3. THE POWER SECTOR

3.1 LAWS AND REGULATIONS

The legal and regulatory framework of the power sector of Cambodia is governed by the following laws:

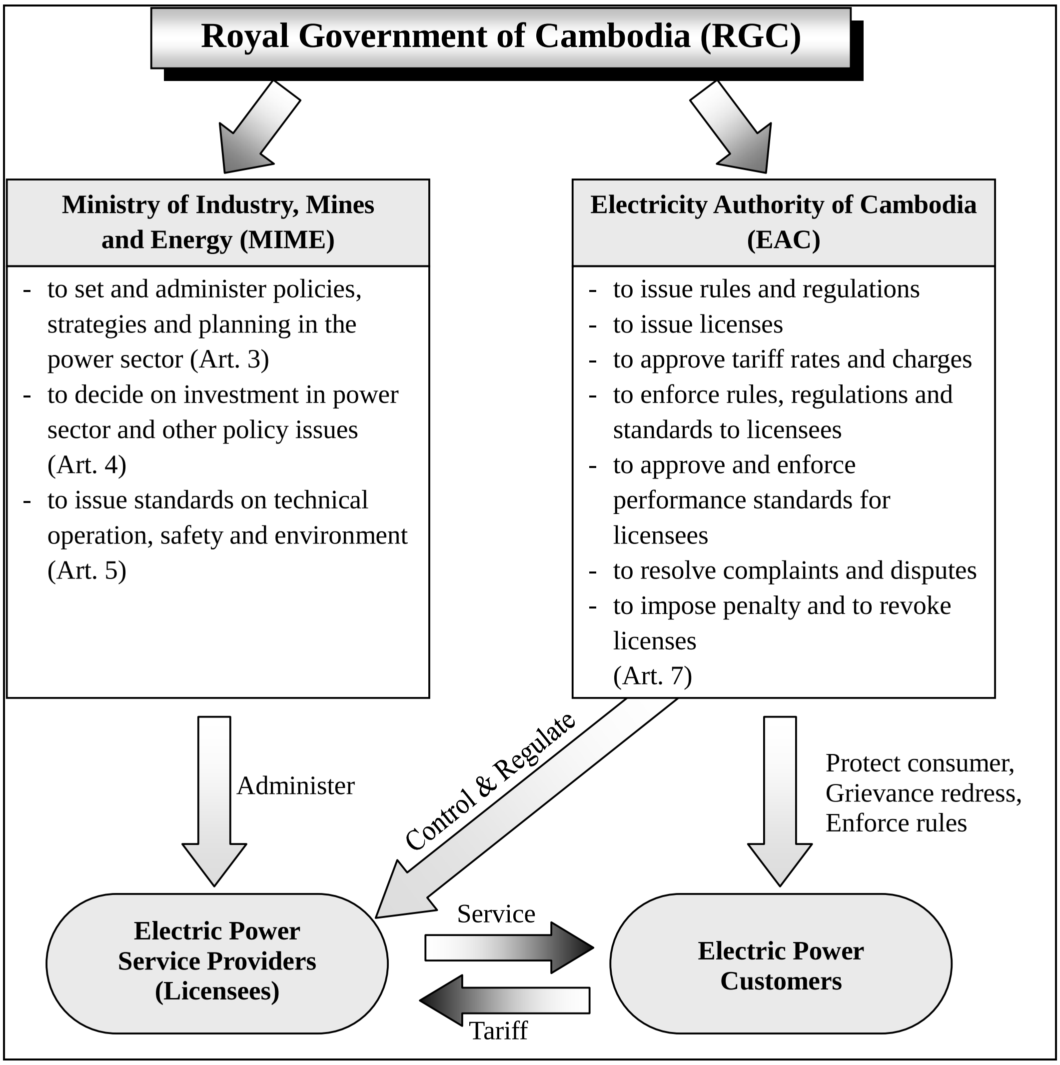
- Electricity Law
- Other applicable laws, polices and regulations

3.1.1 Electricity Law

The power sector of Cambodia is administered and managed under the Electricity Law which was enacted in February 2001. The Law provides a policy framework for the development of a largely unbundled sector, with substantial private sector participation in generation and distribution on a competitive basis. The Law aims at establishing:

1) the principles for operations in the electric power industry;
2) favourable conditions for investment and commercial operation;
3) the basis for the regulation of service provision;
4) the principles for
    - protection of consumers interests to receive reliable services at reasonable cost;
    - promotion of private ownership of the facilities; and
    - establishment of competition.
5) the principles for granting rights and enforcing obligations; and
6) the Electricity Authority of Cambodia (EAC) for regulating the electricity services.

The Law has two key objectives: 1) establishing an independent regulatory body, EAC; and 2) liberalizing generation and distribution functions to private sectors. Two functions of policy making and regulation are clearly separated as shown in Figure 3.1.1. The Ministry of Industry, Mines and Energy (MIME) is responsible for policy making, including drafting laws, declaring policies, formulating plans, deciding on investments, etc. EAC is responsible for regulatory functions, including licensing service providers, approving tariffs, setting and enforcing performance standards, settling disputes, etc. The liberalization and deregulation of the sector has stimulated the private sector with resulting proliferation of independent power producers (IPP) and rural electricity enterprises (REE) in addition to the traditional public utility, the Electricite du Cambodge (EDC).



Source: Study Team

Figure 3.1.1 Institutional Responsibility of Electric Power Sector (Stipulated by the Electricity Law)

3.1.2 Other Applicable Laws, Policies and Regulations

The general legal framework applicable to the power sector development includes the following though legislation remains incomplete or unclear:

- Decree on private participation in the electric power sector;
- Commercial, corporate and bankruptcy laws;
- Laws of land and right-of-way.

The Sub-Decree on promoting Private Sector Participation (PSP) on which the Electricity Law lays stress has been drafted. The objectives of the Sub-Decree are: 1) to attract private sector investment in the power generation projects; 2) to clarify under what rules and conditions the private and public sector entities can develop, construct and operate the electric power projects; 3) to clarify the public sector roles and responsibilities; and 4) to establish a transparent and efficient procurement process for private power projects. This law stipulates a transparent and predictable process of investment promotion, including clear division of roles and duties of public and private entities, which is one of the key factors in the private sector decision to enter the power market.

Legislation governing land ownership, resettlement and compensation in Cambodia includes the Land Law of 1992 (being revised) and the Constitution. There are further decrees and edicts that affect land ownership. In Prime Ministerial Edict of 1999, measures to eliminate anarchical grabbing, declares public land on the verge of roads and railways must not be occupied.

The status and relevance of consumer and business protection, taxation and company law has been published in a guide to investment in Cambodia by the Dept. of Legal Affairs, including Laws & Regulations on Investment of 1999.

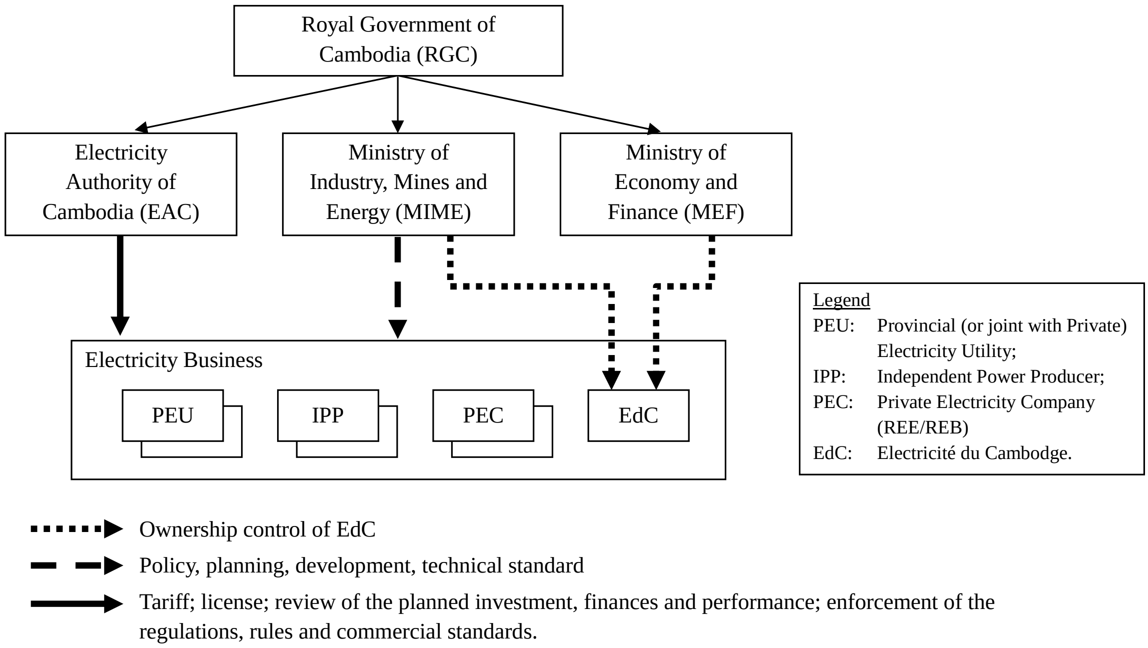
3.2 ORGANIZATIONS

In the electricity sector of Cambodia, the Electricity Law enacted in 2001 has clearly defined, under the private sector participation and beneficiaries-pay principle, the roles of concerned parties: 1) MIME as policy maker, 2) EAC as regulatory and supervisory agency, and 3) REEs (Rural Electricity Enterprises) to provide electricity supply services. EDC, which constructs and operates the National Grid, is also regarded as one of the REEs. The other private REEs (including Community Electricities Cambodia, CEC) have opportunities to distribute electricity, receiving power from the grid inside the potential area for grid extension (PAGE), as well as to electrify communities in the off-grid areas (MIME 2006)[1].

3.2.1 MIME

As shown in Figure 3.2.1, MIME is responsible for planning and development of power projects through granting study rights and concession of power generation business to REE and Independent Power Producers (IPPs). EIA of generation projects will be undertaken by IPPs in accordance with the requirements of MOE. EIA of transmission projects will be undertaken by EDC. MOE will evaluate the EIA report. If the project is situated inside the Protected Areas and is considered to meet the national interests, MOE would ask the RGC for decision on approval.

1 MIME Cambodia, Nippon Koei Co., Ltd. and KRI 2006, “The Master Plan Study on Rural Electrification by Renewable Energy, Summary” 3p. JICA.



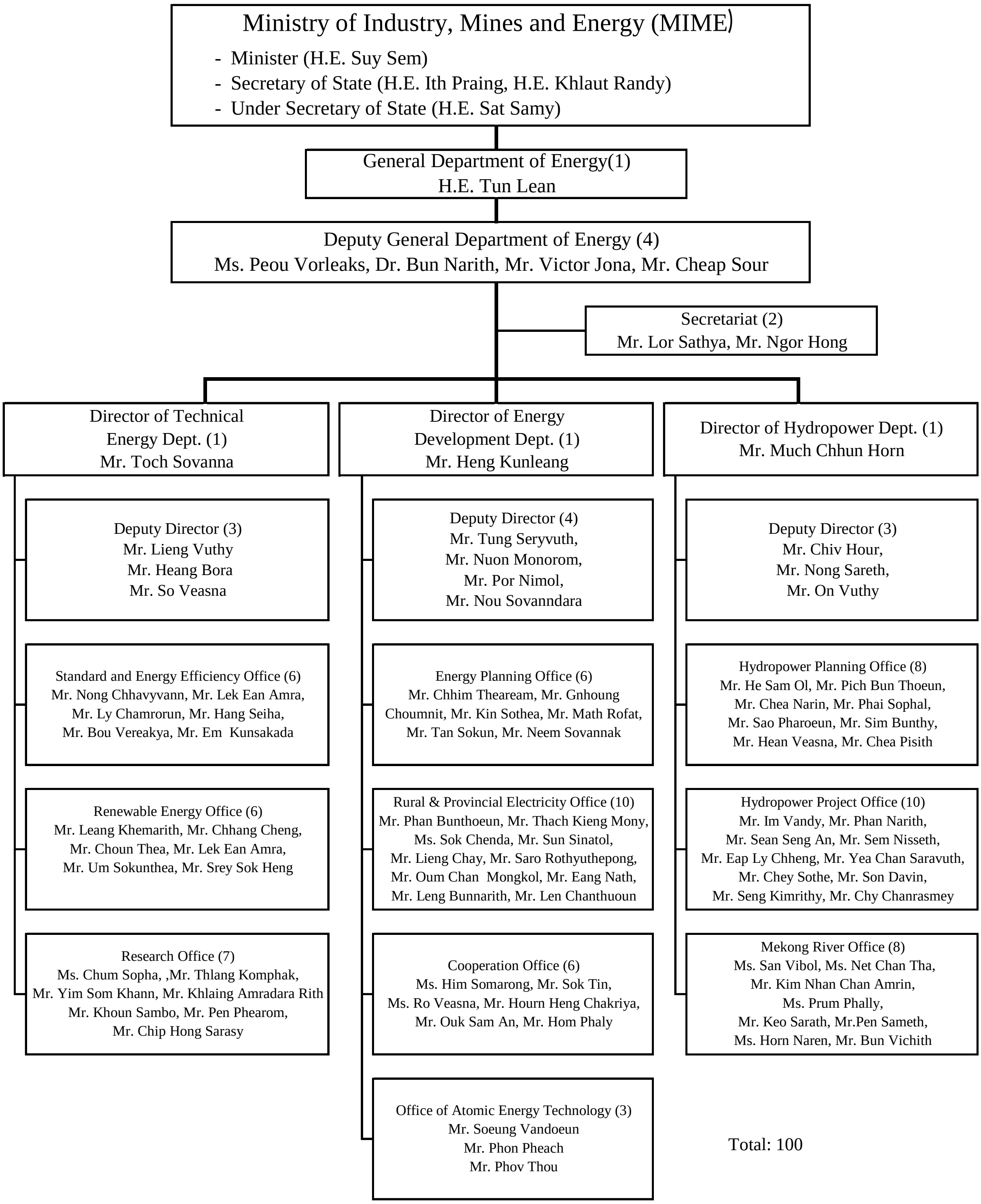
Source: MIME

Figure 3.2.1 Related Organizations

More specific responsibilities of MIME include:

- Approval of investments in the rehabilitation and development of the power sector in the short, medium and long term;
- Developing policies and strategies related to restructuring, private sector participation and privatization of public utilities;
- Promotion of the use of indigenous energy resources in the generation of electricity;
- Planning related to the export and import of electricity, as well as approval of electricity export/import agreements;
- Planning/approval of subsidies to specific classes of customers and priorities regarding consumers of electricity;
- Promotion of efficiency in generation, transmission, distribution and consumption of electricity;
- Creation of a comprehensive electricity conservation program for Cambodia;
- Development of electricity sector emergency and energy security strategies; and
- Issuing and publishing standards related to technical operation, safety and environment.

Under the Minister of MIME, the Secretary of State and the Under Secretary of State are in charge of the energy sector. The General Department of Energy has three departments as shown in Figure 3.2.2. The Hydropower Department deals with the identification and development of mini, small, medium and large hydro power projects.



Note: The number in each block indicates the number of staff as of Aug. 2008.
Source: MIME

Figure 3.2.2 Organization Chart of the General Department of Energy of MIME

There is no department in charge of the environment. The Deputy Director of the Hydropower Department has been assigned as a counterpart covering environmental aspects in addition to a counterpart from the Ministry of Environment.

MIME has limited experiences related to EIA including environmental implications of dam-hydropower projects. Authority for conducting feasibility studies may be granted to foreign or local companies on potential hydropower sites regardless of the relative location to the Protected Areas. Most of the potential hydropower sites of Cambodia are located either fully or partly in the Protected Areas. Therefore, preliminary examination would be needed, before granting the authority, to conduct the study to determine whether there would be any potential intolerable impacts to the national interests of Cambodia or to the requirements of the Mekong Agreement. If any potential significant/intolerable impact is foreseen, an authority to conduct a study would be granted only for the purpose of clarifying the type and magnitude of such impacts, without committing any further authority, in order to judge whether the full study should be undertaken or not.

The present Master Plan Study could contribute to such preliminary identification and examination of potential environmental impacts of the hydropower projects. Such impacts could include those on sediment transport; inundation area within the Protected Areas; households, and farmland and forest land situated in the envisaged reservoir area. If any significant impact is identified, recommendations should be made for measures to mitigate the impacts as part of the Master Plan Study.

3.2.2 EAC

The EAC was established in 2001 under the Electricity Law. The EAC is responsible for the control and regulation of the provision of electricity services in Cambodia. The responsibilities of EAC include among others:

- to issue, revise, suspend, revoke or deny the licenses for the provision of electric power services;
- to approve tariff rates and charges as well as terms and conditions of electric power services of licensees;
- to enforce regulations, procedures and standards for investment programs by licensees;
- to review the financial activities and corporate organization structure of licensees;
- to approve and enforce the performance standards for licensees;
- to evaluate and resolve consumer complaints and contract disputes involving licensees; and
- to impose monetary penalties, disconnect power supplies, suspend or revoke licenses for violations of the laws, standards and regulations.

Each licensee is required to have licenses issued by EAC and to abide by the provisions of the Law and those of its license, regulations and procedures of EAC. EAC will see if the licensees use the standards on technical operation, safety and environment issued by MIME. There are 8 types of licenses: generation, transmission, distribution, consolidated, dispatch, bulk sale, retail, and subcontract.

3.2.3 EDC

The EDC is a leading service provider and a 100% state-owned power company responsible for power generation and transmission throughout Cambodia and in the licensed area for power distribution. EDC is a juridical organization established by the Public Enterprise Law, with administrative, financial and managerial autonomy. The Planning and Technology Department of Electricite du Cambodge (EDC) consists of the Generation Department, the Cooperation Planning & Project Department, and the

Transmission & Distribution Department. The Social Environmental & Public Relations Office is in the Cooperation Planning & Project Department. The Environmental Office was organized in order to meet the recent requirements of EIA. Two staff members are in the office and two more staff members will be added in the future. In the Master Plan Study, the Office will support the Study Team.

EDC is a 100% state-owned limited liability company under control of MIME and the Ministry of Economy and Finance (MEF). EDC acquired the consolidated license from EAC in Feb. 2002. EDC is a juridical organization with administrative, financial and managerial autonomy, so that it is responsible for its profit and losses and liable for its debts to the extent of the value of its assets.

EDC is authorized to undertake the following main functions by the Royal Decree that came into effect in March 1996:

- Generation and sale of electricity as well as electricity import from and export to neighboring countries;
- Construction and operation of the National Grid and distribution networks to ensure the reliable delivery of electric power and rural electrification;
- Acquisition, transfer and exchange of electric power; and
- Enactment of all legal acts necessary to achieve its commercial and corporate objectives.

The Special Purpose Transmission license was issued to CPTL (Cambodia Power Transmission Line Co.) in 2007, who constructed 115 kV single circuit transmission lines from Thailand border to Banteay Meanchey, Battambang and Siemreap in the north-west region of the country for importing electric power from Thailand. The import from Thailand has commenced by EDC since the end of November of 2007 and the transmission facilities have been operated and maintained by CPTL.

EDC recognizes the importance of environmental and social consideration. EDC had experience of EIA for the Kamchay project.

3.2.4 MOE

The Ministry of Environment was set up in late 1993 to establish comprehensive legal, policy, and institutional frameworks. The new constitution requires the state to ensure rational use of natural resources and environmental protection.

The purposes of the environmental laws are:

- to protect and promote environmental quality and public health through prevention, reduction and control of pollution;
- to assess environmental impacts of proposed projects prior to issuing the decision by the RGC;
- to ensure rational and sustainable conservation, development, management, and use of the natural resources of the Kingdom of Cambodia;
- to encourage and enable the public to participate in environmental protection and natural resource management; and
- to suppress any acts that cause harm to the environment.

One of the staff of the Department of EIA is taking part in the present Master Plan Study of Hydropower Development in Cambodia as a counterpart in charge of the social and natural environment.

3.3 POWER SUPPLY FACILITIES

3.3.1 General

As explained in the above, electric power supply industries have managed by the providers licensed by EAC except providers in some minor areas. EDC is the biggest power provider among them, who has consolidated license consisting of generation, national transmission and distribution licenses. In this connection, up to the end of 2007, EAC has issued 192 licenses in total to the electric power service providers including EDC, i.e. EDC: 1, Generation (IPP): 22, Special Purpose Transmission: 1, Distribution: 15, Retail: 1, Consolidated: 152. However, total 180 licenses were valid at the end of 2007, i.e. EDC: 1, Generation (IPP): 14, Special Purpose Transmission: 1, Distribution: 16, Retail: 1, Consolidated: 147.

The Special Purpose Transmission license was issued to CPTL (Cambodia Power Transmission Line Co.) in 2007, who constructed 115 kV single circuit transmission lines from Thailand border to Banteay Meanchey, Battambang and Siemreap in the north-west region of the country for importing electric power from Thailand. The import from Thailand has commenced by EDC since the end of November of 2007 and the transmission facilities have been operated and maintained by CPTL. Power import from the neighboring countries to the areas near the borders has been made by EDC (mainly from Vietnam) and distribution licensees (mainly from Thailand) over the 22 kV up to this time and its capacity has been limited in a few thousand kW level. The commencement of electricity import over the high voltage transmission line is an important step not only for strengthening the economic relation with neighboring countries but also in the development of the National Grid in Cambodia.

3.3.2 Generating Facilities

Power generating facilities are owned and operated by EDC, IPP and consolidated licensees. Total capacity of generating facilities at the end of 2007 was 314.6 MW, i.e. by EDC: 76.9 MW, by IPP: 202.5 MW, by the consolidated licensees: 35.2 MW. However, an available output of the generating facilities of the consolidated licensees seems to be considerably small than that Figure, because the capacity of generating facilities owned by the consolidated licensees more than half is less than 100 kW and much aged.

Furthermore, electric power was imported by EDC and the distribution licensees from Thailand and Vietnam to supply to the some cities near the borders and its contract capacity was reached to the level of 104.7 MW in total at the end of 2007. The contract capacity of 104.7 MW is much bigger than that of 2006 (23.8 MW). This is caused by the commencement of import from Thailand over the CPTL transmission system (contract capacity: 80 MW). Then, simple sum of power supply capacity at the end of 2007 can be said as 419.3 MW including an import from the neighbouring countries.

In addition to the these power supply, captive plants having considerably big capacity are owned and operated by the private firms for their own use for factories, hotels, commercial buildings, etc., however, no detail information on these captive plants was available. Master plan on generation expansion plan and power transmission extension plan has been established and power supply by these captive plants will be switched over time to time to the national grid supply in the progress of these development and reinforcement plans. In these circumstances, however, actual situation of the captive plants in the countries has not been reflected to the demand forecast which is a base of the above master plans due to the shortage of information. Therefore, it is strongly recommended to collect exact information on the captive plants having more than fixed capacity as soon as possible and to reflect to the review study of the demand forecast for the whole country.

3.3.3 Transmission and Distribution Facilities

The transmission line voltages presently used in the country are of 220 V and 400 V (low voltage), 6.3 kV, 11 kV, 15 kV and 22 kV (medium voltage), and 115 kV. The demand centers except for some areas in the country are isolated each other and served through low voltage system only and/or medium-low voltage system.

For the Phnom Penh system, 115 kV 1-cct transmission lines (23.5 km in 3-section) for connecting 3 substations in the city and generating plants of IPP and 115 kV 1-cct line (105 km) for transmitting power of the Kirirom I hydropower plant (12 MW) to Phnom Penh are presently operated. In addition to these 115 kV transmission system, new construction of 230 kV double circuits transmission line, related 230/115 kV substations and the rehabilitation and up-grade works of the existing 115 kV system are under way for importing electric power from Vietnam.

For importing electric power from Thailand to the north-west areas of the country, 115 kV 1-cct transmission lines have been constructed from the border to Banteay Meanchey (1x25 MVA), Battambang (1x25 MVA), Siemreap (1x50 MVA) through Poipet (transformer not installed) at the end of 2007 and operated by the special purpose transmission licensee.

As of the end of 2007, summary of transmission and distribution facilities is: total length of 115 kV 1-cct transmission line: 332.5 km, number of 115 kV/MV transformers: 10 units, total length of MV lines: 1,454 km (22 kV: 1,322 km, 15 kV: 20 km, 11kV: 22 km, 6.3kV: 90 km), total length of low voltage lines: 2,639 km (incl. 166 km under ground cables), number of distribution transformers: 1,440 units and total capacity of distribution transformers: 895 MVA. (Source: EAC Annual Report for 2007)

3.4 POWER SUPPLY AND DEMAND

3.4.1 Power Supply

Power supply to the electricity suppliers of the past 5 years is given in the Table 3.4.1 by supplier groups. As shown in the table, total supplied energy has increased at very high averaged rate of 21.5% for the past 5 years. However, it is clear that the generation by EDC has shown a tendency to decrease and the generation by IPP and import from neighbouring countries have increased at a higher rate than that of total energy. Import from Thailand over the high voltage transmission line has commenced from the end of 2007 and an operation of 230 kV transmission systems which is presently under construction is scheduled to be started in 2009. In this connection, it is noted that operation of power supply system depending largely on imported energy will be continued for the time being, even though large scaled hydropower stations are under construction. In the meantime, power supply by the consolidated licensees has also increased at considerably higher rate to promote rural electrification of the Government policy。

Table 3.4.1 Electric Energy Supply in the Past 5 Years

Unit: GWh

	2003	2004		2005		2006		2007		Average
EDC Own Generation	165.29	273.30	65.3%	233.45	-14.6%	208.87	-10.5%	171.89	-17.7%	1.0%
IPP (Sent-out)	456.24	450.85	-1.2%	625.13	38.7%	853.99	36.6%	1,141.27	33.6%	25.8%
Consolidated	15.23	19.37	27.2%	20.79	7.3%	24.24	16.6%	36.16	49.2%	24.1%
Import	58.27	59.49	2.1%	82.25	38.3%	109.70	33.4%	167.41	52.6%	30.2%
Total	695.03	803.01	15.5%	961.62	19.8%	1,196.80	24.5%	1,516.73	26.7%	21.5%

Source: EDC & EAC Annual Reports

Total sent-out energy to their distribution systems was 1,516.7 GWh in 2007. EDC served 1,370.6 GWh (90.4% of the total sent-out energy) including own generated energy, purchased energy from IPP and imported energy from Vietnam. The distribution licensees served 105.0 GWh (6.9%) including purchased energy from IPP and imported energy. The consolidated licensees served 40.4 GWh (2.7%) generated by small scale diesel generators. In other words, IPP was the biggest power provider and they supplied 1,141.3 GWh (75.2% of the total sent-out energy). The second was 171.9 GWh (11.3%) of EDC and the third was 167.4 GWh (11.0%) imported from the neighbouring countries.

3.4.2 Load

Recently, EDC has collected detail hourly output of generators including IPP and maximum demand of imported electric power for not only the Phnom Penh system but also isolated systems and its annual maximum demand have been reported in their annual reports. From this information, rough peak demand of whole county is able to estimate, because EDC supply shared around 90% of the total of the country. In this study, slightly more detail estimation was made as shown in Table 3.4.2. For the calculation of peak load, annual load factor of the consolidated licensees is estimated at 30% and for the imported electric power at 50% based on the actual annual load factor of imported power of EDC in 2007, at 51.1%. As a result of such estimation, peak demand of the country was 301 MW and its annual load factor of the country was calculated at 57.5%.

Table 3.4.2 Peak Demand in the Past 5 Years by Group

Unit: MW

	2003	2004		2005		2006		2007		Average
EDC	115.70	136.60	18.1%	162.12	18.7%	201.92	24.5%	249.12	23.4%	21.1%
a) Phnom Penh	100.90	116.30	15.3%	133.10	14.4%	165.00	24.0%	204.50	23.9%	19.3%
b) Others *1	14.80	20.30	37.2%	29.02	43.0%	36.92	27.2%	44.62	20.9%	31.8%
Consolidated	5.80	7.37	27.2%	7.91	7.3%	9.22	16.6%	13.76	49.2%	24.1%
Import	13.30	13.58	2.1%	18.78	38.3%	25.05	33.4%	38.22	52.6%	30.2%
Total	134.80	157.55	16.9%	188.81	19.8%	236.19	25.1%	301.10	27.5%	22.3%

Source: EDC & EAC Annual Reports
(Remarks)
*1 : Demand of areas imported from Vietnam is included in the bellow "Import".

3.4.3 Sold Energy

Sold energy of the past 5 years by provider group is given in Table 3.4.3. As shown in the table, total sold energy has grown with an averaged annual increase rate of 22.4% during the past 5 years. Averaged increase rate of consolidated licensees of 31.2% is the highest among the provider groups and it is caused by the sudden increase with very high rate of 64.8% in 2007. For the customer group of EDC, averaged increase rate of industry was the highest of 41.7%, but sold energy for the resident customers was the highest and shared 33.7% of total sold energy of EDC, followed by commercial and services at 29.5% and industrial at 30.9%.

Table 3.4.3 Sold Energy of the Past 5 Years

Unit: GWh

	2003	2004		2005		2006		2007		Average
EDC	540.50	643.67	19.1%	820.73	27.5%	971.70	18.4%	1,221.81	25.7%	22.6%
a) Residential	*262.70*	*300.44*	*14.4%*	*309.47*	*3.0%*	*346.52*	*12.0%*	*411.40*	*18.7%*	11.9%
b) Industrial	*63.40*	*89.63*	*41.4%*	*157.22*	*75.4%*	*160.38*	*2.0%*	*255.80*	*59.5%*	41.7%
c) Commercial	*121.40*	*163.37*	*34.6%*	*193.71*	*18.6%*	*286.22*	*47.8%*	*360.07*	*25.8%*	31.2%
d) Others	*93.00*	*90.22*	*-3.0%*	*160.33*	*77.7%*	*178.58*	*11.4%*	*194.54*	*8.9%*	20.3%
Consolidated	10.78	13.32	23.6%	15.45	16.0%	19.40	25.5%	31.96	64.8%	31.2%
Distribution	50.41	47.27	-6.2%	57.67	22.0%	75.14	30.3%	95.91	27.6%	17.4%
Total	601.69	704.25	17.0%	893.85	26.9%	1,066.23	19.3%	1,349.67	26.6%	22.4%

Source: EDC & EAC Annual Reports

Total sold energy by the providers was 1,349.7 GWh (transmission and distribution losses: 11.0%) including 1,221.8 GWh (10.9%) by EDC, 95.9 GWh (8.7%) by the distribution licensees and 32.0 GWh (20.9%) by the consolidated licensees in 2007. Distribution loss of the distribution licensees is the lowest among the provider groups, because the distribution licensees import electric power for their own use or to supply to their big customers like casinos, hotels, factories, etc. and power supply to households is presently limited to the small areas.

3.4.4 Number of Customers

Number of customers of the past 5 years is given in Table 3.4.4. Electricity tariff of EDC was basically classified in 6 customer groups like: Domestic, Commercial (business), Industrial, Customers paying by Government Budget, Embassy/NGO/Foreigner's Resident, Hotel/Guesthouse, and detail information like sold energy, number of customers, etc. were recorded. However, sold energy and number of customers of other providers were not classified by customer group in the EAC annual reports.

Table 3.4.4 Number of Customers of the Past 5 Yeas

	2003	2004		2005		2006		2007		Average
EDC	140,611	201,261	43.1%	215,515	7.1%	264,575	22.8%	286,823	8.4%	19.5%
a) Residential	*128,713*	*183,994*	*42.9%*	*197,336*	*7.3%*	*242,467*	*22.9%*	*262,256*	*8.2%*	19.5%
b) Industrial	*670*	*837*	*24.9%*	*842*	*0.6%*	*959*	*13.9%*	*1,055*	*10.0%*	12.0%
c) Commercial	*10,281*	*12,549*	*22.1%*	*13,026*	*3.8%*	*16,157*	*24.0%*	*17,930*	*11.0%*	14.9%
d) Others	*947*	*3,881*	*309.8%*	*4,311*	*11.1%*	*4,992*	*15.8%*	*5,582*	*11.8%*	55.8%
Consolidated	32,106	45,472	41.6%	56,565	24.4%	68,231	20.6%	89,999	31.9%	29.4%
Distribution	16,609	20,816	25.3%	24,551	17.9%	25,785	5.0%	51,991	101.6%	33.0%
Total	189,326	267,549	41.3%	296,631	10.9%	358,591	20.9%	428,813	19.6%	22.7%

Source: EDC & EAC Annual Reports

Number of the customers at the end of 2007 was 428,813, including EDC: 286,823 (66.9% of the total). Number of customers of other providers was 141,990 and their increase rates of 2007 were 32% of consolidated licensees and 102% of distribution licensees. Number of domestic customers of the providers excluding EDC was not available as explained above. For the customers of EDC, number of domestic customers were 262,256 (91.4% of EDC total), and followed by 17,930 (6.3%) of commercial customers and 1,055 (0.4%) of the industrial customers.

3.4.5 Electricity Tariff

Electricity tariff of providers is subject to approval of EAC. An averaged tariff by tariff category of EDC in the past 3 years is given in Table 3.4.5.

Table 3.4.5 Averaged Tariff by Customer Groups of EDC

	2005		2006		2007	
	Riel	US¢	Riel	US¢	Riel	US¢
Residential	628.3	15.7	733.7	18.3	736.5	18.4
Industrial & Handicraft	464.9	11.6	733.4	18.3	692.1	17.3
Commercial	677.6	16.9	754.7	18.9	732.3	18.3
Hotel & Guest House	614.7	15.4	712.5	17.8	706.2	17.7
Embassy, Foreigners' House, NGO	824.6	20.6	873.8	21.8	887.2	22.2
Government Institutions	731.3	18.3	808.3	20.2	802.7	20.1
Others	416.6	10.4	467.7	11.7	459.1	11.5
Average	621.2	15.5	745.6	18.6	730.0	18.2

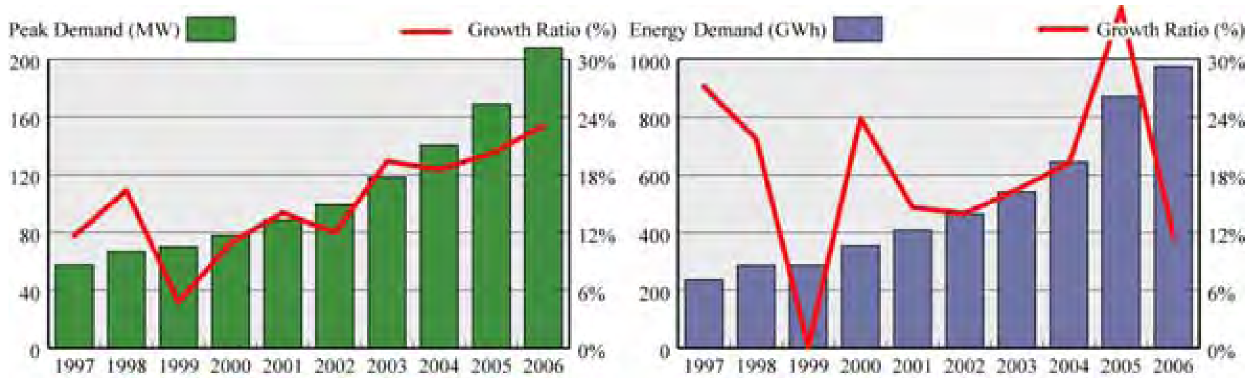
The electricity tariff level of Cambodia was much high comparing with neighbouring countries. Averaged electricity tariff of EDC in 2007 was 18.2 ¢/kWh. The tariff of low voltage customers (mainly households and small commercial customers) of consolidated licensees was ranged roughly between 18.0 ¢/kWh (Kandal) and 120.0 ¢/kWh (Siemreap). These high electricity tariff were considered to be caused by high fuel cost, generation by small scaled and aged diesel generators, high price of purchased energy from IPP except from IPP of hydropower (7.0 ¢/kWh), i.e. 9.9 ¢/kWh (Kampot Power Plant, December 2007) to 34.9 ¢/kWh (SHC Ratanak Kiri), etc. (source: EAC annual report for 2007).

3.5 ELECTRICITY DEMAND IN CAMBODIA

3.5.1 Historical Change in Electricity Demand in Cambodia

Figure 3.5.1 illustrates change in the peak demand and energy demand of EDC supply area during the past decade. Annual average growth rate during the past decade was 15.3% for peak demand and 17.3% for energy demand. Except for year 1999 affected by the Asian economic crisis, they had been growing rapidly at growth rate of 12 – 35% per year. Especially, peak demand shows stable increase, and achieved more then 20% increase per annum for two consecutive years from 2004 and 2006. Expansion of the EDC's supply area and their enhancement of generating capacity were considered to realize potential demand in the country.

Based on the Cambodia's annual average GDP growth rate of 9.2% during the past decade, demand elasticity with respect to GDP during the period was calculated at 1.67 for peak demand and 1.86 for energy demand.



Source: EDC Annual Report 2006, EDC Statistical Handbook 1995-2005

Figure 3.5.1 Change in the Energy Demand and Peak Demand in EDC Supply Area (1997-2006)

3.5.2 Review on Existing Demand Forecasts in Cambodia

Planning office of energy development department of MIME has a responsibility of demand forecast in Cambodia. In reality, MIME usually adopted the demand forecast made under the study of international cooperation project, after providing comments on the study.

Recently, demand forecast of Cambodia was made by two different corporations namely KEPCO (Korea Electric Power Corporation) and EGAT (Electricity Generating Authority of Thailand). The former was made under the "Power Development Master Plan" financed by the World Bank, and the latter was prepared under the "Establishment of Electricity Network Master Plan in Cambodia" financed by EGAT's own resources. Final reports were submitted by KEPCO in December 2006 and by EGAT in May 2006.

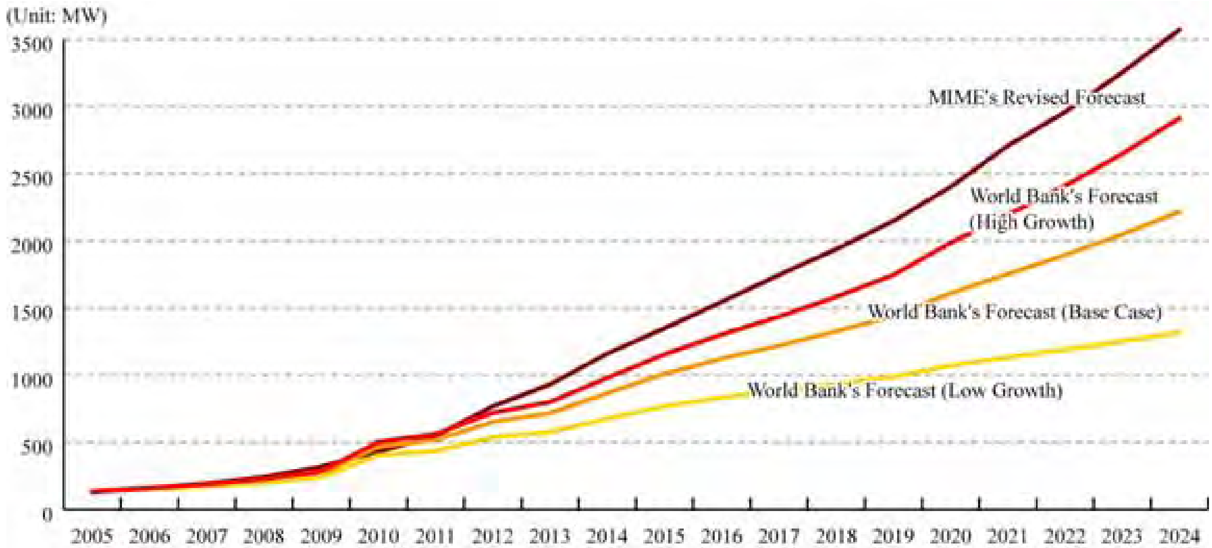
Of which, MIME has judged the World Bank's forecast was more dependable than that of EGAT, and thus selected the World Bank's base case forecast as the official demand forecast in the country. After that, taking recent rapid increase in the demand in the country, MIME has revised the forecast based on the

World Bank's high growth case forecast in December 2007. The revised forecast was then approved by the Government in January 2008.

These forecasts included not only demand of whole country but also demand of the EDC's main grid. The EDC's main grid is currently only covering capital city of Phnom Penh and its surrounding areas. Demand forecast of the main grid was made taking the Cambodia's transmission expansion plan into consideration.

The EDC's main grid occupied only 38% of total electricity demand in the country in 2005. The EDC's main grid is forecast to supply 71% of the total demand in 2010 after the connection with Sihanoukville System, 88% in 2012 after connection with Siemreap - Battambang System, and covering most of demand in the country in 2024 (96%).

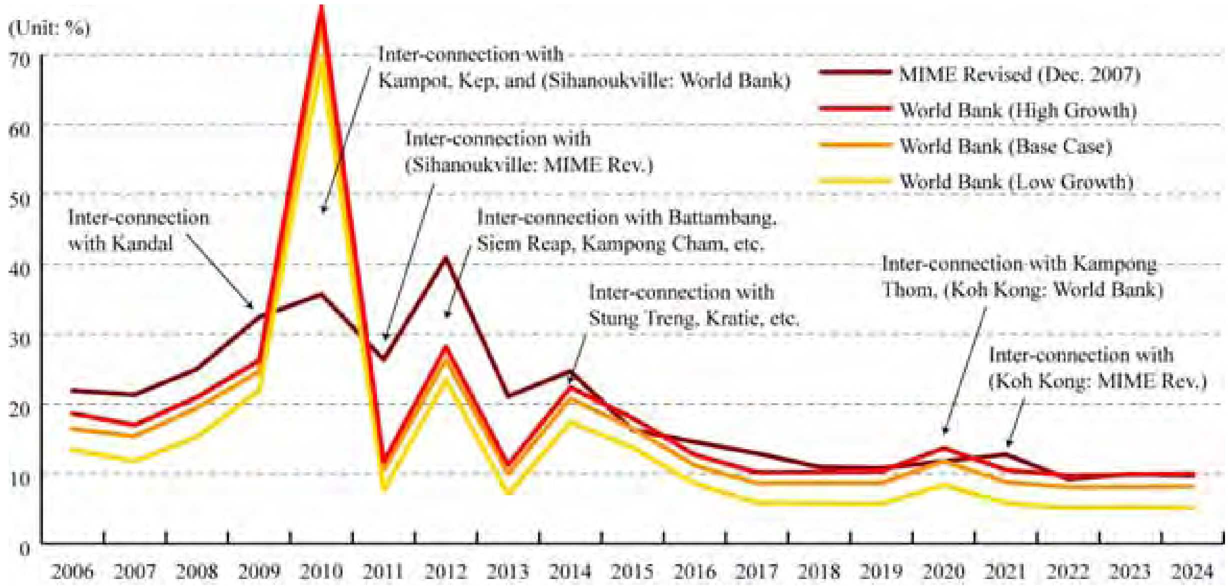
The relation between the World Bank's forecast (low growth, base case, and high growth scenario) and MIME's revised forecast are illustrated in Figure 3.5.2. As shown in the Figure, the official forecast shows much higher growth in electricity demand. According to the World Bank's forecast, peak demand was forecast to increase from 134 MW in 2005 to 1,316 MW (low growth scenario), 2,216 MW (base case scenario) and 2,912 MW (high growth scenario) in 2024. Annual average growth rates of each scenario are 12.1% (low growth scenario), 15.5% (base case scenario) and 17.3% (high growth scenario). On the other hand, MIME's revised forecast indicates annual average growth rate of 18.8%, and peak demand of 3,571 MW in 2024.



Source: Power Development Master Plan, World Bank/KEPCO、MIME

Figure 3.5.2 Comparison of the Peak Demand of the Main Grid System (World Bank's Forecast vs. MIME Revised Forecast)

Figure 3.5.3 illustrates year-wise growth rates of the forecasts above. The main grid's power demand will increase rapidly when the gird system will be connected with the other isolated gird systems. The World Bank's forecast was prepared based on the transmission expansion plan prepared by them. On the other hand, since MIME also revises the World Bank's transmission expansion plan, timing of demand increase (namely timing of inter-connection with the other systems) are different.



Source: Power Development Master Plan, World Bank/KEPCO、MIME

Figure 3.5.3 Comparison of the Growth Rate of the Peak Demand of the Main Grid System (World Bank's Forecast and MIME Revised Forecast)

Table 3.5.1 Peak Demand of the Main Grid System (World Bank's Forecast and MIME Revised Forecast)

	World Bank/ KEPCO			MIME Revised
	Low Growth	Base Case	High Growth	
"2005"	134.00	134.00	134.00	129.96
"2006"	152.00	156.00	159.00	158.43
"2007"	170.00	180.00	186.00	192.22
"2008"	196.00	215.00	225.00	240.27
"2009"	239.00	268.00	284.00	318.19
"2010"	404.00	467.00	502.00	431.74
"2011"	435.00	516.00	561.00	545.51
"2012"	537.00	652.00	719.00	768.46
"2013"	575.00	717.00	800.00	930.64
"2014"	675.00	866.00	979.00	1160.36
"2015"	768.00	1009.00	1155.00	1349.12
"2016"	834.00	1122.00	1302.00	1545.79
"2017"	883.00	1219.00	1435.00	1745.74
"2018"	934.00	1325.00	1582.00	1937.49
"2019"	987.00	1440.00	1746.00	2147.54
"2020"	1070.00	1610.00	1985.00	2400.88
"2021"	1132.00	1752.00	2195.00	2707.83
"2022"	1190.00	1894.00	2409.00	2958.47
"2023"	1252.00	2048.00	2647.00	3253.65
"2024"	1316.00	2216.00	2912.00	3571.42

Source: Power Development Master Plan, World Bank/KEPCO、MIME

3.6 ENERGY RESERVES AND ELECTRICITY DEMANDS IN CAMBODIA AND NEIGHBORING COURTIERS

Unlike Japan, Indonesia, and Philippines, Cambodia is located on a continent and have border with Thailand, Vietnam, and Laos. In recent years, electricity trading among GMS*[2] countries using interconnected transmission have been progressively progressed. 115 kV transmission line connecting the Thai boarder via Banteay Meanchey and to Battambang and to Siemreap will be completed in 2008. Also, 230 kV transmission line connecting the Vietnam boarder to Phnom Penh through Takeo will be energized in 2009.

Interconnected transmission lines among Cambodia and its neighboring countries will be utilized mainly for importing electricity from the neighbors to Cambodia in short term. However, if Cambodia is able to have hydropower stations that can generate stable electricity at reasonable price, neighboring countries may become potential “market” of electricity export from Cambodia. Therefore, this section will examine possibility of electricity export from Cambodia to the neighbors thorough review of demand forecasts and power development plans of these countries.

3.6.1 Population, GDP and Electricity Consumption

Table 3.6.1 compares population, GDP, electricity consumption, and per capita electricity consumption in Cambodia and its neighboring countries. As the table shows, GDP and electricity consumption of Thailand were dominant with others. Cambodia is the second smallest among the countries, in terms of population, GDP, and electricity demand. Per capita electricity consumption of Cambodia was far below those of the other countries.

While Thailand and Vietnam occupied 73.7% and 24.8% of the total electricity consumption of 4 countries, the electricity consumption of Cambodia and Laos accounts only 0.8% and 0.7% respectively.

Table 3.6.1 Population, GDP and Electricity Consumption in Cambodia and its Neighbors

	Thailand	Cambodia	Vietnam	Laos
Population	65,068,149	13,995,904	85,262,356	6,521,998
GDP (million $)	206,338	7,272	60,995	3,437
Electricity Consumption (GWh)	134,827	1,496	45,460	1,193
Per Capita Electricity Consumption (kWh/year)	2,072.1	106.9	533.2	182.9

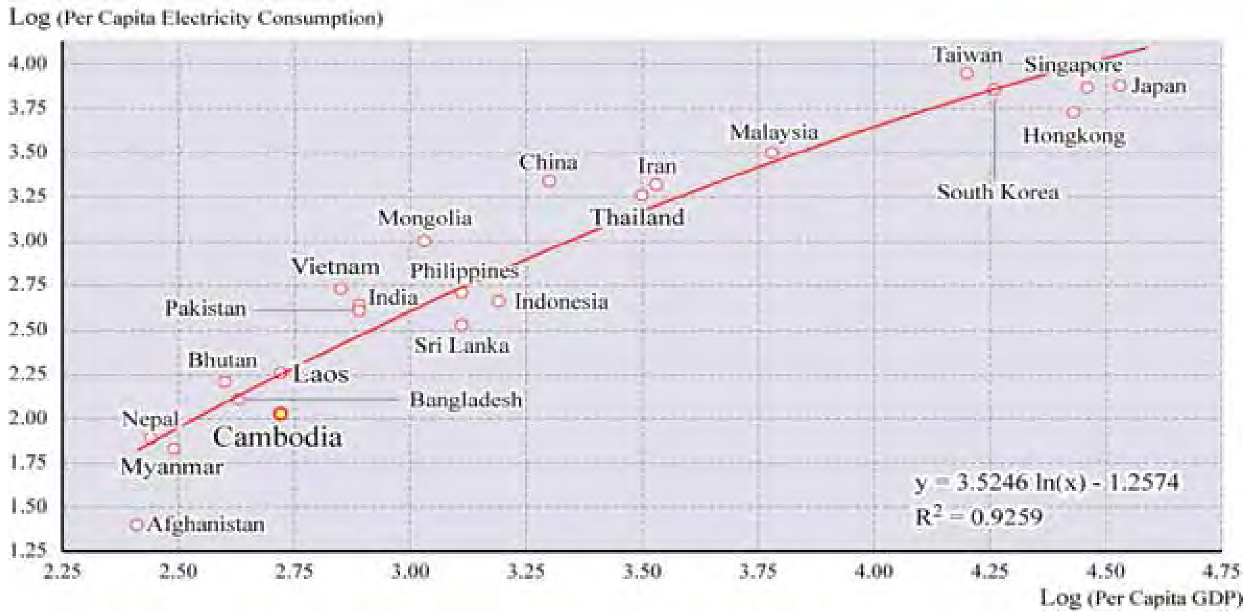
Source: Population= CIA World Fact Book (July 2007 estimated), GDP= IMF, World Economic Outlook Database, October 2007 (2006 data), Electricity Demand= EDC, EGAT and World Energy Outlook 2007 (2005 data)

Figure 3.6.1 illustrates the correlation between per capita GDP (2006 data) and per capita electricity consumption (2005 data) of the major Asian countries. The Figure shows obvious positive correlation between these indicators. Red line indicates approximating curve of data. Points of Thailand, Vietnam,

[2] The Greater Mekong Sub-region (GMS) comprises Cambodia, China, Laos, Myanmar, Thailand, and Vietnam.

