No.

Ministry of Energy and Mines
Lao People's Democratic Republic

PREPARATORY SURVEY

ON

NAM NGUM 1 HYDROPOWER STATION EXPANSION

IN

LAO PEOPLE'S DEMOCRATIC REPUBLIC

FINAL REPORT

SUMMARY

January 2010

Japan International Cooperation Agency

NIPPON KOEI

POWER

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Preface

In response to the request from the Government of Lao PDR, the Government of Japan decided to conduct the Preparatory Survey on Nam Ngum 1 Hydropower Station Expansion, and entrusted the Survey to the Japan International Cooperation Agency (JICA).

JICA dispatched the Survey Team, headed by Mr. Takuji KATAOKA of the joint venture, composed of Nippon Koei and J-Power, to Lao PDR five times from February 2009 to November 2009. The Survey Team consisted of experts of hydropower expansion plan, power demand and supply analysis, hydrology and reservoir operation, geology, electric power civil engineering, electrical equipment, mechanical equipment, power system analysis, economic and financial analysis, and environmental and social consideration.

The Survey Team had a series of discussions with the organizations concerned such as the Electricite du Laos and the Ministry of Energy and Mines etc., and conducted the field surveys. The Study Team conducted further studies also in Japan to complete the Final Report.

I hope that this report will contribute to the reinforcement of power supply capacity for the country as well as to enhancement of the amity between our two countries.

I wish to express my sincere appreciation to the officials concerned for their cooperation and supports provided throughout the Survey.

January 2010

Atsuo Kuroda
Vice President
Japan International Cooperation Agency

January 2010

Mr. Atsuo Kuroda
Vice President,
Japan International Cooperation Agency
Tokyo, Japan

Letter of Transmittal

We have the pleasure of submitting to you herewith the Final Report upon completion of the Preparatory Survey on Nam Ngum 1 Hydropower Station Expansion in Lao PDR. The joint venture, composed of Nippon Koei and J-Power, executed the Study under an agreement with your Agency over a period of about 13 months from January 2009 through to January 2010.

The Survey has been conducted in accordance with the Scope of Works concluded in February 2009. Power demand forecast, power development plan and basic design for the optimum expansion plan were conducted to prepare the expansion plan of the existing Nam Ngum 1 Hydropower Station.

In course of the Survey, particular efforts were made on technology transfer through various joint works with the counterparts from the Electricite du Laos and the Ministry of Energy and Mines etc., and the steering committee meetings. The related technologies to expansion projects, that shall be useful for the future implementation of expansion project, were also introduced by holding the seminar.

We hope this report would contribute to developing the socio-economy of the Lao PDR through the stable supply of electricity.

We would like to note that we have received the sincere cooperation and supports from the relevant organizations such as the Electricite du Laos and the Ministry of Energy and Mines etc. We also would like to express our deep appreciation to the valuable advices and cooperation provided by the staff and experts of the Embassy of Japan in the Lao PDR, the JICA Headquarter, and the JICA Laos Office.

Very truly yours,

The Study Team of Preparatory Survey on
Nam Ngum 1 Hydropower Station Expansion
Leader Takuji KATAOKA

Location Map of the Project Area

Nam Ngum 1 Dam and Power Station (February 2009)

Downstream View from Nam Ngum 1 Dam (February 2009)

Salient Features of Nam Ngum 1 Hydropower Station Expansion Project

Descriptions			Dimensions
1.	Reservoir (Existing)	River System	Nam Ngum river
		Catchment Area	8,460 km^2 (Completion Report 1972)
		Max. Flood Level	El. 215.0 m
		Full Supply Level (FSL)	El. 212.0 m
		Minimum Operation Level (MOL)	El. 196.0 m
		Gross Storage Capacity at FSL	7,030 x 10^6 m^3
		Active Storage Capacity	4,700 x 10^6 m^3
		Annual Average Inflow	375 m^3/s (*)
		Flood Inflow Peak (PMF)	8,800 m^3/s
2.	Dam (Existing)	Type	Concrete gravity dam
		Dam Crest Level	El. 215.0 m
		Max. Height of Dam	75 m
		Length of Dam Crest	468 m
		Volume of Dam	358,000 m^3
3.	Spillway (Existing)	Type	Open channel with flip bucket
		Width of Chute Channel	57.5 m
		Length of Chute Channel	95.2 m
		Overflow Crest Level	El. 202.5 m
		Gates (radial type)	4 nos. @W12.5 m x H10.0 m
4.	Intake (Existing Units)	Type	Horizontal bell-mouth
		Diameter of Penstock	3.4 m (for Units 1 & 2) 6.0 m (for Units 3, 4 & 5)
		Center Elevation of Penstock	El. 189.0 m (for Units 1 & 2) El. 186.0 m (for Units 3, 4 & 5)
		Trashrack	Removable type
		Staoplogs	Inserted in trashrack slot
		Type of gate	Rope-hoisted fixed wheel gate
	(Expansion)	Type	Horizontal bell-mouth installed in a hole excavated in dam
		Diameter of Penstock	5.5 m
		Center Elevation of Penstock	El. 185.25 m
		Trashrack	Removable type
		Staoplogs	Inserted in trashrack slot
		Type of gate	Bonnnet type (with hydraulic hoist)
5.	Powerhouse (Existing Units)	Type	Surface type concrete building
		Height (Bottom to Roof)	42.1 m
		Width x Length	43.95 m x 138.4 m
	(Expansion)	Type	Surface type concrete building
		Height (Bottom to Roof)	42.1 m
		Width x Length	42.45 m x 25.74 m
6.	Tailrace	Type	Open Channel
		Water Level (no flow)	El. 164.0 m
		Water Level (Units 1 to 5)	El. 168.0 m
		Water Level (Units 1 to 6)	El. 168.4 m (after expansion)

Descriptions			Dimensions
7.	Turbine (Expansion)	Type	Vertical Shaft Francis Type
		Number	1
		Rated Output	40.90 MW
		Revolving Speed	142.9 rpm
		Rated Net Head	40.0 m
		Rated Dischrage	111.2 m^3/s
8.	Generator (Expansion)	Type	Umbrella Type
		Rated Output	50.00 MVA
		Frequency	50 Hz
		Voltage	11 kV
		Power Fcator	0.8
9.	Transformer (Expansion)	Type	Single-phase, oil-immersed type
		Capacity	50 kVA (for three phase)
		Voltage	11kV / 115kV
		Cooling	ONAF
10.	Switchyard (Expansion)	Type	Conventional type on roof
		Voltage	115 kV
		Bus	HDCC 725 mm^2
11.	Generation (Expansion)	Incremental Capacity	35 MW (95% dependable)
		Incremental Energy Production	56 GWh/year
12.	Project Cost for Expansion		US$ 7,006 million (**)
	Construction Period (including Bid Preparation)		5 years

(*): Including inflow from Nam Song and Nam Luek diversions

(**): US$ 1.0 = JPY 95.0 = Kip 8,510

THE PREPARATORY SURVEY
ON
EXPANSION OF NAM NGUM 1 HYDROPOWER STATION
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Terms

Abbreviations	English
Lao PDR Agencies	**Lao PDR Agencies**
DMH	Department of Meteorology and Hydrology
CDEP	Committee for Development of Electric Power
CPC	Committee for Planning and Cooperation
DOE	Department of Electricity, MEM
EdL	Electricite du Laos
FIMC	Foreign Investment Management Committee
GOL	Government of Lao PDR
LNCE	Lao National Committee for Energy
LWU	Lao Women's Union
MEM	Ministry of Energy & Mines
NN1	Nam Ngum No.1 Poser Station
STEA	Science, Technology & Environment Agency
WREA	Water Resources and Environment Agency
Foreign Organizations	**Foreign Organizations**
ADB	Asian Development Bank
EGAT	Electricity Generation Authority of Thailand
EVN	Electricity of Vietnam
IMF	International Monetary Fund
IUCN	World Conservation Union (Switzerland)
JICA	Japan International Cooperation Agency (Japan)
MOI	Ministry of Industry of Vietnam
MPI	Ministry of Planning and Investment of Vietnam
NEPO	National Energy Policy Office of Thailand
NTEC	Nam Theun 2(NT2) Electricity Company
NTPC	Nam Theun 2(NT2) Power Company
PEA	Provincial Electricity Authority in Thailand
PRGF	Poverty Reduction and Growth Fund
UNDP	United Nations Development Program
WCD	World Commission on Dams
Others	**Others**
AAU	Assigned Amount Unit
B.	"Ban" Village in Laotian language
BOT	Built-Operate-Transfer
CA	Concession Agreement
CDM	Clean Development Mechanism
CER	Certified Emission reduction
COD	Commercial Operation Date
DPRA	Development Project Responsible Agency
ECA	Export Credit Agencies
ECC	Environmental Compliance Certificate
ESIA	Environmental and Social Impact Assessment
EMMU	Environmental Management & Monitoring Unit
EPC	Engineering, Procurement and Construction
EPMs	Environmental Protection Measures
ERU	Emission Reduction Unit
ESMP	Environmental and Social Management Plan
FS	Feasibility Study
FARD	Focal Area for Rural Development
GHG	Green House Gas
GIS	Geographic Information System
GMS	Greater Mekong Sub-region
GPS	Global Positioning System
HEPP	Hydroelectric Power Project
ICB	International Competitive Bidding
IEE	Initial Environmental Examination

Terms

Abbreviations	English
IPDP	Indigenous Peoples Development Plan
IPP	Independent Power Producer
IWRM	Integrated Water Resources Management
JI	Joint Implementation
LA	Loan Agreement
LEPTS	Lao Electric Power Technical Standard
LLDC	Least Less-Developed Countries
MOU	Memorandum of Understanding
NBCA	National Biodiversity Conservation Area
NEM	New Economic Mechanism
NGOs	Non Governmental Organizations
NN1	Nam Ngum 1 Hydropower Station
NNRB	Nam Ngum River Basin
O&M	Operation and Maintenance
ODA	Official Development Assistance
PDA	Project Development Agreement
PDP	Power Development Plan
PO	Project Owner
PPA	Power Purchase Agreement
S/W	Scope of Works
SIA	Social Impact Assessment
SPC	Special Purpose Company
SPP	Small Power Producer
TOR	Terms of Reference

Unit/Technical Terms	Unit/Technical Terms
B-C, B/C	B: Benefit and C: Cost
EIRR, FIRR	Economic/Financial Internal Rate of Return
EL.( ) m	Meters above Sea level
FSL.	Full Supply Level of Reservoir
GDP	Gross Domestic Product
GWh	Giga Watt Hour (one billion watt hour)
IRR	Internal Rates of Return
LWL	Low Water Level of Reservoir
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
MCM	Million Cubic Meter
MOL.	Minimum Operation Level of Reservoir
MW	Mega Watt (one million watt)
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
US$	US Dollar
Kip	Kip
THB	Thai Baht
JPY	Japanese Yen

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CHAPTER 1 INTRODUCTION

1.1 BACKGROUND OF SURVEY

In Laos, the domestic peak power and energy demand requirements are increasing at an average rate of 10% from 2000 up to 2006. Existing power sources in Laos are not enough to cover the rapid increase of power demand, thus installation of additional power sources is necessary. The amount of power export, excluding those of the independent power plants (IPP), was more than the power import up to 2005. However, the amount of power import exceeded the power export in 2006 due to the increase in domestic power demand.

The Government of Lao PDR has prepared the power development plan (PDP 2007-2016) in 2006 aiming at social development founded on sufficient power supply and acquisition of foreign exchange through the power export. In the PDP 2007-16, hydropower development with the practical use of high hydropower potential in Laos, through the positive introduction of IPP, is emphasized. However, power demand is increasing more than the expected especially in the metropolitan area. The implementation of power development projects tend to be got behind the PDP project schedule. The present power supply to the C1 area relies on the Nam Ngum 1 (NN1) Power Station (155 MW), Nam Leuk Power Station (60 MW) and Nam Mang 3 Power Station (40 MW), and surplus power is exported to the Thailand. However, the peak power supply of Laos during the dry season partially relies on the power import from Thailand, and it is expected that the peak power demand in 2010, even during the rainy season, would rely on power imports.

Because of these conditions, the Government of Lao PDR has requested the cooperation of the Japanese Government, who has a lot of previous experience on hydropower development in Laos, for the Nam Ngum 1 Hydropower Station Expansion. In response to the request, the Japan International Cooperation Agency (JICA) confirmed and signed on the scope of the preparatory survey of the Nam Ngum 1 Hydropower Station Expansion on 10 February 2009. This preparatory survey was carried out based on the scope of work agreed between JICA and the Lao PDR government.

1.2 PURPOSE OF THE SURVEY

The preparatory survey is being implemented to study the viability of the expansion of NN1 which is located in Nam Ngum River Basin (NNRB), about 65 km north of Vientiane. In the survey, the policy of the Government of Lao PDR on the implementation of the expansion of NN1 will be confirmed, and the implementation of expansion plan will be taken shape with source of Japanese fund.

1.3 SURVEY AREA

The study area consists of Lao PDR, Vientiane Province, NNRB, NN1 Hydropower Station and its surrounding areas, and the whole of the NNRB. The existing and planned substation(s) around Vientiane City are also included in the survey area.

1.4 COUNTERPART OF THE SURVEY

The main counterpart for the preparatory survey is the Electricite du Laos (EdL), with technical support from the Department of Electricity (DOE) of MEM. The NN1 Hydropower Station is under the control of EdL.

1.5 LOCAL SULETTING WORKS

In order to select the optimum expansion plan and implement the basic design for the selected plan, the topographic survey for surrounding areas of NN1 Hydropower Station and boring investigations along the waterways of each alternative expansion plan have been carried out. Regarding the downstream river stretch, the daily water level fluctuation due to peak operation by additional power generation may affect the water users in the downstream area. In order to confirm the scale of the impact of expansion of the power generation facilities, the river cross section survey and environmental investigation (IEE) were carried out.

1.6 STEERING COMMITTEE MEETING

In order to disclose information and achieve leveling of opinions on the scope of the preparatory works, processes and results of the survey, the steering committee was organized. The steering committee meetings were held to discuss the important issues and disseminate information. Members of steering committee are shown in following list:

1	Electricite du Laos
2	Department of Energy, Ministry of Energy and Mines
3	Department of Environmental and Social Impact Assessment, WREA
4	Department of Water Resources, WREA
5	Ministry of Public Works and Transport
6	Vientiane Provincial Office

The steering committee had joint meeting in February, June and November 2009 to discuss the study process and confirm the study results as follows.

1st	Presentation of Inception Report	February 2009
2nd	Presentation of Selected Optimum Expansion Plan	June 2009
3rd	Presentation of Draft Final Report	November 2009

CHAPTER 2 PRESENT SUTUATION OF POWER SECTOR

2.1 OUTLINE OF POWER SECTOR IN LAO PDR

Outline

Electricite du Laos (EdL) was established in 1959. At that time, EdL was an organization only having small scale generation sources and supplying electricity to French Base and a part of Vientiane city. The Nam Ngum 1 hydro power station (NN1) was constructed under the Nam Ngum Development Fund Agreement (1966) and its operation was has started in 1971 by EdL with the generation capacity of 30 MW.

From 1976 to 1979, the capacity of NN1 was extended to 110 MW and total generating capacity of the country became 122 MW. Thereafter, additional extension was performed in NN1 from 1983 to 1990 and the capacity became 150 MW in total. The units No.1 and No.2 were overhauled in 2003-04 by assistance of Japan's Grant Aid and the total capacity was up-graded to 155 MW.

Present Status and Organization of EdL

EdL is the national power entity which manages generation, transmission and distribution of electricity in whole Laos under the supervision by DOE and also manages power import and export.

As of 2007, there are about 560,000 customers in Lao PDR to which EdL is supplying power. Recent records show that the number of customer has drastically increased to about 2.5 times over past 10 years. Especially, the number of household customers has accounted for large portion in growth rate among all customers. EdL has 3008 employees as of 2008. Operation and maintenance of the existing power stations including the NN1 power station are conducted by Generation & Project Department of EdL.

Organization of Nam Ngum 1 Hydro Power Station

The administration system of the NN1 power station consists of nine departments. One of the departments is in charge of NN1 operation. The department for operation of the Nam Song Diversion exists in NN1. There are about 140 members of staff working in the NN1 organization.

2.2 PRESENT SITUATION OF ELECTRICAL POWER SUPPLY AND DEMAND

Total Energy Demand and Peak Demand in Lao PDR

As of 2007, peak power demand in Lao PDR reached 369 MW. Although the peak demand in 2007 in C1 area decreased a little to 203 MW from 217 MW in 2006, the growth rate from 1999 to 2007 shows almost 2.5 times and the average growth rate of peak demand is over 12%. In the same year, total generated energy reached 3,935 GWh/year in total. Excepting IPP generation, the total installed capacity was 330 MW and yearly generated energy was 1,640 GWh in 2007. The power import exceeded the export in gross energy in 2007.

Power Consumption by Power Sector

In 2007, the power consumption in industry sectotr accounts for 44% which recorded the largest portion in total consumption, and followed by 31% of households sector, 13% of enterprises and followed by sector of government office and foreign embassies. The power consumption in households which accounts for the largest in contracted number by sector also accounted for the largest consumption in total demand consumotion. But, in 2007, the demand consumption of industries has exceeded that of household and become the top in the list.

Present Situation of Power Interchange

Electricity interchange is being conducted with Thailand, China and Vietnam and the interchange with Thailand accounts for the largest volume in transaction. International power interchange with Thailand is conducted by EdL. For Sepon mining company in C2 area, electricity is purchased from EGAT and EdL pays electricity charge to EGAT and later collects the charge from the company.

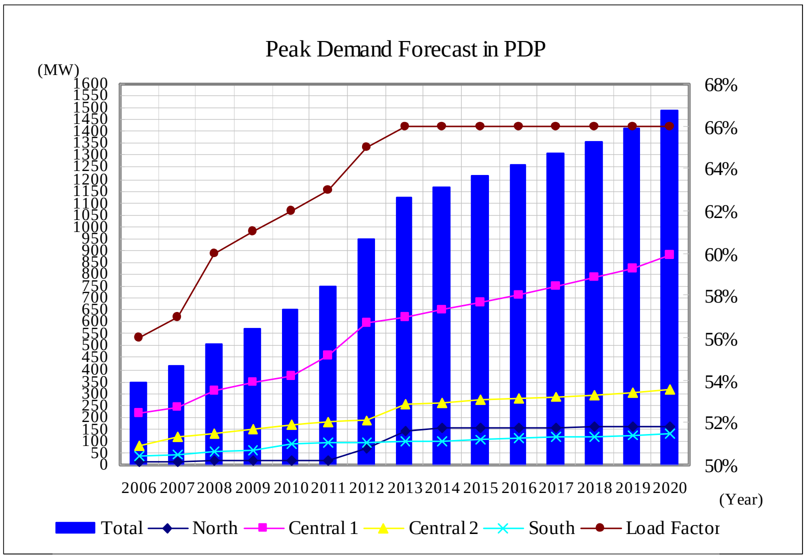
Since March 2, 2006, NN1 has been operated based on the TOU (Time of Use) operation pattern which are divided into two ranges, i.e. peak time and off-peak time. However, since the rule curve for reservoir operation is not revised yet from TOD (Time of Day) operation pattern, NN1 is currently operated based on a pattern close to TOD.

In import and export of electricity with EGAT, different tariffs have been applied for peak and off-peak times respectively. In regular power interchange with EGAT, the import unit price per kWh is set about 0.19 THB higher than the export unit price even though the import quantity is equal to export quantity in yearly total. Provided that import exceeds export in yearly total, another excess charge will be applied for the import price calculation. In calculation of the excess charge, the retail prices of power in Thailand is taken into consideration since major source of power in Thailand is thermal power stations. Then, the excess charge of the year is calculated using the induced unit excess tariff.

2.3 POWER DEMAND FORECAST

Power Demand Forecast in PDP

In the latest PDP, EdL projects future power demand until 2020 which totals provincial demands at substation points along with future large scale loads of plants and mining from 2007 to 2020. The applied method for demand projection in the latest PDP is the one that introduced in the previous study performed by JICA in 2002. The forecasting method is to calculate the power demand by province classified to households, industries, agriculture and services, and those are totaled together. If there is any change in the operation plans of large scale consumers, EdL updates the demand projection accordingly. The projection tends to be revised upwards.



Prepared by JICA Survey Team

Figure 2.1 Peak Demand Forecast in PDP

Generation Expansion Plan in PDP

According to the updated PDP (2007-2016) as of June 2009, by 2030, the aggregate installed capacity of the power stations excepting IPP plans for power export will increase to 2,375 MW from the present 258.7 MW in Northern and C1 areas. However, most of those future development plans account for IPP plans. This means that they are very susceptible to the economic conditions and so they have uncertain factors for realization schedule.

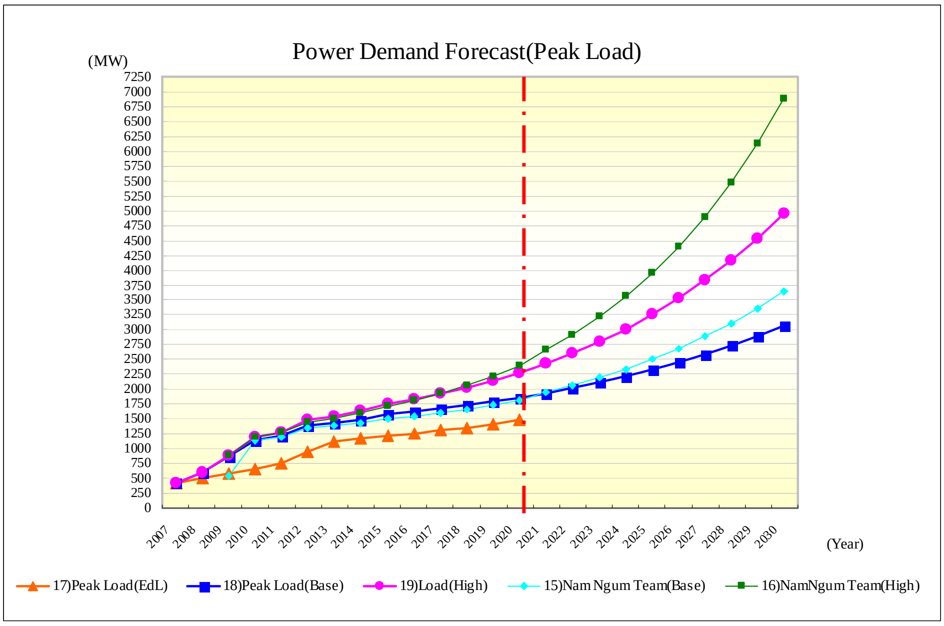
Power Demand Projection for Lao PDR

In another on-going JICA study “The Study on Power Network System Plan in Lao PDR” (The Network System Team), a method of power demand projection for whole Lao PDR is elaborated based on the macro-analysis of the relation between economic growth rate and electricity demand intensity, then a regression curve on the relationship between electricity demand intensity and GDP/capita. This method is regarded as reasonable in power demand projection. In this survey, the same method is applied for verification of existing power demand projection.

Power demand growth up to 2030 is examined by setting a base case as 7% and a high case as 9% in economic growth rate. In the Southern area, an aluminum refining plant named SLACO with about 1,000MW power load is to be operated from around 2014. If this load is considered in power demand projection, another scenario has to be introduced. But the load of SLACO is eliminated in this demand projection since this plant is in the Southern area.

The population growth rate up to 2020 was taken from the report of March 2005 census. The population after 2020 is estimated from the population data of United Nations. The value of transmission loss was set at 15% in 2020-2030. The load factor was assumed to gradually grow and reach 70% in 2030.

These results are shown in Figure 2.2. Large discrepancy from the projection by “The Network System Team” drawn by blue line and pink lines, especially demand growth after 2020 for the high rowth case. Use of different the population data virtually becomes the main reason of the discrepancy in demand.



Prepared by JICA Survey Team

Figure 2.2 Power Demand Forecast

It can be recognized that the discrepancy after 2023 in the projected peak demand is not so large between base cases. Provided that the growth rate is kept as 7% in GDP, the result of our projection is worked out. However, it seems unrealistic that the GDP keeps 7% annual growth until 2030 because of the economic recession nowadays. The demand growth would be saturated at around 2030 because GDP/per capita will be saturated at around 2030. Therefore, actual peak demand growth tendency will become closer to that of “The System Network Team”. Accordingly, this future peak demand value should be applied for the peak demand projection of North and C1 areas.

Power Demand Projection for North and C1 areas

Based on the peak demand value and the growth rate aforementioned, each regional demand in whole Lao PDR has been assumed after adding specific demand in each region after projection of future load of substations located in each province. This demand forecast will be used for projecting future daily load curves.

2.4 ANALYSES OF POWER SUPPLY AND DEMAND

General

In the power interchange with EGAT, the balance of interchanging volume between import and export has recently reversed, and the import volume exceeded export volume in 2006. Under circumstances of power transactions advantageous to EGAT, the domestic development of power sources is regarded as a prime task. However, the present power development plans mostly accounting for IPP project are susceptible to economic situations. Therefore, the development plans are prone to be delayed. In the expansion of NN1, it is important to properly grasp future demand and act properly in concert with the demand by working out an optimal operating pattern and to introduce the pattern to maximize benefit based on appropriate installed capacity.

Balance of Present Power Supply and Demand

The electric power for C1 area is supplied by NN1 (155 MW), Nam Mang 3 (40 MW) and Nam Leuk (60 MW), of which the respective outputs are mutually controlled so as to meet the demand pattern as much as possible. On the other hand, small-scaled hydropower station such as Namdon, Nam Ko and Namggay are supplying the power to decentralized small-scaled consumers in the Northern area. The data of 2008 shows that the the total domestic power output was insufficient in dry season and highly dependent on the power import from EGAT. In the rainy season, because EdL had surplus power, therefore the power has been exported to EGAT.

Present Daily Load Trend

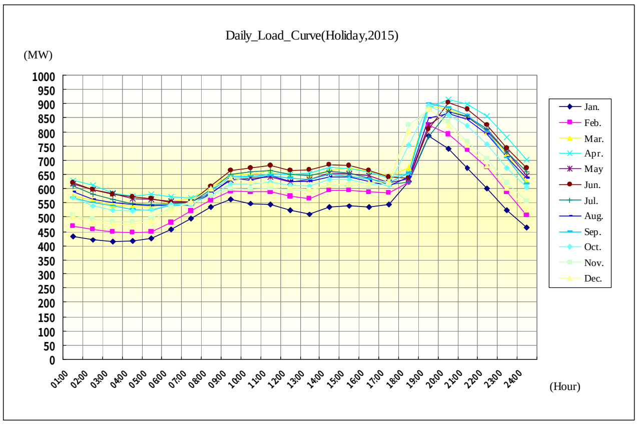
According to the daily load curve as of 2008, the daily peak load appears in night time in which much lamp load is consumed. On the other hand, a middle peak load appears in daytime because of the load of business and factory use. The daytime middle peak distinctively appears in week days, but in holiday high peak does not appear. The night peak demand summit is moving between 19:00 and 20:00 in dry and rainy seasons. The peak load of the dry season tends to emerge at 19:00 in January and in June at 20:00 differently, which show that the line shape of June is more moderate than that of January. The data from 2004 to 2008 shows that the peak loads are increasing every month.

Balance of Power Supply and Demand in Future

According to the relationship between power supply and demand until 2030, which are based on the latest PDP, the supplying capacity in C1 and Northern area could catch up with the demand around 2016 in the plan. However, most of these development plans are hydropower schemes which are highly influenced by rainfalls irrespective of run-of-river type or reservoir type. This is different from the thermal power plants. Accordingly, even in rainy season, it is sometimes impossible to keep generating at the installed capacity. Therefore, the average available output in rainy season should be set as about 50% of the installed capacity judged from a graph of probability curve projecting available amount of water. On the other hand, the average available output of the dry season could be set as about 30% of the installed capacity in the same manner. This result indicates that the total generated energy could not satisfy the demand even in 2015, which means that volume of import will still exceed that of the export.

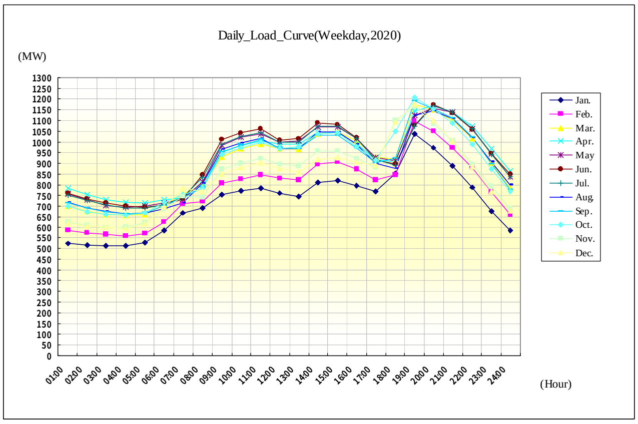
Assumption of Future Daily Load Curve Trend

Since no noticeable change has been recognized in the pattern of the daily load curves from 2004 to 2008, the pattern of future load curves has been assumed as keeping the same pattern as the past load curve. In order to work out the pattern of the future daily load curves, the past data were averaged and divided by past peak power value. Finally the daily load curves can be demonstrated applying the future peak demand in C1 and Northern area. Thus the load curves for monthly, weekday and holiday cases for 17 years from 2009 to 2025 have been analyzed. Figures 2.3 to 2.5 show daily load curves of weekday as of 2015, 2020 and 2025. It is the year 2015 that the extension of NN1 will be completed and will begin operation. The figure of daily load curve is presumed to show the same trend, therefore, the difference between the peak powers of off peak and peak time become larger.



