly to the rapid spread of HIV/AIDS. By signing a memorandum of understanding on HIV/AIDS has been, a common

understanding was reached among ASEAN countries; campaign was spread headed from September to December in 2001 on the behavioral change communication, sexually transmitted infections, service including counseling and condom promotion should be provided to mobile populations such as transport operators and construction workers from sending. Integration of HIV prevention program as a precondition for construction activity of infrastructure project would be expected to reduce HIV vulnerability for mobile population. Also in November 1999, Chiang Rai Recommendation (Key Policy Recommendation of Chiang Rai ASEAN Consultation) has been endorsed by the ASEAN taskforce on AIDS that the member countries of ASEAN recommends that ASEAN governments adopt a common policy requiring contractors/commercial developers/ investors in major construction projects to fund HIV prevention strategy and program in their activities as a pre-condition of approval of construction project. Table 10-3-13 shows HIV infection case and AIDS reported to National Center for HIV/AIDS in recent years.

Table 10-3-13 HIV Infection, AIDS Reported to National Center for HIV/AIDS

Year	HIV infection case	AIDS case	AIDS deaths case
1992	91		
1993	204	1	0
1994	646	14	9
1995	2,520	91	15
1996	4,241	300	72
1997	4,102	572	69
1998	6,152	1,494	229
1999	7,726	2,556	314
2000	13,854	3,684	533

Source: Dermatology and STDs, Health Information System Unit, Ministry of Health

10.3.5 Project Affected Persons (PAPs)

(1) Project affected persons

Based on the Prime Minister Declaration on 27 September 1999, the ROW of National Road No.1 (NR-1) is 60 meters in rural and it is varied and flexible in urban area but not less than 30 meters. A tentative ROW will be announced within the permanent ROW (60 meters) by MPWT to keep necessary space for road improvement, and all the precarious and illegal occupants within a tentative ROW should be resettled outside the boundary by the due procedure in accordance with the Prime Minister Declaration on 27 September 1999. Adoption of tentative ROW of 30 meters has been confirmed in the course of study.

Within the tentative ROW of 30 meters (15 meters from the center of road), detail survey on affected houses and structures was conducted during September to early October. Affected house and building types were identified as zinc plate roofed house, roofing tiled, leaf roofed and concrete building on the site throughout the NR-1. Also for structure, fence types were identified as concrete, wooden and barbed wire fence.

The survey result shows that three mains assets of households are affected: The house, the fence and the fruit trees. The information on the type of house, the fence style and the fruit tree species affected are presented in Table 10-3-14. Detailed inventory of affected houses and structures by each 500-meter intervals in both left side and right side of the road is available in Appendix Table H-4-1 to Table H-4-4.

Table 10-3-14 Affected Houses and Structures (15 meters from the Road Center on Both Sides)

Station (Km)	Affected House/Building								Affected Fence Type					
	Leave Roof		Zinc Plate Roof		Tile Roof		Concrete		Concrete		Wood		Barbed Wire	
	No.	m^2	No.	m^2	No.	m^2	No.	m^2	No.	m	No.	m	No.	m
0+000 to 15+000	8	341.8	562	16,761.4	93	2,497.3	66	3,029.1	87	2,940	7	162	35	1,624
15+000 to 30+000	30	506.4	406	8,744.1	26	547.2	6	185.2	43	1,642	4	116	5	104
30+000 to 45+000	49	713.7	304	6,236.5	23	558.1	3	42.4	3	74	0	0	0	0
45+000 to 44+800	29	348.3	191	4,077.2	8	143.9	1	10.4	5	131	1	36	1	22
Total	116	1,910	1,463	35,819	150	3,747	76	3,267	138	4,787	12	314	41	1,750

(2) Project affected fruit trees

Numbers of affected trees (fruit trees) such as mango, coconut, jack fruit, guava, kampinreach, lemon, pulasan and papaya within 30 meters of temporally ROW are shown Table 10-3-15. Detailed inventory of affected fruit trees by each 500-meter intervals in both left side and right side of the road is referred Table H-5-1 to Table H-5-4 in Appendix.

Table 10-3-15 Affected Fruit Trees (15 meters from the Road Center on Both Side)

Station (Km)	Fruit Trees								Others
	Mango	Coconut	Jack fruit	Guava	Kampinreach	Lemon	Pulasan	Papaya	
0+000 to 15+000	418	811	556	167	214	15	144	355	1,366
15+000 to 30+000	486	1,098	636	151	283	13	169	273	1,635
30+000 to 45+000	170	514	517	195	26	17	34	469	2,221
45+000 to 54+800	221	429	245	258	54	9	56	217	1,272
Total	1,295	2,852	1,954	771	577	54	403	1,314	6,494

10.3.6 Natural Environment

(1) Vegetation

There are a variety of plant species growing along the road, especially in Kien Svay district. The important trees for commercial purposes are jackfruit, mango, coconut, tamarind, and bamboo and palm tree. Among these plants, the numbers of mango and coconut trees were the highest. In Mean Chey district, there are residential houses rather than farmland. In Leuk Daek district, there are a lot of rice fields, forest and some village communities. In this district, there are some birds and wildlife species, but it is not a wildlife habitat.

Firewood is usually collected for subsistence by the rural population. 14 plant species in the areas are used for fuel wood by local communities. Some high quality fuel woods are produced by shrubs such as Vitex holadenon, Hymenocardia wallichii, Combretum

quadragulare and Terminalia cambodiana. The latter species hardly ever reach their natural arborous stature in this region. Some species are natural to the inundated floodplains, and some (which are said to produce the highest quality) for firewood and timber.

A number of plants are cultivated or collected to supplement the village consumption of fruits and vegetables. Seeds and fruits are collected and eaten from the following native plants:

Lotus (Nelumbo nucifera), Hymenocallis wallichii, Popowia diospyrifolia, Persimmon (Diospyrus embryopteris) and local wild grasses as well as a number of introduced species such as Schleichera, jujube (Zizyphus) and tamarind (Tamarindus indica). Wild vegetables that present an important component of local diet include: water chestnut (Trapa bicornis), Polygonum barbatum, Alternanthera sessilis, and Mazus pumila. Equally important are the local plants that provide fodder for the livestock. The fertile water of canals and ponds provides abundant forage for domestic mammals.

(2) Agricultural crops and vegetables

A wide variety of agricultural crops are cultivated within and around these wetland/ floodplain areas. During the rainy season rice is planted in some parts within the shallow floodplain areas while in the dry season commonly planted are the so-called dry seasonal rice. At this time vegetables are grown widely in these areas. These areas, which are not flooded, also support seasonal, annual and perennial vegetables, and firewood and non-timber forest products for rural population. As flooded areas dry up between November to May, farmers plant legumes, oilseed, vegetables, tobacco, sweet potatoes, watermelons, and sugar cane which are the important cash crops.

In lower parts of the floodplain, which are flooded regularly for shorter or longer periods, rice is cultivated in successive stages. A number of varieties of local rice are grown even though fertilizers are not so much in use. An important element in the recognition of the value of wetlands/floodplain ecosystems is that they are multi-product producing systems.

(3) Bird species

The flood plain and wetland area are recognized as important for water-birds. A total of more than 70 bird species are reported in the project area. Most of these species are wetland birds and some forest-dwelling birds. These species inhabit open country, scrub and floodplain vegetation.

(4) Aquatic fishes

A total of more than hundred species of fishes belong to the families of Channidae, Eleotriditae, Tetraodontidae, Cyprinidae, Balitoridae etc., and most of these species are indigenous to Cambodia. Local people and fishermen balance their agricultural and fishing activities according to time and season.

(5) Natural Monuments and Protected Area

The Study area does not belong to a historical area; it is residential village or farm area. There is no National park or Protected area. There are four recreational areas along the

Mekong River: Mohaleap, Kien Svay Khnong, Kien Svay Khroa and Recreational Center.

(6) Surface and Underground Water Condition

Around NR-1 along Mekong River, there is plenty of groundwater and its water level is not very deep. There are four canals and two small creeks with two concrete bridges and other four wooden bridges across the road. Also there are many ponds, wells and small lakes in the vicinity of the road.

(7) Water, Air and Noise Conditions

Laboratory testing was conducted by MOE to examine the quality of water, soil, air and noise. Sampling of water, air and noise were taken at four sites along the road. Four sampling sites were points at 20.70 and 45.30 km points from Monivong Bridge, Neak Loueng and Monivong Bridge.

(8) Water

The amount of BOD in sampling stations 1, 3 and 4 is low, especially in stations 1 and 4. However, the amount of COD at stations 1, 2 and 4 is high, but it is still under the standard level stated in the sub-decree on Water Pollution Control. The amount of SS at stations 1 and 2 is very high; it exceeds the standard level. The amount of Fecal of all station is also high: over the standard level stated in sub-decree on Water Pollution Control. These were caused by polluting activities at sampling sites (near the card board factory and the boat port). The quality of water at four stations is shown in the Table 10-3-16.

Table 10-3-16 Quality of Water at Four Stations

No.	Station	pH	BOD (mg/l)	COD (mg/l)	SS (mg/l)	FECAL (MPN/100ml)
			Winkler Method	Open Reflux Method	Dried at 105°C	Multi Tubes Method
1	1	8	2.4	42.28	136	1.1×10^5
2	2	7.32	45.79	88.41	109	4.3×10^2
3	3	7.8	4.2	23.06	117	4.3×10^3
4	4	8.4	46.12	46.12	154	2.4×10^3
Standard Level		5 ~ 9	< 80	< 100	< 120	< 5000

(9) Air Quality

Sulfur Dioxide (SO_2)

Concentrations of SO_2 at all sampling stations are below the ambient air quality standard of 0.112 ppm. Concentrations vary between 0.0009 and 0.001 ppm for the rural areas and between 0.0018 and 0.014 ppm for urban areas. SO_2 concentrations in urban areas are generally higher than those in rural areas. This is due to the higher traffic volume in urban area.

Nitrogen Dioxide (NO_2)

Concentrations of NO_2 at all sampling stations are below the ambient air quality standard of 0.052 ppm. Concentrations vary between 0.0304 and 0.0349 ppm for the rural area

and between 0.0454 and 0.0494 ppm for the urban area. NO_2 concentrations in urban area are generally higher than those in rural area. This is also due to the higher traffic volume in urban area.

Carbon monoxide (CO)

Concentrations of CO at all sampling stations are below the ambient air quality standard of 17.21 ppm. Concentrations vary between 1.45 and 1.66 ppm for the rural area and between 2.08 and 3.75 ppm for urban area. CO concentrations in urban area are generally higher than those in rural area. This is due to the higher traffic volume in urban area too.

These three parameter levels at four sampling stations in comparison to the standard of sub decree on Air quality and Noise Disturbing are shown in Table 10-3-17.

Table 10-3-17 Quality of the Air at Four Stations

Parameter	Station 1	Station 2	Station 3	Station 4	STANDARD
SO_2 (ppm)	0.0018	0.0010	0.0009	0.014	0.112
NO_2 (ppm)	0.0494	0.0304	0.0349	0.0454	0.052
CO (ppm)	3.75	1.66	1.45	2.08	17.21

(10) Noise level:

The Noise levels at all sampling stations are below the standard of sub decree on Air quality and Noise Disturbing. Noise level varies between 54.0 and 78.4 dB (A) for the rural area and between 68.6 and 77.7 dB (A) for urban area as shown in table 10-3-18. Maximum level of noise exists for a short time, made by cars and motorcycles, while the minimum level is rather constant most of the time.

Table 10-3-18 Noise Level at Four Stations

Location	Min (dB(A))	Max (dB(A))	Date/Time	STANDARD (dB(A))
Station 1	68.6	77.5	June 19, 2002, 9:00 AM	70
Station 2	54.0	74.9	June 17, 2002, 11:30 AM	60
Station 3	56.5	78.4	June 17, 2002, 3:50 PM	60
Station 4	68.6	77.7	June 18, 2002, 11:35AM	70

(11) Natural Disasters

1) Flooding Condition of 2000 Flood

Serious inundation happened widely in the left bank side flood plain of the Mekong River during 2000 flood, which have inundated about 40 to 50 km around Phnom Penh and about 17 to 20 km around Neak Loueng.

In the right bank side flood plain, which is called as Colmatage Area surrounded by NR-1 and the road along the left bank of the Bassac River, the area is also wide spread inundated like lake. The inundation water came into this area through the existing openings such as existing Colmatage canals, Cut-off No.1 and No.2 along the NR-1, and through the existing openings such as Colmatage canals along the right

bank of the Bassac River.

2) Flood Water Level along the NR-1(C-1)

The maximum water level during 2000 flood was almost same as the road elevation with total length of about 29 km. Overflow happened at three places with total length of about 1100 meters and overflow depth of 0 to 0.5 meter. There were no natural breached sections along the NR-1 by 2000 floods. However, although both of the artificial Cut-offs was originally about 10 to 20 meters length each, only after 3 days, due to erosion by strong current, they already became longer to the existing length of about 160 meters.

3) Flood damage

Flood damage along NR-1(C-1)

Along the NR-1(C-1), overflowed portion during 2000 flood were only three. However, as the flood water level was very near to the edge of embankment of the road, surface condition of the NR1 was deteriorated by the water.

At the three new water gates (Prek Pol, Prek Yourn and Koki Thom), erosion in the downstream channel was happened by the strong current through the gate structure. Furthermore, at the Cut-off No.1, local scouring with depth of about 4 to 5 meters was caused around the opening by strong current. The scouring around the Cut-off No.2 was also caused by the current, but its depth was only about 1 to 2 meters.

Flood shelter

Almost all local people stayed at their own house during the flood. On the contrast, 40% of all livestock evacuated to nearby road. At kilo-post of 20 km to 55 km, nearby road is likely to be used as an evacuation place. As submergence due to floods, agricultural land is more vulnerable against floods than houses and fishery, as income reduction due to floods, half of all local people got little income reduction. However, the remains suffered more than 50% income reduction. As benefit due to floods some local people think there is benefit for agriculture and fishery due to increased water supply from floods.

10.3.7 Major Environmental Issues

Major environmental issues from a socio-economic point of view according to the interviews with local representatives are as follows:

(1) Resettlement Consideration.

In accordance with the Prime Minister Declaration on 27 September 1999, the ROW of National Road No. 1 (NR-1) is 60 m in rural area and it is varied and flexible in urban area but not less than 30 m.

A tentative ROW will be announced within the permanent ROW (60m) by MPWT to keep necessary space for road improvement, and all the precarious and illegal occupants within a tentative ROW should be resettled outside of the boundary by the due procedure as described in 10.5. Total number of affected households from Monivong Bridge to Neak

Loueng is estimated 1,805.

The Inter-Ministerial Resettlement Committee (IRC) will make a survey on the people affected by the project in proceeding phase. Affected persons will be registered on the data document, so this constitutes their rights to receive compensation. Properties belonging to people within a tentative ROW will be compensated for their house and others fruit trees plantations. The compensation amount of cost will depend on the type of construction material of the house, fence and fruit tree, the rates of which are fixed by the Government.

(2) Traffic Condition and Facilities

1) Traffic volume

Due to the fact that NR-1 connects to other provinces and neighboring country, Vietnam; it is a some what busy traffic at a specific time. There are a variety of vehicles move everyday such as moto-remork, motorbike, car, van, bus, bicycle and animal cart...etc. There are two period of the heaviest traffic on the road in each day as follows:

i) From 6:30-9:30 am, the traffic is very busy especially near Chbar Ampov market (approximately 0.5 km from the Monivong Bridge) and Kokir market because most of people move to buy and sell their products. More over, students, governmental officers and private employee move to school or work.
ii) From 4:00-6:00 pm, the traffic will be busy again because peoples get out from working place to home also it is the time that bus from / to Neak Loueng.

As roadside traffic volume, the JICA Study team conducted 14-hours continuous traffic volume counts. Data obtained from the survey is summarized in table 10-7-15. As shown in the table, the daytime traffic volume varied from 2,300 to 11,200 units (2,000~8,500 PCU) per 12-hours, and peak hour traffic volume also varied from 300 to 1,300 units (240~880 PCU) per hour, by station to station. 14/12-hr ration and peak hour ratio is assumed to be around 1.07, and 0.13, respectively, at all stations.

2) Traffic jams and congestion

During construction phase, traffic jams and congestions are one of the major issues which occurred at construction operation sections in order to regulate and control one-way traffic, proper measures should be considered to relieve the congestion through better coordination among the project implementation body, the contractor, the provincial transportation department, and the police department. As loss of access due to construction of such bridges and culverts, temporary bypasses have to be considered to install and maintain ordinary traffic flow during the construction period.

3) Road safety; collisions between vehicles, people and livestock

Also during the construction phase, controlling speed of construction vehicles through road safety education and management are quite essential for safety provision of

adequate traffic flow around construction areas. Provision of proper signage of information, control regulation, warning and caution, barriers and flag persons for traffic control will be considered. For public relations on the road improvement project, communication to the public through radio, TV, and newspaper announcements regarding the scope and timeframe of projects, as well as certain construction activities causing disruptions or access restrictions are vitally required.

4) Public Facilities distribution

Public facilities as hospitals and markets, cultural and religious facilities such as schools and pagodas are described in sub-section 10-3-2. And they may not be affected as they are located at the backward of NR-1.

(3) Natural Conditions

1) Hydraulic condition and water quality

i) Alteration of drainage: In sections along watercourses, earth and stones will be properly disposed of so that they do not block rivers and streams, resulting in adverse impact on water quality and flow regime.

ii) Water pollution: Earthworks and stone works related to the road may cause temporally impeding cross drainage at channels/ steams and canals or existing irrigation and drainage systems.

2) Soil

i) Soil Erosion is on slopes and other potentially erodible places along the roadside. Appropriate vegetation that retards erosion should be planted. The sections with high filling and deep cutting, the slopes should be protected by stone or planted with appropriate vegetation. Arable lands should not be used as earth borrowing or storage sites whenever possible. If needed, the topsoil (15 cm or so) should be kept and refilled after excavation is over to minimize the impact on productive lands.

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 so as to avoid losses to agricultural lands.

ii) Compaction of Soil: Construction vehicles should operate within the Corridor of impact, to avoid damaging soil and vegetation. It will be most important to avoid soil compaction around trees.

3) Flora

Loss of trees: A tree-cutting and replanting scheme will be prepared by the Provincial Forestry Department, the contractor and the Project execution body, within the first four months of the start of civil works. Tree clearing within the ROW of NR-1 should be avoided beyond what is directly required for construction activities and what should be removed to reduce accidents.

4) Fauna

Construction workers should be told to protect natural resources and wild animals. Hunting is strictly prohibited. Stream crossings that are dry during the work period should be kept unobstructed at all times and the channels should not be altered, since during the monsoon periods these dry riverbeds become fishing areas for local people.

(4) Pollution

Most of pollution related with ambient air, water quality, noise and waste disposal may generate during the construction phase. Followings are some of this pollution to be presumed.

1) Air pollution and dust

Emission gas would be generated from construction vehicles and machinery through out of the construction phase. Due operational activities by construction vehicles especially through transportation of the borrowed materials may generate dust way through the route of temporary access to quarry site also during the activity of embankment earth works of the road. Vehicles delivering materials at the construction sites may cause spills of materials as borrowed earth. Mixing and crushing plants/ operations may produce dust in vicinity area.

2) Noise and odor

Asphalt application will be heated liquid bitumen sprayed onto an aggregate base. Bitumen preparation sites may be noisy, with some odor and a considerable risk of fire. Aggregate crushing plants and bitumen preparation sites may generate noise easily. Construction activity with vehicles and machines may produce permissible noise level if sensitive areas such as hospitals and schools are located nearby.

3) Waste disposal

As results of road improvement, quite large amount of materials of existing pavement may be produced for disposal. Also after dismantling, Bailey bridge parts should be considered as debris.

For the construction workers camp site, generated solid waste and garbage may cause pollution if proper management is not programmed.

4) Water pollution

As for contamination of water body or surface drainage, for the road improvement the most severe possible water quality impact could come from spilled bitumen or any petroleum products used to thin the bitumen. Entering bitumen into either running or dry streambeds may cause water quality degradation when proper management may not be conducted. As contamination from fuel and lubricants, vehicle maintenance and refueling may cause spilled lubricants into outside if proper management system is not applied.

As for siltation problems, construction materials generally contain fine particles, e.g., limestone or laterite and they often drain into nearby watercourses if proper management is not applied. Also the wastewater may cause water pollution during construction from entering directly into water bodies and irrigation systems if

justifiable measures are not taken.

10.3.8 Consideration of Mitigation Measure and Management

The project will establish an Environment Desk Officer (EDO) in the Project Management Unit (PMU) of MPWT, preferably staffed by support from the Environmental Impact Assessment Department of the MOE. With Assistance from the Consultant Environment Specialist, this officer will have responsibility to commission the work of designing environmental training modules for road rehabilitation, developing a database of natural resource management programs, safety and health of the population, and facilitate working relations between them and road construction (contractors) activity, and organize and facilitate the environmental monitoring program. The primary functions are:

a) Implement and coordinate environmental management activities of the project.
b) Develop training and public awareness materials on environment, for use by all stakeholders.
c) Coordinate the implementation of surveys and studies.
d) Develop and implement the environmental monitoring program

The major considerations and responsibilities are:

a) Development of environmental training modules for inclusion in curricula for Contractor management personnel and Consultant supervision and control of the road construction.
b) Develop an information base of environment and natural resource management training capability, which could be called upon by the contractor to support their program.

Implement field survey and assist study teams when requested in

a) Design and implement an environmental monitoring program for the contractor on construction activities, in collaboration with the Department of Environmental Impact Assessment of the MOE.
b) Perform such other duties related to environmental management as may be assigned from time to time by the Project Management Unit (PMU) Manager.

Preliminary suggested mitigation measures with regard to socio-economic factors are:

a) Project management should take account of people affected by relocation and resettlement before and during the construction.
b) Installation of traffic signs, especially in high commercial area, to warn drivers to pay attention.
c) To control driving speed of drivers: Installation of warning signs and lighting in necessary locations; enforce traffic regulations together with driver education and public relations.
d) Administrative provision is required for waste control, maintenance of road damage and potholes.
e) Development of car parking areas adjacent the area of public markets and commercial facilities to secure safe traffic movement.

f) Public Information and public relations
g) Compensation systems for resettlement.

10.4 Formulation of Further Environmental Study

Various considerations including environmental conditions are made in determining the recommended road width of the route. According to the Cambodian system, it will be conducted covering each environmental item and location highlighted by the MOE in their evaluation. After finalization of a recommended road width of the route, the detailed alignment as well as road facilities and structure will be clearly identified. Furthermore, construction methods, method of acquiring construction material resources and choice of a construction management system is determined.

Further environmental study has proceeded by the Study Team together with MPWT since the project proponent submitted IEIA report and approved by MOE.

10.4.1 Recommendation from Further Environmental Study

The Study has to take recommendation of the environmental background of Cambodian biodiversity conservation philosophy and historical, cultural heritage of use of natural resources.

Due to flood-affected conditions in the Study area, land and environment of the area is maintaining its status in quite sensitive balance. Meanwhile modern Cambodian people and the Government as well as local provinces are willing to activate social, economic development for their prosperity and welfare. Thus sustainable environmental resource management will be an essential point of view to the further environmental study.

Results of IEIA Study has been received an approval letter from MOE, and there are some comments added in the letter that more detail environmental study would provided by MPWT. Therefore further environmental study has conducted which focus on other view points of environmental management and monitoring during and after construction of the road in addition to the most important mitigation measures for construction activities. Recommendation of environmental management and monitoring for construction activities and operation, maintenance of the road are most essential components to further maintaining of sustainable environment by MPWT and MOE as well as residents of the Study area.

10.4.2 Works for Further Environmental Study

To reflect of the comments on the approval letter by MOE, the following items are conducted in the course of the further environmental study.

- Mitigation measures recommendation: Mitigation measures for anticipated impacts.
- Alternative countermeasure recommendations: Recommendations for alternative solutions to the anticipated impacts.
- Environmental protection and risk management during the construction and operation stage.
- Environmental monitoring recommendations during and after construction.
- Monitoring plan for protection and conservation during and after construction.

10.4.3 Environmental Protection Objective

According to the environmental impact assessment, following protection objectives have been identified through each category of the environmental items.

(1) Social environmental items:

The NR-1 project may give impacts to the social conditions. Followings are summary of both negative and positive impacts through assessment results.

1) Project affected persons for resettlement

Negative impacts

Negative impact will be brought about to the Project Affected Persons (PAPs) due to the improvement of road. In total, 1,805 households have to be relocated outside of the tentative ROW, 15 meters from the centerline of existing road on both sides.

Some security problem to community people when construction starts, and probabilities of the traffic accidents due to traffic congestion. According to origination of construction activities, it may affect negatively on community life and health condition of the people and generated noise will affect negatively the people of the settlements. .

Positive impacts

No positive impact is expected.

2) Traffic jam, congestion and road safety

Negative impacts

Public nuisances such as interruption, detour and traffic congestions that will take place during construction are one 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 safety traffic flow in and 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 ensuring road transport through out a year, securing traffic safety and conserving environment.

3) Stagnant water as insect-borne disease vectors

Negative impacts

The formation of standing waters 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 the settled area especially it is anticipated for construction workers at their camps.

Positive impacts

The roadside drainage and sidewalk will be installed in urban area, and such an improvement of NR-1 C-1 will contribute to preventing standing water along the road.

4) Deterioration of health of worker's condition and HIV/AIDS as a specific problem

Negative impacts

Prostitution and illicit drug are factors directly or indirectly to the rapid spread of HIV/AIDS. Migrant workers such as equipment operators and labors 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, the education and dissemination of prevention will be achieved to prevent the spread of HIV/AIDS.

(2) Natural environmental items:

1) Hydraulic condition

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.

2) Geological condition

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 affects 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 well guided and proper protection is constructed where the velocity will be high enough. After NR-1 C-1 is improved, all the vehicles will pass the paved road without any dusts and fertile topsoil will be

properly preserved.

3) 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 give 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 flood season.

Positive impacts

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

(3) Pollution items

1) Air and dust pollution

Negative impacts

Emission gases are expected to be generated from construction vehicles and machinery through out the construction period. Due operational activities as transportation of the borrowed materials may generate dust way through the route, also during the activity of earth works of the road embankment. Mixing and crushing plants and operations may produce dust at vicinity area.

Positive impacts

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

2) Water pollution

Negative impacts

Entering bitumen as well as fuel/lubricants into either running or dry streambeds may cause water quality degradation when proper management may not be 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

No positive impact is expected.

3) Noise, vibration and odor

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 through a year by improving a flood-free road to an all-weather standard.

4) Waste disposal and sanitation

Negative impacts

Considerable materials will be wasted from existing road as disposal debris. Such disposal will bring adverse environmental impacts to the surrounding.

Positive impacts

There is no expected positive impact.

10.4.4 Environmental Protection Measures

According to the environmental protection objectives mentioned in sub-chapter 10.4.3 following protection measures would be recommended in each category of the environmental impact parameters.

(1) Social environmental parameters:

1) Project affected person for resettlement and compensation

Project Affected Persons (PAPs) for resettlement will be one of the most important issues for protection measures. 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 existing road.

On this subject, as explained in the sub-section 10-5-5 Resettlement Action Plan to be referred accordingly.

2) Traffic jam and congestion

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 for complying traffic rule and regulation.

Provide adequate signage, 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.

3) Stagnant water as insect-borne disease vectors

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 waterborne diseases in standing water and how to prevent them. In cases where standing waters are managed by their owners (users), e.g., through fish or waterfowl stocking, they will be held responsible for insect control. The owners/ users should be given information about the dangers of waterborne diseases in standing water and how to prevent them.

4) HIV/AIDS

Through education program and management to migrant workers as well as local people on health care promotion will become a public knowledge in vicinity areas.

Provision of education and control for HIV/AIDS infections for workers should be taken and it is necessary for contractors to fund HIV prevention strategy and program in their activities as a pre-condition of approval of the 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.

(2) Natural environmental parameters:

1) Hydraulic condition

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.

2) Geological condition

Arable lands should not be used as earth borrowing or storage sites whenever and wherever 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 so as to avoid losses to agricultural lands.

During construction, the contractor should pay attention to the prevention of erosion and loss of top soil on condition that the provision of protection work will be stipulated in the conditions of contract and specifications.

3) Flora and fauna

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.

(3) Pollution parameters:

1) Air and dust pollution

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 sites must be included in the dust suppression program. Vehicles delivering materials to and from the construction sites should be covered to avoid spills.

2) Water pollution

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. Spilt of oil products into 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 will be taken to treat the wastewater properly before disposing them to watercourse.

3) Noise and odor pollution

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.

4) Waste disposal issues

All construction materials should try 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 try to reuse of them.

Sufficient 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.

10.5 Compensation for Resettlement and Land Acquisition

10.5.1 Compensation for Land Acquisition

The prevailing land legislation is based on the Land Law that goes into effect on 30th August 2001. The current legislation recognizes Right of Occupation as claim to ownership through Article 30 of the Land Law which states that "if any tentative possessor peacefully, honestly, publicly without ambiguity got land for five consecutive years and the land is free with no record in the enrolment register and does not belong to anybody, the tentative possessor shall become the owner."

However, the government's ownership of land is again defined in Article 10 of the Land Law through "The State is the owner of the immovable goods of the national territory enumerated in Article 58 of the Constitution and of all property which is escheat or which has not been the subject of a due and proper private appropriation or which is not in the process of being appropriated pursuant to the provision of chapter 4 of this statute.

While Article 13 of the Land Law stipulates that " The following property falls within the public domain of the State and public bodies:

- Property with a specific natural constitution, such as courses of navigable or floatable, water, natural lakes, banks of navigable and floatable rivers and sea shores.
- Property, which is specially, developed for general use, such as quays of harbors, railways, stations and airports.
- Property, which is made available, either in its natural state or after development, to the public, such as roads, pathways, gardens and public parks.
- Property, which is allocated to render a service to the public, such as schools or educational institutions and administrative buildings.
- Property which is a natural resource protected by law.

Article 44 of the Constitution of the Kingdom of Cambodia (1993) states that the government has "the right to confiscate properties from any person shall be exercised only in the public interest as provided for under law and shall require fair and just compensation in advance", while Article 20 maintains that "Nobody shall be forced to transfer his/her ownership, if forcing is not necessary in the public interest and (if) no proper and just indemnity has been paid to the owner."

However, the Article 48 of Land Law stipulates that "Property within the public domain of the State can in no case be the subject acquisitive possession. The situation of an occupant of the public domain of the State remains precarious and illegal if such occupation does not arise from contractual title or any authorization of the type expressly provided by law.

The illegal occupant must be requested to vacate the premises immediately in accordance with the Prime Minister Declaration on 27 September 1999. Such occupant incurs sanctions in accordance with Article 259. The illegal occupant is not entitled to any indemnity for any works and improvements carried out on the land or the building.

The improvement of NR-1 C-1 is planned within the permanent ROW (60 meters), and accordingly no compensation to the land is expected.

10.5.2 Resettlement Procedure of Project Affected Persons (PAPs) within Road Right-of-Way (ROW)

According to the Prime Minister Declaration on 27 September 1999, the ROW of National Road No. 1 (NR-1) is 60 meters in rural area and it is varied and flexible in urban area but not less than 30 meters.

A tentative ROW will be announced within the permanent ROW (60 meters) by MPWT to keep necessary space for road improvement, and all the precarious and illegal occupants within a tentative ROW should be resettled outside of the boundary by the due procedure. Fig. 10-5-1 shows the diagram of a relationship between ROW and Resettlement.

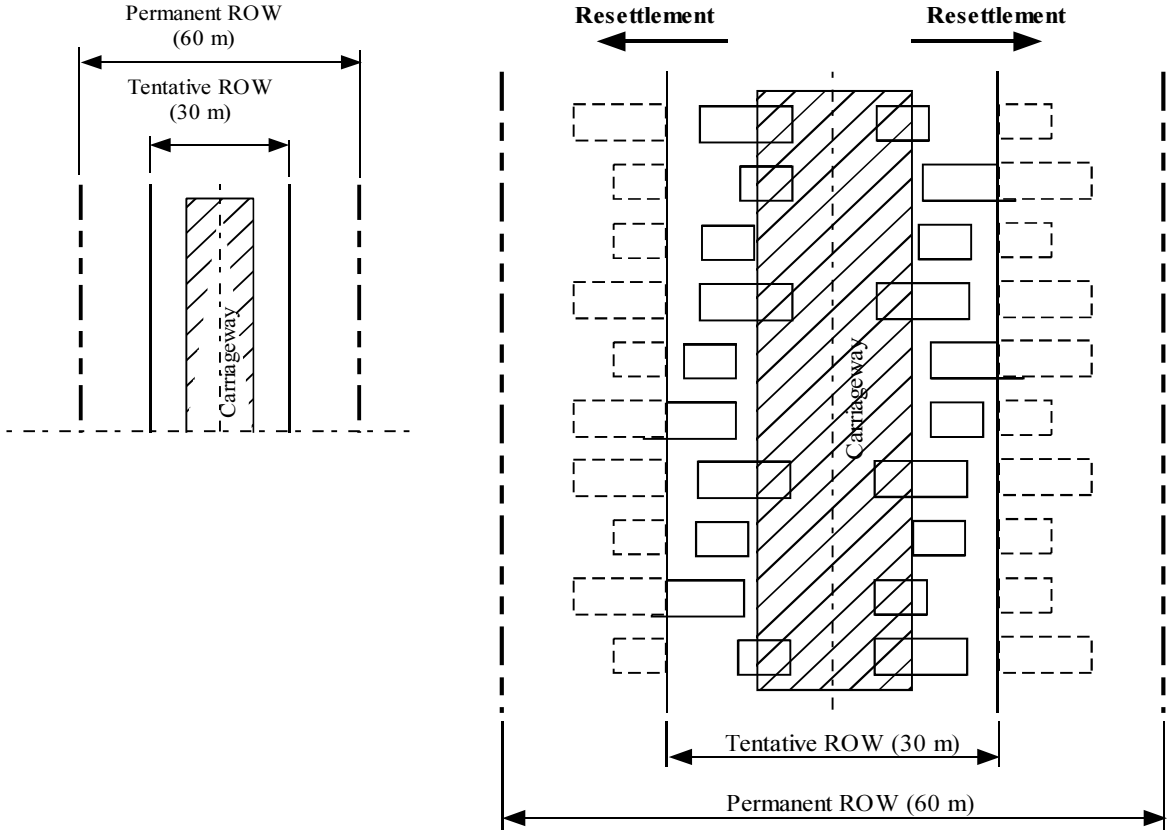


Fig. 10-5-1 Relation between Road Right-of-Way and Resettlement

The scheme of tentative ROW of 30 meters has many advantages in the aspect of social impacts. It is well known that resettlement problems of PAPs become serious in case that land acquisition should be required. It necessitates not only to acquire new land but also to maintain community and job of PAPs. The scheme of tentative ROW of 30 meters is only the way how to manage to avert such troublesome problems. Alternative schemes are also examined, namely variable ROW of 14 meters to 24 meters and no resettlement in urban area as given in Appendix-H-6. 1,600 households will be affected in the former and 1,200 households in the latter. Both are not acceptable to MPWT because the former violates the

minimum ROW of NR-1 stipulated in the Prime Minister Declaration on 27 September 1999 and the latter cannot meet the requirement of improvement plan. Accordingly, adoption of tentative ROW of 30 meters has been confirmed in the course of study.

