d) Operation Building

The operation building is composed of the following:
Administration room, distribution pump room, stores, and others.
In the premises of the plant, there are detached houses used as quarters and warehouses.

3.4.3.4 Mechanical Equipment

The mechanical equipment is completely out of order.

3.4.3.5. Electrical Equipment

The electrical equipment is completely out of order.

3.4.4 Transmission and Distribution

3.4.4.1 Outline

The service area of the Phnom Penh Water Supply is divided into 7 districts. Among the districts, the Don Penh, Seven January, Toul Kork, and Chamcar Morn districts receive 24-hour service, whereas the other three districts i.e., Russei Keo, Dang Kor, and Mean Chei, are supplied little water to the service area.

3.4.4.2 Distribution Pressure

During the field survey, pressure measurement was carried out. According to the results, distribution pressure is generally very low in all districts. In outer limits of the service area, no water is supplied. The pressure at locations just adjoining to the PPWTP is about 20 - 25 m. It was found that even in the four districts, 21% of the districts receive no water, the pressure is less than 0 m in about 28%, 0 - 2.5 m in 44 %, 2.5 - 5.0 m in 4 %, and more than 5.0 m in 3 % of the total area of the four districts. Fig-3.17 shows the pressure distribution.

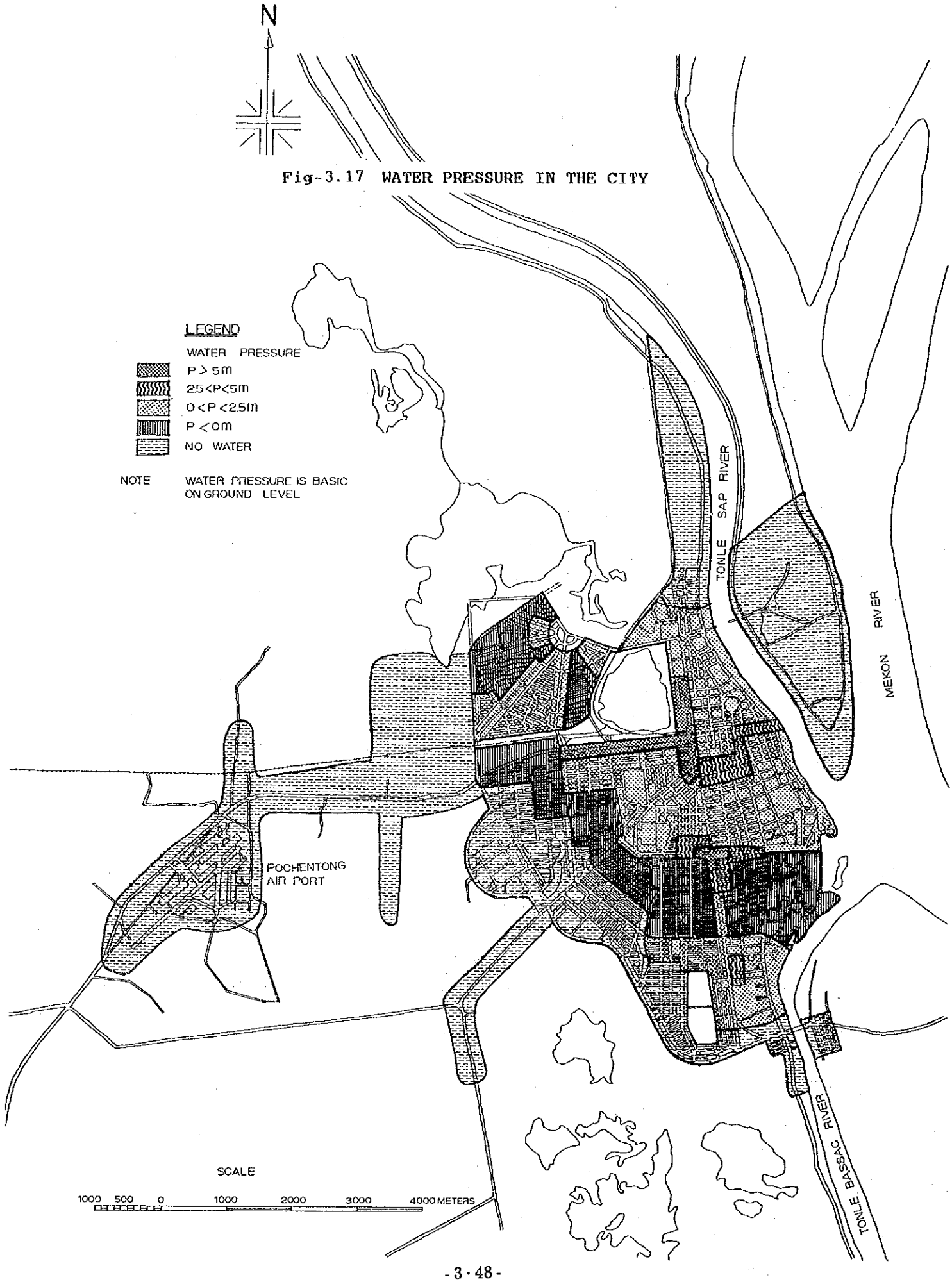


Fig-3.17 WATER PRESSURE IN THE CITY

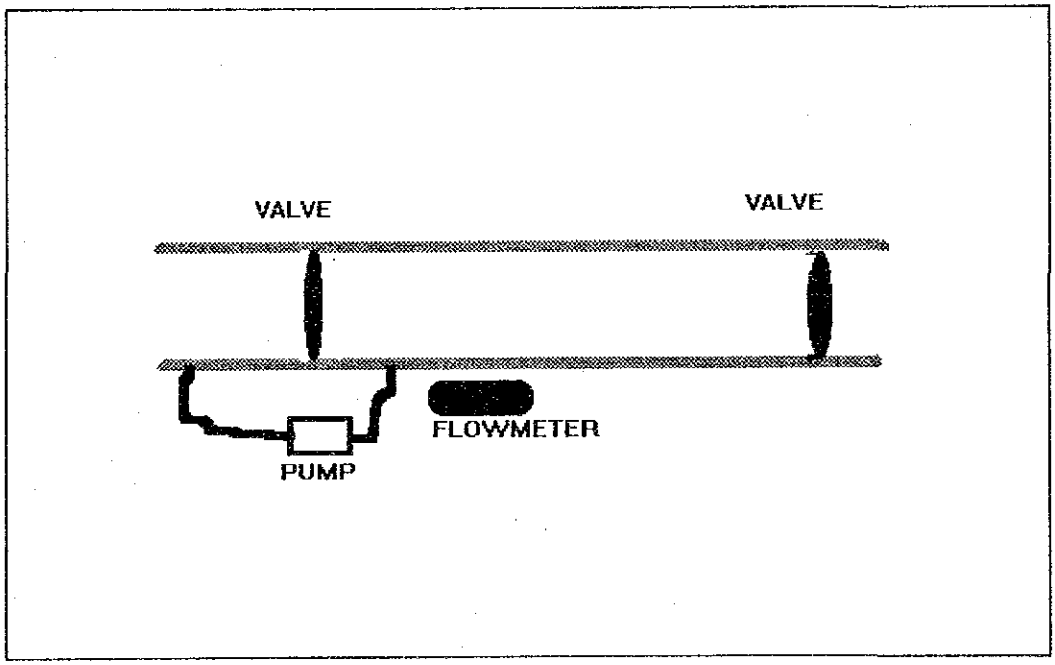
3.4.4.3 Drinking Water for the Citizen

In Phnom Penh, bottled water is available everywhere. Well-off people buy it. The urban population without water supply connections uses open wells, private vendors, and streams. Although there are shallow wells in some areas, it is reported by the UNICEF that most wells are not suitable for drinking purposes.

3.4.4.4 Leakage

Water leakage from the mains was measured in a pilot area. The survey method is summarized below and illustrated in Fig-3.18.

Fig-3.18 LAYOUT OF FLOW MEASUREMENT



-Installation of two valves along a main (diameter is 100 mm and the distance between two valves is about 100 m)
-Setting of a ultra-sonic flowmeter at upstream of the survey section.
-Setting of a pump.
-Closing of the two valves and all incorporation taps along the section.
-Applying pressure into the section.
-Checking the pressure and leakage.

When the pressure was about 35 - 45 m, leakage occurred from the service pipes and some service pipes were disconnected from the distribution main. From the measurements, the leakage was found to be 0.01 m^3/hr/m with 7 m and 0.031 m^3/hr/m with 34 m.

Leakage ratio was estimated in two ways, one from field test results and the other from supply and demand water volume. In the former, since the leakage was occurring from the turning points of service pipe or the service pipe itself, and service pipes were branched from the pipes with less than 250 mm diameter, all pipes with less than 250 mm were accounted for in the leakage ratio calculation. Table 3.11 shows the details. The leakage ratio was calculated as 45%. Using supply and demand data, water demand is estimated by multiplying population by the per capita consumption. The supplied amount is determined from the operation hours of the distribtution pumps. Then, the leakage amount is derived by subtracting demand from the supply amount (refer to Table 3.12). The leakage ratio is calculated as 44% by this method. Finally, the leakage ratio is set as 50% considering power supply improvement, because if there is no power supply failure, the pumps can be operated for 24 hours, then, pressure is increased resulting in more leakage.

3.4.4.5 Distribution Network

1) Distribution Mains

Fig-3.19 shows the pipe diameters and years in which they were laid. The diameter of pipes ranges from 60 mm to 800 mm. Pipes with less than 150 mm account for 70% of the total length of pipes. Pipes were laid in the years 1895, 1957, 1959, and 1960. Corresponding pipe ages in 1993 are 98, 36, 34, and 33 years respectively. Between 1957 to 1960, 84 percent of total pipes were installed. Diameter of existing pipes is shown in Fig-3.20 and age of existing pipes is shown in Fig-3.21. Length and installation year of distribution pipe is shown in Table-3.13.

a) Materials

Cast iron pipes are mostly used. Since cast iron pipes are weak to shock loards, cast iron pipes should be replaced with ductile cast iron pipes to meet future increases in supplied water volume.

b) Corrosion (external surface)

According to measurements with a corrosion meter, the degree of corrosion is from 0.1 to 1.1 mm. In the case of the 98 years age pipe, it is

Table-3.11 LEAKAGE RATIO (Demand and supply)

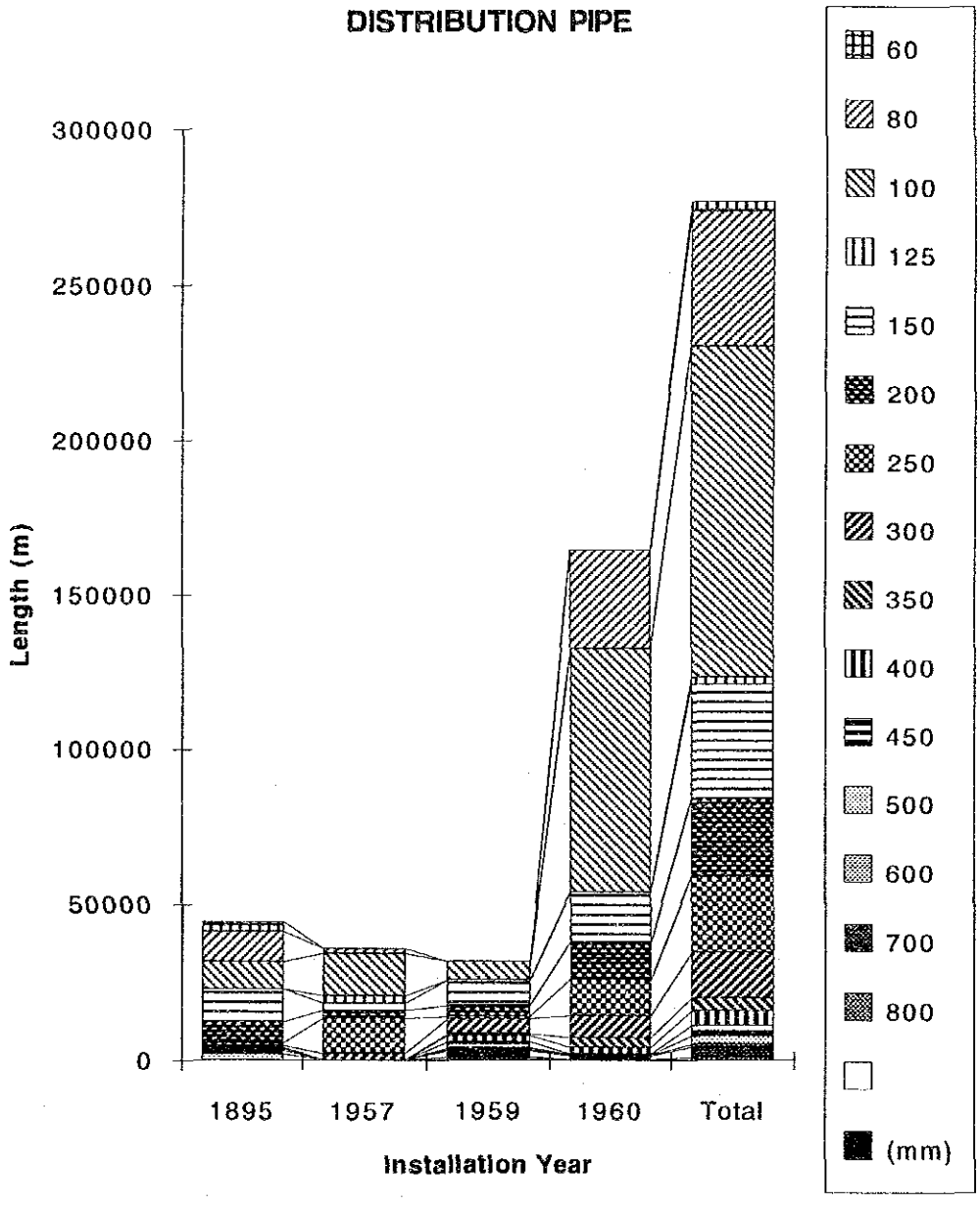
No.	District or Water treatment plant name	Population	Area	Unit C/D	No water area	Supply area D-F	Supply population ExG	Percapita	Cosumption flow HxI	Supply flow	Leakage flow K-J	Leakage ratio L/K	Remarks
a	b	c	km2 d	p/km2 e	km2 f	km2 g	h	lpcd i	m3/d j	m3/d k	m3/d l	% m	n
1	Don Phen	109,647	7.60	14,427		7.60	109,645	100	10,965				
2	Chamcar Morn	118,133	9.50	12,435	3.6	5.90	73,367	100	7,337				
3	Toul Kork	101,006	9.25	10,920	2.4	6.85	74,802	100	7,480				
4	Seven January	88,727	2.35	37,756		2.35	88,727	100	8,873				
5	Phum Prek W.T.P.									56,000			
6	Chamcar Morn W.T.P.									7,000			
	Total	417,513	28.70	75,538	6.0	23	346,541		34,655	63,000	28,345	45	

Note :
p/km2 : persons/km2

Table-3.12 LEAKAGE RATIO (Measurement of leakage)

No.	Pipe size or Water treatment plant	Length	No water area		Leakage unit		Leakage flow				Supply flow		Leakage ratio				Remarks
			Retio	Length	Nomal pressure	Pump pressure	13 Hour		24 Hour		13 Hour	24 Hour	13 Hour		24 Hour		
					0.7m	0.34m	0.7m	3.4m	0.7m	3.4m			0.7m	3.4m	0.7m	3.4m	
		m	%	m	m3/h/m	m3/h/m	C-ExFx13 m3	C-ExGx13 m3	C-ExFx24 m3	C-ExGx24 m3	m3	m3	%	%	%	%	
a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r
1	250	24,550															
2	200	24,850															
3	150	37,100															
4	125	2,300															
5	100	107,050															
6	80	43,350															
7	60	3,100															
	Total	242,300	21	50,883	0.01	0.031	24,884	77,141	45,940	142,414			39	122	44	137	
8	Phum Prek W.T.P.										56,000	93,600					
9	Chamcar Morn W.T.P.										7,000	10,000					
	Total										63,000	103,600					

Fig-3.19 LENGTH AND INSTALLATION YEAR OF DISTRIBUTION PIPE



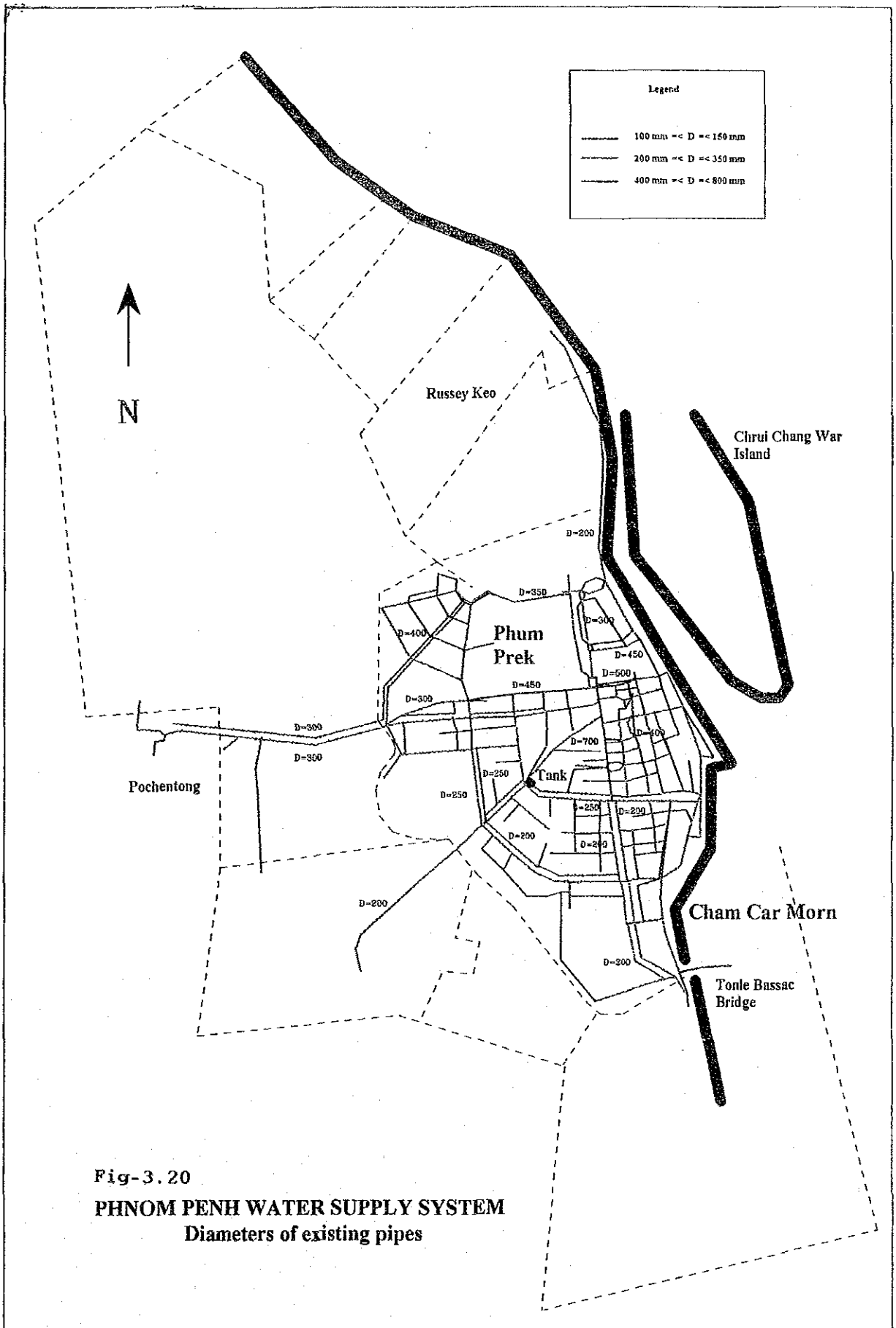


Fig-3.20

PHNOM PENH WATER SUPPLY SYSTEM
Diameters of existing pipes

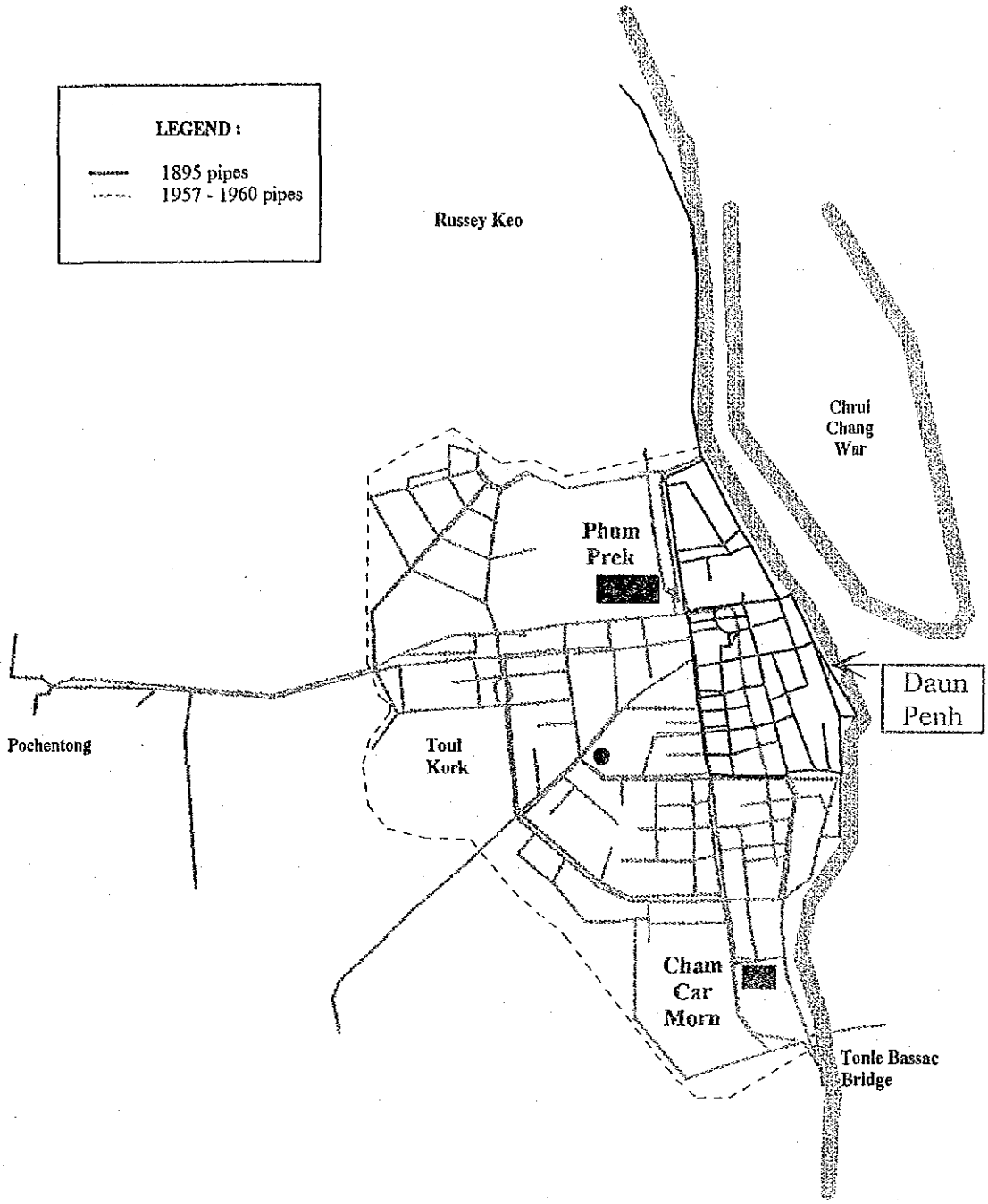


Fig-3.21

ANALYSIS OF PHNOM PENH WATER SUPPLY SYSTEM
Age of existing pipes

60 mm. Generally, as corrosion margin is 2mm in terms of the pipe strength, existing pipes are mostly still tolerable. The corrosion measurement also shows that the soil is not corrosive. Thus, corrosion protection is not needed.

c) Corrosion (internal surface)

Field observations of pipe samples (100 mm Dia. see Fig-3.22) indicate that rust, clay, and colloidal materials are sticking inside the pipes and the cross-sectional areas of the pipes are reduced by 36 to 67 percent. It is strongly recommended to improve functioning of the pipes by cleaning and lining of the trunk mains (D300-800), and replacement of the secondary pipes (D60-250) considering cost and easiness of work.

d) Joint

Two types of joints are used, viz. the socket & spigot joints and the mechanical joints. The socked & spigot joints were installed in 1895. Considering that most areas were in a low pressure zone for a long time, it is difficult to judge the current functional situation of the joint. However, a couple of rubber gaskets inside the joints from different areas were physically checked and it was found that they were still usable.

e) Earth cover and position of secondary mains

Secondary distribution pipes are mostly laid under roads although there are sidewalks. The depth of earth cover varies from 0.4 to 1.2 m. Some portion of the pipes have no earth cover, especially in unpaved roads.

