Chapter 5. Water Supply Scheme

Chapter 5. Water Supply Scheme

5-1 Basic Development Concept

The basic principles for the expansion of the water supply in the Study Area will be finalized by taking into consideration the projected water demand of priority supply areas. The basic design policy will include the following:

(1) Establishment of service area

In addition to the existing service area, any extension will be finalized based on a priority analysis of the said area. Furthermore, the service area must be designed with attention given to its overall expanse; while management efficiency and economy should be the prime considerations in studying the plan of the facility to be constructed.

(2) Service level

For the existing service areas, increasing water pressure and hours of service are the main improvements needed to upgrade service levels. For those areas not yet supplied with water service, the object of the completion of a piped water supply is in serving the most number of people in the Study Area within the shortest time frame, giving due attention to the social and economic importance of the area as well as the efficiency and effectiveness of the investment. Remote areas that cannot be cost-effectively reached by the existing central distribution system (CDS) will be supplied by means of local groundwater source development.

The piped water supply system will be discussed in chapter 7, Urban Water Supply Development Plan, while groundwater source development will be discussed in chapter 8, Peri-Urban Water Supply Development Plan.

(3) Supply coverage

Water supply coverage will be the total of supply coverage by the CDS, plus areas developed with groundwater sources, determined by comparing supply capacity with the goals established by the relevant National Sector Plans and the technical and economic practicability of the proposed project.

(4) Service population

Total service population will be computed based on the final service areas, their projected populations and supply coverage over the entire Study Area.

(5) Unit consumption rate

Unit consumption rate will be determined taking into account the required improvement in service levels compared to the existing and planned water supply capacity and in relation to economic growth in the Study Area.

(6) Projection of water demand

Water demand in the selected priority areas is computed based on service population and unit consumption rate by categories of water uses; that is, domestic and non-domestic, which includes commercial, industrial, institutional, etc., with total water demand being the sum of the categories of use, fluctuation ratio of water use pattern, and NRW (non revenue water).

5-2 Service Area

In Greater Phnom Penh, the service coverage is 100 percent in the central four districts of Chamkar Mon, Doun Penh, Prampir Meakkara, and Toul Kouk. Surrounding the central four districts, in Dangkao, Mean Chey, and Ruessei Kaev, the service coverage is estimated at below 60 percent. In the province of Kandal, only the northern portions of the Ta Khmau district are supplied by the PPWSA water supply system at present.

The current water supply conditions in the Study Area differ between each district and commune. However, the master plan will be very specific about the entire population having access to a water supply system that provides safe and adequate water supply at reasonable cost by the year 2020. Such water supply system should be one that can be economically and efficiently managed.

The service area will cover the whole Study Area, namely, the entire Municipality of Phnom Penh (MPP) and part of Kandal province, as shown in the previous chapter. In its entirety, the service area will be comprised of the seven districts of Phnom Penh and five districts in the province of Kandal, as listed in Table 1.1 in the first chapter.

Priority is given based on land use planning and water supply scheme. Said analysis classifies the urgency of development and allocates to it a weighted priority. The amount of water being supplied to an area is not directly proportional to it being a priority for water development. In analyzing supply amount, water currently consumed will be evaluated. Then the weighted distribution amount will be derived. This figure considers the amount of unit consumption rate by development potential, water supply capacity, and examination of the management efficiency of the facility development plan.

5-3 Service level

There are three water supply levels, namely: Level I or point source; Level II or communal faucet system; and Level III or waterworks system with individual house connection. Generally speaking, Level I is a protected well or spring with no distribution system and currently used in the peri-urban areas of Phnom Penh. Level II, which is not applied in PPWSA service areas, is intended for rural areas where houses are clustered densely enough to justify a simple piped distribution system with public standpipes. Level III water supply service, on the other hand, is widely applied in PPWSA and refers to a pipe system with individual house connections. However, these general definitions of water supply service can also include these aspects: supply pressure, supply amount, and convenience to accessing water.

A development gap still exists in the service areas, comparing the central four districts, three surrounding districts, and Kandal Province. It would be well that this master plan focus on how to extend the central distribution system toward the farthest reaches of the service areas, which have a present population of 1.5 million and which form the hub of the country.

In the long term, for the major part of the Study Area, Levels I or II would not be a suitable level of service. A piped water supply system drawing from a surface water source would be more appropriate. Level I may be applicable for the peri-urban area water supply system.

Water supply should be on a 24-hour basis. Intermittent water supply or fluctuation of pressure causes operational problems and affects water quality.

In chapter 7, Urban Water Supply Development Plan, three ways of improving water supply services by providing a Level I or III, 24-hour water supply in the major areas of the Study Area. Likewise, peri-urban water supply systems will be discussed in chapter 8, Peri Urban Water Supply Development Plan, where Level III piped water supply systems are not applicable in terms of economic and managerial aspects. Alternative development plans will be made considering the financial (the minimum expense), economic (benefits, large and small), technological (particularly, ease of O & M and management), social, and environmental aspects, in relation to coverage and to reducing NRW, including the following possibilities:

- the reinforcement of the existing Central Distribution System (CDS);
- the possibility of extension from the existing CDS;
- the independent distribution areas whose water supply sources will be switched from groundwater to the existing or a newly developed piped water supply system; and
- the peri-urban areas whose supply sources will be dependent on available groundwater sources.

As to the existing service areas, water service will be maintained with a suitable water pressure. In the non-supplied areas, completion of a piped water supply will mean serving the most number of people within the shortest time frame giving due attention to the social and economic importance of each area as well as the efficiency and effectiveness of the investment.

5-4 Supply Coverage

5-4-1 Present Supply Coverage

The current water supply coverage by district/commune for domestic use is summarized in Table 5-1. The population supplied by direct house connection quadrupled over the last 10 years, reaching over 100,000 at the end of 2004.

Table 5-1 Present Coverage by Districts

Districts	Population in 2004	House Connection		No. of connection	
		Coverage (%)	Supplied Population	Domestic	Non-domestic*
Municipality of Phnom Penh (MPP)					
Chamkar Mon	237,822	100	237,822	22,296	3,419
Doun Penh	156,691	100	156,691	15,335	3,464
7 Meakkara	118,664	100	118,664	13,754	2,378
Toul Kouk	202,355	100	202,355	21,204	2,641
Dangkao	118,466	11.5	30,506	2,547	958
Mean Chey	233,348	55.3	128,957	15,266	1,203
Ruessei Kaev	267,546	56.0	149,793	14,004	1,487
Sub Total	**1,334,892**	**77.6%**	**1,024,788**	**104,406**	**15,550**
Kandal Province					
Kandal Stueng	16,068	0	0	0	0
Kien Svay	57,765	0	0	0	0
Angk Snuol	37,892	0	0	0	0
Ponhea Lueu	14,427	0	0	0	0
Ta Khmau	68,955	16.2	11,143	1,464	4
Sub Total	**195,107**	**5.7**	**11,143**		
Total	**1,529,999**	**67.7%**	**1,035,931**	**105,870**	**15,554**

Source: Based on the data from "Statistic Water Sold by Quarter, Billing Period、2004" of PPWSA. Non-domestic includes commercial, administration, autonomy, wholesaler, and RDE, which is categorized by PPWSA. The coverage of those districts, except for the 4 central districts of Phnom Penh, are estimated by the Study Team.

The coverage of Chamkar Mon, Doun Penh, 7 Meakkara, and Toul Kouk is considered to be 100 percent, based on the fact that no other water sources except for the PPWSA piped water supply system are available in these areas. In the surrounding areas, useful data showing the present water supply coverage is not available, so the figures shown in Table 5-1 are estimated, as analyzed in section 4.3, applying the computed average household size of 9.76.

5-4-2 Definition of Supply Coverage

Supply coverage is sometimes defined as the ratio between the supplied population and the population in a limited or defined area, or service area, where a water supply system is available at the moment. However, in the master plan, it is the ratio between the supplied population using direct house connections through a central distribution system, or equivalent system that will be expanded in the future, and the total population within the Study Area. The served population which utilizes private wells, ambulant vendors, or undetermined sources is excluded from the supply coverage. The current supply coverage data of PPWSA counts only the water supplied by the central distribution system.

5-4-3 Planned Supply Coverage

As of 2004, 67.7 percent of the total population in the Study Area had access to the central distribution system. The service area coverage included 76.8 percent in the Municipality of Phnom Penh and likely less than 10 percent in Kandal Province.

In preparing the target supply coverage, two plans, as shown in Table 5-2, are considered. The first plan reflects Cambodia Millennium Development Goals, which aim to increase urban coverage to 80 percent by 2015. The second is envisaged in the PPWSA Business Plan in conformity with the policy of the Ministry of Industry, Mines and Energy for the target year 2009.

Table 5-2 Present Supply Coverage and Plan Targets

Plans	Target Year	Planned Supply Coverage
Supply Coverage in 2004	N/A	Central Areas of Phnom Penh : 100% Municipality of Phnom Penh : 76.8% Study Area : 67.7%
SEDP II	2005	Urban Area : 87%
CMDGs	2015	Urban Area : 80%
PPWSA	2009	Municipality of Phnom Penh : 90% Kandal Province : 50%

5-4-4 Applied Supply Coverage

In targeting the year 2020, the two scenarios for the Municipality of Phnom Penh and Kandal Province are shown in proposing a useful plan which provides a realistic guideline for the expansion of water supply service in the Study Area. The proposed supply coverage by districts/communes in each five year period is illustrated in Figure 5-1 and Figure 5-2.

(1) Municipality of Phnom Penh

This scenario is set for the Municipality of Phnom Penh and complies with the CMDGs, which target an urban coverage level of 80 percent by the year 2015. Scenario 1 holds that toward the master plan target year of 2020, 100 percent coverage is substantially maintained, which is also targeted by the PPWSA Business Plan; namely 100 percent coverage by the central distribution system (CDS) will be set as a target level for the central four districts including Chamkar Mon, Doun Penh, Prampir Meakkara, and Toul Kouk of the Municipality of Phnom Penh.

The target coverage of the entire area of the Municipality of Phnom Penh will then be set at 80 percent in 2015 and 90 percent in the master plan target year 2020 by using both the central distribution system and available well water sources in the three Phnom Penh suburban districts. This is slightly less optimistic than the CMDGs and PPWSA Business Plan in the sense that it allows for the fact that the Study Area includes some rural areas (with lower coverage targets) and it also provides some additional allowance for PPWSA quality assurance.

A staged target level is then utilized as shown in Table 5-3, taking into consideration the current state of coverage, schedule of planned project implementation, and the priority of each district/commune. Mean Chey and Ruessei Kaev, located to the south and north of the four central districts of Phnom Penh, are given higher priority than Dangkao district based on the city development plan of the Bureau of Urban Affairs (BAU) of the Municipality of Phnom Penh (see above section 2-3). The Kakab and Chaom Chau communes of Dangkao District are given preferential treatment due to their important location along National Road No.4.

Table 5-3 Proposed Supply Coverage (%)

Year	2005	2010	2015	2020
Scenario 1 : Municipality of Phnom Penh (MPP)				
Phnom Penh Central 4 Districts				
♦ Chamkar Mon	100	100	100	100
♦ Doun Penh,	100	100	100	100
♦ Prampir Meakkara,	100	100	100	100
♦ Toul Kouk	100	100	100	100
Phnom Penh Suburb 3 Districts				
♦ Dangkao	25.8 (47.2)	40.0 (52.3)	50.0 (58.6)	65.0 (80.0)
♦ Mean Chey	55.3 (55.6)	70.0 (70.3)	80.0 (80.2)	90.0 (90.2)
♦ Ruessei Kaev	56.0 (59.1)	60.0 (62.4)	70.0 (71.9)	90.0 (91.6)
Average Supply Coverage for MPP	76.8 (79.4)	77.3 (79.6)	**80.3** (82.2)	88.6 (**91.9**)
Scenario 2 : Kandal Province:				
♦ Kandal Stueng	0	0	0 (92.9)	0 (80.0)
♦ Kien Svay	0	0 (66.6)	0 (76.6)	10.0 (80.1)
♦ Angk Snuol	0	10.0	20.0 (85.0)	30.0 (79.9)
♦ Ponhea Lueu	0	.0	8.3	7.9 (80.8)
♦ Ta Khmau	16.2	52.5	60.0	60.0 (80.2)
Average Supply Coverage of Kandal	5.7	20.0 (38.9)	25.0 (69.9	30.0 (**80.1**)
Coverage of the entire Study Area	67.7 (70.0)	70.1 (74.5)	73.3 (80.7)	**81.0** (**90.4**)

Notes:
1)The coverage in 2005 is assumed to be same as the present coverage in 2004.
2)Figures in ( ) show the coverage including both piped water supply of PPWSA and well water supply by MRD.

