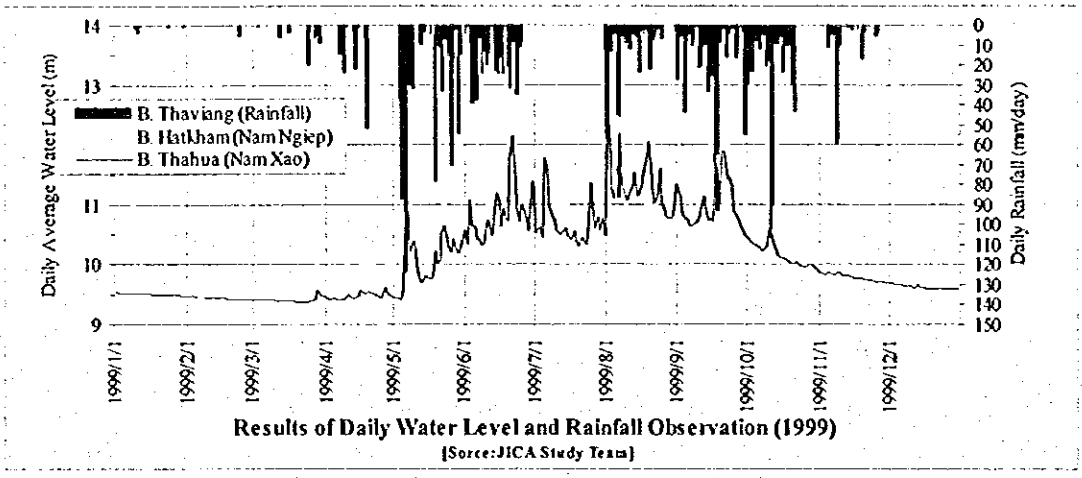


Figure 4.2.4 Rainfall and Water Level Data measured by the Study Team

4.3 COLLECTION OF METEOROLOGICAL & HYDROLOGICAL DATA

4.3.1 GENERAL

Collected meteorological and hydrological data during the Study are shown in Table 4.3.1. Most of the collected data are not in a uniform format nor electrified. Data are kept by related authorities in a format of hardcopy, typewriter output or handwriting. Only the records of major points are reported to the Ministry of Agriculture and Forestry, Department of Meteorology and Hydrology (hereinafter referred to as DMH). Only these data reported to DMH were published and reported to Mekong River Commission as annual reports. Following are outlines of meteorological and discharge records based on a report by "Scope of Works Mission" and interviews at DMH.

4.3.2 METEOROLOGICAL DATA

(1) General

The proposed dam site is located at 18°39'N and 103°30'E. The Project is located in a tropical area, which is characterized by a well-defined dry season in the winter and a rainy southwestern monsoon in the summer months.

The meteorology of the Project area is influenced by the southwestern monsoon, with the wet season from May to October and dry season from November to April as shown in Figure 4.3.1.

Table 4.3.1 Corrected Meteorological and Hydrological Data

No	Type	Name of Data		Observation Station	Province	Latitude	Longitude	Altitude	Start	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	Agency
1)	MAPS	Hydrological Observation Station Map		ALL LAO P.D.R.	-	-	-	-	-	-	●	●	●	●	-	●	●	-	-	-	-	●	●	●	●	●	●	●	●	●	-	-	●	-	-
2)	Level	Daily Water Level Data		B.Muang-Mai (Nam Ngiep)	Borikhamxay	18°30'30"N	103°39'07"E	153m	1978	×	×	×	×	×	●	●	●	-	●	●	-	●	×	●	●	●	●	●	●	●	●	●	●	DMH
3)	Discharge	Daily Discharge Data							1987	×	×	×	×	×	×	×	×	×	×	×	×	×	×	-	●	●	●	●	●	●	●	●	●	Mekong
4)	H-Q	H-Q Relation Curve Data								×	×	×	×	×	×	×	×	×	×	×	×	×	×	-	●	●	●	●	●	●	●	●	●	DMH
5)	Rain	Daily/Monthly Rainfall Data	R1	Pakthouay	Borikhamxay	18°17'00"N	103°26'30"E	159m	1988	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	●	●	●	●	-	DMH
			R2	Paksane	Borikhamxay	18°22'18"N	103°40'00"E	155m	1929	◎	●	● 31	● 183	●	●	●	●	-	○	● 92	○	-	-	●	●	●	●	-	●	●	●	●	◎	Hydromet
			R3	B.Muang Mai	Borikhamxay	18°30'00"N	103°40'00"E	158m	1978	-	-	-	-	-	●	●	-	-	-	-	-	● 33	-	-	● 30	●	●	●	●	●	●	●	◎	Hydromet
			R4	Muong Kao (M.Borikhane)	Borikhamxay	18°33'42"N	103°44'12"E	158m	1986	-	-	-	-	-	○	-	-	-	-	-	-	-	-	-	-	●	-	●	●	●	●	●	●	DMH
			R5	M.Khoun(B.Thoun)	Xiengkhuang	19°18'00"N	103°24'25"E	1,110m	19967	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	◎	DMH
			R6	Xiengkhuang(M.Pek)	Xiengkhuang	19°28'00"N	103°08'00"E	1,050m	1929	-	-	-	-	-	-	-	-	-	◎	◎	◎	◎	◎	●	◎	●	●	●	●	●	●	●	◎	DMH
			R7	M.Phaxay(B.Hoxai)	Xiengkhuang	19°17'00"N	103°07'50"E	1,100m	19967	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	◎	DMH
			R8	Naluang	XaysombounSP	18°54'00"N	102°48'00"E	460m	?	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	-	●	●	●	●	●	●	●	●	DMH
			R9	Houayleuk(Tadleuk)	Borikhamxay	18°26'00"N	103°06'00"E	220m	?	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	●	●	DMH
			R10	Thabok	Borikhamxay	18°22'30"N	103°12'00"E	160m	1986	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	●	●	●	●	-	-	Hydromet
			R11	Vientiane	Vientiane	17°57'00"N	102°31'00"E	170m	1907	◎	●	●	●	●	◎	●	●	◎	◎	◎	◎	●	●	●	●	●	●	●	●	●	●	●	◎	Hydromet
			R12	Vang Vieng	Vientiane	18°56'00"N	102°27'00"E	215m	1929	◎	●	● 214	● 92	◎ 61	◎	● 61	●	◎	◎	◎ 30	◎ 150	◎	-	●	● 30	●	●	●	●	●	◎ 61	◎ 61	◎	◎	Hydromet
			R13	B.Mork	Xiengkhuang	18°54'40"N	104°00'20"E	900m	?	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	●	DMH
			-	Long cheng	XaysombounSP	19°06'50"N	102°55'30"E	1,000m	Can't see	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	DMH
			-	Phonemuang (M.Longxan)	Xaysomboun SP	18°33'00"N	103°00'40"E	230m	Can't see	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	DMH
6)	Meteoro-logical	Monthly Temperature (Maximum, Minimum)		(1) Paksan (Paksane)	Borikhamxay	18°22'18"N	103°40'00"E	155m		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	●	Hydromet
				(2) Xiengkhuang(M.Pek)	Xiengkhuang	19°28'00"N	103°08'00"E	1,050m		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	△	●	●	●	●	●	●	DMH
				(3) Vangviang	Vientiane	18°56'00"N	102°27'00"E	215m	1929	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	△	●	●	
				(4) Vientiane	Vientiane	17°57'00"N	102°31'00"E	170m		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	Hydromet
		Monthly Humidity (Maximum, Minimum)		(1) Paksan (Paksane)	Borikhamxay	18°22'18"N	103°40'00"E	155m		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	●	Hydromet
				(2) Xiengkhuang(M.Pek)	Xiengkhuang	19°28'00"N	103°08'00"E	1,050m		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	△	●	●	●	●	●	●	DMH
				(3) Vangviang	Vientiane	18°56'00"N	102°27'00"E	215m	1929	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
				(4) Vientiane	Vientiane	17°57'00"N	102°31'00"E	170m		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	Hydromet
		Monthly Pan-Evaporation		(1) Paksan (Paksane)	Borikhamxay	18°22'18"N	103°40'00"E	155m		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	-	Hydromet
				(2) Xiengkhuang(M.Pek)	Xiengkhuang	19°28'00"N	103°08'00"E	1,050m		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	△	●	●	●	●	●	●	DMH
				(3) Vangviang	Vientiane	18°56'00"N	102°27'00"E	215m	1929	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
				(4) Vientiane	Vientiane	17°57'00"N	102°31'00"E	170m		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	-	Hydromet
		Wind-Velocity(speed)		(1) Paksan (Paksane)	Borikhamxay	18°22'18"N	103°40'00"E	155m		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	●	Hydromet
				(2) Xiengkhuang(M.Pek)	Xiengkhuang	19°28'00"N	103°08'00"E	1,050m		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	△	●	●	●	●	●	●	DMH
				(3) Vangviang	Vientiane	18°56'00"N	102°27'00"E	215m	1929	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
				(4) Vientiane	Vientiane	17°57'00"N	102°31'00"E	170m		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	-	Hydromet
		Vapour(Atmospheric)Pressure		(1) Paksan (Paksane)	Borikhamxay	18°22'18"N	103°40'00"E	155m		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	●	Hydromet
				(2) Xiengkhuang(M.Pek)	Xiengkhuang	19°28'00"N	103°08'00"E	1,050m		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	-	DMH
				(3) Vangviang	Vientiane	18°56'00"N	102°27'00"E	215m	1929																						-		
				(4) Vientiane	Vientiane	17°57'00"N	102°31'00"E	170m		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	Hydromet
		Total Sunshine Hour		(1) Paksan (Paksane)	Borikhamxay	18°22'18"N	103°40'00"E	155m		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	Hydromet
				(2) Xiengkhuang(M.Pek)	Xiengkhuang	19°28'00"N	103°08'00"E	1,050m		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	△	●	●	●	●	●	●	DMH
				(3) Vangviang	Vientiane	18°56'00"N	102°27'00"E	215m	1929																						-		
				(4) Vientiane	Vientiane	17°57'00"N	102°31'00"E	170m		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	▲	-	Hydromet

notes) "●":Collected Data, "-":Cannot see Data (Not Avairable to Collect), "×":Un Measurement, "◎": Daily data not avairable (only monthly data collected), "○":only Annual(yearly) data avairable, "30"(number): number of not avairable days

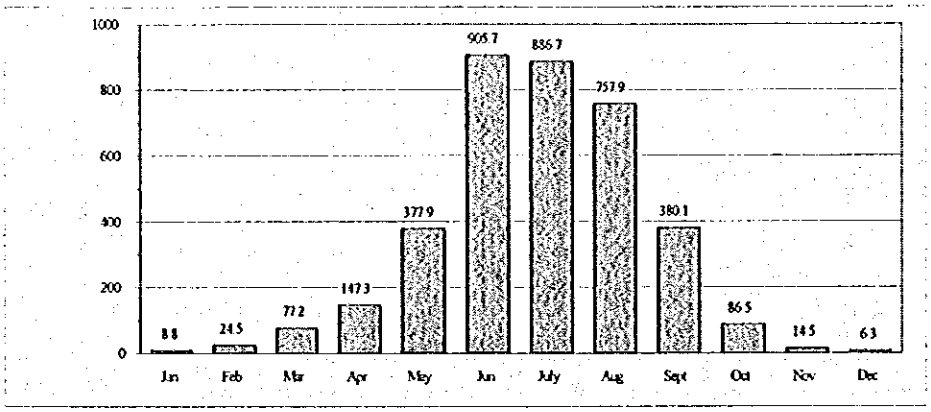


Figure 4.3.1 Monthly Rainfall Average (mm) at Muangmai Rain-gauge Station

Because of a high altitude of hydrological topography, the basin rainfall is fairy high. Cyclones, which come in from the China Sea, usually run up the Mekong valley either on the left bank (in the most cases) or on the right bank. When they reached in the Nam Ngiep basin, the high ridges in the western and northern areas disturb them further running up to the north and make them stagnate until atmospheric depression disappears.

