Wind speeds at Nikhon34 are about 1 m/s in terms of annual average, while in terms of monthly average, the maximum is 2.8 m/s and the minimum 0.6 m/s. In terms of daily average, the maximum is 5.9 m/s.

3.2 Calculation of Dam Site Discharge

3.2.1 Runoff Calculation Procedure

In Section 1.3 of Chapter II, river runoffs at various sites in the Xe Namnoy River Basin were calculated. In this chapter, the information obtained after start of the present study, such as the results of runoff measurements and water level gauging were studied in detail, and the discharge of the Xe Katam River, which is a basic data for the final formulation of plans in this study, is calculated. It was decided to apply the runoff analysis method by Sugawara's Tank Model for calculation of runoff. The procedure of runoff calculations are given below.

1) Calculation of river discharge for the period of runoff investigation on the Xe Katam River based on the investigations results

2) Examinations of the average rainfall in the Xe Katam River Basin to be used in runoff analysis

3) Examinations of the average evaporation in the Xe Katam River Basin to be used in runoff analysis

4) Establishment of rainfall runoff model of the Xe Katam River Basin (Determing parameters of Sugawara's Tank Model)

5) Calculation of long-term discharge of the Xe Katam River by applying obtained rainfall-runoff model

Further, as described in 1.3 of Chapter II, it was considered to estimate the river runoff of the Xe Katam River by using runoff data of the Xe Kong River which is the mainstream of the Xe Namnoy River, or the Xe Don River used in the discharge calculation for the Xe Set Project. However, as a result of examining these data, differences were found in discharge characteristics compared with rivers which have basin on the Bolaven Plateau, since the scales and topographical conditions of the Xe Kong River and the Xe Don River are different.

Therefore, in this report, it was decided to use the runoff data of the Xe Set River which flows through the Bolaven Plateau for preliminary estimation. Then, analizing in detail based on the data added through the investigation, the river runoff of the Xe Katam River was calculated for the period of 10 years from 1981 to 1990.

3.2.2 Runoff Observed at Xe Katam River

As mentioned in 1.3 of Chapter II, runoff measurements and observations of river water level are being carried out at Ban Nonghin (catchment area is 171 km^2) on the Xe Katam River. During the period from the end of December 1990 to July 1991, runoff measurements were made several times near the intake dam site of the Xe Katam Project (catchment area is about 290 km^2). The discharge of the Xe Katam River from January to June 1991 was calculated based on the results of these investigation. The method of calculation is described below.

(1) Calculation of Discharge at Ban Nonghin Site

Rating curves were prepared based on the results of runoff measurements at the Ban Nonghin site as shown in Fig. III-3-5. Two rating curves of (A) and (B) are shown in this figure. Considering the fact that the Xe Katam Project is a run-of-river type power generation scheme, Curve (A) with good correlation at the low water level range (below 70 cm) was adopted (Correration coefficient is 0.982 for curve (A), in contract with 0.964 for curve (B)). The daily discharge at the Ban Nonghin site was calculated as shown in Table III-3-6 by applying rating curve (A) to the river water level observed at the same site.

(2) Calculation of Discharge at Intake Dam Site of Xe Katam Project

Firstly, the relationship between the discharge at Ban Nonghin calculated under (1) and the result of runoff measurements at the intake dam site was examined. The discharges at the two sites on the days of runoff measurements are shown in the table below.

Date	River Discharge		Ratio
	[a] B. Nonghin 171 km^2	[b] Dam-site 290 km^2	[b]/[a] 1.70
1990/12/28	1.8 m^3/S	3.3 m^3/S	1.83
1991/ 3/28	0.64 m^3/S	0.79 m^3/S	1.23
1991/ 3/30	0.58 m^3/S	0.75 m^3/S	1.29
1991/ 7/ 5	7.1 m^3/S	13.3 m^3/S	1.87

According to the above table, the ratios of discharges at the two sites in December 1990 and July 1991 they are 1.83 and 1.87 respectively, are close to their catchment area ratio of 1.70. However, ratio of discharges at the end of March 1991 in the season of lowest water, are 1.23 to 1.29 so that the discharge at the intake dam site was not increased very much in comparison with the discharge at upstream of Bar Nonghin. The difference in the rainfalls at the upstream and downstream parts of the Xe Katam River Basin, that was mentioned in 3.1.2, may be considered as a reason for this phenomenon. However, since the difference in the specific runoffs of the two sites in March is so large that it cannot be explained by only the distribution of rainfall, it is imagined that topography and geology are also factors. Whether this phenomenon occurs constantly must depend on the result of future investigation. However, in this study, emphasiizing the results of runoff investigations, the discharge at the Xe Katam intake dam site was calculated based on the thinking below.

Assuming the difference in rainfall amount between the upstream and downstream areas is a phenomenon which occurs constantly due to the basin characteristics of the Bolaven Plateau, the discharge at the intake dam site were calculated using the discharge at Ban Nonghin in the equation below considering the difference in specific runoffs at the two sites in the dry season.

$$Q\ (\text{Intake Site}) = 1.49 * (Q(\text{Nonghin}))^{1.87}$$

The discharge at the intake dam site from January to June 1991 calculated in this way are shown in Table III-3-7. According to the table, the minimum discharge during the abovementioned period is estimated to be 0.77 m^3/s at the end of March and in the Middle of April.

3.2.3 Rainfall Data used in Runoff Analysis

(1) Selection of Rainfall Data

The correlation between the rainfall data of the Xe Katam River Basin obtained after beginning of this study and the rainfall data of the Nonghin site used in calculation of the discharges in the Xe Namnoy River Basin discharge in 1.3 of Chapter II, was examined. The results are given below.

Month	Nonghin	Ban Xekatam	Ban Tongvay
Feb.	1.2	8.0	0.0
Mar	120.1	112.5	66.0
Apr.	156.9	238.5	124.0
May	355.6	188.5	141.5
June.	326.4	280.0	343.5
Correlation Coefficient	-	0.79	0.79

Although a definite statement cannot be made based on only the results given in the above table, the following may be figured out concerning rainfall from February to June 1991.

That is, although a monthly variation is seen in the rainfall ratios between the rainfalls at the Nonghin site and inside the Xe Katam River Basin, a correlation to a certain extent is found in the trends of rainfall occurrence. As stated in 1.3 of Chapter II, the only places on the Bolaven Plateau where rainfall observations have been carried out continuously over a long term are the KM42 and Nonghin sites. Of the two, the KM42 site is located even farther west of the Xe Katam River Basin than the Nonghin site. In addition to this, the amount of rainfall is considerably larger at KM42 than at Nonghin. Therefore, the same as the analysis in Chapter II, it was decided to use the rainfall data at Nonghin for the runoff analysis of the Xe Katam River Basin.

(2) Correction of Rainfall Amount

a) Ratio of Total Rainfall at rainfall stations to that of Nonghin Site

According to the rainfall data observed in the period during from February to June 1991, the ratios of rainfalls at Ban Xekatam and Ban Tongvay sites to the rainfall at Nonghin are given as below.

Site	Nonghin	[a] Ban Xekatam	[b] Ban Tongvay	[a] & [b] Average
Total Rainfall (mm)	978	828	675	751
Ratio to Nonghin (%)	100	86	70	77

According to the table above, the rainfall at Ban Xekatam is 88% of the rainfall at Nonghin. At Ban Tongvay, it is even less at 70% of Nonghin. The locations of these three sites are in order from the west, Nonghin, Ban Xekatam, and Ban Tongvay, and as mentioned in 3.1.2, the trends of rainfalls at each site are in agreement with the trend of existing rainfall data in the Bolaven Plateau, that is, rainfall decreases from west to east.

b) Correction of Rainfall at Nonghin to Average Rainfall in Xe Katam River Basin

Rainfall observed at a certain site is strictly amount at that "point" and does not represent the mean rainfall of the region. Nonghin is located out of the Xe Katam River Basin, and according to the trend of rainfall distribution on the Bolaven Plateau, it cannot be said that the rainfall at Nonghin represents the rainfall over the Xe Katam River Basin. Therefore, in order to express the mean rainfall over the Xe Katam River Basin by using the rainfall amount at Nonghin, it is necessary to correct the rainfall amount at Nonghin. The correction factor, in this case, is estimated to be around 0.75 from the beforementioned relationship between the rainfall observed in the Xe Katam River Basin and the rainfall observed at Nonghin.

On the other hand, by examining the water balance of the Xe Set River Basin in 1985 and 1986, annual runoff height of the basin is estimated to be around 2,100 mm as the difference between the mean annual rainfall of 2,900 mm in the Xe Set Basin estimated from the isohyetal map shown in the "Lower Mekong Hydrologic Yearbook, 1985-1986" and the mean annual evaporation assumed to be approximately 800 mm. This is much more than the observed mean annual runoff height of 1,350 mm. According to this fact, it can be estimated that the loss of discharge due to infiltration in the Bolaven Plateau area is fairly large, and the effective rainfall before reduction of evaporation is small compared with the actual rainfall. Since it is thought that this trend will be adoptable also to the Xe Katam River Basin, assuming the annual evaporation in the basin to be 800 mm, trial calculations were made applying the rainfall-runoff model prepared for the Xe Set River Basin to the Xe Katam River Basin. As a result of the calculations, the rainfall correction factor of 0.65 reproduced a discharge which is the most similar among the cases to the observed discharge at the Ban Nonghin gauging station on the Xe Katam River for the period from December 1990 to June 1991. Therefore, it was decided to carry out runoff analysis with the mean effective rainfall of the Xe Katam River Basin obtained by multiplying 0.65 to the rainfall at Nonghin.

Further, the relationship among rainfalls at different sites often vary by season. To be accurate, it is necessary to change the correction factor of rainfall monthly to match this vacation. However, because the period of rainfall observation carried out in the Xe Katam River Basin is short, it is not possible to find the trend of monthly variation in the correlation with rainfall at the Nonghin site. Therefore, it was decided to apply a constant correction factor of 0.65 throughout the year in this analysis.

The estimations concerning the discharge calculation of the Xe Katam River Basin described above were applied to the periods of 1985 to 1986 and 1981 to 1990. The results are as shown below.

			1985-1986	1981-1990
[a]	Nonghin site annual rainfall (mm)		3230	2860
[b]	Basin mean rainfall (mm)	[a]*0.75 =	2420	2140
[c]	Basin mean effective rainfall (mm)	[a]*0.65 =	2100	1860
[d]	Basin mean evaporation (mm)		800	800
[e]	Basin mean discharge (mm)	[c]-[d] =	1300	1060
[f]	Basin mean discharge ratio (%)	[e]/[b] =	54	50

3.2.4 Evaporation Data used in Runoff Analysis

(1) Selection of Evaporation Data

As the same as data of rainfall, the data of evaporation is not available in the Xe Katam River Basin. In this report the data observed at Nikhon34 located in adjacent to the Xe Katam River Basin is used for the analysis.

(2) Correction of Evaporation Data

As mentioned in 3.1.4(2), the evaporation data at Nikhon34 were observed with a pitcher and the values are fairly small compared with expected evaporation. In this study, in the same manner as for rainfall, the observed evaporation values at Nikhon34 are corrected to obtain the mean evaporation in the Xe Katam River Basin.

The actual annual evaporation at Nikhon34 is estimated to be approximately 800 mm as mentioned in 3.1.4 (2). This value and the mean observed evaporation of 560 mm were compared and the correction factor of 1.4 was employed.

Actually, to be exact, it is also necessary to vary the correction factor of evaporation monthly. However, since there are no evaporation records available in the Xe Katam River Basin, the relationship with the evaporation at Nikhon34 is unknown. However, concerning evaporation, since there is not as much variation among sites as in case of rainfall, and except for special cases, there will be no problem even if a constant correction factor were to be used. Therefore, in this analysis, it was decided to apply a constant correction factor of 1.4 throughout the year for the evaporation values observed at Nikhon34.

3.2.5 Runoff Model of Xe Katam River Basin

Sugawara's Tank Model was applied for the runoff analysis of the Xe Katam River Basin as applied in the study of the Xe Namnoy River Basin described in 1.3 of Chapter II. With regard to the type of runoff model, four-stage series type model including a soil-moisture structure was applied. The soil-moisture structure expresses the continuous base flow in the dry season brought out by the water retention function of soil.

The Tank Model has two basic parameters. One is the parameters for adjusting the sizes of infiltration and discharge holes of each tank which expresses the discharge structure of the basin. And the other is the parameters for adjusting the rainfall and evaporation data to be input in discharge calculations. Rainfall-runoff phenomenon of objected basin is expressed by adjusting the magnitude of these parameters. In this study, the parameters of the Tank Motel were adjusted to reproduce the discharges at the Xe Katam intake site during the period from the end of December 1990 to the end of June 1991 as shown in Table III-3-7. The runoff model was established by adjusting the parameters as the discharge hydrograph reproduced by the Tank Model with the rainfall at Nonghin comes to match the observed hydrograph at the intake dam site. In this study, the fact that the Xe Katam Project is planned as a run-of-river type was taken into consideration, and the parameters were adjusted by focussing especially on the discharge in the low river flow season.

The structure of the runoff model obtained as a result of above study, and the the parameters of the sizes of infiltration and discharge holes are shown in Fig. III-3-6.

3.2.6 Discharge Calculation Results

The daily runoffs at intake dam site of the Xe Katam Project were calculated inputing the rainfall data at Nonghin for the 11-year period from 1980 to 1990 in the runoff model obtained above and shown in Fig. III-3-6. Here, the calculated discharge for the starting year is unstable because of being affected by a set of the initial storage value of each tank of the runoff model. Therefore, the year of 1980 was excluded from the result and the discharges calculated for the 10-year period from 1981 to 1990 were adopted. As a result, the 10-year average of discharge at the Xe Katam intake dam site is estimated for various durations as follows:

Duration (%)	20	30	40	50	60	70	80	90	95	100	Average
Discharge (m^3/S)	17.3	12.9	9.7	6.5	4.2	2.9	1.9	1.2	1.1	1.0	9.8

Monthly mean discharge of each year and average flow-duration curve for the period of 10 years from 1981 to 1990 are shown in the Table III-3-8 and Fig. III-3-7 respectively. Daily discharges are listed in Appendix 3.

3.3 Calculation of Flood Discharge at Project Site

The probable flood discharges at the intake dam site (on the Xe Katam River) and the powerhouse site (on the Xe Namnoy River) of the Xe Katam Project are calculated in this section.

3.3.1 Calculation Method of Probable Flood Discharge

Long-term runoff observation data which can be directly used for calculation of probable floods is not available on the basins of the Xe Namnoy River mainstream and the Xe Katam River, and their surroundings. In this study, rainfall data observed at out of the basins over a comparatively long term are used for the calculation of probable discharge by the method given below.

1) A suitable rainfall station located in the area of Bolaven Plateau is selected as the representative rainfall site.

2) The probable rainfall at the selected site is calculated.

3) The relationship between the rainfall at the representative site and the average rainfall over the basin of objected site is examined and the average probable rainfall over the basin is determined.

4) Using the several coefficients determined from the characteristics of the river basin and the estimated average probable rainfall over the basin, the probable flood discharge at the objected site is calculated by the Snyder-Linsley Method. Only the peak flood discharge is calculated in this study.

3.3.2 Calculation of Probable Flood Discharge

(1) Selection of Representative Rainfall Site

The annual maximum daily rainfalls observed at the four existing rainfall stations on the Bolaven Plateau are given in Table III-3-9. Among the four stations, KM42 and Nonghin are only the stations at which data are available for 10 or more years. Of these two, the Nonghin station, at which the data of 12-year periods are available and the site is comparatively close to the Xe Katam River Basin, was selected as the representative rainfall site.

(2) Selection of Probable Flood at Representative Rainfall Site

Analyses were performed using the annual maximum daily rainfall data at Nonghin with the period of 12 years given in Table III-3-9, and the probable rainfall at the site was calculated. The Gumbel distribution was applied for the probability distribution function. The results are given in Fig. III-3-8 and the table below.

Return Period	Probable Rainfall at Nonghin Site (mm/day)
5	154
10	174
20	192
50	216
100	233
200	251

The maximum daily rainfalls at the various sites in the period from January to June 1991, including the newly installed five rainfall stations in the Xe Namnoy River Basin, together with the daily rainfalls of all sites on those days are shown in Table III-3-10. Although judgements cannot be made only by these data since the observation period was short, at least by the data up to the present time, the maximum daily rainfalls of each sites do not show a consistent trend as that of total rainfall. Theerefore, it cannot be said that maximum daily rainfalls are necessarily greater the more to the west on the plateau. Accordingly, the value of probable rainfall at Nonghin was used without modification as the probable rainfall at a site in the Xe Katam River Basin.

(3) Estimation of Basin Mean Probable Rainfall over Basin

a) Basin of Xe Katam Intake Dam Site (Xe Katam River, 290 km^2)

The extent of the rainfall areas assumed to be represented by the four rainfall stations in the Bolaven Plateau are shown in Fig. III-3-9. The areas of this extent has roughly the same magnitude as the catchment area of 290 km^2 at the Xe Katam intake dam site. Therefore, regarding the days with 100 mm or more of mean rainfalls over the four stations, the relationships between mean rainfall and rainfall at a site which has maximum rainfall among the four sites were examined. The result of this is shown in Fig. III-3-10.

The envelope lines shown in the figure indicate that, in the range of probable rainfall of 154 mm (for 5 years return period) to 251 mm (for 200 years return period) at the Nonghin site given in (2) above, the ratio of the mean rainfall to the maximum rainfall at a site is in a range from 0.8 to 0.7 (Envelope Line A), or in a range from 0.76 to 0.55 (Envelope Line B). Here, the values of the each envelope line are taken into consideration, and the mean probable rainfall over the basin of the Xe Katam intake dam site was assumed to be 75% of the probable rainfall at Nonghin. (The correction factor of probable rainfall at Nonghin was assumed to be 0.75.)

b) Basin of Xe Katam Powerhouse Site (Mainstream of Xe Namnoy River Mainstream, 784 km^2)

The catchment area of the Xe Namnoy River at the Xe Katam powerhouse site is 784 km^2. This is 2.7 times of the catchment area of the Xe Katam intake dam site. Accordingly, the ratio of mean rainfall of the basin to rainfall at a site which has maximum rainfall among the sites is expected to be smaller than that of the basin of the Xe Katam intake dam site. However, since there is no means for quantitative judgement of the rainfall distribution in the catchment area at this time, 70% of the probable rainfall at Nonghin was assumed to be as the mean probable rainfall at the basin of the Xe Katam powerhouse site. (The correction factor of probable rainfall at Nonghin is 0.70.)

(4) Calculation of Probable Flood Discharge by the Snyder-Linsley Method

a) Unit Peak Flood Discharge

According to the method modified by Linsley based on the Snyder Method, the specific peak flood discharge ($m^3/s/km^2$) per 25.4 mm (1 inch) is obtained by the equation below with the river length L (mile) along the mainstream from the objected site to the upstream end of basin boundary, the distance L_c (mile) from the same objected site to the site on the mainstream and closest to the centroid of the basin, the average river gradient S, and C_p and C_t as coefficients.

Time lag $t_p = C_t(L*L_c/S^{1/2})^{0.38}$ (hr)

Specific peak Discharge $q_p = 7.0\ C_p/t_p$ ($m^3/s/km^2$)

The value of C_t is generally within the range of 0.35 to 1.2 depending on topography, and here the value on the most conservative side, 0.35, was adopted. For C_p, a value within the range of 0.56 to 0.69 is normally adopted, and 0.60 was taken here.

As a result of applying the above equation and coefficients to the Xe Katam intake dam site and powerhouse site, the unit peak flood discharges were obtained as listed below.

Item	Unit	Site	
		Xe Katam	Xe Namnoy
L	mile	32.5	35.7
Lc	mile	14.5	16.9
S	-	0.0154	0.0125
t_p	hour	8.02	9.17
q_p	$m^3/s/km^2/Inch$	0.52	0.46

b) Rainfall Duration

The rainfall duration t_r (hour) is given by the equation below.

Rainfall Duration $t_r = t_p/5.5$ (hour)

The rainfall durations calculated by putting the time lag t_p in this equation are 1.46 hour for the intake dam site and 1.67 hour for the powerhouse site, and these are fairly short. This is because that the value of C_t had been taken from the conservative side. On the other hand, according to the records of the rain gauges obtained in 1991 in the Xe Namnoy River Basin, rainfalls exceeding 100 mm and occurring concentrated in short periods of time are recognized. For the annual maximum rainfall, the duration time is thought to be longer than the abovementioned times, However, there are no available data for making judgements at present, so that the maximum daily rainfall at Nonghin was directly used and correction by rainfall duration was not considered.

c) Rainfall Loss

Using the discharge and rainfall data at the time of the flood in June 1986, which is the maximum flood observed during a 2-year period on the Xe Set River, the rainfall loss during that flood was estimated. In contrast to the estimated cumulative rainfall of 450 mm during the 9-day period from June 16 to 24, the

Return Period	Flood Discharge	
	Intake Dam Site (Xe Katam River 290 km^2)	Powerhouse Site (Xe Namnoy River 784 km^2)
5	490	1,050
10	570	1,210
20	650	1,390
50	760	1,630
100	840	1,800
200	920	1,970

According to the "Xe Set Hydropower Project Hydrology Design Memorundum (Feb. 1985, Norconsult)", the 100-year return period flood discharge at the Xe Set Project site (catchment area is 325 km^2) has been calculated as 1,000 m^3/s, and the value shown above is roughly at the same level.

3.4 Calculation of Sedimentation at Project Site

3.4.1 General Description of Sediment Yield Supply Source in Xe Katam River Basin

As mentioned in 3.1, the Xe Katam River Basin from the upstream area to the midstream area, has a comparatively flat topography with vegetation mainly consisting of grassland and shrubbery. Bare ground can be seen at parts of cultivated fields, around houses, and at roads, and the area of which is small. The mountainlands, existing at the northern part of the midstream to upstream basin and over the downstream basin, consist more or less of virgin forests of deciduous trees except partially where slash-and-burn farming is being performed. According to the results of aerial photo interpretations and field reconnaissances made at parts, there are hardly any slopes in the Xe Katam River Basin where collapses have occurred. Accordingly, it is estimated that the outflow of topsoil by erosion and supply of sedimentation yield due to collapsing of slopes within the basin are comparatively small.

Reflecting the abovementioned conditions, the Xe Katam River shows almost no muddying in stream flow not only during in the dry season, even in the rainy season except during flood, clear stream flows are maintained. At the time of field reconnaissances made in the end of June 1991 when the rainy season had started and runoff had increased, prominent turbidity was not recognized except immediately after severe rainfall. The results of water quality tests of samples taken at that time show no detection of such turbidity as to affect sedimentation at the intake dam.

However, immediately after a severe rainfall which occurred during the period of field reconnaissance, slight muddying of river water due to sediment inflow was observed. In observations during field reconnaissance, at parts along the river bed on the downstream stretch of the Xe Katam River, although small in quantity, deposits of gravel and rock blocks containing almost no fines were confirmed. From this fact, it cannot be denied that there is possibility of soil and sand-gravel production by new collapses of mountain slopes at times of intensive severe rainfall, and traction of sand-gravel with various particle sizes deposited at the river bed being moved and carried down into the intake dam. The reason why almost no fine-grained sizes are found is probably due to the fact that among the soil, sand-gravel, and rock blocks brought down during floods, a part of the coarse sizes remains on the river bed and fines are carried down to the downstream.

