社会開発調査部報告書

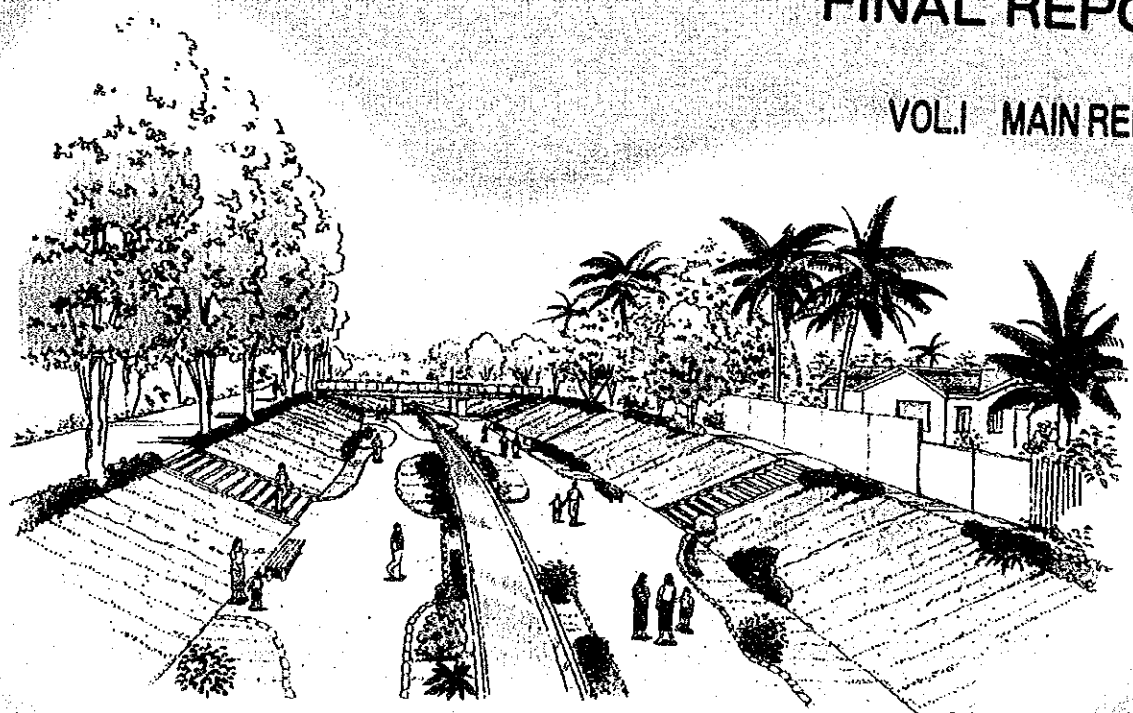
No. 32

LAO PEOPLE'S DEMOCRATIC REPUBLIC

FEASIBILITY STUDY ON IMPROVEMENT OF DRAINAGE SYSTEM IN VIENTIANE

FINAL REPORT

VOL.I MAIN REPORT



MARCH 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

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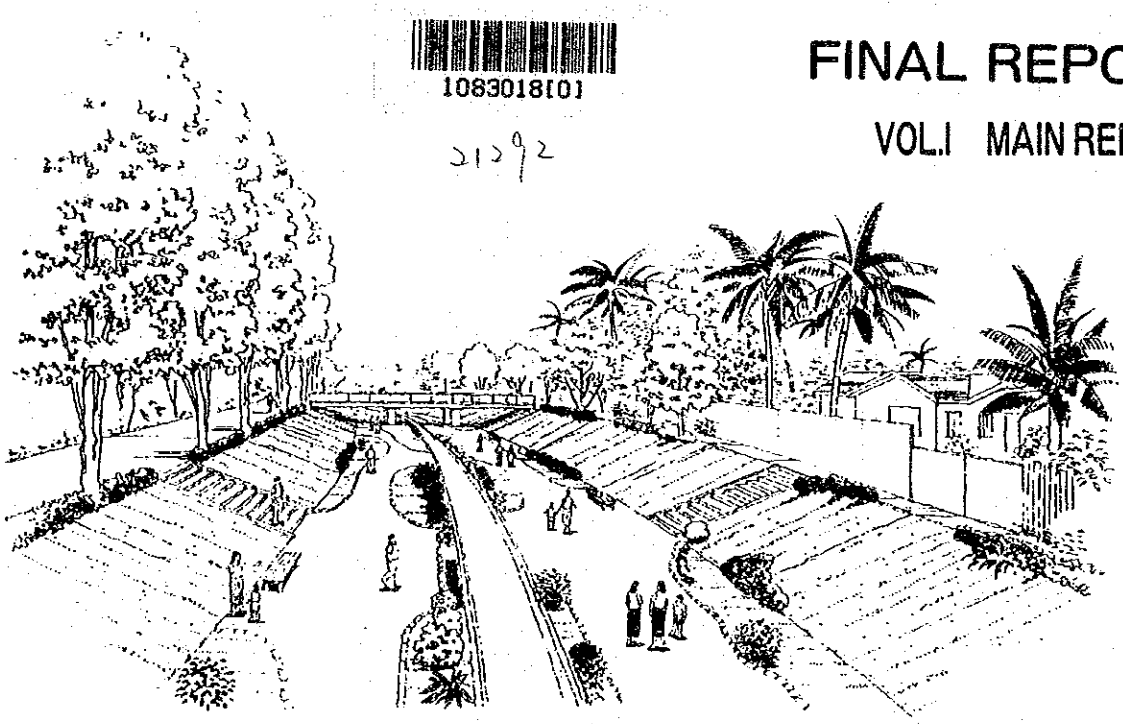


MARCH 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

FEASIBILITY STUDY ON IMPROVEMENT OF DRAINAGE SYSTEM IN VIENTIANE

LIST OF VOLUMES

This is VOLUME I. MAIN REPORT.

PREFACE

In response to a request from the Government of Lao People's Democratic Republic, the Japanese Government decided to conduct a feasibility study on the improvement of drainage system in Vientiane and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Laos a survey team headed by Mr. Norio Takayanagi, Nippon Koei Co., Ltd. from April 1989 to February 1990.

The team held discussions with concerned officials of the Government of Laos, and conducted field surveys. 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 Lao People's Democratic Republic for their close cooperation extended to the team.

March 1990

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

FEASIBILITY STUDY ON
IMPROVEMENT OF DRAINAGE SYSTEM
IN VIENTIANE

Mr. Kensuke Yanagiya
President
Japan International Cooperation Agency
Tokyo, Japan

March 1990

Dear sir,

Letter of Transmittal

We are pleased to submit to you the Final Report for Feasibility Study on Improvement of Drainage System in Vientiane. This report proposes improvement measures of storm water drainage in Vientiane to the Government of the Lao People's Democratic Republic for implementation.

The report presents a basic plan for storm water drainage improvement in the entire Study Area and feasibility plans for the identified priority area. The study recommended improvement of several existing drainage channels and construction of retarding basins in order to counter the extensive inundation damage caused by storm rainfalls.

The Report consists of the Main Report with Summary and three volumes of Supporting Reports. The Summary briefs the findings and the feasibility plans recommended in the Study. The Main Report contains full description of the study results, conditions of the study, recommended drainage improvement plans, conclusions and recommendations. Supporting Reports contain background data and technical details.