To improve the maintenance efficiency and safety, pipes need to be laid under the sidewalk and a standard of depth of earth cover needs to be established.

Fig-3.22 PIPE INTERNAL CONDITION

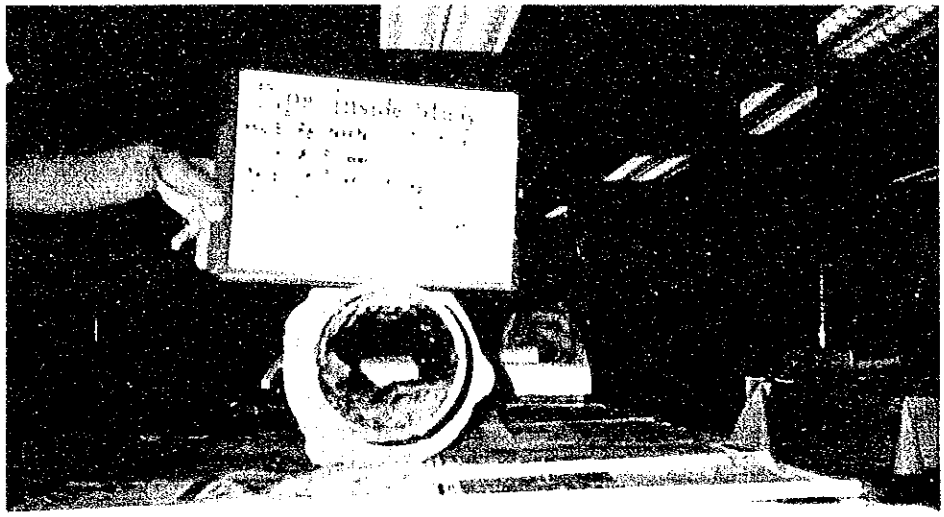


Table-3.13 LENGTH AND INSTALLATION YEAR OF DISTRIBUTION PIPE

Diameter (mm)	1895 (m)	1957 (m)	1959 (m)	1960 (m)	Total (m)	Remarks
800			1,000		1,000	
700			2,000	1,400	3,400	
600			400	350	750	
500	2,100		550		2,650	
450	1,100		2,000	250	3,350	
400	650		1,850	2,200	4,650	
350	300		750	3,150	4,200	
300	650	2,250	4,700	6,950	14,550	
250	800	11,250	750	11,750	24,550	
200	6,800	2,450	3,600	12,000	24,850	
150	10,500	2,500	8,100	16,000	37,100	
125		2,300			2,300	
100	8,800	13,600	6,100	78,550	107,050	
80	9,750	1,550		32,050	43,350	
60	3,100				3,100	
Total	44,500	35,900	31,800	164,650	276,850	

2) Elevated Service Reservoir (Elevated Tank)

Beside the Olympic Sports Complex situated in the middle of the service area, the elevated tank is constructed which is one of the treated water reservoirs in the service area. The size and related dimensions are given below:

Capacity	: 2,000 m3
Height from the ground	: +9.10 m
Water Level	: H.W.L. +34.10 m
	L.W.L. +30.00 m
Piping	: Inlet cum outlet D250 CIP
	: Overflow cum drain pipe D250 CIP

After the construction, the elevated tank has never been utilized because of low pressure caused by significant leakage and consumption upstream of the inlet pipe. At present the tank is used as an advertising tower by a cigarette company.

3) Gate Valves

Although the locations of sluice valves are shown on the network maps, it is difficult to find them on site. In terms of maintenance, safety, pressure control, and leakage survey, each sluice valve need to be installed with a sign. Opening and closing directions of valves also need to be indicated.

4) Fire Hydrants

The locations of hydrants are not shown on the maps. During the field survey, fire hydrants could hardly be seen. Fire hydrants should be installed, if the water pressure is enough.

5) Blowoffs

The situation is the same as for fire hydrants. Due to low pressure, it is easier to have deposits inside of the pipes. Thus, washout is needed.

6) Air Valves

Since they could hardly be seen at the sites and it is expected that there will be air in the pipes due to the current operation style (on-off operations), air valves should be installed as soon as possible.

3.4.5 House Connection and Service

3.4.5.1 Ways to get Treated Water

Under the current low pressure situation in the entire system, consumers are using one of the following ways:

1) In areas where the piezometric pressure level is lower than the ground level (GL). People living in this area were estimated to be around 84,500.

   - Installation of a pit between the distribution line and houses

- The pipe, connected to the distribution line from the pit, is normally installed at the bottom of the distribution lines so as to get water anytime so long as there is water in the distribution pipe.
- The stored water in a pit is transferred to water tanks in the house via portable pumps or hand-carried with a bucket.

2) Areas, where the pressure is higher than the GL and the people are living at ground level. (about 225,000 inhabitants)

- Water tanks or jars to store water.

3) Areas, where the pressure is higher than GL and the people are living at higher ground level. (about + 29,000 inhabitants)

- Whenever water is needed, people bring down a portable pump, a power extension line, and a hose from their house to the ground level.
- Connect pumps with the hose and power, and boost the water to their tanks or jars. In some cases, potable pumps were set in the pits jars.

People who live in the second and third area as above were estimated to be about 257,000 (45,000 families). House connections are estimated to be about 24,000, based on the assumption that about half of the 39,000 families do not have house connections. To improve the above undesirable conditions, improving the water pressure is urgently recommended.

3.4.5.2 Materials of Service Lines

The service pipes materials used are steel pipes, but recently, PVC is used. In areas with very low pressure, even vinyl hoses are in service. Considering weather conditions in this area, pipes of material which have heat-resistance and light-resistances such as steel are recommended.

3.4.5.3 Connection Between Distribution and Service Pipe

Since distribution pipe material is mostly cast iron pipe, corporation cocks are not installed in many cases. Due to the low pressure, PVC or vinyl hose is directly connected to the distribution pipe with rubber bands in some of the worst cases. This causes serious problem in the wet season due to waste water infiltration.

3.4.5.4 Water Meter

It is reported that about 2,300 water meters had been installed as of April, 1993. According to the field survey, some water meters were determined to be defunct. The location of the water meter is within a house building site in most cases. But the location of the meters is not good. For example, the location of some of the meters were in the kitchen, under the refrigerator, in the drainage etc.. The situation makes meter reading difficult. When the meter is set outside of the site, meters are in the pit and some times the pit is locked.

The meter should be installed around the boundaries of the house premises and above the ground for easy reading.

3.4.5.5 Water Tap

In as much as water tanks or jars are in practice, the number of water taps is one to two at most for normal houses. Houses with the pit supply have no water taps.

3.5 Hydraulic Analysis of the Existing Water Distribution Network

3.5.1 Model Formulation

1) Presentation of Piccolo Software

The method of the existing Phnom Penh water distribution network has been created using the computer program "Piccolo", written and developed by Safege. Piccolo is a multipurpose software, used to solve pressure flow problems in meshed pipe networks. Using network data, Piccolo calculates velocity, flow rates, pressure, etc.

Computation may be carried out for a single instant (point in time mode), or over a period of time, which may or may not be divided into constant intervals (dynamic mode).

A network may be described as a series of points, called nodes, connected by branches. Water flows through the branches and consumptions are only allocated to the nodes. Many kinds of reservoirs and items of hydraulic equipment can be modeled within the network.

It should be emphasized that Piccolo is only a model and consequently does not reflect small details of the operation of the network. For example, it is clear that the distribution of consumptions over the network is changing slightly all the time, while the node consumption used as input to the computer model are monthly or yearly averages.

2) Modeling of Pipes

In Piccolo, a standard pipe is defined with the following features:

- initial node;
- final node;
- length;
- diameter;
- Colebrook wall roughness coefficient, or Hazen Williams equivalent;
- singular head loss if necessary.

In the case of Phnom Penh, all the pipes with diameter over 125 mm, have been included in the model. Some pipes of smaller diameter have also been taken into account when important for hydraulic reasons (completion of loops, areas with only tertiary networks, etc.).

The length and diameter of each pipe has been digitalized or taken from network maps of the year 1972, at scale 1/10,000. The Colebrook wall roughness coefficient of the pipes has been assumed to be 5 mm for the 1895 pipes and 3 mm for all other pipes. A reduction of diameter has also been taken into account as field surveys have shown major encrustations in the pipes, especially in dead-end pipes. This reduction is assumed to range from 1.5 cm to 3 cm.

The total number of pipes included in the model is 443.

3) Nodes and Allocation of Consumptions

In Piccolo, a node can only exist if linked to a network through a pipe.

A node is defined with the following features:

- planimetric coordinates (x , y);
- altimetric coordinate - ground level (z):
- different kinds of consumptions (domestic, industrial, etc.).

In the case of Phnom Penh, all the nodes corresponding to the pipe connections and to the changes in pipe diameter have been included in the model. Nodes corresponding to the plants, to the elevated tank, and to the major valves have also been taken into account. Additional nodes have been defined in some areas to allow for a more accurate allocation of water consumptions.

The planimetric coordinates have been digitalized as for the pipes length. The topography data were first taken from a 1972 topographical map, then improved, taking into account the topographical survey carried out by the Study Team. The water consumption allocated at a node is the average per capita consumption multiplied by the population allocated at the node.

The total number of nodes included in the model is 318.

4) Leakage

It is difficult to assess leakage in the existing network because there are no accurate figures either for production or for water sales. It is assumed that leakage is currently 50% of the production.

5) Pumping

The reference service reservoir for the hydraulic analysis is the 11,000 m^3 ground storage reservoir in the PPWTP, from which water is pumped into the distribution network. The effective water depth in this reservoir is 4.5 m.

The assumed delivery head of the pumps at Phum Prek is 23 m head of water.

For the other existing pumping station at CCWTP, the pumped output has been fixed as an input of water into the distribution system at a constant rate. This input flow is 330 m^3/hr, which corresponds to 8,000 m^3/day. It must be born in mind that at least one valve located downstream of the plant is presently closed, thus rendering the hydraulic influence of CCWTP to most part of the network as relatively minor.

3.5.2 Calibration

Calibration is necessary to confirm and to improve the assumptions set up during the creation of the model. Calibration is basically made through comparisons between field survey measurements and results from the computations with the model.

In the case of Phnom Penh, the field survey focused on pressure measurements. Because of the numerous domestic pits acting as buffers in the field survey it was roughly assumed that there was no fluctuation of the consumption during the daytime. This allows the assumption to be made that there is consequently no fluctuation of the pressure at a given point in the network during the daytime.

A total of 34 locations for calibration was chosen from amongst the sites investigated by the field survey, covering the four city districts. Fig-3.23 shows the location of these sites. Table-3.14 shows the comparison between the measurements of the field survey and the results of the computations with the model. It can be seen that figures are very similar. It should be noted that a calibration is commonly considered as valid when the difference between the computed and the measured pressures is less than 3 m for 90% of the investigated points. Accordingly, the results of the calibration that was carried out may be considered as good.

The assumptions used for the simulation with the model are those detailed above concerning the creation of the model plus three additional ones. Two of these additional assumptions are related to two valves which are probably acting as pressure-reducing

Fig-3.23 LOCATION OF SITES SELECTED FOR THE CALIBRATION

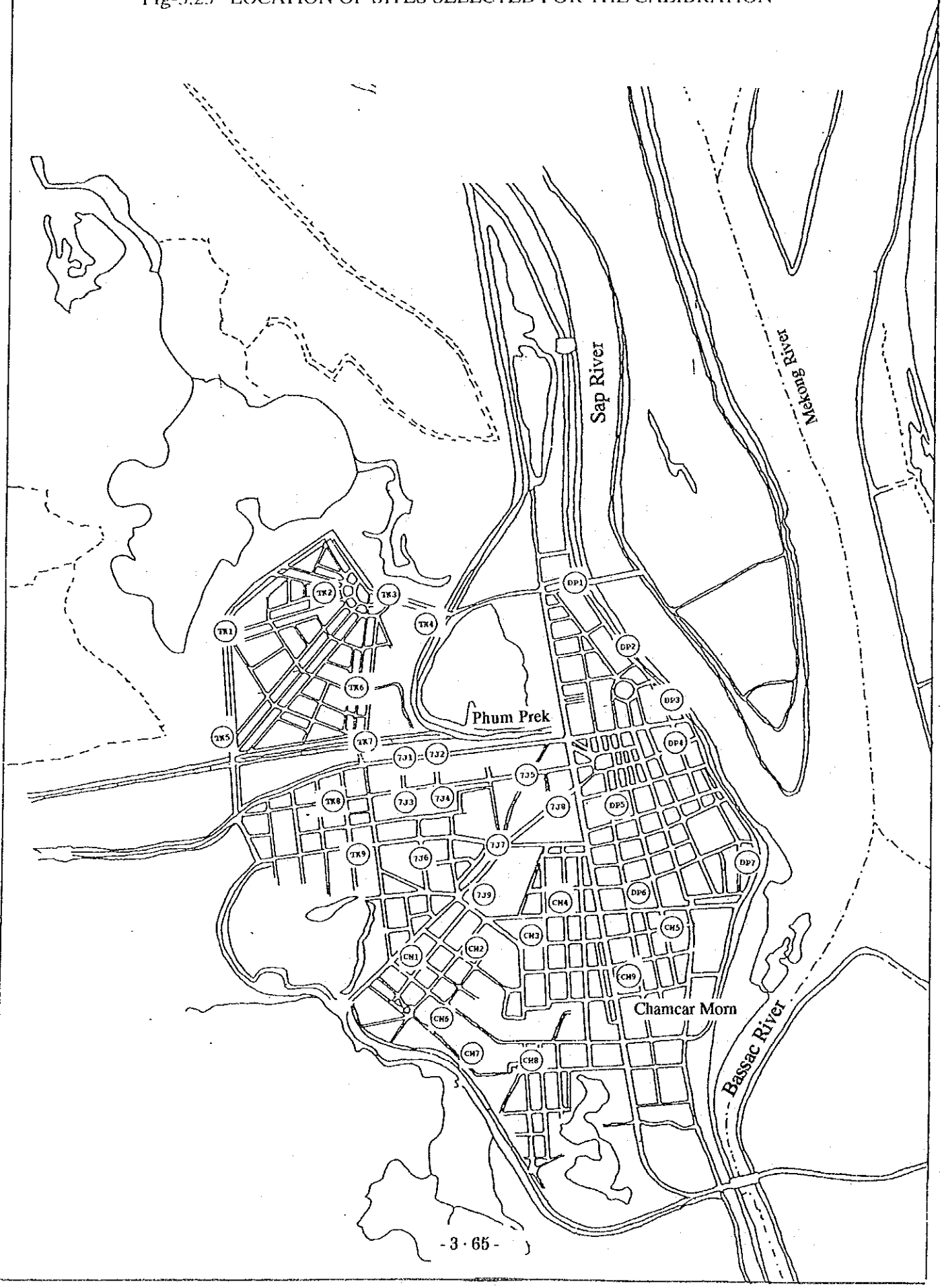


Table-3.14 COMPARISON OF FIELD SURVEY WITH NETWORK MODEL

Unit: Meter

District	Site code	Pressure from field survey	Pressure from the model	Pressure difference
Toul Kork				
	TK1	-0.4	0.1	0.5
	TK2	1.0	0.9	-0.1
	TK3	1.3	3.4	2.1
	TK4	7.0	8.4	1.4
	TK5	1.8	2.0	0.2
	TK6	0.3	2.0	1.7
	TK7	6.0	8.2	2.2
	TK8	1.4	2.1	0.7
	TK9	0.0	1.2	1.2
Seven January				
	7J1	9.0	10.0	1.0
	7J2	13.0	13.1	0.1
	7J3	0.5	1.0	0.5
	7J4	0.6	0.6	0.0
	7J5	-0.5	1.1	1.6
	7J6	2.0	2.8	0.8
	7J7	11.0	11.6	0.6
	7J8	0.2	1.1	0.9
	7J9	8.0	10.3	2.3
Don Penh				
	Dp1	1.1	1.3	0.2
	Dp2	1.1	2.6	1.5
	Dp3	1.8	2.4	0.6
	Dp4	3.5	2.4	-1.1
	Dp5	6.0	6.4	0.4
	Dp6	2.7	3.7	1.0
	Dp7	0.9	2.5	1.7
Chamcar Mom				
	Cm1	-0.8	-0.9	-0.1
	Cm2	-1.1	-0.9	0.2
	Cm3	2.4	3.5	1.1
	Cm4	8.0	7.3	-0.7
	Cm5	5.0	5.9	0.9
	Cm6	-0.8	-2.4	-1.6
	Cm7	-0.7	0.9	1.6
	Cm8	0.8	-0.3	-1.1
	Cm9	2.9	2.7	-0.2

valves : the first one located just downstream of the Phum Prek water treatment plant (creating an assumed 8 m singular head loss) and the second one upstream of Boeng Kak 1 subdistrict (creating an assumed 7 m singular head loss). The third additional assumption is related to the area surrounding the Chamcar Morn water treatment plant. For strategic reasons, this area is presently supplied as a particular compartment in the system. To be consistent with the pressure records from the field survey, it has been necessary to assume that one of the pipes leaving the plant was closed.

3.5.3 Low Pressure Areas

Using the model allows to know precisely the distribution of pressures within the system. Fig-3.24 shows this pressure distribution, computed within the framework of the assumed average daily consumption and leakage for the year 1992.

It appears that most of the present served area is supplied at pressure below 2 m head. The only areas where the pressure in the distribution network is above 5 m head are the following:

- the area surrounding the PPWTP
- the area surrounding CCWTP
- the blvd. USSR, towards the Pochetong area;
- the southern part of the blvd. Keo Many, near the crossroad with the blvd. Achar Mean.

This represents a population served of only about 20,000 inhabitants. This confirms the results of all the field surveys that have been carried out during the study.

Some outer parts of the study area, despite being connected to the main network, are not at all supplied with water form the treatment plants. These areas are the following:

- to the North, towards Rusey Keo;
- to the West, towards Pochentong;
- to the Southeast, on the East bank of the Bassac river.

The average supply conditions can consequently be described as being very bad. Moreover, it may occur during the daytime that the pumps of the Phum Prek water treatment plant stop working mainly as a consequence of the suspension of power supply. The water supply conditions then worsen.

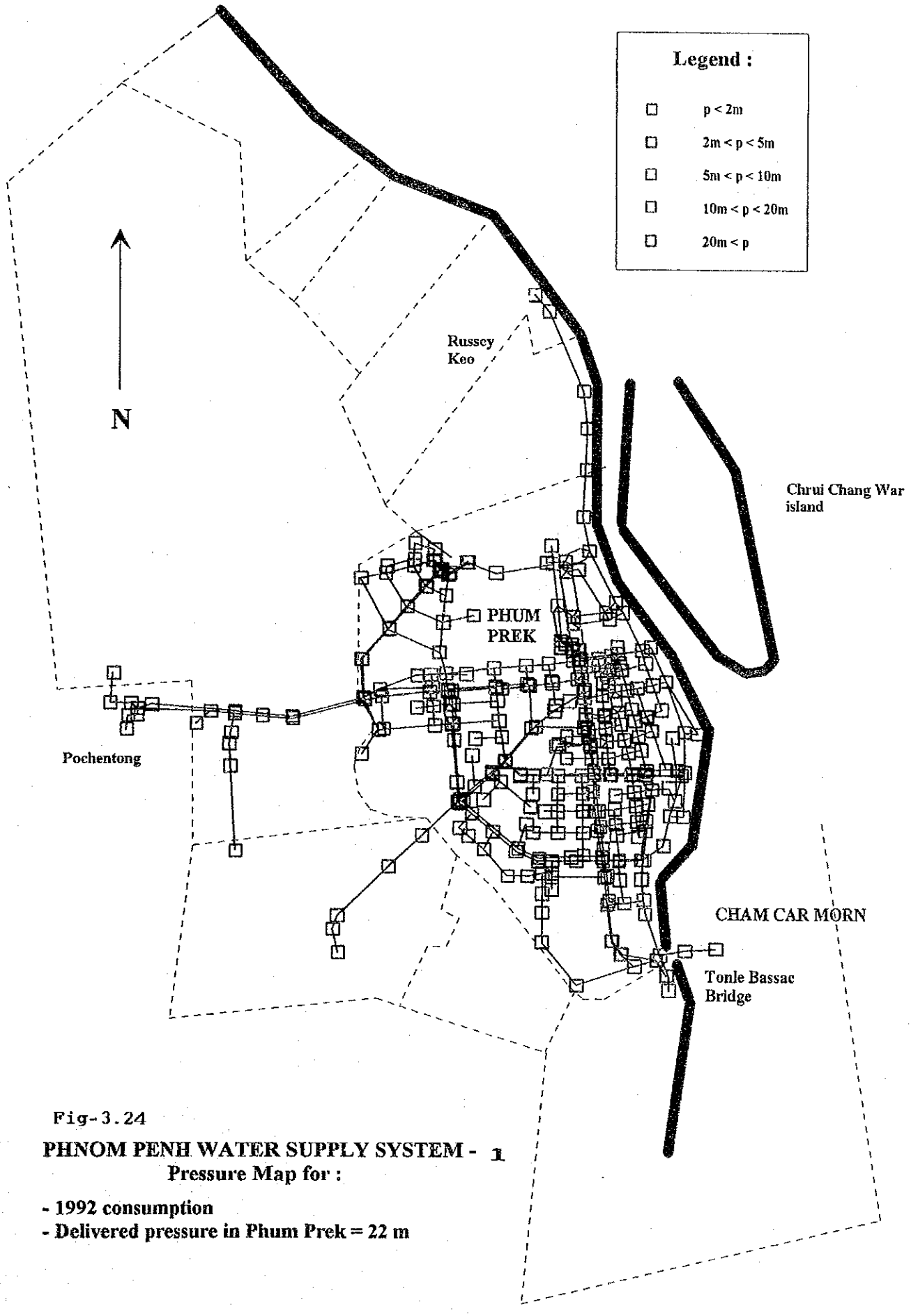


Fig-3.24

PHNOM PENH WATER SUPPLY SYSTEM - 1
Pressure Map for :

- 1992 consumption
- Delivered pressure in Phum Prek = 22 m

Besides the lack of comfort for the consumer, these very low service pressures pose a very serious sanitation problem, as external polluted water can easily enter the distribution mains. These low pressures also explain the existence of private pumps, directly connected to the distribution pipes by the consumers, in order to get water from the network.

The pumps are generally used to fill domestic tanks installed on the roofs of buildings, ensuring a little pressure to the consumers. Such private pumps taking water from the network pose a serious problem, prohibiting any accurate monitoring of the consumptions distribution. Indeed, it appears that users of these pumps often take more water than needed for their own consumption, then sell extra water to other consumers.

3.5.4 Flow Velocities

Using the model allows to evaluate what should be the flow velocity in distribution mains. This is highly valuable as in the field surveys carried out during the study, it was very difficult to measure the flow velocities on site. Fig-3.25 shows the present range of flow velocities in the pipes, according to the network model, in the framework of the assumed average daily consumption for the year 1993.

It appears that most flow velocities are acceptable (below 1.5 m/s) and that many are even lower, except in the vicinity of the Phum Prek water treatment plant.

