MINISTRY OF FOREIGN AFFAIRS OF FINLAND
FINNISH INTERNATIONAL DEVELOPMENT AGENCY

THE PEOPLE'S COMMITTEE OF HANOI CITY

HANOI WATER SUPPLY PROJECT PHASE II

WATER MASTER PLAN

INTERIM REPORT
Draft, July 1989

YME group

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1. INTRODUCTION AND PROJECT BACKGROUND

1.1 Location, climate and population

The Socialist Republic of Vietnam is situated in South-East Asia, bordered to the north by the People's Republic of China, to the West by Laos and Kampuchea and to the East by the South China Sea (Figure 1.1-1). The surface area of the Republic is about 329,566 square kilometers. The estimated population of the whole country was some 65 millions at the end of 1987. Vietnamese form 80% of the population. There are also significant minority groups like Tay, Nung, Khmer, Thai. The growth of the population is currently running at 2.2 %.

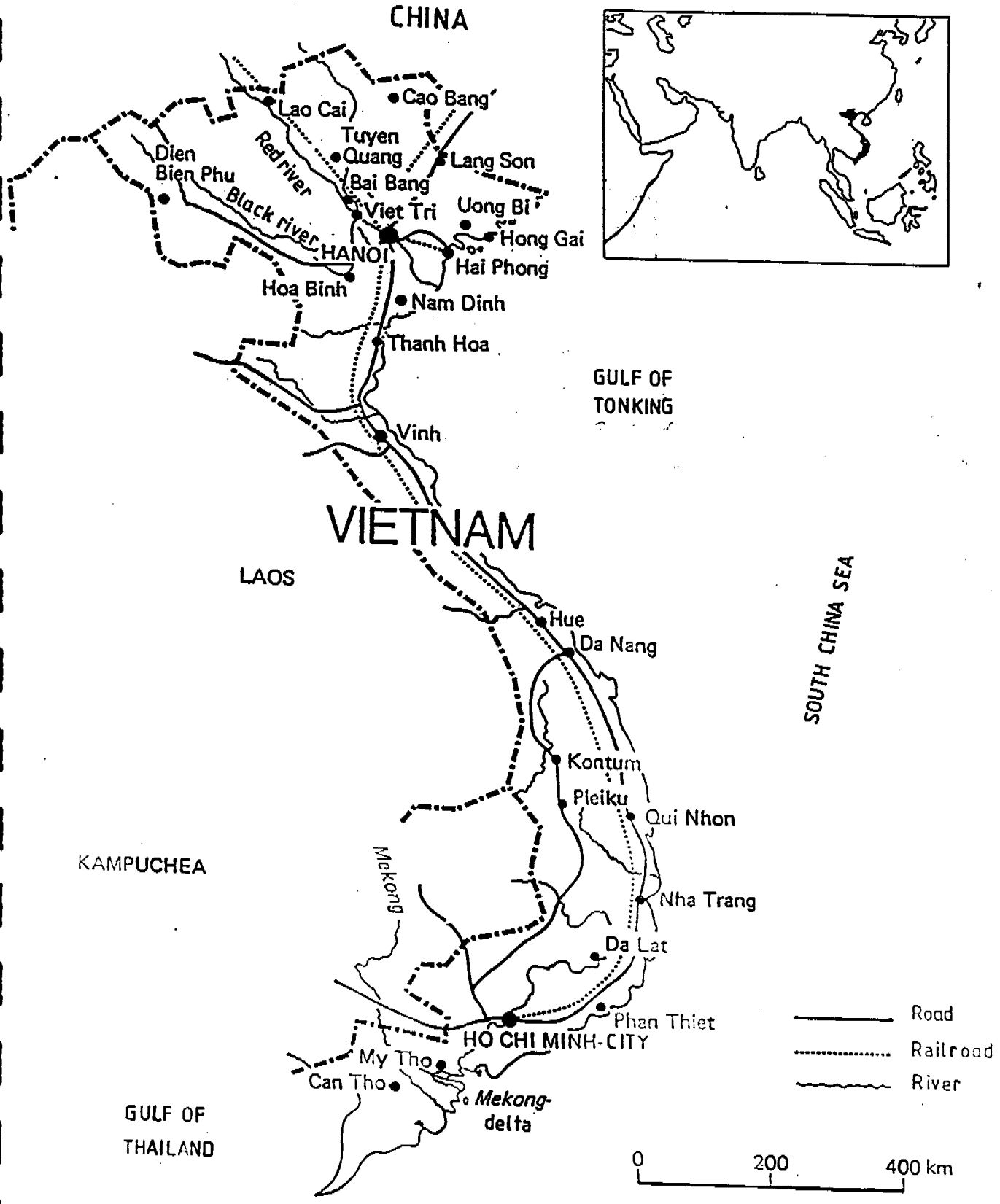
Hanoi is the Capital City of Vietnam and is located in the Red River (Song Hong) delta about 100 km from the sea. The urban city area is approximately 49 km2 with a population of 937,000 in 1988 and the total administrative area is 2139 km2 with a population of around 2.9 million people in 1988.

Due to the delta character of the area the topography is generally flat and low lying, the elevation being from 4.0 m to 11.0 m above the mean sea level. There is a flood protection embankment to separate the city from the Red River.

The geology of the area is also typical for the ancient delta area. The top layer of the ground is clay, silty clay or silt, the thickness of the layer varying from 5 m to some tens of meters. Beneath the city area there is a quaternary cobble-stone-gravel aquifer. Within the city boundaries there are several small lakes, canals and rivers. Many of them are shallow and heavily polluted.

Vietnam might be assumed to be wholly within the zone of the tropical monsoon climate. However, the Song Hong delta, where Hanoi is located, is not strictly tropical in the climatological sense, as, owing to its exposure to cold northern air during the season of the north-east monsoon, it experiences a recognizable cool season from December to March, and in both January and February the mean monthly temperatures in Hanoi are only 17 C, while the average yearly temperature is 23.4 C. The annual rainfall is varying in between 1,200-2,200 mm.

The monthly average meteorological values are given in table 1.1-1.



FIGUR 1.1 - 1 MAP OF THE SOCIALIST REPUBLIC OF VIETNAM

TABLE 1.1-1 MONTHLY AVERAGE METEOROLOGICAL VALUES IN HANOI

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Year
Average temperature (C)												
15.3	17.6	19.2	23.6	27.4	29.0	28.4	28.6	27.1	24.4	21.4	18.4	23.4
Average rainfall (mm)												
18	36	31	121	194	250	214	325	290	181	115	7	1794
Average evaporation (mm)												
68	51	55	66	94	99	101	86	91	95	88	94	938
Average humidity (%)												
83	86	89	88	85	84	85	87	86	82	81	81	85

The main geographical landmark of Hanoi is the Red River, which is about 1.0-1.5 km wide by Hanoi. The minimum flow of the river during the period 1956-1985 was 350 m3/s and the maximum 22,000 m3/s. The recorded HW-level has been +14.13 m and NW +1.73 m. The MW-level varies from +2.18 m during the dry season to + 10.18 m in the rainy season. Water in the River has a relatively high content of total solids, from 0.2-0.3 kg/m3 in dry season to 2-3 kg/m3 in rainy season.

1.2 Economic Overview

The Vietnamese economy was severely disrupted by the war, however, since the cessation of hostilities in 1975 substantial progress has been made towards reconstruction and development.

No reliable up-to-date macro-economic or trade statistics exist for Vietnam. The best available estimates suggest that per capita income is currently in the range of 200 to 250 US$ and that the real growth in GDP averaged about 6 % per annum over the 1981-85 Five Year Plan. In 1986, the share of agriculture in GDP was some 45 % as against 35 % for industry. The agricultural sector employs approximately 70 % of the labour force.

Although the country has become virtually self sufficient in food in recent years, it still remains vulnerable in periods of bad harvests. The staple food crop is rice although considerable quantities of fruit, vegetables, cassava, sweet potatoes and maize are also grown. Cash crops produced include sugar cane, rubber, coconuts, tobacco, tea and coffee. Substantial numbers of pigs, poultry, buffaloes and cattle are also raised. Since the end of the war the Government has gradually introduced the collectivised agricultural system into the south. The area under cultivation has been increased by the establishment of New Economic Zones, which has involved major transfers of population from urban to rural areas.

Most of the country's mineral resources are located in the north. The principal resource and main export is hard coal, with a production of 5.2 million tons in 1984. The major industries are also largely concentrated in the north, the principal sectors being food processing, iron and steel, chemicals, paper, heavy engineering and textiles.

Vietnam's main trading partner is the USSR which in 1983 accounted for some 67 % of the value of imports and 53 % of exports. The other important trading partners are Japan, Hong Kong, Singapore and members of the Comecon block. Principal imports are foodgrains and flour, petroleum, wool and agricultural machinery. The main exports include coal, textiles, chromium, timber, rubber and tea.

At the Sixth National Congress held in December 1986 a thorough reappraisal of certain aspects of economic policy was carried out. The Congress stated the need for the 'abolition of the centralized bureaucratic state-subsidy system'. The Congress also recognised the need for proper regulation of the money supply, and the end of the practice of printing money to cover the budget deficit, if inflation was to be controlled. The intention is also to allow more freedom for the forces of supply and demand to determine prices, where considered appropriate. A decision has been taken to allow state enterprises more latitude in the determination of prices, the need for product research and development and new investment decisions. As a corollary to this, enterprises will be subject to more financial discipline and the need to achieve an acceptable level of profitability.

1.3 Report background

Water Master Plan study was one of the sub-projects included in the Phase I of the Hanoi Water Supply Project, which was started in June 1985 by the agreement between the Government of the Republic of Finland and the Government of the Socialistic Republic of Vietnam.

In September 1987 an Evaluation Mission visited Vietnam to review the project. The evaluation report indicated that there were a number of deficiencies in the Water Master Plan and in particular the amount and reliability of the data base for the long-term planning of the Hanoi Water Supply System was not sufficient. The report recommended that more studies such as a hydrogeological, an economic and a sewerage study, should be carried out and that the Master Plan should be updated and completed to be more comprehensive. Consequently the execution of these studies were included in the Phase II of the project.

Water Master Plan Expert was nominated for the work in October 1988. By that time it was already clear that hydrogeological studies are being delayed and do not give very much support for the Master Plan preparation. Later on it was decided that Master Plan will be prepared in two parts. The Interim Report was to include the basics for the work and the planning and design of technical alternatives of the water supply system and the Final Report the economic analysis of the options and the choice of preferred development strategy and recommendations for implementation.

This is the Water Master Plan Interim Report prepared by the Water Master Plan Expert during his stay in Hanoi between 3.11.1988-7.7.1989.

Water Master Plan Expert

2. DESCRIPTION OF THE EXISTING WATER SUPPLY SYSTEM

2.1 General

2.1.1 Hanoi city

Administratively Hanoi City consists of four urban districts, called quan (Ba Dinh, Hoan Kiem, Dong Da, Hai Ba Trung) and 11 suburban towns and districts, eg. Tu Liem, Gia Lam, Thanh Tri etc. In practice the urban area of Hanoi consists of the four quans. This is also the principal area covered by the existing water supply network. There are only a few extensions outside these four quans, the most important being Dich Vong area to the North-West in Tu Liem district, and a minor area surrounding the old airport in Gia Lam district to the left side of the Red river. The approximate location of Hanoi urban area is shown in figure 2.1-1.

The total area of these four quans is about 43 km2. The quans are divided into 83 smaller units called phuong, which are named according to a remarkable building, big street ect. The location and approximate borderlines of each phuong as obtained from local police station are shown in drawing No...

The population of the city is counted in annual census. The results of the census from the year 1988 are shown in Appendix 1 as the number of inhabitants in each phuong. The total number of inhabitants in the Hanoi urban area was 927,000. In drawing... the surface area of each phuong and respective population density have also been marked. Population density in phuongs varies from 78 p/ha to 1,321 p/ha, the average value in the urban area being 224 p/ha. The most densely populated parts of the city are the old centre area (quan Hoan Kiem) and some nearby phuong in Hai Ba Trung and Dong Da districts.

Hoan Kiem district is a residential and commercial area. Houses are mainly one or two-storey buildings of multifamily type, and generally old. Very few new buildings are under construction. Infrastructure of the area is rather complete, but very old and somewhat deteriorated and underdimensioned.

Hai Ba Trung is mainly residential area. The northern parts of the districts are oldest, the other area being of later origin. Houses are mainly multi-family buildings, many of them being old and dilapidated. In the southernmost zones of this area there exists squatter type settlement. A big textile factory is located in the southeastern corner of this area. Infrastructure

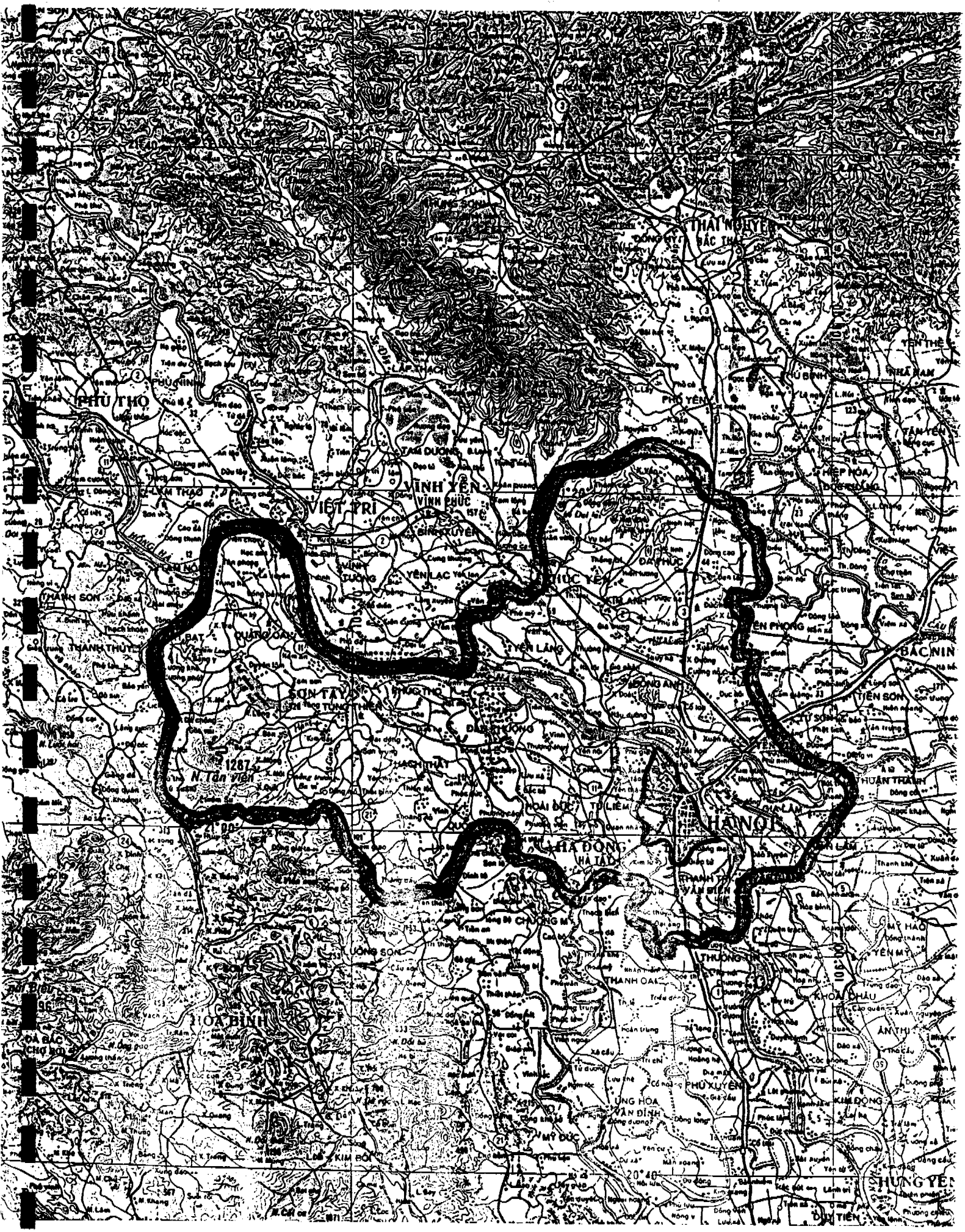


FIGURE 2.1-1 HANOI PROVINCE AND HANOI CITY AREA

is defective, the worst situation being in the southern parts of the district.

Ba Dinh is a district of a more varied type. The city centre zone is a concentration of the political and administrative organizations. There are numerous ministries, offices and embassies. The northwestern part of the area is a single family dwelling settlement. The Southern zone consists of several multi-storey building areas. There are some concentrations of middle-size industrial establishments mainly in the northern part of the district nearby lake Ho Tay. The infrastructure of the district is mostly newly built and in relatively good condition, but is probably lagging behind other development.

Dong Da or the southwestern district consists of several different types of settlement. There are areas of mainly multi-family houses, surrounding areas of multi-storey buildings. In the southwestern corner of the district (Ha Dinh) there is remarkable industrial concentration of many types of factories. In many areas the infrastructure is insufficient for the present population.

2.1.2 Water supply organization

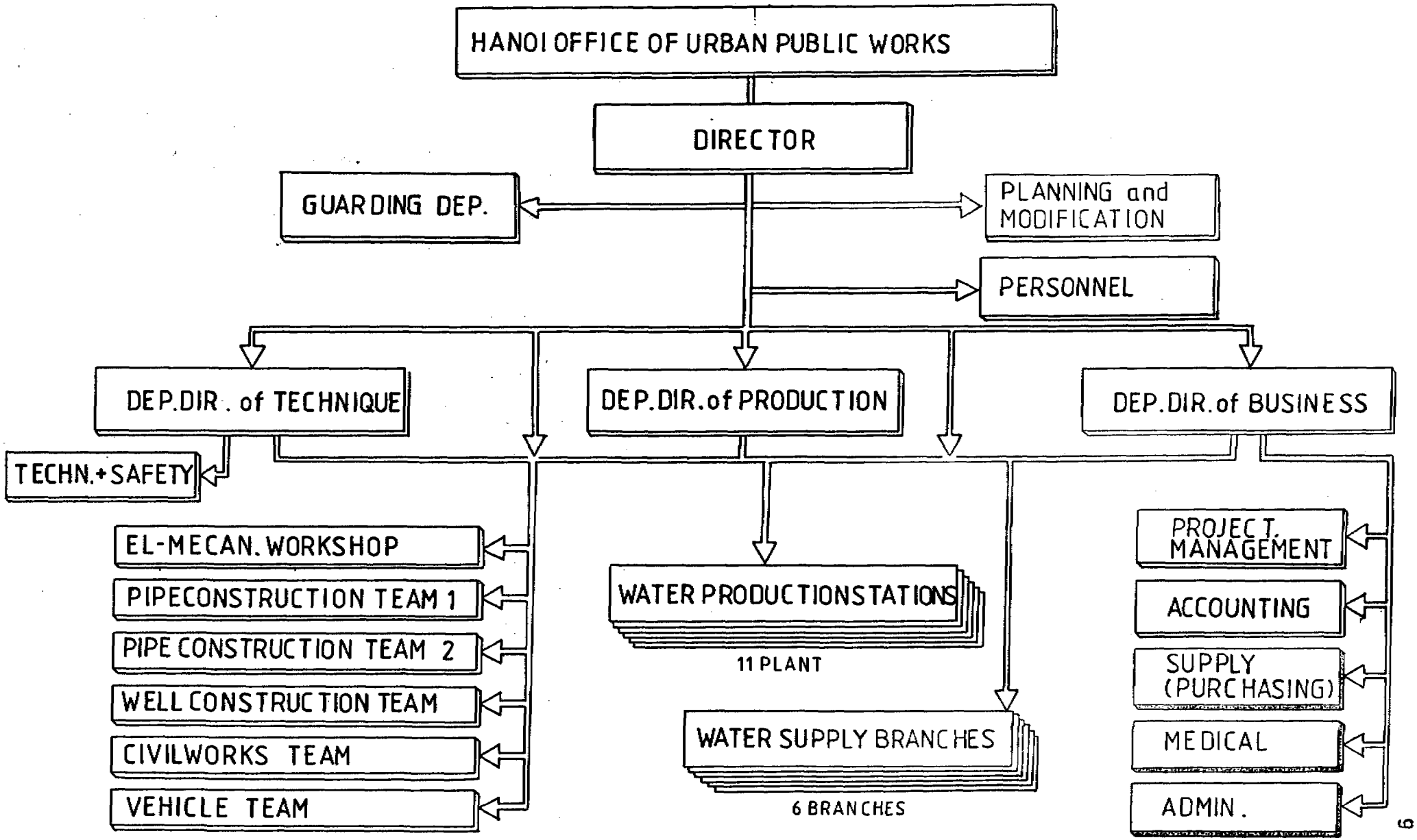
Hanoi Water Supply Company is a branch of Hanoi Office of Urban Public Works which is an authority of Hanoi People's Committee.

The Water Supply Company is in responsible for the operation and maintenance of the system. The company is headed by a director and three deputy directors, one being responsible for the technical affairs, one for the economy and one for production. The staff of the company consists of 1,700 employees, out of which about 70 are university or college graduates. The organisation chart as in May 1989 is presented in fig. 2.1-2.

Continuous planning and design work as well as major investments are at the moment carried out under a separate project organisation by the Management Board (MB) for Hanoi Water Supply Project and YME-Group experts. HWSCo has only limited resources for this purpose.

The organisation of HWSCo has been reviewed by the UNDP assisted Hanoi Water Supply Management Project (VIE/82/011). According to their findings the main problems in the existing organisation are lack of authority on the operational level, complicated decision procedures and unclear allocation of rights, duties and responsibilities.

FIGURE 2.1-2 ORGANIZATION CHART OF HANOI WATER SUPPLY COMPANY (APRIL - 1989)



According to the director of HWSCo the main problems in the water supply sector are:

- extensive leakage in the distribution network,
- lack of pressure in the main parts of the network,
- interruptions in the energy supply,
- lack of telephone connections,
- lack of competent workers and foremen,
- complicated organisation.

The reorganisation of HWSCo has been ongoing since March 1988 with the following main principles:

- water production technology to be utilized should be appropriate, advanced and economically feasible,
- water distribution should be continuous with minimal breakdowns and leaks,
- allocation of responsibilities between different units should be clear.

It has been proposed that there should be the following departments under the HWSCo:

- water production department for running the water treatment plants
- water network department for water distribution to the consumers
- construction department for planning and design and for major investments
- economy department for personnel, purchasing, storing, administration, transport and other general services

In addition to the above mentioned departments it has been proposed that there should be units for development (budgeting and master planning) and for training.

So far (May 1989) only minor changes in the organisation have been realized, namely the establishment of pilot organisations for Ngo Si Lien water plant (water production) and for Dong Da district (water distribution).

The reorganisation of the water supply sector is

discussed more in details in the report of the Management Project of UNDP (VIE/82/011) "Reorganisation, tariffs, information for management, April 1989".

2.1.3 Water tariffs and billing

The HWSCo has been until very recently heavily subsidised by the Government. The Sixth National Congress held in December 1986 stated the need for 'abolition of the centralized bureaucratic state-subsidy system' and consequently also for the water supply sector it has been set the target to become step by step a self-financing unit. The water prices have been increased to gradually meet the cost of operation and maintenance and investment repayments.

Hanoi Water Supply Management Project made a proposal to increase the average tariff of 51 dong/m3 to 100 dong/m3 for the period of FINNIDA investments 1989-1990 and to 250 dong/m3 thereafter. There were three categories proposed, namely private houses, living quarters and public use & industries. These tariffs are enough for cash flow (operation costs and yearly investments).

Based on the a.m. proposal, beginning on the 1 st of May 1989 HWSCo has been applying rates as follows (1US$=4300 dong, May 1989):

1. Rate of 80 dong/m3

   Domestic water consumed by private houses, by flat renters (in living quarters allocated by State or Government offices to cadres on Government pay roll) and schools.

2. Rate of 250 dong/m3

   For business enterprises, state, collective and private service enterprises having contracts with army, hospital and non-profitable administrative units.

3. Rate of 600 dong/m3

   For private business and enterprises or for others not mentioned in articles 1 and 2.

4. Rate of 0.45 US$/m3 or 0.625 Roubles/m3

   For international offices.

The a.m. rates are for the water consumption quota set by the Government. Water consumption beyond the quota is charged from 2 to 5 times higher than the current rate.

These rates mean in an average about 225 dong/m3.

Calculation of tariffs is presented in the report of the Hanoi Water Supply Management Project.

Water billing is done monthly by water branches. There are special groups for metering and billing of water. As there exist only very few functioning water meters at the time being, the billing is based almost totally on estimated consumption figures. In table 6.3-1 is presented the water sale in 1988 based on the billing work by HWSCo.

2.2 Source of Supply

The present source of supply is groundwater exploited from a confined cobblestone gravel aquifer from Quaternary period laying beneath the city.

There exist 3-18 groundwater wells located in a wellfield around each main treatment plant to pump raw water through raw water lines to purification. There is totally over 120 wells of about 60 to 75 m depth to supply water to the Hanoi water supply system. The main groundwater wellfields and their estimated pumping capacities are presented in table 2.2-1.

In addition to the a.m. main plants there exist a number of small plants to supply water for domestic purposes, institutions, factories etc. The information regarding to these, as it has been possible to obtain from different Vietnamese sources, is presented in tables 2.3-3 and 2.3-4. Their estimated total pumping capacity is about 80,000-100,000 m3/d making the total pumping capacity of all the wells in Hanoi city area to about 400,000 m3/d.

The location of wells is presented in drawing no...

The present source of supply, groundwater wells and the potential of groundwater resources will be discussed in detail in a separate report by the hydrogeologist.

TABLE 2.2-1 MAIN GROUNDWATER WELLFIELDS AND THEIR ESTIMATED PUMPING CAPACITIES

Water plant / wellfield	Renovated until 2/1989	New wells completed until 2/1989	Wells under constr. 2/1989 2)	Old wells not renov. until 2/1989	Total in use 2/1989	Pumping capacity 2/1989 (m3/d) 1)	PROJECTIONS FOR THE PERIOD 2/1989 - 12/1990 Wells to be drilled 2)	Wells to be renovated 2)	Total in operation 12/1990	Pumping capacity 12/1990 (m3/d)
Right side of Red River:										
Don Thuy 3)	3				3	13600			3	13600
Ha Dinh	4			10	14	35000			14	35000
Luong Yen	4	1		1	6	29200	9		15	61500
Mai Dich		8			8	41500	6	3	17	73300
Ngo Si Lien 4)	12	2	3	3	17	47300			20	58100
Ngoc Ha	6		2	1	7	34800	2		11	49200
Phap Van			9		0				9	32400
Tuong Mai	9	1		2	12	37000			12	37000
Yen Phu	12	2	2	4	18	78300			18	78300
Right side tot	50	14	16	21	85	316700	17	3	119	439100
Left side of Red River:										
Gia Lam	2				2	11000			2	11000
Total	52	14	16	21	87	327700	17	3	121	450100

Notes:
1) Capacities calculated for each existing well with new submersibles separately, old well capacity estimated to be 35
2) Capacity for a new submersible pump estimated to be 50 l/s
3) Don Thuy wellfield might be connected to to Luong Yen in the near future, because the lifetime of the plant is reaching its' end
4) Wells under construction will be connected to the wellfield in 3/1989

2.3 WATER PLANTS

2.3.1 General

There have been eight major water plants supplying water to the water distribution network before the HWSP, contributed by Finland started in 1985. These plants located quite evenly over the whole service area.

The year of the construction and the initial capacities of the plants have been presented in the table below:

Station	Year of construction	Initial capacity (m3/d)
Yen Phu	1909	15,000
Bach Mai	1930	1,000
Don Thuy	1939	5,000
Ngoc Ha	1939	1,000
Ngo Si Lien	1942	3,000
Luong Yen	1959	9,000
Tuong Mai	1960	18,000
Ha Dinh	1967	18,000

During the phase I of the Development Project two new water plants have been constructed, Mai Dich water plant to the West and Phap Van to the South of the city.

All the old water plants have been extended during the years by constructing more wells and by extending the plant itself. The development of the city, however, has given some constraints to the development of these stations. Quite many of the stations are pressed inside dwelling areas and today there are limited possibilities to extend the plants, or even to construct new wells without demolishing the existing dwellings around the pumping stations and well fields.

Almost all of the major water plants have the same process of water treatment. The treatment aims mainly at the removal of iron and manganese and it consists of aeration, contact basin, rabid sand filtration and chlorination.

The dimensioning of treatment units is not always in conformity with the quality of the raw water, some units of the process may be under dimensioned. This applies especially to the sedimentation which in many plants is working mainly as a contact basin due to the high surface load and the hydraulic form of the basin. The underdimensioning of the treatment units is quite often due to the fact that more wells have been taken into use without extending the structures of treatment plant.

Generally, the treatment process employed is proper for the raw water. If the dimensioning of treatment units were according to the normal criteria and if the plant operated well, it would be possible to get good quality treated water. In practice, however, the quality of treated water does not often comply with the accepted standards due to overloading of treatment units and the malfunctioning of mechanical and electrical installations.

All the old water plants needed urgently rehabilitation of mechanical and electrical installations and therefore in the phase I of the HWSP th rehabilitation of Ngo Si Lien, Yen Phu, Luong Yen and Tuong Mai have been carried out.

Detail reports have been prepared on the current situation of the following old plants :

- Ngo Si lien
- Tuong Mai
- Yen Phu
- Ngoc Ha
- Luong Yen
- Ha Dinh

and the new plants constructed during the development project:

- Mai Dich
- Phap Van

2.3.2 Description of Major Water Plants

2.3.2.1 NGO SI LIEN water plant

1.History

Ngo Si Lien water plant was built first in 1942 with an initial capacity of 3,000 m3/d. The plant had two wells and the treatment process consisted of aeration, slow sand filtration and chlorination. Chlorine was produced of salt by electrolysis. This plant was taken out of use in 1962.

The same year a new water treatment plant was constructed with a capacity of 16,000 m3/d. The plant had 6 wells and the treatment process includes aeration, rapid sand filtration and chlorination. The plant was taken out of use in 1980 because there were settlements and damage in the structures.

A new water treatment plant was constructed in 1978 with a design capacity of 60,000 m3/d. The number of wells was 16 and the treatment process the same as in the plant constructed in 1962.

The new plant built in 1978 has been in operation until the development project started. At that time the plant could not anymore reach the design capacity of 60,000 m3/d.

In the course of the rehabilitation all process units were renovated:

- aeration/ contact basin
- filtration
- treated water pumping station
- disinfection

The rehabilitation consisted of mechanical and electrical works.

After the rehabilitation the capacity of the plant is 50,000 m3/d.

2. Wells

Until February 1989 five wells have been drilled and 12 old wells rehabilitated (see table 2.2-1).

In addition to these three non-rehabilitated wells are still in use. Thus the total number of wells is 20 pcs and the estimated total flow 58,000 m3/20 h. The drawdown has increased in every well where new pumps have been installed, in some wells the yield shall be decreased to get the drawdown back to the acceptable level.

3. Raw water pipelines

NSL raw water network consist of 3200 m old known rehabilitated cast iron lines and 860 m of new PVC and PEH lines. Diameters vary from 200 mm up to 600 mm.

The old lines are leaking all over but limited resources have made impossible to rehabilitate the lines yet. During the second phase of the

project all raw water lines have been planned to be repaired.

4. Treatment plant

*_Aeration:

The aeration is performed by spraying water through perforated pipes. The total height of the aeration is 6 m and there are two intermediate hollow floors. There are four separate units, the area of each unit is 49 m2 and the total area is 196 m2. Thus the aeration rate is 12.8 m3/m2/h, if the flow is 2,500 m3/h.

The aeration is suitable for this raw water and is effective enough to oxidize iron. However, the piping of the aeration tower are in need of urgent repair.

* Contact_sedimentation:

This stage consists of 2 parallel basins, total surface area is 196 m2 and total of volume is 250 m3. The basins are situated below the aeration tower and operate mainly as contact basins where the oxidized iron is flocculated and only slightly sedimentated. This depends on the hydraulic form of the basins and is illustrated as follows:

Flow (m3/d)	Detention time (min)	Surface load (m3/m2/h)
2,000	37	10
2,500	30	13

* Filtration:

The filtration process consists of eight rapid sand filters. The filters have combined air-water washing. The renovated filter bottom is fitted with modern plastic filter nozzles. Total area of filter bed is 380 m2.

The grain size of the filter sand is 0.9-2.3 mm and thickness of the sand layer is 1.5 m.

Designed filtering rate is 6.0 m3/h/m2 and washing rates as follows:

- air water washing phase 500-850 m3/h
- water washing phase 2,030 m3/h

For operation of filters special operation desks have been installed and all the needed valves are electrically operated.

* Disinfection:

Disinfection of the treated water will be carried out by using chlorine gas. The whole unit has been constructed and new dosing equipment installed during the phase I of the HWSP.

5. Reservoirs

The treated water reservoirs are in 4 units:

- 1 circular unit V= 500 m3
- 1 circular unit V= 1,300 m3
- 2 square units V= 3,000 m3 each

The reservoirs are in good condition, but the valves in connecting pipelines are partly out of the operation.

6.Treated Water Pumping Station

The treated water pumping station houses all the pumps and the electrical controls of the plant. The total floor area of the pumping station is about 1,300 m3. There are:

- 3 new treated water pumps
  a 1,440 m3/h x 9 m,
  N=55 kW, 980 r/min
- 2 old treated water pumps
  a 1,260 m3/h x 37 m,
  N=160 kW, 960 r/min
- 1 filter wash pump a 1,940 m3/h x 15 m
  N=135 kW (old)
- 1 air compressor a 3,360 m3/h x 0.4 bar
  N=55 kW (stand-by)

During the normal consumption one or two new pumps are used to pump water to the network, but during the peak consumption also the old pumps have been used.Pressure of the old pumps have been reduced by the valve to meet the pressure of the network.

7. Pilot Pumping Station

7.1 General

In the beginning of Phase I of the HWSP a special pilot area was established around Ngo Si Lien water plant to study water distribution with the higher pressure. For this purpose a special pilot pumping station was also constructed.

7.2 Pumping Station

The pumping station has been equipped with two centrifugal pumps, one as stand-by, and control panels:

- 90 l/s x 30 m, N = 37 kW, 1,470 r/min

During the construction of distribution lines and house connections on the influence area of Ngo Si Lien water plant, the Pilot pumping station was the only source of high pressure water. Therefore new lines were connected together with the original extent of pilot area. At the moment, because of too large extent of the consumption area, the pumping station is working on 170 l/s flow and 21 m head.

Since additional water from MD has been available the pilot consumption area has been decreased step by step in order to reach the planned pressure of 30 m.

8. Water quality

The quality of raw and treated water is presented in tables 2.3-1 and 2.3-2.

The quality of the treated water after the rehabilitation has been improved. The water is slightly corrosive and PH value should be a little bit higher.

2.3.2.2 YEN PHU water plant

1. History

Yen Phu water plant was first built in 1909 with an initial capacity of 15,000 m3/d. The treatment process included aeration by a perforated concrete layer and a gravel bed and slow sand filtration.

In 1963 the plant was rehabilitated and the total area of the aeration/contact basin was increased up to 1,400 m2 and the area of slow sand filter to 1,450 m2. Thus the filtrating rate was 0.63

m3/m2/h.

In 1970 the whole station was rehabilitated and the capacity is increased from 20,000 m3/d to 40,000 m3/d. The plant had 15 wells and the filtration process was changed to be rapid sand filtration.

The plant built in 1970 has been in use since the rehabilitation was started during the Development Project, but could not reach the design capacity.

The rehabilitation with the design capacity of 45,000 m3/d consisted of following works:

- improvement of aeration
- rehabilitation of filtration
- construction of new pumping station for raw water pumping to filtration
- construction of the treated water pumping station including transformers and control rooms
- construction of the new reservoir

The present situation of the plant has been described under.

2. Wells

In Yen Phu 10 wells have been rehabilitated and 4 wells drilled until February 1989. Four pcs of old non rehabilitated wells are operating simultaneously. (see table 2.2-1)

These 18 wells have been estimated to produce raw water 78,000 m3/20h. Installation of new pumps has caused the increase of drawdown by more than 10 m. It seems that a new balance situation has been reached at the moment.

3. Raw water lines

YP raw water network consists of 3100 m old non rehabilitated cast iron lines and 1150 m of new PVC and PEH lines.

Diameter varies from 200 mm up to 400 mm. The repairing of old leaking raw water lines has been planned to be carried out during the II phase of the project.

4. Treatment plant

* Aeration

The aeration is performed by spraying the water through perforated pipes. The total height of the aeration tower is only 2.5 m, but is suitable for this raw water and is effective enough to oxidize iron. The total area of the aeration is 180 m2 and the aeration rate is 10.4 m3/m2/h.

* Contact/Sedimentation

From aeration, water flows to the old filter tanks which have been converted to contact basins. The total area of the contact basin is 1,725 m2, which theoretically give a surface load of 1.1 m3/m2/h. During contact time Fe2+ turns completely to Fe3+.

* Filtration

From the contact basin, water is pumped to the filtration with two new propel pumps.

For filter back washing two old pumps are used, Q = 3,000 m3/h, h = 23 m each.

The filtration process, rapid sand filtration, consist of six units with total area of 294 m2. The filters have combined air-water washing. The filter bottoms were renovated during the last rehabilitation being now equipped with plastic nozzles.

The grain size of the filter sand is 0.9-2.3 mm and the thickness of the sand bed is 1.5 m.

