ANNEX CASE STUDY ON SURFACE WATER INTAKE

1 USE OF SURFACE WATER

1.1 GENERAL

Hanoi city has been taking groundwater for its public water supply. Although it is said that groundwater is available enough in Hanoi, draw down of the groundwater level has been progressing at some well fields. And a possibility of serious land subsidence due to the excessive groundwater exploitation is feared. In addition, it is reported that a problem of water quality, that is, high concentration of ammonia, is becoming serious at treatment plants in southern part of Hanoi.

A necessity to find an alternative water source is advocated for a solution of these problems. Moreover, a comprehensive study for future water sources is necessary for the future demand increase. This study focuses on a surface water system to supply Hanoi city.

1.2 ALTERNATIVE PLANS

A number of alternative plans for surface water intake can be proposed, considering the river as water source, the intake site, etc. Among them, five (5) alternative plans have been considered. Their water source and intake sites are as follows :

Alternattive	Water Source	Intake Site
Alternative A	Da River	Ky Son
Alternative B	Da River	Hoa Binh Dam Reservoir
Alternative C	Da River	Trung Ha
Alternative D	Da River	Bat Bat
Alternative E	Red River	Upstream of Thang Long Bridge

Their locations are mapped on Figure 1-1. Longitudial profiles for transmission pipelines from intake sites to Hanoi are shown in Figure 1-2. Their characteristics are compared in Table 1-1. As for surface water quality, details are described in the attached sheets, DATA 1.

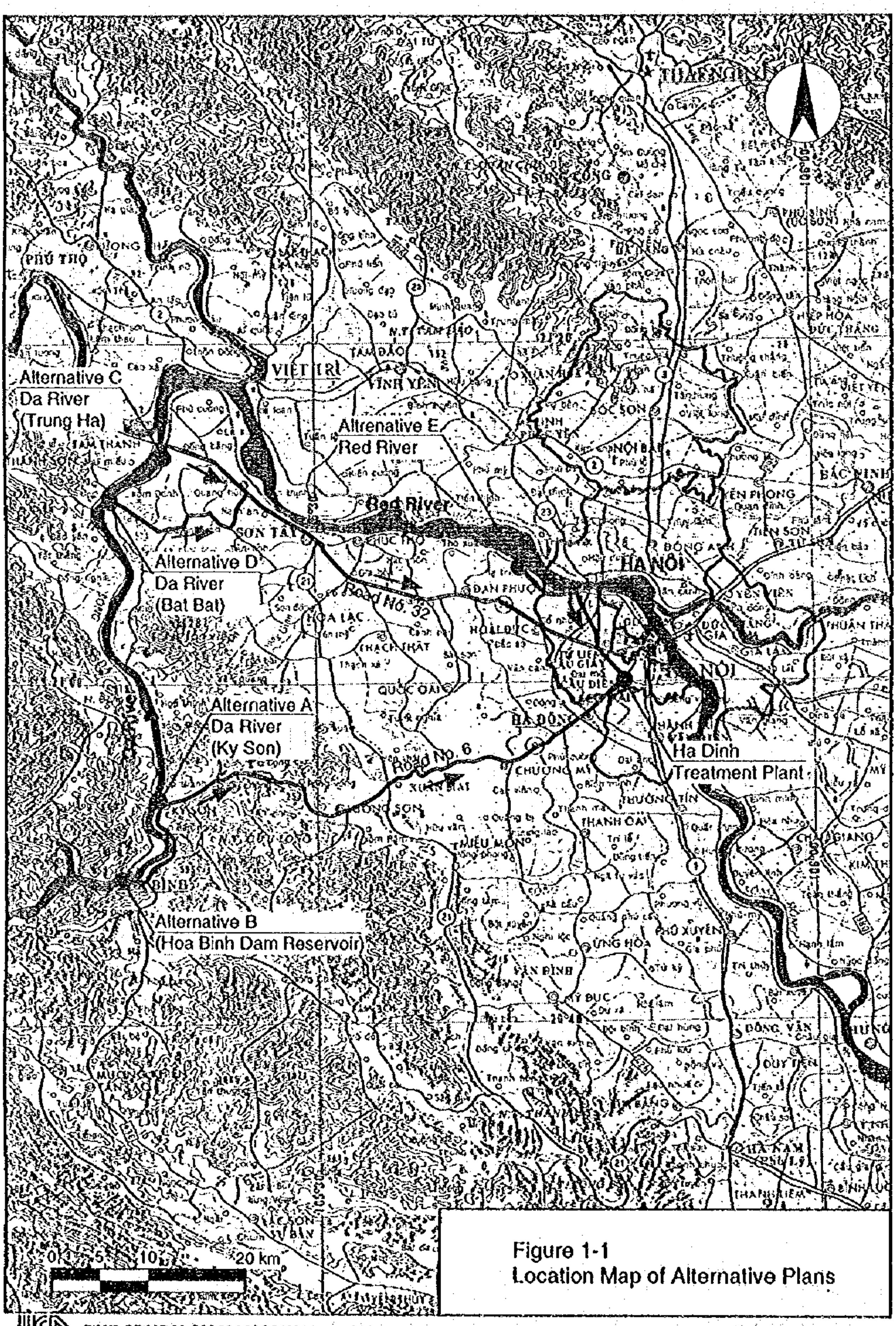


Figure 1-1
Location Map of Alternative Plans

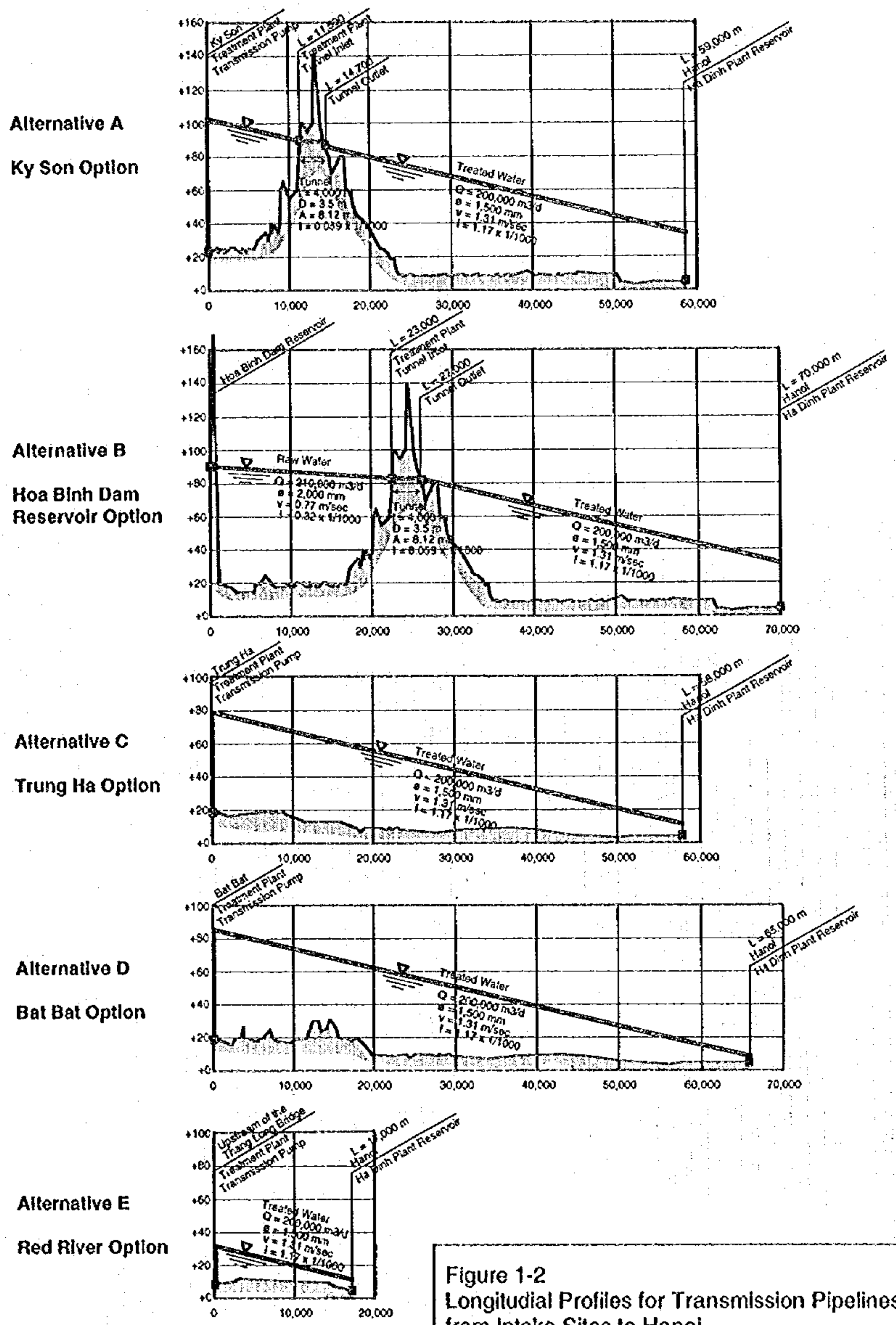


Figure 1-2
Longitudial Profiles for Transmission Pipelines from Intake Sites to Hanoi

Table 1-1 Comparison of the Alternative Plans

	A Ky Son	B Hoa Binh Dam Reservoir	C Trung Ha	D Bat Bat	E Red River
River for intake	Da River	Da River	Da River	Da River	Red River
Intake site	Ky Son	Hoa Binh Dam Reservoir	Trung Ha	Bat Bat	5-10 km upstream of Thang Long Bridge
Accessibility to the site from Hanoi	59 km	Far from Hanoi (70 km)	58 km	65 km	Easy (17km)
Water level of the River	about +10.0 m	LWL + 88.0 m	about +10.0 m	about +10.0 m	about +10.0 m
Water flow	Abundant enough more than 1,260 m3/sec	Abundant enough more than 1,260 m3/sec	Abundant enough more than 1,260 m3/sec	Abundant enough more than 1,260 m3/sec	Abundant enough more than 2,950 m3/sec
Water quality	Not so good Concentration of As, Pb and Phenol does not always meet the requirement of the domestic water supply	Good However, Turbidity sometimes shows high value during rainy season	Not so good Concentration of As, Pb and Phenol does not always meet the requirement of the domestic water supply	Not so good Concentration of As, Pb and Phenol does not always meet the requirement of the domestic water supply	Not so good Concentration of As, Pb and Phenol does not always meet the requirement of the domestic water supply
Proposed location of treatment plant	Ky Son	Mountainous site on National Road No.6 at latitude of + 80.0 m or in/nearby Hanoi	Trung Ha or in/nearby Hanoi	Bat Bat or in/nearby Hanoi	Upstream of Thang Long Bridge or in/nearby Hanoi
Distance of transmission pipeline	L = 59,000 m	L = 70,000 m (Longest)	L = 58,000 m	L = 65,000 m	L = 17,000 m (Shortest)
Land acquisition	Not so difficult	Not so difficult	Not so difficult	Not so difficult	More difficult than Da River Sides
Proposed route of transmission of pipeline	National Road No.6	National Road No.6	National Roads No. 32	National Roads No. 32	
Topographical particulars on the pipeline route	There exists a mountain-pass to cross (+ 140 m) on the route	There exists a mountain-pass to cross (+ 140 m) on the route	Almost flat + 15 m - + 10 m	Almost flat + 15 m - + 10 m	Almost flat about + 10 m
Power or energy required for water transmission to Hanoi	Transmission pump p = 2,550 kW for 200,000 m3/d	By gravity of the reservoir (No additional power is necessary)	Transmission pump p = 1,860 kW for 200,000 m3/d	Transmission pump p = 1,860 kW for 200,000 m3/d	Transmission pump p = 930 kW for 200,000 m3/d
Construction Cost	B > A > C/D > E				
Operation and Maintenance Cost	A/C/D > E > B				

1.3 DESIGN CAPACITY

This study deals with the surface water system to Hanoi taking raw water from Da River of which design capacity is 200,000 m3/d. For this purpose, one representative plan has been tentatively studied.

Note 1 :

As the case study, this has been examined independently from the Master Plan of Hanoi Water Supply Systems towards 2010.

Note 2 :

The treatment capacity of 200,000 m3/d has been set up from the following points of view :

(i) The existing treatment plants, which are obliged to take groundwater that contains high concentration of ammonia and iron, have the following capacities :

- Ha Dinh Treatment Plant	:	25,000 m3/d
- Phap Van Treatment Plant	:	30,000 m3/d
- Tuong Mai Treatment Plant	:	30,000 m3/d

(ii) Future increase (Estimation) : 100,000 m3/d

(i) + (ii)= 185,000 m3/d ... approximately 200,000 m3/d has been concluded.

1.4 TREATMENT PROCESS

The treatment process consists of mainly the following process :

1) Coagulation and Sedimentation
2) Filtration
3) Chlorination

Figure1-3 shows the surface water system flow, including the treatment process.

1.5 INTAKE FACILITIES

The type of intake facility is planned to be the intake tower to be constructed on the river bed side. The intake pumps installed inside the tower transmit the raw water to the receiving tank of the treatment plant across the river dyke.

The intake tower should be designed so as to accommodate the future intake capacity extension, since the intake structure is difficult to be expanded.

1.6 TREATMENT PLANT

Tentative layout plan of the treatment plant is shown in Figure 1-4. The general description of the main structures is tabulated in Table 1-2.