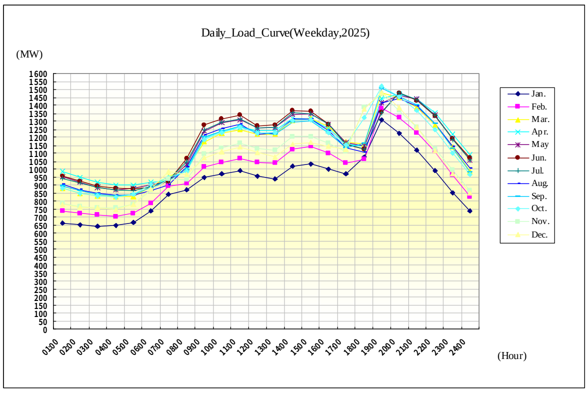
Prepared by JICA Survey Team

Figure 2.3 Daily Load Curve (2015)



Prepared by JICA Survey Team

Figure 2.4 Daily Load Curve (2020)



Prepared by JICA Survey Team

Figure 2.5 Daily Load Curve (2025)

CHAPTER 3 PRESENT CONDITIONS OF NN1 HYDROPOWER STATION AND NAM NGUM RIVER BASIN

3.1 PRESENT CONDITIONS OF NN1 HYDROPOWER STATION

Historical Power Generation of NN1 Hydropower Station

The Nam Ngum 1 (NN1) Hydropower Station started the generation of power in 1971. It was developed in the Nam Ngum River system with the largest reservoir in Laos with 7 billion m^3 capacity. The NN1 Hydropower Station has been expanded as the main power source for the metropolitan area (C1 area) and the present installed capacity is 155 MW. The plant factor of the power station was 66 % at the beginning, and it became 74 % due to the increase of inflow to the reservoir from the Nam Son diversion developed in 1995 at 65 m^3/s and the Nam Leuk Hydropower Project developed in 2000 at 15 m^3/s. The principal features of NN1 are shown in Table 3.1.

Table 3.1 Principal Features of the Nam Ngum River Basin andNN1 Hydropower Station

Feature	Data	Description
River Basin Area	8,460 km^2	Nam Ngum basin only (referred to Report in 1972)
Annual Average Inflow	382 m^3/s	Including inflows from Nam Song Diversion and Nam Leuk Hydropower Station (Average for 2001 - 2008)
Installed Capacity	155MW	Unit - 1, 2 : 17.5 MW x 2, Unit - 3, 4, 5 : 40 MW x 3
Reservoir Capacity	7.03 bil m^3	at W.L. 212.0 masl
Reservoir Area	370 km^2	at W.L. 212.0 masl
Dam Height	75 m	Concrete Gravity Type
Dam Length	468 m	-
Dam Volume	360,000 m^3	-

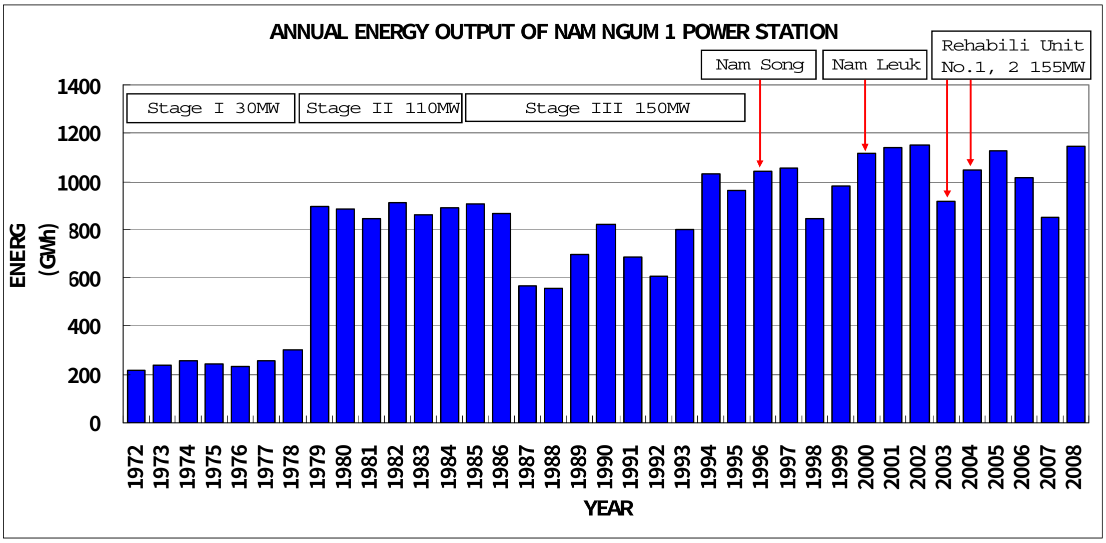
Prepared by JICA Survey Team

The NN1 Hydropower Station is being operated to meet the power demand in the C1 area by coordination with Nam Leuk Hydropower Station and Nam Mang 3 Hydropower Station commensurate to each capacity of power generation. The power generation of NN1 is being planned aiming at optimum reservoir management. The total power output and time period of power generation of each unit is decided on the basis of reservoir operation rule curve relative with its season and reservoir water level.

NN1 Hydropower Station

(1) Power Generation History

The power generation history of NN1 Power Station from 1971 up to now is shown in Figure 3.1.2. The NN1 has started its power generation with 30 MW installed capacity. Consequently, it was expanded up to 110 MW with additional 2 units of 40 MW in 1979. Then, in 1985, NN1 was expanded up to 150 MW, with an additional one unit of 40MW. Afterwards, the annual power generation was increased due to the increase of inflow into the NN1 reservoir from Nam Song Diversion in 1996, and diversion from Nam Leuk Hydropower Station in 2000. Furthermore, Units No.1 and No.2 were rehabilitated from 2003 to 2004, hence the total installed capacity became 155MW at present. The recent annual power generation ranges between 1,000 and 1,150 GWh except in drought year 2007.



Source: NN1 Hydropower Station

Figure 3.1 Historical Energy Output of Nam Ngum 1 Power Station

(2) Daily Load Curve and Power Generation Pattern

The NN1, Nam Leuk and Nam Mang 3 Hydropower Stations are all hydropower stations. They generate power in full capacity in rainy season and with limited power generation during the dry season due to less inflow into the reservoir. The total power output of the three power stations in rainy season is 275 MW with full capacities and it exceeds the daily load curve for 24 hours. In this case, the surplus of generated power is exported to Thailand.

The NN1 Hydropower Station is operated to meet each power demand in off-peak, day peak and night peak times as much as possible. However, the total power output of the three power stations falls below the daily load curve for some hours. In this case, the power shortage is supplemented with power import from Thailand. However, the amount of import power from Thailand is limited to 100 MW due to the capacity of power transmission of the existing system in Thailand. Therefore, the NN1 is required to operate to meet the power demand as shown in the daily load curve to minimize as much as possible getting the power supply imported from Thailand. The daily load will increase with similar load curve pattern year by year. The power demand in off-peak time is expected to be covered with the new hydropower development plan such as domestic IPP in the PDP, and the power demand of night peak time should be covered with NN1 Power Station with expansion because it has high capability of flexible control of power output with its huge reservoir.

Maintenance of NN1 Hydropower Station

The regular maintenance of the generating equipment is carried out once a year in dry season within 20 days for Units No.1 and No. 2 and 30 days for Unit Nos. 3 to 5. Units No.1 and No.2 were refurbished in 2003-04. On the other hand, Units No.3 and No.4, which have not undergone any overhaul since commencement of power generation in 1979, are scheduled to have overhaul in dry season of 2010 and 2011, respectively. The Unit No.5, which started the power generation in 1985, received the overhaul from mid-February to mid-June 2009.

Although all power generation units undergo yearly maintenance, the chance to undergo major rehabilitation works is quite limited. It is important to develop a plan and budget appropriation for the proper and adequate maintenance works for Units No.1 to No.5 to maximize the economic life of the infrastructure in Laos. If the NN1 Hydropower Station has an additional power generation unit, the operation ratio of existing power generation units will be lowered and the arrangement of maintenance schedule for the existing five units would be easier than the present conditions. Further, due to reduction of the operation ratio of existing power generation, the frequency of repair of consumable parts of generation units will be decreased and the yearly maintenance cost will also be reduced.

3.2 PRESENT CONDITION OF HYDROPOWER DEVELOPMENT PLAN IN NNRB

In the NNRB, many hydropower development plans are in process aiming at effective utilization of plentiful rainfall and river flow. There are several big IPP projects for the power export to Thailand, which are under construction or planning. On the other hand, the domestic IPP project for domestic power supply is also on going. These hydropower development plans are classified into two groups which consist of the projects located in the upstream area of NN1 and the projects located on the neighboring rivers having possibility of coordinating with the NN1's generation.

Hydropower Development Plan in Upper NNRB

The project features of hydropower project located upstream of NN1 Dam are summarized below.

Table 3.2 Project Features of IPP Project Located in the Upstream of Nam Ngum 1 Dam

Items＼Project	Nam Ngum 2	Nam Ngum 3	Nam Ngum 4	Nam Ngum 5	Nam Bak 1	Nam Bak 2
Purpose	IPP (e)	IPP (e)	IPP (e)	IPP (d)	IPP (e)	IPP (d)
Status	Under construction	Under PPA negociation	Pre-F/S	Under construction	Pre-F/S	Pre-F/S
Main Developer	Southeast Asia Energy Limited	GMS Power	Saigon Invest Group	NN5PC	Southeast Asia Energy Limited	Southeast Asia Energy Limited (Thailand)
Planed Commecement of Power Generation	2011 January	-	-	2011	-	2016
Principal Feature						
Catchment area (km^2)	5,640	3,888		483	597	320
Storage at FSL (MCM)	6,774	1,407		314	250	190
Avarage annual inflow (MCM)	6,270	3,090		719	750	400
Type of dam	CFRD	RCC		RCC	RCC	RCC
Dam Height (m)	181	220	125	99	83	85
Design flood of spillway (m^3/s)	10,855	7,900		3,231	1800	963
Powerhouse	Above ground	Underground		Semi-ground	Semi-ground	Semi-ground
Rated output (MW)	615	440	185	120	115	68
Avarage annual energy (GWh)	2,310	1,919	748	400	600	357

Prepared by JICA Survey Team

The impact from each development plan to the NN1 Hydropower Station is explained as follows:

(1) Nam Ngum 2 Hydropower Project

The Nam Ngum 2 (NN2) Hydropower Development Project is under construction at the upstream of the Nam Ngum 1 reservoir, aiming to commence the power generation beginning 2011. The project has a concrete-faced rockfill dam of 181 m in height. The installed capacity is 615 MW and all the generated power will be exported to Thailand on the basis of the PPA with EGAT. The catchment area of NN2 is 67% of NN1 and the effective reservoir volume is 2,994 MCM. Therefore, once NN2 is commissioned, the seasonal fluctuation of inflow into the NN1 reservoir will be considerably flattened due to reservoir storage effect.

(2) Nam Ngum 3 Hydropower Project

The Nam Ngum 3 (NN3) hydropower development project is planned at the further upstream of NN2 project site and the catchment area is 69% of NN2. Although the detailed design of the project has been completed, the timing of commencement of power generation is not yet fixed because the PPA was not finalized between the developer and EGAT. The effective storage volume of NN3 reservoir is 979 MCM, which is 33% of the NN2 reservoir. It is expected that the river flow downstream of the NN3 reservoir will be regulated compared to NN3 before construction.

(3) Nam Ngum 4 Hydropower Project

The Nam Ngum 4 (NN4) hydropower development is planned at still further upstream of the NN3 project site and the Pre-FS has been carried out. The project site and construction schedule have not been fixed yet. It is expected that the NN4 project will also regulate the river flow of Nam Ngum River and it will affect the future inflow into the NN3 reservoir.

(4) Nam Ngum 5 Hydropower Project

The Nam Ngum 5 (NN5) hydropower project is under construction at the Nam Ting River which is the right tributary located upstream of the NN3 project site. The RCC dam, 99 m in height, will be constructed and power generation is scheduled to start in 2011. The catchment area is 413 km^2 and the effective storage volume of the reservoir is 314 MCM. It is less than 10% of the scale of NN2 hydropower project. Although the installed capacity is 120 MW, the power output generated in the dry season is limited to 45 MW. The change of river flow pattern due to NN5 hydropower project does not seem to affect the inflow into the NN1 reservoir because of the size of reservoir of NN5 and the distance between NN5 project site and NN1 reservoir.

(5) Nam Bak 1 Hydropower Project

The Nam Bak 1 (NB1) hydropower project is planned at Nam Bak River, which is the left tributary of Nam Ngum River, by the same developer of NN2. The RCC dam of 83 m in height will be constructed and the installed capacity is 115 MW. The purpose of this power generation is to export power to Thailand. It is planned to have a cascade hydropower development with the Nam Bak 2 hydropower project to be developed at the upstream of NB1.

In the NB1 hydropower project, the river flow of Nam Bak River will be diverted into Nam Ngum River just at the downstream side of NN2 power station. Since the inflow into Nam Ngum River from Nam Bak River will be regulated by the NB1 hydropower project, the total seasonal inflow into NN1 reservoir will not change drastically because of the huge inflow released from NN2.

(6) Nam Bak 2 Hydropower Project

The Nam Bak 2 (NB2) hydropower project is planned at the upstream of NB1 project site by the IPP developer of NN2. The RCC dam of 85 m in height will be constructed and the installed capacity is 68 MW. The generated power will be supplied to C1 and north area for domestic consumption. It is planned to have a cascade hydropower development with the Nam Bak 1 hydropower project to be developed at downstream of NB2.

The inflow into NB2 reservoir will be regulated and re-used in NB1, and finally flow into NN1 reservoir finally. The pattern of inflow into NN1 reservoir will not be changed so much throughout the year because of the development of NB2 too.

Hydropower Development Plan for Domestic Power Supply around NNRB

The project features of hydropower projects located near the Nam Ngum River Basin and related to NN1 with regards to coordination of power generation are summarized in Table 3.3.

Table 3.3 Project Features of Hydropower Project Related with NN1 Power Generation

Items＼Project	Nam Leuk	Nam Mang 3	Nam Lik 1/2	Nam Lik 1
Purpose	IPP (d, e)	IPP (d, e)	IPP (d)	IPP (d)
Status	Existing	Existing	Under construction	F/S
Main Developer	EdL	EdL	China International Water & Electric Corp.	Hydro Engineering Co.
Planed Commecement of Power Generation	2000	2004	2010	2011
Principal Feature				
Catchment area (km^2)	274	65	1,993	5,050
Storage at FSL (MCM)	154	45	1,095	61.3
Avarage annual inflow (MCM)	438	-	2,690	5,786
Type of dam	Rockfill	RCC	CFRD	Rockfill
Dam Height (m)	46.5	22	101.4	21
Design flood of spillway (m^3/s)	2,100	57	2,080	9,150
Powerhouse	Above ground	Above ground	Above ground	Above ground
Rated output (MW)	60	40	100	61
Avarage annual energy (GWh)	230	134	395	249

Prepared by JICA Survey Team

Regarding the hydropower projects which consist of two existing power plants, one project under construction, and one project in planning stage and the relation with NN1 power generation is summarized as follows:

(1) Nam Leuk Hydropower Project

Dam and reservoir of the Nam Leuk hydropower project are located on the Nam Leuk river which is the left tributary of the Nam Mang river which drains into the Mekong river. The river flow of Nam Leuk river is being diverted from the upstream end of Nam Leuk reservoir to Nam San river which is located in the NNRB. The dam is 46.5 m high concrete dam. Generation capacity is 60 MW with water head of 181 m. The power generation started in 2000. By diversion from Nam Mang river basin to NNRB, the inflow into NN1 reservoir increases by 15 m^3/s on the average and the annual energy production at NN1 Hydropower Station has also increased.

The Nam Leuk Hydropower Station is generating power to supply to the C1 and northern areas to complement with NN1 and Nam Mang 3 Hydropower Stations. The power generated at the Nam Leuk Hydropower Station is supplied to the surrounding area first and the excess electricity is supplied to the Vientiane City through the NN1 Hydropower Station.

(2) Nam Mang 3 Hydropower Project

The Nam Mang 3 (NM3) hydropower project is located at the Nam Gnong River, which is the most upstream tributary of Nam Mang River. The water of Nam Gnong River is diverted from the upstream end of Nam Mang 3 reservoir to Nam Ngum River, which is located in the downstream NNRB, with a RCC dam 22 m in height. The installed capacity is 40 MW and the power generation started in 2004. While the main purpose of this diversion scheme was hydropower generation, the released water used for the power generation is being supplied for the 2,900-ha paddy field for multipurpose water use. The Nam Mang 3 hydropower station is supplying electricity to cover the domestic power demand in cooperation with NN1 and Nam Leuk hydropower stations. The size of the reservoir is small and the power output in the dry season is limited to less than half of the installed capacity.

(3) Nam Lik 1/2 Hydropower Project

The Nam Lik 1/2 hydropower project is located at the Nam Lik River, which is the right tributary of Nam Ngum River. The confluence of Nam Lik River with Nam Ngum River is about 3.5 km downstream from NN1 hydropower station. The river flow will be stored with the concrete-faced rockfill dam (CFRD), 101 m in height. The hydropower station is located at the downstream of the dam and generates power of 100 MW. The Nam Lik Hydropower Station is under construction aiming to commence the power generation in the first half of 2010.

The generated power will be supplied to the domestic demand center on the basis of PPA with EdL. Since the effective reservoir volume of Nam Lik 1/2 is 1,095 MCM which is quite bigger than Nam Leuk and Nam Mang 3 Hydropower Stations, it has the possibility to be main power source for domestic power supply in the future, similar to the NN1 Hydropower Station. There is possibility of that the Nam Lik 1/2 will be operated under coordination with NN1 because of its huge size of the reservoir.

(4) Nam Lik 1 Hydropower Project

The Nam Lik 1 hydropower project is planned as run-off river type at the downstream of the confluence of the Nam Lik River and Nam Song River. The height of concrete dam will be 21m and the generating capacity will be 61 MW. The F/S is already completed and the commencement of the power generation is planned in 2011. The Nam Lik 1 dam will receive water from the Nam Lik River regulated at Nam Lik 1/2 reservoir and the flow from the Nam Song River. The river flow of Nam Song is being limited to small volume due to the Nam Song Diversion which diverts the river flow to NN1 reservoir since 1996.

Outline of "Nam Ngum River Basin Development Sector Project"

The Nam Ngum River Basin Development Sector Project was implemented aiming to conform with the integrated water resources management plan (IWRM) of NNRB, which was co-financed by ADB and AFD. The project consists of three components, ie., 1) Strengthening the capacity of the Water Resources Coordination Committee (WRCC), 2) Development of a river basin model for the Nam Ngum-1 reservoir to optimize power generation, mitigate floods, and improve water use efficiency in the Basin and 3) Improvement of watershed management by strengthening the capacity of rural communities and concerned government departments.

As the results of confirmation of the final report of 「Nam Ngum River Basin Development Sector Project, the possibility of the analysis for optimum reservoir management by PERCIFAL is explained. However, the concrete proposal for the optimum reservoir management in the future is not mentioned. Therefore, the JICA Survey Team carried out the "NN1 Reservoir Management Plan" and "Optimum Reservoir Management Plan of the NNRB" by using the original program developed in this preparatory survey.

CHAPTER 4 PURPOSE AND OPERATION POLICY OF EXPANSION OF NAM NGUM 1 HYDROPOWER STATION

4.1 CIRCUMSTANCES OF NN1 HYDROPOWER STATION

Growth of Night Peak Power in Daily Load

The recent increase in the night peak power is growing every month. During weekdays, peak power is drastically increasing not only at night time but also in the daytime, with the latter gradually reaching the night time peak demand. The future demand projection presumes that this tendency will last for the time being. In addition, there is a risk that some supplying restriction or power outage is forced for Lao PDR due to reasons of power exporting country such as accident in the country. Accordingly, in terms of enhancing power security, it is expected that EdL would supply as much possible power required in Lao PDR from their power stations. It is expected that NN1 will assume the role of supplying the power to cover the peak demand on a priority basis.

Effect on River Flow Condition due to Hydropower Development in Upstream NNRB

The NN1 Hydropower Station generates power since 1971. The annual energy production was increased by additional inflows into NN1 reservoir which consist of Nam Song Diversion in 1996 and implementation of Nam Leuk Hydropower Project in 2000. Although there is some variation between wet and drought years, the annual power generation has increased gradually. In addition, several hydropower development plans with dam construction are in progress and as first one of these plans, the Nam Ngum 2 Hydropower Project will commence power generation for export to Thailand in 2011. The inflow into NN1 reservoir will be regulated throughout the year due to storage function of NN2 reservoir. As a result, the power generation of NN1 Hydropower Station at a relatively higher reservoir water level will be possible and the inefficient water release through the spillway will be decreased. The annual power generation is expected to increase by 6% on the average.

Considering such inflow condition after 2011, the NN1 Hydropower Station is being planned to be expanded aiming at more efficient water usage. In this expansion, the new rule curve for the reservoir operation with additional power generation facilities will be studied to seek the effective use of river water.

For the time being, the NN1 Hydropower Station is affected by the commencement of the power generation of NN2. After that, the Nam Ngum 5, Nam Ngum 3 and Nam Ngum 4 are scheduled to be developed in the near future and the total storage function of the upstream area of NNRB will be enhanced. This means that the power generation capacity of NNRB will increase efficiently and it will contribute to the expansion of the power generation capacity in Laos.

In this preparatory survey, the Survey Team confirmed the study concept of prior implemented "Nam Ngum River Basin Development Sector Project" (NNRBDSP) funded by ADB and AFD, and selected the optimum expansion plan through the effective utilization of data collected from the NNRBDSP.

Aging of Existing Power Generation Facilities and Maintenance Schedule

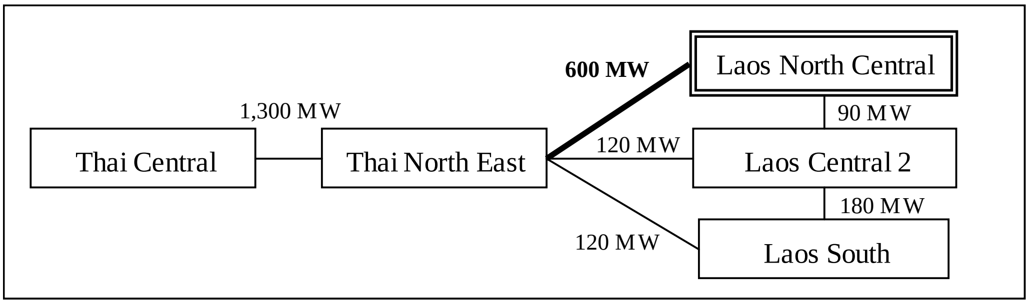
The purpose of the expansion of NN1 is to provide adequate power supply during night peak demand of the future daily load curve by shifting the power generation pattern from off-peak time to peak time. On the other hand, the increase of annual power generation due to the relatively higher reservoir water level and reduction of the inefficient water release through the spillway is realized by commencement of the power generation of NN2 in 2011 and it may be considered as benefit from NN2 project. For the expansion of NN1 Hydropower Station in 2015, the same kind of benefit can be counted.

However, the increase of annual power generation due to regulated inflow into NN1 reservoir from NN2 means that the operation ratio of power generation facilities increases throughout the year. As a result, the time period allocated for the yearly maintenance which is carried out during the dry season at present will be shortened. According to the information from the staff of the NN1 Hydropower Station, it is necessary to ensure sufficient period for adequate maintenance of NN1 power generation facilities which are very important infrastructure in Lao PDR.

The Survey Team will therefore evaluate the indirect benefits such as decrease of frequency of repairs in the future and prolonged economic life of the power generation facilities.

Transmission Interchanging Capacity with Neighboring Country

Based on the present power development plan, transmission interchanging capacity as of 2016 is shown in Figure 4.1, At present, the capacity for power interchange is limited to 100MW, but in 2016, the total capacity of power interchange is expected to become about 600MW in the northern and C1 areas. At the same time, interchanging capacity between the C1 and C2 areas will be about 90MW. It is important for NN1 to supply the generated power at a possible high price. Furthermore, it is necessary to grasp the future transmission network configuration because the development progress will highly affect the economical efficiency of power supply and demand analysis.



Source: The Study on Power Network System Plan in Lao People's Democratic Republic

Figure 4.1 Power Interchange in 2016

4.2 PRINCIPLE FOR OPERATION OF NN1

General

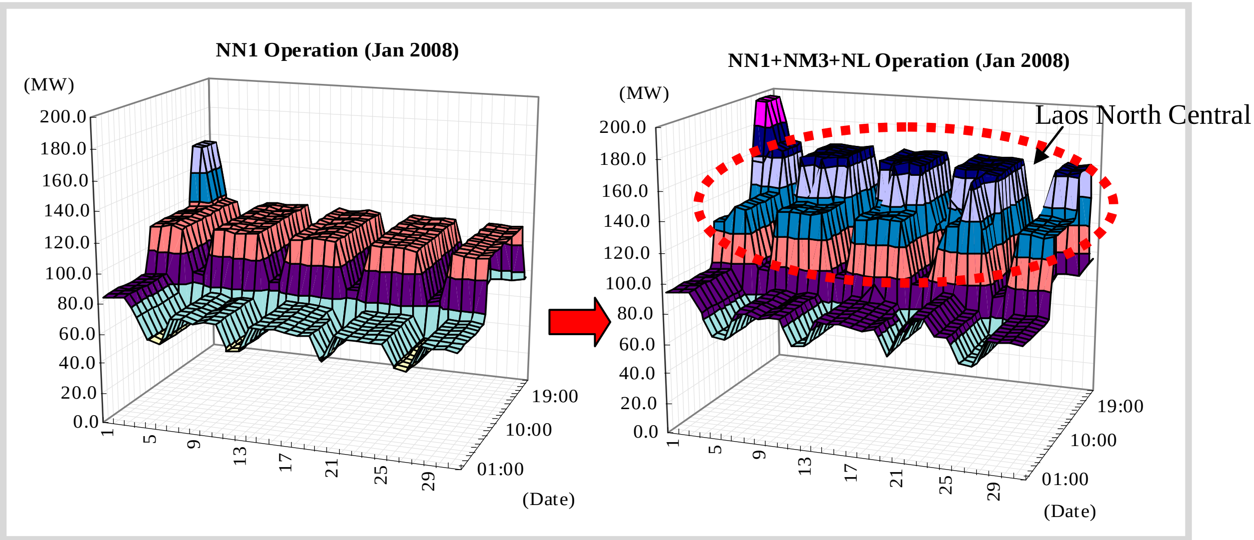
The top priority expected for NN1 operation will be given to satisfy the domestic power demand of the northern and C1 areas. Given that the transmission network of the C1 area will be connected to the C2 area in the future, it is expected that the power supply for the C2 area will likewise be covered.

Moreover, one of the prerequisites for the operation policy of the expanded NN1 in the future is to maintain its function as the important power station for the power supply to the capital area with sufficient reliability. On the other hand, the maximization of economic benefits should be sought in drawing up the operation plan.

At present, the operation plan of NN1 is made for two patterns: one for weekdays and the others for holidays, referring to the latest recorded load patterns. The projection of operation patterns for week day and holiday cases are often referred to the recorded load of the previous week. In drawing up the operation plan, power generation for night peak should be the first priority, and daytime peak and off-peak is the second priority and the third priority, respectively. The plan should be based on the Rule Curve determined by the available volume of water. This methodology to be applied is reasonable in terms of the present tariff rates of import and export, but it is necessary to review the operation plan according to the revision of the conditions based on the PPA, which will be revised in the future.

<u>Present Operation Pattern</u>

Figure 4.2 shows the present dry season operation patterns of NN1, NM3 and NL power stations (as of January 2008). NN1 follows the TOU operation which is separated into two ranges of off-peak and peak, based on the PPA with EGAT. The shortage of power is expected to be supplemented by NM3 and NL, but the power stations only have small capacity of reservoirs. Even with the addition of NM3 and NL power generation in the dry season, the power supply of the three main power stations cannot meet all the power demand requirements.



Prepared by JICA Survey Team

Figure 4.2 Operation Records in Jan. 2008 (Dry Season)

On the contrary, in the rainy season, it was found out that NN1 is operated to its maximum capacity determined by the volume of available water irrespective of the off-peak and peak time ranges. Similarly, NM3 and NL have been operated at maximum capacity level following the available volume of water for generation. During the rainy season, the surplus power generated can be exported. Figure 4.3 shows the present rainy season operation patterns.

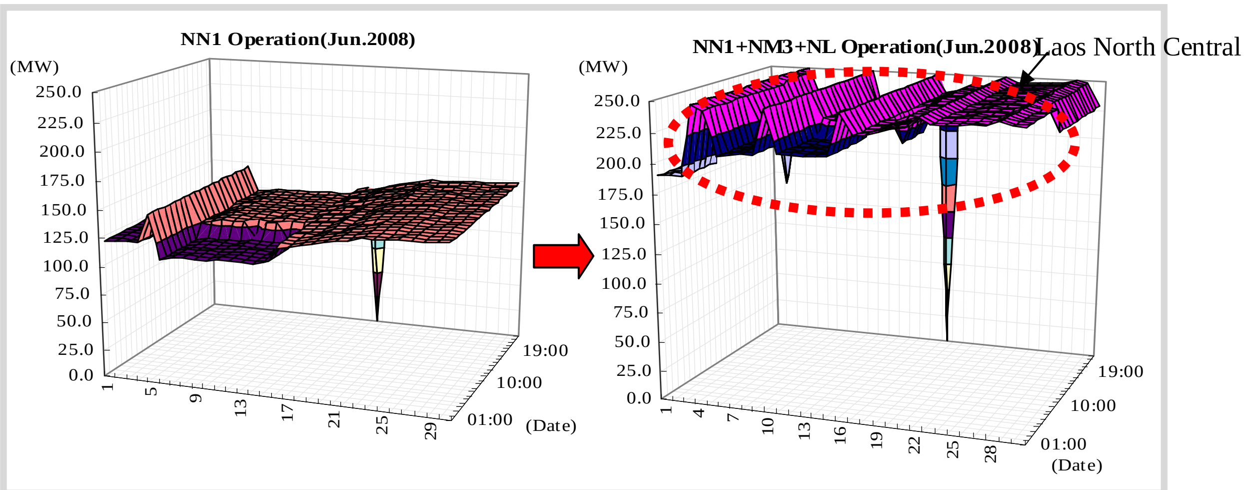


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Figure 4.3 Operation Records in June 2008 (Rainy Season)

Study of Operation Pattern in 2015

For the graph of the daily load curve studied before, an available volume of water necessary for the output of 40 MW of the candidate capacity has been allocated according to the order of the supply priority for the night and daytime peaks so as to maximize the economic benefits while maintaining the minimum water level in the downstream. As a result, regardless of the rainy and dry seasons, the supply capacity cannot satisfy the total annual demand requirements in the year 2015. In this situation, given that economic benefit is taken, it is prerequisite to operate generators based on the import tariff with EGAT.