10.5.3 Compensation Procedure for Resettlement

The ROW of National Road No. 1 (NR-1) is 60 meters in rural area and it is varied and flexible in urban area but not less than 30 meters. A tentative ROW will be announced within the permanent ROW (60 meters) by MPWT to keep necessary space for road improvement, and all the precarious and illegal occupants within a tentative ROW should be resettled outside of the boundary by the due procedure.

Control mile stone for set up the PAPs resettlement procedure stably, five major control key steps are considered as follows:

(1) Control key step-1: Preparation

i) Request of the approval of project to the Council of Ministers
ii) Public information campaigns (Actual practices given in Appendix H-7)
iii) Property survey and data & questionnaire conducting

(2) Control key step-2: Organize IRC and Sub-working group for inventory and survey

i) MPWTs Committee with Ministry of Economy and Finance (MEF), Ministry of Land Management, Urban Planning and Construction (MLMUPC), reporting to the Council of Minister the estimated cost for resettlement
ii) Inter-ministerial Resettlement Committee (IRC) organizes the IRC Working Group; IRC Working Group organizes IRC Sub-working Group by Kandal Province and Phnom Penh Municipality
iii) The IRC Sub-working Group conducts own survey to Project Affected Persons (PAPs)
iv) Affected household survey records, entitling reserve right for compensation. Inventory and evaluation task through talks
v) Survey confirmation by IRC and documents preparation for compensation

(3) Control key step-3: Request and preparation of budget for resettlement

i) IRC requests budget to MEF
ii) MEF's preparation of necessary documents for compensation

(4) Control key step-4: Signing of the contract and payment for compensation

i) PAPs signing of the agreement for compensation cost
ii) Compensation cost payment preparation to PAPs after the public meeting
iii) Compensation cost payment to the families by IRC

(5) Control key step-5: Resettlement and confirmation of activity

i) IRC working group formulates final confirmation after PAPs resettlement

For stable and smooth procedure on the resettlement, a organizational procedure as shown in Fig. 10-6-1, a diagram of the Inter-Ministerial Resettlement Committee (IRC) through ad hoc committee between MPWT and MEF, and Fig. 10-5-2, a diagram of IRC's organization and

Fig. 10-5-3 , a diagram of composed members is to be formulated.

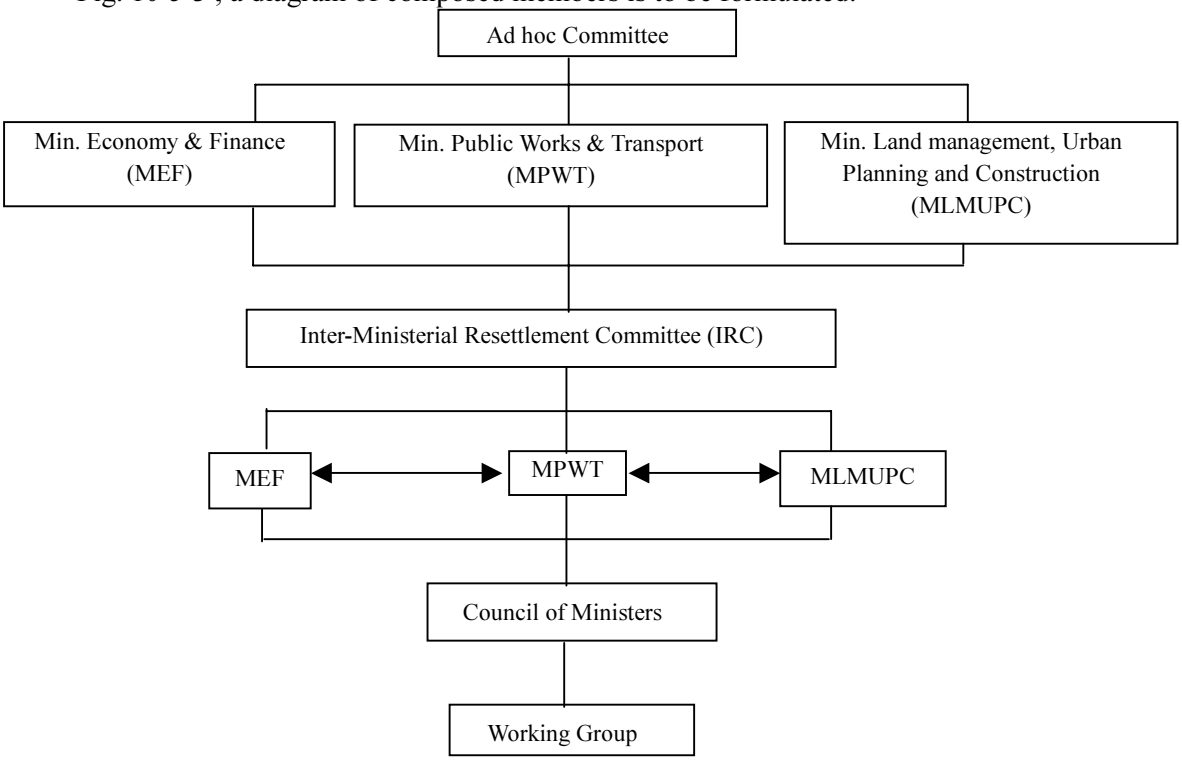


Fig. 10-5-2 Diagram of Inter-Ministerial Resettlement Committee Establishment

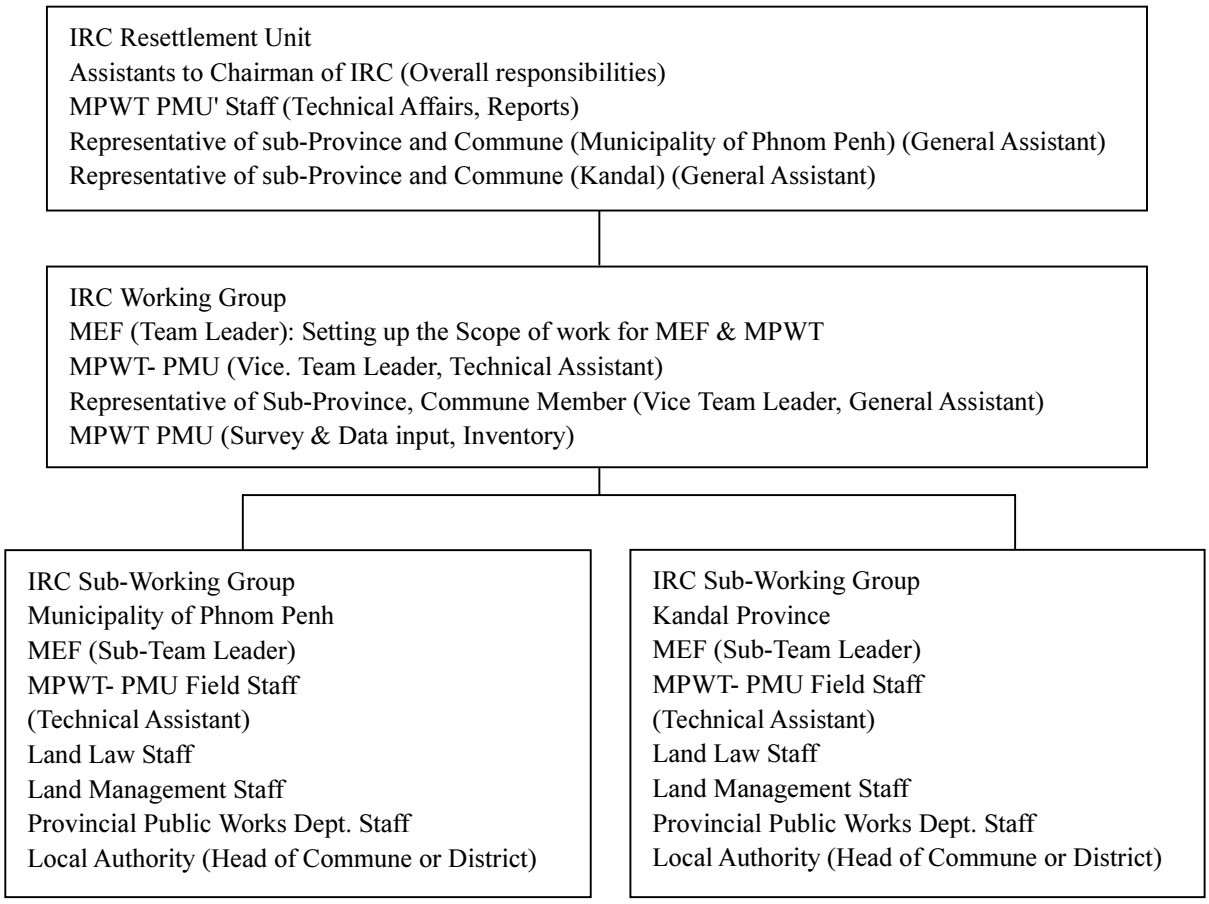


Fig. 10-5-3 Diagram of Inter-Ministerial Resettlement Committee and Organization Members

10.5.4 Compensation Cost Application based on the Government's Policy

The Government has adopted a policy to compensate the people whose interests are affected by the project. Note that, the compensation amount of money will depend on the type of construction material of the house, fence and fruit tree, the rates of which are fixed by the government in Appendix Table H-6 (resettlement compensation cost base).

On the basis of compensation cost base, the estimated compensation cost for house, fence, fruit tree and allowance are estimated in Table 10-5-1, 10-5-2, 10-5-3, and Table 10-5-4.respectively.

Table 10-5-1 Estimated Compensation Cost for House and Building

House Category	Area (m²)	Unit Cost (US$)	Total Cost: (US$)
House Type 1 (Leave roofed)	1,910.20	4.5	8,595.90
House Type 2 (Zinc plate roofed)	35,819.20	12	429,830.40
House Type 3 (Tile roofed)	3,746.20	85	318,427.00
House Type 4 (Concrete)	3,267.10	140	457,394.00
Total	44,742.70		1,214,247.30

Table 10-5-2 Estimated Compensation Cost for Fence

Fence Category	Length (m)	Unit Cost (US$)	Total Cost: (US$)
Concrete	4,787	4.86	23,264.80
Wooden	314	0.75	235.50
Barbed wire	1,750	0.75	1,312.50
Total	6,851		24,812.80

Table 10-5-3 Estimated Compensation Cost for Fruit Trees

Fruit Tree	No.	Unit Cost (US$)	Total Cost: (US$)
Mango	1,263	30	37,890.00
Coconut	2,753	15	41,295.00
Jack fruit	1,959	20	39,180.00
Guava	772	2.5	1,930.00
Kampinreach	577	25	14,425.00
Lemon	54	3.5	189.00
Pulasan	403	20	8,060.00
Papaya	1,317	2.5	3,292.50
Total	9,098		146,261.50

Table 10-5-4 Estimated Allowance for Resettlement Compensation Cost

Allowance	No.	Unit Cost (US$)	Total Cost: US$
Widow (number 20%)	400	20	8,000
Households income <10$/month (5%)	100	20	2,000
Total	500		10,000

On the basis of survey, female headed household as widow accounts for 20% of 891 hearing samples and also households who have less than US$ 10 per month income accounts for 5% of the samples.

Finally the total amount of resettlement compensation cost for this project is estimated as shown in Table 10-5-5. Accordingly, the total estimated amount of resettlement compensation cost is US$1,395,321.6 for the improvement of NR-1 from Monivong Bridge to Neak Loueng accordingly.

Table 10-5-5 Summary of Compensation Cost

Item	Total Cost US$
House & Building	1,214,247.30
Fence	24,812.80
Fruit tree	146,261.50
Allowance	10,000.00
Total	1,395,321.60

10.5.5 Resettlement Action Plan

The Study Team conducted the IEIA and ISIA considering the related items of the laws and regulations in Cambodia and JICA guideline. Although additional items mentioned in 10.3.1 were not included in the standard process, the Study Team carried them out as a part of the study. The Study Team recommends the contents of Resettlement Action Plan as follows;

(1) Principles and objectives

The following principles have been adopted since the formulation of the Resettlement Action Plan (RAP) to offset the negative impact of the road improvement project on individual, households and communities and their assets in the vicinity of the project roads:

- Population displacement will be minimized
- Training working group by MPWT staff at time of correspondent practical activities for PAPs
- Community participation including NGOs is assured
- Sufficient plans and procedures are prepared for those to be affected
- Resettlement will be monitored by the government.

Project Affected Persons (PAPs) are grouped into three categories as individual, household and communities. Within the households category there are vulnerable group that suffer, economically and socially from relocation more than the general population which are described in sub-chapter 10.5.4. Households below the Cambodian poverty line, defined as having a total households income of less than US$ 10.00 per month.

Before the project is implemented, the Inter-Ministerial Resettlement Committee (IRC) shall settle the resettlement matter with the PAPs so as to compensate PAPs and remove affected their properties. Then, the project can be implemented.

(2) Compensation System for Resettlement Land Acquisition

1) Person of officially allowed to receive a compensation

The IRC will make a census on the people affected by the project. Those people will be registered on the census book, so this constitutes their rights to receive

compensation. Any of his belonging that are affected by the project and has not been registered in the census process will not have the rights to that compensation.

i) Compensation on the properties

In the NR-1 improvement project is not any compensation to the land located within the limit of the right of way (ROW), but the people using that land will be compensated for their house and others fruit tree plantations.

The compensation amount will depend on the type of construction material of the house and plantations, the rates of which are fixed by the Government.

The inhabitants who have received the compensation on their house have the right to collect the used material and reuse them to rebuild their house on a new location not affected by the project. If the affected land contains the agricultural plantations, more time will be allowed to their owner to collect the crops, or if the land is needed before the crop collection, the villager will receive a compensation for their crops. Wells and fences affected by the project will also be compensated.

ii) Compensation on the relocation

For the dismantling and the relocation of their house, a reasonable time will be allowed. For this dismantling and the transportation of materials from the ROW, every family which has to be relocated, will obtain a compensation for the relocation.

iii) Financial support for the people having difficulties

Details of financial support for those people are described in sub-chapter 10.5.4.

iv) Community Properties

All kind of Community Properties which are affected by the Project will be reconstructed through a tender process.

For any modification, the leader of the community shall obtain an agreement from the representative of the IRC.

2) Timing of relocation and proceeding of the compensation

The relocation of the villagers has to be preceded before the construction work of the Project starts and it takes around one month as estimated from actual practices. The IRC shall have already given all the compensation sum of amount hand-to-hand to the affected householders.

(3) Issues on relocation.

It is expected that the problems on relocation may become significant, because of the numbers of those to be resettled. Land acquisition and resettlement will be minimized as much as possible. And the compensation and resettlement measures consist of assistance for rehabilitation and relocation with financial supports. Also effective and timely announcement, guidance, survey, planning, and consultation for PAPs, are conducted by IRC in accordance with each implementation step.

(4) Conduct the RAP with Focus on the Implementation Schedule

The RAP implementation schedule will be conducted taking into consideration of the implementation schedule of the Project.

1) Estimate quantities of land to be acquired and the number of affected houses and structures by the Project as;

   (a) Land to be acquired
   (b) Number of affected houses and structures
   (c) Legal status of affected houses

2) Land acquisition and compensation program as;

   (a) Legal procedures and organization for land acquisition and compensation
   (b) Estimation of land acquisition and compensation cost

3) Relocation schedule and transfer schedule to resettlement sites

4) Public involvement as;

   (a) Public hearing meeting
   (b) Public consultation
   (c) Grievance procedure

5) Supervision and monitoring

6) Financial plan as;

   (a) Costs for compensation and resettlement
   (b) Financial sources
   (c) Budget allocation plan

(5) The RAP Implementation Schedule of the Whole Project

The Removal of existing structures and the resettlement activities are most significant works of the RAP. Monitoring activities will start after the resettled people are established at the relocated place and it will take around one month as estimated from actual practices.

(6) Organization for Land Acquisition and Compensation

Project Management Unit (PMU)

The MPWT is the responsible agency for the implementation of Land Acquisition and Compensation. Project Management Unit (PMU) will be established for the NR-1 improvement project and of which has full responsibility to supervise and manage all the activities relating to the Project implementation and coordinate with other concerned agencies.

The organization of the PMU should be simple and streamlined so that the decisions made by the General Director or other supervisory persons can be sent to the responsible person in charge directly without any delay. The PMU shall be organized directly under the MPWT for clearly defined lines of coordination and communication in order to promote smooth operations and management of the Project.

(7) Supervision and Monitoring

There is no regulation concerning the supervision and monitoring of resettlement in Cambodia. However, MPWT-PMU recognizes the importance of the monitoring activity for the resettlement.

It is recommended that MPWT-PMU should supervise the progress of the implementation immediately after the procedures for compensation and resettlement are commenced. After the relocatees move into the resettlement locations, monitoring activities will be implemented periodically and checked for the following items:

- Relocation and reconstruction of house and facility
- Income restoration
- Community relationships
- Any grievances and/or problems

It is recommended that monitoring activities should start around one month after commencement of the move to the resettlement location. After completion of the Project, resettled people who are employed in the Project should be monitored as to whether they find and engage in a new job. The followings are also proposed to take into consideration:

1) Prepare Any Necessary Sub-Programs for RAP Implementation

To proceed with the successful implementation of the Resettlement Action Plan (RAP), a sub-program for considering proper mitigation measures shall be prepared. Public involvement such as public hearings, public consultations, grievance, procedures during the sub-working group's survey periods and income restoration measures are recommended.

2) Monitoring the Progress of the Resettlement Action Plan

The preparation of a sound RAP is only the first stage in the process of implementing a successful RAP. After the process for implementation is initiated for land acquisition, compensation, and resettlement of PAPs, the progress must be carefully supervised and monitored by the MPWT-PMU.

3) Evaluating and Reporting the Progress of the RAP Implementation

The tasks of evaluation and reporting are to:

- Verify the results of monitoring;
- Assess whether resettlement objectives have been met; specifically whether the livelihoods and living standards of the PAPs have been restored or enhance. Assess resettlement efficiency, effectiveness, impact and sustainability, drawing lessons as a guide to future resettlement policy making and planning activities.
- Ascertain whether the resettlement entitlements were appropriate to meeting the objectives, and whether the objectives were suited to the environmental, social, and economic conditions of the resettlement sites and the PAPs.

10.5.6 Environmental Monitoring Program

The project will establish an Environment Desk Officer (EDO) in the Project Management Unit (PMU) of the Ministry Public Works and Transport, preferably staffed by support from the Environmental Impact Assessment Department of the Ministry of Environment.

The primary functions are:

1) Implement and coordinate the environmental management activities of the project.
2) Develop training and public awareness materials on environment, for use for all stake-holder.
3) Coordinate the implementation of surveys and studies.
4) Develop and implement the environmental monitoring program

And the mains duties and responsibilities are:

1) Development of environmental training modules for inclusion in curricula for Contractor management personnel and Consultant supervision and control of the road construction.
2) Develop an information base of environment and natural resource management training capability, which could be called upon by the road contractor to support their program.
3) Implement fielding of survey and study teams where requested
4) Design and implement an environmental monitoring program for contractor road construction activities, in collaboration with the Department of Environmental Impact Assessment of the Ministry of Environment.
5) Perform such other duties related to environmental management as may be assigned from time to time by the Project Management Unit (PMU) Manager.

It is recommended that the PMU should be strengthened the institutional capability and organization from the environmental viewpoint. One of practical measures is that an environment specialist should be appointed from the external resources such as qualified consultant or expert through JICA technical cooperation. The Environmental Specialist will have responsibility to the PMU to work in designing environmental training modules for road rehabilitation, to develop a database of natural resource management programs, to secure safety and health of the population, to facilitate working relations between local community and road construction activity, and to organize and facilitate the environmental monitoring program.

Following tables shows the environmental monitoring programs for each major categories.

Table 10-5-6 Monitoring Program on Atmosphere and Air

No.	Parameters for monitoring	Work items	Sampling location	Monitoring period	Permitted rate mg/m^3
1	Total suspended particles	1) Sampling 2) Laboratory testing	Sampling and testing on road sections located at quarry sites with in 1 km from the community and construction site	Twice a year in dry and rainy season	0.33 (8 hr Ave.)
2	Carbon monoxide: CO	Same	Construction site	1 to 2times during construction	40 (1hr Ave.)
3	Nitrogen dioxide: NO_2	Same	Construction site	Same	0.3 (1hr Ave.)
4	Content of sulfur dioxide: SO_2	Same	Construction site	same	0.5 (1hr Ave.)

Table 10-5-7 Monitoring Program on Surface Water

No.	Parameters for monitoring	Work items	Sampling location	Monitoring period	Permitted rate
1	BOD mg/l	1) Sampling 2) Laboratory testing	Lower and end part of temporary stream may affect heavy rain. Area of flow confluence into water course.	In time of stream by intensive rain, once a month during the construction	6.5-8.5mg/l
2	Organic Substances mg/l	Same	Same location	Same	1000-2000mg/l
3	COD mg/l	Same	Same location	Same	1-8 mg/l
4	Suspended solids mg/l	Same	Same location	Same	25-100mg/l
5	Fecal coliform	Same	Same location	same	5000MPN/100ml

Table 10-5-8 Monitoring Program on Hygienic Condition of Work Site

No.	Parameters for monitoring	Work items	Sampling Location	Monitoring Period	Remarks
1	Condition of work site: Hygiene, Lighting Safety management of tools and equipment, Risk management, Fire escape extinguish, Planning of community protective measures	Observation	Worker's camp site Construction site	3 times a year	Observation & hearing
2	Health condition of workers	Observe workers	Worker's camp site	Once a year	Observation

10.5.7 Environmental Management Action Plan

Based on the environmental protection objectives, monitoring program and followed protection measures, the environmental management action plan is proposed as recognized that the construction phase will be most essential to be managed due to reverse impact presumed.

Regular monthly and quarterly report will be prepared in the agreed format describing all activities for the review, as appropriate, and the progress for the previous month.

Actual monthly progress will be compared with scheduled progress and all problems encountered or anticipated will be discussed, together with the appropriate steps or measures to be undertaken for their solution. Following series of Table 10-5-9 (1/4) to Table 10-5-9 (4/4) show proposed environmental management action plans for each environmental impact categories.

Table 10-5-9 (1/4) Environmental Management Action Plan (EMAP)

-	Mitigation Measures to be taken	Location	Time Frame	Implementing Organization/ Supervising Organization
1. Pollution				
Air / Dust Pollution				
1	Vehicles and machinery are to be regularly maintained so that emissions conform to national standards. Since Cambodia's standards for emissions controls are still being developed, International standards for construction vehicle and truck emissions will be applied.	Throughout corridor	Beginning and throughout construction	Contractor/ with monitoring from PIU or Environment Cell of MPWT
2	Water should be spared during the construction phase in any mixing area where dry materials are handled and/ or crushed. Temporary access roads to Quarry and borrow sites must be included in the dust suppression program. A spraying schedule will be prepared by the contractor and will serve as the basis of a dust control program. The Project Implementation Unit will monitor this schedule should problems arise.	Throughout corridor during construction	During reconstruction of grade and between asphalt removal and replacement	Contractor/ MPWT and it's PIU. It will come from new Environment Cell within MPWT.
3	Vehicles delivering materials to and from the construction sites should be covered to reduce spills.			
Noise Pollution				
4	Noise standards at aggregate crushing plants and bitumen preparation sites will be strictly enforced to prevent excess of acceptable noise standards. Maintenance of machinery and vehicles should be enhanced to minimize noise.	Throughout corridor	Beginning and throughout construction	Contractor/ with monitoring from PIU or Env. Cell of MPWT
5	When construction is taking place at less than 100 m from the villages along the route, or the road passes within 150 m of sensitive areas such as hospitals, construction should be stopped from 20:00 to 06:00. This will reduce nighttime noise levels.			
Water Pollution				
	Siltation			
6	Construction materials containing fine particles, e.g., limestone or laterite should be stored in an enclosure such that sediment-laden water does not drain into nearby watercourses, but rather percolates slowly into the soil.	Construction site	Through out Construction Period	Contractor// PIU and Env. Cell of MPWT, input from MOE
	Contamination from waste water (other than sewage)			
7	All justifiable measures will be taken to prevent the wastewater produced during construction from entering directly into rivers and irrigation systems.	Area of waste water system installation	Throughout Construction period	Contractor/ PIU and Env. Cell of MPWT
	Contamination of water table or surface drainage			
8	For this type of road rehabilitation the most severe possible water quality impact could come from spilled bitumen or any petroleum products used to thin the bitumen. Bitumen is stored in drums which may leak or which are often punctured during handling after long periods (>6 months in the elements) of storage. No bitumen must enter either running or dry streambeds and none can be disposed of in ditches of small waste disposal sites prepared by the constructor. Bitumen storage and mixing areas must be properly handled according to MOE or other acceptable standards. As a minimum these areas must be contained, such that any spills can be immediately contained and cleaned up. Prior to initiating the work, the contractor will meet with the MOE to determine the proper site of the mixing areas and the handling and management of such spills. 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 table.	Construction site	Through out Construction Period	PIU and Env. Cell prepares spill contingency plan Monitoring by PIU and Env. Cell, with advice from Pollution Control Dept.

Table 10-5-9 (2/4) Environmental Management Action Plan (EMAP)

-	Mitigation Measures to be taken	Location	Time frame	Implementing Organization/ Supervising Organization
1. Pollution				
Water Pollution				
	Contamination from fuel and lubricants			
9	Vehicle maintenance and refueling should be confined to areas in construction camps designed to contain spilled lubricants and fuels. Waste petroleum products must be collected, stored and taken to the approved disposal sites, according to MOE requirements.	Construction camp lease area	Throughout Construction period	Contractor/ PIU and Env. Cell of MPWT
	Sanitation and Waste Disposal in Construction Camps			
10	Sufficient measures will be taken in the construction camps, I.e., provision of garbage bins and sanitation facilities. All sewage sources or toilet facilities should be at least 300m from water sources or existing residences. Prior to initiation work, the contractor will present a simple sewage management plan to the MOE and Project Implementation Unit for approval.	Construction camp lease area	Before and during building of construction camps	Contractor/ PIU and Env. Cell of MPWT
11	Drinking water will meet national potable water standards.			
12	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 and approved by the MOE and the Project Implementation Unit, prior to the commencement of civil works.			
	Soil Erosion			
13	On slopes and other potentially erodible places along the roadside, appropriate vegetation that retards erosion should be planted.	Primarily at water crossings and sections where fill heights are >3 m.	Upon Completion of construction activities at these sites	Contractor/ PIU and Env. Cell of MPWT
2. Natural environmental Impact				
Alteration of Drainage				
1	In sections along watercourses, earth and stones will be properly disposed of so that they do not block channels and streams, resulting in adverse impact on water quality and flow regime.	Refer to Cross Drainage Structure of the Study Report	Whenever encountered during construction	Contractor// PIU and Environment Cell of MPWT
Loss of Topsoil				
2	Arable lands should not be used as earth borrowing or storage sites whenever possible. If needed, the topsoil (15 cm or so) should be kept and refilled after excavation is over to minimize the impact on productive lands.	Along corridor	During Construction	Contractor/ PIU and Env. Cell of MPWT
3	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 so as to avoid losses to agricultural lands. Contractors will be required to present proposed construction road alignments and hauling schedule to the Project Implementation Unit for approval, 4 weeks before construction is to commence.	Nearby quarry and borrow sites		

Table 10-5-9 (3/4) Environmental Management Action Plan (EMAP)

-	Mitigation Measures to be taken	Location	Time frame	Implementing Organization/ Supervising Organization
2. Natural environmental Impact				
Compaction of Soil				
4	Construction vehicles should operate within the Corridor of impact to avoid damaging soil and vegetation. It will be most important to avoid soil compaction around trees. Generally the rule will be to avoid driving heavy equipment or trucks anywhere into the ' drip-line ' of a tree.	Throughout corridor	During Construction	Contractor/ PIU and Env. Cell of MPWT
Flora: Loss of trees				
5	A tree-cutting and replanting scheme will be prepared by APSARA, the Provincial Forestry Department, the contractor and the PIU, within the first four months of the start of civil works. Tree clearing within the ROW of NR-1 should be avoided beyond what is directly required for construction activities and what should be removed to reduce accidents. A replanting scheme must be developed by the Provincial Forestry Dept., the contractor and the Project Implementation Unit, within the same 4-month time period.	Area of Tree Plantations along roadsides.	Soon after completion of construction activities in immediate area during clearing operations	MAFF Forest Dept. / PIU, Env. Cell of MPWT and contractor
Fauna				
7	Construction workers should be told to protect natural resources and wild animals. Hunting is strictly prohibited.	Vicinity of construction	During Construction	Contractor Dept. / PIU, MOE and Env. Cell
8	Stream crossings that are dry during the work period should be kept unobstructed at all times and the channels should not be altered, since during the monsoon periods these dry riverbeds become fishing areas for local residents. Materials are not to be borrowed from these riverbeds.			
9	In the NR-1 corridor, during road construction existing channel and stream may have to be moved back away from the carriageway, and if so this must be done with great care to make sure that the natural water movement (in terms of flow and volume) is maintained.			Contractor Dept. / PIU, MOE and Env. Cell
3. Social environmental Impact				
Loss of Access				
1	Temporary bypasses should be constructed and maintained during the construction period, particularly at bridge crossings.	wherever necessary	During Construction	Contractor/ PIU, Env. Cell
Traffic Jams and Congestion				
2	If there are traffic jams during construction, measures should be taken to relieve the congestion through better coordination between the contractor, the Provincial Transportation Department, and the police department.	High traffic and urban areas	During Construction	Contractor/ PIU, and police authority
Road Safety; Collisions between Vehicles, People and Livestock				
3	Control speed of construction vehicles through road safety education and fines.	Throughout road corridors	During Construction	Contractor/ PIU
4	Allow for adequate traffic flow around construction sites.	Throughout road corridors	During Construction	Contractor/ PIU

Table 10-5-9 (4/4) Environmental Management Action Plan (EMAP)

-	Mitigation Measures to be taken	Location	Time frame	Implementing Organization/ Supervising Organization
3. Social environmental Impact				
Road Safety; Collisions between Vehicles, People and Livestock				
5	Provide adequate signage, barriers and flag persons for traffic control.			
6	Communicate to the public through radio, TV, and newspaper announcements regarding the scope and timeframe of projects, as well as certain construction activities causing disruptions or access restrictions	Throughout road corridors	Month previous	
Stagnant Water as Insect - borne Disease Vectors				
7	The formation of standing waters on construction sites in tropical areas often leads to the spread of insect-borne diseases such as malaria, dengue fever and schistosomisis. Therefore there must be a vigorous program by the constructor to avoid such standing water. In cases where standing waters are managed by their owners (users), e.g., through fish or waterfowl stocking, they will be held responsible for insect control. The owners/ users should be given information about the dangers of waterborne diseases in standing water and how to prevent them.	Refer to Cross Drainage Structure of the Study Report	Whenever encountered during construction	Contractor// PIU and Environment Cell of MPWT
8	All necessary measures will be taken to prevent earthworks and stone works related to the road from impeding cross drainage at channels/ steams or existing irrigation and drainage systems. 'Side-borrow' sites will be used as drainage ditches and designed such that they drain into the nearest water course.			
Deterioration of health of workers due to poor camp conditions				
9	Make certain that there is good drainage at all construction areas, to avoid creation of stagnant water bodies especially in urban/ industrial areas.	Construction camps	During Construction	Contractor// PIU, Env. Cell of MPWT, Health Dept. and MOE.
10	Provide adequate sanitation and waste disposal at construction camps.		At start-up	
11	Provide adequate health care for workers and locate camps away from sensitive areas. Education and control for HIV/AIDS infections for workers.		At start-up	
Littering with waste construction materials				
12	All construction materials should be reused, recycled or properly disposed of. This will become particularly important at the many small bridge replacement sites, where old reinforced concrete will need to be properly disposed of. All worn out parts, equipment and empty containers must be removed from the site to a proper storage location designated by the provincial government and the MOE.	Throughout road corridors	Throughout road corridors	Contractor with PIU, Env. Cell of MPWT and Provincial Center
13	After dismantling, all Bailey bridge parts will be returned to the closest MPWT provincial center. Special attention shall be paid when dismantling to allow the further re-use of those parts for bridging purposes.			

10.6 Summary of Environmental Impact

The IEIA was conducted by the proponent in accordance with the environmental rules and regulations of Cambodia, and it is concluded that there are neither substantial nor irreversible adverse environmental and social impacts arising from the Project. Even though impacts on resettlement issues and activities remain as great concern due to identification of ROW, no adverse social impact is expected because the project involves the improvement of existing roads where no land acquisition for road right-of-way is required.

In the course of the Study, the activities design 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. Results of IEIA Study has been received an approval letter from MOE, and there are some comments added in the letter that more detail environmental study would be provided by MPWT.