China, and India were located above the approximating curve, which indicates these countries were consuming more electricity to achieve certain amount of GDP compared with others.

Countries located below the approximating curve are achieved GDP with relatively lower electricity consumption. Of these countries, in the case of Japan, Singapore and Hong Kong, well-developed tertiary industries and advanced energy conservation technologies are considered to have contributed to energy saving. Although Cambodia, Myanmar and Afghanistan are plotted below the line as well, insufficient electricity infrastructure seems to have suppressed the electricity consumption.



Source: a) CIA World Fact Book 2007 (2007 estimated), b) IMF, World Economic Outlook Database, October 2007 (2006 data), c): World Energy Outlook 2007 (2005 data)

Figure 3.6.1 Correlation between per capita GDP and Electricity Consumption of the Major Asian Countries

3.6.2 GDP and Electricity Demand in Cambodia and its Neighbors

Table 3.6.2 compares growth of GDP and electricity demand of 4 countries for past and coming decades.

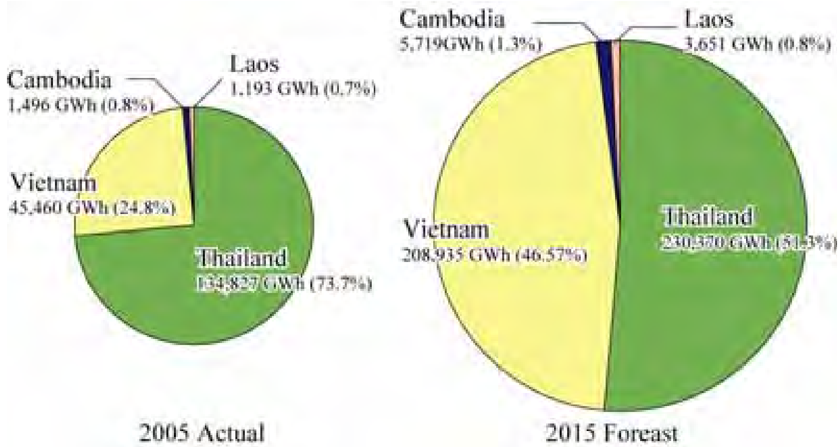
Table 3.6.2 Growth of Electricity Demand and GDP of Cambodia and its Neighbors

	Thailand	Cambodia	Vietnam	Laos
Growth of GDP during the past decade [*a]	1.30 times	2.33 times	1.99 times	1.84 times
Growth of electricity demand during the past decade [*b]	1.62 times	5.26 times	3.84 times	3.88 times
Growth of electricity demand during the coming decade [*c]	1.72 times	2.88 times	4.58 times	2.27 times
Growth rate of electricity demand during the coming decade [*c] (annual average %)	5.58%	11.16%	13.62%	8.54%

Source: a=The World Bank (1996- 2006), b=national power company in each country (Laos: 1995- 2005, other countries: 1996- 2006), c= Cambodia: MIME, Laos: Power System Development Plan 2004 EDL, Thailand: Power Development Plan 2007, EGAT, Vietnam: 6th Power Development Plan Revised, Institute of Energy

GDP of Cambodia, Vietnam and Laos were about doubled (1.84 times - 2.33 times) in real term during the past decade (1997 – 2006). Electricity demand in these countries had increased more rapidly, and had increased 3.84 - 5.26 times during the period. On the other hand, in the case of Thailand, which achieved economic development much earlier than the others, growths of GDP and electricity demand were slower than the others.

Electricity demands of 4 countries are forecast to increase at annual average growth rates of 5.6% - 13.6% and increase from 1.72 times to 4.58 times during the coming decade. As a result of rapid growth (13.6% per annum), Vietnam's electricity demand is forecast to share 46.6% of the total demand in 4 countries in 2015. In the case of Cambodia, even if envisaged demand growth (11.1%) is realized, electricity demand of the country will occupy only 1.27% of the total demand in 4 countries.



Source: MIME of Cambodia, EGAT/TLFS, Institute of Energy/ EVN, and EDC

Figure 3.6.2 Energy Demand of Cambodia and its Neighbours in 2005 and 2015

3.6.3 Energy Resources and its Usage in Cambodia and its Neighbors

Electricity demands of Cambodia and its neighbors were reviewed previously. In addition, this section will review energy resources and its use for electric generation in above-mentioned 4 countries as well as Myanmar, which will be potential competitor in exporting electricity to Thailand.

Substantial energy reserves are available in GMS countries, but being the same as electricity demand, they are unevenly distributed between these countries. Myanmar and Vietnam are rich in both fossil energy resources and hydropower resources. In the case of Thailand, the country is rich in the fossil energy resources. Of fossil energy reserves in Thailand, their coal resources are mainly lignite (brown coal) which has high inherent moisture content, and very high ash content compared with bituminous coal, and thus are not suitable for power generation.

Table 3.6.3 Energy Reserves and Resources in Cambodia and its Neighbors

	Thailand	Cambodia	Vietnam	Laos	Myanmar
Hydropower (MW)	8,314*2	10,000*1	20,500*3	26,500*1	108,000*1
Oil (Million Barrel)	527*4	0*4	3,119*4	0*4	199*4
Natural Gas (Billion Ft^3)*	1,250*4	0*4	830*4	0*4	1,765*4
Coal (Million short ton)*	1,493*4	7*4	3,972*5	600*1	2*4

Source: *1: ASEAN Secretariat, 2002, *2: EGAT Hydropower Database, *3: Vietnam, Institute of Energy, *4: BP (British Petroleum) Statistical Review of World Energy, June 2006, *5: Vietnam, Ministry of Industry, End of 2003

Cambodia and Laos have limited fossil energy resources, but are rich in the hydropower resources enough to satisfy domestic demand. Taking load characteristics of hydropower station and seasonal fluctuation of hydrology into consideration, it is, however, impossible to depend all the generation on hydropower. Since hydropower potentials of Cambodia have not been developed yet, the country heavily depends on imported fuel oil and electricity import from Thailand and Vietnam.

Hydropower

Hydropower resources in Laos, Myanmar are abundant and exceed those countries' own demand. Hydropower potentials in Laos are particularly rich in northern part of the country in the Mekong River Basin. In the case of Myanmar, hydropower potentials are abundant in the Irrawaddy and Salween River Basin. Vietnam has rich potentials in the Hong River Basin in Northern part of the country.

Source: EGAT Hydropower Engineering Division

Figure 3.6.3 Major Tributaries in Indochina

Compared with these countries, hydropower resources in Cambodia are inferior, because of relatively flat geographical features and less rainfall. Even though, they are sufficient for satisfying domestic demand and may meet the export demand to some extent. On the other hand, Thailand has already developed their major hydropower potential, and thus there is no major hydropower station development plan in the future, except for small hydropower projects (installed capacity less than 10 MW).

In the case of Laos, which is rich in the hydropower resources, electricity generation at domestic power stations for the EDL grid was all of hydropower. The ratios of the electricity production from hydropower stations to total electricity production in the country of Vietnam and Myanmar were also high at 40.1% and 49.8%, respectively. In the case of Thailand which has limited potential compared with their domestic demand, the ratio was only 4.4%. Since hydropower in Cambodia has not been developed yet, the ratio in Cambodia was only 5.0% in 2005.

Table 3.6.4 Generation by Hydropower and its Occupation to Total Generation in 5 Countries

	Thailand	Cambodia	Vietnam	Laos	Myanmar
Generation by Hydro (GWh)	5,798	44	21,454	1,345	2,997
% to whole generation	4.4%	5.0%	40.1%	100.0%	49.8%

Source: OECD, IEA Database (2005 data)

Coal

Good quality coal deposits exist in the Northern Vietnam mainly in Quang Ninh Province. In 2005, electricity production from coal-fired thermal power stations accounted for 16.7% of the country's total electricity production. The Vietnamese government plans to increase the contribution of coal-fired power plant up 40% of the total electricity production by 2025.

Lignite (brown coal) deposits in Thailand are unlikely to be exploited further due to a combination of economic and environmental reasons unless cost-efficient emission control technologies are advanced. EGAT currently operating 2,400 MW lignite fired power station, and was generating 15.1% of the total generation in the country. But EGAT has no plan to construct coal-fired power stations using domestic lignite any more (power development plan in Thailand and Vietnam will be mentioned in Section 3.7).

Myanmar is producing certain amount of coal, and 86% of total production in the country was exported to abroad. And no coal was utilized for the electricity generation in the country. Cambodia and Laos currently have neither active coal mines nor the coal-fired power stations.

Table 3.6.5 Coal Production, Import/Export and Consumption in 5 Countries

	Thailand	Cambodia	Vietnam	Laos	Myanmar
Production (1,000 ton)	20,878	0	32,396	No Data Available	1,360
Imports (1,000 ton)	8,572	0	101		0
Exports (1,000 ton)	0	0	-17,987		-1,164
Domestic Supply (1,000 ton)	29,618	0	14,510		196
- Electricity Plants (1,000 ton)	17,276	0	3,807		0
- Others (1,000 ton)	12,342	0	10,703		196
Stock Changes (1,000 ton)	168	0	0		0
Generation by Coal (GWh)	19,974	0	8,941	0	0
% to whole generation	15.1%	0.0%	16.7%	0.0%	0.0%

Source: OECD, IEA Database (2005 data)

Natural Gas

There are substantial recoverable reserves of natural gas, mainly from offshore fields in Myanmar, Thailand and Vietnam. Vietnam and Myanmar are exporting 21% and 78% of natural gas to the other counties, respectively. Although Thailand's natural gas productions were about twice of Myanmar and thrice of Vietnam, it was not enough to satisfy huge domestic demand. And thus, Thailand imports natural gas from abroad (mainly from Myanmar).

Electricity generation of Thailand heavily depends on natural gas. In 2005, natural gas-fired power stations solely generated 71.4% of the total generation in Thailand. Natural gas is also important source of electricity generation in Vietnam and Myanmar. Vietnam and Myanmar were dependent on gas-fired power stations for 39.0% and 39.8% of their total generation, respectively. Cambodia and Laos have neither natural gas resources nor gas-fired power station.

Cambodia has six potential oil and gas fields in off-shore Sihanoukville. One of them has so far been explored. A foreign consortium led by Chevron including GS Caltex of South Korea and Japan's Mitsui Oil confirmed "significant finds" from its initial exploration in 2005 and then more test drills were conducted. However, the technical and financial feasibility of exploration has not been confirmed yet.

Table 3.6.6 Natural Gas Production, Import/Export and Consumption in 5 Countries

	Thailand	Cambodia	Vietnam	Laos	Myanmar
Production Volume (TJ)	860,821	0	288,471	0	457,413
Export Volume (TJ)	0	0	-59,829	0	-358,856
Import Volume (TJ)	345,246	0	0	0	0
Domestic Consumption (TJ)	1,206,067	0	228,642	0	98,557
- Electricity Plants (TJ)	884,734	0	223,991	0	34,584
- Others (TJ)		0		0	
Generation by Natural Gas (GWh)	94,419	0	20,856	0	2,396
Percentage to whole generation (%)	71.4%	0.0%	39.0%	0.0%	39.8%

Source: OECD, IEA Database (2005 data) Note: TJ= 1,000,000,000,000 Joule

Oil

While Thai, Myanmar, and Vietnam are producing oil within the countries, its contribution for power generation sector is limited. On the other hand, Cambodia manages to meet all of their domestic oil demand by import, and 95% of the total electricity production in the country was by fuel oil.

Table 3.6.7 Oil Production, Import/Export and Consumption in 5 Countries

	Thailand	Cambodia	Vietnam	Laos	Myanmar
Production Volume (1,000 ton)	50,317	0	19,056	0	1,687
Imports Volume (1,000 ton)	41,791	1,223	12,005	No Data Available	1,251
Exports Volume (1,000 ton)	-8,514	0	-18,247		-395
Stock Changes (1,000 ton)	1,086	0	-633		0
Domestic Supply (1,000 ton)	84,680	1,223	12,181	2,950	2,543
- Electricity Plants (1,000 ton)	1,963	338	682	No Data Available	145
- Others (1,000 ton)	82,717	885	11,499		2,398
Generation by Oil (GWh)	5,798	836	2,482	0*	622
% to whole generation	6.6%	95.0%	4.6%	0.0%*	10.3%

Source: OECD, IEA Database (2005 data) Note: * EDL Supply Area Only

3.7 MARKET PROSPECTS OF ELECTRICITY EXPORT TO THAILAND, AND VIETNAM

Thailand, Vietnam and Laos share respective boarders with Cambodia. Of these, Laos is blessed with hydropower resources, while its domestic electricity demand is quite small at present. Accordingly, Laos is considered to be not “market” but “competitor” for the hydropower stations in Cambodia.

On the other hand, Thailand and Vietnam have huge domestic demand compared with Cambodia and Laos. Thailand aims at breaking heavy dependence on natural gas based generation. However, hydropower resources in Thailand has already been developed and quite limited potential remains for further development. The lignite reserve in Thailand is not suitable for power generation. In the case of Vietnam, while their domestic electricity demand is currently smaller than that of Thailand, it is expected to grow rapidly along with favorable economic development. In addition, since hydropower potentials of the southern part of Vietnam bordering with Cambodia is relatively small, lack of peak generation capacity in the area is being forecast.

Taking the given conditions above into consideration, possibility of electricity export from the Cambodia’s hydropower stations was examined below only for Thailand and Vietnam.

3.7.1 Thailand

(1) Historical Change in the Electricity Demand

Growth rate of electricity demand in Thailand recorded negative figures in 1998 and 1999 due to Asian economic crisis hit the country. Growth rates of electricity demand reached around 8% in 2000, and thereafter fluctuated between the ranges from 2% to 9% with gradual decreasing trend (see Figure 3.7.1).

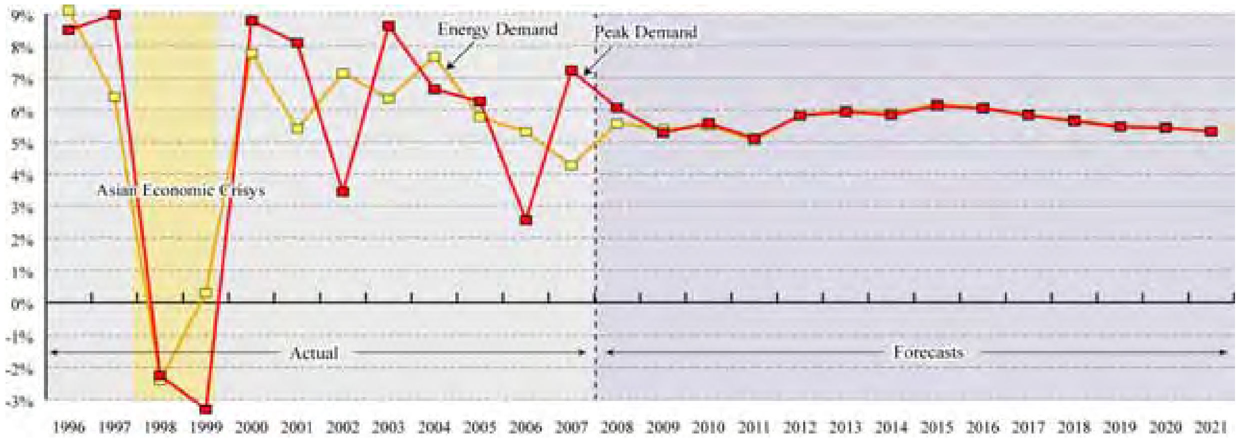
(2) Demand Forecast

Demand forecast in Thailand is made by Thailand Load Forecast Sub-committee (TLFS), which consists of Electricity Generating Authority of Thailand (EGAT), Metropolitan Electricity Authority (MEA)[*3], Provincial Electricity Authorities (PEAs), the Association of Private Power Producers, Department of Alternative Energy Development and Efficiency (DEDE), Energy Policy and Planning Office (EPPO), National Economic and Social Development Board (NESDB), Thailand Development Research Institute (TDRI), the Federation of Thai Industries (FTI), and Board of Trade of Thailand.

The latest demand forecast covering the 15 years period (2007 - 2021) was prepared in September 2007, which was already approved by the National Energy Policy Committee (NEPC) and the Cabinet. According to the forecast, energy demand is expected to increase from 142,005 GWh in 2006 to 320,376

[3] The MEA is responsible for distributing power to customers in the Bangkok Metropolitan area, including Nonthaburi and Samut Prakan provinces. The PEA is tasked with distributing power to customers in the rest of the country.

GWh in 2021 with an annual average increase rate of 5.57%. Also, peak demand is forecast to grow from 21,064 MW in 2006 to 48,958 MW by 2021 with an annual average increase rate of 5.78%.



Source: EGAT and TLFS (Thailand Load Forecast Sub-committee)

Figure 3.7.1 Past Trend and Forecast of Energy Demand and Peak Demand in Thailand

According to NSEDB's GDP forecast, GDP will increase at 5.0% per annum during 2007 – 2011, 5.58% during 2012 – 2016, and 5.60% during 2017-2021 in real term. This forecast was made based on 3.5 - 4.7% growth of world economy and $55–60 of crude oil price. High growth and low growth scenario forecasts were ±0.5% of base case forecast.

Electricity demand elasticity to GDP[*4] was 1.11 for Bangkok metropolitan area (MEA supply area) and 1.65 for other area (PEA supply area) during 2001 - 2006. Government of Thailand as well as EGAT aims at realizing the average demand elasticity of 1.0 (MEA: 0.65, PEA: 1.10) by 2021 by promoting demand side management (DMS). This elasticity was adopted in the base case forecast.

(3) Power Development Plan

Peak demand was forecast to increase by 27,894 MW during 2007 - 2021. To cope with such increasing demand, augmentations of generating capacities to 32,151 MW are being planned in the EGAT's National Power Development Plan 2007. There are 3 alternative scenarios, B1) minimize long-run marginal cost (LRMC) of the power system, B2) minimize LRMC with the limitation on the number of coal-fired power plants[*5] to 700 MW x 4 units, and B3) minimize LRMC with the limitation on the number of coal-fired power plants to 700 MW x 4 units as well as the limitation of LNG import at 10 million ton per year.

These alternatives have been proposed to the NEPC for approval. In June 2007, the NEPC and the Cabinet approved B2 plan as the recommended plan and the B3 plan as an alternative plan.

4 Here, elasticity is the ratio of the proportional change in electricity demand with respect to proportional change in GDP. Generally, electricity demand elasticity to GDP gradually decreases along with the economic development. For example, the elasticity of Japan was about 1.2 during the period of rapid economic growth (1955 - 1973). The central research institute of Energy in Japan forecast the elasticity at 1.01 during 2000 – 2010, 0.90 during 2010 – 2020, and 0.71 during 2020 – 2025.

5 Lignite (brown coal)-fired power stations in Thailand had no flue gas desulphurization facility at the inception stage of their operation, and thus causing serious environmental pollution. In order to reduce the impacts on the environment, EGAT plans to import high quality coal from Australia. However, protest movement against coal-fired power station is still intense. (Reference: hearing from EGAT, and NEDO documents)

Thailand has a high degree of expectation for energy import from neighboring countries, particularly from Laos, Myanmar and China. The recommended plan envisaged 5,451 MW of power import from neighboring countries in 2021. The alternative plan envisaged 13,851 MW of power import in the same year (see Table 3.7.1). Both plans well exceed current import from Malaysia and Laos at 640 MW (detail will be mentioned later on).

Table 3.7.1 Generating Capacity of Thailand by Fuel Type in 2021

	Gas C.C.	Coal	Nuclear	Biomass/ Small Hydro	**Import**	Total
Recommended Plan	18,200 MW	2,800 MW	4,000 MW	1,700 MW	**5,451 MW**	32,151 MW
Alternative Plan	9,800 MW	2,800 MW	4,000 MW	1,700 MW	**13,851 MW**	32,151 MW

Source: Thailand Power Development Plan 2007, EGAT

There seems no suitable site for developing large-scale hydropower station in Thailand. While the PDP 2007 lists up several small and medium scale hydropower stations of less than 10 – 90 MW by SPP (Small Power Producer) and below 10 MW by VSPP (Very Small Power Producer), large-scale hydropower plant is not under planning.

According to the Hydropower Engineering Division of EGAT, there are 23 promising candidate small hydropower sites with installed capacity of more than 2.0 MW (total installed capacity of 146 MW, total annual generation of 461 GWh, average construction cost of 44,164 Bath/kW or $1,419/kW, and average generation cost of 2.4 Bath/kWh or 7.71 Cent/kWh). In addition, 50 hydropower projects utilizing the existing irrigation dams were identified by EGAT (total install capacity of 168 MW, total annual generation of 544 GWh, average construction cost of 48,113 Bath/kW or $1,546/kW, and average generation cost of 2.57 Bath/kWh or 8.26 ¢/kWh).

(4) Electricity Trade Plan

The National Power Development Plan 2007 (the PDP 2007) plans to depend considerable amount of supply capacity on import from neighboring countries, which is expected to account for 17.0% (recommended plan) or 43.1% (alternative plan) of the capacities to be added during the period from 2008 to 2025. Import volume of electricity will be increased from 4,461 GWh in 2007 to 28,627 GWh (recommended plan) or 91,124 GWh (alternative plan) in 2021.

The PDP 2007 includes year-wise commissioning plan of power stations from 2007 – 2021, which included power import from neighboring countries. According to the power import from neighboring countries included in the year-wise power station commissioning plan, specific projects names were only given for 6 hydropower projects in Laos, which are the Nam Theun 2 (920 MW, 2010), the Nam Ngum 2 (597 MW, 2011), the Theun Hinboun expansion (220 MW, 2012), the Nam Ngum 3 (440 MW, 2013), the Nam Theun 1 (523 MW, 2013), and the Nam Ngiep (261 MW, 2014). Of these, power purchase agreements have already conclued for the Nam Theun 2 the Nam Ngum 2.

Other candidate hydropower stations for import (3,060 MW: recommended plan, and 11,450 MW: alternative plan) were not identified, and were only mentioned as "power purchase from neighboring countries". The PDP 2007 mentioned the Hong Sa hydropower station (1,800 MW, Laos), the Hutgyi hydropower station (1,200 MW, Myanmar), the Tasang hydropower station (7,000 MW, Myanmar), and the Chiang Tung coal-fired power station (270 MW, China) as the promising projects. However, these projects were not listed in the said year-wise commissioning plan of the PDP 2007.

As mentioned, Thailand has high degree of expectation for the hydropower projects in Laos and Myanmar. In the case of Myanmar, EGAT especially pays great attention to the large-scale hydropower projects along the Salaween (Thanlwin) River in the Eastern Myanmar, located near the Thai boarder. According to the document prepared by the hydropower Engineering Division of EGAT, 6 hydropower projects along the Salaween River with total installed capacity of 13,600 MW were mentioned as promising projects, including the Tasang (7,000 MW), the Upper Salaween (4,000 MW), and the Hutgyi (1,200 MW, under construction). However, since there are serious concerns about unstable security and political issues in Myanmar especially in the eastern part of the country, being in the Salaween River Basin, smooth project implementation cannot be expected[*6].

(5) Possibility of Electricity Export to Thailand

The PDP 2007 did not mention about electricity import from Cambodia. However, if the price of electricity is reasonable, EGAT have willingness to purchase electricity from Cambodia. EGAT is particularly paying attention to the Koh Kong coal-fired power station and the Stung Metoek (Stung Mnam) hydropower station as candidates.

The Koh Kong coal-fired power station is being planned for construction in Koh Kong Province, West Cambodia. Italian-Thai development corporation (ITD), one of the biggest construction company in Thailand, plans to hold 30% of the share, EGCO and RATCH holds 20% each, Chinese company holds 15%, EAT International holds 8% and Sinothai, construction company in Thai, holds 7% share. According to their plan, the generating capacity of 1,830 MW (915 MW x 2 units) will become available in 2019, and additional 1,830 MW (915 MW x 2 units) will be commissioned in the succeeding year.

According to the document prepared by the Hydropower Engineering Division of EGAT, major features of the Stung Mnam (Stung Metoek) hydropower station are as follows; installed capacity of 103 MW, annual generation of 479 GWh, plant factor of 53%, and construction cost of $160 million.

In addition, the Stung Russey Chrum (installed capacity of 210 MW, annual generation of 718 GWh, plant factor of 40.2%, and construction cost of $240 million) was listed as a promising project by the Hydropower Engineering Division of EGAT.

6 According to the Bangkok Post, 5 September, 2007, one staff of EGAT was killed by the Karen's antigovernment armed group at the construction site of the Hutgyi hydropower station (1,200 MW). Since then, construction work has been suspended. Also, a geologist was killed by the land mine in May 2005. 3 Thai workers were seriously injured by the attack of the guerrillas.

The planned hydropower projects in Laos and Myanmar are expected to have bigger generating capacity and lower generation cost based on well-endowed hydrological conditions and geographic features. It seems quite difficult for the hydropower projects in Cambodia to compete with the hydropower projects in Laos and Myanmar. However, number of committed hydropower projects with confirmed financial closure is limited in Laos. Also, taking possible security and political risk of Myanmar into consideration, there are still some chances to export electricity from Cambodia to Thailand.

Taking the huge Thailand's demand for electricity import into consideration, economically feasible hydropower potential in Cambodia needs to be developed as far as environmentally acceptable. Export of surplus power from Cambodia to Thailand during the rainy season as well as import of electricity from Thailand to Cambodia during the dry season will be in great need in the future.

3.7.2 Vietnam

(1) Change in the Electricity Demand

In recent years, electricity demand in Vietnam has increased rapidly along with the high economic growth in the country. Except for 1998 during the Asian economic crisis hit the country, peak demand has increased at growth rates of more than 10% per annum. Particularly, growth rates of peak demand exceeded 15% in 2000 and 2001 (see Figure 3.7.2).

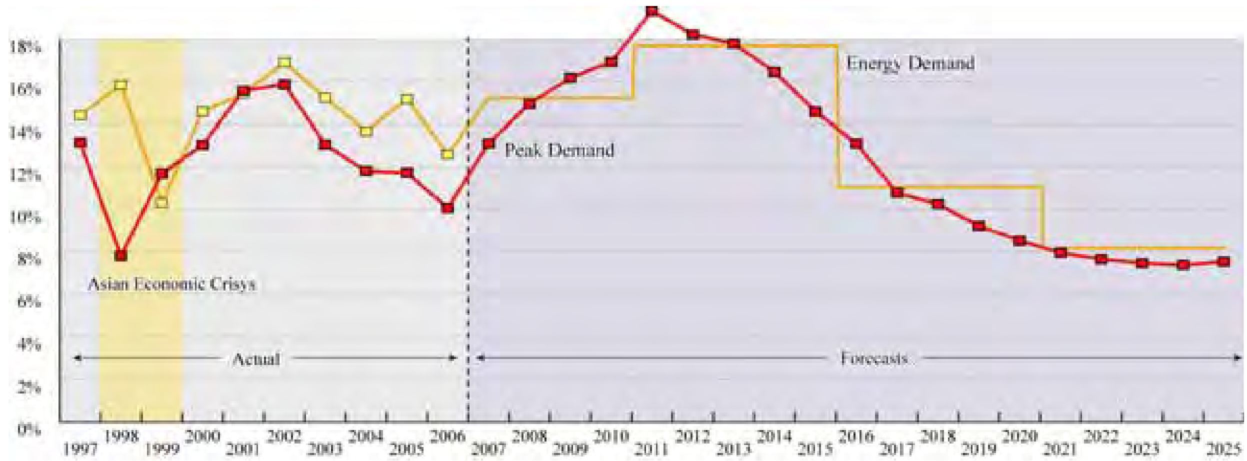
(2) Demand Forecast

Demand forecast, power development plan, and transmission expansion plan in Vietnam are prepared by the Institute of Energy, and then Minister of the Ministry of Industry and Prime Minister will approve these. The 6th National power development plan, covering 20 year period (2006 – 2025), was prepared in 2006 by the Institute of Energy, and then revised in July 2007. Demand forecast was also revised in July 2007 and is currently the latest available.

Demand forecast in Vietnam is deemed the bullish forecast based on the past rapid demand growth after recovery from the Asian economic crisis. According to the forecast, power demand is expected to increase from 53,462 GWh in 2005 to 592,341 GWh in 2025 at an annual average growth rate of 12.78%. Also, peak demand is forecast to increase from 9,255 MW in 2005 to 93,915 MW in 2025 at an annual average growth rate of 12.28% (the JICA Study[*7] in 2006 forecast the power demand of 11.15% per annum and peak demand of 10.39% per annum on an average). As such, both energy demand and peak demand are expected to grow to more than 10 times during the two decades from 2006 onwards.

Growth rate of peak demand is expected to increase progressively from 10.1% in 2006 to 19.3% in 2011, then shows gradual decline owing to the demand side management (see Figure 3.7.2).

[7] The study on national power development plan for the period of 2006-2015, perspective up to 2025 in Vietnam, JICA/ Tokyo Electric Power Co., Inc. and Tokyo Electric Power Services Co., Ltd., May 2006.



Source: Institute of Energy, Revised Forecast 2007
Note: Forecast of power demand shows average growth rate by 5 years period, due to data availability.

Figure 3.7.2 Past Trend and Forecast of Energy Demand and Peak Demand in Vietnam

Since the Vietnamese government intended to set more ambitious growth rates, demand forecasts made by JICA and the Institute of Energy were not approved by the government.

According to the forecast revised by the Vietnamese government, annual average growth rate of energy demand during 2006 – 2015 was 17% for Base Case Scenario, 20% for High Growth Case Scenario, and even 22% for Sudden Growth Case Scenario (GDP was forecast to grow at 8.5% to 9.0% per annum for these scenarios). The demand forecast was revised by the government politically disclosing the methodologies and assumptions.

(3) Power Development Plan

1) Energy Mix and Electricity Trade in the Future

The Government of Vietnam places the highest priority on the hydropower projects (particularly multi-purpose projects, which contribute to flood control, water supply, and irrigation) in preparing a power development plan. However, since the promising hydropower potential sites are not enough to meet the envisaged high demand growth, the percentage of the installed capacity of hydropower plants to the total installed capacity of the grid is forecast to reduce gradually.

In 2007, installed generating capacity in the country consisted of 36.0% of hydropower, 43.5% of oil and gas-fired power stations, 14.3% of coal-fired power plants, 5.0% of import and 1.2% of renewable energy. According to the revised 6th national power development plan prepared by the Institute of Energy, the share of hydropower capacity is expected to reduce from 36.0% in 2007 to 24.9% in 2025. During the same period, the share of the gas and oil-fired power stations is also forecast to reduce from 43.5% to 19.8%.

On the other hand, coal-fired power station is expected to play vital role in the electricity supply, and to occupy 41.9% in 2025 by fully utilizing the rich coal reserves in the country, which is far higher than 14.3% in 2007. The share of power import is expected to increase slightly from 5.0% in 2007 to 6.2% in

2025. The Government of Vietnam plans to construct nuclear power stations with total installed capacity of 4,000 MW by 2025, which is equal to 4.7% of the total installed capacity in 2025.

2) Hydropower Development Plan in Vietnam

The Institute of Energy estimates total hydropower potential in the 11 major river basins in the country as 20,500 MW. Of these, 51.6% is in North, 31.9% is in Central, and only 16.5% is in South.

The revised 6th national power development plan shows that 4,063 MW of hydropower stations will be put into operation during 2007 – 2010, and 6,806 MW during 2011- 2015. However, new hydropower is expected to reduce 1,374 MW during 2016-2020, and only 200 MW during 2021 – 2025 (except for pumped storage hydropower station).

Total installed capacity of hydropower stations (except for pumped storage hydropower station) is expected to be 15,452 MW in 2015 and 17,026 MW in 2025, which account for 75% and 83% of the hydropower potentials in the country, respectively. As such, the slowdown of hydropower development will result from the lack of economic hydropower potentials.

To cope with the increasing peak demand, 600 MW to 1,200 MW of pumped storage hydropower stations are being planned for commissioning every year from 2019 onwards. Lack of sufficient power stations for meeting the peak demand is expected to become increasingly serious. Especially, it will be more serious in Southern Vietnam, which has smaller hydropower potential.

3) Hydropower Development Plan in the Mekong River Basin within Vietnam

Of the whole Mekong River Basin, 14% or 111,300 km^2 are located in Vietnam. The Se San River and the Sre Pok River, major tributaries of the Mekong River, flow across the boarder of Vietnam and Cambodia, and have rich hydropower potential.

In Vietnam, there are three hydropower stations in operation along the Se San Rivers, namely the Yali hydropower station (720 MW, commissioned in 2000 - 01, EVN), the Se San 3 hydropower station (260 MW, commissioned in 2006, EVN), and the Se San 3A hydropower station (108 MW, commissioned in 2006 - 07, IPP). In addition the Se San 4 hydropower station is under construction on the Se San River on the Vietnamese side by EVN. The power station will start operation in 2009 (120 MW) and in 2010 (240 MW). The Se San 4A hydropower station with installed capacity of 63 MW is under construction, and will be completed in 2010.

Currently there are no hydropower stations in operation on the Sre Pok River. According to the 6th revised National Power Development Plan, the Sre Pok 3 hydropower station (220 MW, 2010, EVN) and the Sre Pok 4 hydropower station (70 MW, 2012, IPP) are being planned.

Se San 3A (104 MW, IPP)
Source: Song Da Construction Corp.

Sre San 4 (120 MW, EVN) 7 Jan 2007
Source: Song Da Construction Corp.

(4) Electricity Trade Plan with Neighboring Counties

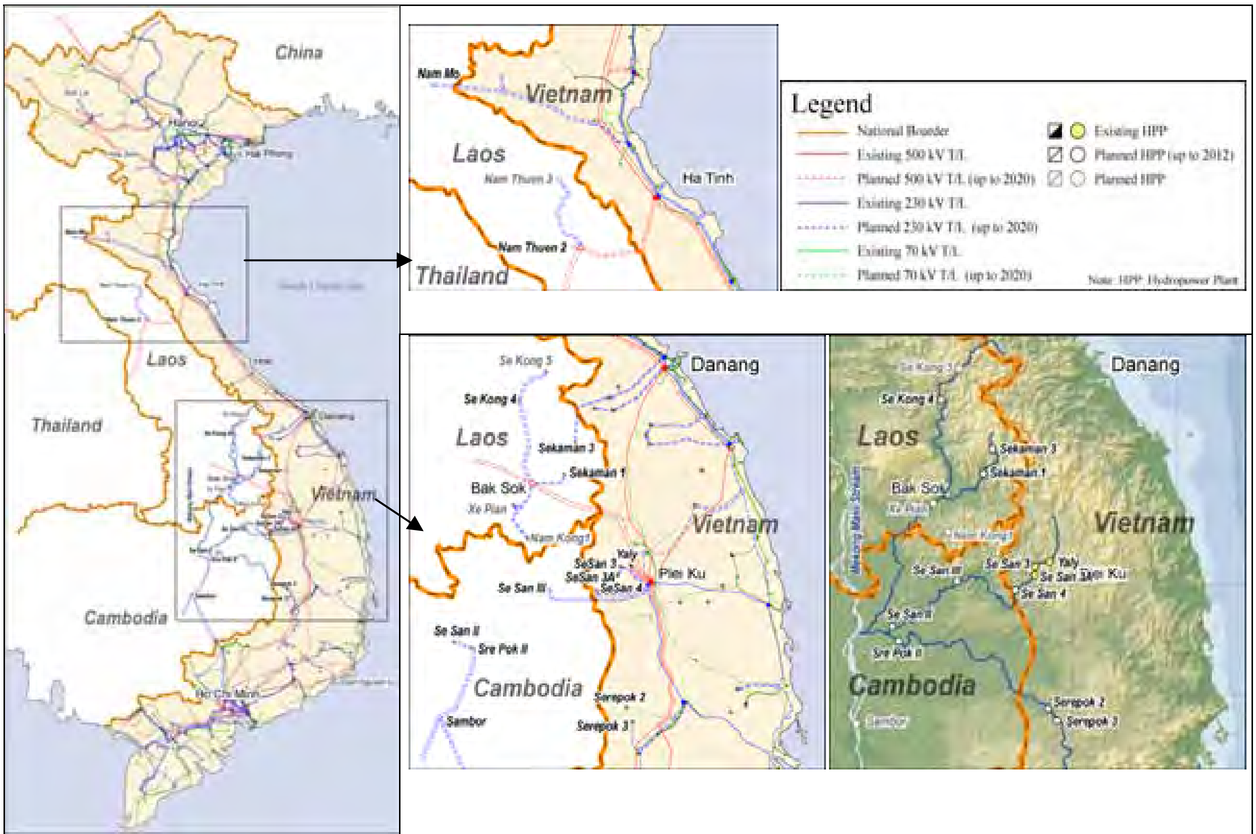
Currently, Vietnam import electricity from China through the 5 routes: 1) Hongha – Laocai (110 kV, single circuit), 2) Vanson – Hagiang (110 kV), 3) Van Son – Lao Cai (230 kV, double circuit), 4) Dong Hung – Mong Cai (110 kV, single circuit), and 5) Van Nam – Hiep Hoa (230 kV, double circuit). According to the Institute of Energy, average purchase price at the boarder is around 4.5 ¢/kWh. Since the sources of electricity are hydropower stations, no fuel surcharge is levied.

EVN also plans to construct the hydropower stations along the lower reach of the Sre Pok River and the Se San River on the Cambodian side in cooperation with Cambodia. MOUs of these projects have already obtained from the Government of Cambodia. In addition, the revised 6th national power development plan lists up 3 hydropower projects in Cambodia as the candidates, namely the Lower Se San 2 (207 MW, 2014), the Lower Sre Pok 2 (222 MW, 2015), and the Lower Se San 3 (375 MW, 2017).

Vietnamese side also have great interest on the hydropower projects on the Mekong Mainstream, namely the Sambor hydropower project with proposed installed capacity of 3,000 MW (China obtained MOU on F/S) and the Stung Treng hydropower project.

EVN plans to construct 230 kV transmission line connecting the Plei Ku substation in mid-western Vietnam and the Lower Se San 3. The Lower Se San 2, and the Lower Sre Pok 2 will be interconnected with the Binh Long substation in South Vietnam, 80 km northwest from Ho Chi Minh City, by 230 kV transmission line. If the 3,000 MW Sambor project is materialized, EVN will construct 500 kV transmission line between Sambor – Binh Long (refer to Figure 3.7.3).

Electricity generated at the Lower Se San 2 and the Lower Sre Pok 2 may be transmitted to the Southern part of Vietnam, expecting to meet the top and middle peak demand. However, since there is no re-regulating dam planned on the downstream reaches of the Sre Pok River that can absorb hourly fluctuation in the power discharges, it is forecast that peak power generation if made at these stations would have greater impacts compared to the operation with scheduled hourly pattern for middle load.



Reference: The 6th Revised National Power Development Master Plan, Institute of Energy and EVN documents

Figure 3.7.3 Hydropower Development Plan in the Mekong River Basin within Vietnam

The 6th revised national power development plan includes the import from the planned hydropower stations in Laos, which will be constructed by Joint Stock Company with Laos and EVN and/or Vietnam's private company. Son Da Corporation, the biggest construction company in Vietnam, already committed to invest in the Nam Mo (100 MW, 2012), and the Se Kaman 1 (488 MW, 2013). Power purchase price from the Se Kaman 1 would be slightly lower than 5.0 Cent/kWh.

EVN and Son Da Corporation plans to invest in the Se Kong 4 (475 MW, 2014), the Se Kong 5 (375 MW, 2016), the Nam Kong 1 (229 MW, 2016), and the Nam Theun (382 MW, 2019) or Nam U (382 MW, 2019). Most of the electricity generated at these power stations would be imported to Vietnam.

The Nam Mo is expected to supply electricity to the Northern Vietnam through 230 kV transmission line. The others will be interconnected to the Plei Ku or the Da Nang substation in Central Vietnam through 230 kV or 500 kV transmission line (see Figure 3.7.3).

(5) Possibility of Electricity Export to Vietnam

Electricity demand of Vietnam is unevenly distributed in the country, and is polarized in the capital city of Hanoi and its surrounding area in Northern Vietnam and in the Mekong Delta area in Southern Vietnam including Ho Chi Minh City. Northern part of the country is rich in hydropower resources, and thus the generating capacity of hydropower is dominant compared with that of thermal power stations. Southern Vietnam mainly depends on thermal power. Electric power is usually transmitted from north to south during the peak hours, and from south to north during the off-peak hours using 500 kV double circuit transmission line running across the country. Such distorted distribution of generating capacity and demand are deemed to remain unchanged also in the future.

According to the 6th revised National Power Development Plan, most of the promising hydropower site in the country is planned to be developed by 2020. There is concern about lack of the peak generating sources that have quick response to load changes. To meet the peak demand, costly pumped storage power as well as electricity import from neighboring countries are being planned in the 6th revised power development plan. Vietnam’s need for import of hydropower from neighboring countries is expected to be increasingly important in the future.

In recent years, EVN and Son Da Corporation are aggressively planning to develop hydropower projects in Cambodia and Laos, and to import electricity from them. Planned hydropower stations in Cambodia seem smaller in generating capacity and more expensive in generation cost compared to those in Laos and Southern part of China. However, Cambodia have chance to export electricity to Southern part of Vietnam, which is expected to be increasingly suffer from lack of peak generating capacity, fully utilizing the geographical advantage.

4. REVIEW OF 29 CANDIDATE PROJECTS

4.1 PAST STUDIES

4.1.1 Major studies in the past

Major studies conducted in the past on hydropower potential in Cambodia are as listed in Table 4.1.1. Except for Ref. 4.1 and Ref. 4.8, most of the studies are of desk level with limited hydrological data and on 1:50,000 topographic maps. As no field investigations had been conducted in the past, geological conditions particular to each site were not known.

Table 4.1.1 Major Studies in the Past

No.	Name of the Study	Outlines
Ref. 4.1	COMPREHENSIVE RECONNAISSANCE REPORT ON THE MAJOR TRIBUTARIES OF THE LOWER MEKONG BASIN September 1961 Government of Japan, Mekong River Study Team	Comprehensive and general investigations for 34 major tributaries of the lower Mekong basin. Based on the investigations, detailed investigations were conducted and reports were compiled for 16 prospective tributaries in terms of development interest. Study area covers four countries of Cambodia, Thailand, Laos, and Vietnam.
Ref. 4.2	Inventory of Promising Tributary Projects in the Lower Mekong Basin October 1971	Desk study results of promising projects in the Lower Mekong basin located in four provinces of Stung Treng, Ratanak Kiri, Mondul Kiri, Kratie.
Ref. 4.3	Inventory of Promising Water Resources Projects outside the Lower Mekong Basin November 1973	Desk study results of promising projects outside the Lower Mekong basin located in four provinces of Battambang, Pursat, Koh Kong, Kampot.
Ref. 4.4	Lower Mekong Water Resources Inventory September 1984	Review study of 149 water resources development projects in the Lower Mekong basin. Out of 149, 17 projects are in the stage of Pre-feasibility Study or Feasibility Study. The rest of 132 projects are in the desk study level.
Ref. 4.5	Mekong Mainstream Run-of-river Hydropower September 1984 MRC	A study on run-of-river type hydropower development in the mainstream of Mekong river, through review works using existing maps and reports. The study includes identification, formulation, screening, evaluation and prioritization of candidate projects.
Ref. 4.6	Review and Assessment of Water Resources for Hydropower and Identification of Priority Projects, Cambodia June 1995 MRC	An integrated study on hydropower development with the following four purposes: (i) Identify the priority area(s) for electrification through the development of hydropower projects; (ii) Formulate short- and medium-term development plans for hydropower projects to meet the power demand in the priority area(s). (iii) Prepare an inventory of promising projects for a long-term development plan of the whole country;

No.	Name of the Study	Outlines
		and (iv) Recommend further actions to be taken in the power sector relating to the hydropower development of the country.
Ref. 4.7	Se Kong – Se San and Nam Theun River Basins Hydropower Study July 1999 ADB	Potential studies and prioritization of 37 projects on three tributaries of the Lower Mekong basin.
Ref. 4.8	Comprehensive Development Study of Hydropower In Se San River Basin in Cambodia October 2006 EVN/PECC1	A comprehensive development study on projects located on the main river and tributaries of Se San river. Target project area is from the border of Cambodia and Vietnam down to the confluence of Se San and Sre Pok rivers. Target development scale is more than 30 MW.

4.2 INVENTORY OF 29 CANDIDATE PROJECTS

4.2.1 Conditions before formulating inventory of 29 candidate projects (confirmation of existing information)

Upon commencement of the Master Plan Study, the existing information on hydropower development, especially for the 29 candidate projects, were collected and arranged as summarized Table 4.2.1. The sources of data are shown at the bottom of the table. For the projects #7 Lower Sre Pok II and # 8 Lower Se San II, Electricity of Vietnam (EVN) is conducting a study that integrates both projects into one. The integrated project is to construct a dam at the confluence of the Se San and Sre Pok Rivers. This integrated project is also added into the list of candidate projects.

When one project has several studies in the past, each study is shown in the list.

As may be seen from Table 4.2.2, some projects have only their names and locations, without any detailed features for the development planning. For such projects, to confirm the necessary features for the first screening, the following additional desk studies were conducted:

1) Measurement of catchment area
2) Preparation of layout of power development, decision of power development type (selection of dam and power house locations)
3) Estimate of available discharge at the proposed dam site
4) Measurement and calculation of reservoir surface area and volume, preparation of area and capacity curves, estimate of sediment volume
5) Setting of full supply level (FSL), minimum operation level (MOL), and effective storage volume
6) Estimate of flood discharge
7) Setting of maximum plant discharge for power generation
8) Calculation of effective head
9) Calculation of firm peak power
10) Calculation of annual power generation
11) Construction cost estimate
12) Economic evaluation

Sediment volume was calculated with assumption of horizontal deposit using the specific sediment transport rate at 200 m^3/km^2/year, which was assumed as an average of existing estimates for dam development plans in the Indochina region. With this value, 100-year sediment volume and surface elevation of sediment deposits were estimated for each project. There are several cases of which 100-year sediment deposit level would affect the intake. Even for such case however, several countermeasures could be considered like: 1) difference in sediment production rate from river to river, 2) different deposition profile of sediment from the assumed horizontal deposition surface, 3) modification of intake shape (wide and low height rectangular shape of intake, to allow a higher sediment level), 4) introduction of several sediment flushing method using excess water during the flood season. In some projects, the sedimentation elevation became very high not to allow to keep flow regulation storage, i.e., the project is obliged to be planned as a run-of-river (RoR) type in view of the reservoir function. However, at this stage of the first screening, such project will not be screened out solely for that reason.

