

CHAPTER 4 WATER SUPPLY MASTER PLAN

4.1 Population, Service Area and Water Demand

For a competent water supply master plan, population projection, fix of service area and water demand in the target year are significant. Based on the water required, a suitable water source can be selected.

4.1.1 Future Population Forecast

The target year of the Study is 2010. A most probable scenario was set for the estimation of population in the Siem Reap Region.

(1) Population Data Available

A general population census was held in Cambodia in 1998. National Institute of Statistics under the Ministry of Planning compiled the results into a report. Recent population data was used from this report. In addition, various other sources were used to collect population data available. The population of Siem Reap Province is given in the following two tables.

Population of Siem Reap Province (Year: 1997)

Area	Nos. of Household	Household Size	Population	Male	Female	Density (per/km ²)
Cambodia	1,976,926	5.2	10,310,626	4,944,500	5,357,126	57.0
Siem Reap	119,455	5.6	669,875	316,626	353,249	65.0
Share	6.0%		6.5%	6.4%	6.6%	

Source: Provincial Development Plan of Siem Reap, 1998

Population of Siem Reap Province (Year 1998)

Area	Nos. of Household	Household Size	Population	Male	Female	Density (per/km ²)
Cambodia	2,187,238	5.2	11,426,223	5,509,204	5,917,019	63.1
Siem Reap						
Urban	20,980	5.7	119,484	58,625	60,859	
Rural	106,106	5.4	576,001	278,115	297,886	
Total/Avg.	127,086	5.5	695,485	336,740	358,745	67.5
Share	5.8%		6.1%	6.1%	6.1%	

Source: General Population Census, 1998

Population growth rate of Siem Reap Province is given in the following table.

Population Growth Rate of Siem Reap Province

Year	Population	Growth Rate per annum (%)
1991	555,344	
1992	578,118	4.10
1993	599,064	3.62
1994	608,400	1.56
1995	637,451	4.77
1996	659,761	3.50
1997	669,875	1.53
1998*	695,485	3.82
1991-1998		3.27
1993-1998		3.03
1995-1998		2.95
Cambodia*		2.4

Source: Provincial Development Plan of Siem Reap, 1998

Source of *: General Population Census, 1998

In Siem Reap Province, there are 14 districts. District wise population in 1997 is shown in the following table.

District wise population of Siem Reap Province(1997)

District	Population in 1997
Angkor Chum	45,549
Angkor Thom	16,052
Chi Kreng	100,304
Sotnikum	87,944
Prasat Bakong	49,877
Kralanh	54,740
Puok	105,969
Chong Kal	14,817
Samrong	24,801
Siem Reap	98,816
Varin	12,842
Srei Snam	26,434
Banteay Srei	22,771
Svay Leu	8,959
Total Province	669,875

Source: Provincial Development Plan of Siem Reap, 1998

There are 10 communes in the Siem Reap District and they are shown in Figure 4.1.1. Commune wise population in different year with growth rate is given in the following table.

Communes	1992* ¹	1993* ²	1997* ³	1998* ⁴	Annual Growth Rate (93-98)%
Chong Khnies		4,744		4,883	0.58
Chreav		5,384		6,344	3.34
Kouk Chak		11,884		14,394	3.91
Nokor Thum		3,111		3,575	2.82
Sala Kamraeuk		8,459		12,511	8.14
Sambuor		2,372		2,513	1.16
Siem Reap		11,134		12,158	1.78
Sla Kram		15,218		21,334	6.99
Srangae		3,892		4,500	2.95
Svay Dangcum		18,381		21,540	3.22
Total District	74,900	84,579	98,816	103,752	4.17

Sources:

*1: UNTAC Survey, from APSARA-UNESCO Report, 1996

*2: Office of Planning, Siem Reap Province

*3: Provincial Development Plan of Siem Reap, 1998

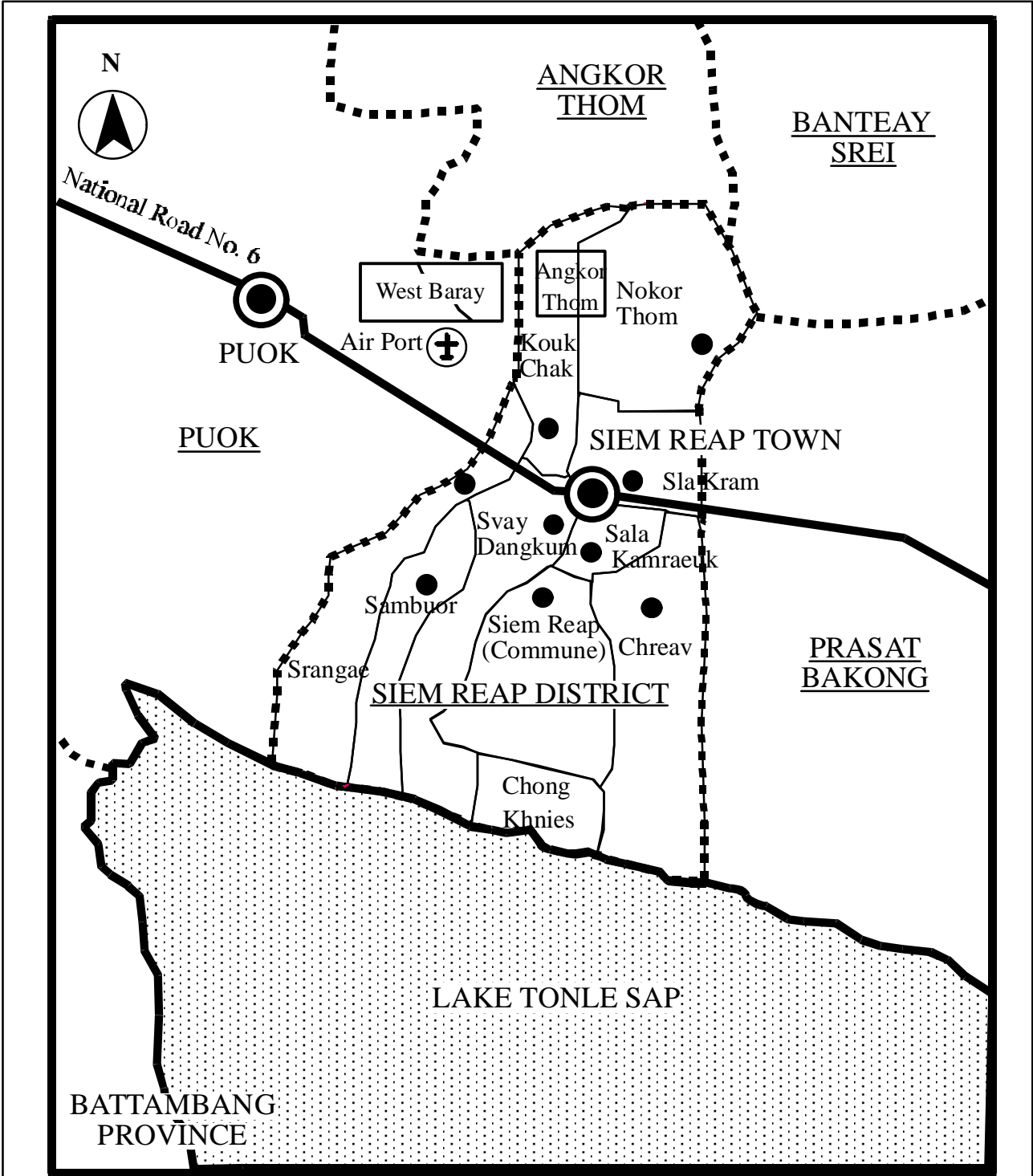
*4: District Office of Siem Reap

From this table, the annual growth rate for the whole district can be calculated as 3.97% during 93-97, 5.70% during 92-97, 5.58% during 92-98, and 4.17% during 93-98.

Each commune has a number of villages. The detail village wise population distribution of all 10 communes in the Siem Reap District is given in the Table 4.1.1.

