GOVERNMENT OF MALAYSIA

FEASIBILITY STUDY
SMALL SCALE HYDROELECTRIC POWER PROJECTS IN SARAWAK

VOLUME- I

MAIN REPORT

FOR

FEASIBILITY STUDY

ON

MUKOH HYDROELECTRIC POWER PROJECT

JULY 1988

JAPAN INTERNATIONAL COOPERATION AGENCY

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LIST OF REPORTS

P R E F A C E

In reponse to the request by the Government of Malaysia, the Japanese Government decided to conduct a feasibility study on the Small Scale Hydroelectric Power Project in Sarawak and entrusted the study to the Japan International Cooperation Agency.

JICA sent to Malaysia a study team headed by Mr. Yasuo Iwasaki, Nippon Koei Co Ltd., from August, 1986 to March, 1988.

The team had discussions with the officials concerned of the Government of Malaysia and conducted a field survey in the State of Sarawak.

After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of Malaysia for their close cooperation extended to the team.

July,1988

Kensuke Yanagiya

Kensuke Yanagiya

President

JAPAN INTERNATIONAL

COOPERATION AGENCY

FEASIBILITY STUDY

SMALL SCALE HYDROELECTRIC POWER PROJECTS IN SARAWAK

Mr. Kensuke Yanagiya
President
Japan International
Cooperation Agency

July, 1988

LETTER OF TRANSMITTAL

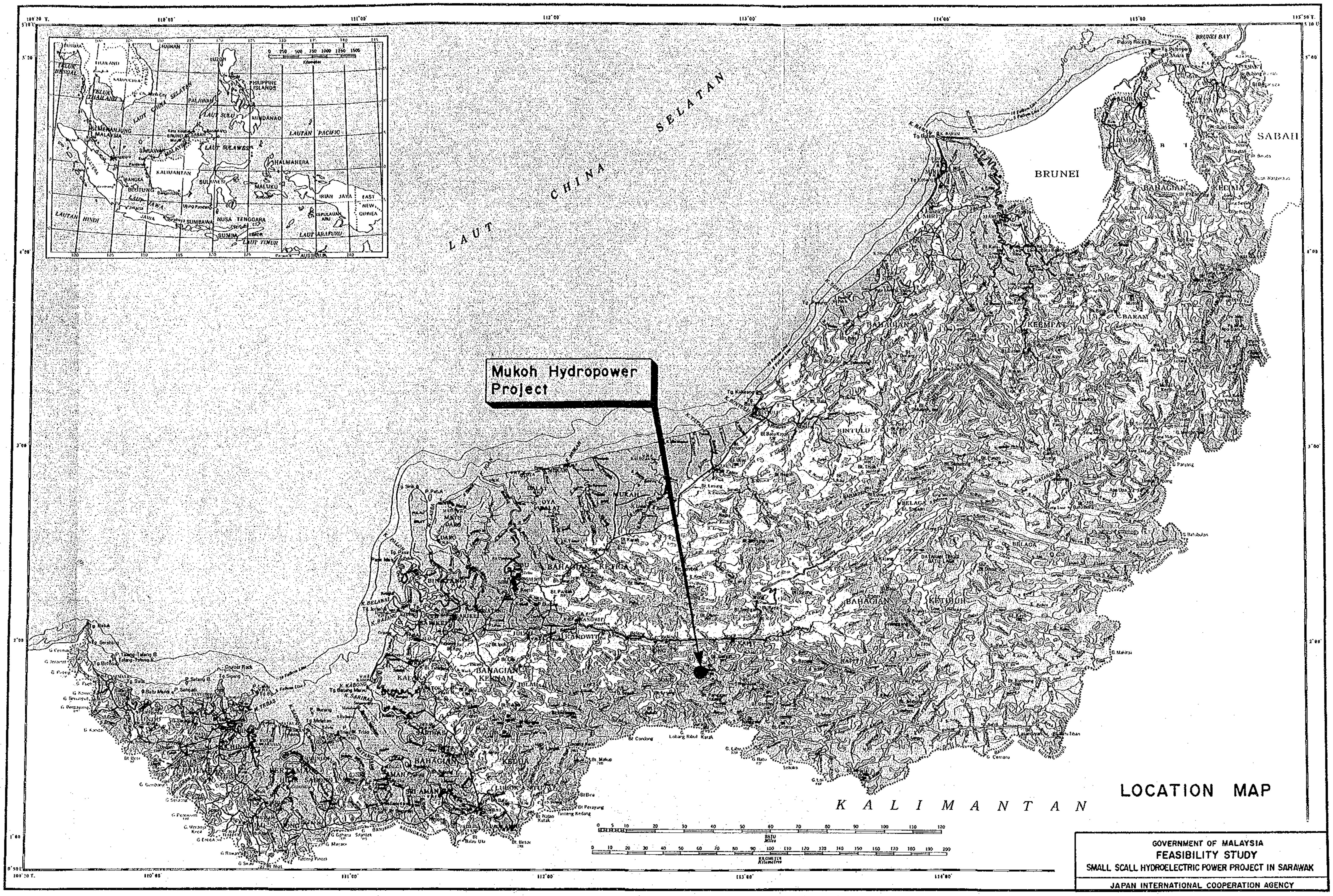
We have the pleasure to submit herewith the Final Report for the Feasibility study on Small Scale Hydroelectric power Projects in Sarawak. The Study is consistent with energy diversification policy launched by the Fredral Government of Malaysia to the effect that the proposed hydroelectric power projects will contribute to the oil conservation.

The eight Reports in total consist of the Feasibility Study on the Mukoh and the Medamit-2 small hydroelectric power projects, and the Study on site selection relating to optimal power development. The Feasibility Study Reports are the Main, the Supporting and the Data Book. The Study Reports on site selection relating to optimal power development are the Main and Supporting Report. The Main and Supporting Report contains study results and technical details respectively, and the Data Books are compiled by all data necessary for this study.

We would like to express our grateful acknowledgement to the personnel of your Agency, Ministry of Foreign affairs, Ministry of International Trade and Ministry, and Embassy of Japan in Malaysia as well as officials and individuals concerned of Malaysia for their kind assistance/advise extended to the Study Team. We sincerely hope that the study result would contribute to the future development of small scale hydro electric Power project in Sarawak.

Yours Sincerely

Yasuo Iwasaki
Team Leader



Mukoh Hydropower Project
LAUT CHINA SELATAN
BRUNEI
SABAH
KALIMANTAN
LOCATION MAP
GOVERNMENT OF MALAYSIA
FEASIBILITY STUDY
SMALL SCALL HYDROELECTRIC POWER PROJECT IN SARAWAK
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SUMMARY

Background and objective of the study

1. Hydropower potential sites of a small scale development were, first of all, identified for the demand centres, Sri Aman, Sarikei, Limbang and Kapit. The selection of schemes to proceed into the feasibility study was carried out following the identification work. The Mukoh project for the Kapit demand centre was, then, selected as one of schemes to advance to the feasibility study.

2. The objective of this Volume I together with Volumes II and III is to formulate the optimal development plan of the Mukoh project and furthermore to assess the technical, economic and financial viability, taking into account power and energy requirements of the Kapit system until year 2010.

Kapit demand centre and Mukoh project site

3. Kapit, headquarters of Seventh Division of Sarawak, is located at the southern riverside of the Rajang River flowing down westwardly, about 200 km upstream from its estuary.

4. Power demand in Kapit has increased from 529 kW in 1980 to 1,358 kW in 1986, resulting in an average growth rate of 17.0 percent. Power demand in 2000 and 2010 is expected to grow to the level of 2,800 kW and 4,300 kW, respectively.

5. On the other hand, the proposed site of the Mukoh project is located in the northward stretch of the Mukoh River and some 27km southwest from Kapit in a beeline.

Project site condition

6. Mountains along the Mukoh River are steep relieves formed by erosion of small valleys and tributaries. However, small terraces and gentle slopes are developed along rivers in the downstream area. Furthermore, collapses and landslides are found on the mountain slopes.

7. The project area is underlain by Stage II (the Kapit member) of the Belaga Formation in Paleocene to Eocene age. The formation consists of a thick succession of weakly metamorphosed shale with intercalation of graywacke (sandstone) and subgraywacke.

8. The climate of Sarawak is classified into the tropical rain forest zone characterized by high moisture throughout the year. The northeast monsoon, which brings the rainy season, generally begins in the middle of October and lasts until the middle of April, while the southeast monsoon, which coincides with the dry season, prevails from the

middle of April to the middle of October.

