2-2-2 Basic Plan (Construction Plan/Equipment Plan)

The primary objectives of this section is to review the planning fundamentals of F/S, which is the basis of request made by RGC, to evaluate the appropriateness of the Project in reference to the present state of population increase, current and future land use plan, and related development plan in the service areas.

2-2-2-1 Service Area

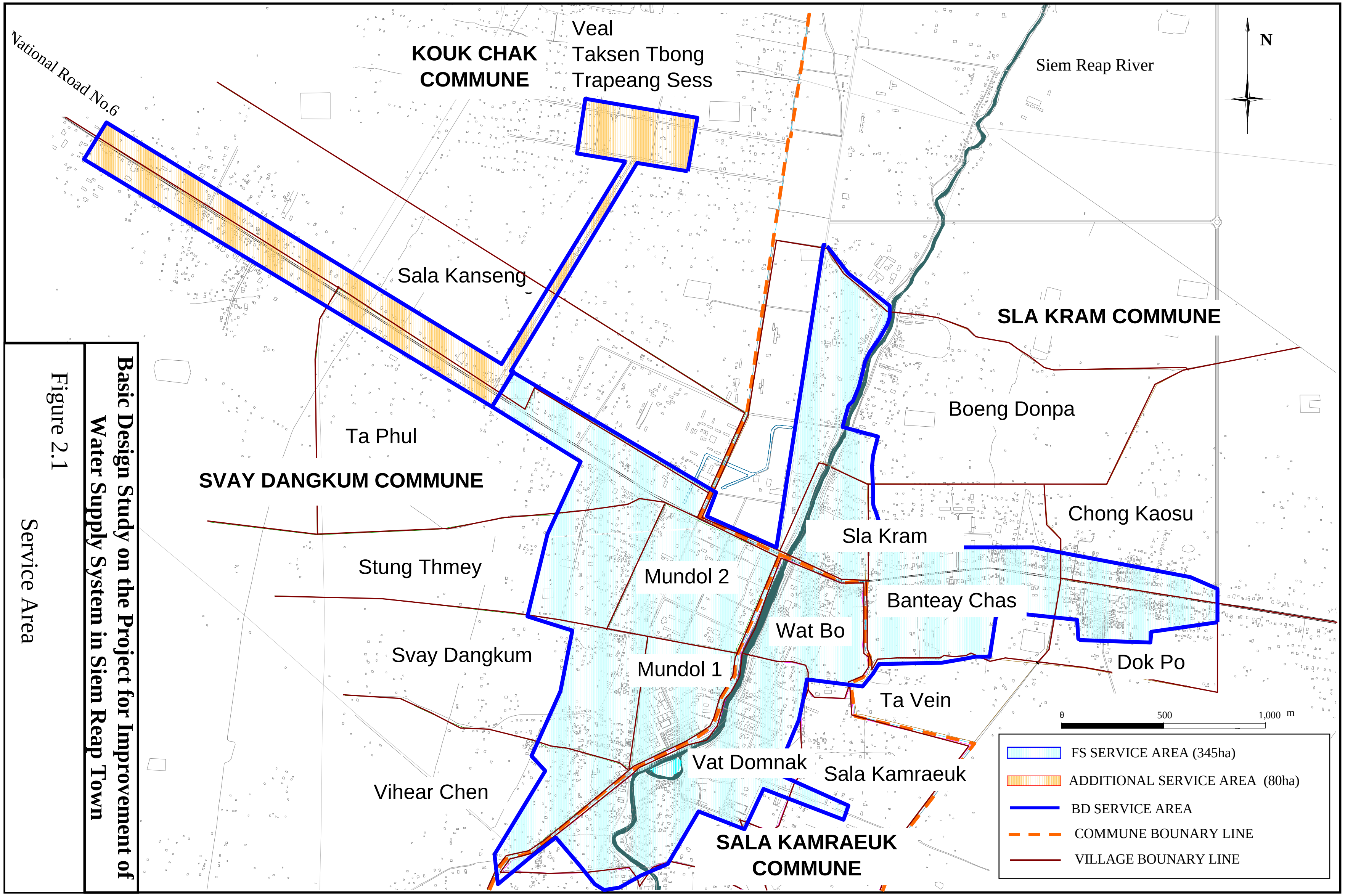
The requested service areas are located in the center of the Siem Reap Province in which the regional offices of RGC, local government offices, and residential and commercial zones are situated. The trend of population increase in the requested service areas is declining as shown in the following table for the population trend in the last ten years, however the ratio is still at very high of approximately four percent, comparing to two percent of the average population increase ratio of Cambodia. Especially, those communes in the requested service areas remarked between 3.23 to 5.07 percent in population increase, much higher population increase ratio rather than the other communes in the Siem Reap District. Likewise, land use plan of some area of Kokchak Commune, which is situated in the northwestern neighbor of the originally requested service area, has been recently amended from military use to residential use after the F/S conducted in 2000. The population in the Kokchak Commune is then so rapidly increased that results in lack of water supply from the existing water supply system of SRWSS.

The total service area to be involved in the Project will therefore be 425 ha. This is based on the 345 ha requested by RGC in accordance with the F/S conducted in 2000 and an additional 80 ha requested area raised during the first field survey in Cambodia including the area along the Route No. 6. The proposed service area in the Basic Design Study is identified as listed in Table 2.2 and delineated in Figure 2.1.

Table 2.2 Service Areas

Communes	Villages	Area（ha）
Svay Dangkum	Svay Dangkum	22
	Vihear Chen	8
	Mundol 1	19
	Stung Thmey	27
	Mundol 2	35
	Ta Phul	24
	Sala Kanseng	4
Sala Kamraeuk	Wat Bo	24
	Vat Domnak	39
	Sala Kamraeuk	3
Sla Kram	Sla Kram	14
	Banteay Chas	45
	Boeng Donpa	40
	Dok Po	30
	Chong Kaosu	11
Kokchak	Trapeang Sess	30
	Taksen Tbon	
	Veal	
Area along with the Route No. 6		50
Total Service Area		**425ha**

Note：Shade part shows newly included areas to the service area.



Basic Design Study on the Project for Improvement of Water Supply System in Siem Reap Town

Figure 2.1 Service Area

2-2-2-2 Service Population

A census was carried out in 2001 by the Planning Department of Siem Reap Province. Table 2.3 shows the past population records in the Siem Reap District from 1993 to 2001 in comparison to the F/S and the updated data in 2001. It can be seen from the table that there was a decline in the annual population growth rate during the year 1993 to 1998 from 4.17 percent to 3.85 percent. In almost all of communes, the population predicted in the F/S is over-estimated varying from zero to 2.99 percent, except for the Siem Reap and Sambuor Communes which is located out of the identified service area as shown in Table 2.3. Different population growth rates for different areas were used for this evaluation depending on the present population growth rates. As a result of analysis in applying the latest population growth trend, the projected population in the identified service area is estimated to be 40,000 as tabulated in Table 2.4.

Table 2.3 Population Data in the Last 10 Years in the Study Area

Communes		1993	1998	2001	Growth Rate (1993-1998)%	Growth Rate (1998-2001)%	Diff. between F/S and B/D
1	Svay Dangkum	18,381	21,540	23,695	3.22	3.23	0.01
2	Sala Kamraeuk	8,459	12,511	15,506	8.14	7.42	-0.73
3	Sla Kram	15,218	21,334	24,748	6.99	5.07	-1.92
4	Siem Reap	11,134	12,158	13,653	1.78	3.94	2.17
5	Chong Khnies	4,744	4,883	4,793	0.58	-0.62	-1.20
6	Chreav	5,384	6,344	6,410	3.34	0.35	-2.99
7	Srangae	3,892	4,500	4,743	2.95	1.77	-1.18
8	Kokchak	11,884	14,394	16,147	3.91	3.91	-0.00
9	Nokor Thum	3,111	3,575	3,883	2.82	2.79	-0.03
10	Sambuor	2,372	2,513	2,633	1.16	1.57	0.41
Total		84,579	103,752	116,211	4.17	3.85	-0.32

Source: Data in 1993 and 1998 are based on the 2000 F/S.
Data in 2001 is based on the latest census conducted by the Planning Department of Siem Reap Province.

The service area is situated only 5 km south of the Angkor heritage. The number of tourists who visited Cambodia sharply increased in the last two or three years. "Tourism Statistical Report; Year Book 2002" prepared by the Ministry of Tourism showed that numbers of tourists visited Cambodia from 1998 to 2002 increased by 30 percent yearly. MIME pointed out during the first field survey that it was high possibility that visitors to Cambodia in 2003 would exceed one million due to the recent sharp increase and was expected that the number of visitors would reach at the full capacity of accommodation available currently in the target year 2008, dependent on the development of accommodation and transportation.

Based on the above conditions, a projection on tourists and visitors in Siem Reap was made by the Study Team as shown in "6-1 Tourists and Visitors Projection in Siem Reap" and the projected numbers of tourists in the target year 2008 were confirmed as shown in "4-3 Technical Notes (First Field Survey)".

Assuming that from the 5.8 days which was confirmed as an average length of stay of international visitor in 2002 in the "Tourism Statistical Report; Year Book 2002", the visitors would stay three days in Siem Reap, one day longer than the estimated length of stay in the F/S in 2000. The yearly and daily total number of tourists arrival to Siem Reap is then estimated to be 1.11 million yearly and 9,000 daily, respectively in the target year 2008 (see Appendix 6-1; Tourists and Visitors Projection in Siem Reap). Public water use demand including hospitals, schools, government officers, royal residence, and temples, which keeps constant, is basically counted as the same as the F/S.

Basic Design Study on the Project for Improvement of Water Supply System in Siem Reap Town

Table 2.4 Water Supply Service Population

Estimated Total Population in the Service Areas

Communes	Villages	TTL Populatioin 1998	TTL Populatioin 2001	Population Coverage[1]	Population served/area FS	Population served/area BD	Population served/area (ha)	Growth rate (%) FS	Growth rate (%) BD[2]	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1. Svay Dangkum																				
i	Svay Dangkum	1,124		0.7	787		22	7.0		842	901	964	1,031	1,104	1,181	1,263	1,352	1,446	1,548	1,656
			1,299			909			4.9			909	954	1,001	1,051	1,103	1,157	1,214	1,275	1,337
ii	Vihear Chen	3,528		0.1	353		8	7.0		377	404	432	462	495	529	567	606	649	694	743
			3,745			375			2.0			375	382	390	398	406	414	422	430	439
iii	Mundol 1	1,723		1.0	1,723		19	7.0		1,844	1,973	2,111	2,259	2,417	2,586	2,767	2,960	3,168	3,389	3,627
			2,144			2,144			7.6			2,144	2,306	2,480	2,668	2,870	3,086	3,320	3,571	3,800
iv	Strung Thmey	2,459		0.8	1,967		27	7.0		2,105	2,252	2,410	2,579	2,759	2,952	3,159	3,380	3,617	3,870	4,141
			2,469			1,975			3.2			1,975	2,039	2,105	2,173	2,243	2,315	2,390	2,467	2,547
v	Mundol 2	480		1.0	480		35	7.0		514	550	588	629	673	720	771	825	882	944	1,010
			539			539			3.9			539	560	582	605	629	654	680	706	734
vi	Ta Phul	2,478		0.8	1,982		24	7.0		2,121	2,270	2,429	2,599	2,780	2,975	3,183	3,406	3,645	3,900	4,173
			2,529			2,023			3.2			2,023	2,089	2,156	2,226	2,297	2,372	2,448	2,527	2,609
vii	Sala Kanseng	3,448		0.1	345		4	7.0		369	395	422	452	484	517	554	592	634	678	726
			4,259			426			7.3			426	457	490	526	564	606	650	697	748
Sub total	**FS**	**15,240**		**0.5**	**7,637**		**139**			**8,172**	**8,744**	**9,356**	**10,011**	**10,711**	**11,461**	**12,263**	**13,122**	**14,040**	**15,023**	**16,075**
	BD		**16,984**			**8,391**						**8,391**	**8,787**	**9,205**	**9,646**	**10,112**	**10,604**	**11,124**	**11,674**	**12,256**
2. Sala Kamraeuk																				
i	Wat Bo	3,916		1.0	3,916		24	8.1		4,233	4,576	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800
			4,675			4,675			6.1			4,675	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800
ii	Vat Domnak	2,560		0.9	2,304		39	8.1		2,491	2,692	2,910	3,146	3,401	3,677	3,974	4,296	4,644	5,020	5,427
			3,210			2,889			7.8			2,889	3,115	3,359	3,623	3,906	4,212	4,542	4,898	5,282
iii	Sala Kamraeuk	957		0.1	96		3	8.1		103	112	121	131	141	153	165	178	193	209	225
			1,298			130			10.7			130	144	159	176	195	216	239	264	293
Sub total	**FS**	**7,433**	**9,183**	**0.85**	**6,316**	**7,694**	**66**			**6,827**	**7,380**	**7,831**	**8,077**	**8,342**	**8,629**	**8,939**	**9,275**	**9,637**	**10,029**	**10,452**
	BD											**7,694**	**8,059**	**8,318**	**8,599**	**8,901**	**9,228**	**9,581**	**9,962**	**10,374**
3. Sla Kram																				
i	Sla Kram	2,043		1.0	2,043		14	7.0		2,186	2,339	2,503	2,678	2,800	2,800	2,800	2,800	2,800	2,800	2,800
			1,994			1,994			5.1			1,994	2,095	2,201	2,313	2,430	2,554	2,683	2,800	2,800
ii	Banteay Chas	4,629		0.9	4,166		45	7.0		4,458	4,770	5,104	5,461	5,843	6,252	6,690	7,158	7,659	8,195	8,769
			4,370			3,933			5.1			3,933	4,133	4,342	4,562	4,794	5,037	5,292	5,561	5,843
iii	Boeng Donpa	2,059		0.5	1,030		40	7.0		1,102	1,179	1,261	1,349	1,444	1,545	1,653	1,769	1,893	2,025	2,167
			2,529			1,265			7.1			1,265	1,354	1,450	1,553	1,663	1,781	1,908	2,043	2,188
iv	Dok Po	2,361		0.8	1,889		30	10.0		2,078	2,285	2,514	2,765	3,042	3,346	3,681	4,049	4,454	4,899	5,389
			2,234			1,787			5.1			1,787	1,878	1,973	2,073	2,178	2,289	2,405	2,527	2,655
v	Chong Kaosu	6,236		0.1	624		11	7.0		667	714	764	817	875	936	1,001	1,071	1,146	1,227	1,313
			7,772			777			7.6			777	836	900	969	1,042	1,122	1,207	1,299	1,398
Sub total	**FS**	**17,328**		**0.56**	**9,751**		**140**			**10,490**	**11,287**	**12,146**	**13,071**	**14,004**	**14,879**	**15,825**	**16,847**	**17,952**	**19,146**	**20,438**
	BD		**18,899**			**9,756**						**9,756**	**10,296**	**10,867**	**11,470**	**12,108**	**12,783**	**13,496**	**14,230**	**14,884**
4. Kok chak[5]																				
1	Trapeang Sess	3,269		0.4	1,308					n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
			4,575			1,830	30		4	n/a	n/a	1,830	1,903	1,979	2,059	2,141	2,226	2,316	2,408	2,504
2	Taksen Tbong	1,526		0.5	763					n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
			1,895			948			4	n/a	n/a	948	985	1,025	1,066	1,108	1,153	1,199	1,247	1,297
3	Veal	2,229		0.2	446					n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
			2,121			424			4	n/a	n/a	424	441	459	477	496	516	537	558	581
Sub total	**FS**	**7,024**		**0.36**	**2,516**															
	BD		**8,591**			**3,202**						**3,202**	**3,330**	**3,463**	**3,601**	**3,746**	**3,895**	**4,051**	**4,213**	**4,382**
Grand Total	**FS**	**47,025**		**0.59**	**26,220**		**345**			**25,489**	**27,411**	**29,333**	**31,159**	**33,057**	**34,969**	**37,028**	**39,244**	**41,630**	**44,198**	**46,965**
	BD		**53,657**			**29,043**	**375**			**n/a**	**n/a**	**29,043**	**30,472**	**31,853**	**33,317**	**34,867**	**36,510**	**38,252**	**40,080**	**41,896**
		Coverage in 2001:29,043/53657=			54%				Figures[3]	top shows FS[3]										
										bottom shows BD[3]										

Notes:

1 Population coverage is set at 2000FS based on priority analysis.

2 BD growth rate is of between the year 1998 to 2001 based on the 2001 Cencus conducted by the Department of Planning of Siem Reap Province.

