No. 5

Japan International Cooperation Agency (JICA)

P.T. PLN (PERSERO)
The Republic of Indonesia

Feasibility Study
for
The Upper Cisokan Pumped Storage Hydroelectric Power Development Project
in
The Republic of Indonesia

FINAL REPORT

March 1995

NEWJEC Inc.

No. 5

Japan International Cooperation Agency (JICA)

P.T. PLN (PERSERO)
The Republic of Indonesia

Feasibility Study
for
The Upper Cisokan Pumped Storage Hydroelectric Power Development Project
in
The Republic of Indonesia

FINAL REPORT

March 1995

NEWJEC Inc.

PREFACE

In response to a request from the Government of Republic of Indonesia, the Government of Japan decided to conduct the Feasibility Study for the Upper Cisokan Pumped Storage Hydroelectric Power Development Project in the Republic of Indonesia and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to the Republic of Indonesia a study team headed by Mr. Yutaka MATSUI of NEWJEC Inc., nine times during the period from October 1992 to March 1995.

The team held discussions on the project with officials concerned of the Government of the Republic of Indonesia and conducted the survey. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Republic of Indonesia for their close cooperation extended to the team.

March, 1995

Kimio Fujita
President
Japan International Cooperation Agency

March, 1995

Mr. Kimio Fujita
President
Japan International Cooperation Agency
Tokyo, Japan

Dear Mr. Fujita,

Letter of Transmittal

We are pleased to submit herewith the Final Report on Feasibility Study for the Upper Cisokan Pumped Storage Hydroelectric Power Development Project in West Java of the Republic of Indonesia. The report contains the results of the Study which was carried out from October 1992 to March 1995 by Study Team organized by NEWJEC Inc.

The major contents of the Study are load demand forecast in Java-Bali electricpower supply system, optimal development scale of the Project and its commissioning year, preliminary design of project structures, cost estimate and economic evaluation of the Project and environmental impact assessment.
The Study revealed that the Project with an installed capacity of 1,000 MW can be put into commercial operation in 2004 with a fairly high internal rate of return.

We ought to a lot of people concerned with the Study for accomplishment of the report. We express our deep appreciation to all those who extended their kind assistance and cooperation to the Study Team, in particular, P.T. PLN (PERSERO) who directly conducted field investigation works, the Ministry of Mines and Energy, BAPPENAS.

And we also wish to take this opportunity to express our sincere gratitude to your Agency and the Ministry of International Trade and Industry.

We wish the report would contribute to the development of the Java-Bali electricpower supply system in the future.

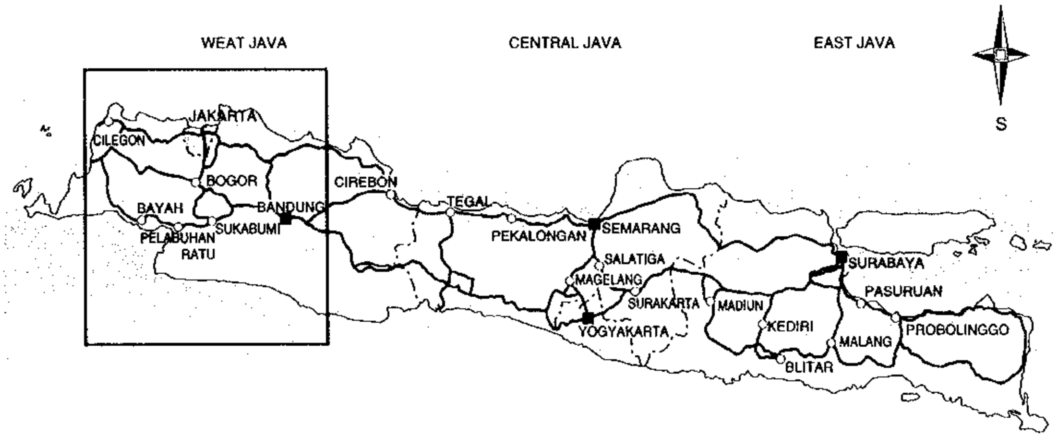
Very truly yours,

Y. Matsui

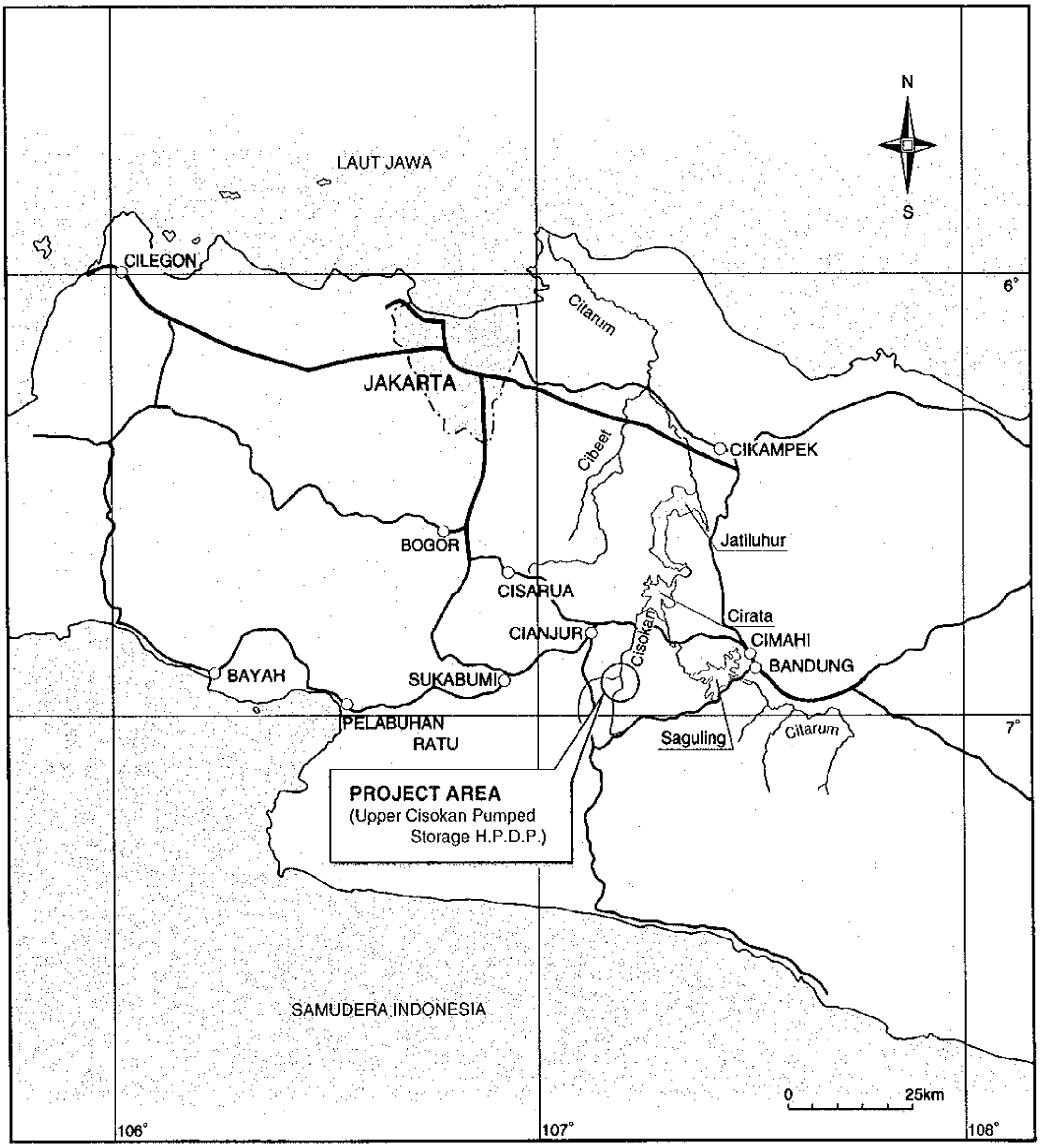
Yutaka Matsui
Team Leader
The Upper Cisokan Pumped Storage
Hydroelectric Power Development Project
in the Republic of Indonesia

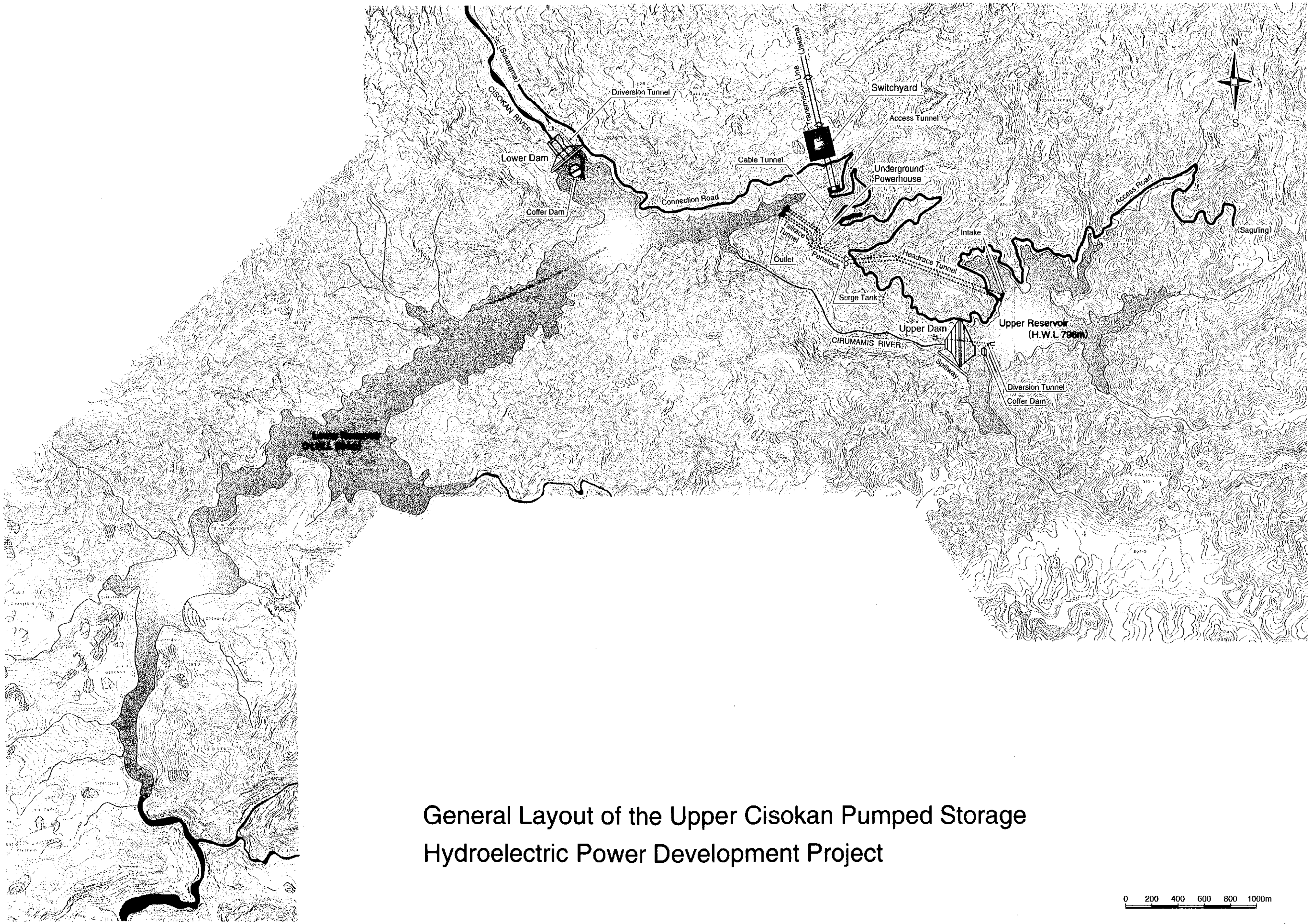
Location of Project Area

Java Island



West Java





General Layout of the Upper Cisokan Pumped Storage Hydroelectric Power Development Project

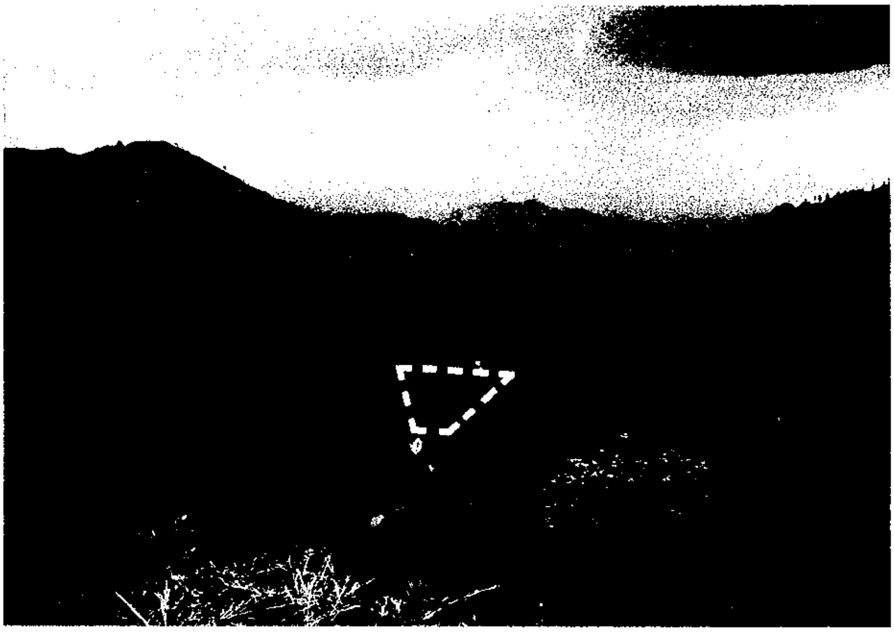


Plate-1 View of the proposed lower dam site, loooking from upstream

Plate-2 View of the proposed upper dam site, looking from downstream at the Cirumamis River

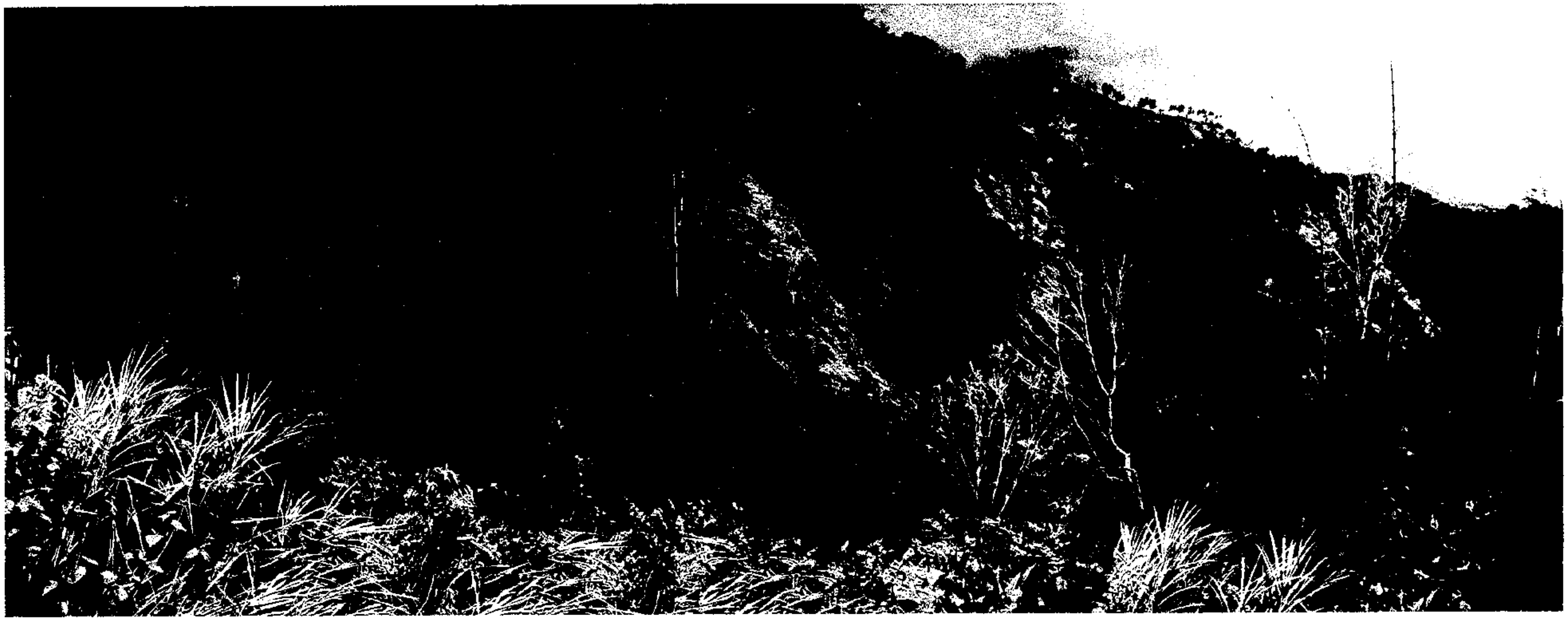


Plate-3 View of the ridge where waterways run through inside

Contents

List of Tables

List of Figures

List of Drawings

List of Appendices

1. INTRODUCTION

1. INTRODUCTION

1.1. Background

A rapid increase of load demand and peak load of the Java-Bali power system in the Republic of Indonesia has been forecasted by P.T. PLN.
According to the P.T. PLN's 1993 forecast which covers the decade of 1992 to 2003, the annual increase rate of demand in java-Bali area is 12.3 % in energy.

To meet such a big increase of load demand, especially to provide a reliable power supply in peak time, PLN has planned to apply a pumped storage hydropower plant to the Java-Bali power system.

