Since the sludge or wastewater from water treatment plants is not hazardous or harmful to human health, it is recommended to discuss with the Ministry of Environment and obtain permission to continue directly discharging wastewater from the existing water treatment plants.

7-3 Rehabilitation Works

Water treatment plants consist of concrete structures, piping, mechanical equipment, electrical equipment, instrumentation etc. Usually, concrete structures and piping last 30 to 50 years while mechanical equipment, electrical equipment and instrumentation deteriorate over a shorter period, such as 10 to 20 years. Also, the equipment requires replacement of certain spare parts as annual maintenance, and major rehabilitation entailing overhaul/repair/replacement of equipment every decade or so.

These costs should be recognized as regular O&M cost in the annual operating budget. Several O&M budget items should be considered for a water treatment facility. These items include staffing, chemicals, utilities, ongoing training, and equipment.

Equipment costs should be budgeted over several separate categories. Smaller new equipment will be purchased during the operation of the facility to replace broken equipment, add new types of equipment, and to upgrade the facility. These costs tend to increase with the age of the plant.

There should be a spare parts category in the budget to cover costs of maintaining an inventory of critical and hard-to-locate parts. Another budget category is consumables necessary to keep equipment in operation, such as oil, grease, nuts, and bolts. Finally, although some tools will be initially purchased, a budget allowance should be included for constantly replacing and upgrading the tools required for plant maintenance.

Large equipment is usually a budgeted capital cost for rehabilitation works. This could include such items as vehicles, construction equipment, new pumps and generators, and high capacity process equipment. Replacement of large equipment is usually a one-time expense, so it is budgeted by setting aside a certain amount annually in an equipment fund to purchase new equipment or replace old equipment that has failed or is a planned replacement because it is either out of date or no longer economically practical to maintain.

Rehabilitation works are estimated with the following assumed percentage ratios to initial construction cost for mechanical/electrical/instrumentation:

Years	10 years	20 years	30 years
Ratio to Initial Cost	20%	30%	50%

Table 7-14 Chrouy Changva – Outline of Facility

Name of Water Treatment Plant : Chrouy Changva

Capacity	130,000 m3/d
Water Source	136,500 m3/d Mekong River HWL = 10.0 m, LWL = 0.0m
Construction	2002 costruction of 1st stage plant
	2007 costruction of intake and 2nd stage
Name of Water Treatment Plant :	Chrouy Changva - 2nd Stage
Capacity	65,000 m3/d
Treatment Process	
1. Rapid Mixing 2. Flocculation 3. Sedimentation 4 Filtration 5 Disinfection	
Intake Facilities	Pump Pit HWL = 10.0 m, LWL = -0.10m
Type	Raw Water Pumping
Intake Pump	23.7 m3/min x 19.5 m x 5 units
Receiving Well	
Type	Recutangular
Retention Time	5.6 min
Size & Q'ty	10 mW x 10 mL x 5 mD x 1 unit
Rapid Mixing	
Type	Mechnical Mixing
Retention Time	85 sec
Size & Q'ty	2.5 mW x 2.5 mL x 5.1 mD x 2 units
Equipment	Vertical Mixer 2 units
Flocculation	
Type	Horizontal Flow
Retention Time	27.5 min.
Size	4.6 mW x 4.6 mL x 4.9 mD
Q'ty	12 units
Equipment	Vertical Flocculator 6 units
Sedimentation Tank	
Type	Up Flow with Inclined Tube
Retention Time	104.7 min 1.7 hr
Size	38.4 mL x 13.1 mW x 4.7 mD
Q'ty	2 units
Surface Load	44.9 mm/min
Trough/Pipe	Orifice Trough
Sludge Removal	Sludge Scraper 12 units, Sludge Extraction Valve
Equipment	Inclined Tube, Sludge Scraper 6 units, Sludge Extraction Valve
Operation	Sludge Collection - Automatic, Sludge Removal - Automatic
Filter	
Type	Gravity, Single Media, Declining Flow
Filtration rate	141 m/d (5.87 m/hr) 188 m/d at washing
Filter Bed Area	57.67 m2 x 8 filters
Size & Q'ty	3.65 mW x 7.9 mL x 2 beds
Filter Media	Sand : 0.9 - 1.2 mm x 950 mm
Washing System	Air Scouring (54 m/hr) + Backwashing (14.4 m/hr)
Equipment	Inlet Gate, Outlet Valve, Washwater Valve, Air Scouring Valve, Washwater Drain Gate
	Washwater Pump, Air Scouring Valve, Air Blower
Operation	Manual
Clear Water Reservoir	HWL = 6.35 m, LWL = 10.5 m
Reservoir No. 3	5,000 m3
Reservoir No. 4	5,000 m3
Clear Water Pump	
Distribution-1	15.5 m3/min x 30 m x 2 units
Distribution-2	25.0 m3/min x 50 m x 4 units