Hence, annual rainfall will reach as close as 3,000mm/year, compared with other adjacent areas of 2,000mm/year order in the region. The showers concentrate during a short summer period and thus the runoff is particularly high in spite of the dense vegetation in the basin.

(2) Rainfall Gauging Stations

The existing rainfall gauging stations ever installed in the Nam Ngiep River basin are only the three stations as shown below:

(i) M.Khoun installed in the uppermost river basin (year of establishment is unknown),

(ii) M.Phaxay installed in the uppermost river basin (year of establishment is unknown), and

(iii) B.Muangmai installed in the lowermost river basin in 1978.

The rainfall gauging stations are owned and operated by Department of Meteorology and Hydrology (DMH), Ministry of Agriculture and Forestry.

The additional rainfall gauging station with an automatic recorder (located in the Thaviang Sub-District) was newly installed by the Study Team in 1998. The Thaviang Sub-District is situated in almost the center of the Nam Ngiep River basin for the purpose of better estimate of basin mean rainfall and its aerial pattern in the basin.

A total of twelve (12) gauging stations exist in and around the Nam Ngiep River basin as tabulated in Table 4.3.2 and the location of those stations is shown in Figure 4.3.3 afterward.

Table 4.3.2 List of Observation Station

No.	River Basin	Name of Station	Province
1.	Nam Ngiep	M.Khoun	Xiengkhuang
2.		M.Phaxay	
3.		B.Muangmai	Bolikhamxay
4.	Other Basin	Pathouay	Bolikhamxay
5.		Pakxan	
6.		Muan Kao	
7.		Houayleuk	
8.		Thabok	
9.		Xiengkhuag	Xiengkhuang
10.		Naluang	Xaysomboun Special Zone
11.		Vientiane	Vientiane
12.		Van Vieng	

(3) Rainfall Data

Available rainfall data observed at the above stations are extremely limited as shown in Table 4.3.2 above. Long-term historical rainfall records of more than thirty years are not available in and around the Nam Ngiep River basin.

4.3.3 HYDROLOGICAL DATA

(1) Hydrological Topography

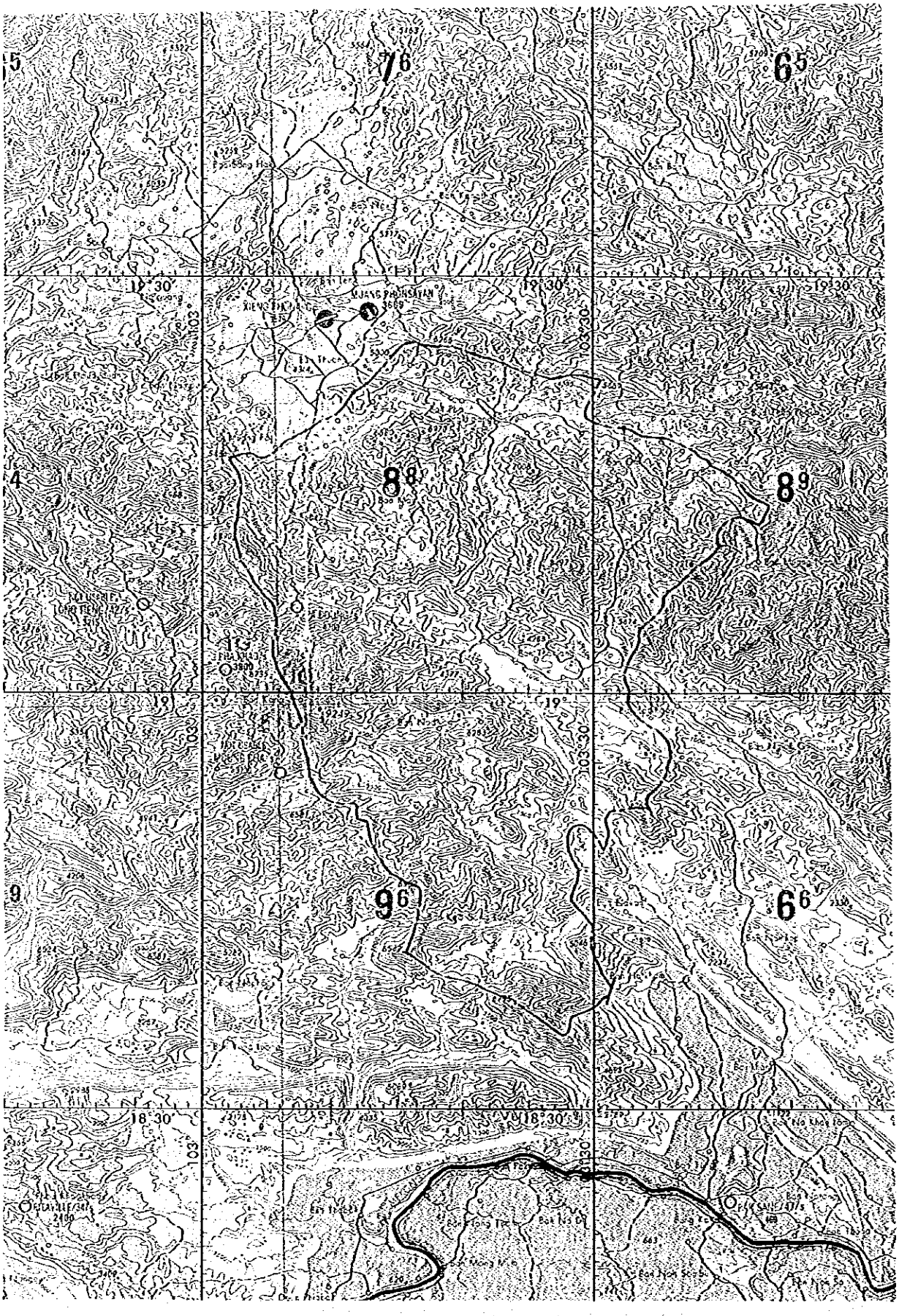
As shown in Figure 4.3.2, the Nam Ngiep River flows down from north to south in a dense forest area for the distance between its origin the Tra Ninh plateau at EL.1,200m (3,940ft) and the Mekong plain at EL.160m (520ft). The western and northern edges of the basin form a gorge of the result of erosion. The maximum altitude of the ridge is 2,819 m (9,249ft), which is located west of the basin.

Using a topographical map of a scale 1:100,000, the Nam Ngiep basin was divided into six (6) sub-basins and the area of the respective watershed was measured by plani-meter. The result is as shown in Table 4.3.3 and Figure 4.3.3.

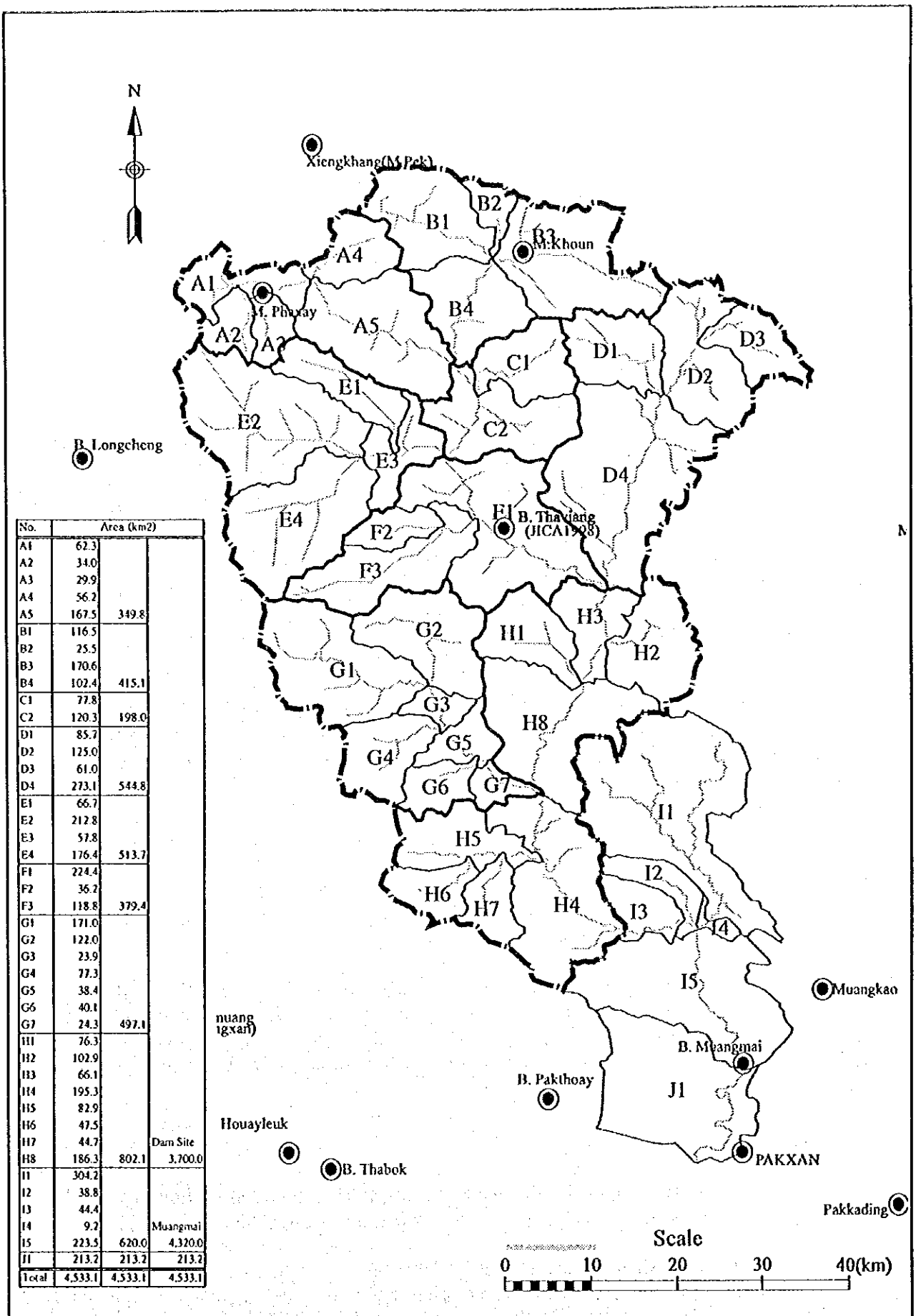
Table 4.3.3 Watershed Areas of Major Hydrological Sites

No.	Site/Station	Catchment Area (km^2)
1.	Upper Run-of-River type intake site	765
2.	Nam Phouan Run-of-River type intake site	473
3.	Proposed Nam Ngiep 1 Dam site	3,700
4.	Nam Xao river basin	313
5.	Muangmai hydrological gauging station	4,320
6.	Total Nam Ngiep basin (confluence with Mekong river)	4,533

Among the several existing reports, there found notable discrepancies of the watershed area at Muangmai gauging station as shown in below. As the areas between the measurement during this Study and those in the Pre-F/S Report are relatively close, the figures (4,320 km^2) of the Pre-F/S Report were adopted as the watershed area at the Muangmai station.