Further, it was confirmed as the results of inspection in the field reconnaissances and water quality tests that the Xe Katam River has a slightly higher degree of turbidity during low flow compared with that of the Xe Namnoy River. This is surmised to be due to the fact that the Xe Katam River Basin has a larger population with a greater degree of social activity, whereas the population is sparse in the Xe Namnoy River Basin. It is expected that human activities will become even greater in the Xe Katam River Basin in the future, and it is thought that the influence of this cannot be ignored.

3.4.2 Tractive Force of Xe Katam River

The river gradient of the Xe Katam River is about an average of 1/130 at the upstream and midstream stretches and about an average of 1/20 at the downstream stretch. The relationship between the magnitude of discharge and the flow velocity at the downstream stretch is shown in Fig. III-3-11. As this figure shows, the flow velocity during flood becomes very high, exceeding 5 m/s, so that the tractive force is great. Although the maximum particle-size of the sand-gravel swept down will vary depending on the condition of the river bed, since the Xe Katam River does not have much river deposits and the river bed is relatively smooth at many stretches, when flow velocity exceeds 5 m/s, it is conceivable that rock blocks of fairly large sizes will be transported down. In this way, the Xe Katam River has a potential of tractive force to move fairly large size gravels along its river bed. Therefore, if there were a supply source of bed load, the quantity of sand-gravel coming down into the intake dam site can be fairly large. However, at least under present conditions, no large-scale source of sand-gravel supply is existing in the river basin, and therefore it is expected that the actual inflow quantity will not be so large.

3.4.3 Estimation of Sediment Inflow Volume

The Xe Katam Project is planned as a run-of-river type power generation scheme which does not have a large reservoir and draws river water by a small-scale intake dam. In this case, the storage capacity in the upstream of the intake dam is extremely small in relation to the inflow volume of river flow except during the period of lowest flow, so that there will not be deposition of suspended load due to storage of river flow settling in large quantity. However, movement of bed load components of large-particled sand-gravel will be obstructed by the intake dam and be deposited at the upstream side. Accordingly, the volume of sediment that will flow into and be deposited at the intake dam site of the Xe Katam Project was estimated by dividing it into suspended load and bed load.

(1) Estimation of Suspended Load

It is only during flood that suspended load is observed in the Xe Katam River, but since observations of suspended load during flood has not been performed at present, it is not possible to estimate the inflow of soil and sand-gravel directly. Therefore, in this Report, estimation was made referring to the data observed on the Namsai River, which is a stream in the neighborhood, and the data of which were used for the study of the Xe Set Project. The data of the Namsai River are given below.

Catchment Area (km^2)	Annual Runoff (m^3x10^6)	Av. Concentration of Suspended Load (g/m^3)	Annual Suspended Load Inflow (t/yr)	Specific Suspended Load ($t/yr/km^2$)
203	321	226	87,000	429
223	344	226	93,000	417

Since the middle-upper basin of the Xe Katam River has a comparatively flat topography, it will result over estimation to apply the unmodified specific sediment of the Houay Namsai River. Therefore, taking this into consideration, assuming the specific suspended load of the Xe Katam River Basin to be 300 tons/year/km^2, which is approximately 70% of the value for the Houay Namsai River Basin, the sediment inflow at the Xe Katam intake dam site (290 km^2) was estimated to be 87,000 tons/year.

If all of this quantity would settle, assuming the average deposited density of a clay-silt-sand mixture to be 1.0 t/m^3, a volume of approximately 87,000 m^3/yr would be deposited in upstream of the intake dam. However, as mentioned previously, the greater part of the suspended load will flow downstream along with flood water, and there will not be a large volume settling and being deposited upstream of the intake dam.

(2) Estimation of Bed Load

Observation of bed load at a natural stream is very difficult to carry out practically, and although an accurate prediction cannot be made quantitatively. However, when it is taken into consideration that the tractive force at the downstream part of the Xe Katam is strong, there is a great possibility that the quantity of sand-gravel and rock blocks transported into the intake dam site will be of a degree which cannot be ignored in relation to storage capacity.

According to "Handbook of Applied Hydraulics", that bed load hardly ever exceeds 25% of suspended load. Therefore assuming that bed load in the Xe Katam River is of a quantity corresponding to 25% of the suspended load inflow of 87,000 tons/year in consideration of the fact that the tractive force of the river is strong, the annual inflow of bed load is calculated as 22,000 tons/year. Although depending on the grain-size distribution of sand-gravel, if the average unit density is taken to be 1.7 tons/m^3, and assuming that all of the inflow quantity is deposited, the volume will be approximately 13,000 m^3/year. If bed load moving down along the river bed is obstructed by an intake dam, a fairly large proportion will be deposited upstream of the intake dam. Therefore, in the event sand-gravel exceeding 10,000 m^3/year flows into the intake dam, the reservoir pond would be filled to its capacity within 2 to 3 years.

The values estimated in this study strictly refer to values analogized based on data of a neighboring stream, and when the present condition of the Xe Katam River Basin is considered, it is conceivable that the actual value can be less than this value. However, it may be quite possible that sources of sdeiment supply will increase when the human activity in this region and development in the basin increased in the future. Therefore, in design of the intake dam, it is necessary to take consideration on measures for discharging of sand-gravel and soil which flow into the intake dam.

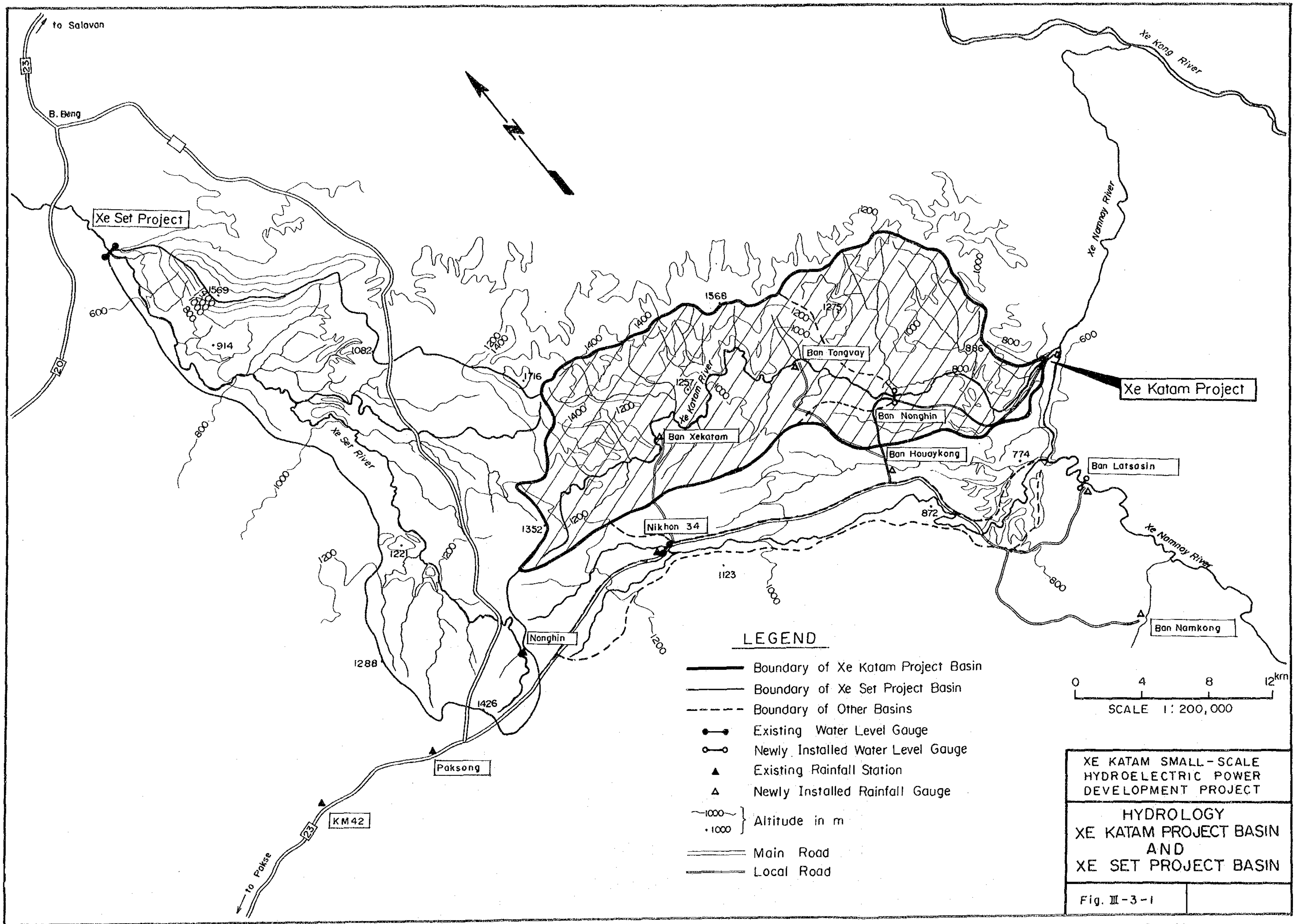

to Salovan
B. Beng
Xe Set Project
Xe Kong River
Xe Namnoy River
Xe Katam Project
Ban Tongvay
Ban Nonghin
Ban Xekatam
Ban Houaykong
Ban Latsasin
Nikhon 34
Xe Katam River
Xe Set River
Nonghin
Paksong
KM42
Ban Namkong
to Pakse
LEGEND
Boundary of Xe Katam Project Basin
Boundary of Xe Set Project Basin
Boundary of Other Basins
Existing Water Level Gauge
Newly Installed Water Level Gauge
Existing Rainfall Station
Newly Installed Rainfall Gauge
Altitude in m
Main Road
Local Road
0 4 8 12 km
SCALE 1 : 200,000
XE KATAM SMALL-SCALE HYDROELECTRIC POWER DEVELOPMENT PROJECT
HYDROLOGY
XE KATAM PROJECT BASIN AND XE SET PROJECT BASIN
Fig. III-3-1

Fig.Ⅲ-3-2 Area - Elevation Curve of Xe Katam Project Basin

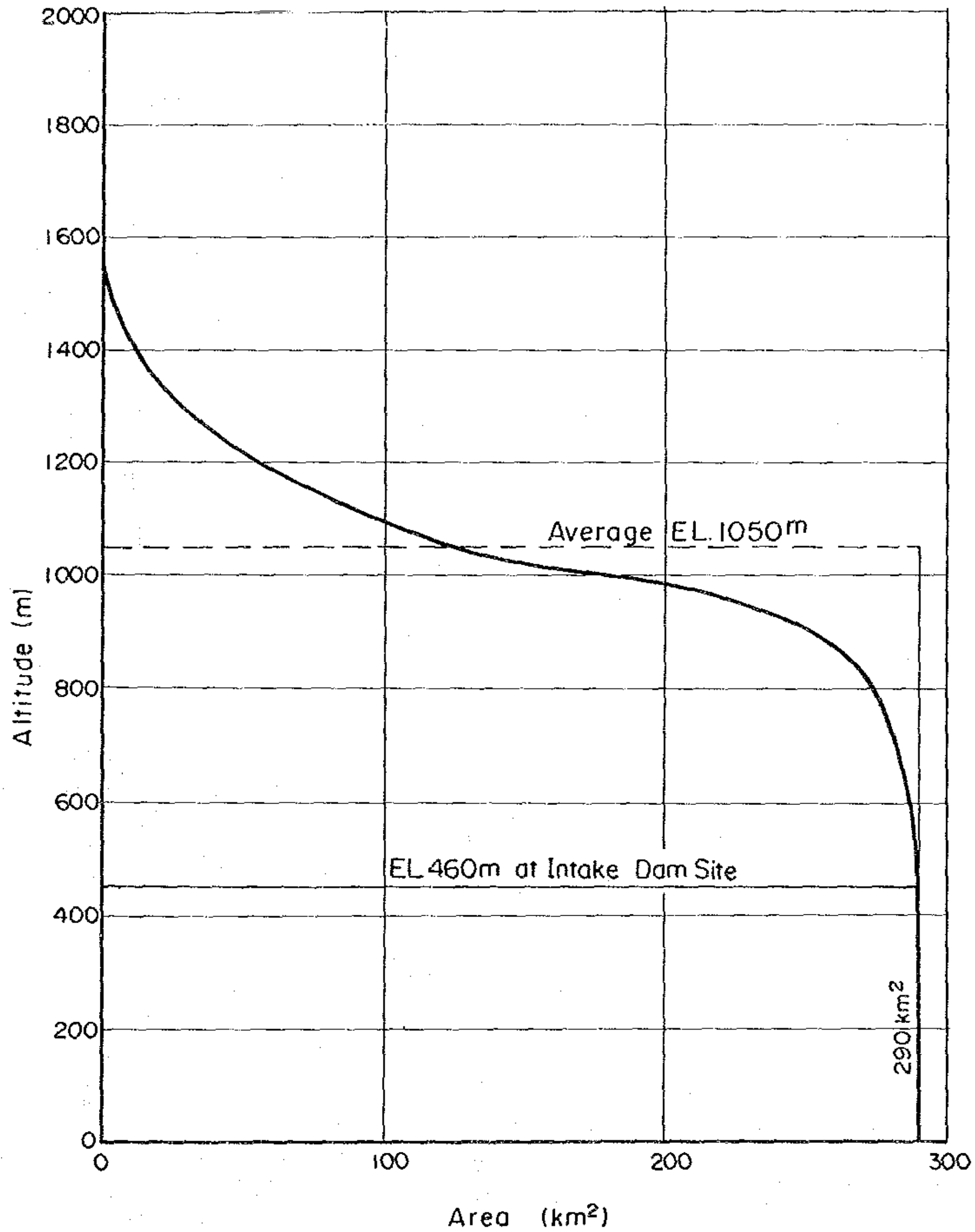
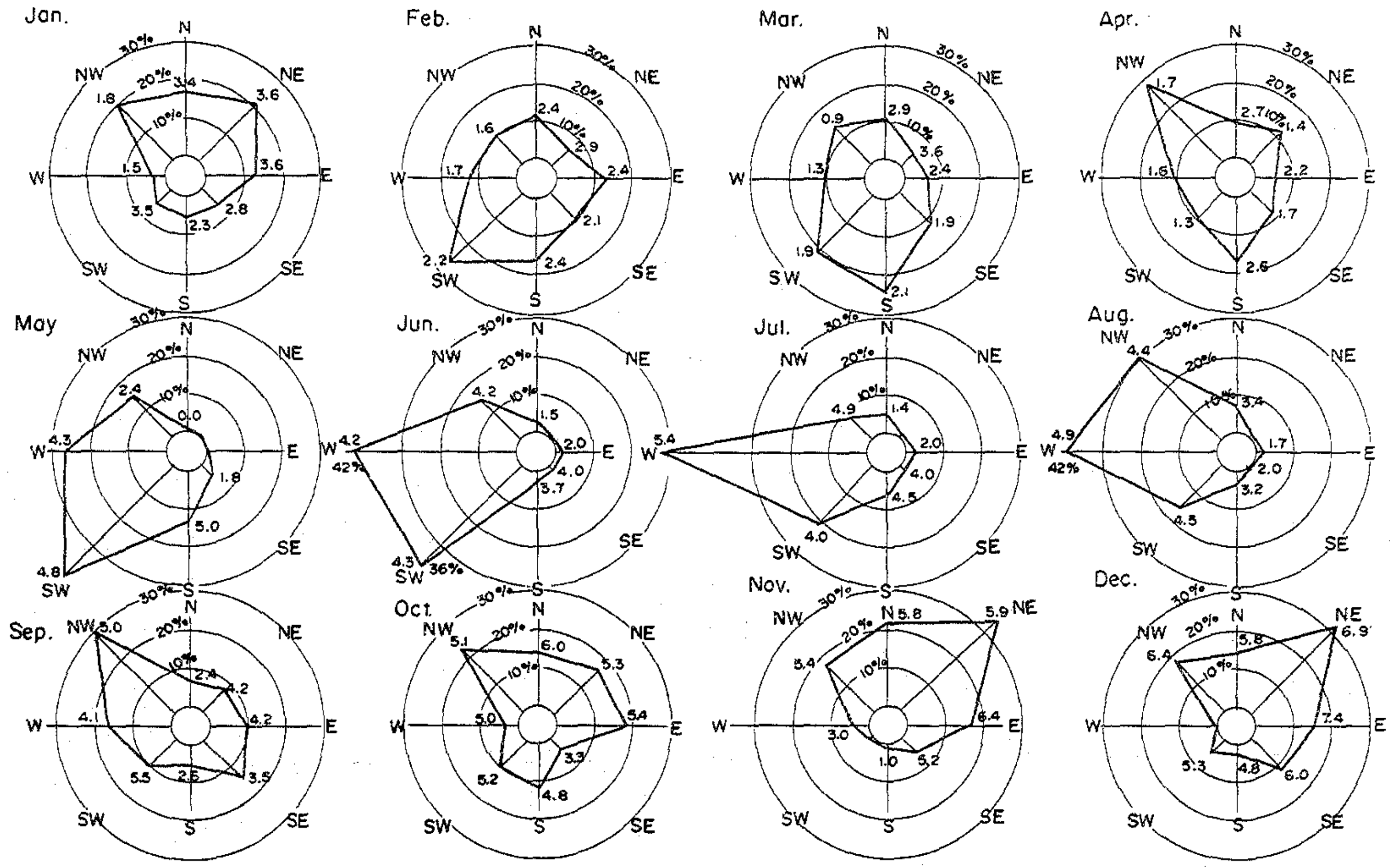
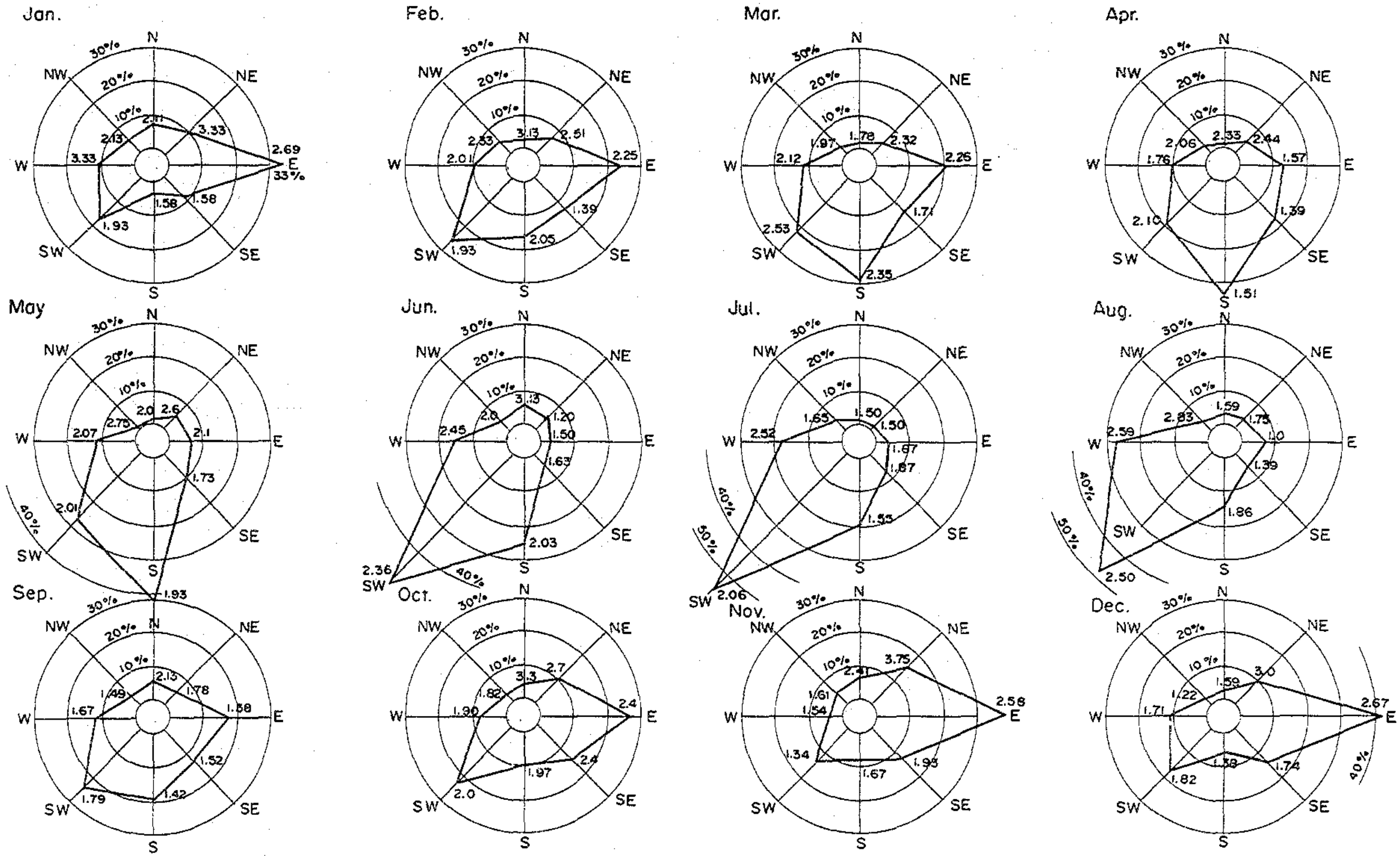


Fig. III-3-3 Frequency of Surface Wind Direction at Nikhon 34 (1986)



* Figures in each diagram indicate monthly mean wind velocity of each direction.

Fig. III-3-4 Frequency of Surface Wind Direction at Paksong (1983-1987)



* Figures in each diagram indicate monthly mean wind velocity of each direction.