- Operation pattern in order to catch up with the peak demand in the peak time wherever possible.
- Operation pattern so as to increase the generated power output in off-peak time as well as in peak time. The pattern suppresses the peak imported power of the month that records the highest power consumption assumed in the dry season in order to reduce the excess charge in the status of imports over exports.

As the hydropower stations other than NN1 in the C1 area will be operated for the daily base load, the operation patterns shown in Figures 4.4 and 4.5 will be the best:

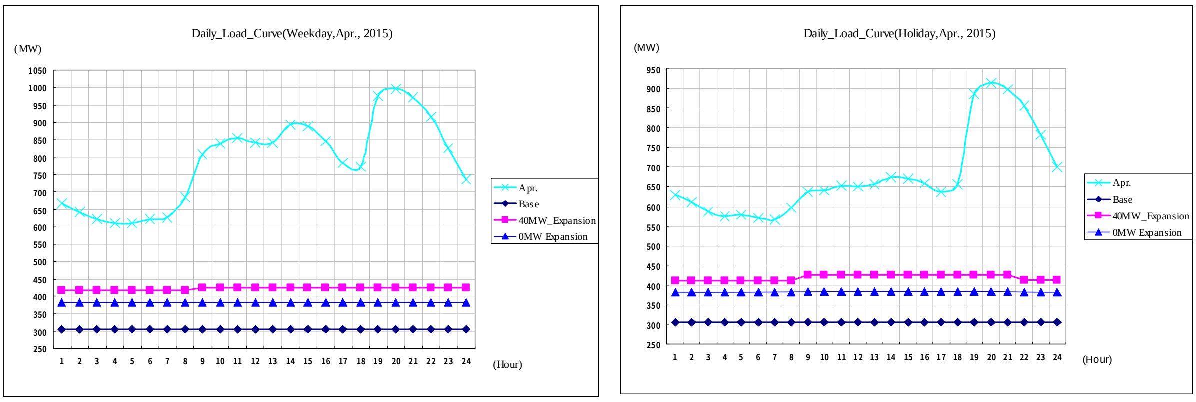

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Figure 4.4 Expected Operation Pattern in Apr.2015

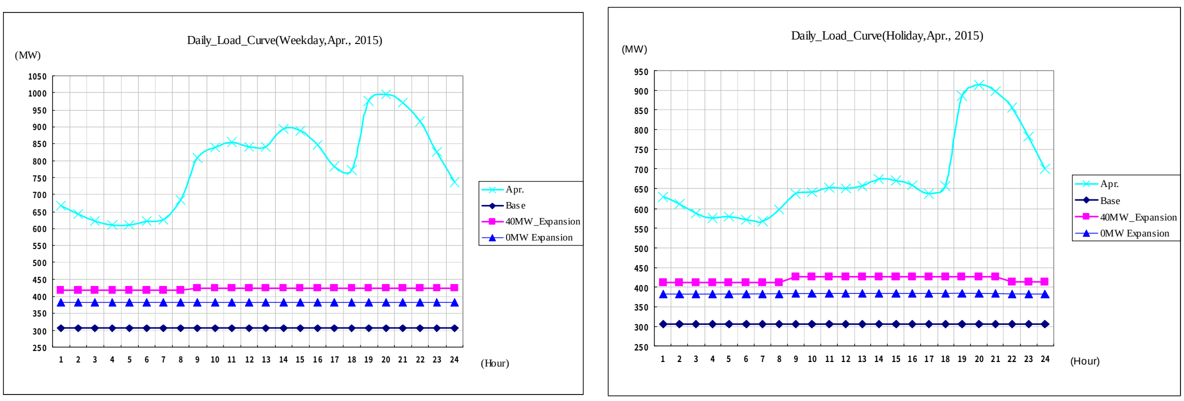

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Figure 4.5 Expected Operation Pattern in Sep.2015

Study of Operation Pattern in 2020

Figures 4.6 and 4.7 show the operation patterns anticipated for 2020. The same method as that of 2015 has been applied for 2020 for the projection of the curve, and the power stations other than NN1 are assumed as power stations for the base load in this stage of the Survey. In the dry season, the generated available output is not expected to meet the peak power. On the other hand, in the off-peak time of the season, there could be some surplus power supply for export. It is suggested that minimizing volume of the import rather than supplying the power for export in off-peak time can make a greater economic benefit. Basically, surplus electric power in the off-peak time should be supplied to the C2 area within a capacity of at least 90 MW as much as possible. In addition, in order to know the comprehensive operational patterns in the whole area, it is important to know the patterns taking into account the flexibility of the output in the operation of relatively large-sized power stations such as Nam Mang 3 and Nam Leuk, along with Nam Ngum 1 for both dry and rainy seasons.

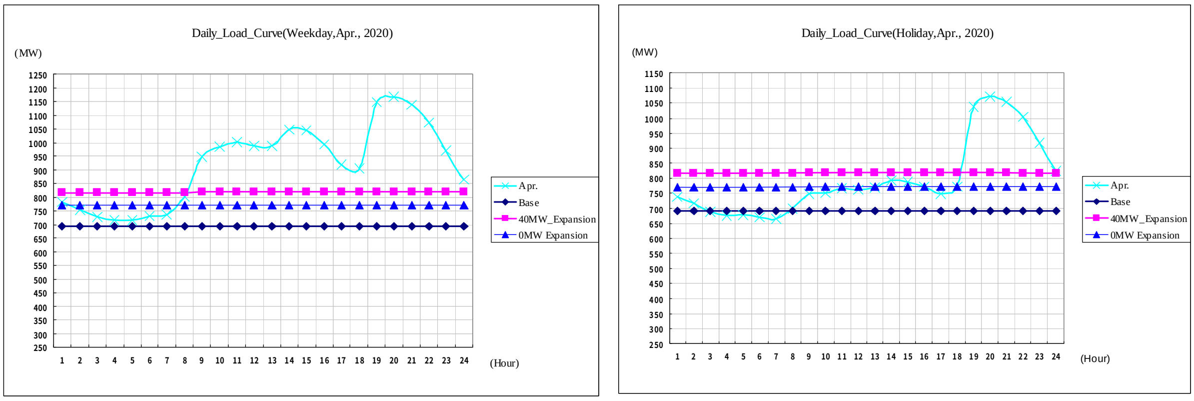

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Figure 4.6 Expected Operation Pattern in Apr.2020

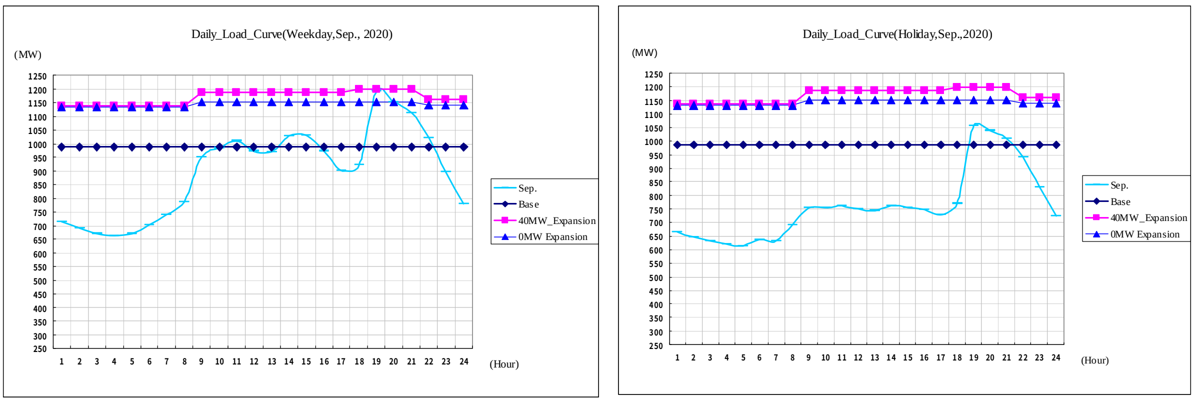

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Figure 4.7 Expected Operation Pattern in Sep.2020

Study of Operation Pattern in 2025

As of 2025, the power demand after the year 2020 is assumed to be drastically increasing. Especially in the dry season, power supply capacity will have difficulties in satisfying the power demand requirements. On the other hand, in the rainy season, except for night peak time, the supply capacity can satisfy the demand for its service area. In the present network plan in Lao PDR, part of the power supply surplus generated in off-peak time can be allocated for the supply to the C2 area within a network capacity of 90 MW. However, most of the generated power in off-peak time will be allocated for export. In terms of the capacity of the network and power interchange tariff with EGAT, the generated power in off-peak time should be shifted to night peak time, given that the agreement with EGAT is continuously applied in accordance with the present PPA. However, in 2025, the network capacity in the C2 area is expected to be strengthened by developing transmission line network across Lao PDR. Essentially, most of the surplus power generated in off-peak time is expected to be supplied for adjacent areas including C2.

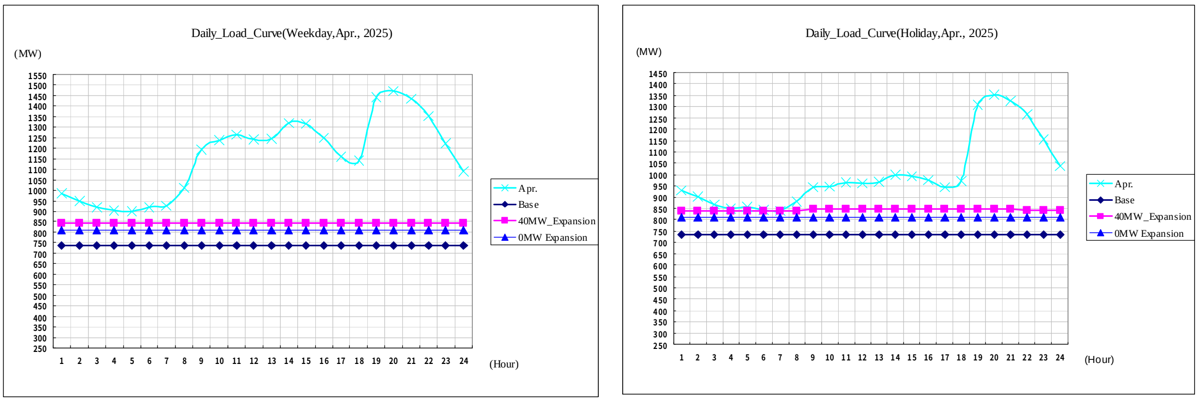

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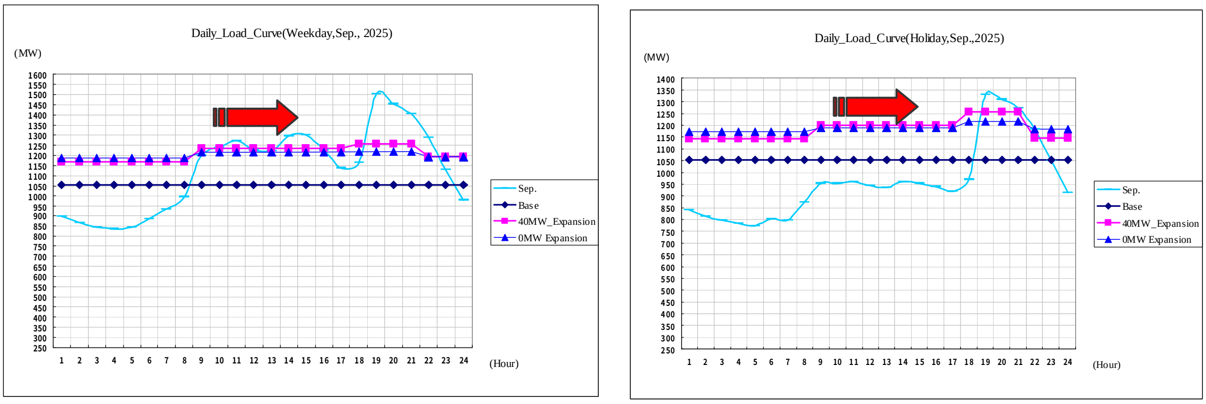
Figure 4.8 Expected Operation Pattern in Apr.2025



Prepared by JICA Survey Team

Figure 4.9 Expected Operation Pattern in Sep.2025

4.3 POLICY OF POWER TRANSMISSION

System Configuration around Nam Ngum 1 Hydropower Station

(1) Current Situation of System around Nam Ngum 1 Hydropower Station

As shown in Figure 4.10, five circuits of 115 kV transmission lines are connected at Nam Ngum 1 Hydropower Station as of 2009. Four circuits of the above lines are connected as power supply line to the Vientiane Municipality, including the C1 area. Another single circuit is the interconnection line between Nam Ngum 1 Hydropower Station and Nam Leuk. In case either one of the generators of the two power stations becomes in faulty condition, this interconnection line will be operated in order to make up for the power supply, which shall be generated by the fault power station. Two circuits of the four circuits that supply to the Vientiane Municipality are connected to Naxaythong S/S which is located about 61km from Nam Ngum 1 P/S, and supply power to Phontong S/S in Vientiane via Naxaythong S/S. The other two circuits are connected to Thalat S/S which is located about 5 km from Nam Ngum 1 P/S and also supply power to Phontong S/S via Phon Soung S/S. Phontong S/S and Thanaleng S/S are interconnected with the system of EGAT. Surplus power supply of Phontong S/S and Thanaleng S/S are exported to Thailand through the interconnection line of EGAT.

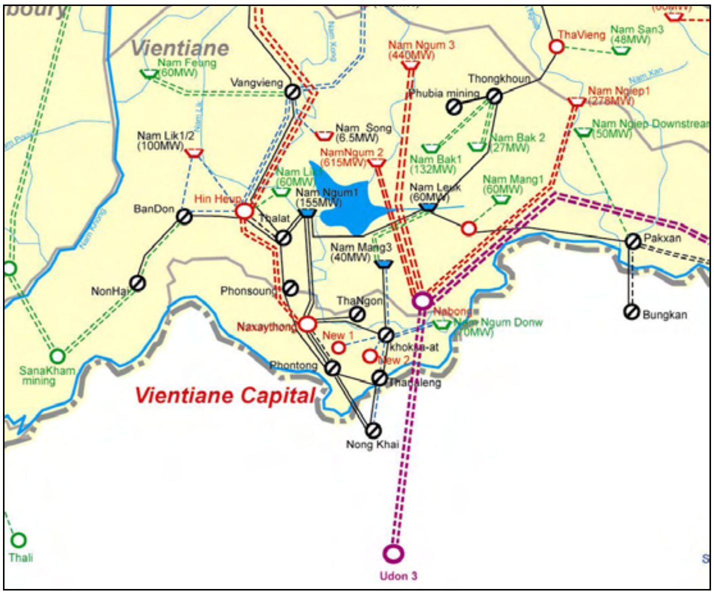
A single circuit of 115 kV transmission line leaving from Thalat S/S goes to Luang Prabang S/S over 212 km via Vangvieng substation. The line leaving from the Xieng Ngen switching yard is connected to the Xayaboury substation. The other single circuit line leaving from the Thalat substation is connected to the Non Hai substation via the Ban Dong substation.

Source: System Planning Office, EdL

Figure 4.10 System Configuration of C1 Area, Vientiane Municipality, 2009

(2) System Configuration around Nam Ngum 1 Hydropower Station after Expansion

The system configuration in 2016 around Nam Ngum 1 P/S after the completion of the expansion of Nam Ngum 1 Hydropower Station is shown in Figure 4.11.



Source: System Planning Office, EdL

Figure 4.11 System Configuration of C1 Area, Vientiane Municipality, 2016

The system configuration of the 115 kV transmission line around Nam Ngum 1 P/S will not be changed in 2016, and there is no plan for the additional transmission line from Nam Ngum P/S to the Vientiane Municipality. Generated power of Nam Lik 1/2 will be supplied to the Vientiane Municipality by a 230kV transmission line, which will be constructed from Hin Heup S/S to Naxaythong S/S by 2011. Surplus power of Nam Leuk P/S and Nam Mang 3 P/S will be supplied from the C1 area to the C2 area by 115 kV transmission line which will be connected from Pakxan S/S to Pakbo S/S via Thakek S/S.

Although Thalat S/S is presently supplying power to Vanvieng S/S and Ban Don S/S, all power supplied from Nam Ngum 1 to Thalat S/S will be supplied to Vientiane in 2016, since hydropower stations will be actively constructed in the northern area.

Fundamental Technical Criteria and Study Conditions

Basically, the power system of EdL is to be planned so as to maintain appropriate system voltage and fault current level, without causing power outage for Laos's domestic power demand. EdL's technical criteria for power system planning are described below.

(1) Power Flow

1) Under normal operation, loads of transmission lines and transformers shall be within their rated capacities.

2) In case of a single circuit fault for the section with more than double circuits, the power flow of the remaining facilities shall be within the rated capacities.

3) Power transmission from the generators with single circuit transmission line is allowed when the generator rejection is not significant in case of a single circuit fault.

4) In case of a single fault of a 115/22 kV transformer, the loads of the remaining transformers shall be within 110% of the rated capacities.

5) In case of a single fault of a 230/115kV transformer, the loads of the remaining transformers shall be within the rated capacities after reducing the power export to Thailand by restricting the specified power outputs of generators.

(2) System Voltage

1) Under normal operation condition, the bus voltage in the transmission system shall be within the range from 95% to 105% of the nominal voltage. In case of a single contingency, bus voltages shall be within the range from 92% to 108% of the nominal voltage.

2) The power factors of generators shall be between 90% (leading) and 85% (lagging).

(3) Fault Current

Based on the system planning standard of EdL, the fault current of the transmission system shall not exceed the maximum fault current shown in Table 4.1.

Table 4.1 Allowable Maximum Fault Current

Voltage Level	Maximum Fault Current
230 kV	40 - 50 kA
115 kV	25 - 31.5 kA
22 kV	25 - 31.5 kA

Prepared by the JICA Survey Team

(4) Stability

1) Power system stability shall be maintained without restricting the generation output of the principal power plants or interrupting the power supply to the demand in case of a permanent three-phase short circuit fault, after clearing the fault by main protection relays, not considering any reclosing operations.

2) Fault clearing times by main protection relays are shown in Table 4.2.

Table 4.2 Fault Clearing Times by Main Protection Relays

Voltage Level	Maximum Fault Current
230 kV	100 ms
115 kV	140 ms

Prepared by the JICA Survey Team

(5) Transmission Line and Main Bus of Substations

The allowable current carrying capacity of the transmission line and the main bus of substations and the transmission capacity of transmission lines in case of normal conditions and N-1 contingency are shown in Table 4.3. In addition, the temperature within the ( ) indicates the allowable maximum temperature rise of conductors.

Table 4.3 Allowable Current and Transmission Capacity of Standard Conductors

Location	Conductor	Normal Condition (80)		N-1 Contingency (90)	
		A	MVA	A	MVA
Transmission Line	ACSR240	480	96	590	120
Main Bus of Substations	ACSR240			590	120
	ACSR300x2			1394	278
	HDCC325			875	174
	HDCC400			950	189

Prepared by the JICA Survey Team

(6) Substations

PSS/E data of the power system for 2009 to 2016 were provided by EdL. For newly planned substations which were not considered in the PDP 2007-2016, the following conditions are assumed.

1) As a 230 kV bus configuration, one-and-half (1+1/2) method is basically applied. Application of double bus arrangement is also considered by role of each substation.

2) 115/22 kV Transformers

a) 30 MVA, 3 banks in maximum in a substation

b) Maximum load target is 60 MVA

3) 230/115 kV Transformers

a) The capacities of primary and secondary sides are determined with the predicted power flow.

b) The voltage of 22kV and the delta winding are applied to the tertiary sides. The capacity of the tertiary side is basically 30% of that of primary and secondary sides.

c) On-load tap changers are applied.

4) Standard Impedance

The impedances of power supply transformers are as shown in Table 4.4.

Table 4.4 Standard Impedance

Voltage	Impedance between Primary and Secondary Sides
230/115kV	12.0%
115/22kV	8.5%

Prepared by the JICA Survey Team

CHAPTER 5 HYDROLOGY AND RESERVOIR OPERATION

5.1 HYDROLOGY

Climate of the Nam Ngum River Basin

The Nam Ngum River originates in Xieng Khouang plateau and extends to the confluence of the Mekong River. It extends up to 345 km with a river basin area of 16,841 km^2 which is the fourth largest river basin area in the Lao PDR. The Nam Ngum River basin has tropical monsoon climate, dominated by the wet southwest monsoon from mid-May to early October and the dry northeast monsoon from early November to April. The recorded annual rainfall in the region ranges from 1,420 mm in Xieng Khouang to 3,500 mm in Vangvieng, over 75% of which falls during the rainy season. The amount of annual rainfall is not uniformly distributed over the basin.

The annual average maximum temperature reaches 34 °C in the downstream plain area, and 28 °C in the upstream mountainous area. The average minimum temperature is 8 °C in the upstream mountainous area and 16 °C in the downstream plain area.

Data Collection of Hydrological Data

(1) General

The hydrologic data, i.e. rainfall, discharge and other meteorological data, are monitored in the hydrologic gauging stations operated by the Department of Meteorology and Hydrology (DMH) under the Water Resources and Environmental Administration (WREA). . The hydrologic data managed by DMH are collected, and its observation errors are corrected by the consultant, Électricité de France (EdF) in the Nam Ngum River basin Development Sector Project (NNRBDSP) Components 2 under ADB and ADF cooperation. In the Nam Ngum River basin, the rainfall and discharged data are also monitored in the existing hydropower stations (NN1, Nam Leuk, Nam Mang 3). The Survey Team collected those hydrological data from DMH, NNRBDSP and existing hydropower stations.

(2) Rainfall Data

The rainfall data at the rainfall gauging stations are collected by the consultant (EdF) in the NNRBDSP component 2. The collected data are examined by visiting the gauging station, and cross checking the data consistency with the other rainfall gauging stations using double-mass-curve analysis. The Survey Team received the verified data and hydrological study report of NNRBDSP through DOE. The Survey Team checked the methodology and procedure of verification of the rainfall data. The method of the data verification is appropriate and such data can be used for the Survey.

(3) Discharge Data

The discharge data in the Nam Ngum River basin is available in the NNRBDSP hydrological study as well as in the past studies of the hydropower station developments. The operation data with the discharge record of the existing hydropower stations are also used in the Survey.

Hydrologic Analysis

The Survey Team carried out the following hydrologic analysis.

- Collection of hydrological data and checking the data consistency
- Analysis of the NN1 dam catchment average annual rainfall by Thiessen method.
- Confirmation of correlation of observed hydrological data
- Estimation of runoff ratio
- Confirmation of discharge data of NN2 as well as flow regime change due to NN2 existence.
- Confirmation of water-use and irrigation demand in the Nam Ngum River basin.

The main points of the hydrologic analysis are summarized below.

(1) Average rainfall in the Nam Ngum River Basin

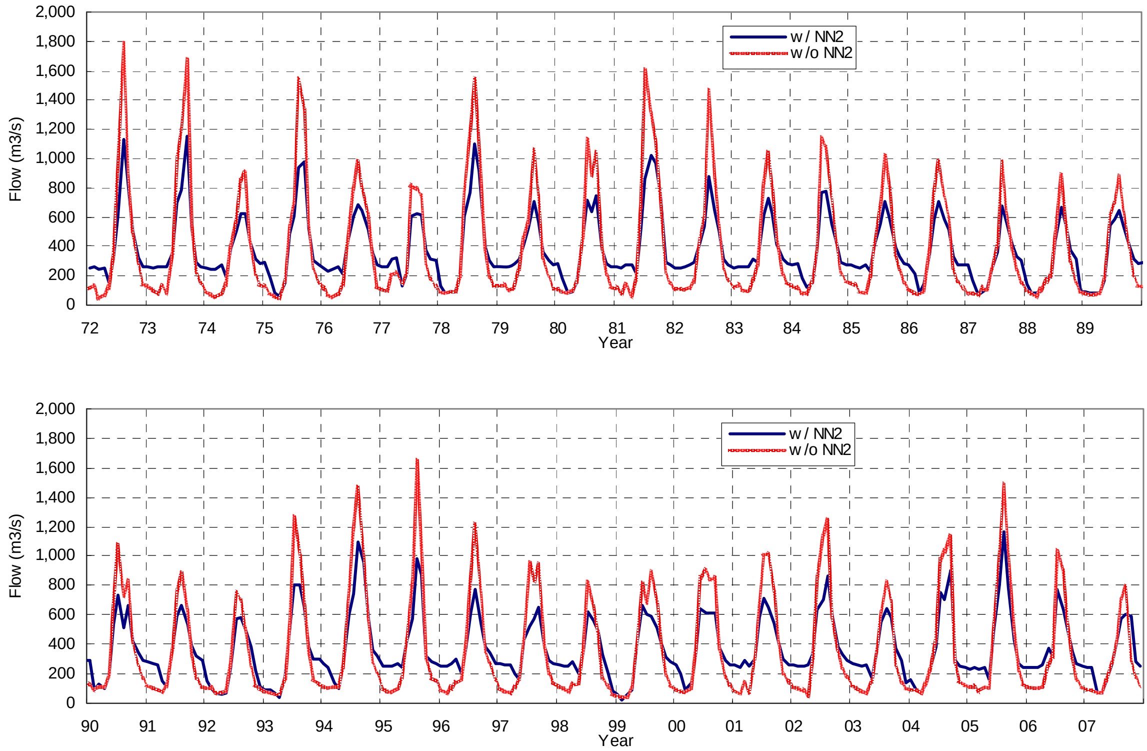
The annual average rainfall of the catchment of NN1 dam is calculated by Thiessen method. NN1 dam has the catchment area of 8,275 km^2 (*) and the area is divided by the Thiessen method to distribute the area covered by gauging stations. The annual average basin rainfall is calculated at 2,079 mm.

(*): referred to NNRBDSP report (2009).

(2) Change of flow regime due to NN2

NN2 is located at just upstream of NN 1 reservoir and this existence of NN2 is important for the NN1 expansion plan. After the commencement of NN2 power plant, the river flow into NN1 reservoir will be regulated through the year because of storage effect of NN2 reservoir. This will change the flow regime into NN1 reservoir.

The Survey Team received the NN2 discharge simulation data from NN2 project entity. The Survey Team estimated the inflow into the NN1 reservoir using NN2 discharge data, diversion flow from Nam Song diversion, Nam Leuk hydropower discharge and inflow from the residual basin. The hydrographs of the inflow into the Nam Ngum 1 reservoir with and without Nam Ngum 2 scenarios are shown in Figure 5.1.



Prepared by JICA Survey Team

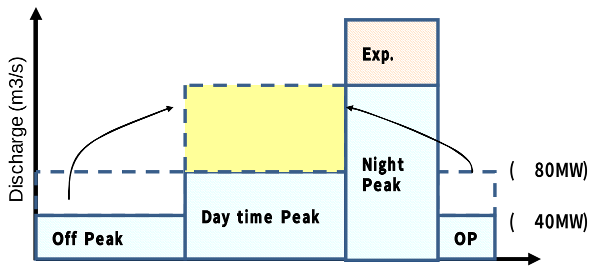
Figure 5.1 Inflow Hydrographs into the Nam Ngum 1 reservoir with and without Nam Ngum 2

The blue line in Figure 5.1 is the estimated inflow after NN2 completion. As shown in Figure 5.1, the inflow into the reservoir in dry season is increased as inflow in the wet season is decreased.

5.2 ESTIMATION OF FIRM DISCHARGE

The firm discharge is the stably available discharge throughout a year for a specific water use, i.e. hydropower in this case. The quantity of the firm discharge is an important factor to determine the plant size of the hydropower station. In this study, the firm discharge is estimated by a mass-curve analysis using the inflow into the Nam Ngum 1 reservoir which is prepared in the Hydrologic Analysis. According to the mass-curve analysis, the firm discharge is calculated to 306 m^3/s.

The firm discharge is the guaranteed discharge available for the 24 hours. As NN1 is also responsible for peak hour power supply, the water is fist allocated 4 hours in night peak and 9 hours in daytime peak as shown in Figure 5.2.



Prepared by JICA Survey Team

Figure 5.2 Typical Operation Pattern for Night and Day time

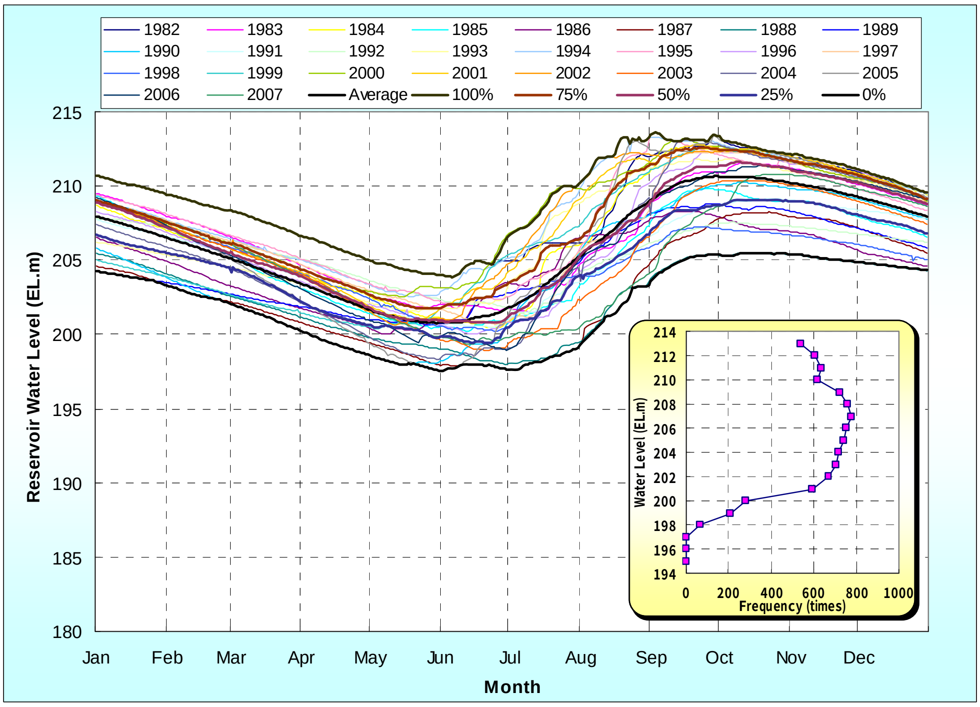
The allocation of the water is determined by selecting optimum expansion plan as described in Chapter 8, and the discharge in off-peak hours is determined by the environmental aspects in Chapter 6.

