Chapter 7 Water Resources and Water Supply

7.1 Situation, Prospects and Issues

7.1.1 General Conditions

(1) Geography

The territory of Cambodia covers 181,035 km^2 in the Indo-Chinese Peninsular and is bordered by three countries which are Thailand, Lao PDR, and Vietnam. The territory is hilly along its international border but the dominant features of its landscape represent the extensive flood plains of the Mekong River and the Tonle Sap Lake.

The geographical characteristics of the territory are broadly classified into; (i) Central Plain, (ii) Northern Mountains, (iii) Eastern Highlands, (iv) Southwestern Mountains, and (v) Southern Coastal Region. Siem Reap District is located in Central Plain, which represents a low-lying alluvial plain surrounding the Tonle Sap Lake, and at the upstream end of the Mekong River Delta. Transitional plains extending outward are thinly forested with slight elevations not higher than 50 m above the sea level.

Figure III.7.1 Geography of Cambodia

(2) Climate

The climate in Cambodia is classified as Tropical Monsoon with the definite wet and dry seasons affected by the direction of the monsoons. The southwest monsoon prevails in the wet season from May to October. This monsoon brings warm and moist air from the Indian Ocean and provides rainfall to Cambodia before passing the mountains along the Vietnamese border. The northeast monsoon with dry and cold air dominates in the dry season from November to April.

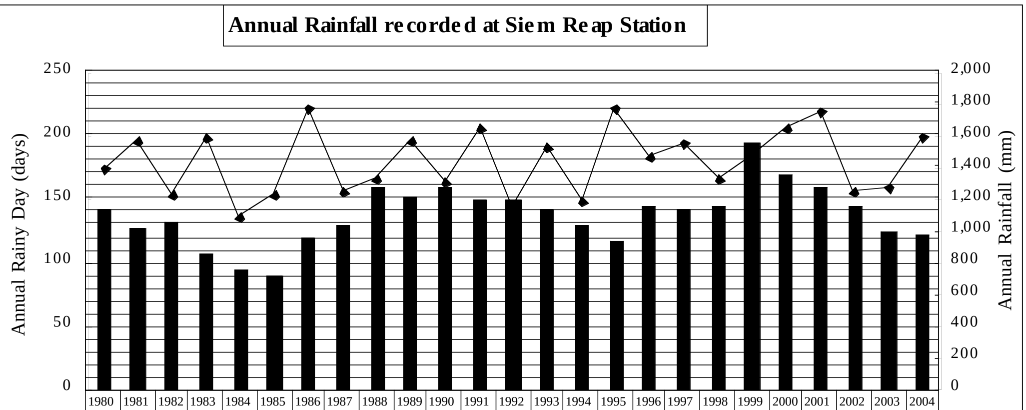
Average annual rainfall in Cambodia varies from 1,500 mm or less in the Central Plain, from 1,500 to 2,500 mm in the surrounding mountains such as Northern Mountains, Eastern Highlands, and Southwestern Mountains, from 2,500 to 3,000 mm or more in Southern Coastal Region. The monthly variation of rainfall shows that the peak of the rainy season takes place in August or September and the rainfall during the wet season from May to October amounts some 80% to 90% of the annual rainfall. In the dry season, the rainfall becomes scarce from December to February.

The temperature across the country ranges from a mean daily minimum of 19 °C in January to a mean daily maximum of 35 °C in April. In general, there is only a little spatial variation in the temperature throughout the country.

(3) Rainfall, Temperature and Evaporation

1) Rainfall

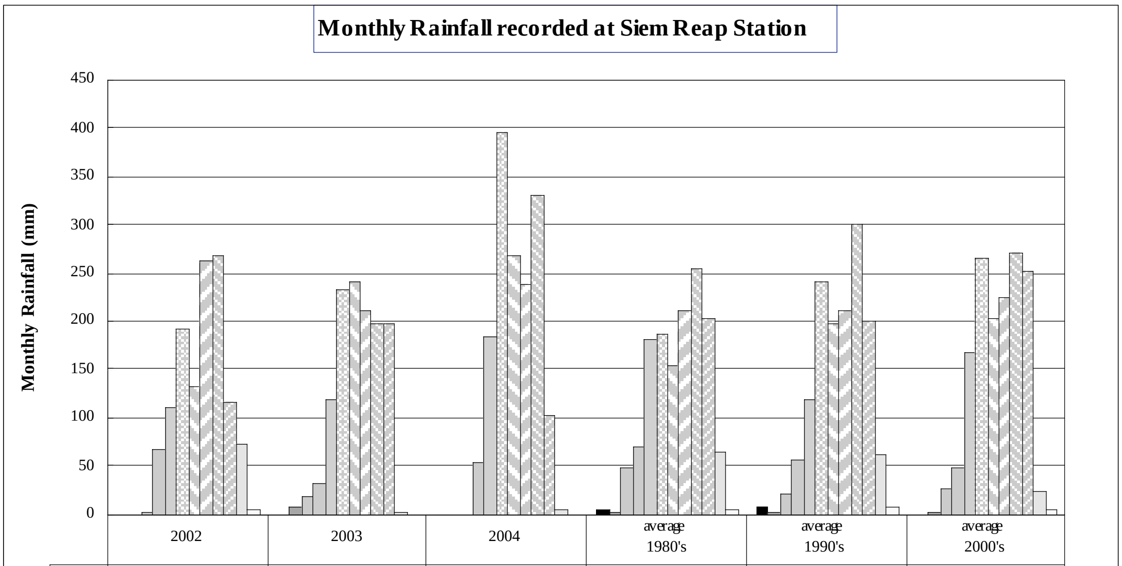
The average annual rainfall for last 25 years is 1,434 mm. It was increased from 1,398 mm in 1980's, 1,438 mm in 1990's, 1,499 mm in 2000's, and average for last 10 years is 1,507 mm. Also rainfall ratio during wet season has been increasing from average rainfall of 85% in 1980's, 89% in 1990's and 93% in 2000's. Those trend shows that the rainfall was increased and concentrated in wet season.



	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Rainy Day (day)	142	127	133	108	95	91	119	130	159	152	160	151	149	142	130	118	145	142	145	194	169	159	145	124	122
Annual Rainfall (mm)	1,391	1,561	1,225	1,586	1,082	1,228	1,773	1,247	1,328	1,563	1,302	1,643	1,158	1,524	1,180	1,766	1,463	1,551	1,324	1,469	1,637	1,753	1,242	1,271	1,591

Source: Department of Water Resource and Meteorology, Siem Reap Province.

Figure III.7.2 Annual Rainfall (mm) and Rainy Day (days) Recorded at Siem Reap Station



	2002	2003	2004	average 1980's	average 1990's	average 2000's
Jan	1	0	1	5	9	0
Feb	0	8	0	4	3	2
Mar	5	21	0	50	21	28
Apr	69	33	56	70	59	49
May	112	119	186	183	121	168
Jun	193	234	398	188	243	266
Jul	133	241	269	154	198	205
Aug	265	213	240	211	212	225
Sep	268	200	331	256	301	272
Oct	117	198	104	203	202	252
Nov	74	4	7	66	62	26
Dec	5	0	0	7	8	6

Source: Department of Water Resource and Meteorology, Siem Reap Province.

Figure III.7.3 Monthly Rainfall (mm) Recorded at Siem Reap Station

2) Temperature and Evaporation

In 2003, the monthly average temperature varies form 24.5 ºC in January to 29.9 ºC in April. The annual average temperature is slightly deferent between 27.6 ºC in 1999 and 28.8 ºC in 1998. For the last seven years, the temperature seems in stabile conditions.

The Study on Water Supply System for Siem Reap Region in Cambodia (JICA, 2000) presents the mean monthly relative humidity based on the records for the period from 1989 to 1996. The mean monthly relative humidity varies from the highest of 85.9% in September and the lowest of 69.8% in March.

Irrigation Rehabilitation Study in Cambodia – Final Report (Mekong Secretariat, 1994) gives the average annual evaporation of 1,541.8 mm. The mean monthly evaporation ranges from 111.0 mm in November to 155.0 mm in March.

Irrigation Rehabilitation Study in Cambodia – Final Report also presents the mean monthly sunshine hours varying from the highest of 9.4 hours/day in January to the lowest of 6.0 hours/day in August or September.

Table III.7.1 Average Monthly Temperature Recorded at Siem Reap

Source: Department of Water Resource and Meteorology, Siem Reap Province.

Temperature (℃)	1998	1999	2000	2001	2002	2003	2004
January	27.5	26.4	26.9	26.9	26.4	24.5	26.2
February	28.5	**27.7**	27.6	27.0	27.5	27.2	26.9
March	**30.8**	**29.9**	**30.0**	**28.8**	**29.7**	**28.8**	**29.6**
April	**31.8**	**28.9**	**30.0**	**31.4**	**30.8**	**29.9**	**29.8**
May	**31.9**	**28.4**	**28.9**	**29.2**	**29.5**	**29.4**	**29.7**
June	**29.7**	**28.5**	**28.9**	**28.8**	**29.1**	**28.4**	27.9
July	**29.0**	**28.3**	**28.0**	**28.8**	**29.0**	**28.0**	28.1
August	28.6	**28.8**	**28.6**	**28.6**	27.6	**28.0**	n.a.
September	28.2	**27.7**	27.7	**28.2**	27.9	**27.8**	n.a.
October	28.1	27.2	27.0	27.8	27.6	**27.9**	n.a.
November	26.4	26.3	26.4	26.2	27.5	27.5	n.a.
December	25.4	23.5	26.5	25.9	26.9	24.9	n.a.
annual average	28.8	27.6	28.0	28.1	28.3	27.7	28.3

Legend:

wet season

bold higher than annual average

7.1.2 Present Water Resource Condition

(1) Surface Water System

Present surface water system for Siem Reap district consists of Siem Reap River, West Baray (reservoir), Tonle Sap Lake, and diversion water during dry season from North East Baray, which is located at Roluos River basin to Siem Reap River. All of those surface waters are mainly used for an irrigation purpose, not for water supply.