The design value of the filters with flow 1,875 m/h are:

-	filtering rate	6.4 m3/m2/h
-	washing rate, air-water	530-880 m3/h
-	Washing rate, water	2,115 m3/h

All the valves and connecting pipes have been renovated. Process valves are electrically operated from the filter control desks.

* Disinfection

Disinfection of the treated water will be carried out using chlorine gas. The whole unit has been constructed and new dosing equipment installed during the last rehabilitation.

5. Reservoirs

There are three reservoirs still in use in the plant.

- 1 circular reservoir 500 m3
- 1 old reservoir 100 m3
- old slow sand filter tank is converted to a reservoir with total volume of 2,000 m3 and effective volume of 1,200 m3

Structurally, the reservoirs are still in good condition. The valves are partially out of use.

During the last rehabilitation one new reservoir piping between the old and new reservoirs has been installed to use them all in parallel.

6.Treated water pumping station

A new treated water pumping station was built also during the latest rehabilitation phase. New transformers and control rooms were fitted also in the pumping station.

There are the following pumps installed:

- 3 treated water pumps
  720 m3/h x 40 m, N = 160 kW
- 2 treated water pumps
  180 m3/h x 32 m, N = 30 kW

7. Water quality

The quality of raw water and treated water at the plant is shown in the tables 2.3-1 and 2.3-2.

2.3.2.3 LUONG YEN water plant

1. History

Luong Yen water plant was constructed in 1959 with design capacity of 12,000 m3/d. Initially there were 3 wells and the capacity of the plant was 9,000 m3/d.

In the 1973 the plant had 3 wells and the actual capacity was 15,000 m3/d.

Treatment process consists of aeration, contact basin, rapid sand filtration and chlorination.

All treatment units, but chlorination, were rehabilitated during the HWSP 1986-1988.

2. Wells

There are 4 pcs of rehabilitated wells, one new well drilled and one old well operating together. Total estimated capacity is 29,000 m3/20h.
(see table 2.2-1)

3. Raw water lines

There are no accurate data available concerning the raw water lines in the area. The estimated length of the lines is 450 m and informed diameter of all lines is 200 mm, obviously made of cast iron.

Rehabilitation of the lines takes place together with the new Luong Yen water plant construction.

4. Treatment plant

* Aeration

Aeration is performed in 2 aeration towers, each having 4 intermediate levels. The distribution of water is done with perforated pipes. The total area of aeration is 90 m2 and the aeration rate with actual raw water flow is 9 m3/m2/h.

The piping in the towers have been renovated as well as other metal and concrete structures.

* Contact basin

There are 4 parallel units of contact basins. The total surface area is 85 m2 and total volume 460 m3. The surface load with flow 820 m3/h is 9.6 m3/m3/h and the retention time 33 minutes.

* Filtration

The filtration consists of 5 rabid sand filters with combined air-water washing. Filter bottoms including distribution nozzles were renovated in the phase I of the HWSP in 1986-1988. Grain size of the filter sand is 0.9-1.6 mm and the depth of the filter bed is approx. 1.5 m.

The total area of the filters is 92 m2 and the loads by flow 625 m3/h are as follows:

- filtering rate 6.8 m3/m2/h
- washing rate, air-water 200-330 m3/h
- washing rate, water 800 m3/h

All pipes and valves were renovated during the rehabilitation and all the control valves are electrically operated.

* Disinfection

Disinfection of the treated water will be carried out later in the connection of the enlargement of the plant.

5. Reservoirs

The treated water reservoirs are in two units, the volume of each is 1,000 m3.

6. Treated water pumping station

The treated water pumping station was also rehabilitated in 1986-1988. All the pumps were renovated and new control rooms equipped. There are following pumps:

- 2 pumps 290 m3/h x 16.5 m, N = 22 kW

- 1 filter back-wash pump
  650 m3/h x 13 m, N=37 kW

7. Water quality

The quality of raw and treated water is presented in tables 2.3-1 and 2.3-2.

The iron content of raw water is low, 1.2-2.9 mg/l, However, no analyzes of the treated water after the rehabilitation exists and the effectiveness of the improved process can not be stated.

8. Enlargement

According to the project document an additional capacity of 30,000 m3/d will be constructed during the phase II of the project.

2.3.2.4 TUONG MAI water plant

1. History

Tuong Mai water plant was first constructed in 1962 with an initial capacity of 18,000 m3/d. The plant had 6 wells and the treatment process consisted of aeration, sedimentation, filtration and chlorination. Chlorine was produced by electrolysis of salt.

In 1976 the capacity was again increased up to 40,000 m3/d by taking into use one more well. Thus the capacity had been raised by more than 120 % without extending treatment units.

Before the last rehabilitation started in 1986 the plant was operating with the capacity of 29,000 m3/d (1,200 m3/h) and the treatment units were so much overloaded that the quality of treated water was not satisfactory. Design capacity for the rehabilitation was selected to be 30,000 m3/d.

2. Wells

Eight rehabilitated wells, one new well and two old non rehabilitated wells are operating together, producing the estimated of 37,000 m3/20h. One additional well was also rehabilitated, but after electro-mechanical installations it was found out that the raw water line is totally broken, and this well can not be used. One borehole was drilled and casing installed as a reserve well. (see table 2.2-1)

3. Raw water lines

The length of old cast iron pipes is 2400 m and the length of new PVC line is 65 m. Old lines are leaking and rehabilitation takes place during the II phase of the HWSP.

4.Treatment plant

Previously there were five aeration towers and two round steel tanks with blowers for aeration.

In the last rehabilitation only aeration towers were renovated and taken into use. Steel tanks were demolished.

The total area of aeration is 274 m2 and aeration rate by the flow of 1,250 m3/d is 4.6 m2/m2/h.

* Contact basin

The stage consists of 12 parallel units. The total area is 300 m2 and the total volume 1,300 m3. The load is:

Flow	Retention time	Surface load
1,250 m3/h	6.2 min	4.2 m3/m2/h

Mechanical and structural rehabilitation of the basins was carried out in 1986-1988.

* Filtration

The process consists of 12 units of rabid sand filters, having combined water-air washing. The total area of filters is 216 m2. The grain size of filter sand is 1.2-2.0 mm and the thickness of filter bed is 2.1 m.

The design values of filters are by the flow of 1,250 m3/h as follows:

- filtering rate 5.7 m3/m2/h
- washing rate, air-water 200-300 m3/h
- washing rate, water 775-970 m3/h

Filter bottom, distribution nozzles, valves and pipes in the unit were renovated. All process operation valves are electrically controlled.

* Chlorination

Totally new chlorination house and dosing equipment have been constructed and installed during the latest rehabilitation in 1986-1988.

5. Reservoir

The treated water reservoirs are in two units, the volume of each being 1,000 m3. Structurally the reservoirs are in good condition.

6. Treated water pumping station

The treated water pumping station including the control room have been renovated in 1986-1988.

At the moment there are following pumps installed:

- 2 pumps 900 m3/h x 22 m,
  N = 90 kW for treated water
- 1 pumps 650 m3/h x 13 m,
  N = 37 kW for back-wash pumping

7. Water quality

Raw water contains 8-13 mg/l of iron and about 0.4 mg/l of manganese.

The iron content of treated water before the rehabilitation varied from 0.5 mg/l to 1.3 mg/l.

Analyzes after the rehabilitation have not been taken and therefore present effectiveness of the treatment process is not known exactly.

2.3.2.5 NGOC HA water plant

1. History

Ngoc Ha water plant was constructed in 1939 with an initial capacity of 1,000 m3/d. Thereafter, the plant has been enlarged in several phase up to 9,000 m3/d. In 1979 the plant was extended to the capacity of 25,000 m3/d. Treatment process consists of aeration, contact basin, filtration and chlorination.

Today the actual capacity of the plant is estimated to be 27,000 m3/d. The plant is structurally in miserable condition. The common problems with wells exist also at this plant.

2. Wells

At present there are seven rehabilitated wells in operation producing the total capacity of 35,000 m3/d. Two wells are drilled and casings installed, two more wells are needed for the II phase extension.

3. Raw water pipelines

There are no accurate data available of the raw water pipelines from the wells to the treatment plant. Site inspection show, however, big leakages all over. Rehabilitation takes place in connection with the plant construction.

4. Treatment plant

* Aeration

Aeration is performed by perforated pipes. The total area of the aeration towers is 40 m2 and so the aeration rate is 31 m3/m2/h with the flow of 1,250 m3/h.

The concentration of iron in raw water is about 1-3.5 mg/l and the aeration process seems to be efficient enough for oxidation of this amount.

* Contact basin

The contact basin has a surface area of 40 m2 and

a volume of 200 m3. The surface load is thus 32 m3/m2/h and the detention time is 0.16 h. In practice only part of water goes through contact basin in the old system, and in the new system, after aeration it goes directly to filtration.

* Filtration

Filtration process consists of 9 filters, with a total area of 117 m2. The filtration rate is 10.6 m3/m2/h, which is very high for this kind of raw water.

5. Reservoir

The treated water reservoir has a volume of 155 m3. In addition, there is a water tower, with a volume of 160 m3 and a height of 30 m, but out of use.

6. Treated water pumping station

In the treated water pumping station there are in total five pumps out of which two pumps are in operation:

- 1 pc 1,250 m3/h x 14 m
- 1 pc 180 m3/h x 14 m

7. Enlargement of the plant

According to the project document for the phase II of the HWSP a new water plant with capacity of 30,000 m3/d should be constructed. Location of the plant is apr. 0.2 km to the West of the old plant.

After the construction of the new plant the capacity of the old plant has been suggested to be reduced to 14,000 m3/d.

2.3.2.6 HA DINH water plant

1. History

Construction of Ha Dinh water plant was started in 1963 and it was taken into operation in 1967. The first plant had 4 wells and total capacity of 18,000 m3/d.

Afterwards, the actual capacity of the plant has been increased by constructing more wells. Today the production of the plant is 30,000 m3/d, and construction works are being planned to enlarge

the plant to 40,000 m3/d by:

- 6 filters, A = 144 m2
- 2 sedimentation basins, A = 193 m2
- 2 reservoirs, V = 3,000 m3

2.Wells

At present there are 10 non rehabilitated old wells and four rehabilitated wells with a total raw water flow of 35,000 m3/20 h.

The wells have declined so much, that there have been difficulties with pump installations. Most of the wells have not been blown for a long time and the depth of the wells has decreased. In general the problem with wells are the same as in other water plants.

It seems, based on the available information from hydrogeological studies, that the capacity of Ha Dinh water plant should be reduced to extend the technical life time of the facilities established.

3. Raw water pipelines

Raw water pipelines from the wells to the water plant are made of cast iron. Pipe diameter varies from 200 mm to 600 mm. Accurate data of raw water lines does not exist.

4. Treatment plant

*Aeration

The aeration is performed in an aeration tower by concrete gutters. The tower has 5 intermediate level of hollow concrete floors. The distribution of water is not even due to the inexact level of gutters and blockages of iron deposits, decreasing aeration efficiency.

The total area of aeration is 193 m2 and aeration rate 9 m3/m2/h.

*Sedimentation

There are three horizontal sedimentation basins in the plant. The total surface area of sedimentation is 193 m2 and the total volume 1,350 m3. Thus with a flow of 1,750 m3/h the load is:

- surface load 9.1 m2/m2/h

- retention time 46 min

Sedimentation operates mainly as a contact basin. It has been planned that after enlargement the capacity will be 45,000 m3/d without any additional sedimentation basin.

* Filtration

The filtration process consists of 8 rapid sand filters. The filters have a combined air-water washing and the filter bottom is of perforated concrete, holes 10 x 10 mm2, c/c 100 mm. Filter sand has a nominal grain size of 1.2 mm and below there are coarser layers of 2-4 mm, 4-8 mm, 8-16 mm, 16-32 mm.

The air distribution pipes are under the filter sand bed and the distribution pipes under the filter bottom.

There are two wash water pumps, 1 pc 900 m3/h + 1 pc 600 m3/h giving a wash rate of 62.5 m3/m2/h. The flow to individual filter is not uniformly distributed, some control valves are not operational and the filter sand is not uniform.

5. Reservoirs

The plant has two reservoirs with a total volume of 2,000 m3.

6. Treated water pumping station

The treated water pumping station houses all the pumps of the plant and the electrical controls. There are:

-	2 pumps	1,260 m3/h x 39 m
-	1 pump	580 m3/h x 46 m
-	1 pump	600 m3/h x 28 m

The pressure in the transmission main line at the plant is in the day time 9 m and in the night time 18 m above ground level. Thus the pumps are operating far outside their nominal capacity range.

Rehabilitation work carried out by Vietnamese has not proceeded very satisfactorily. After the rehabilitation of some wells in 1986-1988 the ground water level has dropped alarmingly. The development of the plant has to be considered carefully in the near future.

2.3.2.7 MAI DICH water plant

1. General

The construction of Mai Dich water plant was included in the phase I of HWSP.

The design capacity of the plant was 30,000 m3/d. The pumping station has been designed for the later enlargement of the plant to the capacity of 60,000 m3/d.

The treatment process of the plant is the same as in the old plants in the city:

- aeration
- contact basin
- filtration
- disinfection

The first phase of the plant was completed in the end of the year 1988.

2.Wells

In MD area nine wells have been drilled, eight of them are equipped with new pumps and pipes, one well (No 6) has been rejected due to a clog (at 42 m depth) which was caused on purpose. The total flow from the eight wells is 41,500 m3/20 h. (see table 2.2-1)

3. Raw water lines

The new raw water lines are made of ductile iron, and PVC, total length is 2,660 m, diameter varying between 225 mm and 600 mm.

4. Treatment plant

* <u>Aeration</u>

The aeration is performed by spraying the water through perforated pipes. The total height of the aeration unit is 2.5 m and there is one intermediate hollow floor. There are 6 separate units and the total area of the units is 216 m2. Thus the aeration rate is 5.8 m3/m3/h.

Because of the low content of iron in the raw water the process is effective enough to oxidize iron.

* Contact basin

Contact basin has been constructed under the aeration towers, total surface area is 210 m2 and the volume is 715 m3. In the basin the oxidized iron is flocculated and only sightly sedimentated.

* Filtration

The filtration process consists of six parallel rapid sand filters. The filters have combined air-water washing through the filter bottom equipped with plastic filter nozzles.

The filter sand has the grain size of 0.9-1.6 mm. (because of the lack of proper sand grain size the size 0.9-2.3 was used at the beginning)

The thickness of filter bed is 1.5 m including the support layer of 0.15 m and grain size is 2.3-4.0 mm.

Designed filtering rate is 5 m3/m2/h and washing rate as follows:

- air-water phase 540-700 m3/h
- water phase 2,160 m3/h

All process valves for operation are electrically controlled. Filtering rate is regulated with the hydraulic valve.

* Disinfection

Disinfection of the treated water is carried out by using chlorine gas. Gas is dosed to the water before the reservoirs in order to have proper contact time.

5. Reservoirs

There are two reservoirs constructed for the treated water. Total volume is 2 x 3,000 m3. For the enlargement two new reservoirs with the total volume of 6,000 m3 will be constructed.

6. Treated water pumping station

The treated water pumping station houses all the treated water pumps, filter back wash pumps, technical water pumps, air compressor and the electrical control of the plant.

The total floor area of the pumping station is 475 m2. The floor area of administrative wing is 315 m2.

There is:

- 3 treated water pumps
  720 m3/h x 40 m, N = 160 kW

- 2 filter back wash pumps
  1,225 m3/h x 25 m, N = 132 kW

- 1 air compressor
  3,360 m3/h x 0.4 bar, N = 55 kW

The treated water pumping station has been designed to accommodate 3 more treated water pumps in the enlargement phase.

The capacity of the pump has been designed so, that during the peak consumption two pumps are in operation and one is stand-by. Later after the enlargement four pumps can be used parallel and two stand-by.

Filter back-wash pumps are designed so, that in the air-water washing phase one pump is needed and in the water washing phase both two pumps are operating.

7. Water quality

Quality of raw water in MD area is rather good and quality of the treated water will probably meet all the requirements. Analyzes to state the effectiveness of the process will be taken later when the plant has passed the test period. Some results of the analysis are presented in tables 2.3-1 and 2.3-2.

2.3.2.8 PHAP VAN water plant

1. General

In the first phase of the HWSP also Phap Van water plant was decided to be constructed during the years 1986-1988. The design capacity of the plant has been 30,000 m3/d.

The treatment process is conventional:

- aeration

- contact basin

- filtration

- disinfection

The plant was completed in the end of 1988.

2. Wells

In Phap Van nine new wells have been drilled. At the moment (March 1989) electro-mechanical installations are being carried out in three wells. The rest of the installations will be made during the first half of 1989. Thus three wells enable to take the plant into use with a capacity of 15,000 m3/d.

3. Raw water lines

The raw water lines are constructed of ductile iron and PVC. The total length is 1,558 m, and diameter varying from 225 mm up to 600 mm.

4. Treatment plant

* Aeration

The aeration is performed by spraying the water through perforated pipes. The total height of the aeration unit is 2.5 m and there is one intermediate hollow floor. There are 6 separated units and the total area of the units is 216 m2. Thus the aeration rate is 5.8 m3/m2/h.

* Contact basin

Contact basin is constructed partly under the aeration tower and other section beside that one. Because of the form of iron more detention time is required than in other plants. The total area of the units is 420 m2 and volume is 1,430 m3. Oxidated iron is flocculated in the basin and only sightly sedimentated.

* Filtration

The filtration process consists of 6 parallel rapid sand filters. The filters have combined air-water washing through the filter bottom equipped with plastic filter nozzles.

The filter sand has the grain size of 0.9-1.6 mm (because of the lack of proper sand grain size the size 0.9-2.3 was used at the beginning). The thickness of filter bed is 1.5 m including the support layer of 0.15 m and the grain size 2.3-4.0 mm.

Designed filtering rate is 5 m3/m2/h and washing rate as follows:

- air-water phase 540-900 m3/h
- water phase 2,160 m3/h

All process valves needed for operation are electrically controlled. Filtering rate is regulated with the hydraulic valve.

* Disinfection

Disinfection of the treated water is carried out using chlorine gas. Gas is dosed to the water before the reservoirs in order to have proper contact time.

5. Reservoirs

There is one reservoir with the volume of 6,000 m3 constructed for the treated water.

6. Treated water pumping station

The treated water pumping station houses all the treated water pumps, filter back wash pumps, technical water pumps, air compressor and the electrical controls of the plants. The total floor area of the pumping station is 475 m2. In addition to that there is an administrative wing with the floor area of 315 m2.

There is:

- 3 treated water pumps
  720 m3/h x 40 m, N = 150 kW
- 2 filter back wash pumps
  1,225 m3/h x 25 m, N = 132 kW
- 1 air compressor
  3,360 m3/h x 0.4 bar, N = 55 kW

The treated water pumping station has been designed to accommodate three more treated water pumps.

The capacity of the pumps has been designed so, that during the peak consumption two pumps are in operation and one is stand-by.

Filter back-wash pumps are designed so, that in the air-water washing phase one pump is in operation and in the water washing phase both two pumps are in operation.

TABLE 2.3-1 RAW WATER QUALITY IN HANOI WATER PLANTS IN 1988 (Source: HWSCo)

Water plant	pH	NH4	NO2	NO3	PO4	Iron cont. Fe2O3 mg/l	Salinity NaCl mg/l	Cl-	Alkalinity CaCO3, mg/l Total cont.	Perm. cont.	Hardness Total cont.	Perm. cont.	CaO	MgO	MnO	Organic mg/l Acid	Alkal.
Tuong Mai	6.4	2	0		0.54	7	28.1	17	180	80	6.7	1.3	33.6	24	0.2	2.2	1
	6.8	5	0.05	1.25	2.68	21	150	90.8	240	120	9.4	4.3	60.4	38.4	0.7	7.2	1.8
Yen Phu	6.6	0.5	0	0	0.54	1.5	18.7	11.4	180	60	6.6	2.2	25.8	12.8	0.2	0	0
	7.2	4	0.5	1.25	2.68	8.9	65.5	39.8	260	120	17	7.6	83	79.2	1.76	3.7	1.7
Ngo Si Lien	6.6	0	0	0	0.8	0.6	56.2	34	200	80	7.8	1.6	35.8	32	0.1	0.2	0
	6.8	2	0.15	2.5	1.34	3.7	140.4	85	300	200	15	4	71.6	61.6	1.4	1.9	0.9
Ngoc Ha	6.4	-	0		0.54	0.8	63.2	38.4	200	80	8.1	2.7	26.8	51.1	0.8	0.2	0
	6.8	2	0.3	5	1.34	2.7	120.2	72.4	260	120	14.1	6.8	51.5	65.6	1.4	1.6	1
Luong Yen	6.4	0.5	0		1.34	1.4	11	8.5	148	80	6.5	2.2	31.4	12.8	0.15	0.5	0
	6.8	2	0.05	2.5	2.68	4.7	32.8	19.9	180	120	9.9	4	67.2	31.2	0.8	1.8	1.3
Don Thuy	6.8	1	0	1.25	1.34	3.3	11	7.1	160	60	6	1.8	22.4	14.4		0.3	0.2
	7	2	0.05	2.5	2.68	7	28.1	17	220	120	11.6	6.7	69.5	32	0.2	2.4	2.2
Ha Dinh	6.6	4			0.54	6.2	32.8	19.9	200	60	6.5	0.9	26.9	9.7	0	2.2	1.9
	7	8	0.15	1.25	2.68	12	51.5	31.2	220	120	7.8	2.5	53.8	22.4	0.1	0.1	4.5
Gia Lam	6.4	1	0		0.27	10.5	21.1	11.8	160	40	5.8	2.9	22.4	23.2	0.6	1.2	0.5
	6.6				1.34	15	39.8	24.1	200	100	8.7	3.1	44.8	35.2	1	2.2	1.3
Kim Lien	6.6	2			0.8	4.9	72.5	44	240	100	9.2	3.1	49.3	27.7	0.2	3.2	1.8
	6.8	6	0.05	1.25	1.34	8.2	79.6	48.3	280	160	11.6	5.2	53.8	44.8	0.8	7.5	2.6
Trung Tu	6.6	4		1.25	1.08	8	93.2	56.8	260	100	11.9	3.8	60.5	36	0.3	2.7	2.2
		6		2.5	1.34	8.2	100.6	61.1					48.3	43.2	0.6	5.6	2.9
Mai Dich	6.4	0	0	1.25	0.54	0.1	30.4	18.5	100	60	4.7	0.7	9	14.1	0.3	0	0
	6.8	0.25	0.05	5	1.34	0.3	51.5	31.2	160	100	5.3	1.1	24.6	22.4	1.6	8	0.2
Su Pham	6.4	0	0	0	0.88	0.2	28.1	17	148	60	4.1	2.1	17.9	17.9	0.4	0.2	0
	6.8			1.25	2.68	0.8	37.4	22.7	160	80	4.7	2.5	26.9	26.9	0.7	0.5	0.5

TABLE 2.3-2 TREATED WATER QUALITY IN HANOI WATER PLANTS IN 1988 (Source: HWSCo)

Water plant	pH	Transp. (mg/l)	NH4 (mg/l)	NO2 (mg/l)	NO3 (mg/l)	PO4 (mg/l)	Alk. (mg/l)	Organic acid (mg/l)	alkal (mg/l)	NaCl (mg/l)	Cl (mg/l)	Iron cont. Fe2O3 (mg/l)	Hardn. total
Yen Phu	7.2	100	0.3	0.2	2.5	0.1	200	0.6	0.3	28.9	17.0	0.2	10.3
	8.0	100	0.5	0.5	10.0	1.1	220	1.1	1.3	28.1	17.0	0.8	12.1
Ngoc Ha	6.8	100	0.3	0.1	1.3	0.3	200	0.3	0.2	46.8	28.4	0.4	10.9
	7.2	100	0.5	0.2	5.0	2.7	220	1.2	0.6	84.2	51.1	0.1	12.5
Ngo Si Lien	7.0	100	0.3	0.1	5.0	0.8	220	0.6	0.3	46.8	28.4	0.2	11.2
	7.0	100	0.3	0.1	1.3	1.3	220	0.3	0.2	110.0	66.7	0.4	12.7
Bach Mai	7.2	100	6.0	0.1	1.3	1.3	220	1.9	1.8	107.6	65.3	0.2	9.2
	7.4	100	8.0	0.4	5.0	1.1	220	1.6	1.2	98.3	59.6	0.4	9.0
Bach Khoa	7.6	100	6.0	0.0	1.3	0.1	200	0.2	0.2	56.2	34.1	0.5	7.8
	7.4	100	8.0	0.1	5.0	2.7	220	1.6	1.1	93.6	56.8	1.6	11.4
Ha Dinh	7.0	45	8.0	0.1	2.5	0.5	200	1.3	0.6	42.1	25.6	2.5	6.7
	7.2	55	6.0	0.5	5.0	1.3	220	3.0	2.5	74.9	45.4	5.0	7.8
Luong Yen	7.6	100	0.3	0.1	2.5	0.3	140	0.8	0.6	11.0	8.5	0.2	6.7
	7.4	100	1.0	0.2	10.0	1.3	160	1.2	1.3	32.2	14.1	0.7	8.8
Don Thuy	6.8	100	0.5	0.0	1.3	0.5	140	0.3	0.5	11.8	8.5	0.3	6.2
	6.8	90	2.0	0.0	10.0	1.3	160	0.8	0.6	23.4	14.2	0.9	7.8
Tuong Mai	7.6	60	6.0	0.1	1.3	0.3	180	0.8	0.6	11.0	8.2	4.0	5.0
	7.4	90	5.0	0.5	10.0	2.7	180	1.9	1.3	62.1	25.5	1.0	6.9
Kim Lien	7.0	100	4.0	0.1	1.3	0.6	240	0.8	0.5	46.0	28.0	0.6	8.3
	8.0	40	6.0	0.3	5.0	2.7	200	2.8	1.9	79.6	48.3	2.0	10.9
Trung Tu	7.0	90	4.0	0.0	2.5	0.5	220	0.6	0.2	74.9	45.4	1.3	10.5
	8.0	95	8.0	0.3	5.0	2.1	260	3.4	2.5	88.9	34.0	0.8	12.1
Thuy Khue	7.4	100	2.0	0.1	1.3	0.5	200	0.4	0.3	56.2	34.1		9.0
	7.2	100	8.0	0.6	5.0	2.7	240	2.4	1.6	74.9	45.4	0.3	11.2
Gia Lam	6.8	100	0.1	0.1	2.5	8.2	100	0.4	0.0	28.1	17.0	0.1	6.9
	6.8	100	0.2	0.2	5.0	1.3	180	0.8	0.9	37.4	22.7	0.4	8.3
Sai Dong	6.8	40	0.0	0.0	1.3	0.5	160	0.0	0.0	40.8	28.0	0.6	6.9
	7.2	80	0.5	0.2	5.0	1.3	200	1.2	0.5	74.9	43.4	2.0	9.2
Thanh Cong	7.0	90	0.0	0.0	1.3	0.5	160	0.0	0.0	46.8	28.0	0.6	6.9
	8.0	100	0.3	0.2	5.0	1.3	200	1.2	0.0	74.8	45.4	2.0	9.2
Mai Dich	8.0	100	0.0	0.0	1.3	2.0	160	0.0	0.0	14.0	8.5	0.2	3.9
	8.0	100	0.0	0.0		1.0	180	0.0	0.0	28.1	17.0	0.3	5.2

2.3.3 Small Water Plants

In addition to the eight major treatment plants described above, there are one other major plant (Don Thuy) and a number of small pumping stations with or without treatment. These plants have been constructed during the last 25 years and most of them serve a separate area, i.e an institute, a residential block of flats, a factory etc.

More detailed data of the small plants operated by the distribution branches of HWSCo is given in table 2.3-3. The total estimated raw water capacity of these plants is 40,000-60,000 m3/d, ie. 10-15% of the total capacity of all HWSCo operated plants. Therefore, the small plants have a certain role when serving separate areas.

Small pumping stations (plants) operated by factories etc. are presented in table 2.3-4. Their total estimated raw water capacity is 55,000 m3/d and plant capacity 45,000 m3/d. The data concerning these plants has been collected from different sources and therefore should be considered as indicative only.

Some of the small plants operated by HWSCo have been visited and studied. The plants are well operated and they are in rather good condition. This mainly depends on the fact that the equipment is mostly manually operated and of simple nature.

The plants have quite effective aeration by perforated pipes or perforated steel sheets, and a quite well working sedimentation basin. Filtration rate is normally 6-8 m3/m2/h. However, the wash rate of the filters is 8-18 m3/m2/h ie. only about 200 % of the filter rate, which does not keep the filters clean enough.

All these plants have a ground level reservoir with a volume between 150-800 m3. In Kim Lien and Trung Tu there is also a water tower, but they are not in use because of the low pressure in the distribution network.

One more common feature of the small plants are difficulties of surface drainage, and several plants suffer flooding problems, making the operation of plants during rainy periods difficult, even impossible.

Some plants are connected to the main network of the whole city either to take more water from the network, or to pump part of the production of the plant to the distribution network.

TABLE 2.3-3 SMALL WATER PLANTS OPERATED BY HANOI WATER SUPPLY COMPANY

Name	Year of constr.	Wells No.	Wells Capacity (m3/h)	Aeration No.	Aeration Area (m2)	Aeration Rate (m/h)	Sedimentation No.	Sedimentation Area (m2)	Sedimentation Volume (m3)	Sedimentation Retent. (h)	Filters No.	Filters Area (m2)	Filters Filt. Rate (m/h)	Filters Wash. Rate (m/h)	Reservoir (m3)	Clean water Pump No.	Clean water Pump Capacity (m3/h)	Clean water Pump (m)
Bach Khoa	1984	2	200	1	10	10-15	1	16	64	0.5	2	18	6-8	16-18	800	2	340	30
Bach Mai	1954	3	300	1	20	10-15	1		200							2	300	15
Dong Anh	1980	1/4	1) 100	1	160	10-15	1	120	500	0.5	4	64	6-8	8-12	2000	2	720	15
Gia Lam	1961	2	310	1	48	10-15	2	40	220	0.5	3	38	6-8	8-12	500	2	300	
Giang Vo	1985	2	200															
Giap Bat	1976	1																
Kim Giang	1985	2	200	1	4	10-15	1	16	64	0.5	2	18	6-8	16-18	200	2	90	30
Kim Lien	1978	3	400	1	86	10-15	1	16		0.5	3	45	6-8	8-12	500	3	500	30
Nguyen Ai Quoc	1961	1	110	1	4	10-15					4	64	6-8	8-12	150	3	230	25
Quynh Loi	1984	2	200	1	10	10-15	1	16	64	0.5	2	18	6-8	16-18	200	2	135	30
Sai Dong	1973	2	140	1	20	10-15	2	13	62	0.5	3	19	6-8	16-18	200	2	180	17
Supham Ngoai Ngu	1979	1	140	Out of use														
Tay Bac	1970	3	2) 500	Pumping directly to the network														
Thanh Cong	1985	2	200	1	4	10-15	1	16	60	0.5	2	18	6-8	16-18	800	3	500	25
Thuy Khue	1977	1/4	1) 150	For Ho Chi Minh mausoleum only											200			
Thuy Loi	1961	2	190	Pumping directly to the network														
Trung Tu	1984	2	200	2	4	10-15	1	16	64	0.5	1	18	6-8	16-18	800	3	460	25
Van Cong Mai Dich	1963	3	700	Pumping directly to the network														
Van Don		2	200															

Notes: 1) 1/4 = one pump in use out of total four
2) new pumps with a nominal capacity of 80 l/s each
3) data as on January 1989, collected from different sources
4) total estimated pumping capacity 40,000-60,000 m3/d (15-25 l/s/pump, 20 h/d pumping)

TABLE 2.3-4 SMALL PUMPING STATIONS OPERATED BY FACTORIES ETC.

Refer. No. 1)	Name	Year of constr.	Wells No. 2)	Wells Capacity (m3/h)	Plant Capacity (m3/d)	Type of factory
140	Bia Hanoi	1958	3	300	3000	beer production
139	Bo NN (drill. co.)	1960	1	50	1000	private use
38&107	Cao Xa La	1962	5	700	15000	rubber, cigarette, soap
133	Cau Dien	1978	4	400	5000	frozen storage
141	Co Khi Giai Phong	1981	1	80	1500	mechanical
120	Det 8-3	1979	3	300	6000	textile
55&56	Det Kim Dong Xuan	1985	1	150	2000	textile
23	Nha May Cong Cu I	1965	1	180	2000	instruments, tools etc.
142	Pin Phan Lan	1959	2	240	2500	batteries
68	Ruou (alcohol f.)			120	3000	alcohol
135	San Bay Bach Mai	1984	2/4	240	3000	airport
130	VTTH Viet Nam	1976	1	30	1000	Vietnamese television
Total				2790	45000	

Notes: 1) refers to the number on the map showing the location of the factories
2) 1/4 = one pump in use out of total four
3) data as on 1/1989, collected from different sources
4) type of water treatment process not known

2.4 Water Supply Network

2.4.1 General

The oldest part of Hanoi city water supply network originates from the French period at the beginning of this century. Between years 1900-1930 about 55 km of cast iron pipes with diameters between 40-500 mm were installed mainly in the old city centre. Between years 1931-1954 the network was extended to 85 km of cast iron pipes mostly with small diameters.

After 1954 the network has been continuously constructed to cover the urban area. Also other materials than cast iron has been used to a minor extent, namely concrete and steel. Total length of the public pipelines was appr. 302 km in the year 1989. This figure includes the part of the network (6.3 km) located in Gia Lam area on the left side of the Red River. Excluded are, however, the pipelines distributing water to the high-rise building areas from a booster pumping station.

There is 4.2 km of concrete pipes mainly of a big diameter and 1.4 km of steel pipe. The classification of water pipes in Hanoi according to the diameter and construction period is presented in table 2.4-1.

When the FINNIDA aided water supply project started in Hanoi in 1985 the 'crash programme' policy was chosen to be the initial strategy in implementation of the network system. The strategy made it possible to achieve some immediate improvements in the service level:

- increased amounts of water for consumers
- establishment of high pressure zone near Ngo Si Lien water plant and later on its extensions.

Network implementation was started in the influence area of Ngo Si Lien water treatment plant in June 1986 by distribution line construction followed by house connection implementation, which was started in July 1987. Transmission line implementation was started in March 1987.

Raw water line implementation has been connected with the water plant construction and rehabilitation.

TABLE 2.4-1 WATER SUPPLY NETWORK IN HANOI, CLASSIFICATION ACCORDING TO THE CONSTRUCTION PERIOD AND DIAMETER (HWSCo & YME-Group)

unit: km

Diameter (mm) 1)	1900-1930 Hanoi Water Supply Company	1931-1954	1955-1965 3)	1966-1980	1981-1985	1985-3/1989 FINNIDA	Total 2)
40 - 60 (63)	23.6	15.5	-12.0			6.6	33.7
75 - 80 (90)	4.2	1.1	1.2	1.9		8.5	16.9
100 - 150 (110)	15.8	9.1	12.4	27.4		19.4	84.1
180 - 200 (160)	3.1	0.9	13.9	16.7	1.5	19.6	55.7
250 - 280 (225)	0.3	2.2	3.5			8.1	14.1
300 - 350 (315)		0.6	13.0	30.1	3.4	5.6	52.7
400 (400)	6.3		5.0	2.3	5.2	5.2	24.0
500	1.9		0.1				2.0
600 (600)				4.6	0.5	13.9	19.0
	55.2	29.4	49.1	83.0	10.6	86.9	302.2

Notes:
1) Sizes used by Hanoi Water Supply Project
2) Includes the lines disconnected during Phase I of the Water Supply Project
3) 12 km of small pipes deleted between years 1955-65
4) 6.3 km of pipelines in Gia Lam excluded
5) 18 km of PEL 50 mm and 21 km of PEL 32 mm pipelines installed by HWSP until 3/1989 mainly for house connections

2.4.2 Transmission mains

The water is delivered to the distribution network from the wells and treatment plants through the transmission lines. Main network is characterized by two principal criteria:

* The dimension of the pipes is 300 mm or more.

* In general no house connections are allowed to the main pipes.

In Hanoi there are approximately 98 km of these main lines. (table 2.4-1)

The existing system of Hanoi water supply network including the transmission mains constructed by the HWSP is presented in drawing...

About 8 % of the total main lines have been constructed during the period 1900-1930, only 0.6 % from year 1931 to 1954, 19 % between 1955-1965, 47 % between 1966-1985 and the rest 25 % after year 1985 by the support of HWSP.

The established strategy in transmission mains development has been to connect Mai Dich and Ngo Si Lien water plants together with pressure sustaining transmission lines. This work was started in 1986 and completed in January 1989. Now the improved pressure and service level is available for all areas along the new network system within the limits of the capacity of 30,000 m3/d from Mai Dich water plant.

Testing and repairing of existing transmission lines is an important factor in network development. The distribution losses and Water Loss Reduction Programme (WLRP) will be discussed in chapter 2.5.2.

2.4.3 Distribution Network

Approximately 210 km of the public network has a diameter below 300 mm, and it is called in this context the distribution network. Before the commencement of HWSP the only material used has been cast iron. In 1985 when the project started it was decided that PVC and PEH pipes shall be used as distribution lines. Thus today about 26 % of the distribution lines are of plastic.

About 22 % of the total length has been constructed between years 1900-1930, 14 % between 1931-1954, 15% between years 1955-1965, 23 % between the years 1966-1985 and the remaining 26 % during the last 4 years by the HWSP.

