No.

The Lao People's Democratic Republic

THE MASTER PLAN STUDY
ON
SMALL-HYDRO IN NORTHERN LAOS

Final Report: Volume 3

SMALL-HYDRO MANUAL

December 2005

Japan International Cooperation Agency

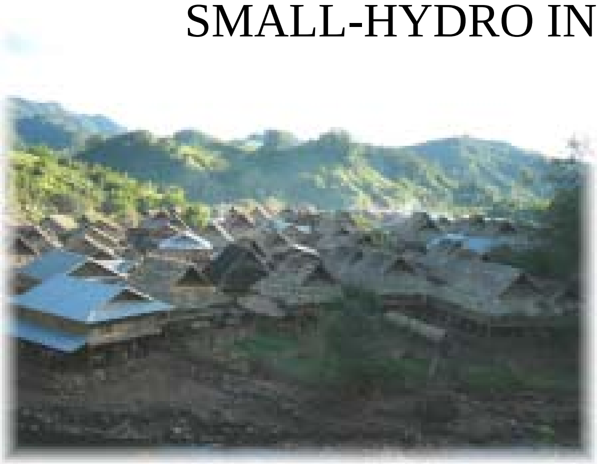
Economic Development Department

ED
JR
05-113

Japan International Cooperation Agency

Ministry of Industry and Handicrafts of Lao PDR

THE MASTER PLAN STUDY ON SMALL-HYDRO IN NORTHERN LAOS



FINAL REPORT : VOLUME 3

SMALL-HYDRO MANUAL

Part A: Small-Hydro Planning Manual
Part B: Operation & Maintenance Manual

December 2005

NIPPON KOEI CO.,LTD.

KRI International Corporation

Preface

In response to a request from Lao People's Democratic Republic, the Government of Japan decided to conduct The Master Plan Study on Small Hydropower in Northern Laos and entrusted the study to Japan International Cooperation Agency (JICA).

JICA sent a study team led by Mr. Ichiro Araki, Nippon Koei Co., Ltd. and KRI International Corp., to Laos six times from February 2004 to November 2005.

The study team held discussions with the officials concerned of the government of Laos and conducted a series of field surveys. After returning to Japan, the study team carried out further studies and compiled the final results in this report.

I hope this report will be utilized for contributing to develop the small hydropower in Northern Laos and to the promotion of amity between our two countries.

I also express my sincere appreciation to the officials concerned of the government of Laos for their close cooperation throughout the study.

December 2005

Tadashi IZAWA
Vice President
Japan International Cooperation Agency

NIPPON KOEI CO.,LTD.
Consulting Engineers

December 2005

Mr. Tadashi IZAWA

Vice President
Japan International Cooperation Agency
Tokyo, Japan

Dear Sir,

LETTER OF TRANSMITTAL

We are pleased to submit herewith the Final Report of Master Plan Study on Small-Hydro in Northern Laos. We, Nippon Koei Co., Ltd. and KRI International Corp. had studied it for about two years from January 2004 to December 2005 under contract with your Agency.

The Final Report proposes the Government of Laos to utilize it for supporting tools with a master plan to achieve the Lao golden goal with 90% electrification until 2020. In addition, it comprehends the pre-feasibility study results for small-hydro potential sites executed by our Study Team supported by the Lao counterparts through comprehensive capacity building during whole study periods. We believe that the implementation of our proposed projects in the Study would contribute both to a rural development and a poverty reduction by electrification at the least-less developed area of remote villages in northern Laos. And, the Study had been carried out with three mottoes, Free access to information, Public involvement and Environmental friendly in line with JICA's own principles. Precisely, in consideration of the recent worldwide criticism on hydropower development, we have tried to investigate carefully for the negative impacts to the social/natural environments through a village socio-economic study and a public involvement at workshops showing our study results to the maximum extent.

Once again, we believe the Final Report would contribute both the smooth implementation of the Rural Electrification through the small-hydro projects and the good foot prints for future similar studies in other developing countries.

The Final Report consists of four volumes; Main Report, Executive Summary, Small-Hydro Manual and Small-Hydro Visual Guide. The main report covers all the study results including mainly the process of master plan study and Pre-F/S results on some small-hydro potential sites. The manual is expected for the Lao engineers to give a good valuable guidance for studying and designing of a small-hydro project. Especially, as the visual guide is translated into Lao language completely with full visual texts, it results in a unique beginner's book for the Lao local staff.

We wish to take this opportunity to express sincere gratitude to your Agency. We also wish to express our deep gratitude to the Ministry of Industry & Handicrafts of GOL, Electricite du Laos, Provincial Department of Industry & Handicrafts in northern eight provinces, the Embassy of Japan in Laos, the JICA Laos Office for close cooperation and assistance extended to our Study Team during field investigations and studies in Lao PDR.

Sincerely yours,

Ichiro ARAKI, Team Leader

The Master Plan Study on
Small-Hydro in Northern Laos

THE MASTER PLAN STUDY
ON
SMALL-HYDRO IN NORTHERN LAOS

FINAL REPORT

COMPOSITION OF REPORTS

Volume 1	Main Report	: English & Japanese
Volume 2	Executive Summary	: English & Japanese
Volume 3	Small-Hydro Manual	: English
Volume 4	Small-Hydro Visual Guide	: English & Lao
Volume 5	Supporting Data Files	: English

Front Cover Photo

Village in Mountainous Area along Nam Ou River in Phongsaly

Girl taking Seaweed at Nam Xeng River in Luangphrabang

Slogan Logo for Small-Hydro Rural Electrification

VOLUME 3 : SMALL-HYDRO MANUAL

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PART B OPERATION & MAINTENANCE MANUAL

CHAPTER 1 OPERATION AND MAINTENANCE ORGANIZATION AND REGULATION

ABBREVIATIONS

ABBREVIATIONS		**ABBREVIATIONS**	
Lao PDR agencies		**Others (continued)**	
CDEP	Committee for Development of Electric Power	GHG	Green House Gas
CPI	Committee for Planning and Investment	GIS	Geographic Information System
DMH	Department of Meteorology and Hydrology	GMS	Greater Mekong Sub-region
DOE	Department of Electricity, MIH	GPS	Global Positioning System
EDL	Electricite du Laos	HPP	Hydropower Project
FIMC	Foreign Investment Management Committee	ICB	International Competitive Bidding
GOL	Government of Lao PDR	IEE	Initial Environmental Examination
LHSE	Lao Holding State Enterprise	IPDP	Indigenous Peoples Development Plan
LNCE	Lao National Committee for Energy	IPP	Independent Power Producer
LWU	Lao Women's Union	JI	Joint Implementation
MIH	Ministry of Industry and Handicrafts	LA	Loan Agreement
PDIH	Provincial Department of Industry & Handicrafts	LLDC	Least Less-Developed Countries
STEA	Science, Technology & Environment Agency	MOU	Memorandum of Understanding
Foreign organizations		M/P	Master Plan Study
ADB	Asian Development Bank	NBCA	National Biodiversity Conservation Area
EGAT	Electricity Generation Authority of Thailand	NEM	New Economic Mechanism
EVN	Electricity of Vietnam	NGOs	Non Governmental Organizations
IMF	International Monetary Fund	O&M	Operation and Maintenance
IUCN	World Conservation Union (Switzerland)	ODA	Official Development Assistance
JBIC	Japan Bank for International Cooperation	OPS	Off-grid Promotion & Support Program
JICA	Japan International Cooperation Agency (Japan)	PDA	Project Development Agreement
MOI	Ministry of Industry	PDP	Power Development Plan
MPI	Ministry of Planning and Investment	PPA	Power Purchase Agreement
NEPO	National Energy Policy Office	PPP	Public-Private Partnership
NTEC	Nam Theun 2(NT2) Electricity Company	PRF	Poverty Reduction Fund
NTPC	Nam Theun 2(NT2) Power Company	PTD	Power Transmission & Distribution Project
PEA	Provincial Electricity Authority in Thailand	PVP	Public-Village Partnership
UNDP	United Nations Development Program	SHS	Solar Home System
WB	World Bank	SIA	Social Impact Assessment
WCD	World Commission on Dams	SPC	Special Purpose Company
Others		SPP	Small Power Producer
AAU	Assigned Amount Unit	SPRE	Southern Province Rural Electrification Project
ATP	Ability to Pay	S/W	Scope of Works
B.	"Ban" Village in Laotian language	TOR	Terms of Reference
BOO	Build-Operate-Own	WTP	Willingness to Pay
BOT	Build-Operate-Transfer	**Unit and**	**Technical Terms**
CA	Concession Agreement	B-C, B/C	B: Benefit and C: Cost
CDM	Clean Development Mecah	EIRR, FIRR	Economic/Financial Internal Rate of Return
CER	Certified Emission Reduction	EL.( ) m	Meters above Sea level
COD	Commercial Operation Date	FSL	Full Supply Level of Reservoir
ECA	Export Credit Agencies	GDP	Gross Domestic Product
EIA	Environmental Impact Assessment	GWh	Giga Watt Hour (one billion watt hour)
EMMP	Environmental Management & Monitoring Plan	HH	Household
EPC	Engineering, Procurement and Construction	IRR	Internal Rate of Return
EPMs	Environmental Protection Measures	MAP	Mean Annual Precipitation
ERU	Emission Reduction Unit	MAR	Mean Annual Runoff
ESCO	Electricity Supply Company	MOL	Minimum Operation Level of Reservoir
ET	Emission Trading	MW	Mega Watt (one million watt)
F/S	Feasibility Study	PMF	Probable Maximum Flood
FARD	Focal Area for Rural Development	PMP	Probable Maximum Precipitation
GEF	Global Environmental Fund	US$	US Dollar

Japan International Cooperation Agency

Ministry of Industry and Handicrafts of Lao PDR

THE MASTER PLAN STUDY ON SMALL-HYDRO IN NORTHERN LAOS

FINAL REPORT : VOLUME 3

SMALL-HYDRO MANUAL

PART A	**SMALL-HYDRO PLANNING MANUAL**
PART B	OPERATION & MAINTENANCE MANUAL

December 2005

NIPPON KOEI CO.,LTD.

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THE MASTER PLAN STUDY
ON
SMALL-HYDRO IN NORTHERN LAOS

FINAL REPORT

VOLUME 3 SMALL-HYDRO MANUAL
PART-A: SMALL-HYDRO PLANNING MANUAL

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CHAPTER III PRE-FEASIBILITY STUDY

CHAPTER I GENERAL

1.1 PURPOSE AND SCOPE OF THE MANUAL

1.1.1 SCOPE OF THE MANUAL

This manual for small-hydro was prepared as one of outcomes of the Master Plan Study on Small-Hydro in Northern Laos which was commenced in February 2004 and will be completed December 2005. The purpose of the manual is to present guidelines for identifying, planning, designing and evaluating small-hydro schemes.

The manual mainly comprises:

(i) Preliminary Power Planning

(ii) Pre-Feasibility Study

(iii) Beginners' Manual of Small-Hydro (in separate volume titled by "Visual Guide")

(iv) Operation and Maintenance Manual for Small-Hydro (in separate volume)

The Operation and Maintenance Manual for Small-Hydro is prepared based on the request of MIH/DOE considering the fact that there are many small-hydro stations which are not functioning well due to poor maintenance and operation.

1.1.2 DEFINITION OF SMALL-HYDRO COVERED

In general, the scale of small-hydro generation varies from several hundreds kilowatt to several thousands kilowatt capacities. Under the manual, the following definition is made in terms of the installed capacities as follows:

(i) Micro hydropower : less than 100 kW

(ii) Mini hydropower : 100 to 1,000 kW

(iii) Small-Hydro : 1,000 to 5,000 kW

This manual provides guidelines for identification and planning of small-hydro schemes covering the installed capacity of not greater than 5,000 kW.

1.1.3 TARGET USERS OF THE MANUAL

The manual for small-hydro shall be used by engineers of various technical levels from MIH/DOE officers to PDIH staffs. Accordingly, the manual contains the simple part for beginners in addition to regular part for the upper grade of engineers. The manual aims to be pragmatic and available for all users.

1.2 OFF-GRID SMALL-HYDRO

1.2.1 NECESSITY OF OFF-GRID SMALL-HYDRO


Village Girls in Oudomxay

As of September 2001, Lao PDR has about 36% of the electrification ratio in the whole country and only about 20% in rural areas. In the eight (8) northern provinces covered by the recent study, which are the most behind in electrification (which includes 61 districts, about 5,000 villages and about 272,000 households), the rate stays approximately at some 15 %. The Government of Lao PDR intends to increase the electrification ratio for the whole country to 90% by 2020. This goal will lead to poverty reduction in the rural area where more than 80% of the nation lives.

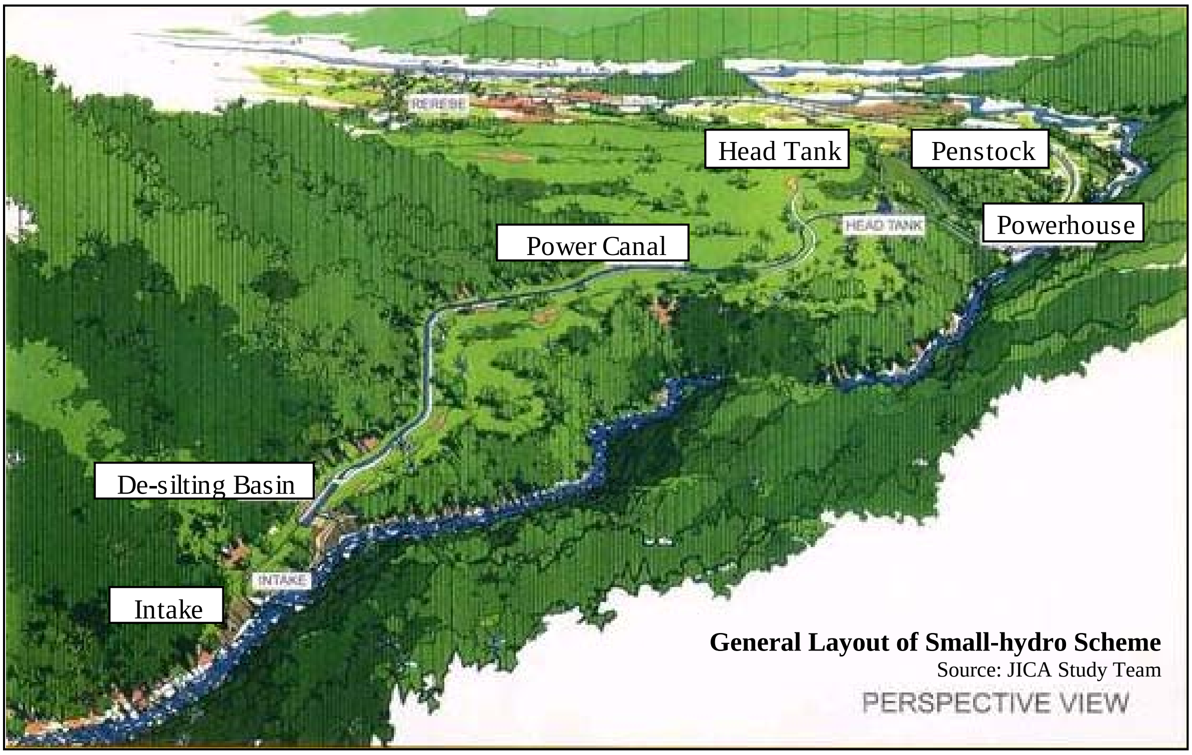
In order to raise the electrification rate, along with the grid electrification by ADB/EDL, the World Bank has been applying solar home system and micro hydropower. However, the grid electrification covers only the areas along main roads while the solar home system and micro hydropower cover scattered households for individual electrification. Contributing effectively to raising electrification ratio would be achieved not through the individual electrification but through the off-grid electrification for relatively highly-populated central districts in each province which are not covered by the grid electrification.