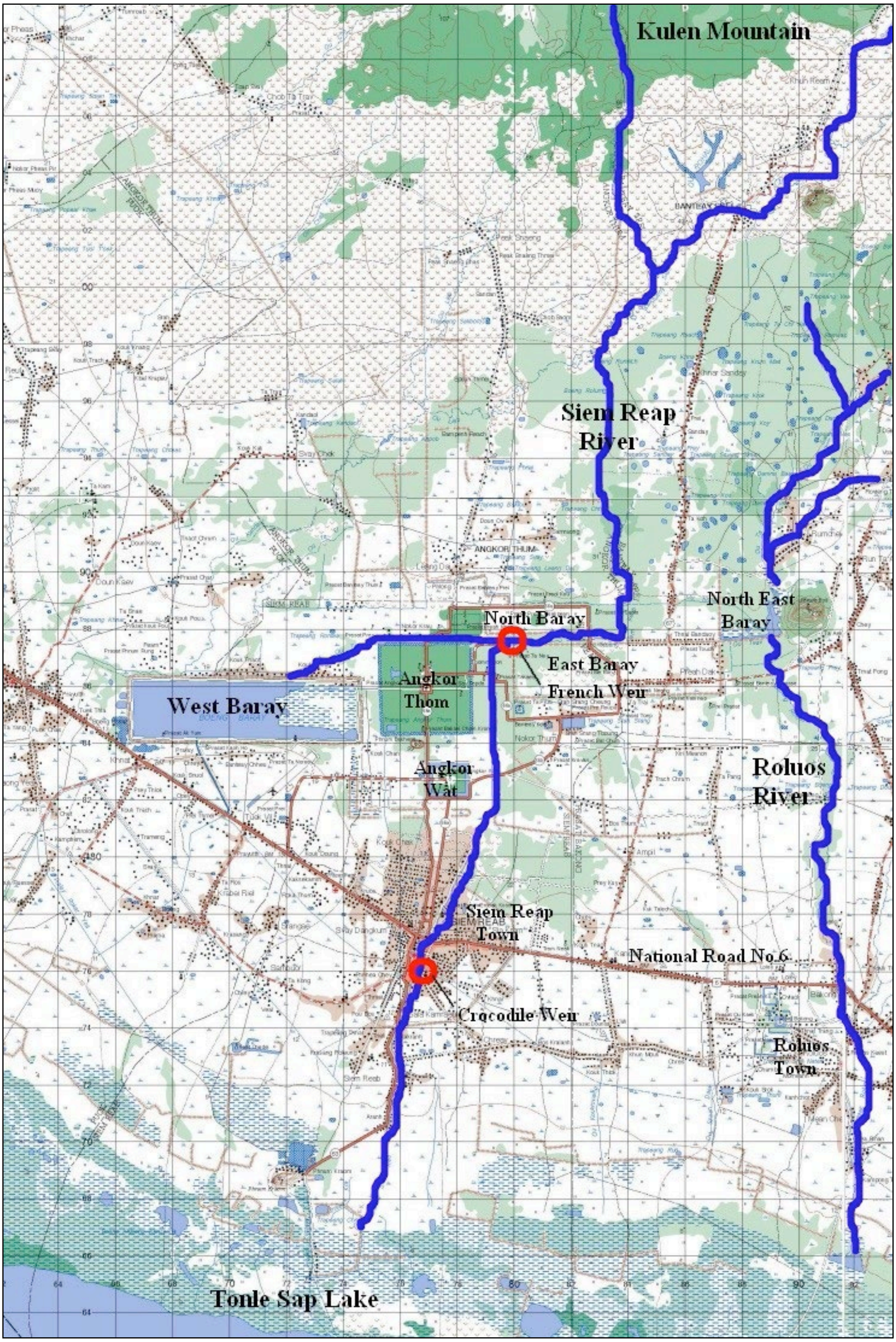


Figure III.7.4 Surface Water System around Siem Reap / Angkor Town

1) Siem Reap River

The Siem Reap River is only a perennial stream in Siem Reap / Angkor Town. The basin of the river is a part of the basin of Tonle Sap Lake. The total length of the river is some 80 km with catchment area approximately 670 km^2. The river rises in the Kulen Mountains at the highest elevation of 420 m above the sea level and flows through alluvial fans expanding to Siem Reap / Angkor Town and eventually pours into Tonle Sap Lake. The average bed gradient becomes to 1/2,000 in the lower reaches along the area of Angkor Heritage. The basin area mainly consists of agricultural lands.

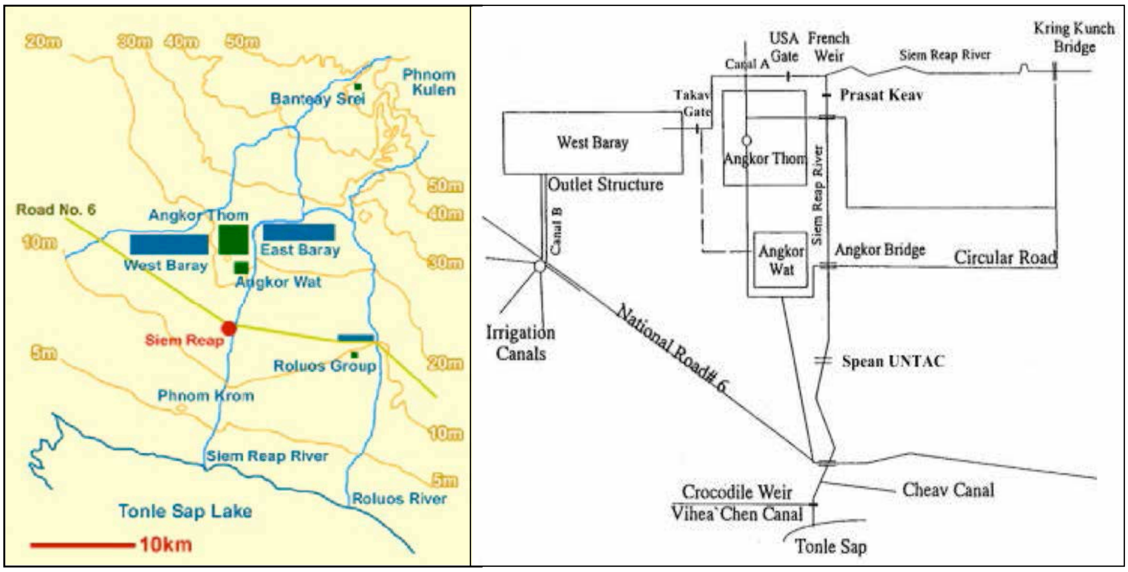


Figure III. 7.5 Siem Reap River System

The present river course to the area of Angkor Heritage is resulted by the ancient diversion structure constructed in the 10th century for the use of domestic and irrigation purposes. There are two weirs called French Weir and Crocodile Weir. French Weir, which is located on the upstream of Siem Reap / Angkor Town, was constructed in 1937 functions to divert the river water to West Baray, which is a major reservoir located to the west of Angkor Heritage. Crocodile Weir, which is located on the downstream of the Town, functions to control irrigation water to the southern part of the Town.

<u>River Water Capacity at Phnom Kulen</u>

The JICA Study Team on Basic Study for Mini-Hydropower Project for Rural Electrification in the Province of Siem Reap, surveyed water flow capacity of Siem Reap River at Phnom Kulen. The surveyed point located at about 300 m upper stream of waterfall (tourism site). The water gauge was installed on the pier of the bridge.

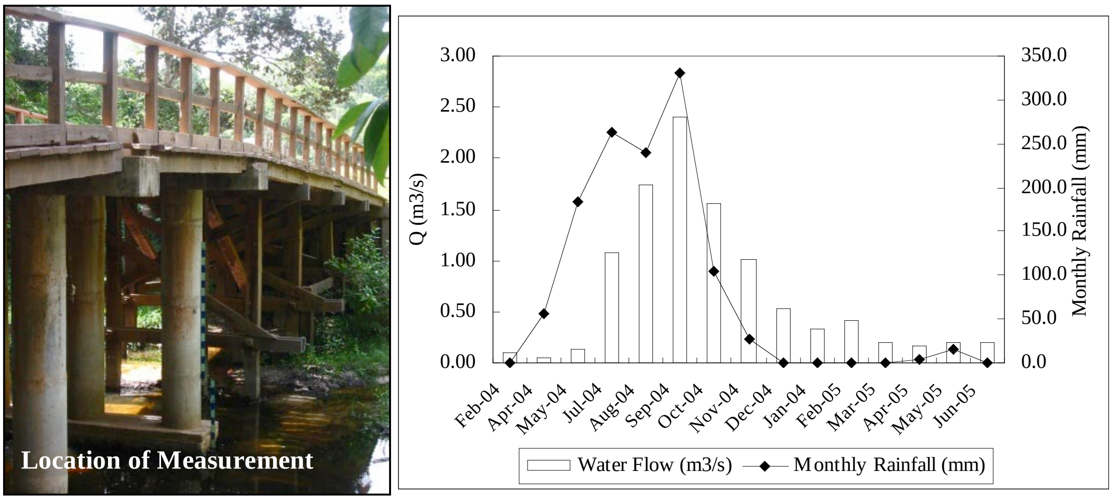


Figure III.7.6 Siem Reap River Water Flow Capacity at Phnom Kulen

The result shows a huge difference on water flow capacity between the end of the dry season and that of the wet season. The flow is ranges from 0.052 m^3/s on April 2004 up to 2.406 m^3/s on September 2004, which is 46 times difference.

Due to the differences and lack of capacity during dry season, river water at Phnom Kulen is not suitable as a source for public water supply system.

River Water Capacity at Siem Reap District

The surface water level of Siem Reap River is measured at Prasat Keav and Spean Untac by Department of Water Resources and Meteorology (DOWRAM), continuously since 1998. However, water level data for Spean Untac is not available since year 2003.

The water level shows the pattern with ascending and descending links to the rainfall. The difference of water level between the wet season and the dry season is around 2m on average.

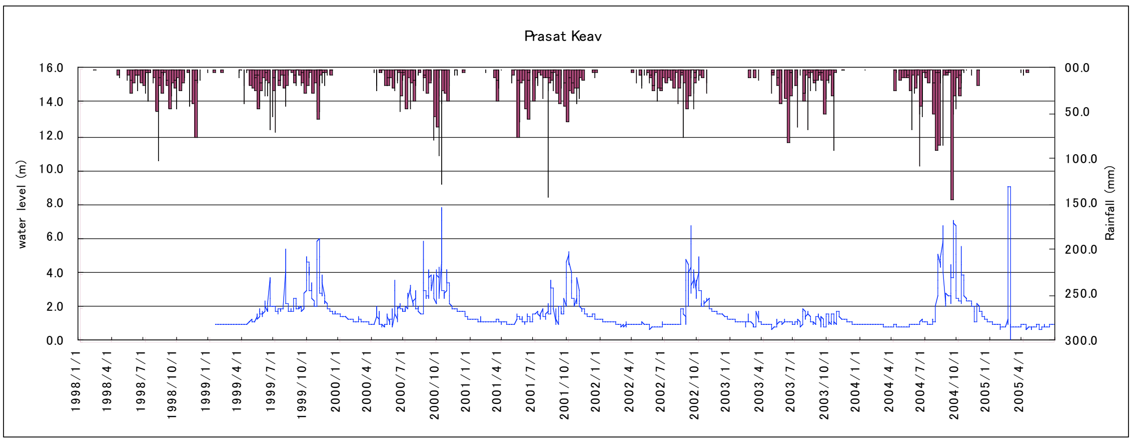


Figure III.7.7 Surface Water Level Fluctuation of Siem Reap River at Presat Keav

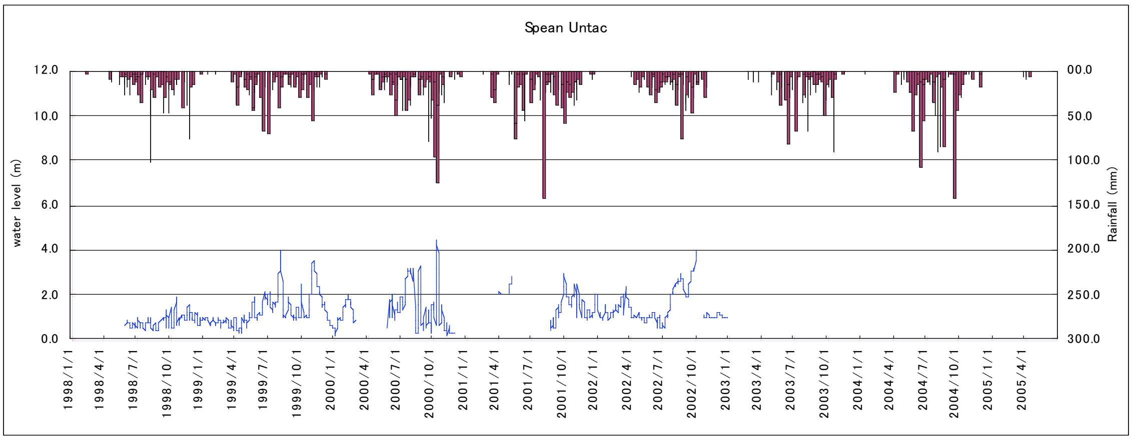


Figure III.7.8 Surface Water Level Fluctuation of Siem Reap River at Spean Untac

However, the water level does not mean the capacity or availability of river water. Water levels of the river are controlled by the gate at Crocodile Weir, which is located at the downstream of both measuring points. During dry season 2005, almost no water flows were observed during month of May to July and Crocodile gate was closed during that period to keep water level. At the end of dry season, river water quality becomes worst due to lack of flow and wastewater from the Town, which can be detected by smell and look.

There is no water flow data and gate control record. Due to lack of necessary data, the capacity of the river water is difficult to obtain. Only data measured by The Study on Water Supply System for Siem Reap Region (JICA, 2000) during January 1997 to January 1999 at Untac bridge is available.