The Upper Cisokan Pumped Storage Hydroelectric Power Development Project was originally identified by NEWJEC Inc., who carried out the following preliminary studies in 1985.

a) Review of the potential sites in Java Island utilizing topographic maps available at a scale of 1:50,000.
b) Initial selection of prospective sites
c) Site reconnaissance for the selected sites
d) Preliminary technical/economic assessment

As a result of the above studies, the Upper Cisokan Project was recommended as a most promising site in Java-Bali area.

PLN carefully reviewed this recommendation, and subsequently in 1991, through the Government of the Republic of Indonesia, requested the Government of Japan for technical assistance in the execution of a feasibility study of the Project.

In response to this request, the Government of Japan agreed to undertake the feasibility study of the Project, and Japan International Cooperation Agency (JICA) responsible for the implementation of the feasibility study, dispatched a preparatory study team to Indonesia in 1991 to set the scope of work of the feasibility study.

Upon the conclusion of the agreement on the scope of work between JICA and PLN, the feasibility study of the Upper Cisokan Project was initiated by the JICA Study Team in October, 1992 and completed in March, 1995. PLN participated in the feasibility study in some fields such as hydrologic, geologic and environmental investigations.

1.2. Objective of the Study

The Feasibility Study aims at formulating the optimum development plan of the Upper Cisokan pumped storage hydroelectric power plant and associated facilities including transmission line, and assessing its technical, financial, economic and environmental feasibility.
Transfer of technology on pumped storage hydroelectric power development to PLN counterparts was also intended throughout the period of the study.

1.3. Schedule of the Study

The study was initiated with the first visit to Indonesia by JICA Study Team for the period November 2 to December 1, 1992.

The Study was executed in Two Phases;

Phase-I (October, 1992 ~ March, 1993)

i) Justification of necessity of a pumped storage hydroelectric plant in Java-Bali power system (by JICA Study Team)

Phase-II (August, 1993 ~ March, 1995)

i) Field investigation (by PLN) (August, 1993 ~ July, 1994)

ii) Environmental investigation (by PLN) (February, 1994 ~ January, 1995)

iii) Preliminary design of the project structures, environmental impact assessment, economic/financial analysis and implementation schedule (by JICA Study Team) (July, 1994 ~ January, 1995)

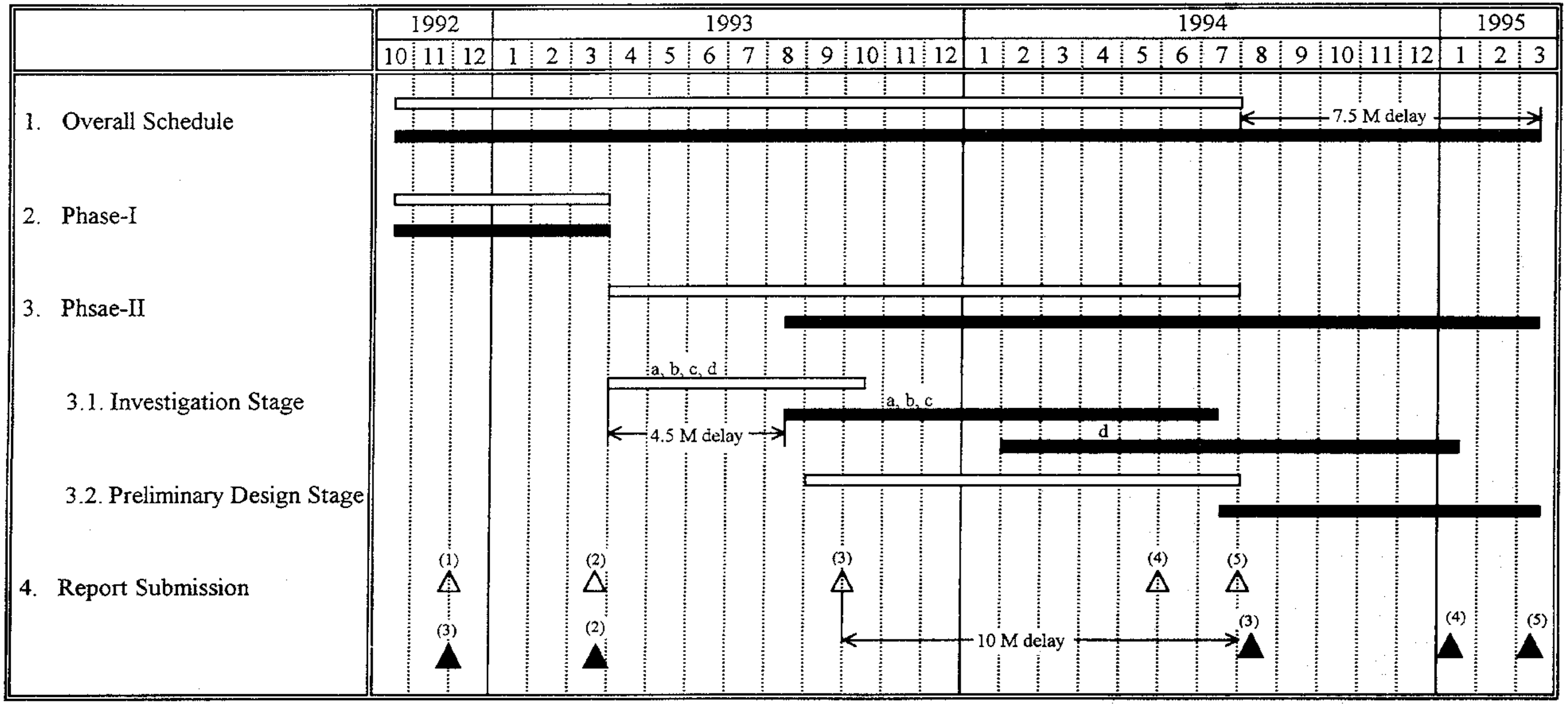
The Reports were submitted as follows:

i)	Interim Report-I	(March, 1993)
ii)	Interim Report-II	(August, 1994)
iii)	Draft Final Report	(January, 1995)
iv)	Final Report	(Marcch, 1995)

In the course of the Study, JICA and NEWJEC invited the personnel three times in total (one trainee each) from PLN for training in Japan and JICA Study Team also held a two-days seminar on pumped storage hydroelectric power development at Jakarta in September, 1994.

The chronology for the Study is referred to in Figure 1-1.

Figure 1-1 Work Schedule of the Project



: Original Schedule
: Actual

Note :
a : Topographic Study
b : Geological Study
c : Hydrologic Study
d : Environmental Study

(1) : Inception Report
(2) : Interim Report-I
(3) : Interim Report-II
(4) : Draft Final Report
(5) : Final Report

2. CONCLUSIONS AND RECOMMENDATIONS

2. CONCLUSIONS AND RECOMMENDATIONS

2.1. Conclusions

(1) The feasibility study indicates that the Upper Cisokan Pumped Storage Hydro-electric Power Development Project with 1,000 MW installed capacity enjoys the following favourable conditions for its construction:

a) Geographically the Project is nicely located. The project is close to the power demand center, Jakarta and will be linked with Java-Bali EHV grid with short distance. Because the Project situates near big cities such as Bandung, Cianjur etc., administrative affairs are easy to be managed.

b) Topographically the Project has advantageous conditions. Higher available head is utilized with shorter waterway length (L/H ≒ 6.7).

c) Geologically the Project has favourable conditions. The dam sites, waterway routes and underground powerhouse site are dominated by sandstone, breccia and andesite promising for construction of giant structure complex.

d) Less problems on environmental impact are expected. There are no significant adverse effect on environment in the project area.
Reservoir aquacalture is considered to be the most promising new job for affected persons.

(2) The total construction cost of the Project was estimated at about US$ 673 million equivalent based on the price level in 1994 excluding the interest during construction, price contingency, and customs and taxes.

(3) The Project has an excellent economic feasibility interms of the economic internal rate of return at 23.8 %. Financially the Project is expected to be run soundly with the financial internal rate of return at 20.1 %.

(4) The Project would be commissioned in 2004 if the financing arrangement is made by the middle of 1995. The total implementation period is estimated to be 104 months: 43 months for the detailed design, tendering procedures for the main works and preparatory works, 61 months for the main construction works.

(5) The Study results lead the conclusion that development of the Upper Cisokan Pumped Storage Hydroelectric Power Development Project with the installed capacity of 1,000 MW has been sociologically, technically and economically justified and this Project is worth proceeding in the next Detailed Design Stage.

2.2. Recommendations

It is recommended that the Project be implemented as early as possible to cope with the rapid increase of the electricity demand and to reinforce the peak load supply capacity in the Java-Bali power system.

For the implementation of the Project, the following arrangements will be necessary.

(1) Financial Arrangement

The Project is a large size hydropower development needing large amount of investment which is a critical problem for construction of the Project. Therefore, it is necessary to raise funds through various channels.

(2) Detailed Investigation and Design

Detailed investigation should be carried out following the financial arrangement. It should include topographical survey and mapping, additional drilling, construction material survey, route survey for transmission lines and so forth. Detailed design and preparation of tender documents should then be proceeded.

(3) Preparatory Works

Prior to the commencement of the main construction works, the preparatory works including access roads, camp facilities, construction power supply facilities shall be completed.

3. PROJECT DESCRIPTION

3. PROJECT DESCRIPTION

The Upper Cisokan Project is located at the upstream basin of the Cisokan River, one of the major tributaries of the Citarum River in West Java, shown in Drawing 3-1.

In the vicinity of the Project, there are two existing power stations: The Saguling Power Station, about 15 km east of the Project was completed in May, 1986, and the Cirata Power Station, about 30 km north was completed in October, 1988.

The Project has been planned as the first pumped storage hydroelectric power plant in Indonesia, and two dams, an upper and a lower, will be constructed. The upper dam is a concrete faced rockfill type with a height of 74 m and a 391 m long crest, and the lower dam is a concrete gravity type with a height of 100 m, a 322 m long crest. Both dams will create active storage of 10.1 million cubic meter. And in combination, these dams will provide a maximum gross head of 296 m.

The waterway facilities to connect the two reservoirs are located through the right side mountain and will consist of two intakes, two headrace tunnels each approximately 1.3 km long, and two restricted orifice type surge tanks. Extending beyond the downstream end of the surge tanks will be two penstocks, each approximately 480 m long, four (4) tailrace tunnels and outlets.

An egg shaped underground powerhouse 49.0 m high, 32.5 m wide and 138.0 m long will house four (4) generating units with 250 MW each.

Power generated from the total installed capacity of 1,000 MW will be transmitted to Jakarta and linked with Java-Bali power grid system through a 500 kV transmission line.

Access to the Project will be provided both by construction of a new road approximately 15 km long from the Saguling Dam and by upgrading the existing road or construction of a new road 5 km long from Sukarama.

A general layout of the major components of the Project is shown in Drawing 3-2 and its principal characteristics are summarized in Table 3-1.

Main construction works will be commenced in February, 2000, after detailed design, tendering and preparatory works for about three and a half years.

Completion of the Project is estimated approximately five years after the commencement of the main construction works on which basis commercial operation for Units No.1 and No.2 is scheduled in September, 2004, and in March, 2005 for Units No.3 and No.4.

Table 3-1 Main Features of the Project

(1) Plant Data			
Installed Capacity	(MW)	1,000 (250 MW × 4 units)	
Maximum Input	(MW)	1,112 (278 MW × 4 units)	
Maximum Turbine Discharge	(m^3/s)	432	
Maximum Gross Head	(m)	296	
Minimum Gross Head	(m)	273	
Loss head	(m)	14	
Rated Net Head	(m)	272	
(2) Reservoir Scale and Hydrology			
		Upper Reservoir	***Lower Reservoir***
Drainage Area	(km^2)	10.5	355.0
Reservoir Area at H.W.L	(km^2)	0.8	2.8
H.W.L	(m)	796	504
L.W.L	(m)	777	500
Effective Depth	(m)	19	4
Active Storage	(10^6m^3)	10.1	10.1
Average River Discharge	(m^3/s)	0.4	14.9
Design Flood	(m^3/s)	100	1,100
(3) Main Civil Structures			
1) Dam			
Type		Concrete faced rockfill	Concrete gravity
Height	(m)	74	100
Crest Length	(m)	391	322
Elevation of Crest	(m)	799	507
Volume of Dam Body	(m^3)	1,431,000	617,000
2) Spillway			
Type		Open channel	Center overflow
Discharge Capacity	(m^3/s)	100	1,100
Gate Type		Radial gate	Roller gates
Height × Width	(m)	8 × 5	7.5 × 10
Number		1	3
3) Intake			
Type		Side intake	
Gate		Steel slide gate	
Number		2	
4) Headrace Tunnel			
Length	(m)	Approx. 1,260	

(3) Main Civil Structures			
		Upper Reservoir	*Lower Reservoir*
4) Headrace Tunnel			
Cross-Section		Circular section with inside diameter 6.8 m	
Number		2	
5) Surge Tank			
Type		Restricted orifice type	
Inside Diameter	(m)	15.0	
Height	(m)	67.5	
Number		2	
6) Penstock			
Type		Embedded steel pipe	
Length	(m)	Approx. 480	
Inside Diameter	(m)	5.9	
Thickness	(mm)	17 ~ 50	
Number		2	
7) Underground Power House			
Cavern Section Type		Egg shape	
Height	(m)	49.0	
Max. Width	(m)	32.5	
Length	(m)	138.0	
8) Tailrace Tunnel			
Length	(m)	210 ~ 260	
Cross-Section		Circular section with inside diameter 4.8 m	
Number		4	
9) Outlet			
Type		Side outlet	
Gate		Steel slide gate	
Number		4	
(4) Electro-Mechanical Equipment			
1) Pump-Turbine			
Type		Vertical shaft, single stage Francis type reversible	
Rated Net Head/ Min Pump Head	(m)	272 / 276	
Max. Turbine Discharge/ Max Pump Discharge	(m^3/s)	108/90	
Rated Turbine Output/ Max Pump Input	(MW)	256 / 272	
Rated Speed	(rpm)	333	
Number of Units		4	

(4) Electro-Mechanical Equipment		
2) Generator - Motor		
Type		Verttical shaft, 3-phase AC synchronous
Rated Generator Output/ Motor Input	(MVA)/ (MW)	278 / 278
Rated Voltage	(kV)	18
Rated Power Factor		0.9 lagging
Rated Frequency	(Hz)	50
Rated Speed	(rpm)	333
Number of Units		4
3) Generator Transformer		
Type		3-phase oil immersed outdoor use
Rated Power	(MVA)	556
Rated Frequency	(Hz)	50
Rated Voltage		
LV winding	(kV)	18
HV winding	(kV)	500
Number of banks		2
4) Switchyard		
Type		Outdoor
Rated Voltage	(kV)	500
Number of Feeders		4
5) Associated Transmission Line		
Rated Voltage	(kV)	500
Number of Phase		3
Number of Circuits		2
Conductors		1,600 MCM class, 4 bundled
Tower		Double circuit steel tower
Route Length	(km)	Approx. 80

4. JUSTIFICATION OF UPPER CISOKAN PROJECT

4. JUSTIFICATION OF UPPER CISOKAN PROJECT

4.1. Load Demand Forecast

4.1.1. Preface

Accurate and most probable system load demand forecast is an essential factor in establishing the construction, operation and maintenance plan of the system. Load demand, in terms of both kilowatt and kilowatt-hour, is usually categorized into several demand sectors. Future demand growth is usually forecasted as the aggregated sum of sector wise demand forecast, such as for residential, commercial, and industrial sectors.

The current forecast methods can be classified into two major approaches Cumulative Method and Trend Method. These methods can also be classified as Microscopic Method and Macroscopic Method from the view point of analytical methodology employed.

4.1.2. Load Forecast Approach

The load forecast for this feasibility study was made by basically a kind of macroscopic method. The load forecast was carried out based on the method of regression from historical demand data.

In order to project the system demand throughout the period of 1990 to 2010, the projection of GDP and population growth rate for the same period are duly required. Although the official projection of those parameters for the time span is not yet available, several agencies and organizations have presented their own projections for use in their studies as shown on Table 4-1.

Table 4-1 Various GDP Growth Projection

(Unit in %)

Name of Study		1990 - 1995	1995 - 2000	2000 - 2005	2005 - 2010
MARKAL *1)		4.60	4.60 ~ 5.50	5.50 ~ 4.20	4.20 ~ 5.00
World Bank		4.63	5.72	5.51	5.50
MEDEE-S *2)	Low Scenario	2.00	2.00	2.00	
	Base Scenario	3.50	3.50	3.50	
	High Scenario	5.00	5.00	5.00	
RESGEN *3)		5.40	5.40	5.40	5.40
LPEM - UI *4)	Low Scenario	6.57	6.57		
	Base Scenario	7.52	7.52		
	High Scenario	8.32	8.32		
NEMA *5)	Base Scenario	6.50	6.50	6.00	6.00
	High Scenario	6.90	6.90	6.50	6.50

Note : *1) Study conducted by Agency for the Development and Application of Technology, (BPPT), Draft Summary, July 1992. BPPT uses 7th Five - Year Development Plan (REPELITA) staring from 1989 as the period of the study.

*2) Study conducted by ESCAP/UNDP : Regional Development Project, November, 1989

*3) Study conducted by Directorate General of New Energy and Electricity

*4) Study conducted by LPEM - University of Indonesia, 1987

*5) Study conducted by National Atomic Agency (BATAN)
: National Energy Market Analysis (NEMA), 1993

(1) GDP Projection

In this forecast, GDP growth rate projection is adopted based on the Base Scenario of the NEMA study mentioned above.