The existence of this range of flow velocities is especially interesting, as it shows that the present pressure problems within the system are more related to the pressure delivered downstream of the water treatment plants than caused by regular head losses during transportation and distribution. The existing distribution network appears to have adequately sized to carry and to deliver in acceptable conditions the water corresponding to the present assumed water demand, including high level leakage.

It should be noted that 30% of the pipes have velocities below 0.3 m/s, which pose a problem of potential water quality degradation in some parts of the system.

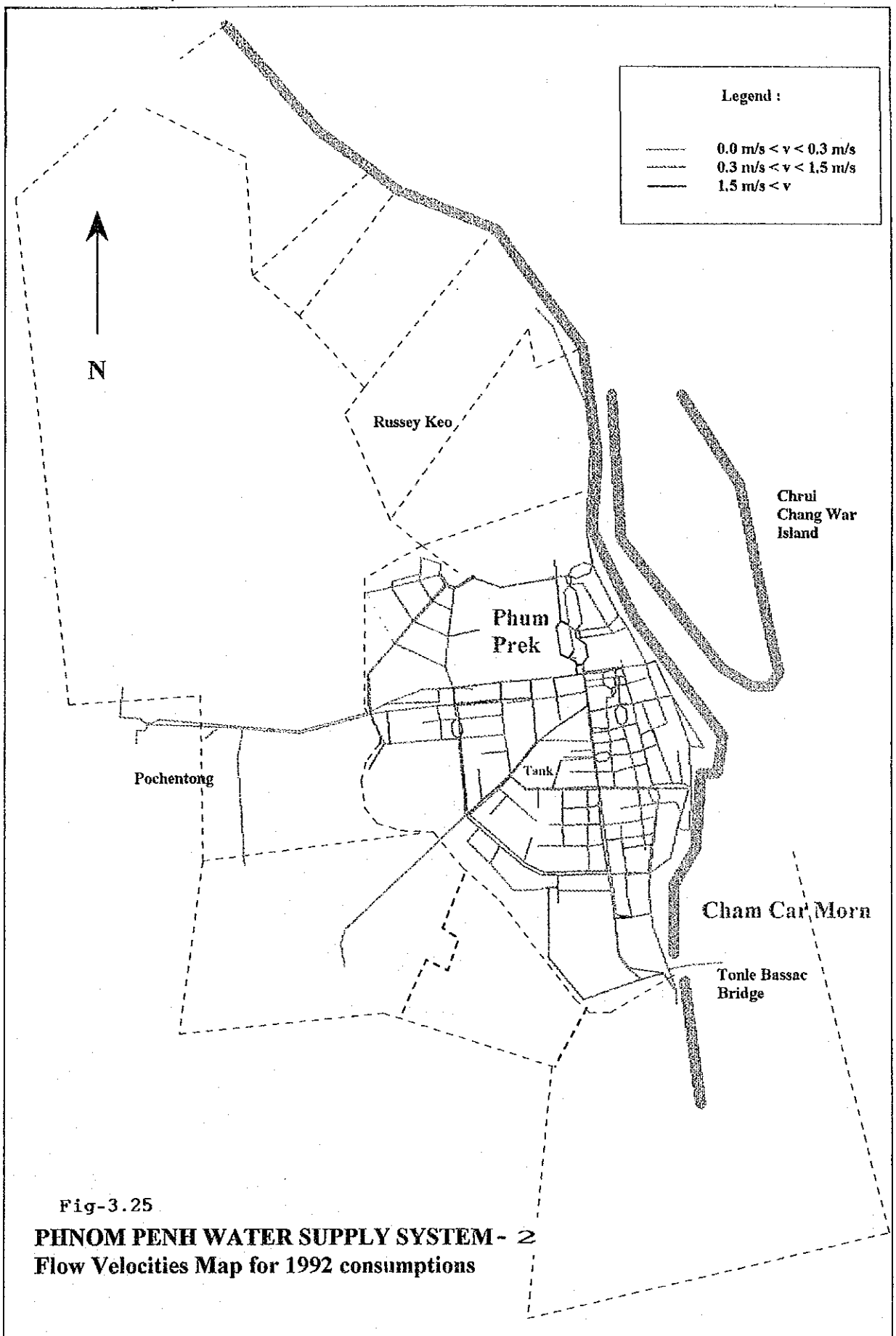


Fig-3.25

PHNOM PENH WATER SUPPLY SYSTEM - 2
Flow Velocities Map for 1992 consumptions

3.5.5 Influence of the Pressure Delivered Downstream of the Water Treatment Plants

As already mentioned, it appears that present pressure problems within the network are mainly due to the low delivered pressure downstream of the plants.

It is possible to check with the Piccolo network model that immediate improvements can be easily obtained in the following ways:

- firstly, by opening the valves assumed to act as pressure-reducing valves in the vicinity of the existing treatment plants. Three valves are at least supposed to be concerned.
- then, by increasing the delivered pressure downstream of the Phum Prek water treatment plant.

Fig-3.26 shows the new pressures that will be met in the distribution system when the delivered pressure downstream of Phum Prek is 40 m, and when the pressure-reducing valves are open. The improvements would concern all the districts, and especially the following;

- Wat Phnom;
- Sras Chark;
- Boeng Kak 1;
- Boeng Kak 2;
- Phsar Thmay 1;
- Phsar Thmay 2;
- Phsar Thmay 3;
- Beang Reang;
- Monorom;
- Mitapheap;

However, increasing the delivered pressure can only be planned in a step-by-step approach, including a segmentation of the network, a step-by-step rehabilitation of the existing service connections, and at least replacing of the very old pipes totaling 44 km. A comprehensive leakage detection campaign should moreover be planned prior to any increasing of the service pressure, since this work has never been undertaken in the last three decades. In addition, metering all the connections is the most important, otherwise, too large part of water will be consumed in the areas in the vicinity of the water treatment plants.

It should be noted that the replacement of some old pipes has already been initiated, under a French Cooperation program (some 4 km will be replaced). But this work has yet to be completed.

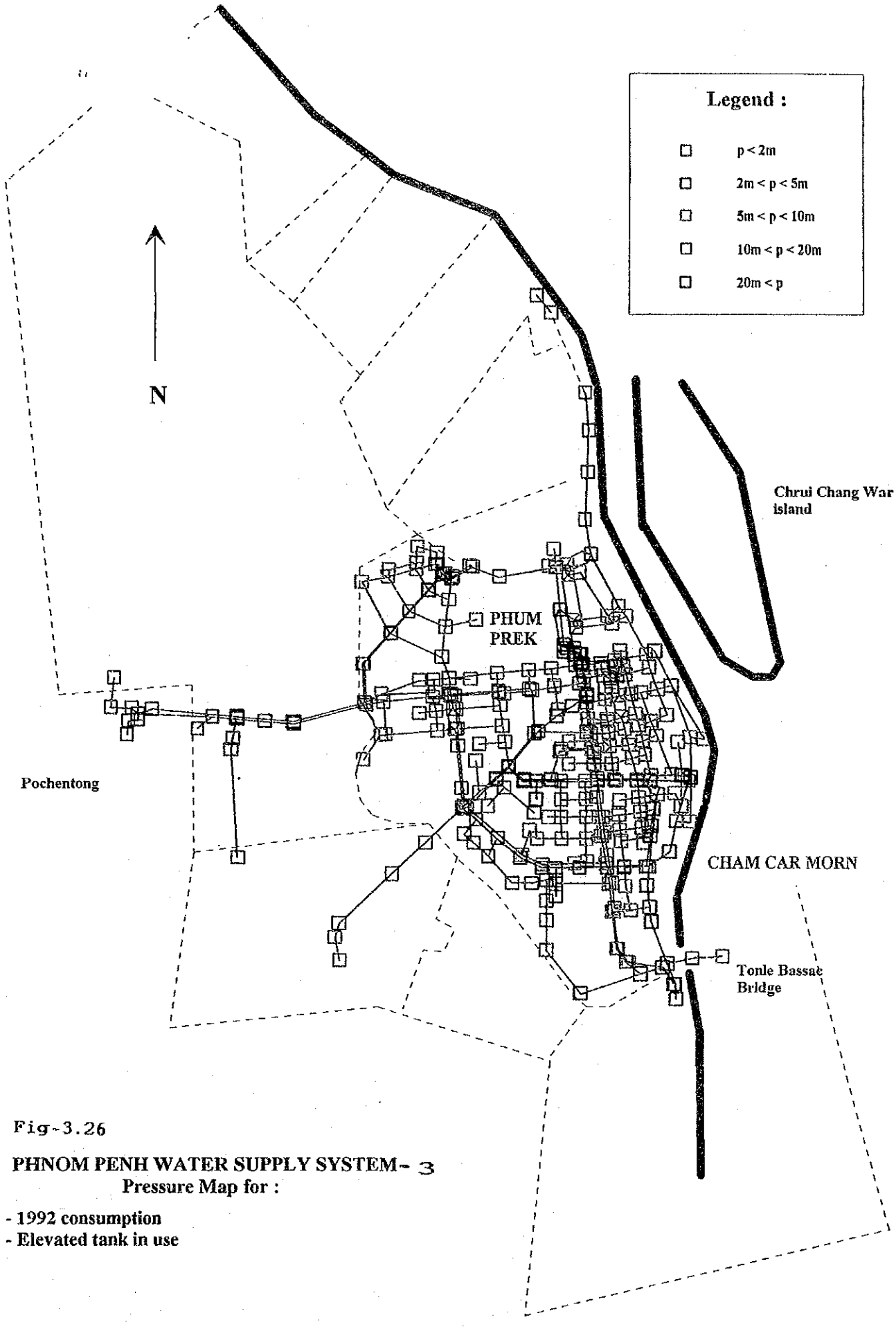


Fig-3.26

PHNOM PENH WATER SUPPLY SYSTEM- 3
Pressure Map for :

- **1992 consumption**
- **Elevated tank in use**

3.5.6 Hydraulic Influence of the Existing Elevated Tank

Increasing the delivered pressure downstream of Phum Prek could also be planned in order to fill the existing elevated tank. To use this tank according to the model and to the consumption assumptions, the installation of a new pumping station, boosting an average 1,000 m^3/h at 25 m head, and the laying of a new transmission line of diameter 600 mm will be needed.

Fig-3.27 shows the new pressure that will be met in the distribution system when the existing tank is filled. The improvements will mainly concern the following subdistricts:

- Phsar depot 1;
- Phsar depot 2;
- Phsar depot 3;
- Phsar Deum Kor;
- Toul Svey Prey 2;
- Phsar Olympic;
- Veal Vong.

3.5.7 Conclusions and Recommendations Related to the Increase in the Service Pressure within the Network

The existing system provides water in very poor pressure conditions on almost all of the service area, mainly because of the low pressure delivered from the existing treatment plants. A major improvement in the supply conditions could only be obtained by increasing this delivery pressure.

Due to the very poor condition of the facilities of the system, especially pipes, joints, and service lines, it is only possible to plan such and increase in a step-by-step approach. The recommended steps are as follows:

- to carry out a segmentation of the network, using as a basis the existing twin pipes;
- to rehabilitate segment by segment the service lines;
- to replace the old mains in the concerned segments (Daun Penh district)
- to carry out a comprehensive leakage prevention campaign;
- to increase the delivered pressure either directly downstream of Phum Prek or indirectly using the existing elevated tank. Pressure-reducing valves should be temporarily used.

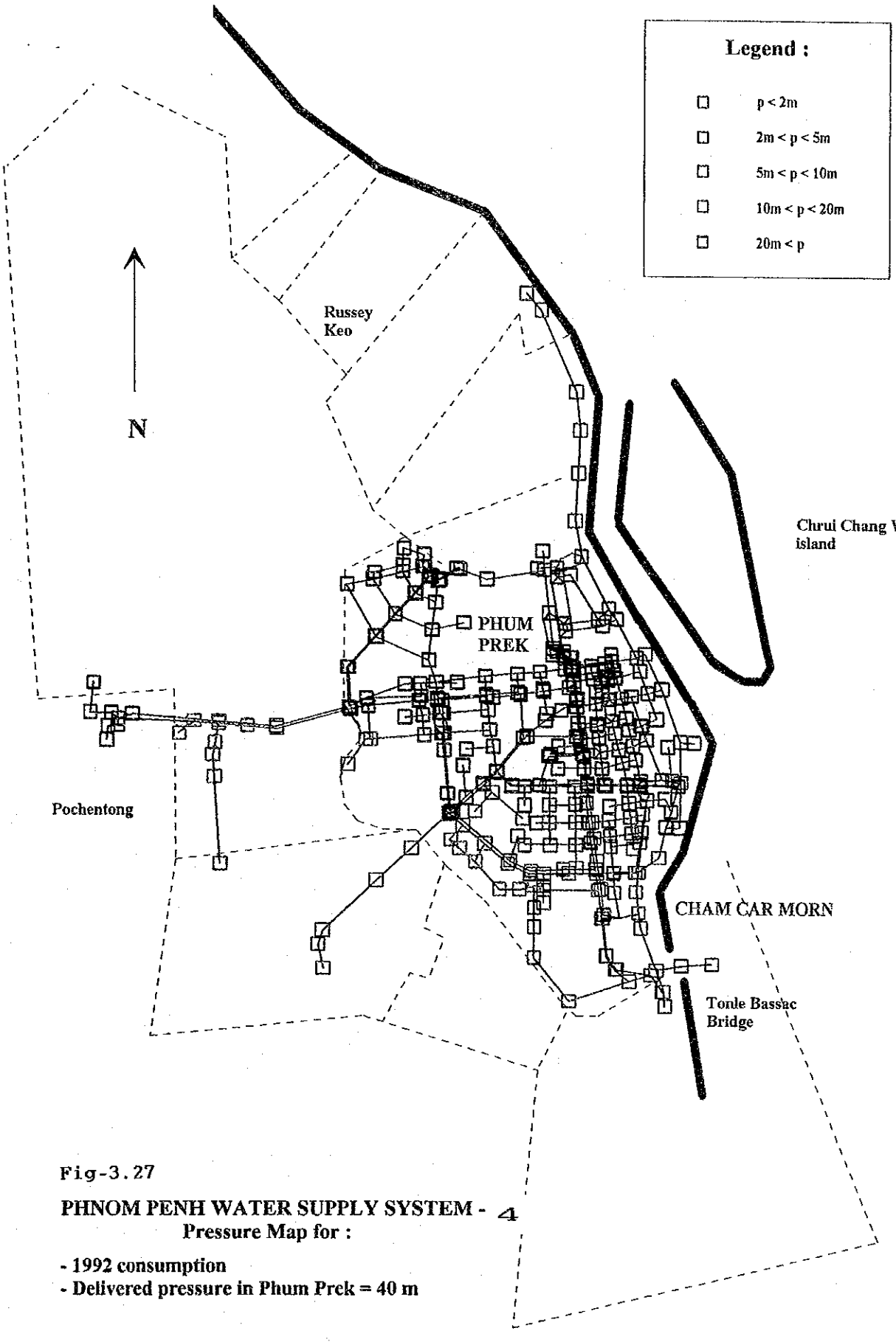


Fig-3.27

PHNOM PENH WATER SUPPLY SYSTEM - 4
Pressure Map for :

- 1992 consumption
- Delivered pressure in Phum Prek = 40 m

3.6 Relevant Water Supply Projects

Assistance related to water supply in Cambodia was mainly given by nongovernmental organizations (NGO), and after the Cambodia peace international conference held in Paris in 1991, bilateral aid agencies and the United Nations commenced their major assistance programs for rehabilitation of water supply facilities. The main activities for the Phnom Penh city's water supply are described below:

3.6.1 Bilateral/Multilateral Assistance Activities

1) Assistance by French

France started the activities from 1991 with 6.5 million French Franc (FF) (U.S. Dollars 1.2 million) for the study of the pipe materials, and FF 1.5 million (U.S. Dollars 0.3 million) for the study of the pipe networks. The grant aid for 1992 amounting to FF 17 million (U.S. Dollars 3.million) covers rehabilitation of 12 filters at the Phum Prek water treatment plant and the associated electrical equipment.

The French Government also committed to give a grant aid for rehabilitation of the Chamcar Morn intake and water treatment facilities so as to expand the plant output from 10,000 m^3/day to 20,000 m^3/day. However, the aid does not include technical assistance and training components. The design of the rehabilitation and expansion works has been prepared by Italian consultants, but the works have not started yet.

The schedule of the French for the years to come for other projects has yet to be fixed.

2) UNDP

Technical assistance for the rehabilitation of the water utilities of Phnom Penh and Sihanoukville is as follows:

Starting date	: June 1993
Duration	: 3 years
Financing	: World Bank, U.S. Dollars 4,110,900
National implementing agencies	: Supreme National Council
Cooperating Agencies	: Phnom Penh & Sihanoukville Municipalities
Executing Agency	: UNDP

The purpose of the project is to develop and strengthen the managerial and operational capacities of the water utilities of the cities of Phnom Penh and Sihanoukville through:

a) seconding technical experts, including United Nations Volunteers (UNV), for improving the operation of water utilities, and providing on-the-job training to the staff
b) training, both locally and abroad, of Cambodians in technical and management skills
c) carrying out studies critical for the institutional development and assessing the viability of the sector
d) providing equipment and materials for the immediate rehabilitation needs.

Budget for technical assistance (U.S. Dollars 1.7 million), trainings, (U.S. Dollars 1.2 million) and materials (U.S. Dollars 0.9 million) are already allocated, but equipment is not as signed yet.

3) Assistance from the ex-Soviet Union

The ex-Soviet Union had been carrying out the rehabilitation works of Chamcar Morn water treatment plant from 1985 to 1988. The strengthening of the plant was designed and several steel filter vessels were imported. After the collapse of the ex-Soviet Union in 1990, all of the works related to rehabilitation and expansion were stopped and unfinished works were left.

At the Phum Prek water treatment plant as well, construction of two 5,000 m^3 reservoirs were started, but this also was ceased under the same situation as above.

3.6.2 NGO Activities

1) OXFAM

The OXFAM had been engaged in rehabilitation works at the Phum Prek water treatment plant since 1979. An engineer were assigned for the works from 1986 till 1992. The OXFAM conducted the systematic overhaul of the water production facilities. The items of rehabilitation works are shown below:

a) Rehabilitation of Equipment
Intake pumps and motors : 3 sets replaced

Flash mixer motors	: 2 sets replaced
Flocculator motors	: 12 sets replaced
Compressors for valve operation	: 2 sets replaced
Oil pressure system	: Overhauled
Blower for backwashing	: 1 set repaired
Chemical dosing (Alum and Cl_2)	: Overhauled
Machinery parts & office equipment	: Supplied

b) Civil Works

Intake tower	: Repaired
Transformer with housing	: 1 set constructed

c) On-the-Job Training for Staff : Implemented

The OXFAM has withdrawn from its involvement in the water supply sector in the end of 1992.

CHAPTER 4

ORGANIZATION, MANAGEMENT AND FINANCE OF THE WATER WORKS

4. ORGANIZATION, MANAGEMENT AND FINANCE OF THE WATER WORKS

The contents of this report, particularly of this chapter are written with information gathered during a field work between February 1993 and May 1993. However, various changes have taken place in the organization, management and finance of the water works, since May 1993 and Section 4.4 also shown present activities of PPWSA as of August 1993.

4.1 Organization

4.1.1 Water Supply Decree

The decree, titled "Government Decree on the Supply and Consumption of Drinking Water" and numbered "Decree 32, Council of Ministers, the People's Republic of Cambodia", was promulgated on 31 December 1987. It is the basic regulation for water supply in Cambodia, consisting of six chapters and thirty-one articles. This section outlines the principal contents of the six chapters.

4.1.1.1 Chapter 1 : General Matters

In the 1st to 4th articles of Chapter 1, the following matters are defined:

1) PPWSA is the state monopolistic agency as "the supplier".
2) Users of the PPWSA are called "the consumer".
3) Ownership and responsibility for operation and maintenance between the supplier and consumer is separated at the water meter.
4) Two types of supply, metered and un-metered are used.
5) The supplier is responsible for supplying safe water abundantly under normal conditions, and exempted from the responsibility under abnormal conditions.

4.1.1.2 Chapter 2 : Supply and Consumption of Water

The 5th to 12th articles stipulate the following matters:

1) Installation of fire hydrants.
2) The supplier's obligations to the consumers.
3) The consumer's rights of making requests to the supplier.

4) Transfer and inheritance of the consumer's property and contractual rights with the supplier.
5) The ground floor inhabitant's duty with a metered connection, to facilitate access to water for residents who live on higher floors.
6) Prohibition of re-selling water without authorization and procedural regulations in the case of re-selling.
7) Rules of estimating un-metered consumption.
8) Pricing of water by the People's Revolutionary Committee.
9) Payment of connection fee, repairs, replacement of meter, etc. by the consumer.
10) The consumer's duty to pay for the water consumed.
11) Distinction of the water used for normal living and for commercial and industrial activities.
12) State subsidy for the benefit of government employees.
13) Payment obligation by foreign agencies and foreigners for water foreign currency.

4.1.1.3 Chapter 3 : Irregularities in Water Consumption in Payment of the Cost of Water

The 13th to 17th articles stipulate the following matters:

1) Repair, replacement or removal of faulty meters.
2) Prohibition of using pumps connected to the distribution pipe.
3) Meter reader's reading and recording.
4) Intentional prevention of meter reading by the consumer and consequent cut-off of supply.
5) Tolerance of meter's error.
6) Correction of over - and under - payment due to mistaken meter reading and/or faulty meter.
7) Payment of water bill by the consumer.

4.1.1.4 Chapter 4 : Competent Bodies for Controlling and Settling Problems Related to Water Consumption

The 18th to 20th articles detail the following matters:

1) PPWSA's rights to make inspection on rightful uses of water by entering consumer's premises and/or requesting documentary evidence.
2) PPWSA's rights to take executive or legal actions against minor or major violations by the consumers.

3) Procedural regulations for enforcing the actions stated in 2).

4.1.1.5 Chapter 5 : Penalties

The 21st to 28th articles stipulate in detail a variety of penalties to be imposed corresponding to the type and degree of violations.

The penalties vary in:

1) Cut-off of supply, provisional or permanent.
2) Taking away of operation permit, provisional or permanent.
3) Addition of a small fine for delayed payment of water bill.
4) A medium to high fine for re-selling water at unreasonable price.
5) A very high fine for evil-mind violations, such as illegal connection, pump installation, stealing water.
6) Presenting lawsuit against such criminal acts as drilling water main, conducting water supply business, poisoning water, stealing public properties, etc.
7) Presenting lawsuit against non-payment of fine.

4.1.1.6 Chapter 6 : Final Disposition

The decree is authorized officially by Mr. Hun Sen, President of the Council of Ministers at the end of this Chapter.

4.1.1.7 Essential Problems of the Decree

As shown in the comments hereafter, the decree is unrealistic and impracticable in some key matters and as a result, it is openly and widely disobeyed.

Article 4 stipulates, "The water supplier must produce water which is safe, which is analyzed in conformity with the usual technique and must supply in sufficient quantity in conformity with the clauses of the contract signed between the water supplier and the water consumer, except in the following cases : (1) deterioration of electric cables leading to failure of the electric supply, breakdown of the machines, breakdown of the production system or distribution, (2) fire or panic breaking out in the water treatment plant, (3) war."

However, even under the conditions not including the above three cases, water produced is not safe for drinking and the supply is never sufficient.

Though installation of fire hydrants is stipulated in Article 5, they are non-existent in reality.

By Article 9, the consumer is not allowed to "resell water" to a third person without authorization of the supplier and the price of "resale water" is fixed by the decision of the provincial or municipal People's Revolutionary Committee. However, this is openly and widely disobeyed, as witnessed at many locations in the city.

Article 11 stipulates, "The price of water is fixed by the decision of the provincial or municipal People's Revolutionary Committee, based on the advice of the Minister of Planning and the Minister of Finance."

This is undoubtedly against the principle of both autonomy and enterprise and, as a matter of fact, results in pulling down the PPWSA's self-sustainability after 1991.

Though "selling water at a price above that fixed by the provincial or municipal People's Revolutionary Committee will be liable to fine" is stipulated in Article 23, it is rarely applied.