Table 1-2 General Description of the Main Structure

Structure	Design Criteria	Description
Receiving Tank	1.5 minutes	400 m3 x 1 tank
Chemical Mixing Chamber	5 minutes	72 m3 x 4 chambers = 288 m3
Floculation Tank	40 minutes	750 m3 x 8 tanks = 6,000 m3
Sedimentation Tank	4 hours	1,100 m2 x 4mH x 8 tanks = 35,200 m3
Rapid Sand Filter	120 m/day	110 m2 x 16 beds = 1,760 m2
Clear Water Reservoir	1 hour	4,200 m3 x 2 tanks = 8,400 m3

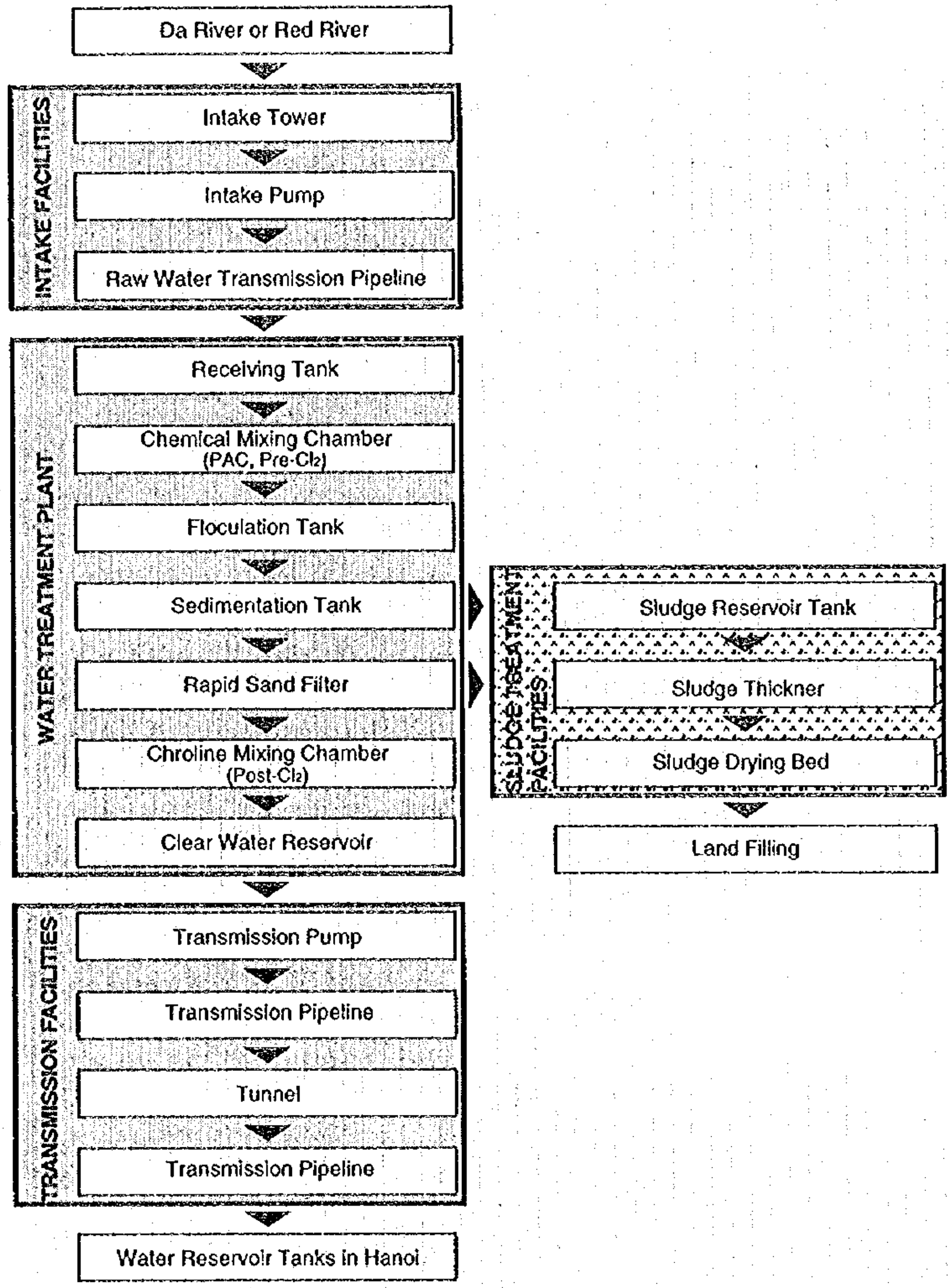
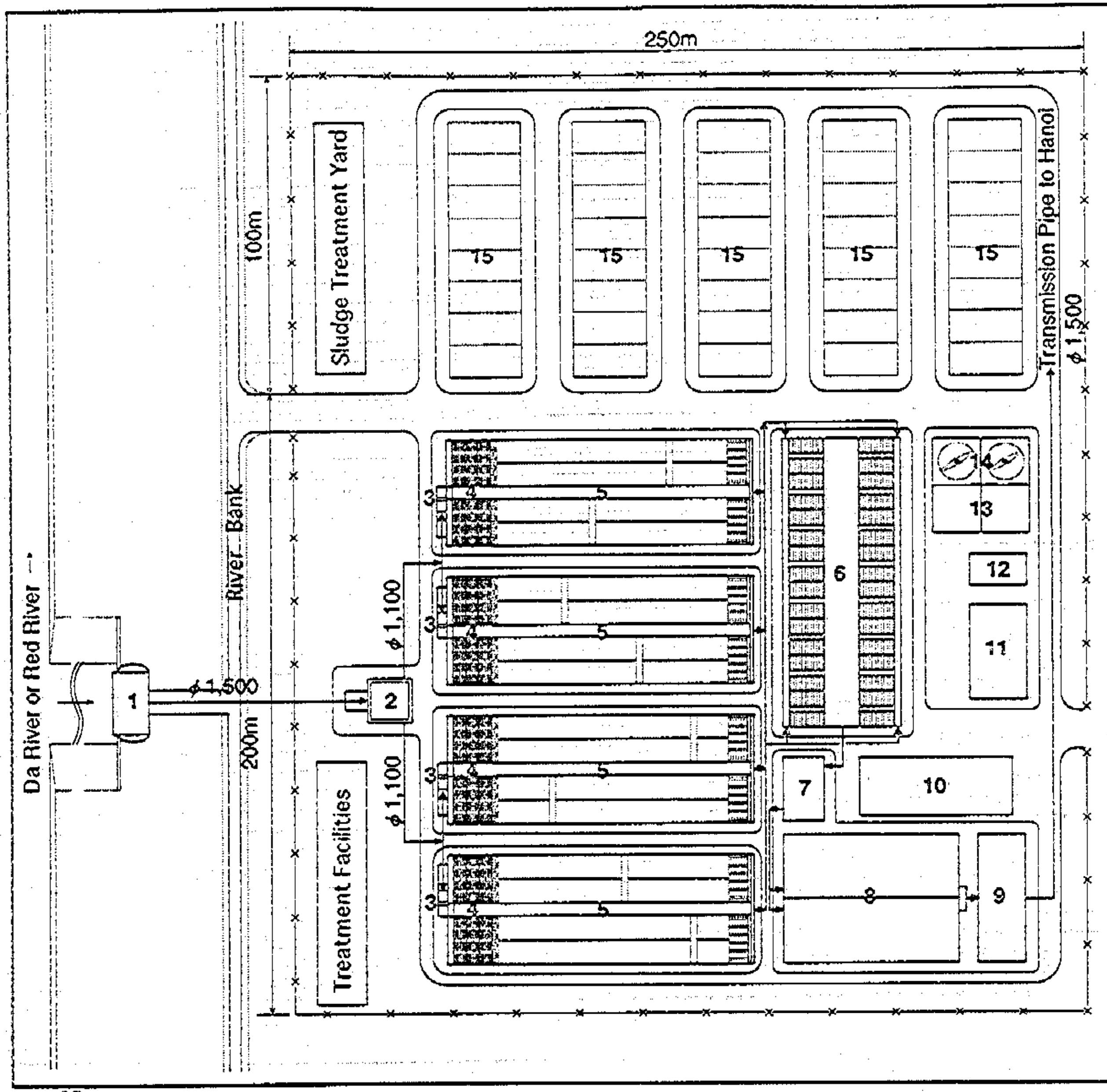


Figure 1-3 System Flow Sheet



No.	Facility
1	Intake Pumping Tower
2	Receiving Tank
3	Chemical Mixing Chamber
4	Floculation Tank
5	Sedimentation Tank
6	Rapid Sand Filter
7	Chroline Mixing Chamber
8	Clear Water Reservoir
9	Transmission Pumping Station
10	Administration Building
11	Chemical Building
12	Power Substation
13	Sludge Reservoir Tank
14	Sludge Thickner
15	Sludge Drying Bed

Figure 1-4 Tentative Layout of a Water Treatment Plant for Surface Water Q=200,000 m3/d

2 CASE STUDY OF KY SON OPTION (Alternative A)

In the preceding section, five (5) alternative plans were explained. Among them, the Alternative A (Ky Son Option) is studied in more detail hereunder, as a representative case for surface water intake.

The reason for dealing with Ky Son Option is :

- Water quality of Da River is better than that of Red River.
- This option has many technical issues such as 1) long distance transmission of water, 2) high pressure in the pipeline, 3) tunnel construction on the pipeline route, 4) effective utilization of potential energy of water, etc.
- The transmission pipeline of this option can supply water to small villages/towns located along the pipeline route, if required.

The Ky Son Option, therefore, is to present various technical considerations.

2.1 INTAKE SITE

Da River has been tentatively selected to be the water source, taking into consideration of its good water quality and abundant discharge.

As for the intake point, the river side at Ky Son, 3 km north of Hoa Binh Town, is selected on the basis of the following advantages :

1) Better water quality at the upper stream where water contamination is lower
2) Stability of the river bed
3) Availability of suitable lands to construct the intake facility and the treatment plant
4) Accessibility to the site

2.2 LOCATION OF THE TREATMENT PLANT

Location of the treatment plant is tentatively selected at Ky Son on account of the following advantages :

1) An enough land space for the plant is available nearby the intake point.
2) Total power energy for water transmission can be reduced, because treated water is about five percent less in amount than raw water owing to the treatment process loss. (If the treatment plant is placed in Hanoi, the energy cost for raw water transmission requires five percent more than that of treated water transmission.)
3) Treated water can be supplied to the small villages or towns along the transmission pipeline towards Hanoi, if required.

The treated water is planned to be transmitted to the distribution reservoirs of the existing treatment plants in Hanoi.

The location map is shown in Figure 2-1 and the hydraulic profile of the transmission pipeline in Figure 2-2.

2.3 TRANSMISSION PIPELINE

Based on the field survey, the National Road No. 6 is selected as the transmission pipeline route from the Ky Son treatment plant to Hanoi, the total distance of which is about 59,000 m. Its pipe material is assumed to be the ductile cast iron. Taking into account of the economical diameter in the case of pumped-up pipeline, the diameter of 1,500 mm is selected for the amount of 200,000 m3/d.

The profile of the pipeline is shown in Figure 2-2. It shall be noted that the mountain-pass exists on the transmission pipeline route, National Road No. 6, the altitude of which is +140 m above sea level. To transmit water across the mountain-pass, two alternative plans have been studied.
They are :

(A) Booster Pump Plan :
The booster pumps are installed on the way of the pipeline to transmit the treated water across the mountain-pass. The profile of its plan is attached in Appendix CS-01.

(B) The Tunnel Plan :
The treated water is transmitted through the tunnel constructed at the altitude of +86 m above sea level. This tunnel acts as a regulation tank, and water can be gravitated to Hanoi from the tunnel.

Note 1 :
In order to transmit water to Hanoi, water level (i.e., potential energy of water) required at this mountain site is +80 m - +90 m above the sea water level.

Note 2 :
Allowable high pressure in the pipeline is decided to be about 80 m (= 8.0 kg/cm2)

As a result of the economic comparative study, the alternative (B) was found to be more economical than the alternative (A). Accordingly, the alternative (B), the tunnel construction, is proposed in this study. The comparative study is detailed in the attached sheets, DATA 2.