3 Figures shown in top is FS data and bottom is BD adopted based on the updated population data provided.

4 Saturated population is assumed in the max. population density of 200/ha.

5 Kokchak commune is requested to added to the service area by SRWSS in BD study.

2-2-2-3 Water Demand

Providing water supply priority to residents, the coverage for residential water supply demand will be set at 65 percent as proposed in the F/S, considering realistic expansion ratio of the required distribution and service pipes. The coverage for public water supply demand will be 65 percent, which is given the same priority as the residential water supply demand. However, due to the limitation of water production to control the influence of groundwater development upon the Angkor heritage within an acceptable limit, the coverage for tourism water supply demand will be limited to 40 percent. Expansion of service coverage from the present 10 percent towards the targeted water supply coverage in 2008 will be gradually conducted depending on the needs or request of the residents in the service areas, by installing the consumer flow meters to be procured by GOJ at RGC's cost.

There are three factors governing the water demand of a particular water supply system, i.e. the water use pattern, water loss, and peak ratio. For accurate assessment of theses factors, intensive studies involving previous production and consumption records are important, together with some field studies/tests.

The water use pattern is identified by per capita consumption, and the water loss by Non Revenue Water (NRW). The peak ratio is the factor used to evaluate the maximum day demand from the average day demand for a system. In the absence of accurate data, the trend of practices carried out in the Phnom Penh Water Supply Authority (PPWSA), South Eastern Asian countries, and Japan is adopted.

The Second Water Utilities Data Book published by the Asian Development Bank (hereinafter referred to as "ADB") in October 1997 shows that an average per capita consumption rate in the selected 50 cities in Asian countries was 157 lpcd (litter per capita per day). For example, similar cities vary in per capita consumption rate from 45 in Hanoi to 265 in Bangkok as listed below.

Cities	Rate (lpcd)	Cities	Rate (lpcd)
Bangkok	265	Chang Mai	135
Calcutta	202	Colombo	165
Cebu	173	Hanoi	45
Dhaka	95	Ho Chi Min	136

The B/D on the project for Expansion of Phnom Penh Water Treatment Plant conducted in 2000 specified that the designed domestic per capita consumption in Phnom Penh was 132 lpcd. The F/S indicated that the domestic per capita consumption for the Project will be increased from 100 to 120 lpcd in the year 2010, based on a comparative study in the other towns of Cambodia, other previous study data, and field study. The Study Team also conducted a field survey study and study on the relation between water production and tariff collection recorded in 2001 and 2002, which supports 120 lpcd is appropriate. Tourism water supply demand is confirmed based on information collected through an interview/questionnaire on the exiting water supply system of hotels during the field survey. The water supply facilities provided with the hotels shows a relatively large capacity which covers equivalent to 500 lpcd for drinking, washing, bathing, and miscellaneous water uses. It is noted that washing and bathing are not only once a day but several times due to its tropic climate, which pushes up the per capita consumption to approximately 500 lpcd.

As a result of these studies, 120 lpcd in the target year 2008 is identified as a reasonable unit consumption rate in the Project area. The peak ratio is then set at 1.2 and 1.57 for domestic and tourist, respectively as the F/S proposed in reference to the past records in Siem Reap Town and the similar scale towns in Japan. The unit consumption rates will be gradually increased over years towards the target year 2008. The present NRW ratio is identified approximately 50 percent in accordance with the record of water production and tariff collection in this field survey. The NRW ratio is expected to drop accordingly to the target level of 15 percent in the target year 2008 as the deteriorated existing pipes will be replaced under the Project as achieved in the PPWSA through the same manner. Even after the Project completion, SRWSS is requested to keep replacing the existing deteriorated pipes at their own cost so that the NRW can be reduced to the target level. Table 2.5 summarizes the proposed water demand projection.

On the basis of the projected water demand for the Project areas, the proposed design basis has been determined as per the following Table 2.6.

Table 2.5 Water Demand Projection

Descriptions	2003	2004	2005	2006	2007	**2008**
Population	31,853	33,317	34,864	36,510	38,252	**40,000**
Served population	3,185	3,332	6,973	18,255	24,864	**26,000**
Service coverage (%)						
Domestic water (%)	10	10	20	50	65	**65**
Tourism water (%)	10	10	20	20	25	**40**
Public water (%)	10	10	40	50	60	**65**
Per capita consumption rate						
Domestic water (little)	100	100	105	110	115	**120**
Tourism water (little)	300	300	400	400	400	**500**
Peak factor	Domestic/Public water:1.2, Tourism water 1.57					
NRW（%）	50	50	50	40	30	**15**
Daily average water supply (m^3)	850	1,140	2,950	4,710	5,574	**6,000**
Daily maximum water supply (m^3)	1,083	1,526	4,022	6,082	7,160	**8,000**

Table 2.6 Comparison Between Requested and Planned Design Basis

Descriptions	Requested by RGC	Proposed for B/D
Target year	2006	2008
Service area	345 ha	425 ha
Population in the service area	39,244	40,000
Tourists in the service area	3,686	9,132
Service coverage (domestic and public waters)	65 %	65 %
Service coverage (tourism water)	95 %	40 %
Served population	25,508	26,000
Served tourists	3,500	3,652
Daily domestic water demand	3,061 m^3	3,126 m^3
Daily public water demand	156 m^3	169 m^3
Daily tourism water demand	2,060 m^3	1,826 m^3
Daily average water demand	5,277 m^3	5,121 m^3
NRW	15 %	15 %
Daily average water supply	6208 m^3	6,000 m^3
Daily maximum water supply	**8,352 m^3**	**8,000 m^3**

Note: Estimated daily served tourists is 3,653.

2-2-2-4 Water Demand and Production

As mentioned above, the proposed water production capacity will be set at 8,000 m^3/d in accordance with the daily maximum water demand. It is clear that the present water supply does not satisfy the existing water demand until such time that the proposed water supply system will commence in 2006. With the implementation of the

Project, the full satisfaction for the maximum water demand basis through the target year 2008 can be achieved as shown in Figure 2.2, and in and beyond year 2010 for the average day demand basis.

According to the situation with regard to deterioration of the facilities/equipment, Cambodian side will consider whether the existing water treatment plant with a capacity of 1,400 m^3/d should be kept in operation or abandoned in 2006 when the proposed water supply system will be commenced.

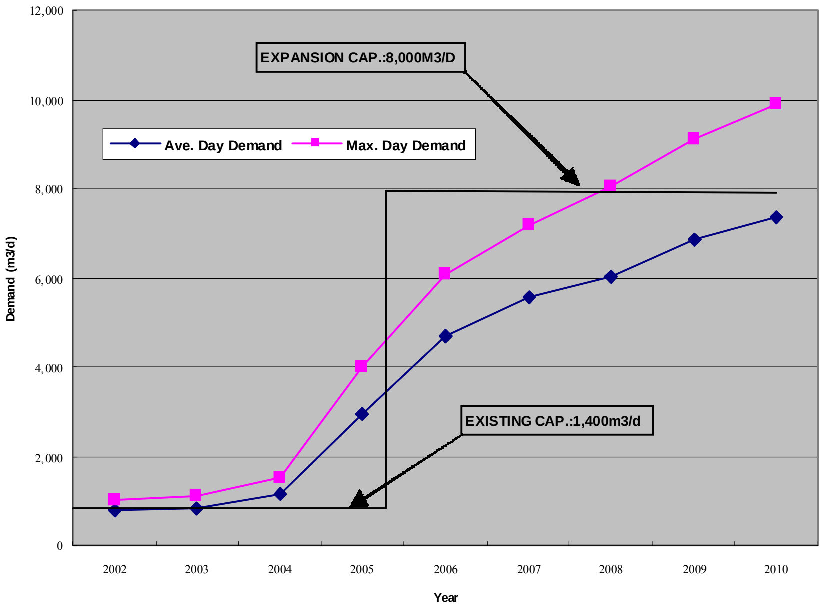


Figure 2.2 Water Demand and Production

2-2-2-5 Groundwater Development

This Project was planned as the groundwater-fed water supply system in Siem Reap Town based on the feasibility study completed in 2000. In this feasibility study, groundwater was confirmed as the most suitable water source for the future water supply system because of the low cost for construction and maintenance, easy operation of the system, and minimal environmental impact, particularly in terms of protective of the Angkor Heritage site. The Study Team reviewed this recommendation contained in the feasibility study and confirmed that there was no disparity between the conditions existing at the time of the survey in 2000 and the present, from the point of view of selection of the optimum water source.

Additionally, the Study Team were somewhat apprehensive that the surface water fed system operated by the SRWSS might not be adequate since the water intake facility as well as the sedimentation basin and downstream treatment processes were supposed to also cater for the demands of much technical strengthening if the West Baray Reservoir or the Lake Tonlesap scheme were developed.

Consequently, the following groundwater field survey was conducted, based on the plan set out in the year 2000 feasibility study.

(1) Groundwater Survey

Field surveys relating to "Well Facility Designing" were categorized into Pumping Test, Electric Prospecting and Water Quality Examination as shown in the left column of Table 2.7 for the first fieldwork. Upon completion of this fieldwork, data and critical information were found to be lacking in respect of the well facility design, notably those required to determine aquifer potential and well field area. Specific unknowns related to the lower pumping rates compared to the F/S, and an apparent inadequate thickness of aquifer over at least half if not more of the well field.

Therefore, a third fieldwork was carried out as shown in the right column of Table 2.7. Pumping tests were conducted after rehabilitation in order to compare the pumping rates at the existing two test wells and the new test well so as to confirm the development potential of the Pliocene series underlaying the Quaternary system. Also, additional electric prospecting was undertaken across the wider well field in case the development potential of the Pliocene series proved to be insufficient. The locations of the groundwater surveys in the first and the third fieldworks are indicated in Figure 2.3.

Table 2.7 Survey Contents of the First and the Third Fieldworks

The 1^{st} Fieldwork		The 3^{rd} Fieldwork	
Survey Item	Survey Content	Survey Item	Survey Content
Pumping Test	2 wells (existing)	Well Rehabilitation	2 wells (existing)
		Test Well Construction*	1 well (new)
		Pumping Test	3 wells
Electric Prospecting	15 points	Electric Prospecting	11 points
Water Quality	17 Parameters at 20 wells	Water Quality	None

Note: New Test Well was constructed for development of Pliocene Series, which is underlay of Quaternary System.

(2) Pumping Test

The aims of the pumping test were to define the reliable potential of the well intake and to estimate the required well spacing so as to avoid interferences with other wells in the well field. The selected pumping tests as well performance and aquifer tests were as shown below.

- Well Performance: Step Drawdown Test (5 steps) with observation of sand pumping and conductivity
- Aquifer: Time Drawdown Test (24 hrs) and Recovery Test (4 hrs)

Table 2.8 and Table 2.9 show the number of the pumping tests and the portion of developed aquifers at the test wells. The results of the "Well Performance Test " and "Aquifer Test" are discussed below.

Table 2.8 Test Well and Quantity of Pumping Test

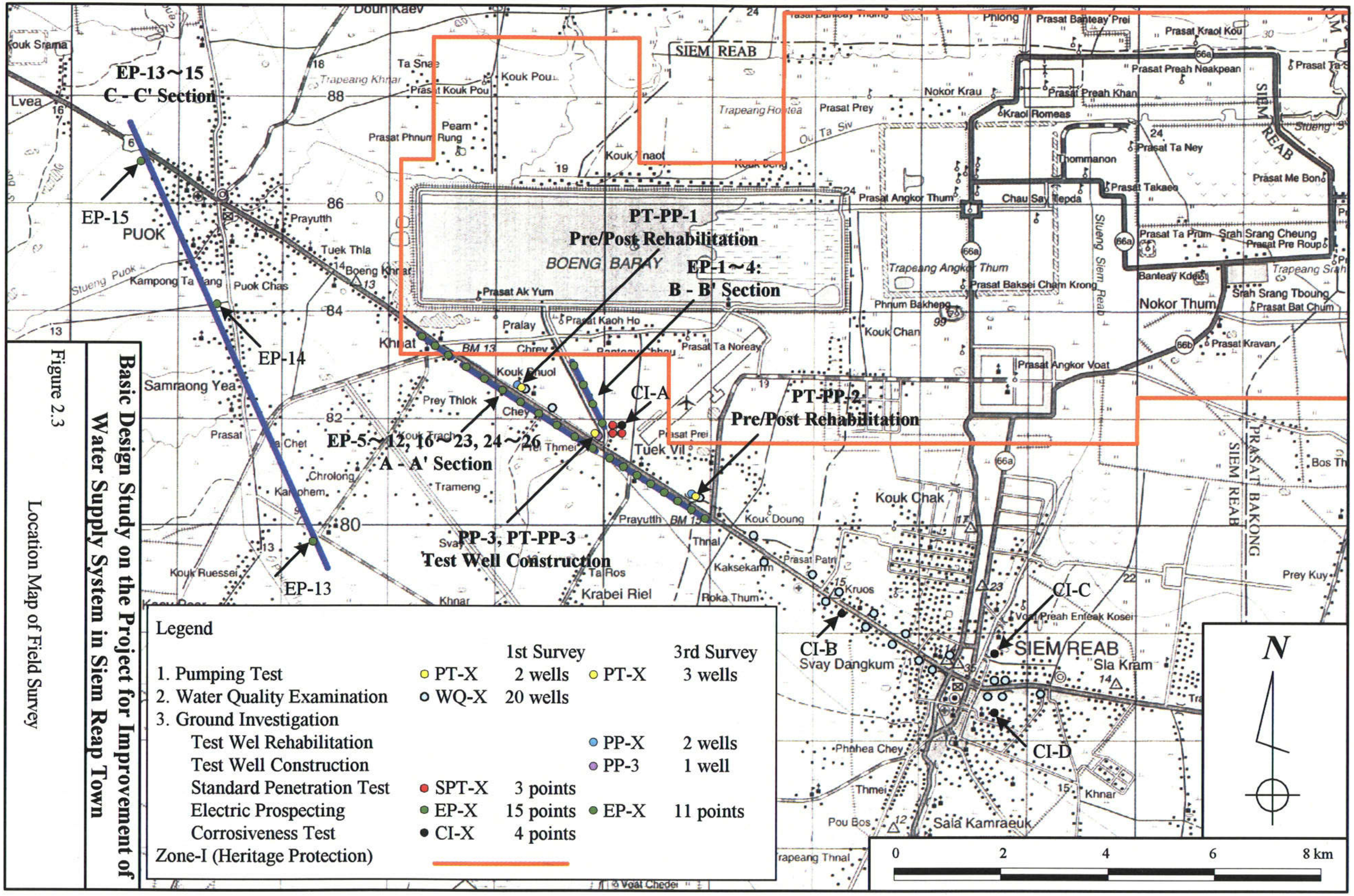
Pumping Well			Test Quantity		
Completion	ID	Location (along National Road No.6)	1^{st}*	3^{rd}*	Test Time
Feasibility Study	PP-1	Approximate 1.8 km to west from PP-3	1	1	Pre/Post Rehabilitation
	PP-2	Near T-Junction of Airport Access	1	1	
Basic Design	PP-3	Near T-Junction of West Baray Reservoir	none	1	After Construction

Note: Meanings of "$1^{st}$and 3^{rd}" are the 1^{st} and the 3^{rd} fieldworks in March and July 2003.

Table 2.9 Structures and Development Aquifers of Test Wells

ID	Well Structures				Screen Length		
	Dia.	Depth	Type of Screen	Slot×Opening	Qa*	Qd*	Tp*
PP-1	200A	51.5m	Slit by uPVC	1.0mm× 1.8%	12m	8m	4m
PP-2		51.2m			16m	4m	4m
PP-3		55.4m	Wound Wire by SUS	1.0mm×27.8%	-	-	24m

Note: "Qa" means Holocene series (Alluvium), "Qd" is Pleistocene series (Diluvium) and "Tp" is Pliocene series, respectively.