"Using a pump to pump from the water distribution network" is forbidden by Article 24 but it is openly and widely disobeyed.

This open and wide disobedience is to be interpreted as acts of self-defense by the people, against the enforcement of unrealistic and unpracticable rules, rather than acts of challenge to the authorities. To improve the extreme shortage of water in both quality and quantity, solutions need to be found, not by making rules but by improving the physical conditions and the quality of administrative and entrepreneurial services.

4.1.2 Organization of PPWSA

4.1.2.1 Organizational Structure of the PPWSA

Before the suspension of autonomy in 1991, the director was fully authorized to change the structure. But after 1992, the authority has been limited to the lower level structure of the director's office and the higher level structure has been entrusted to the Mayor.

Fig-4.1 shows the present organizational structure of the PPWSA which was formed in May 1992. Figures in parenthesis are the numbers of permanent staff belonging to the

units. About 150 temporary staff members employed on contract are distributed among the units. All in all, some 440 people work for the PPWSA presently.

Roles of the nine office-level departments, including the three water treatment plants, five Offices and the Revenue Collection Department, are specified, as seen by the divisions and untitled units belonging to each of them.

Fifty-three of the 300 permanent staff members are women, most of them serving with the same responsibility and authority and some staying with the PPWSA for more than 10 years. The breakdown of the permanent staff by age was 30 in the 21-31 years group, 93 in the 31-40 years group, 99 in the 41-50 years group and the 41 in the over-51 the group, while the total number was 272. The average is supposed to be about 40 and it is probably higher than that of the country's total workforce.

The age of retirement is fifty-five years. Since the establishment of the PPWSA in 1987, six persons have retired, but when specially requested by the PPWSA, a person can continue working after 55.

4.1.2.2 Changes in Recent Years

Noticeable changes in the recent years are:

1) An office-level unit which had handled meter reading, billing and revenue collection was divided into two units.: the Exploitation Office for meter reading, billing, etc. and the Revenue Collection office for collecting water tariff and other revenues. The change was made in January 1993.

2) The Vice-Director in charge of the Exploitation Office resigned in March 1993, leaving the position vacant.

3) The Laboratory belonging to the Phum Prek water treatment plant was re-assigned to the Technical Office.

4.1.2.3 Necessity for Re-organizing PPWSA

1) Oversized structure

Regarding the governmental organizations in Cambodia, oversizing of the structures in general is pointed out in the report, "Cambodia, Agenda for Rehabilitation and Reconstruction, the World Bank, June 1992". Excessive number of units results in two types of

difficulties. First, they increase staffing requirements beyond necessity which result in increase in the number of civil servants. Second, they increase coordination requirements which result in slowing down of decision making and dilution of the authority of the responsible units. The same could be said of the organization structure of PPWSA.

Of the nine office-level departments, the Chroy Changwar plant has not been operational for some years, without any possibility of rehabilitation. Presently, five employees take care of the site and live there. Moving from office level and positioning under the Administration Office would be appropriate.

Below the office level, numerous units named after their roles are grouped, seemingly under direct control of the Office Chief or Vice-Chief. Their roles are to be redefined and they are to be regrouped and integrated to lesser units of division and at the section level.

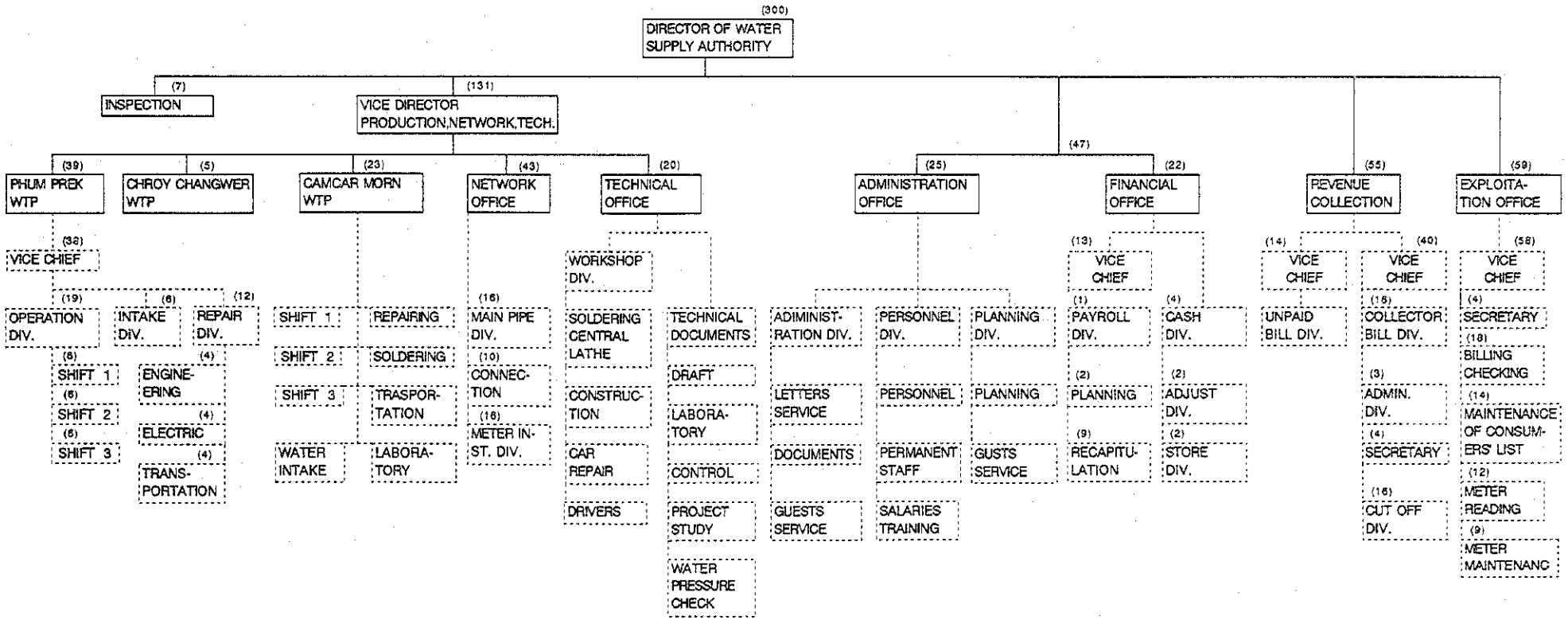
2) Overstaffing

The World Bank Report also points out overstaffing of the administrative organizations stating, "International comparison would suggest that in a country like Cambodia the size of the civil service should not exceed 1 percent of the population (in this case, 90,000 civil servants)". Presently, the number of about 150,000 employees equals 1.65 percent.

In the old days when the city's water supply was at the peak, producing about 140,000 m3/day and serving a population of 1 million, the PPWSA employees numbered 575 reportedly. Recruitment was made on a competitive basis and the employees' educational level was higher than now.

Though overstaffing is obvious and a state enterprise is given authority to regulate the number of employees, both increasing and decreasing are realistic for the time being, because "Employment generation is essential both to repair the nation's infrastructure and to avert social unrest which could destabilize the fragile political process "(Cambodia, Socio-economic Situation and Immediate Needs, ADB/IMF/UNDP/IBRD). On the other hand, recruiting unqualified persons will end in meaningless increase of the operating cost.

Fig-4.1 STRUCTURE OF PHNOM WATER SUPPLY AUTHRITY OGANIZATION (April, 1993)



4.2 Management

4.2.1 Personnel

4.2.1.1 Salary of Civil Servants and PPWSA staff

Public servants are paid a basic average annual salary of 440,000 - 450,000 Riels per year or about 37,000 Riels per month. This is equivalent to U.S. Dollars 10, while the minimum living cost of low income families is estimated at about U.S. Dollars 50.

Public servants are entitled to receive some allowances, such as 2,500 Riels/month for a child under 15-years-old, 3,000 Riels/month for spouse, and 3,100 Riels/month for an orphan in the kinfolk. In addition, as fringe benefits, electricity and water bills are subsidized by the government and free foodstuff as allowance in kind are distributed on an irregular basis. After retirement at the age of 55, they are also entitled to a pension which is 60% of the salary at the time of their retirement.

Despite their low salary, guaranteed employment, pension and absence of competition among colleagues are certainly attractive to government employees. Therefore, not many civil servants quit to seek better-paying jobs in the private sector.

4.2.1.2 Capability of PPWSA Staff by Educational and/or Vocational Background

Table-4.1 shows the classification of civil servants. The staff categories are A, B and C which are further sub-classified as A1 to A10, B1 to B4, C1 to C4.

Regarding the senior staff of the PPWSA, the ranks are: A8 for Director and Vice Director, A10 for Chief of the Exploitation Office, B1 for Chief of Technical Office, B2 for Chief of Financial Office, B3 for Chief of Administration Office, C1 for Chief of Phum Prek Water Treatment Plant and C2 for Chief of Distribution Office. Typically a chief officer's age is around 50.

There are a limited number of key staff members who are 30 to 40 years old and educated in the 1980s in the ex-Soviet Union and the Eastern Europe countries. Though trained in a different cultural environment from the western one, they are adaptable to the new systems because of their capability to understand basic and essential matters logically as well as systematically.

4.2.1.3 Characteristics of PPWSA Staff

Senior staff are well informed about matters related to their responsibility and authority and are willing to discuss them. They are always careful as not to overstep the boundaries of their authority. This may be attributed to the structural oversizing of the PPWSA and the relatively small area of designation of each senior staff's responsibility and authority.

For rebuilding the Cambodian society active participation of the people is indispensable. For rehabilitation and development of the PPWSA management, active cooperation of all staff is absolutely necessary.

4.2.2 Operational and Administrative Problems

4.2.2.1 Operation and Maintenance of Facilities

Aside from the problems related to physical aspects of the facilities, operation and maintenance need to be looked into in terms of staff capability, organization functions and institutional and existing framework.

1) Intake and PPWTP

The intake pumps are often kept running, wasting water and electricity, even after the service reservoirs are full. While the laboratory routinely conduct water quality analysis and jar test, the result is not taken into account for the chemical dosage control of water treatment processes.

A ledger of major machines has been made, but not used as a checklist for repair and regular overhaul and replacement.

The staff needs to be given adequate technical training to improve operation and maintenance of the treatment plant.

For both water treatment plants, Phum Prek and Chamcar Morn, there are different groups for repair and transportation. They could be merged for better efficiency.

Table-4.1 CLASSIFICATION OF CIVIL SERVANTS

Category A: Positions in the Party, the government, and mass organizations (line position system). The category is subdivided into:

A1: Party posts (11 positions, ranging from Secretary-General of the Party to deputy head of the Party bureau at the district level);

A2: Posts in the Executive Branch (11 positions, ranging from Prime Minister to deputy head of a direct bureau);

A3: Posts in the Executive Branch (8 positions, ranging from Secretary-General of a particular association to a deputy head of the district association).

and so on until A10

Category B: Administrative career positions. This category is subdivided into four levels 'which in principle correspond to different levels of training. In practice, what accounts is not necessarily formal training attested by a diploma, but the job performance of the level of responsibility. The four levels are as follows:

B1 : Holders of a university degree awarded after at least four years of post-secondary education;

B2 : Holders of a diploma awarded after at least two years of post-secondary education. This category comprises senior technicians, health officers, etc.;

B3 : Holders of diploma or persons with vocational training: state-registered nurses, primary school teachers, etc.;

B4 : Holders of a primary school certificate, office personnel, etc.

Category C: Manual workers: This category is also subdivided into four levels which correspond either to the degree of skill required by the job or to the degree of physical effort necessary to perform for high-rank officials, driver of buses or heavy trucks, etc. Some employees in Category C may actually perform tasks that in principle come within Category B (nursing auxiliaries, supervisors, or teaching assistants, etc.).

Source: Cambodia, Agenda for Rehabilitation and Reconstruction: The World Bank, June 1992

2) Network Office

This office is responsible for water distribution. One of its tasks is to control valves in the distribution network to achieve as even a distribution as possible. It is also responsible for leakage detection and repair.

Due to the extreme shortage in water supply at present and the lack of reliable pipe network maps and drawings, the above-mentioned routine works are not carried out at all. Instead, house connection and meter installation work is assigned to this office.

When more water is produced and delivered, the lack of distribution network maps will become a fatal handicap for normal operation. The locations and sizes of water mains, control valves, air valves and drain valves need to be identified as soon as possible for drawing updated, reliable maps.

House connection and meter installation work should be transferred to the customer services unit.

3) Technical Office

This office should be the think tank and planning arm of the PPWSA on technical and engineering matters.

However, the office is handling not only the major activities of planning and designing, but is also handling miscellaneous matters such as repair, document-keeping, checking distribution pressure, testing water quality and so on. Such miscellaneous works were originally the responsibility of the production and distribution departments, but they are poorly staffed and are not able to assume such responsibility. In effect, the most capable engineers and technicians are assigned to attending miscellaneous matters.

In future, within the framework of the organization of the PPWSA, the role of this office needs to be re-defined.

4.2.2.2 Administrative and Financial Operations

As seen in Fig-4.1, personnel management and planning is the most important function of this office. Other functions are of secretarial nature.

Due to the centralization of power in the State Government and the Party, the PPWSA does not have much discretionary powers to recruit or manage its own employees.

When necessary, the director calls a meeting of about 10 senior staff members for considering promotion of employees. The decision needs to be approved by the mayor.

No significant planning works have been undertaken by the office. Regular weekly meetings are attended by the 12 managers. The yearly budget proposed by each office is reviewed, modified, finalized and summed by this office prior to the director's approval and submission to the mayor's office.

1) Financial Office

The functions of this office are, as seen in Fig-4.1, processing and accounting of revenues and expenses, procurement, property management, store-keeping and the preparation of monthly and yearly financial reports.

The balance sheet is made in a form as shown in Table-4.2.

Table-4.2 BALANCE SHEET FORMAT

Item	Debt	Credit	Balance
I. Assets			
Capital Asset			
1. Material & Equipment			
2. Cash in Hand			
3. Bank Account			
4. Budgeting Expenditure (total) from Municipality			
II. Liabilities			
5. Accounts Payable			
6. Budget Offset			
7. - not used -			
8. Account Receivable			
9. Budget Capital			
III. Equity			

In 1986, the assets were re-evaluated only for the two treatment plants and distribution network. The total amounted to 5,332 million Riels, of which, 4,606 million Riels (86%) were for distribution pipes.

As a matter of fact, any amount of proposed expenditures need to be approved by the mayor's office, the ministry of finance, and the UNTAC prior to disbursement, due to the suspension of autonomy.

Obviously, not much financial management works are undertaken by this office, due to limited PPWSA autonomy. Strengthening this office should be given the top priority towards realizing the self-supporting nature of the organization.

2) Customer Services

In most countries, routine works of meter reading, billing and collection of water tariff is the responsibility of the "customer services" unit which is considered as one of most important units of the water supply service. Usually, this unit also handles house connection and installation and repair of meters.

Presently, meter reading, billing and meter maintenance are undertaken by the Exploitation Office, while water tariff collection, processing unpaid bills and suspension of supply are carried out by the Revenue Collection Office. This reorganization and redemarcation of responsibilities was made in January 1992. No satisfactory explanation for the change has been given. House connection and meter installation is the responsibility of the Network Office.

a) Meter Reading and Billing

Of the 87,300 house connections, only 2,300 are metered. Bills of 24,000 are prepared every other month. As stipulated in Decree 32, un-metered connections are charged based on estimated consumption.

b) Water Tariff Collection

In 1992, the ratio of collected revenue to issued bills was 45.8% and 60.2% respectively, for the local and foreign currency bills. Details are given in Fig-4.3.

As stipulated in Decree 32, penalty, fine and cut-off of supply apply to customers not paying. Due to the extremely poor conditions of supply, customers are usually uncooperative, making the work of meter readers and tariff collectors very difficult.

For the collectors employed on temporary basis, a bonus system is used to improve their performance by supplementing their low salary.

c) Mapping of House Connections

Although all customers are listed, house connections have not been located in the distribution network maps.

4.2.2.3 Improvement of PPWSA Operation

To make operations of administrative and financial affairs more functional, structural reform of the PPWSA is needed in the following aspects.

1) Enlightenment of Employees

There are various important basic principles to be firmly understood by PPWSA's employees: the raison d'être of water supply in the society, the social obligation and responsibility as a public servant, and the significance of order and discipline in a public service organization. Methods for saving costs, improving performance and raising productivity needs to be taught.

2) Training

The importance of vocational training needs to be understood as it is essential to improve the employees' capability and eventually the organization's performance. As a minimum requirement, the training programs shown in Table-4.3 should be prepared.

3) Organizational Changes

Along with the proposals for reorganizing the PPWSA discussed in Section 4.1.2, the structure needs to be rebuilt at four levels, namely, director, deputy directors, division managers and subdivision managers. At least three Deputy Directors need to be appointed to manage Technical, Administrative/Financial and Customer Services.

After completion of the urgently required rehabilitation works, to operate and maintain the facilities it is essential for engineers to understand the intentions of the designer of the plants and other facilities and their unit operations and the system as a whole; the technicians need to have good knowledge of the mechanism of the unit operations. The staff need to be exposed to new theories and methodologies of management and operation.

To achieve this, abolishing the present seniority and experience oriented system and introducing a new responsibility and capability oriented system is indispensable. Promotion and assignment of staff to the office-chief level and division manager level chief's position, strictly based on their performance and capability needs to be considered.

4) Changing Internal Regulations for Motivating Employees

Improvement of the PPWSA's management could be achieved only by motivating ambitious and aspiring staff by rewarding them with more authority quick promotions and better salaries. The present personnel management system and pay-roll system needs to be changed after a systematic review.

The participants of training programs need to be evaluated for implementing and realizing improvements due to their training and need to be given more responsible posts.

The newly-appointed middle level managers need to be compensated and rewarded for the increased responsibility, within the framework of the public servants remuneration rules.

The reorganization shall be accompanied by improved procedures for processing documents and publicizing information among the units of the PPWSA. Bureaucracy and secretiveness needs to be uprooted.

4.2.3 Roles of State and Municipal Governments

4.2.3.1 Self-sustainability as the Long Term Target

Self-sustainability of the PPWSA on every aspects of management, including operation and maintenance of the facilities and administrative and financial operations, is the main target of the Study.

Very much needed are the concentrated efforts by, not only the management and all employees of the PPWSA but also the state and municipal governments concerned.

Self-sustainability of water supply service is conditional. The conditions required are essentially economic and financial. However, whether a water supply service could be made self-sustainable or not is affected largely by political and administrative environments.

Table-4.3 TRAINING PROGRAMS

Fields	Main Curriculum	Demonstration/Practices
Water Treatment	principles of coagulation, sedimentation, filtration	chemical dosage, turbidity measurement, desludging, backwashing,
Leakage Reduction	principles of pipeline flow and concept of the non-revenue earning water	pressure measurement, pipe laying, valve control, leakage detection/repair
House Connection	underground utilities, public and private properties	tapping mains, plumbing, meter installation, detecting illegal connections
Customer Services	key matters of public relation, procedural matters reporting on leakage	meter-reading, calculation for billing, money handling, finding meter faults,
Administration	matters on legislation & execution, personnel management, coordination on training	discussion on subjects in curriculum, use of computer for administrative processing
Finance	matters on legislation & execution, budget planning & monitoring	discussion on subjects in curriculum, use of computer for financial processing

A small community water supply could be self-sustainable, when the community people are willing to pay for the capital and operation costs, to offer their voluntary labor for operation and maintenance, to pay attention for saving water and energy.

A large city water supply may not be self-sustainable, if the water price is set unrealistically low, operation and maintenance are neglected and the consumers use water in wasteful manners.

Even when a city water supply is so managed as to generate a sufficient profit for paying interest and principal of the capital, if it is taken away by higher authorities for the uses of, such as, defense or other un-related purposes, the service level will be degraded gradually and the self-sustainability will be lost.

4.2.3.2 Roles of State and Municipal Governments

The leading players for attaining self-sustainability are PPWSA, the supplier, and people, the customer. The state and municipal governments' role shall be limited to giving advice, guidance and assistance to them on administrative and financial matters.

Fig-4.2 shows the cash flow between the state and municipal governments and the PPWSA. Practically no cash is allowed to be retained by the PPWSA and every payment shall be requested, approved by the higher authorities for disbursement. The input spent in the procedures is not meaningful. The amount of money itemized in the budget could be
left for the PPWSA's discretion.

PPWSA cannot collect enough revenue to pay for electricity which is the largest item of expenditure, while the governmental agencies and employees do not pay water tariff. Managing the cross credit/debit among governmental agencies may be a bureaucratic means of controlling them, but the same role is played by the Clearing House in the capitalistic system.

In all Asian countries developing at a remarkable speed in recent years, improvement of water supply has been made consistently resulting in longer life expectancy, less medical care expenditure, increased manpower input for productive activities.

A political consensus is to be made in that improving water supply service should be given the top priority and administrative and financial resources should be used.

Presently, no governmental agency is assigned to manage the water supply services in the country, except that the Ministry of Health is handling water supply in rural areas by liaising with external aid agencies. A department-level unit shall be established in a ministry to prepare plans for improving water supply sector.

4.2.3.3 Transition from Administrative Service to Public Enterprise

Presently, water supply by the PPWSA is at a transitional stage from administrative service to public utility service.

While administrative and financial assistance are not given to the PPWSA, it is not authorized to fix the water price, handle cash flow, recruit and/or dismiss employee, change the organizational structure, appoint senior staffs to responsible positions, etc. Without delegation of powers on these matters from above, PPWSA will never be able to function efficiently and effectively.

1) Raise of Water Tariff

As long as the current water tariff is maintained in force, the PPWSA's financial conditions will never be improved.

166 Riels per cubic meter is too low definitely. A five-person family using an unmetered house connection is paying only 2,000 Riels, while the household income may be in a range of 200,000 Riels per month. Water tariff can easily be raised without impairing consumers' affordability.

Immediate raise of the water tariff is needed, because the stable economic development will take a long time under the present political conflicts.

2) Tentative Delegation of Powers

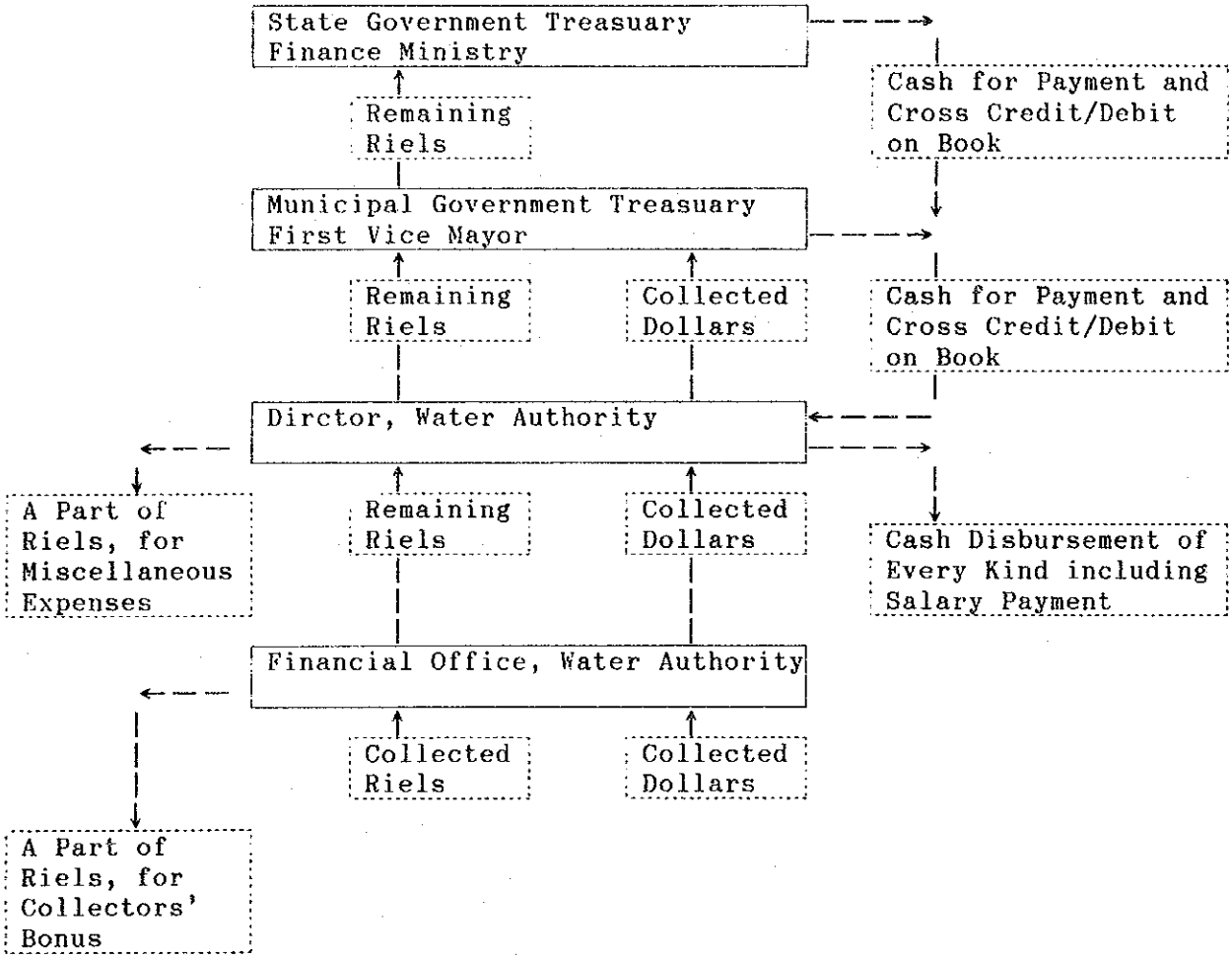
Some powers are to be delegated to the PPWSA tentatively.