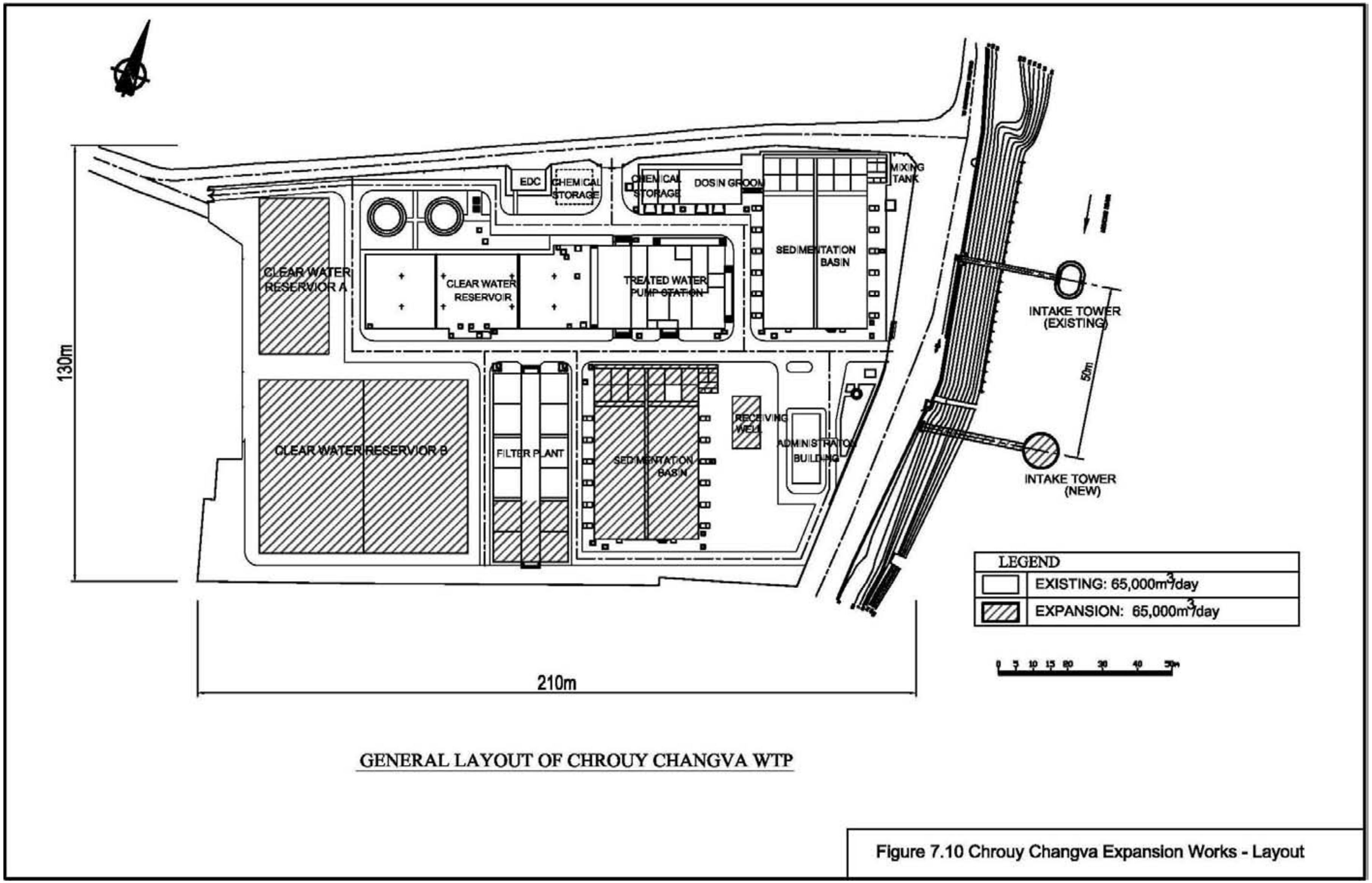


Figure 7-10 Chrouy Changva Expansion Works – Layout

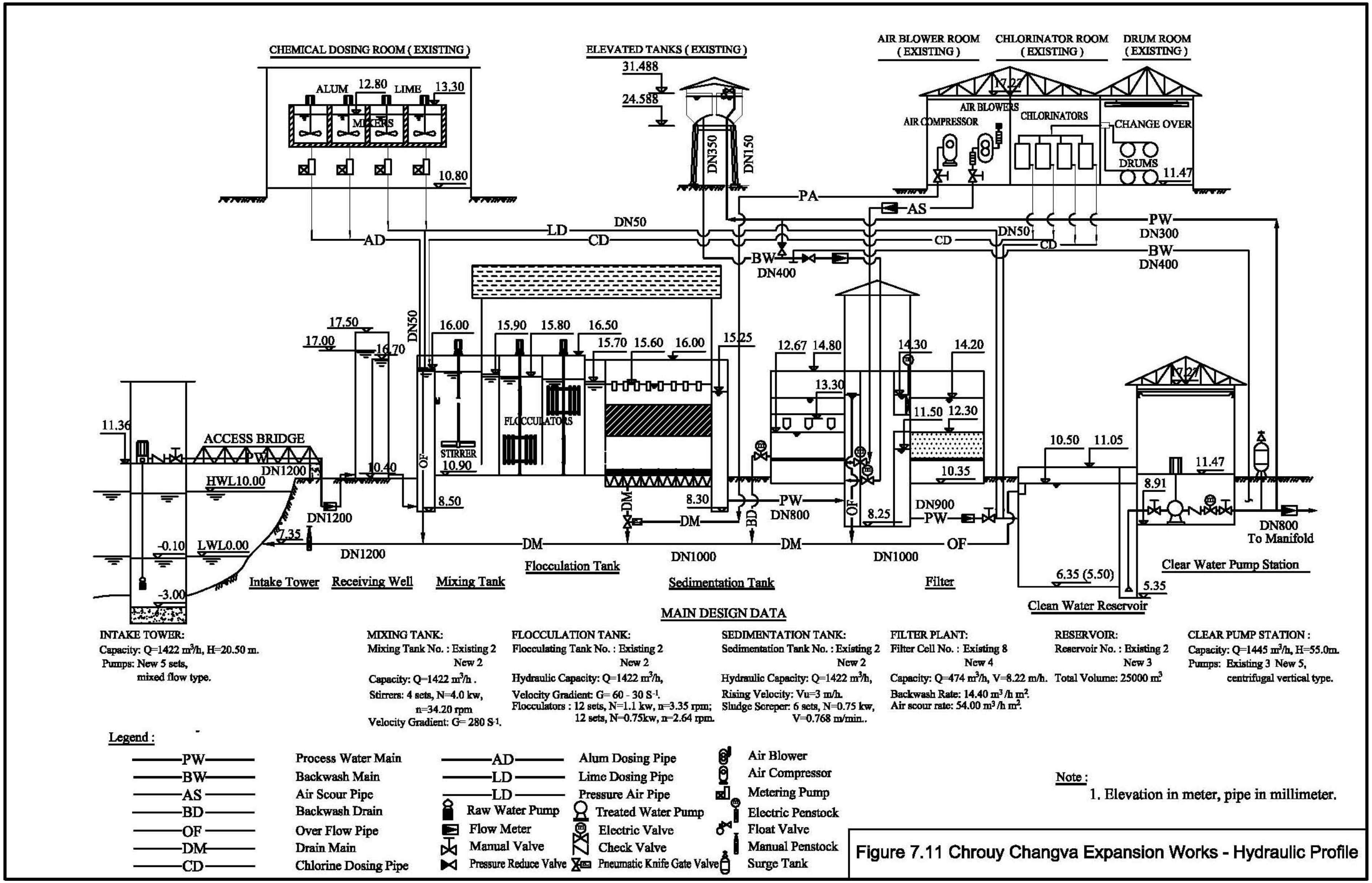


Figure 7.11 Chrouy Changva Expansion Works - Hydraulic Profile

Figure 7-11 Chrouy Changva Expansion Works – Hydraulic Profile

Table 7-15 Nirouth WTP Stage 1 – Outline of Facility

Name of Water Treatment Plant : Nirouth

Capacity	100,000 m3/d (1st Stage) 100,000 m3/d (2nd Stage)
Water Source	210,000 m3/d Mekong River HWL = 10.9 m, LWL = 1.5m
Construction	2013 costruction of intake and 1st satage plant
	2019 costruction of 2nd satage plant
Name of Water Treatment Plant :	Nirouth - 1st Stage
Capacity	100,000 m3/d
Intake Facilities	Mekong River HWL = 10.78 m, LWL = 1.46m
Type	Raw Water Pumping
Intake Pump	(1st Stage) : 37.0 m3/min x 22 m x 3 units
Treatment Process	
1. Rapid Mixing 2. Flocculation 3. Sedimentation 4 Filtration 5 Disinfection	
Receiving Well	
Type	Recutangular
Retention Time	3.0 min
Size & Q'ty	5.3 mW x 15 mL x 5.3 mD x 1 unit
Rapid Mixing	
Type	Weir
Retention Time	74 sec
Size & Q'ty	1.8 mW x 5.0 mL x 4.7 mD x 1 unit x 2 trains
Equipment	None
Flocculation	
Type	Horizontal Flow
Retention Time	26.6 min.
Size	11.3 mW x 7.0 mL x 2.9 mD
Q'ty	4 units x 2 trains
Equipment	Vertical Flocculator 8 units x 2 trains
Sedimentation Tank	
Type	Horizontal Flow
Retention Time	147.8 min 2.5 hr
Size	43.4 mL x 11.3 mW x 2.6 mD
Q'ty	4 units x 2 trains
Flow Velocity	0.29 m/min
Surface Load	17.6 mm/min
Trough/Pipe	Orifice Trough
Sludge Removal	Sludge Extraction Valve (Manual)
Equipment	Sludge Extraction Valve
Operation	Sludge Removal - Manual
Filter	
Type	Gravity, Single Media, Constant Flow, Level Control
Filtration rate	128 m/d (5.33 m/hr) 146 m/hr at washing
Filter Bed Area	48.8 m2
Size & Q'ty	4.5 mW x 10.85 mL x 8 filters x 2 trains
Filter Media	Sand : 0.8-1.0 mm x 1000 mm
Washing Rate	Air Scour : 1.024 m/min Wash : 0.375 m/min Rincing : 0.42 m/min
Washing System	Backwashing (0.5 min), Air Scouring + Backwashing (4 - 7 min), Rincing (10 - 15 min)
Wash Trough	None
Equipment	Inlet Gate, Outlet Valve, Level Control Siphon, Siphon Regulation System
	Washwater Inlet Valve,Washwater Discharge Gate, Washwater Pump
	Scour Air Inlet Valve, Air Blower
Operation	Automatic & Step-by-step
Filter Backwash Recovery	
Recovery Tank	5.0 mW x 20.0 mL x 2 tanks
Sludge Disposal	
Sludge Lagoon	40.0 mW x 100.0 mL x 4 tanks
Chemicals	

Table 7-16 Nirouth WTP Stage 2 – Outline of Facility

Name of Water Treatment Plant :	Nirouth - 2nd Stage
Capacity	50,000 m3/d
Intake Facilities	Mekong River HWL = 10.78 m, LWL = 1.46m
Type	Raw Water Pumping
Intake Pump	(2nd Stage) : 37.0 m3/min x 22 m x 2 units
Treatment Process	
1. Rapid Mixing 2. Flocculation 3. Sedimentation 4 Filtration 5 Disinfection	
Rapid Mixing	
Type	Weir
Retention Time	2 sec
Size & Q'ty	1.8 mW x 5.0 mL x 4.7 mD x 1 unit x 2 trains
Equipment	None
Flocculation	
Type	Horizontal Flow
Retention Time	0.9 min.
Size	11.3 mW x 7.0 mL x 2.9 mD
Q'ty	4 units x 2 trains
Equipment	Vertical Flocculator 8 units x 2 trains
Sedimentation Tank	
Type	Horizontal Flow
Retention Time	147.8 min 2.5 hr
Size	43.4 mL x 11.3 mW x 2.6 mD
Q'ty	4 units x 2 trains
Flow Velocity	8.85 m/min
Surface Load	530.2 mm/min
Trough/Pipe	Orifice Trough
Sludge Removal	Sludge Extraction Valve (Manual)
Equipment	Sludge Extraction Valve
Operation	Sludge Removal - Manual
Filter	
Type	Gravity, Single Media, Constant Flow, Level Control
Filtration rate	128 m/d (5.33 m/hr) 146 m/hr at washing
Filter Bed Area	48.8 m2
Size & Q'ty	4.5 mW x 10.85 mL x 8 filters x 2 trains
Filter Media	Sand : 0.8-1.0 mm x 1000 mm
Washing Rate	Air Scour : 1.024 m/min Wash : 0.375 m/min Rincing : 0.42 m/min
Washing System	Backwashing (0.5 min), Air Scouring + Backwashing (4 - 7 min), Rincing (10 - 15 min)
Wash Trough	None
Equipment	Inlet Gate, Outlet Valve, Level Control Siphon, Siphon Regulation System
	Washwater Inlet Valve,Washwater Discharge Gate, Washwater Pump
	Scour Air Inlet Valve, Air Blower
Operation	Automatic & Step-by-step
Sludge Disposal	
Sludge Lagoon	40.0 mW x 100.0 mL x 4 tanks
Clear Water Reservoir	HWL = 13.2 m, LWL = 9.3 m
Reservoir	5,000 m3 x 4 reservoirs
Clear Water Pump	HWL = 13.2 m, LWL = 8.5 m
Distribution-1	(5 to 6) 56.0 m3/min x 50 m x 2 units

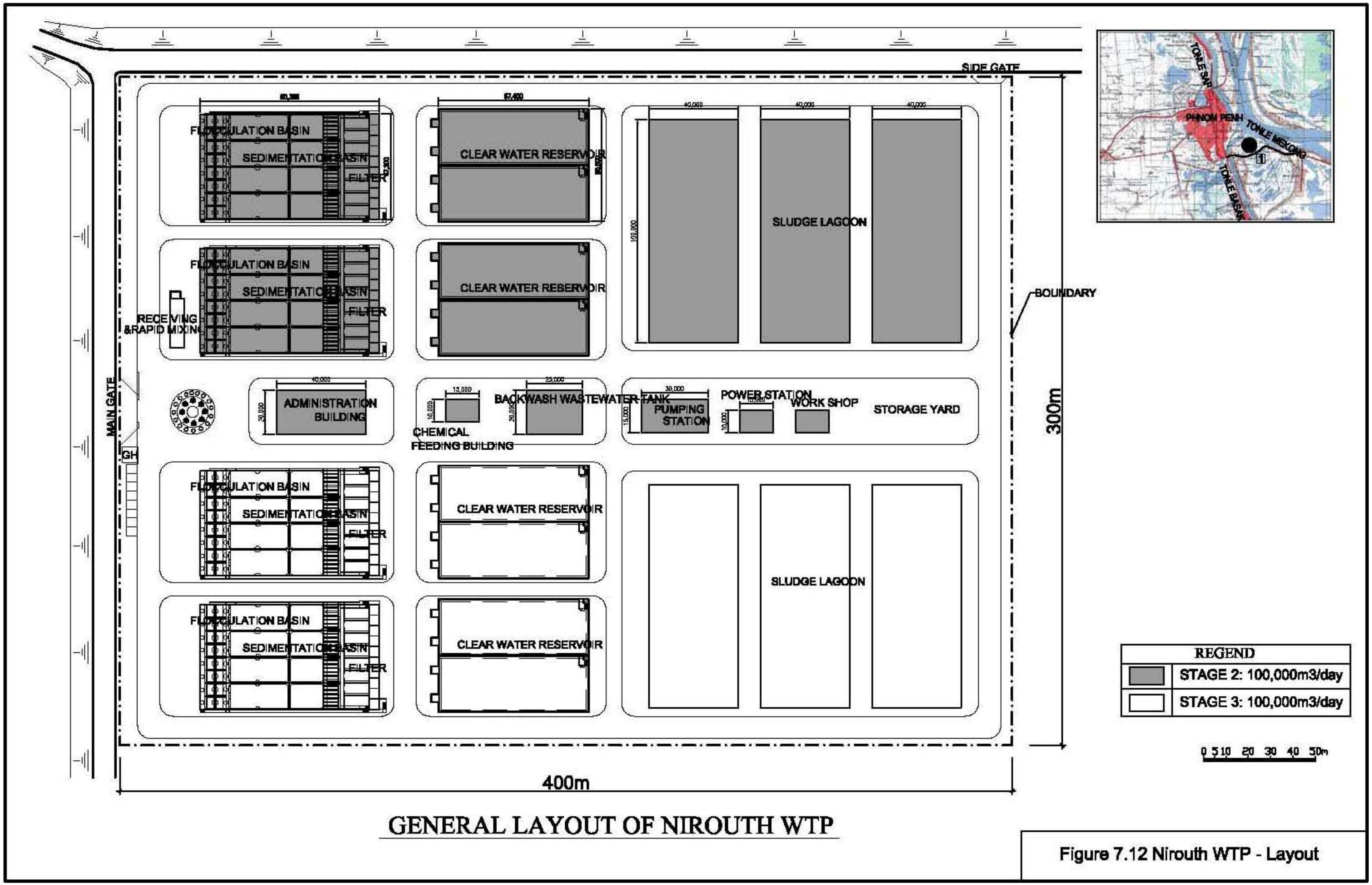


Figure 7-12 Nirouth WTP – Layout

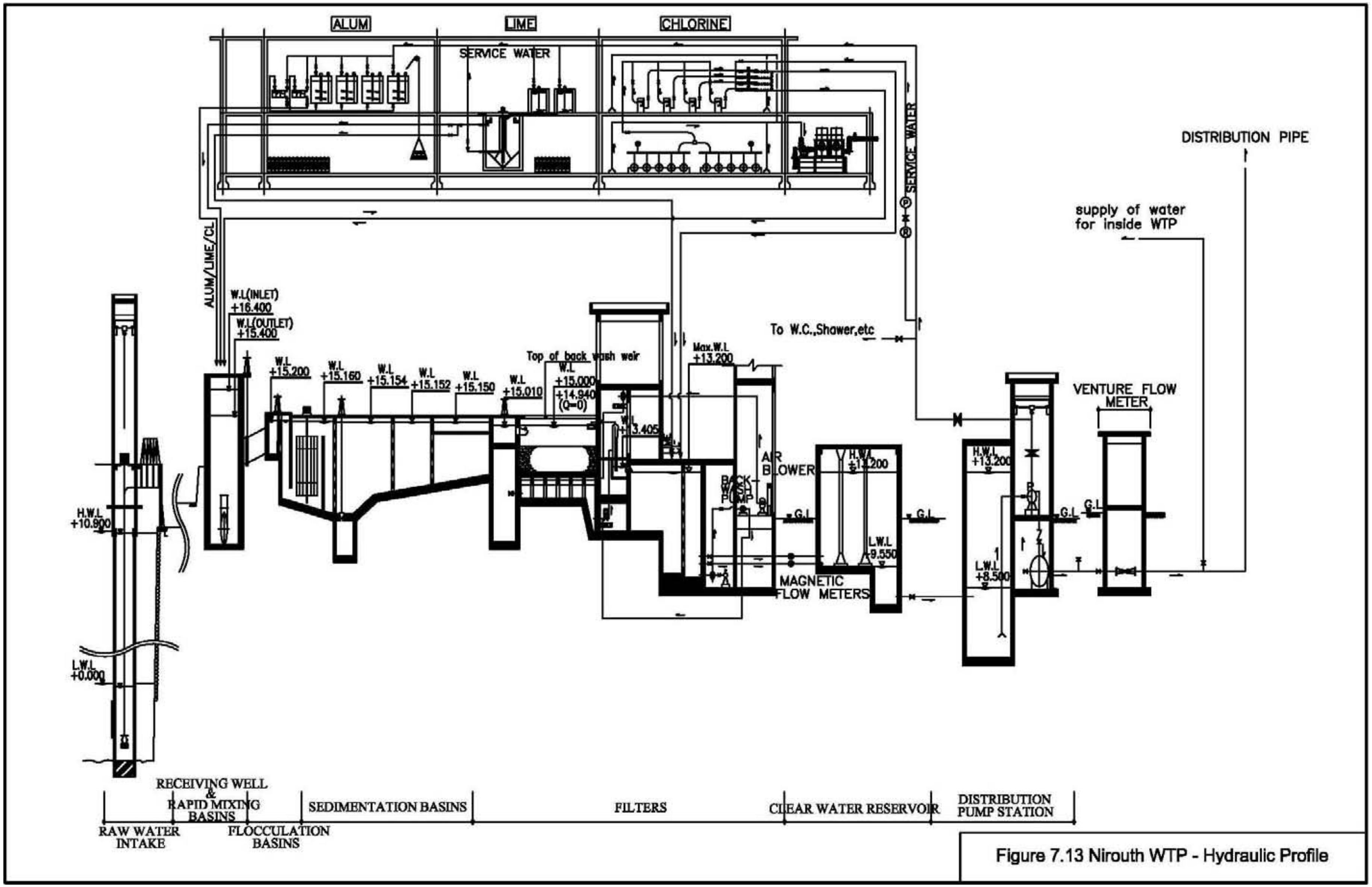


Figure 7-13 Nirouth WTP – Hydraulic Profile

7-4 Water Transmission and Distribution Development Plan

The water transmission and distribution system will be expanded in parallel with the development of additional production facilities, paying close attention to the patterns of demand from the growing areas and the long term hydraulic requirements of the system itself. The demand forecast adopted for network expansion follows the demand forecast already determined as the basis for this Master Plan. The network expansion plan also assumes the increase of production in accordance with the previous section, that is, the doubling (phase 2) of Chrouy Changva during Stage I of the Master Plan (2005-2010), followed in the Second and Third Stages by the construction of a new treatment plant at Nirouth.