Condition of the old distribution network, specially concerning the smaller pipes, is known only in broad outlines. As the age structure is, however, remarkably older than the main network's, it is reasonable to estimate the old part of the distribution network to be generally in bad condition.

In addition to those pipelines described above, there exists a separate pipe network and booster station system to supply water for the high-rise building areas. It is most usually constructed by the contractor of the housing area, but the completed network belongs to and is managed by the Water Supply Company. There is no information available concerning the length and diameters of these pipelines.

The development of distribution network by the HWSP was started in Dong Da district, which is the main influence area of Ngo Si Lien water plant. Implementation continued in the southern Ba Dinh district and further to the west in Dong Da district reaching out to Lang Thuong, Lang Trung, Lang Ha, Giang Vo, Hao Nam and Tho Quan areas until the end of 1988.

In this situation new strategies had to be established:

* to keep the old and new constructed networks separated from each other to ensure high pressure in the new network

* systematic disconnection of old distribution system in the areas with new water supply

It is a must to follow the a.m. strategy to avoid extensive losses and to enable proper working conditions to the network.

The total length of new distribution lines is presented in table 2.4-1.

2.4.4 House Connections, Public Standpipes and Network Appurtenances

Water is distributed to the consumers principally either through house connections or public stand pipes. Occasionally, specially during the summer time, water is also supplied to the consumer by tank trucks or water carriers.

According to the information from HWSCo there are totally 21,000 private house connections including offices etc. and 1025 public taps. It

is not known what is the share of population served between house connections and public taps. Some estimates suggest average figures of 300-500 pers./public tap and 15-35 pers./houseconnection. This means roughly 50 % for both categories.

The diameter of public taps varies from 15-25 mm. Before the HWSP there were practically no meters in the connections. Many of the taps are still missing and continuously flowing.

The house connections have been metered in principal, too. However the great majority of the old meters is out of order and the rest are inaccurate. The diameter of the connection pipes varies from 12 to 30 mm, the most common sizes being 15-20 mm. The materials used are galvanized steel and cast iron.

There are in Hanoi water supply network over one hundred fire hydrants, with diameter of the connecting pipe varying from 40 to 100 mm. Probably almost all of them are out of order.

Of the totally 1050 valves and 60 blow-off valves (estimate by HWSCo) most are not used at all and there is no clear indication of their condition.

No reliable statistics concerning the quantities, diameters etc. of the existing public taps, private connections, fire hydrants and valves have been made available for the consultant by the Hanoi Water Supply Co.

The implementation of house connections by the HWSP started in July 1987 and has been carried out along with the distribution line implementation.

Design of service connections has been developed all the time in order to reduce the cost and serve as many inhabitants as possible. The principles of design and implementation of service connections have been under discussion with Hanoi Office of Urban Public Works, but have not yet been approved.

The replacement of existing connections is necessary to enable the disconnection of old lines.

The lack of firm basis in tariff policy has caused difficulties in connection and metering design. The classification of different consumer groups is still under development. The permanent town structure exists only along the main streets, the structure of alleys and sub-alleys as well as 'villages' keep changing all the time rapidly. Connections are designed at the moment

for the consumers having a permanent address. Other areas are served through public taps.

Until now it has been a standard to install a water meter for each connection. This practice does not seem to be correct leading to enormous number of meters to be looked after and is now under discussion.

A regular water meter reading and pressure level study has been started from pilot area and extended to all the areas with new water supply system.

By the end of February 1989 totally 3770 connections had been installed by HWSP divided

into categories as follows:

-	private house conn.	3280 pcs
-	public taps	110 pcs
-	industries, offices and public buildings	380 pcs

During the whole implementation period the importance of maintaining and repairing the internal pipeworks has been emphasized by the consultant. Unfortunately, Vietnamese organisations have not been able to solve these problems.

New fire hydrant installation has not yet been started. It has to be considered whether fire fighting could be organized in an other way than using purified water as even in the city area there exist plenty of lakes, rivers and channels which can be used for this purpose.

2.4.5 Water Towers

There are seven elevated reservoirs in the distribution network. List of them is presented in table 2.4-2 and their location is shown in drawing...

No one of these reservoirs is in use at present. The main reason is the existing low pressure in the network, which makes their use impossible.

Hang Dau, Don Thuy and Trung Tu reservoirs are in relatively good condition. All the others necessarily need to be repaired before considered to be used.

TABLE 2.4-6 ELEVATED WATER RESERVOIRS IN HANOI

Name/locat.	Material	Volume (m3)	Head (m)
Hang Dau	concrete	1,250	16.45
Don Thuy	concrete	1,250	16.45
Bach Mai	concrete	250	25.00
Ngoc Ha	concrete	250	25.00
Trung Tu	concrete	250	25.00
Kim Lien	steel	200	25.00
Gia Lam	concrete	150	20.00

2.5 Standard of distribution

2.5.1 Water Quality

The task for monitoring and maintaining the good quality of drinking water in the network belongs to HWSCo and the Hygienic Service of the city. The resources for sample taking and analysis are, however, scarce and this fact seriously hampers the implementation of the control programs.

From analysis results it can be generally noticed that water quality is most commonly rather well within the limits of the standard values. The biggest problems arise from the high values of iron and manganese. The treatment method applied in the plants reduces rather effectively iron and manganese, even if the results are not always good because of the operational deficiencies of the water plants.

A more difficult problem is the hygienic quality of the water. The disinfection equipment using chlorine gas will be installed for all the major treatment plants, but at the moment the work has not yet been completed. The low pressure and leaking of the old network may bring about contamination at any point of the pipe system. Therefore, the water used by the consumers cannot be considered as hygienically safe.

2.5.2 Distribution losses

2.5.2.1 Level of Losses

System efficiency is a basic parameter used to appreciate the condition of the water supply and distribution system and to control the level of water losses.

One method of estimating the technical efficiency of a water supply system is to define the ratio

between the volume of water accounted for and volume of water introduced to the system. In the volume of water accounted for, a distinction should be made between:

- the metered amount (whether or not invoiced)
- the estimated amount (flat-rate consumers)

This efficiency varies from 50 % to 90 %. The lower the efficiency the greater the benefit to be obtained from a water loss reduction programme. This efficiency has been estimated to 50 % in the existing Hanoi water supply system.

2.5.2.2 Factors influencing the leakage

The main factors affecting the level of leakages (physical losses out of all the unaccounted for water can be considered only because the consumption is not metered) in Hanoi old water supply system can be listed as follows:

* deterioration of pipes and fittings due to poor maintenance and lack of spare parts
* poor pipe installation work due to use of wrong back filling material
* poor quality materials used in installation work (e.g. cement has been used instead of lead in cast iron pipe joints)
* traffic loads, caused by too shallow installation depth of pipelines
* inadequate design (e.g. missing underground structures and levels)
* age of distribution system
* poor water use habits, (perhaps low pressure in the old system has resulted to destroyed public taps and leaking connections or even illegal connections)

With the exception of poor water use habits, these factors can not be easily altered after the installation of the pipeline. Therefore they must be taken into consideration during the design and construction phases, followed by adequate supervision to ensure the quality demand.

2.5.2.3 Water Loss Reduction Programme

Water Loss Reduction Programme was introduced in the beginning of the project and the first two years were spent in building up strategies and studying water use habits of citizens in Hanoi City.

Field activities in form of testing and repairing of old mains to be used in the new network, have been progressively carried out since the beginning of 1988. 5.6 km of mains have been tested and repaired by the end of March 1989.

Disconnection of old distribution network has been another important activity and was started in summer 1988. It continues parallel to the new distribution system implementation.

Water consumption follow-up and pressure level studies have been commenced in pilot area since August 1988. The number of recording points will be increased to cover all the implemented distribution system. Also a pilot study of old network has been commenced to define the level of leakage and to give guidelines for future rehabilitation plans.

By continuous recording of leaks and repairs over a certain period and by water consumption and pressure level studies the total leakage of from the system can be estimated. For this purpose leak detecting and leak repair reports have been introduced to the programme.

Maintenance of old network is a natural part of activities in a water supply company and should be developed along with the WLRP considering the fact that a total replacement of network will be unrealistic to reach in the scope of available project funds. HWSCo has now established a special group to be in responsible for the tasks of WLRP.

Systematic leak detection in form of passive control method and sounding of mains will be commenced as soon as manpower requirements are satisfied.

2.5.3 Distribution pressure

The water pressure in the whole network is not regularly followed. Some control measurements have been carried out using hand manometers and temporary labour. This kind of measurement shows only a momentary situation. Variations according to the pumped water amount and different consumption situations can only be found out by a

continuous, registering pressure measurement, which are planned to be used in future pressure level studies.

HWSP has carried out regular pressure measurements in the 'Pilot area' near Ngo Si Lien water plant, where new distribution lines and house connections have been constructed, since July 1988. Since the capacity of the pumping station is only 14,000 m3/d it can only serve a small limited area. In the beginning of pipeline implementation the amount of water pumped through the pilot pumping station was enough for the consumption and pressure sustained good, above 1.5 bar. In the course of construction additional streets were connected into the pilot area network and finally the water demand exceeded production. During the morning peak consumption the lowest pressure was only 0.1 bar while the supply pressure at the station was 2.0 bar. Later on the area has been reduced to coincide with the production.

Today a transmission line connects Mai Dich and Ngo Si Lien water plants. There exist three separate high pressure zones (figure 2.5-1):

- Ngo Si Lien pilot area
  (14,000 m3/d * 22 m)
- Ngo Si Lien
  (17,000 m3/d * 20 m)
- Mai Dich
  (30,000 m3/d * 35 m)

The high pressure area covers the areas with new distribution lines and house connections. However, a big part of that area is still having a parallel network of old pipelines which have not yet been disconnected. The disconnection of old network will be carried out in parallel to the new distribution pipeline implementation. Total disconnection of old network is important as they are sometimes illegally connected to the new network causing huge amounts of water losses and reduction of pressure.

The rest of the present production capacity, appr. 240,000 m3/d, is still pumped in to the old network with low pressure. The pressure level in many places of the old network equals to zero at certain times.

The existing pressure level in old network makes it impossible for multistory buildings to obtain water directly from the pipeline. Therefore, in these areas almost all the new housing areas with high-rise buildings have used an own ground level reservoir and a booster pumping station to secure their water supply.

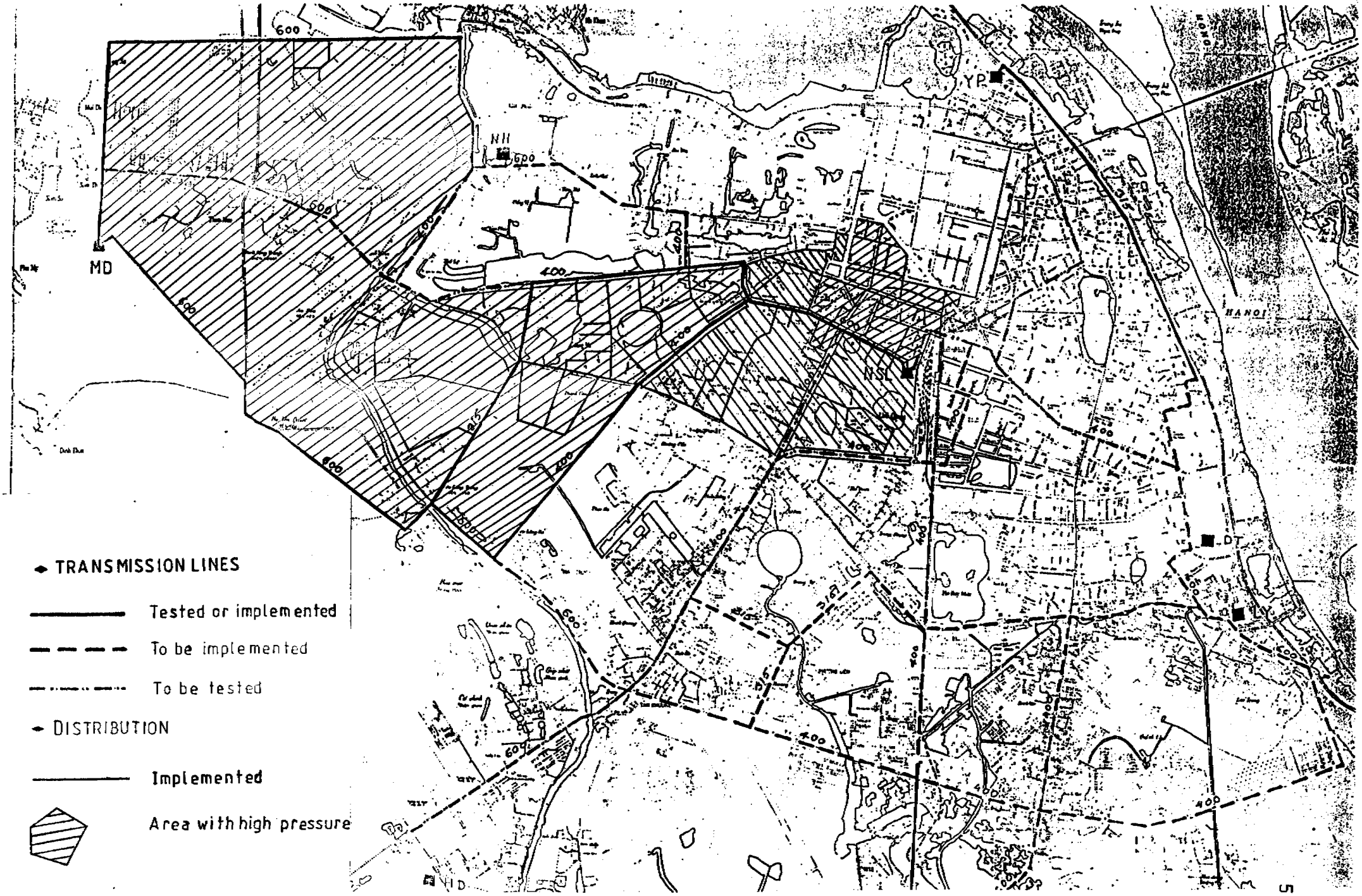


FIGURE 2.5 - 1 HIGH PRESSURE ZONES IN HANOI (June 1989)

2.5.4 Coverage and continuity of supply

There is no reliable information available concerning the coverage of water supply within the urban area. According to the estimate by HWSCo all the inhabitants have access to a drinking water source, 80 % of the population or about 740,000 people use public taps or private house connections and 20 % or 190,000 people are depending on illegal connections or other sources.

At the moment the demand of water is higher than the production of the existing plants, but should be satisfied if the targets of the second phase of the HWSP are met in the end of 1990 with the total production capacity of about 400,000 m3/d. This results today in temporary shortages of water and intermittent water supply. Even some immediate relief methods, such as water trucking, has to be applied during the worst times.

In Hanoi continuity highly depends on availability of power supply. In this respect the situation has improved to some extent, but still supply failures are daily repeating.

3. WATER RESOURCES APPRAISAL

3.1 Surface Water Resources

3.1.1 General

A comprehensive surface water resources appraisal study for any purposes should include the following:

* description of the river system
* analysis of the rainfall-runoff statistics
* analysis of the hydrological data (discharge data, flow duration etc.)
* appraisal of the availability and dependability of the flow
* appraisal of the water quality and usability
* appraisal of the water demands
* utilization proposals

For Water Master Plan study purposes for a big city like Hanoi the area to be covered by the studies should be big enough to enable to take all the possible alternatives for resources utilization into consideration. This means that, as a rule of thumb, all the water resources within a minimum radius of 50 km measured from the utilization area should be studied.

In this report, however, it is not possible to present such a comprehensive study, as only very limited amount of basic data concerning the surface water resources has been made available for the consultant by the Vietnamese organizations responsible for data collection.

The Hydrometeorological Institute is in responsible for the collection and analysis of river basin data in Vietnam. There exist a rather well covering network of river gauging stations in the country. In figure 3.1-1 is presented the network of river gauging stations in Northern-Vietnam. There exists daily discharge data for a period of 10-30 years for many stations. The General Department of Hydrometeorological Institute and some other organizations are possessing extensive studies concerning the surface water resources and have proven to be capable of preparing such studies.

BẢN ĐỒ MẠNG LƯỚI SÔNG NGÒI VIỆT NAM

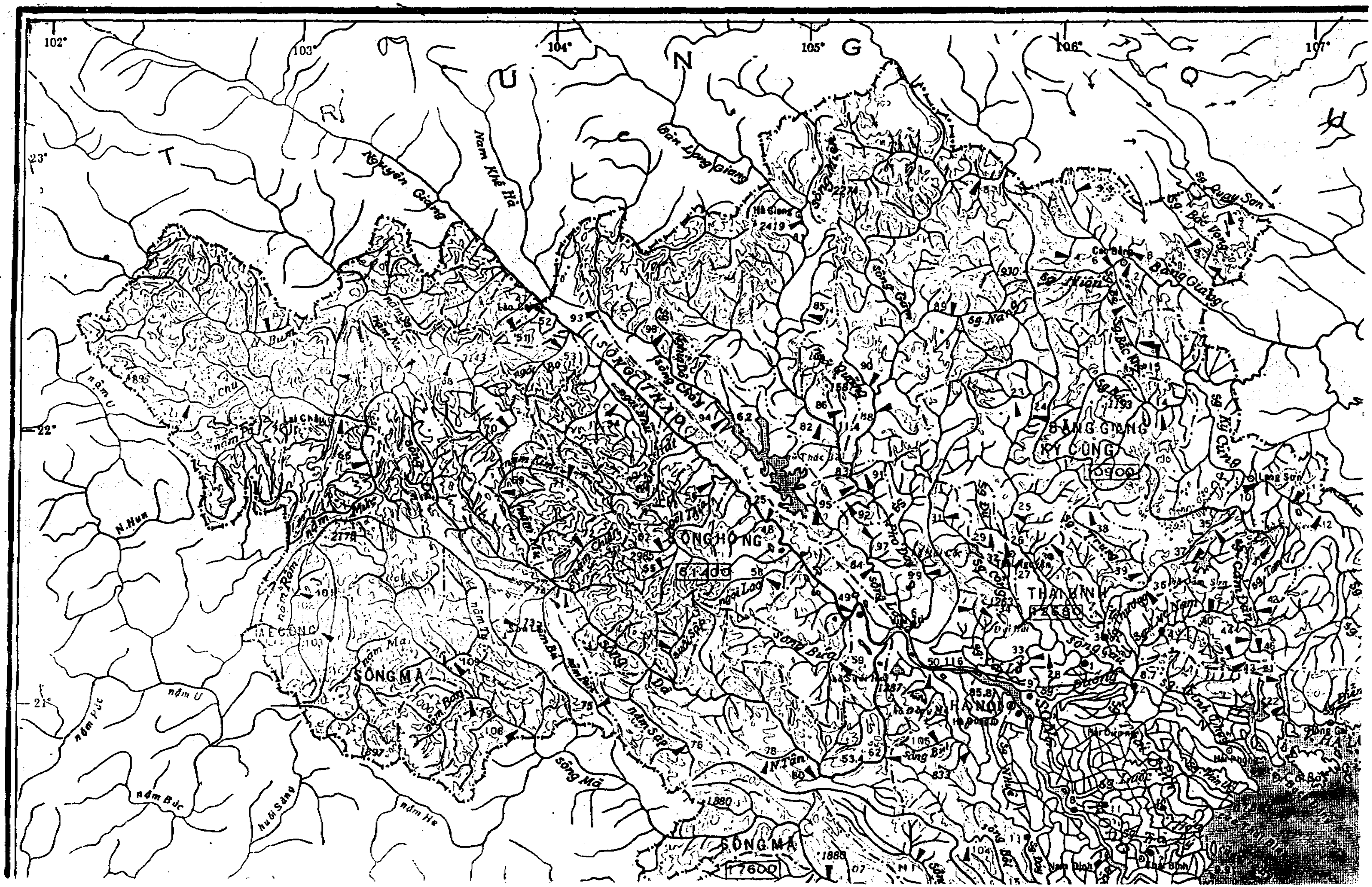


FIGURE 3.1-1 THE MAIN RIVERS AND RIVER GAUGIN STATIONS IN NORTHERN VIETNAM

The basic data made available for this study are as follows:

- rainfall and runoff statistics mainly from Hanoi Province
- river discharge data of Song Hong, Song Day, Song Tich and Song Bui
- assessment of tide and salinity effect limits in Bac Bo Plain (delta area of Song Hong)

The results and conclusions of these studies as well as recommendations for further studies are presented in this chapter.

3.1.2 The river system

The main rivers of Northern Vietnam are presented in figure 3.1-1.

The main river is Song Hong (Red river) named Song Thao at the upper stream from Viet Tri where the river is having a confluence with two main tributaries, namely Song Da on the right side and Song Lo on the left side. All these rivers are flowing North-West/South-East direction. The main river and its tributary Song Da originate from South-China.

Other main rivers on the right bank side of Song Hong are Song Nhue (Black river), Song Tich and Song Boi, which are all tributaries of Song Day, and Song Bui, a tributary of Song Tich. Song Day is discharging to South-China Sea at the Southern part of the delta.

Song Nhue and Song Day serve mainly for irrigation and flood protection purposes for the city as they originate from Song Hong. The flow of both these rivers is highly regulated by the gates at the bank of Song Hong. Accordingly these rivers have not been considered as a possible source of water supply for the city.

Main rivers on the left bank side of Song Hong are Song Lo, a tributary of Song Hong, Song Duong and Song Cau, tributaries of Song Thai Binh, which is draining to the South China Sea south of Hai Phong city, and Song Cong, a tributary of Song Cau. Song Duong forms a connection between the two rivers Song Hong and Song Thai Binh.

The overall drainage in delta area like Bac Bo is rather complicated and there is several inter-connections in between the different rivers. The delta with a total area of about 15,000 km2 is

rather plain, the average gradient towards the sea being only about 9 mm/km. As the whole river system in the delta area is affected by tide and regulated for irrigation purposes, it is very difficult to determine the exact flow rates and directions of the rivers. More simple are the hydrological characteristics of the rivers in the mountain areas in the north, west and south-west of the delta.

3.1.3 Tich River resources

The map showing the average annual rainfall isohyetals of Tich River basin is presented in figure 3.1-2. The map is based on data collected from 40 rainfall stations located inside and around the basin during the period 1961-1985.

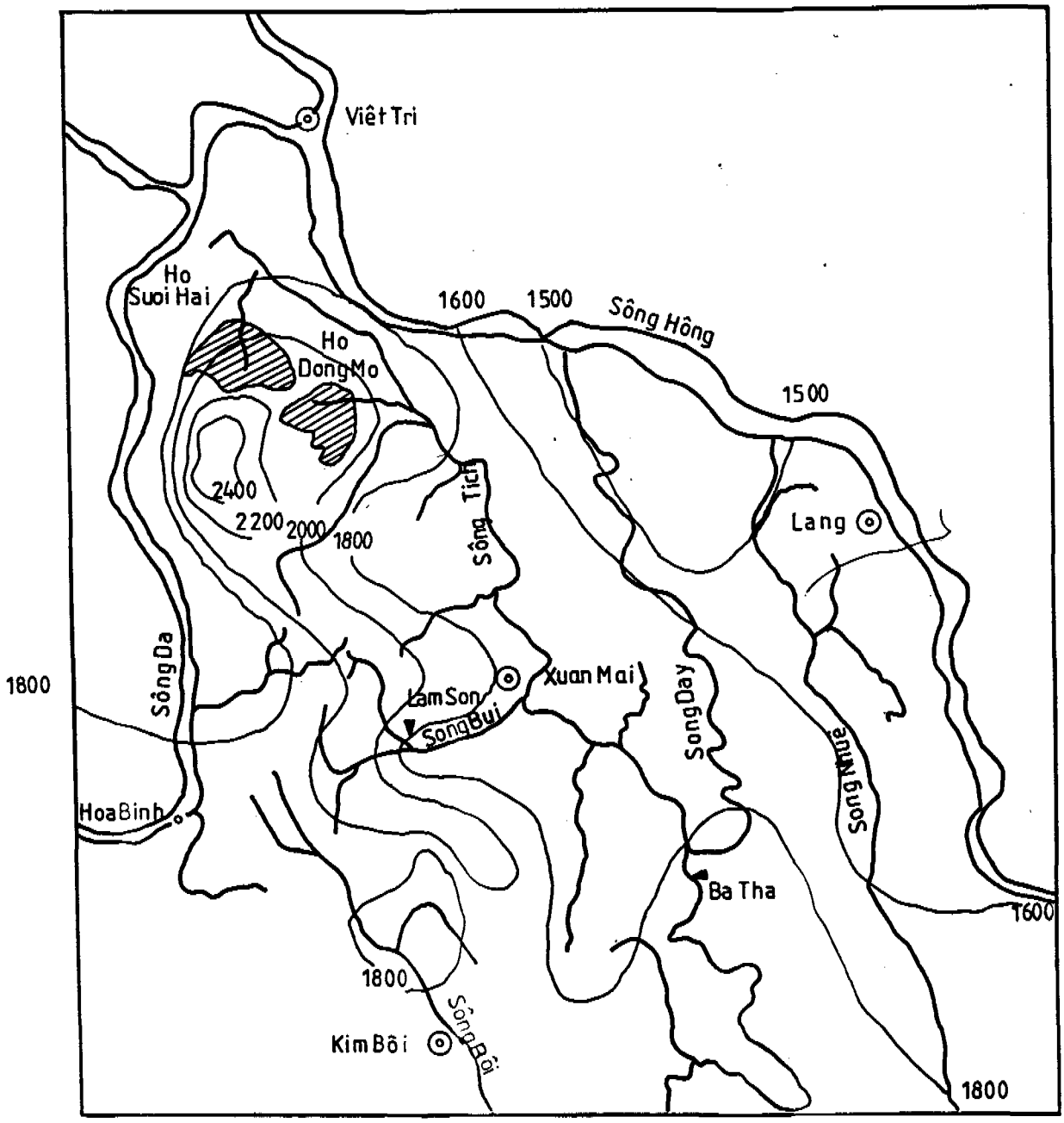
The rainfall is varying from 1500-1600 mm in the delta area to 2400 mm at Ba Vi mountains. In general the rainfall is increasing with the elevation and the slope of mountain where the south-east winds are stopped is experiencing more rainfall than the other side. The Ba Vi mountains form the main hydro source of Tich River.

The mean annual specific run-off isohyetals for Tich River basin are presented in figure 3.1-3. The map is based on the rainfall studies presented above and rainfall and run-off studies of 15 rivers nearby with the catchment area of some tens to over 2,000 km2.

The results of the studies prepared by the Hydrometeorological Institute on the annual run-off at three locations of Tich River basin are presented in table 3.1-1. Bui River includes the catchment above the confluence with Tich River, Xuan Mai the catchment of Tich and Bui Rivers at Xuan Mai and Tich River the catchment of the river at the confluence with Day River.

When considering water supply projects they should be based on 99% dependable flow, if a reservoir is not being considered. Therefore annual run-off data is not enough, but also the daily variations of the flow should be studied.

In the area concerned the flow regime of the rivers is highly depending on the rainfall variations. A general description of the rainfall variations in Hanoi area has been presented in chapter 1.1. In general there is a dry season starting in November and ending in April. The lowest flows occur thus usually in March or April. The average monthly discharges at Lam Son and Ba Tha stations are presented in table 3.1-2.



LEGEND : RIVER

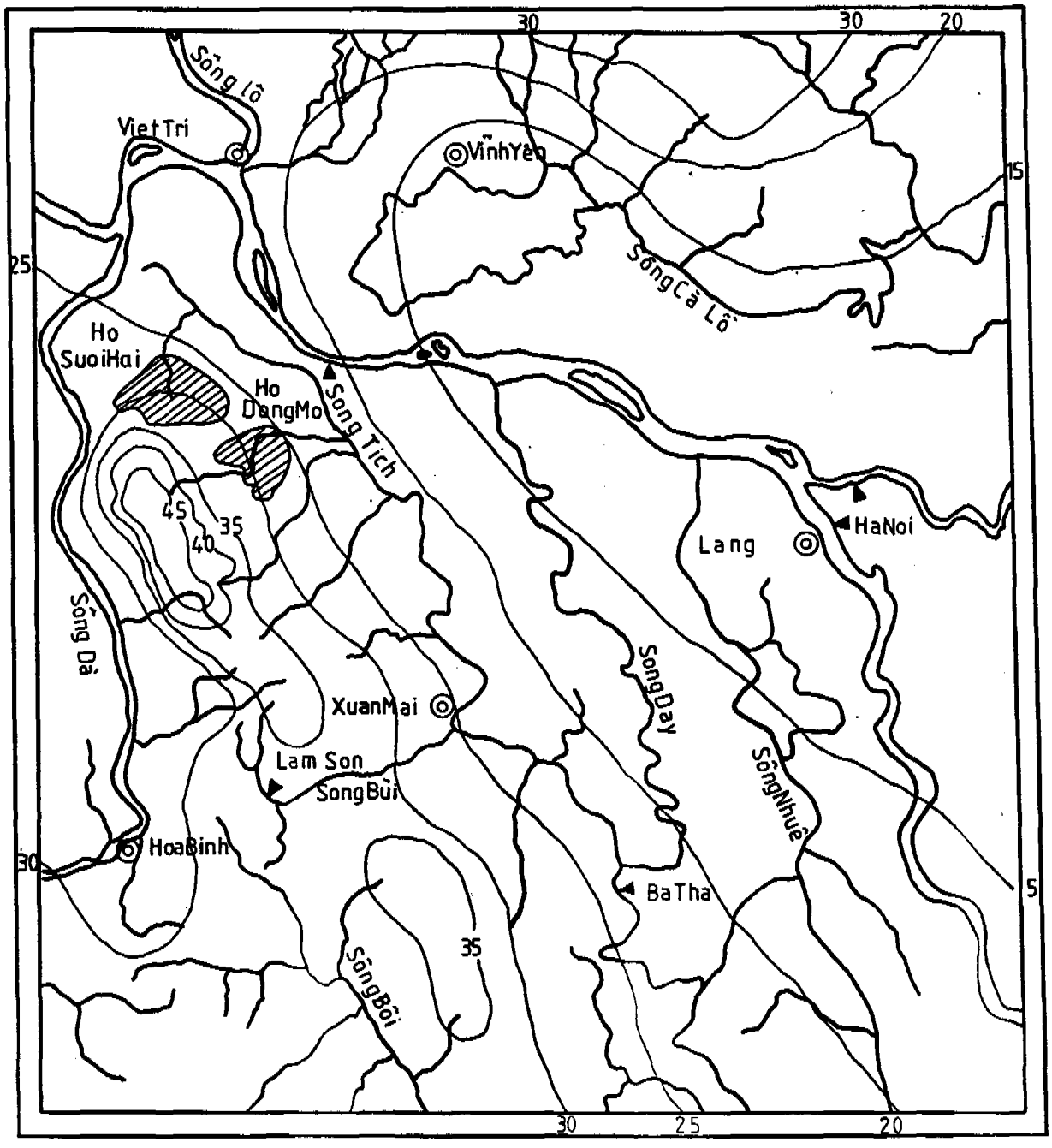
RIVER GAUGING STATION

1800 ISOHYETAL WITH RAIN FALL OF 1800 mm

SCALE 1 400 000

FIGURE 3.1 - 2 AVERAGE ANNUAL RAINFALL ISOHYETALS (mm) FOR TICH RIVER BASIN

HWS/WMP89
JP 6.6.1989



LEGEND: RIVER

RIVER GAUGING STATION

35 ISOHYETAL WITH RUN OFF OF 35 l/s / km2

SCALE 1 : 400.000

FIGURE 3.1 - 3 MEAN ANNUAL SPECIFIC RUN OFF ISOHYETAL (l/s / km2) FOR TICH RIVER BASIN

HWSP/WMP89
JP 6.6.1989

TABLE 3.1-1 CALCULATED RUNOFF VALUES IN TICH RIVER BASIN

	Xuan Mai (Tich R.)	Bui River	Tich River
Catchment area (km2)	1040	196	1330
Aver. annual rainfall (mm)	1890	1900	1868
Aver. annual runoff (m3/s)	31.4	5.96	39.4
Aver. annual runoff (l/s/km2)	30.2	30.4	29.6
Aver. annual runoff (mm)	952	960	935
Annual runoff (m3/s) with the frequensies:			
1 %	70.0	13.8	86.1
10 %	49.8	9.7	61.8
25 %	39.7	7.6	49.7
50 %	29.8	5.6	37.5
75 %	21.4	3.9	27.1
90 %	15.0	2.7	19.3
95 %	11.5	2.0	15.0

TABLE 3.1-2 MONTHLY AVERAGE DISCHARGE VALUES AT LAM SON AND AND BA THA STATIONS

Month	Lam Son		Ba Tha	
	discharge (m3/s)	% of the year total volume	discharge (m3/s)	% of the year total volume
January	0.29	2.2	11.3	1.9
February	0.23	1.8	12.0	2.0
March	0.19	1.5	10.6	1.7
April	0.26	2.0	17.2	2.8
May	0.50	3.9	36.7	6.0
June	0.93	7.2	56.5	9.3
July	1.62	12.5	84.4	13.9
August	2.51	19.4	119.0	19.6
September	3.33	25.7	140.0	23.1
October	1.80	13.9	75.9	12.5
November	0.91	7.0	30.2	5.0
December	0.38	2.9	13.1	2.2
Year	1.08	100.0	50.6	100.0

As a reference, the flow dependabilities (durations) of daily discharges of a wet year, average year and a dry year for Ba Tha and Lam Son stations have been presented in table 3.1-3.

The minimum recorded flow at Ba Tha station during the periods 1971-74 and 1976-80 has been 2.59 m3/s. There is no statistics showing the minimum flow of Tich River at Xuan Mai, but it has been calculated that the average runoff of the dry period is 4.5 m3/s above the confluence with Bui river and 5.3 m3/s beyond the same confluence.

It has been estimated that the demand for irrigation accounts for 20-25 % of the total average runoff during the dry season and about 40 % of the runoff during the most dry months.

3.1.4 Red River resources

Red River water resources are abundant. The minimum recorded flow at Hanoi station during the period 1956-1988 has been 350 m3/s and the maximum 22,200 m3/s. Thus in quantity wise it could easily meet the water demand for the whole city of Hanoi.

Statistics on the average, maximum and minimum flow recorded at Hanoi station over the period of 1978-1988 has been presented in tables 3.1-4 to 3.1-6.

The dependabilities of flow of a wet year, average year and a dry year have been presented in table 3.1-7.

3.1.5 Water quality

There is rather well statistics on the quality of the water in the Red River. The results of the monthly sampling during the period 1979-1986 are presented in table 3.1-8.

The total suspended solids has been reported to be 200-300 mg/l during the dry season and up to 3,000 mg/l in the rainy season, and that would probably be the main problem in water treatment. There has been reported some sudden changes in pH values which could indicate the existence of some industrial waste waters.