The PPWSA is to be empowered to handle its own cash flow except for the debt for electricity. In return for it, the generated surplus will have to be paid to the higher authorities.

Restructuring of the organization, appointment of senior staffs to positions and recruitment and dismissal are to be delegated fully.

Intensification of disciplinary actions against absenteeism, negligence and illegal behaviors of the employee shall be allowed. Rewarding for hard work, diligence and contribution to improvement of performance shall be authorized, too.

Fig-4.2 Cash Flow among Water Authority, Municipal and State Government



4.3 Financial States

4.3.1 Introduction

The following financial documents of PPWSA were collected.

(a) Yearly Reports 1988 - 1991.
(b) Monthly Report for 1992 and 1993 (Jan. to Apr.)
(c) Balance Sheet for 1992

Those documents are from the Financial Office, originally written in Khmer. In addition to these documents, other information to figure out the financial status was obtained through interviews with managerial staff at each office as well as from reports written by international organizations such as ADB, UNDP, WB, ECFA, and so on. (List of interviews are given in Appendix J.)

Before starting analysis of the mentioned information, the following two points should be noted for better understanding of current PPWSA financial status.

1) Historical Change of PPWSA

PPWSA has been changed as follows:

1979 - 1985	After the Pol Pot regime, PPWSA was under the transportation department of the Municipality.
Mar. 1, 1985	Ministry of Finance issued a letter (No. 19) to PPWSA regarding its financial responsibility.
Aug. 1, 1987	Phnom Penh People Committee issued a letter (No. 286), for PPWSA to become autonomous from January 1, 1988.
Dec. 31, 1987	Decree No. 32 was enacted by the Council of Ministers. (see Section 4.1.1 for details)
Jan. 1, 1988	PPWSA became autonomous.
July 1991	PPWSA came under the control of the Municipality.

From the above, it is inferred that current organization set up basically started from middle of 1991.

Table-4.4 PRICE DEVELOPMENTS
(1989=100)

Description	1987	1988	1989	1990	1991
CPI (mid-year)	n.a	67.4	100.0	249.8	580.7
Food Prices (mid-year)	n.a	60.9	100.0	239.3	548.3
Construction Goods	65.1	83.5	100.0	322.5	500.0
GDP Deflator	47.1	80.8	100.0	260.4	521.8

Source: Cambodia Agenda for Rehabilitation and Reconstruction, World Bank, June 1992.

The exchange rate (Riels - U.S. Dollar) in recent years has been unstable and the Riel has lost in value very steeply as shown in Table 4-5. Several explanatory factors have been suggested for the behavior of the exchange rate. It is reported that about 400 % of high inflation after 1988 was mainly caused by printing Riels to cover the deficit 1989-1990 budget and defense expenses.

Table-4.5 EXCHANGE RATES

Year	Rate : U.S. Dollar =	Source
1981	50 Riels	IDE[1]
1986	155 - 160 Riels	ditto
1987	120 Riels	ditto
1988	150 - 155 Riels	ditto
1989	180 - 190 Riels	ditto
1990	n.a	ditto
1991	700 Riels	ditto
1992 Feb.	800 Riels	Council of Ministers[2]
1992 Dec.	2,300 Riels	ditto
1993 Jun.	4,000 Riels	ditto

Note: 1: IDE ; Institute of Developing Economy, Report, 1992-3.
2: Report on the Socio-Economic Situation in 1993 and Plan for 1993.

4.3.2 Present Financial Situation

Due to the long internal war and limited financial resources of the country, adequate investment has not been allocated to the water supply sector. At present, PPWSA is not so prepared as to meet the requirements of self sustainability. It needs rehabilitation in both the hardware, that is, facilities of water intakes, water treatment, distribution and services, and the software, that is, skill transfer in developing capabilities for operation and maintenance,administrative and financial control, and customer service.

4.3.2.1 Analysis of Water Sale and Cash Flow

The revenue and related figures for consecutive years (1988 -1992) are shown below in Table-4.6. The data for 1988 to 1991 is obtained from the PPWSA yearly report and 1992 figures were prepared by the accounting staff of PPWSA.

Table-4.6 REVENUE OF PPWSA

Description		1988	1989	1990	1991[1]	1992
Water Sale (Riels)	(A)	1,110,142	4,498,865	34,907,432	14,610,106 (25,045,896)	415,031,774
House Connection Charge Fee (Riels)	(B)	n.a	8,180,904	10,520,690	8,021,276 (13,750,758)	78,607,970
Revenue (A)+(B) (Riels)	(C)	1,110,142	12,679,769	45,428,122	22,631,382 (38,796,654)	493,639,744
No. of Staff	(D)	298	292	378	264	270
Total Expense (Riels)	(E)	34,200,597	54,743,802	165,187,226	181,357,859 (310,899,186)	1,302,817,924
Water Production (m3/year)	(F)	23,319,953	20,880,000	19,345,000	10,271,082 (17,607,569)	26,952,000[2]
Deficit (Riels)	(G)	33,090,455	42,064,033	119,759,104	158,726,477 (272,102,532)	809,178,180

Note: 1; All figures are for 7 months operation from Jan. to July.
The numbers in parentheses are estimation for 12 months operation, multiplied by 12/7.
2; This figure is from 1992 monthly report.

From Table-4.6, some fundamental analyses can be done. The water production (F) which had decreased gradually from 1988 to 1991 and jumped up in 1991-1992, while no works for increasing production capacity was made.

In 1991-1992, the water sale revenue (C) increased remarkably, due to water tariff raise and improvement of money collection ratio. The sharp rise of water production was

supposed to be a make-up for rationalizing the revenue increase.

Using the data in Table-4.6, Table-4.7 shows the average cost, the total revenue and expenditure per capita of PPWSA staff(C/D, E/D) and the ratio of deficit to expenditure (G/E).

Table-4.7 THE CHANGE OF AVERAGE COST

Description	1988	1989	1990	1991	1992
Average Cost	1.47	2.62	8.54	17.66	48.34
(C)/(D)	3725.31	43423.87	120180.22	146957.03	1828295.35
(E)/(D)	114767.1	187478.77	437003.24	1177648.43	4825251.57
(G)/(E)	0.97	0.77	0.72	0.88	0.62

Where;

Average Cost= Total Expenditure/Amount of Water Production (Riel/m^3)
(C) = Total Revenue
(D) = Number of staff
(E) = Total Expenditure
(G) = Deficit

The average cost is increasing, most probably due to the inflation. By using the Consumer Price Index, each equivalent average cost corresponding to 1992 average cost is roughly calculated below.

	1988	1989	1990	1991	1992
Average Cost (Riel/m^3)	1.47	2.62	8.54	17.66	48.34
Equivalent to 1992	14.2	12.1	15.0	20.32	48.34

It is observed that the average cost in 1992 is far higher than in other years, and the average cost multiplied 3.4 times from 1988 to 1992.

Total revenue divided by number of staff (C/D, revenue per capita) indicates some extent of the revenue efficiency. To normalize each year's revenue, each year's water tariff has to be considered. According to the PPWSA administration office, water tariff rates have been changed as follows:

1981	2 Riels/m^3
1988	3 Riels/m^3
1989 Jan.	8 Riels/m^3
1991 Jan.	32 Riels/m^3
1992 Jan.	166 Riels/m^3

Using these values, the revenue per capita (C/D) in terms of 1992 price level are calculated as follows:

1988	206,133 Riels/person
1989	901,045
1990	2,493,739
1991	762,339
1992	1,828,295

The revenue per capita increased in 1988-1990, but dropped suddenly in 1991 and, in 1992 it did not recover to the 1990 level.

The rise and fall are though to have been affected by the water tariff raise and the PPWSA staff number's increase and decrease partly. But, they could not fully explain the fluctuation.

Anyhow, the revenue per capita of PPWSA in 1988-1992 multiplied 9 times.

Based on the amount of water sale and the tariff for each year, the growth rates in terms of volume of water sold for the period are calculated as follows:

1988 - 1992	4.5
1989 - 1992	4.5
1990 - 1992	0.57
1991 - 1992	3.2

Relatively high growth rates are observed.

The percentages of deficit in total expenditure (G/E) seem to be decreasing year by year. It was 97 percent in 1988 and 62 percent in 1992, which indicates increasing efficiency in terms of revenue collection.

4.3.2.2 Billing

As stated before, of about 25,000 house connections in the city, only 10 % is metered and the remaining 90 % is charged based on a rule of estimating consumption.

The billing are categorized into two, normal and special. The normal bill is for domestic consumption of the people and the governmental offices. The special is for foreigners, diplomatic agencies and business, etc.

1) Consumption Estimation for Normal Bill

A person, regardless of the age and sex, is assumed to consume 80 liter per capita per day (lpcd). For a household, the estimated consumption per month is calculated as:

2.4 m^3/month x Number of Persons

A person working in the governmental offices is assumed to consume 30 lpcd and an office's consumption becomes:

0.9 m^3/month x Number of Persons

2) Consumption Estimation for Special Bill

Table-4.8 shows 13 categorized users of the special bill.

Table-4.8 ESTIMATION OF SPECIAL BILL

No.	CATEGORY	Currency	ESTIMATION
1	Foreign Houses	U.S.D.	2.4 m^3/person/month * 0.20 U$
2	Water Selling	Riel	m^3 * 166 riel
3	Car Cleaning	Riel	a) m^3 * 166 riel b) 0.5 m^3/car * 166 riel
4	Hotel	Riel	a)Room: 0.3 m^3/day/room * 166 b)Staff: 30 l/day/staff * 166/1000
5	Restaurant	Riel	a)Table: 0.4m^3/table/day * 166 b)Staff: 80 l/day/person * 166/1000
6	Movie House	Riel	100 m^3/month/house * 166
7	Embassy	U.S.D.	same as No.1
8	Foreign Company	U.S.D.	same as No.1
9	Ice Mill	Riel	3 m^3/ton of ice * 166
10	Hair Cut Shop	Riel	16 l/Chair/day * 166/1000
11	Offices	Riel	30 l/day/person * 166/1000
12	School	Riel	a)Student:30 l/day/person * 166/1000 b)Staff: 15 l/day/person * 166/1000
13	Hospital	Riel	a)Bed: 60 l/bed/day * 166/1000 b)Staff: 30 l/day/person * 166/1000

Source: Exploitation Office

Note : 80 lpcd or 2.4 m^3/Person/Month is lower than a finding by the JICA study team which made the estimation at 100 lpcd in 1992.

4.3.2.3 Collection of Bills

Table-4.9 shows the ratio of collected bills to issued bills from January to December in 1992.

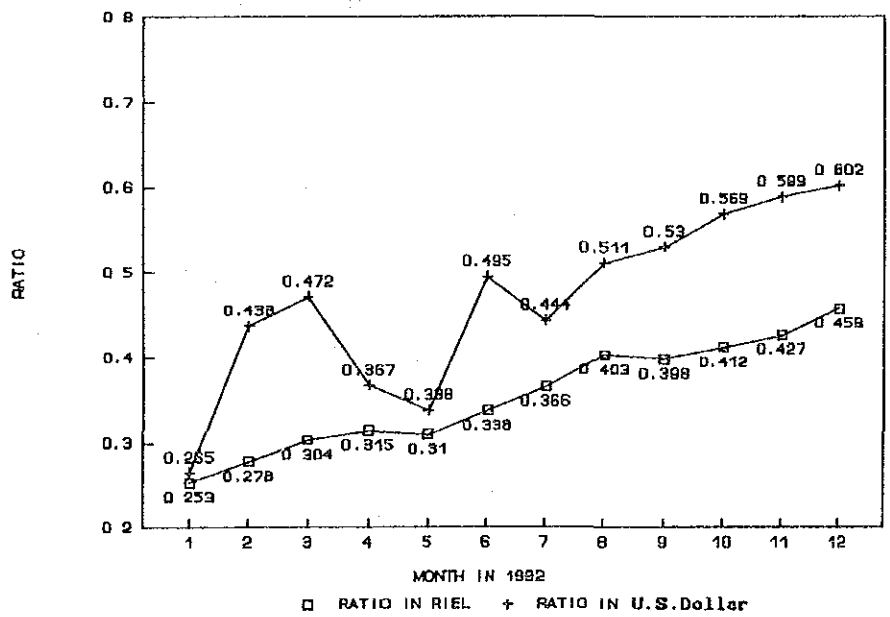
Table-4.9 RATIO OF COLLECTED BILLS TO ISSUED BILLS IN 1992

Month	Type	Issued Bill (A)		Actual (B) Collected Money	Ratio B/A	Cumulative Number		
		No.	Amount			Issued Amount	Collected Amount	Ratio
JAN.	People (Riel)	19,462	65,583,044.00	18,820,228.60	0.253	34,412,907.00	18,820,228.60	0.253
	Special (U.S.Dollar)	243	2,580.76	684.61	0.265	2,580.76	684.61	0.265
	Special (Riel)	1,004	8,829,863.00	n.a				
FEB.	People (Riel)	17,854	53,958,441.00	18,996,069.69	0.308	136,113,881.00	37,816,298.29	0.278
	Special (U.S.Dollar)	129	1,760.86	1,214.99	0.690	4,341.62	1,899.60	0.438
	Special (Riel)	399	7,742,533.00	n.a				
MARCH	People (Riel)	16,929	50,500,080.00	23,163,624.39	0.360	200,510,207.00	60,979,922.68	0.304
	Special (U.S.Dollar)	191	3,115.37	1,620.47	0.520	7,456.99	3,520.07	0.472
	Special (Riel)	767	13,896,246.00	n.a				
APRIL	People (Riel)	18,313	53,229,090.00	23,790,079.06	0.345	269,390,422.00	84,770,001.74	0.315
	Special (U.S.Dollar)	168	3,264.52	410.86	0.126	10,721.51	3,930.93	0.367
	Special (Riel)	665	15,651,125.00	n.a				
MAY	People (Riel)	19,137	57,991,111.00	20,859,712.62	0.291	341,106,189.00	105,629,714.36	0.310
	Special (U.S.Dollar)	260	5,010.62	1,392.50	0.278	15,732.13	5,323.43	0.338
	Special (Riel)	593	13,724,656.00	n.a				
JUNE	People (Riel)	19,378	55,634,691.00	31,727,360.50	0.482	406,962,753.00	137,357,074.86	0.338
	Special (U.S.Dollar)	116	2,883.90	3,894.76	1.351	18,616.03	9,218.19	0.495
	Special (Riel)	425	10,221,873.00	n.a				
JULY	People (Riel)	19,010	60,214,279.00	41,212,113.02	0.508	488,128,495.00	178,569,187.88	0.366
	Special (U.S.Dollar)	273	6,135.29	1,761.45	0.287	24,751.32	10,979.64	0.444
	Special (Riel)	555	20,951,463.00	n.a				
AUG.	People (Riel)	19,123	54,594,482.00	46,046,975.88	0.661	557,742,203.00	224,616,163.76	0.403
	Special (U.S.Dollar)	236	4,895.20	4,170.44	0.852	29,646.52	15,150.08	0.511
	Special (Riel)	567	15,019,226.00	n.a				
SEP.	People (Riel)	19,670	86,895,920.00	39,083,643.39	0.374	662,234,386.00	263,699,807.15	0.398
	Special (U.S.Dollar)	222	4,313.03	2,843.06	0.659	33,959.55	17,993.14	0.530
	Special (Riel)	676	17,596,263.00	n.a				
OCT.	People (Riel)	18,904	56,693,343.00	40,163,665.79	0.528	738,311,696.00	303,863,472.94	0.412
	Special (U.S.Dollar)	252	4,584.77	3,922.74	0.856	38,544.32	21,915.88	0.569
	Special (Riel)	700	19,383,967.00	n.a				

Month	Type	Issued Bill (A)		Actual (B) Collected Money	Ratio B/A	Cumulative Number		
		No.	Amount			Issued Amount	Collected Amount	Ratio
NOV.	People (Riel)	19,826	57,288,285.00	42,684,559.42	0.583	811,496,468.00	346,548,032.36	0.427
	Special (U.S.Dollar)	273	5,367.71	3,949.63	0.736	43,912.03	25,865.51	0.589
	Special (Riel)	695	15,896,487.00	n.a				
DEC.	People (Riel)	20,627	66,533,755.00	63,983,895.65	0.758	895,956,219.00	410,531,928.01	0.458
	Special (U.S.Dollar)	255	5,474.61	3,865.95	0.706	49,386.64	29,731.46	0.602
	Special (Riel)	755	17,925,996.00	n.a				
TOTAL	People (Riel)	228,233	719,116,521	410,531,928.01	0.458			
	Special (U.S.Dollar)	2,618	49,387	29,731.46	0.602			
	Special (Riel)	7,801	176,839,698	n.a				

The cumulative ratio (collected bills amount/issued bills amount) is shown in Fig-4.3.

Fig-4.3 THE COLLECTED BILLS/ISSUED BILLS IN U.S.DOLLARS AND IN RIELS



The cumulative percentage goes up slowly from January to December in both currencies, indicating that the collection efficiency could be improved by strict enforcement of the collection rules and the collectors' efforts. At the end of the year,

the cumulative ratio was 45.8 % in Riels and 60.2 % in U.S.Dollar.

Roughly saying, the 1992 revenue would have doubled if the bills were collected hundred percent and the deficit shown in Table-4.7 would have been decreased from 62 % to 25 %.

The bill collection is a most immediate and important issue for improving the PPWSA management.

1) Bonus System for Collectors

To improve the money collecting efficiency, a bonus system has been introduced since July 1991, with the municipality's approval. According to the Revenue Office, The rates of bonus are as follows:

a) Normal Bill

Percent of Collected Bill	Bonus Rate
100 %	10% of total bill amount
more than 70%	5% of total bill amount
less than 70%	2% of total bill amount

b) State Bill

Flat Bonus rate: 2% of total bill amount.

c) Special Bills in U.S. Dollar

No bonus.

Every collector gets the cash bonus every three days.

It is said that the highest and lowest bonus (actually paid) are as follows:

The Highest Bonus per week: 8,000 Riels
The Lowest Bonus per week: 3,100 Riels

Since the basic collector's salary is 5,500 Riels/month, the approximate highest and the lowest monthly salary are worked out to be 37,500 Riels/month and 17,500 Riels/month respectively. (The permanent staff salary is divided into 24 ranks; the highest is 48,500 riels/month and the lowest is 19,200 Riels/month.)

4.3.2.4 Expenditures

The expenditures of PPWSA in 1992 are categorized into six items as shown in Table-4.10.

Table-4.10 EXPENDITURES IN 1992

ITEMS	Riels
Salaries	121,974,757
Office Supplies	30,662,085
Maintenance	5,323,532
Chemicals	
Alum	148,680,000
Chlorine	8,025,600
Power	986,736,950
Miscellaneous	1,415,000
Total	1,302,817,924

Source: Financial Office

It is noted that Power expenditure accounts for nearly 75.7 percent, and that expenditure for salaries is only about 9 percent, while that for chemicals is about 12 percent of the total expenditure. The average salary is derived as 451,758 Riels per person per year, or 37,646 Riels per person per month, which is only 47 U.S. Dollars with per exchange rate of 800 Riels/U.S.Dollar (1992 Feb).

4.3.3 Water Tariff Rates and Affordability

New water tariff rates has been introduced since Jan. 1992, which is a flat charge of 166 Riel per m^3. As mentioned previously, article 11 of Decree No.32 stipulates that the price of water is fixed by the provincial or municipal Peoples Revolutionary Committee, based on the advice from the Minster of Planning and the Minister of Finance.

It is estimated that about 2,300 water meters were functioning as of April, 1993, of

which Don Penh District has 1094, Chamcar Morn 722, Toul Kork 399, and 7 January 588 according to the information obtained from the Exploitation Office.

The people's affordability to pay for water is a major concern of the PPWSA management and a case study is needed to see it.

Through interviews with people of different working classes and groups, it is expected that a minimum living cost for the lowest-income families is about 50 U.S.Dollars, (refer section 2.2.3) which is about 150,000 Riels using exchange rate at the beginning of April, 1993. Based on the assumption that each person consumes 80 lpcd and that the monthly income of a family is 150,000 Riels, water tariff rates and their percentages to the income are calculated as follows. Considering the percentages to the income, i.e. 1.3 % to 2.1 %, water tariff rates for the lowest-income family still remain in an affordable range.

Number of Family Members	Water Tariff	Percentage to the income
5	1,992 Riels	1.3 % (1,992/150,000)
6	2,390 Riels	1.5 %
7	2,789 Riels	1.8 %
8	3,187 Riels	2.1 %

In case of the PPWSA staff's average monthly income (37,646 Riels/month) and an average number of family members (6), the water tariff rate is 6.3 % of the income. This is not considered to be affordable. However, the income level around 37,000 Riels/month does not reflect the real situation in Phnom Penh.

4.4 UNDP Activities in 1993

After adjustment of financial tables by UNDP experts using personnel computer, several facts are discovered.

4.4.1 Water Revenue Comparison for 1992/1993

	1992/January-July	1993/January-July
Total Revenue		
(Riel)	446,195,424	591,768,100
(US Dollar)	18,617.00	36,273.00

The main reason for the increase in revenue in 1993 is due to increase in the number of bills from 24,000in 1992 to 26,000 in 1993.

4.4.2 Billing System from 1993

The bill collection period was changed from once a month to once in two months from 1993 to save collection expenditure. The water tariff was also changed for the two customer categories. Water tariff for domestic use is 166 Riel/m^3 and for foreigners and commercial establishments is 0.2 U.S.Dollar/m^3.

The improvement measures being adopted under the guidance of UNDP experts since May 1992.

4.4.3 New UNDP Experts from July 1993

Four (4) new UNDP experts are working at PPWSA from July 1993, covering the four (4) fields of administration, production, distribution and finance. The period of engagement is more than two years.

The experts have prepared a report entitled "The Plan for Reaching Financial Autonomy" for the PPWSA with the target year set as 1997.

CHAPTER 5

MASTER PLAN

5. MASTER PLAN

5.1 Framework

5.1.1 Target Year

After years of civil strife, the environment is now suitable for starting the process of sustained economic and social rehabilitation and development. Cambodia faces both challenges and opportunities as it transforms from a planned economy to a market-oriented economy. To facilitate the transition and prepare for long-term development, many international donor agencies are prepared to make financial and human resource commitments for the reconstruction of Cambodia.

