CHAPTER 7 NATURAL CONDITION EXAMINATION AND ENGINEERING SITE SURVEY

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7.1 Basic Data for the Study

Collected basic data for the Study are topography, geology, meteo-hydrology, socio-economy, landuse, national and regional development plans and others. Following list shows the collected basic data.

Table 7-1-1 Collected Basic Data

Category of Data	Data	Data Source
1. Topograpy	1) Topographic maps (scale: 1/100,000) made after 1997.	MPWT
	2) Topographic maps (scale: 1/50,000) made after 1969.	Unknown
	3) Aerial Photographs (scale: 1/25000) taken in 1992.	FINMAP
	4) Landsat Image on Sep.26, 2000	NASA
	5) Bathymetric survey map along the Mekong River and Tonle Sap River (scale: 1/20000) made in 1999.	MPWT
2. Geology	1) Geological maps (scale: 1/500,000) made after 1997.	MPWT
	2) CBR data of NR 1	JICA Expert
3. Meteo-hydrology	1) Water level and discharge 2) Meteorology and rainfall	MoWRAM
4. Socio-economy	1) Population 2) GDP etc.	
5. Landuse	1) Landuse maps (scale: 1/150,000) made after 1997.	MPWT
6. Environment	—	—
7. National and Regional Development Plan	—	—
8. Others	1) Relating plan such as Road plan, flood control plan	MPWT MoWRAM Others
	2) Construction cost and construction method	
	3) Meeting Documents of Expert Group Meeting on Development of The Asian Highway Network, 2002	ESCAP
	4) Road Infrastructure Rehabilitation Project Map	MPWT

7.2 Physical Conditions of the Study Area

The Cambodia extends over area 181,035 km2 while the total area of the cities/ provinces of Plain Region (Phnom Penh, Kandal, Kampong Cham, Svay Rieng, Prey Veng, and Takeo) are 25,100km2. The geographical feature of Cambodia can be divided into the Plains, Tonle Sap, Coastal, and Plateau and Mountain Regions based on the topographical feature classification by Terrain.

The ratio of population in Plains Region including Phnom Penh is 51% of total population, 13,100,000 in Cambodia.

Capital Phnom Penh of beginning point for the project road is located at junction of three rivers, Tonle Sap River, Mekong River and Bassac River. The National Road No.1 (NR-1) is connecting between Capital Phnom Penh and Svay Rieng of Southern Area, even Vietnam. A part of this NR-1 is also defined as Asian Highway No. A-1.

The objective facilities on NR-1 shall be planned to be safe enough against floods and also not to cause negative impact on the surrounding environment and inhabitants because of NR-1

paralleled flood plain of the Mekong River. The functions of the objective facilities should be maintained even during the floods because of its importance as a main trunk road for ordinal transportation.

Therefore, the physical conditions for topographical, climatic and hydrological, geological, and others, shall be studied in the project.

(1) Topographic Feature

Since the city and suburbs have been constructed on the flat swampy hinterland of Mekong and other rivers, topography of Study Area is generally flat. Along the project road in parallel with right bank of Mekong River, the swampy areas and ponds are studded in places. However, the some reclaimed lands are utilized for local commercial, factory and other areas, currently.

The highest area of the beginning point around commercial area of near Monivong Bridge is the elevation of 11 meters above sea level with the datum plane at Ha Tieng in Vietnam. The elevation height of the project road is in the range of 11 meters of beginning point and 8 meters of ending point of project area.

(2) Geological Feature

The project area lies on flat alluvial plain between the confluences at Phnom Penh city and downstream at Neak Loueng along the right bank of Mekong River.

The soils underlying the project area are generally sandy silt and clay with soft, and their bearing capacities are relatively low. Exampled bearing stratum for bridge foundation is with depth in G.L.-20 to 30 meters.

Accordingly, road structures shall be required with large-scale foundation. Poor bearing capacity of subsoil also results in shorter life period of pavement structures.

(3) Climatic Feature

The climate of the study area is characterized as two pronounced seasons composed of wet season with frequent and heavy rainfall brought by southwest monsoon from mid-May to November and dry season from December to April influenced by northeast monsoon and short transitional periods in between these two seasons. The average annual rainfall in the study area is about 1400mm and highest rainfall occurs in September.

Annual average temperature in the study area is about 28^{o}C with a minimum of 21^{o}C in December and maximum of 34.6^{o}C in April. Relative humidity varies from 67% in March to 84% in September. Monthly average wind speed ranges from 5.6m/s to 12.5m/s and the highest speed is about 16-18m/s.

(4) Hydrological Feature

The Mekong River that is the longest river in South East Asia flows through the study area. The Grate Lake drains into the Mekong River at Phnom Penh and bifurcates as Bassac River and Mekong River mainstream. The National Road No.1 from Phnom Penh city to Neak Loueng passes along the right bank of Mekong River mainstream for about 56 km reaches traversing across the flood plain of Mekong Delta. The severe

floods occurred in recent past, especially year 2000 flood, inundated a vast area of the flood plain, and overflowed the road at several locations and water level reached close to the Phnom Penh city.

(5) Earthquake Feature

The Cambodia locates among the earthquake blank zone of southwest of circum-pacific seismic zone. According to data of International Seismic Center, earthquake is not recorded in Cambodia, South Vietnam, South Laos, Thailand and Malaysia. Furthermore, according to the table of recorded damages by earthquake in the world, injury/ damage is not recorded in Cambodia since human history. Considering the above conditions, it can be judged that influence of earthquake for structures is negligible.

7.3 Topographic Survey

The configuration of the existing road and topography within 30 meters from the road center was surveyed by a local survey company employed by the Study Team. The items of survey are as the followings:

- Establishment of bench marks
- Centerline survey
- Profile survey
- Topographic survey (within 30 meters from the road center)
- Cross section survey (road and water channel at opening of Km 42+800 and Km 47+967)

All the field woks were planned to be completed by the middle of July 2002, before the water level in Mekong River start to rise, and actually completed in mid-July 2002.

The survey data were processed and submitted to the Study Team with both CAD files and hard copies in accordance with the scales shown below.

Table 7-3-1 Scale of Drawings for Each Survey Items

Survey Item	Scale
Centerline and Plan View of Road	1/2,000
Road Profile	Horizontal 1/2,000, Vertical 1/200
Cross Section of Road	1/400
Cross Section of Water Channel	1/200

7.3.1 Centerline Survey and Profile Survey

The centerline of the existing road was surveyed using survey equipment with “Total Station” program. The surveyed data were compiled and processed in the computers to draw horizontal alignment of the existing road. Location of houses, utility poles and other items within 30 meters distance from the center of the road which were surveyed in the topographic survey and may need to be relocated were drawn on the same drawings with the configuration of the road.

Starting point of the survey was set at the expansion joint of Monivong Bridge on its east side abutment. The chainage of this point corresponds Pk 5+600 of the MPWT's chainage system.

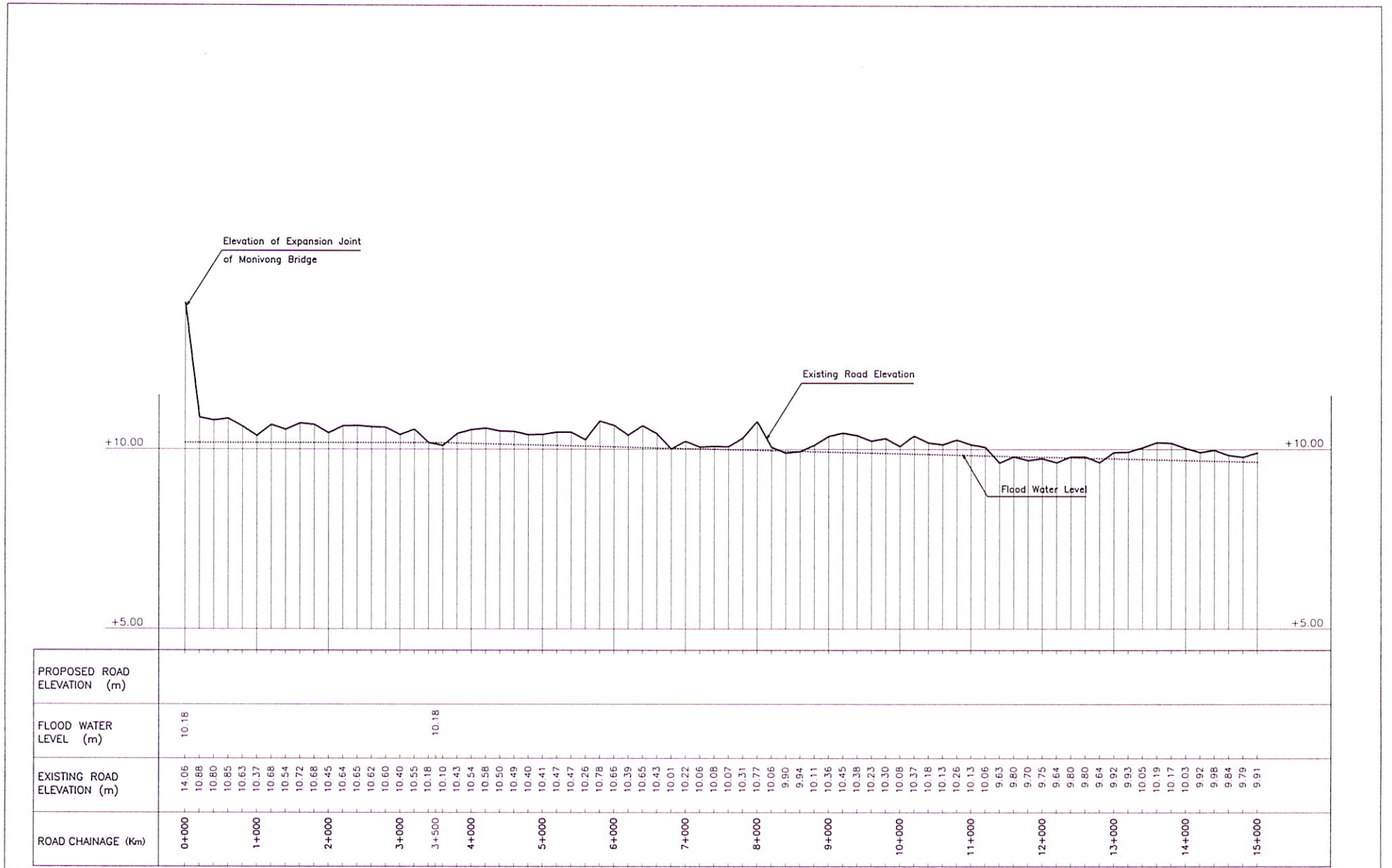
The benchmark of MPWT located at the rotary intersection in the west of the Monivong Bridge was used as the reference point of the profile survey. There used to be another benchmark in the ferry terminal area at Neak Loueng. However, this benchmark had been damaged and could not be used.

Temporary benchmarks, made of concrete stakes with dimension of 16 cm x 16 cm x 70 cm were set along the Study Road at intervals of approximately 5 km. These benchmarks are set at the locations not affected by the works near the Study Road and, thus, are expected to be used as reference points in the stages of design and execution of works in the future. In addition to these temporary benchmarks, concrete stakes with same size with the benchmarks were installed along the shoulder of the road at every kilometer. These kilometer posts, together with the nails driven into the pavement surface, were used for identifying the locations in the soil investigation, road inventory survey and other surveys.

The centerline survey and profile survey confirmed the following

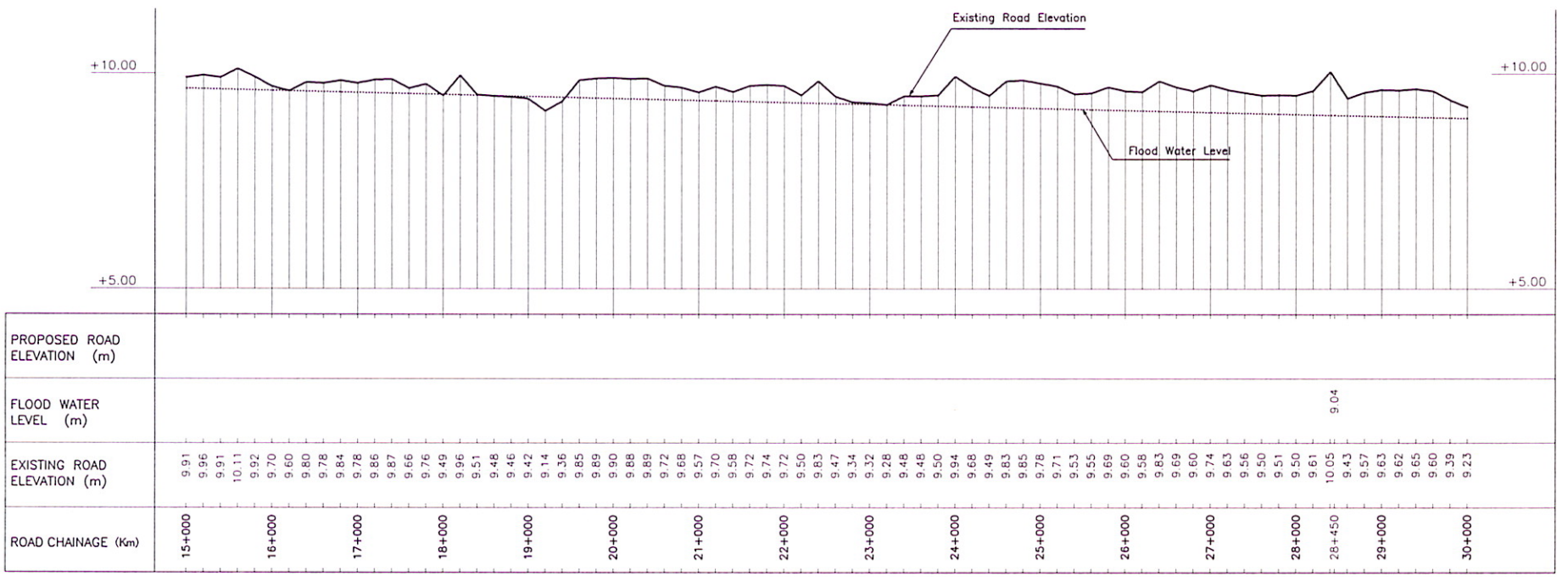
i) Distance from the starting point in on the east-side abutment of Monivong Bridge to Neak Loueng Ferry Terminal on the west bank of Mekong River is 55.34 km.
ii) The formation of the Study Road is highest at the starting point (Elv. 14.06 m), but this is because the starting point was set at the abutment of Monivong Bridge. More general road elevation near the starting point is approximately 10.8 meters. Road elevation generally lowers towards the end point (Neak Loueng) where the elevation is around 8.0 meters.
iii) The centerline generally follows favorable alignment both in horizontal and vertical direction. The only exception to this is the section from Km 32+600 to Km 32+900 where the Study road horizontally curves with small radii.

Fig. 7-3-1 shows the summary profile of the Study Road.



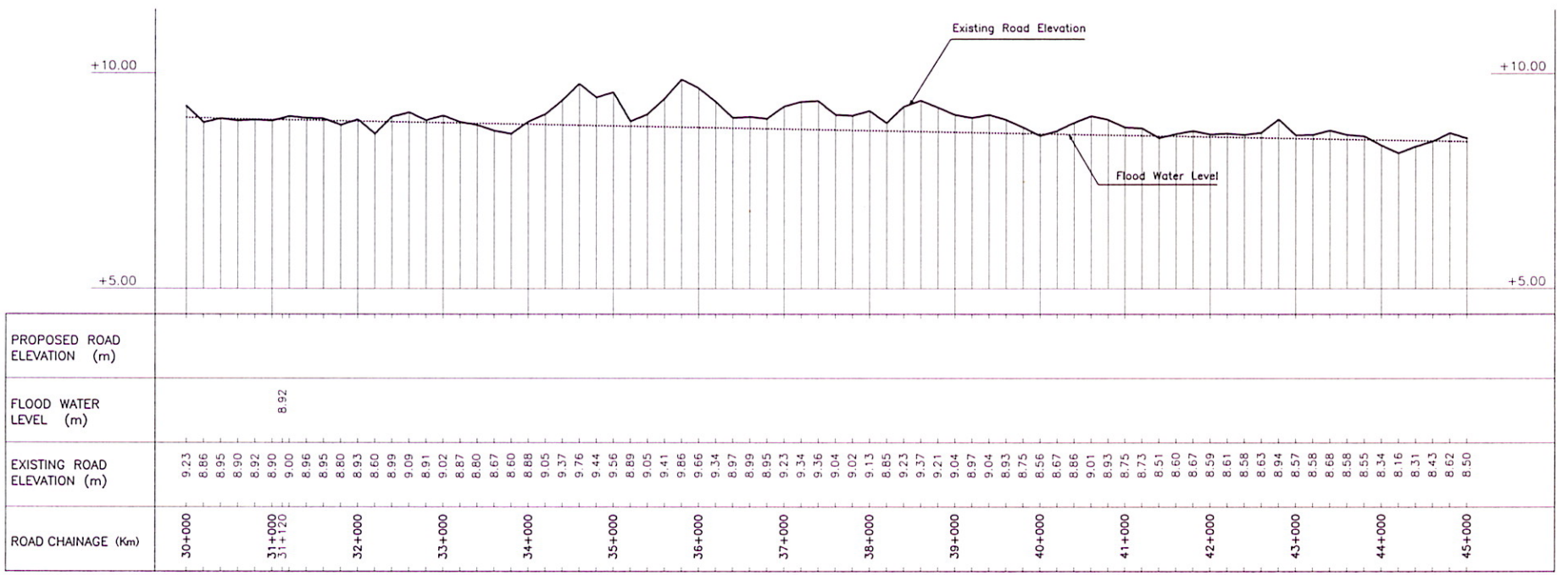
MINISTRY OF PUBLIC WORKS AND TRANSPORT	THE FEASIBILITY STUDY ON THE IMPROVEMENT OF NATIONAL ROAD No.1 (PHNOM PENH-NEAK LOEUNG SECTION) IN THE KINGDOM OF CAMBODIA	JAPAN INTERNATIONAL COOPERATION AGENCY PACIFIC CONSULTANTS INTERNATIONAL & KATAHIRA & ENGINEERS INTERNATIONALA	TITLE : PLAN AND PROFILE Km. 00+000 - 15+000	SCALE	Drawing No. L-01 Sheet No. L-01