Basic Design Study on the Project for Improvement of Water Supply System in Siem Reap Town

Figure 2.3 Location Map of Field Survey

(3) Analysis of Well Performance by Step Drawdown Test

The relationship between discharge and drawdown is determined by the Step Drawdown Test. There are two well variables in the "Drawdown Equation", namely the constant B (aquifer loss relating to transmissivity) and constant C (well loss indicating inflow resistance) as shown below.

Drawdown Equation $sw = BQ + CQ^n$

Where
- sw: drawdown in well (gap between SWL and PWL,m)
- Q: discharge (m^3/day)
- B: aquifer loss (day/m^2)
- C: well loss (day^2/m^5)
- n: square will be adopted due to pressure loss relationship

Figure 2.4 shows the Q (discharge) - sw/Q (specific drawdown) relationship to enable well performance to be analyzed. The results in terms of the constants B and C are summarized in Table 2.10. The test results from the year 2000 feasibility study for test wells PP-1 and PP-2 are also compared in the same graph and table.

Drawdown lines of each test are shown as additional fine lines in Figure 2.4. The area where the actual drawdown rate exceeds the additional fine line indicates the range of excess pumping rate. It is apparent that safe pumping rates at test wells PP-1 and PP-2 become excessive at rates of approximately 600 to 800 m^3/day. However, a pumping test rate up to 1,100 m^3/day was still in the safe yield zone for test well PP-3.

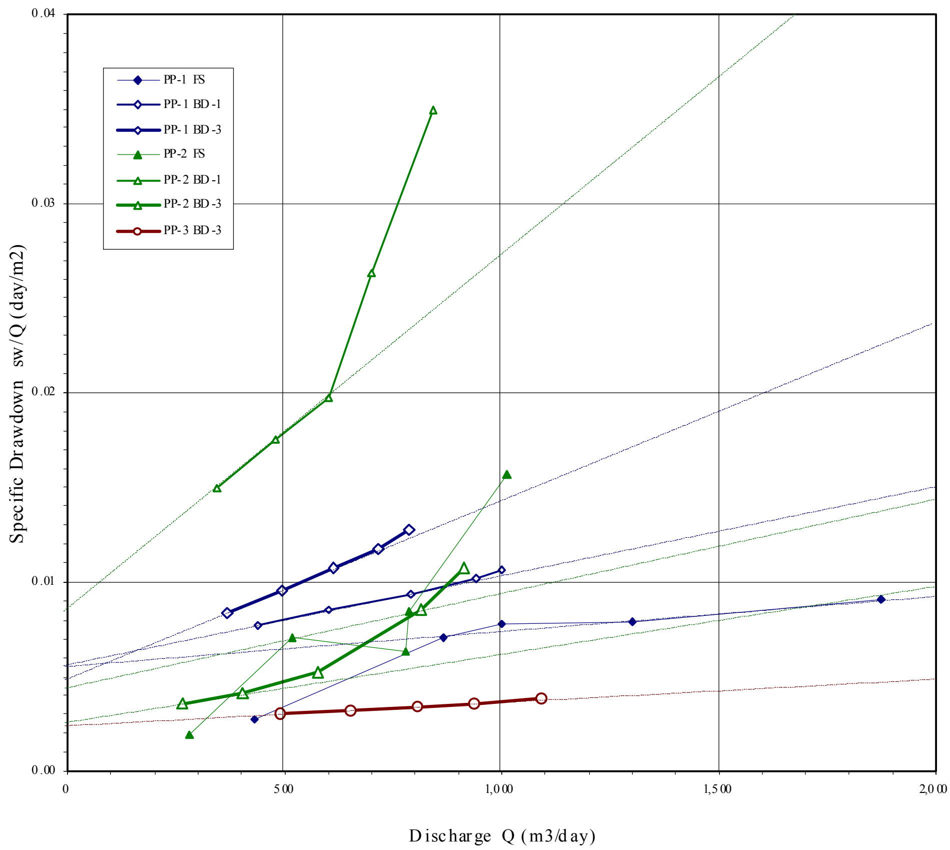


Figure 2.4 Q - sw/Q Graph

According to Figure 2.4, most of the constant B (aquifer loss; intercept of the additional fine line) is located in the same value field. To the contrary, each constant C (well loss; inclination) value indicates different relatives relative to the period of test and well structure. This is because the constant C is related to the increased inflow resistance resulting from the well rehabilitation, since a well screen with larger openings was used for test well PP-3.

Target aquifers are the Quaternary system and Pliocene series at test wells PP-1 and PP-2, and the single Pliocene series at test well PP-3. The filtration layer between the well screen and aquifers at test well PP-1 had collapsed during well rehabilitation, whereas the gravel filters at test wells PP-2 and PP-3 were well sorted by the rehabilitation and well development works. Therefore, the recommended values of constant B (aquifer loss) and constant C (well loss) for estimation the intake potential rate are those as shadowed in Table 2.10.

- Quaternary + Pliocene :Aquifer Loss B = 2.01 x 10^{-3} day/m^2, Well Loss C = 1.40 x 10^{-6} day^2/m^5
- Pliocene :Aquifer Loss B = 3.01 x 10^{-3} day/m^2, Well Loss C = 1.40 x 10^{-6} day^2/m^5

Table 2.10 Analysis Results of Well Performance Tests

Test Well ID	Aquifer Loss B (day/m^2)				Well Loss C (day^2/m^5)			
	F/S	Pre-rehab.	Post-rehab.	New Well	F/S	Pre-rehab.	Post-rehab.	New Well
PP-1	5.58×10^{-3}	5.64×10^{-3}	4.92×10^{-3}	-	1.77×10^{-6}	4.70×10^{-6}	9.45×10^{-6}	-
PP-2	4.36×10^{-3}	8.53×10^{-3}	2.01×10^{-3}	-	5.22×10^{-6}	1.86×10^{-5}	3.86×10^{-6}	-
PP-3	-	-	-	3.01×10^{-3}	-	-	-	1.40×10^{-6}

Note: F/S means Feasibility Study, Pre-rehab. and Post-rehab. mean before and after rehabilitation, and New Well means new test well.

(4) Analysis of Aquifers by Time Drawdown and Recover Tests

The relationship between time and drawdown is determined by the Time Drawdown (Recover) Test. The necessary hydraulic constant for the design of well structures is the transmissivity analyzed as the value T by the Jacob Formula shown below, values of which are related to permeability and thickness of aquifers. Figure 2.5, Figure 2.6 and Figure 2.7 show t (time) - sw (drawdown) graph for analysis of the well hydraulics. The results, as well as the T values are summarized in Table 2.11. For test wells PP-1 and PP-2, results from the pre-rehabilitation are also included.

Jacob Formular T = (Q/4 x 3.14 x delta s) x ln (t/t')

where T: transmissivity (m^3/day /m)

Q: discharge (m^3/day)

delta s: (drawdown in a cycle time since pumping started, m)

ln: natural logarithm

t (t'): time since pumping started (stopped, day)

Table 2.11 Analysis of Results of Aquifer Tests

Test Well ID	Transmissivity T (m^3/day/m)				Permeability Coefficient k (cm/sec): screen 24m			
	F/S	Pre-rehab.	Post-rehab.	New Well	F/S	Pre-rehab.	Post-rehab.	New Well
PP-1	145	105	125	-	7.00×10^{-3}	5.06×10^{-3}	6.01×10^{-3}	-
PP-2	207	62	281	-	1.00×10^{-2}	2.98×10^{-3}	1.36×10^{-2}	-
PP-3	-	-	-	246	-	-	-	1.19×10^{-2}

Note: F/S means Feasibility Study, Pre-rehab. and Post-rehab. mean before and after rehabilitation, and New Well means new test well.

As noted above, the filtration layer at test well PP-1 collapsed during well rehabilitation, with the result that the lower transmissivity had to be estimated since the gravel filtration layer was blocked by soil or backfilling. Hence, the result from test well PP-1 has been used as a reference value. Recommended values for the test wells are indicated with shadow in Table 2.11.

- Test Well PP-2: Transmissivity T = 281 (m^3/day/m), Permeability Coefficient k = 1.36 x 10^{-2} (cm/sec)
- Test Well PP-3: Transmissivity T = 246 (m^3/day/m), Permeability Coefficient k = 1.19 x 10^{-2} (cm/sec)

Two test wells (PP-2 and PP-3) had screens in portions of Quaternary + Pliocene or only Pliocene. Based on the hydraulic constants above, the permeability coefficient k of the Quaternary system could be calculated. Using the permeability coefficients for Quaternary and Pliocene, the intake potential rates under different distributions of the aquifers can be estimated. Furthermore, the Pliocene aquifer has enough water source potential for the SRWSS, because the value of the permeability coefficient in the Pliocene series is 85 percent of that in the Quaternary system.

- Quaternary : Permeability Coefficient k = 1.39 x 10^{-2} (cm/sec)
- Pliocene : Permeability Coefficient k = 1.19 x 10^{-2} (cm/sec)

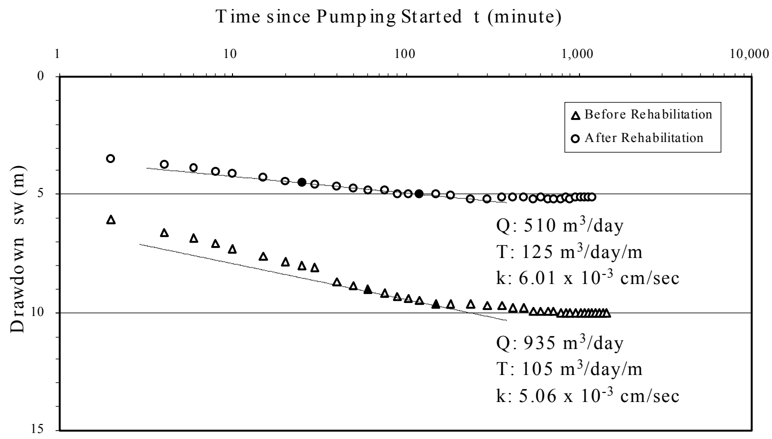


Figure 2.5 t – sw GRAPH (Test Well PP-1)

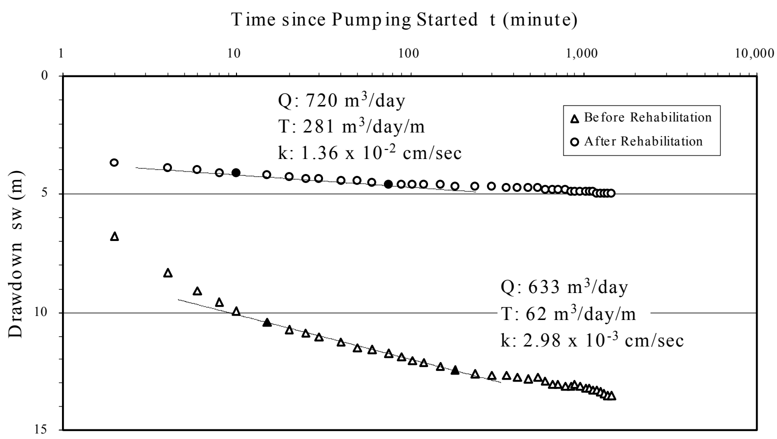


Figure 2.6 t – sw Graph (Test Well PP-2)

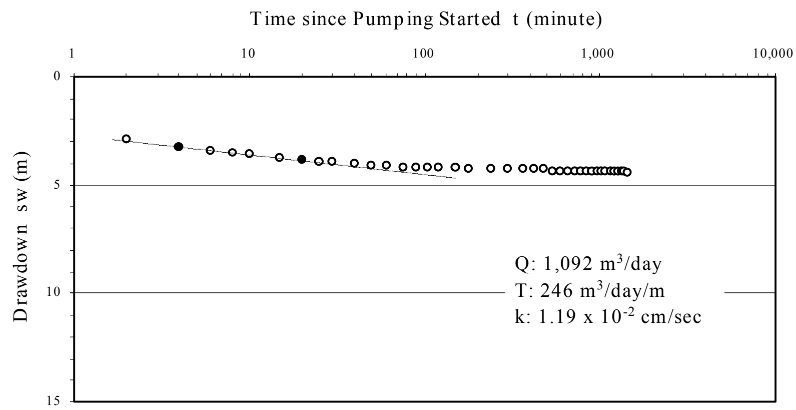


Figure 2.7 t – sw Graph (Test Well PP-3)

(5) Observation of Sand Pumping (during Step Drawdown Test)

Information on sand pumping and turbidity conditions related to pumping rates are very helpful for the design of the filtration structures (maximum grain size, minimum thickness and permissive velocity). Filtration structures at three test wells are shown in Table 2.12. Observation results (including pre-rehabilitation at test wells PP-1 and PP-2) are indicated in Table 2.13. For construction of new test well PP-3, sand pumping and turbidity problems were practically eliminated with the application of a larger screen-opening rate (refer to values with shadow in Table 2.12). Therefore, the same type of wound wire screen should be adopted for the design of production wells.

Table 2.12 Filtration Structures of Test Wells

Portion	Dimension		PP-1	PP-2	PP-3
Filter	Thickness	mm	108	108	115
	Grain Size	mm	3～9	3～9	3～9
Screen	Outside Diameter	mm	216	216	216
	Opening Size	mm	1.0	1.0	1.0
	Opening Rate	%	1.8	1.8	27.8
	Length	m	24	24	24

Source: Specifications of test wells PP-1 and PP-2 are referred to Feasibility Report, established in 2000.

Table 2.13 Observation Results During Step Drawdown Tests

Step	Discharge	Drawdown	Turbidity	Sand	Discharge	Drawdown	Turbidity	Sand
	m^3/day	m	Observation		m^3/day	m	Observation	
PP-1: Pre-rehabilitation (SWL: 1.95 m)					PP-1: Post-rehabilitation (SWL: 1.43 m)			
1	438	3.37	Clear	<50	367	3.08	Clear	<50
2	600	5.11	Little	<100	492	4.71	Clear	<100
3	790	7.38	Little	<150	611	6.53	Clear	<150
4	942	9.58	Clouded	<300	715	8.43	Clear	<300
5	1,001	10.62	Clouded	<500	785	10.02	Little	<500
PP-2: Pre-rehabilitation (SWL: 2.54 m)					PP-2: Post-rehabilitation (SWL: 1.57 m)			
1	344	5.14	Clear	<100	265	0.95	Clear	<100
2	447	8.35	Little	<150	403	1.66	Clear	<150
3	600	11.81	Clouded	<200	578	3.03	Clear	<200
4	702	18.48	Clouded	<500	816	6.94	Clear	>1,000
5	842	29.41	Turbid	>1,000	912	9.81	Turbid	>3,000

Notes:	PP-3: Newly Constructed (SWL: 1.37 m)				
1. Sand pumping rate is permitted to 50mg/L due to pump structures (manufacture's design standard). Such rate shall be minimized with due consideration of aquifer protection and long life usage. 2. Upper screen portions at test well PP-1; GL-12 m, PP-2; GL-12 m and PP-3; GL-15 m.	1	492	1.48	Clear	<5
	2	653	2.11	Clear	<5
	3	805	2.76	Clear	<5
	4	937	3.38	Clear	<5
	5	1,092	4.17	Clear	<5

(6) Electric Prospecting

Stratigraphy in Siem Reap Town is shown in Table 2.14, comprising Mesozoic erathem, Tertiary and Quaternary systems forming the lower portion. The hydraulic basin is Mesozoic tuff and volcanics. For groundwater development, upper formations on the Mesozoic erathem are available with different potential. According to the pumping tests carried out during the F/S, only groundwater-bearing formations in Miocene series were developed with potential of several m^3/day. Pliocene (Tertiary period) series and Quaternary system also have an economic potential for water source development for the SRWSS.