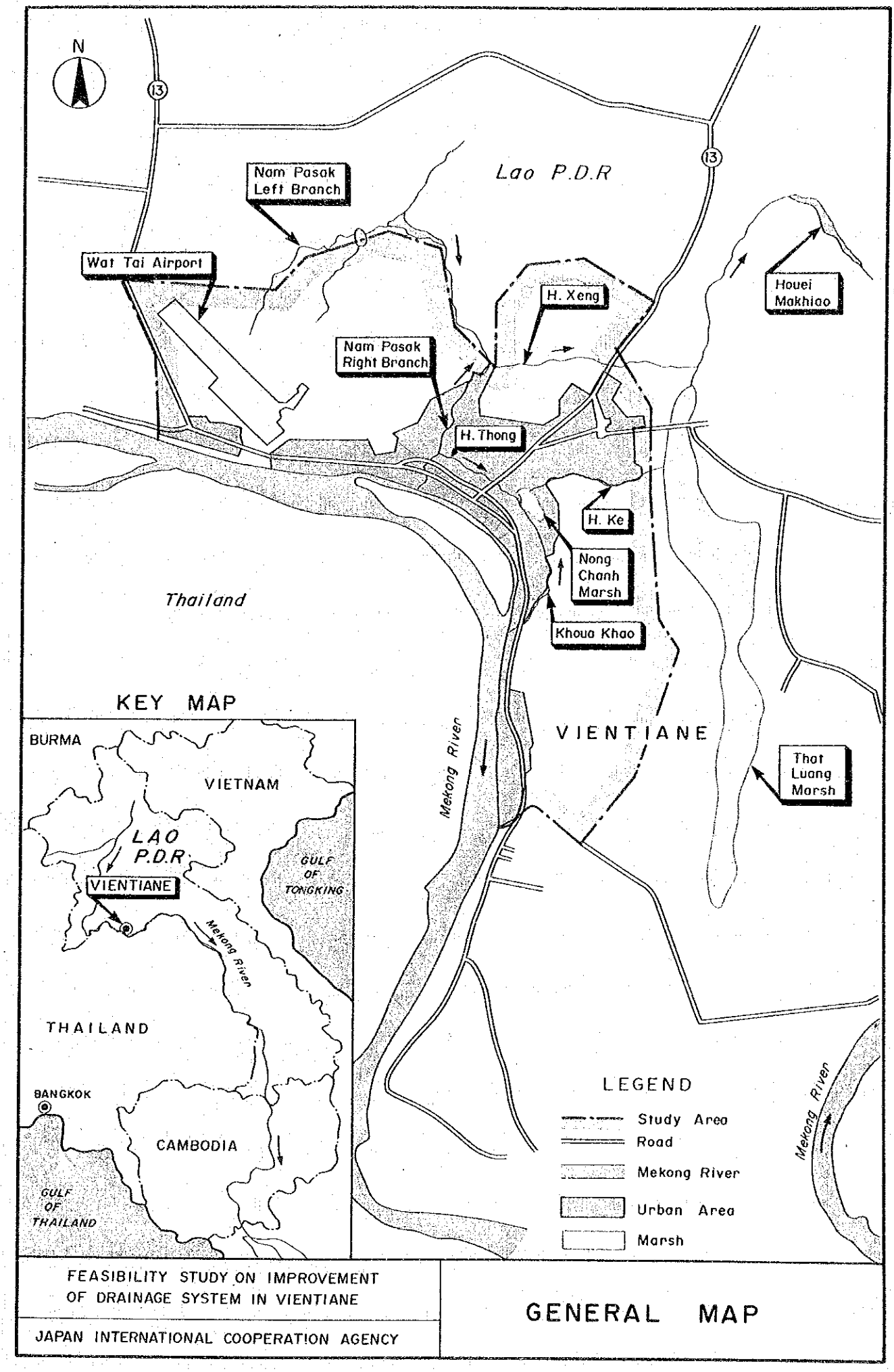
All members of the Study Team wish to express sincere gratitude to the personnel of your Agency, Advisory Committee, Ministry of Foreign Affairs, Ministry of Construction and Embassy of Japan to the Lao P.D.R., as well as officials of the Government of the Lao P.D.R. for their assistance. The Study

Team sincerely hope that the study results will contribute to development of well-being in Vientiane.

