JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

MINISTRY OF INDUSTRY AND HANDICRAFT
LAO PEOPLE'S DEMOCRATIC REPUBLIC

MASTER PLAN STUDY ON HYDROELECTRIC POWER DEVELOPMENT IN THE SE KONG BASIN IN THE LAO PEOPLE'S DEMOCRATIC REPUBLIC

FINAL REPORT

MARCH, 1995

ELECTRIC POWER DEVELOPMENT CO., LTD., TOKYO
NEWJEC INC., OSAKA
PASCO INTERNATIONAL INC., TOKYO

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PREFACE

In response to a request from the Government of Lao People's Democratic Republic (Lao P.D.R.), the Government of Japan decided to conduct a master plan study on hydroelectric power development in the Se Kong Basin, one of the major tributary of the Mekong river, and entrusted the study to the Japan International Cooperation Agency (JICA).

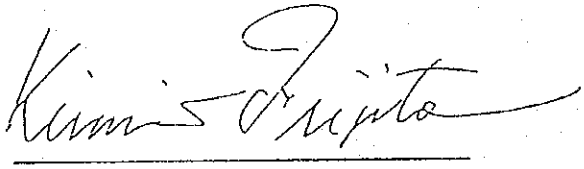
JICA sent to Lao P.D.R. a study team headed by Mr.Tokuji TEZUKA of Electric Power Development Company Ltd. six times during the period from June 1993 to March 1995.

The team held discussions on the project with officials concerned of the Government of Lao P.D.R. 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 projects and the enhancement of friendly relation between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of Lao P.D.R. for their close cooperation extended to the team.

March 1995



Kimio FUJITA
President
Japan International Cooperation Agency

March 1995

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

Dear Mr. FUJITA,

Letter of Transmittal

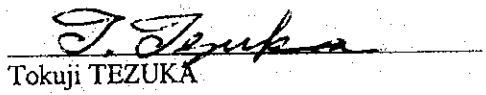
We are pleased to submit to you a master plan study report on hydroelectric power development in the Se Kong Basin, Lao People's Democratic Republic. The report contains the conclusion and recommendation of the authorities concerned of the Government of Japan and your Agency as well as the formation of the above mentioned project. Also included are comments made by the Ministry of Industry and Handicraft of Lao P.D.R. during technical discussions on the draft final report which were held in Vientiane.

This report presents a hydropower potential study in the Se Kong Basin and a pre-feasibility study for the selected three priority projects out of the development plan inventory of the basin. Resulting the pre-feasibility study, the three projects are promising projects to be developed mainly for power export purpose from Lao P.D.R. to the neighboring countries from technical, economical and financial point of view.

In view of the urgency of power development in Lao P.D.R., we recommended that the Government of Lao. P.D.R. be carried out feasibility study for the projects as a top priority.

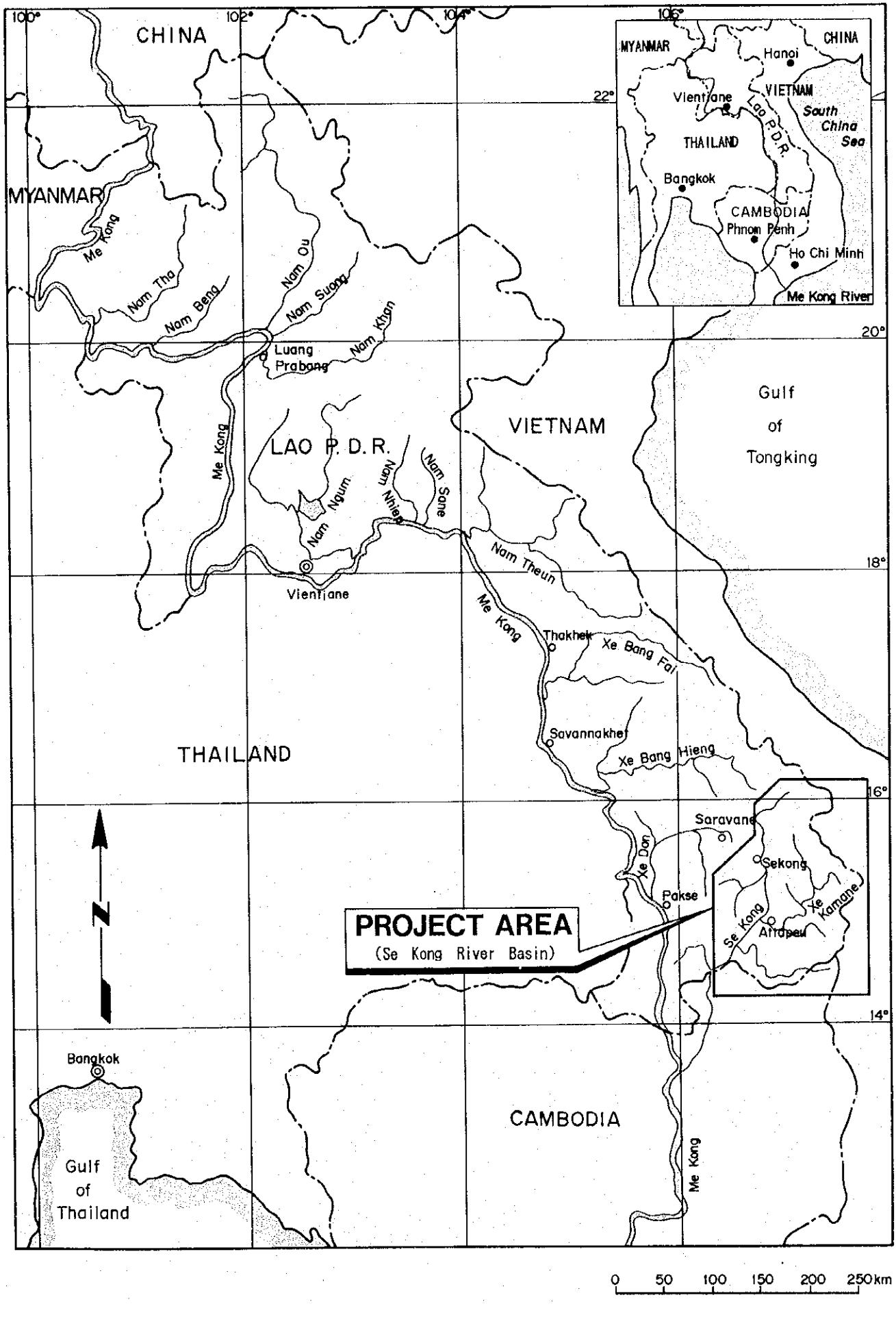
We wish to take this opportunity to express our sincere gratitude to your Agency, the Ministry of Foreign Affairs and the Ministry of International Trade and Industry. We also wish to express our deep gratitude to the Ministry of Industry and Handicraft and other authorities concerned of the Government of Lao P.D.R. for the close cooperation and assistance extended to us during our investigations and study.

Very truly yours,

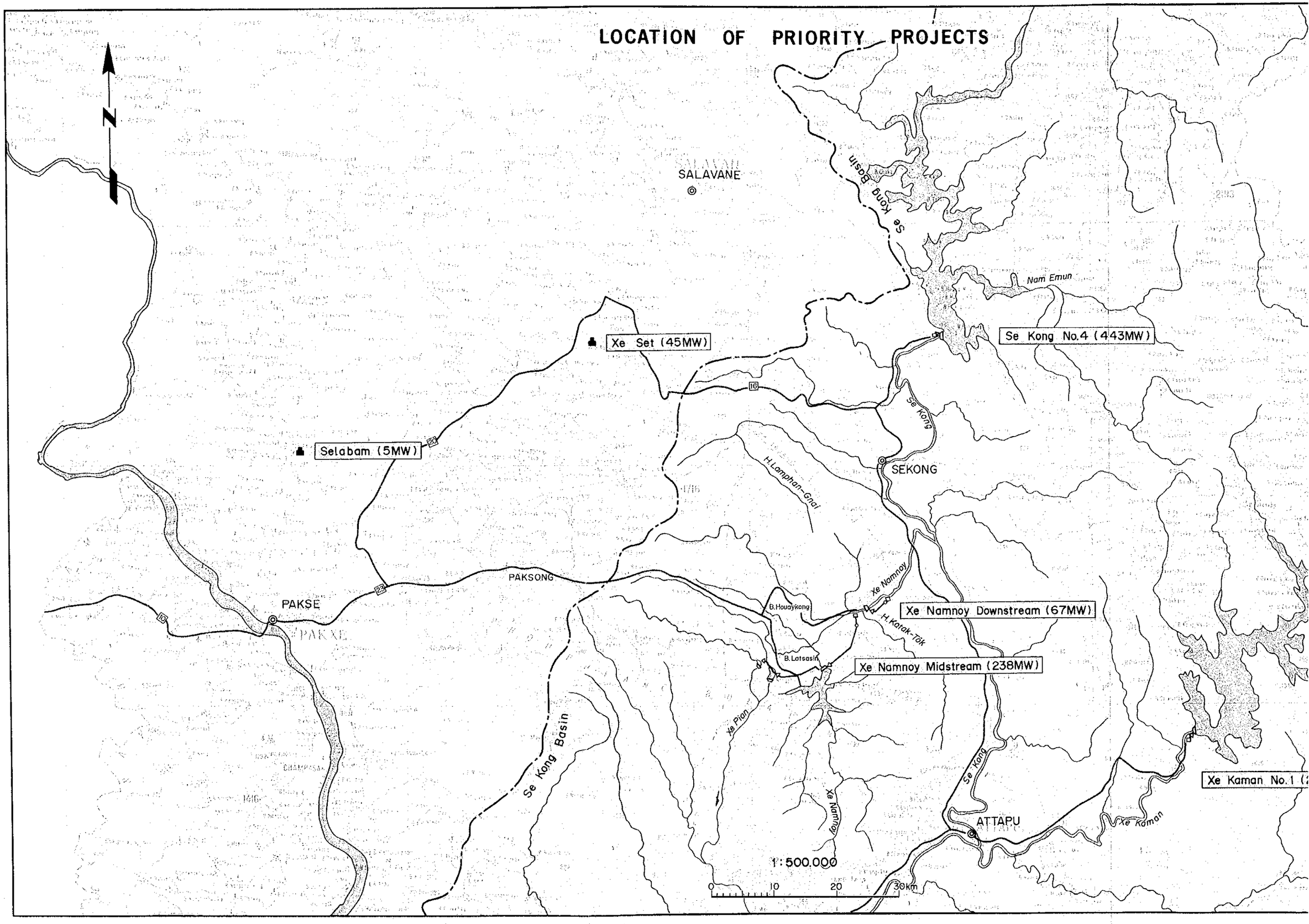


Tokuji TEZUKA
Team Leader
Master Plan Study on Hydroelectric Power
Development in the Se Kong Basin

