Appendix I Water Resources

#### THE STUDY ON REGIONAL DEVELOPMENT OF THE PHNOM PENH-SIHANOUKVILLE GROWTH CORRIDOR IN THE KINGDOM OF CAMBODIA

## Appendix I Water Resources

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## APPENDIX I WATER RESOURCES

## I.1 NATURAL CHARACTERISTICS OF CAMBODIA

## I.1.1 Introduction

Cambodia is a predominantly rural and forested tropical country. About 86% of the country is in the catchment of the Tonle Mekong, which shares the catchment area with Vietnam, Laos, Thailand, Myanmar, and China. The remaining drainage directly to the Gulf of Thailand. The cultivable area is approximately 26% of the total land area and more than 60% is forested. However, the annual deforestation rate is estimated at  $0.5\%/annum^1$ .

The country is hilly around its international boundary, but the dominant feature of landscape is the extensive flood plains of the Tonle Mekong, Tonle Sap, and the Tonle Sap Lake (the Great Lake). The Mekong system represents a valuable resource for the Cambodia, particularly in terms of crop and fish production, and a future potential for hydropower. These water bodies are unique а hydrological system.



From May to October, when the water level of the Tonle Mekong is high, the river flows backwards along the Tonle Sap into the Lake, which increases in surface area from 2,600 km<sup>2</sup> to 13,000 km<sup>2</sup>. In November, the river drains from the Lake to the Mekong and thence to the South China Sea. The change in the volume of lake water is estimated at around 500 billion  $m^3/annum$ .

## I.1.2 Geographical Characteristics of Cambodia

## (1) Central Plain

Cambodia covers an area of  $181,035 \text{ km}^2$ . The central region is a low-lying alluvial plain surrounding the Tonle Sap (Great Lake) and the head of the Mekong River delta that lies in the southeast of the plain. Extending outward from this region are transitional plains, thinly forested with prevailing elevations no higher than several

<sup>&</sup>lt;sup>1</sup> The Water Sector in Cambodia, Capacity Building in MOWRAM, ADB, MOWRAM with Sir M.MacDonald & Partners and BCEOM, March 2001.

hundred feet above sea level.

## (2) Northern Mountains

On the north along the border with Thailand, the Cambodian plain abuts a sandstone escarpment that marks the southern limit of the Dangrek Mountains. A southward-facing cliff, stretching for more than 300 km from west to east, rises abruptly from the plain to the heights ranging from 180 to 550 meters.



Source: IDI-Japan, GIS for the Mekong River Basin 1999

Figure I.1.2 Landscape Image of Cambodia

## (3) Eastern Highlands

East of the Mekong, the transitional plains gradually merge with the eastern highlands, a region of forested mountains and high plateaus that extend into Laos and Vietnam.

## (4) Southwestern Mountains

In southwestern Cambodia two distinct upland blocks, comprising the Cardamom Mountains and the Elephant Mountains, form another highland region that covers much of the land area between the Tonle Sap and the Gulf of Thailand. In this remote and largely uninhabited area, there is Mount Aoral (1,813 meters), Cambodia's highest peak.

## (5) Southern Coastal Region

The southern coastal region facing the Gulf of Thailand is a narrow lowland strip, heavy wooded and sparsely populated . This area is isolated from the central plain

with the southwestern highlands in between.

## I.1.3 Climate

Cambodia's climate is dominated by the monsoon weather. In the period from mid-May to November, the north-west monsoon brings some 90% of the rainfall, which varies generally between 1,200 and 2,000 mm/year across the country, wile the north-east monsoon results in dry weather in the period from December to April. In any location, rainfall varies significantly from year to year. Even in the rainy period from June to July, no rain for 15 days in maximum is common. Apart from rainfall, other climatic elements vary slightly form place to place throughout the year<sup>2</sup>.

The temperature across the country ranges from a mean daily minimum of 19  $^{\circ}$ C in January to a mean daily maximum of 35  $^{\circ}$ C in April. There is very little variation across the region with differences in the order of 1  $^{\circ}$ C. The mean annual temperature is 27.7  $^{\circ}$ C at Phnom Penh.

Cambodia experiences high relative humidity with mean annual relative humidity ranging from 76% at Kampong Cham to 80% at Phnom Penh. The country rarely experiences relative humidity below 70% throughout the year.

Wind speed data indicate a variation in the mean wind speed across the country. The inland regions experiences much lower wind speed than that in the coastal regions. Mean wind speeds range from 82 km/day in the inland regions to 179 km/day at Kampot. Maximum wind speed occurs in January.

Mean annual evaporation varies from 1,020 mm/year at Siem Reap to 1,445 mm/year at Kompong Cham. In the Study area, the mean annual evaporation varies from 1,348 mm/year at Phnom Penh, 1,233 mm/year at Kampot to 1,408 mm/year at Sihanoukville<sup>3</sup>.

## I.1.4 Rainfall

The mean annual rainfall varies from 1,200 mm/year in the north-western part of the country to over 4,000 mm/year in the south-eastern coastal area with an overall mean across the country of about 2,000 mm/year. The mean annual rainfall in the central plains, where most irrigation schemes are located, varies from 1,200 to 1,600 mm/year. Isohyetal map of mean annual rainfall in the Cambodia is shown in **Figure I.1.3**.

<sup>&</sup>lt;sup>2</sup> Capacity Building in MOWRAM, Final Report, Annex 2 - Water Resources Planning, ADB, Sir M. MacDonald & Partners, BCEOM, August 2001.

<sup>&</sup>lt;sup>3</sup> Irrigation Rehabilitation Study in Cambodia, Mekong Secretariat, Halcrow, June 1994.

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Figure I.1.3 Isohyetal Map of Mean Annual Rainfall in Cambodia

Mean monthly rainfall at representative rainfall stations in the Study area is shown in **Figure I.1.4**. The monthly rainfall distribution pattern shows a distinct rainy season from May to November with a peak in August/September. Approximately 85~90% of annual rainfall occurs during this period. The period from December to April is the dry season and January is the driest month. In general the rainfall pattern shows a single peak in many years. However, it is reported that there is often a short dry period the rainy season, which varies in timing from year to year. It is the unpredictable nature of this short dry period, which makes rain-fed rice farming risky and requires, for supplementary irrigation water in the wet season.



Figure I.1.4 Mean Monthly Rainfall in Study Area

## I.1.5 Hydrology

In Cambodia, the Mekong River joins the Tonle Sap River near Phnom Penh and receives a considerable discharge from the Tonle Sap Lake (Great Lake) during the dry season, from November to March. Near Phnom Penh, the Mekong River is divided into four branches: the upstream and downstream Mekong River branches, the Tonle Sap River and the Bassac River.

The Mekong River traverses from the north to the south of Cambodia with a distance of about 480 km. Its total drainage covers about 86% of the land area of the country and the remaining 14% of the land is located outside the Mekong River Basin and pours into to the Gulf of Thailand.

According to the MOWRAM (2001), hydrological characteristics in the Cambodia are described as follows:

The Mekong River brings yearly floods of about 475,000 million m<sup>3</sup>. Before reaching downstream, the river runs through lowland where the flood water enters partially the Great Lake and both sides along the Mekong and Bassac Rivers. The silt plays an important role in the maintenance of soil fertility for rice and other crops. The Mekong River carries the silt of between 300 to 600 g per m<sup>3</sup>, resulting in several mm of silt per year. The water quality is rich in lime and potash; its neutrality (pH 6.3-7.4) helps in reducing to some extent the acidity of the soil.

The mean annual discharge entering Cambodia is over 300 billion  $m^3$ /year. It is estimated that with the contribution of downstream tributaries, some 500 billion  $m^3$ /year are discharged into the sea annually. At Kratie of the Mekong River, the peak discharge occurs during the August/October monsoon and reaches 70,000  $m^3$ /sec.



The hydrological gauging stations in Cambodia are shown in Figure I.1.5.

