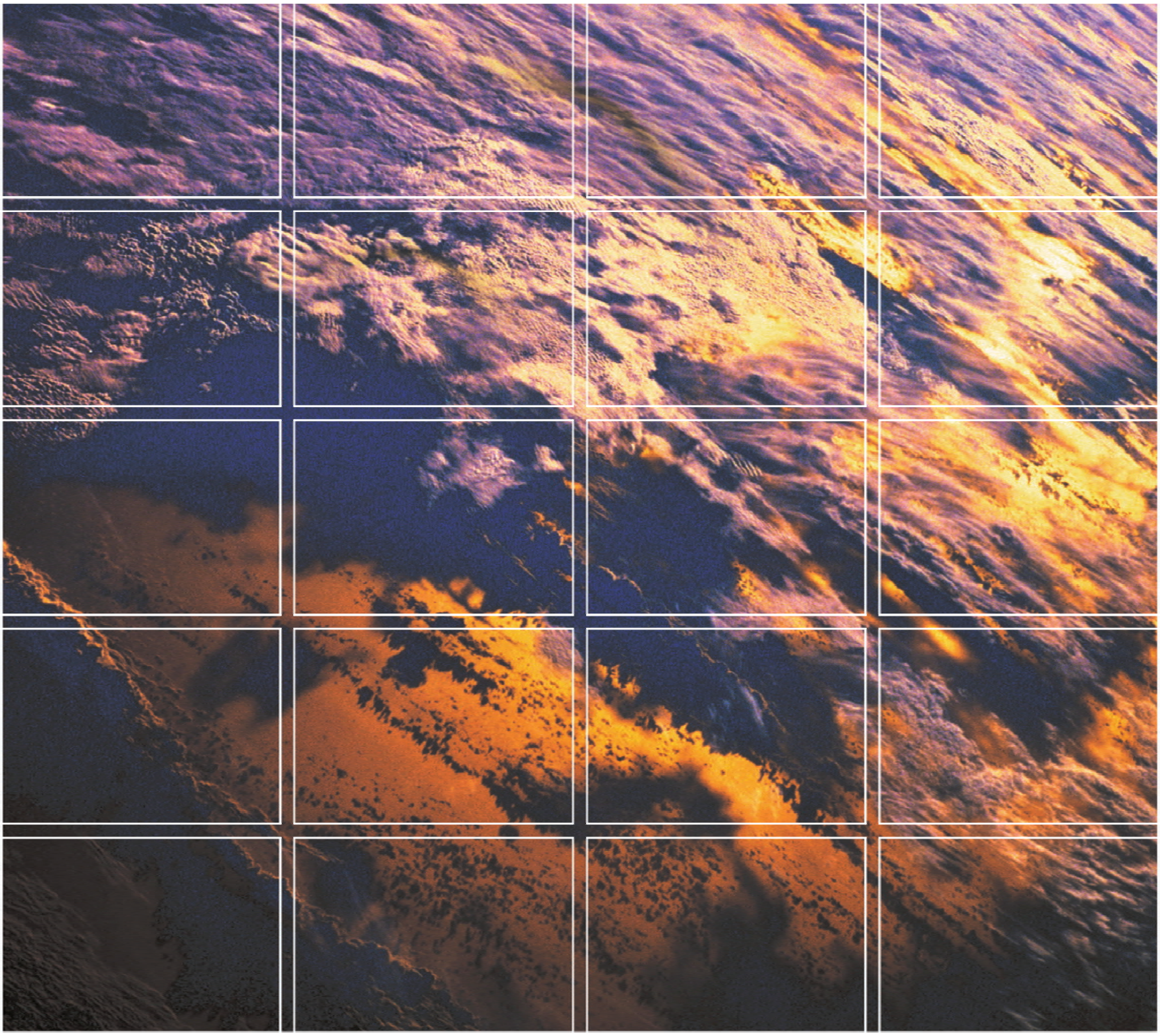
Appendix D

Environmental Flow Assessment Report *(Originally Prepared by Kansai and Amended by ERM)*



Nam Ngiep 1 Hydropower Project

Environmental Flow Assessment Report

NAM NGIEP 1 POWER COMPANY LIMITED

May 2014

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FINAL REPORT

NAM NGIEP 1 POWER COMPANY LIMITED

Environmental Flow Assessment Report

Prepared by The Kansai Electric Power Company, Inc., (Kansai, January 2012)
Updated by ERM-Siam Co., Ltd. (May 2014)

Reference 0185065

For and on behalf of
ERM-Hong Kong Co., Ltd.

Approved by: Terence Fong

Signed: ______________________________

Position: Partner

Date: 22 May 2014

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CONTENTS

ANNEXES

ABBREVIATIONS

ADB	Asian Development Bank
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
EFA	Environmental Flow Assessment
EGAT	Electric Generating Authorities of Thailand International
KANSAI	Kansai Electric Power Co., Inc
IAP	Independent Advisory Panel
IUCN	International Union for Conservation of Nature and Natural Resources
LHSE	Lao Holding State Enterprise
MSL	Height above Mean Sea Level
NNP	Nam Ngiep
NNP1PC	Nam Ngiep 1 Power Company Limited
TDS	Total Dissolved Solids

<u>CHEMICAL ABBREVIATIONS</u>

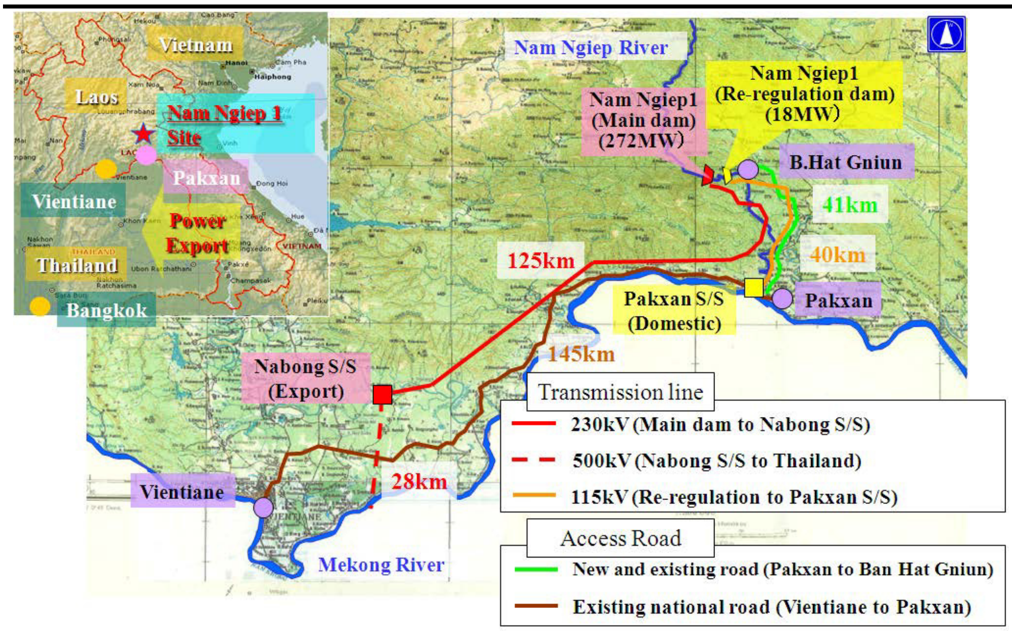
As	Arsenic
Cd	Cadmium
Cu	Copper
Fe	Iron
Hg	Mercury
Mn	Manganese
Ni	Nickle
P	Phosphorus
Pb	Lead
PO4 3-	Phosphates
N	Nitrogen
NH3	Ammonia
NO3-	Nitrate
Zn	Zinc

1 INTRODUCTION

1.1 BACKGROUND

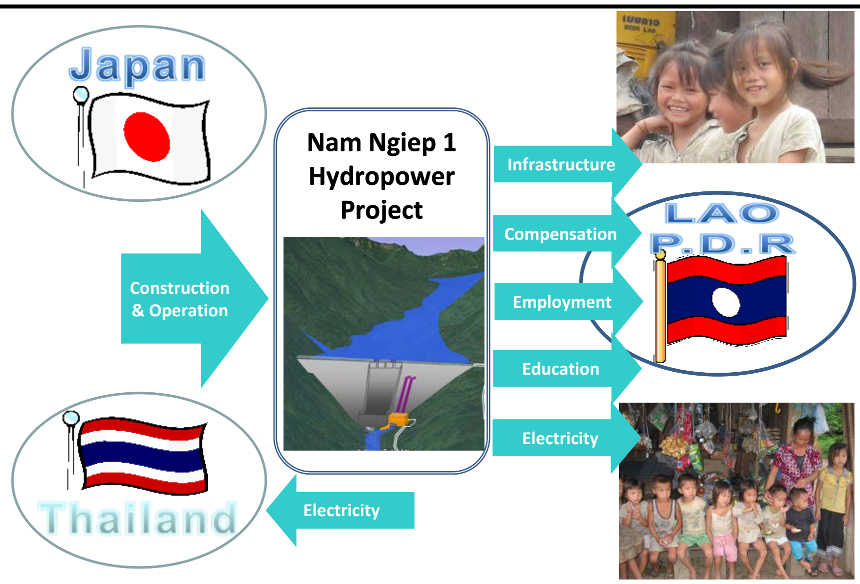
The Nam Ngiep 1 Hydropower Project (NNP1 Project) involves construction and operation of a 290 megawatt (MW) hydroelectric power generation facility on a build-operate-transfer basis on the Nam Ngiep (NNP) River, Lao PDR. The NNP1 Project site is located on the NNP River (*Figure 1.1*), in the provinces of Vientiane, Xieng Khouang and Bolikhamxay, approximately 145 km northeast from the city of Vientiane or 50 km north from Pakxan District. The NNP1 Project will generate 272 MW of its capacity for export to Thailand and 18 MW for domestic supply.

Figure 1.1 Project Location



The Project will be funded predominantly by private sector funds and the Project proponent is Nam Ngiep 1 Power Company Limited (NNP1PC) whose owners include Kansai Electric Power Co., Inc. (KANSAI) of Japan, Electric Generating Authorities of Thailand International (EGAT) of Thailand and Lao Holding State Enterprise (LHSE) of Lao PDR. Therefore three (3) countries will each benefit from the NNP1 Project which also aims to contribute to poverty reduction amongst the local Lao population through provision of infrastructure, employment and compensation, education and electricity (*Figure 1.2*).

Figure 1.2 Benefit of the Project



An initial Environmental Flow Assessment (EFA) was prepared for the NNP1 Project by KANSAI in August 2012. The Asian Development Bank (ADB) and the Project's Independent Advisory Panel (IAP) made comments on the initial EFA report and requested that NNP1PC revise it. NNP1PC has therefore contracted Environmental Resources Management ERM- Siam Co. Ltd (ERM) to undertake this task to fill gaps in the initial EFA study to the satisfaction of ADB's requirements.

1.2 *PROJECT DESCRIPTION*

The NNP1 project consists of a main power station and a re-regulation power station. The main power station is designed to have a capacity of 272.0 MW and annual power generation of 1,515.0 GWh. The re-regulation dam is planned to re-regulate and stabilize the maximum plant discharge of 230.0 m^3/s released from the main power station for the safety to the downstream area of the re-regulation dam. The re-regulation power station is designed to have 18 MW and annual power generation of 105 GWh. The main dam creates a reservoir with the normal water level (NWL) at Elevation Level (EL) 320 m and minimum operating level (MOL) at EL 296 m. The effective storage capacity is 1,192 Mm^3 at NWL 320 m. The dam inundation area is approximately 72 km length and includes a total surface area of just under 70 km^2. The basic specifications of the main features are shown *Table 1.1.*

Table 1.1 Main Features of the Project

Facility	Items	Unit	Specifications
Main Power Station			
Main Reservoir	Flood water level	EL. m	320.0
	Normal water level	EL. m	320.0
	Rated water level	EL. m	312.0
	Minimum operating level	EL. m	296.0
	Available depth	m	24.0

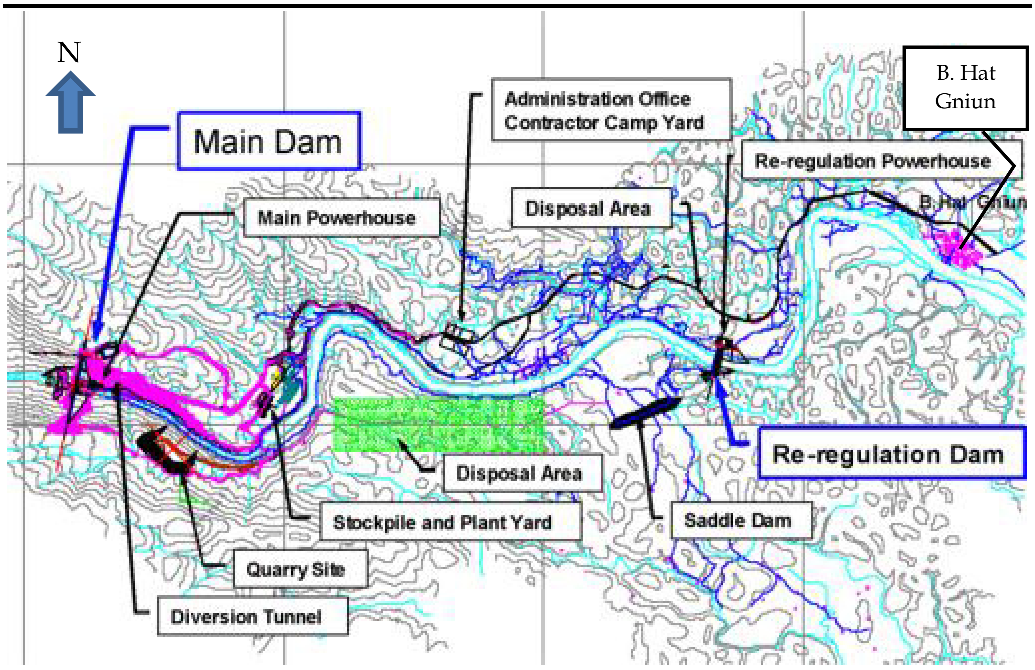
Facility	Items	Unit	Specifications
	Reservoir surface area	km^2	66.9
	Effective storage capacity	$10^6\ m^3$	1,192
	Catchment area	km^2	3,700
	Average annual inflow	m^3/s $mill.m^3$	148.4 4,680
Main dam	Type	-	Concrete gravity dam (Roller-Compacted Concrete)
	Dam height	m	148.0
	Crest length	m	530.0
	Dam volume	$10^3\ m^3$	2,034
	Crest level	EL. m	322.0
Spillway	Gate type	-	Radial gate
	Number of gates	-	4
	Design flood	m^3/s	5,210 (1,000-year)
Intake	Type	-	Bell-mouth
	Number	-	2
	Discharge capacity	m^3/s	230.0
Penstock	Type	-	Embedded and concrete-lined
	Number	-	2
	Length	m	185.81
	Diameter	m	5.2
Powerhouse	Type	-	Semi-underground
	Length	m	25.0
	Width	m	62.5
	Height	m	47.2
Turbine and generator	Maximum plant discharge	m^3/s	230.0
	Gross head	m	132.7
	Effective head	m	130.9
	Type of turbine	-	Francis
	Rated output	MW	272 (at Substation)
	Annual power generation	GWh	1,546 (at Substation)
Transmission line	Voltage	kV	230
	Distance	km	125
	Connecting point	-	Nabong S/S
	Width of right of way	m	80 (40 m each side of CL)
	Number of towers	-	262
Re-regulation Power Station			
Re-regulation reservoir	Flood water level	EL. m	185.9
	Normal water level	EL. m	179.0
	Rated water level	EL. m	179.0
	Minimum operating level	EL. m	174.0
	Available depth	m	5.0
	Reservoir surface area	km^2	1.27 at NWL
	Effective storage capacity	10^6m^3	4.6
	Catchment area	km^2	3,725
Re- regulation Dam	Type	-	Concrete Gravity dam
	Dam height	m	20.6
	Crest length	m	290.0
	Dam volume	$10^3\ m^3$	23.9
	Crest level	EL. m	187.0 (non-overflow section)
Re-regulation Gate	Type	-	Fixed wheel gate
	Number	-	1
	Discharge capacity	m^3/s	5,210 (1,000-year)
Saddle dam	Type	-	RCC associate with rock fill dam
	Crest length	m	507.1
	Dam height	m	14.6
Spillway	Gate type	-	Ungate spillway (labyrinth type)
	Design flood	m^3/s	5,210 (1,000-year)
Intake	Type	-	Open
	Number	-	1
	Discharge capacity	m^3/s	160.0

Facility	Items	Unit	Specifications
Powerhouse	Type	-	Semi-underground
	Length	m	46.4
	Width	m	22.05
	Height	m	49.10
Turbine and Generator	Maximum plant discharge	m^3/s	160.0
	Gross head	m	13.1
	Effective head	m	12.7
	Type of water turbine	-	Bulb
	Rated output	MW	18 (at Substation)
	Annual power generation	GWh	105 (at Substation)
Transmission line	Voltage	kV	115
	Distance	km	40
	Connecting point	-	Pakxan S/S
	Width of right of way	m	50 (25 m each side of CL)
	Number of towers	-	110

The NNP1 project has been developed on a 'Built Operate and Transfer' basis. The Project will generate and sell electricity to EGAT and Electricite du Laos EDL for 27 years under a concession provided by the Government of Laos (GoL) and the Power Purchase Agreements with EGAT and EDL respectively.

The general layout of the Project is shown in *Figure 1.3*.

Figure 1.3 ***General Layout of the Project***



1.3 *PURPOSE OF THE ENVIRONMENTAL FLOW ASSESSMENT*

Environmental flow is described in "Flow: the essentials of environmental flows" (Dyson, Megan, ed. ; Bergkamp, Ger, ed. ; Scanlon, John, ed. ; IUCN, Water and Nature Initiative, 2003) as:

'An environmental flow is the water regime provided within a river, wetland or coastal zone to maintain ecosystems and their benefits where there are competing

water uses and where flows are regulated. Environmental flows provide critical contributions to river health, economic development and poverty alleviation. They ensure the continued availability of the many benefits that healthy river and groundwater systems bring to society.'

The primary objective of the EFA revision Study is to assess whether the projected environmental flow rate(s) are sufficient to maintain the basic needs of the downstream biodiversity and ecosystem services of the NNP River i.e. that below the re-regulation dam. This revised EFA Report was developed in response to ADB and IAP's comments, based on the initial EFA prepared by KANSAI in 2012 using data and study results provided to ERM by NNP1PC, as well as the biodiversity baseline information collected by ERM in 2013.

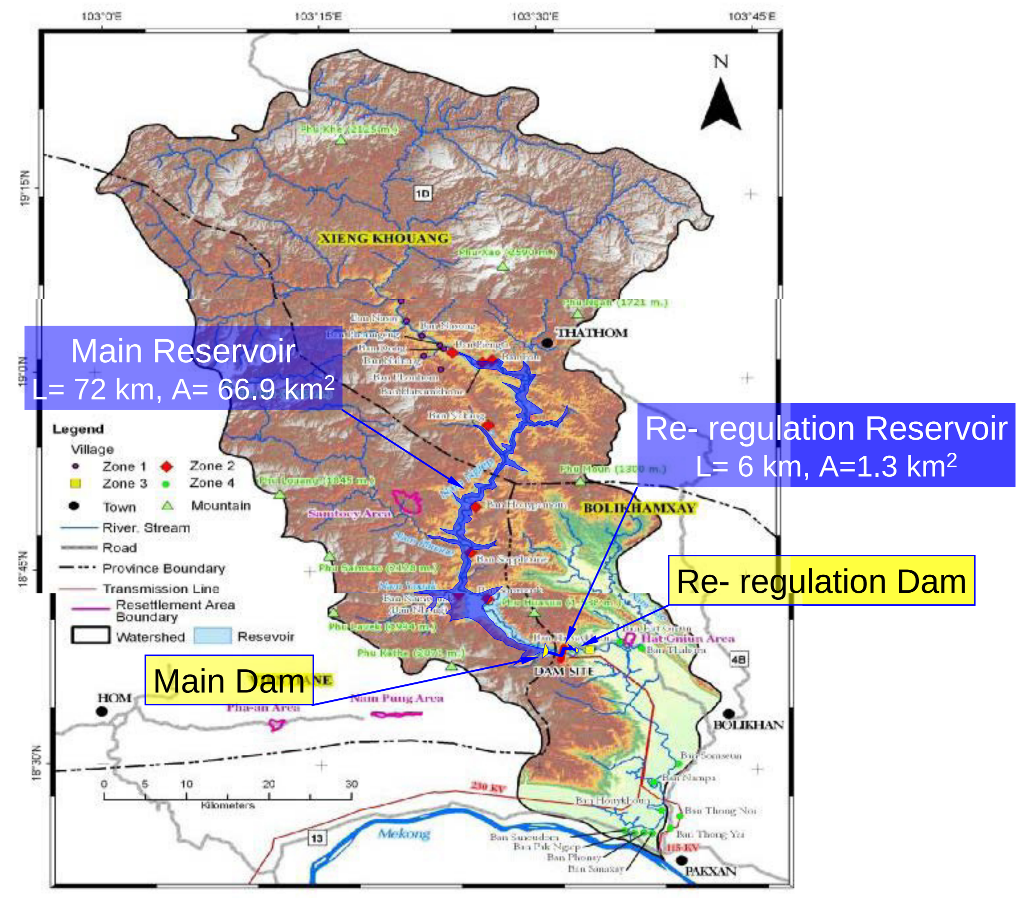
Following the introduction, the remainder of the report is set out as follows:

- *Chapter 2* describes the physical environment of the NNP River including topography, meteorology and hydrology.
- *Chapter 3* describes the existing biodiversity and ecosystem services, particularly in the downstream NNP River.
- *Chapter 4* explains the predicted changes in flow regime and water quality due to the Project.
- *Chapter 5* defines the environmental flow
- *Chapter 6* Assesses how changes in flow in the downstream NNP River are predicted to affect the existing biodiversity and ecosystem services.
- *Chapter 7* provides a suggested monitoring plan.

2.1 TOPOGRAPHY

The NNP River basin has a total catchment area of 4,680 km² with the NNP River measuring 160 km in length. The NNP River originates near Phonsavan in the upstream area of Xieng Khouang Province and travels south-southeast through the mountain regions of Hom district in Vientiane Province and Bolikhan district in Bolikhamxay Province (*Figure 2.1*). It emerges from the more mountainous region via a narrow gorge approximately 7.7 km upstream of the village of Hat Gniun, where the main NNP1 Project dam will be constructed. While the upstream section of the river is located in a highly mountainous area with some intermittent, narrow, inhabited plains, downstream it follows a relatively flatter, hilly river plain as it flows out into the Mekong River at Pakxan.

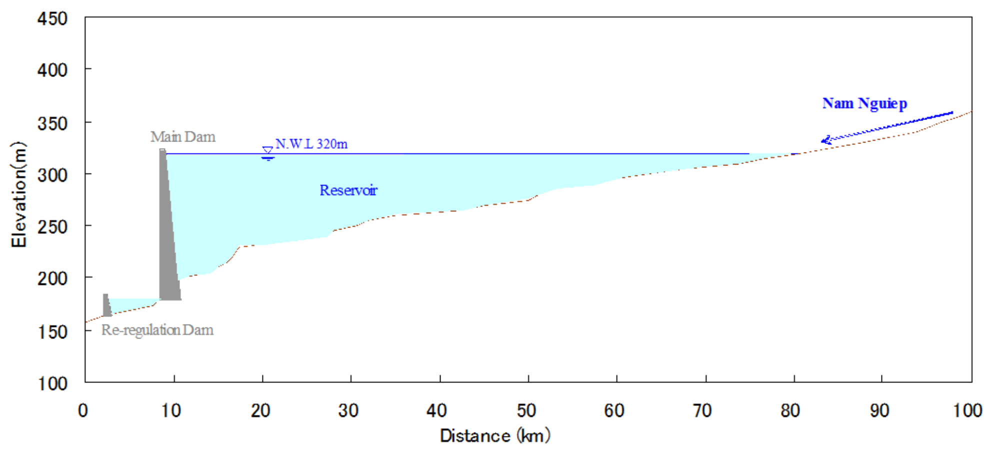
Figure 2.1 The NNP River Basin



The dam site will be located 145 km northeast of Vientiane city and 40 km north of Pakxan, along the NNP River. The upstream catchment area that drains to the main dam reservoir covers about 3,700 km².

The main reservoir will be quite narrow along most of its length and will cover an area of just under 70 km². *Figure 2.2* shows the longitudinal profile of the river, illustrating that the average river gradient drops from approximately 1 to 515 upstream of the dam to around 1 to 2,141 for the lower river segment before it joins the Mekong River.

Figure 2.2 Longitudinal Profile of the Main Reservoir

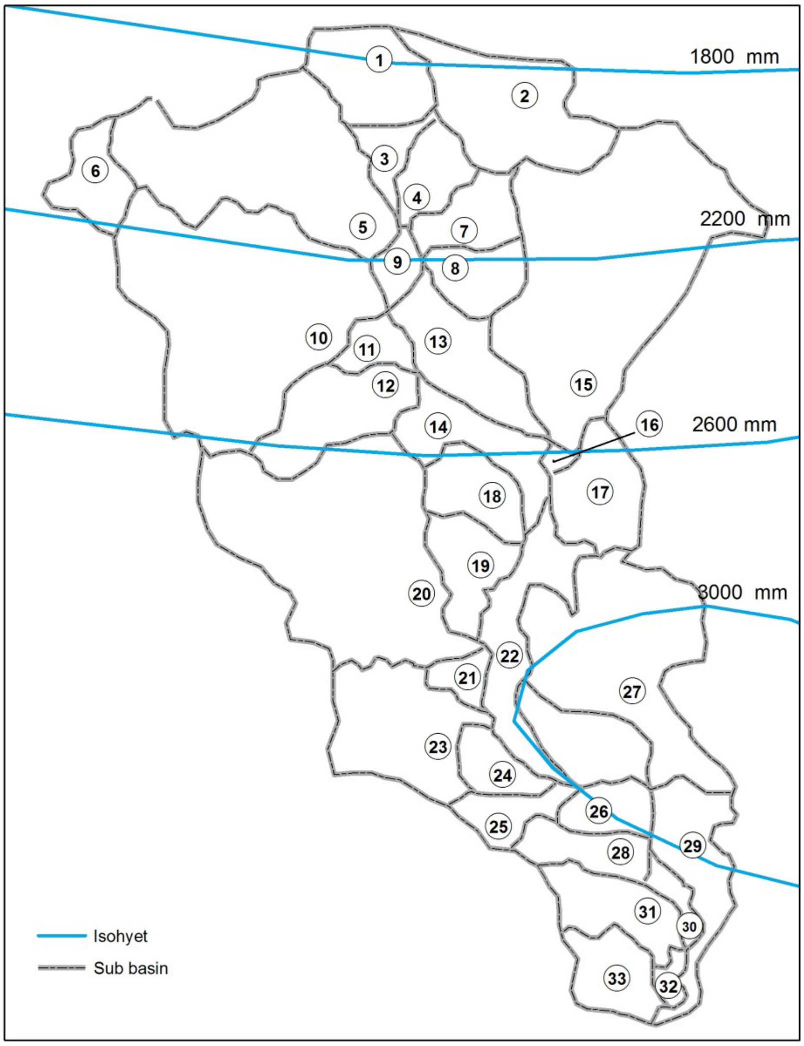


Source: Kansai and EGAT, Technical Report, 2011

2.2 *NNP RIVER BASIN*

NNP River basin is divided into 33 sub-basins that receive runoff from the tributaries of the NNP River and are nested within the large NNP River basin as shown in *Figure 2.3*. Most of the sub-basins are rather small with only 10 of them being bigger than 100 km². The 33 sub-basins are presented in this report.

Figure 2.3 Sub-basins of NNP River



The contribution of flow from each sub-basin is calculated using the information of sub-basin area and the isohyet generated from the average annual rainfall from existing stations inside and around the basin. In addition the estimated water yield that includes both runoff and underflow is also used in the calculation. The sub-basin areas, contribution of flow discharge, and annual volume of each sub-basin are summarized in *Table 2.1.* The contribution of each sub-basin to the NNP River basin in terms of annual volume shows a wide range, with the biggest contribution being 542 mcm (million cubic meters) (Nam Phouan) and the smallest one only 10 mcm (North Nam Hok).

Table 2.1 Sub-basins of NNP River and Their Flow Contribution

No	Name of sub-basin	Area		Flow Contribution	Annual Volume
		km²	%	(m³/s)	(mcm)
1	Nam Ngiou	93.7	2.51	2.7	84.8
2	Nam Linsoung	159.5	4.28	4.6	144.4
3	N.W. Nam Chiat	28.8	0.77	0.9	29.0
4	N.E. Nam Chiat	51.5	1.38	1.6	51.8
5	Nam Sen	299.5	8.04	9.6	301.3
6	Longmat Internal Drainages	56.6	1.52	2.0	62.6

No	Name of sub-basin	Area		Flow Contribution	Annual Volume
		km²	%	(m^3/s)	(mcm)
7	Nam Palan	53.5	1.44	1.9	59.2
8	Nam Phou Xao	53.5	1.44	1.9	59.2
9	N. Nam Siem	25.7	0.69	0.9	28.5
10	Nam Siem	433.3	11.63	16.6	523.0
11	S. Nam Siem	30.9	0.83	1.2	37.3
12	Nam Thong	104.0	2.79	4.1	130.7
13	Nam Phadoy	115.3	3.09	4.4	139.1
14	Nam pang	81.3	2.18	3.4	106.3
15	Nam Chian	461.1	12.38	16.9	533.4
16	N. Nam Hok	7.2	0.19	0.3	9.4
17	Nam Hok	89.5	2.40	3.9	121.6
18	Nam Mang	57.6	1.55	2.5	78.3
19	Houay Sam Liou	75.1	2.02	3.4	105.8
20	Nam Phouan	399.4	10.72	17.2	542.3
21	S. Nam Phouan	17.5	0.47	0.8	24.6
22	Nam Sou	187.3	5.03	8.7	273.2
23	Nam Ngok	150.3	4.03	6.7	211.6
24	Nam Pamom	40.1	1.08	1.9	58.5
25	Houay Katha	36.0	0.97	1.7	52.5
26	Houay Soup	23.7	0.64	1.1	35.7
27	Nam Xao	273.8	7.35	13.1	413.1
28	Houay Khinguak	49.4	1.33	2.3	72.1
29	Houay Kokkhen	96.8	2.60	4.6	146.0
30	Houay Poungxang	18.5	0.50	0.9	27.0
31	Nam Pa	76.2	2.04	3.4	107.3
32	S. Nam Pa	15.4	0.41	0.7	21.7
33	Nam Tek	62.8	1.69	2.8	88.4
All	**Nam Ngiep**	**3,725**	**100**	**148.4**	**4,680**

2.3 *METEOROLOGY AND HYDROLOGY*

2.3.1 *Climate Condition*

The construction area and downstream area for the NNP1 Project is located in the Bolikhamxay Province, Lao PDR, which is influenced by a southwest monsoon tropical climate regime. The weather there is dominated by monsoons which divide the year into clearly defined wet and dry seasons. The wet season begins from May and extends until October, while the dry season runs from November to April. The NNP River basin generally experiences better weather conditions than elsewhere in the Lao PDR, with less extremes of temperature.

Precipitation (mm), air and river water temperature (°C), and humidity (%) have been measured at B. Hat Gniun since April 2011, at the location shown in *Figure 2.4* and *Table 2.2*. These data found that air temperature ranged from 12°C to 38°C. In the middle of the wet season, from the beginning of June to the end of September, air temperature ranged from approximately 22°C to 36°C and from December to February (considered to be the high dry season) temperatures ranged from approximately 12°C to 38°C. *Figure 2.5* shows climate data from B. Hat Gniun meteorological station, Bolikhamxay Province.