9. Annual rainfall in Sarawak is abundant, about 3,700 mm on an average, and about 30 to 40 percent of annual rainfall is expected in the dry season.

10. Long-term mean daily runoff at the project site with an catchment area of 292 km^2 is estimated at 19.1 m^3/sec. From the flow duration curve, dependable flow in the dry season is about 6 m^3/sec or so.

Power demand forecast

11. Power demand was projected by sector; domestic, commercial, industrial and public lighting sectors. Power consumption (energy sale) in the Kapit demand centre was estimated by totalling the consumption in each sector. Furthermore, energy generation and maximum demands were predicted based on the estimated power consumption. Following are the summary of demand forecast in the Kapit load centre:

Demand Forecast (Normal)

Year	Energy Consumption (MWh)	Energy Generation (MWh)	Maximum Power Demand (KW)	Annual Load Factor (%)
1984	3,689	4,209	948	50.7
1985	4,611	5,038	1,184	48.6
1986	5,045	5,528	1,358	46.5
1987	5,410	6,150	1,430	49.0
1988	5,760	6,545	1,490	50.0
1989	6,130	6,970	1,590	"
1990	6,520	7,410	1,690	"
1995	8,710	9,900	2,260	"
2000	11,260	12,800	2,810	52.0
2005	13,840	15,730	3,450	"
2010	17,080	19,410	4,260	"

12. The high and low cases of power demand were projected by changing the values for the electrification ratio in the domestic sector and growth rate of power consumption in the industrial sector, resulting in 23% and 32% higher power consumption in 2000 and 2005 respectively in the comparison of high and normal cases, whilst 13% and 16% lower power consumption in 2000 and 2005 respectively in the comparison of low and normal cases.

Optimum development plan and installation timing

13. An optimal development scale and timing of the Mukoh project

was determined by searching the installation scale and timing of it in the optimal power development programme of a long time span.

14. Three alternatives were conceived for the hydropower development of the Mukoh project (refer to Figure 5.3). The basic development idea of those three alternatives is as follows:

Alt-1 : A plan to create head for hydropower generation with a dam and to have a powerhouse just at the dam toe.

Alt-2 : A plan to utilize head of some 13 m created by rapids with a 1,120 m long headrace tunnel basides head created by the dam

Alt-3 : A plan to make the headrace longer (1,740 m) and to increase available head.

The principal dimensions of these three alternatives are summarized as follows:

Unit: m

Alternatives	Alt-1	Alt-2	Alt-3
Full supply level	89 to 110	89 to 110	89 to 110
Minimum operating level	87	87	87
Tailrace level	73	60	56
Headrace tunnel length	0	1,120	1,740
Penstock length	50	50	70

15. Following were proposed to be optimal for the development of the Mukoh project as the results of optimization study:

Alternative plan	:	Alt-1
Full supply level	:	90.0m
Minimum operating level	:	87.0m
Tailrace water level	:	73.0m
Type of dam	:	Concrete gravity
Penstock length	:	50 m
Plant discharge	:	18.8 m^3/sec
Firm discharge	:	6.3 m^3/sec
Peaking operation hours for firm discharge	:	8 hours
Rated net head	:	14.98 m
Maximum output	:	2.32 MW
Annual energy generation	:	13.0 GWh
Construction cost	:	M$27.5 million
Net benefit (capitalized)	:	M$1.7 million
EIRR	:	11.3%

16. The search for the optimal installation timing of the Mukoh

project was made by shifting the installation year of the scale determined to be optimal (2.32 MW) in the long-term installation programme. The study results to search the optimal installation timing are summarized as follows:

Installation year	Net benefit in 10 % discount rate, M$ million	EIRR, %
1995	1.74	11.3
1996	2.13	11.9
1997	2.22	12.1
1998	2.17	12.3

The installation of Mukoh in 1997 gave the maximum net benefit of M$ 2.22 million. The variation of net benefit is, however, insensitive for the shift of installation year, and furthermore the Mukoh project keeps high viability in spite of shifting the installation year, so that earliest installation (1995) is recommended.

Basic design for main structures

17. The project involves the construction of a 23 m high gated intake dam on the Mukoh River in which an intake structure is incorporated, a 44 m long penstock line, a power plant with 2.32 MW installed capacity, for which the number of units was selected to be two considering system reliability and maintenance of turbines and generators. The project also includes the construction of a 35 km long 33 KV transmission line to deliver power to the Kapit substation and a 7 km long access road between the existing road and the site.

18. The design was made at a feasibility study level, to the extent required for the purpose of estimating construction cost (refer to Figs. 6.1 and 6.2).

Construction schedule and cost

19. The construction of project is scheduled to extend over seven years from 1988 to 1994. First four years between 1988 and 1991 are required for the arrangement of construction finance, the selection of engineering consultant, the detailed engineering services and the tendering. Latter three years between 1992 and 1994 are required for the construction work of the project (refer to Fig. 7.1).

20. The construction cost for the Mukoh project was estimated to be M$27,478,060 in total, consisting of M$18,255,497 in foreign currency portion and M$9,222,563 in local currency

portion. The annual disbursement of construction cost for foreign and local currencies was estimated as follows:

Year	Foreign currency (M$)	Local currency (M$)	Total (M$)
1992	2,227,777	2,433,139	4,660,916
1993	9,185,620	4,270,468	13,456,088
1994	6,842,100	2,518,966	9,361,066
Total	18,255,497	9,222,563	27,478,060

Economic and financial viability

21. The economic viability of the Mukoh project was discussed in the optimization study based on the future power expansion programme in the Kapit system. The economic viability for the optimal development scale of the Mukoh project was re-evaluated by assessing the valuation of goods in economic sense, conversion from financial cost to economic cost and so forth in more detail as follows:

Installation year	Net benefit (M$ million)	EIRR (%)
1995	1.74	11.3
1996	2.13	11.9
1997	2.22	12.1
1998	2.17	12.3

22. The discount rate of 10 percent was applied to estimate net benefit. Since net benefits are positive in all cases, the Mukoh project is economically viable.

The optimal installation time was identified to be 1997. The variation of net benefit is however insensitive for the shift of installation year and the project keeps high economic viability in terms of EIRR in spite of shifting the installation year, so that the earliest installation is recommended, namely year 1995.

23. Financial analysis discussed financial viability of the project and manageability of the implementing agency, SESCO, to repay foreign and local portion of investment costs or to finance local portion of them, if cost of the local portion is to be entirely funded by SESCO.

FIRR of the Mukoh project was calculated to be 6.7%. If local and foreign costs are financed by the federal government loan and soft loan from OECF respectively, this result of FIRR turns out to be marginally lower than local interest rate (7.5%) and higher than foreign interest rate (4%). From an overall point of view, FIRR of 6.7% would be justifiable in terms of financial viability, since the combined interest rate on both foreign and local loans is around 5.2% per annum. If local cost is financed by SESCO's internal cash generation, financial viability of the project is satisfactorily assured.

24. The manageability of SESCO to repay foreign and local loans was discussed by preparing the financial statements between revenue and interest plus repayment to be outlayed. In case that local cost is funded by the federal government (interest of 7.5%) and foreign cost is funded by soft loan (4%), the net cash flow was continuously negative in the maturity period except for a few years of the grace period.

In case that local cost is funded by SESCO itself and foreign cost is funded by soft loan, balance turned to be positive in the commission year (1995) of the Mukoh project. The accumulation of net cash amount turned to be positive in around 2004. Thus, SESCO, the implementing agency, will enjoy the favourable financial position under the operation of the Mukoh project within the maturity period. Furthermore, local cost and the repayment foreign cost including interest will be in the amount order of internal cash generation of SESCO. Consequently, as far as funding method is concerned, the case that local cost is funded by SESCO it self, foreign cost is by soft loan is desirable.

Comparison studies of net cash flow and its accumulation between the system with all diesel and the Mukoh are also conducted under assumptions that oil price would increase according to IBRD's forecast or would be costant at 18 US$ per barrel. Despite of the assumptions, financial results turn out to be favourable condition in the system with the Mukoh in terms of net cash flow and its accumlation.

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CHAPTER 1. INTRODUCTION

1.1 Background of Study

The State of Sarawak is located in the northern part of the Borneo Island with a latitude in a range from 1 to 5 North and a longitude from 110 to 115 East. The total land area is 124,450 sq. km. Alluvial and coastal plains mostly extend over its northwestern part and are intersected by numerous rivers flowing from hilly and mountainous hinterlands. The climate is classified into the tropical rain forest zone characterized by constantly moist days all the year round. Air temperature and relative humidity are normally high with little variation.