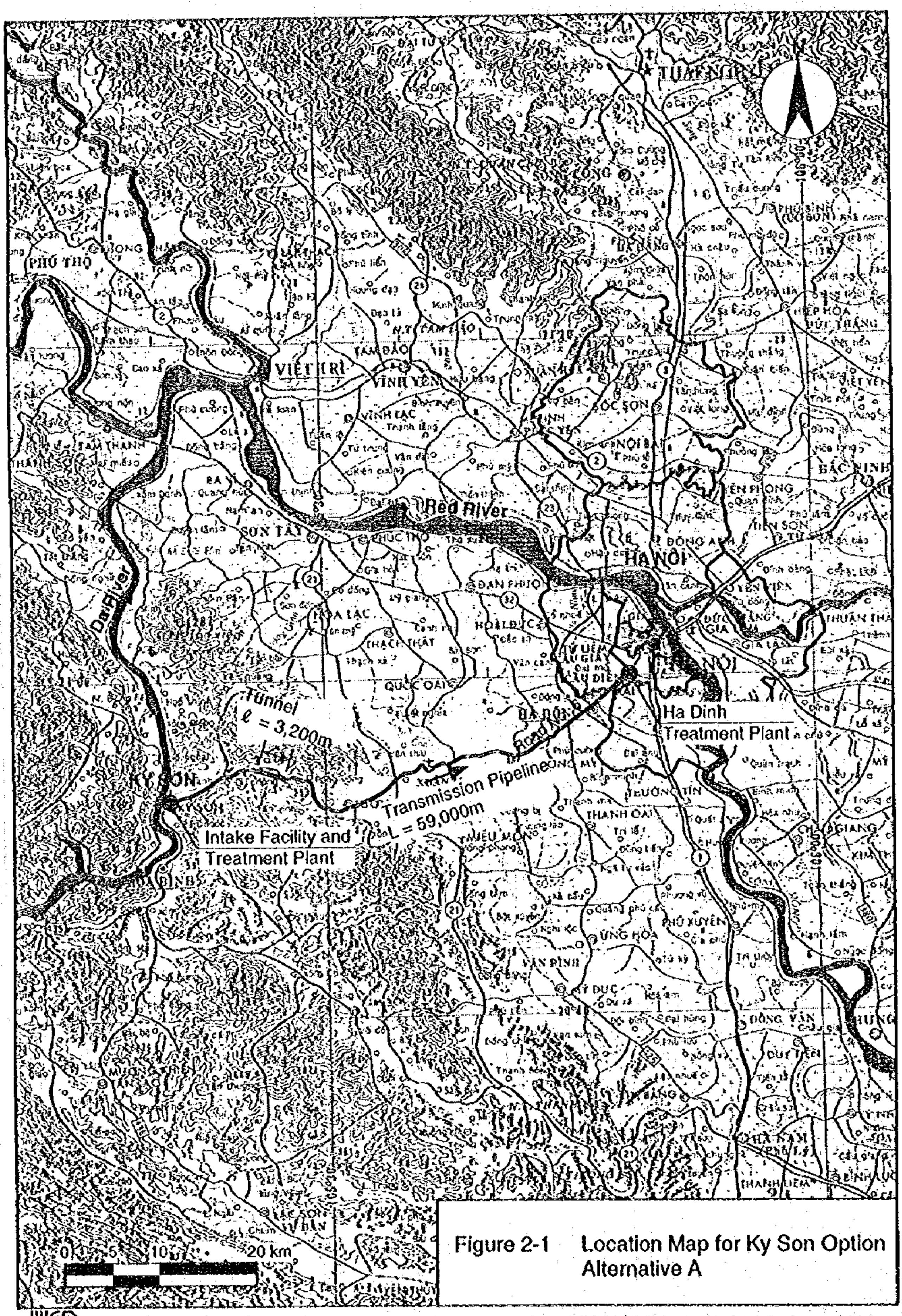


Figure 2-1 Location Map for Ky Son Option Alternative A

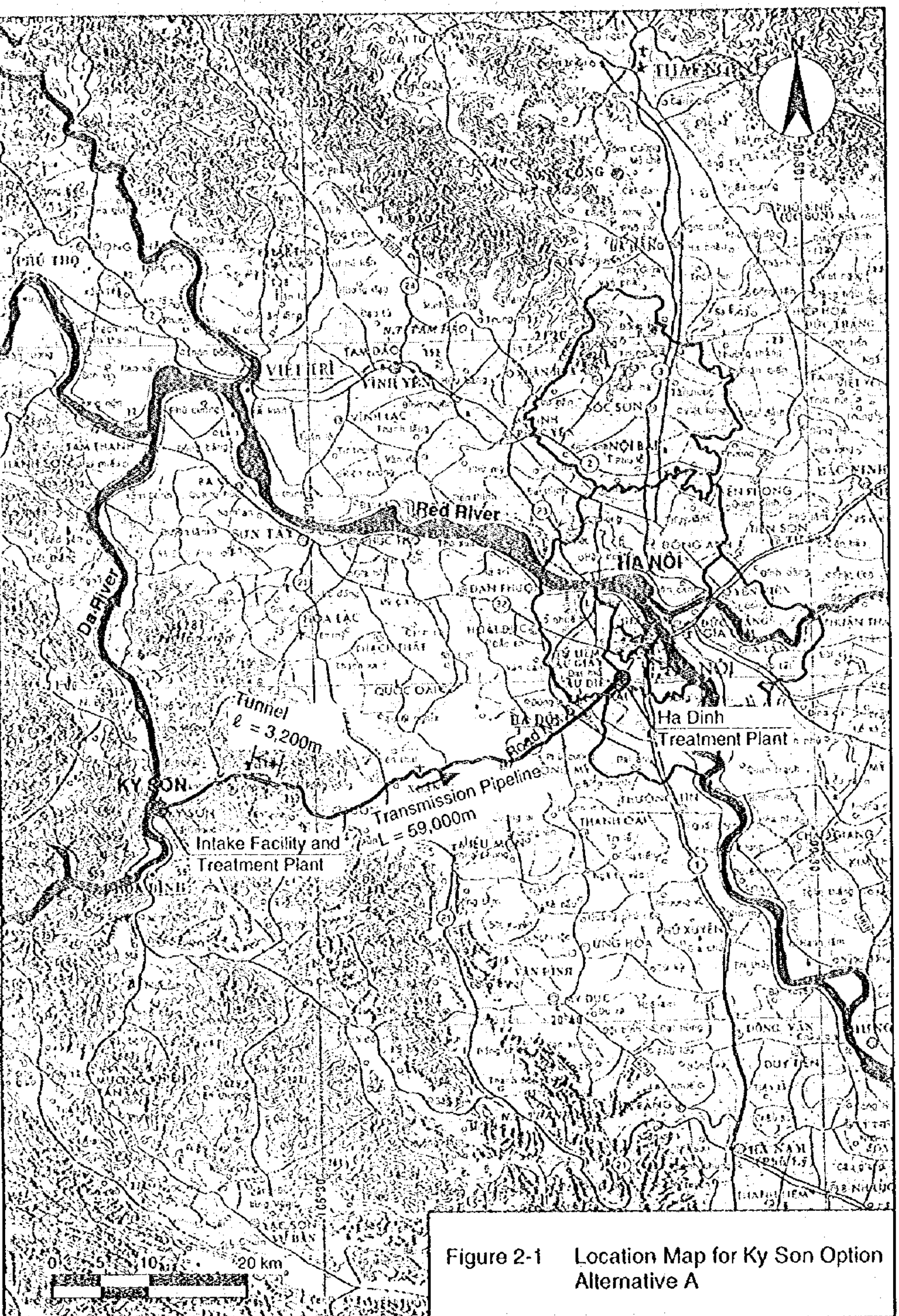


Figure 2-1 Location Map for Ky Son Option Alternative A

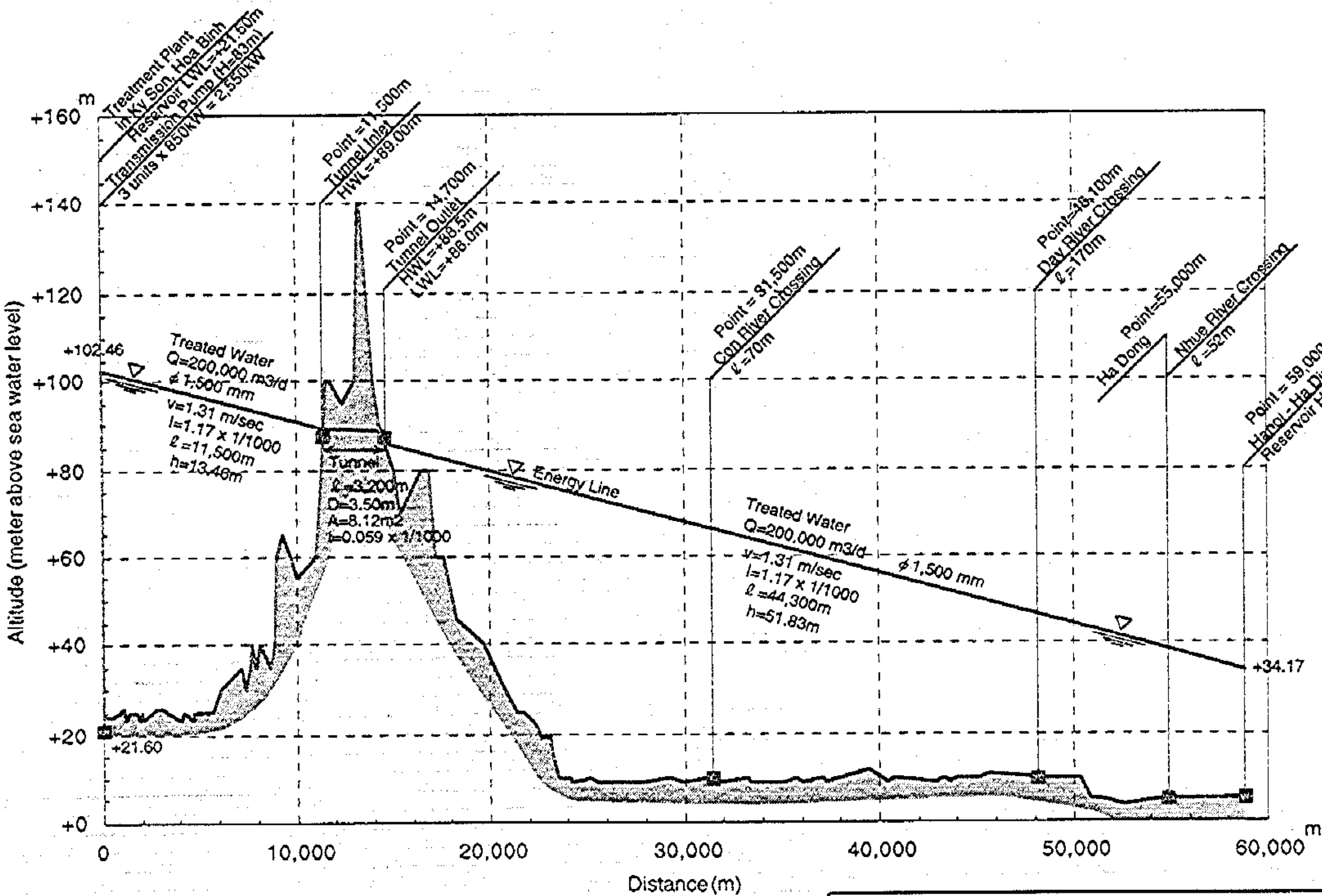


Figure 2-2
Hydraulic Profile of Transmission Pipeline
from Da River (Ky Son) to Hanoi (Ha Dinh Plant Reservoir),
Ky Son Option (Alternative A)

2.4 COST ESTIMATION

2.4.1 CONSTRUCTION COST

Tentative cost estimation of the plan is described in Table 2-1.

Table 2-1 Tentative Cost Estimation (Ky Son Option : Q=200,000 m3/d)

Item		Cost (1,000 US$)		
		Total	Foreign Currency Portion	Local Currency Portion
A	INTAKE FACILITIES (210,000 m3/d)			
	(A1) Intake structures (Tower, Bridge, Channel)	10,365	5,701	4,664
	(A2) Intake pumps (270 kW x 4 units)	3,377	3,208	169
	Total A (A1+A2+A3)	13,742	8,909	4,833
B	TREATMENT PLANT (210,000 m3/d)			
	(B1) Treatment plant	34,650	17,325	17,325
	(B2) Land cost	750	-	750
	Total B (B1+B2)	35,400	17,325	18,075
C	TRANSMISSION FACILITIES (200,000 m3/d)			
	(C1) Transmission pumps (850 kW x 4 units)	4,025	3,824	201
	(C2) Pipeline (ϕ1,500 DIP, 55.8 km)	73,043	67,072	5,971
	(C3) Tunnel (Dia. 4.4 m, ℓ = 3.2 km)	15,566	8,561	7,005
	(C4) Pipe bridges (River crossing, 3 sites)	2,697	2,023	674
	Total C (C1+C2+C3+C4)	95,331	81,480	13,851
Total (A+B+C)		144,473	107,714	36,759

2.4.2 OPERATION AND MAINTENANCE COST

The operation and maintenance cost is tentatively estimated as below Table 2-2.

Table 2-2 Tentative Cost Estimate of Operation and Maintenance for Surface Water System

Q = 200,000 m3/day Ky Son Option

(Constant price of 1996 level, US$1.00 = VND 11,000, VND:Vietnamese Dong)

(A)	(B) Operation and Maintenance Cost (US$/year)						(C) = (B) / (A)
	(B1)	(B2)	(B3)	(B4)	(B5)	(B)	
Water Production (m3/year)	Staff	Chemical	Electricity	Repair	Others	Total	Cost of Operation and Maintenance per Production
73,000,000	$36,000 0.9%	$486,031 11.8%	$1,605,469 39.1%	$1,440,920 35.1%	$535,263 13.0%	$4,103,683 100.0%	0.056 $/m3 (616 VND/m3)

Calculation Note :

(A) Water Production
(A) = 200,000 m3/d x 365 days = 73,000,000 m3/year

(B1) Staff Cost
(Base salary = 660,000 VND/month, 1996 price)
(Number of stuffs = 50 persons)
(B1) = 660,000 VND/month + 11,000 $/VND x 12 months x 50 persons = $36,000

(B2) Chemical Cost (Liquid chlorine and PAC)
Chemical for disinfection : Liquid chlorine
Unit cost of liquid chlorine = 4,500 VND/kg
Chlorine dosage = [Pre-Chlorination] + [Post-Chlorination] = 3 ppm = 0.003 kg/m3
Chemical for coagulation : PAC
PAC dosage = 7.5 mg/l = 0.0075 kg/m3
Unit cost of PAC = 7,500 VND/kg
(B2) = (A) x 1.05[plant loss : 5%] x {(0.003 kg/m3 x 4,500 VND/kg) + (0.0075 kg/m3 x 7,500 VND/kg)} + 11,000 $/VND
= 486,031 $/year

(B3) Electricity Cost
(Operation : Three units of Intake pump and three units of distribution pump)
Electricity unit cost = 600 VND/kW
(B3) = (270 kW x 3 units + 850 kW x 3 units) x 24 hours x 365 days x 600 VND/kW + 11,000 $/VND
= 29,433,600 kW/year x 600 VND/kW + 11,000 $/VND = 1,605,469 $/year

(B4) Repair Cost
(Pumps : 2%, Tunnel : 0.5 %, Others : 1%)
(B4) = ($7,402,000 x 2%)[pumps] + ($15,566,000 x 0.5%)[tunnel] + ($121,505,000 x 1%)[others]
= 1,440,920 $/year

(B5) Others
Other cost = 15 % of (B1 + B2 + B3 + B4)

2.4.3 COSTS INCLUSIVE OF DISTRIBUTION NETWORKS

Costs calculated in the preceding sections do not include costs for distribution facilities, such as networks cost and distribution pump operation cost. In this section, costs including distribution facilities for the case of the surface water intake are tentatively calculated for the reference purpose.

Construction Cost

(For 200,000 m3/d system, Da River surface water, Ky Son Option)

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1) Intake facilities, treatment plant, transmission facilities = $ 144,473,000
2) Distribution networks = $ 83,636,000

Total (1+2) = $ 228,109,000

($ 228,109,000 for 200,000 m3/d —> $ 1,141 m3/d)

Annual Operation and Maintenance Cost

(For 200,000 m3/d system, Da River surface water, Ky Son Option)

1) From Da River to Hanoi = $ 4,103,683
(Staff, chemical, electricity, repair and others)
2) For distribution = $ 2,335,541 (see below)

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a) Repair cost of networks = (Construction cost) x 1 %
= $ 83,636,000 x 1 % = $ 836,360

b) Electricity cost for distribution pumps
= 200,000 m3/d x 0.3 kW/m3 x 365 days x 600 VND/kWh
= 13,140,000,000 VND = $ 1,194,545

c) Others = (a+b) x 15 % = $ 304,636

Total (a+b+c) = $ 2,335,541

Total operation and maintenance cost (1+2) = $6,439,224 /year (for 200,000 m3/d)
(—> 0.0882 $/m3 = 970 VND/m3)

DATA 1

Surface Water Quality in Hanoi and the Surroundings

(1) Water Quality Criteria

As for criteria for drinking water, same limit values as WHO's guidelines are adopted for most parameters prescribed in Vietnamese criteria. As for criteria for raw water, surface water should be evaluated by "water quality standard (class A for surface water)".

(2) Water Quality of the Sources for Water Supply

Table D1 shows averaged water quality characteristics of rivers in Hanoi and its surroundings. Data are derived from three sources; the first one is results monitored in 1994 by Hydrometeorological Service of Vietnam, the second one is a result occasionally surveyed by HPC and FINNIDA, and the third one is a result occasionally surveyed in this study. Locations of these monitoring stations and survey points are shown in Figure D1.