FEASIBILITY STUDY ON THE NAM NGIEP-I HYDROELECTRIC POWER PROJECT IN THE LAO PEOPLE'S DEMOCRATIC REPUBLIC JAPAN INTERNATIONAL COOPERATION AGENCY	**Figure 4.3.2** Topographic Map of Watershed Area of Nam Ngiep Basin



No.	Area (km2)		
A1	62.3		
A2	34.0		
A3	29.9		
A4	56.2		
A5	167.5	349.8	
B1	116.5		
B2	25.5		
B3	170.6		
B4	102.4	415.1	
C1	77.8		
C2	120.3	198.0	
D1	85.7		
D2	125.0		
D3	61.0		
D4	273.1	544.8	
E1	66.7		
E2	212.8		
E3	57.8		
E4	176.4	513.7	
F1	224.4		
F2	36.2		
F3	118.8	379.4	
G1	171.0		
G2	122.0		
G3	23.9		
G4	77.3		
G5	38.4		
G6	40.1		
G7	24.3	497.1	
H1	76.3		
H2	102.9		
H3	66.1		
H4	195.3		
H5	82.9		
H6	47.5		
H7	44.7		Dam Site
H8	186.3	802.1	3,700.0
I1	304.2		
I2	38.8		
I3	44.4		
I4	9.2		Muangmai
I5	223.5	620.0	4,320.0
J1	213.2	213.2	213.2
Total	4,533.1	4,533.1	4,533.1

FEASIBILITY STUDY ON THE NAM NGIEP-1 HYDROELECTRIC POWER PROJECT IN THE LAO PEOPLE'S DEMOCRATIC REPUBLIC	**Figure 4.3.3** **Watershed Areas of Major Hydrologial Sites**
JAPAN INTERNATIONAL COOPERATION AGENCY	

Table 4.3.4 Difference of the Watershed Area at Muangmai Station

No.	Published Reports	C/Area at Muangmai (km^2)
1.	Lower Mekong Hydrologic Yearbook (Mekong River Commission)	4,270
2.	Hydrological Data Book (1997,DMH(MAF) & JICA)	4,305
3.	Hydropower Layout of Nam Ngiep 1 Pre-Feasibility Study (Jan 1991,Sogreah & HEC)	4,320
4.	Power System Planning in MIH, Final Report (1998,MIH & Knight Piesold)	4,367

(2) Water Level Data

The existing water level gauging station in the Nam Ngiep River basin is only one station installed at B.Muangmai. The water level observation by a staff gauge at B.Muangmai started by DMH in 1978 and has been facilitated with an automatic recorder by the Mekong River Commission since 1986. The water level station for the staff gauge is owned and operated by DMH and the water level station with the automatic recorder seems to be owned by the Mekong River Commission and be operated by DMH. The water level records are regularly sent to DMH on a half-monthly basis. Water level data at B.Muangmai are available from 1978 to 1992.

The additional two (2) stream gauging stations with a staff gauge (located in B.Hatkham and B.Thahua) were newly installed by the Study Team in 1998 to better estimate project inflows at the dam site. B.Hatkham is situated about 8.5km downstream of the proposed dam site and B.Thahua is located about 3.0km upstream of the Nam Xao River which drains into the Nam Ngiep River 10km downstream of the proposed dam site.

The Study Team has confirmed that the second stream gauging station with a staff gauge was installed by DMH in B.Phoneyeng located the uppermost area of the Nam Ngiep River. The catchment area is reported to be 279 km^2 by DMH. The year of installation and detailed location were not obtained from DMH.

(3) Discharge Measurements and H-Q Curves

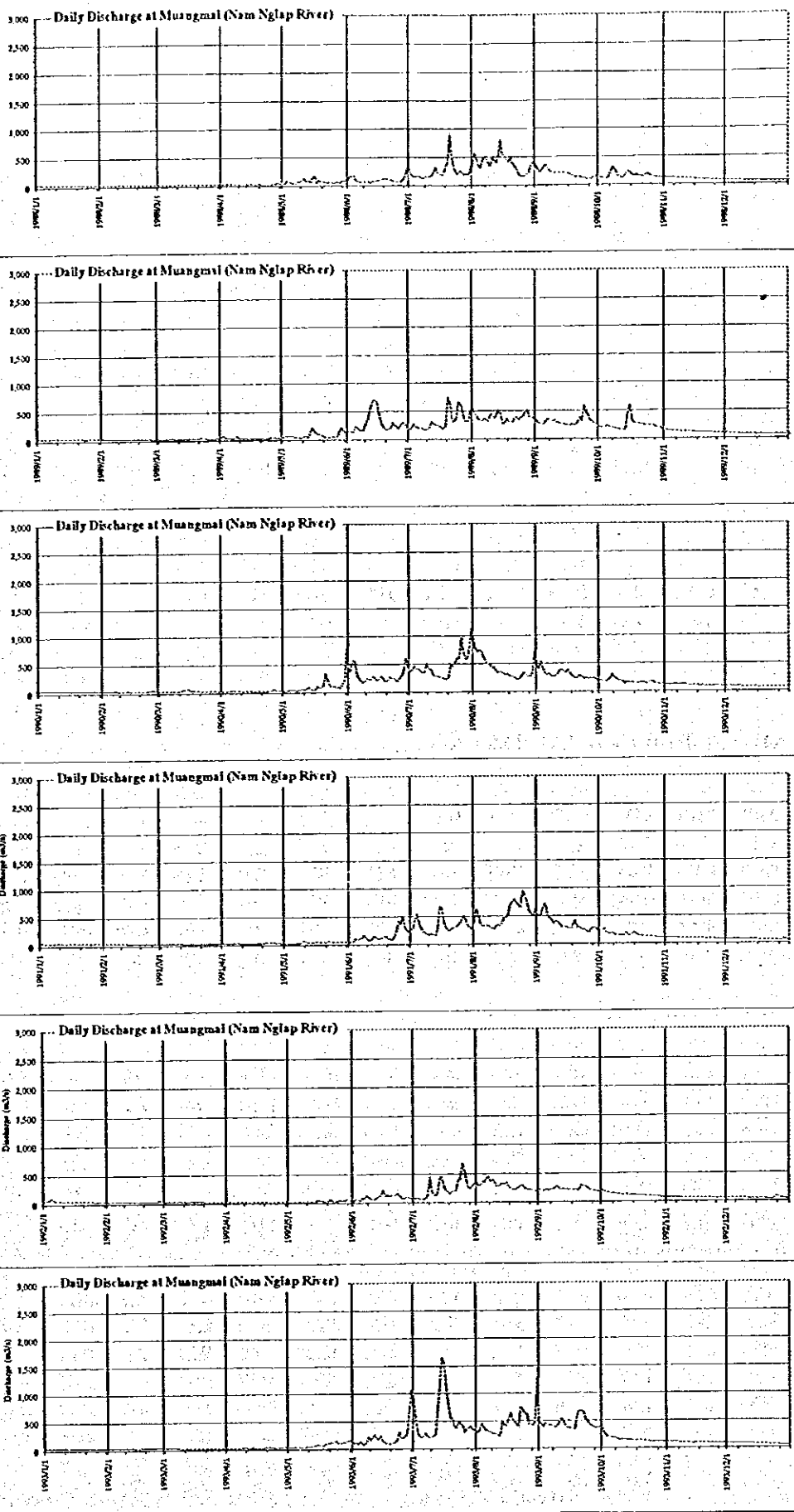
Discharge measurements at B.Muangmai have been carried out by DMH since 1987 and been sent to the Mekong River Commission through DMH and then finally reported in the Lower Mekong Hydrologic Yearbook since 1988.

H-Q curves have annually been evaluated and established by the Mekong River Commission on the basis of the discharge measurements in each year since 1988. The number of discharge measurements and the constructed H-Q curve for each year are only reported in the Lower Mekong Hydrologic Yearbook from 1988 to 1993. The hydrologic yearbook after 1993 has not been published yet.

(4) Discharge Data

The discharge data at B.Muangmai estimated by the above H-Q curves are officially compiled in the Lower Mekong Hydrologic Yearbook from 1988 to the latest in 1993.

The discharge data at B.Muangmai from 1994 to 1997 (as a computer output) were also obtained by the Study Team in 1999 from DMH with discharge measurement records. The adopted H-Q curves for the periods from 1994 to 1997 were not obtained from DMH.



FEASIBILITY STUDY
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Figure 4.3.4

Hydrograh at Muangmai (1988-1993)

(5) Daily Discharge Fluctuation

Using the daily average water level records measured at Muangmai gauging station for the period 1988 to 1993 and the water level-discharge relations (H-Q Curve) established, their daily discharge fluctuations were determined as shown in Figure 4.3.4. It was quoted from the converted data in the Lower Mekong Hydrologic Yearbook published by the Mekong River Committee. The hydrographs show a clear difference in discharges between the dry season and wet season and also show especially large variations of discharges in the wet season.

On the other hand, the flood recession pattern on hydrographs shows a rather quick recession after sharp peaking, in spite of the run-off from the dense forest area. It suggests that the watershed has a shallow impermeable layer with thin topsoil cover or low permeable topsoil along the steep river banks, though precipitation pattern in the area is also one of the factors.

4.4 EVALUATION OF METEOROLOGICAL & HYDROLOGICAL DATA

4.4.1 METEOROLOGICAL DATA

(1) Observation Network for Rainfall

As discussed in the previous chapter, the observation network for the estimate of basin mean rainfall in the Nam Ngiep River is inadequate and inaccurate presently. Even with other rainfall gauging stations around the basin, no reliable estimate of basin mean rainfall can be made by either the local isohyetal map method or the Thiessen polygon method.

(2) Estimate of Basin Mean Rainfall

The isohyetal map of annual rainfall has been constructed by the Mekong River Commission since 1989 and officially reported in the Lower Mekong Hydrologic Yearbook from 1989 to the latest in 1993, covering the whole lower Mekong River basin.

An attempt was made by the Study Team to estimate the annual mean basin rainfall in the Nam Ngiep River basin using the above regional isohyetal map constructed by the Mekong River Commission. Results of the analysis are summarized below:

Table 4.4.1 Mean Annual Basin Precipitation in the Nam Ngiep River Basin at B.Muangmai

Year	Mean Annual Rainfall (mm)
1989	2,150
1990	3,070
1991	1,870
1992	1,550
1993	2,950
Average	2,320

These values of MAP (Mean Annual Precipitation) are not regarded to be the long-term ones and only as reference values, but can be comparable with the mean annual runoff at B.Muangmai in each year as explained in Chapter 4.4.2 (3) later.

4.4.2 HYDROLOGICAL DATA

(1) Water Level Records at B.Muangmai

The reliability of water level records at B.Muangmai station shall first be reviewed and checked since water level measurements are the only direct means of quantifying the amounts and degree of runoff in the basin.

Water level readings of staff gauge are properly performed once per day at 7 a.m. normally and twice at 7 a.m. and 5 p.m. on rainy days by a nearby resident assigned as a gauge keeper. Water level readings by pressure-typed automatic recorder are well operated and maintained by DMH.

The river flow at B.Muangmai water level gauging station is almost uniform and the river course is straight. The cross section at the gauge site is almost a single trapezoid with no flood plains. The staff gauge is suitably installed up to 8 m from the river bed covering low to high flow regimes.

The backwater effect to the gauging site by water level of the Mekong River was checked by the comparison of historical water level records at B.Muangmai and at Pakxan of the Mekong River which is located downstream about 12 km from B.Muangmai station and at the confluence to the Nam Ngiep River.

The most critical condition occurred on of September 9, 1993 on the basis of available water level records from 1988 to 1993 in the Lower Mekong Hydrologic Yearbook as summarized in the following.

Table 4.4.2 Minimum Water Level Difference between Pakxan and B.Muangmai (1988-1993)

Date of Occurrence	Measure at Pakxan		Measure at B.Muangmai		Difference of Water Level (m)
	W.L Gauge (m)	W.L (EL.m)	W.L Gauge (m)	W.L (EL.m)	
Sept. 9, 1993	11.34	153.465	3.59	156.102	2.637

Note : Zero of gauge at Pakxan and B.Muangmai is 142.125 and 152.512 m above M.S.L., respectively.

The analysis reveals the following:

(i) Difference of zero of gauge at Pakxan and B.Muangmai is 10.387m.