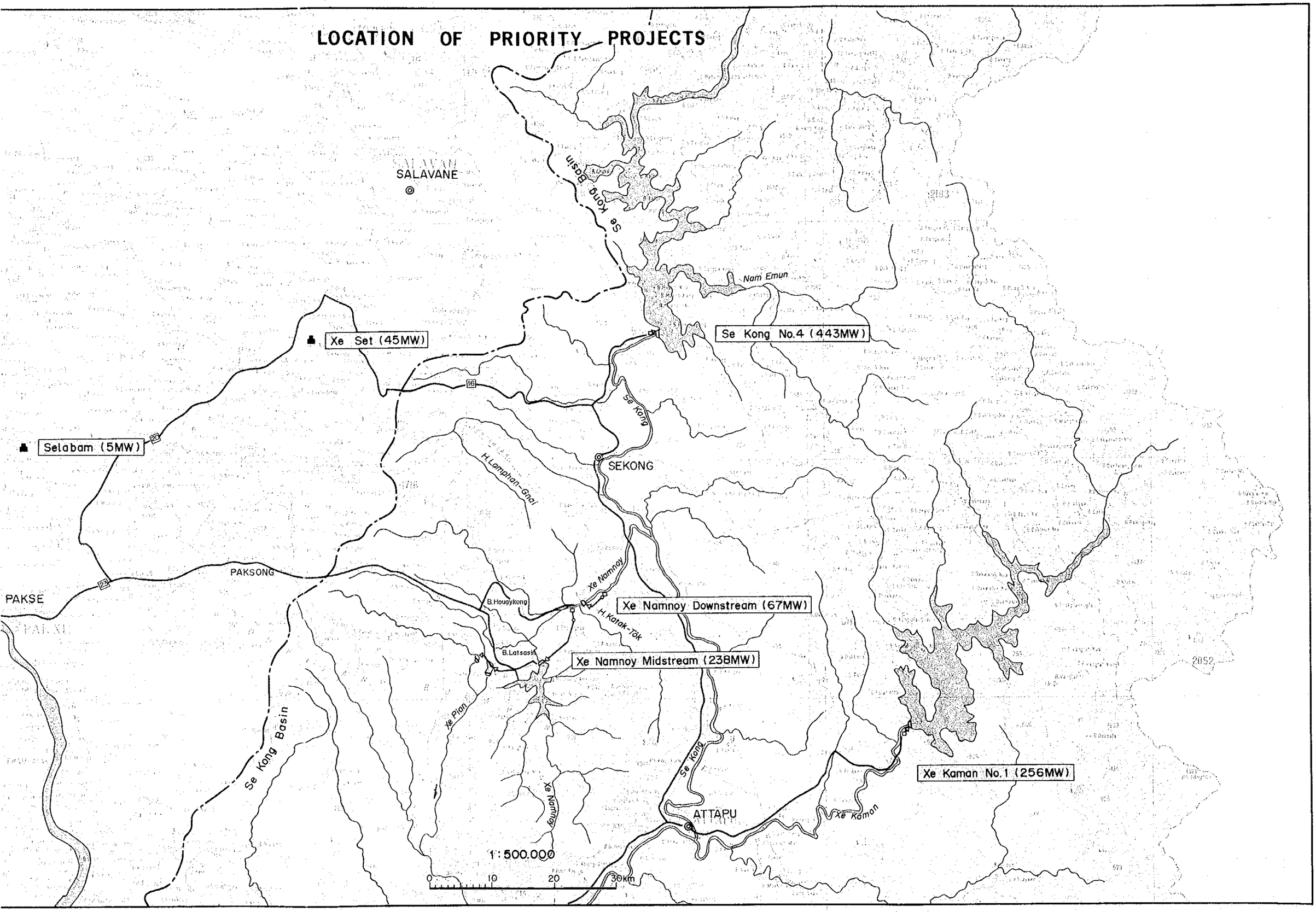
LOCATION OF PROJECT AREA



LOCATION OF PRIORITY PROJECTS



LOCATION OF PRIORITY PROJECTS



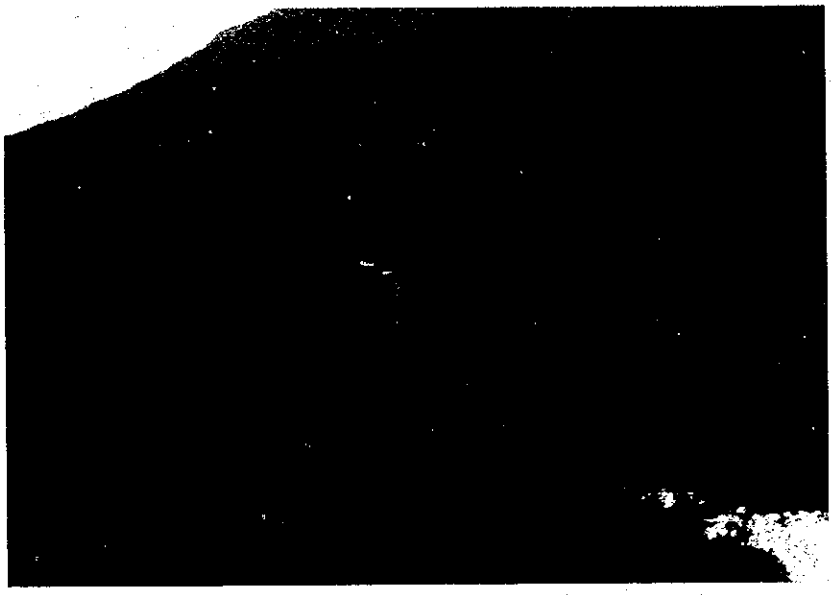
(1) Se Kong No. 3 Site
(View from upstream)

(2) Se Kong No. 4 Site
(View from downstream)

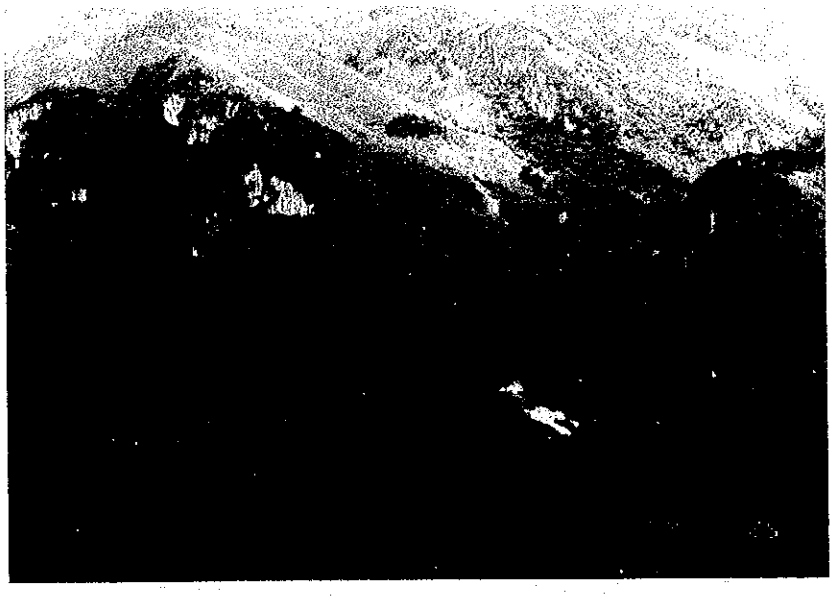
(3) Se Kong No. 5 Site
(View from downstream)

Photo A-1 Se Kong River Main Stream

(1) Downstream of
Xe Kaman No. 1 Site
(View from upstream)

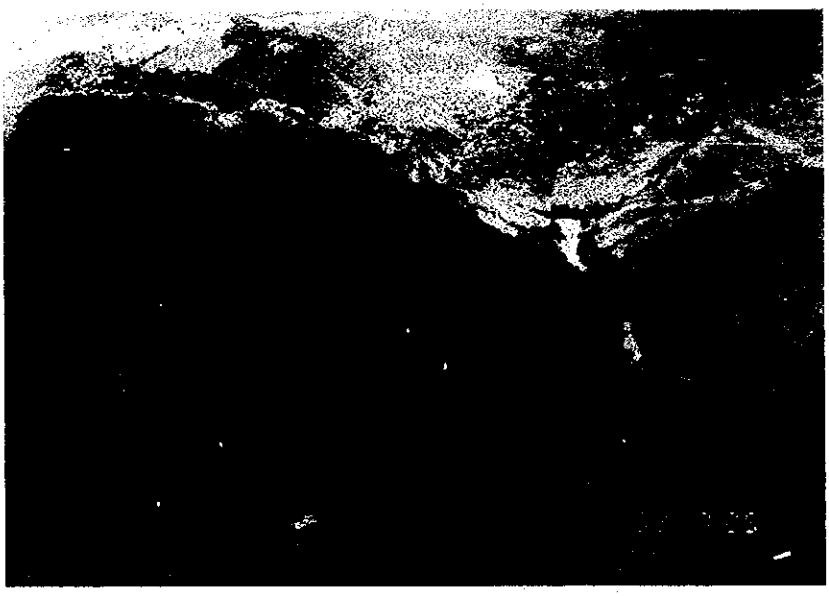


(2) Xe Kaman No. 1 Site
Mid-stream Site
(View from upstream)



(3) Xe Kaman No. 2 Site
(View from downstream)

Photo A-2 Xe Kaman River (1)



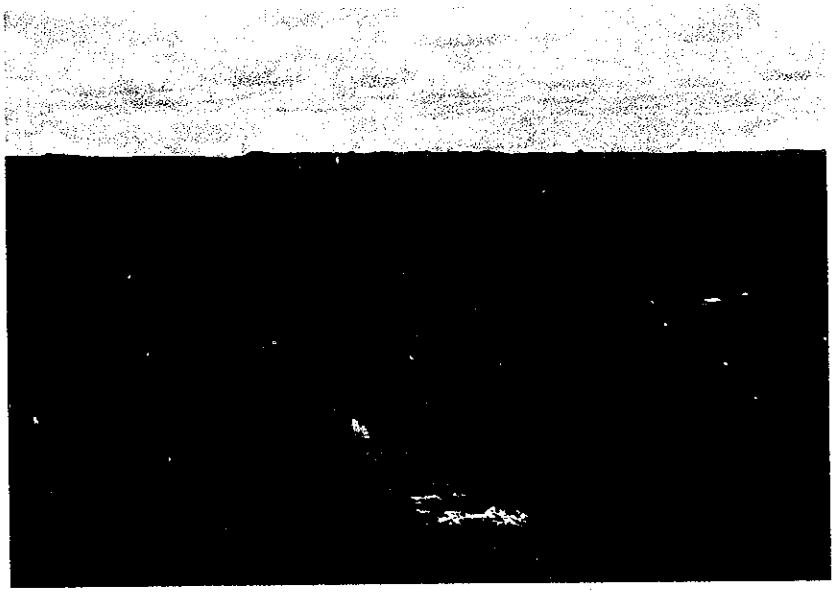
(1) Xe Kaman No. 3 Site
(View from downstream)

(2) Xe Kaman No. 4 Site
(View from downstream)

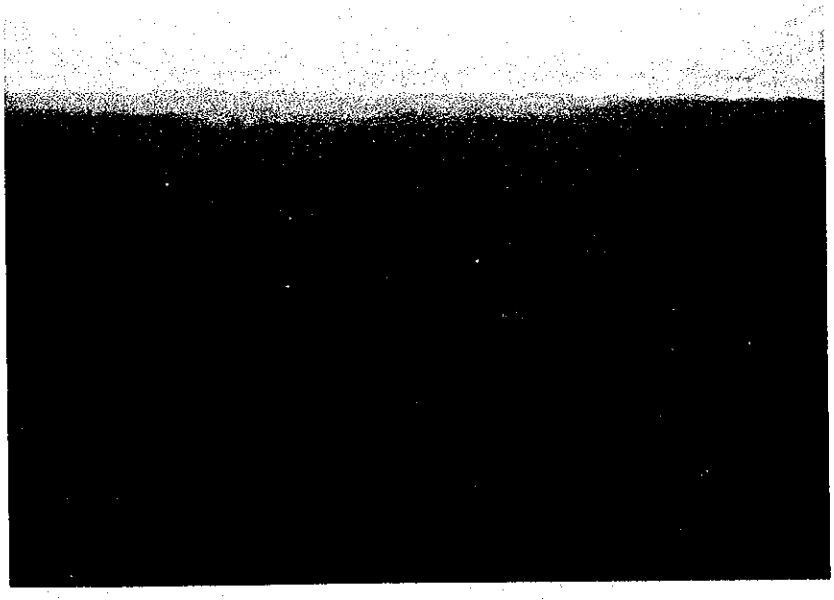
(3) Xe Kaman No. 4 Site
(View from downstream)