Conclusion of IEIA and ISIA on the NR-1 improvement project

Summary of the IEIA and ISIA on the NR-1 improvement project is shown in Table 10-6-1. "The project of improvement of the National Road No.1" has negative impact unless proper measures by the proponent for social & natural environmental considerations are fully taken into account. Therefore, in the implementation of the project, it is recommended that it is necessary to set up protection management measures in order to integrate the social and natural environments fully so that negative impacts are reduced. Also it is imperative to follow the resettlement action plan, the monitoring program and the environmental management action plan in detail, to know differences between comparative measures and control index as well as to report these results through suitable channels.

Table 10-6-1 Summary of Environmental Impact of the NR-1 Improvement Project

No	Environmental items	Evaluation	Remarks
Social environment			
1	Resettlement	B	The Project Affected Persons (PAPs) may comprise 1,805 numbers of household within the Right of Way (ROW) of 30m. Proper relocation procedure and sufficient compensation as well as allowance should be required stably through detail survey by the working group of Inter-ministerial Resettlement Committee (IRC).
2	Economic activities	D	Commercial activities along the National Road No.1 (NR-1) will get affected inconveniently during the construction period but there are temporary in nature.
3	Traffic and public facilities	B	Traffic jam and congestion may occur during construction temporally, public relation on the project schedule and traffic control shall be required. But after the project the traffic condition and safety will be greatly improved. No negative impacts expected on public facilities.
4	Split of communities	D	No negative impacts expected.
5	Cultural property	D	Protected valuable cultural properties don't exist. No negative impacts on schools and pagodas are expected.
6	Water right and rights of common	D	No negative impacts expected.
7	Health and sanitation	D	Prevention program for insects bore diseases from stagnant water, sanitation health care and HIV/AIDS is required for contractor during the construction period.
8	Waste	D	Mass-solid waste and disposal dumps may not be produced by construction, but those disposal materials should be reutilized as other resources for public works.
9	Hazards, risk	B	Traffic accidents will be anticipated temporally during the construction period so that proper traffic control measures to be taken. After the construction to secure the traffic safety design criteria and standards will be applied.
Natural environment			
10	Topography and geology	D	Changes of valuable topographic and geological conditions will not be anticipated.
11	Soil erosion	D	Soil erosion will not be anticipated due to design criteria of slope protection of the NR-1, but earth work activity during the construction period may cause temporary soil loss in some section. Therefore prevention management will be required by the contractor.
12	Ground water	D	Activity of such excavation to affect ground water is not planned.
13	Hydrological situation	D	No reclamation and no activities for affecting hydrological regime in general, but small channels and streams crossing of NR-1 may not be disturbed during the construction. Designed cut-off sections through NR-1 will contribute great efforts of flood inundation fears in the past.
14	Coast and sea area	D	There is no sea area passing the route.
15	Flora and fauna	D	Designed route passes the area of no habitat of valuable and protected species.
16	Climate	D	There are no such large-scale activities for affecting climatic condition planned.
17	Landscape	D	No specific aesthetic area is existed, rather enhanced roadside environmental scenes.
Environmental Pollution			
18	Air pollution	B	Back ground level of emission gas from traffic is quite lower than the Cambodian standard; dust may affect during the construction period temporarily so that proper management should be taken by the contractor.
19	Water pollution	B	Most of structures will be constructed during dry season so that such activities may not cause water pollution, but earthworks and bitumen preparation will be affected if proper management is not applied.
20	Soil contamination	D	No such serious soil contamination affected by constructions is planned.
21	Noise and vibration	B	Impact by noise and vibration due to construction activities increase temporally during construction period, after construction smooth surface of the pavement will contribute less noise and vibration.
22	Ground subsidence	D	There is no impact for ground subsidence anticipated.
23	Offensive odors	D	There are no anticipated factors of producing offensive odors, but bitumen process may cause odors in some points temporally during construction period.
Total evaluation		B	Resettlement of the Project Affected Persons is one of major impacts. During construction period temporary impacts will be expected but they could be solved by proper mitigation measures through procedure of environmental monitoring and environmental management action plan.

Classification of Evaluation: A: Serious impact B: Impact will be anticipated.
C: Unknown (Investigation will be necessary) D: No impact

10.7 Cost Estimation

For succeeding the NR-1 improvement project with safety and environmentally protective manners, in this section shows the proposed cost estimation for those of environmental monitoring program, resettlement action plan and environmental management action plan in each following sub-sections.

10.7.1 Cost on Environmental Monitoring Program

On the basis of the environmental monitoring program during the construction phase is proposed in sub-section of 10.5.6 for reference. Cost estimation on each of major parameters has been made as following Table 10-7-1. In the table total amount of cost includes salary of environmental specialist and researchers, cars, per diem, and VAT 10% and profit, insurance costs are included.

Table 10-7-1 Cost Estimate for Monitoring Program

Parameter for Monitoring	Work Items	Monitoring Period	Quantity	Amount,US$
Atmosphere and Air				
Total suspended particles.	1) Sampling 2) Laboratory testing	Twice a year in dry and rainy season	1 lmp.	2,830
Carbon monoxide. CO		1 to 2times during construction	1 lmp.	390
Nitrogen dioxide. NO_2			1 lmp.	390
Content of sulhur dioxide SO_2				390
Surface Water				
BOD mg/l	1) Sampling 2) Laboratory testing	In time of stream by intensive rain, once a month during the construction	1 lmp.	990
Organic Substances mg/l			1 lmp.	730
COD mg/l			1 lmp.	730
Suspended solids mg/l			1 lmp.	730
Fecal coliform			1 lmp.	730
Hygienic Condition of Work Site				
Condition of work site:	Observation	3 times a year	1 lmp.	4,250
Hygiene				
Lighting				
Safety management of tools and equipment				
Risk management				
Fire escape extinguish				
Planning of community protective measures				
Health condition of workers	Observe workers	Once a year		
Total				12,160

10.7.2 Cost for Resettlement Action Plan

On the basis of the resettlement action plan proposed in sub-section of 10.5.5, cost estimation is done in table 10-7-2. In the table, working period may be presumed as five months. Total amount of cost includes salary of environmental specialists, supervisor and supporting staffs, cars, per diem.

Table 10-7-2 Cost for Resettlement Action Plan

Work items	Assignment/Expenses	Qty	Unit	Unit Cost	Cost
1. Preparation					
1) Conducting property measuring survey, and data & questionnaire conducting by detail management survey (DMS).	Environmental specialist (US$500 x 2.5Man=US$1,250)	5	M/M	US$ 1,250	US$ 6,250
2. IRC sub-working group for inventory and survey					
1) Report documentation to the Council of Minister on the estimated cost for resettlement.	Supervisor and supporting staff (US$400 x 2.5Man=US$1,000)	5	M/M	US$ 1,000	US$ 5,000
2) IRC Sub-working Group's confirmation survey for entitled affected persons by the project.	Car rental	5	month	US$ 400	US$ 2,000
3) Inventory and evaluation task to be conducted through the talk with the affected persons including the compensation.	Per Diem	1	lmp		US$ 450
4) Entitlement to reserve the right for compensation					
5) Preparation of necessary documents for compensation cost after the above survey					
3. Resettlement and confirmation of activity					
1) Formulate the IRC working group for task force to facilitate PAPs to be resettled.					
Total					US$ 13,700

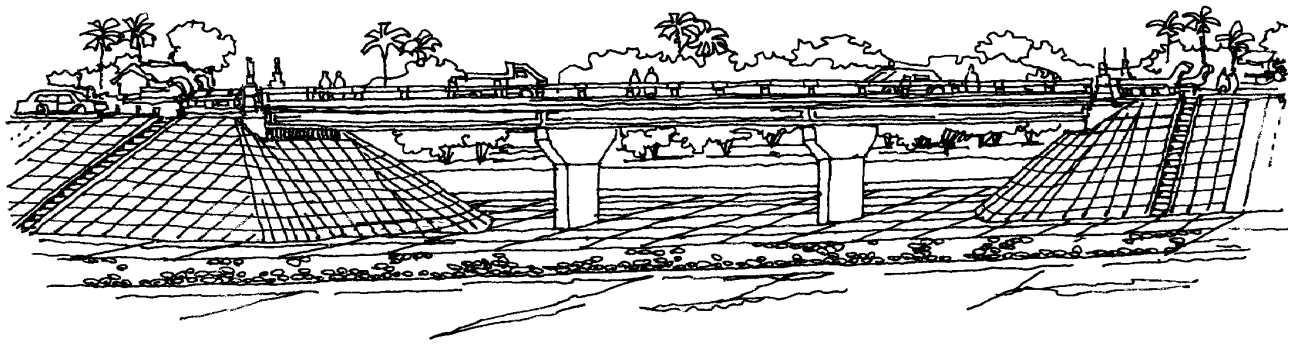
10.7.3 Cost for Environmental Management Action Plan

On the basis of the environmental management action plan proposed in sub-section of 10.5.7, the cost estimation is done as shown in table 10-7-3. In the table, working period may be presumed as 24 months. Total amount of cost includes salary of environmental specialists, supervisor and supporting staffs, cars, per diem.

Table 10-7-3 Cost for Environmental Management Action Plan

	Work Items	Assignment/Expenses	Qty	Unit	Unit Cost	Cost
Pollution						
Air / Dust / Noise Pollution						
1	Maintenance of Vehicles and machinery	Environmental specialist (US$500 x 2.5Man =US$1,250)	12	M/M	1,250	15,000
2	Water spray management					
3	Reduction of material spills					
4	Minimize of Noise generation, Maintenance of machinery and vehicles					
5	Mitigate noise level at sensitive areas and control					
Siltation, Contamination, Waste Disposal and Soil Erosion						
6	Siltation control for construction materials					
7	Prevention of wastewater discharge to water body					
8	Water quality protection against spilled bitumen and management of such spills.	Inspector /supervisor/ support staff (US$400 x 2.5Man =US$1,000)	18	M/M	1,000	18,000
9	Vehicle maintenance and refueling management for prevention of spilled lubricants and fuels.					
10	Management and control of garbage and sanitation facilities.					
11	Management of drinking water					
12	Management of solid waste and garbage collected system					
13	Protection of slopes and other potentially erodible places					
Natural environment						
Alteration of Drainage						
1	Management of disturbance of water course					
Loss of Topsoil and Compaction of Soil						
2	Control management of land degradation	Car rental	24	month	400	9,600
3	Control of damaging surface soil and vegetation					
Flora and Fauna						
4	Protective trees for prevention					
5	Prohibition of wildlife damage					
6	Maintain of stream crossing area for undisturbed					
Social environmental Impact						
Loss of Access and Traffic Congestion						
1	Management of temporary access during the construction	Per diem	1	lmp		1,350
2	Management of traffic jams during construction					
3	Management of control speed of construction vehicles					
4	Safety traffic flow management around construction sites					
5	Provision of adequate signage etc for traffic control.					
6	Provision of public relation on construction activities					
Stagnant Water as Insect-borne Disease Vectors						
7	Formation of standing waters on construction sites for insect-borne diseases					
Deterioration of Health of Workers at Camp Site						
8	Provision of sanitation and waste disposal at construction camps.					
9	Provision of adequate health care for workers					
10	Education and control of HIV/AIDS for workers					
Littering with Waste Construction Materials						
11	Management of waste materials for reuse					
Total						43,950

CHAPTER 11 ESTABLISHMENT OF DESIGN CRITERIA



CHAPTER 11 ESTABLISHMENT OF DESIGN CRITERIA

11.1 Design Criteria for Geometric Design and Pavement

11.1.1 Design Concept

The following factors are considered to establish the design criteria for the Study Road.

(1) The Study Road is affected by flooding of Mekong River. As one of the most important national highways, the Study Road needs to be safely used even during the flood season of Mekong River. Therefore, appropriate margin of road elevation should be secured against the flood water level.

(2) The Study Road forms a part of Asian Highway Route A-1, Connecting Thailand – Phnom Penh – Ho Chi Min City.

(3) 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 the few urbanized sections, this policy should be always applied.

11.1.2 Design Criteria for Geometric Design

(1) Basic Design Factors (Classification, Design Speed and Lane Width)

In deciding the criteria for basic design factors of geometric design of the Study Road, some design standards are referred. They are summarized below:

(a) Cambodian Standard

MPWT drafted Design Standards for road in 1999, and these Standards have bee authorized. Part 1 of the Standard is on geometry. Basic design factors of Cambodian Standard are summarized in the table below;

Table 11-1-1 Summary of Major Geometric Design Factors of Cambodian Standard

Road Category	Arterial		Collector		Local	
	Urban	Rural	Urban	Rural	Urban	Rural
	U6	R6	U4	R4	U3	R3
Access Control*	F	F	P	P	P/N	P/N
Design Speed (Level Terrain) (km/hr)	100	120	70	90	60	70
Lane Width (m)	3.50	3.50	3.25	3.25	3.00	3.00
Shoulder Width (m)	3.00	3.00	3.00	3.00	2.50	2.50
Min. Radius of Curve (Horizontal)** (m)	345	N/A***	165	N/A***	115	165

*F: Full access control P: Partial access control N: No access control

**The Standard gives values of radii in relation to superelevation.
Values shown here are minimum one in the table of the Standard.

***Values of radii for these speeds are not given in the Standard.

The access of the Study Road is undivided, 2-lane road and also will be operated as non-access- controlled road. Therefore, it is not appropriate to apply the criteria for the Arterial or Collector to the Study Road in a straightforward manner.

(b) Design Standard of Asian Highway

As stated above, the Study Road is a part of Asian Highway A1 Route. Design factors of Asian Highway (for level terrain) are summarized as shown below:

Table 11-1-2 Summary of Design Factors of Asian Highway (for Flat Terrain)

Highway Classification	Primary (Access controlled, divided 4 or more lanes)	Class I (4 or more lanes)	Class II (2 lanes)	Class III (2 lanes)
Design Speed (km/hr)	120	100	80	60
Lane Width (m)	3.75	3.50	3.50	3.00 (3.25)
Shoulder Width (m)	3.00	3.00	3.00	3.00
Width of Median (m)	4.00	3.00	N/A	N/A
Pavement Slope (%)	2	2	2	2
Shoulder Slope (%)	3 - 6	3 - 6	3 – 6	3 – 6
Max. Superelevation (%)	10	10	10	10

As stated above, the Study Road is operated as non-access-controlled, undivided, 2-lane road. Therefore, application of the standards for "Primary Class" or "Class I" is considered to be inappropriate, at least under the present circumstances.

(c) AASHTO Standard

"A Policy on Geometric Design of Highways and Streets", 2001, AASHTO (AASHTO Standard) suggests the following design factors.

Table 11-1-3 Basic Design Factors by AASHTO

	Rural Arterial	Urban Arterial
Design Speed (km/h)	100 - 120	50 - 100
Lane Width (m)	3.6	3.6
Shoulder Width	3.0 – 3.6	(Depend on ROW)
Pavement Slope	1.5 – 2.0	1.5 – 3.0

(d) Road Structure Ordinance of Japan (RSOJ)

Basic design factors of RSOJ are summarized in the table below.

Table 11-1-4 Basic Design Factors by RSOJ (Flat Terrain)

	Rural Arterial (Category 3, Class 1)	Urban Arterial (Category 4, Class 1)
Design Speed (km/h)	60 - 80	40 - 60
Lane Width (m)	3.5	3.25
Shoulder Width (m)	Minimum 1.25	Minimum 0.5
Pavement Slope (%)	1.5 – 2.0	1.5 – 2.0

(e) Consideration on the Design Criteria Applied to the Study Road

The followings are commonly considered in deciding criteria for geometric design of a road.

(i) Design Speed

Design speed is the maximum safe speed that can be maintained over a specified section of road when conditions are so favorable that design features of road govern. The design speed is determined logically considering such factors as;

- Type or classification of the road
- Road-side land use and degree of access control
- Type of terrain
- Available right of way, and especially in case of improvement of existing road, alignment of the existing road
- Design speed of adjacent section(s)

Although travel speed is the dominant consideration for regional arterial road, urban arterial roads should be capable of carrying high traffic volumes. Moreover, it is sometimes necessary to compromise on physical constraints and **economic limitations to fit certain elements of design within availability of right-of-way.** The followings may warrant the design speed of 80 km/h applied to the through traveled lanes for the NR-1:

- The Study road is not access controlled and there are many at-grade intersections. Accordingly, actual traffic operation will not allow 100 km/h of vehicle speed.
- Similarly, the Study Road is not divided 4-lane road which is common configuration for design speed of 100 km/h. Therefore, straightforward application of design speed of 100 km/h is hazardous.
- Application of high design speed may not allow the new (design) alignment closely follow the alignment of the existing road. This may result in unnecessary increase in construction cost and social impact.

(ii) Lane Width

3.0 meters to 3.75 meters lane widths are generally used, with 3.5 meters lane predominant on most type of highways. 3.75 meters lane width is internationally accepted as the widest possible lane width since the lane wider than 3.75 meters is hard to regulate traffic flow. In case of the design speed of 80 km/h applied to highway, 3.50 meters wide lane width is desirable on both rural and urban facilities.

Lane width of 3.50 meters is adopted as the standard width in Cambodian Standard as described above, and is also commonly used as standard of national roads in foreign counties.

Table 11-1-5 Standard Lane Width in Major Countries

Countries	U.S.A.	Sweden	Holland	France	Japan	Cambodia
Lane width	3.66 m (12 ft)	3.50 m	3.63 m	3.50 m	3.50 m	3.50 m

Although the standard of Asian Highway stipulates the lane width of 3.75 meters for “Primary Class”, it is based on assumption of other factors such as

"access-controlled, divided 4-lane". In case of the Study Road, access is not controlled and the intersections are at-grade intersections. In addition, Majority of the section of the Study Road is "undivided 2-lane" configuration. Accordingly, application of the standard of "Primary Class" is not appropriate. For the classes of "Class I" or lower, lane width of 3.5 meters or less is stipulated.

As for economic aspects, the construction cost of highway may be increased by up to 7% in general, if the lane width of 3.75 meters be applied,

It should be noted that actual pavement structure used in Japan, includes marginal strips of 0.25 meters which is outside of the lane width, and, therefore, the actual width of the pavement for lane width of 3.50 meters is 3.75 meters or wider. Hence, the pavement of 3.50 meters lane width can be operated as "3.75 meters lane width" by changing the location of lane mark.

Considering these facts, it is proposed to use lane width of 3.5 meters in the Study Road.

(f) Proposed Criteria for Basic Design Factors

In addition to the consideration on the relevant design criteria as described above, the following facts are considered:

(i) The existing alignment of the Study Road is generally favorable, both horizontally and vertically. The radii of smaller horizontal curves are lager than 300 meters, except at Pk 32+600 - 800. Thus, application of 80 km/hr is not considered to result in large-scale realignment, and, accordingly, large-scale social impact nor civil works.

(ii) There are many at-grade intersections along the whole section of the Study Road. Also there are small towns along the Study Road where many pedestrian cross the road. Accordingly, in actual operation of the Study Road, careful consideration needs to be given to the regulation on speed. To allow the speed of 80 km/hr is hazardous particularly in and near the urbanized or semi-urbanized section.

(iii) The observed traffic volume of 4 wheel vehicles is rather small, particularly from Pk 7+000 towards Neak Loueng (around 3,000 veh/day or less).

(iv) On the contrary, traffic volume of motorcycles is large, particularly on the section from the starting point (Monivong Bridge) to around Pk 2+000.

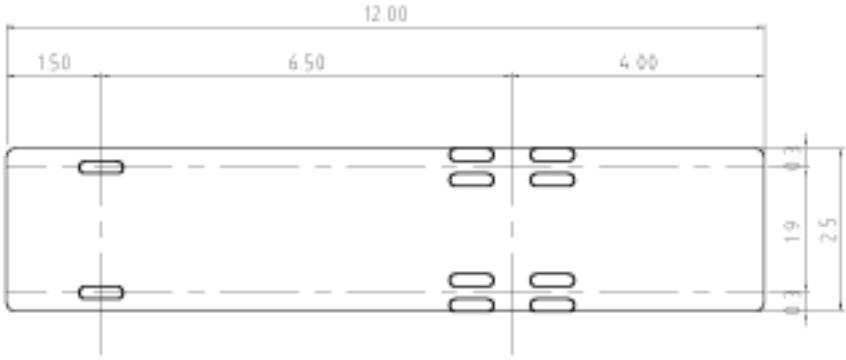
Considering the above, the following design criteria are proposed:

Table 11-1-6 Proposed Criteria for Basic Design Factors

Item	Proposed Value	Remarks
Design Speed	80 km/hr	Speed regulation may be needed
Lane Width	@3.50 m x 2 = 7.0 m	
Shoulder Width (Paved)	@ 2.5 m	
Shoulder Width (Unpaved)	1.0 m	
Pavement Cross Fall	3 %	
Shoulder Cross Fall	4 %	

(2) Design Vehicle

In geometric design, the most governing type of vehicle is semitrailer. Fig. 13-1-1 shows the dimensions of single truck and semitrailer adopted in RSOJ and WB-15 semitailer adopted in AASHTO. Cambodian Standard stipulates WB-15 trailer of AASHTO. Accordingly, WB-15 semitrailer is adopted as the design vehicle.



(a) Single Unit Truck (RSOJ)

(b) Semi-trailer (RSOJ)

(a) WB-15 Semitrailer (42.5 feet Trailer, AASHTO)

Fig. 11-1-1 Design Vehicle

(3) Vertical Clearance

Presently, there are no structures spanning over the Study Road. Accordingly, there is no problem of obstruction in vertical clearance. However, criterion for vertical clearance becomes necessary when over-head type traffic signs or pedestrian crossing are to be constructed.

Criteria for vertical clearance of AASHTO, RSOJ and Cambodian Standard are compared in the table below.

Table 11-1-7 Criteria for Vertical Clearance

Standard	AASHTO	RSOJ	Cambodian Standard
Vertical Clearance	(4.1 m)*	4.5 m	(4.1 m)*

* Height of design vehicle

It is recommended to adopt 4.5 meters as the vertical clearance.

(4) Criteria for Other Design Elements

Proposed criteria for other design elements such as minimum radius of curve and maximum grade are summarized in the table below. For detailed discussion for proposed criteria is presented in Appendix G-1.

Table 11-1-8 Elements 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

(5) Proposed 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. On the side of the road design, most important consideration may be seepage of water into subgrade/pavement and decrease in the bearing capacity of pavement. In highway engineering, it is widely accepted that the influence of traffic load needs to be considered up to 1 meter deep from the surface of the

subgrade. Therefore, it is desirable that the table of seepage water produced by the flood water is below 1 meter from the top of subgrade, or the top of subgrade is set 1 meter above the seepage water line. Because of the complexity of permeability of soils in the embankment and movement of flood water level, it is very difficult to know the configuration of water table in the highway embankment. However, it is easily understood that the water table seeping into the embankment is higher near the slope than near the center of embankment when level of flood water is rising. Therefore, it is desirable that the top of subgrade at the shoulder of slope is set 1 meter above the design high-water level. However, this may result in unjustifiably large volume of earthwork, and thus, large cost and other draw-backs. Three alternatives are considered for the selection of road elevation (embankment height).

Table 11-1-9 Alternatives for Embankment Height

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

*Top of subgrade at the shoulder of slope

Alternative A is proposed for the reason that this elevation satisfies the requirement of minimum freeboard as described in Chapter 9. Alternatives B and C are to examine pros and cons for the cases lowering/raising the embankment height by 30 cm. These alternatives are compared for several aspects in the following.

(a) Earthwork Volume

The result of preliminary estimation of volume of additional embankment is summarized in Table 11-1-10. In estimating the volume of earthwork, it was assumed that the additional embankment for widening

Table 11-1-10 Earthwork Volume for Alternatives

Alternative	Alternative A	Alternative B	Alternative C
Approximate Volume of Additional Embankment	1,000	610	1,400

(Unit: '000 m^3)

(b) Seepage of Water into Pavement Structure

As stated before, it is very difficult to estimate the configuration of water table seeping into the embankment. However, considering the water table in the embankment produced by the flood water is lower near the road centerline than near the slope of embankment and that 2 – 3 % of cross fall will be provided on the top surface of embankment, the following can be said:

(i) In case of Alternative C (embankment height = flood water level + 80 cm), water table in the embankment is expected to be well below 1 meter from the top of embankment, at least near the road centerline.

(ii) In case of Alternative B (embankment height = flood water level + 20 cm), there is a possibility that water table in the embankment comes within 1 meter from the

top of the embankment.

(iii) In case of Alternative A (embankment height = flood water level + 50 cm), water table in the embankment may come within 1 meter from the top of the embankment, but is not supposed to come within 50 cm from the top of the embankment. This is significant in pavement design as explained below.

(c) Seepage of Water into Selected Subgrade Material

Considering the low CBR value of the existing embankment/subgrade, it is assumed that placement of selected subgrade material with minimum thickness of 30 to 50 cm is necessary. To fully utilize the baring capacity of the selected subgrade material, seepage of water into this selected material has to be avoided.

Considering the facts as explained in (1) to (3) above, it is recommended to se the embankment height of flood water level + 50 cm.

11.1.3 Design Criteria of Pavement

The criteria stipulated in "AASHTO Guide for Design of Pavement Structures" (AASHTO Standard) are used as the basic criteria for pavement design. AASHTO Standard is adopted because it is accepted as the standard textbook of this kind and is used as the base of pavement design manuals in many countries. Also, other criteria, such as "Asphalt Pavement Manual" by Japan Road Association (JRO) may be referred, as deemed appropriate. (Detailed explanation on actual process of pavement design is given in Appendix G-3)

(1) Strength of Pavement

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

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

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

Fig. 11-1-2 shows the flow of determining pavement strength. Detailed explanation of pavement design is presented in Appendix G-3.

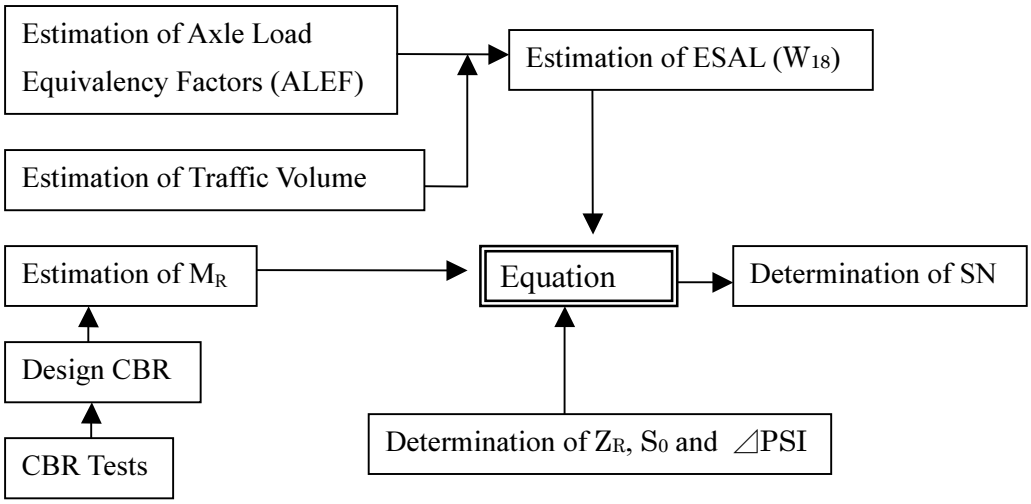


Fig. 11-1-2 General Flow of Determining Pavement Strength

(2) Design factors used in the AASHTO formula

Factors used in the AASHTO's methods are determined as described below.

(i) Traffic volume: Traffic volume estimated in Chapter 4 "Forecast of Future Traffic Demand" shall be used

(ii) ALEF: ALEF shall be estimated from the data obtained by "Vehicle Weight Survey" conducted in this Study. (For details vehicle weight survey and estimation of ALEF, refer Appendix G-4)

(iii) CBR (M_R): CBR values are estimated based on the data of CBR obtained through the CBR test of this Study with reference to the CBR data of previous studies.

(3) Minimum thickness of layers

In considering the pavement structure, the following minimum thicknesses of layers shall be maintained. These criteria are adopted from JRO standard with reference with AASHTO Design Guide. (Detailed explanation is given in Appendix G-3)

Table 11-1-11 Minimum Thickness of Surface Course

Class of Design Traffic Volume	Thickness (cm)
L, **A**	**5**
B	**10 (5)***
C	15 (10)*
D	20 (15)*

* Thickness in ( ) can be used where the base course material is asphalt-stabilize

The classes of traffic volume used in Table 11-1-12 are as shown in the table below.

Table 11-1-12 Class of Traffic Volume for Pavement Design

Class of Design Traffic Volume	Traffic Volume of Heavy Vehicles (Vehicle/day/direction)
L	Less than 100
A	100 – 249
B	250 – 999
C	1,000 – 2,999
D	3,000 or more

In case of the Study Road, traffic volumes of Section 1 to 3 (Start Point to St. 14/Pk 19.6) are classified into "Class B", while traffic volumes of Sections 4 and 5 (St.14/Pk19.6 to End Point) are classified as "Class A".

As for base course and subbase course, the following criteria shall be applied.

Table 11-1-13 Minimum Thickness of Base Course and Subbase Course

Material/Construction Method	Minimum Thickness of Layer
Asphalt-stabilized	2 times of the maximum grain size and 5 cm
Other than above	3 times of the maximum grain size and 10 cm

(4) Consideration on Cost

With a given required SN, wide range of variation in pavement structure (combination of surface, base and subbase with different thicknesses) is possible. Alternatives of pavement structure with different thickness of layers shall be compared and the structure with the least cost will be adopted.

Actual process of pavement design is described in detail in Appendix G-3

11.2 Design Criteria for Bridge and Structure

11.2.1 Application of Design Standard

The Cambodian Standard was established in 1999 with the assistance of Australian Aid and was authorized by the Minister of Public Works and Transport in 2001 based on study among several donors' standards including AASHTO applied in Asian Highway Project and/or Japanese Specifications applied in Grant Aid Project.

Design Standards for recent constructed bridges and culverts by donors are applied variously such as Cambodian, American AASHTO, Australian, and Japanese Standards, etc.

Considering whole National Road No.1 (NR-1 C1, C2 Section) named Asian Highway A-1, American AASHTO and Japanese Standards will be applied to this Project NR-1 (C1) referring Cambodian Standard, and other Country Standards.

Applicable Design Standard for Structures;

- Standard Specifications for Highway Bridges: AASHTO American, 1996
  (Design of Highway Bridges; based on AASHTO LRFD Bridge Design Specifications, 1997)
- Specifications for Highway Bridges: Japan Road Association, 1996, 2002
- Specifications of River Facilities: Japan River Association, 1998
- Bridge Design Standard: Cambodia, Ministry of Public Works and Transport, 1999
- Road Design Standard: Cambodia, Ministry of Public Works and Transport, 1999

11.2.2 Typical Cross Section and Design Condition for Bridge and Culvert

(1) Typical Cross Section of Bridge and Culvert

The defined width in Cambodia Standard is 3.5m/lane for carriage way, 2.5 or 1.5m/lane for slow vehicle way and shoulder width. To keep the over geometric design standard and design speed for the project, the carriage way and slow vehicle way including shoulders will be proposed 14 meters corresponding to traffic volume of study results. Newly constructed water gates and existing large size bridge such as Monivong Bridge on the Project Road shall also be referred.

The proposed typical cross sections in all cases such as bridge, box culvert are shown in below Fig. 11-2-1.

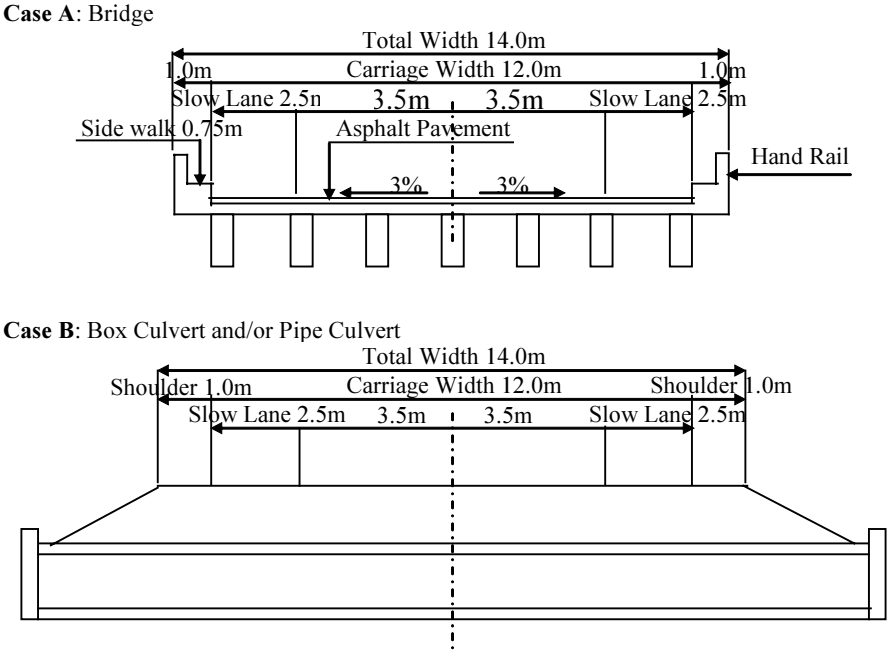


Fig. 11-2-1 Proposed Cross Sections on the Structures

(2) Elements of Design Condition for Bridge and Culvert

The elements for structural design conditions are as follows;

- Scale of Structures:

  Topographical survey, Plan and longitudinal alignment of road, Cross section, Superstructures: HWL, Width of design river bed and water surface, Free board,

Substructures: Height of design river bed, Embed depth of foundation, Protection,
Foundations: Bearing layer by geological survey,
Culverts: HWL, Width of design river bed and water surface, Free board, Height of invert level, Cover on culvert, Protection.

- Type of Structures:

Bridge: Construction cost, Period, Method, Stability, Maintenance degree, Construction experience,
Culvert: Construction cost, Period, Method, Stability, Construction experience.
Protection: Wet masonry for embankment slope,
Gabion mat for substructure at river bed.

11.2.3 Design Loads

(1) Classification of Design Loads

Referring the previous Clause, appropriate design standards for the bridge and structures shall be applied to this project.

Design loads will be applied for American AASHTO and Japanese Specifications referring Cambodia Criteria "Bridge Design Standard (Ministry of Public Works and Transport, Kingdom of Cambodia 1999)", and other Standards.

The design loads for structure are classified as shown in Table 11-2-1.

Table 11-2-1 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

(2) Dead Load

The intensity of materials for dead load is shown in below Table 11-2-2.