Yours sincerely,

N. Takayanagi

Norio Takayanagi
Team Leader



FEASIBILITY STUDY ON IMPROVEMENT OF DRAINAGE SYSTEM IN VIENTIANE

JAPAN INTERNATIONAL COOPERATION AGENCY

GENERAL MAP

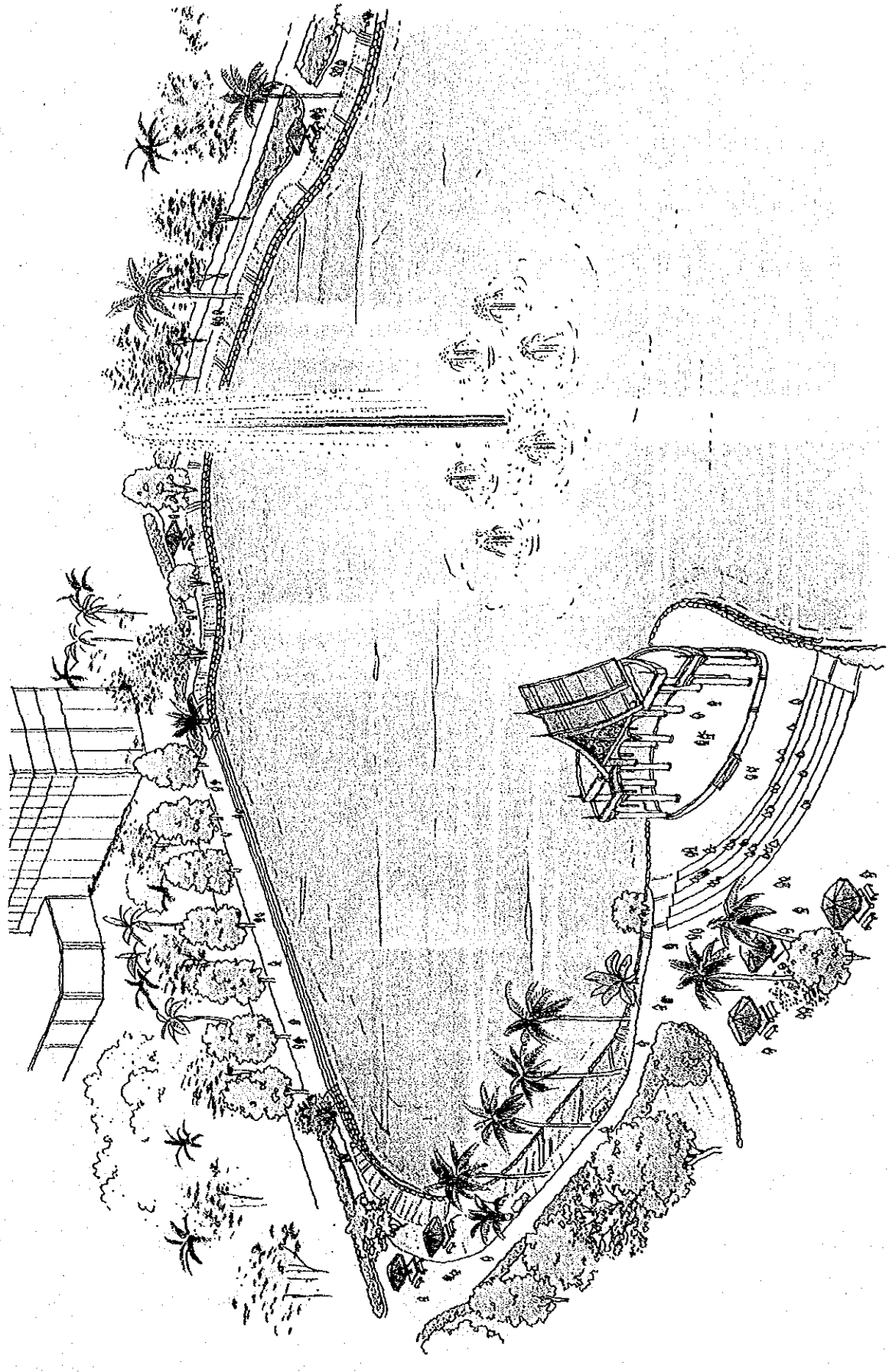


Plate 1 Image of Improved Nong Chanh Marsh

LAO PEOPLE'S DEMOCRATIC REPUBLIC
FEASIBILITY STUDY ON IMPROVEMENT
OF DRAINAGE SYSTEM IN VIENTIANE

JAPAN INTERNATIONAL COOPERATION AGENCY

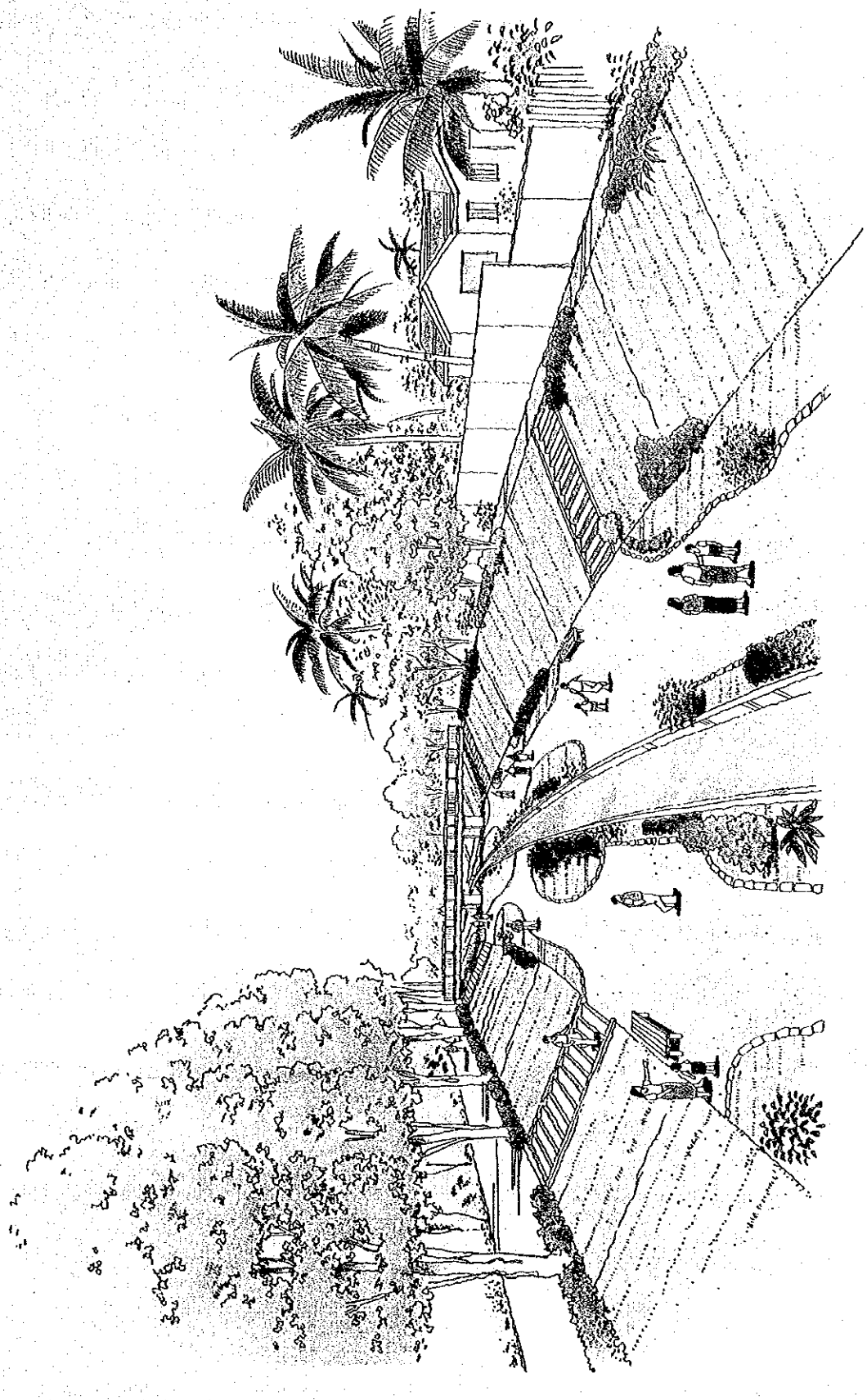
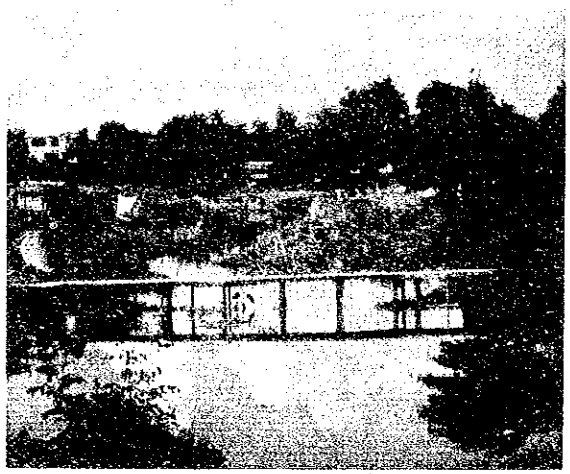


Plate 2 Image of Improved Drainage Canal

LAO PEOPLE'S DEMOCRATIC REPUBLIC
FEASIBILITY STUDY ON IMPROVEMENT
OF DRAINAGE SYSTEM IN VIENTIANE
JAPAN INTERNATIONAL COOPERATION AGENCY

Hong Thong

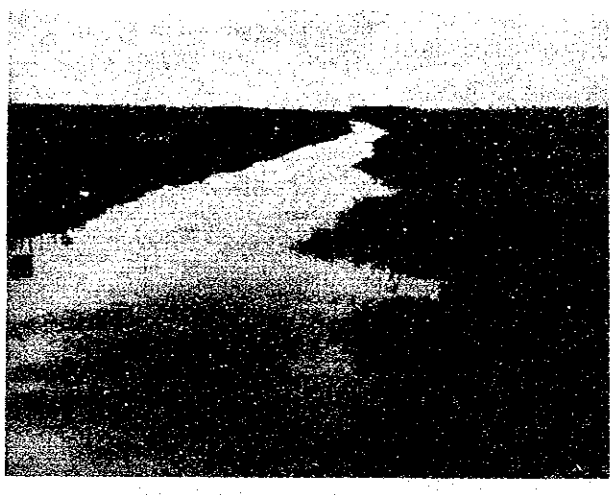


Junction of the Hong Thong with Khoua Khao

Nong Chanh Marsh

Hong Ke in the Middle Reach

Khoua Khao near Nong Chang Marsh



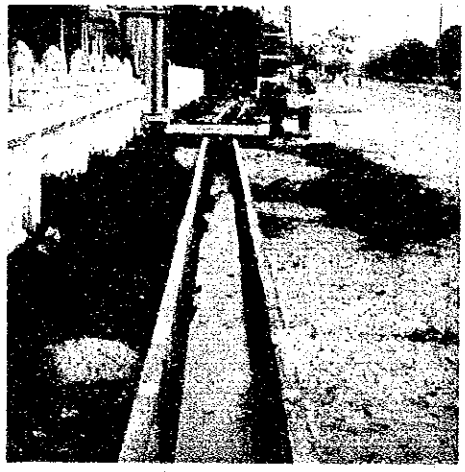
Drainage Canal in That Luang Marsh

Plate 3 (1) Drainage Canals in Vientiane

LAO PEOPLE'S DEMOCRATIC REPUBLIC FEASIBILITY STUDY ON IMPROVEMENT OF DRAINAGE SYSTEM IN VIENTIANE
JAPAN INTERNATIONAL COOPERATION AGENCY

Hong Xeng near the Junction with Nam Pasak

Upstream Reach of Nam Pasak Left Branch



Lateral Canal near Wat Tay Airport

Drainage Canal in Sub-area M

Nam Pasak Right Branch

Nong Douang Marsh

Plate 3 (2) Drainage Canals in Vientiane

LAO PEOPLE'S DEMOCRATIC REPUBLIC FEASIBILITY STUDY ON IMPROVEMENT OF DRAINAGE SYSTEM IN VIENTIANE
JAPAN INTERNATIONAL COOPERATION AGENCY

Storm Rainfall on 12/9/1989

New Market (Talat Mai) Inundated

An Inundated Local Restaurant (Sub-area H)

Temple (Wat) Inundated
(Sub-area H)

An Inundated Backyard of a House
(Sub-area H)

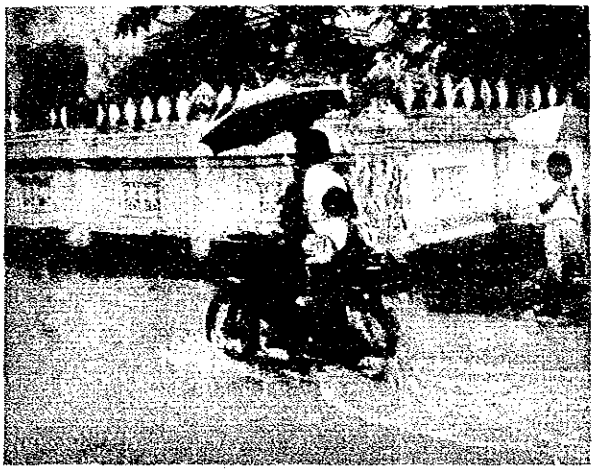
A Houseyard Inundated
(Sub-area H)

Plate 4 (1) Inundation in Study Area

LAO PEOPLE'S DEMOCRATIC REPUBLIC FEASIBILITY STUDY ON IMPROVEMENT OF DRAINAGE SYSTEM IN VIENTIANE
JAPAN INTERNATIONAL COOPERATION AGENCY

Central City Area Inundated
(Sub-area H)

A Trunk Road Inundated
(Sub-area L)



Motor Cyclist in Inundated
Urban Street (Sub-area L)

Pedestrians in an Inundated
Rural Road (Sub-area P)

Submerged Paddy Field
(Outside of Study Area)

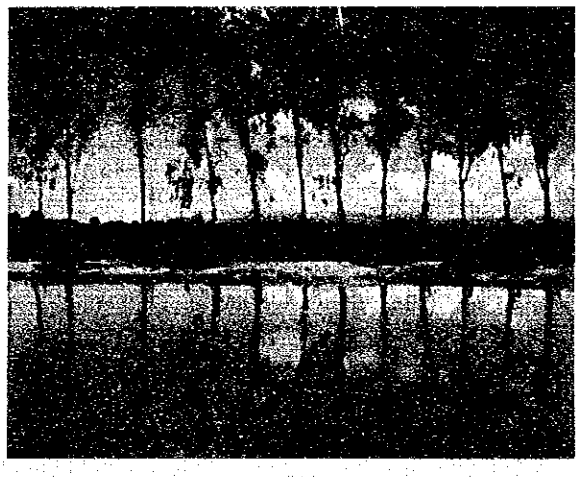
Gas Station Suspended Operation
due to Inundation (Sub-area H)