Red River and Da River Basins

Monthly water quality characteristics of four (4) monitoring stations in the Red River basin and the Da River basin are shown in Appendix. The characteristics are summarized as follows.

As for parameters such as pH and nitrate, all data for all rivers never exceed values of surface water quality standard "class A" that are applied for the purpose of using for source of domestic water supply. On average iron and BOD5 also satisfy the standard. Manganese of monitoring stations never exceed the standard value (0.1mg/l as class A), however higher values around 0.2mg/l were observed at all sampling points in the occasional survey.

As for toxic substances, averages of Pb and phenol do not satisfy the standard (Pb $\leq$ 0.05mg/l, phenol$\leq$0.001mg/l as class A) at almost all points except Hoa Binh reservoir. Annual averages of Arsenic (As) satisfy the standard, however monthly averages sometimes exceed the standard value (0.05mg/l as class A) in all monitoring stations.

These parameters often show contamination by human activities such as industry and mining, especially phenol never originates in nature. If these data are correct, it must be a serious problem and it can not be recommended to utilize these rivers for drinking water sources.

However, it is not so easy to approve these higher concentration by looking over the river basins. Because, it seems that at least Da River basin has not been heavily developed for industrial or mining industry, and the river seems to have a big volume of waterflow enough to dilute wastewater discharged from the industry. These values were obtained from monthly sampling only for one year (in 1994) and one time sampling, therefore further consecutive water quality monitoring of these rivers will be necessary for more reliable conclusion.

<u>Cau River Basin</u>

The characteristics are summarized as follows.

SS in both rivers and NH4-N in Cau River exceed standard values for class A. Other parameters like pH, nitrate, iron satisfy the standard "class A" in both rivers. Manganese of both rivers surveyed in June, 1995 never exceed the standard value (0.1mg/l as class A), however higher values around 0.2mg/l were observed at all sampling points in this study.

As for toxic substances, averages of Pb and phenol do not satisfy the standard (Pb $\leqq$ 0.05mg/l, phenol $\leqq$ 0.001mg/l as class A) in both rivers. These parameters often show contamination by human activities such as industry and mining, especially phenol never originates in nature. If these data are correct, it must be a serious problem and it can not be recommended to utilize these rivers for drinking water sources. Concentration values of organophosphate in all sampling points exceed a generally acceptable limit of 0.1mg/l. High concentration of organophosphate shows contamination by pesticide. These values were obtained from occasional sampling, therefore further consecutive water quality monitoring of these rivers will be necessary for more reliable conclusion.

Table D1 Surface Water Quality in Ha Noi and the Surroundings

River Name		Hong/Red			Da (upper)			Da (lower)		Cau (upper)	Cau (lower)		Cong		Water Quality Criteria				
Sampling Point		Son Tay St.	Ha Noi St.	Thang Long Bridge	Hoa Binh Reservoir	Hoa Binh St.	(Ngoc Port)	Trung Ha		Soi village	Tan Hung commune		Da Phuc bridge		Standard for Environment		Criteria for Drinking Water		
Sampling Period		1994.3~12	1994.3~12	1996.7	1996.7	1994.3~12	1996.7	1994.3~12	1996.7	1996.7	1995.6	1996.7	1995.6	1996.7	class A	class B	Urban	Distribution System & Rural	WHO's Guidelines
Sampling Frequency		10	10	1	1	10	1	10	1	1	1	1	1	1					
Parameter	unit	Concentration (Average)																	
pH		7.4	7.3	7.6	7.8	7.2	7.7	7.3	7.4	7.2	6.0	7.1	6.0	6.8	6~8.5	5.5~9	6.5~8.5	6.5~8.5	—
Nitrate (NO_3)	mg/l	0.9	1.0	1.9	2.2	1.1	2.2	0.9	2.7	1.6	0.1	1.2	0.1	1.3	10 (as N)	15 (as N)	10	10	50
Ammonia (NH_4)	mg/l	0.17	0.09	0.00	0.00	0.18	0.13	0.13	0.00	0.00	0.09	0.04	0.07	0.00	0.05 (N)	1 (N)	0	0	1.5
SS	mg/l	497	591	521	254	65	318	143	331	99	60	39	42	22	20	80	5	10	—
TDS	mg/l	—	—	81	68	—	68	—	68	63	—	47	—	29	—	—	500	1,000	1,000
BOD_5	mg/l	2.7	2.0	—	—	2.6	—	1.8	—	—	—	—	—	—	4	25	—	—	—
Turbidity (SiO_2)	mg/l	221	178	—	—	83	—	144	—	—	—	—	—	—	—	—	—	—	—
	NTU	—	—	880	311	—	389	—	445	126	—	70	—	43	—	—	—	—	5
Hardness	mg/l	83	81	76	66	75	69	80	65	55	50	64	40	64	—	—	500	500	—
Alkalinity	mg/l	102	106	106	36	98	66	102	72	99	—	110	—	64	—	—	—	—	—
Total Iron	mg/l	0.24	0.30	0.77	1.01	0.22	1.28	0.20	1.12	0.75	0.35	0.59	0.50	0.45	1	2	0.3	0.5	0.3
Zn	mg/l	0.0	0.0	—	—	0.0	—	0.0	—	—	—	—	—	—	1	2	5	5	3
As	mg/l	0.047	0.030	0.000	0.000	0.027	0.000	0.025	0.000	0.000	—	0.000	—	0.000	0.05	0.1	0.05	0.05	0.01
Cd	mg/l	<0.001	<0.001	—	—	0.000	—	<0.001	—	—	—	—	—	—	0.01	0.02	0.005	0.005	0.003
Cr (total)	mg/l	0.033	0.022	—	—	0.023	—	0.021	—	—	—	—	—	—	—	—	0.05	0.05	0.05
(III)		—	—	—	—	—	—	—	—	—	—	—	—	—	0.1	1	—	—	—
(VI)		—	—	0.000	0.000	—	0.000	—	0.000	0.000	—	0.020	—	0.000	0.05	0.05	—	—	—
Cu	mg/l	0.01	0.02	—	—	0.01	—	0.01	—	—	—	—	—	—	0.1	1	1	1	1 (complaint) 2 (health)
CN	mg/l	—	—	0.003	0.001	—	0.001	—	0.001	0.001	—	0.003	—	0.004	0.01	0.05	0.1	0.1	0.07
Pb	mg/l	0.034	0.033	0.120	0.068	0.028	0.099	0.034	0.051	0.098	—	0.050	—	0.069	0.05	0.1	0.05	0.05	0.01
Hg	mg/l	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	—	0.000	—	0.000	0.001	0.002	0.001	0.001	0.001
Ni	mg/l	0.02	0.02	—	—	0.02	—	0.01	—	—	—	—	—	—	0.1	1	—	—	0.02
Mn	mg/l	0.01	0.02	0.21	0.22	0.01	0.22	0.01	0.22	0.22	0.05	0.21	0.07	0.19	0.1	0.8	0.1	0.1	0.1 (complaint) 0.5 (health)
Phenol	mg/l	0.014	0.014	0.022	0.000	0.006	0.000	0.010	0.050	0.020	—	0.018	—	0.020	0.001	0.02	—	—	—
DDT	mg/l	0.001	0.002	—	—	0.001	—	0.000	—	—	—	—	—	—	0.01	0.01	0.001	0.001	0.002
Organophosphate	mg/l	—	—	0.0	0.0	—	0.0	—	0.0	0.6	—	2.0	—	1.0	—	—	—	—	—

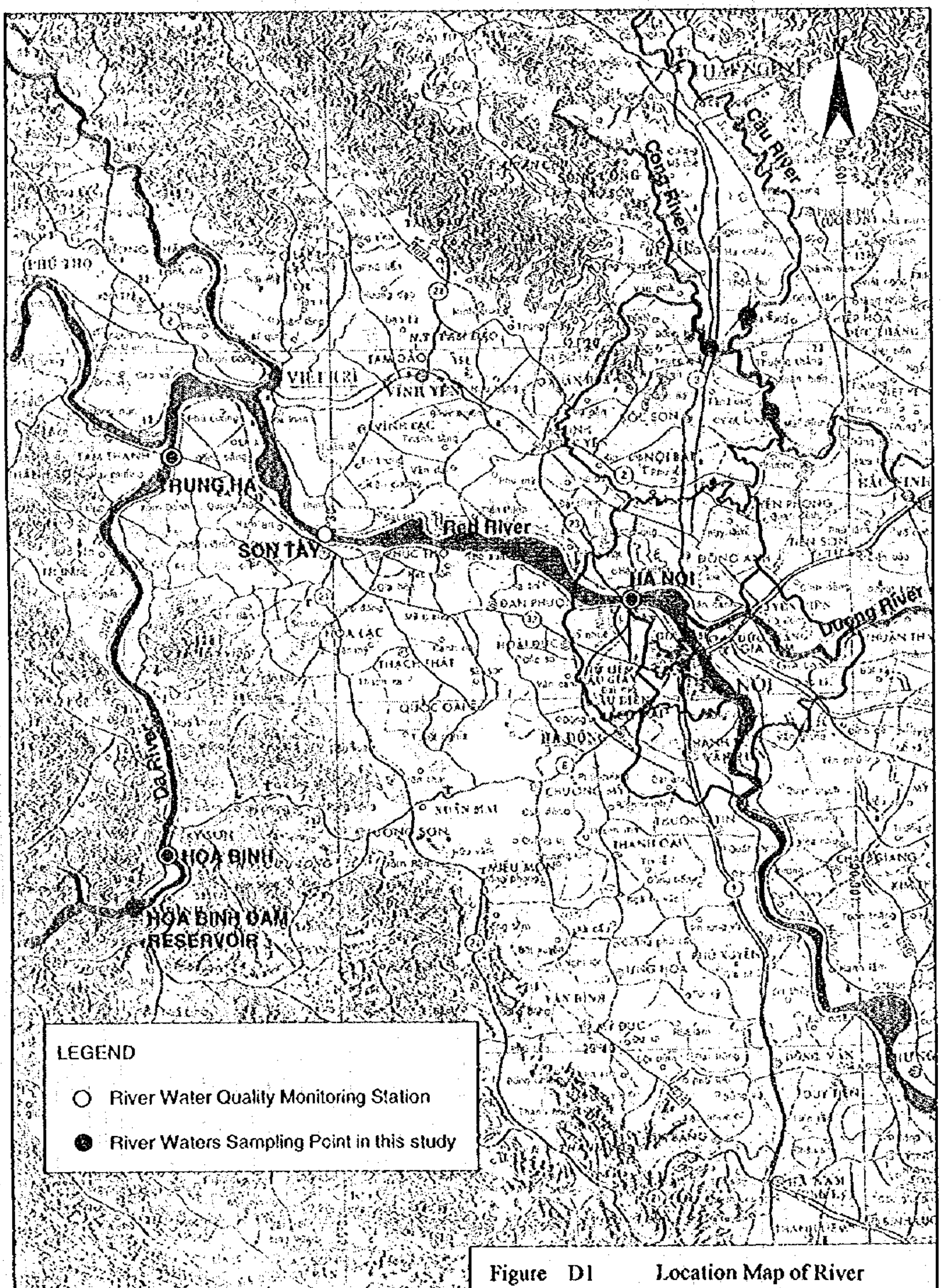


Figure D1 Location Map of River Water Quality Sampling Points

DATA 2

Economic Comparison on a Tunnel Construction
(Ky Son Option)

- Transmission Method of Passing-over the Mountain on the Pipeline Route -

For the treated water transmission method in Ky Son Option, two alternative plans are taken into account. The first is the booster pump plan and the second is the tunnel plan. The hydraulic profile of the transmission pipeline showing the tunnel plan is given in the main body; and that for the booster pump plan in the next page.

In order to find more advantageous plan between the two, an economic comparison has been studied in respect to both the construction cost and the operation and maintenance cost (O&M cost). It is understood that the booster pump plan is less expensive than the tunnel plan in construction cost, and the tunnel plan is lower in O&M cost. In comparison between the total costs (construction cost and O&M cost) for the period of 40 years after completion of the facilities, the tunnel plan was found to be more economical than the booster pump plan. Accordingly, the tunnel plan is proposed to the transmission system.

The calculation for the comparison is performed by the present value analysis method as presented in the following pages. The discount rate of 10 % per annum is applied for the calculation. Total costs in terms of the present value for the two plans are as below:

Tunnel Plan = US$ 50,997,827
Booster Pump Plan = US$ 52,051,804

Note 1

The height of the mountain at the peak = +140 m
The water energy required to transmit to Hanoi is about +80 m to +90 m. The altitude of the tunnel to be constructed is + 86 m.

Note 2

The maximum allowable water pressure in pipes is 8 kg/cm2 (equals to water pressure of 80 m). In the case of direct transmission from the pumping station of the treatment plant, the water pressure is required to be 140 m which exceeds the maximum allowable pressure. Therefore, installation of the booster pumps is proposed, on the way of the pipeline route.