Table 11-2-2 Dead Load Intensity

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

(3) Live Load

(a) Magnitude of Live Load

The various loading capacity expected to increase along with future development of economy. For the project structures, the live loading system shall be applied corresponding to **actual conditions**[1] of heavy vehicles passing project road surveyed June 2002, and consideration of Cambodian Standard and laws/regulations, comparing with Standards of Overseas.

A comparison of the live loading systems in use around the world expressed as Live Loading Method, and Bending Moment of girder is given in Table 11-2-3 and Fig. 11-2-2.

[1] actual conditions of heavy vehicles passing project road NR-1 (June 2002 surveyed);
The ratio of heavy vehicle was 13.9% (PCU), and there were 19.1% of over 25 ton truck, with average 26.3 ton, on the project road NR No.1. (refer to Chapter 5, measured axle load and truck weight on NR-1)

Table 11-2-3 Live Loading Method in the World

	Loading Type			Combination
	Truck Load	Lane Load	Others	
AASHTO LRFD	HL-93 4.3 m, 4.3 to 9.0 m 35 kN, 145 kN, 145 kN	q = 9.3 kN/m	1.2 m Tandem 110 kN, 110 kN	Truck + Lane Load Tandem + Lane Load
Cambodian	T44 48 kN, 96 kN, 96 kN, 96 kN, 96 kN	L44 1.20 m 90 kN/lane, 90 kN/lane 12.5 (kN/m/lane)	HLP240 12 axiles @ 200 kN spaced at 1.80 m = total 2400 kN Overall length 19.8 m	T44 only L44 only HLP240 only
Japanese B-Load	0.5 P2 | 0.5 (P1+P2) | 0.5 P2 P2 | P1+P2 | P2 0.5 P2 | 0.5 (P1+P2) | 0.5 P2 5.5 m, Width between kerbs 10.0 m			B-Load only
Ontario	OHBD Truck 3.6 m, 1.2 m, 6.0 m, 7.2 m 60 kN, 160 kN, 160 kN, 200 kN, 160 kN	q = 10 kN/m		OHBD only 0.7 OHBD + Lane Load

	BENDING MOMENT	SHEAR
P1	9.81 kN/m2	11.77 kN/m2
P2	3.43 kN/m2	3.43 kN/m2

1.2 m, 1.2 m, 1.2 m
196.2 kN, 196.2 kN, 196.2 kN, 196.2 kN

Span Length (m)	10	20	30	40	50	60	70	80
AASHTO LRFD	1524.4	4241.0	7557.2	11342.1	15593.6	20310.8	25493.4	31141.4
Ontario	1697.2	4067.0	8242.6	12696.5	17889.2	23588.1	29787.5	36487.4
Cambodia	1561.7	5600.0	11536.2	17532.2	23529.7	29528.1	35526.9	41526.1
Japan B-Load	1329.9	4120.2	7379.0	11137.3	15409.8	20204.1	25524.7	31374.3

Figure Comparison of Live Load for 2-Lane Bridge

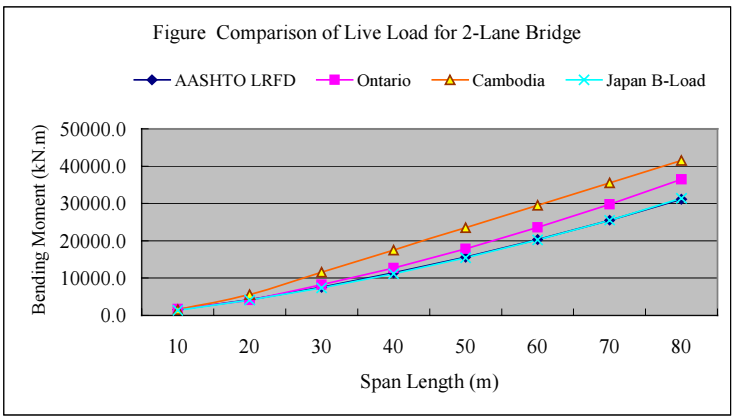


Fig. 11-2-2 Comparison of Bending Moment for Live Loading in the World

Regarding the results of computed bending moment for live loadings in the above 4 cases, the values of AASHTO HL-93, Japan B-Load and Ontario are similar except Cambodian Load.

To meet existing live loading conditions of vehicles, and to avoid excessive design, the live loading system shall legally be applied corresponding to the National Road No.1 as well as becoming Asian Highway as trunk road network.

(b) Axle Load and Total Weight of Transport Vehicles

Based on Cambodian Laws and Regulations adopted 1997-2000, maximum axle load and total weight of transport vehicles circulating on National Road was published. The weight of transport vehicles among American AASHTO (HS20-44, HL-93), Japanese Specification (TL-25, B-Live Load) and Cambodian Laws and Regulations can be compared as below Table 11-2-4.

From below table, maximum total weight as well as axle load by Japanese Specification (TL-25, B-Live Load) is obviously the heaviest among other Specifications.

Table 11-2-4 Comparison of Weight of Transport Vehicles among Each Country

Specification of Live Loading System in Each Country	Axle Load	Maximum Total Weight of Vehicle
AASHTO HS20-44 (HL-93)	Rear (Front) 14.5 t 3.6 t	Truck 20 t Semi-trailer 33 t
Japan TL-25, B-Live Load	Rear (Front) 20.0 t 5.0 t	Truck 25 t Semi, Full trailer 36 t
Cambodia, Compendium of Cambodian Laws adopted in 1997-2000	Single Axle 10.0 t Tandem Axle 19.0 t (10.0t for each axle)	for Category (A) on NR-4, 6, 7 16 t (double axle), 25 t (triple axle) including Trailer 35 t (4 axles), 40 t (5 axles) for Category (B) on other NR 16 t (double axle), 20 t (triple axle) including Trailer 30 t (4 axles), 35 t (5 axles)

(c) Applied Design Standard for Newly Constructed Structures

The newly constructed structures on NR-1, C-1 and C-2 section, were applied Japanese and/or American AASHTO as follows.

Newly constructed structures:

- New water gates (4 nos.) by JICA Grant Aid on NR-1 C-1 Section- applied Japanese Specification
- Culverts and road structures by ADB on NR-1 C-2 Section- applied American AASHTO Specification

In viewpoint of above ****loading elements of a), b) and c)**, it is recommended to apply the **live loading system of Japanese specification (TL-25, A, B-Live Load System)** for this project referring American AASHTO (HL-93, HS20-44 System) and Cambodian Standards/ Laws and Regulations.

For the reference, the scales and dimensions of the typical truck and trailer in cases of American AASHTO (HL-93, HS20-44) and Japanese Specification (TL-25, A,B-Live Load) are illustrated as shown in below Fig.11-2-3 and Fig.11-2-4, respectively.

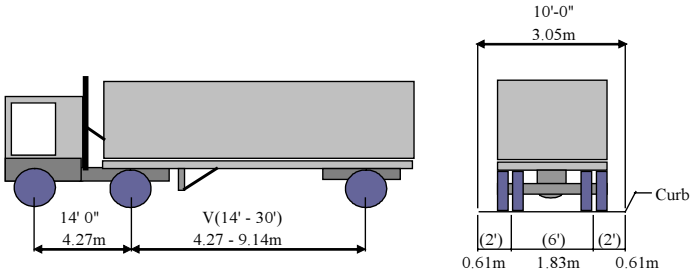
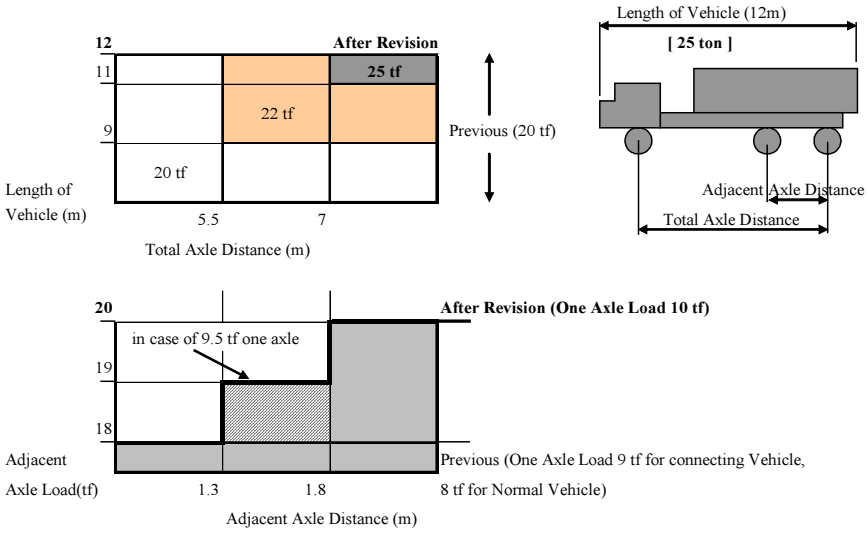


Fig.11-2-3 American AASHTO- Tractor Truck with Semitrailer

Case 1: The total weight of vehicle for transportation [except Trailer]



Case 2: Expansion of total weight of vehicle as special vase [for Trailer]

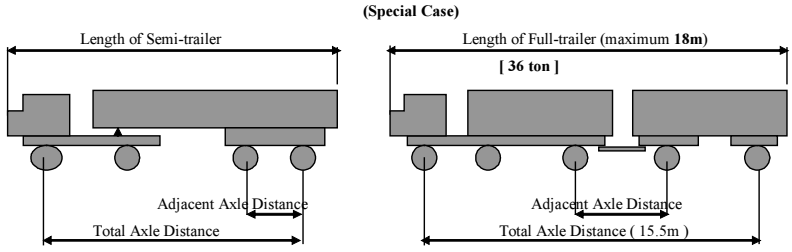


Fig 11-2-4 Japanese New Specification- Truck and Trailer[2]

Other Main Loads:

The local conditions are to be considered in this Study as specified applicable Cambodian Characteristic Standard and/or other Standards.

The items to be applied for structural design in this study are following loads.

- Earthquake load: Kh=0.05 (Seismic Horizontal coefficient)

  According to data of International Seismic Center, earthquake is not recorded in Cambodia. It can be judged that influence of earthquake for structures is

[2] Based on the above Case1, 2, and conditions of continuous traffic flow of 25 ton vehicles, Live Load System was defined the two kind of scale (A & B Load), taking into account of heavy/large traffic with high frequency, as International Transportation.

negligible. Thus, minimum seismic horizontal coefficient (Kh=0.05) shall be applied.

- Earth Pressure, Shrinkage and Creep, Differential Settlement
- Water Flow and Lift Force, Buoyancy
- Wind Load, Flood Load,
- Other Loads

(4) Material and Strength

The strengths of material for concrete, reinforcing steel bar and the others are to be determined in consideration of the Cambodian useful materials and laboratory testing.

Gathering the data, record of materials, strengths for concrete, and reinforcing/pre-stressing steel bar from many executed Projects as ADB, WB, and JICA Grant Aid of Japan in Cambodia, the main materials and basic strength of standard for applying structures are listed as shown in Table 11-2-5.

Table 11-2-5 List of Material and Strength

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 Hand Rail	σ ck = 21N/mm^2	Pipe Culvert (Precast)	σ ck = 30N/mm^2

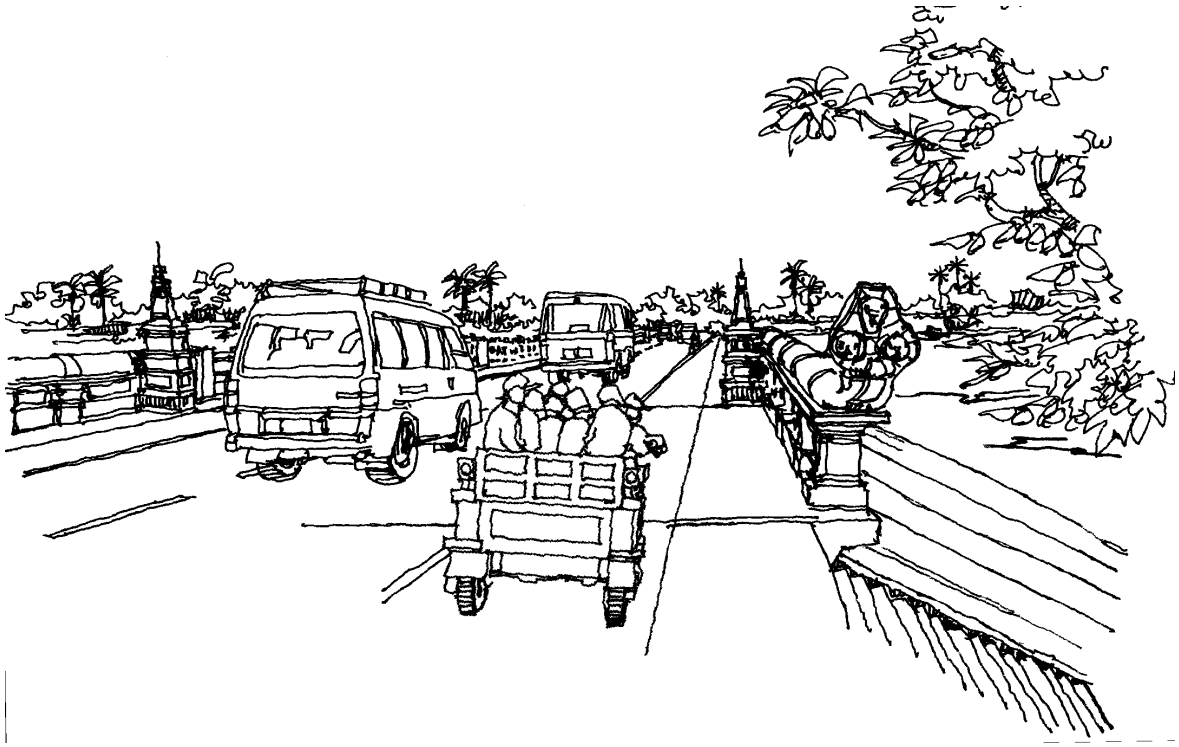
* Concrete Compressive Strength σ ck (28 days)

Steel Grade (deformed Bar)	Diameter (mm)	Length (mm)	Chemical Composition (%)					Strength (N/mm^2)	
			C	Si	Mn	P(max)	S(max)	Yield	Tensile
SD295	9-32mm	6-12m	0.16-0.18	0.15-0.37	0.60-0.90	0.04	0.04	295 min	440-600
SD345			0.18-0.20	0.15-0.37	0.80-1.00	0.04	0.04	345-440	490 min

* 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)

Constants of Backfill Soil	Friction angle ϕ=30 deg. Unit weight r=19 kN/m^3

CHAPTER 12 SETTING AND EVALUATION OF ALTERNATIVE PLANS



CHAPTER 12 SETTING AND EVALUATION OF ALTERNATIVE PLANS

12.1 Study Methodology

This chapter is to envisage the outline of alternative plan setting on the assumption that each technical aspect is deliberated individually in this report to reveal salient features pertaining to each planning parameter based on the results of survey and analysis.

However, the issue on social impacts especially the resettlement of PAPs is so crucial that in-depth study was conducted to reveal actual practice on this matter. The prevailing and practical procedure is described in Chapter 10, and the scheme of tentative ROW of 30 meters is only the way how to manage to avert such troublesome problems as land acquisition and community disruption. Alternative schemes are also examined, namely variable ROW of 14 meters to 24 meters and no resettlement in urban area as given in Appendix H-6. Both are not acceptable to MPWT because the former violates the minimum ROW of NR-1 stipulated in the Prime Minister Declaration on 27 September 1999 and the latter cannot meet the requirement of improvement plan. Adoption of tentative ROW of 30 meters has been confirmed in the course of study, and accordingly no consideration is taken to set alternative plans.

The following five planning parameters are examined to set alternative plans.

(1) Inflow Capacity of Opening
(2) Location and Type of Structure
(3) Design Embankment Level
(4) Cross-sectional Configuration
(5) Type of Pavement

Technical aspects and design elements in the Study are so complicated that they should be segregated neatly. Accordingly, two schemes and two modules are prepared to discuss individually at the first step.

The scheme-1 is represented as the scheme of improvement considering the present condition, especially inflow capacity of floodwater to the Colmatage area, while the scheme-2 is represented as the adoption of spillway for discharging floodwater to the Colmatage area in lieu of opening by bridges and culverts. These two schemes are selected respectively to cover all the possible type of countermeasures that attract a great deal of general attention.

Flood aspects are discussed mainly in Module-1 to find appropriate scheme for drawing up an improvement plan focusing on flood plain management. This aspect is studied comprehensively in Chapter 9 according to the results of hydraulic model covering the Mekong River, the Bassac River and the flood plains on the both banks of the Mekong River along NR-1.

Road and road traffic aspects are discussed in Module-2 to a considerable extent. Within Module-2, engineering studies are carried out to find appropriate scheme covering practical countermeasures from technical viewpoints.

Several schemes are selected from both Modules-1 & 2, and they are combined to set

alternative plans. These alternative plans proceed to the comprehensive evaluation after revealing project scale, technical features and cost-wise matter through the preliminary engineering study.

After the setting of alternative plans is made to cover all the issues encompassing NR-1 improvement as well as flood mitigation measures in Phnom Penh and its surrounding, the comprehensive evaluation is made to select an optimum scheme for formulating a road improvement plan.

Fig. 12-1-1 illustrates the relationship between planning parameters and each alternative plan.

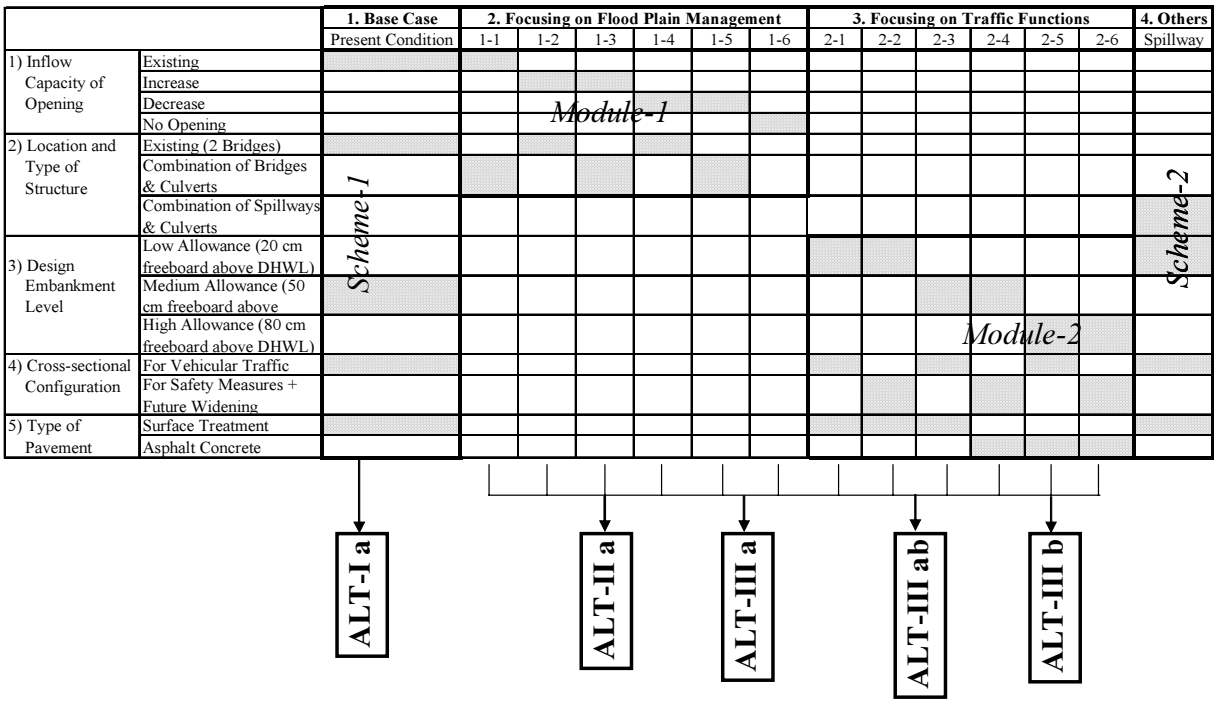


Fig. 12-1-1 Relationship between Planning Parameters and Each Alternative Plan

12.2 Planning Parameters

(1) Inflow Capacity of Opening

The floodwater from the Mekong River may flow into the flood plain in between the Mekong River and the Bassac. However, the discharge of the flood plain has its own limitation due to the terrain and hydrological characteristics. The flood plain likely has more capacity than it is, and the present condition of two bridges contributes to mitigating flood risk to Phnom Penh. Accordingly, the effects of opening are examined in cases of more or less than the existing condition. In addition to such examination, no opening case is also tested for the purpose of envisaging the flood situation before 2000 Flood.

(2) Location and Type of Structure

After the location and scale of opening are carefully examined investigating the land use along NR-1, 12 locations and 4 sections totaling 6,800-meter long are confirmed to enable floodwater to discharge to the flood plain. Existing two bridges have considerable inflow capacity compared with other facilities such as watergates and culverts.

However, since a peak discharge is to have limitation due to present residential area and land use, a suitable type of structure is to be selected, namely bridge or culvert in principle.

A bridge has advantages in the aspect of inflow capacity, while a culvert has advantages in the aspects of deceasing velocity and retarding floodwater to flow in and out.

In addition to the types of such structures, spillway is also deliberated to pursuit a low-cost countermeasure.

(3) Design Embankment Level

The concept of design High Water Level (HWL) plus freeboard is applied to determine a design embankment level of NR-1 in order to secure roles and functions by improving a flood-free road to an all-weather standard. ADB Emergency Flood Rehabilitation Project is underway from Km 19 to Km 55 to raise embankment level 20 cm above 2000 Flood Level at three over-flow sections, and it will be the basis for the improvement plan of the Study. Although a pavement thickness is not determined yet, practical freeboards are assumed 20 cm, 50 cm and 80 cm on condition that 2000 Flood Level is the HWL. It is a fact that bigger freeboard will require more fill material, and it will lead to high cost.

In case of 50 cm freeboard that is applied in prevailing projects as shown in Fig. 12-2-1, the level of road surface will be approximately 1 meter higher than the HWL at the lowest section.

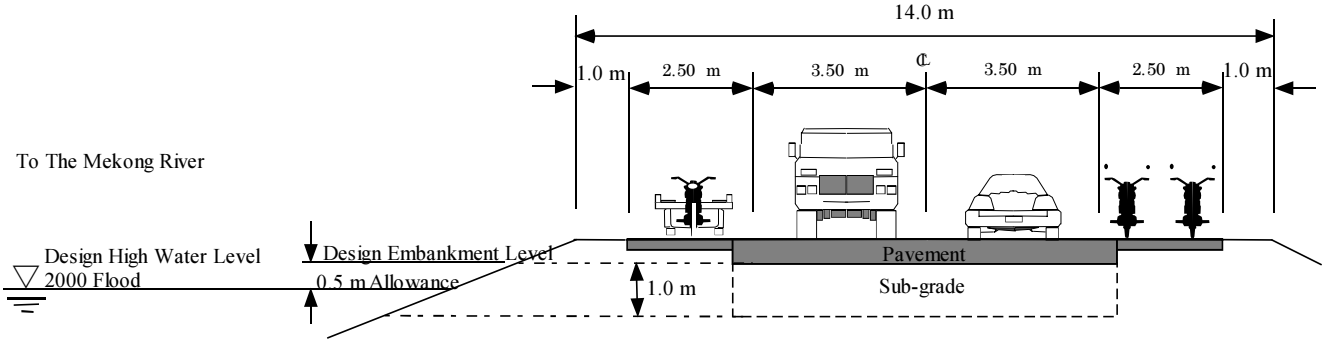


Fig. 12-2-1 Relationship between HWL and Elevation of Road Surface

(4) Cross-sectional Configuration

Prior to selecting an optimum configuration of cross section among several alternative cross sections which are deemed feasible technically and economically, the design section should be determined. Four design sections are contemplated considering traffic volume and land use along NR-1:

Section-1: Monivong Bridge to Intersection to Tiger Beer factory at Km 7
Section-2: Intersection to Tiger Beer factory at Km 7 to Kokir Market at Km 14
Section-3: Kokir Market at Km 14 to Neak Loueng at Km 55 except Kokir Market
Section-4: In the vicinity of Kokir Market

These four sections have different traffic characteristics and typical cross sections are prepared to meet each traffic situation.

Fig. 12-2-2 shows the typical cross sections of NR-1 in urban and rural area to meet minimum requirement for vehicular traffic. However, it is practical to secure traffic safety that the space for slow-moving vehicles is optionally provided on 2.5-meter wide shoulder where high percentage of slow-moving vehicles such as motorcycles, moto-dops and moto-remorks are expected

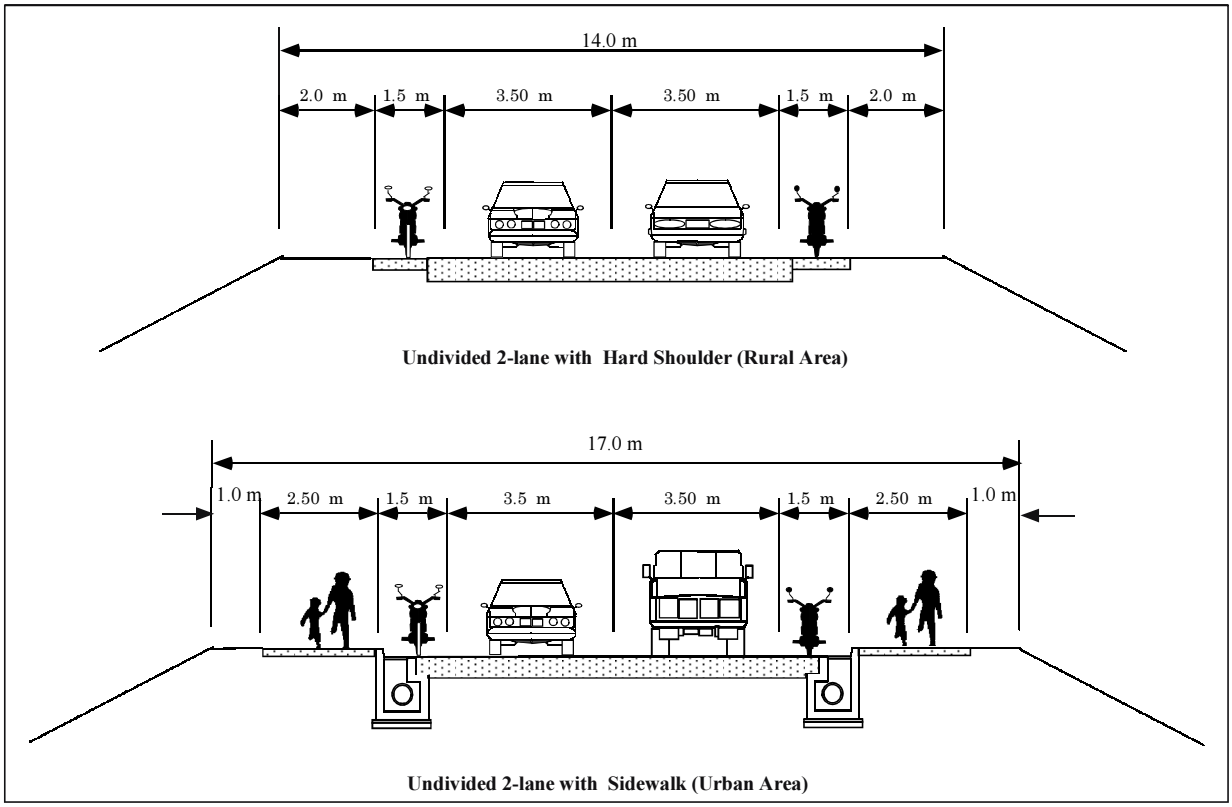


Fig. 12-2-2 Typical Cross Sections in Urban and Rural Area to meet Minimum Requirement for Vehicular Traffic

Section-1 is located in urban area and has heavy traffic with high percentage of slow-moving vehicles. Since additional 2-lane bridge parallel to the existing Monivong Bridge is planned to build in the southern side in future and traffic demand forecast can justify a widening scheme, one alternative plan is prepared to keep space for widening to 4-lane in future as shown in Fig. 12-2-3.

Section-2 is located in rural area and presently has rather high percentage of slow-moving vehicles. However, the improvement of NR-1 will bring development impact to generate traffic considerably since high development potential is expected along NR-1. Section-3 has comparatively low traffic in rural area but there still exist many slow-moving vehicles such as motorcycles, moto-dops and moto-remorks that are a convenient transport means of citizen.

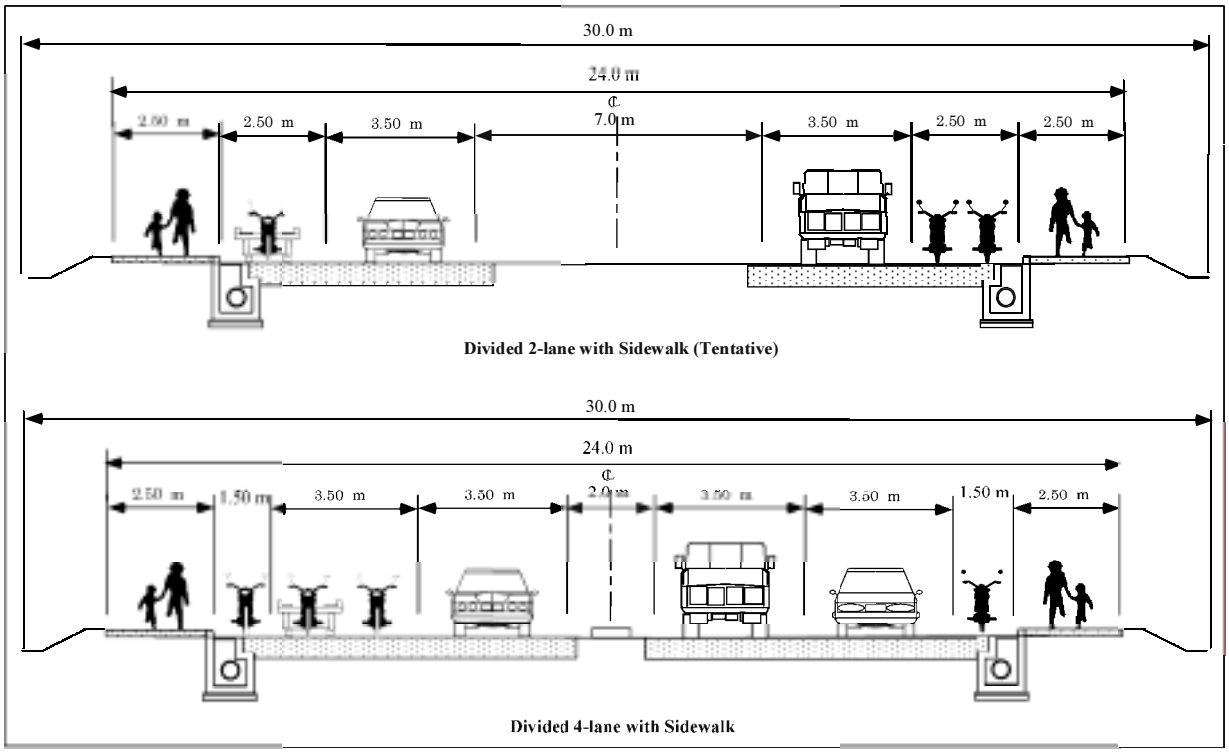


Fig. 12-2-3 Typical Cross Section between Monivong Bridge and Km 7+000 to keep Space for Widening to 4-lane

Section-4 is located in the vicinity of Kokir Market and has high demand of car parking together with rather high percentage of slow-moving vehicles as shown in Fig. 12-2-4.

Accordingly, there are two alternatives, to meet traffic requirement or to keep space for safety measures and future widening as shown in Figs. 12-2-5 and 12-2-6.

According to actual practices to evacuate occupants from Road Right-of-Way (ROW) on National Roads in Cambodia, it is possible to vacate the land by a due procedure taken as the fair and just compensation to make Project Affected Persons (PAPs) resettled stably.

4,100 households exist within the permanent ROW (60 m) on NR-1 in 56 km long stretch between Phnom Penh and Neak Loueng. However, 30-meter width of space along the study road will be required to provide the sufficient space for carriageway, shoulder and slope of embankment and this is so-called "the tentative ROW". In case that 30-meter wide ROW should be applied to the study road, number of affected households will decrease up to 1,805, which comprises 570 households in 7 km stretch between Monivong Bridge and Intersection to Tiger Beer factory and 1,235 households in rural area.

These figures will not vary even though cross-sectional configuration is changed because PAPs within the tentative ROW should move outside of the boundary.