Table 4.2.1(1/2) The existing project features before starting Master Plan Study

No.		1	2	3	4	5	6	7	8	7 & 8		9	10	11	12	13	14	15
Project Name		**Sambor (*2)**	**Prek Chhlong II**	**Prek Ter III**	**Prek Ter II**	**Sre Pok IV (*2)**	**Prek Por I**	**Lower Sre Pok II**	**Lower Se San II**	**Lower Sre Pok II + Lower Se San II(*2)**		**Stung Treng**	**Se Kong**	**Lower Se San III**	**Prek Liang I**	**Prek Liang IA**	**Prek Liang II**	**Lower Sre Pok III(*2)**
(Different Name in the Report)						**(Upper Sre Pok 5 in MRC**												
	Unit																	
1. Source of Data (*1)		CPEC (1995)	CPEC (1995)	CPEC (1995)	CPEC (1995)	MRC (1971)	MRC (1971)	PECC1(2006)	PECC1(2006)	PECC1(2006)	MRC (1971)	MRC (1994)		PECC1(2006)	PECC1(2006)		PECC1(2006)	CPEC (1995)
		Final Report P137, Annex No.4.2 & Drawing	Final Report P146	Final Report P146	Final Report P146	Report P.V-12 (CPEC 1995)	Report P.V-11 (CPEC 1995)	Main Report P.152	Main Report P.148	Main Report P.156	Report Tabler IV-3 (CPEC 1995)	Report Table S-1 (CPEC 1995)		Main Report P.143	Main Report P.172		Main Report P.166	Final Report P137, Annex No.13
2. Name of Basin																		
Location		Kratie	Kratie	Kratie	Kratie	Mondul Kiri	Mondul Kiri	Stung Treng	Stung Treng	Stung Treng	Stung Treng	Stung Treng	Stung Treng	Rattanak Kiri	Rattanak Kiri	Rattanak Kiri	Rattanak Kiri	Rattanak Kiri
Name of River		Mekong	Prek Chhlong	Prek Ter	Prek Ter	Sre Pok	Prek Por	Sre Pok	Se San	Se San	Se San	Mekong	Se Kong	Se San	Prekliang	Prekliang	Prekliang	Sre Pok
Catchment Area	km^2	646,000				13,800	195	30,620	18,550	49,200	46,480	635,000		15,400	883		595	
Anuual Run-off	mcm							21,731	20,438	42,201				16,969	1,117		754	
Average Discharge	m^3/sec	13,950				327	6.25	689	648	1,338	1,490	13,710		538	35.4		23.9	775
Firm Discharge	m^3/sec																	
Specific Discharge	$m^3/s/100km^2$							2.25	3.49	2.72				3.49	4.01		4.02	
3. Reservoir																		
Surface Area	km^2	6				480	8	394		394	1,405	640		414	3.86		10.6	985
Gross Capacity	mcm					9,000	89				12,510						170.8	
Sediment Volume	mcm									2,136					46.8		36.2	
Effective Capacity	mcm	105				2,680	59			280	1,400	(70)			21.94		134.6	5,310
4. Power Plan																		
Power System		Dam type					Dam waterway	Dam type	Dam type	Dam type	Dam type	Dam type		Dam type	Dam waterway		Dam waterway	
Maximum Plant discharge	m^3/sec	3,600	114	79	59.2	327	8.7			2,011	1,440	8,000		813.6	74.7		50.9	775
Full supply level	EL.m	20-30	64.0	70.0	90.0	190.0	520.0	75.0	80.0	75.0	90.0	55.0		120.0	330.0		510.0	
Minimum operating level	EL.m					185.0	510.0	74.0	79.0	74.0	89.0			119.0	320.0		490.0	
Dead water level	EL.m												***No Data***			***No Data***		
Tail water level	EL.m	3.4-17.9				135.0	360.0					12						
Effective Head	m	15	25	20	20	52.5	145.5			28	24.5	16.9		26.0	104.9		154.0	31.5
Maximum Installed Capacity	MW	465	24.2	13.4	10.1	235.0	17.3	180.0	204.0	420.0	480.0	980.0		180.0	64.0		64.0	330.0
Firm Output	MW							44	73.5	128				69.5	19.5		20.1	
Annual Energy Production	GWh/yr	2,800	159.3	88.3	66.1	1,233	90	953	1,085	2,220	2,537	4,870		953	260		258.5	1,754
Firm Energy Production	GWh/yr									1,488		2,940		647.2	153.5		171.5	
5. Structures																		
1) Dam Type		Gravel dike with cut-off						Earth fill	Earth fill	Earth fill		Earth fill		Earth fill	Concrete Gravity Dam		Concrete Gravity Dam	
Crest Length x Height	m	20,000 x 30				3,650 x 70	950 x 55	5,882	4,311 x 29	6,185 x 36	(7,600 x 40)	(10,000 x 22)		6,650 x 35	335 x 57.5		316 x 55	3,800 x 50
Dam Volume	mcm	30				(29.8)	(4.8)	5.4	3.2	3.6	(20.27)	(8.07)		7.8	0.07		0.07	15.83
Design Flood	m^3/sec							28,666	30,957	49,443		79,100		28,312	2,934		2,234	
2) Waterway																		
Type		-													Tunnel		Tunnel	
Dimension x Length	D x L (m)						4,000								6 x 3,403		4.5 x 4,626.7	
Penstock pipe	d x L (m)						660										4.0 x 294	
3) Powerhouse																		
Generator Type		Bulb						Kaplan	Kaplan	Kaplan		Bulb		Kaplan				
Capacity x Units	MW x nos	51.7 x 9						60 x 3	68 x 3	70 x 6		61.25 x 16		60 x 3				
4) Transmission Line																		
Length to Load Center (km)	kV x cct x km	250				500	180	220 kV x 2 x 125 km	220 kV x 2	220 kV x 2 x 250 km	(390)	(400)		220 x 2	220 kV x 50 km		220 kV x 2 x 50 km	440
5) Access Road	km	25				55	35	110	110	220	(10)	(60)		50	50		50	90
6. Construction Cost	mil.$	700				103.3 (504.8)	15.3 (85)	333.22	367.34	220	195.4 (901.3)	2,280		387.37	114.21		111.7	812
7. Economic																		
Cost per kW	$/kW					440	885		1,460		407	2,330		2,150	1,790		1,750	
Cost per kWh	¢/kWh	25				6.5 (40.94)			28		5.4 (35.53)	5.1 (46.82)		41	44		43	46.29
8. Resettlement																		
Number of Houses		0						341	883	1,224		1,830		1,307	0		0	

(*1) Source of Data: MRC (1971) : Inventory of Promising Tributary Projects in the Lower Mekong Basin Volume I October 1971, Mekong Secretariat Working Paper (First Draft)
MRC (1973) : Inventory of Promising Water Resources Projects outside the Lower Mekong Basin October 1973, Mekong Secretariat Working Paper (First Draft)
MRC (1994) : Mekong Mainstream Run-off-River Hydropower December 1994, Mekong Secretariat
CPEC (1995) : Review and Assessment of Water Resources for Hydropower and Identification of Priority Projects June 1995, Mekong River Commission
PECC1(2006) : Comprehensive Development Study of Hydropower in Se San River Basin in Cambodia, October 2006, Power Engineering Consulting Company 1 (PECC1)
(*2) Projects which private companies have already got permission for Pre-F/S or F/S

Table 4.2.1(2/2) The existing project features before starting Master Plan Study

No.			16	17		18	19	20	21	22	23	24	25	26	27	28	29
Project Name			**Middle St. Russey Chrum (*2)**	**Stung Chhay Areng (*2)**		**Stung Tatay (*2)**	**Stung Metoek I**	**Stung Metoek II**	**Stung Metoek III**	**Stung Kep II**	**Upper St. Russey Chrum (*2)**	**Stung Pursat I**	**Stung Pursat II**	**Stung Sen**	**Stung Battanmbang II (*2)**	**Stung Battanmbang I (*2)**	**Bokor Plateao**
(Different Name in the Report)				**(Stung Kampong Saom)**				**(Stung Mnam 2)**	**(Stung Mnam 1)**								
		Unit															
1. Source of Data (*1)			MRC (1973)	Vimean Seila	MRC (1973)	MRC (1973)		MRC (1973)	MRC (1973)	CPEC (1995)	CPEC (1995)	MRC (1973)	MRC (1973)	MRC (1971)	MRC (1971)	MRC (1971)	MRC (1973)
			Report P.38 (CPEC 1995)	JICA Hashimoto's Report (2007), P.180	Report P.62 & Table VII-3 (CPEC 1995)	Report Table VII-2 (CPEC 1995)		Report P.129	Report P.129	Final Report P145, Annex 42BB	Final Report P144	Report Table VI-5 (CPEC 1995)	Report Table VI-5 (CPEC 1995)	Report Table XII-1 (CPEC 1995)	Report Table XX-2 (CPEC 1995)	Report Table XX-1 (CPEC 1995)	Report Table X-1 (CPEC 1995)
2. Name of Basin																	
	Location		Kh Kong	Kh Kong	Kh Kong	Kh Kong	Pursat	Pursat	Kh Kong	Kh Kong	Pursat	Pursat	Pursat	Preah Vihear	Battanmbang	Battanmbang	Kampot
	Name of River		Stoeng Russey	Stung Chhay Areng	Stung Chhay Areng	Stung Tatay	Stung Metoek	Stung Metoek	Stung Metoek	Stung Kep	Stoeng Russey	Stung Pursat	Stung Pursat	Stung Sen	Stung Battanmbang	Stung Battanmbang	
	Catchment Area	km^2	474	965	950	353		430	670			1,000	2,080	10,500	120	2,135	24.5
	Anuual Run-off	mcm															
	Average Discharge	m^3/sec	25 (43)		85.5	20.5 (32.1)		31.8	49.5			31 (18.1)	31		5.9	61	2.41
	Firm Discharge	m^3/sec						24.5									
	Specific Discharge	$m^3/s/100km^2$															
3. Reservoir																	
	Surface Area	km^2	15.4 (28.4)	180	110	32.9		25.5	15.4			95 (23)	41 (28.3)	530	16	92	4.1
	Gross Capacity	mcm	275	5,500	1,750	609		470	280			1,165	520	3,660	150	970	27
	Sediment Volume	mcm															
	Effective Capacity	mcm	235 (377)	4,000	1,600	596		430	220			285 (123)	295 (130)	2,890	110	770 (1,040)	25
4. Power Plan																	
	Power System		Dam	Dam	Dam	Dam		Dam	Dam			Dam type	Dam	Dam type	Dam	Dam type	Dam
	Maximum Plant discharge	m^3/sec	43	115	83.6	32.1		31.0	17	60.6	15.1	43	57 (8.7)	145	5.8	52	2.32
	Full supply level	EL.m	385.0		210.0	420.0		250.0	130.0	90.0	610.0	200.0	50.0	43.5	670.0	75.0	950.0
	Minimum operating level	EL.m	360.0		190.0	390.0		220.0	110.0			196.0	41.0	35.0	658.0	63.0	930.0
	Dead water level	EL.m															
	Tail water level	EL.m	120		140	210	***No Data***	20	10			60	23	20	170	35	10
	Effective Head	m	218	195	56	180		209	107	50.0	250.0	128	23	19.3	450	34	885
	Maximum Installed Capacity	MW	125.0	260.0	65.0	80.0		90.0	25.0	25.8	32.1	75 (3.5)	17.0	38.0	36.0	24.0	28.0
	Firm Output	MW															
	Annual Energy Production	GWh/yr	668	1,200	339 (1,358)	416		466	134	169.4	211.3	399 (9)	91 (71.5)	201	187	127 (120)	147
	Firm Energy Production	GWh/yr	364		277	395		443	127			338	80				98
5. Structures																	
1) Dam	Type			Concrete Gravity Dam													
	Crest Length x Height	m	350 x 60 (1,100 x 60)	3,200 x 55	1,200 x 55	750 x 55		650 x 65	350 x 60	h=30m	h=30m	400 x 50 (200 x 15)	1,100 x 45 (250 x 28)	2,700 x 38	225 x 50	3,850 x 55 (4,200 x 49.5)	800 x 45
	Dam Volume	mcm	(6.6)	2.0	6.05	3.78		4.58				(0.08)	(0.33)	(6.50)	(0.94)	(17.15)	(2.70)
	Design Flood	m^3/sec						2,100									
2) Waterway																	
	Type																
	Dimension x Length	D x L (m)	19,500	11,500	2,600	7,400		2,100	750				6,100		7,000		5,600
	Penstock pipe	d x L (m)	1,000	2,500	270	1,100		600	550				650		1,600		3,700
3) Powerhouse																	
	Generator Type			Francis				Francis									
	Capacity x Units	MW x nos		52 x 5				45 x 2									
4) Transmission Line																	
	Length to Load Center (km)	kV x cct x km	(180)	230 kV	150	170		75				(45)	(75)	(220)	(80)	(45)	(65)
5) Access Road		km	(60)	140	60	85		16				(5)	(25)	(60)	(55)	(10)	(6)
6. Construction Cost		mil.$	68 (274.6)	535	44.1 (501.8)	41.0 (214.8)		20.7	17.2			31.9 (18.6)	8.1 (59.6)	13.4 (80.4)	13.0 (65.1)	10.1 (48.9)	14.9 (63.8)
7. Economic																	
	Cost per kW	$/kW	544		680.00			230	690			420	420	350	360	420	530
	Cost per kWh	¢/kWh	(41.1)	45.00	8.4 (36.95)	(51.63)		19.64				5.8 (2.07)	7.1 (83.36)	3.5 (40)	5.3 (34.81)	5.9 (40.75)	8.0 (43.40)
8. Resettlement																	
	Number of Houses							0									

(*1) Source of Data: MRC (1971) : Inventory of Promising Tributary Projects in the Lower Mekong Basin Volume I October 1971, Mekong Secretariat Working Paper (First Draft)
MRC (1973) : Inventory of Promising Water Resources Projects outside the Lower Mekong Basin October 1973, Mekong Secretariat Working Paper (First Draft)
MRC (1994) : Mekong Mainstream Run-off-River Hydropower December 1994, Mekong Secretariat
CPEC (1995) : Review and Assessment of Water Resources for Hydropower and Identification of Priority Projects June 1995, Mekong River Commission
PECC1(2006) : Comprehensive Development Study of Hydropower in Se San River Basin in Cambodia, October 2006, Power Engineering Consulting Company 1 (PECC1)
(*2) Projects which private companies have already got permission for Pre-F/S or F/S

4.2.2 Preparation of inventory of 29 projects

After additional examination works as described in the previous Sub-section 4.2.1, technical features of 29 projects were prepared as a baseline of the selection. Table 4.2.2 shows the summary and Table 4.2.3 technical features. Review result of main projects will be described in Section 4.4.

Table 4.2.2 Inventory of 29 Projects (Summary)

No.	Project	Symbol	Location (Province)	Catchment Area (km^2)	Annual run-off (m^3/sec)	Effective Head (m)	Installed Capacity (MW)	Anuual Energy (GWh/yr)	Reservoir area (km^2)	Map Index (1/100,000)	Maximum Plant discharge (m^3/sec)
1	Sambor *	SBR	Kratie	646,000	13,414	15	2,394.4	8,893	6	6134, 6135	19,163
2	Prek Chhlong II	PC2	Kratie	3,368	70	15	12.4	51	70	6233	100
3	Prek Ter III	PT3	Kratie	3,377	70	18	14.8	92	179	6233	100
4	Prek Ter II	PT2	Kratie	2,769	58	17	11.4	55	98	6234, 6334	82
5	Sre Pok IV	SRP4	Mondul Kiri	13,800	358	16	68.2	255	52	6435	511
6	Prek Por I	PP1	Mondul Kiri	135	4	124.3	5.0	32	12	6433, 6434	5
7	Lower Sre Pok II	LSP2	Stung Treng	30,620	1,067	18	228.0	990	122	6236	1,524
8	Lower Se San II	LSS2	Stung Treng	18,550	616	23	169.0	710	341	6236	880
7&8	Lower Sre Pok II + Lower Se San II *	LL2	Stung Treng	49,200	1,637	22	430.5	1,724	489	6236	384
9	Stung Treng	STG	Stung Treng	635,000	12,945	43	6,623.9	24,590	640	6136	18,493
10	Se Kong	SK	Stung Treng	26,500	1,245	10	148.2	551	114	6236	1,779
11	Lower Se San III	LSS3	Rattanak Kiri	15,600	519	26	161.1	692	409	6437	742
12	Prek Liang I	PL1	Rattanak Kiri	883	36.7	115.7	50.6	220	7	6437	52
13	Prek Liang IA	PL1A	Rattanak Kiri	943	39	52.3	22.5	106	0	6437	52
14	Prek Liang II	PL2	Rattanak Kiri	595	24.7	163	48.0	260	14	6437	35
15	Lower Sre Pok III *	LSP3	Rattanak Kiri	26,200	679	29	235.2	988	697	6435, 6335	970
16	Middle St. Russey Chrum *	MSRC	Koh Kong	461	24.4	193.9	56.4	345	23	5632	35
17	Stung Chhay Areng *	SCA	Koh Kong	965	51.1	179	109.2	668	135	5632, 5732	73
18	Stung Tatay	STY	Koh Kong	353	18.7	168.4	37.6	230	46	5632	27
19	Stung Metoek I	MTK1	Pursat	140	7.4	122.9	10.6	66	5	5533	11
20	Stung Metoek II	MTK2	Pursat	416	22	109.8	28.8	174	19	5532	31
21	Stung Metoek III	MTK3	Koh Kong	656	34.7	56.5	23.3	103	11	5532	50
22	Stung Kep II	KP2	Koh Kong	1,060	56	170	113.6	458	8	5632	80
23	Upper St. Russey Chrum *	USRC	Pursat	163	9	368	37.6	231	4	5633	12
24	Stung Pursat I	PST1	Pursat	1,000	13	116	17.6	108	96	5633	18
25	Stung Pursat II	PST2	Pursat	2,080	27	32	10.0	62	32	5733	38
26	Stung Sen	SEN	Preah Vihear	10,540	181	27	58.0	356	939	6035, 6036	258
27	Stung Battambang II *	BB2	Battambang	120	4.1	347.3	16.8	104	14	5533	6
28	Stung Battambang I *	BB1	Battambang	2,135	72.7	28	24.0	149	105	5534	104
29	Bokor Plateao	BP	Kampot	24.5	2	911.7	21.6	133	3	5830	3

Note: A mark * denotes those projects to which LOP has been issued for pre-feasibility study or MOU for feasibility study as of July 2007.

Table 4.2.3 (1/2) Inventory of 29 Projects

No.				1	2	3	4	5	6	7	8	7 & 8	9	10	11	12	13	14	15
Project Name				Sambor *	Prek Chhlong II	Prek Ter III	Prek Ter II	Sre Pok IV	Prek Por I	Lower Sre Pok II	Lower Se San II	Lower Sre Pok II + Lower Se San II *	Stung Treng	Se Kong	Lower Se San III	Prek Liang I	Prek Liang IA	Prek Liang II	Lower Sre Pok III *
Abbreviation				SBR	PC2	PT3	PT2	SRP4	PP1	LSP2	LSS2	LL2	STG	SK	LSS3	PL1	PL1A	PL2	LSP3
1. Name of Basin		Symbol	Unit																
	Location			Kratie	Kratie	Kratie	Kratie	Mondul Kiri	Mondul Kiri	Stung Treng	Stung Treng	Stung Treng	Stung Treng	Stung Treng	Rattanak Kiri	Rattanak Kiri	Rattanak Kiri	Rattanak Kiri	Rattanak Kiri
	Name of River			Mekong	Prek Chhlong	Prek Ter	Prek Ter	Sre Pok	Prek Por	Sre Pok	Se San	Se San	Mekong	Se Kong	Se San	Prekliang	Prekliang	Prekliang	Sre Pok
	Catchment Area	A	km^2	646,000	3,368	3,377	2,769	13,800	135	30,620	18,550	49,200	635,000	26,500	15,600	883	943	595	26,200
	Anuual Run-off	Qa	mcm	423,314	2,206	2,212	1,815	11,291	110	33,680	19,455	51,699	408,507	39,302	16,385	1,158	1,234	779	21,437
	Average Discharge	Qm	m^3/sec	13,414	69.9	70.1	57.5	357.8	3.5	1,067	616	1,637	12,945	1,245	519	36.7	39.1	24.7	679.3
	Firm discharge	Qd (=Q90)	m^3/sec	2,094.0	10.9	10.9	9.0	28.9	0.3	64.2	94.7	251.1	1,900.0	188.9	79.6	6.6	7.1	4.5	55.0
	Specific Discharge	qa	m^3/s/100km^2	2.08	2.08	2.08	2.08	2.59	2.59			3.33	2.04	4.70	3.33	4.16	4.15	4.15	2.59
2. Reservoir																			
	Surface Area	Ar	km^2	6	70	179	98	52	12	122	341	489	640	114	409	7	0.0	14	697
	Gross Capacity	Sg	mcm		493	1,590	667	313	162	3,400	1,580	3,400	-	581	4,598	157	66.0	269	5,599
	Sediment Volume	Ssd	mcm	12,920	67	68	55	87	3			647	12,700	530	163	18	-	12	336
	Effective Capacity	Se	mcm	105	128	981	290	61	94	3,400	1,580	2,600	-	51	1,585	120.8	-	217.8	1,749
	Ratio (Se/Qa)		%	0.02%	5.80%	44.35%	15.98%	0.54%	85.45%	10.10%	8.12%	5.03%	0.00%	0.13%	9.67%	10.43%	10.43%	27.96%	8.16%
3. Power Plan																			
	Power System			Dam type	Dam type	Dam type	Dam type	Dam type	Dam Waterway	Dam type	Dam type	Dam type	Dam type	Dam type	Dam type	Dam waterway	Dam waterway	Dam waterway	Dam type
	Maximum Plant discharge	Qmax	m^3/sec	19,163	100	100	82	511	5	1,524	880	2,339	18,493	1,779	742	52	52	35	970
	Firm discharge	Qf	% to Qm	15.6%	25.3%	86.2%	47.1%	*8.1%*	86.2%	34.8%	30.5%	23.5%	14.7%	*15.2%*	33.9%	35.6%	35.6%	69.0%	30.6%
			m^3/sec	2,094.0	17.7	60.4	27.1	28.9	3.0	371.8	187.9	384.3	1,900.0	188.9	176.2	13.1	13.1	17.0	207.8
	Average Discharge for Power Generation	Qp	m^3/sec	8,118.8	46.3	70.1	44.0	218.4	3.5	753.2	422.7	1,072.9	7,831.6	755.1	364.3	26.0	27.7	21.8	466.4
			% to Qm	60.5%	66.3%	100.0%	76.5%	61.0%	100.0%	70.6%	68.6%	65.5%	60.5%	60.6%	70.2%	70.9%	70.9%	88.5%	68.7%
	Full supply level	F.S.L	EL.m	20-30	62.0	60.0	80.0	140.0	560.0	70.0	80.0	75.0	55.0	60.0	120.0	340.0	210.0	520.0	120.0
	Minimum operating level	M.O.L	EL.m		60.0	52.0	75.0	138.0	550.0	-	-	69.0	1.0	72.0	115.0	315.0	190.0	495.0	116.0
	Dead water level	D.W.L	EL.m		52.0	42.0	68.0	132.6	540.0	-	-	65.2		59.0	100.0	307.2	182.7	483.3	101.3
	Tail water level	T.W.L	EL.m	3.4-17.9	45	38	60	122	420	50	55	50	12	48	90	210	155	340	88
	Intake Diameter				4.5	4.5	4.0	8.5	3.0			9.0		8.0	8.5	4.5	5.0	4.0	8.5
	Effective Head	He	m	15.0	15.0	18.0	17.0	16.0	124.3	18.0	23.0	22.0	43.0	10.0	26.0	115.7	52.3	163.0	29.0
	Installed Capacity	Pi	MW	2,394.4	12.4	14.8	11.4	68.2	5.0	228.0	169.0	430.5	6,623.9	148.2	161.1	50.6	22.5	48.0	235.2
	Dependable Peak Power	Pd	MW	1046.6	8.8	14.8	11.4	15.4	5.0	223.0	144.0	281.7	2722.2	62.9	152.6	50.3	22.5	48.0	200.8
	Annual Energy Production	Ea	GWh/yr	8,893	51	92	55	255	32	990	710	1,724	24,590	551	692	220	106	260	988
	Firm Energy Production	Ef	GWh/yr	2,294	19	79	34	34	27	489	316	617	5,966	138	334	110	50	203	440
4. Structures																			
1) Dam	Type			Gravel dike with cut-off	Earth fill	Earth fill	Earth fill	Earth fill	Rockfill	Earth fill	Earth fill	Rockfill	Earth fill	Earth fill	Rockfill	Rockfill	-	Rockfill	Rockfill
	Crest Length x Height		m	20,000 x 30	1,700 x 21 + 1,650 x 7.5	9,600 x 29 + 800 x 5	6,950 x 23 + 2,900 x 2	3,700 x 23	3,350 x 37	3,500 x 24	5,000 x 30	7,750 x 32	4,810 x 22	820 x 20	6,200 x 35	230 x 61	-	240 x 75	3,650 x 39
	Dam Volume	V	mcm	30	0.98	9.5	4.9	3.3	4.8	1.9	3.7	3.2	8.1	0.44	5.0	0.95	-	1.1	6.7
	Design Flood	IDF	m^3/sec	63,656	1,985	1,991	1,632	15,387	151			64,524	-	51,929	20,459	1,656	1,768	1,116	29,212
2) Waterway																			
	Type			-	-	-	-	-	Tunnel	-	-	-	-	-	-	Tunnel	Tunnel	Tunnel	-
	Dimension x Length		D x L (m)						3 x 6,900							4.5 x 3,350	4.5 x 3,000	4.5 x 4,850	
	Penstock pipe		d x L (m)		4.0 x 40	4 x 30	3.5 x 30	7.5 x 30	1.6 x 510			9.0 x 40	-	-	7.5 x 40	4 x 240	4 x 250	3.5 x 340	7.5 x 40
3) Powerhouse																			
	Generator Type			Bulb	Kaplan	Kaplan	Kaplan	Kaplan	Pelton	Bulb	Bulb	Kaplan	Kaplan	Tubular	Kaplan	Francis	Francis	Francis	Kaplan
	Capacity x Units		MW x nos		6.2 x 2	7.4 x 2	5.7 x 2	34.1 x 2	2.5 x 2	57 x 4	42.25 x 4	86.1 x 5	414 x 16	37 x 4	53.7 x 3	25.3 x 2	11.3 x 2	24.0 x 2	58.8 x 4
4) Transmission Line																			
	Voltage (kV) x Circuit x Length (km)		kV x cct x km	500 x 33 (Kratie)	115 x 50 (Kratie)	115 x 45 (Kratie)	115 x 24 (Kratie)	115 x 250 (St.Treng)	115 x 170 (Kratie)			230 x 2 x 40 (St.Treng)	230 x 2 x 5 (St.Treng)	115 x 51 (St.Treng)	230 x 2 x 265 (St.Treng)	115 x 310 (St.Treng)	-	115 x 320 (St.Treng)	230 x 2 x 265 (St.Treng)
5) Access Road		L	km	0	1	35	10	25	25	12	12	12	0	15	25	40	35	50	15
5. Construction Cost (incl. Resettlement cost)		C	mil.$		52.5	152.4	84.8	191.5	117.6			587.6		305.1	467.5	121.9	38.8	119.8	435.9
6. Economic																			
	Cost for kW (excl. Resettlement cos	UCC	$/kW		3,545	9,625	7,394	2,808	23,504			1,273		2,007	1,973	2,409	1,723	2,496	1,757
	Cost for kWh	UGC	¢/kWh		13.91	22.18	20.94	10.18	49.27			4.70		7.63	9.05	7.43	5.02	6.16	6.00
7. Resettlement																			
	Number of Households		hh	0	308	103	0	0	0	0	0	1,479	0	503	1,349	0	0	0	726
8. Others	Reference Report			CPEC	CPEC	CPEC	CPEC		CPEC			PECC1	MRC (1994)		PECC1	PECC1		PECC1	CPEC

Table 4.2.3 (2/2) Inventory of 29 Projects

No.				16	17	18	19	20	21	22	23	24	25	26	27	28	29
Project Name				Middle St. Russey Chrum *	Stung Chhay Areng *	Stung Tatay	Stung Metoek I	Stung Metoek II	Stung Metoek III	Stung Kep II	Upper St. Russey Chrum *	Stung Pursat I	Stung Pursat II	Stung Sen	Stung Battambang II *	Stung Battambang I *	Bokor Plateao
Abbreviation				MSRC	SCA	STY	MTK1	MTK2	MTK3	KP2	USRC	PST1	PST2	SEN	BB2	BB1	BP
1. Name of Basin		Symbol	Unit														
	Location			Koh Kong	Koh Kong	Koh Kong	Pursat	Pursat	Koh Kong	Koh Kong	Pursat	Pursat	Pursat	Preah Vihear	Battambang	Battambang	Kampot
	Name of River			Stung Russey	Stung Chhay Areng	Stung Tatay	Stung Metoek	Stung Metoek	Stung Metoek	Stung Kep	Stung Russey	Stung Pursat	Stung Pursat	Stung Sen	Stung Battambang	Stung Battambang	
	Catchment Area	A	km^2	461	965	353	140	416	656	1,060	163	1,000	2,080	10,540	120	2,135	24.5
	Anuual Run-off	Qa	mcm	770	1613	590	234	694	1,095	1,774	271.0	404.0	839.0	5,699	129	2,294	63
	Average Discharge	Qm	m^3/sec	24.4	51.1	18.7	7.4	22	34.7	56	9	12.8	26.6	181	4.1	72.7	2
	Firm discharge	Qd (=Q90)	m^3/sec	2.0	4.1	1.5	0.6	1.8	2.8	4.5	0.7	0.5	0.9	1.8	0.5	9.5	0.1
	Specific Discharge	qa	$m^3/s/100km^2$	5.29	5.30	5.30	5.29	5.29	5.29	5.30	5.28	1.28	1.28	1.71	3.42	3.41	8.16
2. Reservoir																	
	Surface Area	Ar	km^2	23	135	46	5	19	11	8	4	96	32	939	14.2	105	3.1
	Gross Capacity	Sg	mcm	585	2,917	994	170	285	178	134	185	1,380	661	10,024	354	1,444	43.5
	Sediment Volume	Ssd	mcm	9	19	7	3	8	13	22	3	20	42	211	2	43	0
	Effective Capacity	Se	mcm	441	1222	349	117	265	128	91	128	342	486	3,390	98.5	1,058	28.3
	Ratio (Se/Qa)		%	57.27%	75.76%	59.15%	50.00%	38.18%	11.69%	5.13%	47.23%	84.65%	57.93%	59.48%	76.36%	46.12%	44.92%
3. Power Plan																	
	Power System			Dam Waterway	Dam Waterway	Dam Waterway	Dam Waterway	Dam Waterway	Dam Waterway	Dam Waterway	Dam Waterway	Dam Waterway	Dam type	Dam type	Dam Waterway	Dam type	Dam Waterway
	Maximum Plant discharge	Qmax	m^3/sec	35	73	27	11	31	50	80	12	18	38	258	6	104	3
	Firm discharge	Qf	% to Qm	86.2%	86.2%	86.2%	86.2%	84.4%	38.3%	23.7%	86.2%	86.2%	86.2%	86.2%	86.2%	86.2%	86.2%
			m^3/sec	21.0	44.0	16.1	6.4	18.6	13.3	13.3	7.4	11.0	22.9	155.7	3.5	62.7	1.7
	Average Discharge for Power Generation	Qp	m^3/sec	24.4	51.1	18.7	7.4	21.7	25.0	36.9	8.6	12.8	26.6	180.6	4.1	72.7	2.0
			% to Qm	100.0%	100.0%	100.0%	100.0%	98.7%	72.2%	65.6%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
	Full supply level	F.S.L	EL.m	400.0	210.0	420.0	400.0	240.0	120.0	200.0	800.0	200.0	70.0	50.0	560.0	75.0	945.0
	Minimum operating level	M.O.L	EL.m	370.0	200.0	410.0	360.0	215.0	103.5	166.5	760.0	196.0	50.0	45.0	550.0	60.0	935.0
	Dead water level	D.W.L	EL.m	360.4	127.5	363.8	306.0	208.0	95.0	158.0	708.6	161.7	41.8	24.0	462.9	44.3	860.0
	Tail water level	T.W.L	EL.m	170	10	240	260	120	55	10	400	70	30	20	200	40	10
	Intake Diameter			4.0	5.0	4.0	3.0	4.0	5.0	5.0	3.0	3.0	3.0	6.5	3.0	4.5	3.0
	Effective Head	He	m	193.9	179.0	168.4	122.9	109.8	56.5	169.9	367.5	116.0	32.0	27.0	347.3	28.0	911.7
	Installed Capacity	Pi	MW	56.4	109.2	37.6	10.6	28.8	23.3	113.6	37.6	17.6	10.0	58.0	16.8	24.0	21.6
	Dependable Peak Power	Pd	MW	56.4	109.2	37.6	10.6	28.8	23.3	75.4	37.6	17.6	10.0	58.0	16.8	24.0	21.6
	Annual Energy Production	Ea	GWh/yr	345	668	230	66	174	103	458	231	108	62	356	104	149	133
	Firm Energy Production	Ef	GWh/yr	298	576	198	57	149	55	165	199	93	54	307	90	128	115
4. Structures																	
1) Dam	Type			Rockfill	Rockfill	Rockfill	Rockfill	Rockfill	Rockfill	Rockfill x 2	Rockfill	Rockfill	Rockfill	Earth fill	Rockfill	Rockfill	Rockfill
	Crest Length x Height		m	490 x 67	1,880 x 100	1,650 x 90	960 x 120	410 x 55	285 x 35	600 x 65 + 360 x 45	660 x 115	420 x 45	920 x 43 + 1030 x 33	3,470 x 35	540 x 125	4,100 x 45	540 x 90
	Dam Volume	V	mcm	1.6	21.7	14.7	12.8	1.2	0.5	2.1	6.5	0.72	3.2	6.0	8.2	7.8	2.0
	Design Flood	IDF	m^3/sec	1,957	4,097	1,499	594	1,766	2,785	4,500	692	773	1,608	8,962	241	4,295	189
2) Waterway																	
	Type																
	Dimension x Length		D x L (m)	4.0 x 16,000	5 x 8,500	4.0 x 4,300	3.0 x 2,020	4.0 x 3,500	5.0 x 2,800	5.0 x 9,000	3.0 x 8,000	3.0 x 7,250	-	-	3.0 x 4,500	-	3.0 x 5,200
	Penstock pipe		d x L (m)	3.5 x 650	4.2 x 1,100	2.8 x 420	2.2 x 180	3.2 x 260	4.8 x 200	4.0 x 520	2.2 x 1,550	2.6 x 400	2.6 x 50	6 x 40	1.6 x 600	4 x 45	1.5 x 2,500
3) Powerhouse																	
	Generator Type			Francis	Francis	Francis	Francis	Francis	Francis	Francis	Pelton	Francis	Kaplan	Kaplan	Pelton	Kaplan	Pelton
	Capacity x Units		MW x nos	28.2 x 2	54.6 x 2	18.8 x 2	5.3 x 2	14.4 x 2	11.7 x 2	56.8 x 2	18.8 x 2	8.8 x 2	5.0 x 2	29.0 x 2	8.4 x 2	12.0 x 2	10.8 x 2
4) Transmission Line																	
	Voltage (kV) x Circuit x Length (km)		kV x cct x km	115 x 160 (Pursat)	230 x 165 (Phnom Phen)	115 x 130 (Kampong Spueu)	115 x 180 (Pursat)	115 x 190 (Pursat)	115 x 210 (Pursat)	230 x 140 (Kampong Speue)	115 x 95 (Pursat)	115 x 95 (Pursat)	115 x 85 (Pursat)	115 x 100 (Kampong Thum)	115 x 105 (Battambang)	115 x 55 (Battambang)	115 x 15 (Veal Renh)
5) Access Road		L	km	40	15	5	10	25	40	5	30	5	10	0	30	0	5
5. Construction Cost (incl. Resettlement cost)		C	mil.$	145.3	570.3	283.3	242.4	107.6	96.8	350.1	180.4	65.1	82.5	255.9	149.0	173.1	80.4
6. Economic																	
	Cost for kW (excl. Resettlement cos	UCC	$/kW	2,574	5,105	7,499	22,555	3,331	4,153	3,082	4,799	3,697	8,248	2,730	8,867	6,609	3,723
	Cost for kWh	UGC	¢/kWh	5.66	11.45	16.51	48.71	8.25	12.52	10.28	10.52	8.05	17.79	9.59	19.20	15.63	8.14
7. Resettlement																	
	Number of Households		hh	0	277	0	0	168	0	0	0	0	0	3,157	0	871	0
8. Others	Reference Report			MRC (1973)	Vimean Seila	CPEC				CPEC		MRC (1973)	MRC (1973)	CPEC	CPEC	CPEC	MRC (1973)

4.2.3 Ongoing Private-financed projects and studies

Several projects including 29 projects as described in the previous section, are under study by foreign enterprises. Table 4.2.4 shows the list of related studies which were obtained from MIME in September 2007.

Table 4.2.4 Development Project List Committed or Under Study

No.	Project	Province	Catchment Area (km^2)	Annual Run-off (m^3/sec)	Effective Head (m)	Installed Capcity (MW)	Annual Energy (GWh)	Full Supply Level (m)	Reservoir Area (km^2)	Remarks
Committed Projects (excluded from candidate for master plan study)										
1	Kirirom III	Koh Kong	105	4.10	271	18	73	315	4.30	CETIC, Negotiation. IA, PPA (China)
2	Kamchay	Kampot	710	54	122	193.20	498	150	20.40	Under construction by Sinohydro (China)
3	Stung Atay	Pursat	590+567	79.2+77	181+35	120	465	450/508	16	Start Construction soon by CYC (China)
4	Lower St. Russey Chrum	Koh Kong	1,020	57	103	235	805	120	1.40	CYC-MOU F/S;by TEPSCO (Japan)
Under Study										
5	Battambang II	Battambang	120	5.90	450	36	187	672	16	Pre-F/S by KTC (Korea) Letter of Permission
6	Battambang I	Battambang	2,135	27	35	24	120	77	92	Pre-F/S by KTC (Korea) Letter of Permission
7	Middle St. Russey Chrum	Koh Kong	474	25	218	125	668	385	15	Pre-F/S. KTC (Korea) Letter of Permission
8	Upper St. Russey Chrum	Koh Kong				32	211	610		Pre-F/S. KTC (Korea) Letter of Permission
9	Stung Chhay Areng	Koh Kong	965	83.60	163	300	1,475	245	110	Pre-F/S; F/S by China Southern Grid Power (CSG), China, MoU
10	Stung Tatay	Koh Kong	353	32.10	180	80	250	420	35	Pre-F/S; F/S by CHMC, China, MoU
11	Sambor	Kratie	646,000	7,775	20	467 or 3,300	2,800 or 14,870	20/30	880	Pre-F/S; F/S by China Southern Grid Power (CSG), China, MoU
12	Lower Se San II	Stung Treng	49,200	1,440	24	420	2,220	75	691	Pre-F/S; F/S by EVN Vietnam, MoU
13	Lower Se San I	Ratanak Kiri	11,070	378	25	90	480	141	910	Pre-F/S; F/S by EVN Vietnam, MoU
14	Lower SrePork III	Ratanak Kiri	26,200	775	32	330	1,754	125	985	Pre-F/S; by Yunnan Copper Industry, Permission MoU
15	Lower SrePork IV	Ratanak Kiri	13,800	327	53	235	1,233	190	480	Pre-F/S; by Yunnan Copper Industry, Permission MoU
16	Stung Pursat I	Pursat	1,000	11.70	125	75		200	95	Pre-F/S; by Guangxi Guohong Development Corporation, Letter of Permission

Source: MIME
(Note) Information on study concession changes from time to time, that does not match with other tables.

4.3 ENVIRONMENTAL ALTERNATIVES OF CANDIDATE PROJECTS

The concept of Strategic Environmental Assessment (SEA) was introduced into the Master Plan Study. SEA includes two basic approaches: 1) examination of environmental alternatives at the very early planning stage, and 2) principle of information disclosure as shown in Figure 4.3.1.

Alternatives 'without project' are preliminarily examined at the beginning of the first screening to select 10 priority projects. The 29 hydropower projects include two Mekong Mainstream projects, 2 trans-basin diversion projects, 25 projects situated inside or bordering the Protected Areas.

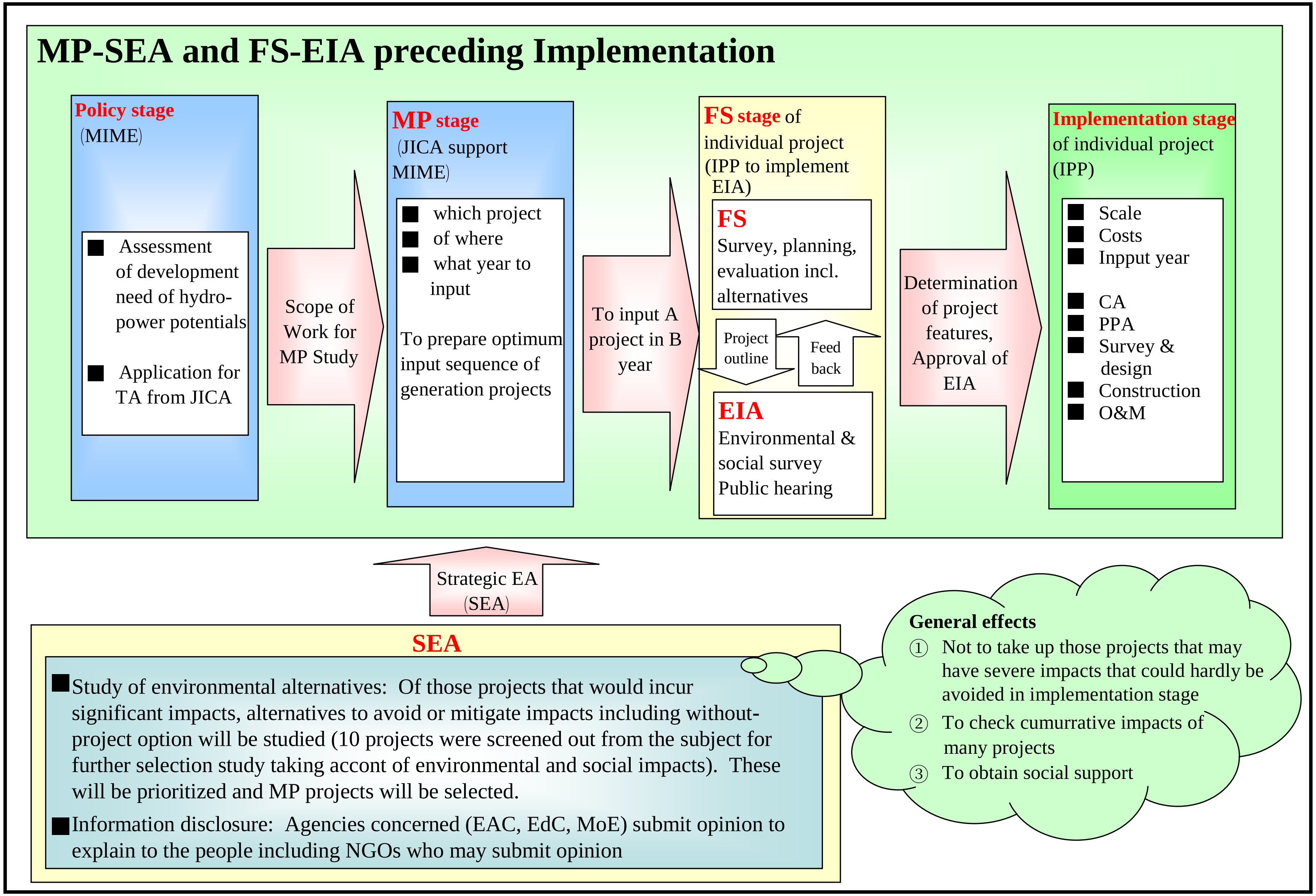


Figure 4.3.1 MP Study and SEA

4.3.1 Dam as Essential Element for Hydropower Development in Cambodia

In order to mitigate environmental impacts due to land inundation by dams, there may be two alternatives in general. One is to change the project type from the dam/reservoir type to the run-of-river (RoR) type. The other is to change from the trans-basin diversion type to the cascade type within the same river basin.

There are two potential hydropower areas in Cambodia, in the northeast and the southwest. The northeast area has a great amount of river flow (referred to also as runoff or discharge) thanks to wide basin areas; however, the topography is gentle and flat. Accordingly, dams are necessary in order to create the water head (difference in water levels upstream and downstream of the dam) required for power generation (two elements of hydropower potential are the head and river flow). In the southwest area, there is a good head available on the steep river course thanks to the mountainous topography, but the river discharge in the dry season drops distinctly. Therefore, it is difficult to generate electricity without a dam for flow regulation to facilitate power generation also in the dry season.

Accordingly, from the viewpoint of effective tapping of renewable energy resources the alternative of RoR might have some technical and economic difficulties to apply to potential hydropower areas in Cambodia.

4.3.2 Mekong Mainstream Projects

A preliminary examination was made on the environmentally critical sites mainly in terms of sediment transport as described below:

(1) #9 Stung Treng dam project

- Trapping of sediment transport if taken place by a dam on the Mekong Mainstream would cause significant impacts on the downstream reaches such as riverbed scouring, riverbank erosion, regression of the Mekong Delta, and reduction in the fertility of floodplain.
- The capacity inflow ratio of the Stung Treng reservoir is about 1%, and the sediment trap efficiency would be in an order of 40%. That is, about 40% of the sediment transport would be trapped and deposit in the reservoir while the rest would be transported downstream of the dam (USBR Design of Small Dams, 1977).
- Riverbed scouring/lowering may result from the reduction in the sand transport while washing/carrying/denuding sand from riverbeds continues; sand mining from riverbed may face difficulty in supply of materials for land embankment and concrete aggregate.
- Nutrients generally adhere to soil particles and are transported by the flow on the Mekong River during the rainy season and foster the floodplain agriculture in Cambodia and Mekong Delta.

- The project scale might exceed the level that would be required in Cambodia in the 20 year period.
- This project will raise the tailwater level of the #7&8 Lower Se San II/Lower Sre Pok II (LL2), so it cannot coexist with the LL2.
- It is recommended that Stung Treng high dam project be excluded from the subjects for further selection study but #7&8 Lower Se San II/Lower Sre Pok II be examined in place of Stung Treng project.

(2) #1 Sambor dam project

- The same issues as with Stung Treng can be pointed out in terms of sediment trap and development scale.
- The capacity inflow ratio is about 1%. The sediment trap efficiency would be in an order of 40%.
- C.A. = 646,000 km^2 would produce sediments in an order of 60 mcm per annum if specific sediment production is assumed at 100 $m^3/km^2/yr$. The dam has a possibility to interrupt around 40% of such sediment transport.
- Reservoir capacity of 2,050 mcm would correspond to the sediment volume that would be trapped over 80 years. In other words, from a macroscopic viewpoint, sediment of about 40% would be trapped for over 80 years and the rest 60% would be carried downstream on an average. Actually, as the sedimentation progresses, the capacity of the reservoir will decrease and the trap ratio would lower. Therefore, the ratio of sediment volume released from the dam toward downstream will increase year by year from the initial assumption at 60%.
- Its feasibility has been under study by CSG since Oct 2006.
- Mainstream Project needs prior consultation for agreement by Joint Committee of MRC.
- It is recommended that Sambor dam project be excluded from the subjects for further selection study since the sediment trap issue has not been cleared as of July 2007 and the domestic demand would not necessarily need these over the 20 years.

(3) #1 Sambor RoR project

- Technical feasibility of intake facilities has not been examined especially on 2 m high submerged weir and 30 m high and 20 km long gravel dike along the power channel for:
  - the stability of the gravel dike against flooding, and
  - the sediment entered and deposited in the power channel, and its impacts on the turbine.

- It is recommended that the Sambor RoR project, which was proposed in CPEC (1995) study, be excluded from the subjects for further selection study.
- On the Mekong River between Stung Treng and Sambor, there are river sections have several flow channels. These channels could be used as a headrace channel in place of the aforementioned gravel dike. Such ideas may be a subject of future study.

(4) Khone Falls RoR project

- The Khone Falls are within Laos.
- Partial exploitation of the potential would cause little sediment issue.
- There is a plan in Laos to build Don Sahong project (240 MW-1,640 GWh) at Khone Falls without creating an intake reservoir.
- Such RoR project could be developed without trapping sediment transport.

(5) Tonle Sap project

- In order to generate power utilizing the flow of the Tonle Sap River during the dry season and a head to be created by a dam, Tonle Sap will have to be kept at its peak level (October) by the dam for about 1.5 months until the Mekong water level subsides by over 3 m.
- Impacts are foreseen on the coastal agriculture and fishery on the Tonle Sap due to artificially prolonged inundation along the coastal area at peak water level.
- Power generation is not economically efficient as it is limited only to December to May at the maximum.
- A great number of turbines, gates and lock systems will be required not to hamper the reverse flow from the Mekong to fill the Tonle Sap during the wet season and fish migration as well.
- It is recommended that the Tonle Sap project be excluded from the subjects for further selection study in view of 1) small scale of power generation compared to the cost scale of structures and equipment required (it would not be feasible from economic viewpoint), 2) environmental impacts, and 3) premature status of the concept.

4.3.3 Trans-Basin Diversion Project

(1) #20&21 Stung Metoek projects

The Stung Metoek project site is located near the southern border with Thailand. It is of a trans-basin-diversion type from Cambodia to Thailand. The MIME has a strong desire to develop the project domestically. The project is valuable as domestic resources for electric power as well as for water supply. Accordingly, cascade development of the projects is examined and adopted in the Study as an alternative.

(2) #18 Stung Tatay project

The #18 Stung Tatay project, situated upstream of the #22 Stung Kep II, will divert the water to the Stung Chhay Areng river. Accordingly, if the #18 Stung Tatay project is implemented, the downstream #22 Stung Kep II would not be feasible due to decreased river flow. On the other hand, if the #18 Stung Tatay project is not implemented, economic viability of the #17 Stung Chhay Areng would be lowered due to limited water coming only from the Stung Chhay Areng basin itself (without diverted river water from #18 Stung Tatay project). Among the three projects, #22 Stung Kep II has been ranked at top as a hydropower project. The #18 Stung Tatay trans-basin diversion project would not be taken up for its low EIRR at 8.0% as well as for its social and environmental impacts. Instead, it would be better to develop the water of Stung Tatay river by the #22 Stung Kep II which is located downstream of #18 Stung Tatay project.

4.4 REVIEW OF PROJECT DEVELOPMENT

4.4.1 Screening Criteria of 10 Priority Projects

The 10 priority projects were selected through the first stage study in a three month period from July to September 2007. Detailed comparison of all the projects were not intended in the Terms of Reference (ToR). The first stage is to screen out those inappropriate projects: 1) having issues on technical feasibility, and such issues that have not yet been clarified, for example, sand flushing issues on Mekong Mainstream projects, 2) scale would be too big to include it into the 10 priority projects that would be implemented in the 20 year period, 3) economic viability appears too low, 4) environmental impacts would be too big and would significantly discount the advantages of hydropower as clean and renewable energy. In other words, 1) sand-trapping by the dam on Mekong Mainstream would cause environmental impacts while the feasibility of sand-flushing technology, if applied to the Mekong dams, is not known at this study stage, 2) development of the Stung Treng and Sambor dam projects needs consideration to the progress of the establishment of the regional power exchange system in GMS, 3) projects with low EIRR less than 5% should be excluded, and 4) projects having very wide inundation area compared to its power output[1] and the loss of land is very large, such projects should be excluded from the subjects for further selection study.