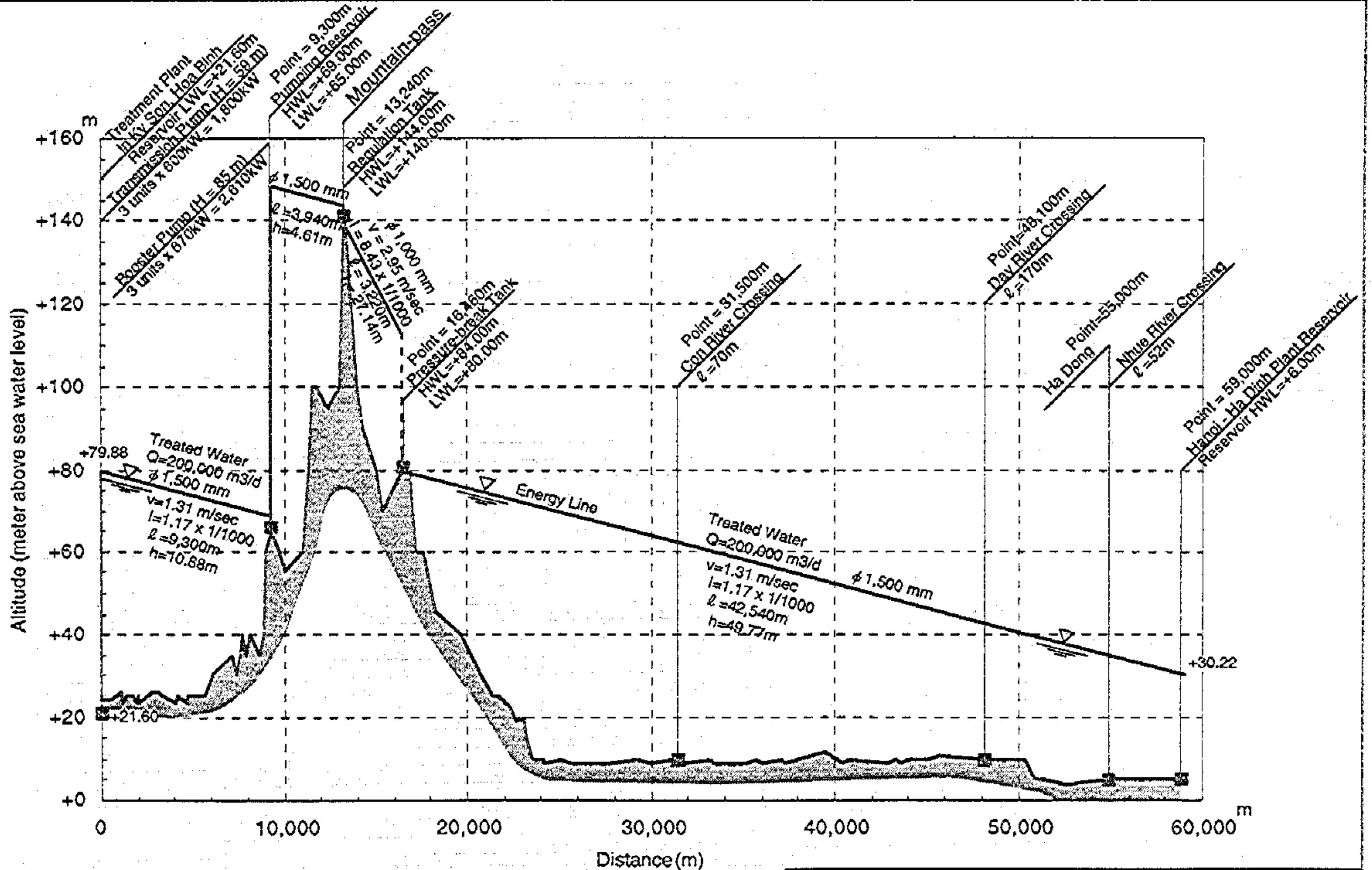
Calculation on the Construction Cost and the Operation and Maintenance Cost

Tunnel Plan

Construction Cost	T1	Transmission Pumps	850 kW x 4 units	$4,025,000
	T2	Transmission Pipeline	ϕ 1,500 mm; L = 13,260 m	$17,344,080
	T3	Tunnel	Dia. 4.4m; L = 3,200 m	$15,566,000
		Total		$36,935,080
Operation and Maintenance Cost (per annum)	T4	Electric Power Cost	850 kW x 3 units, 600 VND/kW	$1,218,437
	T5	Repair Cost (Pumps)	2% of (T1)	$80,500
	T6	Repair Cost (Pipe)	1 % of (T2)	$173,441
	T7	Repair Cost (Tunnel)	0.5% of (T3)	$77,830
		Total		$1,550,208

Booster Pump Plan

Construction Cost	B1	Transmission Pumps	600 kW x 4 units	$3,421,000
	B2	Booster Pumps	870 kW x 4 units	$4,120,000
	B3	Power Sub-station		$904,920
	B4	Transmission Pipeline ϕ 1,500 mm	ϕ 1,500 mm x 13,240 m	$17,317,920
	B5	Transmission Pipeline ϕ 1,000 mm	ϕ 1,000 mm x 3,220 m	$2,150,960
	B6	Reservoir		$1,060,455
	B7	Regulation Tank		$187,727
	B8	Pressure Breaking Chamber		$187,727
		Total		$29,350,709
Operation and Maintenance Cost (per annum)	B9	Electric Power Cost (Transmission)	600 kW x 3 units, 600 VND/kW	$860,073
	B10	Electric Power Cost (Booster)	870 kW x 3 units, 600 VND/kW	$1,247,106
	B11	Repair Cost (Power units)	2% of (B1 + B2 + B3)	$168,918
	B12	Repair Cost (Others)	1% of (B4 + B5 + B6 + B7 + B8)	$209,048
		Total		$2,485,145



Hydraulic Profile of Transmission Pipeline
from Da River (Ky Son) to Hanoi (Ha Dinh Plant Reservoir)
Q=200,000m3/d
(Case of the Booster pump use)

Cost Calculation with Present Value Method
Case of Tunnel Plan

n	Year	1996 Price Cost: Construction Cost (A)	Operation and Maintenance Cost (B)	Total (C) = (A) + (B)	Discounted Cost: Discount Rate = 10% (D,) = (C) x (1-0.1)ⁿ
0	1996	$ 36,935,080	$ 0	$ 36,935,080	$ 36,935,080
1	1997	$ 0	$ 1,550,208	$ 1,550,208	$ 1,395,187
2	1998	$ 0	$ 1,550,208	$ 1,550,208	$ 1,255,668
3	1999	$ 0	$ 1,550,208	$ 1,550,208	$ 1,130,102
4	2000	$ 0	$ 1,550,208	$ 1,550,208	$ 1,017,091
5	2001	$ 0	$ 1,550,208	$ 1,550,208	$ 915,382
6	2002	$ 0	$ 1,550,208	$ 1,550,208	$ 823,844
7	2003	$ 0	$ 1,550,208	$ 1,550,208	$ 741,460
8	2004	$ 0	$ 1,550,208	$ 1,550,208	$ 667,314
9	2005	$ 0	$ 1,550,208	$ 1,550,208	$ 600,582
10	2006	$ 0	$ 1,550,208	$ 1,550,208	$ 540,524
11	2007	$ 0	$ 1,550,208	$ 1,550,208	$ 486,472
12	2008	$ 0	$ 1,550,208	$ 1,550,208	$ 437,825
13	2009	$ 0	$ 1,550,208	$ 1,550,208	$ 394,042
14	2010	$ 0	$ 1,550,208	$ 1,550,208	$ 354,638
15	2011	$ 0	$ 1,550,208	$ 1,550,208	$ 319,174
16	2012	$ 0	$ 1,550,208	$ 1,550,208	$ 287,257
17	2013	$ 0	$ 1,550,208	$ 1,550,208	$ 258,531
18	2014	$ 0	$ 1,550,208	$ 1,550,208	$ 232,678
19	2015	$ 0	$ 1,550,208	$ 1,550,208	$ 209,410
20	2016	$ 0	$ 1,550,208	$ 1,550,208	$ 188,469
21	2017	$ 2,898,000	$ 1,550,208	$ 4,448,208	$ 486,718
22	2018	$ 0	$ 1,550,208	$ 1,550,208	$ 152,660
23	2019	$ 0	$ 1,550,208	$ 1,550,208	$ 137,394
24	2020	$ 0	$ 1,550,208	$ 1,550,208	$ 123,655
25	2021	$ 0	$ 1,550,208	$ 1,550,208	$ 111,289
26	2022	$ 0	$ 1,550,208	$ 1,550,208	$ 100,160
27	2023	$ 0	$ 1,550,208	$ 1,550,208	$ 90,144
28	2024	$ 0	$ 1,550,208	$ 1,550,208	$ 81,130
29	2025	$ 0	$ 1,550,208	$ 1,550,208	$ 73,017
30	2026	$ 0	$ 1,550,208	$ 1,550,208	$ 65,715
31	2027	$ 0	$ 1,550,208	$ 1,550,208	$ 59,144
32	2028	$ 0	$ 1,550,208	$ 1,550,208	$ 53,229
33	2029	$ 0	$ 1,550,208	$ 1,550,208	$ 47,906
34	2030	$ 0	$ 1,550,208	$ 1,550,208	$ 43,116
35	2031	$ 0	$ 1,550,208	$ 1,550,208	$ 38,804
36	2032	$ 0	$ 1,550,208	$ 1,550,208	$ 34,924
37	2033	$ 0	$ 1,550,208	$ 1,550,208	$ 31,431
38	2034	$ 0	$ 1,550,208	$ 1,550,208	$ 28,288
39	2035	$ 0	$ 1,550,208	$ 1,550,208	$ 25,459
40	2036	$ 0	$ 1,550,208	$ 1,550,208	$ 22,913
Total		$ 39,833,080	$ 62,008,320	$ 101,841,400	$ 50,997,827

Tunnel

Cost Calculation with Present Value Method
Case of Booster Pump Plan

n	Year	1996 Price Cost			Discounted Cost
		Construction Cost	Operation and Maintenance Cost	Total	Discount Rate = 10%
		(A)	(B)	(C) = (A) + (B)	$(D_n) = (C) \times (1-0.1)^n$
0	1996	$ 29,350,709	$ 0	$ 29,350,709	$ 29,350,709
1	1997	$ 0	$ 2,485,145	$ 2,485,145	$ 2,236,631
2	1998	$ 0	$ 2,485,145	$ 2,485,145	$ 2,012,967
3	1999	$ 0	$ 2,485,145	$ 2,485,145	$ 1,811,671
4	2000	$ 0	$ 2,485,145	$ 2,485,145	$ 1,630,504
5	2001	$ 0	$ 2,485,145	$ 2,485,145	$ 1,467,453
6	2002	$ 0	$ 2,485,145	$ 2,485,145	$ 1,320,708
7	2003	$ 0	$ 2,485,145	$ 2,485,145	$ 1,188,637
8	2004	$ 0	$ 2,485,145	$ 2,485,145	$ 1,069,773
9	2005	$ 0	$ 2,485,145	$ 2,485,145	$ 962,796
10	2006	$ 0	$ 2,485,145	$ 2,485,145	$ 866,516
11	2007	$ 0	$ 2,485,145	$ 2,485,145	$ 779,865
12	2008	$ 0	$ 2,485,145	$ 2,485,145	$ 701,878
13	2009	$ 0	$ 2,485,145	$ 2,485,145	$ 631,691
14	2010	$ 0	$ 2,485,145	$ 2,485,145	$ 568,521
15	2011	$ 0	$ 2,485,145	$ 2,485,145	$ 511,669
16	2012	$ 0	$ 2,485,145	$ 2,485,145	$ 460,502
17	2013	$ 0	$ 2,485,145	$ 2,485,145	$ 414,452
18	2014	$ 0	$ 2,485,145	$ 2,485,145	$ 373,007
19	2015	$ 0	$ 2,485,145	$ 2,485,145	$ 335,706
20	2016	$ 0	$ 2,485,145	$ 2,485,145	$ 302,136
21	2017	$ 6,081,062	$ 2,485,145	$ 8,566,207	$ 937,306
22	2018	$ 0	$ 2,485,145	$ 2,485,145	$ 244,730
23	2019	$ 0	$ 2,485,145	$ 2,485,145	$ 220,257
24	2020	$ 0	$ 2,485,145	$ 2,485,145	$ 198,231
25	2021	$ 0	$ 2,485,145	$ 2,485,145	$ 178,408
26	2022	$ 0	$ 2,485,145	$ 2,485,145	$ 160,567
27	2023	$ 0	$ 2,485,145	$ 2,485,145	$ 144,511
28	2024	$ 0	$ 2,485,145	$ 2,485,145	$ 130,059
29	2025	$ 0	$ 2,485,145	$ 2,485,145	$ 117,054
30	2026	$ 0	$ 2,485,145	$ 2,485,145	$ 105,348
31	2027	$ 0	$ 2,485,145	$ 2,485,145	$ 94,813
32	2028	$ 0	$ 2,485,145	$ 2,485,145	$ 85,332
33	2029	$ 0	$ 2,485,145	$ 2,485,145	$ 76,799
34	2030	$ 0	$ 2,485,145	$ 2,485,145	$ 69,119
35	2031	$ 0	$ 2,485,145	$ 2,485,145	$ 62,207
36	2032	$ 0	$ 2,485,145	$ 2,485,145	$ 55,986
37	2033	$ 0	$ 2,485,145	$ 2,485,145	$ 50,388
38	2034	$ 0	$ 2,485,145	$ 2,485,145	$ 45,349
39	2035	$ 0	$ 2,485,145	$ 2,485,145	$ 40,814
40	2036	$ 0	$ 2,485,145	$ 2,485,145	$ 36,733
Total		$ 35,431,771	$ 99,405,800	$ 134,837,571	$ 52,051,804

Booster Pumps

SUPPORTING REPORT C

FEASIBILITY STUDY

FOR

URBAN WATER SUPPLY SYSTEM

SUPPORTING REPORT C   FEASIBILITY STUDY FOR URBAN WATER SUPPLY SYSTEM

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1 BASIC CONDITIONS OF THE PROJECT

1.1 OBJECTIVE OF THE PROJECT

1.1.1 Background

The priority project selected through the Master Plan study is planned in this Feasibility Study (F/S) with the target year of 2005.

(1) Urbanization of Hanoi

Urbanization of Hanoi tends to spread out toward west, north and south. Especially, new urban development plan seems to put stress on the west. Urbanization toward the west will probably reach the Nhue River within the coming decade.

Accordingly, spatial development and social structure is planned on the basis of the basic policy and principles mentioned above. Urban facilities with various functions are planned to be built in or near by the project area. The National Sports Complex, Diplomatic Area, New Business Center will be developed to support the urban functions of the capital city of Hanoi. For all that, several minor developments are still going on but almost all of the above major developments will be realized beyond the year 2005.

New development for commercial or residential purpose will be probably concentrated along the planned Ring Road No.3.

Existing urban area without having sufficient water supply will be covered by the on-going projects assisted by FINNIDA and the World Bank.

(2) New Development Plan

Not a few development plans have been in the north-east side of the project area. However, new city master plan has not been officially announced yet, or the layout of the development plan has not yet been clarified in detail. Nevertheless the area undoubtedly has high potential for commercial or residential development.

(3) Groundwater Lowering

Production capacity of the existing wells should be reduced in order to recover the depressed groundwater level and to control land subsidence in the central part of the city.

1.1.2 Proposed Water Supply System

Considering the above mentioned background, the water supply system proposed by F/S will have to meet three major categories of the water demand. Basic contents of the goal in the year 2005 are as follows :

A. Water supply to the project area

According to the M/P study, the project area being adjacent to the existing water service area needs piped water supply system for basic human needs and future development, since the project area is still non-water service area. The rate of population served in the area will reach 100 % by means of house connections, by the year 2005.