(ii) River length between two sites is measured as 11.8km.

(iii) Average river slope between two sites is measured as 1/1,136.

(iv) Critical condition of small difference of water level between Pakxan and B.Muangmai occurs annually at the end of rainy season when water level of the Mekong River at the Pakxan is still high and water level at the B.Muangmai is low.

(v) Minimum water level difference (= 2.637m) from 1988 to 1993 occurred on September 9, 1993.

(vi) Discharge at water level of 3.59m on September 9, 1993 was measured as 384m^3/s.

(vii) Velocity at water level of 3.59m on September 9, 1993 was estimated to be around 1.0m/s by discharge measurement records in 1994.

Based on the results of the above analysis on river and flow conditions of the most critical condition, it is preliminarily considered that the possibility of backwater effect by the water level of the Mekong river at Pakxan to the B.Muangmai stream gauging station seems to be very low and negligible, if occurred, in terms of river hydraulics.

(2) H-Q Curves Established at B.Muangmai

The number of discharge measurements in each year as shown in the Lower Mekong Hydrologic Yearbook from 1988 to 1993 is tabulated below:

Table 4.4.3 Number of Discharge Measurements

No.	Year	Range of Measurements (m)	Number of Measurements	Maximum Daily Water Level (m)
1.	1988	0.35 - 6.90	16	7.00 (July 21)
2.	1989	0.34 - 4.03	18	7.20 (July 20)
3.	1990	0.38 - 4.89	19	7.56 (July 31)
4.	1991	0.32 - 5.03	20	6.85 (August 25)
5.	1992	0.56 - 4.01	15	6.95 (July 25)
6.	1993	N/A	N/A	9.71 (July 15)

The H-Q rating curve in each year was determined through the annual discharge measurements as shown in the Lower Mekong Hydrologic Yearbook. However, in 1993, the rating of the station was constructed through 24 discharge measurements during 1991-1993 as explained in the above yearbook. The number of measurements in 1993 is not shown in the yearbook.

The number of discharge measurements per year is seemingly suitable for the determination of a rating curve for each year. However, the reliability and adaptability of each rating curve are still to be checked by collecting discharge measurement records from MRC or DMH.

(3) Discharge Records at B.Muangmai

The estimated daily discharge data series at B.Muangmai from 1988 to 1993 obtained from the hydrologic yearbook and from 1994 to 1997 obtained from DMH are to be evaluated by further data collection such as discharge measurement records and method of H-Q rating determination by the Mekong River Commission.

An attempt was made by the Study Team to compare the estimated mean annual discharge with the estimated mean annual precipitation at B.Muangmai as follows:

Table 4.4.4 Comparison of Mean Annual Precipitation and Runoff at B.Muangmai

Year	Mean Annual Precipitation (mm)	Mean Annual Runoff (mm)	Runoff Ratio
1988	-	880	-
1989	2,150	1,200	0.56
1990	3,070	1,290	0.42
1991	1,870	1,150	0.61
1992	1,550	770	0.50
1993	2,950	1,320	0.45
Average (89-93)	2,320	1,150	0.51
1994	-	1,930	-
1995	-	1,720	-
1996	-	1,280	-
1997	-	1,640	-
Average (94-97)	-	1,640	-
Average (89-97)	-	1,367	-

The results of this analysis reveal:

(i) Runoff ratio (1989-1993) is calculated ranging from 0.42-0.61. The mean runoff ratio is 0.51,

(ii) Mean annual runoff from 1989 to 1997 is estimated to be 1,367mm, and

(iii) Mean annual runoff from 1994 to 1997 is estimated to be 1640 mm (43% higher than mean annual runoff from 1989 to 1993).

4.5 REVIEW AND EVALUATION OF LONG-TERM MONTHLY MEAN INFLOW AT DAM SITE

4.5.1 REVIEW OF PREVIOUS HYDROLOGICAL STUDIES

(1) Inventory Studies on Lower Mekong Water Resources

According to the Interim Report on Hydropower Development Plan for the Lao PDR, Lahmeyer and HP, February 1997, Nam Ngiep 1 Project was listed among the previously identified hydroelectric schemes in the Lao PRD by the following inventory studies on Lower Mekong Water Resources.

(i) Inventory of Promising Tributary Projects in the Lower Mekong Basin, Mekong Secretariat, December 1970.

(ii) Lower Mekong Water Resources Inventory, Summary of Project Possibilities, prepared by WATCO for the Mekong Secretariat, September 1984.

The following brief hydrological data are referred to in the Interim Report on Hydropower Development Plan for the Lao PDR, Lahmeyer and HP, February 1997.

Table 4.5.1 Hydrological Data of Nam Ngiep Dam Site

Drainage Area of Nam Ngiep Dam Site (km^2)	Mean Annual Runoff (m^3/s)
3,730	152

The mean annual runoff was supposedly estimated by regional hydro-meteorological analysis using mean annual basin rainfall for the dam site and regional runoff ratio. No further details were obtained by the Study Team.

(2) Pre-F/S on Hydropower Layout on Nam Ngiep-1

The Pre-F/S on hydropower layout of Nam Ngiep 1 was carried out by Sogreah and HEC and completed in January 1991. The updating of revised Pre-F/S was later carried out and completed in November 1995.

The Study Team has gathered the following reports regarding hydrological study.

(i) Pre-F/S on Hydropower Layout of Nam Ngiep 1, Sogreah and HEC, January 1991 (both in English and in French).

(ii) Hydropower Development of Nam Ngiep 1, updating of revised prefeasibility study, Sogreah, November 1995.

The Pre-F/S had carried out the following hydro-meteorological analyses:

(i) Calculation of catchment area at Nam Ngiep 1 dam site (= 3,700km^2)

(ii) Estimation of mean annual basin precipitation at Nam Ngiep 1 dam site carried out by means of regional rainfall analysis

- Mean Annual Precipitation (MAP) = 2,960mm

(iii) Estimation of mean annual runoff at Nam Ngiep 1 dam site carried out by a probabilistic theory

- Mean Annual Runoff (MAR) = 1,798 mm (or 210.8m^3/s)
- Runoff ratio = 0.61

(iv) Estimation of monthly discharge data series at Nam Ngiep 1 dam site obtained by generation model, using monthly distribution of the annual total, the correlation coefficients between monthly and annual discharges and the variation coefficients of the square roots of the monthly discharges, derived from those observed at B.Nanay (the Nam Xedon River) and at Nam Ngum dam

- Two 20-year series of monthly generated discharges at Nam Ngiep 1 dam site

(3) Hydropower Development Plan for the Lao PDR

The Hydropower Development Plan for the Lao PDR was initiated in June 1994 and the Interim Report containing the results of hydropower inventory study was completed in February 1997 by Lahmeyer International and HP (Hydrotecnica Portuguesa).

The Hydropower Development Plan reviewed the following items:

(i) Previously identified hydropower projects

(ii) Availability of hydro-meteorological data

(iii) Characteristics of previously identified projects (location and hydrology)

The Nam Ngiep-I HEPP was excluded by the Hydropower Development Plan due to the existence of Memorandum of Understanding on the development by IPP. However, hydro-meteorological study carried out by the Hydropower Development Plan provides the Study Team useful information on the estimate of reliable long-term monthly discharge series at the Nam Ngiep dam site.

The Hydropower Development Plan carried out the following hydro-meteorological analyses covering the entire the Lao PDR:

(i) Examination of the periods of availability of the precipitation and discharge data up to the year 1991 obtained from the Mekong River Commission,

(ii) Estimation of the mean annual precipitation and mean discharge over the standard period (30 years from 1962 to 1991),

(iii) Elaboration of Isohyetal map of mean annual precipitation over the standard period in the Lao PDR,

(iv) Establishment of a simple discretised river basin model for each of the Mekong tributary river basins, and

(v) Derivation of monthly discharge series at the project sites over the standard period, using hydrological characteristics obtained from the river basin models.

The estimated mean annual precipitation and runoff at B.Muangmai station (1962-1991) are tabulated below:

Table 4.5.2 Estimated Mean Annual Precipitation and Runoff at B.Muangmai (1962-1991)

Area (km^2)	MAP (mm)	MAR (mm)	MAR (m^3/s)	Runoff Ratio
4,367	2,409	1,332	184.5	0.55

(4) Nam Theun 2 Study of Alternatives

Nam Theun 2 Study of Alternatives was carried out by Lahmeyer and Worley and the Final Report was presented in March 1998. The study reviewed hydrology of non-Nam Theun 2 IPP, including the following analyses:

(i) Review on previous hydrological studies

(ii) Flow estimation at IPP sites

The estimated annual discharge at Nam Ngiep 1 is tabulated below. The same procedures are adopted to this analysis with the Hydropower Development Plan.

Table 4.5.3 Estimated Mean Annual Runoff at Nam Ngiep 1 Dam Site (1966-1995)

Catchment Area (km^2)	Mean Annual Runoff (mm)	Mean Annual Runoff (m^3/s)
3,700	1,383	162

The estimated 30-year monthly runoff series from 1966 to 1995 at the Nam Ngiep dam site are shown in Table 6.3.7 hereinafter. The estimated mean annual precipitation at the Nam Ngiep dam site is not described in the report.

(5) Power System Planning in the Ministry of Industry and Handicraft

A Power System Planning within the Lao PDR was carried out by Knight Piesold Ltd. in 1996 to assist in developing the appropriate skill mix within the Ministry of Industry and Handicraft (MIH). The study excluding the Nam Ngiep 1 HEPP was completed and the Final Report was presented in January 1998.

The study reviewed the previous studies and basically adapted the estimate of annual mean precipitation and runoff at stream gauging stations and project sites in the Lao PDR obtained by the Hydropower Development Plan for the Lao PRD. Therefore no new hydro-meteorological estimates were carried out by the study.

4.5.2 REVIEW RESULTS ON MONTHLY MEAN INFLOWS ESTIMATES

(1) Catchment Area

The catchment areas at the Nam Ngiep-I proposed dam site and B.Muangmai stream gauging station estimated by the previous studies are shown in Table 4.5.4.

The JICA Study (1998) calculated the catchment areas at Nam Ngiep-I dam site and B.Muangmai gauging station using a 1:100,000 map and its results are the same as the ones of the Pre-feasibility Study by Sogreah (1991).

(2) Mean Annual Precipitation and Runoff

Mean annual precipitation and runoff at the Nam Ngiep-I proposed dam site and B.Muangmai stream gauging station estimated by the previous studies are shown in Tables 4.5.5 and 4.5.6.

Table 4.5.4 Comparison of Catchment Area at Nam Ngiep-1 Dam Site and B.Muangmai Station

Study (or Organization)	C/A at Dam Site (km^2)	C/A at B.Muangmai (km^2)
1. Mekong River Commission (*)	-	4,270 (98.8%)
2. DMH (1997) (**)	-	4,305 (99.7%)
3. Inventory Study by MRC (1970)	3,670 (99.2%)	-
4. Pre-feasibility Study (1991)	3,700 (100%)	4,320 (100%)
5. Hydropower Development Plan (1997)	-	4,367 (101.1%)
6. Nam Theun 2, Study of Alternatives (1998)	3,700 (100%)	-
7. JICA Study (1998)	3,700 (100%)	4,320 (100%)

Note : (*) Lower Mekong Hydrologic Yearbook (1988-1993)
(**)Hydrological Data Book on the Mekong River Basin in Lao PDR (An Interim Report)

Table 4.5.5 Estimated Mean Annual Precipitation and Runoff at Nam Ngiep-I Dam Site

Study	Mean Annual Precipitation MAP(mm)	Mean Annual Runoff MAR(mm)	Mean Annual Runoff MAR(m^3/s)	Runoff Ratio	Note
Inventory Study (MRC in 1970)	-	1,607	187	-	No further data is available.
Pre-F/S (Sogreah in 1991)	2,960	1,798	210.8	0.61	Annual rainfall-runoff Model (20-year) Synthetic Flow Model to generate monthly runoff series.
Nam Theun 2 Study of Alternatives (Lahmeyer & Worley in 1998)	-	1,383 (1966-1995)	162 (1966-1995)	-	30-year monthly runoffs at the dam site were estimated. The same procedure was adapted with Hydropower Development Plan.