If the above-mentioned cases are found through the review described below or it will be judged whether to exclude such project or not.

1 4 MW per km^2 of reservoir surface area is a lower limit of power density that CDM board accepts to use designated value of unit reservoir emission. The Study Team treated those projects that have a density of 0.5 MW per km^2 or greater as the subjects for selection study of the 10 priority projects since the selection at this stage was to be made by desk study without field survey on environment and social conditions.

4.4.2 Review of 29 Projects

For the target 29 projects, project features of each project were checked, or prepared if not available. The followings are the major points to be kept in mind for review and formulation of the 29 projects.

#2 Prek Chhlong II

Due to geographical limitation, full supply level (FSL) is set at EL. 60 m. The maximum elevation that can form a dam lake in and around the dam axis is EL. 60 m. A dam higher than FSL 60 m will require a large ring dike to form a reservoir, which is less economic.

#3 Prek Ter III

From the existing study, FSL is set at EL. 70 m, however, it was reviewed and re-set as EL. 60m. The reason is due to geographical limitation, the same as #2 Prek Chhlong II. As there is no narrow gorge near the dam axis, the dam length becomes as long as 10 km.

#4 Prek Ter II

FSL of #3 Prek Ter III was set as the tail water level of this project. Considering the geography around dam axis, FSL is set at EL. 80 m.

#5 Sre Pok IV

In the existing study, dam axis is located inside the territory of Cambodia, but the reservoir extends over the territory of Vietnam. FSL is set at EL. 140 m, as this master plan study targets the development scale which can be exploited within the territory of Cambodia.

To estimate the sediment volume, sediment trap effect by the planned Sre Pok 3 dam (to be completed in 2009) is considered, which is located upstream in the territory of Vietnam. By subtracting catchment area of Sre Pok 3 dam, remaining catchment area of 4,350 km^2 (= 13,800 -9,450) is used.

#6 Prek Por I

Dam waterway type development. With the project features of existing study, required head can not be secured. Therefore modification was made on the development layout. However, with insufficient plant discharge, only 5 MW in installed capacity is available.

#7&8 Lower Sre Pok II + Lower Se San II

Preliminary review result gives the 100-year sediment deposit elevation exceeding the full supply level. Further detailed study is needed in the next stage to examine the sand flushing method and shape of sediment deposit.

#10 Se Kong

Tailwater level of EL. 48 m is selected from the backwater of Mekong mainstream. If FSL is set at or higher than EL. 70 m, the reservoir area extends over the territory of Laos. Such FSL also inundates the main road. Thus, FSL is set at EL. 60 m. Being the same as #7&8 Lower Sre Pok II + Lower Se San II, the 100-year sediment deposit elevation exceeds the FSL. Detailed studies would be needed in the next stage.

#12-14 Prek Liang I, IA, II

Cascade development of 3 projects are conceivable from upstream to downstream, namely, #14 Prek Liang II, #12 Prek Liang I, #13 Prek Liang IA. A development plan was formulated by adjusting tailwater level of upstream project with full supply level of downstream project. #13 Prek Liang IA is planned to utilize tailrace water of #12 Prek Liang I directly, which omits the intake dam and reservoir. Therefore, #13 Prek Liang IA can be realized only after construction of #12 Prek Liang I project.

#20&21 Stung Metoek II, III

#19-21 Stung Metoek projects originally formulated as international diversion projects to Thailand side, were preliminarily reviewed as cascade type development inside the territory of Cambodia with dam waterway type development. #20 Stung Metoek II project was planned with FSL at EL. 240 m, tailwater level at EL. 120 m. The downstream project #21 Stung Metoek III was planned with FSL at EL. 120 m and tailwater level at EL. 55 m.

#22 Stung Kep II

This development project was originally planned to construct a dam downstream of the confluence of Kep and Tatay rivers with FSL at EL. 90 m. In the review, the following two alternatives were examined:

(i) to heighten the FSL up to EL. 200 m to increase the regulating capacity of the reservoir; or

(ii) The dam site of existing development plan is located on the steep river course. The confluence of Kep and Tatay rivers is located about 1 km upstream of the dam site. Both the Kep and Tatay rivers have gentle river slopes in respective river reaches a few km upstream of the confluence. Accordingly, compared to original dam site two low dams, one each on two upstream rivers, can develop significant reservoir capacity. Then setting the FSL at EL. 200 m being the same with the above, two separate dams, one each on Kep and Tatay rivers will be constructed and two reservoirs will be connected by a tunnel. This option is to save the dam construction cost.

As a result of preliminary examination, the second alternative was adopted as it can save the construction cost while significantly improving the dry season power output owing to the enhanced capacity of the reservoirs.

#24&#25 Stung Pursat I, II

As a result of review works, it was realized that the installed capacity of #25 Stung Pursat II project was less than 10 MW. Therefore, adjustment was made on FSL and tailwater level of both projects to increase the total installed capacity. FSL of #25 Stung Pursat II and tailwater level of #24 Stung Pursat I was set at EL. 70 m.

4.5 POWER TRANSMISSION NETWORK

4.5.1 Transmission Network Master Plans

In Cambodia, a real nationwide transmission network maser plan up to 2016 was established in the study of “Power Transmission Master Plan and Rural Electrification Strategy (May 1998)”. The proposed transmission network extension plan however was inevitably limited, from the viewpoint of promoting rural electrification all over the country, in its priority and timing of the extension of transmission lines. Because the plan was formulated with main motivation for development of new power plants and aiming to transmit the power from the plants to the Phnom Penh system. However, following this master plan study, a series of studies for implementing a 230 kV cross border transmission line for importing electric energy from Vietnam were conducted,. The construction works for Vietnam border – Takeo – Phnom Penh 230 kV, double circuit line of 105 km and reinforcement and rehabilitation works of the 115 kV transmission facilities for connecting to the existing system have been commenced in 2007 by contractors with the financial assistance of WB and ADB-NDF.

After the above master plan, a nationwide transmission network plan up to 2020 aiming to promote rural electrification by a national grid has been formulated and proposed under the JICA study “Rural Electrification by Renewable Energy (Nippon Koei, June 2006, hereinafter called as the JICA Study 2006)”. An extension plan of sub-transmission system (22 kV) has also been formulated in the study.

In parallel with the JICA Study 2006, a master plan for nationwide transmission network extension plan has been established in the study “Power Development Master Plan and Institutional Strengthening (KEPCO, December 2006, hereinafter called as MP 2006). In MP 2006, transmission line extension plans up to 2022 has been proposed. It aimed not only the development of new power plants but also for the promotion of rural electrification of all over the country. In MP 2006 however there are some small contradictions between the preset basic criteria for the study and some proposed extensions of transmission lines, e.g. the extension of 230 kV system to Siemreap was proposed to be constructed by 2020, which is the second biggest demand center at present and its power demand is expected to increase strongly and continuously for her great tourism potential.

In addition to these extension plans, a study “The Establishment of Electricity Network Master Plan (EGAT, June 2007) “ has also been conducted. A transmission network extension plan was also proposed in the study. However, grounds of timing of some extensions of transmission line are seemed not to be so clear and there is less consideration for providing necessary funds for implementation of those facilities.

"Power Supply Development Plan in Cambodia from 2007 to 2020" has been made public in the annual report of EAC "Report on Power Sector of The Kingdom of Cambodia for The Year 2006" (hereinafter called as "EAC Annual Report 2006"). It is the first official announcement on long term power development plan covering whole country by the Government and is an epoch-making event in Cambodia. In the development plan, concrete and detail transmission network extension plans up to 2022 which is principally based on MP 2006 have been introduced and classified in stage like the Fist Stage from 2007 to 2010, the Second Stage from 2011 to 2015, the Third Stage from 2015 to 2017, the Forth Stage from 2017 to 2019 and the Fifth Stage from 2020 to 2022.

In 2008, the generation expansion plan and the transmission extension plan introduced in the EAC Annual Report 2006 has been further reviewed by MIME and other related authorities.

4.5.2 Transmission Network for the Study

As of the end of February 2008, the following 115 kV 1cct transmission lines aiming at import of electricity from Thailand have been constructed by private firm (Cambodia Power Transmission Line Co., CPTL) and their operation has been started since the end of 2007:

1) Thailand border – Poipet 115 kV, 1 circuit, 5 km, ACSR 1x400
2) Poipet – Banteay Meanchey 115 kV, 1 circuit, 55 km, ACSR 1x400
3) B. Meanchey – Siemreap 115 kV, 1 circuit, 85 km, ACSR 1x400
4) B. Meanchey – Battambang 115 kV, 1 circuit, 60 km, ACSR 1x400

In addition to the above, the following transmission lines are under construction:

1) Vietnam border – Takeo 230 kV, 2 circuit, 52 km, ACSR 1x400
2) Takeo – Phnom Penh (WPP) 230 kV, 2 circuit, 53 km, ACSR 1x625
3) WPP – Existing 115 kV System 115 kV, 2 circuit, 14 km, AAC 2x250
4) Additional 2nd circuit 115 kV, 1 circuit, 21 km, AAC 2x250
5) Rerouting of the Kirirom line 115 kV, 1 circuit, - km, ACSR 1x150

The existing, under construction and committed transmission lines are given in Figure 4.5.1. The transmission lines which are expected to be completed up to 2010 in the EAC Annual Report 2006 except for the above lines are classified as "committed" and indicated in the Figure.

In the Master Plan Study, the 29 candidates except for the committed ones will be narrowed down to 10 priority projects in the stage of the first screening for further study. In this case, project cost including transmission line for connecting to the national grid is one of the very important factors for assessing project cost and judging its priority. In general, features of facilities of the hydropower development project except for the transmission line are technically designed on the basis of topographical geographical conditions, annual inflow, available discharge water, development method, etc. Its construction costs are estimated, with less influence of the timing of the development. However, the construction cost of the transmission line for the project will be much influenced by the timing of the project implementation and location relative to the national grid at the time of development of the hydropower project. The national grid aims to transmit and distribute electric power to the demand centers. The purpose of the transmission line of each hydropower project is to connect the power plant newly developed to the national grid. In other words, major features such as line voltage, size of conductor, length of line, etc. may be much influenced by the situation of the national grid at that time of the project implementation and its construction cost may also be much influenced.

Major demand centers are isolated and served separately at present. No national grid exists in Cambodia. Under these situations, a transmission line to the area having enough demand more than the maximum output of the planned power plant. If electric power of 10s MW to be transmitted up to Phnom Penh, in most cases in Cambodia, the feasibility of the project will be spoiled due to high construction cost of transmission line. Because a 115 kV line voltage will be technically un-applicable due to its distance and higher line voltage may become necessary. It is to be noted that the assessment of the projects under such conditions does not meet the purpose of the Study, that all candidate sites will be evaluated under the similar conditions as much as practically possible.

On the other hand, electric power generation and distribution to the customers by private sector is granted by the Government as their basic policy, which is an anticipated policy for privatization of a power sector. In general, power transmission facilities are a keystone of the electric power industries of the country and its operation will influence to the national benefit. Therefore, in the most of the countries in the world, they are intending to run power transmission business as state undertaking or by organization under the strong management and control of the Governments. As for Cambodia, similar company and/or organization for operating power transmission network under the strong control of the Government shall be established, for purchasing electric energy from IPPs, electric power wheeling with neighboring countries including power import/export, management of power and energy balance of the national grid, granting the supply of stable electric power to the power distributors in the country with reasonable price, etc. Transmission facilities of the national grid therefore shall be planed, constructed, operated and managed under the initiative of the Government.

Form the point of above-mentioned views, a probable nationwide transmission network extension plan at the time of 2015 has been reviewed based on the extension plan of EAC Annual Report 2006, the study results of the JICA Study 2006 and discussion with EDC in June 2007. The results are given in Figure 4.5.2.

The power plant for each project is assumed to be connected to national grid through the nearest substation or switching station indicated on Figure 4.5-2 for selecting 10 priority projects through the first screening. When some reinforcement and/or rehabilitation of the national grid is required for transmitting the electric power received from power plant to the bigger demand centers on the grid, such cost for reinforcement and/or rehabilitation is assumed not to be charged to the project. Timing of development of each project is unknown at this stage of assessing all projects.

4.5.3 Transmission Lines for Power Import/Export

In case of the development of large scale hydropower project, it is a difficult problem for the comparatively small scale power system how to economically manage electric power/energy deficit and surplus electric energy. For the development of thermal power plant, the development meeting demand increase is not so difficult due to selection of proper unit capacity and number of units, and adjustment of installation schedule of generating equipment, although unit generating cost will slightly increase. However, the following difficulties will be considered for developing hydropower to meet demand increase:

1) It is rather difficult to develop economically a hydropower plant meeting the size of power demand, because its scale of development is technically and economically decided on the geographical features of the project site, available water, reservoir capacity, etc.

2) Most of the civil works, intake structures, power house, transmission line, etc. need to be constructed at the initial stage. Adjustable items to meet demand increase like intake gate, draft gate, generating equipment, etc. are much limited and its construction cost is remarkably small in comparison with the initial cost.

3) The biggest special feature of hydro resources is seasonal fluctuate in a wide range. Especially in Cambodia, it is not avoidable to waste water during rainy season, if the capacity of reservoir is not enough to control water discharge throughout the year, because different of precipitation in both the rainy and dry seasons is remarkably big.

In the rather small scale power supply system, these difficulties become a bottleneck of hydropower development. Even in the power supply system having enough big demand than the total capacity of hydropower plants, countermeasures for using effectively renewable water resources such as adjustment of scheduled outage of thermal power plants, application of lower electric tariff in rainy seasons to the high-consumption factories, etc. have been taken from the economic point of view.

However, above-mentioned difficulties are considered to be negligible small in Cambodia, because two huge electric power markets of neighbour countries are expected to work as control valve for regulating the seasonal fluctuation of power output of hydropower plants to be developed. In addition, if positive utilization of such control mechanism, i.e. power import in dry season to compensate power deficit and export in rainy season to consume surplus energy will contribute to decreasing the required reserve capacity for stable system operation and lowering its total generating cost.

As explained in the above, the 115 kV lines (receiving point: Poipet) for importing electric power from Thailand have been operated from the beginning of 2008 and a 230 kV line (receiving point: Takeo) from Vietnam is under construction. In addition to these lines, the construction of a 115 kV line (receiving point: Stung Treng) from Laos and a 115 kV line (receiving point: Krek) have been committed as given in Figure 4.5.1. Further more, a 115 kV line (receiving point: Svay Rieng) from Vietnam is planned as given in Figure 4.5.2. It is noted that these transmission lines constructed for importing electric power from neighbour countries will be used for exporting electric power generated in Cambodia without any technical difficulties. These should be used positively for effective use of constructed facilities.

Technical carrying capacity of transmission line will be determined from line voltage, conductor size, line length, etc. In general, capacity of short distance line (less than 100 km) will be determined by the line voltage and the carrying capacity of conductors which is limited by conductor size, ambient temperature, assumed wind velocity, etc. For long distance line (more than 300-400 km) it is limited by the line voltage and its line constants (inductance and capacitance). For middle distance line, it is in inverse proportion to the line distance. Namely, technical capacity limit of above-mentioned transmission lines is estimated at about 500 MW in total for exporting electric power. Of course, in most of cases, facilities for compensating line voltage drop may become additionally necessary at the receiving substations for exporting electricity.

In the case of the development of hydropower for exporting electric energy, water resources for those generating facilities shall be originally utilized for the people of Cambodia. It is absolutely necessary and very important to have a right for using fully generated energy for stable power supply in the country in emergency cases. For that purpose, even almost of all generated energy will be exported in normal cases, power transmission facilities having capacity for supplying full output of the hydropower plant to the national grid shall be provided. In this study, conditions for assessing the candidate projects are not changed for such hydropower projects to be developed for exporting electric energy, because power transmission facilities for connecting to the national grid have been commonly considered for the all projects and are put in the project cost. However, transmission lines only for energy export shall be constructed by the developers in the scope of the hydropower project and cost of such facilities will be reflected to the contracted unit price of energy. When power export will be made through the existing transmission lines in Cambodia, fee for electric power transmission on the national grid shall be additionally considered in unit price of energy to be exported.

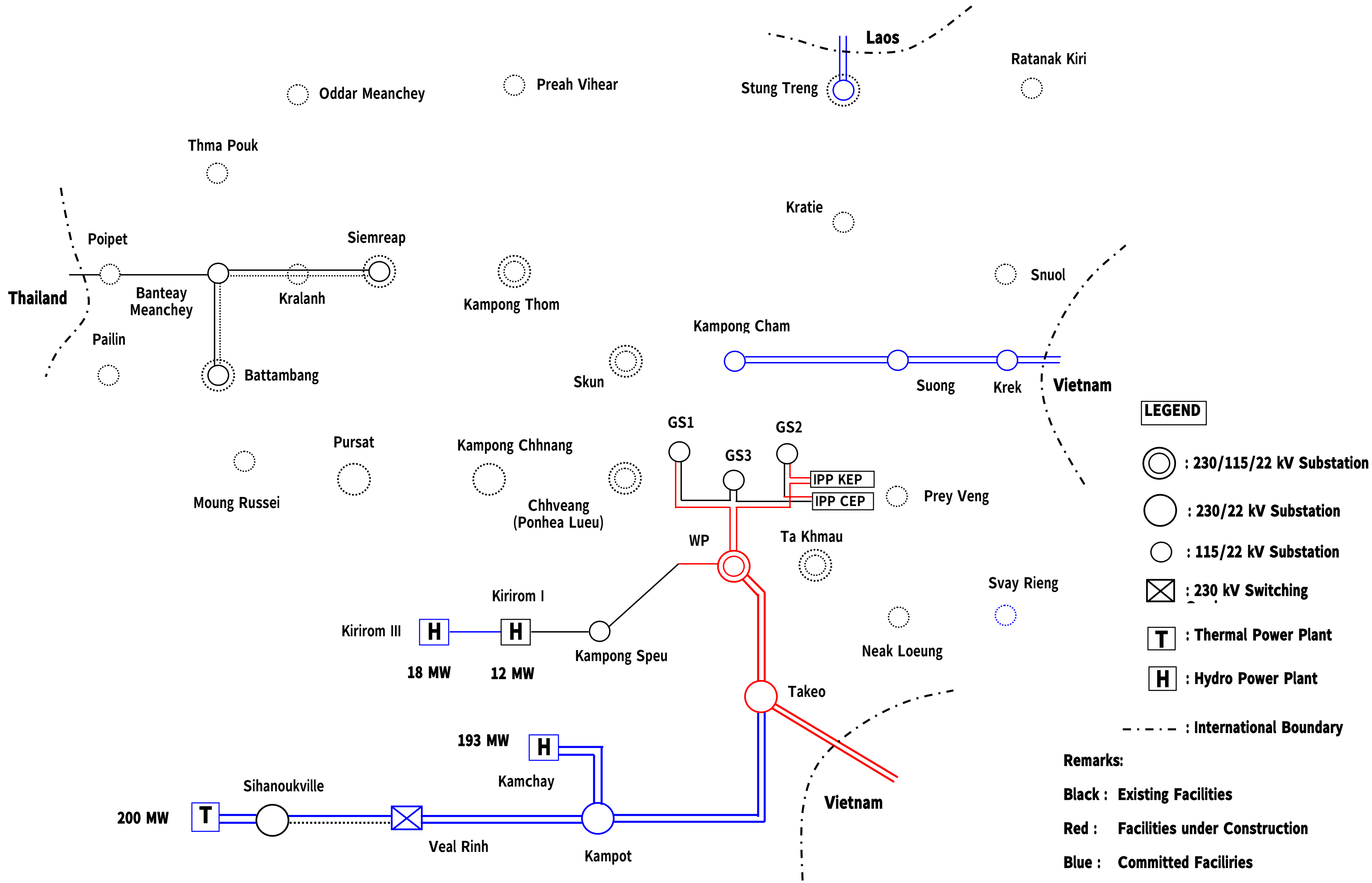


Figure 4.5.1 Existing, Under Construction and Committed Transmission System (Up to 2010)
(Based on the Introduced Power System Development Plan in the EAC's Annual Report 2006)

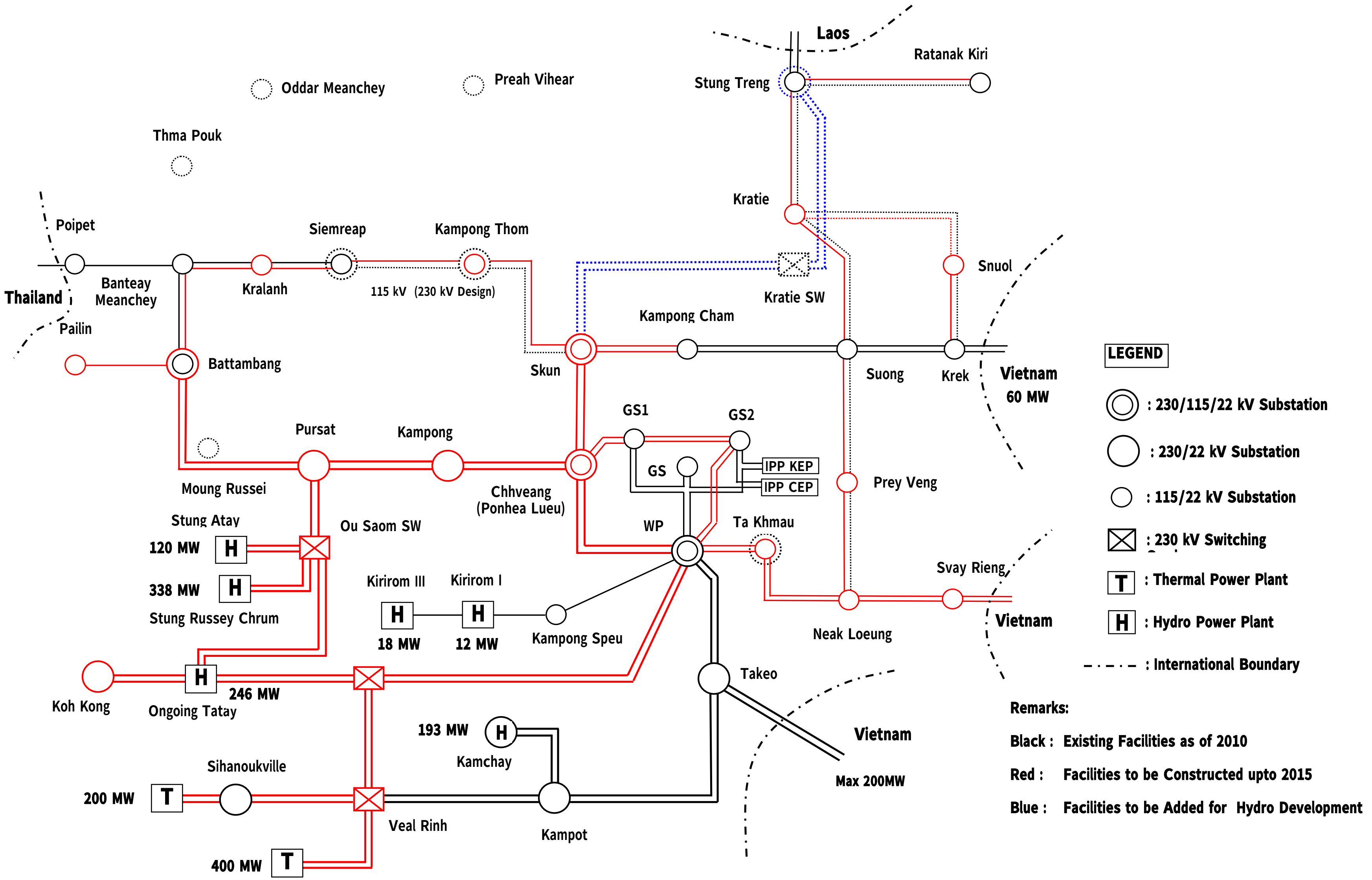


Figure 4.5.2 Proposed Transmission System up to 2015
(Based on the Power System Development Plan in the EAC's Annual Report 2006)

4.6 SOCIAL DATABASE

In order to understand the socio-economic conditions of the candidate project sites in Cambodia, two approaches of methodology may be considered: qualitative analysis and quantitative analysis.

The observation of sites, interviews, and discussions with related agencies and inhabitants are important for finding essential points of site environment and development constraints. Through discussion with related agencies including the Ministry of Environment, the Ministry of Commerce, the Ministry of Agriculture, Fishery and Forestry, and so on, positive and negative impacts of hydropower development were examined.

While carrying out the interview and discussion, the socio-economic statistical data “Rural Development Database” collected under the Seila-supervised program was reviewed. The agricultural statistical data and other economic indicators were referred to as well.

In this Section, the pictures of whole Cambodia are reviewed by referring to the socio-economic database, and then the outlines of the project sites are discussed in more details.

4.6.1 Socio-Economic Conditions in Cambodia

(1) Social Conditions by Province

Population: The population of Cambodia was 13.88 million in 2005, and it is growing. National Institute of Statistics (NIS) estimated the population would increase to 18.7 million by 2020.

Table 4.6.1 Projected Annual Rate of Growth by Province (%)

Year	1998-1999	2004-2005	2009-2010	2014-2015	2019-2020
Cambodia	**1.79**	**1.93**	**2.06**	**2.07**	**1.93**
Banteay Meanchey	2.84	2.71	2.73	2.65	2.46
Battambang	1.57	1.82	2.07	2.13	2.00
Kampong Cham	1.21	1.45	1.60	1.64	1.54
Kampong Chhnang	2.13	2.31	2.52	2.60	2.50
Kampong Speu	2.05	2.16	2.31	2.32	2.15
Kampong Thom	1.80	1.90	1.97	1.96	1.80
Kampot	0.95	1.27	1.52	1.62	1.53
Kandal	1.28	1.47	1.62	1.67	1.55
Koh Kong	5.61	4.17	3.72	3.40	3.11
Kratie	2.75	2.63	2.53	2.42	2.27
Mondul Kiri	3.11	2.90	2.84	2.90	2.91
Phnom Penh	3.56	3.21	2.92	2.62	2.34
Preah Vihear	2.70	2.64	2.58	2.56	2.43
Prey Veng	0.50	0.84	1.05	1.12	1.03
Pursat	1.17	1.56	1.98	2.16	2.05
Ratanak Kiri	2.77	2.82	2.90	2.95	2.89
Siemreap	2.25	2.34	2.42	2.39	2.24
Sihanoukville	3.66	3.42	3.27	3.08	2.84
Stung Treng	2.84	2.73	2.67	2.62	2.47
Svay Rieng	0.86	1.07	1.27	1.34	1.21
Takeo	0.99	1.24	1.46	1.57	1.47
Oddar Meanchey	2.48	2.48	2.60	2.65	2.48
Kep	3.29	3.21	3.16	3.07	2.81
Pailin	6.39	3.89	3.55	3.34	3.08

Source: First Revision Populations for Cambodia 1998-2020, NIS (http://statsnis.org/projcam/Index_Proj.htm)

It has been observed that provinces close to the national borders, industrial bases and new frontiers tend to have higher population growth rates. Typical farming areas in the southeastern provinces grow more slowly. In the rapidly growing provinces at the new frontiers such as the northeastern provinces and newly de-mined areas, migration from low growing farming areas is taking place.

1) High Growth Rate (greater than 2.5%)

Close to border: Banteay Meanchey, Koh Kong, Krong Pailin, Preah Vihear
Industrial bases: Phnom Penh, Sihanoukville, Kep
New frontiers: Mondul Kiri, Ratanak Kiri, Stung Treng, Kratie

2) Low Growth Rate (lower than 1.5%)

Farming areas: Prey Veng, Svay Rieng, Takeo Representative indicators of social condition are population, education and public health.

The population density level by district is shown in Figure 4.6.1. Population density along the Tonle Sap Lake and Mekong River is very high because most people there are engaged in farming and fishing. In addition, the conditions of security in the forest areas were uncertain due to the presence of land mines placed during the turbulent history, preventing people from migrating into the forest areas and isolated remote areas. As the population has increased and national security has improved, migration from conjoining areas such as Takeo and Prey Veng to the new frontiers of the northeast area has occurred. Some of the forest of the northeast provinces, Stung Treng, Kratie, Ratanak Kiri and Mondul Kiri have been opened to acquire farmland to cultivate.

Education Level: According to the Rural Development Database, the illiteracy ratio of adults over the age of 15 years in Cambodia was 17.6% in 2003. From the viewpoint of gender, the female illiteracy ratio is higher, at 19.5% in comparison to 15.5% for males.

As shown in Figure 4.6.2, the high illiteracy ratio in the northern mountain areas are resulted from not only the low education level but also from the fact that the ethnic groups living there do not speak the Cambodian language.

Koh Kong Province, Kampong Speu Province and a part of Pursat Province, which are isolated being surrounded by mountains, are also low education level areas. Historically, those areas were territories of the Pol Pot party supported by the Khmer Rouge and were war-torn. People were deprived of right and chance for having the ordinary education. The situation has been changing and the condition of the education system in these areas has now been improving.

Access to Public Health Facilities: There are six national hospitals, five military hospitals and six national programs in Cambodia according to the latest information released by the NIS and the Ministry of Health. Referral health facilities are listed in Table 4.6.2.

According to interviews with village chief in rural areas, access to health care facilities is one of the highest priorities and they put priority to the road improvement and electrification.

Table 4.6.2 Number of Hospitals and Health Posts in the Provinces

Provinces	Referral Hospital	Operational District	Health Center	Health Post	Provinces	Referral Hospital	Operational District	Health Center	Health Post
Banteay Meanchey	4	4	52	-	Preah Vihear	1	1	12	4
Battambang	4	5	74	1	Prey Veng	7	7	90	1
Kg Cham	10	10	128	1	Pursat	2	2	31	4
Kg Chhnang	2	2	34	1	Ratanak Kiri	1	1	10	9
Kg Speu	3	3	50	2	Siemreap	3	3	53	3
Kg Thom	3	3	50	-	Sihanoukville	1	1	9	-
Kampot	4	4	47	-	Stung Treng	1	1	8	-
Kandal	5	8	88	-	Svay Rieng	3	3	37	-
Koh Kong	2	2	12	3	Takeo	5	5	70	-
Kratie	2	2	22	4	Oddar Meanchey	1	1	11	1
Mondul Kiri	1	1	6	10	Kep	1	1	4	-
Phnom Penh	1	4	21	4	Pailin	1	1	3	1
					Total	**68**	**75**	**922**	**49**

Source: National Institute of Statistics (http://statsnis.org/others/ahfm.htm)

(2) Economic Condition by Districts

The Study Team selected assets of the family such as material of roof, TV sets and accessibility to the markets as the representative economic indicators of the districts after the basic analysis of survey items of the Rural Development Database. Since income data were not available for all of Cambodia, these data were utilized to estimate the economic level of each district. The proportion of the number of households having motorcycles and vehicles was analyzed as well.

Facility and Assets of Living: Thatch roof is one of the indicators to assess the degree of improvement of living conditions. The poverty districts are identified by the light color (see Figure 4.6.3).

The diffusion level of TV set represents not only wealth but also electrification, which is regarded as one of the important public infrastructures. There are two types of electrification systems, 'On Grid' and 'Off Grid.' On Grid is the facility established by EDC and REE and linked from the grid by distribution lines to the end users. Off Grid instead consists of private power stations, i.e. using diesel generator to supply electricity to the end users or to charge batteries of consumers. The electrification should be taken into planning of hydropower projects considering the synergy effect of economic development of remote villages (see Figure 4.6.4).

Motorcycle / Vehicle and Accessibility to Market: Accessibility of markets is one of the indicators of the advantages of living conveniences when assessing fairness or equal opportunity (see Figure 4.6.5). The districts that have a provincial capital and the surrounding districts are relatively accessible to markets. But some of the provincial capitals have not been well developed as the center of trading activities and the access roads to the markets are not well maintained, as shown in Preah Vihear Province, Stung Treng Province, Mondul Kiri Province and Ratanak Kiri Province.

Anlong Veeng District in Oddar Meanchey Province is regarded as a less developed district in terms of population density, education level and living standards. However, they might obtain commodities from the border and have chances to trade them. According to the record of foreign visitors through the border there, more than 67,843 visitors crossed the border of Oddar Meanchey in 2004. This suggests a significant number of Cambodian people might cross it too. There are big markets in places such as Surin Province and Si Sa Ket Province in Thailand having populations of 1,327,901 and 1,405,500 respectively. Trade at Oddar Meanchey Province has been accelerating rapidly.

Speaking of potential bases functioning as hubs in the region, Pursat Province has one of the potential areas to be developed. Since Pursat is located at the middle of the Route No. 5 (RN5), drivers are stopping to rest there. There is a surplus of agricultural products. The potential of agriculture is high if the irrigation system is improved. If the access to the border with Thailand is developed, access to the Industrial Park along the coast near Bangkok will be improved.

In terms of the proportion of households having motorcycles, there is a close correlation between the diffusion level of roof type and TV and the households ratio having motorcycles. 24.4% of the households, which are 603,837 households in total, have motorcycles. The number of motorcycles is increasing along with the rise in the living standards. On the other hand, the ratio of households having a vehicle, 3.4% of the households on a national average and 83,175 households in national total has the distribution by district as shown in Figure 4.6.6. There is some correlation with living standards but also with geographic location.

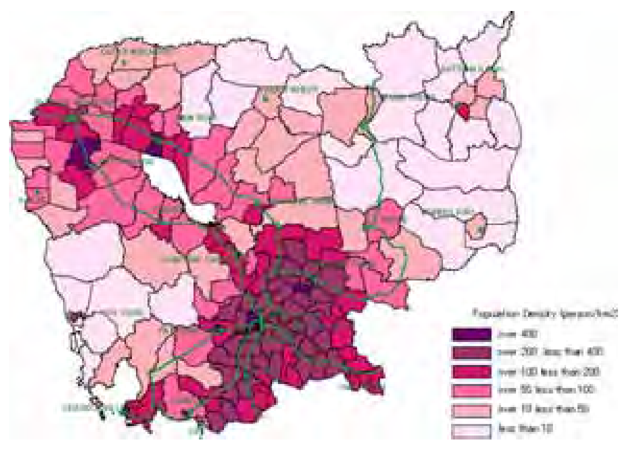


Figure 4.6.1 Population Density

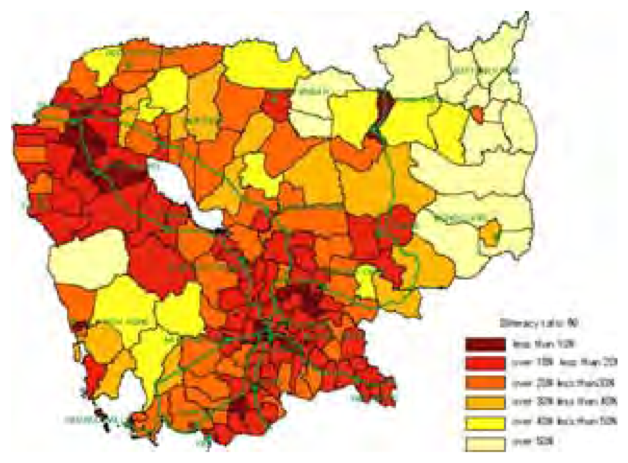


Figure 4.6.2 Illiteracy Ratio

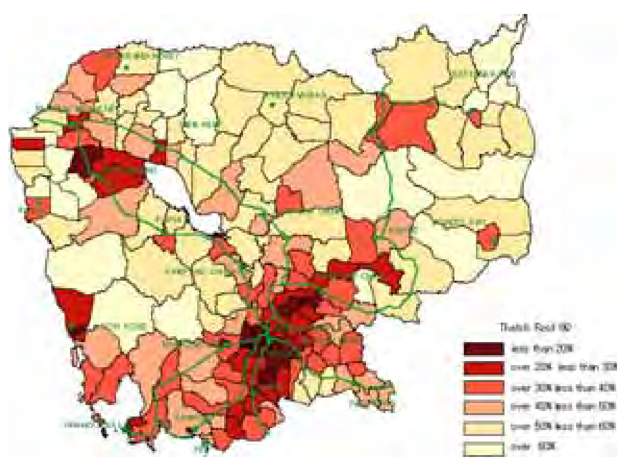


Figure 4.6.3 Thatch Roof Ratio

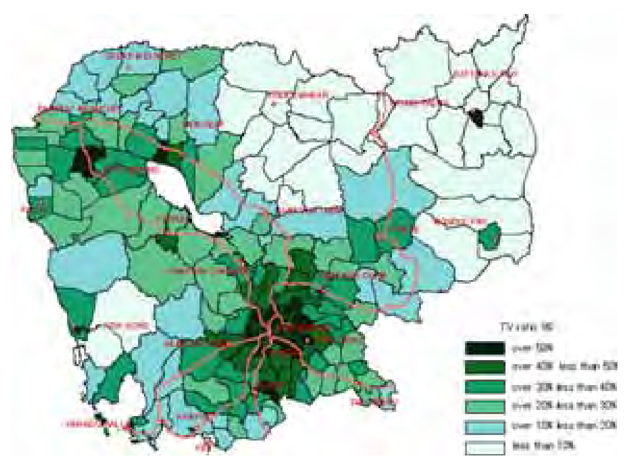


Figure 4.6.4 TV Ratio

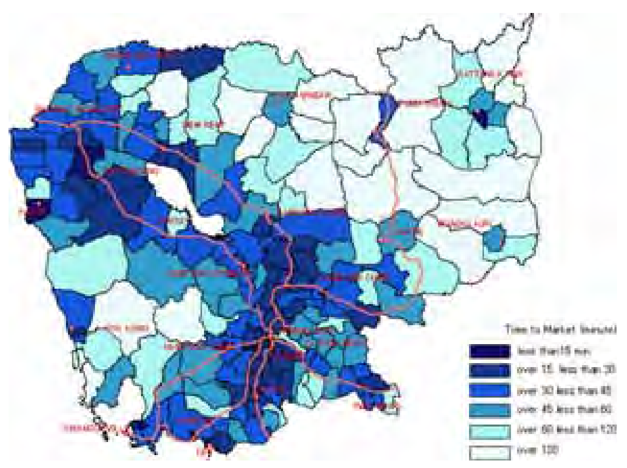


Figure 4.6.5 Time to Market

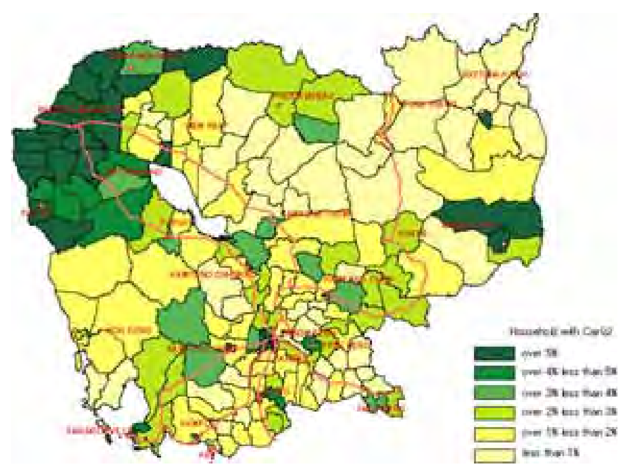
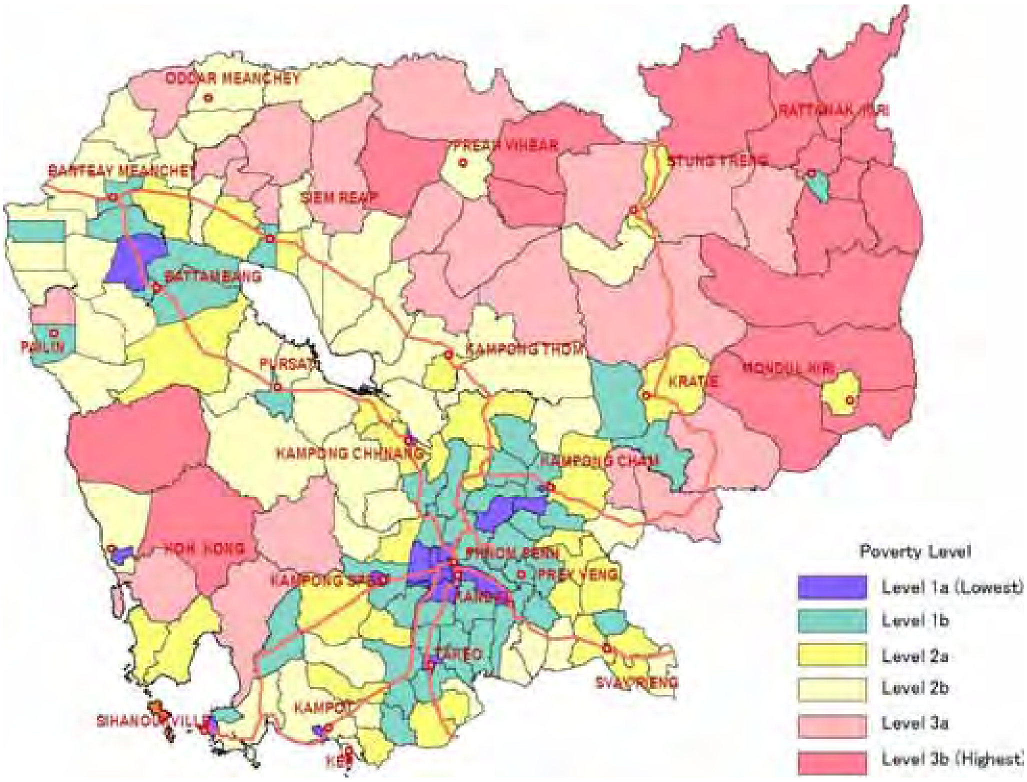


Figure 4.6.6 Household with Car

Source: Study Team, based on the Rural Development Database 2003

There is no doubt that households in Phnom Penh have a high ratio of car ownership, being more than 10%. However, it was beyond expectation based on the living standards that more than 5% of households in the poor provinces of Banteay Meanchey and Oddar Meanchey had vehicles. The people might be using vehicles in border trading activities. In terms of the border with Vietnam, they have the alternative of using boats to carry agricultural products.

Poverty Level: According to the World Bank (2006), the poverty ratio in Cambodia fell by 1 - 1.5% per year from 45-50% in 1993/94 to 35% in 2003. Due to lack of income data, the illiteracy level, type of roof, and TV diffusion level are employed to estimate the levels of education, living conditions and assets, and to assess the overall level of poverty. Figure 4.6.7 illustrates the poverty level by district estimated by the Study Team based on commune database, Seila 2003.



Source: Study Team, based on Rural Development Database, Seila Program 2003

Figure 4.6.7 Poverty Level

(3) Culture and History

Ethnic Groups: According to the Ministry of Tourism, Cambodia, ethnic Khmers make up 90% of the Cambodian population, Vietnamese 5%, Chinese 1%, and a variety of ethnic minorities 4%. As shown in Table 4.6.3, according to the publications of NIS the minority ratio is 1.2%.

Table 4.6.3 Populations of Minority Groups

No	Province	Total Population	Total Minorities	Ratio (%)	No	Province	Total Population	Total Minorities	Ratio (%)
1	Banteay Meanchey	678,882	114	0.0	13	Preah Vihear	150,220	177	0.1
2	Battambang	971,894	264	0.0	14	Prey Veng	1,013,086	583	0.1
3	Kg Cham	1,655,349	547	0.0	15	Pursat	455,793	267	0.1
4	Kg Chhnang	531,516	0	0.0	16	Ratanak Kiri	100,248	79,657	79.5
5	Kg Speu	676,821	96	0.0	17	Siemreap	755,404	103	0.0
6	Kg Thom	606,918	209	0.0	18	Sihanoukville	186,762	66	0.0
7	Kampot	596,199	148	0.0	19	Stung Treng	89,923	115	0.1
8	Kandal	1,203,134	250	0.0	20	Svay Rieng	513,616	0	0.0
9	Koh Kong	118,495	0	0.0	21	Takeo	880,405	148	0.0
10	Kratie	328,885	48,238	14.7	22	Oddar Meanchey	130,491	206	0.2
11	Mondul Kiri	37,048	16,744	45.2	23	Kep	58,166	0	0.0
12	Phnom Penh	1,043,669	646	0.1	24	Pailin	41,247	0	0.0
						Total	12,824,171	148,578	1.2

Source: Cambodia Inter-census Population Survey 2004, National Institute of Statistics, Ministry of Planning

According to the Cambodian Social Economic Survey (CSES 2004), the ethnic minorities generally live in villages in Kampong Cham and neighbouring provinces. The smallest ethnic groups, Khmer Loeu, Chunchiet, and highland tribal groups, mainly live in northeastern provinces where many potential hydropower sites are located. In Ratanak Kiri, almost 80% of the population belongs to minority groups, 45.2% in Mondul Kiri, and 14.7% in Kratie. In the other provinces minority ratios are below 0.2%, clearly showing that the ethnic minority are living centering on specific regions and their geographic diffusion has not been progressed. Figure 4.6.8 shows distribution of ethnic groups, which is published by the University of Texas at Austin and was prepared in 1970s at the time of French administration.[2].

[2] **Austroasiantic, Malayo-Polynesian are major languages**

1. Khmer: Cambodian largest ethnic group
2. Khmer Loeu : Different from Khmer, but the background is not clear. People in the mountains had named Khmer Loeu to assimilate them into Cambodian during 1960s.
3. Vietnamese: Immigrants from Vietnam, living along the Mekong River
4. Cham: Descendants of once-flourishing Kingdom of Champa in Vietnam
5. Mountain Cham: Descendants of Kingdom of Campa. Most of them are Muslim living in mountains.
6. Lao: Ethnic group of Laos

Source: http://www.lib.utexas.edu/maps/middle_east_and_asia/cambodia_ethnic_1972.jpg

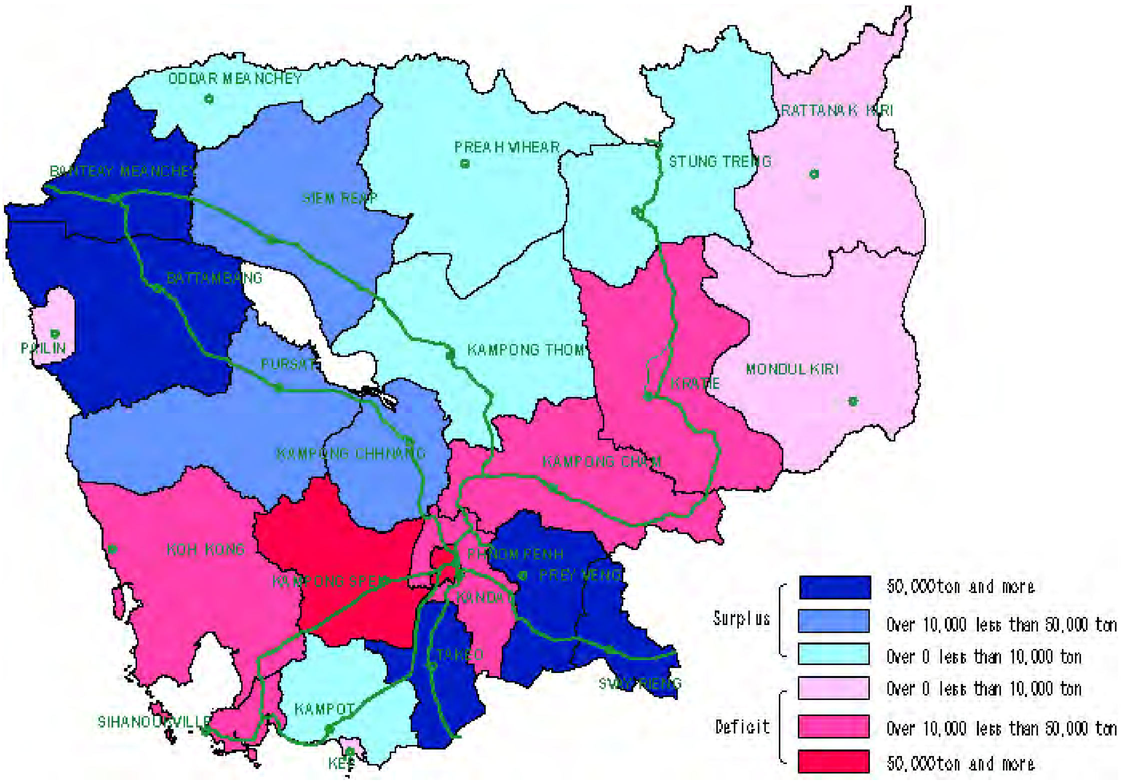
Figure 4.6.8 Distribution of Ethnic Groups

Archaeological Heritage and Custom: Siemreap is famous as a place of Angkor World Heritage. Other than the registered World Heritage, there are many archaeological heritages in Cambodia. Religious landmarks such as temple and pagoda have been respected by the rural inhabitants. People in most villages in the remote areas believe in ethnic animism or shamanism and keep the old customs. They thank to abundant gift from nature, learn a lesson from nature, and then pray for nature. Although the mapping of landmarks and symbols of animism in the project sites is not ready, it should be carefully researched from the viewpoint of inhabitants.

(4) Economic Aspects

The GDP annual growth rate was recorded at 7.7% and the GDP per capita reached $361 in 2006. The service sector contributed 37.9% of the GDP and leads the economy of Cambodia, whereas the industrial sector, which accounts for 29.2% of the GDP, recorded the highest growth rate at 16.1% in 2006. The agriculture sector accounts for 32.9% of the GDP and still plays an important role in the Cambodian economy but its growth rate has not been stable in recent years.