Photo A-3 Xe Kaman River (2)

(1) Xe Namnoy Midstream Site
(View from downstream)



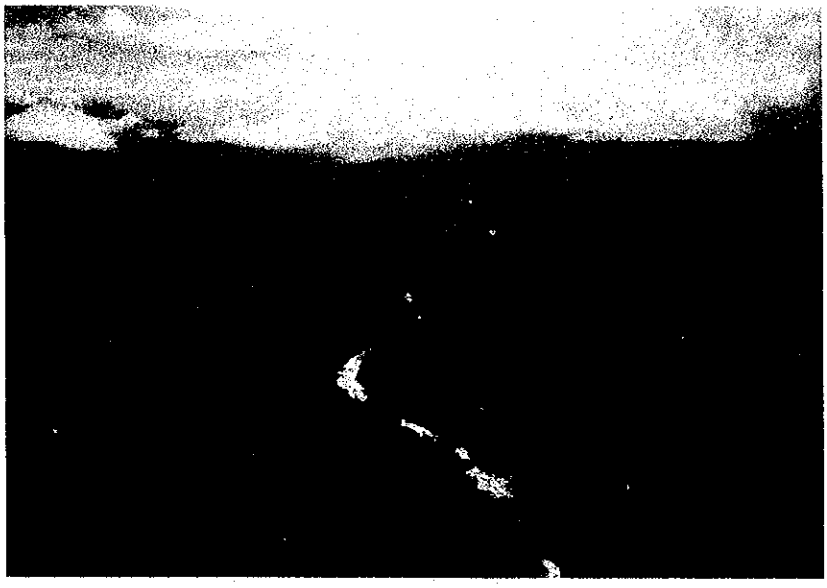
(2) Xe Namnoy Midstream Site
(View from downstream)



(3) Xe Namnoy Midstream Site
(View of reservoir area)

Photo A-4 Xe Namnoy River (1)

(1) Xe Namnoy Downstream Area
(View from upstream)



(2) Xe Namnoy Downstream Site
(View from upstream)

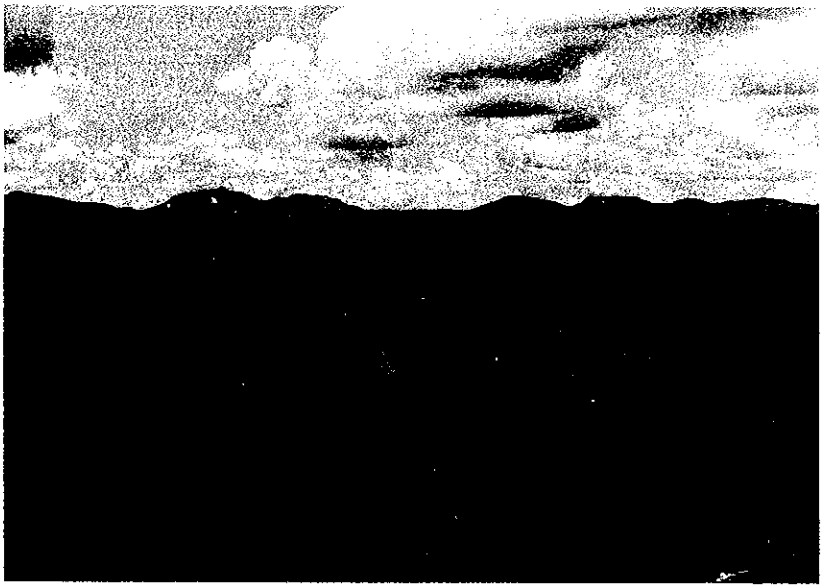
Photo A-5 Xe Namnoy River (2)

(1) Downstream of
Xe Pian Site
(View from downstream)

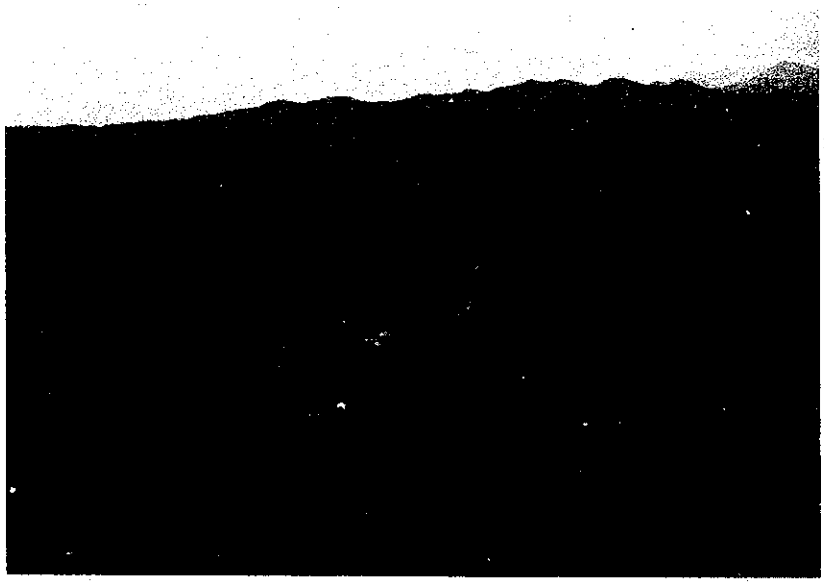
(2) H. Katak Tok Site
(View from downstream)

(3) H. Katak Tok Site
(View from downstream)

Photo A-6 Xe Pian, H. Katak Tok Rivers

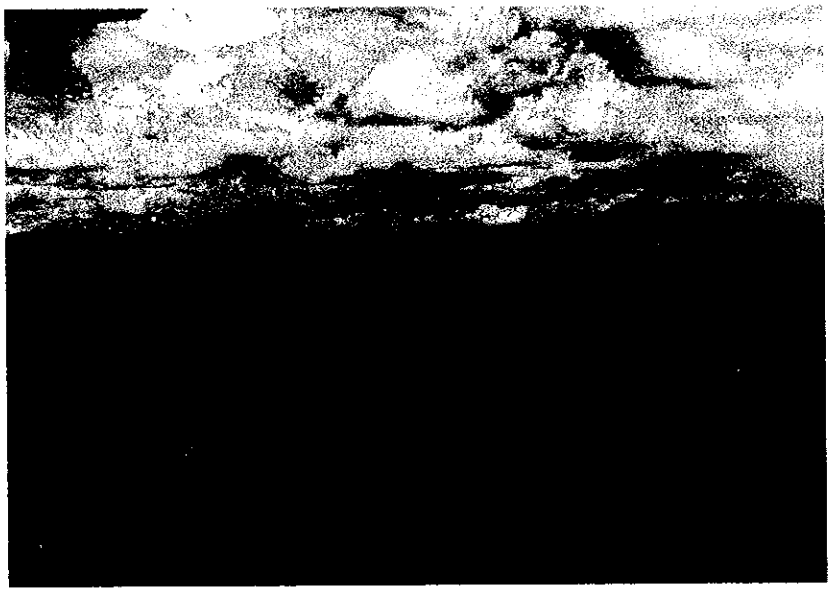


(1) Nam Kong No. 1 Site
(View from downstream)

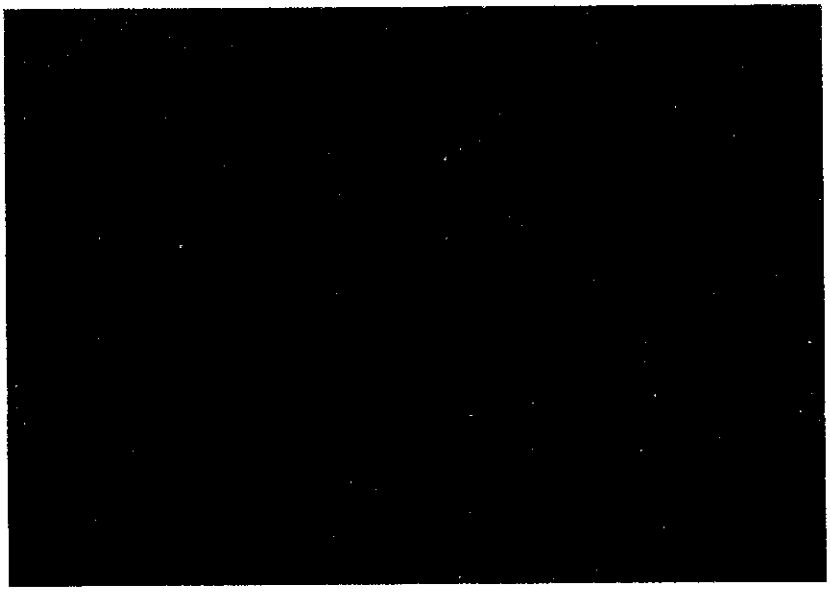


(2) Xe Xou Reservoir Area
(View from downstream)

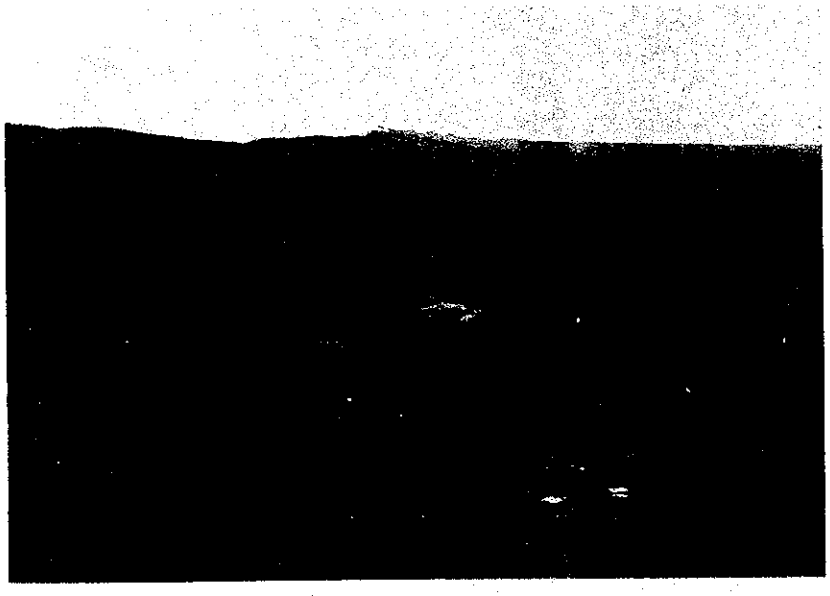
Photo A-7 Nam Kong, Xe Xou Rivers



(1) Dak E Meule Site
(View from downstream)