Fig. 7-3-1 Plan and Profile (1/4)



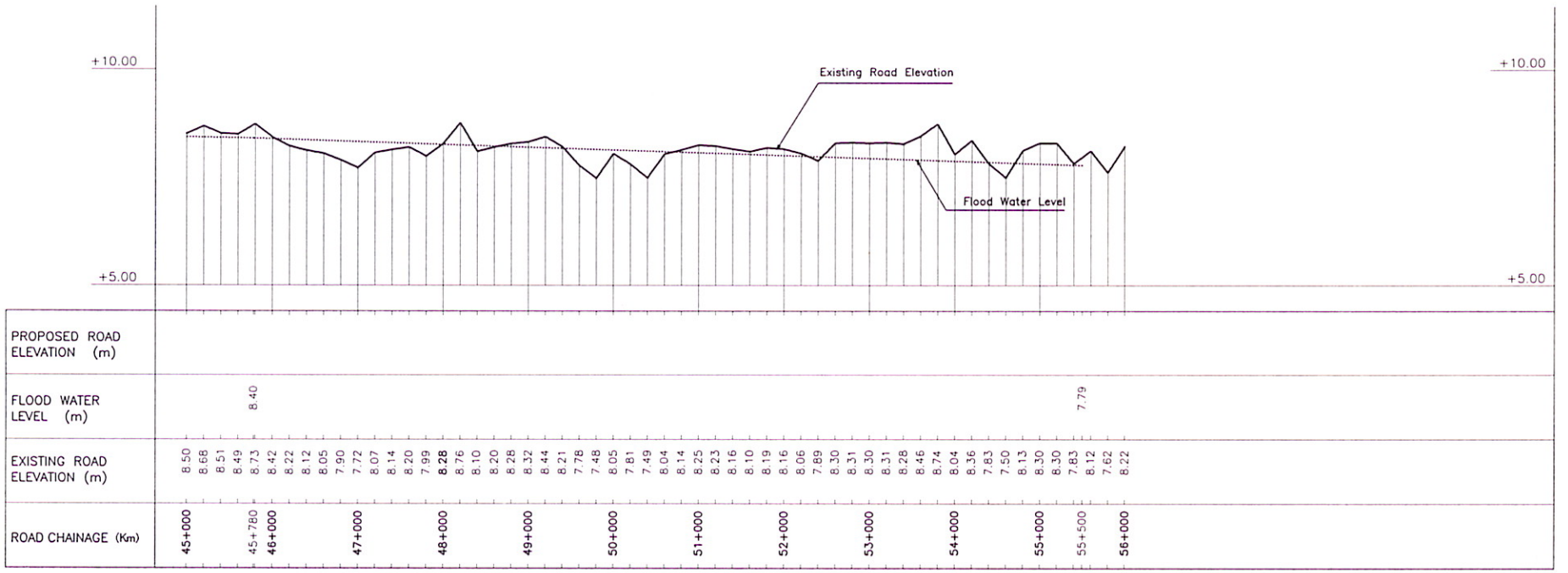
MINISTRY OF PUBLIC WORKS AND TRANSPORT	THE FEASIBILITY STUDY ON THE IMPROVEMENT OF NATIONAL ROAD No.1 (PHNOM PENH-NEAK LOEUNG SECTION) IN THE KINGDOM OF CAMBODIA	JAPAN INTERNATIONAL COOPERATION AGENCY PACIFIC CONSULTANTS INTERNATIONAL & KATAHIRA & ENGINEERS INTERNATIONALA	TITLE : PLAN AND PROFILE Km. 15+000 - 30+000	SCALE	Drawing No. L-02 Sheet No. L-02

Fig. 7-3-1 Plan and Profile (2/4)



MINISTRY OF PUBLIC WORKS AND TRANSPORT	THE FEASIBILITY STUDY ON THE IMPROVEMENT OF NATIONAL ROAD No.1 (PHNOM PENH-NEAK LOEUNG SECTION) IN THE KINGDOM OF CAMBODIA	JAPAN INTERNATIONAL COOPERATION AGENCY PACIFIC CONSULTANTS INTERNATIONAL & KATAHIRA & ENGINEERS INTERNATIONALA	TITLE : PLAN AND PROFILE Km. 30+000 - 45+000	SCALE	Drawing No. L-03 Sheet No. L-03

Fig. 7-3-1 Plan and Profile (3/4)



MINISTRY OF PUBLIC WORKS AND TRANSPORT	THE FEASIBILITY STUDY ON THE IMPROVEMENT OF NATIONAL ROAD No.1 (PHNOM PENH-NEAK LOEUNG SECTION) IN THE KINGDOM OF CAMBODIA	JAPAN INTERNATIONAL COOPERATION AGENCY PACIFIC CONSULTANTS INTERNATIONAL & KATAHIRA & ENGINEERS INTERNATIONALA	TITLE : PLAN AND PROFILE Km. 45+000 - 56+000	SCALE	Drawing No. L-04 Sheet No. L-04

Fig. 7-3-1 Plan and Profile (4/4)

7.3.2 Cross Section Survey

Cross sections of the Study Road were surveyed as shown in the table below.

Table 7-3-2 Specification for Cross Section Survey

Item	Specification
Survey Area	30 m from the centerline on both side
Interval of Cross Section	20 m

The data and drawings of cross sections will be used in the design of the road.

7.4 Geotechnical Investigation and Material Test

Geotechnical surveys were conducted for the following objectives:

i) To know the foundation conditions at the locations where bridges, culverts and water gates may possibly be constructed/reconstructed.
ii) To assess the bearing capacity of the existing subgrade.
iii) To know the properties of the candidate materials for aggregate, base course, subbase course and selected material for improvement of subgrade.
iv) To know the soil properties and the thickness of soft layers of the possible soft ground.

The kinds of soil tests for the above objectives are as shown in the table below:

Table 7-4-1 Objectives and Kinds of Soil Tests

Objectives	Kinds of Soil Test
Foundation condition for bridges etc.	SPT*, Physical Properties of Soil**
Bearing capacity of the existing subgrade	Filed CBR Test, Laboratory CBR Test on the samples taken from test pit, DCPT***, Physical Properties of Soil
Soft ground	Unconfined Compression Test, Direct Shear Test and Consolidation Test on Undisturbed samples
Properties of Materials	Laboratory CBR Test, Physical Properties of Soil

* SPT: Standard Penetration Test
** Physical Properties of Soil: Water Content, Atterberg Limits (Liquid Limit and Plastic Limit), Particle Size, Specific Gravity
*** DCPT: Dynamic Cone Penetrometer Test

The locations of boring/tests are as summarized in the table below:

Table 7-4-2 Location of Geotechnical Investigation

Type of Test/Survey	Location	Remarks
Foundation of Bridges etc		
STP, Physical Properties of Soil	Km 32+780	Formerly there was culvert, curved section
	Km 41+030	Old water gate
	Km 42+800	First opening: (Bailey bridge)
	Km 48+050	Second opening (Bailey bridge)
	Km 50+050	Old water gate (Phnom Penh side)
	Km 50+055	Same as above (Neak Loueng side)
Bearing Capacity of Existing Subgrade		
Test Pit, Field CBR Test, Laboratory CBR Test, Physical Properties of Soil	Every 5 km in principle	Actual locations were adjusted depending on the observation of the pavement condition.
Dynamic Cone Penetrometer Test	Every 1 km	For 1 m in vertical direction starting from 15 – 25 cm from ground surface.
Soft Ground		
Undisturbed Sampling, Unconfined Compression Test, Direct Shear Test, Consolidation Test etc	Km 2+300	There are "Boeng"s on both side of the road
	23+003	There is a large Boeng on the right side

The quantities of soil tests actually conducted are as summarized below:

Table 7-4-3 Quantities of Geotechnical Investigation

Item	Unit	Quantity
Bearing Capacity of Existing Subgrade		
Pitting and Sampling	Location	11
Field CBR Test	Location	11
Dynamic Cone Penetration Test	Points	57
Natural Moisture Content	Sets	11
Atterberg Limits	Sets	11
Particle Size Analysis	Samples	11
Specific Gravity	Sets	11
CBR Test	Samples	11
Material for Aggrigate		
Natural Moisture Content	Sets	9
Sieve Analysis	Samples	9
Specific Gravity	Sets	9
Atterberg Limits	Sets	9
CBR Test	Samples	9
Abrasion Test	Samples	3
Bridge Foundation and Soft Ground		
Boring A (D>65 mm)	M	181
Boring B (D>85 mm)	M	20
Standard Penetration Test	Set	173
Disturbed Sampling	Sample	188
Undisturbed Sampling	Sample	2
Natural Moisture Content	Set	203
Particle Size Analysis	Sample	108
Atterberg Limits	Set	152
Specific Gravity	Set	198
Unconfined Compression Test	Set	3
Direct Shear Test	Set	3
Consolidation Test	Set	2

The boring logs and other data are shown in Appendix D- 1.

The result of the investigation is summarized below:

(1) Foundation of bridges and culverts

Types of soils are mainly fine sand and silt. Generally, these soils are loose. SPT was conducted up to 40 meters from the ground surface at the deepest boring. Layers with N value larger than 30 were encountered only from - 24.0 to 24.45 meters and from - 27.00 to 30 meters at Km 47+967 (Bailey bridge of Neak Loueng side) and from –16.00 to 20.45 meters at Km 32+780 (curved section). At other locations, layers with N value lager than 30 were not found within 30 meters from the ground surface.

Discussion on the foundation of bridges and culverts is given in Section 14.2.

(2) Bearing capacity of existing subgrade

Bearing capacity of the existing subgrade was assessed using three kinds of tests; field CBR test, laboratory CBR test on the samples taken from the test pits and dynamic cone penetrometer (DCP) test. Filed CBR tests were conducted at 15 to 25 cm below the surface of the unpaved shoulder to avoid the influence of top soil which is often different from the subgrade material and also compacted to higher degree than ordinary subgrade material below.

Laboratory CBR tests were conducted on the samples taken from the tests pits excavated after the field CBR tests were completed. The locations of the test pitting and field CBR tests are as follows:

Table 7-4-4 Location of Test Pitting, Field CBR and Laboratory CBR Values

No.	Location(KP)	CBR Value		Remarks
		Field*	Laboratory	
1	1+184 R	15.0	7.4	
2	7+050 L	14.6	3.2	
3	11+381 R	45.7	2.7	
4	16+000 R	9.1	8.8	
5	23+002 L	16.9	3.3	
6	30+000 R	8.0	2.5	
7	34+980 L	7.9	2.2	Pavement severely damaged
8	39+900 L	14.0	2.0	Pavement severely damaged
9	44+600 R	11.7	3.3	Pavement severely damaged
10	45+290 L	7.4	1.5	Pavement severely damaged
11	51+132 R	5.0	2.1	

Dynamic cone penetrometer tests (DCPT) are commonly used in Cambodia to assess in-situ CBR values because it does not need large test equipment, and, thus, can be easily conducted. In this Study, DCPTs were conducted at every 1 km to obtain supplementary data of field CBR values.

Because of the nature of its test procedure (measure amount of penetration and number of dropping of the weight), DCPT yielded CBR values at every 10cm of penetration up to 1 meter deep. Average CBR at each location was obtained by the following formula:

$$CBRAVE = [\{(h1 \times CBR1)^{1/3} + (h2 \times CBR2)^{1/3} + \cdots\}/100]^3$$

Where h1, h2: thickness of each layer in cm

CBR1, CBR2: CBR of each layer

Fig. 7-4-1 shows the CBR values obtained by the DCPT.

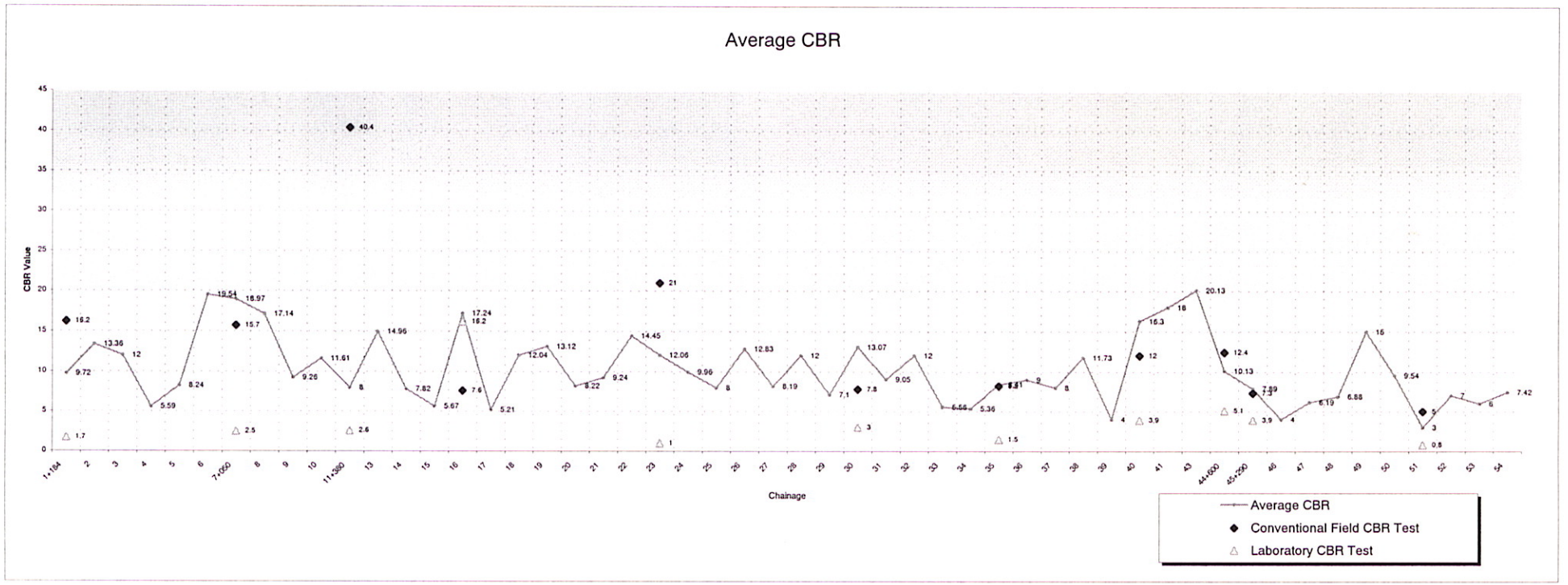


Fig. 7-4-1 Average CBR Value

Followings can be said based on the test results:

i) No substantial difference in CBR values, both for field tests and laboratory tests, are observed between the locations where pavement is severely damage and other location.
ii) The CBR values measured through filed tests are ranging from 5.0 to 16.9 with an exceptional value of 45.7 measured at Km 11+381. These values are considerably higher than those of laboratory tests.
iii) CBR values obtained through laboratory tests conducted on 4-day soaked samples are generally very low, ranging 1.5 to 8.8.
iv) There are considerable differences between CBR values obtained by conventional field CBR test and those obtained by DCPT. Nevertheless, general tendency is that DCPT showed relatively high CBR values where the ordinary field CBR test indicated relatively high values.

More detailed interpretation is made in designing of pavement.

(3) Soft ground investigation

Investigation of soft ground was conducted in lieu of the fact that embankment failure occurred at in at the location where C-2 Section of NR-1 is crossing marshy land near the city of Svay Rieng. Existence of soft soil layer was suspected at two locations (Km 2+300 R and Km 23+003 R) where lakes (Boeng) exist near the road.

Undisturbed sampling using thin-walled sampler was conducted near the toe of the slope at these locations. At Km 2+300, thin-walled sampling was tried after drilling through relatively firm soil layers including the topsoil. Drilling was conducted up to 10 meters deep form the ground surface and sampling was tried several times. Every time, however, sampling was not possible because the soil was firm and sampler could not be thrust in. Accordingly, it was concluded that there is no soft soil layer at this location.

At Km 23+002, soft soil was found from 3.00 meters to 7.00 meters, from the ground surface, and undisturbed samples were obtained. Unconfined compression tests were conducted and unconfined compressive strength qu = 13.8 kPa was obtained. This qu value is considered to be very small even among soft soil. One of the possible causes of this small qu value is that the thin-wall tube used in the sampling had relatively “thick” cutting edge compared with those used in the United States and Japan, and disturbance of the sample during the sampling was also relatively large. It is supposed, however, the relatively firm soil layer existing on top of the soft soil layer is considered to distribute the load of the embankment and there should not be serious problem of stability of embankment.

(4) Pavement materials

CBR tests and soil property tests were conducted on the samples obtained from three candidate quarries. Location of these candidate quarries are described in Section 14.3 “Cost Estimates for Alternatives”.

The results of the test are summarized in the table below.

Table 7-4-5 Summary of the Results of Pavement Material Tests

Quarry	CBR			Abrasion of Aggregate (%)
	Base Course	Subbase Course	Selected Subgrade	
Phnom Ba Phnom	95	62	40	22.0
Phnom Srangam	85	48 (laterite)	←	13.1
Chueng Chhnok	80	45	-	11.5

7.5 General Condition of Existing Agriculture and Land Use

7.5.1 Existing Agricultural Condition

(1) General Condition of Agriculture

Kandal province is approximately 3,591 km^2, and its population is 1,075,000 persons (1998). It is the highest density in the whole province with 299 per km^2 excluding Phnom Penh City. Most villages are located along the natural levee of the Mekong and the Bassac Rivers. Most of the people engage in agriculture along Colmatage canals.