Table 2.14 Stratigraphy in Well Field

Geologic Age & Stratigraphy			Lithofaces in Siem Reap Town	Permeability
Quaternary	Holocene	Alluvium	Unconsolidated sandy and clayey soil (brown)	Excellent
	Pleistocene	Diluvium	Lateritic clayey and sandy soil (grayish brown)	Excellent to good
Tertiary	Pliocene		Sand/Clay Stone, (reddish to dark brown)	Good to Fair
	Miocene		Sand Stone/Shale, (reddish to dark brown)	Fair to Bad
Mesozoic			Tuff and Volcanics	Hydraulic Basin

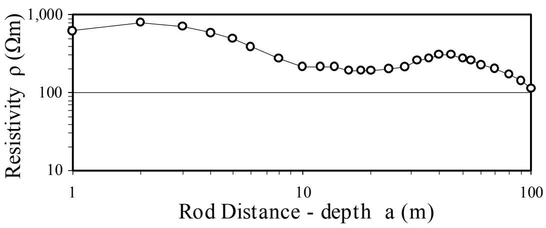
Under the above hydrogeologic conditions, electric prospecting was conducted in order to analyze the bottom depth of the Pliocene series. According to the feasibility study report, the maximum distribution depth of the Pliocene series was about 70m below ground surface. Hence, earth resistivities were measured up to a depth of 100 m. The arrangement of measuring points followed three lines (A, B and C) as described below. Detailed locations of A and B lines are shown in Figure 2.8 (general locations including C line are referred to in Figure 2.3).

- A Line: along the National Road No. 6 — 19 points
- B Line: along the Provincial Road to West Baray Reservoir — 4 points
- C Line: Puok Commune — 3 points

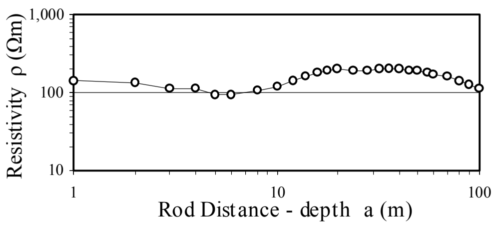
The earth resistivities at each point and depth indicated different values depending on the grounding conditions of the four-probes (two current and two potential rods), being influenced by soil moisture and groundwater level. Consequently, boundary depths of potential formations need to be analyzed with due consideration of not only apparent resistivities (resistivity layers based on ρ - a curve analysis; referred to in Figure 2.9 and Figure 2.10) but should also take into account the stratigraphy comparing logging information from the observation well WT-04 and test wells PP-1, PP-2 and PP-3.

The ρ - a curves have the following trend and typical curves are shown in the figures below.

- Generally, earth resistivity values are high, low, high and low classified into two types.
- Starting from High-Resistivity (400 to 1,000 ohm m) and continuing to Low, Medium and Low
- Starting from Medium-Resistivity (50 to 400 ohm m) and continuing to slightly Low, Medium and Low



High→Low→Medium→Low



Medium→slightly Low→Medium→Low

The following relationships between resistivity layer and stratigraphy can be observed comparing stratigraphy (based on the ρ - a curves) and the logging results (four points in A-Line).

- Depths with High to Low are considerable as alluvium and dilvium (Quaternary system)
- Next depths with Medium to Low correspond to Pliocne and Miocene (Tertiary system)
- Starting from Medium value, until head portion of next Low will be evaluated as alluvium
- Second medium portion can be divided into increase and decrease, these are Diluvium and Pliocene
- Low portion is reasoned to be Miocene

Apparent resistivity layer profiles with lines of A, B and C are shown in Figures 2-9 and 2-10 based on the comparison and examination explained above. According to these figures, the Pliocene series will be distributed up to a minimum of 50 m below ground surface in the well field. In the surrounding areas where test wells of PP-1 and PP-2 are located, Pliocene series are distributed up to 65 m below ground level.

(7) Groundwater Quality

Groundwater quality is examined on the basis of the 17 parameters below.

- Raw Water Observation: EC
- On-site Examination: Temperature, pH, Fe, Mn
- Laboratory Examination: Total Hardness, Color, As, F, NO_2, NO_3, NH_4, Mg, Ca, Cl, SO_4, COD

Sampling wells have to be in daily use, otherwise raw groundwater cannot be sampled easily. To comply with this condition, 17 existing wells owned by hotels along the National Road No. 6, two test wells and one tube well were selected. Table 2.15 shows the examination results for pH (4.5 to 6.1) and Fe (maximum 0.69 mg/L), which exceeded WHO guidelines. Other parameters (refer to Appendix 6-2) are within the WHO guideline limits.

The well field for this project is located within the same area of sampling wells WQ-18 to 20 (shadowed in Table 2.15). The pH values are 4.8 to 5.1 and Fe concentrations 0.47 to 0.63 mg/L, respectively. According to examination records at WT-04 (observation well; refer to Appendix 6-2), during the feasibility study, pH values were 5 to 8, and Fe values ranged from 0 to 1 mg/L. Groundwater quality results from this study as well as the previous F/S indicate the same seasonal variation.

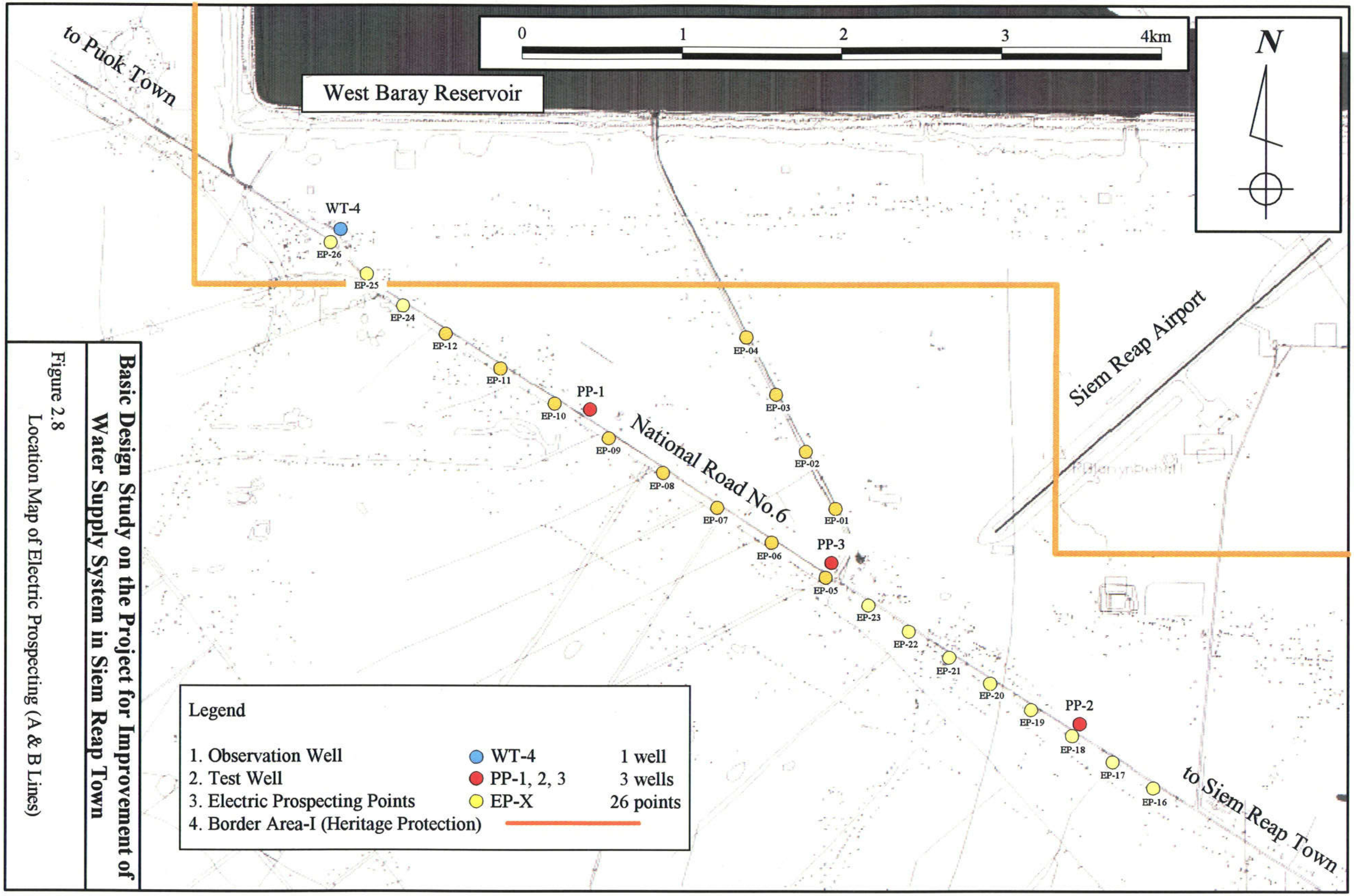


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Figure 2.8
Location Map of Electric Prospecting (A & B Lines)

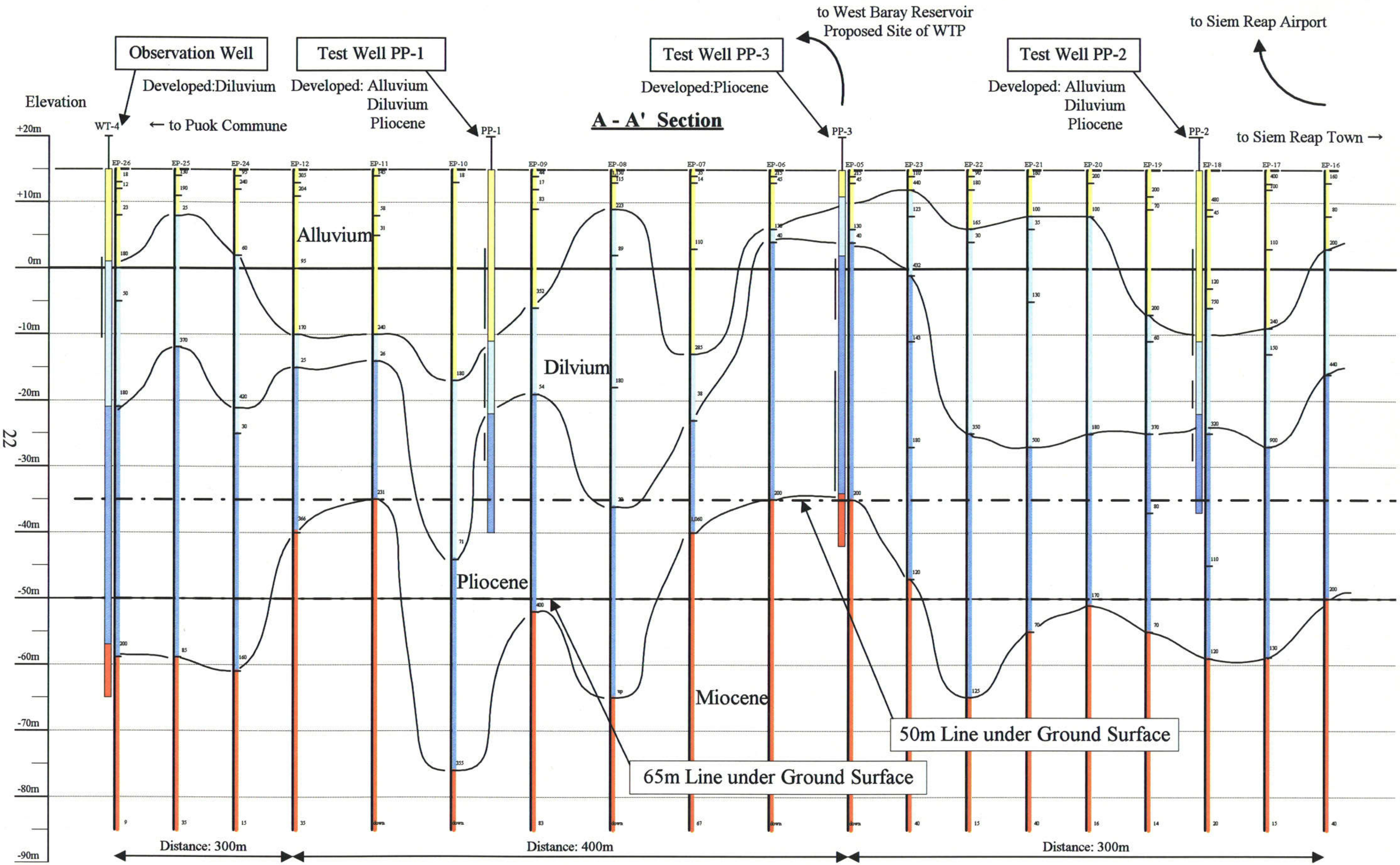


Figure 2.9 Resistivity Layer Profile (A Line)

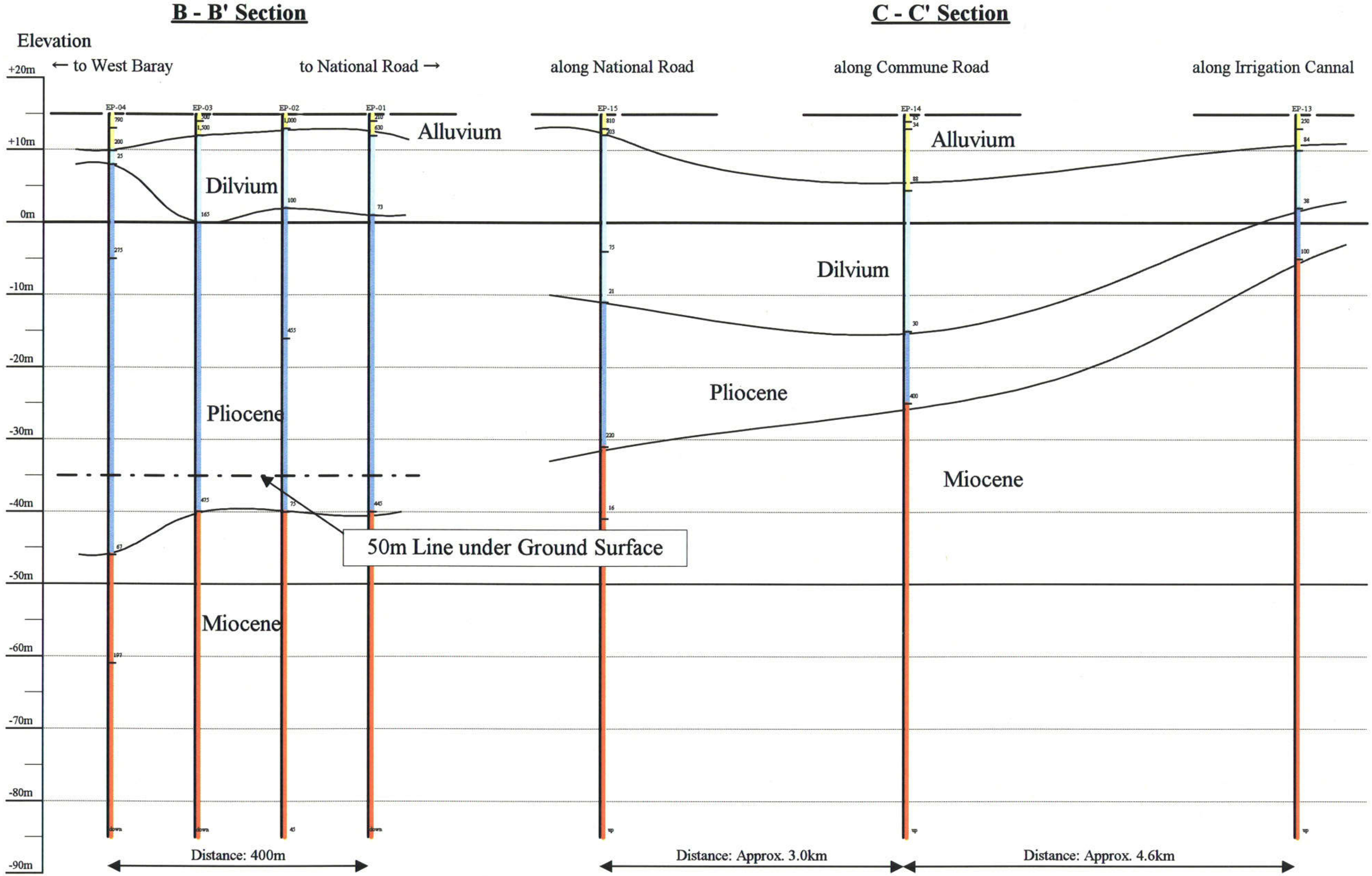


Figure 2.10 Resistivity Layer Profile (B and C Lines)

Table 2.15 Groundwater Quality Examination Summary (March 2003)

Location of Sampling Well		On-site		Location of Sampling Well		On-site	
ID	Location	pH	Fe	ID	Location	pH	Fe
WQ-01	Phnom Bok Hotel	5.0	0.25	WQ-11	Hotel City Royal	4.5	**0.43**
WQ-02	Rama Hotel	5.4	**0.31**	WQ-12	Banteaysrey Hotel	4.7	**0.69**
WQ-03	Freedom Hotel	4.5	**0.57**	WQ-13	APSARA Angkor Hotel	4.8	**0.35**
WQ-04	Siem Reap Town Hotel	6.1	**0.35**	WQ-14	Hotel City Angkor	4.7	**0.59**
WQ-05	Borei Angkor	4.6	**0.45**	WQ-15	Princess Angkor Hotel	4.9	**0.42**
WQ-06	Grand Hotel	4.8	**0.69**	WQ-16	Nokon Phom Hotel	4.5	**0.65**
WQ-07	Angkor Pich Hotel	4.8	**0.42**	WQ-17	Angkor Reach Hotel	4.5	**0.53**
WQ-08	Golden Angkor Hotel	4.5	**0.42**	WQ-18	Test Well No. PP-99-02	4.8	**0.63**
WQ-09	Angkor Hotel	4.8	**0.43**	WQ-19	House Construction Site	5.1	**0.47**
WQ-10	Prum Bayon Hotel	4.7	**0.57**	WQ-20	Test Well No. PP-99-01	5.0	**0.54**

Notes: pH unit is negative exponent, Fe in mg/L. Values exceeding WHO guidelines are indicated by bold. Shadow results are in the well field.