Any network expansion inevitably comes up against constraints imposed by the limitations of the existing system and above-ground reality. For example, the social and economic costs and disruption associated with installing new or additional mains through the central part of the City are so prohibitive as to virtually preclude further consideration or analysis if such a dire scenario can in any way be avoided. Once transmission lines have been laid and development occurs, it usually becomes increasingly difficult and expensive to increase transmission capacity in those areas. This is problematic in the context of Phnom Penh because the existing treatment plants are sited in the east near the river, naturally enough, but the areas of most rapid development are now to the north, west and south. This means that the existing transmission capacity under the central city is facing increasing demand from the developing suburbs, a situation that is bound to continue. From an operational point of view, this means that transmission pressure near the plant and under the City must be increased in order to maintain adequate pressure in the outlying areas. Higher pressure means more pumping and more leaks, thus higher operating cost and more maintenance.

The objectives for the expansion plan outlined below are therefore to 1) serve the additional demand, while 2) enhancing overall system performance. The strategy for accomplishing these objectives incorporates the following critical concepts: a) division of the network into discrete zones, most with their own reservoirs, permitting more intensive and flexible control of flow and pressure, b) creation of transmission network loops for greater redundancy and pressure balancing options, and c) completion of the distribution system, as at present, in closed, metered blocks.

The transmission and distribution system expansion proposed here covers three stages ending in years 2010, 2015, and 2020. The concept-level designs were developed utilizing the WaterCad system modeling software incorporating all available, relevant, actual and forecast data. Hydraulic analyses were carried out in order to identify the required transmission connections and distribution reinforcement where water demand will increase during each Stage. The initial network model incorporates 2410 sections representing a total length of 283 km of main pipelines.

The analysis focused on pipes with diameters greater than 150 mm., which increases to about 480 km in 2020.

7-4-1 Analysis of Existing Conditions and Future Requirements

The entire transmission and distribution network was constructed or rehabilitated in the early 1990s and is presently in good working order, with ample capacity to meet the demand in currently served areas.

Table 7-17 Present facilities

WTP	Nominal capacity		235 000	(m^3/d)	*Peak day water demand = WTP nominal capacity*
					Hourly coef max = 1.63
	Required capacity		200 000	(m^3/d)	Hourly coef min = 0.37
Water Tanks	Olympic stadium	T1	2000 m^3	Not used	
	Chaom chau	T2	1500 m^3	projected	
	Pochentong airport	T3	1500 m^3	projected	
	Chrang chamreh	T4	1500 m^3	projected	
Clear water reservoir	Phum Prek	25000 m^3			
	Chrouy Changva I	5760 m^3			
	Chamkar Mon	1500 m^3			
Transmission network	Ø > 150 mm	283 km			

The existing system consists of six principal branches radiating from the three existing treatment plants, as shown in the figure below. The transmission system feeds distribution networks that end in closed, telemetered blocks serving customers.

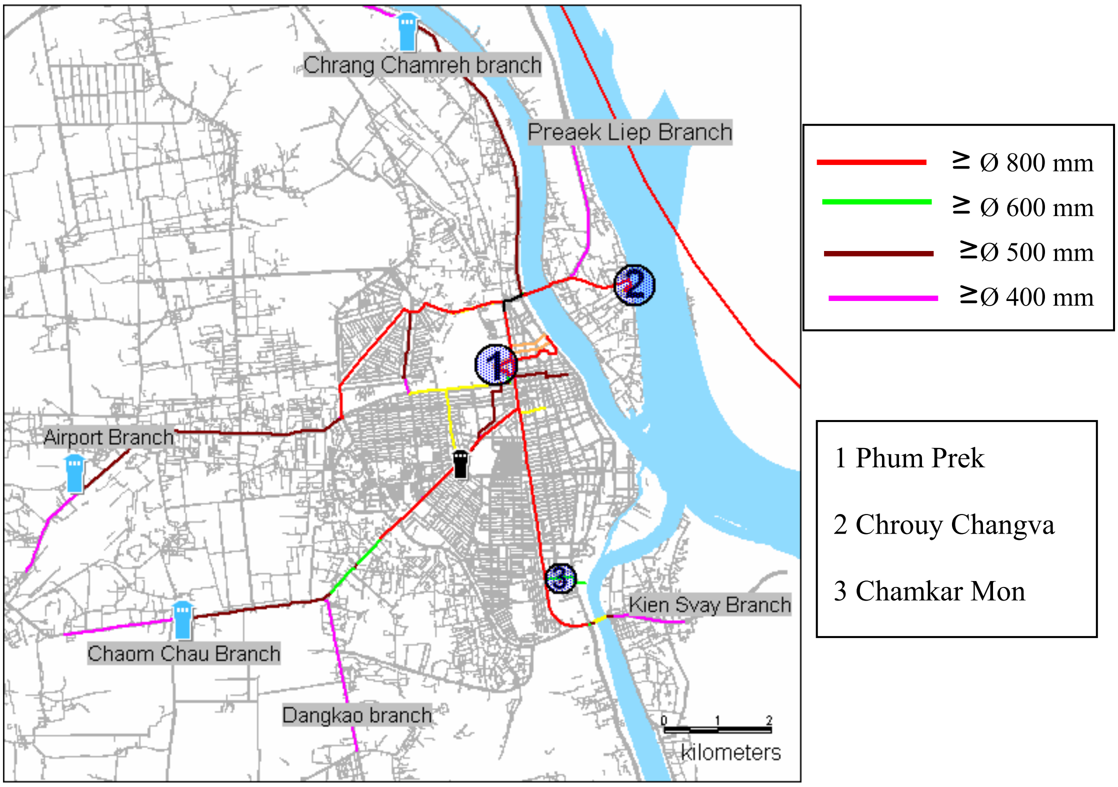


Figure 7-14 The Six Main Network Transmission Branches

The main network branches are briefly summarized as follows:

- **Preaek Liep Branch** – The Chrouy Changva treatment plant directly supplies the Preaek Leaep and Chrouy Changva districts via an independent 6 km (400 mm shrinking to 300 mm) transmission line along highway No. 6. Directly connected to the WTP, the pressure on this network is rather high.
- **Chrang Chamreh Branch** – From Chrouy Changva treatment plant this branch parallels the Tonlé Sap supplying the sangkats (sub-districts) along national road No.5. The length is about 7500 m. This transmission pipe will supply the Water Tank that is under construction at Chrang Chamreh.
- **Airport Branch** – The Airport Branch follows national road No.3. About 7900 m in length, it is connected at Tuol Kork University to the main transmission of 900 mm. A 1500 m^3 Water Tank is presently under construction, which will help to meet downstream peak demand and alleviate the upstream pressure requirement.
- **Chaom Chau Branch** – Supplies Stung Mean Chey and Chaom Chau. The transmission pipe follows the Veng sreng road, where another 1500 m^3 Water Tank will be constructed.
- **Dangkao Branch** – There is a southern extension of the Pochentong branch that passes the bridge of Vat Sambor toward Cheung Aeck, where development is presently occurring. This branch is 400 mm.
- **Kien Svay Branch** – This branch follows the Monivong Bridge over the Tonle Bassac, supporting two main pipelines of 350 mm. The Kien Svay branch is also of a diameter of 400 mm.

The recently opened connection with the existing Ta Khmau network has caused its upstream structures to perform the function of transmission although they are not suited for it. An urgent project to rectify the situation is included in the Stage 1 Feasibility Study.

The existing distribution systems cover the area shown in gray in the following figure. The area totals approximately 112 km^2.

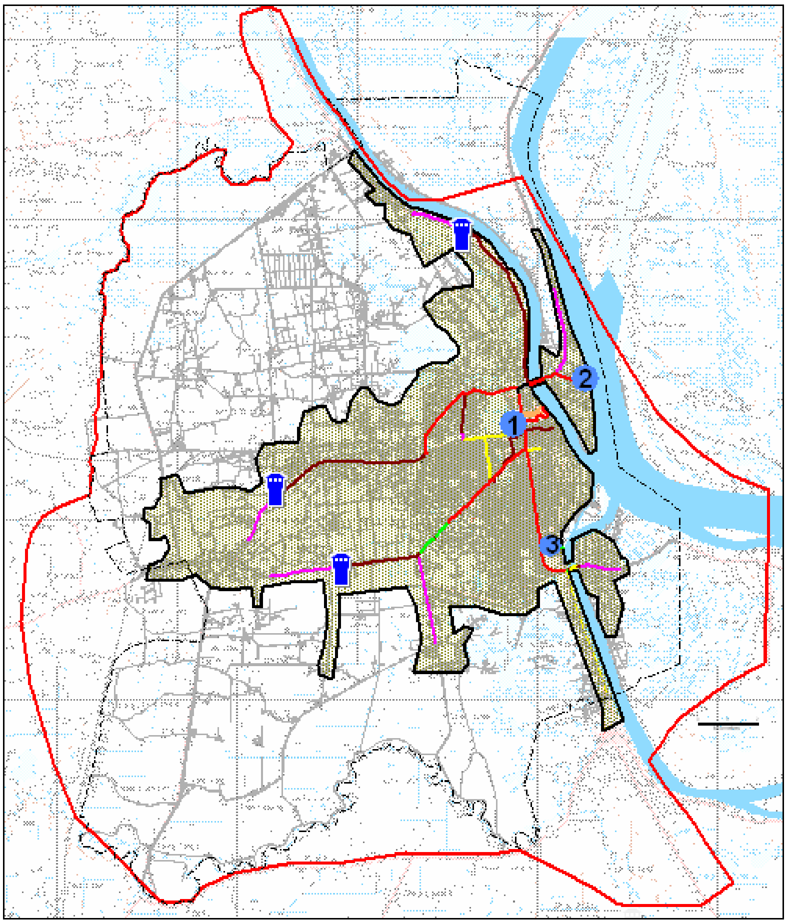


Figure 7-15 Existing Distribution Coverage

In summary, the existing situation presents the following challenges and limitations:

- Demand is growing at the outer fringes of the network necessitating expansion of the transmission and distribution system overall.
- The transmission network lacks loops to permit treatment plants to redundantly supply branches of the network to which they are not directly connected.
- The existing treatment plants are located east of the major existing demand area, but the new development areas are to the north, west and south, placing a heavy future burden on the transmission network in the existing central area to pass water through to the new areas. Transmission capacity in the central City cannot be easily increased further without undue disruption and cost.

The three Water Tanks presently under construction will help to alleviate supply and pressure shortfalls in the outlying areas and thus conserve transmission pressure and pumping requirements in the upstream areas under the City and from the plants. The branches and towers constitute the building blocks for the definition of network Zones, as described further below.

7-4-2 Design Objectives and Strategy

There are two overall objectives for the network expansion plan. The first is to meet growing demand. The second is to improve system performance, specifically, to provide the basis for management of system pressures resulting in balanced operation.

The strategy for realizing the first objective is relatively straightforward. The demand forecast, based on the City Development Plan and described in a previous chapter of this report, provides the basis for estimating short, medium and long term requirements for system expansion in relation to both geographic location and capacity. The expansion areas and the network capacity increases required to serve them are detailed in the descriptions of the relevant stages of the expansion plan provided further below.