The annual GDP growth rate for Java-Bali is taken as 6.5 % per year for the period of 1990 ~ 2000, and 6 % per year for year of 2000 ~ 2010. The scenario is based on the envisaged growth rate mainly in the industrial sector, particularly the manufacturing sector, which also correlates to and reflect the growth in financial sector.

(2) Population Growth Rate Projection

The demand for energy, particularly the energy for the household sector is influenced by population growth. Therefore, the population growth rate projection for this study was done based on the population growth projection made by the Central Bureau of Statistics and is extended. The results are shown in Table 4-2 and Figure 4-1.

Table 4-2 Population Growth Projection

Year	Population Growth (%)
1990 - 2000	1.43
2000 - 2010	1.28
2010 - 2019	1.14

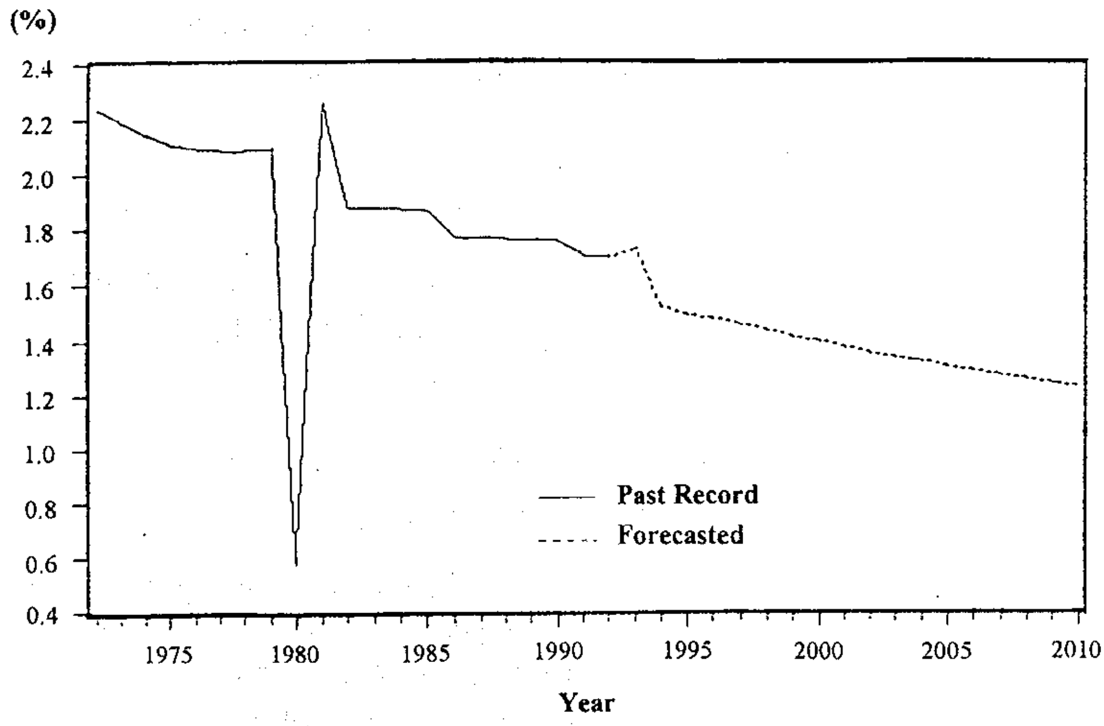


Figure 4-1 Population Growth Rate Projection (Java-Bali)

(3) Formulas Used for Demand Forecasting

The energy generation per capita and GDP per capita are used to obtain the correlation regression equation for the household power demand sector, and the energy generation and GDP of each sector are used for other demand sectors. The formulas obtained by regression analysis of the actual consumption by each sector and GDP growth rate from 1974 to 1990 (partly from 1975 to 1990) are shown below.

For residential sector, past actual growth of consumption was used to obtain the regression formula. Consequently it can be interpreted that the additional demand growth by progress of rural electrification is also reflected and integrated in the formula.

a) Household Power Demand

$$ln\ (Qhh/POP) = -1.64 + 1.97\ ln\ (GDP/POP)$$

where, Qhh : Forecasted house hold power demand (GWh)
GDP : Total GDP (10^9 Rp)
POP : Population (10^3 person in Java-Bali)
Correlation Coefficient (R2) = 0.98

b) Industrial Power Demand

$$ln\ (Qman) = -2.55 + 1.30\ ln\ (GDPman)$$

where, Qman : Forecasted industrial power demand (GWh)
GDPman : GDP in manufacturing (10^9 Rp)
Correlation Coefficient (R2) = 0.95

c) Commercial, public, and Other Sectors Power Demand

$$ln\ (Qser) = -11.51 + 1.94\ ln\ (GDPser)$$

where, Qser : Forecasted power demand for commercial, public and other sectors (GWh)
GDPser : GDP in service sector (10^9 Rp) (commercial, public, and others)
Correlation Coefficient (R2) = 0.97

Power demands of each sector, of course, are also directly or indirectly affected by business fluctuation, development processes of industrialization, events inside or outside of the country, weather and natural conditions etc.

Since it is difficult to forecast the cycle of business fluctuations in a long term forecast of economy, forecasted demand may have some differences compared to the actual demand increase affected by the unexpected trend of an economy. Thus, power demand should be reviewed periodically in line with changes in the economic situation.

(4) Peak Generation

The peak generation from 1993 to 2010 is calculated from the annual energy generation and load factor assumed.

(5) Results of Calculations

a) Results of Calculation Based on Regression Formulas

i) Household Power Demand

An average annual demand increase from 1991 to 2010 is forecasted to be 11.48 %. For forecasting power demand in the household, regression analysis was carried out based on the GDP growth rate, population increase and energy at receiving end (GWh) from 1974 to 1990 which includes the additional demand for electrification

ii) Industrial Power Demand

Industrial power demand is forecast based on the energy at receiving end plus captive power generation. Regression analysis was carried out based on the data from 1975 to 1990.

iii) Power Demand in Service Sectors (Commercial, Public, and Others)

Regression analysis is normally carried out by classifying commercial sector, public sector and others. However, no GDP related data on each sector in the Java-Bali System were available, other than those classified as services as a whole, the regression analysis was carried out based on the data from 1975 to 1990.

Since the purpose of this study is to make power generation expansion plan after 2000, the results of power demand forecast using the regression formulas in the previous section are applied to the forecast data from 2000 to 2010. Also, the forecast data both 1993 and 1994 are based on the latest forecast; REVIEW RUKN July 1994.

The forecast data from 1995 to 1999 are based on RUKN June 1993.

The power demand forecast is shown in Figure 4-2 and Tables 4-2, 4-4.

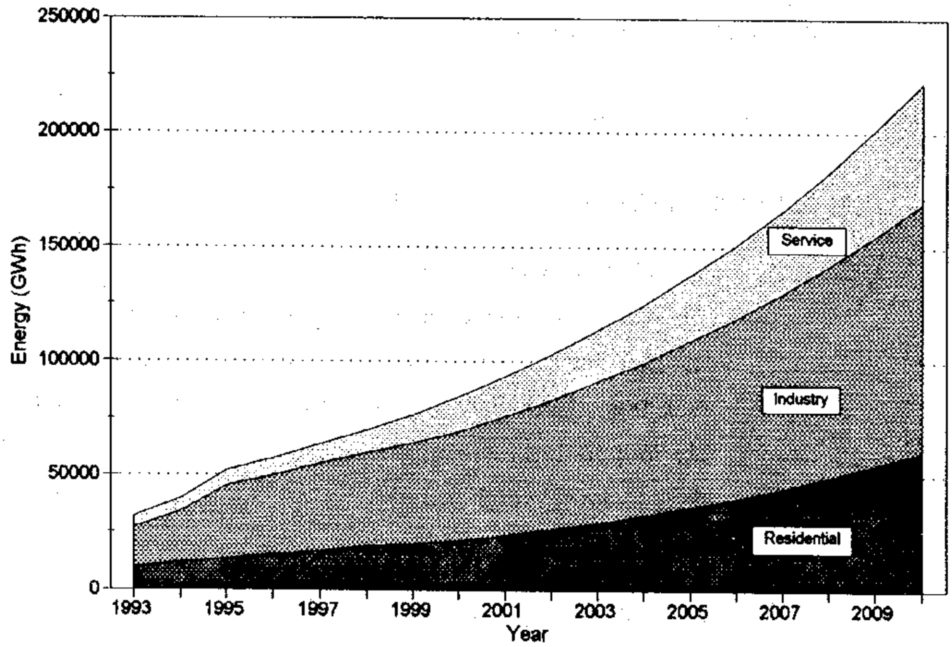


Figure 4-2 Forecasted Load Demand (Energy at Receiving End)

In general, forecast demand up to 2003 computed by applying macro forecasting by the trend method is consistent with PLN's forecast case computed by the accumulation method. (refer to the following results)

Item	Forecasted Demand in this Study	PLN Forecast
Growth rate (%) (From 1992 to 2003)	13.1	12.3
Power Demand in 2003 (GWh) (Gross Output)	135,913	125.722
Peak Demand in 2003 (MW)	21,927	20,356
Growth rate (%) (From 2003 to 2010)	9.8	NA

Table 4-3 Energy and Load Demand Forecast, Java-Bali System (1/2)

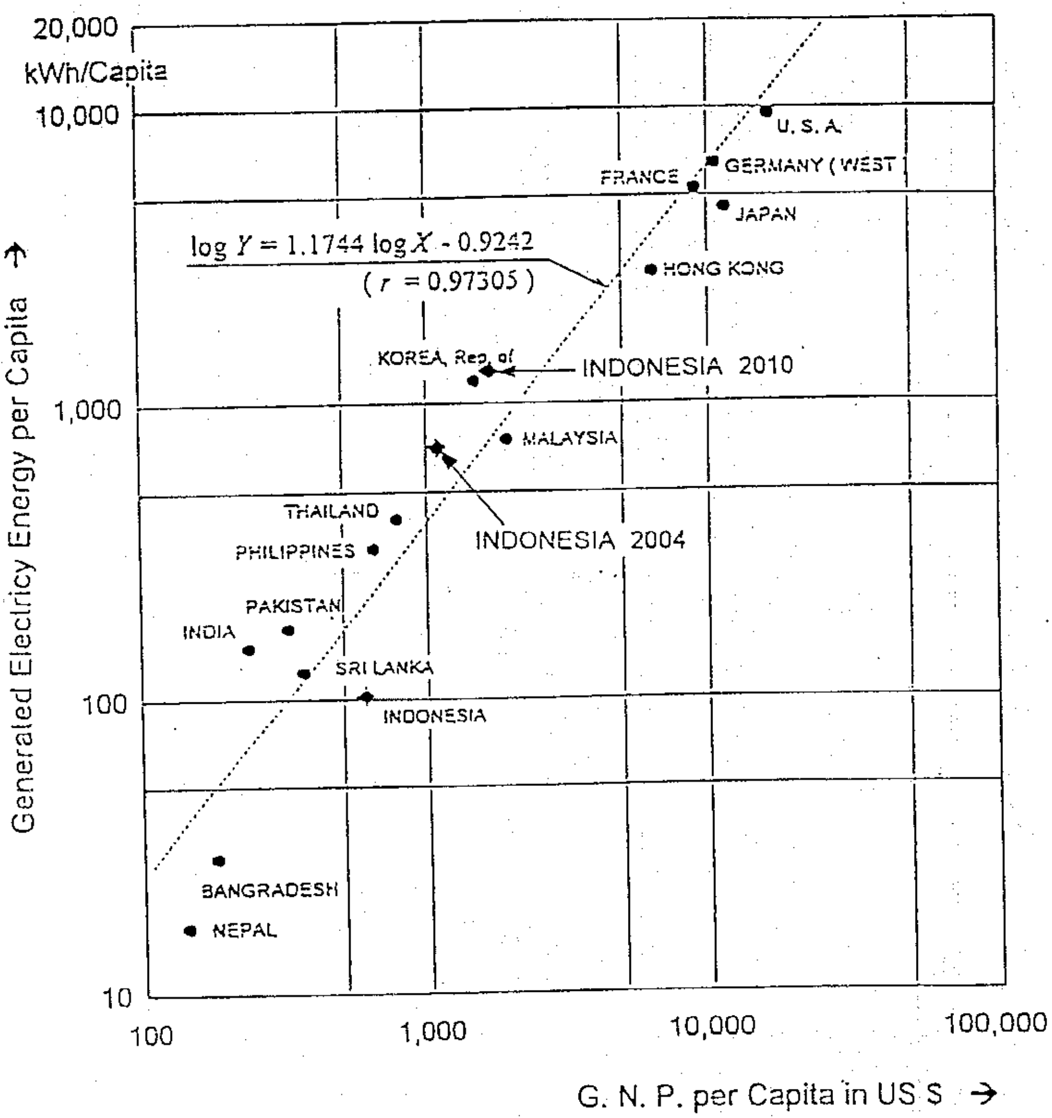
		1993	1994	1995	1996	1997	1998	1999	2000	2001
Residential										
Population	(x 10^6)	115.9	117.7	119.6	121.4	123.3	125.1	127.0	130.1	131.9
Growth Rate of Pop.	(%)	1.7	1.6	1.6	1.5	1.5	1.5	1.5	1.4	1.4
Growth Rate of GDP	(%)	7.6	7.0	7.0	7.0	7.3	7.6	7.5	6.6	6.1
Energy at Rec. End	(GWh)	9,826.0	11,891.1	13,273.6	15,030.7	16,909.3	18,936.9	19,952.9	21,350.3	23,685.9
Growth Rate	(%)	11.8	21.0	11.6	13.2	12.5	12.0	5.4	7.0	10.9
Share to Total	(%)	31.0	30.0	25.6	26.2	26.6	27.1	26.1	25.2	25.4
Industry										
Growth Rate of GDP	(%)	15.3	10.9	11.8	12.7	12.9	10.9	10.7	9.1	8.1
Energy Ind. Demand	(GWh)	26,271.7	31,339.2	35,671.9	39,989.2	44,893.7	49,521.1	54,025.1	59,544.5	65,914.6
Captive Power	(GWh)	11,179.7	9,405.6	3,711.8	5,200.5	6,891.6	8,487.2	9,758.7	11,551.6	13,578.4
Share of PLN to Total	(%)	60.5	70.0	89.6	87.0	84.6	82.9	81.9	80.6	79.4
Energy at Rec. End	(GWh)	17,092.0	21,933.4	31,960.1	34,788.8	38,002.1	41,033.9	44,266.4	47,992.8	52,336.2
Growth Rate	(%)	11.6	28.3	45.7	8.9	9.2	8.0	7.9	8.4	9.1
Share to Total	(%)	53.9	55.4	61.6	60.6	59.8	58.7	57.8	56.6	56.0
Services										
Growth Rate of GDP	(%)	7.2	7.3	6.8	6.3	6.4	7.8	7.7	7.7	6.5
Energy at Rec. End	(GWh)	4,795.0	5,789.6	6,624.0	7,568.4	8,614.4	9,896.9	12,337.5	15,421.9	17,422.7
Growth Rate	(%)	12.0	20.7	14.4	14.3	13.8	14.9	24.7	25.0	13.0
Share to Total	(%)	15.1	14.6	12.8	13.2	13.6	14.2	16.1	18.2	18.6
Total										
Energy at Rec. End	(GWh)	31,713.0	39,614.1	51,857.7	57,387.9	63,525.8	69,867.7	76,556.8	84,765.1	93,444.7
Growth Rate	(%)	11.7	24.9	30.9	10.7	10.7	10.0	9.6	10.7	10.2
T & D Losses	(%)	12.2	11.5	12.1	12.1	12.1	12.1	12.1	12.1	12.1
Energy Sent Out	(GWh)	36,348.3	44,995.8	59,334.0	65,661.4	72,684.2	79,940.5	87,593.9	97,019.1	106,953.5
Plant Use	(%)	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Gross Output Energy	(GWh)	37,932.0	46,953.9	61,907.5	68,509.4	75,836.8	83,407.7	91,393.1	101,272.5	111,642.5
Load Factor	(%)	75.2	74.0	71.8	71.6	71.4	71.2	71.0	70.5	70.6
Max. Gross Output	(MW)	5,757.0	7,243.3	9,839.4	10,921.5	12,118.5	13,372.4	14,692.7	16,409.9	18,064.6

Table 4-4 Energy and Load Demand Forecast, Java-Bali System (2/2)

		2002	2003	2004	2005	2006	2007	2008	2009	2010
Residential										
Population	(x 10^6)	133.7	135.5	137.3	139.0	140.8	142.6	144.4	146.1	147.9
Growth Rate of Pop.	(%)	1.3	1.3	1.3	1.3	1.3	1.3	1.2	1.2	1.2
Growth Rate of GDP	(%)	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1
Energy at Rec. End	(GWh)	26,278.1	29,155.3	32,349.0	35,894.4	39,830.6	44,200.8	49,035.4	54,441.8	60,425.9
Growth Rate	(%)	10.9	11.0	11.0	11.0	11.0	11.0	10.9	11.0	11.0
Share to Total	(%)	25.5	25.6	26.0	26.2	26.4	26.6	26.8	27.0	27.2
Industry										
Growth Rate of GDP	(%)	8.1	8.1	8.2	8.2	8.2	8.2	8.2	8.2	8.2
Energy Ind. Demand	(GWh)	72,970.0	80,754.6	89,440.1	99,027.2	109,646.1	121,408.1	134,436.3	148,867.2	164,851.7
Captive Power	(GWh)	15,834.5	18,418.9	22,342.1	26,192.7	30,613.2	35,694.0	41,500.5	48,143.6	55,752.8
Share of PLN to Total	(%)	78.3	77.2	75.0	73.6	72.1	70.6	69.1	67.7	66.2
Energy at Rec. End	(GWh)	57,135.5	62,365.7	67,098.0	73,834.5	79,032.9	85,714.1	92,935.8	100,723.5	109,098.9
Growth Rate	(%)	9.2	9.2	7.6	10.0	7.0	8.4	8.4	8.4	8.3
Share to Total	(%)	55.4	54.8	53.9	53.1	52.4	51.6	50.8	50.0	49.2
Services										
Growth Rate of GDP	(%)	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5
Energy at Rec. End	(GWh)	19,683.6	22,238.5	25,125.7	28,388.4	32,075.5	36,242.3	40,951.2	46,272.8	52,286.9
Growth Rate	(%)	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
Share to Total	(%)	19.1	19.6	20.2	20.7	21.3	21.8	22.4	23.0	23.6
Total										
Energy at Rec. End	(GWh)	103,097.1	113,759.4	124,572.6	138,117.3	150,939.0	166,157.3	182,922.4	201,438.2	221,811.6
Growth Rate	(%)	10.3	10.3	9.5	10.9	9.3	10.1	10.1	10.1	10.1
T & D Losses	(%)	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1
Energy Sent Out	(GWh)	118,001.3	130,204.9	142,581.3	158,084.1	172,759.3	190,177.6	209,366.4	230,558.8	253,877.6
Plant Use	(%)	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Gross Output Energy	(GWh)	123,174.6	135,913.3	148,832.3	165,014.7	180,333.3	198,515.2	218,545.3	240,666.8	265,007.9
Load Factor	(%)	70.7	70.8	70.9	71.0	71.1	71.3	71.4	71.6	71.9
Max. Gross Output	(MW)	19,902.4	21,926.5	23,970.1	26,535.1	28,941.4	31,792.3	34,921.7	38,365.3	42,086.9

b) Reference Comparison of Demand Forecast

Figure 4-3 shows a comparison with actual historical data between GNP and generated energy per capita just for reference.