2-2-2-6 Examination of Groundwater Intake Facility

(1) Basic Concept of Well Facility Planning

The basic concepts of well facility planning to be considered are as follows:

- Water Source Stability : well potential and reduction of interference
- Less Environmental Impact : interference of water level at Angkor Heritage area
- Economic Arrangement : low construction and maintenance costs for raw water intake facility
- Easy Operation : simple operation of production wells by the SRWSS
- Area for Heritage Protection : protection of heritage and difficulty of securing construction permission
- Land Acquisition : land availability and population relocation issue

(2) Target Aquifers for Groundwater Development

Over the master plan period, the Quaternary system (alluvium and diluvium) is confirmed as the target aquifer source to be developed for the SRWSS water source, according to the geological survey covering approximately 400 km^2 areas. According to Figure 2.11, the area where the provincial road to West Baray Reservoir connects to the National Road No.6 is proposed for the well field.

In the first field survey period, electric prospecting with three measuring points in the area of Puok commune was conducted. The aim of the geological survey was to confirm the thickness of aquifers (Quaternary) in the southern and west perimeters of the proposed well field. Such aquifer thickness was estimated to be 20 m or less. Therefore, the predominant well field confirmation was defined in terms of aquifer thickness.

The results of electric prospecting in the proposed well field were used to determine the effective thickness of the dominant formation comprising Quaternary deposits only in the areas where test wells PP-1 and PP-2 were constructed. The distribution of the Pliocene layer at shallower depths was found in an area along the provincial road to West Baray Reservoir. The development potential of the Pliocene series was analyzed using the new test well PP-3 during the third field survey. The permeability coefficient (k) of the Pliocene was estimated at 85 percent of that of the Quaternary, hence, both the Pliocene series and the Quaternary system can be developed for the water source for the SRWSS.

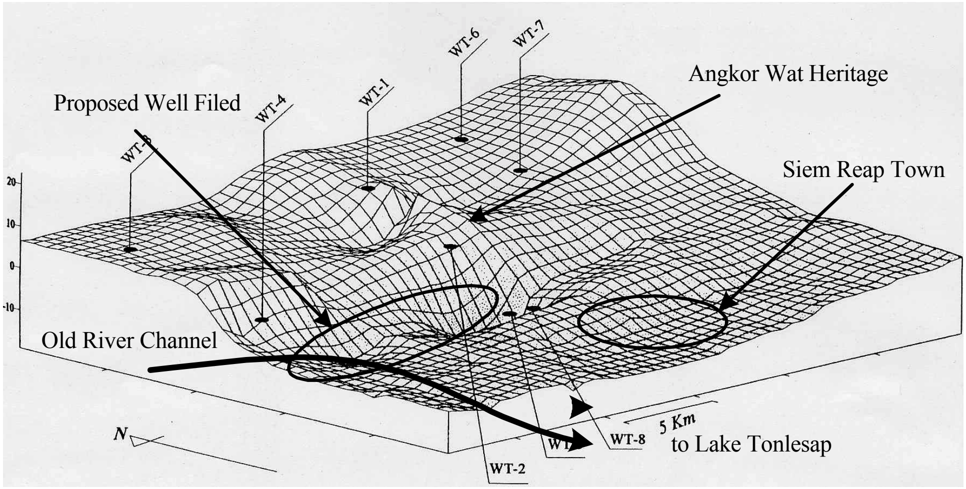


Figure 2.11 Bird's Eye Viewing of Quaternary Bottom Depth (Master Plan)

(3) Intake Condition Relating to Heritage Protection

Over the period of the master plan, the potential magnitude of interference drawdown at the Angkor Heritage site was simulated using a range of well drawdown values in the proposed well field. Thee well drawdown values of 2.3 m, 5.5 m and 8.5 m resulted in interference drawdown values at the heritage area of 15 to 20 cm, 20 to 30 cm and 30 to 40 cm, respectively.

Based on the records of ground subsidence from the LTb station (west side of Angkor Wat), the displacement of the ground surface level was 1.3 mm, with a seasonal water level variation of 2.3 m. It was presumed that an additional maximum drawdown value of 30 cm (fluctuation in water level of 2.3 to 2.6 m) might result in an additional displacement of 0.3 mm (1.3 to 1.6 mm). Such environmental impact was evaluated as acceptable in the master plan study. A well drawdown of 5m in the well field was proposed for design of the production wells.

Minimization of water level interference at the Angkor Heritage site is a key concept of this study. It is also considered that a well drawdown of 5m (another 0.5m is anticipated as interference drawdown from other wells) is not economically disadvantageous.

(4) Well Arrangement

Necessary intake amount shall be estimated to add the operation and maintenance (O&M) water amount to the daily maximum water supply amount (8,000 m^3/day). Detailed estimated amount of additional water is referred to Appendix 6-3. Total intake amount of raw water source is estimated at 8,800 m^3/day.

Survey results from the electric prospecting show that groundwater can be developed at a depth of 50 m below ground surface at location in the well field. From the pumping tests, the minimal intake potential (for the aquifer comprising entirely the Pliocene series) is estimated at 1,100 m^3/day well (refer to calculation below). On the other hand, there are some locations where a development depth up to 65 m below ground surface is possible. The least productive point is that surrounding area EP-09 (refer to Figure 2.9) but even here the minimum intake potential is estimated at 1,470 m^3/day. The Constant B value at test well PP-2 (well screen 24 m: 2.01, refer to Table 2.10) was adopted to estimate a new Constant B at EP-09 (aquifer thickness 36 m: 1.34 = 2.01 x 24 m/36 m).

Drawdown Equation $sw = BQ + CQ^2$ Qp (Intake Potential) = $\{(sw/C) + (B/2C)^2\}^{1/2}$-B/2C

- 50m: Constant B = 3.01×10^{-3}, Constant C = 1.40×10^{-6} and Intake Potential = 1,100 m^3/day
- 65m: Constant B = 1.34×10^{-3}, Constant C = 1.40×10^{-6} and Intake Potential = 1,470 m^3/day

In order to minimize the construction cost of the raw water transmission pipeline, production wells should be arranged near to the WTP. Since the aquifer has a development depth of 50 m in the vicinity of the WTP it will be possible to provide four production wells including one well in the WTP yard. The total intake from these four well is estimated at 4,400 m^3/day.

A development depth up to 65m below ground surface is available in the next well field (refer to Figure 2.9). The balance of 4,400 m^3/day (total intake amounts to 8,800 m^3/day) can be developed by arranging three production wells (4,410 m^3/day = 3 wells x 1,470 m^3/day). However, it is recommended that another four wells be provided in case the previous 50 m depth continues into the next well field. If necessary, groundwater could also be developed from more widely field and shallow wells, say from a total of ten production wells (same as proposed in the F/S).

The following three alternatives for production well arrangement are evaluated:

i) 10 wells 880 m^3/day x 10 wells
ii) 8 wells 1,100 m^3/day x 8 wells
iii) 7 wells 1,100 m^3/day x 4 wells + 1,470 m^3/day x 3 wells

(5) Safety Spacing of Wells and Well Structures

Since intake potential proportional to the value of the permeability coefficient (k) and the thickness of the aquifer (b), the required transmissivity (T) values are estimated for the three alternatives as shown in Table 2.16.

Formations of the Quaternary system and Pliocene series are classified as an unconfined aquifer without any prominent aquicludes. The nonequilibrium formula (epsilon method by Theis) without recharge source is applied to estimate the interference from other wells, a time factor of six months during the dry season is also applied.

Table 2.16 Relationship between Intake Potential and Transmissivity

Well Number	Intake Amount (m^3/day/well)	Transmissivity T (m^3/day/m)
10 wells	880	≧190
8 wells	1,100	≧230
7 wells	Pliocene: 1,100	≧230
	Quaternary + Pliocene: 1,470	≧310

Note: Transmissivity is estimated based on 70% aquifer thickness available with arrangement of well screen (3m long).

Figure 2.12 shows the relationship between the distance from the pumping well and interference drawdown, which can be estimated from the following formula using the values of Q_0 (intake amount: refer to Table 2.16), T_0 (transmissivity: refer to Table 2.16) and t (time: 6 months).

The distances between the production wells will be arranged according to Figure 2-12.

- 10 wells: 410 m
- 8 wells: 450 m
- 7 wells: 550 m (Quaternary + Pliocene), 470 m (Pliocene)

Theis Formula $s = Q_O/(4 \times 3.14 \times T_O) \times \ln((2.25 \times T_O \times t)/(r^2 \times e))$

Where
- s : interference drawdown (0.25 m)
- Q_O : intake amount (substitution m^3/day)
- T_0 : transmissivity (substitution m^3/day/m)
- ln : natural logarithm
- r : distance from pumping well (solution ,m)
- e : specific yield (25% (Eckis; fine sand))
- t : time since pumping started (183 day (6 months))

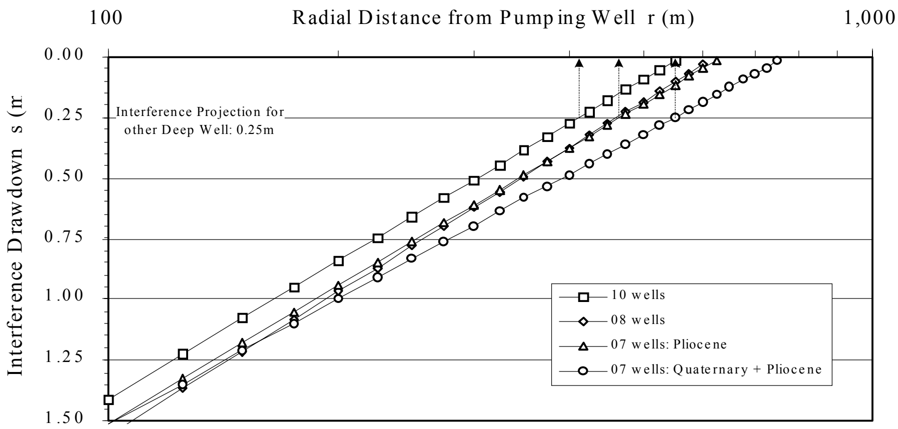


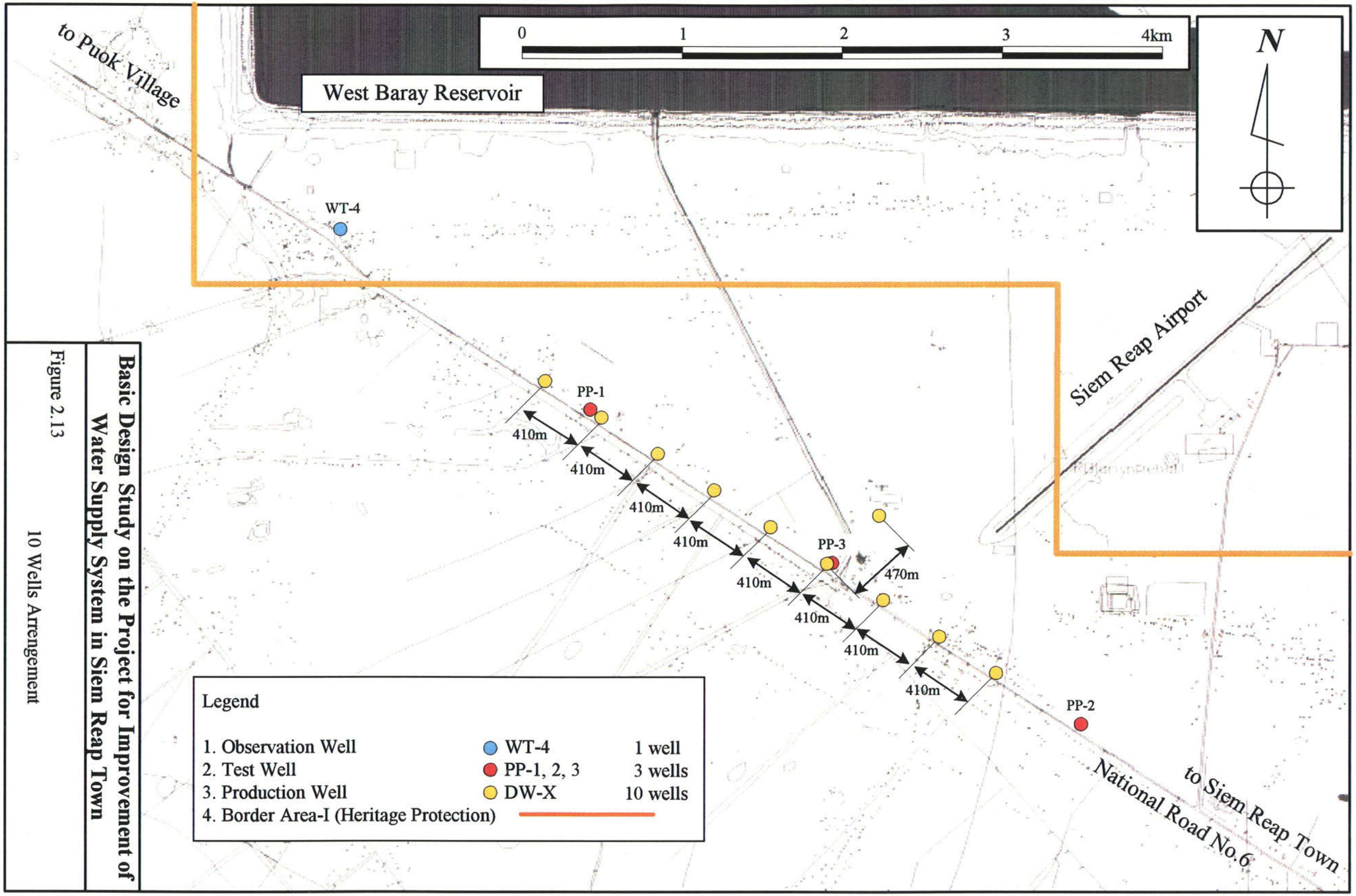
Figure 2.12 Distance r (m) – Interference Drawdown s (m) Graph

Production wells can be arranged as shown in Figure 2.13 (10 wells), Figure 2.14 (8 wells) and Figure 2.15 (7 wells) using the above well distances and the geological distribution in the well field. Actual transmissivity values and well depths are shown in Table 2.17.

Table 2.17 Design Criteria of Production Well Arrangement

Alternatives		Design Criteria		Well Depth
Well Number	Intake Amount Q (m^3/day/well)	Transmissivity T (m^3/d/m)	Well Spacing r (m)	
10 wells	880	190 ～ 235	410 m	50 m ～ 56 m
8 wells	1,100	235 ～ 250	450 m	54 m ～ 59 m
7 wells	Pliocene:4 x 1,100	235 ～ 250	470 m	54 m ～ 59 m
	Quaternary + Pliocene: 3 x 1,470	320 ～ 335	550 m	76 m ～ 79 m

Note: Transmissivity is estimated based on 70% aquifer thickness available with arrangement of well screen (3m long).