(2) Future Population Growth Rate

Not all communes of Siem Reap District will come under the service area. The proposed service area of Siem Reap comprises with area that lies in the communes of Svay Dangcum, Sala Kamraeuk and Sla Kram. To make the projection most realistic, different growth rates are considered for each communes rather than single growth rate for whole service area. Since the 1993 – 1998 growth rates of Svay Dangcum, Sala Kamraeuk and Sla Kram are 3.22, 8.14 and 6.99, respectively, growth rates of 7.0, 8.1 and 7.0% are considered up to 2010 for the three communes respectively. These comply with the future land use plan. Because of non-availability of acceptable data of pre-1993 period, only six years data was used to make the future projection.



Legend

<u>SIEM REAP</u> : District Name	— : Commune Boundaries
Svay Dangkum : Commune Name	● : District Center
■■■■■ : District Boundaries	● : Commune Center



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Figure 4.1.1
Location Map of Siem Reap District
with Commune Names

Table 4.1.1 Detailed Population Data in 1998 (1/2)

(Year 1998)

No. Village	Families	Population	Female % of Female	
Commune: Svay Dangcum				
1 Po Bos	82	473	255	53.9%
2 Phynea Chey	93	519	256	49.3%
3 Thmey	123	707	386	54.6%
4 Svay Prey	115	636	335	52.7%
5 Svay Dangcum*	186	1,124	564	50.2%
6 Kok Krasang	117	651	357	54.8%
7 Kan Trak	197	1,025	512	50.0%
8 Vihear Chen*	565	3,528	1,968	55.8%
9 Mundol 1*	296	1,723	883	51.2%
10 Kruos	384	2,289	1,209	52.8%
11 Stung Thmey*	408	2,459	1,296	52.7%
12 Mundol 2*	76	480	240	50.0%
13 Ta Phul*	438	2,478	1,318	53.2%
14 Sala Kanseng*	607	3,448	1,730	50.2%
Total	3,687	21,540	11,309	52.5%
Remarks: Villages with * are included in the service area.				
Commune: Sala Kamraeuk				
1 Wat Bo*	649	3,916	2,078	53.1%
2 Vat Svay	499	3,054	1,606	52.6%
3 Vat Domnak*	424	2,560	1,357	53.0%
4 Sala Kamraeuk*	169	957	497	51.9%
5 Ta Vein*	177	1,084	548	50.6%
6 Chun Ling	93	505	289	57.2%
7 Trapaing Treng	77	435	219	50.3%
Total	2,088	12,511	6,594	52.7%
Remarks: Villages with * are included in the service area.				
Commune: Sla Kram				
1 Chong Kaosu*	1,121	6,236	3,168	50.8%
2 Dok Po*	381	2,361	1,217	51.5%
3 Banteay Chas*	757	4,629	2,402	51.9%
4 Boeng Donpa*	365	2,059	1,030	50.0%
5 Mondol 3	360	2,043	1,066	52.2%
6 Sla Kram*	347	2,043	1,068	52.3%
7 Treang	344	1,963	1,026	52.3%
Total	3,675	21,334	10,977	51.5%
Remarks: Villages with * are included in the service area.				
Commune: Siem Reap				
1 Spean Chreav	313	1,936	695	35.9%
2 Po	329	2,088	1,095	52.4%
3 Aranh	383	2,366	1,238	52.3%
4 Phnom Krom	358	2,039	1,093	53.6%
5 Kar Kranh	270	1,665	844	50.7%
6 Pra Laay	91	526	264	50.2%
7 Krasang Roloeung	111	619	329	53.2%
8 Triek	155	919	480	52.2%
Total	2,010	12,158	6,038	49.7%

Table 4.1.1 Detailed Population Data in 1998 (2/2)

(Year 1998)

No. Village	Families	Population	Female % of Female	
Communes: Chong Khnies				
1 First	95	748	396	52.9%
2 Second	92	570	291	51.1%
3 Third	99	642	336	52.3%
4 Fourth	85	566	286	50.5%
5 Fifth	75	462	246	53.2%
6 Sixth	80	425	207	48.7%
7 Seventh	192	1,470	770	52.4%
Total	718	4,883	2,532	51.9%
Commune: Chreav				
1 Boeung	101	577	298	51.6%
2 Kra Sang	145	789	407	51.6%
3 Veal	204	1,117	562	50.3%
4 Chreav	88	530	257	48.5%
5 Ta Chek	97	572	296	51.7%
6 Bos Kralanh	156	904	450	49.8%
7 Khnar	312	1,855	966	52.1%
Total	1,103	6,344	3,236	51.0%
Commune: Srangae				
1 Ta Chark	61	374	200	53.5%
2 Chon Long	93	587	315	53.7%
3 Srangae	123	620	315	50.8%
4 Prey Thom	89	496	252	50.8%
5 Roka Thom	68	380	213	56.1%
6 Kak Sekam	175	987	496	50.3%
7 Thnal	180	1,056	559	52.9%
Total	789	4,500	2,350	52.2%
Commune: Kouk Chak				
1 Trapeang Sess	661	3,269	1,612	49.3%
2 Taksen Tbong	282	1,526	783	51.3%
3 Veal	400	2,229	1,113	49.9%
4 Nokor Krao	368	2,238	1,106	49.4%
5 Kok Tachan	141	712	416	58.4%
6 Kok Beng	176	930	472	50.8%
7 Kok Thnot	336	1,937	996	51.4%
8 Khvien	290	1,553	805	51.8%
Total	2,654	14,394	7,303	50.7%
Commune: Nokor Thom				
1 Roharl	166	963	491	51.0%
2 Srahsrang Choeung	134	741	377	50.9%
3 Srahsrang Tbong	76	413	230	55.7%
4 Kra Vann	114	646	443	68.6%
5 Arak Svay	71	405	202	49.9%
6 Anh Chanh	65	407	189	46.4%
Total	626	3,575	1,932	54.0%
Commune: Sambuor				
1 Sambuor	118	577	297	51.5%
2 Veal	85	474	241	50.8%
3 Phnaov	100	530	291	54.9%
4 Chrey	84	476	226	47.5%
5 Takong	89	456	237	52.0%
Total	476	2,513	1,292	51.4%

For the Svay Dangkum Commune, only about 50% of 7 villages are included in the service area out of 14 villages. These are locations close to urbanized area. As a result, a growth rate of 7.0% is projected considering the growth rate of other urbanized adjoining area. In addition, within the commune Sla Kram (whose growth rate is considered as 7.0%), the growth rates of two villages (namely Dok Po and Ta Vein) are set at 10.0% considering the expected urbanization proposed by APSARA.

(3) Tourist Projection

Tourist arrival to Siem Reap from 1986 to 1998 is given in the Table 4.1.2. It shows that in 1996, highest 55,560 tourists purchased tickets to enter Angkor heritage. Since some social disorder prevailed in 1997 and 1998, tourist arrivals during those periods are considered as not normal. Subsequent calculation was done cautiously to avoid this special occurrence. It is evident from the table that peak season for tourist is from November to March.

Annual growth rate of tourists in Siem Reap is calculated as follows:

Annual Growth Rate of Tourists in Siem Reap

Range of years	Annual Growth Rate (%)
1986 – 1998	39.3
1986 – 1993	45.1
1993 – 1998	31.7
1986 – 1996	58.2
1993 – 1996	93.8

Before privatization of entrance fee collection, Government did not charge official delegates, members of NGOs, UN agencies and other international organizations working in Siem Reap, and tour leaders. Their share among the total tourist is given below:

Visitors Data in 5 Years from Oct. 1993 to Sep. 1998

Category of visitors	Number	Share of Total Visitors (%)	Share to Tourists Only (%)
Tourists	188,809	76.6	100
Delegations	22,985	9.3	12.2
NGO, UNO, IO	21,914	8.9	11.6
Tour Leaders	12,792	5.2	6.8
Total Visitors	246,500	100.0	131

Source: Tourism Office in Siem Reap

Table 4.1.2 Tourist Arrivals to Siem Reap

Data source: Tourist Office, Siem Reap

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1986													565
1987													732
1988													1,552
1989													2,296
1990													2,160
1991													5,432
1992													10,904
1993	1,079	1,092	1,018	735	53	35	372	400	245	549	1,014	1,046	7,638
1994	1,458	1,649	2,130	1,806	1,678	818	1,393	2,142	1,181	2,467	4,776	3,795	25,293
1995	3,549	3,968	4,724	2,905	2,560	2,306	2,850	4,158	2,716	3,802	5,803	5,492	44,833
1996	6,581	7,468	6,721	5,928	3,487	2,760	3,259	3,667	2,123	3,013	5,878	4,675	55,560
1997	7,488	6,456	5,842	3,026	2,188	1,603	311	212	163	622	1,040	2,521	31,472
1998	3,597	3,789	4,155	3,488	2,783	1,624	1,570	1,970	1,395	1,062	2,094	2,728	30,255
1999													

Remarks: Social disorder prevailed in Cambodia and Siem Reap from July 1997 till December 1997.
 General election in 1998 caused a certain social instability in Cambodia from May to October 1998.
 Tourists means the visitors who bought an entrance ticket to the Angkor Heritage.