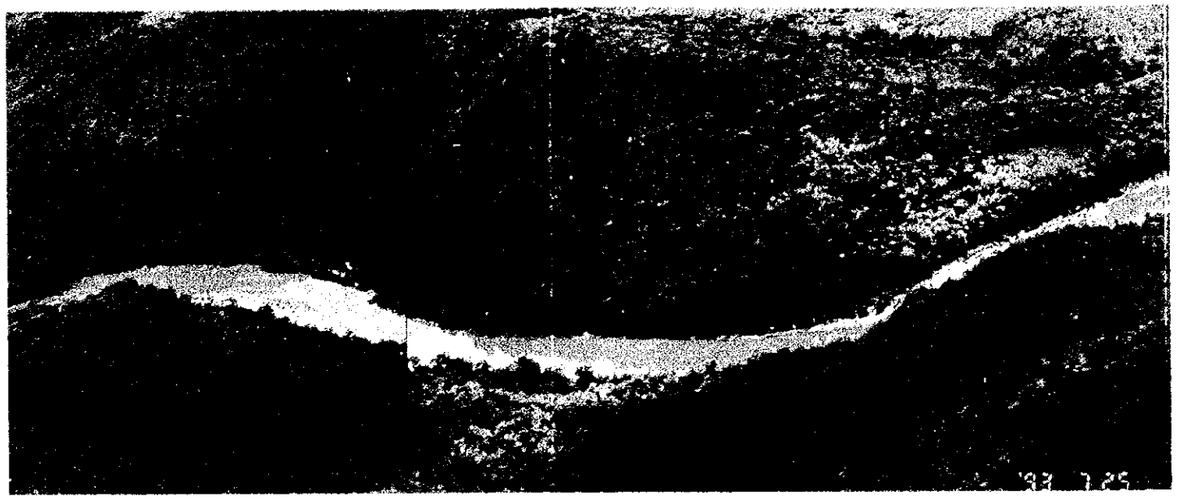


(2) Dak E Meule Site
(View from downstream)



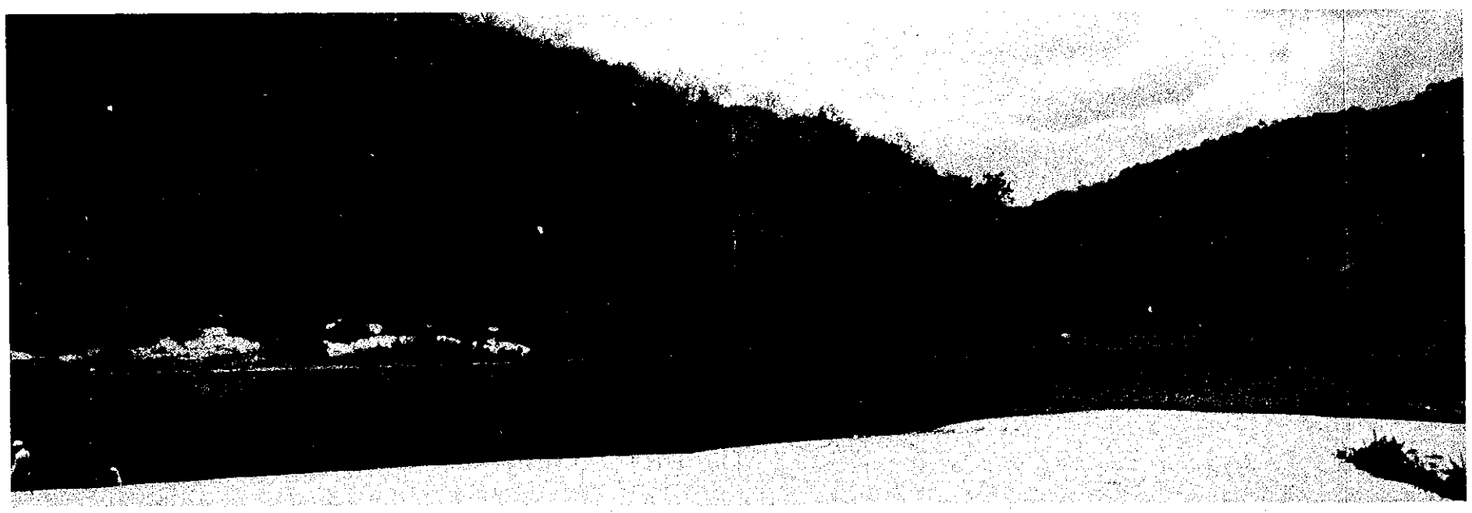
(3) H. Lamphan Gnai Site
(View from downstream)

Photo A-8 Dak E Meule, H. Lamphan Gnai Rivers



(1) View from Right Bank

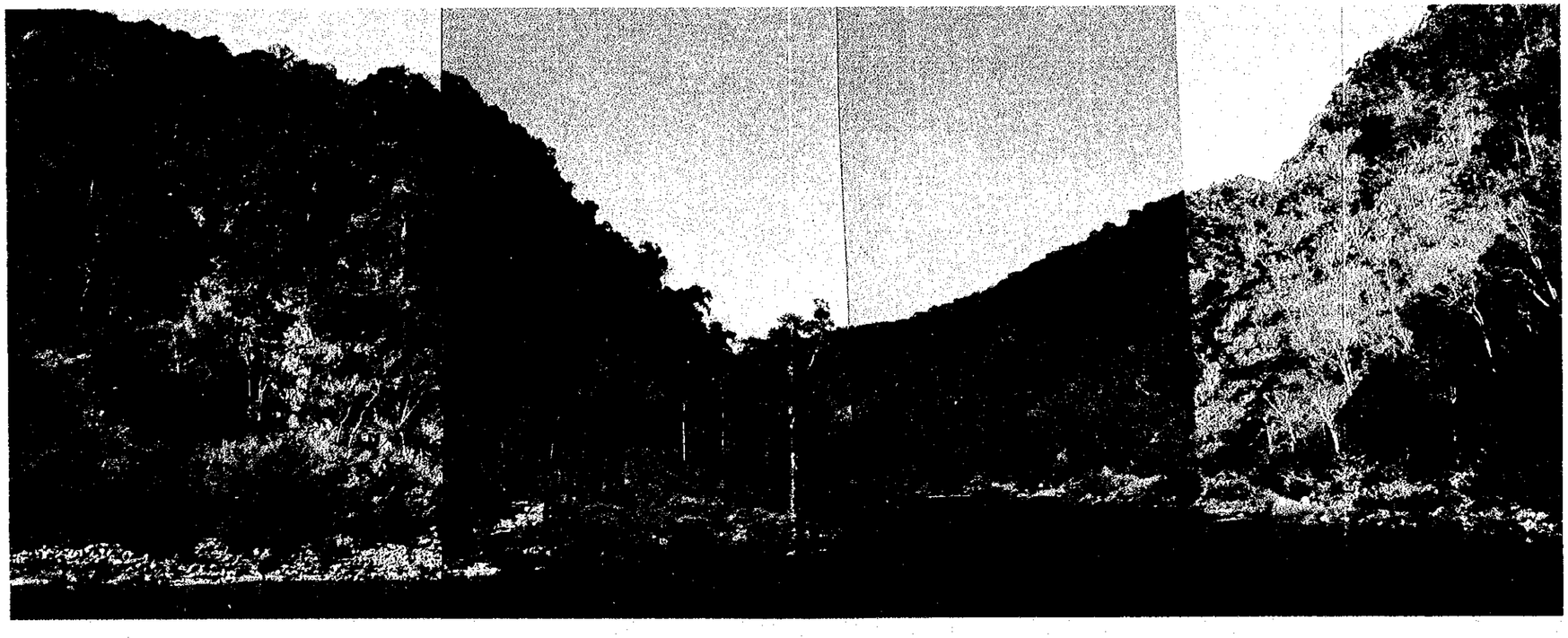
(2) View from Upstream



(3) View from Downstream

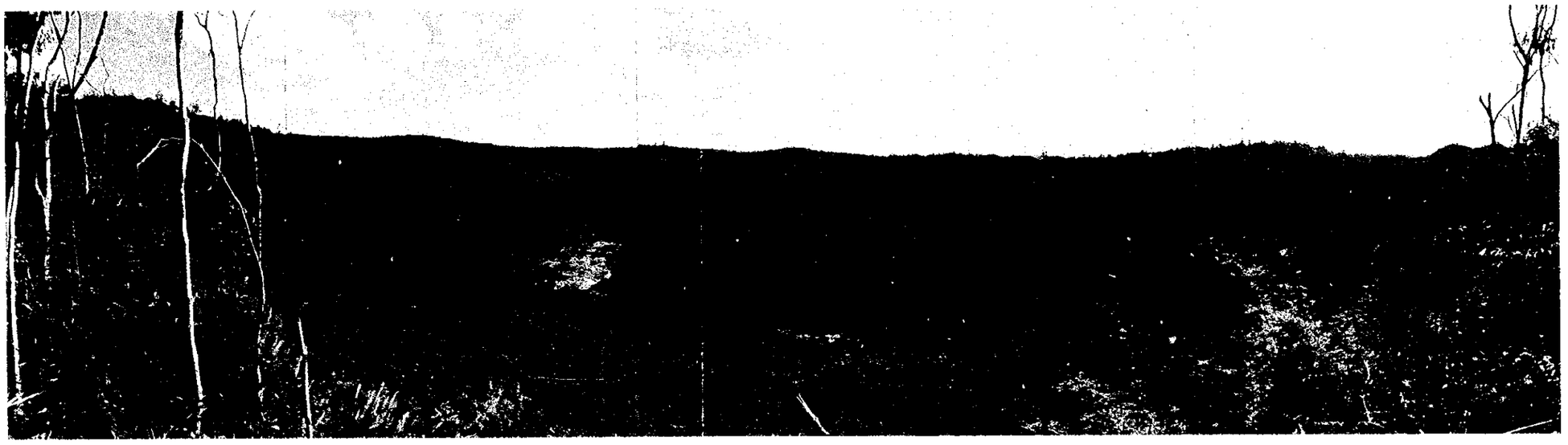
Photo B-1 Se Kong No.4 Dam Site

(1) View from Downstream



(2) View from Upstream

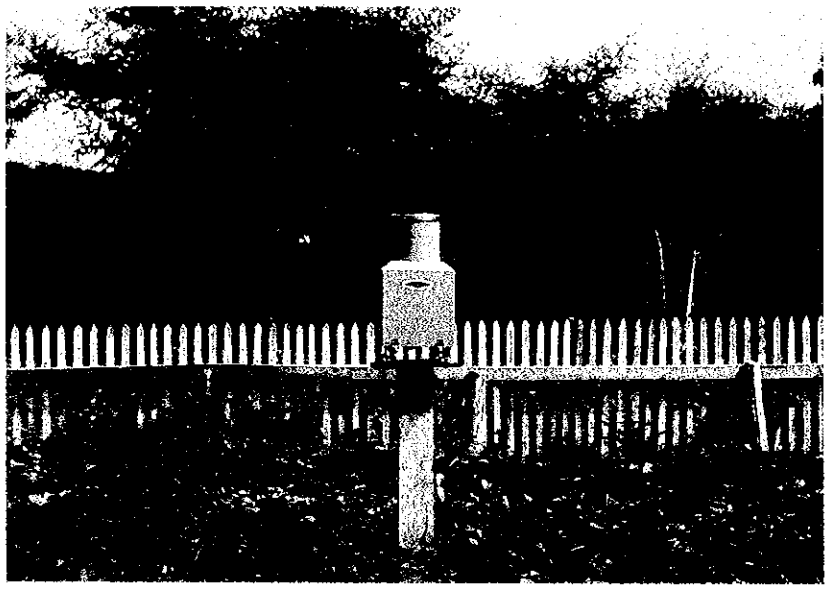
Photo B-2 Xe Kaman No.1 Dam Site



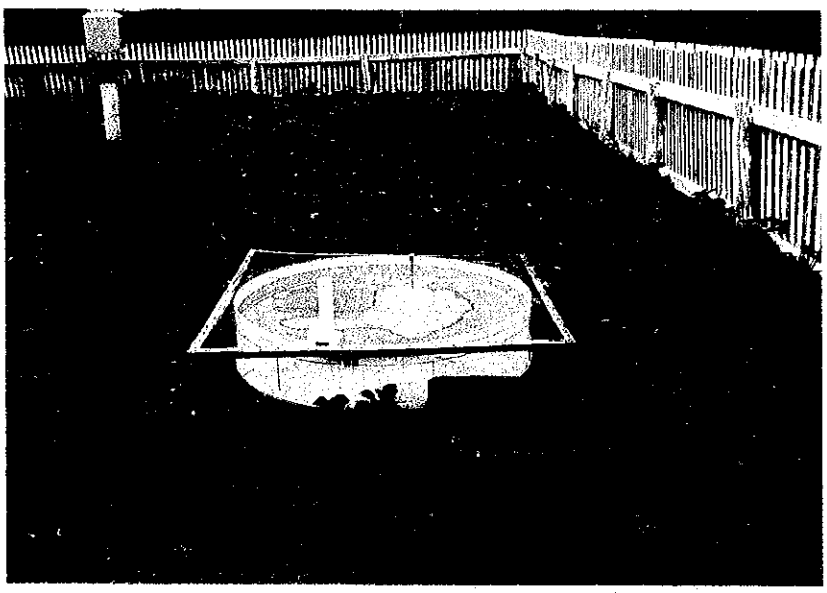
(1) View from Right Bank

(2) View from Downstream Left Bank

Photo B-3 Xe Namnoy Midstream Dam Site



(1) Rain Gauge



(2) Evaporation Pan

Photo C-1 Meteorological Gauging Station (Sekong Town)