The second objective is more problematic. Growing demand from outlying areas at increasingly greater distances from the principal treatment plants necessitates raising pressures in the transmission lines closer to the plants and, under certain circumstances, even causing the treatment plants to push against each other. This was actually the case in Phnom Penh, with the pumps at Phum Prek having to work against Chrouy Changva's greater head. The problem has since been alleviated with the installation of a valve on the main connecting the two plants, but this also means that said main is no longer available for Chrouy Changva to supply areas on the other side (i.e., south) of Phum Prek. Such problems will be reduced under the Master Plan. The strategy for achieving the objective of efficient system management is three-pronged and entails:

- ✓ division of the system into zones,
- ✓ creation of loops, and
- ✓ distribution by closed blocks.

These three strategies are summarized in the following paragraphs.

7-4-2-1 Zones

By dividing the system into discrete Zones, pressure in each Zone can be independently regulated and the requirement to maintain high pressure at the treatment plants will be reduced. The key to realizing this strategy is the construction of reservoirs. Presently, three Water Tanks are under construction. Their completion is assumed in the expansion plan presented here. Thus each Zone can be said to have its own reservoir, although in the future additional reservoirs may become necessary as the system continues to expand. The southern location of the proposed new treatment plant at Nirouth will contribute to postponing this necessity, since it will bypass the City and directly supply the growing areas to the south and west. Therefore, additional reservoirs are not presently contemplated in this Master Plan.

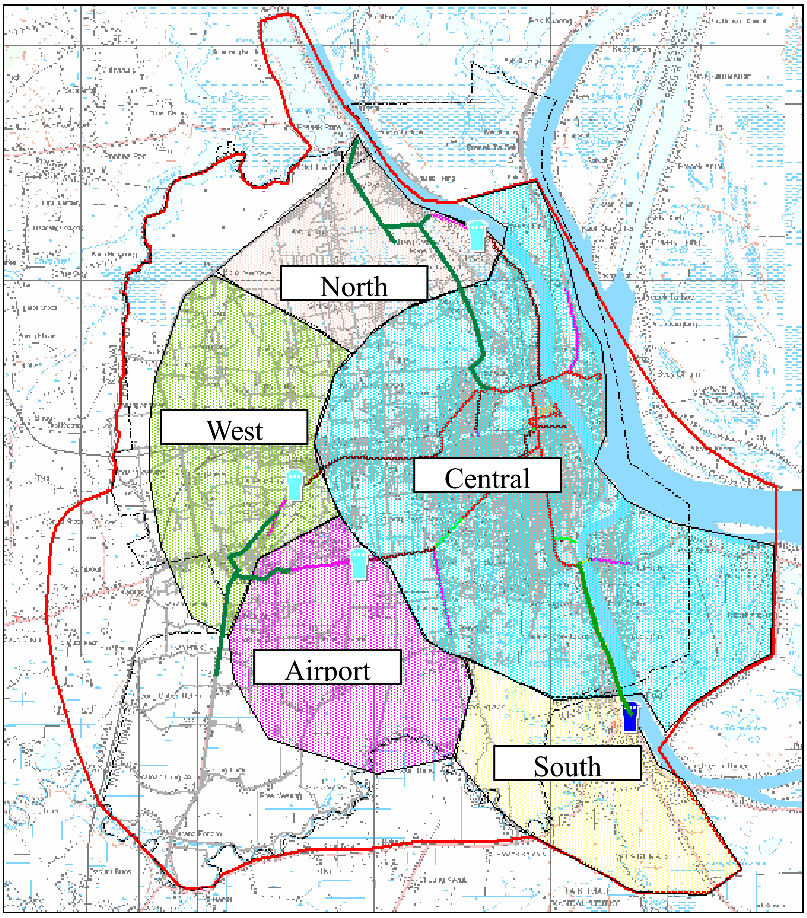


Figure 7-16 Distribution and Zones

7-4-2-2 Loops

The looping strategy, introduced in the Progress Report, encompasses three stages of development that are synchronized with the three stages of development of the Master Plan. These are described as follows:

(1) Inner Loops

The rationale of this first scenario is to join the existing main transmission pipes in order to form loops that will, with limited investment, enabling the following:

- to distribute the water from the expanded/new (north and south) treatment plants,
- to cover a slightly extended area, particularly towards local areas where development is planned,
- to ensure in covered areas the benefits of a meshed system to better balance system pressure and provide alternate routes to supply water when one branch or plant must be temporarily disabled.

The completion of the inner loops will be carried out in Stage I and is illustrated in the following figure.

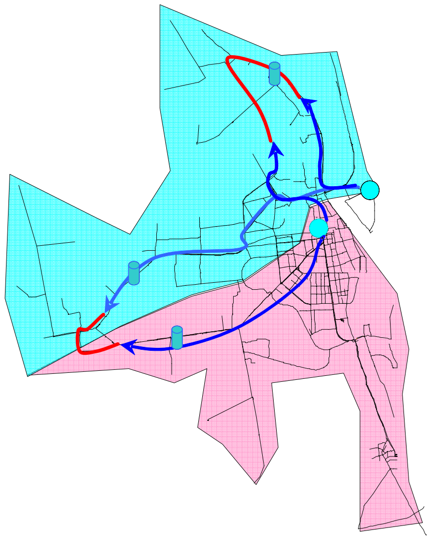


Figure 7-17 Typical Local Loops

(2) Middle Loop

This second scenario extends the above one to the south, creating a loop across the most populated suburban zone.

This second scenario is complementary to the first one. Crossing both main transmission lines westwards, it would hence create three more main line loops. These loops would further improve the meshed quality of the network, while enabling the efficient extension of the service area toward the north-west and south-west.

(3) Outer Loop

This last scenario accounts best for the wide extent of the Study Area, and the likely required service area in the long term, by forming a much larger loop around the current city limits, encompassing even the airport. To ensure sufficient pressure in every branch of these large loops will require that adequate installations be designed, dimensioned and budgeted.

7-4-2-3 Blocks

The third prong of the efficiency strategy is blocking. This is to continue the existing practice of completing the distribution system with closed, telemetered blocks, providing detailed control and management of consumption and water loss at the consumer end of the system. The existing telemetering layout is shown in the figure below. Distribution by closed blocks is essential for effective control of NRW. However, one result compared to an open distribution system is that the network has less absorptive/reactive capacity and is thus subject to greater fluctuations in pressure throughout the day as demand rises and falls and the plants attempt to accommodate. In other words, the blocking strategy requires a higher level of pressure management overall, which in turn necessitates implementation of the above-described Zoning and Looping strategies. The three prongs of the strategy are thus inter-connected and inter-dependent. Implemented together, the result will be an ideal network structure.

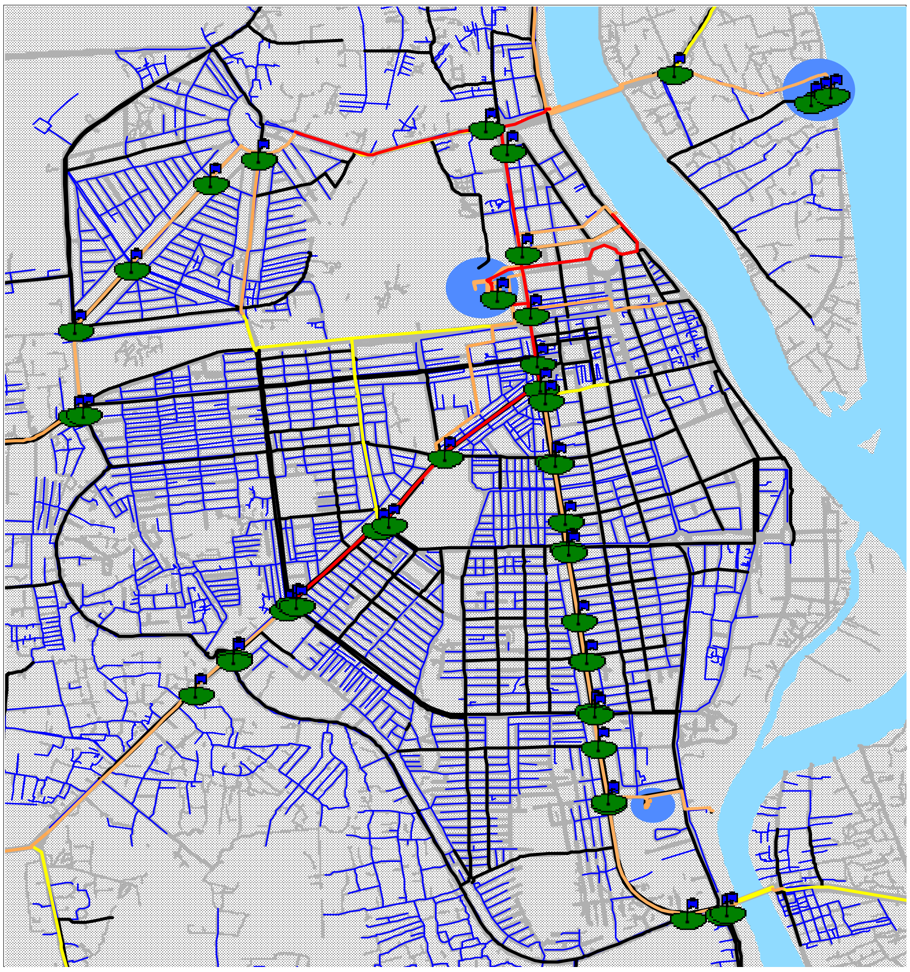


Figure 7-18 Existing Telemeters

7-4-3 Proposed CDS for 2005-2010

The 2005-2010 plan is designed to meet short-term demand in new areas up to 2010 and to complete the inner loops described in the strategy above. The pressure gradient at Chrouy Changva will be reduced so the pumps can function efficiently, maintaining a targeted minimum system pressure of 150 kPa.

Major transmission lines (400mm to 800mm) will be extended to the north and to the south, encompassing the following expansion areas: Ta Khmau; Ruessei Kaev Nord (Khmuonh); and Dangkao (Kakab, Trapeang Krasang, Dangkao Branch to Cheung Aek). In addition, booster pumps to fill the new storage tanks may be added if needed.

Stage I assumes the completion of three water tanks and execution of the master plan recommended expansion of Chrouy Changva treatment plant.

The Phase I expansion plan is summarized in the following table:

Table 7-18 Stage I Expansion Plan

2010

Base:	**WTP Production**	Phum Prek		150 000	(m3/d)	
		Chrouy Changva II		130 000	(m3/d)	
		Chamcar Morn		20 000	(m3/d)	
		Nominal capacity		300 000	(m3/d)	*Peak day water demand*
						Hourly coef. max. = 1.63
		Required capacity		255000	(m3/d)	Hourly coef. min. = 0.37
	Water Tanks	Olympic stadium	T1	2000 m^3	In use	
		Chaom Chau	T2	1500 m^3	In use	
		Pochentong Airport	T3	1500 m^3	In use	
		Chrang chamreh	T4	1500 m^3	In use	
		Ta Khmau	T5	1500 m^3	In use	
	Clear water reservoir	Phum Prek		25000 m^3	In use	
		Chrouy Changva I		5760 m^3	In use	
		Chamcar Morn		1500 m^3	In use	
		Chrouy Changva II		10000 m^3	Existing (2008)	

the main gaps to respect	**Pipes**	Hydraulic grade	In WTP		55.0	m
			In the main network		55.0	m
			everywhere as objective		30.0	m
			minimum		20.0	m
		Velocity	> 1000 mm	1.6 m/s		
			> 500 mm	2.0 m/s		
			< 500 mm	1.6 m/s		
					Min.	Max.
	Pumps	Head (m)	Phum Prek		39.0	500
			Chrouy Changva II		43.0	50.0
			Chamcar Morn		30.0	50.0
		Flow (l/s)	Phum Prek		640.0	2830.0
			Chrouy Changva II		560.0	2450.0
			Chamkar Morn		86.0	380.0

The following quantities of transmission pipes will be laid during the first Stage:

CDS 2005 - 2010

Lengths by diameter

Length (m)	Diameter (mm)	Material
1955	900	Ductile Iron
967	800	Ductile Iron
4572	600	Ductile Iron
16672	500	Ductile Iron
10718	400	Ductile Iron
10056	300	Ductile Iron
5834	250	Ductile Iron
1351	225	HDPE