Total A	23,752	24,422	24,590	17,888	12,749	9,146	9,755	12,549	7,823	11,515	20,605	20,257	195,051
Share A	12.18%	12.52%	12.61%	9.17%	6.54%	4.69%	5.00%	6.43%	4.01%	5.90%	10.56%	10.39%	100.00%
Total B	12,667	14,177	14,593	11,374	7,778	5,919	7,874	10,367	6,265	9,831	17,471	15,008	133,324
Share B	9.50%	10.63%	10.95%	8.53%	5.83%	4.44%	5.91%	7.78%	4.70%	7.37%	13.10%	11.26%	100.00%

Remarks: Total A is the sum of visitors from 1993 to 1998.
 Total B is the sum of visitors from 1993 to 1996 to avoid special occurrence.
 Case B is applied to Table 4.1.3, Projection of Tourist Numbers.

Length of stay by the tourists is given in the following table. The average length of stay is 1.77 in days.

Length of Stay	Number	Share (%)	Man-day
1/2 day	1,150	0.6	575
1 day	124,481	65.9	124,481
3 days	58,487	31.0	175,461
7 days	4,691	2.5	32,837
Total	188,809	100.0	333,354

For the future tourist projection, three scenarios are considered. The annual increases in these three scenarios are considered as 30,000, 50,000 and 70,000, respectively. Also, a future average stay is considered as 2 days for tourists, 2 days for tour leaders, 6 days for delegations and 30 days for the members of NGOs, UNOs and IOs. A detail projected tourist arrival by monthly basis is given in Table 4.1.3. According to these scenarios, the projected tourist numbers in 2010 are 475,560, 755,560, and 1,035,560, respectively. In consideration of tourist projections made by various agencies, the most logical scenario is the scenario B that considers an annual increase of 50,000. According to this scenario, the expected tourists in 2000, 2005 and 2010 are 255,560, 505,560 and 755,560, respectively.

Considering a uniform distribution over entire year, the number of tourists per day in 2000, 2005 and 2010 are 700, 1,385 and 2,070, respectively. Since it is considered that average stay is 2 days per tourist, this effectively means that average number of tourists per day in 2000, 2005 and 2010 are 1,400, 2,770 and 4,140, respectively.

The number of tour leaders will increase with the increase of tourists. Considering the same relative percentages to total foreigners in Siem Reap as shown above, the number of tour leaders are 95, 188 and 280 in 2000, 2005 and 2010, respectively. However, the number of foreigners working in various international organizations and the number of foreign delegates are assumed to remain constant. From the 5-year data shown above, the number of delegates (average stay 6 days) and organization staffs (average stay 30 days) are 76 and 360 per day, respectively. The projected per day number of foreigners in Siem Reap is shown below.

Category of Visitors	2000	2005	2010
Tourists	1,400	2,770	4,140
Tour Leaders	95	188	280
Delegations	76	76	76
NGO, UNO, IO	360	360	360
Total	1,931	3,394	4,856

Table 4.1.3 Projection of Tourist Numbers

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual Total
Share B in Table 4.1.2	9.5 %	10.63 %	10.95 %	8.53 %	5.83 %	4.44 %	5.91 %	7.78 %	4.70 %	7.37 %	13.10 %	11.26 %	100.00
	Annual Increase: 30,000 (Scenario A)												
2000	16,680	18,668	19,216	14,977	10,242	7,794	10,368	13,651	8,250	12,945	23,006	19,762	175,560
2005	30,931	34,618	35,634	27,774	18,993	14,453	19,227	25,315	15,298	24,006	42,662	36,648	325,560
2010	45,183	50,569	52,052	40,570	27,744	21,113	28,086	36,979	22,347	35,067	62,318	53,533	475,560
	Annual Increase: 50,000 (Scenario B)												
2000	24,281	27,175	27,972	21,802	14,909	11,346	15,093	19,872	12,009	18,844	33,489	28,768	255,560
2005	48,033	53,759	55,336	43,130	29,494	22,445	29,858	39,311	23,757	37,279	66,249	56,910	505,560
2010	71,785	80,342	82,700	64,458	44,079	33,544	44,623	58,751	35,504	55,713	99,010	85,052	755,560
	Annual Increase: 70,000 (Scenario C)												
2000	31,881	35,682	36,729	28,627	19,576	14,897	19,818	26,092	15,768	24,743	43,972	37,773	335,560
2005	65,134	72,899	75,038	58,486	39,995	30,436	40,489	53,308	32,215	50,552	89,837	77,172	685,560
2010	98,388	110,116	113,347	88,345	60,414	45,974	61,159	80,523	48,662	76,360	135,702	116,571	1,035,560

4.1.2 Service Area

Service area was selected in such a way so that maximum benefit could be obtained given that the system would be sustainable.

(1) Future Land Use Plan

As explained in Section 3.6.1, urban development will be concentrated to the east of the Siem Reap River. Residential areas and new public services will be extended south of National Road No. 6. An international hotel zone will be developed in the northeast area. Area immediately south of the Angkor heritage will be reserved for forestation. The west area will be used primarily for agricultural purposes.

(2) Service Area

Because of the high population density and concentration of major facilities, the central part of the town will form the core of the future water supply. As explained in Section 3.6.1, the basic urban characteristics of the town outside of the central part is determined by two defining features, the river and the National Road No.6. The river imposes a north-south orientation on the urban landscape and the road repeats the same characteristics in the east-west direction. The urbanized sectors of the town have no depth beyond several hundred meters nearest to the river or the road. Because of this unique urban development characteristic, the future water supply service area will essentially extend linearly in four directions from the town center.

Based on the future land use plan, there will be no future urban expansion in northwest and southwest sectors except for the proposed hotel zone in northeast. So those portions can principally be kept out of future service area. However, separate water supply will be provided to the proposed hotel zone. Since the urban plan calls for an extension of urbanization in the southeast part, service area should include that portion. The extent of the urbanization in the southwest part will be less, so as the future water supply service.

In order to delineate the actual service area boundary, the Study Team visited all the peripheral places and took consideration of the actual situation. A future water supply service area is delineated in the field based on:

- Population,
- Population density,
- Expected urbanization,
- Current situation of land use,
- Future land use plan,
- Development plans,
- Cover ratio for expected service area, and