Kandal province is adjacent to capital Phnom Penh, and condition of transportation is good, and many kinds of crops are produced. The rice production is 239,780 tons per year, which is only 6% of the whole country. However, amount per hectare is the highest (3.14 t/ha) compared to nationwide average of 1.97 t/ha. In the dry season, rice production is the most active with favorable conditions by Colmatage canals. As for the maize production, Kandal Province had the highest production in the country until 1999. Afterwards, it was outstripped to the expansion of a rapid maize production of another province, and the maize production of Kandal Province at present acquires the third place of the whole province.

Referring to the regional statistics, the maize production of Kandal Province in 2000 is 19,137 ton. The vegetable growing is active and it is 4,800 ha of the crop area. The production is 26,644 tons per year. This shows the second place with the rice production in Cambodian Province (Refer to Table 7-5-1). These agricultures are supported by Colmatage canals that have the flood circulation from the Mekong River and the Bassac River.

Table 7-5-1 Production of Main Crops in Cambodia (2000 - 2001)

	Province	Rice (t)	Rice (%)	Maize (t)	Maize (%)	Vegetable (t)	Vegetable (%)
1	Phnom Penh	12,584	0.3%	455	0.2%	5,552	2.8%
2	Kandal	239,780	6.0%	19,137	6.9%	26,664	13.6%
3	Kampong Cham	465,733	11.6%	15,586	5.6%	38,942	19.9%
4	Svay Rieng	255,307	6.3%	125	0.0%	3,775	1.9%
5	Prey Veng	461,315	11.5%	3,802	1.4%	6,716	3.4%
6	Takeo	466,360	11.6%	290	0.1%	22,683	11.6%
7	Kampong Thom	176,547	4.4%	532	0.2%	3,566	1.8%
8	Siem Reap	327,565	8.1%	1,295	0.5%	14,563	7.4%
9	Battambang	313,850	7.8%	193,490	69.6%	6,725	3.4%
10	Banteay Meanchey	244,391	6.1%	28,545	10.3%	4,534	2.3%
11	Pursat	154,055	3.8%	560	0.2%	2,807	1.4%
12	Kampong Chhnang	208,529	5.2%	766	0.3%	18,176	9.3%
13	Sihanouk Ville	16,230	0.4%	25	0.0%	790	0.4%
14	Krong Kep	4,669	0.1%	30	0.0%	765	0.4%
15	Kampot	287,722	7.1%	2,521	0.9%	18,097	9.2%
16	Koh Kong	10,021	0.2%	250	0.1%	785	0.4%
17	Kampong Speu	157,180	3.9%	626	0.2%	9,680	4.9%
18	Preah Vihear	25,226	0.6%	730	0.3%	1,505	0.8%
19	Stung Treng	27,837	0.7%	709	0.3%	2,545	1.3%
20	Rattanak Kiri	26,195	0.7%	663	0.2%	1,268	0.6%
21	Mondul Kiri	11,616	0.3%	280	0.1%	600	0.3%
22	Kratie	46,383	1.2%	3,617	1.3%	4,118	2.1%
23	Oddar Meanchey	84,041	2.1%	320	0.1%	710	0.4%
24	Pailin	2,956	0.1%	3,583	1.3%	350	0.2%
	Total	4,026,092	100.0%	277,937	100.0%	195,916	100.0%

Source: Agricultural Statistics (Department of Planning)

(2) Agriculture in the Study Area

Cropping pattern in the area is limited because agricultural activities can be practiced only during non-flooded period. At present, two patters of dry season paddy cultivation including flood recession paddy and dry season paddy with irrigation are main activities. Among these paddy cultivation, flood recession paddy is transplanted as the flood recedes and then irrigated supplementary water using impounded water in reservoirs built by low dikes and in canals. In addition to the paddy cultivation, some upland crops are cultivated in early wet season before flooding. Deep-water paddy is also planted in small area, but its planted area has been decreased gradually, and has been converted to dry season paddy cultivation. The reason of decreasing of the deep-water paddy is that it is necessary to adapt to wide range of environmental changes like duration of floods and varying depth of floodwater every year, and the unit yield is low and unstable.

For the areas where irrigation water is secured in dry season due to the provision of water control facilities, it is possible to expand dry season paddy cultivation and upland crops farming after receding of floodwater till the commencement of rain in wet season.

Recording time is influenced by elevation, geography, flood extent, and it varies every year.

At present, whole district of the study area is the most productive areas. Kien Svay and S'ang district have a wide range of agriculture due to its geographical advantage that is the presence of the capital suburbs. In particular, S'ang is an important area for supplying vegetable to capital demands. Various kinds of vegetable and fruit are planted both during wet and dry seasons.

The dry season paddy that starts in December, January and February is common in the study area. Wet season paddy usually begins in May and June. The harvest time of wet season paddy depends on the variety.

On the river banks and its back slops areas, field crops are widely practiced. During the wet season, farming for field crops starts in May simultaneously with the occurrence of rainfall. Harvesting ends before September when the flood covers the area. Maize represents more than 80 % of all field crops area in wet season. In dry season, the land that contains enough moisture for plant growing or located near available irrigation water is cultivated. Some of the farmers use movable pumps from Colmatage canal to irrigate upland field. Vegetable, beans and maize is the main crops in the dry season.

(3) Agricultural Infrastructure

Type of farm production system in the Study Area is categorized into low land irrigation agriculture around swamps and lakes, rain fed agriculture in higher elevation land and Colmatage farming along the main rivers. The agricultural infrastructure facilities, Colmatage canals, dikes and pumps are provided in the low land irrigation agricultural area and the Colmatage farming area.

1) Lowland Irrigation System

Lowland irrigation system is distributed around lakes and reservoir. It consists of a canal, a dike, a reservoir, a small-scale pump, and traditional lifting facilities. Facilities in the study area were constructed in the Pol Pot regime, and it has become superannuated. However, it is rehabilitated afterwards and it is being used now.

2) Colmatage System

The Colmatage system is to introduce the flood into the back lowland by the river intake and the canal, which are artificially built. In the Study Area, along the Mekong and Bassac Rivers, "Colmatage" farming systems are practiced. This is a traditional reclamation method in Cambodia.

The function of Colmatage system has a lot of effects, such as nutrient supply to arable land by water containing fertile silt, expansion of farmland to the lowlands and bogs by natural deposition of the silt, and to supply irrigation water to the paddy field and the upland field for the dry season. Swamp is important habitat for fishes that migrate from the Mekong and Bassac Rivers through the Colmatage canals and streams.

3) Rainfed agriculture

In the area concerned, wet season rained paddy is predominantly practiced. Rainfed paddy is generally defined as surrounded by levee and submerged for some period during growth period, not deeper than 0.5 meter for more than 10 continuous days. There are usually no water control facilities on these rainfed paddy fields, and the farmers cannot control water level of the fields adjusting the growth stage and the climate condition. This means that it has much possibility to receive drought/flooding damage. Consequently, the farmers adopt the cropping pattern taking into account possible risks and various conditions, and practice farming without using expensive input material.

At present, in the beginning of the rainy season, which is May or June, the amount of the rainfall and the rainfall distribution are irregular. Therefore, a lot of farmers start cultivating paddy in August from July. However, when a big flood occurs where the peak of the flood is in September or October, rainfed paddy receives flood damage.

7.5.2 Inland fishery

(1) Institution of the Inland Fishery

Fishery law of Cambodia is known as Fiat-Law. It is based on Fishery Management and Administration Law in 1987 based on the previous law before 1970. By law, temporary and all of the permanent waters are assumed to be a fishery possible area, which is divided into (1) fishery domain assigned by grope and (2) fishery domain protected. The fishery domain is divided into the fishery right area and the prohibition of fishing area specified further.

The fishery right domain has been authorized by the auction of opening to the public, which is done in every two years. The fishery period is generally from October to May. Earnings by the auction of the fishery right domain become the income sources of the government.

The medium scale and the family scale fishery with the fishing lot are admitted by the law besides a commercial fishery in the fishery right domain. A small-scale fishing lot of the family scale does not have the necessity of permission, and the fishery is admitted through year. However, a medium-scale fishing lot should obtain the establishment authorization.

(2) Back Wetland

Wetlands are controlled by the flood circulation of the Mekong and Bassac Rivers. In the rainy season, the floodwater flows through the Colmatage canals into the wetlands forms the vast waters in the lowland. When it becomes a dry season, a part of the water stored into the wetland returns from the wetlands to the Mekong and Bassac Rivers through the Colmatage canals. A part of the water flows directly to the downstream delta. In this natural situation, the fish lays eggs, grows, and breeds in the wetlands. The fishery right is set to the wetlands in the area.

(3) Inland Fishery in the Study Area

The area between the Mekong River and the Bassac River consists of a lot of wetlands in a wide flood submerging area, and the fishery right domain is set up in this area. It is fish's habitat with the fishery in the submerging area. The fish lays the egg at the beginning of the rainy season, and it moves to lakes, reservoir and inundated shrub land according to the flood pattern. This behavioral pattern is repeated in each flood.

In general, the fishermen in the fishery right area do for lakes and reservoir and wetlands to drain it for the capture of the fish. One side, the farmer hopes to store the water for the irrigation. The former wants to keep the submerging woods around lakes and marshes as habitat of fish. However, the latter hopes for the deforestation of the tree for firewood and the farmland use. Though the farmer who is doing the fishery by the family scale is capturing the fish in the fishery right area, the fishery right owner monopolizes the profit in the area.

Many of rural areas do the fishery of a small and medium scale. In many cases, as work outside agriculture, the farmer is engaged in fishing in the fishery right domain and fish's processing industry. As a result, the fishery section has absorbed a lot of agriculture laborers.

(4) Inland fishery activity

The inland fishery activity in Cambodia is divided into caught fish and aquaculture. According to the Data from Department of Fisheries, all of the caught fish of inland fishery increased to 63,510 tons and 72,500 tons in 1995 and 1996 respectively. Total production in Kandal Province shows a rising tendency in the past six years (refer to Table 7-5-2).

Table 7-5-2 Annual Fish Production from Commercial Fisheries in Cambodia

Year	Production (t)			
	Cambodia	Kandal Province		
		Natural Fish	Aquaculture	Total
1995	72,500	12,525	1,045	13,570
1996	63,510	8,855	1,245	10,100
1997	73,000	14,645	1,450	16,095
1998	75,700	14,600	2,300	16,900
1999	71,000	9,944	2,400	12,344
2000	85,600	14,184	1,946	16,130

Source: Statistic of Inland and Marine Production (Department of Fishery)

7.5.3 Kien Svay Irrigation Area

This area is located at the middle of Kien Svay District, and it belongs to the "Lowland Irrigation System". The area is irrigated with water source from lot of ponds scattered in the northwest of road where wetlands are crossed. Total irrigation area is 3250 ha composed of wetlands side 1330 ha and southeast side 1920 ha of crossing road. Mainly, paddy cultivation is practiced.

The irrigation facilities were constructed in the Pol Pot regime, afterwards irrigation facilities are repaired, but facilities show superannuation. The operation and maintenance is done, and it is well maintained compared with other irrigation facilities. The intake facilities of water from the pond are installed at five places. Water is controlled by the gate or the stop log. The water level in the pond side decreased at the dry season, the pump is installed. But it is broken down and it is not used.

Among the cultivated crops, paddy cultivation is the main and, the vegetable is grown in the area without the submerging. Rice farming is different, period of paddy cultivation varied according to the flood submerging period, but double cropping is practiced in the dry and the rainy seasons. That is April to July, and after the flood, January to October. The vegetable is grown only in the rainy season, which is harvested before the water level rises.

7.5.4 Colmatage Canal

(1) Distribution of Colmatage

In and around the Study area, 50 Colmatage canals including canals with no function are distributed along the Mekong and Bassac River. It is divided into two regions. Along the right bank of the Mekong River, there are 12 Colmatage canals between Phnom Penh and Neak Loueng of the National Road No.1. Along the left bank of the Bassac River, there are 38 Colmatage canals in the Kien Svay and S'ang Districts.

Table 7-5-3 Colmatage between the Mekong and Bassac Rivers

District	Mekong River	Bassac River	Total
Kien Svay	9	13	22
S'ang	0	25	25
Leuk Daek	3	0	3
Total	12	38	50

(2) Situation of Colmatage Utilization

Among the twelve Colmatage canals located along Mekong River, five canals are being effectively used now. Other Colmatage canals do not have the function for the following reasons: (1) the inflow part in the Colmatage canal was buried by developing a private investment, (2) large landowner's house was built on the way of the canal and the canal was intercepted, (3) facilities were destroyed due to a past flood, (4) from the beginning the Colmatage have not functioned, because canal was not constructed. Only five Colmatage are in operation. Among those, four Colmatage facilities were repaired or newly constructed by Japan Grant Aid, and they are effectively used.

Most Colmatage canals along the Bassac River have functioned. However, there are canals which are difficult to take water from the Bassac River in normal year. It is because the heights of their intakes for water from the Bassac River are different in each facility. In addition to this, the canal bottom is raised by siltation. Moreover, the operation and maintenance is not done. If silt piles up in the bottom of the canal, the effect of silt deposition for reclaiming lands decreases. Moreover, for the Colmatage without gate, its canal is intercepted with soil to prevent damage to the rainy season crops

against inundation. An appropriate operation and maintenance is necessary (Refer to Table 7-5-4).

Table 7-5-4 Existing Colmatage Function in the Study Area

Mekong River right bank				
District	Commune	Colmatage	Function	Main Village
Kien Svay	Banteay Daek	Prek Hlong	none	Khsom
〃	〃	Prek Rohat Kchall	none	Kandal Leu
〃	〃	Prek Pol	Exist	Kandal Kraom
〃	Samrong Thom	Prek Yourn	Exist	Chey Otdam
〃	〃	None	none	-
〃	〃	Prek Tuol Pongro	none	Steng
〃	〃	Prek Chrey	Exist	Prek Traeng
〃	〃	Samrong Thom	none	Samraong K'aer
〃	Kokir Thom	Kokir Thom	Exist	Reng Dek
Leuk Daek	Kampong Phnom	Prek Onchuk	none	Khbal Chrouy
〃	〃	Kampong Phnom	Exist	Kampong Pou
〃	〃	W. Kampong Phnom Knong	none	Ampil Tuek
Bassac River left bank				
District	Commune	Colmatage	Function	Main Village
Kien Svay	Prek Thmei	Prek Pra	Exist	Campuh K'aek
〃	〃	Prek Ta Ev	Exist	Kaoh Krabei
〃	〃	Prek Ta Vang	Exist	Prek Thmei
〃	Chheu Teal	Prek Ruessei Srok	Exist	Ruessei Srok
〃	〃	Prek Som	Exist	Chheu Teal
〃	〃	Prek Ta Has	Exist	Prek Svay
〃	Kampong Svay	Prek Doung	Exist	Prek Doung
〃	〃	Prek Takoy	none	Prek Doung
〃	〃	Prek Thma Da	Exist	Prek Doung
〃	〃	Prek Kampong Svay	Exist	Kampong Svay
〃	〃	Prek Thmei	Exist	Kampong Svay
〃	〃	Prek Ta Nob	Exist	Prek Ta Nob
〃	〃	Prek Ta Ten	Exist	Prek Ta Nob
S'ang	Svay Prateal	Prek Ta Chour	Exist	Thum II
〃	〃	Prek Tasau	Exist	Thum IV
〃	〃	Prek Ta Khut	Exist	Paraen Leu
〃	〃	Prek Ta Hong	none	Paraen Leu
〃	Traeuy Sla	Prek Chheu	Exist	Pou Kandal
〃	〃	Prek Om	Exist	Pou Kandal
〃	〃	Prek You Heung	Exist	Pou Kraom
〃	〃	Prek Aek	Exist	Prek Ta Aek
〃	〃	Prek Thmei	Exist	Prek Ta Aek
〃	〃	Prek Phum Prek	Exist	Prek Pan
〃	〃	Prek Pan	Exist	Prek Pan
〃	〃	Prek Choung	Exist	Preah Balat Chhoeng
〃	〃	Prek Talok	Exist	Preah Balat Chhoeng
〃	Ta Lon	Prek Tam Lo	Exist	Chong Kaoh Touch
〃	〃	Prek Thmei	Exist	Kandal Kaoh Touch
〃	〃	Prek Phe	Exist	Preah Phe
〃	〃	Prek Krang	Exist	Ta Lon
〃	〃	Prek Wat Ta Lon	Exist	Ta Lon
〃	〃	Prek Prak	Exist	Prek Ta Prak
〃	Khpob	Prek Ruesei Srok	Exist	Ruessei Srok
〃	〃	Prek Chkea Kveam	Exist	Khpob Leu
〃	〃	Prek Choun	Exist	Khpob Kraom
〃	〃	Prek Wat Kpad	Exist	Roka Leu
〃	〃	Prek Thmei	Exist	Roka Kraom
〃	〃	Prek Duy	Exist	Roka Kraom

Source: JICA Study Team

(3) Open & Close the Gate and Flood Water Level

There are functionally two kinds of Colmatage. One is with facilities which have the intake gate function, and the other is only with facilities to take the river water to which a fertile soil was abundant. The former gate is installed in the road crossing point in the canal, which is called prek. It has the function that inflow water can be adjusted. And as for the latter, the canal is merely constructed. The bridge is only built across the road crossing point.

Among 50 Colmatage canal facilities, only seven places is used gates are; 4 places along the Mekong and 3 places along Bassac. Though other facilities have the installation facilities at the gate, they do not use it, or they do not have the installation facilities. These facilities were constructed in the Poll Pot regime of 1970's. Even if there are gate facilities, it is difficult to open and shut. It has been hardly used since they were constructed. Afterwards, the gate was repaired or the gate was newly installed in the bridge crossing point. Getting water with gate operation is executed now at only 4 places along the Mekong and 3 places along the Bassac.