The water quality in Tich River basin has been studied in four places during the last quarter of 1983. Two of the sampling places have been the two lakes in the catchment area, one in Tich River some 20 km north from Xuan Mai and one in

TABLE 3.1-3 DEPENDABILITY OF DAILY DISCHARGES AT LAM SON AND BA THA STATIONS

Dependability	Lam Son (1970-1985)			Ba Tha (1971-74,1976-80)		
	Dry year	Av. year	Wet year	Dry year	Av. year	Wet year
	1973	1975	1976	1971	1972	1977
(days)	(m3/s)	(m3/s)	(m3/s)	(m3/s)	(m3/s)	(m3/s)
1	5.32	89.70	67.60	174.0	294.0	782.0
5	3.30	10.00	20.50	140.0	270.0	620.0
10	1.89	4.60	12.70	116.0	242.0	469.0
30	0.80	2.20	5.90	76.0	161.0	300.0
60	0.52	1.80	3.10	50.5	102.0	240.0
90	0.37	1.65	1.80	34.5	76.0	168.0
120	0.28	1.58	1.05	25.0	52.0	84.0
180	0.19	1.22	0.50	18.0	35.0	32.0
240	0.14	0.95	0.35	13.5	19.0	12.0
270	0.12	0.85	0.30	11.0	15.0	8.0
355	0.10	0.30	0.12	6.2	5.0	6.0
Year average	0.39	1.16	2.18	25.9	53.8	102

TABLE 3.1-4 AVERAGE MONTHLY FLOW IN SONG HONG AT HANOI STATION DURING THE PERIOD 1965-1988

Unit: m3/s

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average	Max	Min	Std
1965	991	814	681	1010	1130	3890	5240	4150	2580	3060	3340	1690	2381	5240	681	1478
1966	1100	839	605	687	830	4360	8440	6370	5920	3380	2150	1250	2994	8440	605	2571
1967	1050	883	721	786	1140	2060	3510	6050	3950	2450	1740	1330	2139	6050	721	1554
1968	1140	954	916	1190	1530	3130	6950	7330	5640	3610	2620	1330	3028	7330	916	2274
1969	937	739	626	672	1090	2220	4300	10400	4000	2100	1910	1030	2502	10400	626	2662
1970	944	887	649	828	2070	3280	8680	6760	4900	2610	1670	2080	2947	8680	649	2460
1971	1000	921	676	891	1660	4300	7930	11800	5770	3230	2120	1270	3464	11800	676	3321
1972	1080	877	681	910	1460	2760	4950	5420	4510	3430	2300	2000	2532	5420	681	1616
1973	1130	971	1180	1120	2210	4250	6230	7380	6780	3230	2440	1480	3200	7380	971	2287
1974	1090	968	816	892	1340	3500	5360	5140	5640	3470	2010	1280	2626	5640	816	1816
1975	1180	821	721	1240	2130	5740	4720	4460	4870	2630	2050	1280	2654	5740	721	1726
1976	1020	1170	825	1040	2260	3360	4060	6360	3980	2500	2540	1340	2538	6360	825	1595
1977	1040	929	765	957	1160	1520	6070	5780	3030	2390	1690	1110	2203	6070	765	1781
1978	1140	798	755	715	2470	5470	5970	6410	6650	4090	2030	1380	3157	6650	715	2295
1979	1100	1020	789	790	1310	3370	4850	7270	8030	2700	1610	1150	2832	8030	789	2456
1980	994	979	623	616	1170	1630	6230	7210	5530	2430	1310	1020	2479	7210	616	2292
1981	953	857	815	1360	2710	4350	5610	7810	5830	3890	3260	1760	3267	7810	815	2192
1982	1200	987	658	1130	779	2200	4190	7880	5430	4080	2470	1490	2708	7880	658	2154
1983	1020	842	1010	731	1080	1750	2420	6280	6100	4300	3660	1700	2574	6280	731	1943
1984	1380	934	700	754	1880	4610	7010	4840	4680	4110	2170	1290	2863	7010	700	2000
1985	1110	1020	989	1130	1340	3440	4610	5340	7600	3030	3290	1840	2895	7600	989	2011
1986	1140	860	710	1320	2470	3910	6880	6580	5130	4120	2170	1410	3058	6880	710	2122
1987	1170	972	750	715	812	1690	3790	4870	4180	3040	2070	1240	2108	4870	715	1420
1988	906	839	664	542	1580	1580										
Aver.	1076	912	764	918	1567	3265	5565	6604	5249	3212	2288	1424				
Max	1380	1170	1180	1360	2710	5740	8680	11800	8030	4300	3660	2080				
Min	906	739	605	542	779	1520	2420	4150	2580	2100	1310	1020				
Std	103	91	137	226	562	1215	1564	1739	1302	651	593	285				

TABLE 3.1-5 MINIMUM FLOW IN SONG HONG AT HANOI STATION DURING THE PERIOD 1965-1988

Unit: m3/s

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average	Max	Min	Std
1965	860	640	598	580	622	1750	2960	2550	1770	1740	1640	1310	1418	2960	580	763
1966	965	664	528	556	485	1350	5030	3580	2690	2540	1570	1020	1748	5030	485	1374
1967	895	745	655	525	630	1300	1910	2880	2530	1680	1330	1120	1350	2880	525	734
1968	925	830	734	701	1220	1290	3020	3080	3840	2630	1740	1060	1756	3840	701	1047
1969	799	643	564	500	616	720	3010	3730	2390	1780	1220	896	1406	3730	500	1039
1970	871	695	575	555	1050	1890	4700	4630	3530	1880	1330	1340	1921	4700	555	1454
1971	852	744	575	589	1020	2160	4940	8950	3660	2250	1330	1120	2349	8950	575	2370
1972	857	764	536	596	469	1350	2520	3710	3250	2390	1620	1270	1611	3710	469	1060
1973	918	820	749	708	1410	2740	4050	4720	4700	2200	1960	1150	2177	4720	708	1471
1974	1020	856	746	728	894	1580	4060	3170	3290	2260	1620	1080	1775	4060	728	1103
1975	882	746	620	788	893	3830	3370	3160	2670	1770	1380	1090	1767	3830	620	1120
1976	904	858	676	704	915	2320	2840	4310	2810	2090	1590	1040	1755	4310	676	1091
1977	905	827	698	712	712	744	3000	2810	1960	1880	1220	938	1367	3000	698	805
1978	868	665	637	587	736	2470	3250	3230	4000	2430	1740	1150	1814	4000	587	1168
1979	919	708	698	588	939	1430	2830	2830	3490	1950	1350	1040	1564	3490	588	942
1980	908	850	436	417	417	835	2470	5540	2780	1780	1030	742	1517	5540	417	1428
1981	862	721	692	934	1270	2980	4560	5080	3140	2840	2260	1400	2228	5080	692	1447
1982	933	754	555	742	570	968	2700	4180	4000	2660	1890	1050	1750	4180	555	1269
1983	865	752	711	533	589	955	1200	3640	3930	2310	1980	1320	1565	3930	533	1121
1984	1020	721	594	594	764	2670	3970	3000	3340	2630	1560	1110	1831	3970	594	1163
1985	1000	909	923	957	1000	2140	3270	3150	3620	2200	1930	1370	1872	3620	909	959
1986	972	774	594	634	1520	2290	2980	4600	2940	2880	1690	1120	1916	4600	594	1186
1987	988	844	625	529	538	810	1500	3240	2820	1870	1570	740	1340	3240	529	865
1988	850	682	530	488	658	840										
Aver.	910	759	635	635	831	1726	3223	3903	3180	2202	1589	1108				
Max	1020	909	923	957	1520	3830	5030	8950	4700	2880	2260	1400				
Min	799	640	436	417	417	720	1200	2550	1770	1680	1030	740				
Std	58	74	98	130	297	813	996	1335	687	366	287	173				

TABLE 3.1-6 MAXIMUM FLOW IN SONG HONG AT HANOI STATION DURING THE PERIOD 1965-1988

Unit: m3/s

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average	Max	Min	Std
1965	1170	955	810	1700	3460	6020	7370	7020	3810	9500	8950	3300	4505	9500	810	3025
1966	1350	1300	725	1050	1940	8080	13800	12900	12300	5260	4040	1550	5358	13800	725	4867
1967	1270	1150	780	1280	2520	3540	5740	11000	6460	3870	2670	1600	3490	11000	730	2951
1968	1930	1280	1300	2030	2140	5340	11300	16400	8860	4780	3890	1730	5082	16400	1280	4569
1969	1040	831	662	1320	2120	4270	5980	17800	6160	2980	3600	1200	3997	17800	662	4553
1970	1120	1310	844	1460	5820	6120	14900	11400	6910	5090	2010	3140	5010	14900	844	4237
1971	1330	1060	748	1420	3410	7220	11200	22200	10600	5170	3900	1380	5803	22200	748	6052
1972	1300	1020	831	1160	3340	6690	9240	8340	7940	4420	3640	3560	4290	9240	831	2933
1973	1260	1480	3340	2020	4260	7720	9060	9710	11500	5160	3400	1920	5069	11500	1260	3402
1974	1130	1080	890	1060	2460	6970	7500	8230	7940	5900	2960	1560	3973	8230	890	2924
1975	1950	995	872	1960	5510	9020	7480	6440	8710	3750	3660	1620	4331	9020	872	2879
1976	1230	2370	1000	1510	4010	5270	6980	9670	5180	4010	5170	1640	4003	9670	1000	2525
1977	1220	1140	887	1550	1510	3900	10700	10700	4210	4210	2510	1300	3653	10700	887	3353
1978	1714	1060	928	958	7480	9260	11100	11900	12200	9730	2660	1780	5898	12200	928	4553
1979	1490	1670	988	1100	2630	6800	9840	13800	1430	3460	1960	1350	3877	13800	988	3947
1980	1060	1180	1030	884	2360	5290	15100	10100	8320	3260	1770	1260	4301	15100	884	4383
1981	1350	1150	1720	1830	7940	7010	1160	12200	7800	6480	5890	2230	4730	12200	1150	3486
1982	1370	1210	791	1880	1660	3580	6610	11100	7610	6770	3590	3460	4136	11100	791	3073
1983	1340	1020	1400	937	1830	2880	4730	12400	7820	10200	7910	2400	4572	12400	937	3831
1984	2600	1110	754	1280	4700	9140	10000	9380	6460	5490	3300	1560	4648	10000	754	3289
1985	1220	1190	1060	1640	2820	5700	7020	11600	1370	3920	8670	2580	4066	11600	1060	3313
1986	1350	950	939	2130	4870	7800	14600	12600	9140	8380	2930	1670	5613	14600	939	4579
1987	1620	1190	968	901	1670	2560	5520	8330	5750	3990	3330	1590	3118	8330	901	2253
1988	952	1080	1040	642	3000	3420										
Aver.	1390	1199	1054	1404	3478	5983	8997	11531	7325	5469	4018	1973				
Max	2600	2370	3340	2130	7940	9260	15100	22200	12300	10200	8950	3560				
Min	952	831	662	642	1510	2560	1160	6440	1370	2980	1770	1200				
Std	353	299	529	416	1752	1977	3477	3480	2866	2075	1973	722				

Day River besides the main road bridge. The results of these studies are presented in table 3.1-9.

Tich River resources are also suffering from the high contents of suspended solids, unfortunately there does not exist any statistics. Alkalinity values are very low which could make the coagulation and sedimentation process difficult. Oxygen values in the upper catchment are rather uniform and high and could indicate pollution free water. Day River water is probably polluted by human wastes.

TABLE 3.1-7 THE DEPENDABILITIES OF DAILY DISCHARGES AT HANOI STATION

Dependability (days)	Dry year 1967 (m3/s)	Av.year 1982 (m3/s)	Wet year 1971 (m3/s)
1	10,500	11,000	22,000
5	8,900	10,000	14,300
10	7,000	9,000	12,000
30	4,850	6,500	9,400
60	3,600	4,850	6,900
90	2,800	3,900	5,000
120	2,150	3,100	3,500
180	1,500	1,800	1,900
240	1,150	1,100	1,000
270	1,000	900	800
355	550	600	600
Year average	2,150	2,720	3,460

3.1.6 Appraisal and recommendations

Red River resources are plentiful even during the dry season, and the possible exploitation for Hanoi water supply would purposes should obviously have no visible effect on the hydrological parameters of the river. The water quality varies rather much and specially during the flood period silt content is very high (even the colour of the river is red). The required treatment process would probably include at least the following: intake, pre-settling, chemical application, flocculation and clarification, filtration, disinfection and clean water storage.

Tich River resources are rather limited and as such could only serve as an additional source, groundwater resources being the main source of supply. Probably a raw water storage would be

TABLE 3.1-8 SONG HONG WATER QUALITY IN 1979-1986

Year	Month	Water level (cm)	Temp.C	pH	Fe (mg/l)	SiO2 (mg/l)	Ca (mg/l)	Mg (mg/l)	Na,K (mg/l)	HCO3 (mg/l)	SO4 (mg/l)	Cl (mg/l)	Total ion (mg/l)	Total alkal	Hardn.
1979	5	416	28.2	7.0	0.1	2	17.6	9.2	10.8	110	12	0.7	160	1.8	1.64
	6	546	27.4	7.2	0.1	3	16.0	9.2	8.8	92	17	1.8	144	1.5	1.56
	9	1131	25.0	7.2	0.1	24	14.4	13.1	0.5	97	3	5.7	134	1.6	1.80
	11	419	21.0	7.2	0.5	8	23.7	9.6	17.5	134	10	9.2	204	2.2	1.97
	12	328	19.8	7.2	0.5	8	31.1	6.2	14.8	140	6	7.8	206	2.3	2.06
1980	1	310	18.2	7.4	0.0	12	27.8	7.7	12.3	134	10	3.6	195	2.2	2.02
	2	302	15.6	7.4	0.0	14	29.7	6.0	12.3	134	6	5.0	193	2.2	1.98
	3	243	22.2	7.8	0.1	10	29.0	9.2	11.6	146	8	3.6	207	2.4	2.20
	4	339	29.7	7.2	0.2	12	25.2	6.4	13.8	122	11	3.6	182	2.0	1.79
	5	785	28.0	7.5	0.2	16	35.1	5.1	5.7	131	6	4.2	187	2.2	2.17
	6	1165	25.1	7.6	0.2	16	30.5	5.1	4.7	119	6	1.8	167	2.0	1.94
	7	902	26.8	7.4	0.1	16	32.0	5.6	1.4	125	1	1.4	167	2.1	2.05
	8	370	25.0	7.0	0.2	12	26.7	8.3	3.6	131	3	1.4	175	2.1	2.01
	9	307	20.3	7.2	0.2	12	22.9	1.4	27.8	128	10	2.1	192	2.1	1.25
1981	1	319	18.7	7.6	0.1	14	22.0	7.4	10.5	113	10	2.5	165	1.9	1.71
	2	302	22.8	7.8	0.2	8	28.3	5.1	11.0	128	4	2.5	179	2.1	1.82
	4	362	25.4	7.0	0.2	14	19.6	11.1		109	2	1.8	144	1.8	1.89
	6	859	27.3	7.4	0.1	16	25.1	5.7	5.2	104	7	3.6	150	1.7	1.72
	7	814	27.4	7.0	0.2	16	27.3	4.9	5.0	104	4	3.6	149	1.7	1.67
	8	940	27.6	7.4	0.0	16	26.3	4.4	7.2	104	4	6.4	152	1.7	1.67
	9	882	27.4	7.4	0.2	20	25.2	6.3	4.8	101	10	4.2	152	1.7	1.79
	10	672	25.0	7.2	0.1	16	22.2	7.3	3.2	101	7	2.1	142	1.7	1.71
	11	610	20.0	7.2	0.2	12	30.3	6.8	14.0	107	36	4.2	198	1.8	2.07
	12	420	19.0	7.6	0.3	10	21.8	5.7	11.5	113	4	2.8	159	1.9	1.56
1982	2	336		6.8	0.0	16	27.1	7.6	16.6	119	8	4.2	182	2.0	1.99
	3	286					27.3	7.3	9.6	134	4	2.1	192	2.2	1.96
	4	504					36.1	8.3	2.6	150	6	0.4	210	2.5	2.48
	5	277					29.7	6.3	7.7	128	8	1.4	176	2.1	2.00
	6	615					30.5	8.3	7.3	131	4	0.7	182	2.2	2.20
	7	780					25.7	7.3	28.6	140	4	1.4	180	2.3	1.28
	8	989					25.7	5.8	5.9	113	4	2.1	179	1.9	1.75
	9	790					25.7	7.3	1.3	107	6	2.1	149	1.8	1.88
	10	680		6.6	0.2	12	26.1	5.7	11.3	122	8	2.1	175	2.0	1.77
	11	470		6.0	0.2	14	28.1	6.3	6.1	122	8	1.8	172	2.0	1.97
	12	409		6.4	0.4	10	29.7	8.3	4.3	131	6	2.1	181	2.2	2.16
1983	2	332	17.8	6.4	0.3		28.1	5.8	10.5	128	5	3.6	181	2.1	1.88
	3	323	19.6	6.5	0.4		29.7	5.8	7.2	122	8	2.8	175	2.0	1.96
	4	262	27.3	6.5	0.2	16	27.3	7.3	6.8	122	6	3.9	173	2.0	1.96
	5	290	31.2	6.3	0.3	12	26.5	5.8	32.0	116	54	2.1	236	1.9	1.80
	6	554	29.6	6.4		10	28.1	3.9	7.0	110	6	2.8	157	1.8	1.72
	7	417	31.2	7.1	0.3	16	26.5	1.5	3.0	85	5	2.1	124	1.4	1.44
	8	738	28.5	7.4	0.3	16	26.5	1.0	14.5	110	5	2.8	160	1.8	1.40
	9	881	26.8	7.0	1.0	8	20.2	6.4	11.5	97.6	8	8.5	152	1.6	1.54
	10	672	26.0	7.4	0.6	4	21.1	7.8	10.2	113	10	1.4	163	1.9	1.69
	11	913	20.8	7.4	0.4	12	27.1	4.3	12.8	122	8	1.8	176	2.0	1.70
	12	454	18.3	7.2	0.4	8	15.7	13.6	9.0	122	8	3.6	172	2.0	1.90

(to be continued)

TABLE 3.1-8 SONG HONG WATER QUALITY IN 1979-1986 (continued)

Year	Month	Water level (cm)	Temp.C	pH	Fe (mg/l)	SiO2 (mg/l)	Ca (mg/l)	Mg (mg/l)	Na,K (mg/l)	HCO3 (mg/l)	SO4 (mg/l)	Cl (mg/l)	Total ion (mg/l)	Total alkal	Hardn.
1984	1	385	17.3	7.0	0.4	16	29.3	5.5	6.2	122	3	3.6	170	2.0	1.91
	2	336	16.8	7.0	0.8	16	33.7	5.5	18.1	146	20	1.4	225	2.4	2.13
	3	282	20.8	7.8	0.4	16	28.9	8.3	12.2	140	10	3.6	203	2.3	2.12
	4	279	25.4	7.4	0.3	16	29.7	6.8	8.2	122	11	5.0	182	2.0	2.04
	5	306	28.6		0.3	20	27.3	6.8	12.7	134	7	2.8	190	2.2	1.92
	6	636	29.0		0.3	24	25.7	5.4	16.1	134	5	2.1	188	2.2	1.72
	7	1014	26.5	7.2	0.4	16	28.1	3.9	18.4	134	9	2.1	195	2.2	1.72
	8	846	28.0	6.8	0.4	10	26.5	4.3	13.0	116	7	5.0	171	1.9	1.67
	9	680	26.5	7.0	0.5	24	25.9	6.7	23.8	152	9	3.3	221	2.5	1.83
	10	806	24.2	7.2	0.5	24	24.1	4.8	22.2	134	9	3.6	197	2.2	1.60
	11	523	25.5	7.2	0.4	16	27.3	7.3	23.2	152	13	4.3	227	2.5	1.96
	12	368	22.5	7.6	0.0	20	28.7	7.7	17.7	152	5	5.7	217	2.5	2.06
1985	1	282	19.8	6.6			25.7	8.8	16.2	140	10	5.0	206	2.3	2.00
	2	325	15.8	7.6	0.8	20	29.5	8.4	2.6	128	5	2.1	175	2.1	2.16
	3	312	17.5	6.6	1.2	16	25.4	7.9	8.7	122	5	5.7	174	2.0	1.92
	4	360	22.4	7.2			22.4	7.3	14.2	122	8	4.2	178	2.0	1.72
	5	314	29.0	7.8	0.2	16	22.9	7.0	6.8	103	4	7.1	151	1.7	1.71
	6	655	28.0	7.8	0.6	16	23.7	4.5	18.4	128	6	2.1	182	2.1	1.55
	7	810	27.0	7.8	0.6	16	27.8	5.0	2.7	110	4	0.7	150	1.8	1.80
	8	614	28.7	7.2	1.3	16	15.5	14.4	5.4	119	8	2.1	164	2.0	1.96
	9	1114	25.0	6.8	0.0	12	28.7	5.0	13.0	109	20	5.0	181	1.8	1.84
	10	520	26.5	6.6	0.0	12	27.9	7.4	10.7	134	8	2.1	190	2.2	2.00
	11	530	22.6	7.6	0.6	16	26.3	5.0	8.3	109	7	3.6	160	1.8	1.71
	12	442	19.0	7.8	0.3	12	28.7	5.5	11.7	128	8	2.8	184	2.1	1.88
1986	1	338	18.3	6.8	0.2	24	29.5	7.9	11.8	128	18	4.2	199	2.1	2.12
	2	278	19.0	7.0	0.1	24	31.1	8.4	16.7	152	12	5.7	226	2.5	2.24
	3	278	22.5	7.8	0.2	16	31.1	9.4	7.5	146	6	3.6	204	2.4	2.32
	4	378	25.7	6.9	0.0	16	22.0	10.9	6.7	122	10	2.1	173	2.0	2.00
	5	546	27.0	6.8	0.0	16	22.8	8.4	7.2	115	8	2.1	164	1.9	1.84
	6	686	27.4	7.4	0.1	8	19.6	6.0	4.9	92	6	1.4	129	1.5	1.47
	7	739	27.5	7.6	0.1	6	24.6	7.4			7	2.1			1.84
	8	865	27.6	7.6	0.3	4	26.2	7.4			7	1.4			1.92
	9	803	26.8	7.0	0.1		31.1	7.4	12.2	140	10	5.0	206	2.3	2.16
	11	518	22.5	7.4	0.2	28	29.5	7.4	17.8	140	15	6.4	216	2.3	2.08
	12	393	21.2	7.8	0.2	10	22.8	11.9	2.5	128	2	2.8	170	2.1	2.12
Average			24.1	7.2	0.3	14.2	26.3	6.9	10.8	123.1	8.5	3.2	178.7	2.0	1.9
Min			15.6	6.0	0.0	2.0	14.4	1.0	0.5	85.0	1.0	0.4	124.0	1.4	1.3
Max			31.2	7.8	1.3	28.0	36.1	14.4	32.0	152.0	54.0	9.2	236.0	2.5	2.5
Std			4.1	0.4	0.3	5.3	4.2	2.3	6.5	15.3	7.0	1.8	23.7	0.3	0.2

TABLE 3.1-9 TICH RIVER BASIN WATER QUALITY

Date of sampling	pH	O2 (mg/l)	CODMn (mg/l)	Ca (mg/l)	Mg (mg/l)	Na+K (mg/l)	HCO3 (mg/l)	SO4 (mg/l)	Cl (mg/l)	NH4 (mg/l)	Fe (mg/l)	SiO2 (mg/l)	Total ion (mg/l)	Total hardn. mekv/l	Alkal. mekv/l
Lake: Ho Suoi Hai															
09.08.1983	7.5	7.5	1.7	13.6	2.4	0.1	42.7	5.0	2.8	0.0	0.2	12.0	66.6	0.88	
12.09.1983	7.2	8.1	1.6	4.5	2.1	8.0	33.6	5.0	2.1	0.0	0.4	10.0	55.3	0.39	
10.10.1983	6.8	8.6	2.5	3.9	1.4	7.6	24.4	5.0	3.6	0.1	0.1	4.0	45.8	0.30	0.4
14.11.1983	6.8	9.1	2.4	3.8	3.7	2.4	24.4	6.0	2.1	0.1	0.3	4.0	42.4	0.49	0.4
07.12.1983	7.0	9.2	1.9	7.5	1.1	6.8	36.6	3.0	2.8	0.1	0.3	4.0	57.8	0.47	
Lake: Ho Dong Mo															
09.08.1983	7.5	8.0	2.4	12.8	3.4	2.2	48.8	7.0	2.1	0.0	0.4	4.0	76.3	0.92	
12.09.1983	7.2	7.3	1.3	7.9	3.0	4.9	42.7	5.0	1.1	0.0	0.6	8.0	64.6	0.64	0.7
10.10.1983	6.2	6.9	2.5	24.1	7.3	43.5	143.4	11.0	34.0	0.2	0.2	20.0	263.3	1.80	2.4
14.11.1983	7.2	9.3	4.8	26.4	7.8	24.8	109.8	30.0	18.4	0.1	0.3	6.0	217.2	2.00	1.8
06.12.1983	7.0	9.8	1.0	12.7	5.0	8.2	64.1	5.0	7.8	0.1	0.5	12.0	102.8	1.05	
Tich River at Cau Thach That															
10.08.1983	7.2	7.5	3.6	12.0	1.5	9.1	48.8	6.0	5.7	0.0	0.8	10.0	83.1	0.72	
12.09.1983	7.4	6.9	2.2	12.8	2.5	8.8	58.0	6.0	4.2	0.0	0.8	12.0	92.3	0.84	
06.10.1983	7.0	7.8	2.6	11.3	0.9	7.0	48.8	1.0	3.6	0.2	0.2	8.0	72.6	0.64	0.8
14.11.1983	7.3	8.9	3.3	21.8	9.1	25.0	109.8	24.0	19.2	0.1	0.3	6.0	208.9	1.84	0.8
06.12.1983	7.3	9.6	1.1	28.1	23.9	46.1	213.6	15.0	49.6	0.9	0.4	20.0	376.3	3.37	
Day River at Cau Mai Linh															
04.08.1983	7.4	4.4	4.6	21.6	5.4	15.2	103.7	10.0	7.8	0.0	0.4	8.0	163.7	1.52	
12.09.1983	7.2	6.0	3.3	19.9	3.0	11.8	88.5	7.0	3.9	0.0	0.6	12.0	134.1	1.24	1.5
07.10.1983	7.2	8.5	1.3	15.0	2.4	8.2	61.0	5.0	5.7	0.2	0.2	8.0	97.2	0.94	1.0
14.11.1983	7.2	12.4	2.7	25.7	9.6	20.8	137.9	22.0	8.5	0.1	0.3	10.0	224.5	2.07	2.2
06.12.1983	7.3	9.3	0.8	49.5	10.0	30.4	244.1	11.0	9.9	2.0	0.3	20.0	354.9	3.29	

Notes: CODMn * 3.95 = KMnO4

1 mekv. total hardness * 2.8 = dH

required to overcome the driest periods. Also the demand for irrigation is increasing and therefore, to base a water supply project on these resources, more detailed studies would be required.

There is plenty of resources which have not yet been studied, the most important of them being perhaps the Da River and Lo River. There is plenty of reasons that speak in favour of these resources. They are located in the mountain areas and probably the silt content would be remarkably lower than in the rivers in the delta area making the purification process simpler. Another advantage is their location in higher elevation making it possible to gravitate the water by it self without external energy down to Hanoi city. There is a hydropower station in Da River at Hoa Binh about 70 km south-west of Hanoi with a huge water reservoir. The minimum water level of the reservoir is about +75 m. This possibility should be considered in long-term planning of water supply.

It is recommended that a comprehensive study on surface water resources and their usability for water supply purposes will be carried out in the nearest future.

3.2 Groundwater resources

Groundwater resources will be discussed in details in a separate report by the hydrogeologist.

4. STANDARDS, CRITERIA AND DESIGN PRINCIPLES

Standards, criteria and design principles to be adapted in Hanoi water supply project are discussed in details in the Water Master Plan report of 1987.

5. DEVELOPMENT FORECASTS

5.1 General

Hanoi General Plan (HGP) work was started in 1971 by Russian experts and the plan was approved by the Council of Ministers of the Socialist Republic of Vietnam on the 24th April 1981. The plan extended to the year 2000.

During the period passed for preparation of the General Plan the development rate of the city proved to be slower than expected and accordingly, it was seen necessary to start the revision work of the plan. The time horizon was also extended to the year 2010.

Hanoi Water Master Plan (HWMP) of 1987 was based mainly on the original General Plan but extended to the year 2010, because official information regarding the revision of the HGP was not available. After the updating and revision work of WMP had started late 1988, it was seen a must for such a study, as being a long term strategy document for water supply development, to utilize the latest and most reliable information available concerning the city development.

The revised document of HGP was made available for WMP revision purposes by the Design Institute for Planning and Construction with the acceptance from Hanoi People's Committee in December 1988.

In this chapter a description of the population and land use trends in Hanoi city as per the revised document of HGP are presented.

5.2 Population

5.2.1 Present trends

Hanoi province is administratively a composition of several districts in the surroundings of Red River, comprising a total land area of 2,139 km2 and approximately 2.9 million inhabitants. However, the actual urban city area at present consists of the four Quan, named Hoan Kiem, Ba Dinh, Hai Ba Trung and Dong Da, and parts of the surrounding extension areas and occupies an area of about 4,890 ha out of which the area of the four Quan is about 4,300 ha.

The population of the city to be used in calculations is the number of inhabitants within the urban area which are shown for different time horizons i.e. 1988, 1995, 2000 and 2010 on the land use maps (drawing...). This is also the area to be covered by WMP studies.

According to the population census held in April 1988 the total population of the four main Quan was 927,000. The results of the latest census and the one held in 1985 as well as the average annual growth rates and population densities in the each four Quan and further in the 83 Phuong are presented in Appendix 1 and Drawing No...

The average, maximum and minimum annual growth rates and population densities in each quan are presented in table 5.2-1.

TABLE 5.2-1 THE AVERAGE, MAXIMUM AND MINIMUM ANNUAL GROWTH RATES AND POPULATION DENSITIES OF PHUONGS WITHIN EACH QUAN OF HANOI CITY IN 1988

Quan	Annual growth rate (%)			Population density (p/ha)		
	Average	Maximum	Minimum	Average	Maximum	Minimum
Ba Dinh	2.6	13.2	-1.1	171	584	95
Dong Da	3.4	15.8	-3.4	211	592	81
Hoan Kiem	0.4	5.9	-5.6	407	1321	225
Hai Ba Trung	3.0	8.7	-0.1	266	729	78
City total	2.5	15.8	-5.6	224	1321	78

The average growth rate figure 2.5% is in conformity with the one recorded during the years 1980-1985 of about 2.4%.

By studying the figures of individual Quan and Phuong, it can be seen that:

- Population is growing fast in Dong Da and Hai Ba Trung quans and very slowly in Hoan Kiem (the old city centre) Quan.
- The area with very fast (>10%) growth rate are located in the South-Western part of the city (Phuong 21, 25, 26, 38)and are those with new dwelling houses.

- The areas with fast (>5%) growth rate are located mainly in the South or South-Eastern side of the city (Phuong 14, 16, 69, 74, 77, 79).

- The areas with very slow or even negative growth rate are located mainly in the urban centre around the Central Lake.

- A prominent concentration of population is living in the old centre, mainly Hoan Kiem district and its immediate surroundings where population densities may be over 1000 persons /ha.

5.2.2 Future trends

Future trends for population growth are based on the estimates and calculations by the Planning Institute of Fundamental Construction Committee of Hanoi. They are presented below.

The past urban population growth and that proposed for the future in the revised HGP document are as follows :

Year	Population	Growth /Year
1980	733,000	
1985	861,000	3.25 %
1988	937,000	2.85 %
1995	1,048,000	1.61 %
2000	1,120,000	1.35 %
2010	1,400,000	2.25 %

The figures for the year 1980 and 1985 are the total for the a.m. four Quan. The growth rate figure of 3.25 % per year includes also the population of completely new areas incorporated into the urban city during the a.m. years, 20,428 persons in Hai Ba Trung and 14,421 persons in Dong Da. After revising the figures to describe the net population increase, total annual growth rate will be about 2.4 % .

All the other figures include Gia Lam on the left side of Red River and the other extension areas to be incorporated in to the present urban area as presented in the land use maps. The average annual growth rate over the whole planning period 1988-2010 is about 1.85 % . When judging this figure, some attention has to be paid to the amount of people who are living at present in the future development areas, as they are not included in the initial values. No exact figure is available of their number, but according to the estimate by Planning Institute there are roughly 110,000 people who are living in areas which shall be included in Hanoi urban centre up till 2010. Therefore, the real rate of growth will be on the average something between 1.3-1.5 annually, which is clearly less than the 1.85 % calculated before, but may be considered a reasonable although moderate figure. The absolute estimated population growth is presented in figure 5.2-1.

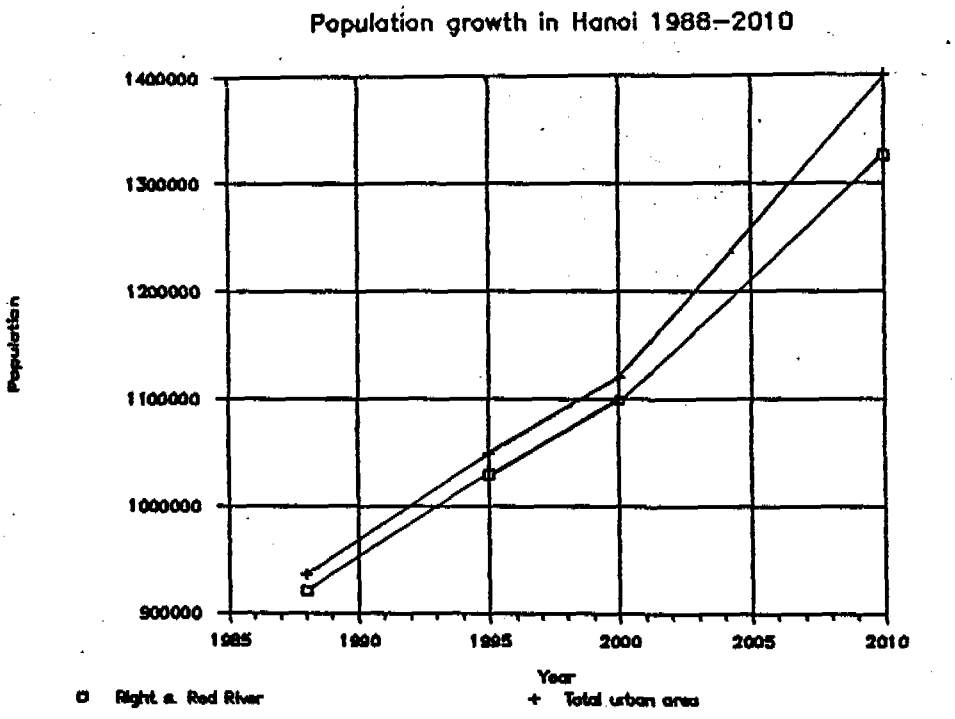


FIGURE 5.2-1 Urban population growth projection for Hanoi in 1988-2010

The population has been classified according to the occupational status as follows :

- Main component, including persons in industrial enterprises, central and offices, institute, universities , external communication transportation etc.

- Service component, including persons in domestic, cultural, service and commercial branches.

- Subordinate component, including retired persons, children and disabled persons.

The division of Hanoi urban population into these components by the years 1988, 1995, 2000 and 2010 is presented in table 5.2-2.

The share of service component is expected to grow from 13% to 23% until 2010 while the shares of main component and subordinate component are reducing 5% each.

For city planning purposes the civil area of Hanoi has been divided into 43 blocks. For each of them a population and area growth prognosis have been prepared with time horizons to 1995, 2000 and 2010. Accordingly the population densities over the whole civil area, which includes also the land for public use, small industries and green plantations, have been calculated. In table 5.2-3 the population projections, civil area development and respective population densities have been presented.

The overall development strategy of population location is to divert the population from the densely populated city centre area towards the new extension areas South-West, West and North-West of the present city centre and thus even the population densities between different areas and lower the overall average population density by increasing the total urban area.

In the year 1995 little change in the existing residential areas have occurred. New residential areas have been constructed for a total population of about 70,000 people.They are located mainly North-West (blocks 25, 26, 29 and 31) and West (block 15) of the old city centre.

Until the year 2000 the population densities in the old city centre are lowered a little, some present residential areas located mainly to the South of West Lake have disappeared and the land is used for other purposes, mainly for public

TABLE 5.2-2 POPULATION CLASSIFICATION IN 1988, 1995, 2000 AND 2010

Component	1988 population	/ %	1995 population	/ %	2000 population	/ %	2010 population	/ %
Main component	299840	32.0	330120	31.5	352800	31.5	378000	27.0
- R	295040		324135		346185		358178	
- L	4800		5985		6615		19822	
Service component	121810	13.0	162440	15.5	173600	15.5	322000	23.0
- R	119860		159495		170345		305114	
- L	1950		2945		3255		16886	
Subordinate comp.	515350	55.0	555440	53.0	593600	53.0	700000	50.0
- R	507100		545370		582470		663293	
- L	8250		10070		11130		36707	
Total R	922000	98.4	1029000	98.2	1099000	98.1	1326585	94.8
Total L	15000	1.6	19000	1.8	21000	1.9	73415	5.2
Total population	937000	100.0	1048000	100.0	1120000	100.0	1400000	100.0

Note: R = right side of Red River
L = left side of Red River

TABLE 5.2-3 POPULATION PROJECTIONS, CIVIL AREA DEVELOPMENT AND POPULATION DENSITIES IN HANOI CITY TO 2010

Block	Population				Civil area (ha)				Popul. dens. (p/ha)			
	1988	1995	2000	2010	1988	1995	2000	2010	1988	1995	2000	2010
Right side of Red River:												
1	141629	136629	103673	46631	256.2	256.3	256.2	256.2	553	533	405	182
2	143973	138973	126870	74608	324.2	324.2	324.2	324.2	444	429	391	230
3	80758	75758	60158	43555	234.3	234.3	234.3	234.3	345	323	257	186
4	43970	43970	39753	34322	130.5	135.5	196.5	196.5	337	325	202	175
5	9903	9903	39696	49066	38.0	43.0	100.0	152.0	261	230	397	323
6	11459	8459			135.0	135.0	135.0	135.0	85	63	0	0
7	135754	140754	127065	65688	314.9	314.9	314.8	314.8	431	447	404	209
8	59301	59301	50537	41749	224.0	224.0	224.0	224.0	265	265	226	186
9	19510	16510	32672	72290	70.9	70.9	70.9	270.9	275	233	461	267
10	10681	7681			28.3	28.3	28.3	28.3	377	271	0	0
11	52719	52719	65460	69622	277.3	277.3	277.2	277.2	190	190	236	251
12	9720	6720			37.2	37.2	37.2	37.2	261	181	0	0
13	12978	12978	17619	12187	99.4	99.4	99.4	99.4	131	131	177	123
14	10923	24923	26297	30565	90.0	105.0	111.0	111.0	121	237	237	275
15		30000	48969	105101		100.0	200.5	241.6		300	244	435
16	5000	5000			25.0	35.0	41.3	41.3	200	143	0	0
17	8200	8200			50.0	60.0	76.0	76.0	164	137	0	0
18	3000	3000			5.0	5.0	29.0	29.0	600	600	0	0
19	5000	5000			7.0	32.0	115.0	115.0	714	156	0	0
20		8000	9975	12551	20.0	30.0	150.0	190.3	0	267	67	66
21	3000	16000	22293	51011	10.0	40.0	80.0	186.8	300	400	279	273
22	10000	10000			55.0	95.0	101.3	101.3	182	105	0	0
23	16000	35000	38305	80879	85.0	165.0	219.1	314.1	188	212	175	257
24	10000	20000	41732	56786	45.0	65.0	150.0	223.6	222	308	278	254

(to be continued)

TABLE 5.2-3 POPULATION PROJECTIONS, CIVIL AREA DEVELOPMENT AND POPULATION DENSITIES IN HANOI CITY TO 2010 (continued)

Block	Population				Civil area (ha)				Popul. dens. (p/ha)			
	1988	1995	2000	2010	1988	1995	2000	2010	1988	1995	2000	2010
25		9000	18143	24733		20.0	35.0	78.6		450	518	315
26		15000	40179	104181		30.0	40.0	359.8		500	1004	290
27								22.0				0
28								28.5				0
29		10000	28143	106160		22.0	40.0	388.2		455	704	273
30								46.8				0
31		7000	23393	62417		15.0	40.0	208.7		467	585	299
32							48.0	48.1			0	0
33	14104	15104	26446	42110	40.0	40.0	40.0	161.8	353	378	661	260
34			14250	42483			35.0	139.7			407	304
35	22355	25355	34590	73415	57.0	60.0	60.0	223.0	392	423	577	329
36			13246	24475			38.8	98.0			341	250
38								10.0				0
39	24065	24065	8482		30.0	30.0	30.0	120.0	802	802	283	0
40								205.0				0
41	23135	23135	24768		80.0	80.0	80.0		289	289	310	
42	18402	16402	16286		58.0	58.0	58.0		317	283	281	
43	16461	8461			31.0	31.0			531	273		
S.tot	922000	1029000	1099000	1326585	2858.2	3298.3	4116.0	6318.2	323	312	267	210
Left side of Red River:												
37	15000	19000	21000	73415	45.0	58.0	57.0	227.0	333	328	368	323
Total	937000	1048000	1120000	1400000	2903.2	3356.3	4173.0	6545.2	323	312	268	214

offices etc. and the construction works of the new residential areas has been going on mainly in the south (blocks 5 and 8), South-West and North-West of the city centre.