From the political point of view, a strategic planning of the off-grid small-hydro project is essential for encouragement of the villages in northern areas, alleviation of the dependence on imported electricity, and substitution of power generation by diesel plants.

The overall goal of the Master Plan Study is improvement of the electrification rate, the poverty alleviation, and the economic growth targeting the eight (8) northern provinces (Phongsaly, Luangnamtha, Oudomxay, Bokeo, Luangphrabang, Huaphanh, Xayabury and Xiengkhuang) in Lao PDR. Thus, the Master Plan aims at, (i) promotion of electrification in un-electrified provinces/district centers, (ii) reduction of the electricity import from neighboring countries, and (iii) preparation of alternative power sources in such areas depending on diesel generation. The basic approach is to distribute electricity generated by small-hydro to each village to form a mini-grid with an independent power source in each load center without EDL grid connection.

1.2.2 FEATURES, ADVANTAGES AND DISADVANTAGES OF SMALL-HYDRO GENERATION

Since old times hydropower generation has been developed worldwide utilizing natural river water. Development of electrification firstly began with local power generation on a small scale, and then progressed to larger scale power generation according to an increase of power demand. Through this process, power transmission lines and distribution networks have been formed. Small scale hydropower generation has played an important role in rural electrification. Small-hydro generation diverts part of river flow into a channel and steel pipe (called penstock) and then through a turbine. Although there are many variations on the system arrangement, major components of a typical small-hydro scheme is schematically shown below.



General Layout of Small-hydro Scheme
Source: JICA Study Team

1.2MW Nam Ko Power Hydropower Station
Oudomxay Province

70 kW Nam Mong Hydropower Station
Luangphrabang Province

Lao PDR is water rich and has favorable topography for hydropower generation. These are really valuable natural resources in this country. Lao PDR is thus endowed with much hydropower potential. Advantages and disadvantages of small-hydro generation are enumerated below.

Advantages:

(i) Small-hydro plant may ensure electric power supply to non-electrified areas and areas where there is habitual power shortage. Small-hydro generation may much contribute to rural electrification.

(ii) Small-hydro plant may serve as an alternative to the existing costly methods for electricity generation such as diesel plants (minimize oil consumption for power generation), imported electricity (saving procurement cost) etc.

(iii) Small-hydro plant may either serve a load center isolated from transmission networks (off-grid), or a load center which is part of established networks.

(iv) Hydropower could be considered as the safest, cleanest, and cheapest power generation method.

Disadvantages:

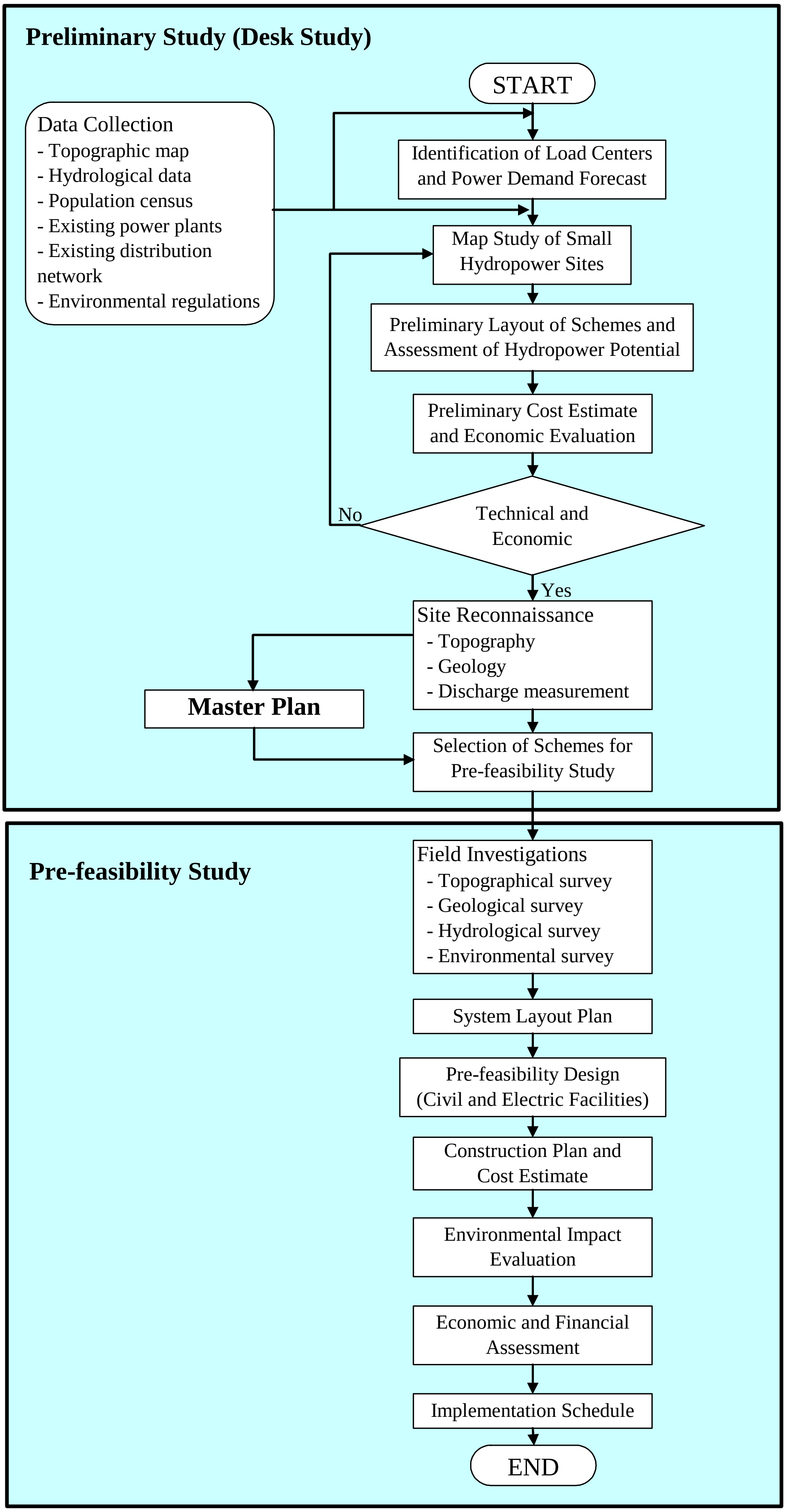
(i) River flow may vary from rainy to dry seasons of the year and from year to year. Thus, the annual energy generation highly depends on river conditions.

(ii) Hydropower generation is forced to stop when river water seriously decreases or for the worst dries up due to severe drought.

1.3 WORK FLOW OF SMALL-HYDRO PLANNING

The overall work flow of the small-hydro planning is shown in the next page.

As shown, there are two (2) steps of study commonly conducted to establish a small-hydro potential of the study area. The first one is a preliminary study (so-called a desk study, or a map study, or a resource assessment study), which identifies potential sites, and the second one is a pre-feasibility study on the favored selected schemes. The purpose of these studies is to identify technically and economically feasible small-hydro sites close to the load centers.


Preliminary Study (Desk Study)
START
Data Collection
- Topographic map
- Hydrological data
- Population census
- Existing power plants
- Existing distribution network
- Environmental regulations
Identification of Load Centers and Power Demand Forecast
Map Study of Small Hydropower Sites
Preliminary Layout of Schemes and Assessment of Hydropower Potential
Preliminary Cost Estimate and Economic Evaluation
Technical and Economic
No
Yes
Site Reconnaissance
- Topography
- Geology
- Discharge measurement
Master Plan
Selection of Schemes for Pre-feasibility Study
Pre-feasibility Study
Field Investigations
- Topographical survey
- Geological survey
- Hydrological survey
- Environmental survey
System Layout Plan
Pre-feasibility Design (Civil and Electric Facilities)
Construction Plan and Cost Estimate
Environmental Impact Evaluation
Economic and Financial Assessment
Implementation Schedule
END

For reference, the Master Plan Study on Small-Hydro in Northern Laos was carried out according to the following three (3) stages:

STAGE 1 Preliminary Study on Small-hydro Planning

- Study on the electrification plans in 8 northern provinces up until 2010 (EDL/ADB grid extension, etc.)
- Demand forecast on districts which will be kept un-electrified up until 2010
- Map study on small-hydro potential sites
- Draft Master Plan for 8 northern provinces up until 2020
- Policy framework in the power tariff, financing and Institutional framework for rural electrification

STAGE 2 Investigation of Selected Off-Grid Small-hydro

- Selection of survey sites, and conducting a site reconnaissance
- Pre-FS on small-hydro potential sites
- Study on issues and policies for the promotion of off-grid hydropower development
- Analysis of the local Institutional capacity, financing mechanism, and financial conditions of existing projects

STAGE 3 Master Plan Formulation

- Finalization of the off-grid hydropower plan at the province level
- Finalization of Master Plan including recommendation on policies for the implementation of potential small-hydro plans after Pre-FS
- Preparation of Small-hydro Manual
- Suggestions & recommendations on policies for the power tariff, financing, and legal /Institutional framework

1.4 TECHNICAL STANDARDS

The Lao Electric Power Technical Standards was established by MIH/DOE on February 12, 2004 under the technical cooperation between the Governments of Lao PDR and Japan. The Lao Electric Power Technical Standards prescribes the fundamental requirements for power facilities and technical contents that should satisfy the fundamental requirements.

The Lao Electric Power Technical Standards comprises 194 articles with three (3) main chapters as follows:

Chapter 1 : General Provisions

Chapter 2 : Hydropower Civil Engineering Facilities

Chapter 3 : Electric Facilities

The Lao Electric Power Technical Standards shown below is available for use at DOE.

CHAPTER II PRELIMINARY STUDY FOR SMALL-HYDRO SCHEMES

2.1 SELECTION OF PROMISING DEVELOPMENT SCHEMES

2.1.1 SELECTION OF SMALL-HYDRO SCHEMES FROM DESK STUDY

As explained earlier in Section 1.3, small-hydro planning shall be undertaken with a two (2) step approach. The first one is a preliminary study (desk study or map study) which identifies potential sites, and the second one is a pre-feasibility study of the selected favorable schemes.

Major work items to be carried out in the preliminary study are as follows:

(i) Identification of load centers and power demand forecast

(ii) Identification of potential small-hydro sites based on available topographical maps (map study)

(iii) Preliminary estimation of the dry-season river discharge at site by means of hydrological analysis and/or river flow measurement

(iv) Preliminary system layout planning for each scheme

(v) Preliminary assessment of the hydropower potential of each scheme

(vi) Preliminary cost estimation of each scheme

(vii) Preliminary economic evaluation for arranging schemes in order of economic priority

Work items above are introduced in the succeeding sections below. Preliminary hydrological analysis for estimating the dry-season river discharge at site is described in Section 3.1.

A pre-feasibility study is the next step towards project development following the preliminary study mentioned above. The procedural steps in the pre-feasibility study are basically the same as those for the preliminary study, although it is a higher and deeper level study on the sites based on more detailed information and data together with field investigations (i.e. topographical and geological surveys) to be carried out. Further details of the pre-feasibility study is discussed in Chapter III. Table below shows the list of small-hydro schemes for the map study under the current Master Plan Study.