The abundant rainfall of 3,700 mm per annum on an average and suitable topography bring a great hydropower potential. Economically exploitable hydropower potential is estimated to be approximately 63,000 GWh per annum, corresponding to about 53 per cent of that of the whole of Malaysia.

The hydropower potential in the State of Sarawak however remains untapped, although Batang Ai Hydropower Project with installed capacity of 108 MW was completed in 1985 as the first major hydropower plant in the State of Sarawak.

In the State of Sarawak, public electricity is supplied by Sarawak Electricity Supply Corporation (hereinafter called SESCO) through a number of isolated power supply systems. The power generation mainly relies on diesel and gas-turbine. In 1984, SESCO operated the power plants with total installed capacity of 229 MW and produced the annual energy of 601 GWh as given in Table 1.1. Peak power demand and annual energy production increased at a growth rate of about 13 per cent per annum on an average during a 10-year period from 1975 to 1984. With the commissioning of Batang-Ai Hydropower Project, the total installed capacity and total energy generated by SESCO expanded to 352 MW and 704 GWh in 1985, respectively. In July 1986, SESCO operated 60 power plants as shown in Fig. 4.1.

The Governmet of Malaysia has established its energy policy for the period from 1986 to 1990 in the Fifth Malaysian Plan formulated in 1986. The Plan stresses the four-energy diversification strategy; namely oil, hydro, gas and coal, aimed at ensuring reliability and security of supply, while reducing the dependence on oil in energy consumption. The objective of this strategy is primarily to utilize indigenous non-oil energy resources, particularly gas and hydropower. In line with the energy policy, SESCO has planned to harness the abundant hydroelectric resources in Sarawak in an attempt to reduce the over-dependence on fossil fuel for generation of electricity whenever possible and feasible.

The Fifth Malaysian Plan also refers to the energy policy of the State of Sarawak as follows:

The energy generation capacity of SESCO will reach 1,600 GWh/year by 1990 compared with 704 GWh/year in 1985. The main project that will be implemented is the Ulu Ai Hydroelectric Project with a capacity of 54 MW. To identify potential projects worthy for implementation, several feasibility studies are planned to be undertaken. These include studies on small hydro projects for Sri Aman, Kapit, Sarikei and Limbang, and major hydro projects at Murum, Baleh and Belaga. As the single most capital-intensive component of the power sector development plan, which requires large capital outlay, the Bakun Hydroelectric Project will be carefully assessed in terms of financial affordability and its impact on balance of payments prior to decision of its implementation.

In July 1984, the Government of Malaysia requested to the Government of Japan to extend a technical assistance on the feasibility study on small scale hydropower development for power supply to three (3) urban areas; that is, Sarikei, Sri Aman and Limbang. In response to this request, Japan International Cooperation Agency (hereinafter called JICA), the official agency responsible for the implementation of the technical cooperation programme of the Government of Japan, dispatched a contact mission to Malaysia during the period from January 24 to February 6, 1985 and carried out a reconnaissance survey for Sri Aman and Sarikei areas. During this reconnaissance survey, the Government of Malaysia further requested to JICA to add Kapit area as one of the objective areas.

JICA then dispatched again a preliminary survey mission to Malaysia during the period from October 8 to 27, 1985. The mission conducted a supplementary survey over Limbang and Kapit areas and discussed with the Government of Malaysia about the Scope of Works.

The Scope of Works of the Study was officially signed on the date of August 8, 1986 between Economic Planning Unit of Prime Minister's Department (hereinafter called EPU) and JICA. Immediately after, this Study was commenced on August 11, 1986.

1.2 Objective of Study

This report on the small scale hydroelectric power projects in Sarawak consists of eight volumes. Volume VII to VIII deal with identifying hydropower potential sites for the damand centres, Sri Aman, Sarikei, Limbang and Kapit, and selecting schemes to proceed into the feasibility study stage. In fact, Mukoh and Medamit-2 are selected as the schemes to advance to the feasibiltiy study stage.

The objective of this Volume I including Volume II and III is to formulate the optimal development plan of the Mukoh hydroelectric power project selected as one of promising schemes to develop and furthermore to assess the technical, economic and financial viability, taking into account power and energy requirement of the Kapit power supply system until year 2010. Volumes IV through VI deal with the feasibility study of Medamit-2 project.

1.3 Work Progress

The feasibility study of the Mukoh project was substantially initiated in May 1987 with a dispatch of JICA study team, based on the decision of steering committee meeting held at Kuching on January 21, 1987 for selecting the schemes to proceed into the feasibility study stage among five promising schemes selected for four load centres as discussed in Volume VII, Project Indentification.

The investigation for the demand forecast, hydrological analysis and field survey such as topographic survey, seismic exploration, boring work and construction materials survey was commenced immediately after the arrival of JICA study team, and completed in September, 1987 including the analysis.

The feasibility study mainly consisting of optimization of the project, feasibility level design of hydraulic structures, construction planning and cost estimates, and economic and financial analysis was carried out based on the results of field investigation. The JICA study team returned to Tokyo for the preparation of Draft Final Report in the middle of December 1987.

A steering committee meeting was held on March 4, 1988 for discussing Draft Final Report submitted in advance. Incorporating the discussions for Draft Final Report, Final Report was prepared and submitted on July, 1988.

Through the field investigation and feasibility study stages, SESCO's counterparts participated in full and part time base and they engaged in data collection and supervision of field work as well as analysis.

1.4 JICA Study Team Members

Members of JICA Study Team participated in the Study are listed as follows:

Y.Iwasaki	Team Leader	Nippon Koei
K.Abe	Structural Design Engineer	Nippon Koei
T.Takenaka	Hydopower Planner	Nippon Koei
T.Udo	Soil Mechanical Engineer	EPDCI
Y.Inoue	Hydrologist/Computer Analyst	Nippon Koei
K.Miyajima	Electrical Engineer	EPDCI
T.Omori	Transmission Line Engineer	EPDCI
F.Sadohara	Geologist	EPDCI
H.Koizumi	Geophysicist	EPDCI
M.Yanase	Survey Expert	EPDCI
M.Sato	Construction Planner	EPDCI
M.Tada	Project Economist	Nippon Koei

CHAPTER 2. PROJECT AREA

2.1 Kapit Demand Centre

Kapit, headquaters of Seventh Division of Sarawak and damand centre of the Mukoh project, is located at the southern riverside of the Rajang River flowing down westwardly, about 200 km upstream from its estuary.

The access to Kapit, insolated from other towns even if the development of road network is in progress around the town area, is mainly relied on vessels which travel the Rajang River. Other means to access to Kapit is the commercial air services which fly between Sibu and Kapit twice a week.

Kapit District, one of three districts in Seventh Division, has the population of 38,429 in 1980 for a land area of 15,597 km^2; that is, the area is sparsely populated with a density of 2.5 persons/km^2. It is then expected that one-tenth of total population is lived in the Kapit urban area. Kapit serves as a communication and commercial centre for the people who live in the interior part of the Division including other two districts, Belaga and Song. Furthermore, timber industry is being developed around the Kapit area.

Reflecting the situations mentioned above, power demand in Kapit has increased from 529 kW in 1980 to 1,358 kW in 1986, resulting in an average growth rate of 17.0%. This growth rate is high compared with that in other load centres of Sarawak. Power demand in 2000 and in 2010 is expected to expand to the level of 2,800 kW and 4,300 kW.

2.2 Mukoh Project Site

The Mukoh River originates from the western slope of mountain ridges bordering the Song and Kapit Districts and flows down northwards after gathering small tributaries. The Mukoh River changes its name to Tekalit after change of its direction to west near Rumah Kilat (name of longhouse). The Tekalit River finally drains into the Katibas River, a major tributary of the Rajang River.

The proposed site of the Mukoh project is located in the northward stretch of the Mukoh River and some 27 km southwest from kapit in a beeline. In the upper basin from the site there are no villages.

The most common way to the site is to use small boats from Song located at the confluence of the Rajang and Katibas rivers with the help of local people. However, it is possible to use logging roads extended almost upto the project site from the shipping yard located at the riverside (some 11 km upstream from Song) of the Rajang River in the construction period. There is no direct way to access from Kapit to the project site at this moment.

2.3 Socio-economy

Major tribes and races in Sarawak are Malays, Melanaus, Ibans, Bidayuhs, other indigenous tribes, Chinese and others. According to the population census in 1980, ethnic majority is Ibans (368,500), followed by Chinese (360,600), Malays (248,800), Bidayuhs (104,900) and Melanaus (69,000).