As concluded by the Study on Water Supply System for Siem Reap Region, the possible amount of intake is 0 m^3/s. The calculation was based on estimated 10-years drought flow (assumed to be 0.48 m^3/s), maintenance flow (adopted daily minimum flow of 0.36 m^3/s in year 1990) and vested water use (approximately 1.0 m^3/s).

Therefore it is difficult to consider Siem Reap River water at the Town area as an alternative source of water supply.

The analysis result of Siem Reap River water quality conducted by the Study (December 2004 and July 2005) shows the number of total coliform is very high through the year. It was recorded 49,000 MPN/100ml and 86,000 MPN/100ml in December 2004 and 7,500 MPN/100ml in July 2005, while the standard of Ministry of Environmental is below 5,000 MPN/100ml.

In terms of water quality, it is also not sufficient enough to be used as a source for public water supply. It should be noted that, in 1995, the past water supply system named American System was terminated its operation due to deterioration of river water.

Detailed water quality analysis results are shown in attached Appendix-D for dry season (December 2004) and Appendix-E for wet season (July 2005).

2) Roluos River

The Roluos River basin is located to the east of the Siem Reap River basin. DOWRAM has no water record related to this river.

From its geographical features, hydraulic condition of Roluos River can be assumed same as Siem Reap River. Roluos River catchments area is estimated at 281 km^2, which is 0.562 times of Siem Reap River. The water flow roughly estimated by comparison to Siem Reap River will be 1.62 m^3/s for average flow and 0.27 m^3/s for 10-years drought flow. Since water inflow of 0.54 m^3/s recorded in April 2005 (end of dry season) by APSARA Authority, the estimation above can be ensured. However, is still necessary to have continuous monitoring and record of actual river flow to make sure the real capacity throughout a whole year.

3) West Baray

West Baray is located around 3 km west of Angkor Thom and 10 km northwest of the center of Siem Reap / Angkor Town. West Baray was constructed in 11th century to retain water from Siem Reap River with an approximate capacity of 60 million m^3.

Overall View of West Baray

The surface area of West Baray expands over 2 km in north-south direction and 8 km in east-west direction approximately. Water depth of West Baray tends to be deep in western part and shallow in the eastern part. An average water depth is some 3 m. It was reported that West Baray was operating well to contribute to flood mitigation, irrigation, and recreation purposes. However, it is pointed out that the reservoir capacity of West Baray has been reducing due to sedimentation.

The water level of West Baray was recorded by DOWRAM since 1993. However, due to lack of operation/transportation cost, since 1999 the measurement work could not be conducted frequently. According to the record shown in Figure III.7.10, the surface water level of West Baray seems to have a similar seasonal fluctuation for initial six years (1993-1998).

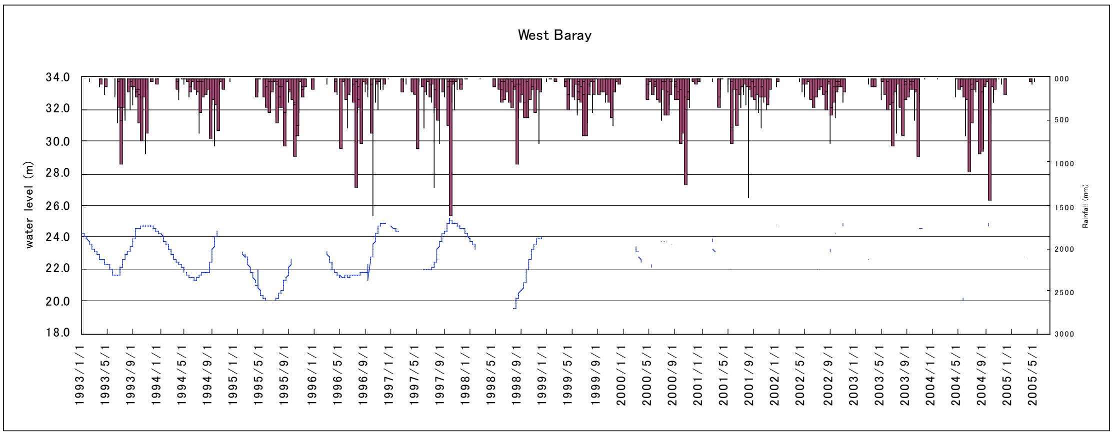


Figure III.7.9 Surface Water Level Fluctuation of West Baray

The Study on Water Supply System for Siem Reap Region (JICA, 2000) estimated minimal annual potential of West Baray at 40.7 million m^3. The estimation was considered water inflow of 34.1 million m^3, rainfall storage of 6.6 million m^3, and maximum annual irrigation water consumption of 36 million m^3, which includes evaporation loss. As conclusion, the surplus water is estimated at 4.7 million m^3/year which is equivalent to average of 12,900 m^3/day.

Government of India plans to recover and increase capacity of West Baray up to 73.31 million m^3. Their study estimated the amount of required irrigation water including evaporation volume is 64.31 million m^3/year, and surplus water would be 9.0 million m^3/year which was proposed to be utilized for urban water supply and other purposes.

As a result of water quality analysis sampled in December 2004 and July 2005, the quality was certified as source for water supply and no fluctuation on water quality throughout a year.

However, according to Ministry of Water Resources and Meteorology (MOWRAM), to utilize water from the baray for water supply is necessary to get an agreement or consensus from the “Water Forum”. The “Water Forum” will consists of; (i) Ministry of Water Resources and Meteorology, (ii) Ministry of Industry, Mines and Energy, (iii) Ministry of Agriculture, Forestry and Fishery, (iv) Ministry of Rural Development, (v) Ministry of Environment, (vi) Ministry of Land Management, Urban Planning and Construction, (vii) Provincial Government, and (viii) APSARA Authority. The coordination works to get an agreement can only start soon after confirmation of the exact volume of surplus water. Therefore, it is necessary to monitor water balance and operation of the Baray system for at least one year after completion of the construction. Also due consideration that there is no water related law executed yet to set water use right, it can not be assumed how long it will take to get an agreement from Water Forum.

To fully utilize water resource of West Baray, the appropriate operation and maintenance system, including recording system for capacity of inflow and outflow as well as gates operation, is necessary to be innovated.

4) North East Baray

Since 1965, the Roluos River was intercepted by dyke crossing from east to west at the foot of Bok Mountain. The reservoir named North East Baray has been formed by the Ta Neav Dam and utilized as a fishing pond, irrigation and domestic water reservoir.

The dyke was once destroyed in 1997 by the flood, and it was rehabilitated in June 1998 assisted by the European Community. Also World Bank made rehabilitation of the dyke and canal by social fund in 2003.

Overall view of North East Baray

APSARA Authority conducted preliminary survey to measure the size and depth of the Baray on April 2005. As a result, the capacity of North East Baray was assumed approximately 218,000 m^3.

The area of North East Baray based on geological condition bordered by existing road/dike is 4 million m^2 (2 km length and 2 km wide). Considering the average depth of 4 m, the physical capacity as well as development potential of the Baray can be assumed at 16 million m^3.

Based on the water charging period of four months during wet season (August to November; same as West Baray) and estimated average river flow of 1.62 m^3/s, the maximum capacity for rechargeable water can be estimated 17 million m^3, which is more than physical capacity of North East Baray.

DOWRAM officer estimated the irrigation water demands at 17.6 million m^3 for 3,000 ha. Based on preliminary estimation above, the North East Baray almost can cover the water required by irrigation.

Also as a result of site investigation, the different water level about 2 m during dry season and wet season can be ensured from the discoloration of the existing concrete outlet structure.

To ensure the preliminary estimation above; (i) present annual monthly storage capacity, (ii) actual Roluos River flow capacity, (iii) required Roluos River water flow on down stream of the Baray, and (iv) topological and geological condition to enlarge the storage capacity, should be confirmed.

5) Other Baray

In the vicinity of Siem Reap / Angkor Town, there were two (2) ancient reservoirs, i.e. North Baray and East Baray. However, both of these have been occupied by houses, road and paddy field, and does not functions as reservoir anymore.

6) Tonle Sap Lake

Tonle Sap Lake is the largest freshwater lake in Southeast Asia with water shade area of approximately 2,000 to 3,000 km^2 in the dry season and 10,000 km^2 in the wet season. Minimum storage is 1,300 million m^3, which can be considered physically as unlimited water resource. The water level varying largely from some 1 m above sea level in the dry season and rose up to some 11 m above sea level in the wet season, which makes the difference of water edge during dry season and wet season about 16 km.

There are huge differences on water quality between dry season and wet season, which can be considered as a different water characteristic. Contents of SS are high, and content of Total-N (1.123 mg/L) and Total Coliform (11,000 MPN/100ml) is very high during dry season, which is not suitable to be used for source of water supply.

SS was recorded 102.2 mg/L in December 2004 and 2,668 mg/L in July 2005, where the standard of Ministry of Environmental is below 60 mg/L. Detailed water quality analysis results are shown in attached Appendix-D for dry season (December 2004) and Appendix-E for wet season (July 2005).

(2) Groundwater System

1) Geology

The Study on Water Supply System for Siem Reap Region (JICA, 2000) was conducted as detailed geological investigation. It was verified that the area of Siem Reap / Angkor Town is characterized with alluvial fan deposits, diluvia deposits, Pleistocene sediments, Pliocene clay stone, and basement rocks. Alluvial deposits consist of coarse sand in the north and fine sand to silt in the south. Topsoil of cultivated upland, paddy field, and the bottom of Barays is composed of organic clay and silty clay. Thickness of alluvial deposits is 20 to 30 m in the north and 10 to 20 m in the south.

Diluvial deposits underlying the alluvial deposits are composed of coarser materials. Thickness of diluvial deposits is some 20 m in most part of the area of Siem Reap / Angkor Town. Alluvial and diluvial deposits are considered as an unconfined aquifer being exploited by shallow wells.

Pleistocene deposits have various components, i.e. unconsolidated coarse sand, fine sand, and boulders. It is observed that the middle to bottom part of the deposits contains Laterite, basal pebbles, and gravels at many locations. Thickness of the deposits varies from 10 to 30 m.

Pliocene formation is mainly composed of clay stone with a thickness of 20 to 50 m. It is observed that upper part of this formation contains laterite patches at many locations. Groundwater potential is poor in this formation characterized with well-consolidated clayey matrix.

Basement rocks are characterized with Mesozoic sedimentary rocks and Paleocene volcanic and igneous rocks. Mesozoic sedimentary rocks comprise sandstone in general. Tuff breccia is mostly developed in the southeast and ryolitic tuff is narrowly developed in the west. Paleocene volcanic and igneous rocks are granodiorite around West Baray and andesine dykes in the northeast.

Table III.7.2 Geological Sequences around Siem Reap / Angkor Town

Source: The Study on Water Supply System for Siem Reap Region (JICA, 2000).