Figure 2.4 Location of Hydrological Gauging Locations within and Peripheral to the Project Basin Area

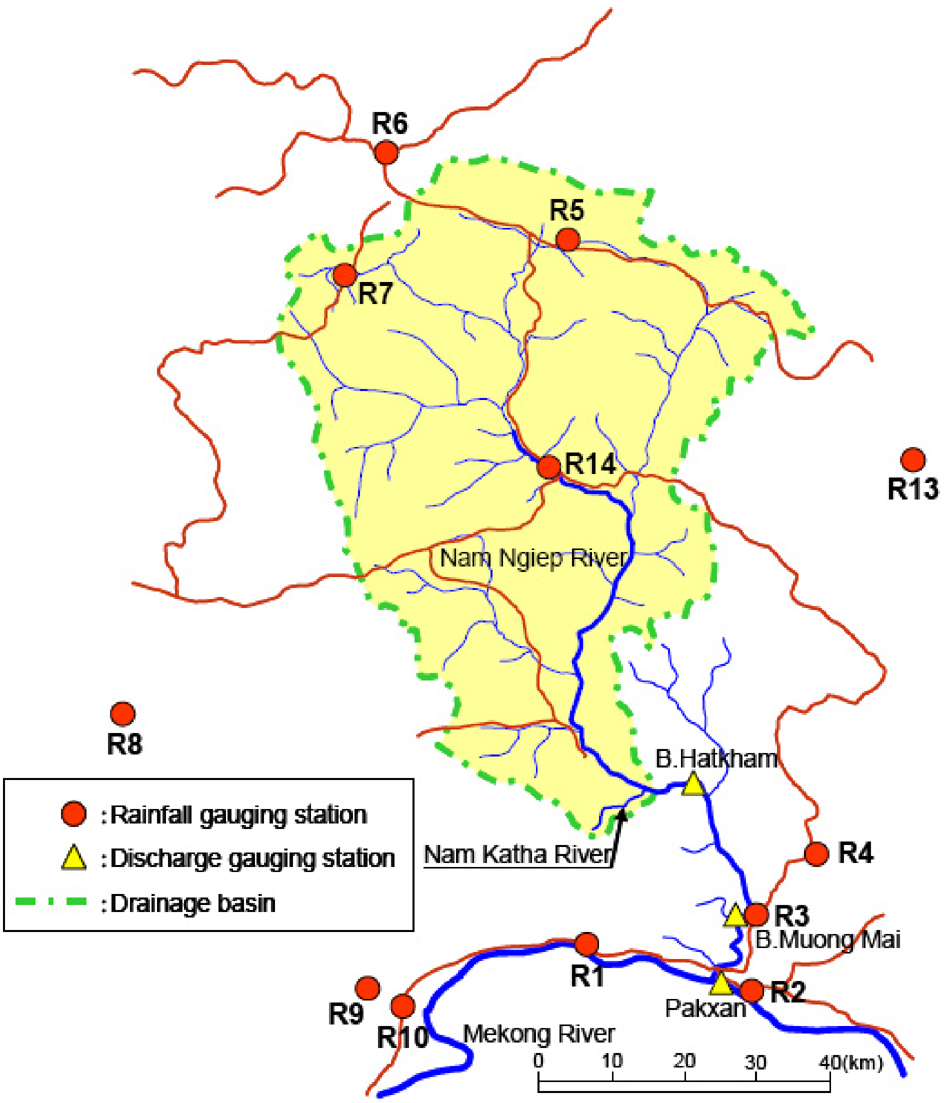
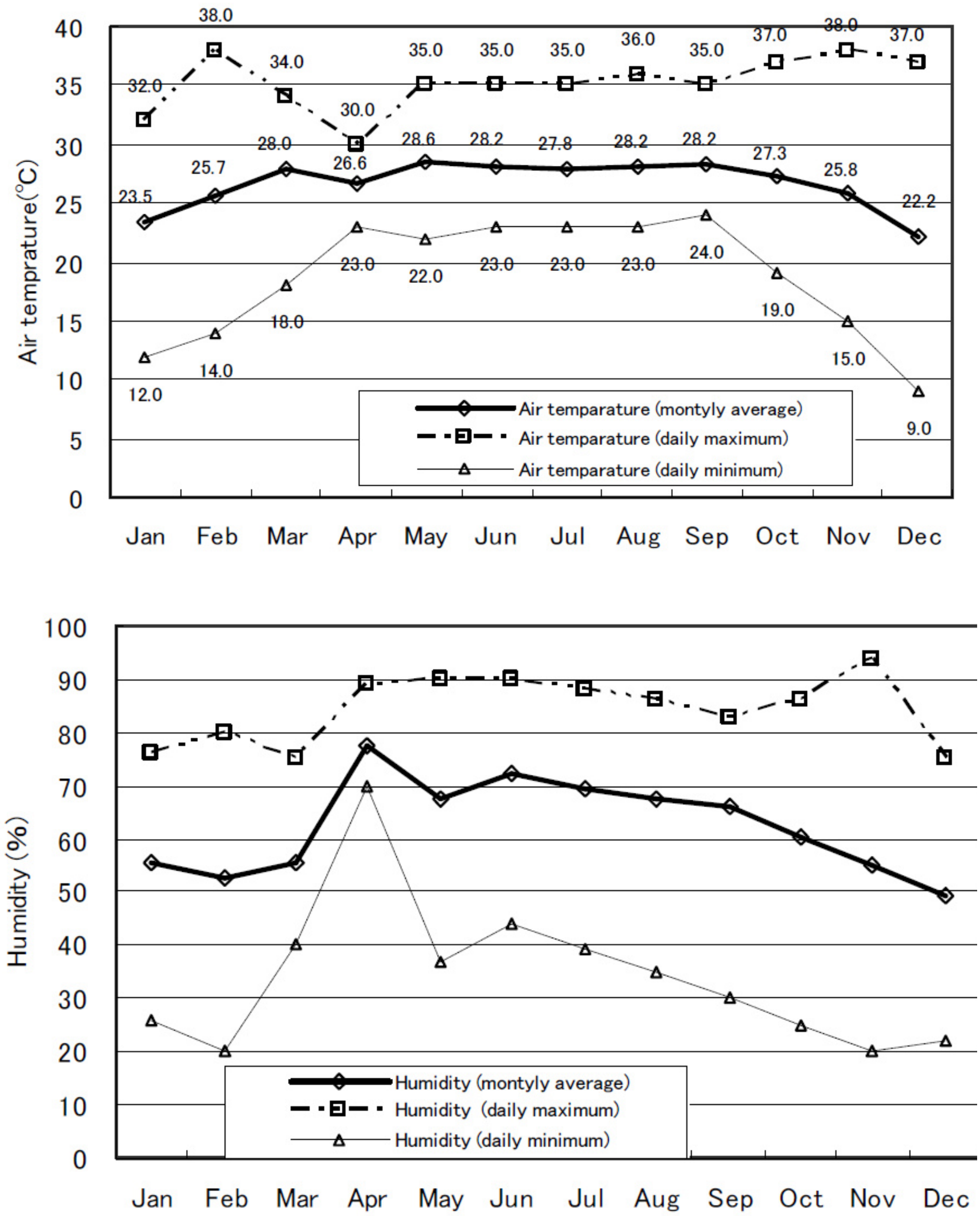


Table 2.2 List of Hydrological Gauging Stations within and Peripheral to the Project Basin Area

Gauging Station		Elevation (m)
Rainfall		
R1	B. Nakham (B. Pakthouei)	159
R2	Pakxan	155
R3	Muong Mai	158
R4	Muong Kao (Bolikhan)	158
R5	M. Khoun (B. Thoun)	1,110
R6	Xieng Khouang	1,050
R7	M. Phaxay (B.Hokai)	1,100
R8	B. Naluang	460
R9	Houayleuk (Tadleuk)	220
R10	B. Thabok	160
R11	Vientiane	170
R12	Vangvieng	215
R13	Muong Mork	900
R14	B. Thaviang	370
Discharge/River water level		
	B. Hat Gniun	-

Gauging Station	Elevation (m)
Muong Mai	153
River water level	
Pakxan	142

Figure 2.5 *Air Temperature and Humidity Data at B. Hat Gniun Station, Bolikhamxay Province*

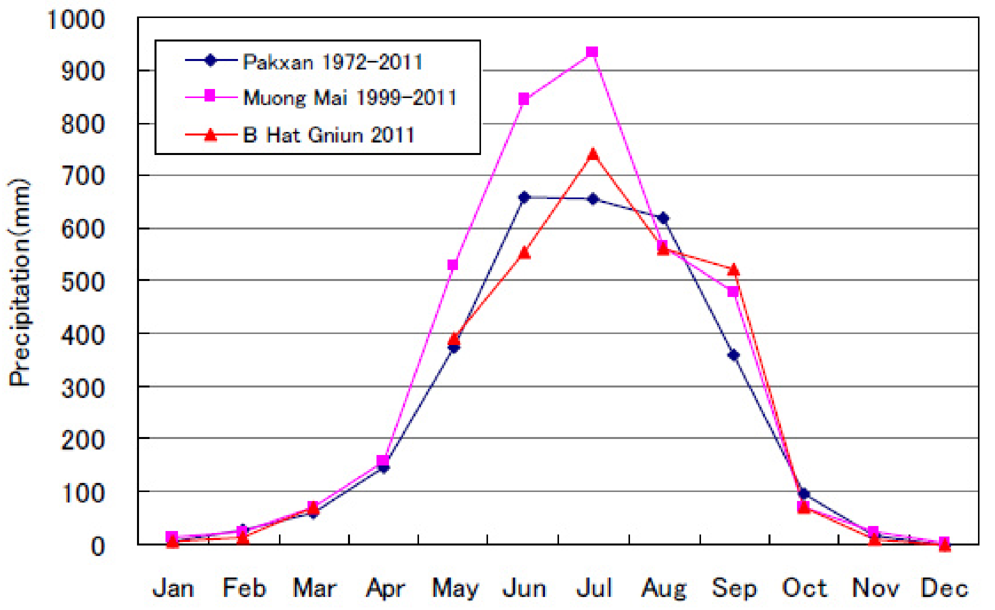


2.3.2 *Rainfall*

Rainfall data were collected from three (3) gauging stations near Houay Soup along the NNP River – Pakxan (R2), Muong Mai (R3) and B. Hat Gniun. The rainfall station at B. Hat Gniun has collected data since 2011. Average annual rainfall in these locations is: Pakxan (3,000 mm), Muong Mai (3,700 mm), B. Hat Gniun (2,950 mm). Monthly rainfall at each of these locations is shown in *Figure 2.6*.

According to the meteorological data from Pakxan, the seasonal variation of monthly rainfall follows the general pattern of the Southeast Asia monsoon, with about 90% of rainfall during the six month wet season from May to October. In the dry season from November to April, the monthly precipitation levels are quite low, ranging from 3.7 mm to 150.0 mm, equating to approximately 10% of the annual precipitation for this region over the whole dry season.

Figure 2.6 *Rainfall at Pakxan, Moung Mai and B. Hat Gniun Station*



These rainfall data available for areas within the basin and from peripheral areas were used in the Thiessen method (1) to obtain the mean basin rainfall for the NNP River basin. Missing data during the measurement period are derived using interpolations on the basis of the records of the available rainfall stations.

Table 2.3 presents calculated mean basin rainfall in the NNP River basin every year. In the basin, annual rainfall fluctuates from a minimum of 1,342 mm at to a maximum of 2,653 mm. This is equivalent to approximately 71% and 141% of the mean annual rainfall (1,873 mm). The rainfall during a wet season in a preceding year basically affects a minimum inflow during a dry season in the following year.

The mean rainfall of NNP River basin was assumed to be 1,870 mm/year. This value is considerably less than the annual rainfall of Pakxan (3,000 mm).

(1) Thiessen polygons, also known as Voronoi diagrams, are a method used to divide up an area given a set of known values at a relatively small number of points. This interpolation method was first applied to weather station data by A.H. Thiessen (1872-1956), an American meteorologist for the Weather Bureau (now NOAA).

Table 2.3 Calculated Monthly Mean Basin Rainfall (1971-2000) (mm)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual Rainfall (mm)
1971	0	65	56	120	280	432	551	302	164	39	0	10	2,019
1972	0	2	27	120	192	395	316	350	75	107	16	2	1,603
1973	0	0	16	25	244	278	277	484	296	13	0	0	1,634
1974	3	11	13	111	195	216	403	471	152	49	16	0	1,642
1975	23	12	27	27	304	421	189	340	285	119	3	0	1,752
1976	0	54	4	53	210	230	385	427	250	170	0	0	1,783
1977	6	0	12	72	122	269	402	242	194	9	6	8	1,342
1978	10	12	39	122	38	518	400	313	360	87	5	0	1,904
1979	1	29	10	51	404	253	324	189	146	26	0	0	1,433
1980	0	7	29	67	236	415	433	367	256	39	0	0	1,849
1981	0	0	5	119	214	292	519	346	221	196	0	0	1,913
1982	2	0	72	134	240	304	363	540	508	42	21	0	2,226
1983	0	63	52	141	185	263	393	500	226	131	45	0	1,999
1984	26	33	10	100	191	301	351	356	222	74	24	0	1,688
1985	0	2	6	129	508	363	404	276	182	35	0	22	1,928
1986	0	31	42	158	133	333	250	332	229	67	25	0	1,601
1987	0	11	10	47	167	357	397	556	189	192	7	0	1,932
1988	85	0	120	123	215	460	523	285	320	128	5	5	2,270
1989	12	0	120	145	189	435	382	313	229	117	0	0	1,942
1990	4	36	66	99	173	644	717	305	267	311	30	0	2,653
1991	2	0	33	115	164	359	379	438	233	30	6	4	1,762
1992	35	28	1	41	127	315	354	263	140	26	0	35	1,365
1993	0	5	35	94	262	448	464	337	198	15	0	3	1,863
1994	9	32	106	118	171	401	413	330	219	115	38	9	1,960
1995	1	0	8	94	222	398	567	552	119	54	14	0	2,029
1996	0	8	41	107	251	337	451	555	215	29	84	3	2,080
1997	9	4	85	220	250	302	485	416	243	94	4	0	2,111
1998	0	11	17	86	231	295	364	282	156	45	9	8	1,503
1999	7	3	60	119	521	426	320	537	293	125	26	8	2,445
2000	4	46	7	178	296	359	293	382	312	93	2	0	1,972
Maximum	85	65	120	220	521	644	717	556	508	311	84	35	2,653
Minimum	0	0	1	25	38	216	189	189	75	9	0	0	1,342
Average	8	17	38	104	231	361	402	380	230	86	13	4	1,873

2.3.3 *Hydrology*

Hydrological analysis is divided into two types of analysis: Low flow analysis and high flow analysis [(2)] [(3)(4)(5)(6)(7)(8)]. The purpose of low flow analysis is to generate long term runoff data for the purpose of reservoir operation and/or energy generation studies. At least 20 years monthly runoff data are necessary to obtain reliable results of these studies but such long term runoff data are usually not available. Thus, the runoff data need to be synthesized with short term data and/or related information by use of various methods, such as conversion from rainfall by runoff coefficient and tank model.

Inflow

The NNP River basin does not have long term and well maintained hydrological data. There are only two kinds of river flow (inflow) data available for the NNP1 Project:

- Analyzed data from the past 30 years(1971-2000) by "Tank model" runoff analysis based on rainfall data in the NNP River basin; and
- Measured data at B. Hat Gniun from 2007 to 2011.

Inflow is computed based on basin rainfall data by using "Tank Model" runoff analysis. A Tank Model is a simple concept that uses one or more tanks illustrated as reservoirs in a watershed, that consider rainfall as the input and generates the output as the surface runoff, subsurface flow, intermediate flow, sub-base flow and base flow. In addition, various phenomena such as infiltration, percolation, deep percolation and water storages in the tank can be explained by the model. Many researchers have reported that the Tank Model has demonstrated its ability to model the hydrologic response of a wide range of watersheds (Sugawara *et al*., 1984; Sugawara, 1961; Basri *et al*., 1998; Kuroda *et al* 1999; Basri et al, 1999; Jayadi *et al*., 1999, Fukuda *et al*., 1999; Sutoyo *et al*., 2003; Basri *et al*., 2002; Setiawan, 2003; Kuok *et al*., 2010; Azmeri *et al*., 2012).

The automatic calibration [(9)] is done not by a hill-top climbing method but by a trial and error method carried out automatically by a computer program. The feedback procedure is made by comparing some criteria obtained from the observed hydrograph and the calculated hydrograph output from the working tank model. The two criteria are discharge volume and the shape of the hydrograph. The feedback of these two criteria corresponds to displacement feedback and velocity feedback in automatic control. The

(2) APPLIED HYDROLOGY, Ven Te Chow, David R.Maidment, Larry W.Mays, McGraw-Hill Book Company, 1988

(3) DESING OF SMALL DAMS, A Water Resources Technical Publication, Third Edition, 1987

(4) EM1110-2-1417 Flood-Runoff Analysis, US Army Corps of Engineers, 1994

(5) EM1110-2-1416 River Hydraulic, US Army Corps of Engineers

(6) EM1110-2-1415 Hydrological Frequency Analysis, US Army Corps of Engineers

(7) EM1110-2-1413 Hydrological Analysis of Interior Area, US Army Corps of Engineers

(8) HEC-1 Flood Hydrograph Package User's Manual, US Army Corps of Engineers, 1998

(9) Automatic calibration of the tank model / L'étalonnage automatique d'un modèle à Cisterne, M. SUGAWARA a Hydrological Sciences Bulletin published online: 25 Dec 2009..

output of the working tank model is composed of components, the outputs from each of the tanks. Correspondingly, the whole period is divided into sub-periods, in each of which each of the components plays the main part. The volume and shape are calculated in each sub-period and are used for the adjustment of the respective tanks.

It should be noted that Tank Model analysis is introduced to estimate long-term inflow and therefore might not best reflect momentary values, although the model was checked against measured data. The difference between measured discharge and calculated discharge was minimized through trial-and-error method based on years of actual measurement of discharge at Ban Hat Gniun and B. Muong Mai from 1999 to 2000. The feedback procedure starts from some initial model and converges very quickly after several (usually less than 15) iterations, and the result obtained is very good. The predicted inflow and actual measured inflow data agreed fairly well. The model was considered to be suitable for the inflow analysis.

The results of the inflow analysis by Tank Model (using data from 1971 to 2000) at the NNP1 main powerhouse is summarised in *Table 2.4*, and presented in *Figure 2.7* (estimated annual rainfall and discharge) and *Figure 2.8* (seasonal inflow change). The key findings are:

- Annual average discharge (inflow): 148.4 m^3/s
- Minimum monthly inflow: 26.4 m^3/s (in April 1973)
- Minimum daily flow: 23.5 m^3/s (on 4 May 1973, full dataset not presented in this report)

Table 2.4 Estimated Monthly and Annual Mean Inflow at NNP1 Main Power House (Minimum Numbers Highlighted)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
1971	76.2	67.6	83.4	65.4	119.1	233.8	418.9	275.0	226.9	136.4	108.7	90.7	158.5
1972	75.1	62.7	52.6	64.1	71.3	198.2	178.5	242.5	106.7	86.8	66.0	54.4	104.9
1973	45.1	37.8	31.6	26.4	66.0	119.3	158.8	247.9	313.1	117.3	89.0	74.1	110.5
1974	61.5	51.6	43.1	38.6	55.3	116.1	196.7	303.1	224.8	101.4	83.4	69.3	112.1
1975	57.9	48.2	40.3	35.3	127.4	333.6	173.6	220.3	242.8	177.3	103.3	85.9	137.2
1976	71.3	73.4	50.6	47.3	77.0	154.4	202.4	335.3	253.8	210.1	116.2	94.7	140.5
1977	78.6	65.8	55.2	47.4	48.1	103.5	288.2	159.5	196.4	85.2	70.9	59.1	104.8
1978	49.0	41.3	35.1	51.5	28.7	287.3	248.1	312.0	349.8	154.3	108.1	89.9	146.2
1979	74.6	63.5	52.6	48.4	185.6	191.0	217.7	217.9	167.0	98.1	79.3	66.0	121.8
1980	54.8	45.9	39.6	36.8	99.7	252.6	299.8	341.7	318.1	144.8	116.9	97.3	154.0
1981	80.7	67.6	56.6	67.2	102.4	186.1	348.7	288.9	306.2	224.9	121.7	101.3	162.7
1982	84.1	70.4	64.5	85.2	128.3	234.9	276.8	427.9	409.6	244.6	151.0	124.8	191.8
1983	103.5	102.5	85.1	76.0	100.1	149.2	319.3	359.6	303.9	203.8	141.9	109.5	171.2
1984	94.1	79.1	64.1	63.7	99.4	176.9	232.1	293.4	281.1	140.4	109.6	90.6	143.7
1985	74.8	62.6	52.5	57.5	277.3	307.5	341.7	268.4	256.7	144.7	116.5	99.1	171.6
1986	80.7	68.0	56.8	71.6	78.9	225.2	163.6	262.5	219.2	137.3	96.5	79.3	128.3
1987	65.8	55.2	46.2	38.9	56.7	205.1	260.7	327.7	308.1	193.0	111.8	92.7	146.8
1988	95.6	72.0	62.8	85.7	131.5	307.7	345.1	316.4	263.6	213.9	128.1	106.7	177.4
1989	88.5	74.0	70.8	106.8	104.2	272.7	222.1	296.7	241.8	166.9	111.6	92.9	154.1
1990	77.1	64.9	57.7	52.8	68.9	346.3	546.7	331.5	281.8	301.0	149.1	122.7	200.0
1991	101.9	85.3	71.7	79.7	72.3	160.4	257.0	297.5	218.7	126.3	96.4	80.3	137.3
1992	71.6	58.1	47.6	40.9	37.5	153.6	195.4	194.1	120.1	80.9	66.2	61.2	93.9
1993	46.4	38.9	32.6	31.4	81.5	209.6	370.2	266.4	157.2	121.5	91.0	75.8	126.9
1994	63.3	56.2	61.1	70.0	80.0	244.2	259.3	303.9	250.4	167.9	119.3	96.2	147.7
1995	79.8	66.8	55.9	56.8	111.9	206.9	399.0	483.0	300.4	159.3	128.7	106.6	179.6
1996	88.5	73.8	63.7	61.3	116.4	223.4	306.5	454.4	303.3	164.5	165.3	114.5	178.0
1997	95.2	79.5	72.5	122.4	157.6	181.9	349.5	361.4	341.0	180.7	136.0	113.2	182.6
1998	93.9	78.7	65.9	60.1	84.6	152.9	243.2	213.4	178.1	98.9	81.5	67.9	118.3
1999	56.3	47.1	42.0	48.0	262.9	304.6	282.4	381.2	335.1	184.6	136.4	113.1	182.8
2000	93.9	81.6	66.0	95.6	175.8	258.4	228.2	319.0	318.7	153.9	116.5	96.7	167.0
Ave	76.0	64.7	56.0	61.1	106.9	216.6	277.7	303.4	259.8	157.4	110.6	90.9	148.4
Max	103.5	102.5	85.1	122.4	277.3	346.3	546.7	483.0	409.6	301.0	165.3	124.8	255.6
Min	45.1	37.8	31.6	26.4	28.7	103.5	158.8	159.5	106.7	80.9	66.0	54.4	74.9

Figure 2.7 *Basin Annual Mean Rainfall and Discharge (Inflow) at NNP1 Main Power Station*

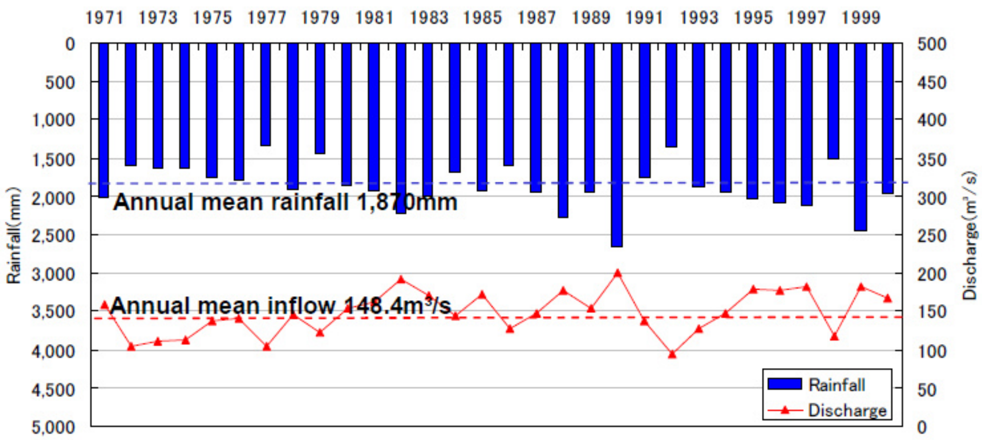
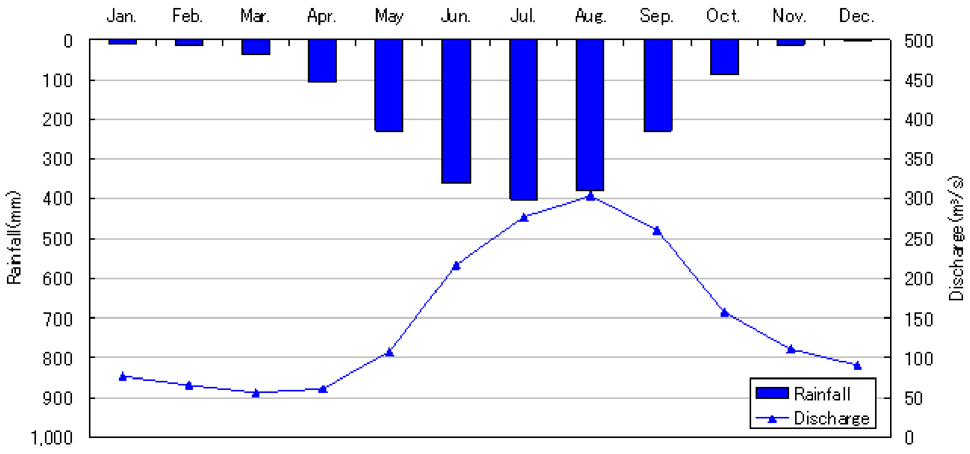


Figure 2.8 *Seasonal Change in Discharge (Inflow) at NNP1 Main Power Station*



Measurement at B. Hat Gniun

The observed daily discharge at B. Hat Gniun gauging station from 2007 to 2011 is shown in *Figure 2.9* and *Table 2.5*. The actual flow measurement recorded a minimum daily inflow of 12.8 m^3/s on 25th and 26th April 2009 (*Figure 2.10*).

Figure 2.9 Observed Daily Discharge at B. Hat Gniun

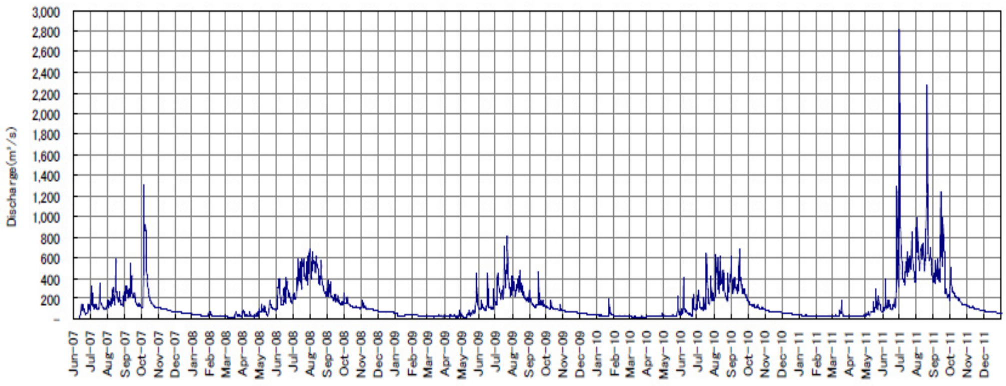


Table 2.5 Measured Data at B. Hat Gniun

Daily miminum dishcarge

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	av.
2007							87.3	119.0	120.2	108.6	72.9	51.0	
2008	36.8	27.0	18.1	23.3	40.1	92.6	196.0	223.1	141.8	103.5	79.5	58.8	86.7
2009	34.8	30.8	22.2	12.8	15.7	85.7	147.3	176.9	119.7	84.3	57.2	46.0	69.5
2010	36.4	29.0	25.9	23.4	25.0	36.7	92.3	175.1	186.7	89.2	59.9	44.1	68.6
2011	32.9	28.2	26.1	24.4	34.8	66.5	332.9	371.1	181.5	132.9	80.8	56.4	114.0
Ave	35.2	28.8	23.1	21.0	28.9	70.4	171.2	213.0	150.0	103.7	70.0	51.2	84.7

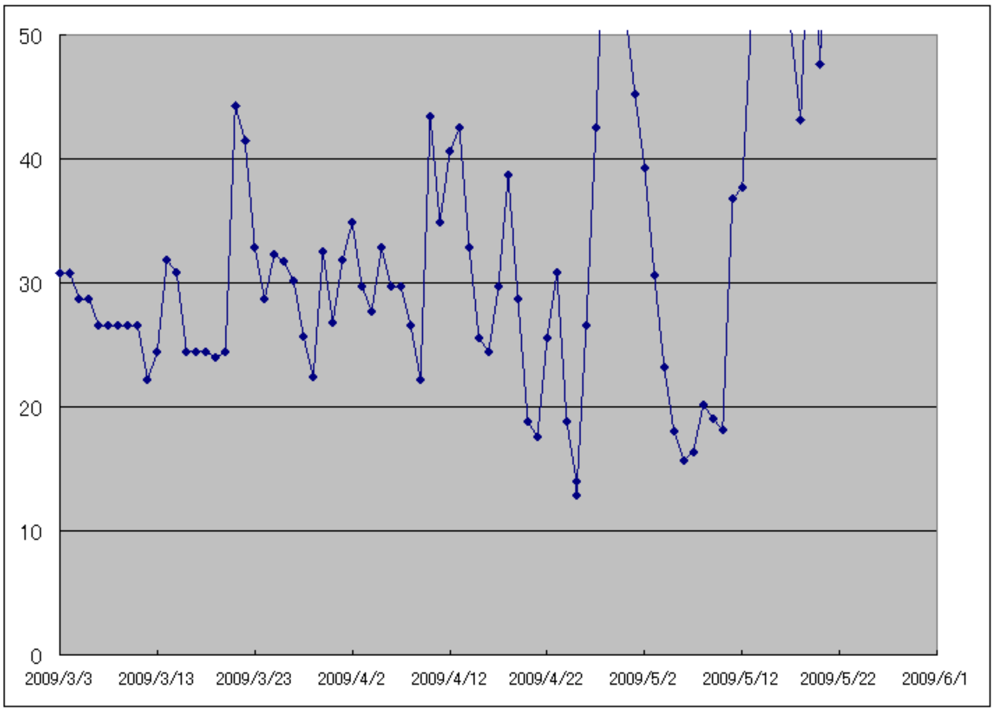
Daily maximum discharge

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	av.
2007							338.1	548.9	388.2	885.8	112.3	71.1	
2008	54.3	70.9	62.0	75.5	176.1	382.9	606.9	627.8	358.5	244.7	170.0	78.3	242.3
2009	57.4	46.0	44.3	66.8	348.2	272.2	733.2	420.6	386.0	140.5	81.6	56.7	221.1
2010	169.0	39.4	29.3	51.3	225.0	268.3	434.6	601.8	643.1	170.1	88.5	59.1	231.6
2011	43.5	33.1	146.0	48.9	288.5	1287.8	2818.6	2271.1	1245.7	505.1	139.4	79.4	742.3
Ave	81.0	47.4	70.4	60.6	259.5	552.8	986.3	894.0	604.3	389.2	118.4	68.9	359.3

Daily mean discharge

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	av.
2007							137.2	191.0	222.9	277.1	89.3	60.3	
2008	43.2	38.3	28.0	42.1	88.0	220.2	398.4	424.7	204.4	138.4	103.1	68.8	149.8
2009	44.3	38.0	29.1	32.1	79.6	129.8	325.7	278.4	157.9	102.6	67.1	50.6	111.2
2010	49.3	32.8	27.4	27.2	38.8	90.2	189.0	358.2	321.8	122.4	72.3	52.2	115.2
2011	38.6	30.5	41.4	29.7	98.0	242.4	617.6	667.8	468.9	207.3	103.1	67.6	217.7
Ave	43.8	34.9	31.5	32.8	76.1	170.6	333.6	384.0	275.2	169.6	87.0	59.9	148.5

Figure 2.10 Change of River Flow in March to May 2009 at B. Hat Gniun



Comparison of Hydrological Characteristics with other Projects

Hydrological characteristics of the NNP River basin was compared with other projects located in the middle of Laos (the Nam Theum River basin) and in the northwest (the Nam Ngum River basin) in terms of catchment area, annual average rainfall, annual average discharge, specific yield and runoff coefficients (*Table 2.6*) to reference the environmental flow for this Project against comparable river basins in Laos with planned and/or existing hydropower projects.

Table 2.6 Comparison of Hydrological Characteristics with other Projects in North and Middle of Laos

Project	Source	Year	Catchment Area km²	Annual average rainfall mm/year	Annual average discharge m³/s	Specific yield m³/s/ 100km²	Runoff coefficient
Nam Ngiep 1	KANSAI Update F/S	2007	3,700	1,874	148.4	4.01	0.67
	Feasibility Study on the NAM NGIEP 1 Project (Phase II) Final Report: volume1 Main Report (JICA)	2002	3,700	1,874	147.2	3.98	0.67
Nam Ngum 2	Hydropower Development Strategy for LAO Draft Final Report (LAHMEYER)	2000	5,640	2,166	200.6	3.56	0.52
Nam Ngum 3			3,873	2,166	106.2	2.74	0.40
Nam Ngum 5			483	1,944	22.7	4.70	0.76
Nam Theun 3			2,338	-	110.00	4.70	-
Nam Theun 2	Water Management Plan for the NAM THEUN Final Report (NORPLAN A.S.)	1997	4,013	2,250	233.0	5.81	0.81
Nam Ngum 1	Nam Ngum5 Hydropower Project Feasibility Study (LAHMEYER)	1997	8,460	-	308.0	3.64	-
Nam Ngum 5			483	2,200	22.8	4.72	0.68
Nam Ngum 1	NAM NGUM1 Hydropower Station extension Feasibility and Engineering study Mid-term Report (LAHMEYER)	1995	8,460	2,250	301.2	3.56	0.50
Nam Ngum 2			5,750	1,950	163.0	2.83	0.46
Nam Ngum 3			3,810	1,600	74.1	1.94	0.38

Flood analysis

The aim of high flow analysis is to set design floods for the purpose of safety studies on dams and auxiliary facilities. In order to estimate the magnitude and duration of design flood, the following methods are used:

(For peak discharge)

- Rational formula
- Creager type equation
- Frequency analysis with runoff data

(For hydrograph)

- Unit hydrograph method
- Storage function model

The methods are documented in detail in the Technical Report on Nam Ngiep 1 Hydropower Project [(10)]. The results of the analysis are summarized in *Table 2.7* and consequently, a probable flood discharge of 5,210 m^3/s in 1,000 years was adopted for designing the dam (*Table 2.7)*.

Table 2.7 Flood Analysis Result

Probable year	**Probable flood discharge (m^3/s)**
Probably Maximum Flood	8,430
1,000	5,210
500	4,560
200	3,800
100	3,290
50	2,840
30	2,530
20	2,300
10	1,930
5	1,590
2	1,150
1.01	680

2.3.4 *Sediment*

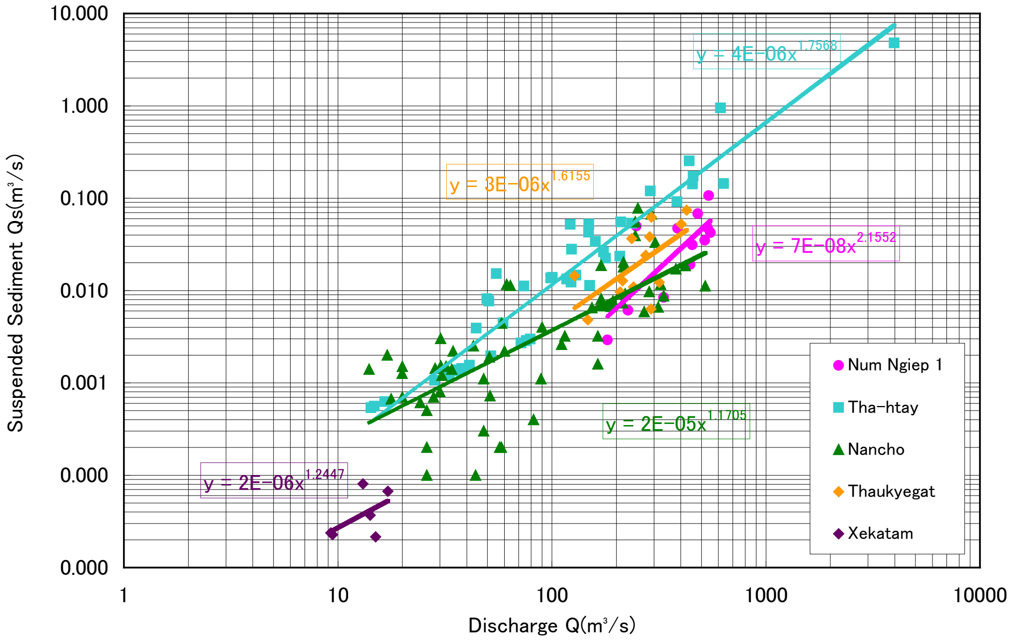
Data of suspended load at B. Hat Gniun were collected by KANSAI from April 2010 to March 2011 (*Figure 2.11)*. The following formula is obtained from the relationship between discharge and suspended sediment. In the figure, data from other projects such as Xekatam in Lao PDR and Tha-htay, Nancho, Thaukyegat in Myanmar are plotted for reference.

$$Q_S = 7.063 \times 10^{-8} Q^{2.155}$$

where Qs: Suspended Sediment (m^3/sec), Q: Discharge (m^3/sec)

(10) Kansai, May 2013. Technical Report on Nam Ngiep 1 Hydropower Project.