: Forecasted point by this study

Figure 4-3 Relation between GNP and Generated Energy per Capita (GNP : UN data, 1985)

4.1.3. Load Curve Forecast

(1) Preface

Load curve forecast is also very important to optimally plan the unit capacity, the share, the type and operation scheme of the constituent generating plants in the system such as coal fired thermal, oil/gas fired thermal, combined cycle, gas turbine, pumped storage hydro, etc. Load curve forecast is normally given in two forms :

(a) Typical daily load patterns
(b) Load duration curve

(2) General Procedure

For a realistic prediction of the future load curve forecast, in the first place, collection and analysis of past historical daily load curve data, preferably separated in each demand sector and in time series, is the most essential work. In case such sectorwise past data is not available, there could be an approach to use the sectoral patterns of another country under similar conditions as a reference. The following figures are examples of typical daily load curves of some countries.

As is observed in the figures, in the developing countries where the consumption per capital remains still in low to moderate level, the weight of residential load occupies relatively high share in the system demand, and thus evening peak surpasses the daytime load. Along with the increase of consumption in industrial and commercial sectors, daytime load increases, and the peak time gradually shifts to office hours.
On the other hand, the change in overall system load factor shows an interesting trend, in the early stage of increase in industrial and commercial sectors demand, load factor will normally go up, but further increase in industrial and commercial sectors demand works to deteriorate the load factor by solely pushing up the daytime load.
In developed countries, this significant load difference between daytime and midnight to early morning, and resultant low load factor is the biggest problem in operation itself and in operating economy for the utility power suppliers. A typical example is shown in Figure 4-4.

As is seen, the evening peak pattern gradually changes into day peak pattern by increase of the share of day time industrial sector load along with the progress of industrialization.

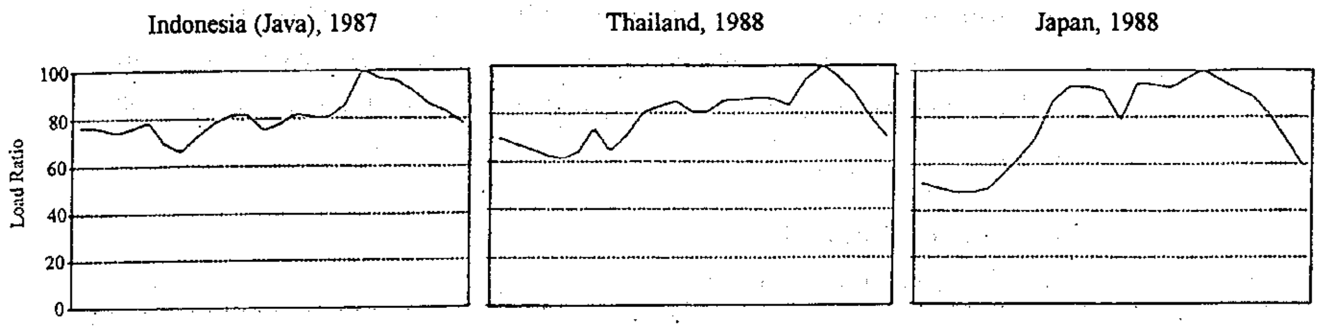


Figure 4-4 Typical Daily Load Curves of Some Countries

Actual load pattern of Java-Bali system is shown on Figure 4-5.

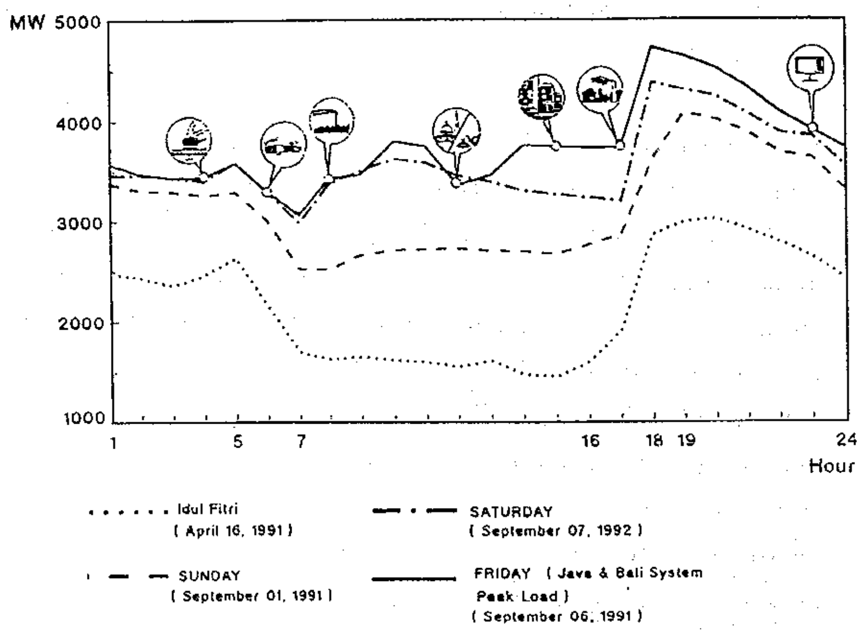


Figure 4-5 Characteristic of Daily Load in Java-Bali System

(3) Future Load Curve Forecast for Java-Bali System

Future forecast of load curve and load duration curve has been made as follows:

a) Load curves in the future are predicted based on the following data.

- Actual daily load patterns of the total system measured by PLN, mainly for the period from August 29 to September 4, 1994. The patterns are shown in Figure 4-6.

- Electricity use survey data for each sectorial load in 1992 on the final report "Power Demand Analysis for Java Indonesia" prepared by Hyundai Engineering Co. Ltd., in June, 1993.
  The survey data is shown in Figure 4-7.

- Predicted demand growth rates in the future for each sector obtained by works in the previous Section 4.1.2.

b) Typical daily load cuarve with each sectorial load patterns in 1994 are assumed with reference to the data in "a)" above.
The daily load curve patterns accumulated from the electricity use survey data for each sectorial load are different from the actual daily load curve especially at morning peak and day time periods, as shown in Figure 4-8, since the electricity use survey was investigated from 160 sampling points through one year, 1992.
Thus sectorial load patterns are adjusted to match the actual daily load curve. These load patterns are shown in Figures 4-9 and 4-10.

c) Sectorial load patterns in the future are derived by using the predicted demand growth rates for each sector. The load curves of each sector are accumulated to produce the total system daily load curve.

d) Daily load duration curves are produced based on the daily load curves.

Figures 4-11 and 4-12 presents forecasted daily load curves in 2004 and 2010 in the Java-Bali System. The forecasted daily load duration curve in 2004 is shown in Figure 4-13.

The load demand forecast and load curve forecast thus obtained is used for studying the optimal generation expansion program.

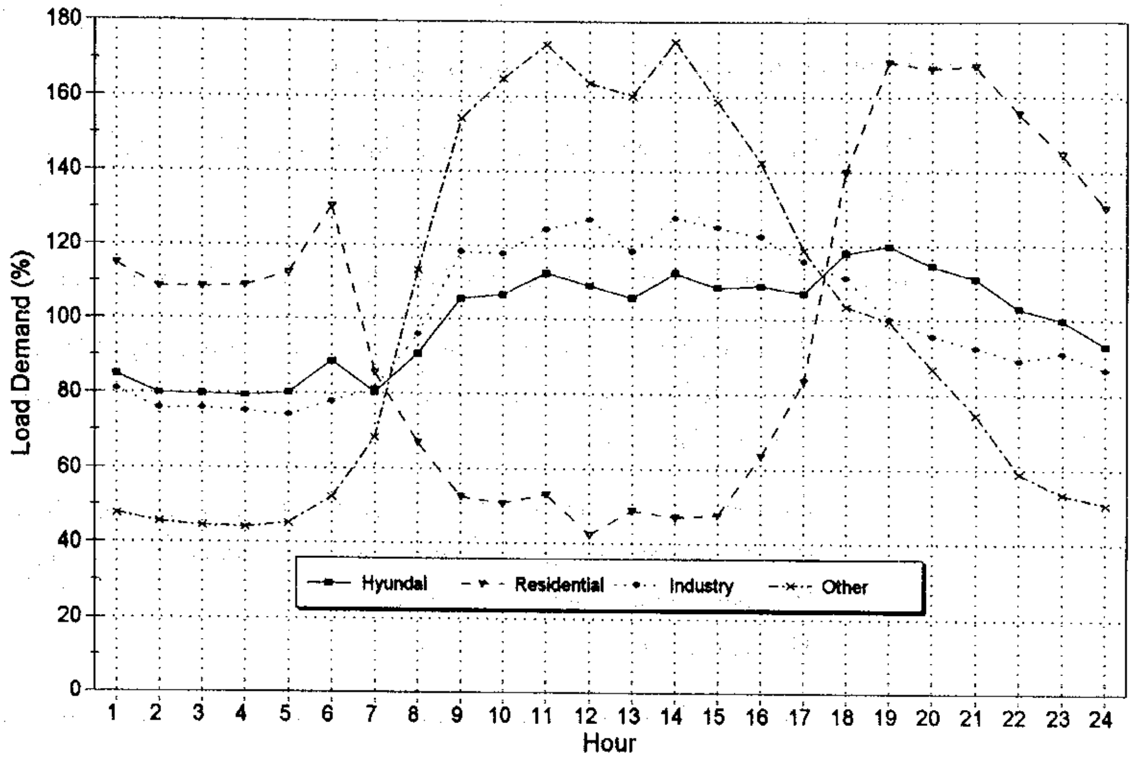


Figure 4-6 Actual Daily Load Patterns in 1994

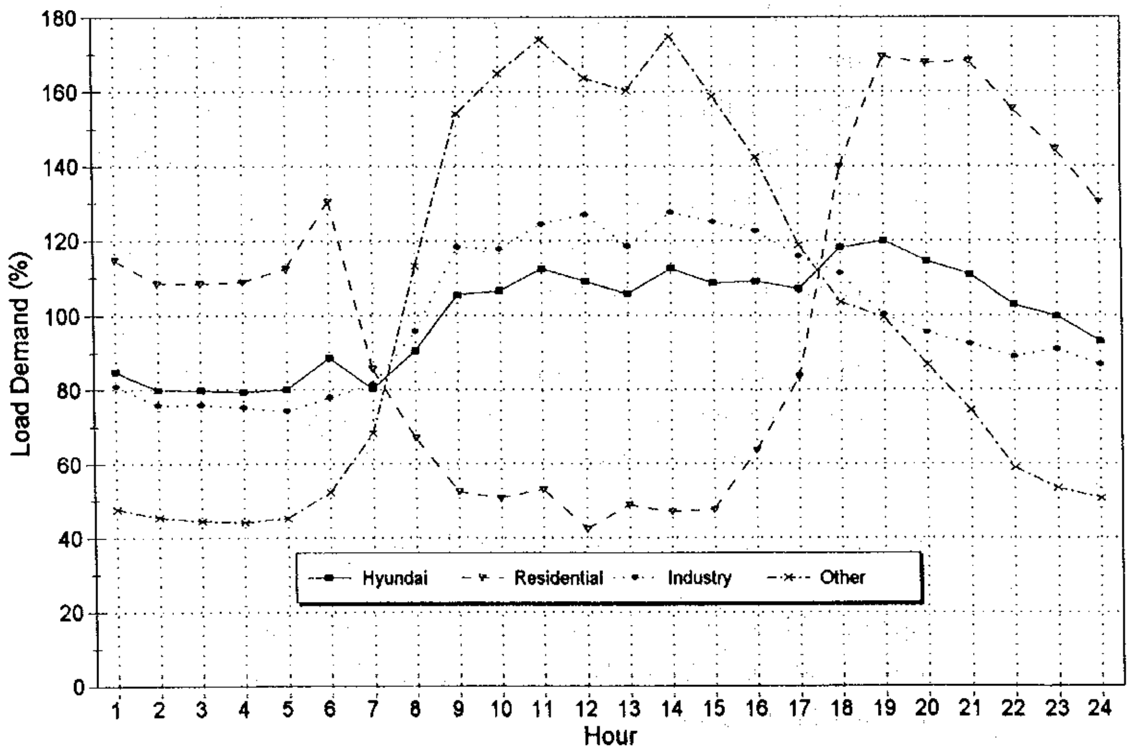


Figure 4-7 Electricity Use Survey Data (Normalized)

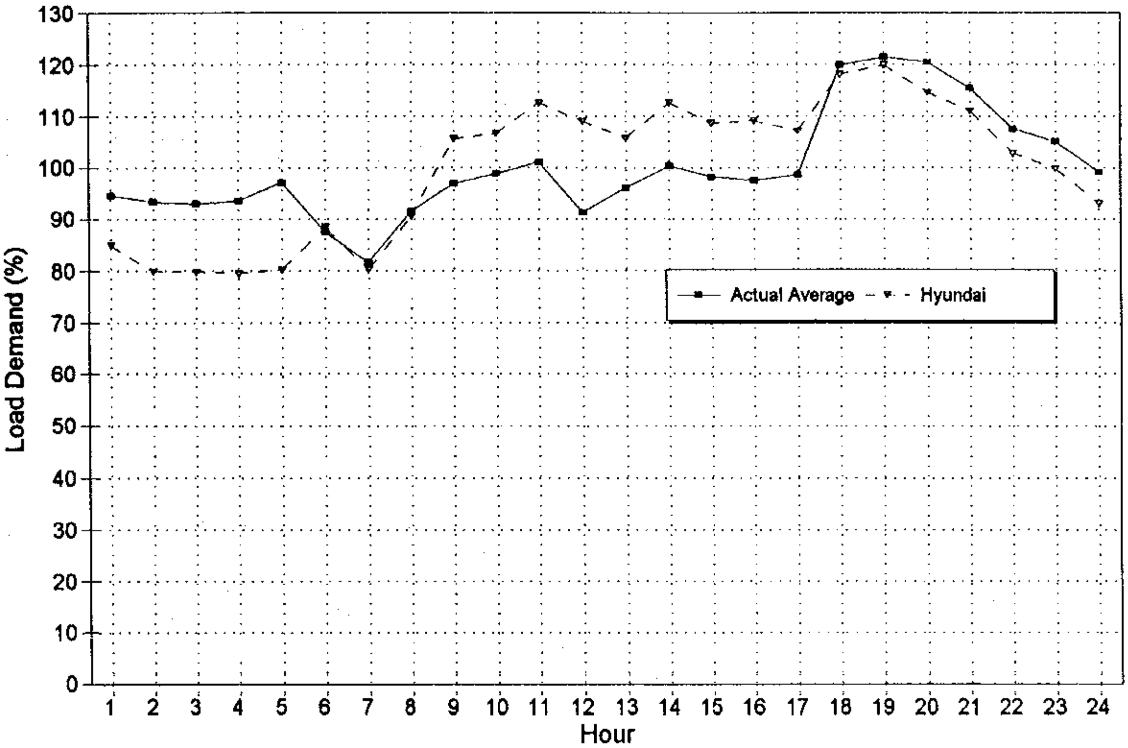


Figure 4-8 Comparison between Actual Daily Load Curve and Accumulated Curve by Hundai Survey Data (Normalized)