5.3 PRESENT NAM NGUM 1 RESERVOIR AND NAM NGUM RIVER HYDROPOWER OPERATION

NN1 Reservoir

(1) NN1 Reservoir Operation Record

The daily water level fluctuation of the NN1 reservoir received from the NN1 hydropower station is shown in Figure 5.3.



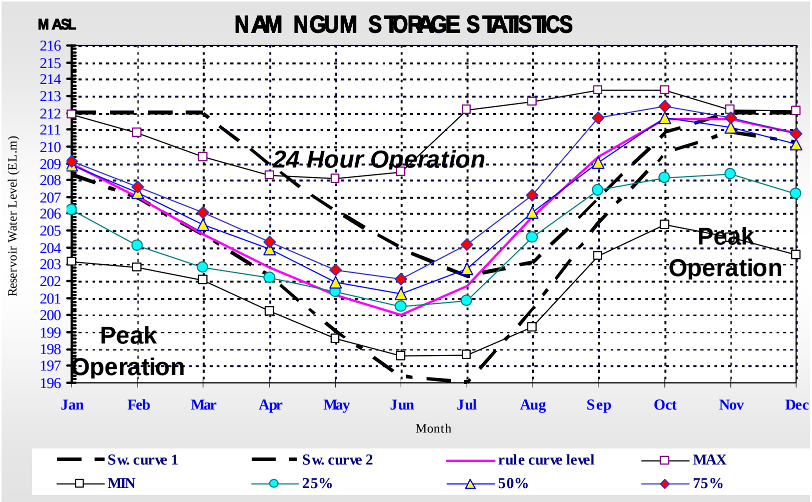
Data Source: NN1 Hydropower Station

Figure 5.3 Daily Water Level Record of Nam Ngum 1 Reservoir (1982 - 2007)

According to the water level record from 1982 to 2007, the frequency of water level is peaked in the range between 206 m to 207 m. This water level range occurs 777 days in 26 years which is equivalent to 8.2% of total duration.

(2) Current Operation Rule of NN1

The current operation rule and median of reservoir water level record (50%) is shown in Figure 5.4.



Data Source: NN1 Hydropower Station

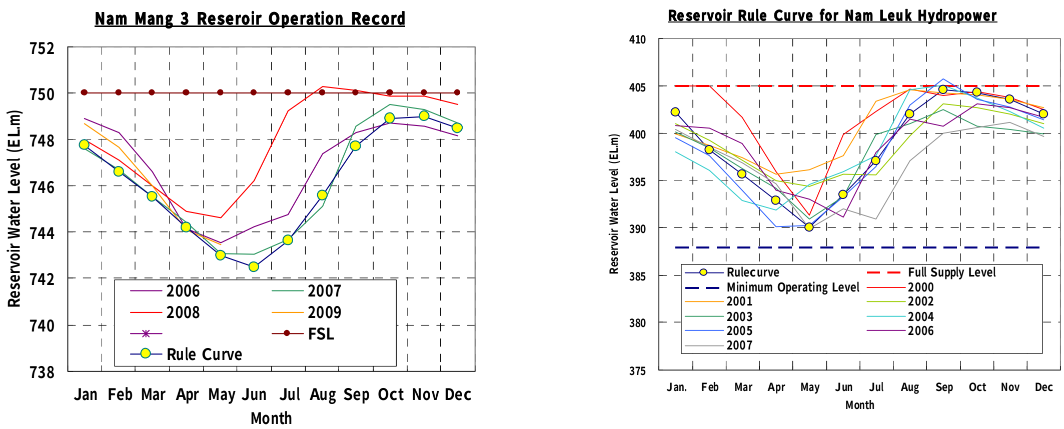
Figure 5.4 Current Reservoir Operation Rule and Actual Operation Statistics

As shown in the figure, median of reservoir water level (50% line) is almost coincides to current rule curve shown in magenta colored line.

However, those guide curve and rules do not follow the current TOU tariff structure. It is expected that the reservoir operation will be studied by EdL and DOE using PARSIFAL for the future operation.

Reservoir Operation Other Than NN1

The water level record of the Nam Mang 3 and Nam Leuk reservoir that are provided from the both hydropower stations superimposed in the reservoir operation rule as shown in Figure 5.5



[Nam Mang3 Reservoir Operation Rule] [Nam Leuk Reservoir Operation Rule]

Source: Nam Mang 3 Hydropower Station, Nam Leuk Hydropower Station

Figure 5.5 Reservoir Water Level Record of Nam Mang 3 and Nam Leuk Reservoir

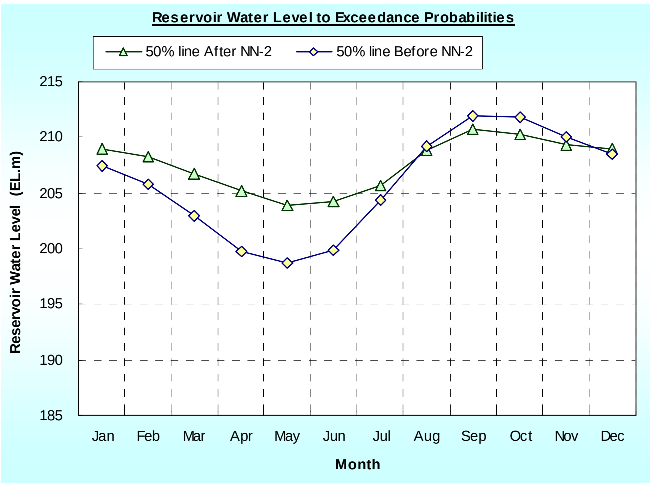
As shown in the figure, the water level of the reservoirs seems to targeting the reservoir operation rule curve although there are some deviations observed in some years.

5.4 RESERVOIR OPERATION FOR SELECTION OF OPTIMUM ALTERNATIVE PLAN

The reservoir operation rules were developed for expansion scale of 40 MW, 60 MW, 80 MW and 120 MW by assuming NN2 commencement in 2011. The energy production is estimated following by determining reservoir operation rule that results to additional annual power generation of 52 GWh in case of the expansion of 40 MW. The increment in the energy production is limited regardless of the magnitude of expansion scale, when the expansion capacity is more than 60 MW. On the basis of these results, the expansion alternatives were compared with respect to the construction cost, and the 40 MW expansion plan was selected as the optimum plan.

5.5 EFFECT OF NAM NGUM 2 OPERATION

The effect of the NN2 operation to the NN1 reservoir operation is studied. The results of the median of the water level for before and after Nam Ngum 2 completion are plotted in Figure 5.6.



Source: JICA Survey team

Figure 5.6 Comparison of Optimum Reservoir Operation between with and without NN2

As shown in the figure above, based on the change of the flow regime due to NN2 Hydropower operation, the water level in the dry season remains in the higher water level of EL.204 m than before NN2 completion case. In the rainy season, the water level is lower than that before NN2 case because the spillage is reduced due to expansion.

5.6 OPERATION STUDY OF NN1 RESERVOIR AND HYDROPOWER STATIONS IN THE NAM NGUM RIVER BASIN AFTER NN1 EXPANSION

Principles on NN1 Reservoir and Hydropower in NNRB Operation Study

The reservoir operation is further studied using characteristics of the additional 40 MW turbine and generator determined in the basic design. The reservoir operation study has two aspects of policies which are: 1) effective utilization of water resources as economic aspects, and 2) revenue improvement from domestic electricity sales and profit of electric power interchange with EGAT as accounting aspect.

The first approach on the reservoir operation study focuses more on economic aspects, i.e. energy production. Meanwhile, the latter approach focuses on the account of selling electricity to domestic consumers and exporting to EGAT using the current tariff system. The first case aims at energy maximization while the latter case employs revenue maximization as the objective of optimization. However, if the reservoir operation is solely targeting either energy maximization or revenue maximization, the results tend to import electricity during dry season and generate electricity for export in the rainy season to maintain the reservoir water level in high elevation. The Lao PDR government's policy is that the power import from EGAT should be as less as possible and the domestic electricity demand should first be served by the domestic power sources. Therefore, the operation study considers minimization of the imported energy as prerequisite of energy and revenue maximization. Both approaches consider the scenario of the power demand supply balance in the year 2015, 2020 and 2025, and for the cases of with/without NN2, and before/after expansion.

Nam Ngum River Compensation Flow and Its Allocation

The effect to the downstream due to the change of discharge pattern is studied in the "Initial Environment and Social Examination (IESE)" in parallel with the Nam Ngum 1 expansion survey as described in Chapter 6. IESE confirmed that the discharge quantity less than 117.1 m3/s causes adverse impacts to the downstream fishpond and boat transportations. . Therefore, the study of the reservoir operation is based on the minimum release of 117.1 m^3/s during off-peak hours.

In addition, the reservoir operation study, the expansion NN1 will enable to achieve more flexible operation than present condition.

Reservoir Operation Plan (Draft)

In the reservoir operation study for economic and financial analysis of the expansion project, the reservoir operations of EdL's Nam Mang 3 and Nam Leuk hydropower stations were also considered since NN1 expansion could affect to the these power stations operation. The energy production of NN1 is simulated for the year of 2015, 2020 and 2025 with the cases of with/without NN2 and after expansion.

The reservoir optimization result of monthly average reservoir water level of three reservoirs (NN1, Nam Mang 3 and Nam Leuk) for the year 2015, 2020, and 2025 for each case (after expansion and w/ or w/o NN2 in before expansion) is shown in Figure 5.7.

As shown in Figure 5.7, the average water level of NN1 reservoir is different between with and without NN2 cases, and Nam Leuk and Nam Mang 3 reservoir water levels also exhibit some changes in the dry season in the year 2015 between with and without NN2 cases. Expansion of the NN1 hydropower station changes the reservoir operation of Nam Leuk and Nam Mang 3 within one meter, which is less than one percent of total head. Consequently, the changes in annual energy of Nam Mang 3 and Nam Leuk hydropower due to NN1 expansion are less than one percent. Therefore changes in energy production are negligibly small.

The monthly average power output in a day by NN1 is shown in Figure 5.8. As shown in the figure, It is noted that NN1 can be operated for 24 hours a day with full capacity of generators for the before expansion. However, for the after expansion case, the water is allocated more on the peak hours in TOU system. Therefore 24 hours with full capacity operation can not be realized after expansion.

As the results, that the present average annual power generation of 1,012 GWh can be increased to 1,071 GWh (59 GWh rise) after the commencement of power generation of NN2, and to 1,127 GWh (56 GWh rise) by the expansion of 40 MW.

Nam Ngum River Basin Hydropower Operation Plan (Draft)

For the study of the reservoir operation in the Nam Ngum River basin with revenue maximization, EdL hydropower stations (NN1, Nam Mang 3, and Nam Leuk) supplying electricity to the C1 area were taken into consideration. Nam Lik 1/2 hydropower station is further considered in the after expansion case. The optimization studies were carried out, and it was found that the revenue balance and import energy is generally a trade-off relation. The increase in imported energy in the dry season may contribute to increase in annual revenue. However, importing too much energy from Thailand will result in increase of excess charges that will worsen the annual revenue balance.

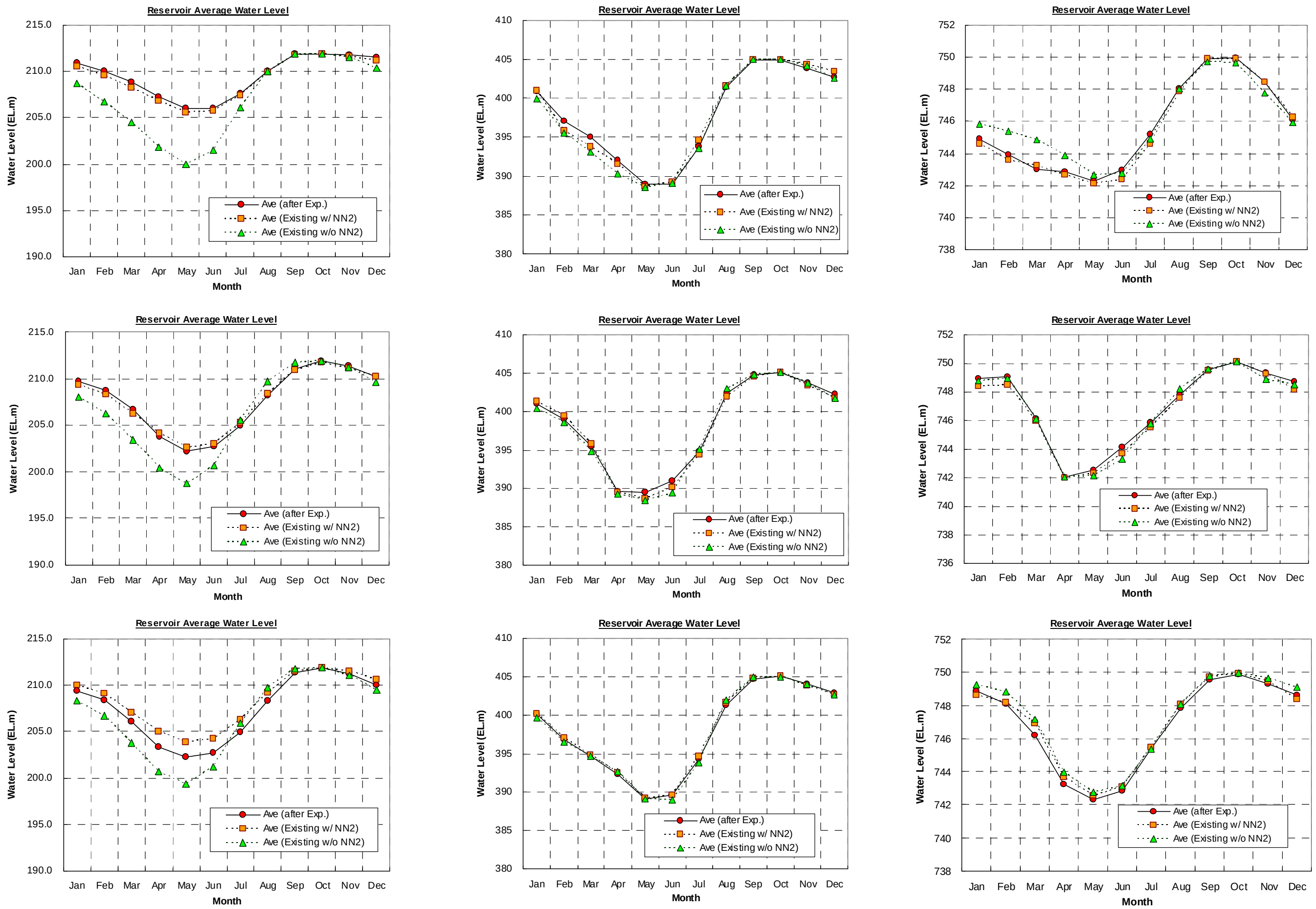
If Nam Lik 1/2 is operated together with NN1, Nam Leuk and Nam Mang 3, it will contribute to the significant reduction of energy import when the electricity demand exceeds domestic supply capacity throughout the year. However, the effect of involving Nam Lik 1/2 operation is limited when the domestic power supply and demand is almost balanced.

Nam Ngum 1 Reservoir | Nam Leuk Reservoir | Nam Mang 3 Reservoir

Year 2015

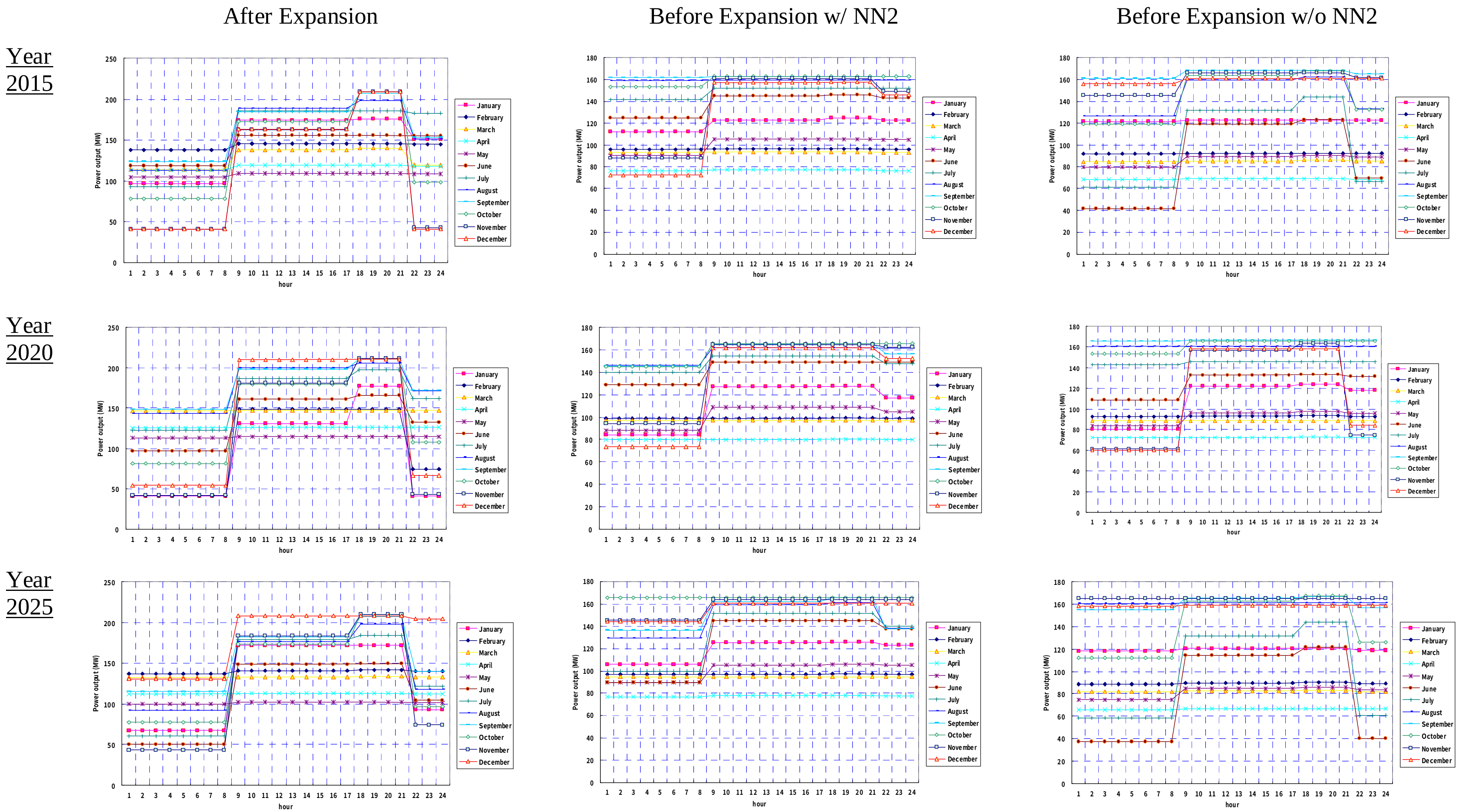
Year 2020

Year 2025



Prepared by the JICA Survey Team

Figure 5.7 Result of Optimization for Each Case in Each Year



Prepared by the JICA Survey Team

Figure 5.8 Monthly Average Power Output of the Nam Ngum 1 Hydropower Station

CHAPTER 6 ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

6.1 LEGISLATION AND INSTITUTIONAL FRAMEWORK

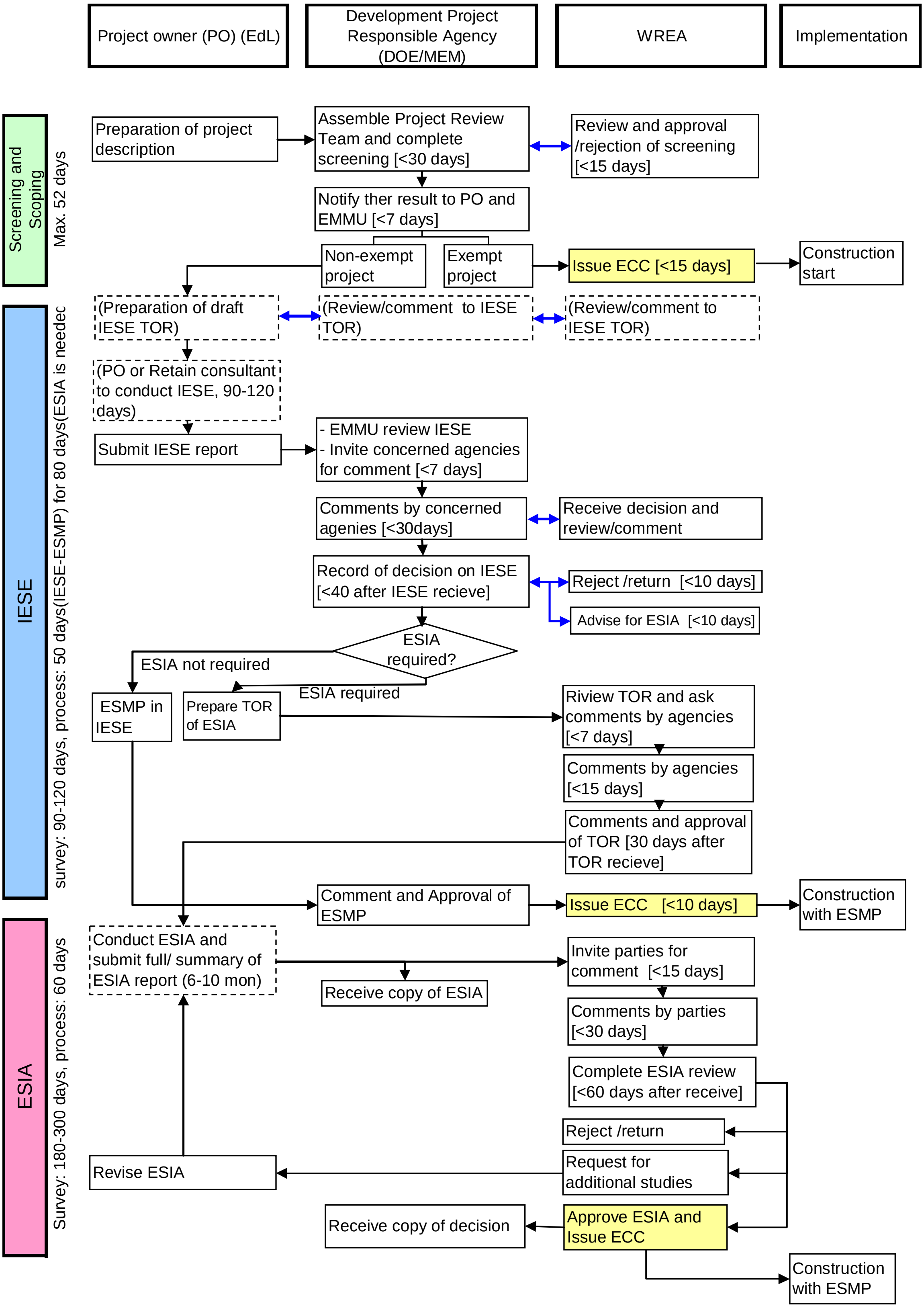
"The Environmental Protection Law, 1999" stipulates responsibilities of the national agencies for environmental administration. The administrative organization in charge of environmental matters in Lao PDR is WREA which is under the control of the Prime Minister Office. The department in charge of the administration of environmental assessment (EA) is ESIAD, which was previously under the Department of Environment in WREA The organization responsible for environmental administration of development project for power sector is Social and Environmental Management Division under DOE of MEM. It formulates environmental standards for implementation and monitoring of electricity development project EdL is the Project Owner of the expansion plan of Nam Ngum 1 Hydropower (NN1). Environmental Office under Technical Department of EdL is the main body for environmental procedure for EA. Responsibilities for conducting the EA process are shown in the table below.

Table 6.1 Environmental Assessment Process Responsibilities

Organization	Responsibility
DOE/MEM	- Undertake project screening to determine EA requirements. - Reviews, requires revision, and recommends approval of IESEs with ESMSP or ToR of ESIA - Reviews and decides on IESE ESMPs for all projects in its sector area of responsibility - Endorses TOR for ESIA - Concurs in consultants that are proposed to conduct IESE and EISA - Review and endorses ESIA and ESIA's ESMP prior to final approval by WREA - Implements inspection, monitoring, validation and evaluation requirements - Implements relevant public involvement requirements - Oversees implementation of ESMPs
Project Owner (EdL)	Implements EA process and prepares the EA reports including - Preparing project descriptions - Implementing public involvement requirements - Implementing IESE and/or EISA requirements and ESMP requirements - Implementing monitoring and evaluation requirements
WREA	- Referring to the Regulation on Environmental Assessment in the Lao - Issue of Environmental Compliance Certificate (ECC)

Source: Regulation on Implementing Environmental Assessment for Electricity Projects in Lao PDR

Environmental and Social Management Plan (ESMP) and environmental management and monitoring plan are integral parts of EA process that describe the measures to be implemented for ensuring appropriate management for project. "Environmental Management Plans for Electricity Project (No.584/MIH DOE, 2001)" provides ESMP procedure for electricity project in Lao PDR.



* The terms "IESE", "ESIA", "EMP", and "STEA" corresponds to "IEE", "EIA", "ESMP", and "WREA" in Lao PDRNo.1770/STEA. In this figure, terms for "IESE", "ESIA", "ESMP"、 and "WREA" is applied since those are already used in official documents in Lao PDR.

Prepared by JICA Survey Team referring to "Regulation on Implementing Environmental Assessment for Electricity Projects in Lao PDR" and "Regulation on Environment Assessment in the Lao PDR (Lao PDRNo.1770/STEA)",

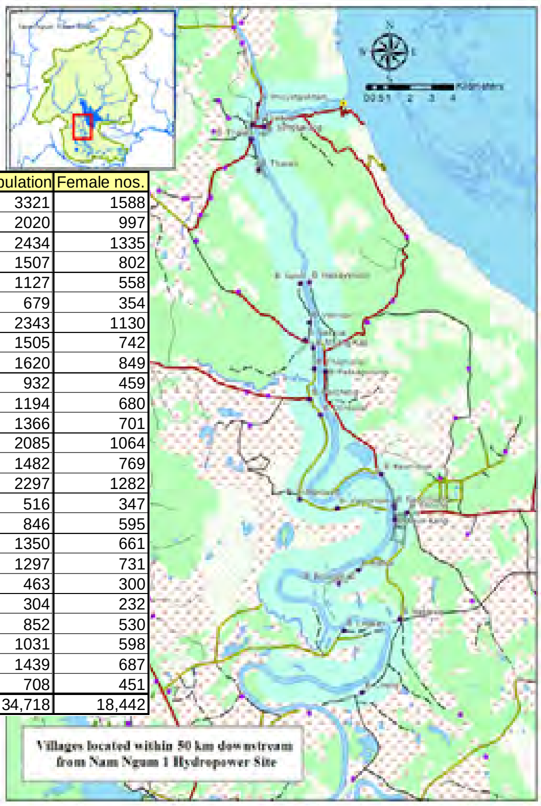
Figure 6.1 Procedure for Environmental Assessment for Hydropower Project

6.2 ENVIRONMETNAL ASPECT OF EXPANSION PROJECT AREA

Perimeter around the project site is covered with upper mixed deciduous, bamboo, unstocked forest, shifting cultivation, savannah, paddy rice, agriculture plantation, other agricultural land, grassland, swamp, and urban or built up area. Shifting cultivation is performed mainly upstream areas but not much seen in the downstream plain areas. The Nam Ngum Reservoir and the Nam Ngum River is an important source of aquatic lives and produces plenty of fishery products. The downstream areas are already affected by human activity such as agriculture, fishery and transportation. Water quality is monitored over the past 15 years and water quality is reportedly still good and not significantly changed due to such human activities yet. The expansion project site is apart from NBCA or biological corridors which is designated to be the protected areas. Meanwhile, Phou Khao Khouay NBCA, located southeast to Nam Ngum Reservoir, is included in the catchment of the Nam Leuk River, of which water is diverted into the Nam Ngum reservoir.

As for ethnicity, although Hmong-Mieng lives in the upstream of NNRB, Lao-Thai is the major ethnic group in downstream of NN1. Out of 20 districts in NNRB, six districts are identified as “poor”, however, the economic condition of main affected area of NN1 downstream is relatively good. Socio-economic survey was conducted in this IESE study for 24 villages located along the Nam Ngum River within 50 km downstream from NN1 and 1 km width from river bank. The area comprises of the District of Keooudom, Viengkham and Thoulakhom in Vientiane Province. Those are considered to be the main affected area due to the project.