Development of the water supply sector is an important development programs. For the Phnom Penh water supply, urgently needed work is undoubtedly the restoration of existing water supply facilities to meet current requirements. Simultaneously, medium to longterm development programs must be established to cater to future requirements. The setting up of many infrastructural facilities, including water supply systems require adequate lead time. Accordingly, the plan is set for 20 to 30 in the future.

In this Study, the target year is set as 2010, a relatively short period because of current instability and unforeseen social developments. Needless to say, after the existing facilities are restored and citizens' lives stabilize, the master plan itself may need to be modified reflecting a more stable society and based on more reliable forecasts.

5.1.2 Population Projection

5.1.2.1 Population of Phnom Penh City

In the 1930s the population was estimated as approximately 100,000, which increased to 1.5 million in 1975 because the Vietnam War drove people in rural areas into Phnom Penh. The succeeding Pol Pot Regime, forced urban-dwellers to move to rural areas reducing the population of Phnom Penh. After the revolution in 1979, people started moving to the city, and the population increased to 320,000 in 1980 and 700,000 in 1992. Fig-5.1 shows the trend of population growth. Fig-5.1 also shows the projected population up to the year 2010. This projection will be explained later.

The long-term population growth of Phnom Penh is difficult to predict based on the present data. Because of the urgent demands for reconstruction, less attention has been paid to the completion of statistical information by the authorities in Phnom Penh. Estimates were therefore made, based on the population records during previous stable periods.

Historically, one stable period was during the Sihanouk regime, between independence in 1953 and before the installation of the Lon Nol regime in 1970. In the first half of this period, the country was generally peaceful and the process of development reached a level approaching the take-off stage for economic growth. In the second half of 1960s, the government terminated aid from the United States and a new era of self-help was inaugurated. Although the economic growth dropped to less than half that of the first decade of the Sihanouk period, it was a progressive era. The annual population growth rate reached as high as 6% between 1959 and 1969 as shown in Fig-5.1.

In January 1979, the "People's Republic of Kampuchea" was created in Phnom Penh. In 1989 the name of the regime was changed to the "State of Cambodia". The task of rehabilitation and reconstruction began immediately. The annual population growth rate was around 6% between 1983 and 1992.

The annual population growth rates in the two stable periods were both 6% approximately. This rate is higher than the current growth rate of about 2.5% for the whole country. Nevertheless, 6% is taken as the future growth rate for Phnom Penh city, because growth rate in urban areas is higher than in rural areas due to migration. Cambodia is a relatively small country and the majority of the people live in the Central Plain. As development takes place, transportation will improve, accelerating economic activity in Phnom Penh as well as migration to Phnom Penh. Phnom Penh serves as a key trading point and is an important junction for a wide variety of transactions, being the center of commercial, financial and political power. In addition, the city is the traditional center of education, health and cultural activities. This scenario, using a 6.0% growth rate, gives Phnom Penh a population of 1 million in 2000 and 1.85 million in 2010.

The above estimate is based on population counts done annually by village heads. However, the counting does not include unregistered people. It is reported that there are now numerous unregistered persons, particularly in the non-agricultural area or during the dry season in Phnom Penh, seeking cash revenue to supplement low income from agricultural activities in villages. If such unregistered persons are counted, the current population is estimated, as between 800,000 and 1 million depending on season according to the Municipality.

The number of registered voters supports the above estimates. The registration procedure

started from October 5 to November 23, 1992 and ended on February 6, 1993. The figure 5,710,774 was only 4 percent higher than the estimated figure 5,534,405 for the whole country. Nevertheless, the figure for Phnom Penh was much higher than expected; the registered volume was 498,943 against the expected 360,424. Persons over 18 years old were eligible for registration. If the assumption that persons above 18 years of age constitute 50 percent of the country is applied to Phnom Penh, the population of Phnom Penh is around 1 million. For planning the water supply system, these people also must be taken into account.

The projected populations in 2000 and 2010 are considered valid. Once the country is stabilized, this an abnormal situation will disappear. Also, the estimated 6% growth rate is relatively high compared to cities in the neighboring countries and the whole of Cambodia which has a growth rate of 2.5 percent. According to the United Nations population projection, the population in Cambodia will increase to 11,539,000 in 2010. The projected population of Phnom Penh is 16 percent of the whole population, increasing from the current 7 percent.

Throughout the world, the population of major cities has been growing on an average of 3.6 percent per annum over the past three decades. This growth is attributed to natural increase, the higher percentage of young people in urban areas, and migration from the rural hinterland. Growth has occurred concurrently with an increase in the volume and diversity of economic activities in urban centers. Production and trade are vigorous at points of entry and exit for goods and services.

5.1.2.2 Subdistrict Population

Planning of the water supply system requires knowledge of distribution of population, in the network system. The distribution unit used is the subdistrict. Phnom Penh consists of seven districts (called "Khan" in the central area and "Srok" in the peripheral area). Each district has approximately 100,000 persons. A district is further divided into subdistricts. Fig-5.2 shows the districts and the subdistricts. It also shows population growth rates during the late 1980s by subdistricts.

The population has not changed in the Don Penh district, a densely built-up central area. Its population density is 141 persons per hectare (p/ha). Excluding the large lake in this district, the net population density is of the order of 200 p/ha. The most populous district is the "7 January" district with 374 p/ha. In both districts a large number of people reside in apartments.

Surrounding the Chamcar Morn and Toul Kork districts districts, there is a "suburban

zone" with a mixture of apartments, villas and temporary accommodations. The annual population growth rate was 2.6% in the former and 5.4% in the latter during the late 1980s.

The above four districts are within the "protected areas" from flooding. A distribution system is provided in all the four districts.

Outside the "protected areas," there are "peri-urban zones" with traditional housing. There are three such districts; Mean Chey, Russey Keo and Dang Kor. They are less developed but are protected from flooding by the construction of outer dams. The population has been increasing at around 7-8% annually. UNICEF has recently provided wells for each village in the three districts.

The population for each sub-district was estimated assuming that the above-mentioned growth rate will continue. The aggregated population is almost equal to the estimated population for Phnom Penh city. Therefore, these estimates are rational. Fig-5.3 shows the projected population in each district while Appendix C shows the figures for each subdistrict. Appendix C also shows the annual population growth rate and population density.

From Fig-5.4 and Fig-5.5, which show the population density in 1992 and the projected population density in 2010 respectively, the trend of urbanization can be predicted. Urbanized areas currently confined in four districts will expand to neighboring districts within a 10 km radius to accommodate an additional population of 1 million.

5.1.2.3 Development Projects Affecting Population Distribution

The projected subdistrict population reflects the effect on various development projects, as explained below.

According to the Phnom Penh Municipality, the Municipality is preparing several development projects to be implemented in the coming five years. The following five projects are under consideration for expanding the urban area and improving the living conditions.

1) O Bek Kaam Project: to relocate about 2,000 cottage industries (with about 6,000 workers), which at present lie scattered in the city, to O Bek Kaam area in Dang Kor district, on the southwest outskirts of the city.

2) Russey Keo Project: to reclaim about 230 ha of land in Russey Keo, north of the city, and develop 3,000 new residential lots for about 16,000 people.

3) A town scheme: to construct new embankments in the area between the Mekong River and the Sap River, and develop motels and low story housing.

4) A land reclamation project: to reclaim 500-600 ha of land to the south of the city for an industrial area, where the existing light industries to the north of the city will be relocated.

5) A plan was developed in the 1960s for relocation of the Phnom Penh port facilities to Chrouy Chang War, further north of the Mekong River. The plan included construction of four new piers of 105 meters each, new warehouses and access roads, and other equipment and facilities, as well as the dredging of the river estuary to accommodate larger vessels. The Japanese-assisted Chrouy Chang War Bridge over the Sap river was the first phase of the relocation project. The central portion of the bridge was destroyed in 1973, and has yet to be repaired. In addition to road access to the new port site, the bridge provided direct access to Kompong Cham.

There seems to be no concrete financial plan for the projects mentioned above. There is a pressing need for a master plan, but there are only a limited number of skilled staff members. Lack of financial resources is another constraint. The city of Paris has been assisting the Phnom Penh Municipality in preparing the master plan. The first product of the cooperation was the production of aerial photographs taken in January 1993.

To develop Phnom Penh, a framework or master plan is required, and all governmental plans and concepts must be considered. Such a study must be linked with budgetary processes to ensure proper funding of the urban redevelopment program.

There seems to be an unregulated "real estate development boom" mostly by foreign investors to construct hotels, commercial facilities and residences. These unregulated activities by the private sector will create serious difficulties for planning and development management in future.

5.1.3 Service Area and Service Population

The existing service area will naturally be a major part of the service area in the future. The distribution system covers the inner four districts and some parts of three suburban districts. The inner four districts are covered with a dense distribution network while the three suburban districts have a sparse system, occasionally lacking tertiary or even secondary mains.

The existing service area (shown as "Option 1" in Fig-5.6) had a population of 520,000 in 1992, out of the total population of 700,000 in Phnom Penh. The population in the existing service area will increase to 1.25 million in 2010 while the total population will be 1.85 million in the same year.

Population Served : 1.25 million as against 1.85 million for the entire Phnom Penh city
Service Area : 77.75 km^2 as against the total of 284.45 km^2

If the service area is confined to the existing area, the served population as a percentage of the total population will decrease from 78 percent to 68 percent.

The water supply system as well as other infrastructural facilities must be expanded to cater to new development. The new service area should be decided, taking into account the progress of urbanization, financial capability of the Phnom Penh Water Supply Authority (PPWSA) and the development policy of the Municipality. The progress of urbanization will be influenced by the development of roads. These activities should be guided by the Municipality to realize sound and harmonious development. Unfortunately, no city plan exists. Therefore, the service area is determined by the Study Team based on the criterion of the projected population density, which represents a measure of urbanization.

The outside areas, near the inner area and along the National Highways, will be developed and they will be served by the water supply system. These areas are shown in Fig-5.6 as "SCENARIO 2." The population density for these areas are predicted to exceed 40 inhabitants per hectare in 2010. If they are served, the population served and the area will be as follows;

Population Served : 1.62 million as against 1.85 million for the entire Phnom Penh city
Service Area : 110.94 km^2 as against 284.45 km^2

In the above scenario, the served population as a percentage of the total population will increase from 74 percent to 88 percent. Which scenario should be targeted depends on the will, capability, and the financial resources available with the PPWSA and the Municipality. For the time being, the Study Team recommends the former conservative scenario. The population served will increase by 2.4 times.

According to this scenario, a developing area, on the east side of airport is included in the

service area, but other areas of development projects are not included.

The project area is shown in Fig-1.1

The breakdown of service area and the service population is given below Appendix C shows the service population by sub-districts.

Table-5.1 SERVICE AREA AND SERVICE POPULATION

District	Sub-district	Service Area (km^2)	Service Population 1992	2010
Don Penh	Full district	7.60	106,907	166,738
Chamcar Morn	"	9.50	111,301	250,326
Toul Kork	"	9.25	96,022	259,625
7 January	"	2.35	87,840	105,070
Inside Total		28.70	402,070	781,759
Mean Chey	Chbar Ampouv 1	0.39	9,016	16,350
	Chbar Ampouv 2	1.53	15,460	54,477
	Beung Toum Poun	4.42	14,948	62,458
	Stung Meanchey	10.67	14,601	77,923
	Sub Total	17.01	54,025	211,208
Russey Keo	KM-6	4.24	10,678	25,724
	Russey Keo	5.79	12,631	27,169
	Toul Sangke	2.34	13,705	40,952
	Chroy Changwar	8.07	12,003	37,163
	Toek Tla	6.23	16,338	42,350
	Sub Total	26.67	65,355	173,358
Dang Kor	Kakab	5.37	10,710	87,818
	Sub Total	5.37	10,710	87,818
Suburban Total		49.05	130,090	472,384
Grand Total		77.75	532,160	1,254,143

5.2 Water Demand Projection

As some water meters have been installed in the city, meter readings were taken to investigate per capita consumption. The per capita consumption investigated is high because the selected houses were owned by relatively wealthy families and located close to the trunk mains, with comparatively high pressures. In addition, most houses were equipped with individual pumps. The selected areas were a) La Rue 19 and 130,

Don Penh district and b) La Rue 93, Acharmean street, Chamcar Morn district. As shown in fig-5.7, the per capita consumption was between 130 and 150 liters per day. This distribution of values of per capita consumption appears reasonable.

The values obtained are lower than those in the capitals of other countries in the region, e.g., Thailand and Indonesia, which are about 200 liters per day. The difference seems to reflect economic activity, living standards, etc. Once the country is stabilized and economic activity and living standards grow, the per capita consumption will undoubtedly increase. We expect that, the per capita consumption will reach the 200 lpcd level in the year 2010, assuming a growth rate of 4 percent per annum. This figure includes industrial, public, and all other uses, which cannot be identified from the meager statistical data.

Another design factor governing the size of the water supply system is the magnitude of water leakage. Current leakage is estimated as 50% of the produced quantity by the Study team. If no measures are taken, leakage will drastically increase with the increase in water pressure resulting from the proposed rehabilitation works. Therefore, improvement programs for the distribution system including leakage prevention should be undertaken. For the present study, it is assumed that the level of leakage will decrease to 20 percent of the total water produced in 2010. If the measures are implemented properly and systematically, the 20 percent leakage level is an achievable target.

Design factors including the above are set as follows;

	1992	2000	2010
Per capita consumption (a) (daily average)	100 lpcd	150 lpcd	200 lpcd
Max. to ave. daily demand ratio (b)	1.3	1.3	1.3
Per capita consumption (c)=(a)x(b) (daily maximum)	130 lpcd	195 lpcd	260 lpcd
Leakage ratio (d)	50%	40%	20%
Per capita demand (e)=(c)/{1-(d)} (daily maximum)	260 lpcd	325 lpcd	325 lpcd

Table-5.2 shows the water demand. The demand (daily maximum base) will increase from 138,000 m^3/day to 408,000 m^3/day in 2010.

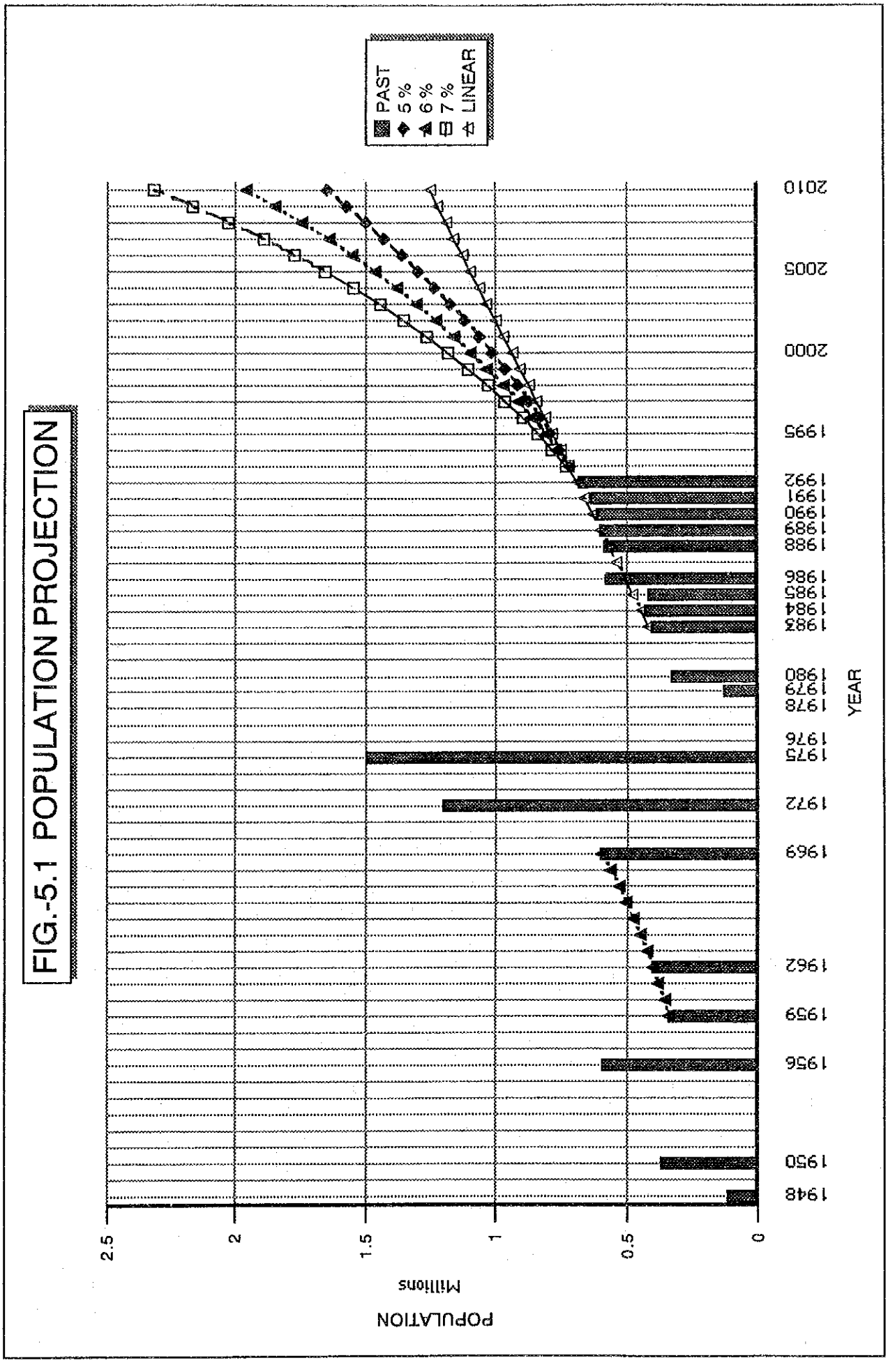


FIG.-5.1 POPULATION PROJECTION
PAST
5%
6%
7%
LINEAR
POPULATION
Millions
2.5
2
1.5
1
0.5
0
YEAR
1948
1950
1956
1959
1962
1969
1972
1975
1976
1978
1979
1980
1983
1984
1985
1986
1988
1989
1990
1991
1992
1995
2000
2005
2010

Fig-5.2 POPULATION GROWTH RATE (DURING 1980s)

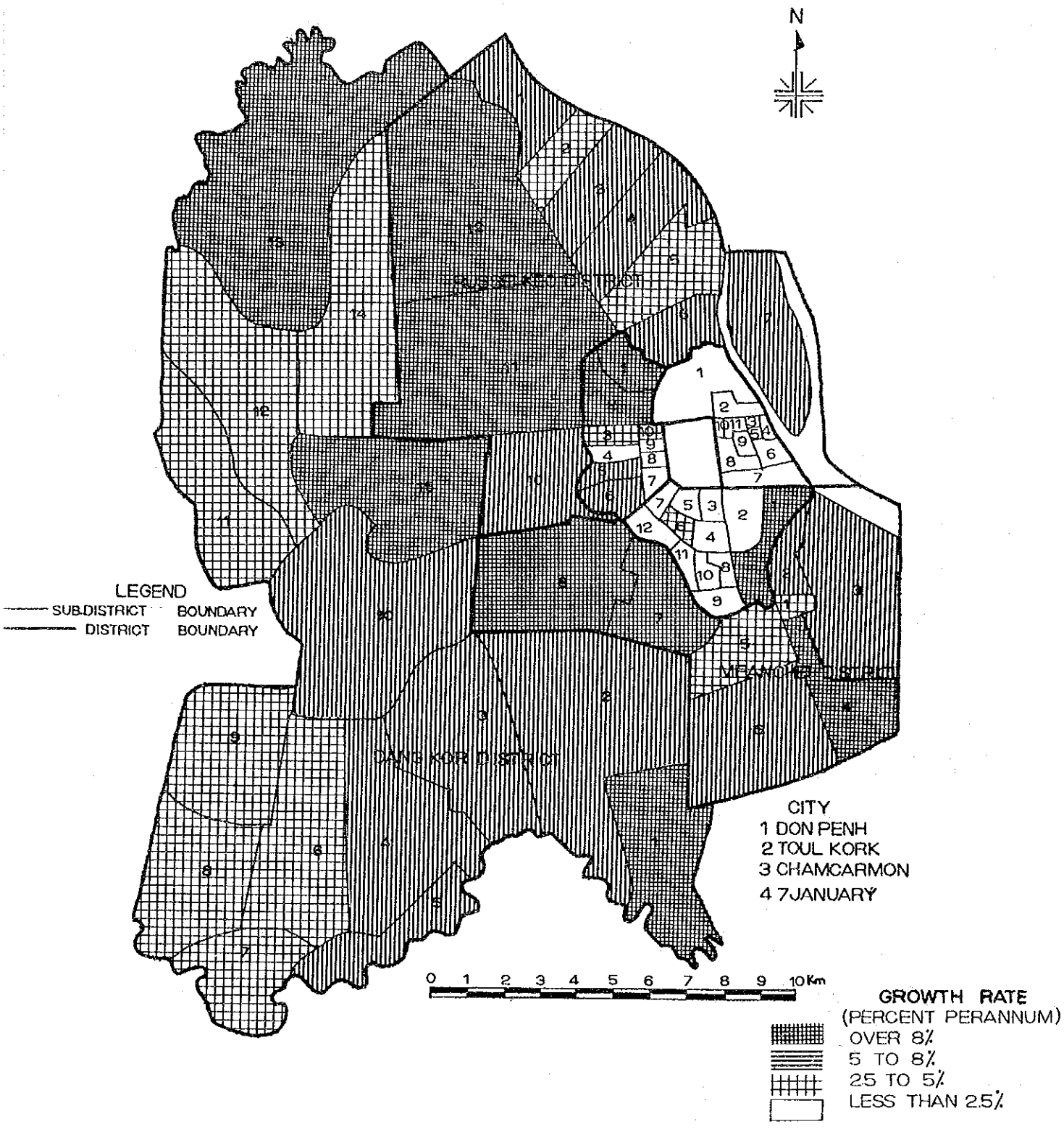


FIG-5.3 POPULATION PROJECTION
(BY DISTRICY)