In the year 2010 there has happened a radical change. Population densities in the old urban centre has decreased to about 50% of the present situation. The construction of the new residential areas have come to it's final shape. The population densities are rather uniform varying between 180-320 persons/ha over the civil areas. The highest population density of 435 persons/ha is in Quan Nhan and Hoa Ma on the West side of To Lich river. The average civil area population density has decreased from today's 323 persons/ha to 214 persons/ha.

When compared the above described development to the targets of the original HGP it can be noticed that the plan to carry out a huge construction programme of new houses and necessary infrastructure involving immense financial resources have been postponed for about 10 years and there is a radical slowdown in the development programme. This seems to be reasonable as the financial situation of the country has been experiencing some depression during the last few years.

5.3 Land use

5.3.1 General

The present and future land use in the years 1989, 1995, 2000 and 2010 have been presented in drawings No... The urban land use classification at present and the estimated future development is presented in table 5.3-1.

The total urban area is estimated to grow from today's 4,890 ha to 5,615 ha in 1995, to 7,007 ha in 2000 and to 10,938 ha in the year 2010. The present urban area is expanded mainly to the South-West, West and North-West direction. An urban settlement of about 740 ha is going to be developed in Gia Lam area on the left side of the Red River. The land for urban purposes is going to be deprived from agriculture.

When compared to the original HGP,there has been a remarkable reduction of urban area from 13,500 ha in 2010 to 10,098 ha or about 19% .

TABLE 5.3-1 LAND USE CLASSIFICATION IN 1988, 1995, 2000 AND 2010

Classification	1988 Total area (ha)	%	R	L	1995 Total area (ha)	%	R	L
Total civil area	3244	66.3	3195	49	3744	66.7	3680	64
- residential	1720	35.2	1689	31	2029	36.1	1987	42
- public works	679	13.9	673	6	840	15.0	834	6
- green plantations	116	2.4	114	2	193	3.4	190	3
- small industries	106	2.2	104	2	130	2.3	126	3
- roads, squares	341	7.0	337	4	388	6.9	382	6
- other	282	5.8	278	4	164	2.9	161	3
Industrial area	920	18.8	830	90	1145	20.4	1040	105
Other areas	726	14.8	676	50	726	12.9	676	50
Total city area	4890	100.0	4701	189	5615	100.0	5396	219

R = right side of Red River
L = left side of Red River

Classification	2000 Total area (ha)	%	R	L	2010 Total area (ha)	%	R	L
Total civil area	4773	68.1	4709	64	7345	67.2	7088	257
- residential	2292	32.7	2250	42	3594	32.9	3414	180
- public works	1202	17.2	1195	7	1658	15.2	1647	11
- green plantations	524	7.5	519	5	1044	9.5	1013	31
- small industries	155	2.2	152	3	249	2.3	244	5
- roads, squares	600	8.6	593	7	800	7.3	770	30
Industrial area	1542	22.0	1392	150	2481	22.7	2191	290
Other areas	692	9.9	607	85	1112	10.2	920	192
Total city area	7007	100.0	6708	299	10938	100.0	10199	739

5.3.2 Civil area development

The civil area development, which are occupying about 67% of the total urban area, will be based on 43 blocks. Each of them are including:

- residential areas,
- public works areas (offices, schools, institutes, hospitals, services, etc.),
- areas for green plantations (parks),
- areas for small industries and
- areas occupied by roads, squares etc.

The development of each unit block is presented in table 5.3-2.

The overall development of residential areas has been discussed in chapter 5.2.2 in connection with the population location and growth trends. The main development targets are summarized below:

- The population densities in the old city centre will be lightened to about half of the present.

- New residential ares will be constructed to the South-West, West and North-West of the present city centre and in Gia Lam on the left side of Red River.

- Present residential areas to the South of the West Lake will be changed to public areas and green plantations.

- Present settlements behind the flood embankment East of the city will be removed.

The main development target of public works areas is to create a uniform band of offices, hotels etc. to the South-West and North-West of West Lake. Generally, the public services are going to be evenly distributed over the whole urban area and within each unit block.

One of the targets is to retain the beauty of the city by scattering green plantations evenly over the whole city. The main idea, however, is to create a green zone around the main lake of the city, namely West Lake.

Small industrial are also going to be evenly distributed over the planning area.

TABLE 5.3-2 CIVIL AREA DEVELOPMENT BY DIFFERENT CATEGORIES BETWEEN THE YEARS 1988 AND 2010

Block	Land use in 1988 (ha)						Land use in 1995 (ha)					
	resid.	public works	green plant.	small indust.	other use	total	resid.	public works	green plant.	small indust.	other use	total
Right side of Red River:												
1	153.8	75.1	19.0	8.3		256.2	156.0	75.1	19.0	6.2		256.3
2	241.2	24.6	40.7	15.7	2.0	324.2	244.5	20.0	45.7	12.0	2.0	324.2
3	155.7	40.5	20.0	13.1	5.0	234.3	150.3	46.0	25.0	10.0	3.0	234.3
4	83.6	18.7	2.0	15.1	11.1	130.5	83.6	23.7	6.1	15.1	7.0	135.5
5	23.0	3.7		4.3	7.0	38.0	23.0	8.7	2.0	4.3	5.0	43.0
6	30.1	103.1			1.8	135.0	22.1	111.1			1.8	135.0
7	196.5	75.3	6.0	7.7	29.4	314.9	211.6	75.3	7.0	6.0	15.0	314.9
8	127.0	73.0		5.7	18.3	224.0	127.0	73.0	3.0	5.7	15.3	224.0
9	34.9	11.2		7.8	17.0	70.9	34.9	11.2	2.0	7.8	15.0	70.9
10	17.4	5.0		2.0	3.9	28.3	10.0	14.2		2.0	2.1	28.3
11	206.5	13.0		7.8	50.0	277.3	206.5	18.0	25.0	7.8	20.0	277.3
12	19.8	5.5		1.2	10.7	37.2	12.5	18.5		1.2	5.0	37.2
13	37.6	20.8	24.0	1.2	15.8	99.4	37.6	30.8	26.0	1.2	3.8	99.4
14	30.0	18.0		3.2	38.8	90.0	65.0	18.0		3.2	18.8	105.0
15						0.0	75.0	25.0				100.0
16	10.0	1.0	2.0	1.0	11.0	25.0	10.0	1.0	12.0	1.0	11.0	35.0
17	21.6	6.7		0.4	21.3	50.0	21.6	16.7		0.4	21.3	60.0
18	4.0	1.0				5.0	4.0	1.0				5.0
19	5.5	1.5				7.0	5.5	26.5				32.0
20		20.0				20.0	10.0	20.0				30.0
21	4.0	6.0				10.0	30.0	7.0	3.0			40.0
22	12.0	40.0			3.0	55.0	12.0	64.3		18.7		95.0
23	38.0	47.0				85.0	91.0	67.0	5.0	2.0		165.0
24	12.0	21.0			12.0	45.0	32.0	21.0	2.0	2.0	8.0	65.0
25						0.0	17.0	3.0				20.0
26						0.0	30.0					30.0
27						0.0						0.0
28						0.0						0.0
29						0.0	17.0			5.0		22.0
30						0.0						0.0
31						0.0	10.0		2.0	3.0		15.0
32						0.0						0.0
33	15.0	20.0		2.0	3.0	40.0	18.0	20.0		2.0		40.0
34						0.0						0.0
35	37.0	10.0		2.0	8.0	57.0	43.0	10.0	2.0	5.0		60.0
36						0.0						0.0
38						0.0						0.0
39	26.0	0.5			3.5	30.0	26.0	0.5	3.5			30.0
40						0.0						0.0
41	73.0	3.7		2.0	1.3	80.0	73.0	3.7		2.0	1.3	80.0
42	48.0	1.8		3.0	5.2	58.0	48.0	1.8		3.0	5.2	58.0
43	29.0	2.0				31.0	29.0	2.0				31.0
	main streets and squares:					337.0						382.0
Sub total	1692.2	669.7	113.7	103.5	279.1	3195.2	1986.7	834.1	190.3	126.6	160.6	3680.3
Left side of Red River:												
37	31.0	6.0	2.0	2.5	3.5	45.0	42.5	6.0	3.0	3.0	3.5	58.0
	main streets and squares:					4.0						6.0
Total	1723.2	675.7	115.7	106.0	282.6	3244.2	2029.2	840.1	193.3	129.6	164.1	3744.3

TABLE 5.3-2 CIVIL AREA DEVELOPMENT BY DIFFERENT CATEGORIES BETWEEN THE YEARS 1988 AND 2010
(continued)

Block	Land use in 2000 (ha)					Land use in 2010 (ha)				
	resident.	public works	green plant.	small industr.	total	resident.	public works	green plant.	small industr.	total
Right side of Red River:										
1	160.2	75.1	19.0	2.0	256.3	160.2	75.1	19.0	2.0	256.3
2	256.2	7.0	57.0	4.0	324.2	256.2	7.0	57.0	4.0	324.2
3	124.1	57.2	47.0	6.0	234.3	124.1	57.2	47.0	6.0	234.3
4	97.8	36.7	56.0	6.0	196.5	97.8	36.7	56.0	6.0	196.5
5	78.0	11.0	9.0	2.0	100.0	130.0	11.0	9.0	2.0	152.0
6		135.0			135.0		135.0			135.0
7	225.6	75.3	8.0	6.0	314.9	225.6	75.3	8.0	6.0	314.9
8	119.0	73.0	29.0	3.0	224.0	119.0	73.0	29.0	3.0	224.0
9	24.9	34.0	10.0	2.0	70.9	205.9	34.0	29.0	2.0	270.9
10		28.3			28.3		28.3			28.3
11	207.2	7.0	60.0	3.0	277.2	207.2	7.0	60.0	3.0	277.2
12		37.2			37.2		37.2			37.2
13	34.6	34.8	29.0	1.0	99.4	34.6	34.8	29.0	1.0	99.4
14	91.0	18.0		2.0	111.0	91.0	18.0		2.0	111.0
15	144.3	53.2		3.0	200.5	165.5	73.2		3.0	241.7
16			41.3		41.3			41.3		41.3
17		73.0		3.0	76.0		73.0		3.0	76.0
18		9.0	19.0	1.0	29.0		9.0	19.0	1.0	29.0
19		112.0		3.0	115.0		112.0		3.0	115.0
20	29.4	88.4	28.2	4.0	150.0	37.3	112.2	35.8	5.0	190.3
21	66.0	4.0	5.0	5.0	80.0	151.8	5.0	15.0	15.0	186.8
22		71.3		30.0	101.3		71.3		30.0	101.3
23	118.9	70.7	25.5	4.0	219.1	177.9	99.7	32.5	4.0	314.1
24	123.0	15.0	7.0	5.0	150.0	169.0	24.6	15.0	15.0	223.6
25	24.0	3.0	6.0	2.0	35.0	54.0	5.0	9.6	10.0	78.6
26	30.0		10.0		40.0	218.6	80.6	55.7	5.0	359.9
27					0.0		22.0			22.0
28					0.0		28.5			28.5
29	24.0	8.0	6.0	2.0	40.0	223.7	63.1	86.3	15.0	388.1
30					0.0		46.8			46.8
31	10.0	2.0	20.0	8.0	40.0	141.0	17.3	25.4	25.0	208.7
32		20.0		28.0	48.0		20.1		28.0	48.1
33	19.0	15.0	1.0	5.0	40.0	103.8	38.0	5.0	15.0	161.8
34	28.0	3.0	2.0	2.0	35.0	104.7	20.0	5.0	10.0	139.7
35	43.0	10.0	2.0	5.0	60.0	155.0	43.0	10.0	15.0	223.0
36	25.8	5.0	5.0	3.0	38.8	60.0	12.0	23.0	3.0	98.0
38					0.0			8.0	2.0	10.0
39	25.0		5.0		30.0			120.0		120.0
40					0.0			205.0		205.0
41	73.0	1.0	5.0	1.0	80.0					
42	48.0	2.0	7.0	1.0	58.0					
	main streets and squares:				593.0					770.0
Sub total	2250.0	1195.2	519.0	152.0	4709.2	3413.9	1606.0	1054.6	244.0	7088.5
Left side of Red River:										
37	42.0	7.0	5.0	3.0	57.0	180.0	11.0	31.0	5.0	227.0
	main streets and squares:				7.0					30.0
Total	2292.0	1202.2	524.0	155.0	4773.2	3593.9	1617.0	1085.6	249.0	7345.5

5.3.3 Industrial development

At present there are some industries scattered within and around the urban city. There are also some concentrations in Ha Dinh, Vinh Thuy and Giap Bat within the city and Lang Chem, Tam Hiep and Gia Lam outside the city. A list of main industrial enterprises is presented in table 6.3-2 (chapter 6). Their location is shown in drawing No...

The principle of industrial development in Hanoi is to concentrate the enterprises on clearly separated industrial areas. Totally 7 areas have been proposed to be identified in the future land-use programme. In water supply and sewerage point of view the idea of concentration can be considered good as the management and control of water supplies and industrial effluent is in such a case much easier than in decentralized solution.

The development of industrial areas concerning the type of industries, total areas allocated and manpower requirements are presented in table 5.3-4. The location of these industrial concentrations in each development phase is shown on land-use maps, drawings No...

The total area allocated for these main concentrations is anticipated to grow from today's 920 ha to about 2,500 ha in 2010 and the manpower respectively from about 90,000 to about 130,000.

Tam Hiep industrial area (I6) is located some 2 km to the south outside the present and proposed future urban area boundaries. Besides the industrial area there is a remarkable civil area concentration, town called Van Dien. That area was not included into the urban area of Hanoi with the result that it was nor included into the master plan studies. In the discussions with the Vietnamese it was decided that water supply for both the industrial and civil areas will be planned jointly and separated from master plan studies.

In addition to the main industrial concentrations, there will be also in the future some industrial enterprises remaining within the residential areas. The type of these factories will be 'environmentally acceptable within residential areas' i.e. electrical, electronics etc. The total area of them and the manpower engaged is presented in table 5.3-4. Their approximate locations are presented in the relevant land use maps.

TABLE 5.3-4 DEVELOPMENT OF INDUSTRIAL AREAS IN HANOI BETWEEN 1988 - 2010

Industrial area No.	Location	Type of industry	1988 Area (ha)	1988 Manpower	1995 Area (ha)	1995 Manpower	2000 Area (ha)	2000 Manpower	2010 Area (ha)	2010 Manpower
Right side of Red River:										
I 1	Long Chem	constr.materials glassvares, ceramics	55	8210	65	8600	75	9230	101	10630
I 2	Phu Dien	mechanic industries	30	10230	40	11200	97	11630	130	13370
I 3	Ha Dinh	consumer goods, mechanic industries	260	21500	300	22300	335	22850	460	30000
I 4	Vinh Tuy	textile, dying, clothes, food processing	250	21800	300	22500	400	22930	580	35000
I 5	Giap Bat	printing,cultural commodities, mechanic repairing	85	4000	85	4000	85	3000	85	3000
I 6	Tam Hiep	chemical, mechanic repairing, constr. materials	150	15470	250	15500	400	15830	835	27000
Sub total			830	81210	1040	84100	1392	85470	2191	119000
Left side of Red River:										
I 7	Gia Lam	chemical,mechanic repairing,storage	90	9020	105	9400	150	9530	290	12000
Total main areas:			920	90230	1145	93500	1542	95000	2481	131000
Other areas:			180	20500	200	21100	250	21800	300	35000
Total industries:			1100	110730	1300	114600	1800	116800	2800	166000

6. WATER DEMANDS

6.1 Division of water use

The total quantity of water may be described by term specific consumption or daily per capita consumption, which means the daily average of water produced by water plants, divided by the total number of inhabitants in the service area. It is a combination of several different water use types, which are generally categorized as follows:

* Domestic use

* Urban services use

* Industrial use

* Other use and losses (unmetered use)

Domestic use means the water used in private households for drinking, cooking, cleaning, hygiene, washing and irrigation of gardens, etc.

Urban service use includes the water for public utilities, offices, schools, hotels, hospitals and the water used in small enterprises, shops and small industries.

Industrial use includes the water used in industries for production and it can be further divided into process water, cooling water, flushing water and sanitary water.

Other use and losses is usually the non-metered water, which is the balance between the total amount of water pumped into the network and the billed water. It includes the water used for irrigation of parks and other areas, cleaning of roads and public areas, pipe flushing, fire fighting and losses in the water supply system, which accounts usually about three quarters of the group.

The actual figures for specific consumption and the different consumption types are dependant on several factors, e.g. climate, standard of living, condition of the water works system, water use habits of the people and coverage of sewerage network.

For the Hanoi water supply studies we may use the categorization as follows:

- Domestic

- Public works (urban services)

- Industries
- Small industries
- Cleaning and irrigation
- Other use and losses

This is the practical division for Hanoi conditions, where the measuring of water is still almost non-existent and even the total amount of water pumped to the network is not exactly known.

The categories are the same as generally except the categories 'small industries' and 'cleaning and irrigation'. Cleaning and irrigation is in this connection only the public component including only the water used for public area watering, i.e. cleaning of roads and squares and irrigation of parks etc. Thus the 'domestic irrigation' is considered to be included into the 'domestic use' category.

Normally the a.m. two categories are included into the 'urban services' or 'industry' and 'other use and losses' categories respectively. In the prevailing conditions of Hanoi, it has been seen useful to separate these categories because of the following reasons:

- There exists nowadays plenty of private business, which has become possible after the changes in Government policies.
- The streets are in need of regular washing because of the non-existing sewerage pipeline and the methods of solid waste collection.

At present, the water for streets washing is taken from the treatment plants and is thus not pumped into the network. In the WMP-study, however, it has been assumed that also this water will be taken from the network. This is to make the reservation for such water in the network and remain also this option if found more convenient in the future.

6.2 Review on standards and reports

Before making any demand estimates we shall review some standards and actual values of water consumptions in some countries:

* Vietnam

Guideline values for the estimation of water use in different categories are given in 'Water use standards'. The following values have been proposed to be used for domestic consumption:

Type of use	Consumption (l/c/d)	Peak hour
1. Public taps	40 - 60	2.5 - 2.0
2. Yard taps	80 - 100	2.0 - 1.8
3. Internal water, sewerage connection	120 - 150	1.8 - 1.5
4. 3. + sanitary equipment + bath	150 - 200	1.7 - 1.4
5. 3. + water heater	200 - 300	1.5 - 1.3

For road and square washing and irrigation of parks and plantations a figure of 0.5 - 1.0 l/m2/d of area to be watered has been given.

* Finland

The generally used design criteria for the year 2010 are as follows:

Domestic use	160 - 220	l/c/d
Urban services	40 - 70	l/c/d
Other use and losses	40 - 60	l/c/d
Total	240 - 350	l/c/d

To the total figure shall be added industrial water use, which in Finland is generally between 10-25 % of the total value. The final limits are therefore approximately 280-440 l/c/d.

In 1986 the average specific consumption in the whole country was 288 l/c/d out of which the domestic use was 153 l/c/d (53 %), industrial use 43 l/c/d (15 %), public services 40 l/c/d (14 %) and other use including losses 52 l/c/d (18 %).

In the capital city of Helsinki the specific consumption in 1986 was 347 l/c/d out of which the domestic consumption was 216 l/c/d.

In 1974 the average specific water consumption in the whole country reached its highest level of 333 l/c/d so far. Since that the specific consumption has decreased reaching its lowest level in 1984 of 279 l/c/d and has remained approximately to that level until now.

The decrease of specific water consumption has been the result of energy conservation activities, introduction of sewage charges in 1974, improved water use devices, recirculation of water in industry, leakage control, changes in consumer attitudes towards water saving etc.

* Soviet Union

In the official norms for water use design, the total urban specific consumption including domestic, public, industry, irrigation and other use has been 450 l/c/d in 1975, 500 l/c/d in 1980 and 600 l/c/d in 2000.

The division of domestic consumption is as follows:

Type of use	Consumption (l/c/d)
1. Public taps	30 - 50
2. Houses with internal water and sewerage connections	125 - 160
3. 2. + bath + local water heaters	160 - 230
4. 3. except centralized water heating	230 - 350

* Western Europe

The development of domestic consumption in some European countries has been represented in the table below:

Country	Domestic consumption (l/c/d) 1972	1977	1983
Austria	131	149	137
Belgium	77	88	105
Denmark	-	-	193
F. R. of Germany	121	135	148
France	98	112	123
G. Britain	196	204	125
Holland	126	137	148
Italy	225	208	215
Norway	-	-	200
Spain	135	145	145
Sweden	209	199	200
Switzerland	284	255	264

The total specific consumption in most of the a.m. countries was below 300 l/c/d.

* South-East Asia

Some figures for domestic consumption are available:

Country	Domestic consumption (l/c/d) Present	2000	2005	2010
Burma	-	-	-	125
Laos (Vientiane)	160	225	-	
Malaysia	-	-	-	220
Sri Lanka (Colombo)	-	-	-	240
Philippines (Manila)	200	250	-	
Indonesia (Jakarta)	150	-	220	-

* Other countries

The total specific water consumption in big cities of some countries have been presented below. This data is rather old, from the beginning of 1970's.

Country	Specific Cons.(l/c/d)	Peak day coefficient
Brasilia	300	2.0
Hungary	270 - 330	1.3 - 1.4
Japan	300 - 470	1.2
Poland	200 - 230	1.2 - 1.3
Soviet Union	260 - 520	1.2 - 1.5
South Africa	270	1.2
USA	500 - 800	1.4

6.3 Present water consumption

In table 6.3-1 is presented the breakdown of HWSCo's water sales in 1988 based on the monthly billing of individual consumers. This is official information from HWSCo giving an average daily sales of 244,000 m3/d. To come to the total production of treated water, 30 % of total production is being added to account for leakages. The official estimate for production is thus approximately 346,000 m3/d.

As there are practically no water meters functioning neither in the pumping stations nor at the connections, the figures presented in table 6.3-1 are nominal only.

The official figure of 346,000 m3/d of produced water is probably too high, as the total capacity of the main treatment plants plus small treatment plants when taking into account also the direct pumping into the network is only about 300,000 m3/d as presented in chapter 2.

Distribution losses are officially estimated to be 30 % of the total production. There exists, however, plenty of reasons to assume even remarkably higher values. They have been discussed in detail in chapter 2.5.2 'Distribution losses'.

It has been estimated by the Finnish experts that wastage through leakages is 50 % of the total production or even more. A pilot study is being planned to prove the level of leakages.

TABLE 6.3-1 HANOI WATER SUPPLY COMPANY'S WATER SALES IN 1988

Category	Total sales in 1988 (m3)	Average sales (m3/d)	Percent of total (%)
Domestic use	37507975	102800	42.1
- private houses	14544795	39800	16.3
- resid. quarters	15718563	43100	17.6
- public taps	7244617	19800	8.1
Public use	31098819	67900	27.8
- admin. offices	7730233	21200	8.7
- hospitals	3097348	8500	3.5
- army	5308558	14500	5.9
- diplom. offices	1117336	3100	1.3
- cult. & educ. off.	7522225	20600	8.4
Private business	6323119	17300	7.1
Industrial use	20586668	56400	23.1
- co-operatives	801072	2200	0.9
- industry	17143327	47000	19.2
- construction	2642269	7200	2.9
Total sales	89193462	244400	100.0

Note: All the figures are based on estimated consumptions

After deducting the leakage from the real production capacity the estimate for sales, if metered, is something like 150,000 m3/d, which suggests an overestimation of about 90,000 m3/d.

The consultant's estimate for the present consumption is as follows:

Category	(m3/d)	(l/c/d)
Domestic use	66,000	70
Public use	43,000	46
Industrial use	44,000	47
Losses	153,000	164
Total	306,000	327

In the group 'public use' are included the water for small industries and cleaning and irrigation.

A list of the main industrial enterprises with a consumption of over 5,000 m3/d is presented in table 6.3-2. In the table it has been presented the estimated consumption in 1988 as per billing by HWSCo, and the possible existence and capacity of their own water plant. Similarly, a list of the main public consumers is presented in table 6.3-3. Their location is shown in drawing No...

Generally it can be said that the water consumption in Hanoi at present do not meet the demand as it would be under proper circumstances. This is also reflected by the fact that there exists a number of factories and institutes etc. with a water supply system of their own. They have been established in many cases due to the scarcity of the water in the municipal network.

6.4 Consumption variations

The consumption variations during different days of the year (daily variations) and during different hours of the day (hourly variations) are depending on different factors e.g. the number of inhabitants connected to the system (the bigger the system, the lower the variation), climate, water use habits etc.

The poor network and undeveloped water use habits, together with lack of exact measurements of flows, make it very difficult to present reliable estimates of consumption variations as a function of time.

Obviously, in the present network they are very small, and the flow rather uniform during the daytime, or more dependant on the ability of the water plants to produce water than actual demand.

According to the Finnish studies the daily coefficient (kd) is hardly higher than 1.3 in a system serving over 100,000 people. Similarly the recommendations for hourly variation coefficient (kh) are 1.6...1.5.

There exist some information from South-East Asia concerning the civil consumption variation coefficients:

* Manila:	kd = 1.3	in 1982
	kd = 1.5	in 2000
	kh = 1.5	in 1982
	kh = 1.2	in 2000

* Jakarta:	kd = 1.2	in 1982
	kd = 1.5	in 2000
	kh = 1.4	in 1982
	kh = 1.2	in 2000

In the Hanoi General Plan the variation coefficients proposed for the year 2010 are as follows:

Civil consumption:

- daily coefficient (kd) 1.3
- hourly coefficient (kh) 1.4

Industrial consumption:

- daily coefficient (kd) 1.1
- hourly coefficient (kh) 1.5

After discussions with Vietnamese, the consumption variation coefficients to be used in system dimensioning were fixed as follows:

Civil consumption:

- daily coeff. (kd) 1.3 in 1995
  1.4 in 2000
  1.4 in 2010

- hourly coeff. (kh) 1.4 in 1995
  1.3 in 2000
  1.2 in 2010

Industrial consumption:

- daily coeff. (kd) 1.1 in 1989-2010
- hourly coeff. (kh) 1.5 in 1989-2010

Consultant's opinion is that the daily coefficient in 2000 and 2010 should be lower, i.e. 1.3.

In implementation this difference means an incremental capacity of 270 l/s or 23,000 m3/d in 2000 and 400 l/s or 35,000 m3/d in 2010 of water to be produced. The extra investment due to the choice of bigger coefficient would roughly be 5,000,000 to 8,000,000 US$.

TABLE 6.3-2 LIST OF MAIN INDUSTRIAL ENTERPRISES WITHIN HANOI CITY

Ref. no. 2)	Type of industry	Address	Estimated consumption from public network (m3/month)	(m3/d)	Estim. capacity of own water plant	(m3/d)
DONG DA district:						
1	Chemical-pharmaceutical Ent.	124 Tay Son	6000	200		
2	Chemical-pharmaceutical Ent.	82 Vinh ho	6000	200		
3	Chemical-pharmaceutical plant	Tay Son	10000	330		
4	Mechanical factory of Dong Da	125 Tay Son	6000	200		
5	Mechanical plant of Dong Da	Tay Son	16000	530		
6	Pharmaceutical Ent. no. 1	160 Phan Van Tri	6000	200		
8	Wool carpet Enterprise	Nam Dong	8000	260		
16	'Cu Doanh' textile mill	Tran Quy Cap	25000	820		
21	Glassware factory	356 Tay Son	6000	200		
22	Train maintenance station	118 Nam Bo	7000	230		
23	Mashinery tool plant no.1	Cau Moi	10000	330		2000
26	Locomotive repairing station	2 Kham Thien	5000	165		
27	Ruber product plant of Hanoi	21 Cat Linh	20000	660		
29	Cotton shoes factory of Hanoi	Thuong Dinh	80000	2600		
32	The Thong Nhat bicycle factory	Tay Son	20000	660		
33	Mechanical tool factory	Vinh Ho	10000	330		
34	'To chau' dying mill	Ngo Si Lien	8000	260		
35	'To chau' dying mill	Ngo Si Lien	6000	200		
36	Union of tobacco factories	Thanh xuan	60000	2000		
38	Hanoi soup factory	Thanh xuan				
39	The pulp and thermo flask f.	Thuong Dinh	40000	1320		
40	The pulp and thermo flask f.	Ha Dinh	35000	1150		
41	The pulp and thermo flask f.	Thanh Xuan	10000	330		
42	Sophisticated mechanical f.	Nga Tu So	6000	200		
43	'Hoa Binh' car factory	Trieu Khuc	5000	165		
44	'Hoa Binh' car factory	Trieu Khuc	10000	330		500
107	'Sao vang' rubber factory	Thanh xuan			1)	15000
109	Photographical paper factory	Thanh xuan				
110	Vehical factory '19-8'	Thanh xuan				
111	Magnetic material enterprise	Thanh xuan				
112	Cinematography instrument f.	Nguyen trai				
113	Bulb-Thermos factory	Nguyen trai				
114	High accuracy mechanical fact.	Nguyen trai				
128	Tradditional medicine factory	Thanh xuan				500
DONG DA total:			421000	13870		18000
HOAN KIEM district:						
91	Plastic product factory	27 Hai Ba Trung	5000	165		
127	Hanoi ice factory	Tranh Nhat Dnat				4000
HOAN KIEM total:			5000	165		4000

Notes: 1) The plant is common with 38

(to be continued)

2) The number refers to the map showing the location of factories

TABLE 6.3-2 LIST OF MAIN INDUSTRIAL ENTERPRISES WITHIN HANOI CITY (continued)

Ref. no. 2)	Type of industry	Address	Estimated consumption from public network (m3/month)	(m3/d)	Estim. capacity of own water plant	(m3/d)
HAI BA TRUNG district:						
49	'Mai Dong' mechanical factory	Minh Khai	15000	490		
50	Electro-mechanical factory	Tuong Mai	10000	330		
51	Tran Hung Dao mechanical f.	Mai Hac De	8000	260		1500
52	Tran Hung Dao mechanical f.	Mai Dong	15000	490		
53	Pharmaceutical Enterp. no.2	Thanh Tong	16000	530		
54	'Ba Nhat' chemical factory	300 Bach Mai	55000	1810		
55	Dong Xuan textile plant	Ngo Thoi Nhan	15000	490	I	2000
56	Dong Xuan textile plant	Nguyen Cong Tru	20000	660	I	
59	'Hai chau' sweet factory	Minh Khai	12000	400		
60	'Hai Ha' sweet factory	25 Truong Dinh	34000	1120		
61	'Hai Ha foodstuff factory	25 Hoang Mai	6000	200		
62	The factory of canning prod.	Tuong Mai	10000	330		
63	The factory of canning prod.	Tuong Mai	40000	1320		
64	The towel textile mill	Minh Khai	6000	200		
65	The foodstuff fact. of Hanoi	Ngo Quynh	8000	260		
66	The foodstuff fact. of Hanoi	Minh Khai	26500	870		
67	The foodstuff fact. of Hanoi	254 Minh Khai	5000	165		
68	Beer and wine factory	94 Lo Duc	45000	1480		3000
69	The Hanoi alcohol factory	Nguyen Cong Tru	100000	3290		
73	'Hoang Mai' powder Ent.	'57 truong dinh	8000	260		
115	Minh khai locks enterprise	Minh khai				
116	Carpenter workshop	Minh khai				
117	Hanoi fibre factory	Minh khai				2000
118	Thang long tailosing enterprise	Minh khai				
119	Hanoi intustirial textile fac.	Mai dong				
120	Textile factory 8-3	Minh khai				6000
121	Hanoi thread factory	Minh khai				
122	Glasswere factory 'thanh duc'	Truong dinh	3000	100		
HAI BA TRUNG total:			457500	15055		14500
BA DINH district:						
98	The documentary film studio	122 Hoang Hoa Tham	12000	400		
123	'Hong ha' chemical enterprise	Buoi ba dinh	150	5		
124	'Truc bach' paper enterprise	Thuy khe Ba dinh	4500	150		
125	Leather factory	Thuy khe Ba dinh	4500	150		
140	Hanoi beer factory	Hoang Hoa Tham				3000
BA DINH total:			21150	705		3000
HANOI total:			904650	29795		39500

TABLE 6.3-3 LIST OF MAIN PUBLIC CONSUMERS WITHIN HANOI CITY
(consumption over 5000 m3/month)

Ref. no.	Type of user	Address	Estimated consumption from public network (m3/month)	(m3/d)	Estim. capacity of own plant (m3/d)
DONG DA district:					
7	Service co. for passengers	Tran Quy Cap	6000	200	
9	Restaurant co. of Dong Da	27 Quoc Tu Giam	7600	250	
10	The college of conservation	Thai Ha	18500	610	
11	The college of bank	Chua Boc	6000	200	
12	The college of trade union	Tay Son	5000	165	
13	The college of medicine	Khuong Thuong	5000	165	
14	Constr.co. (Light ind. minist.)		5000	165	
15	Civil constr. co.	Van Chuong	7000	230	
18	Account sect.of propagation dep.	Thai Ha	20000	660	
19	Account sect.of propagation dep.	Thai Ha	6000	200	
20	Account sect.of propagation dep.	Thai Ha	14000	460	
24	The office of railway dept.	3 Kham Thien	5000	165	
25	The office of railway dept.		7000	230	
28	Bac Mai hospital		30000	990	
30	Children hospital	Lang Thuong	30000	990	
31	The union of bike factories	Thai Ha	8000	260	
45	Dong Da hospital	Nam Dong	5000	165	
46	Institute of foodstuff ind.	Thanh Xuan	6000	200	
47	Institute of foodstuff ind.	Ha Dinh	6000	200	
48	Printing house of bank	Chua Boc	5000	165	
129	Giap Bat railway station				2500
130	Viet Nam Television station				1000
134	Communic. & transport. college				500
DONG DA total:			202100	6670	4000

(to be continued)

TABLE 6.3-3 LIST OF MAIN PUBLIC CONSUMERS WITHIN HANOI CITY (Continued)

Ref. no.	Type of user	Address	Estimated consumption from public network (m3/month)	(m3/d)	Estim. capacity of own plant (m3/d)
HAI BA TRUNG district:					
57	Installation constr. co.	250 Minh Khai	5000	165	
58	Enterp. of garment for export	250 Hai Dong	6000	200	
70	The office of Forestry Ministry	127 Lo Duc	20000	660	
71	Constr. machinery Enterp.	199 Minh Khai	6000	200	
72	Foodstuff company	141 Thuong Dinh	8000	260	
74	Foreign Trade Ministry	9 Le Qui Don	5000	165	
75	Hanoi university		5000	165	
76	The polytechnic college	Bach Mai	29500	970	
77	The polytechnic college	Bach Mai	20000	660	500
78	The polytechnic college	Kim Lien	14200	470	
79	The college of National Economy	Dai La	16000	530	
80	Hygienic and Epidemic institute	Tho Lao	5000	165	
81	Army hospital 108	Tran Hung Dao	40000	1320	
82	Industrial construction co.	Mai Huong	5000	165	
83	Union of machinery install. Ent.	Minh Khai	5000	165	
84	Vietnam - USSR hospital	Tran Khanh Du	65000	2140	
85	Vietnam - USSR hospital	Tran Khanh Du	12000	400	
86	Civil construction co.	Thanh Nhan	12000	400	
HAI BA TRUNG total:			278700	9200	500
HOAN KIEM district:					
87	Power company	16A Tran Nguyen Ha	5000	165	
88	Vietnam - Germany hospital	Trang Thi	8000	265	
89	Ministry of Internal affairs	44 Yet Kieu	8000	265	
90	Vietnam - Cuba hospital	92 Tran Hung Dao	6000	200	
92	Vietnam - USSR palace		5000	165	
93	Union of textile enterprise	46 Hang Quat	4500	150	
94	Don Xuan market		4000	130	
95	Power supply department	24 Ly Thai To	5000	165	
96	'Thong Nhat' rubber factory (head office)	141 Le Duan	6000	200	
HOAN KIEM total:			51500	1705	0

(to be continued)

TABLE 6.3-3 LIST OF.MAIN PUBLIC CONSUMERS WITHIN HANOI CITY (Continued)

Ref. no.	Type of user	Address	Estimated consumption from public network (m3/month)	(m3/d)	Estim. capacity of own plant (m3/d)
BA DINH district:					
97	The State financial commission	Quang An	13000	430	
99	Construction co. no. 3	Doi Can	7000	230	
100	Education office (Defend Min.)	Hoang Dieu	7000	230	
101	Education office (Defend Min.)	Quan Ngua	5000	165	
102	Education office (Defend Min.)	Hoang Van Thu	6000	200	
103	Unit 14113 (military)	Quan Ngua	6000	200	
104	Unit 17331	Kim Ma	8000	265	
105	Unit 14067	Cong Vi	7000	230	
106	Tuberculosis Institute	Cong Vi	5000	165	
BA DINH total:			64000	2115	
HANOI total:			596300	19690	

6.5 Future trends in water consumption

6.5.1 Water demand projection to 2010

The consumption estimates for Hanoi city are being presented in this chapter based on the presented values in chapter 6.2 and the general tendencies in water use habits during the recent years.