Figure 2.11 Suspended Sediment in NNP River Basin



Annual sediment yield at the dam site is estimated by the following equation. Sediment transport is divided into suspension load, wash load and bed load, normally suspension load and watershed load dominant. Bed load is assumed to be 5 to 10 % of basin sediment yield, so a conservative rate of 20 % is added to suspended load and wash load [11].

$$V_y = Vy_s + Vy_b$$

$$Vy_s = R \times \frac{1}{\gamma} \times \frac{1}{(1-n_s)}, \quad Vy_b = R \times 0.2 \times \frac{1}{\gamma} \times \frac{1}{(1-n_b)}$$

R= Suspended load curve × D_h

where,

V_y : Annual sediment yield (m³/yr)

Vy_s, Vy_b: Sediment yield of suspended load, bed load (m³/yr)

R : Sediment weight (kg)

γ: Specific gravity (2,650 kg/m³)

n_s, n_b: Void content; Suspended load: 0.7, Bed load: 0.4

D_h : Discharge of duration curve (sec)

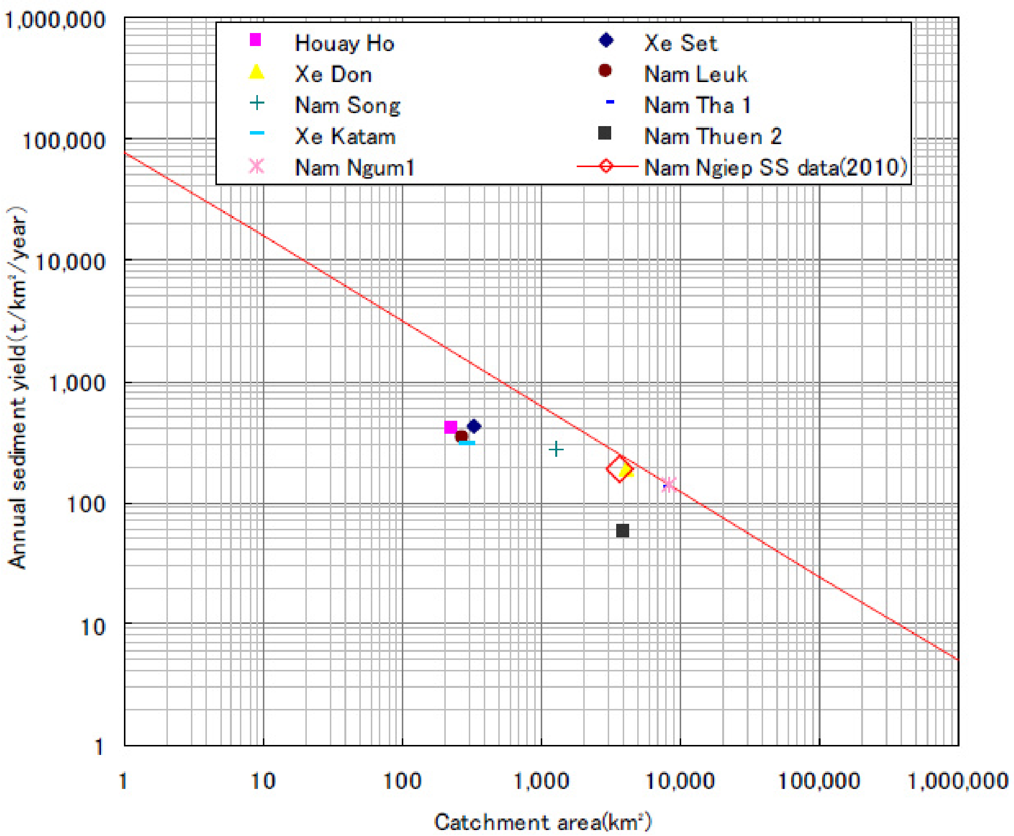
By using the above equation, the annual sediment yield of NNP1 is estimated to be 178 ton/ km²/ year.

Annual sediment yield of NNP1 estimated based on measured data is plotted in *Figure 2.12* covering design value of other hydropower projects in Laos. The

(11) confirmed with Kansai Engineers via email communications in April 2014.

estimated data are plotted below the red coloured solid line in *Figure 2.12*, which envelops all other projects' data. NNP2 has a just one-seventh basin area, though it also has the potential to trap sediment at the NNP2 dam. The effect of NNP2 was not accounted for in the estimation of sediment for NNP1. No other mining projects in the upstream watershed were evident at time of calculation. Assuming future deforestation of the basin of the Project, the specific sediment yield of the Project is conservatively raised to 248 ton/ km^2/ i.e. more than calculated estimate annual sediment yield of the Project (178 ton/ km^2/ year). The volume for 50 years is approximately 35 million m^3 and sediment level in the reservoir for 50 years is estimated to reach EL.233 m, which is much lower than the minimum operation level of the Project, EL.296 m. The estimated volume of sediment during the Project life time is quite small compared to the reservoir storage capacity and therefore sand flushing and dredging is not considered necessary.

Figure 2.12 Annual Sediment Yield Applied in Hydropower Project in Laos



2.3.5 *Water Quality*

NNP River Water Quality Sampling during July/August 2012

Surface water quality data from July and August 2012 at B Hat Gniun and Houay Soup were provided by NNP1PC. Results are presented in *Table 2.8.*

Table 2.8 Results of Water Quality Sampled in July/August 2012

	Unit	Ambient Surface Water Quality Standard	B Hat Gniun	B Hat Gniun	Houay Soup	Houay Soup
Date	dd/mm/ yyyy		24.7.2012	25.7.2012	24.7.2012	10.8.2012
Time	hh:mm		9:45 AM	9:34 AM	13:30 PM	13:45 PM
Climate	Fine, Cloudy, Rain		Cloudy, Rain	Cloudy, Rain	Cloudy	Rain
Air temperature	°C		28		29.8	31.1
Humidity	%		81%		80%	0.78
Water temperature	°C		25.4		25.4	24.8
pH	-	5~9	7.9		6.2	6.4
DO	mg/l	>6.0	9.7		8	8.8
Turbidity	FTU		192.3		153.84	153.84
BOD	mg/l	2	3		2	2
COD	mg/l	5	4		2	4
Total coliform	MPN/100	5000		176	-	24
Nitrate-N	mg/l	5		0.118		0.25
Ammonium (NH4-N)	mg/l	0		0.033		0.014
Conductivity	µS/cm			69.3		7.8
Orto-Phosphate (PO4-P)	mg/l			0.002		0.005
TDS	mg/l			36		3.8
Manganese (MN)	mg/l	1		<0.01		0.018
Total Iron	mg/l			0.109		<0.02
Sodium (Na)	mg/l			1.15		0.276
Calcium (Ca)	mg/l			9.3		0.9
Magnesium (Mg)	mg/l			1.9		0.18
Cupper (Cu)	mg/l	0		<0.01		<0.01
Mercury (Hg)	mg/l	0		<0.0005		<0.0005
Cyanide (CN)	mg/l	0		0.024		0.027
Arsenic (As)	mg/l	0		<0.005		<0.005
Cadmium (Cd)	mg/l	0		<0.002		<0.002
Chromium (Cr)	mg/l	0		<0.02		<0.02
Zinc (Zn)	mg/l	1		<0.005		<0.005

The parameters were measured against the relevant water quality standard for drinking water and surface water listed in Lao PDR National Environmental Standard (Lao PDR 2009) and analysed. The results of water quality analysis indicate that Cyanide exceeds the water quality standard at both Hat Gniun and Houay Soup. BOD exceeds the BOD standard of 2 mg/L at B Hat Gniun. A higher average DO level of 8.8 mg/L was noted during these wet season samples compared to samples collected in the dry season at locations indicated in *Figure Figure* 2.13 which showed an average DO level of 6.5 mg/L.

NNP River Water Quality Sampling during March 2013

As part of the NNP1 Biodiversity Offset Assessment Study, ERM consultants conducted water quality monitoring along the NNP River and the Nam Xan River at strategic locations to assess water quality conditions and facilitate the biodiversity offset study. Water quality sampling results along the Nam Xan River were presented in the *NNP1 Biodiversity Offset Design Report* and the key findings are presented in *Annex A*. Surface water quality samples along the length of the surveyed NNP River were taken at six (6) stations (*Table 2.9*) every 1 km on 15 March 2013 (*Figure 2.13*).

Table 2.9 Locations for Surface Water Quality Sampling along the Surveyed Stretch of NNP River

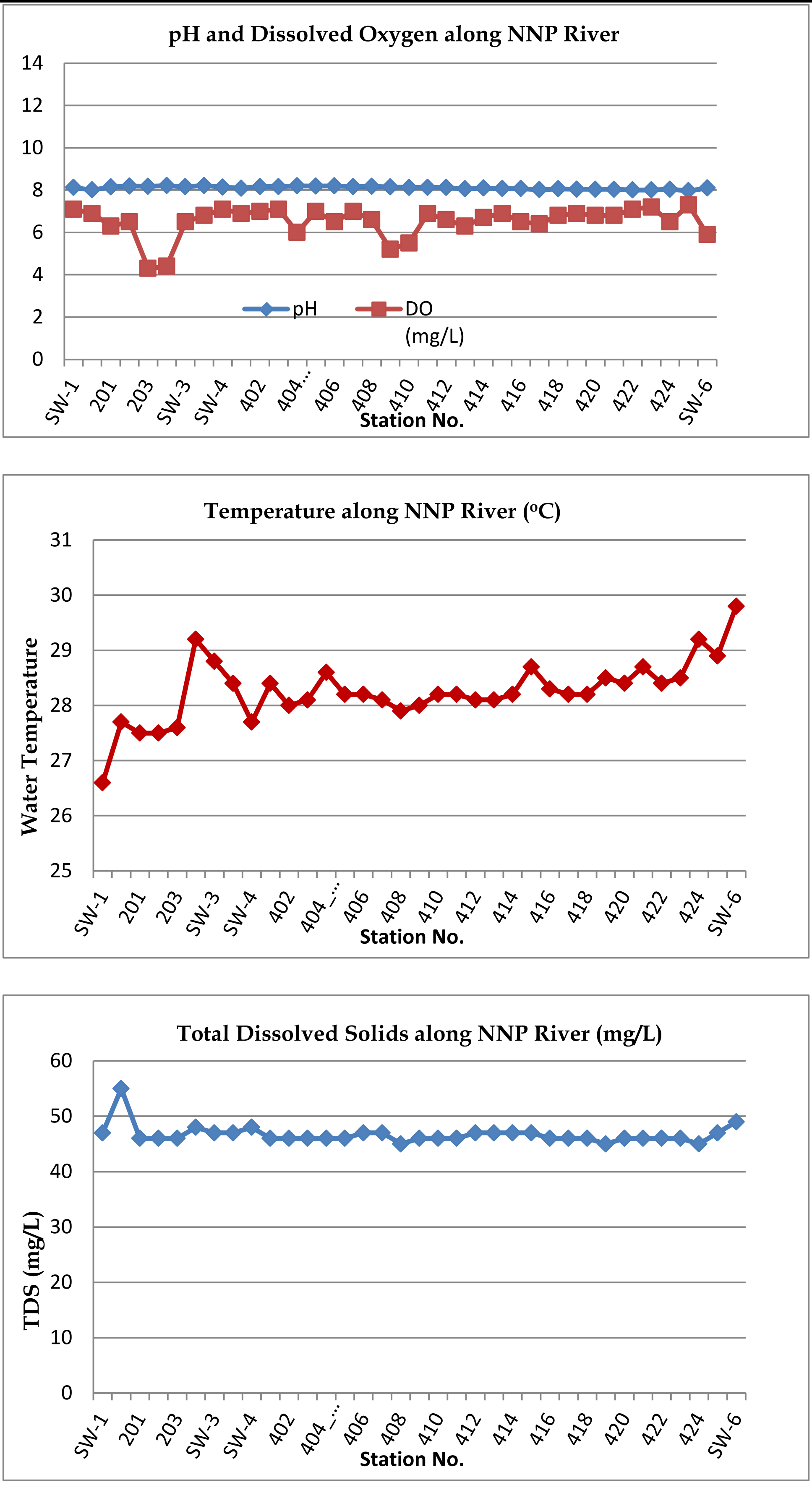
Station	Location
SW-1	Upstream of main dam and powerhouse (PH)
SW-2	Downstream of main dam and PH, and upstream re-regulating dam and PH
SW-3	Downstream re-regulating dam and PH, and upstream of one tributary (Nam Xao)
SW-4	Downstream of Nam Xao
SW-5	Upstream of one tributary (Nam Pa)
SW-6	Downstream of Nam Pa

Figure 2.13 Water Quality Sampling Sites along the NNP River in March 2013

The parameters were measured against the relevant water quality standard for drinking water and surface water listed in Lao PDR National Environmental Standard (Lao PDR 2009) and analysed. All parameters were recorded as well as date and time, GPS UTM (Zone 48, based on WGS 84 datum), physical conditions such as weather, water colour, odour, visible oil and grease, floating solids and any activities near the sites that were considered useful for helping to interpret the water quality data.

Figure 2.14 shows the results of water quality analysis, which indicate that along the NNP River the average DO level of 6.5 mg/L complies with the Ambient Surface Water Quality Standard of Lao PDF. TDS was measured at the sites and showed an average level of 46.7 mg/L.

Figure 2.14 pH, Dissolved Oxygen, Temperature and Total Dissolved Solids along the Surveyed Section of NNP River in March 2013



3 *EXISTING BIODIVERSITY AND ECOSYSTEM SERVICES OF THE DOWNSTREAM NAM NGEIP RIVER*

The flow regime of any aquatic ecosystem plays a role in the health and productivity of the system and influences the nearby biodiversity and ecosystem services; for some species, flows can trigger movement during certain periods. This section provides information on the terrestrial/ riparian habitats of the NNP River downstream of the re-regulation dam and goes on to report on the exiting aquatic biodiversity and ecosystem services in that section of the river.

Data from two key surveys have been used to determine the existing biodiversity and ecosystem services in the downstream NNP River, and dry season study in 2008 and studies conducted by the Thailand Institute of Scientific and Technological Research in 2013. In addition, three separate fish surveys have been undertaken (ERIC 2007, TISTR 2013, Kottelat 2014), and a number of village interviews have been undertaken to inform the understanding of the fish biota within the NNP River and its tributaries. All these fish surveys, however, have focused principally on the upper NNP River inundation area.

The dry season, baseline survey conducted along the NNP River in January 2008 included three aquatic sampling stations downstream of the main dam. Examination of aquatic fauna and flora included distribution of indigenous fish species and their abundance in particular areas of the river. Plankton, benthos and aquatic plants, which provide nutrients to young fish, were also studied. *Annex B* shows how six stations were located upstream from the Project's main dam site, one between the main dam and the re-regulation dam and the other three located downstream of the re-regulation dam.

A further biodiversity study, including a detailed aquatic biota survey, was conducted by the Thailand Institute of Scientific and Technological Research in March (dry season) and July (wet season) 2013 in four different areas potentially affected by the NNP1 Project. One area was along the NNP River and included five (5) sampling sites (NNg1 through to NNg5) upstream of the proposed main dam and thee (3) sampling sites (NNg6 through to NNg8) downstream of the proposed main dam. The aquatic biota survey included collection and identification of phytoplankton, zooplankton and benthos as well as capture and identification of fish species and discussion with local fishermen.

3.1 *DOWNSTREAM BIODIVERSITY*

3.1.1 *Terrestrial/ Riparian Habitat and Flora Downstream of Re-Regulation Dam (Lower NNP River)*

Downstream of the re-regulation dam, the terrain is predominately flat and tilts gradually towards the Mekong River. In this area, the NNP River runs parallel to the Nam Xan before it merges with the Mekong at Pakxan.

Forest along the Lower NNP River is dominated by disturbed mixed deciduous forest with approximately 60-70% canopy cover. The forest is highly respected by local people and well preserved with a top canopy height of 20-30 m. Records from the 2007 and 2013 surveys indicate that forest species include, among others, *Gironniera nervosa*, *Ficus racemosa* L., *Morus alba* L. and *Xanthophyllum lanceatum* as well as *Callicarpa arborea*, *Litsea glutinosa*, *Crudia Chrysantha,* and *Cratoxylum formosum* in the middle canopy and saplings an seedlings of higher canopy trees in the lower canopy such as *Trewia nudiflora* L., *Baccaurea ramiflora*, *Pseuduvaria rugosa* and *Mallotus philippinensis.* This NNP River downstream area is, however, disturbed and dominated by agricultural land use with high human activity

Aquatic riverine and tributary habitats show seasonal variation in terms of water depth, clarity, flow and wetted width. In general river habitats are fast flowing with greater water depth and flows during the wet season, flooding all banks and vegetation. Erosion always happens due to the strong water flow resulting in steep bank along the river. Dry season river habitats exhibited riffle zones which are flooded during the wet season and while the main river flows rapidly in the wet and dry season, in the tributary areas the water course in some areas dried to isolated pools. For the Lower NNP River, depth in the typical dry season was recorded as 2-3 m but shallower in riffle zones where water flows fastest, and 4-5 m deep in the wet season.

The river bed is generally dominated by sand and gravel with some boulders and the width of the river varies from 50-100 m in the dry season to 100-150 m during the wet season during surveys. While the riparian zone is mainly covered by large trees and bamboos, aquatic plants are sparsely present on the river bank which is generally exposed and dried in the dry season. Over the course of the 2007 and 2013 surveys, 22 plant species were recorded along the downstream NNP River. Most of these are common but three tree species are listed under IUCN as 'Endangered' and two trees/shrubs as 'Vulnerable'.

The three endangered trees species are *Dipterocarpus alatus, Shorea roxburghii* and *Afzelia xylocarpa* and those listed as vulnerable are *Hopea odorata* and *Syzygium vestitum*. All five species were listed as endangered in 1998 by IUCN, generally due to the rate of habitat loss or selective logging for their wood, but the IUCN records now require updating. *Dipterocarpus alatus* is mainly found along river banks, *Shorea roxburghii* is unusual for its adaptation to withstand adverse climatic conditions and soil types, *Afzelia xylocarpa* is highly exploited for its hard, attractive wood quality and *Hopea odorata* is a widespread tree which usually occurs in lowland riparian forest on deep rich soils.

3.1.2 Provincial Protected Area

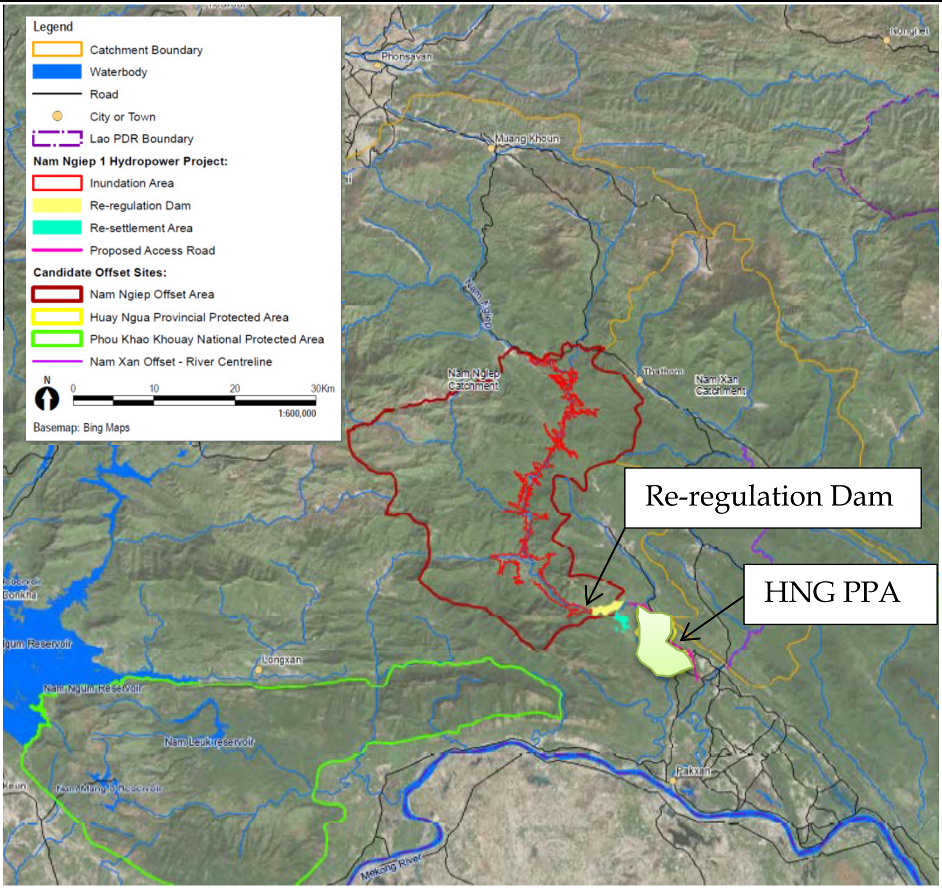
Protected areas in Bolikhamxay Province cover 382,404 ha or about 24% of the Province. Of this 296,070 ha are National Protected Areas, 52,152 ha are Provincial Protected Areas and 34,182 ha are District Protected Areas. Below are more specific details for each protected area:

- National Protected Areas cover 18.5% of the Province's land base.
- Provincial Protected Areas cover 3.4% of the Province's land base.
- District Protected Areas cover 2.1% of the Province's land base.

One provincial protected area close to the Project Area is that of Houy Ngua PPA, which falls to the east of the downstream NNP River as it flows towards the Mekong River. The Houy Nghua Provincial Protected Area ("HNG PPA") (*Figure 3.1*) is 5,495 ha and approximately 6 km from the Provincial Administration Office. There is a HNG PPA Management Plan for which the Provincial Agriculture and Forestry Office is ultimately responsible and this management plan includes an Aquatic & Wildlife Unit. There are five (5) villages in the management zone including Ban Sisavath, Ban Nonsomboun, Ban Sisomxeun, Theu Hua and B. Hat Gnuin (which is the nearest village to where the NNP1 Project dam will be built).

The HNG PPA has been established since 1995 with various changes to the area is covers but it contains abundant biodiversity and natural resources which are reported to be very important to the livelihoods of communities in adjacent villages and within the district as well. HNG PPA is also a significant natural property of the district, with the possibility to create income in the future from eco-tourism.

Figure 3.1 Houy Nghua PPA Boundary



3.1.3 *Aquatic Biota*

Fish

The fish community of the Mekong River is one of the largest in the world with most of the production based on migratory river species (Poulsen *et al*., 2004). Fish migration is an important component for many fish species life cycle. In the Mekong, fish migration can be generally described in terms of (Poulsen et al., 2004):

- Annual movement between inundated floodplains (where most fish production originates) and dry season refuges;
- Movement into spawning areas within the river system (usually upstream) from dry season refuges, generally upon start of flooding; and
- Passive migration of fish fry downstream from spawning areas.

The January 2008 dry season survey found 42 fish species along the NNP River at ten sampling stations located both upstream (6 stations) and downstream (4 stations) of the main dam site. The community detected included relatively similar proportions of surface feeders, column feeders and bottom feeders and was made up of species common to the Mekong tributaries and dominated by fish from the Cyprinidae family. Cyprinidae family species were reported to adapt to different environmental in various sections of the river, and this family was also the dominant group recorded during 2013 surveys. The 2013 surveys (wet and dry) recorded 75 fish species across four different areas potentially affected by the NNP1 Project, just one of which was the NNP River. In total 47 species of fish have been recorded in the NNP River downstream of the main dam site during the surveys.

Results of the January 2008 survey reported in the Project EIA note that larger species of fish such as *Bagarius yarrelli*, mud carp *Cirrhinus molitorella*, Asian red tailed catfish *Hemibagrus wyckioides* and *Labeo erythropterus* were found in the NNP River upstream of the dam site. Many of these larger fish, particularly mud carp, Asian red tailed catfish and *Labeo erythropterus* are migratory species of the lower Mekong basin that move upstream along the river and its tributaries during the wet season spawning activities (EIA citing Poulsen *et al.*, 2004). The Kottelat 2014 fast water fish survey also reported *Labeo pierrei* and the mud carp, known to be long distance migrators (i.e. into other tributaries of the Mekong River). These larger species, such as mud carp and Asian red tailed catfish *(Hemibagrus wyckioides*) were detected in 2007 (ERIC) and 2013 (TISTR) surveys and the 2013 (TISTR) surveys recorded the following migratory species in the lower NNP River:

- Horseface loach *Acantopsis choirorhynchos*
- Java barb *Barbonymus gonionotus*
- *Henicorhynchus lineatus*
- *Hypsibarbus venayi*
- Shark minnow *Luciosoma bleekeri*
- *Mystacoleucus atridorsalis*
- Marbled goby *Oxyeleotris marmorata*
- Sikuk barb *Sikukia gudgeri*

Both surveys also noted a number of juvenile individuals of migratory species (e.g. Opsarius pulchellus, Puntius brevis, Rasbora danioconius, Raimas guttatus and Poropuntius spp.) and overall the collected data suggesting that the NNP River plays a role in providing habitat for the reproductive cycle (EIA citing Lowe-McConnell, 1995) of various migratory fish species.Benthic Fauna

Benthic sampling detected individuals from 30 invertebrate families across whole the Project area and candidate offsets sites. Species richness varied at each sampling site with no specific trends in richness across sampling areas. For the downstream NNP River, benthic family richness ranged from seven (7) families at NNg6 & NNg7 to eleven families at NNg8, and included species such as earthworms, the Stonefly Nymph and Mayfly Nymph as well as Damselfly Nymph.

A higher density of earthworms at stations further downstream towards the convergence with the Mekong River, indicate the soils around these areas are in a virgin or near virgin stage. Earthworms and other insects are excellent food for many kinds of local fish.

Plankton Community

The NNP River is host to a great diversity of plankton species. Of the 104 species found during the January 2008 surveys, 64 were phytoplanktons and the other 40 species were zooplanktons (EIA, 2012). The highest density of planktons were found at the site furthest downstream and closest to the convergence with the Mekong River, followed by stations just upstream, at and just downstream of the dams.

In the NNP River, the dominant phytoplankton species is *Nitzschia* sp. from phylum Bacillariophyta and the dominant zooplankton species is *Testudinella patina.*

During the dry season, most of the river becomes shallow, so that light can penetrate into the water for longer periods and with higher light intensity. This can accelerate photosynthesis for the planktons and algae to grow. The relative richness of plankton species is due to substantial variations in ecosystems, caused by the range of climatic and geological conditions of the NNP River.

Threatened Species

Biodiversity surveys in the Lower NNP River area have recorded 47 fish species of which one (1) species is listed as Protected (List II) in the Regulation of Ministry of Agriculture and Forestry No. 0360/MAF (2003) and six (6) species are listed as endangered, vulnerable or near threatened on the IUCN Red List. Information on these threatened species are summarised in *Table 3.1*.

Fish species recorded in the wider Project Area that are listed as critically endangered or endangered by IUCN are considered candidates for critical habitat and these species records have been queried in the EIA as well as any species listed a Restricted under the Regulation of the Ministry of Agriculture and Forestry No. 0360/MAF or endemic. The only fish species considered to potentially have critical habitat in the Project Area is *Luciocyprinus striolatus,* listed as Endangered by IUCN Red list. A number of surveys and interviews in the Nam Ngiep and neighbouring catchments identified spawning locations for this species in the upper NNP River and tributaries. This species was observed in the lower NNP River only at the end of the rainy season, when the discharge is highest; these were apparently vagrant individuals that came downstream with the current and do not appear to be migrating individuals. Since the exact distribution of this species is not well understood, an additional survey is planned to assess the distribution and inform the design of a species action plan. ***Table 3.1*** provides information about this species and further detail in the Biodiversity Baseline Report.

Overall, the aquatic biodiversity of the lower NNP River was highlighted within the critical habitat assessment, as an area where indirect impacts may be of significance.

Table 3.1 Threatened Fish Species Recorded in Lower NNP River Area

Species / Common Name	Status	IUCN Status	Habitat requirements	Relative Abundance
Poropuntius deauratus Yellow tail brook barb (Cyprinidae family)		EN	Yellow tail brook barb is the dominant species in the river. It generally occurs in medium size and small rivers and streams (Serov *et al*., 2006), and is usually found in clear water with rapid current. During surveys for the Project juvenile fish were recorded in the rivers and tributaries. This species has been recorded in coastal freshwater river drainages in Central Viet Nam, between the Thu Bon River and the Quang Tri River (Huckstorf & Freyhof, 2011) and sometimes large clear rivers from Thailand, Cambodia and Vietnam (Rainboth, 1996) although Kottelat (2000) notes records from Cambodia, China, Laos, Malaysia and Thailand are due to misidentification (Huckstorf & Freyhof, 2011). Yellow tail brook barb is at least 6 cm Standard Length (SL) (Fishbase, 2013) feeds on fine debris, algae, diatoms and aquatic insects (Rainboth, 1996) and does not persist in confined bodies of waters or reservoirs.	VC
*Cirrhinus cirrhosis** Mrigal carp* (Cyprinidae family)		VU	Mrigal carp is an introduced species in Lao PDR being native to India and introduced in a number of other countries (Rema Devi, 2011) largely in connection with aquaculture, such that its distribution can no longer be determined. This species is a potamodromous (migrates within freshwater) benthopelagic fish, inhabiting fast flowing streams and rivers. It is a plankton feeder with juveniles being omnivorous to about 5 cm Total Length (TL) and adults being almost entirely herbivorous. This fish has a rapid growth rate; by the age of two individuals can reach a length of 60 cm and can weigh as much as 2 kg. It is commonly 40 cm (TL) (with average weight of 1 kg) and can reach up to 100 cm. There is a maximum published weight of 12.7kg from a 1991 specimen in India (Fishbase, 2013). These fish are widely cultured, and although adults thrive in ponds, they fail to breed naturally in ponds, needing swift rivers to spawn. Spawning occurs in water bodies with a depth of 50-100cm and over sand or clay substrate (Fishbase, 2013).	LC
Yasuhikotakia splendida Jaguar loach (Cobitidae family)		VU	Jaguar loach is native to Lao PDR and found in the Sekong River, the Mekong at Savannakhet as well as in the Mun River at Keng Tana, Thailand (Baird, 2011b). The species is reported to inhabit swift or moderately swift, clearwater, freshwater streams and rivers with predominantly rocky or cobblestone bottoms. It has a reported maximum SL of 10 cm (Fishbase, 2013).	C

Species / Common Name	Status	IUCN Status	Habitat requirements	Relative Abundance
Mekongina erythrospila (Labeoninae family)		NT	The *Mekongina erythrospila* is endemic to the Mekong basin in Thailand, Lao PDR and Viet Nam. *Mekongina erythrospila* is found in rapidly flowing medium and large-sized rivers. It has a reported maximum SL of 45 cm and inhabits slower deeper reaches during the dry-season but prefers rocky stretches with rapids and fast-flowing current (Fishbase, 2013). It feeds on aquatic chlorophytes, periphyton and phytoplankton and spawning is thought to occur in the Mekong mainstream at onset of the monsoon (Poulsen, 2004). Juveniles migrate in big schools comprising several hundred fish (usually with other cyrpinids and loaches) from upper basin areas to the mainstream and back while adults remain in upper catchment areas (Baird, 2011).	VC
Bagarius bagarius & *Bagarius yarrelli* Gnooch & Giant Gnooch (Sisoridae family)		NT	The confused taxonomy surrounding the identities of *Bagarius* species in the Indian subcontinent and IndoChina is badly in need of resolution in order to accurately assess their conservation status. Adults inhabit a variety of fluviatile habitats, although it is typically associated with rapid and rocky pools of large and medium-sized rivers. This species is potamodromous and benthopelagic and feeds on insects, small fish, frogs and shrimps. It is thought to breed in rivers prior to the beginning of the annual flood season (Fishbase, 2013). These fish are relatively large, predatory fish and are actively fished for food and, in places, for ornamental trade as sport fish.	C
Luciosoma bleekeri Apollo shark minnow	□✓	LC	The Apollo shark minnow was recorded during project surveys within the Nam Ngiep study sites (upper and lower) and as well as being recorded in other locations within the Mekong basin, this species is also known from Cambodia, Thailand and Viet Nam (Vidthayanon, 2012b). The Apollo shark minnow is mainly found in rivers. It also inhabits tributaries and flooded forests, moving to marshlands and floodplains in the rainy season and into permanent water as flood waters recede (November and December) (Rainboth, 1996). The Apollo shark minor feeds on insects, small crustaceans and some small other crustaceans and fish (Vidthayanon, 2012b).	VC

Species / Common Name	Status	IUCN Status	Habitat requirements	Relative Abundance
Luciocyprinus striolatus	☐	EN	This large predatory fish is known from the Upper Se Kong, upper Nam Kading (Nam Theun and Nam Ngouang), upper Nam Ou, upper Nam Tha rivers in Lao and the Nala and Buyuan rivers in Xishuang Banna, China, however it is uncertain as to whether this species still occurs in China. It inhabits deep pools in the upper reaches of large rivers and it is not considered migratory (IUCN, 2013). The species is reported to reach up to 70-100 kg in weight, however there are almost no recent reports of large specimens (greater than 60 kg) (Warren 2014a). Interviews with local fishermen and observations of the species in the Nam Theun drainage indicate that adults live in deep pools, with a possible preference for the upper and lower parts of the pool, near rapids, riffles and runs (Kottelat 2014). Interviews by Baird *et al*. (1999, cited in Warren 2014a) indicate that the species occupies middle to surface water strata and prefers rivers with small stones substrate or large slabs of rock. Deep pools of between two and six metre depth during dry season conditions are expected to be preferred (Warren 2014b). The species population size is not well documented with the specialist studies in and around the Project Area identifying a number of locations where the species is known by local villagers that have not been previously reported in literature. As this species is not considered a long distance migrator, the upper and middle Nam Ngiep may be considered a management unit. Collation of information regarding the distribution of the species, and as such the location of populations, identified at least 8 river basins where there are known records of the species occurring. Village interviews indicate that although rare there are regular occurrences of the species in the lower Nam Ngiep. As such this population may be one of 10 or fewer discrete management sites globally for the species (Tier 1) and therefore potential critical habitat.	VC

Status = Protected by Regulation of the Ministry of Agriculture and Forestry No. 0360/MAF, dated 8th December 2003

IUCN Stats = EN-Endangered; VU-Vulnerable; NT-Near Threatened; LC-Least Concern; DD-Data Deficient

Relative abundance = VC: Very Common, C: Common, LC: Less Common

* = Introduced species

3.2 DOWNSTREAM ECOSYSTEM SERVICES

It is evident that villagers in the Project area regularly use aquatic fauna, e.g. fish, as a food source, however, the dependence on the NNP River and tributaries varies by village and is largely associated with accessibility. This section describes the downstream ecosystem services supported by the NNP River and uses and much of the data is from village and market surveys undertaken by ERM in February and March 2013.

Table 3.2 provides a summary of the villages located in the downstream area of the re-regulation dam, including the number of households and population. There are nine (9) villages located within this zone; three (3) are located in the Bolikhan District and six (6) are located further downstream in the Pakxan District.

Table 3.2 Households and Population in the Project Area

Province	District	Village	No of Households	Population
Bolikhamxay	Bolikhan	Nampa	84	584
		Somseun	221	1,207
		Houykoun	358	2,180
Bolikhamxay	Pakxan	Thong Noi	165	839
		Thong Yai	86	437
		Sanaxay	274	1,156
		Phonsy	137	719
		Pak Ngiep	173	859
		Sanoudom	94	457

Source: SDP of the Nam Ngiep 1 Hydropower Project

The villages are home to three main ethnic groups - lowland Lao, Hmong and Khmu. Despite traditional ways of living, conditions are changing in Laos PDR. This in part is being driven by government policy, which is consolidating smaller villages into larger ones to improve access to infrastructure, such as roads, and communication technology. This has meant considerable population increases, particularly over the past four to five years, in a number of the villages in the Project area (refer to *Social Impact Assessment Report – Nam Ngiep 1 Hydropower Project*) and it is likely that the overall growing population is causing more pressure on the natural resources, including through over-fishing. Indeed villagers have noted that availability of naturally occurring resources, especially forest animals and fish, has been declining in recent years.

3.2.1 *Fisheries*

When compared to hunting, fishing occurs on a more regular basis. This is largely because of the close proximity of villages to waterways. The most common fishing method is with a cast weighted net, an item commonly seen in most houses. Larger nets are used during the rainy season to catch larger fish that swim up river from the Mekong River. At Hatsaykham, the survey team observed other methods such as scaring fish into a net hung across a short section of the river and gathering by hand. Other equipment observed in villages included lines, hooks and spear guns. Fishing takes place at established riverside sites at which small shelters are built.