Formation	Geology	Thickness (m)	Electric Sounding	Electric Logging		N-value (blows/30cm)
				Resestivity	Gamma (cps)	
Alluvial Deposits	Coarse to medium Sand (North area)	10 to 15	50 - 3,000 (ohm/m)	WT-1: 500 WT-3: 60-120 WT-6: 70-100 WT-7: 160	WT-1: 1 WT-3: 4-25 WT-6: 4-16 WT-7: 8-16	WT-1: 4-43 WT-3: 8-32 WT-6: 4-17 WT-7: 2-20
	Medium to fine Sand (South area)	10 to 20	50 - 1,100 (ohm/m)	WT-2: 100-160 WT-4: 40-200 WT-5: CP WT-8: 10-20	WT-2: - WT-4: 8-18 WT-5: 4-10 WT-8: 5-20	WT-2: 6-50 WT-4: 4-17 WT-5: 6-22 WT-8: 8-38
Pleistocene Deposits	Coarse to medium Sand (Stone) with Boulders (North area)	10 to 25	74 - 1,900 (ohm/m)	WT-1: 200-500 WT-3: 80 WT-6: 60-100 WT-7: 120-160	WT-1: 1 WT-3: 14-16 WT-6: 10-20 WT-7: 6-16	WT-1: 18-50 WT-3: 21-50 WT-6: 22-50 WT-7: 18-40
	Medium to fine Sand (Stone) with Boulders (South area)	20 to 30	20 - 400 (ohm/m)	WT-2: 80-120 WT-4: 120-200 WT-5: 200-400 WT-8: 10-20	WT-2: 6-12 WT-4: 6-18 WT-5: 8-18 WT-8: 10-20	WT-2: 18-50 WT-4: 16-50 WT-5: 21-50 WT-8: 25-50
Pliocene Claystone	Silty Claystone (North area)	25 to 50	11 - 300 (ohm/m)	WT-1: 200 WT-3: 20-60 WT-6: 40-60 WT-7: 120-200	WT-1: 1 WT-3: 5-25 WT-6: 12-20 WT-7: 12-16	WT-1: 50< WT-3: 50< WT-6: 50< WT-7: 50<
	Claystone (South area)	50	70 - 200 (ohm/m)	WT-2: 40 WT-4: 30-70 WT-5: 100-200 WT-8: 10-20	WT-2: 4-16 WT-4: 8-18 WT-5: 10-18 WT-8: 10-15	WT-2: 50< WT-4: 50< WT-5: 50< WT-8: 50<
Bed Rocks Tertiary to Upper Jurassic	Shale, Sandstone, Siltstone		less than 10 (ohm/m)	WT-1: 10 WT-5: 20 WT-6: 10 WT-7: 5	WT-1: 5 WT-5: 8-18 WT-6: 10-18 WT-7: 14-16	
	Ryolitic Tuff		11-40 (ohm/m)	WT-4: 20-30	WT-4: 8-18	
	Tuff Breccia		12-110 (ohm/m)	WT-8: 5-10	WT-8: 10	
	Granodiorite		63-540 (ohm/m)	WT-3: 100-200	WT-3: 10	
	Andesite Intrusive		30-3,000 (ohm/m)	WT-2: 30-40	WT-2: -	

2) Hydrogeology

The Study on Water Supply System for Siem Reap Region in Cambodia (JICA, 2000) presents the results of hydrogeological investigations through groundwater monitoring at 96 existing wells in the area of Siem Reap / Angkor Town.

It was reported that the groundwater level ranged from 1.0 to 3.5 m below the ground surface in the end of the wet season and from 2.0 to 4.5 m below the ground surface in the beginning of the wet season. From the results of two years observation, there was no notable seasonal fluctuation of groundwater level.

3) Monitoring Well

The Study on Water Supply System for Siem Reap Region (JICA, 2000) installed eight monitoring wells, one of which was stolen. The water table data for seven wells was recorded continuously since July 2003, however data recording error was occurred on well WT-4 and WT-6.

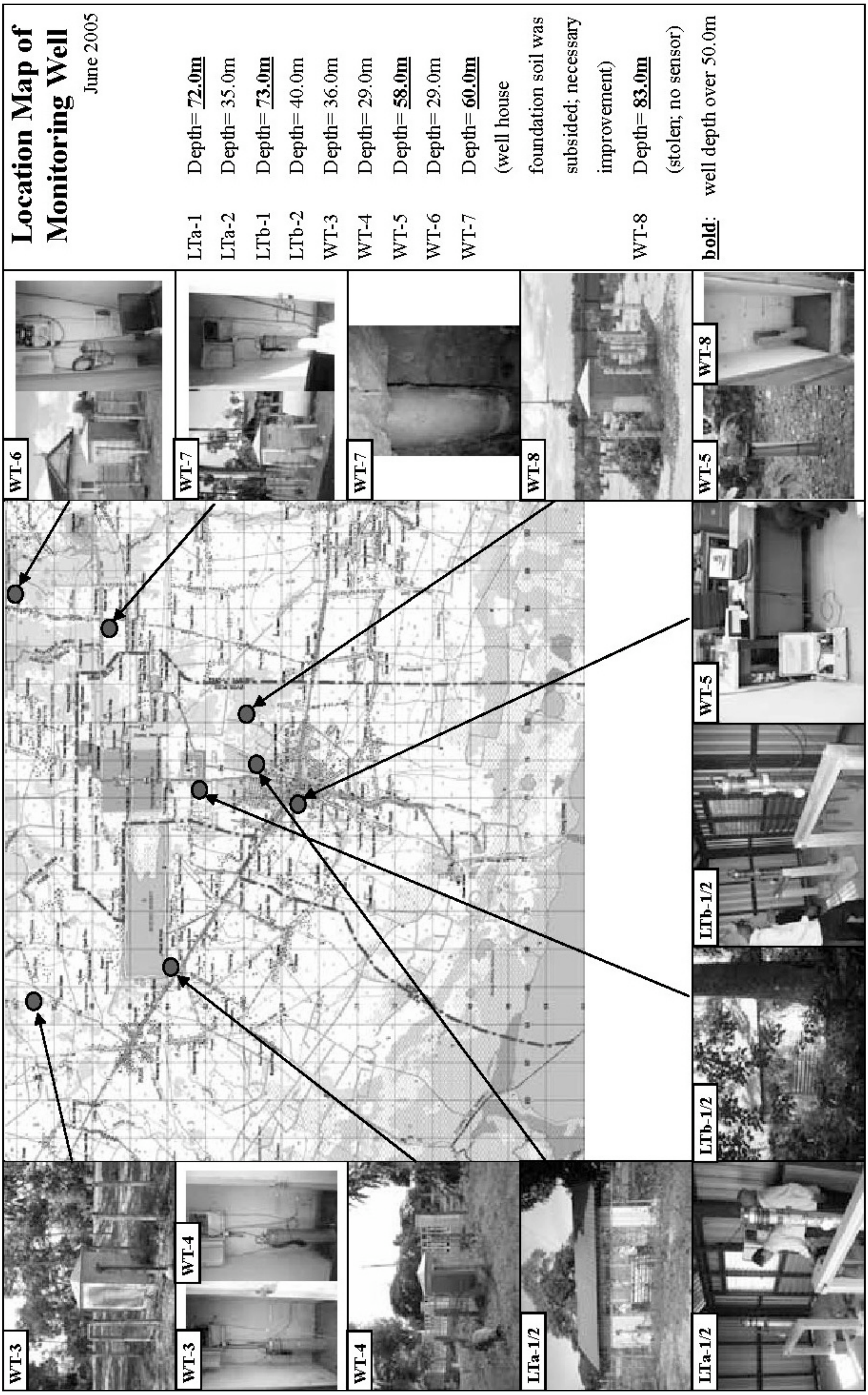


Figure III.7.10 Location Map of Monitoring Well

As a general trend, the water tables are reducing during dry season (October to May) and immediately recovering during wet season (May to August). During August to October, water table stabilizes at the high level. Compared to deep wells, shallow wells have larger water table differences between wet and dry seasons. The difference recorded is ranged from 2 to 4 m for shallow well and only around 0.5 m for deep well.

Land table sensors for deep well of LTa-1 and LTb-1 are located at the depths of 72 m and 73 m, respectively, with land fluctuated for about 5 mm for 2004 to 2005. Land table sensors for shallow wells of LTa-2 and LTb-2 are located at the depths of 35 m and 40 m respectively, and land fluctuated from 2004 to 2005 is about 2 mm. As a trend, the fluctuation of land table is linked with water table of shallow well.

LTa is located beside Angkor Wat, near to West Gate. LTa-1 shows different water table sequential pattern compared to others. The water table trend is increasing gradually about 0.5 m by the last 21 months. The water table difference between wet and dry season is also very large, is about 4.5 m.

The detailed monitoring data is attached in Appendix-K as a Monitoring Records of Groundwater Monitoring Well.

4) Tonle Sap Groundwater

Hydrogeological Map of Lower Mekong Basin prepared by Mekong River Committee in 1999, characterized Siem Reap province around Tonle Sap Lake into Younger Alluvium Aquifer, which is consists of extensively well-sorted sand and gravel. It is good aquifer with average depth of 30 to 50 m and water retention capacity estimated 5 to 30 m^3/hr. Water quality is commonly fresh.

Protection and Management of Critical Wetlands in Lower Mekong Basin (ADB/MOE, 2000) conducted groundwater survey at the Tonle Sap Lake basin in Siem Reap province. As a result, it became clear that the transmissivity in the area is very high; more than 1,000 m^2/day, it is evaluated that the aquifer in the area have a high recharge from Tonle Sap Lake. Storage coefficient is also high at around 5×10^{-5}. Water quality satisfies the WHO standard for drinking water, except Fecal Coliform and Manganese (Mn) which is a bit higher than the standard.

Actual pumping test result was also conducted. 45 m^3/hr (equal to 1,080 m^3/day) can be ensured from 6-inch diameter well, and estimated for nominal capacity of 90 m^3/hr (equal to 2,160 m^3/day).

The investigation done only for one well, therefore it is necessary to conduct further hydrogeological investigations and pumping tests based on planned capacity to ensure the exact capability of Tonle Sap groundwater.

7.1.3 Present Water Use Condition

(1) Water Supply

1) Public Water Supply

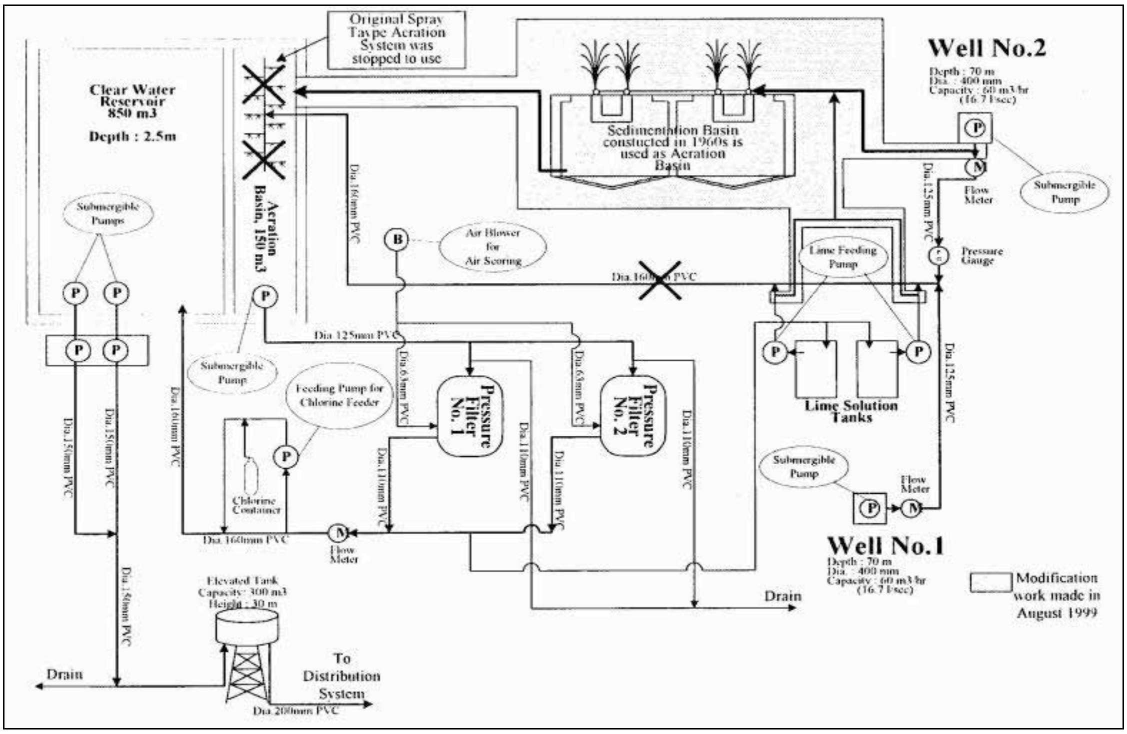
Public water supply services for Siem Reap / Angkor Town was under responsibility of Siem Reap Water Supply Authority (SRWSA), the one of the sections of Department of Industry, Mines and Energy (DIME) of Siem Reap province, and directly supervised by Department of Water Supply of Ministry of Industry, Mines and Energy (MIME)

<u>Water Supply System</u>

In the area of Siem Reap / Angkor Town, the first water supply system called “Old French System” was constructed by French aid in the 1930’s. This system was composed of a treatment plant using water from the Siem Reap River and a limited distribution system.