No.	Village Name	Latitude	Longitude	HH	Population	Female nos.
1	B. Kangmuang	18.36643	102.57216	402	3321	1588
2	B. Keun-Nua	18.37982	102.56649	361	2020	997
3	B. Keun-Kang	18.36116	102.57259	473	2434	1335
4	B. Boungphao	18.33459	102.54855	349	1507	802
5	B. Hatxai	18.34005	102.55707	222	1127	558
6	B. Nakhong	18.32055	102.57547	140	679	354
7	B. Cheng	18.29024	102.55956	458	2343	1130
8	B. Lingxan	18.31531	102.55108	300	1505	742
9	B. Phonhe	18.36374	102.57810	323	1620	849
10	B. Thaxan	18.50274	102.51100	167	932	459
11	B. Thalat	18.51543	102.50797	214	1194	680
12	B. Thinkeo	18.52145	102.50801	280	1366	701
13	B. Phoukhaokham	18.52996	102.51068	443	2085	1064
14	B. Sengsavang	18.52064	102.51344	299	1482	769
15	B. Pakkagnoung	18.42086	102.54141	468	2297	1282
16	B. Thaphoxai	18.42184	102.53665	108	516	347
17	B. Muang-Kao	18.43068	102.53614	158	846	595
18	B. Veunsan	18.44083	102.53437	251	1350	661
19	B. Nakhua	18.43380	102.53248	262	1297	731
20	B. Nanin	18.45688	102.53004	87	463	300
21	B. Hatxaykhoun	18.45727	102.53403	54	304	232
22	B. Pakcheng	18.40949	102.53473	147	852	530
23	B. Donkouat	18.40301	102.53965	176	1031	598
24	B. Thingnoung	18.36893	102.53104	280	1439	687
25	B. Viangkham	18.36542	102.54758	126	708	451
	Total			6,548	34,718	18,442



B. Kangmuang was not surveyed because it is included in KengKang village. Accordingly, target village number became 24.
Prepared by JICA Survey Team, using GIS Database of National Geographic Department 2005

Figure 6.2 Location of villages situated at the Downstream 50 km from NN1

6.3 INITIAL ENVIRONMENTAL AND SOCIAL EXAMINATION (IESE)

As the environmental and social considerations for the expansion project, the Survey Team conducted Initial Environmental and Social Examination (IESE) based on "Regulation on Environment Assessment in Lao PDR, STEA, 2002".

No significant and irreversible impacts on social and natural environment are expected in the NN1 Hydropower Station Expansion Project, different from a new dam and hydropower project. The expansion project needs neither creation of reservoir nor construction of new transmission lines. In terms of socio-economic impact, no relocation or land acquisition is required. Compensation is not necessary in the selected optimum scale of the project. As a result of IESE study, it is concluded that environmental and social impact of the NN1 expansion project are basically not significant. Negative impacts can be avoided or mitigated by conventional construction management with proper instruction and operation with mitigation plans.

On the other hand, continuous impact that may affect to natural and social environment is expected due to larger daily water level fluctuation at the downstream of the Nam Ngum River. This is due to the change of operation pattern in NN1 power station after the expansion work. In the off-peak time, downstream river water level is reduced and increased during peak-time.

Downstream discharge fluctuation comes from the change of output and generation discharge at the NN1. River side gardening is possibly affected from water level increase during peak time. Meanwhile, boat transportation and fishery may be affected by water level decrease during off-peak time. Irrigation and river water pumping may also be affected by the water level decrease. This water level fluctuation will happen only in dry seasons. The summary of anticipated positive and negative environmental and social impacts is shown in the tables below.

Table 6.2 Possible Negative Impact

Category	Type	Possible Negative Impact	Stage
Social Environment	Social infrastructure	Labors coming from outside may affect. Security of nearby villages and sanitation of workers during construction work may have adverse impact if proper management is not held.	Construction
	Water usage	In dry season, irrigation and water use at downstream of Nam Ngum 1 will be affected if off-peak output is zero or only with single 18 MW unit. To confirm minimum river maintenance flow required by downstream society, at least single 40 MW unit should be operated during off-peak time. It needs to monitor the Nam Lik flow at the same time. In addition, rapid water level increase during off-peak to peak time shift may affect downstream safety of people.	Operation
	Sanitation	Sanitation of workers during construction work may affect to water quality or health condition of surrounding areas. The expected scale of amount of workers is approx. 400 and not quite large.	Construction
Natural Environment	Water pollution	It is expected that temporary water pollution occurs due to concrete mixing, aggregate collection and washing, and excavation works during construction. The affect is temporary and small but should be minimized.	Construction

Category	Type	Possible Negative Impact	Stage
	Hydrological Situation	In dry season, river discharge will increase during peak generation hours and decrease during off-peak hours. For 40 MW expansion, maximum output during peak time does not affect to downstream. However, water decrease will affect to downstream if zero operation or smallest operation with single 18 MW unit is conducted during off-teak time. The condition is also affected by discharge amount of the Nam Lik River.	Operation
	Landscape	Additional powerhouse slightly changes appearance of the NN1. If optional work of river bed excavation is conducted to obtain additional head and energy output, downstream scenery is also slightly changed but this is not significant.	Cosntruction

Prepared by JICA Survey Team

Table 6.3 Possible Positive Impact

Category	Type	Possible Positive Impact	Stage
Social Environment	Local Economy	Employment will be created by the construction works.	Construction
Natural Environment	Global warming	It will have positive impact due to utilization of spilled water for additional energy of 56 GWh due to expansion, which can save fossil fuel in the grid in Thailand owing to the reduction of power import from Thailand.	Operation

Prepared by JICA Survey Team

Number of household and population affected by the expansion project is shown in the table below.

Table 6.4 Category and Number of the Affected

	Category	Amount	Remarks	Source
1)	Population of Nam Ngum River basin	69,559	Indirectly affected people	NNRB Profile, 2009,. WREA
2)	Riverside < 1km villages downstream < 50 km of NN1	24	Villages in affected area	GIS database, 2007, NGD
3)	Riverside < 1km households downstream < 50 km of NN1	5,800	Households in affected area	NN1 Expansion IEE Socio-economic Interview Survey
4)	Riverside < 1km population downstream < 50 km of NN1	30,347	Population in affected area	Ditto
5)	Nos of river water general users of 4)	28,648	Affected people	Ditto
6)	Nos of boat transporter users of 4)	11,714	Affected people	Ditto
7)	Nos of gardening household of 3)	2,285	Affected households	Ditto
8)	Nos of fishery household of 3)	400	Affected households	Ditto
9)	Nos of commercial fish cage hh of 3)	64	Affected households	Ditto
10)	Nos of irrigation pumping station	15	Affected infrastructure	Ditto
11)	Area of irrigation in dry season (ha)	1,035	Affected infrastructure	Ditto

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Detailed Study of Environmental and Social Impact

Non-uniform flow calculation was conducted from 10 km downstream NN1 to upstream leaching NN1 for peak time water level increase at 40 MW. It can be concluded that 0.4-0.5 m increase is shown in case of peak 40 MW increase (195 MW output in total), which gives no problem at downstream.

For off-peak time, water level decrease for Case-40 MW is 0.3-0.4 m which would be within acceptable level to downstream people. However, Case-18MW with decrease of 0.7-0.9 m is possibly affects some activities in the area. As mentioned above, the condition is dependent on the discharge amount of the Nam Lik. Accordingly, the basic operation rule is formulated in the Preparatory Survey with the assumption that off-peak operation is held with a minimum of single 40 MW unit.

As for irrigation system, water level has been kept at least 2 m at the downstream irrigation location, even at the worst case of ten years possibility. Accordingly, irrigation pumps have margins of at least 0.7 m from water surface. Thus, water level decrease at 0.5 m during the off-peak generation with single 40 MW units is considered not to affect the irrigation pumping.

Meanwhile, water level change at the time of operation transition from off-peak time to peak time also needs consideration. Figure above also indicates water level difference between off-peak and peak time. When off-peak time is shifted to peak time, and 40 MW is increased to maximum operation at 195 MW, water level at downstream will suddenly increase to 2.0-2.3 m within a few minutes. This rapid water level increase may induce accident of downstream river uses. At the present operation of shifting from off-peak to peak time, 80 MW (2 x 40 MW units) opening at one time is already conducted. Accordingly, it is considered that 80 MW increase from off-peak to peak time is not a problem. However, larger increase at one time more than the present level should be avoided. When large output increase is required, step-wise increase by 80 MW at maximum has to be kept, and additional output increase should be conducted after 30 minutes or 1 hour to reach the maximum operation at 195 MW. It is necessary to set operation rule accordingly. In addition, precaution should be explained to for downstream people regarding the peak time water level which will be increased at about 0.4-0.5 m than before. In addition, warning sign board should be installed at every location of river water use to inform the residents about this matter. In detailed design stage, it is recommended to study the requirement of automatic warning system.

Flow from the Nam Lik will also affect the downstream water level condition. When starting the operation of NN1 expansion, it is necessary to confirm the daily operation pattern of Nam Lik 1/2 and maintenance flow amount, assess downstream water level condition, and request adjusting the peak operation pattern of Nam Lik 1/2 if necessary. Maintenance flow from Nam Lik 1/2 is required so that the flow of the Nam Lik becomes more than that of 90% dependable discharge. These are required to ensure that downstream of the Nam Ngum River is not affected.

<u>Environmental Affect Comparison of Alternative Plans</u>

For the comparison of with/without the project, the assumption of advantages and disadvantages was assessed for the cases if the expansion project will be held and will not be held.

Table 6.5 Advantage and Disadvantage of the Case without Expansion Project

Advantage	Disadvantage
- No downstream affect will be seen. The condition is the same as present. - No construction will be held and temporary impact due to construction will be avoided. - Project cost at about US$60 will be saved.	- No expansion will be held, and Lao PDR must import expensive energy at peak power in dry season from Thailand, which will be a burden of foreign currency balance of nation. EdL needs to cover the cost which may deprive other development opportunity for poverty reduction such as rural electrification. - No additional annual power output, namely 56 GWh, will not be obtained. - Thermal power in Thailand will be used for peak power import to Lao PDR, which releases CO_2.

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There were 12 alternative plans divided into several output, i.e., 40, 60, 80, and 120 MW plans. Subsequently, 40 MW was selected as the most prospective plan. The selected A1 40 MW plan has the least cost and least environmental impact among all plans. The environmental affect expected in each alternative plan is summarized in the following table.

Table 6.6 Advantage, Disadvantage and Environmental Impact of Alternative Plans

Plan	Advantage	Disadvantage	Environmental Impact
A1 (40MW)	Intake coffer construction is easy. Overall layout is compact. Headloss in waterway is least.	Land space is narrow. Access way to existing transformers is blocked during intake construction.	Affect to downstream can be mitigated in by selecting off-peak operation output. Conventiona mitigation measurement is sufficient for construction.
A2 (60MW)	Intake coffer construction is easy. Overall layout is compact. Less headloss.	Land space is very narrow. Spillway wall foundation requires special slope stabilization. Existing building width is not enough. Existing carne is not usable. Roof of unit-5 bay requires replacement. Unit-5 is not operable during replacement.	Gardening of few riverside households may be affected due to water level fluctuation. Conventional mitigation measurement is sufficient for construction.
A4-1 A4-3 (40MW)	Land space is sufficient. Intake coffer construction is easy. Tailrace outlet of A4-3 is apart from existing tailbay.	Existing Nam Leuk GIS S/S has to be relocated. Construction of tailrace outlet of A4-1 disturbs operation of existing units 1&2. Existing crane is not usable. Locating switchyard on roof is not allowed due to lack of safety distance below existing 115kV lines	Affect to downstream can be mitigated in by selecting off-peak operation output. Conventional mitigation measurement is sufficient for construction.
A4-2 A4-4 (60MW)	Land space is sufficient. Intake coffer construction is easy. Tailrace outlet pf A4-4 is apart from existing tailbay.	Construction of tailrace outlet of A4-2 disturbs operation of existing units 1&2. Existing crane is not usable. Locating switchyard on roof is not allowed due to lack of safety distance below existing 115kV lines passing over the roof.	Gardening of few riverside households may be affected due to water level fluctuation. Conventional mitigation measurement is sufficient for construction.
B2-1 (80MW) B2-2 (120MW)	Land space is sufficient. Intake coffer construction is easy. New powerhouse is independent from existing powerhouse .	Existing Nam Leuk GIS S/S has to be relocated. Tunnel waterways are long and require steel lining in full length. 120MW case needs new 54 km long	Several riverside households may be affected. For 120 MW, water level increase in peak time will be more than 1m, which may require compensation.
D2-1 (40MW) D2-2 (60MW) D2-3 (80MW) D2-4 (120MW)	No obstructive structure in expansion area. Up to 80MW, generated power is transmitted through existing T/L via exiting switchyard.	Intake tower is independent in deep reservoir (>30 m deep). Construction of tower without lowering WL is very difficult. 120MW case needs new 54 km long transmission line.	Several riverside households may be affected. For 120 MW, water level increase in peak time will be more than 1m, which may require compensation. Construction scale is large and EMP needs mitigation for especially for tunneling work.

Prepared by JICA Survey Team

Environmental and Social Management Plan (ESMP)

Environmental and social management plan (ESMP) is prepared as a component of IESE. For the expansion project, required environmental management items are set as follows:

(i) Anti-pollution measure: air quality, water quality, material collection, waste management, soil contamination, noise and vibration, and management of abandoned site;

(ii) Natural environment: topography and geology; and

(iii) Social environment: living, hygienic condition, and landscape.

The key matter for social management plan is to provide information about dry season water level fluctuation and provide warning sign to riverside residents. Especially, the following mitigation measures shall be conducted to avoid social effects:

- At off-peak time, NN1 operation shall be held with at least 40 MW single unit. Zero operation is not allowed since maintenance flow is required. Single operation with 18 MW is possible only if the Nam Lik discharge is sufficient, more than 117.1 m^3/s[1].

- If dry season peak water level increase of Nam Lik 1/2 overlaps with that of NN1 in dry season at the downstream of the confluence, NN1 should request to the project owner of Nam Lik 1/2 to modify peak operation time of Nam Lik 1/2 so that overlapped downstream water level increase can be avoided. In addition, maintenance flow from Nam Lik 1/2 is required so that flow from the Nam Lik is more than 90% dependable discharge.
- Hourly data of downstream water level and discharge of NN1 power station and the Nam Lik River shall be monitored during detailed design and in the first half year of the operation. It needs to confirm that the maintenance flow of Nam Lik 1/2 is sufficient to supply 90% dependable discharge of the Nam Lik.
- When shifting from off-peak to peak operation, step-wise increase by 80 MW at maximum has to be kept. Additional output increase should be conducted after 30 minutes or 1 hour to reach the maximum operation. Operation rule should be set accordingly.
- Warning sign board about rapid water level increase at riverside shall be provided where people have activities such as fishery, washing, pumping, gardening, and swimming before the completion of the construction. Requirement of warning system should be studied in detailed design stage.

Contractor's Environmental Management Plan (CEMP) was prepared to provide responsibility of contractors in bidding for works, for the items of public morality, safety, sanitary and hygiene arrangement, air, water, and soil conservation, tree preservation, waster material, and noise control. All ESMP requirements shall be included in the contract documents.

Based on above description, Environmental and Social Monitoring Plan was set as shown in the table below with responsibility and frequency.

[1] When assuming the worst case of 10 years possibility, discharge at 29.1 m^3/s can be added to discharge from NN1. Then, discharge of Base Condition (present) becomes 203.2 m^3/s, Case-40MW is 146.2 m^3/s, and Case-18MW is 86.1 m3/s. Accordingly, 203.2-86.1=117.1m^3/s is needed for the Nam Lik when single 18 MW is operated.

Table 6.7 Environmental and Social Monitoring Plan

	Description	Mitigation Plan	Responsibility	Monitoring	Frequency
1. Study Stage (conducted in IEE)					
	Environmental permits	Environmental Clearance Certificate must be obtained before construction.	EdL	-	Done
	Explanations to the Public	Explanation to all downstream 24 villages were held during survey. Public Consultation was held on 16 June 09 and consensus was obtained for project implementation.	EdL and consultants	-	Done
2. Construction Stage					
2.1 Anti-pollution measures					
	Air quality	- Sprinkle water to control dust - Minimize travel distance	Contractor	Contractor	Daily
		- Regular checking of engine and exhaust of machinery, and its recording and reporting	Contractor	Enineer	Monthly
		- Respiratory protection for workers at site	Contractor	Enineer	Daily
	Water quality	- Regular water sampling and quality analysis at downstream of construction site. In case not acceptable level, find reason and trap waste water.	NN1PS/Engineer	EdL	Monthly
	Waste	- Dispose of materials to approved area so as no to disturb scenery and not to contaminate water.	Contractor	Enineer	Weekly
	Soil contamination	- Capture insulation oils in barrel and use oil proof sheet to avoid any leakage.	Contractor	Enineer	Weekly
	Noise and vibration	- Instructuction to driver to comply speed limit. - Check proper material loading and unloading. - To use silnecer and muffler for equipment.	Contractor	Enineer	Weekly
	Management of abandoned sites	- Site rehabilitation with topsoil recovery, reshaping, revegetation, and remediation with site clean up work - Stabilization of waste disposal area	Contractor	Enineer	At finishing stage
2.2 Natural Environment					
	Topography and geology	- Prevention with rock support and prompt concrete work in construction.	Engineer	EdL	Before construciton
2.3 Social Environment					
	Sanitation	- Provision of proper sanitation with septic facilities. - Prohibition of untreated human waste to enter any watercourse.	Contractor	Enineer	Weekly
	Living and livelihood, safety	-Source workforce from qualified locals and orient workers on desirable working relationship with skill enhancement and employment program.	Contractor	Enineer	Work commence ment
	Landscape	- Provision of explanation to villagers and tourists for the meaning that the work is enhancing energy, which can reduce CO2 and benefit to global environment.	Engineer/NN1PS	EdL	At finishing stage
3. Operation Phase					
	Hydrology/ Social and economic environment, public safety	- Daily monitoring downstream water level including the Nam Lik. Avoid zero or single 18 MW operation for off-peak hours to keep downstream water level.	NN1PS	EdL	Every day
		- Precaution to downstream communities for rapid increased/decrease of river water level with sign board and public consultation. Keep present output increase rate and conduct gradual opening output as possible.	NN1PS	EdL	Every day
4. Monitoring and Audit					
	Environmental audits	Undertake third party monitoring audits	WREA,	-	1year after construction
	Environmental monitoring	Monitoring by EMMU for compliance of ESMP and ECC.	NN1PS, EMMU	WREA, Steering Committee	Quartely

Prepard by JICA Survey Team

The cost for environmental management is shown in the table below.

Table 6.8 Cost Estimation for Environmental Management

Description	Unit price	Qty	Unit	Amount
Detailed Design				
Environmental Specialist (international)	20,000	1	P/M	20,000
Hydrologist	4,000	2	P/M	8,000
Miscellaneous expenses	14,000	1	L.S.	14,000
Subtotal				***42,000***
Construction				
Environmental Specialist (international)	20,000	3	P/M	60,000
Environmental specialist (local)	4,000	18	P/M	72,000
Water quality Analysis	2,000	18	set	36,000
Governmental monitoring cost	1,200	12	times	14,400
Miscellaneous expenses	91,200	1	L.S.	91,200
Subtotal				***273,600***
Operation				
Environmental Specialist	4,000	3	P/M	12,000
Hydrologist	4,000	2	P/M	8,000
Governmental monitoring cost	1,200	4	times	4,800
Environmental audit cost	5,000	1	time	5,000
Miscellaneous expenses	14900	1	L.S.	14,900
Subtotal				***44,700***
TOTAL				**360,300**

* Compensation is not included Unit:US$

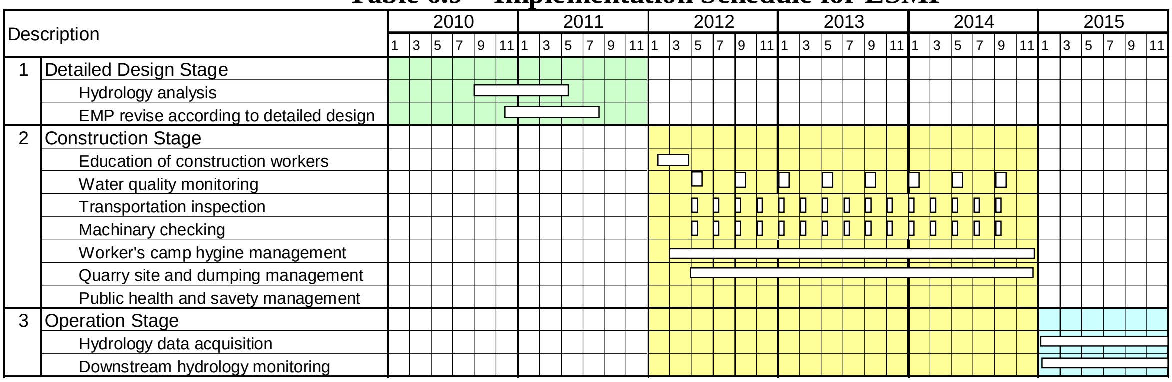
* Miscellaneous expenses includes transportation, communication, reporting, etc.

Prepared by JICA Survey Team

As shown in the table above, the costs of detailed design and construction stages (in total US$0.32 million) will be covered under the construction cost with a loan component once the loan has materialized. However, cost of operation stage (US$45,000) has to be covered by the Project Owner.

The implementation schedule of ESMP is shown in the table below. The ESMP will be conducted during detailed design stage and construction period. Furthermore, it is necessary to continue one year after the onset of operation. The schedule is tentative and might change according to the funding schedule.

Table 6.9 Implementation Schedule for ESMP



Prepared by JICA Survey Team

Public Consultation

Village Consultation was conducted from 29 May to 5 June during village socio interview survey in all 24 downstream villages within 50 km from NN1. Public Consultation was conducted in 16 July 2009 at conference hall of NN1 Power Station with local authorities, village heads, officials of district and provincial organizations, WREA, and EdL officers. Project component and possible impact and affect were explained to participants and they show clear understanding to the project. Basic consensus toward the construction of NN1 expansion project was obtained by participants.

6.4 CO_2 EMISSION REDUCTION BY THE EXPANSION PROJECT

The Project could possibly apply for Clean Development Mechanism (CDM), since the expansion is for hydropower of renewable energy. The methodology of ACM0002 (Version 07), “Consolidated baseline methodology for connected electricity generation from renewable sources”, in effect in December 2007, could be possibly adapted for CDM application of the expansion project. Although EdL grid is supplied mainly by hydropower, the methodology can be applied when EdL grid is considered to be combined with EGAT grid in Thailand. The increase of the energy output in NN1 can substitute the energy for thermal power and save the use of fossil fuel in Thailand.

However, the main objective of the expansion project is to shift the energy from off-peak to peak time. Thus, above additional energy is considered to be a minor component. Of the estimated 1,120 GWh total annual output of 40 MW expansion, only 56 GWh can be considered to correspond as additional output as shown in the table below. This is only a small fraction of general new hydropower. When the price of Certified Emission Reduction (CER) is 20 US$/ton-$CO_2$, revenue of CER will be as shown in the table below.

Table 6.10 Emission Reduction and Revenue from CER

Method	JICA Method*	EGAT Grid Average
CER Price	US$20/ton-$CO_2$	
Emission Reduction	39,650 ton-CO_2/year	31,135 ton-CO_2/year
Emission Coefficient	0.708 ton-CO_2/MWh	0.56 ton-CO_2/MWh
Revenue from CER	About 0.7 mil US$/year	About 0.5 mil US$

*: Considers the hydropower will substitute from petroleum thermal energy first. Prepared by JICA Survey Team

Theoretically, it is considered possible to apply the expansion project to CDM. However, the actual procedure will be quite complicated. When considering the new hydropower with the same output as the expansion scale, CDM of new hydropower will have more simple process and larger CER revenue.

CHAPTER 7 TOPOGRAPHY AND GEOLOGY

7.1 TOPOGRAPHY

The existing NN1 dam was constructed at the narrow neck section (river width of 100-150 m) of the Nam Ngum River. At 200 m downstream from the dam axis, the river width abruptly spreads to 300 m. The width of river is most narrow at 140 m downstream from the dam axis. The bottom level of the river at this point is estimated to be around EL. 164 m. A map prepared in the 1960s shows severely eroded river bed at the 200 m section downstream of the narrow neck and the deepest river bed would be around EL. 145 m. Rock outcrops are seen across the river channel 500 m downstream of the powerhouse. It is therefore supposed that the river bed is mostly covered with intact rock in the downstream vicinity.

Approach road to the dam and powerhouse runs along the left bank of the Nam Ngum River. The road comes from the national route No. 13 and crosses a bridge over the Nam Ngum River at 4 km downstream from the dam. The bridge was built in 1968 for the purpose of the original dam construction.

The right bank area just downstream of the dam is relatively flat but does not have vehicle road and there is no bridge across the Nam Ngum River that connects the left to the right bank. Only the way possible to go by car to the right abutment area near the dam is the dam crest road.

The topography of the dam vicinity is presented in a 1:1000 contour map prepared in the 1960s. However, since the topography around the dam was changed by the construction works for the dam carried out in 1968-1971, the 1:1000 map is partly not usable for the study of the expansion plan. The altered topography is shown in a 1:500 map prepared in the former expansion F/S stage (1995) but the map does not cover the tail bay under water. Therefore, additional topographic survey and river cross section survey were carried out by the JICA Survey Team during the present study.

7.2 GEOLOGY

(1) Geological Investigation Works

The geological investigation by drilling was carried out during the present Survey. The drilling locations were selected to the alternative options B2 and D2 where no drilling data was available and to the alternative option A1 assumed as the most optimum plan. The purpose of these drillings are 1) to confirm the geological condition at the B2 and D2 powerhouse sites, 2) to confirm the depth of weathered zone on each bank and 3) to execute the permeability test in the basement rock at the intake of the D2 option and at the new powerhouse of the A1 option.

Routine down hole testing comprises standard penetration tests (SPT) and water table measurement at all holes. In addition, the outcrop observation was carried out to confirm the geological conditions of basement rock. The geologic investigation works carried out are listed as follows;

Table 7.1 List of Geological Mapping and Drawings Prepared in This Study

area	type	output	remarks
Dam Site Area	Outcrop Mapping	Appendix "Outcrop Map"	
ditto	Geological Plan	Drawing "Geological Plan"	revision (integration of all investigation results)
Water Way	Geological Profile	Figure 7.2.14-19	all alternatavive options
New Power House	Geological Section	Drawing "Geological Section"	optimum option(A1) only

Prepared by the JICA Survey Team

Table 7.2 List of Investigation Drillings Carried Out in This Study

drill hole No.	length (m)	elevation (m)	inclination (degree)	direction (degree)	location	coordinates E	N	stage	in-situ test
JCA-1	20	177.296	90	(N/A)	A1 option	18,240,872.7	2,051,663.3	preparatory survey,2009	Standard Penetration Test water pressure test
JCB-1	25	177.689	90	(N/A)	B2 option	18,240,810.6	2,051,466.8	preparatory survey,2009	Standard Penetration Test
JCB-2	25	204.893	90	(N/A)	B2 option	18,240,869.3	2,051,458.8	preparatory survey,2009	Standard Penetration Test
JCD-1	25	176.887	90	(N/A)	D2 option	18,240,736.2	2,051,800.3	preparatory survey,2009	Standard Penetration Test
JCD-2	55	224.777	90	(N/A)	D2 option	18,240,938.0	2,051,859.8	preparatory survey,2009	Standard Penetration Test water pressure test

Prepared by the JICA Survey Team

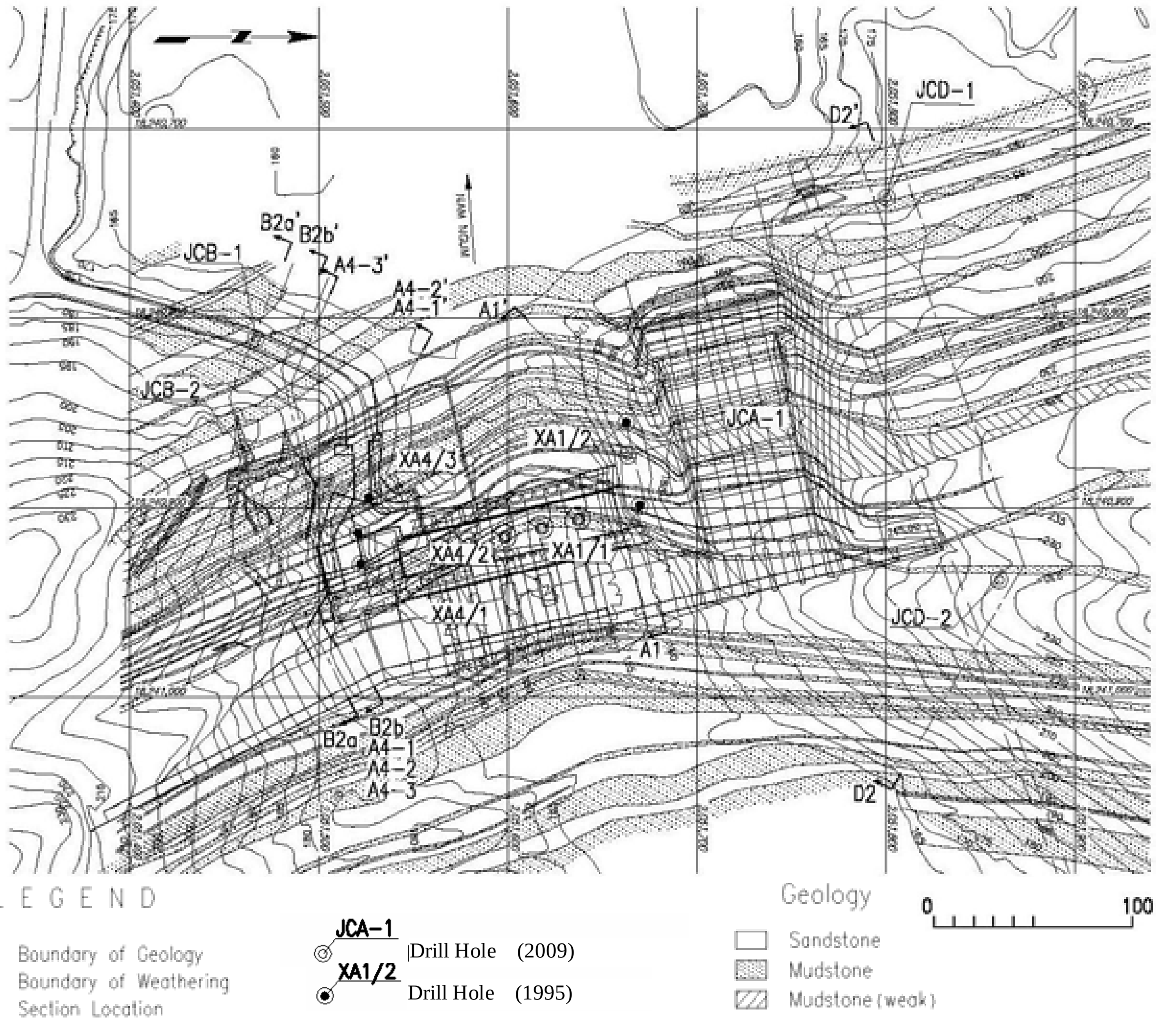
Table 7.3 List of Laboratory Tests Carried Out in This Study

test name	JCA-1 nos.	JCB-1 nos.	JCB-2 nos.	JCD-1 nos.	JCD-2 nos.
Specific Gravity and Absorption test	2	2	2	2	4
Unconfined Compression Strength test	6	0	0	0	0
Splitting Tensil Strength test	6	0	0	0	0

Prepared by the JICA Survey Team

(2) Comparison of Alternative Options

The geological plan revised by the Survey Team is shown in Figure 7.1. Any serious geological characteristics such as major fault or large landslide have not been identified in the expansion sites. Therefore every alternative option can be regarded as feasible from the geological viewpoint. The rock strata are distributed parallel to the dam axis, so the foundation rock of each alternative option is basically the same. However, the superiority or inferiority for each stratum occurs by the difference of the structure formation and position. The geological issues which need careful attention to are, 1) mudstone is not strong and is prone to deteriorate after excavation, 2) sandstone is jointed in the eminent bedding planes and blocks can slip on the joints easily, 3) permeability is high in the sandstone strata. Additionally, the geological concerns caused by the layout of each structure are summarized as, 1) stability of long cutting slope, 2) stability of the tunnel, 3) firmness of the powerhouse foundation rock, 4) water-tightness of temporary enclosure foundation rock, and 5) stability of existing structures. The geological issues for each option are summarized in Figure 7.2.