Table 4.5.6 Estimated Mean Annual Precipitation and Runoff at B.Muangmai Gauging Station

Study	Mean Annual Precipitation MAP(mm)	Mean Annual Runoff MAR(mm)	Mean Annual Runoff MAR(m^3/s)	Runoff Ratio	Note
Hydropower Development Plan (Lahmeyer & HP in 1997)	2,409 (1962-1991)	1,332 (1962-1991)	184.5 (1962-1991)	0.55	The estimated monthly runoff at B.Muangmai is not obtained by the Study Team.
Hydrologic Yearbook (MRC)	2,320 (*) (1989-1993)	1,150 (1989-1993)	157.5 (1989-1993)	0.51	Annual isohyetal maps and runoff data from 1989 to 1993 are also obtained from MRC. Runoff data from 1994 to 1997 are obtained from DMH.
	- (1989-1997)	1,367 (1989-1997)	187.3 (1989-1997)	-	

Note : Mean annual precipitation was estimated by the Study Team.

(3) Annual Average Inflow Series

An attempt was made by the Study Team to compare the annual average runoffs at B.Muangmai gauging station estimated by Nam Theun 2 Study of Alternatives and Hydrologic Yearbook by MRC as follows:

Table 4.5.7 Comparison of Estimated Annual Average Runoff at B.Muangmai

Year	Annual Average Runoff by Nam Theun 2 Study of Alternatives (m^3/s) (*2)	Hydrologic Yearbook by MRC (m^3/s)
1988	117	120
1989	159	164
1990	172	177
1991	151	158
1992	105	106
1993	173	181
1994	281	264 (*1)
1995	221	236 (*1)
Average	172.4 (98.1%)	175.8 (100%)

Note : (*1) Runoff data in 1994 and 95 were obtained from DMH.
(*2) Annual average runoff was originally estimated at the Nam Ngiep dam site by Nam Theun 2 Study. Annual average runoff at B.Muangmai was estimated using Catchment area ratio (=4,367/3,700) by the Study Team.

4.5.3 PRELIMINARY EVALUATION

(1) Catchment Area

The deviation of seven different estimates of catchment area at B.Muangmai and Nam Ngiep-I dam site is within +/- 1% to the latest estimate by Study Team.

Therefore, the following estimates of catchment at B.Muangmai stream gauging station and the Nam Ngiep-I dam site by the Pre-feasibility Study (1991) are considered to be adapted to the further study since the same estimates were recalculated by the Study Team.

Table 4.5.8 Adapted Catchment Area at Nam Ngiep-I Dam Site and B.Muangmai Station

Study	Catchment Area at Nam Ngiep Dam Site (km^2)	Catchment Area at B.Muangmai Station (km^2)
Pre-feasibility Study (1991)	3,700	4,320
JICA Study (1998)	3,700	4,320

(2) Mean Annual Precipitation (MAP)

Based on the review on the estimates of mean annual precipitation (MAP) as shown in 3.2 (1), the value estimated by Hydropower Development Plan (Lahmeyer & HP in 1997) is considered to be the long-term MAP (= 2,409mm/year) for the B.Muangmai gauging station since this value was obtained by regional isohyetal map of 30-year annual rainfall records (1962-1991) covering the entire the Lao PDR.

The long-term MAP for the Nam Ngiep-I dam site is still to be checked by further data collection, if any, or estimated by the further study.

(3) Mean Annual Runoff (MAR)

Based on the review on the estimates of mean annual runoff (MAR) as shown in 3.2 (1), the value estimated by Hydropower Development Plan (Lahmeyer & HP in 1997) is considered to be the long-term MAR (= 184.5m^3/s) for the B.Muangmai gauging station since this value was estimated and extended by correlation of monthly runoff records at B.Muangmai gauging station with near-by stream gauging stations for 30 years (1962-1991).

The long-term MAR for the Nam Ngiep-I dam site (= 162m^3/s) was also estimated by the same method in the Nam Theun 2 Study of Alternatives.

(4) Annual and Monthly Runoff Series

The deviation of the estimate of mean annual runoff (1988-1995) by the Nam Theun 2 Study of Alternatives is only 2% of the observed mean annual runoff by the Hydrological Yearbook as shown in Chapter 4.5.2 (3).

Therefore, 30-year monthly mean runoffs estimated by the Nam Theun 2 Study of Alternatives are considered to be usable as the reliable inflows at the Nam Ngiep dam site for the present study.

4.6 REVIEW ON FLOOD DISCHARGE

4.6.1 ESTIMATE AT PRE-F/S

According to the Pre-F/S Report, peak discharges of the flood at the respective recurrence intervals are obtained by the following equation by Duret.

$$Q_{(T)} = \frac{2}{1000} \times S^{0.80} \times I^{0.32} \times P_{(T)}^{1.39}$$

Where, Q(t) : Peak discharge at T-years recurrence interval (m^3/s)
P(t) : Daily rainfall at T-year recurrence interval (mm)
S : Basin drainage area (km^2)
I : h / L x 100 (%)
L : Length of waterway (km)
H : Height difference between both u/s and d/s ends (m)

Applicability of the above equation was confirmed in the flood analysis made for the Nam Leuk hydropower project.[1]

Probable floods obtained at major points in the Nam Ngiep basin using the above equation are as shown in the table below.

Table 4.6.1 Probable Floods at Major Points in Nam Ngiep Basin (m^3/s)

No.	Site	S (km^2)	I (%)	T=2yr	10yr	20yr	50yr	100yr	1000yr	10000yr	PMF
1.	Muong Mai	4,320	0.724	1,545	2,885	3,445	4,220	4,820	-	-	-
2.	Ban Hatkham	3,748	0.840	1,447	2,701	3,226	3,952	4,514	-	-	-
3.	Berrage	3,700	0.870	1,448	2,704	3,230	3,956	4,519	6,530	8,730	15,900

Refer to : Hydropower Development of Nam Ngiep 1 – Updating of Revised Pre-feasibility Study, p.10, SOGREAH, Nov.1995.

4.6.2 REVIEW ON ESTIMATE

In 1997, a pressure-type automatic water level gauge was installed at Muangmai gauging station. If the continuous data measured at this station are used, hourly data and 10-minutes data of flood hydrographs may be able to be drawn. However, water level-discharge relation should be carefully established taking into consideration changes of river cross sections due to yearly flooding. It is necessary to further review the probable floods and design flood discharges by using the data at the above station.

[1] cf. Nam Leuk Hydropower Development Project-Detailed Engineering and Tender Documentation-Hydrology, SOGREAH, March 1995

5. POWER MARKET SURVEY

5.1 GENERAL

A mountainous country with a population of about 5 million, Lao PDR is one of the least developed countries in Asia with a per capita Gross National Product (GNP) of about US$370 in 1997. Agro-forestry production dominates the economy and the industry base is very small, contributing to about 21% of the GNP. However, since opening its door to international investment and trade, Lao PDR has experienced robust economic growth, with GDP expanding at around 7% between 1992 and 1996.

Despite economic downturn in Thailand and other Asian countries, the Lao economy grew by a solid 7.2% in 1997, the second fastest in Asia, only after Vietnam. Power sector contributes to this rapid economic growth, and the installed capacity increased at a rate of 14.5% per annum since 1991. Based on the Bank of Lao's estimate, electricity is the largest net export in total value in 1998, contributing to about 22% of total export and at least 6% of GDP.

Nevertheless GDP in 1998 grew only 4% against the previous year, as the economy was adversely affected both by Asia's economic crisis and by flooding in the central and southern parts of the country.

5.2 POWER MARKET IN GREATER MEKONG SUB-REGION

The Greater Mekong Sub-Region (GMS), comprises Cambodia, Lao PDR, Myanmar, Thailand, Vietnam, and the Yunnan Province of the PRC. Among these countries and region, Thailand is energy deficient and will increasingly rely on imports, in spite of its own oil, gas, and lignite reserves.

China's Yunnan and Vietnam have significant deposits of coal. There are substantial recoverable reserves of natural gas, mainly from offshore fields in Myanmar and Thailand, and possibly Vietnam. Thailand will remain a net importer of gas.

In power generation, EGAT has agreed to purchase Lao hydropower and lignite. In these agreements with the GOL both on June 4, 1993 and June 19, 1996, EGAT agreed to purchase up to 3,000MW of Lao electricity by the year 2006. However, under the revised power development plan (Revised PDP-01) of Thailand, EGAT changed the amount to be purchased to about 1,600MW and 1,700MW in 2006 and 2008 respectively.

Thailand also entered into the Memorandum of Understanding (MOU) on July 4, 1997 expressing its intention to import power generated from both hydro and natural gas-fired power plants from Myanmar. The Government of Thailand will encourage EGAT or other agencies to

buy up to 1,500MW by 2010. Four (4) projects, the Nam Nok HEPP (55MW), the Hutgyi HEPP (400MW), the Tasen HEPP (3,600MW), and the Kanbauk Combined Cycle Project (1,500MW) were included in the initial program for power export to Thailand at the first meeting on April 29, 1998.

The Governments of Thailand and People's Republic of China entered into a MOU on November 12, 1998 for power export of 3,000MW including Jinghong HEPP (1,500MW) to Thailand by the end of 2017.

The GOL reached an MOU with the Government of Vietnam to supply 1,500 to 2,000MW by the year 2010. Lao PDR has also agreed to exchange power with China's Yunnan province at the bordering area.

5.3 POWER MARKET IN LAO PDR

5.3.1 GENERAL

The basic power policy of Lao PDR stresses self-sufficiency of electricity for internal demand, rural electrification and increase in earning from electricity sales to abroad.

Energy consumption in the country relies on wooden fuel (90%) and consumption of fossil fuel and electricity is only 5% each. Consequently, development of hydropower potential in the country is also important from Lao PDR's point of view of mitigation of environmental impact and conservation of national forestry.

In 1986, the New Economic Mechanism was introduced under which particular urgency at power sector development was given to the following:

(i) Increase in export earnings from electricity sales,

(ii) Encouragement of private participation in power sector development,

(iii) Expansion of the domestic grid system to increase the domestic customer base, and

(iv) Consolidation of the long-term financial viability of the national power utility, EDL.

Improvement has been made to provide a sound legal and regulatory framework, and new laws, including Contract Law (1990), Foreign Investment Law (1994), and Electricity Law (1997) have been enacted. During the same period, the government opened up banking and financial sector for private and foreign banks to operate in Lao PDR.

The GOL has attached high priority to hydropower expansion in pursuit of its macroeconomic and social objectives. The power sector policy calls for the development of power projects at two levels to meet the different market requirements:

(i) Small/Medium projects (up to about 60MW) shall be developed for supplying domestic market, either by servicing isolated loads or feeding into the domestic grid systems, and

(ii) Medium/Large projects (greater than about 60MW) shall be developed for satisfying

export requirements and adjacent local demand.

As part of these efforts, the GOL has signed with the Government of Thailand to commit 1,600MW of power capacity by the year 2006 and 1,700MW by 2008, and reached an MOU with the Government of Vietnam to supply 1,500 to 2,000MW by the year 2010. The GOL's plan is to expand the installed capacity to over 3,000MW, most of which will be implemented by IPP projects and dedicated to export.