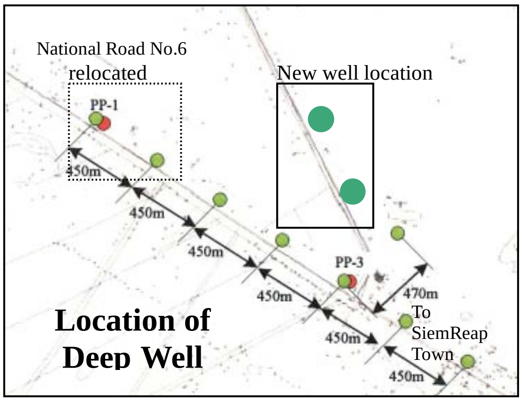
The second water supply system called “American System” with a supply capacity of 300 m^3/day was constructed in 1960’s and Old French System was replaced. The Siem Reap River was utilized as the water resource and the distribution system was expanded to cover the central part of the town. In 1995, the Waterworks terminated the services due to the deterioration of the raw water quality and the treatment facilities.

At the same time, MIME commenced construction of a new water supply system using groundwater with a supply capacity about 1,500 m^3/day, called “New French System”. It was funded by French aid and completed in September 1998. Water source consists of two deep wells which are located inside the treatment plant. The water contained a high proportion of iron and required additional treatment facilities for aeration devices and pressured filters. Finally the construction of the treatment plant was completed by a grant from UNDP in the middle of the year 1999, and the operation started in July 1999 after the distribution system tentatively fixed. The high iron content pushes the price of water up due to the required additional treatment process, which cost more for electricity.



Source: JICA Study on Water Supply System for Siem Reap Region in Cambodia, 1999.

Figure III.7.11 Schematic Flow of Modified New French System (1999 – Present)



A new water treatment plant with a capacity of 8,000 m^3/day using groundwater resourced by 8 deep wells was constructed by the Japanese Grant Aid, which also included expansion of the distribution system. All deep wells are located along National Road no.6, western part of Siem Reap City with 450 m distance between each well. Total length of raw water conveyance pipeline is about 4,000 m. The well casing depth is around 60 m.

The water treatment plant is consists of; (i) receiving well [42 m^3], (ii) chemical [Lime and Cl_2] building, (iii) oxidation tank [130 m^3 x 2 units], (iv) filtration units [15 m^3 x 3 units], (v) clear water reservoir [app. 1,400 m^3 x 2 units], (vi) pumping station [1 distribution pump, 1 back-wash pump, with 1 standby for each], and (vii) elevated water tank [500 m^3 with 38 m height]. Due to the high content of iron, chlorine will be injected at the beginning of the process together with lime to adjust the pH of the raw water.

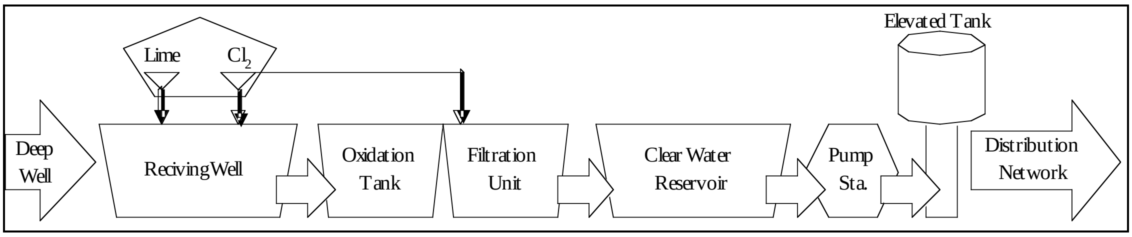


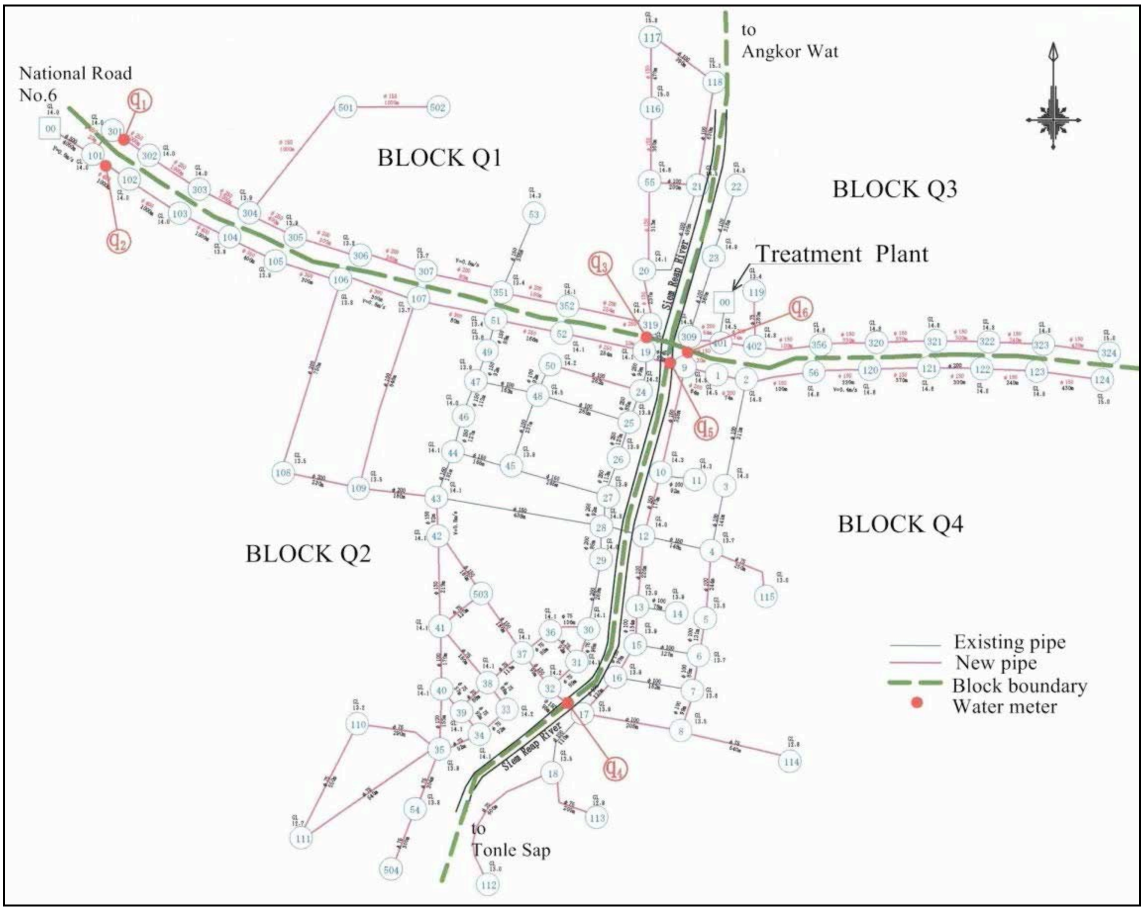
Figure III.7.12 Schematic Flow of New Water Treatment Plant (2006 - Present)

From early 2006, the total supply water supply capacity by two water supply systems will be 9,500 m3/day. However, due to the limited capacity of the distribution system, mainly limited number of individual connection, the total capacity of 9,500 m3/day can not be utilized right after the completion of the new water supply system. The operation of new water treatment plant will be prioritized. New French System will be re-operated as soon as distribution system capacity exceeds 8,000 m3/day. To re-operate New French System, rehabilitation works for the system will be required.

<u>Water Distribution System</u>

Present distribution system is covering area of 425 ha, which was divided into 4 zones. The zone sets in line with improvement plan and monitoring system of Unaccounted for Water (UFW).

Distribution system consists of; (i) transmission pipeline, (ii) distribution pipeline and (iii) individual connection. Clean water reservoir and elevated water tower only exists at the water treatment plant.



Source: Source: Basic Design Study on the Project for Improvement of Water Supply System in Siem Reap Town (JICA, 2003)

Figure III.7.13 Distribution Network and Zones

Ductile Iron Pipe (DIP) is utilized for transmission pipeline with diameter of 500 mm and distribution pipeline with diameter of 250 mm and over. Polyvinyl Chloride Pipe (PVC) is utilized for distribution pipeline with diameter below 250 mm. The total length of transmission pipeline is 4,050 m and 33,735 m for distribution pipeline.

Table III.7.3 Existing Distribution Pipeline

Source: Basic Design Study on the Project for Improvement of Water Supply System in Siem Reap Town (JICA, 2003).

diameter (mm)	length (m)	diameter (mm)	length (m)
250	5,419	75	5,239
300	410	100	6,965
350	700	150	10,070
400	2,000	200	1,840
450	1,092	**Total**	**33,735**

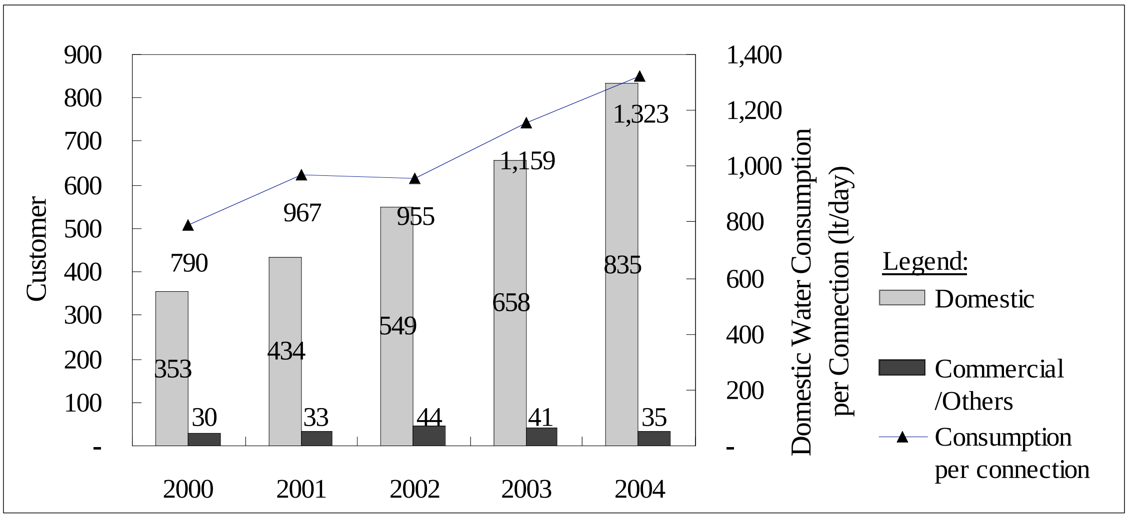
Among 33,735 m distribution pipelines, there are some 6 km of old pipes that were installed in 1960's. Those pipes consist of Asbestos Cement Pipe (ACP) and PVC pipe. Due consideration on water leakage and water quality, those old pipes are to be replaced as soon as possible.

Customer Connections

For the last 5 years, there is almost no difference on the number of commercial/others customer. However, the number of domestic customer was increased for more than 2.3 times. Average on annual increasing number for last 4 years is 120 connections, and it was increased 170 connections for the year 2003-2004. To distribute new production capacity of 8,000 m^3/day, another 4,000 customer connections plans to be installed by the end of year 2008.

Annual average domestic water consumption per connection also was increased drastically. Considering average person per household of 5.4, as result of census 1998, the average consumption per capita per day for year 2000 can be estimated 146 liter and 245 liter for year 2004.

Through field hearing investigation, it was verified that some guesthouses and restaurants are registered as a domestic user. Considering the rapid increase on domestic water consumption unit demand and low connection number of commercial/others customer, it may exist many faults on registration.