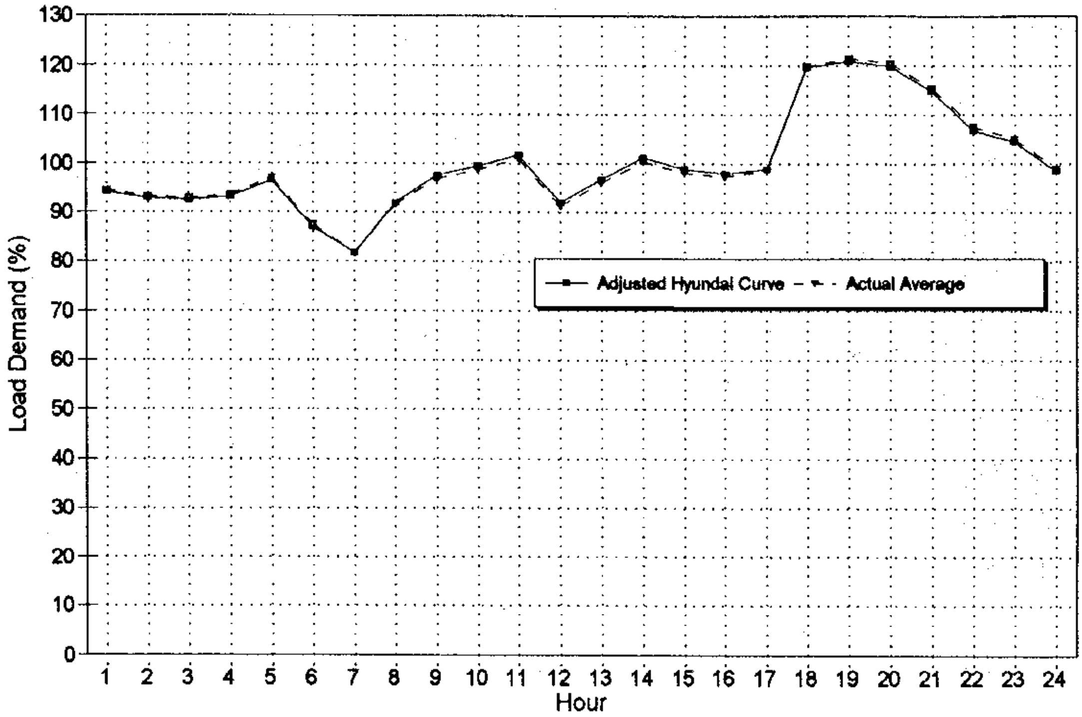


Figure 4-9 Load Pattern Adjusted to match The Actual Daily Load Curve (Normalized)

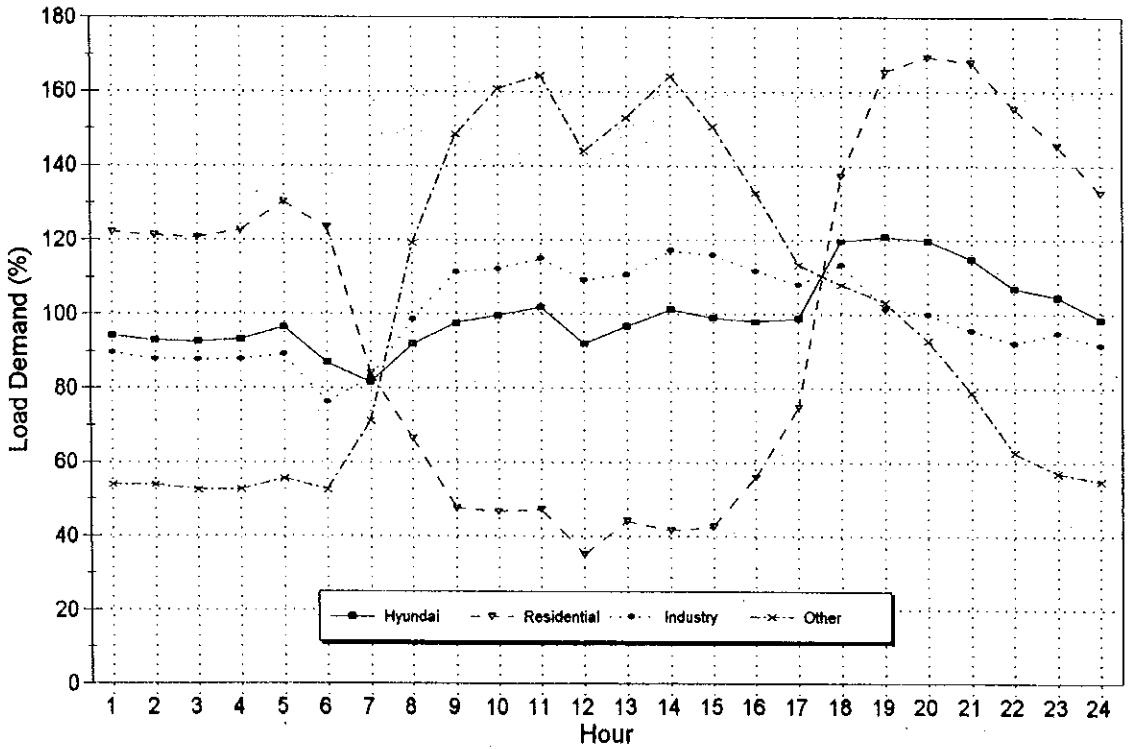


Figure 4-10 Adjusted Sectorial Load Patterns (Normalized)

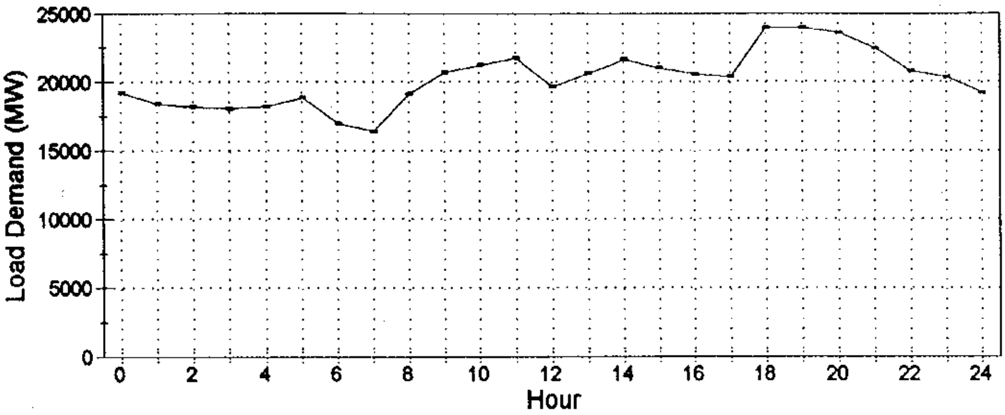


Figure 4-11 Forecasted Daily Load Curve in 2004

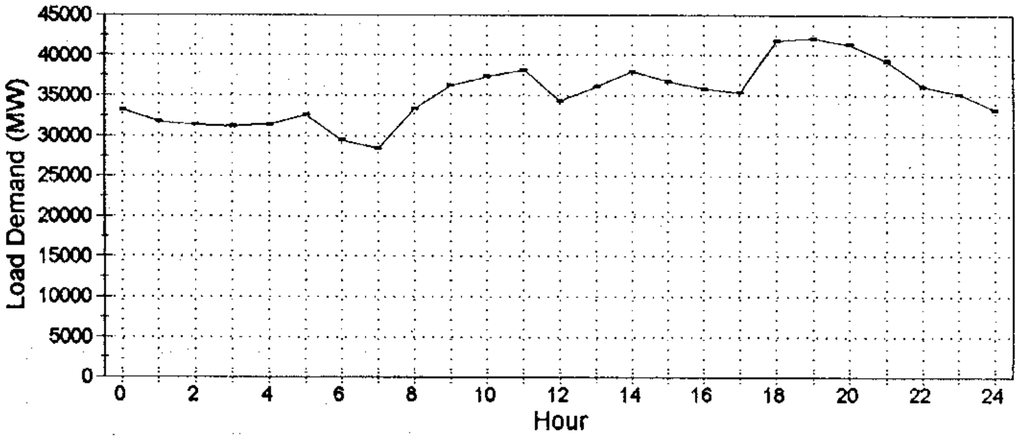


Figure 4-12 Forecasted Daily Load Curve in 2010

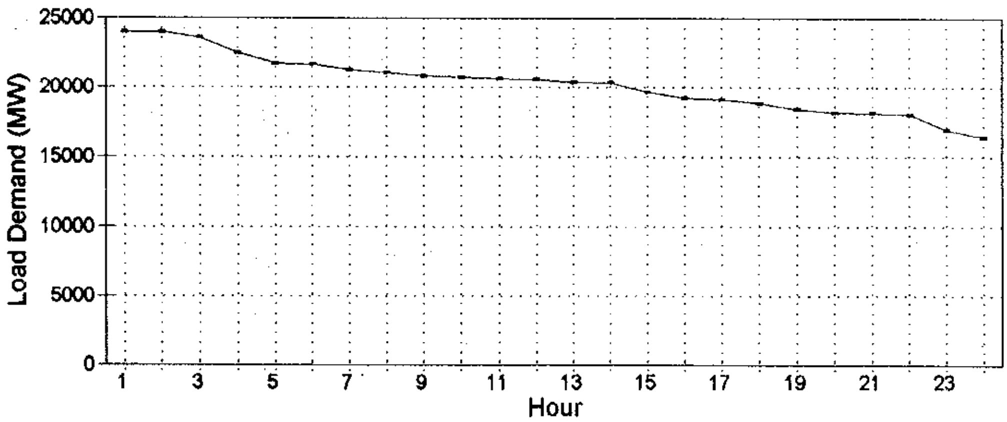


Figure 4-13 Forecasted Daily Load Duration Curve in 2004

4.2. Project Scale

A development scale of the Upper Cisokan Pumped Storage Project was selected through sociological, technical and economical considerations such as topographical limitations, geological site conditions, environmental impact, requirements of the power system operation etc.

4.2.1. Required Storage Volume of Reservoirs

The Upper Cisokan Project is classified as a pure pumped storage plant which has no significant surface water flow.

According to the forecasted daily load curve, an available night pumping time is expected to be about 6.5 hours and consequently an available full output generation time for a daily cycle will be about 5.0 hours, which is explained by the following formulation;

$$\text{Available pumping time (6.5 hours)} \times \text{cycle efficiency (0.7)} \times \text{charge to discharge ratio (1.09)} \fallingdotseq 5.0 \text{ hours}$$

On the other hand, the amount of energy to be stored in the upper reservoir is that the plant can generate through the peak demand periods of days during which the electrical demand is the greatest. A required equivalent full output generation time is estimated to be about 4.0 hours per day.

With reference to the study above, both upper and lower reservoirs are planned to have active storage volume required for the equivalent full output generation time of 6.5 hours, including an emergency power reserve and to cope with change in daily load shapes in the future.
The pumping energy for a recovery operation of the upper reservoir water level for emergency operation is likely to be available on the week end.

Typical daily operation patterns are shown in Figures 4-14 and 4-15.

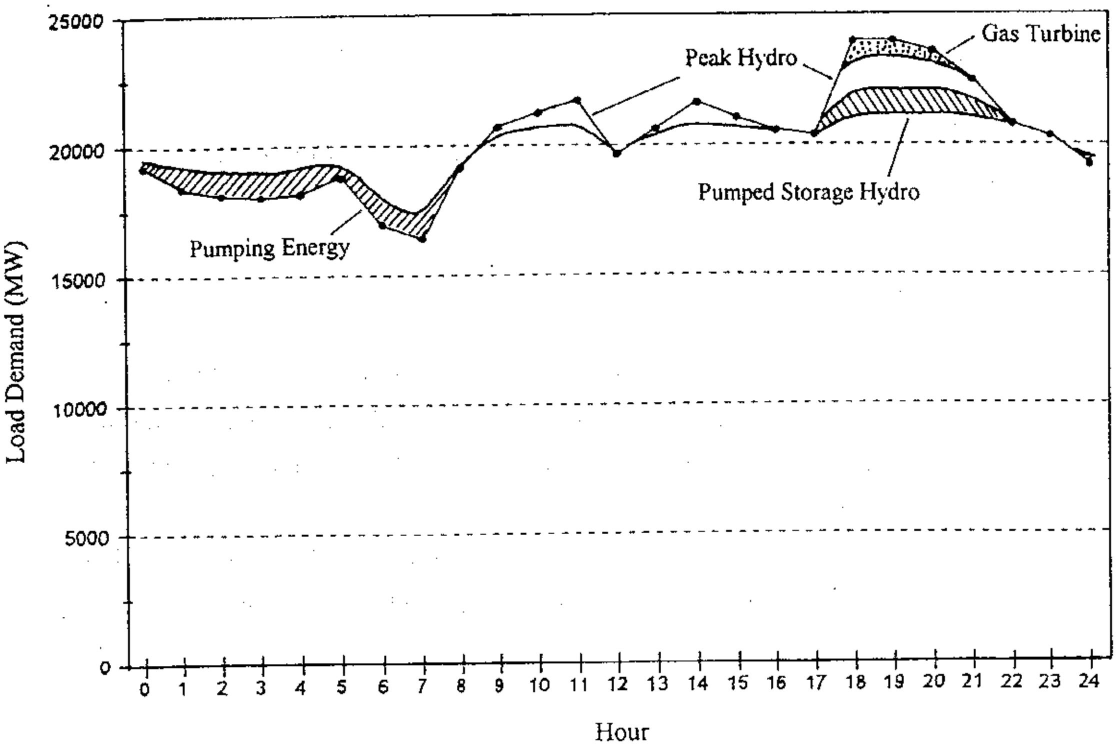


Figure 4-14 Typical Daily Operation Pattern in 2004

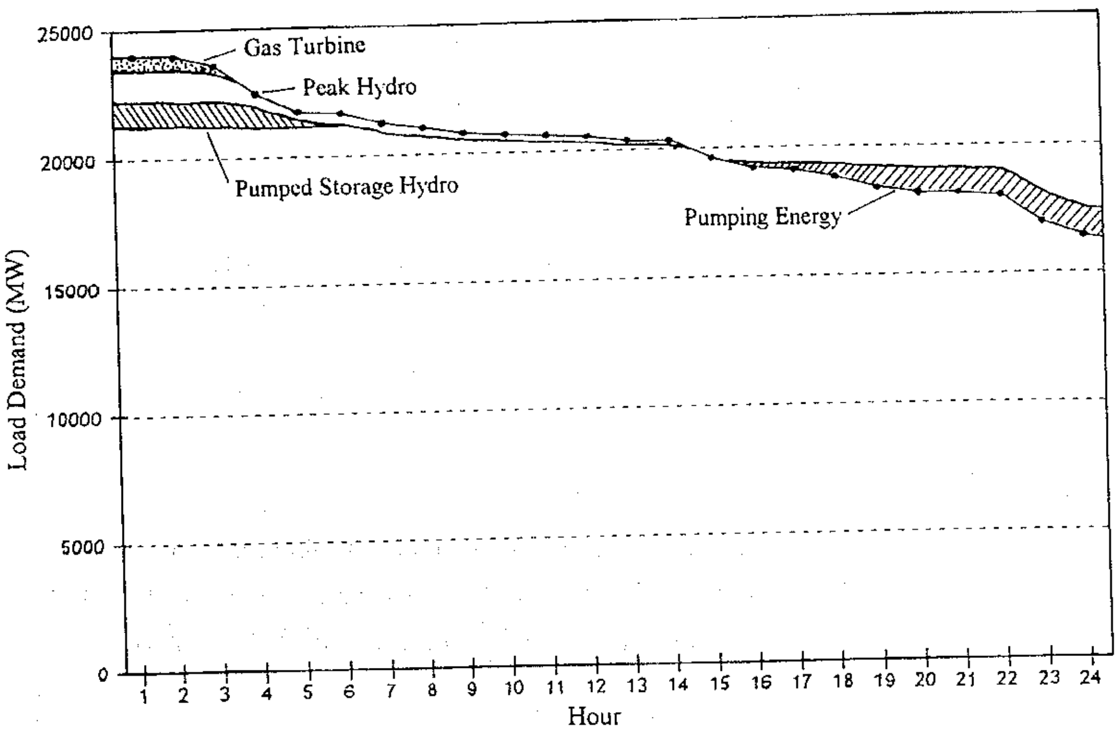


Figure 4-15 Typical Daily Operation Duration in 2004

4.2.2. Formulation of Alternative Installed Capacity (refer to Table 4-5)

4.2.2.1. Determination of High and Low Water Level of Reservoirs

H-V curves and H-A curves in both reservoirs each are shown in Figure 4-16 ~ 4-19.

(1) Upper Dam

As pointed in the Chapter 5, the existence of a saddle in the north tail of the upper reservoir creates the critical conditions on determination of the high water level, which leads the restriction that the high water level should be lower than EL. 800.0 m.
Under this consideration the following case studies with changing the high water level below EL. 799.0 m have been conducted in the optimization study.

	H.W.L.
• Case-1 :	EL. 799.0 m
• Case-2 :	EL. 796.0 m
• Case-3 :	EL. 793.0 m

While, the low water level has been decided as follows:

- Sedimentation Level : EL. 766.3 m
- Sill Level of Intake : EL. 767.0 m
- Water Depth from Sill of Intake to L.W.L. : 1.5 times of Headrace Tunnel Diameter D
- L.W.L. : EL. 767.0 + 1.5 D

(2) Lower Dam

The lower water level has been initially determined taking into account the sedimentation level of EL. 492.0 m and necessary water depth over 1.7 times of the tailrace tunnel diameter D. Consequently, the low water level is:

- L.W.L. : El. 492.0 m + 1.7 D

The high water level has been calculated to keep the same active storage volumes as the upper reservoir and that is;

		H.W.L.
• Case-1	:	EL. 505.0 m
• Case-2	:	EL. 504.0 m
• Case-3	:	EL. 503.0 m

4.2.2.2. Other Conditions

(1) On the basis of the selected H.W.L.s and L.W.L.s of the upper and lower reservoirs, the rated gross head and the active storage volume are computed.