Intake period of water differs according to elevation at intake point of Colmatage canal. Generally, planting of wet season crops is practiced so that they can be harvested before river water goes into the farmland. The area with the gate is opened after the harvest of crops grown in wet season, and takes the inflow water. The canal throws the river water into Colmatage canal, which does not have the gate according to the water level of the river.

Some of the canals are blocked by temporary embankment crossing the canal to prevent the floodwater into the farmland. After crops are harvested, the temporary embankments in the canals are removed. However, a lot of Colmatage is left to the rise of the water level of nature. Intervals of Colmatage canals, which are located along the Bassac River, are short with about 1 km. Therefore, the profit area of Colmatages with gates also suffers from flood damage to farm products by the water which inflows from other Colmatage canals without gates.

Four places installed the gate on the National Road No.1 with facilities completed by the Grant Aid Program of Japanese Government. The gate was closed May 2001 after facilities had been handed over. Afterwards, the gate of one place was opened in August 2001. However, other three gates were not opened until September 2001. This is because, as the water level on the Mekong River side Colmatage rose up rapidly in 2001, it was anticipate a risk of collapsing the canal slope protection in the downstream channel by the swift water flow by opening of gates. After the water level decreases, two gates were opened in October 2001. However, Kokir Thom gate remained closed.

According to the Interview survey, the Bassac side gate was opened in August after the rainy season crops were harvested. After the water level was decreased, the gate has been closed from December to January (Refer to Table 7-5-5).

Table 7-5-5 Intake Facilities and Gate of Existing Colmatage

Mekong River right bank							
Name of Commune	Name of Colmatage	Colmatage Function	Intake Facilities	Gate	Gate Function	Gate	
						Close	Open
Banteay Daek	Prek Hlong	none	S. Pipe	-	-	-	-
〃	Prek Rohat Kchall	none	C. Pipe	-	-	-	-
〃	Prek Pol	Exist	Culvert	Steel Gate	Use	May	Oct
Samrong Thom	Prek Yourn	Exist	Culvert	Steel Gate	Use	May	Aug
〃	None	none	-	-	-	-	-
〃	Prek Tuol Pongro	none	-	-	-	-	-
〃	Prek Chrey	Exist	Culvert	Steel Gate	Use	May	Oct
〃	Samrong Thom	none	Culvert	Stop Log	Unused	-	-
Kokir Thom	-s	-	-	-	-	-	-
〃	Kokir Thom	Exist	Culvert	Steel Gate	Use	May	
Kampong Phnom	Prek Onchuk	none	-	-	-	-	-
〃	Kampong Phnom	Exist	Culvert	Stop Log	Unused	-	-
〃	W. Kampong Phnom Knong	none	-	-	-	-	-
Bassac River left bank							
Name of Commune	Name of Colmatage	Colmatage Function	Intake Facilities	Gate	Gate Function	Gate	
						Close	Open
Prek Thmei	Prek Pra	Exist	Bridge	-	-	-	-
〃	Prek Ta Ev	Exist	Culvert	Stop Log	Use	Jan	Aug
〃	Prek Ta Vang	Exist	Culvert	Wooden Gate	Use	Jan	Aug
Chheu Teal	Prek Ruessei Srok	Exist	Culvert	Stop Log	Unused	-	-
〃	Prek Som	Exist	Culvert	Steel Gate	Use	Jan	Aug
〃	Prek Ta Has	Exist	Bridge	-	-	-	-
Kampong Svay	Prek Doung	Exist	Culvert	Stop Log	Unused	-	-
〃	Prek Takoy	none	C. Pipe	-	-	-	-
〃	Prek Thma Da	Exist	Bridge	-	-	-	-
〃	Prek Kampong Svay	Exist	Bridge	-	-	-	-
〃	Prek Thmei	Exist	Culvert	Stop Log	Unused	-	-
〃	Prek Ta Nob	Exist	Culvert	Stop Log	Unused	-	-
〃	Prek Ta Ten	Exist	Bridge	-	-	-	-
Svay Prateal	Prek Ta Chour	Exist	Bridge	-	-	-	-
〃	Prek Tasau	Exist	Bridge	-	-	-	-
〃	Prek Ta Khut	Exist	Culvert	Steel Gate	Use	Dec	Aug
〃	Prek Ta Hong	none	Bridge	-	-	-	-
Traeuy Sla	Prek Chheu	Exist	Bridge	-	-	-	-
〃	Prek Om	Exist	Bridge	-	-	-	-
〃	Prek You Heung	Exist	Culvert	Stop Log	Unused	-	-
〃	Prek Aek	Exist	Bridge	-	-	-	-
〃	Prek Thmei	Exist	Bridge	-	-	-	-
〃	Prek Phum Prek	Exist	Bridge	-	-	-	-
〃	Prek Pan	Exist	Bridge	-	-	-	-
〃	Prek Choung	Exist	Bridge	-	-	-	-
〃	Prek Talok	Exist	Culvert	Stop Log	Unused	-	-
Ta Lon	Prek Tam Lo	Exist	Culvert	Stop Log	Unused	-	-
〃	Prek Thmei	Exist	Bridge	-	-	-	-
〃	Prek Phe	Exist	Bridge	-	-	-	-
〃	Prek Krang	Exist	Bridge	-	-	-	-
〃	Prek Wat Ta Lon	Exist	Bridge	-	-	-	-
〃	Prek Prak	Exist	Bridge	-	-	-	-
Khpob	Prek Ruesei Srok	Exist	Bridge	-	-	-	-
〃	Prek Chkea Kveam	Exist	Bridge	-	-	-	-
〃	Prek Choun	Exist	Bridge	-	-	-	-
〃	Prek Wat Kpad	Exist	Bridge	-	-	-	-
〃	Prek Thmei	Exist	Bridge	-	-	-	-
〃	Prek Duy	Exist	Culvert	-	-	-	-

Source: JICA Study Team

(4) Agricultural Infrastructure for Colmatage

Colmatage distributed on the NR-1. In recent years intercepted canals were not usable because of a developer. Moreover, a lot of facilities (bridge and culvert, etc.), which had been constructed on NR-1, were destroyed due to a past flood. The abandoned Colmatage where only the canal is left, it seems that their function can be revived by constructing culvert at NR-1 crossing points. According to the interview survey of the farmers, local people are hoping for the construction of culvert at the road crossing part.

In Colmatage canal in the Study area, there are canals of various types, and extent of 41 canals, which functions as Colmatage, is presently 113 km. The profit area around the canal becomes 9,170 ha. As for the irrigation facilities, there are some division facilities in Colmatage canal, and the secondary canals are constructed. Secondary canals are constructed in Pol Pot regime, and many of them do not function for superannuation.

The operation and maintenance activities for the facilities are composed of removal of sediment in canal, operation and maintenance at gates, cleaning the canal slope and maintenance of road. In a part of the canal placed between the Mekong River and the Bassac River, the canal is dredged by the beneficiary under a guidance of district office of irrigation and Commune chief. However, most Colmatage canals are poorly maintained at present because the organizations for maintenance do not function.

(5) Farming Practice

In the Study area, rice farming of the rainy season rice and the dry season rice is a subject. On the non- flooded upland fields, farmers plant a wide range of crops such as maize, mung bean, sesame, sweet potato, and vegetable, etc. On the natural levee, where they have the least possibilities of receiving flood and are residential areas with mixed cultivation of home consuming crops and fruits trees such as banana, mango and so forth is usually practiced. In the short-term submerging farmland, short duration crops such as corn, mung beans, and sesame are commonly cultivated before the flood. At the dry season when the flood begins to leave, crops with a little amount of the water consumption such as peanut and vegetable, etc. are practiced. However, the area between the Mekong and the Bassac Rivers are almost inundated in 2000 and 2001 year. Therefore, maize of the rainy season was practiced in mainly from May to August.

The situation of the area is good situation, which is adjacent to capital Phnom Penh, with easy access, and it functions as a vegetable supply base to the capital (Refer to Table 7-5-6).

Table 7-5-6 Agricultural Product in Kandal Province (2000 - 2001)

Crops	Season	Cultivated area (ha)	Harvested area (ha)	Yield (t/ha)	Production (ton)
Rice	Wet	48,133	29,868	2.6	77,030
	Dry	47,500	46,500	3.5	162,750
Maize	Wet	12,700	7,112	1.5	10,668
	Dry	1,452	1,230	1.8	2,189
Cassava	Wet	161	85	7.4	625
	Dry	108	106	12.0	1,270
Sweet Potato	Wet	73	67	5.0	335
	Dry	284	282	2.8	801
Vegetable	Wet	2,082	1,618	9.0	14,562
	Dry	2,720	2,715	4.5	12,081
Mung Been	Wet	355	144	0.6	91
	Dry	3,007	1,505	0.7	978
Sugar Cane	Wet	650	620	25.0	15,500
	Dry	900	855	26.3	22,427
Peanut	Wet	21	20	0.6	12
	Dry	1,186	1,186	0.7	854
Sesame	Wet	665	625	0.5	313
	Dry	-	-	-	-
Total		121,997	94,538	104	322,486

Source: Agricultural Statistics (Department of Planning)

7.5.5 Land Use

Both sides of the NR-1 between Phnom Penh and Neak Loueng, has been used as farmland, which are located in outskirts in the Phnom Penh City. After the annual flood, rice, maize, and various vegetables, etc. are mainly grown. This area is Kien Svay and S'ang district and a part of Leuk Daek District in Kandal Province located on the Mekong river left bank and the area is about 104,600ha.

Table 7-5-7 Number of Commune and its Area

District	Commune	Area (ha)
Kien Svay	12 Commune	38,211
S'ang	16 Commune	51,496
Leuk Daek	1 Commune	14,906
Total		104,613

The area is divided into six land uses of (a) Village & Garden crops、(b) Upland field (c) Paddy & Floating rice field、(d) Grass land、(e) Shrubland & Inundated shrubland、(f) Lake, Reservoir & River. When it measures the area according to each land use classification, it accounts for about 70% of all area with upland field, paddy & floating rice field and Grassland (refer to Fig. 7-5-1).

Table 7-5-8 Land Use Classification

Land Classification		Total (ha)	Percent
(a)	Village & Garden crops	9,415	9.0%
(b)	Upland field	22,073	21.1%
(c)	Paddy & Floating rice field	23,433	22.4%
(d)	Grass land	29,501	28.2%
(e)	Shrubland & Inundated shrubland	16,633	15.9%
(f)	Lake, Reservoir & River	3,557	3.4%
Total		104,613	100.0%

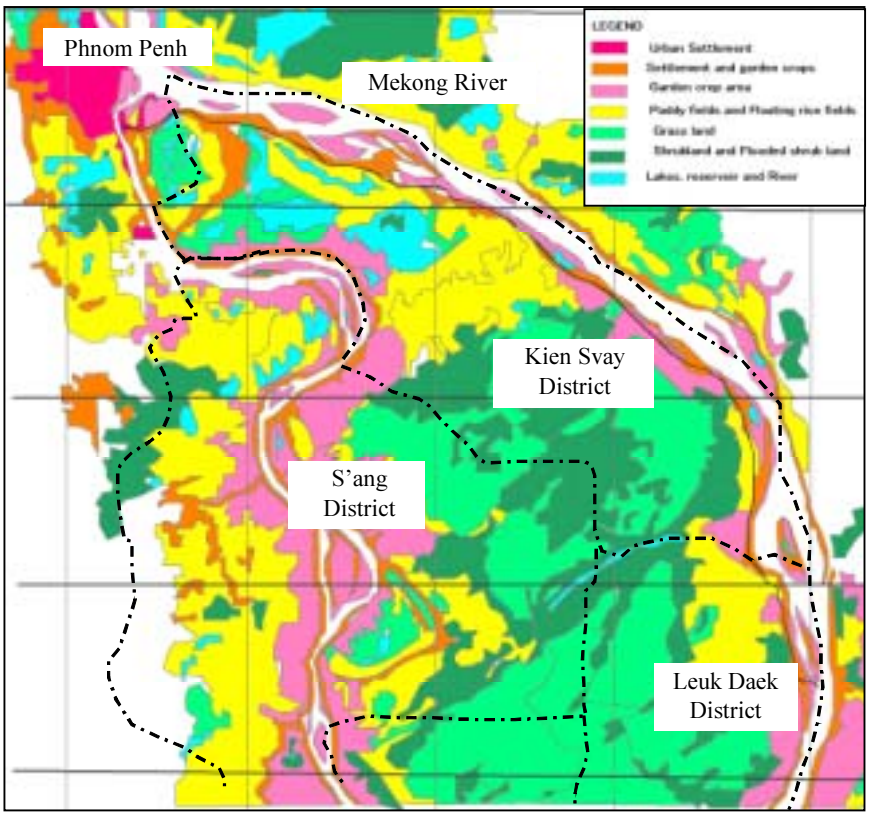


Fig. 7-5-1 Land Use Map

The distribution of the land use is basically divided into two, which are high land and low land. The high land is formed as a village on the natural levee, which develops along the river, and land uses such as orchards and fields are centered as for it.

In the low land, consolidated land use is impossible because the long term flood retention. Though, the area of Shrubland & Inundated shrubland are not used as farmland, as they provide fish habitats for egg laying and hatching in submerging period, and also it is used for a water source for irrigation as lakes and reservoir. Land use form in the study area at present is not constant, because submerging period change with the season. In the area without the submerging in the dry season, rice and field crops are practiced, but this area is flooded in the rainy season. Shrubland and Grassland are used as only a dry season pasture.

At the beginning of the rainy season, maize and the vegetable, etc. are practiced, to use the period until the submerging starts. As the water level rises and the waters expand, it is shifted to the fishery.

7.5.6 Damage Situation of 2000 Flood

Data of rice production could be acquired only from Kien Svay District, in 1999-2000. According to this data, rice was harvested through the rainy and the dry season in 1999. However, in 2000, the rainy season rice was not harvested, because of the big flood and the rise of the flood water level was violent. Compared harvested areas in 1999 with 2000, it is lower 1999 than 2000. On the other hand, total rice production of 2000 is increased by 4000 tons than 1999.

Table 7-5-9 Rice Production of Kien Svay District (1999-2000)

Item	1999			2000		
	Wet	Dry	Total	Wet	Dry	Total
Harvested Area (ha)	405	3,537	3,942	0	4,703	4,703
Production (t)	1,215	14,148	15,363	0	19,753	19,753

Source: Analysis of Environmental System at Kien Svay District

It is likely, that the flood in 2000 did not cause a big damage to the farmers. In the interview survey, "it was executed that 47 Colmatage systems where located between Mekong and Bassac", annual income of 7 villages was decreased in 2000 than 1999. Oppositely, the annual income from 14 villages in 2000 had increased than that of 1999. Annual income of other villages did not change. It is supposed that farm products were not affected on the 2000 Flood in the farmland between the Mekong River and the Bassac River.

7.5.7 Possibility of Farmland Expansion

As shown in the land use map, the farmland is formed on both sides of the Bassac River respectively with 2 km width. This farmland is made from the effect of silt deposition. And, the area where the irrigation water can be secured is a rice field even in the submerging area by the flood. Along the Mekong River, the width of the farmland is half of the farmland along the Bassac River, and farmland by the effect of silt deposition also exists. It is supposed that the flood is intercepted by NR-1, and moreover, the number of Colmatage is less than the Bassac side. Therefore, the farmland expansion by the effect of silt deposition was not done.

From about Km 20 of NR-1, a road crosses to the Bassac River left bank side (NR-369) through wetland. This road intercepts wetlands of the northwest area, where a lot of swamp zones are formed. These wetlands decrease the water level in the dry season. However it does not dry up in the dry season and, it was used as an irrigation water source to the downstream farmland. The surrounding of this crossing road and southeast area are formed the paddy field of about 3250ha to use this water source. In other regions, rice farming is practiced in the area where the dry season water source is secured.

The area that is difficult to obtain the irrigation water is left as wasteland/grassland. As for these lands, the creation of the farmland is advanced with the silt deposition, which the flood brings. However, it is thought that securing the irrigation water greatly influences the farmland expansion in the future. In an existing farmland, the yield shows a big change by irrigation water.

As a problem in the future, if these land is supplied the irrigation water by repairing an existing Colmatage canal, land, which has been left as a grassland of 29,500ha at present, becomes possible development as the farmland. This corresponds to 28% of all study area.

Master Plan Study on The Agricultural Development Project is carried out in the area between Mekong and Bassac Rivers by the Ministry of Water Resources and Meteorology. According to this study result, the irrigation plan of about 26,400ha is formulated to supply the irrigation water of the Mekong and the Bassac River.

7.5.8 Investigation of NR-1 Opening Point

Farmland of the right side of NR-1 is fewer than the farmland of the Bassac River side. Because the effect of silt deposition, which the Colmatage canal brings, is little. In the interview survey, they said that these lands are poor in soil. And a lot of farmers are hoping for the repair of Colmatage.

Basically, it seems as unquestionable to cross NR-1 and to throw the flood of the Mekong River to wetlands side, if it does not cause flood at the village in wetland side. In a word, farmland "both sides of NR-1" have inundated by the flood of 2000. If the flood does not damage the house and the domestic animals, it is thought that the flood of the farmland does not have the problem. Also, silt deposition is effective.

However, the effect of silt deposition of Colmatage is low except the Colmatage systems which were constructed by Grant Aid Program of Japanese government, because the intake of Colmatage on the Mekong River side is high, and the stream inflow time is late.

On the other hand, along NR-1, there are Colmatage canals which have lost the function by land development and facilities were destroyed due to a past flood. The present situation of these Colmatages is as follows.

(1) Prek Hlong

This point is located about 24.7 km from the Monivong Bridge, to the Neak Loueng. To the point, steel pipe of ϕ500 mm is laid underground with crossing of NR-1. Therefore, the function as Colmatage is not provided from the beginning. According to the interview survey, the village to the wetlands side of this point is inundated by the flood of 2000 and 2001 years. Therefore, the canal was buried with the soil to intercept the stream from the Mekong River. This village is located to inundate height in the normal flood. This village prevented their residence area from the flood by small embankment that was constructed around the village.