Plate 4 (2) Inundation in Study Area

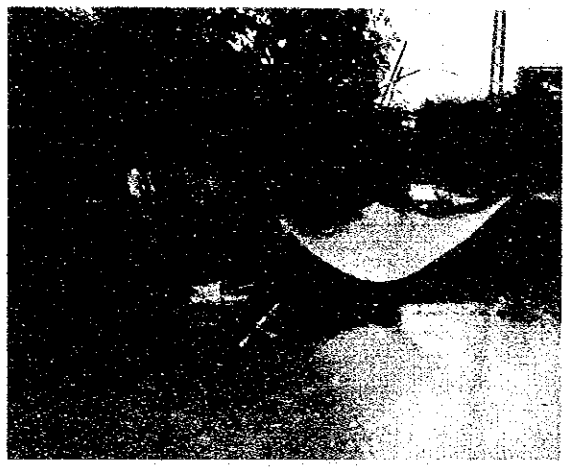
LAO PEOPLE'S DEMOCRATIC REPUBLIC FEASIBILITY STUDY ON IMPROVEMENT OF DRAINAGE SYSTEM IN VIENTIANE
JAPAN INTERNATIONAL COOPERATION AGENCY

Pak Bon, Popular Water Plant,
Sold Along Hong Ke

View of a Bank with Sod Facing
(Saam Haa Park)



Fish Pond with Tree on the Banks
(Sub-area M)



Girls Catching Fish by a Hand Net

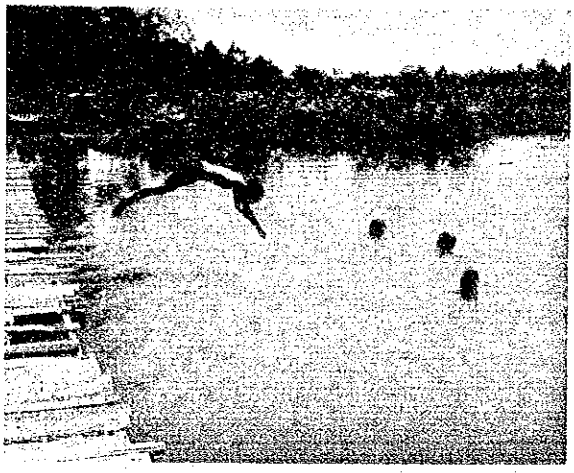
A Man Harvesting Lotus Stalks
(Nong Tha Nay)

A Man Catching Fish by Bow (Nong Bon)

Plate 5 (1) Water and People in Vientiane

LAO PEOPLE'S DEMOCRATIC REPUBLIC FEASIBILITY STUDY ON IMPROVEMENT OF DRAINAGE SYSTEM IN VIENTIANE
JAPAN INTERNATIONAL COOPERATION AGENCY

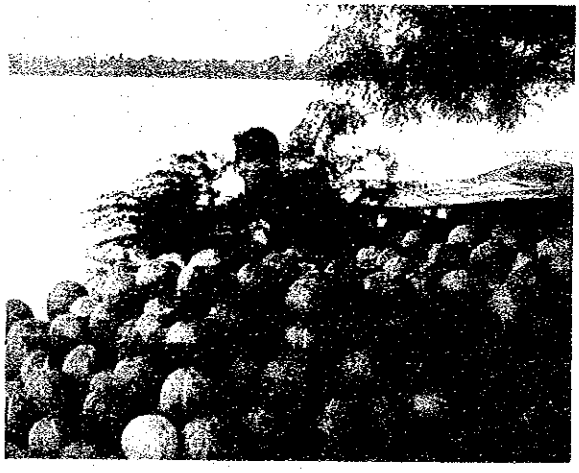
Young Girls Playing on a Boat (Nong Chanh)



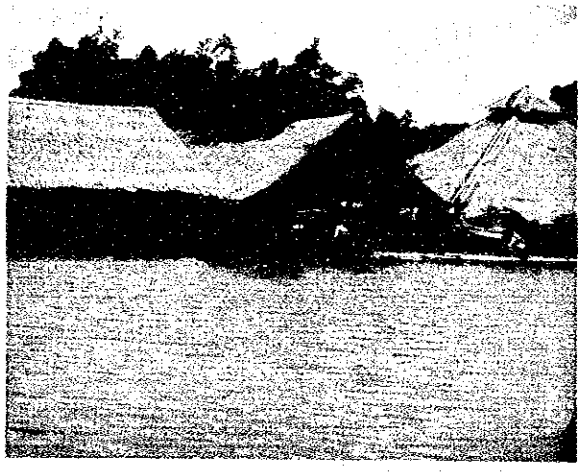
Children Swimming in a River (Nam Pasak)

Lotus Blossoms

Children Having Fun by Splashing Water (Nong Tha Nay)



A Fruit Seller on the Bank of the Mekong



A Floating Restaurant (Nam Ngum Reservoir)

Plate 5 (2) Water and People in Vientiane

LAO PEOPLE'S DEMOCRATIC REPUBLIC FEASIBILITY STUDY ON IMPROVEMENT OF DRAINAGE SYSTEM IN VIENTIANE
JAPAN INTERNATIONAL COOPERATION AGENCY

FEASIBILITY STUDY ON IMPROVEMENT OF DRAINAGE SYSTEM IN VIENTIANE

LIST OF VOLUMES

LOCATION MAP

PLATES

SUMMARY

Table of Contents

PART II. BASIC PLAN

Page

PART III. FEASIBILITY STUDY ON THE PRIORITY PROJECT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ORGANIZATIONS

AASHTO	American Association of State Highway and Transportation Officials
ASTM	American Society of Testing and Matierials
JICA	Japan International Cooperation Agency
JIS	Japan Industrial Standard
JSCE	Japan Society of civil Engineers
Lao PDR	Lao People's Democratic Republic
MOV	Municipality of Vientiane
UNDP	United Nations Development Program
US	United States
USAID	United States Agency for International Development
USBR	United States Bureau of Reclamation
USSR	Union of Soviet Socialist Republics

TECHNICAL

EL (el)	Elevation
Dai.	Diameter
GL	Ground Level
MSL	Mean Sea Level
RC	Reinforced Concrete
HWL	High Water Level
FWL	Flood Water Level
LWL	Low Water Level
F.M.	Fineness Moduls
L.A.	Abrasion by Los Angeles Method
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
BOD	Biochemical Oxygen Demand
TSS	Total Suspended Solid
T-P	Total Phosphate
T-N	Total Nitrogen
NO_3-N	Nitrate Ion

NH_4-N	Ammonium Ion
CL	Chlorine

SOCIO-ECONOMY

EIRR	Economic Internal Rate of Return
GDP	Gross Domestic Product
GRDP	Gross Regional Domestic Product
GVA	Gross Value Added
NRMP	Net Regional Material Products
OMR	Operation, Maintenance and Repair

UNIT

mm	millimeter	cm	centimeter
m	meter	km	kilometer
m^2	square meter	ha	hectare
m^3	cubic meter	mg	milligram
lit.	litter	km^2	square kilometer
sq	square	cu.	cubic
kgf	kilogram-force	tf	ton-force
s(sec)	second	min.	minutes
hr	hour	d	day
%	percent	p.a.	per annum
o/oo	per mille (1/1,000)	no.	number
nos.	numbers	kw	kilowatt

PART I.

GENERAL

PART I. GENERAL

CHAPTER 1. INTRODUCTION

1.1 Authority

In response to a request of the Government of Lao People's Democratic Republic (Lao P.D.R.), the Government of Japan decided to carry out the Feasibility Study on Improvement of Drainage System in Vientiane (hereinafter referred to as the Study). The Study was entrusted to the Japan International Cooperation Agency (hereinafter referred to as JICA), the official agency responsible for implementing the technical cooperation programs of the Japanese Government.

From the 15th to 18th of December, 1988, JICA dispatched a mission to Lao P.D.R, chaired by Dr. Yamaguchi, to carry out a preliminary survey and to discuss the scope of works for the Study. The scope of works has been agreed upon by and between the Government of Lao P.D.R. and the JICA Mission. The scope of works is the basis of the Study and govern the entire aspects of the Study.

1.2 The Objective of the Study

The Study has following threefolds objectives;

(1) To formulate a Basic Plan for storm water drainage system improvement in the Study area of 56.2 km^2 in the urbanized part of Vientiane municipality and to identify the priority project,

(2) To conduct a Feasibility Study on the identified priority project and

(3) To carry out technology transfer to the Laotian staff through the implementation of the Study.

1.3 The Study

JICA duly organized an advisory committee chaired by Dr. Yamaguchi to steer the Study. Meanwhile JICA selected a group of consultants to organize the Study Team to implement the agreed scope of works of the Study.

The Government of Lao P.D.R. assigned the Municipality of Vientiane (MOV) as the counterpart agency. MOV selected staff from various agencies and authorities to organize a team of counterpart officers.

The Study was carried out both in the field and in the home office of the Study team as follows;

First field study	:	from April to June 1989
First home work	:	from July to August 1989
Second field study	:	from August to November 1989
Second home work	:	from November 1989 to February 1990

During the Study period, the Advisory Committee meetings were held several times to steer the Study. The meetings among the government of Lao P.D.R., the Advisory Committee and the Study team were held as well to exchange views. The basic plan and the feasibility plan proposed reflect the comments and views presented at the meetings.

Since the Study is aimed at formulating a master drainage plan, it focussed on the main drainage canals which collect and drain the storm water of respective catchment areas. However, the Study selected some sample lateral canals which feed and drain water to the relevant main canal to examine the discharge capacities of the present canals and to identify the necessary works required to improve them.