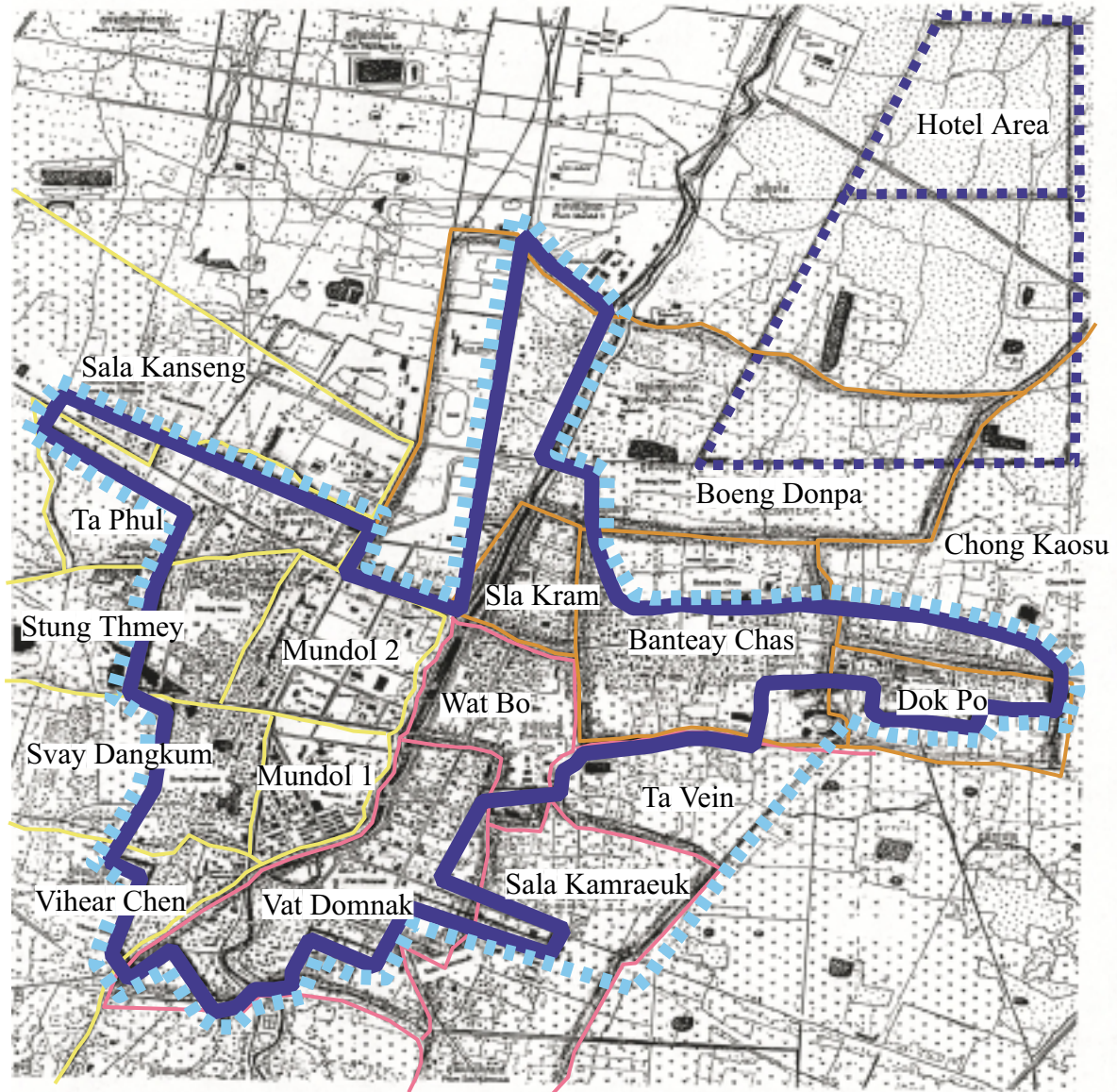
- Economic strength of the population.

Considering present urban use and potential future growth, the service area is proposed by divided into two stages. The service area is shown in the Figure 4.1.2. The proposed service area of Stage 1 includes portions of 7 villages of Svay Dangkum commune, portions of 3 villages of Sala Kamraeuk commune and portions of 5 villages of Sla Kram commune. The total service area is 345 ha. In Stage 2, although only one village of Sla Kram Commune included in the service area additionally, the cover areas of some of the villages are increased. The total service area at the end of Stage 2 is 436 ha.






(3) Future Population in Service Area

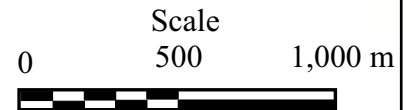
It is explained in Section 4.1.1 that different population growth rates are considered for each commune in the service area and sometimes for each village. Also, population coverage is estimated in case of partial inclusion of a village in the service area. This population was estimated by comparing the total village area with included area. A saturation population density is assumed as 200 persons per hector.

Detail calculation is given in the Table 4.1.4. This shows future populations of 37,028 in 2005 in Stage 1 service area. The future population in Stage 2 service area is 53,151 in 2010. The yearly growth is shown by a growth curve in Figure 4.1.3.



Legend

	Service Area in 2006		Village Boundaries Commune:Sla Kram
	Service Area in 2010		Village Boundaries Commune:Svay Dangkum
Dok Po	Village Name		Village Boundaries Commune:Sala Kamraeuk



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**Figure 4.1.2
Service Area**

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Table 4.1.4 Population in Service Area**Stage 1**

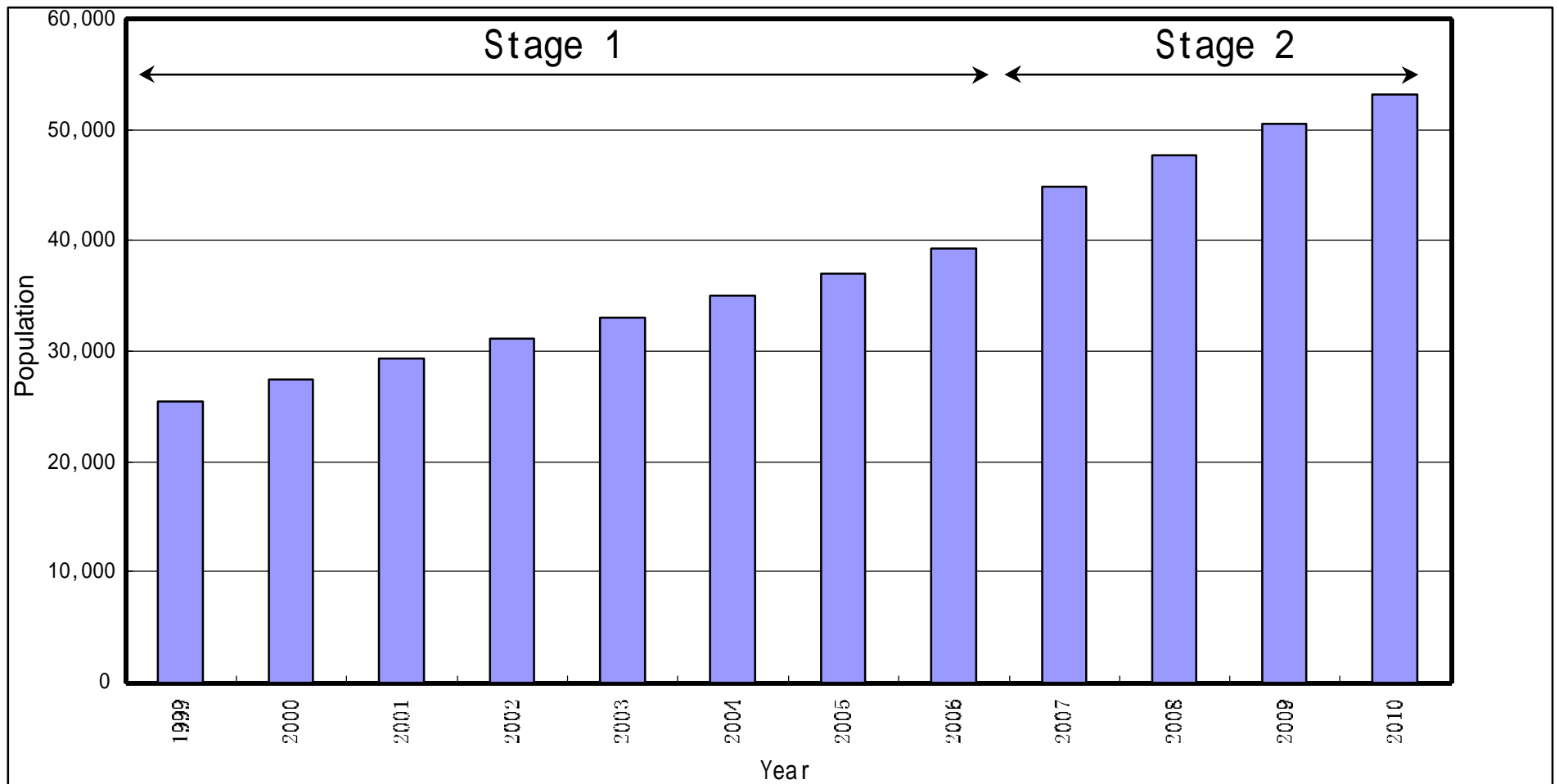
Communes	Villages	Year 1998 Population	Population Coverage	Service Area		Growth Rate	2000	2005	2010
				Population	(ha)				
Svay Dangcum									
	Svay Dangcum	1,124	0.70	787	22	7.0%	901	1,263	1,772
	Vihear Chen	3,528	0.10	353	8	7.0%	404	567	795
	Mundol 1	1,723	1.00	1,723	19	7.0%	1,973	2,767	3,800
	Stung Thmey	2,459	0.80	1,967	27	7.0%	2,252	3,159	4,431
	Mundol 2	480	1.00	480	35	7.0%	550	771	1,081
	Ta Phul	2,478	0.80	1,982	24	7.0%	2,270	3,183	4,465
	Sala Kanseng	3,448	0.10	345	4	7.0%	395	554	777
	Subtotal	15,240	0.50	7,637	139		8,744	12,263	17,119
Sala Kamraeuk									
	Wat Bo	3,916	1.00	3,916	24	8.1%	4,576	4,800	4,800
	Vat Domnak	2,560	0.90	2,304	39	8.1%	2,692	3,974	5,867
	Sala Kamraeuk	957	0.10	96	3	8.1%	112	165	244
	Ta Vein								
	Subtotal	7,433	0.85	6,316	66		7,380	8,939	10,910
Sla Kram									
	Sla Kram	2,043	1.00	2,043	14	7.0%	2,339	2,800	2,800
	Banteay Chas	4,629	0.90	4,166	45	7.0%	4,770	6,690	9,000
	Boeng Donpa	2,059	0.50	1,030	40	7.0%	1,179	1,653	2,319
	Dok Po	2,361	0.80	1,889	30	10.0%	2,285	3,681	5,928
	Chong Kaosu	6,236	0.10	624	11	7.0%	714	1,001	1,404
	Subtotal	17,328	0.56	9,751	140		11,287	15,825	21,451
Total		40,001	0.59	23,704	345		27,411	37,028	49,481