The canal has been left with the superannuation at both sides of the road-crossing pipe. And, large landowner's house is constructed in the point of 700 meters on the downstream side from the NR-1 crossing point. The canal is intercepted in this point by the house. According to the explanation of the farmer, even if they construct the culvert in the crossing part of NR-1, it is difficult to solve the restoration problem of the intercepted canal.

(2) Kandal Leu

This point is located about 25.5 km from the Monivong Bridge to the Neak Loueng. Only a concrete pipe of ϕ1000 mm is laid to the road crossing point, therefore it was through that the function as Colmatage is not possessed. This point describe in"a. Preeak Hlong", the canal exists. However, there is a village in 700 meters from the road crossing point. The canal is intercepted in this point. Describe in"a. Preeak Hlong", it is extremely difficult to reconstruct the canal.

(3) S-shape curve point on the road

This point is located about 33.9 km from the Monivong Bridge, and NR-1 has curved with semicircle shape to the Mekong River side. To this point, a road crossing facility for Colmatage was constructed in the past. Afterward, the facilities were thrown by the flood in 1978, it does not exist now. At that time, when the facilities were constructed in the past, the canal was not constructed. Therefore, the farmland on wetlands side does not receive the benefit of the effect of silt deposition. The farmland in the downstream area is poor. In the downstream farmland, it irrigates from the small ponds scattered in wetlands on a small scale, almost practices in agriculture by using rainfall. All farmers are hoping for the construction of the Colmatage canal. It seems that the construction of the culvert is possible if the canal can be constructed.

(4) Prek Tuol Pongro

This point is located about 38 km from the Monivong Bridge. Though the bridge had been constructed in the past, there is no road crossing facilities now. When the bridge was constructed, the canal was not built, and the farmland on wetlands side has not received the benefit in the effect of silt deposition. In this reason, the agronomic performance of land on wetlands side is extremely low. The distance from the Mekong River to the point on the NR-1 is about 300 meters. In both, right and left side on the road, the scattered private house not to mention the village does not exist either. Commune chief strongly hopes for the flood taking of this point, and if the canal can be constructed by the government in the future, it is unquestionable for the culvert construction to the flood leading.

(5) Prek Samrong Thom

This point is located at about 42.3 km from the Monivong Bridge, a facility with stop log gate exists and its condition is in good. Land is bought up by the wooden company on the Mekong River side, and the canal of this point is buried by the soil. The canal buried by soil is diverted to surround the wooden company, and diverted canal is not connected to the existing canal. Therefore, the function as Colmatage facilities is not possessed.

Because the canal on the Mekong River side was intercepted, the farmland on right side of NR-1 takes the irrigation water depend on the water level rise of wetlands from the Bassac River. However, here to about 2.2 km on the Phnom Penh, Prek Chrey was constructed by the Grant Aid program of Japanese Government. The water flows from "Prek Chrey" into wetlands can be used. The supply of the irrigation water has been eased a little.

The flood taking facilities of NR-1 is in good condition, and the effect of silt deposition expected with canal in this facilities. If the intercepted canal can be connected, the function of the Colmatage will be recovered to retain flood. Therefore, the join of the canal is essential.

(6) Opening point of Km 42+800

This point is located about 42.8 km from the Monivong Bridge. This point was excavated in September, 2000 for prevent the rise of the flood of NR-1 left bank. Facilities of the flood inflow Colmatage were not here in the past either. Commune chief and the farmer do not oppose, and are pleased for excavation to make the farmland fertile by the effect of silt deposition. This village also hopes for the construction of other regional similar canals, and the canal construction is requested to the government. The government consented to the canal construction. However, there is no definite answer like the construction time etc.

(7) Prek Onchuk (Opening Point of Km 47+967)

This point was excavated in September, 2000 for prevent the rise of the flood of NR-1 left bank by reducing the water level in the Mekong River. Earlier near to this point was a culvert, but it was broken by 2000 flood. It is used for the drain of floods inundated in wetlands, because the canal was not constructed. And the land ownership in this area is a resident of Commune Kampong Phnom. There is no land such as large landowners who reside as in other regions. An administrative village does not make the complaint to the government about opening the road. They hope for the canal construction more than it.

(8) Kampong Phnom

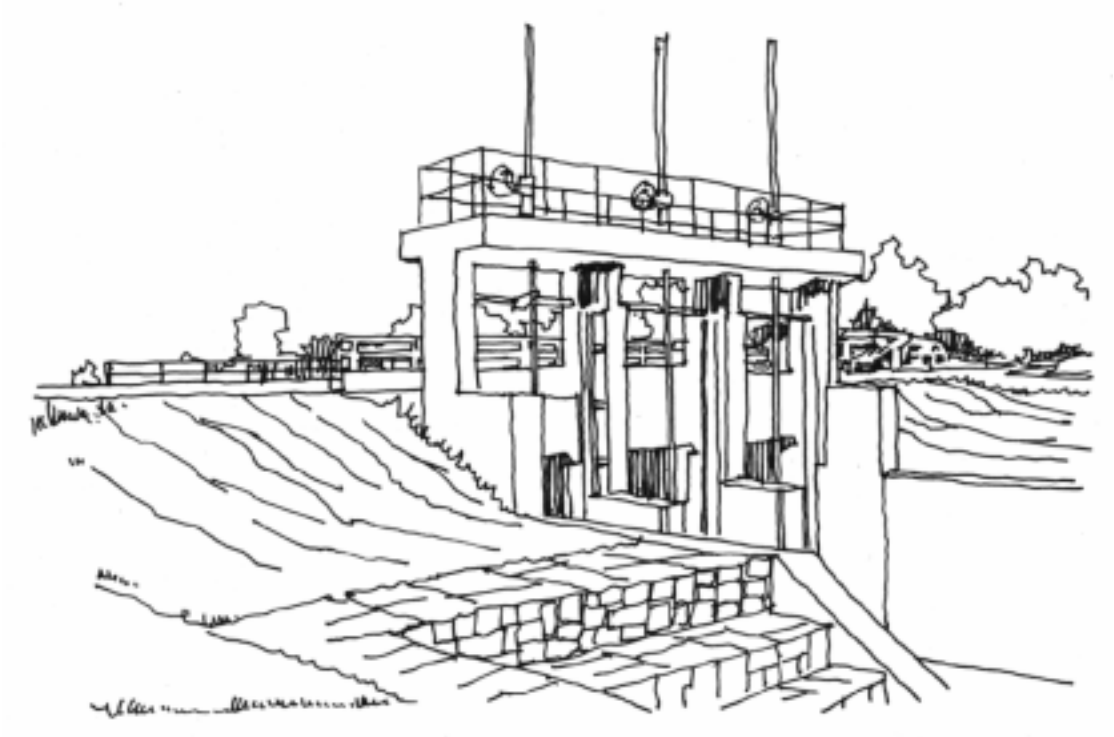
This point is located about 53.8 km from the Monivong Bridge. A culvert with stop log slots exists. The canal exists, but bends like the crank, because there is a landowner's large land and the canal is connected to the Mekong River. Therefore, the function of Colmatage can be recovered by improving the system.

The above mentioned is summarized below. Among the Colmatage facilities there are eight places, which do not have the function now. Among those, the points in three places can construct culverts. It is "Curve point on road", "Prek Tuol Pongro" and "W. Kampong Phnom Knong"

Table 7-5-10 Possibility of Culvert Construction

Colmatage Name		Road crossing facilities	Canal	Possibility of Culvert construction
a	Prek Hlong	ϕ500x1, Steel Pipe	Exist	No
b	Kandal Leu	ϕ1000x1, Concrete Pipe	Exist	No
c	S-shape curve point on the road	None	None	Possible
d	Prek Tuol Pongro	None	None	Possible
e	Prek Samrong Thom	Culvert	Exist	No
f	Opening point of Km 42+800	Bridge	None	No
g	Prek Onchuk (Opening Point of Km 47+967)	Bridge	None	No
h	Kampong Phnom	Water gate/bridge (L=11m)	Exist	Possible

CHAPTER 8 HYDROLOGICAL STUDY



CHAPTER 8 HYDROLOGICAL STUDY

8.1 River System

The Mekong River is the longest river in South East Asia originating in Tibet and flowing through China, Myanmar, Thailand, Laos, Cambodia and Vietnam. The length of the Mekong River is about 4,200 km, and its catchment area is 783,000 km^2. Among this catchment area, upstream area of Phnom Penh is 663,000 km^2. The catchment area of the Mekong River Basin in Cambodia is 154,895 km^2 (20 % of the whole catchment area) composed of the Mekong River Main Stream Basin (61,337 km^2), the Tonle Sap River Basin including the Grate Lake or the Tonle Sap Lake (79,310 km^2) and the Bassac River Basin (14,248 km^2).

8.2 Observation Networks

Meteo-hydrological observation network in Cambodia is shown in Fig.8-2-1. The meteorological stations located close to the study area are at Phnom Penh, Kampong Cham, Kratie and Pursat. The water level gauging stations are located at Kratie, Kampong Cham, Chrouy Changvar, Chaktomuk and Neak Loueng along the Mekong River. In the Great Lake, gauging stations are located at Kampong Loung and Kampong Chhnang whereas at Prek Kdam and Phnom Penh Port in the Tonle Sap River and at Kaoh Khael at the Bassac River.

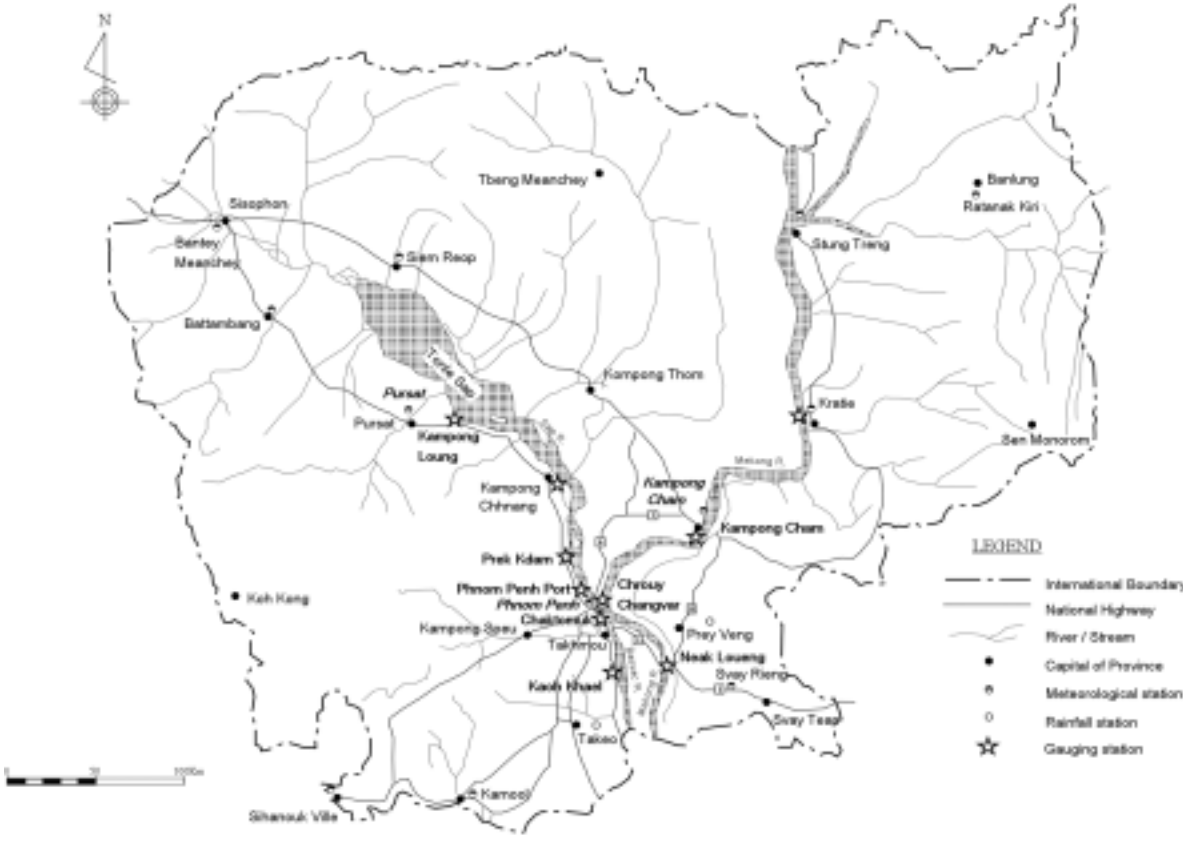


Fig. 8-2-1 Meteo-Hydrological Observation Network in Cambodia

8.3 Meteorological Conditions

8.3.1 Collected Data

Meteorological data were collected from Department of Meteorology of Ministry of Water Resources and Meteorology (MoWRAM). Table 8-3-1 shows the list of collected meteorological data.

Temperature, relative humidity, wind speed and rainfall data were available at Phnom Penh and Kampong Cham. On the contrast, only precipitation data were available at Kratie and Pursat.

Table 8-3-1 List of Collected Meteorological Data

No	Item	Data	Location	Data Period
1	Temperature	Monthly Max., Average, and Mini.	Phnom Penh	1985～2001
			Kampong Cham	1985～2001
			Kratie	-
			Pursat	-
2	Relative Humidity	Monthly Average	Phnom Penh	1985～2001
			Kampong Cham	1985～2001
			Kratie	-
			Pursat	-
3	Wind Direction, and Speed	Monthly Maximum	Phnom Penh	1986～1995
			Kampong Cham	1986～1995
			Kratie	-
			Pursat	-
4	Precipitation	Daily	Phnom Penh	1981～1985, 1991～2002/9
			Kampong Cham	1981～1985, 1991～2002/9
			Kratie	1981～2002/9
			Pursat	1981～2002/9

8.3.2 Annual Precipitation

Figure 8-3-1 shows distribution of averaged annual precipitation (1981 – 2001) in Cambodia. Annual rainfall ranges from 900 mm to 2800 mm. The maximum appears at near Sihanouk Ville, whereas the minimum appears around Takeo.

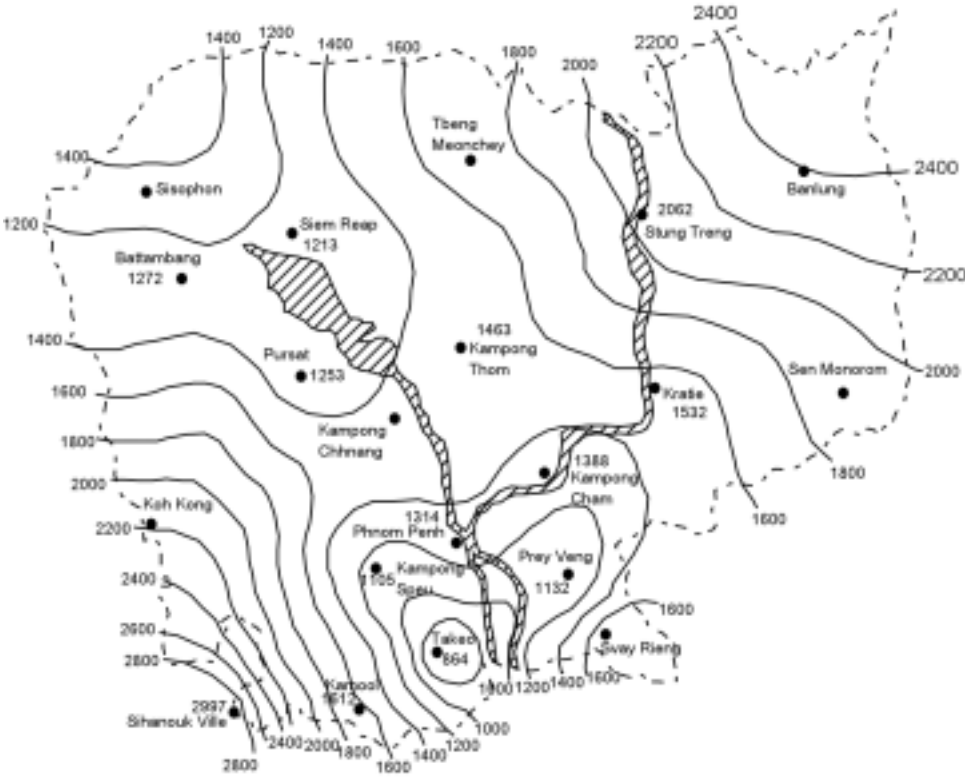


Fig. 8-3-1 Distribution of Averaged Annual Precipitation in Cambodia

8.3.3 Monthly Variation of Temperature, Relative Humidity, Wind Speed and Precipitation

Monthly variation of meteorological conditions near the study area is summarized in Table 8-3-2 based upon the collected data.

Monthly averaged temperature

Annually averaged temperature is about 28 ℃ at Phnom Penh and Kampong Cham. Variation of the monthly averaged temperature is relatively small, ranging about 26 ℃ to 33 ℃.

Monthly averaged relative humidity

The monthly averaged relative humidity do not vary thorough a year, keeping high value of about 75%. Kampong Cham has slightly higher relative humidity than Phnom Penh.

Monthly maximum wind speed

The monthly maximum wind speed at Phnom Penh in summer time is higher than that in other seasons. Kampong Cham has smaller monthly maximum wind speed than Phnom Penh, especially in summer season.