The hydrologic study estimated the probable storm rainfall in the Study area. It projected the runoff on the basis of the projected land use by areas in the future. The study on the area of possible inundation for the cases with and without the drainage improvements was another subject of the hydrologic study.

The study on socio-economy and land use projected the future land use. Thereby the potential inundation damages are estimated by areas and by years. The projection of population and GRDP are the key factors for the pollution load projection of the drainage water in the future. The drainage system proposed were so laid out as to be consistent with the land use plan of the municipality of Vientiane.

The study on the rivers and the existing drainage canals was taken into account in the demarcation of the catchment areas. It determined the alignment of the proposed canals as well. The hydraulic features of the proposed canals were obtained on the basis of the topographic survey results. The comparative study examined the advantages of the conceivable alternative ideas for drainage systems. The alternatives were assessed from economical and environmental points of view.

The results of the soil mechanical surveys and material tests were fully utilized in planning of structural facilities. The conceivable alternative structures were compared in terms of economy and environment.

The prices of necessary materials for the project construction were surveyed in the market and at the similar construction sites. The rates of the necessary works were estimated taking account of the local conditions. These are the basis of the construction planning and cost estimation.

The benefit of the project was estimated through the damage reduction by means of the provision of the drainage improvement. The benefit thus obtained and the cost to be incurred by the project yielded the economic international rate of return as an index for the project evaluation.

1.4 Final Report

The Draft Final Report was submitted to the Lao P.D.R. in February 1990 by JICA. The basic drainage plan and the feasibility plans proposed in the report were discussed in the joint meeting among Vientiane municipality, the Advisory Committee and the Study team. The contents of the report were generally accepted by the meeting. This Final Report was prepared on the

basis of the Draft Final Report reflecting the conclusions of the meeting mentioned above.

The report comprises four volumes as follows;

Volume 1	:	Main Report
Volume 2, 3 and 4	:	Supporting Report (1), (2) and (3)

Main report covers all aspects of the Study. It describes the features of the proposed plan and the assessment thereof. Meanwhile Supporting Reports describe specific topics in detail. Readers of Main Report are invited to refer to the relevant volume of the Supporting Report, if he or she feels it necessary to trace the logic and the reason for a description.

1.5 Acknowledgement

The study team would like to acknowledge the Municipality of Vientiane and other authorities concerned for their sincere cooperation during the whole Study period. There is no doubt that such progress as this could not have been achieved without their cooperation. The data and information furnished to the team have been utilized as the basic materials for the study. Meeting and discussion were held in a very effective and constructive setting. The activities of counterpart officers complied sufficiently with the requirements. The facilities provided for the study were satisfactory. Availing this opportunity, JICA study team would like to express hearty gratitude to all the people of Lao P.D.R. concerned.

The Study team also would like to acknowledge the support received from the government of Japan in various aspects of the Study. Among others, special acknowledgement is due to the Embassy of Japan to Lao P.D.R. and the Advisory Committee of JICA for their valuable suggestions and guidance given in the course of the study. Their comments and recommendations have been given our sincerest considerations.

It is our great pleasure to report that, with this cooperation and support, the Study team was able to make successful study.

CHAPTER 2. THE STUDY AREA

2.1 The Profile and Socio-Economy of the Study Area

Lao P.D.R. is a land-locked country bordered by China, Burma, Thailand, Cambodia and Vietnam. The country area tallies 236,800 km^2 with the population of about 3,600,000 according to the result of census carried out in 1985. The average population density is estimated to be about 15 person/km^2 in 1985.

Vientiane municipality, the capital of Lao P.D.R., plays the most important role in the political and economic activities in the country. The central part thereof is located at 19°87' north in latitude and 102°48' east in longitude. It faces the left bank of the Mekong which flows at the southern end of the Vientiane Plane. The other side of the Mekong is Thailand bounded by the river.

The area of Vientiane municipality is 3,267 km^2 comprising 8 administrative districts. The population of the municipality is 381,000 persons in 1985, or 10% of the national population. The topography of the municipality is generally flat. The elevation varies from El. 164 m to El. 175 m. Elevated areas, which are free from flooding, have been developed and public facilities such as factories, government agencies, universities are situated along the trunk roads running in elevated areas. However due to recent growth of population, residential areas have had to expand into low-lying ground. Thus there has been a recent increase in inundation damage incidental to growth of the urban population.

The Wat Tay Airport is located in the western part of Vientiane city and is utilized for international and domestic air flights. Roads in the municipality have a total length of 1,196 km, composed of 227 km asphalt paved, 533 km lateritic paved and 536 km unpaved. Three trunk roads connect the municipality with principal cities such as Luang Prabang, Savannakhet, etc. One of four existing river ports on the Mekong is located in the municipality.

Domestic water of about 60,000 m^3/day is supplied from Chinaimo and Kaoliao treatment plants, both of which intake the water of the Mekong.

Electricity is supplied from the Nam Ngum power station constructed in 1971 with an installed capacity of 150,000 kW. Electrical connection in Vientiane has not been fully completed yet. Sewerage is virtually non-existent in Vientiane.

The Study area of 56.2 km^2 is located in the southern part of the municipality as presented in GENERAL MAP. It forms the most urbanized area of the municipality comprising 4 districts, Sykottabong, Chanthaboury, Saysetta and Sysatthanak. It includes most of the public and governmental offices, embassies from foreign countries, treatment plants for water supply and public establishments. The total length of roads in the Study area is about 230 km with 140 km or 60% paved. Submergence of roads due to inundation is a major disturbance to inland transportation. Water and electricity supply are well developed in the area and the supplies are stable. Drainage systems utilize either natural water courses or ditches along the roads. The main canals which drain the water in the urbanized area are the Khoua Khao, Hong Thong, Hong Ke, Nam Pasak and the Hong Xeng. These are all natural rivers although some improvements have been provided. The Municipality is constructing drainage ditch networks inside the urbanized area to convey water to the main canals. However, flooding often take place in the rainy season due to inadequate capacity and poor maintenance of the existing drainage system. Submergence causes damage to the assets of people and disturbs inland transportation. Further, storm water stagnating in canals and the low lying marshes is a major health hazard to the people, due to the large number of mosquitoes.

Frequent flooding and inundation in the area have deprived the people of the will to work and have hampered regional economic development. In view of this, the Government of Lao P.D.R. emphasizes the necessity to improve the existing drainage and to construct new drainage structures to improve the sanitary environment and to stabilize the people's livelihood.

The 1985 Census provides the most reliable population data of 3.6×10^6 persons in March 1985. In September 1988 the World Bank estimated the population in 1986. Meanwhile Laos Politics, Economics and Society produced a projection for the year of 2000 on the basis of the United Nations Assessment Data. The population growth rates applied in this projections were examined and the projections were made available as a basis for the Study. The

figures were simply extrapolated up to the year 2020. The estimated annual growth rates and population in 1,000 persons were as follows;

Year:	1985	1986	1990	2000	2010	2020
Rate (%):	2.90	2.40	2.20	1.92	1.60	1.30
Population:	3,585	3,671	4,016	4,825	5,645	6,426

where the growth rate in 1985 of 2.9% p.a. is the average rate from 1980 through 1984.

The population in the year of 1990 in Vientiane Municipality of 474,000 is estimated through extrapolation of the populations in 1985 and 1988. The shares of the municipality in relation to the national population are assumed by means of the smoothing. The population in 1,000 persons derived from the assumed shares are presented as follows;

Year:	1985	1986	1990	2000	2010	2020
Rate (%):	10.5	11.3	11.8	14.1	16.5	19.0
Population:	377	433	474	680	931	1,221

The population share of the Study area (56.19 km^2) against Vientiane Municipality (3,267 km^2) was arbitrarily assumed to be 25% in the year 2000. The shares in percent for other years and the consequent populations in 1,000 persons are estimated through extrapolation to be as follows;

Year:	1985	1988	1990	2000	2010	2020
Share(%):	39.5	35.5	34.5	29.5	27.0	25.0
Population:	149	158	164	201	251	305
Person/km^2:	2,651	2,811	2,918	3,577	4,467	5,427

The gross domestic product (GDP) and per capita GDP in 1986 are estimated to be Kip. 62,891 million and Kip. 17,132 (US$180 equivalent). The economy has been growing rapidly during 1982 to 1986, recording an increase of 6.4% per annum. However, in 1987 the GDP fell by 3.8% due to the impact of the 1987 drought which drastically reduced agricultural production and electricity generation. Net Material Product and GDP during 1982 to 1987 are shown in Table 2.1.

The shares of GDP and employment by industrial origins in 1986 are shown as below;

Agriculture	65.2% (GDP)	80.0% (Employment)
Industry	14.0%	2.2%
Service	20.8%	17.8%

Source: World Bank, 1988

Foreign trade in Lao P.D.R. is characterized by a persistent disequilibrium and a large share of a few commodities for export; namely, electricity, logs and wood products, and coffee. Most of industrial commodities, machinery, vehicles, petroleum, medicine and medical equipment depend on import.