Prepared by the JICA Survey Team

Figure 7.1 Geological Plan

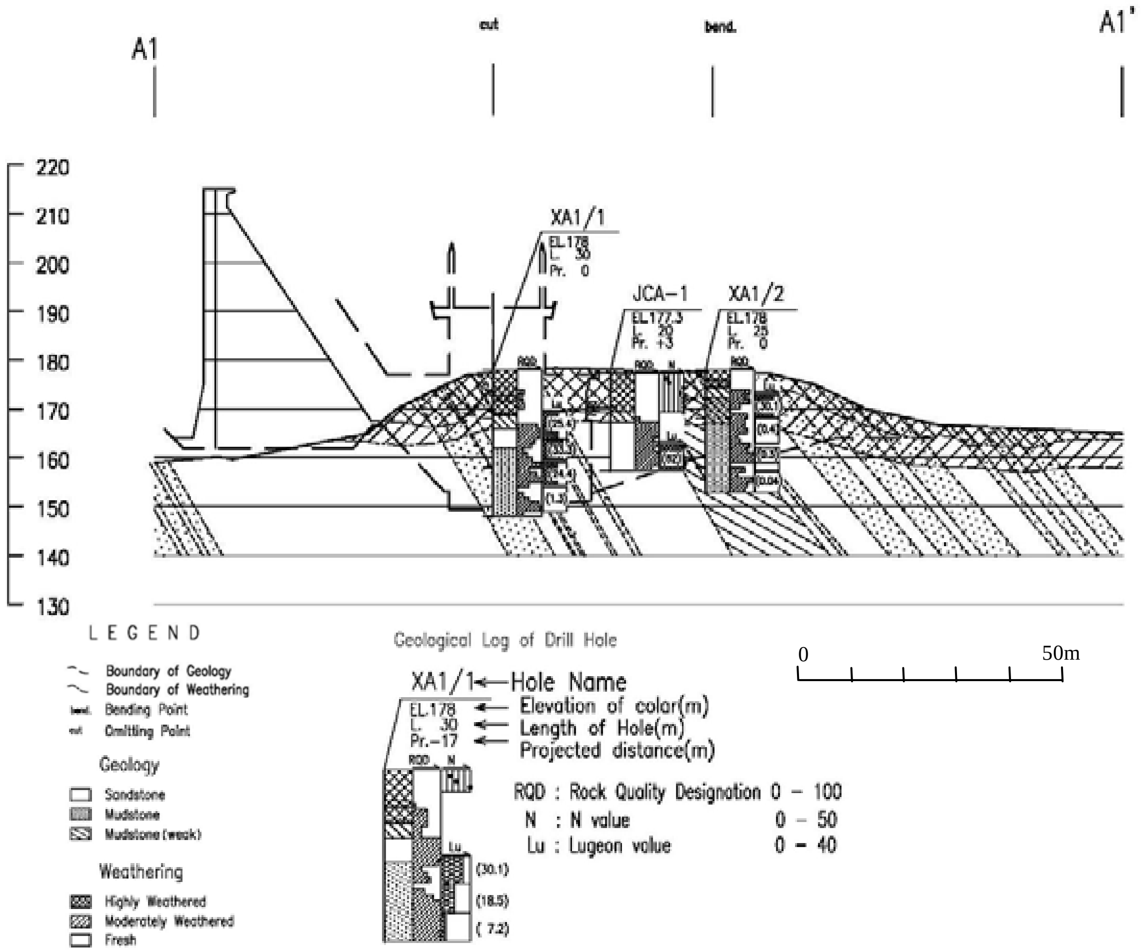
	Fatal Geology	Long Cut Slope			Mudstone Sections in Basement Rock		Seepage along Sandstone strata	
		existing structure		new structure	new structure		temporal closure	
	fault, landslide	toe of dam	side of spillway	behind power house	tunnel	generator / power house	inlet portal	outlet portal
A1,A2	-	O	O	-	-	O	-	O
A4	-	O	-	-	O	O	-	O
B2	-	-	-	O	O	O	-	O
D2	-	-	-	O	O	O	O	O

"O" indicates the requirement of countermeasures.
Prepared by the JICA Survey Team

Figure 7.2 Geological Issues for Each Alternative Option

(3) Engineering Geology of Optimum Option（Plan A1）

The new powerhouse is situated between the existing powerhouse and the spillway. The existing tail bay is shared by the new unit. The space for the new powerhouse is so narrow that steep cut slopes are required to reach the foundation rock. Further, the temporary enclosure in the tail bay is required to prevent the restriction of generation during the construction. The longitudinal profile of the waterway alignment is shown in Figure 7.3.



Prepared by the JICA Survey Team

Figure 7.3 Geological Profile (Plan A1)

It is necessary to consider the influence of cutting out the basement rock very near to the spillway and the dam. As the cut slope at the spillway faces perpendicularly to the strike of the bedding plane, the slope will be basically stable, but the slope will be so long that surface protection is necessary and the reinforcement for the foundation rock should be considered if necessary. On the other hand, the cut slope at the dam faces almost parallel to the bedding planes of dam foundation sandstone. Therefore some bedding joints may cause the slope failure as indicated in Figure 7.4. The estimated dip of the bedding plane is about of 55° but additional drilling investigation is necessary to confirm the failure type and plan suitable countermeasures. Some mudstone layers are distributed at the foundation of the new powerhouse, the immediate facing protection to the mudstone part is necessary to prevent deterioration of the mudstone. As the basement rock of the tail bay consists mainly of mudstone, its permeability will relatively be low. However, there are some permeable sandstone layers in mudstone, hence, the grouting at the sandstone parts may be necessary to prevent the seepage under the temporary enclosure.

(a) Sliding Failure (b) Buckling Failure, Toppling Failure

Prepared by the JICA Survey Team

Figure 7.4 Slope Failure Types

CHAPTER 8 SELECTION OF OPTIMUM EXPANSION PLAN

8.1 SELECTION PROCEDURES

In the beginning of the present Survey, eight alternatives of the expansion plan were taken up referring to the results of the feasibility study conducted in 1995. In order to select the optimum plan for expansion, the initial screening was carried out to choose three or four prospective alternatives out of the eight candidates. The initial screening was made during the inception stage of the Survey by means of engineering assessment without quantitative comparison. In the next step, the selected prospective alternatives were compared in detail by analyzing power generation efficiency, designing the powerhouse expansion layouts and estimating construction cost of respective alternatives. The final selection of the optimum expansion plan was made on the basis of economic/ financial assessment on the alternatives.

8.2 INITIAL SCREENING OF EXPANSION ALTERNATIVES

The candidates of alternatives for the initial screening are the following eight plans.

Plan A1-A3: An additional unit building is arranged between the spillway and the existing powerhouse. A penstock is built in a horizontal hole excavated through the existing concrete dam. (40-80 MW)

Plan A4: An additional unit building is arranged outside the southern end of the existing control building. (40-60 MW)

Plan B1: A new powerhouse building is arranged just on the left margin of the existing tail bay (80 MW)

Plan B2: A new powerhouse building is arranged on the left bank downstream of the existing tail bay. (80 MW)

Plan C: A new powerhouse building to accommodate 2 additional units is arranged on a space between spillway and tail bay. (80 MW)

Plan D1: A new underground powerhouse is arranged in right abutment hill. The existing diversion tunnel is intended to be utilized as one of two headrace tunnels. New intake structures are independent from the existing dam.（80-120 MW）

Plan D2: A new surface type powerhouse is arranged on right bank of the spillway plunge pool. The diversion tunnel is to be utilized as one of two headrace tunnels. New intake structures are independent from the existing dam.（80-120 MW）

Plan E: An independent intake tower is built in the reservoir upstream of left bank dam. A headrace tunnel crossing the dam foundation is extended from the intake to a new powerhouse located downstream of ridge similarly to B2.（80-120 MW）

As the result of technical assessment in the initial screening, it was judged that land space for plans B1 and C is not adequately large and plans D1, D2 and E requiring costly independent intake tower are apparently uneconomical compared with the other plans. Based on the result, the Survey Team selected three alternatives (A1-A2, A4 and B2) as the prospective alternatives to be further studied in detail. The Survey Team presented this result to DOE/EdL at the first steering committee meeting held in February 2009 and received DOE/EdL's concurrence. However, at the meeting, DOE/EdL strongly requested to add the plan D (new powerhouse on right bank) to the prospective alternatives since the plan D would not give any impact to the existing dam/powerhouse and would result in less land problem for additional transmission line if necessary. The Survey Team accepted the request of DOE/EdL and finally selected four alternatives for further study, i.e., plans A1-A2, plan A4, plan B2 and plan D2.

8.3 SELECTION OF OPTIMUM PLAN

The four prospective alternative layouts selected in the initial screening have major differences in terms of the powerhouse locations. To consider two or more different installed capacities at each alternative location, a total of 12 comparative plans as listed below was set up for the further study:

Plan A1(40 MW), Plan A2(60 MW): A building for additional unit is arranged between the spillway and the existing powerhouse.

Plan A4-1(40 MW), Plan A4-2(60 MW): A building for additional unit is arranged outside the southern end of the existing control building. Outlet of new tailrace is located beside the existing tailbay.

Plan A4-3(40 MW), Plan A4-4(60 MW): A building for additional unit is arranged outside the southern end of the existing control building. Outlet of new tailrace is located on left bank downstream of the existing tailbay.

Plan B2-1(80 MW), Plan B2-2(120 MW): A new powerhouse building is arranged on the left bank downstream of the existing tail bay.

Plan D2-1(40 MW), Plan D2-2(60 MW), Plan D2-3(80 MW), Plan D2-4(120 MW):

A new surface type powerhouse is arranged on right bank of the spillway plunge pool. The existing diversion tunnel is not utilized for future waterway because of old age. New tunnels are required.

Waterway

The penstock diameter is determined to be the same flow velocity as the existing units 3-5. Intake center level is determined so as to avoid air entrainment into the intake. The required penstock diameter is 8.5m for 80 MW and 10.5m for 120 MW in case of single unit installation. The width (15 m) of No. 11 dam block is not large enough for such large penstock. Therefore, two 40 MW and 60 MW intakes and penstocks are installed in the 80 MW and 120 MW plans, respectively, in order to maintain the stability of the dam.

For construction of intake on the existing dam including break-through work for excavating a large hole in the dam, a temporary enclosure structure is fixed to the upstream face of the dam. The selected type of the steel enclosure is the square type since there are many precedents and its construction is relatively easy. A concrete pedestal is adopted to support the enclosure structure. For construction of independent intake tower in Plan D, temporary coffer enclosure made of large steel pipe piles is considered. Diameter of the hole to be excavated in the dam for penstock is 7.2 m for 40 MW plans and 8.6 m for 60 MW plans. Construction method for the piecing dam is SD (Slot-drilling) method which has many precedents in Japan.

All plans other than D2 require excavation of large hole in the existing dam for providing the intake. The dam body with excavated hole becomes lighter because of reduced weight and increased uplift force acting on temporary enclosure structure when the inside of enclosure is dewatered. This results in lowering of safety factor of the dam. By the stability calculations on the dam body after piercing the dam, it was revealed that the dam is safe enough in all alternatives as far as the temporary enclosure is supported by pedestal concrete.

Powerhouse and Tailrace

There are 12 alternative plans determined based on the location of power stations and the installed capacity. Major features of such alternatives are summarized below.

Table 8.1 Major Features of Powerhouse and Tailrace for Each Alternative Plan

Alternative Plans	1	2	3	4	5	6	7	8	9	10	11	12
	A-1	**A-2**	**A4-1**	**A4-2**	**A4-3**	A4-4	**B2-1**	B2-2	**D2-1**	D2-2	**D2-3**	D2-4
(MW)	40	60	40	60	40	60	80	120	40	60	80	120
Powerhouse:												
- Building	Extended to the exist		Independently constructed				Independently constructed		Independently constructed			
- Turbine inlet valve	-		-				-		-		2 sets	
- Add. OHT crane (ton)	-	250	170	250	170	250	170	250	170	250	170	250
Tailrace:												
- Type	Open channel		Short tunnel		Long tunnel		Open channel		Open channel			
			D6	D7.4	D6	D7.4						
- Gate (ton) & Gantry crane	Exist.	New	New				New		New			
		80	56	80	56	80	56	80	56	80	56	80

*) OHT: Overhead Traveling
Prepared by the JICA Survey Team

For the above alternative plans, the drawings of plan, profile and sections for plans A1 (40 MW), A2 (60 MW), A4-1 (40 MW), A4-2 (60 MW), A4-3 (40 MW), B2-1 (80 MW), D2-1 (40 MW), D2-3 (80 MW) were prepared.

Electro-Mechanical Equipment

In selection of the optimal expansion plan, the electro-mechanical equipment for each alternative plan was preliminary designed especially for the following items.

1) Turbine, rated net head
2) Turbine, rated output
3) Turbine, type
4) Turbine, rated speed
5) Inlet valve
6) Generator, rated output
7) Generator, type
8) Overhead traveling crane for the additional units
9) Main transformer, rated power
10) Main transformer, type
11) Necessity of relocation of the existing 115 kV GIS
12) How to connect the additional units to the 115 kV transmission lines
13) Conductor size of 115 kV main bus for the existing outdoor switchyard
14) Station-service power supply equipment for the additional units
15) DC power supply equipment for the additional units
16) Control and relay boards for the additional units
17) Conductor size of 115 kV main bus for the existing Thalat Substation

Mechanical Equipment

The following mechanical equipment were studied for designing alternative options to select the optimum plan:

1) Intake trashracks
2) Intake stoplogs
3) Intake gate
4) Steel Penstock
5) Facilities for Drainage of Additional Power Station and Dewatering of Draft Tube
6) Draft Tube Gate Facilities

System Analysis

Analyses for power flow, voltage regulation, fault current and stability were conducted in order to confirm if the transmission system satisfies the EdL's power system planning criteria in the C1 area including Vientiane in 2016 after expansion of Nam Ngum 1 hydropower station.

The analysis for power flow and voltage was carried out for the transmission system in the C1 area taking into account the various scales of the NN1 expansion. The N-1 contingency (single circuit failure) was also considered. As the result, the followings are concluded:

1) Transmission Line

a) No additional transmission line will be required on the NN1 expansion plans with additional unit up to 80 MW.

b) In case of the 120 MW expansion of NN1, a single circuit of 115 kV transmission line between Thalat substation and Phon Soung substation will be overloaded. Large-scale extension or replacement of Phon Soung substation will be required in order to connect a new transmission line in Phon Soung substation, because the main bus configuration of Phon Soung substation is T-branch. Therefore, a single circuit of 115 kV transmission line between Nam Ngum 1 power station and Naxaythong substation or Hin Huep substation will be required in order to reduce the transmission load between Thalat substation and Phon Soung substation.

c) No additional transmission line around Vientiane will be required in any expansion plan.

2) Main Bus of Substations

a) In any expansion plan, the main bus conductors in Nam Ngum 1 power station and Thalat substation should be replaced by bigger conductors.

b) In case of the 120 MW expansion plan, replacement of the main bus conductors for Phon Soung substation will also be required.

c) In case of expansion plans over 60 MW, replacement of the main bus conductors for Naxaythong substation will be required.

d) In any expansion plan, the main bus conductors of Phonetong substation will be overloaded. However, the overloading in the main bus of these substations will also occur in the 2016 system even in case of no expansion of Nam Ngum 1 power station.

The fault current analysis was also conducted to define the maximum three-phase short circuit fault currents in the system in 2016. As the result, it is concluded that the maximum fault current is below the allowable level in any expansion option.

The system stability analysis was conducted to confirm whether all synchronous generators connected to the system including additional unit in NN1 can be on stable condition even in case of an equipment fault. The analysis result concludes that large diffusion does not occur in expansion plan up to 80 MW. However, in case of 120 MW expansion plan, the system is not stabilized due to large diffusion. In addition, a single circuit fault of 115 kV transmission line between NN1 and Naxaythong substation is not stabilized more than a single circuit fault of 115 kV transmission line between Nam Ngum 1 and Thalat substation.

Technical Assessment

In case of the 40 MW expansion, the plan A1 is technically most superior to the other plans since the layout of waterway and powerhouse becomes most compact and the existing equipment of overhead crane and draft tube gates can be effectively utilized for the additional unit 6. In case of the 60 MW expansion, the plan A2 has the most compact layout, but the deep excavation below the exiting spillway wall endangers the wall stability and the existing overhead crane and draft tube gates cannot be utilized for the 60 MW unit. Therefore, the plan A4-4 having sufficient land space is technically most superior to the other 60 MW plans. In case of the 80-120 MW expansions, the left bank plan such as B2, which the intake is provided in the existing dam, is technically superior. The right bank plan (D2) requires independent intake tower to be built in deep reservoir and difficult and costly underwater works are necessary for construction of temporary coffer enclosure.

The environmental impacts caused by the powerhouse expansion was preliminarily studied. The most notable impact is the increase of daily water level fluctuations in the downstream river reaches caused by increased peak generation of the NN1 power station. It was revealed that the increment of water level fluctuation is within 0.5 m if the expansion capacity is 40 MW or less. Such small increase of water level fluctuation does not cause serious impacts to the downstream riparian people and does not require particular measures to mitigate the impact.

Economic Comparison

For economic comparison, conceptual design was prepared for each alternative and construction costs of civil works, hydro-mechanical works and electro-mechanical works were estimated based on the work quantities calculated from the conceptual design.

The benefit of the powerhouse expansion is brought from increase of power generation potential (energy production and dependable capacity). The incremental potential of generation is expressed by the difference of generation potentials between “with expansion” and “without expansion” with NN2 in both cases. The generation potentials were calculated by the reservoir operation simulations based on the inflow data of 36 years (1972-2007).

For the economic benefit of each alternative, a diesel generation is considered to be the lowest cost alternative for the expansion scheme and its unit costs are regarded as the unit benefits of the expansion scheme. The financial benefit of each alternative was calculated on the basis of the current average tariff rate of domestic electricity supply. The following table shows summary of economic comparisons of the alternatives.

Table 8.2 Summary of Economic Comparison of Alternatives

Expansion Scale	Alter native	Project cost (M US$)	Incremental capacity and energy (*)		Benefit (M US$ /year)		Benefit-cost ratio	
			Capacity increment (MW)	Energy increment (GWh/year)	Economic benefit	Financial benefit	Economic B/C	Financial B/C

40 MW	A1	57.31	33.83	51.93	13.39	3.00	**2.06**	**1.65**
	A4-1	66.66	33.61	50.75	13.22	2.93	1.75	1.38
	A4-3	66.11	33.54	50.27	13.18	2.91	1.76	1.38
	D2-1	83.82	33.76	51.56	13.34	2.98	1.40	1.12
60 MW	A2	80.96	51.02	54.56	18.32	3.15	1.99	1.22
	A4-2	87.56	50.71	52.59	18.08	3.04	1.82	1.09
	A4-4	87.12	50.61	51.95	18.01	3.00	1.82	1.08
	D2-2	106.26	51.04	54.70	18.33	3.16	1.52	0.94
80 MW	B2-1	130.79	78.09	66.56	26.71	3.85	1.80	0.92
	D2-3	133.87	77.16	62.40	26.14	3.61	1.72	0.85
120 MW	B2-2	171.49	116.53	71.73	37.71	4.15	1.94	0.76
	D2-4	180.40	114.52	65.49	36.66	3.78	1.79	0.66

Prepared by the JICA Survey Team

Higher value of B/C ratio expresses the higher cost performance. As indicated in the above table, the B/C ratio of Alternative A1 (40 MW) is highest in both economic B/C (= 2.06) and financial B/C (=1.65).

Optimum Plan Selected

The Alternative A1 (40 MW) is judged to be highest in terms of cost performance among 12 alternative options considered. The Alternative A1 is to build a new machine bay building for 40 MW plant in the space between the existing powerhouse and the spillway. The existing overhead cranes and draft tube gates can be utilized for the additional unit. Layout of the new powerhouse is most compact and economical among the all options. As the length of penstock and tailrace is short and waterway head loss is less, available water head can be most effectively utilized for power generation. Furthermore, environmental impact due to increased daily fluctuation of downstream river water level is insignificant and no compensation is required. By comprehensively judging from technical, environmental, economical and financial viewpoints, the Alternative A1 (40 MW) was selected as the optimum expansion plan for the Nam Ngum 1 power station.

CHAPTER 9 BASIC DESIGN OF OPTIMUM EXPANSION PLAN

9.1 PRINCIPAL WATER LEVEL AND WATERWAY DIMENSIONS

Rated Reservoir Water Level for Unit-6

The Nam Ngum 2 (NN2) hydropower project being constructed at the upstream margin of the NN1 reservoir will be put into operation in 2011 and, 4 years later, the additional 40 MW unit of NN1 will be commissioned in 2015. The NN2's reservoir has an effective storage capacity corresponding to almost half of the annual river flow volume at the NN2 site. By the NN2's flow regulation function, the inflow patterns to the NN1 reservoir will considerably be flattened, i.e., the dry season inflow rates increase and contrarily the rainy season inflow rates decrease.

According to the actual records of the NN1's past reservoir water level (1982-2007), the long term average water level is EL. 206.0 m. This water level coincides with the water level on which the design head of the units 3-5 turbines is based. However, once the NN2 commences its operation, the NN1 can operate the reservoir at a higher level since seasonal fluctuations of the NN1 inflows are reduced. For the condition after the 40 MW expansion, the Survey Team carried out reservoir operation simulation inputting the past 36 years inflow data. The result shows that the long term average reservoir water level after the expansion is EL. 209.6 m that is 3.6 m higher than the present average water level, as illustrated in Figure 9.1. Therefore, the design water level for the turbine of the additional unit-6 is decided to be EL. 209.6 m.

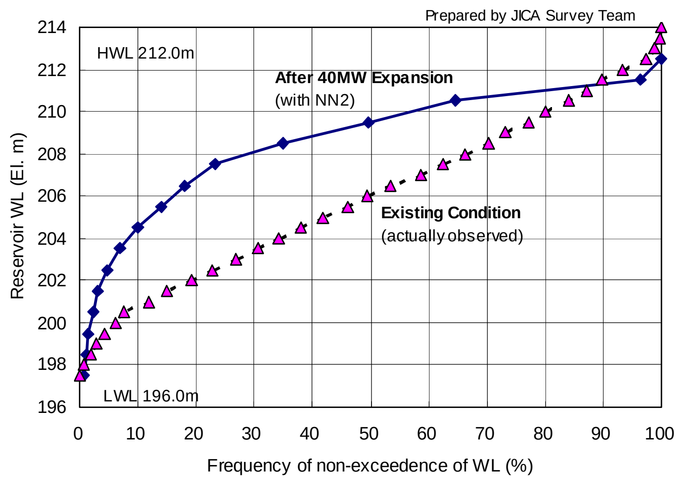


Figure 9.1 Reservoir WL Frequency

The tail water level of the NN1 power station is EL. 168.0 m at present when all units (155 MW in total) are operated at their full capacities with no spillway outflow. After the 40 MW expansion, the tail water level rises to EL. 168.4 m.

The head loss in the waterway of the unit-6 is estimated at 1.2 m when fully operated. Therefore, when the reservoir water level is EL. 209.6 m, the effective head for the unit-6 is 40.0 m (= 209.6-168.4-1.2). This effective head (40.0 m) is adopted as the design net head (rated head) for the unit-6 turbine.

Optimum Penstock Diameter for Unit-6

The penstock diameter of the existing units 3 to 5 (40 MW each) is 6.0 m. At the location of the unit-6 penstock, dam foundation level is higher than the deepest level of the penstock. In order not to threaten the stability of the existing dam, smaller diameter of penstock is preferable. However, if the penstock diameter becomes smaller, the head loss in waterway increases and the generation benefit decreases. The optimum (economic) diameter of the unit-6 penstock was sought by comparing the construction cost saving with reduced energy benefit resulting from application of smaller diameters such as 5.5m, 5.0m and 4.5m. According to the result of economic comparison based on the cost estimate and the generation simulation, the diameter of 5.5 m is most economical since the net present value for 50 years is highest. Therefore, the diameter of the unit-6 penstock was decided to be 5.5 m.

Intake Center Elevation of Unit 6

The minimum operation level of reservoir for the existing units 3 to 5 is EL. 196.0 m. After the NN1 expansion with NN2, the reservoir water level in the dry season will be kept at considerably higher level than the present level. However, the generation simulation for 36 years shows that the water level sometimes falls down to around EL. 197 m. Therefore, it is not recommendable to raise the minimum operation level for the unit-6. The present minimum level of EL. 196.0 m is used also for the unit-6.

The intake entrance level should be deep enough from the water surface to prevent formation of vortex and consequent air-entraining into the intake conduit. Required intake submergence above the top of intake conduit is calculated for the 5.5 m diameter penstock. The center level of the unit-6 intake is thus decided to be EL. 185.52 m.

9.2 INTAKE AND PENSTOCK

The intake and penstock (5.5 m diameter) are installed in the horizontal hole excavated in the existing dam. The hole to be excavated is 6.7 m in diameter. This diameter allows a working clearance of 0.6 m on both sides of the penstock steel pipe installed.

Inside of the temporary enclosure has to be dewatered during the works of final penetration of the hole and bell-mouth pipe and stoplog installation at the intake. If it is possible to lower the reservoir water level to a certain level throughout the dewatering period, the type of temporary enclosure can be changed to steel girder support type which is economical because its construction is easier than the pedestal concrete support type. However, if the reservoir water level is compulsorily lowered, the EdL's power selling income decreases due to reduction of generation output. Economic comparison was carried out to seek realization of lowering the reservoir water level during intake construction.

According to the reservoir operation simulations made so far, the reservoir water level falls to EL. 207 m or below at the end of the dry season in almost all years. The maximum limit of water level during the water level restriction is provisionally set at EL. 207 m. The period of the water level restriction required is 3.5 months in one dry season. The generation output reduced due to the water level restriction is estimated by the reservoir operation simulation for 36 years and the average reduction is adopted as the reduced income. The simulation result showed that the reduced energy production is 34 GWh on average if the reservoir water level restriction is applied. This corresponds to US$ 2.1 million reduction of power selling income (unit rate = 0.0631 US$/kWh).

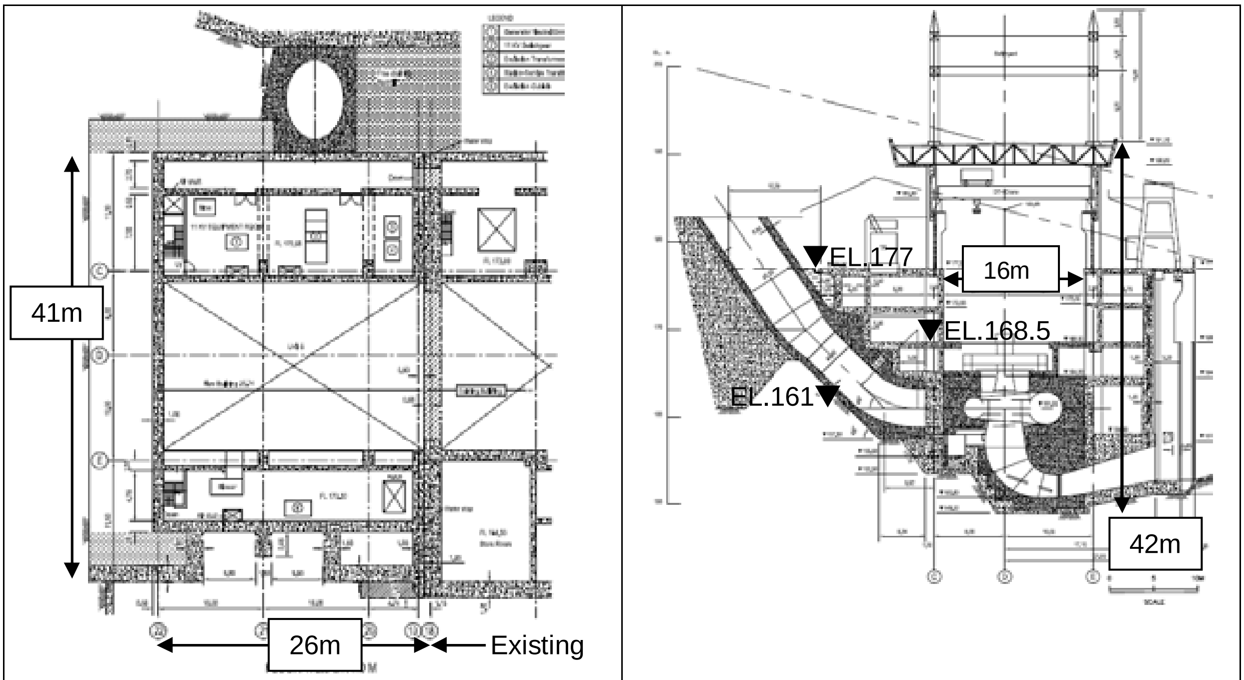
However, the construction cost of temporary enclosure can be much reduced by providing the reservoir water level restriction. In case that the reservoir water level is restricted to be EL. 207 m or below, the cost saving of temporary enclosure is US$ 4.9 million. This means that the amount of cost saving is much more than the reduced power selling income. Therefore, the temporary enclosure is designed on the condition that the reservoir water level is lowered to EL. 207 m by the beginning of March and kept below EL. 207 m until middle of June.