Figure I.1.5 Hydrological Gauging Stations in Cambodia

In the Mekong and in a few of the largest tributaries, the Sekong, the Sesan and the Srepok on the east bank, there remains a substantial flow during the dry season. However, in the smaller catchments, flows reflect more closely local rainfall patterns, and fall to minimum levels during the dry season. Smaller streams dry up altogether. The hydrologic characteristics of the Mekong tributaries are summarized in the **Table** below.

	Table I.1.1 H	<b>Iydrological</b>	Characteri	stics of the M	ekong Trib	utaries
No.	TRIBUTARY	Catchment	Annual	Mean Annual	Annual	Natural
	NAME	Area	Flow	Discharge	Runoff mm	Low flow
		km <sup>2</sup>	million m <sup>3</sup>	m <sup>3</sup> /sec		m <sup>3</sup> /sec
1	Sekong	28,500	32,200	1,368	1,310	40
2	Sesan	17,100	17,300	547	1,010	28
3	Sre Pok	29,450	29,800	942	1,010	118
4	Prek Preah	1,510	760	24	505	3
5	Prek Krieng	2,450	1,240	29	505	5
6	Prek Kampi	1,150	580	18	505	2
7	Prek Te	4,170	2,530	80	610	10
8	Prek Chhlong	5,750	2,910	92	505	3
9	Stung Chinit	4,130	1,360	43	330	3
10	Stung Sen	14,000	6,190	196	440	8
11	Stung Staung	1,900	840	27	440	1
12	Stung Chikreng	1,030	450	14	440	1
13	Stung Streng	32,101	1,140	36	355	1
14	Stung Sisophon	4,310	1,900	60	440	2
15	Stung Mongkolborei	2,700	1,980	63	730	3
16	Stung Battambang	2,135	1,960	62	920	3
17	Stung Pursat	4,480	1,660	52	370	1
18	Prek Thnot	5,050	1,560	49	310	1
19	Stung Kratie	646,000	441,600	13,974	680	1,750

Source: MOWRAM (2001); Inventaire des ressources hydrauliques du bassin inférieur du Mekong, Resumé des possibilités de projets (WATCO1984)

The Mekong system in Cambodia is characterized by the nature of the Tone Sap Lake. The lake functions as a natural flood retardation reservoir in which some 20% of the flood volume of the Mekong River are regulated by reverse flows mainly during the months between June and September. The remaining 80% spread over the delta lowland of the country, as well as in the delta in Viet Nam. During the monsoon flood season the overflow from the Mekong is diverted, expanding the size of the Lake area in many times, sitting and fertilizing the rice plain, and providing abundant supplies of fish. By September/October, the volume of water in the Lake increases to 72 billion m<sup>3</sup> and the surface area expands to 16,000 km<sup>2</sup>. As the water level in the Mekong subsides, fall, the water starts draining back, enhancing the dry season flows downstream, and the lake eventually shrinks to about 2,700 km<sup>2</sup> with the volume of 1.3 billion m<sup>3</sup>. The annual water rise in the Mekong River also causes extensive flooding in the Mekong Basin delta. A part of land is utilized for agricultural purposes and is less than 5 m above the sea levelin the downstream strtch of the Phnom Penh.

The flow of the Mekong River is closely linked to the rainfall pattern. Large areas of Cambodia around the Tonle Sap, Tonle Bassac and Mekong Rivers are flooded during the rainy season. Thus, the Great Lake region functions as a large natural retarding reservoir for storing flood water. Any pollution generated along the rivers and especially around Chaktomuk may be transported during the rainy season to the Great Lake, thus causing damage to the flora.

The rich natural resources of the Mekong River and its tributaries contribute not only to Cambodia, but also to the neighboring riparian countries, playing an important role in socio-economic development.

Water level and stream flow data in the Cambodia had recorded at 35 and 22 stations before 1975, when the hydrological network was abandoned. In the 1980s, attempts were made to rehabilitate the stations but these met with only limited success. Since

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1995, some 28 stations have been rehabilitated by MOWRAM under the contract with MRC. It was planned to have a network of some 40 water level/stream flow stations in Cambodia by the end of 2001.

## I.1.6 Hydrogeology

According to the MOWRAM (2001), hydrogeological characteristics in the Cambodia are described as follows:

Groundwater is currently used in Cambodia for community and town water supply and for irrigation. There have been two studies, both under the auspices of the US Geological Survey. The first (Cushman, 1958) was a reconnaissance of the lowland area, to determine the availability of groundwater for dry season irrigation. The second was a general description of groundwater availability based on test drilling data and well records obtained in the course of a USAID rural well development programme between 1960 and 1963. At that time, the programme drilled 1,100 wells, of which 72% were productive. Depths ranged from 2 m to 209 m, with an average of 23 m. Information is also available from well drilling programmes undertaken by NGOs and international organizations since the 1980s. In particular by OXFAM and UNICEF, the latter having been responsible for drilling more than 5,000 wells throughout the country, generally to depths of 20 m to 50 m. The most recent information on those wells, mainly relates to their location and characteristics (Compiled by Pang Peng, 1998).

To date, some 15,000 wells of various types have been installed but the use of groundwater for irrigation has been limited.

The geology of the Mekong lowland consists broadly of alluvial material overlying shale, slate and sandstone bedrock. The low hills and plateau areas situated above the general level of the plain are generally underlain by igneous intrusion or limestone. The depth of the alluvium is 70 m or more. The alluvium consists of sandy silt in the upper part and of clayey silt in the lower. There are occasional sand beds of up to 1.0 m thickness. Two types of alluvium are recognized, an older one and a younger one. The younger alluvium is situated under the Mekong and Tonle Sap Lake flood plain.

Except for the occasional thin sandy beds and lenses, the alluvium is of low hydraulic conductivity and the rate of yield is very low, typically 0.2 l/s (17.3 m<sup>3</sup>/d). Yields from the sandy layer are higher, typically of the order of 1 l/s (86 m<sup>3</sup>/d). For those wells that have UNICEF records, almost 7,600 yield more than 3 l/s (260 m<sup>3</sup>/d), while less than 3% are reported as having yields in excess of 10 m<sup>3</sup>/hr (240 m<sup>3</sup>/d).

From a hydrogeological point of view, Anderson (1978) described the Mekong Delta region. The brief hydrogeological conditions of a part of the Study area are mapped in the "Hydrological Map of Lower Mekong Basin" (**Figure I.1.6**).



Source: Mekong Secretariat (1992)

Figure I.1.6 Hydrogeological Map of Cambodia

In June 1996, the Japanese Government has signed an agreement to fund a project to supply clean water to the Phnom Penh municipality and rural areas by using groundwater. About 30% of this groundwater were obtained around Phnom Penh. No artesian aquifers were found, the area being underlain at depths ranging from 18 m to 80 m by hard crystalline rock. The best well yielded 200 l/min (280  $m^3/d$ ), and the average of seven production wells was 80 l/min (115  $m^3/d$ ).

Detailed evaluations of groundwater quantity have been conducted in 2002 by JICA<sup>4</sup>. Five provinces (Kandal, Prey Veng, Takeo, Kompong Speu, Svay Rieng) have been covered. A further two provinces, Kompong Cham, Kompong Chhnang are included in a follow-up programme. GTZ/IFAD may carry out similar survey in Kompong Thom and Kampot.

According to the groundwater quality survey in the five southern provinces by JICA (2002), multi-layered aquifer can be found in quaternary layers in the eastern section of the Mekong River. Groundwater development potential is, therefore, considered high in this area. In the western section, aquifers are found in the weathered zone and fissures of basement rocks. The groundwater development potential in this area is comparatively low. The results of test drilling and pump tests in the 24 villages were used to determine the optimal well in the hydrogeological units as shown in the **Table** below:

<sup>&</sup>lt;sup>4</sup> The Study on Groundwater Development in Southern Cambodia, JICA, Kokusai Kogyo, Jan. 2002.