Agriculture: Figure 4.6.9 illustrates the self-sufficiency of paddy by province in 2004. The potential hydropower sites are located in the rather paddy-deficient areas. Paddy is the main food-crop of Cambodia. In other words, area of paddy fields is limited while water management such as irrigation system would be immature in those areas.



Source: Ministry of Agriculture, Forestry and Fisheries

Figure 4.6.9 The Self-sufficiency of Paddy by Province in 2004

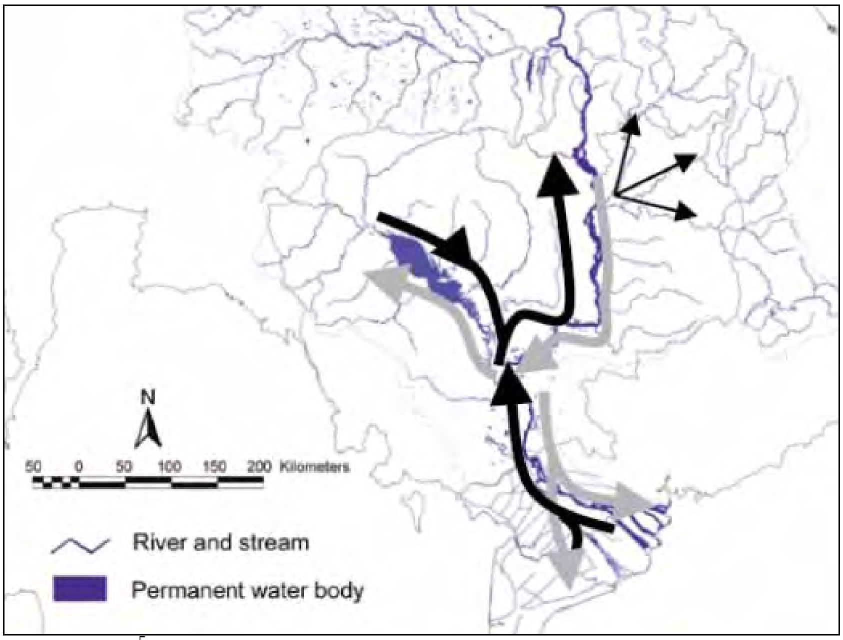
Fisheries: Historical records show that Cambodia's inland fisheries have been of major importance for centuries. Almost all Cambodians eat fish, and most participate in fishing and fishing-related activities. In the eight provinces around the Tonle Sap, rural people in fishing communes reportedly eat between 22 – 68 kg/year of fresh fish and 10 – 24 kg /year of preserved fish products, including fermented fish, fish paste, smoked fish, salted dried fish and fish sauce[3]. The fishery industry is estimated to account for about 12% of Cambodia's GDP, being ahead of the rice production which contributes 10% to the GDP[4]. Many other industries depend upon fishing: making fishing nets, supply of boats, fuel, ice and preservatives, and transportation and marketing, as well as some downstream industries (MRC 2004).

The Mekong River hosts over 1000 species of fish, one of the highest species among river systems in the world (Coates et al., 2003). Some fish species spawn on floodplains, but many migrate upstream at the start of the flood to spawn in tributaries such as the Se San, Se Kong and Sre Pok Rivers, and rapids on the Mekong mainstream between Kratie and the Laos border (Poulsen et al., 2002). The rising rivers during the rainy season carry the fish larvae and fry downstream and onto the productive floodplains. During the flood, fish are dispersed in a large volume of water. In order to protect fry from catching, use of medium and large-scale fishing gear is prohibited during the official closed season, 1 July to 31 October to the south of Phnom Penh and 1 June to 30 September to the north. Figure 4.6.10 shows the migration system on the lower Mekong Basin (only the major routes are illustrated). Black arrows

3 Ahmad, M., Hap, V.Ly, and M. Tiengco, 1998. Socio-economic Assessment of Freshwater Capture Fisheries of Cambodia: Report on a Household Survey, MRC, 185p.

4 Starr. P. 2003. Fisheries production in Cambodia. Catch and Culture 9 (1): 6

represent migration at the beginning of the flood season; grey arrows represent migrations during the flood season when inundation of floodplains has started.



Source: MRC[5]

Figure 4.6.10 A Simplified Illustration of the Fish Migration on the Lower Mekong System

Irrawaddy Dolphins (Orcaella brevirostris) were formerly common and widespread on the lower Mekong River, but now only 60 – 100 reportedly remain, mainly as a result of massive killing during the Khmer Rouge period (Beasley et. al., 2003)[6]. In Cambodia, dolphins are found from the Laos border down to Kratie. During the annual flood season, the dolphins enter large tributaries, the Se San and Se Kong, probably pursuing migrating fish (MRC, 2004).

World's top 10 rivers at risk, WWF, March 2007, states: In the Mekong, the importance of fisheries for human subsistence cannot be understated, but this naturally bountiful resource is not being managed for future use. In the Mekong, inappropriate fishing practices, inadequate distribution of fishing rights and the high level of fish consumption, exceeding the sustainable level of fish reproduction, have led to destructive levels of fishing.

The fishing rights should be reviewed and re-defined based on the sustainable level of fishery production, to avoid critical situation of over-catching. The substantial reason of over-catching is in the fact that the fishery demand has been in excess of the natural reproduction level of fish in the Mekong region. The fishery in the Mekong region having been practiced since the hunting and gathering era is now facing the marginal level. Cultivation type fishery such as releasing fry and aquaculture are required to be promoted. Conservation of fish resources, restoration of fishing habitats, and innovation of fishery are essential.

5 MRC 2002. "Fish migrations of the Lower Mekong River Basin: implications for development, planning and environmental management, MRC Technical Paper No.8, 33p 34p

6 Beas;eu.O., S. Phay, K Sean and S. Yim. 2003 Mekong Dolphin Conservation Project: Status Report, July 2003. Cambodia. 30p

A comprehensive management system is essential and should be established; otherwise the sustainable development of the fisheries sector will not be realized. The exotic species is one of the threats to the inland fisheries. Dam construction in general would affect fish migration and inland fisheries.

Transportation: The road traffic situation in Cambodia has been improved from year to year. However, many of the primary and secondary roads are still unpaved. These are of low dependability in the rainy season. River transportation is very important, especially in rural areas. More than one third of the population lives in remote areas more than 10 km away from year-round roads. Many still depend on the waterways (MRC: 2003). People depend on waterways in the northeastern and southwestern provinces where many potential hydropower sites are located.

1-digit National
: 2,052km

2-digit National Road
: 2,463km

Provincial Road
: 6,615km

Rural or Tertiary Road
: app.28,000km

Source: The Study on the Road Network Development in the Kingdom of Cambodia, 2006

Figure 4.6.11 Road Network of Cambodia

In Cambodia, road transport has an overwhelming share of the transported volume of passengers and freight, and other means of transportation play a complementary role in road transport as shown in Table 4.6.4.

Table 4.6.4 Passenger and Cargo Transportation Volume by Mode

Mode of Transport	Person-km/year (million)	Ton-km/year (million)
Roadway	146.8 (65%)	274.0 (69%)
Railway	45.0 (20%)	41.0 (10%)
Inland Waterway	35.0 (15%)	80.0 (20%)
Total	226.8 (100%)	395.0 (100%)

Source: The Study on the Road Network Development in the Kingdom of Cambodia, 2006

4.6.2 Review of Socio-Economic Environment at the Project Sites

(1) Outline of Living Conditions in the Project Sites

The village names in the project sites were identified with GIS database in accordance with the information from planning engineers of the Study Team. The map scale,1:100,000, is useful only for Master Plan Study Level, project designs of constructions are not fixed yet and the submerged lands cannot be clearly defined at this stage, however, pictures of the living conditions and economic activities of the inhabitants around the sites can be inferred from the database of villages. Followings are outline of the livelihood of inhabitants in reservoir area and surrounding area.

Inhabitants inside Potential Reservoir Area: 10 projects out of 29 are peopled area. Table 4.6.5 shows the number of villages, number of family and population in the reservoir areas of these projects. Stung Sen Project having 3,157 families in its assumed reservoir area would have difficulty in implementation from the viewpoint of resettlement process such as consensus building and costs required for resettlement and compensation.

For reference, illiteracy ratio by gender is shown also in Table 4.6.5. The illiteracy ratio in Se Kong Project Site and Lower Se San III Project Site are comparatively high, because the inhabitants are mostly ethnic groups who speak different languages. Furthermore, it is said that there is correlation between electrification and literacy. This means lighting at night contributes people to read books and helps children study, so that illiteracy ratio decline as electricity disseminate (i.e. correlation between illiteracy and TV, which is one of the indicators of electricity, is -0.697 in Cambodia)

Table 4.6.5 Inhabitants in Potential Reservoir Areas

Project Number	Project Name	Number of Villages	Num. of Family	Female	Male	Population	Female Illiteracy (15<)	Male Illiteracy (15<)	Illiteracy ratio
2	Prek Chhlong II	2	308	825	793	1618	31.8%	21.9%	26.9%
3	Prek Ter III	1	103	562	489	1051	9.1%	9.4%	9.2%
7	Lower Sre Pok II + Lower Se San	13	1479	3685	3301	6986	29.9%	27.7%	28.9%
10	Se Kong	5	503	1256	1113	2369	45.1%	41.2%	43.3%
11	Lower Se San III	24	1349	3192	3277	6469	47.5%	45.2%	46.3%
15	Lower Sre Pok III	7	726	1891	1896	3787	42.8%	31.4%	37.1%
17	Stung Chhay Areng	7	277	597	564	1161	37.9%	31.0%	34.5%
20	Stung Metoek II	3	168	358	377	735	25.7%	27.6%	26.7%
26	Stung Sen	31	3157	7962	7561	15523	25.4%	15.7%	20.7%
28	Stung Battambang I	8	871	2044	2140	4184	19.2%	18.9%	19.0%
	Whole Cambodia								

Source: Rural Development Database, Seila Program, 2003

Inhabitants within 40 km radius from power station site: In order to infer the positive impacts and negative impacts on surrounding environment, the village database within 40 km radius from power station site were reviewed. These villages have potential for future electrification by extending 20 kV distribution lines from the hydropower station upon its implementation (see paragraph (1) in Sub-section

4.7.4 for more details). In principle, it is favorable to have more potential beneficiaries of electrification around the hydropower projects.

Table 4.6.6 Inhabitants within 40km Radius from Power Station Site

Project Number	Project Name	Number of Villages	Num. of Family	Female	Male	Population	Female Illiteracy (15<)	Male Illiteracy (15<)	Illiteracy ratio
2	Prek Chhlong II	79	13,895	35,614	34,432	70,046	27.9%	22.5%	25.2%
3	Prek Ter III	123	27,302	70,877	68,496	139,373	13.0%	10.8%	11.9%
4	Prek Ter II	42	6,485	17,541	16,759	34,300	25.6%	22.9%	24.3%
5	Sre Pok IV	13	1,464	3,740	3,712	7,452	35.3%	27.6%	31.4%
6	Prek Por I	35	3,566	8,015	7,964	15,979	30.8%	23.9%	27.3%
7	Lower Sre Pok II + Lower Se San II	57	10,189	27,369	26,228	53,597	13.4%	11.3%	12.4%
10	Se Kong	63	7,605	20,765	19,458	40,223	24.6%	22.7%	23.7%
11	Lower Se San III	127	12,572	31,307	31,342	62,649	38.5%	30.3%	34.4%
12	Prek Liang I	30	1,776	4,325	4,318	8,643	51.2%	45.3%	48.2%
13	Prek Liang IA	56	3,828	9,599	9,447	19,046	52.0%	45.1%	48.6%
14	Prek Liang II	7	413	948	941	1,889	43.9%	44.1%	44.0%
15	Lower Sre Pok III	111	13,271	33,068	32,737	65,805	34.7%	26.8%	30.8%
16	Middle St. Russey Chrum	30	8,251	21,244	22,089	43,333	12.8%	7.6%	10.2%
17	Stung Chhay Areng	33	2,857	6,402	6,481	12,883	34.4%	20.8%	27.6%
18	Stung Tatay	21	1,654	3,397	3,525	6,922	26.6%	18.5%	22.5%
19	Stung Metoek I	32	2,515	5,954	6,047	12,001	14.3%	11.4%	12.8%
20	Stung Metoek II	13	688	1,542	1,558	3,100	22.4%	19.7%	21.1%
21	Stung Metoek III	6	1,172	2,244	2,371	4,615	21.3%	12.7%	16.9%
22	Stung Kep II	40	9,620	24,489	25,345	49,834	13.6%	8.3%	10.9%
23	Upper St. Russey Chrum	14	653	1,411	1,440	2,851	31.8%	25.8%	28.8%
24	Stung Pursat I	69	13,201	34,534	33,600	68,134	15.5%	12.9%	14.2%
25	Stung Pursat II	126	23,305	62,622	59,165	121,787	11.3%	9.5%	10.4%
26	Stung Sen	153	17,661	43,870	42,206	86,076	21.8%	17.4%	19.6%
27	Stung Battambang II	69	7,347	17,454	17,832	35,286	16.8%	14.3%	15.6%
28	Stung Battambang I	297	47,420	118,798	117,201	235,999	10.6%	8.8%	9.7%
29	Bokor Plateau	183	49,988	134,637	126,274	260,911	15.5%	12.4%	14.0%
	29 Projects Total/ Mean	1,750	288,698	741,766	720,968	1,462,734	25.4%	20.5%	22.9%
	Cambodia Total/ Mean	12,847	2,471,834	6,455,835	6,047,566	12,503,401	12.8%	9.9%	11.4%

Source: Rural Development Database, Seila Program, 2003

Their life will provably influenced by the changes of environment caused by dam construction. Table 4.6.7 shows the indicators to infer the agriculture and fisheries activities; i.e. whether they use irrigation system, fertilizers and/or pesticide for growing agricultural products.

People in western regions, where the projects of Stung Battambang, Stung Pursat and Bokor Plateau are located, fertilizer and pesticide have already been in use for modern agriculture as business. They have tried to improve yield and quality of agricultural products. The agricultures in these areas are something like monocultures or specialized agriculture plantations. In such matured agricultural circumstances, water management and electrification would be helpful for them to improve their business.

Breeding cow and pig are also indicators of lifestyle of villagers. Ethnic minorities in northeast mountains mostly breed livestock and carry out sustainable agriculture for self-consumption. They seldom use fertilizer and pesticide for farming.

In terms of fisheries, majority of rural people are engaged in fishing more or less for self-consumption. Women in mountain areas go to brooks to catch small fish by using gravel traps and baskets, for obtaining foods of families. The indicators of row boat and motorboat in the village database show the degree of dependence on rivers. The location of house and size of river have surely influence to the ownership ratios of boats, therefore, the indicators tell something about relations between the people and rivers. In terms of the project site of Se Kong, around 50% of inhabitants have boats; it means their lives are much depending on the river.

Table 4.6.7 Indicators Concerning Agriculture and Fisheries

		Agriculture				Livestock husbandry		Fisheries	
Pro. Num.	Project Name	Irrigation	Fertilizer	Pesticide	Price of Paddy	Cow	Pig	Row Boat	Motor Boat
2	Prek Chhlong II	4.6%	5.1%	5.7%	346.9	63.1%	47.7%	3.9%	1.2%
3	Prek Ter III	9.6%	15.1%	19.7%	396.9	58.0%	49.3%	14.2%	4.0%
4	Prek Ter II	2.0%	2.9%	3.9%	400.0	81.9%	65.8%	5.5%	0.1%
5	Sre Pok IV	0.0%	1.2%	0.5%	260.0	79.8%	64.8%	6.6%	4.2%
6	Prek Por I	0.0%	3.1%	5.3%	351.3	28.5%	35.8%	0.0%	1.0%
7	Lower Sre Pok II + Lower Se San II	0.5%	3.2%	6.6%	328.4	49.5%	39.2%	28.9%	13.5%
10	Se Kong	0.7%	3.7%	8.1%	339.9	66.5%	54.3%	34.4%	17.9%
11	Lower Se San III	0.4%	1.3%	11.0%	348.3	33.7%	48.7%	5.5%	3.6%
12	Prek Liang I	0.0%	0.0%	0.3%	425.0	29.8%	60.2%	9.3%	5.1%
13	Prek Liang IA	0.2%	0.0%	2.4%	366.7	42.4%	59.6%	7.7%	6.2%
14	Prek Liang II	0.0%	0.0%	0.0%	471.4	23.2%	63.7%	12.3%	7.0%
15	Lower Sre Pok III	0.7%	1.7%	5.2%	330.4	40.8%	45.2%	3.5%	1.7%
16	Middle St. Russey Chrum	0.0%	2.1%	2.1%	176.7	3.2%	4.3%	1.8%	9.7%
17	Stung Chhay Areng	0.2%	25.0%	17.9%	353.9	40.7%	33.4%	11.2%	2.8%
18	Stung Tatay	0.4%	3.9%	6.3%	441.3	9.3%	12.0%	22.6%	11.3%
19	Stung Metoek I	0.8%	3.7%	8.5%	254.5	33.4%	52.5%	0.2%	0.0%
20	Stung Metoek II	0.0%	0.9%	1.0%	92.3	30.4%	35.3%	0.1%	0.0%
21	Stung Metoek III	0.0%	4.3%	4.9%	0.0	6.4%	10.1%	1.5%	5.5%
22	Stung Kep II	0.1%	2.3%	2.5%	259.8	2.3%	5.4%	4.0%	16.4%
23	Upper St. Russey Chrum	0.0%	1.1%	2.0%	273.3	21.3%	10.9%	4.0%	0.3%
24	Stung Pursat I	1.8%	45.7%	13.5%	252.9	67.9%	45.3%	0.9%	2.0%
25	Stung Pursat II	3.8%	54.6%	9.2%	344.3	75.3%	59.5%	1.4%	1.2%
26	Stung Sen	4.4%	10.5%	9.1%	332.2	78.1%	64.8%	11.6%	1.2%
27	Stung Battambang II	0.4%	5.7%	11.9%	299.3	27.7%	37.9%	0.3%	0.8%
28	Stung Battambang I	4.4%	35.6%	21.4%	318.3	41.3%	17.9%	0.7%	0.8%
29	Bokor Plateau	15.1%	56.3%	23.0%	370.1	52.8%	54.4%	6.1%	4.9%
	29 Projects Mean	25.4%	25.4%	25.4%	312.9	25.4%	25.4%	25.4%	25.4%
	Cambodia Mean	15.6%	59.5%	31.9%	385.8	58.4%	54.7%	8.0%	n.a.

Source: Rural Development Database, Seila Program, 2003

Accessibilities of market and information are important criteria to assess the maturity of industries. In case the people already enjoy benefits of infrastructure of road network and electricity, the development impacts of hydropower projects will be introduced immediately. They are ready to get positive impact of electrification and the projects will activate local economy.

On the other hand, people, who live in remote areas without using TV and modern transportation means, would face culture shock from development activities. It is significant to review their life stile and ask them what type of life style they prefer. Awareness of culture and civilization should be carefully maintained and promoted by the government and project owners, otherwise the conflict would become serious.

Recently, farmers' debt to money render and micro finance institutes are becoming critical issues because they take lands as mortgage. As population grows, farmlands are subdivided for sharing among family members. It is the anxiety of farmers. Some of the people already started entering into the forest to open new farmland. At the same time, the land price is rising in the developing areas, and so speculative land buying is booming in some areas. These aspects should be addressed in formulating resettlement plan and project area development plan to improve the living standards of the people.

Table 4.6.8 Indicators Concerning Degree of Modern Civilization

Project Number	Project Name	Household having TV	Household having Motorbike	Household having CAR	KM_ROAD (km)	Minuets to Road	Minuets to Markets	Land Complain
2	Prek Chhlong II	13.1%	22.4%	1.2%	9	48	87	1.0%
3	Prek Ter III	28.1%	25.4%	2.2%	5	30	68	1.1%
4	Prek Ter II	16.7%	14.4%	1.0%	13	76	134	1.1%
5	Sre Pok IV	2.9%	14.4%	0.8%	95	517	529	1.0%
6	Prek Por I	7.7%	31.5%	4.2%	9	46	83	1.4%
7	Lower Sre Pok II + Lower Se San II	2.6%	7.4%	0.5%	7	45	82	0.6%
10	Se Kong	2.8%	7.0%	0.6%	30	161	211	0.7%
11	Lower Se San III	6.3%	14.9%	0.6%	4	22	70	0.7%
12	Prek Liang I	0.9%	4.7%	0.0%	9	39	147	0.5%
13	Prek Liang IA	1.4%	9.1%	0.1%	8	33	121	0.6%
14	Prek Liang II	0.2%	0.7%	0.0%	7	23	156	0.2%
15	Lower Sre Pok III	6.2%	19.6%	1.1%	18	95	130	0.9%
16	Middle St. Russey Chrum	29.9%	13.8%	1.5%	8	33	51	0.8%
17	Stung Chhay Areng	7.8%	9.6%	1.1%	16	81	140	1.0%
18	Stung Tatay	6.7%	7.7%	1.6%	24	124	142	0.4%
19	Stung Metoek I	19.2%	32.5%	8.9%	2	15	53	2.0%
20	Stung Metoek II	12.4%	26.5%	4.1%	1	4	84	0.1%
21	Stung Metoek III	13.1%	18.5%	2.0%	1	7	142	0.1%
22	Stung Kep II	27.3%	12.0%	1.4%	6	24	60	0.7%
23	Upper St. Russey Chrum	5.5%	10.9%	1.1%	37	168	206	0.6%
24	Stung Pursat I	18.4%	8.0%	1.6%	7	36	64	1.7%
25	Stung Pursat II	20.4%	11.3%	1.9%	2	10	46	1.5%
26	Stung Sen	5.5%	10.6%	0.7%	22	72	134	0.7%
27	Stung Battambang II	19.2%	26.6%	8.1%	5	28	64	4.8%
28	Stung Battambang I	26.0%	21.5%	5.4%	2	13	38	2.3%
29	Bokor Plateau	19.4%	18.4%	2.0%	1	8	45	1.2%
	29 Projects Mean	12.3%	15.4%	2.1%	13	68	119	1.1%
	Cambodia Mean	31.7%	19.3%	2.4%	5	20	49	1.2%

Source: Rural Development Database, Seila Program, 2003

(2) Initial Assessment of Socio-Economic Environment in the Project Sites

Based on the considerations mentioned above, the socio-economic impacts were preliminarily assessed as shown in Table 4.6.9. The key points for rating are described below:

1) The impacts of resettlement and potential electrification are measured by numbers of households and population (refer to Figure 4.6.2 Illiteracy Ratio, Figure 4.6.4 TV Ratio, Table 4.6.5 Inhabitants in Potential Reservoir Area, and Table 4.6.6 Inhabitants within 40 km Radius from Power Station Site).

2) There are no sound data on the numbers of minorities in those villages situated inside reservoir areas. The situation was assumed based on documents (refer to Table 4.6.3 and Figure 4.6.8).

3) Famous historical remains and cultural heritages are mentioned on documents. However, there is no description on local spiritual shrines in villages. The rating at this stage was based on the general information.

4) Potential of agriculture, fisheries, commerce and industries were assessed based on the general information plus individual statistical data mentioned above. Topographic conditions were also taken into consideration (refer to Figures 4.6.9, 4.6.10 and 4.6.11, Tables 4.6.7 and 4.6.8).

Table 4.6.9 Initial Assessment of Socio-Economic Impacts

		Number of households for re-settlement	Potential number of households for electri-fication	Minorities maintaining traditional style of life	Historical remains and cultural heritages	Potential of irrigated agriculture	Potential of fishery	Potential of commerce and industry
2	Prek Chhlong II	C	B	B	A	B	D	B
3	Prek Ter III	B	A	B	A	A	C	B
4	Prek Ter II	A	C	A	A	B	D	C
5	Sre Pok IV	A	E	C	A	C	D	C
6	Prek Por I	A	D	C	A	C	C	A
7	Lower Sre Pok II + Lower Se San II	E	B	E	B	C	E	C
10	Se Kong	D	C	E	B	D	E	C
11	Lower Se San III	E	B	E	C	C	C	C
12	Prek Liang I	A	E	D	A	C	D	D
13	Prek Liang IA	A	D	D	B	C	D	C
14	Prek Liang II	A	E	D	A	D	D	D
15	Lower Sre Pok III	D	B	D	A	B	C	A
16	Middle St. Russey Chrum	A	C	A	A	A	B	A
17	Stung Chhay Areng	C	D	B	A	B	B	B
18	Stung Tatay	A	E	B	A	A	B	A
19	Stung Metoek I	A	D	A	A	B	D	A
20	Stung Metoek II	B	E	A	A	A	C	A
21	Stung Metoek III	A	E	A	A	B	B	A
22	Stung Kep II	A	C	A	B	A	B	A
23	Upper St. Russey Chrum	A	E	A	A	D	D	A
24	Stung Pursat I	A	B	A	B	B	C	B
25	Stung Pursat II	A	A	A	B	A	C	A
26	Stung Sen	E	B	C	E	D	C	C
27	Stung Battambang II	A	C	B	D	A	C	B
28	Stung Battambang I	D	A	B	D	C	B	B
29	Bokor Plateau	A	A	A	A	B	C	A

Note: A = superior, B = good, C = medium, D = poor, E = poorest
Source: Study Team

4.7 GIS DATABASE

4.7.1 Collection of Digital GIS Map Coverage

While targeting the need of the project, required geospatial digital GIS data has been collected from existing sources and archived in GIS Database at Project Server located at Hydroelectricity Department of Ministry of Industry, Mines and Energy, Phnom Penh, Cambodia. At the moment, list of collected datasets have been presented in Table 4.7.1.

Table 4.7.1 List of GIS Data Archived in Project GIS Database

S.No.	Name of Coverage	Description	Source
1	cont_lin	Contour Line of Cambodia; 20 meter interval supplemented with 10 and 5 m.	MOPWT
2	lu_topo	Land Use/Land Cover of Cambodia	MOPWT
3	District_HQ.shp	Location of District Capital in Cambodia	MOPWT
4	Province2_HQ.shp	Location of Province Capital in Cambodia	MOPWT
5	khet50.shp	Province Boundary	MOPWT
6	srok50_poly.shp	District Boundary	MOPWT
7	REE.shp	Command Area of REE	Study Team
8	Seila2003.shp	Location of Village Center and related socioeconomic data	SEILA, Cambodia
9	geology	Geological coverage	MOPWT
10	dn_lin & dn_pol	River network coverage	MOPWT
11	Landmine & UXO	Landmine & UXO data of various types	CMAA

Source: Study Team CMAA: Cambodian Mine Action and Victim Assistance Authority

More data can be added from the available sources as required in the future.

4.7.2 Creation of New Geospatial Data

(1) Hydrological and Meteorological Station Location

From the XY point location text data following Geospatial Datasets have been created. These data have been used to create the national level 1) Meteorological and 2) Hydrological station location maps.

- Meteorological Station Location
  Name of the GIS coverage in GIS Database: metro_st.shp
- Hydrological Station Location
  Name of the GIS coverage in GIS Database: hydro_st.shp

These are the point coverage data that specify the location of the station along with their specific IDs and the Latitude and Longitude coordinates in degree decimal unit.

(2) Extent of Inundation Due to Damming

In order to estimate the inundation area and the volume of water in reservoir due to damming at the identified potential hydropower sites, it is necessary to create the inundation polygon coverage. For this purpose, using existing contour coverage (20 meter intervals supplemented with 10 m and 5 m (few places) contour lines) and river network coverage of Cambodia, the various levels (elevation in meter above MSL) of aerial extent polygon for possible inundation have been delineated after identifying the damming site. Created GIS coverage includes 1) the outermost boundary of inundation and 2) various level of inundation by elevation in meter above MSL. The location of the hydropower potential sites and the boundary of possible inundation area due to damming are illustrated in Figure 4.7.1. As a sample different level of inundation area is illustrated in Figure 4.7.2.

In GIS database a separate folder was created for damming inundation. The structure of the folder is: 1) one folder for each potential hydropower projects and 2) inside the folder separate GIS Map Coverage for each level (elevation in meter above MSL) of inundation plus the outermost boundary of the reservoir.

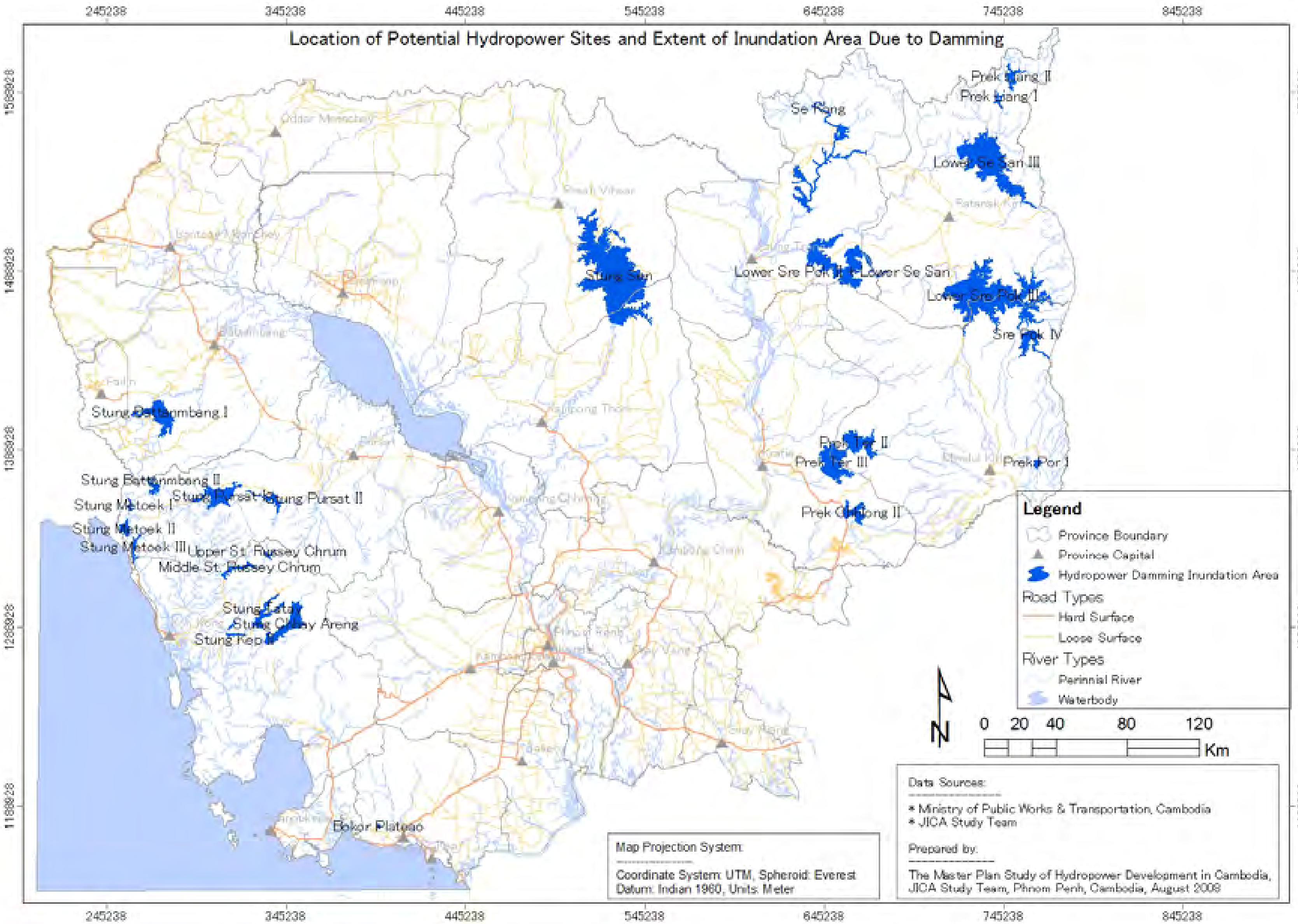


Figure 4.7.1 Location and Extent of Inundation Area due to Damming for Potential Hydropower Project

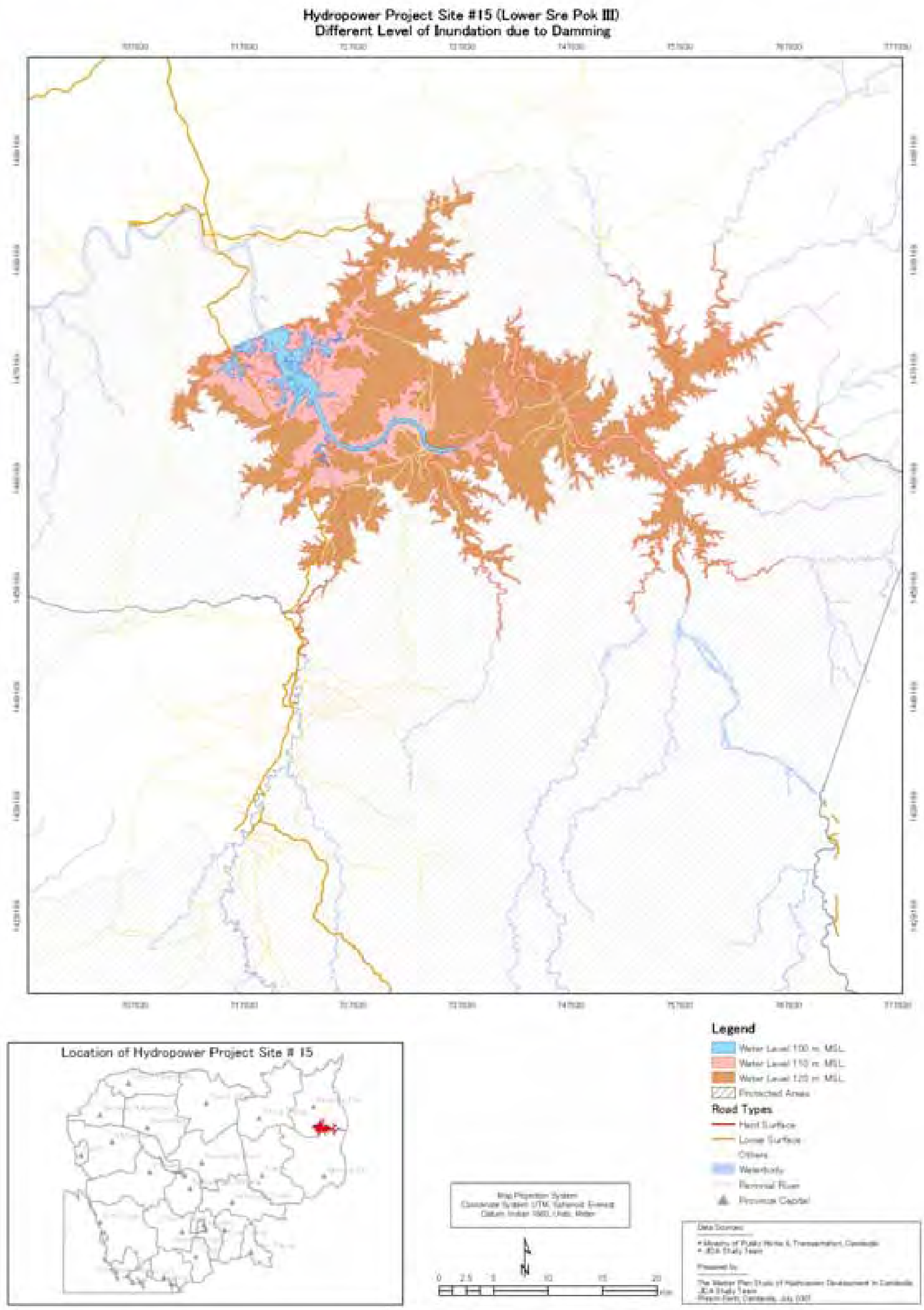


Figure 4.7.2 A Sample of Different Level of Inundation Extent Due to Damming

4.7.3 Methodology for Calculation of Inundation Area due to Damming

A simple but comprehensive methodology has been derived to estimate upstream impoundment area due to damming for hydropower potential project sites using GIS. Flow diagram (Figure 4.7.3) shows steps of such calculation.

The process starts from creating the inundation area polygon as briefly described in Sub-section 4.7.2. Using this data, the inundation area was calculated. The summary of the results is presented in Table 4.7.2.

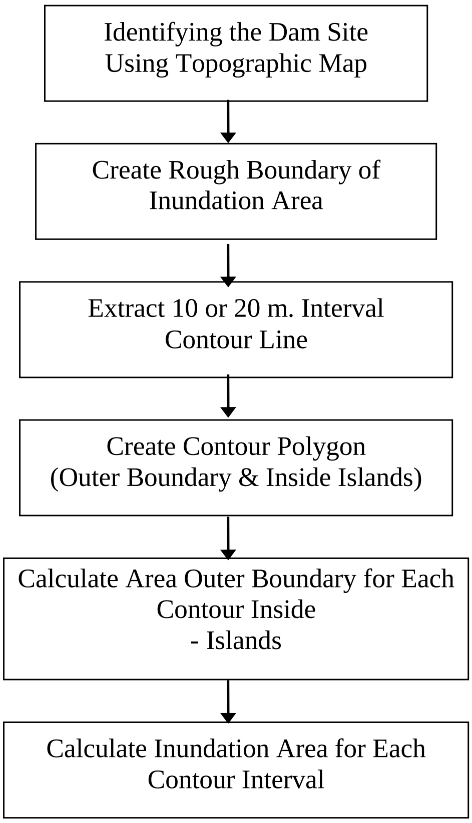


Figure 4.7.3 Flow Diagram of Inundation Area Calculation

Table 4.7.2 Summary of the Inundation Area Calculation Due to Damming

Project Number	Project Name	Minimum Elevatation (m MSL)	Maximum Elevatation (m MSL)	Total Inundation Area (ha)
2	Prek Chhlong II	50	60	5,811.99
3	Prek Ter III	40	60	17,879.01
4	Prek Ter II	70	80	10,154.57
5	Sre Pok IV	130	140	5,261.81
6	Prek Por I	540	560	1,151.26
7	Lower Sre Pok II + Lower Se San II	50	75	35,513.56
10	Se Kong	50	60	11,710.62
11	Lower Se San III	100	120	46,068.05
12	Prek Liang I	300	340	715.39
14	Prek Liang II	480	520	1,415.82
15	Lower Sre Pok III	100	120	70,978.09
16	Middle St. Russey Chrum	360	400	2,258.87
17	Stung Chhay Areng	140	210	13,510.04
18	Stung Tatay	360	420	4,706.26
19	Stung Metoek I	300	400	460.23
20	Stung Metoek II	180	240	2,021.68
21	Stung Metoek III	100	120	1,120.13
22	Stung Kep II	40	200	754.59
23	Upper St. Russey Chrum	700	800	445.28
24	Stung Pursat I	180	200	10,154.26
25	Stung Pursat II	40	60	2,474.68
26	Stung Sen	30	50	93,940.10
27	Stung Battambang II	460	560	1,431.34
28	Stung Battambang I	40	80	13,229.91
29	Bokor Plateau	860	945	193.50

Source: Study Team

4.7.4 Extraction of Socioeconomic and Natural Environment Data for Potential Hydropower Projects

It is well known fact that most of infrastructure development activities bring both socioeconomic benefits as well as some degree of adverse impacts on society and surrounding environment. Thus it is essential to evaluate all possible adverse impacts and environmental damage of infrastructure development projects and find the means and ways to minimize it.

Hydropower development projects provide much needed energy, however they are not immune to adverse impact on society as well as surrounding environment. In order to evaluate benefit and related adverse impacts, a number of basic data on socioeconomic and natural environment, which are listed below, have been extracted. These data are helpful to devise appropriate mitigation plan and strategies to minimize the adverse impacts.

(1) Villages falling within 40 km from the potential hydropower powerhouse

Figure 4.7.4 shows the spatial distribution of village centers (point location of villages using arbitrary village center) which fall within the 40 km aerial radial distance from each of potential hydropower powerhouse. Some of the powerhouses are located immediate downstream of the dam (referred to as dam type hydropower) while others at some distance downstream of the dam (to create an appropriate head by waterway, referred to as dam-waterway type hydropower). The total number of villages located within a circle of 40 km in radius with center at planned power station site, total number of households and total population have been extracted for socioeconomic analysis. It should be noted that some of the villages have been counted in duplication as they fall inside command areas of more than one hydropower project (circle of 40 km radius).

(2) Villages situated inside the assumed reservoir area

The village center point location data (prepared by SEILA) has been intersected with the outermost boundary (representing the reservoir area) of a reservoir of interest to check if some of the villages would be submerged therein. The number of villages situated in the reservoir area and the number of households has been extracted, and their spatial distribution is illustrated in Figure 4.7.5. Again it should be noted that the reference is the village center meaning that many of the households might not be affected by the reservoir at all, thus field verification will be necessary. The hydropower projects not listed in Table 4.7.4 are devoid of any village center in their to-be reservoir, however it does not guarantee that these reservoirs will not affect any household (village data is only point, not parcel coverage of land use).

(3) Land use/land cover categories and their area falling inside reservoir area

Table 4.7.5 and Figure 4.7.6 respectively illustrate the statistics and spatial distribution of current land use/land cover of to-be reservoir. It can be observed that majority of reservoirs are devoid of agricultural land. Almost all of them will be consuming significant percentage of forest land, comparing with the land use/land categories distribution (Table 4.7.5).

There might be agreement with the view that it is easier to substitute the other land categories (including forest) than that of agricultural land. It is difficult to substitute the agricultural land because of their relationship with socioeconomic and cultural value of the local population. In this sense the situation is favorable for most of the candidate hydropower projects since these would have little social impact or social impacts could be mitigated. However, some projects, specifically those where submersion of agricultural land is wide, for example project numbers 11 and 26 would have significant impacts.

(4) Proportion of the reservoir area falling in the protected areas and reserve

Figure 4.7.7 illustrates; using linear hatching; the spatial coverage of reservoir that will be falling inside areas proclaimed as protected areas and reserves. Usually, wild life sanctuaries/protected areas located in mountain areas, which is also home to most of the watersheds thereby potential hydropower sites. Thus it is obvious that majority of potential hydropower projects have substantial proportion of reservoir area inside protected areas and reserves (Table 4.7.6). It might give the negative evaluation while observing with the eye of environmentalist and people who are actively involve in the protection of protected areas and reserve. However, there is another side of story to tell such as one has to consider the proportion of protected area would be submerged in the reservoir.

Furthermore, A reservoir would provide important watering places for various animals in the dry season in particular. We should be aware that the reservoir impacts are not necessarily negative but sometimes positive.

Main benefit coming from the hydropower projects is the much needed electricity that could be made available also to the surrounding settlements/villages and industries, while the main social and environmental adverse impact is coming from the reservoir, which is created by damming of river for potential hydropower project. Creation of reservoir may create, primarily, two problems, namely 1) submerge upstream land area and 2) alter downstream river flow regime.

It would necessary to study strategies, at the time of preparation of the Master Plan, for mitigation of the adverse impacts on socioeconomic and surrounding natural environment. Such mitigation might include but not limited to the following:

- **Substitution of Forest Area**: In the case of project location outside the Protected Area, nearby area may be converted into comparable forest area by including entire, but within possible extent, flora found in the planned reservoir area. The land use/land cover categories, such as shrubland, grassland, barren land etc. may be selected for such replacement. Furthermore, conservation program for the fauna may also be studied in newly created forest and surrounding areas.
- **Downstream Flow:** Design and operate the reservoir so that it will not adversely affect the present downstream flow conditions or it will minimize adverse impacts if any. Among the downstream impacts, significant one would be changes in river flow caused due to the sudden changes of the power discharges. Countermeasures are 1) construction of a re-regulating reservoir[7], 2) installation of an early warning system on the power discharges. These should be studied at feasibility stage for their needs, and planned and designed at detailed design stage.
- **Fauna Movement:** Create structures that can facilitate the existing movement of fauna, specifically for fish.
- **Watershed Management:** An integrated upstream watershed management plan would contribute to the socioeconomic betterment of the people residing inside the watershed and, at the same time, reduction of silt-load of the river.
- **Utilization of the Reservoir:** Utilization of the reservoir for the betterment of surrounding community may be studied including 1) fish farming; both high value indigenous as well as hybrid species, 2) recreational activities, and 3) tourism.

[7] The discharge (water outflow) released from a hydropower station will abruptly increase upon start of power generation and will be almost constant during operation hours but it will drop to zero upon shutdown of the generation. In the case of peaking power station that would be operated only for several peak-loading hours a day, a small re-regulating reservoir is constructed downstream of the power station, to once store the power discharge inside the re-regulating reservoir and release it continuously at average rate over 24 hours. Thus the downstream flow conditions could be maintained stable without impact of peaking operation.