52 125 meters

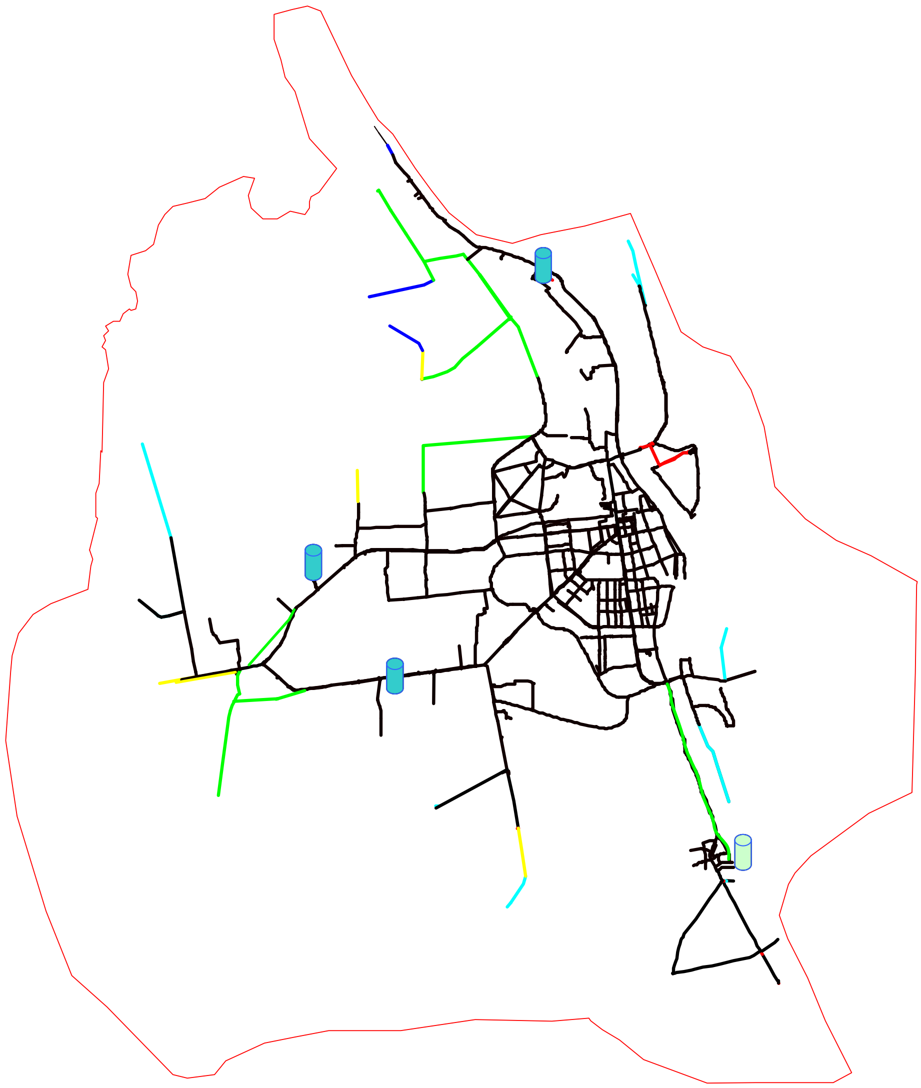


Figure 7-19 Pipes Installed Between 2005 to 2010

7-4-4 Proposed CDS for 2010-2015

Stage II accompanies the development of the proposed new Nirouth treatment plant with a supplementary production capacity of 100,000 m^3. The transmission line from Nirouth (1200 mm) will cross the Tonle Bassac heading toward the west. Once west of the City it will connect to a new north/south line (600-800 mm) that connects at the north end to the transmission line (800 mm) coming from Chrouy Changva. In this way the strategy of the middle loop will be realized, providing a complete route around the City as an alternative to the existing central north/south transmission line. The entire developing western area (north of the airport) will be served by the middle loop, which can be fed by either (or both) of the two largest treatment plants.

The following figure shows the pipes recommended for the period 2011-2015.

Table 7-19 Stage II Expansion Plan

2015							
the main gaps to respect	**Pipes**	**Hydraulic grade**	In WTP	< 60.0	m		
			In the main network	< 50.0	m		
			Everywhere as objective	> 30.0	m		
				Max.		Min.	
		velocity	> 1000 mm	1.6	m/s	1.6	m/s
			> 500 mm	2.0	m/s	2.0	m/s
			< 500 mm	1.8	m/s	1.8	m/s
		Material	Ductil Iron	≥ 225			
			PHD	≤ 225≤			
					Min.	Max.	
	Pumps	**Head (m)**	Phum Prek		39.0	48.0	
			Chrouy Changva II		40.0	47.0	
			Chamcar Morn		30.0	41.0	
			Nirouth I		47.0	50.0	
		Flow (l/s)	Phum Prek		780	2830	
			Chrouy Changva II		680	2450	
			Chamcar Morn		100	380	
			Nirouth I		1000	3700	

CDS 2010 - 2015

Lengths by diameter

Length (m)	Diameter (mm)	Material
3510	1200	Ductile Iron
6960	1000	Ductile Iron
4340	800	Ductile Iron
1370	600	Ductile Iron
5100	500	Ductile Iron
1720	400	Ductile Iron
14570	300	Ductile Iron
10140	250	Ductile Iron
16320	225	HDPE

64 030 meters

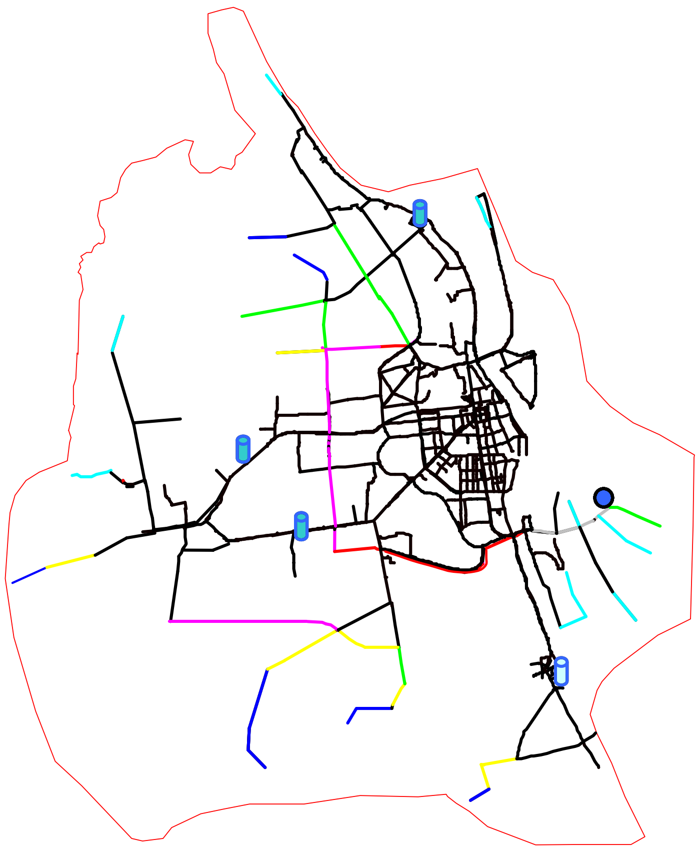


Figure 7-20 Pipes to be Installed Between 2011 to 2015

7-4-5 Proposed CDS for 2015 - 2020

Stage III is marked by the expansion (phase 2) of Nirouth, bringing another 100,000 m^3/d in production capacity, and continued growth in demand and service area. More than 80 percent of the entire Study Area will be covered by the CDS. The key characteristic of the network expansion plan will be the realization of the outer loop, which will reach from the southwestern corner of the middle loop south, around the airport, then north and finally connecting back to the east toward Chrouy Changva. The result is nested, interconnected loops providing a high level of long term security, balance and flexibility to the overall system.

Table 7-20 Stage III Expansion Plan

2020							
Base:		Nominal capacity	500 000	(m^3/d)			
		Required capacity	415 000	(m^3/d)			
		Hourly coef max	= 1.63				
		Hourly coef min	= 0.37				
the main gaps to respect	**Pipes**	Hydraulic grade	In WTP	< 60.0	m		
			In the main network	< 55.0	m		
			everywhere as result	> 30.0	m		
				Max.		Min.	
		Velocity	> 1000 mm	1.6	m/s	0.2	m/s
			> 500 mm	2.2	m/s	0.3	m/s
			< 500 mm	1.8	m/s	0.3	m/s
				Min.		Max.	
	Pumps	Head (m)	Phum Prek	39.0		48.0	
			Chrouy Changva II	40.0		47.0	
			Chamcar Morn	30.0		41.0	
			New WTP I + II	47.0		50.0	
		Flow (l/s)	Phum Prek	780.0		2830.0	
			Chrouy Changva II	680.0		2450.0	
			Chamcar Morn	100.0		380.0	
			New WTP I + II	2000.0		7400.0	

CDS 2015 – 2020

Lengths by diameter

Length (m)	Diameter (mm)	Material
1000	600	Ductile Iron
9000	500	Ductile Iron
13800	300	Ductile Iron
8100	250	Ductile Iron
24500	225	HDPE

56 400 meters

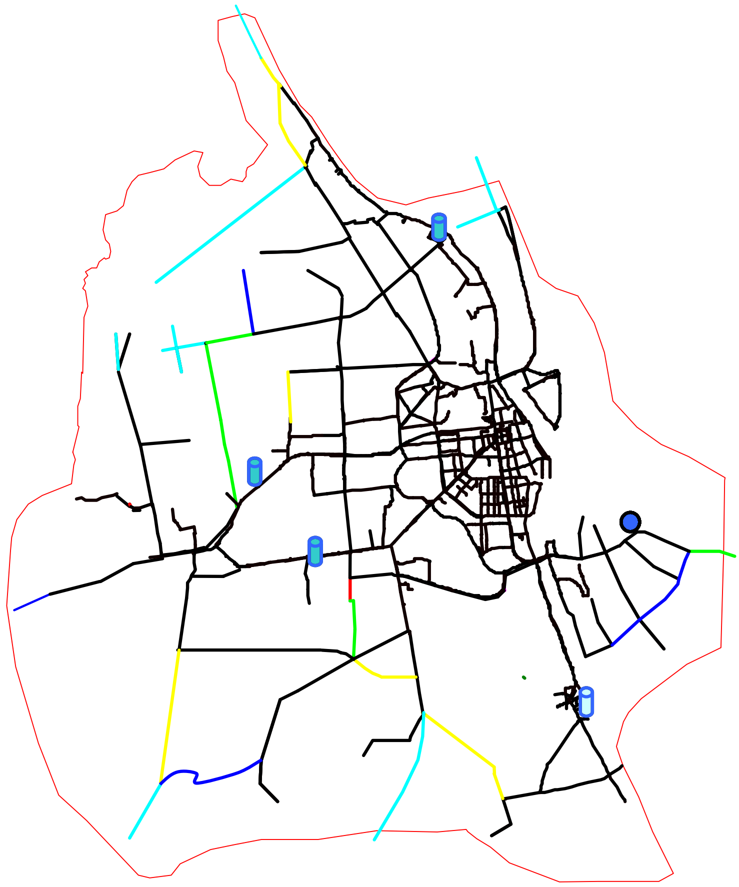


Figure 7-21 Pipes To Be Installed Between 2016 to 2020

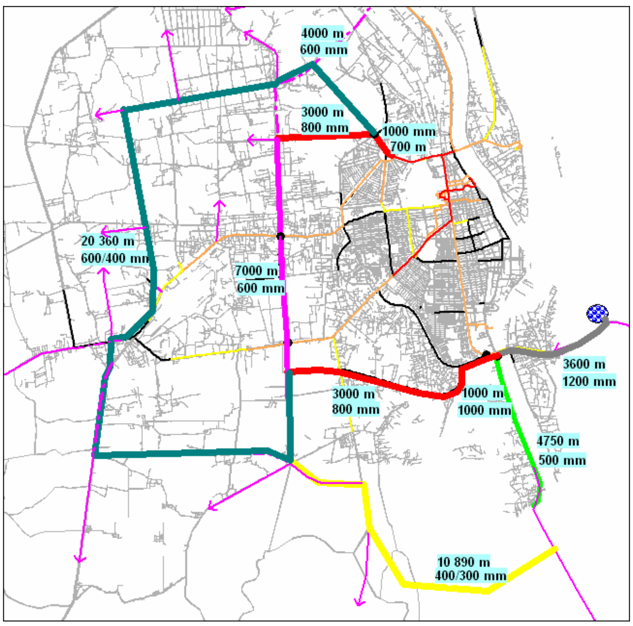


Figure 7-22 Main Loops at 2020

Chapter 8. Peri-Urban Water Supply Development Plan

Chapter 8. Peri-Urban Water Supply Development Plan

8-1 Present Water Supply in Peri Urban Areas

8-1-1 General

The Peri-Urban Area is defined as the suburbs of the Municipality of Phnom Penh (MPP) plus a part of Kandal Province, as follows:

- Suburban areas of MPP -- Mean Chey and Ruessei Kaev districts
- Kandal Province -- Ponhea Lueu, Angk Snuol, Kandal Stueng, Ta Khmau City, Kien Svay

In this master plan, water supply means a safe water supply by piped water or public deep well. Private, shallow, hand-dug wells and shallow tube wells with a depth of less than 30 meters are excluded.

