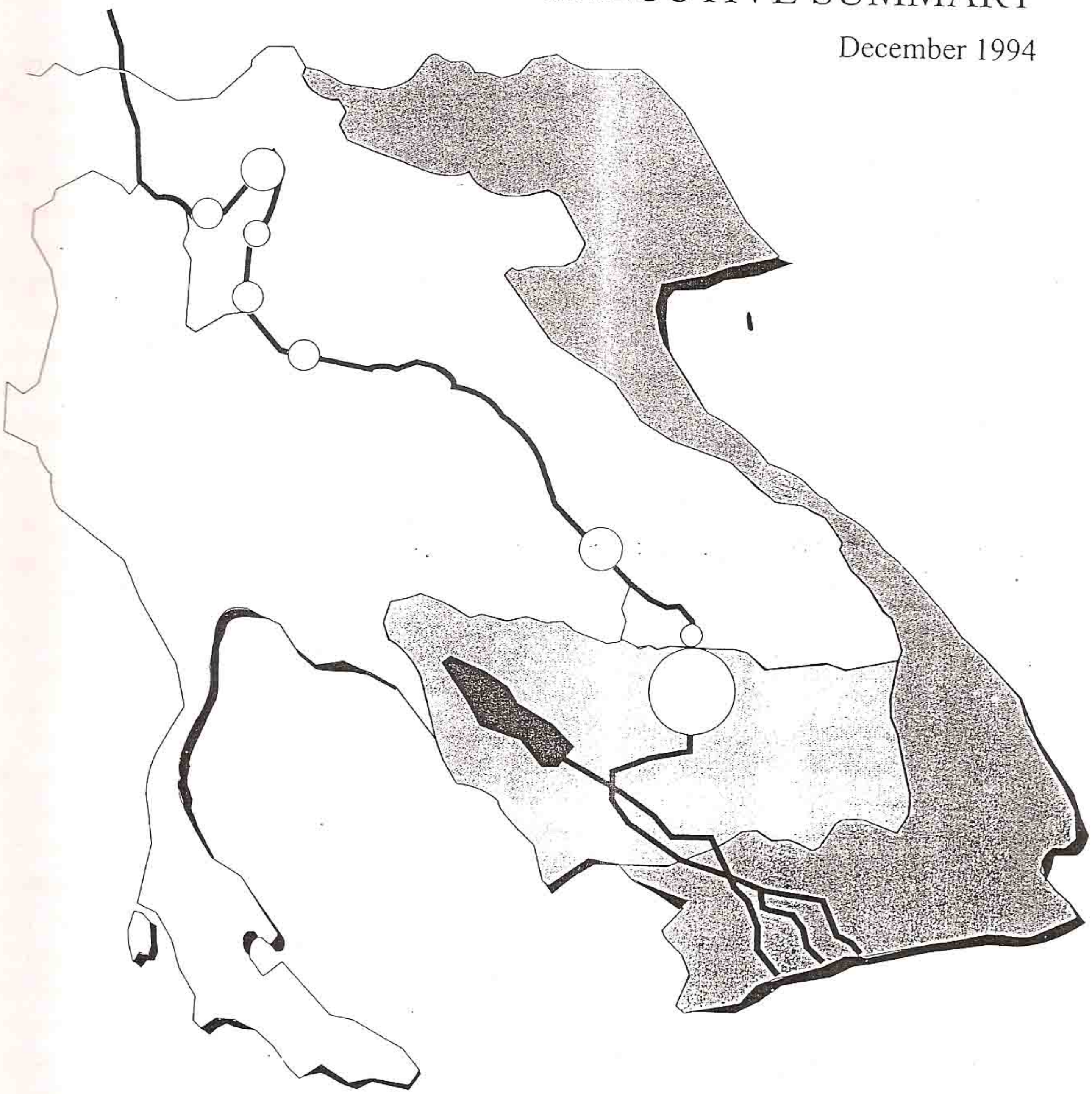
MEKONG SECRETARIAT

MEKONG MAINSTREAM RUN-OF-RIVER HYDROPOWER

EXECUTIVE SUMMARY

December 1994



Compagnie Nationale du Rhône, Lyon, France
in cooperation with

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MEKONG MAINSTREAM RUN-OF-RIVER HYDROPOWER

EXECUTIVE SUMMARY

INTRODUCTION

STUDY CONCEPT

The Lower Mekong River is a large potential source of energy which has been examined in numerous studies. Past studies have concentrated on possible development of projects which would create large storage reservoirs. The merits of the reservoirs are that the natural variations in river flow could be tempered somewhat, leading to an increase in the dry season water supply and some degree of reduction in the wet season flows. The largest projects were even considered to possibly have a flood control function. One of the costs of creation of a storage reservoir is its physical impact and consequent social and environmental effects. Large reservoirs inundate large areas and would displace large numbers of people. Past studies have shown that economic optimization of possible projects on the Lower Mekong River almost always leads to consideration of large reservoirs with a commensurate scale of impacts. Increasingly it has come to be recognized that such large social and environmental effects are unacceptable, no matter how great the economic rewards would be, and that definition of constraints rather than economic optimization must establish the maximum size of projects.

Some rivers have been developed for power and navigation, yielding great regional benefits, without constructing storage reservoirs. A hydroelectric project which does not have a reservoir to regulate the river flow must operate using the day to day water flows naturally available. Such projects are referred to as "run-of-river" projects.

The Run-of-River Study was carried out in accordance with a project proposal approved by the Mekong Committee in 1991 and included in the Work Program of 1992 and 1993. The study was financed by the United Nations Development Program and the Government of France. The study was undertaken to determine to what extent viable hydroelectric power developments might be considered on the Lower Mekong River if the scale of development is deliberately constrained to avoid or to minimize impacts. It was expected that in some circumstances projects without reservoirs for regulation of streamflows would be economic. The objective of the study was to make an inventory of suitable projects which will avoid, to the maximum extent that seems practical, environmental impacts, relocation of communities and disturbance of valuable agricultural and other resources.

SCOPE OF THE STUDY

The study was based on existing information from ongoing data collection, mapping and resource inventory activities of the Mekong Secretariat, and included a review of previous studies and project reports. The work was undertaken in three main parts:

- Identification of candidate projects;
- Development and screening of candidate projects; and
- Refinement and evaluation of candidate projects.

leading to:

- Ranking of projects; and
- Recommended priorities for follow-up.

Figure S-1 is a flow chart of the main activities undertaken in the study.

The study was undertaken by consultants working closely with riparian staff from each of the four Mekong Committee countries and technical units of the Mekong Secretariat. The work program also included training for the riparian staff.