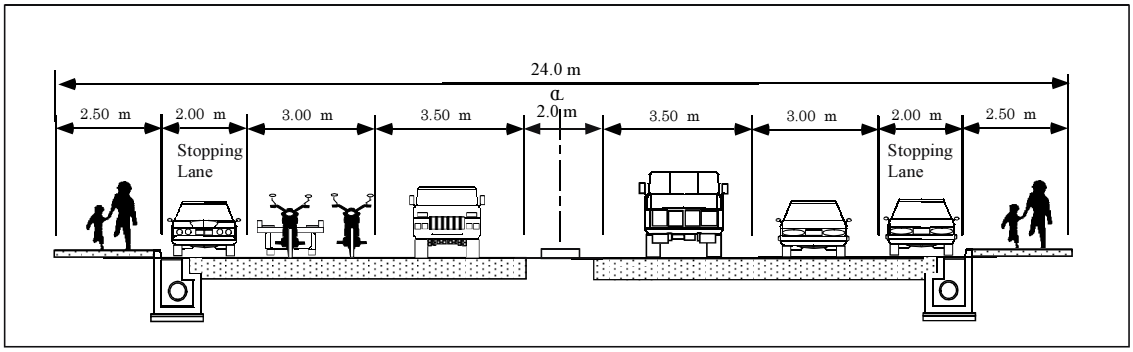


Fig. 12-2-4 Divided 4-lane with Stopping Lane and Sidewalk at Kokir Market

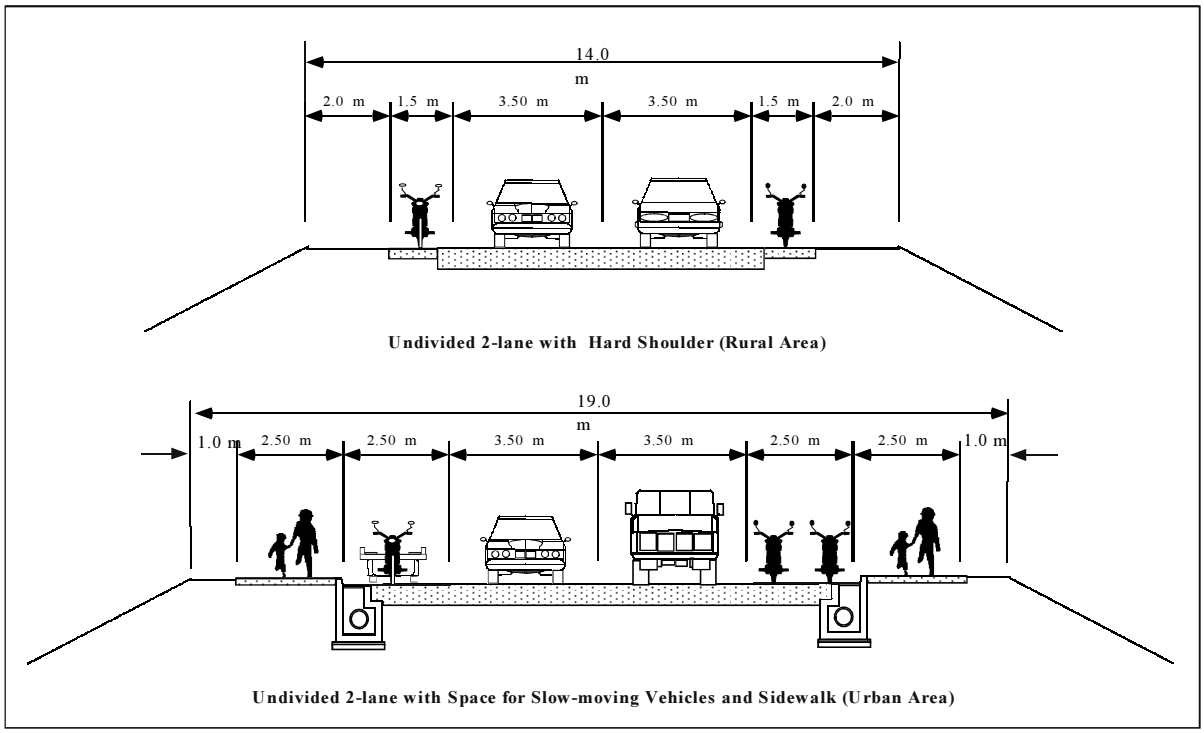


Fig. 12-2-5 Typical Cross Section to meet Traffic Requirement

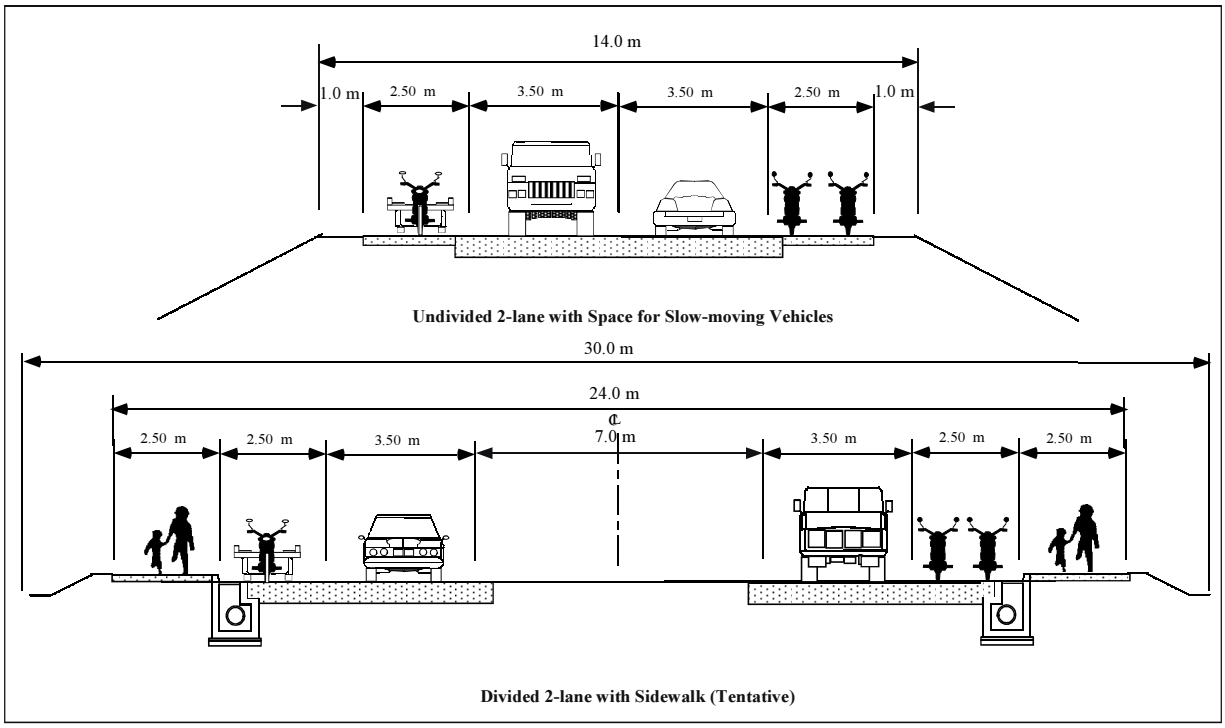


Fig. 12-2-6 Typical Cross Section to keep Space for Safety Measures and Future Widening

(5) Type of Pavement

The pavement structure should be bearable and durable enough for all-weather use.

The pavement is to be designed to fulfill such functions as:

1) sufficient total thickness and internal strength to carry expected traffic loads;
2) adequate compaction to prevent the penetration or internal accumulation of moisture; and
3) a top surface that is smooth, skid resistant, and resistant to wear, distortion, and deterioration by weather and deicing chemicals.

Both flexible pavements of asphalt concrete (AC) pavement and bituminous surface treatment (BST) pavement theoretically have the same function on the basis of similar pavement structure. The pavement spreads the wheel load to the subgrade so that the maximum pressure on the subgrade is small enough to be easily supported by the subgrade in case of proper selection of pavement materials and with adequate pavement thickness. Simultaneously, the surface of a flexible pavement exposed to vehicular traffic should be tough to resist distortion and provide a smooth, skid resistant riding surface. It should be waterproof and sloped to shed surface water to the roadside to protect the entire flexible pavement structure and the subgrade from the weakening effects of moisture. It should resist wear and retain necessary anti-skid properties. It should also be bonded to the layer or course beneath it.

AC pavement that is designed strong enough will require bigger initial investment but lessen maintenance cost. Moreover, an excessive investment to pavement might result in shortage of fund to build a necessary road in anticipated length.

On the other hand, BST that has similar pavement thickness will require comparatively small initial investment but bigger maintenance cost to keep the same serviceability as AC pavement. Furthermore, it will incur additional investment to execute intensive rehabilitation works unless appropriate repair works are undertaken timely at damaged portion.

However, AC pavement has many advantages except cost-wise matter compared with BST pavement from technical viewpoints, provided that plant-mix asphalt concrete and construction equipment are available.

AC pavement is superior to BST pavement in general that badly requires in-situ technique in the aspects of resisting distortions and disintegrations as well as no risk of problems caused by BST.

12.3 Setting of Alternative Plans

12.3.1 ALT-I a: Maintaining Existing Inflow Capacity (refer to Fig. 12-3-1)

This scheme is that major physical conditions on NR-1 are kept as it is. The scale of opening is totaling 216-meter long to keep the same flow area to discharge approximately 2,200 m^3/sec at a peak time, and two bridges are located at St. 42+800 and St. 48+400. Other road crossing structures such as pipe culverts and old water gates are replaced. 0.5 meter freeboard is adopted to determine the design embankment level at the lowest section. The cross-sectional configuration is undivided 2-lane with 1.5-meter wide hard shoulder in the whole stretch. The type of pavement is Double Bituminous Surface Treatment (DBST).

The following minimum improvement works are to be carried out:

- Replacement of two Bailey bridges by PC bridges
- Replacement of two damaged water gates by new box culverts
- Replacement of two damaged pipe culverts by new pipe culverts
- Removing existing pavement to form roadbed and subgrade as designed width and level
- Construction of pavement structures of subbase and base course followed by surface of DBST.

This scheme is deemed the basis of evaluation and will enable to reveal the degree of mitigating flood risk and the scale of improvement works compared with other alternative plans.

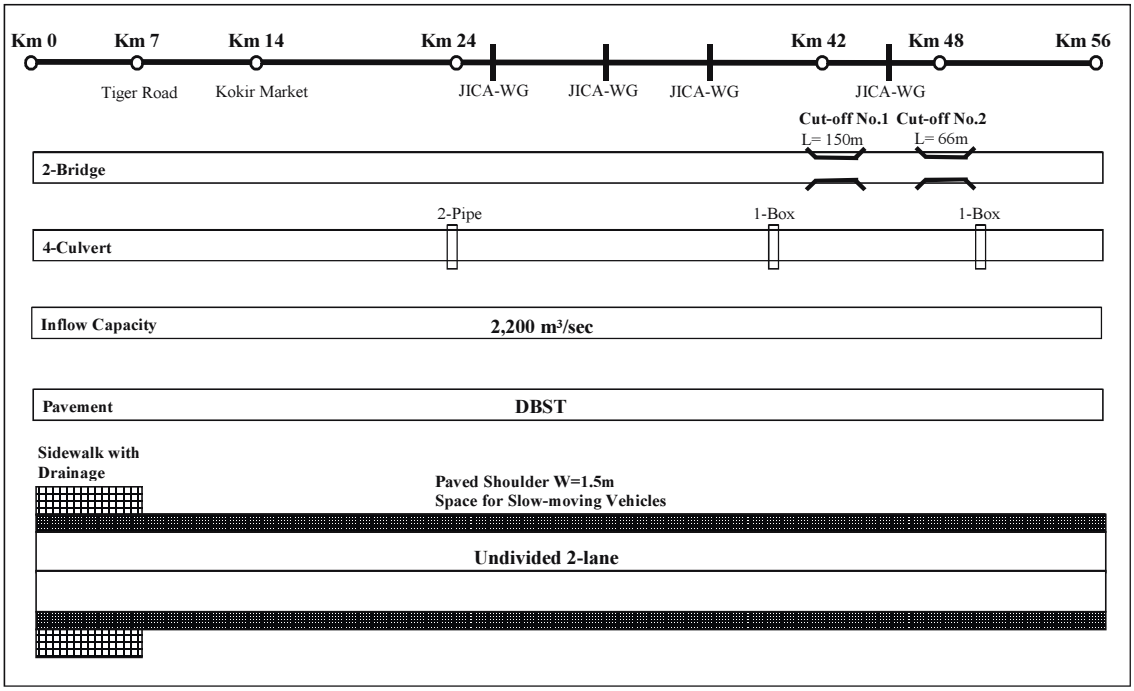


Fig. 12-3-1 ALT-I a: Maintaining Existing Inflow Capacity

12.3.2 Focusing on Flood Plain Management in Module-1

This module contains one of important technical aspects pertaining to improvement plan from viewpoint of flood plain management, and it examines the degree how to mitigate flood risk along NR-1. Two planning parameters are studied, namely inflow capacity of opening to Colmatage area and location & type of structures.

The inflow capacity of opening varies in the range from increased capacity of existing one to minimum capacity as it was before 2000 Flood, and accordingly location and type of structure are selected based on the survey results of possible sites to accommodate designed discharge.

However, it is pointed out that appropriate location and scale of opening should be selected otherwise they would bring adverse impacts to residential area, land use and farming system along the study road. Bridge has advantage in the aspect of traffic management during construction because of reduction of construction sites unless volume and velocity of floodwater become excessive, while a culvert has advantages in the aspects of deceasing velocity and retarding floodwater to flow in and out. Therefore, a combination of bridges and culverts is the most practical plan from hydrological viewpoint because the location of structure is scattered.

Through the study and evaluation on flood plain management made in Chapter 9, the inflow capacity of approximately 2,700 m^3/sec at a peak time is recommended to mitigate flood risk along NR-1 including Phnom Penh and Neak Loueng. Accordingly, the following two alternative plans are set in Module-1 referring to the scheme of ALT-I a:

ALT-II a: Decreasing Inflow Capacity by Closing of 2 Cut-offs (refer to Fig. 12-3-2)

For the purpose of comparison, ALT-II a is formulated on the basis of ALT-I a. This plan has no bridge opening to close two cut-offs on NR-1, which is the quite same situation before 2000 Flood. It enables to discharge approximately 470 m^3/sec at a peak time by 4 existing water gates and 4 culverts.

ALT-III a: Improvement on Flood Risk Mitigation (refer to Fig. 12-3-3)

ALT-III-a is formulated on the basis of ALT-I a to mitigate flood risk along NR-1 including Phnom Penh and Neak Loueng by increasing the inflow capacity up to approximately 2,700 m^3/sec at a peak time through 3 bridges, 13 culverts and 4 existing water gates.

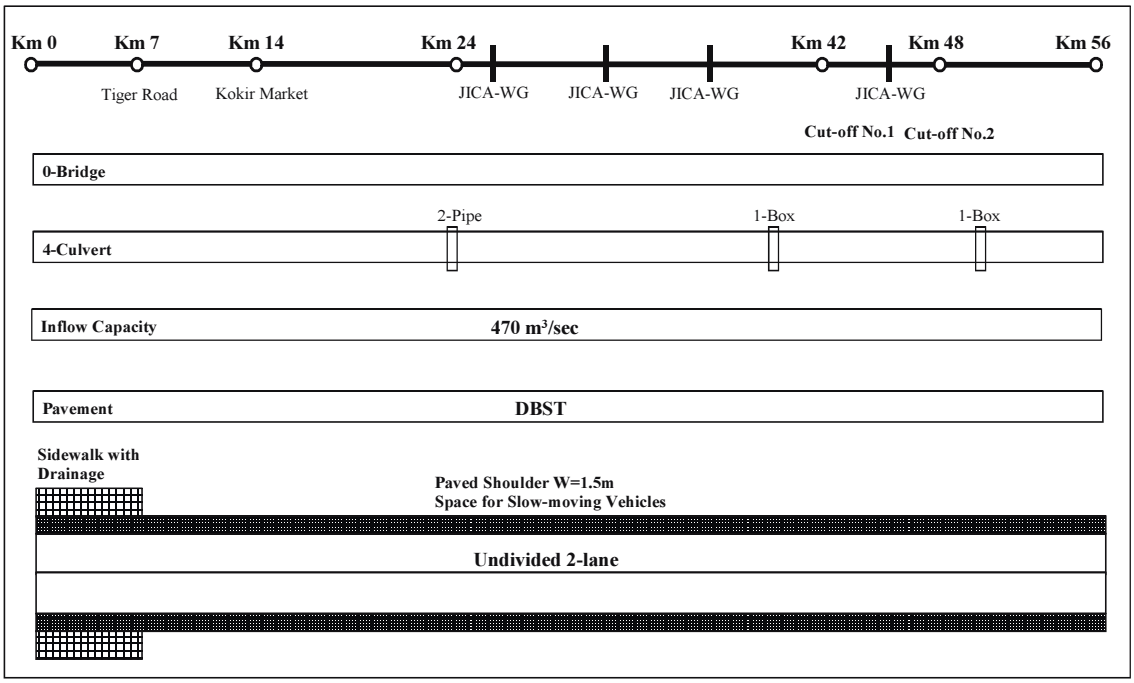


Fig. 12-3-2 ALT-II a: Decreasing Inflow Capacity by Closing of 2 Cut-offs

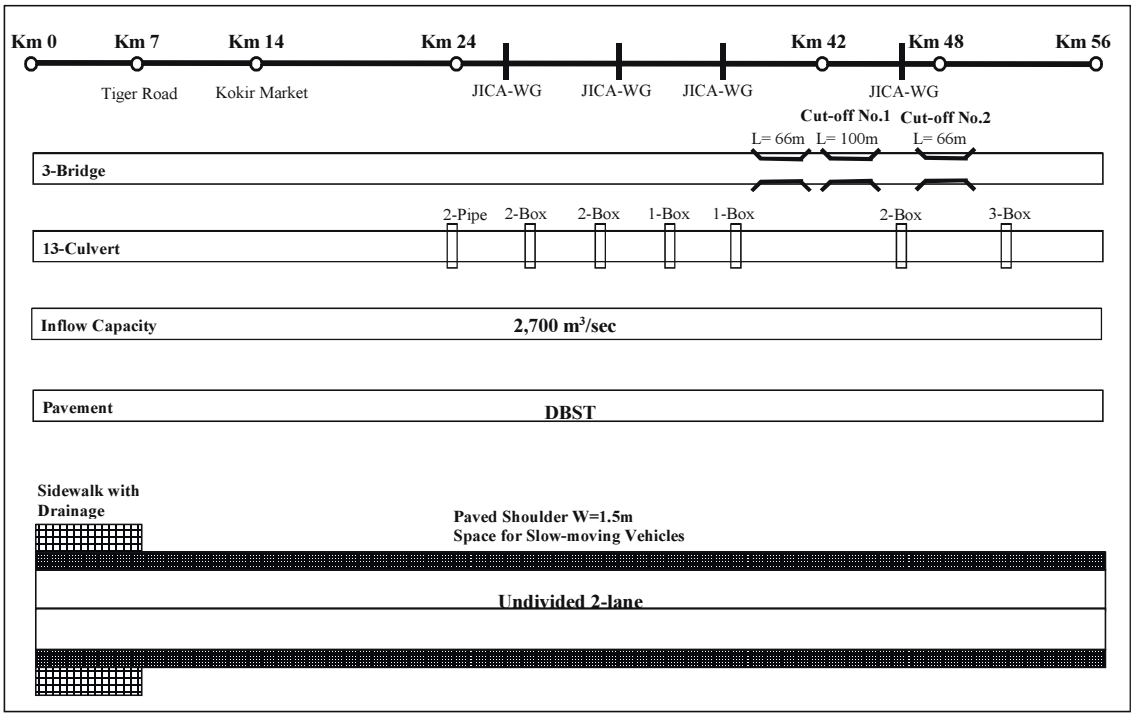


Fig. 12-3-3 ALT-III a: Improvement on Flood Risk Mitigation

12.3.3 Focusing on Traffic Functions in Module-2

This module comprises three planning parameters, namely design embankment level, cross-sectional configuration and type of pavement. These are very important to achieve the target of road improvement "Provision of a Flood-free Road to an All-weather Standard", and they are close relations each other in terms of scale of improvement works.

Design embankment level that is almost the same level of subgrade becomes as high as the design high water level plus free-board of 0.5 meter that is applied commonly in similar projects in Cambodia, and it makes earthwork volume appropriate.

Cross-sectional configuration is studied to clarify features of each scheme from the viewpoint of traffic function including traffic safety, cost-wise matter and necessity of future widening.

Asphalt concrete (AC) pavement is selected by the Life Cycle Cost (LCC) Analysis.

Accordingly, the following two alternative plans are set in Module-2 referring to the scheme of ALT-III a:

ALT-III ab: Improvement with Minimum Requirement (refer to Fig. 12-3-4)

For the purpose of comparison, ALT-III ab is formulated on the basis of ALT-III a. This plan has 2.5-meter wide space for slow-moving vehicles up to Kokir Market where 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.

This plan has the following improvement works:

- Replacement of two Bailey bridges by PC bridges
- Construction of an additional PC bridge at St.42+110
- Replacement of two damaged water gates by box culverts
- Replacement of two damaged pipe culverts by pipe culverts
- Installation of nine new box culverts
- Removing existing pavement to form roadbed and subgrade as designed width and level
- Construction of pavement structures of subbase and base course followed by surface of asphalt concrete.

ALT-III b: Improvement on Traffic Function (refer to Fig. 12-3-5)

ALT-III b is formulated on the basis of ALT-III ab to secure steady traffic flow and to enhance traffic safety by providing 2.5-meter wide space for slow-moving vehicles in the whole stretch and to keep the space for future widening up to Kokir Market.

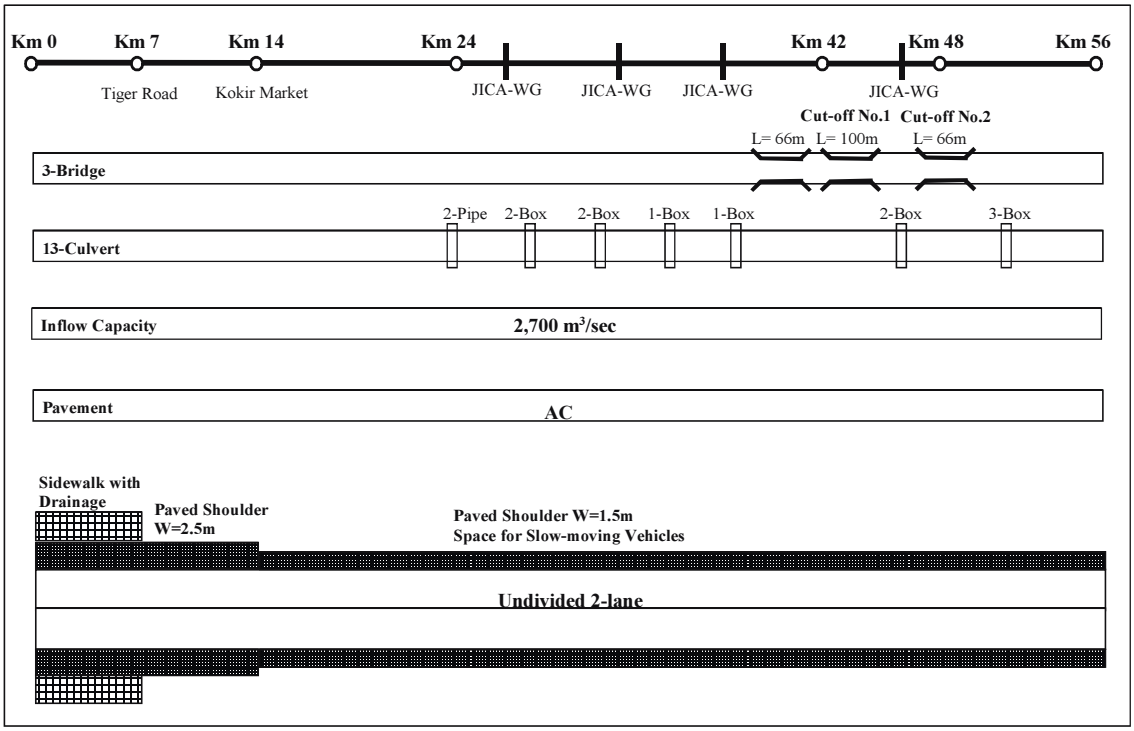


Fig. 12-3-4 ALT-III ab: Improvement on Minimum Requirement

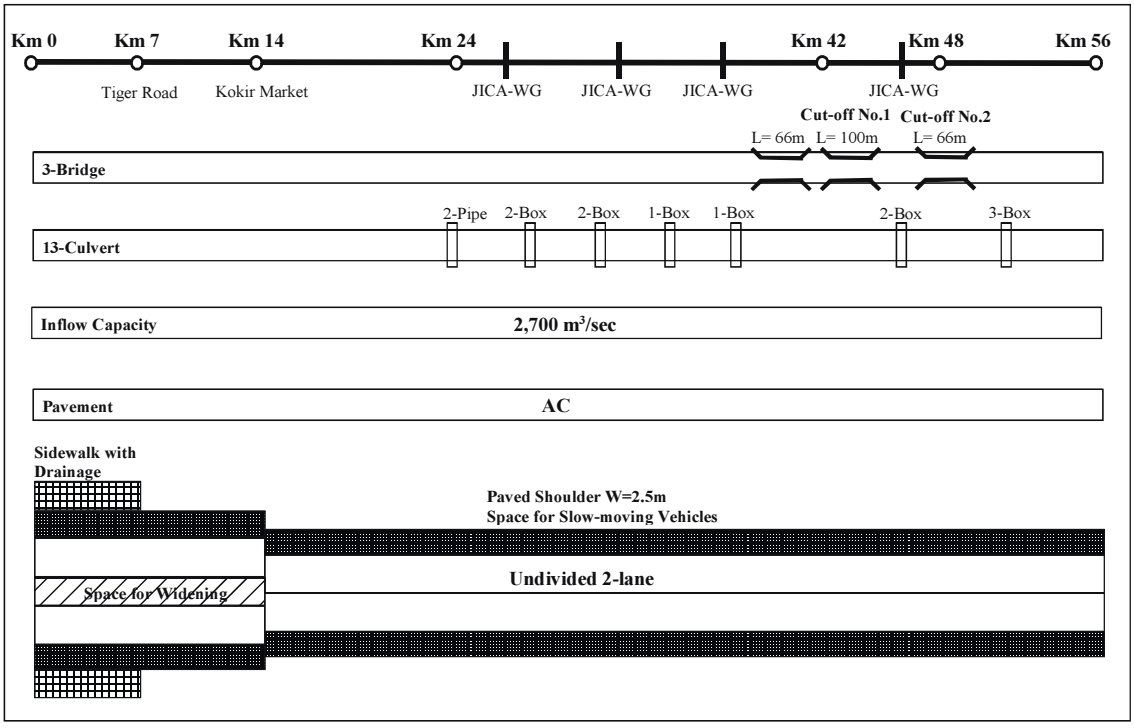


Fig. 12-3-5 ALT-III b: Improvement on Traffic Function

12.3.4 Scheme-2: Adoption of Spillway

The concept of this scheme is the similar to that of ALT-II a: Decreasing Inflow Capacity by Closing of 2 Cut-offs except the crossing structure to envisage low-cost improvement. Two cut-offs are closed since two Bailey bridges crossing existing two openings on NR-1 are operated temporarily. The floodwater may overflow on NR-1 at St. 42+800 and St. 48+400 to a certain extent of roadway to discharge floodwater to the Colmatage area in lieu of opening by bridges and culverts. To cope with overflow, the road structure is protected against erosion. This scheme is applied to NR-3 and other national roads of double digit or less on the assumption that the construction cost would be cheaper and the maintenance would be easy.

According to observation during flood on NR-3, the road traffic was interrupted by floodwater for several weeks. Moreover, it was revealed through the examination of this scheme that the cost difference would be 2% higher than ALT-II a and 13% lower than ALT-I a.

Therefore, it is unlikely that this scheme would be suitable for the national roads of single digit like NR-1 because this study has the target of road improvement "Provision of a Flood-free Road to an All-weather Standard".

12.4 Evaluation of Alternative Plans

12.4.1 Study Approach and Methodology

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 facts are revealed through the results of study and analysis:

(1) There exist two defected pipe culverts, two obsolete and damaged water gates, four newly constructed water gates and two temporary bridges on NR-1 C-1. They have total inflow capacity of approximately 2,200 m^3/sec at a peak period, and it contributes to mitigating flood risk along NR-1 including Phnom Penh and Neak Loueng and bring benefits to Colmatage area as well.

(2) Totaling 12 locations and 4 sections totaling 6,800-meter long are confirmed to enable floodwater to discharge to the flood plain because the location and scale of opening are carefully examined investigating the land use along NR-1.

(3) Narrow deteriorated pavement width and high percentage of slow-moving vehicles such as motorcycles, moto-dops and moto-remorks cause to disturb steady traffic flow and traffic accidents.

(4) It is possible to vacate the land by a due procedure taken as the fair and just compensation to make Project Affected Persons (PAPs) resettled stably according to actual practices to evacuate occupants from Road Right-of-Way (ROW) on NR-1 C-1. Number of PAPs will not vary even though cross-sectional configuration is changed because PAPs within the tentative ROW should move outside of the boundary.

(5) The existing pavement is inferior in the aspect of waterproof and crossfall to shed surface

water to the roadside to protect the entire flexible pavement structure and the subgrade from the weakening effects of moisture.

Under such circumstances, the Study has the target of road improvement "Provision of a Flood-free Road to an All-weather Standard".

At the first step, the salient features of improvement plan on NR-1 C-1 are examined in ALT-I a that major physical conditions on NR-1 C-1 are kept as it is. The costs of earthwork and pavement are estimated to occupy 80% of construction cost, while structural cost will be 15%.

At the second step, the inflow capacity and location and type of structure are examined among ALT-I a (Q=2,200 m^3/sec), ALT-II a (Q=470 m^3/sec) and ALT-III a (Q=2,700 m^3/sec) to mitigate flood risk. It makes sense that the increased inflow capacity of ALT-III a may contribute to mitigating flood risk along NR-1 C-1 including Phnom Penh and Neak Loueng. Accordingly, ALT-III a is selected as a basis for ALT-III ab and ALT-III b to the next step.

At the third step, the free board of 0.5 meter for design embankment level and asphalt concrete pavement are selected through individual study and evaluation, and cross-sectional configurations are examined among ALT-I a (17m+14m), ALT-III ab (19m+14m) and ALT-III b (24m+14m) to compare cost-wise matter and planning viewpoint.

12.4.2 Summary of Evaluation

Table 12-4-1 summarizes the comparison of salient features and differences revealed in association with each alternative plan of which the scheme of improvement will bring about impacts physically, technically, socially and economically.

The comprehensive evaluation reveals the superiority of ALT-III b quantitatively and qualitatively. The superiority is summarized as follows:

(1) Expected roles and functions of NR-1 is 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 concentrate in 14% of national land and agriculture as well as inland fishery are very productive. ALT-III b will be able to achieve such expected roles and functions to a considerable extent.

(2) Proposed opening on NR-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. 1 in the regional context.

(3) ALT-III b has advantages such as spaces for slow-moving vehicles and future widening in the planning viewpoints. 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 is to accommodate providing additional lanes to cope with incremental traffic demand in future.

(4) Such remarkable effects brought by improvement works will increase construction cost slightly at a range of 5% against ALT-III ab as shown in Table 12-4-2, and it will be acceptable provided that an economic feasibility is confirmed in the succeeding study.