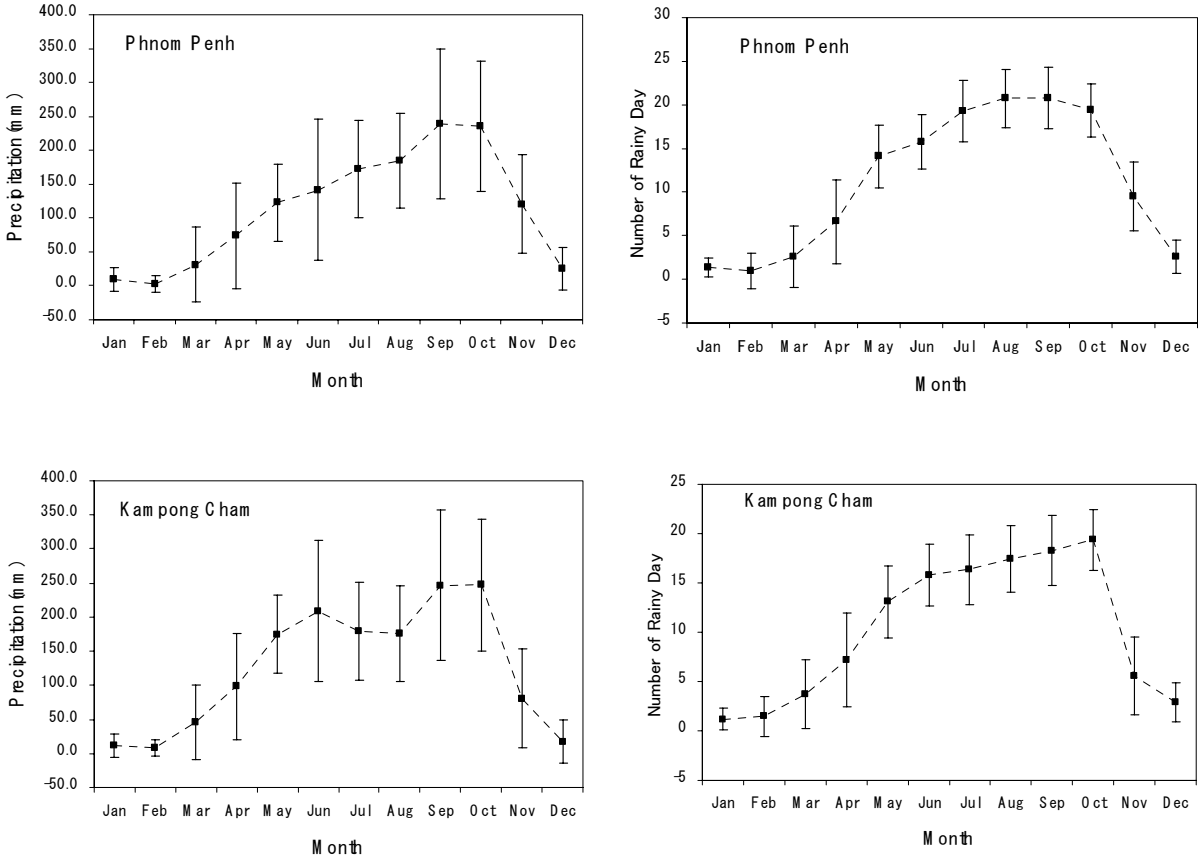
Table 8-3-2 Meteorological Conditions near Study Area

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1. Monthly averaged temperature														(unit: ℃)
Phnom Penh (Pochentong)	Max	31.2	32.7	34.4	34.7	33.8	33.4	32.4	32.2	31.8	30.6	30.2	30.0	34.7
	Average	26.2	27.5	29.1	30.2	29.7	29.5	28.9	28.4	28.2	27.2	26.6	26.3	28.1
	Min	21.5	22.6	24.1	25.6	25.5	24.9	24.8	24.6	24.4	24.0	23.1	21.2	21.2
Kampong Cham	Max	31.1	32.8	34.2	34.7	33.8	32.8	32.0	31.1	30.8	30.4	29.6	29.5	34.7
	Average	26.1	27.4	27.9	29.6	28.8	27.9	27.4	27.3	27.2	26.8	26.1	25.4	27.3
	Min	21.4	22.2	21.9	24.7	24.5	23.3	23.2	23.8	23.9	24.2	22.7	21.0	19.7
Data:	Pochentong, Kampong Cham: 1985～2001													
2. Monthly averaged relative humidity														(Unit: %)
Phnom Penh (Pochentong)		71.0	69.2	68.5	71.0	76.1	78.6	80.3	80.7	84.4	84.3	79.8	73.2	76.4
Kampong Cham		73.1	73.5	72.5	75.5	80.1	83.2	84.0	85.1	84.5	85.0	80.8	76.1	79.5
Data:	Pochentong, Kampong Cham: 1985～2001													
3. Monthly precipitation and rainy day														(Unit: mm)
														(Unit: Day)
Phnom Penh (Pochentong)		9.4	2.7	30.9	73.7	122.9	141.4	172.7	184.8	238.9	235.2	120.0	25.4	1358.1
		1	1	3	7	14	16	19	21	21	19	10	3	134
Kampong Cham		11.0	7.9	45.2	98.2	175.0	209.2	178.8	175.2	246.8	247.0	80.7	17.3	1492.2
		1	1	4	7	13	16	16	17	18	19	6	3	122
Kratie		4.3	8.6	45.0	82.4	185.7	260.0	237.6	283.3	283.0	184.4	61.7	10.4	1585.1
		1	1	2	6	12	16	18	20	19	13	5	1	119
Pursat		5.2	6.0	40.1	83.1	173.5	154.0	155.1	181.8	236.8	252.8	121.4	11.4	1420.3
		1	1	4	6	14	14	16	17	17	14	9	2	117
Data:	Pochentong: 1981～1984, 1990～2001 Kampong Cham: 1981～1985, 1990～2001 Kratie: 1981～2001 Pursat: 1981, 1983～1985, 1987～1990, 1993～2001													
4. Monthly maximum wind speed														(Unit: m/s)
Phnom Penh (Pochentong)		5.6	6.1	9.8	11.0	12.2	12.5	10.7	9.5	9.1	9.7	7.3	6.6	12.5
Kampong Cham		6.4	6.4	5.7	5.7	6.4	7.9	7.9	7.9	7.9	7.1	7.1	6.4	7.9
Data:	Pochentong, Kampong Cham: 1986～1995													

Monthly precipitation

Annual precipitation near study area is about 1400 mm. Among four stations, Kratie has the highest annual precipitation. The lowest is seen at Phnom Penh.

The monthly precipitation ranges between 3–239 mm at Phnom Penh meteorological station. The wet season with frequent and heavy rainfall brought by southwest monsoon usually starts from mid-May and ends in November. As soon as the wet season finishes, the dry season starts from and continues to April influenced by northeast monsoon. These patterns are almost same among four stations. The monthly variation of averaged monthly precipitation and number of rainy day through past 20 years and those standard deviations at Phnom Penh and Kampong Cham are shown in Fig. 8-3-2.



Note: Error bar represents standard deviation.

Fig. 8-3-2 Monthly Variation of Averaged Precipitation and Number of Rainy Day

8.3.4 Rainfall with Short-Duration

Rainfall intensity-duration relation at Phnom Penh has been developed by the JICA study[1] for drainage improvement of Phnom Penh. They analyzed probable rainfall for several rainfall duration based upon the data observed from 1980 to 1997. Because there is no clear tendency of change of rainfall according to observed annual maximum daily precipitation up to 2001, the relationship developed by the previous JICA study can be still available. The relationship is as follows (see also Fig.8-3-3):

$$R_I = a(T+b)^c \qquad (8.3.1)$$

where R_I = rainfall intensity(mm/hr), T = rainfall duration(min), and a, b, c = constants.

For T<6hr,

10 year return period: a=6974.09, b=34.29, c=-1.01
5 year return period: a=5009.12, b=31.38, c=-0.98
2 year return period: a=2556.07, b=25.48, c=-0.93

For T>6hr,

10 year return period: a=903.62, b=-78.21, c=-0.71
5 year return period: a=666.67, b=-86.23, c=-0.69
2 year return period: a=381.76, b=-94.66, c=-0.65

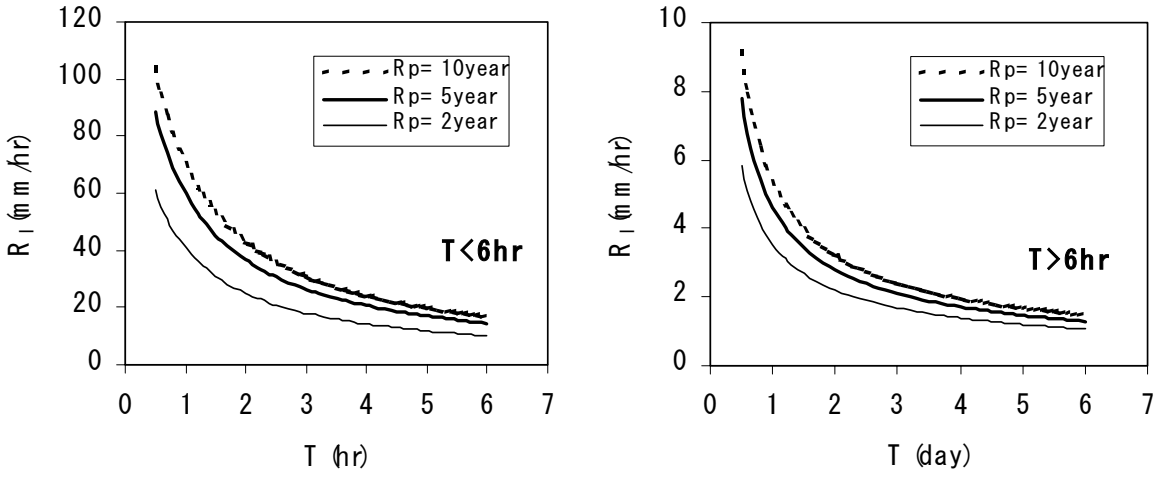


Fig. 8-3-3 Rainfall Intensity

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1 JICA; "The study on drainage improvement and flood control in the municipality of Phnom Penh, Final Report Volume II, Main Report", August 1999.

8.4 Water Surface Level and Discharge

8.4.1 Collected Data

Water surface level and discharge data were collected from Department of Hydrology and River Works of Ministry of Water Resources and Meteorology (MoWRAM). Table 8-4-1 shows the list of collected water surface level and discharge data.

At Chrouy Changvar Station, daily water level data is available from 1983, and annual maximum water level data is available from 1960. In addition to these, annual maximum data at Chrouy Changvar is also available from 1894 to 1959[2] in the ADB NR-1 Study Report in 1997. However, accuracy of the old data cannot be confirmed anymore.

As the discharge measurements for updating rating curves have been conducted in very few times or not been conducted, available discharge data is very few.

Table 8-4-1 List of Collected Water Surface Level and Discharge Data

Data	Item	Station	River	Data Period
Water Surface Level	Annual Max.	Kratie	Mekong River	1981 - 2001
		Kampong Cham	Mekong River	1960 - 2001
		Chrouy Changvar (Phnom Penh)	Mekong River	1960 - 2001
		Neak Loueng	Mekong River	1988 - 2001
		Kampong Loung	Tonle Sap	1995 - 2000
		Prek Kdam	Sap River	1960 - 2001
		Phnom Penh Port	Sap River	1993 - 2001
		Chakthomuk	Bassac River	1960 - 2001
		Koah Khael	Bassac River	1991 - 2001
	Daily Mean	Kratie	Mekong River	1981/1 - 2001/12
		Kampong Cham	Mekong River	1981/1 – 2002/9
		Chrouy Changvar (Phnom Penh)	Mekong River	1983/1 – 2002/9
		Neak Loueng	Mekong River	1988/6 - 2002/5
		Kampong Loung	Tonle Sap	1995/5 - 2000/12
		Prek Kdam	Sap River	1986/7 - 2002/5
		Kampong Chhnang	Sap River	1994/5 - 2001/12
		Phnom Penh Port	Sap River	1993/1 – 2002/9
		Chakthomuk	Bassac River	1981/1 – 2002/9
		Koah Khael	Bassac River	1991/1 – 2002/6
Discharge	Daily Mean	Kratie	Mekong River	1981/1～2001/12
		Kampong Cham	Mekong River	1989/1～1999/12
		Chrouy Changvar (Phnom Penh)	Mekong River	1989/1～1999/12
		Neak Loueng	Mekong River	1998/8～2000/7 (20 times of discharge measurement data)

[2] ADB; "Ho Chi Minh City to Phnom Penh Highway Improvement Project, Final Report Volume VI, Hydrology and Hydraulics Studies", November 1997.

8.4.2 Equations for Converting Water Surface Level from Gauge Reading to MSL

Table 8-4-2 shows the equations for converting the gauge-reading water level to elevation in MSL.

Table 8-4-2 Conversion of Water Surface Level from Gauge Reading to MSL

Water Level Gauging Station	Equation for Conversion
Kampong Cham	H=D-0.93
Chrouy Changvar	H=D-1.08
Kampong Loung	Not made cleared yet.
Kampong Chhnang	Not made cleared yet.
Prek Kdam	H=D+0.08
Phnom Penh Port	H=D+0.07
Chaktomuk	H=D-1.02
Neak Loueng	H=D-0.33
Kaoh Khael	H=D-1.00

D: Gauge reading at water level gauging station (meters), H: Water level (El. meters in MSL)
Data Source: Department of Hydrology and River Works of MoWRAM.

8.4.3 Long Term Tendency of Water Surface Level

(1) Historical Water Surface Level

Table 8-4-3 shows the annual maximum water levels at above gauging stations. Recent major floods in and around Phnom Penh happened in 1996, 2000, 2001 and 2002. Flood in 2000 was the largest flood around Phnom Penh and the National Road No.1 including Neak Loueng in these 40 years. On the other hand, the flood water level of 1996 Flood was the highest at Kampong Cham in these 40 years as shown in Table 8-4-4.

(2) Long-term Tendency of Annual Maximum Water Surface Level

The annual maximum water level at Chrouy Changvar from 1894 to 2002 is shown in Fig. 8-4-1. From the figure, we can know that similar order of the maximum water level of 2000 Flood at Phnom Penh (Chrouy Changvar) has happened at least 4 times in these 42 years (1961, 1966, 1996 and 2000), which means once in 11 years on an average. The maximum water level of 2001 and 2002 was slightly lower than these 4 water levels. It can also be confirmed that once in 10 to 15 years, maximum water level with similar order of 2000 Flood has happened in these 108 years. Furthermore, it seems that there is no clear tendency of increase of the maximum water level of floods.

Table 8-4-3 Annual Maximum Water Surface Level

Year	Kampong Cham	Chrouy Changvar	Kampong Loung	Kampong Chhnang	Prek Kdam	Phnom Penh Port	Chaktomuk	Neak Loueng	Kaoh Khael
	(El. m -MSL)	(El m -MSL)	(El m -GH)	(El m -GH)	(El m -MSL)	(El m -MSL)	(El m -MSL)	(El m -MSL)	(El m -MSL)
1960	13.73	8.87			8.99		8.93		
1961	14.48	9.90			10.14		9.96		
1962	13.68	9.14			9.37				
1963	13.70	8.75			8.86				
1964	13.93	9.11			9.01		9.04		
1965	12.52	8.31			8.28		8.29		
1966	14.51	9.94			10.02		9.91		
1967	13.23	8.76			8.83		8.74		
1968	14.05	8.71			8.38		8.66		
1969	13.21	8.81			8.83		8.77		
1970	14.09	9.16			9.15		9.14		
1971	13.03	8.83			9.01		8.82		
1972	14.15	9.20			9.04		9.16		
1973	13.13	8.87					8.86		
1974	13.65	8.74					8.82		
1975									
1976									
1977									
1978									
1979									
1980									
1981	13.34						9.45		
1982	13.03						8.92		
1983	11.77	8.65					8.72		
1984	13.59	9.62					9.61		
1985	12.21	8.84					8.87		
1986	12.11	8.69			8.32		8.70		
1987	12.35	8.18			7.38		8.07		
1988	9.99	6.64			7.72		7.30	5.31	
1989	10.84				7.89		7.80	5.71	
1990	12.63	8.78					8.80	6.57	
1991	14.77	9.61			10.13		9.54	7.35	6.62
1992	13.13	8.01			7.62		7.99	5.91	5.99
1993	12.50	7.90			7.87	7.86	7.93	5.87	5.85
1994	14.24	9.50		11.46	9.77	9.52	9.51	7.19	6.53
1995	14.33	9.12	10.03	11.46	9.48	9.10	9.12	6.99	6.40
1996	15.18	9.92	9.17	11.50	9.82	9.91	9.92	7.67	6.78
1997	14.81	9.00	8.71	10.53	9.15	9.03	9.03	6.91	6.40
1998	11.31	6.88	6.22	8.02	6.78	6.82	6.90	5.09	5.44
1999	13.79	8.82	8.33	10.20	8.89	8.83	8.96	6.67	6.28
2000	14.98	10.13	9.72	11.61	10.98	10.16	10.18	7.79	6.94
2001	15.16	9.69		11.16	10.06	9.71	9.73	7.52	6.72
2002	14.98	9.82				9.85	9.63		

Table 8-4-4 Maximum Water Surface Level of 1996, 2000, 2001 and 2002 Floods

(Unit: El. meters in MSL)

Flood	Neak Loueng St.	Bassac Chaktomuk St.	Chrouy Changvar St. (Phnom Penh)	Kampong Cham St.
	Mekong R.	Bassac R.	Mekong R.	Mekong R.
1996 Flood	7.67	9.91	9.92	**15.18**
2000 Flood	**7.79**	**10.18**	**10.13**	14.98
2001 Flood	7.52	9.73	9.69	15.16
2002 Flood		9.63	9.82	14.98