(1) Water Level Gauging Station

(2) Gondla and Winch for Cableway

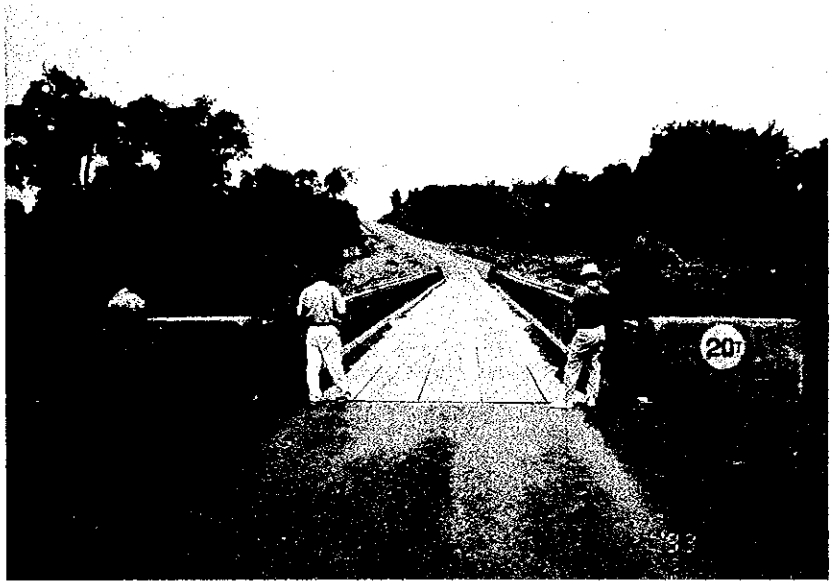
Photo C-2 Discharge Measurement
(B. Latsasin)

(1) Aerial Photogrammetry

(2) Seismic Prospecting Survey

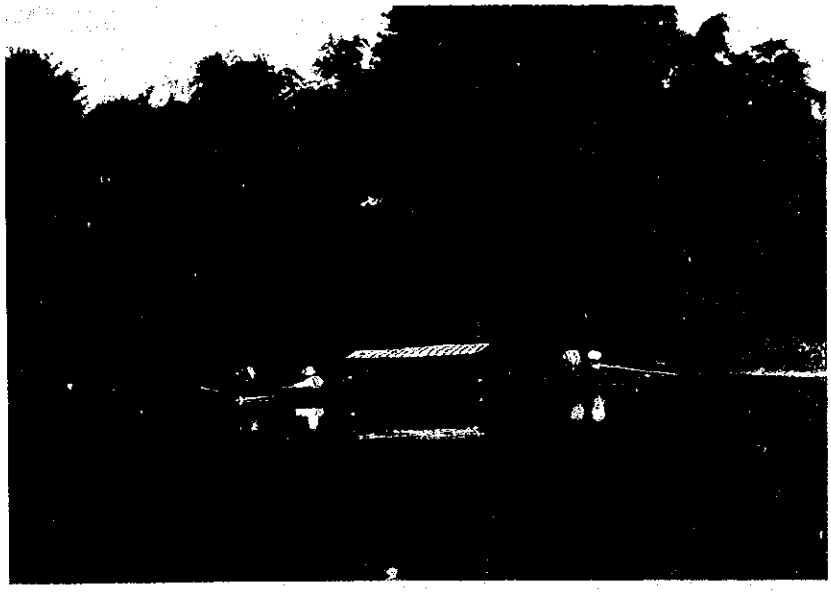
(3) Core Drilling Work

Photo C-3 Field Investigation



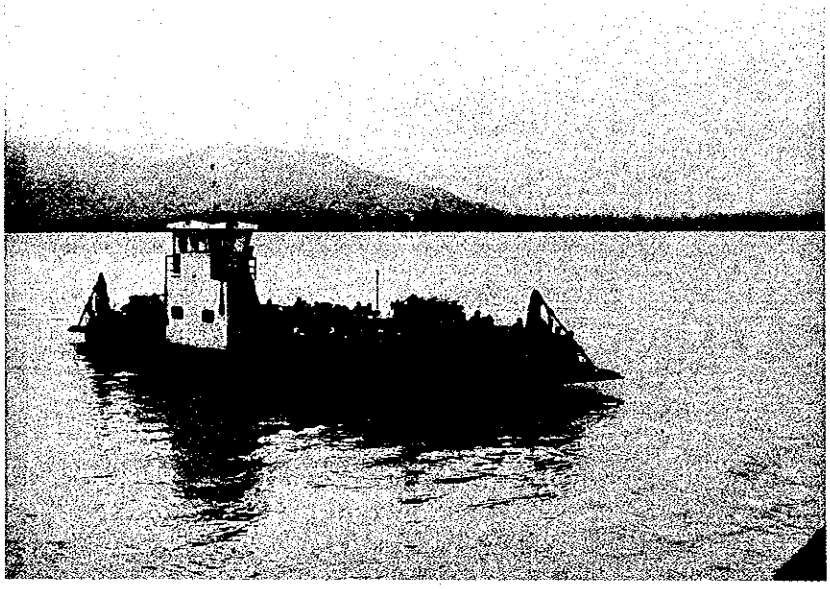
(1) Route 20
(at H. Champi)

(2) Route 16 B
(at Xe Khampho)

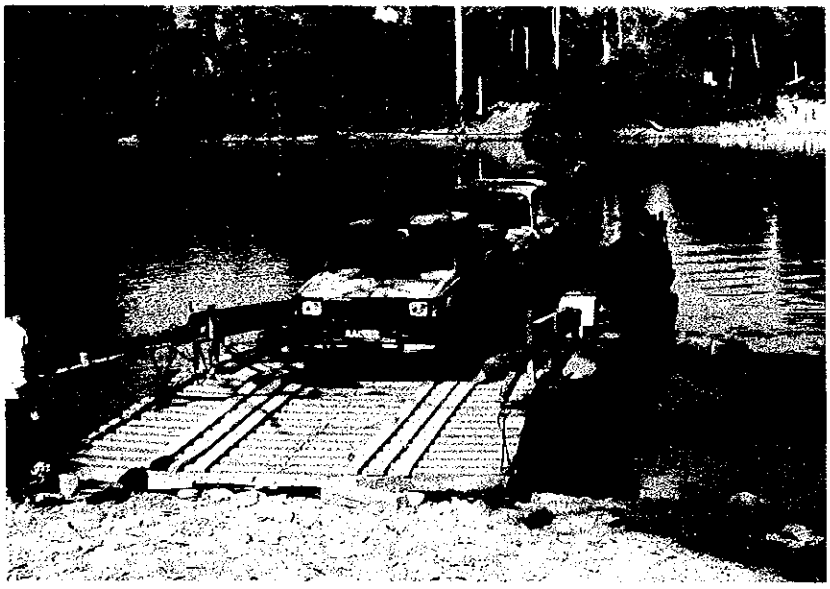


(3) Access to Se Kong No. 4
(by boat)

Photo C-4 Access Survey (1)



(1) Ferry Boat at Mekong River
(Route 13, Pakse)



(2) Ferry Boat at Xe Namnoy
River
(Route 16 A)

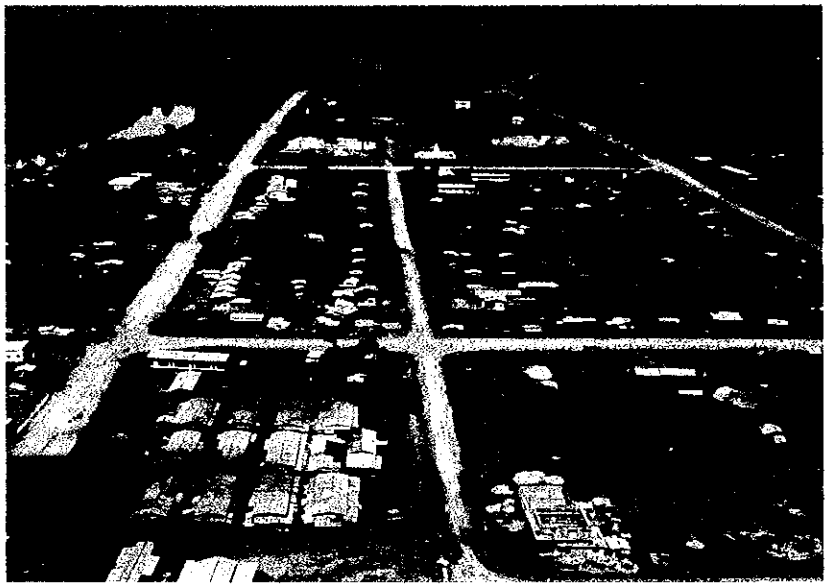
(3) Ferry Boat at Se Kong River
(Local road, Attapu)

Photo C-5 Access Survey (2)

(1) Small Village along
Se Kong River

(2) Small Village along
Xe Kaman River

Photo C-6 Environment (1)



(1) Sekong Town

(2) Xe Katam Fall

Photo C-7 Environment (2)

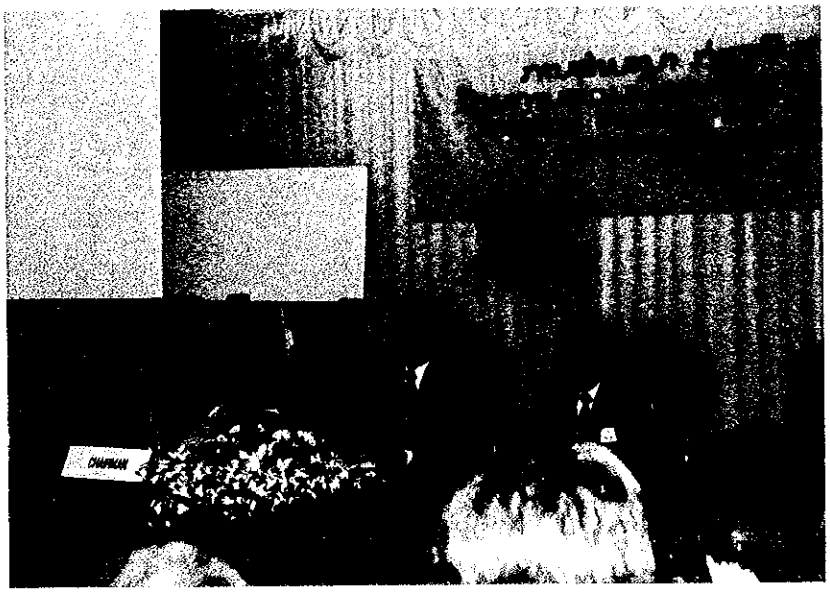


Photo C-8 Technical Transfer
(Seminar on Hydropower Development)