5.3.2 IPP GOVERNMENTAL AGENCIES

A vertically integrated state-owned company, EDL used to be responsible for power construction, generation, and distribution. The GOL established the Hydropower Office (HPO) in 1991 for the planning and implementation of the IPP program. HPO, under the Department of Electricity at the Ministry of Industry and Handicrafts (MIH), is now the management and administrative focus for the IPP program in Lao PDR, leaving EDL to concentrate more on its prime responsibility of domestic electricity generation, transmission and distribution.

All foreign investment in Lao PDR is channeled through and coordinated by the Foreign Investment Management Committee (FIMC) within the Prime Minister's Office. FIMC provides a "one-stop shop" service for developers seeking a mandate to build power projects in the country. The organization chart of principal GOL agencies involved in IPP implementation is shown in Figure 5.3.1.

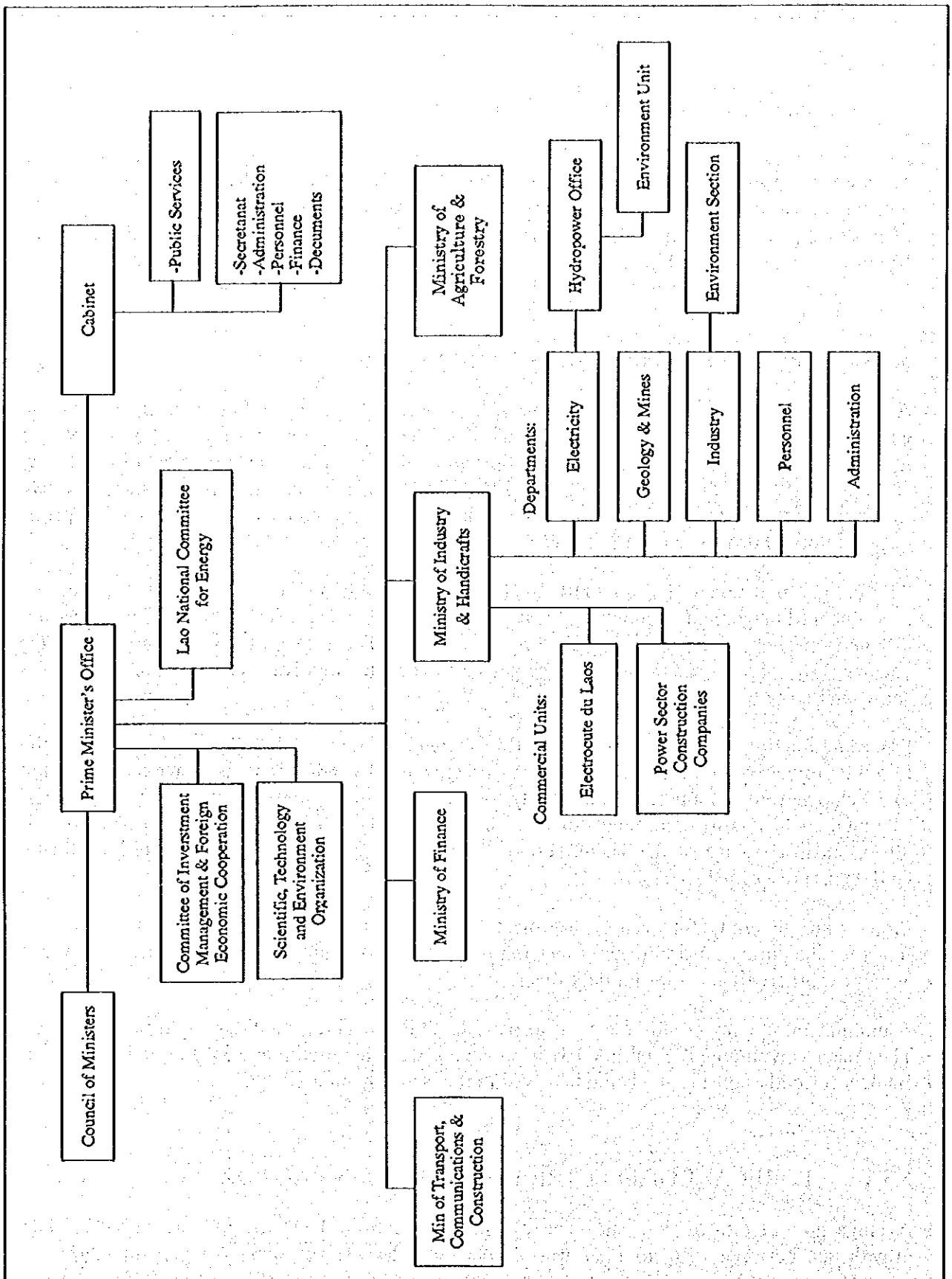
Procedure for IPP Participation in Lao PDR is shown in Figure 5.3.2. The modality used for the Lao IPP projects is a traditional BOOT arrangement whereby a developer is granted a concession to develop a project and takes responsibility for its evaluation, design, construction and operation. The GOL policy is to hold equity in each project, usually a minority stake (typically 20% to 30%), but in the case of the Theun-Hinboun HEPP commenced operation in April 1998, the GOL takes 60% of the shares.

Projects are generally financed on a project finance basis by consortiums using their internal funds for the equity portion of the financing package and a combination of commercial sources and/or export credit agencies for debt finance.

A multilateral agency could be sought to participate in financing the GOL equity contribution. The Asian Development Bank (ADB) is financing the Theun-Hinboun HEPP, and the World Bank is currently considering being involved in the Nam Theun 2 HEPP.

5.3.3 FORECAST OF ELECTRICITY DEMAND IN LAO PDR

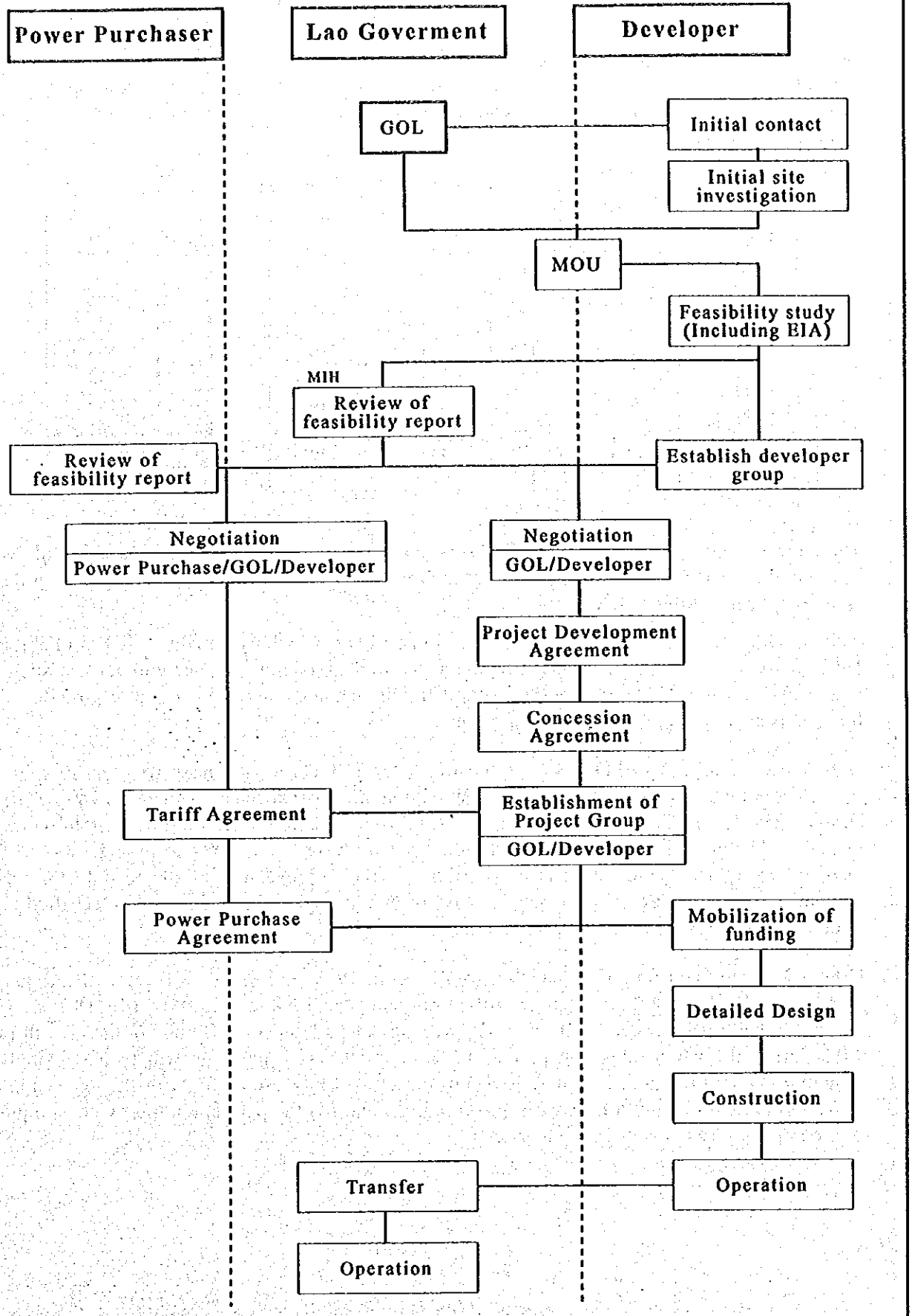
Average growth rate of domestic energy consumption from 1991 to 1997 was 12.4%. The growth rate between 1996 to 1997 was 14.7%. The largest consumer category in 1997 was residential usage, accounting for 52% of total demand, followed by industry: 20%, business: 11% and government: 11%. Industrial usage's share increased from 9% of total in 1992 to 20%. The business usage's share decreased from 21% to 11%.



FEASIBILITY STUDY
ON THE NAM NGIEP-1 HYDROELECTRIC POWER PROJECT
IN THE LAO PEOPLE'S DEMOCRATIC REPUBLIC

JAPAN INTERNATIONAL COOPERATION AGENCY

Figure 5.3.1
Organization Chart of Principal GOL Agencies involved in IPP Implementation



FEASIBILITY STUDY
ON THE NAM NGIEP-1 HYDROELECTRIC POWER PROJECT
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JAPAN INTERNATIONAL COOPERATION AGENCY

Figure 5.3.2
IPP Project Implementation Process in Lao PDR

Domestic consumption continued to grow in 1998, yet power generation declined by 22% from the previous year due to 1998's dry weather, as shown in Table 3.5.1. Accordingly, power supply for net export was decreased considerably, because of growing domestic consumption and less power generation.

Table 5.3.1 Energy Generation and Trade Balance in Lao PDR

No.	Year	Capacity (MW)	Energy (GWh)	Power Supply (GWh)			
				Domestic	Export	Import	Net Export
1.	1990	163.56	821	165	595	28	567
2.	1991	209.21	835	221	563	35	528
3.	1992	209.9	752	253	460	41	419
4.	1993	211.75	920	265	596	48	548
5.	1994	217.39	1,198	279	829	57	772
6.	1995	218.25	1,085	338	676	77	599
7.	1996	218.6	1,248	380	792	88	704
8.	1997	221.8	1,219	434	710	102	608
9.	1998	415.0	948	471	405	142	263

Source: EDL

The largest energy consumption area (74%) is in Central-1 where Vientiane is located, followed by Central-2 area 16% and Southern area 8%. Only 2% of the total is consumed by the Northern area, as shown in Table 5.3.2.

According to the power consumption forecast in Lao PDR, which was made by EDL in February 1999, deriving from recent trends in demand as well as taking into account factors such as increasing new electrification area, improved living standards and the economic growth. The forecast is based on the following assumptions:

GDP growth rate in Lao PDR is expected to be about 3-4% for the next 10 years in spite of Asian economic stagnation as shown below. Population is expected to increase by 2.5% per annum. The electrification ratio will be increased from 30% in 1997 to 60% of the total villages in 2005. The annual load factor will be improved from 44.6% in 1997 to over 50% in 2005. Demand Side Management will also contribute to the improvement of the load factor. The demand forecast also expects a larger increase of energy consumption in newly electrified area than the increase in the presently served area.