B. Supplement to Mai Dich system

Mai Dich water supply system has supplied water to urban district area being adjacent to the project area. At present, Mai Dich system seems to have sufficient capacity to meet the demand of its own service area and to allocate water to the other service areas. However, Mai Dich system itself has to reduce the groundwater discharge from its well field by around 20,000 m^3/day to prevent the groundwater from lowering. Therefore, Mai Dich system needs supplemental water to sustain the present service conditions.

C. Water allocation to the new development area

Vietnamese authorities of urban planning have prepared a new city development plan, but the plan has not been disclosed in detail. According to a partial information, NBC (New Business Center) of 200 ha seems to be planned in communes Xuan La and Xuan Dinh, even though its location and the details of plan have not yet been clear. On the other hand, the study on Master Plan of Hanoi Urban Transportation assisted by JICA has proposed the CBD (Central Business District) for this area. Although the new urban development plan has not been cleared, the new development plan will be certainly realized in the near future. Therefore, the water distribution system will be planned in F/S to support the new development plan actively. The service area will be supplied with the clean water by way of bulk water supply system, because the development plan seems to be implemented as a package project which will construct all infrastructure.

1.2 PROJECT AREA AND POPULATION

The location of the project area is defined as shown in Fig. 1.2-1 which consists of nine communes: Thuy Phuong, Dong Ngac, Co Nhue, Mai Dich, Dich Vong, Me Tri, My Dinh, Trung Hoa and Yen Hoa. Some parts of these communes which have been already covered by the existing water supply systems or the on-going projects are excluded from the F/S.

Parts located in the west side of the Nhue River are also excluded, because the water supply for these areas is expected to be carried out in the next stage of the development plan.

Determination of the future population based on the development direction was formulated under the following conditions :

(a) The population of the project area was applied in the same manner and growth rates as the population projection study in the Master Plan.

(b) Yen Hoa and Trung Hoa communes in Cau Giay are supposed as if in one group for a reason of unity with the same characteristics and integrated land use, for population estimate.

The trend of population by Commune (Xa) in every five years is shown in Table 1.2-1. The table shows trends of average annual population growth during the feasibility study period until 2005 : rates of 2.8% (1995 to 2000), 5.4% (2000 to 2005) in Tu Liem District ; and 4.5% (1995 to 2000), 8.4% (2000 to 2005) in Cau Giay District. Therefore, the average of the whole project area is 3.5% up to 2000 and 6.6% up to 2005, while the projected population growth rates for the whole suburban area of Hanoi are 4.20% up to 2000 and 3.4% up to 2005.

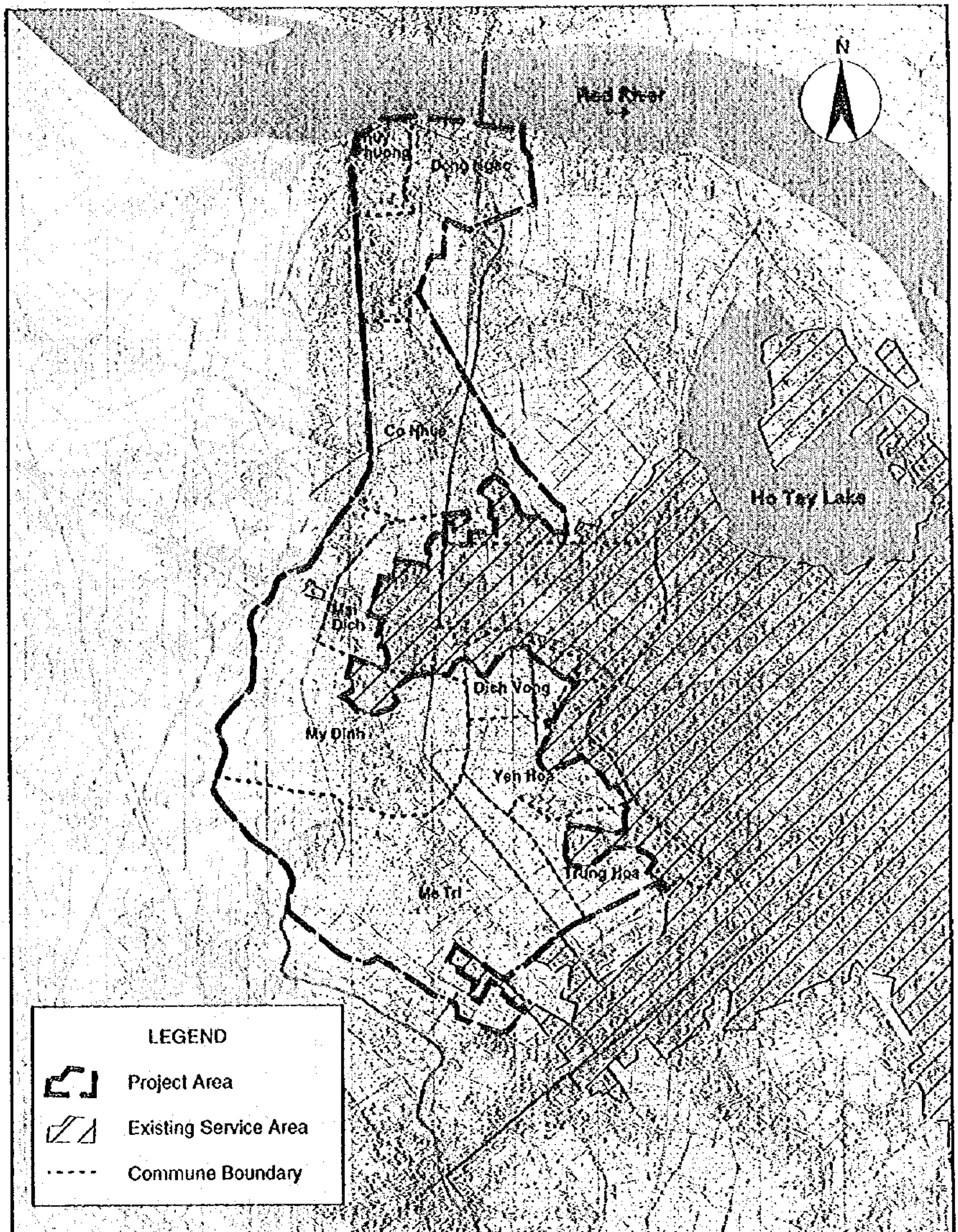

Fig. 1.2-1
Location of the Project Area

Table 1.2-1 Area and Population of the Priority Project Area

District	Commune	Area (ha)							Population of Whole Commune					Population of Priority Project Area					
		Whole ommune (A)	Present Service Area (B)	% (B)/(A)	Non Service Area (D)	% (C)/(A)	Priority Project Area (D)	% (A)/(C)	Year 1995 (E)	Year 2000 (F)	Growth Ratio (1995 ~ 2000)	Year 2005 (G)	Growth Ratio (2000 ~ 2005)	Year 1995 (H)	Ratio of Newly Served (H)/(E)	Year 2000 (J)	Ratio of Newly Served (J)/(F)	Year 2005 (K)	Ratio of Newly Served (K)/(G)
Tu Liem	Thuy Phuong	250.0	0.0	0.0%	250.0	100.0%	125.0	50.0%	5,945	6,459	1.7%	6,973	3.2%	2,973	50.0%	3,230	50.0%	3,487	50.0%
	Dong Ngac	366.4	0.0	0.0%	366.4	100.0%	366.4	100.0%	17,982	19,737	1.9%	21,491	3.6%	17,982	100.0%	19,737	100.0%	21,491	100.0%
	Co Nhue	570.0	230.0	40.4%	340.0	59.6%	340.0	59.6%	12,437	14,078	2.5%	15,719	4.8%	7,419	59.7%	8,397	59.6%	9,376	59.6%
	My Dinh	460.6	46.0	10.0%	414.6	90.0%	414.6	90.0%	7,357	8,768	3.6%	10,179	6.7%	6,622	90.0%	7,892	90.0%	9,162	90.0%
	Me Tri	706.6	50.0	7.1%	656.6	92.9%	656.6	92.9%	12,645	15,734	4.5%	18,823	8.3%	11,750	92.9%	14,621	92.9%	17,491	92.9%
	Sub Total	2,353.6	326.0	13.9%	2,027.6	86.1%	1,902.6	80.8%	56,366	64,776	2.8%	73,185	5.4%	46,746	82.9%	53,877	83.2%	61,007	83.4%
Cau Giay	Mai Dich	187.9	94.0	50.0%	93.9	50.0%	93.9	50.0%	13,493	13,870	0.6%	14,247	1.1%	0	0.0%	188	1.4%	377	2.6%
	Dich Vong	349.1	269.0	77.1%	80.1	22.9%	80.1	22.9%	8,340	13,755	10.5%	19,170	18.1%	0	0.0%	1,242	9.0%	2,485	13.0%
	Yen Hoa & Trung Hoa	443.1	177.2	40.0%	265.9	60.0%	265.9	60.0%	13,878	16,909	4.0%	19,940	7.5%	0	0.0%	1,819	10.8%	3,637	18.2%
	Sub Total	980.1	540.2	55.1%	439.9	44.9%	439.9	44.9%	35,711	44,534	4.5%	53,357	8.4%	0	0.0%	3,249	7.3%	6,499	12.2%
	Total	3,333.7	866.2	26.0%	2,467.5	74.0%	2,342.5	70.3%	92,077	109,310	3.5%	126,542	6.6%	46,746	50.8%	57,126	52.3%	67,506	53.3%

Note:

1) Target population of the priority project area was applied in the same manner and growth ratio of the population projection.
2) Service population of each commune in the priority project area is estimated by the area ratio of project area to whole commune area.
3) Present population with "0" (zero) is nobody in the settled area under the agricultural land use in Cau Giay District which was recognized by site reconnaissance.
4) Yen Hoa and Trung Hoa communes in Cau Giay district are designated in one commune for a reason of unity with the same characteristics and integrated land use.

1.3 WATER DEMAND

1.3.1 Unit Water Demand

According to the M/P study, every unit water demand has been formulated as shown in Table 1.3-1.

Table 1.3-1 Unit Water Demand

	2000		2005	
	Domestic Water (l/c/d)	Non-Domestic Water (ratio to domestic water, %)	Domestic Water (l/c/d)	Non-Domestic Water (ratio to domestic water, %)
Group U	150	30	165	30
Group D	105	17.5	135	17.5

1.3.2 Water Demand

The water demand is estimated based on the following conditions:

(1) Project area

The average daily water demand is estimated to be 8,900 m3/day in the year 2000, and 12,600 m3/day in the year 2005. Further breakdown of the water demand by district is shown in Table 1.3-2.

Table 1.3-2 Water Demand for the Project Area

Group	Commune	Year 2000					Year 2005				
		Population Served	Domestic		Non-Domestic	Total Water Demand (m3/d)	Population Served	Domestic		Non-Domestic	Total Water Demand (m3/d)
			Unit Demand (l/c/d)	Water Demand (m3/d)	Water Demand (m3/d)			Unit Demand (l/c/d)	Water Demand (m3/d)	Water Demand (m3/d)	
D5	Thuy Phuong	3,230	105	339	59	399	3,487	135	471	82	553
D5	Dong Ngac	19,737	105	2,072	363	2,436	21,491	135	2,901	508	3,409
D5	Co Nhue	8,397	105	882	154	1,036	9,376	135	1,266	222	1,488
U1	Mai Dich	188	150	28	8	36	377	165	62	19	81
U1	Dich Vong	1,242	150	186	56	242	2,485	165	410	123	533
U1	Me Tri	14,621	150	2,193	658	2,851	17,491	165	2,886	866	3,752
U1	My Dinh	7,892	150	1,184	355	1,539	9,162	165	1,512	454	1,966
U1	Trung Hoa & Yen Hoa	1,819	150	273	82	355	3,637	165	600	180	780
Total		57,126		7,158	1,736	8,893	67,506		10,108	2,454	12,562

(2) Supplemental water to Mai Dich system

Mai Dich system will need supplemental water to sustain the present service level. It is estimated to be constant 20,000 m3/day at the average daily distribution capacity.

(3) Future development area

According to partial information, water demand of NBC (New Business Center) of 200 ha is estimated to be 9,900 m^3/day.

According to Master Plan of Urban Hanoi Transportation assisted by JICA, water demand of the Central Business District in the year 2005 is estimated to be 12,600 m^3/day.

Considering these figures, the water demand of the new city development plan such as NBC or CBD is estimated about 11,000 m^3/day on average.

Water demand of this area without new development plan such as NBC or CBD is estimated at a range of 11,000 m3/day. The figure shows that water for NBC or CBD can be diverted to meet the water demand of this area at least until the year 2005, even if such development plan would not be implemented by the year 2005. In the area, the new city development seems to be planned but no water is to be supplied by the on-going water supply projects of "Hanoi Water Supply Program" funded by FINNIDA or "1A Project" by the World Bank.

Average daily water demand in year 2005 is summarized in Table 1.3-3.

Table 1.3-3 Average Daily Water Demand in the Priority Project (Year 2005)

Category of Water Demand	Average Daily Water Demand (m^3/day)	Average Daily Water Distribution (m^3/day)
(1) Project Area	12,600	14,800
(2) Mai Dich Water Supply System	-	20,000
(3) Future Development Area	(11,000)	12,900
Total	-	47,700

Note: A physical loss of 15% is included in a distribution volume, that is, [Distribution] = [Water Demand] / (1-0.15)

1.4 WATER SOURCE

1.4.1 Wellfield

In the "Water Master Plan of Hanoi City" of FINNIDA, 1993, a computerized groundwater model in Hanoi area was established, with which groundwater conditions in future was simulated for the assessment of groundwater resources.

In the "Water Supply Master Plan of Hanoi City" of JICA, 1996, the groundwater development potential in Hanoi area, especially in the south Hanoi was studied following the results of the simulation.

In the "Water Master Plan" of FINNIDA, through the simulation, it is reported that the discharge of 700,000 m^3/d (exactly 725,000 m^3/d, including Ha Dong) can be exploited from the lower main aquifer Qa in the area south and west of the Red River without causing serious environment impacts and it proposes the location of the wellfields (including existing ones) and the their most feasible exploitation discharge as shown in Table 1.4-1 and Fig.1.4-1. This has been approved by the State Council for Approval of Mineral Reserves.

According to the Table 1.4-1 and Fig.1.4-1, Cao Dinh - Bac Chem - Thuong Cat area is the most favorable wellfield area for the priority project to the proposed water supply area from the view points of location and development potential. Therefore, Cao Dinh - Bac Chem - Thuong Cat area has been selected as the wellfield considering the relation to the ongoing project (1A project, World Bank Program), etc.