Fish is generally caught only for household consumption, but it is also a common item used in inter-household exchange and transactions. Surplus fish tends to be sold at below market rates suggesting such transactions may more likely be part of a local gift economy rather than a commercial transaction. This being said, it was common to hear that small fish are eaten at home while big fish, when found, are sold. The Project EIA (2012) also reports that fish is the main source of protein for the people in the villages along the river.

Aside from the importance of fishing for subsistence living, fishing may have been more important for income generation in earlier times but with greater availability of alternative protein sources and reported reduction in fish stock availability and size, villages have adapted. Incomes of the downstream communities are shown in *Table 3.3* and *Table 3.4.*

Table 3.3 Sources of Income for Villages in downstream Area

Village	Items									
	On Farm						Off Farm		Total	
	Crop		Livestock		Fishery					
	Income	%	Income	%	Income	%	Income	%	Income	%
Thahuea	4,214,286	42.69	3,157,142	31.98	285,714	2.89	2,214,286	22.43	9,871,429	100
Nampa	5,727,273	40.38	4,636,364	32.69	181,818	1.28	3,636,364	25.64	14,181,818	100
Somseun	5,816,667	34.88	5,276,667	31.64	466,667	2.8	5,166,667	30.68	16,676,667	100
Houykhoun	1,533,333	12.79	1,079,167	9	20,833	0.17	9,354,167	78.03	11,987,500	100
Tong Noi	4,422,727	27.81	1,727,273	10.86	1,369,091	8.61	8,386,364	52.73	15,905,455	100
Thong Yai	3,233,333	21.86	683,333	4.62	125,000	0.85	10,750,000	72.68	14,791,667	100
Sanaxay	194,286	1.36	337,143	2.36	0	0	13,771,429	96.28	14,302,857	100
Phonsy	852,941	9.99	705,882	8.26	294,118	3.44	6,688,235	78.31	8,541,176	100
Pak Ngiep	15,140,909	54.53	1,436,364	5.17	977,273	3.52	10,213,646	36.78	277,681,820	100
Sanoudom	2,258,333	12.23	458,333	2.48	500,000	2.71	15,250,000	82.58	18,466,667	100

Table 3.4 Sources of Income of the Host Villages

	On Farm						Off Farm		Total	
	Crop		Livestock		Fishery					
Village	Income	%	Income	%	Income	%	Income	%	Income	%
Hat Gniun	9,874,341	52.7	95,952	0.5	3,626,047	19.3	5,150,896	27.5	18,747,236	100
Thahuea	4,214,286	25.5	3,157,143	43.4	285,714	7.2	2,214,286	23.9	9,871,429	100

3.2.2 Navigation

A total of 829 boats consisting of wooden boats with engines and canoes are operated by villagers along the NNP River sections surveyed for the Project. These are used for fishing purposes and transportation of passengers and materials (*Table 3.5*). Especially in the wet season, river navigation is a crucial means of transport between villages along the NNP River and further downstream to Pakxan.

There is no obvious navigation system or rules of navigation for the NNP1 River and jetties are not abundant.

If the road between Nongsomboun and B. Hat Gniun is improved so that it can be used through the year, the frequency of navigation is expected reduce.

The boats using by villagers along the NNP River are specially designed with shallow draft that can be operated in river of minimal flow and depth, photograph of the typical boats is shown in *Figure 3.2*.

Figure 3.2 Photograph of the Typical Boats using along NNP River

Table 3.5 Kinds of Boat and Usages

		XomXuen	HuayKhoun	Hat Gniun	HatSayKham	ThaHue	ThongNoy	ThongYai	NamPa	XaNaXay	NamNgiep	PhoneSy	SaenOuDom
Total		1196	2191	610	217	273	849	529	521	1185	955	753	NA
M		597	1108	323	105	152	433	279	270	599	484	373	NA
FM		599	1083	287	112	121	416	250	251	586	471	380	NA
Boat with engine		221	5	68	10	18	30	7	85	5	70	100	30
Usage type	private	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	share	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Initial cost (kip)/boat	4,500,000	1,500,000	6,500,000	2,080,000	1,000,000	3,900,000	3,900,000	1,300,000	1,500,000	1,820,000	3,900,000	3,900,000
	Maintenance cost(kip)	NA	NA	1,000,000	500,000	300,000	260,000	1,040,000	1,500,000	NA	200,000	520,000	100,000
	service life (years)	10	5	4	6	3	5	10	5	10	3	6	3
Boat without engine		NA	NA	NA	8	11	NA	20	20	NA	100	20	NA
Usage type	private	NA	NA	NA	✓	✓	NA	✓	✓	NA	✓	✓	NA
	share	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Initial cost (kip)/boat	NA	NA	NA	1,300,000	500,000	NA	1,040,000	520,000	NA	520,000	600,000	NA
	Maintenance cost(kip)	NA	NA	NA	400,000	NA	NA	NA	500,000	NA	100,000	200,000	NA
	service life (years)	NA	NA	NA	6	3	NA	NA	5	NA	3	5	NA
Canoe with engine		NA	NA	NA	NA	10	NA	NA	NA	25	NA	NA	NA
	private	NA	NA	NA	NA	✓	NA	NA	NA	✓	NA	NA	NA
Usage type	share	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Initial cost (kip)/boat	NA	NA	NA	NA	200,000	NA	NA	NA	500,000	NA	NA	NA
	Maintenance cost(kip)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	service life (years)	NA	NA	NA	NA	2	NA	NA	NA	10	NA	NA	NA
Canoe without engine		NA	50	NA	NA	NA	60	NA	NA	NA	NA	NA	35
	private	NA	✓	NA	NA	NA	✓	NA	NA	NA	NA	NA	✓
	share	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Initial cost (kip)/boat	NA	500,000	NA	NA	NA	600,000	NA	NA	NA	NA	NA	780,000
	Maintenance cost(kip)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	100,000

3.2.3 *Other Activities related to the NNP River*

The NNP River in the Project Area is utilized for various activities other than fisheries and navigation by villagers (*Table 3.6*). The river water is used for essential activities for residents such as drinking, irrigation, laundry, bathing and washing. It is also used for micro-hydro power generation at B.Hat Gnuin.

With regards to drinking water, villagers mainly get their drinking water from gravity flow water systems, with the water obtained from springs or other sources with all-year flows, or from wells, with the NNP River and tributaries as a supplemental source of domestic water rather than the principle one. In fact, of all the villages in the affected area of the Project, only the community of Houayphamom in the reservoir area and the sub-village of Hatsaykham near B. Hat Gniun depend entirely on the Nam Ngiep and nearby tributaries for all their water. *Table 3.6* shows the total drinking water demand of 280 m^3/day plus some daily use in the XomXue village before the year of 2000. The household usage takes up a flow amount of 4800 m^3/day plus some daily use in the XomXue village by carrying or pumping. For most of its course, the Nam Ngiep passes through valleys with steep embankments and even farther downstream, where the topography is less mountainous, the river flows through a valley between higher hills.

Nearly all the agricultural fields are on lands above the river and the main agriculture production – vegetables, lowland rice, upland crops, and tree crops – depends upon rainfall rather than river water. A few areas are irrigated, but these use water from streams flowing down toward the Nam Ngiep from the mountains. Farmers use river and/ or local stream water only for some small plots, about 0.08 to 0.3 ha with bamboo fences, near the embankments. Those are mostly vegetable plots, and they are planted when the waters are high and more accessible, just after the rice harvest in October or November. The vegetables that are grown tend to be for household consumption, while any surplus is sold at local markets. No irrigation system was observed during surveys. Villagers typically rely on rainfall or nearby local streams rather than the NNP River. In the event of a drought (or a decrease in rainfall), villagers often let their crops die.

Some materials are extracted from the river, such as gravel and sand for construction (e.g. of houses) but mining, such as for gold dust, is not carried out.

Table 3.6 Other Activities Related to the NNP1 River

		XomXuen	HuayKhoun	Hat Gniun	HatSayKham	ThaHue	ThongNoy	ThongYai	NamPa	XaNaXay	NamNgiep	PhoneSy	SaenOuDom
Total		1196	2191	610	217	273	849	529	521	1185	955	753	NA
M		597	1108	323	105	152	433	279	270	599	484	373	NA
FM		599	1083	287	112	121	416	250	251	586	471	380	NA
Laundry	description	some HH	NA	NA	for HH consuming	NA	villager using	NA	NA	general using	NA	HH consumption	NA
	number of occupation	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	annual income (kip)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	operation period (year-year)	NA	NA	NA	NA	NA	1937-2012	NA	NA	NA	NA	1964-2012	NA
Bathing	description	some person	When go to upland ,garden	NA	NA	NA	villager using	NA	people go to take shower in NamNgiep river	take shower	take shower	HH consumption	NA
	number of occupation	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	annual income (kip)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	operation period (year-year)	NA	NA	NA	NA	NA	1937-2012	NA	until 2012	NA	until 2012	NA	NA
Power generation	description	NA	NA	use generator	NA	NA	NA	NA	NA	NA	NA	NA	NA
	number of occupation	NA	NA	20	NA	NA	NA	NA	NA	NA	NA	NA	NA
	annual income (kip)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	operation period (year-year)	NA	NA	6	NA	NA	NA	NA	NA	NA	NA	NA	NA
Extracting sand/gravel	description	NA	By use Excavator, at unit 26;27 in village	NA	excavate sand by them sift for build house	NA	NA	NA	By use Excavator, machine to pump sand and gravel	NA	Excavate sand in NamNgiep estuary	NA	NA
	number of occupation	NA	1	NA	NA	NA	NA	NA	1	NA	NA	NA	NA
	annual	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

		XomXuen	HuayKhoun	Hat Gniun	HatSayKham	ThaHue	ThongNoy	ThongYai	NamPa	XaNaXay	NamNgiep	PhoneSy	SaenOuDom
	income (kip)												
	operation period (year-year)	NA	2010	NA	NA	NA	NA	NA	1992-1993;1996-2000;2002-2005	NA	NA	NA	NA
Mining	description	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	number of occupation	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	annual income (kip)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	operation period (year-year)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Drinking	supplied HH or area(ha)	221	NA	NA	30	NA	NA	NA	58	NA	NA	NA	NA
	quantity of water supply(m3/day)	based on using	NA	NA	100	NA	20	NA	10	NA	NA	150	NA
	water supply period(days/year)	365	NA	NA	180	NA	NA	NA	180	NA	NA	NA	NA
	charge (kip)	NA	NA	NA	NA	NA	4000	NA	NA	NA	NA	NA	NA
	method of intake	carry, pump	NA	NA	carry	NA	pump	NA	carry	NA	NA	pump	NA
	operation period (year-year)	until 2000	NA	NA	1994-2012	NA	1937-2012	NA	until 2008	NA	NA	2002-2012	NA
HH consuming	supplied HH or area(ha)	221	NA	NA	30	NA	NA	NA	97	unit 1,2,3 of village	100	NA	NA
	quantity of water supply(m3/day)	based on using	NA	NA	200	NA	4000	NA	200	NA	200	200	NA
	water supply period(days/year)	365	NA	NA	180	NA	NA	NA	365	NA	365	NA	NA
	chage (kip)	NA	NA	NA	NA	NA	NA	NA	NA	NA	20,000	NA	NA
	method of intake	carry, pump	NA	Carry	carry	NA	pump	NA	pump	pump	pump	NA	NA
	operation period (year-year)	until 2000	NA	NA	1994-2012	NA	1937-2012	NA	until 2012	NA	until 2012	NA	NA

		XomXuen	HuayKhoun	Hat Gniun	HatSayKham	ThaHue	ThongNoy	ThongYai	NamPa	XaNaXay	NamNgiep	PhoneSy	SaenOuDom
Irrigation	supplied HH or area(ha)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	pumping for supply paddy rice field private HH	NA
	quantity of water supply(m3/day)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	water supply period(days/year)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	chage (kip)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	60,000/day	NA
	method of intake	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	operation period (year-year)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fishery	approving organization	Luxembourg project	NA	NA	word vision	NA	NA	NA	Luxembourg project	NA	WWF;MoAF, Supporting Food Security and Aquatic Biodiversity/community Fisheries	NA	NA
	period of right(year)	3	NA	NA	2007-2012	NA	NA	NA	2008-2012	NA	2001	NA	NA
	approved date	NA	NA	NA	10/05/2007	NA	NA	NA	2008	NA	2011	NA	NA
	expense of right (kip)	NA	NA	NA	800,000	NA	NA	NA	900,000	NA	NA	NA	NA
Irrigation water	approving organization	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	period of right(year)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	approved date	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	expense of right (kip)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

4.1 CHANGE OF FLOW REGIME

Due to lack of long term observed data, the annual, monthly and daily discharge downstream of the re-regulation dam has been calculated by Tank Model method using 1971 to 2000 data. The calculated mean annual inflow is estimated to be 148.4 m^3/s at the main dam and 149.4 m^3/s at the re-regulation dam.

Figure 4.1 presents seasonal inflow and outflow of the main dam (top panel) after construction; and *Figure 4.2* shows inflow to the re-regulation dam before and after construction (bottom panel). *Figure 4.3* and *Figure 4.4* show monthly and annual natural inflow to the main dam, outflow from the main dam and outflow from the re-regulation dam over the 30-year period.

The dam-reservoir systems regulate the flood discharge during the wet seasons and increase the flow rates during the dry seasons, so that the seasonal flow regime shows less fluctuation over the year. Daily and monthly flow fluctuations are also likely to be less evident after the regulation.

Figure 4.1 Seasonal Inflow and Outflow of the Main Reservoir

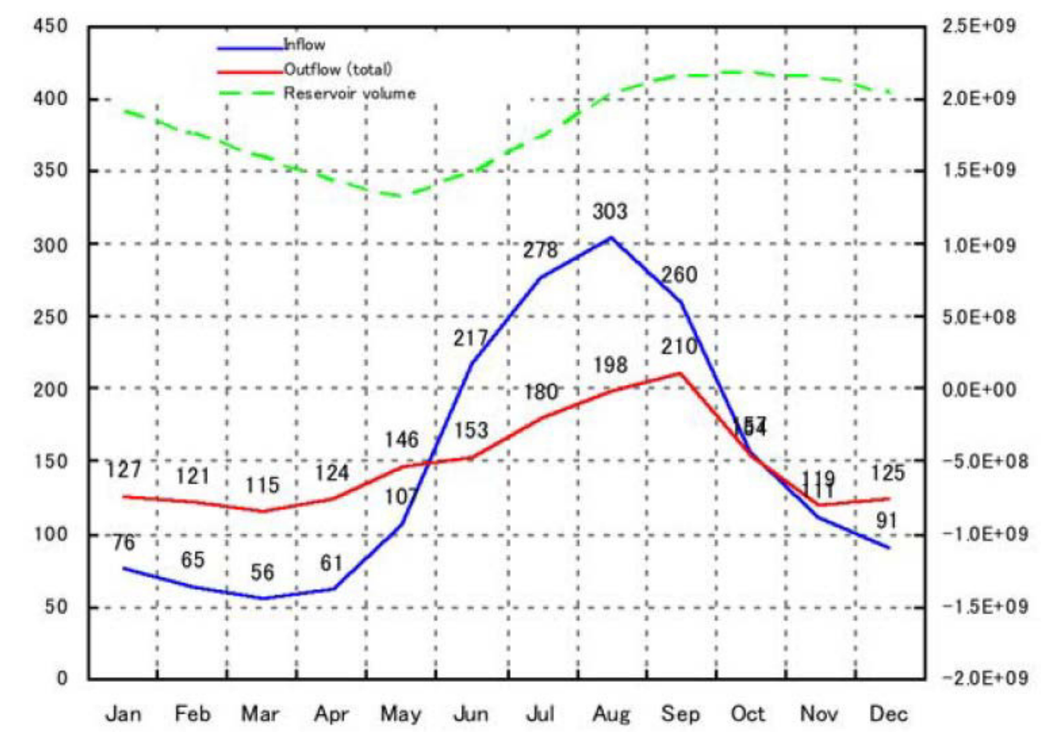


Figure 4.2 Seasonal Inflow to the Re-Regulation Dam before and after the Dam Construction

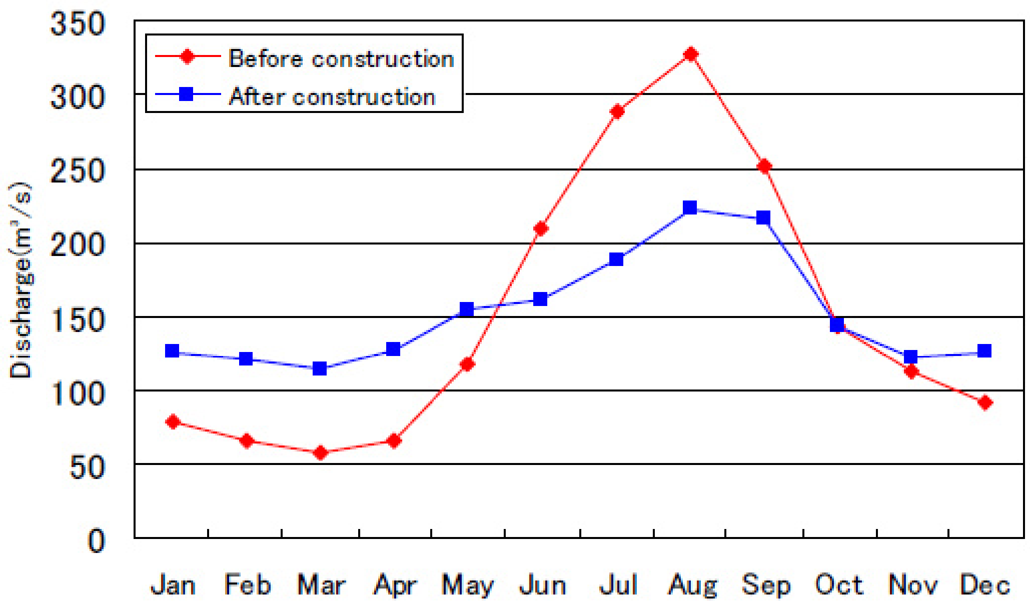


Figure 4.3 Annual Natural Inflow to the Main Dam and Outflow from the Main Dam and the Re-regulation Dam over the 30-year Period

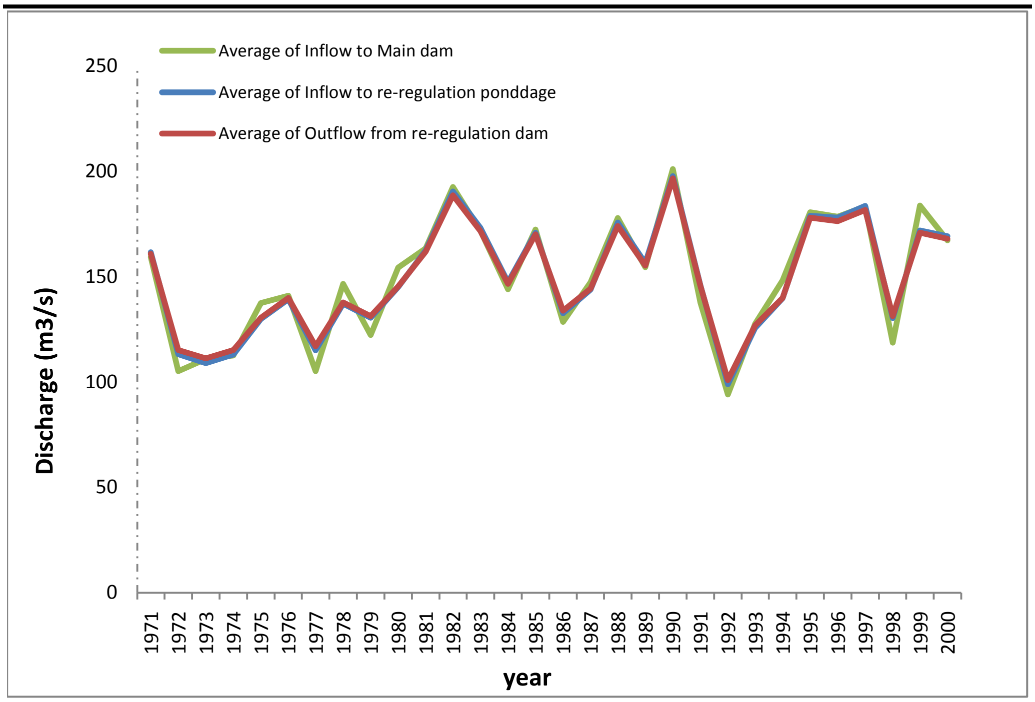
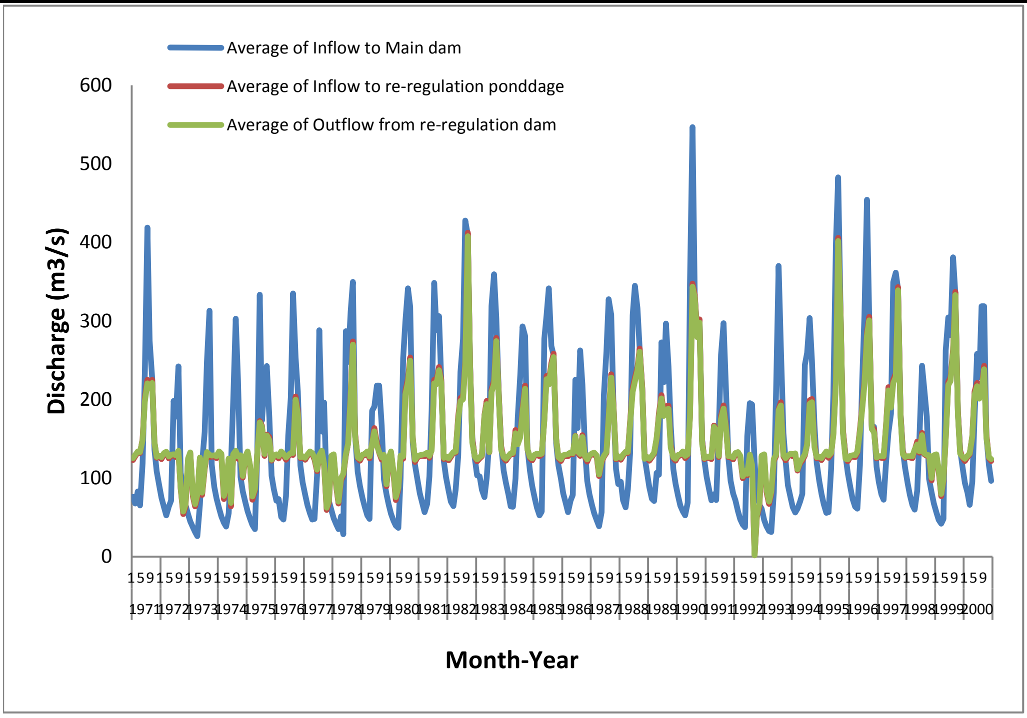


Figure 4.4 ***Monthly Natural Inflow to the Main Dam and Outflow from the Main Dam and the Re-regulation Dam over the 30-year Period***



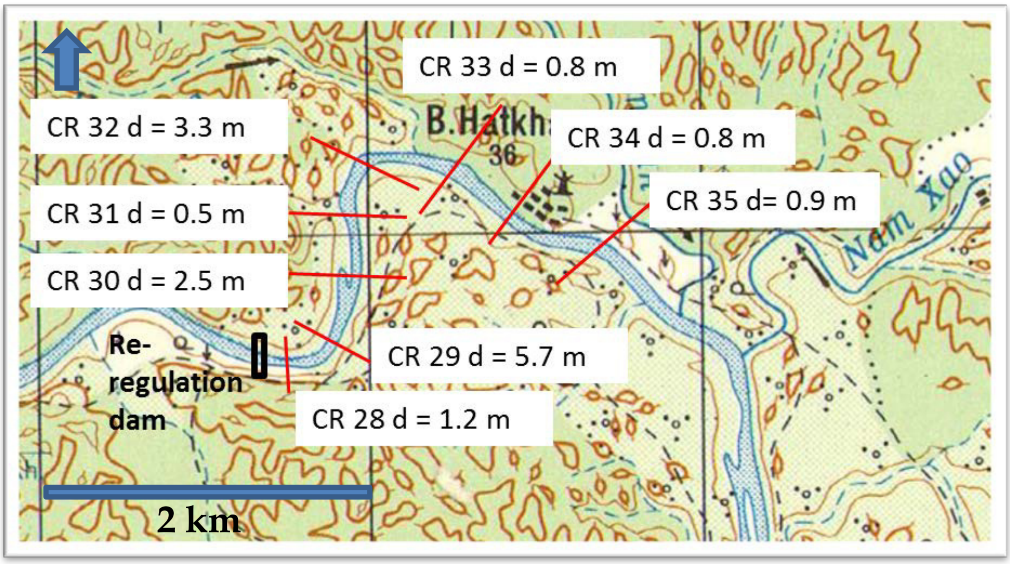
4.1.1 *During Construction*

The river water will be discharged through a diversion tunnel during construction without blocking the running flow. The river diversion is a single-row water pressure tunnel with inner diameter of 10.0 m, length of 653 m and standard horseshoe-shaped tunnel. The capacity of passing water is 1.5-year probable flood discharge, which is 1,000 m^3/s with open channel. . The flow regime during construction is, thus, equivalent to that of the natural river. According to the general construction schedule, two flood seasons shall be faced during the dam and powerhouse construction period. In the first flood season, the dam will be still low and overtopping in case of a sizable flood will certainly occur. In the second flood season the dam is expected to be much higher: except in case of very large floods, it shall be expected that overtopping will not occur and the entire flood shall then be passed through the diversion tunnel. Should the dam construction period be longer than presently considered, the same conditions will apply to a third flood season.

4.1.2 *During Initial Impounding*

During the initial impounding the environmental flow is set to 5.5 m^3/s. Non-uniform flow analysis was applied to estimate the downstream water level, water depth and flow velocity for the environmental release of 5.5 m^3/s during the initial impounding (*Annex C*). *Figure 4.5* presents the analysed water depths along the 3km downstream of the re-regulation dam. The minimum water depth, river surface width and flow velocity occurring at the Section CR31, CR33 and CR29 between the regulation dam and Ban Hat Gnuin respectively during initial impounding of 5.5 m^3/s are 0.5 m, 16.1 m and 0.02 m/s. The maximum drop in water level is found to be 1.3 m at CR29 and CR28. However with taking into account inflow from groundwater seepage and delayed subsurface flow in wet season the flow regime would be larger than the predicted minimum condition.

Figure 4.5 ***Water Depth along the 3km downstream of the Re-regulation Dam during Initial Impounding (Environmental Flow of 5.5 m^3/s)***



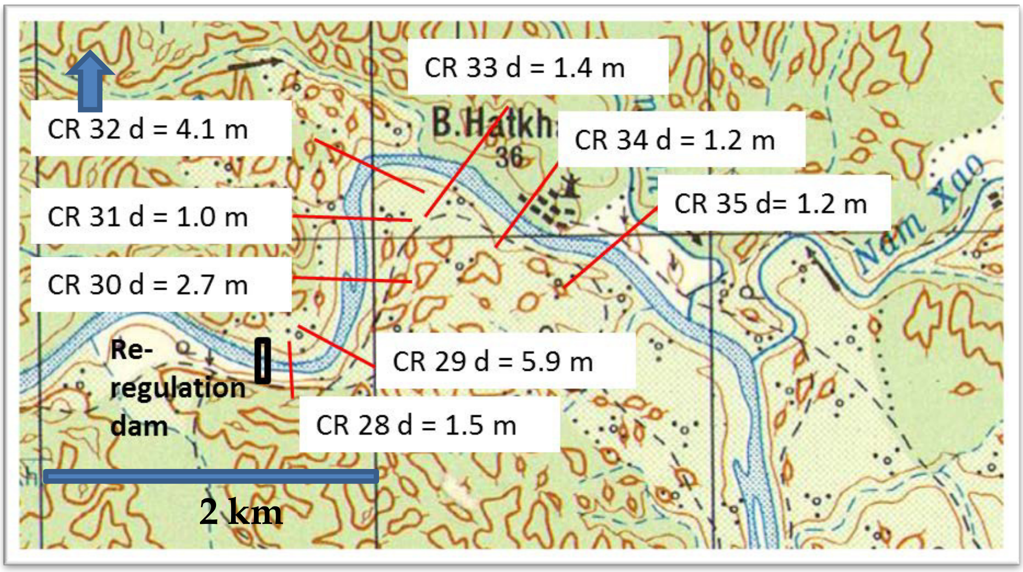
4.1.3 *During Operation*

During the normal operation when the environmental flow is set to 27.0 m^3/s, the minimum flow encountered between immediate downstream of the re-regulation dam and the Nam Xao will be increased to at least 39.1 m^3/s near the Nam Xao confluence (see Section 5.2.2 *Table 5.3* this report), which is higher than the observed minimum daily natural inflows at Hat Gniun (Section 2.3.3 Hydrology *Table 2.5* highlighted).

The predicted minimum water depth, river surface width and flow velocity occurring downstream of the re-regulation dam are 1.0 m, 58.1 m and 0.1 m/s respectively under the environmental flow discharge of 27.0 m3/s. During the 4-hour ramp down period on each Saturday the release flow drops from 160.0 to 27.0 m^3/s for 17 hours, resulting in a maximum reduction of water surface width of 160.0 m shrinkage at the cross section CR33 near the B. Hatkham village (see the location of CR33 on *Figure 4.6*). The maximum reduction of the water level of a 1.5 m drop occurs further downstream (not shown on *Figure 4.6*) at 15.9 km upstream of the confluence with the Mekong River. In these typical operation patterns, the fluctuation of water level would be controlled not to cause a change of over 0.6 m /hour or 1.7 m / 24 hours according to the Concession Agreement (the limitation is not applied in the case of flood period).

The maximum reduction in the flow velocity drops by 0.7 m/s at the most at the section CR 31, where the minimum water depth of 1.0 m was also predicted under the release rate of 27.0 m^3/s. Meanwhile, the shallow river water depths of 1.2, 1.2 and 1.4 m occurred at locations between Nam Miang and Nam Tak River at respective cross sections of CR 35, 34 and 33.

Figure 4.6 ***Water Depth along the 3km downstream of the Re-regulation Dam during the Operation (Environmental Release of 27.0 m³/s)***



4.2 CHANGE OF WATER QUALITY

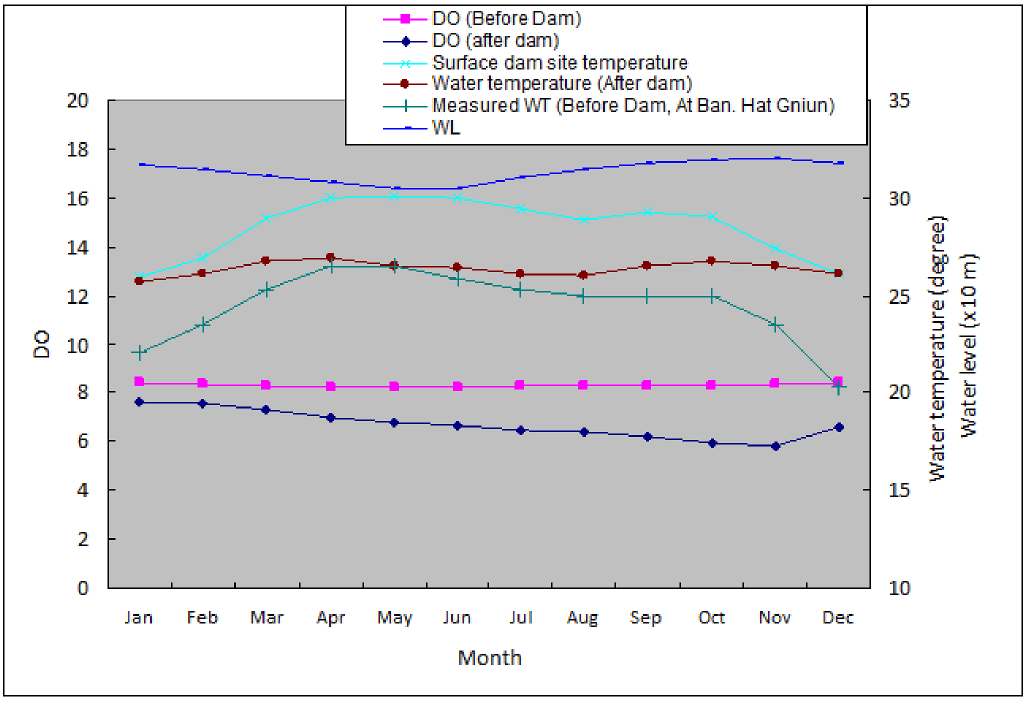
In initial impounding, water will come through the riparian conduit and the water will be still fresh as the impounding will take only one rainy season. During operation and extreme drought conditions, the change of temperature, SS and DO were simulated by computation modelling to help understand how the water quality would be affected by the dam construction. The water quality models were calculated to predict the quality change of inflow and outflow or discharge due to the project. The variation of water quality, as predicted by the variations of DO and water temperature, was found to arise largely from the seasonal variation rather than hourly variation. In addition, since the NNP1 reservoir is considered as an annual regulation reservoir, the water quality simulation in the reservoir was conducted on a daily interval rather than an hourly interval.

Extreme drought conditions occur in the latter period of the rainy season, when the reservoir water exists at close to full level and minimum discharge will be released through the turbine. In the case of extreme drought conditions, assuming the reservoir/dam had been in place for the past 30 years, the model predicts that the environmental flow would be released from the water depth 35 – 40 m below the reservoir water surface. In comparison, during off-peak discharge at weekends, water will be released from the water depth 22 – 45 m below the reservoir water surface. Significant differences in the environmental flow water quality are not expected during normal operation and extreme drought conditions.

4.2.1 *Water Temperature*

The water temperatures of the downstream river before and after the dam construction were significantly different. The released water temperature is around 25 – 27°C (*Figure 4.7*) because water release is conducted form the boundary of stratification. The average temperature downstream after the dam construction would be about 4°C higher in winter than the measurement water temperature at B Hat Gnuin before the construction (*Figure 4.7*).

Figure 4.7 Water Temperature and DO before and after Dam



4.2.2 *Dissolved Oxygen*

The prediction of DO change due to the Project was conducted by reviewing the impacts of similar dam projects, using eight (8) years (1991-1998) of data collected from those dams and comparing the results with that of natural inflow. The result of the computation shows that the DO in the discharged water from the main dam has a significant tendency to be lower than that of inflow. The predicted range of the DO in the main reservoir outflow discharge varies from 3.5 mg/L to 7.9 mg/L through the year (*Annex C*). The DO concentration increases gradually as the water flows further downstream due to oxygenation and dilution. DO concentration of discharged water from the re-regulating dam is over 6 mg/L almost all the year.

4.2.3 *Turbidity*

The computation of SS concentration of the reservoir was conducted based on the hydraulic data over an eight year period (1991-1998) (*Annex C*). The SS concentration was computed and the results showed only about 10 mg/L to 20 mg/L of SS in the discharged water headed downstream, which is less than one-tenth of that in the water before the Project since most turbidity would be trapped and settled in the reservoir within eight years of reservoir operation. Any phenomenon of long-term turbidity was not predicted over the eight years used for computation.

4.2.4 *Eutrophication in the Main Reservoir*

Eutrophication of the reservoir occurs naturally in situations where nutrients accumulate, or where they flow into systems on an ephemeral basis. Eutrophication generally promotes excessive plant growth and decay, favouring simple algae and plankton over other more complicated plants, and causes a severe reduction in water quality. When the algae sink to the bottom, they are decomposed, and the nutrients contained in organic matter are converted into inorganic form by bacteria. The decomposition process consumes oxygen, and deprives the deeper waters of oxygen, which in turn kills fish and other organisms, as well as decreases the water quality.