Table 12-4-1 Comprehensive Evaluation

Salient Features of Each Plan	ALT-I a: Maintaining Existing Inflow Capacity	ALT-II a: Decreasing Inflow Capacity by Closing of 2 Cut-offs	ALT-III a: Improvement on Flood Risk Mitigation	ALT-III ab: Improvement with Minimum Requirement	ALT-III b: Improvement on Traffic Function
Outline	To cope the planned volume with 2-bridge and 4-culvert	Closing 2-cut-off to reinstate floodwater level in Colmatage area before September 2000	Increasing inflow capacity to mitigate flood risk along NR-1 C-1 and Phnom Penh/Neak Loueng as well	Focusing on improvement with minimum traffic requirement on a basis of ALT-III a	Focusing on improvement of traffic function such as traffic safety and future widening on a basis of ALT-III ab
Inflow Capacity	2,200 m3/sec	470 m3/sec	2,700 m3/sec	2,700 m3/sec	2,700 m3/sec
Improvement					
No. of Bridge	2-location (Cut-off No.1& No.2)	N/A	3-location (Km 42+400, Cut-off No.1& No.2)	3-location (Km 42+400, Cut-off No.1& No.2)	3-location (Km 42+400, Cut-off No.1& No.2)
Total Bridge Length	216 m	0 m	232 m	232 m	232 m
Culvert	2-Box & 2-Pipe	2-Box & 2-Pipe	11-Box & 2-Pipe	11-Box & 2-Pipe	11-Box & 2-Pipe
Design Embankment Level	DHWL + 50cm	DHWL + 50cm	DHWL + 50cm	DHWL + 50cm	DHWL + 50cm
Road Width	14m (Rural), 17m (Urban)	14m (Rural), 17m (Urban)	14m (Rural), 17m (Urban)	14m (Rural), 19m (Urban)	14m (Rural), 24m (Urban)
Type of Pavement	Surface Treatment (DBST)	Surface Treatment (DBST)	Surface Treatment (DBST)	Asphalt Concrete	Asphalt Concrete
Spillway	N/A	N/A	N/A	N/A	N/A
Rough Quantity					
Earthwork volume (cu.m)	1,088,000	1,088,000	1,088,000	1,109,000	1,163,000
Pavement Area (sq.m)	553,000	553,000	553,000	581,000	678,600
Bridge Area (sq.m)	3,024	0	3,248	3,248	3,248
Cost Index	**1.00**	**0.85**	**1.06**	**1.19**	**1.24**
Effect of Improvement					
1) Flood risk mitigation	Fair	Poor	Good	Good	Good
2) Securing traffic function	Fair	Fair	Fair	Good	Good
3) Adverse social impact	Negligible Small	Negligible Small	Negligible Small	Negligible Small	Negligible Small
4) Traffic safety measures	Poor	Poor	Poor	Fair	Good
5) Planning viewpoint	Poor	Poor	Poor	Poor	Good
Comprehensive Evaluation					
Point-1	The Sub-zone in Colmatage area still has enough discharge capacity to mitigate flood risk.	Floodwater could not contribute to exploiting potential Colmatage agriculture and inland fishery.	Since the Sub-zone in Colmatage area has sufficient discharge capacity, flood risk will be mitigated due to discharging floodwater effectively.	It will contribute to separation of slow-moving vehicles from mixed traffic that is issued in urban area, and accordingly traffic safety will be enhanced.	It will facilitate to widen NR-1 to divided 4-lane in Phnom Penh conurbation because the space for widening is reserved.
Point-2	A bridge at Cut-off No.1 has excessively deep riverbed that is not desirable from hydrological viewpoint.	Since the Sub-zone in Colmatage area has considerable discharge capacity, it will be in vain to mitigate flood risk.	Proposed locations of opening will incur neither adverse impact to social activities nor natural environment because of investigating practical places.	Asphalt concrete is very steady type of pavement with high durability, and it will result in strengthening road structure against external factors such as intensive rainfall, flood and so forth.	It will accommodate traffic characteristics in Cambodia such as high percentage of slow-moving vehicles and moto-rumoks/moto-dops to secure smooth traffic flow and enhance traffic safety.
					Recommended

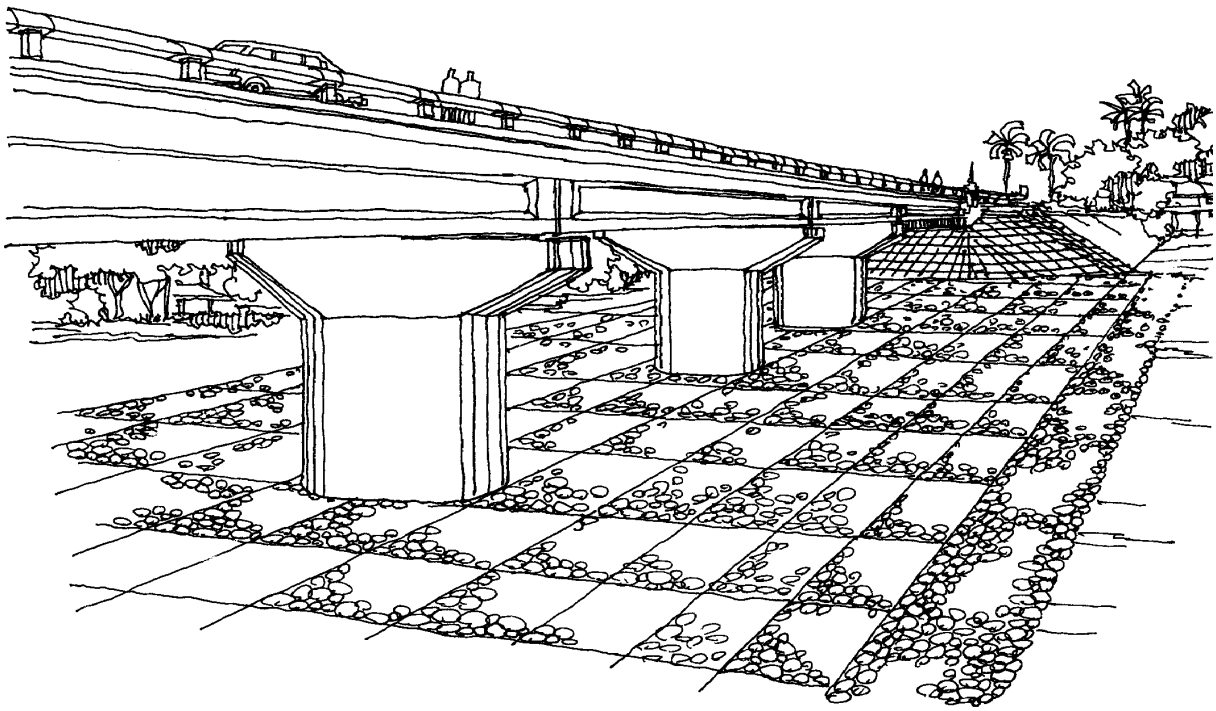
Table 12-4-2 Cost Comparison by Index

	ALT-I a	ALT-II a	ALT-II a	ALT-III ab	ALT-III b
	Maintaining Existing Inflow Capacity	Decreasing Inflow Capacity by Closing of 2 Cut-offs	Improvement on Flood Risk Mitigation	Improvement with Minimum Requirement	Improvement on Traffic Function
Inflow Capacity	2,200 m3/sec	470 m3/sec	2,700 m3/sec	2,700 m3/sec	2,700 m3/sec
Bridge	2-Br. L=216m	N.A.	3-Br. L=232m	3-Br. L=232m	3-Br. L=232m
Culvert	2-Pipe, 2-Box	2-Pipe, 2-Box	2-Pipe, 11-Box	2-Pipe, 11-Box	2-Pipe, 11-Box
Road Width	17m+14m	17m+14m	17m+14m	19m+14m	24m+14m
Type of Pavement	DBST	DBST	DBST	AC	AC
Earthwork Volume	0.35	1.00	1.00	1.03	1.04
Pavement Area	0.44	1.00	1.00	1.25	1.34
Bridge	0.15	0.00	1.21	1.21	1.21
Culvert	0.02	1.00	2.21	2.21	2.21
Incidental Works	0.01	1.00	1.00	1.00	1.00
Temporary Works	0.02	1.00	1.00	1.47	1.47
Total	1.00	0.85	1.06	1.19	1.24

Ratios within ALT-

Ratios to each item of ALT-I

CHAPTER 13 PRELIMINARY DESIGN



CHAPTER 13 PRELIMINARY DESIGN

13. 1 Highway Design

13.1.1 General Policy

In designing the improvement of the Study Road, the following facts are considered as the basic policy.

(1) The Study Road is affected by flooding of the Mekong River. As one of the most important national highways, the Study Road needs to be safely used even during the flood season of the Mekong River. Therefore, appropriate margin of road elevation should be secured against the flood water level.
(2) For the same reason to the above, the road structure should be sufficiently resistant against the flood water with respect to erosion and seepage of water.
(3) The Study Road forms a part of Asian Highway Route A-1, connecting Thailand – Phnom Penh – Ho Chi Min City.
(4) 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 the few urbanized sections, this policy should be always applied.
(5) When a road is improved, vehicles tend to drive at a speed higher than that of before the improvement. Therefore, sufficient consideration should be given to traffic safety.

13.1.2 Alignment

(1) Control Point for Horizontal Alignment

The following points are considered as control points in selecting the horizontal alignment of the Study Road. The data of alignment are listed in Appendix G-4.

1) Colmatarge water gates

The water gates which have been recently renovated under Japanese Grant Aid cannot be moved. Thus, the centerline of the Study Road has to pass the centers of these water gates.

2) Starting point in the east of Monivong Bridge

Approximately 200-meter long section near Chbar Ampov Market passes through the established urbanized area. Accordingly, road alignment cannot be altered in this section. Therefore, the starting point set at the western end of the median division is taken as a control point.

3) End point near Neak Loueng Ferry Terminal

Ferry Terminal Area cannot be moved. Therefore it is considered as a control point. Specifically, the branch-out point, approximately 550 meters from the Terminal Area, is regarded as a control point.

(2) Basic Policy for Selecting Horizontal Alignment

The followings are considered as the basic policy for selecting the horizontal alignment.

1) Follow the existing alignment as much as appropriate

The existing alignment is generally favorable with generous curve radii. To minimize relocation of roadside buildings, the existing alignment was maintained as much as possible. For this reason, usage of transition curve was limited to the following cases

(a) Where radius of circular curve is smaller than the value of absolute minimum stipulated in the criteria.
(b) Where traffic engineering consideration requires, such as;
- S-shape curve
- circular curve with a radius smaller than the desired minimum and adjacent to relatively long straight section where vehicles tend to travel at high speed

2) Correct irregularity of the existing alignment

There are some irregularities in the existing alignment (e.g. the existing alignment deviates from regular circle or straight line on several sections). In such case, the alignment shall be corrected to form regular circle (with transitional curve as necessary) or straight line.

3) Correct where the existing alignment does not meet the criteria

Where the existing alignment does not meet the requirement of the criteria, it is corrected.

4) Follow the criteria as proposed in Chapter 11

The criteria for geometric design proposed in Chapter 11 shall be followed.

(3) Consideration on Proposed Alignment

In designing the improvement of the Study Road, provided improvement of alignment, the following points were considered.

1) Start Point ~ St. 13+000 (PK 5.6 ~ 18.6)

There is no serious problem with the existing alignment. Transitional curves are inserted on the both side of the curve at PI 19 (St. 12+300 ~ 12+700; PK 17.9 ~ 18.3). The radius of circle here is 500 meters and larger than the minimum radius of curve which require transitional curve. However, there is a relatively long straight section on the north side of this curve which will lead to higher travel speed of vehicles. Thus, inserting transitional curve is recommended. There is also a curve with a radius of approximately 500 meters (495 meters) at PI 10 (St. 3+200 ~ 3+800). This curve is located close to the existing urbanized area, and, thus, the actual operating speed of vehicles will not be high. Therefore, transitional curve is considered to be unnecessary.

2) St. 13+000 ~ 18+000 (PK 18.6 ~ 23.6)

There are many curves in this section with relatively short intervals. It is desirable to insert transitional curves to enable smooth steering operation and, thus, safe and comfortable driving. There are also some curves with relatively small intersecting

angle and short curve lengths. These curves need to be improved to secure desirable minimum curve length.

(a) St. 13+500 ~ 13+800 (PK 19.1 ~ 19. 4) (Kokir Market)

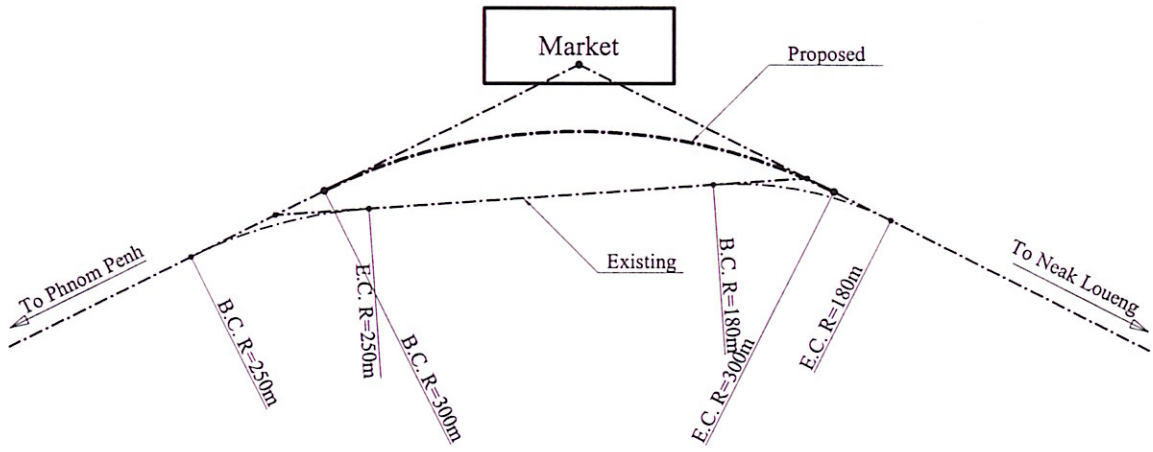
The existing alignment seems to be combination of straight lines connects by circles with small radii. Improvement to a circle with a radius of R = 300 meters and transitional curve is proposed. (See Fig. 13-1-1)

(b) St. 14+100 ~ 14+900 (PK 19.7 ~ 20.5) (PI 21,22,23)

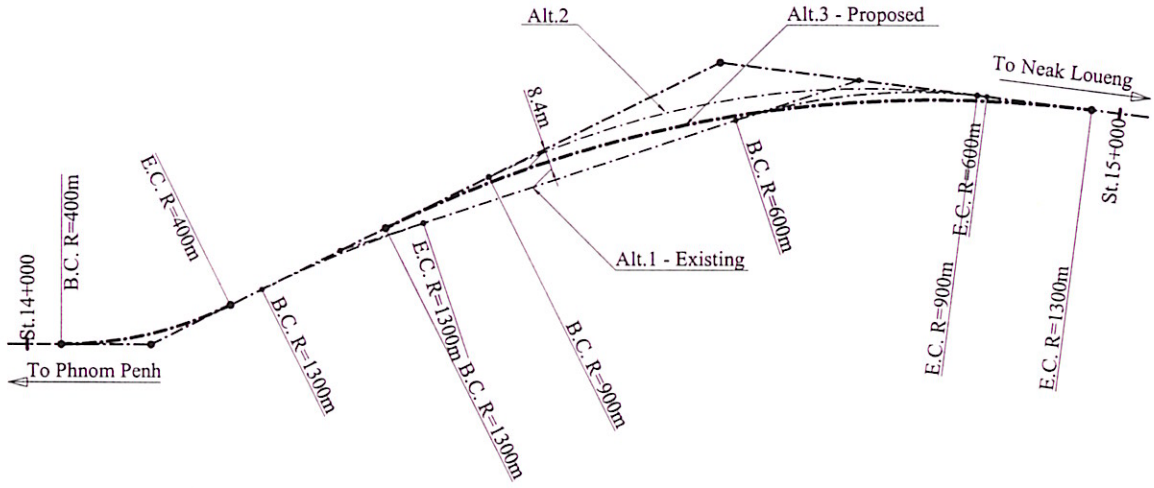
There is three short curves with relatively small intersecting angles from St. 14+200 to St. 14+800 (PK 19.8 ~ 20.3)(PI 21, PI 22 and PI 23). The existing curves at PI 21, PI 22 and PI 23 are circles with R = 400 meters, 1,300 meters and 600 meters, respectively. With these radii, the curve lengths are less than 70 meters (minimum curve length). It is desirable to eliminate the curve at the middle (PI 22: St. 14+400 – 14+500; PK 20.0 -20.1) by connecting the curves at PI 21 (St. 14+230; PK 19.8) and PI 23 (St. 14+750; PK 20.3). Alternative 1 is to change the radius of the curve at PI 23 from 600 meters (existing) to 900 meters, which results in diversion of the centerline near St. 14+650 by approximately 4.6 meters to Mekong River side. (See Fig. 13-1-1) Connecting PI 21 and PI 23 directly by a straight line was also considered (Alternative 2). However, this result in deviation of centerline by 8.4 meters towards Bassac River side (urbanized area), and this is not recommended for it will cause relatively large social impact. The recommended alignment is R = 400 meters with transitional curves at PI 21, R = 1,300 meters (single circle) at PI 22 and PI 23 (PI 22 and PI 23 are connected with single curve). With the recommended alignment, the deviation of centerline is slightly less than Alternative 1 (approximately 5 meters) and larger radius is adopted.

(c) St. 15+280 ~ St. 15+400 (PK 20.88 ~ 21.0) (PI 24)

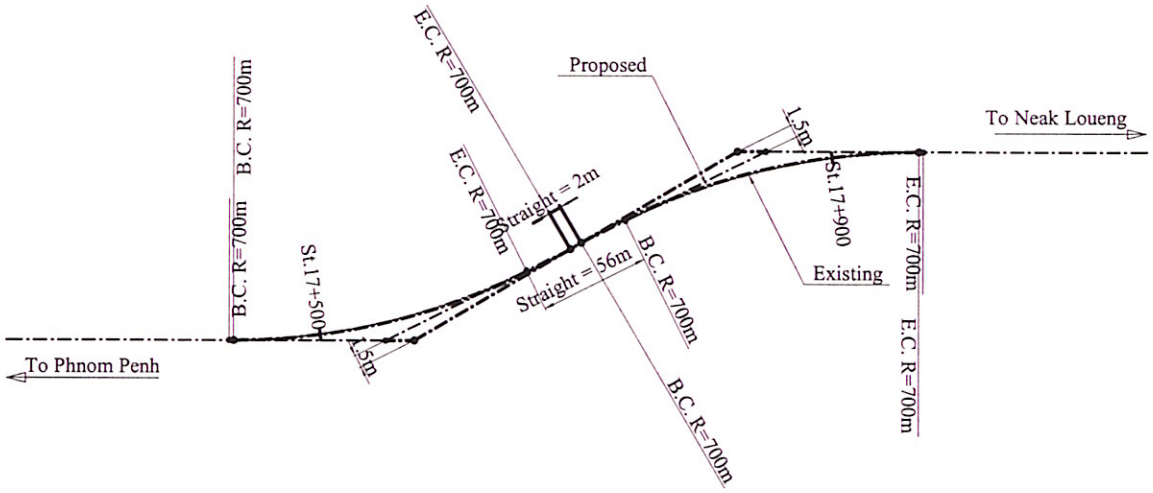
The existing alignment is a circle with R = 455 meters and curve length of 56 meters. To secure recommended curve length, it is proposed to change to R = 600 meters with curve length of 144 meters. Deviation of the center line for this improvement is 0.93 meter. (See Fig. 13-1-1)



(a) Kokir Market



(b) St.14+100 ~ 14+900



(c) S-Curve from St.17+500 to St.17+820

Fig. 13-1-1 Adjustment of Alignments

(d) St. 15+600 ~ 16+200 (PK 21.2 ~ 21.8) (PI 25)

The existing alignment of this section consists of series of short straight line and circular curves connecting them. To provide smoother curve with radius of 600 meters is recommended. This results in deviation of centerline towards Mekong River by 3.54 at maximum (at St. 16+060) but this shift is considered to be desirable.

(e) St. 17+500 ~ 17+820 (PK 23.1 ~ 23.42)

The existing alignment follows irregular S-shape curve. Simple application of circles and transition curves result in undesirable length of straight between the transitional curves (approximately 56 meters). To reduce the length of the straight section between the transitional curves, it is better to slightly rotate the straight line counter-clockwise (1.5 meters at both intersecting points). This result in deviation of new centerline from the existing one by approximately 0.8 meter which is considered to be within a acceptable range. Therefore, this rotation of short straight section is recommended.

3) St. 18+000 ~ 33+000 (PK23.6 ~ 38.6)

After passing the section described in (2), there is no section where improvement of alignment is necessary, except St. 32+600 ~ 32+800 where three curves with small radii exist in sequence. The Study Team has been informed that this section used be almost straight and there was a water gate (a culvert) crossing the road. After collapse of the water gate, the detour route was constructed which eventually became the present alignment. To correct this t

Irregularity, a circular curve with R = 2,000 meters is proposed.

4) St. 33+000 ~ 54+740 (PK 38.6 ~ Entrance to Ferry Terminal)

Existing alignment is favorable with straight lines or circular curves with radii nearly 1,000 meters or more and does not need substantial improvement. Only recommended improvement is to insert transitional curve at PI 70 (St. 53+600 ~ 54+000; PK 59.2 ~ 59.6) with R = 490 meters. Here, inserting transitional curve is recommended, considering the relatively long straight section on the north side of the curve. Deviation of the centerline due to this improvement is 1.5 meters.

5) Points of small change in horizontal alignment

There are many points where the existing alignment changes its direction by very small deflection angle (less than 1 degree). These small changes of alignment are not sensed by the drivers and do not give adverse affect on the traffic. Cambodian Standard stipulates that curve is not needed for deflection angle less than 1 degree, for design speed of 80 km/h. Nevertheless, it is considered to be desirable to eliminate these small changes of alignment when the road is improved. Here, it is recommended to eliminate these points when alteration of centerline results in the deviation from the existing alignment less than 1 meter. These points which are proposed to be improved are listed in the attached table.

(4) 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. Maximum grade actually used was 1.6 % on the southern approach of Bridge No. 1 (St. 42+200 – 42+300; Pk 47.8 – 47.9) and northern approach of Bridge No. 2 (St. 48+200 – 48+300; Pk 53.8 – 53.9).

(5) Comparison of Criteria of Geometric Design Elements and Actually Used Values.

Values of criteria for geometric design elements proposed in Chapter 11 and those actually used in the proposed alignments are compared in Table 13-1-1. Also, the data of horizontal alignment are listed in Appendix G-4.

Table 13-1-1 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	(m)	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

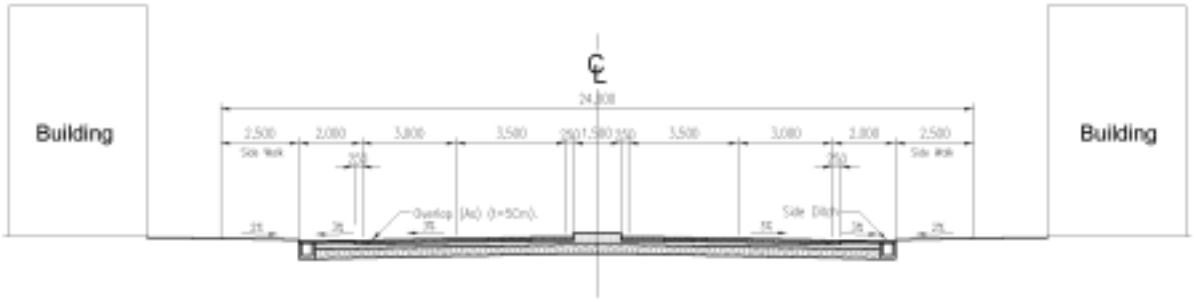
13.1.3 Road Structure

(1) Cross Section

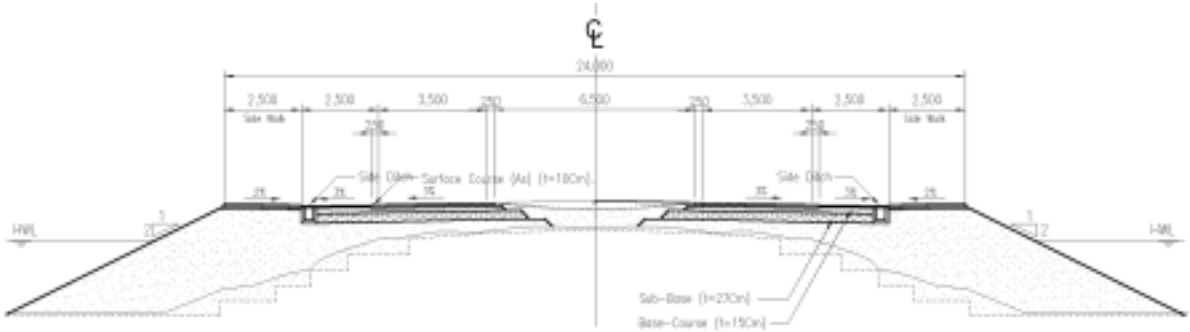
Fig.s 13-1-2 shows some of the typical cross section adopted in the design of improvement. (All the typical cross sections are shown in the “Drawings”.) As explained in Chapter 12, full 4-lane section is proposed urbanized sections near Chbar Ampov Market (300 meters) and Kokir Market. Between Cbbar Ampov and Kokir Market is proposed to be provided with embankment with the width for future widening for 4-lane and pavement width for divided 2-lane with paved shoulder for slow-going vehicles. From Kokir Market to End Point is proposed to be opposed 2-lane with paved shoulder for slow-going vehicles.

As described before, the elevation of top of the subgrade is set at Design High Water Level plus 50 cm. This 50 cm of free board is maintained also at the curved sections with superelevation. Accordingly, profile of curved section with superelevation (at the centerline) is raised to cancel the lowering of the subgrade surface due to provision of superelevation.

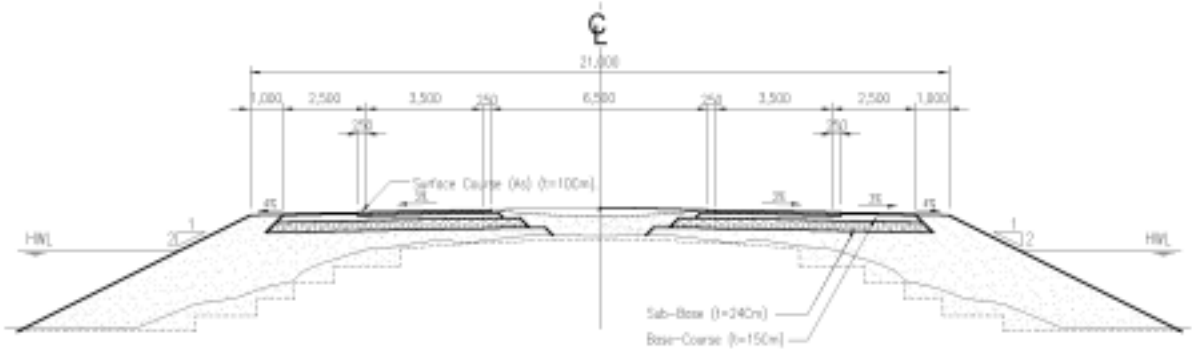
Type A0: (St. 0+100~0+300)



Type B: (St. 3+500~7+000)



Type C: (St. 7+000~13+500)



Type D: (St. 13+500~14+000)

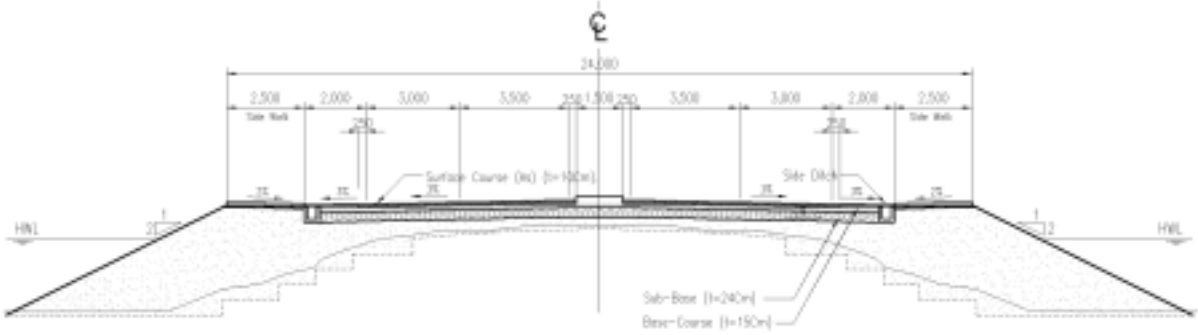
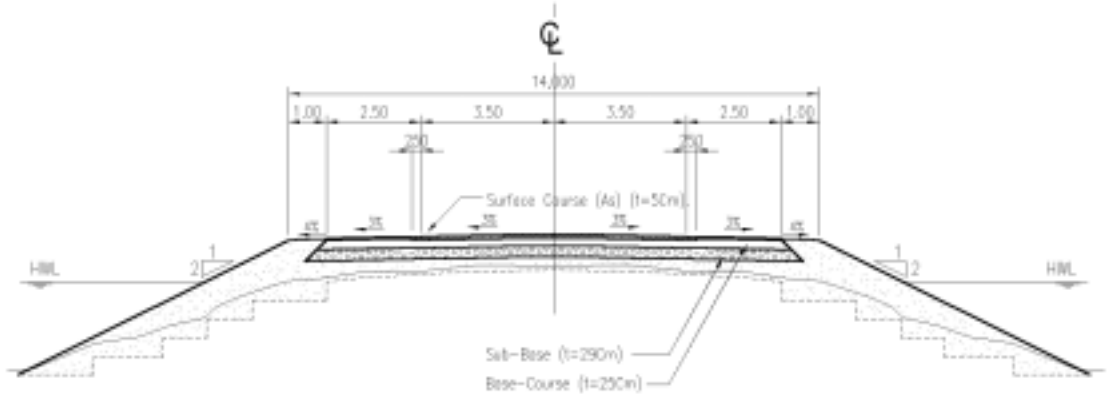


Fig. 13-1-2 (1/2) Typical Cross Section

Type E (STA. 14+000~36+000)



Type F: (St. 36+000~55+300)

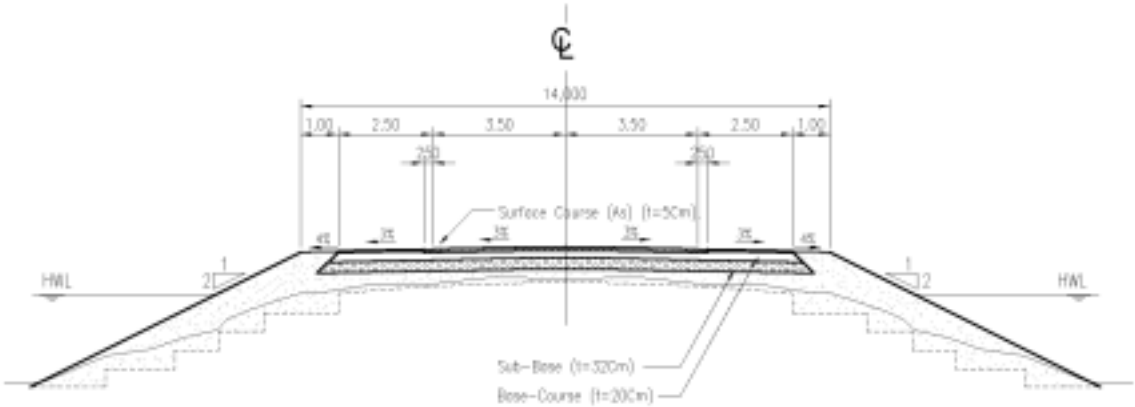


Fig. 13-1-2 (2/2) Typical Cross Section

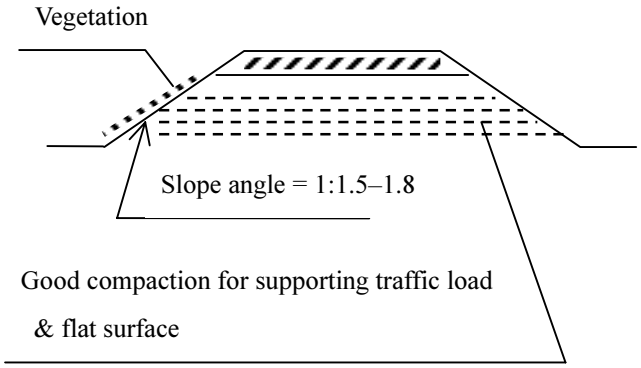
(2) Embankment Structure

To secure sufficient width of road bed, additional embankment is necessary at almost entire section. In designing the additional embankment, consideration was given to secure sufficient safety against floodwater of Mekong Rover. For this purpose, basic requirement for river bank was followed. Fig. 13-1-3 schematically illustrates the differences between highway embankment, river bank and the structure of embankment proposed for the Study Road.

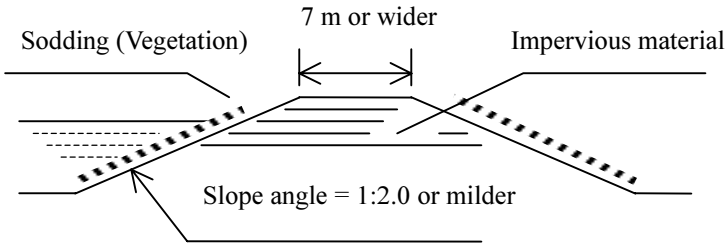
1) Material

The material of embankment is planned to be borrowed from nearby borrow pits. Since the borrowed materials are deposits of Mekong River, it is anticipated that the properties of borrowed material varies depending on the location of excavation. Sandy materials are preferable as subgrade material from viewpoint of bearing capacity, while cohesive (silty and clayey) materials are preferable as embankment material from viewpoint of resistance against water. Wherever necessary, sandy materials and cohesive materials shall be mixed. (Consideration on the protection against flood water is described in Subsection (3) “Slope Protection” below.)

(a) Highway Embankmnet



(b) River Bank



(c) Study Road

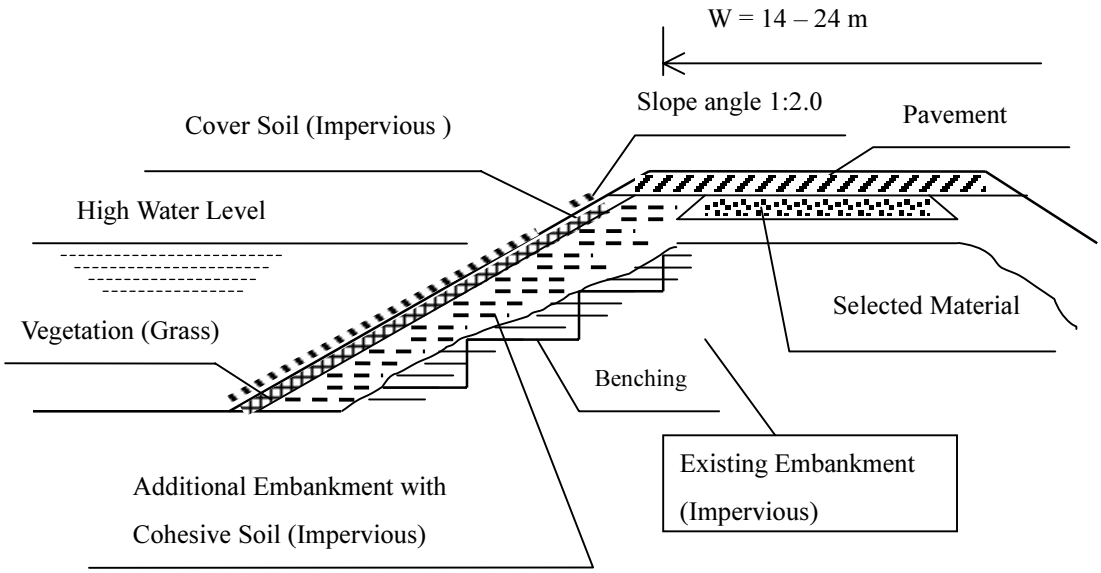


Fig. 13-1-3 Structure of Highway Embankment, River Bank and Study Road

Total volume of the materials needed for embankment is estimated at approximately 1.5 million m^3. Out of 1.5 million m^3, approximately 300,000 m^3 is the selected material needed to secure required bearing capacity of subgrade. (For more detailed explanation of materials, please refer 13.4 "Construction Planning and Cost Estimation".)

2) Slope Protection and Overall Strength against Flood Water

For designing slope protection, the following facts were taken into consideration.

i) Protection of the existing slope is basically vegetation (grasses) and fairly resistant to erosion.
ii) The existing embankment has been functioning as the bank and has been safe against the flooding in the past.
iii) By constructing additional embankment for widening of the road, overall strength against will be increased.
iv) Therefore, the most important problem is strength of additional embankment.

Based on the above consideration, the followings are recommended as the measures to make the additional embankment resistant to flood water.

i) Use cohesive soil (mixture of clay and silt/sand) for embankment.

Cohesive soils are available from the borrow pits. If properly compacted (such as 90 % or more of maximum dry density obtained by laboratory compaction test), this type of soil is considered to possess sufficient resistance against erosion. For reference, "Ordinance for River-Related Structures" of Japan (ORRSJ) stipulates that 85 % or more of compaction for river bank. It is also expected that the compacted soil have small permeability (in the order of 10^{-6} cm/s or less). Usually soil with permeability, k, less than 10^{-6} cm/s is considered "practically impervious". (Table 13-1-2 shows the relation between soil type and permeability)

Table 13-1-2 Permeability and Drainage Characteristics of Soils*

Permeability, k (cm/s)	10^2	10^1	1.0	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}	10^{-8}	10^{-9}
Drainage	Good						Poor		Practically Impervious			
Soil Types	Clean gravel		Clean gravel, clean sand and gravel mixture			very fine sands, organic and inorganic silts, mixtures of sand, silt and clay, glacial till, stratified clay deposits, etc			"Impervious" soils, e.g., homogeneous clays below zone of weathering			

*After Casagrande and Fadum (1940); quoted from "Soil Mechanics in Engineering Practice", K. Terzaghi and R. B. Peck, 1967

ii) Secure good compaction both on embankment and slope

This is very important both as highway embankment and as river bank. Usual technical specification of highway requires degree of compaction of 90 % or more. This requirement is same to the degree of compaction required for river bank or higher, as stipulated in ORRSJ. Good compaction is effective for both securing bearing capacity and strength against water, as well as minimizing settlement of the top of embankment after completion.