Table 1.4-1 Wellfields and Exploitation Water (m^3/d)

No.	Wellfield	FINNIDA M/P, 1993	JICA M/P, 1996 [1]	JICA F/S, 1996 [2]
1	Yen Phu	110,000	44,500	80,000 (increased)
2	Luong Yen	80,000	79,500	79,500
3	Mai Dich	45,000	64,200	44,200 (decreased)
4	Ngoc Ha	30,000	50,300	50,300
5	Ngo Si Lien	30,000	43,200	43,200
6	Tuong Mai	30,000	29,200	29,200
7	Phap Van	30,000	27,700	27,700
8	Ha Dinh	25,000	27,200	27,200
9	Thuong Cat	60,000 (not exploited)	-	38,800[3] (proposed by JICA)
10	Bac Chem	30,000 (not exploited)	-	11,400[3] (proposed by JICA)
11	Cao Dinh	80,000 (not exploited)	-	30,000 (proposed by 1A)
12	Nam Du Thuong	120,000 (not exploited)	-	30,000 (proposed by 1A)
13	An Khanh	15,000 (not exploited)	-	-
14	Ha Dong	40,000 (out of Hanoi)	-	(22,000)
12 Small Wellfields		-	23,600	23,600
300 Private Wells		-	100,000	100,000
Total		725,000	489,400	615,100 (637,100[4])

1) Raw water discharge in 1995

2) HPC's plan at JICA F/S stage

3) Total average daily intake, 50,200 m^3/d is divided in proportion to well number in the area, for convenience.

4) Including Ha Dong

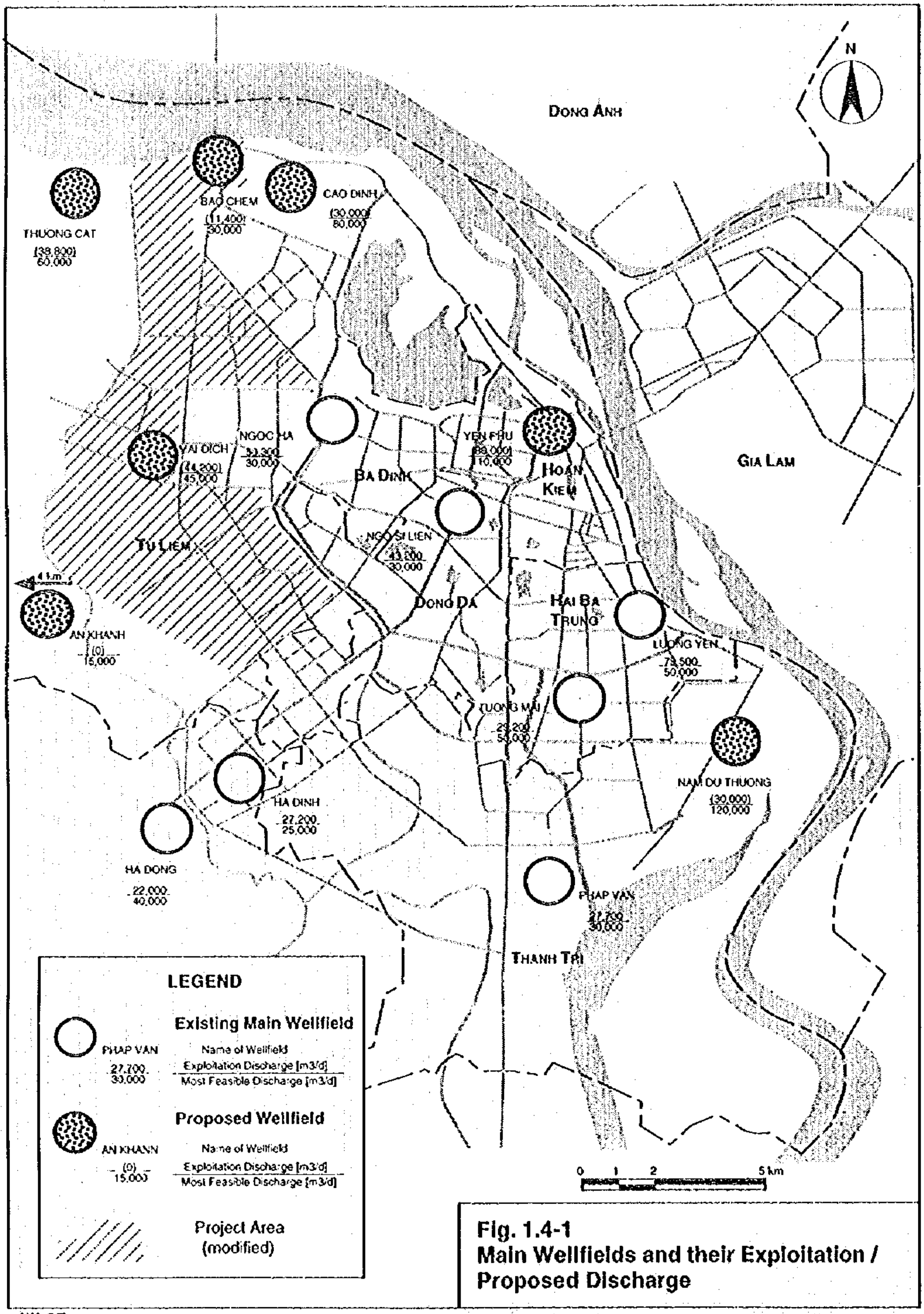

Fig. 1.4-1
Main Wellfields and their Exploitation / Proposed Discharge

1.4.2 Groundwater Potential

Groundwater potential at the proposed wellfield was inspected in the following three cases (See, Fig.1.4-2) .

"Water Master Plan" of FINNIDA, 1993 defines that the exploitable groundwater resource on the area south and west of the Red River is approximately 700,000 m^3/d (exactly, 725,000 m^3/d including Ha Dong) and shows the most feasible exploitation discharge of each wellfield is shown in Table 1.4-1. According to the Table 1.4-1, groundwater of 170,000 m^3/d are exploitable in Cao Dinh - Bac Chem - Thuong Cat wellfields area (Northwest Area of the south Hanoi).

Case I:

At present, the existing exploitation groundwater discharge in this area is 4,000 m^3/d by 10 private wells and the proposed exploitation discharge is only 30,000 m^3/d by the 1A project of the World Bank Program. If add the groundwater discharge of 50,200 m^3/d which is proposed by JICA project to them, 34,000 m^3/d, the total is 84,200 m^3/d. As the total of 84,200 m^3/d is less than 170,000 m^3/d, it is feasible.

Case II:

On the other hand, in the "Water Master Plan" of JICA, 1996, it is studied that the existing exploitation groundwater in the south Hanoi (All south Hanoi Area) are 365,800 m^3/d with 8 main wellfields, 23,600 m^3/d with 12 small wellfields and 100,000 m^3/d with 300 private wells; their total is 489,400 m^3/d.

At present, proposed wellfileds in the all south Hanoi Area are Cao Dinh - Chem of 30,000 m^3/d and Nam Du Thuong of 30,000 m^3/d by 1A project. If add 50,200 m^3/d proposed by this JICA project to the 1A project, the total comes to 110,200 m^3/d. Furthermore, if add 22,000 m^3/d of the current (1995) Ha Dong exploitation to the total, and the difference between the increased Yen Phu and decreased Mai Dich, the grand total is 637,100 m^3/d. Here, the expression of 700,000 - 637,100 = 62,900 $m^3/d > 0$ is still satisfied. Accordingly, the exploitation groundwater of 50,200 m^3/d proposed by JICA is feasible from this point of view as well.

Case III:

One more trial of the groundwater potential is described below.
As described above, groundwater of 725,000 m^3/d is exploitable in south Hanoi. According to the FINNIDA Master Plan, groundwater of 725,000 m^3/d is allocated to 14 wellfields (See, Table 1.4-1). The 345,000 m^3/d of 725,000 m^3/d is allocated to six unexploited wellfields (only Ha Dong is exploited partially) and the 170,000 m^3/d of 345,000 m^3/d is allocated to Thuong Cat - Bac Chem - Cao Dinh area. That means 345,000 m^3/d is exploitable in future in south Hanoi and the 170,000 m^3/d is in Thuong Cat - Bac Chem - Cao Dinh area.

On the other hand, according to the JICA M/P in 1996, the 200,000 m^3/d (exactly, 725,000 - 489,400 = 235,600 m^3/d) is exploitable in future in the south Hanoi. Because, 489,400 m^3/d is exploited already with eight main wellfields, 12 small wellfields and 300 private wells (See, Table 1.4-1).

Therefore, 235,600 m^3/d was tried to reallocate to the six(6) unexploited wellfields proportion to their original allocation. Table 1.4-2 shows the results of reallocation. According to the reallocation, exploitable groundwater in future is 41,000 m^3/d in Thuong Cat, 21,000 m^3/d in Bac Chem and 55,000 m^3/d in Cao Dinh, and the total of them is 117,000 m^3/d. As 117,000 m^3/d is larger than the total demand of 80,200 m^3/d, it is feasible.

Table 1.4-2 Results of reallocation (Case III)

	Wellfield	Original Allocation (m^3/d)	Reallocation (m^3/d)
1	Thuong Cat	60,000	41,000
2	Bac Chem	30,000	21,000
3	Cao Dinh	80,000	55,000
	Sub Total	170,000	117,000
4	Nam Du Thuong	120,000	82,000
5	An Khanh	15,000	10,000
6	Ha Dong	40,000	27,000
	Grand Total	345,000	236,000

Case I : Northwest Area of South Hanoi

Exploitable G.W

60,000 (Thuong Cat) + 30,000 (Bac Chem) + 80,000 (Cao Dinh)

170,000 m³/d

Existing Exploitation G.W.

4,000m³/d
(10 private wells)

Proposed Exploitation G.W

50,200 (Thuong Cat + Bac Chem) proposed by JICA + 30,000 (Cao Dinh) proposed by 1A

80,200 m³/d

4,000 + 80,200 = 84,200 m³/d

170,000 - 84,200 = 85,800 > 0.......OK

Case II : All South Hanoi Area

Exploitable G.W.

South Hanoi
725,000 m³/d

Existing Exploitation G.W.

365,800 (8 Main Wellfields) + 23,600 (12 Small Wellfields) + 100,000 (300 Private Wells)

489,400 m³/d

Proposed Exploitation G.W.

30,000 (Cao Dinh) proposed by 1A + 30,000 (Nam Du Thuong) proposed by 1A + 50,200 (Thuong Cat + Bac Chem) proposed by JICA

110,200 m³/d

Current Exploitation G.W. in Ha Dong

22,000 m³/d

Difference between Yen Phu & Mai Dich

15,500 m³/d

489,400 + 110,200 + 22,000 + 15,500 = 637,100 m³/d

725,000 - 637,100 = 87,900 > 0 .... OK

Fig.1.4-2
Groundwater Balance

1.4.3 Water Quality

There exist two types of groundwater quality data for the project area. One is the data obtained from periodic (once or twice a year) sampling, and the other is obtained from occasional sampling. As periodic sampling data, data for four existing monitoring wells were used for this study. Occasional sampling data were quoted from the existing survey reports made by the Subdivision 64 - Hydrogeological Division II (Vietnam Geological Survey). Additionally, some parameters such as Al, Cd and Pb were checked in this Study to confirm groundwater quality at the project site. The data are shown in Appendix.

(1) General Features

pH

Values for monitoring well P21a and Q62a show around 6 of pH value on average that is slightly less than the required range (6.5~8.5) by the Vietnamese criteria for drinking water, though values for monitoring well P47a and P55a shows around 7 on average that meets the criteria. These values are not unusual nor problem for water supply, because a groundwater generally shows slightly acid due to free carbon dioxide (CO_2) generated by microbiological activities in the ground and it can be controlled by normal aeration process of water treatment plant.

Ammonia

Values for monitoring well P21a show around 0.4 mg/l on average and never exceed the maximum value of 3.0 mg/l required by the Vietnamese criteria for drinking water. Values for monitoring well Q62a and P47a show around 0.5mg/l on average that meet the criteria, though one fourth of values slightly exceed the maximum value of 3.0 mg/l required by the Vietnamese criteria. Only values for monitoring well P55a show high concentration of 8.0 mg/l on average. High ammonia concentration of groundwater is considered to have some relation to the existence of layer with peat or other organic matters. According to "The Distribution Map of Mud, Peat and Organic Matter - bearing Soil Layers" made by the Subdivision 64 - Hydrogeological Division II (Vietnam Geological Survey), a layer with peat exists at the monitoring well P55a, however it does not exist at other three wells.

Iron (total)

Values for all monitoring wells show higher concentration than the maximum value of 0.3 mg/l required by the Vietnamese criteria for drinking water. Among them, well P47a show the highest value of 13 mg/l on average, and average values for other three wells are 5~8 mg/l. Fluctuation of the ratio of ferrous iron (Fe^{2+}) to total iron is shown, but it seems to have been caused by sampling manner. Samples from these monitoring wells were taken by air-lift pump, which might have changed ferrous iron into ferric iron (Fe^{3+}) to some extent. The data periodically sampled from existing production wellfields show that the ratio of Fe^{2+} to total iron is around 9:10 on average, and these samples were not oxidized to such extent because they were taken by submerged pump.

Manganese

Values for most private wells show higher concentration than the maximum value of 0.1 mg/l required by the Vietnamese criteria for drinking water. The average value for all sampling data is 0.4 mg/l.

Nitrite (NO_2^-)

All values for private wells show around 0.1 mg/l and meet WHO's guideline of 3 mg/l, though some of them show higher concentration than the maximum value of 0.0 mg/l required by the Vietnamese criteria for drinking water.

Aluminum

Three among five data exceed the maximum value of 0.2 mg/l required by the Vietnamese criteria for drinking water. The average of all data is total 0.1 mg/l. However, the concentration checked in this study at the project site meets the criteria.

Other Substances (NO_3^-, Hardness, As, Zn, Cd, Pb, CN, Hg, Cu, Cr, phenols)

Almost all data meet the Vietnamese criteria for drinking water.

(2) Design Condition

Design raw water quality is basically estimated referring the graphs of concentration appearance probability as shown in Appendix. As for some substances such as Al, Cd and Pb, the values checked at the project site in this Study are used for design concentration. The results are summarized in Table 1.4-3.