The international values presented did clearly stand for different models in the future development of water use pattern.

The high values represent the water use model prevailing in 1950-60's. It was a time of rapid, almost uncontrolled increases in the amount of water consumed for different purposes. Therefore also the future design criteria were high.

The realised consumption values from 1980's in several countries indicate, however, a definite turn in the development. The short time passed make it not possible to draw very detailed conclusions, but it seems probable that the factors effecting for the turn will remain constant. The most important are economical reasons: the financial burden of constructing, operating and maintaining a water supply and distribution system was growing unbearable. Another increasingly decisive factor is environmental protection, which is directing water use towards more efficient utilization of resources, recirculation and improved treatment processes.

A questionnaire among Vietnamese specialists and organizations concerned was being carried out to establish a sound and proper basis for the future consumption estimates. The results of this study is presented in figure 6.5-1.

It can be seen that there is about 100,000 m3/d difference in the estimates of the present consumption. If this is taken as zero then the difference between the lowest and highest estimates in 2000 and 2010 are 150,000 m3/d and 200,000 m3/d respectively. The speed of water consumption growth is rather uniform in all the estimates after the year 2000.

Generally the high estimates were due to difficulties in estimating the industrial and public works consumptions. Also there were some difficulties in estimating the values for the group 'cleaning and irrigation', as some considered the 'domestic irrigation' belonging to this group. Very important factor to note was that the estimates for domestic use and other use

ESTIMATOR:

2. YME
3. HANOI FUNDAMENTAL CONSTRUCTION COMMITEE
4. CONSTRUCTION MINISTRY /STANDARDIZATION DEPT.
5. CONSTRUCTION MINISTRY/ DESIGN COMPANY
6. HANOI OFFICE OF URBAN PUBLIC WORKS
7. HANOI FUNDAMENTAL CONSTRUCTION COMMITEE / PLANNING INSTITUTE
8. HANOI OFFICE OF URBAN PUBLIC WORKS / DESIGN ENTERPRISE
9. HANOIOFFICE OF URBAN PUBLIC WORKS / ENGINEERING SECTOR
10. HANOI WATER SUPPLY COMPANY
11. CONSTRUCTION MINISTRY

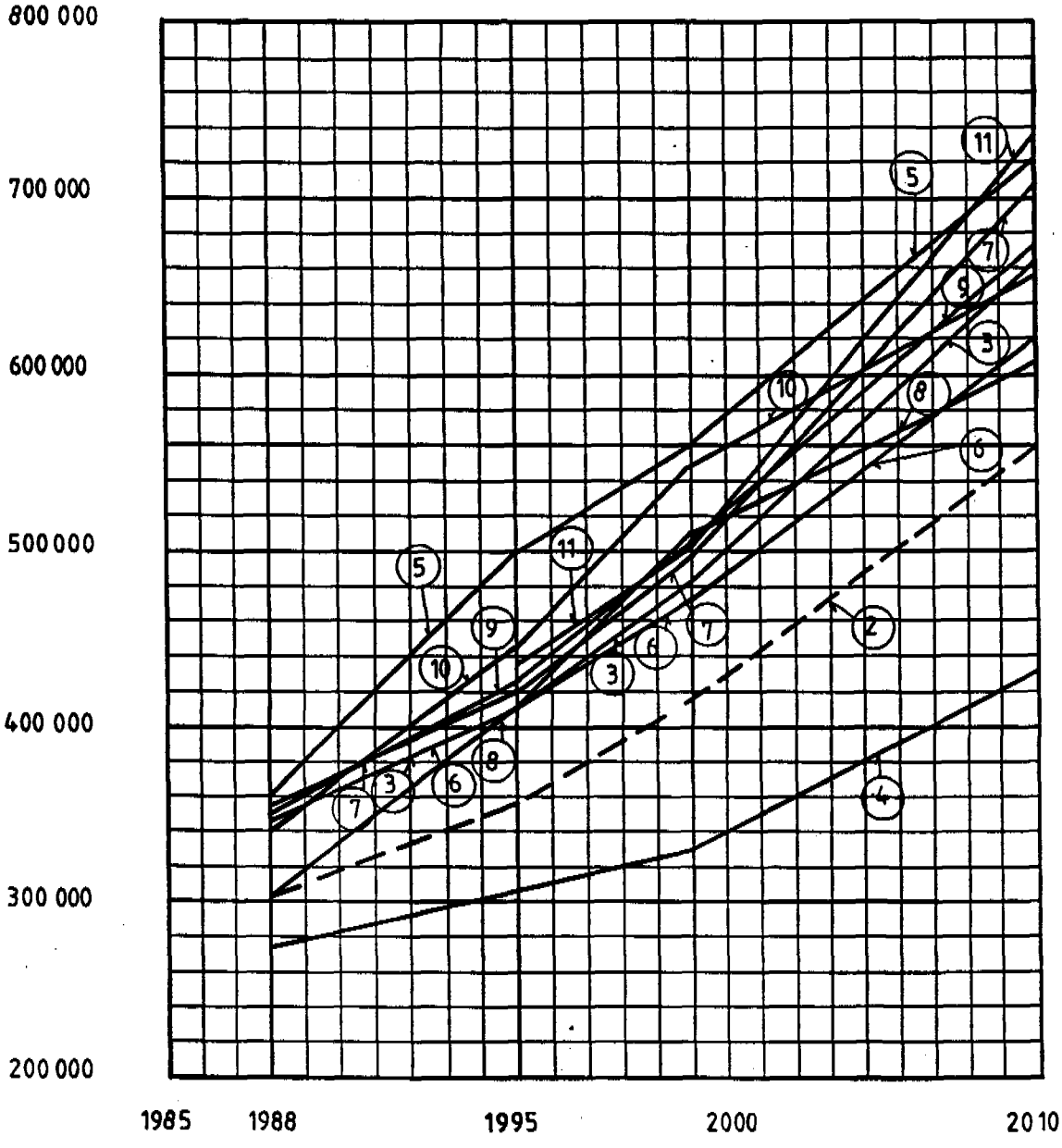


FIGURE 6.5-1 WATER CONSUMPTION ESTIMATES FOR HANOI CITY FOR THE PERIOD 1988-2010 BY DIFFERENT SOURCES

that the estimates for domestic use and other use and losses (loss reduction) were rather uniform. The highest value proposed for domestic use was 200 l/c/d.

After discussions with the Vietnamese representatives the specific consumption figures to be used in system dimensioning were fixed as presented in tables 6.5-1 to 6.5-3 and figures 6.5-2 and 6.5-3. There is also the consumption calculations for each user category presented. In table 6.5-1 is presented the total consumption projection for the whole urban area as defined in chapter 5, including also Tam Hiep industrial area (I6). In table 6.5-2 is presented the consumption projection for right side of Red River excluding Tam Hiep industrial area, and in table 6.5-3 the consumption projection for Gia Lam on the left side of Red River.

The calculations for Gia Lam are based on information obtained from Planning Institute rather than average unit consumption figures as the area includes only one separate industrial area (I7) and one civil area (37).

Average and peak day consumption calculations are presented in tables 6.5-4 and 6.5-5.

There was a difference between the final figures and the consultant's proposals as follows:

Category	Final figures	Consultant's prop.
Domestic 1995 (l/c/d)	120	100
Domestic 2000 (l/c/d)	150	125
Domestic 2010 (l/c/d)	180	160
Industry 2010 (m3/ha/d)	35	30
Total consumption (m3/d)		
- 1955	393,000	358,000
- 2000	458,000	415,000
- 2010	622,000	564,000

TABLE 6.5-1 WATER CONSUMPTION PROJECTION FOR HANOI CITY FOR THE YEARS 1988 - 2010

Year	Population	Industrial areas		CONSUMPTION IN EACH USER CATEGORY								
		Area	Manpower	Domestic	Small industry	Public works	Cleaning & irrigation	Industry	Losses & other use	Total consumption	losses included	losses excluded
		(ha)		(l/c/d)	(l/c/d)	(l/c/d)	(l/c/d)	(m3/ha/d)	(%)			
				(m3/d)	(m3/d)	(m3/d)	(m3/d)	(m3/d)	(m3/d)	(m3/d)	(l/c/d)	(l/c/d)
				(% of total specific consumption)								
				1	2	3	4	5	6			
1988	937000	1100	111000	70	5	35	5	40	50			
				66000	5000	33000	5000	44000	153000	306000	327	163
				22	2	11	2	14	50			
1995	1048000	1300	115000	120	8	40	8	40	40			
				126000	8000	42000	8000	52000	157000	393000	375	225
				32	2	11	2	13	40			
2000	1120000	1800	117000	150	10	40	10	35	35			
				168000	11000	45000	11000	63000	160000	458000	409	266
				37	2	10	2	14	35			
2010	1400000	2800	167000	180	15	40	15	35	28			
				252000	21000	56000	21000	98000	174000	622000	444	320
				41	3	9	3	16	28			

Note: The industrial consumption figures include the demand for Tan Hiep (I6) area, which is not included in WMP studies, 4,500 m3/d in 1988, 7,700 m3/d in 1995, 10,700 m3/d in 2000 and 23,900 m3/d in 2010.

TABLE 6.5-2 WATER CONSUMPTION PROJECTION FOR HANOI CITY FOR THE YEARS 1988 - 2010
(Right side of Red River excluding industrial area I6: Tan Hiep)

Year	Population	Industrial areas		CONSUMPTION IN EACH USER CATEGORY						Total consumption	losses included	losses excluded
		Area	Manpower	Domestic	Small industry	Public works	Cleaning & irrigation	Industry	Losses & other use			
		(ha)		(l/c/d)	(l/c/d)	(l/c/d)	(l/c/d)	(m3/ha/d)	(%)			
				(m3/d)	(m3/d)	(m3/d)	(m3/d)	(m3/d)	(m3/d)	(m3/d)	(l/c/d)	(l/c/d)
				(% of total specific consumption)								
				1	2	3	4	5	6			
1988	922000	860	86240	70	5	35	5	40	50			
				65000	5000	32000	5000	34000	141000	282000	306	153
				23	2	11	2	12	50			
1995	1029000	945	89700	120	8	40	8	40	40			
				123000	8000	41000	8000	38000	145000	363000	353	212
				34	2	11	2	10	40			
2000	1099000	1250	91440	150	10	40	10	35	35			
				165000	11000	44000	11000	44000	148000	423000	385	250
				39	3	10	3	10	35			
2010	1326585	1675	127000	180	15	40	15	35	28			
				239000	20000	53000	20000	59000	152000	543000	409	295
				44	4	10	4	11	28			

TABLE 6.5-3 WATER CONSUMPTION PROJECTION FOR GIA LAM FOR THE YEARS 1988 - 2010
(Left side of Red River)

Year	Population	Industrial areas			CONSUMPTION IN EACH USER CATEGORY								
		Area	Manpower		Domestic	Small industry	Public works	Cleaning & irrigation	Industry	Losses & other use	Total consumption	losses included	losses excluded
		(ha)			(l/c/d)	(l/c/d)	(l/c/d)	(l/c/d)	(m3/ha/d)	(%)			
					(m3/d)	(m3/d)	(m3/d)	(m3/d)	(m3/d)	(m3/d)	(m3/d)	(l/c/d)	(l/c/d)
					(% of total specific consumption)								
					1	2	3	4	5	6			
1988	15000	90	9020	I	70	7	19	4	31	50			
				I	1050	110	290	60	2790	4300	8600	573	287
				I	12	1	3	1	32	50			
1995	19000	105	9400	I	120	10	16	4	32	40			
				I	2280	190	300	80	3360	4190	10400	547	327
				I	22	2	3	1	32	40			
2000	21000	150	9530	I	150	10.3	12.5	5	28	35			
				I	3150	220	260	110	4200	4260	12200	581	378
				I	26	2	2	1	34	35			
2010	73415	290	12000	I	180	5.7	5.2	7	29	28			
				I	13210	420	380	510	8410	8870	31800	433	312
				I	42	1	1	2	26	28			

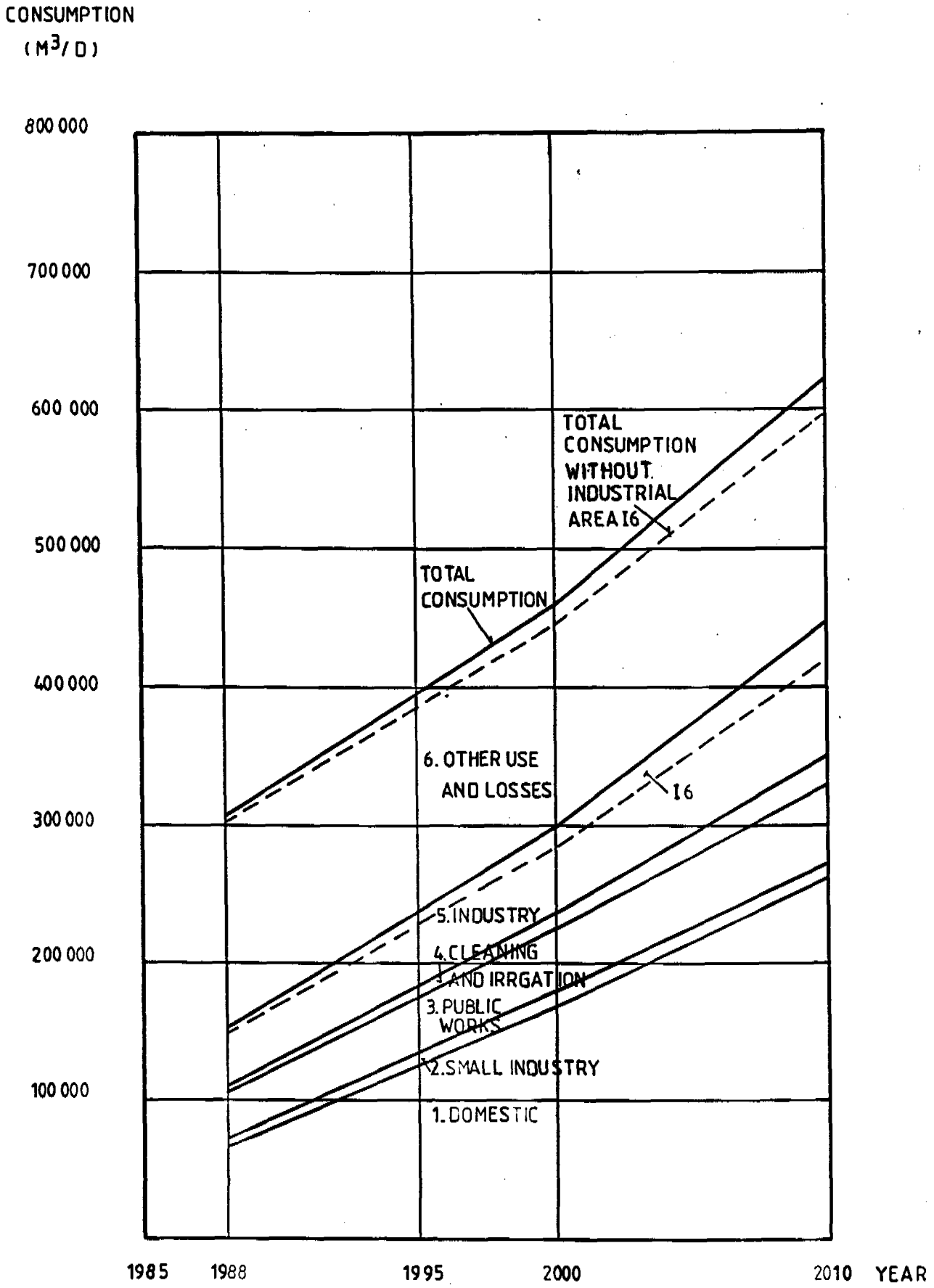


FIGURE 6.5-2 WATER CONSUMPTION PROJECTION FOR HANOI CITY FOR THE YEARS 1988-2010

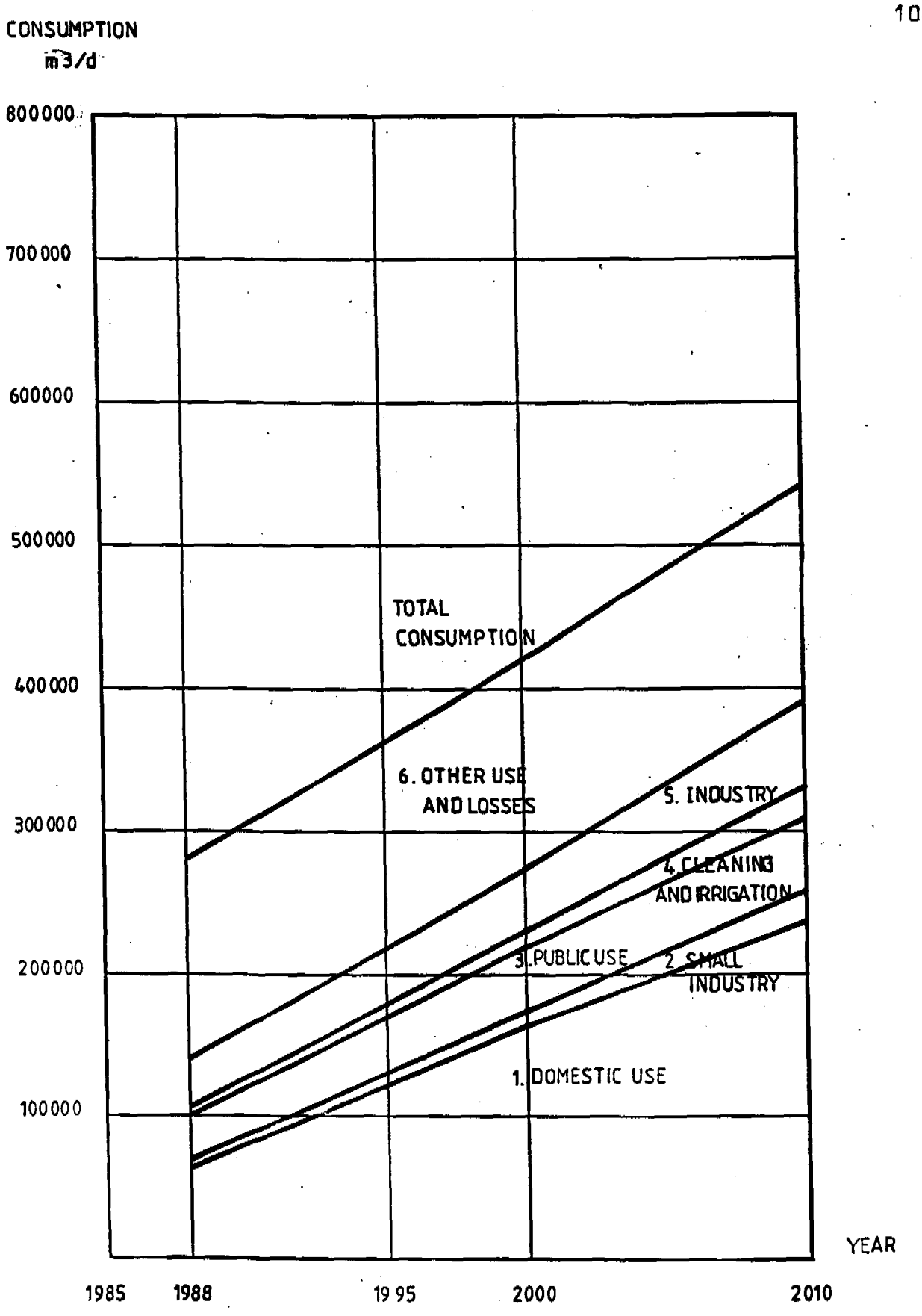


FIGURE 6.5 -3 WATER CONSUMPTION PROJECTION FOR RIGHT SIDE OF RED RIVER EXCLUDING INDUSTRIAL AREA I6

TABLE 6.5-4 AVERAGE AND PEAK DAY CONSUMPTION CALCULATIONS FOR THE YEARS 1988, 1995, 2000 AND 2010
(Right side of Red River excluding Tam Hiep industrial area I6)

Year	Category of use	Population	Area (ha)	Unit cons. (l/c/d) (l/ha/d)	Average consumpt. (l/s)	(m3/d)	Peak day coeffic.	Peak day consumption (l/s)	(m3/d)
1988	Domestic	922000		70	752	65000	1.2	903	78000
	Small industry	922000		5	58	5000	1.2	69	6000
	Public works	922000		35	370	32000	1.2	444	38400
	Cleaning & irrig.	922000		5	58	5000	1.2	69	6000
	Industry		860	40	394	34000	1.1	433	37400
	Other use & losses			50 %	1632	141000		1632	141000
Totals in 1988		922000		306	3264	282000		3551	306800
1995	Domestic	1029000		120	1424	123000	1.3	1851	159900
	Small industry	1029000		8	93	8000	1.3	120	10400
	Public works	1029000		40	475	41000	1.3	617	53300
	Cleaning & irrig.	1029000		8	93	8000	1.3	120	10400
	Industry		945	40	440	38000	1.1	484	41800
	Other use & losses			40 %	1678	145000		1678	145000
Totals in 1995		1029000		353	4201	363000		4870	420800
2000	Domestic	1099000		150	1910	165000	1.4	2674	231000
	Small industry	1099000		10	127	11000	1.4	178	15400
	Public works	1099000		40	509	44000	1.4	713	61600
	Cleaning & irrig.	1099000		10	127	11000	1.4	178	15400
	Industry		1250	35	509	44000	1.1	560	48400
	Other use & losses			35 %	1713	148000		1713	148000
Totals in 2000		1099000		385	4896	423000		6016	519800
2010	Domestic	1326585		180	2766	239000	1.4	3873	334600
	Small industry	1326585		15	231	20000	1.4	324	28000
	Public works	1326585		40	613	53000	1.4	859	74200
	Cleaning & irrig.	1326585		15	231	20000	1.4	324	28000
	Industry		1675	35	683	59000	1.1	751	64900
	Other use & losses			28 %	1759	152000		1759	152000
Totals in 2010		1326585		409	6285	543000		7890	681700

TABLE 6.5-5 AVERAGE AND PEAK DAY CONSUMPTION CALCULATIONS FOR THE YEARS 1988, 1995, 2000 AND 2010
(Left side of Red River, Gia Lam)

Year	Category of use	Population	Area (ha)	Unit cons. (l/c/d) (l/ha/d)	Average consumpt. (l/s)	(m3/d)	Peak day coeffic.	Peak day consumption (l/s)	(m3/d)
1988	Domestic	15000		70	12	1050	1.2	15	1260
	Small industry	15000		7	1	110	1.2	2	130
	Public works	15000		19	3	290	1.2	4	350
	Cleaning & irrig.	15000		4	1	60	1.2	1	70
	Industry		90	31	32	2790	1.1	36	3070
	Other use & losses			50 %	50	4300		50	4300
Totals in 1988		15000		573	100	8600		106	9180
1995	Domestic	19000		120	26	2280	1.3	34	2960
	Small industry	19000		10	2	190	1.3	3	250
	Public works	19000		16	3	300	1.3	5	390
	Cleaning & irrig.	19000		4	1	80	1.3	1	100
	Industry		105	32	39	3360	1.1	43	3700
	Other use & losses			40 %	48	4190		48	4190
Totals in 1995		19000		547	120	10400		134	11590
2000	Domestic	21000		150	36	3150	1.4	51	4410
	Small industry	21000		10.3	3	220	1.4	4	310
	Public works	21000		12.5	3	260	1.4	4	360
	Cleaning & irrig.	21000		5	1	110	1.4	2	150
	Industry		150	28	49	4200	1.1	53	4620
	Other use & losses			35 %	49	4260		49	4260
Totals in 2000		21000		581	141	12200		163	14110
2010	Domestic	73415		180	153	13210	1.4	214	18490
	Small industry	73415		5.7	5	420	1.4	7	590
	Public works	73415		5.2	4	380	1.4	6	530
	Cleaning & irrig.	73415		7	6	510	1.4	8	710
	Industry		290	29	97	8410	1.1	107	9250
	Other use & losses			28 %	103	8870		103	8870
Totals in 2010		73415		433	368	31800		445	38440

6.5.2 Industrial demand breakdown

The standards for industrial demand calculations are usually on per unit product or per employee basis. Very rough methods are based on the area required for the specific industries. The differences in reported specific water amounts are wide, and that reflects differences in technologies.

Usually the water from the municipal water supply systems is being used by industries, whose water demand when compared to the other industries, is relatively small, but the quality requirements are high like food processing, textiles, a part of metal and chemical industries, breweries and laundries.

The industries whose water demand is high like ferrous and steel industries, pulp and paper and petrochemical industries usually take only the sanitary waters from the municipal networks, while the main part is being produced by themselves.

Efforts towards achieving greater efficiency in the use of water resources in industry should consider the application of new/advanced technologies that would enable: the reduction of water withdrawals from natural water bodies by further development of wastewater recycling systems; the use of treated municipal wastewater, treated industrial wastewater; the reduction of consumptive losses by eliminating leakages and process losses in industry; the introduction of dry cooling techniques and eliminating non-productive water losses; and effective control over maintaining low water consumption rates.

The available information concerning industrial development in Hanoi city, i.e. the location of main industrial areas, the type of industries and their area and manpower requirements are presented in table 5.3-4 and the relevant land use maps. Some information concerning the present main industries are presented in table 6.3-2 and their location in drawing No...

In this study the consumption calculations shall be based on known international standard rates, as information on industrial water requirements, production capacities and methods of industrial plants etc. from concerned departments and agencies are not available. One very rough, but simple method is to use standard unit consumption per hectare for an 'average' industrial area.

According to literature this unit consumption varies in between 20-33 m3/ha/d and the figure of 25 m3/ha/d can be considered as an average. In South-East Asia, some figures have been reported:

- 45 m3/ha/d for Manila
- 35 m3/ha/d for Jakarta

For Hanoi it is rather difficult to calculate this figure, as the withdrawal from the city network is not known and even the area allocated for industries is not that accurate. The limits for this figure have been estimated to be 35 - 50 m3/ha/d. It has to be kept in mind, that these figures include the losses inside the factories (beyond the meter if existing), but not these of the city network. Thus for an industrial area, in Hanoi case, the total allocation is the unit consumption plus 50 - 28 % of losses depending on the year concerned.

It should be rather easy to decrease the unit consumption by the passage of time by applying new and advanced technologies as presented earlier in this chapter.

The industries have been categorized into three groups according to their water need:

I Textile and dying industries

II Food processing industries

III Mechanical, chemical, construction material, ceramics, glassware etc, industries.

The following unit consumptions have been used for different development phases:

Group	Industrial consumption (m3/ha/d) 1989	1995	2000	2010
I	88	88	78	75
II	77	76	71	70
III	30	30	25	25
Average	40	40	35	35

It has been assumed, based on experiences from different international studies, that group 1 water consumption is roughly three times and

group 2 water consumption 2.7 times group three water consumption. The figures have been adjusted to come to the presented average figures representing the total of industrial areas of the city by weighing with the areas concerned.

The share of each individual industrial area into these categories as estimated by the Planning Institute as well as the consumption calculations by different development phases have been presented in table 6.5-6.

For the industries outside these main industrial areas an average figure in each planning year, as presented above, will be adopted.

6.5.3 Civil demand breakdown

Civil water consumption includes the categories domestic use, small industries, public works use and cleaning and irrigation. The total consumption estimates of each category in different development phases have been presented in tables 6.5-1 to 3. The methods of dividing these total consumption figures to each planning blocks as presented in table 5.3-2 and land use maps are described in this chapter.

The calculated total consumptions have been allocated on the planning area on the basis of land use and population information, supplied by the Planning Institute. The practical method has been as follows:

- Domestic consumption has been divided on the basis of population amount in each separate residential subarea.
- Public works consumption has been divided in proportion to the public works subarea of the total public works area.
- Small industries use has been divided in proportion to the small industries subarea of the total small industries area.
- Cleaning and irrigation consumption has been first divided into two components, cleaning of roads and squares and irrigation of green plantations, then allocated 1.0 l/m2/d for green plantations and the same for squares and roads in proportion to the civil or industrial subarea of the total city area.

TABLE 6.5-6 INDUSTRIAL CONSUMPTION CALCULATION BY DIFFERENT CATEGORIES FOR THE YEARS 1989, 1995, 2000 AND 2010

Year	Ind. area No.	Category I			Category II			Category III			Totals		
		(%)	Area (ha)	Consump. (m3/d)	(%)	Area (ha)	Consump. (m3/d)	(%)	Area (ha)	Consump. (m3/d)	Area (ha)	Consumption (m3/d)	(m3/ha/d)
1989	I 1	7.0	3.9	339				93.0	51.2	1535	55	1873	34.1
	I 2				14.0	4.2	323	86.0	25.8	774	30	1097	36.6
	I 3				3.0	7.8	601	97.0	252.2	7566	260	8167	31.4
	I 4	41.0	102.5	9020	20.0	50.0	3850	39.0	97.5	2925	250	15795	63.2
	I 5							100.0	85.0	2550	85	2550	30.0
	I 6							100.0	150.0	4500	150	4500	30.0
	I 7				3.0	2.7	208	97.0	87.3	2619	90	2827	31.4
Totals		11.6	106.4	9359	7.0	64.7	4982	81.4	748.9	22468	920	36809	40.0
1995	I 1	7.0	4.6	400				93.0	60.5	1814	65	2214	34.1
	I 2				14.0	5.6	426	86.0	34.4	1032	40	1458	36.4
	I 3				3.0	9.0	684	97.0	291.0	8730	300	9414	31.4
	I 4	42.0	126.0	11088	20.0	60.0	4560	38.0	114.0	3420	300	19068	63.6
	I 5							100.0	85.0	2550	85	2550	30.0
	I 6				2.0	5.0	380	98.0	245.0	7350	250	7730	30.9
	I 7				5.0	5.3	399	95.0	99.8	2993	105	3392	32.3
Totals		11.4	130.6	11488	7.4	84.9	6449	81.2	929.6	27888	1145	45825	40.0
2000	I 1	7.0	5.3	410				93.0	69.8	1744	75	2153	28.7
	I 2				15.0	14.6	1033	85.0	82.5	2061	97	3094	31.9
	I 3				3.0	10.1	714	97.0	325.0	8124	335	8837	26.4
	I 4	43.0	172.0	13416	20.0	80.0	5680	37.0	148.0	3700	400	22796	57.0
	I 5							100.0	85.0	2125	85	2125	25.0
	I 6				4.0	16.0	1136	96.0	384.0	9600	400	10736	26.8
	I 7				6.0	9.0	639	94.0	141.0	3525	150	4164	27.8
Totals		11.5	177.3	13826	8.4	129.6	9202	80.1	1235.2	30879	1542	53906	35.0
2010	I 1	6.0	6.1	454				94.0	94.9	2374	101	2828	28.0
	I 2				17.0	22.1	1547	83.0	107.9	2698	130	4245	32.7
	I 3				4.0	18.4	1288	96.0	441.6	11040	460	12328	26.8
	I 4	45.0	261.0	19575	21.0	121.8	8526	34.0	197.2	4930	580	33031	57.0
	I 5							100.0	85.0	2125	85	2125	25.0
	I 6				8.0	66.8	4676	92.0	768.2	19205	835	23881	28.6
	I 7				9.0	26.1	1827	91.0	263.9	6597	290	8425	29.1
Totals		10.8	267.1	20030	10.3	255.2	17864	78.9	1958.7	48969	2481	86862	35.0

- Other use and losses have been divided for all user categories in proportion to their water consumption.

- The industrial consumption within civil areas has been divided for the civil areas having today industries within them in proportion to the area.

6.5.4 Peak consumption calculations

The peak consumption calculations based on the population and land use forecasts as presented in chapter 5 and specific consumption figures and variation coefficients as presented earlier in this chapter for each of the 43 'civil blocks' and 7 industrial areas are presented in Appendix 2 of this report.

The calculations presented in Appendix 2 along with the relevant land use maps form the database for the Hanoi water supply network planning and dimensioning. The method of network dimensioning is presented in chapter 7.

7. WATER SUPPLY SYSTEM OPTIONS

7.1 General

In this chapter are presented the results of the water supply option designs. They are based on data and studies presented in Chapters 2 to 6. The main difficulty in the option design has been the co-ordination with the groundwater studies, which did not go along with master planning. Therefore the option studies had to be based on assumed groundwater resources potentials. Before any decisions can be made the water resources availability have to be secured by comprehensive hydrogeological studies.

The basic idea in the option design has been to design as uniform systems as possible for the nearest five year period to avoid risk investments and to allow time for hydrogeological studies. This has, however, not been possible in full extent, but it should be possible to accommodate the nearest development in any of the options without big risks.

7.2 Water production requirements

7.2.1 Clean water production demand

Future clean water production has to be based on the water demand estimates of the city discussed in chapter 6. The production capacity of the plants has to meet the peak day demand in order to satisfy the water demand also during the peak day consumption situation without huge reservoirs. The peak hour situation is usually handled with the adjustment of the pumping capacity and the capacity of the reservoirs.

The water production demand curves for the whole planning period 1989-2010 are presented in figure 7.1-1 separately for the right side of Red River and for Gia Lam. The present (June 1989) estimated total production capacity of the main plants is about 230,000 m3/d and the capacity of the small plants about 60,000 m3/d making the total production capacity to about 290,000 m3/d. At the end of the second phase of HWSP in 1991 the production capacity should have increased to about 400,000 m3/d, if the project is successful. The total production demand of the city in 2010 will be about 720,000 m3/d. This means that about 320,000 m3/d of extra capacity has to be identified and implemented in 20 years time.

In this context the design capacity of a water treatment plant is considered to be the peak day capacity, f.ex. Mai Dich treatment plant capacity of 30,000 m3/d is representing the peak day

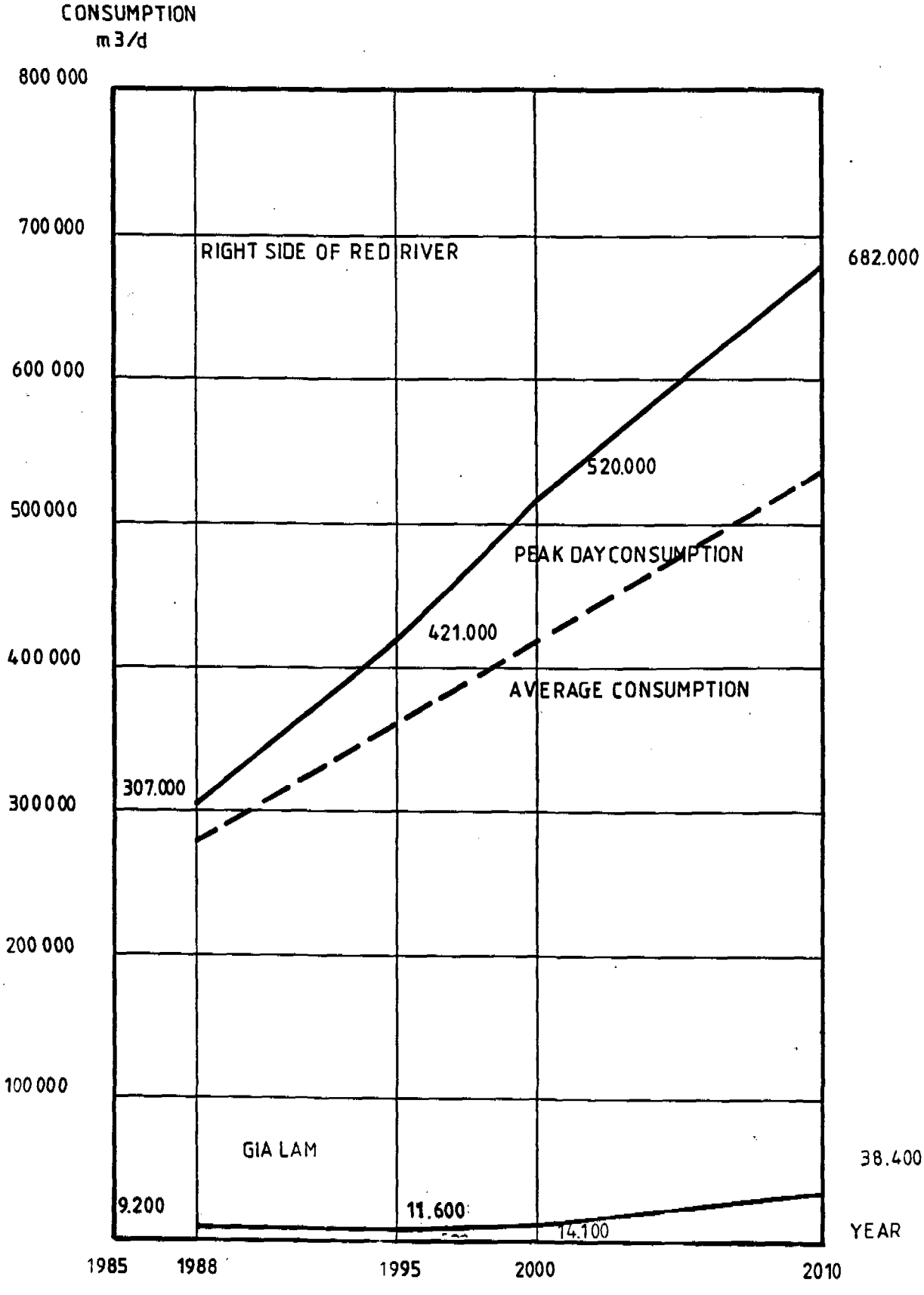


FIGURE 7.1-1 WATER PRODUCTION DEMAND CURVES
FOR THE PERIOD 1988-2010

HWSP/WMP89
JP6.6.1989

production capacity. It has been a standard during the FINNIDA aided Hanoi Water Supply Project to adapt a unit of 30,000 m3/d in new capacity implementation and extension. This means that 11 such units has to be constructed during the coming 20 years, 10 for the right side of Red River and one for Gia Lam.