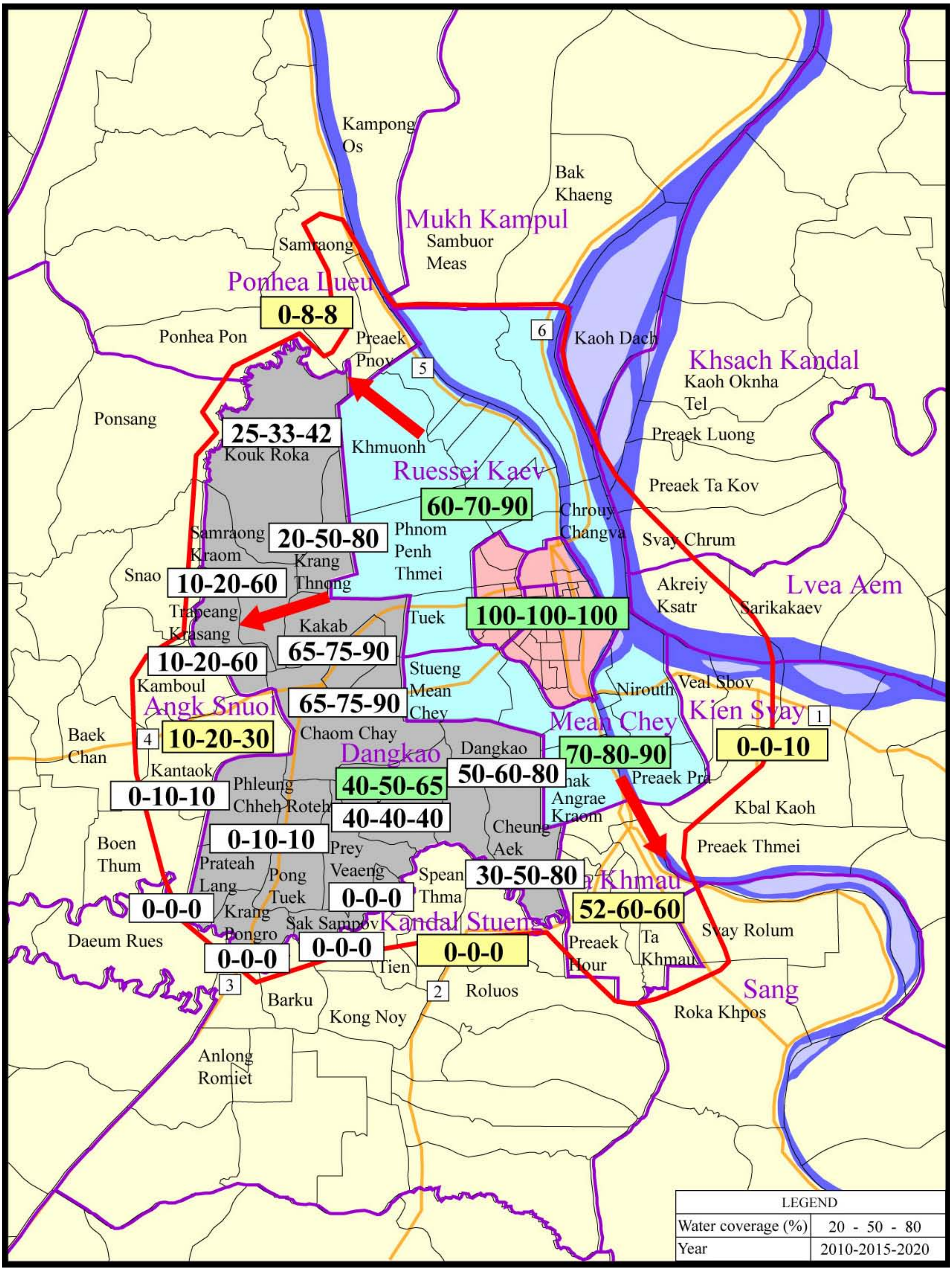


Figure 5-1 Staged Coverage Extension of the Central Distribution System (CDS)

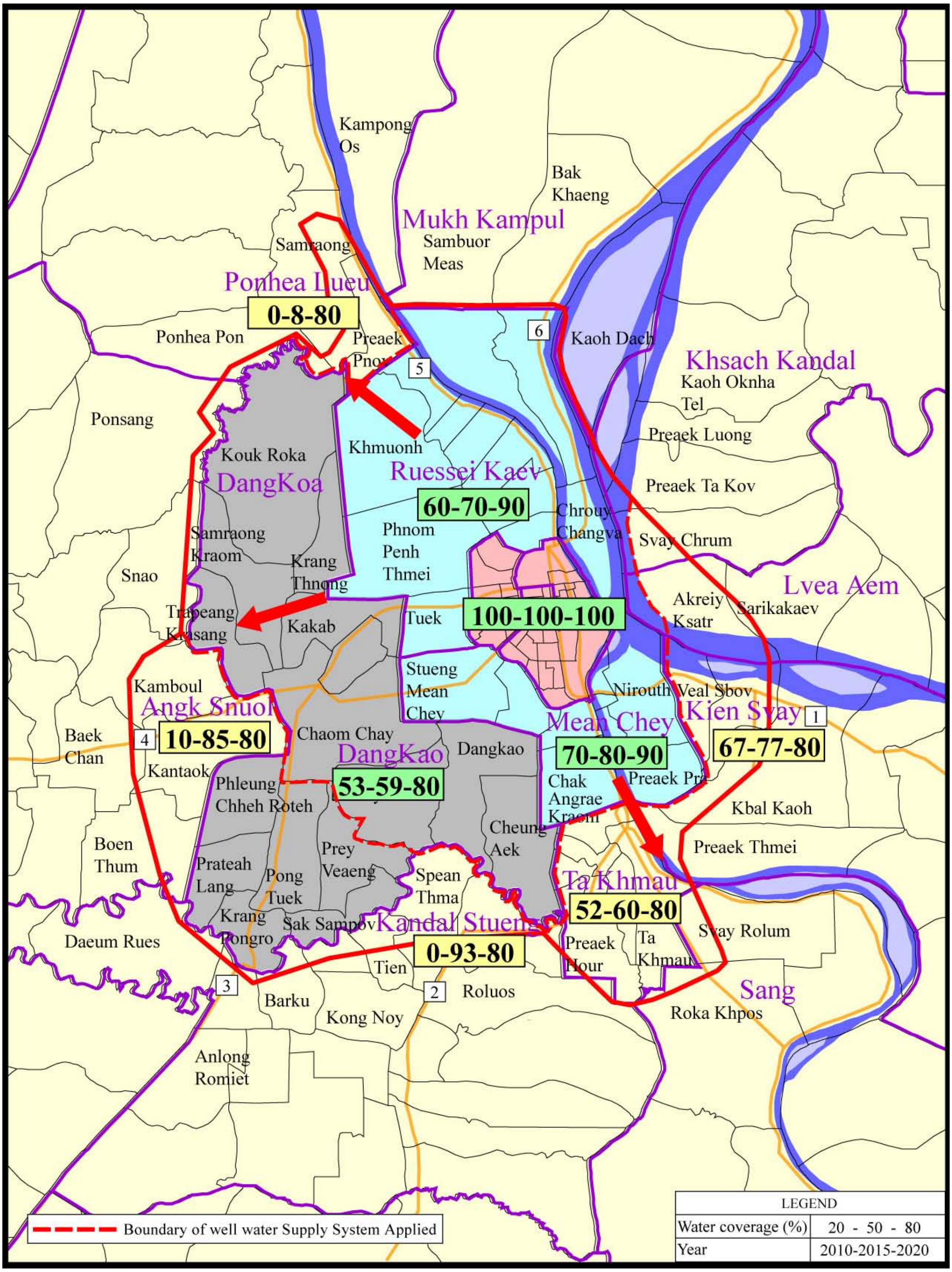


Figure 5-2 Staged Coverage Extension of the CDS plus Well Water Supply Systems

(2) Kandal Province

Scenario 2 covers Kandal Province and is based on an optimistic view of the CMDGs and PPWSA plans in respect of the implementation schedule, taking into consideration the area's importance as a part of Greater Phnom Penh. Under this scenario, coverage of 80 percent is achieved by making use of both the central distribution system and locally available groundwater source development by the master plan target year of 2020. Allocation of coverage in each year will be set in the same manner as Scenario 1, as shown in Table 5-3. The supply coverage in year 2009, which is PPWSA Business Plan target year, is proposed to be 50 percent.

Allocation of the supply coverage to each municipality/district will still be based on priority. The staged expansion of coverage (tentative) is summarized in Table 5-3.

5-5 Served Population

There are two categories of served population, namely: 1) direct house connection by CDS and 2) indirect house connection by well water. Served population by direct house connection is derived by multiplying population and coverage in each planned year. The population supplied by well water is assumed that one well covers 200 populations in the area based on the previous groundwater supply development scheme financed by the Government of Japan.

5-5-1 Served Population by the Central Distribution System (CDS)

As discussed in the previous chapter (2), a population projection was made as the basis for estimating the future water demand in the service area. The Study Team reviewed the analysis of past trends and the latest census data of 1998, as well as the present and future physical, socio-economic, and development trends identified by the BAU that affect the rate of population growth. Population projections by area are summarized in Table 5-4.

Table 5-4 Summary of Population Projection

Year	2005	2010	2015	2020
Municipality of Phnom Penh	1,334,892	1,551,479	1,776,646	2,006,009
Phnom Penh Central 4 Districts	715,532	704,810	694,088	683,360
Phnom Penh Suburb 3 Districts	619,360	846,669	1,082,558	1,322,649
Kandal Province	195,107	223,412	258,222	297,817
Study Area Total	**1,529,999**	**1,774,891**	**2,034,868**	**2,303,826**

By the target year of 2020, the population in the whole Study Area is projected to be 2.3 million, 1.5 times the current level. The total increase in population will be about 773,800, composed of 703,300 (91 percent) in the three suburban districts of Phnom Penh, 102,700 (13%) in Kandal, and a decrease of 32,100 (-4%) in the Phnom Penh central areas. Applying the proposed supply coverage to the projected population, population supplied is summarized in Table 5-6. The detailed analysis is given in the Supporting Report (SR-1) on Population Projection, taking into consideration the current state of coverage, schedule of planned project implementation, and the priority of each district/commune.

5-5-2 Population Served by Well Water

Coverage by well water will be increased from the current level of 34,650 to 216,720 for the target year, as shown in Table 5-5, which supplements the piped water supply in the remote areas to achieve the coverage goal set in the previous section.

Table 5-5 Population Served by Well Water

Year	2005	2010	2015	2020
Population	34,650	76,860	150,570	216,720

5-5-3 Total Served Population

The total population served by the CDS and groundwater sources is summarized in Table 5-6.

Table 5-6 Served Population(x 1,000)

Year	2005	2010	2015	2020
Total Population in Study Area	1,529,999	1,774,891	2,034,868	2,303,826
Population Served by Central Distribution System (CDS)				
MPP Total				
Served Population	1,024,789	1,200,056	1,426,557	1,776,757
Coverage	76.8%	77.3%	**80.3%**	88.6%
Phnom Penh Central 4 Districts (Scenario 2 is same as Scenario 1)				
Served Population	715,532	704,810	694,088	683,360
Coverage	100%	100%	100%	100%
Phnom Penh Suburban 3 Districts				
Served population	309,257	495,246	732,469	1,093,397
Coverage	49.9%	58.5%	67.7%	**82.7%**
Kandal Province				
Served Population	11,143	44,682	64,556	89,345
Coverage	5.7%	20.0%	25.0%	30.0%
Study Area Total				
Served Population	1,035,931	1,244,738	1,491,113	1,866,102
Coverage	**67.7%**	**70.1%**	**73.3%**	**81.0%**
Served Population by CDS +Well Water Supply				
Study Area Total				
Served Population	1,070,582	1,321,598	1,641,684	2,082,822
Coverage	70%	74.5%	**80.7%**	**90.4%**
MPP Total				
Served Population	1,059,439	1,234,706	1,461,208	1,844,167
Coverage	79.4%	79.6%	**82.2%**	**91.9%**
Phnom Penh Central 4 Districts	**same as Scenario 1**			
Phnom Penh Suburban 3 Districts				
Served Population	343,907	529,896	767,119	1,160,807
Coverage	55.5%	62.6%	70.9%	**88.0%**
Kandal Province				
Saved Population	11,143	86,892	180,476	238,655
Coverage	5.7%	38.9%	69.9%	**80.1**
Study Area Total				
Served Population	1,070,582	1,321,598	1,641,684	2,082,822
Coverage	**70.0%**	**74.5%**	**80.7%**	**90.4%**

5-6 NRW Reduction

Non-revenue water was a nagging problem for PPWSA before 2000. The issues and problems concerning NRW are described as follows:

- Maximum utilization of limited water sources

  It is difficult and costly to develop water sources as well as treatment and distribution systems. All efforts, including cost and time, will be wasted if NRW is a significant portion of water production.