Basic Design Study on the Project for Improvement of Water Supply System in Siem Reap Town

Figure 2.13

10 Wells Arrengement

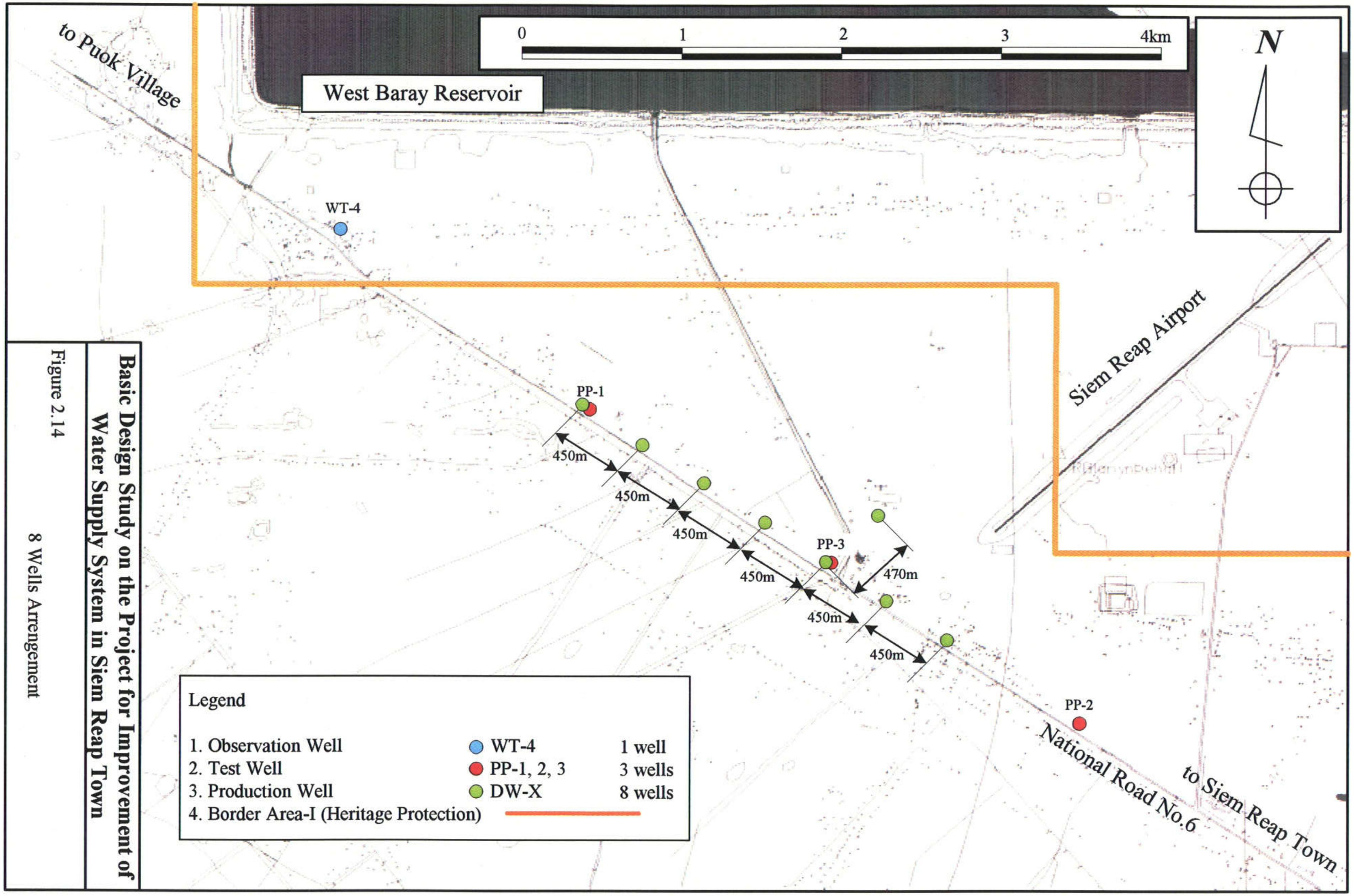


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Figure 2.14

8 Wells Arrangement

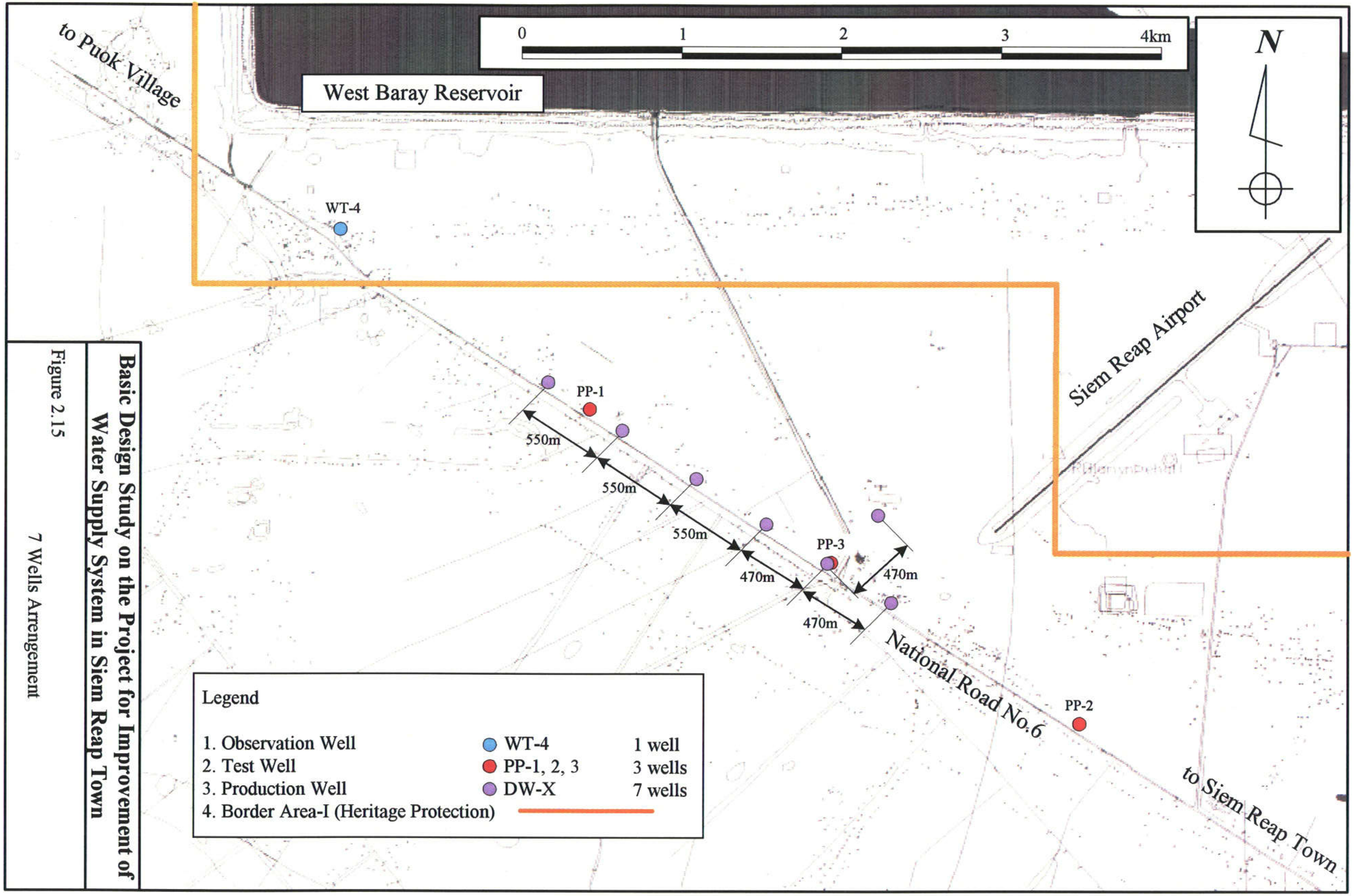

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Figure 2.15

7 Wells Arrengement

(6) Proposed Intake Facility

Comparison of Construction Cost

Construction costs for alternative production well arrangements are shown in Table 2.18. It should be noted that a small number of wells, even wells with deeper depth, is less costly than alternatives based on a larger number of well.

Table 2.18 Cost Comparison

Alternative Plans	Intake Amount	Cost Rate
10 wells	10 wells x 880 m^3/day	123.3 %
8 wells	8 wells x 1,100 m^3/day	103.8 %
7 wells	4 wells x 1,100m^3/day + 3 wells x 1,470 m^3/day	100.0 %

Note: Construction cost includes production well, pump with control panel, pipeline, etc.

The Recommended Plan

Construction costs increase in proportion to the number of wells, however, there is only 4 percent difference between schemes with 7 and 8 wells. Since this groundwater development forms the basis of the public water supply system for Siem Reap Town, it is important to take into account technical issues including operation and maintenance as well as the cost.

Upon completion of the system construction in 2006, the water supply of approximately 4,000 m^3/day will be increased to 8,000 m^3/day, with additional distribution pipelines and metering continuing through to 2008. During this period, the production wells will be operated to be regular or stand-by to allow for maintenance of the wells, intake pumps, electric equipment, etc.

When the system is working at full capacity, it will be possible to stop individual wells for routine and/or preventive maintenance without adversely affecting the overall scheme capacity. If well production amounts were to be very different, the system would become unstable, but under the arrangement proposed of identical pump capacities, the scheme can be operated by switching production wells and/or exchanging their parts, also management, control and purchase of spare parts will be easier.

Strengthening of the SRWSS staff will be supported by the soft-component under the Project. The facilities will in any case be simple to operate and maintain, compatible in design and incorporate some allowances for fail-safe operation.

On the basis of the above, it is recommended that a scheme comprising 8 production wells (test well PP-3 will be converted to a production well) be adopted. The structure of a standard production well is indicated in Figure 2.16

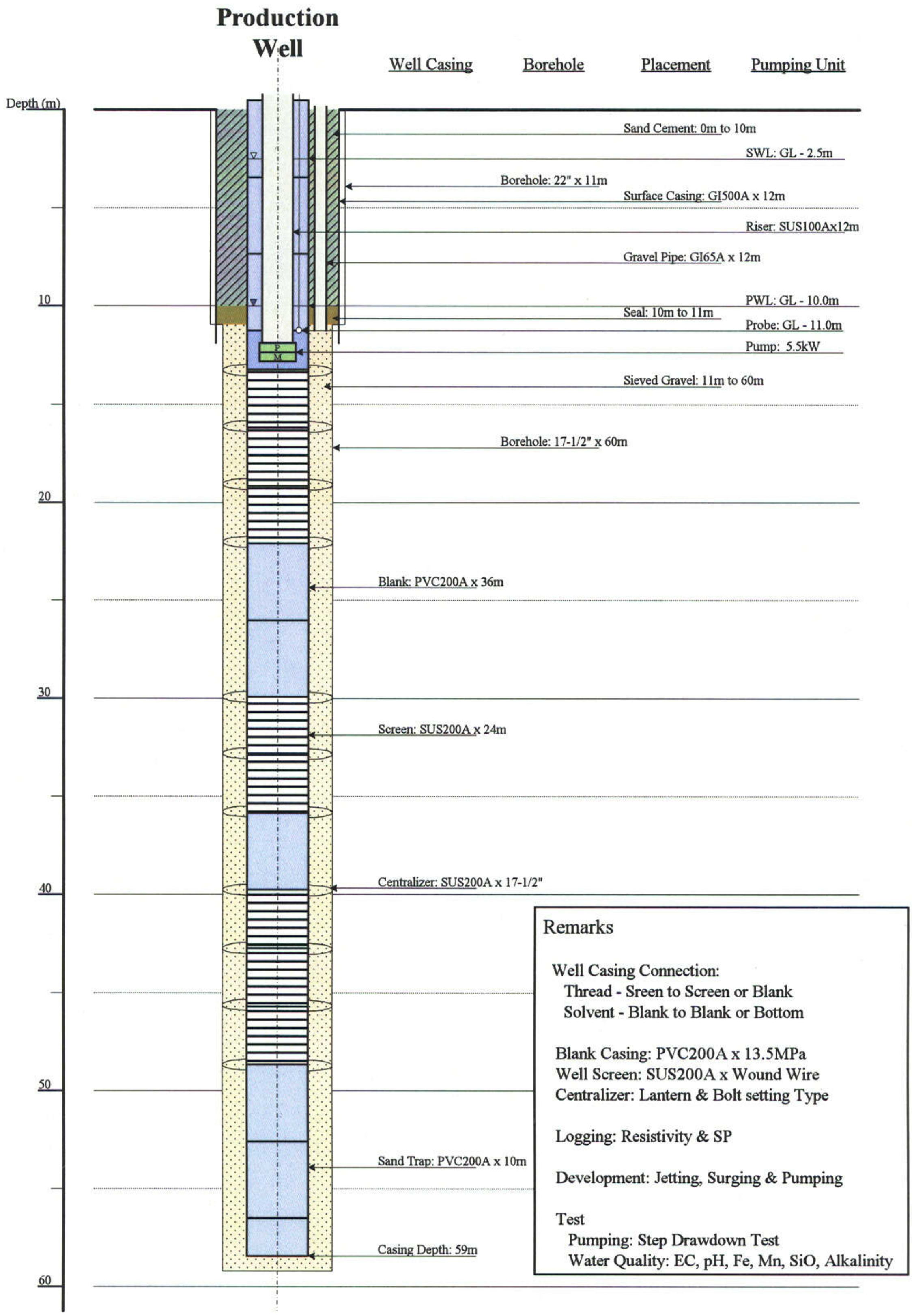

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Figure 2.16

Standard Well Design

2-2-2-7 Water Treatment Plant

The proposed water supply system is shown in Figure 2.17 and the basic design drawings are referred to the following section 2-2-3.

The proposed water treatment plant site is situated 300 m north along with a road towards the West Baray near by the Taisho Elementary School constructed through a Japanese assistance. The site has been selected taking into consideration the conditions as i) ease of land acquisition and resettlement, ii) efficient receive of raw water from each well site, iii) accessible for conveyance for the required chemicals, fuels, etc. for the water treatment, iv) less environment effect area, and v) permissible for the related Cambodian regulations/laws.

As for the existing WTP, RGC will consider whether the existing water treatment will be kept in operation or abandoned in 2006 when the Project will be completed.