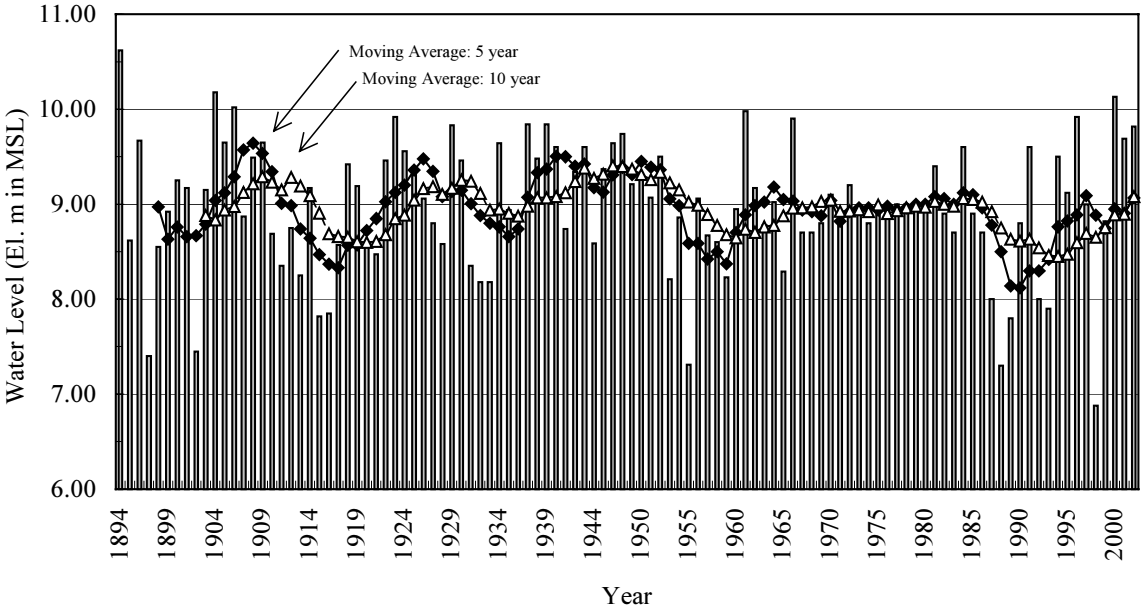


Fig. 8-4-1 Annual Maximum Water Surface Level at Chrouy Changvar (1894 to 2002)

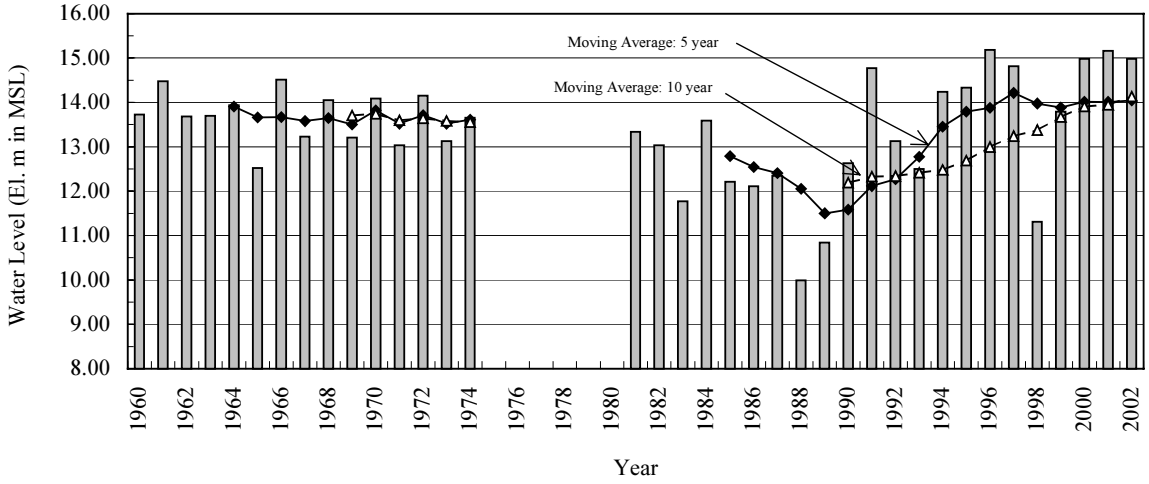


Fig. 8-4-2 Annual Maximum Water Surface Level at Kampong Cham (1960 to 2002)

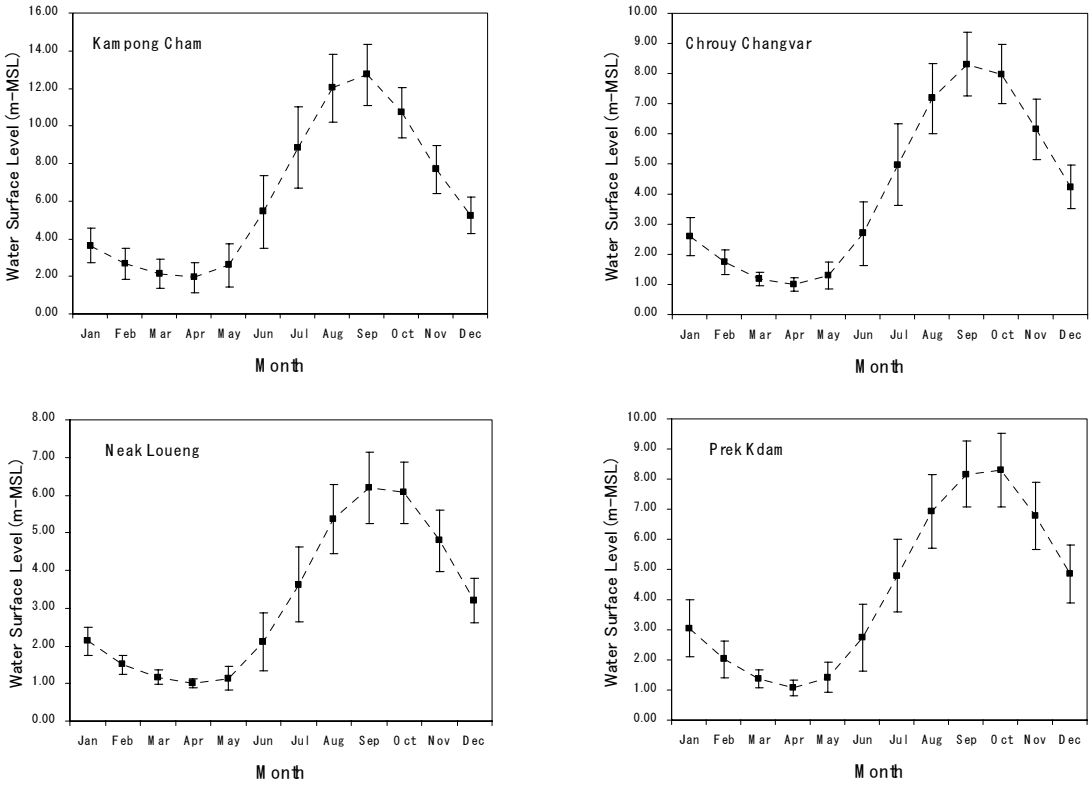
Based on the historical annual maximum water level data at Kampong Cham from 1960 to 2002, the historical annual maximum water levels in these 42 years are plotted as shown in Fig.8-4-2. The moving averaged data indicates that there is the tendency of increase of the annual maximum water surface level within last decade. The averaged annual maximum water surface

level within last five years is about 40 cm higher than that in 1970s. However, it is still quite unknown whether the tendency will continue in near future or not, because of lack of long-term data.

The reason of the increase of the annual maximum water surface level could be influence of the intensive development in Cambodia after 1990s. Deforestation within the Mekong River Basin might be one of the reasons. However, deforestation was generally intensive during 1970s and 80s, and the movement of the conservation of forest started after 1990s in a worldwide view. In Fig. 8-4-2, there is no clear tendency of the increase during 1970s and 1980s. It does not support that deforestation is the main reason of the increase. More intensive and comprehensive study will be needed to clarify the reason. The effect of global warming should also be investigated more intensively in near future.

8.4.4 Monthly Variation of Water Surface Level

The Monthly variation of monthly averaged water surface level through past almost 20 years and those standard deviations at Kampong Cham, Chrouy Changvar, Neak Loueng and Prek Kdam are shown in Fig. 8-4-3.



Note: Error bar represents standard deviation.

Fig. 8-4-3 Monthly Variation of Averaged Water Surface Level

The water surface elevation varies like a sinusoidal curve with a period of one year. The lowest and highest peaks appear in April and September, respectively, at each station. The standard deviation tends to be larger in June and July. This means that the water surface elevation in June and July is easy to vary year by year.

8.4.5 Rating Curve

In addition to the collected discharge data, some directly measured data in the Chaktomuk project of MRCS[3] during 2000 Flood are available to establish a rating curve for each station.

(1) Rating Curve at Kampong Cham, Neak Loueng and Kaoh Khael

Using available discharge data, a rating curve for each of Kampong Cham, Neak Loueng and Kaoh Khael is established as shown in Fig.8-4-4. These curves are employed in the hydraulic simulation model described in Chap.9.

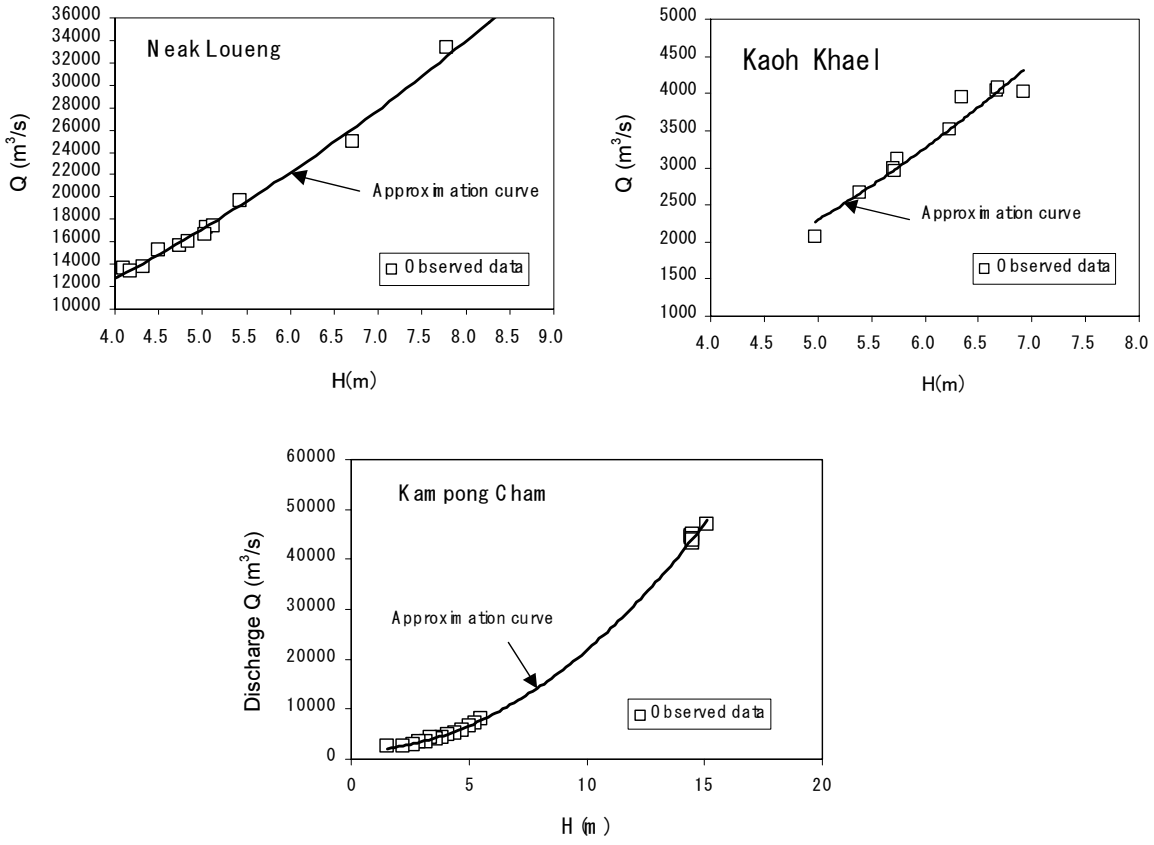


Fig. 8-4-4 Rating Curve at Kampong Cham, Neak Loueng and Kaoh Khael

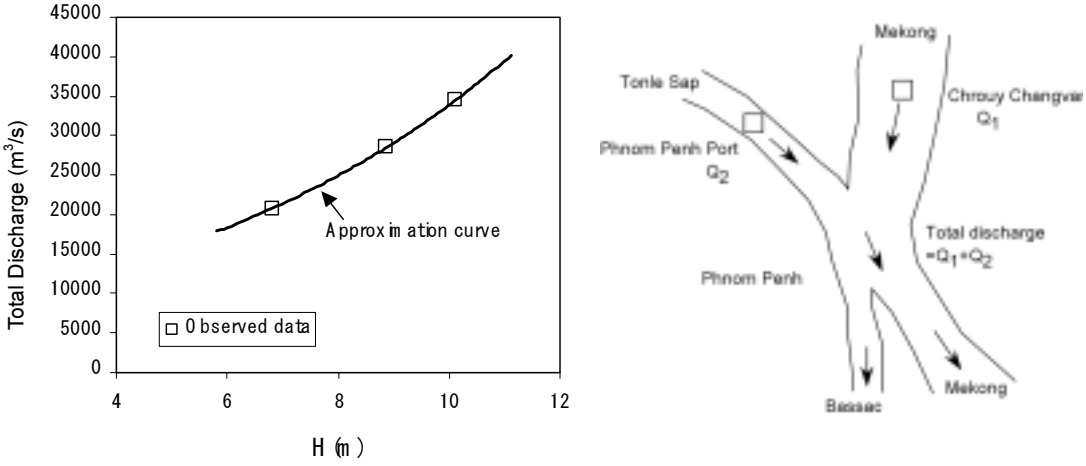
(2) Rating Curve at Chrouy Changvar

According to the directly measured discharge during 2000 Flood, there seems to be no unique relationship between the discharge and the water surface level at Chrouy Changvar. It may be because of the effect of the Tonle Sap River. The flow direction of the Tonle Sap

3 MRCS: "A Comprehensive Study on the Chaktomuk Area. Environment, Hydraulics and Morphology. Phase 1", 2002.

River varies depending upon the water surface level of the Tonle Sap River and the Mekong River. The flow condition near Chrouy Changvar could be affected by the flow direction of the Tonle Sap River.

In this study, it is assumed that there is a unique relationship between the total discharge, which is added discharge at Chrouy Changvar of the Mekong River and at Phnom Penh Port of the Tonle Sap River, and the water surface level at Chrouy Changvar. Figure 8-4-5 shows the relationship and its approximation curve. Although the available data are limited, the curve is temporally employed in the hydraulic simulation in the present study. Further comprehensive study will be required to clarify the effect of the Tonle Sap River on the flow pattern near Chrouy Changvar of the Mekong River.



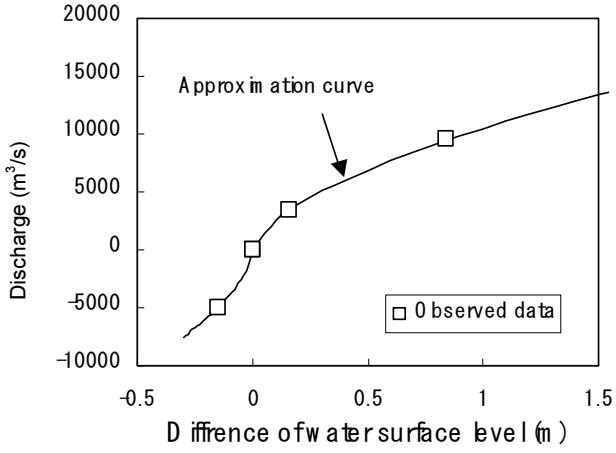
Note: Total discharge is added discharge at Chrouy Changvar of the Mekong River and at Phnom Penh Port of the Tonle Sap River

Fig. 8-4-5 Relationship between Total Discharge and Water Surface Level at Chrouy Changvar

(3) Discharge at Phnom Penh Port

The flow direction at Phnom Penh Port varies depending upon the water surface level of the Mekong River and the Tonle Sap River. The rating curve at Phnom Penh Port is thereby very hard to be established.

Based upon the directly measured discharge at Phnom Penh Port, it is found that the discharge has an almost unique relationship with the difference between the water surface level at Phnom Penh Port and that at Prek Kdam. Figure 8-4-6 shows the relationship and its approximation curve. The curve is temporally employed in this study. Further study will be required to establish more accurate one.



Note: Water surface levels are observed at Prek Kdam and Phnom Penh Port

Fig. 8-4-6 Relationship between Discharge and Difference of Water Surface Elevation at Phnom Penh Port and Prek Kdam

8.5 Frequency Analysis on Flood Water Level

8.5.1 Frequency Analysis of Annual Maximum Water Surface Level

Probable water levels at Kampong Cham, Chrouy Changvar, Neak Loueng along the Mekong River, Prek Kdam along the Tonle Sap River and Chaktomuk along the Bassac River are calculated by Gumbel Method. The probable water levels are shown in Table 8-5-1.

Based on the above probable water levels, the return periods of the maximum water levels of 1996, 2000 and 2001 Floods at Kampong Cham, Chrouy Changvar and Chaktomuk are estimated as shown in Table 8-5-2. Based on the above return periods, in terms of flood water levels, the 2000 Flood was about 12 year return period around Phnom Penh.

Table 8-5-1 Probable Water Surface Levels with Return Periods

(El. meters in MSL)

Return Period	Station					
	Kampong Cham	Prek Kdam	Chrouy Changvar	Chaktomuk	Neak Loueng	Chrouy Changvar**
100	17.73	12.41	11.63	11.52	10.09	11.22
50	16.98	11.81	11.16	11.07	9.49	10.83
25	16.23	11.21	10.68	10.61	8.90	10.43
10	15.21	10.39	10.04	10.00	8.09	9.90
5	14.41	9.75	9.53	9.51	7.45	9.48
2	13.19	8.78	8.76	8.77	6.49	8.84
Data Period	1960-1974 & 1981-2001	1960-1972 & 1986-2001	1960-1974 & 1983-2001	1960-1974 & 1981-2001	1988-2001	1894-2001

Table 8-5-2 Return Periods of the Maximum Water Surface Levels of Floods

(Unit: Year)

Flood	Neak Loueng	Chrouy Changvar	Kampong Cham	Chaktomuk	Chrouy Changvar** (1984-2001)
	Mekong R.	Mekong R.	Mekong R.	Bassac R.	Mekong R.
1996 Flood	6.0	8.1	**9.6**	7.5	10.2
2000 Flood	**6.8**	**10.9**	7.8	**12.2**	**13.5**
2001 Flood	5.3	5.9	9.4	6.2	6.7
2002 Flood		7.8	7.8	5.7	9.0

8.5.2 Frequency Analysis of Quasi-Water Volume of Flood

Not only maximum water level but also duration that higher water level continues could play an important role for damage by flood. In the present study, an index that indicates the duration has been introduced. The index is an integrated water surface elevation (quasi-water volume) during rainy season (from July 1 to November 30), which is defined as follows:

$$I \equiv \int_{July1}^{Novemver30} WLdt \qquad (8.5.1)$$

where WL = Water surface elevation, and t = time.