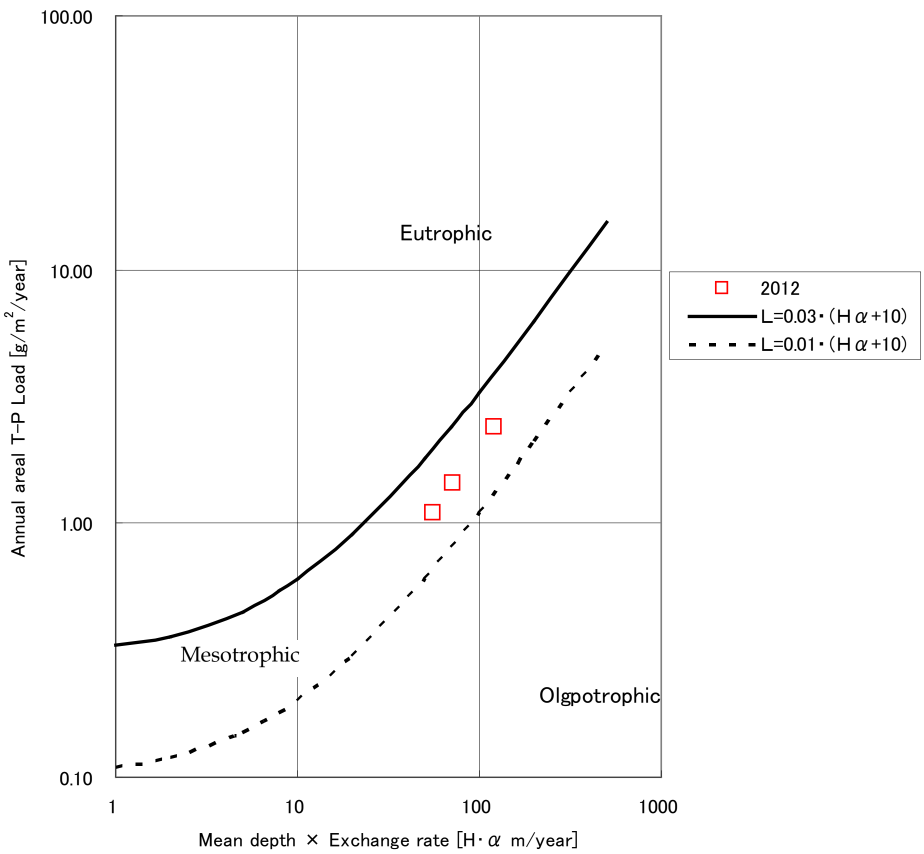
Another major potential source of nutrients in water bodies is cleaning detergent (due to the nitrogen and phosphorus content), which can often be found in domestic wastewater. However, this is not an issue for the Project as there are no dwellings, and thus no detergent discharge, in the reservoir area.

In the first several years after the filling of the reservoir, the level of oxygenation will be heavily determined by the organic material (biomass) left on the inundated land. This consists of wood, leaves, roots, other plant debris and organic acids in the soil.

Potential changes in nutrient levels during the reservoir operational period are assessed using eutrophication analysis. Regarding eutrophication of the reservoir, a detailed simulation model was not considered necessary given the limited availability of all required input data. Rather, it was recommended that a simplified index be used for the preliminary judgement of eutrophication. Such an index uses annual reservoir circulation (annual inflow/reservoir capacity) and nutrient of inflow, i.e. phosphorus, data inputs.

Since phosphorus is the limiting factor of eutrophication in many cases of dam reservoirs and natural lakes of fresh water, impact on the eutrophication due to phosphorus is often studied. According to Vollenwinder (1969, 1975, 1976) and studies on many dam reservoirs, there is a close relationship between the exchange rate of a reservoir, mean water depth and water surface area load of phosphorus. The trophic state is indirectly assessed based on typical ranges for phosphorus, nitrogen, chlorophyll a and water clarity values reported in the reservoir lifecycle. The latest data of water quality tested at Hat Gniun indicates mesotrophic qualities of the NNP1 reservoir and its potential does not change when the reservoir volume varies, as shown in *Figure 4.8*.

Figure 4.8 Mean reservoir Depth and Water Phosphorus



Methane and ammonia in the reservoir are not considered to be key concerns considering that the intake of NNP1 is located at a reasonably high level from the bottom of the dam and the predicted mesotrophic state of the NNP1 reservoir.

Sediment transferred from the upper stream watershed will be trapped within the reservoir storage as the dams will act as physical barriers to transport of larger sediment downstream. Smaller particulate suspended load is the main source of sediment, however, and much of this will be flushed away through slipway during flooding during flood. The regulated flow discharged downstream is deprived of larger sediments which may result in downstream erosion at a rate dependent on flow rate, river slope and river bank/bed characteristics.

Quantitative analysis of reduction of nutrients due to the reservoir caption is currently not available, but given reduction in sediment load there is likely to be some reduction in nutrient level also.

5 ENVIRONMENTAL FLOW FOR NNP1 PROJECT

Environmental flow or "Riparian release" should be designed to maintain the basic level of natural processes and ecological value of the aquatic ecosystem for the Project during the initial impoundment and normal operation and even in a drought year or an emergency event such as an unexpected shutdown of the main power station. In this context, the amount of environmental flow release will be proposed and assessed by taking into account practice of environmental flow of other projects in Laos, various needs from downstream biodiversity and ecosystem services, reservoir operations, as well as the dry flow features at the dam site and downstream reaches from the historical measurement records.

5.1 ENVIRONMENTAL FLOW OF OTHER HYDROPOWER PROJECTS IN LAOS

It is found that there is no standard for environmental flow in the Mae Kong riparian countries including all Mekong River Commission reports. Therefore the riparian release from the other projects in Lao PDR have been reviewed, as shown in *Table 5.1* , showing the catchment area, minimum discharge and specific discharge for the proposed dams to be developed in Lao PDR. The specific discharge ranges from the lowest value of zero (0) to the maximum value of 0.10 $m^3/s/100\ km^2$.

Table 5.1 Riparian Flow of Other Projects in Laos

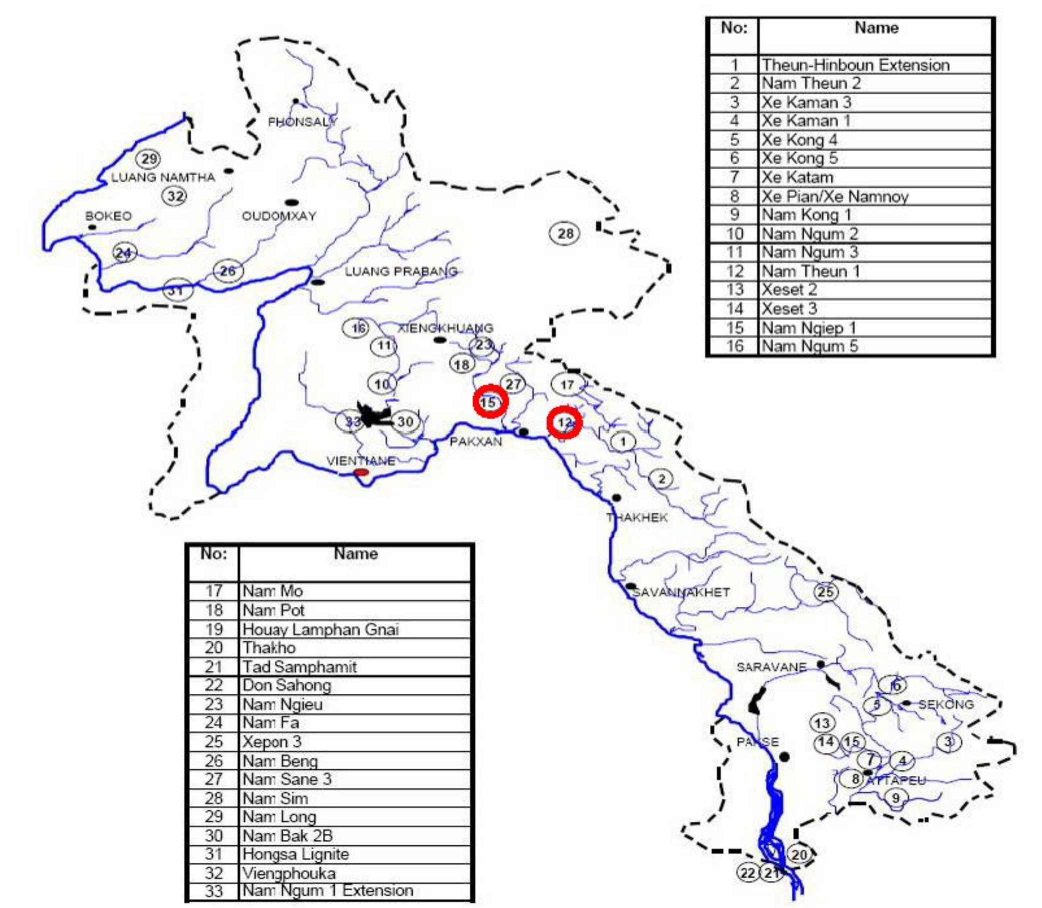
Name of the project	Catchment area	Minimum discharge	Specific discharge
	(km²)	(m³/s)	(m³/s/100km²)
Nam Theun 2	4,031	2.0	0.05
Theun Hinboun	8,937	5.0	0.06
Thuen Hinboun Exp	4,903	5.0	0.10
Houay Ho	192	0.0	0.00
Nam Leuk	274	0.0	0.00
Nam Ngum 3	3,890	1.0	0.03
Nam Mang 3	82	0.0	0.00
Xe Set	320	0.0	0.00

*1: Under construction, commencement of commercial operation in 2009.

*2: The minimum discharge of Nam Ngum 3 is a proposed value from the EIA draft final report (Dec 2007, Norplan)

According to the location and the rainfall condition, NNP1 Project (No. 15 in *Figure 5.1*) has a similarity to Nam Theun 2 project (No. 12). If the same method that was used to estimate the riparian flow for Nam Theun 2 project (a specific discharge rate of 0.05 $m^3/s/100\ km^2$) is used for NNP1, the minimum riparian flow for the NNP1 Project (with a catchment area of 3,700 km^2) is approximately 1.85 m^3/s (=0.05 $m^3/s/100\ km^2$ x 3,700 km^2 catchment area).

Figure 5.1 Location of Proposed Dams to be Developed in Lao PDR



5.2 PROPOSED ENVIRONMENTAL FLOW

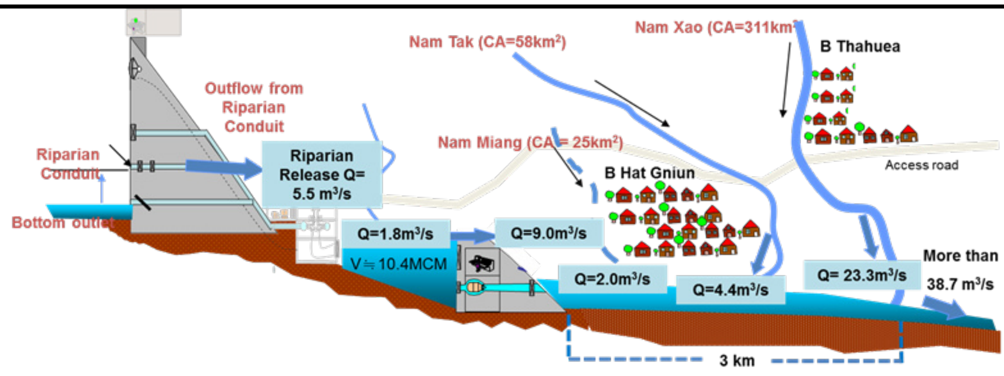
Considering the practice of environmental flow of other projects in Laos, a minimum environmental flow discharge of 5.5 m^3/s has been adopted for the NNP1 Project during the initial impounding. This is a higher specific minimum discharge than that of other projects in Laos. The proposed environmental flow rate during the initial pounding has also considered the restrictions by the designed capacity of the re-regulation pond and riparian release conduit.

The proposed minimum environmental flow (27 m^3/s) from the re-regulation dam during operation has been derived based on (i) the minimum environmental flow of the river of the without-dam scenario, (ii) the minimum discharge of other hydropower projects in Lao PDR, and (iii) assumed water quantity and quality requirements of downstream priority ecosystem services.

During Initial Impounding, a riparian release conduit is planned for riparian release for environmental protection of the downstream area. Water velocity inside the pipe has to be set at 20 m/sec, because the velocity in the slide valve section needs to be limited to within 10 m/s under any conditions in order to avoid harmful vibrations. Considering these conditions, one (1) row of 0.8 m diameter discharge pipe and two (2) sluice valves, each 1.1 m in diameter, are installed inside the dam body. The upstream slide valve is for back-up. The range of flow for the riparian conduit is 0.0 - 9.3 m^3/s, depending on the water level. At NWL (EL 320 m) and MOL (EL 296 m), the conduit capacity is 9.3 m^3/s and 5.5 m^3/s, respectively [(12)].

According to the tentative programme the initial impounding starts on 1st July 2018. The discharge scheme during initial impounding is summarized in *Figure 5.2*. At the start of the initial impounding, the elevation of the riparian release conduit on the main dam is set at EL 244.6 m so that the river water would be unable to discharge through the riparian conduit until the reservoir water level reaches EL 244.6 m. In average hydrological conditions within about one week the main reservoir water level would reach the elevation EL. 244.6 m and start releasing some flow to the re-regulation pond. The riparian release conduit will reach the required discharge capacity of 5.5 m^3/s within 2 weeks. After that, the discharge from the riparian release conduit increases gradually as the reservoir water level increases (the pink area in *Figure 5.3*). It will take about one wet season to fill the reservoir at the first impoundment but it could vary depending on climate conditions according to the past 30 year inflow data.

Figure 5.2 Minimum Recovered Discharge 3 km Downstream of the NNP1 Re-regulation Dam during Initial Impounding in July 2018

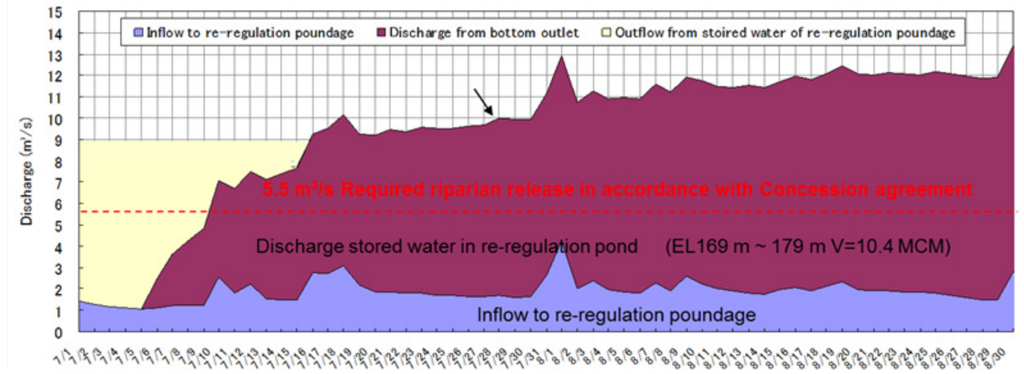


The breakdown of environmental flow to ensure a release of 5.5 m^3/s from the re-regulation dam is shown in *Figure 5.3*. It is comprised of three (3) sources for discharge (1) natural inflow into re-regulation dam pondage: 1.8 m^3/s; (2) release of storage water from re-regulation pondage: Q = 10.4 x 10^6 m^3; and (3) release from the main dam 5 days after the start of impoundment. The total volume of the re-regulating reservoir is about 7.4 million m^3, which will be sufficient to maintain the required minimum release for about 15 days, without any inflow from the main reservoir during the start of initial impoundment. For the first 5 days the re-regulation reservoir releases just under 8 m^3/s and this release decreases to zero after approximately 30 days except for natural inflow to re-regulation dam pondage of 1.8 m^3/s. The main reservoir release starts after 5 days and increases gradually so that, along with the re-regulation pond stored water (1.8 m^3/s), the outflow from the re-regulation dam increases above 9 m^3/s. Therefore the released

(12) Technical Report on Nam Ngiep River 1 Hydropower Project

environmental flow is actually more than the minimum requirement of 5.5 m³/s during the entire initial impounding period.

Figure 5.3 *Breakdown of Discharge Volume*



Below the re-regulation dam the minimum flow in the NNP River at the Nam Miane, Nam Tak and Nam Xao confluences will increase to 11.0, 15.4 and 38.7 m³/s respectively with the July tributary inflows from the Nam Miang (2.0 m³/s), Nam Tak (4.4 m³/s) and Nam Xao River (23.3 m³/s) (tributary flows in July see *Table 5.3*).

5.2.1 *During Operation*

A. *Environmental flow of 27.0 m³/s through re-regulation dam during off-peak on the weekend during normal operation*

After the construction of the NNP1 main dam and the re-regulation dam, stable outflow downstream of the re-regulating powerhouse can be secured. As shown in *Table 5.2*, the discharge from the normal operation of the main power station is designed at 16-hour peak generation on weekdays and Saturday. The main power station would not operate on Sunday. The discharge from the main dam would be stored in the re-regulation reservoir and then discharged downstream.

The re-regulation reservoir will be operated between NWL of EL179.0 m and MOL of EL 174.0 m. From Monday to Saturday, the re-regulation reservoir will store part of the discharge from the main dam as it operates for 16-hours and release it downstream evenly over the 24-hour period in order to augment the downstream river flow for the remaining 8-hours when the main dam is not discharging, thus flattening the peak discharge from Monday to Saturday. On the weekend, the outflow from the re-regulation reservoir will be reduced to 48 m³/s for a period of 17 hrs (3pm on Sun to 6am Mon) (*Figure 5.4*). An environmental flow of 27 m³/s at minimum will be maintained for the remaining 15 hrs (10pm on Sat to 3pm on Sun) *Figure 5.5* , during which time the flow will be released through the re-regulation dam gate. This typical operation accounts for over 97% of the reservoir simulation period of 30 years.

Table 5.2 Typical Operation Pattern during Week Day and Saturday and Sunday

No	Case	Timing	Period	Discharge (m^3/s)		Explanation
				Main P/S	Re-regul. P/S	
N-1	Normal operation	6am Mon - 10pm Sat	16 hrs/day	230.0	160.0	Nearly maximum plant discharge re-regulation P/H
N-2		10pm Mon- 6am Sat	8 hrs/day	0	160.0	Nearly maximum plant discharge re-regulation P/H
N-3		10pm Sat - 3pm Sun	17 hrs/ week	0	27.0	Water release through spillway during off-peak
N-4		3pm Sun - 6am Mon	15 hrs/ week	0	48.0	Minimum plant discharge of re-regulation P/H during off-peak
E-1	Extreme	When there is zero inflow from the Nam Ngiep basin-		27.0	27.0	Riparian release from main reservoir through spillway during extreme drought year

Figure 5.4 Outflow Pattern from the Main Dam and Re-regulation Dam

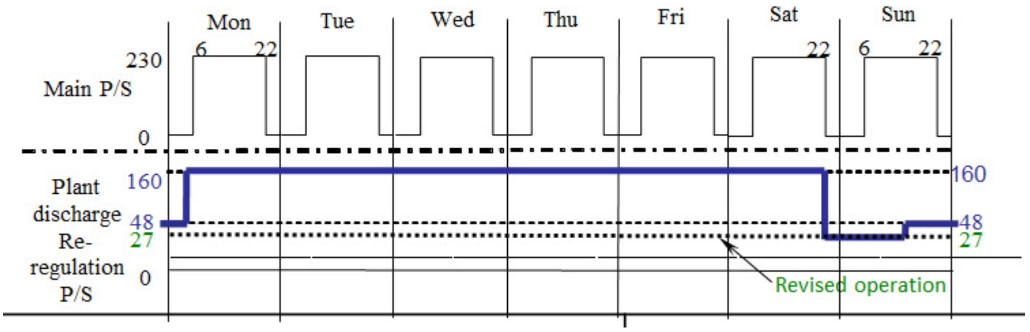
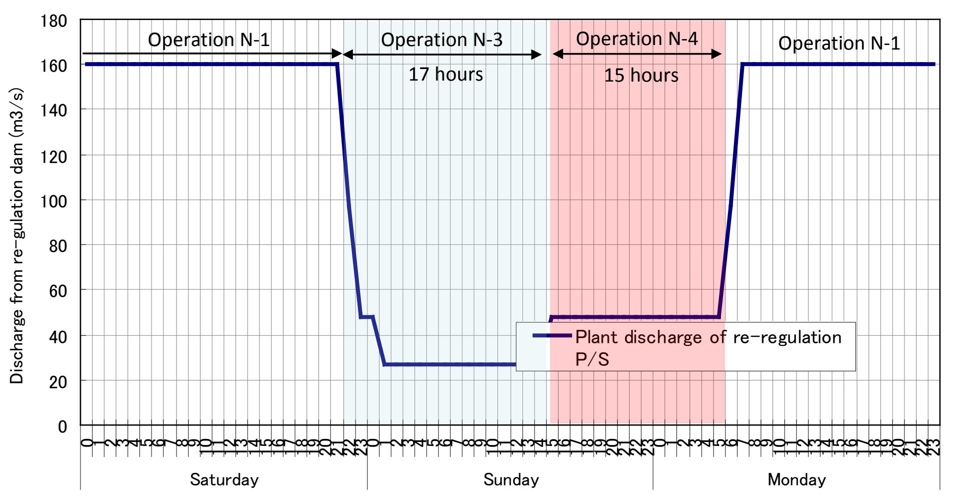


Figure 5.5 Discharge Pattern from Re-Regulation Reservoir during Weekend



During most time of the normal operation, the environmental flow released from the re-regulation dam gate would be more than 27.0 m^3/s, but in dry conditions, the minimum water release of 27.0 m^3/s is likely to occur through the re-regulation dam during off-peak periods at the weekend, when there is not have enough inflow to the main reservoir to supplement the minimum environmental flow. *Figure 5.6* and *Figure 5.7* present the frequency of the discharge of 27.0 m^3/s during operation on a monthly and yearly basis (using Tank Model to review the past 30 years of data). Seasonal frequency of daily outflow 27.0 m^3/s from the re-regulation dam is on average 4.5 days in January and reduces to about 1.5 days in July.

In the past 30 years, the number of days when outflow reaches 27.0 m^3/s ranges from the minimum 19 days in 1997 to the maximum of over 50 days in 1972, 1973, 1974 and 1977 (drought years). On average, the frequency when the daily outflow is 27.0 m^3/s from the re-regulation dam is 0.5 % (less than 1.5 days /year over 30 years).

Figure 5.6 ***Monthly Occurrence (Days) of Discharge of 27.0 m³/s through the Re-regulation Dam***

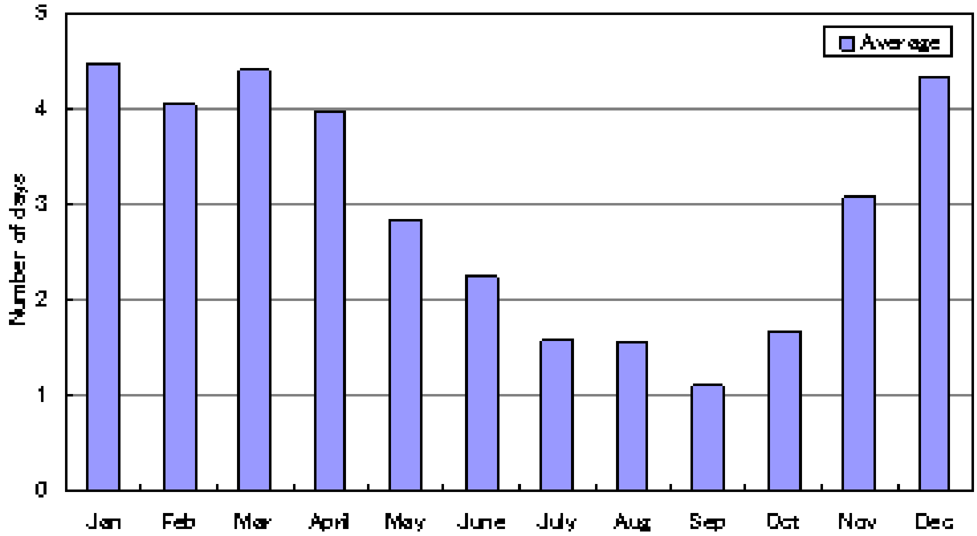
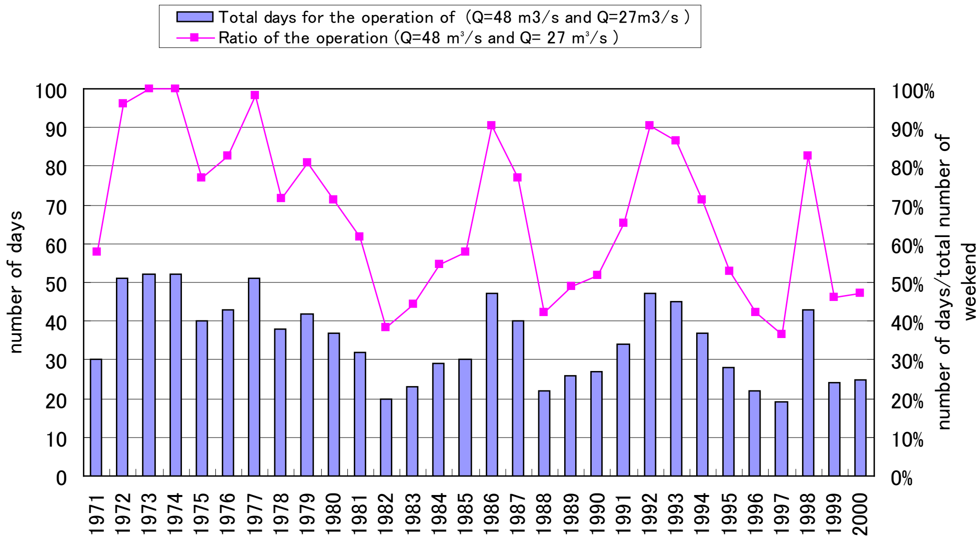


Figure 5.7 ***Annual Occurrence (Days) of Discharge of 27.0 m³/s through the Re-regulation Dam***

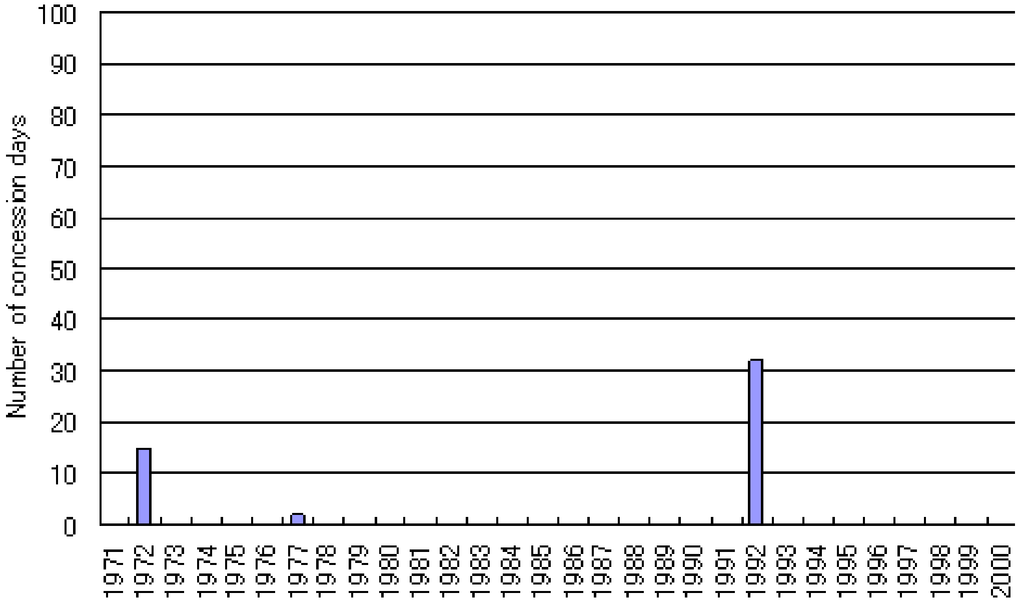


B. Environmental release of 27.0 m³/s in case of extreme draught year

During years of extreme drought when there is insufficient water in the main reservoir for normal operation, a discharge of environmental flow of 27.0 m³/s will be secured and released continuously downstream through the main powerhouse intake at EL 274.4 m.

Extreme drought years have happened in the past 30 years and the model estimated that an environmental flow (assuming with the dam existed) would have occurred on 49 days continuously in September and October 1972, 1977 and 1992. *Figure 5.8* shows the number of concession days over the past 30 years when there would have been an outflow of 27.0 m³/s through the powerhouse intake in the main dam. During these periods natural inflow is used to store water in the main reservoir without operation of the main powerhouse to keep the reservoir water level above the rule curve for the reservoir operation.

Figure 5.8 Occurrence of Environmental Flow of 27.0 m³/s through the Main Dam



The numbers of days when the environmental flow occurred are listed below and as shown in *Annex D*.

- 1972: 15 days in September to October
- 1977: 2 days in October
- 1992: 32 days in September to October

Extreme drought is predicted to happen in the latter period of the rainy season when the reservoir water lever exists at close to full tank level and minimum discharge would be released through the turbine.

It is indicated by the model that the occurrence of the minimum environmental flow could be postponed by months as compared to the timing of the driest natural inflow to the main reservoir, benefiting from the reservoirs storing water in wet seasons for release in the dry seasons. By the time minimum environmental flow occurred (in the predicted September and October), the natural inflow to the main reservoir would have recovered from the minimum flow of the year and reached more than 80 m^3/s. The minimum flow immediately downstream of the re-regulation dam will also increase to more than 27.0 m^3/s. At the confluence with the Nam Xao River such minimum in-stream flow would increase to more than 39.1 m^3/s due to the recovered natural inflows from the Nam Tak and Nam Xao (*Table 5.3*), which is higher than the observed minimum daily mean natural inflows at Hat Gniun.

Table 5.3 ***Nam Tak and Nam Xao Monthly Minimum Flow to the NNP River and NNP River Minimum Flow at the Confluence with the Nam Xao River***

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Nam Miang	0.5	0.5	0.4	0.4	0.8	1.5	2.0	2.1	1.8	1.1	0.8	0.6
Nam Tak minimum daily flow	1.2	1.0	0.9	1.0	1.7	3.4	4.4	4.8	4.1	2.5	1.7	1.4
NamXao minimum daily flow	3.3	2.7	1.8	1.3	1.6	3.7	8.7	11.2	12.0	8.5	7.3	4.4
Environmental flow from the main dam	-	-	-	-	-	-			27.0	27.0		
sum										39.1		

Note: The minimum daily flow is predicted for the tributary Nam Xao stream by multiplying ratio of basin area to NNP River basin area to the minimum daily flow recorded in the NNP River in *Table 2.5*.

Figure 5.4 presents the summary of minimum natural inflow to the main dam, outflows from the immediately downstream of re-regulation with the release of the environmental flow. The proposed minimum weekly release of 27.0 m^3/s is higher than the observed and modelled minimum average monthly and also daily river flow in the past 30 years.

Table 5.4 ***Minimum Natural Inflows to the Main Dam and Minimum Outflows from the Immediately Downstream of the Re-regulation Dam***

Condition	Cases	Flow rate (m^3/s)
Without Dam (Natural inflow to main dam)	Min. average monthly river flow in 30 yr (1971-2000), estimated by Tank Model	26.4
	Min. daily river flow in 30 yr (1971-2000) , estimated by Tank Model	23.5
	Min. daily inflow measured at B. Hat Gniun (25th and 26th April 2009)	12.8
With Dam	Min. daily/weekly flow rate during dry condition	27.0

The present minimum release of 27 m^3/s represents 9% to 480% of the available mean monthly flow, based on the predicted averaged monthly data from 1973 – 2000 using the Tank Model. From 1973 to 2000, the proposed environmental flow exceeds 10% of the mean natural monthly inflow 84% of the time. This 10% figure has been recommended as the minimum flow releases in maintaining healthy aquatic habitats in Europe, North America and Australia in the absence of quantitative studies although given the diverse nature of tropical fish faunas and the generally higher water temperatures of tropical rivers, it is probable that the figure of 10% of mean monthly flow is insufficient to maintain a healthy aquatic environment in Asian countries such as Laos. If the minimum requirement is increased to 20% of the mean monthly flow, this is achieved 64% of the time.

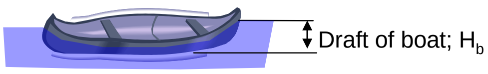
6 ENVIRONMENTAL FLOW ASSESSMENT

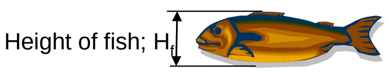
6.1 EVALUATION OF CHANGE IN ENVIRONMENTAL FLOW ON DOWNSTREAM BIODIVERSITY AND ECOSYSTEM SERVICES

Further to a review of the downstream biodiversity and ecosystem services as detailed in *Section 3*, the characteristics of flow regime and water quality of the environmental flow, this section is to assess whether the projected environmental flow rate(s) released from the re-regulation dam are sufficient to maintain the basic needs of the downstream biodiversity and ecosystem services of the NNP River focusing on the river section below the re-regulation dam.

The terrestrial/ riparian habitats and flora including the endangered trees species downstream of re-regulation dam (Lower NNP River), as well as the Houy Ngua PPA, are less dependent on the NNP River, while the aquatic biota and fishery resources on the NNP River are expected to be more sensitive to the change of water flow due to NNP1 Project. The evaluation of change in environmental flow on downstream biodiversity and ecosystem services in the following section therefore focus on aquatic biota and fishery resources.

Required minimum water depth for navigation and fish has been considered. A villager at B. Hat Gniun stated that the minimum required water depth for navigation (given the shallow draft of their boats as shown in *Figure 3.2*) is 0.5 m (Hb) and suggested that the required water depth for fish is usually double the height of the fish. In case there is a point where the river depth is not enough for boat navigation, the villagers can convey boat by hand so far. A depth of 0.5 m enables boat navigation and appears to be sufficient for the ecology of most fish. Required minimum water depth for navigation and fish are 0.5 m.





As a result of assessment for environmental flow and discussions with related authorities, the required environmental flow and water depth is determined as shown in *Table 6.1*, which is set in *Annex C of the Concession Agreement* between the GoL and the NNP1 PC. The compliance status with the below threshold will be adequately monitored during impoundment and operational phase.

Table 6.1 Flow Requirement in Annex C of Concession Agreement

[During impoundment]			
River reach	Absolute Minimum Flow		Water depth (measured at a fixed point immediately downstream of the re-regulation dam)
Downstream of the re-regulation dam	• Min 5.5 m3/s at all times in the dry season and in the rainy season		• 0.5 m
[During the Operational Phase]			
River reach	Absolute Minimum Flow	[Water depth]	Max Fluctuations
Downstream of the re-regulation dam	Min 5.5 m^3/s at all times in the dry season and in the rainy season	• Min water depth in m in the entire reach from downstream of the re-regulating pond until 4.3km during dry and rainy season respectively (measured at the deepest point in any cross-section)	• 1.7 m Max fluctuation in any 24 hour period • 1.7m Max fluctuation in any period of seven consecutive days • Max rate of change is 0.6n m/h • Max frequency in events per 24 hours and in any 7 days consecutive period

6.1.1 *Navigation*

During initial impoundment the minimum water depth is actually higher than the minimum water depth (0.5m) by 0.3 m due to more outflow from the re-regulation dam. So the ability to navigate by local boats or canoe with shallow draft will continue.