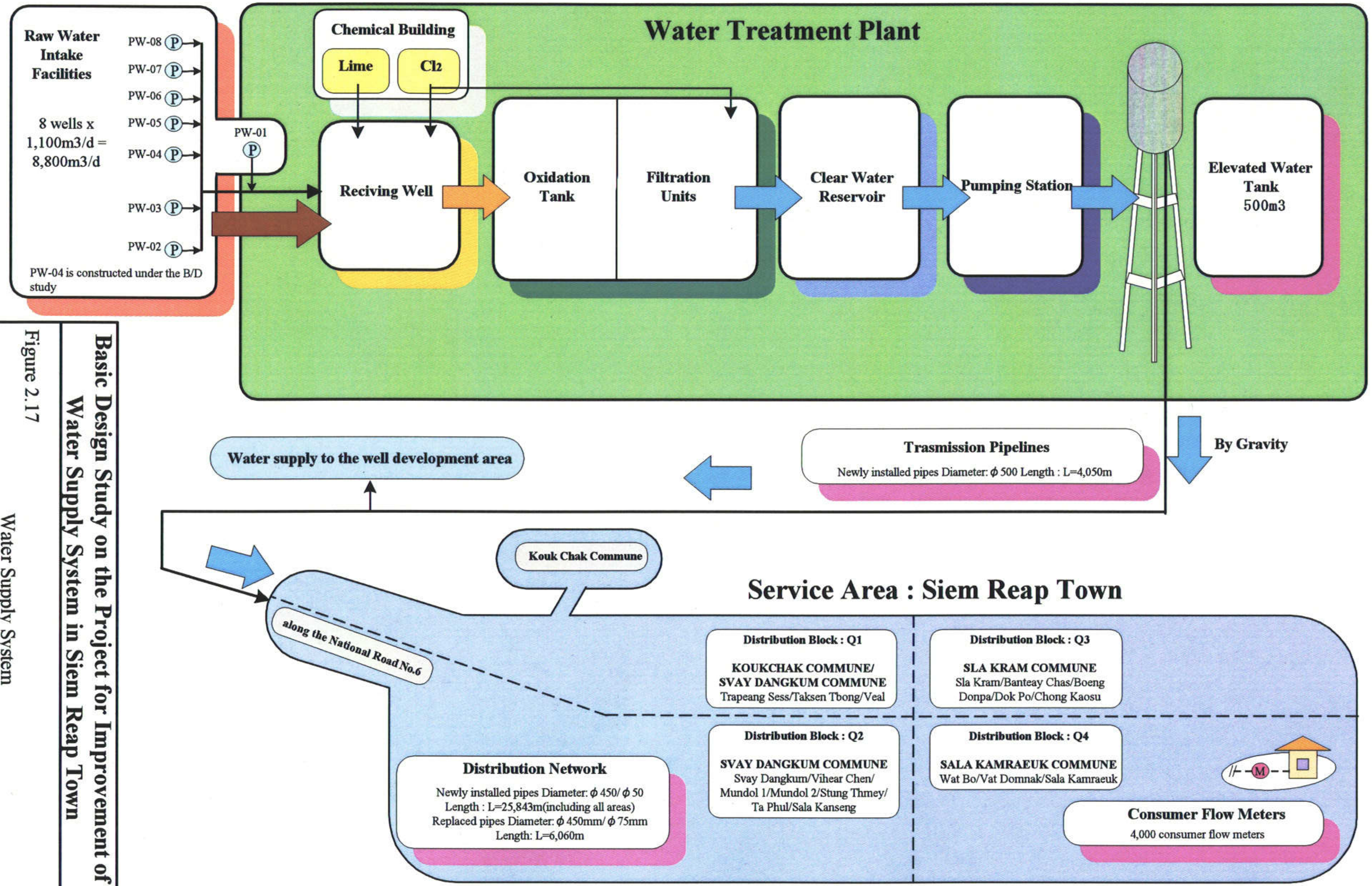
Task force has just drafted a Cambodian Drinking Water Quality Standards. The drafted "Cambodian Standards" is closely based on the latest WHO guidelines (2003) and have not yet finalized. Therefore, the water treated at the proposed water treatment plant will be potable and safe as per the WHO guidelines for drinking water quality. Generally accepted guidelines for the necessary standards of treated water have been developed by the WHO, and are acceptable to the Project. Other donor agencies have agreed so far that water quality objectives will be based on the WHO guidelines.

(1) Water Treatment Process

The data of water quality analysis conducted by the Study Team and the F/S conducted in 2000 shows that pH varying from 4 to 7 showed acidic properties and iron contents varying from 0 to 1.0 mg/l exceeded the WHO guidelines or the proposed Cambodian national Drinking Water Quality Standards. In reference to the water quality investigation conducted in the F/S as shown in Appendix 6-2, the iron concentrations were found to fluctuate with the seasonal change; low and acceptable during rainy season and occasionally exceeding the WHO guidelines level in the dry season. Other parameters analyzed in the field survey including Mn, EC, total hardness, color, As, F, NO_2, NO_3, NH_4, Mg, Ca, Cl, SO_4, and COD indicated within the WHO guidelines. It is, however, noted that SiO_2 detected over 10 mg/l in the F/S as well as in the Study Team analysis may affect iron oxidization by forming insoluble ferric hydroxide.

Since the SiO_2 contents over 10mg/l and may increase beyond 30 mg/l in the future, removal of the iron by aeration only may not be accomplished effectively. In case oxidation is not sufficient, the remaining iron content which will be in the form of fine colloidal particles would cause clogging of pipes and facilities. To avoid the above mentioned problems, treatment facilities consisting of chlorine oxidation, filtration, pH control, and disinfection processes are recommended in the B/D.

The detailed design parameters are shown below in comparison between the original request by RGC and the proposed scope of work in the B/D:



Basic Design Study on the Project for Improvement of Water Supply System in Siem Reap Town

Figure 2.17 Water Supply System

(2) Receiving Well

Lime for pH control and chlorine as an oxidant are employed on the proposed receiving well, similar to the existing water treatment plant. Those chemicals are to be mixed with the raw water by rapid mixing. In line with the design basis/concepts proposed in the previous section, the intensity of turbulence is preferably generated hydraulically through the hydraulic jump caused by weir to be installed at the receiving well.

Original Request by RGC	Proposed Scope of Works
RC tank of 42 m^3 with a five minutes detention time.	Same as original request by RGC.
(Reasons to alter) Five minutes detention time is sufficient to regulate surplus pressure of the raw water, measures the inflow rate, and expect effective mixing for raw water and chemicals to be added.	

(3) Oxidation Tank and Filter Units

Chlorine will oxidize soluble iron. However, the particle size of the precipitated material is usually so fine as to require further treatment and settling prior to filtration. After oxidization of iron to insoluble compounds, a stage is often preferred which gives the precipitates time to settle prior to filtration. Particles of precipitated iron which have not been removed by settling must be removed by filtration. The filter required to accomplish this process can be determined in the selection of filter media. Inflow weirs, without filter controllers, are recommended to hydraulically distribute the oxidized raw water evenly to each filter unit. Effluent weirs to be installed at the tale end of filter units are recommended to achieve a constant rate filtration system. The water level in each filter unit rises as necessary to accept an equal portion and indicates head loss. The highest filtration level at which washing will start will be controlled automatically by means of the water level in each filter and surface/backwashing will then run for a pre-set time period. The mechanization and automation will ensure the reliability of the system. The backwashed water will be stored in a pond in which major sediments will be removed and supernatant will overflow into the existing canal outside of the water treatment plant.

Original Request by RGC	Proposed Scope of Works
Not included	2 x 130 m^3 oxidation tanks with 45 minutes of detention time. 3 filter units with a filtration velocity of 200 m/d and filtration area of 15 m^2/filter unit
(Reasons to alter) Iron removal processes by oxidation tanks and filtration units are added.	

(4) Clear Water Reservoir

The filtered water will be transferred to clear water reservoirs after disinfected by chlorine. The clear water reservoir is to be constructed with two compartments on the plant site. The facility has a total volume corresponding to at least 8 hours of operation which accommodates a fluctuation of water demand. A sufficient number of baffles are installed in order to prevent dead zones in the clear water reservoir. The dosage of chlorine may be adjustable manually in accordance with the raw water quality during commissioning test operation.

Original Request by RGC	Proposed Scope of Works
2 tanks with 8 hours detention time, W15m x L25m x D3.5m	2 tanks with 8 hours detention time, W11m x L27.5m x D4.6m
Disinfectant-chlorine	Same as left.
（Reasons to alter） Optimization of total arrangement with additional process of iron removal.	

(5) Clear Water Lifting Pump Station

The clear water pumping station is to be constructed besides the clear water reservoirs. The backwash pumps for filter units will be installed in the pumping station together with the clear water lifting pumps to the elevated water tank. The clear water lifting pumps will automatically be operated by sensing the water level in the elevated water tank.

Original Request by RGC	Proposed Scope of Works
Seven pumps including two spare pumps.	Two pumps for clear water lifting and two pumps for backwashing, including one pump stand-by each.
（Reasons to alter） Due to change of distribution system from direct distribution by pumps to by gravity using elevated water tank, number of pumps continuously operated is reduced to one unit for clear water lifting from the clear water tank to the elevated water tank.	

(6) Elevated Water Tank

The direct pump system originally requested by RGC needs to operate the pumps automatically depending on the fluctuated water demand. In order to accommodate the variable water demand, the discharge rate of the pumps is needed to be controlled by means of signal from the discharge pressure, flow rate, or valve operation. The pump capacity may be required to satisfy from the least water demand in the night time to the hourly peak demand in day time. Costly special control devices, such as computer assisted operating system is needed. Likewise, well trained and/or high educated system operators are required to realize a stable water supply.

Therefore, gravity distribution system is highly recommended as an optimum distribution system in Cambodia to accommodate the fluctuated water demand at the service areas. The gravity system only requires clear water lifting pumps, as mentioned in the previous section, and brings about less operation and maintenance cost in the future. The elevated water tank with a detention time of 1.5 hours are designed.

The height of the elevated water tank is designed to be approximately 38m above the ground level as shown in the attached drawing (see Table 2.24, Drawing No. 3-C-6). The designed elevated water tank height accommodates hydraulically for the required head of the minimum hydraulic pressure (150kPa) at the end of distribution pipelines, head loss through transmission pipeline, and clearance for operation and maintenance at the top of elevated water tank. It was confirmed by MIME in consultation with the State Secretariat of Civil Aviation in April 2003 that construction of the elevated water tank in the proposed water treatment site is acceptable in accordance with the related laws.

Original Request by RGC	Proposed Scope of Works
N/A	One tank with 1.5 hours detention time, 500 m^3
(Reasons to alter) As a result of review of the requested distribution system which is recommended in the F/S, the proposed distribution system by elevated water tank is identified to be more advantageous in term of easy operation and maintenance than that of requested system due to reducing the number of pumps continuously operated. RGC has experiences on operation and maintenance for the proposed distribution system.	

(7) Chlorination/Disinfectant

Chlorine will be supplied in tonne containers of liquid chlorine. The facilities will include all equipment for storage, handling, dosing and injection of chlorine, together with safety equipment. The operation of the chlorinators will be controlled on a “START-STOP” basis according to the level in the receiving well, and/or clear water reservoir.

One chlorine drum of each row will be supported on a weighing machine, which will be provided with an adjustable tare lever and with supports for the drums. A row of chlorinators will be equipped with one immersion pit, to reduce the damage in case of chlorine leakage. Evaporators are not necessary as a tonne container can feed evaporated chlorine about 10 kg/hr with no additional heat input or evaporator in premises at 20 to 25℃. The necessary number of chlorine cylinders will be provided without evaporators based on the said conditions.

The dosing points for pre and post chlorine shall be selected accordingly to the raw water quality and operation and maintenance purpose. Subsequently, post chlorine shall be adjusted to retain necessary chlorine residual in the distribution network.

(8) pH Control

Lime will be delivered in bags, containing 25 or 50 kg of imported hydrated lime. The maximum lime dosage is not likely to exceed 20 mg/l in accordance with the operating record of the existing water treatment plant, but provisions will be made to enable the operator to satisfy dosage demands up to 30 mg/l with a 10 percent solution. The flow of lime slurry will be manually controlled according to the lime demand and the actual water flow.

Two slurry tanks will be provided, having a total net capacity equivalent to at least one or two days retention time at the maximum dosing rate. Two tanks, one for duty and another for stand by with volume of 3 m^3 will be built in mild steel. Each slurry tank will be provided with a loading hatch, an electrically driven mixer, overflow pipe, drain pipe and slurry outlet valve, each with manual diaphragm or ball valve, level gauge (float and counterpoise along a graduated scale).

2-2-2-8 Administration Building and Work Shop

(1) Administration Building

At present, SRWSS is operated by seven permanent and five casual staff. The operation includes operation and maintenance of the existing water treatment plant using groundwater source, distribution, billing and collection, and general affairs. For appropriate operation and maintenance for the proposed new water supply system, 40 members will be necessary including shift workers.

Descriptions	Proposed No. of Staff	Floor area (m²)	Remarks
[First Floor]			
Customer service room	3	45	Customer services
Administration and finance room	4	30	3-customer services, 1-administration staff
Laboratory room	1	20	
Storage room	-	10	
Kichen/Toilet	-	20	
Entrance, reception, and stairs	-	60	
[Second Floor]			
Director	1	20.5	
Deputy director	1	7.5	Engineering
Deputy director	1	15	Administration and finance
Deputy director	1	15	Customer services
Monitoring room	21	40	21-engineers including shift staff
Conference room	-	30	
Toilets for male and female	-	10	
Kitchen	-	10	
Corridor and stairs	-	30	
Total	**33***		Including shift workers.

Notes: Total number will be increased from 33 to 40 in future.

Therefore, a two-storey building is to be constructed in the plant site where entire management for the new water supply system will be handled. The ground floor will include an entrance with receptionist area, general office area, laboratory, storage room, kitchen, and toilets and stairs to the second floor. The second floor will include offices for the director, deputy directors, engineers, conference room, monitoring room, toilets and stairs to the first floor.

(2) Work Shop

A workshop to be constructed will include a garage, workshop, and warehouse. In the workshop, all equipment such as consumer flow meters, tools, etc. procured under the Project will be stored. The detailed equipment is listed in the following section.

2-2-2-9 Outline of the Proposed Water Treatment Plant

The Project will include the following facilities /equipment.

(1) Civil and Architectural Structures

Descriptions	Dimensions/Specifications	Quantity	Remarks
[Civil Structures]			
Receiving well	W3.0m x L3.2m x D3.2m	1 well	5 min. detention time
Oxidation tank	W4.5m x L7.4m x D4.5m	2 tanks	45 min. detention time
Filter tank	W3.5m x L4.5m x D3.5m	3 units	200 m filtration velocity
Clear water reservoir	W11m x L27.5m x D4.6m	2 tanks	8 hours detention time
Elevated water tank	Dia. 12.5m x D4.5m x HGL+ approx. 38m	1 tank	1.5 hours detention time
Yard pipes		L.S.	
[Architectural Structures]			
Pumping station	W6.0m x L20m	1	
Chemical building	W12m x L20m	1	
Electrical building	W8m x L14m	1	
Administration building	1st floor : W12m x L15m 2nd floor :W12m x L15m	1	
Workshop	W6m x L25m	1	

(2) Mechanical and Electrical Facilities

Descriptions	Specifications	Quantity	Remarks
[Mechanical Equipment]			
Filter unit	Filter sand, underdrain, surface washing equipment wash drain trough	3 units	15m^2/ filter
Inflow gate	Sliding gate, W500mm x L500mm x 0.4kW	3 units	
Operation valves	Butterfly valve, Dia.150～400mm	For 3 filter units	
Control panels	Console type outdoor use	3 panels	Including relay
Detector for loss of head	Ultrasonic type	3	
Backwash pump	Double suction volute pump Dia.(350x300)mm × 13.5m^3/min x10m x 37kW	2	
Clear water lifting pump	Double suction volute pump Dia.(250x200)mm × 7.0m^3/min x 43m x 75kW	2	
Crane	Manual type crane, 3 tons	1	
Lime solution tank	Steel made tank, 3m^3	2	
Lime feeding pump	Screw pump with a single shaft 0.4～1.1L/min x 20m x 2.2kW	3	
Chlorine cylinder	Ton cylinder	3	
Weighing scale	Load cell type, for a ton container	2	
Chlorinator	Vacuum operated, ejector, 2Max.5kg-Cl_2/hr	3	
Chlorine leak detector	Leak detector, exhaust fan, control panel	L.S.	
Chemical feeding valves	For each dosing point	L.S.	
[Electrical Equipment]			
Transformer	22kV, 380V, 500kVA	1panel	Oil, outdoor use
Power receiving panel	380V MCCB 600AF	1panel	Self-standing indoor
Low tension panel	380V	1panel	Self-standing inner
Generator	380V, 400kVA Diesel	1	Inner
Fuel tank	Steel made, 8,000L	1	Outdoor
MCC for filter	380V	1panel	

Control panel for chemical feeder		1panel	
Control panel for clear water lifting pump	380V, 75kW, Auto-transformer Starter	2panels	Self-standing inner
Local control panel	Backwash pump x 1, Clear water lifting pump x 1	2 panels	
Power source panel		1panel	
Flow meter	Electro-magnetic type：intake x 1, backwash x 1, surface wash x 1, distribution x 1	L.S.	
Water level detector-1	Submerged type：clear water reservoir x 2, elevated water tank x 1	L.S.	
Water level detector-2	SUS electrode：receiving well x 1, Lime solution tank x 2	L.S.	
Water quality detector	pH meter x 2, temperature meter x 2, turbidity meter x 2, residual chlorine meter x 1	L.S.	
Water quality control panel		2 panels	
Instrumentation panel		1panel	
SQC panel		1panel	
Relay panel		1panel	
Monitoring panel for PC		1pair	
UPS	10kVA	1pair	
Cables		L.S	

2-2-2-10 Distribution Facilities

The existing distribution network covers only the central areas of Siem Reap Town. The pipe sizes varying from 100 to 250 mm are made of asbestos and have been deteriorated since installation approximately 40 years ago. Some of isolation valves are superannuated, which results in a remarkable high NRW ratio as estimated to be 50 percent currently.