Stage 2

Communes	Villages	Year 1998 Population	Population Coverage	Service Area		Growth Rate	2000	2005	2010
				Population	(ha)				
Svay Dangcum									
	Svay Dangcum	1,124	0.70	787	22	7.0%	901	1,263	1,772
	Vihear Chen	3,528	0.10	353	8	7.0%	404	567	795
	Mundol 1	1,723	1.00	1,723	19	7.0%	1,973	2,767	3,800
	Stung Thmey	2,459	0.80	1,967	27	7.0%	2,252	3,159	4,431
	Mundol 2	480	1.00	480	35	7.0%	550	771	1,081
	Ta Phul	2,478	0.80	1,982	24	7.0%	2,270	3,183	4,465
	Sala Kanseng	3,448	0.10	345	4	7.0%	395	554	777
	Subtotal	15,240	0.50	7,637	139		8,744	12,263	17,119
Sala Kamraeuk									
	Wat Bo	3,916	1.00	3,916	24	8.1%	4,576	4,800	4,800
	Vat Domnak	2,560	0.90	2,304	39	8.1%	2,692	3,974	5,867
	Sala Kamraeuk	957	0.30	287	33	8.1%	335	495	731
	Ta Vein	1,084	0.50	542	51	10.0%	656	1,056	1,701
	Subtotal	8,517	0.83	7,049	147		8,260	10,326	13,099
Sla Kram									
	Sla Kram	2,043	1.00	2,043	14	7.0%	2,339	2,800	2,800
	Banteay Chas	4,629	0.95	4,398	45	7.0%	5,035	7,062	9,000
	Boeng Donpa	2,059	0.50	1,030	40	7.0%	1,179	1,653	2,319
	Dok Po	2,361	1.00	2,361	40	10.0%	2,857	4,601	7,410
	Chong Kaosu	6,236	0.10	624	11	7.0%	714	1,001	1,404
	Subtotal	17,328	0.60	10,455	150		12,123	17,117	22,933
Total		41,085	0.61	25,141	436		29,127	39,706	53,151

Remarks:

1. Year 1998 population is taken from village population marked * in Table 4.1.1
2. Population coverage is estimated by comparing the population in the service area with the village total population.
3. Population growth rate is taken from Table shown in Section 4.1.1 for the communes Sala Kamraeuk and Sla Kram.
4. In view of the wide area of the commune Svay Dangcum, population growth rate in the service area is assumed to be 5 % p.a.
5. Maximum density is assumed to be 200 persons/ha. Population is judged to be saturated when the density reaches the maximum density.



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**Figure 4.1.3
Population Projection in Service Area**

4.1.3 Water Demand

Water demand is calculated separately for domestic demand, tourism demand, and special use demand. Special use includes water demand for hospitals, schools, government offices, royal residence, temples, and markets. Summation of all these demands will give the total water demand in 2010 for the service area.

(1) Potential Domestic Water Demand

To determine the domestic water demand, a stepwise method is followed. The steps are:

- Population forecast (as explained in Section 4.1.1)
- Setup of service area (as explained in Section 4.1.2)
- Future population in service area (as explained in Section 4.1.2)
- Per capita water consumption
- Service ratio
- Domestic water demand

In this section, per capita water consumption and service ratio are fixed and based on that domestic water demand is determined.

According to French Emergency Project per capita consumption is considered as 100 liters per capita per day (lpcd) until 1998 and 125 lpcd after 1998. On the other hand, Urbanization Plan of APSARA considered 100 lpcd in 2000. Per capita water consumption in other towns of Cambodia is given in the Table 4.1.5 as a reference. This table shows the maximum per capita water consumption is around 120 lpcd in Phnom Penh. Recently started emergency water supply system considers 100 lpcd consumption at present (1999).

Based on the present design consumption of 100 lpcd and other baseline data, the Study Team proposes to consider a unit consumption of 100 lpcd in 2002. The unit consumption is considered to follow a linear growth up to 2006 to reach a unit consumption of 120 lpcd. However, it is considered to remain at that level until the target year 2010. This gives a potential domestic demand of 6,380 m³/day in 2010.

Table 4.1.5 Per Capita Consumptions in Other Towns of Cambodia

Towns	Urban Population	No. of Household	No. of Connections	Leakage (% of Production)	Per Capita Consumption (lit/pers/day)
Banlung	12,000	2,000	79	26	60
Battambang	70,320	11,700	2,769	67	46
Kompong Thom	33,000	5,500	490	36	66
Kompong Cham	35,400	5,899	1,055	nd	nd
Prey Veng	12,000	2,055	207	70	33
Pursat	16,840	4,216	862	20	72
Koh Kong	16,000	2,666	240	22	104
Sisophon	44,500	7,420	140	40	90
Sihanoukville	47,700	7,950	1,000	nd	nd
Stung Treng	13,200	2,200	460	41	80
Phnom Penh	569,190	96,980	42,572	59	56-122*

* If the population in the service area is the served population, per capita consumption is 56 lit/day.
If 6 persons/domestic consumption is assumed, it is 122 lit/day.

Source: Report on Institutional Support to the Water Supply Sector
By Thames Water, Final Report, Volume 2, Main Report, March 1998

Service ratio will be low in the beginning of the service. In 2002, it is assumed to be 30%. However, given the expected urbanization and relative ease of water availability, it is expected to reach the 75% level in 2008. Further increase is relatively difficult in any situation. One of the major reasons is existing shallow well used for domestic water consumption. Proper education and public awareness are required to reach this ratio. Service ratio is expected to remain at the 75% level until the target year 2010. This gives a service population of 39,863 in 2010 and a net average domestic demand of around 4,800 m³/day. A summary of domestic water demand is given below:

Domestic Water Demand

Year	Service Area Population	Per Capita Consumption (lpcd)	Service Ratio (%)	Domestic Water Demand (m ³ /day)
2002	31,159	100	30	935
2003	33,057	105	40	1,388
2004	34,969	110	50	1,923
2005	37,028	115	60	2,555
2006	39,244	120	65	3,061
2007	44,832	120	70	3,766
2008	47,701	120	75	4,293
2009	50,540	120	75	4,549
2010	53,151	120	75	4,784

Note: Domestic water demand shown above does not include loss and peak factors.