List of Small-Hydro Schemes for Map Study

Seq No.	Project Name	C/A (km^2)	Spec. Dis. (l/kw^2)	Effec. Head (m)	Capacity in Dry (kW)	Installed Capa. (kW)	District	Province
1	Nam Nga	86	3.1	15	24	100	202 Mai	Phongsaly
2	Nam Kai	220	2.7	24	82	250	203 Khoua	Phongsaly
3	Nam Pok	401	3.2	80	604	150	204 Samphan	Phongsaly
4	Nam Ou Neau	579	3.7	40	504	380	206 Gnod Ou	Phongsaly
5	Nam Long	156	3.6	215	710	2,000	303 Long	Louangnamtha
6	Nam Pha	217	3.0	25	96	250	303 Vienhphoukha	Louangnamtha
7	Nam Heng	265	1.9	30	89	100-	305 Nalae	Louangnamtha
8	Nam Phak	595	2.7	100	945	5,100	403 Namo	Oudomxay
9	Nam Ngao	299	2.0	70	230	840	405 Beng	Oudomxay
10	Nam Tale	89	1.0	80	42	80	407 Pakbeng	Oudomxay
11	Nam Gnone	121	2.7	30	60	500	501 Houasay	Bokeo
12	Nam Khanoy	82	3.6	20	35	80	503 Meung	Bokeo
13	Nam Hat	501	1.0	15	44	170	504 Pha Oudom	Bokeo
14	Houay Kouang	37	2.4	34	18	20	610 Vieng Kam	Luangphrabang
15	Nam Xeng	429	2.5	20	126	170	610 Vieng Kam	Luangphrabang
16	Nam Peun	211	3.0	40	149	70	705 Houamouang	Houaphan
17	Nam Hang	89	2.5	80	105	70	703 Viengthong	Houaphan
18	Nam Hao	453	3.0	129	1028	5,000	704 Viengxay	Houaphan
19	Nam Ngen 2	1159	1.0	30	204	610	802 Khorb	Xayabury
20	Nam Ken	415	1.5	30	83	380	803 Hongsa	Xayabury
21	Nam Lay	245	1.3	40	75	220	807 Paklay	Xayabury
22	Nam Ham 2	97	1.0	176	100	3,000	809 Boten	Xayabury
23	Nam Xan	134	4.0	60	189	110	904 Khoune	Xiengkhuang
24	Nam Chao	129	4.0	25	76	100	905 Morkmay	Xiengkhuang

2.1.2 SELECTION OF PROMISING SCHEMES FOR SITE RECONNAISSANCE

Based on the estimated power demand of the identified load centers, the potential sites for small-hydro development scheme shall be selected. For the selected sites, preliminary hydropower plan shall be formulated by use of basic data on such as discharge and total head. Finally, promising development site shall be selected considering the following parameters:

(i) Technical soundness for construction (including accessibility),

(ii) Economic viability (lower kW cost: construction cost per kW), and

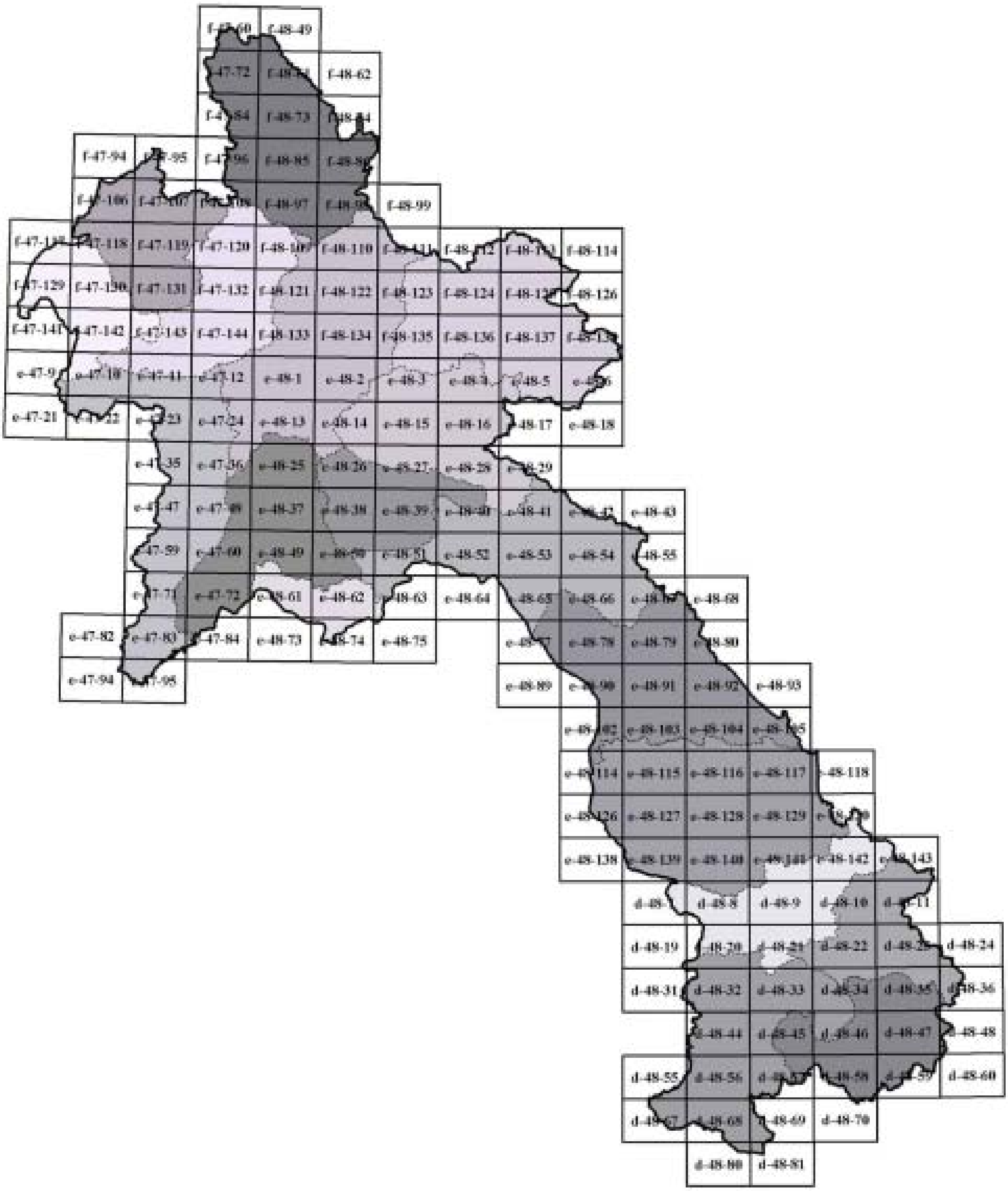
(iii) Priority for development (balance between the power demand and supply during the dry season).

2.2 FIELD SURVEYS

2.2.1 TOPOGRAPHIC MAPS

Topographic maps are of minimum requirement for field studies. These maps are required to measure a catchment area, head and waterway length. The catchment area at the proposed site is necessary for estimating river flow at the intake. The head is roughly determined by the difference of elevations between the proposed intake site and tailrace of the powerhouse. The waterway route connecting these locations is also determined on topographic maps.

The 1:100,000 scale maps of Lao PDR (contour interval is 20-40 m depending on maps) are available and obtainable at the National Geographic Department in Vientiane. Index map is shown below.



Index Map of 1:100,000 Scale Topographic Maps in Lao PDR

2.2.2 VERIFICATION OF POWER GENERATING FACILITY LOCATIONS AND STUDY OF GEOGRAPHICAL AND GEOLOGICAL CONDITIONS

When the proposed site is deemed worthy for further detailed study from a map study, it is essential to make a site reconnaissance on the proposed facility locations. Using 1:100,000 scale topographic map, differences between the topographic map and actual topography, geological conditions, existing facilities, and road access conditions shall be checked through the site reconnaissance. The results shall feed back to the study for planning. The following points shall be carefully examined in the site reconnaissance:

(1) Topography

The site topography shall be confirmed at site as topographical maps of 1:100,000 are not always of reliable accuracy. Check items are listed below.

Location	Check Point
Intake site	River section, width of water surface, gut, riverbed, outcrop, river slope, gradient of bank slope, bank vegetation, etc.
Headrace route	Topography, gradient of slope, vegetation of slope, landslide, slope collapses, slope deposits, gulleys, etc.
Power house site	Slope situation of penstock route, nature and kind of outcropped rocks, vegetation, river bed at the river outlet, etc.

For the sites where further survey is considered to be necessary after the site reconnaissance, topographic survey will be required near the sites.

(2) Geology

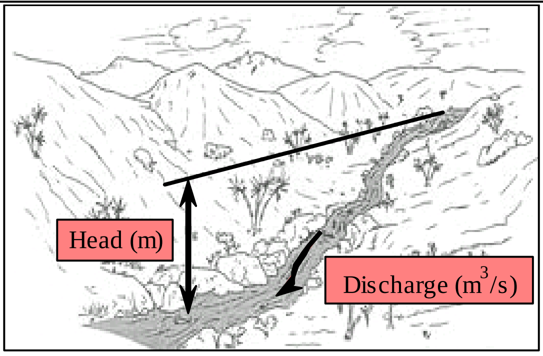
The purpose of geological survey is to identify the best placement of installations of system components such as waterway channel, penstock and powerhouse. A small amount of efforts on site geology is easily repaid in cost savings in channel construction, sound penstock and turbine foundations, and safety from channel collapse due to slope instabilities. Site geology shall be confirmed through the survey. Use the map and photographs to sketch out basic geological characteristics of the area. Check and identification items for the site survey are listed below.

Geological Phenomena	Identification
Loose slope	Debris, dry mud, lack of vegetation
Storm gulley	Debris
Flood plain	Local resident’s knowledge and experience
Landslide, fault	Semi-circular crack or step in hillside

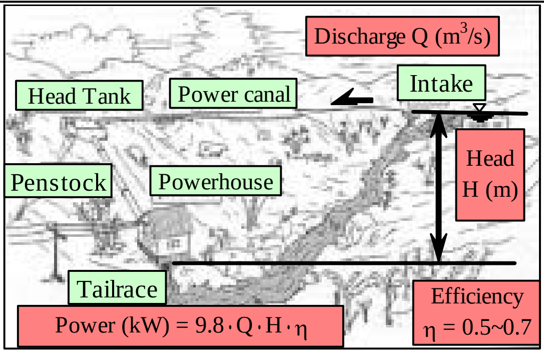
2.2.3 HEAD MEASUREMENT

Head is the vertical distance that can be utilized to generate hydropower. The detailed planning and design are to be made based on a topographic map with a scale of 1/500 or prissier, but in the stage of preliminary planning, much quicker and less costly methods can be used for measurement of the head.

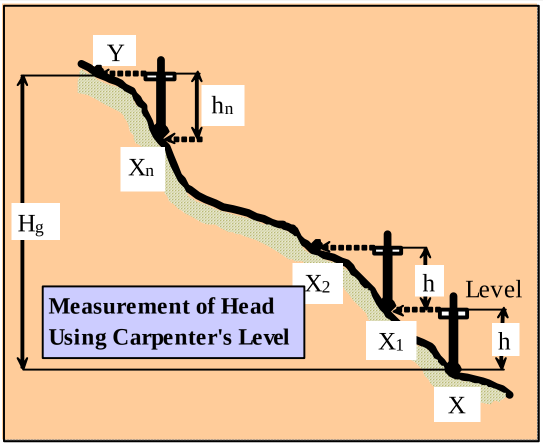
The following tools are available to measure the head for the preliminary planning.



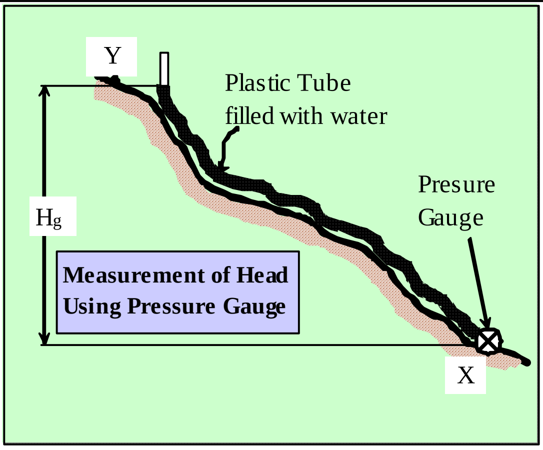
Measurement of Discharge and Head



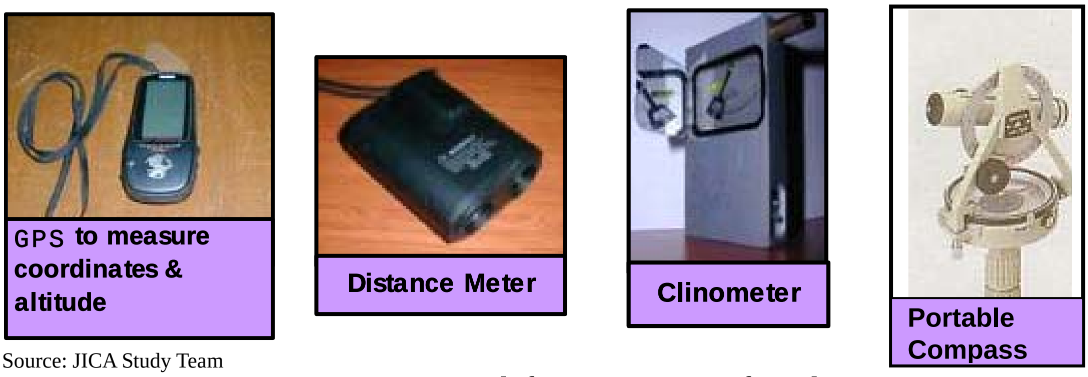
Preliminary Planning of Layout Based on Q &



Measurement of Head Using Carpenter's Level



Measurement of Head Using Pressure Gauge



Source: JICA Study Team

Tools for Measurement of Head

2.2.4 SURVEY OF SURROUNDING ENVIRONMENT

Hydropower development is impossible when environmental regulations prohibit any development activities in the planned area. When some part of the planned area is located in such a restricted area, the plan shall be formulated not to infringe regulations. In general, development activities are strictly controlled in the special areas such as:

(i) Natural park

(ii) Wildlife conservation area

Relevant laws and guidelines in Lao PDR are as follows:

(i) Environmental Protection Law (1999)

(ii) Electricity Law (1997)

(iii) Regulation on Environmental Assessment in the Lao PDR (2000)

(iv) Regulation on Environmental Impact Assessment for Electricity Development in the Lao PDR (2001)

(v) Environmental Management Standard for Electricity Projects (2001, 2003)

2.2.5 RIVER CONDITION SURVEY

After tentative selection of the locations of intake and outlet of powerhouse, the river condition survey shall be made to investigate:

(i) Stream line (gut) in the river channel

(ii) Riverbed slope

(iii) Riverbed materials and suspended load materials

(iv) River water quality

(v) Current use of river water

2.2.6 SITE RECONNAISSANCE MEMO

When you make a site reconnaissance to the proposed small-hydro scheme site, it is highly recommendable to make a *Site Reconnaissance Memo* for each site. This Memo shall include topographical maps for the site location, river condition, site and access conditions, your interviews results to local people and concerned agencies, site photos, your sketches, your various site observations, your comments and initial evaluations on the site, etc. The Memo will be very helpful to you after the site reconnaissance.

An example of the site reconnaissance memo is shown in the following five (5) pages. This example is for the Nam Gnone scheme in Bokeo province. The site reconnaissance was undertaken by the JICA study team in collaboration with PDIH in Bokeo on December 3, 2004.

An Example of Site Reconnaissance Memo

General Condition (Access, Electrification Status, etc)

Access to B. Namkat
- From Houaysay to the crossroad is 45 min n paved road. From crossroad to B. Phouxai is 20 min on dirt road.