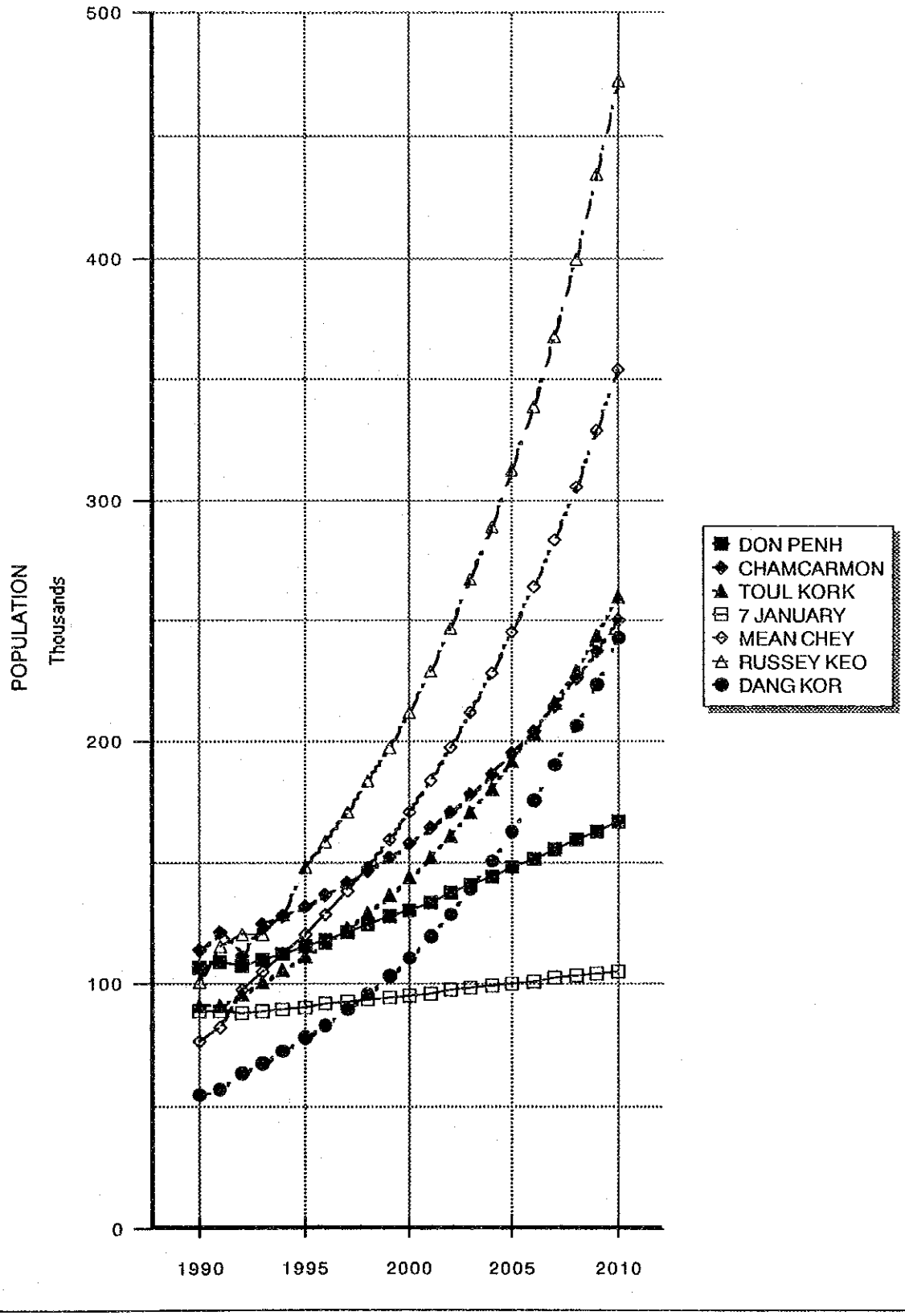


Fig-5.4 POPULATION DENSITY IN 1992

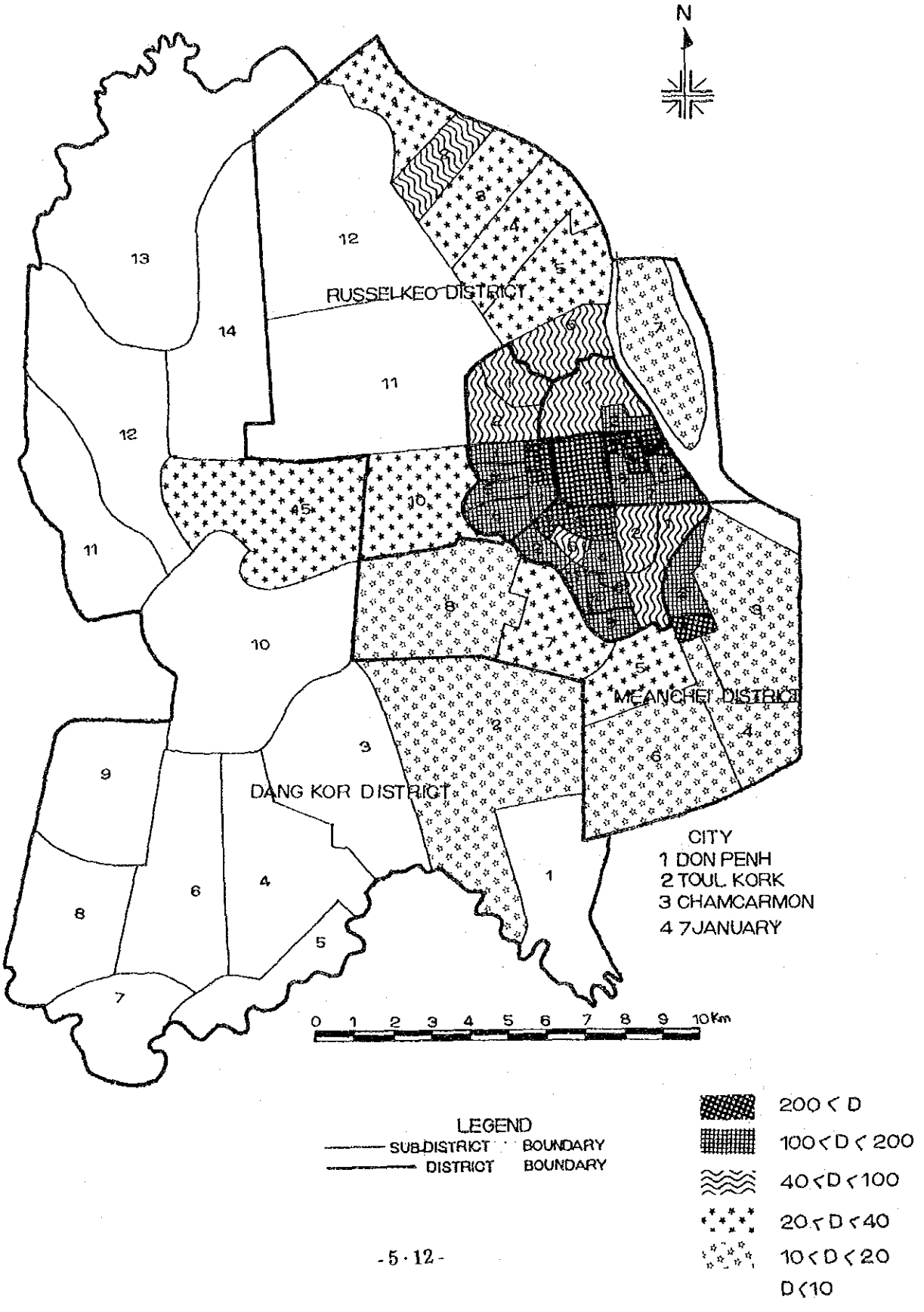


Fig-5.5 POPULATION DENSITY IN 2010

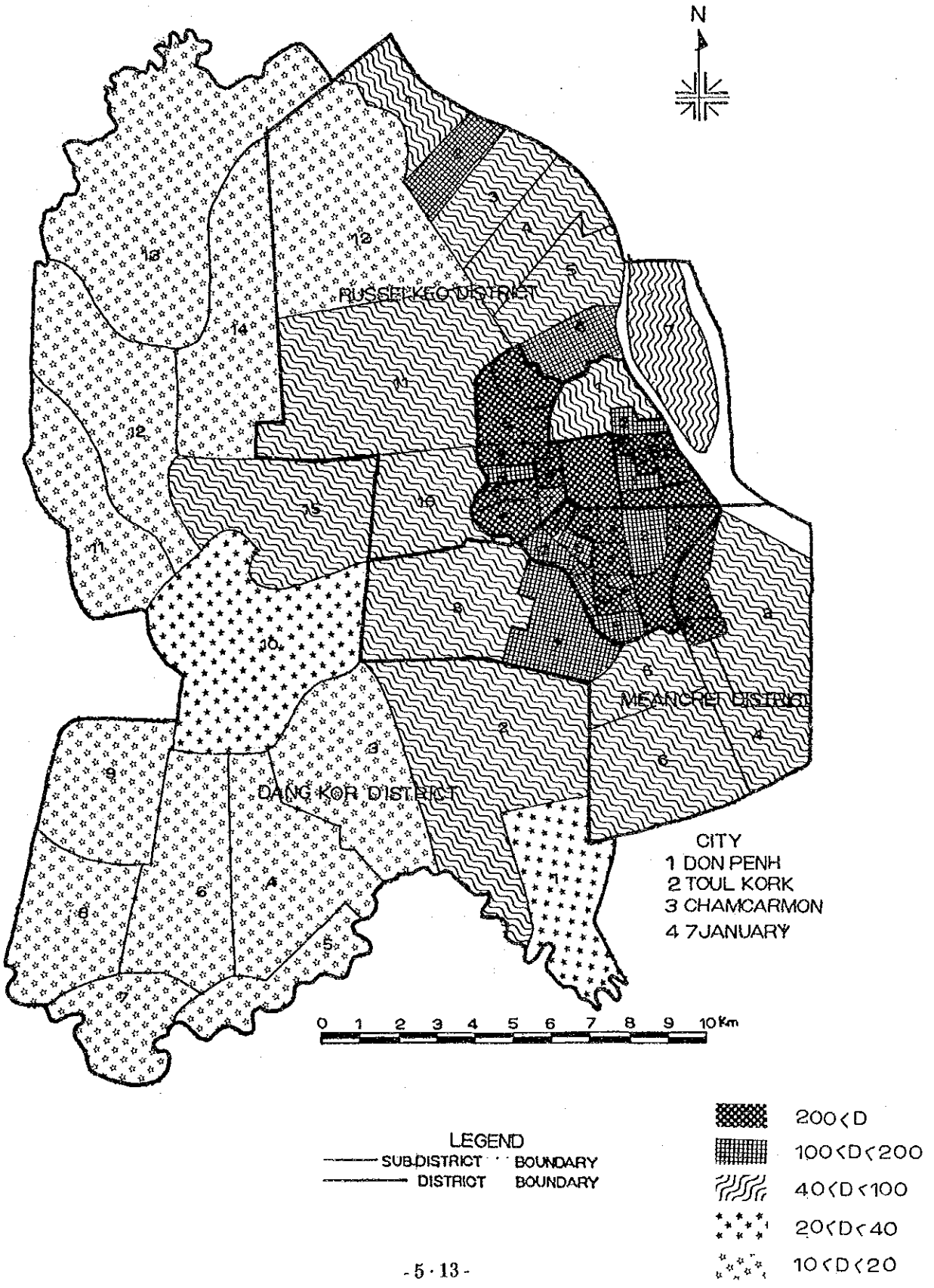
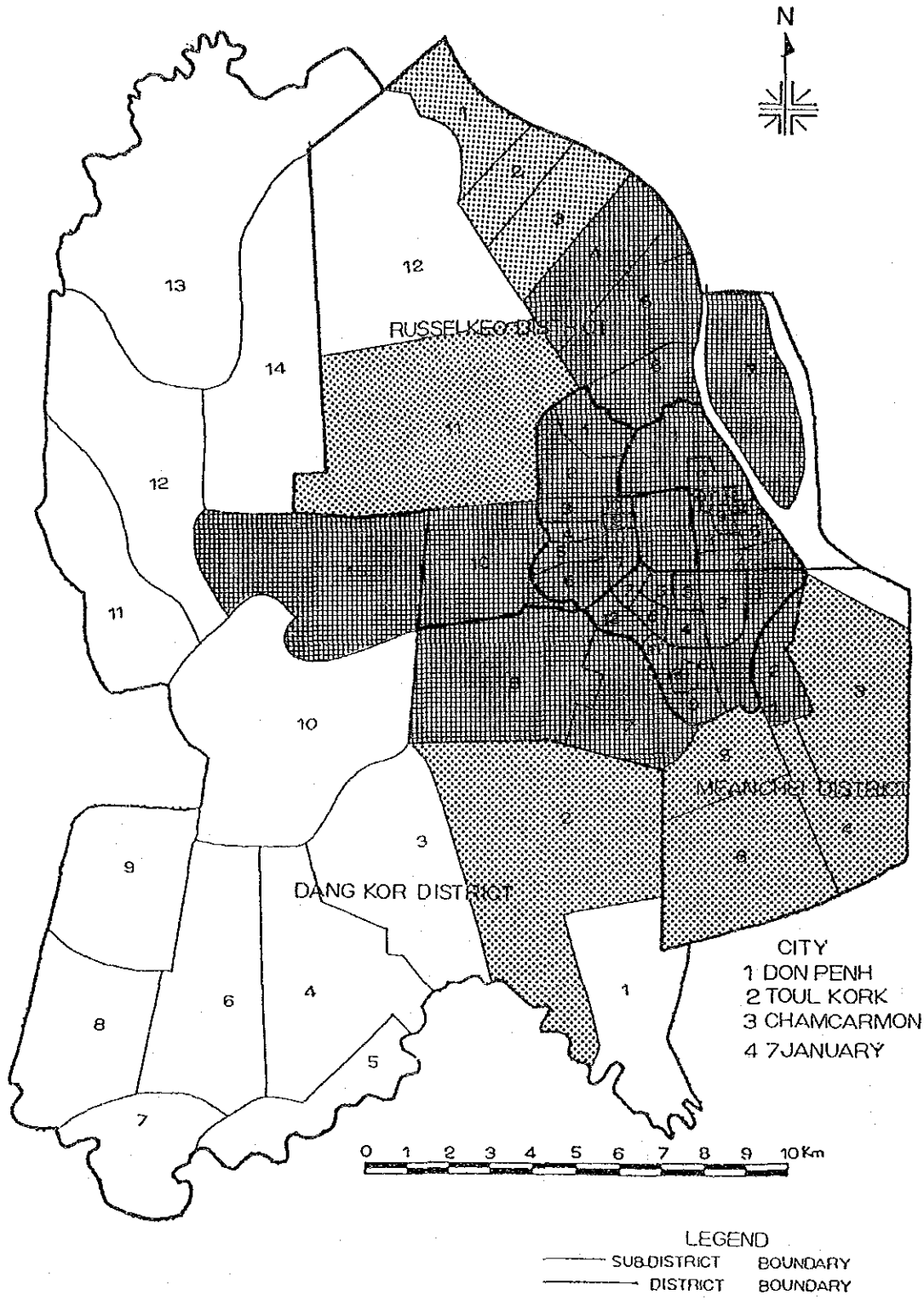


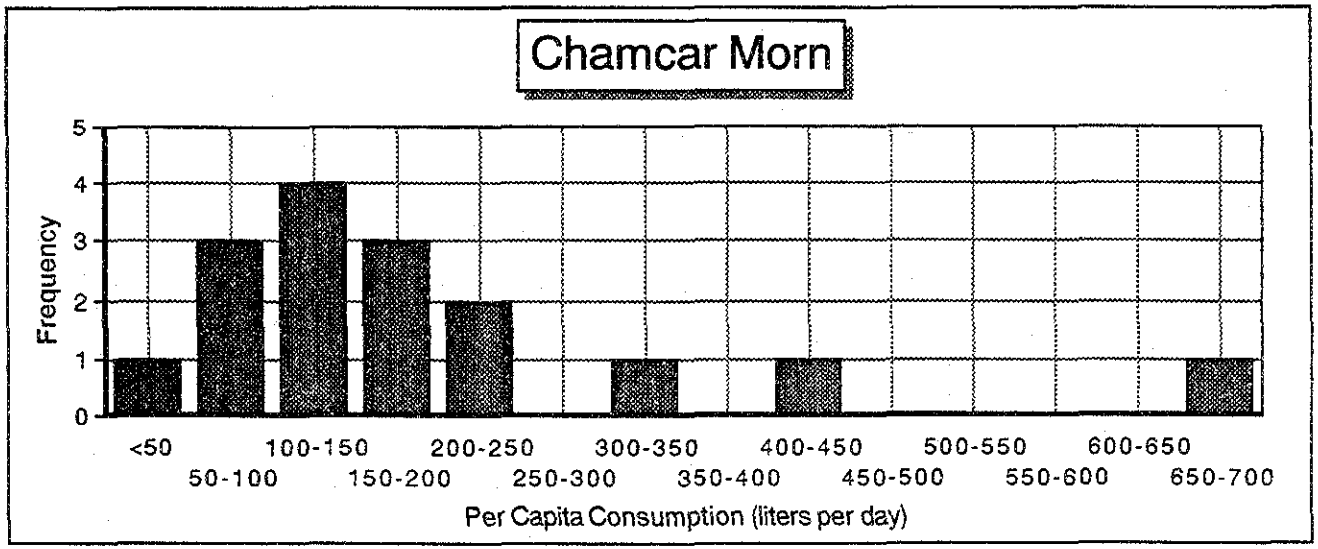
Fig-5.6 SERVICE AREA



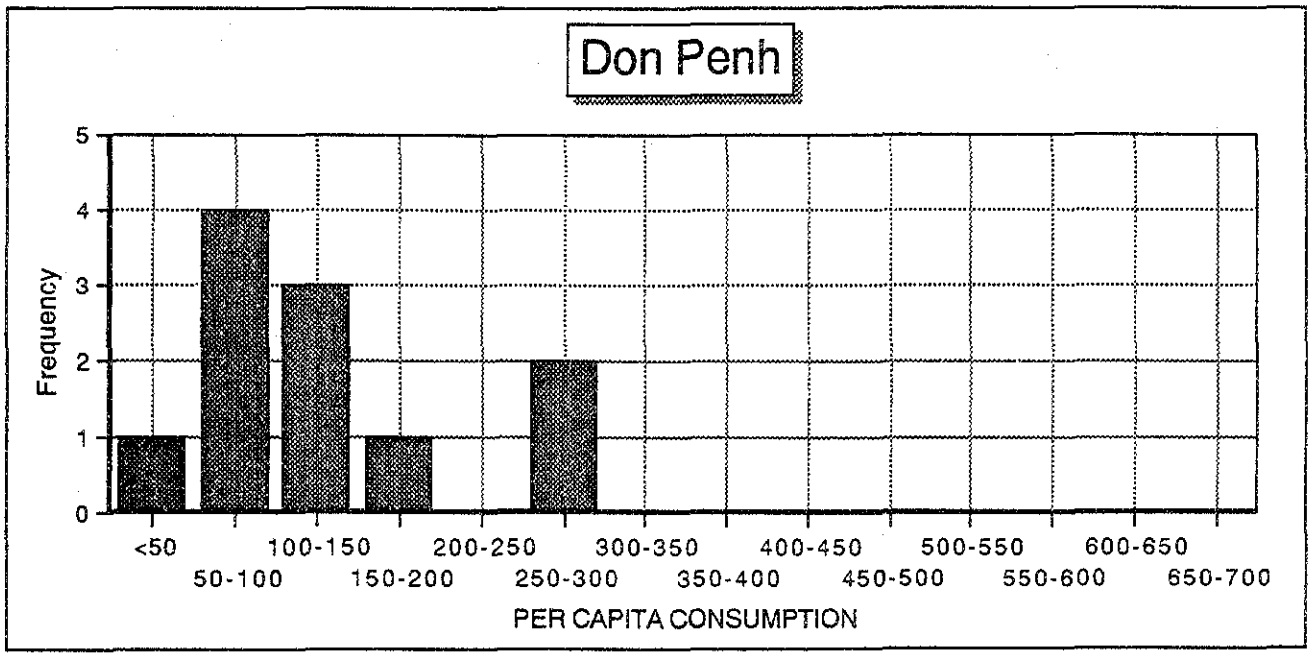
SCENARIO1 (EXISTING SERVICE AREA AS WELL AS FUTURE SERVICE AREA)

SCENARIO2(FUTURE SERVICE AREA)

FIG-5.7 PER CAPITA CONSUMPTION INVESTIGATION



(La rue 93, Acharmean)



(La rue 19 AND 130)

TABLE 5.2 DAILY MAXIMUM WATER DEMAND

(m3/day)

No.	NAME OF DISTRICT	YEAR 1992	2000	2005	2010
	DON PENH				
1	SRAS CHORK	4,046	6,161	6,971	7,887
2	WAT PHNOM	2,218	3,379	3,822	4,325
3	PHSAR CHARS	2,251	3,429	3,879	4,389
4	PHSAR KANDAL 1	3,071	4,677	5,291	5,986
5	PHSAR KANDAL 2	2,081	3,169	3,585	4,057
6	CHEY CHOUMNEAS	2,610	3,975	4,498	5,089
7	CHAK TO MOUK	2,793	4,254	4,813	5,446
8	BEANG REANG	1,871	2,850	3,224	3,648
9	PHSAR TMEY 1	1,902	2,896	3,277	3,707
10	PHSAR TMEY 2	2,111	3,215	3,638	4,116
11	PHSAR TMEY 3	2,842	4,328	4,897	5,540
	TOTAL	**27,796**	**42,333**	**47,896**	**54,190**
	CHAMCAR MORN				
1	TONLE BASAK	5,398	16,996	26,939	42,700
2	BEUNG KENG KANG 1	2,417	3,503	3,724	3,958
3	BEUNG KENG KANG 2	2,314	3,253	3,415	3,584
4	BEUNG KENG KANG 3	2,987	4,150	4,341	4,541
5	PHSAR OLYMPIC	1,848	2,791	3,010	3,246
6	TOUL SVAY PREY 1	1,044	1,894	2,193	2,539
7	TOUL SVEY PREY 2	2,439	3,461	3,649	3,847
8	BEUNG TRABEK	1,719	2,325	2,402	2,482
9	PHSAR DEUM TKOV	2,744	4,086	4,396	4,729
10	TOUL TOUM POUNG 1	2,076	2,949	3,107	3,273
11	TOUL TOUM POUNG 2	1,554	2,263	2,406	2,557
12	TOUM NOUP TEUK	2,401	3,465	3,677	3,901
	TOTAL	**28,938**	**51,136**	**63,256**	**81,356**
	TOUL KORK				
1	BEUNG KAK 1	2,465	6,495	10,352	16,500
2	BEUNG KAK 2	3,760	8,680	12,736	18,689
3	TOEUK LOAK 1	2,583	4,618	5,775	7,223
4	TOEUK LOAK 2	2,239	2,782	2,772	2,762
5	TOEUK LOAK 3	1,940	3,793	5,017	6,635
6	BEUNG SALANG	3,668	8,401	12,267	17,912
7	PHSAR DEUM KOR	2,538	3,222	3,254	3,286
8	PHSAR DEIPO 1	1,995	2,948	3,273	3,634
9	PHSAR DEIPO 2	1,857	2,731	3,024	3,348
10	PHSAR DEIPO 3	1,922	3,140	3,713	4,390
	TOTAL	**24,966**	**46,812**	**62,184**	**84,378**
	7 JANUARY				
1	MITAPHEAP	2,798	3,787	3,980	4,183
2,3	MO NOROUM 1,2	3,239	4,384	4,608	4,843
4	VEAL VONG	4,151	5,619	5,905	6,206
5	BEUNG PROLIT	2,961	4,008	4,213	4,428
6	PHSAR O RUSSEY 1	2,439	3,302	3,470	3,647
7	PHSAR O RUSSEY 2	2,731	3,697	3,885	4,083
8	PHSAR O RUSSEY 3	2,131	2,885	3,032	3,187
9	PHSAR O RUSSEY 4	2,388	3,232	3,397	3,571
	TOTAL	**22,838**	**30,913**	**32,490**	**34,148**
	INSIDE TOTAL	**104,538**	**171,194**	**205,826**	**254,072**
	MEAN CHEY				
1	CHBAR AMPOUV 1	2,344	3,818	4,504	5,314
2	CHBAR AMPOUV 2	4,020	8,794	12,478	17,705
7	BEUNG TOUM POUN	3,886	9,172	13,645	20,299
8	STUNG MEANCHEY	3,796	9,989	15,905	25,325
	TOTAL	**14,047**	**31,773**	**46,532**	**68,642**
	RUSSEY KEO				
4	KM-6	2,776	5,130	6,549	8,360
5	RUSSEY KEO	3,284	5,770	7,138	8,830
6	TUOL SANGKE	3,563	7,245	9,820	13,309
7	CHROY CHANG VAR	3,121	6,446	8,824	12,078
10	TOEK TLA	4,248	8,108	10,564	13,764
	TOTAL	**16,992**	**32,699**	**42,894**	**56,341**
	DANG KOR				
15	KAKAB	2,785	8,868	15,909	28,541
	TOTAL	**2,785**	**8,868**	**15,909**	**28,541**
SUBURB TOTAL		**33,823**	**73,339**	**105,334**	**153,525**
GRAND TOTAL		**138,362**	**244,533**	**311,161**	**407,596**

5.3 Design Criteria

The design criteria mentioned herein are applied to the preliminary design of the present project.

5.3.1 Peak Factors

The table below shows the peak factors planned for the water supply system of the Project.

Peak Factor by Day (Max Day/Ave Day)	Peak Factor by Hour (Max Hour/Ave Hour)
1.30	1.00

(Note) Ave Hour = 1/24 Max Day

Using the peak factors, the average day demand, maximum day demand and maximum hour demand are calculated. To minimizing the initial investment cost, the above peak factor by hour is determined for following reason.