FINAL REPORT

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PART 2 HYDROPOWER POTENTIAL STUDY IN THE SE KONG BASIN

PART 3 PRE-FEASIBILITY STUDY

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ABBREVIATION

1. Countries

Lao P.D.R. or Laos	Lao People's Democratic Republic
Cambodia or Kampuchea	Cambodia
China	People's Republic of China
Myanmar	The Union of Myanmar
Thailand	Kingdom of Thailand
Vietnam	Socialist Republic of Viet Nam

2. Domestic Organizations of Lao P.D.R.

MIH	Ministry of Industry and Handicraft
EDL	Electricite du Laos
MCTPC	Ministry of Communication, Transportation, Post and Construction
DGM	Department of Geology and Mines, Ministry of Industry and Handicraft
NGD	National Geographic Department
DHM	Department of Hydrology and Meteorology, Ministry of Agriculture and Forestry
HEC	Hydropower Engineering Consultants

3. International and Foreign Organizations

JICA	Japan International Cooperation Agency
IBRD	International Bank for Reconstruction and Development
ADB	Asian Development Bank
OECF	Overseas Economic Cooperation Fund, Japan
ESCAP	Economic and Social Commission for Asia and the Pacific
Mekong Committee	Mekong Secretariat, or Interim Committee for Coordination of Investigations of the Lower Mekong Basin
UNDP	United Nations Development Programme
EGAT	Electricity Generating Authority of Thailand

3. Technical Terms

C.A.	Catchment area
PMF	Probable Maximum Flood
EL	Elevation(m) above sea level

HWL	High water level
LWL	Low water level
IWL	Intake water level
TWL	Tailrace water level
AC	Alternating current
DC	Direct current
cct	Circuit
GIS	Gas insulated switchgear
EHV	Extra high voltage
HVDC	High voltage direct currency
ACSR	Aluminum conductor steel reinforced
GPS	Global positioning system

4. Economic Terms

GDP	Gross domestic production
B/C	Benefit cost ratio
B-C	Net benefit
EIRR	Economic internal rate of return
FIRR	Financial internal rate of return
ARI	Accounting rate of interest
DSC	Debt service coverage ratio
IDC	Interest during construction
F/C	Foreign currency
L/C	Local currency
BOT	Built operate and transfer

5. Other Terms

S/W	Scope of Work
F/S	Feasibility Study
Pre-F/S	Pre-feasibility Study
PS	Power station
T/G	Turbine and generator
T/L	Transmission line
T/D	Transmission and distribution
O&M	Operation and maintenance

6. Measurement

<u>Length</u>	
mm	Millimeter
cm	Centimeter
m	Meter
km	Kilometer
ft	Foot
<u>Area</u>	
cm^2	Square centimeter
m^2	Square meter
ha	Hectare
km^2	Square kilometer
<u>Volume</u>	
cm^3	Cubic centimeter
l	Liter
kl	Kiloliter
m^3	Cubic meter
MCM	Million cubic meter
m^3/s-d	Cubic meter per second-day (86,400 m^3)
<u>Weight</u>	
g	Gram
kg	Kilogram
t /ton	Metric ton
<u>Time</u>	
s	Second
min	Minute
h	Hour
d	Day
M	Month
yr	Year
<u>Meteorology</u>	
°C	Degree in centigrade
mb	millibar
°K	Degree in kelvin-grade (thermodynamic unit)

Electrical Measures

V	Volt
kV	Kilovolt
A	Ampere
Hz	Hertz (cycle)
W	Watt
kW	Kilowatt (10^3 W)
MW	Megawatt (10^6 W)
GW	Gigawatt (10^9 W)
kWh	Kilowatt hour
MWh	Megawatt hour
GWh	Gigawatt hour
kVA	Kilovolt ampere
MVA	Megavolt ampere
MCM	Mil circular mils

Others

Btu.	British thermal unit
rpm	Round per minute
%	Percent
Lu	Lugeon

7. Currencies

US$ or $	US dollar
M.US$ or M.$	Million US dollar
US¢	US cent
kip	Lao kip
M.kip	Million kip
Baht	Thai baht
¥	Japanese yen

SUMMARY

SUMMARY

1. Introduction

This Study was undertaken during the period June, 1993 to February, 1995 to formulate the Master Plan Study on the Hydroelectric Power Development in the Se Kong Basin, Lao P.D.R. In the Study, a hydropower potential study in the Se Kong Basin was carried out at first stage. Then pre-feasibility studies were carried out for the three projects selected from the projects in the development plan inventory.

The Study was carried out requested by the Government of Lao P.D.R.. The Scope of Work (S/W) for the Master Plan Study on the project was agreed, and duly signed on March 11,1993 between Ministry of Industry and Handicraft (MIH) of the Lao P.D.R. and Japan International Cooperation Agency (JICA).

In order to promote the Study, JICA selected the consultant firm and awarded the study works to the joint venture consisting of Electric Power Development Co. Ltd. (EPDC, leading firm), NEWJEC Inc. and PASCO International Inc.

The study team, organized in accordance with the above consultancy contract and headed by Mr. T. TEZUKA (EPDC), immediately started study works in June 1993.

The study team first prepared an Inception Report and presented the same to MIH in July, 1993. This Report contained the policy of the study, method of the study and works to be undertaken by the MIH and JICA. In the Report, the study team divided the works into two stages; a hydropower potential study stage and a pre-feasibility study stage.

Secondly, the study team carried out site reconnaissances, a hydropower potential study to prepare hydropower development inventory. Then the three priority projects were selected from the 15 projects in the inventory. These studies were reported in the Interim Report and submitted to MIH in November, 1993.

Thirdly, field investigations such as hydro-meteorological survey, topographic survey by aerial photogrammetry, geological investigation, environmental impact survey were carried out at the three selected project sites. Details of these field investigations were reported in the Progress Report and submitted to MIH in July, 1994.

Finally, pre-feasibility studies were carried out for the three selected projects.

The field works for the study were carried out in cooperation with the team's counterparts from the MIH. During this study, the study team provided technical transfer to their counterparts through the field investigations. In the mean time, JICA invited two counterparts in Japan and provided technical training for them.

The study team also held a technical seminar at Vientiane in July 1994.

All works were completed in March, 1995.

2. Power Survey

2.1 Present Situation of Electric Power Industry

(1) Most of electric utilities in Laos are being operated under state or public management. The greater part of them is run by Electricite du Laos (EDL). EDL is now under the control of Ministry of Industry and Handicraft(MIH) which is its supervisory office and conducts integrated management including power generation, transmission and distribution, and electricity export to Thailand.

(2) The total generating capacity in Laos is 210 MW as of 1994 and about 94 % of them are hydroelectric generating equipment. Main power plants include the Num Ngum hydroelectric power plant (150 MW) and Xe Set hydroelectric power plant (45 MW).

(3) As for main power system, Nam Ngum power plant and Vientiane system, Xe Set power plant and the southern system and Thakhek and Savanakhet system where electric power is supplied from Thailand are operated respectively in an isolated system.

2.2 Development Plan and Power Export

(1) According to the latest estimate by EDL, the demand for electric power in Laos is 195 GWh in 1993, 398 GWh in 2000 and 502 GWh in 2003. When only domestic demand considered, the existing facilities are capable of satisfying that demand despite power export to Thailand.

(2) On the other hand, the demand for electric power in Thailand, is increasing by 8% to 9%. Subsequently, Thailand's expectations of Laos for the supply of electric power has increased. On June 1993, both countries agreed that 1,500 MW of the power are to be supply to Thailand by year 2000. Furthermore, more power supply will be expected after year 2000. Recently, investigations and construction of the hydroelectric power projects for the power export to Thailand have been expanded by the private investors.

(3) In Laos, electric power development plan is not basically linked to domestic demand alone. The majority of the nation's power is exported. Assuming construction is carried out as scheduled in the plan, the total capacity will amount to 2,255 MW (8,451 GWh annual power generation) in 2000, 6,279MW (30,797 GWh annual power generation) in 2010.

(4) The Se Kong river basin provides abundant hydropower resources. Therefore, the basin is taken notice of the hydro- electric power development area for the purpose of power export to the neighboring countries.

3. Results of Hydropower Potential Study in the Se Kong Basin

3.1 Field Survey

JICA study team visited Laos six times to carry out the field survey. The surveys were carried out at Vientiane and in the Se Kong basin. Meeting with MIH, data collection, report of the results of the field investigation works to MIH and etc. were carried out at Vientiane. Overall site survey by helicopter, topographic survey and geological reconnaissance at the accessible sites were carried out in the Se Kong basin. Furthermore, meteorological observation stations and water level gauging stations around the basin were improved and advised observation technology by the study team.

On the other hand, the study team visited Mekong Committee Secretariat in Bangkok and EGAT for data collection.

3.2 Selection of Development Plans

(1) Basic Conditions for the Hydropower Potential Study

- The Study covers all the Se Kong river basin of which located within the Lao territory.
- The Study covers hydropower development projects to be developed mainly for the energy export to the neighboring countries..
- The Study covers hydropower development projects to be proposed as a medium to large scale ones with an installed capacity of 10 MW or more..
- The development plan inventory is produced with a purpose to evaluate basin's hydropower potential by proposing a combination of project layouts which provides maximum net benefit.

  However, development plans of each project are studied as independent projects but not as series of incorporated projects.
- Development scales (installed capacities) of each project are so determined to provide a plant factor of approximately 60%.

(2) Basic Data applied in the Study

- The Study was conducted mainly by using 1/50,000 scaled topographic maps which are the largest maps in the existing maps.

- Currently, very little hydrological data is available in the Se Kong basin. It is, therefore, impossible to acquire precise flow data of specific sites throughout the broad reaches in the Se Kong basin. In this study, monthly flow data for the five years from August 1988 to July 1993 at Attapu gauging station were applied. Location of the observation stations are shown in **Fig. 5.2-1**.

(3) Review of Development Plans of the Previous Study

Prior to the inventory study, the development plan of the Se Kong basin proposed by the Mekong Committee in 1984, and the development plan of the Xe Namnoy river proposed in the study of Xe Katam Small-Scale Hydroelectric Power Development Project reported by JICA in 1992 were reviewed.

(4) Study of Development Plan Inventory

After reviewed the development plans proposed in the previous studies, 15 development plans which cover the most part of hydropower potential in the Se Kong basin were selected as follows. Location of each development plan is shown in **Fig. 7.3-1**.

Se Kong river main stream	3 plans
Xe Kaman river including tributaries	4 plans
Xe Namnoy river including Xe Pian river	2 plans
Nam Kong river	3 plans
Xe Xou river	1 plan
Nam Emun river	1 plan
Houay Lamphan Gnai river	1 plan

(5) Preparation of Development Inventory

Each development plans were studied on the some cases taking into consideration the basin's conditions of topography, geology, environmental impact and other site conditions.

The development inventory in the Se Kong basin was prepared as shown in **Table 7.3-2**.

3.3 Selection of Projects to be subjected to Pre-feasibility Study

(1) Evaluation Indexes for Project Ranking

15 plans (projects) listed in the development inventory were ranked based on the following indexes.

- Development scale (MW)
- Annual energy production (kWh)
- Construction cost including transmission line
- Net benefit (B-C)
- Cost benefit ratio (B/C)
- Generation cost (US$/kWh)
- Construction cost per kW

From the results of ranking study, 5 candidate priority development projects were selected as shown in **Table 7.4-2**.