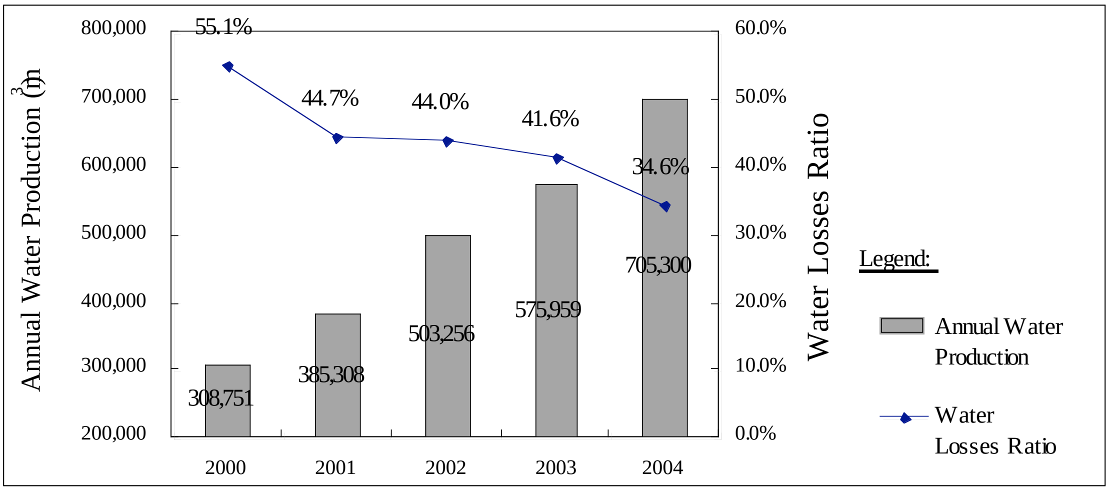
Source: Annual Report, SRWSA.

Figure III.7.14   Trends of Customer Number and Water Consumption

Water Losses

In line with increase of customer number, the production capacity also increased for nearly 2.3 times. Since 2003, standby deep well pump also has been utilized to meet the demands. In the year of 2004, the daily production capacity was reached 1,930 m^3/day, which is nearly 1.3 times of the design capacity of 1,500 m^3/day.

For last 4 years, the water loss ratio has also improved from 55.1% to 34.6%. In the latest year, it was improved by 7%. It is due to the improvements on the administrative system, such as customer record, water metering and billing systems.



Source: Annual Report, SRWSA.

Figure III.7.15 Annual Water Productions and Water Losses Ratio

Water Tariff

During the operation period of Old French System and American System, there was no water meter installed in individual connections. Water tariff was determined by flat rate based on the water pressure investigated by Waterworks staff individually.

Table III.7.4 Water Tariff Structure

Source: SRWSA.

Category	before New French System		Siem Reap (present)		*Phnom Penh*	
	Pressure Range	Tariff (riel/mnt)	Block (m^3/mnt)	Tariff (riel/m^3)	*Block (m^3/mnt)*	*Tariff (riel/m^3)*
Domestic	high	3,700	fix rate	1,200	*0-7*	*550*
	medium	2,500			*8-15*	*770*
					16-50	*1,010*
	low	1,500			*50<*	*1,270*
Government Office	high	3,700	n.a.		*fix rate*	*1,030*
	medium	2,500				
	low	1,500				
School	high	3,700	n.a.		*n.a.*	
	medium	2,500				
	low	1,500				
Grand Hotel	NA	18,000	n.a.		*n.a.*	
Villa Apsara	NA	8,000	n.a.		*n.a.*	
Hospital	NA	5,500	n.a.		*n.a.*	
Commercial/ Others	none		fix rate	1,400	*0-100*	*950*
					101-200	*1,150*
					201-500	*1,350*
					500<	*1,450*

Present Siem Reap water tariff is basically higher than Phnom Penh and also much more higher compared to the past tariff. From the result of hotel questionnaire survey, it is figure out that 35% of the claim to the services is related to the high price. Average of the proposed willingness price is 558 riel/m^3, which is 40% lower than the current price.

The tariff is set in accordance with its operation cost, which requires high cost for energy and chemicals to treat groundwater with high iron content. However, to promote utilization of public water supply service, the adjustment of tariff system is necessary.

2) Exiting Individual Well

Due to the low water supply coverage ratio and water production quantity, almost all houses and buildings in the Siem Reap district have a private individual well to supply water demand by own self.

In the year of 2004, DIME conducted a well investigation for overall Siem Reap district. Individual well was categorized into three types, which are electric pump, handy (butterfly) pump and shallow (open) well. The result shows that 71.35% of the total are using electric pumps, 11.77% using handy pumps and 16.88% are using shallow wells.

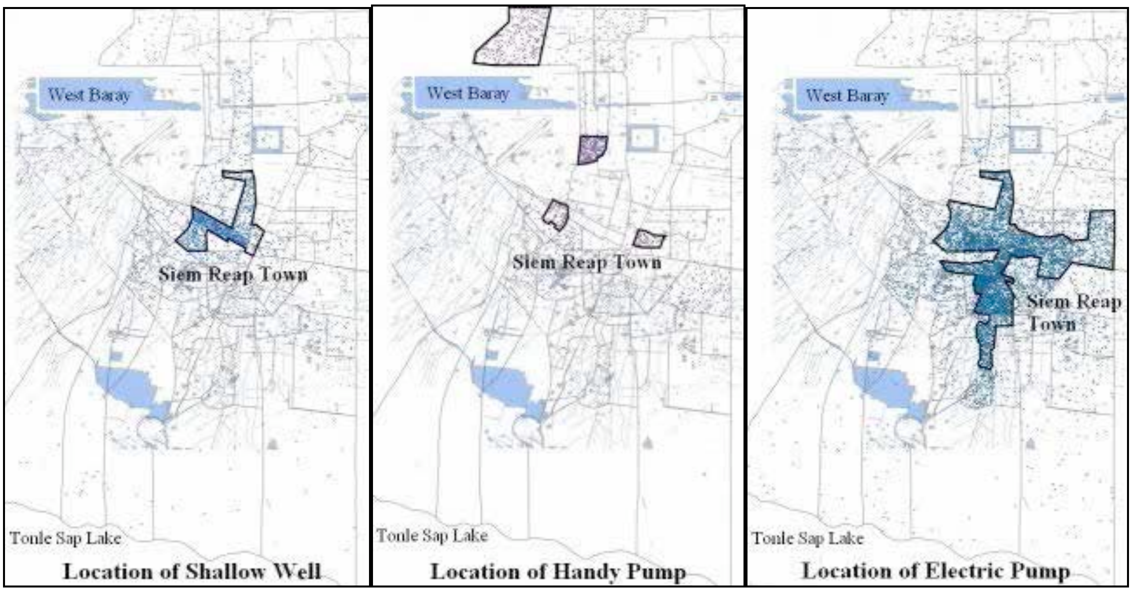
There is no water meter installed in the electric pump, also no any record for water consumption of all types. Therefore, there is no means to exactly the total consumption of groundwater by existing individual wells.


Shallow


Handy Pump

Most of the wells are located in Svay Dangkum commune (32.0%) and followed by Kouk Chak (18.5%), Sla Kram (17.5%) and Sala Kamraeuk (12.6%) communes. Those four communes covered more than 80% of total wells, which is higher than its population coverage ratio of 68%.

The concentration of individual well allocation can be confirmed form the figures below. The location of electric pumps concentrates in the center of the town. However, handy pumps are located more in the suburban area.



Source: DIME survey result, 2004.

Figure III.7.16 Location of Private Individual Wells

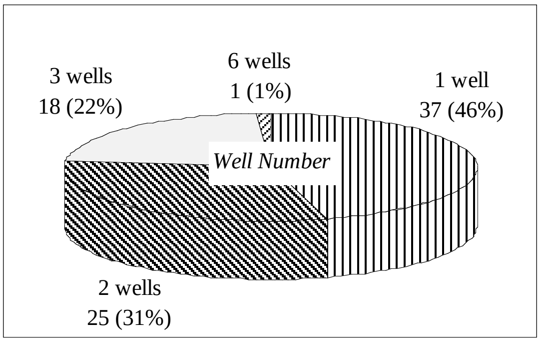
Table III.7.5 Individual Well at Siem Reap District 2004 (unit: wells)

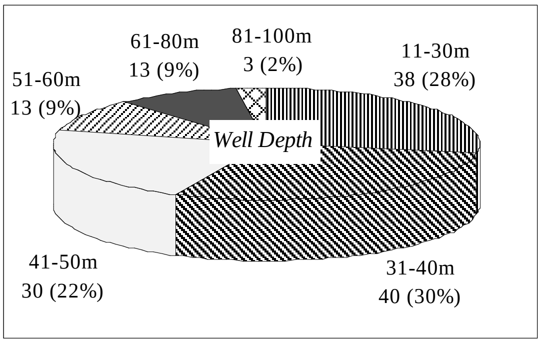
Commune	Handy Pump		Electric Pump		Shallow Well		**TOTAL**		Population 2004	
Sla Kram	105	8.9%	1,542	21.5%	117	6.9%	1,764	17.5%	29,283	21.0%
Svay Dangkum	104	8.8%	2,360	32.9%	757	44.6%	3,221	32.0%	30,082	21.6%
Kouk Chak	715	60.3%	715	10.0%	436	25.7%	1,866	18.5%	18,115	13.0%
Sala Kamraeuk	12	1.0%	1,206	16.8%	52	3.1%	1,270	12.6%	17,229	12.3%
Nokor Thum	19	1.6%	175	2.4%	98	5.8%	292	2.9%	5,076	3.6%
Chreav	125	10.5%	277	3.9%	74	4.4%	476	4.7%	8,371	6.0%
Chong Khnies	-	0.0%	3	0.0%	1	0.1%	4	0.0%	6,396	4.6%
Sambuor	19	1.6%	142	2.0%	62	3.6%	223	2.2%	3,264	2.3%
Siem Reab	4	0.3%	619	8.6%	23	1.4%	646	6.4%	16,128	11.6%
Srangae	82	6.9%	145	2.0%	79	4.6%	306	3.0%	5,622	4.0%
Siem Reap District	1,185	100.0%	7,184	100.0%	1,699	100.0%	**10,068**	**100.0%**	139,566	100.0%

Chong Khnies commune with population of 6,396 has only 4 wells. They utilize rain and public well water for cooking, and Tonle Sap Lake water for other purposes. Water vender is active during dry season at this commune.

3) Existing Hotel/Commercial Wells

As the result of hotel questionnaire survey, the average of well number is 1.8 units per hotel. 54% of the hotels have more than 2 wells. The average of well depth is 43 m, where the shallowest well is 11m and the deepest is 100 m. Nearly half of the wells are more than 40 m in depth.





Among 81 hotels, only 26 hotels (32%) answered the pump operation period. The rest have no pump operation records. Average operation period of pumps is 7.58 hrs/day in the peak season and 5.68 hrs/day as an average through the year. Certainly, the pump operated over 12 hrs/day is only 5 units, which means the operation performance of the pump is very low.

Almost no water meter installed in the groundwater intake well, therefore the answers on the groundwater abstraction/consumption capacities are based on their assumption. Estimated average water consumption per guest is 313 L/day, and it is ranged from 53 L/day to 866 L/day.

Considering maximum guest occupation number of 11,784, estimated total maximum water demand of the hotel will be 3,688 m^3/day. Only some part of the total demand was supplied by public water supply and the remaining are taken from the individual well.