The stability of the dam (Bl. No. 20) was examined for the condition that intake and penstock are installed in the hole excavated in the dam body. The temporary enclosure considered was the steel girder type without concrete pedestal. The result of the stability analysis showed that the safety of dam is assured under any loading condition such as usual loading, flood time, seismic time and construction time.

9.3 POWERHOUSE AND TAILRACE

Powerhouse Layout

The basic design of the powerhouse was conducted through a more detailed examination of the existing powerhouse structures, current topography and necessary equipment to be installed. As shown in Figure 9.2, size of the powerhouse is 41 m width, 26 m length and 42 m height.



Floor Plan (EL. 172.5 & 173.0 m) Cross Section (Unit Center)

Source: JICA Survey Team

Figure 9.2 Plan and Section of Powerhouse

In addition, the major equipment such as switchgears, control equipment, water turbine auxiliaries etc. were arranged on each floor of the powerhouse.

Powerhouse Stability

The safety against overturning (eccentricity), sliding (safety factor) and maximum stress in foundation for stability of the powerhouse building were examined by stability analysis. As the result, it was verified that the additional powerhouse building for unit 6 would be structurally stable under any loading condition.

Tailrace Layout

In addition to the powerhouse, basic design of the tailrace was undertaken referring to the topographic survey results around the powerhouse, which were obtained through subletting works. The tailrace channel is an open channel having trapezoidal section. The length of the channel is 52 m and the bottom width gradually spreads from 11.5 m to 20.5 m.

General arrangement of the optimum expansion plan is shown in the last figure of Chapter 9.

9.4 ELECTRO-MECHANICAL EQUIPMENT

(1) Basic Design for Unit 6

Based on the study results on the reservoir rated water level, the preliminary design of the selected optimal expansion plan was reviewed and confirmed especially for the following items:

1) Turbine, rated net head
2) Turbine, rated output
3) Turbine, rated speed
4) Turbine, centerline elevation
5) Generator, rated output
6) Generator, rated power factor
7) Main transformer, type
8) Main transformer, rated power

The review results in the basic design of unit 6 and the comparison with the existing unit 5 are shown in Table 9.1.

Table 9.1 Comparison of Principal Features of Electro-Mechanical Equipment

	Item	Unit 6	Existing Unit 5	Remarks
(a)	Unit Rated Output	40,000 kW	40,000 kW	
(b)	Turbine			
	1) Rated net head	40.0 m	37.0 m	Note 1
	2) Type	Francis turbine	Francis turbine	
	3) Rated output	40,900 kW	40,000 kW	Note 2
	4) Rated speed	142.9 rpm	136.4 rpm	Note 3
	5) Turbine centerline elevation	EL. 161.0 m	EL. 161.0 m	
(c)	Generator			
	1) Construction	Umbrella type	Umbrella type	
	2) Rated output	50,000 kVA	50,000 kVA	
	3) Rated voltage	11 kV	11 kV	
	4) Rated frequency	50 Hz	50 Hz	
	5) Rated power factor	0.8	0.8	
(d)	Main Transformer			
	1) Type	Single-phase	Single-phase	
	2) Rated power	50,000 kVA	50,000 kVA	
	3) Rated voltage ratio	115/11 kV	115/11 kV	

Note 1: Due to change of reservoir rated water level
Note 2: Due to change of rated net head
Note 3: Due to change of turbine rated output and rated net head
Prepared by the JICA Survey Team

(2) Countermeasure against Influence of Additional Installation of Unit 6 to Existing Facilities

As a result of the additional installation of unit 6, the current carrying capacities of the 115 kV main bus conductors for the Nam Ngum 1 switchyard and Thalat Substation will become insufficient. Therefore, it is required that the 115 kV main bus conductors should be replaced as shown in Table 9.2.

Table 9.2 Replacement of 115 kV Main Bus Conductors

	Item	Existing Conductor	New Conductor
(a)	Nam Ngum 1 Power Station		
	1) 115 kV main bus conductor	HDCC 325 mm^2	HDCC 725 mm^2
	2) Current carrying capacity	875 A	1,420 A
(b)	Thalat Substation		
	1) 115 kV main bus conductor	ACSR 240 mm^2	ACSR 410 mm^2
	2) Current carrying capacity	590 A	825 A

Prepared by the JICA Survey Team

(3) Improvement in Operation of Power Station by Additional Installation of Unit 6

Along with the additional installation of unit 6, the following modification of the existing facilities is planned for making improvement in operation of the power station.

a) Improvement of reliability of station-service power supply system

The 22 kV circuit, which is now used as a power source for the station-service power supply system, is often unstable especially in rainy season. Therefore, the station-service power supply system is modified to use unit 6 generator as a back-up power source of the 22 kV circuit, in order to improve the power supply reliability.

b) Improvement in operation of 115 kV switchyard main bus

The existing 115 kV outdoor switchyard employs a single bus scheme, and four generators for units 3 to 6 and two transmission lines are connected to the same single bus. Just in case the 115 kV bus is troubled, all of these facilities will be forced to be tripped and cannot be restarted until the 115 kV bus is restored completely. In order to make possible flexible operation of the 115 kV main bus, a 115 kV sectionalizing disconnector is added to the existing 115 kV main bus.

9.5 MECHANICAL EQUIPMENT

The results of the basic design conducted for mechanical equipment are summarized as below:

(1) Intake Trashracks

The trashracks are of movable type in one span with two guide rollers on each side. Screen panels with bar pitch of 100 mm are fixed on frames of trashracks with net dimensions of 7.15 m x 7.15 m. Both screens and frames are of the welded structure with the rolled steels for welded structure. The maximum flow velocity at the thrashracks is estimated to be approximately 2.9 m/s which is much higher than the usual intake velocity. Special design of the screen bars will be required to prevent vibration damage caused by the high flow velocity.

(2) Intake Stoplogs

The stoplogs are of the welded structure with rolled steels. The clear span and total effective height of the stoplogs are decided to be 7.15 m so as to fit the intake bell mouth. The guide frame for the stoplog panels is common to the tarshrack panels. Painting is adopted for the protection of steel members, and zinc chlorinated rubber paint will be applied taking its durability and better performance against ultraviolet ray. As the existing gantry crane for the units 1 to 5 is commonly used for the expanded unit-6 intake facilities, one segment weight of new stoplogs is to be less than 6 tons so as not to exceed the lifting capacity of gantry crane.

The sealing seat plates of stainless steel are provided on four edges of a circular bellmouth. The guide frames located on both sides of the bellmouth are of the high strength structures encased in concrete to support the water pressure load from the stoplogs. The guide rails above the bellmouth location are of stainless steel structures fixed to the upstream face of dam with chemical anchors. The storing spaces for the stoplog panels are provided on the upstream surface of dam beside the stoplog slot.

(3) Intake Gantry Crane

The rails and power supply cables for the gantry crane are extended from the existing unit-5 intake up to the new unit-6 intake location. The existing gantry crane is commonly used for trashracks and stoplogs of the expansion plan.

(4) Intake Gate

The selected intake gate is a bonnet type circular slide gate operated by hydraulic cylinder The gate is designed for internal water pressure of 30 m head. The water passage clear diameter of the gate is 5.50 m. Sealing system of the gate is the downstream 4 edges rubber seal. The gate is the welded structures made of rolled steels. Aluminum bronze is adopted for the bearing shoes to prevent the shoe from sticking with seat. Stainless steel materials are adopted for fixing plates and bolts of seal, sealing seat, and bearing plates for future maintenance. A by-pass pipe system with valves is provided on the gate to fill water into the downstream penstock so that the gate is opened under pressure-balanced condition.

The normal hoisting speed is decided to be 150 mm/min considering the operation time of approximately 30 minutes for the stroke of 5.50 m open or close. In case of an emergency shut-down operation, the intake gate is required to be closed quickly, within around ten minutes, the gate closing speed for shut-down operation is decided to be 550 mm/min accordingly.

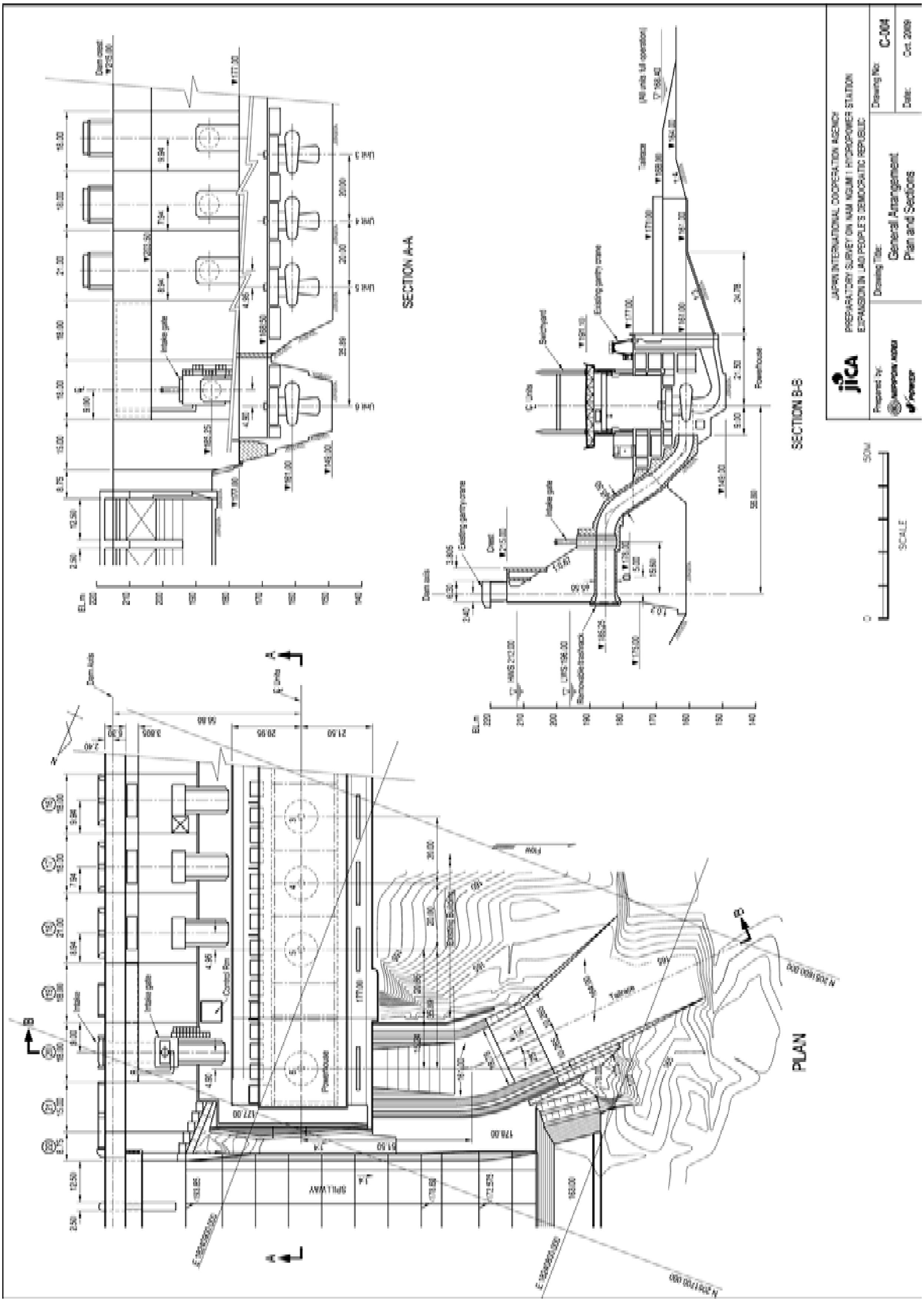
(5) Steel Penstock

The diameter of the penstock is 5.50 m in most of the length except for the 4.40 m diameter lower portion. The minimum shell plate thickness of the steel penstock is 16 mm pursuant to the technical standards for gate and penstock in Japan. The design internal pressure is decided from the summation of static water pressure and water hammer pressure. As for the design external pressure, a half of the head difference between the reservoir water level and penstock center elevation is adopted.

An air vent valve is provided at the upstream of the intake gate to vent air from the upstream penstock when the water filling is made for the penstock through the by-pass valve of the intake stoplogs.

(6) Draft Tube Stoplogs and Gantry Crane

The existing draft tube stoplogs for the units 1 to 5 are used commonly for the new unit-6 draft tube outlet. The guide frames to be installed in the unit-6 are of the same dimensions of guide frame installed in the existing units accordingly. The traveling rails and power supply cable are extended from the unit-5 bay to the unit-6 draft tube outlet to use the existing gantry crane commonly for the expansion plan.



Prepared by JICA Survey Team

Figure 9.3 Drawing of General Arrangement of the Optimum Expansion Plan

CHAPTER 10 STUDY ON THE TAILRACE WATER LEVEL

10.1 PRESENT CONDITION OF TAILRACE WATER LEVEL

At the section 500 m downstream from the Nam Ngum Hydropower Station, there is a line of rock outcrops at the riverbed in the transverse direction. There is water fall of 40 to 50 cm depth at this river section as shown in the photo below. Due to these rock outcrops, the water level at upstream of this section is lifted up and tailrace water level is affected.

According to the historical record of tailrace water level, the yearly minimum level is basically not lower than EL.166.00 m. This means that power generation has continued through many years. However, there is a record of minimum tailrace water level with EL.165.00 m in 2003. According to the information related to the power station, this tailrace water level was recorded when all power generation units were stopped. This was made only once in the past power generation history.

In the discharge-tailrace water level curve, the lowest tailrace water level at no discharge is at EL.164.00 m. However, the recorded minimum tailrace water level was EL.165.00 m. This is because the downstream area of units 1 and 2, in which there is the tailrace water level measurement device, has the lowest riverbed elevation of EL.165.00 m at the tailrace channel outlet and it is enclosed with concrete separation wall located between the downstream areas of units 2 and 3. Therefore, the tailrace water level measured at the draft tube outlet area of units 1 and 2 could not be lower than EL.165.00 m.

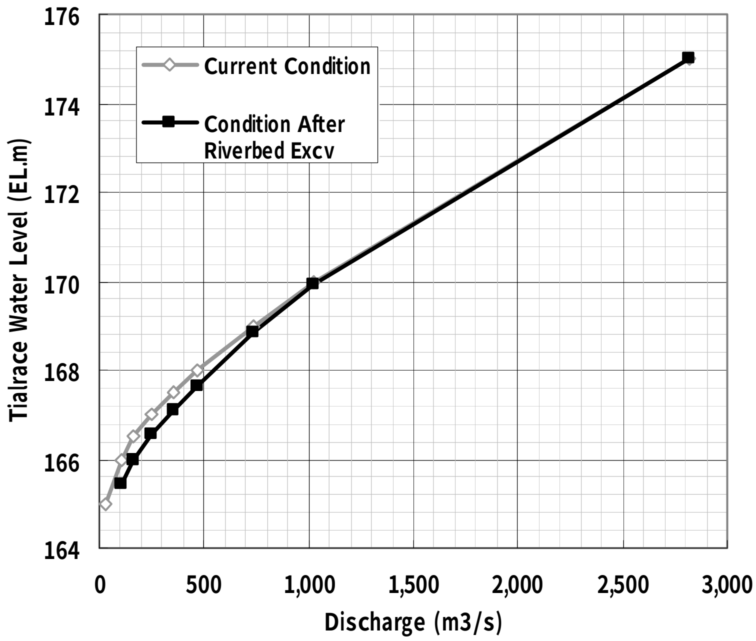
10.2 POSSIBILITY OF LOWERING OF TAILRACE WATER LEVEL

Through the excavation of the exposed riverbed located at about 500 m downstream of the powerhouse, tailrace water level (tail water level) is lowered, the effective head is increased, consequently increasing the generated energy.

In order to estimate the lowered depth of tailrace water level, the following works were conducted:

- River Cross Section Surveys
- Regeneration of the current river condition
- Prediction of the river condition after excavation of exposed riverbed
- Estimation of lowered depth of tailrace water level
- Confirmation of difference of water velocity due to excavation of exposed riverbed

The tailrace water level rating curve after riverbed excavation prepared by the hydraulic calculation is shown below:



WL (El.m)	Q (m3/s)
175.0	2,815
169.9	1,025
168.9	735
167.7	467
167.1	351
166.5	247
166.0	167
165.5	105

Prepared by the JICA Survey Team

Figure 10.1 Tailrace Water Level Rating Curve After Riverbed Excavation

In accordance with the calculation results, there are almost no changes between the water velocities before and after the riverbed excavation. Consequently, it is most likely that erosions of the river course will not occur.

10.3 INFLUENCE ON EXISTING TURBINES

(1) Unit 1 and Unit 2

The turbine centerlines of the existing Unit 1 and Unit 2 are set at EL. 165.5 m without any safety margin to the calculated cavitation limit.

In case the drawdown of the tailrace water level is expected, a mound or another structure should be provided at the tailrace outlet bottom of the existing Unit 1 and Unit 2, so that the operating tailrace water level should not be lowered down below EL. 164.0 m.

(2) Unit 3, Unit 4, Unit 5

The actual setting values of the turbine centerlines for the existing Unit 3, Unit 4 and Unit 5 have safety margins of more than 1.8 m. However, their runners have experienced some pitting erosions due to cavitation. In case the tailrace water level is lowered, there is a possibility of increasing the cavitation damages on the runners slightly. Even in such case, the cavitation damages will not exceed the allowable limit and repairable limit on site.

This means that the existing turbines for Unit 3, Unit 4 and Unit 5 are possible to secure a necessary suction head to prevent the occurrence of excessive cavitation on condition that the drawdown of the tailrace water level is less than 1.8 m. Therefore, it is expected that the drawdown of the tailrace water level will not affect seriously to the existing turbines for Unit 3, Unit 4 and Unit 5. In case that Unit 6 is additionally installed, the tailrace water level will be raised and this will mitigate the influence to Units 3, 4 and 5.

10.4 BENEFIT AND COST OF LOWERING OF TAILRACE WATER LEVEL

Based on the calculation using the tailrace water level rating curve after excavation of exposed riverbed, it is estimated that an increase of the annual generated energy of the NN1 power station after expansion is 5 GWh.

Cost of the excavation (13,000 m^3) of exposed riverbed is estimated as about JPY 74 million (=US$ 0.78 million).

CHAPTER 11 IMPLEMENTATION AND COST ESTIMATE

11.1 EXECUTION OF THE PROJECT

The Project includes three major construction works of 1) civil works, 2) hydro-mechanical works, and 3) electro-mechanical works. The overall implementation period was planned at 5 years including 3 years construction period. No stoppage of existing Nam Ngum 1 power plants is planned during construction of the expansion works.

The Project will be implemented by the Department of Electricity (DOE), Ministry of Energy and Mines of Lao PDR who, as the executing agency, will also undertake management and supervision of project construction. The DOE will organize an implementation team/management board, as an internal organization, during the construction. After completion of all construction works, the permanent structures and facilities will be transferred to the Electricite du Laos (EdL) who will be the project owner. The selected international consulting firm and associated local consulting firms will be employed for the detailed design including preparation of tender documents and construction supervision, to assist the DOE in implementing the Project. For the funding arrangement, Japan's soft Yen loan for LDC (Least Developed Countries) is expected to be applied for the Project. In selecting contractors for the following 3 lots, the International Competitive Bidding (ICB) process will in principle be adopted through a pre-qualification. The contractors will be selected in accordance with the guidelines of the JICA and the DOE.

- Lot 1: Civil works
- Lot 2: Hydro-mechanical works
- Lot 3: Electro-mechanical works

11.2 CONSTRUCTION PLAN AND SCHEDULE

Construction Resources

Construction resources required for the project will be local products and imported products. Skilled labor such as divers for welding and rigging works in reservoir water for temporary intake enclosure and open air, drilling operators for piecing dam body, operators of heavy lifting crane and etc will have to be recruited from the neighboring countries or Japan.

Construction Order

The construction works will be conducted separating into 2 sections for intake and penstock (upstream side), and powerhouse and tailrace (downstream side), and be preceded in parallel mostly after mobilization.

Construction Schedule

Construction period is scheduled to be 3 years for Lots 1, 2 and 3. In planning the time schedule, the monthly variation of reservoir water level is taken into account since the water level variation affects the work of temporary enclosure for intake. Influence of the NN2 operation is taken into account in estimating the NN1 reservoir water level variation.

Temporary Enclosure

A temporary coffer enclosure requires in reservoir for the construction of intake. The gate and/or rectangle type steel structure coffering has been planned in this basic design stage having following dimensions situated the new intake side in the reservoir.

Inside: 11.5 m x 4.0 m (46.0 m^2) Outside: 13.1m x 4.8m (62.88 m^2) Depth: 30 m

Intake and Penstock

Major civil construction work items are 1) construction of temporary working platform at EL. 181.0 m and access ramp, 2) piercing the dam, 6.7 m x 6.7 m, length 22.0 m for horizontal part of penstock, and 9.0 m x 5.0 m for vertical intake gate part, and 3) concrete fill for penstock.

The slot-drilling and breaking method will be adopted for the dam piercing. After the slot-drilling, the penstock hole is bored through the dam remained 5.0 m long for bell mouth part of penstock. Concrete are filled after the penstock installation. Dewatered period in the coffer enclosure is scheduled 3.5 months. Breakthrough of piercing for 5.0 m remaining part is to be performed in initial stage of the dewatered period, so that following works of bell mouth pipe installation, setting the stoplog guide frame, stoplog installation and other works could be done within the dewatered period.

Powerhouse and Tailrace

Major civil works are 1) foundation excavation of powerhouse and tailrace, 2) underwater excavation outside tailrace, and 3) building and tailrace concrete. The construction of powerhouse and tailrace including the electro-mechanical works is critical path work of 36.0 months. The excavation for the extension of powerhouse will take up most of the area between the ends of the present building and the spillway. The powerhouse and tailrace excavation will carried out by 2 steps that are open excavation of 39,000 m^3 above EL. 168 m (upstream side) and pit excavation of 24,000 m^3 below EL. 168 m to the bottom (downstream side). Rock excavation in the powerhouse extension area would be by rock breakers or blasting, depending on the hardness and degree of jointing encountered. Where the use of heavy breakers or blasting is required, the transmission of vibration to the existing machine foundations will be limited by line drilling the perimeter of the excavation and by the use of delay detonators.

Excavation in the tailrace area would be by 1,300 kg class giant breaker equipped with 0.8 m^3 class backhoe base machine. The excavation volume of underwater outside tailrace and coffer is 2,600 m^3 that will be giant breaker for excavation and 0.8 m^3 class backhoe for loading on pontoon barge. A small barge will be provided for hauling excavated soil and rock. A 60 m^3/h class batcher plant will be provided for concrete work of about 15,000 m^3.

Removal of Rock Outcrops at Downstream Stretch

The underwater removal work of 13,000 m^3 will be done by applying giant breaker on pontoon barge. A 0.8 m^3 class backhoe on pontoon barge will be used for loading of excavated rock and soil. A small barge will be provided for hauling excavated soil and rock.

Hydro-mechanical Works

The hydro-mechanical works are conducted by selected contractor under contract package of lot 2 comprising the design, manufacturing, delivering, installation and water filling in penstock and gate operating test. These works are conducted to meet the construction time schedule of civil works. The installation of hydro-mechanical equipment is scheduled to start from 2nd year after the site delivery that needs 15.5 months.

Electro-mechanical Works

The electro-mechanical works are conducted by selected contractor under contract package of lot 3 comprising the works of same procedures as hydro-mechanical works. The period assumes at 22.0 months till the site delivery for electro-mechanical equipment excluding draft tube steel liner that plans earlier deliver in about 6 months.

11.3 COST ESTIMATE

Basic conditions for the cost estimate are as follows:

- Exchange rates : US$ 1.00 = JPY 95.0 = Kip 8,510.0

- Base year for cost estimate is August 2009
- Costs for hydro-mechanical equipment and for electro-mechanical equipment are estimated on the basis of the consultant's data base related to the recent international bid prices for similar works.
- Consulting service cost comprises the related cost and fee. For estimating the cost and fee, scope of the necessary consulting services and corresponding manning schedule are defined through the coordination with DOE/EdL.
- It is assumed that foreign currency portion of 85% and local currency portion of 15%.
- No value added tax (VAT) and import duties are accounted assuming that the tax exemption measure is taken by the Government of Lao PDR.
- Price contingency is estimated at 2.4% per year for foreign currency portion and at 7.32% per year for local currency portion.
- Physical contingency is estimated at 10% of total construction cost and 5.0% of total consulting services cost.
- No commitment charge is accounted.

Financial costs of the NN1 expansion project are as follows:

Financial Cost	Unit	Without outcrop removal	With outcrop removal
Total of foreign currency portion (FC)	JY million	5,546	5,621
Total of local currency portion (LC)	Kip million	122,224	124,066
Total of FC and LC	JY million	6,910	7,006

Direct construction costs estimated for major work lots are summarized below.

Direct Cost	Unit	Without outcrop removal	With outcrop removal
Civil works	JY million	2,446	2,520
Hydro-mechanical works	JY million	307	307
Electro-mechanical works	JY million	1,882	1,882
Consulting services	JY million	739	739
Total:	JY million	5,374	5,448

CHAPTER 12 ECONOMIC AND FINANCIAL ANALYSIS

12.1 ECONOMIC ANALYSIS

Methodology

The economic analysis aims at measuring the economic effects brought about to the national economy by implementing the expansion project. Cost-benefit analysis is made in the discounted cash flow method. Indices such as Economic Internal Rate of Return (EIRR) are calculated.

Economic Cost of the project

The economic cost of the project is calculated based on the project cost estimation presented in Chapter 11. Annual operation and maintenance cost and reinvestment (replacement cost) are also estimated. Economic cost is calculated by excluding transfer items such as taxes and conversion of the local currency portion with the standard conversion factor presented above.

(1) Initial Investment (Construction Cost)

The initial investment at economic price is calculated as US$64,702 thousand in total, based on the project cost estimation and disbursement schedule presented in Chapter 11. Local currency cost is converted to economic price by standard conversion factor of 0.95 and transfer items (taxes, etc.) and price escalation is excluded in the calculation.

(2) Operation and Maintenance Cost and Reinvestment (Replacement Cost)

Annual operation and maintenance cost is calculated as US$281 thousand based on the construction cost and coefficient assumed for each item. Replacement cost for hydro- and electro-mechanical works is estimated as US$16,363 thousand and assumed 30 years after commissioning.

Economic Benefit

(1) Economic Benefit by Alternative Thermal Power

The economic benefit of the expansion project is estimated through valuation of alternative thermal power. The costs of construction and operation of a thermal power plant alternative to the hydropower are assumed as the benefits of the subject hydropower station. Capacity benefit (kW value) of the hydropower is represented by the annualized construction cost and fixed operational cost; and energy benefit (kWh value) is calculated as variable costs of the thermal power such as fuel cost. Lao PDR is a landlocked country and its imports of primary energy are basically limited to land transport. Petroleum product supply for transport and domestic uses is dependent on the imports from neighboring countries. In such circumstances, middle-speed diesel power is selected to estimate the kW value and kWh value. The following table shows the results of economic benefit calculation.

Table 12.1 Annual Energy and Capacity Benefits

Item	Unit	Without Project	With Project	Net
Annual Energy				
Year 2015 -	GWh	1,067.85	1,121.47	53.62
Year 2020 -	GWh	1,072.75	1,144.80	72.05
Year 2025 -	GWh	1,071.16	1,114.98	43.81
Dependable Peak Capacity				
Year 2015 -	MW	67.9	108.5	40.63
Year 2020 -	MW	78.2	115.9	37.69
Year 2025 -	MW	76.0	101.4	25.40
Energy Benefit: kWh Value (US$0.0783/kWh)				
Year 2015 -	US$1,000	83,579	87,776	4,197
Year 2020 -	US$1,000	83,963	89,603	5,639
Year 2025 -	US$1,000	83,839	87,268	3,429
Capacity Benefit: kW Value (US$275.35/kW)				
Year 2015 -	US$1,000	18,688	29,875	11,188
Year 2020 -	US$1,000	21,526	31,904	10,378
Year 2025 -	US$1,000	20,920	27,914	6,994
Total Annual Benefit				
Year 2015 -	US$1,000	102,267	117,652	15,385
Year 2020 -	US$1,000	105,489	121,507	16,018
Year 2025 -	US$1,000	104,758	115,182	10,423

Prepared by JICA Survey Team

(2) Reduction of Operation and Maintenance Cost for Existing Generation Units

The expansion project will improve operational efficiency of the whole power station. It is envisaged that operation and maintenance cost of the existing generation units will be reduced as effect of the project by 12.4% in average. The O&M cost reduction is estimated as US$136 thousand annually.

Calculation of EIRR

EIRR is calculated as 17.68%. NPV is US$36,758 thousand and B/C is 1.76 with 10% discount rate. The results show the EIRR exceeding 10% of social discount rate and positive NPV value. Therefore the project is evaluated economically feasible.