- Improvement of financial condition

  NRW represents the loss of produced water which includes the manpower, chemical, and power costs. The increase of NRW will aggravate the financial position of the waterworks system.

- Improvement of supplied water pressure and quality as well as prevention of supplied water contamination

  Leakage will cause low and inadequate water supply. Low pressure will further contribute to the deterioration of distributed water quality due to the inflow of contaminated water from outside. This is a breach of the important aims of the public water supply body.

- Prevention of traffic accident due to road depressions caused by pipe damage

  Leaked water floods the residential areas. Pipe damage will cause a depression of road as well as traffic congestion.

Through a number of projects and programs, particularly over the past 10 years, corrective measures have been instituted aimed at reducing NRW through every effort against leakage/breakage and unauthorized use of water as well as improving metering, billing and collection efficiency. As a result, significant permanent reductions in NRW have been accomplished, as shown in Figure 5-3. As an indication of administrative and technical efficiency, the present NRW ratio (the ratio of unbilled/non-revenue water to production volume) reached a respectable 13.7 percent. The key indicators are shown below:

- Production volume 56,470,608 m^3/year
- Water sold 48,732,168 m^3/year
- NRW volume 7,738,440 m3/year
- NRW ratio 13.7 percent

Future projects shall include pipe replacement/renovation to renew old and defective distribution components, adoption of stricter quality control and quality assurance of construction activities, and research and development of new pipe materials, techniques and technologies to lengthen the useful life of distribution facilities. Past experience confirms that it is reasonable to assume that the NRW of PPWSA can be controlled below 15 percent up to the target year of 2020.

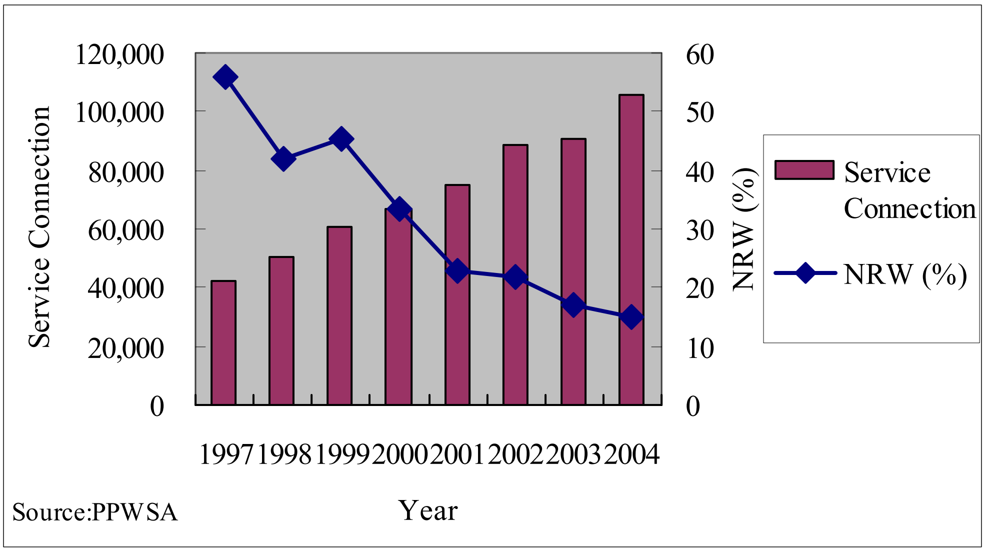


Figure 5-3 NRW Reduction from 1997 to 2004

Chapter 6. Water Demand Projection

Chapter 6. Water Demand Projection

6-1 General

The water demand projection serves as the fundamental basis for preparing the master plan. The projection is largely dependent on the past trend, that is, the future is forecast based on past experience. The water demand projection is based on the revenue water amount which is known from past water use trends. The classification of PPWSA by use is categorized into domestic, commercial, administration, autonomy, wholesaler, and RDE. The consumption for wholesaler and RDE is minimal, so this master plan will project the water demand in only two categories, namely domestic and non-domestic. In addition, the estimated NRW and the required fluctuation of distribution capacity, which is represented by a peak factor or an allowance for production capacity, will be summed up to determine the total water demand. This chapter presents the water demand projection for the CDS or piped water supply system.

Table 6-1 presents the record of total water distribution in 2004. As mentioned in the Progress Report submitted in March 2005, water production increased rapidly over the last five years to keep pace with the increase of population and extension of service area. Especially after construction of the new Chrouy Changva and Phum Prek WTPs in 2002 and 2003, respectively, water distribution shows significant fluctuation between dry and rainy seasons. The trend shows that the water consumption before Chrouy Changva and Phum Prek were constructed was depressed due to lack of water production. However, after the construction of those two WTPs the production meets the actual water demand in 2004.

Therefore, as for water demand projection for the target year 2020 in the Study Area, the analysis of present water use in terms of the unit consumption rate is useful as a measure of actual water demand in the present water supply areas, which will be applicable to the water demand projection for the other areas.

Table 6-1 Yearly Water Consumption in Each District in 2004

Districts	Chamkar Mon	Doun Penh	7 Meakkara	Tuol Kouk
Domestic	7,056,794	4,023,786	3,129,245	6,763,351
Non-domestic	3,853,059	4,791,697	1,946,202	2,799,797
Total Consumption	10,909,853	8,815,483	5,075,447	9,563,148
Districts	**Dangkao**	**Mean Chey**	**Ruessei Kaev**	**Ta Khmau**
Domestic	779,436	3,765,536	4,373,970	46,799
Non-domestic	1,553,708	1,759,129	1,709,033	16,245
Total Consumption	2,333,144	5,524,665	6,083,003	63,044

Source: The data is derived from “the Statistic Water Sold in District by Billing Period” of the Commercial Department of PPWSA. The unit is shown in m^3/year. Non-Domestic consumption does not include wholesaler and RDE.

6-2 Domestic Water Demand

6-2-1 Unit Consumption Rate

Table 6-2 presents the current unit domestic water consumption rate, based on the population projection in the previous chapter and records of individual domestic connections in 2004 derived from the data shown in Table 6-1.

Consumption in the central districts varies between approximately 70 to 90 liters/capita/day (lpcd). Toul Kouk district consumed 92 lpcd while Doun Penh district consumes only 71 lpcd (in 2004). An average unit consumption rate for the Phnom Penh central districts is 80 lpcd.

The average household size, the ratio of household to number of connections, and the average monthly consumption per connection are determined, assuming that all of the population is supplied by the piped water supply systems of PWSA without any groundwater supply in the present service area of the Phnom Penh central districts. These figures are presented in Table 6-2. The projected household sizes in the city plan vary from 5.57 to 5.73, while the computed household size for one consumer meter is calculated to be 8.63 to 10.67, with an average of 9.76, or 1.54 to 1.92 times the projected household sizes. This is attributable to the fact that customer meters are not necessarily used for one household in the central districts; rather, they are frequently shared by multiple households.

Table 6-2 Domestic Water Supply by Phnom Penh Central Districts in 2004

Districts	Chamkar Mon	Doun Penh	7 Meakkara	Tuol Kouk	Total
Population	237,822	156,691	118,664	202,355	715,532
Coverage	100%	100%	100%	100%	100%
Served Population	237,822	156,691	118,664	202,355	715,532
Yearly Water consumption (m^3)	7,056,794	4,023,786	3,129,245	6,763,351	20,973,176
Unit consumption rate (lpcd)	82	71	73	92	**80**
Nos. of connection	22,296	15,335	13,754	21,204	72,589
Computed HH size per connection	10.67	10.22	8.63	9.54	9.76
Projected HH size	5.57	5.72	5.61	5.71	5.65

Note: 100% coverage for the Phnom Penh Central 4 districts is assumed based on the actual water supply conditions that groundwater sources are not applicable in these areas. Nos. of connection is based on the registration record of the Commercial Department of PPWSA.

In the unit consumption rate projection, the following assumptions are made:

⇒ Based on past experience in Phnom Penh and from other countries, growth in per capita consumption will be modeled according to three scenarios, low, medium and high, applying respective growth rates of 1 percent, 2 percent, and 3 percent;

⇒ priority will be differentiated between high and low consumption areas as shown in Table 6-3, based on present water consumption trends in the Phnom Penh central districts; and

⇒ for the purpose of estimating present piped water supply coverage, 9.76 is taken to be the average household size for the central distribution system expansion areas, including Dangkao, Mean Chey, Ruessei Kaev, and Kandal.

Table 6-3 presents the classification of present domestic per capita consumption by each district. 80 lpcd for high consumption areas is based on the average domestic water consumption recorded in the Phnom Penh four central districts, while 70 lpcd, which is recorded as the lowest unit consumption rate among the central districts (Doun Penh), will be applied for the distribution system expansion areas.

Table 6-3 Applied Category of Per Capita Domestic Consumption

Classification	Districts	Applied present unit water consumption (lpcd)
High Consumption Area	Chamkar Mon, Doun Penh, 7 Meakkara, Tuol Kouk, Mean Chey, Ruessei Kaev	**80**
Low Consumption Area	Dangkao, Kandal	**70**

Based on the unit consumption level in 2004, unit consumption in the target year 2020 is computed at five consumption levels; namely 90, 95, 100, 110, and 130 lpcd in accordance with the applied growth rate of 1 percent, 2 percent, or 3 percent as shown in Table 6-4.

Table 6-4 Applied Scenario for Unit Consumption Rate Increase

Classification	2005	2010	2015	2020
Scenario A: 1% growth				
High consumption areas	80	85	90	95
Low consumption areas	70	80	85	90
Scenario B : 2% growth				
High consumption areas	80	90	100	110
Low consumption areas	70	80	90	100
Scenario C: 3% growth				
High consumption areas	80	95	110	130
Low consumption areas	70	80	95	110

For the projection of unit consumption increase of domestic water use, a time series trend analysis was conducted and the following trend analysis formula applied using constant annual growth rates. This method is often utilized for a developing area that is expected to grow at a relatively constant average rate for a considerable period of time.

$y = y_0(1+r)^x$ where,

y : consumption after x-year from the reference year
y_0 : consumption of the reference year
r : yearly average increase ratio (= 1%, 2%, 3%)
x : number of years after the reference year

6-2-2 Domestic Water Demand

Total domestic water demand was obtained for each scenario as shown in Table 6-5.

- Served Population
  = Projected population in each district/commune in each year x Coverage (%)

- Domestic water demand
  = ∑(Served population in each distinct/commune in each year) x unit consumption rate in each year as shown in Table 6-4.

Table 6-5 Average Daily Domestic Water Demand (m^3/d)

Year	2005	2010	2015	2020
Scenario A	82,676	103,103	130,215	171,366
Scenario B		106,627	141,141	193,444
Scenario C		110,151	152,067	218,938
Total population	1,529,999	1,774,891	2,034,868	2,303,826
Served population	1,035,931	1,244,738	1,491,113	1,866,102
Computed Unit Consumption Rate (lpcd):				
Scenario A	79.8	82.8	87.3	91.8
Scenario B		85.7	94.7	103.7
Scenario C		88.5	102.7	117.3
Coverage (%)	67.7	70.1	73.3	81

6-3 Non-Domestic Water Demand

The main non-domestic water consumption categories are commercial and administrative. The wholesaler and bulk sales categories (Others) constitute a very small portion of total consumption. The role of wholesalers will naturally decrease as the water supply system expands.

The trend of PPWSA water supply for commercial use in the year 2004 is presented in Table 6-6.