Fig. III-3-5 Rating Curve at Ban Nonghin Gauging Station

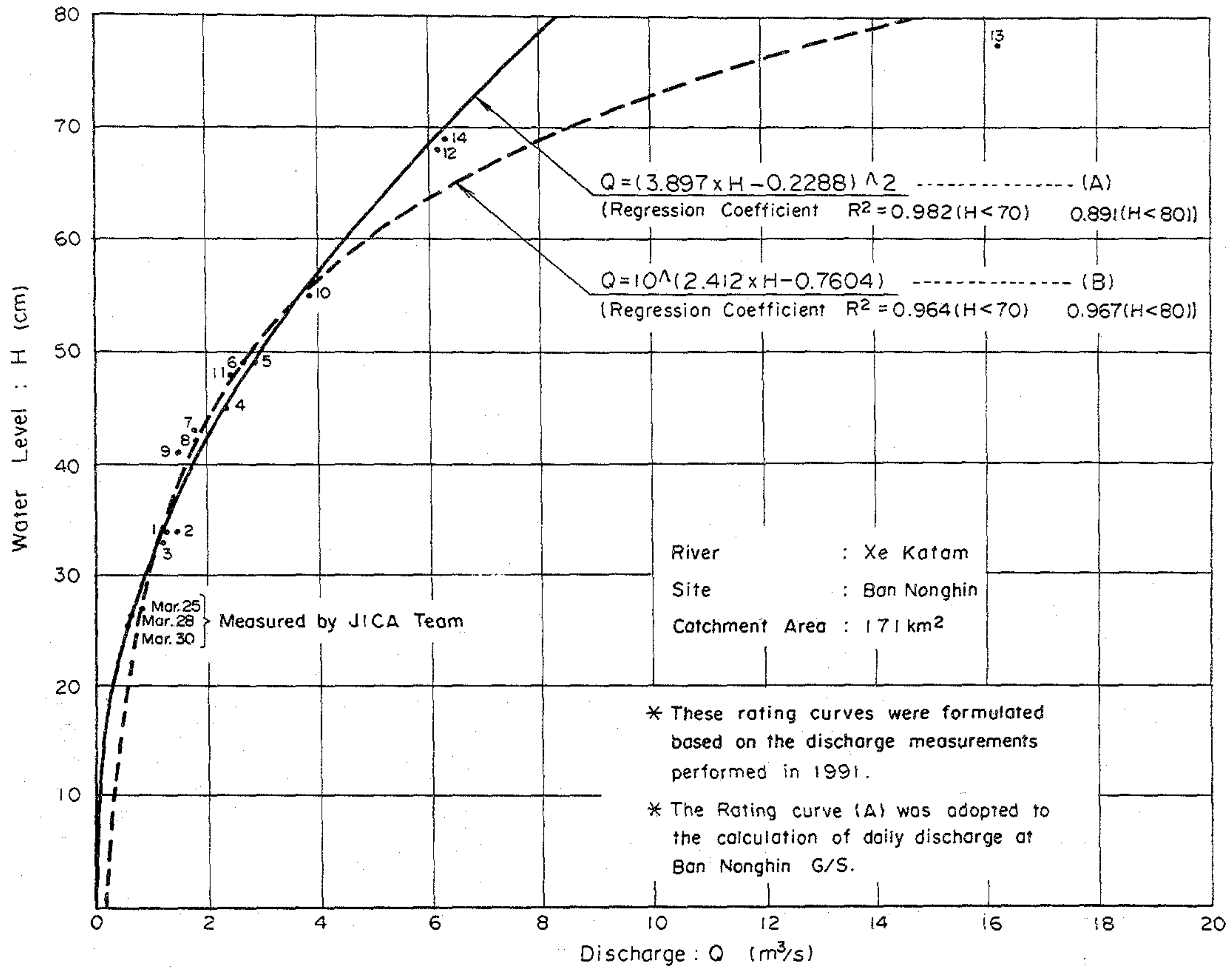
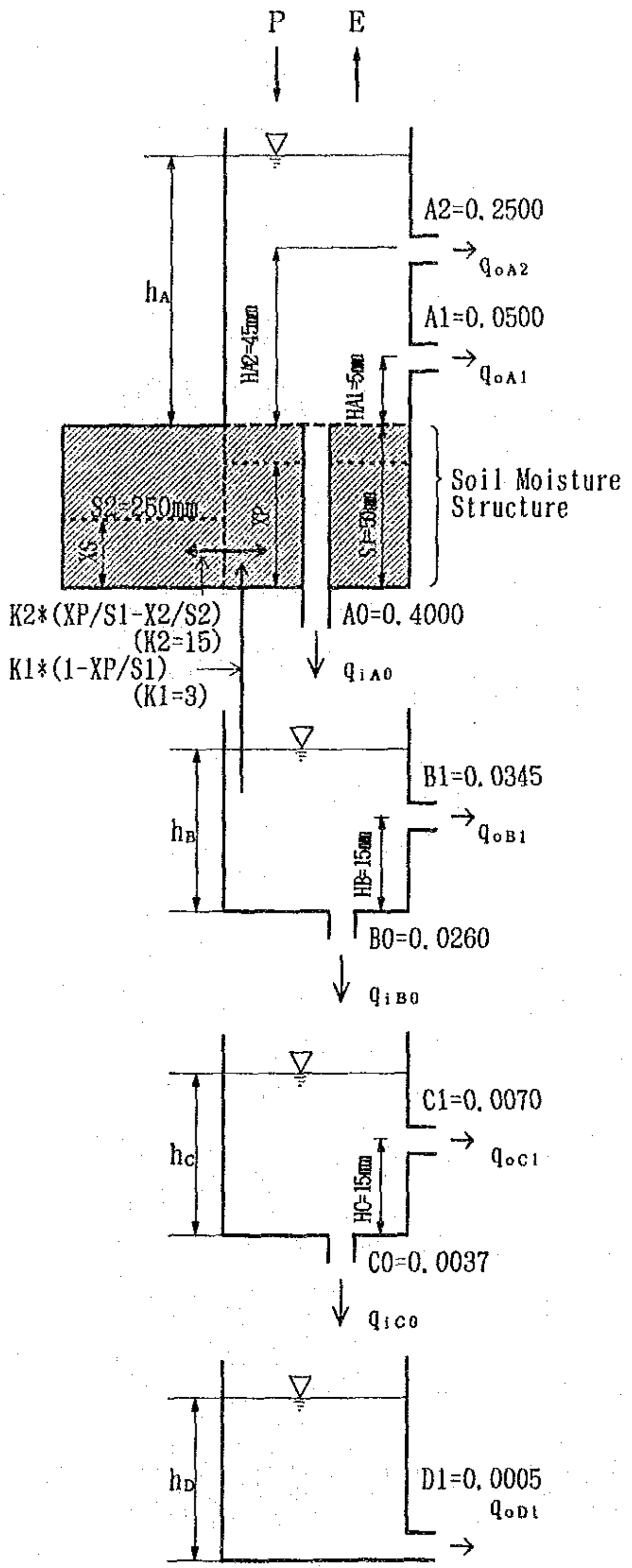


Fig. Ⅲ-3-6 Sugawarás TANK MODEL applied to Xe Katam River Basin



P = 75% of observed rainfall at Nonghin

E = 140% of observed evaporation at Nikhon34

$q_{oA2} = (h_A - HA2) * A2$

$q_{oA1} = (h_A - HA1) * A1$

} Surface Runoff (short-term runoff)

$q_{iA0} = h_A * A0$ Infiltration

$q_{oB1} = (h_B - HB) * B1$ Mid-term Runoff

$q_{iB0} = h_B * B0$ Infiltration

$q_{oC1} = (h_C - HC) * C1$ Mid-term Runoff

$q_{iC0} = h_C * C0$ Infiltration

$q_{oD1} = h_D * D0$ Base Runoff (long-term Runoff)

Runoff Height (mm/day) $= q_{oA2} + q_{oA1} + q_{oB1} + q_{oC1} + q_{oD1}$

Fig.III-3-7 DURATION CURVE OF CALCULATED DISCHARGE AT XE KATAM INTAKE SITE

1981−1990(MEAN)

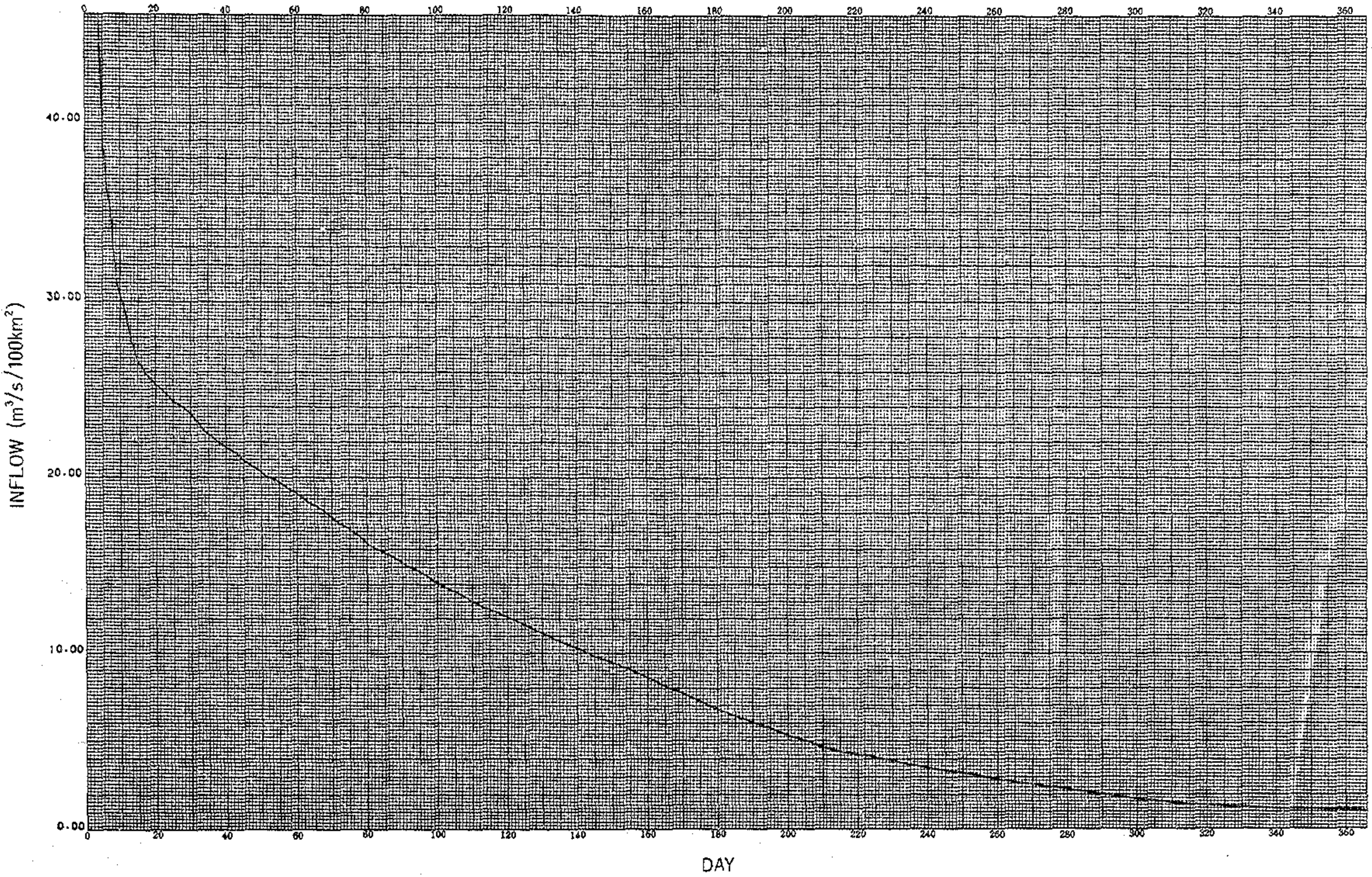


Fig.III-3-8 Frequency Analysis of the Annual Maximum Daily Rainfall Series at Nonghin Station

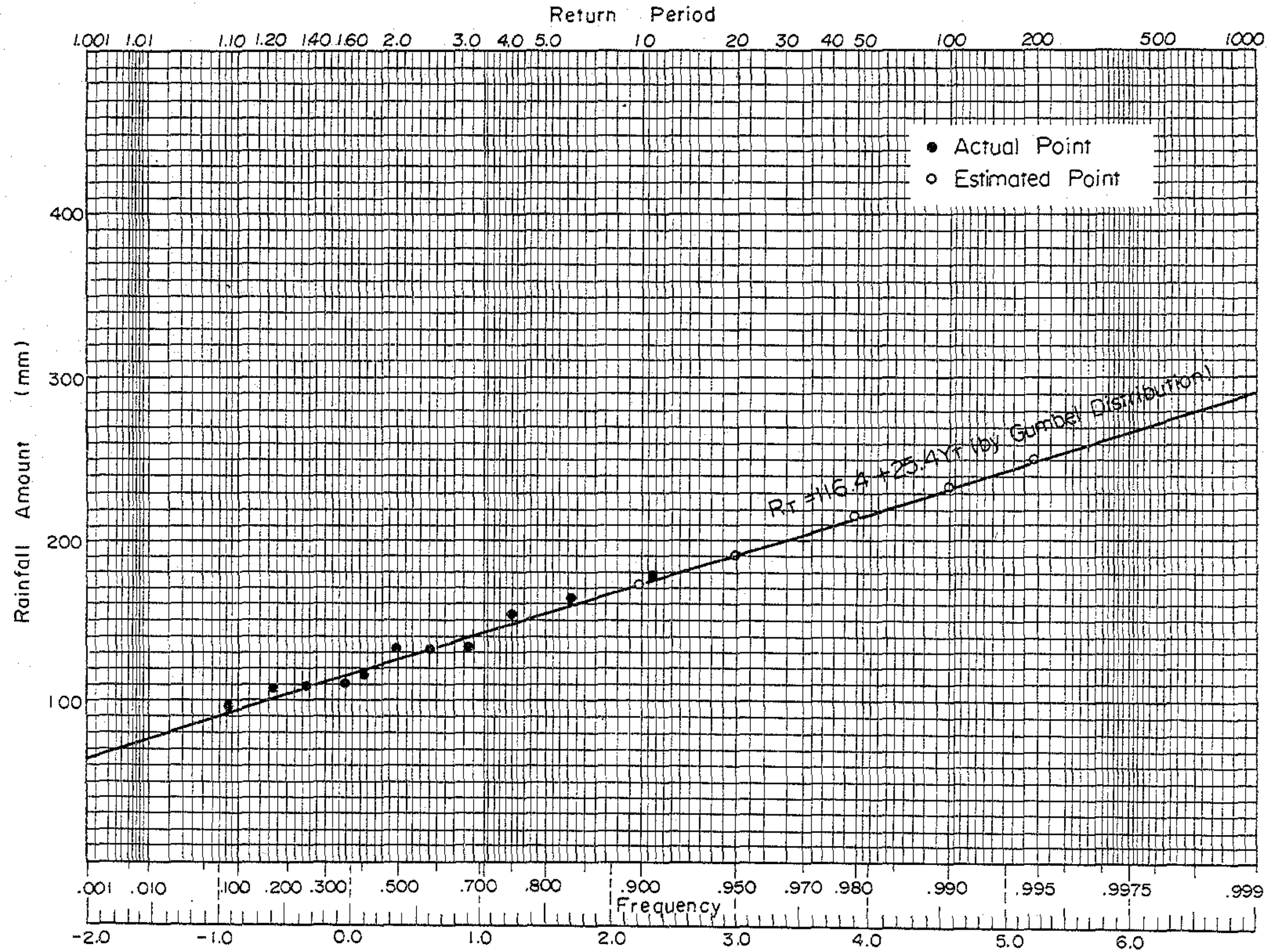


Fig. III-3-9 Covering Area of Existing Rainfall Stations in Bolaven Plateau

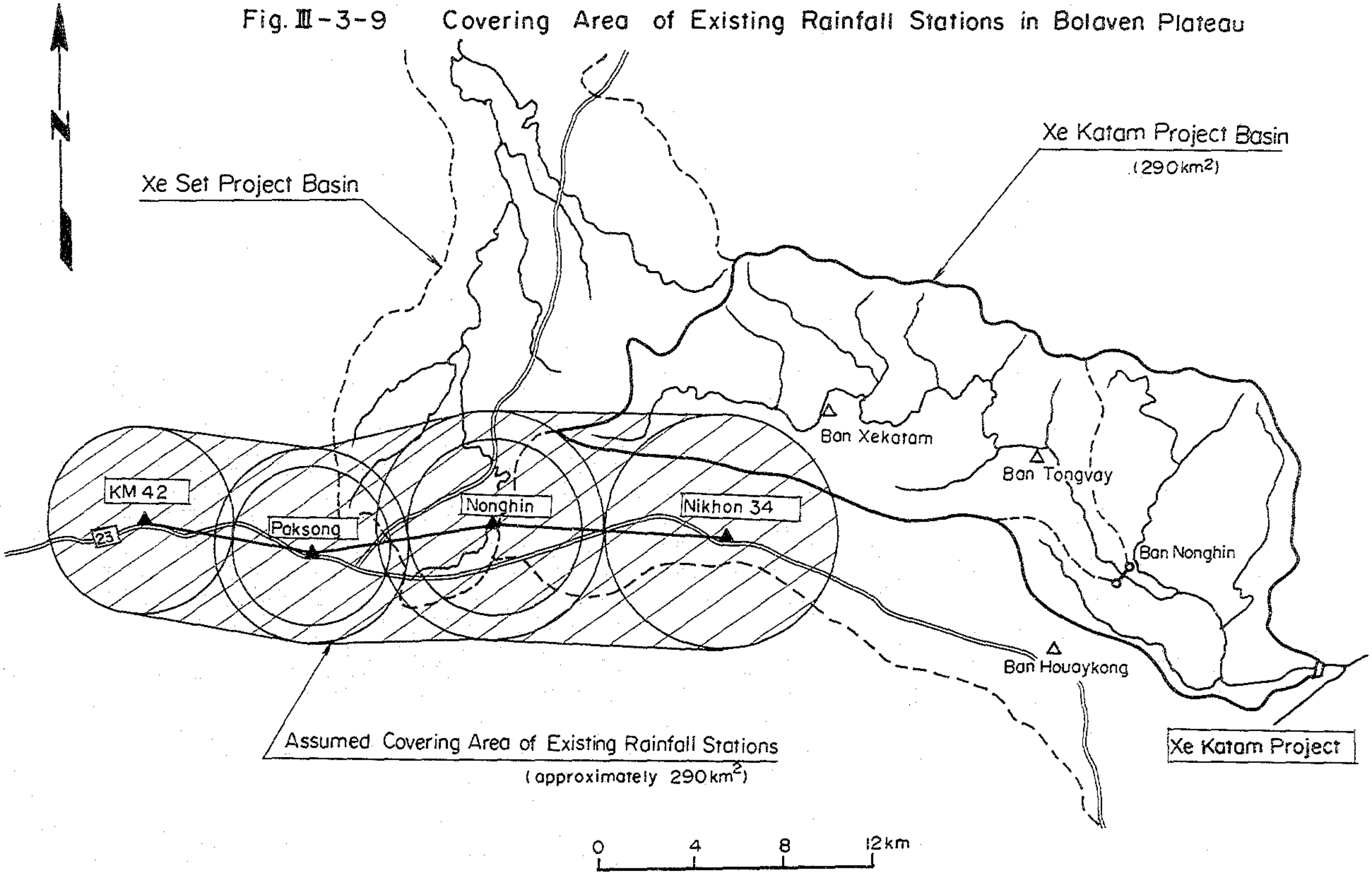


Fig. Ⅲ-3-10 Area Average-Point Maximum Rainfall Ratio in Bolaven Plateau

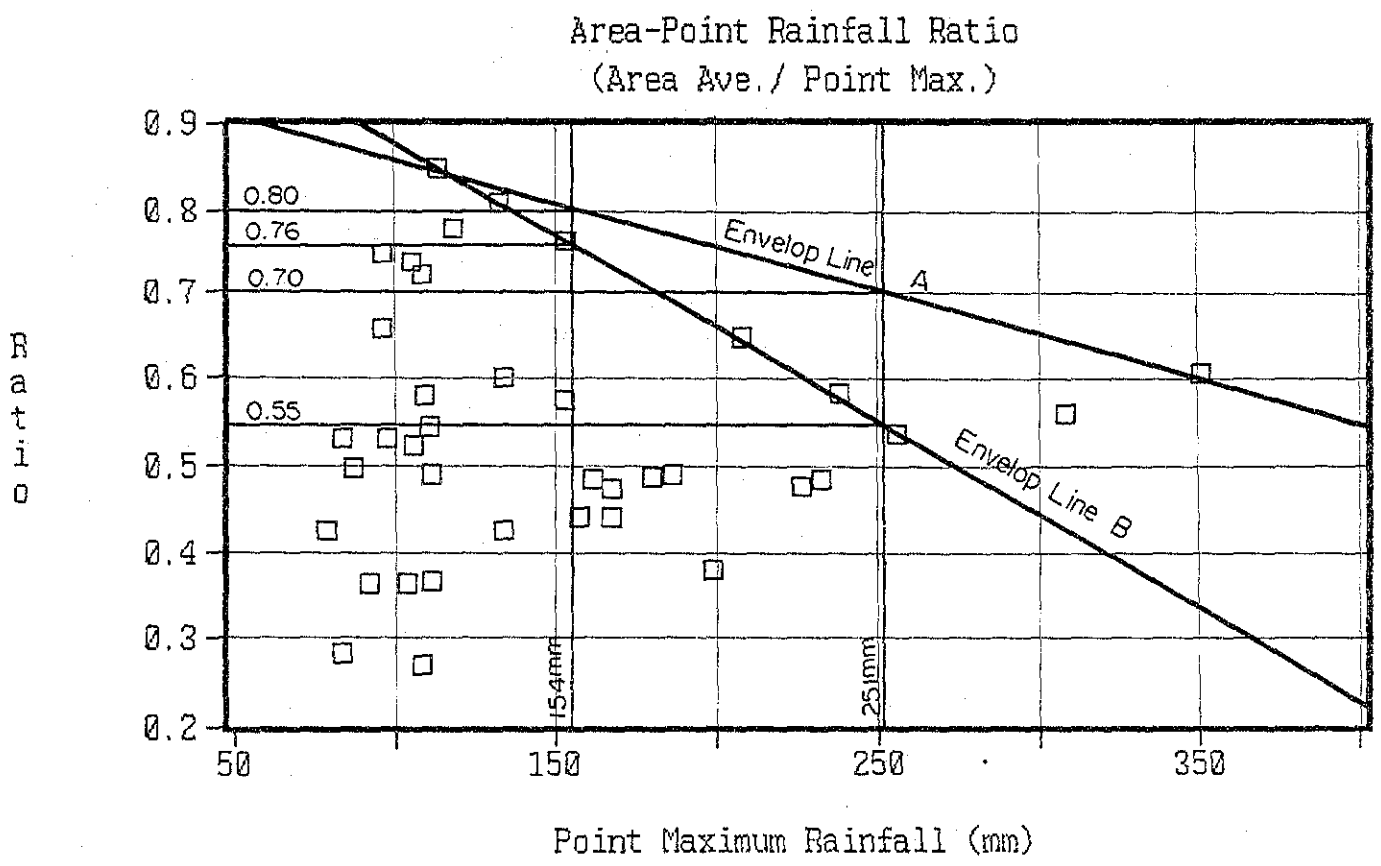


Fig. III-3-11 River Flow Velocity Curve of Xe Katam River Downstream

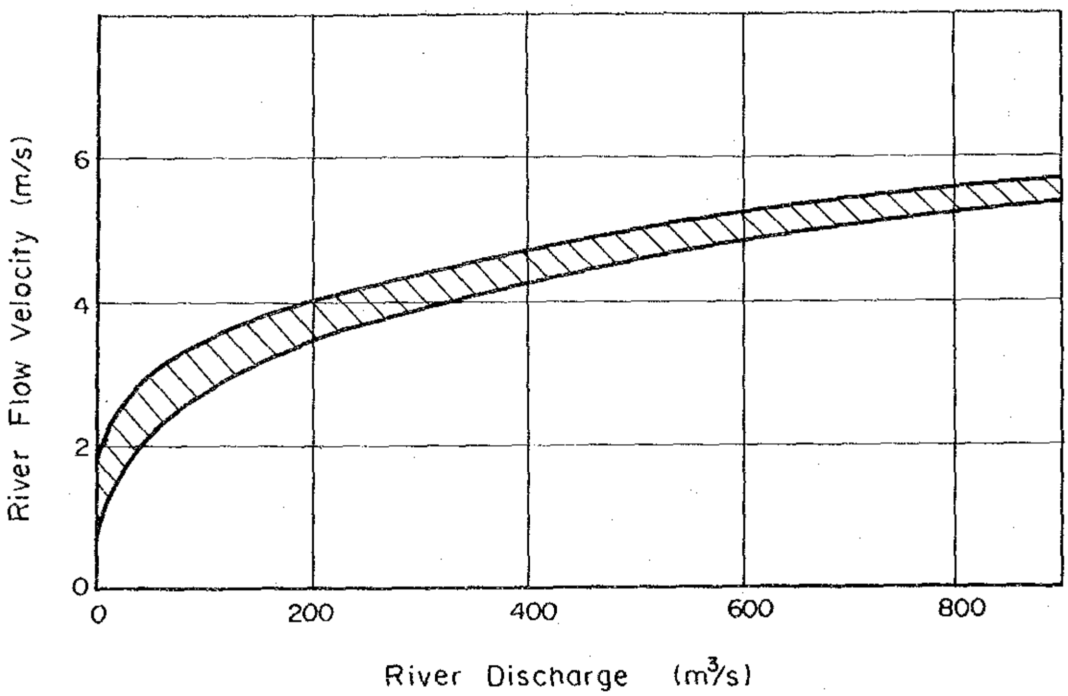


Table III-3-1 Monthly Rainfall in Bolaven Plateau (1991)