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Table I.1	.2 Optimal Well Yield in Southern	Provinces
Hydrogeological Divisions	Area	Optimal Well Yield
Quaternary Aquifers	Svay Rieng, Prey Veng, southern Kandal	$500 \sim 800 \text{ m}^3/\text{day}$
Basement Rock Aquifers	Peri-Urban Areas, northern Kandal, Kompong Speu, Takeo	1.5 ~ 150 m <sup>3</sup> /day

Source: The Study on Groundwater Development in Southern Cambodia, JICA, Kokusai Kogyo, Jan. 2002.

Although, the results of the groundwater quality survey in the 260 villages by above Study (JICA, 2002), arsenic (As) of more than 0.01 mg/l (WHO guideline) was found at 9 target villages. High arsenic zone is located in the alluvial lowland along the Mekong and Tonle-Bassac Rivers (Kandal and Prey Veng Provinces and urban districts of Phnom Penh). A more comprehensive survey was proposed. Also, groundwater quality in the west bank of the Mekong River tends to have high levels of sodium (Na) ions and chloride (Cl). On the other hand, the level of ferrous (Fe) ions in groundwater in this area is high; ferrous ions in water from most wells exceed the WHO level (0.3 mg/l).

## **I.2** WATER RESOURCES POTENTIAL IN THE GROWTH CORRIDOR

#### I.2.1 Surface Water

Mean monthly flows at available gauging stations in the Study Area are shown in the **Table** below.

River	Station	Province/			Mean Monthly Discharge (m <sup>3</sup> /sec)							Annual	C.A.				
		Municipality		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	(m <sup>3</sup> /s)	(km <sup>2</sup> )
Mekong	Phnom Penh	Phnom Penh	*1	3,450	2,380	1,980	1,890	2,800	9,510	21,660	33,370	37,680	24,420	11,400	6,200	13,062	663,000
Prek Thnot	Anlong Touk	Kampong Spueu	*1	2	1	1	3	16	26	35	67	105	141	44	8	37	3,650
Kamchay	Proposed Dam Site	Kampot	*2	2.1	3.4	13.2	34.1	57.1	74.1	108.1	153.1	90.6	88.1	28.4	5.3	55.2	709
Preak Tuek Sub	Kbal Chay WL St.	Sihanoukville	*3	0.8	0.3	0.4	0.8	3.2	6.7	6.0	12.7	6.0	7.5	3.2	1.3	4.1	46
Huai Soto	Huai Soto	Thailand (near Pursat	4	1.6	1.0	0.9	1.1	3.8	14.0	18.3	28.8	24.4	17.7	6.1	3.0	10.1	190
Source *1) : *2) :	Source *1): Irrigation Brahubilitation Study in Cambodia, Medong Secretariat, Halterow, June 1994. *2): Emarchar Mythorescher Projet Fenshillty Study, MME, Expero International, June 2002. (Extended flow record 1931-1993).																

 Table I.2.1
 Mean Monthly Discharge at Key Stations in Study Area

\*3): River cross section survey and daily discharge estimation by JICA Study Team (2002). Daily gauge height record from Hydrology office, Department of Water Resources and Meteorology, Sihanoukville (Feb.2001 - Aug 2002) \*4): Pertnimary Study on the Stumg Mann Hydrologterin Power Project, Elsevicir Power Development Company (EPDC) Japan, Sep. 2001.

In general, annual total surface water is abundant in the Study Area. However, approximately 85~90% of annual flow occurs during the rainy season from May to November. In rainy season, flood damage occurrs annually. On the contrary during dry season, some rivers are almost dried-up. At the Anlong Touk gauging station of the Prek Thnot River, which is located at upstream of the town of Kompong Speu, average minimum and 80% reliable monthly mean discharge are occurred in February and March at only 1 m<sup>3</sup>/s and 0.2 m<sup>3</sup>/s respectively<sup>5</sup>. At the Kbal Chay gauging station of the Prek Tuek Sub River, which is located in the Sihanoukville municipality, the river flows is almost dried-up during dry season. On the other hand, rivers in the coastal area of the plateau and mountain area in the Kampot and Koh Kong Provinces, have abundant flow comparatively in the Study Area.

The average runoff coefficient of above key gauging station can be estimated by

<sup>&</sup>lt;sup>5</sup> Irrigation Rehabilitation Study in Cambodia, Mekong Secretariat, Halcrow, June 1994.

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#### annual rainfall and runoff rate as shown in Table I.2.2.

River	Station	Province/	C.A.	Annual	Annual	Annual	Runoff	
				Rainfall	Runoff	Runoff	Coefficient	
		Municipality	(km <sup>2</sup> )	(mm)	(m <sup>3</sup> /s)	(mm)	(%)	
Prek Thnot	Anlong Touk	Kampong Speu	3,650	1,900 <sup>*1</sup>	37	323	17.0%	
Kamchay	Proposed Dam Site	Kampot	709	3,100 *2	55.2	2,455	79.2%	
Preak Tuek Sub	Kbal Chay WL St.	Sihanoukville	46	3,220 *3	4.1	2,792	86.7%	
Huai Soto	Huai Soto	Thailand (near Pursat)	190	3,100 *4	10.1	1,670	53.9%	

Table I.2.2 Runoff Coefficient at Key Stations in Study Area

Note \*1) : Annual rainfall from Isohyetal Map (Irrigation Rahabilitation Study in Cambodia, Mekong Secretariat, Halcrow, June 1994) \*2) : Kamchay Hydroelectric Project Feasibility Study, MIME, Experco International, June 2002.

\*3): Rainfall data from Hydrology office, Department of Water Resources and Meteorology, Sihanoukville (Feb.2001 - Aug.2002).
 \*4): Preriminary Study on the Stung Mnam Hydroelectric Power Project, Electric Power Development Company (EPDC) Japan, Sep. 2001.

#### I.2.2 Groundwater

In general, groundwater potential is comparatively low. Data on the yield of existing wells were corrected from Ministry of Rural Development (MRD), Sihanoukville Water Supply Authority and existing groundwater survey reports. Yield of existing wells in the Study Area are summarized in the Table below:

Zone (Region)	Province / Municipality	Major Hydrogeological Divisions	Range of Yield (m <sup>3</sup> /day)	Average Yield (m³/d)	Range of Well Depth (m)	Ave. Depth (m)				
Disin Degion	Phnom Penh	Basement Rock, Alluvium	$2.4 \sim 960^{*1)}$ $1.5 \sim 20^{*2)}$	<b>50.5</b> <sup>*1)</sup>	8.1 ~ 100 *1)	28.5 *1)				
Plain Region	Kandal	Basement Rock, Alluvium	1.5 ~ 150 <sup>*2)</sup>							
	Takeo	Basement Rock, Alluvium	1.5 ~ 150 <sup>*2)</sup>							
Plateau & Mountain	Kampong Speu	Basement Rock, Alluvium	$\begin{array}{c} 2.4 \sim 1900 \ ^{*1)} \\ 0 \sim 15 \ ^{*2)} \end{array}$	70.5 <sup>*1)</sup>	6 ~ 100 <sup>*1)</sup>	28.3 *1)				
	Kampot	Sand stone, limestone	N.A.	< 72 <sup>*3)</sup>	N.A.	N.A.				
Coastal Region	Koh Kong	Sand stone, limestone	N.A.	< 72 <sup>*3)</sup>	N.A.	N.A.				
	Sihanoukville	Sand stone, Silt stone	3.6 ~ 246 *1)	<b>58.1</b> <sup>*1)</sup>	16 ~ 72 <sup>*1)</sup>	31.8 *1)				
a	OTT 11 3 61 1		1000							

Table I.2.3 Well Yield in Study Area

Source \*1): Database of Well, Ministry of Rural Development, UNICEF, 1980.

\*2): Optimal yield. The Study on Groundwater Development in Southern Cambodia, JICA, Kokusai Kogyo, Jan. 2002.