In the Kapit District of Seventh Division, the population of Ibans is some 30,000 out of 38,429 (1980 census), followed by Chinese of some 3,000 and Malays of some 700. Most Ibans live near rivers or in the interior parts of the District and engage in subsistence agriculture like hill paddy farming or collecting jungle products like wild vegetable for sale or home comsumption. On the other hand, Chinese are more prosperous among the races and tribes in the District. They engage in commercial services and small industry prevailing in the District.

The primary production sectors in the District are agriculture and forestry. The most important crops grown in the agriculture are rubber, pepper, paddy and fruit trees such as rambutans (a fruit with hairy skin), durian and banana. Vegetables are mostly grown by Chinese around the vicinity of Kapit town for town supply. Paddy is extensively grown by Iban farmers throughout the district even though the yield for this crop is low.

The District situated in the tropical rainforest is endowed with rich forest resources. The timber logging industry is the major source of revenue to the District and gives the largest job opportunity to the region.

The region has fairly good potentials for development in view of its resource endowments. Major constraints to development have been the lack of appropriate road network to communicate within the region and with other regions. The extension of road network accelerates the development of region, resulting in the higher growth in the electricity demand.

CHAPTER 3 PROJECT SITE CONDITION

3.1 Location and Topography

The Mukoh River originates from the easterly-striking ridges connected Mt. Bakak (1,021 m high above the mean sea level) and Mt. Tingan (853 m), and flows towards northwest gathering tributaries and changing its course repeatedly to the north and northwest.

Mountains along the Mukoh River are steep relieves formed by erosion of small valleys and tributaries. However, small terraces and gentle slopes are developed along rivers in the downstream area, furthermore, collapses and landslides are found on the mountain slopes.

Mukoh project is located at the mountainous region ranged elevation from 250 to 300 m above mean sea level, some 27 km southwest of Kapit town.

The Mukoh project has three alternative layouts as discussed in subsequent Chapter 5 (refer to Fig 5.3). General plans of each alternative are as follows:

Powerhouse of Alternative-1 plan is located on the left bank, immediately downstream of the dam.

Powerhouse of Alternative-2 plan is located on the left bank, about 950 m downstream from the dam.

Powerhouse of Alternative-3 plan is located on the right bank, about 1,600 m downstream from the dam.

The damsite is identical for every alternative.

3.2 Geology

3.2.1 Regional geology

The project area is underlain by Stage II (the Kapit member) of the Belaga Formation in Paleocene to Eocene age. The formation consists of a thick succesion of weakly metamorphosed shale with intercalation of graywacke (sandstone) and subgraywacke as shown in Fig. 3.1.

With the rock mentioned above as the bedrock, Quaternary terrace deposits and talus (slope washed) deposits along the river are distributed in a small scale, especially in the downstream area from the gorge (about 120 m downstream from the damsite) being formed by sandstone.

3.2.2 Site geology

Mukoh project area consists of essentially two lithologic units. One is of shale intercalated within beds of sandstone. The other is of massive sandstone. The shale unit which accounts for about 80 per cent coverage of the area is slightly metamorphosed, fractured and folded. The sandstone unit can be found at the headrace tunnel near the surge tank of Alternative-2 plan and near the powerhouse of Alternative-3 plan.

Folding and fault in the area are recognized. Folding occurs commonly in the shale unit and the common form is isoclinal folding. Associated with the folding are the cleavages, usually striking N80W and dipping steeply NE-SW. Small scale faulting is common too. Only one major fault was observed at the upstream from the proposed powerhouse of Alternative-3 with striking N80W and dipping vertically, where breccia appears consisting of sandstone and shale fragments in hard sandstone matrix.

In general, the shale units in the area have been subjected to strongly weathered, although fresh and hard shale can be found in the river bed. Thick lateritic residual soil zones distributed on the ridges and mountain side slopes are common.

A detailed geological map on a scale of 1 to 500 will be prepared by the hand of SESCO after settling the local problems.

3.2.3 Assessment on engineering geology

The condition of foundation rock for three alternatives is based on the interpretation and evalution of the geological investigations.

(1) Alternative-1 Plan

Since powerhouse is located just behind the dam at the left bank, geological assessment of powerhouse is discussed with the dam.

(a) Damsite and powerhouse

Core drilling at two boreholes (BMk-1 and 2) and seismic prospecting at three lines (Mk A,H and I) were carried out at the damsite.

Foundation rocks of the dam and powerhouse site are underlain by shale intercalated with thin sandstone beds.

Slightly weathered to fresh shale intercalated with thin sandstone beds, which is adequate as the foundation of the dam and powerhouse, will be met by stripping by 5 m from ground surface at the riverbed and right bank, whilst 10 m at the left bank.

(2) Alternative-2 Plan

(a) Waterway

Headrace tunnel

The headrace tunnel will pass through one stream named the Angkat River.

Geology in the headrace tunnel consists of the shale intercalated with thin beds of sandstone. Two thick massive sandstone units will be met at two sections, i.e. 250 to 400 m and 850 to 1,150 m from the intake.

Under the Angkat River, thickness of rock mass covering the tunnel is seemed to be some 100 m from the map of 1:50,000. However, true thickness would be smaller than this value, and thickness of slope wash deposits is estimated at about 10 to 15 m.

Judging from the geological condition, the tunnel will cut through the slightly weathered rocks. It is a high possibility that leakage would appear in tunneling near the Angkat River area.

Surge tank and penstock line

Geology of surge tank and penstock line is underlain by shale intercalated with thin beds of sandstone. The surge tank would sit on the moderately weathered rock, and anchor blocks of the penstock would sit on slightly weathered rock.

(b) Powerhouse

Geology of powerhouse site area consists of moderately to slightly weathered shale intercalated with thin beds of sandstone. Therefore, rock foundation of the powerhouse would base on the slightly weathered shale, of which bearing force is adequate.

(3) Alterative-3 Plan

(a) Waterway

Headrace tunnel

Core drilling at one borehole (BMk-3) and seismic prospecting at four lines (Mk B,C,D and E) were carried out at the powerhouse region.

Geology along this tunnel consists of the shale intercalated with thin beds of sandstone, some massive sandstone and shale to siltstone. Among these lithofacies, the shale intercalated with thin beds of sandstone will be mainly exposed in the tunnel.

Massive sandstone will dip 70 to 80 degrees towards downstream and will be exposed in two sections, i.e. 400 to 600 m and 900 to 1,100 m from the intake towards surge tank.

Judging from these geological and topographic conditions, the tunnel will mainly pass through a good geological foundation. However, moderatly weathered rock will be exposed in the tunnel near the surge tank. Groundwater will possibly appear in the tunnel near the Poncur River underlain by massive sandstone.

Surge tank and penstock line

Core drilling at one borehole (BMk-4) and seismic prospecting at one line (Mk F) were carried out at this site.

Surge tank will be based on the moderately weathered siltstone of 9 to 10 m deep from ground surface. The anchor blocks of penstock will base on the slightly weathered siltstone, the depth of which is deeper than 5 m from ground surface.

(b) Powerhouse

Core drilling at two boreholes (BMk-5 and 6) and seismic prospecting at two lines (Mk F and G) were performed in the powerhouse area.

Geology of the powerhouse consists of shale with laminated sandstone and some 20 m thick sandstone covered with the terrace and slope wash deposits of about 8 to 20 m thickness.

Foundation rock of powerhouse is slightly weathered shale, 11 m deep from the ground surface. Terrace deposits and highly to moderatly wheathered shale should be removed.

One minor fault was observed 200m downstream of the proposed powerhouse striking N80W and dipping vertically where breccia appears consisting of sandstone shale fragments in hard sandstone matrix. This fault will have no influence on the proposed powerhouse construction.

3.2.4 Seismicity

Sarawak is located outside the Circum-Pacific seismic zone and is situated on the Sunda Shield, a stable block where almost no recent activity or block tectonics have been recorded.

During the period of late Tertiary and Quaternary, extensive volcanism occurred in the folded Upper Tertiary strata of Central Sarawak. Volcanic eruptions and subsequent basaltic extensions built the Hose Mountain Range, the Usun Apau plateau and the

Linau Balia plateau.

The youngest igneous rock in Western Sarawak is an andestic lava at Sematan, possibly of early Quaternary age. However, no volcanic activity has been detected recently in Sarawak, therefore, possibilities of earthquake occurrence are scarce.

Earthquake records in Sarawak are available in "MICRO-SEISMIC STUDY OF MALAYSIA AND ADJACENT AREA" prepared by Malaysian Meteorological Service, in which 17 events in Peninsula Malaysia, 7 events in Sabah and 2 events in Sarawak during the period from 1896 to 1976 are recorded.