Table 4.7.3 Summary of Present Land Use/Land Cover Categories for Candidate Reservoir

Project Number	Project Name	Total Area (ha)	Area (ha) Distribution in Different Land Use/Land Cover Categories			% of Area Under Agriculture	% of Area Under Forest
			Agriculture	Forest	Others		
2	Prek Chhlong II	5,811.99	668.49	4,829.83	313.67	12	83
3	Prek Ter III	17,879.01	854.58	15,796.46	1,227.96	5	88
4	Prek Ter II	10,154.57	49.30	8,631.10	1,474.17	0	85
5	Sre Pok IV	5,261.81		4,658.97	602.84	0	89
6	Prek Por I	1,151.26	6.48	1,129.58	15.21	1	98
7&8	Lower Sre Pok II + Lower Se San II	35,513.56	1,347.20	30,794.18	3,372.19	4	87
10	Se Kong	11,710.62	536.39	6,723.65	4,450.58	5	57
11	Lower Se San III	46,068.05	12,935.69	12,682.87	20,449.49	28	28
12	Prek Liang I	715.39	0.00	685.04	30.35	0	96
14	Prek Liang II	1,415.82	0.00	1,017.40	398.42	0	72
15	Lower Sre Pok III	70,978.09	1,784.80	64,169.45	5,023.84	3	90
16	Middle St. Russey Chrum	2,258.87	8.52	2,116.95	133.39	0	94
17	Stung Chhay Areng	13,510.04	1,059.31	10,620.46	1,830.27	8	79
18	Stung Tatay	4,706.26	121.65	3,958.41	626.20	3	84
19	Stung Metoek I	460.23	0.00	295.80	164.43	0	64
20	Stung Metoek II	2,021.68	723.65	1,129.66	168.37	36	56
21	Stung Metoek III	1,120.13	0.00	669.84	450.29	0	60
22	Stung Kep II	754.59	0.00	625.94	128.66	0	83
23	Upper St. Russey Chrum	445.28	0.00	445.28	0.00	0	100
24	Stung Pursat I	10,154.26	0.00	10,154.26	0.00	0	100
25	Stung Pursat II	2,474.68	2.56	2,407.75	64.38	0	97
26	Stung Sen	93,940.10	7,715.51	81,972.05	4,252.55	8	87
27	Stung Battambang II	1,431.34	0.00	1,351.61	79.72	0	94
28	Stung Battambang I	13,229.91	1,020.04	11,144.46	1,065.41	8	84
29	Bokor Plateau	193.50	0.00	110.79	82.72	0	57

Note: Being Located in Rural Areas, the Settlements (sparsely populated areas) are mapped under Agriculture due to Mapping Scale

Source: Study Team

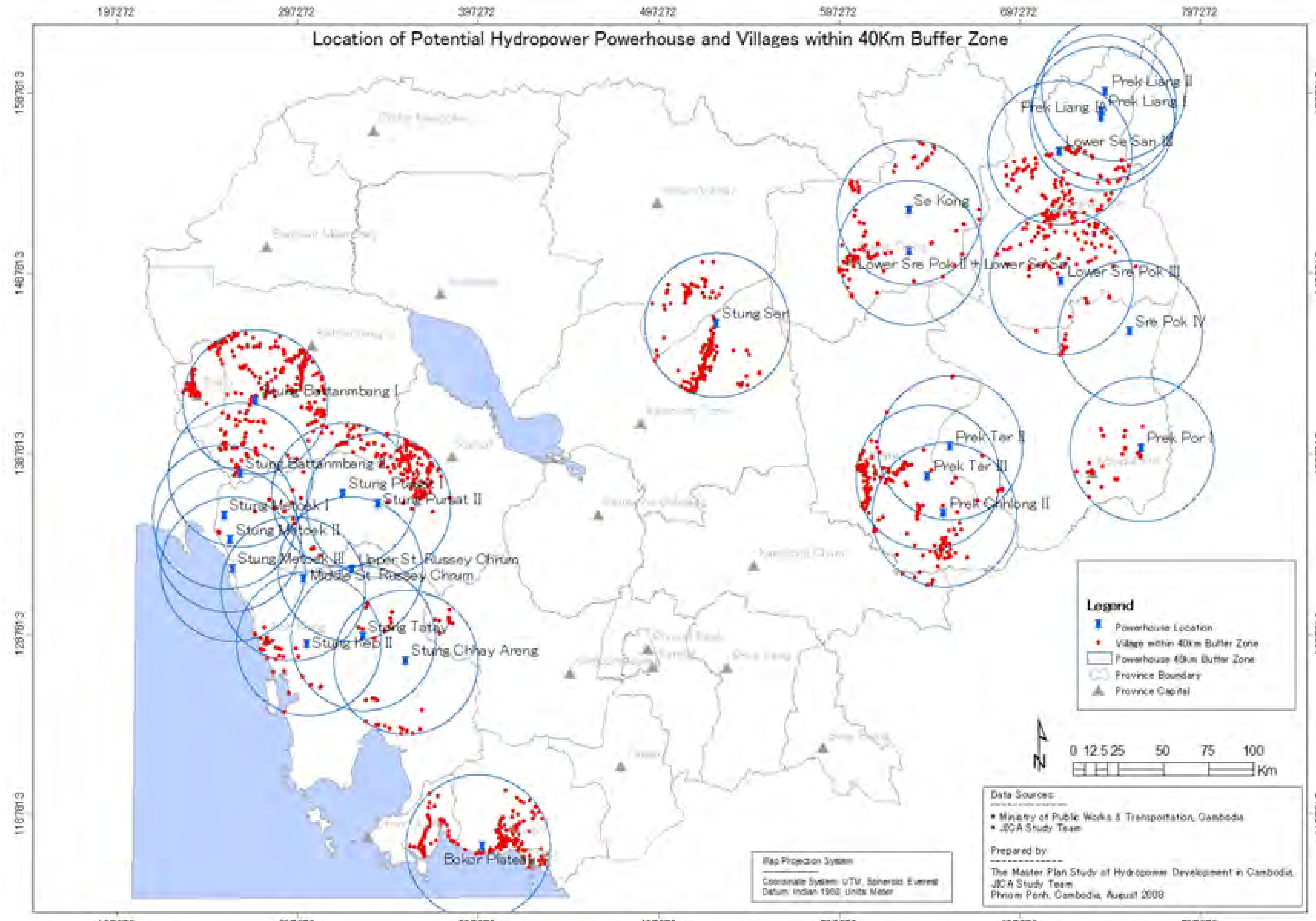


Figure 4.7.4 Location of Candidate Powerhouse and Villages within 40 km Radius

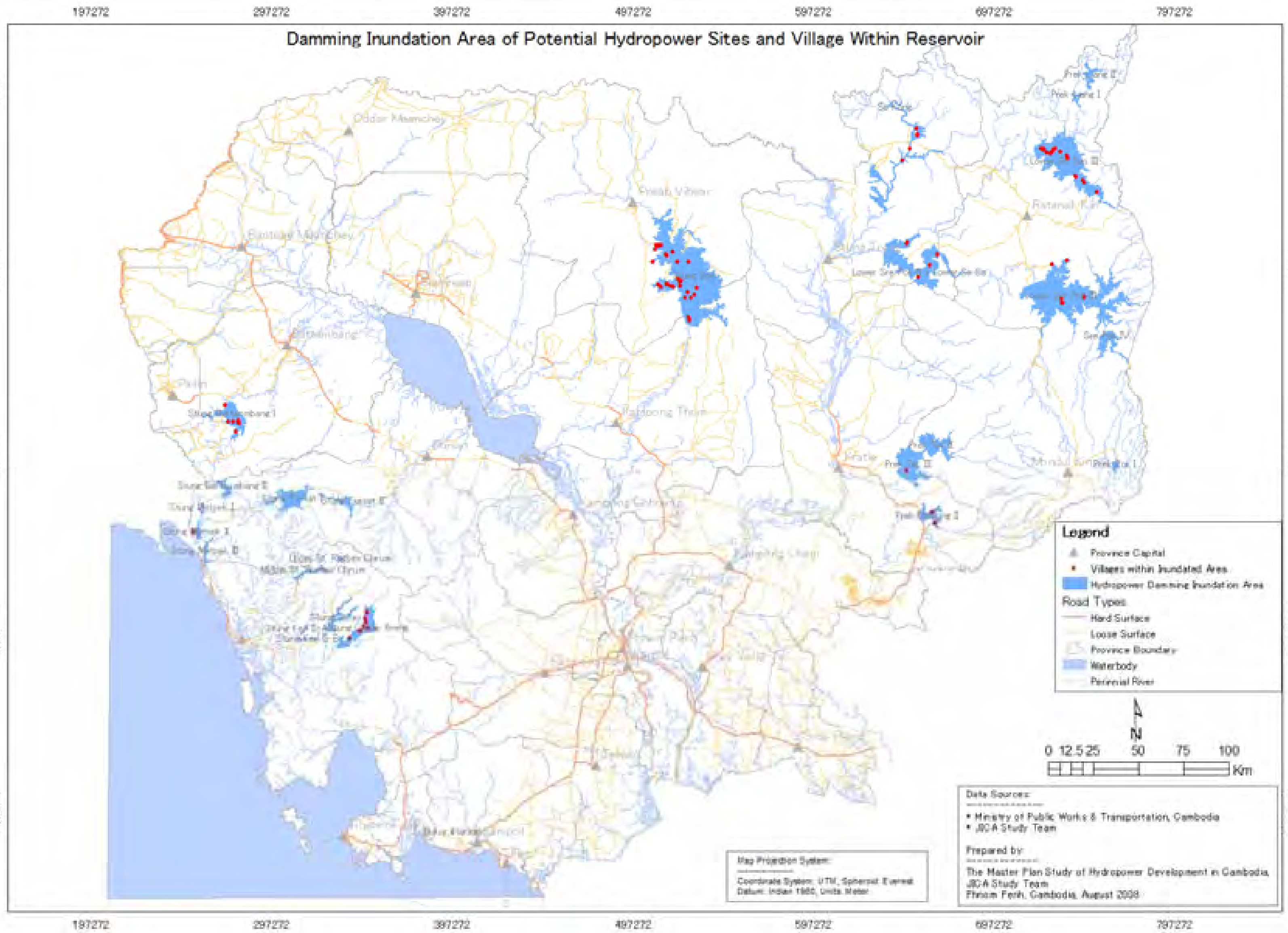


Figure 4.7.5 Reservoir of Candidate Projects and Village Center Location Likely to Fall Inside

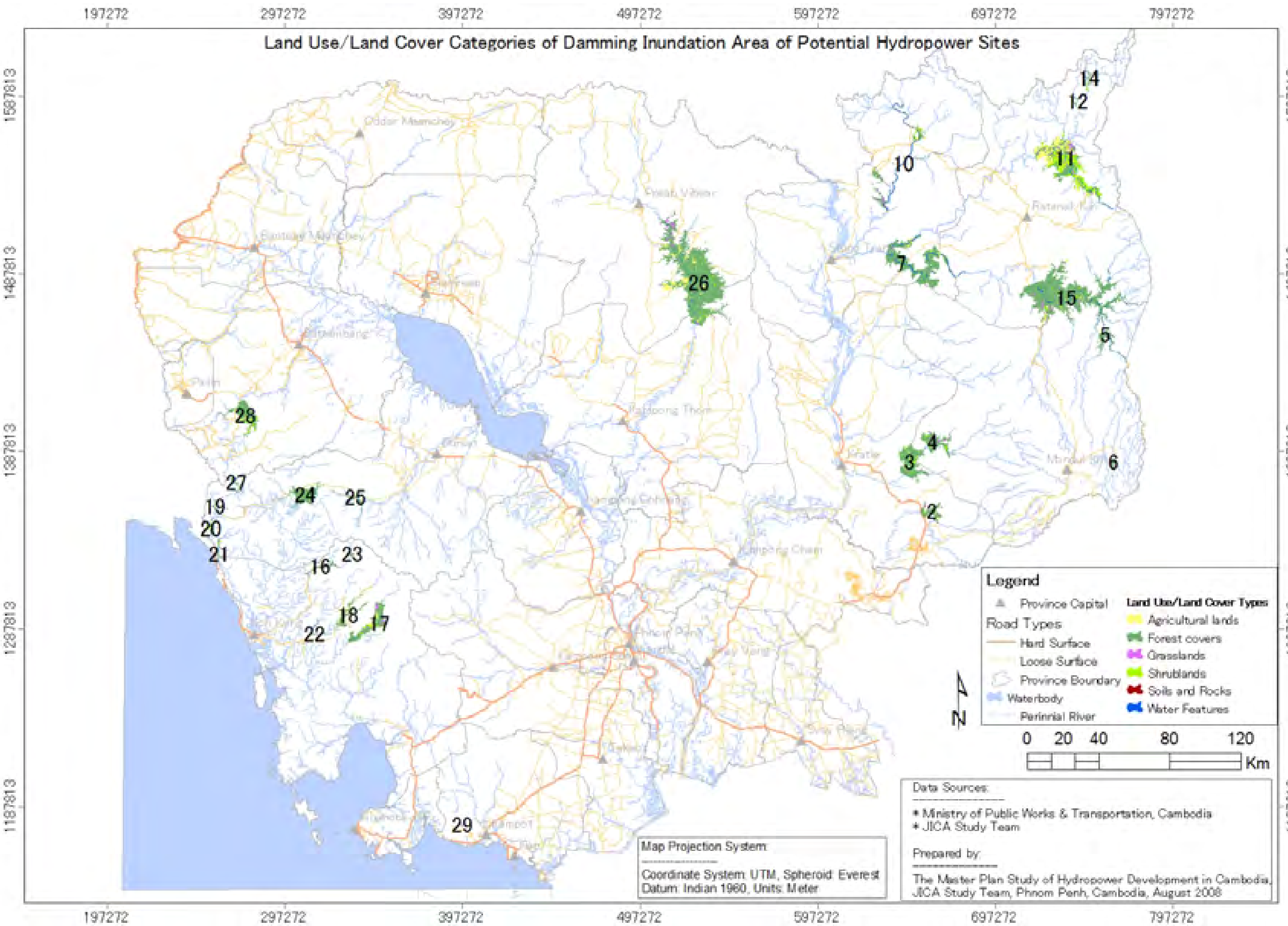


Figure 4.7.6 Present Land Use/Land Cover Distribution of Reservoir of Candidate Projects

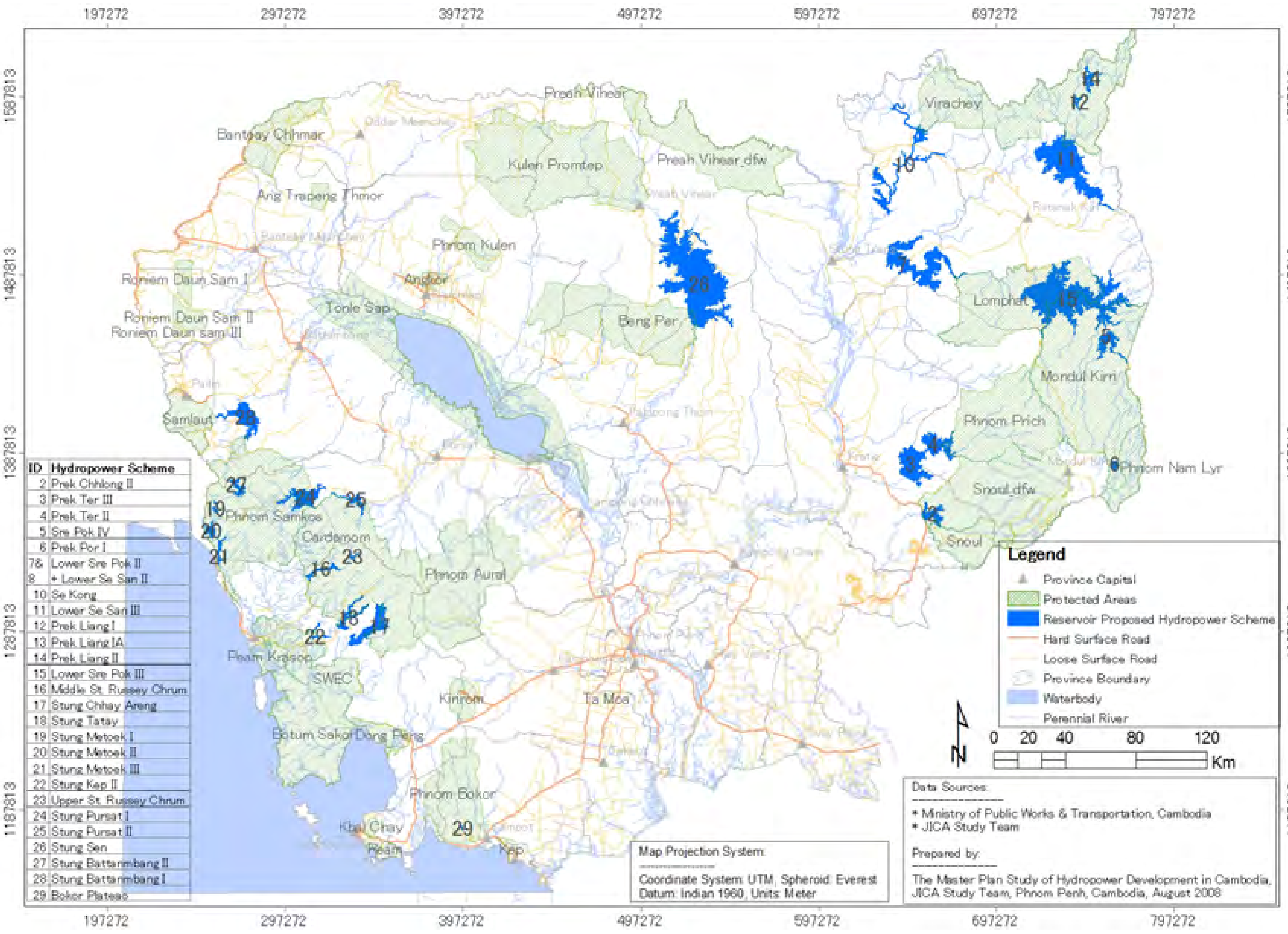


Figure 4.7.7 Relative Location of Reservoir of Candidate Projects to Protected Areas and Reserves

4.8 NATURAL ENVIRONMENT

4.8.1 Environmental Law and Regulations

(1) Environmental Law, 1996

The First Law on Environmental Protection and Natural Resources Management was prepared by the MOE from 1993 to 1995 and was passed by the National Assembly on 24 December 1996[8]. In the legal hierarchy, the law is the supreme legal instrument governing environmental protection and natural resources management.

(2) Royal Decree on the Creation and Designation of Protected Areas

The Royal Decree on the Creation and Designation of Protected Areas was promulgated on 1 November 1993. The Royal Decree established 23 Protected Areas in Cambodia with a total area of 3,273,200 ha, accounting for 18% of the country's surface area.

(3) EIA Procedure

EIA procedure is stipulated in the sub-decree on environmental impact assessment process, August 11, 1999 (URL: http://www.camnet.com.kh/moe/sub_EIA.htm). The procedure of EIA is shown in Figure 4.8.1. A project owner (PO) shall submit Initial Environmental Impact Assessment (IEIA) report to the Ministry of Environment (MOE). MOE examines the report. If MOE requires PO to revise it or to prepare full EIA report, PO has to follow and submit again. If the requirement is fulfilled, revised IEIA or EIA report is approved by MOE[9].

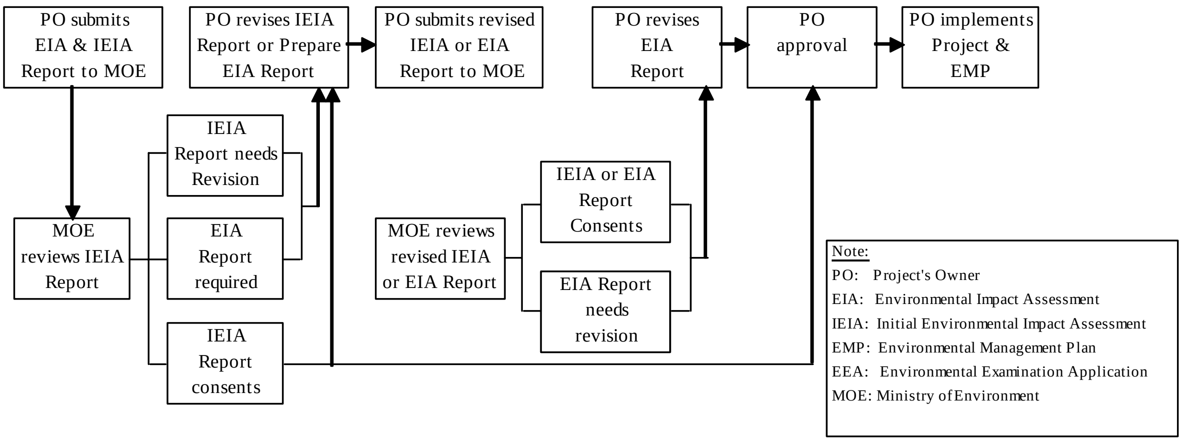


Figure 4.8.1 Flow Chart of EIA Process

Source: Sub-decree on Environmental Impact Assessment Process, No.72 Council of Minister, August 11 ,1999

[8] URL: http://www.camnet.com.kh/moe/EnvironmentLow.htm
[9] Progress Report, The Study on the Road Network Development in the Kingdom of Cambodia, Nippon Koei

When an IEIA/EIA report is submitted to MOE, MOE organizes a review team consisting of experts concerned from the relevant ministries and agencies to examine it.

(4) Projects that Need EIA

According to the sub-decree on Environmental Impact Assessment Process, 1999, the following five types of projects need an Environmental Impact Assessment (EIA):

1) Newly proposed projects which are approved by the Government or Development Committee of Cambodia
2) Newly proposed projects which are implemented and approved by presiding ministries
3) Newly proposed projects which are approved by provincial or city governments
4) Existing projects which are approved by presiding ministries
5) Existing projects which are approved by provincial or city governments

It is also presented in Table 4.8.1. Hydropower projects are classified under No. 4, “IX Other industries”, “A Industrial”. Of the project types that need EIA, those projects having a development scale greater than a certain prescribed level need an EIA. Hydropower projects greater than 1 MW need an EIA.

The Master Plan Study is out of the scope of EIA because it does not include a pre F/S or F/S.

Table 4.8.1 List of the Projects That Require an IEIA or EIA

No.		Type and activities of the projects	Size / Capacity	No.		Type and activities of the projects	Size / Capacity
A Industrial	1	Food processing and canning	> 500 Tonnes/year		10	Flooring tile manufacturing	90,000 piece /month
I .Foods, Drinks, Tobacco	2	All fruit drink manufacturing	> 1,500 Litres / day		11	Calcium carbide plants	All sizes
	3	Fruit product manufacturing	> 500 ones/year		12	Production of construction materials(Cement)	900 tonnes/month
	4	Orange juice manufacturing	All sizes		13	Cow oil and motor oil manufacturing	All sizes
	5	Wine manufacturing	All sizes		14	Petroleum study research	All sizes
	6	Alcohol and beer brewery	All sizes	VII Metal industries	1	Mechanical industries	All sizes
	7	Water supply	> 10,000 Users		2	Mechanical storage factory	All sizes
	8	Tobacco product manufacturing	> 10,000 Boxes/day		3	Mechanical and shipyard enterprise	All sizes
	9	Tobacco leaf processing	> 350 Tonnes/ year	VIII Metal Processing Industries	1	Manufacturing of harms, barbed wires, nets	> 300 Tonnes/month
	10	Sugar refinery	> 3,000 Tonnes / year		2	Steel mill, iron, aluminum	All sizes
	11	Rice mill and cereal grains	> 3,000 Tonnes / year		3	All kinds of smelting	All sizes
	12	Fish, soy beans, chilies, tomato sauces	> 500,000 Litres/ year	IX Other Industries	1	Waste processing, burning	All sizes
II. Leather tanning, Garment and Textile	1	Textile and dyeing factory	All sizes		2	Waste water treatment plants	All sizes
	2	Garments, washing, printing, dyeing	All sizes		3	Power plants	> 5 MW
	3	Leather tanning, and glue	All sizes		4	Hydropower	> 1 MW
	4	Sponge- rubber factory	All sizes		5	Cotton manufacturing	> 15 Tonnes/month
					6	Animal food processing	> 10,000 Tonnes/year
III. Wood production	1	Plywood	> 100,000m3/year(log)	B. Agriculture	1	Concession forest	> 10,000 Hectares
	2	Artificial wood	> 1,000 m3/year (log)		2	Logging	> 500 Hectares
	3	Saw mill	> 50,000m3/year (log)		3	Land covered by forest	> 500 Hectares
IV. Paper	1	Paper factory	All sizes		4	Agriculture and agro-industrial land	> 10,000 Hectares
	2	Pulp and paper processing	All sizes		5	Flooded and coastal forests	All sizes
V. Plastic, Rubber and Chemicals	1	Plastic factory	All sizes		6	Irrigation systems	> 5,000 Hectares
	2	Tire factory	> 500 Tonnes /year		7	Drainage systems	> 5,000 Hectares
	3	Rubber factory	> 1,000 Tonnes /year		8	Fishing ports	All sizes
	4	Battery industry	All sizes	C. Tourism	1	Tourism areas	> 50 Hectares
	5	Chemical production industries	All sizes		2	Golf course	> 18 Holes
	6	Chemical fertilizer plants	> 10,000 Tonnes /year	D. Infrastructure	1	Urbanization development	All sizes
	7	Pesticide industry	All sizes		2	Industrial zones	All sizes
	8	Paint manufacturing	All sizes		3	Construction of bridges-roads	> 30 Tonnes weight
	9	Fuel chemicals	All sizes		4	Buildings	Height > 12 m or floor > 8,000 m2
	10	Liquid, powder, and solid soap manufacturing	All sizes				
VI Mining production other than metal	1	Cement industry	All sizes		5	Restaurants	> 500 Seats
	2	Oil refinery	All sizes		6	Hotels	> 60 Rooms
	3	Gas factory	All sizes		7	Hotels adjacent to coastal area	> 40 Rooms
	4	Construction of oil and gas pipelines	> 2 Kilometers		8	National road construction	> 100 Kilometers
	5	Oil and gas separation and storage facilities	> 1,000,000 Litres		9	Railway construction	All sizes
	6	Fuel stations	> 20,000 Litres		10	Port construction	All sizes
	7	Mining	All sizes		11	Airport construction	All sizes
	8	Glass and bottle factory	All sizes		12	Dredging	> 50,000 m3
	9	Bricks, and roofing tile manufacturing	150,000 piece /month		13	Damping site	> 200,000 people

Source: http://www.camnet.com.kh/moe/sub_EIA.htm by Ministry of Environment, Cambodia

(5) National Environmental Action Plan 1998-2002

The Ministry of Environment (MOE) prepared a “National Environmental Action Plan 1998-2002”. The Action Plan has been adopted, reviewed and revised in a rolling plan system, which includes the following regulations applicable to the electricity sector: 1) environmental and safety standards; 2) guidelines for prospective investors on Environmental Impact Assessment (EIA); 3) Sub-Decree specifying requirements and procedures for EIA and Initial EIA; 4) specific guidelines for environmental assessment for thermal power stations and for power transmission lines; 5) Sub-Decree for water pollution ; and 6) national resettlement policy for Cambodia.

4.8.2 Protected Areas

Cambodia has 33 protected areas (under MOE 23 areas, and under MAFF 10 areas, refer to Sub-section 4.8.1). Of the 29 candidate sites, as many as 25 potential hydropower sites are inside or border the protected areas.

The Protected Natural Areas are under the jurisdiction of the Ministry of Environment amounting to 18% of Cambodia’s total area. In addition, by 2002 the Forest Administration (FA) of the Ministry of Agriculture, Forest and Fisheries (MAFF) had defined an additional 1,346,225 ha or 7.5% of the country as Conservation Areas. Therefore, the total Protected Areas had increased to 25.5% of the country. In 2003, there was an amendment to the Protected Natural Areas (under MOE), reducing their total area to 3,194,471 ha.

Table 4.8.2 shows Cambodia’s Protected Areas (under MOE) after the amendment in 2003. Some or all of the inundation areas of the 25 reservoirs in the 29 candidate sites affect the Protected Areas.

Table 4.8.2 Protected Areas of Cambodia (under jurisdiction of MOE)

Protected Area	Total Size (ha)	Some Unique Characteristics
Kirirom National Park	35,000	High elevation pine forest with large mammals including elephants.
Phnom Bokor National Park	140,000	High elevation sphagnum bogs, Podocarpus forest with large mammals including tigers, elephants, and sun bear.
Kep National Park	5,000	Secondary lowland evergreen forest.
Preah Sihanouk (Ream) National Park	15,000; now 21,000	Secondary lowland evergreen forest with some mangrove forest plus two islands.
Botum-Sakor National Park	171,250	Lowland evergreen forest heavily degraded by illegal logging, mangrove forest, and the only coastal Dacrydium/Podocarpus swamp forest in Cambodia.
Virachey National Park	332,500	High altitude forest in northeast Cambodia with a different set of biogeographic influences than in the southwest. An important habitat for several threatened species, including tigers, elephants and douc langur.
Koulen National Park	37,500	Located in the catchment area of Siem Reap stream. It is an important historic area.
Aural Wildlife Sanctuary	253,750	Highest mountain (1743 m) in Cambodia with a wide diversity of vegetation ranging from dry Dipterocarpus/Podocarpus forest to medium altitude evergreen forest.

Protected Area	Total Size (ha)	Some Unique Characteristics
Peam Krasop Wildlife Sanctuary	23,750	Most important mangrove forests in Cambodia and possibly the most extensive within the Gulf of Thailand.
Phnom Samkos Wildlife Sanctuary	333,750	High altitude area with a wide diversity of forest types. Supports a range of threatened birds in the area.
Ronien Daun Sam Wildlife Sanctuary	178,750; now 40,021	Lowland evergreen and semi-evergreen forest of unknown condition.
Kulen Promtep Wildlife Sanctuary	402,500	The largest area in the protected areas system intended to protect wildlife. The principal habitats are lowland evergreen / semi-evergreen forest, and the largest swamp in northern Cambodia. Very important for large waterbirds such as Giant Ibis and Sarus Cranes.
Boeng per Wildlife Sanctuary	242,500	A previous wildlife sanctuary, it reportedly has good populations of wild cattle and deer. The area has some important archaeological sites.
Lomphat Wildlife Sanctuary	250,000	The area comprises mostly evergreen forest on basaltic soils, grassy glades, open deciduous forest, mixed deciduous forest, pockets of evergreen/semi-evergreen forest, riverine habitats and small wetlands. Banteng and Asian wild dog are present and elephants migrate into the area at certain times of the year. Also a breeding ground for Sarus Crane.
Phnom Prich Wildlife Sanctuary	222,500	The habitats in this area are similar to those at Lomphat – mostly evergreen forest on basaltic soils. Grassy glades, and open deciduous forest. Mixed deciduous forest, riverine habitats and small wetlands.
Phnom Namlear Wildlife Sanctuary	47,500	Mainly evergreen forest which harbors the Green Peafowl, Germain's Peacock Pheasant, and Great Hornbill.
Snuol Wildlife Sanctuary	135,000	Consists mostly of logged evergreen forest on a heavily dissected plateau.
Angkor Protected Landscape	10,800	This mostly forested area includes the Angkor temple complex, perhaps the single-most important archaeological/cultural site in southeast Asia.
Banteay Chhmar Protected archaeological / cultural landscape	81,200	The area includes an important temple site.
Preah Vihear Protected landscape	5,000	The area was included for its archaeological/cultural value, it includes an important temple.
Dong Peng Multiple-Use Area	27,700	Lowland coastal wetlands – mostly mangrove and melaleuca swamp forest.
Samlaut Multiple Use Area	60,000	An evergreen forest area within the watershed of the Sangke River. It has been denuded by mining operations causing severe erosion and increased sedimentation of the river, which flows into Tonle Sap Lake.
Tonle Sap Multiple Use Area	316,250	Long-standing icthyological (aquatic) reserve. Great biological, hydrological and cultural / economic importance.
Total area	3,194,471	17.64%

Source: Ashwell, 1994 / State of Environment Report 2004, MOE and DANIDA

4.8.3 Hydropower Project Sites in Protected Areas

Most of the Cambodia's hydropower project candidate sites are located in Protected Areas (refer to Figure 4.7.4 Relative Location of Reservoir of Candidate Projects to Protected Areas and Reserves). Important features of the Protected Areas with respect to the candidate project sites are summarized below based on the information in Table 4.8.2 and the project location:

Northeastern Provinces

- Virachey National Park exists on the northern bank of the Se San River and offers important habitats for several threatened species including tigers, elephants and douc langur. Three sites, #11 to 13, on the Prek Liang River are situated in this park.

- Lomphat Wildlife Sanctuary is in the Lower Sre Pok Basin. Elephants reportedly migrate into the area at certain times of the year. It is also a breeding ground for Sarus Crane. Two candidate projects are located inside the Sanctuary: #5 Sre Pok IV and #15 Lower Sre Pok III.

- Phnom Namlear Wildlife Sanctuary is located in the eastern part of Mondul Kiri Province. Evergreen forest harbors the Green Peafowl, Germain's Peacock Pheasant, and Great Hornbill. A candidate site, #6 Prek Por I, is situated inside this Sanctuary.

- Snuol Wildlife Sanctuary consists mostly of logged evergreen forest on a heavily dissected plateau. Candidate site #2 Prek Chhlong II is situated inside this Sanctuary.

Southwestern Provinces

- #29 Bokor Plateau is situated inside Phnom Bokor National Park where tigers, elephants, and sun bear live.

- Most important mangrove forests in Cambodia are seen in Peam Krasop Wildlife Sanctuary in the southwestern coast facing the Gulf of Thailand. Mangrove forests are also seen in Preah Sihanouk (Ream) National Park, Botum-Sakor National Park located to the northwest of Sihanoukville, and Dong Peng Multiple-Use Area along Route 138, all facing the Gulf of Thailand. Because of the locations of these Protected Areas near the coast, the candidate hydropower sites are not included in these Areas except one project, #22 Stung Kep II, which is located inside the Peam Krasop Wildlife Sanctuary.

- Aural Wildlife Sanctuary includes the highest mountain (1,743 m) in Cambodia with a wide diversity of vegetation. To the west is the Cardamon Protected Area. Four candidate sites are inside or border these Areas: #16 Middle St. Russey Chrum, #17 Stung Chhay Areng, #18 Stung Tatay, and #23 Upper Stung Russey Chrum.

- Phnom Samkos Wildlife Sanctuary includes a high altitude area with a wide diversity of forest types. It supports a range of threatened birds. Five candidate sites are within this Sanctuary: #19 to 21, all on Stung Metoek that drains the narrow valley bordering Thailand, #24 Stung Pursat I, and #27 Stung Battambang II.

4.8.4 Newly Enacted Protected Area Law

The Protected Area Law was passed by the National Assembly of the Kingdom of Cambodia on December 27, 2007, and was signed and sealed by President of National Assembly on January 4, 2008.

The Protected Area Law consists of 11 chapters with 66 articles.

PROTECTED AREA LAW

Chapter I	General Provisions
Chapter II	Responsible Institutions
Chapter III	Establishment and Modification of Protected Areas
Chapter IV	Zoning
Chapter V	National Strategic and Active Plan for Protected Area Management
Chapter VI	Involvement and Access Rights of Local Communities and Indigenous Ethnic Minority Communities
Chapter VII	Education, Dissemination, Rehabilitation, Improvement and Funding of Protected Areas
Chapter VIII	Permit and Prohibition and Environmental and Social Impacts Assessment
Chapter IX	Law Enforcement and Procedures to Resolve Offences
Chapter X	Natural Resource Offenses and Penalties
Chapter XI	Final Provisions

Most significant part of the law in relation to the hydropower development is Chapter IV Zoning, which classifies a protected area into 4 zones by conservation level as shown in the box below. Article 36 in Chapter VIII prescribes "all clearances and bulldozing within the open land or forestland in protected areas for the purposes of building all types of public infrastructure through the core zone and conservation zone shall be strictly prohibited". These activities can only be carried out in the sustainable use zone and community zone with approval from the Royal Government of Cambodia at the request of the Ministry of Environment. If the project sites are situated inside a core zone or conservation zone, no development will be allowed.

DEFINITION OF ZONING

1. Core zone: management area(s) of high conservation values containing threatened and critically endangered species, and fragile ecosystems. Access to the zone is prohibited except to the Nature Conservation and Protection Administration's officials and researchers who, with prior permission from the Ministry of Environment, conduct nature and scientific studies for the purpose of preservation and protection of biological resources and natural environment with the exception of national security and defense sectors.
2. Conservation zone: management area(s) of high conservation values containing natural resources, ecosystems, watershed areas, and natural landscape located adjacent to the core zone. Access to the zone is allowed only with prior consent of the Nature Conservation and Protection Administration in the area with the exception of national security and defense sectors. Small-scale community uses of non-timber forest products (NTFPs) to support local ethnic minorities' livelihood may be allowed under strict control, provided that they do not present serious adverse impacts on biodiversity within the zone.
3. Sustainable use zone: management area(s) of high economic values for national economic development and management, and conservation of the protected area(s) itself thus contributing to the local community, and indigenous ethnic minorities' livelihood improvement. After consulting with relevant ministries and institutions, local authorities, and local communities in accordance with relevant laws and procedures, the Royal Government of Cambodia may permit development and investment activities in this zone in accordance with the request from the Ministry of Environment.

4.	Community zone: management area(s) for socio-economic development of the local communities and indigenous ethnic minorities and may contain existing residential lands, paddy field and field garden or swidden (Chamkar).

Zoning maps of the protected areas should be defined by a Sub-decree of the Protected Area Law but have not been worked out. The Ministry of Environment is responsible for formalizing the zoning maps for each Protected Area in cooperation with MIME, MOPWT, MAFF, the Ministry of Land Management, Urban Planning and Construction, local authorities, local communities and relevant agencies.

Ministries implementing national development projects such as MIME, MOPWT and MAFF have started preparing project applications to MOE. Within the Protected Area, unless project sites are situated inside the Sustainable Use Zone or Community Zone and unless the projects bring benefits to the community, those projects would not be approved by MOE. Otherwise, that is, if any project is located inside the Core Zone or Conservation Zone, any project like road construction, hydropower, eco-tourism, and mining will not be approved. Trading off between environmental conservation and utilization of natural resources poses a dilemma. Coexistence of the environment and development should be pursued to achieve consensus among the stakeholders.

4.8.5 Wildlife

The Ministry of Environment and the Ministry of Agriculture, Forestry and Fisheries, with assistance from international organizations such as the International Union for the Conservation of Nature and Natural Resources (IUCN), the World Wildlife Foundation (WWF), Wildlife Conservation Society (WCS), Flora and Fauna International (FFI), WildAid, International Crane Foundation (ICF), Wetlands International (WI), Birdlife International, etc, have undertaken habitat and wildlife surveys inside and outside the Protected Areas. Table 4.8.3 shows the number of recorded species and number of endangered species.

Table 4.8.3 Endangered Species in Cambodia

Items	Number of Species
1) Mammal species terrestrial & aquatic (approximated)	110 species
Critically endangered, endangered and vulnerable species of mammals	28 – 39 species*
2) Bird species (recorded)	530 species
Endangered, endangered and vulnerable species of birds	21 – 44 species*
3) Reptiles and Amphibians	Not known
Critically endangered, endangered, vulnerable, near-threatened	15 species
4) Fish species	
(a) Freshwater	486 species
(b) Marine / brackish	357 species
Critically endangered, endangered and vulnerable species of fish	7 species
5) Known flora species for Cambodia	2308 species
Threatened species of flora	30 – 38 species*
6) Extinct species since 1990	4 species

Source: State of Environment Report, 2004 (Seng et al. 2003, DFW 2003, MAFF 2002, Ashwell 1998, www.redlist.org IUCN 2002, MOE 2002, Colin People, Pers.comm, 2003, FishBase, www.fishbase.org 2003)

* The number regarded as endangered is different by the various organizations

North and northeast of Cambodia is one of the last great refuges for large herbivorous species. Of particular interest in this respect are the Kouprey (*Bos sauveli*), Banteng (*Bos javanicus*), Gaur (*Bos gaurus*), Wild Water Buffalo (*Bubalus arnee*), Sambar Deer (*Cervus unicolor*), Eld’s Deer (*Cervus eldii*), Hog Deer (*Axis porcinus*) and Barking Deer (Muntjac). Populations of tiger (*Panthera tigris*) and leopard (*Panthera pardus*) are associated with these species.

River dolphins living in the Mekong River attract international attention. The population of river dolphins reportedly decreased to 60–100 individuals and conservation programs are being funded by donations and being implemented by international NGOs.

Bird Life International listed, in a publication in 2003, 44 species as globally threatened or near threatened. The giant ibis (*Pseudibis gigantean*), white-shouldered ibis (*P. davisoni*), and the masked finfoot (*Heliopais personata*) have been rediscovered in Northeastern Cambodia, along the Se Kong River. Sarus crane (*Grus antigone*) have been observed to breed in remote northeastern Cambodia. Some of the most detailed observations of water birds show that the populations of Sarus Crane observed in Takeo and Kampot Provinces migrate to the Tonle Sap floodplain wetlands that border Siemreap and Banteay Meanchey Province in northwestern Cambodia.

4.9 ECONOMIC AND FINANCIAL ANALYSIS

4.9.1 Economic Analysis of the Candidate Projects

(1) General Assumptions for the Economic Analysis

Economic evaluations were made for the candidate projects. Economic evaluation aims at measuring the "economic" impact on the country by implementing a project from a viewpoint of national economy.

The EIRR calculation is based on the following assumptions: 1) all revenues and costs are in 2007 constant prices and are expressed in US dollar ($); 2) assessment period is set at 30-year after the completion of the projects*10; 3) the local portion of the every project cost estimated was converted to border price by applying a conversion factor of 0.90, which is commonly adapted in economic analysis in Cambodia. Detailed assumptions adopted for financial analysis will be mentioned in Section 7.1 of this report.

(2) Economic Costs

The financial cost of the candidate projects was estimated at $52.8 million (#2 Prek Chhlong II) to 680.5 million (#7&8 Lower Sre Pok II + Lower Se San II). Unit construction cost, excluding land acquisition and compensation cost, of the candidate projects varied from $1,495 per kW (#7&8 Lower Sre Pok II + Lower Se San II) to $22,909 per kW (#6 Prek Por I).

After deducting price contingency and taxes, and adopting standard conversion factor of 0.90 for local cost portion, the economic cost of the candidate projects was calculated at $46.3 million (#2 Prek Chhlong II) to $596.0 million (#7&8 Lower Sre Pok II + Lower Se San II).

The fixed operation and maintenance (O&M) cost is required annually during the economic life of the project. The fixed O&M cost includes daily operation and

Table 4.9.1 Cost of the Candidate Projects (Financial, Economic Cost and Cost per kW)

Name of the Project	Installed Capacity (MW)	Financial Cost		Economic Cost
		$1,000	$/ kW	$1,000
Prek Chhlong II	10.8	52,830	4,093	46,338
Prek Ter III	15.0	152,386	9,487	131,615
Prek Ter II	12.3	85,297	6,881	73,604
Sre Pok IV	68.1	191,476	2,811	167,501
Prek Por I	5.2	118,672	22,909	102,664
Lower Sre Pok II + Lower Se San II	428.6	680,533	1,495	596,022
Se Kong	148.2	305,148	2,007	267,796
Lower Se San III	160.6	466,868	1,975	413,032
Prek Liang I	52.7	121,297	2,301	106,344
Prek Liang IA	26.2	129,412	4,931	112,959
Prek Liang II	49.4	121,716	2,463	106,633
Lower Sre Pok III	226.3	419,758	1,755	368,600
Middle St. Russey Chrum	58.2	148,551	2,550	128,828
Stung Chhay Areng	116.4	659,668	5,557	568,075
Stung Tatay	37.5	283,325	7,524	243,768
Stung Metoek I	11.7	241,965	20,392	208,498
Stung Metoek II	29.6	143,756	4,460	125,218
Stung Metoek IIII	29.8	115,124	3,861	100,403
Stung Kep II (New Tatay)	47.9	167,119	3,486	144,662
Upper St. Russey Chrum	38.6	179,953	4,658	155,351
Stung Pursat I	17.4	65,220	3,746	56,715
Stung Pursat II	12.0	86,799	7,214	75,129
Stung Sen	60.2	253,058	2,585	223,006
Stung Battambang II	16.9	148,970	8,792	128,487
Stung Battambang I	28.5	173,200	5,560	149,881
Bokor Plateau	21.7	83,572	3,844	71,910

Source: Study Team

10 With referring to the concession period of the existing contract agreement between CETIC and MIME for the Kirirom III Hydropower Station, commercial operation period of the candidate hydropower project was assumed 30 years.

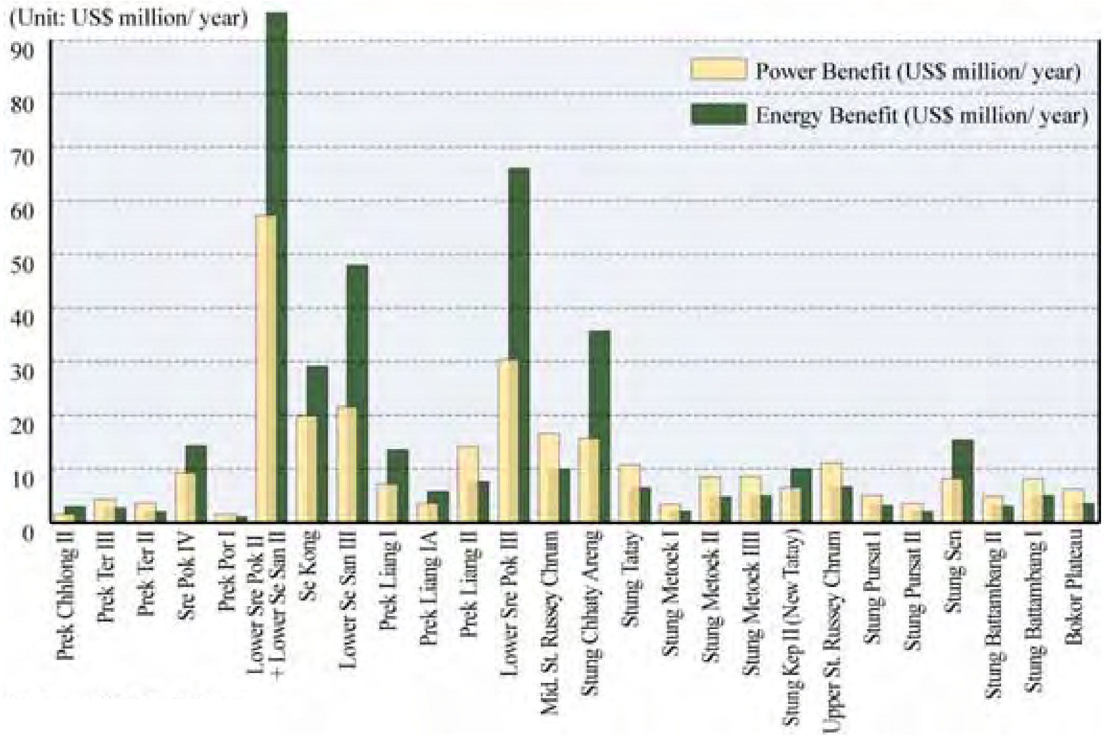
maintenance activities as well as semi-overhauling executed every 6 years of operation, and was assumed at 0.5% for civil and metal works and 1.5% for electromechanical equipment, and transmission related facilities.

Variable O&M cost includes only the cost for lubricant. In Cambodia, water charge/tax is not levied on the project operating entities. Cost of lubricant was assumed at 0.0151 ¢/kWh, based on actual average expenditure for lubricant at the hydropower stations in Indonesia in 2006.

(3) Economic Benefits

The economic benefit can be calculated as a sum of avoided costs of Alternative Thermal Power Plant. In this study, gas-fired combined cycle power plant was selected as the most promising alternative thermal power plant in terms of cost and technical suitability (detail will be mentioned in Section 7.3.1).

Avoided costs can be divided into two components, one is construction and fixed O&M costs of firm peak capacity of the hydropower project, and the other consists of fuel cost and variable O&M cost saving of energy generation. The former benefit is called a "capacity benefit" and the latter is known as "energy benefit". While power benefit is worked out at $1.45~57.32 million/year, energy benefit is worked out at $0.88 ~ 95.18 million/year (refer to Figure 4.9.1 and Table 4.9.2).



Source: Study Team

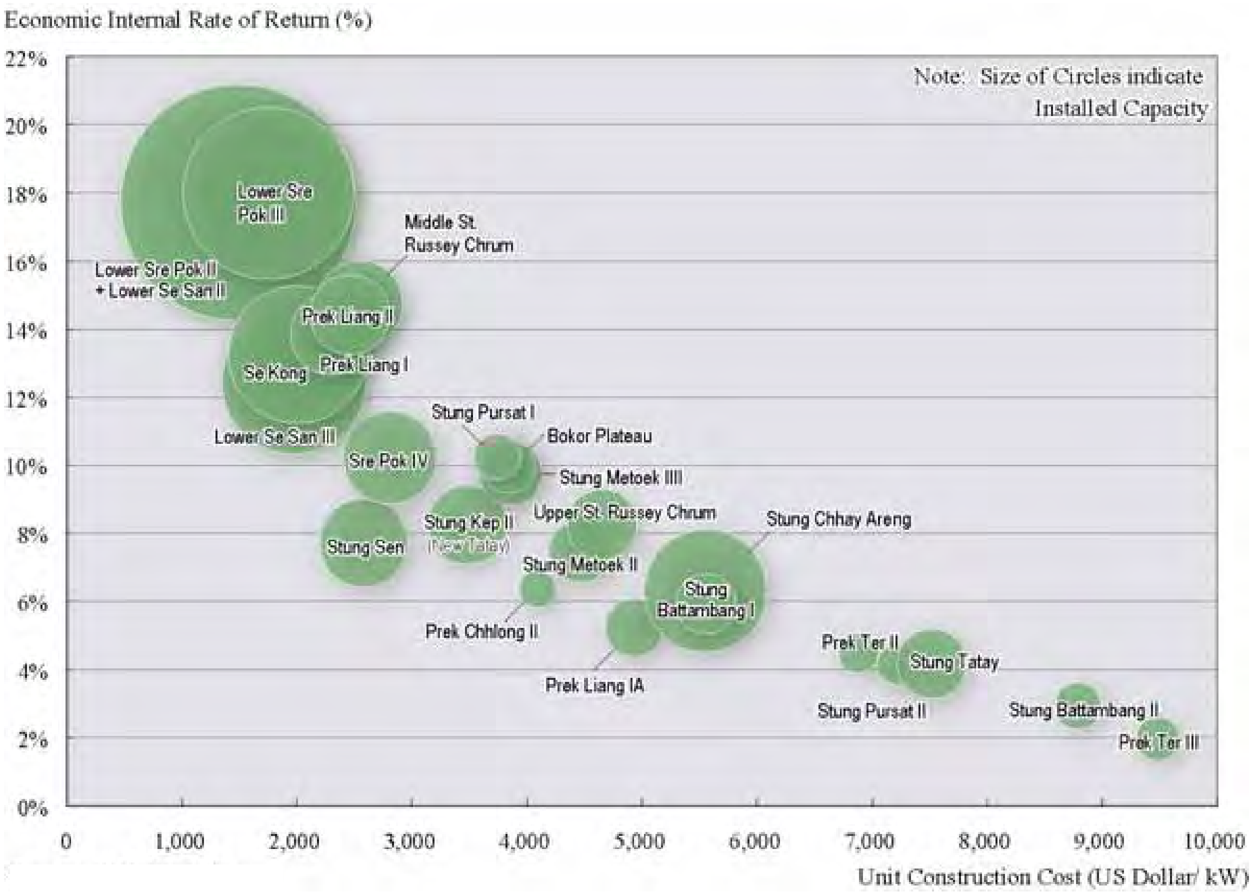
Figure 4.9.1 Summary of Power Benefit and Energy Benefit of the Candidate Projects

(4) Results of the Economic Analysis

Figure 4.9.2 shows the relation among the calculated EIRR, unit construction cost in $ per kW, and installed capacities of the candidate projects. Generally, lower unit construction costs will have higher EIRR of the projects.

Of the 26 candidate projects, the EIRR of the 24 projects varied between 2.0% to 18.0%. With regard to the EIRR of the remaining 2 projects, the EIRR of Prek Por I was calculated at negative value and that of Stung Metoek I was not calculated (economic net present values of the projects were negative even with discount rate of 0%).

#15 Lower Sre Pok III shows the highest EIRR of 18.0%. In addition, the EIRR of the 3 projects (#14 Prek Liang II, #7&8 Lower Sre Pok II + Lower Se San II, and #16 Middle St. Russey Chrum) were with in the range of 14% and 18%, and those of the 3 projects (#10 Se Kong, #12 Prek Liang I, and #11 Lower Se San III) were between 12% and 14% (refer to Table 4.9.2).