Rated Gross Head = Upper (H.W.L. + L.W.L.)/2 - Lower (H.W.L. + L.W.L.)/2

Further, the maximum discharge is also calculated by the required generation time and active storage volume.

(2) The headrace tunnel is in a range of 6.1 m and 7.5 m inner diameter depending on the maximum discharges under the constant velocity of 6.0 m/sec.

(3) The inner diameters of the penstocks and tailrace tunnels have been determined in the same manner as (2) with constant velocity in the penstocks being 8.0 m/sec.

4.2.2.3. Case-4 (Ref. to Fig. 4.15 and 4.16)

In order to minimize the possible environmental problem this case has been studied. This case is termed the upstream Alternative II site in the upper reservoir. The sedimentation level at this case is at EL. 784.0 m which is 18 m higher than that of the other case.

Since the high water level is restricted below EL. 800.0 m, the active storage volume is computed only 1.8 M m^3. It is noted that the storage volume is too small to meet the requirement comparing with other cases.

Table 4-5 Alternative Capacity

Case		1	2	3	4
Site in the Upper Reservoir			***Downstream***		***Upperstream II***
Main Features of the Project					
(1) Generation Time		6.5	6.5	6.5	6.5
(2) Reservoir Scale					
Upper reservoir H.W.L.	(m)	799.0	796.0	793.0	800.0
Upper reservoir L.W.L.	(m)	776.0	777.0	776.0	790.5
Lower reservoir H.W.L.	(m)	505.0	504.0	503.0	498.0
Lower reservoir L.W.L.	(m)	500.0	500.0	499.5	497.0
Rated gross head	(m)	285	285	283	298
Active storage	($x10^6$ m^3)	13.0	10.1	8.2	1.8
(3) Waterway Structures					
1) Headrace tunnel					
Number		3	2	2	1
Inside diameter	(m)	6.3	6.8	6.1	4.0
Velocity	(m/s)	5.9	5.9	6.0	6.1
2) Penstock					
Number		3	2	2	1
Inside diameter	(m)	5.4	5.9	5.3	3.5
Velocity	(m/s)	8.1	7.9	7.9	8.0
3) Tailrace tunnel					
Number		6	4	4	2
Inside diameter	(m)	4.4	4.8	4.3	2.9
Velocity	(m/s)	6.1	6.0	6.0	5.8
Head Losses		14.9	13.6	15.0	21.7
Installed Capacity					
(1) Max. Discharge	(m^3/s)	556	432	350	77
(2) Rated Net Head	(m)	270.1	271.4	268.0	276.3
(3) Machine Efficiency	(%)	87.0	87.0	87.0	87.0
(4) Installed Capacity	(MW)	***1,280***	***1,000***	***800***	***181***

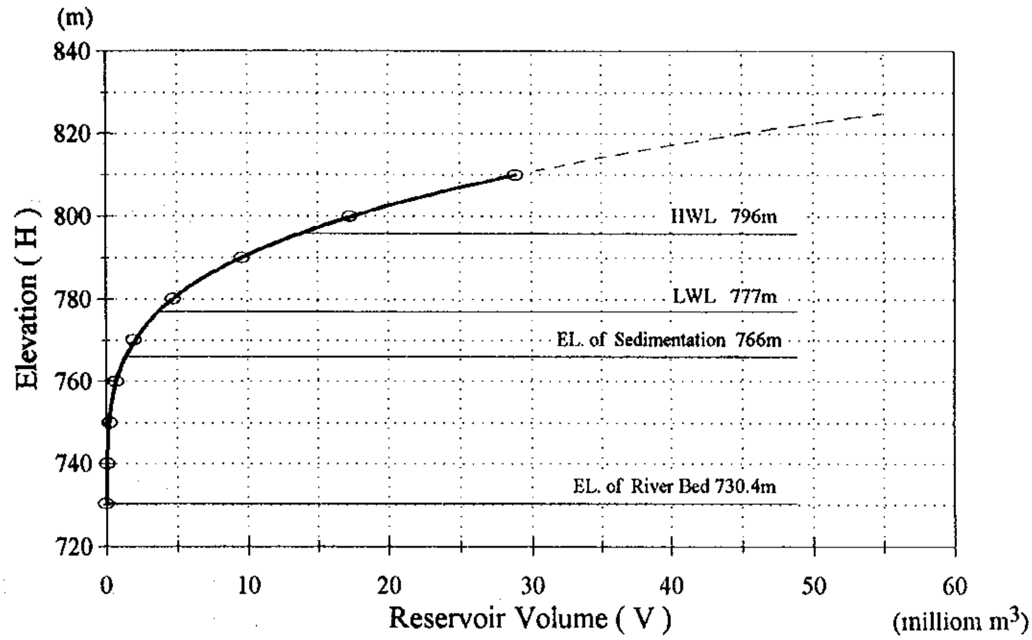


Figure 4-16 Upper Reservoir H-V Curve

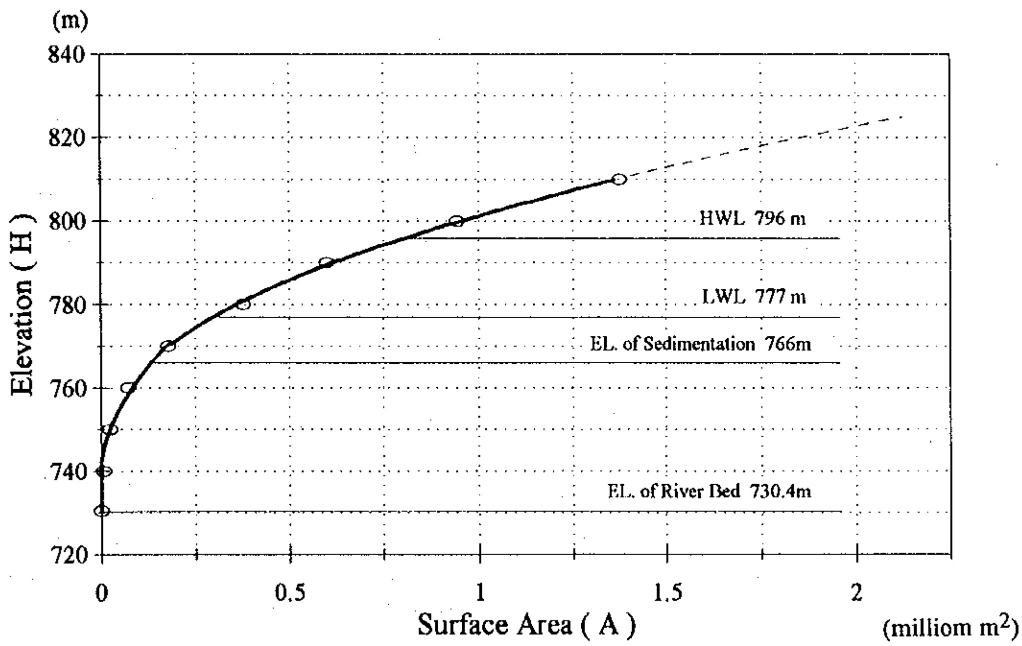


Figure 4-17 Upper Reservoir H-A Curve

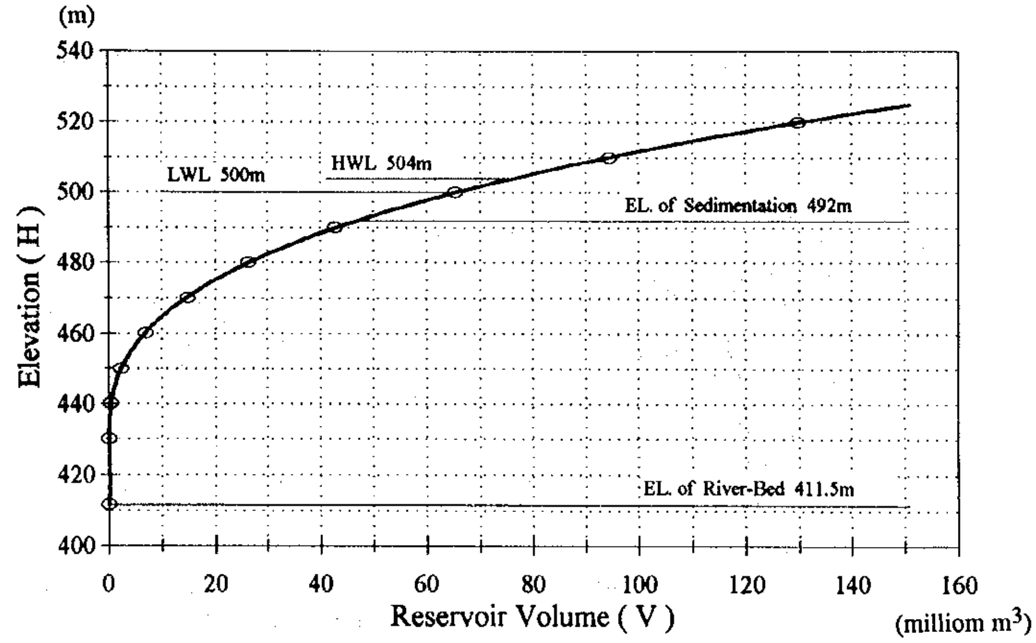


Figure 4-18 Lower Reservoir H-V Curve

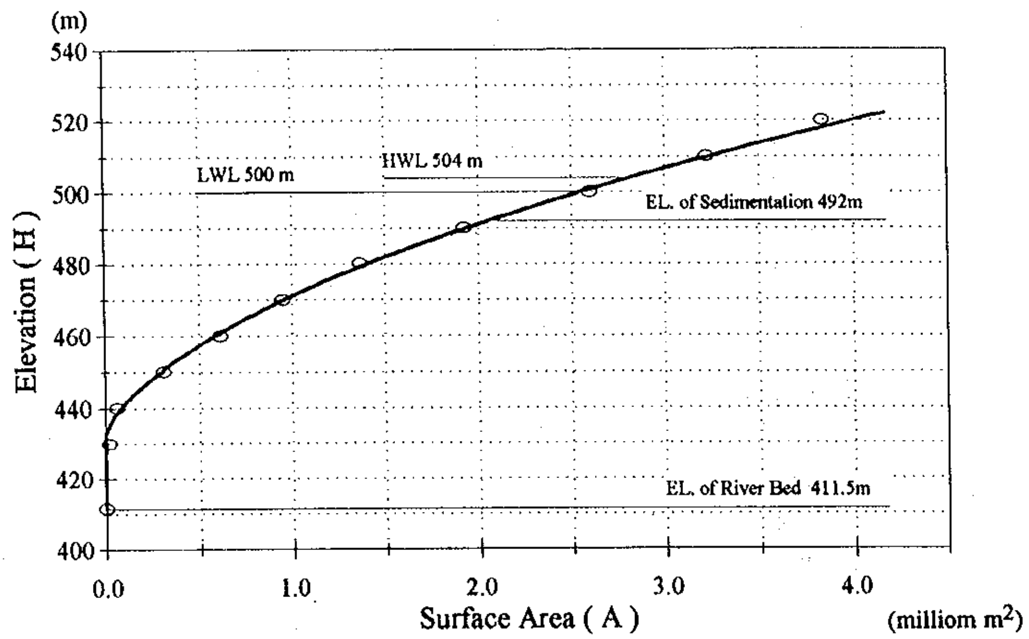


Figure 4-19 Lower Reservoir H-A Curve

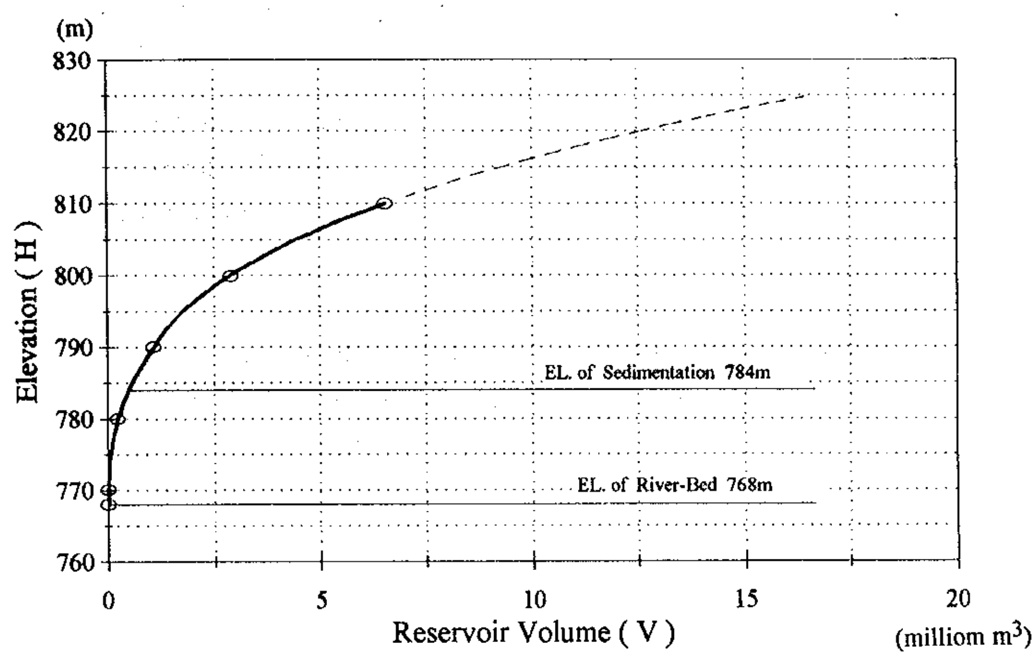


Figure 4-20 Upper Reservoir (Alternative II) H-V Curve

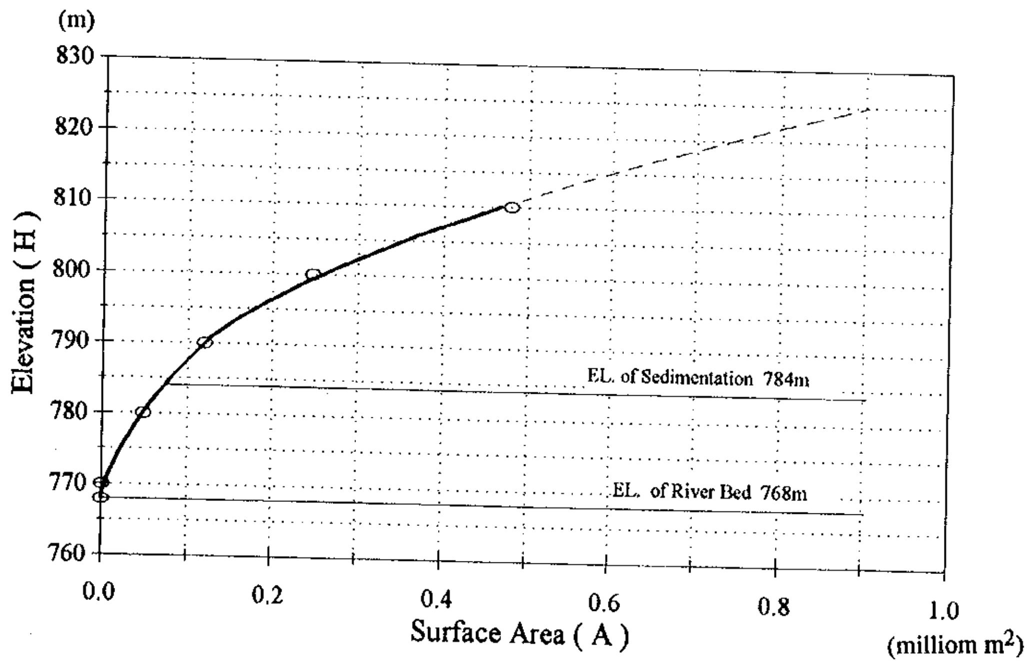


Figure 4-21 Upper Reservoir (Alternative II) H-A Curve

4.2.2.4. Result of Case Studies

The possible installed capacity for each case is summarized below;

		Upper Reservoir	Installed Capacity
• Case 1	:	H.W.L. 799.0 m	around 1,280 MW
• Case 2	:	H.W.L. 796.0 m	around 1,000 MW
• Case 3	:	H.W.L. 793.0 m	around 800 MW

The optimization of the project scale is finalized after comparative study on the project cost and environmental impact study, etc. in Section 4.2.3.

4.2.3. Comparative Study of Alternative Project Scales

Economic comparison of three alternative project scales, excluding Alternative Case-4 was made.

Maximum unit size is limited to 250 MW according to the study on unit size described in Section 7.3.1. Economic evaluation for the pumped storage plants after a site selection could generally be made by comparison of project cost per plant capacity (project cost/total installed capacity)

The results of the comparative study are given in Table 4-6.

From this results, it follows that the most economical project scale is decided as 1,000 MW among these alternatives because this scale leads the cheapest project cost per unit installed capacity of 673 US$/kW among the cases studied.