\*3): Hydrogeological Map of Lower Mekong Basin, Bangkok Thailand (Scale 1:1,000,000), U.S.G.S., 1978.

Results of the groundwater quality survey in the 260 villages by JICA<sup>6</sup>, arsenic (As) of more than 0.01 mg/l (WHO guideline) was found at 9 target villages. High arsenic zone is located in the alluvial lowland along the Mekong and Tonle-Bassac Rivers (Kandal and Prey Veng Provinces and urban districts of Phnom Penh). A more comprehensive survey was proposed. Also, groundwater quality in the west bank of the Mekong River tends to have high levels of sodium (Na), ions and chloride (Cl). On the other hand, the level of ferrous (Fe) ions in groundwater in this area is high; ferrous ions in water from most wells exceed the WHO level (0.3 mg/l).

#### I.2.3 Water Balance

Preliminary hydrological water balance study for the eastern five (5) provinces (Kandal, Prey Veng, Takeo, Kompong Speu, Svay Rieng) have been also carried out

The Study on Groundwater Development in Southern Cambodia, JICA, Kokusai Kogyo, Jan. 2002.

Nippon Koei/ IDCJ/ KRI International

by JICA<sup>7</sup>. The data used for the water balance calculation were daily rainfall data from 1986 to 1995 and average monthly evaporation data for a period from 1929 to 1960 in Phnom Penh. Result of the water balance computation is summarized in the **Table** below.

Year	Rainfall	Evaporation	Interception	Surface	Evapo-	Soil Moisture	Groundwater	Recharge
	(Phnom Penh)	(Class-A Pan)	Loss	Runoff	Runoff transpiration		Recharge	Ratio
	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(%)
1986	1,351.3	1,348.3	21.0	75.8	797.0	8.6	448.9	33.2%
1987	1,551.8	1,348.3	17.1	147.0	738.7	8.0	649.6	41.9%
1988	1,369.0	1,353.0	26.1	118.9	839.0	7.0	386.1	28.2%
1989	1,437.7	1,348.3	21.5	183.2	701.6	7.0	531.5	37.0%
1990	1,142.1	1,348.3	19.8	34.1	732.5	7.8	354.9	31.1%
1991	1,253.6	1,348.3	20.2	98.7	686.4	2.9	453.2	36.2%
1992	1,094.8	1,353.0	25.0	53.1	703.8	0.4	315.4	28.8%
1993	1,327.3	1,348.3	22.6	77.9	758.1	11.3	457.8	34.5%
1994	1,223.6	1,348.3	23.0	107.0	727.6	1.8	375.5	30.7%
1995	1,413.3	1,348.3	24.5	124.3	754.8	1.5	510.0	36.1%
Average	1,316.5	1,349.2	22.1	102.0	744.0	5.6	448.3	34.1%
(%)	100.0%		1.7%	7.7%	56.5%	0.4%	34.1%	

 Table I.2.4
 Estimated Water Balance in the Southern Cambodia

Source: The Study on Groundwater Development in Southern Cambodia, JICA, Kokusai Kogyo, Jan. 2002.

## I.3 PRESENT CONDITION OF WATER INFRASTRUCTURES

## I.3.1 Irrigation and Drainage

Cambodia is an agricultural country. Approximately 84% of the population lives in rural areas and 80% are farmers. Hydraulic engineering for irrigation and water supply was developed to a very high level in Angkorian times, but many facilities built under the French and Khmer Rouge regime are required to rehabilitate at present.

In Cambodia, only about 16.6% (473,000 ha in 1998) of the total rice-growing area (1.93 million ha) presently receives supplementary irrigation water. About 83% of the total cultivated area are fully dependent on rain (rain-fed); a "flood-recession" system of production is used on 7% of the area, and deep-water floating rice on 6% (source: MOWRAM). However, given the temporal variability of rainfall patterns crop production is often threatened by drought, so that the production of supplementary crops is not possible. Almost all the rice area is single-cropped, resulting in low production. Distribution of the rice cropping area by water source type in the Cambodia was illustrated as shown in the **Figure** below (Irrigation Rehabilitation Study in Cambodia, Mekong Secretariat, Halcrow, June 1994).

<sup>&</sup>lt;sup>7</sup> The Study on Groundwater Development in Southern Cambodia, JICA, Kokusai Kogyo, Jan. 2002.

Nippon Koei/ IDCJ/ KRI International



Source : Irrigation Rehabilitation Study in Cambodia, Mekong Secretariat, Halcrow, June 1994.

Figure I.3.1 Rice Cropping Areas by Province

**Figure I.3.2** and **Table I.3.1** shows the cultivated area of rice paddy during wet and dry seasons in the Study Area by Province. As shown the **Figure** below, almost all the rice paddy area is single-cropped except Kandal and Takeo Provinces at present.



Figure I.3.2Cultivated Paddy Area in Study Area (Year 2000)

PROVINCE	Season	1980	1985	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
ALL CAMBODIA	Wet	1,346	658	854	896	832	1,702	1,754	928	945	1,827	888	1,916	2,061
	Dry	99	132	158	164	155	155	170	216	214	228	211	242	262
Phnom Penh	Wet	2.1	2.0	12.0	12.0	8.9	8.0	8.6	8.6	7.7	7.8	8.0	8.0	8.0
	Dry	0.3	1.0	1.0	1.0	0.8	0.6	1.3	1.3	1.3	1.2	1.1	1.2	0.6
Kandal	Wet	55.0	48.0	57.0	57.0	47.0	45.2	45.0	48.5	46.8	42.9	44.2	45.1	48.1
	Dry	25.0	30.0	36.0	38.0	34.0	39.0	38.8	44.1	45.0	46.0	44.2	46.4	48.0
Sub Total (Metropolitan)	Wet	57.1	50.0	69.0	69.0	55.9	53.2	53.6	57.1	54.6	50.7	52.1	53.1	56.1
Sub Total (Metropolitan)	Dry	25.3	31.0	37.0	39.0	34.8	39.6	40.1	45.4	46.3	47.2	45.3	47.6	48.6
Takeo	Wet	144.5	110.0	172.0	181.0	176.3	174.2	185.2	184.9	188.1	170.6	170.6	176.1	182.3
	Dry	23.5	32.0	39.0	40.0	40.0	42.0	42.6	52.7	57.0	61.0	58.3	59.0	49.1
Kompong Speu	Wet	63.0	65.0	79.0	80.0	67.9	65.4	77.8	84.7	86.4	81.9	83.6	86.6	85.5
	Dry	-	1.0	1.0	2.0	1.4	1.0	1.0	1.0	1.3	1.0	1.0	1.1	1.0
Kompot	Wet	78.5	98.0	102.0	112.0	110.6	102.3	123.7	132.2	136.1	136.5	130.5	136.0	141.3
	Dry	0.5	2.0	2.0	1.0	1.3	1.0	1.0	2.0	2.6	4.7	1.0	2.5	5.0
Kaoh Kong	Wet	8.0	6.0	5.0	6.0	5.3	4.7	3.5	5.2	7.4	7.3	7.1	7.5	8.5
	Dry	-	-	-	-	-	-	-	-	-	-	-	-	-
Sub Total (Mid Area)	Wet	294.0	279.0	358.0	379.0	360.1	346.6	390.2	407.0	417.9	396.4	391.9	406.2	417.6
	Dry	24.0	35.0	42.0	43.0	42.7	44.0	44.6	55.7	60.9	66.7	60.3	62.6	55.1
Sihanouk Ville	Wet	9.0	9.0	10.0	12.0	9.9	8.4	9.3	8.8	9.1	9.5	9.6	9.6	9.5
1	Dry	-	-	-	-	-	-	-	-	-	-	-	-	na

 Table I.3.1
 Paddy (Rice) Area Cultivated by Province in Study Area 1980 -2000

Note: Details may not add up to totals due to rounding.