Table 6-6 Non-Domestic Water Consumption in 2004 (unit in m^3/d)

	Commercial	Administrative	Others	Total
Chamkar Mon	7,939	2,562,	55	10,556
Doun Penh	7,974	4,883	271	13,128
7 Meakkara	4,019	1,194	119	5,332
Tuol Kouk	6,427	1,234	10	7,671
Dangkao	4,025	232	**0**	4,257
Mean Chey	4,690	128	**2**	4,820
Ruessei Kaev	4,268	413	12	4,692
Kandal	**216**	**55**	**0**	271
Total	**39,377**	**10,654**	**458**	**50,490**

Source: Commercial Department of PPWSA

The assumptions underlying the projection for non-domestic water use are set out below:

⇒ the commercial, administrative, and others water uses are combined as non-domestic water consumption and their trend will continue to be the same as the current trend by district;

⇒ non-domestic water consumption will increase more rapidly than domestic consumption, so the applied growth rate will be stepped up. However, growth in administrative and autonomy water use are assumed to more or less constant at 1 percent. The growth rates for the respective scenarios are therefore as shown in the following Table 6-7.

Table 6-7 Applied Scenario for Non-Domestic Water Demand Increase

	Commercial	Administrative	Others
Scenario A	2%	1%	1%
Scenario B	3%	1%	1%
Scenario C	4%	1%	1%

⇒ In Mean Chey and Dangkao districts and Kandal province, the "others" consumption in 2004 was very minimal, 2 and 0 m^3/d, respectively. 10m^3/d will be applied using the present trend in Tuol Kouk district as a reference.

⇒ In Kandal province, non-domestic water consumption was unusually low compared to the other districts due to its underdeveloped distribution system. The commercial and administrative consumption levels are assumed to start from 1,000m^3/d and 100m^3/d in 2010, respectively.

For the projection of non-domestic water consumption, a time series trend analysis is adopted in the same manner as the domestic water demand projection in the previous section.

The projected non-domestic water demand is tabulated in Table 6-8

$y = y_0(1+r)^x$ where,
- y : Non-domestic consumption after x-year from the reference year
- y_0 : consumption of the reference year (2004)
- r : yearly average increase ratio (Table 6-7)
- x : number of years after the reference year

Table 6-8 Non-Domestic Water Demand in Daily Average Basis (unit in m^3/d)

Year	2005	2010	2015	2020
Scenario A				
Commercial	39,558	45,305	50,021	55,227
Administrative	10,700	11,400	11,982	12,593
Others	468	525	552	580
Total for Scenario A	**50,726**	**57,230**	**62,554**	**68,400**
Scenario B				
Commercial	39,558	47,976	55,618	64,476
Administrative	10,700	11,400	11,982	12,593
Others	468	525	552	580
Total for Scenario B	**50,726**	**59,901**	**68,151**	**77,649**
Scenario C				
Commercial	39,558	50,780	61,782	75,167
Administrative	10,700	11,400	11,982	12,593
Others	468	525	552	580
Total for Scenario C	**50,726**	**62,705**	**74,315**	**88,340**

6-4 Average Daily Demand

The average daily demand scenarios will be the total of domestic water and non-domestic water demand projected in the previous sections. These average daily demand projections, shown in Table 6-9, will be utilized in the financial and economic analyses in the following chapters.

Table 6-9 Average Daily Demand (m^3/d)

Year	2005	2010	2015	2020
Scenario A				
Domestic	82,676	103,103	130,215	171,366
Non-Domestic	50,726	57,230	62,554	68,400
Total for Scenario A	**133,402**	**160,334**	**192,769**	**239,766**
Scenario B				
Domestic	82,676	106,627	141,141	193,444
Non-Domestic	50,726	59,901	68,151	77,649
Total for Scenario B	**133,402**	**166,529**	**209,292**	**271,093**
Scenario C				
Domestic	82,676	110,151	152,067	218,938
Non-Domestic	50,726	62,705	74,315	88,340
Total for Scenario C	**133,402**	**172,856**	**226,382**	**307,278**

6-5 Maximum Daily Demand

6-5-1 Peak Daily Demand Factor

Table 6-10 presents the monthly water supply from the treatment plants in 2004. The monthly variation in distributed water is from a low of 134,366 m^3/d in October to a high of 182,124 m^3/d in May. The May peak was 17 percent above the annual average while the October low was 14 percent below the annual average.

Table 6-10 Monthly Water Distribution Trend in 2004

Month	Phum Prek WTP (m^3)	Chrouy Changva WTP (m^3)	Chamkar Mon WTP (m^3)	Total Distribution (m^3)	Daily Average (m^3/d)	Monthly Variation (%)
Jan.	3,249,510	891,128	295,966	4,436,604	143,116	-8
Feb.	3,271,990	723,759	275,311	4,271,060	147,278	-5
Mar.	4,203,880	822,319	296,305	5,322,504	171,694	+10
Apr.	4,080,250	1,089,235	94,142	5,263,627	175,454	+13
May	4,164,200	1,106,895	374,735	5,645,830	182,124	+17
Jun.	3,685,736	569,715	592,437	4,847,888	161,596	+4
Jul.	3,588,605	613,926	514,449	4,716,980	152,161	-2
Aug.	4,025,800	342,746	303,389	4,671,935	150,708	-3
Sept.	3,691,180	314,882	293,609	4,299,671	143,322	-8
Oct.	3,543,080	321,884	300,368	4,165,332	134,366	-14
Nov.	3,856,800	322,740	296,282	4,475,822	149,194	-4
Dec.	3,884,450	491,052	282,590	4,658,092	150,261	+3
Total	45,245,481	7,610,281	3,919,583	56,775,345	**155,549**	N/A

Source: Production & Distribution Department of PPWSA

Maximum daily demand factor varies from 0.97 to 1.24, with the average at 1.07. Therefore, 1.3, the maximum rounded number in 2004, will be applied for the maximum daily demand factor to cope with unforeseen circumstances. Recorded loading ratio is 1/1.24=80% and design loading ratio will be 1/1.3= 77%.

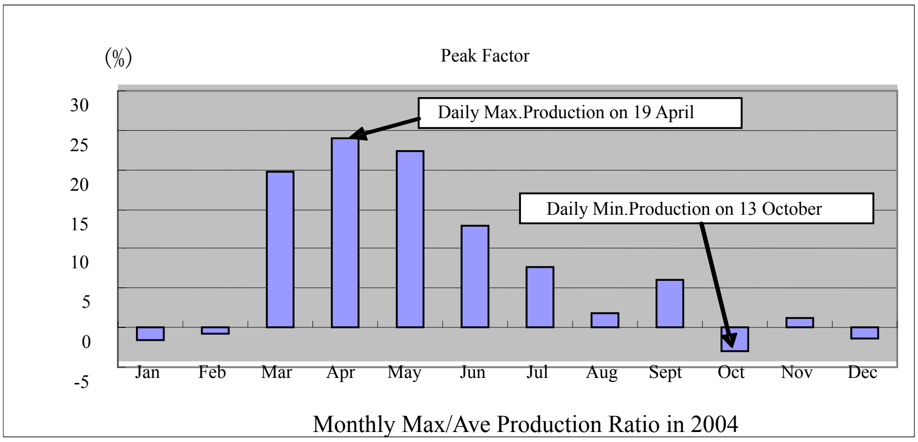


Figure 6-1　Peak Daily Demand Factor

The maximum daily water production in 2004 was 192,951 m^3/d, reached on 19 April during the dry season. The daily minimum was 91,758 m^3/d, on 13 October 2004. The maximum daily demand factor or peak factor, which is the ratio between the daily maximum and average water production, is 1.24, as shown in Figure 6-1and Table 6-11.

Table 6-11　Daily Max/Min Production of Each WTP in 2004

Descriptions	Phum Prek WTP	Chrouy Changva WTP	Chamkar Mon WTP	Total
Year Total (m^3/year)	45,245,481	7,610,281	3,919,583	56,775,345
Daily Max. (m^3/d)	147,420	42,768	20,311	192,951
Daily Ave. (m^3/d)	123,606	20,798	10,702	155,549
Daily Min. (m^3/d)	69,690	5,469	0	91,758
Nominal Cap. (m^3/d)	150,000	65,000	20,000	235,000
Max/Ave ratio =	1.19	2.06	1.90	**1.24**

Source: Production & Distribution Department of PPWSA

6-5-2　NRW Ratio

An NRW ratio of 15 percent will be added to the average daily demand, to be applied to the calculation of maximum water demand, in order to secure the adequate production capacity of the WTPs.

6-5-3　Maximum Daily Demand

Summarizing the above study, the three scenarios by water use increase rate for domestic and non-domestic water uses are summarized in Table 6-12. A 1.3 peak factor and 15 percent NRW ratio are applied to the peak daily demand for combined domestic and non-domestic water use.

Table 6-12 provides a total water demand projection broken into five year periods for the 15 years up to the target year 2020.

The projected figure shows the estimated water demand in each scenario in the target year 2020 ranging from 367,000 m^3/d to 469,995 m^3/d, or from 1.8 times to 2.3 times the present water use in 2004.

Table 6-12 Total Water Demand by Scenario (m^3/d)

Year	2005	2010	2015	2020
Scenario A				
Ave. Daily Demand	**133,402**	**160,334**	**192,769**	**239,766**
UCR for Total use	**129**	**129**	**129**	**129**
UCR for Domestic use	**80**	**83**	**87**	**91**
Peak Factor	1.3	1.3	1.3	1.3
Peak Daily Demand	**173,423**	**208,434**	**250,600**	**311,695**
UCR for Total use	167	161	168	167
UCR for Domestic use	104	108	113	119
Peak Day Demand	173,423	208,434	250,600	311,695
NRW	15%	15%	15%	15%
Max. Daily Demand	**204,027**	**245,216**	**294,823**	**366,700**
UCR for Total use	**197**	**189**	**197**	**196**
UCR for Domestic use	**122**	**97**	**102**	**108**
Scenario B				
Ave. Daily Demand	**133,402**	**166,529**	**209,292**	**271,093**
UCR for Total use	**129**	**134**	**140**	**145**
UCR for Domestic use	**80**	**86**	**95**	**104**
Peak Factor	1.3	1.3	1.3	1.3
Peak Daily Demand	**173,423**	**216,487**	**272,080**	**352,420**
UCR for Total use	167	174	182	189
UCR for Domestic use	104	111	123	135
NRW	15%	15%	15%	15%
Max. Daily Demand	**204,027**	**254,691**	**320,094**	**414,612**
UCR for Total use	**197**	**204**	**214**	**222**
UCR for Domestic use	**122**	**131**	**144**	**158**
Scenario C				
Ave. Daily Demand	**133,402**	**172,856**	**226,382**	**307,278**
UCR for Total use	**129**	**139**	**152**	**165**
UCR for Domestic use	**80**	**85**	**102**	**117**
Peak Factor	1.3	1.3	1.3	1.3
Peak Daily Demand	**173,423**	**224,713**	**294,297**	**399,461**
UCR for Total use	167	180	197	214
UCR for Domestic use	104	115	133	152
NRW	15%	15%	15%	15%
Max. Daily Demand	**204,027**	**264,369**	**346,231**	**469,955**
UCR for Total use	**197**	**212**	**232**	**251**
UCR for Domestic use	**122**	**135**	**156**	**179**

UCR: Unit Consumption Rate (lpcd)

Towards the target year 2020, the average unit domestic water consumption rate is projected to increase from the present 80 lpcd to 91 lpcd, 104 lpcd, and 117 lpcd for scenarios A, B, and C, respectively. The peak domestic unit consumption rate increase after application of 1.3 peak factor will be to 120 lpcd, 135 lpcd, and 152 lpcd, respectively, for each scenario. The combined total for domestic and non-domestic water demand with peak factor applied is projected to be 167 lpcd, 189 lpcd, and 214 lpcd. On the basis of maximum domestic water demand, the projected domestic water demand will increase to 108 lpcd, 158 lpcd, and 179 lpcd in each scenario. The total water demand on a per capita basis is projected between 196 lpcd to 251 lpcd.