Two earthquake records in Sarawak are as follows:

a.	Year and Date	:	1958 June 30th
	Place	:	Kuching
	Intensity (MM Scale)	:	V
	Report of Damages	:	Two tremors reported, sleepers awakened
	Source	:	North Borneo News and Sabah Times, Jessel. July 5, 1958 Sabah State Library
b.	Year and Date	:	1965 July 21
	Place	:	Niah and Bekenu, Sarawak, Forth Division
	Intensity (MM Scale)	:	IV
	Report of Damages	:	Light tremors reported. Slamming doors and smashing window panes, no major damages
	Source	:	The Sarawak Tribune July 22 1965 Sabah State Library

Above earthquakes occurred in the coastal region along the South China Sea, but no reports in inland area. For safty reason, it is prudent to assume that there is a possibility of earthquake occurrence in the inland area. The proposed horizontal ground acceleration of 0.05g is therefore considered for Mukoh project. Indeed, in designing the Batang Ai and Bakun rockfill type dams, the seismic design coefficient (k) of k=0.05 g was adopted, while k=0.15 g for the Bakun project.

Further discussions on geology are referred to Appendix I of Volume II.

3.3 Hydrology and Meteorology

3.3.1 General features

The climate of Sarawak is classified into the tropical rain forest zone characterized by high moisture throughout the year. The northeast monsoon generally begins in the middle of October and lasts until the middle of April, while the southwest monsoon prevails from the middle of April to the middle of October. Since the southwest monsoon is generally weaker than the northeast one, the rainy season of Sarawak coincides with the period of the northeast monsoon. The southwest part of Sarawak having the distinct rainy and dry seasons is well affected by the prevailing of northeast monsoon, while the northeast part, especially in the vicinity of state boundary between Sabah and Sarawak, has no distinctive rainy and dry seasons because of the effects of southwest monsoon.

Annual rainfall in Sarawak is abundant, about 3,700 mm on an average, and about 30 to 40 per cent of annual rainfall is expected in the dry season.

3.3.2 Meteorology

Meteorological data have been recorded for relatively long period at four (4) stations under the control of Malaysian Meteorological Service (hereinafter called MMS).

The daily mean temperature is constant at about 26^{O} C througout the year, and the diurnal change of air temperature is about 15^{O} C between 35^{O} C and 20^{O} C. The mean relative humidity is also almost constant in a range from 85 per cent to 87 per cent, although there is a seasonal change slightly.

Mean sunshine hours is 5.7 hours a day on an arithmetric average of the stations. It corresponds to annual sunshine hours of 2,080 hours.

Maximum surface wind speed of 31.8 m/sec was recorded at Kuching aerodrome on September 1964, however, usual wind is quite weak. The mean surface wind velocity has been recorded in a range from 0.9 m/sec to 1.3 m/sec.

Evaporation data have been recorded at fourteen (14) stations under the control of MMS and Drainage and Irrigation Department (hereinafter called DID). Among the stations, Kapit is the nearest to the Mukoh site. The mean monthly evaporation at Kapit is almost constant throughout the year, ranging from 120 mm to 145 mm. Mean annual evaporation is 1,652 mm for the period from 1963 to 1977.

The Sarawak Hydrological Year Book for 1981 and 1982 published in 1986 contains the values of mean monthly rainfall recorded at 136 rainfall stations. The mean annual rainfall depth over Sarawak is estimated at about 3,700 mm for the past 20 years.

The wettest year is 1970 with annual rainfall depth of 4,310 mm, and the rainfall depth of 3,272 mm in 1972 was the smallest.

Among 136 rainfall stations, Nanga Bangkit is the nearest station to the Mukoh site. The mean annual rainfall is estimated to be 4,038 mm at the Mukoh site from the correlationship between Nanga Bangkit and Kapit based on the data for 31 years from 1956 to 1986. The wettest year was 1966 with annual rainfall depth of 5,233 mm, while 1972 was the driest year with the depth of 2,408 mm.

3.3.3 Hydrology

(1) General

Streamflow measurements were carried out at 49 water level gauging stations in 1982 under the control of DID. Of these, 31 stations are automatic recorder stations, while the remaining 18 are stick gauge stations. Most of the stations are, however, located along the major rivers having the catchment area of more than 1,000 km^2.

The mean annual basin loss is obtained by subtracting the mean annual runoff depth from the mean annual basin rainfall depth. The data of 15 selected river basins having the relatively longer period of rainfall and water level records show that the ratio of the mean annual basin loss to the mean annual basin rainfall depth varies in a range from 0.18 to 0.5.

(2) Low flow analysis

The flow duration curve at the intake site is used to determine the development scale of run-of-river type scheme. The flow duration curve is a figure to express discharges against their excess rates by arranging the daily runoff data in the numerical descending order.

However, none of water level gauge is located along the Mukoh and Tekalit rivers. In order to generate a series of daily runoff at the intake site, the tank model method is applied to the basin. The coefficients of tank model are calibrated on the basis of the low flow analysis of Kp. Git and Buan Bidi whose catchment area of 440 km^2 and 217 km^2 respectively is in the same order with that of the intake site.

Six (6) flow duration curves, in 1972, 1974, 1975, 1984, 1985 and 1986 are established on the basis of the daily rainfall records at the Nanga Bangkit rainfall station. They are shown in Fig 3.2.

A flow duration curve on a weighted average is obtained by assuming that the annual rainfall depth at the Kapit rainfall station is normally distributed. Long-term mean daily runoff is estimated at 19.1 m^3/sec.

From the flow duration curve at Mukoh intake site the dependable flow in the dry season is about 6 m^3/s or so.

(3) High flow analysis

Frequency analysis of rainfall depth at the Nanga Bangkit station is made for various durations and return periods. Three (3) methods, (i) Gumbel, (ii) Iwai and (iii) Log-Pearson Type III, are applied to verify the fitness to the plotting position of recorded data. The results show that significant difference is not observed in their values among the three (3) methods. Therefore, the results of Gumbel method which is adopted by DID in his publications are applied.

The average basin rainfall tends generally to decrease with the increase of catchment area. Although the development of depth-area-duration curve for each storm is required to estimate the conversion factor of point rainfall to average basin rainfall, the lack of sufficient data prevents the derivation of conversion factor by the statistical procedure. In the Study, the conversion factor of 0.93 recommended by DID is applied to estimate the average basin rainfall at the Mukoh site.

Depth-duration analysis is made on the basis of four (4) heavy rainfall data recorded at Kuching aerodrome so as to estimate the distribution of hourly rainfall. According to the data, the heavy rainfall occurs for the duration within 24 hours and has such characteristic that about 80 per cent of 24-hour rainfall depth concentrates in 15 hours after rainfall starts. These torrential showers are usually observed in the evening to the next early morning. The average hourly distribution pattern is obtained as an arithmetic mean of the above four (4) heavy rainfalls.

Probable flood hydrographs at Batang Ai Project having a catchment area of 1,200 km^2 are referred for estimating the duration of design rainfall. The duration of direct runoff for various probable floods is roughly estimated at about 30 hours which correspond to the duration of heavy rainfall within 24 hours.

A unitgraph at the intake site is developed by the Nakayasu's synthetic unit hydrograph method. Initial rainfall loss is disregarded by assuming that the whole basin is saturated by antecedent rainfall, while the retention loss rate after the saturation is assumed to be constant at 2.5 mm per hour.

Probable flood peak discharges at the intake site are estimated at 900 m^3/sec, 1,010 m^3/sec and 1,140 m^3/sec for the return periods of 50, 100 and 200 years, respectively.

It is finally noted that the prediction of runoff was relied on the short records of rainfall and discharge data or was based on the data from other basins which may not be representative of the proposed project site due to lack of data. Meteo-hydrological observations for the project are recommended to successively be carried out for enhancing the reliability of hydrological estimates.

3.3.4 Sedimentation and water quality

Although measurements on sedimentation were carried out from June 24 to June 29, 1987, such data are still insufficient for the derivation of relationship between discharge and sediment volume.

The denudation rate of 1.0 mm per annum is adopted at the intake site on the basis of the results of study on Batang Ai and Bakun Hydroelectric Projects. The annual sediment volume flowing through the intake site is estimated at 0.29 million m^3.

Samplings for water quality were also carried out together with those for sedimentation, and then collected samples were analysed. The data show none of adverse effect on turbine and metal for hydropower use.