Table 4-6 Economic Comparison of Alternative Project Scale

Case	1	2	3
Project Scale			
Total installed capacity	1,280 MW	1,000 MW	800 MW
Unit capacity	213 MW	250 MW	200 MW
No. of units	6 Units	4 Units	4 Units
Project Cost (in US$ 1,000)			
1. Preparatory Works	**45,372**	**42,700**	**40,135**
Temporary Facilities	13,424	12,747	12,045
Access Roads	14,759	14,759	14,759
Land Acquisition and Compensation	17,189	15,194	13,331
2. Civil Works	**247,436**	**210,276**	**187,424**
Upper Dam	34,775	29,922	26,559
Lower Dam	94,569	88,424	84,242
Waterways	56,842	43,253	35,582
Underground Powerhouse	48,800	38,184	30,548
Switchyard	12,450	10,493	10,493
3. Metal Works	**48,207**	**37,838**	**30,177**
Penstocks	41,148	32,210	25,758
Gates	7,059	5,628	4,419
4. Electro-Mechanical Works	**379,900**	**264,000**	**234,000**
Pump-Turbines and Auxiliaries	151,300	108,000	94,700
Generator-Motors and Auxiliaries	167,700	114,000	101,200
Transformers and 500 kV Switchyard	60,900	42,000	38,100
5. Base Cost (1+2+3+4)	**720,915**	**554,814**	**491,736**
6. Engineering Fee	**50,464**	**38,837**	**34,421**
Detailed Design Stage	7,209	5,548	4,917
Construction Stage	43,255	33,289	29,504
7. Owner's Administration	**14,418**	**11,096**	**9,835**
8. Total Base Cost (5+6+7)	**785,797**	**604,747**	**535,992**
9. Physical Contingencies	**83,211**	**68,184**	**60,933**
10. Project Cost (8+9)	**869,008**	**672,931**	**596,925**
Project Cost per Installed Capacity	**679**	**673**	**746**

4.3. Power Generation Expansion Plan

4.3.1. Generating Power Sources

(1) Existing Generating Facilities

The installed capacity of generating facilities owned by PLN in Java-Bali power system in 1992 are 6,357 MW as listed below.

Thermal Plant	**4,393 MW**
Gas Turbine	667 MW
Steam Oil Fired	1,900 MW
Steam Coal Fired	1,600 MW
Geothermal	140 MW
Diesel	86 MW
Hydro Power Plant	**1,964 MW**
Total	**6,357 MW**

New projects with a total installed capacity of 7,320 MW are on-going and committed as listed in Table 4-7.

Load demands are supplied by combination of various type of generation power sources.
Base loads are provided mainly by oil-fired thermal plants, coal-fired thermal plants, geothermal plants and run-of-river type hydro plants. While peak loads are supplied mainly by peak hydro plants with large reservoirs and gas turbine plants.
Figure 4-22 shows composition of power generation loading by each generation power sources on October 7, 1992 for reference.

Table 4-7 ***Power Development Programme***
On-going and Committed Projects

Year	Plant	Capacity (MW)						
		Hydro	Geo-thermal	Coal Thermal	Diesel	Gas turbine	C/C	Total
1992/93	Kedungombo	23						
	Gresik (#1 - #3)						1,080	
	Muara Karang						324	
	Tulungagung	36						
								1,463
1993/94	Ex Tosan Prima					60		
	Paiton (#1)			400				
	Gresik (#1, #2)						332	
	Priok (#1, #2)						780	
	Tambak Lorok						324	
								1,896
1994/95	Paiton (#2)			400				
	Gresik (#3)						166	
	Priok (#1, #2)						420	
	Salak (#1, #2)		110					
	Muara Karang						190	
	Drajat (#1)		55					
	Bali					84		
								1,425
1995/96	Tulls	13						
	Tambak Lorok						190	
								203
1996/97	Suralaya (#5, #6)			1,200				
								1,200
1997/98	Cirata Stage II	500						
	Suralaya (#7)			600				
	Kesamben	33						
								1,133
Total								**7,320**

(2) Peak Supply Capacity

Among the existing hydro power plants, the following hydro power plants have large reservoirs.

Name of Plant	Installed Capacity
Saguling	700.0 MW
Cirata	504.0 MW
Jatiluhur	150.0 MW
Mrica	180.9 MW
K. Kates	105.0 MW
Total	**1,639.9 MW**

Of this five (5) power plants, Jatiluhur and Karang Kates are aimed at multi-purpose operation including irrigation discharge, thus, the flexibility in utilizing for peak generation is relatively small.

However, other three (3) power plants are possible to be operated for supplying peak load since the large reservoirs are utilized only for generation purpose. Installed capacity, annual generation energy and plant factor of these hydro power plants are summarized below:

Name of Plant	Installed Capacity	Annual Generated Energy	Plant Factor
Saguling	700 MW	1,974 GWh (2,078)	32 (33.9)
Cirata	504 MW	1,332 GWh (1,192)	30 (27.0)
Mrica	184 MW	600 GWh	37

Figures in ( ) show the actual record in 1991/92.

However the Saguling and Cirata hydro power plants are operated under control of load frequency control system, peak operation is limited corresponding to available discharge by months.

Table 4-8 presents monthly actual generation records and assumed possible peak generation time on condition that one unit is operated for 24 hours a day with 50 % of maximum output for load frequency control.

Judging from the fact in Figure 4-22 and Table 4-8, the power supply balance in the Java-Bali power system will fall short of the peak supply capacity in the future and new peak load generation sources will be required.

Pumped storage hydro plants gain various advantages as peak load generation source itemized below:

a) storing large energy by the most efficient and practical means
b) leveling peaks and valleys of an electrical load curve
c) providing a higher overall system efficiency than gas turbines
d) regulating frequency to meet sudden load change
e) providing stable peaking power throughout the year

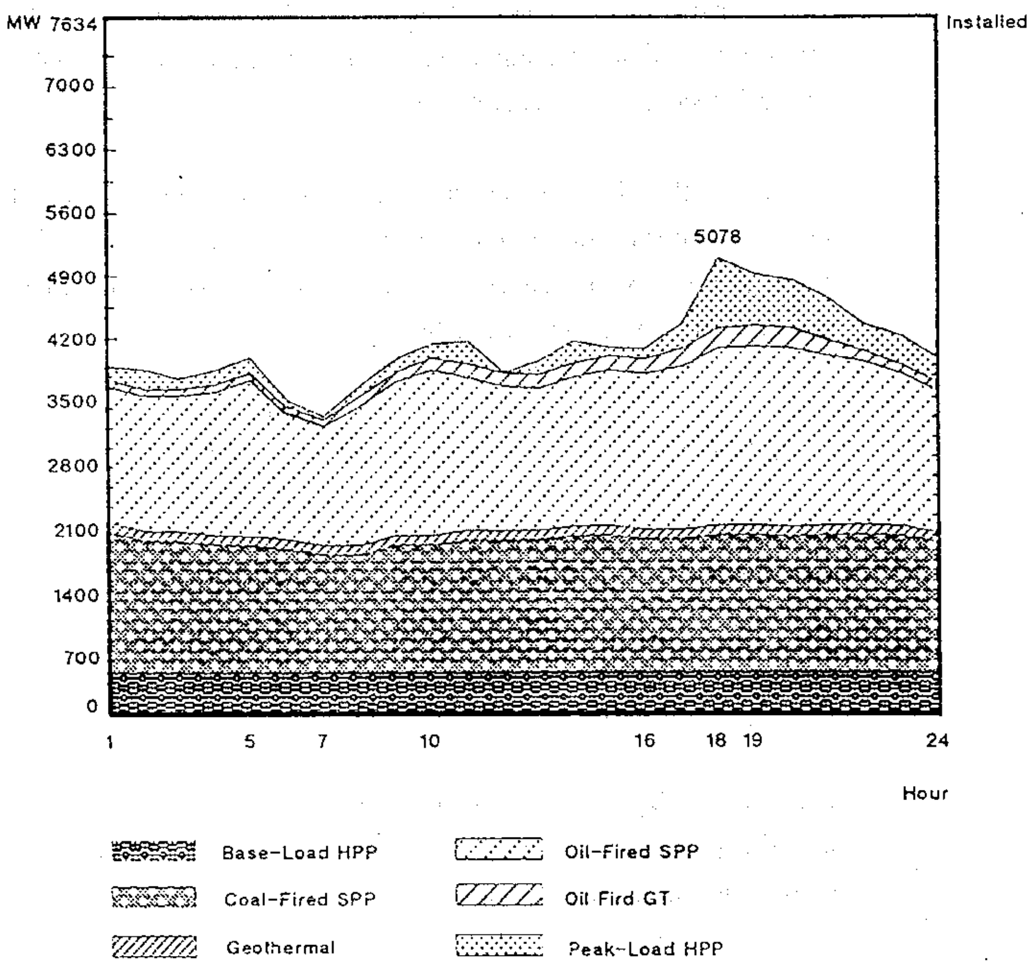


Figure 4-22 Composition of Power Generation Loading in Java-Bali System During Peak Load of 1992/93 on October 7, 1992

Table 4-8 Peak Supply Sources

Month	Saguling (700 MW)			Cirata (504 MW)		
	(1)	(2)	(3)	(1)	(2)	(3)
1991. 4	332 GWh	15.81 hr	12.81 hr	172 GWh	11.38 hr	8.38 hr
5	191	8.80	7.80	103	6.59	3.59
6	196	9.33	6.33	103	6.81	3.81
7	115	5.30	2.30	66	4.22	1.22
8	73	3.36	0.36	51	3.26	0.26
9	73	3.47	0.47	58	3.84	0.84
10	48	2.21	0	52	3.33	0.33
11	51	2.43	0	54	3.57	0.57
12	246	11.34	8.34	145	9.28	6.27
1992. 1	228	10.51	7.51	126	8.06	5.06
2	218	11.12	8.12	108	7.65	4.65
3	307	14.15	11.15	154	9.86	6.86
Total	2,078	8.13	-	1,192	6.58	-

(1) Monthly generation energy in 1991/92

(2) Equivalent full output generation time a day

(3) Possible peak generation time in case one unit out of installed units is operated with half load for load frequency control.

4.3.2. Optimum Power Development Programme

To meet rapid increase of the electricity demand in the future, new generating facilities should be constructed with optimum mix comprised coal fired thermal, geothermal, gas turbine, hydro power, pumped storage hydro power plants etc.

(1) Methodology used for Development Programme

The power development programme was studied by using the software PRO-SCREEN II which is mostly the same as the ELECTRIC module of EN-PEP/WASP III. The optimum power development programme is determined by dynamic programming taking into consideration the least cost system, reliability, and construction restrictions for commissioning years of alternative plants. The development program is developed up to the year 2010.

(2) Criteria for Development Programme Calculation

The following criteria are used for the power development programme.

a) Reserve margin and reliability criteria

- Reserve margin : 25 % minimum and 40 % maximum taking into account loss of load probability (LOLP) and loss of load hours (LOLH)

- LOLP and LOLH : 1 day per year LOLP and 24 hours per year LOLH as maximum target

b) Project costs and parameters of alternative plants

Project costs of the alternative plants are estimated at 1994 price level and excluded price contingencies, interest during construction (IDC) and value added tax (VAT).
Construction costs for associated transmission lines are excepted for this optimization study, since the sites of alternative plants are assumed to be at the same location.
Table shows the project costs and parameters of the alternative plants.

Table 4-9 Project Cost and Parameters of Plants

Type of Plant	Project Cost (US$/kW)	SMD (days/y)	FOR (%)	Fuel Cost ($/MWh)	Plant Life (Years)	Fixed O/M Cost ($/kW·y)	Variable O/M Cost ($/MWh)
Coal Thermal (600 MW)	1,048	56	8	14.87	25	22.40	1.73
Gas Turbine (120 MW)	590	28	4	47.59	15	16.50	2.21
Pumped Storage (1,000 MW/Site)	667	6	1	21.24	40	5.34	-
Nuclear	2,409	51	7	7.103	40	41.89	0.01

Note : SMD : Scheduled maintenance days
FOR : Forced Outage Rate

c) Fuel cost escalation

Domestic Coal	: 1 % per year
Nuclear Fuel	: 2 % per year (yellow cake price basis)

d) Discount rate : 10 %

e) Power losses

Transmission & distribution losses	: 12.1 %
Plant use	: 4.2 %
Total losses	: 16.3 %

(3) Scenarios for Optimum Power Development Programme

The optimization calculations for the power development programme up to the time frame of 2010 were conducted for the following four scenarios:

a) Scenario-1

Power development up to 1999 is fixed with the on-going and committed projects as listed in Table 4-7.
Future power demand increased after 2000 is managed by construction of new power sources such as coal fired thermal and gas turbine plants.

b) Scenario-2

Upper Cisokan and other pumped storage plants are added to the new power sources in the Scenario-1.

c) Scenario-3

Nuclear plants are added to the new power sources in the Scenario-2.

d) Schenario-4

Optimum power development programme was studied based on PLN's load demand forecast (RUKN 1993) and the same new power sources in Scenario-2.

The earliest completion times for the alternative power sources are envisaged taking into account of realistic construction schedules as follows:

- Coal fired thermal power plants : 2000

- Nuclear plants : 2004
- Upper Cisokan pumped storage plant : 2004
- Other pumped storage plants : 2005
- Gas turbine plants : no restriction

(4) Results of Optimization Calculation

The results of the power development program (PDP) optimization calculation are shown in the Appendices with the summary of the results shown in Tables 4-10 to 4-13.

Table 4-10 Results of PDP Optimization Calculation (Scenario-1)

Year	Peak Load (MW)	Installed Capacity (MW)	UPPE 1000	COL6 600	PS10 1000	GT12 120
1994	7,253.4	10,584.2	0	0	0	0
1995	9,856.2	12,277.2	0	0	0	0
1996	10,936.4	15,037.2	0	0	0	0
1997	12,138.5	16,837.2	0	0	0	0
1998	13,386.2	18,851.2	0	0	0	0
1999	14,707.3	20,856.2	0	0	0	0
2000	16,394.5	22,995.2	0	3	0	3
2001	18,048.8	25,515.2	0	3	0	3
2002	19,886.3	28,155.2	0	4	0	2
2003	21,913.3	30,885.2	0	3	0	3
2004	23,963.9	33,494.2	0	4	0	3
2005	26,533.6	36,968.2	0	6	0	3
2006	28,957.8	40,208.2	0	5	0	2
2007	31,792.0	43,768.2	0	6	0	3
2008	34,952.9	48,008.2	0	7	0	3
2009	38,388.1	52,368.2	0	7	0	3
2010	42,102.0	57,288.2	0	8	0	1

UPPE - Upper Cisokan pumped storage station with 1,000 MW capacity
COL6 - typical coal thermal unit with 600 MW capacity
PS10 - typical pumped storage station with 1,000 MW capacity
GT12 - typical gas turbine unit with 120 MW capacity

Table 4-11 Results of PDP Optimization Calculation (Scenario-2)

Year	Peak Load (MW)	Installed Capacity (MW)	UPPE 1000	COL6 600	PS10 1000	GT12 120
1994	7,253.4	10,584.2	0	0	0	0
1995	9,856.2	12,277.2	0	0	0	0
1996	10,936.4	15,037.2	0	0	0	0
1997	12,138.5	16,837.2	0	0	0	0
1998	13,386.2	18,851.2	0	0	0	0
1999	14,707.3	20,856.2	0	0	0	0
2000	16,394.5	22,995.2	0	3	0	3
2001	18,048.8	25,515.2	0	3	0	3
2002	19,886.3	28,155.2	0	4	0	2
2003	21,913.3	30,885.2	0	3	0	3
2004	23,963.9	33,294.2	1	2	0	3
2005	26,533.6	36,568.2	0	4	1	3
2006	28,957.8	39,128.2	0	2	1	3
2007	31,792.0	43,288.2	0	7	0	3
2008	34,952.9	46,928.2	0	6	0	3
2009	38,388.1	51,088.2	0	5	1	3
2010	42,102.0	56,008.2	0	8	0	1

UPPE - Upper Cisokan pumped storage station with 1,000 MW capacity
COL6 - typical coal thermal unit with 600 MW capacity
PS10 - typical pumped storage station with 1,000 MW capacity
GT12 - typical gas turbine unit with 120 MW capacity

Table 4-12 Results of PDP Optimization Calculation (Scenario-3)

Year	Peak Load (MW)	Installed Capacity (MW)	UPPE 1000	COL6 600	NUC6 600	NUC9 900	PS10 1000	GT12 120
1994	7,253.4	10,584.2	0	0	0	0	0	0
1995	9,856.2	12,277.2	0	0	0	0	0	0
1996	10,936.4	15,037.2	0	0	0	0	0	0
1997	12,138.5	16,837.2	0	0	0	0	0	0
1998	13,386.2	18,851.2	0	0	0	0	0	0
1999	14,707.3	20,856.2	0	0	0	0	0	0
2000	16,394.5	22,995.2	0	3	0	0	0	3
2001	18,048.8	25,515.2	0	3	0	0	0	3
2002	19,886.3	28,275.2	0	4	0	0	0	3
2003	21,913.3	31,005.2	0	3	0	0	0	3
2004	23,963.9	33,414.2	1	1	1	0	0	3
2005	26,533.6	36,388.2	0	2	0	1	1	3
2006	28,957.8	39,248.2	0	1	0	1	1	3
2007	31,792.0	42,808.2	0	6	0	0	0	3
2008	34,952.9	47,048.2	0	7	0	0	0	3
2009	38,388.1	51,508.2	0	4	0	1	1	3
2010	42,102.0	55,768.2	0	5	0	1	0	3

UPPE - Upper Cisokan pumped storage station with 1,000 MW capacity
COL6 - typical coal thermal unit with 600 MW capacity
NUC6 - typical nuclear unit with 600 MW capacity
NUC9 - typical nuclear unit with 900 MW capacity
PS10 - typical pumped storage station with 1,000 MW capacity
GT12 - typical gas turbine unit with 120 MW capacity

Table 4-13 ***Results of PDP Optimization Calculation (Scenario-4)***
(Based on PLN's Load Demand Forecast)

Year	Peak Load (MW)	Installed Capacity (MW)	UPPE 1000	COL6 600	PS10 1000	GT12 120
1994	7,907.9	10,584.2	0	0	0	0
1995	9,848.0	12,277.2	0	0	0	0
1996	10,927.3	15,037.2	0	0	0	0
1997	12,128.4	16,837.2	0	0	0	0
1998	13,375.0	18,851.2	0	0	0	0
1999	14,695.0	20,856.2	0	0	0	0
2000	16,056.7	22,995.2	0	3	0	3
2001	17,396.2	24,915.2	0	2	0	3
2002	18,825.5	26,475.2	0	2	0	3
2003	20,351.7	28,605.2	0	2	0	3
2004	22,106.7	31,014.2	1	2	0	3
2005	24,011.0	33,088.2	0	2	1	3
2006	26,056.6	35,648.2	0	2	1	3
2007	28,274.7	38,608.2	0	5	0	3
2008	30,709.1	41,648.2	0	5	0	3
2009	33,330.7	44,608.2	0	3	1	3
2010	36,467.4	48,568.2	0	6	0	3

UPPE - Upper Cisokan pumped storage station with 1,000 MW capacity
COL6 - typical coal thermal unit with 600 MW capacity
PS10 - typical pumped storage station with 1,000 MW capacity
GT12 - typical gas turbine unit with 120 MW capacity

The result of the study shows that :

- the optimum development timing of the Upper Cisokan Project for all Scenarios is 2004 which is the possible earliest completion time of the Project.
- Four (4) sites of pumped storage plants with 4,000 MW of total capacity shall be developed until 2010. This means optimum development share of the pumped storage plants to the total generating facilities is about 7 %.