Gross Regional Domestic Product (GRDP) of Vientiane Municipality was estimated by the Department of Economic Planning and Finance of Vientiane Municipality since 1987, as shown in Table 2.2. GRDP were estimated based on Net Regional Material Products (NRMP) defined as GRDP minus depreciation expenditure and value added of both government sector and private enterprises. The shares of GRDPs of Vientiane Municipality to GDP are estimated to be about 26% and 27% in 1987 and 1988 respectively.

The share of GRDP by industrial sector were estimated to be 76.9% for agriculture, 14.5% for Industry, 4% for Commerce, 1.9% for Construction and 1.8% for Transportation in 1988.

The Study area has been the most important economic center of national and regional economy. The agricultural sector has been the major sector also in the Study area. The major products thereof were paddy, vegetables, mungbeans, tobacco and sugarcane. The major industrial products have been those from agro-industry and consumer goods industry. Tobacco, fertilizer, soap, beer, soft drink and fabric are the principal products. Commerce is the other sector which characterize the Study area. There were most important commercial zone in Chanthabury district and 15 major markets in the Study area where both agricultural products and industrial products were collected from whole Vientiane Municipality.

The importance of the agricultural sector in the Study area is lower than that in whole Vientiane Municipality. In turn it has produced most of the industrial and commercial output in Vientiane Municipality.

The GRDPs by industrial origins are estimated on the basis of the statistics recorded in the four districts located in the Study area. The following are the estimates in 1988 at 1986 constant prices:

Agricultural production	:	$9,183 \times 10^6$ Kip
Industrial production	:	$2,800 \times 10^6$ Kip
Services production	:	$1,480 \times 10^6$ Kip

The share of agricultural production is 68% against the GRDP. That of industry is as high as 21%.

The Government of Lao P.D.R. formulated a socio-economic development plan under the Second Five Year Plan (1986 - 1990).

The plan assumed the annual growth rates of socio-economic figures as follows;

Period	:	1986 - 1990
Population	:	2.9%
GDP (Overall)	:	10.35%
Agriculture	:	9.85%
Industry	:	13.65%
Service	:	7.7%
Transportation	:	11.3%
Construction	:	12.55%

The per capita GDP in the year 2000 is estimated to be Kp. 42,400 applying the same growth rates assumed. The figures were obtained through the accumulation of the future demands and requirements of the detailed items. The plan will be achieved if the global economy, domestic economy and other circumstances such as local climate could maintain the economic environment envisaged. The GDPs projected applying the growth rates presented as above

are adopted as the high growth scenario. In this projection, the GDP's after 2000 are estimated through the tangential curve of GDP at the year 2000.

Meanwhile the GDP of Lao P.D.R. were projected by the World Bank from 1987 to 1995 by industrial origin. The figures are available for the study. The projection yielded the overall annual growth rates of 5.3% from 1987 to 1991 and 5.4% from 1991 to 1995, respectively. The annual growth rates of GDP by industrial origins were estimated as follows:

	1987 - 1991	1991 - 1995
Agriculture	4.7%	4.0%
Industry	8.0%	9.0%
Construction	6.9%	8.3%
Transportation	6.5%	8.0%
Commerce	5.6%	7.0%
GDP	5.3%	5.4%

The GDP in 1990 and 1995 are estimated in 1986 constant price as below:

	1985	1990	1995
GDP (million kip)	58,774	77,300	100,500
Growth rate of GDP (%)	-	5.3%	5.4%
Per capita GDP (kip)	16,394	119,254	22,827
Per capita GDP (US$) (US$1 = Kip 95)	173	202	240
Growth rate of per capita GDP (%)	-	3.1%	3.5%

The growth rate of per capita GDP in the period from 1985 to 1990 is estimated to be 3.1% per annum. Meanwhile that in 1990 to 1995 is estimated to be 3.5%. The annual growth rate of per capita GDP after 1995 is assumed applying the tangential curve of the average annual growth rate in 1990 - 1995 as below:

Period	Average annual growth rate
1985-1990	3.1%
1990-1995	3.5%
1995-2000	4.0%
2000-2005	4.5%
2005-2010	5.0%
2010-2015	5.5%
2015-2020	6.0%

The GDPs in 2020 at 1986 constant price is estimated to be 497,000 x 10^6 Kip.

The per capita GDP in 2020 is projected to be 820 US$ based on above projection. The GDPs projected as above are adopted as the low growth scenario.

In this study figures of the low growth scenario are adopted for the planning to avoid over-investment. GDPs projected on the basis of both scenarios are presented in Table 2.3.

The GRDP of the Municipality is estimated in proportion to the share of GRDP against GDP. The future share of GRDP against GDP will increase because the economic importance of the Municipality will grow for the year to come. The share of future population in the Municipality against national population will increase as well. The shares of GRDP against GDP in 1987 and 1988 was estimated to be 26% and 27% respectively on the basis of the actual data. The future shares are estimated by means of the curve fitting through smoothing and the shares are assumed to increase by constant proportion of 1% per annum. The GRDPs projected up to 2020 at 1986 constant price are shown as follow:

	1990	1995	2000	2010	2020
GDP (million kip)	77,300	100,500	133,900	249,400	497,000
GRDP (million kip)	22,500	34,200	52,200	122,200	293,200
Share (%)	29%	34%	39%	49%	59%
Per capita GRDP (US$)	500	640	810	1,380	2,530

The GRDP in the Study area is estimated applying the following assumptions.

(1) At present most of commercial and industrial productions are born in the Study area. The economic structure and the productivity of the remaining area in the Municipality is assumed to be similar to that of whole nation, characterized as a rural area. Accordingly the per capita GRDP in the remaining area is assumed to be equal to the per capita GDP.

(2) The estimated per capita GDP are applied to the population in the Municipality less the population in the Study area to obtain the GRDP in the area excluding the Study area. The substantial part of differences in two GRDPs are basically assumed to be born in the Study area.

(3) Further, in the future the production of commercial and industrial products in the remaining area is assumed to be increasing due to the expansion of urban area in the Municipality outside of the Study area. The productivity of the remaining area is assumed to increase due to the urbanization. The share of population in the remaining area against the population in the Municipality is assumed to be an index of the increase in the productivity in the remaining area.

The GRDPs in the Study area up to 2020 at 1986 constant price are thus estimated as below:

	1990	1995	2000	2010	2020
GRDP (million kip)	15,800	22,800	32,700	71,100	160,000
Share in GRDP (%) to Municipality	35%	32%	30%	27%	25%
Per capita GRDP (US$)	1,020	1,320	1,710	2,990	5,520

The contributions of industrial sectors for the projected GRDP in the Study area were estimated through applying the rates of land productivity and land use in the Study area.

The land productivity is estimated on the basis of labour productivity by industrial origin in Lao calculated by the World Bank and the density of labour

by industrial origin in the Study area. The proportions of land productivity by industrial sector are assumed as below;

Agriculture	1
Commerce	10
Industry	50

The GRDPs by industrial origin in the Study area at 1986 constant price are estimated as below;

(Unit Million Kip)

	1988		1990		2000		2010		2020	
	GRDP	Share	GRDP	Share	GRDP	Share	GRDP	Share	GRDP	Share
Agriculture	9,183	68%	10,300	66%	16,300	50%	24,300	34%	34,100	21%
Industry	2,800	21%	3,600	23%	11,400	35%	34,000	48%	95,100	60%
Commerce	1,480	11%	1,900	12%	5,000	15%	12,800	18%	30,800	19%
Total	13,463	100%	15,800	100%	32,700	100%	71,100	100%	160,000	100%

2.2 Topography

Vientiane plain extends from west to east along the Mekong. It is located on the left bank of the river about 1,500 km upstream from the estuary. It occupies a part of the alluvial plain of the Mekong. The width of the plain is about 40 to 50 km, bordered by the south-west slope of mountains belonging to the Indochina mountain range on the north and the Mekong on the south.

The northern end of the plain is slightly elevated probably by the alluvial fans formed by rivers from the mountains, although the fans are not distinctively developed. Meanwhile the southern end which forms the left bank of the Mekong has a little higher elevation as compared with the middle portion of the plain because of the natural levees evolved by the frequent floods of the river. The Nam Ngum which is one of the main tributaries of the Mekong run through the plain from west to east along the lowest part of the plain.

The most of the Study area is located on one of the natural levees and adjacent alluvium. Several isolated small hills, so called butte, are distributed

especially in the east of the Study area. The altitudes of the natural levee are around El. 170. The elevation of alluvium range from El. 163 to 168: The hills are El. 175 or more. The low lying lands form back swamps, like Nong Chanh Marsh and That Luang Marsh. The location of the Study area in the Vientiane plain is shown in Fig. 2.1.

The storm rainfall water in the Study area might have flowed down from the natural levee and have discharged either directly to the Mekong or have drained to the Makhiao through the Hong Xeng or That Luang after taking the course which dodges the buttes.

The right side Nam Pasak and the Khoua Khao rivers might have the outlets to the Mekong river. On the other hand, the Hong Thong, the left side Nam Pasak and the Hong Xeng rivers might have collected the water and have disposed it to the Makhiao river.