3.3.5 Right of way in water use

There is no habitant in the Mukoh River basin upstream from the Mukoh site. Uppermost location of longhouse along the Mukoh River is about 2.0 km downstream from the proposed tailrace site.

All the logging activities in the basin are carried out through logging roads traversed the mountain ridge. The Mukoh River is not used as means of transportation of logged timber.

Further discussions on hydrology are referred to Appendix III of Volume II.

3.4 Construction Materials

3.4.1 Introduction

Major hydraulic structures for the project are concrete structures such as a concrete gravity dam, intake, powerhouse and tailrace. Concrete aggregates are therefore mainly discussed as construction materials. Aggregates required for such concrete structures are estimated to be some 26,000 m^3 in total; 17,000 m^3 for gravel and 9,000 m^3 for sand.

Reconnaissances to search the potential borrow pits for concrete aggregates were carried out in the vicinity of project area. Seven areas were investigated as the candidate places of concrete aggregates. Out of them, six areas are dunes consisting of sand and gravel in the Mukoh and Tekalit rivers and remaining one is the sandstone area to have a potential as a quarry. The location of seven potential areas is depicted in Figure 3.3.

3.4.2 Laboratory tests

During the field investigation, samples for laboratory tests were collected by hammering outcrops or by digging test pits.

Collected samples were brought to Kuching for carrying out such test as sieve analysis, specific gravity and absorption and so on.

The technical specifications stipulated by American Society for Testing Materials (ASTM) for the laboratory tests of concrete aggregates are applied to the samples collected from the borrow pits. The maximum size of coarse aggrates is 80 mm for laboratory tests.

The results of laboratory tests are summarized in Table 3.1. It can be said that sand and gravel in the Mukoh River have characteristics of light specific gravity, high absorption rate, high percentage of soft stone in gravel, high soundness rate and much abrasion volume of gravel. However, sand and gravel in the Tekalit River as well as the rock in the potential quarry show good properties as concrete aggregates.

3.4.3 Concrete aggregates

Table 3.2 shows the collectable amount of concrete aggregates as well as hauling distance. Although sand and gravel in the Tekalit River is suitable as concrete aggregates, the hauling distance is long and available amount is not sufficient for the required amount of some 26,000 m^3. Furthermore, it is noted that river bed deposits in the Tekalit River contain many cobbles and boulders. Thus, concrete aggregates required for the concrete structures will be quarried from the sandstone area located on the left bank just downstream from the damsite.

Laboratory tests were carried out for evaluating the quality of rocks from the proposed quarry. Since crushed rock samples show the usable characteristics as concrete aggregates, the proposed quarry is suitable as a concrete aggregate source. Additional laboratory tests will however be conducted for confirming the quality of quarry rock.

Further detailed discussions for construction materials are given in Appendix II of Volume II.

3.5 Environmental Aspect

3.5.1 General

Environmental impact associated with implementing major investment projects is a matter of increasing concern in Sarawak. With this view, an environmental study was carried out at this time as a part of the feasibility study on the Mukoh hydropower development project.

The objectives of the environmental study were first to clarify the existing conditions of the environment in and around the project site, particularly in the Mukoh River basin, and secondly to assess possible environmental impact of the Mukoh project. The environmental impact assessment as discussed below is only at preliminary level, since the project is still at the relatively early planning stage.

3.5.2 Existing environmental conditions

Existing environmental conditions in the Mukoh River basin were studied in many aspects, based on the existing data, reports, hearings and limited field survey. Aspects covered by the study are land use, economic activities, public health, water quality, vegetation, wildlife, fish and fisheries and natural conservation.

<u>Land use and vegetation</u>

Major parts of the Mukoh River basin are covered with permanent forests. In Sarawak, permanent forests are majorly classified into three categories; forest reserves, protected forests and communal forests. The definition of each category is simplified as follows:

Forest reserve	:	Permanent forest to reserve permanently for the benefit of the present and future inhabitants of the country
Protected forests	:	Permanent forest to require protection of land and water where the terrain or vegetation is of such a nature that intensive management as a productive forest is unlikely to be practicable
Communal forests	:	Permanent forest to supply permanently the domestic needs of the specified community.

The forest in the Mukoh River basin belongs to protected forest.

The land of the Mukoh project area is reserved to the Government. However, local people may claim native customary rights for the development of the project.

On the other hand, agricultural activities are performed in a subsistence level by the local dwellers sparsely populated along the riverside majorly for their domestic use. Major crops grown by them are rubber, pepper, hill paddy and fruit trees which are mostly local fruits like rambutans, durian, banana and so on. Shifting cultivation is popularly practised for hill paddy.

Although there exists no permanent house in the upstream reaches from the proposed damsite in the Mukoh River, a field of hill paddy is confirmed, even if it is cultivated in a small scale. This implies that the activities of local people extend upto the upstream area of the proposed damsite.

The life style of local people is conservative, keeping their custom and tradition as the most important thing in their lives. It is therefore wise to respect the custom and tradition of local people, when the Mukoh project is implemented.

Public health

Most of the diseases afflicting local people today are either infectious or due to poor nutrition. The most prevalent disease is malaria and tuberculosis, for which more or less 50 cases are newly reported every year. Even if the number is minimal, new patients of leprosy are still reported.

The probable epidemic disease affected by the hydro-electric development will be malaria. It will be free from the problem of spreading of schistosomiasis which is parasitic and water-borne disease known as bilharzia and is carried by aquatic snails, since the head pond is not a favourable condition for this disease.

Water quality

Water quality tests were carried out near the project site of the Mukoh River as part of this project. The Mukoh water shows clear clour without turbidity and highly dissolved oxygen concentration.

The Mukoh project creates a man-made pondage of a scale that water stored in it does not stay beyond a few days. Thus, the creation of a new pondage has not any adverse effect to water quality of the Mukoh River.

Wildlife

There exist no available data on wildlife of the Mukoh River basin. Hearings from the local people around the damsite indicate that the principal wildlives are as follows:

Mammals
- Wild Boar
- Barking Deer
- Mouse Deer
- Porcupine
- Slow Loris
- Gibbon

Reptiles
- Snake
- Earless Monitor Lizard

Fish and fisheries

Fresh water fish in the Mukoh River are semah, labag, tengadak, kolong and seluwang. Those fish which are edible and a major protein source for local people have habit of local movement to the upstream reaches in wet seasons for seeking clean water.

3.5.3 Effects on environment

Possible impact of the Mukoh project to the environment is assessed at a preliminary level. Since it is only a preliminary assessment, possible effects are classified into following five ranks just to indicate if they would be beneficial, neutral or harmful to natural and human surroundings:

+H : high positive
+L : low positive
O : no effect or negligible effect
-L : low negative
-H : high negative.

Environmental effects of the Mukoh project are assessed as summarized in Table 3.3. Low negative is assessed for land issues and compensation, sedimentation, vegetation, wildlife, and fish and fisheries. However, those effects may turn out to be negligible, if more detailed investigations are made into the existing conditions, and careful approaches are accordingly taken to the project implementation.

CHAPTER 4 POWER SUPPLY AND DEMAND

4.1 Organization of Power Sector

In the State of Sarawak, the Sarawak Electricity Supply Corporation (SESCO) is the sole agency to undertake the responsibility to supply electric power stably to consumers in line with the Ordinance established by the Government of Malaysia, and the Corporation is under statutory duty:

(1) to manage and work the electrical installations tranferred to the Corporation by the provisions of the Sarawak Electricty Supply Corporation Ordinance, 1962 and such other installation and apparatus as may be acquired;

(2) to establish, manage and work such electrical installation as the Corporation may deem it expedient to establish;

(3) to promote and encourage the generation of energy with a view to speeding up the economic development of Sarawak;

(4) to secure the supply of energy at reasonable prices; and

(5) to advise the Government on all aspects relating to the generation, transmission, distribution and use of energy in the State.

In addition, the Corporation has been implementing the rural electrification programmes throughout the State so as to rise the living standard of the rural people according to the Government policy.

4.2 Existing Power Supply System

4.2.1 Whole Sarawak

(1) Power generating facilities

By the end of 1986, SESCO has constructed and operated 60 power stations, as shown in Fig. 4.1, with a total capacity of 364,624 kW and the development of the installed capacity from 1975 in major ten service areas is described in Table 4.1. The installed capacity at the end of 1986 has grown by 4.5 times compared with that in 1975. The generating facilities are comprised mainly of diesel engines as well as gas-turbine units. The first large scale hydropower station in Sarawak, Batang Ai, with an installed capacity of 108 MW (27 MW x 4 units) has been put into commercial operation in 1985.