8-1-2 Present Condition of Rural Water Supply

Rural people can access safe water with coverage of less than 29 percent in Cambodia. Approximately the same conditions apply to the rural part of the Study Area. There is no detailed data available, but water supply coverage including shallow, hand-dug wells may be 20 to 25 percent in Kandal Steung District, 30 to 40 percent in Kien Svay District, 25 to 30 percent in Angk Snuol District, and 30 percent in Ta Khmau City on the basis of unofficial data of the Department of Rural Water Supply (DRWS) in the Ministry of Rural Development (MRD). However, the suburbs of Phnom Penh City are different compared with other rural areas. The Project for Rural Water Supply in Peri-Urban Areas of Phnom Penh City, (JICA 2005, hereinafter referred to as the "Peri-Urban Project") was implemented and completed in 2004. A total of 165 wells were constructed and safe water was supplied to 34,650 persons in the suburbs of Phnom Penh City. The coverage of public safe water supply in 2005 will reach about 70 percent in the whole Study Area, 44 percent in the Peri-urban Area, and only 6 percent in Kandal Province, as shown in Table 5-3.

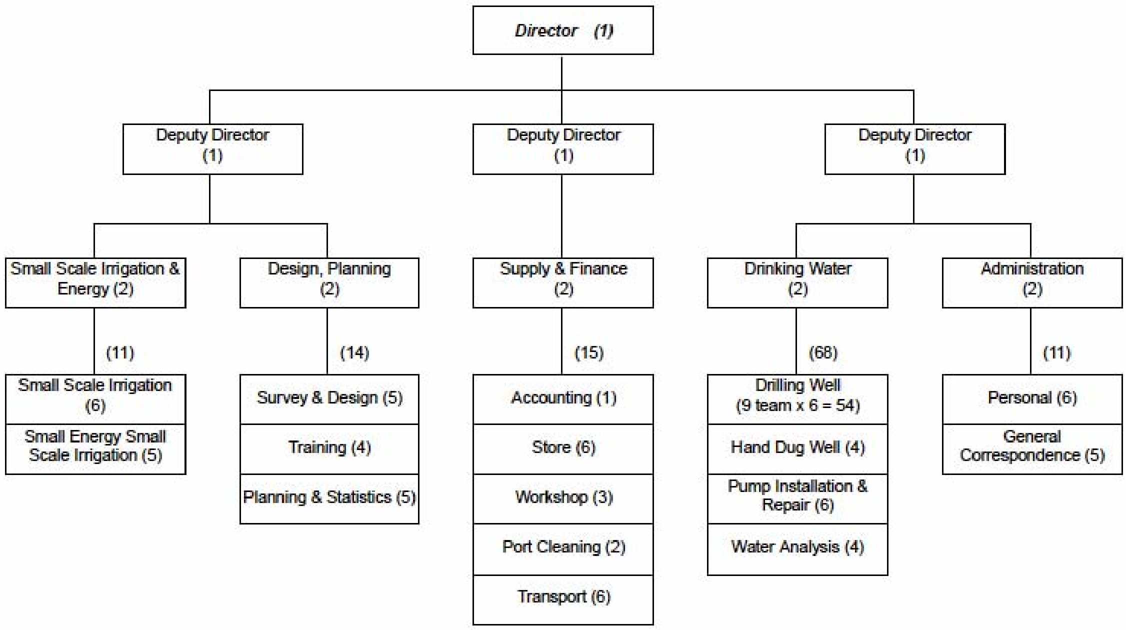
8-1-3 Implementation Organization for Rural Water Supply

The responsible organization for rural water supply is the Department of Rural Water Supply (DRWS) of the Ministry of Rural Development (MRD), as shown in the following chart.

Total staff is 133. The responsible sections for engineering are shown in the following table.

The Peri-Urban Project was implemented by DRWS. 165 production wells were constructed in the suburbs of Phnom Penh City in the Study Area and have since been managed by DRWS.

DRWS also has experience in the implementation of well-based rural water supplies in cooperation with UNICEF and other organizations working in the Study Area and other provinces under the action plan of The Second Five Year Rural Water Supply Plan 2001-2005 (RWSP-II). RWSP-II planned to supply safe water to a rural population of 3,576,000 by constructing 44,700 water supply facilities, including 6,100 deep wells. DRWS therefore has sufficient recent experience in the implementation of well-based, rural water supplies.



Source: MRD/DRWS

Figure 8-1 Organization Chart of DRWS

Table 8-1 Responsible Section & Engineer for the Implementation of Projects in DRWS

Department	Section	Staff	Responsibility
Drinking water	Drilling	54	O/M for machinery Drilling work
	Pump installation & Repair	11	O/M for machinery Installation & repair for pump
	Water analysis	4	O/M for equipment Test & Monitoring for water quality
Design & Planning	Survey & Design	5	O/M for geophysical equipment Field work
	Planning & Statistics	5	Management for well data base
Supply & Finance	Workshop	3	Inspection & repair for machinery
	Total	**77**	

8-1-4 Relevant Plans for the Rural Water Supply

(1) National Strategy

The Royal Government of Cambodia has declared its "Rectangular Strategy" to attain poverty reduction, development, progress, prosperity, national harmony, and happiness of the Cambodian people. Relevant points for rural water supply in the "Rectangular Strategy" are as follows:

- Providing all citizens with clean and safe water,
- Protecting all citizens from water-related diseases,
- Providing adequate water supply to ensure food security, economic activities and appropriate living standards, and

Ensuring water resources and an environment free from toxic elements.

The Government has also set out the Cambodian Millennium Development Goals (CMDGs), reflecting the global Millennium Development Goals (MDGs). MRD has committed to the overall target of rural water supply and sanitation in the CMDGs that the coverage of the rural population with access to safe water will be increased from 24 percent in 1998 to 50 percent in 2015.

The third five year plan, the National Strategic Development Plan (NSDP, 2006-2010) is under preparation. MRD has been shifting its development strategy to community-based integrated (multi-sector) rural development programs and is updating its investment strategy for the timeframe of 2005-2015. MRD plans to develop water supply facilities targeting a population of 3.15 million by 2015. However, the Study Area is not included in their target area.

(2) Relevant Projects by Other Donors

Other donors have implemented rural water supply projects that mainly focused on the rural provinces. UNICEF, China and several NGOs have constructed some water supply facilities (mostly wells) in the peri-urban part of the Study Area. However, about 5 of every 17 wells have malfunctioned.

UNICEF has a plan to construct wells for domestic water supply in several provinces starting in 2005, but these are not expected to affect the Study Area.

8-1-5 Water Sources

Natural water sources for the peri-urban part of the Study Area can be classified into four types, as follows:

- Traditional surface water sources of river and pond,
- Alluvial aquifer,
- Deep fissure aquifer, and
- Rainwater

According to a sample survey of 191 families in areas not served by PPWSA piped water systems, about 23 percent of wells are shallower than 10 meters and a few public wells were donated by UNICEF, NGOs, and JICA.

The surface waters in small streams and small ponds and some of the hand-dug wells (depth of less than 5 meters) on shallow aquifers dry up in the dry season. Ponds located on the premises of

Pagodas play an important role in domestic water supply for villagers in both dry and rainy seasons, especially in the dry season.

Table 8-2 Water Source of the Household in Non-Service Area (multiple choices)

Season	Private pipe system	Well	Pond	River	Rainwater	Buying	Others	Total
Dry season	48	83	17	12	3	71	2	236
Percentage	20.3%	35.1%	7.1%	5.1%	1.3%	30.1%	1.0%	100%
Rainy season	48	83	23	10	144	58	2	366
Percentage	13.1%	22.7%	6.3%	2.7%	39.3%	15.8%	0.1%	100%

Unit: household

Rainwater harvesting is common in the Study Area, stored in vessels for domestic water supply during the rainy season. The poor rely on it during the rainy season in order to avoid buying water; but they are often obliged to buy water in the dry season. Residents usually buy about 30 percent of their total needs in the dry season, versus 16 percent in the rainy season. Water shortages are clear in the rural and peri-urban areas compared with urbanized areas of Phnom Penh City and Kandal Province.

Detailed hydrological and hydrogeological data for water sources in these areas are not maintained, even for wells constructed by UNICEF in the districts of Kandal Province. A survey was conducted for these areas to obtain basic hydrogeological data. PPWSA and a private water company provide water to a part of Ponhea Lueu district and Ta Khmau district. Otherwise, most residents of Kandal Province get water from the above-mentioned four water sources.

Water sources and their characteristics in the suburbs of Phnom Penh City and Kandal Province in the Study Area are summarized in the following table.

Table 8-3 Rural Water Sources and Their Characteristics

Water source	Characteristics			Water quality
Small tributaries & ponds,	Dried up in the dry season, required purification cost			Organic contamination High COD, BOD
Rivers and ponds	Sufficient volume and can be used through year Required purification cost			Organic contamination High COD, BOD
Rain water	Unstable supply			Organic contamination
Water vender	Expensive: 2,500-6,000 Rial/m^3 (PPWSA: 350 R/m^3)			Only for drinking
Groundwater Well type	**Well depth (Diameter)**	**Aquifer type**	**Geology**	**Water quality**
Shallow hand-dug	< 7m (1-1.5 m)	Unconfined Dried up in dry season	Silt & clay	Organic contamination High Cl, TDS
Shallow tubular	< 30 m (10-15 cm)	Unconfined / Confined	Silt & clay Sand & gravel	Less contamination High Fe, Cl, TDS
Deep tubular	> 30 m	Confined	Silt & clay, Sand & gravel,	High Fe
Deep tubular	> 30 m (10-15 cm)	Confined	Sand & gravel, Weathered / Crushed zone	High Fe

8-1-6 Water Quality

The description of water quality is based on the results of water quality testing conducted under the Peri-Urban Project. Water quality testing was conducted on samples from production wells, details of which are shown in Table 8.4. Water quality of groundwater is comparatively worse and yields are lower in Kandal Stueng District.

From the viewpoint of water quality, it is recommended to target water source development from deep alluvial and fissure aquifers.

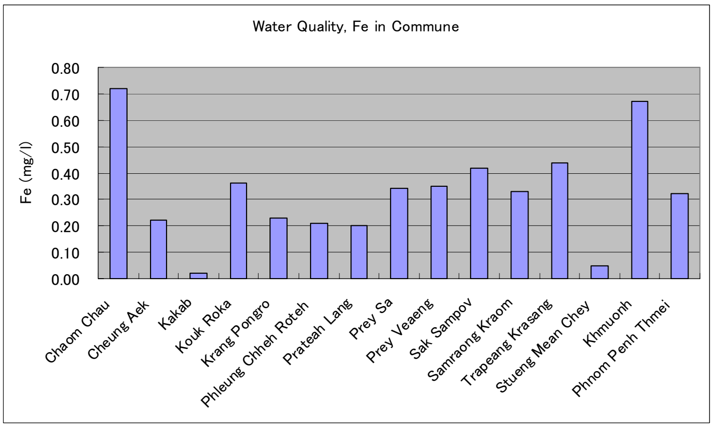
8-1-6-1 Water Quality in Communes

Water quality is summarized for each commune in the following table. pH, N_2, and N_3 do not exceed WHO Guidelines. Turbidity, total hardness, So4, E.coli, and coliform bacteria are few (less than 5 percent in 165 samples), but TDS, Fe and Cl are high in some communes.