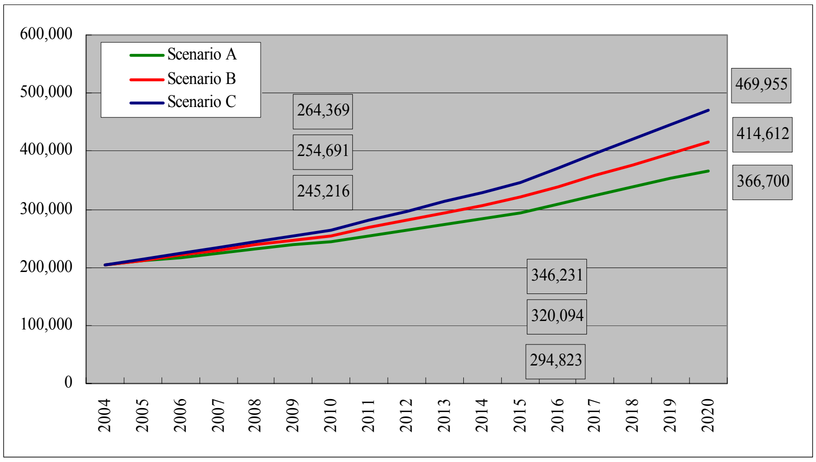


Figure 6-2 Maximum Daily Demand Increase by Scenario

6-6 Water Supply Basic Indicators

6-6-1 Proposed Water Supply Development Indicators

In general, there has been considerable debate over the amount of water people need for domestic purposes and the amount that they actually use. It has often been stated that it depends on the life style of the region; namely, people in hot countries may need to bathe several times in a day, which is not necessarily wasting water. It also often happens that people manage with less water when it is in short supply. However, at 80 lpcd, consumers in Phnom Penh appear to use water relatively efficiently, even though the present water supply capacity could support higher consumption.

With reference to water demand in other Asian countries, 80 lpcd is about the same consumption level as in Jakarta, Indonesia, whose GDP is almost double that of Cambodia. The projected unit domestic water demand for scenario B in 2020 is 135 lpcd for domestic water use, which will exceed the present levels of Manila, Philippines and Kuala Lumpur, Malaysia whose GDPs are respectively 3 times and 10 times higher than Cambodia's. In scenario A, the projected unit consumption rate, 119 lpcd, may not provide sufficient flexibility.

Cities in Asian Countries	Population	Served Population	Domestic Water use (m^3/d)	UCR (lpcd)
• Ho Chi Minh City	2,749,941	2,304,458	850,737	167
• *PPWSA (Scenario C)*	*2,303,826*	*2,006,009*	*399,461*	*152*
• *PPWSA (Scenario B)*	*2,303,826*	*2,006,009*	*352,420*	*135*
• Kuala Lumpur	1,420,000	1,420,000	627,273	132
• Manila	12,660,788	7,312,408	4,084,932	127
• *PPWSA (Scenario A)*	*2,303,826*	*2,006,009*	*311,695*	*119*
• Colombo	642,163	594,492	285,255	115
• Vientiane	616,221	387,098	105,748	109
• Jakarta	9,695,600	4,954,440	1,320,325	77

Source: "Water in Asian Cities", ADB. Data is for 2001 or 2001/2002 fiscal year for each county.

In conclusion, scenario B is the most practical recommendation for the master plan as it fulfills the national sector plans in general. The following analysis regarding the development plan will be based on the conditions assumed in scenario B. Thus, the daily average water demand will increase from 133,402 m3/d in 2004 to 271,093 m3/d in 2020, and the daily maximum will increase from 204,027 m3/d in 2004 to 414,612 m3/d. Supply coverage of 67.7 percent in 2004 will become 81 percent in 2020; while the NRW ratio will be maintained, with PPWSA's continued efforts, at (or below) the current level of 15 percent through the target year 2020.

Table 6-13 Proposed Water Supply Basic Indicators (m^3/d) by Systems

Year	2005	2010	2015	2020
CDS Systems				
Daily Ave. per capita water demand(lpcd)	80	86	95	104
Peak factor	1.3	1.3	1.3	1.3
Peak Day per capita water demand	104	111	123	135
NRW	15%	15%	15%	15%
Daily Max. per capita demand (lpcd)	122	131	144	158
Total population	1,529,999	1,774,891	2,034,868	2,303,826
Served population	1,035,931	1,244,738	1,491,113	1,866,102
Coverage (%)	67.7	70.1	73.3	81.0
Daily Ave. water demand (m^3/d)	133,402	166,529	209,292	271093
Daily Max. water demand (m^3/d)	204,027	254,691	320,094	414,612
Nos. of served households	105,870	136,540	180,736	247,712
No. of non-domestic connections	15,517	18,729	21,640	25,011
Total No. of connections	121,387	155,269	202,376	272,723
CDS + Well Water Systems				
Total population	1,529,999	1,774,891	2,034,868	2,303,826
Served population	1,070,582	1,321,598	1,641,684	2,082,822
Coverage (%)	70.0	74.5	80.7	90.4
Well Water Systems				
Served population	34,650	76,860	150,570	216,720
Unit covering population per well	210	210	210	210
Nos. of wells required	165	366	717	1,032
Unit water consumption per capita (lpcd)	40	40	40	40
Well water supply amount (m^3/d)	1,386	3,075	6,023	8,668

6-6-2 Water Demand and Production

The required production capacity at each stage up to 2020 is illustrated in Figure 6-3 in accordance with the daily maximum water demand. The present production capacity of

235,000 m^3/d can cope with the water demand increase through 2007. With implementation of the project to expand the capacity of the Chrouy Changva WTP by 65,000 m^3/d (bringing total production capacity to 300,000 m^3/d), the maximum water demand during Stage I and through the year 2013 of Stage II can be met. After 2013, a second project for construction of a new water treatment plant with a production capacity of 100,000 m^3/d will be necessary to satisfy the further increased water demand during the latter part of Stage II and beyond. Total production capacity during Stage II will reach 400,000 m^3/d, which will meet demand to 2019 in Stage III. The incremental addition of production capacity in Stage II is recommended to be 100,000 m^3/d in order to ensure that it will cover at least the next five years of growth. In addition, it is a suitable size to develop as a project, considering efficient project preparation and physical issues such as extension of related transmission and distribution network. A third augmentation project will be required in 2019, toward the end of Stage III, to fulfill the expected water demand in 2020 and beyond.

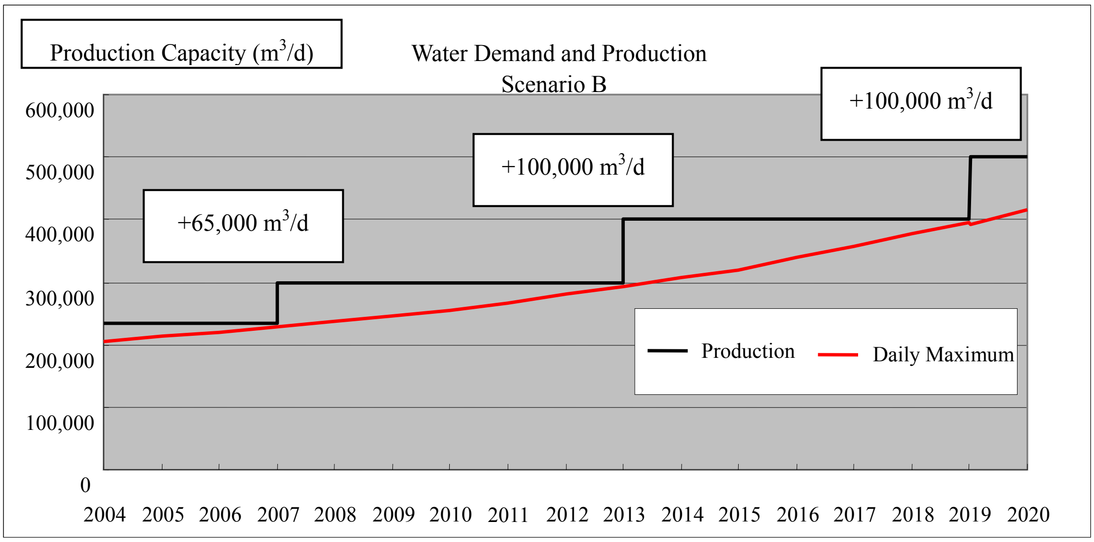


Figure 6-3 Water Demand and Production Capacity

Chapter 7. Urban Water Supply Development Plan

Chapter 7. Urban Water Supply Development Plan

7-1 Water Supply Development Policy for Year 2020

PPWSA stated its "Strategic Focus and Plan" in the *Business Plan for 2005-2009* as follows:

Mission: To continuously and adequately satisfy the needs of the residents of Phnom Penh to have 24-hour per day access to clean water and to expand its coverage to the peri-urban areas bordering Phnom Penh City.
Goal for the five-years from 2005 to 2009: 1) To continue the 'expansion of its customer base' to include residents of peri-urban areas 2) To balance the average tariff by obtaining more industrial and commercial customers; and 3) To continue to 'provide service to the poorest of communities and households'
Core Competency: To develop sufficient capacity to continuously provide optimum service to its customers in terms of water quality that conforms to the National Drinking Water Standard, and adequacy of water supply (24 hours/day) to meet the seasonal demand.

Also, they examined the internal and external factors in the SWOT Analysis as follows (mainly technical part);

Internal Factors	Strengths	Weaknesses
Production and Water Demand	Appropriate and manageable	Skill for O&M still limited
Distribution System	New and Manageable	Database management
Water Loss Control Program	Right policies	New technology (data monitoring system, telemetry) is in beginning stage
External Factors	**Opportunities**	**Threats**
Electricity	Supply 24 hours a day	Depend on sole supplier (EDC)
Water Resources	Adequate supply capacity	Pollution around intake

The water supply development plan targeting the year 2020 is established in this chapter following the above PPWSA's strategy and the water demand projection described in chapter 4 (Water Demand Projection).

Through the Business Plan, it is understood that three key objectives are the most important for water supply service: 1) 24-hour/day water supply with adequate quantity; 2) proper water quality; and 3) expansion of service population/area.

Water supply facilities can be categorized into water production facilities, consisting of intakes and treatment plants, and water distribution facilities, such as service reservoir, pump station and distribution pipe network. This chapter reviews alternatives in these two categories and then proposes the development plan based on the following development policies.

Table 7-1 Development Policies

Objectives	Water Production Facility
1) Stable Water Supply (24-hour/day Supply)	a. Secure water source (Mekong River/Tonle Sap) b. Adequate production capacity (intake/treatment plant) c. Establish proper O&M system and minimize cost
2) Safe/Clean Water (Drinking Water Standard)	a. Protect raw water quality b. Apply proper treatment system c. Apply regular maintenance/replacement of network d. Establish monitoring and control system
3) Expanding Services (Service Population)	a. Make proper allowance for production capacity
Objectives	**Water Distribution Facility**
1) Stable Water Supply (24-hour/day Supply)	a. Adequate distribution capacity (pump/pipe) b. Control NRW c. Establish proper O&M system and minimize cost
2) Safe/Clean Water (Drinking Water Standard)	a. Protect clear water quality (rechlorination) b. Apply regular maintenance/replacement of network c. Establish monitoring and control system
3) Expanding Services (Service Population)	a. Apply network for easy expansion

Among the above development policies, the most important are 1) water source (quality of raw water), 2) production capacity (capacity of the existing and new water treatment plants) and 3) O&M (cost). These should be carefully considered in the water supply development plan.

In order to secure the water source, selection is the key. Fortunately, Phnom Penh has abundant water resources in its three major rivers. In addition to quantity, quality must be considered. Water quality varies with each river and different locations on the same river. Future water quality and risks of contamination need also to be examined. Multiple water sources are sometimes preferable to hedge the risk of accidental contamination of raw water or main pipeline burst, etc.

A stable water supply cannot be secured without providing adequate production capacity to meet increased water demand in the future. New plants have to be constructed in a timely fashion, based on accurate water demand projections and observed actual patterns of water consumption.

Proper O&M system/organization shall be established to keep all water supply facilities in good condition. Regular maintenance, applying preventive maintenance concepts, and rehabilitation of existing facilities, will help to minimize total O&M cost. Existing plants need to be well maintained to keep their original production capacity. At the same time, replacement or rehabilitation shall be periodically implemented on mechanical and electrical equipment in water treatment plants and pumping stations according to the appropriate schedule, such as every decade.

7-1-1 Existing Water Production Facility

The water production requirement for year 2020 is 500,000 m^3/d. The existing facilities, with a total capacity of 235,000 m^3/d, are described below.

The existing water treatment plants are outlined as follows. The details are summarized in the Support Report "Review of Water Supply Systems in the Study Area."

1) **Phum Prek Water Treatment Plant** was constructed in two stages. The old plant, with production capacity of 100,000 m^3/day, was constructed in 1965 and rehabilitated in 1988 and in 1995. New treatment facilities with additional production capacity of 50,000 m^3/day were constructed in 2003. Raw water is taken from the Tonle Sap near the Phnom Penh Port.

   During dry seasons, raw water is slightly poorer. Smell and algae, which are removed by pre-chlorination, can be detected.