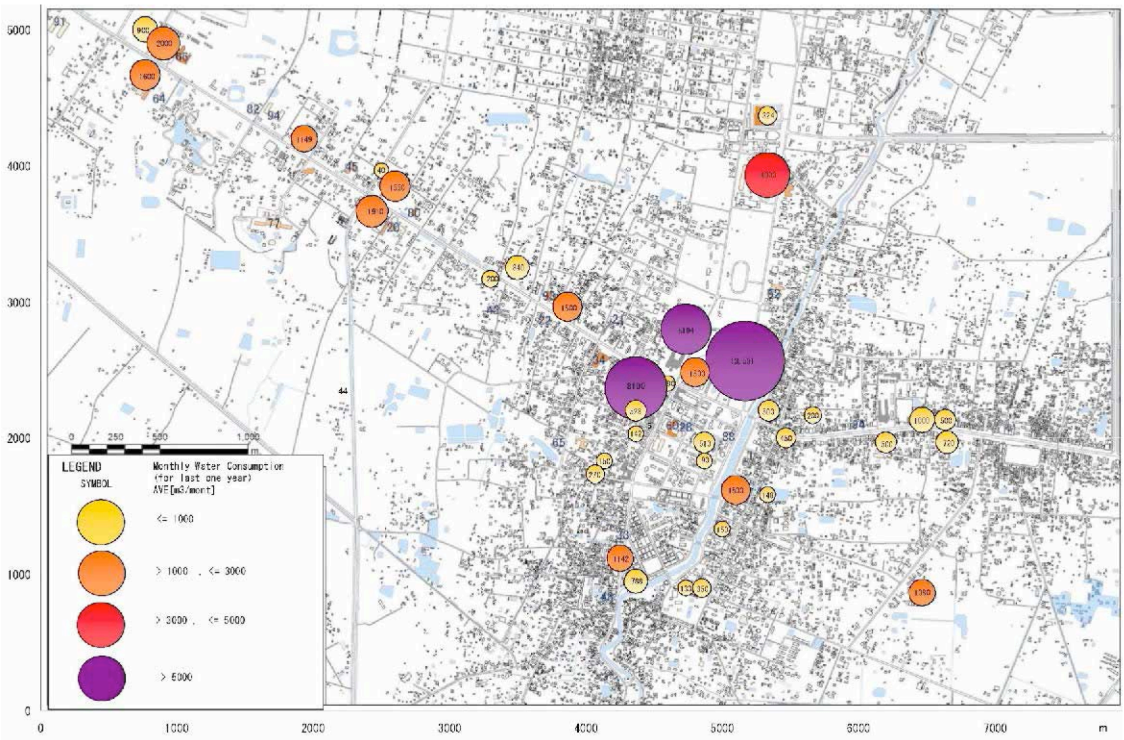


Figure III.7.17   Distribution Map of Monthly Groundwater Abstraction Volume

As seen from the figure above, the location of groundwater abstraction concentrates at the crossing point of National Road No.6 and Siem Reap River, which covers almost half of the estimated total abstraction volume. This concentration links to the location of large hotels.

4) Water Vender

Especially during the dry season, there is water vender company operating at rural area located in southern part of Siem Reap City. Based on interview survey to the water vender, they operated 3 units of water tanker with capacity of 4 m^3 each. For one day, one water tanker can supply for averagely 4 trips with total water volume of 16 m^3. Supplied water was taken from wells owned by the company and sold at cost of 500 riel per 30 liter.

(2) Irrigation

The West Baray system and Crocodile Weir system are the major irrigation systems of Siem Reap district. As of 1998, the average irrigated area through the year is 9,521 ha for West Baray system and 3,900 ha for Crocodile Weir system.

Currently, the supplied water seems not to be exploited efficiently enough for the area due to deterioration of the irrigation canal network, poor irrigation execution and lack of water management.

1) West Baray Irrigation System

The West Baray System, the principal system in the district, is supplied from West Baray. In the wet season, West Baray is fed by inflow from the Siem Reap River as well as rainfall. In the dry season, the water reserved in West Baray is supplied for irrigation from the outlet structure to Canal B and then distributed to several secondary canals through the distribution structure located beside the National Road No.6. The flow capacity of Canal B is estimated around 9.0 m^3/sec. The extent of irrigated area is some 6,300 ha. Meanwhile, an actual amount of intake water at the distribution structure was estimated around 2.0 m^3/sec, based on the periodical measurements carried out under the Study on Water Supply System for Siem Reap Region in Cambodia (JICA, 2000).

The system is subject to control by the weirs such as French Weir, American Weir, and Takav Weir. The sluice gate at the French Weir is closed in the early wet season (June) to divert the water from the Siem Reap River to West Baray through Canal A. American Weir and Takav Weir are opened during the water diversion from French Weir to West Baray. When the water level of West Baray reaches 19.6 m above MSL (or ‘Standard Level’ of 25 m), French Weir is opened together with the closure of American Weir and Takav Weir in order to stop inflow from the Siem Reap River. Therefore, the main function of American Weir and Takav Weir is to control the flood flow from the Siem Reap River during the wet season.

The water released from West Baray through Canal B generally started from the end of November and continued until May, with once stopped to harvest rice for the period of two weeks in the beginning of February.

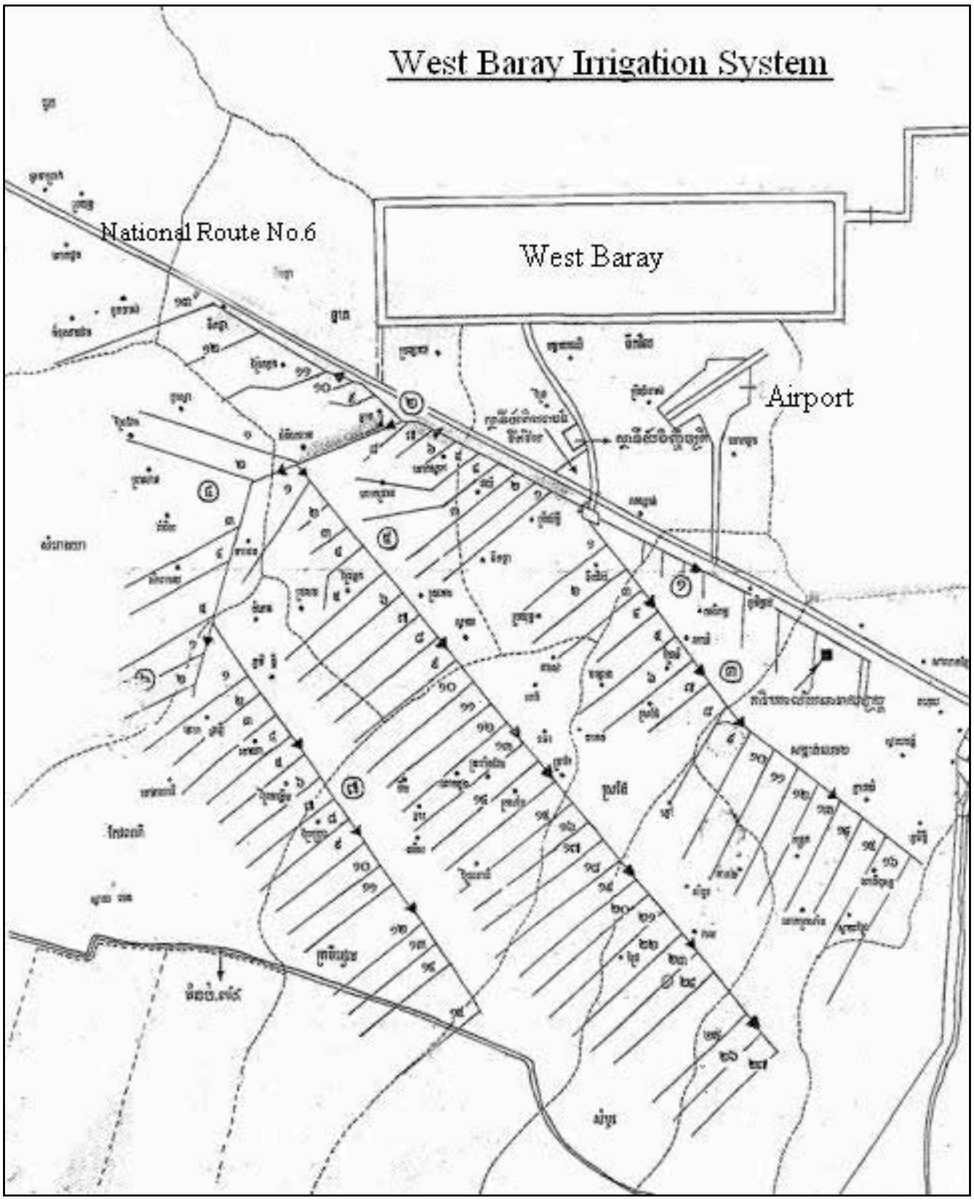


Figure III.7.18 West Baray Irrigation System

2) Crocodile Weir Irrigation System

The Crocodile Weir System is supplied from Siem Reap River. Water for irrigation is taken at the Crocodile Weir located about 1.8 km downstream from the National Road No.6. The irrigated area accounts for some 2,400 ha through two irrigation canal, i.e. Vichear Chin Canal on the right bank and Chreav Canal on the left bank.

According to the periodical flow measurements undertaken by the Study on Water Supply System for Siem Reap Region in Cambodia (JICA, 2000), an average intake rate is estimated around 1.0 m^3/sec. However, the water intakes for two canals are not subject to gate control. Since there is no significant reservoir for the system, it would not be possible to secure 1.0 m^3/sec during the driest period according to the flow measurements carried out in 1998.

7.1.4 Related Laws and Policies

(1) National Water Resources Policy (2004)

The Policy was prepared for the following objectives:

- To protect, manage and use water resources in effective, equitable and sustainable manner;
- To foresee and take measures to assist related institutions to settle the facing problems which might be occurred in water sector;
- To develop and implement the national strategy and formulate national policies and sector policies on water resource management;
- To develop, manage and utilize water resources, management and utilization in the Kingdom of Cambodia for all activities of institutions, private sector and public sector; and
- To improve and uplift the people's living standard of the people to achieve the national policy on poverty reduction and sustainable national economy development.

For appropriate development and management of water resources, the Policy considers water as resource of agriculture, industry, domestic use, hydropower, fisheries/ aquaculture and tourism. However, it is clearly mentioned that the water allocation rule has not been prepared yet due to the lack of information and data on water requirements of the sectors above. Also mechanisms, principles and regulations for determining water use fees are limited.

The following policies were addressed besides the issues above to assure effective and equitable water allocation that achieves the greatest National benefit.

- To promote the equitable sharing and allocation of water, introduce necessary laws, regulations, and procedures to achieve them;
- To apply fees and/ or licenses for water use where they are necessary to conserve the water resources, and administer them in a consistent and timely manner;
- To share water during periods of water shortage, normally in the following order; domestic and municipal uses, irrigation, hydropower, industry and small manufacturing enterprises, navigation, aquaculture and minimum flows for river ecosystem maintenance; and
- To take international agreements fully into account in the use and allocation of water during periods of water shortage in rivers, streams along the borders of neighboring countries.

(2) Law on Water Resources Management (Finalized in March 2002)

The final draft of Water Resources Management Law was submitted to the National Assembly and waiting for its approval. The following items were stipulated in the drafted Law.

- Rights and obligations of water use;
- Fundamental principles of water resource management;
- Institutions in charge of its implementation and enforcement; and
- Participation of users and their associations in the sustainable development of water resources.

Moreover, it is obligated commercial and/or professional use of groundwater to submit; (i) detailed reports on drilling operation, (ii) technical specification, and (iii) other information of well, to Ministry of Water Resources and Meteorology (MOWRAM) to get a license as well as groundwater use right. At the present ministerial task demarcation, the groundwater issue belongs to Ministry of Industry, Mines and Energy (MIME). Therefore, it is required coordination work to confirm the submission and approving agency.

(3) Sub-Decree on the Issuance and Administration of License under the Water Resources Management Law (Drafted in April 2001)

The Sub-Decree consists of water use licenses, extraction and filling licenses, drillers' (groundwater) licenses and wastewater discharge licenses. The Sub-Decree is attached with required forms prepared as simple as possible concerning its practice.

The Sub-Decree proposed to set maximum duration of water use licenses as follows:

- Irrigation: 5 years;
- Domestic/ municipal water supply: 10 years;
- Rural water supply: 10 years;
- Aquaculture: 2 years;
- Commercial livestock watering: 5 years;
- Hydropower: 10 years;
- Industrial use: 2 years;
- Tourism: 2 years.