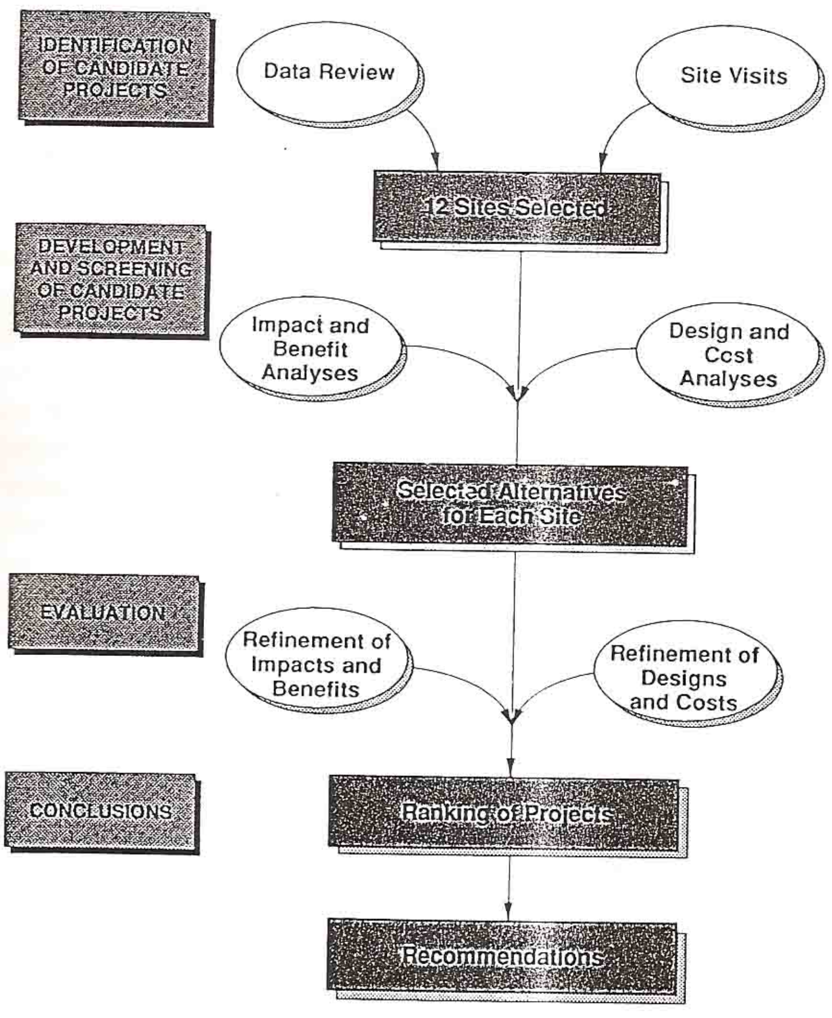

Figure S-1 STUDY FLOW CHART

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THE NEED FOR ELECTRICAL ENERGY

Electricity requirements in the region are increasing rapidly. It has been predicted that 12,000 MW of new generation will be needed between now and year 2003. No matter what hydroelectric projects are built, they can supply only part of the requirements. For the purposes of the study, it has been assumed that all projects except the Tonle Sap project would be connected to the Thai system. Based on the estimated avoided costs in the Thai system, the energy production from the projects was valued at $0.054/kWh for reliable generation and $ 0.020/kWh for secondary generation. The resulting weighted overall values of electricity for benefit estimates varied from $0.035/kWh to $0.050/kWh depending on the amount of reliable generation expected. The Tonle Sap project was assumed to be connected to Phnom Penh and have a value of $0.075/kWh.

SITE SELECTION AND SCREENING

The length of the Lower Mekong River between Chiang Khong and Phnom Penh was reviewed for sites which might be favorable for development of run-of-river hydroelectric projects. A number of populated areas and areas of historic, scenic or environmental importance were recognized as constraints and twelve locations were chosen as possible sites. The sites were identified by river location (km from the sea) and by names associated with the general areas where projects were studied in the past. Several of the actual site locations chosen are quite different from those of their namesakes, in some cases they are separated by as much as 50 km.

Figure S-2 indicates the locations of the candidate projects.

Preliminary design concepts were developed for ten of the sites. At each site, two or three alternative operating pond levels and three sizes of power installation were considered. Two other sites, one at Don Sahong in the Khone Falls area and another at Tonle Sap, were considered for evaluation without preliminary screening. Seventy screening cases were defined.

The ten sites had the same basic design concept to create a low step in the river where electricity could be generated. Each would have a gated spillway, one or two power houses and a navigation lock arranged in line across the river.

At Don Sahong in the Khone Falls area, a power house/barrage would be placed in one river branch of the 7 km wide water falls. The project would not raise river levels outside of that branch and the falls would act as a natural spillway.

At Tonle Sap, the project would add a powerhouse to a water conservation project considered for agricultural purposes. Only a simple power generating facility has been considered.

Categories of social impact were defined. Preliminary estimates of the numbers of people who would be displaced were used to classify the social impacts into five categories of between less that 3,000 persons to more than 30,000.

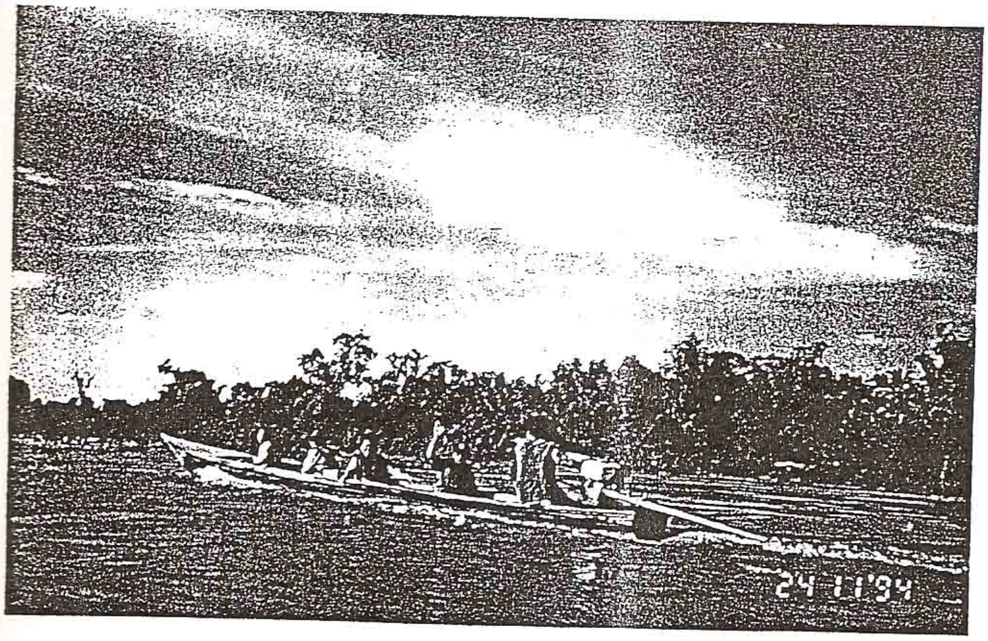
Categories of economic performance were also defined. The economic attractiveness represented by the estimated project internal rate of return and the present value of net benefits, was used to classify the projects in five categories of economic merit.