In addition, it is also important to secure good compaction on slope surface by using heavy equipment, such as bulldozer. Good compaction of slope surface is effective for prevention of both of erosion by flood water and erosion by running water (rain water).

It should be noted that usual practice for in constructing an additional embankment for widening of a road that the slope of existing embankment is so-called "bench-cut" to secure sufficient bondage between the old embankment and the additional embankment. This is very important to prevent longitudinal cracking of pavement occurring after opening to traffic.

iii) Vegetation (or sodding) on slope surface and placement of top soil for coverage of slope surface

Considering the fact that the slopes of existing road is fairly well protected against flood water of Mekong River and sodding (vegetation) is widely used for slope protection in the river banks in Japan where the velocity of current is high, sodding (vegetation) is considered to be sufficiently effective as slope protection of the Study Road. To help growth of grasses on the newly constructed slope, it is proposed to place the top soils collected from the nearby waste land. These top soils are considered to contain seeds and roots of the grasses which grow in the area along the Study Road and, thus, considered to most fitting to the environment of the Study Road.

iv) Placement of covering soil for slope

The top soil to be placed on slope is usually cohesive soils. Therefore, they are resistant to erosion when they are well compacted. Placement of covering soil on slope is often used in Japan as a method of slope protection where embankment material is poor in cohesion.

As a summary, the requirements for river bank and the proposed structure of the Study Road are compared in the table below.

Table 13-1-3 Comparison of Requirement for River Bank and Proposed Structure of the Study Road

Item	Requirement for River Bank	Study Road
Slope Angle	1:2.0 or milder	1:2.0
Compaction of Embankment Soil	85 % of maximum density obtained from laboratory compaction test or higher	90 % or more
Type of Soil	Mixture of sand, silt and clay (ideal)	Mainly fine sand and silt with clay
Slope protection	Sodding (vegetation)	vegetation
Width of embankment at the top	7 m or wider	14 – 24 m

The above discussions are for general sections. **The method of slope protection for the sections where the eroding force of the flood water is considered to be strong, special protections are proposed as described in Section 9.8 "Protection Against Erosion and Scouring".**

13.1.4 Embankment on Soft Ground

Since the Study Road traverses alluvial land of Mekong River, existence of soft ground is suspected. This subsection describes the analysis of this problem.

(1) Judgment by N-value

Usually, "soft ground" with regard to highway embankment is defined a ground with N-value equal to four or less. However, the experience tells that serious problem of stability and settlement is anticipated only where soft layers with N-value of two or less within some 10 meters deep from the ground surface. (Please refer Appendix G-5 for detailed explanation on general consideration on soft ground.)

The data of five boring logs, conducted for design of bridges and culverts were reviewed from such view point. Only the case of a layer with N-value equal to, or less than, 2 and within 10 meters from the ground surface was seen at boring drilled at St. 41+026 (Pk 46.7). This is the layer from 3.0 to 5.0 meters from the ground surface (2-meter thick) and N-value is 1. Using an empirical formula, unconfined compression strength (or shear strength) of this layer is estimated as shown below:

$q_u = 0.1 + 0.15\ N$

where;
q_u : unconfined compression strength
N: N-value obtained by standard penetration test
(Source: Design Manual of Japan Highway Public Corporation; Vol. 1)

Thus, q_u of this soft layer is approximately estimated to be

$q_u = 0.1 + 0.15 \times 1 = 0.25\ (kg/cm^2)$

This value is almost equivalent to that of St. 18+500 (Pk 23.1) described below. Considering the relatively small thickness of the layer, the soft soil at St. 41+026 (Pk 46.7) is judged to be less serious than the case of the soft layer encountered at St 18+500 (Pk 24.1).

Considering these facts as described above, seriousness of the problems of the soft grounds along the Study Road is judged to be generally represented by that of the soft ground at St. 18+500 (Pk 23.1).

(2) Result of Soft Ground Investigation

From the site reconnaissance, existence of soft ground was strongly suspected at two locations; St. 2+480 (Pk 8.1) and St. 18+500 (Pk 23.1). Both are marshy land existing along the Study Road. To obtain "undisturbed" sample for laboratory tests, sampling using a "thin-walled tube" sampler was attempted at these locations. The followings are description of the result of these samplings. Fig. 13-1-4 shows the boring log.

1) St. 2+480

There are swamps on both side of the Study Road. Sampling was attempted nea the toe of the embankment slope on the left side. The top soil was to firm to be sampled by the thin-wall sampler. A screw auger was used to reach soft layer where

thin-wall sampler could be thrust in. Sampling by thin-walled sampler was attempted every 50 cm or so of drilling by the screw auger. Every attempt, however, was unsuccessful because the soils were too firm to be sampled. This attempt was repeated until 10 meters from the ground surface. There was no soft layer which could be sampled by the thin-walled sampler. Therefore, it was concluded that the soils at this location are not soft to the degree that they will pose serious problem on highway construction.

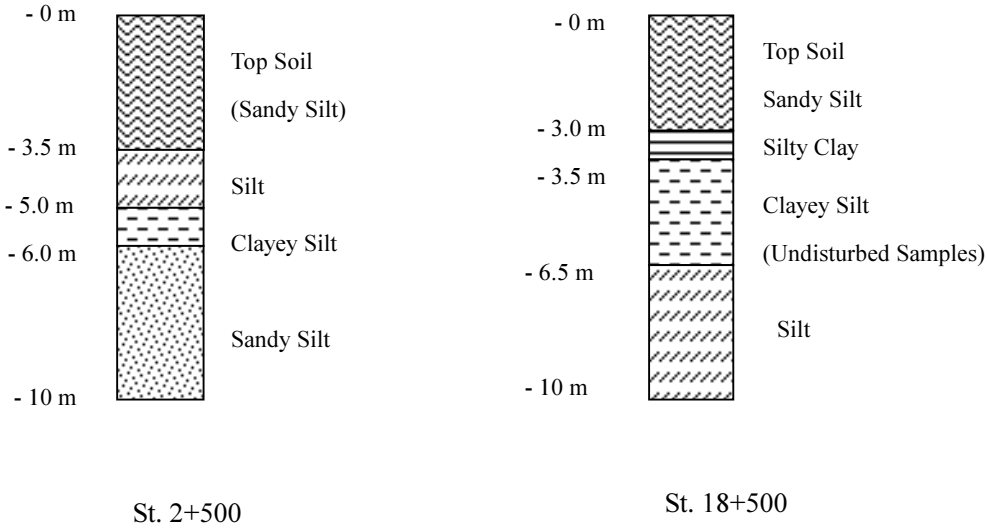


Fig. 13-1-4 Boring Logs of Suspected Soft Ground Area

2) St. 18+500 (Pk23.1)

There is a "boeng" on the right side of the Study Road. Left side of the Study Road is Mekong River. Thus, existence of soft ground is suspected on the right side of the Study Road. Sampling by the thin-walled sampler was attempted after drilling through the top soil. Undisturbed samples were obtained from the soft layer located from 3.5 meters to 6.5 meters below ground surface. Below this layer, there was silty clay which was too firm to be sampled. Therefore, soils below 6.5 meters from the ground surface were judged not to be soft. Unconfined compression strength of the obtained sample was 27 kPa (0.27 kg/cm^2) on average.

(3) Analysis of Stability

Using the data of the unconfined compression tests on the samples obtained from the soft layer, stability of the embankment was analyzed. Factor of safety for failure was calculated to be Fs = 1.51. (Please see Appendix G-6 for explanation of analysis of stability.) Compared with the stipulated value in many design manuals, Fs = 1.5 is considered to indicate sufficient stability of embankment. (For example, Design Manual of Japan Highway Public Corporation stipulates Fs >1.25 as the criterion.)

(4) Estimation of Settlement

Using the data of the consolidation tests on the samples obtained from the soft layer, preliminary estimation of settlement was made (see Appendix G-6). The result showed

that total amount of settlement and amount of residual settlement (settlement occurring after completion of the embankment) were in the order of 10 cm and 2 cm, respectively. The magnitude of residual settlement is very important because it occurs after opening to traffic and often cause longitudinal cracking and/or uneven pavement surface. Based on the past experience, these amounts of total settlement and residual settlement are not considered to pose serious problem on highway embankment.

Another cause of longitudinal cracking is caused by insufficient compaction of additional embankment, as described above. Possibility of cracking of pavement caused by residual settlement and compaction of additional embankment combined or independently should be reviewed in design stage based on the detailed investigations. If necessary, usage of geogrid or other measures should be considered.

(5) Precaution

The geotechnical investigations and analysis were conducted for the locations where existence of soft ground was suspected, as described above. The result of analysis showed that there are no serious problems anticipated for these locations. In addition, the data of standard penetration test (N-values) obtained from the boring at five locations indicated that no serious problems are anticipated at these location. However, **these facts do not mean that no precaution is necessary.**

In the stages of design and execution, due precautions is essential. As briefly explained in Appendix G-5, river deposits are not uniform, and sometime drastically changes their properties in horizontal direction. **Therefore, proper geotechnical investigations should be made wherever existence of soft ground is suspected.** Existence of soft ground is detected easily and quickly by using simple sounding method such as Swedish sounding or Dutch cone penetrometer. (Swedish sounding is most suitable for Study Road because the tools are small and easy to set up at swampy land, and also because it can penetrate relatively firm layer(s) before reaching the soft layer.) Necessary additional survey in design stage is mentioned in Appendix D-2.

If a soft ground is detected at the stage of execution, careful control of speed of embankment together with monitoring of ground movement, as briefly explained in "Section 13.4 Construction Planning", will be effective to prevent failure of embankment.

13.1.5 Road Drainage

On the sections where side walk is not provided, rain water on the road surface can freely flow to the slope and does not concentrate. On the contrary, on the sections where sidewalk is provided, water on the surface of pavement is blocked by the sidewalk and some type of drainage system becomes necessary. Appropriate drainage system is particularly necessary on approximately 300-meter long section near Chbar Ampov Market and approximately 500-meter long section at Kokir Market Section. Followings are outline of proposed drainage systems.

(1) Chbar Ampov Section (St. 0+000 – 0+300)

Water on carriageway is to be drained to side ditches installed on both side of the

carriageway. The side ditches are sloped towards Bassac River and the "boeng" in the east of this section. The outline of flow of water is shown in Fig. 13-1-5. Calculation of drainage is summarized in Table 13-1-4. Drawings of the drainage system are shown in the "Drawings"

Table 13-1-4 Calculation of Drainage for Chbar Ampov Section

Drainage Channel	Drainage Area			Concentration Time			Rainfall Intensity	Rainfall Runoff	Design of Drainage Channel		
	Length	Width	Area	Inlet Time	Traveling Time	Total			Longt. Bed Slope	Width	Height
			A	T1	T2	T	I	Q	1/S	B	H
	(m)	(m)	(ha)	(min)	(min)	(min)	(mm/h)	(m3/s)		(m)	(m)
A1-1	185	25	0.46	10	6.2	16.2	80.0	0.07	1000	0.40	0.50
A1-2	185	25	0.46	10	6.2	16.2	80.0	0.07	1000	0.40	0.50
A2-1	185	25	0.46	10	6.2	16.2	80.0	0.07	1000	0.40	0.50
A2-2	185	25	0.46	10	6.2	16.2	80.0	0.07	1000	0.40	0.50
Total			1.85					0.27			

(2) Kokir Market Section (St. 13+500 – 14+000)

Similarly to Chbar Ampov Section, water on the carriageway is to be drained to side ditches on both side of the carriageway and led to Mekong River and low marshy land on the both side of the Section.

Fig. 13-1-6 shows the outline of the flow of water. Calculation of drainage for Kokir Market Section is summarized in the table below. Drawings of drainage system are shown in the "Drawings".

Table 13-1-5 Calculation of Drainage for Kokir Market Section

Drainage Channel	Drainage Area			Concentration Time			Rainfall Intensity	Rainfall Runoff	Design of Drainage Channel		
	Length	Width	Area	Inlet Time	Traveling Time	Total			Longt. Bed Slope	Width	Height
			A	T1	T2	T	I	Q	1/S	B	H
	(m)	(m)	(ha)	(min)	(min)	(min)	(mm/h)	(m3/s)		(m)	(m)
A1	420	25	1.05	10	14.0	24.0	68.1	0.10	1000	0.50	0.55
A2	180	25	0.45	10	6.0	16.0	80.3	0.05	1000	0.40	0.40
A3	120	25	0.30	10	4.0	14.0	84.1	0.04	1000	0.40	0.30
Total			1.80					0.18			

(3) Other Sections

Sidewalks are proposed also for the section between St. 0+300 and St. 7+000. Water on the carriageway is to be drained through pipes installed across the sidewalks and led to the to the slope at appropriate interval such as 20 meters.

Water on carriageway on other sections is drained across the shoulder as the case in the existing road.

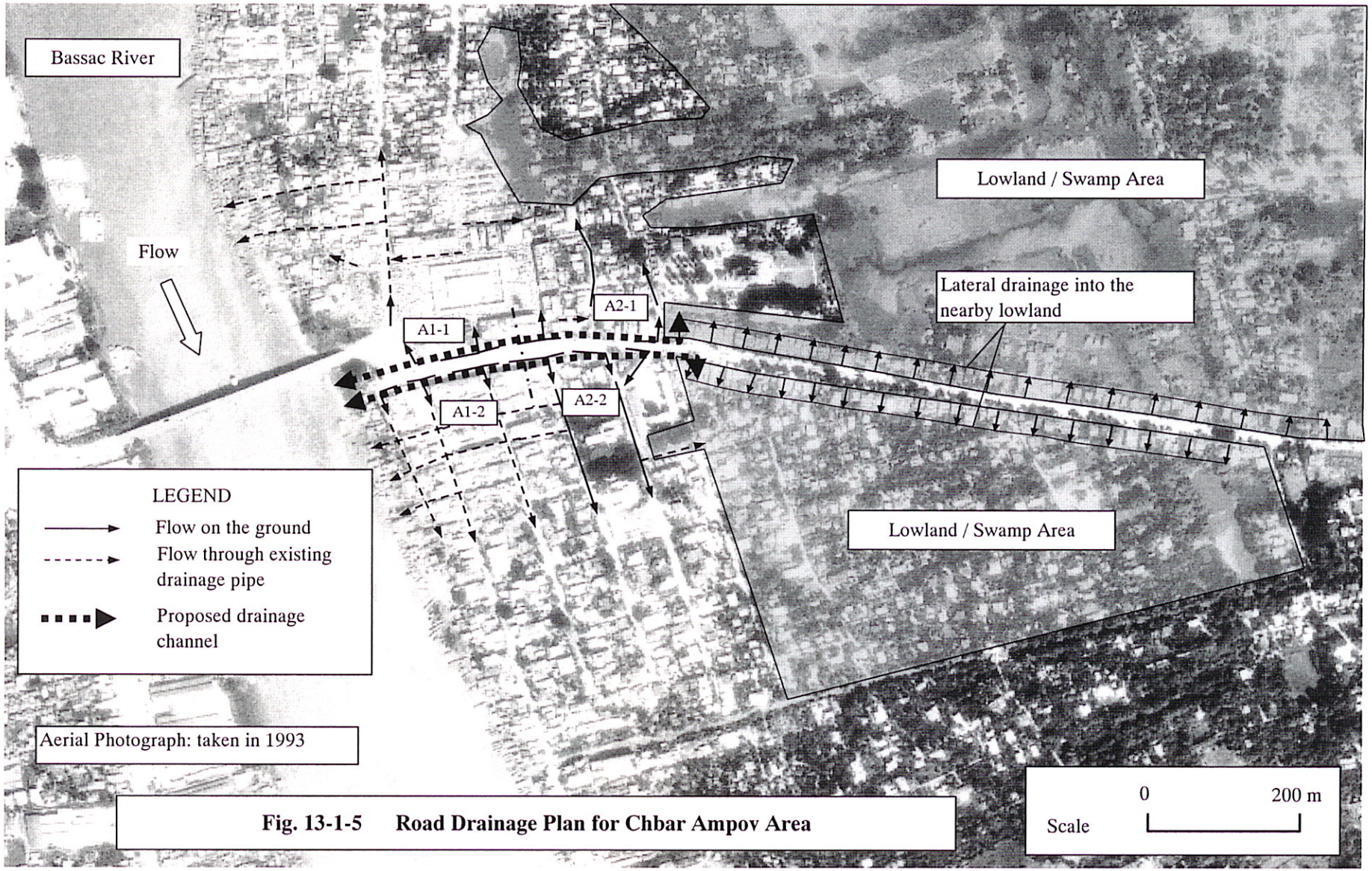


Fig. 13-1-5 Road Drainage Plan for Chbar Ampov Area

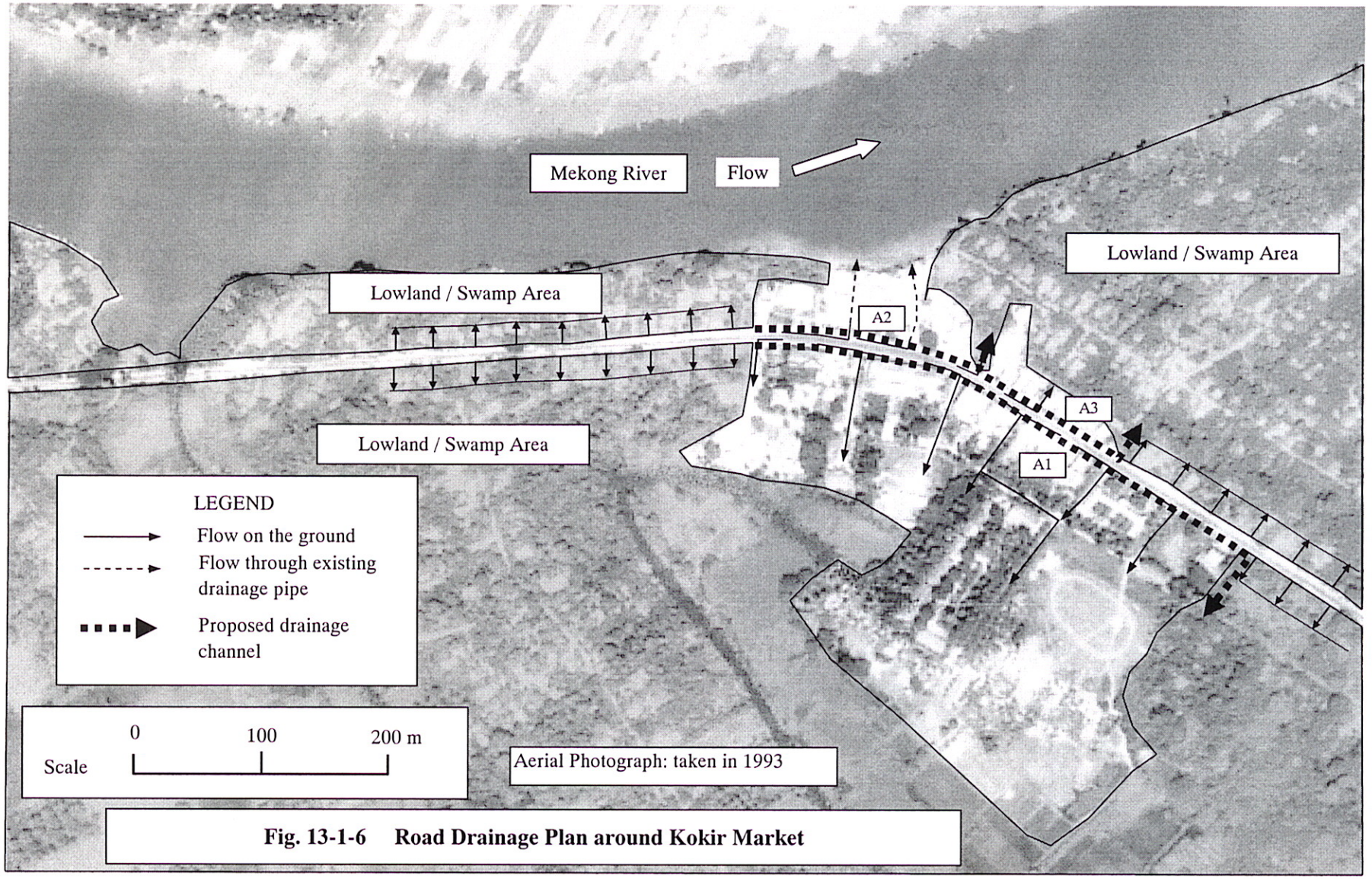


Fig. 13-1-6 Road Drainage Plan around Kokir Market

13.1.6 Traffic Safety Measures and Control Facilities

When a road is improved, vehicles tend to travel at higher speed than that of the present. To secure safe and smooth traffic, the following measures and/or facilities are proposed to be implemented/installed at strategic locations.

(1) Road Marking

Road markings are effective measure for traffic safety. The following types of road markings are proposed as effective ones. These road markings have been installed along the arterial streets in the central Phnom Penh and drivers are now learning the meaning of these markings. Accordingly, it is expected that these markings will be more effective in the future than they are now. Other types of road marking should be considered in the design stage depending on the actual site conditions.

1) Centerline

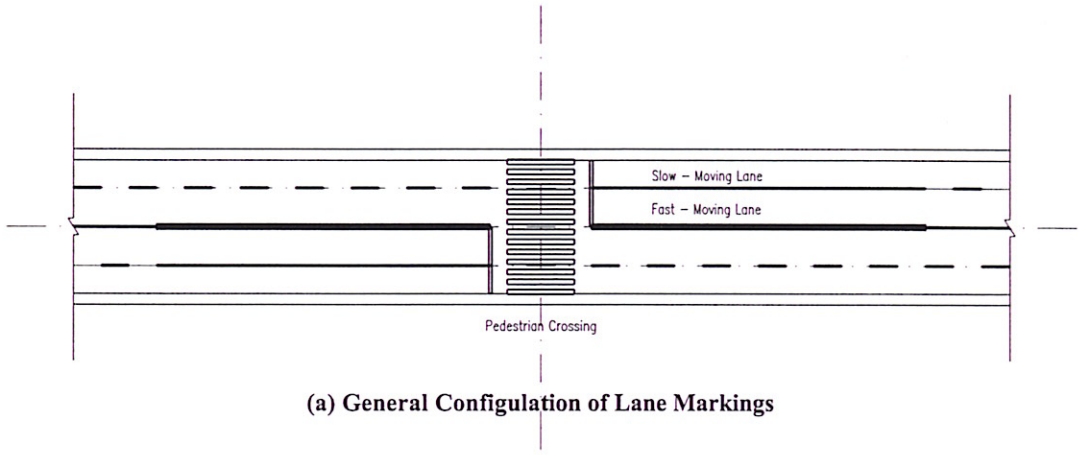
Centerline marking is necessary on the undivided 2-lane sections to encourage drivers to drive on the correct lane. On the ordinary sections, broken-line type of centerline is appropriate while solid line is appropriate where vehicles need to be prohibited of crossing the centerline, such as near pedestrian crossing. Fig. 13-1-7 shows an example of centerline near pedestrian crossing.

2) Pedestrian crossing

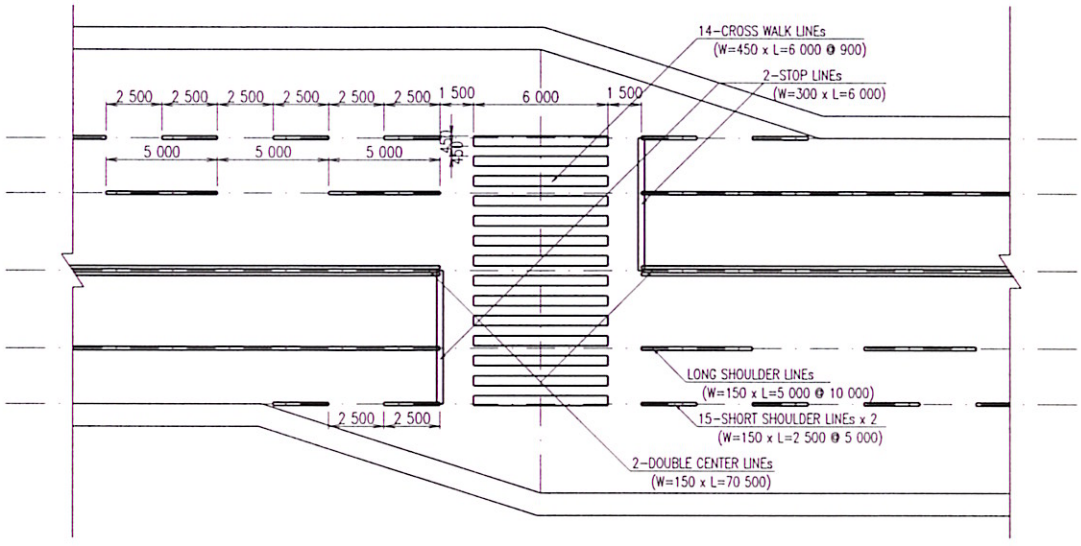
Markings of pedestrian crossing are needed where substantial number of pedestrians cross the road. At present, pedestrian crossings are particularly necessary at urbanized section near Chbar Ampov Market and Kokir Market. They are also necessary in front of school, moto-remork stops, bus stops and others. Fig. 13-1-7 shows an example of road marking for pedestrian crossing.

3) Lane mark between fast-moving vehicle lane and slow-moving vehicle lane

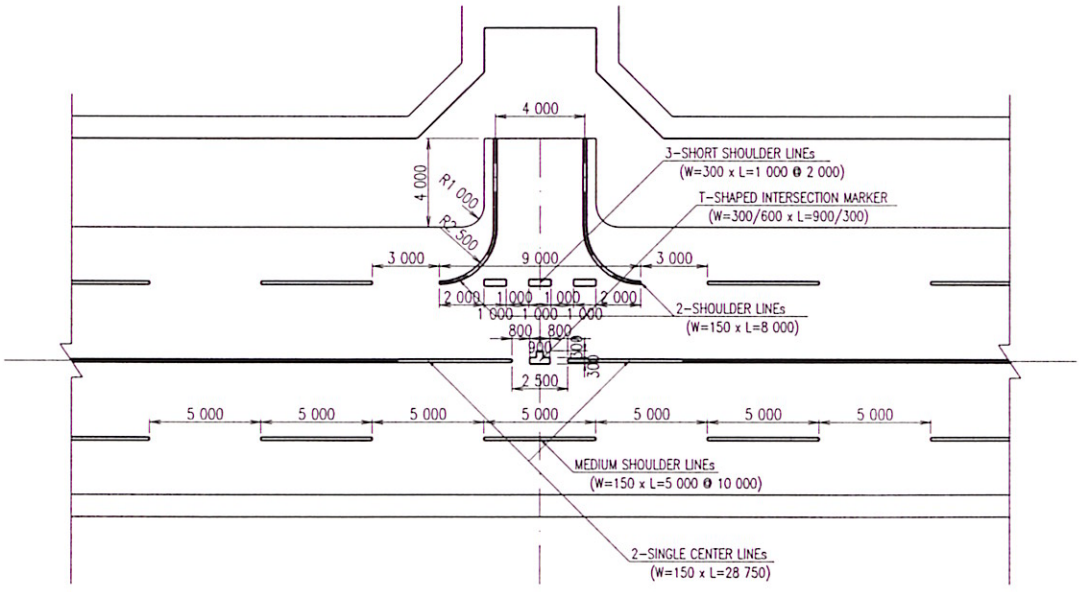
Lane mark is necessary between the fast-moving vehicle lane and slow-moving vehicle lane. This type of lane mark is expected to let the driver (of both slow-moving vehicles and fast-moving vehicles) be aware of their own lane. Separation of slow-moving vehicles and fast-moving vehicles is essential for traffic safety. Fig. 13-1-7 also shows an example of lane mark between slow-moving lane and fast-moving lane.



(a) General Configulation of Lane Markings



(b) Detail of Markings of Pedestrian Crossing



(c) Detail of Markings of Minor Intersection with Moto-Stop

Fig. 13-1-7 Example of Road Markings

(2) Guard Post and Guard Rail

Guard posts are devices installed along shoulder to prevent the vehicles run out of the roadway. They are expected to also function as delineators. Guard posts are proposed to be installed along the following sections. (Urbanized sections and sections where houses are located relatively densely are excluded.)

(i) Curved section with radius R = 500 meters or smaller: Chances of vehicles running out of roadway are relatively high.
(ii) Approach of bridge and culvert: If vehicles run out of the roadway, they fall down high embankment and/or hit against the stiff structure (bridge or culvert).

Considering the above criteria, the following sections are proposed for installation of guard posts.

Table 13-1-6 (1/2) Sections of Proposed Guard Post and Guard Rail (Curved Section)

Curved Section		Section Length (m)	Remarks
Station	Pk (MPWT)		
3+150 – 3+800	8.75 – 9.4	650	R = 495 m
12+300 – 12+700	17.9 – 18.3	400	R = 500 m
16+250 – 16+750	21.85 – 22.35	500	S-shaped curve with R = 410 m and R = 450 m
53+450 – 54+000	59.05 – 59.6	550	R = 495 m

Table 13-1-6 (2/2) Sections of Proposed Guard Post and Guard Rail (Approach of Bridges and Culverts)

Structure	Section of guide post installment
All 3 bridges	50 m each on both sides of bridges
All 11 proposed box culverts and 4 existing culverts	20 m each on both sides of culverts

In addition to the guard posts, guard rail needs to be installed along the bridge sections and culvert sections. On these sections, the elevation of the road surface is more than 5 meters high from the ground surface and it is very hazardous, and even sometimes fatal, if vehicles run out of the roadway.

(3) Traffic Signs

1) Regulatory signs and warning signs

There are 22 traffic signs existing along the Study Road; 20 “school zone (children crossing)” near schools, two “no entry” near Neak Loueng Ferry Terminal. After the road improvement, vehicles tend to travel at high speed. Therefore, installing appropriate regulatory and warning signs such as speed limit are needed at following locations

(i) Urbanized sections (near Chbar Ampov Market and Kokir Market) and their vicinities

(ii) Near schools, pagodas and pedestrian crossing (where many pedestrians cross the road)
(iii) Near moto-remork stops, bus stops and Road Station (where vehicle slow down to uses these facilities and also many pedestrians cross the road)
(iv) high embankment section, bridges, culverts and sharp curve (hazardous sections)

Usually, the authority and responsibility of installing and maintaining regulatory traffic signs rest with Traffic Police Department. It is expected that due consultation will be held between MPWT and Traffic Police Department on installation of regulatory signs.

2) Guide signs

When the Study Road will be improved, driver/passenger to travel long distance will increase. Accordingly, the necessity of guide signs will increase. Guide signs are proposed to be installed at the following locations.

Table 13-1-7 Location of Proposed Guide Signs

Location		For Vehicles going to	Contents/Message
Station	Pk (MPWT)		
0+150	5.75	Phnom Penh	Monivong Bridge (go straight) and Chbar Ampov Market (turn right)
6+900	12.5	Neak Loueng	Neak Loueng (go straight) and Outer Ring Road (turn right)
7+100	12.7	Phnom Penh	Phnom Penh (go straight) and Outer Ring Road (turn left)
13+200	18.9	Neak Loueng	Approaching Kokir Market, slow down
14+ 300	19.9	Phnom Penh	Same as above
54+400	60.0	Neak Loueng	Approaching Neak Loueng Ferry Area, slow down
54+750	60.35	Neak Loueng	Neak Loueng Ferry (go right) and "No Entry" (for going straight)

(4) Kilometer posts

Kilometer posts are effective to let the drivers know their location and the distances to their destinations. Kilometer posts are also useful for maintenance works to identify the location of problems to be inspected and/or repaired.

(5) Traffic Signal

There is no traffic signal on the existing Study Road. In short-term, traffic signals are needed at major intersection represented by the **intersection with Tiger Beer Road** (future Outer Ring Road. For long-term, traffic signals will become necessary at additional locations as traffic volume increases. Such locations for additional traffic signals are listed in the table below. An example of traffic signal is shown in the attached "Drawings".

Table 13-1-8 Location of Proposed Traffic Signal Installation (Long-Term)

Location		Main Reason for Necessity
Station	Pk (MPWT)	
0+100*	5.7	Deal with the heavy traffic going to/coming from Monivong Bridge and Chbar Ampov Market
0+250*	5.85	To improve congested intersection in the urbanized section
0+400*	6.0	Same as above
13+650	19.25	In front of Kokir Market; secure smooth traffic and safe pedestrian crossing

*These signals should be in-line controlled.

13.1.7 Road Related Facilities

It is a matter of course that the primary function of road is to secure traffic function for vehicles. However, the facilities related to road can contribute to improving services considerably for road users in the aspects of utilization of space and development impacts.

(1) Moto-remork Stop cum Spaces for Livestock Refuge

This space is planned as moto-remork stop to avoid hampering through traffic from on-road parking of moto-remorks throughout the year. This space can also provide enough flat space for local traffic to wait merging to through traffic. It is planned at minor intersections to local roads leading to villages, where on-road parking is observed and a number of passengers are expected daily.

Table 13-1-9 shows the proposed locations where it is currently seen that moto-remork/motodops are waiting passengers.

Table 13-1-9 Locations for Proposed Moto-remork Stops

Location		Remarks
Station	Pk (MPWT)	
5+900 L	11.5 L	School and Preak Ampel Market
15+300 L	20.9 L	School
17+700 R	23.2 R	Dei Thmei Language Center
19+350 R	24.95 R	Intersection with the road going to
20+900 R	26.1 R	School

From Km 25 towards Neak Loueng, there is no specific location of moto-remork parking, and passengers usually get on/off moto-remorks at their own destination.

Since many livestock occupy the existing road during flood as presented in Fig. 9-2-5 and it hampers the smooth movement of traffic, it can be used as a flood shelter of livestock during flood where there is no dry land except NR-1 because cultivated land and adjacent secondary road are inundated.