Domestic energy consumption increased by 21.2% in 1998, and the growth rate will gradually decrease to 10.1% in 2001. Average growth rate between 1998 and 2001 will be 18.1%. The annual growth rate between 2001 and 2010 will stay at 10.1% per year, making the growth rate 14% during the whole planning period, 1998 to 2010. This rapid growth is based on two assumptions: (i) the number of new EDL customers will increase along with the expansion of transmission and distribution network in rural areas and (ii) the per capita energy consumption will be increased as personal income rises.

Table 5.3.2 Energy Consumption Forecast in Lao PDR up to 2010

Domestic Demand (GWh)													
Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Northern	10	11	13	16	23	31	43	55	64	73	78	83	88
Central 1	343	400	470	530	627	699	779	903	987	1,085	1,190	1305	1,430
Central 2	86	117	149	187	229	282	335	399	468	549	625	712	811
Southern	47	58	66	75	85	96	108	120	133	147	162	179	197
Total	486	586	698	808	964	1,108	1,265	1,477	1,652	1,854	2,055	2,279	2,526
Growth Rate (%)													
Period	98-99	99-00	00-01	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	98-10
Northern	10.0	18.2	23.1	43.8	34.8	38.7	27.9	16.4	14.1	6.8	6.4	6.0	20.5
Central 1	16.0	17.5	12.8	18.3	11.5	11.4	15.9	9.3	9.9	9.7	9.7	9.6	12.7
Central 2	36.0	27.4	25.5	22.5	23.1	18.8	19.1	17.3	17.3	13.8	13.9	13.9	20.7
Southern	23.4	13.8	13.6	13.3	12.9	12.5	11.1	10.8	10.5	10.2	10.5	10.1	12.7
Total	20.6	19.1	15.8	19.3	14.9	14.2	16.8	11.8	12.2	10.8	10.9	10.8	14.8

Source: EDL(February, 19, 1999)

5.3.4 CANDIDATE PROJECTS FOR POWER EXPORT FROM LAO PDR

(1) General

At present, the GOL has signed 15 MOUs with IPPs and two (2) PPAs with the EGAT of Thailand for power supply. The existing IPP implementation projects in Lao PDR are shown in Table 5.3.3.

Among the projects listed in the table, six (6) projects have been reviewed recently by the GOL for prioritization, namely (i) Nam Theun 2, (ii) Nam Ngum 2, (iii) Nam Ngum 3, (iv) Hong Sa thermal plant, (v) Xe Pian-Xe Namnoy and (vi) Xe Kaman 1. Their combined capacity is 3,346MW. According to the review results, 1,600MW of the project (i) to (iii) will be bought by EGAT in the year 2006 and the project (iv) to (vi) in 2008. These project locations are shown in Figure 5.3.3 afterward.

The above group of projects is considered the candidate projects for export to Thailand before the year 2008. However, from the financial point of view in Lao PDR, the Nam Ngiep-1 HEPP could be selected as a promising candidate for export to Thailand, if it can achieve better returns than one of the six projects listed above and it can be proceeded without financial problems as IPP project.

Table 5.3.3 Present IPP Projects in Lao PDR

No.	Project Name	River Basin	Capacity (MW)	Key Dates
(1)	Under operation			
1.	Nam Theun-Hinboun	Nam Theun (Nam Kading)	210	Operation (Apr.'98)
2.	Houay Ho	Xe Kong	150	Operation (Sep.'99)
(2)	Tariff Agreement signed			
1.	Hongsa Lignite	Thermal	720	PA (Sep.'96)
(3)	Under negotiation of PP A			
2.	Nam Theun 2	Nam Theun / Nam Kading	908	F/S (Nov.'90)
(4)	MOU signed	(Pre-F/S & F/S report submitted.)		
3.	Nam Ngum 2	Nam Ngum	615	F/S (Aug.'95)
4.	Nam Ngum 3	Nam Ngum	460	F/S (Oct.'95)
5.	Xepiann / Xenamnoy	Xe Kong	390	F/S (July'95)
6.	Xekaman 1	Xe Kong	468	F/S (Feb.'95)
7.	Nam Theun 3	Nam Theun / Nam Kading	237	F/S (July'95)
8.	Nam Tha 1	Nam Tha	230	F/S (Nov.'97)
9.	Nam Theun 1	Nam Theun / Nam Kading	540	F/S (Oct.'95)
10.	Nam Lik 1/2	Nam Ngum	100	F/S (Mar.'96)
11.	Nam Mo	Nam Mo	105	Pre-F/S (Nov.'98) F/S (Under preparation)
12.	Nam Ngum 5	Nam Ngum	90	Pre-F/S (Jan.'97)
13.	Nam Ou	Nam Ou	600	Pre-F/S (Aug.'95)
14.	Xe Katam	Xe Kong	100	Pre-F/S (Mar.'95)
(5)	MOU signed	(Study pending)		
15.	Nam Ngiep 2+3	Nam Ngiep	495	MOU (Mar.'95)
16.	Nam Suang 2	Nam Suang	190	MOU (Mar.'95)
	Total		6,608 MW	

Source: EDL on October 1999

Notes; PPA: Power Purchase Agreement, PA: Price Agreement, MOU: Memorandum of Understanding, F/S: Feasibility Study, Pre-F/S: Pre-Feasibility Study

(2) Nam Theun 2 HEPP

The capacity of the project is assumed to be 900MW. The original capacity was 681MW. It has been proposed that the project be changed from operating as a base load project to operating for medium peak demand. The change will not significantly affect the construction cost, which is estimated at US$1.25 billion under the 681MW scheme.

The tariff was calculated based on NTEC's letter to EGAT dated August 13, 1998. The tariff, originally discussed at around USc5.2, will probably be a three-step structure. The GOL's equity share could be 25%.

(3) Other Projects

The capacity of Nam Ngum 2 HEPP is 615MW. The assumed tariff is Usc5.63 leveled. The GOL's equity share could be 25%. The capacity of Nam Ngum 3 is 460MW. The tariff, based on the draft Tariff MOU dated August 18, 1997, is assumed to be a leveled tariff of USc5.7. The GOL's equity share could be 45%. The capacity of Hong Sa Thermal is 720MW. The tariff is assumed to be a leveled capacity charge of USc3.6/kWh and a leveled energy tariff of USc2.19/kWh. The GOL's equity share could be 10%. The capacity of Xe Pian and Xe Namnoy HEPP is 390MW and the tariff has yet to be negotiated. The GOL's equity share could be 40%. The capacity of Xe Kaman 1 HEPP is 468MW. The tariff has not been negotiated yet. The GOL's

equity share is assumed to be 25%.

(4) Recent Development on Power Purchase Price

EGAT has recently proposed an uniformed tariff of USc4.178/kWh from Nam Theun 2, Nam Ngum 2 and Nam Ngum 3. These proposed tariffs are much lower than previously expected. Before the economic crisis, EGAT said the tariff for electricity purchased from the new Lao projects should not exceed USc5.6/kWh. According to EGAT, the proposed tariff is based on a pricing formula no more expensive than the electricity purchased by EGAT from IPPs in Thailand, including an assumed USc0.75/kWh of transmission cost for Lao projects, which was assumed on Thailand side.

Based on a recent National Energy Policy Office statement quoted by The Nation, the real power generation cost in the EGAT system is higher than the 1.08Baht/kWh proposed for Lao projects.

Table 5.3.4 Comparison between Power Generation Cost in Thailand and Proposed Tariff of Lao Projects

No.	Power Source	In Bahts	In US Cents
	Thermal in Thailand		
1.	Fuel Oil	1.98	5.348
2.	Coal-SPP	1.55	4.186
3.	Gas-Now	1.61	4.349
4.	Gas-After Fuel Adjustment (2000)	1.74	4.700
	HEPP in Lao PDR		
1.	Proposed Tariff for Lao Hydro IPPs	1.08	2.917
2.	Originally Expected (Off-Peak)	1.11	2.998
3.	Originally Expected (Peak)	2.14	5.780

This new proposal may impede the power development in Laos with a small domestic market. It is very doubtful that the six (6) proposed projects be profitable without further concessions from the GOL on tax and royalties.

According to the policy plan announced by NEPO in March 1993 "Privatization and Liberalization of the Energy Sector in Thailand," power projects in Lao PDR will be included into the wholesale power pool market from 1993. A careful study is necessary concerning how this market will be operated and what the impact will be on sales prices.

5.3.5 TRANSMISSION SYSTEM DEVELOPMENT

(1) Transmission System Development in Thailand

The EGAT transmission system development covers the expansion of 500kV, 230kV, and 115kV transmission lines and substations to serve the demands of the country and to maintain the quality and security to meet the specified planning criteria. The long-term transmission system development plan for Thailand generally focuses on seven (7) areas, among which the northeast area development has direct impact on power purchase from Lao PDR.

At present, the transmission system voltages of 69kV, 115kV and 230kV have been used in the northeastern region. The 230kV system is used for the main trunk line for the interconnection with the central and northern regions, connecting with the existing domestic power plants such as

Siri Kit hydropower plant, Mae Moh thermal power plant, Nam Phong combined cycle power plant, etc.

The future development of the transmission system in the northeastern region will include the 230kV system for the Lam Takhong pumped storage power plant, which is located near Chaiyaphum. The transmission system development in the region will also include the 230kV and 500kV transmission systems to receive the power from Lao PDR from 2002 to 2010.

(2) Transmission System Development in Lao PDR

The transmission system development in Lao PDR has the objectives: (i) to reinforce and extend domestic transmission system, (ii) to receive export power from IPP projects, (iii) to wheel it to the appropriate metering point on the border, (iv) to minimize cost, and (v) to minimize environmental impacts.

Domestically, EDL will extend the transmission and distribution lines of voltage below 115kV using concessionaire funding to supply priority centers. For export, a Lao National Grid Company will be established to construct a 500kV national grid connecting with collector substations between B.Nabong 500kV Grid Station (G.S.) nearby the Nam Leuk HEPP and B.Sok 230/500kV G.S. near Houay Ho HEPP to wheel the power from IPP projects to the bordering delivery points with Thailand and Vietnam.