While, the total irrigation potential of the Cambodia amounts to 1,667,300 ha have been estimated as shown in **Table I.3.2** and **Figure I.3.3**.

Water Source	Irrigation Potential (in ha)
Mekong Main Stream	734,000
Mekong Tributaries	253,000
Mekong Flooded Area	179,000
Tonle Sap Tributaries	358,900
Outside Mekong Basin	142,400
Total	1,667,300

 Table I.3.2
 Irrigation Potential Area in the Cambodia

Sources: Inventory of Promising Water Resources Projects Outside the Mekong Basin in the Khmer Republic, November 1973; Summary of Project Possibilities of Lower Mekong Water Resources Inventory, September 1994; The Agricultural Development Study of the Mekong Flooded Area in Cambodia, March 1998 (all reported in Veng Sakhon, 2000).



Figure I.3.3 Irrigated Land in 1990 and Possible Reservoir and Irrigation Projects However, due to lack of infrastructure - diversion structures, dams, etc. - to store wet season water for dry season irrigation, remarkable volume of water pours into to the sea. It is noted that if Cambodia attained food self-sufficiency, food security is still a goal to be achieved. Irrigation plays a key role in the efforts to achieve this goal, which is part of the overall national goal of poverty reduction through socio-economic development.

Given the high irrigation potential, there is ample scope for irrigation rehabilitation and for the development of irrigation in the short, medium and long term. As a starting point, the Government plans to increase the total irrigated area from 16.62% to 20% by 2003, in addition to the existing irrigated area (source: MOWRAM).

Most of the present irrigation schemes were formulated in the Khmer Rouge regime, and were not designed according to standards at the outset, thus being the cause of increased flooding and uncontrolled drainage. These schemes now require rehabilitation to provide improved drainage, flood protection and access to water for supplementary irrigation. Irrigation has to harness all water resources, whether surface water or groundwater. Inventory of existing irrigation systems in the Study Area is shown in the **Table** below.

	Neursteinief	Total Area of System Reported (ha) <sup>*1)</sup>						
Province	Systems Reported <sup>*1)</sup>	Exis	ting	Potential				
Tiovince		Wet	Dry	Wet	Dry			
	Reported	Season	Season	Season	Season			
Phnom Penh	N/A.	N/A.	N/A.	N/A.	N/A.			
Kandal <sup>*2)</sup>	114	11,582	21,200	14,224	35,956			
Takeo	43	12,445	41,640	13,319	45,895			
Kompong Speu	95	18,558	743	32,388	3,247			
Kampot	23	4,980	1,370	14,940	10,415			
Koh Kong	N/A.	N/A.	N/A.	N/A.	N/A.			
Sihanouk Ville	N/A.	N/A.	N/A.	N/A.	N/A.			

 Table I.3.3
 Existing and Potential Irrigation Systems in the Study Area

Source: Irrigation Rehabilitation Study in Cambodia, Inventory & Analyses of Existing System, Vol.1 Main Report, Mekong Secretariat, Halcrow, April 1994.

Notes \*1) : Excluded systems less than 10 ha in area.

\*2) : Includes 2 systems in Phnom Penh Municipality N/A. : data not available

The distribution of cropping pattern in each Province is shown in **Table I.3.4**. Yields vary considerable from Province to Province as shown in **Table I.3.5**. Based on the inventory statistics the highest yielding Province in the Study Area is Kandal.

14010 1.5	Table 1.5.4 Cropping I attern and Ticlus in the Study Area												
	Number of	f Operation	al Irrigatio	on Systems	Ave	rage							
Drovince	Cro	pping Patte	ern	-	Yield (t/ha)								
Flovince	Wet	Double	Reces-s	Total	Wet	Dry							
	Season		ion		Season	Season							
Phnom Penh	N/A.	N/A.	N/A.	N/A.	N/A.	N/A.							
Kandal <sup>*2)</sup>	11	8	94	113	1.9	3.3							
Takeo	7	15	27	49	1.2	2.0							
Kompong Speu	73	21	0	94	1.3	2.0							
Kampot	9	10	0	19	1.7	2.2							
Koh Kong	N/A.	N/A.	N/A.	N/A.	N/A.	N/A.							
Sihanouk Ville	N/A.	N/A.	N/A.	N/A.	N/A.	N/A.							

Table I.3.4	Cropping Pattern and Yields in the Study Area

Source : Irrigation Rehabilitation Study in Cambodia, Mekong Secretariat, Halcrow, June 1994. Notes) N/A. : data not available

Table I.3.5	Average Yield of Padd	v Rice by Province	1980, 1985	1990 - 2000
		,		, _// 0 _000

												(Ton	s/hectare)
PROVINCE	1980	1985	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
ALL CAMBODIA	1.19	1.25	1.34	1.39	1.31	1.31	1.49	1.79	1.84	1.78	1.79	1.94	1.97
Phnom Penh	1.10	1.33	1.58	2.11	1.43	1.18	1.68	1.89	2.30	1.80	2.07	1.84	2.00
Kandal	1.21	1.86	1.38	1.92	2.32	2.06	3.18	2.66	2.83	2.58	2.69	2.61	3.14
Sub Total (Metropolitan)	1.21	1.84	1.40	1.94	2.23	1.97	3.04	2.76	2.76	2.50	2.63	2.73	3.06
Takeo	0.99	1.32	1.50	1.58	1.46	1.49	1.28	1.90	2.04	2.64	2.01	2.40	2.63
Kompong Speu	1.50	1.20	1.20	1.28	1.25	1.29	1.36	2.17	1.95	1.49	1.42	1.82	1.87
Kompot	1.18	1.41	1.90	1.31	1.20	1.12	1.34	1.66	1.61	1.80	1.64	2.26	2.19
Kaoh Kong	1.25	1.33	1.80	1.33	1.23	1.27	1.43	1.59	1.30	1.53	1.26	1.30	1.23
Sub Total (Mid Area)	1.14	1.32	1.55	1.44	1.35	1.35	1.31	1.87	1.88	2.15	1.77	2.24	2.29
Sihanouk Ville	1.44	1.12	1.70	1.67	1.21	1.29	1.18	1.71	1.85	1.70	1.60	1.78	1.75
Source : Ministry of Agricul	ture, Forestr	y and Fishe	ries, (Agricu	ultural Statis	stics Bulletin	1)							

Existing irrigation systems which have good economic potential and record of success or potential for low cost rehabilitation were evaluated by the "Irrigation Rehabilitation Study in Cambodia" (Mekong Secretariat, Halcrow, 1994). The results of the evaluation of existing irrigation systems in the Study Area are shown in the **Table** below.