(2) Selection of Projects to be Subject to Pre-feasibility Study

Judging from the detailed consideration, the following 3 projects were selected as the projects to be subjected to Pre-feasibility Study.

- Se Kong No.4 Project
- Xe Kaman No.1 Project
- Xe Namnoy Project (including Midstream and Downstream projects)

4. Results of Pre-feasibility Study

4.1 Field Investigation Works

To perform the pre-feasibility study, the following field investigation works were carried out at the 3 selected project sites.

(1) Topographic Survey

Topographic maps were made out by the aerial photogrammetric survey. The aerial photographs were taken at all reservoir area of the three selected sites. Using the photographs, topographic maps of 1/10,000 scale were prepared for the pre-feasibility study purpose. Mapping area and quantity are as follows.

Se Kong No.4	:	80 km^2 for dam site and a part of reservoir area
Xe Kaman No.1	:	80 km^2 for dam site and a part of reservoir area
Xe Namnoy	:	170 km^2 for all project area including the reservoir areas, of Midstream and Downstream projects and the area of Xe Pian Diversion scheme

(2) Seismic Prospecting Survey

Seismic prospecting surveys were carried out along the dam axises at the selected dam sites as follows.

Se Kong No.4	1,000 m (1 line)
Xe Kaman No.1	1,000 m (2 lines)
Xe Namnoy Midstream	1,000 m (1 line)

(3) Core Drilling

Core drilling works were carried out along the dam axises at the selected dam sites as follows.

Se Kong No.4	260 m (3 holes)
Xe Kaman No.1	260 m (3 holes)
Xe Namnoy Midstream	380 m (6 holes)

(4) **Survey on Environmental Impact and Compensation**

At the selected 3 project sites, environmental impact and compensation were preliminary surveyed. On the environmental impact survey, current status, environmental impacts and their mitigation measures were surveyed. On the compensation survey, compensation cost for the relocation of inhabitants and inundation of the forest caused by the dam construction was preliminary surveyed. Furthermore, surveys needed in future were also studied.

(5) **Access Survey**

Current status of access to the selected project sites such as ports, airports, existing roads were surveyed by the field reconnaissance.

4.2 Meteorology and Hydrology

(1) Using the data obtained at the existing observation stations and at the stations newly installed in the hydropower potential study stage, monthly discharge, probable flood, evaporation and sedimentation at Se Kong No.4, Xe Kaman No.1 and Xe Namnoy projects were analyzed respectively. Because of short term records of the stations, data for the analysis include some estimated data. Review of the analysis, therefore, will be required adding the data which are continuously observed in future .

(2) The monthly discharge at the dam sites of the projects were calculated from those of nearby stations in proportion to the catchment area. Because of the short term records of the stations, monthly discharge was extended to 10-year period from August 1984 to July 1994 using the regression correlation with the discharge data of the nearby basin.

a) **Monthly Discharge at Se Kong No.4**

Ten (10) years' monthly discharge at Se Kong Town was firstly estimated by regression correlation study with the daily discharge calculated from the observed water level at the stations of Sekong Town, Attapu Town, and Xe Done River. Then the monthly discharge of Se Kong No.4 was calculated in proportion to the catchment areas of Sekong Town and the Se Kong No.4 dam site.

b) **Monthly Discharge at Xe Kaman No.1**

Ten (10) years' monthly discharge at B.Fangdeng was firstly estimated by regression correlation study with the daily discharge calculated from the observed water level at the stations at B.Fangdeng, B.Hatsaykhao and Attapu. Then the monthly discharge of Xe Kaman No.1 was calculated in proportion to the catchment areas of B.Fangdeng and the Xe Kaman No.1 dam site.

c) **Monthly Discharge at Xe Namnoy Midstream**

Ten (10) years' monthly discharge at B.Latsasin was firstly calculated from the observed water level at the B.Latsasin station, partly supplementing it by using the data at the Xe Set and B.Fangdeng stations. Then the monthly discharge of Xe Namnoy Midstream was calculated in proportion to the catchment areas of the B.Latsasin gauging station and Xe Namnoy Midstream dam site.

d) **Monthly Discharge at Xe Namnoy Downstream**

The available discharge at the Xe Namnoy Downstream dam site consists of the discharge from the downstream drainage area of Xe Namnoy Midstream and Houay Katak Tok (Houay Ho) dam sites as well as from the Xe Katam basin and the power discharge released from the Midstream power plant. The monthly discharge of the downstream drainage area was estimated from the data extended over 10 years of the stations at B.Latsasin and B.Nonghin in proportion to the catchment areas.

e) **Monthly Discharge at Xe Pian Diversion**

Ten (10) years' monthly discharge was estimated from the extended 10 years data of the B.Nonghin station on the Xe Kaman river, which has the basin adjacent to the basin of the Xe Pian river, in proportion to the catchment areas.

(3) The design floods of the each project are estimated by using the data in Laos and neighboring countries and Creager Curve which envelopes PMF at the similar project. The design floods at dam site of each project are estimated as follows.

Se Kong No.4	16,400 m^3/s
Xe Kaman No.1	14,300 m^3/s
Xe Namnoy Midstream	6,000 m^3/s

Xe Namnoy Downstream 9,000 m^3/s

4.3 Geology of Each Project Site

(1) Se Kong No.4 Project

a) Mountain of some 500 m in elevation was cut by the Se Kong river at Se Kong No.4 dam site. At the dam site, river bed is at elevation of 140 m and around 100 m wide. The valley is about 900 m wide at the high water level of the reservoir. The slope of the both banks is relatively gentle.

b) The dam site is underlain by sandstone, shale and andesitic tuff. Sandstone and shale are distributed on the river bed upstream of dam axis. Tuff layer accompanied by tuff breccia and limestone blocks are distributed on both banks of the dam site and river bed downstream of the dam axis. Tuff layers are overlain by conglomerate. The recent river deposits are inferred to be 10 m deep in maximum from abundant outcrops of tuff on the river bed downstream of the dam axis. Surface deposits such as talus deposits and recent river deposits are thin. This dam site will not provide any serious geotechnical problems, because of shallow surface deposits and weathering and limited limestone distribution.

c) Upstream reservoir area is characterized by narrow valley and steep slopes. While, in midstream and downstream of the reservoir area, valley are widened and with gentle slopes. There is no distinct landslide topography, large scale slope failure. The reservoir area is mainly underlain by shale and sandstone. Limestone distribution is judged from topography to be so limited and discontinuous that it will not cause any problem on reservoir watertightness. Coal seams distributed in the vicinity of B. Chakeui are reported but details are unknown.

It seems like that the reservoir area has few problems on stability for the surrounding slopes and watertightness.

(2) Xe Kaman No.1 Project

a) The dam site is located on the second downstreamost gorge of Xe Kaman river. River bed is at elevation of about 130 m, and 80 m wide. Valley is about 500 m wide at the high water level of the reservoir. The slopes below an elevation of

some 240 m have an average gradient 40° on the left bank and 50° on the right bank. The slopes above that elevation are gentle.

b) The dam site is underlain by sandstone and intercalating conglomerate and shale. Sandstone is fresh and medium to coarse grained and some times get coarser to conglomerate. Talus deposits are limited on the upper slope of the damsite. Recent river deposits are inferred to be some 5 m thick by the outcrops on the river bed at the dam site.

c) Valleys are generally narrow and V shaped in the upstream reservoir area, some basin separated by short gorge appear in the downstream reservoir area. Any distinct landslide topographies and large slope failures are not observed. Close to the backwater of the reservoir, high white cliffs are continued along the Xe Kaman river and seems to be composed by limestone, but typical karst topographies are not found.

Geology in the reservoir area is underlain mainly by sandstone and shale. It seams that the reservoir area is generally watertight.

(3) Xe Namnoy Midstream Project

a) Midstream dam site is located on the Bolaven Plateau where elevation of the mountains are about 800 m and that of Xe Namnoy river is from 700 to 720 m. The valleys of that river system are shallow but large in density. At the dam site, river bed is about 80 m wide and the width of the valley at high water level is about 900 m. Xe Namnoy river has many rapids and waterfalls between 650 m in elevation 4 km of downstream of the dam site and 300 m in elevation near the junction of Xe Katam river where about 2 km upstream of the power station site.

b) The dam site is underlain by sandstone, shale and basalt. Sandstone and shale distribute on the river bed, right bank and upper slope on the left bank. Basalt is distributed on the left bank its bottom is lower than recent river bed. This basalt is characterized by cooling joints and porous in some horizons. Lower part of the basalt shows low ground water level and high permeability. Talus deposits, recent river deposits are thin and limited in distribution.

c) The reservoir area covers upstream of Xe Namnoy river and surrounded by the gentle mountains of 1,000 m in elevation. Basalt is limited to the narrow area near

the dam site. The basalt at the dam site will be treated so as to stop the leakage from the reservoir to downstream. Then the watertightness of the reservoir will be achieved.

d) The headrace tunnel route is located on the right bank of Xe Namnoy river. The tunnel will penetrate same sandstone and shale that is distributed at the dam site. Both sandstone and shale are supposed to be massive and fresh.

4.4 Environmental Impact and Compensation

(1) Outline

Preliminary field surveys on environmental impact and compensation were carried out from November, 1993 to March, 1994 by the Hydropower Engineering Consultants (HEC) entrusted JICA study team.

These surveys were mainly for the collection of data. Some surveys were done in the field including interviews with local authorities and residents. The data of these field surveys was prepared by the HEC in its "Report on Environmental Impact and Compensation".

(2) Summary of Environmental Impact Survey

As this is a preliminary survey at the pre-feasibility study stage, it does not adequately determine the current status of the environment, for which reason some matters must wait until future surveys. However, an overall consideration on the basis of the results of the survey together with other information to date suggests that implementing appropriate measures to alleviate impacts will forestall the occurrence of environmental impacts that would hinder these projects.

The major items of the survey results and the surveys needed in the future are summarized below;

a) Impacts on Local Societies, Inhabitants and Agriculture by Submersion Relocation

The population in the reservoir area is estimated at approximately 3,600 people at Se Kong No.4, 600 people at Xe Kaman No.1 and 900 people at Xe Namnoy Midstream. The greatest impact by these projects on the inhabitants and local

societies will be the submersion of their dwellings, settlements, farmlands and other elements of their livelihood, and the relocation of these.

Almost all the inhabitants of the reservoir areas are minorities who practice slash-and-burn agriculture, and who still pursue a traditional lifestyle. They also prefer living in small, dispersed settlements.

On the other hand, while the government's scheme to move these people is to encourage them to cultivate low lying farmland and abandon slash-and burn agriculture, any attempt to follow this scheme would mean that, in order to ensure the investment, the resettlement areas would have to be large, intensive settlements located on flatlands. In view of this, it is anticipated that the resettled people's lifestyles will change considerably.

It will be necessary to conduct on-site surveys of the reservoir areas and their peripheries to check the inhabitants awareness and desires with regard to resettlement and other matters. Consideration is also needed to ensure the resettlement plan lessens the burden on the inhabitants as much as possible.

b) Infectious Water Area

Construction of a dam reservoir could result in water-related epidemics through the creation of new stagnant water areas that would serve as a habitat for mosquitoes and other disease vectors. With this, different a living environment and various other attendant changes will place a large mental burden on the resettled people.