The sub-degree will be executed soon after Law on Water Resources Management approved by the National Assembly.

(4) National Policy on Water Supply and Sanitation (2003)

The Policy has determined to improve the living standards and general welfare of the people to ensure everybody to access safe water and sanitation services as well as clean lives, healthy and sustainable environment. The Policy consists of three parts; Urban Water Supply, Urban Sanitation, and Rural Water Supply and Sanitation.

The urban water supply policy involves two major approaches to ensure sustainable services and provide the population with access to safe water as shown below.

Supply Driven Approach

To prepare the plan and to construct the water supply system based on the estimated water demands for targeted area and year.

Demand Responsive Approach

To give the people a range of technical options together with cost, operation and maintenance issues for their consideration and decision.

The Policy also mentioned an opportunity of Private Sector Participation (PSP) to expand the water supply services and to promote market competition. However, the Government is not in a position to support the idea yet because the legal framework and the water regulatory body has not been facilitated for PSP.

(5) National Poverty Reduction Strategy (2002)

Council of Social Development (CSD) set up the target for safety water access ratio of 40% for rural population up to the 87% for urban population. Those target sets for year 2005 based on the Socio-Economic Development Plan II.

(6) Drinking Water Quality Standard (2004)

The Task Force prepared this standards based on drinking water quality guidelines (2003) of the World Health Organization (WHO) with particular adaptation to the water quality problems in Cambodia.

The Standard consists of parameters, sampling methods and analytical methods. The parameters and concentrations are summarized in table below.

Table III.7.6 Table of Parameters and Concentrations (TPC)

Inorganic Constituents of Health Significancein Drinking Water

parameter	max. value mg/L (ppm)
Arsenic	0.05
Barium	0.7
Cadmium	0.003
Chromium	0.05
Cyanide	0.07
Fluoride	1.5
Lead	0.01
Mercury	0.001
Nickel	0.02
Nitrate as NO_3^-	50
Nitrate as NO_2^-	3
Selenium	0.01

Organic Constituents of Health Significance to Drinking Water

parameter	max. value _g/L (ppm)
Polychlorinated Biphenyls (PCBs)	0.5
Benzene	10
Disinfection-by-product	
Trihalomethanes	250
Pesticides	
2, 4 D	30
Aldrin and Dieldrin	0.3
Carbofuran	10
Chlordane	0.2
DDT	20
Dichlorvos	1
Dimethoate	6
Endosulfan	30
Endrin	0.6
Glyphosate	10
Heptachlor	0.3
Hexaclorobenzene	1
Methyl Parathion	0.3
Mevinphos	5
Monocrotophos	1
Paraquat	30
Parathion	10
Permethrin	20

Bacteriological Quality for Drinking Water

parameter	max. value
Thermotolerant (Fecal)	
Coliforms or E.Coli	0 per 100 mL
Total Coliform	0 per 100 mL

Physical and Chemical Quality (aesthetic quality)

parameter	max. value mg/L (ppm)
Taste	acceptable
Odor	acceptable
Color	5 TCU
Turbidity	5 NTU
Residual Chlorine	0.2-0.5
pH	6.5-8.5 (no unit)
Aluminum	0.2
Ammonia	1.5
Copper	1
Hardness	300
Hydrogen Sulfide	0.05
Iron	0.3
Manganese	0.1
Sodium	200
Sulfate	250
Total Dissolved Solids	800
Zinc	3

Small water supply system, which serving less than 100 people or delivering less than 10m3/day, should be follow priority parameters below.

Priority Parameter in Small Water Supplies

parameter	max. value
pH	6.5-8.5 (no unit)
Turbidity	5 NTU
Arsenic	0.05 mg/L
Iron	0.3 mg/L
Total Dissolved Solids (TDS)	800 mg/L
Thermotolerant (Fecal)	
Coliforms or E.Coli	0 per 100 mL

7.1.5 Relevant Studies and Projects

(1) Water Management in the Angkor Area (Angkor Foundation-Hungary, 1993)

The Study aims to review the ancient practice and the present state of water management, in order to contribute to identification of the Angkor area and to prepare its water management plan.

As conclusion, the Study brought up a recommendation to conduct a regional master plan study that would cover the catchments area of the Tonle Sap Lake and its northern tributaries. The master plan should consist of:
- Review of the natural environment;
- Survey of surface and groundwater resources;
- Water pollution control;
- Agricultural water use; and
- Domestic water supply and sewage treatment.

It is also mentioned that, the master plan should have an attention to the role of the Kulen Mountain for the water management of the area.

(2) The Study on Water Supply System for Siem Reap Region in Cambodia (JICA, 2000)

The JICA Development Study conducted Study on Water Supply System for Siem Reap Region for the following objectives:
- To evaluate potential of water sources for the water supply system in Siem Reap Region;
- To formulate a master plan for the water supply system in the Siem Reap City;
- To conduct a feasibility study on priority project identified in the master plan; and
- To pursue technology transfer to counterpart personnel in the course of the Study.

The Study consists of three phases shown below.
- Phase I Study on Water Resources
- Phase II Preparation of Master Plan
- Phase III Preparation of Feasibility Study

In the Study, four (4) alternative water sources of groundwater such as West Baray, Siem Reap River, and Tonle Sap Lake were investigated. Considering the cost, operation & maintenance, impacts to Angkor heritage, reliability, water quality, flexibility of the system and environmental impact, and groundwater, the groundwater development especially for hotels were selected as the most suitable alternative of the water source for the Siem Reap water supply system.

The Master Plan targets the year 2010. The water treatment plan with a capacity of 8,000 m^3/d was proposed as the first priority (phase I) project to meet the demand in 2006 and additional 4,000 m^3/d for phase II project in the year 2010.

(3) Basic Design Study on the Project for Improvement of Water Supply System in Siem Reap Town in the Kingdom of Cambodia (JICA, 2003)

JICA prepared the Basic Design for the recommended project of Phase I by the Study on Water Supply System for Siem Reap Region in Cambodia (2000). From February 2004, the implementation work (including detailed design) started under the JICA Grant Aid and construction started from November 2004 until early 2006.

Initially partial service (60% of the capacity) will start in the year of 2006 and the full operation starts in the year 2008. The summary of the project are described as follows:
- Target Year 2008

- Service area 425 ha
- Design coverage 65% of domestic & public and 40% of tourism demand
- Population served 26,000 (in 2008)
- Unit water demand 120 Lpcd (domestic, 2008), 500 Lpcd (tourism, 2008)
- Water source Groundwater (1,100 m^3/d x 8 wells)
- Peak factor 1.2 (domestic & public), 1.57 (tourism)
- Non revenue water 15% (2008)

(4) Protection and Management of Critical Wetlands in Lower Mekong Basin Tonle Sap Port and Navigation Development (ADB TA 5822-REG, 2000)

ADB conducted a feasibility study on port investment and development in the Tonle Sap in 2000. As a part of the study, groundwater investigations in Chong Kneas (Siem Reap province) and Chnok Trou (Kampong Chnang province) were conducted.
The conclusion of the investigation for the Chong Khneas is summarized below:

- Three (3) aquifers were founded:
  1. Shallow aquifer (2.5 to 10.0m), much iron contained
  2. Medium aquifer (15-21m), much iron contained
  3. Deep aquifer (deeper than 21m), less iron contained
- The nominal capacity of the 6-inch diameter with submersible pump at 22m depths is 90 m^3/hrs.
- The transmissivity (penetration rate) in this area is more than 1,000 m^2/day (very high). The well can provide sufficient water for high consumption.
- The aquifer in this area has high recharge/penetration from Tonle Sap Lake.
- Good storage coefficient calculated around $5x10^{-5}$ confined aquifer.
- Good water quality, expect manganese (Mn) which were a bit higher than WHO standard for drinking water.

(5) Vision for Water Resource Management of Siem Reap Angkor Area (WAPCOS-INDIA, 2004)

Water and Power Consultancy Services (WAPCOS) conducted a study funded by Indian Government aims to analyze the water problems and to prepare an action plan with the target year of 2015.

As conclusion, to improve the critical water management, “Integrated Water Resources Management (IWRM)” was proposed integrating the concerns regarding water, land, culture and tourism particularly. The action plan consists of; (i) software solutions, (ii) hardware solutions for rehabilitation, (iii) hardware solutions for enhancing development, and (iv) hardware solutions for promoting sustainability.

The first priority projects are the establishment of information management system, groundwater regulation, integrated water resources management plan and implementation of the West Baray rehabilitation. The second priority projects are water quality modeling, study for capacity building, initiating impact assessments, archaeological restoration and detailed plan for additional storage and groundwater use.

(6) Rehabilitation of West Baray Irrigation Project (WAPCOS-INDIA, 2004)

The Project was conducted as a first priority intervention clarified by the previous study on Vision for Water Resource Management of Siem Reap Angkor Area. The detailed design work was done in October 2004. A consultant for construction supervision will be mobilized in April 2005 and start a bid for the contractor selection. The construction work is scheduled for two years from December 2005 to November 2007

The Project consists of the West Baray rehabilitation, irrigation canal rehabilitation and extension. The total capacity of West Baray was assumed 73.31 million m^3, and it was proposed to provide 9 million m^3/year for water supply and other use.

7.1.6 Sectors Issues

The issues on water resources and water supply sectors can be classified in to three major problems as specified below.

(1) Lack of Water Resources Management

Siem Reap City, which is the center of tourism activity of Cambodia, is facing many water-related issues. Water shortage and river water sanitation during dry season are one of major problems faced. Beside lack of wastewater treatment system, lack of water flow in dry season also accelerates pollution of Siem Reap River.

As stated in the previous section of this chapter, the water resources both for surface water and groundwater are lack of basic information, capacity monitoring data, management and operation plan, and proper general development plan.

There is no gate operation record and water flow data, as well as actual water consumption data for surface water which is mainly utilize for agriculture use. Also there is no record on actual groundwater well abstraction capacity due to almost no water meter installed in the existing wells. Moreover, there is no sufficient actual water resources potential data, which is required as a planning basis.

The law related to the water resources management and water use right also not yet exist in the Cambodia. The people can take surface water and groundwater as they like without any permission and registration. Therefore, it is very difficult for related organization to grasp and monitor the present water use condition.

In addition, it is difficult to quantitative analysis the problems and prepares the optimum countermeasure to solve the present water related issues.

(2) Concentration of Groundwater Abstraction at Town Center Area

Almost all housing, public and commercial buildings in the town have their own individual well to supply water demand by own self. It is due to low service coverage ratio of water supply service which is about 10% in year 2004.

The dense construction in the center of town causes concentration of groundwater abstraction in the limited area. The distance of each well, especially for big capacity wells of the large scale hotels may not be sustainable enough to maintain the well and it may causes groundwater declination and land subsidence.

(3) Weak Public Water Supply Services

Service coverage ratio in 2004 is only around 10%. This figure is far lower than the average of 81% for 50 cities in Asian and Pacific Region, which was stated in the "Second Water Utilities Data Book (ADB, 1997)", also 83% for Phnom Penh.

Judging from the comments which were given by many hotels through the questionnaire survey, customer satisfaction of the water supply service is very low. It is not only limited for the supplied water quantity, but also service of the waterworks and tariff.

Government of Japan has been conducted construction of new water treatment plant with capacity of 8,000 m^3/day, includes distribution pipelines and capacity building of the Siem Reap Water Supply Authority (SRWSA). Target service coverage ratio is set as 65% for 2008 with Non Revenue Water (NRW) of 15%. During the capacity building (soft component) period, the tariff adjustment based on Financial Recovery Action Plan should be conducted by SRWSA themselves with support from the project Consultant. Therefore, the services can be improved drastically after its implementation, expect construction of individual connection to supply water to the customer.

In order to promote the conversion of public water source from groundwater to water supply service, publicity campaign is necessary to be conducted to ensure and change the people's awareness.