Electrification Status of B. Namkat
- B. Namkat is electrified by pico hydro but not so much.

Access to Power Station Site
- There is a foot path to area of the P/H site, which cross a tributary of Nam Gnone. This footpath is used to go to paddy fields along Nam Gnone and to go to see Nam Gnone Falls. It seems difficult to cross the tributary during rainy season.
- The time taken from B. Namkat to wate fallws at downstream end is 3 minutes on foot.

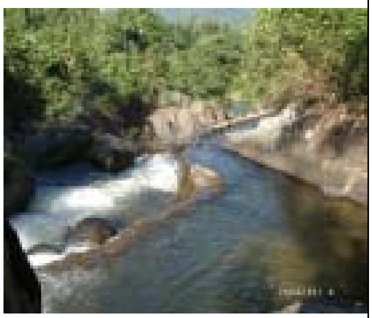
Access to Intake Site
- The same footpath which leads to water falls extends to the I/T with crossing the Nam Gnone by a log bridge. The condition of the footpath near I/T is covered with bamboo grove and not the same as to the P/H.
- The time taken from Powerhouse site to the I/T is approx. 1.0 hours.

Access to Staff Gauge
- Staff gauge is installed at B. Namkat.

Photos


B. Namkat.


Water fall located just upstream of powerhouse site

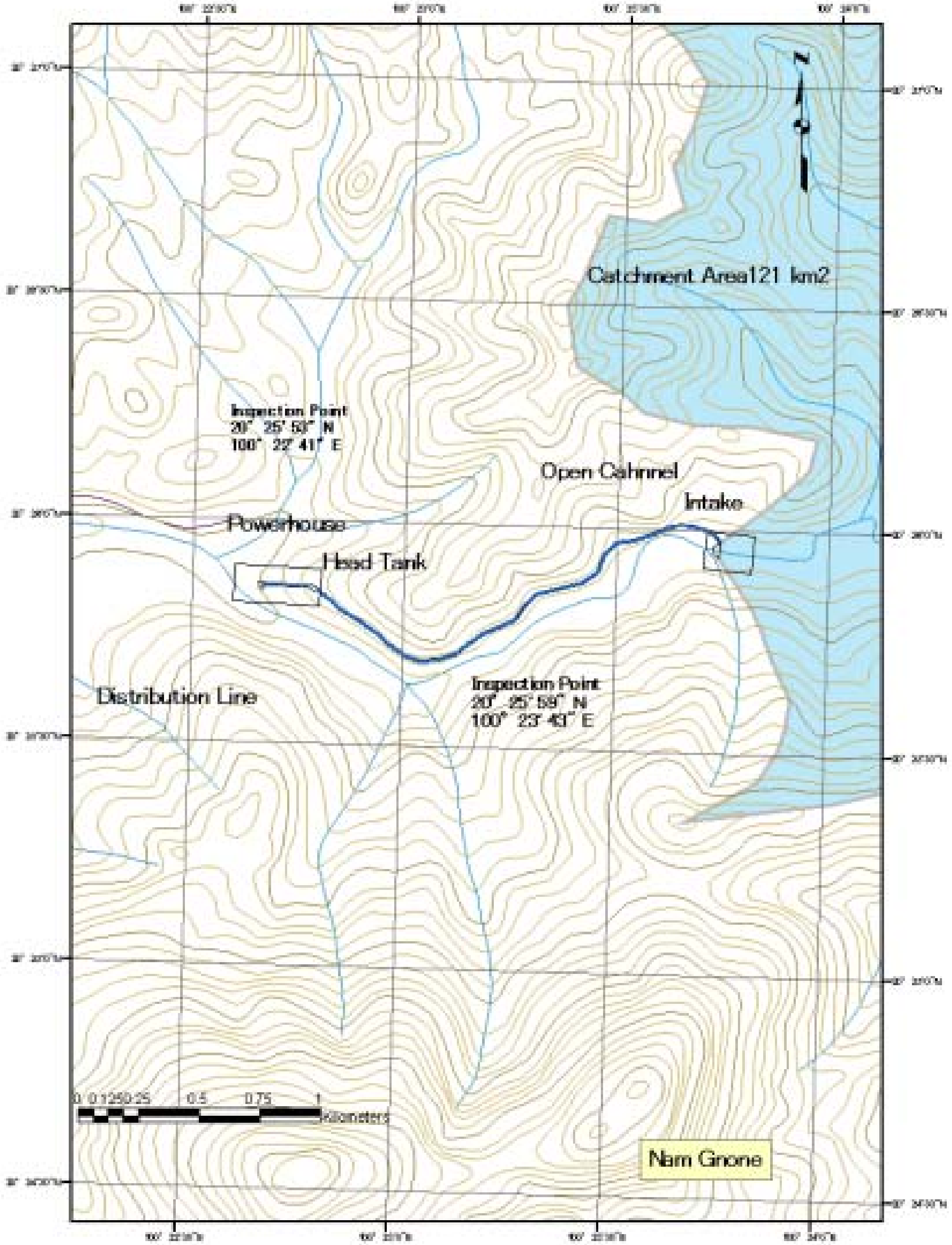

Intake canal constructed for previous piko hydropower, which stopped to operate now.


Rapid continue toward upstream.


Irrigation intake and canal for irrigation at paddy field located downstream area


Paddy field taking water from canal during rainy and dry seasons

Location Map



Intake Facilities (Weir/Dam, Intake, Desilting Basin)

Condition of the Intake Site

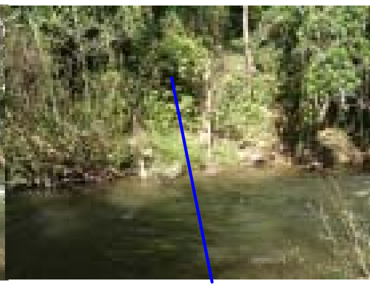
- The intake site proposed through the map study seems to be adequate, but a left bank is flat with paddy field. Right bank has steep slope covered with bamboo grove. At downstream of proposed intake dam site, a steep rapid starts. Further upstream area is very flat and a new village locates near the river on right bank. Access road exists on right bank which lead to new village. Coordinates at center of dam axis is N20°25’58.68”, E100°23’43.45 and elevation is EL.413m.
- There is alternative dam site at downstream of proposed dam site mentioned above. This dam site is little wider than original dam site. This site locates at middle way of steep rapid portion of this river, which has lower elevation than original dam site by 17m. Coordinates at center of dam axis is N20°25’41.16”, E100°23’16.6 and elevation is EL.396m. The condition of access is same as original dam site.
- It is judged that the original axis is more adequate, because it can have higher head as mentioned above.

Environmental Impact

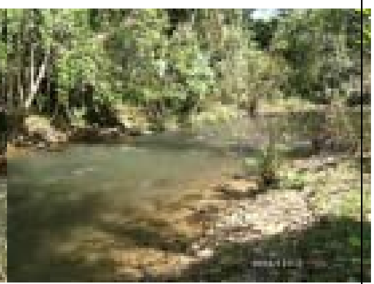
- The weir height needs to be kept low in order not to inundate the paddy fields which extend on left bank.
- There in no serious problem on Fishing activities.
- There is an existing irrigation intake weir and canals which take water and invite it to paddy fields. The water is taken from June to October in rainy season and December to April in dry season. The area of existing paddy fields is 30ha and there is plan to expand the area to 50 ha in rainy season only. According to head of former, the one forth of river water is taken to irrigation canal at driest season. It seems that the water taking for hydropower at upstream of irrigation intake considering the requirement of irrigation water will not affect to irrigation even though the dry season. This water usage for irrigation should be considered in duration curve of river flow.

Photos

Proposed Intake Weir site. Photo taken from upstream. There are steep slope in right bank and flat slope and paddy field in left bank.

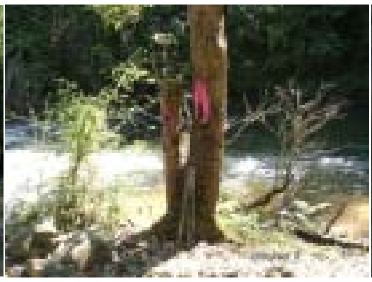


At bottom of weir axis on right bank, a rock is exposed. Upper area of right bank is covered with bamboo grove. (adopted)

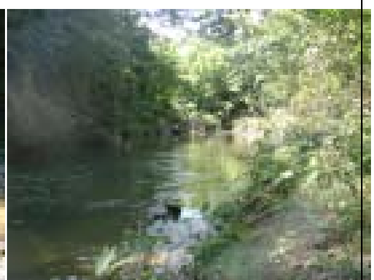


Upstream river has relatively flat slope.

Alternative Intake Weir site. Upstream view. Total head become about 30 m.



Alternative Intake Weir site. Marking for weir axis. (not adopted)



Alternative Intake Weir site. Downstream view.

Powerhouse (Power Station, Tailrace, Outdoor Switchyard)

Conditions of Powerhouse Site

- The riverbed coordinates below the proposed P/H site is N20°25’51.31”, E100°22’43.01”, WL 364 (Trimble GPS Geo explorer CE Series).
- The location is D/S of the lowest water falls, where locates beside water pool.
- The annual FWL is high at approx. 2m above the present WL. In order to lower the P/H as much as possible and to prevent the P/H from the flood, the pond mouth and downstream area of river should be reshaped to have bigger flow capacity.

Alternative Powerhouse Site

- There is alternative powerhouse site at downstream of original powerhouse site. However, this site locates at flat area with paddy field on left bank. In the case of this alternative, the water way should be designed on left bank and the penstock will locates in the paddy fields and became very long. Totally, the water way layout is very difficult. It seems not to be adequate.
- Alternative P/H site is N20°25’57.77”, E100°22’16.03”, WL 350.

Discharge Measurement

- Discharge measurement was conducted on Dec. 03, 2004 at the gauging station.
- Q = XXXX m^3/s (current meter)

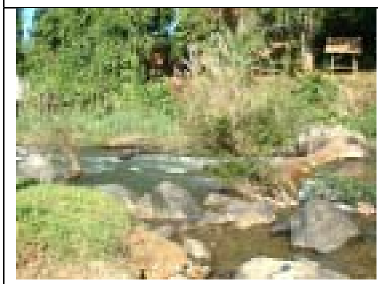
Installed Capacity

- The approximate net head H = 413 - 364 - (2000x(1.5/1000) = 46 m. Assuming Q = 3.8 m^3/s , and ηcomb = 70%, installed capacity P = 1200 kW.

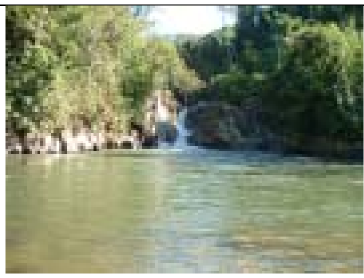
Environmental Impact

- Due to usage of river water for hydropower, the water which flow down through water falls will be reduced and the appeal strength as the sight seen location will be decreased in dry season especially. However, during rainy season, there will no serious problem on sight seen.

Photos

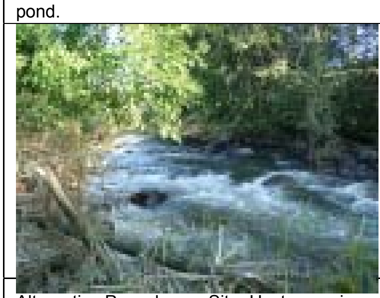


Proposed powerhouse located the flat area of 4 m higher than water surface of pond. Tailrace water will be invited to downstream of pond.



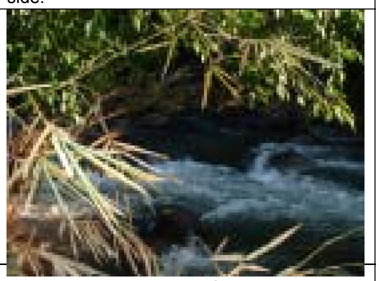
The last water fall flow into pond and spill out to further downstream area.

Proposed powerhouse site is flat area beside the last water fall. There is some huts and steps to go down to see pond at water fall side.



Alternative Powerhouse Site: Upstream view

Alternative Powerhouse Site: Downstream view



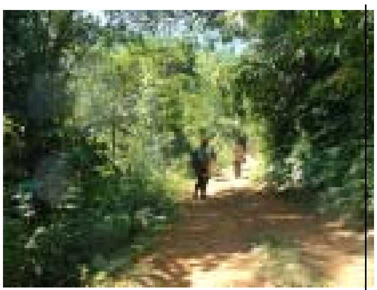
Alternative Powerhouse Site: River Bottom conditions

Waterway (Canal/Tunnel, Head Tank/Surge Tank, Penstock)

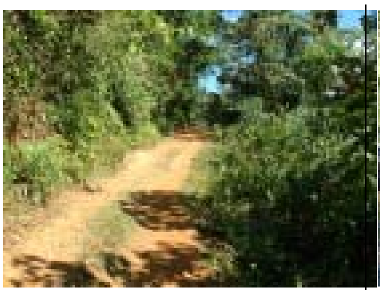
Conditions along Waterway

- The open channel will be constructed on the R/B. The waterway was not directly investigated, but observed from the existing access road on R/B.
- The waterway may be as long as 2 km, but the mountain slope seem to be adequate for construction.
- At the design stage, it should be careful that the excavation for water way should not affect to stability of exsiting accessr road on right bank.
- For discharge Q = 3.8 m^3/s flowing at v = 1 m/s, the channel dimension will be in the order of 2.0 m x 2.0 m.
- The necessity of concrete cover of open canal should be considered site by site.

Photos



There is an access road to village on right bank, which pass through the upper part of Intake Weir Site and Powerhouse site.



Open channel will locate along the access road at lower elevation.

Between Intake Weir site and Powerhouse site, there is irrigation intake and canal on left bank. Same type of wet masonry canal will be adopted for open channel for hydropower.

Distribution Line and Temporary Facilities (D/L, Spoil Bank, Construction Materials, Access Road)

Conditions of Distribution Line Route

- From the proposed P/H site, D/L can easily be constructed to B. Namgnon-Mai along the existing road, which locates near to junction of Nm Gnone and Nam Mekon.
- The nearest villages to the P/H are B. Namkat, and they can easily be reached.
- There is existing T/L which is delivering the electricity imported from Thailand to Tonpheung. The capacity of this T/L should be checked to study the possibility of connection of new T/L from powerhouse into existing T/L.