The breakdown by generating type at the end of 1986 is shown below:

Breakdown of Generating Types

Diesel	Gas-turbine	Hydro	Total
50%	20%	30%	100%

Energy generated at the Batang Ai power station is mostly consumed as base load energy in Kuching area. The gas-turbines are installed only in Kuching, Miri and Bintulu areas. In other load centres including Limbang and Kapit, power supply relies on the diesel engine sets installed for each isolated grid.

(2) Power transimission and distribution

As one component of the Batang Ai project, a 275 kV transmission line of 215 km long was constructed between the Batang Ai and Kuching. Its extension work to Sibu is now in progress as depicted in Fig. 4.2. SESCO has a further plan to extend the 275 kV transmission line to Bintulu, so that these interconnected transmission lines will constitute the main artery in the power system of Sarawak in near future.

Power is distributed in voltage of 33, 11 and 6.6 kV, and power outlet used by consumers is normally wired with the rating AC 50 Hz, 3 phase/single, 400/230 V. According to SESCO's Annual Report in year 1983, a total length of the existing distribution lines is 3,757 km as detailed below:

Length of Distribution Network

(Unit:km)

Voltage	33 kV	11 kV	6.6 kV	400/230 V
Overhead Line	140	702	95	1,864
Underground Cable	22	474	114	346
Total	162	1,176	209	2,210

Most part of these distribution lines, except for river crossing and major town areas, are supported with wooden (Belian) poles.

4.2.2 Kapit area

(1) Power generating facilities

As seen from Table 4.1, the installed capacity of Kapit power station at the end of 1986 was 2,363 kW in total, consisting of 9 diesel engine sets. An output of each generator is given in the single line diagram of Kapit system as seen in Fig. 4.3.

(2) Distribution network

The existing distribution network consists of 11 kV and 400/230 V overhead line and underground cable with a step-down transformers in the range from 16 kVA to 500 kVA, and its route length at the end of 1983 is indicated below:

Distribution Network in Kapit

(Unit:km)

Voltage	11 kV	400/230 V
Overhead Line	13.5	42.5
Underground Cable	4.4	0.2
Total	17.9	42.7

It is judged from the capacity of distribution transformers shown in the single line diagram that power consumption is remarkably concentrated in the town areas.

4.3 Present and Historical Power Demand

4.3.1 Whole Sarawak

(1) Energy generated and sold

The energy generated and sold in 1986 was 706.6 GWh and 568.6 GWh in the whole of Sarawak and their historical data from 1975 are described in Tables 4.2, 4.3 and Fig. 4.4. Taking the year 1980 as the base, the average growth rates of the energy generated and sold were 12.1% and 10.9% per annum, and those rates in four major cities of Sarawak are summarized as follows:

Average Growth Rate (1980-1986)

Service Area	Kuching	Sibu	Miri	Bintulu
Energy Generated	12.1%	7.7%	11.2%	25.6%
Energy Sold	9.8%	7.2%	9.9%	24.9%

It can be observed from the above that Bintulu has been rapidly been growing compared with others because of LNG production and industrial development.

On the other hand, the system losses including station uses increased from 14.2% in 1980 to 19.5% in 1986.

(2) Maximum demand

The maximum demand in 1986 was recorded at 141.4 MW in the whole of Sarawak. As its yearly record from 1975 is indicated in Table 4.4, the maximum demand increased with 12.9% per annum.

The relation between the installed capacity and maximum demand is given in Fig. 4.5, which shows much power supply reserve in 1985 onward brought about by the development of Batang Ai. The annual load factor in these six years is ranged from 51.2% in 1982 to 57.0% in 1986 as shown below:

Annual Load Factor (%)

Year	1980	1981	1982	1983	1984	1985	1986
Sarawak	55.1	54.1	51.2	54.7	55.0	56.1	57.0

(3) Power consumption

Power consumption is in principle divided into four categories, i.e. (a) domestic, (b) commercial, (c) industrial and (d) public lighting, and its ratio for total power consumption of 568.6 GWh in 1986 is listed below:

Power Consumption by Category in 1986

Category	Domestic	Commercial	Industrial	Lighting	Total
Ratio	30.2%	48.3%	20.2%	1.3%	100%

Fig. 4.6 presents the historical data with regard to the power consumption by category in 1980, 1983 and 1986. The increase rate of power consumption in the commercial sector is 11.1% per annum for the period of 1980 to 1986, whilst 12.8% in the domestic sector, 8.4% in the industrial sector and 9.3% in the public lighting.

(4) Number of consumers and power consumption per consumer

Table 4.5 shows the detailed description on record of the number of consumers from 1975, and total consumers at the end of 1986 were recorded at 136,041. The average growth rate for the past six years was 11% approximately, and service areas with the rate larger than the average were Bintulu with 21.7% and Limbang with 12.0%. Annual power consumption per consumer in major cities and the proposed load centres of the project, Limbang and Kapit, is shown in Fig. 4.7.

A drastic increase of power consumption per consumer is recorded from the level of 2,000 kWh/year in 1975 to 6,700 kWh/year in 1986 in Bintulu due to LNG production and industrial plants. Large cities such as Kuching and Miri stay at the level of 5,700 kWh/year in 1986, whilst the demand centres of this project, Limbang and Kapit, are in the level of 3,500 to 3,800 kWh/year on the average.

4.3.2 Kapit area

(1) Energy generated and sold

As given in Tables 4.2 and 4.3, the energy generated and sold in the proposed load centre, Kapit, was 5,528 MWh and 5,045 MWh in 1986, respectively. The average growth rates over the past six years were recorded at 14.5% per annum for generated energy and 15.3% per annum for sold energy. It is judged from the high growth rates that the Kapit area is in the initial stage of electrification.

The system losses including station use were recorded at 10.5% on average in these six years.

(2) Maximum demand

The maximum demand has increased from 529 kW in 1980 to 1,358 kW in 1986, resulting in an average annual growth rate of 17.0% (refer to Table 4.4). This growth rate is very high compared with that in the local load centres of Sarawak.

The relation between the installed capacity and the maximum demand is indicated in Fig. 4.8, realizing the due reserve margin of 74% in 1986.

The average annual load factor from the year 1975 was 50.6% approximately, and the variation of annual load factor from the year 1975 is compared with that in Kuching and Miri in Fig. 4.9, showing a recessing tendency on these four years.

(3) Power consumption

The power consumption by category from 1980 is described in Table 4.6, and the share by category in 1986 was described below:

Power Consumption by Category in 1986

Category	Domestic	Commercial	Industrial	Lighting	Total
Ratio	15.8%	67.5%	15.4%	1.3%	100%

The average growth rate per annum by sector over past six years was recorded at 17.4% for the domestic sector, 13.4% for the commercial sector, 26.7% for the industrial sector and 2.6% for public lighting, respectively.

The monthly variation of power consumption and daily load curve in Kapit are described in Fig. 4.10 and Fig. 4.11 respectively. The daily load factor in Kapit was 63 percent in May 1987.

(4) Major consumers in Kapit

In Kapit, there are five major consumers (a) Water Treatment Plant, (b) Federal Complex, (c) Booster Pump Station, (d) VFH Station and (e) Meligai Hotel, which share around 25% in the power consumptioin in early 1987, showing a rising tendency year by year.

(5) Number of consumers

The number of consumers in the Kapit area has gradually increased every year. At the end of 1986, the number of consumers by category is shown below:

Number of Consumers in Kapit
(At the end of 1986)

Domestic	Commercial	Industrial	Lighting	Total
723	431	5	13	1,172

4.4 Power Demand Forecast

4.4.1 Purpose

The purpose of power demand forecast in this study is to ascertain the future demand in the proposed load centre to be connected with a planned small scale hydroelectric power project so as to set up the timing and scale of development of the project that would be most suitable.

4.4.2 Method

A macroscopic technique, which is the method to predict the growth of power demand by corresponding to that of gross domestic product, is normally applied to the power demand forecast of a long term.

However, it is not suitable to apply the said technique to this study due to the reason that a close correlation cannot be found between power demand and economic activities in the isolated power supply system such as the proposed load centre.

In forecasting power demand, consumers are divided into four categories; domestic sector, commercial sector, industrial sector and public lighting, and then the procedures mentioned below are applied to the power demand forecast of each category.

(1) Domestic sector

The power demand of domestic sector is predicted by estimating the growth rate of two major factors of the electrification ratio and annual average power consumption per household. The procedures to estimate the growth rate of those factors are as follows:

- Firstly, population in the district is forecasted based on the Statistical Bulletin published by the Department of Statistics Malaysia and based on the population growth rate adopted in the Fifth Malaysia Plan 1986 - 1990.