Transmission lines from the existing hydropower stations such as Nam Ngum-1, Xeset, Theun-Hinboun, Houay Ho and Nam Leuk were connected to the respective receiving substations in Thailand as shown below:

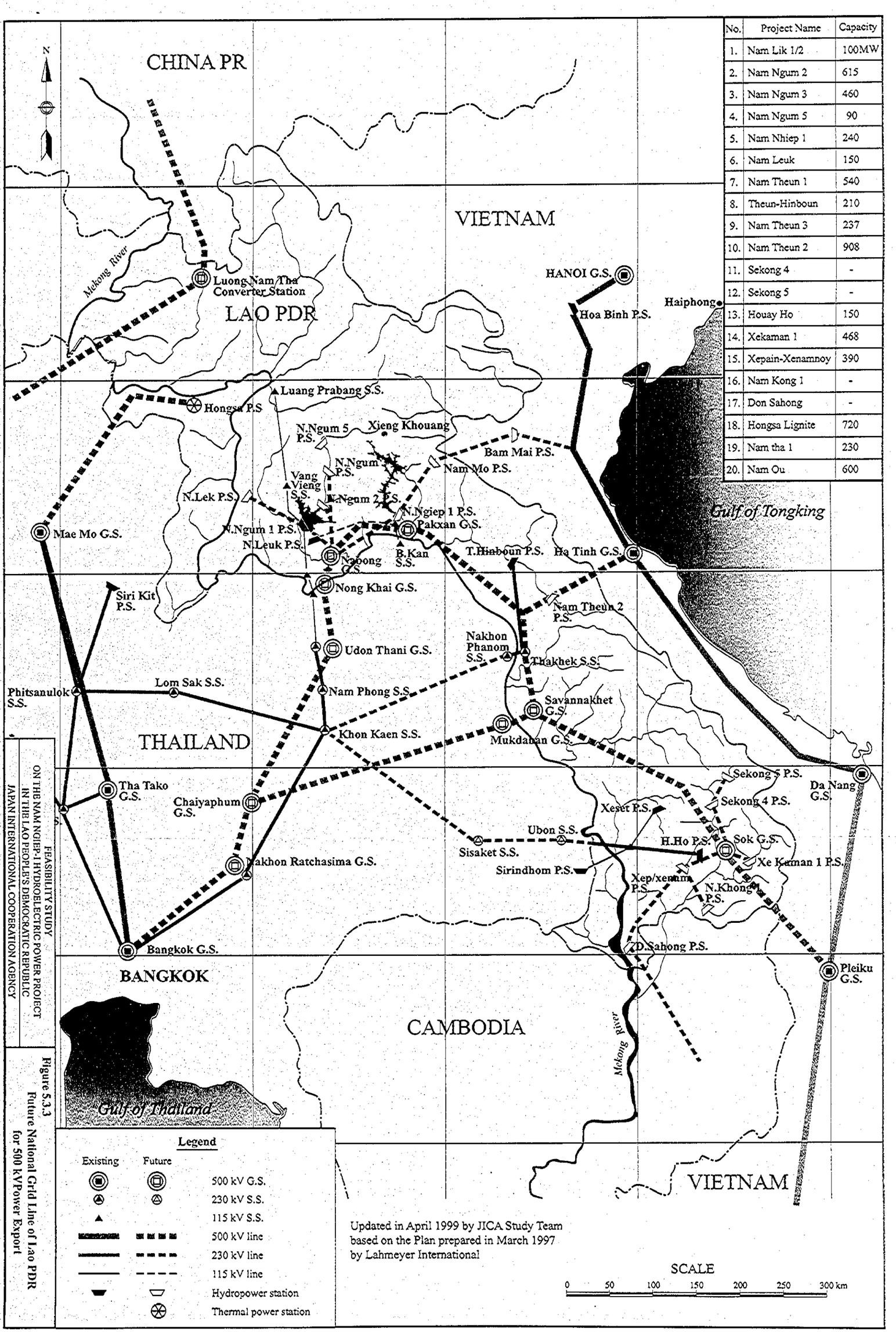
Table 5.3.5 Connecting S.S for Export Power to Thailand from Existing P.S in Lao PDR

No.	Power Station (P.S)	T.L. Voltage	Substation (S.S) in Lao PDR	Substation in Thailand
1.	Nam Ngum-1	115kV	Nam Ngum P.S	Nong Khai S.S
2.	Xeset	115kV	Pakse S.S	Sirindhom P.S
3.	Theun-Hinboun	230kV	Thakhek S.S	Nakhonphanom S.S
4.	Houay Ho	230kV	Houay Ho P.S	Ubon-II S.S
5.	Nam Leuk	115kV	Pakxan S.S	Bung Kan S.S

As for the future transmission network for export power from Lao PDR, there are various plans being studied by foreign consulting companies. Those plans were summarized and updated as shown in Figure 5.3.3 and Figure 5.3.4, respectively as the future national grid of Lao PDR and the route of 500kV line between Pakxan G.S and Nabong S.S.

Power transmission line from Nam Ngiep-1 P.S will be connected with Nabong S.S with 230kV line. Its total length is approximately 110km long, which will be constructed along the route as shown in previous Figure 1.1 of Chapter 1.

No.	Project Name	Capacity
1.	Nam Lik 1/2	100MW
2.	Nam Ngum 2	615
3.	Nam Ngum 3	460
4.	Nam Ngum 5	90
5.	Nam Nhiep 1	240
6.	Nam Leuk	150
7.	Nam Theun 1	540
8.	Theun-Hinboun	210
9.	Nam Theun 3	237
10.	Nam Theun 2	908
11.	Sekong 4	-
12.	Sekong 5	-
13.	Houay Ho	150
14.	Xekaman 1	468
15.	Xepain-Xenamnoy	390
16.	Nam Kong 1	-
17.	Don Sahong	-
18.	Hongsa Lignite	720
19.	Nam tha 1	230
20.	Nam Ou	600



FEASIBILITY STUDY ON THE NAM NGIEP-1 HYDROELECTRIC POWER PROJECT IN THE LAO PEOPLE'S DEMOCRATIC REPUBLIC
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Figure 5.3.3 Future National Grid Line of Lao PDR for 500 kVPower Export

No.	Project Name	Capacity
1.	Nam Lik 1/2	100MW
2.	Nam Ngum 2	615
3.	Nam Ngum 3	460
4.	Nam Ngum 5	90
5.	Nam Nhiep 1	240
6.	Nam Leuk	150
7.	Nam Theun 1	540
8.	Theun-Hinboun	210
9.	Nam Theun 3	237
10.	Nam Theun 2	908
11.	Sekong 4	-
12.	Sekong 5	-
13.	Houay Ho	150
14.	Xekaman 1	468
15.	Xepain-Xenamnoy	390
16.	Nam Kong 1	-
17.	Don Sahong	-
18.	Hongsa Lignite	720
19.	Nam tha 1	230
20.	Nam Ou	600

CHINA PR
VIETNAM
LAO PDR
THAILAND
CAMBODIA
VIETNAM
BANGKOK
Mekong River
Luong Nam Tha Converter Station
HANOI G.S.
Haiphong
Hoa Binh P.S.
Luang Prabang S.S.
Hongsa P.S
N.Ngum 5 P.S.
Xieng Khouang
N.Ngum 2 P.S.
Bam Mai P.S.
Nam Mo P.S.
Vang Vieng S.S.
N.Lek P.S.
N.Ngiep 1 P.S.
Pakxan G.S.
N.Ngum 1 P.S.
N.Leuk P.S.
Nabong G.S.
B.Kan S.S.
T.Hinboun P.S.
Ha Tinh G.S.
Gulf of Tongking
Mae Mo G.S.
Siri Kit P.S.
Nong Khai G.S.
Udon Thani G.S.
Nam Theun 2 P.S.
Nakhon Phanom S.S.
Thakhek S.S.
Lom Sak S.S.
Phitsanulok S.S.
Nam Phong S.S.
Savannakhet G.S.
Khon Kaen S.S.
Mukdahan G.S.
Sekong 5 P.S.
Da Nang G.S.
Sekong 4 P.S.
Xeset P.S.
Tha Tako G.S.
Chaiyaphum G.S.
Ubon S.S.
H.Ho P.S.
Sok G.S.
Xe Kaman 1 P.S.
Sisaket S.S.
Nakhon Ratchasima G.S.
Sirindhom P.S.
Xep/xenam P.S.
N.Khong P.S.
Bangkok G.S.
D.Sahong P.S.
Pleiku G.S.
Gulf of Thailand

Legend

Existing	Future	
◎	◎	500 kV G.S.
△	△	230 kV S.S.
▲		115 kV S.S.
		500 kV line
		230 kV line
		115 kV line
▼	▽	Hydropower station
⊗		Thermal power station

Updated in April 1999 by JICA Study Team
based on the Plan prepared in March 1997
by Lahmeyer International

SCALE
0 50 100 150 200 250 300 km

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IN THE LAO PEOPLE'S DEMOCRATIC REPUBLIC
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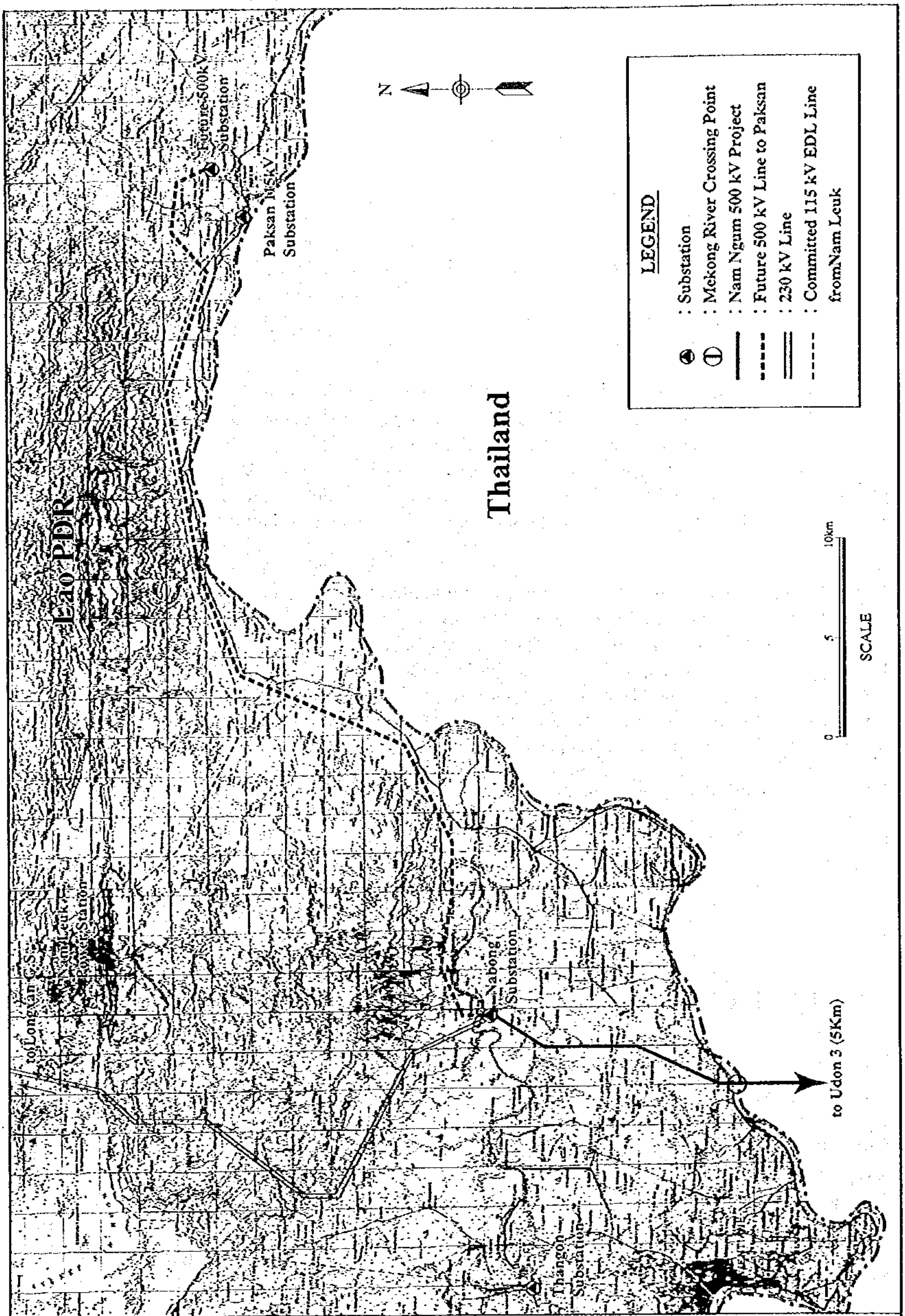
Figure 5.3.3
Future National Grid Line of Lao PDR for 500 kVPower Export



FEASIBILITY STUDY ON THE NAM NGIEP-1 HYDROELECTRIC POWER PROJECT IN THE LAO PEOPLE'S DEMOCRATIC REPUBLIC	Figure 5.3.4 Tentative Rout of 500 kV Line between Ban Nabong S.S and Pakxan G.S
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