Detailed surveys on the state of health and hygiene of the people in the project areas, and on matters including past instances of epidemics will be necessary in the future. Also, countermeasures such as those for the prevention of epidemics, the maintenance of hygiene and adequate guidance for the construction personnel will be very necessary.

c) Impact of Dam Construction on Water Transportation, Water Area Utilization and Fishing

Water transportation is the only means of transportation linking the settlements upstream from the project location with either Sekong Town or Attapu Town, which constitute the primary part of the downstream areas. As a large population in the

upstream area will remain in-place after project completion, upstream to downstream transportation will continue to be of great importance and the construction of a dam will hinder such movement. An alternative means of transportation will have to provided.

The construction of these hydropower projects offers hope of favorable effects, especially wherein that in the downstream regions the river flow will increase in the dry season, and that less flooding will occur in the rainy season. On the other hand, during peak use when daily plant operation and shut down are repeated, it is possible that rising downstream water levels during operation start-up and output changes will present danger to people in boats, who are fishing, bathing, doing laundry, and the like. The requisite future surveys and studies may indicate a need for measures to deal with this situation, such as installing discharge warning devices to be activated when danger is anticipated.

It is possible that changes engendered by dam construction, such as in flow characteristics including water depths and current velocity, as well as in water quality, bottom material, and the like, will affect the aquatic organisms.

While it is difficult to clearly predict what those impacts will be, for migratory fish the dam will affect spawning by hindering the passage of fish which presently traverse the rivers. The project may, therefore, bring about a decline in their numbers. It is also reported that, although rarely, local inhabitants see river dolphins in the Se Kong River. On the other hand, in the case of the Nam Ngum, the dam construction would greatly increase the number of fish inhabiting the reservoir area.

More detailed surveys will be needed on the current state of fish stocks together with careful assessment of the total project impact in the future.

d) Impacts on Fauna

It is reported that many species of irreplaceable animals, including those rarely seen and those seen only in the past, exist in the project areas. Conceivable project impacts on animals include the submersion of forest lands which provide habitats and food, and the blockage of migratory routes by the reservoirs. It would perhaps be effective to provide wildlife protection areas on the peripheries of the reservoirs in order to compensate for the submersion of such habitats.

More detailed surveys will be needed to determine the current state of flora and fauna and the existence of irreplaceable species.

e) **Impacts on the Inter-basin Diversion and River Flow Decrease**

The Se Kong No.4, Xe Kaman No.1 and Xe Namnoy projects will decrease the downstream river water by peak power generation for a limited time in the dry season. Xe Pian river also decrease at the downstream from the intake dam, by the Xe Pian Diversion plan. Therefore, each project are considered a constant river flow discharge throughout a day (24 hours) to the downstream from the dam or powerhouse.

It will be necessary to conduct detailed surveys and investigations concerning these potential problems and institute, in accordance with the need, remedial measures such as releasing the amount of water needed as the water flow to maintain the river.

(3) Summary of Compensation

Compensation for submerged dwellings, farmland and other assets would consist in offering resettled people compensation "in kind" at their new locations. One group resettlement plan with one resettlement area per one project was planned.

Compensation costs were calculated according to the following guidelines and preconditions;

- Land in new settlements would be provided free of charge by the government.
- One (1) ha. of land would be prepared as the property of each household.
- An average per-household budget of 750,000 kip would be set aside as living costs and food aid for the first two years after resettlement.
- The following basic infrastructures would be built. Although apparently the settlements within the reservoir areas have almost no infrastructures such as this, items would be constructed because the settlement areas will be large due to group location, and because it would provide the inhabitants an incentive to resettle.
  Meeting halls, temples, schools, medical care facilities, government offices, markets, wells, electric power, irrigation equipment, roads (unpaved).

The compensation costs estimated above are approximations only and include many assumptions. They will have to be reassessed after conducting surveys of the populations, assets (including houses and farmland), social capital, type of ethnic groups and other matters regarding all the settlements in and around the reservoir areas, and surveys covering the perceptions, hopes, and other feelings, of the inhabitants concerning resettlement, as well as after incorporating the opinions of the central and local government authorities.

At present, only those settlements lying within the reservoir areas are planned for relocation. However, future surveys of inter-settlement interchanges and other circumstances within these areas may indicate the need to relocate the peripheral resettlements as well.

4.5 Operation Plan

In the operation plan, a review of the electric power development programs, transmission line plan, and operation plan of the reservoir and power plant facility are studied.

(1) Review of Electric Power Development Programs

- Laos is blessed with many tributaries to the Mekong River, offering plentiful hydropower potential. However, as population is low and domestic industrial structure is mainly defined by primary industries, domestic demand for electric power is far below the supply potential.
- Medium and large hydroelectric power projects in Laos are not developed solely for domestic supply, but with export to neighboring countries as their primary purpose. And, some areas around Laos have a large and rapidly increasing electric power demand. Taking advantage of these conditions, future strategy for economic growth of Laos will center on the development of domestic hydropower potentials for export.
- For the hydropower development in the Se Kong River Basin, clarification as source of domestic electricity supply and that as electric power export are studied.

(2) Transmission Line Plan

- Current status of transmission line expansion plan in Laos is studied.
- Electric power generated at the projects in the Se Kong basin will be connected to the B. Houaykong substation located in the Bolaven Plateau. From this substation, the

electric power will be transmitted to the neighboring countries by an international power system.

- Comparative studies of the transmission line cost up to the Thai border are carried out as follows:

  Case 1: Allocated transmission line

  Case 2: Independent transmission line

- Transmission line routes for each project and an international linkage line plan are preliminary studied.

(3) Operation Plan of Reservoir and Power Plant

- To guarantee stable supply, hydroelectric power developments in the Se Kong basin will require a holding reservoir. Also, in the plan of operation, it is necessary to place high emphasis on minimizing the unit cost of electric power production.

- Rivers in areas affected by Asian tropical monsoons generally have vast differences in flow volumes from the dry to rainy seasons, and there are also significant differences from one year to the next. In order to take full advantage of the hydropower potentials of a river with wide variances in its flow volumes, it is necessary to fabricate an enough storage capacity of reservoir and thus regulate the natural inflow.

- The hydropower development plan carried out in the pre-feasibility study is referred the recent daily demand load curve of Thailand. Peak power duration of 8 hours is applied in the project scale optimization study.

- In consideration of the effects on the environment, it is necessary to maintain a river flow to the downstream of the dam. In this study, in principle, a condition that two-thirds of monthly mean discharge during the driest month should be maintained at the project downstream throughout a day (24 hours) for maintaining rivers functions is applied power plant operation of each project.

4.6 Selection of Optimum Development Plan

(1) An optimum development study is carried out for the three selected projects in the hydropower potential study. The following basic conditions are applied in the selection of the optimum development plan;

a) Basic Data

- 1/10,000 scale and 1/50,000 scale topographic maps are used in the study.
- Estimated monthly discharge of the 10-year period, 1984-94 are used.
- Reservoir evaporation, design flood, reservoir sedimentation are calculated and used as basic data.

b) Reservoir Operation Rule

- A reservoir operation rule which regulates a series of reservoir inflow over years (carry-over operation) is applied for reservoir type projects.
- Firm discharge is determined for an effective storage capacity by the mass curve calculation with series of inflow data for a 10-year period.

c) Power Plant Operation Condition

- 8 hours is applied as a peak power duration for reservoir type projects.
- As a rule, two-thirds of the river flow during the driest month is conditioned to be maintained as the river retaining flow.

d) Conditions for Estimation of Construction Cost

- Costs of the preparatory works, civil works, hydraulic equipment, electro-mechanical equipment, compensation, engineering fees, administration and etc. are estimated, but the transmission line cost is not included in this study.
- Preliminary work quantities and unit prices are applied in this study.

e) Economic Evaluation Index

- In the economic evaluation, energy cost per kWh (E/C), which is calculated dividing annual cost (C) by annual energy (E), is used as the primary index.
- Addition to the (E/C), benefit cost ratio (B/C), net benefit (B-C) and unit construction cost per kW are calculated and correctly employed.

(2) Se Kong No.4 Project

a) Selection of Basic Project Layout

- The dam site of the Se Kong No.4 Project selected in the study of the development plan inventory is reviewed and selected, using 1/10,000 scale topographic maps.
- A concrete faced rockfill dam is tentatively selected, taking into consideration the topography and dam scale.
- As for layout of the waterway and powerhouse, the power intake is planned at the right bank with the powerhouse downstream from the dam and connected by a headrace tunnel and penstock.

b) Selection of Optimum Development Plan

The following optimum development plan of the Se Kong No.4 Project is selected after the case study, which is a change in the high water level and reservoir capacity, based on the basic conditions and the layout described above.

Reservoir HWL	290.0 m
Reservoir LWL	275.4 m
Effective storage capacity	1,700 MCM
Firm discharge	143 m^3/s
Minimum outflow	30 m^3/s
Peak power duration	8 hours
Maximum discharge	370 m^3/s
Rated intake water level	285.1 m
Rated tail water level	145.0 m
Rated effective head	137.0 m
Installed capacity	443 MW
Firm peak capacity	406 MW
Annual energy	1,816 GWh

(3) Xe Kaman No.1 Project

a) Selection of Basic Project Layout

- The dam site of the Xe Kaman No.1 Project is selected using 1/10,000 scale topographic maps.
- A concrete gravity dam is selected taking into consideration the topography of dam site and the prevalent geology.
- For the waterway and powerhouse, the power intake is planned at the left bank with the powerhouse being downstream from the dam and connected by a headrace tunnel and penstock.

b) Selection of Optimum Plan

The following optimum development plan of the Xe Kaman No.1 Project is selected after the case study, which is a change in the high water level and reservoir capacity, based on the basic condition and the layout described above.

Reservoir HWL	260.0 m
Reservoir LWL	253.2 m
Effective reservoir capacity	1,270 MCM
Firm discharge	89 m^3/s
Minimum outflow	20 m^3/s
Peak power duration	8 hours
Maximum discharge	228 m^3/s
Rated intake water level	257.7 m
Rated tail water level	125.0 m
Rated effective head	129.9 m
Installed capacity	256 MW
Firm peak capacity	245 MW
Annual energy	1,137 GWh

(3) Xe Namnoy Project

The Xe Namnoy River has many rapids in its midstream section and presents potential for a high head hydropower development plan by using the head of approximately 500m. In

the development plan inventory, the Xe Namnoy Project was proposed as a two stage development plan which incorporates the Midstream Project and Downstream Project.

a) Selection of Basic Project Layout

a-1) Xe Namnoy Midstream Project

- The dam site of the Xe Namnoy Midstream Project selected in the inventory is reviewed with alternative sites, using a 1/10,000 scale map and a more suitable site is selected, taking the topography and geology into consideration.
- A zone type rockfill dam is selected in accord with the topographic conditions at the site.
- The Midstream Project is planned as the Xe Pian Diversion to increase the water from Xe Pian River basin. Two intake dams on the Xe Pian River basin and a diversion channel connecting the intake dams and the Xe Namnoy Midstream reservoir are planned.
- The power intake is selected in the right bank tributary located immediately upstream of the dam site. The powerhouse site is selected at the right bank of the Xe Namnoy River. The intake and powerhouse are connected by a headrace tunnel.

a-2) Xe Namnoy Downstream Project

- The dam site of the Xe Namnoy Downstream Project is selected at downstream of the powerhouse of the Midstream Project which is located immediately downstream at the confluence of the Houay Katak Tok River.
- The dam is planned as a regulating pond with daily flow regulation.
- A concrete gravity dam is selected taking into consideration the topography, dam scale and design flood.

b) Selection of Optimum Development Plan

The following optimum development plans of the Xe Namnoy Project are selected based on the basic conditions and layout described above. For the Xe Namnoy Midstream Project, a comparative study is also carried out with and without the Xe Pian diversion.