During the operation phase, the minimum daily flow depth will be further improved to 1 m and the boat navigation is anticipated to be recovered to the pre-dam conditions. Effects on navigation therefore should not pose a concern to downstream river users.

6.1.2 *Drinking, Irrigation, Agricultural Water Demand related to the NNP River*

The villages in the area downstream of the re-regulation dam do not rely on the NNP River for their drinking water. The small amount of drinking water and household consumption (overall estimated to be just over 5,000 m3/d) will be satisfied by the environmental flow. Hence the river flow regulation is not expected cause impacts to downstream drinking water and household consumption.

The downstream agricultural demand is largely dependent upon rainfall rather than river water withno irrigation system observed during surveys. Small vegetable plots that are planted at a time to take advantage of when waters are high and accessible, would be impacted. Considering the small demand for this water, the overall impact is rated to be of minor.

6.1.3 *Aquatic Biota and Fisheries*

Difficulties arise in assessing impacts on fisheries, or making recommendations to mitigate them, because tropical flood-cycle rivers remain one of the most complex ecosystems to understand or study and there is often limited information as to the processes and relationships of species in these areas. This section makes some initial assessments given the information presented earlier in the report regarding baseline condition and predicted changes to the downstream NNP River.

Major impacts to fish populations and fisheries can potentially arise from: changes to habitats e.g. submerging rapids and loss of riffle areas e.g. change to bottom substrates from sandy substrate to rocky bottom e.g. reduction of river width, etc; changes to seasonal/daily flows e.g. increase in the dry season and reduce in the wet season e.g. rapid fluctuations in river depth/ velocity/ width; alteration of aquatic environmental conditions such as nutrient load/ DO levels, temperature; and blocking of any upstream wet-season spawning migration.

Direct and indirect impacts on the aquatic biota and fisheries resources due to the construction of the dams and associated infrastructure, including habitat loss, habitat fragmentation and barrier to movement etc, have been discussed and evaluated, and associated mitigation measures/ offsets (including fish enhancement program) were also recommended in the Project EIA Report and *Biodiversity Offset Design Report*. There were 47 fish species, including one protected species (Apollo shark minnow *Luciosoma bleekeri*) and six endangered, vulnerable or near threatened species (Yellow tail brook barb *Poropuntius deauratus* (EN), Mrigal carp *Cirrhinus cirrhosis* (VU), Jaguar loach *Yasuhikotakia splendida* (VU), *Mekongina erythrospila* (NT), Gnooch *Bagarius bagarius* (NT) and Giant Gnooch *Bagarius yarrelli* (NT)) in the downstream NNP River area as well as the potential existence of critical habitat for one species, *Luciocyprinus striolatus*.

A. *During initial impoundment*

During initial impounding which will last one wet season, the environmental flow will be just below 9 m^3/s taking into account the minimum riparian release of 5.5 m^3/s and natural inflows from tributaries into the regulation dam reservoir. Downstream of the 'Reduced Water 3 km Section' with the combination of minimum environmental flow and confluence with the Nam Xao River, river conditions to the confluence with the Mekong are also predicted to be sufficient to maintain similar ecosystem services as currently provided.

With respect to fisheries and aquatic fauna, potential impacts are confined principally to the local area of 'Reduced Water 3 km Section'. With regards to the potential critical habitat of *Luciocyprinus striolatus*, the studies indicated that this species' spawning sites were all above the main dam site and overall the downstream NNP river is considered relatively less sensitive with the absence of critical habitats for the species. With the temporal impact of the changes considered to be short-term (i.e. one wet season compared to the entire construction and operation duration) and the affected length of river relatively short compared to the total distance of the downstream reach from the re-regulation dam to the confluence with the Mekong River, any potential impacts during initial impoundment are unlikely to be significant.

B. During normal operation

Under normal operation of the Project, the aquatic biota will experience weekly changes of flow from 160.0 m^3/s to 27.0 m^3/s for 17 hours from 10pm Sat to 3pm Sun during which time the environmental flow will be released through the re-regulation dam gate from the reservoir surface water. On average the frequency when the daily outflow from the re-regulation dam is at the minimum 27.0 m^3/s, is 0.5 % (i.e. less than 1.5 days /year over 30 years). For most of the operational period the environmental flow will therefore be higher than the proposed amount.

As noted above, the lower NNP river stretch is regarded a relatively less sensitive compared to the reaches above the dam site. While any reduced flow and water depth of the river may affect the abundance and richness of fish and benthic fauna (also considered as a food source for fish species) in the long term, with the provision of a 27.0 m^3/s minimum environmental flow from the re-regulation dam, any potential impacts are likely to be mainly to the relatively short 'Reduced Water 3 km Section'.

DO levels are maintained above a level that supports aquatic life (considered to be 5 mg/L) almost year round since the DO concentration of discharged water from the re-regulating dam is over 6 mg/L almost all the year.

It is noted that the impact of increased water temperature on aquatic life in the project area was assessed indirectly by referring to the other dam studies of the similar nature in the region (Lessard and Hayes, 2003) and may not be reflective of the real life situation in this case. Nevertheless, the assessment indicates that the main evident downstream change due to increases in temperatures was that macro-invertebrates showed shifts in community composition. With reference to this study, at a minimum it is expected that there will be changes in the community composition of macro-invertebrates in the lower NNP1 River that are predicted to experience significant increases in temperature (up to 4°C).

The reduction in sediment load downstream of dam in the Lower NNP River may affect the natural erosion/ deposition of the river and the change in nutrient of the water may also affect fisheries through a decline in available food. Given the unknown severity of these impacts, as per recommendations in the EIA, it is suggested that an effective and regular monitoring system should be in place to help determine the actual impacts the dam may have on downstream aquatic life and the associated ecosystem services during construction and throughout the operation of the dam.

6.2 *WATERSHED MANAGEMENT ACTIVITIES IN THE NAM NGIEP WATERSHED*

Watershed management activities above and below the Nam Ngiep Dam will provide opportunities to improve the aquatic and riparian habitats of the watershed. Combined with the environmental flow regime, these management actions will have the objectives of:

- Improving knowledge of aquatic biodiversity values in Lao PDR;
- Engaging the community in watershed management;
- Managing key threats to water quality and aquatic habitats; and
- Monitoring and evaluating the effectiveness of management actions on water quality and aquatic habitats.

Management of fish habitat, targeting to protect and enhance habitat for fish species lifecycle, is one of the recommended watershed management activities that can also be considered as a measure for the change of flow due to the Project and details please refer to the *NNP1 Biodiversity Offset Design Report*.

7 MONITORING PLAN

7.1 HYDROLOGIC AND WATER QUALITY MONITORING PLAN

The monitoring will be conducted periodically at selected sites upstream from the reservoir, in the reservoir and downstream from the dam. The monitoring will be divided into two phases, one during construction and the other during operation. The monitoring locations and frequency will be decided in accordance with the Concession Agreement and EIA report. As needed, in response to an emergency (such as fish dying downstream, foul odours, excessive algal growth) or viable complains from people around the reservoir or downstream, additional monitoring and countermeasures should be implemented.

The monitoring parameters, measuring points and frequencies are outlined below.

7.1.1 *During construction phase*

- Monthly to observe parameters of hydrologic (flow depth, velocity, river wetted cross section area, surface width), physical and chemical water quality (temperature, pH, conductivity, turbidity, suspended solid, total dissolved solid), biological water quality (DO, COD, BOD5), and bacteriological water quality (total coliform and faecal coliform) at sites upstream from the dam (at two (2) sites – most upstream and most downstream points within the main reservoir) and downstream (at two (2) sites – one immediately downstream from the re-regulating dam and another farther downstream before the confluence with the Nam Xao River);

- Seasonally (3 times/year in wet, dry and transition period) to report all the above parameters, plus Cyanide;

- Quarterly during the inundation period only, for ambient water quality parameters as listed in *Table 7.1*, in addition to the above parameters, plus Cyanide; and

- At each sampling place, water samples will be taken from three water depths, surface, middle and bottom water layers in the deepest water. Within the reservoir at each station, samples will be collected from at least 5 different depths. In addition, if monitoring results show water quality parameter exceedances or any impacts to water quality occur as a result of the Project, the Project will carry out an investigation in order to discover the cause of such as impact, and remedial actions will be considered;

7.1.2 *During operation phase*

- Bi-weekly tests (short to medium term) – to observe flow depth, velocity, river wetted cross section area, surface width, temperature, pH, conductivity, turbidity, SS, DO, COD, BOD5, total coliform and faecal coliform at sites upstream (at two (2) sites – most upstream and most downstream points within the main reservoir) and downstream (at one (1) site – immediately downstream from the re-regulating dam);

- Seasonally (3 times/year in wet, dry and transition period) (long-term) – to observe physical and chemical water quality (temperature, pH, conductivity, turbidity, suspended solid, total dissolved solid), biological water quality (DO, COD, BOD5, P, PO43-, N, NO3-, NH3), bacteriological water quality (total coliform and faecal coliform) and Cyanide at the three sites;

- Quarterly (long-term)– observe the ambient water quality parameters as listed in *Table 7.1* in addition to the above parameters;

- At each sampling place, water samples will be taken from three water depths, surface, middle and bottom water layers in the deepest water. Within the reservoir, water quality parameters at the intake level should be also measured and analysed. Within the reservoir at each station, samples will be collected from at least 5 different depths. In addition, if monitoring results show water quality parameter exceedances or any impacts to water quality occur as a result of the Project, the Project will carry out an investigation in order to discover the cause of such as impact, and remedial actions will be considered;

- As needed, to observe any parameters considered important in response to an emergency (such as fish dying downstream, foul odours, excessive algal growth) or viable complaints from people around the reservoir or downstream.

Table 7.1 Summary of Water Quality Monitoring

	Construction period				**Operation period**		
	Most upstream in the main reservoir	**Most downstream in the main reservoir**	**Immediately downstream of the re-regulation dam**	**Further downstream from the re-regulation dam**	**Most upstream in the main reservoir***	**Most downstream in the main reservoir***	**Immediately downstream of the re-regulation dam***
Temperature	Monthly	Monthly	Monthly	Monthly	Biweekly- 3 times/year	Biweekly- 3 times/year	Biweekly- 3 times/year
pH	Monthly	Monthly	Monthly	Monthly	Biweekly- 3 times/year	Biweekly- 3 times/year	Biweekly- 3 times/year
Conductivity	Monthly	Monthly	Monthly	Monthly	Biweekly- 3 times/year	Biweekly- 3 times/year	Biweekly- 3 times/year
Turbidity	Monthly	Monthly	Monthly	Monthly	Biweekly- 3 times/year	Biweekly- 3 times/year	Biweekly- 3 times/year
SS	Monthly	Monthly	Monthly	Monthly	Biweekly- 3 times/year	Biweekly- 3 times/year	Biweekly- 3 times/year
TDS	Monthly	Monthly	Monthly	Monthly	Biweekly- 3 times/year	Biweekly- 3 times/year	Biweekly- 3 times/year
DO	Monthly	Monthly	Monthly	Monthly	Biweekly- 3 times/year	Biweekly- 3 times/year	Biweekly- 3 times/year
COD	Monthly	Monthly	Monthly	Monthly	Biweekly- 3 times/year	Biweekly- 3 times/year	Biweekly- 3 times/year
BOD5	Monthly	Monthly	Monthly	Monthly	Biweekly- 3 times/year	Biweekly- 3 times/year	Biweekly- 3 times/year
Total coliform Bacteria	Monthly	Monthly	Monthly	Monthly	Biweekly- 3 times/year	Biweekly- 3 times/year	Biweekly- 3 times/year
Total faecal Coliform	Monthly	Monthly	Monthly	Monthly	Biweekly- 3 times/year	Biweekly- 3 times/year	Biweekly- 3 times/year
Cyanide	3 times/year	4 times/ year	5 times/year	6 times/year	7 times/year	8 times/year	9 times/year
Ambient water quality parameters as listed in *Table 7.2* other than above parameters	Quarterly during inundation only	Quarterly during inundation only	Quarterly during inundation only	-	Quarterly	Quarterly	Quarterly

*First frequency given is for short/medium term and second is for long term monitoring

7.2 *WATER QUALITY STANDARD*

The water quality standard is prescribed in accordance with the *Annex C* in the Concession Agreement. The related water quality standards are shown in *Table 7.2.*

Table 7.2 Ambient Surface Water Quality Standard in Annex C – Concession Agreement

Parameter	Unit	Standard
pH		5-9
Dissolved Oxygen	mg/l	>6.0
BOD5	mg/l	1.5
COD	mg/l	5.0
Nitrogen as nitrate (N-NO3)	mg/l	5.0
Nitrogen as ammonia (N-NH3)	mg/l	0.2
Sulfate	mg/l	500
Total coliform bacteria	MPN/ml	5,000
Total faecal coliform	MPN/ml	1,000
Phenols	mg/l	0.005
Arsenic (As)	mg/l	0.01
Cadmium (Cd) CaCO3 ≤ 100 mg/l	mg/l	0.005
Cadmium (Cd) CaCO3 ≥ 100 mg/l	mg/l	0.05
Chromium (VI) (Cr6+)	mg/l	0.05
Copper (Cu)	mg/l	0.1
Cyanide	mg/l	0.005
Lead (Pb)	mg/l	0.05
Mercury (Hg)	mg/l	0.002
Nickel (Ni)	mg/l	0.1
Zinc (Zn)	mg/l	1.0
Manganese (Mn)	mg/l	1.0
Alpha ¬Radioactivity	Becquerel/l	0.1
Beta ¬ Radioactivity	Becquerel/l	1.0
Total Organochlorine	mg/l	0.05
DDT	mg/l	1.0
Alpha-BHC	mg/l	0.02
Dieldrin	mg/l	0.1
Aldrin	mg/l	0.1
Heptachlor and Heptachlor Epoxide	mg/l	0.2
Endrin	mg/l	0

7.3 *FISH MONITORING PLAN*

Despite extensive studies on fish and fisheries in and around the Project Area, quantitative studies are still necessary to gain a better understanding of this subject relative to the Project. Also, given the uncertainty of the effects of some of the changes due to the environmental flow (e.g. water temperature, potential change in nutrient load), it is imperative that an effective and regular monitoring system be established to determine the actual impact of the NNP1 dam on downstream aquatic life during construction and throughout the operation of the dam and alert relevant authorities to any adverse impacts on fish as early as possible so that mitigation measure might be considered and set up.

In particular the impacts on fish biomass should be addressed by monitoring fisheries as early as possible, prior to the start of construction, to later help assess any potential impacts from the Project. These impacts must be considered in the wider context of the full ranges of fish species and potential cumulative impacts.

The EIA report details several options regarding the mitigation of potential impacts on fish resources including captive breeding; research management, education, monitoring and governance of the watershed including for fishing and poaching; species recovery coordination across government agencies, etc.

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Annex A

Water Quality Test Results

A1 *RESULTS OF WATER QUALITY ANALYSIS NAM NGIEP RIVER AT B HAT GNIUN, B HOUAY SOUP AND B POU IN JULY 2012 AND FEB 2013*

pH						
date	**B Hat Gniun**	**B Houay Soup**	**B Pou**	**Ambient,Effluent(Max)**	**Ambientt(Min)**	**Effluent(Min)**
2012.07.24	9.7	6.2		9	5	6
2012.08.10		6.4		9	5	6
2013.02.15	8.3			9	5	6
2013.02.16			8.1	9	5	6

Do					
date	**B Hat Gniun**	**B Houay Soup**	**B Pou**	**Ambient**	**Effluent**
2012.07.24	9.7	8		6	
2012.08.10		8.8		6	
2013.02.15	10.3			6	
2013.02.16			7.8	6	

BOD					
date	**B Hat Gniun**	**B Houay Soup**	**B Pou**	**Ambient**	**Effluent**
2012.07.24	3	2		2	30
2012.08.10		2		2	30
2013.02.15				2	30

COD					
date	**B Hat Gniun**	**B Houay Soup**	**B Pou**	**Ambient**	**Effluent**
2012.07.24	4	2		5	125
2012.08.10		4		5	125
2013.02.15	2			5	125
2013.02.16			2	5	125

Turbidity			
date	**B Hat Gniun**	**B Houay Soup**	**B Pou**
2012.07.24	192.3	153.84	
2012.08.10		153.84	
2013.02.15	153.84		
2013.02.16			153.84

Water temperature			
date	**B Hat Gniun**	**B Houay Soup**	**B Pou**
2012.07.24	25.4	25.4	
2012.08.10		24.8	
2013.02.15	26.1		
2013.02.16			26.4

A2 RESULTS OF WATER QUALITY ANALYSIS NAM NGIEP RIVER MARCH 2013

Station No.	Cumulative Distance (km)	E	N	Time	Water Temp (°C)	pH	Conductivity (uS/cm)	TDS (mg/L)	DO (mg/L)	Turbidity (FTU)	Turbidity (NTU)	Total Coliform	Physical
SW-1	**0**	**344191**	**2062133**	**10:42**	**26.6**	**8.12**	**95**	**47**	**7.1**	**NM**	**9.17**	**12**	**Sunny/Clear / odourless/ Medium flow**
SW-2	**4.29**	**347507**	**2062246**	**12:41**	**27.7**	**8.01**	**97**	**55**	**6.9**	**NM**	**8.32**	**3**	**Sunny/Clear / odourless/ Medium flow**
201	5.17	348295	2062526	12:48	27.5	8.15	94	46	6.3	NM	-	-	Sunny/Clear / odourless/ Medium flow
202	6.15	349181	2062555	12:51	27.5	8.19	92	46	6.5	NM	-	-	Sunny/Clear / odourless/ Medium flow
203	7.17	350022	2062701	12:56	27.6	8.18	93	46	4.3	NM	-	-	Sunny/Clear / odourless/ Medium flow
204	8.19	350176	2063595	13:00	29.2	8.21	97	48	4.4	NM	-	-	Sunny/Clear / odourless/ Medium flow
SW-3	**9.14**	**350994**	**2063234**	**13:03**	**28.8**	**8.16**	**93**	**47**	**6.5**	**NM**	**6.17**	**3**	**Sunny/Clear / odourless/ Medium flow**
301	10.2	351840	2062703	13:10	28.4	8.22	94	47	6.8	NM	-	-	Sunny/Clear / odourless/ Medium flow
SW-4	**11.2**	**352339**	**2061963**	**13:14**	**27.7**	**8.14**	**96**	**48**	**7.1**	**NM**	**7.16**	**6**	**Sunny/Clear / odourless/ Medium flow**
401	12.2	352375	2060981	13:20	28.4	8.09	94	46	6.9	NM	-	-	Sunny/Clear / odourless/ Medium

Station No.	Cumulative Distance (km)	E	N	Time	Water Temp (°C)	pH	Conductivity (uS/cm)	TDS (mg/L)	DO (mg/L)	Turbidity (FTU)	Turbidity (NTU)	Total Coliform	Physical
													flow
402	13.2	352361	2060033	13:23	28	8.17	94	46	7	NM	-	-	Sunny/Clear / odourless/ Medium flow
403	14.1	352496	2059277	13:27	28.1	8.17	93	46	7.1	NM	-	-	Sunny/Clear / odourless/ Medium flow
404_DS of Houy Soup	15.4	352318	2058113	13:31	28.6	8.2	94	46	6	NM	8.05	-	Sunny/Clear / odourless/ Medium flow
405	16.2	352290	2057567	13:34	28.2	8.19	93	46	7	NM	-	-	Sunny/Clear / odourless/ Medium flow
406	17.3	352596	2056700	13:38	28.2	8.2	93	47	6.5	NM	-	-	Sunny/Clear / odourless/ Medium flow
407	18.2	353258	2056287	13:41	28.1	8.17	94	47	7	NM	-	-	Sunny/Clear / odourless/ Medium flow
408	19.2	352768	2055462	13:44	27.9	8.18	91	45	6.6	NM	-	-	Sunny/Clear / odourless/ Medium flow
409	20.4	353014	2054559	13:48	28	8.15	98	46	5.2	NM	-	-	Sunny/Clear / odourless/ Medium flow
410	21.2	353480	2053919	13:51	28.2	8.13	94	46	5.5	NM	-	-	Sunny/Clear / odourless/ Medium flow
411	22.2	354140	2053232	13:54	28.2	8.13	92	46	6.9	NM	-	-	Sunny/Clear / odourless/ Medium

Station No.	Cumulative Distance (km)	E	N	Time	Water Temp (°C)	pH	Conductivity (uS/cm)	TDS (mg/L)	DO (mg/L)	Turbidity (FTU)	Turbidity (NTU)	Total Coliform	Physical
													flow
412	23.2	354940	2052645	13:57	28.1	8.12	94	47	6.6	NM	-	-	Sunny/Clear / odourless/ Medium flow
413	24.5	355942	2051955	14:00	28.1	8.06	92	47	6.3	NM	-	-	Sunny/Clear / odourless/ Medium flow
414	25.2	355734	2051360	14:03	28.2	8.1	92	47	6.7	NM	-	-	Sunny/Clear / odourless/ Medium flow
415	26.1	356360	2050922	14:05	28.7	8.07	92	47	6.9	NM	-	-	Sunny/Clear / odourless/ Medium flow
416	27.3	357160	2050357	14:09	28.3	8.07	94	46	6.5	NM	-	-	Sunny/Clear / odourless/ Medium flow
417	28.1	356692	2049737	14:11	28.2	8.02	93	46	6.4	NM	-	-	Sunny/Clear / odourless/ Medium flow
418	29.1	356750	2048962	14:14	28.2	8.06	92	46	6.8	NM	-	-	Sunny/Clear / odourless/ Medium flow
419	30.2	357308	2048258	14:18	28.5	8.04	93	45	6.9	NM	-	-	Sunny/Clear / odourless/ Medium flow
420	31.2	357798	2047445	14:21	28.4	8.04	93	46	6.8	NM	-	-	Sunny/Clear / odourless/ Medium flow
421	32.2	358252	2046605	14:24	28.7	8.04	94	46	6.8	NM	-	-	Sunny/Clear / odourless/ Medium flow

Station No.	Cumulative Distance (km)	E	N	Time	Water Temp (°C)	pH	Conductivity (uS/cm)	TDS (mg/L)	DO (mg/L)	Turbidity (FTU)	Turbidity (NTU)	Total Coliform	Physical
422	33.3	357509	2045919	14:27	28.4	8.01	95	46	7.1	NM	-	-	Sunny/Clear / odourless/ Medium flow
423	34.1	357196	2045265	14:30	28.5	8.01	93	46	7.2	NM	-	-	Sunny/Clear / odourless/ Medium flow
424	35.1	356700	2044695	14:33	29.2	8.04	92	45	6.5	NM	-	-	Sunny/Clear / odourless/ Medium flow
SW-5	**36.5**	**355618**	**2044464**	**14:41**	**28.9**	**7.97**	**92**	**47**	**7.3**	**NM**	**5.03**	**5**	**Sunny/Clear / odourless/ Medium flow**
SW-6	**37.9**	**354831**	**2044030**	**14:48**	**29.8**	**8.1**	**99**	**49**	**5.9**	**NM**	**6.81**	**7**	**Sunny/Clear / odourless/ Medium flow**

NM = Not measurable

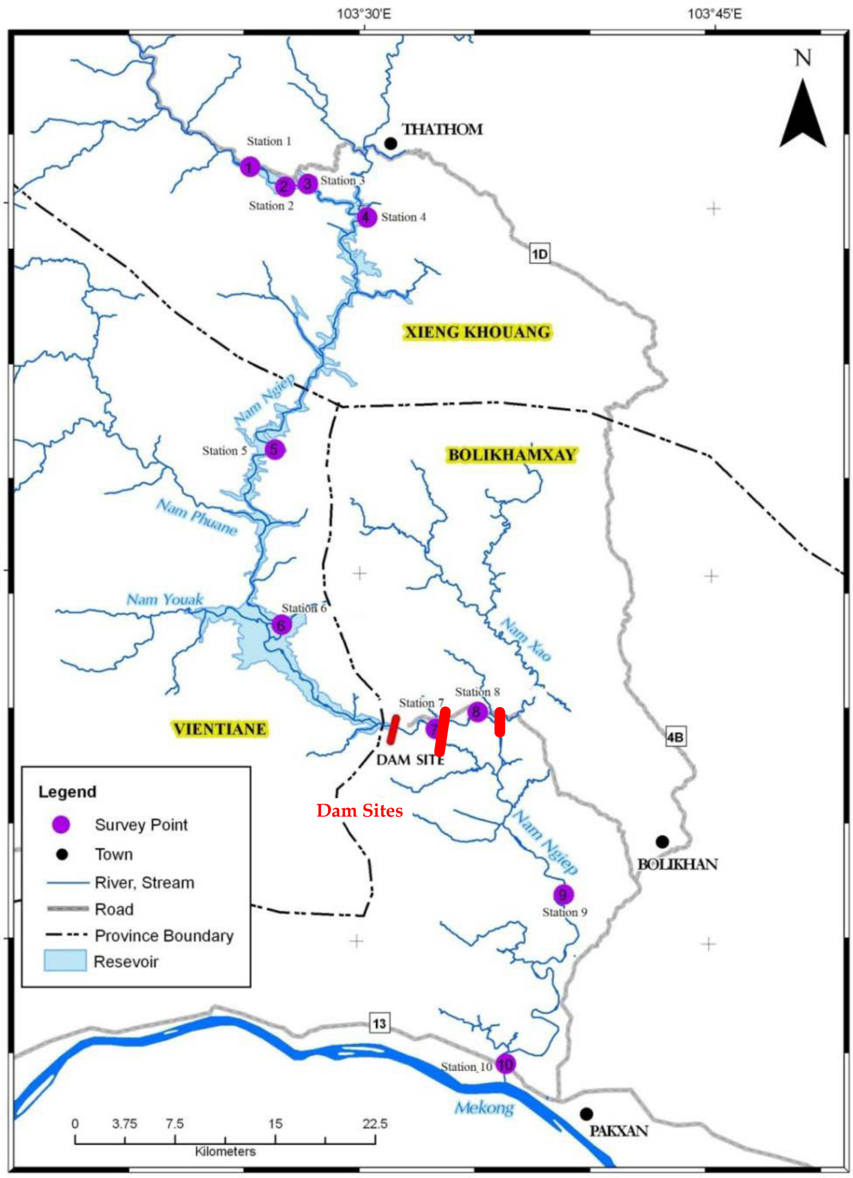
Annex B

Fish and Fisheries Survey Locations along the Nam Ngiep River in January 2008

B1 *FISH AND FISHERIES SURVEY LOCATIONS ALONG THE NAM NGIEP RIVER IN JANUARY 2008*

No.	Name	Location			Coordinate	
		Village	District	Province	N	E
1	Station 1	Piengta	Thathom	Xieng Khouang	19°01′33.6″	103°25′09.6″
2	Station 2	Hatsamkhone	Thathom	Xieng Khouang	19°00′46.0″	103°26′40.3″
3	Station 3	Pou	Thathom	Xieng Khouang	19°00′52.5″	103°27′37.7″
4	Station 4	Houypamom	Hom	Vientiane	18°59′32.6″	103°30′10.5″
5	Station 5	Sopphuane	Hom	Vientiane	18°50′01.9″	103°26′19.9″
6	Station 6	Sopyouak	Hom	Vientiane	18°42′53.7″	103°26′40.9″
7	Station 7	Hatsaykham	Bolikhan	Bolikhamxay	18°38′41.1″	103°33′17.4″
8	**Station 8**	**Hat Gniun**	**Bolikhan**	**Bolikhamxay**	**18°39′23.6″**	**103°35′03.6″**
9	Station 9	Somseun	Bolikhan	Bolikhamxay	18°25′03.5″	103°36′22.6″
10	Station 10	Pak Ngiep	Pakxan	Bolikhamxay	18°31′58.8″	103°38′48.3″

FIGURE B1 FISH AND FISHERIES SURVEY LOCATIONS ALONG THE NAM NGIEP RIVER



Annex C

Results of Non-uniform Flow Analysis

C1. SUMMARY OF ANALYSIS

C1.1ANALYTIC METHOD

Water flow condition downstream of the re-regulation dam is analyzed through non-uniform flow analysis.

Unknown hydraulic value such as water level, water velocity and etc., upstream are calculated by the hydraulic value downstream by applying the energy constant law as follows;

$$z_1 + h_1 + \frac{v_1^2}{2g} + h_l = z_2 + h_2 + \frac{v_2^2}{2g}$$

Here, *z: elevation of rive bed*

h: water depth

v; water velocity

h; loss in head

$$h_L = \frac{\Delta x}{2g}\left(\frac{n_1^2 v_1^2}{R_1^{4/3}} + \frac{n_2^2 v_2^2}{R_2^{4/3}}\right)$$

n; coefficient of roughness by manning equation = 0.04 checked by observed data

R; hydraulic mean depth

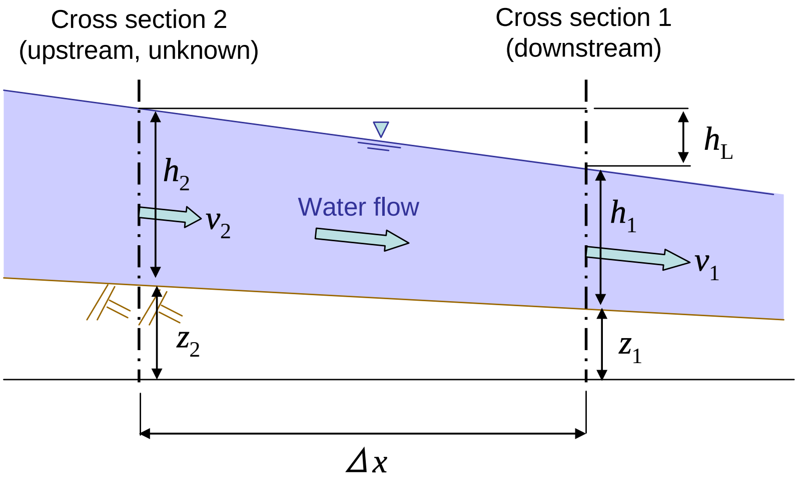


Figure C1 Image of hydraulic value

Software for non-uniform analysis named “ELNORE FUJITSU FIP Japan” is used for the analysis

C1.2 ANALYTIC CONDITION

C1.2.1 River cross section

The analysis is conducted in the sections between the downstream of the re-regulation dam and the confluence of Mekong River as shown in figure below. The total 37 sections are used for analysis. The drawings of river cross section of total 37 sections are attached in Appendix.

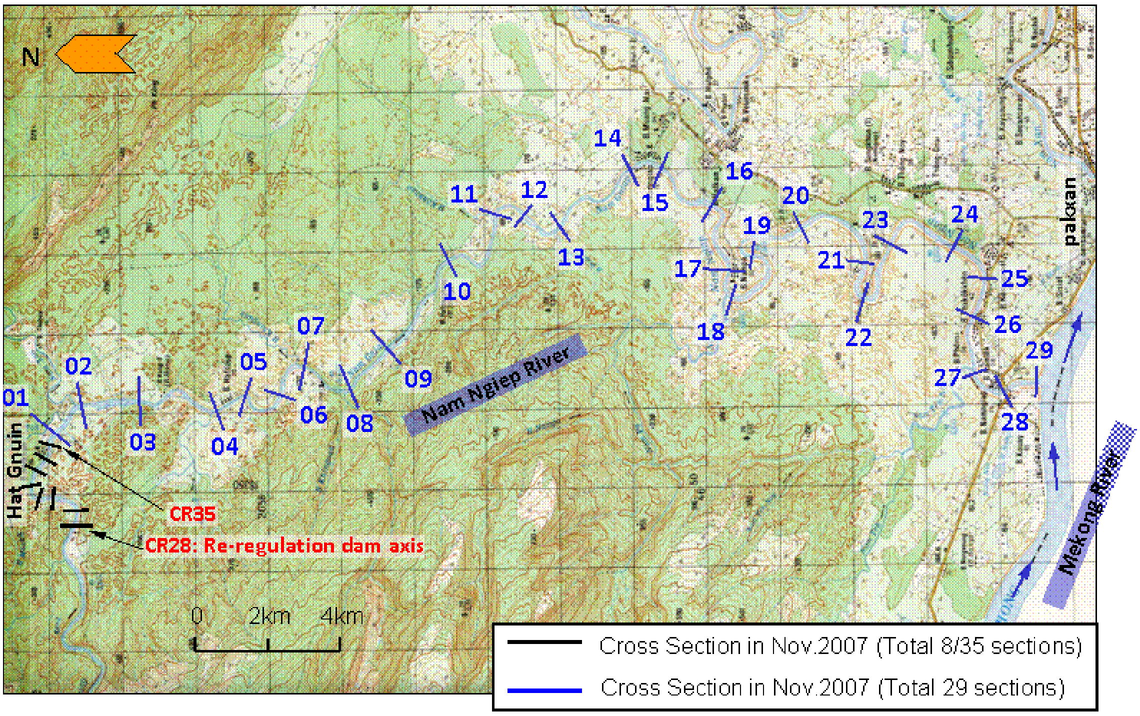


Figure C2 Analyzed section

1.2.2 Inflow from tributary of the Nam Ngiep River

Inflow from 12 tributaries of the Nam Ngiep River between the re-regulation dam and the confluence of the Mekong River are counted. The each inflow from these tributary is calculated by multiplied with the ratio of the basin area at the Nam Ngiep 1 dam site, respectively. The inflow from each tributary is calculated by multiplied the ratio of each river basin area to that of the Nam Ngiep River at the re-regulation dam.

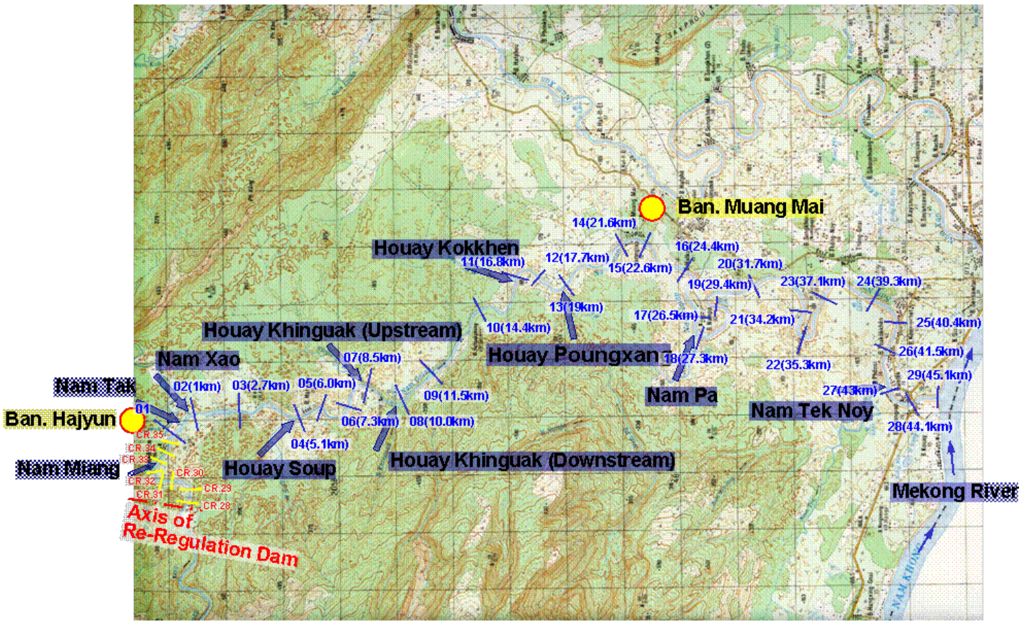


Figure C3 *Tributaries of Nam Ngiep River*

Table C 1 *Catchment area of tributary*

Tributary	Catchment area (km^2)
1 Nam Miang	33
2 Nam Tak	58
3 Nam Xao	311
4 Houay Soup	60
5 Houay Khinguak (Upstream)	27
6 Houay Khinguak (Downstream)	61
7 Houay Kokkhen	42
8 Houay Poungxang	12
9 Small tributary around B Muong Mai village	27
10 Nam Pa	90
11 Nam Tek Noy	102
12 Small tributary around Mekong	10
Total	833
Ref) Nam Ngiep at re-regulation dam	3,725

Table C2 Annual average inflow by applying inflow from tributaries in the case of release discharge of 48 m³/s from re-regulation dam

Section	Tributary	Catchment area (km^2)	Inflow from tributary (m^3/s)	Inflow at Nam Ngiep (m^3/s)
29				80.9
28				80.9
27	Nam Teknoy	102	4.1	80.9
26				76.8
25				76.8
24				76.8
23				76.8
22				76.8
21				76.8
20				76.8
19				76.8
18	Nam Pa	90	3.6	76.8
17				73.2
16				73.2
15	B Muong Mai	27	1.1	73.2
14				72.2
13	Houay Poungxan	12	0.5	72.2
12				71.7
11	Houay kokkhen	42	1.7	71.7
10				70.0
9				70.0
8	Houay khinguak	61	2.4	70.0
7	Houay Khinguak	27	1.1	67.6
6				66.5
5				66.5
4	Houay Soup	60	2.4	66.5
3				64.1
2	Nam Xao, Nam thak	369	14.8	64.1
1				49.3
CR35				49.3
CR34				49.3
CR33	Nam Miang	33	1.3	49.3
CR32				48.0
CR31				48.0
CR30				48.0
CR29				48.0
CR28	Re-regulation dam			48.0

1.2.3 Water level at the downstream end of Nam Ngiep River

For the calculation, the water level at the confluence of the Nam Ngiep River and the Mekong River is input as an initial condition. The observed water level data at Pakxan Gauging Station from 1991 to 2000 are applied as below.