Table I.3.6         Existing Irrigation Systems in the Study Area									
				Econ	omic		Low		
Duovinos	Catahmant	Irrigation	System	Pote	ntial	Successful	Cost	Sta-	EIRR
Flovince	Catchineitt	System Name	No.	G - 11	Weter	Systems	(Reces	tus	%
				5011	water		sion)		
Phnom Penh	Prek Thnot	Prateaslang	DK1			F		Μ	
			KST1,						
Kandal	Prek Thnot	System No.63, Canal	KST2,			F		Μ	
			PP4						
Kandal	Lake Side 1b	Ta Mouk Reservoir	PL1			F	R	S	23
Kandal	Mekong Riverine	O Andoung Gate	SA3			Ex	R	S	22
Kandal	Mekong Riverine	Maleach Krobeaykon	KT1			F	R	-	
Kandal	Mekong Riverine	Sras Bram Beay	KT2			F	R	-	
Kandal	Mekong Riverine	Toul Khtom	KT3			F	R	-	
Kandal	Prek Thnot	Kompong Tram	PP4			F		Μ	
Kandal	Mekong Riverine	Boeng Thom Reservoir	KSV1			Ex		S	
Kandal	Mekong Riverine	Boeng Chomno	KSV2			F	R	-	
Kandal	Mekong Riverine	Kvenh Dach Reservoir	KSV3			F	R	-	
Kandal	Mekong Riverine	Tasen	MP1				R	-	
Kandal	Mekong Riverine	Chhey Thom	KD12			F		-	
Takeo	South Catchments	Koh Chhoeung Damrey Res	KV5			F	R	-	
Takeo	South Catchments	Dang Kgnorm Reservoir	TK2				R	-	
Takeo	Mekong Riverine	Canal 15	TK1				R	-	
Takeo	Mekong Riverine	Takeo River	T4			F	R	S	-
Takeo	Mekong Riverine	Thnot Konchhrung	KA1				R	-	
Takeo	Mekong Riverine	Ang Kok Reservoir	KA2				R	-	
Takeo	Mekong Riverine	Canal 92	KA4			F	R	-	
Takeo	Stung Slakou	Takeo Reservoir	TK3	0	0			Μ	
Takeo	Stung Slakou	Thnot Te Reservoir	SR1			F		ADB	
Takeo	Stung Slakou	Doeunm Krolanch Reservoir	SR2			F	R	-	
Takeo	Prek Toul Lokok	Ang Bot Rokar Resevoir	SR4			F	R	-	
Takeo	Prek Toul Lokok	Sen Pe Ream Reservoir	SR6				R	-	
Takeo	Mekong Riverine	Thorm Viney	SR9				R	-	
Takeo	Mekong Riverine	Kompong Chak Reservoir	PK3				R	-	
Takeo	Mekong Riverine	Canal 03	BCH1			F	R	S	21
Takeo	Mekong Riverine	Canal 87	AB1				R	-	
Takeo	Mekong Riverine	Komnop Reservoir	AB2			F	R	-	
Takeo	Mekong Riverine	Ton Leap Reservoir	KV1			F	R	-	
Takeo	Prek Thnot	Kompong Damrei Reservoir	BT2	0	0			Μ	
Takeo	Prek Thnot	Kompong Dan Ko	BT3				R	-	
Vomeono Snou	Duals Thuat	Chan Thnal, Relang Chrey &	OD1,			Б	1	м	
Kampong Speu	Piek Thilot	Chen Ke	St1, Pt2			r		IVI	
Kampong Speu	St. Karang Ponley	Krope Trom	OD2			F		Μ	
Kampot	South Catchments	Trapeang Boeng Dam	CH1			F		S	12
Kampot	South Catchments	Pasla Dam	DT1			F		-	

Source: Irrigation Rehabilitation Study in Cambodia, Mekong Secretariat, Halcrow, June 1994.

Notes) O : Good Condition of Soil / Water

Ex : existing yield > 2 t/ha in wet season and/or 3 t/ha in dry season.

F : future yield > 2 t/ha in wet season and/or 3 t/ha in dry season.

L : Recession Cropping

M : Catchment master plan required, S : Shortlisted for pre-feasibility study,

: Not shortlisted for pre-feasibility study or master plan.

(Recession cropped schemes can be treated in dependently of master plans for the purpose of rehabilitation)

## I.3.2 Water Supply

#### (1) Urban Water Supply System

In the Study Area, there are 9 towns have access to piped water supply at present (see **Table** below). Four (4) water supply were operated by a private sector, which include a BOT (Built-Own-Transfer) project in Kampong Speu.

		Table	I.3.7 Existing	g Urba	an Wate	er Supj	ply Sys	stems i	n Stud	ly Are	a
No.	Province	District	Name of Water Supply	Manage- ment	Established Year	District Population (1998 Census) (nos.)	Poplation of Served Communes (1998) (nos.)	No. of Connec- tions (2001) (HH)	Estimate Household Size (nos/HH)	Estimated Supply Population (2001) (nos.)	Service Ration (2001) (%)
1	Phnom Penh	Peri-Urban	Phnom Penh Water Supply Authority (PPWSA)	Authority	1895, 1991	999,804	999,804	74,945			** 65%
2	Kandal	Ta Khmau (U)	Ta Khmau Water Utility	Public	1942	58,264	41,171	968	8.0	7,744	19%
3	Kandal	Kien Svay	Mekong Water Electric Supply	Private	1998	148,358	59,791	1,105	8.0	8,840	15%
4	Takeo	Doun Kaev (U)	Water Supply Company of Doun Kaev District	Private	1958, 1993	39,186	28,276	634	8.0	5,072	18%
5	Kampong Spueu	Chbar Mon (U)	Kampong Spueu Province Water Supply Company	Private (BOT)	1997	41,478	52,092	1,915	8.0	15,320	29%
6	Kampong Spueu	Odongk	Odongk Water Supply	Private	1983	99,773	6,556	800	5.3	4,240	65%
7	Kampot	Kampong Bay (U)	Kampot	Public	1951	33,126	28,042	1,346	8.0	10,768	38%
8	Kaoh Kong	Smach Mean Chey (U)	Koah Kong Waterworks	Public	1998	29,329	29,329	367	8.0	2,936	10%
9	Krong Preah Sihanouk Ville	Mittak Pheap (U)	Sihanoukville Water Supply Authority (SWSA)	Public	(1959) 1994	67,440	66,723	1,204	8.0	9,632	14%

No	Province	District	Design	Present	Daily	Poto of	Watar	Watar	Present	Watar	Capacity	Tune	Dietri	Ent
NO.	Flovince	District	Capacity	Capacity	Average	Facility	Tariff	Production	Water	Source	of	of	bution	Rehabilitation
			cupacity	(2002)	Production	Utilization		Cost	Demand	bource	Water	Treatment	System	Plan. Donor
				,		(2002)					Source	Plant		
			(m <sup>3</sup> /d)	(m <sup>3</sup> /d)	(m <sup>3</sup> /d)	(%)	(Riel/m <sup>3</sup> )	(Riel/m <sup>3</sup> )	(m <sup>3</sup> /d)					
1	Phnom Penh	Peri-Urban	235,000 (2003)	120,000			350			River (Mekong, Tonle Sap, Bassac)	Enough	Sedi	Pump	
2	Kandal	Ta Khmau (U)	1,200	1,200	700	58%	900	888	?	River, GW	Enough (Riv), Limited (GW)	Clarifier	Gravity (TP), Pump(Well)	Social Fund, O going
3	Kandal	Kien Svay	1,500	1,500	300	20%	1,200 (Industry) 1,400 (Domestic)	1,050	> 300	River	Enough	Sedi	Gravity	
4	Takeo	Doun Kaev (U)	1,300	1,300	200	15%	1,800	?	200	Lake	Enough	Sedi	Gravity	
5	Kampong Spueu	Chbar Mon (U)	1,400	1,300	550	42%	1,500	1,125	> 550	Prek Thnot River	Limited (Dry)	Sedi	Gravity	
6	Kampong Spueu	Odongk	1,500	1,500	400	27%	1,500	1,200	500	Reservoir	Enough	Sedi	Gravity	
7	Kampot	Kampong Bay (U)	4,800	4,800	2,500	52%	1,200	1,166	5,000	Kamchay River	Enough	Clarifier (*not use)	Gravity	ADB, (On going)
8	Kaoh Kong	Smach Mean Chey (U)	>1,000	>1,000	Dry:340, We t: 0	34%	15B=1,300	?	> 1,000	Reservoir	Limited (Dry)	Clarifier	Gravity	
9	Krong Preah Sihanouk Ville	Mittak Pheap (U)	8,000 (2003)	3,000	2,500	83%	$1 \sim 15 \text{ m}^3/\text{M} : 1,000,$ $16 \sim 100 \text{ m}^3/\text{M} : 1,400,$ $> 100 \text{ m}^3/\text{M} : 1,540.$	1,114	> 5,000	Lake, GW	Limited (Dry)	Mechanical Clarifier	Gravity	WB, (On going)
	Source : MIME; PPWSA; JICA Expert Report; Dept. of IME Dry: Dry Season GW: Groundwater Sedi: Flocculation and Sedimentation Basin													
	Wet: Wet Season *: Not in use													

About 65% of the population in the service area of the Phnom Penh and Odonhk, and from 10 to 38% of that in other towns have access to piped water supply. 714,425 people in total are supplied by piped water, which is only 16.7% of total population of the Study Area at present.