The topographic map as shown in Fig. 2.2 prepared in 1954 supports the assumptions mentioned above. In this map, the alignment of the Hong Ke is not shown. The topographic map prepared in 1984, however, enunciates the river as shown in Fig. 2.3. The Hong Ke river might have been emanated either to divert storm water to the Makhiao. It takes the course which deems to be reasonable from topographic point of view. The actual flow directions of water were recorded in the drainage canal in the Study area. The results of the observation were depicted as shown in Fig. 2.4. The figure shows the current in line with the topographic condition.

At present the alignments of all the rivers except the Nam Pasak right branch Ke seem to be stable. No serious river morphologic difficulty may occur if the existing rivers as discussed above are adopted as the main canal or canals for the proposed drainage plan.

Meanwhile the closure of the outlets from the Khoua Khao to the Mekong seems to be abrupt manipulation to the flood flow. The opening thereof should be maintained and, therefore, be considered in the alternative plans for further study.

2.3 Meteoro-Hydrology

2.3.1 General Meteorology and Hydrology

The climate of Vientiane is classified as tropical, with distinctive effects of monsoons. The south-western monsoon picks up moisture from the Indian Ocean and causes rainfall in the areas along the lower reaches of the Mekong, starting in mid-May until around mid-October. This period is known commonly as the rainy season. Heavy monsoonal storms occur in this rainy season.

After the rainy season, the north-eastern monsoon will carry over cool air of the Polar Pacific Airmass from Siberia and the mainland of China until mid-February. This period is called the cool season, with generally cool and dry weather in Vientiane. Following this is the hot season characterized by hot and dry weather, which lasts until the next south-western monsoon sets in.

Another factor that influences the storm rainfall is the passing of typhoons. Usually, a typhoon or a tropical depression that originates in the Pacific Ocean or the South China Sea subsides before reaching Lao P.D.R., but very rarely, passes near the Study area. In such an event, with the additional effects of activated fronts, heavy storm rainfall may occur. Most typhoons occur in the south-west monsoon period, when the Study area is generally covered by humid airmass.

Temperatures in Vientiane ranges from a low of about 16 to 18°C during the coolest months of December and January to a high of 31 to 32°C during the hottest months of March through May. The relative humidity is in general 75 to 80 per cent during the rainy season and 65 to 70 in other periods. The average annual rainfall is around 1,600 mm in Vientiane, of which about 86 per cent occurs during the period of May through September.

Storms in Vientiane can be classified by the causes into (1) monsoonal and (2) depressional. Rainfall due to monsoonal storms lasts usually for around 3 hours with high intensity, but tends to subside soon after the peak.

The annual maximum one-day rainfall is generally in the range of 70 to 140 mm. For 79 years of observation records at Vientiane, the recorded maximum one-day rainfall of 224.2 mm was observed in August 26, 1976. This

storm lasted for 14 hours, which is an exceptionally long duration in Vientiane. Another recent heavy storm rainfall occurred in July 20, 1981, with the daily rainfall of 181 mm. This is of the third order in the 79 years of observation. Heavy rainfall intensity lasted for about 3 hours.

The main rivers relevant to the Study area are the Mekong, Nam Ngum and Houei Makhiao. The Mekong, which bounds the Study area on the south and west, is the principal water source of municipal supply and irrigation. The Nam Ngum is a tributary of the Mekong which drains most of the northern Part of the Vientiane Plain. The Houei Makhiao, a minor tributary of the Mekong, drains areas in-between the Mekong and lower reaches of the Nam Ngum. The Study area is located at the western end of the Houei Makhiao basin as shown in Fig. 2.1.

The Mekong rises at the rim of the Great Tibetan plateau. It enters its lower basin at the common Burma - Laos - Thailand boundary point and flows for some 2,380 km to the ocean. Almost the whole of Lao P.D.R. is located on the left bank of the Mekong, and drains into the Mekong. At the Vientiane gauging station at Wat Sop, about 4 km downstream of Vientiane, the Mekong river has the drainage area of 299,000 km^2. The average discharge at Vientiane station for the period of 1913 through 1986 is 4,594 m^3/sec, which corresponds to the annual run-off depth of 484 mm.

On the regional scale, the Study area is located in the middle of the southern rim of the Vientiane plain, which is chiefly drained by the lower reaches of the Nam Ngum and Houei Makhiao. The Vientiane plain extends in the elevations ranging from 160 to 180 m with mild undulations gently sloped toward the south and southeast. The soil in the Vientiane plain can be classified into the two groups; brown lateritic old alluvial soil group, which is accumulated on residuals of the sand stone and silt stone; and grey brown hydromorphic alluvial soil, recently transported by the Nam Ngum and Mekong.

The Houei Makhiao drains to the Mekong near Ban Makhiao village. The confluence of the Makhiao with the Mekong is located about 64 km downstream of Vientiane along the Mekong, or about 1,524 km from the river mouth. The main water courses in the Study area such as the Nam Pasak, Hong Ke and Hong

Xeng are all tributaries of the Houei Makhiao. The Houei Makhiao has the drainage area of 441 km^2 at the outlet to the Mekong.

2.3.2 Past Floods of the Mekong

The recorded maximum flood during the 73 years of observation was recorded in 1966. At the Vientiane station, the water surface exceeded the flood level (gauge height of 11.5 m) for 19 consecutive days from August 28 to September 15. The highest daily gauge height of 12.70 (El. 170.74 m) was obtained on September 4, 1966, with the estimated daily average flood discharge of 25,900 m^3/sec, after being adjusted for the overbank flow. The estimated peak discharge was 26,000 m^3/sec. The recurrence interval of this flood is estimated to be around 50 years.

An extensive flood damage occurred along the Mekong river. The river dikes were topped at several locations including one upstream of the Wat Tay airport, and flooded most of the area below 170 m in elevation in Vientiane.

Another large flood was experienced in 1971. The Vientiane station's gauge reading exceeded the flood level for 23 days from August 17 through September 8. The daily peak discharge occurred on August 22, with the gauge height of 12.51 m (El. 170.55 m). This flood was not confined by the dikes, either, and caused extensive submergence throughout the Study area. This flood is the fourth largest flood in terms of the peak discharge in the 73 years of observation. The recurrence interval of this flood is estimated to be around 20 years.

The present flood dyke, constructed by the Mekong Committee under phase I of the Flood Protection and Reclamation of Swamp and Marshland in the Vientiane Plain, will result in a top elevation of 170.8 m MSL at Chinaimo. This top level of the dykes is slightly above the 10-year flood level (fully-dyked). The Mekong Committee is proposing Phase II of the same project, which will protect the whole areas of Vientiane and Nong Khai against the 25-year flood.

2.3.3 Hydrology of Study Area

The Study area is drained by the Nam Pasak, Hong Xeng and Hong Ke through the Houei Makhiao to the Mekong. The Nam Pasak river used to flush to the Mekong near the Vientiane city, but the outlet is clogged now. Most of the upstream (presently the left branch) Nam Pasak basin forms a flat area with an extensive swamp/marsh topography. There is an area of 575 ha in this basin below the elevation 167.0 m which is mostly either swamp or paddy fields. This area thus has a distinctive natural retardation effect. The former downstream reach (presently the right branch) of the Nam Pasak river close to the central city is now redirected to the Hong Xeng. This reach is about 15 to 30 m wide bank-to-bank, with several ox-bows near the former outlet to the Mekong.

The western part of the Study area is drained to the Nam Pasak left bank through irrigation/drainage canals. The Nong Douang Marsh is a natural pond that stretches a water surface area of 11.0 ha at El. 168 m. Despite its potential capacity as a retardation basin, the Nong Douang Marsh is not fully utilized for this purpose due mainly to insufficient inlet/outlet capacities.

The Hong Xeng starts at the confluence with the upstream Nam Pasak and flows eastward. The channel is about 10 to 30 meters wide and is fairly straight. The Hong Xeng joins an irrigation canal that drains the That Luang Marsh and connects to the Houei Makhiao.

The Hong Ke river conveys the outflow of the Nong Chanh Marsh to the That Luang Marsh for about 2.7 km. The Nong Chanh Marsh has water surface of 12.3 ha at El. 167.0 m, and 23.4 ha at El. 168.0 m. The Nong Chanh Marsh receives the discharge of the Hong Thong and Khoua Khao. The Hong Thong, about 10 to 30 m wide, drains most of the central city areas and Khao Luang area. The Khoua Khao usually outflows to the Mekong by gravity. When the water level of the Mekong rises to the level of the sill of the stop-log (about 166.0 m) at the outlet, it is closed to disconnect the Mekong. In this condition, the Khoua Khao flows backward to the Nong Chanh Marsh.

In order to supplement the existing meteoro-hydrologic data, the Study team installed the following recording devices.

Automatic rainfall gauge	:	1 no.
Automatic water level recorders	:	2 nos.
Staff gauges	:	12 nos.

The data taken by these equipment were utilized for hydrological analysis.