2) **Chamkar Mon Water Treatment Plant** was also constructed in two stages. The old plant, with a production capacity of 10,000 m^3/day, was constructed in 1957 and rehabilitated in 1988. Additional treatment facilities were constructed in 1995 raising production capacity to 20,000 m^3/day.

   The raw water intake pump station is located near the Thai Embassy along the Tonle Basak.

   The Chamkar Mon Plant follows a modular water treatment process that is more complicated to operate and maintain the quality of treated water. Eight (8) small filters require laborious daily washing. Operators are facing difficulties with proper operation and good maintenance.

3) **Chrouy Changva Water Treatment Plant** was constructed in 2002 with a production capacity of 65,000 m^3/day. Land is available for future expansion of capacity by another 65,000 m^3/day.

   The intake pump station is located just in front of the plant along the Mekong River.

   This plant has better raw water quality than the others, but it has some difficulties due to algae growth in the sedimentation tanks because of exposure to sunlight.

The table below summarizes the existing production capacity and the requirement in 2020.

Table 7-2 Water Production Capacity

Water Production	Capacity (m^3/d)	Year Constructed
Water Production in 2020	500,000	-
Existing Water Treatment Plant		
- Phum Prek	150,000	1965 (1995), 2003
- Chamkar Mon	20,000	1957 (1988), 1995
- Chrouy Changva	65,000	2002
Sub-Total	235,000	-
Necessary Production Increase	265,000	-

Note: (year) indicates the year of rehabilitation.

Therefore, the necessary additional water production capacity will be 265,000 m^3/day.

7-2 Water Production Development Plan Alternatives

7-2-1 Required Intake/Treatment Facility

Additional production capacity of 265,000 m^3/day should be added by 2020.

PPWSA has a plan to expand the Chrouy Changva Water Treatment Plant within a couple of years, adding 65,000 m^3/day to make a total capacity of 130,000 m^3/day. This expansion of Chrouy Changva Water Treatment Plant will be the first project. A new treatment plant with two-stage construction will follow, as shown below.

Table 7-3 Water Treatment Plant Development

Plant	Capacity (m^3/d)	Year
Chrouy Changva - Stage II	65,000	2007
New Plant - Stage I	100,000	2013
New Plant - Stage II	100,000	2019
Production Increase	265,000	-

The capacity of the new treatment plant is large. Only surface water can serve as the water source. The three existing plants use three different water sources, namely Mekong River, Tonle Sap and Tonle Basak. The Mekong River and Tonle Sap are considered as water sources for the new water treatment plant due to their larger water flow and good water quality.

7-2-2 Water Production Alternatives

The examination of water production alternatives covers two main aspects, water source and water treatment plant site.

As for water source, the Tonle Basak cannot be an alternative because of low flow and more contamination compared with the Tonle Sap and the Mekong River. The location of the water treatment plant should be close to the water source (intake station) and the area where water is consumed. Three alternatives for new intake station and water treatment plant are therefore established as follows.

Table 7-4 WTP Site Alternatives

Item	Alternative – A (Svay Pak)	Alternative – B (Chrouy Changva)	Alternative – C (Nirouth)
Location	Svay Pak	Chrouy Changva	Nirouth
Water Source	Tonle Sap	Mekong River	Mekong River

The locations of the alternatives are shown in Figure 7.1.

The water supply system of the three alternatives is illustrated in Figures 7.2.

The following table shows items to be considered for the planning of the new intake station and water treatment plant. Also the items can be used for evaluation of the alternatives.

Table 7-5 Alternative Evaluation Items

Facility	Intake Station	Treatment Plant
Evaluation Item	**Location (multiple sources)** Quantity of raw water Quality of raw water Difficulty of construction Operation & maintenance cost Silting **Future contamination of water** Construction Cost Social and environmental impact	**Location** Accessibility from main road Distance from intake station **Construction Cost** Distance to network (river crossing etc.) **Operation cost – power consumption** **Operation cost – chemical consumption** Land availability (flooding, residence etc.) Social and environmental impact

Some of the evaluation criteria overlay, but the bold typed items are most important and are carefully evaluated in the following sections.

Location is the most important criteria in alternatives evaluation. Location of water source/intake and treatment plant shall be close, and the location is advantageous if the location is closes to the existing and future distribution network.

As for the water source, the raw water quality is the most important aspect, not only at present but also in the future.

Construction and operation costs are the major concerns to evaluate the treatment plant alternatives.

Social and environmental consideration was carried out as shown in the following chapter.

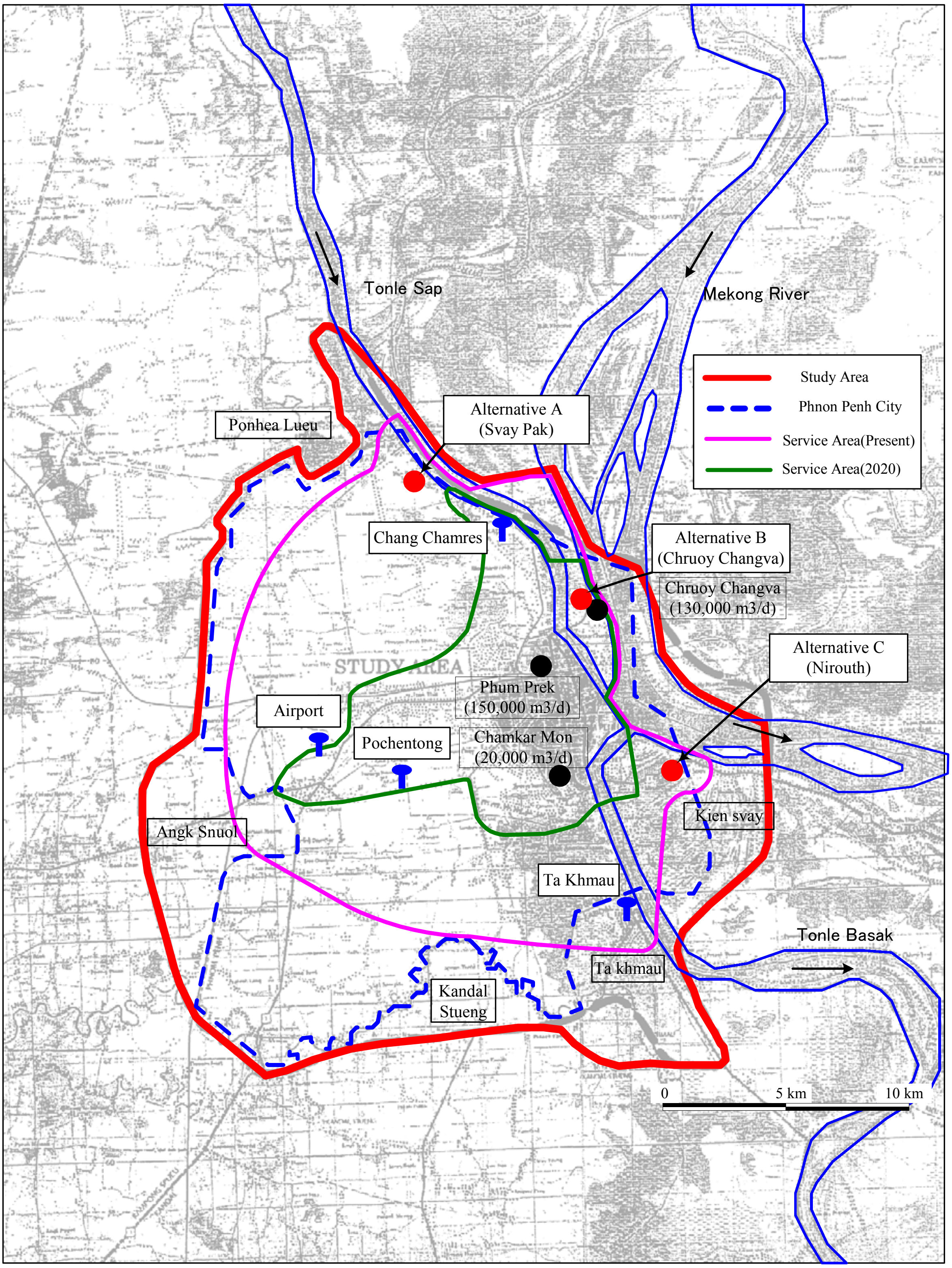
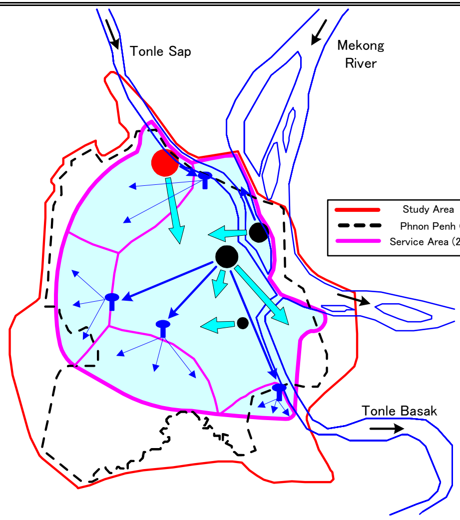
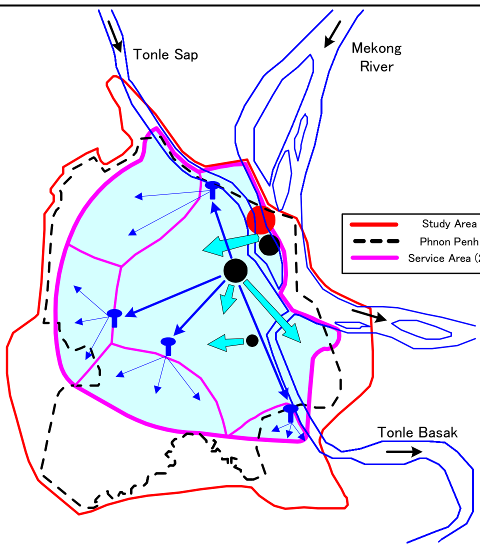
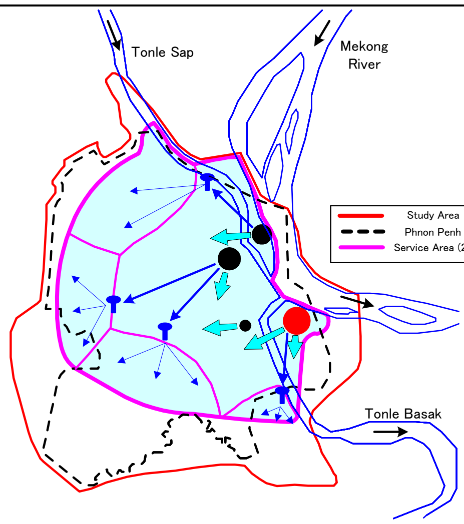


Figure 7-1 Intake/Water Treatment Plant Location Alternatives

<table>
<tr><th>Location</th><th>Facilities</th></tr>
<tr><td>
</td><td>Alternative – A

Water Source: Tonle Sap
Water Treatment Plant:
Phum Prek 150,000 m^3/d
Chrouy Changva - 1 65,000 m^3/d
Chrouy Changva - 2 65,000 m^3/d
Chamkar Mon 20,000 m^3/d
Svay Pak 200,000 m^3/d
Water Distribution:
Phnom Penh Center
Chang Chamres
Airport
Pochentong
Ta Khmau</td></tr>
<tr><td>
</td><td>Alternative – B

Water Source: Mekong River - Upstream
Water Treatment Plant:
Phum Prek 150,000 m^3/d
Chrouy Changva - 1 65,000 m^3/d
Chrouy Changva - 2 65,000 m^{3}d/
Chamkar Mon 20,000 m^3/d
Chrouy Changva - 3 200,000 m^3/d
Water Distribution:
Phnom Penh Center
Chang Chamres
Airport
Pochentong
Ta Khmau</td></tr>
<tr><td>
</td><td>Alternative – C

Water Source: Mekong River - Downstream
Water Treatment Plant:
Phum Prek 150,000 m^3/d
Chrouy Changva - 1 65,000 m^3/d
Chrouy Changva - 2 65,000 m^3/d
Chamkar Mon 20,000 m^3/d
Nirouth 200,000 m^3/d
Water Distribution:
Phnom Penh Center
Chang Chamres
Airport
Pochentong
Ta Khmau</td></tr>
</table>

Figure 7-2 Location/Features of Alternatives

7-2-3 Evaluation of Water Production Alternatives

7-2-3-1 Water Source and Intake Station

The following table summarizes the evaluation of three water sources and intake stations. The major concern in the evaluation is multiple water sources and present and future raw water quality. Three water sources, namely the Mekong River, Tonle Sap and Tonle Basak can be considered. However, the Tonle Basak is not recommended as a future water source due to limited water flow and low water quality. Therefore, the following three alternatives are set for evaluation.