Source: Study Team

Figure 4.9.2 Relation among the Calculated EIRR, Unit Construction Costs and Installed Capacities of the Candidate Projects

Table 4.9.2 Summary of Economic Analysis of the Candidate Projects

No.	Name of the Project	Installed Capacity (MW)	Firm Peak Capacity (MW)	Annual Energy Production (GWh)	Annual Power Benefit ($1,000)	Annual Energy Benefit ($1,000)	Total Economic Cost ($1,000)	EIRR (%)
2	Prek Chhlong II	10.81	3.14	50.87	1,445.95	2,806.99	46,338	6.34%
3	Prek Ter III	15.02	10.51	96.36	4,245.94	2,549.31	131,615	1.96%
4	Prek Ter II	12.32	6.31	70.80	3,482.76	1,873.05	73,604	4.47%
5	Sre Pok IV	68.13	10.71	258.11	9,109.48	14,242.22	167,501	10.22%
6	Prek Por I	5.18	3.62	33.22	1,463.94	878.97	102,664	-
7 & 8	Lower Sre Pok II + Lower Se San II	428.65	79.94	1,724.98	57,317.09	95,183.54	596,022	17.71%
10	Se Kong	148.20	19.49	527.24	19,817.19	29,093.09	267,796	13.25%
11	Lower Se San III	160.64	69.36	869.30	21,480.35	47,967.70	413,032	12.45%
12	Prek Liang I	52.71	14.39	242.63	7,048.66	13,388.32	106,344	13.86%
13	Prek Liang IA	26.24	4.67	103.90	3,509.05	5,732.97	112,959	5.22%
14	Prek Liang II	49.41	24.94	282.51	13,971.67	7,474.40	106,633	14.43%
15	Lower Sre Pok III	226.34	91.60	1,197.14	30,265.85	66,057.70	368,600	17.99%
16	Middle Stung Russey Chrum	58.22	40.75	373.59	16,462.20	9,884.09	128,828	14.75%
17	Stung Chhay Areng	116.39	54.15	646.62	15,563.10	35,680.28	568,075	6.31%
18	Stung Tatay	37.47	26.23	240.48	10,596.62	6,362.33	243,768	4.17%
19	Stung Metoek I	11.70	8.19	75.10	3,309.33	1,986.96	208,498	-
20	Stung Metoek II	29.61	16.40	174.96	8,372.77	4,629.02	125,218	7.46%
21	Stung Metoek III	29.81	18.72	184.13	8,430.44	4,871.53	100,403	9.72%
22	Stung Kep II (New Tatay)	47.94	7.33	179.85	6,410.69	9,924.29	144,662	8.24%
23	Upper Stung Russey Chrum	38.63	27.04	247.92	10,924.44	6,559.16	155,351	8.24%
24	Stung Pursat I	17.41	12.19	111.72	4,923.11	2,955.89	56,715	10.25%
25	Stung Pursat II	12.03	6.76	71.42	3,401.33	1,889.57	75,129	4.14%
26	Stung Sen	60.18	16.35	276.54	8,046.54	15,259.23	223,006	7.71%
27	Stung Battambang II	16.94	11.86	108.74	4,791.51	2,876.88	128,487	2.94%
28	Stung Battambang I	28.55	19.98	183.20	8,072.95	4,847.09	149,881	5.92%
29	Bokor Plateau	21.74	12.30	129.41	6,147.84	3,423.88	71,910	9.95%

Source: Study Team

4.9.2 Financial Analysis of the Candidate Projects

(1) General Assumptions for the Financial Analysis

The financial analysis of a project examines the adequacy of returns to the project-operating entity, whereas economic analysis measures the effect of the project on the national economy, as a whole. Detailed assumptions adopted for financial analysis will be mentioned in Section 7.2 of this report.

(2) Financial Costs of the Candidate Projects

The financial cost of the 26 candidate projects was estimated at $52.8 million (#2 Prek Chhlong II) to 680.5 million (#7&8 Lower Sre Pok II + Lower Se San II). Unit construction cost of the candidate projects varied from $1,495 per kW (#7&8 Lower Sre Pok II + Lower Se San II) to $22,909 (#6 Prek Por I) per kW (refer to Table 4.9.1 for details).

Regarding operation and maintenance (O&M) cost of the project facilities, the same assumption as financial analysis was adopted.

(3) Financial Benefits of the Candidate Projects

Financial benefit was measured as the revenue from sales of electricity to be received from EDC. Generated energy was assumed to be sold to EDC at the nearest substation (delivery point). Sales revenue can be measured as the products of average sales price of electricity, and sales volume of electricity at delivery point. Sales volume of energy was calculated by deducting auxiliary loss of the power station, transmission loss from annual generation volume. Auxiliary loss of 0.3% and transmission loss between the power stations to the substations of 1.0% were used for calculating sales volume of energy at the delivery point.

In this financial analysis for the first stage selection of 10 priority projects, whole sale price of 7.25 ¢/kWh (weighted average of the installed capacity and price of the existing/committed 4 hydropower projects[*11]) was adopted for all the candidate projects.

(4) Results of the Financial Analysis

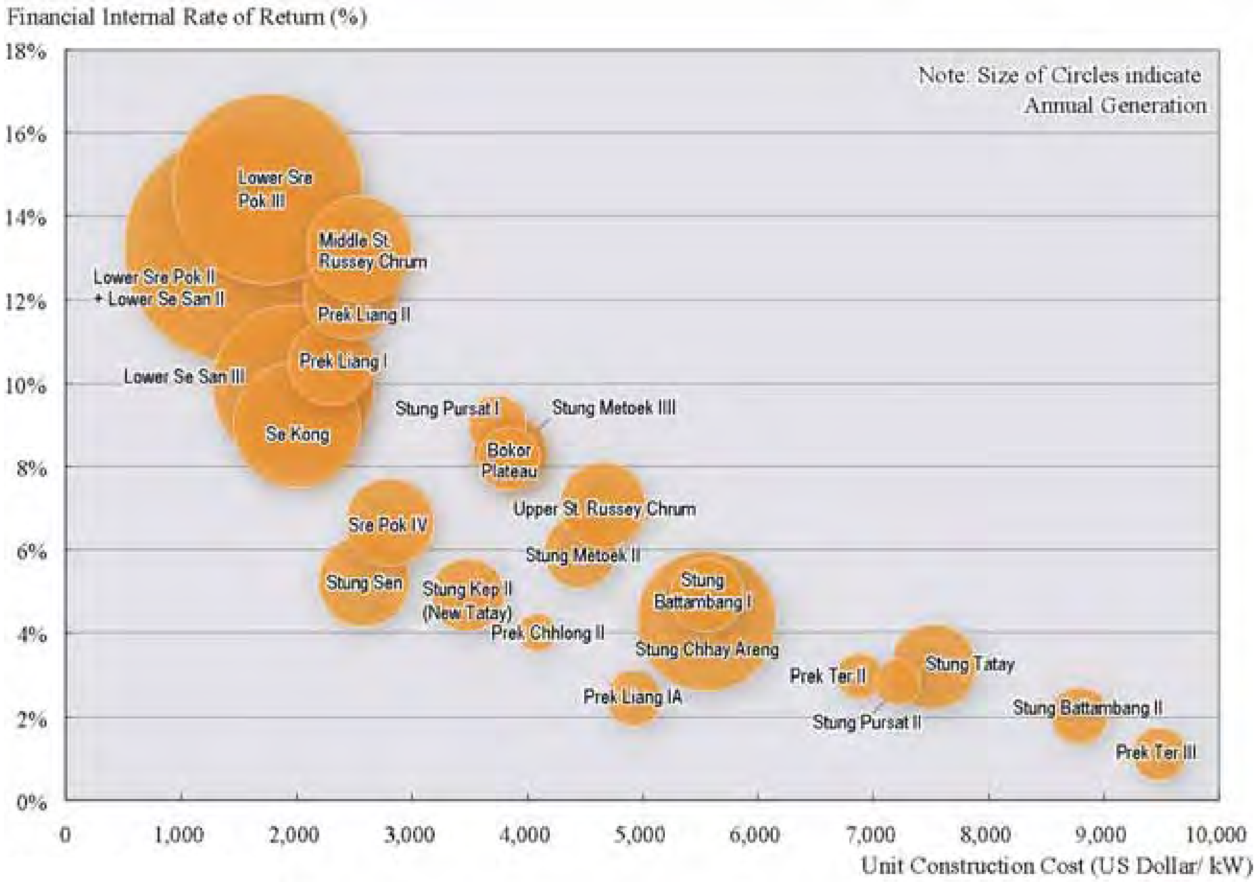
Figure 4.9.3 shows the relation among the calculated FIRR, unit construction cost in $ per kW and annual energy productions of the candidate projects. Generally, lower unit construction costs would have higher FIRR of the projects.

Of the 26 candidate projects, the FIRR of the 24 projects varied between 1.1% and 14.7%. The FIRR of the remaining 2 projects (#6 Prek Por I and #19 Stung Metoek I) were not calculated (financial net

[11] Kirirom I (12 MW): 7.00 ¢/kWh, Kirirom III (18 MW): 8.10 ¢/kWh, Kamchay (193 MW): 8.08 ¢/kWh, and Stung Atay (120 MW): 5.81 ¢/kWh, Source: MIME, EAC, and EDC (Note: except for Kirirom I, power purchase price data is provisional figure and thus subject to change)

present values of the projects, that is, present value of revenue minus present value of cost, were negative even with discount rate of 0% (refer to Table 4.9.3).

#15 Lower Sre Pok III shows the highest FIRR of 14.7%, followed by #7&8 Lower Sre Pok II + Lower Se San II (13.2%), #16 Middle St. Russey Chrum (13.2%) and #14 Prek Liang II (12.2%). In addition, the FIRR of the 6 projects were within the range of 8% and 12% (#10 Se Kong, #11 Lower Se San III, #12 Prek Liang I, #24 Stung Pursat I, #29 Bokor Plateau, #21 Stung Metoek III), and the FIRR of the 2 projects were between 6% and 8% (#23 Upper St. Russey Chrum, #5 Sre Pok IV).



Source: Study Team

Figure 4.9.3 Relation among the Calculated FIRR, Unit Construction Costs and Annual Energy Productions of the Candidate Projects

Table 4.9.3 Summary of Financial Analysis of the Candidate Projects

No.	Name of the Project	Annual Energy Production	Sales Volume	Annual Sales Revenue	Total Project Cost	Unit Cost of Construction	Financial Cost of Gen	FIRR
		(GWh)	(GWh)	($1,000)	($1,000)	($/kW)	(¢/kWh)	(%)
2	Prek Chhlong II	50.87	50.21	3,640.2	52,830.0	4,885.55	14.14	4.00%
3	Prek Ter III	96.36	95.11	6,895.2	152,385.9	10,148.63	21.30	1.11%
4	Prek Ter II	70.80	69.88	5,066.1	85,297.0	6,925.43	16.30	2.96%
5	Sre Pok IV	258.11	254.76	18,470.0	191,475.7	2,810.65	10.23	6.66%
6	Prek Por I	33.22	32.79	2,377.4	118,672.2	22,922.55	48.50	-
7 & 8	Lower Sre Pok II + Lower Se San II	1,724.98	1,702.60	123,438.8	680,533.1	1,587.64	5.43	13.24%
10	Se Kong	527.24	520.41	37,729.4	305,148.2	2,058.99	8.00	8.99%
11	Lower Se San III	869.30	858.03	62,206.9	466,867.5	2,906.29	7.29	9.94%
12	Prek Liang I	242.63	239.48	17,362.6	121,297.2	2,301.07	6.92	10.50%
13	Prek Liang IA	103.90	102.55	7,434.8	129,411.8	4,931.41	17.12	2.45%
14	Prek Liang II	282.51	278.84	20,216.2	121,715.6	2,463.40	5.96	12.15%
15	Lower Sre Pok III	1,197.14	1,181.61	85,667.0	419,758.4	1,854.53	5.81	14.66%
16	Middle Stung Russey Chrum	373.59	368.74	26,733.8	148,551.1	2,551.67	5.43	13.21%
17	Stung Chhay Areng	646.62	638.23	46,272.0	659,668.1	5,667.82	13.75	4.29%
18	Stung Tatay	240.48	237.36	17,208.4	283,325.2	7,560.57	15.89	3.19%
19	Stung Metoek I	75.10	74.13	5,374.2	241,964.8	20,675.14	43.46	-
20	Stung Metoek II	174.96	172.69	12,520.3	143,756.4	4,855.06	13.46	5.94%
21	Stung Metoek IIII	184.13	181.74	13,176.2	115,123.8	3,861.46	8.59	8.30%
22	Stung Kep II (New Tatay)	179.85	177.52	12,870.3	167,118.7	3,485.83	12.64	4.91%
23	Upper Stung Russey Chrum	247.92	244.70	17,740.8	179,953.4	4,657.98	9.84	7.07%
24	Stung Pursat I	111.72	110.27	7,994.9	65,219.5	3,746.06	7.99	9.01%
25	Stung Pursat II	71.42	70.49	5,110.8	86,799.2	7,216.11	16.52	2.82%
26	Stung Sen	276.54	272.95	19,788.9	253,058.1	4,205.31	12.27	5.24%
27	Stung Battambang II	108.74	107.33	7,781.2	148,970.1	8,791.51	18.54	2.03%
28	Stung Battambang I	183.20	180.83	13,110.1	173,199.8	6,066.69	12.75	4.90%
29	Bokor Plateau	129.41	127.73	9,260.7	83,571.6	3,843.91	8.72	8.19%

Source: Study Team

4.9.3 CO_2 Reduction by the Candidate Hydropower Projects

(1) Reduction of CO_2 by the Implementation of the Hydropower Projects

Hydropower projects will avoid emissions of CO_2 that would be generated by alternative thermal plants of fossil fuel-fired. In addition, the hydropower project would also mitigate the other pollutants, such as SO_2, NO_x and particulates associated with power generation from fossil fuels.

In 2006, 95% of energy production in Cambodia was generated by diesel generators using heavy fuel oil (HFO) and/or light diesel oil (LDO). After the commissioning of the hydropower projects, some of the diesel generators will be abolished. Thus, the hydropower projects will be contributed for reducing CO_2 emission from existing diesel generators. Amount of reductions of CO_2 by the hydropower projects (Y) can be calculated following formula;

Y= – CO_2 emission from the diesel generators + CO_2 emission by the hydropower projects – disappearance of CO_2 absorption resulted from deforestation – CO_2 emission from reservoir

Since hydropower is a clean energy source there will be no CO_2 emissions that are directly related to hydropower generation.

(2) CO_2 emission from the Diesel Generators

After commencement of the hydropower project, its electricity will replace the existing diesel power stations. CO_2 emission from the existing diesel generator per kWh of electric generation in Cambodia was worked out using following formula and assumptions. As a result, it was estimated 0.755 kg-CO_2/kWh.

$$Y = \frac{E_h \times SFC_h \times RD_h \times EF_h \times HV_h + E_d \times SFC_d \times RD_d \times EF_d \times HV_d}{E_h + E_d}$$

Where

Y= Emission from the Existing Diesel Generator per kWh of generation

h= Heavy Fuel Oil or Heavy Fuel Oil-fired Generating Units

d= Light Diesel Oil or Light Diesel Oil-fired Generating Units

E= Energy Production (LDO-fired diesel unit: 219.8 GWh/year, HFO-fired diesel unit: 587.3 GWh/year. Source: Statistical Handbook 2005, EDC)

RD= Relative Density (LDO = 0.876, HFO= 0.900)

SFC= Specific Fuel Consumption (LDO-fired diesel unit: 0.285 liter/kWh, HFO-fired diesel unit: 0.233 liter/kWh. Source: Statistical Handbook 2005, EDC)

EF= Emission Factor (LDO= 0.0741 kg-CO2/GJ, HFO= 0.0770 kg-CO2/GJ, Source: CDM Executive Board, June 2006)

HV= Heat Value of Fuel (LDO= 48.61 GJ/ton, HFO= 43.39 GJ/ton. Source: Annual Energy Outlook 2005, DOE/EIA, February 2005)

(3) Disappearance of CO_2 Absorption Effect by Deforestation

All the 26 candidate hydropower projects included construction of dam in order to create a head for power generation and to regulate the flow of water, and therefore certain area of the land will be submerged in the reservoirs. Thus, after the implementation of the candidate projects, certain area of forest land will be submerged.

In this analysis, tropical forest's annual absorption of CO_2 was estimated based on the following formula and data quoted from the IPCC guidelines for National Green House Gas Inventories 2006. Annual CO_2 absorption of tropical forest in Cambodia was estimated at 5.19 ton-CO_2/ha/year.

$$\text{Annual } CO_2 \text{ Absorption (ton-}CO_2\text{/ha)} = AGBG \times (1 + R) \times CF \times MW_{CO_2} \div MW_C$$

Where:

AGBG= Above Ground Biomass Growth (2.2 ton d.m./ha/year, Tropical Rain Forest in Asian Continent)

R= Ratio of Below-ground Biomass to Above-ground Biomass (0.37 ton rood d.m./ton shoot d.m., tropical rainforest)

CF= Carbon Fraction (0.47 ton-C/ton d.m, Tropical and Subtropical, All Part of Tree)

MW= Molecular Weight (CO_2= 44, C= 12)

In the case of the #26 Stung Sen project having biggest reservoir among the candidate projects, 93,940 ha of land area will be submerged under the reservoir, of which 87.3% or 81,972 ha of forest. Submerge of the forest will be resulted in loss of 425,773 ton/year CO_2 absorption.

(4) CO_2 emission from the Reservoirs

CO_2 emission from reservoir results from the decomposition of leaves, twigs and other rapidly degradable biomass. Slowly decaying woody biomass, organic matter washed into the reservoir from upstream, and the growth of biomass in the reservoir provide long-term sources of CO_2 and methane production. Reservoir emissions last for many decades at least, and presumably for the life of the reservoir.

According to the "thresholds and criteria for the eligibility of hydroelectric power plants with reservoirs as CDM project activities" of CDM executive board, emission of CO_2 from reservoir is defined as follows based on thresholds in terms of power density (installed power generation capacity divided by the flooded surface area: W/m^2).

1) Hydroelectric power plants with power densities (installed power generation capacity divided by the flooded surface area) less than or equal to 4 W/m^2 cannot use current methodologies;
2) Hydroelectric power plants with power densities greater than 4 W/m^2 but less than or equal to 10 W/m^2 can use the currently approved methodologies, with an emission factor of 90 g-CO_2/kWh for project reservoir emissions;
3) Hydroelectric power plants with power densities greater than 10 W/m^2 can use current approved methodologies and the project emissions from the reservoir may be neglected.

With referring to these criteria, CO_2 emission from reservoir was calculated at 90 g-CO_2/kWh with power density less than 10 W/m^2, and zero with power density greater than 10 W/m^2.

4.9.4 Net Decrease (Increase) of CO_2 Emission

Of the 26 candidate projects examined, the 24 candidate projects were expected to contribute to reducing CO_2 emission. Net decreases of CO_2 emissions were estimated in a range between 8,453 ton-CO_2/year of

#2 Prek Chhlong II and 937,969 ton-CO_2/year of #7&8 Lower Sre Pok II + Lower Se Sang II. On the other hand, CO_2 emission was estimated to be increased by 9,526 ton-CO_2/year (#3 Prek Ter III) and 217,636 ton-CO_2/year (#26 Stung Sen) (refer to Table 4.9.4).

Table 4.9.4 Summary of Net Decrease (Increase) of CO_2 Emission Resulted from the Candidate Projects

No.	Nam of the Project	Annual Generation	Power Density	Reservoir Area	Submerging Forest Area by Reservoir	Increase in CO_2 by Submerge of Forest	CO_2 Reduction by Replacement with existing Diesel Units	CO_2 Emission from Reservoir	Net Increase (Decrease) of CO_2 Emission by Project
		(Unit: GWh)	(Unit: W/m^2)	(Unit: ha)		(Unit: 1,000 CO_2-ton/year)			
2	Prek Chhlong II	50.9	0.19	5,812.0	4,829.8	-25.09	42.87	-4.58	13.20
3	Prek Ter III	96.4	0.08	17,879.0	15,796.5	-82.05	81.19	-8.67	-9.53
4	Prek Ter II	70.8	0.12	10,154.6	8,631.1	-44.83	59.66	-6.37	8.45
5	Sre Pok IV	258.1	1.29	5,261.8	4,659.0	-24.20	217.49	-23.23	170.07
6	Prek Por I	33.2	0.45	1,151.3	1,129.6	-5.87	27.99	-2.99	19.14
7 & 8	Lower Sre Pok II + Lower Se San II	1,725.0	0.52	82,719.7	69,427.0	-360.61	1,453.56	-155.25	937.70
10	Se Kong	527.2	1.27	11,710.6	6,723.6	-34.92	444.28	-47.45	361.91
11	Lower Se San III	869.3	0.35	46,068.0	12,682.9	-65.88	732.52	-78.24	588.41
12	Prek Liang I	242.6	7.37	715.4	685.0	-3.56	204.45	-21.84	179.06
13	Prek Liang IA	103.9	9.51	275.8	119.7	-0.62	87.55	-9.35	77.58
14	Prek Liang II	282.5	3.49	1,415.8	1,017.4	-5.28	238.06	-25.43	207.35
15	Lower Sre Pok III	1,197.1	0.32	70,978.1	64,169.4	-333.30	1,008.77	-107.74	567.73
16	Middle Stung Russey Chrum	373.6	2.58	2,258.9	2,117.0	-11.00	314.80	-33.62	270.19
17	Stung Chhay Areng	646.6	0.61	19,164.1	16,028.5	-83.25	544.88	-58.20	403.43
18	Stung Tatay	240.5	0.80	4,706.3	3,958.4	-20.56	202.64	-21.64	160.43
19	Stung Metoek I	75.1	2.54	460.2	295.8	-1.54	63.28	-6.76	54.99
20	Stung Metoek II	175.0	0.88	3,381.5	2,152.9	-11.18	147.43	-15.75	120.50
21	Stung Metoek IIII	184.1	1.33	2,246.0	1,516.7	-7.88	155.16	-16.57	130.71
22	Stung Kep II (New Tatay)	179.9	24.08	199.1	124.5	-0.65	151.55	0.00	150.91
23	Upper Stung Russey Chrum	247.9	8.68	445.3	445.3	-2.31	208.91	-22.31	184.28
24	Stung Pursat I	111.7	0.17	10,154.3	10,154.3	-52.74	94.14	-10.06	31.35
25	Stung Pursat II	71.4	0.49	2,474.7	2,407.7	-12.51	60.18	-6.43	41.25
26	Stung Sen	276.5	0.06	93,940.1	81,972.0	-425.77	233.03	-24.89	-217.64
27	Stung Battambang II	108.7	0.43	3,967.5	3,884.2	-20.17	91.63	-9.79	61.67
28	Stung Battambang I	183.2	0.22	13,229.9	11,144.5	-57.89	154.38	-16.49	80.00
29	Bokor Plateau	129.4	2.48	876.6	654.7	-3.40	109.05	-11.65	94.00

Source: Study Team

Remarks: In the above table, submerging forest area by reservoir of some projects exceed those reservoir area. The reason of the difference is that reservoir area and submerging forest area by reservoir are derived from H-A curves (considering sandbank area) and 1/100,000 topographic map with 20m contour interval, respectively.

5. SELECTION OF 10 PRIORITY PROJECTS

5.1 METHODOLOGY OF PROJECT SELECTION

5.1.1 Utilization of AHP (Analytic Hierarchy Process)

Decision-making in selecting a priority project(s) that have environmental issues in particular is typically a complex and confusing exercise, characterized by trade-offs between socio-political, environmental and economic impacts. Cost-benefit analyses are often used in concert with comparative risk assessment. However, project selection inevitably involves multiple criteria such as costs, benefits, environmental impacts, safety and risks. Some of these criteria cannot easily be condensed into a monetary value, which complicates the integration problem inherent to multiple criteria comparisons and trade-offs.

Analytic Hierarchy Process (AHP) is one of the strategic methods for multiple criteria decision making. The AHP was developed by Thomas Saaty in late 1960s. As the AHP have evolved into wide variety of styles, the AHP has been in use for decision making of development projects including road construction projects and hydropower projects. For example in United States, Environmental Protection Agency, the Department of Energy, and US Army Engineering Research and Development Center have adopted the AHP method by using information from GIS. Besides, the AHP is used for Environmental Impact Assessments of water development project in Finland, liquefied petroleum gas (LPG) recovery plant in an industrial area in India[1] and other countries[2]. The AHP also produced an effect of technical assistance for prioritization of hydropower projects in Vietnam[3]. A lot of study about the AHP has been addressed by local governments of Japan how to utilize it for Strategic Environment Assessment (SEA) of their projects.

In the present Master Plan Study, the AHP was introduced and used aiming at:

- handling complex prioritization issue with multiple criteria, such as environmental issues, technical issues and cost-benefit issues;
- logically selecting the evaluation elements by introducing the hierarchical structure into the multiple evaluation criteria;
- securing the transparency and accountability of the prioritization process through the simplified Pair-wise Comparison to be made between all the combinations of two evaluation elements at the same level;

1 MULTI-CRITERIA DECISION ANALYSIS: A Framework for Structuring Remedial Decisions at Contaminated Sites, "Comparative Risk Assessment and Environmental Decision Making" Kluwer, 2004, p.15-54

2 Decision Support Systems for Large Dam Planning and Operating in Africa, Matthew P. McCartney, International Water Management Institute (IWMI), 2007, p19-21

3 Clean Development Mechanism Simplified Project Design Document for Small-scale Project Activities, version 02 (SSC-CDM-PDD), UN CDM-Executive Board, 2007, p7

- encouraging counterparts to aware the complex issues in selecting priority projects;
- encouraging counterparts to participate in decision making process of Hydropower Master Plan Study as policy makers; and
- promoting consensus building among stakeholders for its accountability of the Evaluation Criteria and selection process.

5.1.2 Procedure of the Selection

The Procedure of the selection of 10 priority projects is described in Figure 5.1.1.

At Step 1, the current situation and candidate potential projects are reviewed as shown on the right hand. On the left hand, the initial idea of the development goal and strategies were discussed among the Study Team and Counterparts nominated from MIME, EAC, EDC and MOE. Consequently, the *Evaluation Criteria* were established based on the development strategies.

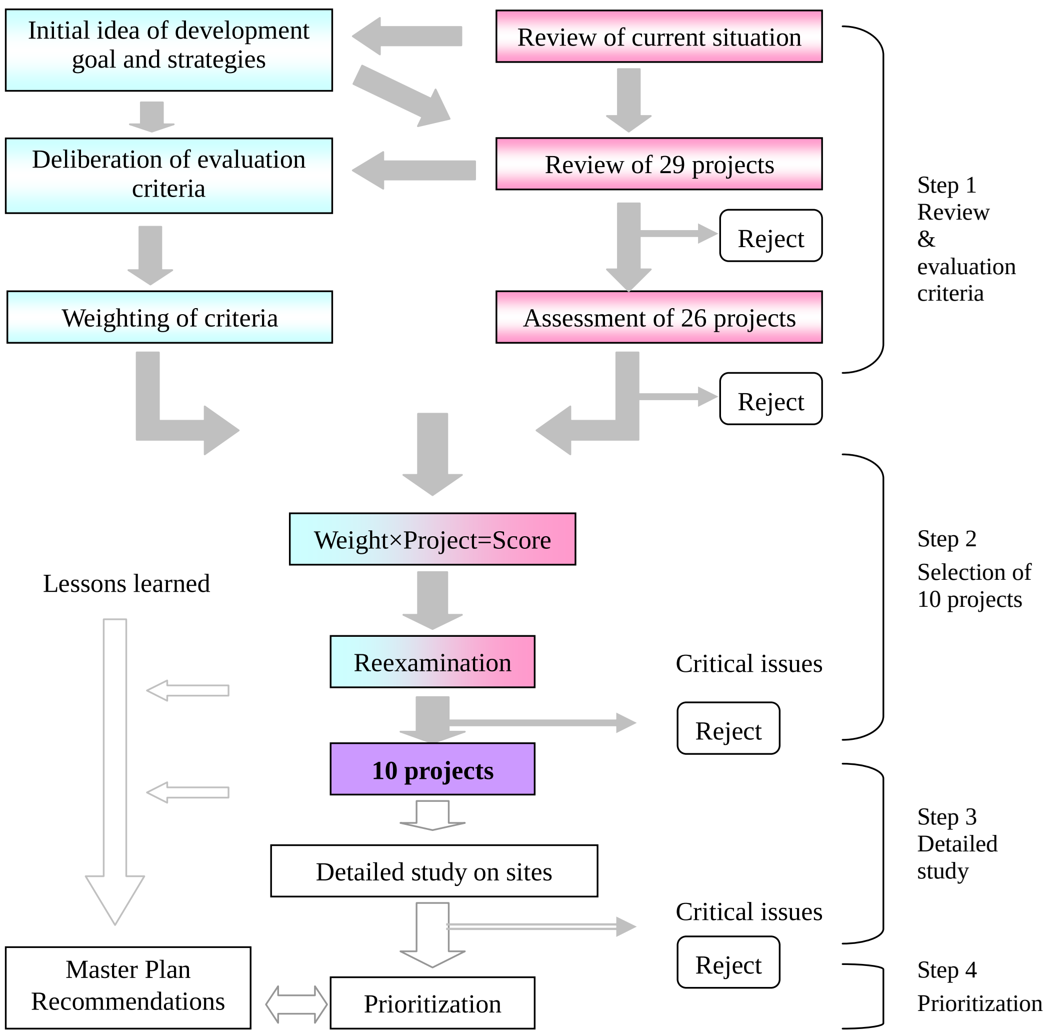


Figure 5.1.1 Conceptual Work Flow of Project Prioritization

The potential projects were evaluated by using the multiple evaluation criteria formulated in hierarchical structure. Weighting of each evaluating element was carried out by applying *Pair-wise Comparison*[4] of the AHP. There are three methods to calculate weights of each element based on the *Pair-wise Comparison*. A simple method of "*Arithmetic Average Method*"[5] was used at the workshops held in July 2007. The weights of elements of certain level of the *Evaluation Criteria* are obtained as:

$$\frac{w_1}{\Sigma w}, \quad \frac{w_2}{\Sigma w}, \quad \cdots\cdots \quad \frac{w_m}{\Sigma w}$$

where,

w_m = weight of m^th^ element in the level of interest of the *Evaluation Criteria*;

m = number of evaluation elements;

Σw = total weight of all the elements.

The project evaluation sheets scored and filled by individual participants were examined and compiled by the Study Team. On the process of examination, some of the candidate projects were rejected due to critical issues from the technical and environmental viewpoints. Score totals of the projects were recalculated in accordance with formula below:

$$\boldsymbol{PW} = \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1m} \\ \vdots & & & \vdots \\ p_{n1} & & \cdots & p_{nm} \end{bmatrix} \times \begin{bmatrix} W_1 \\ \vdots \\ W_m \end{bmatrix} = \begin{bmatrix} p_{11}\, w_1 + \ldots + p_{1m}\, w_m \\ \vdots \\ p_{n1}\, w_1 + \ldots + p_{nm}\, w_m \end{bmatrix}$$

where,

p_{nm} = score of n^{th} project and m^{th} element

It comes up with the scores of each project. The scores were reviewed in detail and some more consideration of experts were added. The 10 projects out of 29 projects were finally selected at the end of Step 2.

Further detailed study for prioritization of the 10 projects will be conducted in the Step 3 during the next field study. Lessons learned through the Study will be incorporated into the Draft Master Plan. The Draft Master Plan will be finalized after presentation to the stakeholders at the Seminar.

4 Saaty, 1980

5 The other methods are "*geometric average method*" and "*eigenvector method*". It is said that *geometric average method* and *eigenvector method* are more precise formula of *Pair-wise Comparison* to calculate weights but due to time constraints the Study Team used the free software of *simple arithmetic average method*.

5.2 EVALUATION CRITERIA

5.2.1 Identification of *Evaluation Criteria*

The elements of the *Evaluation Criteria* were identified as presented in Table 5.2.1. The *Evaluation Criteria* were formulated with 3 levels of hierarchical structure. Level 1 is the top category and consist of five elements: 1) socio-economic environment impacts, 2) natural environment impacts, 3) project (technical aspects), 4) economic and financial aspects, and 5) speed of implementation.

Table 5.2.1 *Evaluation Criteria* for Project Priority

Level 1		Level 2		Level 3	
1	**Socio-Economic Environmental Impacts**	1.1	Life	1.1.1	Number of households for resettlement
				1.1.2	Potential number of households for electrification
				1.1.3	Flood control effect
		1.2	Culture	1.2.1	Minorities maintaining traditional style of life
				1.2.2	Historical remains and cultural heritages
		1.3	Economy	1.3.1	Area of farmland to be expropriated
				1.3.2	Number of households along the river stretches between intake and outfall (water outlet to river)
				1.3.3	Potential of irrigated agriculture
				1.3.4	Potential of fishery (promotion of fish culture)
				1.3.5	Potential of commerce and industry
2	**Natural Environment Impacts**	2.1	Regional natural environment	2.1.1	Environment-protected areas
				2.1.2	Trapping of sediment transport (riverbed scouring, riverbank erosion, regression of delta)
				2.1.3	Reduction in CO_2 emission
		2.2	Physical environment around dam (water, land)	2.2.1	Pollution during construction period
				2.2.2	Access roads
				2.2.3	Possibility of water quality deterioration
		2.3	Ecological environment (bio-diversity, fauna and flora, forests)	2.3.1	Reservoir surface area (inundation of forests)
				2.3.2	Rare species of fauna and flora
3	**Project (Technical issues)**	3.1	Natural conditions	3.1.1	Characteristics of flow duration curve
				3.1.2	Topography (storage volume and head for power generation)
				3.1.3	Geology
				3.1.4	Sedimentation
		3.2	Scale of power generation		
		3.3	Unit generation cost		
4	**Economic and Financial Aspects**	4.1	Power market and demand	4.1.1	Contribution to domestic peak demand
				4.1.2	Excess energy for export
		4.2	Power policy and national interests	4.2.1	Contribution to lowering the domestic power tariff
				4.2.2	Contribution to earning foreign currency and tax revenue
		4.3	Internal rate of return	4.3.1	EIRR
				4.3.2	FIRR

Level 1		Level 2		Level 3	
5	**Speed of Implementation**	5.1	Physical factors of delay	5.1.1	Existence of large bridges in flat region, and length of required access roads in mountain region
				5.1.2	Reservoir surface area
				5.1.3	Construction period
				5.1.4	Extent of un-cleared landmines
		5.2	Social factors of delay	5.2.1	Agreement of households for resettlement
				5.2.2	Scale of project costs and financial arrangements
				5.2.3	Preparation for project implementation
				5.2.4	Agreement of MRC

5.2.2 Weighting of *Evaluation Criteria* by *Pair-wise Comparison*

Pair-wise Comparison is a possible regression formula of all the elements. It will ask which is more important between one pair of two elements A and B. When the criteria in the same level have 5 elements from A to E for example, *Pair-wise Comparison* has to be made for 10 times[6], that is, A:B, A:C, A:D, A:E, B:C, B:D, B:E, C:D, C:E and D:E.

The Study Team and Counterparts exercised *Pair-wise Comparison* separately and come up with each result. Figure 5.2.1 shows the results of weighting by *Pair-wise Comparison* in Levels 1 and 2.

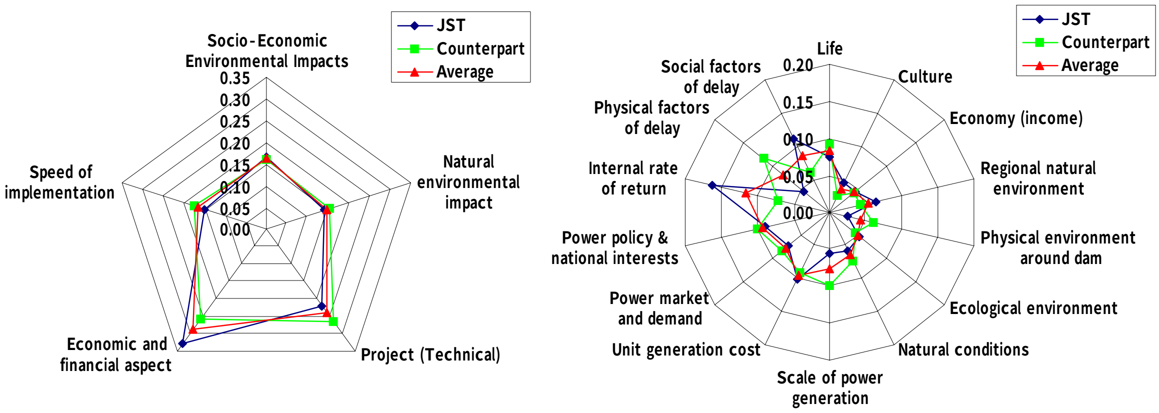


Figure 5.2.1 Weight of the *Evaluation Criteria*, Level 1 on the left and Level 2 on the right

Active discussions were exchanged through and after *Pair-wise Comparison*. The representative topics of discussion were as summarized below:

- Socioeconomic issues are more important than the natural environment. We need to care about resettlement sites, stable income sources, and living standards for resettlements.
- The natural environment is more important than the socioeconomic environment because the world is in peril from environmental ills such as global warming and abnormal climate.
- Living standards and economic growth are more important than the natural environment.
- A technical assessment should be carried out first, and then we can consider the social environment.
- Even if the project is environmentally friendly, we cannot implement it if it is technically unfeasible.

[6] ${}_mC_r = n! / \{ r! (n-r) ! \} = {}_5C_2 = 5 \times 4 \times 3 \times 2 \times 1 / \{(2 \times 1) \times (3 \times 2 \times 1)\} = 20/2 = 10$

- Even if the project has no negative environmental impacts, we will not implement it if it is unprofitable. If the project is not financially sustainable, we would need to raise the electricity tariff even to an unacceptably high level.
- The speed or maturity of the projects is important since energy supply is in short and it is one of the critical constraints on economic growth in Cambodia.

The points of argument were identified and made clear through the discussion using the *pair-wise comparison*. The consensus was built rather smoothly among the members of both Japanese and Cambodian teams. An average of weights of both parties was adopted as the weight for each element of the *Evaluation Criteria* of the Study as shown in Figure 5.2.2.

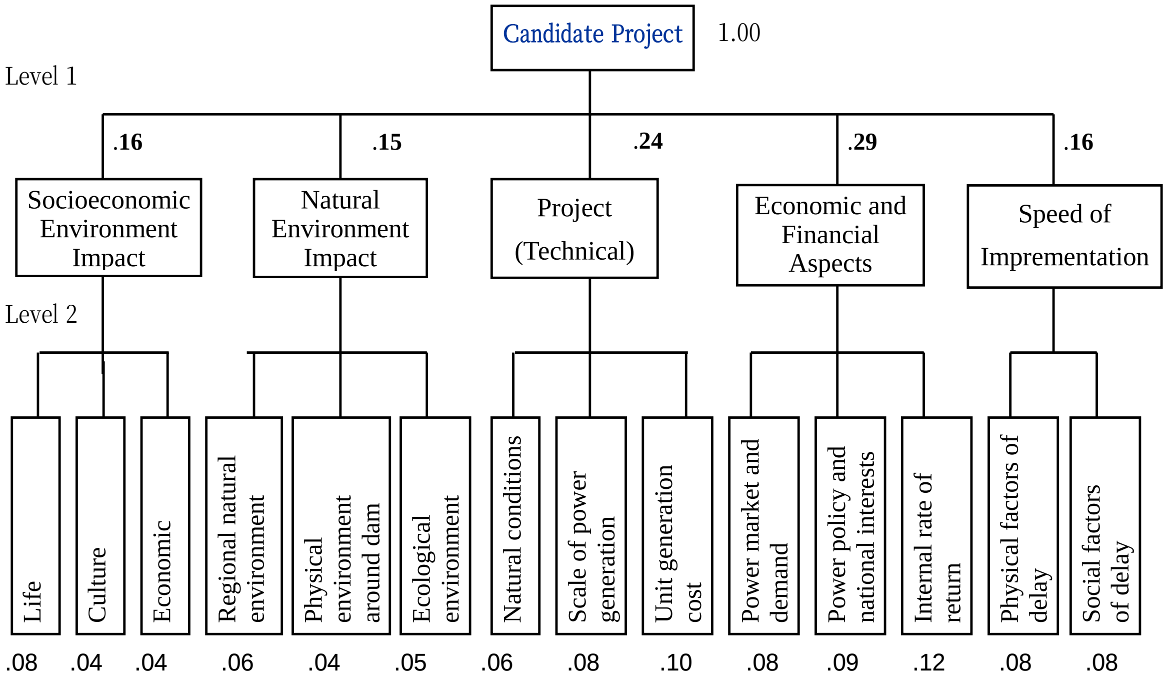


Figure 5.2.2 Results of the Weighting

5.2.3 Scale for Each Element of *Evaluation Criteria*

Each element of the *Evaluation Criteria* was measured with a predetermined scale for each project based on the review results of hydropower planning, digital maps and geographic information (GIS), and village databases of NIS. The scale and units of the elements are presented in Table 5.2.2. The scale has been improved as described below through preliminary assessment of 29 projects:

(1) Element 2.1.1 Impacts on Protected Areas: Initially the four zones were set as the measuring scale of impacts on the Protected Area. Thereafter it was found that all the Protected Areas concerned with the 25 candidate projects had not been zoned. Then, the scale was changed to the inundation area that falls within the Protected Area. Such area was newly measured by the Study team with GIS database. The area includes those of islands that would be created in the reservoir.

(2) Element 2.1.3 CO_2 emission reduction effect: Initially, net reduction in CO_2 emission (t-CO_2) was set as the measuring scale. The loss of CO_2 absorbing and fixing capacity of forests (sink effect) due to inundation was taken into consideration in calculation of the net reduction. However, this scale will favour the greater net reduction (the greater reservoir is favoured as long as the net reduction is greater) regardless of the land efficiency for power generation. Hydropower in Cambodia will consume CO_2 absorbing and fixing capacity of forests while reducing CO_2 emission by alternative thermal power plant. Accordingly, the scale was changed from net reduction to the efficiency in net reduction, that is, the reduction in CO_2 emission per unit area of inundation (t-CO_2/km^2).

(3) Element 3.1.2 Topography: Initially the product of gross reservoir capacity and rated head was set as the measuring scale. However, this will favour also those projects that have huge dead storage as the topographic advantage. Accordingly, the gross capacity was replaced with effective capacity.

(4) Element 4.1.1 Primary discharge: In the first screening, a dimension less flow duration curve developed from runoff records of Lumphat stream gauging station on the Sre Pok River was used to estimate primary discharge Q_f and primary energy E_f. Two Mekong Mainstream projects have nearly zero effective capacity–inflow ratio (CIR: Sambor: 1.0%, Stung Treng: 1.0%). Sre Pok IV (0.54%) and Se Kong (0.13%) also have very small CIR. For these projects, the flow duration curve used underestimates the primary energy. Accordingly, the dry season discharge (as 90% dependable discharge) of gauging station nearby was used in estimating the primary energy: Kratie GS for Sambor project, Stung Treng GS for Stung Treng project, Lumphat GS for Sre Pok IV project, and Ban Khmon for Se Kong project.

(5) Element 4.2.2 Contribution to foreign currency earning and tax revenue: Initially total energy generation was used as approximate scale. However, it favours the greater energy regardless of unit generation costs that could not be exported. Accordingly, the scaling was applied only to those projects that have unit generation cost lower than 7 cents/kWh.

(6) Elements 4.3.1 and 4.3.2 IRR: It was initially set as the common scale for both EIRR and FIRR that IRR lower than 8% was given with zero point while the higher IRR than 8% got points in proportion to IRR. Based on the actual value of IRR, points were given to EIRR higher than 10% and FIRR higher than 7%.

(7) Element 5.2.2 Scale of project costs: It was assumed that those projects having costs greater than 1,000 m$ was given zero point. After trial assessment, it was found that there was no project of which cost exceeded 1,000 m$ as a result of exclusion of large scale Mekong Mainstream projects. Then, it was changed that those projects having costs greater than 500 m$ was given zero point.

Table 5.2.2 *Evaluation Criteria*: Scale and Units of Elements

Level 1		Level 2		Level 3		[1]+/–	[2]Quality/ Quantity	Scale and Units of Elements (0, 25, 50, 75, 100)				
								0	**25**	**50**	**75**	**100**
1	**Socio-Economic Environmental Impact**	1.1	Life	1.1.1	Number of households for resettlement	–	Quantity	> 1,000 hh	500~1,000	200~500	50~200	0~50
				1.1.2	Potential number of households for electrification	+	Quality	0~ 2,000 hh	2,000~5,000	5,000~ 10,000	10,000~ 20,000	> 20,000
				1.1.3	Flood control effect	+	Quantity	< 5%	5~10%	10~20%	20~30%	> 30%
		1.2	Culture	1.2.1	Minorities maintaining traditional style of life	–	Quality	Serious impact	Certain impact	Small impact	Almost no impact	No impact
				1.2.2	Historical remains and cultural heritages	–	Quality	Serious impact	Certain impact	Small impact	Almost no impact	No impact
		1.3	Economy	1.3.1	Area of farmland to be expropriated	–	Quantity	> 2,000 ha	1,000~2,000	100~1,000	0~100	0
				1.3.2	Number of households along the river stretches between intake and outfall (water outlet to river)	–	Quantity	-	-	-	-	-
				1.3.3	Potential of irrigated agriculture	+	Quality	Negative	No change	A little positive	Positive	Much positive
				1.3.4	Potential of fishery (promotion of fish culture)	+	Quality	Negative	No change	A little positive	Positive	Much positive
				1.3.5	Potential of commerce and industry	+	Quality	Negative	No change	A little positive	Positive	Much positive
2	**Natural Environmental Impacts**	2.1	Regional natural environment	2.1.1	Environment-protected areas	–	Quantity	> 5,000 ha	1,000~5,000	100~1,000	1~100	0
				2.1.2	Trapping of sediment transport (riverbed scouring, riverbank erosion, regression of delta)	–	Quality	Seriously large impact (large dam on Mekong mainstream)	Large impact (dam on Mekong mainstream)	Certain impact (large dam on Mekong tributaries)	Small impact (dam on Mekong tributaries)	No impact (out of Mekong basin)
				2.1.3	Reduction in CO_2 emission	+	Quantity	Minus (emission increase)	0~500 $t\text{-}CO_2/km^2$	500~2,000 $t\text{-}CO_2/km^2$	2,000~10,000 $t\text{-}CO_2/km^2$	> 10,000 $t\text{-}CO_2/km^2$

Level 1		Level 2		Level 3		[1]+/–	[2]Quality/ Quantity	Scale and Units of Elements (0, 25, 50, 75, 100)				
								0	**25**	**50**	**75**	**100**
		2.2	Physical environment around dam (water, land)	2.2.1	Pollution during construction period	–	Quantity	> 30 mcm	10~30 mcm	5~10 mcm	1~5 mcm	< 1 mcm
				2.2.2	Access roads	–	Quantity	> 40 km	30~40 km	20~30 km	10~20 km	~10 km
				2.2.3	Possibility of water quality deterioration	–	Quantity	> 50%	30~50%	20~30%	5~20%	< 5%
		2.3	Ecological environment (bio-diversity, fauna and flora, forests)	2.3.1	Reservoir surface area (inundation of forests)	–	Quantity	> 50 km^2	25~49 km^2	10~24 km^2	5~9 km^2	< 5 km^2
				2.3.2	Rare species of fauna and flora	–	Quality	Serious impact	Certain impact	Small impact	Almost no impact	No impact
3	**Technical Feasibility**	3.1	Natural conditions	3.1.1	Characteristics of flow duration curve	–	Quantity	< 0.10 m^3/s	0.10~ 0.20 m^3/s	0.20~ 0.30 m^3/s	0.30~ 0.50 m^3/s	> 0.50 m^3/s
				3.1.2	Topography (storage volume and head for power generation)	+	Quantity	< 5,000 mcm·m	5,000~10,000	10,000~ 20,000	20,000~ 50,000	> 50,000 mcm·m
				3.1.3	Geology	–	Quality	Serious issue	Some special issue	No special issue	No issue	Good condition
				3.1.4	Sedimentation	–	Quality	Serious issue	Some special issue	No special issue	No issue	Good condition
		3.2	Scale of power generation			+	Quantity	< 50 GWh	50~100 GWh	100~500 GWh	500~ 1,000 GWh	> 1,000 GWh
		3.3	Unit generation cost			+	Quantity	> 10 ¢/kWh	8~10 ¢/kWh	7~8 ¢/kWh	6~7 ¢/kWh	< 6¢/kWh
4	**Economic and Financial Aspects**	4.1	Power market and demand	4.1.1	Contribution to domestic peak demand	+	Quantity	< 20 GWh	20~50 GWh	50~250 GWh	250~500 GWh	> 500 GWh
				4.1.2	Excess energy for export	+	Quantity	< 50 GWh	50~100 GWh	100~500 GWh	500~ 1,000 GWh	> 1,000 GWh
		4.2	Power policy and national interests	4.2.1	Contribution to lowering the domestic power tariff	+	Quantity	> 10 ¢/kWh	8~10 ¢/kWh	7~8 ¢/kWh	6~7 ¢/kWh	< 6¢/kWh
				4.2.2	Contribution to earning foreign currency and tax revenue	+	Quantity	< 50 GWh	50~100 GWh	100~500 GWh	500~ 1,000 GWh	> 1,000 GWh
		4.3	Internal rate of return	4.3.1	EIRR	+	Quantity	< 10%	10%~12%	12%~14%	14%~16%	> 16%
				4.3.2	FIRR	+	Quantity	< 7%	7%~9%	9%~11%	11%~13%	> 13%

Level 1		Level 2		Level 3		[1]+/ –	[2]Quality/ Quantity	Scale and Units of Elements (0, 25, 50, 75, 100)				
								0	**25**	**50**	**75**	**100**
5	**Speed of Implementation**	5.1	Physical factors of delay	5.1.1	Existence of large bridges in flat region, and length of required access roads in mountain region	–	Quantity	> 40 km	30~40 km	20~30 km	10~20 km	< 10 km
				5.1.2	Reservoir surface area	–	Quantity	> 500 km^2	250~500 km^2	100~250 km^2	50~100 km^2	< 50 km^2
				5.1.3	Construction period	–	Quantity	> 30 mcm	10~30 mcm	5~10 mcm	1~5 mcm	< 1 mcm
				5.1.4	Extent of un-cleared landmines	–	Quality	Serious	Certain	Small	Almost no	No
		5.2	Social factors of delay	5.2.1	Agreement of households for resettlement	+	Quality	No exist	Almost no exist	A little exist	Exist	Surely exist
				5.2.2	Scale of project costs and financial arrangements	–	Quantity	> 500 m$	300~500 m$	200~300 m$	100~200 m$	< 100 m$
				5.2.3	Preparation for project implementation	+	Quality	No study report, Project feature unknown	General study report exists	Detailed study report exists	Under Pre-F/S	Under F/S
				5.2.4	Agreement of MRC	+	Quality	Dam & river diversion plan on Mekong mainstream	Dam plan on Mekong mainstream	Dam & river diversion plan on Mekong tributaries	Dam plan on Mekong tributaries	Out of Mekong basin

1) "+": Larger value is desirable, "—": Smaller value is desirable, Scores of the both cases are accounted by adding positive values (0, 25, 50, 75, 100).
2) Both of the qualitative values and the quantitative values are scored in accordance with the assumed scale range (0, 25, 50, 75, 100).