2.3.4 Water Levels of Main Channels

For the purpose of clarifying the water surface profiles in the main channels, water levels at the 12 staff gauges were observed several times during the study period. The water levels of the Hong Thong are the highest among the observed water courses, which are in the range of El. 167.5 to 167.9 m. The water levels of the upstream and downstream of the Nong Chanh Marsh are both in the range of El. 166.9 to 167.4 m. The water levels of the Nam Pasak at the confluence with the Hong Thong are in the range of El. 166.7 to 166.8 el.m, which are about 0.8 to 1.1 m lower than those of the Hong Thong. Near the boundary of the Study area, the water levels of the Hong Ke are normally slightly higher than the water levels of the Hong Xeng. The water levels of the That Luang drainage canal are in the range of El. 164.4 to 165.2 m. The water level of the Bueng Khat Khao at a bridge near Ban Xok Noy are in the range of El. 163.4 to 164.1 m, or about 1.1 m below the level of That Luang drainage canal.

The daily water level records of the Hong Xeng river at Ban Phon Khen (near the bridge of the route 13) exist for the years 1961, 1980, 1981 and 1982. The following table shows the monthly maximum water levels of the observed daily data.

Unit: El.m

	May	June	July	Aug.	Sep.	Oct.	Nov.
1961	-	165.7	165.7	166.4	166.6	166.6	164.8
1980	-	-	-	166.5	166.6	166.2	-
1981	-	-	166.7	166.6	166.5	166.2	-
1982	166.2	166.2	-	-	-	-	-

It should be noted that the water levels of the Hong Xeng at Ban Phone Khen are affected by the operation of the gates for irrigation water supply downstream of the bridge of Route 13.

2.3.5 One-Day Storm Intensity

Daily rainfall records at the Vientiane station are said to exist since 1900 and onwards, but older records are hard to locate today. On the basis of four different sources, the annual maximum daily rainfall at Vientiane are collected for 1900 through 1987, with 1911, 1912 and 1942 through 1948 interrupted, as shown in Table 2.4. For the period of 79 years, the recorded maximum daily rainfall occurred in August 26, 1976 with the daily rainfall of 224.2 mm. Fig.2.5 shows the frequency curve for the one-day storm rainfall.

On the basis of these data, a frequency analysis was conducted for estimating the probable rainfalls. The results of the estimation are as follows;

2-year	:	104.0 mm/day
5-year	:	132.1 m m/day
10-year	:	150.6 mm/day
20-year	:	168.4 mm/day
100-year	:	208.7 mm/day

2.3.6 Storm Rainfall Intensities for Short Durations

The Vientiane Meteorologic stations is equipped with an automatic rainfall gauge, and has some accumulation of rainfall intensity data for the durations of 15, 30, 60, 120 and 180 minutes, although the measurement is limited to rainy season. A frequency analysis was conducted for storm rainfalls based on the available data. The results of the analysis is summarized below:

Probable Rainfall for Short Duration

Unit: mm

Duration in minutes	Return Period in Years				
	2	5	10	20	50
15	19.2	25.8	30.1	34.3	39.7
30	30.8	43.9	52.5	60.8	71.6
60	44.9	70.4	87.2	103.4	124.4
120	58.5	88.6	108.6	127.7	152.5
180	65.9	95.9	115.8	134.9	159.5

2.3.7 Probable Water Level of the Mekong

The flood analysis of the Mekong in this study is based on the discharge data as published by U.S.B.R. for the period before 1966, and the Mekong Committee for the period thereafter, with some in-house data of the Department of Meteorology and Hydrology as supplements. Table 2.5 summarizes the annual maxima of daily discharges of the Mekong at Vientiane for 1913 through 1986.

A frequency analysis was conducted for the annual maximum daily discharge of the Mekong at Vientiane. The following table summarizes the results of the analysis.

Probable Discharge of the Mekong

(Unit: m^3/sec)

Method	Return period in years						
	1.01	2	5	10	20	50	100
Gumbel	11,860	16,725	19,632	21,558	23,404	25,795	27,586
Peason III	11,265	16,880	19,653	21,306	22,790	24,602	25,900

Based on the rating curves of the Mekong as given by the Mekong Committee, the probable water levels of the Mekong at Vientiane (Watsop) were estimated as follows:

Probable Water Level of the Mekong

(Unit: El. m)

Method	Return period in years						
	1.01	2	5	10	20	50	100
Gumbel	166.9	169.0	170.0	170.7	171.3	172.1	172.6
Pearson III	166.6	169.0	170.0	170.6	171.1	171.7	172.1

Concerning the recent large floods of the Mekong in 1966 and 1972, the return periods were estimated below:

Return Periods of Recent Floods

Flood	Peak discharge (m^3/sec)	Return Period (years)
1966	26,000	50
1972	23,000	20

Note: Based on Gumbel's distribution.

2.3.8 Water level of Downstream Ends of Main Canals

For the Hong Ke system, the boundary condition of the flow in the main canals will be given by the water level of the That Luang marsh. Unfortunately, there are no reliable records of the water levels in the That Luang Marsh. Local residents familiar with the water level conditions at the location were asked to point the highest water level in the last five years on one of the existing structures on site. Based on the water level reading of the staff gauge at the time of the survey, the pointed level was converted to the elevation by adding the difference between the pointed level and the water surface.

For the System for Sub-area L (Nam Pasak), the flow condition of the Nam Pasak will be affected by the backwater of the Hong Xeng.

The water levels of That Luang range from 165.0 to 165.4 m. With the possible error in such hearing survey taken into consideration, the HWL at Point 11 was assumed on the safe side as 165.5 m. The water levels of the Hong Xeng at Dongdeng obtained in the hearing survey range between 167.3 and 167.5 m. The HWL at Dongdeng was thus determined as 167.5 m. Table 2.6 summarizes the water levels at downstream ends of the main canals.

2.4 Land Use and Urban Planning

The urban area of Vientiane Municipality occupies 29 km^2 or 0.9 percent of the municipality area. This urban area has developed as the core of Vientiane Municipality in the rather elevated areas extending along the Mekong and the "butte" scattered in the north-east.

The structure of the town is formed by the existing urbanized area as the core thereof and three highways which link the town with Luang Prabang, Savannakhet and Phonngan Thadua. The Study area covers this urbanized area and its environs.

Present land use of the Study area of 5,619 ha is summarized as follows;

Residential area	2,164.4 ha	38.5%
Public commercial area	400.6 ha	7.1%
Industrial area	38.2 ha	0.7%
Water area	167.7 ha	3.0%
Green area	2,499.3 ha	44.5%
Others	349.4 ha	6.2%

Residential area and green area occupy 83% of the total. Most of the green area are cultivated lands.

Since the present population density is not high, services such as commerce and business will be more concentrated in the part of the city in the future. Meanwhile residential and industrial area may extend in the outer

zones of the city. The historical and possible future expansions of urban area are illustrated in Figs. 2.6 and 2.7 respectively. Present land uses in the Study area by sub area are summarized in Table 2.8.

The urban planning of Vientiane was once formulated in 1961. The envisaged population was 120,000 person in this plan. Thereafter several plans were studied and the most updated plan was formulated in 1989.

For this planning, the present and future populations and land uses were studied. The topographic condition and transportation were comprehensively studied as well. On the basis of these study, an effective zoning by land use categories was conducted.

The plan divided the area into urbanized blocks and reserved blocks. The plan specified and programmed the land use and the method of the development in the urbanized block. Table 2.7 and Fig. 2.8 present the land use envisaged by the plan as follows:

Residential	2,653.3 ha
Public and business	575.1 ha
Industrial	107.4 ha
Water	116.5 ha
Green	1,772.2 ha
Others	389.1 ha
Total	5,618.6 ha

The plan will present an appropriate land use in the Study area up to the year 2000.

The further future land use in the Study area may conform to the plan for the year 2000. The projected population therein is 305 x 10^3 in 2020. The projected increase is about 104 x 10^3 from 2000 of 201 x 10^3. This increase is considered to be accommodated within the Study area without causing any significant change in land use pattern for the year 2000 because of the following reason;

- The average population density of 5,427 person/km^2 is not so high as compared with principal towns in other country.

- The population of 305 x 10^6 in 2020 is lower than the envisaged limit of 350 x 10^6 by the Municipality.

- The urbanized area may improve its various functions and may increase its capacity to accommodate larger population.

- The land use in the proposed urban areas have sufficient allowances for intensification and concentration.

Along this line, it is assumed that the land use in the Study area will not be changed from that in 2000. The urbanized area will increase 9 km^2 from the existing 29 km^2 by 2000. The remaining area about 18 km^2 is the water areas and the reserved for agricultural land. After the year 2000, the urbanized area will maintain 38 km^2. The urban population density become 7,400 person/km^2 in the year 2020. Table 2.8 shows the projected areas by land use. Fig. 2.8, which was once referred to, shows the proposed land use pattern.

2.5 Soil Mechanical Study

2.5.1 Surveys and Tests

The Study conducted soil surveys through core drillings, auger borings, STP's test pittings and samplings at the strategic sites. Samples thus obtained are tested in the laboratory and the fields. The results of surveys and tests indicate as follows;

(1) Soil in the Study area has N-values shown below.

Layer of surface -8 m	:	More or less 10
Layer of 10 m deep	:	More than 50