Fig. 13-1-8 A View of Moto-remork Stop cum Space for Livestock Refuge

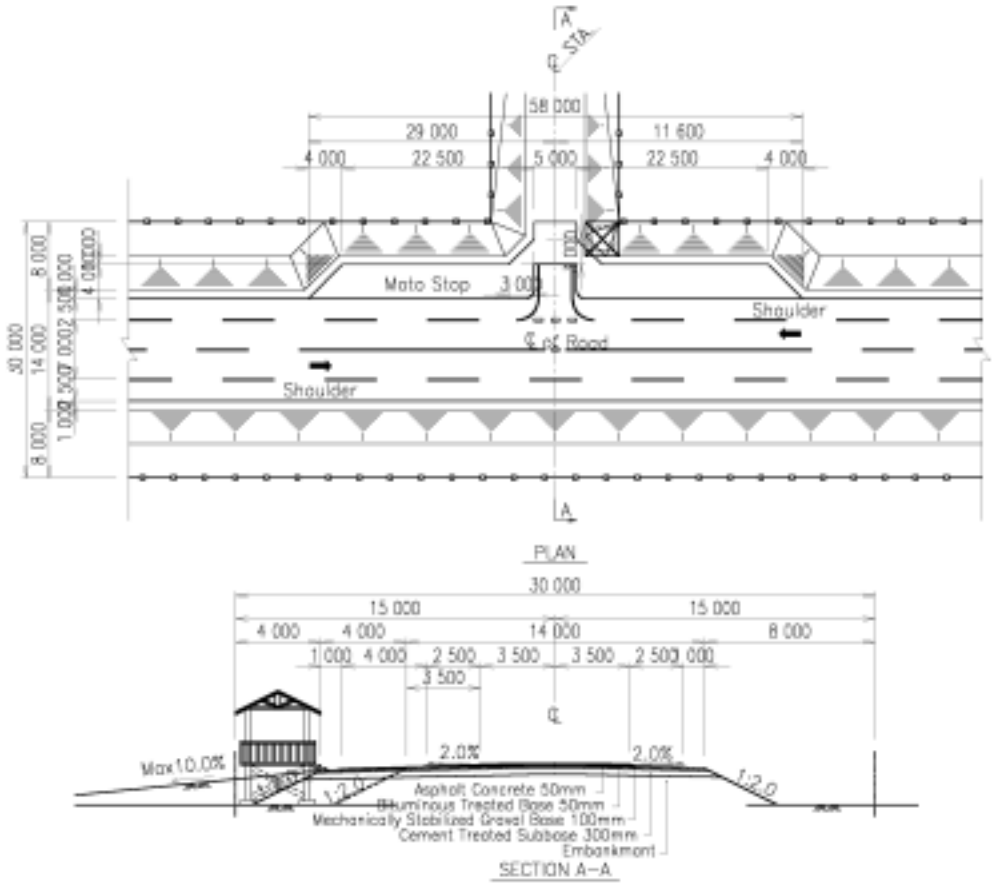


Fig. 13-1-9 Layout Sample of Moto-remork Stop cum Space for Livestock Refuge

For the purpose of moto-remork stop and flood shelter of livestock, the proposed locations are listed in Table 13-1-10.

Table 13-1-10 Locations for Moto-remork Stop cum Space for Livestock Refuge

Location		Remarks
Station	Pk (MPWT)	
32+570 L	38.2 L	Road going to nearby community and many cattle on shoulder
42+300 L	47.9 L	Same as above
47+100 L	52.7 L	Same as above

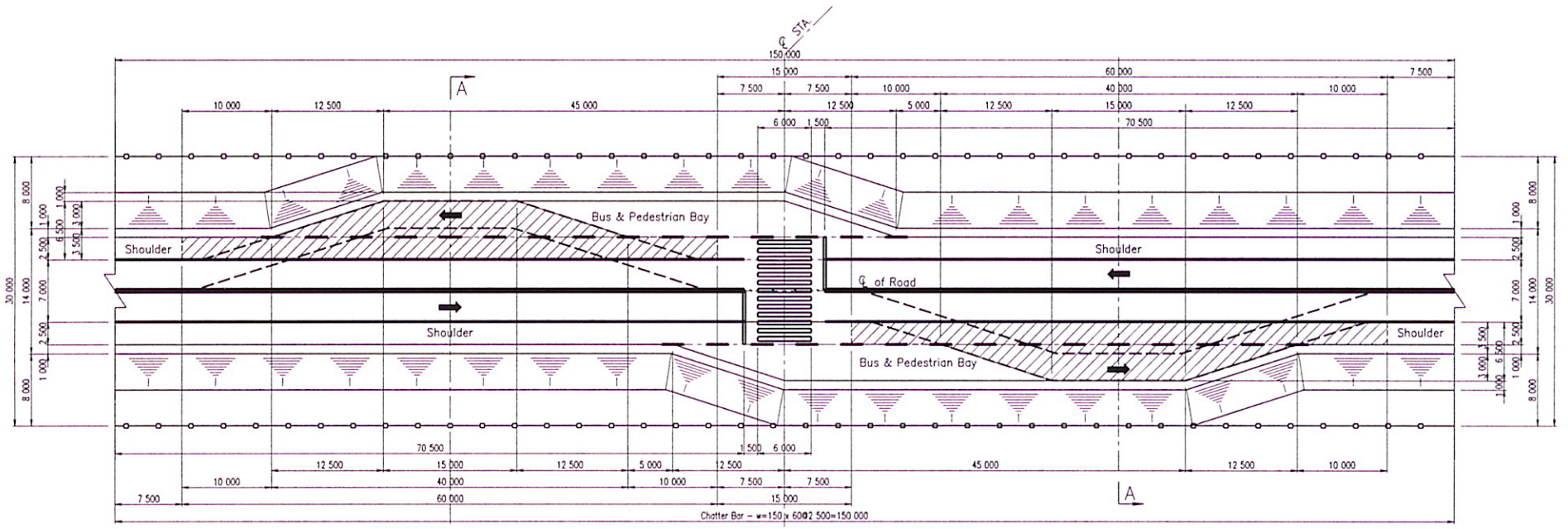
This facility seems to be a long-term improvement and it will be required at intersections at a certain interval, provided that the land use along the road is developed and the volume of 4-wheel vehicles increases closely to the capacity. However, it is recommended to build a moto-remork stop cum space for livestock refuge as a symbolic model of facility along the road in the inundation area in the short-term improvement.

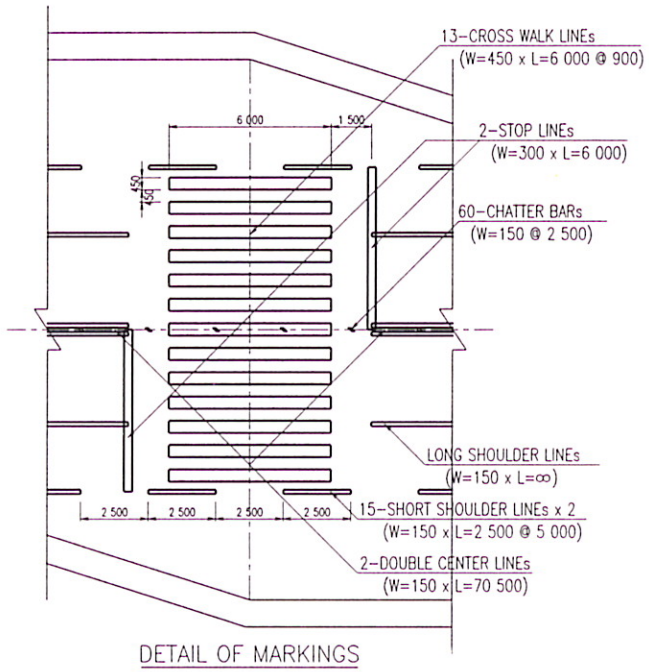
(2) Bus Stop

Currently, there is no bus stop along NR-1 C-1. However, bus stops will become necessary as the road network in Cambodia will be improved and traffic volume of long-distance inter-city bus will increase. One of the candidate locations of such a bus stop is the vicinity of the intersection at St. 7+000 (Pk 12.6) (intersection with Tiger Beer Road). This intersection is the possible intersection of the Study Road and planned Outer Ring Road. After Outer Ring Road will be completed, modal interchange facilities such as a long-distance terminal will be built in the vicinity of the intersection. Therefore, bus stop will be necessary for those passengers who use these facilities.

Smaller scale bus stops (bus bays) are needed at where light buses for short-trips stop frequently. Such bus stops are proposed to be installed near markets, schools, community centers, pagodas to avoid the buses from blocking moto-remork and other vehicles using slow-moving lane.

Fig. 13-1-10 shows a conceptual layout of smaller scale bus stop (bus bays).





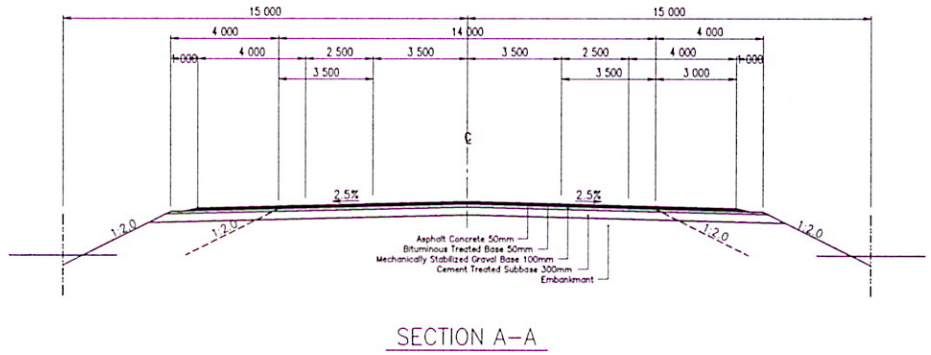


Fig. 13-1-10 Conceptual Layout of Bus Stop

(3) Road Crossing Structures

1) Utilization of culverts

When a road is improved, pedestrians crossing the road often face difficulties because of the higher speed the vehicles than before. One of the solutions to this problem is to utilize box culverts. Total eleven box culverts are proposed. The inner clearance of these culverts is 4 meters or more. Therefore, they can be used as the path for pedestrians, cattle and cattle carts. Fig. 13-1-11 shows the image of a box culvert used as a path for pedestrians and cattle.

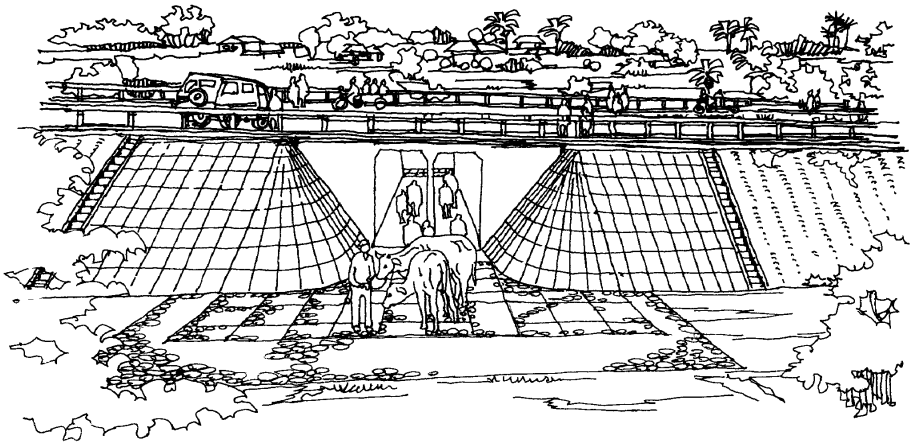


Fig. 13-1-11 Image of Box Culvert Used as Crossing Facility

2) Pedestrian Bridge

Another facility for pedestrian crossing is a pedestrian bridge. Pedestrian bridge is effective where there are many pedestrians who cross the road and the width of the road to be crossed is wide. Separation of pedestrians by provision of pedestrian bridge is also effective to secure smooth flow of traffic.

Pedestrian bridges will be necessary on long-term basis when traffic volume and/or number of pedestrians will increase. Locations where pedestrian bridges will be necessary are as follows:

i) Urbanized section near market (Chbar Ampov Market and Kokir Market)
ii) Near schools, pagodas
iii) Large factories where large number of worker cross the road

Fig. 13-1-12 shows a conceptual layout of pedestrian bridge.

(4) Weighbridge Station

Over-loaded trucks are serious problems for maintenance of road. The Cambodian Government is exerting strenuous effort to enforce regulation of loading. One fixed weighbridge has been constructed along NR-6 near Thnal Keng. MPWT is planning to construct weighbridge stations at 10 locations along the principal national roads under financial assistance by ADB. However, there is no plan to construct weighbridge station along NR-1 C-1. If there will be no weighbridge station in the future, illegally over-loaded trucks will avoid other national roads where weighbridge stations are

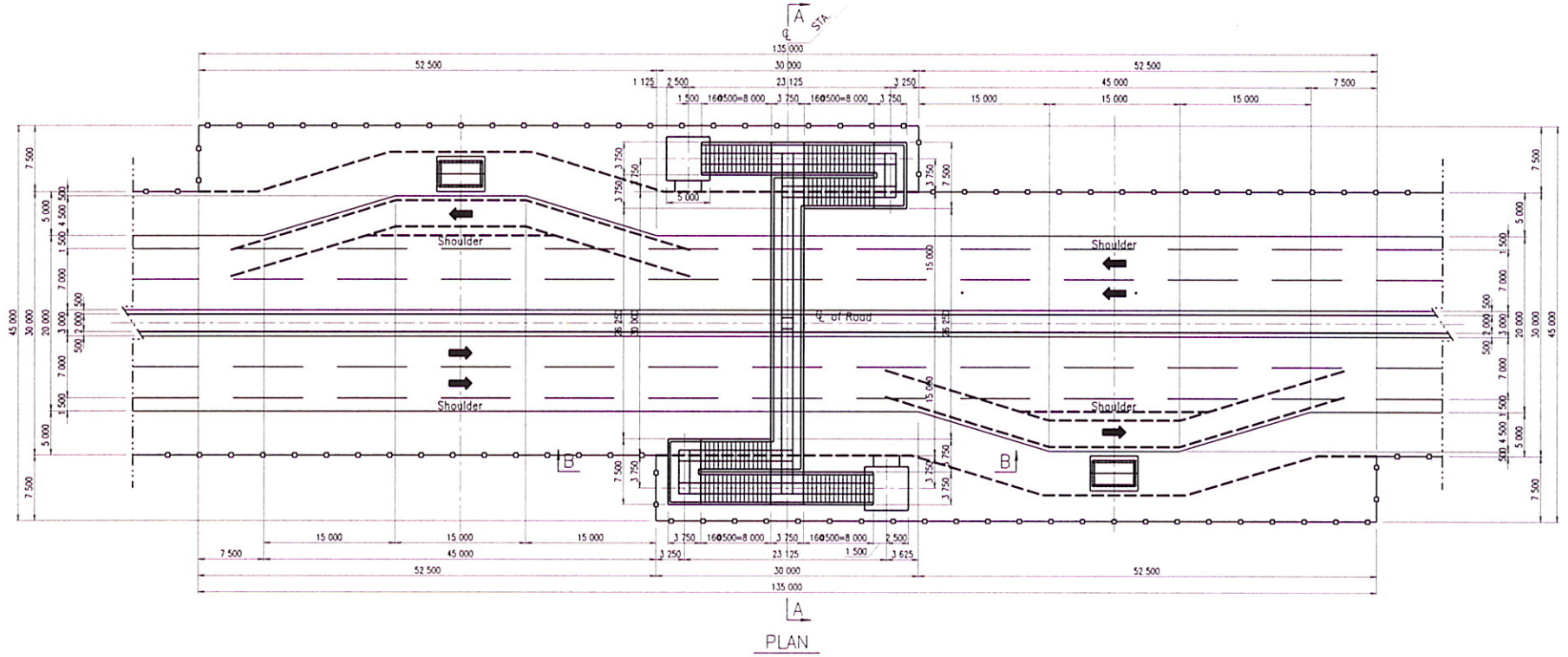


Fig. 13-1-12 Example of Pedestrian Bridge

provided and concentrate on NR-1 C-1. Therefore, weighbridge needs to be constructed at strategic location(s) of NR-1 C-1 to enhance enforcement against overloading. Weighbridge station needs to be constructed simultaneously with the improvement of NR-1 C-1 so that damage of the newly constructed pavement will be effectively prevented.

(5) Approach Slope for Local Road

Substantial part of NR-1 C-1 is embankment. The height of embankment needs to be further raised as described in Subsection 11.1 "Design Criteria for Geometric Design and Pavement". When the road surface of NR-1 C-1 is raised, the existing local roads connected to NR-1 C-1 also need to be raised. The slopes of these local roads need to be gentle enough so that cattle carts or other non-motorized vehicle can easily climb. Otherwise, these vehicles need to run up the slope at high speed to maintain the momentum, and as a result, can not stop before entering NR-1 C-1. This is rather risky for both road users of NR-1 and local road, and this situation may cause accident. It is also necessary to provide the local road with an appropriate length of flat section where the vehicle can stop before entering NR-1 C-1. Fig. 13-1-13 shows a schematic illustration of slopes of local roads connected NR-1 C-1. There are approximately 160 local roads according to the Road Facility Inventory Survey.

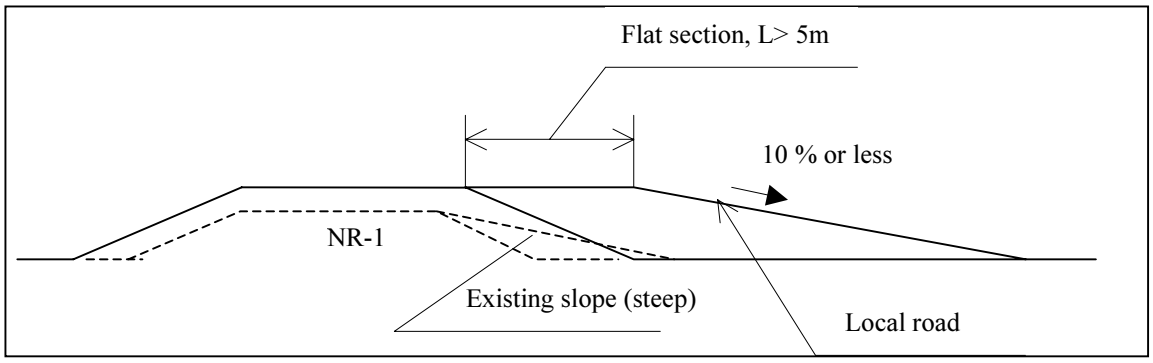


Fig. 13-1-13 Slope of Local Road

(6) Road Station

Major features through highway planning in the study area are long travel distance and passing productive area of agricultural crops. Long travel distance force driver into long time driving, and risk for traffic accident become high due to tiredness and boredom. Therefore, it is considered to rest from their drive at periodic intervals and care for them by provision of relaxation and recreation. Since various road functions contribute to reduce a severe burden from driver, the scheme of Road Station is envisaged to restrain from traffic accident and to enhance amenity.

Road Station is the functional and desirable elements of road and provides road users with the traffic safety, convenience and opportunity to come in touch with local products and culture. Road Station is located at a roadside together with parking facilities, rest facilities, gas station, repair shop and kiosk separated from the roadway, provided for the motorist to stop and rest for short periods.

The recreation area may provide services such as drinking water, restaurant, toilets, tables and benches, telephones, information facilities, selling space for local products and other necessary facilities for travelers. Only parking facilities and approach road is recommended to provide as minimum requirement in the study. Other facilities are preferable to provide by private sector.

Fig. 13-1-14 Image of Road Station

Site selection for safety rest areas should consider the scenic quality of the area, accessibility, and adaptability to development. Other essential considerations include an adequate source of water and a means to treat and /or properly dispose of sewage. The objective is to give maximum weight to the appropriateness of the site rather than adherence to constant distance or driving time between sites

Table 13-1-11 Required Number of Parking Lots

	Car	Bus	Small Truck	Medium Truck	Large Truck
Required Number of Parking Lots	6	2	0	3	1

Although the scale of road station depends on the projection of traffic demand, it is necessary for parking lots of six passenger cars and six heavy vehicles such as bus, truck and trailer as a minimum requirement. Fig. 13-1-15 shows a conceptual layout for reference.

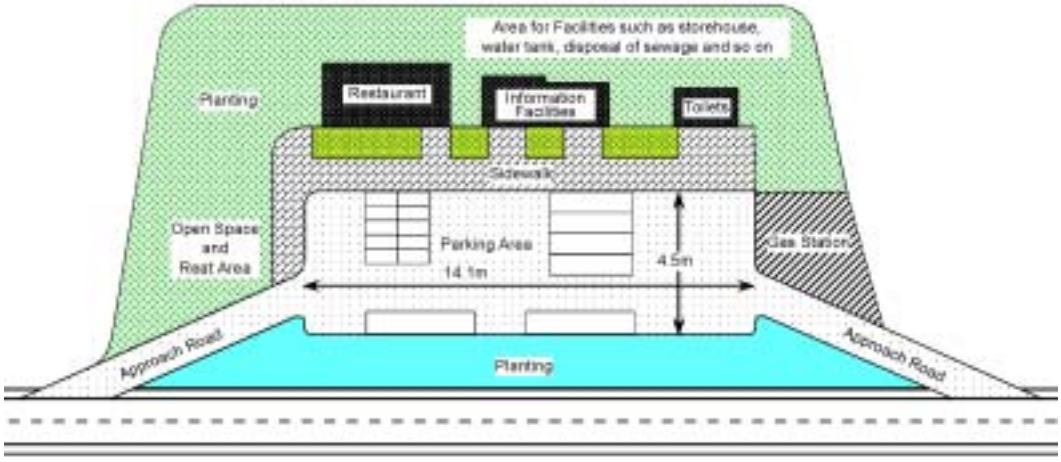


Fig. 13-1-15 Conceptual Layout of Road Station

This facility seems to be a long-term improvement and it will be required at a certain interval if the land use along the road is developed. However, it is recommended to build a Road Station as a symbolic model of facility along the road in the short-term improvement.

13.1.8 Major Intersection

(1) Intersection with Outer Ring Road

At present there is no large intersection along NR-1 C-1. There is a plan to construct Outer Ring Road of Phnom Penh by year 2015, connecting such principal national roads as NR-1 C-1, NR-2, NR-3, NR-4, NR-5 and NR-6. The location of the interchange of NR-1 and Outer Ring Road is tentatively assumed at, or in the vicinity of, the present intersection with Tiger Beer Road (St. 7+000 of Pk 12.6). Upon completion of NR-1 C-1 and Outer Ring Road, this intersection will become major intersection. In the future, a grade-separation structure will be required. Therefore, Right of Way to allow such grade-separated intersection needs to be secure at the time of the proposed improvement of NR-1 C-1. Fig. 13-1-16 shows a conceptual plan of the intersection with a space for future development.

(2) Intersection in front of Chbar Ampov Market

The intersection in front of Chbar Ampov Market (adjacent to east abutment of Monivong Bridge) is severely congested at present. When the traffic volume will increase in the future, the traffic congestion will become more severe and some measure(s) will be necessary.

Among the several measures needed to alleviate the traffic congestion in front of Chbar Ampov Market, increasing the capacity of Monivong Bridge (by widening of the existing bridge or new construction of an additional bridge parallel to the existing one) is indispensable. The “Study on the Transport Master Plan of the Phnom Penh Metropolitan Area”, JICA, 2001 recommended construction of an additional bridge although the exact location of additional bridge was not identified in the “Transport Master Plan” Study.

The construction of additional bridge is badly required to solve the problems related to road traffic in this area even though it is out of the scope of work for the Study. However, the scheme of additional bridge surely leads to the drastic change of Kbal Ntal Intersection where National Roads No.2 & 3 connect to National Road No. 1. Therefore, it is not appropriate to draw a plan for improvement of the intersection in front of Chbar Ampov Market.

Under such circumstances, however, the further study including preliminary design was attempted for improvement of this intersection. The further study is presented in Appendix G-8.

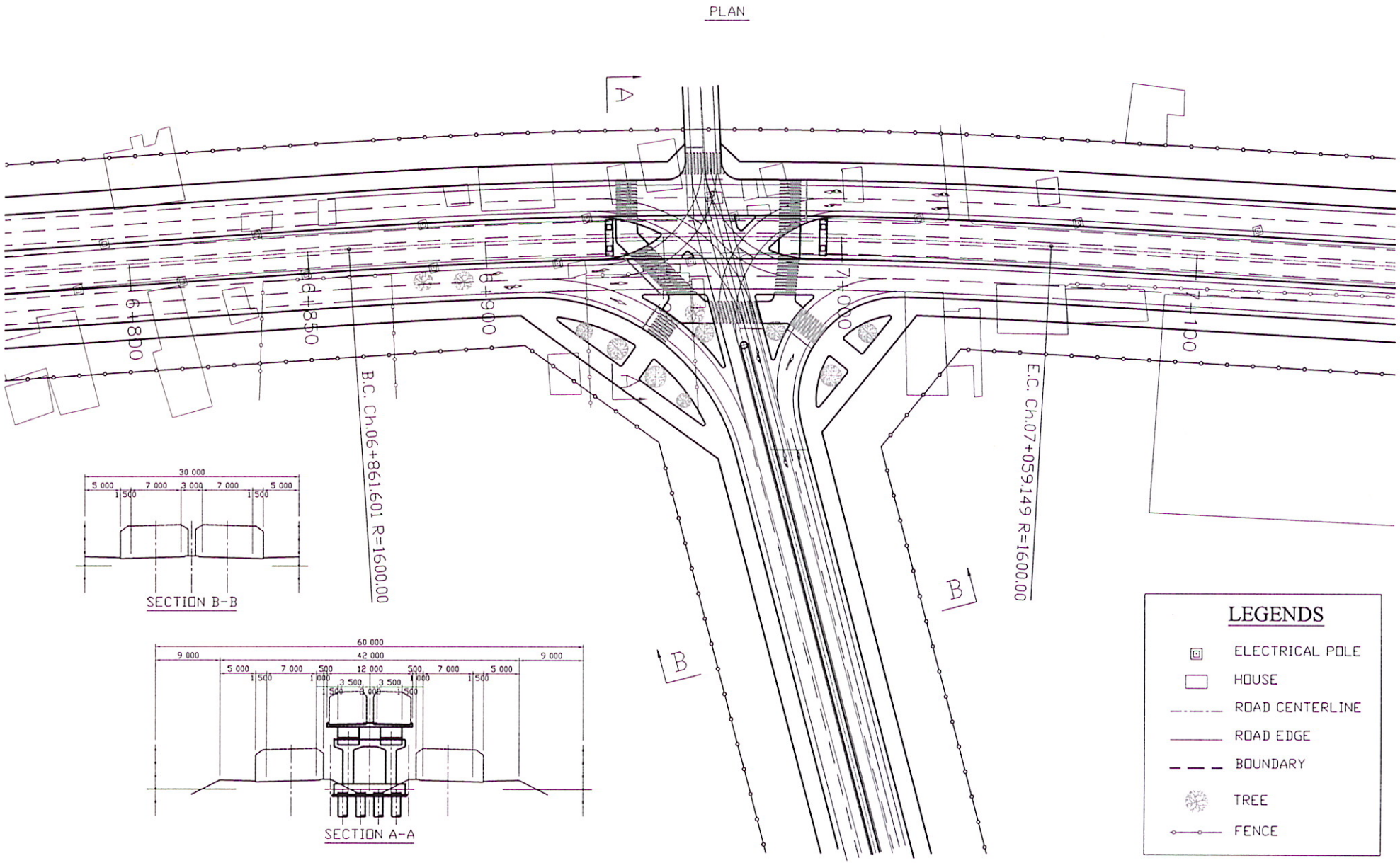


Fig. 13-1-16 Conceptual Plan for Intersection with Tiger Beer Road with a Space for Future Development

13.2 Pavement Design

13.2.1 Design of Asphalt Pavement

(1) Design Criteria

As explained in Chapter 11, "Design Guide for Pavement Structure" of AASHTO was used as the basis of design procedures. Other relevant standards/manuals, such as "Asphalt Pavement Manual" of Japan Road Association (JRO) and "Road Design Standard; Part II Pavement" of Cambodia were referred as appropriate.

Followings are the summary of the process of pavement design. Detailed explanation of the design is rather lengthy and, thus, given in Appendix G-3.

(2) Calculation of Required Strength of Pavement

Required strength, denoted as SN (Structure Number) is calculated by the following formula:

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

------- (Eq. 1)

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, and
M_R = resilient modulus (psi) (of subgrade); calculated from CBR.

Fig. 13-2-1 shows the general flow of design of pavement.

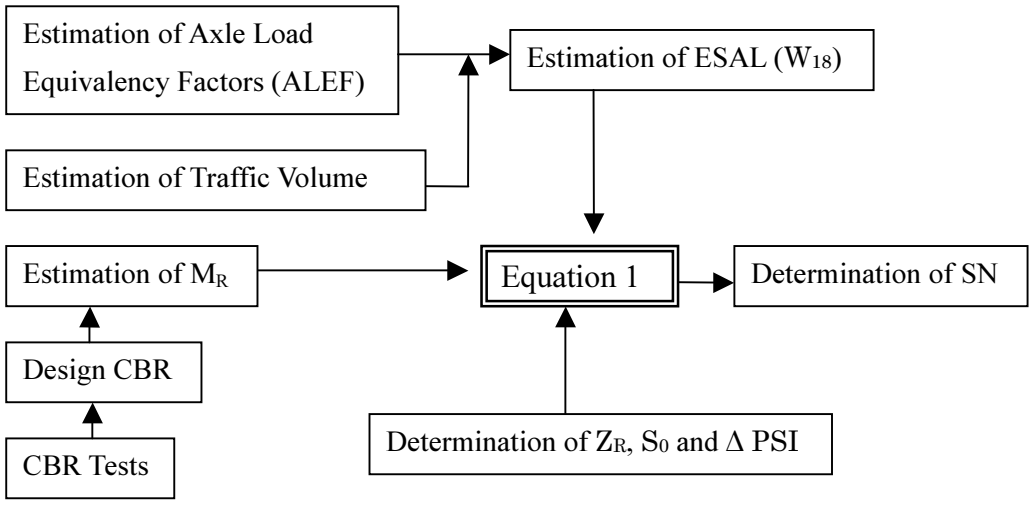


Fig. 13-2-1 General Flow of Pavement Design

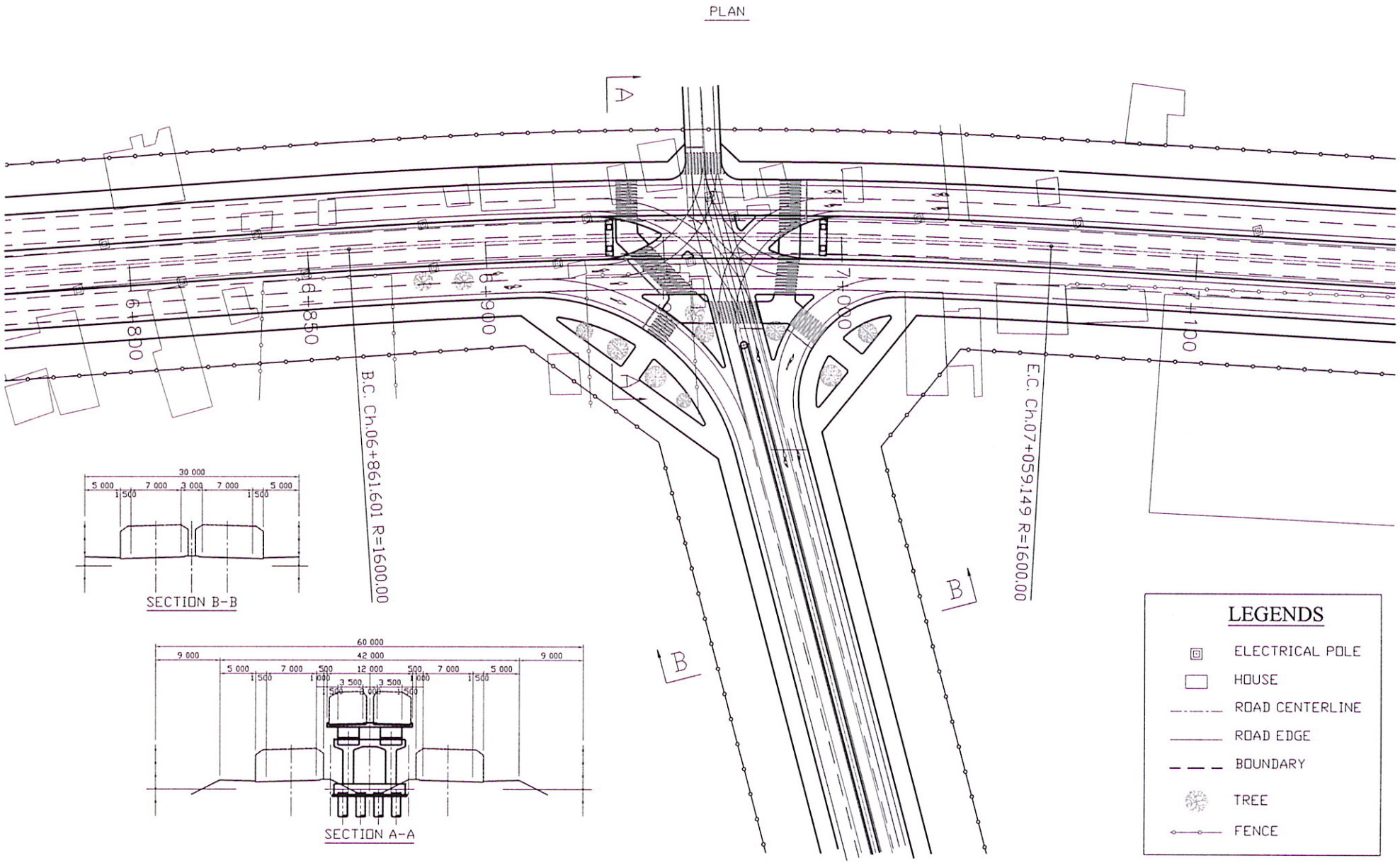


Fig. 13-1-16 Conceptual Plan for Intersection with Tiger Beer Road with a Space for Future Development