Access Road

- Access road can easily constructed along the existing road to the village on right bank.

Construction Materials and Spoil Bank

- Boulders are mostly available from the river.
- There are enough spoil bank area near the I/T.
- The excavated much from the diversion channel of the river will be used to construct a levy along the diversion channel.

Evaluation and Remarks

- As a alternate dam site and powerhouse site, two numbers of sites for both structure were planned and each site was investigated. As the result of total evaluation, the upper dam site and upper powerhouse site were selected for the layout in Pre-F/S.
- According to DOE, there is information that the generator with 60m head is available in order to save the construction cost.
- If this hydropower plant will be constructed with 1.2MW installed capacity, the huge electricity imported from Thailand will be reduced.

Others

- The existing irrigation system was constructed in 2000 by IFAT. The construction period was 1 year. According to the former team, they feel no problem with construction of hydropower project.
- The other private company was investigating this same hydropower scheme on same day. They are making cross section survey. It seems that their layout has the downstream site for intake dam and downstream site for powerhouse also.

2.3 RIVER FLOW MEASUREMENT SURVEY

2.3.1 COLLECTION AND UTILIZATION OF EXISTING RUNOFF DATA

Hydrological (river water level and discharge) observation in Lao PDR is undertaken by Department of Meteorology and Hydrology, Ministry of Agriculture and Forestry. In the northern Laos, there are only 5 hydrological stations where the daily discharge data is available as listed below.

Station Name	**River Name**	**Catchment Area (km^2)**	**Availability**
M. Ngoy	Nam Ou	19,698	1991 - date
Sieao	Nam Xuang	5,800	1991 - date
Kok Van	Nam Pa	700	1994 - date
Pak Bak	Nam Khan	6,503	1990, 1995 - date
B. Mixay	Nam Khan	6,777	1991 - date

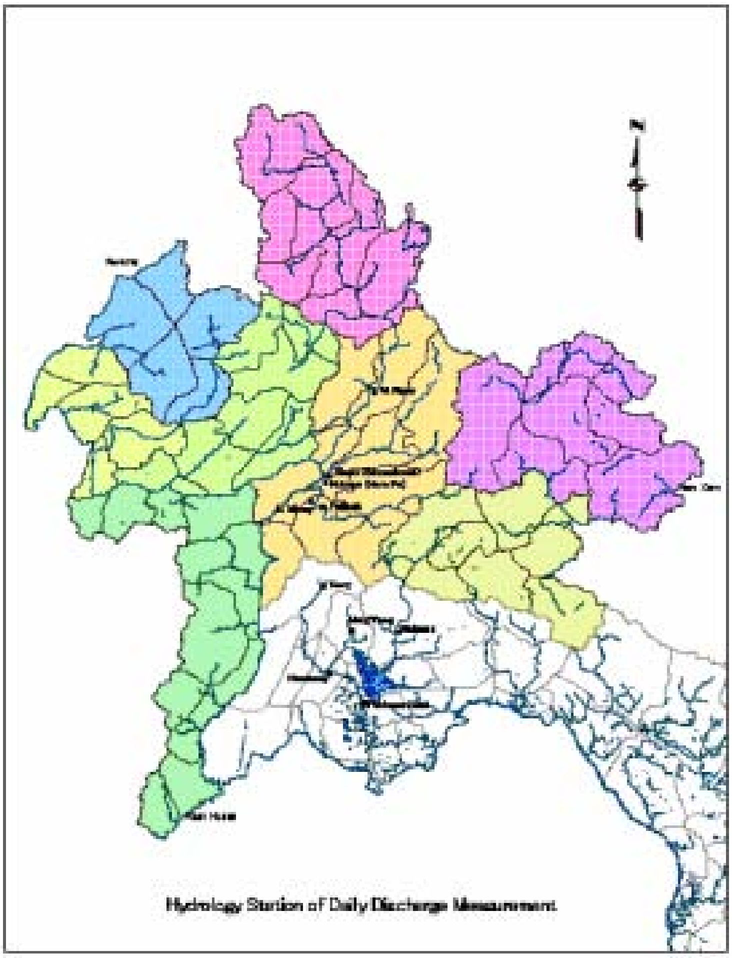
The location map of these stations is shown in the next page.

2.3.2 RIVER DISCHARGE MEASUREMENT METHOD

Either discharge records or information on water level gauging stations is not generally expected to be enough at the rivers where a small-hydro station is planned. When a small-hydro site is identified by a map study, it needs the discharge measurement of the river through a year. Hydropower planning requires the procedure for a river discharge measurement as follows:

(i) Discharge measurement of more than 10 times within a proper range that enables establishment of the river stage (water level)-discharge rating curve at the intake site.

(ii) Establishment of the water level gauge and gauge reading as many time as possible, especially during the dry season. The task of gathering such information may be sublet to the local inhabitants.



Location Map of Hydrological Station in the Northern Laos

The river discharges are likely to decrease significantly in the dry season in Laos compared with those in the rainy season. It is, accordingly, essential to investigate discharges, especially in the dry season, for the planning of a small-hydro scheme with the isolated grid system to supply stable energy throughout the year.

In practice the following methods are available to measure river discharges:

(i) Current meter method

(ii) Float method

(iii) Weir method

Each method is briefly introduced below:

(1) Current meter method

This is the most common method to measure flow velocities where the stream is not irregular and turbulent. A location for the measurement should be selected in the straight stretch of a river. Simple measurements as below may be sufficient for streams where the small-hydro scheme is planned:

i) 2-point method $V_m = 1/2 \times (V_{0.2} + V_{0.8})$ for depth > 1 m

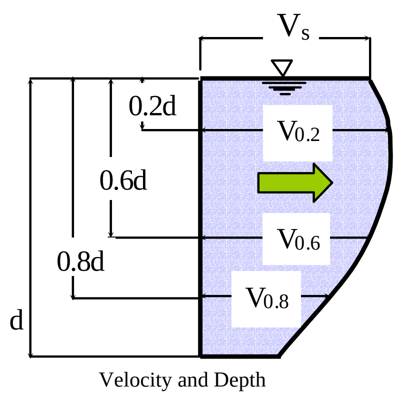
ii) 1-point method $V_m = V_{0.6}$ for depth < 1 m

where, V_m : mean velocity

$V_{0.2}$: velocity at 20% depth from surface

$V_{0.6}$: velocity at 60% depth from surface

$V_{0.8}$: velocity at 80% depth from surface



Velocity and Depth

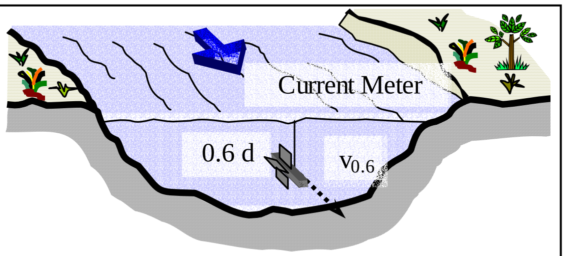

Current Meter owned by DOE

Photos below are discharge measurement by DOE.

Discharge Measurement with a Current Meter

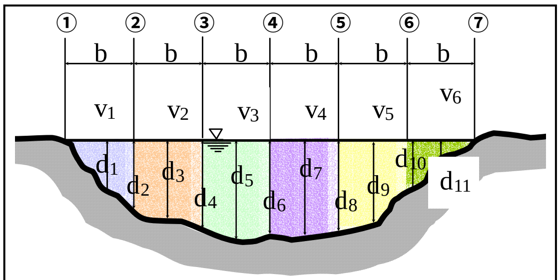
Discharge Measurement with a Current Meter

In practice, the discharge measurement by a current meter is conducted, dividing the river cross-section into several sub-sections as schematically shown below.



Source: JICA Study Team

Velocity Measurement by Current Meter



Source: JICA Study Team

Measurement of Sectional Area & Velocity

The river discharge can be derived using the following equation:

$$Q = V \cdot A$$

where, Q : discharge (m^3/s)
V : mean velocity (m/s)
A : cross sectional area (m^2)

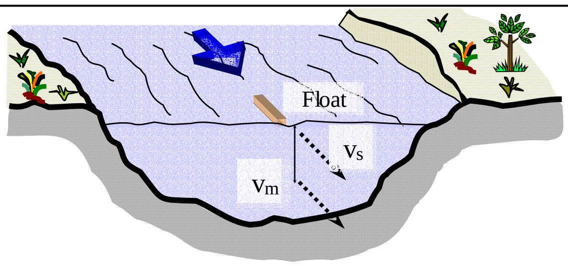
A form for discharge measurement is shown in the next page.

(2) Float method

This is the easiest method to measure velocities in the stream without any special equipment when the flow velocity is relatively high during the wet season. However, high accuracy cannot be expected where the stream is irregular, wide, and shallow. The river flow discharge is obtained by the following formula:

$$Q = c \cdot V \cdot A$$

where, c = 0.85 for concrete channel
0.80 for smooth stream
0.65 for shallow stream



Source: JICA Study Team

Measurement by Float

Illustration below shows typical kinds of float.

Surface Float and Bar Float

Table in the next page shows the form of field discharge measurement by DOE.

JICA-DOE Study Team (Field Notebook of Discharge Observation)

FIELD WORKS									
No. of measure-ment	Distance from bank (m)	Depth of Water. (m) First (on way)	Depth of Water. (m) Second (return)	Depth of Water. (m) Average	Velocity Mesurement (Flow speed) Depth of observation(m)	Velocity Mesurement (Flow speed) Count of current meter	Mesu. Velocity 1st	Mesu. Velocity 2th	Mesu. Velocity Average
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									

HOME WORKS						
Velocity: Mesu. Veloc. at point(m/s)	Velocity: Mean meas. Veloc.in vert(m/s)	Area of cross section: Average depth(m)	Area of cross section: Width of section(m)	Area of cross section: Area of Section(m^2)	Total Area(m^2)	Disch-arge (m^3/s)

Station No.			
Observation Date		Year: Mon: Date:	
Observer Name	Mesure		
	Wrote	***Sanhya***	
Weather	Weather	:clear, :fine, :cloudy :rain	
	Wind blows	from Down/s, Up/s, Left, Right	
	Wind power	0:None, 1:light, 2:windy, 3:strong, 4:very strong	
Mesurement Time (Hour, min)	Start		
	End		
	Average		
Water Level at gauging station (m)		Initial Point	No.1 Point
	Start		
	End		
	Average		
Current meter	Type of current meter	Digital	
	Table/formula	V =	
	Useing method	lods・wire・weight	
		by boat / bridge / walk	
Calculator	Calculator		
	Checker		
Result	Total Discharge (m^3/s)		
	Total area cross section(m^2)		
	Average Velocity (m/s)		

Notes

Catchment Area (km^2)=	
Discharge (m^3/s)=	
Specific Discharge ($m^3/s*100km^2$)=	

Remark:

DOE Form of Discharge Measurement

Field Discharge Measurement

Field reconnaissance of the small-hydro sites was carried out from November 17 to December 11, 2004. The reconnaissance aimed at confirmation of the site conditions such as accessibility, river course, river flow, geography, geology, water withdrawal for the local irrigation and so on. Under the site reconnaissance, discharge measurement was conducted jointly by staff of DOE and PDIH.

Photos below show the discharge measurement on site in the Nam Pha River, Vieng Phoukha, Luangnamtha. The measured river discharge was 1.8 m^3/sec on November 25, 2004.

Nam Pha River

Looking for the best discharge measurement point

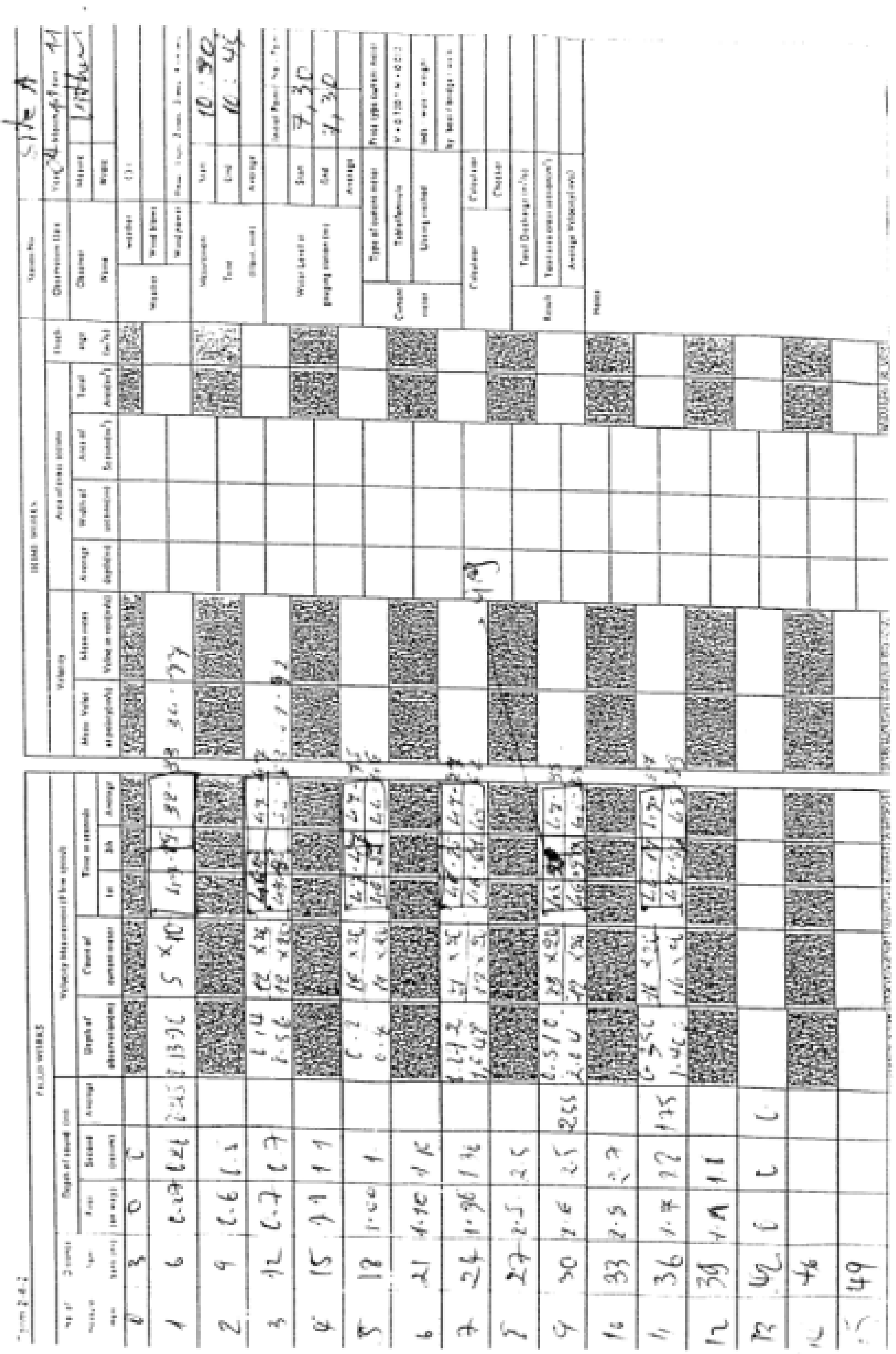
Straining a measurement tape across the river