Table C3 Water level of Mekong River in 1991 to 2000

(m)

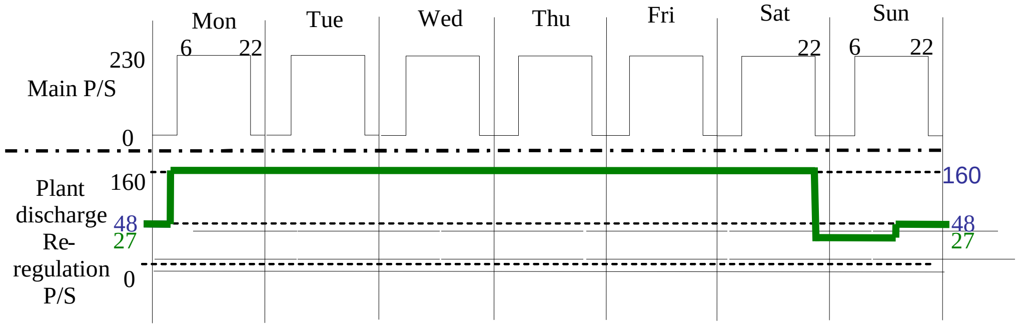
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
145.0	144.4	144.2	144.3	145.4	147.6	151.3	153.2	153.0	149.7	147.7	146.1	147.7

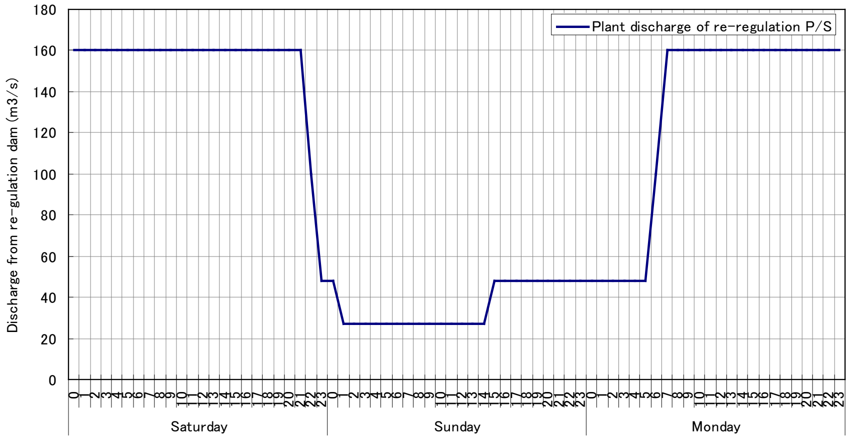
C2 STUDY CASE

Study case is shown in table below.

Table C4 Study case

Case	Operation type		Discharge from re-regulation dam (m^3/s)	Water level at downstream end (EL.m)
	Timing	Period		
1	6am Sat - 6am Mon	15 hrs/week	27	EL 147.7 m "Average of whole season"
2		17 hrs/week	48	
3	6am - 10pm Mon-Sa	16 hrs/day	160	
4	Initial impounding	15 days	5.5	EL 149.25 m "Sep, 1992"





C3 RESULTS OF STUDY

[Original plan in table 3-1]

- Minimum water depth and surface width

  The minimum water depth and surface width occur at the section CR31 and CR33 between the regulation dam and Ban Hat Gnuin respectively during initial impoundings of 5.5 m^3/s: 0.5 m and 16.1 m
- Maximum velocity

  The maximum velocity is around 1.3 m/s during normal operation of 160 m^3/s.
- Maximum fluctuation of water depth

  The maximum fluctuation of the water level change occurs at the section 19 when water release changes from 160 m^3/s to 27 m^3/s: 1.5 m.
- Maximum fluctuation of water flow velocity

  The maximum fluctuation of the water level change occurs at the section CR-31 when water release changes from 160 m^3/s to 27 m^3/s: 0.7 m/s.

[Case-1 to Case-3]

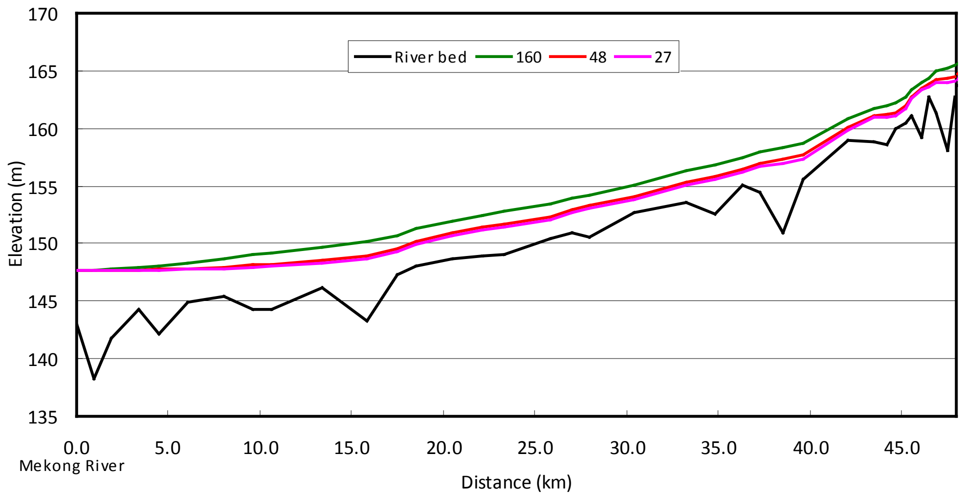


Figure C5 Water level along NNP River

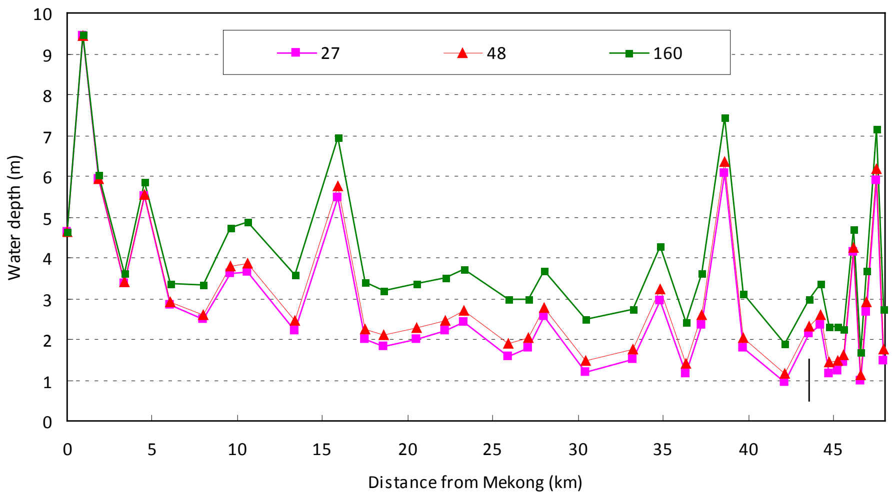


Figure C6 Water depth along the NNP River

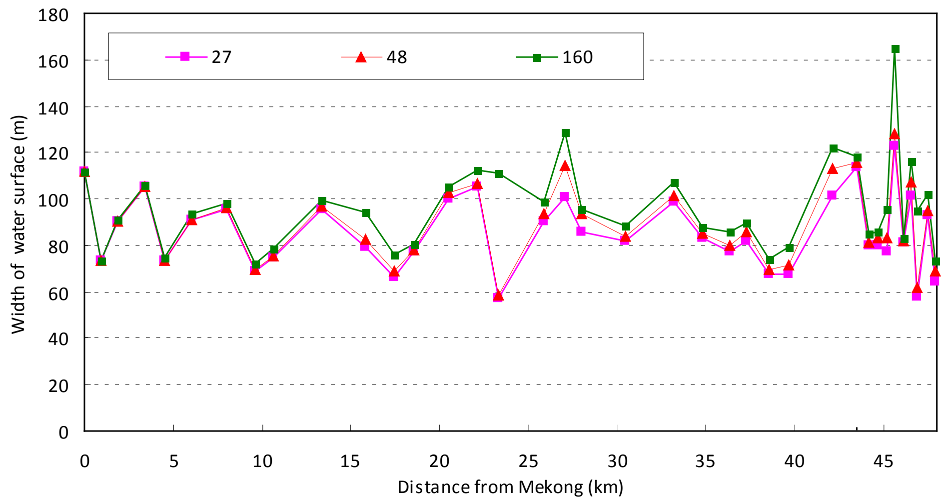


Figure C7 Width of river flow along the NNP River

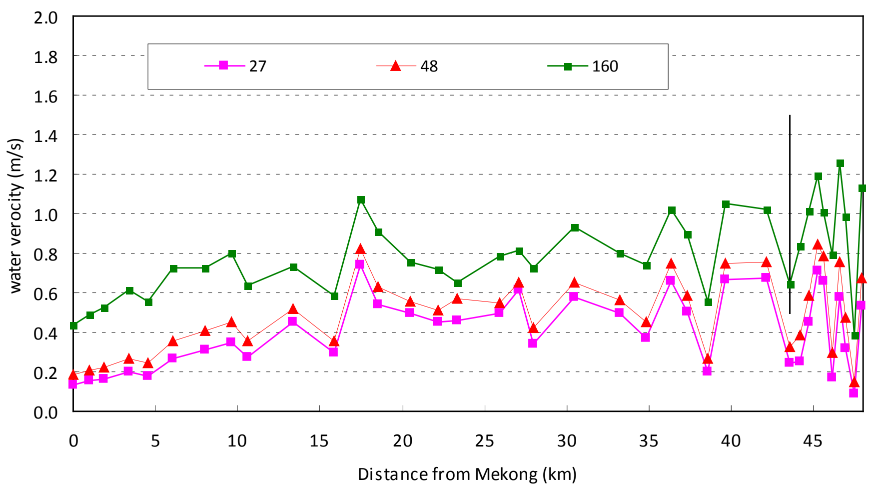


Figure C8 Water velocity along the NNP River

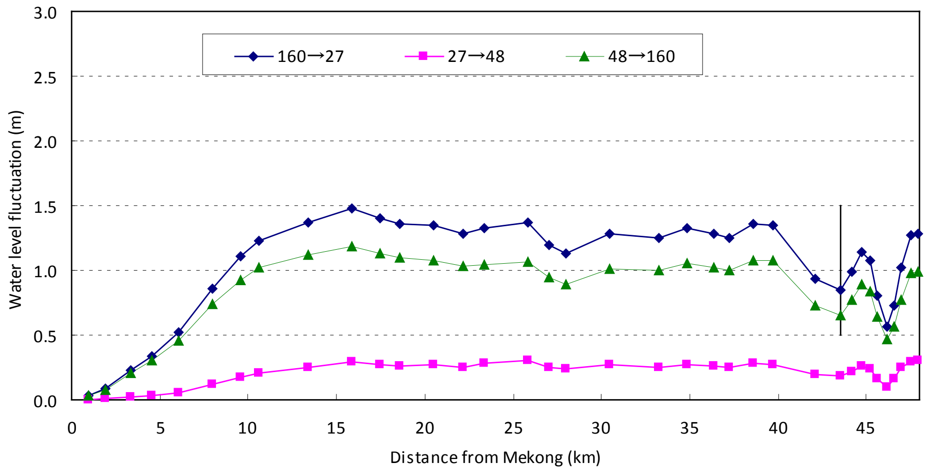


Figure C9 Fluctuation of water level along the NNP River

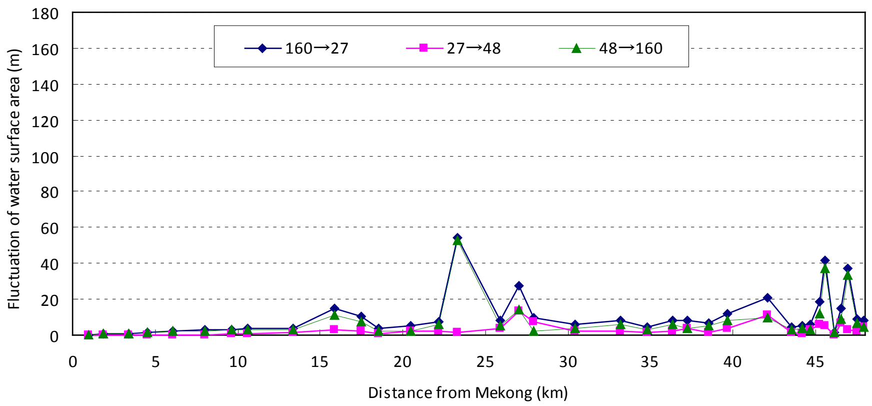


Figure C10 Fluctuation of water surface width along the NNP River

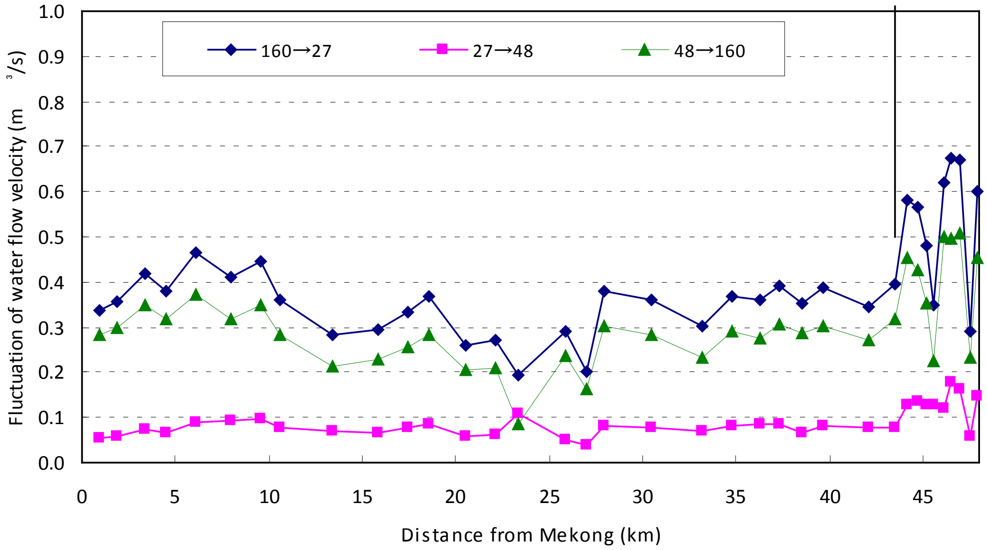


Figure C11 *Fluctuation of water flow velocity width along the NNP River*

Case- 4

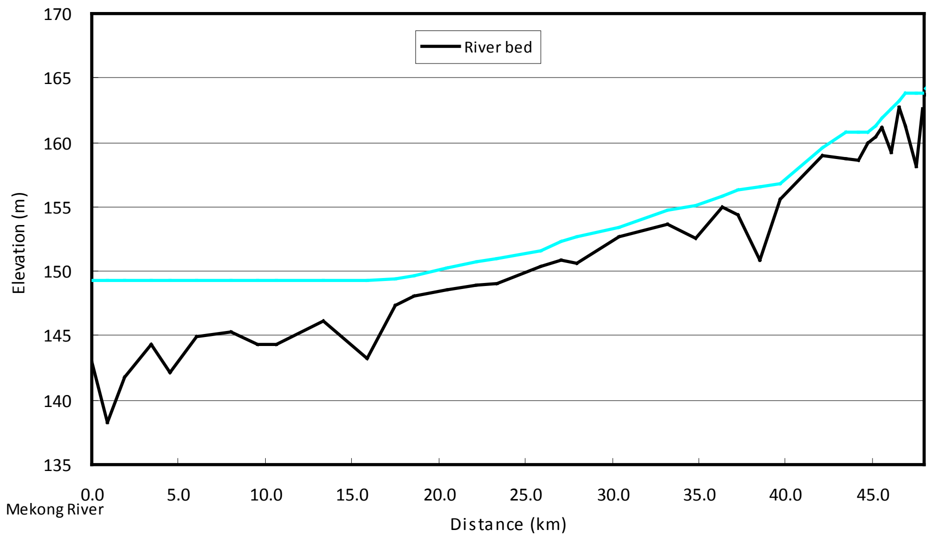


Figure C12 *Water level along NNP River*

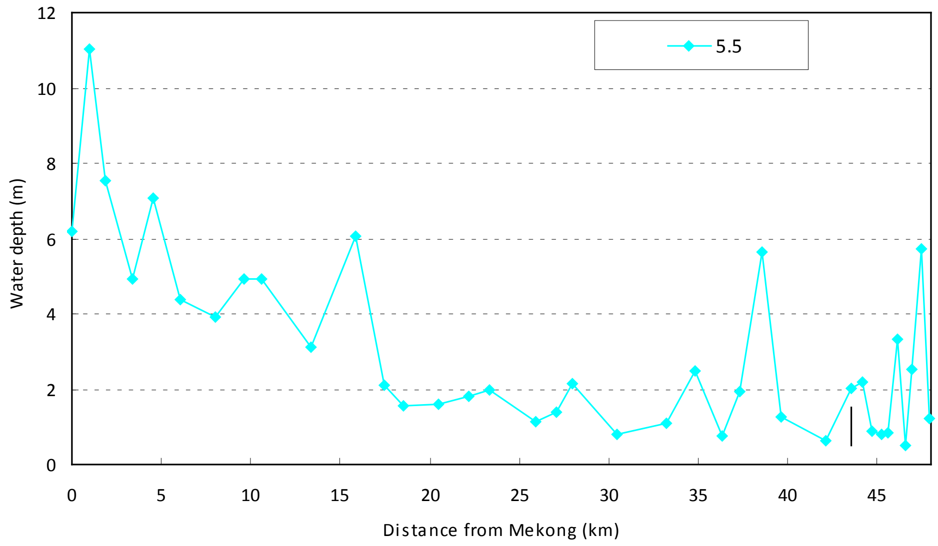


Figure C13 Water depth along the NNP River

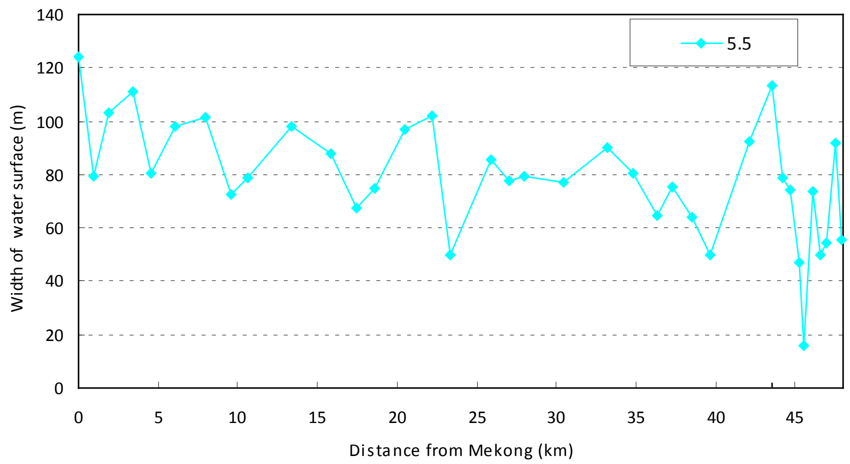


Figure C14 Width of river flow along the NNP River

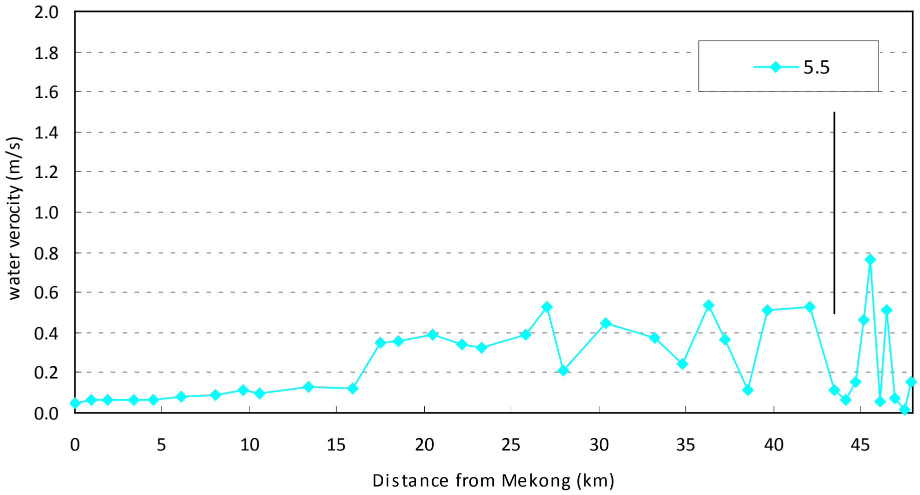


Figure C15 Water velocity along the NNP River

4-1 Data sheet of Case-1(27 m^3/s), Case-2(48 m^3/s), and Case 3(160 m^3/s)

Tributary	Distance from Mekong (km)	No.	River bed	Left bank	Right bank	Discharge (m^3/s)			Water level (EL.m)			Water depth (m)			Width of water surface (m)			Water velocity (m/s)		
						27	48	160	27	48	160	27	48	160	27	48	160	27	48	160
Mekong	0.0	29	143.0	154.3	154.3	59.9	80.9	192.9	147.7	147.7	147.7	4.6	4.6	4.6	112.0	112.0	112.0	0.1	0.2	0.4
	0.9	28	138.2	156.0	156.2	59.9	80.9	192.9	147.7	147.7	147.7	9.4	9.4	9.5	73.3	73.3	73.4	0.2	0.2	0.5
Nam Teknoy	1.9	27	141.7	154.4	154.4	59.9	80.9	192.9	147.7	147.7	147.8	5.9	5.9	6.0	90.3	90.3	90.9	0.2	0.2	0.5
	3.4	26	144.3	156.2	155.0	55.8	76.8	188.8	147.7	147.7	147.9	3.4	3.4	3.6	105.3	105.4	106.2	0.2	0.3	0.6
	4.5	25	142.2	160.3	155.7	55.8	76.8	188.8	147.7	147.7	148.0	5.5	5.5	5.8	73.1	73.3	74.8	0.2	0.2	0.6
	6.1	24	144.9	177.1	159.3	55.8	76.8	188.8	147.7	147.8	148.3	2.9	2.9	3.4	91.0	91.3	93.3	0.3	0.4	0.7
	8.0	23	145.4	156.5	156.4	55.8	76.8	188.8	147.8	148.0	148.7	2.5	2.6	3.3	95.6	95.9	98.3	0.3	0.4	0.7
	9.6	22	144.3	156.8	157.5	55.8	76.8	188.8	147.9	148.1	149.0	3.6	3.8	4.7	69.0	69.4	72.1	0.4	0.4	0.8
	10.6	21	144.3	157.8	156.0	55.8	76.8	188.8	148.0	148.2	149.2	3.7	3.9	4.9	74.6	75.2	78.4	0.3	0.4	0.6
	13.4	20	146.2	156.0	157.0	55.8	76.8	188.8	148.4	148.6	149.7	2.2	2.5	3.6	95.3	96.5	99.3	0.4	0.5	0.7
	15.9	19	143.2	158.0	160.2	55.8	76.8	188.8	148.7	149.0	150.2	5.5	5.8	6.9	79.4	82.7	94.0	0.3	0.4	0.6
Nam Pa	17.5	18	147.3	158.4	158.9	55.8	76.8	188.8	149.3	149.6	150.7	2.0	2.3	3.4	66.2	68.6	76.3	0.7	0.8	1.1
	18.5	17	148.1	159.3	158.7	52.3	73.3	185.3	149.9	150.2	151.3	1.8	2.1	3.2	77.0	78.1	80.4	0.5	0.6	0.9
	20.5	16	148.6	160.2	159.9	52.3	73.3	185.3	150.6	150.9	152.0	2.0	2.3	3.4	100.0	102.6	105.1	0.5	0.6	0.8
B Muong Mai	22.2	15	149.0	160.6	159.6	52.3	73.3	185.3	151.2	151.4	152.5	2.2	2.5	3.5	104.9	106.9	112.6	0.5	0.5	0.7
	23.3	14	149.0	160.4	160.6	51.2	72.2	184.2	151.4	151.7	152.8	2.4	2.7	3.7	56.9	58.4	111.1	0.5	0.6	0.7
Houay Poungxan	25.9	13	150.4	162.1	176.1	51.2	72.2	184.2	152.0	152.3	153.4	1.6	1.9	3.0	90.2	93.6	98.6	0.5	0.6	0.8
	27.0	12	150.9	163.1	162.2	50.7	71.7	183.7	152.7	152.9	153.9	1.8	2.0	3.0	100.7	114.1	128.3	0.6	0.7	0.8
Houay kokkhen	28.0	11	150.6	168.6	163.2	50.7	71.7	183.7	153.1	153.4	154.2	2.5	2.8	3.7	85.9	93.5	95.8	0.3	0.4	0.7
	30.4	10	152.6	164.5	163.3	49.0	70.0	182.0	153.8	154.1	155.1	1.2	1.5	2.5	82.1	84.1	88.1	0.6	0.7	0.9
	33.2	9	153.6	167.1	164.5	49.0	70.0	182.0	155.1	155.4	156.4	1.5	1.8	2.8	99.0	101.1	107.1	0.5	0.6	0.8
Houay khinguak	34.8	8	152.6	165.3	166.4	49.0	70.0	182.0	155.5	155.8	156.8	2.9	3.2	4.3	83.4	84.9	87.6	0.4	0.5	0.7
Houay Khinguak	36.3	7	155.0	182.1	166.0	46.6	67.6	179.6	156.2	156.5	157.5	1.2	1.4	2.4	77.6	79.9	86.0	0.7	0.7	1.0
	37.3	6	154.4	166.4	167.2	45.5	65.5	178.5	156.7	157.0	158.0	2.4	2.6	3.6	81.7	85.7	89.6	0.5	0.6	0.9
	38.6	5	150.9	194.1	165.9	45.5	65.5	178.5	157.0	157.3	158.4	6.1	6.4	7.4	67.6	69.4	74.3	0.2	0.3	0.6
Houay Soup	39.7	4	155.6	168.5	169.3	45.5	65.5	178.5	157.4	157.6	158.7	1.8	2.0	3.1	67.8	71.2	79.4	0.7	0.7	1.1
	42.1	3	158.9	189.0	186.1	43.1	64.1	176.1	159.9	160.1	160.8	0.9	1.1	1.9	101.5	112.8	122.4	0.7	0.8	1.0
Nam Xao, Nam th	43.5	2	158.8	172.4	170.3	43.1	64.1	176.1	160.9	161.1	161.8	2.1	2.3	3.0	114.0	115.5	118.3	0.2	0.3	0.6
	44.2	1	158.6	170.6	172.3	28.3	49.3	161.3	161.0	161.2	161.9	2.4	2.6	3.4	80.1	81.3	85.2	0.3	0.4	0.8
	44.7	CR-35	159.9	172.5	172.0	28.3	49.3	161.3	161.1	161.3	162.2	1.2	1.4	2.3	80.2	83.1	86.0	0.4	0.6	1.0
B Hat Gniun	45.2	CR-34	160.5	172.2	171.2	28.3	49.3	161.3	161.7	161.9	162.8	1.2	1.5	2.3	1.2	83.3	95.6	0.7	0.8	1.2
Nam Miang	45.6	CR-33	161.1	172.6	172.9	28.3	49.3	161.3	162.5	162.7	163.3	1.4	1.6	2.2	1.4	127.9	165.0	0.7	0.8	1.0
	46.1	CR-32	159.2	180.3	171.5	27.0	48.0	160.0	163.4	163.5	163.9	4.1	4.2	4.7	4.1	81.7	83.2	0.2	0.3	0.8
	46.5	CR-31	162.7	174.0	173.3	27.0	48.0	160.0	163.7	163.8	164.4	1.0	1.1	1.7	1.0	107.5	116.4	0.6	0.8	1.3
	46.9	CR-30	161.3	172.4	176.1	27.0	48.0	160.0	164.0	164.2	165.0	2.7	2.9	3.7	2.7	61.4	95.1	0.3	0.5	1.0
	47.5	CR-29	158.1	172.8	178.7	27.0	48.0	160.0	160.0	164.3	165.3	5.9	6.2	7.2	5.9	95.1	101.9	0.1	0.1	0.4
	47.9	CR-28	162.7	173.9	176.2	27.0	48.0	160.0	164.1	164.4	165.4	1.5	1.8	2.8	1.5	69.0	73.2	0.5	0.7	1.1
Average			151.6	166.7	165.0	46.1	67.1	179.1	154.5	154.7	155.5	2.9	3.1	3.9	70.1	88.5	96.1	0.4	0.5	0.8
Maximum			162.7	194.1	186.1	59.9	80.9	192.9	164.1	164.4	165.4	9.4	9.4	9.5	114.0	127.9	165.0	0.7	0.8	1.3
Minimum			141.7	154.4	154.4	27.0	48.0	160.0	147.7	147.7	147.8	0.9	1.1	1.7	1.0	58.4	72.1	0.1	0.1	0.4

Case-1

No.	Distance from Mekong (m)	River bed (EL.m)	Discharge (m^3/sec)	Area (m^2)	velocity (m/sec)	Width (m)	Hydraulic mean depth (m)	Coefficient of roughness	Coefficient of adjustment of energy head	Energy head (m)	Water level (m)	Water depth (m)	Critical water depth (m)	Fr
1	0.000	143.040	59.900	443.717	0.135	112.049	3.87999	0.04000	1.00000	147.661	147.660	4.620	0.700	0.02167
2	938.100	138.230	59.900	391.040	0.153	73.287	5.09915	0.04000	1.00000	147.665	147.664	9.434	2.302	0.02118
3	1877.600	141.730	59.900	361.496	0.166	90.283	3.90667	0.04000	1.00000	147.671	147.669	5.939	1.320	0.02645
4	3383.800	144.310	55.830	282.923	0.197	105.279	2.66714	0.04000	1.00000	147.689	147.687	3.377	0.687	0.03845
5	4511.300	142.190	55.830	313.115	0.178	73.135	4.16430	0.04000	1.00000	147.702	147.701	5.511	0.879	0.02753
6	6061.500	144.880	55.830	211.103	0.264	91.040	2.28985	0.04000	1.00000	147.737	147.733	2.853	0.766	0.05548
7	8002.600	145.350	55.830	178.181	0.313	95.596	1.83884	0.04000	1.00000	147.841	147.836	2.486	0.853	0.07331
8	9595.300	144.320	55.830	158.931	0.351	68.974	2.27792	0.04000	1.00000	147.949	147.942	3.622	1.412	0.07392
9	10606.900	144.340	55.830	202.044	0.276	74.615	2.67170	0.04000	1.00000	147.999	147.995	3.655	0.866	0.05364
10	13378.700	146.150	55.830	124.263	0.449	95.271	1.29360	0.04000	1.00000	148.362	148.352	2.202	1.116	0.12567
11	15862.100	143.230	55.830	190.667	0.293	79.399	2.35800	0.04000	1.00000	148.701	148.696	5.466	1.470	0.06036
12	17466.700	147.320	55.830	75.148	0.743	66.236	1.12980	0.04000	1.00000	149.338	149.310	1.990	1.147	0.22281
13	18547.400	148.080	52.250	96.000	0.544	77.019	1.23799	0.04000	1.00000	149.936	149.921	1.841	0.897	0.15573
14	20490.500	148.620	52.250	105.427	0.496	100.029	1.04973	0.04000	1.00000	150.640	150.628	2.008	1.042	0.15421
15	22160.500	148.970	52.250	115.833	0.451	104.949	1.09632	0.04000	1.00000	151.188	151.178	2.208	1.293	0.13716
16	23327.300	149.020	51.170	110.689	0.462	56.860	1.91157	0.04000	1.00000	151.441	151.430	2.410	0.756	0.10584
17	25870.900	150.440	51.170	102.827	0.498	90.196	1.13597	0.04000	1.00000	152.049	152.036	1.596	0.691	0.14888
18	27030.500	150.910	50.690	82.166	0.617	100.699	0.81401	0.04000	1.00000	152.707	152.688	1.778	0.957	0.21817
19	27961.500	150.570	50.690	148.357	0.342	85.912	1.70885	0.04000	1.00000	153.123	153.117	2.547	0.684	0.08306
20	30435.000	152.640	49.020	85.201	0.575	82.105	1.03560	0.04000	1.00000	153.861	153.844	1.204	0.442	0.18042