(1) Design Basis of Distribution Facilities

The proposed distribution pipelines is designed to supply the safe and stable water into the service areas. The details design concepts are shown in the following:

i) Proposed distribution pipes

The pipelines are sized hydraulically based on the projected population and water demand. The analysis includes the service mains which were not studied in detailed in the F/S.

ii) Coverage of the proposed distribution pipes

The proposed pipelines include the pipelines to the requested areas by RGC during the field survey in addition to the originally requested by RGC. The new pipelines cover the water supply for Kokchak Commune and those areas along the national road No. 6 as shown in Figure 2.1 where sharp increase of population is recognized and surrounding areas of the proposed groundwater source development as shown in Figure 2.32.

iii) Replacement of the Deteriorated Existing Pipelines

The following issues are reviewed based on the RGC request including the pipes varying the size from 100 to 250 mm with a 6,060 m length.

- AFD investigation results conducted in 1999
- Maintenance records done by SRWSS
- Density of service connections
- Difficulties in maintenance

As a result of the review, the proposed replacement plan will follow the concept indicated in the F/S. The pipe sizes are to be designed accordingly to the proposed water demand allocation in the Project.

(2) Fire Hydrant

Regulations on fire hydrant are not available in Cambodia. However, accounting for the roles of public water supply system, 10 fire hydrants will be installed in highly populated dense area in the service area as agreed by the Siem Reap Fire Station during the field survey.

(3) Air Vent Valves

Low points along the profile, such as inverted siphon and washouts, are provided to drain the pipeline between isolation valves for repair. High points, such as a pipe bridge, are provided with air valves to remove air from the pipe during filling and to supply air into the pipe, if a sudden release of water or a water hummer effect may produce a vacuum.

(4) Pipe Bridge

As the Siem Reap River flow down from north to south in the service areas, two pipe bridges will be constructed along the national road No. 6 and river crossing point near by the down town. The pipe bridge will be independently supported from the existing road bridges which are not designed for the additional load.

(5) Pipe location marker tape

In the service areas in the Siem Reap Town, the exiting utilities such as water, individual metered connection, storm water drainage and sewerage networks, and electrical and telephone networks are installed under the ground. All pipelines to be installed should be marked with an acid and alkali resistant polyethylene detectable warning tape.

(6) Pipe Washout

After completion of the Project, the pipelines will be intermixed by new pipes to be expanded under the Project and some existing pipes. Those pipes should be inspected regularly and maintained properly. Pipe washout will be so installed at the low points of pipelines near a river, ditch, or culvert where water can be discharged that facilitates the O&M works of pipelines.

(7) Applied Formula

Pipelines will be sized using the exponential formula developed by Hazen and Williams shown below in metric unit. The designed distribution networks are shown in Figure 2.18.

① Target year :year 2008

② Design production capacity :Q=8,000 m^3/d

③ Peak factor :K=1.2

④ Design distribution capacity: q=9,600 m^3/d=400 m^3/h（Daily maximum distribution capacity）

⑤ Minimum hydraulic pressure:>150 kPa at the end of distribution pipe

⑥ Applied formula :Hazen Williams formula

$$H=10.666 \cdot C^{-1.85} \cdot D^{-4.87} \cdot Q^{1.85} \cdot L$$

Where, H: friction loss (m), C: friction coefficient, D: diameter of pipe (m), Q: rate of flow (m^3/s), L: pipe length (m)

(8) Selection of Pipe Materials

The pipe materials should be of physically and chemically safe for water supply use. At present, ductile iron pipe (DI), steel pipe, polyvinyl chloride pipe (PVC), and polyethylene pipes are normally utilized for water supply. The proposed pipe materials are summarized as shown below in consideration of technical and economical points of view dependent on the pipe sizes and pipe location.

- Raw water conveyance and clear water transmission: Those pipes to be installed along the national road No. 6 need flexibility, in jointing, durability against the traffic load, and good workmanship during construction works. DI will be employed for the pipe diameter of 250mm or larger. PVC will be also used for the pipe diameter of 200 mm or smaller in terms of cost and characteristics.

- Yard pipe in WTP — DI will be used for the pipes to be installed underground as same reason as above. Process pipes to be installed in the building will be of coating steel pipe for water service which is ease of installation in jointing in narrow space. Stainless steel pipe will be specifically used as utilities dependent on its chemical receptivity.
- Pipes for chemical use — PVC, copper tube, carbon steel pipes for pressure services will be selected accordingly to the chemicals (lime and chlorine).

(9) Distribution Block

After completion of the Project, the pipelines will be intermixed by new pipes to be expanded under the Project and some existing pipes. Those pipes should be inspected regularly and maintained properly so that Non Revenue Water can be controlled as planned in the water demand projection. The proposed pipe networks is divided into four blocks , namely Q1, Q2, Q3, and Q4 as shown in Figure 2.18. Each block is separated by isolation valves with flow meters which will contribute to monitor the distributed water amount into each block. The unaccounted for water can be computed as difference between the distributed water amount and billed mount.

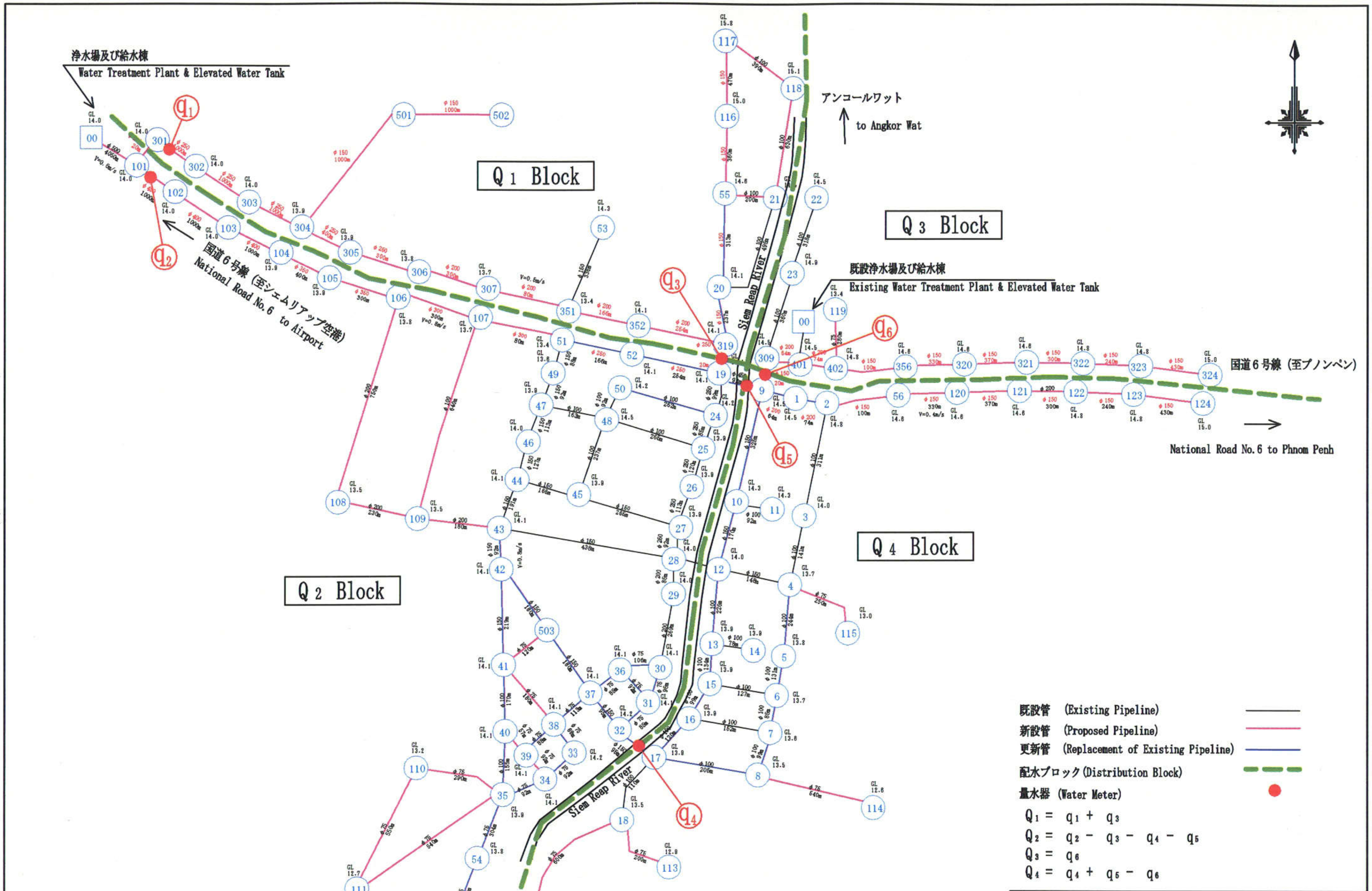
2-2-2-11Outline of the Distribution Facilities

(1) Distribution Pipelines

The designed distribution pipelines are summarized in Table 2.19.

Table 2.19 Proposed Distribution Pipelines

Requested by RGC	Proposed Plan
Newly installed pipes Diameter: 75～500 mm Length: L=17,025 m Pipe materials: 200 mm>=: DI pipe 150 mm<=: uPVC pipe	**Newly installed pipes** Transmission pipes: 500 mm, L=4,050 m Distribution pipes: 50～450 mm, L=25,843 m Total Length : L=29,893 m Pipe materials: 250 mm>=: DI pipe 200 mm<=: uPVC pipe
Service Main Diameter:75～50mm Length: L=6,200 m Pipe materials: uPVC pipe	
Replaced pipes Diameter: 100～400mm Length: L=6,310 m	**Replaced pipes** Diameter: 75～450mm Length: L=6,060 m Pipe materials: same as newly installed pipes
（Reasons to alter） ・alteration of the designed capacity depend on the reviewed water demand. ・review of the existing service main. ・evaluation of the total distribution system.	



Basic Design Study on the Project for Improvement of Water Supply System in Siem Reap Town

Figure 2.18 Proposed Distribution System

(2) Consumer Flow Meters

In order to expand water supply system as discussed in the following section in details, consumer flow meters should be installed by RGC at their own cost. The Project will procure and supply 4,000 sets of consumer flow meters with appurtenances.

Table 2.20 Procurement of Consumer Flow Meter

Requested by RGC	Proposed plan
To procure and install 4,797 sets of consumer flow meter with necessary appurtenances.	To procure and supply 4,000 consumer flow meters with necessary appurtenances. Installation shall be done by RGC.
（Reasons to alter） RGC should install the required number of consumer flow meters in accordance with the needs of customers by the target year 2008. The Project will include only procurement and supply of the consumer flow meters with appurtenances.	

2-2-2-12Equipment Procurement Plan

To facilitate operation and maintenance of the proposed water treatment facilities, expansion of distribution pipes, and installation of consumer flow meters, necessary equipment for water quality analysis and maintenance tools will be procured under the Project as shown below.

In addition, organizational strengthening of SRWSS is urgently necessary to operate the proposed water supply system sufficiently in organizationally and financially. The following office management equipment will be procured under the Project and the required training is planned and provided as the soft component described in detail in the following section to support and achieve the strengthening of the management system.

(1) Tools for Maintenance and Expansion of Service Pipes

4,000 sets of consumer flow meters will be procured under the Project and installed by Cambodian side by the target year 2008. The required numbers of consumer meters are estimated based on the number of households to be supplied.

A total required number of households = (proposed service population)/(average family member).
= 26,052/5.7
= 4,570

SRWSS supplies water over 550 households currently. Thus the proposed number of consumer meters will be 4,000 (≑4,570-550).

At present, SRWSS has no workshop with required tools which will be inevitable in installation of service pipes. Thus, the following equipment shown in Table 2.21 will be procured for SRWSS to facilitate easy operation and maintenance of the water supply system. Those equipment including lathe, boring machine, lifting equipment will be necessary for pipe works. A submersible pump will be necessary for drain for the water treatment tanks. Tools such as spanner, wrench, and chain-block will be necessary for operation and maintenance of pipe network and mechanical/electrical equipment.

In the soft component, consultant will provide a training how to install the consumer flow meters to be procured under the Project using the typical design drawings. The contractor will instruct how to operate and maintain the required O&M equipment based on their operation and maintenance manuals.

Table 2.21 O&M Equipment

Equipment	Specifications	Quantity
Consumer flow meters	13mm including accessory pipes	4,000 sets
Lathe	330mm x 160mm	1
Boring machine	Table size less than 300mm	1
Lifting equipment	1.5 tons	1
Submersible pump	50mm, 1.5kW	1
Tools	Spanner, wrench, chain block	L.S.

(2) Laboratory Equipment

A laboratory will be provided in the Administration Building, complete with the necessary water quality analysis equipment and furniture as shown in Table 2.22 to enable the determination of the main physical and chemical parameters of the water.

A chemist is proposed to assume the laboratory officer who will monitor the necessary parameters including pH, iron, manganese, turbidity, and residual chlorine on a daily basis and manages those data using computer. It is very difficult to mobilize microbiologist in Cambodia so that the chemist will simply monitor microbes as necessary using the microscope to be procured. Monthly analysis of bacteriological quality of drinking water for E. coli and coliform bacteria is proposed to be assisted by the Laboratory of PPWSA in Phnom Penh on a contract basis or the laboratory of MIME headquarters. It is also important to evaluate fully through jar tests the proper doses of lime as pH adjustment and chlorine as oxidant or disinfectant, as well as to assess periodically possible methods of improving the process of water treatment. The amount of glassware, chemicals and reagents will be procured for one year operation so that SRWSS can commence the O&M works smoothly. SRWSS should procure and refill those items after consumed at their own cost.

Table 2.22 Laboratory Equipment

Equipment	Specifications	Quantity
pH meter	portable	1
Multi purpose analyzer	iron, manganese, residual chlorine	1
Thermometer	digital	1
Turbidity meter	Desk type	1
Jar tester	6-beakers (1000L)	1
Microscope	1000 times	1
Refrigerator	180 L	1
Electrical balance	1000 g	1
Oven	150 L, 100 degree	1
Sink, table, shelf		L.S.
Glassware	Desiccator, beakers, graduated cylinder, flask, buret, pipet	L.S.
Chemicals and reagents	HCl (500 ml x 2), H2SO4 (500 ml x 2), NaOH (500 g x 2), others	L.S.

(3) Office Management Equipment

The Project plans to expand SRWSS business volume approximately five times in water supply amount and eight times in number of customer services. The current management system such as customer information management, meter readings, billing, and collection are still operated manually without any systematic way. To facilitate the strengthening of the management system in close cooperate with the soft component the following office management equipment will be procured.

System component is shown in Table 2.23, composed with server, printer and 7 clients desk top micro computers linked with LAN (Local Area Network) in the office. Major objective of each components are as follows:

i) Server

- Manage of application systems including HRM, customer management system, accounting system, E-Mail and LAN
- Manage of transaction data processed by application systems on the system

ii) Printer

- Print out water bill
- Print out other documents

iii) Client computer

- Access to the application systems such as HRM, customer management system, accounting system, e-mail and LAN
- Access to the application systems such as word, excel, etc.

iii) Uninterrupted power supply

- Supply emergency power to the system in the event of power interruption.

Table 2.23 Office Management Equipment

Equipment	Specifications	Quantity
Hardware		
Clients	Desktop PC	7
Server	Desktop PC	1
Equipment for LAN		1
HDD	36.4GB-HDD	3
Extra RAM	512MB RAM	2
Tape Drive for Server	Tape Drive	1
UPS for client		2
UPS for server		1
LAN Switch for server		1
LAN Switch for clients		1
Printer	Laser Printer	1
Software		
Software for network		7
O/S for server	Windows	7
Customer-management-package		1
Accounting package		1