The return period of the index I for 1996, 2000 and 2001 at Neak Loueng, Kampong Cham and Chaktomuk are also estimated by assuming Log-normal distribution as the probability density function (P.D.F.) of index I. The results are shown below:

Table 8-5-3 Return Periods of Index *I*

(Unit: Year)

Flood	Neak Loueng	Kampong Cham	Chaktomuk
	Mekong R.	Mekong R.	Bassac R.
1996 Flood	3.3	6.0	3.3
2000 Flood	**16.1**	**18.1**	**23.3**
2001 Flood	8.0	13.7	10.6

The above table shows larger differences of the return periods among the floods in 1996, 2000 and 2001 and larger return periods in 2000. The flood in 2000 was actually rarer phenomenon than that has been recognized through the analysis of the maximum water levels, if one considers the duration that higher water level continues.

8.6 Hydrological Condition in 2000 Flood

It is said that the wet season in 2000 started earlier and amount of rainfall throughout the Mekong River Basin in May and June was higher than other years, which caused higher water level along the lower the Mekong River in the wet season.

Figure 8-6-1 shows variation of the monthly precipitation at Phnom Penh in 2000 compared to the averaged one through last 20 years. From this figure, we can confirm that the amount of precipitation in June and July in 2000 is higher than the averaged one.

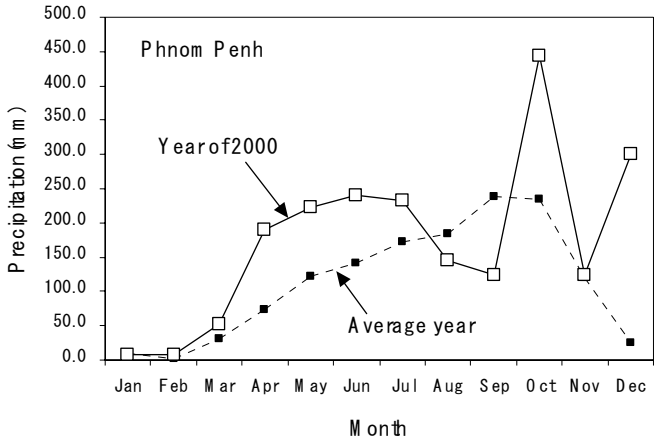
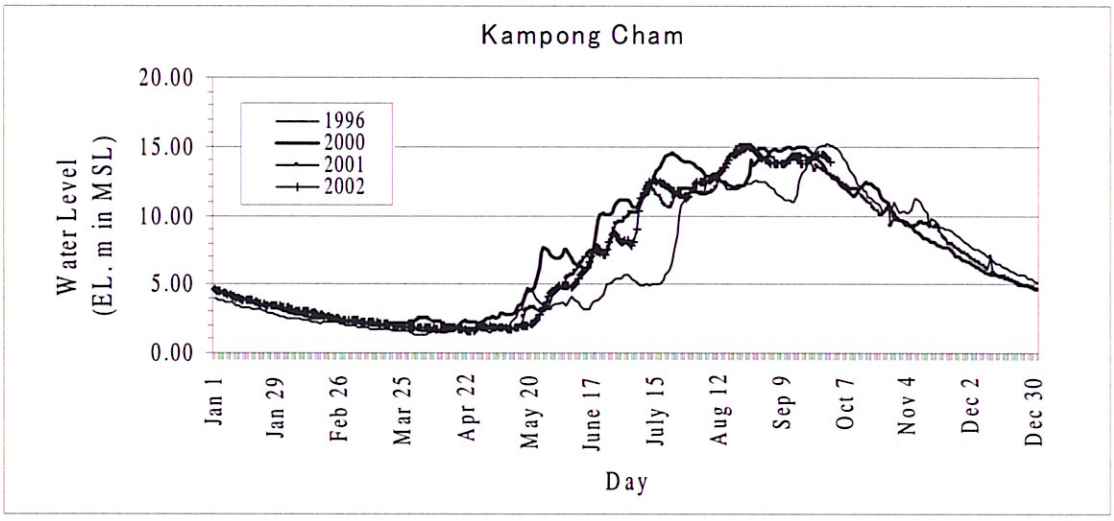
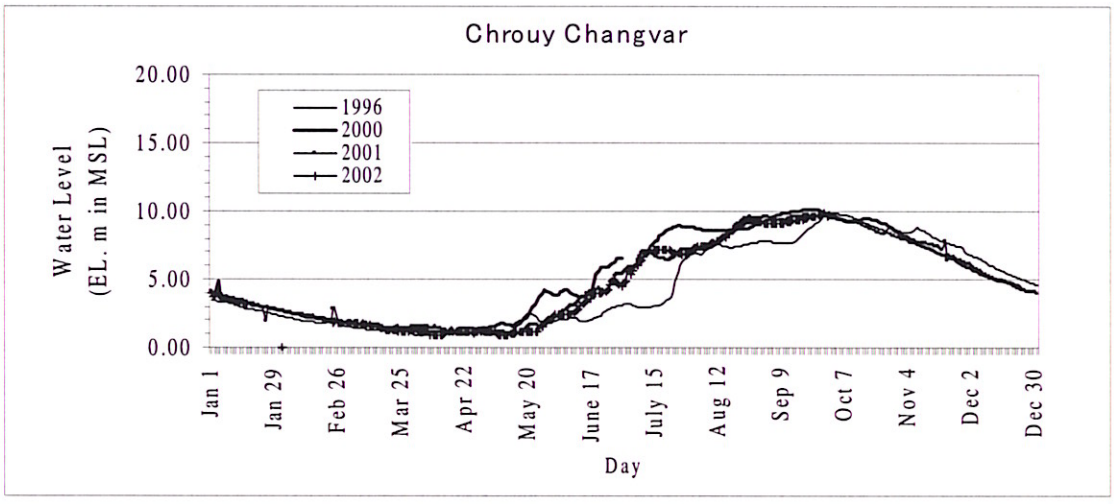


Fig. 8-6-1 Monthly Variation of Precipitation at Phnom Penh in 2000

Figure 8-6-2 shows comparison of water levels of 1996, 2000, 2001 and 2002 along the Mekong River. From this figure, 2000 Flood had different characteristics than other floods with 2 peaks and longer duration of floods. For example, at Phnom Penh, the duration of the 2000 Flood at higher portion (supposing above El. 7.50 m) continued about 85 days in 1996, 120 days in 2000 and 95 days in 2001. It is said that by the 2 peaks and longer duration of 2000 Flood, retention capacity of the Tonle Sap Lake became small and the water level around Phnom Penh recorded the highest value in 2000.

Figure 8-6-3 shows comparison of water levels of 1996, 2000, 2001 and 2002 along the Tonle Sap River. Especially, from the data at Kampong Loung, we can know that the duration of high flood water level in 2000 was much longer than that in 1996. Therefore, it can be confirmed that the retention capacity of the Tonle Sap Lake became small at the timing of the peak water level of the Mekong River.





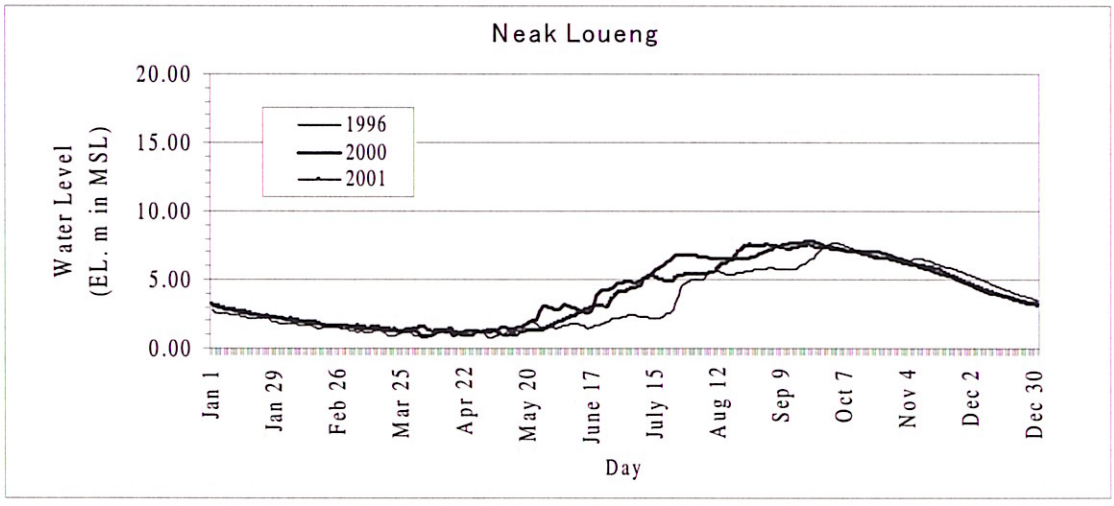


Fig. 8-6-2 Comparison of Daily Water Level of 1996, 2000, 2001 and 2002 along the Mekong River

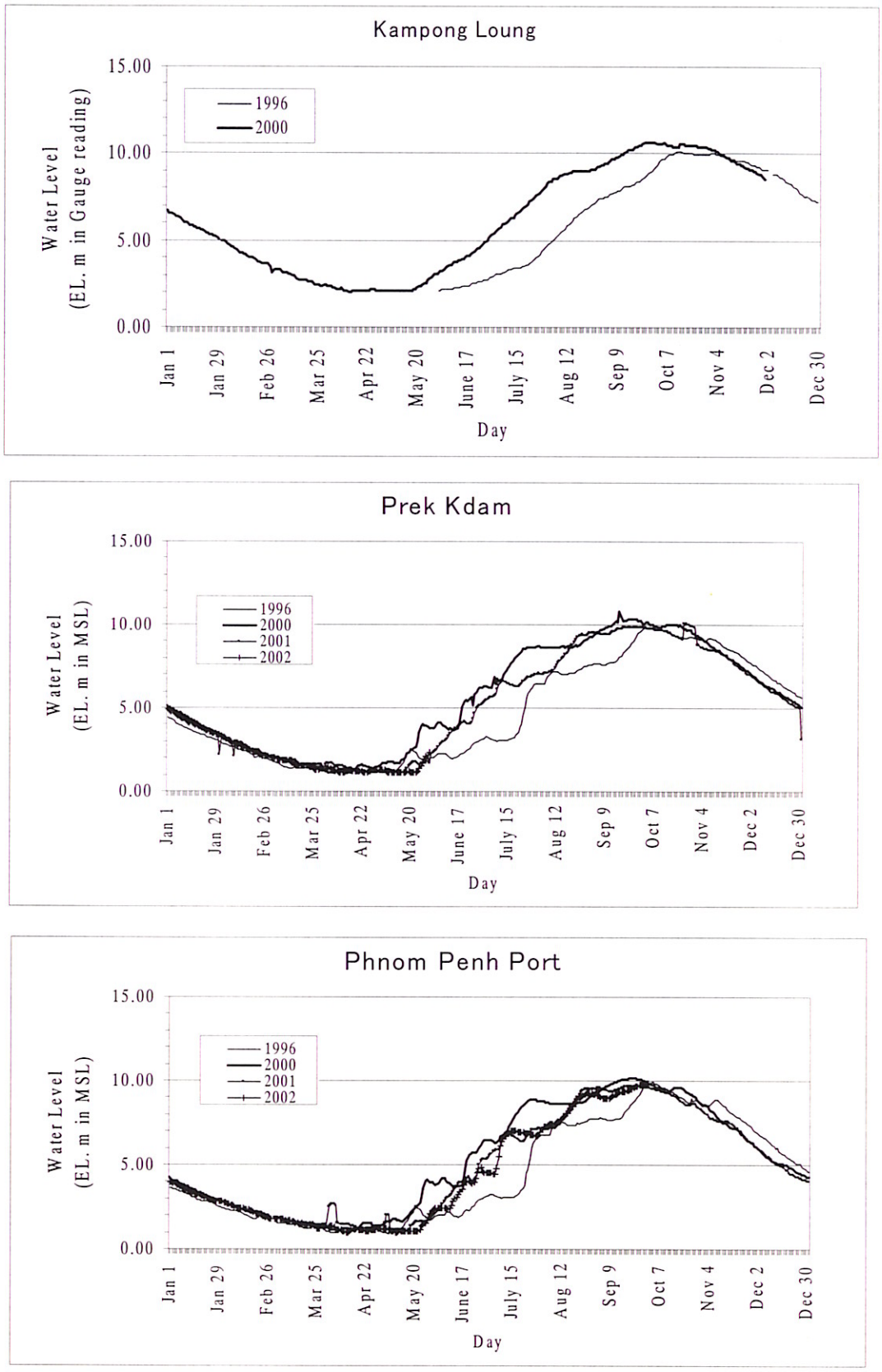


Fig. 8-6-3 Comparison of Daily Water Level of 1996, 2000, 2001 and 2002 along the Tonle Sap River

8.7 Trend of Bank Erosion along the Mekong River

Stability of the river is one of essential factors for sustainability of NR-1. If active bank erosion proceeds and reaches to NR-1, there will be high possibility of collapse of NR-1. In this study, the recent change of shoreline along the Mekong River (Kampong Cham to Neak Loueng) was thereby investigated by analyzing topographic maps made at both 1968 and 1996. The results are shown in Fig.8-7-1. The following locations along NR-1 (C-1) have tendency of bank erosion according to the change of shoreline during last 30 years.

Site A: 8 to 13km (*Pk 13.6 to 18.6*)
Site B: 18 to 26km (*Pk 23.6 to 31.6*)
Site C: 37 to 39km (*Pk 42.6 to 44.6*)
Site D: 45 to 49km (*Pk 50.6 to 54.6*)

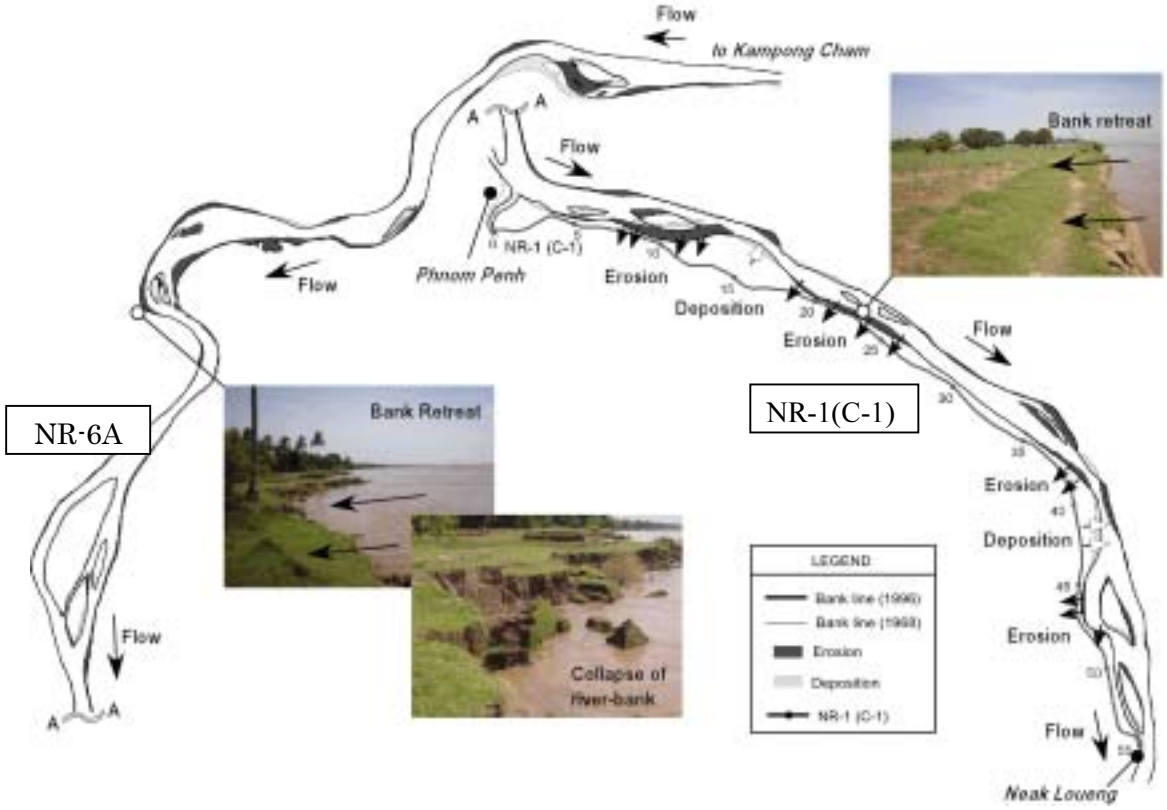


Fig. 8-7-1 Trend of Bank Erosion along the Mekong River between Kampong Cham and Neak Loueng

Among the erosion sites along NR-1(C-1), Site B has the highest risk for bank erosion, because flow along the edge of sand bar in the Mekong River Main Stream directly attacks this site. At this site, retreating rate of bank is estimated at 10 to 15 m/year, and the current distance from NR-1(C-1) to bank is only 70 to 80 meters in the present.

At the above 4 sites, it is recommended to conduct observation of the bank erosion every year, and some countermeasures is to be considered to mitigate threat of erosion of embankment beforehand, so that it will not be really serious problem to NR-1(C-1).