Rainfall Stations	Existing Rainfall Stations				Newly Installed Rainfall Stations					
	Out of the Basin				Xe Katam Basin			Out of the Basin		
					upstream	midstream	up-mid			
	KM42	**Paksong**	**Nonghin**	**Nikhon34**	[a] **B.Xeka -tam**	[b] **B.Tong -vay**	[a] & [b] **Average**	**B.Houay -kong**	**B.Latsa -sin**	**B.Nam -kong**
Month	**Monthly Rainfall (mm)**									
Jan.(1)	11.4	21.4	17.6	53.1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Feb.(2)	11.7	0.3	1.2	1.4	8.0	0.0	4.0	5.5	1.0	n.a.
Mar.(3)	63.0	69.5	120.1	80.4	112.5	66.0	89.3	47.0	2.0	n.a.
Apr.(4)	140.7	294.0	156.9	n.a.	238.5	124.0	181.3	191.0	75.5	78.0
May (5)	321.5	264.0	355.6	305.7	188.5	141.5	165.0	124.5	130.5	119.5
Jun.(6)	537.8	551.1	326.4	296.1	280.0	343.5	311.8	445.0	586.5	672.5
Total 2-6	**1074.7**	**1178.9**	**960.2**	--	**827.5**	**675.0**	**751.3**	**813.0**	**795.5**	--
Total 4-6	1000.0	1109.1	838.9	--	707.0	609.0	658.0	760.5	792.5	870.0
Total 5-6	859.3	815.1	682.0	601.8	468.5	485.0	476.8	569.5	717.0	792.0
Month	**Ratio(%) to the Average of [a] and [b]**									
Feb.(2)	293%	8%	30%	35%	200%	0%	100%	138%	25%	--
Mar.(3)	71%	78%	135%	90%	126%	74%	100%	53%	2%	--
Apr.(4)	78%	162%	87%	--	132%	68%	100%	105%	42%	43%
May (5)	195%	160%	216%	185%	114%	86%	100%	75%	79%	72%
Jun.(6)	173%	177%	105%	95%	90%	110%	100%	143%	188%	216%
Total 2-6	**143%**	**157%**	**128%**	--	**110%**	**90%**	**100%**	**108%**	**106%**	--
Total 4-6	152%	169%	127%	--	107%	93%	100%	116%	120%	132%
Total 5-6	180%	171%	143%	126%	98%	102%	100%	119%	150%	166%

Table III-3-2 Discharge Record at Xe Set Gauging Station

Catchment Area : 325 sq-km (unit : m^3/s-d)

1985	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Annual**
Flow Volume	166.2	105.5	103.2	121.8	280.7	948.4	823.3	890.1	832.7	554.8	296.2	192.0	5314.8
(in mm)	44	28	27	32	75	252	219	237	221	147	79	51	1413
Ratio(%)	3	2	2	2	5	18	15	17	16	10	6	4	100
Daily Ave.	5.4	3.8	3.3	4.1	9.1	31.6	26.6	28.7	27.8	17.9	9.9	6.2	14.6
Daily Max.	6.8	4.5	4.7	7.1	11.1	163.5	47.7	40.0	38.5	26.8	12.3	7.4	163.5
Daily Min.	4.5	3.2	2.6	2.6	5.6	7.8	16.6	19.6	22.0	13.7	7.4	5.0	2.6

1986	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Annual**
Flow Volume	131.1	88.9	78.2	104.5	291.6	339.2	415.5	1054.0	931.9	671.9	493.1	227.2	4827.0
(in mm)	35	24	21	28	78	90	110	280	248	179	131	60	1283
Ratio(%)	3	2	2	2	6	7	9	22	19	14	10	5	100
Daily Ave.	4.2	3.2	2.5	3.5	9.4	11.3	13.4	34.0	31.1	21.7	16.4	7.3	13.2
Daily Max.	5.0	4.0	3.7	6.5	19.0	14.2	19.6	128.0	45.2	54.5	26.2	9.9	128.0
Daily Min.	4.0	2.4	2.0	1.9	4.0	8.4	8.8	13.7	21.4	14.3	9.9	5.0	1.9

Average	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Annual**
Flow Volume	148.6	97.2	90.7	113.1	286.2	643.8	619.4	972.1	882.3	613.4	394.6	209.6	5070.9
(in mm)	40	26	24	30	76	171	165	258	235	163	105	56	1348
Ratio(%)	3	2	2	2	6	13	12	19	17	12	8	4	100
Daily Ave.	4.8	3.5	2.9	3.8	9.2	21.5	20.0	31.4	29.4	19.8	13.2	6.8	13.9
Daily Max.	5.9	4.2	4.2	6.8	15.1	88.9	33.7	84.0	41.9	40.7	19.3	8.7	145.8
Daily Min.	4.2	2.8	2.3	2.2	4.8	8.1	12.7	16.7	21.7	14.0	8.7	5.0	2.2

Table III-3-3 Monthly Temparature at Nikhon34 and Pakse (1/2)

Nikhon34

Mean Temparature (° c)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1984	16.3	17.8	19.1	20.8	20.4	20.8	21.7	20.6	19.8	19.1	17.2	15.7	19.1
1985	16.2	19.9	20.2	20.3	20.7	20.6	20.5	20.4	19.7	18.8	18.1	15.0	19.2
1986	13.5	15.1	17.6	19.5	20.3	20.6	20.1	20.2	19.6	19.3	17.4	16.3	18.3
1989	19.5	18.1	20.5	22.5	22.6	22.5	22.4	22.1	22.0	21.0	18.5	17.6	20.8
1990	13.6	18.8	17.0	19.0	22.2	21.7	22.0	21.7	21.7	21.3	19.6	17.2	19.7
Ave.	15.8	17.9	18.9	20.4	21.2	21.2	21.3	21.0	20.6	19.9	18.2	16.4	19.4
Max.	19.5	19.9	20.5	22.5	22.6	22.5	22.4	22.1	22.0	21.3	19.6	17.6	20.8
Min.	13.5	15.1	17.0	19.0	20.3	20.6	20.1	20.2	19.6	18.8	17.2	15.0	18.3

Monthly Absolute Maximum Temparature (° c)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1984	26.5	29.0	24.3	29.7	28.0	27.0	27.0	26.0	27.5	27.1	27.0	26.8	29.7
1985	26.0	28.6	28.2	28.2	27.5	27.0	27.6	25.5	29.7	27.8	26.8	26.8	29.7
1986	27.0	27.5	28.7	29.0	28.5	28.2	28.3	28.0	28.0	27.5	27.5	26.7	29.0
1989	28.0	29.0	29.5	28.6	28.4	29.0	27.0	27.0	27.5	26.0	27.0	26.6	29.5
1990	26.8	27.0	28.0	28.0	28.2	26.5	26.7	26.3	28.2	27.4	28.3	27.6	28.3
Ave.	26.9	28.2	27.7	28.7	28.1	27.5	27.3	26.6	28.2	27.2	27.3	26.9	29.2
Max.	28.0	29.0	29.5	29.7	28.5	29.0	28.3	28.0	29.7	27.8	28.3	27.6	29.7
Min.	26.0	27.0	24.3	28.0	27.5	26.5	26.7	25.5	27.5	26.0	26.8	26.6	28.3

Monthly Absolute Minimum Temparature (° c)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1984	1.6	1.9	17.9	11.9	12.5	15.3	13.0	16.0	11.8	8.2	2.0	3.3	1.6
1985	4.5	7.2	10.0	10.4	11.5	14.3	13.7	14.4	10.6	8.0	7.5	1.0	1.0
1986	0.0	0.2	10.5	7.3	12.2	12.6	12.5	12.7	9.9	9.7	6.5	1.9	0.0
1989	9.1	5.5	9.5	16.5	8.9	18.2	16.5	17.6	17.5	12.5	6.4	7.1	5.5
1990	0.1	6.5	6.0	6.7	18.2	18.5	18.2	18.1	16.5	14.0	8.0	6.0	0.1
Ave.	3.1	4.3	10.8	10.6	12.7	15.8	14.8	15.8	13.3	10.5	6.1	3.9	1.6
Max.	9.1	7.2	17.9	16.5	18.2	18.5	18.2	18.1	17.5	14.0	8.0	7.1	5.5
Min.	0.0	0.2	6.0	6.7	8.9	12.6	12.5	12.7	9.9	8.0	2.0	1.0	0.0

Table III-3-3 Monthly Temparature at Nikhon34 and Pakse (2/2)

Pakse

Monthly Mean Temparature (° c)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1981	23.4	27.0	29.7	29.3	28.1	26.7	26.7	26.5	27.3	26.3	25.5	22.4	26.6
1982	23.1	27.2	29.6	28.6	28.9	27.3	27.0	26.4	26.0	26.6	26.4	22.3	26.6
1984	23.2	26.5	28.7	29.9	27.9	27.1	26.9	25.5	26.2	25.6	24.9	23.7	26.3
1985	24.2	27.7	28.3	28.8	28.0	27.2	27.0	26.4	26.6	26.4	26.5	23.9	26.8
1986	22.9	26.2	28.4	30.3	27.9	27.6	26.9	26.4	27.0	26.6	24.4	23.7	26.5
1987	34.3	26.4	29.7	30.0	29.4	27.7	26.5	27.5	27.2	27.5	26.5	22.4	27.9
1988	25.7	27.8	29.9	29.4	28.6	27.5	27.7	26.7	27.2	25.3	23.9	22.8	26.9
Ave.	25.3	27.0	29.2	29.5	28.4	27.3	27.0	26.5	26.8	26.3	25.4	23.0	26.8
Max.	34.3	27.8	29.9	30.3	29.4	27.7	27.7	27.5	27.3	27.5	26.5	23.9	27.9
Min.	22.9	26.2	28.3	28.6	27.9	26.7	26.5	25.5	26.0	25.3	23.9	22.3	26.3

Monthly Absolute Maximum Temparature (° c)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1981	34.9	36.2	38.0	38.0	35.4	32.5	32.2	33.2	33.3	33.5	33.0	32.5	38.0
1982	32.1	36.8	37.7	37.5	36.0	34.0	32.9	32.2	32.4	34.2	33.7	33.7	37.7
1984	33.0	35.7	38.2	38.2	34.3	33.5	33.5	31.8	32.9	32.7	33.0	33.0	38.2
1985	33.7	35.9	37.4	37.8	35.0	33.5	32.8	32.0	33.5	33.9	33.5	33.5	37.8
1986	34.2	34.4	38.5	38.0	37.8	33.9	34.0	33.8	34.0	33.5	32.5	33.6	38.5
1987	33.5	35.5	37.9	38.0	37.5	35.5	34.0	33.8	34.0	35.0	34.0	33.7	38.0
1988	35.8	37.0	39.5	38.6	36.0	34.5	34.2	32.2	37.0	32.0	32.8	32.2	39.5
Ave.	33.9	35.9	38.2	38.0	36.0	33.9	33.4	32.7	33.9	33.5	33.2	33.2	38.2
Max.	35.8	37.0	39.5	38.6	37.8	35.5	34.2	33.8	37.0	35.0	34.0	33.7	39.5
Min.	32.1	34.4	37.4	37.5	34.3	32.5	32.2	31.8	32.4	32.0	32.5	32.2	37.7

Monthly Absolute Minimum Temparature (° c)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1981	12.8	17.3	22.4	22.4	21.8	23.1	22.7	23.3	23.0	20.7	17.5	14.1	12.8
1982	14.2	17.4	23.4	20.8	20.5	22.0	22.6	22.4	22.0	20.2	18.6	11.2	11.2
1983													
1984	13.0	15.0	15.0	24.0	22.2	23.0	22.0	22.0	22.3	18.3	17.3	14.0	13.0
1986	12.8	14.5	11.5	23.2	22.5	21.5	21.4	21.5	22.0	20.7	16.0	15.0	11.5
1987	14.9	15.5	21.3	21.5	23.1	22.8	22.3	22.2	22.0	19.2	18.1	13.3	13.3
1988	15.8	17.2	18.0	21.4	23.3	22.3	23.0	21.5	22.3	19.0	16.2	14.0	14.0
Ave.	13.9	16.2	18.6	22.2	22.2	22.5	22.3	22.2	22.3	19.7	17.3	13.6	12.6
Max.	15.8	17.4	23.4	24.0	23.3	23.1	23.0	23.3	23.0	20.7	18.6	15.0	14.0
Min.	12.8	14.5	11.5	20.8	20.5	21.5	21.4	21.5	22.0	18.3	16.0	11.2	11.2

Table III-3-4 Relative Humidity and Evaporation at Nikhon34

Relative Humidity

Nikhon34 — Mean Relative Humidity (%)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1984	69	65	71	81	82	84	83	88	84	78	76	71	78
1985	70	74	72	81	82	87	84	84	83	78	78	74	79
1986	70	70	75	76	82	85	81	84	80	81	76	72	78
1987				75	83	82	84	84	83	78	82	72	
1988	72	73	77			83	85					73	
1989	73	67	75	81	82	83	84	83	82	81	74	69	78
1990	69	69	76	77	85	87	84	84	82	82	79	70	79
Ave.	71	70	74	79	83	84	84	85	82	80	78	72	78
Max.	73	74	77	81	85	87	85	88	84	82	82	74	79
Min.	69	65	71	75	82	82	81	83	80	78	74	69	78

Nikhon34 — Maximum Relative Humidity (%)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1984			95	96	96	94	93	95	96	93	98		95
1985	96	97	95	96	95	94	95	94	96	95	95	94	95
1986	94	95	94	95	95	96	81	96	96	95	94	91	94
1987				94	96	95	95	95	96	96	94	92	
1988	95	95	98			95	96					92	
1989	95	95	95	96	95	95	95	94	94	95	92	93	95
1990	95	94	95	94	96	96	95	95	95	94	93	92	95
Ave.	95	95	95	95	96	95	93	95	96	95	94	92	95
Max.	96	97	98	96	96	96	96	96	96	96	98	94	95
Min.	94	94	94	94	95	94	81	94	94	93	92	91	94

Nikhon34 — Minimum Relative Humidity (%)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1984			48	66	68	75	72	81	73	62	53		66
1985	44	52	49	66	70	80	72	74	70	61	62	54	63
1986	47	45	55	56	70	74	68	72	65	66	58	54	61
1987				56	69	70	74	74	70	61	69	52	
1988	48	52	56			72	74					55	
1989	52	40	56	65	70	71	73	73	70	66	56	46	62
1990	44	45	57	59	74	78	74	73	70	70	65	48	63
Ave.	47	47	54	61	70	74	72	75	70	64	61	52	63
Max.	52	52	57	66	74	80	74	81	73	70	69	55	66
Min.	44	40	48	56	68	70	68	72	65	61	53	46	61

Evaporation (mm)

Nikhon34

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1984	37	70	67	42	40	37	40	26	31	39	47	53	528
1985	65	62	67	28	32	47	27	28	31	42	41	54	524
1986	62	57	43	56	42	43	42	33	37	34	45	55	547
1987				48	37	42	47	24	34	34	47	60	
1988	77	69	81	47	45	32	26			45		61	
1989	55	114	46	47	65	54	23	44	25	48	64	68	652
1990	72	66	62	58	36	14	53	49	25	53	73	50	611
Ave.	61	73	61	47	42	38	37	34	31	42	53	57	572
Max.	77	114	81	58	65	54	53	49	37	53	73	68	652
Min.	37	57	43	28	32	14	23	24	25	34	41	50	524

Table III-3-5 Wind Velocity and Direction at Nikhon34

Mean Wind Velocity (m/s) and Direction

Nikhon34	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1983								0.7	0.7	0.9	1.8		
								W	SW	N	NE		
1984	0.6	0.9	2.8	1.5	0.6	1.5	1.2	1.2	0.6	1.0	1.0	0.8	
	SE	E	NW	SW	SW	NW	SW	W	E	W	NE	NE	
1985	0.8	0.8	0.8	1.6	0.8	1.8	1.0	1.2	0.8	1.2	1.5	1.2	1.1
	E	SW	SW	NE	SW	W	W	W	E	NS	N	E	
1986	0.8	0.6	0.8	0.6	0.6	1.2	1.2	1.0	0.8	1.0	1.0	0.8	0.9
	E	E	N	W	W	SW	W	W	E	NW	NE	NE	
1987				1.6	0.8	1.2	1.2	1.2	1.0	1.0	0.8	0.8	
				N	SW	W	W	NW	SE	N	NE	E	
1988	0.8	0.8	1.5			1.0	2.0					1.2	
	NW	SW	NW			NW	N					NE	
1989	0.8	1.0	1.2	0.8	1.2	1.0	1.2	0.8	1.0	1.0	1.0	1.0	1.0
	NE	N	NE	NE	NW	NW	NW	NW	W	NW	N	NE	
1990	0.8	0.8	1.0	0.8	0.8								
	NE	S	NW	NE	SW								
Ave.	0.8	0.8	1.4	1.2	0.8	1.3	1.3	1.0	0.8	1.0	1.2	1.0	1.0
Max.	0.8	1.0	2.8	1.6	1.2	1.8	2.0	1.2	1.0	1.2	1.8	1.2	1.1
Min.	0.6	0.6	0.8	0.6	0.6	1.0	1.0	0.7	0.6	0.9	0.8	0.8	0.9

Mean of Daily Maximum Wind Velocity (m/s) and Direction

Nikhon34	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1983								1.7	1.5	1.9	3.5		
								W	SW	E	N		
1984	1.2	2.6	1.8	1.7	1.6	3.3	2.7	2.1	1.6	2.1	3.2	2.8	2.2
	E	NE	SW	SW	SW	W	NW	W	W	SE	NE	NE	
1985	2.7	2.3	2.6	1.9	2.3	2.8	2.8	3.5	2.7	3.2	3.1	2.3	2.7
	NE	SW	S	SW	SW	W	SW	W	NW	E	E	NE	
1986	2.7	2.4	2.6	1.8	4.5	4.3	4.8	4.5	4.6	5.2	5.7	6.4	4.1
	NW	SW	S	SW	SW	SW	W	W	NW	S	NE	NE	
1987				0.2	0.5	0.6	0.6	0.5	5.1	0.5	5.0	5.1	
				NW	SW	W	W	NW	SE	NE	NE	E	
1988	5.2	5.7	5.0			5.9	0.4					4.1	
	S	NW	SW			W	W					N	
1989	4.7	4.3	4.5	4.0	4.2	4.5	4.8	4.8	3.9	3.9	3.8	3.4	4.2
	NE	NE	NE	NW	NW	NW	NW	NW	NW	NE	NE	NE	
1990	3.0	3.6	2.9	3.2	3.4								
	NW	NW	NW	NW	NW								
Ave.	3.3	3.5	3.2	2.1	2.8	3.6	2.7	2.9	3.2	2.8	4.1	4.0	3.3
Max.	5.2	5.7	5.0	4.0	4.5	5.9	4.8	4.8	5.1	5.2	5.7	6.4	4.2
Min.	1.2	2.3	1.8	0.2	0.5	0.6	0.4	0.5	1.5	0.5	3.1	2.3	2.2

Table III-3-6 Observed Discharge at Ban Nonghin G/S : 1991

(unit: m^3/s-d)

Date	1990 Dec.	1991 Jan.	Feb.	Mar.	Apr.	May	Jun.
1		1.61	1.04	0.74	0.68	1.67	1.57
2		1.56	1.04	0.74	0.71	1.93	1.62
3		1.52	1.04	0.88	0.68	1.24	1.72
4		1.48	1.04	1.00	0.71	1.29	1.77
5		1.44	1.04	1.00	0.78	1.16	1.72
6		1.41	1.04	1.24	0.68	1.20	2.57
7		1.38	1.04	0.92	0.81	1.00	2.38
8		1.34	0.96	0.88	1.24	1.33	2.32
9		1.32	0.92	0.78	1.08	1.00	2.32
10		1.29	0.88	0.74	0.96	1.16	2.38
11		1.26	0.92	0.74	0.78	1.04	2.51
12		1.24	0.88	0.74	0.78	1.12	2.57
13		1.22	0.88	0.74	0.78	1.33	3.52
14		1.20	0.88	0.68	0.68	2.15	3.59
15		1.18	0.88	0.65	0.65	2.15	3.02
16		1.17	0.88	0.62	0.62	2.38	2.63
17		1.15	0.78	0.62	0.62	3.16	2.57
18		1.14	0.74	0.65	0.62	3.09	2.69
19		1.13	0.74	0.74	0.65	3.37	2.51
20		1.13	0.68	0.88	0.74	3.97	2.44
21		1.12	0.68	0.71	0.85	3.44	2.27
22		1.12	0.68	0.74	0.74	2.89	2.57
23		1.12	0.68	0.85	0.68	2.63	4.45
24		1.12	0.68	0.81	0.65	2.27	4.87
25		1.12	0.68	0.68	0.65	2.21	6.64
26		1.12	0.74	0.68	0.81	2.15	5.67
27		1.04	0.74	0.65	0.96	2.04	4.78
28	1.80	1.04	0.74	0.68	0.78	1.98	3.52
29	1.75	1.04		0.62	0.85	1.98	3.30
30	1.70	1.04		0.62	0.81	1.82	4.21
31	1.65	1.12		0.62		1.72	
Total(m^3/s-d)		38.15	23.92	23.63	22.98	61.86	90.69
Average(m^3/s)		1.23	0.85	0.76	0.77	2.00	3.02
Maximum(m^3/s)		1.61	1.04	1.24	1.24	3.97	6.64
Minimum(m^3/s)		1.04	0.68	0.62	0.62	1.00	1.57

Table III-3-7 Estimated Discharge at Xe Katam Damsite : 1991

(unit: m^3/s-d)