As shown in the Table below, the plant capacity of existing water supply systems are more than  $1,000 \text{ m}^3/\text{day}$ . Surface water (rivers, lakes, and reservoirs) are mostly used for the sources of water of the water supply systems. All systems have treatment plant. However, in the Kampot, existing treatment facilities dose not works properly because of too old and poor maintenance. They distributed law water to supply systems at Kampot.

## 1) Sihanoukville Water Supply System

In the Sihanoukville, existing plant capacity of the water supply system is only 3,000  $m^3$ /day in average and the service ratio is only 13% of the population in the service area in 2002. The World Bank tunded project is on going to extend the capacity up to 6,000  $m^3$ /day in average (maximum 8,000  $m^3$ /day) by the increase of capacity of existing reservoir "Lake Boeng Prek Tup" and additional drilling of 3 wells. The

planned house connection rate at the end of 2003 is to be 50% of the population (4,000 households) in the service area.

The expansion project (funded by World Bank) is on going to extend to the capacity of  $6,000 \text{ m}^3/\text{day}$  (service ratio of 50% for 4,000 households) by increasing capacity of existing reservoir "Lake Boeng Prek Tup" and additional development of 3 wells as summarized below.

-	Project Period :	1999 - 2002
-	Budget : 3.95 r	nillion US\$ (World Bank)
	1.00 r	nillion US\$ (Government of Cambodia)
	4.95 r	nillion US\$ TOTAL
-	Water Source and Sup	oply Capacity:
	1) Lake Boeng Prek	Γup: Catchment Area = 270 ha.
		$V = 290,000 \text{ m}^3$ (original capacity, 2001)
		$V = 400,000 \text{ m}^3$ (rehabilitated, 2002)
		Supply Capacity (Lake) = $4,000 \text{ m}^3/\text{day}$ (2002)
	2) Groundwater (Wel	l): 3 wells (newly installed in 2002)
		Production well No.1 Yield $= 600 \text{ m}^3/\text{day}$
		Production well No.2 Yield = $720 \text{ m}^3/\text{day}$
		<u>Production well No.3 Yield</u> = $480 \text{ m}^3/\text{day}$
		Supply Capacity (Well) $= 1,800 \text{ m}^3/\text{day}$
	Capacity of Treatmen	t Plant : Max.= $8,000 \text{ m}^3/\text{day}$ , Average = $6,000 \text{ m}^3/\text{day}$
	Service Ratio :	
	Oct. 2002 (existing)	: 1,400 household
	end of 2003 (Plan)	: 4,000 household

However, future water demand projection in the Sihanoukville was estimated by World Bank study<sup>8</sup> that will be increased from 11,857 m<sup>3</sup>/d (minimum shortfall for year 2015) to 55,800 m<sup>3</sup>/d (maximum shortfall for year 2020). The capacity of water supply is required to increase.

## 2) Phnom Penh Water Supply System

Water supply in the Phnom Penh City is the responsibility of the Phnom Penh Water Supply Authority (PPWSA). Management of urban water resources is the responsibility of the Municipality of Phnom Penh (MPP), and the Ministry of Rural Development (MRD) is responsible for the rural water supply.

The Municipality's water supply system, which was constructed between 1895 and 1960, has deteriorated profoundly. Decades of civil war and neglect destroyed much of the city's infrastructure, with the water supply capacity shrinking from 155,000  $m^3$ /day in the 1960s to a paltry 63,000  $m^3$ /day by 1992. That was because not only of destruction of the facilities and also its neglected maintenance during the war, lack of

<sup>&</sup>lt;sup>8</sup> Cambodia Urban Water Supply Project, Sihanoukville Water Supply Authority, Draft Report on Long-Term Water Supply, Parsons, Jul., 1999.

spare parts equipment and other materials and shortage of power supply.

By 1992, less than 20 percent of the population received piped water, with the PPWSA, unable to meet the challenges. Staff water demoralized, under-paid and under-qualified; only 13% of connections had water meters; and only 28% of water production was actually sold. Of the water sold, the collection rate was only 50% with illegal connections being prolific. And yet since 1992, Phnom Penh's water infrastructure has undergone a transformation.

With the assistance of external funding and internal reforms, the PPWSA has been transformed into an efficient, self-financed, autonomous organization with a committed and enthusiastic workforce; a computerized billing system of customers, thereby improving customer collections; and earning revenues more than sufficient to cover maintenance and operating costs.

Water coverage now encompasses 100% of inner-city Phnom Penh and is being expanded to surrounding districts, with priority given to urban poor communities; bill collection has risen to 99% in 2002 (from 40% in 1993); and investment in the city's water infrastructure has led to a new 600-km distribution network, replacing the old 280-km network.

			-
Items	1992	Early 2000	End of 2001
Population	About 700,000	About 1,050,000	
Served Population	About 130,000	About 330,000	
Connected Households	About 20,000		74,945
Coverage	35%	60%	
Treatment Capacity	56,000 m <sup>3</sup> /day	120,000 m <sup>3</sup> /day	120,000 m <sup>3</sup> /day
		Phum Prek : 100,000 m <sup>3</sup> /d	Phum Prek : 100,000 m <sup>3</sup> /d
		Cham Carmorn: 20,000 m3/d	Cham Carmorn: 20,000 m3/d
Distribution Pipe Length	280 km		517.6 km
Service Hour	Intermittent, 12 hr/d	Stable, 24 hr/d	Stable, 24 hr/d
Supply Pressure	Almost 0	0 ~ 10 m	> 20 m
Water Quality	Undrinkable	Improved	Improved
Equipped Meter Ratio	12%	99.5%	99.99%
Collection Ratio	40%	91.7%	96.78%
Leakage Ratio	> 70%		23%
Source: DDWS A			

Table I.3.8 Improvement of Water Supply System in Phnom Penh

Source: PPWSA

After the civil war, several development/rehabilitation study and grant aid were conducted to Phnom Penh water supply system as shown in the Table and Figure below.

 Table I.3.9
 Development Study and Grant Aid to Phnom Penh Water Supply System

Study/Project	Scheme	Year	Contents
The Study on Phnom Penh Water Supply	Development	1993	- Master Plan Study
System	Study (JICA)		<ul> <li>Urgent rehabilitation Program</li> </ul>
Basic Design on Improvement of Water	Grant Aid	1993	- Improvement of Phum Prek water treatment
Supply Facilities in Phnom Penh (Phase-I)	(JICA)	~	plant (100,000 m <sup>3</sup> /d)
		1994	<ul> <li>Construction of reservoir</li> </ul>
			<ul> <li>Improvement of distribution pump</li> </ul>
			<ul> <li>Improvement of elevated tank</li> </ul>
Basic Design on Improvement of Water	Grant Aid	1997	- Renewal of distribution pipeline (67 km)
Supply Facilities in Phnom Penh (Phase-II)	(JICA)	~	- Supply of water meter
		1999	
Expansion Project of Phum Prek Water	Grant Aid	2001	- Expansion and rehabilitation of Phum Prek
Treatment Plant		~	W.T.P. (50,000 m <sup>3</sup> /d)



Figure I.3.4 Coordinated Assistance for PPWS

By 2004 (construction will carried out in end of March in 2003), it is predicted that the water supply capacity in the city will have increased to 235,000  $m^3$ /day, making it possible to supply reliable and safe drinking water to all Phnom Penh's 1 million inhabitants.