No.	Distance from Mekong (m)	River bed (EL.m)	Discharge (m^3/sec)	Area (m^2)	velocity (m/sec)	Width (m)	Hydraulic mean depth (m)	Coefficient of roughness	Coefficient of adjustment of energy head	Energy head (m)	Water level (m)	Water depth (m)	Critical water depth (m)	Fr
21	33227.200	153.600	49.020	99.200	0.494	99.007	0.99777	0.04000	1.00000	155.114	155.101	1.501	0.691	0.15770
22	34808.300	152.570	49.020	131.977	0.371	83.415	1.57418	0.04000	1.00000	155.519	155.512	2.942	1.168	0.09433
23	36327.400	155.040	46.590	70.380	0.662	77.567	0.90560	0.04000	1.00000	156.218	156.196	1.156	0.480	0.22199
24	37269.200	154.390	45.510	90.503	0.503	81.735	1.10316	0.04000	1.00000	156.762	156.749	2.359	1.103	0.15265
25	38559.700	150.920	45.510	224.473	0.203	67.601	3.25035	0.04000	1.00000	157.000	156.998	6.078	1.361	0.03554
26	39672.500	155.600	45.510	68.658	0.663	67.794	1.00887	0.04000	1.00000	157.394	157.372	1.772	0.810	0.21040
27	42092.500	158.930	43.120	63.648	0.677	101.471	0.62472	0.04000	1.00000	159.899	159.875	0.945	0.530	0.27325
28	43517.300	158.790	43.120	175.594	0.246	114.040	1.53281	0.04000	1.00000	160.917	160.914	2.124	0.709	0.06322
29	44181.000	158.590	28.320	111.066	0.255	80.142	1.36882	0.04000	1.00000	160.958	160.955	2.365	0.990	0.06919
30	44721.100	159.922	28.320	63.005	0.449	80.185	0.78162	0.04000	1.00000	161.098	161.088	1.166	0.536	0.16198
31	45225.200	160.456	28.320	39.710	0.713	77.286	0.51286	0.04000	1.00000	161.711	161.685	1.229	0.843	0.31781
32	45580.800	161.102	28.320	43.003	0.659	122.985	0.34822	0.04000	1.00000	162.567	162.545	1.443	1.023	0.35577
33	46146.700	159.238	27.000	155.721	0.173	81.377	1.88840	0.04000	1.00000	163.374	163.373	4.135	1.230	0.04004
34	46530.900	162.682	27.000	46.523	0.580	101.144	0.45867	0.04000	1.00000	163.671	163.653	0.971	0.618	0.27335
35	46924.200	161.332	27.000	85.369	0.316	58.088	1.43971	0.04000	1.00000	163.990	163.985	2.653	0.793	0.08334
36	47506.300	158.130	27.000	294.427	0.092	93.156	3.12325	0.04000	1.00000	164.019	164.019	5.889	0.911	0.01648
37	47930.000	162.670	27.000	50.908	0.530	64.634	0.78562	0.04000	1.00000	164.151	164.137	1.467	0.724	0.19090

Case-2

No.	Distance from Mekong (m)	River bed (EL.m)	Discharge (m^3/sec)	Area (m^2)	velocity (m/sec)	Width (m)	Hydraulic mean depth (m)	Coefficient of roughness	Coefficient of adjustment of energy head	Energy head (m)	Water level (m)	Water depth (m)	Critical water depth (m)	Fr
1	0.000	143.040	80.900	443.717	0.182	112.049	3.87999	0.04000	1.00000	147.662	147.660	4.620	0.780	0.02927
2	938.100	138.230	80.900	391.280	0.207	73.295	5.10160	0.04000	1.00000	147.669	147.667	9.437	2.547	0.02859
3	1877.600	141.730	80.900	362.173	0.223	90.329	3.91191	0.04000	1.00000	147.679	147.677	5.947	1.500	0.03563
4	3383.800	144.310	76.830	285.242	0.269	105.365	2.68654	0.04000	1.00000	147.712	147.709	3.399	0.782	0.05229
5	4511.300	142.190	76.830	315.604	0.243	73.299	4.18753	0.04000	1.00000	147.738	147.735	5.545	1.027	0.03748
6	6061.500	144.880	76.830	216.486	0.355	91.288	2.34128	0.04000	1.00000	147.799	147.792	2.912	0.852	0.07362
7	8002.600	145.350	76.830	189.867	0.405	95.886	1.95178	0.04000	1.00000	147.966	147.958	2.608	0.967	0.09186
8	9595.300	144.320	76.830	171.203	0.449	69.422	2.43387	0.04000	1.00000	148.130	148.120	3.800	1.552	0.09128
9	10606.900	144.340	76.830	217.310	0.354	75.244	2.84514	0.04000	1.00000	148.205	148.198	3.858	1.039	0.06646
10	13378.700	146.150	76.830	148.164	0.519	96.536	1.52087	0.04000	1.00000	148.615	148.601	2.451	1.216	0.13371
11	15862.100	143.230	76.830	214.228	0.359	82.692	2.54269	0.04000	1.00000	148.994	148.987	5.757	1.693	0.07118
12	17466.700	147.320	76.830	93.553	0.821	68.559	1.35743	0.04000	1.00000	149.617	149.583	2.263	1.288	0.22458
13	18547.400	148.080	73.250	116.663	0.628	78.085	1.48105	0.04000	1.00000	150.207	150.187	2.107	1.006	0.16409
14	20490.500	148.620	73.250	132.469	0.553	102.614	1.28418	0.04000	1.00000	150.911	150.895	2.275	1.163	0.15546
15	22160.500	148.970	73.250	142.685	0.513	106.855	1.32546	0.04000	1.00000	151.445	151.432	2.462	1.399	0.14191
16	23327.300	149.020	72.170	126.752	0.569	58.387	2.12747	0.04000	1.00000	151.725	151.708	2.688	0.881	0.12344
17	25870.900	150.440	72.170	131.179	0.550	93.553	1.39620	0.04000	1.00000	152.360	152.345	1.905	0.793	0.14841
18	27030.500	150.910	71.690	109.399	0.655	114.095	0.95638	0.04000	1.00000	152.963	152.941	2.031	1.096	0.21378
19	27961.500	150.570	71.690	169.969	0.422	93.501	1.79779	0.04000	1.00000	153.363	153.354	2.784	0.814	0.09993
20	30435.000	152.640	70.020	107.457	0.652	84.122	1.27302	0.04000	1.00000	154.133	154.111	1.471	0.540	0.18417

No.	Distance from Mekong (m)	River bed (EL.m)	Discharge (m^3/sec)	Area (m^2)	velocity (m/sec)	Width (m)	Hydraulic mean depth (m)	Coefficient of roughness	Coefficient of adjustment of energy head	Energy head (m)	Water level (m)	Water depth (m)	Critical water depth (m)	Fr
21	33227.200	153.600	70.020	124.117	0.564	101.094	1.21938	0.04000	1.00000	155.366	155.350	1.750	0.792	0.16264
22	34808.300	152.570	70.020	154.746	0.452	84.902	1.81128	0.04000	1.00000	155.793	155.782	3.212	1.368	0.10706
23	36327.400	155.040	67.590	90.530	0.747	79.867	1.13060	0.04000	1.00000	156.480	156.452	1.412	0.597	0.22401
24	37269.200	154.390	65.510	111.685	0.587	85.686	1.29826	0.04000	1.00000	157.020	157.002	2.612	1.326	0.16412
25	38559.700	150.920	65.510	243.882	0.269	69.361	3.43900	0.04000	1.00000	157.285	157.281	6.361	1.640	0.04576
26	39672.500	155.600	65.510	87.759	0.746	71.201	1.22700	0.04000	1.00000	157.675	157.647	2.047	0.968	0.21478
27	42092.500	158.930	64.120	85.142	0.753	112.800	0.75133	0.04000	1.00000	160.104	160.075	1.145	0.637	0.27690
28	43517.300	158.790	64.120	197.405	0.325	115.492	1.70084	0.04000	1.00000	161.110	161.104	2.314	0.797	0.07936
29	44181.000	158.590	49.320	128.658	0.383	81.253	1.56161	0.04000	1.00000	161.180	161.173	2.583	1.138	0.09731
30	44721.100	159.922	49.320	84.127	0.586	83.070	1.00544	0.04000	1.00000	161.363	161.345	1.423	0.665	0.18609
31	45225.200	160.456	49.320	58.668	0.841	83.330	0.70250	0.04000	1.00000	161.957	161.921	1.465	1.004	0.32004
32	45580.800	161.102	49.320	62.823	0.785	127.939	0.48881	0.04000	1.00000	162.734	162.703	1.601	1.332	0.35788
33	46146.700	159.238	48.000	163.667	0.293	81.689	1.97591	0.04000	1.00000	163.474	163.470	4.232	1.585	0.06619
34	46530.900	162.682	48.000	63.322	0.758	107.480	0.58726	0.04000	1.00000	163.844	163.815	1.133	0.780	0.31547
35	46924.200	161.332	48.000	100.546	0.477	61.423	1.59817	0.04000	1.00000	164.250	164.239	2.907	1.066	0.11919
36	47506.300	158.130	48.000	321.653	0.149	95.149	3.33846	0.04000	1.00000	164.309	164.308	6.178	1.155	0.02593
37	47930.000	162.670	48.000	71.002	0.676	68.954	1.02600	0.04000	1.00000	164.460	164.437	1.767	0.922	0.21282

Case-3

No.	Distance from Mekong (m)	River bed (EL.m)	Discharge (m^3/sec)	Area (m^2)	velocity (m/sec)	Width (m)	Hydraulic mean depth (m)	Coefficient of roughness	Coefficient of adjustment of energy head	Energy head (m)	Water level (m)	Water depth (m)	Critical water depth (m)	Fr
1	0.000	143.040	192.900	443.717	0.435	112.049	3.87999	0.04000	1.00000	147.670	147.660	4.620	1.114	0.06979
2	938.100	138.230	192.900	393.757	0.490	73.374	5.12687	0.04000	1.00000	147.713	147.701	9.471	3.475	0.06755
3	1877.600	141.730	192.900	369.046	0.523	90.909	3.96023	0.04000	1.00000	147.766	147.753	6.023	2.152	0.08287
4	3383.800	144.310	188.830	306.739	0.616	106.162	2.86485	0.04000	1.00000	147.931	147.912	3.602	1.164	0.11569
5	4511.300	142.190	188.830	338.085	0.559	74.762	4.39346	0.04000	1.00000	148.054	148.038	5.848	1.594	0.08390
6	6061.500	144.880	188.830	258.997	0.729	93.282	2.73598	0.04000	1.00000	148.280	148.253	3.373	1.221	0.13977
7	8002.600	145.350	188.830	261.303	0.723	98.277	2.60873	0.04000	1.00000	148.722	148.695	3.345	1.329	0.14157
8	9595.300	144.320	188.830	236.646	0.798	72.099	3.21468	0.04000	1.00000	149.078	149.046	4.726	2.085	0.14069
9	10606.900	144.340	188.830	296.075	0.638	78.388	3.69362	0.04000	1.00000	149.244	149.224	4.884	1.615	0.10483
10	13378.700	146.150	188.830	257.534	0.733	99.306	2.55015	0.04000	1.00000	149.745	149.717	3.567	1.618	0.14544
11	15862.100	143.230	188.830	321.241	0.588	94.002	3.33527	0.04000	1.00000	150.189	150.171	6.941	2.558	0.10157
12	17466.700	147.320	188.830	175.503	1.076	76.296	2.27659	0.04000	1.00000	150.774	150.715	3.395	1.784	0.22661
13	18547.400	148.080	185.250	203.303	0.911	80.444	2.47830	0.04000	1.00000	151.322	151.280	3.200	1.415	0.18309
14	20490.500	148.620	185.250	244.765	0.757	105.113	2.29451	0.04000	1.00000	152.001	151.972	3.352	1.647	0.15843
15	22160.500	148.970	185.250	256.428	0.722	112.584	2.25290	0.04000	1.00000	152.490	152.464	3.494	1.772	0.15291
16	23327.300	149.020	184.170	281.294	0.655	111.140	2.46312	0.04000	1.00000	152.776	152.754	3.734	1.003	0.13146
17	25870.900	150.440	184.170	233.773	0.788	98.560	2.35105	0.04000	1.00000	153.442	153.410	2.970	1.186	0.16340
18	27030.500	150.910	183.690	224.870	0.817	128.348	1.73293	0.04000	1.00000	153.923	153.889	2.979	1.639	0.19714
19	27961.500	150.570	183.690	254.166	0.723	95.754	2.60823	0.04000	1.00000	154.270	154.244	3.674	1.345	0.14170
20	30435.000	152.640	182.020	194.756	0.935	88.080	2.18833	0.04000	1.00000	155.167	155.122	2.482	0.946	0.20077

No.	Distance from Mekong (m)	River bed (EL.m)	Discharge (m^3/sec)	Area (m^2)	velocity (m/sec)	Width (m)	Hydraulic mean depth (m)	Coefficient of roughness	Coefficient of adjustment of energy head	Energy head (m)	Water level (m)	Water depth (m)	Critical water depth (m)	Fr
21	33227.200	153.600	182.020	228.356	0.797	107.069	2.09406	0.04000	1.00000	156.383	156.351	2.751	1.172	0.17435
22	34808.300	152.570	182.020	245.537	0.741	87.640	2.76230	0.04000	1.00000	156.863	156.835	4.265	1.989	0.14148
23	36327.400	155.040	179.590	175.754	1.022	86.013	2.02981	0.04000	1.00000	157.529	157.475	2.435	1.063	0.22835
24	37269.200	154.390	178.510	200.001	0.893	89.566	2.20622	0.04000	1.00000	158.044	158.003	3.613	2.009	0.19080
25	38559.700	150.920	178.510	321.931	0.554	74.338	4.21193	0.04000	1.00000	158.377	158.361	7.441	2.657	0.08512
26	39672.500	155.600	178.510	169.940	1.050	79.409	2.12021	0.04000	1.00000	158.778	158.721	3.121	1.575	0.22937
27	42092.500	158.930	176.120	172.210	1.023	122.395	1.39465	0.04000	1.00000	160.861	160.808	1.878	0.999	0.27542
28	43517.300	158.790	176.120	274.327	0.642	118.298	2.30075	0.04000	1.00000	161.781	161.760	2.970	1.146	0.13467
29	44181.000	158.590	161.320	192.965	0.836	85.192	2.22282	0.04000	1.00000	161.981	161.945	3.355	1.682	0.17744
30	44721.100	159.922	161.320	159.091	1.014	86.024	1.82575	0.04000	1.00000	162.284	162.232	2.310	1.122	0.23819
31	45225.200	160.456	161.320	134.943	1.195	95.585	1.40636	0.04000	1.00000	162.836	162.763	2.307	1.488	0.32140
32	45580.800	161.102	161.320	160.111	1.008	164.983	0.96427	0.04000	1.00000	163.397	163.345	2.243	1.659	0.32671
33	46146.700	159.238	160.000	202.119	0.792	83.184	2.38909	0.04000	1.00000	163.968	163.936	4.698	2.733	0.16222
34	46530.900	162.682	160.000	127.407	1.256	116.361	1.09023	0.04000	1.00000	164.461	164.380	1.698	1.155	0.38337
35	46924.200	161.332	160.000	162.402	0.985	95.120	1.66598	0.04000	1.00000	165.058	165.008	3.676	1.939	0.24085
36	47506.300	158.130	160.000	418.376	0.382	101.917	4.04611	0.04000	1.00000	165.297	165.290	7.160	1.991	0.06029
37	47930.000	162.670	160.000	141.517	1.131	73.186	1.91272	0.04000	1.00000	165.487	165.422	2.752	1.539	0.25972

Fluctuation of water level, water surface area for Case-1 to Case-3

No.	Distance from Mekong (km)	decrease in water level (m)	decrease in water flow velocity (m^3/s)	decrease in water surface width (m)	Increase in water level (m)	Increase in water flow velocity (m^3/s)	Increase in water surface width (m)	increase in water level (m)	Increase in water flow velocity (m^3/s)	Increase in water surface width (m)
		160→27			27→48			48→160		
29	0.00	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.3	0.0
28	0.94	0.0	0.3	0.1	0.0	0.1	0.0	0.0	0.3	0.1
27	1.88	0.1	0.4	0.6	0.0	0.1	0.0	0.1	0.3	0.6
26	3.38	0.2	0.4	0.9	0.0	0.1	0.1	0.2	0.3	0.8
25	4.51	0.3	0.4	1.6	0.0	0.1	0.2	0.3	0.3	1.5
24	6.06	0.5	0.5	2.2	0.1	0.1	0.2	0.5	0.4	2.0
23	8.00	0.9	0.4	2.7	0.1	0.1	0.3	0.7	0.3	2.4
22	9.60	1.1	0.4	3.1	0.2	0.1	0.4	0.9	0.3	2.7
21	10.61	1.2	0.4	3.8	0.2	0.1	0.6	1.0	0.3	3.1
20	13.38	1.4	0.3	4.0	0.2	0.1	1.3	1.1	0.2	2.8
19	15.86	1.5	0.3	14.6	0.3	0.1	3.3	1.2	0.2	11.3
18	17.47	1.4	0.3	10.1	0.3	0.1	2.3	1.1	0.3	7.7
17	18.55	1.4	0.4	3.4	0.3	0.1	1.1	1.1	0.3	2.4
16	20.49	1.3	0.3	5.1	0.3	0.1	2.6	1.1	0.2	2.5
15	22.16	1.3	0.3	7.6	0.3	0.1	1.9	1.0	0.2	5.7
14	23.33	1.3	0.2	54.3	0.3	0.1	1.5	1.0	0.1	52.8
13	25.87	1.4	0.3	8.4	0.3	0.1	3.4	1.1	0.2	5.0
12	27.03	1.2	0.2	27.6	0.3	0.0	13.4	0.9	0.2	14.3
11	27.96	1.1	0.4	9.8	0.2	0.1	7.6	0.9	0.3	2.3
10	30.44	1.3	0.4	6.0	0.3	0.1	2.0	1.0	0.3	4.0
9	33.23	1.3	0.3	8.1	0.2	0.1	2.1	1.0	0.2	6.0
8	34.81	1.3	0.4	4.2	0.3	0.1	1.5	1.1	0.3	2.7
7	36.33	1.3	0.4	8.4	0.3	0.1	2.3	1.0	0.3	6.1
6	37.27	1.3	0.4	7.8	0.3	0.1	4.0	1.0	0.3	3.9
5	38.56	1.4	0.4	6.7	0.3	0.1	1.8	1.1	0.3	5.0
4	39.67	1.3	0.4	11.6	0.3	0.1	3.4	1.1	0.3	8.2
3	42.09	0.9	0.3	20.9	0.2	0.1	11.3	0.7	0.3	9.6
2	43.52	0.8	0.4	4.3	0.2	0.1	1.5	0.7	0.3	2.8
1	44.18	1.0	0.6	5.1	0.2	0.1	1.1	0.8	0.5	3.9
CR-35	44.72	1.1	0.6	5.8	0.3	0.1	2.9	0.9	0.4	3.0
CR-34	45.23	1.1	0.5	94.4	0.2	0.1	82.1	0.8	0.4	12.3
CR-33	45.58	0.8	0.3	163.5	0.2	0.1	126.5	0.6	0.2	37.0
CR-32	46.15	0.6	0.6	79.0	0.1	0.1	77.6	0.5	0.5	1.5
CR-31	46.53	0.7	0.7	115.4	0.2	0.2	106.5	0.6	0.5	8.9
CR-30	46.92	1.0	0.7	92.5	0.3	0.2	58.8	0.8	0.5	33.7
CR-29	47.51	1.3	0.3	96.0	0.3	0.1	89.3	1.0	0.2	6.8
CR-28	47.93	1.3	0.6	71.7	0.3	0.1	67.5	1.0	0.5	4.2
Average		1.0	0.4	26.0	0.2	0.1	18.4	0.8	0.3	7.5
Maximum		1.5	0.7	163.5	0.3	0.2	126.5	1.2	0.5	52.8
Minimum		0.1	0.2	0.6	0.0	0.0	0.0	0.1	0.1	0.6

4-2 Data sheet of Case-4 (5.5 m^3/s)

Tributary	Distance from Mekong (km)	No.	River bed	Discharge (m^3/s)	Water level (EL.m)	Width depth (m)	Width of water surface (m)	Water velocity (m/s)
				5.5	5.5	5.5	5.5	5.5
Mekong	0.0	29	143.0	32.1	149.3	6.2	124.3	0.1
	0.9	28	138.2	32.1	149.3	11.0	79.3	0.1
Nam Teknoy	1.9	27	141.7	32.1	149.3	7.5	103.3	0.1
	3.4	26	144.3	28.8	149.3	4.9	110.8	0.1
	4.5	25	142.2	28.8	149.3	7.1	80.6	0.1
	6.1	24	144.9	28.8	149.3	4.4	97.9	0.1
	8.0	23	145.4	28.8	149.3	3.9	101.4	0.1
	9.6	22	144.3	28.8	149.3	4.9	72.8	0.1
	10.6	21	144.3	28.8	149.3	4.9	78.5	0.1
	13.4	20	146.2	28.8	149.3	3.1	98.3	0.1
	15.9	19	143.2	28.8	149.3	6.1	87.9	0.1
Nam Pa	17.5	18	147.3	28.8	149.4	2.1	67.2	0.3
	18.5	17	148.1	25.9	149.6	1.5	75.0	0.4
	20.5	16	148.6	25.9	150.2	1.6	96.7	0.4
B Muong Mai	22.2	15	149.0	25.9	150.8	1.8	101.9	0.3
	23.3	14	149.0	25.1	151.0	2.0	49.7	0.3
Houay Poungxan	25.9	13	150.4	25.1	151.6	1.2	85.4	0.4
	27.0	12	150.9	24.7	152.3	1.4	77.5	0.5
Houay kokkhen	28.0	11	150.6	24.7	152.7	2.2	79.3	0.2
	30.4	10	152.6	23.3	153.4	0.8	77.2	0.4
	33.2	9	153.6	23.3	154.7	1.1	90.4	0.4
Houay khinguak	34.8	8	152.6	23.3	155.1	2.5	80.5	0.2
Houay Khinguak	36.3	7	155.0	21.4	155.8	0.7	64.4	0.5
	37.3	6	154.4	21.4	156.3	2.0	75.2	0.4
	38.6	5	150.9	21.4	156.5	5.6	64.1	0.1
Houay Soup	39.7	4	155.6	20.5	156.9	1.3	49.6	0.5
	42.1	3	158.9	18.6	159.6	0.6	92.6	0.5
Nam Xao, Nam th	43.5	2	158.8	18.6	160.8	2.0	113.1	0.1
	44.2	1	158.6	6.6	160.8	2.2	79.0	0.1
	44.7	CR-35	159.9	6.6	160.8	0.9	74.3	0.2
	45.2	CR-34	160.5	6.6	161.3	0.8	47.0	0.5
Nam Miang	45.6	CR-33	161.1	6.6	161.9	0.8	16.1	0.8
	46.1	CR-32	159.2	5.5	162.6	3.3	73.5	0.1
	46.5	CR-31	162.7	5.5	163.2	0.5	50.0	0.5
	46.9	CR-30	161.3	5.5	163.9	2.5	54.3	0.1
	47.5	CR-29	158.1	5.5	163.9	5.7	92.1	0.0
	47.9	CR-28	162.7	5.5	163.9	1.2	55.7	0.2
Average			151.6	21.0	154.6	3.0	78.8	0.3
Maximum			162.7	32.1	163.9	11.0	113.1	0.8
Minimum			141.7	5.5	149.3	0.5	16.1	0.02

Case-4

No.	Distance from Mekong (m)	River bed (EL.m)	Discharge (m^3/sec)	Area (m^2)	velocity (m/sec)	Width (m)	Hydraulic mean depth (m)	Coefficient of roughness	Coefficient of adjustment of energy head	Energy head (m)	Water level (m)	Water depth (m)	Critical water depth (m)	Fr
1	0.000	143.040	32.100	630.819	0.051	124.323	4.96245	0.04000	1.00000	149.250	149.250	6.210	0.577	0.00722
2	938.100	138.230	32.100	511.269	0.063	79.272	6.11551	0.04000	1.00000	149.251	149.250	11.020	1.892	0.00790
3	1877.600	141.730	32.100	514.722	0.062	103.291	4.85434	0.04000	1.00000	149.251	149.251	7.521	1.010	0.00892
4	3383.800	144.310	28.800	452.445	0.064	110.812	4.02206	0.04000	1.00000	149.253	149.252	4.942	0.543	0.01006
5	4511.300	142.190	28.800	432.337	0.067	80.597	5.19077	0.04000	1.00000	149.254	149.253	7.063	0.646	0.00919
6	6061.500	144.880	28.800	354.833	0.081	97.850	3.56047	0.04000	1.00000	149.256	149.255	4.375	0.631	0.01362
7	8002.600	145.350	28.800	317.758	0.091	101.435	3.06916	0.04000	1.00000	149.260	149.260	3.910	0.668	0.01636
8	9595.300	144.320	28.800	252.565	0.114	72.820	3.39174	0.04000	1.00000	149.266	149.265	4.945	1.149	0.01956
9	10606.900	144.340	28.800	299.624	0.096	78.517	3.73053	0.04000	1.00000	149.269	149.269	4.929	0.622	0.01572
10	13378.700	146.150	28.800	214.969	0.134	98.275	2.15738	0.04000	1.00000	149.287	149.286	3.136	0.693	0.02894
11	15862.100	143.230	28.800	241.343	0.119	87.940	2.69293	0.04000	1.00000	149.308	149.307	6.077	1.095	0.02301
12	17466.700	147.320	28.800	82.812	0.348	67.219	1.22628	0.04000	1.00000	149.431	149.425	2.105	0.829	0.10009
13	18547.400	148.080	25.900	72.962	0.355	75.024	0.96695	0.04000	1.00000	149.624	149.618	1.538	0.685	0.11499
14	20490.500	148.620	25.900	65.787	0.394	96.662	0.67857	0.04000	1.00000	150.233	150.225	1.605	0.760	0.15244
15	22160.500	148.970	25.900	76.664	0.338	101.926	0.74780	0.04000	1.00000	150.805	150.799	1.829	1.126	0.12444
16	23327.300	149.020	25.100	86.844	0.289	54.244	1.57684	0.04000	1.00000	151.005	151.000	1.980	0.498	0.07297
17	25870.900	150.440	25.100	62.775	0.400	85.228	0.73478	0.04000	1.00000	151.588	151.580	1.140	0.499	0.14882
18	27030.500	150.910	24.680	46.892	0.526	77.445	0.60427	0.04000	1.00000	152.315	152.300	1.390	0.742	0.21606
19	27961.500	150.570	24.680	117.226	0.211	79.269	1.46531	0.04000	1.00000	152.738	152.736	2.166	0.473	0.05530
20	30435.000	152.640	23.300	52.495	0.444	77.162	0.67945	0.04000	1.00000	153.444	153.433	0.793	0.296	0.17190

21	33227.200	153.600	23.300	61.682	0.378	90.374	0.68057	0.04000	1.00000	154.713	154.705	1.105	0.527	0.14606
22	34808.300	152.570	23.300	95.823	0.243	80.468	1.18649	0.04000	1.00000	155.074	155.071	2.501	0.803	0.07118
23	36327.400	155.040	21.400	39.786	0.538	64.352	0.61752	0.04000	1.00000	155.800	155.785	0.745	0.306	0.21852
24	37269.200	154.390	21.400	58.828	0.364	75.198	0.77972	0.04000	1.00000	156.353	156.346	1.956	0.804	0.13138
25	38559.700	150.920	21.400	194.610	0.110	64.125	2.97356	0.04000	1.00000	156.546	156.546	5.626	0.906	0.02016
26	39672.500	155.600	20.480	39.652	0.516	49.638	0.79639	0.04000	1.00000	156.871	156.857	1.257	0.539	0.18460
27	42092.500	158.930	18.550	34.865	0.532	92.571	0.37555	0.04000	1.00000	159.593	159.578	0.648	0.377	0.27694
28	43517.300	158.790	18.550	161.764	0.115	113.104	1.42415	0.04000	1.00000	160.793	160.792	2.002	0.520	0.03063
29	44181.000	158.590	6.570	98.656	0.067	79.037	1.23409	0.04000	1.00000	160.799	160.799	2.209	0.689	0.01904
30	44721.100	159.922	6.570	42.356	0.155	74.324	0.56793	0.04000	1.00000	160.823	160.822	0.900	0.315	0.06564
31	45225.200	160.456	6.600	14.193	0.465	47.047	0.30113	0.04000	1.00000	161.275	161.264	0.808	0.578	0.27045
32	45580.800	161.102	6.600	8.676	0.761	16.072	0.53127	0.04000	1.00000	161.963	161.933	0.831	0.475	0.33072
33	46146.700	159.238	5.500	92.662	0.059	73.466	1.24899	0.04000	1.00000	162.573	162.573	3.335	0.610	0.01688
34	46530.900	162.682	5.500	10.695	0.514	49.980	0.21361	0.04000	1.00000	163.210	163.197	0.515	0.382	0.35510
35	46924.200	161.332	5.500	78.439	0.070	54.349	1.41460	0.04000	1.00000	163.863	163.862	2.530	0.347	0.01864
36	47506.300	158.130	5.500	280.111	0.020	92.050	3.00811	0.04000	1.00000	163.864	163.864	5.734	0.458	0.00360
37	47930.000	162.670	5.500	35.290	0.156	55.701	0.63194	0.04000	1.00000	163.879	163.878	1.208	0.413	0.06255

Annex D

Release of Environment Flow

D1 THE NUMBERS OF DAYS WHEN RIPARIAN RELEASES OCCURRED AT THE YEARS 1972, 1977 AND 1992 (ESTIMATED BY THE MODEL)

Date	Classification	Rule curve (upper)	Rule curve (lower)	Inflow to main dam	Reservoir water level	Discharge from spillway/bottom outlet	Peak plant discharge	Peak discharge (24hour)	Off-Peak discharge	Off Peak discharge (24hour)	Inflow to re-regulation dam
	1: Weekend										
	0: Weekday	m	m	m^3/s	m	m^3/s	m^3/s		m^3/s		m^3/s
20/09/1972	0	318.3	312.8	106.7	312.9	0	227.0131	151.342	0	0	152.1
21/09/1972	0	318.3	313.0	106.7	312.8	27	0	0	0	0	27
22/09/1972	0	318.4	313.2	106.7	312.9	27	0	0	0	0	27
23/09/1972	0	318.5	313.4	106.7	313.1	27	0	0	0	0	27
24/09/1972	1	318.5	313.6	106.7	313.2	27	0	0	0	0	27
25/09/1972	0	318.6	313.8	106.7	313.3	27	0	0	0	0	27
26/09/1972	0	318.7	314.0	106.7	313.4	27	0	0	0	0	27
27/09/1972	0	318.7	314.2	106.7	313.6	27	0	0	0	0	27
28/09/1972	0	318.8	314.4	106.7	313.7	27	0	0	0	0	27
29/09/1972	0	318.9	314.6	106.7	313.8	27	0	0	0	0	27
30/09/1972	0	318.9	314.8	106.7	313.9	27	0	0	0	0	27
01/10/1972	1	319.0	315.0	86.8	314.0	27	0	0	0	0	27
02/10/1972	0	319.0	315.0	86.8	314.1	27	0	0	0	0	27
03/10/1972	0	319.1	315.1	86.8	314.2	27	0	0	0	0	27
04/10/1972	0	319.1	315.1	86.8	314.3	27	0	0	0	0	27
05/10/1972	0	319.1	315.1	86.8	314.4	27	0	0	0	0	27
06/10/1972	0	319.2	315.2	86.8	314.5	0	95.99673	63.99782	0	0	64.6

Date	Classification	Rule curve (upper)	Rule curve (lower)	Inflow to main dam	Reservoir water level	Discharge from spillway	Peak plant discharge	Peak discharge (24hour)	Off-Peak discharge	Off Peak discharge (24hour)	Inflow to re-regulation dam
	1: Weekend										
	0: Weekday	m	m	m³/s	m	m³/s	m³/s		m³/s		m³/s
30/09/1977	0	318.9333	314.8	196.3584	314.7	0	93.22367	62.14911	0	0	63.47586
01/10/1977	0	319	315	85.18534	314.9	27	0	0	0	0	27
02/10/1977	1	319.0323	315.0323	85.18534	315.0	27	0	0	0	0	27
03/10/1977	0	319.0645	315.0645	85.18534	315.1	0	112.6692	75.11279	0	0	75.68836

Date	**Classification**	**Rule curve (upper)**	**Rule curve (lower)**	**Inflow to main dam**	**Reservoir water level**	**Discharge from spillway**	**Peak plant discharge**	**Peak discharge (24hour)**	**Off-Peak discharge**	**Off Peak discharge (24hour)**	**Inflow to re-regulation dam**
	1: Weekend					0					
	0: Weekday	m	m	m³/s	m	m³/s	m³/s		m³/s		m³/s
03/09/1992	0	317.1	309.4	120.1	309.3	0.0	47.0	31.3	0.0	0.0	32.1
04/09/1992	0	317.2	309.6	120.1	309.5	27	0.0	0.0	0.0	0.0	27
05/09/1992	0	317.3	309.8	120.1	309.7	27	0.0	0.0	0.0	0.0	27
06/09/1992	1	317.3	310.0	120.1	309.9	27	0.0	0.0	0.0	0.0	27
07/09/1992	0	317.4	310.2	120.1	310.1	27	0.0	0.0	0.0	0.0	27
08/09/1992	0	317.5	310.4	120.1	310.3	27	0.0	0.0	0.0	0.0	27
09/09/1992	0	317.5	310.6	120.1	310.4	27	0.0	0.0	0.0	0.0	27
10/09/1992	0	317.6	310.8	120.1	310.6	27	0.0	0.0	0.0	0.0	27
11/09/1992	0	317.7	311.0	120.1	310.8	27	0.0	0.0	0.0	0.0	27
12/09/1992	0	317.7	311.2	120.1	311.0	27	0.0	0.0	0.0	0.0	27
13/09/1992	1	317.8	311.4	120.1	311.2	27	0.0	0.0	0.0	0.0	27
14/09/1992	0	317.9	311.6	120.1	311.4	27	0.0	0.0	0.0	0.0	27
15/09/1992	0	317.9	311.8	120.1	311.6	27	0.0	0.0	0.0	0.0	27
16/09/1992	0	318.0	312.0	120.1	311.8	27	0.0	0.0	0.0	0.0	27

Date	Classification	Rule curve (upper)	Rule curve (lower)	Inflow to main dam	Reservoir water level	Discharge from spillway	Peak plant discharge	Peak discharge (24hour)	Off-Peak discharge	Off Peak discharge (24hour)	Inflow to re-regulation dam
	1: Weekend					0					
	0: Weekday	m	m	m³/s	m	m³/s	m³/s		m³/s		m³/s
17/09/1992	0	318.1	312.2	120.1	311.9	27	0.0	0.0	0.0	0.0	27
18/09/1992	0	318.1	312.4	120.1	312.1	27	0.0	0.0	0.0	0.0	27
19/09/1992	0	318.2	312.6	120.1	312.3	27	0.0	0.0	0.0	0.0	27
20/09/1992	1	318.3	312.8	120.1	312.5	27	0.0	0.0	0.0	0.0	27
21/09/1992	0	318.3	313.0	120.1	312.7	27	0.0	0.0	0.0	0.0	27
22/09/1992	0	318.4	313.2	120.1	312.9	27	0.0	0.0	0.0	0.0	27
23/09/1992	0	318.5	313.4	120.1	313.0	27	0.0	0.0	0.0	0.0	27
24/09/1992	0	318.5	313.6	120.1	313.2	27	0.0	0.0	0.0	0.0	27
25/09/1992	0	318.6	313.8	120.1	313.4	27	0.0	0.0	0.0	0.0	27
26/09/1992	0	318.7	314.0	120.1	313.6	27	0.0	0.0	0.0	0.0	27
27/09/1992	1	318.7	314.2	120.1	313.7	27	0.0	0.0	0.0	0.0	27
28/09/1992	0	318.8	314.4	120.1	313.9	27	0.0	0.0	0.0	0.0	27
29/09/1992	0	318.9	314.6	120.1	314.1	27	0.0	0.0	0.0	0.0	27
30/09/1992	0	318.9	314.8	120.1	314.3	27	0.0	0.0	0.0	0.0	27
01/10/1992	0	319.0	315.0	80.9	314.4	27	0.0	0.0	0.0	0.0	27
02/10/1992	0	319.0	315.0	80.9	314.5	27	0.0	0.0	0.0	0.0	27
03/10/1992	0	319.1	315.1	80.9	314.7	27	0.0	0.0	0.0	0.0	27
04/10/1992	1	319.1	315.1	80.9	314.8	27	0.0	0.0	0.0	0.0	27
05/10/1992	0	319.1	315.1	80.9	314.9	0.0	55.7	37.2	0.0	0.0	37.7

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