Table 7-6 Comparison of Water Source/Intake Station

Item	**Alternative – A (Svay Pak)**	**Alternative – B (Chrouy Changva)**	**Alternative – C (Nirouth)**
Location	**Tonle Sap** - 2 (Mekong - Up)	**Mekong** - Up -2 (Tonle Sap)	**Mekong** - Down (Tonle Sap) (Mekong - Up)
Quantity of raw water	Fair	Good	Good
Quality of raw water	Fair	Good	Good
Difficulty of construction	Fair	Fair	Fair
Operation & maintenance cost	Fair	Fair	Fair
Silting	Fair	Fair	Fair
Rapid change of quality	Many	Less	Less
Future contamination of water	High	Low	Low
Social & environmental impact	High	Medium	Low

High and medium social and environmental impact of Alternatives B and C is attributed mainly to requirement for resettlement. Resettlement costs are included in construction cost estimate as Government’s administration expense.

In light of both quantity and quality, the Mekong River is the best option for the future water source. Therefore Alternatives B and C are recommended in terms of water source.

As for variety of water sources, Alternative C has the advantage because it will have three different water sources, namely Tonle Sap (Phum Prek), Mekong River Upstream (Chrouy Changva) and Mekong River Downstream (Nirouth).

Detailed examination on the current and future water quality is as follows.

River water quality observed from the existing plants shows that the pH level of raw water from the Mekong River (for Chrouy Changva), at 8.0, is significantly higher than that of the other two rivers (Tonle Sap, for Phum Prek and Tonle Basak, for Chamkar Mon), at about 7.0. During the rainy season, the three rivers have similar pH due to mixing of the water.

The three sources also have similar turbidity characteristics during the rainy season. However, there is a significant difference in turbidity between the dry season and the rainy season. Turbidity of raw water varies between each plant due to different water sources. Turbidity for each plant in 2004 is summarized in the following table. One significant phenomenon at Phum

Prek Plant is rapid turbidity change between morning and afternoon of the same day due to flow change in the Tonle Sap during the transition between dry and rainy seasons. At these times it is hard for operators to administer the proper chemical dosage.

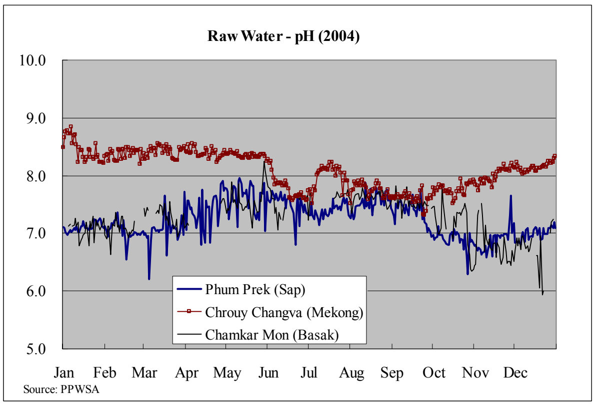


Figure 7-3 pH in Rivers

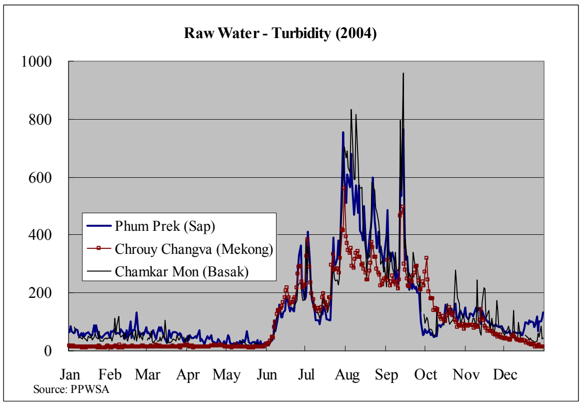


Figure 7-4 Turbidity in Rivers

During the dry season, from November to June, turbidity levels average about NTU 56. During the rainy season, from July to October, the average (in 2004) rose to NTU 281. Turbidity and pH at three raw water sources in 2004 are shown in the table below and the figures above. This pattern recurs every year.

Table 7-7 Turbidity in 2004

Plant	River	Maximum	Average	Median	Minimum
Phum Prek	Sap	766	141	80.0	13.0
Chamkar Mon	Basak	960	153	76.3	15.0
Chrouy Changva	Mekong	562	108	42.8	9.8

Since population and human activities in Phnom Penh have increased significantly over the past decade, some water contamination can be expected in this area. BOD and COD levels in the three rivers recorded by the Ministry of Environment for the last 2.5 years are shown in the following figures:

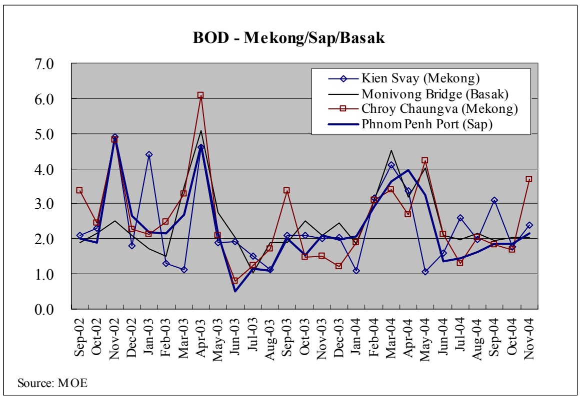


Figure 7-5 BOD in Rivers

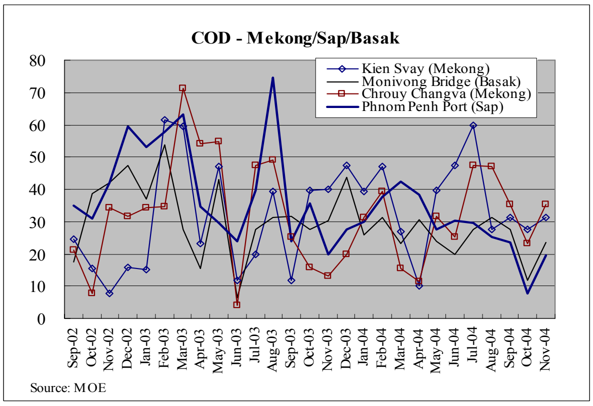


Figure 7-6 COD in Rivers

Differences in BOD levels among the water sources are more significant during the dry seasons than during the rainy seasons at all sampling points. BOD rises 4 to 5 mg/l during the dry season and it drops 1 to 2 mg/l during the wet season. BOD of 4 to 5 mg/l are near the upper limit of acceptability for water sources to be used for water supply. The Phum Prek Water Treatment Plant suffers algae growth at sedimentation tanks and filters in the dry season due to the deterioration of raw water quality.

The following figure summarizes BOD and COD at seven sampling points on the rivers.

The Mekong River shows the better quality based on BOD and COD compared with the other two rivers. This finding clearly indicates some contamination by the population and its activities in Phnom Penh. It also requires conserving the existing water sources from contamination by human activities.

Sewage from the northern part of the city discharges into the Tonle Sap; and from the southern part to the Tonle Basak. The future increase of the water supply will be reflected in greater sewage discharge to both the Tonle Sap and Basak. Sewage flows of 50,000 m^3/d with BOD of 57 mg/l will be discharged to the Tonle Sap at Svay Pak, and flows of 140,000 m^3/d with BOD of 72 mg/l will be discharged to the Tonle Basak (refer to chapter 9, Review of Drainage, Sewerage and Sanitation Systems).

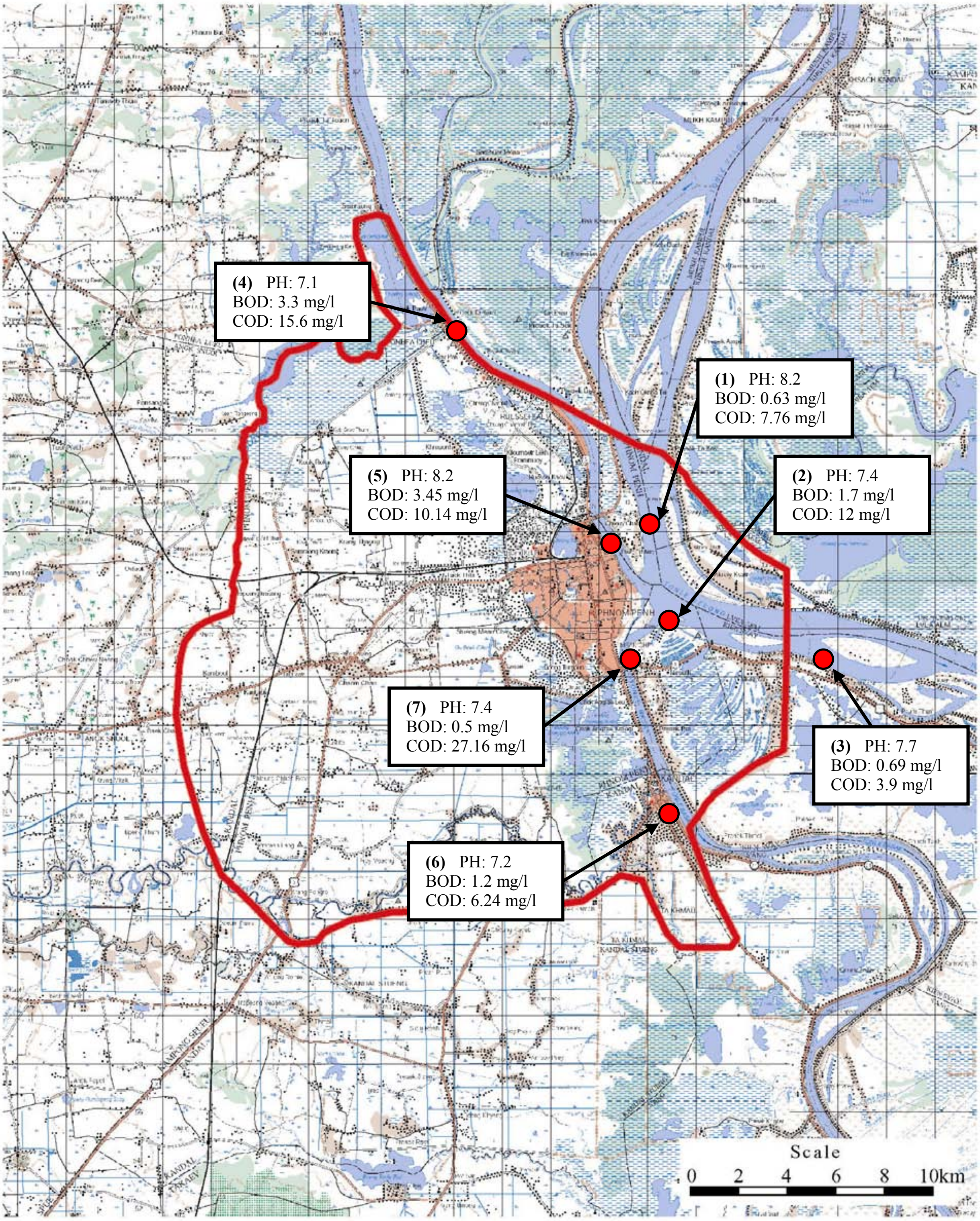


Figure 7-7 Water Quality of Rivers

7-2-3-2 New Water Treatment Plant

The following table compares the three alternatives for siting the water treatment plant.

Table 7-8 Comparison of Water Treatment Plant

Item	Alternative – A (Svay Pak)	Alternative – B (Chrouy Changva)	Alternative – C (Nirouth)
Land	Fish Pond	Marshy Land	Marshy Land
Accessibility from main road	Approx. 300 m from NR No. 5	Approx. 300 m from NR No. 6	Approx. 300 m from NR No. 1
Distance from intake station	Approx. 300 m	Approx. 300 m	Approx. 500 m
Construction cost (million US$) (incl. distribution pipe)	2nd 103.72 (101%)	3rd 108.06 (105%)	Lowest 102.59 (100 %)
Operation cost- • Power consumption • Chemical consumption Total (million US$)	3rd 4.78 1.11 5.89 (115 %)	2nd 4.86 0.93 5.79 (113 %)	Lowest 4.21 0.93 5.14 (100 %)
River crossing	None	Tonle Sap (Japanese Bridge)	Tonle Basak (River Bed Piping)
Flooding	Land filling required	Land filling required	Land filling required
Residence	Many	Many	Less
Social & environmental impact	High	Medium	Low

Schematic drawings for the three alternative treatment plant locations are shown in Figure 7.11. Comparison of estimated construction costs indicates that Alternative C is the lowest cost alternative. Distribution pipe cost is also included in the cost, because the costs for the intake station and treatment plant remain unchanged, while distribution network cost will differ with location of the alternative sources.