(2) Potential Non-Domestic Water Demand

1) Visitors Water Demand

Unit water demand for visitors is estimated as 500 liters/person/day. This will include the water demand of tourism related workers. As explained in Section 4.1.1, all visitors are classified into four categories. Out of these, numbers of tourists and tour leaders will increase annually. However, the numbers of foreign delegates and staffs of UNO, IO, and NGO are assumed to remain constant over the years. Tourist related water demand is given in Table 4.1.6. A peak demand is also calculated in the table to adjust the demand for peak tourist season. Peak month of tourists is November when 13.1% of the annual tourists are concentrated as referred to in Table 4.1.3, which results in a peaking factor of 1.57. From Table 4.1.6, the average visitors water demands for 2000, 2005 and 2010 are 965, 1,697, and 2,428 m³/day, respectively.

Table 4.1.6 Potential Tourism Water Demand Projection

Year	Population (A)	Population (B)	Total Population	Potential Demand (m ³ /day)	Peak Demand (m ³ /day)
1993	45	436	480	240	378
1994	148	436	584	292	459
1995	262	436	698	349	549
1996	325	436	761	380	598
1997	184	436	620	310	487
1998	177	436	613	306	482
1999	836	436	1,272	636	1,000
2000	1,495	436	1,931	965	1,518
2001	1,788	436	2,224	1,112	1,748
2002	2,080	436	2,516	1,258	1,978
2003	2,373	436	2,809	1,404	2,208
2004	2,665	436	3,101	1,551	2,438
2005	2,958	436	3,394	1,697	2,668
2006	3,250	436	3,686	1,843	2,898
2007	3,543	436	3,979	1,989	3,128
2008	3,835	436	4,271	2,136	3,358
2009	4,128	436	4,564	2,282	3,588
2010	4,421	436	4,856	2,428	3,818
2011	4,713	436	5,149	2,574	4,048
2012	5,006	436	5,441	2,721	4,278
2013	5,298	436	5,734	2,867	4,508

Remarks:

Population (A) is the tourists and tour leaders, which is assumed to increase annually at the same numbers, based on Table 4.1.3.

Population (B) is the delegations, NGOs and IOs, which is assumed to be constant.

Unit water demand for visitors is estimated to be 500 lit/day/person including that of tourism related workers.

Peak month of tourists is November when 13.1 % of the annual tourists is concentrated as referred to Table 4.1.2, which results in a peaking factor of 1.57 (= 13.1 / ave. 8.33)

2) Restaurants Water Demand

According to the CODEV Study, the number of restaurant tables in 1995 was 280. Assuming a growth rate equal to the median tourist growth rate of 20%, the number of restaurant tables in 2010 will be 4,314. A uniform unit water demand is considered as 100 liters/table/day. This value is same as French Emergency Plan. It may be noted that APSARA plan didn't consider the restaurant demand separately. With the assumed unit water demand, the restaurant water demand in 2010 is 431 m³/day. To find out the restaurant water demand in each year, a linear increase is assumed from 1995 value of 28 m³/day to 2010 value of 431 m³/day.

Restaurant Water Demand for 2010

	No. of Tables	Unit Demand	Water Demand
		(l/Table/day)	(m ³ /day)
Restaurant Tables in 1995	280	100	28.0
Restaurant Tables in 2010 (Growth Rate = 20 %)	4,314	100	431.4

3) Tourism Water Demand

The daily average tourism water demand is presented in Table 4.1.7. The service ratios for both the visitor water demand and restaurant water demand are assumed as 50% in 2002. Because of potential business profit, this ratio can be expected to rise quickly and reach a maximum value of 95% in 2005. According to this table, the total daily average tourism water demands in 2002, 2005, and 2010 are 738, 1,895, and 2,718 m³/day respectively.

Some of the tourism water demand will occur in the proposed hotel zone. Water would be supplied to that zone from the Waterworks in bulk. Bulk supply required is also given in Table 4.1.7. This demand would be considered during the design of the distribution network.

Table 4.1.7 Daily Average Tourism Water Demand

Visitors Water Demand (Daily Average: m³/day)

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Potential (From Table 4.1.6)	636	966	1,112	1,258	1,404	1,551	1,697	1,843	1,989	2,136	2,282	2,428	2,574	2,721	2,867
Service Ratio	0%	0%	0%	50%	70%	90%	95%	95%	95%	95%	95%	95%	95%	95%	95%
Visitors Water Demand	0	0	0	629	983	1,396	1,612	1,751	1,890	2,029	2,168	2,307	2,446	2,585	2,724
Main				629	718	821	875	909	944	979	1,014	1,048	1,083	1,118	1,153
Bulk Supply for Hotel Zone				0	266	575	737	841	946	1,050	1,154	1,258	1,363	1,467	1,571

Restaurant Water Demand (Daily Average: m³/day)

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Potential	136	163	190	217	244	271	298	325	352	379	406	433	460	487	584
Service Ratio	0%	0%	0%	50%	70%	90%	95%	95%	95%	95%	95%	95%	95%	95%	95%
Restaurant Water Demand	0	0	0	109	171	244	283	309	334	360	386	411	437	463	555

Tourism Water Demand (Visitor + Restaurant) (Daily Average: m³/day)

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Tourism Water Demand	0	0	0	738	1,154	1,639	1,895	2,060	2,224	2,389	2,554	2,718	2,883	3,047	3,279
Main	0	0	0	738	888	1,065	1,158	1,218	1,279	1,339	1,399	1,460	1,520	1,581	1,708
Bulk Supply for Hotel Zone	0	0	0	0	266	575	737	841	946	1,050	1,154	1,258	1,363	1,467	1,571

4) Special Use

In the category of special use, the Study considers water demands in hospitals, schools, government offices, royal residence, temples, and markets. The detail calculation is given in Table 4.1.8.

The total number of hospital beds in 1999 is 750. It is considered that the hospital beds will increase with a rate equal to the Siem Reap District population growth rate of 4.17% (as shown in Section 4.1.1). The hospital beds in 2010 are expected to be 1,176. A constant unit water demand of 150 liters/bed/day is applied. The potential 2010 water demand for hospital is 176 m³/day.

The number of school students in 1995 was 2,231. This number is also assumed to increase at the same pace of Siem Reap District population growth rate of 4.17%. The number of school students in 2010 is found to be 4,118. A constant water demand of 5 liters/student/day is assumed. The potential 2010 water demand for schools is 21 m³/day.

The number of government officers in the central Siem Reap is estimated as 500 in 1998. Assuming a 2% annual growth, the number of officials in 2010 expected to be 634. The present per capita water demand of 15 lpcd is assumed to be remaining same until 2004. It is assumed to increase due to introduction of flush toilet system up to the level of 30 lpcd in 2008. This gives a potential water demand for government offices at 19 m³/day.

The water demands for royal residence, temples, and markets are each estimated at 20 m³/day. These values are double as French Emergency Plan except royal residence whose demand is same as French Emergency plan.

As shown in Table 4.1.8, the total potential water demand for special use is 276 m³/day. Considering same growth pattern for service ratio as for the domestic demand (that is 30% in 2002 to 75% in 2010), the required demand in 2002, 2005, and 2010 are 63, 139, and 207 m³/day, respectively.