7.2.2 Proposed plant development

The proposed development of the existing plants or new plants nearby the existing ones is presented in table 7.2-1. This is based on the recommendations by the hydrogeologist and discussions and considerations with the Vietnamese organisations concerned. The hydrogeological aspects will be discussed in a separate report by the hydrogeologist.

The main principle in increasing the total production capacity has been to locate the extensions along the Red River, where the raw water quality and the yield of the aquifer has been generally good, i.e. Luong Yen, Ngoc Ha and Yen Phu treatment plants. However, these plants are located nowadays in densely constructed areas, and therefore, the expression 'extension' does not strictly mean that the plant should be located to the same site as the existing one, but somewhere nearby where the site is available.

Another principle has been to gradually abandon the small plants, as the use of them is uneconomical and water quality control difficult. If there is still lifetime left beyond 1995, their use should be restricted out of the public network.

The additional capacity proposed above is not enough to meet the demand until 2010. Therefore, new sources amounting totally to about 270,000 m3/d have to be identified. The new wellfields have been proposed to be located outside the city, either in the north-west, upstream along the Red River or in the south-east, downstream along the river or if found feasible, both of these areas. Also a partial utilization of surface water resources from Tich River basin has been studied.

A description of the possible development of the treatment plants is presented hereunder:

Don Thuy

Don Thuy is a small treatment plant and the only one with pressure filters. The lifetime of the plant is expected to be over within 10 years. It has been planned to abandon the plant until 2000

TABLE 7.2-1 WATER PLANT PRODUCTION CAPACITY PROJECTION TO 2010

Water plant		Peak day capacities (m3/d) 1988	1991	1995	2000	2005	2010
Existing:							
Don Thuy		10000	10000	10000			
Ha Dinh		30000	30000	30000	30000	30000	30000
Luong Yen	1)	15000	45000	65000	75000	75000	75000
Mai Dich		30000	60000	60000	60000	60000	60000
Ngo Si Lien		45000	55000	55000	55000	55000	55000
Ngoc Ha	2)	27000	45000	45000	60000	60000	60000
Phap Van			30000	30000	30000	30000	30000
Tuong Mai		30000	30000	30000	30000	30000	30000
Yen Phu		45000	45000	75000	75000	75000	75000
Ha Dong	3)				15000		
Gia Lam	4)	11000	11000	11000	20000	20000	40000
Small plants		60000	50000	21000			
New plants total:					90000	180000	270000
Total production		303000	411000	432000	540000	615000	725000
Peak day demand		316000	369000	432000	534000	621000	720000

Notes:
1) A new plant of 30,000 m3/d will be constructed in 1995, but the total production will be only 65,000 m3/d until year 2000 when Don Thuy wellfield capacity will be connected to it.
2) Existing treatment plant will be abandoned and replased with a new one until the year 2000.
3) Existing treatment plant will be abandoned and replased with a new one until the year 2005.
4) Capacity of the existing plant is only 3,000 m3/d, but it is operated with the total raw water pumping capacity of about 11,000 m3/d.

and connect the wellfield to Luong Yen treatment plant.

Ha Dinh

The present proposed capacity of the plant is 30,000 m3/d. It has been planned to increase the capacity to 45,000 m3/d, but according to the present knowledge about the source it is not advisable, because of the drawdown, which is now over 20 m and is indicating too fast exploitation at the moment. Therefore the capacity of the plant has been proposed to remain on its present level.

Luong Yen

The present capacity of the plant is 15,000 m3/d and is proposed to be increased to 45,000 m3/d by constructing one new unit of 30,000 m3/d even during the second phase of the HWSP. The construction works have been delayed mainly due to difficult site clearance problems. Because of the good groundwater potential of this area, another unit of 30,000 m3/d is being proposed to be constructed before the year 2000. Site availability problems have to be cleared before any decisions can be made.

Mai Dich

The present capacity of this new plant is 30,000 m3/d and the enlargement of the plant is included in to the second phase of the project to reach the design capacity of the plant of 60,000 m3/d. This is also considered to be the maximum exploitable capacity of the nearby wellfield.

Ngo Si Lien

Ngo Si Lien present pumping into the network is estimated to be 45,000 m3/d, but the present raw water pumping capacity and the plant itself makes it possible to increase the capacity to 55,000 m3/d during the second phase of the project. The plant is in risky area in respect of possible contamination of the source, and therefore these resources have to be studied carefully. New investments to enlarge the plant are not being proposed.

Ngoc Ha

The capacity of the plant is today about 27,000 m3/d, but the plant is in miserable condition. Therefore the existing plant has been proposed to be abandoned within 10 years. An enlargement with a new unit of 30,000 m3/d has been included in to the second phase of the project, but has faced some difficulties, and is now being delayed. The

groundwater potential in the area is reported to be good, and therefore another unit of 30,000 m3/d is being proposed to be constructed in the vicinity of the area around the year 2000.

Phap Van

Phap Van is a new plant with a design capacity of 30,000 m3/d and will be taken into use in 1989. Very little information is available about the source potential and water quality and therefore no enlargements have been proposed for this area.

Tuong Mai

The present capacity of the plant is 30,000 m3/d, and due to the risk of contamination and high contents of iron in the raw water no enlargements have been proposed.

Yen Phu

Yen Phu present raw water pumping capacity of about 78,000 m3/d exceeds well the clean water production capacity of the plant, and the raw water pumping capacity can even be increased by locating the new wells upstream along the river. A new unit of 30,000 m3/d has been proposed to be constructed in 1995, but a new site has to be located.

Ha Dong

Ha dong is a small plant with a capacity of about 15,000 m3/d supplying water to Ha Dong town outside the present Hanoi urban area. The area shall be incorporated in to Hanoi area in 2000 and the network shall be connected to Hanoi network. It is proposed that the plant shall be extended in 2005 or totally replaced by a new one to reach the capacity of 30,000 m3/d. The groundwater potential seems to be good, but has to be studied more. The site for an extension is already available.

Gia Lam

The capacity of the present plant in Gia Lam, left side of Red River is only about 3,000 m3/d, but the plant is operated with 11,000 m3/d. The plant is proposed to be replaced with a new one of 20,000 m3/d in 2000 and with an extension of 20,000 m3/d in 2010.

New plants

It is recommended to study the groundwater potential to abstract a maximum of 240,000 m3/d in the north-west upstream the Red River (Cao Dinh and Co Nhue plants) and 90,000 m3/d in the

south-east downstream the Red River (Du Thuong plant). As there is no reliable data concerning these resources, optional water supply designs have been prepared.

A plant utilizing surface water resources with a capacity of 90,000 m3/d located in Ha Dong area is proposed to be studied.

7.3 Method of network dimensioning

7.3.1 Network modelling

The network calculations for the years 1995, 2000 and 2010 have been carried out by using the microcomputer version of the FLOW-programme. It is a simulating dimensioning program, which calculates the static balance of the system. It uses a variation of Newton-Rapson's method for solving a system of non-linear equations and either the Hazen-Williams or Manning flow equations to simulate flows in looped water distribution network. The flow formula used in Hanoi network calculations has been Hazen-Williams.

The process of network lay-out planning and dimensioning is presented hereunder.

The preparation of the network models for each option and for each planning year includes the following:

- formulation of the network geometry and simplification of the system by using the land use maps and the map of the existing network
- numbering of nodes and pipes
- estimating the preliminary pipe sizes
- selecting of pipe roughness coefficients
- definition of the ground level elevation at each node
- measurement of the pipe lengths

After the above described procedure has been carried out the consumptions at each node and the productions at the treatment plants have to be defined. The nodeflow calculations for each node has been based on peak flow calculations presented in Appendix 2, pipe lengths and their service coefficients. The input flow at treatment plants has been calculated in proportion to their capacity with the total input flow equal to the total consumption.

The program output includes the following data:

- flow in each pipe (l/s)
- head loss in each pipe (m)
- flow velocity in each pipe (m/s)
- elevation of pressure level in each node (m)
- pressure in each node (mwp)

The balance of the calculated network can be judged on the following basis:

- the pressure in network is adequate in all consumption points
- flow velocities and head losses of each pipe are within accepted limits

If the system is not in balance after the first run, the necessary revisions of pipe dimensions shall be done until the situation is corrected.

7.3.2 Calculation of Hanoi network

The calculation of Hanoi water supply network has been carried out assuming the system to be one homogeneous pressure area. The initial pressure level has been defined by a theoretical reservoir located by Mai Dich pumping station. It has to be kept in mind that the choice of reservoir location is having a great effect on the pumping head requirements at each separate pumping station and accordingly on the overall pressure level over the whole city. Therefore the results, as far as the pressure levels are concerned, are valid only if the initial pressure is fixed as assumed with a reservoir located at Mai Dich treatment plant. The optimal location of a main water tower has to be studied separately for the preferred water supply option.

Hanoi water supply system with many pumping stations pumping into the same network is rather complicated. The results of the calculations show the static balance of a specified consumption situation. The required pumping head at each pumping station to reach the balance is changing as a function of time and consumption and accordingly the choice of the pumps in order to operate them economically has to be done very carefully. In an integrated system like assumed in Hanoi it is not possible to fix the pumping head or the pressure level of a certain area,

f.ex. the old city area, to a preferred level without reducing the production at the treatment plant. Some adjustment can be done by applying pressure reducing device, but then energy is being lost unnecessarily.

The target pressure levels have been discussed in chapter 4. To avoid too high initial pressure levels at pumping stations, a general target value of 30 m have been set for the maximum head loss in the planning area. This value would result in a peak pressure of 50-55 m in the network. The minimum allowable pressure level in the network has been around 10 m.

The network used is greatly simplified and principally only main lines with diameter 300 mm or bigger have been included in calculations. The dimensioning situation has been the peak day peak hour consumption. The calculations for peak day and average day consumption situations have also been carried out.

The used roughness coefficients in Hazen-Williams flow formula have been C = 80 for the old cast iron pipes and C = 110 for all the new pipes.

The guideline limits for flow velocities have been defined so that in small pipes up to 300 mm the dimensioning velocity should be 0.8-1.0 m/s with respective head loss of 0.2-0.5 % and in big pipes 1.0-1.5 m/s with respective head loss of 0.2-0.5 %. To avoid deposits in the pipelines the velocity should not be less than 0.2-0.3 m/s. It has not been possible to follow these principles strictly, as some other factors may require that values failing to come up to the limit or exceeding the maximum have to be accepted.
For Gia Lam area with only one pumping station the program LOOP has been used to dimension the network. The basic data and principles have been the same as with the FLOW calculations.

7.4 Description of the Water Supply System Options

7.4.1 Option 1

The network layout and dimensioning is presented in figure 7.4-1 and the network calculations for the year 1995 in Appendix 3, for the year 2000 in Appendix 4 and for the year 2010 in Appendix 5.

In this option the incremental raw water capacity of about 265,000 m3/d in the year 2010 to produce 240,000 m3/d of clean water is proposed to be pumped from a big wellfield located in the north-west of the city, upstream along the Red River.

The incremental clean water production beyond the existing plants and their extensions is proposed for two new water plants with a final capacity of 120,000 m3/d each. They are proposed to be located in Cao Dinh (No. 10) and Co Nhue (No. 11) areas. The water plant development program is presented in table 7.4-1.

The pressure requirements at pumping stations and minimum pressure levels in the network during peak day peak hour situation, peak day situation and average day situation as per the network calculations are presented in table 7.4-2.

In this option the network is rather well in balance before the year 2000. In 2000 the new plants are satisfying the demand of the surrounding area, but in 2010 a lot of clean water is pumped towards south to the new areas and rather high pressure is needed in the new plants to keep the balance. In order to meet with the minimum pressure requirements the fixed pressure level in Mai Dich has to be increased in the year 2000 by 9 meters. To keep the balance with production and consumption the the pressure levels at Yen Phu, Ngo Si Lien, Hgoc Ha and Mai Dich water plants have to be increased by some 5-10 meters towards the end of the planning horizon.

Energy demand calculation for each pumping station based on peak day pumping heads over the whole planning period is presented in table 7.4-3. The average energy demand for clean water pumping would be 0.139 kWh/m3.

The list of transmission mains to be constructed during the periods 1991-1995, 1996-2000 and 2001-2010 is presented in table 7.4-4. These are the pipelines to be constructed after the second phase of the project. In an average about 7.6 km of transmission mains should be constructed yearly during the first 5 year period and about 4 km thereafter. Some of the existing pipes will be replaced when the capacity is exceeded and the lifetime of the old pipe is considered to be over, some of the pipes will have a parallel line if considered to be necessary. These are also presented in the table. All the 800 mm pipes will be constructed in two phases as two 600 mm pipes.

The pipes to be included in the rehabilitation program are presented in table 7.4-5. Some of these have already been considered to be included in the second phase of the project. In the table are included only the pipes beyond the construction program. Also the pipes that will be replaced after 1995 have to be tested and their need for repair must be considered separately.

TABLE 7.4-1 WATER PLANT DEVELOPMENT PROGRAM, OPTION 1
(Production on the right side of Red River)

Water plant Node	Name		Peak day capacities (m3/d) 1988	1991	1995	2000	2005	2010
Existing:								
204	Don Thuy		10000	10000	10000			
6	Ha Dinh		30000	30000	30000	30000	30000	30000
3	Luong Yen	1)	15000	45000	65000	75000	75000	75000
8	Mai Dich		30000	60000	60000	60000	60000	60000
2	Ngo Si Lien		45000	55000	55000	55000	55000	55000
7	Ngoc Ha	2)	27000	45000	45000	60000	60000	60000
5	Phap Van			30000	30000	30000	30000	30000
4	Tuong Mai		30000	30000	30000	30000	30000	30000
1	Yen Phu		45000	45000	75000	75000	75000	75000
9	Ha Dong	3)				15000		
Small plants			60000	50000	21000			
New plants:								
9	Ha Dong						30000	30000
10	Cao Dinh	4)				60000	90000	120000
11	Co Nhue					30000	60000	120000
Total production			292000	400000	421000	520000	595000	685000
Peak day demand			307000	360000	421000	520000	595000	682000

Notes: 1) A new plant of 30000 m3/d will be constructed in 1995, but the total production will be only 65000 m3/d until year 2000 when Don Thuy wellfield capacity will be connected to it.
2) Existing treatment plant will be abandoned and replased with a new one until the year 2000.
3) Existing treatment plant will be abandoned and replased with a new one until the year 2005.

TABLE 7.4-2 PRESSURE LEVELS AT PUMPING STATIONS DURING AVERAGE DAY, PEAK DAY AND PEAK DAY PEAK HOUR CONSUMPTION SITUATIONS

OPTION 1

Pumping station Node	Name	Pressure levels (m) 1995 situation pdph	pd	ad	2000 situation pdph	pd	ad	2010 situation pdph	pd	ad
1	Yen Phu	35.5	32.4	31.2	33.0	34.0	34.6	47.0	44.0	41.3
2	Ngo Si Lien	34.9	33.2	32.4	30.2	33.0	34.9	41.2	40.6	40.0
3	Luong Yen	35.3	33.4	32.6	26.8	30.7	33.3	33.2	34.7	36.2
4	Tuong Mai	36.6	34.2	33.3	26.8	30.7	33.3	27.7	30.8	33.6
5	Phap Van	43.6	38.7	36.7	31.8	34.1	35.7	32.3	34.1	35.8
6	Ha Dinh	30.7	30.5	30.3	27.8	31.4	33.8	18.7	24.3	29.2
7	Ngoc Ha	31.2	30.8	30.6	39.3	39.2	39.1	43.3	42.1	41.1
8	Mai Dich	30.0	30.0	30.0	39.0	39.0	39.0	39.0	39.0	39.0
9	Ha Dong				20.9	26.7	30.5	15.3	21.7	27.6
10	Cao Dinh				45.8	43.6	42.2	46.3	44.0	42.0
11	Phu Dien				41.1	40.4	40.0	49.7	46.5	43.6
12	Du Thuong s.									
15	"reservoir"	30.0	30.0	30.0	39.0	39.0	39.0	39.0	39.0	39.0
200	Bach Mai	30.6	30.2	30.2						
201	Bach Khoa	33.3	32.1	31.6						
202	Kim Lien	29.1	29.4	29.6						
203	Trung Tu	24.7	26.6	27.4						
204	Don Thuy	30.2	30.1	30.1						
205	Thanh cong	25.2	26.9	27.7						
65	network min.	19.8	23.5	25.0						
67	network min.				16.8	24.0	28.7			
62	network min.							10.5	18.3	25.3

pdph = peak day peak hour pd = peak day ad = average day

TABLE 7.4-3 ENERGY DEMAND CALCULATION FOR CLEAN WATER PUMPING DURING THE PLANNING PERIOD OF 1991-2010
(Option 1)

Treatment plant No.	Name	Water pumped (mill.m3) 1991-1998	1999-2005	2006-2010	Total	Pumping head (mwp) 1991-1998	1999-2005	2006-2010	Energy demand (MWh) 1991-1998	1999-2005	2006-2010	Total 1991-2010 (MWh)	(kWh/m3)
1	Yen Phu	187	164	103	454	32.4	34.0	44.0	23584	21705	17641	62930	0.139
2	Ngo Si Lien	137	120	75	332	33.2	33.0	40.6	17705	15415	11853	44972	0.135
3	Luong Yen	162	164	103	429	33.4	30.7	34.7	21062	19598	13912	54573	0.127
4	Tuong Mai	75	66	41	182	34.2	30.7	30.8	9984	7887	4916	22787	0.125
5	Phap Van	75	66	41	182	38.7	34.1	34.1	11298	8761	5442	25501	0.140
6	Ha Dinh	75	66	41	182	30.5	31.4	24.3	8904	8067	3878	20849	0.115
7	Ngoc Ha	112	131	82	325	30.8	39.2	42.1	13428	19989	13438	46855	0.144
8	Mai Dich	150	131	82	363	30.0	39.0	39.0	17517	19887	12448	49852	0.137
9	Ha Dong		33	41	74		26.7	21.7		3430	3463	6893	0.093
10	Cao Dinh		131	165	296		43.6	44.0		22233	28260	50493	0.171
11	Phu Dien		66	165	231		40.4	46.5		10379	29866	40245	0.174
12	Du Thuong s.												
200	Bach Mai	12			12	30.2			1411			1411	0.118
201	Bach Khoa	8			8	32.1			1000			1000	0.125
202	Kim Lien	16			16	29.4			1831			1831	0.114
203	Trung Tu	8			8	26.6			828			828	0.104
204	Don Thuy	25			25	30.1			2929			2929	0.117
205	Thanh Cong	8			8	26.9			838			838	0.105
Totals:		1050	1138	939	3127				132319	157350	145118	434787	0.139

Average total productions: 360,000 m3/d in 1995 = 1050 mill m3/8 years
445,000 m3/d in 2002 = 1138 mill m3/7 years
515,000 m3/d in 2008 = 939 mill m3/5 years

Pump efficiency: 0.7

Energy cost (5/1989): 120 dong/kWh

Min. peak day pressure in network:
1995/23.5 mwp
2000/24.0 mwp
2010/18.3 mwp

Note: Peak day theoretical pumping heads used in calculations

TABLE 7.4-4 TRANSMISSION MAINS TO BE CONSTRUCTED DURING 1991-2010, Option 1

Constr. period	225 PVC Pipe no.	225 PVC Lenght (m)	315 PVC Pipe no.	315 PVC Lenght (m)	400 DI Pipe no.	400 DI Lenght (m)	600 DI Pipe no.	600 DI Lenght (m)	800 DI Pipe no.	800 DI Lenght (m)	Period total of >300 mm
1991-1995	39	575	20	1000	3 R	1800	21	1000			
	49	1000	23	900	32	650	26	1450			
	55	1050	24	1350	33	1450	27	1375			
			25	1575	48	1525	31	1000			
			38	1425	54	650	95	625			
			40	750	80	1250	96	1500			
			43	675	83	1500	97	250			
			44	925	87	1300	118	875			
			50	700	94	1650	124	1000			
			51	1250							
			52	1250							
			64	1150							
			67	825							
			79	625							
			91	1425							
			113	1375							7.6 km/year
Total:		2625		17200		11775		9075		0	38050
1996-2000	116	1925	111	1125	63 P	1675	69 R	1125			
	117	1350	112	1125	68 P	1000	72 R	250			
			125	1125	114	400	115	400			
			126	800	123	1000	119	1525			
			127	1125	130	825	120	1450			
					131	1125					
					147	1450					3.5 km/year
Total:		3275		5300		7475		4750		0	17525
2001-2010	141	1200	140	550	137	1250	61 R	1200	153	1450	
	146	975	145	850	138	675	76 R	1000	154	750	
	150	850	149	1250	139	1925	95 P	625	163	1150	
	160	1175	151	975	144	2000	97 P	250			
	171	800	161	1575	148	675	120 P	1450			
	172	1225	162	2350	155	800	121	1075			
			170	1100	156	1100	122	900			
			175	550	157	750	142	350			
					158	1400	143	1400			
					159	825	152	1450			
					166	550	164	750			
					167	1025	165	450			
					168	1000					
					169	950					
					173	1075					
					174	1500					
					176	900					
					177	1000					4.3 km/year
Total:		6225		9200		19400		10900		3350	42850

P = parallel pipe, R = replacement

Total: 98425

7.4.2 Option 2

The network layout and dimensioning is presented in figure 7.4-2 and the network calculations for the year 1995 in Appendix 6, for the year 2000 in Appendix 7 and for the year 2010 in Appendix 8.

In this option the total incremental raw water capacity of about 300,000 m3/d to produce 270,000 m3/d of clean water in the year 2010 is proposed to be pumped from a wellfield in the north-west of the city (165,000 m3/d), from a wellfield in the south-east of the city (100,000 m3/d) and in Ha Dong (35,000 m3/d).

The incremental clean water production beyond the existing plants and their extensions is proposed for three new plants: Cao Dinh and Co Nhue in the north-west and Du Thuong in the south-west. The proposed plant development program is presented in table 7.4-6.

The pumping head requirements and minimum network pressure levels during peak day peak hour, peak day and average day situations as per the network calculations are presented in table 7.4-7.

In this option the pressure is rather uniform over the whole city and the entire planning horizon. As the water is produced in the consumption areas, there is no need for long distance pumping, and the service areas of each treatment plant can be rather easily defined. The fixed pressure level in Mai Dich can be even reduced in the year 2010 by 4 meters, but as the demand of water in the old city area is decreasing, the pressure levels of Yen Phu, Luong Yen and Phap Van plants have to be increased by 5-10 meters to keep the balance.

Energy demand calculation for each pumping station based on peak day pumping heads over the whole planning period is presented in table 7.4-8. The average energy demand for clean water pumping would be 0.122 kWh/m3.

The list of transmission mains to be constructed in this option during the periods 1991-1995, 1996-2000 and 2001-2010 is presented in table 7.4-9. In an average 7.7 km of main lines should be constructed yearly during the first 5 year period and 3-5 km thereafter.

The pipes to be included in the rehabilitation program are presented in table 7.4-10. Some of these have already been considered to be included in the second phase of the project. The possible rehabilitation of the pipes to be replaced after 1995 has to be considered separately. They are not included into the table.

TABLE 7.4-5 TRANSMISSION MAINS TO BE TESTED FOR REHABILITATION
(Option 1)

300 CI		400 CI		600 CI	
Pipe no.	Lenght (m)	Pipe no.	Lenght (m)	Pipe no.	Lenght (m)
11	800	4	1200	7	600
12	850	9	1750	31	1000
14	1350	10	500	45	925
15	650	13	500	46	1125
		28	1400	47	650
		29	1000		
		30	750		
		60	825		
		98	550		
Totals:	3650		8475		4300
				Total:	16425

TABLE 7.4-10 TRANSMISSION MAINS TO BE TESTED FOR REHABILITATION
(Options 2 and 3)

300 CI		400 CI		600 CI	
Pipe no.	Lenght (m)	Pipe no.	Lenght (m)	Pipe no.	Lenght (m)
		4	1200	7	600
		9	1750	31	1000
		10	500	45	925
		28	1400	46	1125
		29	1000	47	650
		98	550		
Totals:	0		6400		4300
				Total:	10700

TABLE 7.4-6 WATER PLANT DEVELOPMENT PROGRAM, OPTION 2
(Production on the right side of Red River)

Water plant Node Name		Peak day capacities (m3/d) 1988	1991	1995	2000	2005	2010
Existing:							
204 Don Thuy		10000	10000	10000			
6 Ha Dinh		30000	30000	30000	30000	30000	30000
3 Luong Yen	1)	15000	45000	65000	75000	75000	75000
8 Mai Dich		30000	60000	60000	60000	60000	60000
2 Ngo Si Lien		45000	55000	55000	55000	55000	55000
7 Ngoc Ha	2)	27000	45000	45000	60000	60000	60000
5 Phap Van			30000	30000	30000	30000	30000
4 Tuong Mai		30000	30000	30000	30000	30000	30000
1 Yen Phu		45000	45000	75000	75000	75000	75000
9 Ha Dong	3)				15000		
Small plants		60000	50000	21000			
New plants:							
9 Ha Dong						30000	30000
10 Cao Dinh	4)				60000	60000	90000
11 Co Nhue						30000	60000
12 Du Thuong south					30000	60000	90000
Total production		292000	400000	421000	520000	595000	685000
Peak day demand		307000	360000	421000	520000	595000	682000

Notes: 1) A new plant of 30000 m3/d will be constructed in 1995, but the total production will be only 65000 m3/d until year 2000 when Don Thuy wellfield capacity will be connected to it.
2) Existing treatment plant will be abandoned and replased with a new one until the year 2000.
3) Existing treatment plant will be abandoned and replased with a new one until the year 2005.
4) Water plant located in the northwest of the city.

TABLE 7.4-7 PREASSURE LEVELS AT PUMPING STATIONS DURING AVERAGE DAY, PEAK DAY AND PEAK DAY PEAK HOUR CONSUMPTION SITUATIONS

OPTION 2

Pumping station Node Name	Pressure levels (m) 1995 situation			2000 situation			2010 situation		
	pdph	pd	ad	pdph	pd	ad	pdph	pd	ad
1 Yen Phu	31.2	29.7	29.0	29.7	28.8	28.2	39.5	35.0	30.9
2 Ngo Si Lien	32.9	31.9	31.4	29.2	29.5	29.6	38.5	35.1	32.0
3 Luong Yen	28.0	28.7	29.0	28.5	29.0	29.3	44.2	39.3	34.8
4 Tuong Mai	36.9	34.4	33.4	37.5	35.1	33.5	44.6	39.5	35.0
5 Phap Van	36.6	34.2	33.2	34.2	32.8	31.9	48.4	42.3	36.8
6 Ha Dinh	29.9	29.9	29.9	27.3	28.2	28.8	26.3	26.3	26.2
7 Ngoc Ha	31.6	31.0	30.8	34.6	33.1	32.2	32.5	30.7	29.1
8 Mai Dich	30.0	30.0	30.0	30.0	30.0	30.0	26.0	26.0	26.0
9 Ha Dong				20.2	23.4	25.5	22.3	23.3	24.2
10 Cao Dinh				34.0	32.4	31.3	24.5	24.6	24.8
11 Phu Dien							26.5	26.1	25.7
12 Du Thuong s.				30.9	30.9	30.9	52.4	45.5	39.2
15 "reservoir"	30.0	30.0	30.0	30.0	30.0	30.0	26.0	26.0	26.0
200 Bach Mai	24.5	26.5	27.3						
201 Bach Khoa	26.8	28.0	28.5						
202 Kim Lien	25.5	27.1	27.8						
203 Trung Tu	23.1	25.6	26.6						
204 Don Thuy	26.7	27.9	28.4						
205 Thanh cong	23.8	26.0	27.0						
67 network min.				15.8	20.4	23.4			
107 network min.	18.7	22.8	24.5						
105 network min.							14.9	17.9	20.7

pdph = peak day peak hour pd = peak day ad = average day

TABLE 7.4-8 ENERGY DEMAND CALCULATION FOR CLEAN WATER PUMPING DURING THE PLANNING PERIOD OF 1991-2010
(Option 2)

Treatment plant No.	Name	Water pumped (mill.m3) 1991-1998	1999-2005	2006-2010		Pumping head (mwp) 1991-1998	1999-2005	2006-2010	Energy demand (MWh) 1991-1998	1999-2005	2006-2010	Total 1991-2010 (MWh)	(kWh/m3)
1	Yen Phu	187	164	103	454	29.7	28.8	35.0	21619	18385	14033	54037	0.119
2	Ngo Si Lien	137	120	75	332	31.9	29.5	35.1	17012	13780	10247	41039	0.124
3	Luong Yen	162	164	103	429	28.7	29.0	39.3	18098	18513	15757	52368	0.122
4	Tuong Mai	75	66	41	182	34.4	35.1	39.5	10043	9018	6304	25364	0.139
5	Phap Van	75	66	41	182	34.2	32.8	42.3	9984	8427	6751	25162	0.138
6	Ha Dinh	75	66	41	182	29.9	28.2	26.3	8729	7245	4197	20171	0.111
7	Ngoc Ha	112	131	82	325	31.0	33.1	30.7	13515	16879	9799	40193	0.124
8	Mai Dich	150	131	82	363	30.0	30.0	26.0	17517	15298	8299	41113	0.113
9	Ha Dong		33	41	74		23.4	23.3		3006	3719	6724	0.091
10	Cao Dinh		131	124	255		32.4	24.6		16522	11874	28395	0.111
11	Phu Dien			82	82			26.1			8331	8331	0.102
12	Du Thuong s.		66	124	190		30.9	45.5		7938	21962	29900	0.157
200	Bac Mai	12			12	26.5			1238			1238	0.103
201	Bac Khoa	8			8	28.0			872			872	0.109
202	Kim Lien	16			16	27.1			1688			1688	0.105
203	Trung Tu	8			8	25.6			797			797	0.100
204	Don Thuy	25			25	27.9			2715			2715	0.109
205	Thanh Cong	8			8	26.0			810			810	0.101
Totals:		1050	1138	939	3127				124636	135009	121272	380917	0.122

Average total productions: 360,000 m3/d in 1995 = 1050 mill m3/8 years
445,000 m3/d in 2002 = 1138 mill m3/7 years
515,000 m3/d in 2008 = 939 mill m3/5 years

Pump efficiency: 0.7

Energy cost (5/1989): 120 dong/kWh

Note: Peak day theoretical pumping heads used in calculations

Min. peak day pressure in network:
1995/22.8 mwp
2000/20.4 mwp
2010/17.9 mwp

TABLE 7.4-9 TRANSMISSION MAINS TO BE CONSTRUCTED DURING 1991-2010, Option 2

Constr. period	225 PVC Pipe no.	225 PVC Lenght (m)	315 PVC Pipe no.	315 PVC Lenght (m)	400 DI Pipe no.	400 DI Lenght (m)	600 DI Pipe no.	600 DI Lenght (m)	800 DI Pipe no.	800 DI Lenght (m)	Period total of >300 mm
1991-1995	49	1000	25	1575	3 R	1800	20	1000	21	1000	
	55	1050	27	1375	40	750	23	900			
			50	700	44	925	24	1350			
			51	1250	48	1525	26	1450			
			52	1250	80	1250	32	650			
			54	650	83	1500	33	1450			
			64	1150	94	1650	36 P	625			
			67	825	95	625	38	1425			
			79	625	96	1500	39	575			
			87	1300	97	250	43	675			
			91	1425			77 P	375			
			113	1375			118	875			
							124	1000		7.7	km/year
Total:		2050		13500		11775		12350		1000	38625
1996-2000	116	1925	112	1125	63 P	1675	69 R	1125	140	550	
	117	1350	125	1125	68 P	1000	72 R	250			
			126	800	111	1125	115	400			
			131	1125	114	400	119	1525			
					123	1000	120	1450			
					147	1450	130	825		3.4	km/year
Total:		3275		4175		6650		5575		550	16950
2001-2010	146	975	145	850	12 R	850	11 R	800	140 P	550	
	150	850	149	1250	14 R	1350	13 R	500	163	1150	
	156	1100	151	975	15 R	650	30 R	750			
	171	800	155	800	80 P	1250	32 P	650			
	172	1225	157	750	83 P	1500	33 P	1450			
			158	1400	137	1250	60 R	825			
			160	1175	138	675	61 R	1200			
			161	1575	139	1925	71 P	575			
			162	2350	144	2000	73 R	450			
			170	1100	148	675	76 R	1000			
			173	1075	152	1450	121	1075			
			174	1500	159	825	122	900			
			175	550	165	450	141	1200			
			177	1000	166	550	142	350			
					167	1025	143	1400			
					168	1000	153	1450			
					169	950	154	750			
					176	900	164	750		5.3	km/year
Total:		4950		16350		19275		16075		1700	53400

7.4.3 Option 3

The network layout and dimensioning is presented in figure 7.4-3 and the network calculations for the year 1995 in Appendix 9, for the year 2000 in Appendix 10 and for the year 2010 in Appendix 11.

In this option, besides ground water, surface water taken from Tich River basin has been introduced as a part of the source of supply with a share of about 15 % of the total demand in the target year of 2010.

The main new wellfields are located in the north-east with raw water pumping capacity of about 130,000 m3/d and in the south-west with raw water pumping capacity of about 65,000 m3/d in the year 2010.

The maximum possible surface water abstraction from Tich River basin has been estimated to be about 1 m3/s or 90,000 m3/d with a storage at the intake. The resources potential has been discussed more in detail in Chapter 3. The necessary arrangements for raw water production and transportation would be an intake with pre-sedimentation, pumping station and raw water line of about 20 km. Detailed studies on water production out of the river water have not yet been possible.

The proposed water treatment plant development program for this option is presented in table 7.4-11.

In this option the pressure in network is also rather uniform and the balance is good during the whole planning period. There is no need for long distance pumping of clean water, as the water is produced in the consumption areas. The fixed pressure level in Mai Dich can be reduced in 2010 by 4 meters but the pumping heads of Yen Phu, Ngo Si Lien, Luong Yen, Tuong Mai and Phap Van plants have to be increased some 6-12 m to keep the balance. Cao Dinh pressure level can be reduced about 10 m from its initial level in 2010.

Energy demand calculation for each pumping station based on peak day pumping heads presented in table 7.4-12 is presented in table 7.4-13. The average energy demand for clean water pumping would be the same as for option 2, i.e. 0.122 kWh/m3.

The list of transmission mains to be constructed in this option during the periods 1991-1995, 1996-2000 and 2001-2010 is presented in table 7.4-14. In an average 7.8 km of main lines should be constructed yearly during the first 5 year

TABLE 7.4-11 WATER PLANT PRODUCTION CAPACITY PROJECTION, OPTION 3
(Production on the right side of the Red River)

Water plant Node	Name		Peak day capacities (m3/d) 1988	1991	1995	2000	2005	2010
Existing:								
204	Don Thuy		10000	10000	10000			
6	Ha Dinh		30000	30000	30000	30000	30000	30000
3	Luong Yen	1)	15000	45000	65000	75000	75000	75000
8	Mai Dich		30000	60000	60000	60000	60000	60000
2	Ngo Si Lien		45000	55000	55000	55000	55000	55000
7	Ngoc Ha	2)	27000	45000	45000	60000	60000	60000
5	Phap Van			30000	30000	30000	30000	30000
4	Tuong Mai		30000	30000	30000	30000	30000	30000
1	Yen Phu		45000	45000	75000	75000	75000	75000
	Small plants		60000	50000	21000			
	New plants:							
9	Ha Dong (surface water)					45000	90000	90000
10	Cao Dinh	3)				60000	60000	90000
11	Co Nhue	3)						30000
12	Du Thuong south	4)					30000	60000
Total production			292000	400000	421000	520000	595000	685000
Peak day demand			307000	360000	421000	520000	595000	682000

Notes: 1) A new plant of 30000 m3/d will be constructed in 1995, but the total production will be only 65000 m3/d until year 2000 when Don Thuy wellfield capacity will be connected to it.
2) Existing treatment plant will be abandoned and replased with a new one until the year 2000.
3) Water plant located in the northwest of the city.
4) Water plant located in the south of industrial area I4 Vinh Tuy.