The construction cost of the system can be divided into the construction cost of the plant and that of the distribution mains, and their ratio is roughly estimated at 2:8 in general. If the construction cost for the treatment facilities (50,000 m^3/day) is U.S.Dollar 14.3 million,the total construction cost is estimated as U.S.Dollar 71.6 million, with U.S.Dollar 57.3 million for the distribution mains required is accordate the increased flow.

Each type of the demand is estimated for different purposes as described below:

Average Day Demand	: financial and economic study
Maximum Day Demand	: production facility design
Maximum Hour Demand	: distribution facility design

5.3.2 Service Pressure

The minimum service pressure for the maximum hourly flow is set at 1.0 kg/cm^2 for general application, except for isolated areas where 0.7 - 0.8 kg/cm^2 can be tolerated.

5.3.3 Pipelines

1) Pipe Material

In selecting pipe material, conditions such as strength against internal and external loads, suitability to ground conditions, workability in existing conditions and influence on water quality must be considered.

Ductile cast iron pipes, with anticorrosion measures applied when necessary, are to be used preferably. For cases requiring light pipe weight such as bridge crossing works and the like, steel pipes are to be employed with enough consideration for anti-corrosiveness.

2) Pipe Size

Pipe size is to be selected pursuant to flow requirement. In this preliminary design the maximum hourly flow is employed for the pipe size selection.

3) Appurtenances

Necessary appurtenances such as valves, drain valves, air release valves, hydrants are to be installed at necessary and appropriate places.

4) Design criteria for transmission and distribution systems

Table-5.3 shows the design criteria used in planning and sizing the transmission and distribution pipes for the future system. Given the poor conditions of the pipes and joints in the existing network, the lower maximum permissible pressure head should be used till 2003. When pipe rehabilitation is completed, the higher value can be applied. This is consistent with the assumption that the existing pumps presently usable at Phum Prek WTP will still be usable in the year 2003, but would have to be replaced by 2010.

Table-5.3 DESIGN CRITERIA FOR DISTRIBUTION SYSTEMS

Description	Year 2003		Year 2010	
Pressure Head	Transmission Pipes	Distribution Pipes	Transmission Pipes	Distribution Pipes
Max	40 m	30 m	50 m	40 m
Min	25 m	20 m	25 m	20 m
Flow Velocity				
Max	1.8 m/s	1.5 m/s	1.8 m/s	1.5 m/s
Min	0.3 m/s	0.3 m/s	0.3 m/s	0.3 m/s

5.4 Development Plan

From the foregoing studies of service area and projections of population, daily average & daily maximum water demands are calculated as shown in Fig-5.8. To cope with these demand, the development plan is established as described below.

5.4.1 Staging of Development Plan

To rehabilitate the present water supply condition and to extend the facilities for the demand of the target year 2010, phase wise expansion, as given in Table-5.4, is planned.

Phasing of investment requirements is based on the following principles.

a) To stagger investment,
b) To make investment in stages
c) To take account into the improvement of institutional and management capability in operation and maintenance under prospective donor country assistance.

Table-5.4 PHASE-WISE IMPROVEMENT OF PRODUCTION CAPACITY

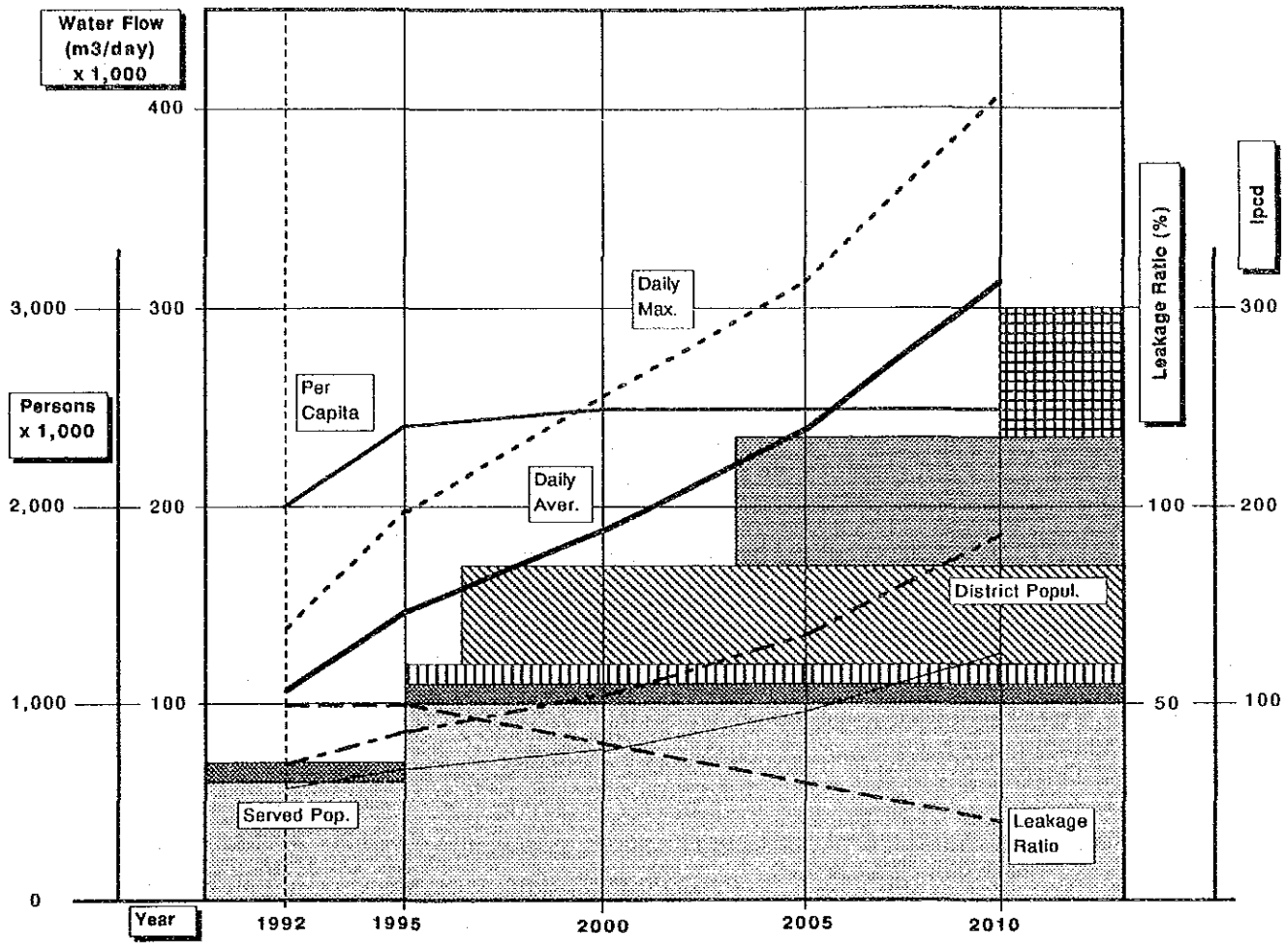
(Unit: m^3/day)

	Year	1992	1995	1996	2003	2010	
Treatment Plant			URW Phase 1 Rehabili-tation	URW Phase 2 Expan-sion	Stage 1	Expansion Stage 2	Total
Phum Prek	Present	56,000					
	Improvement		44,000				
	Expansion			50,000	-	-	150,000
Chamcar Morn	Present	7,000					
	Improvement		3,000				
	Expansion		10,000*1			20,000	
Cham	Proposed	-	-	-	65,000	65,000	130,000
	Total						
	Present	63,000					63,000
	Improvement		47,000				47,000
	Expansion		10,000	50,000	65,000	65,000	190,000
	Cumulative	63,000	120,000	170,000	235,000	300,000	300,000

Note: *1 by French government aid.

Production capacity at each stage up to 2010 is illustrated in Fig-5.8 together with the demand curves. As shown in the figure, expansion of treatment plants is planned based on the daily average demand instead of the daily maximum demand, which is usually used. Moreover, in years between plant expansions, even the daily average demand cannot be satisfied. These are the consequences taking into account the three principles mentioned above.

Fig - 5. 8 WATER DEMAND AND PLANT CAPACITY



Leakage Ratio(%)	50	50	40	30	20
Daily Max. (m3/day)	138,362	189,605	244,533	311,161	407,596
Daily Aver. (m3/day)	106,432	145,850	188,103	239,355	313,536
Per Capita Dem.(lpcd)	200	240	250	250	250
Served Population	532,160	607,710	752,410	957,418	1,254,143
District Population	682,936	793,635	1,020,500	1,352,796	1,851,458

LEGEND

Symbol	Facility	Capacity (m3/day)	Symbol	Facility	Capacity (m3/day)
	New Plant (Expansion)	65,000		Chamcar Morn (Expansio	10,000
	New Plant (Expansion)	65,000		Existing Chamcar Morn	7,000 → 10,000
	Phum Prek (Expansion)	50,000		Existing Phum Prek	56,000 → 100,000

The Urgent Rehabilitation Works (URW) is divided into two phases, viz. Phase 1 Rehabilitation and Phase 2 Expansion, for the same reasons. By 1995,the target year of Phase 1of URW, the Chamcar Morn plant will be expanded to 20,000m^3/day, i.e. a 13,000 m^3/day increase. In 1996, the target year Phase 2, a significant increase of the production capacity of 50,000 m^3/day is envisaged by the expansion of the Phum Prek Plant. The total production capacity in 1996 will, therefore, be 170,000 m^3/day which is well over the daily average demand of 153,000 m^3/day.

To increase the total production capacity, it is considered better to expand Phum Prek plant for the following reasons:

a) Land for the expansion is available
b) Intake facilities are designed with an allowance for future expansion
c) The location of the plant, in the middle of the service area, is convenient
d) The limited staff available at present can be used effectively, and
e) It would be no problem to take raw water from Sap river for the water treatment, even though water quality of Sap river is not same as Mekong river as stated in previous Section 3.4.1.

As seen in Fig-5.8, the total production capacity is to be increased to 235,000 m^3/day in 2003 (New Expansion Stage 1) and to 300,000 m^3/day in 2010 (New Expansion Stage 2) to meet the daily average demand. Therefore, the construction of the new treatment plant whose production capacity is 130,000 m^3/day is planned to be implemented in two stages (65,000 m^3/day capacity in each stage).

In the stage of URW, the water quality of raw water from Tonle River has no problem for wter source of supplied water.

5.4.2 Selection of Options

To meet the water requirement in the target year, a new plant, 137,800 m^3/day capacity (65,000 x 2 x 1.06 loss water), has to be constructed by 2010 after 50,000 m^3/day plant construction. From previous studies the groundwater will not be suitable for such large scale water projects except for isolated or small demand areas. River water is the source of water and the comparison of the rivers is conducted in the succeeding section. (Option of Water Source)

There are a number of options for water treatment plant systems applicable to the

project. Taking into consideration ease of plant operation and maintenance, however, conventional system will be recommended. Plant location will be discussed below (Option of location of Treatment Plant). Sludge treatment is met planned at this stage. However, sufficient area for future sludge treatment is provided at the site of the new treatment plant.

Regarding the transmission system, the following two alternatives have been studied to select the appropriate system for the project (Option Distribution System for Cham WTP).

a) Direct distribution system
b) Distribution system with reservoirs

5.4.3 Water Source Option

The water sources available for the water supply system in Phnom Penh are limited to surface water from three rivers, viz. Mekong, Sap and Bassac rivers. These sources are compared with respect to quality and quantity of water available. Consequently, the Mekong river is selected as the water source for the new facilities to cater for the demand up to the year 2010. The justification for the selection is given below. However, the source of the expanded Phum Prek treatment plant is the Sap river,the same as the existing source to utilize the existing intake tawer.

5.4.3.1 Quantity of Water Available of Water Sources

The quantity of water to be taken at the intake in 2010 will be 137,800 m3/day. This quantity can be obtained from any of the Mekong, the Sap and the Bassac rivers at any time of the year.

5.4.3.2. Quality of Water

Water quality of the three sources were compared based on the data obtained from the water quality analysis conducted by the Study Team and on those obtained from the PPWSA.

1) Pollution of the Water Sources

Current water pollution conditions of the three rivers and were examined by comparing four parameters, viz. the concentrations of nitrate, nitrite, COD, and the coliform count.

As shown in the Table-5.5 below, the Sap river water recorded the highest values for each parameter, followed by that of the Bassac river. The lowest values were recorded in the Mekong river. Similar results were obtained from the analysis conducted from October 1992 to March 1993 by the Water Supply Authority following a request made by JICA.

According to the data furnished by the Authority on the quality of the raw water for the last few years of the Phum Prek WTP which uses the Sap river as the water source, the highest values of both nitrate and nitrite concentrations are around 2 mg/l. The Sap river is considered to be polluted by the wastewater from the Phnom Penh city.

Data on the water quality throughout a year for the Mekong river are not available. It should be confirmed that the Mekong river water is suitable as the source for the new WTP.

Table-5.5 RESULTS OF THE ANALYSIS (WATER POLLUTION)

Item	Unit	Mekong River	Sap River	Bassac River
Nitrate	(mg/l)	0.05	0.47 - 0.88	-
Nitrite	(mg/l)	0.001 - 0.069	~ 0.035	0.006 - 0.027
COD	(mg/l)	3 - 6	5 - 7	5 - 7
N-NH3	(mg/l)	0.1 - 0.5	0.2 - 0.7	-
Fecal coliform (/100 ml)		-	~ 2,000	~ 500
Total coliform (/100 ml)		~ 8,000	4,500 - 12,000	1,300 - 6,000

2) Chemicals of Health Significance

Analysis was conducted for the chemicals of health significance stipulated in the inorganics category of the Table 2 of the WHO Water Quality Guideline. The results are tabulated in Table-5.5. As shown in the Table-5.6, the three sources have almost identical values which are well below the WHO Guideline Value (GV).

Table-5.6 RESULTS OF THE ANALYSIS (CHEMICALS OF HEALTH SIGNIFICANCE)

Item	Unit	WHO GV	Mekong River	Sap River	Bassac River
Arsenic	(mg/l)	0.01	<0.004	<0.004	-
Cadmium	(mg/l)	0.003	<0.001	<0.001	-
Chromium	(mg/l)	0.05	0	0	-
Copper	(mg/l)	2(ATO)	0.00-0.01	0.00-0.01	0.00-0.01
Cyanide	(mg/l)	0.07	0-0.002	0.001-0.002	0-0.001
Lead	(mg/l)	0.01	<0.001	<0.001	-
Fluoride	(mg/l)	1.5	0.09-0.58	0.12-0.57	0.28-0.69
Manganese	(mg/l)	0.5	0-0.1	0-0.1	0
Mercury	(mg/l)	0.001	<0.005	<0.005	-
Nitrate	(mg/l)	50	0.05	0.47-0.88	-
Nitrite	(mg/l)	3	0.001-0.069	0-0.035	0.006 - 0.027

3) Substances giving rise to Consumers' Complaints and those related to Process Selection

Substances and parameters of drinking water that may give rise to complaints from consumers are presented in the WHO GV. Selected substances were analyzed in order to confirm the suitability and to determine the most appropriate water treatment processes as well. The results shown in the Table-5.7 below confirmed the suitability of the three sources with all the substances except turbidity being below the WHO GV. Therefore, the aim of the treatment is to reduce the turbidity in raw water.

The water quality characteristics of the three rivers are summarized as follows.

4) Mekong River

A feature of the Mekong river is that high turbidity prevails during the rainy season. The pH is rather high while turbidity is low, and low during the high turbidity period. The records of the Chrouy Chang War WTP in 1982 and 83 indicate that the maximum turbidity is 822 NTU and pH values are in the range between 6.8 and 8.7. According to the records of Kaolieo WTP located far up-stream in Laos, the maximum turbidity of the raw water is over 3,000 NTU, and the alkalinity is in the range between 65 and 100 mg/l.

Since the distance from this WTP to the Chrouiy Chang War WTP is about 1,000 km, water quality might change considerably, and turbidity and pH values recorded at Kaolieo

Table-5.7 SUBSTANCES FOR CONSUMER'S COMPLAINTS AND FOR PROCESS SELECTION

Item	Unit	WHO GV	Mekong River	Sap River	Bassac River
Aluminum	(mg/l)	0.2	0	0	-
Copper	(mg/l)	1	0 - 0.01	0 - 0.01	0 - 0.01
Hardness			84	72	-
Iron	(mg/l)	0.3	0.00 - 0.08	0.06 - 0.15	0.05 - 0.11
Manganese	(mg/l)	0.1	0.0 - 0.1	0.0 - 0.1	-
pH	preferably	<8.0	7.0 - 8.3	6.0 - 7.8	7.2 - 7.5
Sulfate	(mg/l)	250	~ 18	~ 12	~ 7
Taste and Odour		Should be acceptable	Nil	Nil	Nil
Turbidity	NTU	5	5 - 22	11 - 16	5 - 11
Zinc	(mg/l)	3	0.01 - 0.04	0.0 - 0.1	0.1 - 0.02
Alkalinity	(mg/l)		70 - 78	27 - 63	-

WTP of Laos cannot be applied directly to the Chrouy Chang War WTP. It is difficult to estimate the change in these parameters. It is expected, however, that the maximum turbidity at the Chrouy Chang War WTP would be higher than the maximum value recorded in the two years.

The Study Team measured the turbidity, pH and alkalinity of the Mekong river water on 3 and 10 May 1993, and the average values of 8 NTU, 7.4 and 70 mg/l were obtained, respectively. Jar tests conducted by the Study Team showed better results regarding coagulation than expected. It had been expected that higher coagulant consumption would result due to the high pH and the high alkalinity of the raw water. The test results also indicated the optimum dosage rate of alum to be 5 to 10 mg/l. Since low pH value of 6.8 was recorded while turbidity was high, it should be studied further whether lime dosing will be required or not during the period when high turbidity raw water requires much more alum.

5) Sap River

The Study Team measured pH and alkalinity of the Sap river water during the dry season, and these are in the range between 7.2 and 7.9, and 27 to 63 mg/l respectively. Turbidity values of 15 to 450 NTU were obtained from the Water Supply Authority. pH and alkalinity volumes of 7.7 and of 30 mg/l respectively, were obtained from the report prepared by the JICA Electric Power Supply Study Team.

As the water from the Mekong river flows into the Sap river (flow reversal) in the rainy season, the characteristics of the Sap river water is expected to be similar to those of the Mekong river. Nevertheless, this could not be confirmed because of the non-availability of data.

The jar tests results indicate a narrower pH range, i.e. 6.8 to 7.0, and appropriate for coagulation. Therefore, it may be necessary to use lime when the turbidity is high, since increased alum dosage decreases pH. In general, good coagulation results were obtained for the Sap river waters similar to that for the Mekong river.

The turbidity of the Sap river changed from 10 NTU in the morning to 30 NTU in the afternoon when measured by the Study Team in the middle of May 1993. The reasons for the rapid change in a short period of time are not clear. It might be caused by the frequent operation of the ferryboats, the fluctuation of the water temperature and/or the stirring up of the soil sediments in the intake tower.

The surface of the flocculation and sedimentation basins of the Phum Prek WTP was covered with green algae several times during the dry season. Pre-chlorination will be necessary as a countermeasure to remove green algae.

According to the data obtained from the Water Supply Authority, the ammonia nitrogen value as high as 0.7 mg/l was recorded. Break-point chlorination may become necessary under certain circumstances.

6) Bassac River

It has been observed that the values of pH, electrical conductivity and turbidity of the Bassac river resemble those of the Mekong and the Sap rivers. Essentially, the Bassac river water is the mixture of the Mekong and Sap river waters. Parameters for treatment of the Bassac river water, particularly in the rainy season, cannot be determined clearly since the data on water quality, especially those for the rainy season is very limited.

5.4.3.3 Selection of Water Source

Selection of the water source for the new WTP was conducted based mainly on the comparison of the water quality characteristics of the three rivers.

Currently, the Sap and the Bassac rivers are more polluted than the Mekong river, because these rivers are affected directly by the wastewater from the Phnom Penh city. Taking into account the future development and the population growth of the city, the pollution of the two rivers is likely to worsen.

Regarding chemicals of health significance and substances for consumers' complaints, all items, except for turbidity, are below the WHO GV, and turbidity can readily be reduced to a desirable level by coagulation and sedimentation.

As for the costs for the chemicals for coagulation, more coagulant will be required to treat the Mekong river water than the Sap river water, because of the higher turbidity values. On the other hand, for the treatment of the Sap river water, lime will be necessary, which will load to additional cost. Therefore, the costs for chemicals for coagulation of the two river waters do not differ significantly. Much more chemicals for disinfection will be required for the treatment of the Sap and the Bassac river waters than the Mekong river water because of the greater water pollution of the two rivers. Moreover, it is difficult to treat water containing phyto-planktons which proliferate rapidly in polluted waters when the turbidity is low. Additional chlorine to remove algae will be necessary, which will result in increased chemical costs. Thus, the least total costs for chemicals is expected in the case of Mekong river water.

Taking these factors into account, the Mekong river was selected as the water source for the new WTP.

5.4.4 Selection of the Intake Facilities

5.4.4.1 Location

With the Mekong river is selected as the water source for the new WTP, the location of the intake facilities is narrowed to one location for the following reasons. The existing Chrouy Chang War WTP site is too small to accommodate the new WTP, the new WTP will be located near Cham village where the necessary land is available. In general, the most convenient location of the intake facilities is adjacent to the WTP. In addition to this, the Navy Authority is planning to expand its harbor facilities located between the

Chrouy Chang War WTP and their base. In order to avoid the possibility of contamination caused by the harbor facilities, such as oil leakage, the intake facilities should be located upstream. Consequently, the location near Cham village is selected for the intake facilities.

5.4.4.2 Structures

Three structural alternatives were considered suitable for the intake facilities, viz. intake tower, intake gate and elevating pump tower, taking into account the large fluctuations in the river water levels. Among them, the intake tower with a few inlet gates at different levels was selected after comparing of the advantages and disadvantages of the three systems.

5.4.5 Treatment Facilities

5.4.5.1 Process Selection

The treatment process are selected based on the following factors.

a) To meet WHO guidelines for treated water
b) Easy operation and maintenance
c) Manual operation, as much as possible

The Selected processes are described below

The coagulation-sedimentation and rapid sand filtration system is employed for sedimentation and filtration because this system is most suitable to treat high turbidity water which is the condition during the rainy season.

A hydraulic mixing system is adopted for rapid mixing and flocculation of the plant because it does not require any machinery for mixing. For sedimentation, conventional type can be adopted, taking into account the fact that water production can be decreased when the turbidity is entremely high. Desludging will be carried out manually with flush water. Filters are to be back-washed with water along with surface washing.

Chemicals to be used at the plant will be aluminum sulfate as coagulant, lime, and liquid chlorine.

Sludge treatment is by drying beds, in order to fully utilize the tropical climate.

5.4.5.2 Options for Location of the Treatment Plant

The Phum Prek treatment plant was originally planned for 200,000 m^3/ day capacity. However, the area of the Phum Prek treatment plant is not sufficient for the new plant for the following reasons:

a) The capacity of the plant will be increased to 150,000 m^3/day, by construction of new capacity treatment facilities for 50,000 m^3/day.

b) Area for the future sludge treatment should be secured at the site.

Therefore, the site for the plant has to be somewhere other than the Phum Prek plant. The site to be selected should:

a) have adequate area for the facilities including that for future sludge treatment
b) be easily purchasable.
c) be close to the expected water source and service area.
d) be acceptable for laying the structural foundation.
e) be high enough with respect to the flood level of the river.

It is difficult to obtain sufficient area for the plant on the right bank of the Sap and Bassac rivers because it is already urbanized except for the northern area of Beng Kok lake. A site for the new plant is, therefore, proposed at the site marked as Option No.2-2 in Fig-5.9.

Another site proposed for the new plant is at Cham village located on the right bank of Mekong river marked as Option No. 2-1 in Fig-5.9.

The Location of the intake and the plant, and transmission system for the two options are as follows:

Option No. 1-1

Location of Intake : Right bank of Mekong river at Cham village
Location of Plant : Beside the intake at Cham village
Pipeline System : Distribution mains through the existing Chrouy Changwar bridge consisting of D1000 and D800 pipelines