Table 4.1.8 Water Demand for Special Use

Year	Beds in Hospitals	Unit Demand (lit/bed/day)	Hospital Demand (m ³ /day)	School Students	Unit Demand (lit/stud/day)	School Demand (m ³ /day)	Government Officials	Unit Demand (lit/per/day)	Water Demand (m ³ /day)	Royal Residence (m ³ /day)	Temples (m ³ /day)	Markets (m ³ /day)	Total Demand (m ³ /day)	Service Ratio (%)	Daily Ave. Demand (m ³ /day)
1993	340	150	51.0	2,056	5	10.3	453	15	6.8	20.0	20.0	20.0	128.1		
1994	340	150	51.0	2,142	5	10.7	462	15	6.9	20.0	20.0	20.0	128.6		
1995	340	150	51.0	2,231	5	11.2	471	15	7.1	20.0	20.0	20.0	129.2		
1996	340	150	51.0	2,324	5	11.6	481	15	7.2	20.0	20.0	20.0	129.8		
1997	340	150	51.0	2,421	5	12.1	490	15	7.4	20.0	20.0	20.0	130.5		
1998	540	150	81.0	2,522	5	12.6	500	15	7.5	20.0	20.0	20.0	161.1		
1999	750	150	112.5	2,627	5	13.1	510	15	7.7	20.0	20.0	20.0	193.3	0	0
2000	781	150	117.2	2,737	5	13.7	520	15	7.8	20.0	20.0	20.0	198.7	0	0
2001	814	150	122.1	2,851	5	14.3	531	15	8.0	20.0	20.0	20.0	204.3	0	0
2002	848	150	127.2	2,970	5	14.8	541	15	8.1	20.0	20.0	20.0	210.1	30	63
2003	883	150	132.5	3,093	5	15.5	552	15	8.3	20.0	20.0	20.0	216.2	40	86
2004	920	150	138.0	3,222	5	16.1	563	15	8.4	20.0	20.0	20.0	222.6	50	111
2005	958	150	143.8	3,357	5	16.8	574	18	10.3	20.0	20.0	20.0	230.9	60	139
2006	998	150	149.7	3,497	5	17.5	586	22	12.7	20.0	20.0	20.0	239.9	65	156
2007	1,040	150	156.0	3,643	5	18.2	598	26	15.5	20.0	20.0	20.0	249.7	70	175
2008	1,083	150	162.5	3,794	5	19.0	609	30	18.3	20.0	20.0	20.0	259.8	75	195
2009	1,128	150	169.3	3,953	5	19.8	622	30	18.7	20.0	20.0	20.0	267.7	75	201
2010	1,176	150	176.3	4,118	5	20.6	634	30	19.0	20.0	20.0	20.0	275.9	75	207
2011	1,225	150	183.7	4,289	5	21.4	647	30	19.4	20.0	20.0	20.0	284.5	75	213
2012	1,276	150	191.3	4,468	5	22.3	660	30	19.8	20.0	20.0	20.0	293.5	75	220
2013	1,329	150	199.3	4,654	5	23.3	673	30	20.2	20.0	20.0	20.0	302.8	75	227

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Remarks:

- 1 Hospital beds are actual until 1999, and assumed to increase at the same pace of Siem Reap District population growth rate.
- 2 Unit water demand per bed is estimated to be 150 lit/day, which is assumed to be kept constant.
- 3 Number of school students were 2,231 in 1995, and is assumed to increase at the same pace of Siem Reap District population growth rate.
- 4 Unit water demand per student is estimated to be 5 lit/day, which is assumed to be kept constant.
- 5 Number of government officials in the central area of Siem Reap is estimated to be 500 in 1998, and assumed to increase at 2% p.a.
- 6 Unit water demand per government official is assumed to be at the present level of 15 lit/pers/day until 2004. It is assumed to increase due to introduction of toilet flush system to the level of 30 lit/pers/day.
- 7 Water uses for Royal Residence, Temples and Markets are estimated as shown in the table in the French Report for Emergency Water Supply.

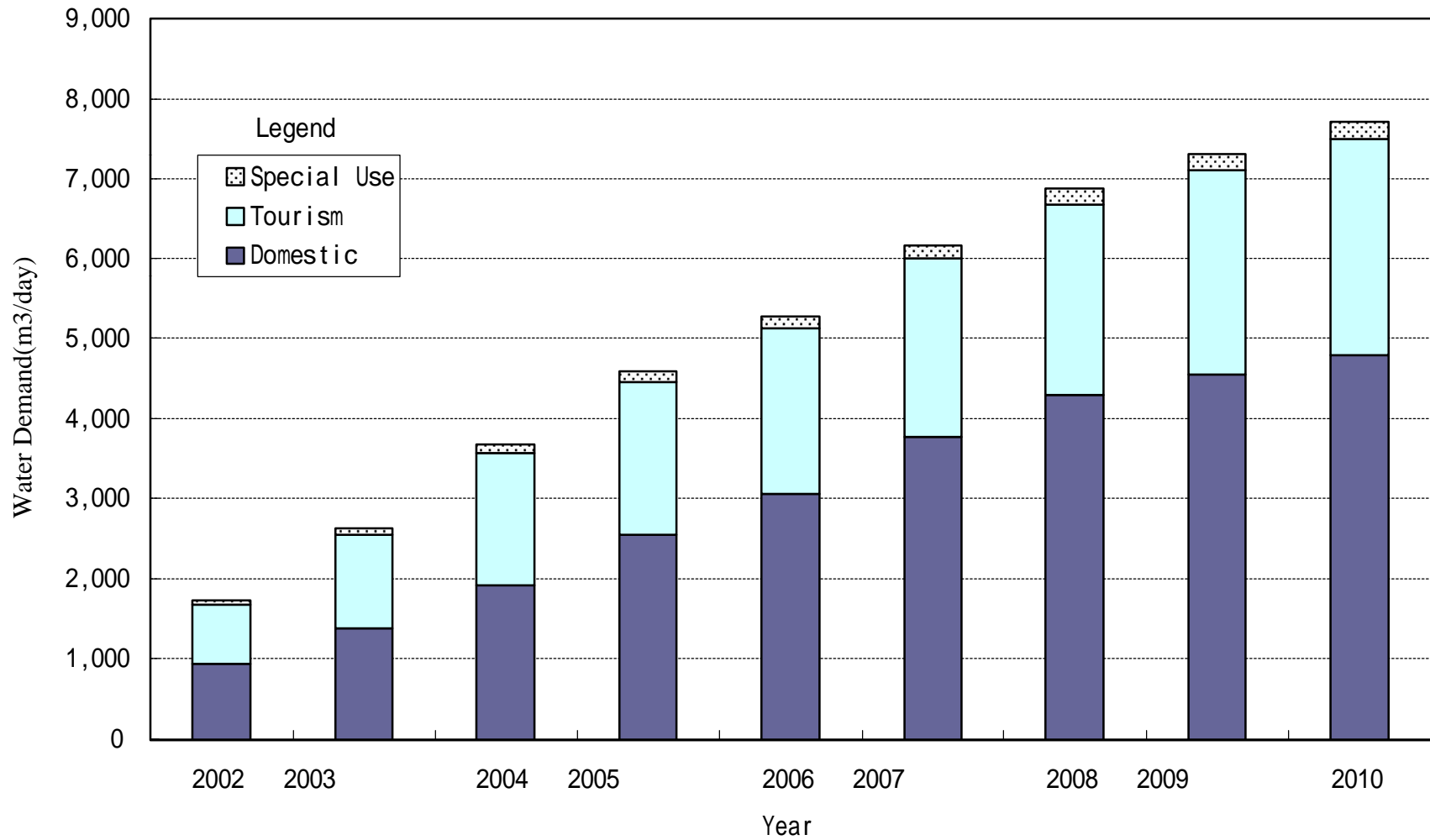
(3) Total Net Average Water Demand, Unaccounted-for Water and Peak Factor

The total net average water demand is the sum of net average water demands for domestic, tourism, and special uses. The summary of net average water demand is given in the following table. In 2010, the total net average demand is around 7,700 m³/day. The share of each type of demands and yearly increase is given in Figure 4.1.4.

Year	Domestic (m ³ /day)	Tourist (m ³ /day)	Special (m ³ /day)	Total (m ³ /day)
2002	935	738	63	1,736
2005	2,555	1,895	139	4,589
2010	4,784	2,718	207	7,709

Any water distribution suffers from system loss. For the present system, unaccounted for water for the entire service period until the target year of 2010 is assumed as 15%. Usually, the major cause of water loss is associated with service connection. Since most of the connections are new in the Project, proper care taken in the connection process can ensure this value. Also, a good portion of the distribution network would be either newly installed or replaced. Considering these factors, a 15% loss is attainable provided a proper maintenance system could be ensured. With this, the gross average water demand in 2010 is around 8,870 m³/day.

Daily maximum demand is higher than daily average demand. A water supply system is designed for daily maximum demand to cope with the extreme situation. Peak factor is defined as Daily Maximum/Daily Average. For Siem Reap Water Supply System, a peaking factor is assumed as 1.2 for domestic and special water demand. This value is within the acceptable norm used in Southeast Asia. The peak factor for the tourism demand is considered as 1.575, which is the same as tourist peak factor in November as shown in Table 4.1.3 and Table 4.1.6. Multiplying the daily average with this factor, gross peak water demand in 2010 comes to 12,000 m³/day.