Table 8-4 Water Quality in Commune Average on Peri-Urban Project

District	Commune	Sample size	TDS	Fe	Mn	Cl	SO_4	F	Coliform bacteria
		(well)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(c/ml)
	WHO Guideline 2004		1000	0.3	0.4	250	250	1.5	0
Dangkao	Chaum Chau	7	567	0.72	0.22	19	38	0.98	0
	Cheung Aek	4	483	0.22	0.12	67	33	0.46	0
	Kakab	8	1522	0.02	0.26	442	69	1.32	0
	Kouk Roka	26	742	0.36	0.22	100	49	0.80	2
	Krang Pongro	2	787	0.23	0.00	61	34	0.54	0
	P.C. Rotel	7	397	0.21	0.02	39	36	0.55	0
	Prateah Lang	5	655	0.20	0.02	54	15	0.28	0
	Prey Sa	14	425	0.34	0.01	46	21	0.70	0
	Prey Veaeng	4	407	0.35	0.02	32	11	1.13	0
	Sak Sampov	10	455	0.42	0.04	18	236	0.81	1
	Samraong Kraom	24	1249	0.33	0.21	308	68	1.10	0
	Trapeang Krasang	10	776	0.44	0.16	287	83	0.85	0
Mean Chey	S. Mean Chey	4	480	0.05	0.02	54	26	0.16	0
Ruessei Kaev	Khmuonh	22	760	0.67	0.17	75	56	0.55	0
	P.P. Thmei	18	494	0.32	0.02	39	41	0.33	1
Total 165 samples (wells)									
JICA Test well in 2002									
Dangkao	Sak Sampov	T-56	794	0.28	0.00	48	76	2.33	0
Mean Chey	Stueng Mean Chey	T-67	849	0.05	0.02	97	41	0.37	0
Ruessei Kaev	Khmuonh	T-71	2343	0.09	0.00	455	383	1.05	0

Notes: Hatched value = exceeds the standard



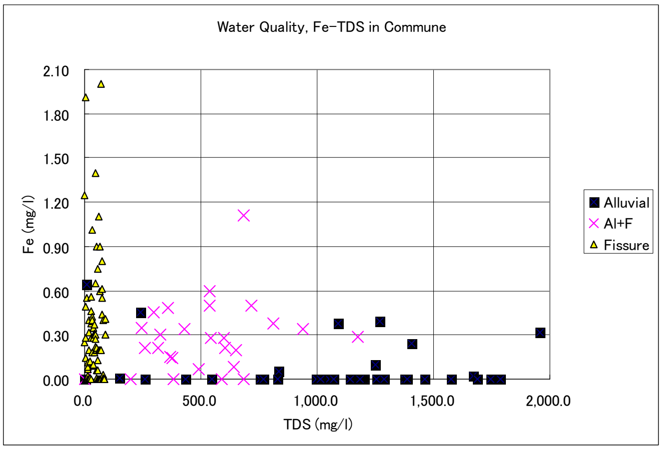
Iron (Fe) exceeds the guideline (<0.3 mg/liter) in 8 of 15 communes, especially Chaum Chau and Khmuonh communes, with an average of more than 0.6 mg/liter.

Chloride (Cl) exceeds the guideline (250 mg/liter) in Kakab, Samraong Kraom, and Trapeang Krasang districts.

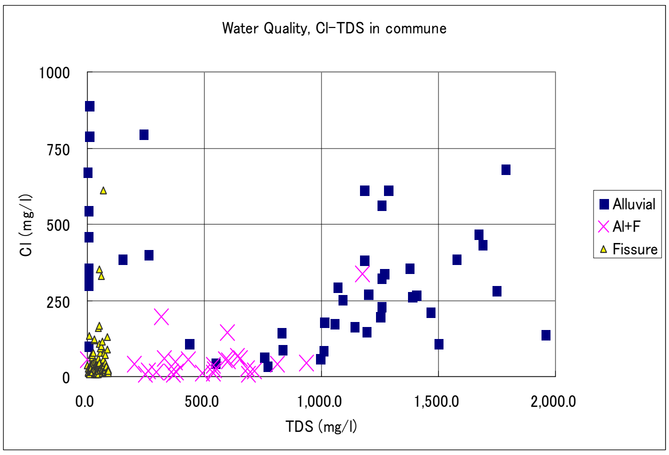
The people in these communes dislike the taste of the water and avoid drinking it. Instead they buy drinking water from vendors at a price of 2500 to 6000 Riels/m^3.

It is noteworthy that arsenic is detected in Kouk Roka Commune and Fluoride is detected in 17 of 165 samples at Chaom Chau, Kakab, Kouk Roka, Phlueung Chheh Roteh, Prey Veaeng, Sak Sampov, and Samraong Kraom communes, and is especially prominent in Kakab, Prey Veaeng, and Samraong Kraom communes. These chemicals are considered to be harmful to human health.

8-1-6-2 Water Quality in Aquifer



Total Dissolved Solids (TDS) exceed the guideline (<1000 mg/liter) in half the samples from alluvial aquifers and even higher from fissure aquifers. In general, it is unusual that the TDS content of alluvial aquifers is lower than fissure aquifers.



Fe content in fissure aquifers and combined alluvial and fissure aquifers (Al+F) is higher than that of alluvial aquifers (Al). It suggests that fissure aquifers exhibit less recharge with low permeability compared with alluvial aquifers.

Chloride (Cl) content shows the same tendency as TDS content in alluvial aquifers. Chloride exceeds the guideline (<250 mg/liter) in more than half the samples from Alluvial aquifers, comparatively higher than from fissure aquifers.

8-1-7 Service Area

The service areas of water supply in Peri-Urban Areas are as follows:

- Phnom Penh City: Dangkao
- Kandal Province: a part of Ponhea Lueu, Angk Snuol, Kandal Stueng, Ta Khmau City, and Kien Svay.

The included areas of Kandal Province are located adjacent to the suburban districts of Phnom Penh City. Piped water has been supplied by a private company in a part of Ponhea Lueu District and Ta Khmau City.

8-1-8 Service Level

Level 1 water supply systems (point source consisting of well with hand pump) are common for safe water supply in peri-urban areas. There are no public faucets (Level 2 water supply system). As mentioned before, water is supplied by pipeline with faucet (Level 3) in two areas.

Both alluvial and fissure aquifers have a small safe pumping yield with an average of 1.2 or 1.7 m^3/hour. Drawdown levels of both aquifers in pumping tests conducted during the construction stage of the Peri-Urban Project showed drops of 15 to 30 meters with a pumping volume of 1.8 to 2.4 m^3/hour. It indicates that hydrogeological conditions in this area are not suitable for withdrawing groundwater by submersible motor pump because of low recharge rate and low permeability, with a range of 1x10-4 to 1x10-6 cm/sec.

8-1-9 Served Population

The present population served with safe water (piped water and public deep well) in communes was shown in Table 5-3 and summarized by district in the following table.

Table 8-5 Present Population Served by Safe Water in the Peri-Urban Areas (2005)

District	Population in 2005	Served by safe water supply		Total served population	Total coverage (%)	Remaining non-served population
		Piped water	JICA well			
Dangkao	118,466	30,506	25,410	55,916	47.2	62,550
Mean Chey	233,348	128,957	840	129,797	55.6	103,551
Ruessei Kaev	267,546	149,794	8,400	158,194	59.1	109,352
Kandal Stueng	16,068	0	0	0	0	16,068
Kien Svay	57,765	0	0	0	0	57,765
Angk Snuol	37,892	0	0	0	0	37,892
Ponhea Lueu	14,427	0	0	0	0	14,427
Ta Khmau	68,955	11,143	0	11,143	16.2	57,812
Total	814,467	320,400	34,650	355,050	43.6%	459,417

The coverage of public safe water supply will become about 44 percent in the peri-urban areas. Safe water coverage for the part of Kandal Province in the Study Area is very low, 6 percent on average, although it is 50 to 60 percent for the three suburban districts of Phnom Penh City.

8-2 Water Demand

8-2-1 Basic Condition

MRD is pursuing the target of raising rural coverage from 24 percent in 1998 to 50 percent in 2015. However, a higher target is set in this study for the peri-urban areas of Phnom Penh City – 80 percent for the peri-urban districts of Dangkao, Mean Chey, and Ruessei Kaev. Accordingly, and in the interest of fairness and equity, the Study Areas in Kandal Province located adjacent to these three districts of MPP shall have the same target water supply ratio of 80 percent.

8-2-2 Served Population

As mentioned before, the safe water coverage will be 80 percent of the population of each commune or district. Therefore, the target population will be 182,070 persons in the suburban districts of Phnom Penh City and districts of Kandal Province. Projected population and served population in five-year increments are shown in Table 8.6.

8-2-3 Water Demand

The population to be covered by safe water will be 182,070 persons and the target Unit Consumption Rate (UCR) will be 40 liters/capita/day in 2020. So, water demand is projected to be 3,839 m^3/day in the peri-urban areas.

Table 8-6 Projected Population to be Served by Safe Water in 2020

District	Projected pop.	Population to be served in 2020		Coverage	To be served by well (80% of district)		
		Piped	JICA well	(%)	Pop.	Demand (m^3/day)	Coverage (%)
MPP	**2,006,009**	**1,776,757**	**34,650**	**90.3**	**32,760**	**1,310**	**91.9**
Urban 4 districts	683360	683360	0	100	0	0	100
Dangkao	387948	252166	25410	71.5	32760	1310	80.0
Mean Chey	395779	356201	840	90.2	0	0	90.2
Ruessei Kaev	538922	485000	8400	91.6	0	0	91.6
Kandal	**297,817**	**89,345**	**0**	**30.0**	**149,310**	**5,972**	**80.1**
Kandal Stueng	25459	0	0	0	20370	815	80.0
Kien Svay	76093	7,609	0	10.0	53340	2134	80.1
Angk Snuol	84546	25364	0	30.0	42210	1688	79.9
Ponhea Lueu	20451	1611	0	7.9	14910	596	80.8
Ta Khmau	91268	54761	0	60.0	18480	739	80.2
Total	**2,303,826**	**1,866,102**	**34,650**	**82.5**	**182,070**	**7,282**	**90.4**

UCR in rural area = 40 liter/capita/day (0.04m^3/day)

Piped safe water and existing public wells will supply 80 percent of the district population in Mean Chey, and Ruessei Kaev districts in Phnom Penh City in 2020. However, Pong Tuek, Prey

Veaeng, Krang Pongro, Sak Sampov, and Cheung Aek communes in Dangkao District are located in remote rural areas and these communes cannot be supplied this way. Accordingly, these communes will be supplied by point water sources, but still with coverage of 80 percent. Safe water shall be also supplied to some districts in Kandal Province bordering on Phnom Penh City with the same 80 percent coverage ratio.

8-3 Groundwater Potential

8-3-1 Groundwater Table

The groundwater table plays an important role with respect to the potential of unconfined aquifers.

Under the Peri-Urban Project, a total 165 production wells were constructed and groundwater levels were measured for each production well in the dry and rainy season before the commencement of pumping tests. Groundwater levels in the rainy season were higher in most cases; but their variation was not great, about 0.5 to 1 meter for tube-wells in general.

Some shallow, hand-dug wells with a depth of 5-6 meters cannot be utilized in the dry season since groundwater levels fall by about 10 cm to 1.0 m. Village residents should be informed about groundwater level conditions prior to constructing any well to ensure sufficient depth for stable availability even during the dry season.

Table 8-7 Average Groundwater Table in Commune

District	Commune	Number of well	Bedrock depth	SWL*2 (dry season)	SWL (rainy season)	Safe yield
		(wells)	(GL-m)*1	(GL-m)	(GL-m)	(l/min)
Dangkao	Chaom Chau	7	35	6.3	9.0	17
	Cheung Aek	4	38	5.4	4.4	39
	Kakab	8	117	21.9	15.5	18
	Kouk Roka	26	59	6.1	5.3	39
	Krang Pongro	2	34	-	5.7	31
	Phlueng Chheh Roteh	7	28	4.4	4.7	20
	Prateah Lang	5	24	-	3.1	24
	Prey Sa	14	32	6.6	5.0	30
	Prey Veaeng	4	33	6.4	-	29
	Sak Sampov	10	31	7.2	5.1	28
	Samraong Kraon	24	121	14.1	9.9	19
	Trapeang Krasang	10	72	9.4	14.7	28
Mean Chey	Stueng Mean Chey	4	35	29.0	-	48
Ruessei Kaev	Khmuonh	22	26	9.7	8.6	22
	Phnom Penh Thmei	18	32	15.6	11.3	19
Total average		165 wells	55m	9.9m	8.8m	26 l/min

Notes: *1: depth from ground level, *2: Static water level Dry season: November to April, rainy season: May to October
Data source: "The Project of Rural Drinking Water Supply in Peri-Urban of Phnom Penh City, 2005, JICA"

8-3-2 Groundwater Aquifers

Two types of groundwater sources are expected in the Study Area as follows:

- Granule Alluvial Aquifer: yielding in the unconsolidated sand and gravel (clay, silt)
- Fissure Aquifer: yielding in the weathered zone or crushed zone in the bedrocks.

These two types of aquifers are detailed below. Groundwater potential will be estimated from the safe pumping yield conducted under the Peri-urban Project for 165 wells as follows.

Table 8-8 Safe Pumping Yield in Aquifer Type

Aquifer	Number of well	SWL	SWL	Safe pumping yield		
		Dry season	Rainy season	Average	Maximum	Minimum
	(wells)	(GL-m)	(GL-m)	(l/min)	(l/min)	(l/min)
Alluvial	48	12.12	11.86	20	40	8
Alluvial with Fissure (included Terrace dt.)	26	8.47	5.56	28	103	10
Fissure	91	9.38	7.66	29	210	8
Average in Total	165	9.9	8.8	26	210	8

Data source: "The project of Rural Drinking Water Supply in Peri-Urban of Phnom Penh City, 2004, JICA"

Alluvial Aquifer

Alluvial aquifers yield in the granular layer of unconsolidated alluvium. In general, excellent alluvial aquifers will be found in sand and gravel without silt and clay.