Sensitivity Analysis

(1) Conditions for Analysis

The sensitivity of economic evaluation indices is analyzed in the following cases with different conditions.

Case 1 (a) 10% increase, (b) 20% increase in the project cost

Case 2 The fuel cost increase of alternative thermal power decreases by (a) 10%; (b) 20%

Case 3 The project cost increases by 20% and the fuel cost of alternative thermal power decreases by 20%

(2) Results

The results of the sensitivity analysis are shown in the table below. EIRRs in the different cases range from 14.08% to 17.21%, which exceed 10% of discount rate. Even in Case 3 with the most unfavorable conditions the project shows its economic feasibility.

Table 12.2 Results of Sensitivity Analysis

Case	1a	1b	2a	2b	3
EIRR	16.20%	14.92%	17.21%	16.73%	14.08%

Prepared by JICA Survey Team

12.2 FINANCIAL ANALYSIS

Methodology

Financial analysis aims at evaluation of financial profitability from the executing agency's viewpoint through calculation of financial internal rate of return (FIRR).

Financial Cost

Financial cost of the expansion project consists of the initial investment cost (construction cost) estimated at the market price in Chapter 11, as well as the operation and maintenance cost and reinvestment (replacement cost) calculated based on the conditions presented in the economic analysis.

(1) Initial Investment (Construction Cost)

The initial investment cost (construction cost) estimated at the market price is US$65,293 thousand excluding price escalation and interest during construction.

(2) Operation and Maintenance Cost and Reinvestment (Replacement Cost)

The operation and maintenance cost is calculated as US$283 thousand/year and the replacement cost (30 years after commissioning) as US$16,487 thousand in line with the calculation method used in the economic analysis.

Financial Benefit

(1) Electricity Tariff Revenue

The table below shows the electricity revenue calculated based on the average domestic tariff in 2008 (USc 6.21/kWh).

Table 12.3 Financial Benefit (Electricity Revenue)

Item	Unit	Without Project	With Project	Net
Annual Energy				
Year 2015 -	GWh	1,067.85	1,121.47	53.62
Year 2020 -	GWh	1,072.75	1,144.80	72.05
Year 2025 -	GWh	1,071.16	1,114.98	43.81
Loss Rates				
Transmission Loss	%	6.0%	6.0%	
Auxiliary Consumption	%	0.5%	0.5%	
Forced Outage	%	0.5%	0.5%	
Electricity Sold				
Year 2015 -	GWh	993.77	1,043.67	49.90
Year 2020 -	GWh	998.33	1,065.38	67.05
Year 2025 -	GWh	996.85	1,037.62	40.77
Electricity Revenue (US$0.0621/kWh)				
Year 2015 -	US$1,000	61,713	64,812	3,099
Year 2020 -	US$1,000	61,996	66,160	4,164
Year 2025 -	US$1,000	61,904	64,436	2,532

Prepared by JICA Survey Team

(2) Reduction of Operation and Maintenance Cost for Existing Generation Units

As explained in the economic analysis, it is estimated that the operation and maintenance cost of the existing units will be reduced by US$136 thousand annually.

Calculation of FIRR

FIRR is calculated as 2.75%. Cheap domestic tariff level is considered as a major factor of the low FIRR. The increase in peak capacity cannot be reflected in the FIRR calculation because of the absence of TOD rates in the domestic tariff system. It is considered that a concessionary loan such as ODA Loan will be necessary to enhance the financial viability for the implementation of the project.

Sensitivity Analysis

(1) Conditions for Analysis

The sensitivity of FIRR is analyzed in the following cases with different conditions.

Case 1 (a) 10% increase, (b) 20% increase in the project cost

Case 2 Electricity tariff variations:

(a) 1,274 kip/kWh (USc14.97/kWh), proposed as “Base Investment Case” in “Tariff Study Update 2009” by World Bank;

(b) 720 kip/kWh (USc8.79/kWh) proposed as “Low Investment Case” in the said study;

(c) USc7.45/kWh, equivalent to 120% of the tariff level in 2008

Case 3 Project cost increase variations in the “Low Investment Case” tariff (USc8.79/kWh):

(a) 10% increase and (b) 20% increase

(2) Results

FIRRs in the different cases range from 1.67% to 9.75%, which exceed the current interest rate of JICA ODA Loan for Lao PDR (0.01% p.a.). However, low financial viability (FIRR 2.17% and 1.67%) is observed especially in Cases 1(a) and 1(b) where construction cost is increased without tariff increase. It is suggested that the tariff increase will significantly improve the financial viability of the project.

Table 12.4 Results of Sensitivity Analysis

Case	1a	1b	2a	2b	2c	3a	3b
FIRR	2.17%	1.67%	9.75%	5.09%	3.92%	4.41%	3.81%

Prepared by JICA Survey Team

Revision Plan of Electricity Tariff

The sensitivity for each electricity tariff variation is analyzed in the above case 2. On the other hand, the latest revision plan of electricity tariff was obtained from EdL and the financial analysis with realistic revision plan of electricity tariff was carried out.

(1) Procedure of Revision of Electricity Tariff

- Preparation of the revision plan of electricity tariff by EdL and confirmation of revision plan by DOE
- Submission of revision plan to the MEM from the DOE
- Submission of the revision plan to the Prime Minister by the MEM for approval
- Consultation in the economic survey unit under the direct control of the Prime Minister and discussion in the meeting with all Ministers
- Report of the results of discussion to the EdL through the MEM

(2) Previous Revision of Electricity Tariff

The revision plan of electricity tariff from 2005 to 2011 was proposed by the EdL and approved by the concerned agency on 24 July 2004. In this revision, the increase in electricity tariff for each category of power demand side was setup and the increase rate of 1 % of electricity tariff on average was approved.

(3) Latest Revision Plan of Electricity Tariff

The study on electricity tariff in Laos was carried out by the World Bank aiming at the review of electricity tariff of EdL and the final report was submitted in June 2009. In this study, the new tariff system was proposed and as the results, the electricity tariff of 1,210 Kip/kWh as of 2015 which is quite higher than present electricity tariff of 530 Kip/kWh was proposed as a base case. This result was disclosed to the concerned agencies in the workshop for the explanation and was not accepted due to high increase ratio. Therefore, the other revision plan was studied and proposed which has electricity tariff of 720 Kip/kWh as of 2015 as a low case. However, since the minimized cost for facility investment of EdL was setup to be low and unrealistic, the EdL decided to review it again.

As of November 2009, the EdL is finalizing the revision plan which has electricity tariff of 750 - 800 Kip/kWh as of 2015 as a middle case. The EdL intends to finalize the electricity tariff within this range and submit to the Lao government through the DOE and MEM. According to tentative financial analysis with such tariff range, FIRR is estimated as 5.11 - 5.60 %.

12.3 EFFECT OF ROCK OUTCROPS EXCAVATION

Cost and Benefit of Rock Outcrops Excavation

The removal of rock outcrops will increase the civil works and administration costs by US$898 thousand at economic price or US$906 thousand at financial price. The O&M and replacement cost are also increased. As for the incremental benefit, the removal will increase annual generated energy by approximately 5 GWh and dependable capacity by 0.9-1.3 MW. This represents increase in economic benefit of US$633 – 764 thousand per year and increase in financial benefit of US$290 – 311 thousand per year.

Results of EIRR and FIRR Calculation

Results of EIRR and FIRR calculation are presented in the following table. Improvement of both EIRR and FIRR shows the economic and financial feasibility of the proposed rock outcrop removal.

Table 12.5 Results of EIRR and FIRR Calculation

	With Project (Without Excavation)	With Project (Excavation)
EIRR	17.68%	18.18%
FIRR	2.75%	3.30%

Prepared by JICA Survey Team

12.4 EFFECTS TO ELECTRICITY TRADE BALANCE

The economic effect of the project to the electricity trade balance with Thailand (EGAT) is estimated as supplementary to the economic analysis through the alternative thermal power method.

In C1 grid, EdL exports its excess energy to EGAT (USc4.70/kWh in peak hours and USc3.52/kWh in off-peak hours) and also import energy as needed (USc5.26/kWh in peak hours and USc4.08/kWh in off-peak hours). The tariff system for C1 has characteristics of (i) small price difference between peak time and off-peak time and (ii) THB 0.19/kWh higher basic import tariff than export to EGAT. Surcharge payment is required additionally in case that the EdL imports exceed exports in a year. The surcharge calculation is based on the domestic tariff in Thailand; and in short, the excess import by EDL is virtually charged similar prices to those for large-scale customers in Thailand.

(1) Change in Trade Balance by the Project

Peak power supply strengthened by the project will improve the trade balance with EGAT by US$3 – 4 million annually. Surcharge payments will also be reduced by around US$1.5 million where the trade deficit of EdL is projected (year 2015, 2016 and 2025).

(2) Estimation of EIRR

With other preconditions adopted from the economic analysis, EIRR is calculated as 5.47%, which is lower than the discount rate of 10%. The low IRR in this analysis is primarily because of the low tariff level with small peak energy value, and not necessarily considered reflecting the economic value of alternative energy source to the project for Lao PDR.

CHAPTER 13 OPERATION AND MAINTENANCE PLAN

13.1 ELECTRO-MECHANICAL EQUIPMENT

The Nam Ngum 1 Hydropower Station has been operated for over 37 years by the power station staffs. The power station has a sufficient number of operators and maintenance crews who have enough experience for operation and maintenance of the power station. Therefore, they will be able to manage the customary operation and maintenance of the additional equipment of unit-6 without the need of modification of their organization.

However, it seems that the power station staffs have not acquired yet satisfactory technical skills for dismantling and re-assembling of the turbines and generators, which are required for their overhaul work. Therefore, upskilling of the maintenance crews and organization of an overhaul team with skilled workers are urgently needed.

13.2 MECHANICAL EQUIPMENT

The operation and maintenance of mechanical equipment for the expansion plan are summarized as below:

(1) Intake Trashracks

When the generator is stopped for yearly maintenance, the trashracks will be removed from the bellmouth position to the dam crest by the existing gantry crane and maintained, such as cleaning, checking/inspecting the damages/deformation of structure, repairing damaged parts and defects of painting.

(2) Intake Stoplogs

The segments of stoplogs will be lowered or raised one by one with the lifting beam by the existing gantry crane. The intake stoplogs are operated under the balanced condition.

After the stoplogs are used for the maintenance of gate/penstock, those are removed from the bellmouth position to the dam crest, and cleaned and maintained such as inspecting the defects and/or damages and repairing such damaged parts including the defects of painting before the storage.

(3) Intake Gate

The intake gate is operated through the local or remote control panel, normally under the pressure-balanced condition, but the gate can be closed under the flow condition in case of shutdown operation.

The intake stoplogs are installed and stop water flow for the maintenance of intake gate. The access is available through the manhole installed just downstream of the gate for inspection purpose. The gate leaf and/or the hydraulic cylinder can be removed from the casing/bonnet for repair/replace by the mobile crane set on the working stage at the dam crest.

(4) Steel Penstock

During the maintenance period of generator/turbine, the steel penstock will be also inspected and maintained. The manholes provided at the spiral casing and intake gate are considered to be entrance into the penstock. As for the inspection at the inclined portion of penstock, some safety equipment and/or tools are required for executing the maintenance safely.

CHAPTER 14 CONCLUSION AND RECOMMENDATIONS

The preparatory survey on Nam Ngum 1 Hydropower Station Expansion was started in February 2009 aiming at confirmation of a policy of the Government of Lao PDR on the implementation of the expansion of NN1 and implementation of expansion plan to be taken shape with source of Japanese fund. As the results of survey, the expansion plan with 40 MW was judged to be feasible from the technical, economical & financial and environmental view points. The conclusion and recommendation are shown below.

14.1 CONCLUSION

(1) Purpose of Expansion of NN1

The power demand in Laos is increasing rapidly, and night peak demand is of particular note. As the countermeasure to ensure the source of power supply in short term period, the expansion of NN1, which has huge reservoir, is considered with concentration power generation in peak time of power demand instead of power generation in off-peak. On the other hand, the NN2 power station will be constructed with huge reservoir at just upstream of NN1 reservoir, and the inflow into NN1 reservoir is regulated through a year. Due to this change of inflow pattern, the power generation can be kept with relatively high reservoir water level and the invalid water release through the spillway can be minimized. As the results of that, the increase of annual power generation can be expected due to expansion.

The existing power generation facilities have been installed since 1971 in series. Though the Unit No.1 and 2 have received rehabilitation, the all units are getting older. The yearly maintenance is carried out only within the dry season to minimize the invalid water release and there is no sufficient time space to adjust the timing of maintenance. The expansion of additional one unit would contribute not only the decrease of power generation time ratio and maintenance cost but also planning of maintenance with sufficient time period and safety power generation.

Furthermore, total installed capacity of NN1 power station will be 195MW due to expansion and surplus power generated in the rainy season would be exported to the Thailand. In this regards, the existing transmission interchanging capacity of 100MW with the Thailand would be strengthened up to 600MW in 2016, and the limitation of power export would be resolved.

On the basis of results of power demand forecast in C1 and northern areas and latest information of EdL power development plan, the balance of power demand and supply was studied. As the result of that, the power supply would be short through the year in 2015, and the generated power can be exported to the neighboring countries in rainy season in 2020. After that the same situation would be continued in several years, and the power supply will be short again in 2025 due to delay of power development for domestic power supply.

(2) Reservoir operation

The reservoir operation plan of NN1 hydropower station is studied on the basis of observed hydrological data, existing data in the previous study report and data collected in the power station through the historical reservoir operation. The change of flow regime into NN1 reservoir is expected due to the commencement of power generation of NN2 hydropower station in 2011. NN2 is located at just upstream of NN 1 reservoir and this existence of NN2 is important for the NN1 expansion plan. After the commencement of NN2 power plant, the river flow into NN1 reservoir will be regulated through the year because of storage effect of NN2 reservoir. By assuming NN2 commencement in 2011, the reservoir operation rules were developed for expansion scale of 40 MW, 60 MW, 80 MW and 120 MW. The energy production is estimated following by determining reservoir operation rule that results to additional annual power generation of 56 GWh in case of the expansion of 40 MW. Quite limited additional annual power generations were confirmed in case of 60 MW, 80 MW and 120 MW in spite of the increment of those installed capacity.

The reservoir operation is further studied using characteristics of additional turbine and generator determined in the basic design. The reservoir operation study approaches to two aspects of policies that are 1) effective utilization of water resources as an economic and financial aspects, and 2) revenue improvement from domestic electricity sales and profit of electric power interchange with EGAT as accounting aspect.

The reservoir operation study for economic and financial analysis employs the former approach with focusing more on the economic aspects rather than financial aspects. The latter approach aims to focus on the account of selling electricity to the domestic and Thailand, which is the practical reservoir operation under the current tariff system. The current domestic tariff and export/import tariff with EGAT interchange is used in the study. The reservoir operation for economic evaluation aims to energy maximization while the latter case employs revenue maximization as the objectives of optimization. However, if the reservoir operation is solely targeting energy maximization or revenue maximization, the results tend to import in electricity in dry season and generates electricity to export in rainy season to enable reservoir water level in high elevation. The Lao PDR policy takes that the power import from EGAT should be as less as possible, and the domestic electricity demand should first be served by the Lao's power sources. Therefore, both of energy and revenue maximization should prerequisite the import energy minimization. The energy and revenue maximization is to be the second priority.

In the reservoir operation study for economic and financial analysis of the expansion project, the reservoir operations of EdL's Nam Mang 3 and Nam Leuk hydropower stations were also considered since NN1 expansion could affect to the these power stations operation. The energy production of NN1 is simulated for the year of 2015, 2020 and 2025 with the cases of with/without NN2 and after expansion. As the results, the present average annual power generation of 1,012 GWh can be increased to 1,071 GWh (59 GWh rise) after the commencement of power generation of NN2, and to 1,127 GWh (56 GWh rise) by the expansion by 40 MW. The power generation pattern after the expansion consists of the night peak power generation with full power and the day time peak power generation adjusted within the available capacity in 13 hours of TOU peak time. NN1 seldom generates electricity for 24 hours with full capacity in rainy season after expansion.

For the study of the reservoir operation in the Nam Ngum River basin, the all power stations supplying electricity to the C1 area were taken into consideration, which are NN1, Nam Mang 3, and Nam Leuk hydropower stations. Nam Lik 1/2 hydropower is further considered in the after expansion case. The optimization studies were carried out using the power demand and supply balance in the year 2015, 2020 and 2025 aiming energy maximization and revenue maximization conditioned on minimization of import energy from Thailand. As the result, it was found that the revenue balance and import energy is generally trade-off relation. Increase of import energy in dry season may contribute to increase in annual revenue. However, importing too much energy from Thailand will result in increase of excess charge that will worsen the annual revenue balance. If Nam Lik 1/2 is involved in operation together with NN1, Nam Leuk and Nam Mang 3, it will contribute to reduce energy import significantly in the year 2015.

(3) Social and environmental consideration

No significant and irreversible impact on social and natural environment is expected in the Nam Ngum 1 Hydropower Station Expansion Project, different from a new dam and hydropower project. The expansion project needs neither creation of reservoir nor construction of new transmission lines. In terms of socio-economic impact, no relocation or land acquisition is required. Compensation is not necessary in the selected optimum scale of the project. Negative impacts can be avoided or mitigated by conventional construction management with proper instruction and operation with mitigation plans.

On the other hand, continuous impact that may affect to natural and social environment is expected due to larger daily water level fluctuation in downstream of the Nam Ngum River. This is due to the change of operation pattern in NN1 power station after the expansion work. In the off-peak time, downstream river water level is reduced than present and increased in peak-time. Downstream discharge fluctuation comes from the change of output and discharge at the NN1. River side gardening is possibly affected from water level increase during peak time. On the other hand, boat transportation and fishery may be affected by water level decrease during off-peak time. Irrigation and river water pumping may also be affected from the water level decrease. This water level fluctuation will happen only in a dry season. As the results of IESE, the waster level fluctuation range within the allowable capacity of village peoples at downstream in case of 40 MW of expansion.

(4) Optimum expansion plan

In the beginning of this Survey, eight (8) candidates of the expansion alternatives ranging 40 MW to 120 MW were taken into account. In choosing those candidates, the results of the feasibility study performed in 1995 by Lahmeyer/Worley under IDA finance were referred to and a new left bank tunnel plan was additionally taken up. In order to select the optimum plan for expansion, initial screening was performed to choose 4 prospective alternatives out of the 8 candidates so that detailed comparison could be done on the prospective alternatives within the limited time. The initial screening was made during the inception stage by means of engineering assessment.

In the next step, the selected prospective alternatives were compared in detail by analyzing power generation efficiency, making design of powerhouse expansion layout and estimating construction cost of respective alternatives. Final selection of the optimum expansion plan was made on the basis of economic/financial assessment on the alternatives.As the results of comparison of alternatives, Alternative A1 (40 MW) is judged to be highest in cost performance among 12 alternative options considered. The Alternative A1 is to build a new unit bay building for 40 MW plant in the space between the existing powerhouse and the spillway. The existing OHT cranes and draft tube gates can be utilized for the additional unit. Layout of the new powerhouse is most compact and economical among the all options. As the length of penstock and tailrace is short and waterway headloss is less, available water head can be most effectively utilized for power generation.

(5) Basic design

The basic design for the optimum expansion plan was carried out. In the basic design, the study items of civil works such as rated reservoir water level, optimum penstock diameter, intake center elevation of unit-6, and the temporary closure for construction of intake and penstock and dam stability analysis were carried out. The comparison of type of gate and stoplog and hydroelectrical facilities also was carried out. The results of the basic design are shown in

Chapter 9.

(6) Lowering of Tailrace Water Level

It was judged that the tailrace water level would be lowered by removal of rock outcrops located at downstream of NN1 Power Station. In order to analyze the change of water surface level due to removal of rock outcrops, the river cross section survey was carried out for hydraulic calculation. On the basis of survey results, it was confirmed that the tailrace water level at downstream of power station would be lowered by 40 cm due to removal of rock outcrops, and it results in additional annual energy of 5 GWh. In case of that the original expansion plan of 40 MW will be combined with the removal of rock outcrops as a one set of expansion plan, total economical and financial benefit would be higher. Therefore, the expansion plan of NN1 hydropower station consists of the additional power generation facilities of installed capacity of 40 MW and removal of rock outcrop located at downstream side.

(7) Implementation plan and cost estimation

Grand total of construction cost has been estimated at equivalent Japanese Yen 7,006 million including the cost for engineering and environmental management. The total construction period from preparation works to commencement of power generation is 36 months, and power generation would be commenced in 2015.

(8) Financial and Economical Analysis

EIRR of the expansion plan is calculated with kW value and kWh value of the middle-speed diesel power. As the results of economical analysis, the economical internal rate of returns (EIRR) is 17.68%, and it is judged that the expansion plan is economically feasible.

On the other hand, FIRR of the expansion plan is calculated with benefit of the tariff revenue from domestic consumers. As the results of financial analysis, the financial internal rate of returns (FIRR) is 2.75%, and it is judged that the expansion plan is financially feasible with soft loan of low interest.

14.2 RECOMMENDATOINS

In Laos, the domestic demands of peak power and energy are increasing with rate of 10%. The increase of power demand of day time and night time peak is remarkable. On the other hand, IPP hydropower projects aiming at domestic power supply are under planning and construction. However, in many case of domestic IPP, the reservoir size is not big by comparison with NN1 and the power plant for peak power supply is minor. Therefore, the expansion of NN1 Power station, which has high potential of peak power generation with huge reservoir, aiming at power supply for domestic peak demand is effective. The early implementation of the expansion of NN1 is required.

This expansion plan would be able to start the power generation in 2015 through the processes of the fund procurement, additional geological survey, detail design and other preparatory works. Prior to the implementation of the expansion, following issues should be resolved.

(1) The expansion plan includes the construction of additional power station with 40 MW and the construction of transmission lines between the power station and demand center is not required. Therefore, it is judged that the construction cost will be minimized and the project is economically viable. Further, the reservoir water level will be the same as the existing condition and no resettlement will be involved. This expansion plan is not harmful to the environment. It is expected that the procedures required for the implementation will be smooth. It should be confirmed again that the NN1 expansion project will be mentioned officially in the power development plan of Lao PDR. Further, it is necessary to start the preparation of discussion about funding between Japan and Lao PDR.

(2) The detailed design should be carried out by following the points of reminder to be described and the results of the additional investigations. The opinion of the staff of the NN1 power station should be taken in the preparation of the tender documents.

(3) Although the new intake structure will be constructed by piercing of dam body, the reservoir water level should be kept so as to keep the power generation. Therefore, the installation of temporary enclosure at reservoir side with deep underwater operation will be an important issue. In this regard, the detailed design and construction planning with attention to safety and economic efficiency should be established considering the experiences of the same type of expansion in Japan.

(4) Since the new power station building will be constructed just beside of the existing power station building, it is possible that the vibration due to foundation excavation may affect the existing power generation facilities and power generation itself. Therefore, the vibration issue should be studied in detail considering geological conditions and vibration during blasting for foundation excavation for establishment of safety measures in the detailed design stage.

(5) The financial analysis of the expansion plan was made on the basis of domestic electricity tariff of 2009. The increase of electricity tariff is connected with the FIRR directly. Therefore, the electricity tariff in Laos should be followed from the view point of financial viability.

(6) The NN2 hydropower station will commence the power generation in 2011, and the inflow into the Nam Ngum Reservoir will be flattened throughout a year. Thus, the operation ratio of power generation facilities will be increased, and the power generation time in dry season will be longer. Therefore, the long term maintenance plan shall be made to ensure the time for the regular maintenance. Furthermore, the maintenance plan after the expansion shall be studied to evaluate the degree of its contributions.

(7) In IESE of this survey, this discharge requirement presumes the maintenance flow is based on that the Nam Lik River flow at least equals to the draught discharge. If the discharge is less than the draught discharge, IESE confirmed that the reduction of the flow will affect to the downstream inhabitants. Therefore, the Nam Lik 1/2 hydropower project is required to release the water at least to fulfill the draught discharge at the confluence of the Nam Lik River and Nam Ngum River. Furthermore, the actual release from the Nam Lik 1/2 should be monitored under DOE supervision to determine whether the discharge pattern of the Nam Lik 1/2 does not cause

adverse effect to the downstream inhabitants. If the adverse impacts are recognized, then DOE together with WREA should request to Nam Lik 1/2 hydropower entity to mitigate such impacts.

CHAPTER 15 SUGGESTIONS FOR PROJECT IMPLEMENTATION

The main component of the expansion plan of Nam Ngum 1 Power Station is the construction of one unit power station with 40 MW capacity to complement the existing five units with 155 MW. The project has shorter construction period and has less social and environmental impact. During the determination of the expansion scale, the basic conditions such as power demand and supply plan, tariff system in Laos and change of river flow due to hydropower development in the Nam Ngum river basin were considered. Such basic conditions should be re-confirmed in the detailed design stage and in the project implementation period.

Towards the implementation stage of the project, the points to be considered after the present preparatory survey are discussed below.

15.1 POINTS TO CONSIDER FOR IMPLEMENTATION

Confirmation of Power Demand and Supply plan in C1 and North Areas

Judgment of the necessity for the NN1 expansion and selection of expansion scale are based on the power demand forecast in C1 and northern areas, and the power supply plan mentioned in the Power Development Plan of Lao PDR. In this survey, the power demand was forecasted considering the power demand of industrial sector with rapid growth. Therefore, the actual power demand within a few years should be monitored while comparing the value of power demand forecast. With regards to the IPP project aiming at domestic power supply, the completion date will be delayed due to difficulties in PPA negotiation and environmental issues such as resettlement and natural negative impact. Furthermore, the power development plans after 2020 are still under concretization stage with shortage of electricity against forecasted power demand. Survey accuracy enhancement and review of power development plan with EdL and DOE are necessary.

Confirmation of River Flow Conditions after Development of Hydropower Project in NNRB

The inflow into NN1 reservoir will be regulated through the year after the commencement of power generation of NN2 in 2011, which is located just upstream of the NN1 reservoir. The annual energy of NN1 will be increased by 6% due to NN2 reservoir operation. The NN1 expansion will be completed and will start power generation in 2015. The annual energy of NN1 will be increased by 5% due to the expansion. The simulation calculation of power generation was carried out on the basis of NN1 reservoir operation policy of EdL and Lao PDR, which is “giving priority to minimization of power supply deficit in domestic power demand”. The annual energy and fluctuation of reservoir water level throughout the years after commencement of NN2 power generation in 2011 should be observed and the results of the simulation calculation in this preparatory survey should also be verified.

15.2 TRANSITION OF ELECTRICITY TARIFF IN LAOS

In the preparatory survey, the FIRR was evaluated with average electricity tariff of US$0.0621 as of 2009. However, the FIRR of the expansion plan is not so high compared with usual hydropower development plan because the purpose of the expansion is strengthening the capacity of peak power supply and no difference of electricity tariff in peak and off-peak electricity is considered. The financial benefit of the expansion project depends on the domestic electricity tariff. In parallel with this preparatory survey, the study on transition of electricity tariff is being studied by the other donors. After this study, the policy of EdL on electricity tariff should be confirmed. The financial benefit of the expansion in 2015 should be verified using a new electricity tariff, if available. In order to re-evaluate the FIRR, the reference values mentioned in the sensitive analysis in this report should be considered.

15.3 FOLLOW-ON WORKS FOR DETAILED DESIGN

Topographic Survey and Geological Investigation

It is recommended to carry out the following investigations in the detailed design stage:

Topographic Survey：	Section surveys of power station expansion site and downstream rock outcrop
Geological Investigation:	Core drilling and rock test at power station expansion site and concrete test of the existing dam body
Material Investigation:	Investigation of concrete aggregate sources and quality and supply capacity of domestic cement

Environmental Survey

It is recommended to review the following items in the detailed design stage:

- Environmental impact mitigation plan, environmental monitoring plan and contractor environmental management plan (CEMP)
- Daily discharge data of the Nam Ngum main stream and Nam Lik River to decide the appropriate river maintenance flow to be released from NN1
- Hourly water level and discharge data of the Nam Ngum and Nam Lik Rivers to estimate the water level fluctuation increase after the expansion
- Confirmation of maintenance flow of Nam Lik 1/2

- Necessity and locations of warning signboards and warning system to be installed in the downstream river reaches

Design Issues

The points to be noticed in detailed design include the following:

Civil Design:

- Structural stability of the dam (Bl. 20) of which downstream foundation rock is removed for Unit-6 powerhouse,
- Stabilization of excavated slope below spillway side wall,
- Stabilization of rock body left unexcavated between the exiting and new tail race channels,
- Stress concentration in the existing dam concrete after excavation of hole in the dam.

Electromechanical Design:

- Construction of turbine and generator for unit-6 to be identical with the exiting units,
- Main transformer for unit-6 to be interchangeable with the existing spare transformer,
- Construction remote control board for unit-6 to be identical with the existing boards,
- Addition of new system for data transfer to a central hydropower control center,
- Replacement of the existing 115 kV main bus conductors in the switchyard

Mechanical Design:

- Vibration prevention measures for intake screen bars against high flow velocity,
- Further study to optimize the type of intake gate though the bonnet type slide gate was tentatively selected at the present study,
- Materials for bearing/sealing of intake gate leaf and backup equipment for hydraulic unit under power failure,
- Modification of gantry cranes for unit 6 at intake and draft tube outlet,
- Device to drain seepage water around penstock pipe at intake

Study on Influence to the Existing Structures

Careful studies on the influence to the existing structures as listed below are required:

- Influence of vibration caused by dam piercing work to the dam concrete around the hole
- Influence of vibration caused by rock blasting for powerhouse foundation excavation to the existing powerhouse building and generating equipment under operation
- The present access way to the existing transformer bays will be blocked by a temporary ramp

way built for piercing dam and installing penstock pipe. Required measures to protect the transformers and methods of emergency repairing of the transformers should be sought.

- Both gantry cranes for the intake and the draft tube outlet need to be temporarily relocated during the expansion work. Method of handling the intake stoplogs and draft tube gates in case of emergency should be sought.