- Secondly, the total number of households belonging to the district is also estimated based on the Statistical Bulletin.

- Thirdly, the electrification ratio is predicted based on the past trend in the district, referring to the electrification ratio in Kuching and Sibu.

- Fourthly, the annual average power consumption per consumer in the domestic sector is estimated based on the past trend of the said consumption in the district by referring its standard and growth rate in Kuching and Sibu.

- Lastly, the power demand in the domestic sector is obtained by multiplying the number of households which will be supplied by SESCO by the annual average power consumption per consumer in the sector.

(2) Commercial sector

The power demand of commercial sector is calculated by multiplying the number of consumers in the commercial sector by the annual power consumption per consumer in the commercial sector as estimated in the domestic sector.

Since the number of consumers in the commercial sector has a close relation with that in the domestic sector, the ratio of the number of consumers in the domestic sector to that in the commercial sector is employed for estimating the number of consumers in the commercial sector in the future.

The annual average power consumption per consumer in the commercial sector is estimated based on the past trend of the said consumption in the district, referring to the growth rate of the power consumption in such field of Kuching and Sibu.

(3) Industrial sector

According to the power market survey by the JICA study team and answers to the questionnaire, there is no notable large industrialization programme to be implemented in the proposed load centre.

Therefore, the power demand of the industrial sector is only predicted based on the past trend of the power consumption by the sector.

(4) Public lighting

Power consumption to be used for the public (street) lighting is small compared with that of other sectors as shown previously. Accordingly, the past trend of power consumption is applied to the calculation of power demand forecast in the street lighting.

The energy generation required to cope with the above mentioned power consumption is determined taking system loss rate and station use into consideration, and maximum demand can be obtained by the following formula:

Maximum Demand (kW) = A / 8,760 / B

where, A: Annual energy generation (kWh)
B: Annual load factor.

4.4.3 Previous studies on power demand forecast

(1) Power demand forecast by SESCO

The recent power demand forecast upto the year 2010 was made for seven major load centres, Kuching, Sibu, Miri, Bintulu, Sarikei, Sri Aman and Limbang as well as other load centres more than 50 by SESCO in 1986.

According to SESCO, demand was projected based on the past trend of power consumption by category, not counting any large individual load planned to be established in the industrial sector.

Two study reports by SAMA Consortium and German Agency for Technical Cooperation Ltd., discuss the power demand forecast for the demand centres in Sarawak. However, the demand forecast for the Kapit area was not included.

4.4.4 Power demand projection for Kapit area

(1) Power demand in domestic sector

Following are the basic data and criteria used in predicting the trend of population, the electrification ratio and the annual average power consumption per household in the captioned sector, which rely mainly on the Statistical Bulletin Sarawak, and data and information furnished by SESCO.

(a) Trend of population

According to the Statistical Bulletin Sarawak, the population in the major cities and the proposed load centres, Limbang and Kapit, are given as follows:

Population in Sarawak

(x 1,000)

District	1970	1980	Growth Rate (%)
Kuching	215	315	3.9
Sibu	98	139	3.6
Miri	58	101	5.7
Bintulu	39	58	4.0
Sarikei	34	44	2.6
Limbang	20	25	2.3
Kapit	30	38	2.4
Whole Sarawak	976	1,308	3.0

As seen from the Table above, the major cities including those newly industrialized, i.e. Bintulu, show rapidly rising tendency in the population growth as well as the concentration of populaton in the said areas.

In order to estimate the number of households in future, the population growth of Kapit area is presumed to be 2.5% in 1985 and 2.4% in 1990, 2000 and 2010 respectively. The Fifth Malaysia Plan is also referred to estimate the future population growth rate.

(b) Prediction of electrification ratio in Kapit area

The electrification ratios in the year 1980 and 1985 of Kapit as well as major cities of Kuching and Sibu are summarized as follows:

Electrification Ratio

Year	Kapit	Kuching	Sibu
1980	5.5%	47%	51%
1985	8.7%	64%	61%

The electrification ratio in Kapit district is assumed to reach 10% in 1990, 12% in 2000 and 14% in 2010 respectively, taking into account both the growth of electrification ratio and the rural electrification programme by SESCO.

(c) Number of households to be electrified by SESCO

The number of households to be electrified by SESCO is estimated based on the electrification ratios and the number of households as follows:

Number of Households to be Electrified by SESCO

Year	1985	1900	2000	2010
- Population (x 1,000)	43.4	48.4	61.4	77.8
- Estimated number of households	7,230	8,070	10,230	12,970
- Number of households to be electrified by SESCO	630	810	1,230	1,820

It is noted that the family number per household is estimated to be six persons from the Statistical Bulletin Sarawak 1984.

(d) Annual power consumption per household

The annual average power consumption per household was 1.14 MWh in 1984, 1.17 MWh in 1985 and 1.18 MWh in 1986 respectively, according to the data collected by the team (refer to Table 4.7). An approximate figure of 1.2 MWh per annum is then used as the base for the estimate of power consumption on the domestic sector.

The growth rate of the annual average power consumption per household is estimated to be in the range of 5% to 2% per annum by referring to the historical growth rates in the Kuching and Sibu areas as shown in Table 4.8.

It is considered that the spread of household appliances such as television, refrigerator, air conditioner, electric fan and so on expedite power consumption with a high growth rate and that the growth rate will drop after their spread.

(e) Energy requirement in domestic sector, Kapit

The annual energy requirement in the domestic sector in Kapit is summarized as shown below:

Annual Energy Requirement in Domestic Sector, Kapit

Year	Energy (MWh)
1984	575
1985	685
1986	799
1987	918
1988	996
1989	1,083
1990	1,175
1995	1,795
2000	2,583
2005	3,480
2010	4,659

More details are shown in Table 4.9.

(2) Power demand in commercial sector

(a) Number of consumers in commercial sector

As mentioned before, the number of consumers in the said sector has a close relation with that in the domestic sector. Using the SESCO historical data, the ratio of the number of consumers in the commerical sector to that in the domestic sector was analysed as follows:

Ratio of Number of Consumers in Commercial Sector
(Domestic = 100)

Year	Kapit	Kuching	Sibu
1980	81.3	23.3	23.9
1982	77.0	22.4	22.9
1984	72.7	(22.0)	(22.2)
1986	59.6	21.8	21.3

Note: Figures in parentheses show the estimated value.

From the above, the ratios are assumed to be 55% in 1990, 40% in 2000 and 30% in 2010 respectively in consideration of scale of the district concerned. The expected number of consumers in the commercial sector is therefore estimated at 450 in 1990, 500 in 2000 and 550 in 2010, respectively.

(b) Annual average power consumption per consumer in commercial sector

The annual average power consumption per consumer in the commercial sector was 7.16 MWh in 1984, 7.93 MWh in 1985 and 7.92 MWh in 1986 respectively as calculated from Table 4.7. The annual average power consumption of 7.92 MWh is taken as the base for predicting power consumption in the commercial sector.

Table 4.8 shows the growth rate of power consumption in the commercial sector of Kuching and Sibu. The growth rate in Kapit is estimated based on it as given below:

Growth Rate of Annual Average Power Consumption

Year	1990	2000	2010
Growth rate	4%	3%	1.5%

(c) Energy requirement in commercial sector, Kapit

The annual energy requirement in the commercial sector of Kapit is summarized as shown below:

Annual Energy Requirement in Commercial Sector, Kapit

Year	Energy (MWh)
1984	2,691
1985	3,352
1986	3,407
1987	3,570
1988	3,757
1989	3,938
1990	4,136
1995	5,159
2000	6,110
2005	6,946
2010	7,876

More details are shown in Table 4.9.

(3) Power demand in industrial sector

Power demand in the industrial sector is projected based on the past trend because there is no specific industrialization plan in the Kapit area.

Power consumption of 775 MWh in the year 1986 (refer to Table 4.6) is taken as the base and the applied growth rates and energy demand in the industrial sector of Kapit are summarized below:

Growth Rate and Energy Demand Industrial Sector in Kapit

Year	1986	1990	2000	2010
Growth Rate	-	10%	8%	6%
Energy Demand (MWh)	775	1,135	2,450	4,388

(4) Power demand of public lighting

It can be seen from Table 4.6 that the power consumption used for the lighting is as small as 1.3% of total power consumption in 1986. The power demand in the public lighting is therefore estimated based on the past trend, and the following growth rates are applied to the power demand forecast in the public lighting: