社会開発調査部報告書

JAPAN INTERNATIONAL COOPERATION AGENCY

HANOI PEOPLE'S COMMITTEE
SOCIALIST REPUBLIC OF VIET NAM

THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY

FINAL REPORT

MAIN REPORT

FEBRUARY 1995

NIPPON KOEI CO., LTD.
CTI ENGINEERING CO., LTD.

ESTIMATE OF PROJECT COST

Estimate of Base Cost : At 1994 Price Level

Currency Exchange Rate : US$ 1 = Dong 10,800 = Yen 100

PREFACE

In response to a request from the Government of Socialist Republic of Viet Nam, the Government of Japan decided to conduct a master plan and feasibility study on Urban Drainage and Wastewater Disposal System in Hanoi City and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Viet Nam a study team headed by Mr. Michito Kato, Nippon Koei Co., Ltd. and composed of staff members of Nippon Koei Co., Ltd. and CTI Engineering Co., Ltd., three times between November 1993 and December 1994.

The team held discussions with the officials concerned of the Government of Viet Nam, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of Socialist Republic of Viet Nam for their close cooperation extended to the team.

February 1995

Kimio Fujita
President
Japan International Cooperation Agency

February, 1995

Mr. Kimio Fujita
President
Japan International Cooperation Agency
Tokyo, Japan

Letter of Transmittal

Dear Sir,

We are pleased to submit herewith the Final Report of the Study on Urban Drainage and Wastewater Disposal System in Hanoi City, Viet Nam. This Final Report compiles the results of the Study conducted by the Study Team, jointly organized by Nippon Koei Co., Ltd. and CTI Engineering Co., Ltd., for one year and four months since November, 1993 under the contract with the Japan International Cooperation Agency.

The Report presents the study results on (i) the master plan for the urban drainage and wastewater disposal system in Hanoi City with a target year of 2010 (Main Report, Part I), and (ii) the feasibility study for the To Lich River Basin Drainage Project selected as the priority project in the master plan (Main Report, Part II). In the course of the Study, we particularly paid attention to reaching mutual understanding for issues related to the Study through intensive and frequent discussions with the Vietnamese side. Many of the Study results therefore largely depend on the cooperation and suggestions given by the Vietnamese agencies concerned.

We wish to gratefully acknowledge the Japan International Cooperation Agency, the Advisory Committee, the Ministry of Foreign Affairs, the Ministry of Construction, and the officials concerned of the Government of Viet Nam, especially the Hanoi People's Committee, the Hanoi Transport and Urban Public Works Service, the Hanoi Sewerage and Drainage Company, the State Planning Committee, the Ministry of Construction, the Ministry of Water Resources, the Ministry of Science, Technology and Environment, and other concerned ministries and agencies, for their kind cooperation and assistance to the Study.

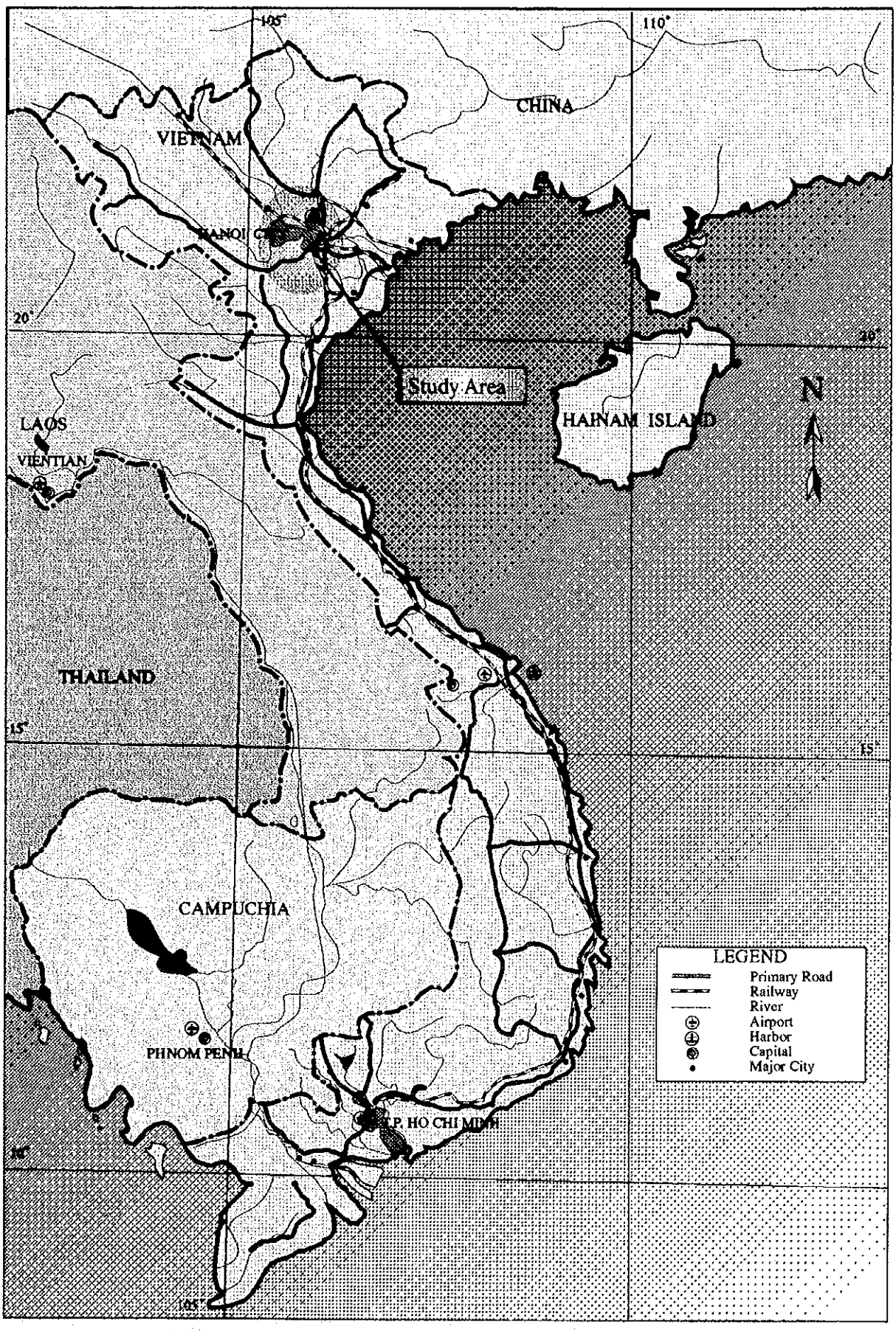
Moreover, we would like to express our sincere appreciation to the counterpart personnel who rendered a lot of efforts to the Study Team throughout the Study period.

We hope that this Report will contribute to the development of Hanoi City.

Very truly yours,

M. Kato

Michito Kato
Team Leader
Study Team for the Study on
Urban Drainage and Wastewater
Disposal System in Hanoi City



LOCATION MAP

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ABBREVIATIONS

(1) Domestic Organizations

DCWSS	Design Company for Water Supply and Sanitation System
GDOMH	General Department of Meteorology and Hydrogy
HEC	Hanoi Environment Committee
HPC	Hanoi People's Committee
HSDC (or SDC)	Hanoi Sewerage and Drainage Company
HUPI (or UPI)	Hanoi Urban Planning Institute
HWSC (or WSC)	Hanoi Water Supply Company
INVESCo	Investment Company for the Development of Water Sector
IURP	Institute of Urban and Rural Planning of MOC
MOC	Ministry of Construction
MOSTE	Ministry of Science, Technology and Environment
MOWR	Ministry of Water Resources
SPC	State Planning Committee
TUPWS	Transport and Urban Public Works Service
URENCO	Hanoi Urban Environment Company
WASECO	Water and Sewerage Construction Organization

(2) International or Foreign Organizations

CIDA	Canadian International Development Agency
FINNIDA	Finnish International Development Agency
JICA	Japan International Cooperation Agency
SIDA	Swedish International Development Authority
OECF	Overseas Economic Cooperation Fund, Japan
UNDP	United Nations Development Programme
UNIDO	United Nations Industrial Development Organization

(3) Others

BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
DAWF	Daily Average Water Flow
DSF	Design Stormwater Flow
EIRR	Economic Internal Rate of Return
EL	Elevation above Mean Sea Level
GDP	Gross Domestic Product
GF	Groundwater Infiltration
HMWF	Hourly Maximum Water Flow
OM	Operation and Maintenance
SS	Suspended Solids
TN	Total Nitrogen
TP	Total Phosphorus

ABBREVIATIONS OF MEASUREMENT

Length

mm	=	millimeter
cm	=	centimeter
m	=	meter
km	=	kilometer
ft	=	foot
yd	=	yard

Area

cm^2	=	square centimeter
m^2	=	square meter
ha	=	hectare
km^2	=	square kilometer

Volume

cm^3	=	cubic centimeter
l	=	litre
kl	=	kilolitre
m^3	=	cubic meter
gal.	=	gallon

Weight

mg	=	milligram
g	=	gram
kg	=	kilogram
ton	=	metric ton
lb.	=	pound

Time

s	=	second
min	=	minute
h	=	hour
d	=	day
y	=	year

Electrical Measurement

V	=	Volt
A	=	Ampere
hz	=	Hertz (cycle)
Ghz	=	Gigahertz
W	=	Watt
kW	=	kilowatt
MW	=	Megawatt
GW	=	Gigawatt
pr	=	pair

Other Measures

%	=	percent
PS	=	horsepower
°	=	degree
'	=	minute
"	=	second
10^3	=	thousand
10^6	=	million
10^9	=	billion

Derived Measures

m^3/s	=	cubic meter per second
mg/l	=	milligram per litre
kWh	=	Kilowatthour
MWh	=	Megawatthour
GWh	=	Gigawatthour
kWh/y	=	kilowatthour per year
kVA	=	kilovolt ampere
lcd	=	litre per capita per day

Currency

US$	=	US Dollar
VND	=	Vietnamese Dong

THE STUDY
ON
URBAN DRAINAGE AND WASTEWATER
DISPOSAL SYSTEM
IN
HANOI CITY

PART I

MASTER PLAN FOR URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY

FEBRUARY 1995

THE STUDY ON
URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM
IN
HANOI CITY

MAIN REPORT – PART I
MASTER PLAN FOR URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY

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1. INTRODUCTION

1.1 Introduction

These Final Reports were prepared and submitted to the Government of the Socialist Republic of Viet Nam (GOV) in accordance with the Scope of Works for the Study on Urban Drainage and Wastewater Disposal System in Hanoi City (the Study), which was concluded between Hanoi People's Committee (HPC) of GOV and Japan International Cooperation Agency (JICA) of the Government of Japan (GOJ) on June 10, 1993.

The Final Reports consist of the following five volumes:

No.1	: EXECUTIVE SUMMARY		
No.2	: MAIN REPORT	– Part I	: Master Plan for Urban Drainage and Wastewater Disposal System in Hanoi City
		– Part II	: Feasibility Study on the To Lich River Basin Drainage Project
No.3	: Appendix-Volume I	– (A) Socio-economy – (B) City Development – (C) Hydrology – (D) Drainage Plan	
No. 4	: Appendix-Volume II	– (E) Wastewater Disposal Plan – (F) Environment and Water Quality – (G) Construction Plan and Cost Estimate – (H) Economic Evaluation – (J) Geotechnical Investigation – (K) Topographic Survey – (L) Urgent Project-Basic Design	
No.5	: Data Book		

1.2 Background of the Study

Hanoi City, which is located in the Song Hong (the Red River) delta, is the capital city of Viet Nam and is the political, economic, and cultural centre of the country. The population of the Study Area is 1,200,000 (as of 1992).

Existing drainage and wastewater disposal systems are becoming falling into a state of disrepair and their conveyance capacities are being educed. This results in the frequent flooding of the urban area and deterioration of water quality in rivers and lakes of the surrounding area. These have been creating serious problems for the urban environment and have hampered economic development activities. In recent

years, several peripheral areas have been subjected to rapid population increase and developments, without any adequate drainage and wastewater disposal systems, which further aggravates problems such like increase of flood damage. GOV is therefore keen to improve the drainage and wastewater disposal systems as quickly as possible in order to sustain economic growth and hygienic conditions.

1.3 Objective of the Study

The objectives of the Study are as follows:

(1) To formulate a master plan on urban drainage and wastewater disposal systems, including its phased implementation program; and

(2) To conduct a feasibility study on urban drainage systems for the prioritized project selected in the master plan.

1.4 Study Area

The Study Area covers the urban area of Hanoi City (approximately 135 km^2) as shown in Figure 1.1.

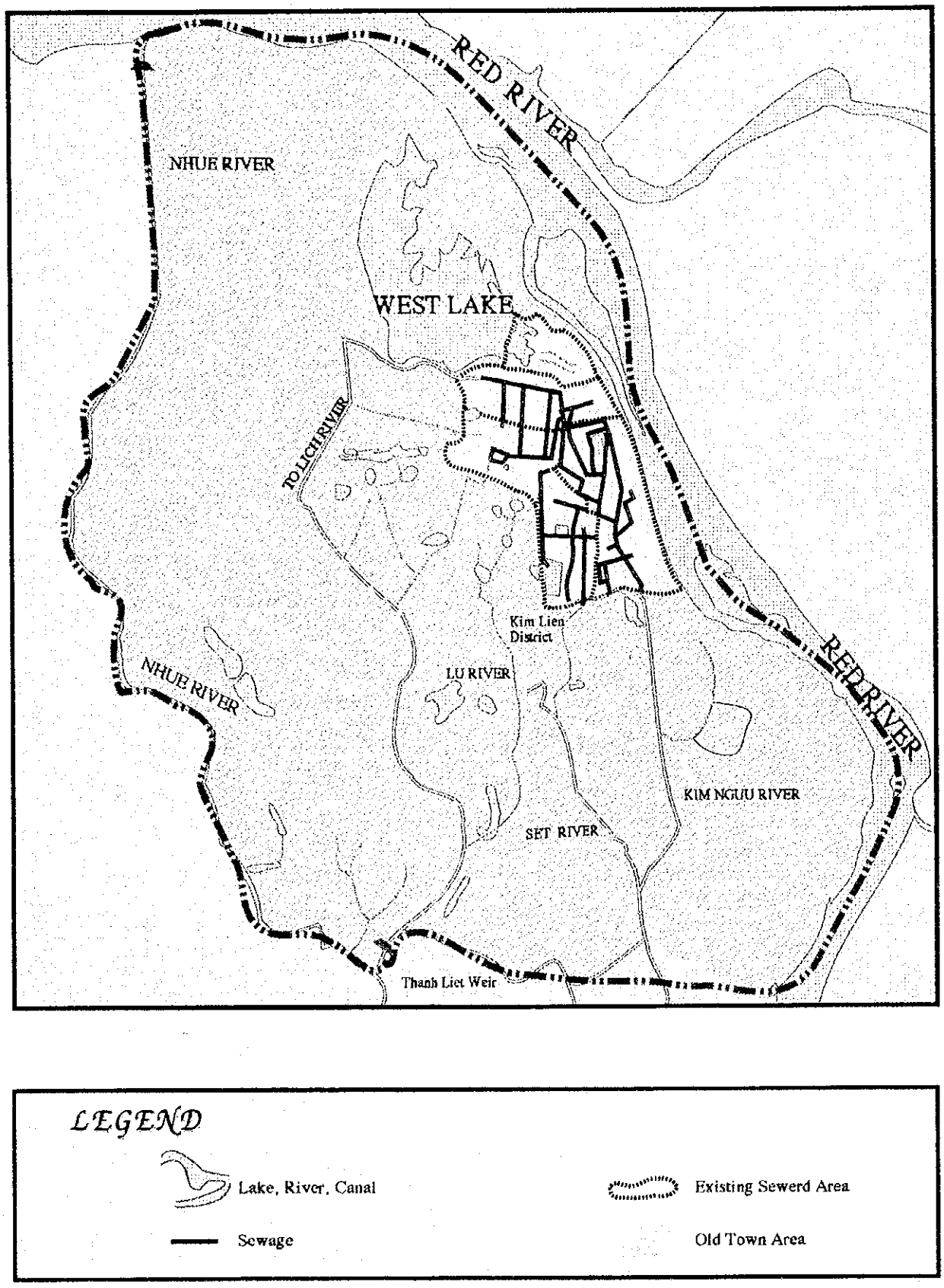

Fig. 1.1 LOCATION MAP OF THE STUDY AREA

2. BACKGROUND INFORMATION

2.1 Socio-Economy

2.1.1 National Economy

(1) Population and GDP

The total population of the country was estimated at around 68.3 million (1992). During the period between 1979 - 1989, the population increased at an average rate of 2.1 % per year. About 80 % of the population still live in the rural area and 46 % constitutes the labour force.

The Gross Domestic Product (GDP) of Viet Nam is estimated at 125,074 billion Dong at the current price (11.58 billion US dollars) in 1993. After the economic reform of 1989, the national economy grew at a steady growth rate of 6.8 % per annum between 1989 - 1993. Particularly over the last 2 years, the economy has attained a rather high growth rate of 8.1 % per annum. The per-capita GDP in 1993 was estimated at 1,794,000 Dong (US$ 166)

In GDP, the agriculture sector produces the highest share of 30.9 %, while the industrial sector, trade sector, tourism and housing sector, and others, including the construction, transport, and financial sectors, share 22.7 %, 12.1 %, 10.3 %, and 23.5 % of GDP, respectively.

(2) Fiscal Budget, Trade, Exchange Rate, and Inflation

Vietnam reduced its fiscal deficit from 7.0 % of GDP in 1989 to 3.0 % in 1992. However, revenue collection was still low, in 1992 it was 15.2 % of GDP, and the deficit amount increased from 1,468 billion Dong in 1991 to 3,845 billion Dong in 1992.

Merchandise exports increased from 1,946 billion Dong in 1989 to 2,571 billion Dong in 1992, while imports decreased from 2,565 billion Dong in 1989 to 2,508 billion Dong in 1992. In 1992 a trade net surplus was attained. The main growth exports were rice and crude petroleum. (Export and import statistics are presented in Table 2.2)

In 1989 the official exchange rate was unified and devalued. Since then the rate has been floated and continuously devalued. Over the last two years the rate has fluctuated between 10,000 - 12,000 Dong per US$. (Historical exchange rates are summarized in Table 2.3)

Inflation during the 1980s was as high, or more, than 100% per annum. After the 1989 reform, the inflation rate slowed down and was reduced to a double digit (67.8% in 1990 and 67.7% in 1991), and further dropped to 17.6% in 1992. The estimated inflation rate in 1993 was 5.2%. (Retail price index is presented in Table 2.4)

2.1.2 Regional Socio - economy

(1) Administrative Unit and Area

Administratively, Hanoi City consists of four urban districts (called "quans") and five suburban districts as presented below:

	Total Area (km^2)	Study Area (km^2)
Urban districts		
(1) Dong Da	14.8	14.8
(2) Ba Dinh	11.7	10.9
(3) Hoan Kiem	4.2	3.5
(4) Hai Ba Trung	11.0	10.2
Sub - total	(41.7)	(39.4)*
Suburban districts		
(1) Tu Liem	109.7	52.0
(2) Thanh Tri	99.9	35.1
(3) Gia Lam	175.7	-
(4) Dong Anh	184.2	-
(5) Soc Son	313.3	-
Sub - total (Hanoi City total)	(882.8)	(87.1)*
Ha Tay Province	-	3.2
Total	924.5	129.7 *

* Excludes the Lake Ho Tay (5.7 km^2)

The total area of Hanoi City is 924.5 km^2, which is equivalent to 0.3 % of the total amount of land in the country. The Study Area basically covers 4 urban districts and 2 suburban districts of Hanoi City*1. The total area of the Study Area is 135.4 km^2, including Ho Tay lake.

*1 The Study Area includes Ha Dong Town which belongs to the Ha Tay Province located outside Hanoi City.

The above districts are further divided into subdistricts (called "phuongs or villages"). In the Project area, there are 84 subdistricts (belonging to the urban districts) and 38 subdistricts (belonging to the suburban districts).

(2) Population

The total population of Hanoi City was estimated at 2.1 million in 1992. The population increased at an average growth rate of 2.1 % (same as the national population) over the past decade (1979 - 1989).

The population of the Study Area is about 1.2 million and the population density is 93 persons per ha. Of the total population in the Study Area, 79 % live in 4 urban districts where the population density is a high of 241 persons per ha, which

indicates that Hanoi City is one of the most densely populated areas in the world. Of the 4 districts, Hoan Kiem district has the highest population density of 410 persons per ha. In the suburban districts the population densities are lower, ranging from of 20 - 30 persons per ha.

The population growth rate in the Study Area between 1979 - 1989 was about 2.2 % per annum, slightly higher than the entire city's average of 2.1 %. Over the last 3 years (1989 - 1992), the growth rate increased to 4.0 % per annum in the Study Area, which reflects recent economic development in the area. Of the 4 urban districts Dong Da and Hai Ba Trung possess relatively high growth rates of more than 3 %, while Ba Dinh and Hoan Kiem possess moderate or low growth rates. In the suburban districts, due to the expansion of the 4 districts' urban area to the suburbs, particularly to the west, the population growth rate of Tu Liem increased to 7.9 %. However, the population growth rate in Thanh Tri is a moderate 1.8 %.

Population of the Study Area

District	Population (1992)	Pop. Density (persons/ha)	Growth Rate 1979-1989	Growth Rate 1989-1992
Dong Da	334,360	225	2.9%	3.6%
Ba Dinh	186,460	172	2.1%	2.6%
Hoan Kiem	147,260	410	0.6%	1.2%
Hai Ba Trung	283,810	277	1.9%	4.1%*
(Urban Total)	(951,890)	(241)	(2.0%)	(3.1%)
Thanh Tri	81,090	23	1.9%	1.8%
Tu Liem	164,300	31	NA	7.9%
Ha Tay Prov	5,400	17	NA	2.5%
Total	1,202,680	93	2.2%	4.0%

* High increase due to the addition of one subdistrict from Thanh Tri district. Without this effect the growth rate is 3.2%

The average family size in Hanoi is about 4.3. In the urban districts the average size becomes smaller (3.9) compared to the suburban districts where it becomes larger (4.5). The total number of households in the Study Area is estimated at about 280,000.

(3) RGDP and Regional Economy

The Regional Gross Domestic Product (RGDP) of Hanoi is estimated at 7,913 billion Dong at the current price (733 million US dollar) in 1993. This is approximately 6.3 % of the National (NGDP). (RGDP of Hanoi city is presented in Table 2.5)

The regional economy of Hanoi enjoyed an economic boom after the 1989 economic reform, and RGDP grew at an unprecedented high rate of 11.8 % per annum, which was 70 % higher than the average NGDP growth rate of 6.8 % .

GDP and RGDP Growth Rates (%.p.a)

	1989	1990	1991	1992	1993
GDP (Vietnam)	7.8	4.8	6.0	8.3	8.0
RGDP (Hanoi city)	9.2	18.6	7.5	13.1	11.2

Per-capita GDP in Hanoi City was estimated at 3,548,000 Dong (US$ 328) in 1993. (The figure estimated by the national statistics office is US$ 565, taking into account the actual parity value of Dong).

In RGDP, the agriculture sector shares only 6 %, while industry and trade sectors share 23 % and 22 %, respectively. The service sector including finance and insurance is predominant 39 % of RGDP. Compared to the components in the national GDP, the economy of Hanoi City shows comprehensive development and diversification from agriculture to industry, trade, finance.

(4) Employment

According to the national census conducted in 1989, the population involved in economic activities is 898,906 (or about 45% of the total population) in Hanoi City.

Although its contribution to RGDP is less than 10 %, the agriculture sector has the largest share of 35.0% of the total number employed. The second largest sector is industry with its share of 34.7%.

The finance and commerce sector has a relatively high share of 13.7 %, followed by the science and culture sector and transport/communication sector which are 9.3 % and 4.4 %, respectively.

Employment in Hanoi City (1989 census)

Sector	No. of Employed	%
Agriculture	314,971	35.0
Industry	311,800	34.7
Transport / Communication	39,197	4.4
Finance and Commerce	123,095	13.7
Science, Culture, & Education	84,068	9.3
Others	25,775	2.9
Total	898,906	100

The rate of unemployment is estimated at 7.6 % in Hanoi City. However, this figure might be larger if underemployment in the rural area is taken into account.

(5) Agriculture

As mentioned above, the agriculture sector is the most important sector in the regional economy, particularly in Tu Liem and Thanh Tri districts, in terms of employment. The total amount of agricultural land in the Study Area is about 4,800 ha, which is equivalent to 35 % of the total amount of land in the Study Area. The major crop is rice which is supplemented by vegetables and other cereals such as maize, potatoes, and sweet potatoes.

According to the interview survey, most of the farmers produce two crops of paddy a year. Winter/spring paddy is planted during Dec/Jan - April/May, while summer/autumn paddy is planted during June/July - Sept./Oct. Based on the estimated productivity of paddy, which is 3.3 ton/ha, about 25,000 tons of paddy are being produced in the Study Area.

However, due to the drainage problem paddy production is affected by floods in the Study Area. It is estimated that 1,900 - 2,400 ha of the land or 40 - 50 % of the total amount of agricultural land is flooded annually.

Fishery is another important activity in the Study Area. In Tu Liem district several fish ponds, the land allocated for which is about 2,200 ha exist. Most of the lakes in the Project area are more or less being used for fishery. The most important lake for fishery is the West lake, which has an area of 570 ha. The fish cultivated are tilapia, carp, black carp, etc. In the Study Area, about 5,000 tons of fish are harvested annually. This fish harvest is also affected by floods and water pollution in the region.

(6) Tourism

In 1993, Hanoi had 51 state hotels, 8 foreign joint-venture hotels, and 24 guest houses with about 2,580 rooms. The number of visitors was estimated at more than 450,000 in 1993, including 300,000 foreigners.

Over the last three years (1990 - 1993) the number of foreign visitors doubled, increasing at an average rate of 26 % per year, while the revenue from the tourism sector increased 5 times with an average growth rate of 71 % per year.

Number of Tourists in Hanoi and Revenue

Year	No. of Tourists Total	(Foreigners)	Revenue (billion Dong)
1990	NA	(150,000)	80
1991	NA	(180,000)	105
1992	425,000	(260,000)	300
1993	450,000	(300,000)	400

Source: Hanoi City Plan 2010

If this trend continues, the total number of visitors in Hanoi is expected to reach 1.5 million (includes 1.0 million foreign tourists) in the year 2000 and 3.5 to 4.0 million (includes 3 million foreign tourists) in 2010.

(7) Health and Hygiene

In Hanoi City, there are 25 hospitals (8,859 beds), 5 health stations (300 beds) in the districts, and 280 village health stations (2,825 beds). The number of medical facilities seem sufficient in Hanoi, but the quality, including the available equipment and medicines, is not sufficient, particularly in rural areas. Beside, all kinds of waste from the above medical facilities discharge directly into the common drainage system in Hanoi, which seriously effects the hygiene of the environment.

According to the information from the Hanoi Center of Hygiene and Epidemiology under the Ministry of Health, water related diseases in Hanoi City are

mainly diarrhoea and dysentery. Other diseases such as typhoid, cholera and poliomyelitis have seldom been recorded in recent years.

Over the last three years (1991 - 1993) the average number of patients recorded having diarrhoea and dysentery were 26,212 and 3,134, respectively in Hanoi. The actual number of patients, which is roughly estimated at around 4 - 5 times of the recorded ones, is larger than the above figures. Though it is not recorded in the official statistics, many people suffered from eye diseases. (Our interview survey indicates that 12.5 % of the total population of sample households suffered from eye diseases).

Patients of Water Related Diseases in Hanoi

	1987	1988	1989	Average 87-89	1991	1992	1993	Average 91-93
Diarrhoea:	13,322	33,951	16,777	21,350	34,389	21,211	24,036	26,212
Dysentery:	14,638	13,004	4,870	10,837	5,824	1,879	1,698	3,134
Typhoid:	3	14	17	11	187	119	3	103
Cholera:	NA	NA	NA	NA	4	0	0	1
Poliomyelitis:	10	6	9	8	NA	NA	NA	NA

Source : Ministry of Health

(8) Household Income and Expenditure.

According to the statistics prepared by the National Statistics Office, the average household income (in Hanoi) for a government employee was 215,700 Dong per month, while that of a farmer was 99,250 Dong per month, in 1993.

However, the results of the interview survey indicate a higher income distribution in the Study Area. The average monthly incomes estimated from the above results are 864,000 (US$ 80) Dong for an urban resident and 797,000 Dong (US$ 74) for a suburban resident.

These figures are considerably higher than the national average, but they represent the actual income of households in the Study Area.

2.1.3. Economic Development Plan

(1) National Goals and Objectives

For the long-term development of the country, a "strategy for socio-economic stabilization and development up to year 2000" was prepared. Under this framework, a five-year plan covering the period between 1991 - 1995 was prepared by the State Planning Committee.

The major quantified objectives of the strategy up to the year 2000 are as follows:

(a) Total population will reach 80 million in 2000. The population growth rate will be reduced to less than 1.8 % per annum;

(b) Increase per-capita income (two-fold increase) during 1990 - 2000 (the expected GDP growth rate is 8 -9 % per year);

(c) Increase staple flood production to approximately 30 million tons by 2000.

(d) Increase electricity output 2.5 to 3 times higher than that of 1990.

(e) Increase exports to 5 times higher than that of 1990.

(2) Regional Economic Development Plan

Under the framework of the national development strategy, a development plan for Hanoi up to 2010 was prepared by the Hanoi Planning Committee. This plan is very aggressive and much more ambitious than the national plan.

According to the plan, RGDP of Hanoi is projected to increase 13 - 14 % per year between 1991 - 2000 and 15 % between 2001 - 2010. RGDP will be 6,142 million Dong (1989 prices) in 2000 and 24,568 million Dong (1989 price) in 2010.

A drastic reduction in the population growth rate is anticipated in the projection for 2010. It is assumed that the population growth rate Hanoi will be reduced to about 1.3 % per annum between 1991 - 2000 and 1.6 % between 2001 - 2010.

The per-capita income of Hanoi, thus estimated, is 2,642,000 Dong (1989 prices) or US$ 1,382 in 2000 and 9,015,000 Dong (1989 prices) or US$ 4,715 in 2010.

Projected RGDP

	1990	2000	Growth rate (1991-2000)	2010	Growth rate (20012010)
(a) RGDP in Hanoi (million Dong)	1,755	6,142	13.3 %	24,568	14.9 %
(b) Population (Thousand)	2,052	2,324	1.3 %	2,725	1.6 %
(c) Per-capita RGDP (Thousand Dong)	855	2,642	11.9 %	9,015	13.1 %
(d) US$	447	1,382		4,715	

Note: RGDP is estimated at 1989 prices
Exchange Rate of US$ = 1,912 Dong is applied (This exchange rate is being applied to most of the national statistical data)
Source : Hanoi Development Plan 2010

In order to attain the above targets, the capital investment required between 1993 - 2010 is estimated at 67,000 billion Dong.

(3) Population Projection

Population projection for the urban area of Hanoi City was carried out by Finnida for the water supply project up to 2010. This projection was authorized by the authority of Hanoi City in December 1993. For the planning of sewerage and drainage in Hanoi City the authorized population will be applied in order to be consistent with the water supply scheme.

Under the above situation, population projection in the Study Area is carried out in the following way:

(a) In the urban areas, the Finnida projection is in principle applied. Since the available population data only covers the population for the water supply district, the projection for each subdistrict is conducted by applying the estimated growth rate in due consideration of the boundary of each subdistrict.

(b) In the suburban areas, the projection is carried out by applying different criteria.

- If the subdistrict is included in the water supply district (Finnida M/P), the same growth rate estimated by Finnida is applied.

- If the subdistrict is included in the development area of the Hanoi 2010 Development Plan, the target population density in 2010 is set for these subdistricts in due consideration of the future land use and present population density.

- For the other subdistricts, it is assumed that the past growth trend will continue up to the year 2000, which will gradually decrease by 10-20% towards 2010.

The results of the projection are summarized in the following table. Details of the projection according to each phuong are presented in Table 2.6.

In the urban areas, the projected population growth rate is quite low in most of the subdistricts, except Dong Da where potential development lands are available and relatively high growth rates of 1.8-2.5 % per year are projected. This reflects the Government's policy to reduce the population growth rates of urban areas.

In the suburban areas, Tu Liem district is expected to have a high population growth rate ranging between 3-5 % per year, while Thanh Tri district will have as relatively low growth rate of 2 % during the planning period.

Projected Population in the Study Area

	GR 1992-2000	Population 2000	GR 2001-2005	Population 2005	GR 2006-2010	Population 2010
I. URBAN						
1. Dong Da	2.5	406,340	2.0	447,660	1.8	488,430
2. Ba Dinh	-0.1	185,220	0.1	186,350	0.8	194,640
3. Hoan Kiem	-0.7	139,780	-0.4	136,950	-0.3	135,020
4. Hai Ba Trung	0.0	284,570	-0.1	283,340	0.8	294,580
Urban Total	0.8	1,015,910	0.7	1,054,300	1.1	1,112,670
II. SUBURBAN						
5. Thanh Tri	2.3	97,240	2.3	109,000	2.4	122,490
6. Tu Liem	5.9	260,550	3.4	307,490	2.8	353,460
7. Ha Tay Province	2.6	6,630	2.3	7,440	2.1	8,250
Suburban Total	4.2	364,420	3.1	423,930	2.8	484,200
TOTAL	1.7	1,380,330	1.4	1,478,230	1.6	1,596,870

Note : GR = Growth rate per year

2.2 City Development Plan

2.2.1 Present Land Use and Urban Development

As presented in the preceding Section 2.1 (socio-economy), the Study Area consists of four urban districts, i.e. Dong Da, Ba Dinh, Hoan Kiem, and Hai Ba Trung, two suburban districts, Tu Liem and Thanh Tri of Hanoi City, and Van Yen of the Ha Tay province. The boundary of the districts and subdistricts in the Study Area are presented in Figure 2.1.

The development of Hanoi City can be explained by the development of four axes, namely, the Gia Lam axis, R.1 axis, R.6 axis, and R.32 axis (see Figure 2.4). The Gia Lam axis runs in a northeastern direction, crosses the Red River, and extends into Gia Lam district where industrial and residential development is predominant.

The R.1 axis runs in a southern direction along the national road No. 1, where the land is predominantly used for industry, residences and public facilities. The R.6 axis runs in a southwestern direction along national road No. 6. This axis is one of the most aggressively developing areas, where the land is used for industry, collective and multi-storied residences, and government institutions. The R.32 axis runs in a western direction along national road No. 32. This axis is also a rapidly expanding area in Hanoi City. A newly constructed highway connects Noi Bai international airport to this R.32 road about 6 km west of central Hanoi. The land of this axis is mostly used for government institutions and industries.

On the basis of available aerophotos taken in December 1991 (1/8,000 scale), a topographic map (1/10,000 scale) and a land use map were prepared by UPI. The land use map was prepared for the Study Area as presented in Figure 2.2 and areas of different land use are estimated as shown in the table below:

Present Land Use, 1991

(ha)

	Urban Area	Suburban Area	Total	
City Centre *	860	60	920	(7%)
Residential				
- Urban	1,900	1,100	3,000	(22%)
- Suburban	510	1,290	1,800	(13%)
Industry	150	450	600	(4%)
Green & Park	150	0	150	(1%)
Lake & Pond	260	2,010	2,270	(18%)
Agriculture	110	4,690	4,800	(35%)
Total	3940	9,600	13,540	(100%)

Note : This information is also contained in Table 2.7 in a comparative form with future land uses (2010)

* : City centre includes an ancient area, public buildings, offices and commercial buildings

Source : Present Land Use Map, JICA Study Team, 1993

As indicated in the table, 35 % of the Study Area is used for agriculture, followed by residential areas where urban residential areas and rural residential areas share 22 % and 13 %, respectively. The city centre consisting of government, public, and commercial areas occupies 7 %, while the industrial area comprises only 4 % of the total Study Area. Due to its historical and topographic background, lake and pond areas share a high rate of 18 %, including Ho Tay.

2.2.2 City Development Plan

The master plan for the development of Hanoi City was prepared by the Urban and Rural Development Institute (URPI) of the Ministry of Construction in collaboration with Hanoi Urban Planning Institute (HUPI), and the report was submitted in March, 1993 addressed to the Council of Ministers, Hanoi People's Committee, and Ministry of Construction (refer to Figure 2.3).

(1) Basic Policies and Principles of the Master Plan

The basic policies and principles of the master plan are as follows :

- The plan will be prepared based on the market economy system
- Targets will be set at the meeting point of technological and economic development
- Urban areas planning will be carried out based on the self-support principle
- Relations with the outside world will be taken into account
- Improvement of urban amenities will be considered
- Management and implementation organizations will be established
- Steady investment and implementation programs will be prepared

(2) Development Direction

Spatial development is planned on the basis of the basic policy and principle mentioned above. Future development in Hanoi is planned along the existing four axis and the new Thanh Long South axis which extends in a north-south direction down to Nghia Do. Of the five axis, R.6, R.32, and Thanh Long South axes are considered to be the strategic development direction of Hanoi City. In the master plan, development along these axes is supported by two ring roads. The urban development structure is schematically presented in Figure 2.4.

Urban facilities with various functions are planned to be built in Hanoi City. The major civic centres are Hoan Kiem Trade and Service Centre, Ba Dinh Political Centre, and Ho Tay Culture, Tourism, and Sports Centre. Of these three facilities, the Ho Tay Centre, to be constructed, will be the development core for the northeastern part of the City. Two sub-centres located on the Thanh Long axis and R.6 axis, will be connected to the centres in order to support their functions. Besides these, thirteen administrative/residential cores will be established as the centres of residential units.

Industrial areas are planned to be located in the suburban areas where a large amount of land will be newly prepared. Small-scale industries will still remain in the urban areas. The major industrial areas will be located downstream of the river basins. Therefore, the urban sewerage system will not be seriously affected.

Lakes and ponds in the City will provide the people with recreational areas, and will become the core of the green network of the City. Green roads and promenades will extend from the core along canals and rivers. The drainage system is also expected to be improved by using these lakes and ponds for natural retention ponds.

One of the characteristics of the plan is that it emphasizes the importance of urban amenities, or conservation both of natural and artificial environments. In the master plan, conservation of old quarters, including domestic houses and buildings in the ancient area, and greenery and water conservation are rated as one of the most important points.

2.2.3 Future Land Use

The future land use plan for the year 2010 was prepared by URPI of the Ministry of Construction and HUPI on the basis of the master plan. The projected land use of the Study Area is presented in Figure 2.3 and summarized in the table below:

Master Plan Land Use, 2010

(ha)

	Urban Area	Suburban Area	Total	
City Centre *	860	120	980	(7%)
Residential				
- Urban	1,970	3,360	5,330	(39%)
- Suburban	510	1,600	2,110	(17%)
Industry	230	600	830	(5%)
Green & Park	150	210	360	(3%)
Lake & Pond	220	1,710	1,930	(14%)
Agriculture	0	2,000	2,000	(15%)
Total	3940	9,600	13,540	(100%)

* : Note : This information is also contained in Table 2.7 attached in comparison with the present land use (1991)

* : City centre includes ancient areas, public buildings, offices and commercial buildings

Source : Master Plan Map, HUPI, 1992

Compared with the present land use (see Table 2.7) the following are the major change:

- Reflecting the rapid urban expansion of the City, the urban residential area will expand in a northwestern and western direction, with an increment of 2,330 ha.

- Agriculture land will provide a source of land for urbanization, therefore, it will decrease by 3,000 ha.

- City centre area will slightly increase 60 ha into the suburban area.

2.2.4 Aspects Related to Drainage/Wastewater Disposal Planning

Some of the aspects related to subsequent drainage/sewerage planning are as follows:

- Large-scale urban development takes place in a northwestern and southwestern direction, along the R.32 and R.6 axes, which have been analyzed as minimum flood areas,

- The land use pattern of southern part of the Study Area, Thanh Tri District, will remain unchanged, agriculture and fishery, because of frequent floods,

- Industrial areas tend to be located downstream of the river basin, which proved to be of an advantage to the sewerage system,

- Major lakes and ponds will be conserved in order to guarantee future urban amenity and beauty, and also for the maximum utilization of their flood control capacity,

- Ho Tay will be carefully conserved from water pollution by inflowing drainage/sewerage water, which will create a recreational area for citizens and a tourism centre, and

- The old part of the City centre, ancient, old. and villa areas will be a conservation area which is controlled and beautified as a priority project area. Drainage and sewerage improvement must be considered to be an urgent project in the conservation project for up-grading living conditions.

2.3 Hydrology

2.3.1 Hydrological Mechanism Causing Inundation

(1) Rainfall

The daily rainfall of storms which have occurred in the past storms in the Hanoi City area are shown in Table 2.8. The one and two days rainfall amounted to 73 % and 91 % of the total amount of rainfall, respectively.

The hourly rainfall hyetgraphs of five major floods which occurred in the past in the Hanoi City area are shown in Figure 2.5.

(2) Water Level

The relationship between rainfall and the water levels of floods which occurred in Jun. 1989 and May and Aug. 1994 were recorded every hour as shown in Figure 2.6.

The water level of the Nhue River rises rapidly to an elevation higher than 5 m, after intensive heavy rainfall and maintains an elevation higher than 3.5 m over a period of ten days. This causes the water level to rise in the To Lich River and, accordingly, flooding in the Hanoi City area. This constitutes a constraint to the discharge of flood water from the To Lich River basin into the Nhue River by gravity.

2.3.2 Rainfall Analysis

(1) Duration of Design Rainfall

Two days rainfall was adopted as a typical design storm duration for drainage planning, considering the coverage ratio of the total rainfall depth to the duration of the high water level period of the Nhue River during the flooding period.

(2) Design Rainfall Depth

Based on the Thiessen polygon coverage and data quality, the probable rainfall at the Lang station was adopted for drainage planning.

Probable 2-day rainfalls at the station were calculated based on annual maximum 2-day rainfalls at the Lang station during the period from 1955 to 1993 (39 years). According to Gumbel's formula, 2-day rainfall of the 10-year return period was 310 mm. A design rainfall depth of 310 mm was adopted for drainage planning.

(3) Rainfall Intensity for Urban Drainage

The rainfall intensity formula for Hanoi City, developed by MOC, was adopted for the wastewater disposal plan. The formula is as follows and the curve is shown in Figure 2.7:

$$I = 0.36 \cdot \frac{5416(1 + 0.25 \cdot \log P \cdot t^{0.13})}{(t+19)^{0.82}}$$

Where

I : Rainfall intensity (mm/hr) (36 mm/hr=100 l/s/ha)

P : Return period (year)

t : Time of flood concentration (minutes)

The probable 10 and 60 minute rainfalls (Gumbel's formula) were also calculated in order to evaluate the formula, using maximum records for the period between 1957 to 1992 (36 years) at the Lang station. The results coincide well with the curves shown in the figure.

As a reference, another curve developed by Hanoi Civil Engineering College in 1990 is also shown in the figure.

2.3.3 Low Flow Condition

(1) Low Flow Measurement

Low flow discharge measurements were carried out at six points on the 15th and 16th December 1993. The results of the measurements are tabulated below:

Measurement Points	Discharge (m^3/s)	Area (km^2)
(1)To Lich River (Cau Moi Bridge)	1.02	16.9
(2)To Lich River (Cau Dau Bridge)	1.57	29.4
(3)To Lich River (Thanh Liet floodgate upstream)	5.83	68.2
(4)Lu River (Tau Bay Bridge)	0.67	4.6
(5)Kim Nguu River (Cau Xa Hoang Van Thu Bridge)	0.40	19.6
(6)Kim Nguu River (conf. with Kim Nguu and Set)	1.47	28.5

(2) Estimation of Natural Flow

Judging from the above results and other measurement records collected in the past, it is considered that the low flow discharge at the Thanh Liet floodgate will be 5 m^3/s throughout the year. The natural flow of the To Lich River was estimated to be around 0.5m^3/s using the regression formula for maintenance flow in Japan($Q(m^3/s) = 0.0069*A(km^2)$).

2.3.4 Flood Runoff Analysis

(1) Calculation of Design Hydrograph

For drainage planning, the design 10-year discharge hydrograph recurrence probability was calculated assuming several alternative cases of lake/reservoir regulations. The river systems were modeled as shown in Figure 2.8. The hydrographs are delineated in Figure 2.9.

The conditions for calculation are summarized below:

- Objective area : To Lich River basin (A=68.2km^2) (excluding West Lake basin)
  : Nhue River basin; four drainage basins
- Design control point : Yen So pumping station site (To Lich River basin)
  : Confluence with Nhue River (Nhue River basin)
- Method of calculation : Storage function method (Assuming land use in 2010)
- Design scale : 10-year (10%) return period
- Duration of design rainfall : 2 days
- Design rainfall depth : 310 mm (2 days)
- Objective storm event : June 1989 flood type (See Table 2.9)
- Enlarging factor used in calculating the design hourly hyetograph of a 10-year period : 1.081 (310mm / 286.7mm)
- Case of calculation
- To Lich River basin : Alternative 0 - 6 (Alternative 0 ; no lakes)
- Nhue River basin : Alternative 1

  Note: For details of the alternatives, refer to Subsection 3.3.1 hereinafter

- Regulation at lakes /ponds : Natural control method (No gated control)

(2) Flood Control Volume of the Regulating Reservoir

(a) Yen So Regulating Reservoir

The required flood control volume of Yen So regulating reservoir corresponding to each alternative and pump capacities was calculated using the hydrographs.

Unit : $10^6 m^3$

Pump Capacity (m3/s)	Case						
	Alt. 0	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6
30	13.90	12.43	12.39	11.92	11.38	12.43	11.35
60	10.22	8.44	7.86	7.57	7.24	7.54	6.83
90	7.49	5.51	4.73	4.51	4.25	4.38	3.87
120	5.23	3.23	2.42	2.26	2.08	2.12	1.75
150	3.41	1.48	0.78	0.68	0.56	0.54	0.32
Qp(m^3/s)	256	203	187	184	181	180	174

Note' Alt. 0 - Alt. 6 = see Subsection 3.3.1 hereinafter

It is noteworthy that the flow retardation effect caused by lakes is relatively significant as represented by the reduction of flood peak discharge and flood control volume at Yen So regulating reservoir.

(b) Nhue River Basin

Regulating reservoirs for four drainage basins are planned at the confluence with the Nhue River. The required flood control volume of the regulating reservoir in Alternative 1 was calculated as shown below:

Drainage Basin	Pump* Capacity (m^3/s)	Required Volume ($10^6 m^3$)	Peak Discharge (m^3/s)
Co Nhue	12	3.02	55
My Dinh	8	1.59	26
Me Tri	9	1.60	31
Ba Xa	6	1.07	14

* : refer to Chapter 3 (Drainage Master Plan)

(3) Assessment of Floods Occurring in 1994

The hydrographs of two large floods which occurred May 20 and Aug. 29 in 1994, were estimated using the runoff model (Alternative 6). The results are delineated in Figure 2.10.

The regulating volume of Yen So reservoir with a pump capacity of $90m^3/s$ was estimated to be 1.93 million m^3 (May 20 flood) and 1.76 million m^3 (Aug. 29 flood) respectively, whereas the flood control volume of the reservoir was 3.87 million m^3. Therefore, these floods will be safely managed by the JICA drainage plan.

2.3.5 Channel Characteristics Analysis

(1) Present Channel Capacity

The bankful present channel capacity was calculated using the non-uniform flow calculation as shown below:

- To Lich : $50m^3/s$(downstream) - $10 m^3/s$(upstream)
- Kim Nguu : $40m^3/s$(downstream) - $20 m^3/s$(upstream)
- Lu : $10\text{-}15m^3/s$
- Set : about $10m^3/s$

The present bankful capacity of four main rivers was assessed to correspond roughly to 1.2-year flood discharge.

(2) Influence of Backwater under Design Section

The influence of backwater on the Yen So regulating reservoir in the receding period of floods (water level of EL. 4.5m and discharge of $90m^3/s$) was studied utilizing the non-uniform flow calculation and using design cross-sections.

According to the results, water levels of an elevation of 4.5 m do not influence the upper reaches. The calculated water level never exceeds the design high water level.

2.3.6 Inundation Analysis

(1) To Lich River Basin

The inundation (landside water) analysis was carried out on the To Lich River basin. The inundation water levels obtained are shown in Tables 2.10 and 2.11.

The conditions for the analysis are as follows:

- Method of calculation : Pond model using the elements of 28 sub-basins as shown below:

1) Hydrograph calculated using the storage function method

2) Drainage channel capacity(refer to Chapter 3)

3) Elevation-Volume relationship

- Alternatives : Case 1; Present Conditions (Pond ; Alternative 1)
  : Case 2; Future Conditions (Alternative 6)

- Magnitude of floods : 1.2, 2, 5, 10, 20, 30, and 50-years for Case 1
  : 20, 30, and 50-years for Case 2
  (June 12, 1989 flood type)

Since there is no planned dike under the present conditions, the probable water level of the Nhue River was adopted instead of the calculated water level when the probable water level of Nhue River was higher than the calculated level.

The calculation for a 10-year period flood inundation level under present conditions closely approximates to the actual water level records of the June 1989 flood. The result coincides with the observed water level, which proves the propriety of the model used.

(2) Nhue River Basin

The inundation analysis was carried out the Nhue River basin in accordance with the procedure mentioned above. The inundation water levels obtained are shown in Table 2.11. Each of the four drainage basins was treated as one sub-basin.

The conditions for the analysis are as follows:

- Alternatives : Future Conditions (Alternative 1) with pump and regulating reservoir

- Magnitude of floods : 20, 30, and 50-years (June 12, 1989 flood type)

2.4 Environment and Water Quality

2.4.1 Environmental Issues Related to Drainage and Sewerage

(1) Environmental Problems in Hanoi

Wastewater is discharged into the surface water system, which is also used for fish farming, irrigation, and recreation. Actual treatment of this wastewater takes place in the aquatic ecosystem, which is overloaded or at the limit and may be totally exhausted by organic matter and toxic industrial waste. The pressure on the aquatic system, at present, is too strong and the capacity for biological treatment has been exceeded. Industrial wastewater and solid waste discharges prevent safe use of water, e.g. for aquatic production.

The pollution of groundwater caused by wastewater is possible, because leakages from sewers are frequent due to the age of pipes and thin solid covering.

During the rainy season, when the groundwater level is high, groundwater penetrates into the pipes. During the dry season, when the groundwater level is low, wastewater infiltrates into the surrounding soil, increasing the risk of groundwater and soil pollution.

Storm water is drained by a system of channels, rivers, and regulating lakes and ponds into the Nhue River. The drainage situation in Hanoi is very difficult because there are many low-lying areas. The elevation is particularly low in relation to the Red River.

Storm water can be polluted by organic matter, heavy metals, and all kinds of bacteria and virus. Water tanks, which are under the water, are directly contaminated by wastewater overflowing from sewers during floods. On the other hand, floods produce a flushing effect on streets and channels, carrying away dust, sediments, and solid waste.

A common practice is to throw all kinds of solid waste into the water and carry out illegal landfill. This decreases water quality and prevents water flow, which increases the possibility of floods. Sedimentation is increasing and water bodies have to be frequently cleaned.

The practice of using fresh excreta and sludges from septic tanks without the proper biological stabilization, results in the pollution of surface water and groundwater. There Overhung latrine are still being used, which results in hygienic hazards occurring.

According to the above-mentioned points, it is very clear that the inadequate conditions and lack of sewerage and drainage systems are the largest environmental and health risks in Hanoi. Collection and use of solid waste and is also problematic, because the level of facilities is low and inadequate.

(2) Lakes and Ponds as Wastewater Treatment Systems

Lakes, ponds, and channels are used to collect and drain wastewater and storm water. They are overloaded by organic waste and nutrients, but the bottom layers and sediment are anaerobic.

It is a requirement that these structures be regularly dredged, due to the high rate of sedimentation and growth of water plants. The velocity of flow in channels is very low except in the rainy season.

A special regulation for bigger lakes is necessary in order to control urban floods, and emphasis should be placed on the possibility of diluting water in lakes and channels during the dry season. The areas of ponds and channels is insufficient for the provision of appropriate storage volume. The larger volume of lakes and additional water from rivers could most probably be utilized for the rehabilitation of these minor water bodies.

With the effective circulation of water, aeration, and harvesting water plants by lakes, it is maintained that lakes could receive domestic wastewater from half a million people. The respective production of aquatic plant biomass could be 1,500 tons/day in theory. However, the maximum utilization of biological productivity is not in harmony with other uses of the City's lakes.

The ecological capacity of the City's waters has been preliminary evaluated and further approaches are recommended for the surrounding areas of the main well fields. The intrusion of polluted surface water can be limited or prevented in many cases by developing the utilization of the ecological capacity.

2.4.2 Water Quality

(1) Wastewater Monitoring Program

The Wastewater Monitoring Program, which started in May 1993, has been carried out by HSDC. The objectives of this program are to obtain information on water quality in some lakes, rivers, and channels, which have been polluted by wastewaters, identify the quantity and quality of wastewaters from industry, hospitals, and households, and identify the main polluters.

According to the results of the monitoring program the influence of wastewater is very clear, especially in channels. BOD varies in channels between 30 - 105 mg/l, in rivers 45 - 100 mg/l and in lakes 14 - 50 mg/l. Water is polluted, if the BOD value exceeds 15 mg/l. Concentration levels of ammonium and phosphate are highest in places where domestic wastewaters are discharged. During the summer, lakes contain a little oxygen, but rivers and channels are partly anaerobic.

It is possible that the load to lakes and rivers is quite stable. Rainfall has a significant dilutive effect on water quality, and variations in water quality during the summer depends mostly on rainfall.

Industrial wastewater samples have been taken from textile and foodstuff factories and breweries, etc. It is noticeable that the concentration levels of nutrients, BOD and COD loads, from factories and hospitals are remarkable. The exact amounts have not been calculated because the quantity of wastewaters is usually unknown.

(2) Water and Sludge Quality Investigations Carried out under the Study

(a) Investigations Carried Out

During the dry season, water sampling were carried out at 15 points: three points from lakes, eight points from the main rivers, and four points from channels. Sampling was firstly carried out in the middle of December 1993 and secondly in the middle of January 1994.

During the rainy season on-site water quality analysis was carried out on lakes, which were proposed to be dredged during the first stage of implementation of the To Lich River Basin Project. An on-site analysis, especially for aerating pilot projects continued in September 1994. In addition, during September water samples were taken from twenty lakes, three of which are included in the Wastewater Monitoring Program which is being carried out by HSDC.

(b) Results of the Dry Season Investigations

Results from the dry season investigations confirm that all lakes, rivers, and channels in Hanoi are at least moderately or highly polluted by domestic and industrial wastewater (Table 2.12). Pollution and eutrophication by organic matter causes the water quality to deteriorate and sedimentation to increase, and results in a lack of oxygen. Turbidity and concentration of suspended solids is high in all places.

All three lakes, Hoan Kiem, Van Chuong, and Bay Mau, which belong to the sampling program, are polluted. The situation is the worst in Van Chuong Lake, which is heavily polluted by industrial wastewater e.g. from textile factories. Water quality at the outlet was about the same level as wastewater, e.g. the average amount of BOD was 76 mg/l and COD was 141 mg/l, also the concentration of nutrients was high.

All the main rivers in Hanoi, To Lich, Lu, Set, and Kim Nguu, are shallow and their flows are small, especially during the dry season. There are a lot of water plants such as water hyacinth, water spinach, fern, and duckweed in many rivers. All the rivers are polluted and the dilution capacity is inadequate. The average amount of BOD was 40-65 mg/l and COD 76-163 mg/l. Water quality was the best in the lower reaches of the Nhue River, where the water volume is larger and, therefore, the dilution capacity is higher than in other rivers. In the Nhue River the average amount of BOD was only 6 mg/l and COD 17 mg/l.

In the channels mainly wastewater exists during the dry season. The color of the water in channels was brown or black, the smell was from domestic wastewater, no oxygen exists, and concentration of nitrogen-ammonia was high due to the domestic wastewater.

The amount of analyzed bacteria is too low compared with the normal amount of bacteria in wastewater.

Heavy metals in water and sludge have been analyzed at five points. Some of the concentrations of heavy metals are a little high, but all are still under the Vietnamese standards. No mercury (Hg) and very little cadmium (Cd) were found. In general, the heavy metal concentrations were highest at Lo Duc outlet and Bay Mau lake.

(c) Results of the Rainy Season Investigation

In August oversaturation of oxygen in lakes occurs, where there was visible algae blooming and the water was a strong green color. The next measurements were carried out in September, when oversaturation of oxygen was not as strong, because storm waters have flushed the lakes. Oversaturation depends on the amount of rainfall and temperature.

Due to heavy rains the amount of nutrients decreased from August to September. Floods occur and water levels become very high in lakes. Storm waters have a flushing effect on water bodies and retardation is shortened in lakes. Turbidity and suspended solids remain at a high level all the time,

especially during rains where they are very high. The number of samples was insufficient for analyzing the impact storm waters have on BOD and COD.

If the water is considered to be polluted when BOD is higher than 15 mg/l, then most of the lakes are at least moderately polluted. The highest concentrations were found in lakes which have been directly affected by the discharge of wastewaters.

At the end of September an on-site analysis on dissolved oxygen from selected lakes for evaluating aeration was conducted. Measurements were carried out on different water layers but stratification was not observed.

In general, all water bodies are polluted, untidy, and water is smelly. The lack of sewers, wastewater treatment and adequate solid waste, and nightsoil collection prove to be the largest environmental problems for Hanoi, especially in the densely populated inner city area where on-site wastewater treatment is impossible.

2.4.3 Aspects to be Considered in Drainage and Sewerage Planning

The targets of the improvement of the drainage system are to prevent floods, mitigate inundation areas, and to clean sewers and channels. It is necessary to re-construct several bridges which prevent flow. Sludge has to be located away from sewers and excavated soil so that it will cause no harm to people or the environment. If all wastewater from the City area is discharged into other areas, other than lakes and rivers, there will be very little water remaining in lakes and rivers, therefore a compensating amount of water has to be discharged.

In general, any improvements to drainage, and especially sewerage will improve the environment and water quality. However, planning has to be carried out so that damage to the environment is as little as possible. Drainage has to be so designed as to prevent floods from moving into other areas.

The monitoring of surface waters and industrial wastewaters has started and should be encouraged and supported. It is necessary to possess a continuous series of data, because up until now information has been scattered and unreliable. The amount of wastewater, especially from industry, and load to the water bodies should be more fully understood. The real water quality of discharging areas of the proposed wastewater treatment plants should be studied before and after implementation in order to obtain information about the impact of treatment plants.

Lake dredging and conservation for drainage purposes require much background information before being implemented in an effect way. The possible bottom fauna and real condition and amount of sediments should, in particular, be studied before and after major changes take place in lakes. During and after implementation the work carried out should be examined in order to check if it has been conducted according to the designs.

In the design and implementation stages not only technical problems will occur, but also problems regarding on the organization, because the management of sewerage and drainage is divided into several offices which are concerned with their own prerogatives.

2.4.4 Conservation of West Lake

The conservation of West Lake (Ho Tay) is a very important subject, because West Lake is a valuable place from the viewpoint of the ecology and as a tourist resort. Comprehensive environmental studies should be conducted before all construction is carried out and changes take place in and around West Lake. A separate project to consider environmental aspects more detailed than is possible here, is proposed. Some of the conservation programs which are anticipated to be conducted in the future are described below:

(1) Reduction of Wastewater Inflow

TUPWS has prepared a future land use plan for the West Lake area, including infrastructure, based on the Hanoi City Master Plan. The West Lake area is divided into six drainage sub-basins. An on-site/community disposal system is proposed as the most suitable system for Zone 1 from the viewpoint of minimizing environmental impacts after development and geographical conditions.

(2) Dredging of the Bottom Sediments

The exact thickness of sediment is unknown and can vary in different parts of the lake. The amount and quality of sediment should be carefully studied before dredging is undertaken. Dredging will affect the lake bottom fauna, which have to be studied to prevent any serious damage occurring. The ecosystem around the lake should also be studied.

Assuming that the average thickness of sediment is 2 m, the dredging quantity is estimated to be about 11 million m3. The dredging work will involve the following technical difficulties: 1) It will require relatively large cost, amounts of money. 2) In the case of pump dredging, the dredged water should be returned to the lake because the natural water inflow into the lake is limited. The work will require the construction of a few large settling basins for disposing of the sediments near the lake and re-disposal of them to the final spoil bank. 3) It will have to be carried out, using a small amount of equipment, area by area in order to protect the bottom fauna. The work will require 10 to 12 years for its completion.

(3) Construction of the Lake Shore Road

Under the future land use plan prepared by TUPWS proposals have also been made for the construction of roads and parks around West Lake. These works are proposed mainly to prevent further illegal landfill and to promote tourism around the lake. The construction of a road with the length of two-thirds of the lake's shoreline is proposed.

The conservation of the lake's shoreline will be carried out by revetment work or the conservation of natural banks. Parks are proposed to be located mostly between roads and the lake's shoreline. At present there are already many people living in the shoreline area. The adequacy and/or suitability of the road construction will be judged by the socio-economic survey carried out on this area.

(4) Comprehensive Socio-environmental Study

All the socio-environmental aspects should be clearly defined before any of the projects, stated above, can be planned and implemented.

It is necessary to immediately organize a socio-environmental study for the West Lake basin. The study shall analyze the various potential problems which might occur concerning water quality and the lake ecosystem, including flora and bottom fauna.

2.5 Geotechncial Investigation

2.5.1 Geography

(1) Geography of Study Area

Hanoi City, the capital of Vietnam, is located approximately in the center of Northern Vietnam. It is located about 100 km upstream of the mouth of the Red River, and which flows down from the mountainous area in a northwest to southeast direction branches into several courses over the alluvial plain. (See Figure 2.11)

(2) Creation of Lakes and Ponds

Even in a limited area 1 ha, there are as many as 111 lakes and ponds, the total area of which accounts for 16 % of the Study Area. These lakes and ponds might have been created by the build up of water in depressions, or old river courses, which were formed by meandering, short-cutting, and bifurcation of rivers on the deltaic low-lying area. Such geographic development has formed the following four distinct types of topography in the Study Area:

(a) A sandbar or a small-scale fan, formed by the Red River, with a slightly higher elevation than the other areas, in the northeast where the Old City Area is located;

(b) Natural levees mainly comprising sandy materials, which develop along the Red River and To Lich River with comparatively narrow widths and higher elevations;

(c) Back marshes mainly comprising clayey materials, which spread over the low-lying areas behind the natural levees. In this area horizontal deposition takes place; and

(d) Existing river courses and lakes/ponds (most of which are considered old river courses).

2.5.2 Geology

(1) Geological History of Vietnam

The territory of Vietnam is geologically intersected by the border between the Eurasian Continent, which is an old continent formed in the Pre-Cambrian Era (before 550 million years ago), and the Indochina Continent which comprises deposits of the Mesozoic Era (250 to 65 million years ago). In both continents, many rows of mountain ranges were created, together with faults and folds, by orogenic movement which occurred several times. Further more, in the Cenozoic Era (65 million years ago), the lava plateau in the center, to the south of Vietnam, was formed by the penetration of basaltic lava. Then, in the Quaternary period, deposits originating from the above base rocks formed plains along rivers and the sea.

(2) Geology of the Hanoi Area

According to a report (Geological Survey of Vietnam), the geology of the area in and around the Study Area is depicted as shown in Figures 2.12 and 2.13. In the Study Area, the Quaternary stratum covering the base rock is generally constituted by, from top to bottom, Thai Binh (tb), Hai Hung (hh), Vinh Phuc (vp), and Hanoi (hn) formations. The characteristics of each layer are as follows:

(a) Alluvial Deposits

- Thai Binh : composed of sand, sandy clay, and silt at a depth of more than 15 m below the ground surface.
- Hai Hung : comprising humic clay at a depth between 5 m and 20 m.

(b) Diluvial Deposits

- Vinh Phuc : mainly composed of sand at a depth between 15 m and 40 m.
- Hanoi : mainly composed of sandy gravel at a depth between 4 m and 35 m below the ground surface.

2.5.3 Ground Subsidence

The water supply of Hanoi City solely depends on groundwater. In the Study Area, there are two aquifers from which groundwater is abstracted: Qa and Qb corresponding to the formations Hanoi and Thai Binh, respectively. The amount of groundwater abstracted has increased immensely. As can be seen in Figure 2.14, areal-average ground subsidence is about 5 mm to 10 mm per annum, and large subsidence was observed at Phap Van and Ngo Si Lien where groundwater abstraction is vigorous. Such ground subsidence may be accelerated by the increase in the amount of groundwatetr abstracted due to the expansion of the population in the Hanoi area.

Ground subsidence, if it is likely to continue in the foreseeable future, will have to be taken into consideration in the planning and design of drainage structures. Some of the approaches include the following:

(1) To provide an extra allowance for the freeboard area above the high water level (e.g., in rivers and drainage channels); and

(2) To assume extra discharge capacities for floodgates, etc.

2.6 Topographic Survey

The following works were executed during the study stage for the master plan, mainly to clarify topographic conditions of the To Lich, Lu, Set, and Kim Nguu Rivers:

(1) Longitudinal and cross-sectional survey of the To Lich River (14.5 km, 88 sections);

(2) Longitudinal and cross-sectional survey of the Lu River (5.4 km, 29 sections);

(3) Longitudinal and cross-sectional survey of the Set River (5.7 km, 33 sections);

(4) Longitudinal and cross-sectional survey of the Kim Nguu River (11.6 km, 66 sections);

(5) Longitudinal and cross-sectional survey of the Old To Lich River (11.6 km, 66 sections); and

(6) Installation of datum points for the execution of the said works by leveling (15 km).