Considering the classifications on both scales, alternatives were ranked in terms of their relative priority for follow-up study in the evaluation phase. Based on the screening the following projects sites, their operating pond levels and ranges of installed generating capacities were selected for further evaluation.

Run-of-River Hydroelectric Sites Selected for Evaluation

Site	Operating Level (m)	Number of Units	Approximate Capacity (MW)
Pak Beng km 2188	345	6 to 12	1,000 t o 1,800
Luang Prabang km 2036	320	10 to 20	1,300 to 2,600
Sayaburi km 1930	270	6 to 10	600 to 1,200
Pak Lay km 1818	250	10 to 14	1,200 to 2,000
Chiang Khan km 1772	230	6 to 10	500 to 1,000
Pa Mong Upper Site km 1651	207.5	10 to 20	1,300 to 2,600
Ban Koum km 927.6	120	16 to 24	2,000 to 3,500
Don Sahong km 719	70-72	determined later	
Stung Treng km 670	55	10 to 20	
Sambor km 560	40	20 to 36	2,500 to 4,000
Tonle Sap km 362TS	10	determined later	

The following site was included in the tables of results for reference:
Low Pa Mong km 1610 207.5 14 2,850 (Original Site as studied in 1992)



Observation of Don Sahong project's intake channel

REFINEMENT AND EVALUATION

ENVIRONMENTAL AND ENGINEERING CONSIDERATIONS

Preliminary designs were refined and data on expected socioeconomic, environmental and fisheries impacts were tabulated for these candidate projects based on results of review and data collection reports carried out in support of this study. In most cases, three alternative sizes of power installations were considered. The designs were guided by requirements to:

- minimize the impacts on upstream and downstream communities;
- minimize the physical changes in the natural river regime;
- provide facilities which can be operated economically and with safety in harmony with other activities along the river;
- comply with modern standards of safety;
- provide lock facilities for passage of river boats and barges past the barrage to meet present day requirements and to facilitate improvement of river navigation in the future and provide highway bridge facilities across the river;
- provide appropriate facilities to assist in the passage of fish past the barrage;
- provide facilities for conveyance of sediments past the barrage so that the natural sediment regime of the river can be maintained and so that the power facilities installed are not harmed by the natural transport of sediments; and
- provide practical and efficient facilities for generation of electricity taking advantage of the favorable experience in Europe and North America in the construction and operation of low head run-of-river projects.

The costs of the candidate projects were estimated based on preliminary design layouts for the required civil works and on experience costs for mechanical and electrical equipment.

RESULTS OF EVALUATION OF CANDIDATE PROJECTS

The overall evaluation of candidate projects was based on the summary presented in Table S-1. The overall evaluation is based only on the benefit due to electricity generation. No benefit has been taken into account for navigation, or road infrastructure improvements.

It was found that nine of the candidate sites appear to offer attractive economic opportunities for generation of electric power. Among those candidates, priorities were suggested based on the apparent and probable social and environmental effects. Projects were classified in categories of relative social and environmental impacts based primarily on the numbers of people who would be displaced and the estimated area of land flooded. Other factors qualitatively considered were the opinion, based on the review of fisheries ecology, that a more complex range of fisheries questions will affect the more downstream projects and the recognised health concerns in the Ban Koum to Don Sahong river reach.

The projects have been evaluated as individual isolated projects for comparison of their merits in selecting promising options. Some of the candidates would be mutually exclusive and others could only be considered in combination if some accommodation of overlaps were made.

The effects on run-of-river projects of possible future large storage projects which might be built upstream were also analyzed.

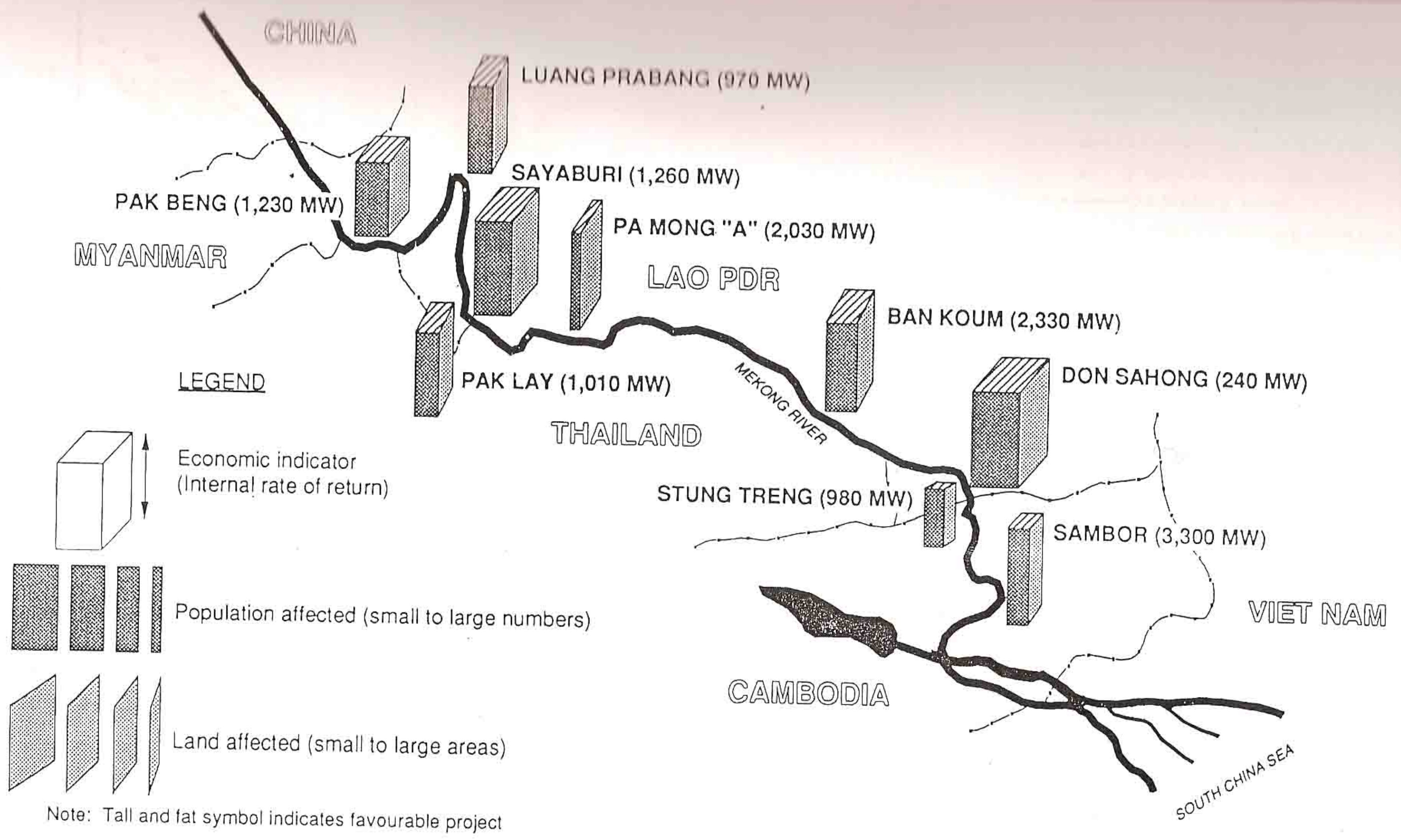


Figure S-3 RANKING OF CANDIDATE PROJECTS

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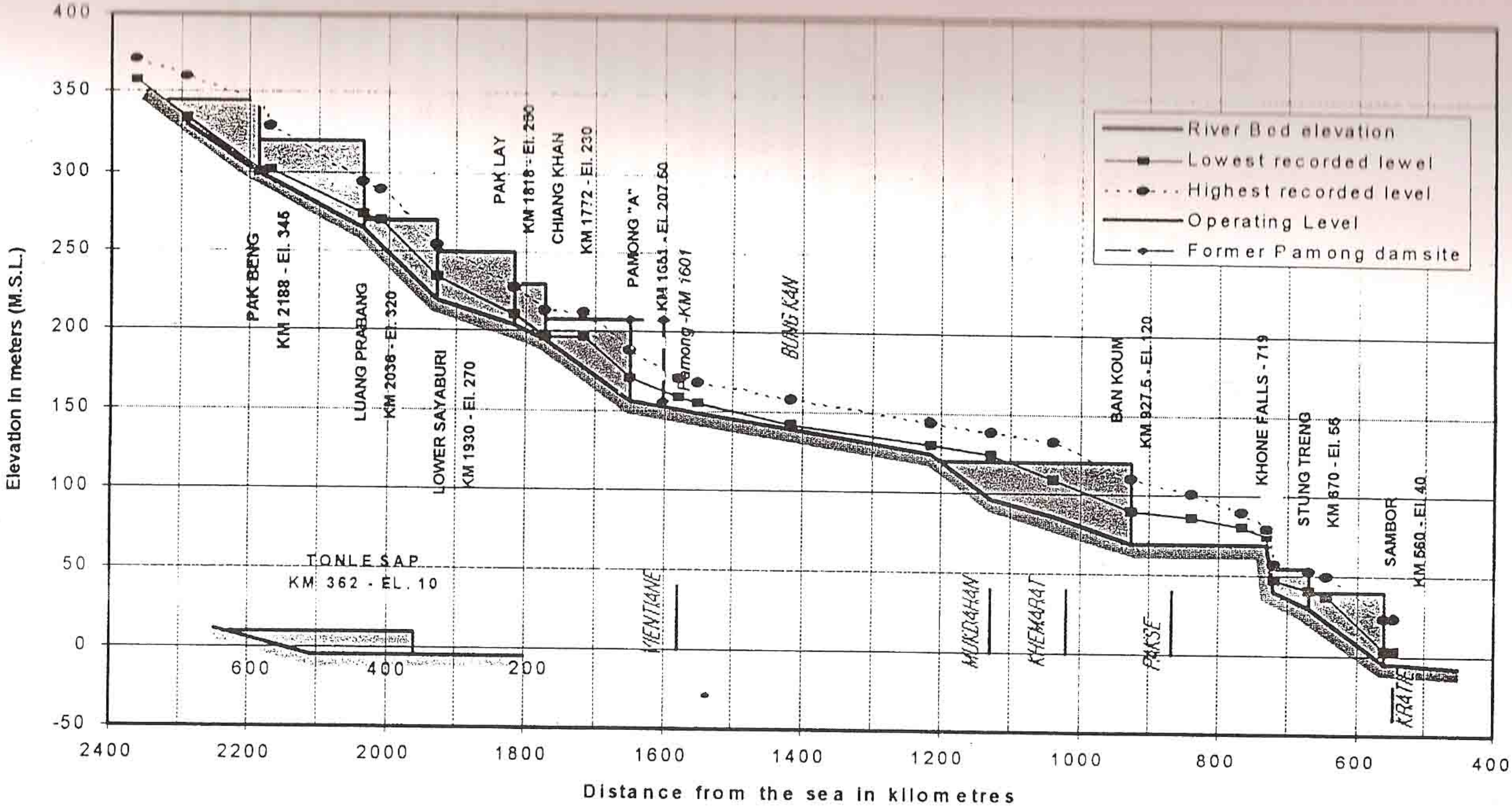

Figure S-4 PROFILE OF ULTIMATE SET OF PROJECTS

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RECOMMENDATIONS

OVERALL

It is recommended that further studies be undertaken for some specific projects. It is also recommended that other programs of investigation and study which will address some general areas of inadequate information be carried out. These general studies would best be done in coordination with other ongoing or planned related activities of the Mekong Secretariat and/or other agencies.

PROJECT STUDIES

It is recommended that prefeasibility studies be undertaken for the four first category projects: Don Sahong, Ban Koum, Sayaburi and Pak Beng followed by the two projects of the second category: Sambor and Luang Prabang. The studies should augment the available data by brief programs of survey and investigation and reduce the major uncertainties affecting the projects. They should reconsider the detailed locations and operating pond levels on the basis of more carefully defined constraints and technical and cost advantages. Study programs should include: socioeconomic, environmental, fisheries, topographic, hydrologic, geotechnical and design studies.

The priority of studies leading to implementation of the first mainstream projects must be determined by the riparian countries, taking into account the findings of this study.

In conjunction with project studies, the following topics should be investigated more broadly.

ESTABLISHMENT OF SPONSORSHIP FOR REGIONAL FISHERIES ECOLOGY STUDIES

Fisheries investigations on a larger scale than directly required for a single project should be undertaken.

It is recommended that fisheries questions be given priority attention in preparation for further consideration of possible projects on the mainstream of the Mekong River. The actions required are include establishing sponsorship for regional fisheries ecology studies, definition of terms of reference and conducting of short and long term studies relevant to the priority projects. As part of this overall program cooperation with other agencies through cost and data sharing arrangements should be investigated.

PUBLIC HEALTH STUDIES

Public health concerns, especially those related to water-borne diseases should be investigated further. The monitoring of effects of the Pak Mun reservoir in this respect will also be of interest.

RUN-OF-RIVER HYDROPOWER WORKSHOP

Following review of the draft report, a workshop attended by representatives of the four riparian countries on November 21 to 25, 1994 considered the findings and the recommendations of the study. Participants proposed that the candidate projects be ranked in three priority groups with regard to further studies up to a pre-feasibility levels. The Low Pa Mong project, which has been studied in details in 1992, remains to be an option for consideration by the countries concerned.

First Priority:

- Don Sahong (on a river branch in the Khone Falls area)
- Ban Koum
- Sambor

These projects can be developed without any interaction with other sites.

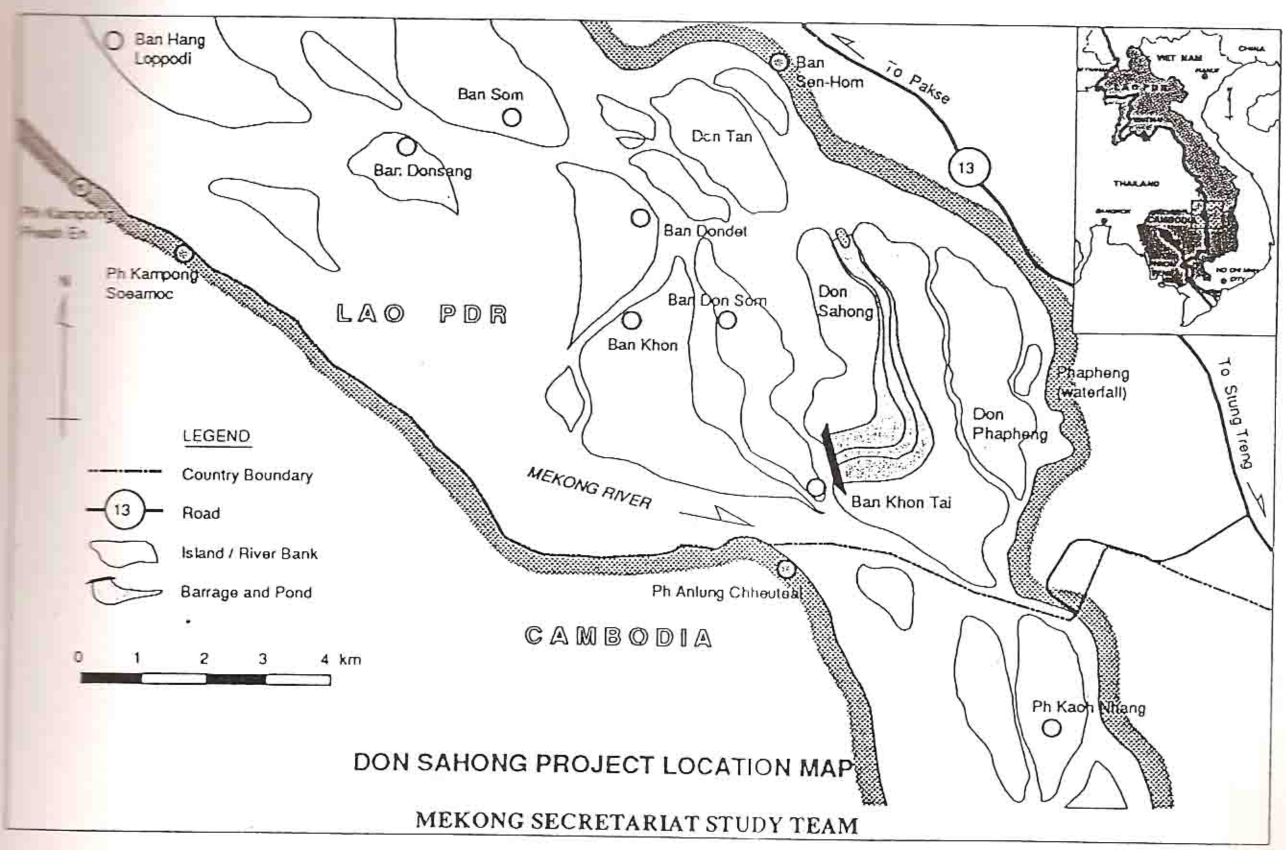
Second Priority:

- Pak Beng and Luang Prabang
- Sayaburi and Pak Lay

These sets of projects would need further studies to define which combinations of projects would be most acceptable and attractive.

Third Priority:

- Pa Mong "A"
- Stung Treng



DON SAHONG PROJECT LOCATION MAP

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[illegible]

Item	Unit	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1. Hydrology							
Catchment area	km^2	218,000	230,000	272,000	283,000	292,000	295,500
Average inflow	m^3/sec	3,170	3,810	3,990	4,030	4,160	4,310
2. River Pondage							
Normal operating water level	m	345	320	270	250	230	207.5
Operating level during flood of 100 years	m	340	315	265	245	225	202.5
Pond area	km^2	110	110	30	110.	90	120
Length of backwater at high flow 1/	km	90	140	50	120	90	80
Length of backwater at low flow 1/	km	140	170	90	150	140	130
Mean retention time	days	1-15	2-20	1-4	1-20	1-8	2-25
Mean natural transit time	days	1	1	1	1	1	2
3. Socioeconomic & Environment Impacts							
Number of villages displaced	Nos	7	27	5	21	22	30
Number of households displaced	Nos	303	1,090	310	1,800	2,140	4,590
Population displaced	Nos	1,670	6,580	1,720	11,780	12,950	23,260
Agricultural land inundated	km^2	5	5	0	10	10	10
Forest inundated	km^2	50	80	5	50	50	15
4. Barrage							
4.1 Spillway and Radial Gates							
Length	m	342	318	294	294	366	342
Design Flood	m^3/sec	29,650	46,700	39,450	38,400	33,880	51,800
Number of gates (18 m x 20 m)	Nos.	14	13	12	12	15	14
4.2 Powerhouse							
Length	m	417	391	417	404	285	577

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1/ As compared to natural condition.
2/ Between minimum flow and 1000 years flood.
3/ At load center after deducting transmission losses.
4/ Discounted at 10 % to the completion year and expressed in 1994 price level.
a/ Feature shown are for individual projects in isolation. A cascade of more than one project would change these features depending on the first choices.
b/ These projects are mutual exclusive.
c/ Only information related to power component are included. Navigation facilities to be provided by the irrigation component.

Table S-1: Salient Features of Individual Projects (cont'd)

Item	Unit	PAK BENG c/ KM [illegible] (Case PBA10)	LUANG PRABANG c/ KM [illegible] (Case LPB10)	XAYABURI KM [illegible] (Case XAC10)	PAK LAY a/ KM [illegible] (Case PLC10)	CHIANG KHAN a/ b/ KM [illegible] (Case CKB6)	PA MONG a/ b/ KM [illegible] (Case PMC16)
Design flow through turbines	m^3/sec	4,750	3,750	5,000	4,500	3,000	6,400
Number of sediment sluices (8m x 15m)	Nos	5	5	5	5	3	8
Tail water fluctuation 2/	m	31.3	23.0	22.6	19.4	18.5	20.4
Maximum head	m	38.9	49.5	34.1	38.5	24.8	44.1
Installed capacity	MW	1,230	1,410	1,260	1,320	570	2,030
Turbine type		Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan
Number of units	Nos	10	10	10	10	6	16
Dependable energy	GWh/yr.	3,240	4,180	3,740	4,210	2,150	5,620
Average energy 3/	GWh/yr.	5,670	7,380	5,990	6,460	3,210	8,870
Plant utilization factor 3/	%	53	60	55	57	65	50
4.3 Navigation Lock							
Number of locks (chamber=195m x 12m x 5m draft)	Nos	2	2	2	2	2	2
4.4 Embankment (closure dike) length	m	0	243	188	627	404	635
4.5 Total barrage length	m	794	987	934	1,360	1,091	1,589
5. Pre-Construction Cost Estimate							
Total cost without transmission line	10^6 US$	1,180	1,130	1,040	1,090	740	1,560
Total cost with transmission line	10^6 US$	1,440	1,510	1,310	1,320	880	1,940
6. Economic Indicators							
Project cost at commissioning 4/	10^6 US$	1,880	1,970	1,710	1,720	1,150	2,540
Cost / kW 4/	US$/kW	1,520	1,400	1,350	1,310	2,010	1,250
Present value of net benefits 4/	10^6 US$	380	970	780	1,050	250	1,200
B/C ratio 4/		1.2	1.4	1.4	1.5	1.2	1.4
Project internal rate of return	%	11.7	14.0	13.8	14.9	11.8	13.9
Energy cost 4/	US Cents/kWh	3.7	3.0	3.2	3.0	4.0	3.2

1/ As compared to natural condition.
2/ Between minimum flow and 1000 years flood.
3/ At load center after deducting transmission losses.
4/ Discounted at 10 % to the completion year and expressed in 1994 price level.
a/ Feature shown are for individual projects in isolation. A cascade of more than one project would change these features depending on the first choices.
b/ These projects are mutual exclusive.
c/ Only information related to power component are included. Navigation facilities to be provided by the irrigation component.

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Table 5-1: Salient Features of Individual Projects (cont'd)

Item	Unit	LOW PAMONG KM 1601 (Case LPM14)	BAN KOUM KM 928 (Case BKC10)	DON SAHONG KM 719 (Case DS4)	STUNG TRENG KM 670 (Case STA16)	SAMBOR KM 560 (Case SBC26)	TONLE SAP c/ KM 362 (Case TS8)
1. Hydrology							
Catchment area	km^2	299,000	419,000	553,000	635,000	646,000	71,000
Average inflow	m^3/sec	5,720	8,520	10,310	13,710	13,950	3,820
2. River Pondage							
Normal operating water level	m	207.5	120	70-72	55	40	10
Operating level during flood of 100 years	m	207.5	115	N.A	52	35	10
Pond area	km^2	560	130	N.A	640	880	N.A
Length of backwater at high flow 1/	km	130	90	-	50	40	N.A
Length of backwater at low flow 1/	km	180	140	-	50	80	N.A
Mean retention time	days	8-110	1-20	-	1-20	1-40	-
Mean natural transit time	days	1	1	-	1	1	-
3. Socioeconomic & Environment Impacts							
Number of villages displaced	Nos	100	7	none	N.A	N.A	none
Number of households displaced	Nos	10,000	330	none	1,830	1,020	none
Population displaced	Nos	52,000	2,570	none	9,160	5,120	none
Agricultural land inundated	km^2	140	5	none	80	150	none
Forest inundated	km^2	330	70	none	340	420	none
4. Barrage							
4.1 Spillway and Radial Gates							
Length	m	350	342	none	798	1,062	N.A
Design Flood	m^3/sec	51,800	53,000	-	79,100	161,000	N.A
Number of gates (18 m x 20 m)	Nos.	14	14	none	33	44	N.A
4.2 Powerhouse							
Length	m	400	747	137	431	945	225

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1/ As compared to natural condition.
2/ Between minimum flow and 1000 years flood.
3/ At load center after deducting transmission losses.
4/ Discounted at 10 % to the completion year and expressed in 1994 price level.
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b/ These projects are mutual exclusive.
c/ Only information related to power component are included. Navigation facilities to be provided by the irrigation component.

Item	Unit	[illegible] KM1601 (Case LPM14)	[illegible] KM [illegible] (Case BKU20)	[illegible] KM 719 (Case DS4)	[illegible] KM 670 (Case STA16)	[illegible] KM 560 (Case SBC26)	[illegible] KM 362 (Case TS8)
Design flow through turbines	m^3/sec	7,700	10,000	1,500	8,000	13,000	2,500
Number of sediment sluices (8m x 15m)	Nos	7	10	2	8	13	4
Tail water fluctuation 2/	m	16.0	18.0	10.5	12.0	20.0	7.0
Maximum head	m	50.5	32.9	19.3	16.9	36.6	7.0
Installed capacity	MW	2,670	2,330	240	980	3,300	140
Turbine type		Kaplan	Kaplan	Bulb	Bulb	Kaplan	Bulb
Number of units	Nos	14	20	4	16	26	8
Dependable energy	GWh/yr.	9,650	6,190	1,430	2,940	9,150	270
Average energy 3/	GWh/yr.	11,800	10,230	1,640	4,870	14,870	310
Plant utilization factor 3/	%	51	51	80	57	52	25
4.3 Navigation Lock							
Number of locks (chamber=195m x 12m x 5m draft)	Nos	none	2	none	1	2	-
4.4 Embankment (closure dike) length	m	200	541	1,127	4,810	8,115	-
4.5 Total barrage length	m	950	1,665	1,264	6,074	10,157	-
5. Pre-Construction Cost Estimate							
Total cost without transmission line	10^6 US$	2,350	1,830	310	1,330	2,600	410
Total cost with transmission line	10^6 US$	2,770	2,190	410	1,750	3,020	440
6. Economic Indicators							
Project cost at commissioning 4/	10^6 US$	3,620	2,860	530	2,280	3,940	570
Cost / kW 4/	US$/kW	1,350	1,230	2,230	2,330	1,190	4,050
Present value of net benefits 4/	10^6 US$	2,110	1,340	300	(300)	2,230	(340)
B/C ratio 4/		1.5	1.4	1.5	0.9	1.5	0.4
Project internal rate of return	%	14.7	13.9	14.6	8.8	14.6	3.8
Energy cost 4/	US Cents/kWh	3.5	3.2	3.6	5.1	3.0	19.4

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1/ As compared to natural condition.
2/ Between minimum flow and 1000 years flood.
3/ At load center after deducting transmission losses.
4/ Discounted at 10 % to the completion year and expressed in 1994 price level.
a/ Feature shown are for individual projects in isolation. A cascade of more than one project would change these features depending on the first choices.
b/ These projects are mutual exclusive.
c/ Only information related to power component are included. Navigation facilities to be provided by the irrigation component.

Table S-2: Classification of the Candidates Projects

Site	Location	Capacity (MW)	Population Displaced	Land Area Flooded (km^2)	Internal Rate of Return
First Category Projects					
* Don Sahong	719	240	0	0	14.6 %
* Ban Koum	928	2,330	2,570	90	13.9 %
* Sayaburi	1,930	1,260	1,720	20	13.85 %
* Pak Beng	2,188	1,230	1,670	50	11.7 %
Second Category Projects					
* Sambor	560	3,300	5,120	590	14.6 %
* Luang Prabang LPB10	2,036	1,410	6,580	90	14.0 %
or LPA10		970	5,200	85	12.9 %
Third Category Projects					
* Pak lay PLC10	1,818	1,320	11,780	80	14.9 %
or PLB 10		1,010	8,710	70	12.4 %
* Chiang Khan	1,772	570	12,950	70	11.8 %
Fourth Category Projects					
* Pa Mong "A"	1,651	2,030	23,260	40	13.9 %
or Low Pamong [1]	1,601	2,674	52,000	290	14.7 %
Least Attractive Project					
* Stung Treng	670	980	9,160	480	8.8 %
No Further Study Required					
* Tonle Sap	362TS	140	0	0	3.8 %
* Bung Kan [2]	1,418	80	6,000	10	8.0 %

1/ Low Pa Mong project features are quoted from the Low Pa Mong Optimization Study for Reference. This Alternative was not investigated further in the Run-of-River study.

2/ Very approximate data based on screening. The Bung Kan site was not considered in the evaluation phase due to its small size, low internal rate of return and relatively large effects on population.

Table S-3: Projected Utimate Set of Projects

Site	Location	Capacity (MW)	Energy (GWh/y)	Population Displaced	Land Area Flooded (km²)	Internal Rate of Return
First Category Projects						
* Don Sahong	719	240	1,640	0	0	14.6 %
* Ban Koum	928	2,330	10,200	2,570	90	13.9 %
* Sayaburi	1,930	1,260	5,990	1,720	20	13.9 %
* Pak Beng	2,188	1,230	5,670	1,670	50	11.7 %
Sub-total		**5,060**	**23,500**	**5,960**	**160**	
Second Category Projects						
* Sambor	560	3,300	14,900	5,120	590	14.6 %
* Luang Prabang LPB10	2,036	970	5,650	5,200	85	12.9 %
Sub-total		4,270	20,550	10,320	675	
Third Category Projects						
* Pak lay PLC10	1,818	1,010	4,840	8,710	70	12.4 %
Fourth Category Projects						
* Pa Mong "A"	1,651	2,030	8,870	23,260	40	13.9 %
Least Attractive Project						
* Stung Treng	670	980	4,870	9,160	480	8.8 %
Grand Total	**9 projects**	**13,350**	**62,630**	**57,410**	**1,425**	
1989 Mainstream Development Scenario	6 or 7 Projects	19,000	93,000	310,000	76,000	

Table S-1: Salient Features of Individual Projects (cont'd)

Item	Unit	[illegible] (Case PBA10)	[illegible] (Case LPB10)	[illegible] (Case [illegible]AC10)	[illegible] (Case PLC10)	[illegible] (Case CKB6)	[illegible] (Case PMC16)
Design flow through turbines	m^3/sec	4,750	3,750	5,000	4,500	3,000	6,400
Number of sediment sluices (8m x 15m)	Nos	5	5	5	5	3	8
Tail water fluctuation 2/	m	31.3	23.0	22.6	19.4	18.5	20.4
Maximum head	m	38.9	49.5	34.1	38.5	24.8	44.1
Installed capacity	MW	1,230	1,410	1,260	1,320	570	2,030
Turbine type		Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan
Number of units	Nos	10	10	10	10	6	16
Dependable energy	GWh/yr.	3,240	4,180	3,740	4,210	2,150	5,620
Average energy 3/	GWh/yr.	5,670	7,380	5,990	6,460	3,210	8,870
Plant utilization factor 3/	%	53	60	55	57	65	50
4.3 Navigation Lock							
Number of locks (chamber=195m x 12m x 5m draft)	Nos	2	2	2	2	2	2
4.4 Embankment (closure dike) length	m	0	243	188	627	404	635
4.5 Total barrage length	m	794	987	934	1,360	1,091	1,589
5. Pre-Construction Cost Estimate							
Total cost without transmission line	10^6 US$	1,180	1,130	1,040	1,090	740	1,560
Total cost with transmission line	10^6 US$	1,440	1,510	1,310	1,320	880	1,940
6. Economic Indicators							
Project cost at commissioning 4/	10^6 US$	1,880	1,970	1,710	1,720	1,150	2,540
Cost / kW 4/	US$/kW	1,520	1,400	1,350	1,310	2,010	1,250
Present value of net benefits 4/	10^6 US$	380	970	780	1,050	250	1,200
B/C ratio 4/		1.2	1.4	1.4	1.5	1.2	1.4
Project internal rate of return	%	11.7	14.0	13.8	14.9	11.8	13.9
Energy cost 4/	US Cents/kWh	3.7	3.0	3.2	3.0	4.0	3.2

Sheet 2/4

1/ As compared to natural condition.
2/ Between minimum flow and 1000 years flood.
3/ At load center after deducting transmission losses.
4/ Discounted at 10 % to the completion year and expressed in 1994 price level.
a/ Feature shown are for individual projects in isolation. A cascade of more than one project would change these features depending on the first choices.
b/ These projects are mutual exclusive.
c/ Only information related to power component are included. Navigation facilities to be provided by the irrigation component.

Table 5-1: Salient Features of Individual Projects (cont'd)

Item	Unit	LOW PA MONG KM 1601 (Case LPM14)	BAN KOUM KM 928 (Case BKC20)	DON SAHONG KM 719 (Case DS4)	STRUNG TRENG KM 670 (Case STA16)	SAMBOR KM 560 (Case SBC26)	TONLE SAP c/ KM 362 (Case TS8)
1. Hydrology							
Catchment area	km^2	299,000	419,000	553,000	635,000	646,000	71,000
Average inflow	m^3/sec	5,720	8,520	10,310	13,710	13,950	3,820
2. River Pondage							
Normal operating water level	m	207.5	120	70-72	55	40	10
Operating level during flood of 100 years	m	207.5	115	N.A	52	35	10
Pond area	km^2	560	130	N.A	640	880	N.A
Length of backwater at high flow 1/	km	130	90	-	50	40	N.A
Length of backwater at low flow 1/	km	180	140	-	50	80	N.A
Mean retention time	days	8-110	1-20	-	1-20	1-40	-
Mean natural transit time	days	1	1	-	1	1	-
3. Socioeconomic & Environment Impacts							
Number of villages displaced	Nos	100	7	none	N.A	N.A	none
Number of households displaced	Nos	10,000	330	none	1,830	1,020	none
Population displaced	Nos	52,000	2,570	none	9,160	5,120	none
Agricultural land inundated	km^2	140	5	none	80	150	none
Forest inundated	km^2	330	70	none	340	420	none
4. Barrage							
4.1 Spillway and Radial Gates							
Length	m	350	342	none	798	1,062	N.A
Design Flood	m^3/sec	51,800	53,000	-	79,100	161,000	N.A
Number of gates (18 m x 20 m)	Nos.	14	14	none	33	44	N.A
4.2 Powerhouse							
Length	m	400	747	137	431	945	225

Sheet 3/4

1/ As compared to natural condition.
2/ Between minimum flow and 1000 years flood.
3/ At load center after deducting transmission losses.
4/ Discounted at 10 % to the completion year and expressed in 1994 price level.
a/ Feature shown are for individual projects in isolation. A cascade of more than one project would change these features depending on the first choices.
b/ These projects are mutual exclusive.
c/ Only information related to power component are included. Navigation facilities to be provided by the irrigation component.

Item	Unit	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Design flow through turbines	m^3/sec	7,700	10,000	1,500	8,000	13,000	2,500
Number of sediment sluices (8m x 15m)	Nos	7	10	2	8	13	4
Tail water fluctuation 2/	m	16.0	18.0	10.5	12.0	20.0	7.0
Maximum head	m	50.5	32.9	19.3	16.9	36.6	7.0
Installed capacity	MW	2,670	2,330	240	980	3,300	140
Turbine type		Kaplan	Kaplan	Bulb	Bulb	Kaplan	Bulb
Number of units	Nos	14	20	4	16	26	8
Dependable energy	GWh/yr.	9,650	6,190	1,430	2,940	9,150	270
Average energy 3/	GWh/yr.	11,800	10,230	1,640	4,870	14,870	310
Plant utilization factor 3/	%	51	51	80	57	52	25
4.3 Navigation Lock							
Number of locks (chamber=195m x 12m x 5m draft)	Nos	none	2	none	1	2	-
4.4 Embankment (closure dike) length	m	200	541	1,127	4,810	8,115	-
4.5 Total barrage length	m	950	1,665	1,264	6,074	10,157	-
5. Pre-Construction Cost Estimate							
Total cost without transmission line	10^6 US$	2,350	1,830	310	1,330	2,600	410
Total cost with transmission line	10^6 US$	2,770	2,190	410	1,750	3,020	440
6. Economic Indicators							
Project cost at commissioning 4/	10^6 US$	3,620	2,860	530	2,280	3,940	570
Cost / kW 4/	US$/kW	1,350	1,230	2,230	2,330	1,190	4,050
Present value of net benefits 4/	10^6 US$	2,110	1,340	300	(300)	2,230	(340)
B/C ratio 4/		1.5	1.4	1.5	0.9	1.5	0.4
Project internal rate of return	%	14.7	13.9	14.6	8.8	14.6	3.8
Energy cost 4/	US Cents/kWh	3.5	3.2	3.6	5.1	3.0	19.4

Sheet 4/4

1/ As compared to natural condition.
2/ Between minimum flow and 1000 years flood.
3/ At load center after deducting transmission losses.
4/ Discounted at 10 % to the completion year and expressed in 1994 price level.
a/ Feature shown are for individual projects in isolation. A cascade of more than one project would change these features depending on the first choices.
b/ These projects are mutual exclusive.
c/ Only information related to power component are included. Navigation facilities to be provided by the irrigation component.

Table S-2: Classification of the Candidates Projects

Site	Location	Capacity (MW)	Population Displaced	Land Area Flooded (km^2)	Internal Rate of Return
First Category Projects					
* Don Sahong	719	240	0	0	14.6 %
* Ban Koum	928	2,330	2,570	90	13.9 %
* Sayaburi	1,930	1,260	1,720	20	13.85 %
* Pak Beng	2,188	1,230	1,670	50	11.7 %
Second Category Projects					
* Sambor	560	3,300	5,120	590	14.6 %
* Luang Prabang LPB10	2,036	1,410	6,580	90	14.0 %
or LPA10		970	5,200	85	12.9 %
Third Category Projects					
* Pak lay PLC10	1,818	1,320	11,780	80	14.9 %
or PLB 10		1,010	8,710	70	12.4 %
* Chiang Khan	1,772	570	12,950	70	11.8 %
Fourth Category Projects					
* Pa Mong "A"	1,651	2,030	23,260	40	13.9 %
or Low Pamong [1]	1,601	2,674	52,000	290	14.7 %
Least Attractive Project					
* Stung Treng	670	980	9,160	480	8.8 %
No Further Study Required					
* Tonle Sap	362TS	140	0	0	3.8 %
* Bung Kan [2]	1,418	80	6,000	10	8.0 %

1/ Low Pa Mong project features are quoted from the Low Pa Mong Optimization Study for Reference. This Alternative was not investigated further in the Run-of-River study.

2/ Very approximate data based on screening. The Bung Kan site was not considered in the evaluation phase due to its small size, low internal rate of return and relatively large effects on population.

Table S-3: Projected Utimate Set of Projects

Site	Location	Capacity (MW)	Energy (GWh/y)	Population Displaced	Land Area Flooded (km²)	Internal Rate of Return
First Category Projects						
* Don Sahong	719	240	1,640	0	0	14.6 %
* Ban Koum	928	2,330	10,200	2,570	90	13.9 %
* Sayaburi	1,930	1,260	5,990	1,720	20	13.9 %
* Pak Beng	2,188	1,230	5,670	1,670	50	11.7 %
Sub-total		**5,060**	**23,500**	**5,960**	**160**	
Second Category Projects						
* Sambor	560	3,300	14,900	5,120	590	14.6 %
* Luang Prabang LPB10	2,036	970	5,650	5,200	85	12.9 %
Sub-total		4,270	20,550	10,320	675	
Third Category Projects						
* Pak lay PLC10	1,818	1,010	4,840	8,710	70	12.4 %
Fourth Category Projects						
* Pa Mong "A"	1,651	2,030	8,870	23,260	40	13.9 %
Least Attractive Project						
* Stung Treng	670	980	4,870	9,160	480	8.8 %
Grand Total	**9 projects**	**13,350**	**62,630**	**57,410**	**1,425**	

1989 Mainstream Development Scenario	6 or 7 Projects	19,000	93,000	310,000	76,000