Measuring the river water depth at 1 m intervals

Measuring the river flow velocity by a current meter at 1 m intervals

Measuring the river flow velocity by a current meter at 1 m intervals

An Example of Record of Field Discharge Measurement

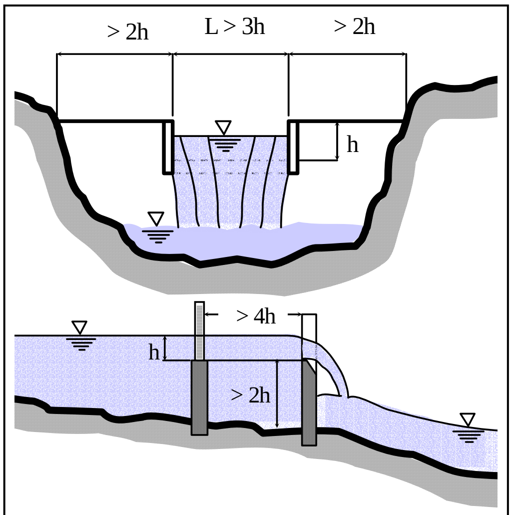


(3) Weir Method

In a small river where the discharge measurement by a current meter is impossible due to small river flow, the weir method is conducted. This method requires construction of a weir across the stream to measure discharge directly in the stream. The flow discharge is given by the following formula:

$$Q = 1.84 \cdot (L - 0.2 \cdot h) \cdot h^{1.5}$$

where, Q : discharge (m^3/s)
L : length of weir (m)
h : overflow depth (m)



Source: JICA Study Team

Figure Discharge Measurement by Weir

2.3.3 DISCHARGE RATING CURVE

The river water level shall be measured daily or hourly. However, it is very hard to measure river flows (flow velocity and flow area) frequently. A discharge rating curve is thus drawn to estimate the river flow from the measured water level. The discharge rating curve is then prepared based on:

(i) Discharge measurement more than 10 times in range required to establish a stage-discharge rating curve

(ii) Water level gauge reading using staff gauge

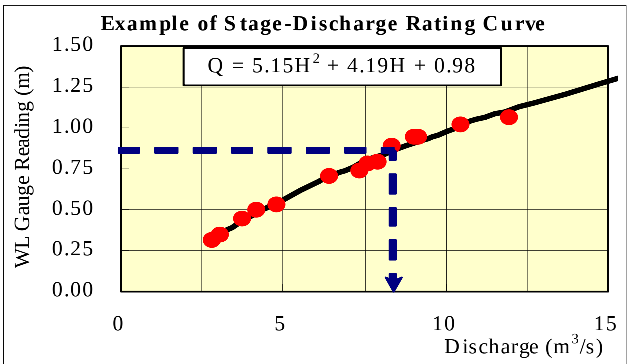
In practice, the discharge rating curve is expressed by the following equation:

$$\mathbf{Q = a + bH + cH^2}$$

Q : River flow (m^3/sec)
H : Water level (m)
a, b, c : Constants

Constants of a, b and c are determined by the least square method.

As shown above, the relation between water level and discharge can be expressed by a quadratic equation. It is noted that the stage-discharge rating curve should be reviewed periodically for calibration, especially after the flood season that may result in erosion or sedimentation on the riverbed.



In view of small-hydro planning, the discharge rating curve during the low flows of the river (dry season) is of great importance. Thus the curve shall be developed based on the actual discharge measurement in the dry season. When the discharge rating curve is already developed, the daily discharge shall be obtained by reading the staff gauge.

:

Water Level Gauge

Water Level Gauge

It is noted:

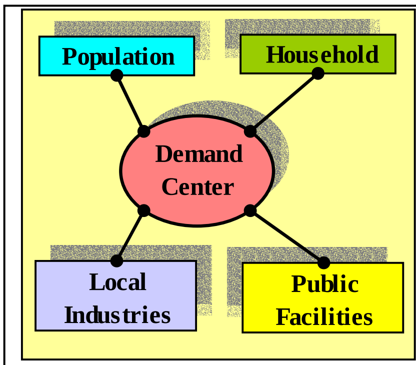
(i) When the relationship between the water level and river flow can not be expressed by one equation, it is recommended that the relation shall be expressed in several equations according to the range of water levels.

(ii) It is required to prepare a new discharge rating curve when the relation changes due to river bed changes after large floods or by season.

2.4 POWER DEMAND FORECAST

2.4.1 POWER DEMAND SURVEY

The development of isolated power systems may be more practical than extension of the power grid for district level electrification. It is essential to estimate accurately the power demand for the target area when a small-hydro scheme is launched. Because hydropower is a site-specific energy, identification of hydro potentials to meet the required demand should be the basis for the planning of rural electrification. For the power supply in an isolated grid system, the generated power should be kept at a higher level than the incurred load, otherwise the following measures are needed:



Power Demand Categories

(i) Backup power by other power sources such as diesel generators

(ii) Adjustment of the power demand

The power demand can be classified into the following categories according to the rural society survey.

(i) Household use : light, TV, radio, refrigerator, rice cooker, etc.

(ii) Public use : streetlight, temple, clinic/hospital, school, etc.

(iii) Industrial use : local industries, etc.

An investigation of the rural society needs to be carried out at the initial stage of the planning to estimate the power demand, of which the main items are summarized as follows:

(i) Numbers of household and population in each village tract

(ii) Numbers, scales, and time zone of electric appliances used in households, public, and local industries.

(iii) Existing power facilities and existing electrification ratio

(iv) Future development

The general information required for the planning is as follows:

(i) Administration that covers the demand centre

(ii) Location, area, and accessibility of the demand centre

(iii) Main industries

(iv) Willingness to electrification

(v) Income and ability to pay for electricity

(vi) Possibility for rehabilitation of the existing power facilities and extension of distribution lines

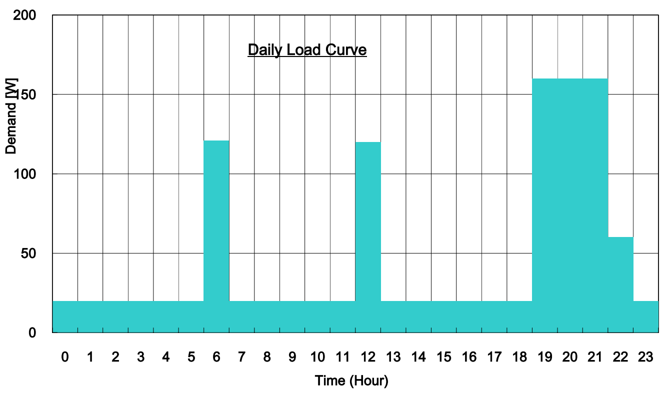
(vii) Land use in the river basin, and agricultural cropping patterns

(viii) Land acquisition

(ix) Sectional map showing the village tracts

2.4.2 POWER DEMAND ESTIMATE

The load curves for seasonal and time fluctuations of the power demand shall be estimated, taking into account the usage patterns of electrical facilities/appliances, ratio of concurrent use, etc. by reference to the existing records in neighboring power stations.



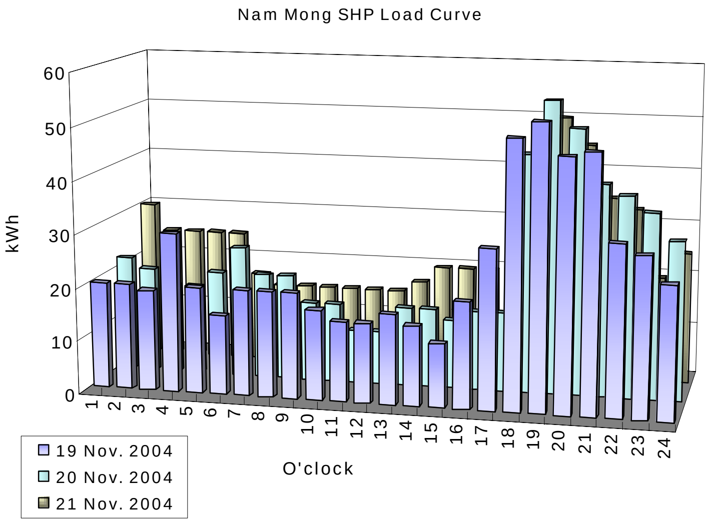
(i) Seasonal fluctuation : Agricultural process, drying process in monsoon regions

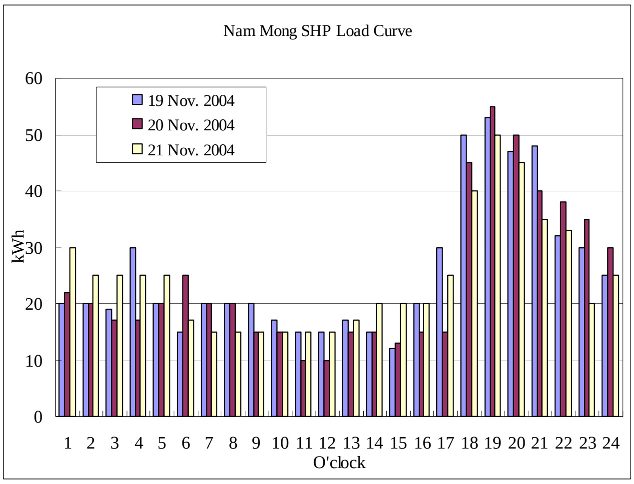
(ii) Time fluctuation : Lighting for night-time use, daytime use by local industries

An example of the load curve is shown above.

2.4.3 POWER DEMAND AND LOAD FACTOR

Figure on the right shows three actual daily power demand curves on 19 to 21 November 2004 at the service area of Nam Mong small-hydro plant. This plant was completed in 2000 in Louangphabang province. Figure on the right below show the comparison of these demand curves. The peak demand of around 50 kW occurs at from 18:00 to 21:00 in the evening. Considering that the Nam Mong station supplies electricity to around 450 households, the peak demand per household in 2004 was around 110 kW.





The power demand is called "load" from the power supplier side. The ratio of the daily average load to the maximum (peak) load is called the load factor (LF) as expressed below.

$$LoadFactor(\%) = \frac{AverageLoad}{MaximumLoad} x100$$

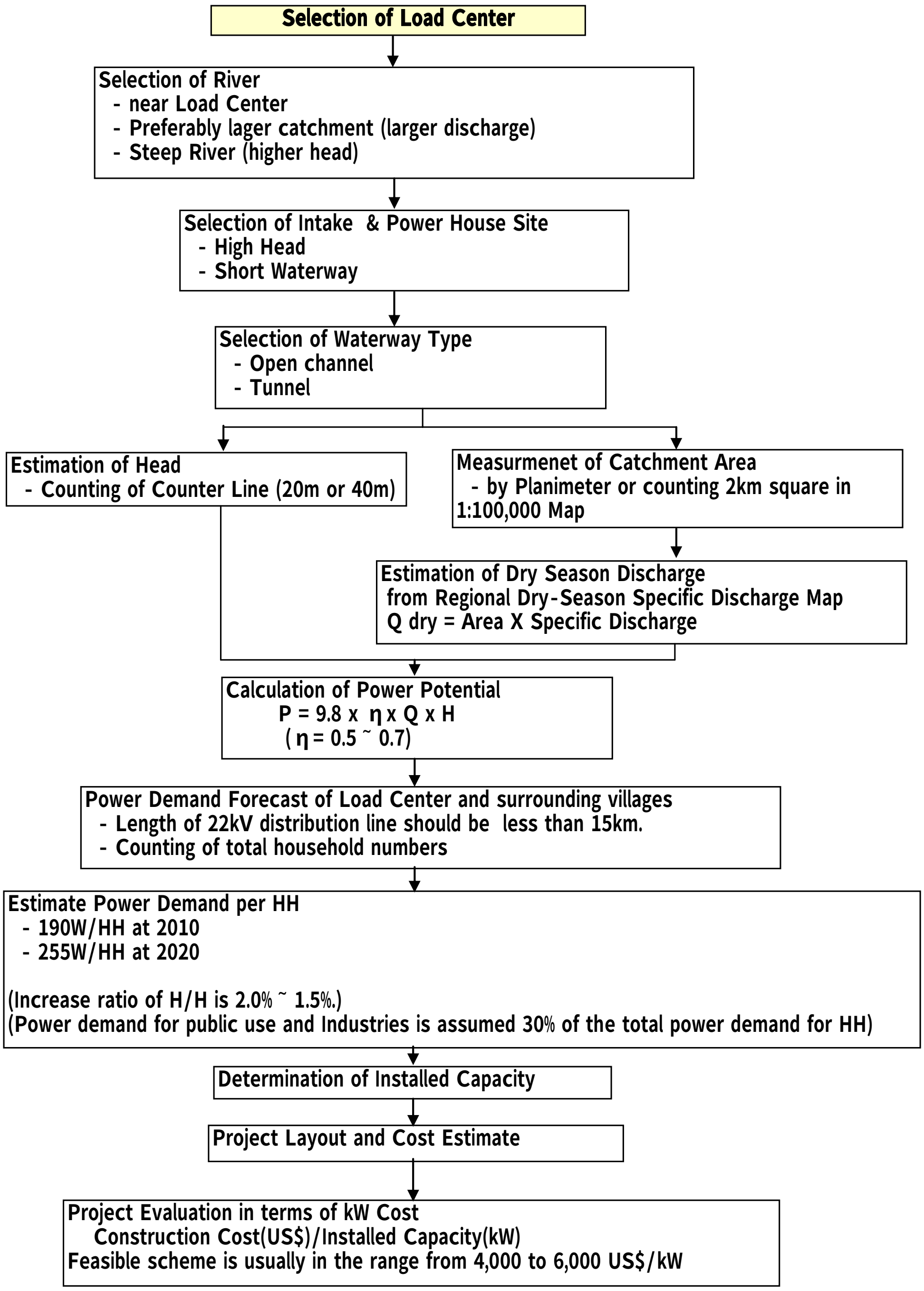
The load factor of the Nam Mong is estimated around 50% as follows:

$$LoadFactor(\%) = \frac{25}{50} x100 = 50(\%)$$

2.5 PRELIMINARY SMALL-HYDRO PLANNING

2.5.1 OVERALL WORK FLOW FOR PRELIMINARY STUDY (DESK STUDY)

Flow Chart of Map Study



2.5.2 TYPE OF HYDROPOWER GENERATION SYSTEM

In general, the hydropower generation system is classified into the following three types in terms of the structures to be applied:

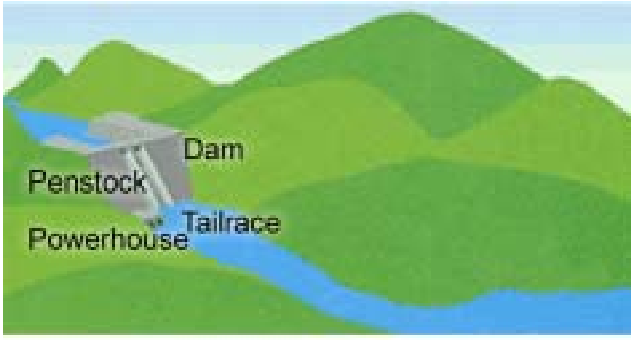
(i) Dam Type

(ii) Waterway Type

(iii) Dam and waterway Type

The type of the generation system to be employed shall be determined mainly based on topographic conditions of the site. Generally for the small-hydro system, a Waterway Type is adopted.