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**Figure 4.1.4
Total Average Water Demand**

Detailed calculation is given in Table 4.1.9. A summary is given below.

Year	Domestic (m ³ /day)	Tourism (m ³ /day)	Special (m ³ /day)	Total (m ³ /day)
2002	1,320	1,364	89	2,773
2005	3,607	3,506	196	7,308
2010	6,753	5,029	292	12,074

(4) Conclusion

Daily average and daily maximum water demand from 2002 to 2010 is given below based on Table 4.1.9.

Total Water Demand

Year	Daily Average Water Demand (m ³ /day)	Daily Maximum Water Demand (m ³ /day)
2002	1,735	2,773
2003	2,629	4,217
2004	3,674	5,905
2005	4,589	7,308
2006	5,277	8,352
2007	5,896	9,678
2008	6,877	10,755
2009	7,303	11,429
2010	7,709	12,074

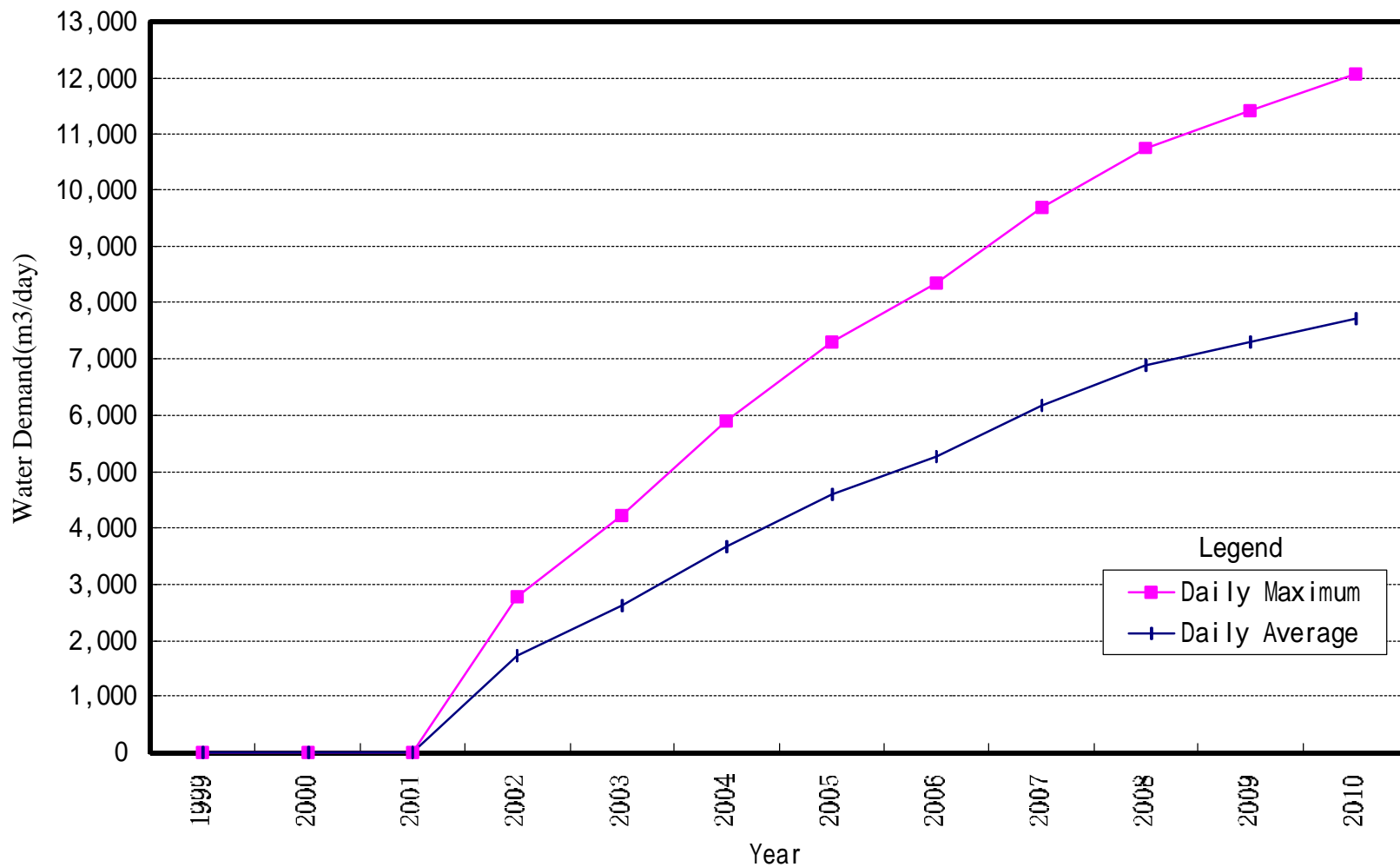
Considering that the system will start its operation in 2002, the yearly increase of the net daily average and gross maximum daily of water demand is given in Figure 4.1.5.

Table 4.1.9 Water Demand Projection

Year	Domestic Water Demand					Tourism Water Demand			Special Use Water Demand			Net Demand (Average)	System Loss (%)	Gross Demand (Average)	Gross Demand (Peak)*
	Service Area Population	Unit Consumption	Potential Domestic Demand	Service Ratio	Average Domestic Demand	Potential Tourism Demand	Service Ratio	Average Tourism Demand	Potential Special Use	Service Ratio	Average Special Use Demand				
	(nos.)	(lit/p/d)	(m ³ /day)	(%)	(m ³ /day)	(m ³ /day)	(%)	(m ³ /day)	(m ³ /day)	(%)	(m ³ /day)				
1999	25,489	100	2,548.9	0	0	772	0	0	193.3	0	0	0		0	0
2000	27,411	100	2,741.1	0	0	1,129	0	0	198.7	0	0	0		0	0
2001	29,333	100	2,933.3	0	0	1,302	0	0	204.3	0	0	0		0	0
2002	31,159	100	3,115.9	30	935	1,475	50	738	210.1	30	63	1,735	15.0	2,042	2,273
2003	33,057	105	3,471.0	40	1,388	1,648	70	1,154	216.2	40	86	2,629	15.0	3,093	4,217
2004	34,969	110	3,846.6	50	1,923	1,822	90	1,639	222.6	50	111	3,674	15.0	4,322	5,905
2005	37,028	115	4,258.2	60	2,555	1,995	95	1,895	230.9	60	139	4,589	15.0	5,398	7,308
2006	39,244	120	4,709.3	65	3,061	2,168	95	2,060	239.9	65	156	5,277	15.0	6,208	8,352
2007	44,832	120	5,379.8	70	3,766	2,341	95	2,224	249.7	70	175	6,165	15.0	7,253	9,678
2008	47,701	120	5,724.1	75	4,293	2,515	95	2,389	259.8	75	195	6,877	15.0	8,091	10,755
2009	50,540	120	6,064.8	75	4,549	2,688	95	2,554	267.7	75	201	7,303	15.0	8,592	11,429
2010	53,151	120	6,378.1	75	4,784	2,861	95	2,718	275.9	75	207	7,709	15.0	9,069	12,074
2011	55,608	120	6,673.0	75	5,005	3,034	95	2,883	284.5	75	213	8,101	15.0	9,531	12,700
2012	57,279	120	6,873.5	75	5,155	3,208	95	3,047	293.5	75	220	8,423	15.0	9,909	13,226
2013	59,028	120	7,083.4	75	5,313	3,451	95	3,279	302.8	75	227	8,818	15.0	10,374	13,886

Remarks:

- 1 Service area population is taken from Table 4.1.4.
- 2 Per capita consumption is assumed to increase from the present level to the target level of 120 lit/person/day.
- 3 Water demands for hotels, guest houses and restaurants are taken from Section 4.1.3 (2)
- 4 Water demands for special uses are taken from Table 4.1.8.
- 5 * Peak factor 1.2 for Domestic and Special Use
1.575 for Tourism



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**Figure 4.1.5
Gross Demand**