5.3 PROJECT EVALUATION BY ELEMENTS

5.3.1 Socio-Economic Impacts

(1) Life: Flood control effect

With regard to the flood control by hydropower projects, the following effects are expected:

- Reservoirs can control sudden increase of river flow due to the flash floods, which tend to occur in the area with steep topography, and
- Reservoirs can re-regulate hourly fluctuation of river flow due to the peak power generation at upstream hydropower stations.

In order to valuate flood control effects of the candidate hydropower projects, two parameters were considered. One is a gradient of rivers, and the other is a ratio of effective reservoir capacity and annual inflow volume into reservoirs. Table 5.3.1 shows the river gradients and the capacity-inflow ratio of candidate projects.

Table 5.3.1 River Gradient and Ratio of Annual Inflow against Reservoir Capacity

No.	Project Name	Region	River gradient (in 1 to)	Capacity-Inflow Ratio (%)
1	Sambor	(Mekong)	3,500	-
2	Prek Chhlong II	East	350	5.8%
3	Prek Ter III	East	700	44.3%
4	Prek Ter II	East	550	16.0%
5	Sre Pok IV	Northeast	2,400	0.5%
6	Prek Por I	East	1,400	85.5%
7	Lower Sre Pok II	Northeast	3,000	10.1%
8	Lower Se San II	Northeast	3,000	8.1%
7&8	Lower Sre Pok II + Lower Se San II	Northeast	3,000	5.0%
9	Stung Treng	(Mekong)	3,000	-
10	Se Kong	Northeast	4,500	0.1%
11	Lower Se San III	Northeast	2,400	9.7%
12	Prek Liang I	Northeast	2,400	10.4%
13	Prek Liang IA	Northeast	2,400	10.4%
14	Prek Liang II	Northeast	2,400	28.0%
15	Lower Sre Pok III	Northeast	2,400	8.2%
16	Middle St. Russey Chrum	Southwest	100	57.3%
17	Stung Chhay Areng	Southwest	150	75.8%
18	Stung Tatay	Southwest	150	59.2%
19	Stung Metoek I	Southwest	170	50.0%
20	Stung Metoek II	Southwest	170	38.2%
21	Stung Metoek III	Southwest	190	11.7%
22	Stung Kep II	Southwest	120	5.1%
23	Upper St. Russey Chrum	Southwest	50	47.2%
24	Stung Pursat I	Southwest	950	84.7%
25	Stung Pursat II	Southwest	575	57.9%
26	Stung Sen	North	3,500	59.5%
27	Stung Battambang II	Southwest	100	76.4%

No.	Project Name	Region	River gradient (in 1 to)	Capacity-Inflow Ratio (%)
28	Stung Battambang I		450	46.1%
29	Bokor Plateau	South	250	44.9%

Source: Study Team

In general, dams on rivers with gentle gradient have less effect of flood control since flash floods would not occur on those rivers. For the 1st screening of the hydropower potential sites, the projects with river gradient gentler than 1 to 1,000 were excluded from the valuation of flood control effect. All the projects located on the Mekong Mainstream and the northeastern region, No. 6, and No. 26 were scored with zero point.

For the other parameter (capacity-inflow ratio), the following valuation was set for the 1st screening of the hydropower potential sites:

Group	*CIR*	*Score*
A	30%≦CIR	100
B	20%≦CIR＜30%	75
C	10%≦CIR＜20%	50
D	5%≦CIR＜10%	25
E	CIR＜5%	0

The projects with large CIR can have high flood control effect. In other words, the projects with high CIR can be valuated as a project with high score on flood control effect. Except for the projects with river gradient gentler than 1 to 1,000, the above valuation was applied to the hydropower potential sites.

The above examinations on flood control effect for the 1st screening are summarized in Table 5.3.2.

Table 5.3.2 Project Score on Flood Control Effect

No.	Project Name	River gradient (in 1 to)	CIF (%)	Score
1	Sambor	3,500	---->	0
2	Prek Chhlong II	350	5.8	25
3	Prek Ter III	700	44.3	100
4	Prek Ter II	550	16.0	50
5	Sre Pok IV	2,400	---->	0
6	Prek Por I	1,400	---->	0
7	Lower Sre Pok II	3,000	---->	0
8	Lower Se San II	3,000	---->	0
7&8	Lower Sre Pok II + Lower Se San II	3,000	---->	0
9	Stung Treng	3,000	---->	0
10	Se Kong	4,500	---->	0
11	Lower Se San III	2,400	---->	0
12	Prek Liang I	2,400	---->	0
13	Prek Liang IA	2,400	---->	0
14	Prek Liang II	2,400	---->	0
15	Lower Sre Pok III	2,400	---->	0
16	Middle St. Russey Chrum	100	57.3	100
17	Stung Chhay Areng	150	75.8	100
18	Stung Tatay	150	59.2	100
19	Stung Metoek I	170	50.0	100
20	Stung Metoek II	170	75.4	100

No.	Project Name	River gradient (in 1 to)	CIF (%)	Score
21	Stung Metoek III	190	43.7	50
22	Stung Kep II	120	1.3	25
23	Upper St. Russey Chrum	50	47.2	100
24	Stung Pursat I	950	84.7	100
25	Stung Pursat II	575	57.9	100
26	Stung Sen	3,500	---->	0
27	Stung Battambang II	100	76.4	100
28	Stung Battambang I	450	46.1	100
29	Bokor Plateau	250	44.9	100

Source: Study Team

According to the result of valuation on flood control effect, the projects in the southwestern region get high score while the projects in the northeastern region get mostly zero score. The result seems reasonable following the general consideration that hydropower projects at rivers with steep gradient may have flood control effect[7].

5.3.2 The Project (Technical Issues)

(1) Characteristics of flow duration curve

The Cambodian rivers often have unfavorable characteristics of river flow (very low flow in the dry season) being affected by the distinct dry season, topographic features, geology-surface soil, and vegetation cover. Accordingly, one of the important issues on hydropower planning in Cambodia is the availability of river discharge in the dry season.

However, in Cambodia there are the following constraints in hydropower planning:

1) There is no stream gauging station at or near proposed hydropower sites and few hydrological data such as river discharges exist.

2) Number of stream gauging stations is limited even if those apart from hydropower project sites are included. There are few stations that have periodical discharge measurements and established stage-discharge curve (H-Q curve).

3) Although rainfall measurement is rather simple and easy compared to stream flow gauging, there are few rain-gauges inside the basins of hydropower projects. Accordingly, even a basin mean rainfall has to be estimated by interpolating from distant raingauges outside the basin.

4) The annual rainfall exceeds 3,000 mm in the south-western coastal region and north-eastern mountainous region while it drops to below one half in the Tonle Sap basin. There is such hydrological

7 Those projects of #5 to #15 are located on Mekong tributaries and could hardly expect flood control effect on the downstream river reaches except for re-regulating effect to the power discharges of a peaking power plant if exists upstream. Because on continental rivers like Mekong, a flood reaches peak through gradual increase over the rainy season. In Cambodia it always causes inundation of both banks of Mekong. Accordingly, some regulation of flood flows by tributary dams could hardly bring flood control effect to downstream Mekong River. On the other hand, in the non-Mekong small basins with steep riverbed gradients, flash floods have took place even in Cambodia that has flat topography in general. Even a relatively small reservoir could exert its control effect to such flash floods.

tendency that when an annual rainfall decreases to one half, annual runoff coefficient[8] will decrease also to about one half, resulting in a reduction of annual runoff height[9] or specific discharge[10] to about one forth.

In order to examine characteristics of flow duration curve under such conditions, the Study Team collected and compiled river discharge data related to the hydropower potential sites. Table 5.3.3 shows the stream (water level) gauging stations used for the 1st screening work.

Table 5.3.3 Stream Gauging Stations Used for1st Screening Work

Station No.	Station Name*	River Basin	Data Used		Specific Discharge (m^3/sec/100km^2)		
			Interval	Period (years)	Annual av. (q_a)	Dry season (q_d)	q_d/q_a
14501	Stung Treng	Mekong river	Daily	20	2.04	0.30	15%
14901	Kratie	Mekong river	Daily	20	2.08	0.32	16%
430101	Ban Khmon	Se Kong	Daily	9	4.70	0.71	15%
440101	Ban Kamphun	Se San	Daily	7	3.33	0.51	15%
440102	Veoun Sai	Se San	Daily	1	4.15	0.75	18%
450101	Lumphat	Sre Pok	Daily	6	2.59	0.21	8%
550101	Treng	St. Sangker	Daily	8	3.41	0.44	13%
580102	Taing Leach	St. Pursat	Daily	4	1.28	0.05	4%
610102	Kompong Putrea	St. Sen	Daily	5	1.71	0.02	1%
-	Huai Sato (Thai)	Huai Sato (Thai)	Monthly	26	5.29	0.43	8%
-	Kbal Chay	Prek Tuek sub river (Sihanoukville)	Daily	1.5	8.20	0.44	5%

Source: Study Team

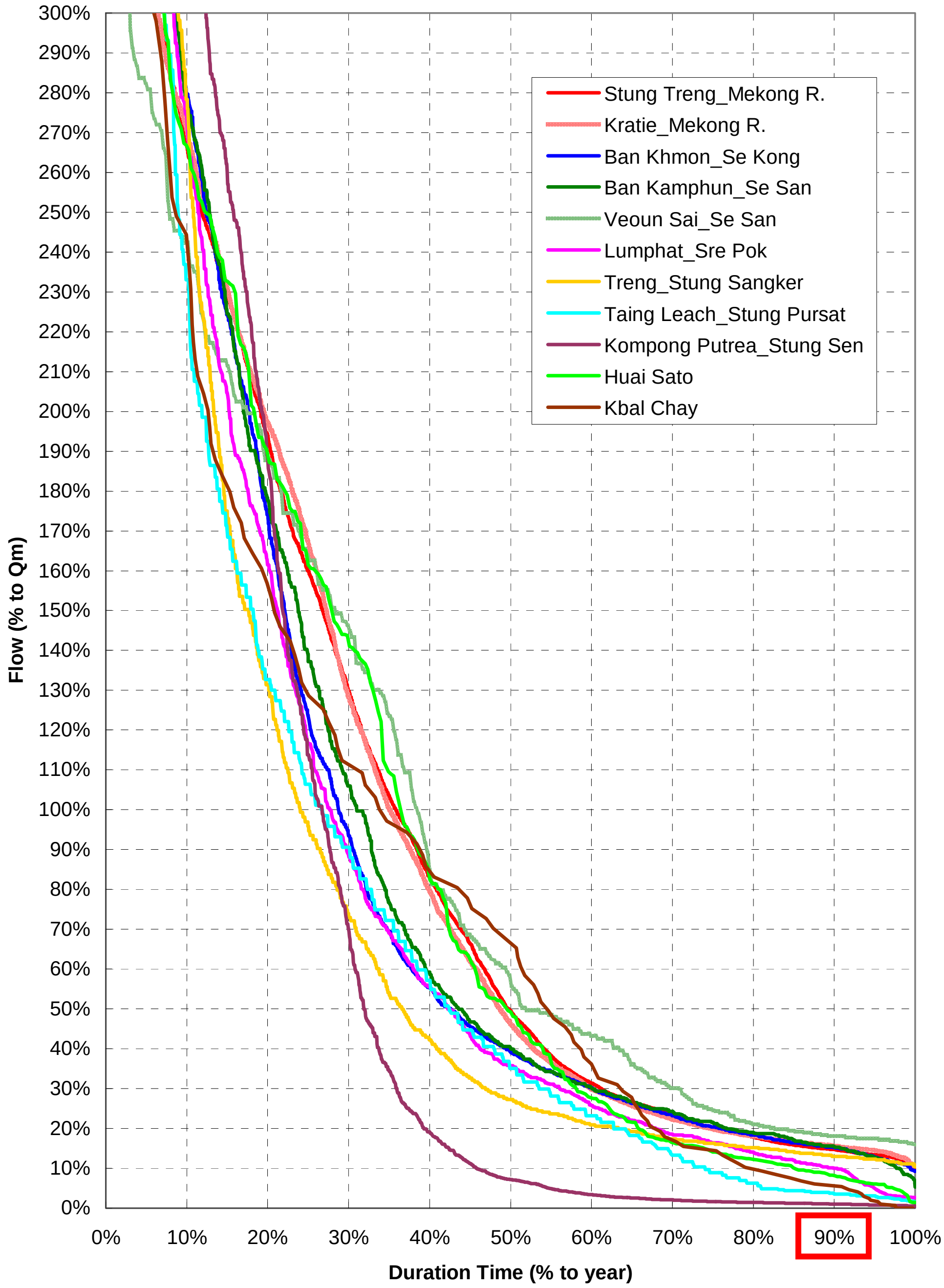
*) Data of the stations referred to data of MRC, MOWRAM, Preliminary Study on the Stung Mnam Hydroelectric Power Project (EPDC, 2001), The Study on Regional Development of the Phnom Penh-Sihanoukville Growth Corridor in the Kingdom of Cambodia (JICA, 2003)

Of the existing stream gauging stations, the stations above were selected considering those locations, data availability and reliability. The specific discharges in Table 5.3.3 were derived from the following flow duration curves, and the discharge in the dry season was defined as the discharge at 90% dependability through a year (365 days x 90% = 328.5 days).

8 Ratio of annual runoff (= annual discharge = annual water flow volume of river) to annual rainfall over a river basin upstream of project site of interest.

9 Annual runoff height is obtained by dividing annual runoff that flows down certain river point (Q: usually expressed in million cubic meter or mcm) with basin area at the same point (A: usually expressed in km^2) and is expressed in mm like rainfall. It may be imaged as a water depth over a hypothetical tank that has the river basin (=watershed) as a tank bottom. For example, $Q / A = (100 \text{ mcm} \times 10^6 \text{ m}^3) / (100 \text{ km}^2 \times 10^6 \text{ m}^2) = 1 \text{ m} = 1{,}000 \text{ mm}$. Annual runoff height is often used together with the following specific discharge for comparison of runoff between different basins. The annual runoff height has such advantage that its absolute value can be easily imaged like rainfall.

10 For example, annual runoff may be expressed as runoff from a unit basin of 100 km^2, for comparison between different basins. Unit of specific discharge is usually taken as m^3/s/100 km^2.



Source: Study Team

Figure 5.3.1 Flow Duration Curves

Figure 5.3.1 indicates that Stung Sen at Kampong Putrea has low dependability of river discharge in the dry season. H-Q curves of the Mekong Mainstream have significant river discharge also in the dry season as represented by the ratio of 90% discharge to the annual average discharge (Q_{90} to Q_m) being around 10%.

Referring to the examination above on the characteristics of flow duration curve, specific discharge in the dry season was selected as the parameter of valuation for the 1st screening work. Table 5.3.4 shows the estimated specific discharges in the dry season and the valuation results (i.e. scores) for each project.

Table 5.3.4 Specific Discharges in Dry Season and Project Score on Flow Characteristics

No.	Project Name	Region	Applied Observation Station	Specific Discharge in dry season (m^3/sec)	Score
1	Sambor	(Mekong)	Kratie	0.32	75
2	Prek Chhlong II	East	Kratie	0.32	75
3	Prek Ter III		Kratie	0.32	75
4	Prek Ter II		Kratie	0.32	75
5	Sre Pok IV	Northeast	Lumphat	0.21	50
6	Prek Por I	East	Lumphat	0.21	50
7	Lower Sre Pok II	Northeast	Lumphat	0.21	50
8	Lower Se San II		Ban Kamphun	0.51	100
7&8	Lower Sre Pok II + Lower Se San II		Ban Kamphun	0.51	100
9	Stung Treng	(Mekong)	Stung Treng	0.30	50
10	Se Kong	Northeast	Ban Khmon	0.71	100
11	Lower Se San III		Ban Kamphun	0.51	100
12	Prek Liang I		Voeun Sai	0.75	100
13	Prek Liang IA		Voeun Sai	0.75	100
14	Prek Liang II		Voeun Sai	0.75	100
15	Lower Sre Pok III		Lumphat	0.21	50
16	Middle St. Russey Chrum	Southwest	Huai Sato	0.43	75
17	Stung Chhay Areng		Huai Sato	0.43	75
18	Stung Tatay		Huai Sato	0.43	75
19	Stung Metoek I		Huai Sato	0.43	75
20	Stung Metoek II		Huai Sato	0.43	75
21	Stung Metoek III		Huai Sato	0.43	75
22	Stung Kep II		Huai Sato	0.43	75
23	Upper St. Russey Chrum		Huai Sato	0.43	75
24	Stung Pursat I		Taing Leach	0.05	0
25	Stung Pursat II		Taing Leach	0.05	0
26	Stung Sen	North	Kompong Putrea	0.02	0
27	Stung Battambang II	Southwest	Treng	0.44	75
28	Stung Battambang I		Treng	0.44	75
29	Bokor Plateau	South	Kbal Chhay	0.44	75

Source: Study Team

The specific discharges in the dry season for the projects were scored following the valuation below:

Valuation grade	Specific discharge in dry season q_d (m^3/sec/100 km^2)	Score
A	$0.5 \leqq q_d$	100
B	$0.3 \leqq q_d < 0.5$	75
C	$0.2 \leqq q_d < 0.3$	50
D	$0.1 \leqq q_d < 0.2$	25
E	$q_d < 0.1$	0

As shown in Table 5.3.4, the hydropower potential sites in the northeastern region are relatively highly valuated compared to the sites in the southwestern region. It is considered that the difference between the two areas results from that in the basin area (wider in the northeastern region). Considering general characteristics of hydro-meteorological and topographic features in Cambodia, the valuation results seem to be reasonable. With regard to the project No. 29 (Bokor Plateau), it applied the data of Kbal Chay station. With referring to the flow duration curve of Kbal Chay, it is noted that its specific discharge in the dry season includes certain risk of overestimate.

(2) Preliminary Geotechnical Considerations

Geotechnical evaluation in the first selection for ten potential sites was carried out, based on the following information:

- Topographic maps at a scale of 1:100,000 or 1:50,000 where available
- Geological maps at a scale of 1:200,000
- Satellite images
- Existing reports on hydropower development study

Four categories (fault, limestone, landslide, and overburden) were selected for the evaluation, considering adverse effect such as technical difficulty in taking measures and/or cost increase for the measures.

- Fault

  Faults are generally associated with weak zones, and the weak zones cause problem on stability of civil structures, in case that faults lie on foundation of civil structures. In addition, the weak zones generally show high permeability, and zones possibly cause leakage problem, in case that faults lie within a reservoir area. Furthermore, if an active fault lies in the vicinity of civil structures or reservoir, fatal problems would associate with the stability of civil structures or slope stability in reservoir areas.
- Limestone

  Although limestone does not cause problem in terms of strength in general, there is concern that it would cause leakage problems because of dissolution cavities created in the limestone. In case leakage problem occurs, it seems to face technical and financial difficulty in taking adequate measures, because of irregularity of distribution and scale of the cavities.
- Landslide

  There is concern about stability of civil structures, if they are constructed in landslide areas. Other case that landslides lie in a reservoir area, the landslides may become instable due to impounding, and may cause overtopping of reservoir water and destruction to dam and downstream areas.
- Overburden

  Thick and soft overburden on foundations of dams will be removed in order to secure dam stability and water tightness, or it requires large-scale countermeasures, resulting in increase of construction cost.

Evaluation on each category above was done as described below:

- Fault

  Lineaments were identified on topographic maps and satellite images, and the clearness and location of the identified lineaments were recorded. On the existing geological maps and reports, faults described in the vicinity of the potential sites were picked up, and then, the assuredness (confirmed or assumed) and location of the fault were recorded.

  In case clear lineaments or confirmed faults were found, characteristic geographic features of active faults such as kinking of water courses/ridges, cliffs on a line, etc. were made out on topographic maps and satellite images for identification of the possibility of active faults.

- Limestone

  Based on the geological maps and existing reports, the location, geological age, lithofacies of limestone in the vicinities of potential sites were clarified.

- Landslide

  Landslide features were identified on topographic maps and satellite images, and the clearness and location of the identified landslide features were recorded.

- Overburden

  Based on the geological maps and existing reports, the distribution of overburden (soft sediments) on the foundation of structures and reservoir was clarified. The location and assumed thickness of overburden were recorded.

Criteria of the evaluation on each category were as follows (four cases, including an exceptional case for fatal problem):

- Fault
  a) No fault was identified on the existing data.
  b) An assumed fault or unclear lineament was found in the vicinity of the potential site.
  c) A confirmed fault (not active fault) or clear lineament was found in the vicinity of the site.
  d) A confirmed fault or clear lineament which was judged to be a possible active fault was located in the vicinity of the site, and there is high possibility that the fault would cause fatal problem
- Limestone
  a) No limestone was identified on the existing data.
  b) There is possibility of distribution of limestone, although no limestone was shown in the vicinity of the potential site on the existing data.
  c) A small body of limestone was found in the vicinity of the site.
  d) A large body of limestone was found in the vicinity of the site.
- Landslide
  a) No landside was identified on the existing data.
  b) There is possibility of distribution of a landslide, although no landslide was found in the vicinity of the potential site on the existing data.
  c) A small-scale landslide was found in the vicinity of the site.
  d) A large-scale landslide was found in the vicinity of the site.
- Overburden
  a) No thick overburden was identified on the existing data.
  b) There is possibility of distribution of thick overburden, although no thick overburden was found in the vicinity of the potential site on the existing data.
  c) Thick overburden was distributed on a part of the potential site.
  d) Thick overburden was locally or widely distributed on the potential site, and there is possibility that the overburden causes serious problem.

In order to evaluate the priority of the potential sites from geological viewpoint, the following rating was done in each category, and then, overall evaluation on geology was done with sum total point.

Rating on each evaluation
For a): 0 point
For b): 25 point
For c): 50 point
For d): 100 point

Criteria for overall geological evaluation in sum total point in four categories

Overall evaluation A: sum total point 0
Overall evaluation B: sum total point 25
Overall evaluation C: sum total point 50
Overall evaluation D: sum total point 75
Overall evaluation E: sum total point 100

The rating result is as shown below, and the overall evaluation result is re-shown in the project sheet:

Table 5.3.5 Project Evaluation Through Geotechnical Considerations

No.	Project Name	1) Fault	2) Limestone	3) Landslide	4) Sediment	Total Point	Overall Evaluation
1	Sambor	0	0	0	50	50	C
2	Prek Chhlong II	0	0	0	50	50	C
3	Prek Ter III	0	0	0	50	50	C
4	Prek Ter II	50	0	0	0	50	C
5	Sre Pok IV	0	0	0	0	0	A
6	Prek Por I	0	0	0	25	25	A
7	Lower Sre Pok II	0	25	0	0	25	C
8	Lower Se San II	0	25	0	0	25	C
7&8	Lower Sre Pok II + Lower Se San II	0	25	0	50	75	D
9	Stung Treng	0	0	0	50	50	C
10	Se Kong	0	0	0	50	50	C
11	Lower Se San III	0	0	0	50	50	C
12	Prek Liang I	25	0	0	0	25	B
13	Prek Liang IA	0	0	0	0	0	A
14	Prek Liang II	50	0	0	0	50	C
15	Lower Sre Pok III	0	0	0	50	50	C
16	Middle St. Russey Chrum	0	0	0	50	50	C
17	Stung Chhay Areng	0	0	0	50	50	C
18	Stung Tatay	0	0	0	0	0	A
19	Stung Metoek I	0	0	0	0	0	A
20	Stung Metoek II	0	0	0	0	0	A
21	Stung Metoek III	0	0	0	0	0	A
22	Stung Kep II	0	0	0	0	0	A
23	Upper St. Russey Chrum	25	0	0	0	25	B
24	Stung Pursat I	25	0	0	0	25	B
25	Stung Pursat II	0	0	0	0	0	A
26	Stung Sen	0	0	0	50	50	C
27	Stung Battambang II	25	25	0	0	50	C
28	Stung Battambang I	25	25	0	50	100	E
29	Bokor Plateau	0	0	0	50	50	C

5.4 SELECTION OF 10 PRIORITY PROJECTS

As described in Chapter 4, the 29 candidate hydropower projects were reviewed starting from hydrological features followed by hydropower planning, power transmission planning, and cost estimate. Economic evaluation and financial analysis of each project will be presented in Chapter 6. Based on these study results, 10 priority projects were selected from the 29 candidates. The selection was made in accordance with the *Evaluation Criteria* with environmental and social considerations as shown in Figure 5.4.1.

Review of 29 hydropower projects
(Hydrology, generation and transmission planning, cost estiamte, environmental & social considerations, economic assessment)

Study of environmental alternatives

(1) Exclusion of two Mekong Mainstream projects due to unsolved issue of sand trapping
(2) Three projects: #19-21 Stung Metoek are changed from international trans-basin diversion type to cascade development within Metoek Valley
(3) Unification of the #7 LSP2 and #8 LSS2 (for higher economic performance and lower environmental impacts)

Comparison of priority of 26 projects

(1) Prioritization by technical and economic factors
(2) Prioritization by Five Aspect Comprehensive Assessment (FACA) including environmental impacts

Re-examination of economy and environmental impacts of 26

(1) Exclusion of 8 projects for low EIRR < 5%
(2) Exclusion of 5 projects for low power density < 500 kW/km^2 since it indicates siginificant environmental impacts but cannot be checked on desk study at this stage of the Study

10 priority projects selected from 13 final candidates

Figure 5.4.1 Work Flow for Selection of 10 Priority Projects

The selection process of 10 priority projects and outlines of the results are described below:

5.4.1 Preliminary Study of Environmental Alternatives

(1) The two dam projects planned on the Mekong Mainstream (#1 Sambor and #9 Stung Treng) would have environmental impacts such as to trap around 40% of the sediment transport over a long

period. However, the feasibility of its technical mitigation measures is not known at this stage of the Master Plan Study. Accordingly, these two projects will be excluded from further examination of the Study.

(2) As to the two projects of #7 LSP2 and #8 LSS2, feasibility study of an integrated plan (#7&8 LL2) was under execution by EVN to integrate the two projects by constructing one dam downstream of the confluence of the Sre Pok River and Se San River. According to the preliminary study of the Study Team, the integrated plan LL2 has the highest comprehensive priority in the order of LSS2＜LSP2＜LL2. As a result, LL2 of the three alternatives will be considered in the further examination.

As a result of the preliminary study above, the further examination of the Study will be made on the 26 candidate projects (= 29 - 2 - 1).

5.4.2 Prioritization of 26 Projects

(1) Balance between Environmental Conservation and Development of Natural Resources in Cambodia

Of the 26 candidate projects, those 25 excluding, the #3 Prek Ter III project are more or less concerned with the Environmental Protected Areas (refer to Figure 4.7.7). According to the Secretary of State, the Ministry of Environment (MOE), the Protected Areas of Cambodia will be classified into four zones[11]. However, most of the Protected Areas have been defined only for their geographic boundaries. Those Protected Areas concerned with the 25 projects have not been zoned yet.

It could be theoretically possible to introduce the strongest regulation as to unconditionally prohibit any development activities inside the Protected Areas. However, in case such extreme environmental regulations are applied to the Protected Areas of Cambodia, development of the hydropower potentials in Cambodia would all be prohibited. The Study Team is of the opinion that such out-and-out environmental regulation will not meet the national interest of Cambodia. As set out in the Environmental Law of Cambodia, a careful promotion of sustainable development of natural resources of Cambodia in harmony with implementation of environmental conservation and protection should meet the national interest.

In the Study, those projects more or less concerned with the Protected Areas will not be excluded from further examination as untouchable saying it is in touch with the Protected Areas. Because 1) although the boundaries of the Protected Areas have been defined, four zonings have not been implemented and development activities are not always prohibited, 2) promising projects can be implemented even inside the Projected Areas by obtaining the approval from the Royal Government of Cambodia (RGC). First the 26 projects will be reviewed with the common planning criteria. Then a balance between the hydropower development and environmental conservation will carefully be studied. In the course of the selection of 10 priority projects, primary balance of hydropower development and environmental conservation will be

[11] 1) Strict conservation zone (core area), 2) Conservation zone, 3) Sustainable use zone, and 4) Community zone.

studied from the viewpoint of *Hydropower Density*. Then at the 2nd stage of the Study on the 10 priority projects, it will be studied whether those environmental impacts are acceptable with mitigation measures or should be avoided by adopting zero option or without project.

(2) Comprehensive assessment of 26 projects

The 26 projects are reviewed with the common planning criteria and the results are presented in Table 5.4.1. The first row of the table presents the assessment results of technical and economic aspects. The next row presents *Five Aspect Comprehensive Assessment* (FACA) adding environmental and social consideration and speed of implementation.

The candidate projects were first prioritized with technical and economic scores only. Comparing the results with those of FACA, the following characteristics may be pointed out:

1) The #7&8 LL2 project, having the top techno-economic score, was ranked 2nd after including the environmental and social considerations.
2) The #11 LSS3 project falls down from 7th in techno-economic score to 19th, outside the candidates of 10 priority projects. This resulted from negative assessment of vast areas of reservoir and inundated farmland. This project is excluded also from the viewpoint of *Hydropower Density* that will be introduced and described later. Similarly, the rank of #10 Se Kong project will go down from 8th in techno-economic score to 15th FACA.
3) The #16 MSRC project has a high environmental score and rose from 3rd to top FACA. Similarly, the #22 KP2 project and the #29 BP project rose by 6 ranks.

It may be understood that environmental impacts have been duly reflected to prioritization through introduction of FACA.

Of the 26 projects, the following 8 projects have low economy being lower than 5% in EIRR. The ranks by FACA are all behind 10th. Although the economic evaluation is of the Master Plan Study level, these are screened out from further study.

1) #3 Prek Ter III
2) #4 Prek Ter II
3) #6 Prek Por I
4) #18 Stung Tatay
5) #19 Stung Metoek I
6) #25 Stung Pursat II
7) #27 Stung Battambang II
8) #28 Stung Battambang I

The #18 Stung Tatay project, situated upstream of the #22 Stung Kep II project, will divert the river flow to Stung Chhay Areng. Therefore, if the #18 Stung Tatay project is implemented, the #22 Stung Kep II project, situated downstream of Tatay, will have less inflow and its economic feasibility would be lost. On the other hand, without implementing the #18 Stung Tatay project, the #17 Stung Chhay Areng project situated on the river that receives diverted water can use only the own river flow of Stung Chhay Areng and the economy will lower. Of the three projects, the #22 Stung Kep II project has the highest EIRR at 9.5% while the other two below 8%. Accordingly, the #22 Stung Kep II project should be adopted as a priority project. The #18 Stung Tatay project of inter-basin diversion type are not recommendable for its low economy (EIRR 4.8%). The #17 Stung Chhay Areng are not recommendable as a candidate for the 10 priority projects for the low economy with EIRR as low as 8.0%, large inundation area of 5,149 ha inside the Protected Area, resettlement of 277 households, and inundation of farmland of 1,064 ha.

Table 5.4.1 Assessment of 29 Candidate Hydropower Projects and Selection of 10 Priority Projects

re with Weight		1	2	3	4	5	6	7	8	7 & 8	9	10	11	12	13	14
		Sambor *	Prek Chhlong II	Prek Ter III	Prek Ter II	Sre Pok IV *	Prek Por I	Lower Sre Pok II	Lower Se San II	Lower Sre Pok II + Lower Se San II *	Stung Treng	Se Kong	Lower Se San III	Prek Liang I	Prek Liang IA	Prek Liang II
Symbol		SBR	PC2	PT3	PT2	SRP4	PP1	LSP2	LSS2	LL2	STG	SK	LSS3	PL1	PL1A	PL2
Total score of technical and economic evaluation			4.9	9.3	7.1	9.2	5.4			49.7		23.1	24.0	28.9	39.9	36.3
Rank			**26**	**21**	**24**	**22**	**25**			**1**		**8**	**7**	**6**	**4**	**5**
Five aspect comprehensive assessment (FACA)			33.7	39.0	37.5	35.5	32.4			69.1		43.8	41.0	55.4	62.6	59.8
Rank			**25**	**20**	**22**	**23**	**26**			**2**		**15**	**19**	**7**	**4**	**6**
Final result of selection of 10 priority projects						35.5				69.1		43.8		55.4	62.6	59.8
Rank						**13**				**2**		**12**		**6**	**3**	**5**
Restriction for implementation on technical, environemntal, and economic aspects																
Exclude projects with sedimentation problems unsolved.		**Sand**									**Sand**					
Select the higher rank alternative.								**Alternatives**	**Alternatives**	**Alternatives**						
Exclude projects with EIRR less than 5%, as economic vialibity is extrimely low.		-	7.1%	**2.3%**	**4.0%**	5.4%	**-1.9%**	-	-	17.6%	-	9.3%	13.0%	19.3%	19.2%	20.3%
Exclude porjects with power density per reservoir area less than 500 kW/km² (0.5 MW/km²)		399.07	**0.18**	**0.08**	**0.12**	1.31	**0.43**	1.87	0.50	0.88	10.35	1.30	**0.39**	7.07	-	3.39
Reasons for rejection		Sand	Power Density	Economic Viability	Economic Viability		Economic Viability	Alternatives	Alternatives		Sand		Power Density			
Power Generation Features and Economic Viability	Unit															
Installed Capacity	MW	2,394.4	12.4	14.8	11.4	68.2	5.0	228.0	169.0	430.5	6,623.9	148.2	161.1	50.6	22.5	48.0
Annual energy generation	GWh	8,893	51	92	55	255	32	990	710	1,724	24,590	551	692	220	106	260
Unit generation cost	Cent/kWh	-	13.91	22.18	20.94	10.18	49.27	-	-	4.70	-	7.63	9.05	7.43	5.02	6.16
EIRR	%	0.0	7.1	**2.3**	**4.0**	5.4	-1.9	0.0	0.0	17.6	0.0	9.3	13.0	19.3	19.2	20.3
FIRR	%	0.0	4.2	0.9	1.2	6.8	0.0	0.0	0.0	15.0	0.0	9.5	7.9	9.8	14.2	11.7
Main Environmental Impacts																
CO_2 emission reduction (t-CO_2/km²)	t-CO_2/km²	0	13	-12	-4	169	18	0	0	941	0	381	457	143	80	191
Reservoir surface area more than 100 km² indicated as red	km²	6	70	**179**	98	52	12	**122**	**341**	**489**	**640**	**114**	**409**	7	0	14
Reservoir surface area inside Protected Areas	ha	0	**5,721**	0	1,902	**5,243**	1,151	0	0	501	0	496	1,527	715	276	1,416
Households to be resettled more than 1,000 hhs indicated as red	hh	0	308	103	0	0	0	0	0	**1,479**	0	503	**1,349**	0	0	0
Farmlands innundated more than 1,000 ha indicated as red	ha	0	668	855	49	0	6	0	0	**3,081**	0	536	**12,936**	0	0	0

re with Weight		15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
		Lower Sre Pok III *	Middle St. Russey Chrum *	Stung Chhay Areng *	Stung Tatay *	Stung Metoek I	Stung Metoek II	Stung Metoek III	Stung Kep II	Upper St. Russey Chrum *	Stung Pursat I	Stung Pursat II	Stung Sen	Stung Battambang II *	Stung Battambang I *	Bokor Plateao
Symbol		LSP3	MSRC	SCA	STY	MTK1	MTK2	MTK3	KP2	USRC	PST1	PST2	SEN	BB2	BB1	BP
Total score of technical and economic evaluation		43.3	40.8	17.8	13.8	10.1	21.3	15.5	13.0	13.0	19.7	8.9	17.8	12.6	11.8	19.1
Rank		**2**	**3**	**12**	**15**	**20**	**9**	**14**	**16**	**16**	**10**	**23**	**13**	**18**	**19**	**11**
Five aspect comprehensive assessment (FACA)		63.7	75.8	43.8	46.8	42.4	51.9	46.1	49.1	48.5	51.3	42.8	33.9	41.5	38.5	59.9
Rank		**3**	**1**	**14**	**12**	**17**	**8**	**13**	**10**	**11**	**9**	**16**	**24**	**18**	**21**	**5**
Final result of selection of 10 priority projects			75.8	43.8			51.9	46.1	49.1	48.5						59.9
Rank			**1**	**11**			**7**	**10**	**8**	**9**						**4**
Restriction for implementation on technical, environemntal, and economic aspects																
Exclude projects with sedimentation problems unsolved.																
Select the higher rank alternative.																
Exclude projects with EIRR less than 5%, as economic vialibity is extrimely low.		17.9%	16.9%	8.0%	**4.8%**	**0.0%**	13.7%	12.2%	9.5%	8.9%	13.3%	**4.8%**	9.3%	**3.9%**	**5.0%**	11.0%
Exclude porjects with power density per reservoir area less than 500 kW/km² (0.5 MW/km²)		**0.34**	2.50	0.81	0.82	2.30	1.54	2.12	14.91	8.44	**0.18**	**0.31**	**0.06**	1.18	**0.23**	6.97
Reasons for rejection		Power Density			Economic Viability	Economic Viability					Power Density	Economic Viability	Power Density	Economic Viability	Economic Viability	
Power Generation Features and Economic Viability	Unit															
Installed Capacity	MW	235.2	56.4	109.2	37.6	10.6	28.8	23.3	113.6	37.6	17.6	10.0	58.0	16.8	24.0	21.6
Annual energy generation	GWh	988	345	668	230	66	174	103	458	231	108	62	356	104	149	133
Unit generation cost	Cent/kWh	6.00	5.66	11.45	16.51	48.71	8.25	12.52	10.28	10.52	8.05	17.79	9.59	19.20	15.63	8.14
EIRR	%	17.9	16.9	**8.0**	**4.8**	**0.0**	13.7	12.2	9.5	8.9	13.3	**4.8**	9.3	**3.9**	**5.0**	11.0
FIRR	%	12.0	12.7	5.8	3.0	0.0	8.7	5.1	6.7	6.5	9.0	2.4	7.4	1.9	3.3	8.9
Main Environmental Impacts																
CO_2 emission reduction (t-CO_2/km²)	t-CO_2/km²	413	250	450	153	49	125	74	342	151	29	34	-157	58	54	97
Reservoir surface area more than 100 km² indicated as red	km²	**697**	23	**135**	46	5	19	11	8	4	96	32	**939**	14	**105**	3
Reservoir surface area inside Protected Areas	ha	**64,699**	2,259	**5,149**	2,910	460	1,869	1,100	430	445	**6,532**	1,427	2,105	3,967	97	877
Households to be resettled more than 1,000 hhs indicated as red	hh	726	0	277	0	0	168	0	0	0	0	0	**3,157**	0	871	0
Farmlands innundated more than 1,000 ha indicated as red	ha	**1,785**	9	**1,064**	122	0	991	0	0	0	0	3	**7,716**	0	**1,020**	0

Total CO_2 emmission reduction for top 10 projects	1000t-CO_2	2,395
Total installed capacity for top 10 projects	MW	833
Total annual power generation for top 10 projects	GWh	3,754

Legend

(light blue)	Top 10 projects
(yellow)	Second top 10 projects
(red box)	Features for rejection

5.4.3 Hydropower Development in Cambodia and Hydropower Density

Having an overview of the results of comprehensive assessment of the 26 projects, the following issues have been identified:

There are five projects that will have such an impact as its inundation area would exceed 5,000 ha within the Protected Areas (including area of islands that would be isolated from the lake shore by the reservoir). In particular the #15 LSP3 would have an inundation area within the Protect Area amounting to 64,699 ha (= 646.99 km^2). It has been estimated that since the reservoir surface area of the #2 Prek Ter III and the #26 Stung Sen projects are wide compared to their hydropower potential, the net reduction of CO_2 emission would be negative, that is, loss of CO_2 fixing function of forest (sink) would be greater than the CO_2 reduction if the CO_2 absorption and fixing capacity of forests[12] within the planned reservoir area is taken into consideration. In Cambodia in the gently-sloped hilly areas in the north-eastern region in particular, the impact on the Protected Areas, especially for the large size of the reservoir area, would be significant. It is considered necessary that hydropower development be balanced or harmonized with environment.

The hydropower development in Cambodia will incur a cost as inundation of forest and grassland (loss of land resources). Then, those projects that have PD higher than certain level may be favored with priority as subjects for the further selection study at Stage 1 of the Study since it indicates possibility of lower environmental impacts[13]. However, the actual degree of environmental impacts could not be checked and assessed in this Stage 1 study, which was based on desk review of existing reports and information without field survey. Such projects not taken up for the low PD as subjects for the further selection study at Stage 1 may be taken up in the future if their environmental impacts are judged tolerable and acceptable with appropriate mitigation measures through field survey and EIA conducted after the Master Plan Study.

The hydropower potential that has PD greater than selected four levels would be as presented in Table 5.4.2.

Table 5.4.2 Hydropower Potential Having Power Density Greater Than Selected Levels

Description	Unit	Level of power density (kW/km^2)			
		500	1,000	2,000	4,000
Potential having higher PD	GWh/yr	5,629	3,007	1,923	1,147
	%	69%	37%	23%	14%
Potential having lower PD	GWh/yr	2,584	5,206	6,290	7,066
	%	31%	63%	77%	86%
Total	GWh/yr	8,213	8,213	8,213	8,213
	%	100	100	100	100

Note: A total of 26 projects, including low EIRR projects.

12 The CO_2 absorption capacity of primary forest of Cambodia was estimated at 5.19 t-CO_2/ha/yr by the Study Team based on the data of IPCC.

13 CDM board accepts to assume unit emission of GHG from reservoir at 90 g-CO_2/kWh for those projects that have power density of greater than 4 MW/km^2 in view of light impacts on environment. It further accepts to neglect the GHG emission in those projects that have power density greater than 10 MW/km^2.

1) The hydropower potential that has PD greater than 1,000 kW/km^2 amounts to about 3,000 GWh or 37% of the technical potential of the 26 projects that includes also non-economic (low EIRR) potential (more than one third would be developed).

2) The hydropower potential that has PD greater than 500 kW/km^2 amounts to about 5,600 GWh or 68% of the total potential (more than two thirds would be developed).

3) From the viewpoint to balance the hydropower development with environment, it would be a focal point of discussion whether to select projects for Stage 2 study from among those that have PD greater than 500 kW/km^2 or 1,000 kW/km^2. In view of the fact that the technical potential of 26 projects includes non-economic potential, those hydropower potentials that have PD greater than 500 kW/km^2 were retained as subjects for further selection study at Stage 1. It was aimed to select the 10 projects for Stage 2 study from among as many potential projects as possible in view of the limited amount of economic hydropower resources in Cambodia while harmonizing the development and environment。

   Then the following 5 projects were not included in the further selection study at Stage 1:
   #2 Prek Chhlong II
   #11 Lower Se San III
   #15 Lower Sre Pok III
   #24 Stung Pursat I[14]
   #26 Stung Sen

4) The #11 LSS3 project would inundate a land of 409 km^2 for power generation at 161 MW. Its PD is low at 0.39 MW/km^2. The farmland inundated by the project would amount to 13,000 ha. Without field survey on the environmental impacts and hearing survey to the project-affected people (PAP), the project (ranked 19th by FACA) could not be retained as subjects for the further selection study.

5) The #15 LSP3 project would inundate a land of 697 km^2 wide to generate 235 MW. The PD is low at 0.34 MW/km^2. The project is ranked at 2nd by technical and economic assessment, and 3rd by FACA, and the power generation scale would be large (the installed capacity at 235 MW and annual energy generation at 988 GWh). Most of the reservoir area are situated within the Protected Area and amount to 647 km^2. The farmland inundated would amount to 1,785 ha. The household resettlement would amount to 726. A possibility was reported that there were routes for seasonal migration of wild elephants in the Protected Area. The reservoir may hamper such migration if any. Accordingly, unless it is proven through future EIA that the environmental impacts are tolerable and acceptable with appropriate mitigation measures, it is recommended that the project be set aside of the subjects for the further selection study at Stage 1.

6) In place of the above, the following two projects were re-ranked to top 10 projects.
   #21 Stung Metoek III（MTK3, 23.3 MW, 103 GWh）
   #23 Upper St. Russey Chrum（USRC, 37.6 MW, 231 GWh）

[14] Provisional EIRR is as high as 13.3%. It could be considered to use the released water from the tailrace after power generation for irrigation of paddy fields in the western part of Pursat city. If this project is developed for multi-purposes (hydropower, flood control, and or irrigation), the criteria of PD will not be relevant. EIA is essential.

7) Density of biomass energy production

As presented in Section 9.4.2 (5), the PD of 0.5 MW/km^2 is close to the level of 0.43 MW/km^2 that could possibly be achieved by cultivating sugarcane and producing bio-ethanol. In other words, there would be a possibility to utilize the land, water resources and sunshine resources to produce the similar level of domestic biomass energy. In view of energy security and national economy, development of hydropower projects with PD much below 0.43 MW/km^2 would need not only EIA but also an alternative study of biomass energy production if the environment permits it.

5.4.4 10 Priority Projects

The selected 10 priority projects are presented in Table 5.4.3.

Table 5.4.3 Principal Features of 10 Priority Projects

No.	Item	ID No.	7 & 8	12	13	14	16	20	21	22	23	29	Summary		
		Project Name	Lower Sre Pok II + Lower Se San II *	Prek Liang I	Prek Liang IA	Prek Liang II	Middle St. Russey Chrum *	Stung Metoek II	Stung Metoek III	Stung Kep II	Upper St. Russey Chrum *	Bokor Plateau	Min	Max	Total/Mean
		Abbrev.	LL2	PL1	PL1A	PL2	MSRC	MTK2	MTK3	KP2	USRC	BP			
	Main Environemtal Impacts														
1	Power density	MW/km^2	1.09	7.07	see note	3.39	2.50	1.54	2.12	14.91	8.44	6.97	1.09	14.91	48.03
2	CO_2 emission reduction per unit resrvoir area	$t\text{-}CO_2/km^2$	1,925	19,954	0	13,499	11,064	6,703	6,738	44,939	33,960	31,341	0	44,939	170,124
3	CO_2 emission reduction	$1000\ t\text{-}CO_2$	941	143	80	191	250	125	74	342	151	97	74	941	2,395
4	Reservori surface area	km^2	394	7	0	14	23	19	11	8	4	3.1	0	394	483
5	Reservoir surface area inside Protected Areas	km^2	5.0	7.2	0.0	14.2	22.6	18.7	11.0	4.3	4.5	3.1	0.0	22.6	90.4
6	Households to be resettled	hh	1,224	0	0	0	0	168	0	0	0	0	0	1,224	1,392
7	Farmlands innudated	ha	1,347	0	0	0	9	991	0	0	0	0	0	1,347	2,347
	Power Generation Features and Economic Viability														
8	Installed capacity	MW	430.5	50.6	22.5	48.0	56.4	28.8	23.3	113.6	37.6	21.6	21.6	430.5	832.9
9	Annual energy generation	GWh	1,724	220	106	260	345	174	103	458	231	133	103	1,724	3,754
10	Unit generation cost	c/kWh	4.70	7.40	5.00	6.20	5.70	8.20	12.50	10.30	10.50	8.10	4.70	12.50	7.86
11	EIRR	%	17.6	19.3	19.2	20.3	16.9	13.7	12.2	9.5	8.9	11.0	8.9	20.3	14.9
12	FIRR	%	15.0	9.8	14.2	11.7	12.7	8.7	5.1	6.7	6.5	8.9	5.1	15.0	9.9

Note: Since PL1A project is to directly get the power discharge from the outfall of upstream PL1 project, PL1A has no reservoir and its power density is not relevant.

Issues of selected 10 priority projects

1) The top ranked #16 MSRC project, 4th #29 BP project, and 9th #23 USRC project are all situated inside the Protected Areas. The 3rd , 5th, and 6th projects (#12-14のPrek Liang I, IA, II) are of cascade type, are not good in access to the site, and are situated inside the Virachey National Park. It will be a focal point in the future whether development of these projects can be approved from the management view of the Protected Area or not.

2) The 2nd #7&8 LL2 project has a very wide reservoir in particular. Assessment of resettlement, farmland, forest, and migratory fishes in the inundation area will be important.

3) The 8th #22 KP2 project has been reviewed as a storage type. However, its flow regulating capacity is still limited to about 5% of the annual inflow volume. It will be studied in the Second Stage Survey if it is feasible to raise the dam height to have a greater regulating capacity while limiting the inundation area inside the narrow valley.

4) The 7th and 10th projects #21-22 MTK2-3 are of cascade type. Clearing of landmines is an essential issue even for the field survey.

Among those projects that have been excluded from the 10 priority projects are six projects that are under pre-feasibility study or feasibility study by foreign firms. However, except for the 3rd ranked #15 LSP3, the others have sand trapping issue or low economy and, therefore, there would be little space for debating. The #15 LSP3 project (installed capacity 235MW, annual energy 988 GWh) has risks/issues as listed below:

1) The reservoir area is as wide as 697 km^2, of which 647 km^2 is situated inside the Protected Area.

2) The power density is low at 340 kW/km^2. This value is lower than 430 kW/km^2 that could be achieved by production of bioethanol from sugarcane in Brazil. Production of ethanol in Brazil would correspond to 1.5 GWh/km^2 and the land of 697 km^2 would have energy potential of over 1,000 GWh[15]. This output level is comparable to that of #15 LSP3 project at 988 GWh.

3) The reservoir area will extend to the Protected Area where wild elephants reportedly migrate seasonally.

4) The number of potential resettlement household would amount to 726.

5) The inundation area of farmland would amount to 1,785 ha.

The Study Team recommend that although it is ranked 3rd the project be excluded from candidates for the 10 priority projects.

15 Refer to 9.4.2 (1) 3)