Table 1.4-3 Design Concentration

Parameter	Unit	Criteria for Drinking Water: Vietnamese (Urban Area)	Criteria for Drinking Water: WHO Guidelines	Design Concentration (Maximum)
pH	-	6.5~8.5	-	6.0~7.0
Fe^{2+}	mg/l	-	-	8.3
Fe^{3+}	mg/l	-	-	0.9
Total Iron	mg/l	0.3	0.3	9.2
Mn	mg/l	0.1	0.5	0.5
NH_4^+	mg/l	3	1.5	1.2f
NO_2^-	mg/l	0	3	0.1
NO_3^-	mg/l	10	50	0.6
Hardness	mg/l	500	-	30
Al	mg/l	0.2	0.2	0.1
As	mg/l	0.05	0.01	0.007
Zn	mg/l	5	3	0.01
Cd	mg/l	0.005	0.003	0.005
Pb	mg/l	0.05	0.01	0.002
CN	mg/l	0.1	0.07	0.01
Hg	mg/l	0.001	0.001	0.0001
Cu	mg/l	1	2	0.01
Cr	mg/l	0.05	0.05	0.003
Phenols	mg/l	-	-	0.001

pH

The pH range of raw water is estimated to be 6.0~7.0, as a possible lower value with excess probability of 75% (equivalent to non-excess probability of 25%) and a possible higher value with non-excess probability of 75%. In other words, three fourths of all sampling data do not exceed the maximum value of this range and three fourths of all sampling data do not fall below the minimum value of the range.

Ammonia

Referring to "The Distribution Map of Mud, Peat and Organic Matter - bearing Soil Layers", the well field for this project has been proposed in the area where there is no layer with peat. Therefore ammonia concentration of raw water is estimated to be 1.2 mg/l by the data of monitoring wells except P55a, as a possible higher value with non-excess probability of 75%.

Iron

Design total iron concentration of raw water is estimated to be 9.2 mg/l as a possible higher value which three fourths of sampling data do not exceed, and 90% of total iron consists of ferrous iron (namely, Fe^{2+}=8.3 mg/l).

Manganese

Design concentration of raw water is estimated to be 0.5 mg/l as a possible higher value which three fourths of sampling data do not exceed.

Aluminum

Design concentration of raw water is estimated to be 0.1 mg/l of total aluminum as a possible higher value at the project site.

1.4.4 Arrangement of the Wells

Fig.1.4-3 shows the location map of the existing wells around the proposed wellfield and the arrangement of the proposed wells.

Arrangement of wells for water supply in a wellfield is usually decided considering the hydrogeological conditions, water supply area, water demand, land acquisition conditions, etc.

(1) Wellfields, Hydrogeological Conditions

Cao Dinh - Chem - Thuong Cat area which is in the northwest of the south Hanoi, has been selected as the wellfield as described before.

Typical hydrogeological conditions of the wellfield are shown in Fig. 1.4-4 together with the well design. The conditions were based on the data of the existing wells especially T-TD12 and T-LK816, because they cover all hydrogeological layers in the south Hanoi.

(2) Well Design

The well design is shown in Fig.1.4-4.
The proposed discharge is 50 lit/sec a well. The diameter of 350 mm (14 inch) for the casing and screen pipe was selected referring to the existing wells in the main wellfields. The diameter of the borehole was set at 500 mm (20 inch) considering the thickness of the packing gravel. The total screen length of the well was decided so that the main target aquifer (Qa) is screened more than 70 % of its total thickness. The depth and length of the screen section were determined considering the unit length (5.50 m) of the casing and screen pipe. Then, the depth of the borehole was decided.

The static water level and the ground elevation of the well were estimated with the records of the existing monitoring wells, especially P21a, P47a, P55a and Q62a. The lowest static water level (depth) in a year is 6.84 m and the ground elevation is 8.00 m.

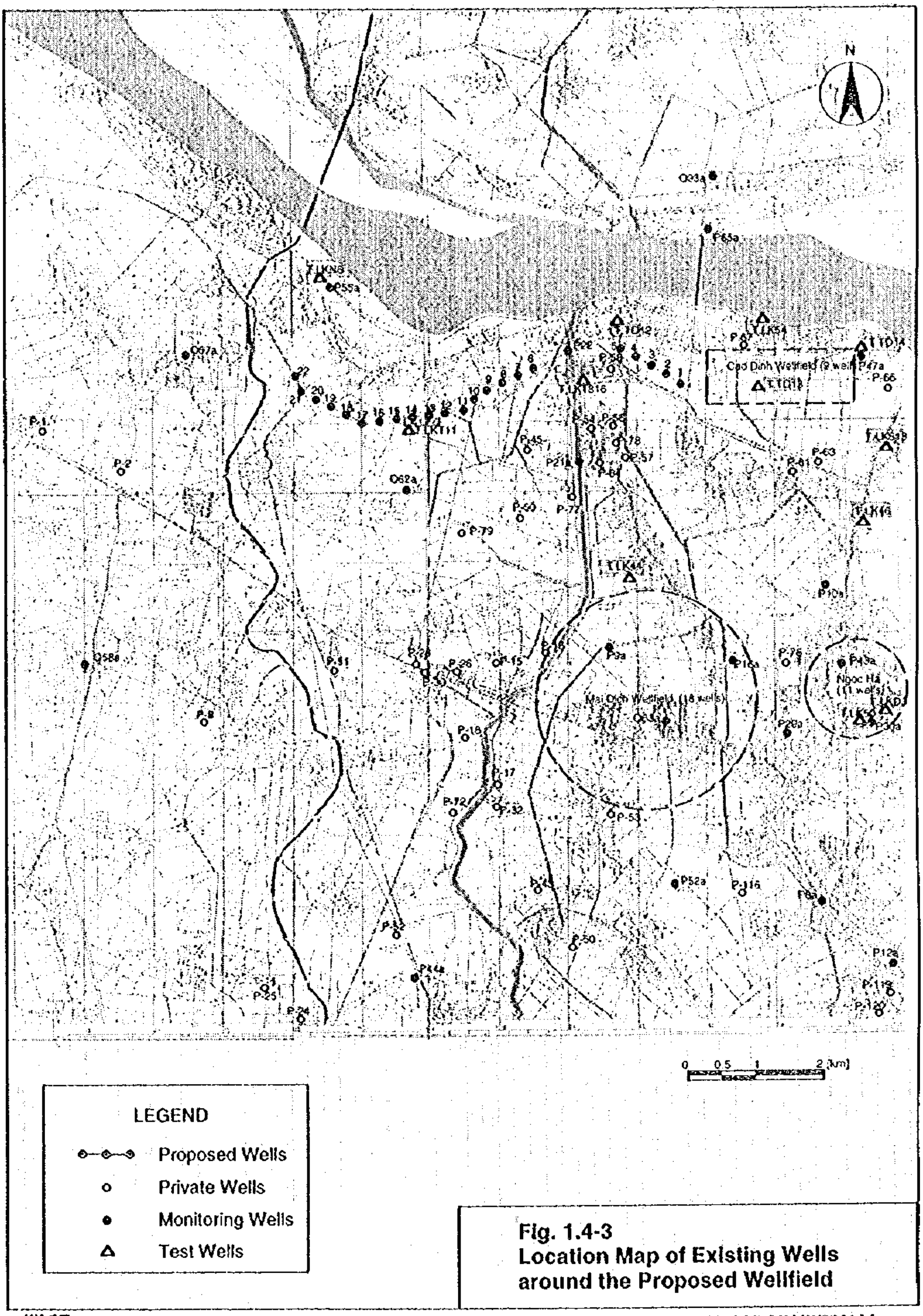

Fig. 1.4-3
Location Map of Existing Wells around the Proposed Wellfield

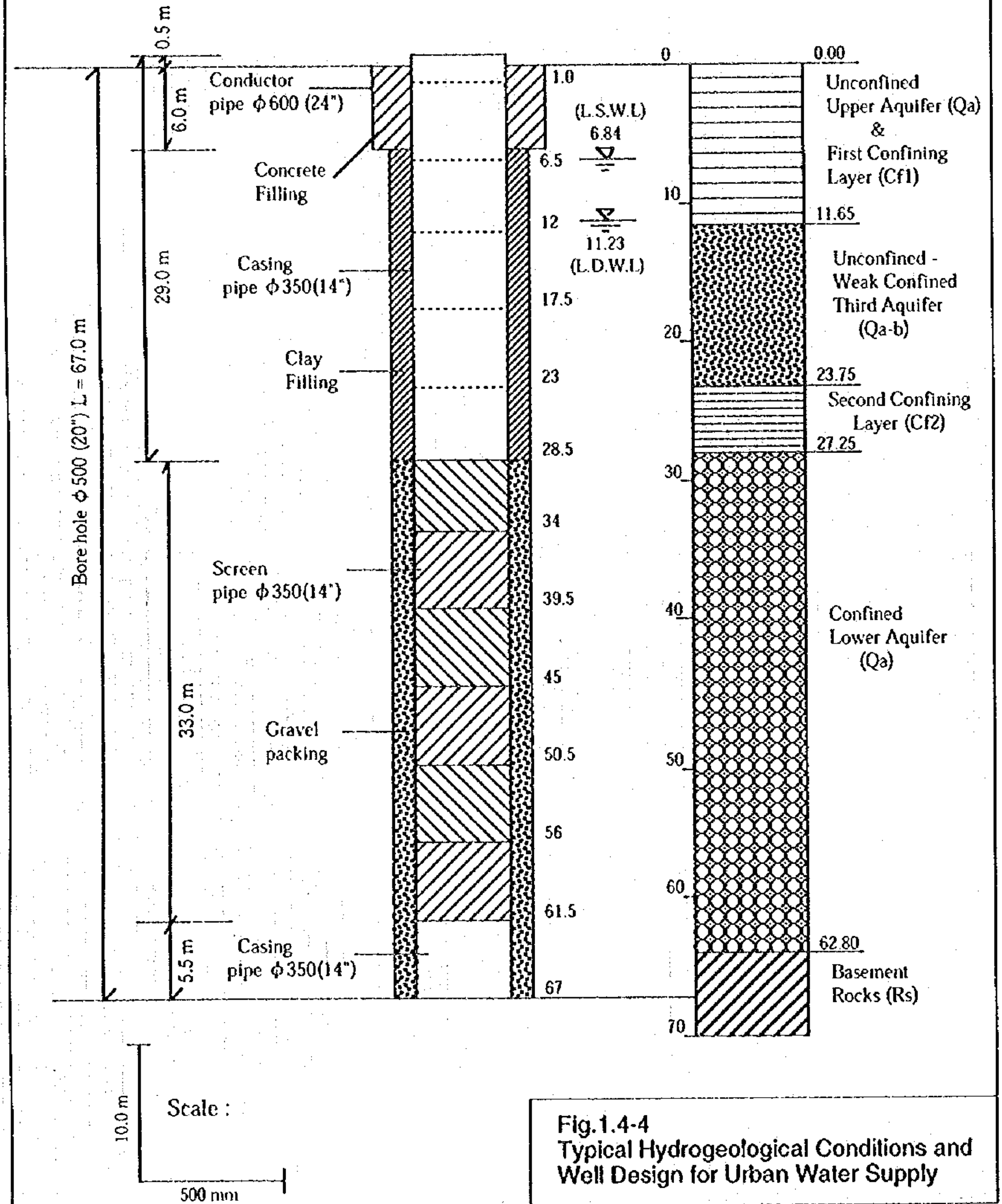

Fig.1.4-4
Typical Hydrogeological Conditions and Well Design for Urban Water Supply

(3) Hydrogeological Parameters

1) Transmissivity (T)

Transmissivity was estimated using the following data.

T-TD12	1,722 m^2/d (1.99 x 10^{-2} m^2/sec)
T-TD13	1,310 m^2/d (1.52 x 10^{-2} m^2/sec)
T-TD14	1,199 m^2/d (1.39 x 10^{-2} m^2/sec)

The average T = 1.63 x 10^{-2} m^2/sec.

2) Storativity (S)

Storativity was presumed to be 1.0 x 10^{-3} which was used as a general value of storativity due to the lack of available data and was lower one power of ten than the order of the transmissivity in m^2/sec.

(4) Drawdown (s)

1) Pumping Discharge (Q)

The proposed pumping discharge is 50 lit/sec (50×10^{-3} m^3/sec).

2) Continuous Pumping Time (t)

The designed continuous pumping time is 20 hours ($20 \times 3{,}600 = 7.2 \times 10^4$ sec)

Theis' formula is as follows;

$s = (Q \cdot W(u)) / (4\pi \cdot T)$..........(1)

where

s : drawdown

W(u) : well function

with Q,T, and equation (1)

$s = (2.44 \times 10^{-1}) \cdot W(u)$..........(2)

while

$u = (r^2 \cdot S) / (4 \cdot T \cdot t)$

where

r : proposed well radius ($350 / 2$ mm $= (35 / 2) \times 10^{-2}$ m)

with r, S, T,and t

$u = 6.53 \times 10^{-9}$

from the Theis' type curve, $W(u) = 18$ against $u = 6.53 \times 10^{-9}$

therefore, with equation (2)

$s = 2.44 \times 10^{-1} \times 18 = 4.39$, that is, drawdown (s) is 4.39 m

(5) Distance between wells (D)

The distance between the adjacent wells was set 250 m referring to the existing main wellfields in the south Hanoi. If the distance between wells is 250 m, the drawdown (x) at the middle point of the adjacent wells is calculated with equation (3)

$(s - x) = (Q \cdot \ln(R/r)) / 2\pi \cdot T$ ....(3)

where

R : distance from a well to the middle point of the adjacent wells (250 /2 = 125 m)

with s, Q, R, r, T, and equation (3)

x = 1.18, that is, the drawdown at the middle point of the adjacent wells is 1.18 m.

(6) Designed Well Number

As the proposed daily maximum production is 60,000 m^3/d and the proposed discharge a well is 3,600 m^3/d/well (50 lit/sec, 20 hrs pumping), required well number is 16.7 (60,000/3,600). Designed well number is a 30% raise of the required well number. Therefore, designed well number is 22 (16.7 x 1.3 = 21.7 ≒ 22), including 30% standby.

(7) Arrangement of Wells

The arrangement of wells in shown in Chapter 2.4 as Fig. 2.4-1.

The wells were arranged on a line which is almost parallel to the Red River dike, keeping the distance more than 700 m (ten times of the proposed well depth) from it. Although the arrangement on plural lines is supposed alternatively, as the lowering of drawdown of the wells arranged on the land side and the bad influence to the land side existing wells seem to occur, because of the groundwater flow line from the river to the land as studied in the JICA Master Plan, the wells were arranged on a single line. Furthermore, the use of the existing roads for construction and maintenance of the proposed wells were considered as much as possible.