As for operation costs, power and chemical consumption are two major items. Energy consumption is the major operation cost. This depends on how much water (m^3/day) and how far (kms) the pumps have to supply. The power consumption estimate indicates that Alternative C has the lowest consumption. The future city development direction expands more toward the south and west, while the existing plants are located in the central and northern part of the city.

Also, if the new water treatment plant is located at Chrouy Changva, most of the water (330,000 m^3/day) for the entire system will be produced at Chrouy Changva and transported over the "Japanese Bridge." This dependency is not desirable, since power failure in the area or an accident on the bridge could affect the ability to supply water to the whole city.

Raw water quality also affects the operation cost of water treatment plants. The following table shows average chemical consumption in 2004.

Table 7-9 Chemical Consumption

Plant/River		Alum	Lime	Chlorine
		(g/m^3)	(g/m^3)	(g/m^3)
Phum Prek	Sap	22.37	6.76	3.08
Chamkar Mon	Basak	45.83	7.06	2.36
Chrouy Changva	Mekong	17.06	0.00	1.80

The Chrouy Changva Plant, which takes water from the Mekong River, has better raw water quality than the others with respect to turbidity. Chemical consumption depends on raw water turbidity. Chrouy Changva consumes less alum and chlorine than the other plants and no lime. Chamkar Mon has the highest consumption due to higher turbidity and difficulties in operation of the chemical dosing equipment. It is expected that deterioration of raw water quality will require more consumption of chemicals by the Phum Prek and Chamkar Mon Plants in the future.

High and medium social and environmental impact of Alternatives B and C is attributed mainly to requirement for resettlement. Resettlement costs are included in the above construction cost.

7-2-3-3 Result of Overall Evaluation

The following table shows the overall comparison of treatment plant alternatives.

Table 7-10 Comparison of Alternatives

Item	Alternative – A (Svay Pak)	Alternative – B (Chrouy Changva)	Alternative – C (Nirouth)
Water Source/Intake Station	Fair	Good	Good
Water Treatment Plant	Fair	Fair	Good
Overall	3rd	2nd	**1st**

As for water source, Alternatives B and C are advantageous. Alternative C is superior with respect to treatment and distribution. Therefore, Alternative C, a new treatment plant with production capacity of 200,000 m^3/day to be constructed in Nirouth, is recommended.

7-2-4 Water Production Facility Development Plan

The major water production facility development plan consists mainly of expansion of the existing treatment plant and construction of new treatment plants.

The proposed water treatment plant development plan is as follows.

Table 7-11 Water Treatment Plant Development

Plant	Capacity (m^3/d)	Year
Chrouy Changva – 2nd Stage	65,000	2007
Nirouth Plant – 1st Stage	100,000	2013
Nirouth Plant – 2nd Stage	100,000	2019
Production Increase	265,000	-

7-2-4-1 Water Treatment Process

All existing treatment plants are operating in fair condition.

The following figure shows water quality of each treatment process in the existing treatment plants during the high turbidity period for 2004. While the raw water turbidity varies between NTU 625 in Phum Prek, NTU 461 at Chrouy Changva and NTU 871 at Chamkar Mon, treated water is approximately NTU 1.0.

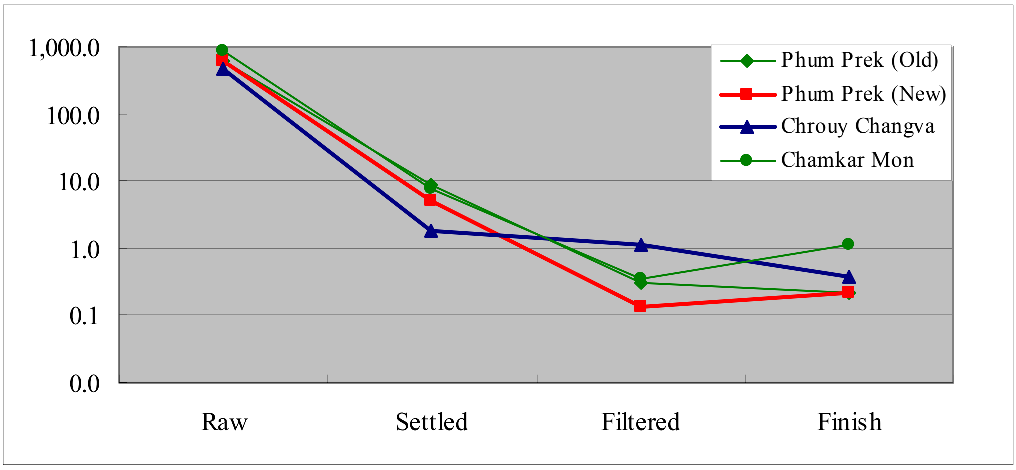


Figure 7-8 Water Treatment Process

There are two major water treatment processes for drinking water treatment plant, namely coagulation-sedimentation and filtration.

The coagulation-sedimentation process in water treatment provides for the settling and removal of heavier and larger suspended particles from water. Most commonly, it is used for removal of flocculated particles prior to filtration. The removal efficiency in the sedimentation basin determines the subsequent loading on the filters and, accordingly, has a marked influence on their capacity, the length of filter runs, and the quality of the filtered water.

The two major classifications for the design of sedimentation basins are:

i. Horizontal flow unit

ii. Up flow unit

Phum Prek Plant applies horizontal flow sedimentation without inclined-plate unit, Chamkar Mon Plant applies sludge blanket type up flow sedimentation, and Chrouy Changva Plant applies up flow sedimentation with inclined-tube.

In general, horizontal flow sedimentation without inclined-plate unit and having longer retention time have superior performance in reducing turbidity and are more easily maintained compared to flow sedimentation with inclined-tube.

Filtration is a physical, chemical, and in some instances biological process for separating suspended impurities from water by passage through porous media. Two general type of filters are commonly used in water treatment: the slow sand filter and the rapid sand filter. Because of higher filtration rates, the space requirement for a rapid filtration plant is about 20 percent of that required for slow sand filters.

All three existing plants apply rapid sand filtration, while Phum Prek and Chrouy Changva Plants apply open gravity filters and Chamkar Mon Plant applies closed pressure filters. Closed pressure filters are only applicable for small capacity plants like Chamkar Mon.

The following table summarizes typical design criteria for the existing water treatment processes. They represent a reasonable range of design and there is no critical problem among them. For the expansion of Chrouy Changva, the same process will be applied to facilitate ease of operation and utilization of the available land at the site. However, the proposed Nirouth Plant will utilize a process similar to that of the new Phum Prek Plant, which has a simpler and more affordable treatment process than Chrouy Changva.

Table 7-12 Typical Design Criteria of Treatment Process

Process	**Phum Prek**	**Chamkar Mon**	**Chrouy Changva**
Sedimentation			
Type	Horizontal flow	Up flow sludge blanket	Up flow with inclined tube
Retention Time	2.1 hrs & 2.4 hrs	1.6 hrs	1.7 hrs
Filter			
Type	Gravity, Single Media	Pressured Single Media	Gravity, Single Media
Filtration Speed	6.5 m/hr & 5.3 m/hr	6.9 m/hr	5.9 m/hr

Details of water production facilities are shown in the following tables and figures:

- Chrouy Changva Outline of Facility (Stage 2) is presented in Table 7-14;
- Chrouy Changva Layout in Figure 7.10;
- Chrouy Changva Hydraulic Profile in Figure 7.11;
- Nirouth Outline of Facility (Stage 1) is presented in Table 7-15;
- Nirouth Outline of Facility (Stage 2) in Table 7.16
- Nirouth Layout in Figure 7.12; and
- Nirouth Hydraulic Profile in Figure 7.13.

7-2-4-2 Sludge Treatment/Disposal Option

The existing treatment plants are not equipped with any wastewater or sludge treatment facilities, such as backwash water recovery tank, sludge lagoon, sludge drying bed etc. It is desirable to provide those facilities in order to minimize discharge of high turbidity water or sludge to natural water bodies.

According to the *Sub-Decree on Water Pollution Control* of April 6, 1999, water purification plants are required not to discharge wastewater containing suspended solids of more than 50 mg/l to “protected public waters,” such as the Mekong River, Tonle Sap and Tonle Basak.

The following figure illustrates three different sludge treatment/disposal processes, namely sludge lagoon, sludge drying bed and sludge dewatering machine.

Sludge lagoon requires a large area in the plant, but capital cost for the facility is low because of no electrical mechanical equipment and easy operation. Therefore, a sludge treatment facility, such as sludge lagoons, is recommended for the Nirouth Water Treatment Plant.

The following table outlines possible sewage treatment facilities that could be applied to the existing water treatment plants. Land at the existing plants is very tight and insufficient for sludge treatment; additional lands would need to be acquired near the existing plants. The treatment processes, gravity thickener and mechanical dewatering equipment, are rather difficult to operate and maintain.

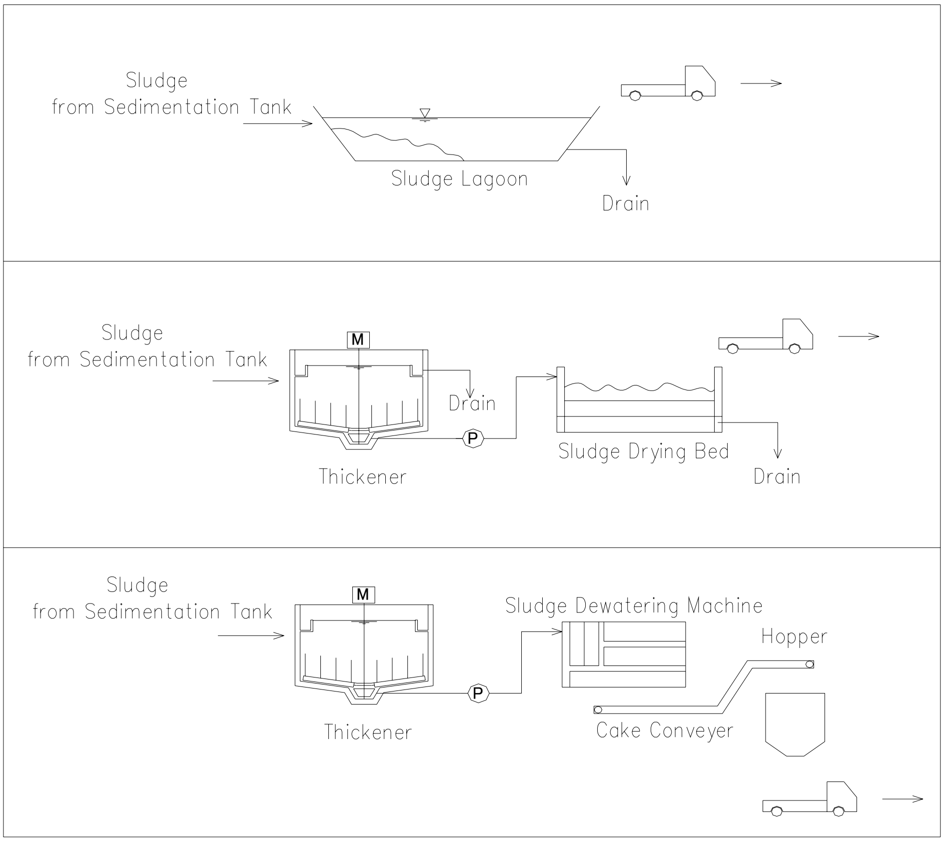


Figure 7-9 Sludge Treatment/disposal Process

Table 7-13 Sludge Treatment Facility

Item	**Phum Prek**	**Chrouy Changva**	**Chamkar Mon**
Production (m3/day)	150,000	130,000	20,000
Treatment Process	Gravity Thickener + Dewatering Machine	Gravity Thickener + Dewatering Machine	Gravity Thickener + Dewatering Machine
Required Land (ha)	0.4	0.36	0.2
Construction Cost (mil. US$)	10.1	8.8	3.4