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Items	End o	of 2001	March, 2003 (Plan)			
Treatment Capacity	120,00	0 m <sup>3</sup> /day	235,000 m <sup>3</sup> /day			
	Phum Prek :	100,000 m <sup>3</sup> /d	Phum Prek :	150,000 m <sup>3</sup> /d		
	Cham Carmorn :	20,000 m <sup>3</sup> /d	Cham Carmorn :	20,000 m <sup>3</sup> /d		
			Chruoy Chang War:	65,000 m <sup>3</sup> /d		
Distribution Pipe Length	517	.6 km	733.0 km			

 Table I.3.10
 Water Treatment Capacity Plan of PPWSA

Source: PPWSA

## (2) Rural Water Supply

About 3.56 million people (83% of the total) were living in the rural areas. There is no definite data on the coverage of clean water supply in the Study Area, it is estimated that tube well with hand pump have a supply rate of 39.7% (1,697,580 people), assuming that each well services 180 persons. There are about 8,500 water supply wells reported in the Study Area as shown in the **Table** below.

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No.	Province	Province's Data			TOTAL	Total	Assumed No.	Population	Popuration	Coverage	
		Year	Unicef/MRD	NGOs	Private	DRWS (7/01)	PCB (6/00)	of User/Well	Served	(estimated)	Rate (%)
1	Phnom Penh	1983-2001	1,014			1,014	2,511	180	182,520	997,967	18.3%
2	Kandal	1985-2001	2,869	244	0	3,113	3,096	180	560,340	1,073,586	52.2%
	Sub-Total (Metropolitan)		3,883	244	0	4,127	5,607		742,860	2,071,553	35.9%
3	Takeo	1988-2001	1,596	405		2,001	1,962	180	360,180	789,710	45.6%
4	Kompong Speu	1985-2001	269	992		2,184	2,170	180	393,120	598,101	65.7%
5	Kampot	1987-2001	641	340		981	832	180	176,580	527,904	33.4%
6	Koh Kong	1992-2001	24	15	2	41	19	180	7,380	131,912	5.6%
	Sub-Total (Mid-Area)		2,530	1,752	2	4,284	6,038		937,260	2,047,627	45.8%
7	Sihanoukville	1989-2001	77	20		97	77	180	17,460	155,376	11.2%
	STUDY AREA TOTAL		6,490	2,016	2	8,508	11,722		1,697,580	4,274,556	39.7%

Table L3.11 Estimated Coverage Ratio of Drilled (Deen) Wells in Study Area

er Supply,

However, this figure is questionable considering that about 30% of the existing hand pumps are broken or not utilized because water produced is high in salinity or iron, etc (see Table I.3.12). As a result, many villages rely on nearby surface water source, e.g. pond, rivers and groundwater from hand-dug wells, despite the fact that some of these water sources get depleted in dry season.

No.	Province	Pump Well			(Shallow) Dug Well			Combination Well			Ponds		
		Good	Broken	Total	Good	Broken	Total	Good	Broken	Total	Good	Broken	Total
1	Phnom Penh	2,059	452	2,511	998	158	1,156	4	0	4	720	87	807
2	Kandal	1,753	1,343	3,096	460	177	637	541	5	546	593	160	753
	Sub-Total (Metropolitan)	3,812	1,795	5,607	1,458	335	1,793	545	5	550	1,313	247	1,560
3	Takeo	1,597	365	1,962	494	55	549	259	67	326	433	0	433
4	Kompong Speu	1,743	427	2,170	825	49	874	34	17	51	0	0	0
5	Kampot	445	387	832	0	0	0	0	0	0	165	0	165
6	Koh Kong	4	15	19	20	18	38	0	0	0	3	11	14
	Sub-Total (Mid-Area)	3,789	1,194	4,983	1,339	122	1,461	293	84	377	601	11	612
7	Sihanoukville	53	24	77	11	9	20	0	0	0	0	0	0
	STUDY AREA TOTAL	7,654	3,013	10,667	2,808	466	3,274	838	89	927	1,914	258	2,172
		71.8%	28.2%	100.0%	85.8%	14.2%	100.0%	90.4%	9.6%	100.0%	88.1%	11.9%	100.0%
Sou	Source : Department Rural Water Supply, Ministry of Rural Development (MRD), 2002.												

 Table I.3.12
 Well Statistic by Provinces in Study Area

Although water can be secured in the rainy season, the sources, i.e. ponds and dug wells, are exposed to human and livestock wastes as most area located near rice fields or ground depression to facilitates intake. Not proper maintained dug wells are common sources of water borne diseases.

According to the result of the study on Groundwater Development in Southern Cambodia (JICA, 2002), most of the villagers in the Study area obtain water from traditional sources such as ponds, rivers and shallow dug wells, which are often unreliable and polluted. In the rainy season, villagers generally use rainwater for drinking and cooking. Aside from these traditional water sources, there are also deep wells and combined wells constructed by UNICEF, MRD, and NGOs since the 1980s. Many of these wells are not used, however, due to hand pump breakdown and poor water quality.

Villagers use ponds as their main water source in additional to rivers, dug wells and hand pump deep wells. Two (2) types of ponds exist in the Study area: the public pond which is constructed by the villagers themselves, and the family pond which is constructed with the assistance of Ministry of Agriculture, Forestry and Fisheries (MAFF).

Many villagers use surface water (pond water) and groundwater (shallow of deep

wells) at the same time. The former is used for drinking, while the latter is used for laundry and bathing. Some villages also use water from nearby rivers and canals.

Groundwater is being utilized by the construction of dug and deep wells. Dug wells are generally less than 10 m deep, from 0.5 to 2.0 m in diameter, and are built manually. They are either lined with a casing of wood staves, brick or concrete, and are generally without hand pumps.

Deep wells are constructed by UNICEF and MRD, and are generally 30 to 50 m deep with 100 mm PVC pipe casing. The deep well drilling operation is usually stopped after the first aquifer has been encountered. Because water quality is not analyzed, many produce inferior water quality, i.e. high in salinity of iron. Many of these tube wells were also constructed by NGOs. In many villages, tube wells producing water of poor quality are not being used or if they are, the usage is limited to laundry, gardening, and livestock raising.

Combined wells were initially constructed by the Groupe de Recherche et d'Enchanges Technologique (GRET) followed by NGOs. This well type is a combination of shallow dug well and deep well, and is constructed as follows: a deep well is drilled, after which a hole is manually dug all the way to a depth deemed suitable. The tube is cut at the bottom of excavated hole, then the water is made to flow into the hole from the tube well. The hole is lined with concrete ring and covered by concrete slab (platform). Usually, the well is capped and equipped with a suction hand pump.

As various kinds of hand pumps were used in rural water supply projects in this country, UNICEF and MRD are recommending the standardization of hand pumps according to lift capacity, availability of spare parts, and ease in maintenance.

Using above figures, total coverage ratio of access to safe drinking water by piped water supply systems and deep wells in the Study Area is estimated as only 56.4% at present (see **Table I.3.13**).

No.	Province	Province's	Estim	Coverage		
		Popuration	Water	Rate		
		(nos.)	by Pipe W.	by Well	TOTAL	(%)
1	Phnom Penh	999,800	649,873	182,520	832,393	83.3%
2	Kandal	1,075,100	16,584	560,340	576,924	53.7%
	Sub-Total (Metropolitan)	2,071,553	666,457	742,860	1409316.6	68.0%
3	Takeo	790,200	5,072	360,180	365252	46.2%
4	Kompong Speu	598,900	19,560	393,120	412680	68.9%
5	Kampot	528,400	10,768	176,580	187348	35.5%
6	Koh Kong	132,100	2,936	7,380	10316	7.8%
	Sub-Total (Mid-Area)	2,047,627	38,336	937,260	975596	47.6%
7	Sihanoukville	156,000	9,632	17,460	27092	17.4%
	STUDY AREA TOTAL	4,274,556	714,425	1,697,580	2412004.6	56.4%
			16 70/	20 79/	56 49/	

 Table I.3.13
 Estimated Coverage Ratio of Safe Water Supplied in Study Area

Source : based on data from MIME and MRD