Date	1990 Dec.	1991 Jan.	Feb.	Mar.	Apr.	May	Jun.
1		2.85	1.56	0.99	0.87	3.00	2.76
2		2.75	1.56	0.99	0.93	3.66	2.88
3		2.65	1.56	1.26	0.87	2.01	3.12
4		2.55	1.56	1.48	0.93	2.11	3.25
5		2.47	1.56	1.48	1.06	1.82	3.12
6		2.38	1.56	2.01	0.87	1.92	5.42
7		2.31	1.56	1.33	1.12	1.48	4.90
8		2.24	1.41	1.26	2.01	2.21	4.73
9		2.17	1.33	1.06	1.65	1.48	4.73
10		2.11	1.26	0.99	1.41	1.82	4.90
11		2.05	1.33	0.99	1.06	1.56	5.25
12		2.00	1.26	0.99	1.06	1.73	5.42
13		1.95	1.26	0.99	1.06	2.21	8.34
14		1.91	1.26	0.87	0.87	4.25	8.58
15		1.87	1.26	0.82	0.82	4.25	6.79
16		1.84	1.26	0.77	0.77	4.90	5.61
17		1.81	1.06	0.77	0.77	7.21	5.42
18		1.79	0.99	0.82	0.77	7.00	5.79
19		1.77	0.99	0.99	0.82	7.88	5.25
20		1.75	0.87	1.26	0.99	9.85	5.07
21		1.74	0.87	0.93	1.19	8.11	4.57
22		1.74	0.87	0.99	0.99	6.38	5.42
23		1.73	0.87	1.19	0.87	5.61	11.51
24		1.73	0.87	1.12	0.82	4.57	13.03
25		1.73	0.87	0.87	0.82	4.41	19.93
26		1.73	0.99	0.87	1.12	4.25	16.07
27		1.56	0.99	0.82	1.41	3.95	12.72
28	3.33	1.56	0.99	0.87	1.06	3.80	8.34
29	3.20	1.56		0.77	1.19	3.80	7.65
30	3.08	1.56		0.77	1.12	3.39	10.66
31	2.96	1.73		0.77		3.12	
Total(m^3/s-d)		61.63	33.84	32.10	31.28	123.75	211.26
Average(m^3/s)		1.99	1.21	1.04	1.04	3.99	7.04
Maximum(m^3/s)		2.85	1.56	2.01	2.01	9.85	19.93
Minimum(m^3/s)		1.56	0.87	0.77	0.77	1.48	2.76

Table III-3-8 Estimated Discharge at Xe Katam Intake Site (1981-1990)

Flow Volume (unit : m^3/s-d)

Year	Jun.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1981	62.7	40.3	60.2	71.6	319.6	767.1	742.6	992.7	515.9	459.1	208.4	136.9	4377.1
1982	82.7	35.0	28.9	42.6	57.1	188.7	711.8	700.6	741.3	360.5	341.8	247.4	3538.3
1983	121.5	63.9	33.3	48.6	395.7	575.4	444.4	530.0	513.9	608.8	244.0	137.2	3716.6
1984	86.1	40.6	63.5	44.9	77.7	269.4	401.1	1120.3	1078.2	674.4	452.1	215.6	4523.7
1985	135.9	92.7	75.9	308.2	338.0	610.4	810.2	830.0	714.0	391.2	238.4	160.1	4705.0
1986	108.5	54.7	42.4	57.7	311.3	306.0	579.6	908.4	743.3	493.4	256.1	153.3	4014.6
1987	99.7	47.7	37.7	36.8	37.4	90.7	519.0	693.6	515.5	429.9	211.8	125.4	2845.1
1988	79.6	38.2	33.3	72.5	264.5	379.1	314.8	570.5	331.1	395.6	189.1	111.0	2779.1
1989	66.3	31.1	29.6	51.3	114.6	238.8	380.2	611.2	499.9	272.8	145.4	100.3	2541.4
1990	57.3	26.4	80.7	52.0	91.6	220.4	280.0	395.7	571.5	500.9	206.5	116.3	2599.2
Total	900.1	470.8	485.3	786.0	2007.5	3645.9	5183.6	7352.8	6224.4	4586.7	2493.5	1503.6	35640.1
Average	90.0	47.1	48.5	78.6	200.8	364.6	518.4	735.3	622.4	458.7	249.4	150.4	3564.0
Mean(m^3/s)	2.9	1.7	1.6	2.6	6.5	12.2	16.7	23.7	20.7	14.8	8.3	4.9	9.8

Minimum Daily Flow (unit : m^3/s-d)

Year	Jun.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1981	1.34	0.80	0.85	0.87	3.12	10.32	16.93	20.32	12.51	9.59	5.26	3.54	0.80
1982	1.89	0.96	0.89	0.86	0.85	2.02	12.62	19.12	15.31	7.80	6.51	4.65	0.85
1983	3.09	1.55	0.95	0.89	2.83	6.03	10.33	11.67	10.87	13.09	5.13	3.63	0.89
1984	2.03	0.99	0.96	0.96	1.37	2.52	7.78	19.73	21.26	14.77	10.41	5.49	0.96
1985	3.45	2.46	1.91	1.79	8.17	5.11	18.30	17.43	14.94	9.77	6.22	4.40	1.79
1986	2.70	1.30	1.19	1.17	3.12	7.25	9.31	13.46	16.48	11.25	5.70	4.10	1.17
1987	2.42	1.26	1.17	1.12	1.10	1.09	4.55	9.96	12.21	9.77	4.71	3.35	1.09
1988	1.86	1.12	1.04	1.01	2.11	7.46	6.67	13.36	9.09	8.17	4.19	2.88	1.01
1989	1.48	1.01	0.91	0.88	1.01	4.20	3.79	13.85	11.77	6.26	3.82	2.56	0.88
1990	1.20	0.88	0.83	0.86	0.90	2.23	6.58	6.65	14.57	10.16	4.42	2.98	0.83
Average	2.15	1.23	1.07	1.04	2.46	4.82	9.69	14.56	13.90	10.06	5.64	3.76	1.03
Minimum	1.20	0.80	0.83	0.86	0.85	1.09	3.79	6.65	9.09	6.26	3.82	2.56	0.80

Table III-3-9 Annual Maximum Daily Precipitation at Rainfall Stations in Bolaven Plateau

Station	KM42		Paksong		Nonghin		Nikhon34	
Year	Date	Pmax	Date	Pmax	Date	Pmax	Date	Pmax
1966			Sep. 9	112.0				
1967			Sep.20	159.8				
1968			Sep. 5	241.6				
1969			Jul.11	269.0				
1970			Jun.19	100.0				
1971								
1972								
1973								
1974								
1975								
1976								
1977	Sep. 4	139.8						
1978	Aug.10	270.0						
1979	Sep.23	159.2			Aug. 9	163.6		
1980	Mar.12	200.4			May 16	134.8		
1981	Aug. 9	149.2			Aug. 9	92.4		
1982	Jun.27	183.8			Jul. 4	110.0		
1983	Jun.26	533.5			Jun.25	178.0		
1984	Aug.17	237.7			Mar.15	111.0	Sep. 6	95.6
1985	Jun.18	255.9			Apr. 5	134.0	Aug.10	110.9
1986	Aug.12	167.4	Jun.22	166.9	Jul.19	117.6	Aug.13	102.2
1987	Aug.21	350.3	Aug.21	242.2	Jul.14	132.6	Aug.21	132.0
1988	Aug. 1	108.3	Oct.15	91.7	May 13	97.4	Jul.25	83.2
1989	Jul.22	232.0	Jul.22	194.7	Jul.23	153.4	Mar.22	83.5
1990	Aug.29	307.5	Aug.29	202.4	Mar.28	108.5	Jul.29	78.1
Number of Data		14		10		12		6

Probable Precipitation by Gumbel Distribution

[Xt (mm) = a + b * ln(Yt)]

Return Period	KM42		Paksong		Nonghin		Nikhon34	
	a	187.7	a	151.9	a	116.4	a	93.5
	b	102.2	b	61.2	b	25.4	b	20.1
Yt(years)		Xt(mm)		Xt(mm)		Xt(mm)		Xt(mm)
5		352		250		157		126
10		423		293		174		140
20		494		335		192		154
50		588		391		216		172
100		658		434		233		186
200		729		476		251		200

Table III-3-10 Maximum Daily Rainfall of each Rainfall Stations in Bolaven Plateau (during from Jan. to Jun.in 1991)

(unit : mm/day

Station	1 KM42	2 Paksong	3 Nonghin	4 Nikhon34	5 B.Xeka -tam	6 B.Tong -vay	7 B.Houay -kong	8 B.Latsa -sin	9 B.Nam -kong
Date	Jun.23	Apr.30	May 18	May 15	Apr.30	Apr.30	Apr.30	Jun.22	Jun.17
1 KM42	**53.5**	2.3	44.5	0.0	2.3	2.3	2.3	28.4	37.5
2 Paksong	52.5	**179.9**	1.5	4.3	179.9	179.9	179.9	18.2	22.4
3 Nonghin	16.7	33.3	**58.8**	24.4	33.3	33.3	33.3	30.3	38.1
4 Nikhon34	33.0	n.a.	3.1	**76.7**	n.a.	n.a.	n.a.	11.5	9.9
5 B.Xekatam	26.0	87.0	6.0	16.5	**87.0**	87.0	87.0	7.5	6.5
6 B.Tongvay	33.0	73.0	18.5	0.5	73.0	**73.0**	73.0	12.5	2.0
7 B.Houaykong	24.0	131.5	2.0	2.0	131.5	131.5	**131.5**	113.5	22.5
8 B.Latsasin	51.5	63.0	1.5	0.0	63.0	63.0	63.0	**143.0**	32.0
9 B.Namkong	54.5	56.0	1.5	0.0	56.0	56.0	56.0	66.5	**74.5**
Average	38.3	69.6	15.3	13.8	69.6	69.6	69.6	47.9	27.3
Average 1-4	38.9	53.9	27.0	26.4	53.9	53.9	53.9	22.1	27.0
Average 5-7	27.7	97.2	8.8	6.3	97.2	97.2	97.2	44.5	10.3
Average 8-9	53.0	59.5	1.5	0.0	59.5	59.5	59.5	104.8	53.3

4. Electrification Plan and Power Demand Forecast for Service Area

Chapter III 4. Electrification Plan and Power Demand Forecast for Service Area

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4. Electrification Plan and Power Demand Forecast for Service Area

4.1 Present Status of Southern Provinces

The Southern Region in which this Project is located, comprises the six provinces of Champassak, Savannakhet, Salavane, Khammouan, Sekong, and Attapeu. The population of this region in 1990 was approximately 1,707,000, making up 40% of the population of entire Laos, while the area takes up 35%. The major products are approximately 20,000 m^3 of lumber from the plentiful forest resources available, coffee grown on the Bolaven Plateau and its foothills, and tea, with the greater parts exported to constitute important income sources. This region produces 45% of the rice produced in the entire country (as of 1990), and the Central Laotian Government's intentions are to comprehensively develop the Southern Region hereafter, especially increasing production of rice, to make the region an important future source of supply of the staple to the various regions in the north.

However, consolidation of electric power, transportation, telecommunication facilities, so-called infrastructure, to serve as the basis for economic development is still at an inadequate state at present. With regard to electric power facilities, Pakse and Paksong in Champassak Province, Salavane in Salavane Province, Savannakhet in Savannakhet Province, and Thakhek in Khammouan Province which are principal cities of the Southern Region or of provinces have been electrified, but still inadequately. In these provinces, Savannakhet and Khammouan are receiving electric power from Thailand across the Mekong River.

Sekong in Sekong Province and Attapeu in Attapeu Province, which are to be the service areas for supply of electric power from this Project, have diesel generators to supply electricity to residences and street lights by a distribution network provided in residential area. The automobile is the principal means of transportation, and although national road connecting among the abovementioned principal cities have been constructed, however, subsequent maintenance has been lacking, in addition to which, because of severe meteorological conditions, some sections become unpassable in the rainy season, and hauling out of products and supply of living necessities and power station fuel are hindered. Regarding telecommunication facilities, there is not telecommunication system covering this region, with only radio equipments installed for communication between bases of the police and EDL and with Vientiane. The Central Government is aggressively pushing ahead with construction of these infrastructure components in the Southern Region, but with Sekong and Attapeu provinces distant from Pakse, the present situation in the provision of these infrastructure are greatly lagging.

4.2 Electric Power Situation in Southern Region

4.2.1 Supply Facilities

The hydroelectric power potential of the Southern Region is estimated to exceed 2,000 MW, made up of the Mekong River mainstream first of all, followed by the major tributaries of the Xe Bang Fai river, the Xe Bang Hieng river, the Xe Kong river, and the Xe Done river, and the small tributaries as the Xe Katam river and the Xe Namnoy river. The development potential of the Xe Katam River of this Project and the Xe Namnoy River together has been to be approximately 364 MW.

However, the hydroelectric power stations which have been developed so far are only Xe Set Power Station of installed capacity 45 MW which started operation in July 1991 with the purposes of supplying power to Champassak and Saravane provinces and exporting them to Thailand, and Selabam Power Station (present installed capacity approximately 2 MW) which started operation in 1972 mainly with the purpose of supplying electricity to Pakse and with its installed capacity now being expanded.

Other than these power stations, there are diesel generators installed to complement these hydroelectric power stations, or installed at the capitals of the provinces to meet lighting peak loads of isolated power systems. There are also exclusive diesel generators installed for motive power of saw mills, which are major industrial facilities, and for polishing rice, and also for telecommunications. Other than these, there are small-capacity engine generators for shops or for private consumption which are used chiefly for lighting and for domestic electrical appliances such as televisions.

4.2.2 Power Transmission and Distribution Lines

Major power transmission line in this region is operating with the 115-kV voltage from Xe Set Power Station which goes via Pakse to cross the Mekong River for interconnection with the substation of Sirindhorn owned by EGAT of Thailand on the opposite bank. The transmission capacity of this line is approximately 100 MW, and interchange of electric power is being done between the two countries of Laos and Thailand as necessary. Further, there is a 22-kV transmission line for supply from Selabam Power Station to Pakse.

In Savannakhet and Kammouan provinces, there are 22-kV cables installed in 1973 crossing the Mekong River and power is being received from Nakhon Phanom and Mukdahan substations in Thailand.

Meanwhile, as power distribution facilities, a high-voltage distribution line of 22 kV constitutes the trunk line in the urban area of Pakse with supply to consumers by low-voltage distribution lines from distribution transformers. At urban areas of provincial centers, electricity is generally being supplied to consumers with only low-voltage distribution lines, but at Attapeu, high-voltage distribution lines of 22 kV has already been adopted, and a distribution grid has been formed with this as the trunk line.

4.2.3 Transitions in Electric Power Demand

As stated above, just Xe Set Power Station commissioned in 1991 is a full-fledged power supply source in this region, others being only antiquated small hydros, micro-hydros of several tens of kilowatts, and diesel generators. That is, during approximately 20 years since the start of operation of Selabam Hydroelectric Power Station, expansion of electric power system had not been done in earnest. It can be easily imagined how chronic the shortage of electric power had become during this time. Because of such a situation, growth in demand has been continuously subjected to limitations by the supply capability, and historical trend data do not reflect the true increase in demand. In other words, demand growth became latent because of this power shortage, and as a result, development of industry was also hindered.

Accordingly, when considering a power demand forecast for this region, this historical trend will be of no reference.

4.3 Electricity Supply Program

4.3.1 Southern Region Electrification Plan

As mentioned in the foregoing, the Laotian Government is aggressively proceeding with construction of the infrastructure of this region, and as one part, the Southern Provinces Electrification Project has been situated as a national project, and a present this work is being aggressively pushed forward. The project is divided into a First Phase and Second Phase with the First Phase now in progress, and excepting the power plant, transmission and distribution line work is scheduled to be completed by the mid-1993.

The First Phase of the project consists of construction of new transmission and distribution systems and expansion of a power station, the principal items being the three points below.

(1) Using the electricity generated at Xe Set Power Station, aim to drastically expand electrification of major cities and towns in the Southern Provinces.

(2) Aim for augmentation of supply capability by carrying out expansion of Selabam Power Station.

(3) Of the principal materials for the power distribution work required for expanding electrification, concrete poles are to be produced domestically.

By the major cities above-mentioned in Item (1) is meant the capital cities of Champassak, Salavane, and Savannakhet provinces and surrounding municipalities. The plan is for 22-kV distribution lines to be constructed along major roads for full-fledged electrification of these cities. However, the service areas of the present Study (Xe Katam), Sekong and Attapeu, are not included in the plan for economic reasons.

The installed capacity of the existing Selabam Power Station is 2,040 kW (680 kW x 3 unites), but according to information obtained from an engineer at the power station, the maximum output available at present with all three units in operation is up to 1,420 kW. The Study Team checked the operation records of the power station and the available capacity was approximately 1,400 kW, and a daily load curve is judged to be the limit. It was explained by the same engineer that this was the limit for stable operation due to the performances of the turbine-generators. Further, in addition, in view of the facts that shafts coupling between turbines and generators are being exchanged yearly, and considering the progress of sedimentation at the intake portion of the power station, it is thought there is a strong possibility for the output of this power station to decline more and more in the future. For these reasons, the facilities at this site are to be expanded to 3,000 kW to meet the increasing demand in the future. (The present facilities are scheduled to be taken out on completion of the present construction work.)

The concrete pole plant of Item (3) is located in adjacency to Bangyo Substation of EDL in Pakse, and the products made there are transported to construction sites. The concrete poles manufactured in Laos are not like the centrifugally-cast reinforced concrete poles and centrifugally-cast prestressed concrete poles produced in Japan, but are made by pouring concrete into square-shaped forms. However, holes for assembling are given consideration beforehand according to type. Distribution lines already constructed using these products were confirmed in carrying out the present study.

Further, a feasibility study has been completed for the Second Phase, the main purpose of which is to expand the object areas of electrification using 22-kV distribution lines from major town already electrified in the First Phase.

4.3.2 Service Area of Xe Katam Project

As mentioned above, the provinces of Sekong and Attapeu, in spite of the fact that they are looked upon to become greatly developed in the future, are not included in the areas as objects of the First Phase of the Southern Provinces Electrification Project. The reason for this is that these provinces are geographically distant from power stations to be developed in the near future or power supply facilities such as 115-kV transmission lines, so that investment amounts would be large, and development was deferred as a result of economic and financial analyses.

Therefore, electricity generated from Xe Katam Hydroelectric Power Station which would be comparatively close to these isolated areas and the development scale is also suitable has been planned.

(1) Present State of Power Demand at Sekong Town

Sekong Province is composed of four townships (Sekong, Tatheng, Kaleum, and Daktune) and 336 villages. The total population is 57,000, of which the population of Sekong Town is said to have been approximately 15,000 as of 1991. Sekong is a new town set up in 1985 by the Laotian Government and being aggressively developed so that it would become a model town among rural communities in four of the Southern Region provinces (P. Saravane, P. Sekong, P. Champassak, and P. Attapeu), putting a stop to slash-and-burn agriculture going on in much of the mountainlands in the southern provinces, and promoting permanent settlement of the agricultural population. The growth rate of the population is high and in recent years there has been a sharp increase in settlers.

The basis of the regional economy centered at Sekong Town will be agriculture, forestry, and livestock raising (rice and coffee cultivation, forest exploitation, livestock raising) into the future, while in addition, processing of agricultural and forestry products (rice polishing, coffee processing, lumbering, etc.) are conceivable as accessory activities.

The present state of electrification of Sekong Town is that electricity is being supplied only from 6 o'clock in the evening to around 9 o'clock with a single new diesel generator of 100 kW (of Soviet manufacture, 1985). The number of electric lamps in Sekong Town is from 600 to 1,000, and the demand in 1990 was less than 50 kW.

Besides lighting demand, there are motive power demands of sawmills, rice mills, etc. in Sekong Town. Diesel generators of 220 kW are installed at sawmills. Seven rice mills are operating as private enterprises, and it is said each has an engine of about 18 HP. Other than these, there is demand of around 50 kW for public buildings (city hall, hospitals, schools, offices, street lighting).

The classification of power demand conceivable under present circumstances are as follows:

> Lighting, sawmills, repair shops, brick factory, ice factory, telecommunication, rice mills, irrigation pumps, miscellaneous

(2) Present State of Power Demand at Attapeu Town

Attapeu Province has a total population of 78,800. Attapeu Town consists of an old town and a new town, the old town of Xaysetha having been a center of trade with Vietnam and Cambodia from ancient times. Xaysetha is located approximately 20 km east of the new Attapeu Town and has a population of 27,700 living there. The new town has a population of 18,000.

Main products of this area are rice and tea. Rice cultivation is in the form of one annual crop grown using rain water (approximately 12,500 ha), although irrigation is being done (300 ha) along the Xe Kong River downstream of Xaysetha.

This area has 2 elementary schools, 11 secondary schools, 2 high schools, 2 vocational training schools, and 3 hospitals. Other than these, 2 saw-mills, 1 rice mill, 1 ice factory, 1 repair shop, and the city hall area the major buildings.

Electrification of Atttapeu town consists of electricity supplied to approximately 800 lamps from 6 o'clock to 9 o'clock in the evening by a diesel generator of 160 kW installed at a sawmill factory. This demand for electricity was 50 kW as of 1990. Inside the compounds of the same sawmill there are two antiquated diesel generators totalling 100 kW installed as spare equipment for general lighting purposes.

Other than for lighting demand, there are private generating facilities at an automobile repair shop, the sawmills, the rice mill, the ice factory, etc. The power demand of Attapeu Town including these demands is estimated to be about 300 kW under present circumstances.

The cultivated land existing in Attapeu Province is said to amount to 14,520 ha, but centered at Attapeu Town there are about 2,000 ha of irrigable land for rice paddies available along the Xe Kong River and the Xe Kaman River.

The classification of power demand conceivable in the present situation area is as follows:

Lighting, sawmills, repair shops, water supply pumps, ice factory, telecommunication, rice mills, irrigation pumps, miscellaneous

4.3.3 Method of Forecasting Demand

For power demand forecast, in general, there are two methods, the first one is a macroscopic method which grasps the relationship of gross production of that area and the trend of increase in electric power consumption, and the second one, a microscopic technique, an analytical method in which demand is subdivided as much as possible according to requirements for households, manufacturing, commerce, etc., with power consumption estimated sector by sector to cumulatively set up the demand forecast. Both of these method cannot be applied unless there are historical trend values available.

In view of above mention, although a method equivalent to the microscopic method was applied to make the demand forecast. In this study, amount of demand of future plans to be realized was added into each existing power demand classified by individual sector. The values used for this are results of studies based on information obtained from MIH and the provincial governments upon thoroughly examining the master plan report for development of the Southern Region. The process of formulating the Third Five-Year Plan of Laos is for provincial governments to submit annual budgets sector by sector, with the Central Government making decisions on projects, and it is conceivable that uncertain items may be included in the information obtained by the Study Team. However, since stable and lower price electric power can be received as a result of completion of this Project, it is thought that industrialization plans which had been delayed would come to be promoted, and therefore, it was decided to include industrialization plans which had been proposed from the past in making the power demand forecast.

4.3.4 Power Demand Forecast

There are various matters to be dealt with in order to complete this Project, such as construction funds arrangement, setting up the construction implementation organization, and otherwise making detailed designs, etc. When these are taken into consideration, although somewhat tight as a schedule, it was assumed that 1995 would be the year possible for the First Phase to be completed, and that year was taken to be the basic year of the power demand forecast. In calculation of the demand forecast, the abovementioned method was used. Based on the information obtained in this study, similar study reports was referred carefully. Power demand forecast was studied based on the hypotheses given below.

(1) Households

Sekong	Attapeu
Approx. 1.5 times the present condition	Approx. 1.5 times the present condition plus Xaysetha
Approx. 50 kW * 1.5 ≒ approx. 80 kW	Approx. 50 kW * 1.5 + approx. 50 kW ≒approx. 130 kW

(2) Sawmill

Sekong	Attapeu
Present installed capacity (220 kW) + planned amount (220 kW) forecast	Present installed capacity (200 kW) + planned amount (200 kW) forecast

(3) Repair Shop

Sekong	Attapeu
Planned amount (100 kW) forecast	Present installed capacity (200 kW) + planned amount forecast

(4) Water Supply Pump

Sekong	Attapeu
Gravity flow type, and thus not considered	Planned amount (50 kW) forecast

(5) Small Industry

Sekong	Attapeu
Planned amount forecast (brick factory 50 kW) (ice factory 40 kW)	Planned amount forecast (ice factory 40 kW) (husk mill 130 kW)

(6) Irrigation

Sekong	Attapeu
Forecast based on information from irrigation Bureau (approx. 200 kW for 400 ha)	Forecast based on information from Irrigation Bureau (approx. 400 kW for 800 ha)

(7) Miscellaneous

Sekong	Attapeu
5% of load not considering irrigation	5% of load not considering irrigation

The results of summarizing the above are referred to and shown in Table III-4-1 and Fig. III-4-1. Regarding the time allocation for this, formulations were made referring to work hours obtained in the Southern Region in the present study. However, as previously mentioned, regarding the method of establishing the Five-Year Plan to be the basis for the forecast, since both the Attapeu and Sekong provinces submit budgets required for projects and the Central Government makes the concrete decisions, the forecasts cannot be said to be definite, but electric power for existing facilities which comprise the basis for formulation are absolutely necessary for the service area, while expansion plans for these can be expected in the future, implementation of the project would be promoted as a stable power supply can be obtained.

Regarding the daily load curve of Fig. III-4-1, there is a considerable difference from the form currently seen for the case of Pakse. This difference is assumed to be because until Pakse began to receive power from Xe Set Power Station, it had been receiving from Selabam Hydroelectric Power Station and the diesel power station of Nam Para, so that there had been a strict limitation to the supply capability. Further, because of the concentration of population for a high density, the form of daily load curve is that of a typical lighting peak.

With regard to forecasting of growth in demand, since there is no full-fledged power supply source, historical data on the demand and supply balance do not exist. Therefore, growth rate of 6% was taken as a measure referring to the average value of the most recent 10-year period in the Northern Region, and assuming an additional rapid growth rate of 2%, just after electrification, 8% was forecast as a high case. On the other hand, EDL has already estimated as 12% immediately after electrification, and subsequently, a growth rate of 7%. Since this EDL's estimation is within the range between the reference level and the high case in this study, this estimated value of EDL is adopted as the growth rate in prediction of demand for this Project. This results of this are shown in Figs. III-4-2 and III-4-3.

4.3.5 Installed Capacity of Xe Katam Hydroelectric Power Station

(1) Installed Capacity in First Phase

Based on the result of the power demand forecast, installed capacity of 2,000 kW is to be provided for the First Phase Project. In case of an independent system, since it is estimated that the inflow (95% firm discharge) at the dam site during the period of dry season, will be 1.1 m^3/s, there will be a risk that a partial shortage will occur. Consequently, in order to reliable power to service area, transmission line through Paksong-Ban Houay Kong or Xe Set-Ban Thateing-Sekong will be required.

(2) Installed Capacity in Second Phase

According to the power demand forecast, since demand will exceed supply capability in the year 2001, it will be necessary for expansion of 2,000 kW. Regarding subsequent plans, it will be appropriate for expansion of 2,000 kW as the final stage around the year 2010 as seen from the trend of demand in the service area. However, regarding final installed capacity and its schedule, it will be necessary to study in order to optimize expansion scheme. The reason of final installed capacity of 6,000 kW is described below.

4.3.6 Development Scale of Xe-Katam Project

(1) Study Condition

Main objective of this project is to electrify Se Kong and Attapeu which are not so for electrified, with stable electric power from Xe-Katam hydropower, located in the neighborhood of these towns.

From the view point of this objective, the development scale for the Project which was studied and optimized based on salable energy of these load centers. That is to say main service areas for this project are these towns, therefore salable energy was calculated from demand forecast and available energy of hydro condition.

Concepts of study condition are shown below.

- Benefit as salable energy was calculated based on demand forecast for service area: Se Kong and Attapeu.

- The period between the first stage and the second stage, and the second stage and final stage are set by demand and supply balance. To avoid too much investment, abovementioned period is set at least around 5 years.

Under these conditions, some development schemes are assumed as follows and are evaluated by economical analysis in order to select most economic scheme.

		Installed Capacity (kW)		
		As of 1995	As of 2001	As of 2011
Basic Scheme	(A)	2,000	4,000	6,000
Alternative-I	(D)	2,000	4,000	7,000
Alternative-II	(E)	2,000	4,000	8,000

From the results of demand forecast, electricity shortage will occur by 2011 and 2013 in case of final installed capacity of 4,000 kW and 5,000 kW respectively.

Therefore, these schemes are out of scope for this optimization study due to system reliability.

Additional conditions for this analysis are; investment for the first stage is zero; however, O&M cost is calculated based on required investment in the first stage; all required investment are included to capital cost for 6,000 kW scheme; larger than 6,000 kW capacity, only electro-mechanical facilities are included to capital cost due to uncertainty; therefore for 7,000 kW and 8,000 kW, investment is lower the actual capital cost; contingency is not included to capital cost; social discount rate of 10% is applied to all schemes.

(2) Results of the Analysis

Each net benefit of net present value between benefit and cost which are calculated with social discount rate, is shown below.

	Final Installed Capacity (kW)	Net Benefit (10^3 US$)	EDR
(A)	6,000	1,229	18.9%
(B)	7,000	932	17.0%
(C)	8,000	880	16.6%

EDR: Equalizing Discount Rate

The value of net benefit and EDR of (A) case are the biggest among other schemes. Therefore 6,000 kW scheme is selected as the optimum development scheme.

Fig. III-4-4 shows salable energy of which was used in economic analysis.

Table III-4-2 ~ 4 show details of calculation of economic analysis, and Table Fig III-4-5 shows demand and supply balance of 6,000 kW scheme.

In addition this results are obtained from the viewpoint of electrification for Se Kong and Attapeu as a main purpose of this project.

Therefore, provided that service area extends drastically according to power system expansion program in future, this scheme will be revised, if necessary.

Table III-4-1 Power Demand Forecast as of 1995 for Xe-Katam Hydro Power Project

Items of Power Demand	Installed Capacity (KW)	Diversity Factor (%)	Daily Hours 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24 (unit=kw)	Total (kwh)
A, Se-Kong Town																											
Households	100	80	10	10	10	20	40	60	60	30	20	10	10	20	20	10	10	20	40	80	80	80	60	40	20	10	770
Street & Public Building	20	80	16	16	16	16	16	10	10	10	10	10	10	10	10	10	10	10	16	16	16	16	16	16	16	16	318
Saw-Mills	440	30	0	0	0	0	0	0	5	61	132	132	132	132	10	61	132	132	132	61	5	0	0	0	0	0	1127
Repair Shops	100	40	0	0	0	0	0	0	5	30	60	60	60	60	10	30	60	60	60	30	5	0	0	0	0	0	530
Water Supply Pumps	0	-																									
Crush Plants	100	-																									
Coffee Process Industry	50	-																									
Bric Factory	50	70	0	0	0	0	0	0	2	18	35	35	35	35	5	18	35	35	35	18	2	0	0	0	0	0	308
Ice Factory	40	80	16	16	16	16	16	16	32	32	32	32	32	32	32	32	32	32	32	32	16	16	16	16	16	16	576
Telecommunication System	10	70	2	2	2	2	2	2	4	7	7	7	7	7	7	7	7	7	7	4	2	2	2	2	2	2	102
Husk-Mills	10	60	0	0	0	0	0	0	1	6	6	6	6	6	1	1	6	6	6	3	0	0	0	0	0	0	54
Irrigation Pumps	200	80	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	3840
Miscellaneous	40	50	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	480
Sub Total with Irrig.	1160		224	224	224	234	254	268	299	374	482	472	472	482	275	349	472	482	508	424	306	294	274	254	234	224	8105
Sub Total without Irrig.	960		64	64	64	74	94	108	139	214	322	312	312	322	115	189	312	322	348	264	146	134	114	94	74	64	4265
B, Attapu Town																											
Households	160	80	16	16	16	32	64	96	96	48	32	16	16	32	32	16	16	32	64	128	128	128	96	64	32	16	1232
Street & Public Building	40	80	32	32	32	32	32	20	20	20	20	20	20	20	20	20	20	20	32	32	32	32	32	32	32	32	636
Saw-Mills	400	30	0	0	0	0	0	0	5	55	120	120	120	120	9	55	120	120	120	55	5	0	0	0	0	0	1025
Repair Shops	200	60	0	0	0	0	0	0	10	60	120	120	120	120	20	60	120	120	120	60	10	0	0	0	0	0	1060
Water Supply Pumps	50	50	5	5	5	5	20	50	50	50	50	50	50	50	50	50	50	50	50	50	10	10	10	5	5	5	735
Crush Plants	0	-																									
Coffee Process Industry	0	-																									
Bric Factory	0	-																									
Ice Factory	40	80	16	16	16	16	16	16	32	32	32	32	32	32	32	32	32	32	32	32	16	16	16	16	16	16	576
Telecommunication System	10	70	2	2	2	2	2	2	4	7	7	7	7	7	7	7	7	7	7	4	2	2	2	2	2	2	102
Husk-Mills	130	60	0	0	0	0	0	0	13	78	78	78	78	78	13	13	78	78	78	39	0	0	0	0	0	0	702
Irrigation Pumps	400	80	320	320	320	320	320	320	320	320	320	320	320	320	320	320	320	320	320	320	320	320	320	320	320	320	7680
Miscellaneous	60	50	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	720
Sub Total with Irrig.	1490		421	421	421	437	484	534	580	700	809	793	793	809	533	603	793	809	853	750	553	538	506	469	437	421	14468
Sub Total without Irrig.	1090		101	101	101	117	164	214	260	380	489	473	473	489	213	283	473	489	533	430	233	218	186	149	117	101	6788
Total with Irrigation	2650		645	645	645	671	738	802	879	1074	1291	1265	1265	1291	808	952	1265	1291	1361	1174	859	832	780	723	671	645	22573
Total without Irrigation	2050		165	165	165	191	258	322	399	594	811	785	785	811	328	472	785	811	881	694	379	352	300	243	191	165	11053

Table III-4-2 Optimization Study of Installed Capacity (6,000 kW)

Case-1: Final installed capacity is up to 6000kW

Unit: 10^3US$

SrlNo	Year	Cost Invstmn	Cost O & M	Cost Total	Benefit Slbl Enrg (MWh)	Benefit Revenue	Net Present Value Cost	Net Present Value Benefit	Net Present Value B-C
1		635							
2		7279							
3		5941							
4	1995		201	201	7650	459	151	314	163
5	1996		201	201	8552	513	137	319	182
6	1997		201	201	9129	548	125	309	185
7	1998	281	201	482	9739	584	272	300	28
8	1999	2721	201	2921	10382	623	1499	291	-1209
9	2000	2925	201	3126	11062	664	1458	281	-1177
10	2001		287	287	11782	707	122	273	151
11	2002		287	287	12540	752	111	264	153
12	2003		287	287	13337	800	101	255	154
13	2004		287	287	14175	851	91	246	155
14	2005		287	287	15055	903	83	238	155
15	2006		287	287	15973	958	76	229	154
16	2007		287	287	16934	1016	69	221	152
17	2008	124	287	411	17940	1076	90	213	123
18	2009	554	287	841	18994	1140	166	205	39
19	2010	1930	287	2217	20099	1206	399	197	-202
20	2011		325	325	21260	1276	53	190	136
21	2012		325	325	22475	1348	48	182	134
22	2013		325	325	23746	1425	44	175	131
23	2014		325	325	25076	1505	40	168	128
24	2015		325	325	26464	1588	36	161	125
25	2016		325	325	27909	1675	33	155	122
26	2017		325	325	29358	1761	30	148	118
27	2018		325	325	30459	1828	27	139	112
28	2019		325	325	31473	1888	25	131	106
29	2020		325	325	32475	1949	23	123	100
30	2021		325	325	33459	2008	20	115	95
31	2022		325	325	34443	2067	19	108	89
32	2023		325	325	35357	2121	17	100	84
33	2024		325	325	35357	2121	15	91	76
34	2025		325	325	35357	2121	14	83	69
35	2026		325	325	35357	2121	13	75	63
36	2027		325	325	35357	2121	12	69	57
37	2028		325	325	35357	2121	11	62	52
38	2029		325	325	35357	2121	10	57	47
39	2030		325	325	35357	2121	9	52	43
40	2031		325	325	35357	2121	8	47	39
41	2032		325	325	35357	2121	7	43	35
42	2033		325	325	35357	2121	7	39	32
43	2034		325	325	35357	2121	6	35	29
Total		22388	11873	20407	976226	58574	5473	6702	1229

Table III-4-3 Optimization Study of Installed Capacity (7,000 kW)

Case-2: Final installed capacity is up to 7000kW
Unit: 10^3US$

SrlNo	Year	Cost Invstmn	Cost O & M	Cost Total	Benefit Slbl Enrg (MWh)	Benefit Revenue	Net Cost	Present Benefit	Value B-C
1		635							
2		7279							
3		5941							
4	1995		201	201	7650	459	151	314	163
5	1996		201	201	8552	513	137	319	182
6	1997		201	201	9129	548	125	309	185
7	1998	281	201	482	9739	584	272	300	28
8	1999	2721	201	2921	10382	623	1499	291	-1209
9	2000	2925	201	3126	11062	664	1458	281	-1177
10	2001		287	287	11782	707	122	273	151
11	2002		287	287	12540	752	111	264	153
12	2003		287	287	13337	800	101	255	154
13	2004		287	287	14175	851	91	246	155
14	2005		287	287	15055	903	83	238	155
15	2006		287	287	15973	958	76	229	154
16	2007		287	287	16934	1016	69	221	152
17	2008	221	287	508	17940	1076	111	213	102
18	2009	984	287	1271	18994	1140	251	205	-47
19	2010	3430	287	3718	20099	1206	669	197	-471
20	2011		352	352	21260	1276	58	190	132
21	2012		352	352	22475	1348	52	182	130
22	2013		352	352	23746	1425	48	175	127
23	2014		352	352	25076	1505	43	168	125
24	2015		352	352	26464	1588	39	161	122
25	2016		352	352	27909	1675	36	155	119
26	2017		352	352	29417	1765	32	148	116
27	2018		352	352	30992	1860	30	142	112
28	2019		352	352	32591	1955	27	136	109
29	2020		352	352	33929	2036	24	128	104
30	2021		352	352	35053	2103	22	121	98
31	2022		352	352	36159	2170	20	113	93
32	2023		352	352	37221	2233	18	106	87
33	2024		352	352	38308	2299	17	99	82
34	2025		352	352	39369	2362	15	92	77
35	2026		352	352	40308	2418	14	86	72
36	2027		352	352	41040	2462	13	80	67
37	2028		352	352	41250	2475	11	73	61
38	2029		352	352	41250	2475	10	66	56
39	2030		352	352	41250	2475	9	60	51
40	2031		352	352	41250	2475	9	55	46
41	2032		352	352	41250	2475	8	50	42
42	2033		352	352	41250	2475	7	45	38
43	2034		352	352	41250	2475	6	41	35
Total		24416	12523	23085	1043411	62605	5893	6825	932

Table III-4-4 Optimization Study of Installed Capacity (8,000 kW)

Case-3: Final installed capacity is up to 8000kW
Unit: 10^3US$

SrlNo	Year	Cost Invstmn	Cost O & M	Cost Total	Benefit Slbl Enrg (MWh)	Benefit Revenue	Net Present Value Cost	Net Present Value Benefit	Net Present Value B-C
1		635							
2		7279							
3		5941							
4	1995		201	201	7650	459	151	314	163
5	1996		201	201	8552	513	137	319	182
6	1997		201	201	9129	548	125	309	185
7	1998	281	201	482	9739	584	272	300	28
8	1999	2721	201	2921	10382	623	1499	291	-1209
9	2000	2925	201	3126	11062	664	1458	281	-1177
10	2001		287	287	11782	707	122	273	151
11	2002		287	287	12540	752	111	264	153
12	2003		287	287	13337	800	101	255	154
13	2004		287	287	14175	851	91	246	155
14	2005		287	287	15055	903	83	238	155
15	2006		287	287	15973	958	76	229	154
16	2007		287	287	16934	1016	69	221	152
17	2008	248	287	536	17940	1076	117	213	96
18	2009	1107	287	1394	18994	1140	276	205	-71
19	2010	3859	287	4146	20099	1206	746	197	-549
20	2011		363	363	21260	1276	59	190	130
21	2012		363	363	22475	1348	54	182	128
22	2013		363	363	23746	1425	49	175	126
23	2014		363	363	25076	1505	45	168	123
24	2015		363	363	26464	1588	41	161	121
25	2016		363	363	27909	1675	37	155	118
26	2017		363	363	29417	1765	33	148	115
27	2018		363	363	30992	1860	30	142	111
28	2019		363	363	32632	1958	28	136	108
29	2020		363	363	34339	2060	25	130	105
30	2021		363	363	36070	2164	23	124	101
31	2022		363	363	37502	2250	21	117	96
32	2023		363	363	38712	2323	19	110	91
33	2024		363	363	39906	2394	17	103	86
34	2025		363	363	41055	2463	16	96	81
35	2026		363	363	42226	2534	14	90	76
36	2027		363	363	43369	2602	13	84	71
37	2028		363	363	44384	2663	12	78	67
38	2029		363	363	45172	2710	11	72	62
39	2030		363	363	45817	2749	10	67	57
40	2031		363	363	46346	2781	9	61	53
41	2032		363	363	46543	2793	8	56	48
42	2033		363	363	46543	2793	7	51	44
43	2034		363	363	46543	2793	7	46	40
Total		24996	12780	23921	1087842	65270	6018	6898	880

Fig. III-4-1 Daily Load Curve

(as of 1995)

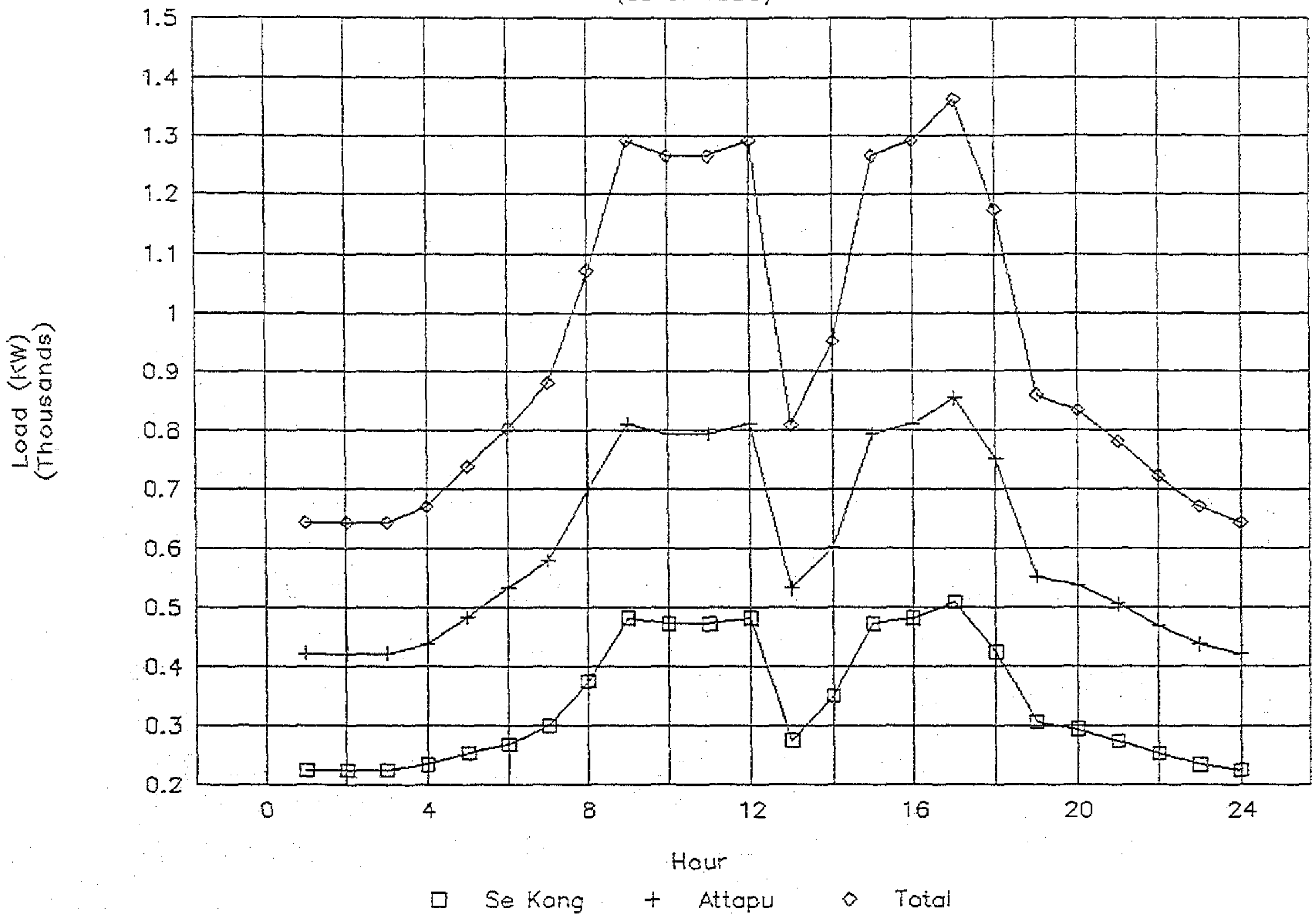


Fig. III-4-2 Electricity Demand Forecast

(From 1995 to 2034)

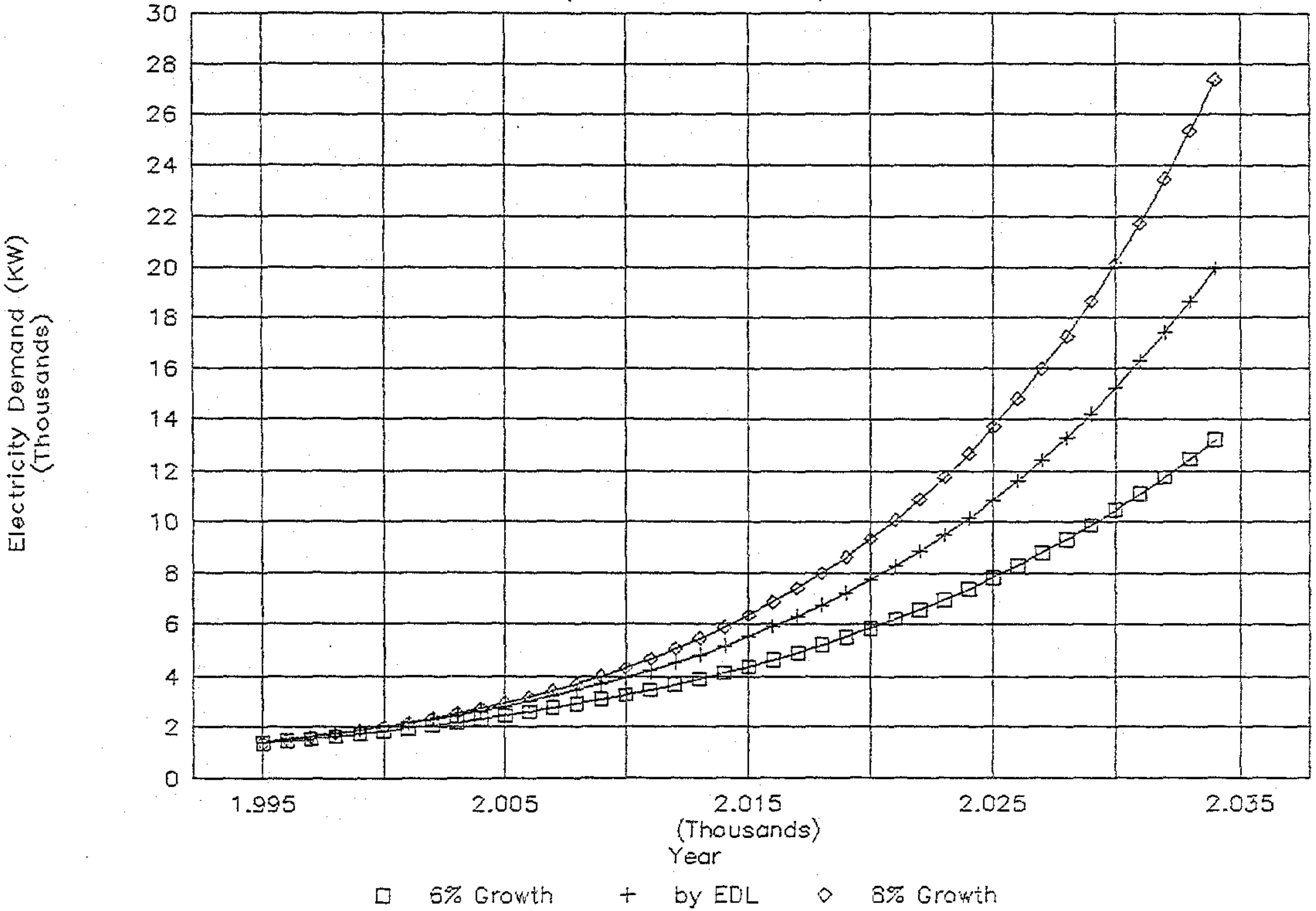


Fig. III-4-3 Annual Energy Demand Forecast

(From 1995 to 2034)

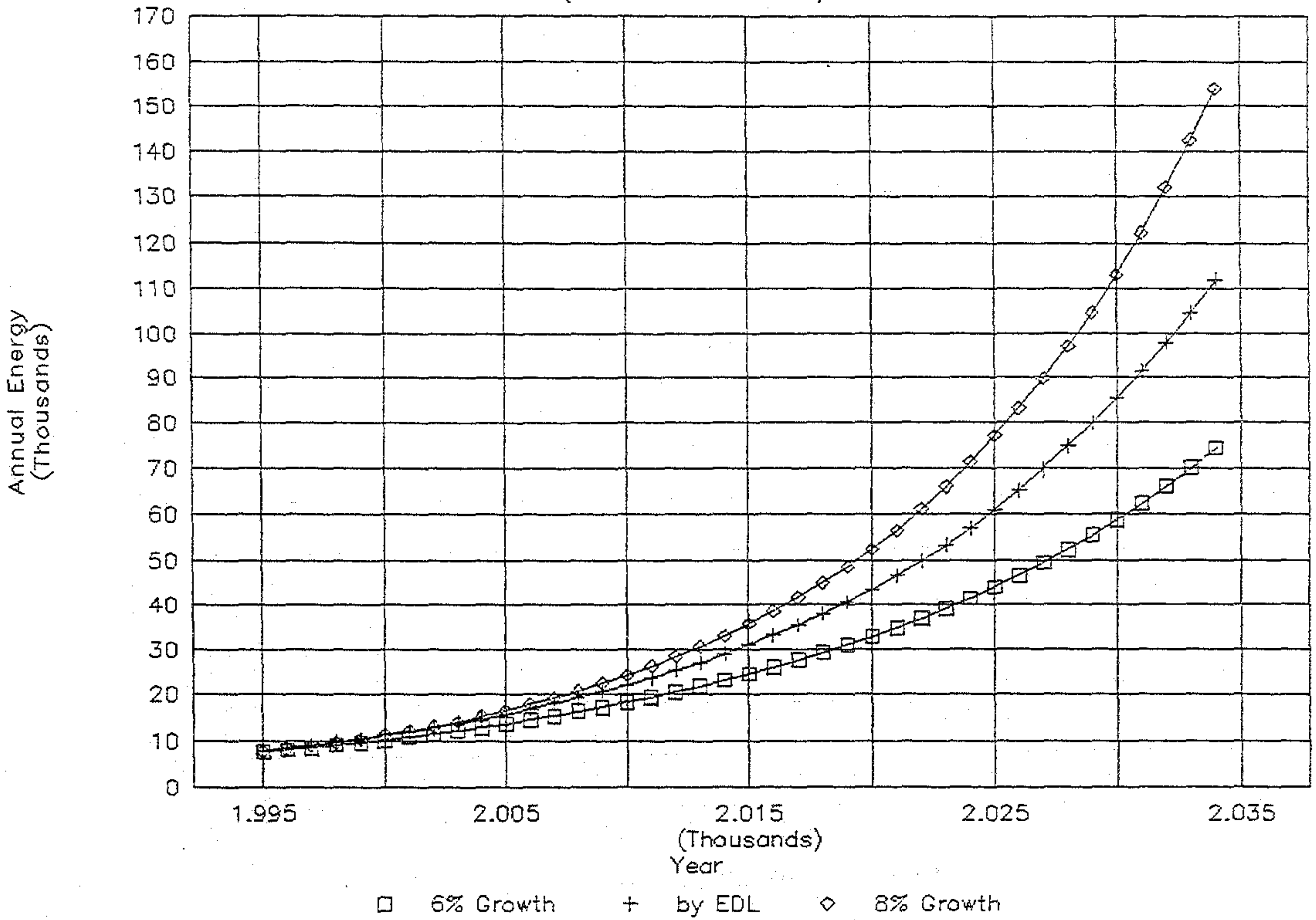


Fig. III-4-4 Salable Energy by Installed Capacity

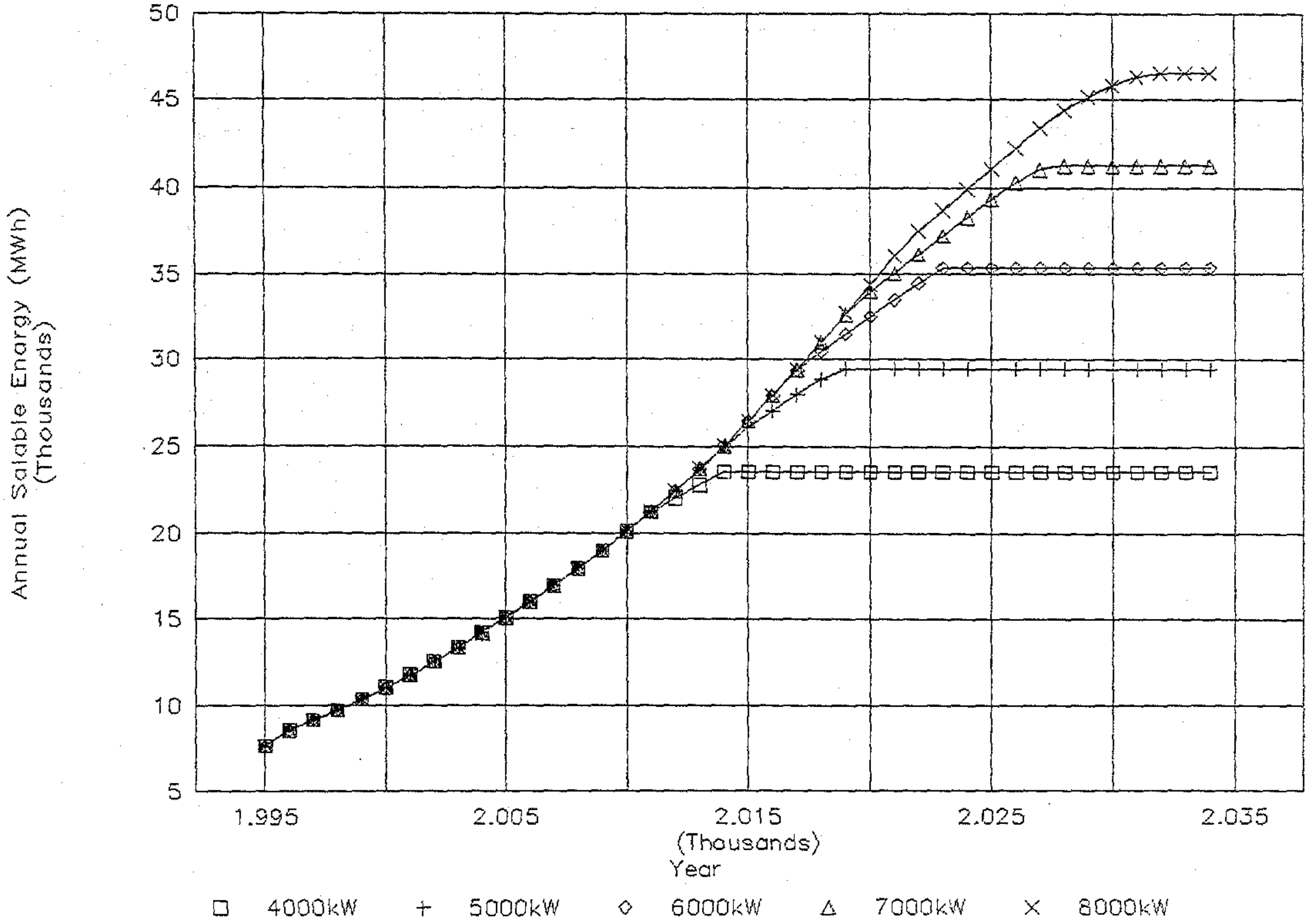
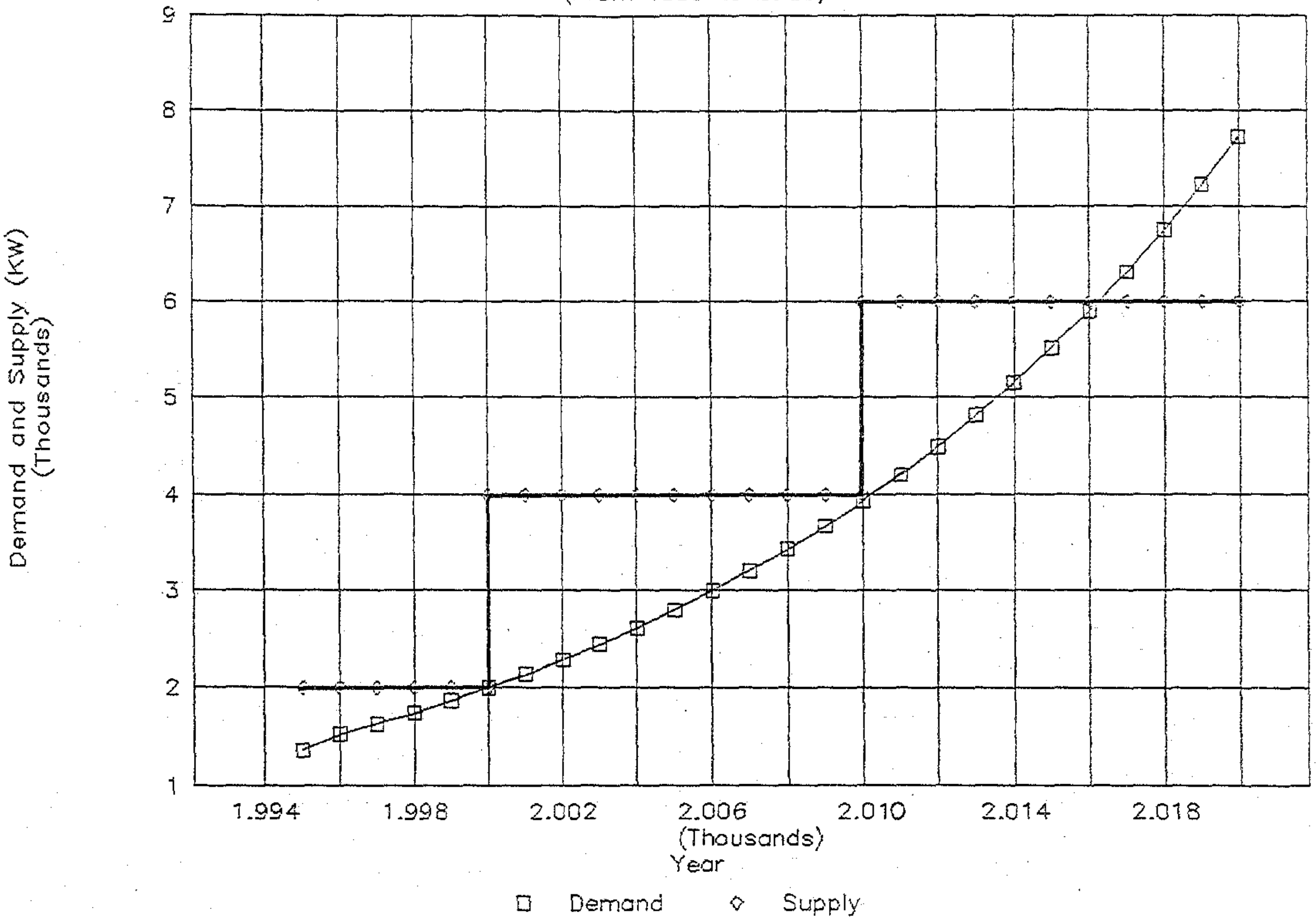


Fig. III-4-5 Projected Power Balance

(From 1995 to 2020)



5. Power Transmission Plan

Chapter III 5. Power Transmission Plan

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5. Power Transmission Plan

5.1 Present State of Existing 22-kV Transmission Lines

The six provinces in the southern part of Laos (Khammouan, Savannakhet, Saravane, Champassak, Sekong, and Attapeu) comprise a region making up 35% of the national territory, which has 40% of the population and produces 47% of the rice. Of these six provinces, those at the western side are adjacent to Thailand with the Mekong River in between, and have close relationships with that country, whereas the eastern side adjacent to Vietnam is a mountainous area with the greater part covered by virgin forests.

The Second World Bank (IDA: International Development Association) started on the electrification plan for the southern provinces in 1987, and the first phase is to be completed by the end of 1992.

The Xe Katam Small Hydro-electric Power Development Project is for the purpose of supplementing the above electrification plan, and when this Project has been completed, electricity from hydroelectric power generation will be transmitted to the capitals of Sekong and Attapeu provinces.

With completion of Xe Set Hydro-electric Power Station (45 MW) in July 1991, the principal communities of Saravane and Champassak out of the remaining four southern provinces will be supplied, while construction of 22-kV transmission lines is scheduled to be completed in 1992.

In the second phase of the electrification plan by IDA (planned years initially 1992-1996), the electrified area is to be further expanded with areas electrified in the first phase as bases. The transmission lines will consist of 22-kV lines from Pakse Substation (main transformers 115 kV/22 kV, 8,000 kVA x 2 units) constructed as the receiving substation of Xe Set Hydro-electric Power Station, with service areas electrified through supply by these transmission lines. However, as a result of reviewing the concept of this electrification plan, the power supply to be made to the electrification plan will be from the switchyard of Xe Set for the Saravane area and from Bangyo Substation of Pakse for the Champassak area. The capacity of the 22-kV circuit of the latter Bangyo Substation is to be 1,600 kVA, but as a result of examining the report of SPE-II, it is considered that this capacity will become inadequate by the year 2013. that is, along with the necessity to increase supply capability by that time, to supply this large area with a 22-kV transmission line cannot be said to be advantageous when the increase in load is considered, and it is judged desirable for a higher voltage, for example, 66-kV or continuation of 115-kV transmission to be aimed for.

Meanwhile, the output of Xe Katam Power Station was selected to be 6,000 kW from studies of the optimum value based on energy sales taking into consideration the service area.

The plan for supplying this 6,000 kW of electric power corresponds to an installed capacity based on the demand predicted for Sekong and Attapeu, the service areas, and loads up to the year 2013 can be dealt with, that year being the time for a fundamental review of the electrification plan for the Southern Region. This period up to 2013 was considered to be the initial supply limit of this Project, and the installed capacities for supply to Sekong and Attapeu were set as 2,000 kW and 3,000 kW, respectively. Further, in 2017, the load for the two areas together will exceed 6,000 kW, and interchange of electric power from other regions or development of promising hydro sites in the vicinity will be absolutely necessary.

In view of this, there is a necessity for the electric power system of the southern provinces including Sekong and Appapeu to be fundamentally strengthened with 2013 as the target year. As a part of this consolidation program, it is necessary for the facilities of Xe Katam to be utilized to the maximum limit, and for a connection to be made to a full-fledged power system by the year 2013 at the latest in order to secure a stable power supply for Sekong and Attapeu. Further, to secure a stable power supply for the service area of Xe Katam, it is necessary for a 22-kV transmission line to be extended to Sekong via Paksong-Ban Houay Kong or Saravane-Ban beng-Thateng-Laman at an early time insofar as practicable.

5.2 Xe Katam Project and Power Transmission Plan

5.2.1 Scope of Power Transmission and Transformation Facilities

From the powerhouse located at the left bank of the Xe Namnoy river immediately upstream of the confluence of the Xe Namnoy and the Xe Katam River, a 22-kV transmission line, single circuit, length 50 km to Sekong Twon, a 22-kV transmission line, single circuit, length 73 km to Attapeu Town, and distribution transformers (including low-voltage cubicles) are to be constructed.

The 20 km from the powerhouse to Route No. 16 is to have two circuits strung on concrete poles.

The principal specifications of power transmission and transformation facilities are given in Table III-5-1.

Table III-5-1 Principal Specifications of Power Transmission and Transformation Facilities

	To Sekong	To Attapeu
22-kV Transmission Line		
Conductor	55 mm^2 HAL	150 mm^2 HAL
Support	Concrete pole	Concrete pole
Insulator	Pin or L.P. insulator	Pin or L.P. insulator
Length	50 km	73 km
22-kV Transformation facilities		
Transformer	3 ph., 50 kVA (OA type)	3 ph., 50 kVA (OA type)
Low-voltage cubicle	Electro magnetic switching equipment, others	Electro magnetic switching equipment, others
Number (Units)	15	15

The scope of this Project is shown in Fig. III-5-2. As for low-voltage distribution lines, because there are existing distribution lines in the cities, and assuming that for the distribution networks which will be expanded in the future, the Laotian side would perform the construction, these are excluded from the scope of the present project.

5.2.2 Selection of Transmission line Routes

(1) Selection of Transmission Line Routes

In selection of the transmission line routes, harmony with the natural and social environments of the areas through which the routes pass were aimed for, with moreover, consideration given to technical feasibility.

In concrete terms, attention was given to the items indicated below.

a) That harmony is achieved with the natural environment.

- Natural scenery such as or nature parks and scenic spots are not to be impaired.
- Habitats of rare animals and plants are to be avoided.
- There is little cutting of natural forests and afforestation areas.

b) That harmony is achieved with the social environment.

- Houses and public facilities are to be avoided.
- Cultural properties and historical sites are to be avoided.
- Land of high productivity and land difficult to restore are to be avoided.
- Conformity is to be achieved with regional development concepts.

c) That harmony is achieved engineering-wise.

- Safety of facilities is of high degree.
- Construction cost is economical.
- Execution of work is easy.
- Work can be completed within the prescribed construction period.
- Maintenance is easy to perform.

These items were given consideration, and while contemplating the measures to be taken in the aspects of design and construction, harmony with the administrative agencies of Laos and with the local communities was sought, and as a result of making a survey concerning the present states of natural and social environments of the routes to be travelled by the transmission lines, the transmission lines were selected to be as shown in Fig. III-5-3.

The transmission lines are to start out from the site of the new powerhouse, run east-northeast next to a road to be constructed along the Xe Namnoy River and reach the existing arterial road connecting Sekong and Attapeu.

The approximately 20 km of this section (the road being scheduled to be completed before construction of the powerhouse) is presently a jungle area, and even though the transmission line were to be constructed adjacent to the new road, although there would be no trouble with the transmission line right-of-way at the beginning, trees would grow in the future, and it can easily be imagined that electrical faults will occur frequently with the trees closing in and contacting conductors. Accordingly, it is though necessary for measures to be taken to prevent electrical faults such as to use insulated conductors in this section.

The transmission lines will separate going in two different directions from the junction of the existing arterial road connecting Sekong and Attapeu and the newly-constructed road (one going north to Sekong, and the other going south toward Attapeu).

Both of these transmission lines will be constructed along the arterial road.

The distance from the junction of the roads to the load area of Sekong will be approximately 30 km.

This section is also a hill area, and although differences in height do not exist, there are rivers and streams scattered along the transmission line route. Small streams are no problem, but for two locations where spans are expected to be close to 100 m (river crossings at vicinity of entrance to Attapeu, and midway from road junction to Attapeu), it is considered necessary to adapt materials capable of withstanding use in long spans when designing in relation to conductors and supports.

Although it is conceivable to make connections from the powerhouse construction site to the individual load areas by straight lines to shorten lengths of transmission lines and hold down costs of major materials and equipment such as conductors, supports, and insulators to the minimum limit, in such case, the transmission line routes would pass through the midst of jungle areas for a considerable degree of difficulty in executing construction, while the amount of natural forests cut down would become enormous, and compared on the basis of overall construction cost, to build transmission lines along existing arterial roads is judged to be more economical. And, when maintenance of transmission lines is considered, the conclusion reached as a matter of course would be for transmission lines to run along arterial roads.

The total length of the transmission lines is to be 123 km. On the whole, the transmission lines would pass through hill areas which do not have much relief, and it is judged there will be difficulty seen from the aspects of both construction and maintenance.

5.2.3 Preliminary Design of Transmission Line

The transmission lines in this Project must possess both the electrical performance as the transportation way for electric power generated at Xe Katam Small Hydro-electric Power Station and the mechanical performance to withstand natural conditions, and transport the power generated efficiently, surely and safely, and moreover, economically. furthermore, although these transmission lines are to be constructed under the predication that it will be an independent system, it is necessary to consider interconnection with existing 22-kV transmission lines in the future.

Preliminary design of the transmission lines of this Project will be carried out with the various preconditions above, but regarding supports (concrete poles), conductor types, insulators, standard spans, etc., the performances in existing transmission lines will be respected and the specifications of these will be followed basically.

(1) Transmission voltage

When the installed capacity and transmission, distance of Xe Katam Small Hydro-electric Power Station are considered, the transmission voltages conceivable are the following:

Alternative	Voltage (V)	Max. System Voltage (V)	Construction Cost Comparison
A	11,000	11,500	2.5
B	22,000	23,000	1.0
C	33,000	34,000	1.4

With the three alternatives above, and with power transmission to Sekong and Attapeu 2,000 kW and 3,000 kW, if a study were to be made predicted on voltage drop to be maintained within 10%, 22,000 V would be the most desirable transmission voltage from the point of view of construction cost.

(2) Conductor

Regarding the conductor type and conductor size, the conductor below was selected based on the transmission power and allowable limit of voltage drop mentioned in (1) above, and the mechanical and electrical characteristics are as follows:

Table III-5-2 Characteristics of Conductors

Conductor Type	Cross-sectional Area	Tensile Load	Resistance	Allowable Current
HAL	55 mm^2 150 mm^2	838 kg 2,270 kg	0.507 Ω/km 0.188 Ω/km	228A at 90°C 431A at 90°C
ACSR	58 mm^2 160 mm^2	1,990 kg 6,980 kg	0.497 Ω/km 0.182 Ω/km	236A at 90°C 454A at 90°C
THCu	22 mm^2 55 mm^2	889 kg 2,200 kg	0.826 Ω/km 0.323 Ω/km	235A at 150°C 437A at 150°C

With regard to mechanical characteristics, steel-core aluminum strand conductor is best with it being possible for the standard span of 60 m to be widened to 70 m, but as a result of comparing construction costs, it was concluded that hard aluminum strand (HAL) would be the most economical.

Table III-5-3 Comparisons of Construction Costs According to Conductor Type

Conductor Type	Conductor Diameter	Standard Span	Construction Cost Comparison
HAL (150 mm^2)	16.0 mm	60 m	1.0
ACSR (160 mm^2)	18.2 mm	70 m	1.2
THCu (55 mm^2)	9.6 mm	60 m	1.3

Even though parts of the transmission line routes to the load centers of Sekong and Attapeu are to be along roads, they will still be in close proximity to virgin forests consisting of tall trees.

Therefore, it may be considered that these trees and aerial conductors will come in contact after construction, which will cause grounding faults of the transmission line, and this will result in a great decline in the reliability of supply to consumers.

The most effective measure for avoiding such power outage trouble is to use covered aerial conductors (vinyl-insulated or polyethylene-insulated conductor) in place of bare aerial conductors, by which it will be possible to resolve the problem. The sections where this covered conductor would be used would be parts of the 20 km from Xe Katam Hydro-electric Power Station at the Xe namnoy River to the junction with Route No. 16 which are adjacent to virgin forest. Regarding the sections where covered conductors are to be used, they are to be decided at the stage of definite study as there will be relationships with road widths along the transmission line and underbrush cutting widths.

(3) Supports

Concrete poles being produced in Laos are to be used in this Project. The concrete poles have square cross sections and come in lengths of 12 m and 8 m. Poles of 8 m are to be used along roads of straight-line portions of this Project, while 12-m poles are to be used at places such as locations of road intersections.

The 12-m concrete poles have 16 piano wires of 5 mm diameter in each, and may be judged to have the necessary mechanical strength, that is, ample strength against ending moment (allowable bending moment of concrete pole about 350 kg) against horizontal wind pressure load. Further, in deciding the span between concrete poles, it was assumed that the height of conductor above ground at road intersections is to be a minimum of 8 m, while the height above ground at other parts of the route is to be maintained at 5.5 m.

(4) Aerial Grounding Wire

The IKL (isokeraunic level) of the project area is not clearly known, but the JICA Study Team did experience thunderstorms during the rainy season.

For an aerial grounding wire, it is necessary to determine the appropriate application sections according to the situation in the region upon overall consideration of the degree of importance, frequency of strikes on transmission lines, etc. The JICA Study Team, with the actual state of the existing 22-kV transmission line in the vicinity of Pakse as reference, decided that the aerial grounding wire would be strung at the 20-km section from Xe Katam Hydroelectric Power Station to the confluence of the Xe Namnoy River and the Xe Kong River.

It was decided that galvanized steel stranded wire (GSW) would be used for the aerial grounding wire, the spacing from 22-kV aerial conductors to be approximately 1 m, one line being strung with the shielding angle approximately 45 deg.

(5) Insulator

Pin insulators or L.P. insulators for 22 kV in strings of three are to be provided at concrete poles located in straight-line portions of the transmission line on arms attached horizontally to the concrete poles.

At dead-end concrete poles, three suspension insulators of 10-inch diameter are to be provided per phase. In effect, a total of 18 insulators would be provided at strain concrete poles.

(6) Receiving Transformer (22,000 V/300-301 V, 50 kVA Tr)

Receiving transformers at Sekong Town and Attapeu Town totalling 50 kVA x 30 units are to be installed with two concrete poles erected by the roadside in H-shape and the transformers placed at the tops of the H-shapes, waterproof low-voltage cubicle boards being located underneath. Inside the low-voltage cubic boards there will be 3-phase electromagnetic contactors and single-phase electromagnetic contactors to make possible power distribution by 3-phase, 4-line systems to supply to low-voltage consumers.

On the 22-kV aerial conductor side, 22-kV power fuses and 22-kW valve resister type lightening arrestors are to be provided for protection of the transformers.

5.2.4 Procurement of Transmission Line Materials and Equipment

Of the transmission line materials and equipment required to this Project, the only materials that can be procured in Laos are concrete poles for power transmission. Factories in Laos capable of producing concrete poles at present are only the ones scattered at the three places of Vietiane, Savannakhet, and Pakse. These plants are being operated as subsidiaries of EDL.

The concrete plant at Pakse started operation in 1990 and the production capacity is as follows:

12-m concrete pole	16 pc/day
8-m concrete pole	24 pc/day

Note: (1) Shipment after 45 days of curing in water.
(2) Cement used is of Vietnamese or Thai manufacture.
(3) Piano wire used in concrete pole is of Indian manufacture.

The total number of concrete poles used for this Project will be about 2,100, so that there will be no problem in particular about procurement from Pakse Concrete Pole Plant.

5.2.5 Method of Executing Transmission Line Work

At Pakse, there is only one contractor capable of performing construction work on a 22-kV aerial transmission line.

When transporting concrete poles by truck, 14 poles can be hauled per truck in case of 12-m products, and with the present condition of roads from Pakse to the transmission line construction sites, it is thought one day would be required to Sekong and two days to Attapeu, but seen from the scale of the plant, there will be no special problem concerning transportation.

In case of concrete poles, erection can not be done manually and mechanical power will be necessary, but the contractor owns three pole erection trucks, and seen from this aspect, it is thought there will be no problem about construction capability.

This contractor also has 55 men capable of engaging in pole erection and line stringing in transmission line construction, and seen from the scale of the Project, it is thought the construction capability will be adequate.

5.3 Specifications of Principal Facilities of Transmission Line

As a result of examinations based on the power transmission plan described in 5.2, the specifications of the principal facilities of the transmission lines in this Project are as given below.

Table III-5-4 Specifications of Principal Facilities of Transmission Line

	To Sekong	To Attapeu
Transmission Line		
Voltage (kV)	22	22
Number of circuits	1	1
Length (km)	50	73
Conductor type	HAL 55 mm^2	HAL 150 mm^2
Support	Concrete pole	Concrete pole
Transmission capacity (kW)	2,000	3,000
Voltage drop (%)	7.8	10.3
Construction period	12 mo	15 mo
Transformation Facilities		
Voltage (V)	22,000/400-231	22,000/400-231
Transformer (kVA x units)	50 x 15	50 x 15
Low-voltage distribution cubicles (units)	15	15

Fig. III-5-1 Present Situation of Related Power Systems

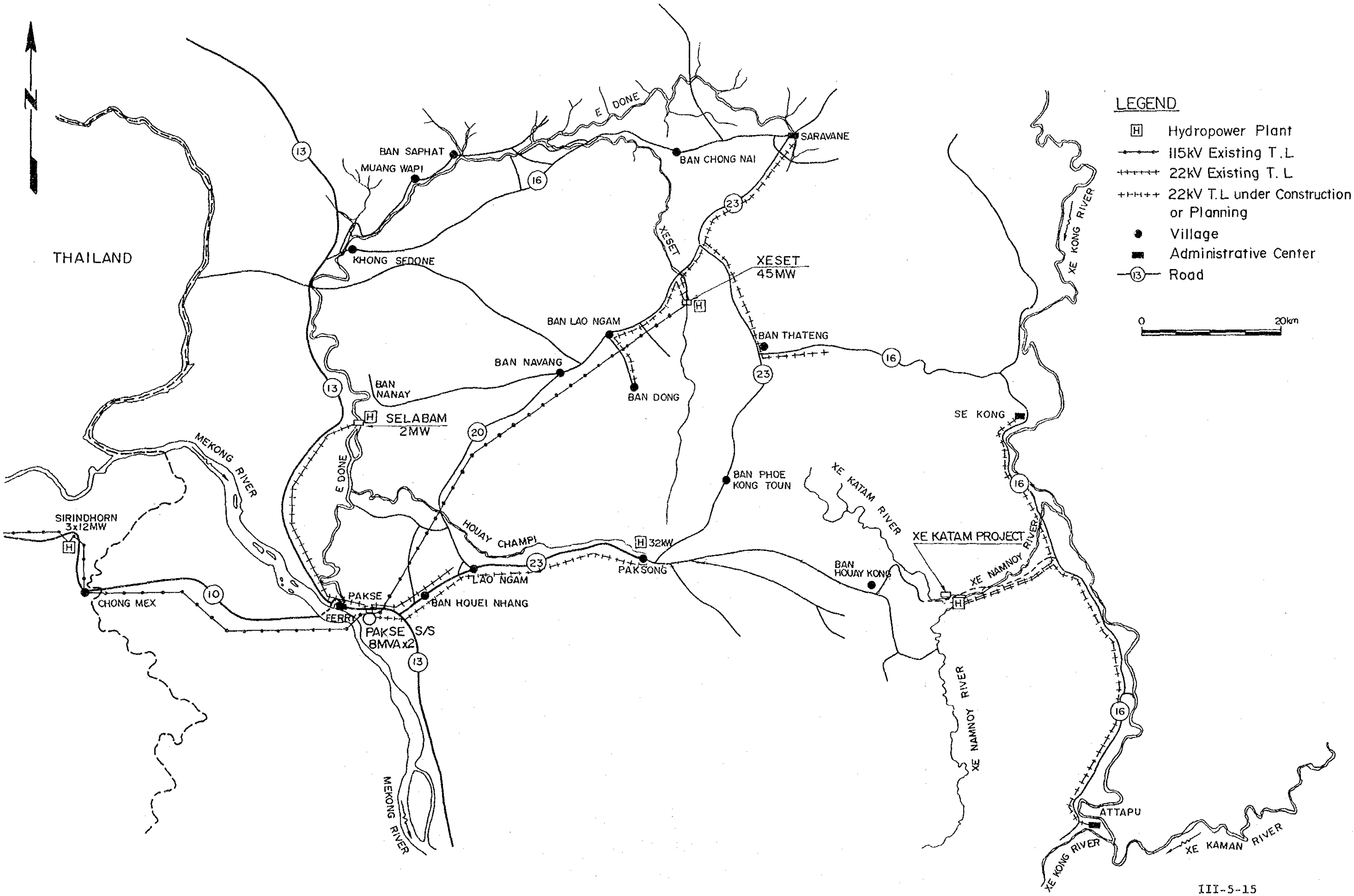

Fig. Ⅲ-5-2 Xe Katam Small-hydropower Project

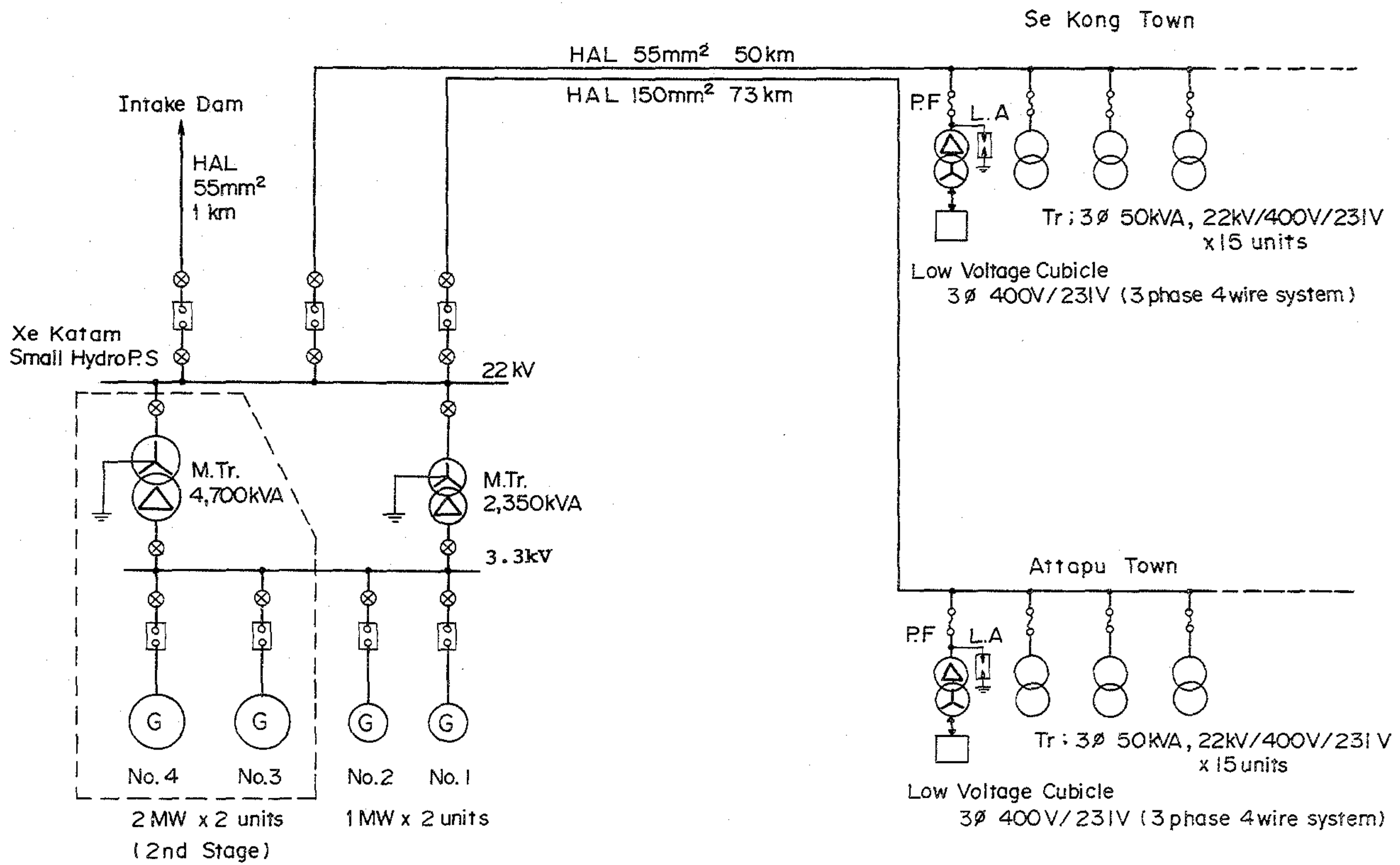

Fig. III-5-3 TRANSMISSION LINE ROUTE

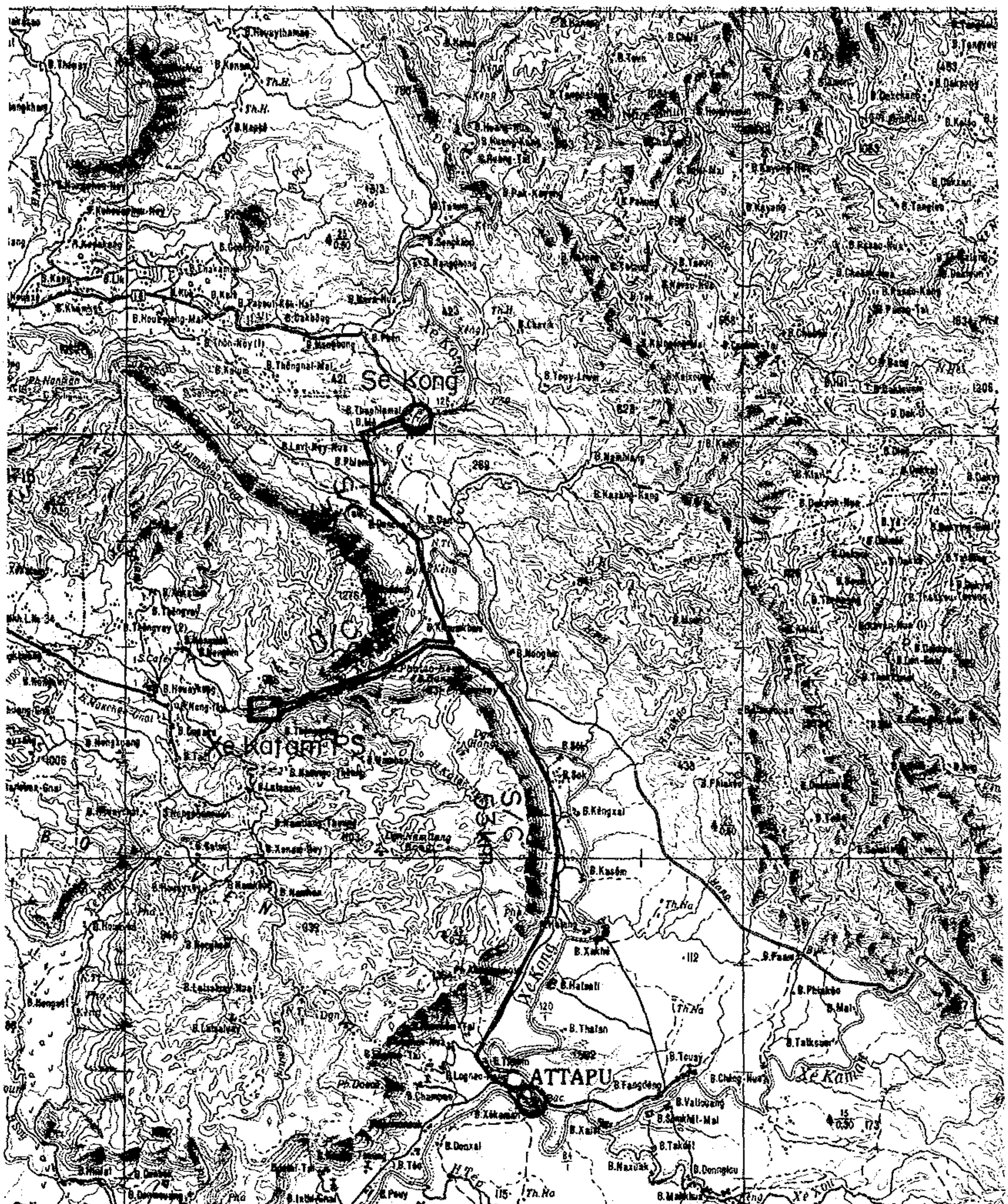

Fig. Ⅲ-5-4 22kV Transmission Line

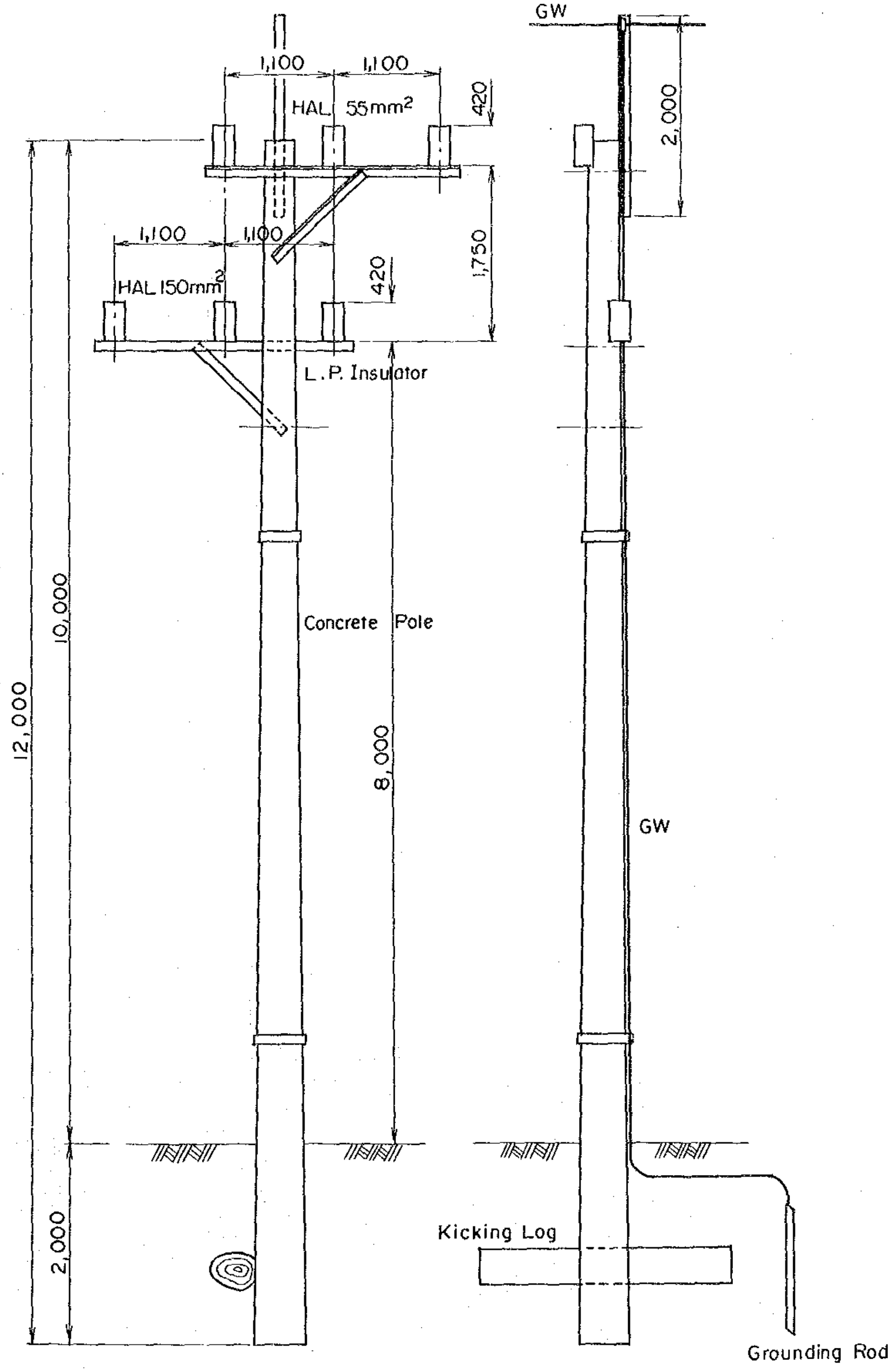

Fig. III-5-5 22kV Transmission Line