(1) Dam Type:

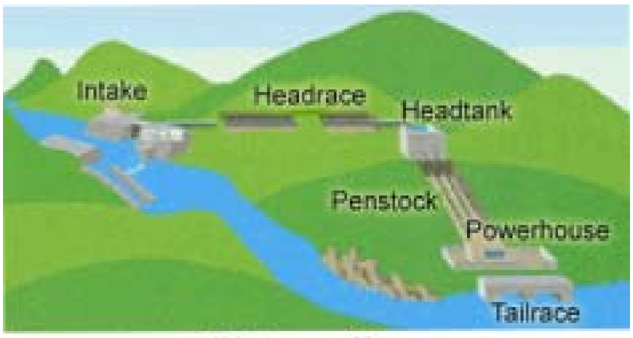


Dam Type

Nam Ngum Hydropower Station (Dam Type)

The Nam Ngum hydropower station (150 MW) shown above is of a typical dam type. The Nam Ngum dam has a watershed area of 8,640 km^2 with a large reservoir of effective capacity of 4,700 million m^3. Such an extensive impoundment of water enables regulation of the river flow. The Nam Ngum dam retains river flows of the wet season and uses the stored water for power generation during the dry season. The Dam Type scheme allows a relatively constant supply of energy over the year.

(2) Waterway type:



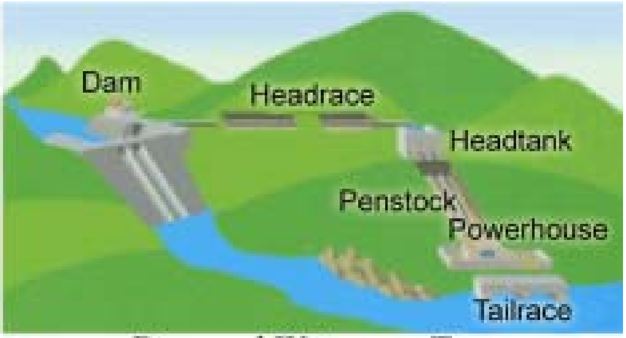
Waterway Type

Typically the Waterway Type builds an intake weir across the river and the created water head is used to generate power energy. The photo shown is the completed Nam Mong (70 kW) hydropower project in Oudomxay province.

Intake of Nam Mong Hydropower Station (Waterway Type)

Nam Mong Hydropower Station (Waterway Type)

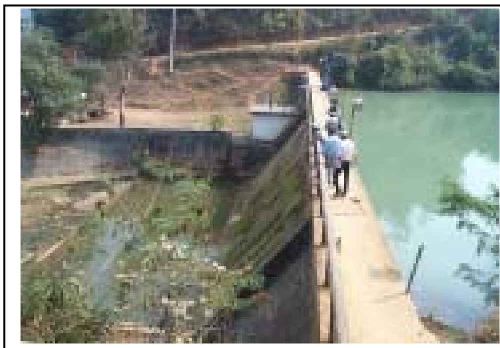
(3) Dam and Waterway Type:



Dam and Waterway Type


Nam Dong Hydropower Station (Dam and Waterway Type)

As mentioned above, a Dam Type has a seasonal regulation reservoir which has a large water storage capacity. A Dam and Waterway Type is a combination of a dam and waterway types, which is usually applied to obtain the higher water head with provision of favorable topography.

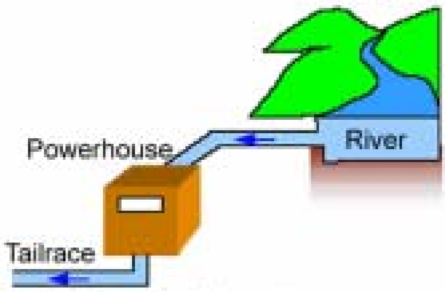

Dam of Nam Dong Hydropower Station (Dam and Waterway Type)

The photos shown above are the Nam Dong (1000 kW) hydropower project in Luangphrabang province.

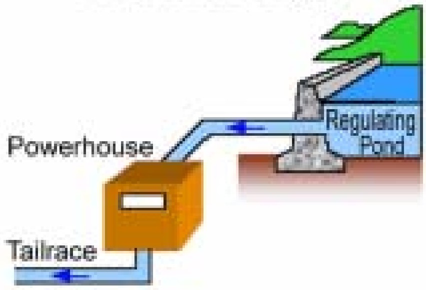
On the other hand, in terms of the water utilization method, the hydropower generation system is broadly divided into three types; Run-of-River Type, Run-of-River Type with Regulating Pond, and Reservoir Type.

(1) Run-of-River Type:

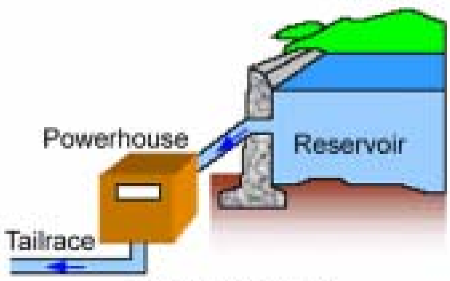
A Run-of-River Type is to use the natural river flow directly for power generation. As mentioned in the Waterway Type above, typically an intake weir is built across the river. Usually a Run-of-River Type has no flow regulations, and thus can use river water (energy generation) only when it is available.



Run-of-river Type



Regulating Pond Type



Reservoir Type

(2) Run-of-River with a Regulating Pond Type:

Usually capacity of a Run-of-River Type plant is low as the river water is not uniform throughout the year. Some plant might have enough upstream pondage to provide partial flow regulation to meet daily power demand variations. A Run-of-River Type with Regulation Pond is thus provided with a pond to regulate the daily river flow. The power discharge of this type is not always constant through the day, usually releasing a larger quantity of water in the daytime and little or even no water during the night.

(3) Reservoir Type:

As explained earlier in the Dam Type, a Reservoir Type created by a dam construction can regulate the seasonal variations of the river flow. A significant storage is often applied for relatively constant energy supply over the year. Due to operation of the Reservoir Type hydropower generation, it is expected to increase the dry season flows in the downstream from a reservoir.

2.5.3 GENERAL LAYOUT OF POWER FACILITIES

(1) Site Selection:

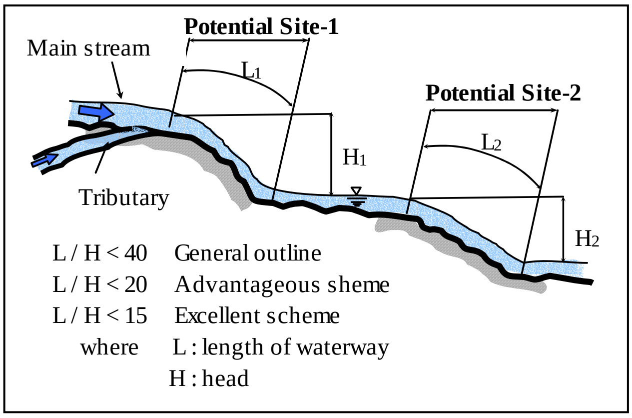
Careful attention should be paid to the following points to identify the potential for a small-hydro scheme with the isolated grid system:

(i) Discharges are stable even in the dry season.

(ii) Specific discharge ($m^3/sec/km^2$) in the dry season is relatively high.

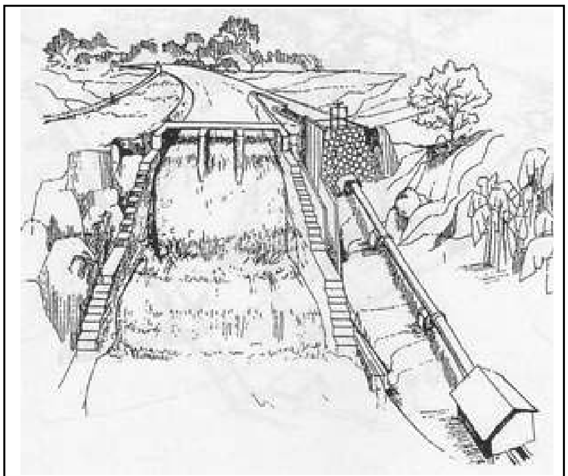
(iii) (L/H) rate is small.

(iv) Distance from the demand centre is short.



(2) General Layout:

The main components of the civil facilities are weir, intake, de-silting basin, power canal, head tank, pondage, penstock, powerhouse, and tailrace. It is rare for the Dam Type power generation or Tunnel Waterway Types to be adopted in a small-hydro facility. However, existing irrigation dams may be utilized for small/mini hydropower in a re-development plan.



Small/Mini Hydro Utilizing Drops or Falls

The existing irrigation canals with drop structures may be utilized for mini/micro hydropower. Penstock pipes can be connected to the intake or the de-silting basin without provision of a power canal. In such a case, since all or part of the irrigation water is to be used for power generation, the discharge fluctuation during irrigation and non-irrigation periods needs to be confirmed.

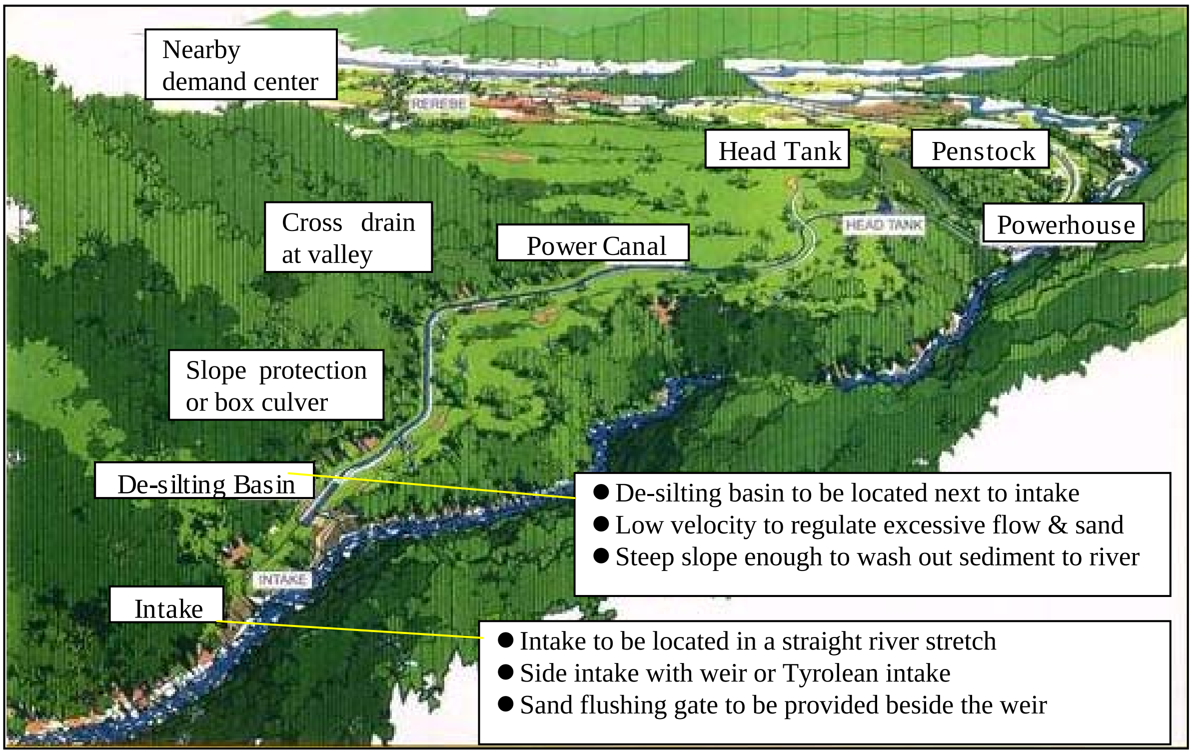

Existing Irrigation Canal in the Nam Chong, Bokeo


Existing Irrigation Intake in the Nam Chong, Bokeo


Existing Irrigation Canal in the Nam Gnone, Bokeo

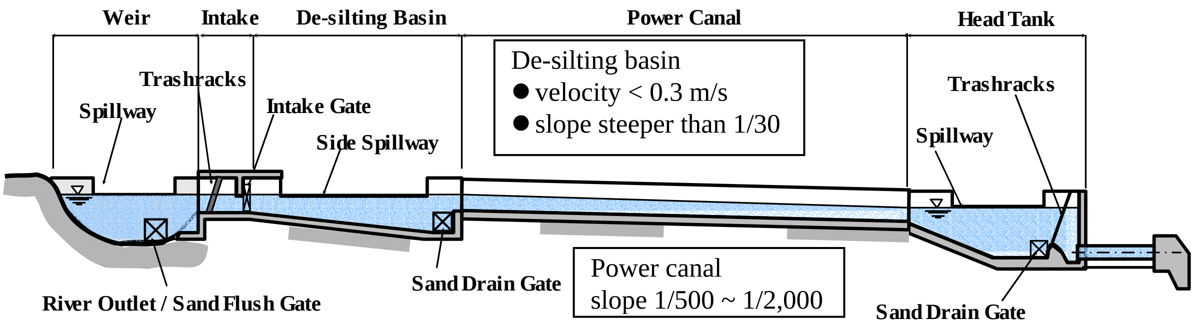

Existing Irrigation Intake in the Nam Gnone, Bokeo

Depending on the nature of work and design conditions involved, the combination of facilities may vary. Relating to the civil structural components, the major issues which have been experienced in many small-hydro plants so far are: i) sedimentation and; ii) flow characteristics of a river during flood. Therefore, the suitable combination and layout responding to the specific site conditions need to be properly reflected in the design. A typical layout and profile of the small-hydro system is shown below together with technical notes:



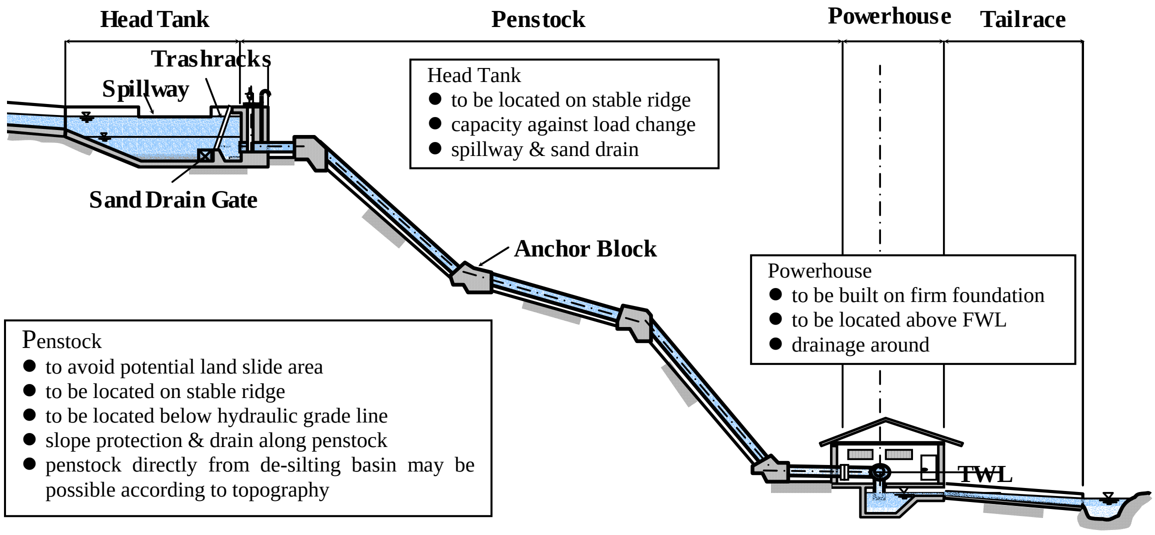
Source: JICA Study Team

General Layout of Small-hydro System



Source: JICA Study Team

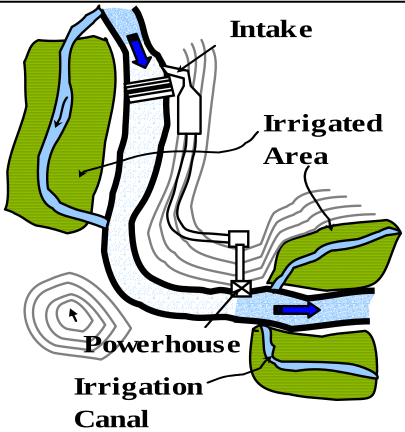
Typical Profile of Open Waterway System



Source: JICA Study Team

Typical Profile of Waterway System

2.5.4 AVAIRABLE DISCHARGE FOR POWER GENERATION



Example of Water Use

If paddy fields with single-cropping are developed in a river basin where the river water is utilized for power generation, the irrigation water supply has to be taken into account. The river discharge is at the minimum level in the end of the dry season when it may hit an irrigation period. Therefore, the available discharge is likely to become the lowest under such circumstances.

The first priority for water utilization is generally given to the irrigation supply in rural areas. It is therefore required to investigate not only the river discharge but also the existing water utilization, irrigation system, and rainfall patterns to estimate the available power discharge. The following items need to be surveyed at the planning stage:

(i) Land utilization in the areas affected by the hydropower station

(ii) Irrigation area, the cropping patterns, and the irrigation supply discharge

(iii) Future development plan for irrigation

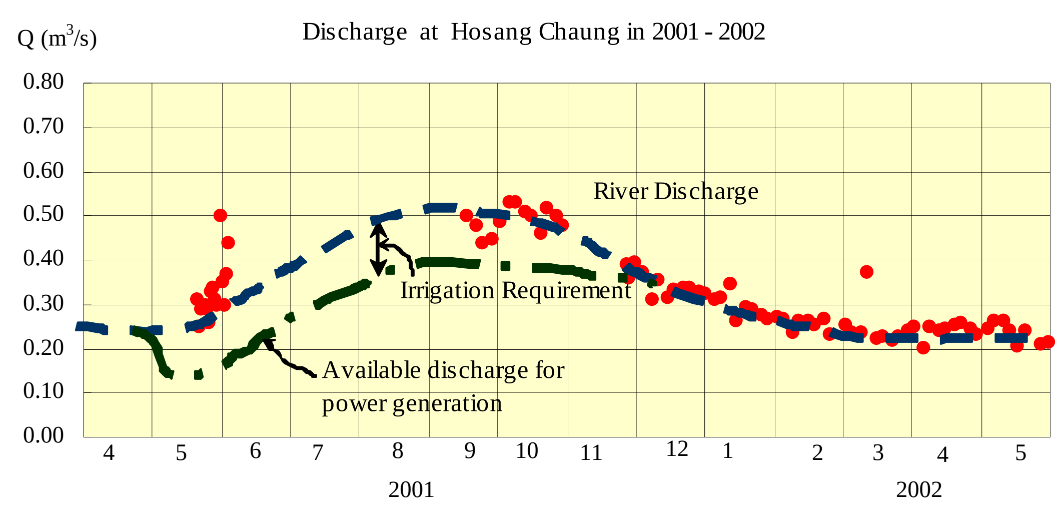
(iv) Basic stance of local inhabitants for the water utilization

When the water use produces a conflict between irrigation and power generation demands, the following needs to be considered:

(i) The location of the power generation facilities should be carefully selected to minimize the conflict between the irrigation water use and power discharge in the area where the river water is utilized for irrigation in the river stretch between the intake and the tailrace.

(ii) The river discharge and the irrigation demand in the areas affected by the hydropower plant should be investigated throughout the year to estimate the available power discharge, taking into account the existing irrigation practices.

(iii) Irrigation water for paddy fields is approximately 1.0 m^3/s for 1,000 ha in general. Areas, cropping patterns, irrigation canal systems, return flow into the river, rainfall and supplemental discharge from the river are major factors to estimate the irrigation demand.



Source: Measurement and Assumption of JICA Study Team

Figure Example of Available Power Discharge

2.5.5 PRELIMINARY ESTIMATION OF POWER OUTPUT AND ANNUAL ENERGY

The hydropower scheme requires both water flow and drop in height (called "head") to produce electric power. The hydropower potential (installed capacity or power output) and energy production of the site depends on the available magnitude and distribution of the river flow and the head. At the level of desk (map) study by use of the available 1:100,000 topographical map, an assessment of hydropower potential (an "installed capacity" or "power output") of the identified site is carried out by the following formula:

$$\mathbf{P = 9.8 \times E_{\mathit{f}} \times Hg \times Q}$$

P	: Power output (kW)
Q	: Power discharge (m^3/s)
E_f	: Combined efficiency of power plant
9.8	: Acceleration of gravity (m/s^2)
Hg	: Effective head (m)

For the preliminary estimates of potential power, the combined efficiency (E_f) of small-hydro varies from 50 to 70%. The pre-feasibility or feasibility study would require a more detailed analysis of load, hydrology and technical factors to establish the generation system parameters. Measurement of the head is also necessary to ascertain power availability.

As for the power discharge, it shall be basically determined based on the available minimum discharge for power generation. The available minimum discharge shall be estimated through the hydrological analysis. Hydrological analysis is discussed in detail in Section 3.1.

The power output above is the magnitude of electric energy generated in one second. When generated continuously, the work load is called the “energy generation” and is expressed in kilowatt-hours (kWh) or megawatt-hours (MWh). The total energy generated in a year is called the “annual energy” as given below.

Annual Energy (kWh) = P (kW) × 24 (hours) × 365 (days)
= P (kW) × 8,760 (hours)

Effective head is obtained by the following equation:

Effective Head (m) = Gross Head (m) – Total Head Loss (m)

The head loss is determined based on the maximum power discharge and basic parameters for the proposed hydropower system (discussed in detail in subsections 3.2.9 and 3.3.7). However, in the early stage of planning, such basic data is not available. Head loss is thus taken as the experimental value in the range of 7 to 9% of the gross head.

2.5.6 PROJECT EVALUATION IN TERMS OF KW COST

The following two tables show the estimated kW cost for the selected small-hydro schemes by the map study. Under the Master Plan Study on Small-Hydro in Northern Laos, totally 18 schemes were selected for site reconnaissance in terms of the kW cost.

Small-Hydro Projects of Off-Grid（15 Sites）

No.	Project	Province	Installed Capacity kW	kW Cost US$/kW
1	Nam Nga	Phongsaly	100	13,431
2	Nam Kai	Phongsaly	250	8,605
3	Nam Pok	Phongsaly	150	14,056
4	Nam Ou Neau	Phongsaly	380	6,296
6	Nam Pha	Louangnamtha	250	8,732
7	Nam Heng	Louangnamtha	100	19,781
10	Nam Tale	Oudomxay	80	21,145
12	Nam Khanoy	Bokeo	80	21,352
13	Nam Hat	Bokeo	170	11.194
14	Houay Kouang	Luangphrabang	200	7,730
15	Nam Xeng	Luangphrabang	170	7,925
16	Nam Peun	Houaphan	70	21,550
17	Nam Hang	Houaphan	70	35,538
23	Nam Xan	Xiengkhuang	110	12,679
24	Nam Chao	Xiengkhuang	100	18,692

Small-Hydro Projects of Grid Connection（9 Sites）

No.	Project	Province	Installed Capacity	kW Cost
			kW	US$/kW
5	Nam Long	Louangnamtha	2,000	1,853
8	Nam Phak	Oudomxay	5,100	3,638
9	Nam Ngao	Oudomxay	840	7,550
11	Nam Gnone	Bokeo	500	3,979
18	Nam Hao	Houaphan	5,000	2,028
19	Nam Ngen 2	Xayabury	610	5,935
20	Nam Ken	Xayabury	380	11,228
21	Nam Lay	Xayabury	220	14,630
22	Nam Ham 2	Xayabury	3,000	4,139

Table blows shows the installed capacity and kW cost of the existing 10 small-hydro projects in Lao PDR for reference. As seen below, the kW costs of both Nam Peun and Nam Mong plants are considerably high compared to other plants. This is because these plants were respectively constructed as a pilot scheme by the Governments of Japan and Germany. All of other plants are made in China. It is found that the kW cost made in China varies 3,000 to 5,000 US$/kW.

Existing Small-Hydro Projects in Lao PDR（10 Sites）

No.	Project	Installed Cap. (kW)	Number of Turbine	Cost (US$)	Unit Cost (US$/kW)	Year	District	Province	Turbine Made in
1	Nam Ko	1,500	3x500	9,815,071	6,543	1996	Xai	Oudomxai	China
2	Nam Sam	110	2x55	678,000	6,163	1995	Xamtai	Huaphan	China
3	Nam Peun	60	1x60	1,791,000	29,850	1986	Huamuang	Huaphan	Germany
4	Nam Sipkha	55	1x55	220,030	4,000	-	Kham	Xieng Khouang	China
5	Nam Tien	75	1x75	227,661	3,035	-	Kham	Xieng Khouang	China
6	Nam Chat	100	1x100	366,451	3,665	-	Mot	Xieng Khouang	China
7	Ban Nong	40	1x40	166,467	4,162	1995	Phaxai	Xieng Khouang	China
8	Nam Ka	81	55+26	312,285	3,855	1995	Phaxai	Xieng Khouang	China
9	Houay Kasen	155	155	758,000	4,890	2002	Pakbeng	Oudomxai	China
10	Nam Mong	70	1x70	820,000	11,714	2000	Nam Bak	Louang Prabang	Japan

Source: The Preliminary Study Report on The Master Plan Study on Small-Hydro Development Project in Northern Part of The Lao PDR

The location map of the existing small-hydro projects is shown in the next page.


CHINA
MYANMAR
VIETNAM
THAILAND
MEKONG
Phongsaly
Luangnamtha
Bokeo
Oudomxay
Luangphrabang
Huaphanh
Xiengkhuang
Xayabury
Xaysomboun
Prov. Vientiane
Pref. Vientiane
Borikhamaxay
Khammouane
Namtha
Huoixai
Xay
Xamneua
Phonsavan
Xayaboury
Xaysomboun
Phonhong
Vientiane
Pakxanh
Thakhek
1500kW Nam Ko
70kW Nam Mong
155kW Huay Kasen
60kW Nam Peun
110kW Nam Sar
55kW Nam Sipkha
75kW Nam Tien
100kW Nam Chat
40kW Nam Nong
81kW Nam Ka
Nam Ou
Nam Phak
Nam Ma
Nam Pha
Nam Beng
Nam Nga
Nam Khan
Nam Heung
Nam Pouy
Nam Ngum
Nam Xan
Nam Mouan
Nam Kading
Nam Hinboun
Nam Xam
Nam Neun
Nam Mo
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