TABLE 7.4-12 PREASSURE LEVELS AT PUMPING STATIONS DURING AVERAGE DAY, PEAK DAY AND PEAK DAY PEAK HOUR CONSUMPTION SITUATIONS

OPTION 3

Pumping station Node No.	Name	Pressure levels (m) 1995 situation pdph	pd	ad	2000 situation pdph	pd	ad	2010 situation pdph	pd	ad
1	Yen Phu	31.4	29.8	29.1	29.1	28.4	28.0	41.8	36.7	32.1
2	Ngo Si Lien	32.9	31.9	31.4	27.2	28.1	28.7	41.2	37.1	33.3
3	Luong Yen	28.2	28.8	29.1	23.5	25.6	27.0	43.9	39.0	34.6
4	Tuong Mai	27.0	28.1	28.5	22.1	24.6	26.3	43.2	38.5	34.3
5	Phap Van	36.6	34.2	33.2	30.3	30.2	30.1	50.1	43.5	37.6
6	Ha Dinh	29.7	29.8	29.8	36.8	34.6	33.2	41.3	37.1	33.4
7	Ngoc Ha	31.6	31.0	30.8	34.8	33.2	32.2	33.1	31.1	29.4
8	Mai Dich	30.0	30.0	30.0	30.0	30.0	30.0	26.0	26.0	26.0
9	Ha Dong				37.2	34.9	33.4	44.8	39.7	35.1
10	Cao Dinh				33.7	32.2	31.2	20.2	21.5	22.7
11	Phu Dien							20.8	22.0	23.0
12	Du Thuong s.							47.0	41.5	36.6
15	"reservoir"	30.0	30.0	30.0	30.0	30.0	30.0	26.0	26.0	26.0
200	Bach Mai	24.1	26.2	27.1						
201	Bach Khoa	27.0	28.1	28.5						
202	Kim Lien	25.5	27.1	27.8						
203	Trung Tu	23.0	25.5	26.6						
204	Don Thuy	26.6	27.9	28.4						
205	Thanh cong	23.8	26.0	27.0						
107	network min.	19.9	23.5	25.0						
27	network min.				18.3	22.1	24.6			
110	network min.							13.1	16.6	19.8

pdph = peak day peak hour pd = peak day ad = average day

TABLE 7.4-13 ENERGY DEMAND CALCULATION FOR CLEAN WATER PUMPING DURING THE PLANNING PERIOD OF 1991-2010
(Option 3)

Treatment plant No.	Name	Water pumped (mill.m3) 1991-1998	1999-2005	2006-2010	Total	Pumping head (mwp) 1991-1998	1999-2005	2006-2010	Energy demand (MWh) 1991-1998	1999-2005	2006-2010	Total 1991-2010 (MWh)	(kWh/m3)
1	Yen Phu	187	164	103	454	29.8	28.4	36.7	21692	18130	14714	54536	0.120
2	Ngo Si Lien	137	120	75	332	31.9	28.1	37.1	17012	13126	10831	40968	0.123
3	Luong Yen	162	164	103	429	28.8	25.6	39.0	18161	16343	15636	50140	0.117
4	Tuong Mai	75	66	41	182	28.1	24.6	38.5	8204	6320	6144	20668	0.114
5	Phap Van	75	66	41	182	34.2	30.2	43.5	9984	7759	6942	24685	0.136
6	Ha Dinh	75	66	41	182	29.8	34.6	37.1	8700	8889	5921	23510	0.129
7	Ngoc Ha	112	131	82	325	31.0	33.2	31.1	13515	16930	9927	40371	0.124
8	Mai Dich	150	131	82	363	30.0	30.0	26.0	17517	15298	8299	41113	0.113
9	Ha Dong		99	124	223		34.9	39.7		13449	19162	32612	0.146
10	Cao Dinh		131	124	255		32.2	21.5		16420	10378	26797	0.105
11	Phu Dien			41	41			22.0			3511	3511	0.086
12	Du Thuong s.			82	82			41.5			13246	13246	0.162
200	Bach Mai	12			12	26.2			1224			1224	0.102
201	Bach Khoa	8			8	28.1			875			875	0.109
202	Kim Lien	16			16	27.1			1688			1688	0.105
203	Trung Tu	8			8	25.5			794			794	0.099
204	Don Thuy	25			25	27.9			2715			2715	0.109
205	Thanh Cong	8			8	26.0			810			810	0.101
Totals:		1050	1138	939	3127				122889	132662	124713	380264	0.122

Average total productions: 360,000 m3/d in 1995 = 1050 mill m3/8 years
445,000 m3/d in 2002 = 1138 mill m3/7 years
515,000 m3/d in 2008 = 939 mill m3/5 years

Pump efficiency: 0.7

Energy cost (5/1989): 120 dong/kWh

Note: Peak day theoretical pumping heads used in calculations

Min. peak day pressure in network
1995/23.5 mwp
2000/22.1 mwp
2010/16.6 mwp

TABLE 7.4-14 TRANSMISSION MAINS TO BE CONSTRUCTED DURING 1991-2010, Option 3

Constr. period	225 PVC Pipe no.	Lenght (m)	315 PVC Pipe no.	Lenght (m)	400 DI Pipe no.	Lenght (m)	600 DI Pipe no.	Lenght (m)	800 DI Pipe no.	Lenght (m)	Period total of >300 mm
1991-1995	49	1000	25	1575	3 R	1800	20	1000	21	1000	
	55	1050	27	1375	38	1425	23	900			
			40	750	39	575	24	1350			
			43	675	50	700	26	1450			
			44	925	80	1250	31	1000			
			51	1250	83	1500	32	650			
			52	1250	94	1650	33	1450			
			54	650	95	625	48	1525			
			64	1150	96	1500	77 P	375			
			67	825			97	250			
			79	625			113	1375			
			87	1300			118	875			
			91	1425			124	1000		7.8	km/year
Total:		2050		13775		11025		13200		1000	39000
1996-2000			111	1125	63 P	1675	69 R	1125	114	400	
			112	1125	68 P	1000	116	1925	115	400	
			125	1125	117	1350	119	1525			
			126	800	123	1000	120	1540			
			131	1125	127	1125	130	825			
					147	1450				4.1	km/year
Total:		0		5300		7600		6940		800	20640
2001-2010	146	975	145	850	12 R	850	11 R	800	114 P	400	
	150	850	149	1250	14 R	1350	13 R	500	115 P	400	
	156	1100	151	975	15 R	650	30 R	750	140	550	
	171	800	155	800	80 P	1250	32 P	650	163	1150	
	172	1225	157	750	137	1250	33 P	1450			
			158	1400	138	675	60 R	825			
			160	1175	139	1925	61 R	1200			
			161	1575	141	1200	71 P	575			
			162	2350	143	1400	73 R	450			
			170	1100	144	2000	76 R	1000			
			173	1075	152	1450	113 P	1375			
			174	1500	165	450	121	1075			
			175	550	166	550	122	900			
			177	1000	167	1025	142	350			
					168	1000	148	675			
					169	950	153	1450			
					176	900	154	750			
							159	825			
							164	750		5.4	km/year
Total:		4950		16350		18875		16350		2500	54075

P = parallel pipe, R = replacement

Total: 113715

period and about 5 km thereafter.

The pipe rehabilitation requirements would be roughly the same as for option 2 (see table 7.4-10).

7.5 Gia Lam Water Supply System

Gia Lam area on the left side of the Red River is proposed to have an own water supply system separated from the Hanoi main system. The system implementation has not yet been included into the FINNIDA aided Hanoi Water Supply Project except the rehabilitation of two wells.

The coverage of the existing network is rather poor. There is actually no transmission mains as the biggest pipe dimension is 250 mm. There exist a small water plant with a raw water capacity of about 11,000 m3/d, but the plant dimensioning capacity is only about 3,000 m3/d. The water demand is projected to increase rather slowly until the year 2000, but after that a rapid growth is expected. The consumption projection presented in table 6.5-3 suggests a growth from today's 8,600 m3/d to 12,200 m3/d in 2000 and to 31,800 m3/d in 2010.

Based on the land use maps, consumption calculations and production demand calculations the design has been carried out, and the network layout with pipe dimensions is presented in the network figures 7.4-1 to 7.4-3 and the network calculations in Appendix 12.

It is proposed, that a new plant with an initial capacity of 20,000 m3/d will be constructed and located as presented in the layout maps around the year 2000 and that the plant would be extended with an other unit of 20,000 m3/d. Only the necessary rehabilitation works to extend the lifetime of the present plant until the completion of the new plant will be carried out. New location has been considered because of the better location in respect of the land use development and unfavorable location of the existing plant inside a military airport.

The proposed main network (diam. = or > 225 mm) development program has been presented in table 7.5-1. The existing network, depending on the condition, is going to serve only as distribution system. Total length of this main network to be constructed within 20 years is 19 km out of which 12 km are transmission mains (diam. > 300 mm). The main implementation should occur during the first five year period with yearly construction of 1.9 km of all the main lines out of which 1.6 km are transmission mains. Thereafter 0.6 km of

TABLE 7.5-1 MAIN PIPES TO BE CONSTRUCTED IN GIA LAM DURING 1991-2010

Constr. period	225 PVC Pipe no.	225 PVC Lenght (m)	315 PVC Pipe no.	315 PVC Lenght (m)	400 DI Pipe no.	400 DI Lenght (m)	600 DI Pipe no.	600 DI Lenght (m)	Period totals > 200 mm (m)	Period totals > 300 mm (m)
1991-1995	3	650	2	1400	1	500				
	5	500	4	1325	6	1300				
			9	1250	7	1200				
					8	1150				
Total (m)		1150		3975		4150		0	9275	8125
km/year									1.9	1.6
1996-2000	10	900			11	1700	18	300		
							20	300		
Total (m)		900		0		1700		600	3200	2300
km/year									0.6	0.5
2001-2010	13	1500	12	950						
	14	1250	16	625						
	15	950								
	17	1250								
Total (m)		4950		1575		0		0	6525	1575
km/year									0.7	0.2
								Total:	19000	12000

these main lines out of which about 0.3 km are transmission mains should be constructed.

7.6 Recommendations

The options presented in this chapter are all based mainly on the groundwater resources and on the 'maximum possible' development of the existing plants. There is, however, a risk that for some reasons some of the existing plants especially in the old city centre area and nearby have to be abandoned earlier than expected. The Water Supply Company should be ready for this kind of situation. Therefore it would be beneficial to study:

- the availability and suitability of surface water resources to cover the whole water supply system of Hanoi,
- methods of transmitting and purifying river water,
- a centralized water supply system with two or three big water plants with a capacity of 200,000-300,000 m3/d utilizing either surface water or ground water.

The above mentioned studies would help to plan the future even beyond the target year of 2010.

Population distribution, increase and densities in 1985 and 1988

Quan: DONG DA

Phuong no	name	Population 1985	Population 1988	Increase	Growth rate (%)	Area (ha)	Pop. density (p/ha) 1985	Pop. density (p/ha) 1988
1	Van mieu	10939	11271	332	1.0	23.0	476	490
2	Van chuong	11840	12028	188	0.5	43.0	275	280
3	Cat linh	12358	13457	1099	2.9	46.2	267	291
4	Quoc tu giam	7548	7662	114	0.5	22.4	337	342
5	Hang bot	12941	13749	808	2.0	27.8	466	495
6	O cho dua	11340	12703	1363	3.9	84.5	134	150
7	Nam dong	10453	11919	1466	4.5	40.2	260	296
8	Quang trung	9096	9051	-45	-0.2	50.2	181	180
9	Trung liet	11509	11738	229	0.7	91.0	126	129
10	Tho quan	11628	12556	928	2.6	24.2	480	519
11	Khan thien	9252	9472	220	0.8	16.0	578	592
12	Trung phung	10634	10604	-30	-0.1	24.1	441	440
13	Phuong lien	9465	10514	1049	3.6	34.3	276	307
14	Phuong Mai	9152	10994	1842	6.3	43.9	208	250
15	Phuong liet	7948	8299	351	1.5	65.0	122	128
16	Kim lien	10175	12390	2215	6.8	33.9	300	365
17	Trung tu	12382	13032	650	1.7	74.3	167	175
18	Kh. thuong	7028	7670	642	3.0	35.1	200	219
19	Nguyen trai	15499	17669	2170	4.5	42.5	365	416
20	Thinh quang	11788	12607	819	2.3	38.3	308	329
21	Lang ha	4806	6561	1755	10.9	80.7	60	81
22	Lang thuong	10923	11643	720	2.2	123.0	89	95
23	Thuong dinh	9047	10784	1737	6.0	35.8	253	301
24	Thanh xuan	7991	7197	-794	-3.4	72.0	111	100
25	Kim giang	4067	5761	1694	12.3	44.6	91	129
26	Th. xuan bac	10354	16070	5716	15.8	146.0	71	110
Total		260163	287401	27238	3.4	1362.0	191	211

Quan: BA DINH

Phuong no	name	Population 1985	1988	Increase	Growth rate (%)	Area (ha)	Pop. density (p/ha) 1985	1988
27	Trung truc	9867	11047	1180	3.8	18.9	522	584
28	Dien bien	10239	12726	2487	7.5	134.2	76	95
29	Cau giay	11578	12221	643	1.8	99.0	117	123
30	Ngoc ha	12401	12849	448	1.2	99.2	125	130
31	Tru bach	11518	12349	831	2.3	38.7	298	319
32	Yen phu	12221	12835	614	1.6	95.5	128	134
33	Phuc xa	10914	10883	-31	-0.1	50.0	218	218
34	Quan thanh	10881	11171	290	0.9	56.0	194	199
35	Thuy khe	11502	11656	154	0.4	51.5	223	226
36	Buoi	12563	13018	455	1.2	106.0	119	123
37	Giang vo	12840	13488	648	1.7	53.5	240	252
38	Thanh cong	11294	16400	5106	13.2	63.6	178	258
39	Kim ma	12382	12788	406	1.1	76.0	163	168
40	Doi can	12880	12453	-427	-1.1	38.0	339	328
41	Cong vi	14040	15396	1356	3.1	136.7	103	113
Total		177120	191280	14160	2.6	1116.8	159	171

Quan: HOAN KIEM

Phuong no	name	Population 1985	1988	Increase	Growth rate (%)	Area (ha)	Pop. density (p/ha) 1985	1988
42	Cua nam	12354	12120	-234	-0.6	34.2	361	354
43	Tr. h. Dao	10991	10334	-657	-2.0	36.0	305	287
44	Hang bai	9683	9380	-303	-1.1	29.4	329	319
45	Ph. c. Trinh	7691	8309	618	2.6	53.5	144	155
46	Ly th. To	6772	8053	1281	5.9	27.8	244	290
47	Trang tien	8021	6755	-1266	-5.6	7.4	1084	913
48	Hang bac	8699	8456	-243	-0.9	22.0	395	384
49	Hang buom	11373	11695	322	0.9	13.2	862	886
50	Dong xuan	11430	11819	389	1.1	12.6	907	938
51	Hang dao	7353	7293	-60	-0.3	8.0	919	912
52	Hang ma	8721	9035	314	1.2	21.7	402	416
53	Hang bo	9622	9904	282	1.0	7.5	1283	1321
54	Cua dong	8329	8496	167	0.7	13.5	617	629
55	Hang bong	8345	8034	-311	-1.3	14.8	564	543
56	Hang gai	10271	10970	699	2.2	12.0	856	914
57	Hang trong	9779	9640	-139	-0.5	37.6	260	256
58	Phuc tan	7258	8117	859	3.8	36.0	202	225
59	Chuong duong	11144	11241	97	0.3	30.0	371	375
Total		167836	169651	1815	0.4	417	402	407

Quan: HAI BA TRUNG

Phuong no	name	Population 1985	1988	Increase	Growth rate (%)	Area (ha)	Pop. density (p/ha) 1985	1988
60	Le Dai Hanh	12273	12813	540	1.4	83.6	147	153
61	Nguyen Du	10503	10640	137	0.4	29.3	358	363
62	Dong nhan	10326	10781	455	1.4	21.7	476	497
63	Ngo thi Nham	11183	12169	986	2.9	18.1	618	672
64	Ph. d. Ho	7659	8191	532	2.3	23.5	326	349
65	Thanh nhan	10550	11479	929	2.9	58.5	180	196
66	Quynh loi	8890	9037	147	0.5	29.0	307	312
67	Bach khoa	9586	9816	230	0.8	29.0	331	338
68	Dong mac	8358	8365	7	0.0	17.0	492	492
69	Thanh luong	10790	12559	1769	5.2	91.2	118	138
70	Bach Dang	13676	14624	948	2.3	54.4	251	269
71	Giap bat	5043	5032	-11	-0.1	64.5	78	78
72	Minh khai	11436	12364	928	2.6	51.0	224	242
73	Bui thi Xuan	10066	12035	1969	6.1	16.5	610	729
74	Vinh tuy	11893	15006	3113	8.1	109.0	109	138
75	Quynh Mai	9663	10194	531	1.8	37.6	257	271
76	Tuong Mai	13032	14271	1239	3.1	45.5	286	314
77	Dong tam	10550	12613	2063	6.1	18.8	561	671
78	Mai Dong	6568	7091	523	2.6	82.5	80	86
79	Cau den	9551	12252	2701	8.7	24.0	398	511
80	Bach Mai	13005	14389	1384	3.4	29.5	441	488
81	Tan Mai	13860	14442	582	1.4	63.7	218	227
82	Truong Dinh	13896	15159	1263	2.9	30.0	463	505
83	Pho Hue	13173	13681	508	1.3	20.1	655	681
Total		255530	279003	23473	3.0	1048.0	244	266
Other areas:						192.0		
Total Hanoi urban area:		860649	927335	66686	2.5	4136.0	208	224

Bl.	Domestic use 70 l/c/d		Urban services 35 l/c/d		Small industr. 5 l/c/d		Clean. & irrig. 1 l/m2/d		Other use & loss. 50 %		Block average		Block peakflow day kd=1.2	hour kh=1.4
	(m3/d)	(l/s)	(m3/d)	(l/s)	(m3/d)	(l/s)	(m3/d)	(l/s)	(m3/d)	(l/s)	(m3/d)	(l/s)	(l/s)	(l/s)
1	9914	115	3645	42	367	4	419	5	14344	166	28689	332	365	445
2	10078	117	1194	14	694	8	696	8	12662	147	25324	293	322	393
3	5653	65	1966	23	579	7	409	5	8607	100	17213	199	219	267
4	3078	36	908	11	667	8	136	2	4789	55	9579	111	122	149
5	693	8	180	2	190	2	34	0	1097	13	2193	25	28	34
6	802	9	5004	58	0	0	120	1	5926	69	11853	137	151	184
7	9503	110	3655	42	340	4	341	4	13839	160	27677	320	352	429
8	4151	48	3543	41	252	3	200	2	8146	94	16292	189	207	253
9	1366	16	544	6	345	4	63	1	2317	27	4635	54	59	72
10	748	9	243	3	88	1	25	0	1104	13	2208	26	28	34
11	3690	43	631	7	345	4	247	3	4913	57	9827	114	125	152
12	680	8	267	3	53	1	33	0	1034	12	2067	24	26	32
13	908	11	1010	12	53	1	329	4	2300	27	4599	53	59	71
14	765	9	874	10	141	2	80	1	1860	22	3720	43	47	58
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	350	4	49	1	44	1	42	0	485	6	970	11	12	15
17	574	7	325	4	18	0	45	1	961	11	1923	22	24	30
18	210	2	49	1	0	0	4	0	263	3	526	6	7	8
19	350	4	73	1	0	0	6	0	429	5	858	10	11	13
20	0	0	971	11	0	0	18	0	989	11	1977	23	25	31
21	210	2	291	3	0	0	9	0	510	6	1020	12	13	16
22	700	8	1941	22	0	0	49	1	2690	31	5381	62	69	83
23	1120	13	2281	26	0	0	76	1	3477	40	6954	80	89	108
24	700	8	1019	12	0	0	40	0	1759	20	3519	41	45	55
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	987	11	971	11	88	1	36	0	2082	24	4164	48	53	65
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	1565	18	485	6	88	1	51	1	2189	25	4379	51	56	68
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39	1685	19	24	0	0	0	27	0	1736	20	3471	40	44	54
40	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41	1619	19	180	2	88	1	71	1	1959	23	3918	45	50	61
42	1288	15	87	1	133	2	52	1	1560	18	3120	36	40	48
43	1152	13	97	1	0	0	28	0	1277	15	2554	30	33	40
S.tot	64540	747	32504	376	4575	53	3686	43	105305	1219	210609	2438	2681	3266
Left side of Red river:														
37	1050	12	291	3	110	1	60	1	1512	17	3024	35	38	47
Total	65590	759	32795	380	4685	54	3746	43	106816	1236	213633	2473	2720	3313

Bl.	Domestic use 120 l/c/d		Urban services 40 l/c/d		Small industr. 8 l/c/d		Clean. & irrig. 1 l/m2/d		Other use & loss. 40 %		Block average		Block peakflow day	hour
	(m3/d)	(l/s)	(m3/d)	(l/s)	(m3/d)	(l/s)	(m3/d)	(l/s)	(m3/d)	(l/s)	(m3/d)	(l/s)	(l/s) kd=1.3	(l/s) kh=1.4
1	16395	190	3747	43	401	5	411	5	13970	162	34925	404	477	603
2	16677	193	998	12	776	9	736	9	12792	148	31979	370	437	552
3	9091	105	2295	27	647	7	452	5	8323	96	20809	241	284	359
4	5276	61	1183	14	977	11	178	2	5076	59	12689	147	173	219
5	1188	14	434	5	278	3	57	1	1305	15	3263	38	45	56
6	1015	12	5544	64	0	0	116	1	4450	52	11125	129	152	192
7	16890	195	3757	43	388	4	341	4	14252	165	35629	412	487	615
8	7116	82	3643	42	369	4	223	3	7567	88	18918	219	258	327
9	1981	23	559	6	505	6	81	1	2084	24	5210	60	71	90
10	922	11	709	8	129	1	24	0	1189	14	2973	34	41	51
11	6326	73	898	10	505	6	489	6	5479	63	13697	159	187	237
12	806	9	923	11	78	1	32	0	1226	14	3065	35	42	53
13	1557	18	1537	18	78	1	346	4	2345	27	5863	68	80	101
14	2991	35	898	10	207	2	91	1	2791	32	6977	81	95	120
15	3600	42	1247	14	0	0	86	1	3289	38	8223	95	112	142
16	600	7	50	1	65	1	150	2	577	7	1441	17	20	25
17	984	11	833	10	26	0	52	1	1263	15	3158	37	43	55
18	360	4	50	1	0	0	4	0	276	3	690	8	9	12
19	600	7	1322	15	0	0	28	0	1300	15	3250	38	44	56
20	960	11	998	12	0	0	26	0	1323	15	3306	38	45	57
21	1920	22	349	4	0	0	64	1	1556	18	3890	45	53	67
22	1200	14	3208	37	1210	14	82	1	3800	44	9500	110	130	164
23	4200	49	3343	39	129	1	192	2	5243	61	13108	152	179	226
24	2400	28	1048	12	129	1	76	1	2436	28	6089	70	83	105
25	1080	13	150	2	0	0	17	0	831	10	2078	24	28	36
26	1800	21	0	0	0	0	26	0	1217	14	3043	35	42	53
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	1200	14	0	0	323	4	19	0	1028	12	2571	30	35	44
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	840	10	0	0	194	2	33	0	711	8	1778	21	24	31
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	1812	21	998	12	129	1	34	0	1983	23	4957	57	68	86
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	3043	35	499	6	323	4	72	1	2625	30	6561	76	90	113
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39	2888	33	25	0	0	0	61	1	1982	23	4956	57	68	86
40	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41	2776	32	185	2	129	1	69	1	2106	24	5265	61	72	91
42	1968	23	90	1	194	2	50	1	1535	18	3837	44	52	66
43	1015	12	100	1	0	0	27	0	761	9	1903	22	26	33
S.tot	123480	1429	41621	482	8190	95	4746	55	118691	1374	296728	3434	4053	5124
Left side of Red river:														
37	2280	26	299	3	194	2	80	1	1902	22	4756	55	65	82
Total	125760	1456	41920	485	8384	97	4826	56	120593	1396	301483	3489	4117	5206

Bl.	Domestic use 150 l/c/d		Urban services 40 l/c/d		Small industr. 10 l/c/d		Clean. & irrig. 1 l/m2/d		Other use & loss. 35 %		Block average		Block peakflow day	hour
	(m3/d)	(l/s)	(m3/d)	(l/s)	(m3/d)	(l/s)	(m3/d)	(l/s)	(m3/d)	(l/s)	(m3/d)	(l/s)	(l/s) kd=1.4	(l/s) kh=1.3
1	15551	180	2799	32	145	2	459	5	10206	118	29159	337	425	517
2	19031	220	261	3	289	3	910	11	11033	128	31524	365	460	559
3	9024	104	2132	25	434	5	716	8	6626	77	18930	219	276	336
4	5963	69	1368	16	434	5	766	9	4593	53	13124	152	191	233
5	5954	69	410	5	145	2	195	2	3610	42	10314	119	150	183
6	0	0	5031	58	0	0	142	2	2785	32	7958	92	116	141
7	19060	221	2806	32	434	5	411	5	12228	142	34938	404	510	620
8	7581	88	2720	31	217	3	525	6	5946	69	16989	197	248	301
9	4901	57	1267	15	145	2	174	2	3493	40	9980	116	146	177
10	0	0	1055	12	0	0	30	0	584	7	1668	19	24	30
11	9819	114	261	3	217	3	891	10	6024	70	17212	199	251	305
12	0	0	1386	16	0	0	39	0	767	9	2193	25	32	39
13	2643	31	1297	15	72	1	394	5	2373	27	6779	78	99	120
14	3945	46	671	8	145	2	117	1	2626	30	7502	87	109	133
15	7345	85	1982	23	217	3	210	2	5253	61	15008	174	219	266
16	0	0	0	0	0	0	456	5	246	3	702	8	10	12
17	0	0	2720	31	217	3	80	1	1624	19	4641	54	68	82
18	0	0	335	4	72	1	220	3	338	4	966	11	14	17
19	0	0	4174	48	217	3	121	1	2429	28	6940	80	101	123
20	1496	17	3294	38	289	3	439	5	2972	34	8491	98	124	151
21	3344	39	149	2	361	4	134	2	2148	25	6136	71	89	109
22	0	0	2657	31	2168	25	106	1	2655	31	7586	88	111	135
23	5746	67	2635	30	289	3	485	6	4929	57	14084	163	205	250
24	6260	72	559	6	361	4	227	3	3989	46	11396	132	166	202
25	2721	31	112	1	145	2	97	1	1656	19	4730	55	69	84
26	6027	70	0	0	0	0	142	2	3322	38	9491	110	138	168
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	4221	49	298	3	145	2	102	1	2566	30	7332	85	107	130
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	3509	41	75	1	578	7	242	3	2371	27	6775	78	99	120
32	0	0	745	9	2023	23	50	1	1518	18	4337	50	63	77
33	3967	46	559	6	361	4	52	1	2660	31	7599	88	111	135
34	2138	25	112	1	145	2	57	1	1320	15	3770	44	55	67
35	5189	60	373	4	361	4	83	1	3234	37	9239	107	135	164
36	1987	23	186	2	217	3	91	1	1336	15	3817	44	56	68
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39	1272	15	0	0	0	0	81	1	729	8	2083	24	30	37
40	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41	3715	43	37	0	72	1	134	2	2132	25	6090	70	89	108
42	2443	28	75	1	72	1	131	2	1465	17	4186	48	61	74
43	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S.tot	164850	1908	44539	515	10983	127	9511	110	123784	1433	353667	4093	5158	6275
Left side of Red river:														
37	3150	36	261	3	217	3	110	1	2012	23	5750	67	84	102
Total	168000	1944	44800	519	11200	130	9621	111	125796	1456	359417	4160	5242	6377

Bl.	Domestic use 180 l/c/d		Urban services 40 l/c/d		Small industr. 15 l/c/d		Clean. & irrig. 1 l/m2/d		Other use & loss. 28 %		Block average		Block peakflow day kd=1.4	hour kd=1.2
	(m3/d)	(l/s)	(m3/d)	(l/s)	(m3/d)	(l/s)	(m3/d)	(l/s)	(m3/d)	(l/s)	(m3/d)	(l/s)	(l/s)	(l/s)
1	8394	97	2601	30	169	2	417	5	4503	52	16084	186	240	277
2	13429	155	242	3	337	4	857	10	5781	67	20648	239	308	356
3	7840	91	1981	23	506	6	678	8	4280	50	15284	177	228	264
4	6178	72	1271	15	506	6	734	8	3379	39	12068	140	180	208
5	8832	102	381	4	169	2	225	3	3736	43	13342	154	199	230
6	0	0	4675	54	0	0	120	1	1865	22	6660	77	99	115
7	11824	137	2608	30	506	6	359	4	5949	69	21245	246	317	366
8	7515	87	2528	29	253	3	489	6	4194	49	14978	173	223	258
9	13012	151	1177	14	169	2	530	6	5790	67	20678	239	308	357
10	0	0	980	11	0	0	25	0	391	5	1396	16	21	24
11	12532	145	242	3	253	3	846	10	5395	62	19268	223	287	332
12	0	0	1288	15	0	0	33	0	514	6	1835	21	27	32
13	2194	25	1205	14	84	1	378	4	1502	17	5363	62	80	92
14	5502	64	623	7	169	2	98	1	2486	29	8878	103	132	153
15	18918	219	2535	29	253	3	214	2	8525	99	30445	352	454	525
16	0	0	0	0	0	0	450	5	175	2	624	7	9	11
17	0	0	2528	29	253	3	67	1	1108	13	3956	46	59	68
18	0	0	312	4	84	1	216	2	238	3	850	10	13	15
19	0	0	3879	45	253	3	102	1	1646	19	5880	68	88	101
20	2259	26	3886	45	422	5	527	6	2758	32	9852	114	147	170
21	9182	106	173	2	1265	15	316	4	4253	49	15189	176	226	262
22	0	0	2469	29	2530	29	90	1	1979	23	7068	82	105	122
23	14558	168	3453	40	337	4	603	7	7370	85	26322	305	392	454
24	10221	118	852	10	1265	15	348	4	4934	57	17620	204	263	304
25	4452	52	173	2	843	10	166	2	2191	25	7825	91	117	135
26	18753	217	2791	32	422	5	876	10	8883	103	31724	367	473	547
27	0	0	762	9	0	0	19	0	304	4	1085	13	16	19
28	0	0	987	11	0	0	25	0	394	5	1406	16	21	24
29	19109	221	2185	25	1265	15	1207	14	9242	107	33008	382	492	569
30	0	0	1621	19	0	0	41	0	646	7	2309	27	34	40
31	11235	130	599	7	2108	24	439	5	5593	65	19974	231	298	344
32	0	0	696	8	2361	27	43	0	1206	14	4306	50	64	74
33	7580	88	1316	15	1265	15	193	2	4027	47	14381	166	214	248
34	7647	89	693	8	843	10	174	2	3639	42	12996	150	194	224
35	13215	153	1489	17	1265	15	298	3	6326	73	22592	261	337	390
36	4406	51	416	5	253	3	317	4	2096	24	7487	87	112	129
38	0	0	0	0	169	2	89	1	100	1	358	4	5	6
39	0	0	0	0	0	0	1306	15	508	6	1814	21	27	31
40	0	0	0	0	0	0	2232	26	868	10	3100	36	46	53
41	0	0	0	0	0	0	0	0	0	0	0	0	0	0
42	0	0	0	0	0	0	0	0	0	0	0	0	0	0
43	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S.tot	238785.	2764	55619	644	20578	238	16146	187	128772	1490	459901	5323	6856	7929
Left side of Red river:														
37	13215	153	381	4	422	5	511	6	5650	65	20179	234	301	348
Total	252000	2917	56000	648	21000	243	16657	193	134422	1556	480079	5556	7157	8277

Year	Ind. area No.	Area (ha)	Ind. consumption (m3/d)	(l/s)	Road cleaning 1 (l/m2/d) (m3/d)	(l/s)	Losses & other use (m3/d)	(l/s)	Totals for areas (m3/d)	(l/s)	Peakflows day (l/s) kd=1.1	hour (l/s) kh=1.5
1989	I 1	55	1873	21.7	49	0.6	1922	22.2	3845	44.5	46.7	59.0
	I 2	30	1097	12.7	27	0.3	1124	13.0	2248	26.0	27.3	34.5
	I 3	260	8167	94.5	232	2.7	8398	97.2	16797	194.4	204.1	257.6
	I 4	250	15795	182.8	223	2.6	16018	185.4	32036	370.8	389.3	491.3
	I 5	85	2550	29.5	76	0.9	2626	30.4	5252	60.8	63.8	80.5
	I 6	150	4500	52.1	134	1.5	4634	53.6	9268	107.3	112.6	142.1
	I 7	90	2827	32.7	80	0.9	2907	33.6	5814	67.3	70.7	89.2
	Other areas	180	7202	83.4			7202	83.4	14404	166.7	175.0	220.9
Totals		1100	44011	509.4	821	9.5	44832	518.9	89663	1037.8	1089.7	1375.0
1995	I 1	65	2214	25.6	56	0.6	1513	17.5	3783	43.8	46.4	60.9
	I 2	40	1458	16.9	34	0.4	995	11.5	2487	28.8	30.5	40.0
	I 3	300	9414	109.0	259	3.0	6448	74.6	16121	186.6	197.8	259.4
	I 4	300	19068	220.7	259	3.0	12884	149.1	32211	372.8	395.2	518.2
	I 5	85	2550	29.5	73	0.8	1749	20.2	4372	50.6	53.6	70.3
	I 6	250	7730	89.5	215	2.5	5297	61.3	13242	153.3	162.5	213.0
	I 7	105	3392	39.3	91	1.0	2321	26.9	5803	67.2	71.2	93.4
	Other areas	200	8004	92.6			5336	61.8	13341	154.4	163.7	214.6
Totals		1345	53829	623.0	987	11.4	36544	423.0	91361	1057.4	1120.9	1469.8
2000	I 1	75	2153	24.9	79	0.9	1202	13.9	3434	39.7	42.3	56.5
	I 2	97	3094	35.8	102	1.2	1721	19.9	4917	56.9	60.6	81.0
	I 3	335	8837	102.3	352	4.1	4948	57.3	14137	163.6	174.3	232.8
	I 4	400	22796	263.8	420	4.9	12501	144.7	35717	413.4	440.3	588.0
	I 5	85	2125	24.6	89	1.0	1192	13.8	3407	39.4	42.0	56.1
	I 6	400	10736	124.3	420	4.9	6007	69.5	17163	198.6	211.6	282.6
	I 7	150	4164	48.2	157	1.8	2327	26.9	6648	76.9	82.0	109.5
	Other areas	250	8740	101.2			4706	54.5	13446	155.6	165.7	221.4
Totals		1792	62645	725.1	1619	18.7	34604	400.5	98868	1144.3	1218.7	1627.8
2010	I 1	101	2828	32.7	90	1.0	1135	13.1	4052	46.9	50.3	68.8
	I 2	130	4245	49.1	115	1.3	1695	19.6	6055	70.1	75.1	102.9
	I 3	460	12328	142.7	408	4.7	4953	57.3	17688	204.7	219.5	300.5
	I 4	580	33031	382.3	514	5.9	13045	151.0	46590	539.2	578.1	791.6
	I 5	85	2125	24.6	75	0.9	856	9.9	3056	35.4	37.9	51.9
	I 6	835	23881	276.4	740	8.6	9575	110.8	34196	395.8	424.3	581.0
	I 7	290	8425	97.5	257	3.0	3376	39.1	12058	139.6	149.6	204.9
	Other areas	300	10503	121.6			4085	47.3	14588	168.8	181.0	247.9
Totals		2781	97365	1126.9	2199	25.4	38719	448.1	138284	1600.5	1715.7	2349.5

Block	1995			2000			2010		
	Area (ha)	% of tot. area	Peak flow	Area (ha)	% of tot. area	Peak flow	Area (ha)	% of tot. area	Peak flow
1	256.3	13.2	28	256.3	11.7	26	256.3	8.5	21
2	324.2	16.7	36	324.2	14.9	33	324.2	10.8	27
3	234.3	12.1	26	234.3	10.7	24	234.3	7.8	19
4	135.5	7.0	15	196.5	9.0	20	196.5	6.5	16
7	314.9	16.2	35	314.9	14.4	32	314.9	10.4	26
8	224.0	11.5	25	224.0	10.3	23	224.0	7.4	18
9	70.9	3.6	8	70.9	3.3	7	270.9	9.0	22
12	37.2	1.9	4	37.2	1.7	4	37.2	1.2	3
20	30.0	1.5	3	150.0	6.9	15	190.3	6.3	16
21	40.0	2.1	4	80.0	3.7	8	186.8	6.2	15
32				48.0	2.2	5	48.1	1.6	4
33	40.0	2.1	4	40.0	1.8	4	161.8	5.4	13
35	60.0	3.1	7	60.0	2.8	6	223.0	7.4	18
39	30.0	1.5	3	30.0	1.4	3	120.0	4.0	10
42	58.0	3.0	6	58.0	2.7	6			
43	31.0	1.6	3						
37	57.0	2.9	6	57.0	2.6	6	227.0	7.5	19
Totals	1943.3	100.0	215	2181.3	100.0	221	3015.3	100.0	248

Note: It has been assumed that blocks having industries today will have them also in the future