Flood plain deposits in the Study Area are mainly composed of deltaic silt and clay with sand lens. Terrace deposits distributed in the western part of the Study Area are mainly composed of sand and gravel with silt and clay. In the Study Area, the former cannot provide a sufficient yield of groundwater and the latter are supposed to contain a lot of fine materials and are not so productive based on the groundwater yield of existing wells.

The safe pumping yield of alluvial aquifers was estimated at only 20 liters per minute on average and 40 liters per minutes at maximum.

Alluvial with Fissure Aquifer

"Alluvial with Fissure Aquifers" mainly yield in the layer of the terrace deposit consisting of sand and gravel plus clay and weathered rock. The safe pumping yield of the sand and gravel layer is estimated at only 28 liters per minute on average and 103 liters per minute at maximum.

Pumping tests have not been conducted for private wells in the Study Area and the hydrogeological constant cannot be investigated in this report. However, field reconnaissance of a commune in Kandal province found shallow-tube wells with a depth of less than 30 meters that cannot yield groundwater every day in the dry season. Shallow-tube wells draw water from unconfined aquifers with a volume of less than 1 m^3/day from fine materials of clay and silt. These aquifers are located in the eastern part of the Study Area, even more aquifer in the terrace deposits. It suggests that permeability and transmissivity of the unconfined aquifers will be very low and little recharge can be expected.

Fissure Aquifer

Three test wells, nos. 56, 67 and 71, were constructed in "The Study on Groundwater Development in Southern Cambodia, 2002, JICA". The objective was to investigate the characteristics of fissure aquifers in the Study Area. The bedrocks, composed of sandstone or slate, were distributed at depths greather than 20 meters. In general, groundwater yields in the loosened, weathered zone without secondary clay in the cracks or in the joint crushed zone without fault clay. But, loosened cracks in the Study Area will be filled by secondary clay and or fault clay and low yield is therefore expected. For these reasons and for planning purposes, the aquifer characteristics are assumed to be as follows:

- Transmissivity: $T = 2 - 6\ m^2/day$
- Specific capacity: $Sc = 0.5 - 3\ m^3/day/m$

91 of the production wells constructed by the "Peri-Urban Project" developed and used fissure aquifers. Safe pumping yields of fissure aquifers were estimated at only 29 liters per minute on average and 210 liters per minute at maximum.

Conclusion

The Study recommends that the deep aquifers located more than 30 meters deep be utilized for the groundwater source.

Near the Airport and along the Route No. 3 of Chaom Chau, Kakab, and P.P. Thmei communes, the safe yield is less than 20 liters/min. This is lower than yields in other communes.

Some of the existing private wells have inadequate safe yields and have poor water quality. These wells will likely dry up in the dry season. These phenomena suggest that the low recharge rate may be caused by the occurrence of an impermeable layer of alluvium, and the low flow rate of groundwater caused by the low permeability in the clashed zone of bed rocks.

Both alluvial aquifers and fissure aquifers will not be suitable for middle to large scale development because of low safe pumping yield and transmissivity, but they can be used for small scale development of rural water supply with hand pumps without damage to the environment. The groundwater potential in the Study Area can only support development of Level I service. Higher withdrawal rates may irreparably damage yield potential.

8-4 Development Plan

The basic concept for the safe water supply development plan is as follows:

Target year:	2020
Coverage of safe water:	80 percent of each district population
Target population:	95,971 persons
Unit Water Consumption:	40 liter/capita/day
Water supply facilities:	Deep well
Safe pumping yield of well:	20 liter/minute (=1.2 m^3/hour)
Coverage person per one well:	210 person/well
Design water supply amount:	8,400 liter/well
Required number of wells:	457 wells (95971 persons/ 210/well)
Water supply level:	Level 1 Tube-well with hand pump (plus a few with adequate yield / recharge for larger population)

The concept is in harmony with the design conditions of the "Peri-Urban Project." Details of each item are mentioned below.

(1) Unit Water Consumption (UWC) for Rural Areas

According to the results of *The Study on Groundwater Development in Southern Cambodia, January 2002* (JICA), UWC was a minimum of 30 l/c/d to a maximum of more than 100 l/c/d in some peri-urban villages of Phnom Penh City. MRD has not established the UWC standard for rural water supply. The WHO standard for water demand is as follows.

Table 8-9 WHO Standard for Water Demand per Capita

Water source	Distance	Standard amount of water consumption
River, pond, well	>1000 m	5 – 10 l/c/d
River, pond, well	500 – 1000 m	10 – 15 l/c/d
Village well	> 250 m	15 – 25 l/c/d
Public faucet	< 250 m	20 – 40 l/c/d

Wells will be constructed near houses within a radius of less than 250 meters, similar to the Peri-Urban Project. UWC will be 40 lcpd based on the results of the JICA Study and the upper limit of the WHO standard.

(2) Water Supply Facilities

Deep wells are recommended for the following reasons.

There are alternative water sources available to Ponhea Lueu District, which lies beside the Tonle Sap River and Trang Lake, Kandal Stueng District which lies beside Preaek Pnov River, and Kien Svay District beside the Bassac and Mekong Rivers. These districts can get water from rivers and lakes, but the raw water must be treated and pumped to the residents. It will be expensive to get safe water compared with “Level 1” water supplies based on wells providing groundwater that is naturally purified compared with surface water.

(3) Safe Pumping Yield of Wells

According to the results of the “Peri-Urban Project,” average pumping yields are as follows:

Alluvial aquifer:	20 liters/minute = 1.2 m^3/hour
Combined alluvial and fissure aquifer:	28 liters/minute = 1.7 m^3/hour
Fissure aquifer:	29 liters/minute = 1.7 m^3/hour

Fissure aquifers are recommended for the target aquifer of groundwater development from the viewpoint of yield. However, some wells had pumping yields of less than 1.5 m^3/hour in fissure aquifers. In the case of low yield or bad water quality from a fissure aquifer well, an alluvial aquifer well may be constructed. Neither types of aquifer contain harmful chemicals or toxic substances, so the target aquifer may be changed based on the hydro-geological conditions in each commune. Accordingly, safe pumping yield will be set as 20 liter/minute or 1.2 m^3/hour.

(4) Coverage per Well

Average family size is 5.2 in rural areas and 40 families can generally be clustered within 250 meters of one well. Therefore, one well can provide for about 210 people or about 40 families.

(5) Design Water Supply Amount per One Well

A yield of 8.4 m^3/day will be required for one well to provide for 210 persons at the UWC of 40 l/c/d. New wells should have a safe yield of 1.2 m^3/hour or more and capacity to supply this amount at least 7 hours per day.

(6) Water Supply Level

Level 1 (well point source with hand pump) is recommended for safe water supply in Peri-Urban Areas. Both alluvial and fissure aquifers have a small safe pumping yield with an average of 1.2 or 1.7 m^3/hour. Drawdown levels of both aquifers in pumping tests have dropped 15 to 30 meters with a pumping discharge of 1.8 to 2.4 m^3/hour in the construction stage of the “Peri-Urban Project.” Hydro-geological conditions in this area are not suitable for withdrawing groundwater by submersible motor pump.

The target water supply service level for peri-urban areas should be periodically reviewed in future considering economic progress, industrial development, population and population density.

8-5 Implementation Plan

8-5-1 Organization for Project Implementation and O&M

The Peri-Urban Project was implemented by DRWS of MRD. 165 production wells were constructed in rural sections of the Study Area and they have been managed by DRWS. DRWS also has experience in the implementation of level 1 rural water supply (by well) in cooperation with UNICEF and other organizations in both the Study Area and other provinces under the action plan of *The Second Five Year Rural Water Supply Plan, 2001-2005* (RWSP-II). RWSP-II was a plan to supply safe water to a rural population of 3,576,000 by constructing 44,700 water supply facilities, including 6,100 deep wells. DRWS has sufficient recent experience in the implementation of level 1 rural water supply.

Accordingly, considering the national plan and their past experience, it is recommended that DRWS be the implementing agency for both the study and the project. The recommended organization for Project Implementation and Operation and Maintenance (O/M) is shown in Table 8-10. This organization system has already been established and was adopted in the Peri-Urban Project (2005).

Table 8-10 Organization for Implementation and O&M

Level	Agency	Implementation stage	O&M stage
Nation	DRWS of MRD	Management & supervision of construction work	1. Major repair & well rehabilitation 2. Technical guidance for PDRD
Province	Water supply section of PDRD	Organizing WPCs and training for villagers	1. Major repair & well rehabilitation 2. Spare parts provision to WPC
Village	WPC (shall be established in each village	1. Assistance for construction work 2. establishing WPC	1. Minor repair for hand pump 2. Spare parts request to PDRD 3. Collecting water tariff, cleaning, and inspection of facilities

Operation and maintenance will be principally the responsibility of Water Point Committees (WPC). These shall be established for every well facility and group of households. The members of the WPCs shall be elected from among the users of the well. They have the duty to operate and maintain the well, collect the water tariff, clean the well site, and implement hygiene education.

<u>Proposed members of WPC:</u>

i. Representative: 1 person (also holding the post of accountant)
ii. Caretaker: 2 persons (man and woman)
iii. Cleaning person: 2 persons (man and woman)

8-5-2 Prioritizing Villages

The criteria for priority the villages are elaborated in the accompanying Feasibility Study. Villages with low safe water coverage who have established their WPC will have higher priority. Therefore, before and during the well construction stage, DRWS has the duty to enhance the awareness of villagers for establishing and joining the WPC.

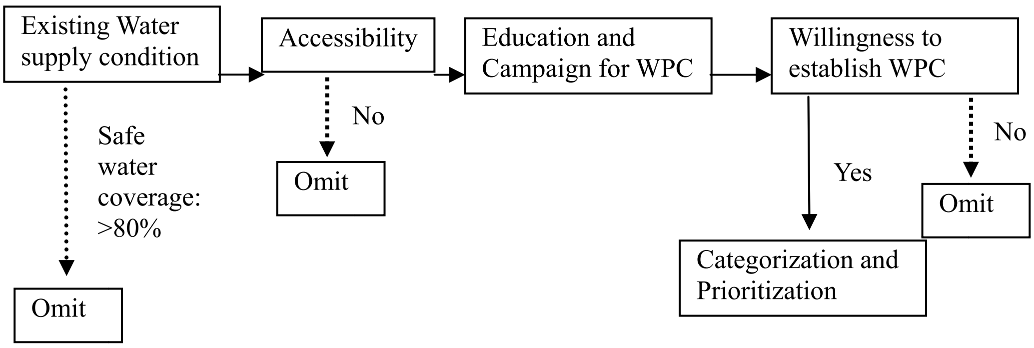


Figure 8-2 Village Prioritization for the Implementation

8-5-3 Implementation Plan

The tentative implementation schedule is shown in Table 8-11.

Table 8-11 Implementation Schedule of Well Construction

Stage						Year 2006 – 2010 – 2015 – 2020
Study	Basic design, Detailed design					
Soft component	Hygine education, Establishment of WPC Cooperation of well construction					
Hard component		Well construction plan*1				
	Province	To be Served in 2020		Target aquifer	Well depth (m)	Implementation schedule
	District	Target population	Reruired well			2006 – 2010 – 2015 – 2020
	Phnom Penh City	**32,760**	**156**			
	Dangkao	32,760	156	Fissure	60	
	Kandal Province	**149,310**	**711**			
	Kandal Stueng	20,370	97	Fissure	60	
	Kien Svay	53,340	254	Fissure	60	
	Angk Snuol	42,210	201	Alluvial	40	
	Ponhea Lueu	14,910	71	Fissure	40	
	Ta Khmau	18,480	88	Fissure	60	
	Grand Total	**182,070**	**867**			

*1: Target = to cover 80% of commune population with safe water

The development plan and implementation schedule shall be elaborated in detail at the basic design (B/D) and detailed design (D/D) stages and financing sources investigated.

After the completion of implementation, safe water coverage will increase from 44 percent in 2005 to 82.5 percent in Peri-Urban Area and from 6 percent to 80 percent in the Kandal Province portion of the Study Area as shown in the following figure:

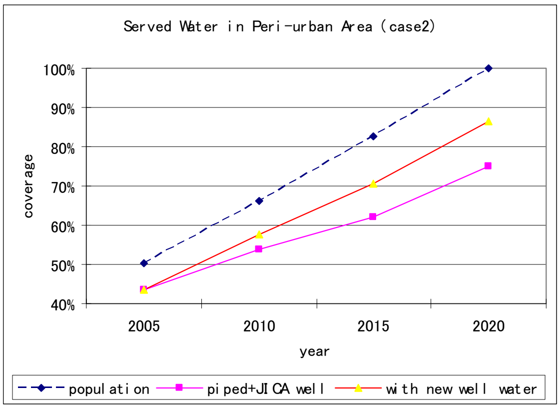


Figure 8-3 Safe Water Coverage in the Peri-Urban Area and Kandal Province