(5) System Costs

System costs after the year of 2000 to 2010 are calculated for Scenario-1 and Scenario-2 as shown on Table 4-14.

The system costs include fuel cost and O/M cost, and capital cost for the plants newly developed after the year of 2000.

The calculation results could be interpreted that introduction of the pumped storage hydro plants will reduce the system costs by difference of the system costs between Scenario-1 and Scenario-2.

Table 4-14 Comparison of System Costs

Units : US$ x 10^6

Year	Scenario-1 Coal-fired plants, Gas turbine plants	Scenario-2 Coal-fired plants, Gas turbine plnats, Pumped storage plants	Difference Reduction of system cost
2000	2,518	2,518	0
2001	3,030	3,030	0
2002	3,656	3,656	0
2003	4,218	4,218	0
2004	4,889	4,819	70
2005	5,800	5,659	141
2006	6,613	6,341	272
2007	7,584	7,373	211
2008	8,692	8,378	314
2009	9,847	9,461	386
2010	11,122	10,716	406

5. PROJECT SITE CONDITIONS

5. PROJECT SITE CONDITIONS

5.1. Topography

5.1.1. Survey Work

The survey work was undertaken by PLN and composed of the ground survey and the aerial photographic one. The former covers the proposed area for the main civil structures such as the upper and lower dam sites, the intake and outlet, and the latter for the entire Project area.

The ground survey (terrestrial mapping) is cumulative to 0.64 km^2 and the aerial photographic survey (photogrammetric mapping) to 103 km^2.
The upper and lower reservoirs in the Project area were mapped by the orthophotographic method with the different scale from the aerial photo map.

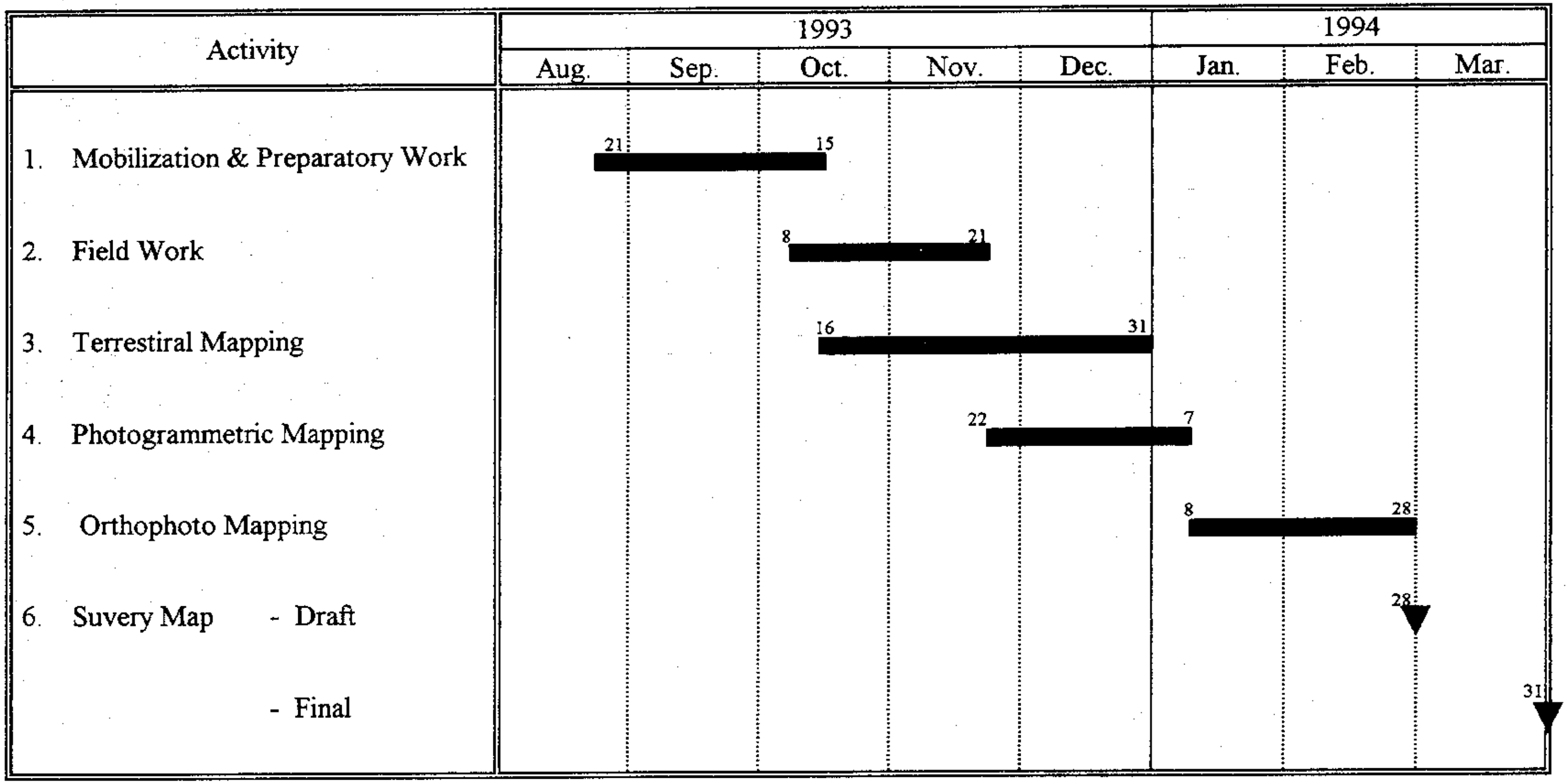
Table 5-1 Survey Works for the Project

Item	Location	Area (km^2)	Scale of Map
Ground Survey	Upper Dam site	0.32	1:1,000
	Lower Dam site	0.24	1:1,000
	Intake	0.04	1:1,000
	Outlet	0.04	1:1,000
		0.64	
Aerial Photographic Survey	Entire Project Area	103.0	1:10,000
Orthophotograph	Upper Reservoir	10.5	1:5,000
	Lower Reservoir	14.0	1:5,000
		24.5	

The location for the conducted survey area is referred to Drawings 5-1 and 5-2.

Mobilization and preparatory works were commenced on August 21, 1993 and field work was completed on November 21, 1993.
The mapping started on October 16, 1993 and draft maps were available in the end of February, 1993 as shown in Figure 5-1.

Figure 5-1 Actual Progress of Survey Works



5.1.2. <u>Topographic Characteristic</u>

5.1.2.1. Reservoir

(1) Upper Reservoir

The Cirumamis River joins a lot of tributaries in the reservoir showing various directions, which will create the reservoir with an evergreen shrub like shape. The reservoir is surrounded by mountains ranging from 900 m to 1,000 m high which consist of Tertiary volcanic and sedimentary rocks.
There are thin ridges in the northern part of the reservoir where has been clarified by the survey work and they are an important factor to determine H.W.L. for the upper reservoir.

(2) Lower Reservoir

The lower reservoir will extend narrowly along the Cisokan River. The Cisokan River joins the Cilengkong River at around 700 m upstream from the lower dam, where the outlet is planned and the reservoir will also extend along the Cilengkong River.
The lower reservoir is surrounded by mountains ranging from 700 m to 800 m high where are underlain by Tertiary rocks.
No particular problem for topography in the lower reservoir is pointed out.

5.1.2.2. Dam site

(1) Upper Dam

At the downstream dam site the Cirumamis River having about 17.0 m wide runs from the east to the west. The water level at the proposed dam centerline is about EL. 731.0 m. A slope inclination of the right bank is about 30° from the river bed up to EL. 775 m and 20° above EL. 775 m, and that of the left bank is about 25° up to EL. 770 m and 35° above EL. 770 m. The slope inclination at the dam site is generally gentle and the ratio of L/H is about 5.3. It is topographically characterized that there are a big creek at about 190 m upstream on the left bank and a waterfall over 50 m high at about 150 m downstream from the dam centerline.
Those topographic conditions restrict a selection of a dam location, type and/or height, respectively.

There is an alternative dam site which is about 360 m upstream from the above site. The water level at the proposed site is about EL. 739 m which is 8.0 m higher than that of the downstream site. The slope inclination of the right bank is about 25° and that of the left bank is about 30° up to EL. 765 m and about 13° above EL. 765 m. The ratio of L/H is about 6.7. It is topographically unfavourable that the left bank shows a very thin ridge for a dam abutment.

The topographic characteristic for the above is summarized below:

	Downstream Dam site	Upstream Alternative
River width	17.0 m	11.0 m
Water Level	EL. 731.0 m	EL. 739.0 m
Slope Inclination		
Right Bank	EL.731 - 775 m : 30° Above EL. 775 m : 20°	25°
Left Bank	EL.731 - 770 m : 25° Above EL. 770 m : 35°	EL.739 - 765 m : 30° Above EL. 765m : 14°
Crest Length (L)	391 m	530 m
Dam Height (H)	74 m	64 m
L/H	5.3	6.7
Dam Abutment	Slightly small at Left Bank	Very thin at Left Bank

Judging from the above comparison the topographic conditions of the downstream dam site are superior to those of the upstream alternative.
It shall be noted, however, that due to the existence of the big creek and waterfall the dam height, type and location will be restricted.

(2) Lower Dam

At the dam site the Cisokan River flows with the southeast - northwest direction. The water level is at about EL. 413 and the river 22.0 m wide.
The slope inclination of the right bank is about 38°. That of the left bank is about 52° up to EL. 470 m, about 23° from EL. 470 m to EL. 507 m and

becomes steeper above EL. 507 m. The ratio of L/H is about 3.2.
The topographic conditions are generally favourable for construction of a dam.

5.1.2.3. Waterway

The intake is located at the right bank of the Cibima River, about 200 m upstream from the confluence of the Cirumamis River. Because of development of small creeks perpendicular to the Cibima River the favourable location for the intake is restricted.
From the intake to STA. 97 m of the headrace tunnel a vertical cover is relatively thin having less than 50 m. From STA. 97 m onward the cover is getting thicker and the maximum cover is about 142 m at STA. 556 m.
From STA. 556 to STA. 1,100 m the cover is in a range of 100 m and 120 m and the surge tank is located at STA. 1,226 showing 50 - 55 m cover.
A minimum cover at H.W.L. of the surge tank is about 38 m and is equivalent to 2.5 times of the inner diameter of the surge tank.
The vertical cover along the penstock is maintained over 45 m and the max. coverage reaches about 240 m at the downstream end of the penstock.
At the underground powerhouse the cover ranges from 165 to 185 and the min. cover is equivalent to 3.3 times of the powerhouse height.
The tailrace tunnel is aligned slightly oblique to contour lines and the outlet is located at a relatively steep slope.
The topographic conditions along the waterway are characterized that the upstream section of the headrace tunnel is situated under the less cover and the surge tank and its surrounding are located in the slightly skinny ridge.

5.2. Geology

5.2.1. Geological Investigations

The geological/geotechnical investigations for the Project site were conducted dividing into the surface and sub-surface ones by PLN and their analytical study by the JICA Study Team.

5.2.1.1. Surface Investigation

The surface investigation was mainly practiced by reconnaissance survey, which covered the following sites using the foresaid topographic maps.

Table 5-2 Reconnaissance Survey Carried Out by PLN

Site	Used Map
(1) Reservoir (Lower & Upper reservoirs)	Scale 1 : 10,000
(2) Upper Dam site	Scale 1 : 1,000
(3) Lower Dam site	Scale 1 : 1,000
(4) Intake	Scale 1 : 1,000
(5) Outlet	Scale 1 : 1,000
(6) Waterway	Scale 1 : 10,000

After the relevant topographic maps were available, the reconnaissance was commenced in the dam sites on January 01, 1994 and followed the intake, outlet, water-way and completed in the reservoir on January 21, 1994.

5.2.1.2. Sub-surface and Other Investigation

The sub-surface investigation was made mainly by core drilling.
The core drilling was aimed at providing foundation conditions of the dam sites, intake, outlet and underground powerhouse, and verifying rock quality of the quarry site and permeability at the skinny ridge of the upper reservoir.
The drill holes ranged in depth from 10 to 300 m and were cumulative to 36 holes with 2,690 m long, the break-down of which is shown in Table 5-3.
In-situ permeability tests were conducted in all core drillings excluding 2 holes in the quarry site.
The location of the drilling holes is shown in Drawing 5-3.

Table 5-3 Detail of Rotary Drilling for the Project

Location		Reference No.	Coordinate X	Coordinate Y	Elevation (m)	Depth (m)	Angle (°)
Upper Dam	Downstream Site	UDF-1	747,056,638	9,230,693,224	821.6720	50	90
		UDF-2	747,024,418	9,230,439,389	731.2810	50	90
		UDF-3	747,104,937	9,230,268,483	796.6150	50	90
		UDF-7	747,157,769	9,230,579,775	799.4950	50	90
		UDF-8	747,120,009	9,230,403,130	735.1720	50	90
	Upstream Site (Alternative-I)	UDF-4	747,372,818	9,230,601,628	784.3720	50	90
		UDF-5	747,412,373	9,230,503,164	755.1400	50	90
		UDF-6	747,474,580	9,230,381,620	792.0170	50	90
Lower Dam		LDF-1	747,675,365	9,231,923,878	453.9734	50	90
		LDF-2	744,045,942	9,231,912,457	433.0326	70	60
		LDF-3	743,970,427	9,231,875,732	428.9964	70	60
		LDF-4	743,928,742	9,231,843,826	468.5133	50	90
		LDF-5	744,183,979	9,231,854,787	473.8762	50	90
		LDF-6	744,138,902	9,231,814,687	438.7522	70	60
		LDF-7	744,057,021	9,231,766,650	438.0478	70	60
		LDF-8	744,021,735	9,231,728,191	472.6084	50	90
Waterway	Intake	IF-1	747,405,482	9,230,747,348	786.8750	30	90
	Underground Powerhouse	UDF-1	746,907,200	9,231,008,466	862.7974	300	90
		UDF-2	746,834,066	9,231,047,195	892.0619	300	90
		UDF-3	745,922,004	9,231,128,739	754.2834	300	90
		UDF-4	745,871,833	9,231,195,653	691.5054	300	90
		UDF-5	746,056,570	9,231,084,575	768.3724	100	90
	Outlet	OF-1	745,656,929	9,231,444,058	467.8760	30	90
Skinny Ridge of Upper Reservoir		SR-1	747,005,284	9,231,300,828	822.8319	40	90
		SR-2	747,147,793	9,231,325,731	868.6409	40	90
		SR-3	747,082,857	9,231,217,319	844.1479	40	90
Quarry Site (G. Kencana)		QUF-1	753,546,660	9,229,748,488	1,104.6615	50	90
		QUF-2	753,606,719	9,229,725,302	1,174.9980	50	90
Borrow Pit		BF-1	747,431,901	9,231,111,374	835.4294	10	90
		BF-2	747,479,891	9,231,004,062	827.1084	10	90
		BF-3	747,554,716	9,230,855,027	802.7179	10	90
Upstream Alternative-II Site		UDF-9	747,435,769	9,230,648,632	787.4830	40	90
		UDF-10	747,513,703	9,230,712,932	753.5135	40	90
		UDF-11	747,513,228	9,230,940,564	818.7119	40	90
		UDF-12	747,722,308	9,230,861,079	768.6350	40	90
		UDF-13	747,784,429	9,230,812,227	800.4835	40	90

Total 36 holes, 2,690 m

The mobilization for the geological investigations was commenced in the beginning of September, 1993.

The core drilling started in the dam site and skinny ridge on September 22, 1993 and completed in the middle of January, 1994.

The other investigations were composed of the field and laboratory tests and seismic prospecting, etc.

The actual progress for the geological investigations is referred to Figures 5-2 and 5-3, respectively.

Figure 5-2 Actual Progress of Core Drilling

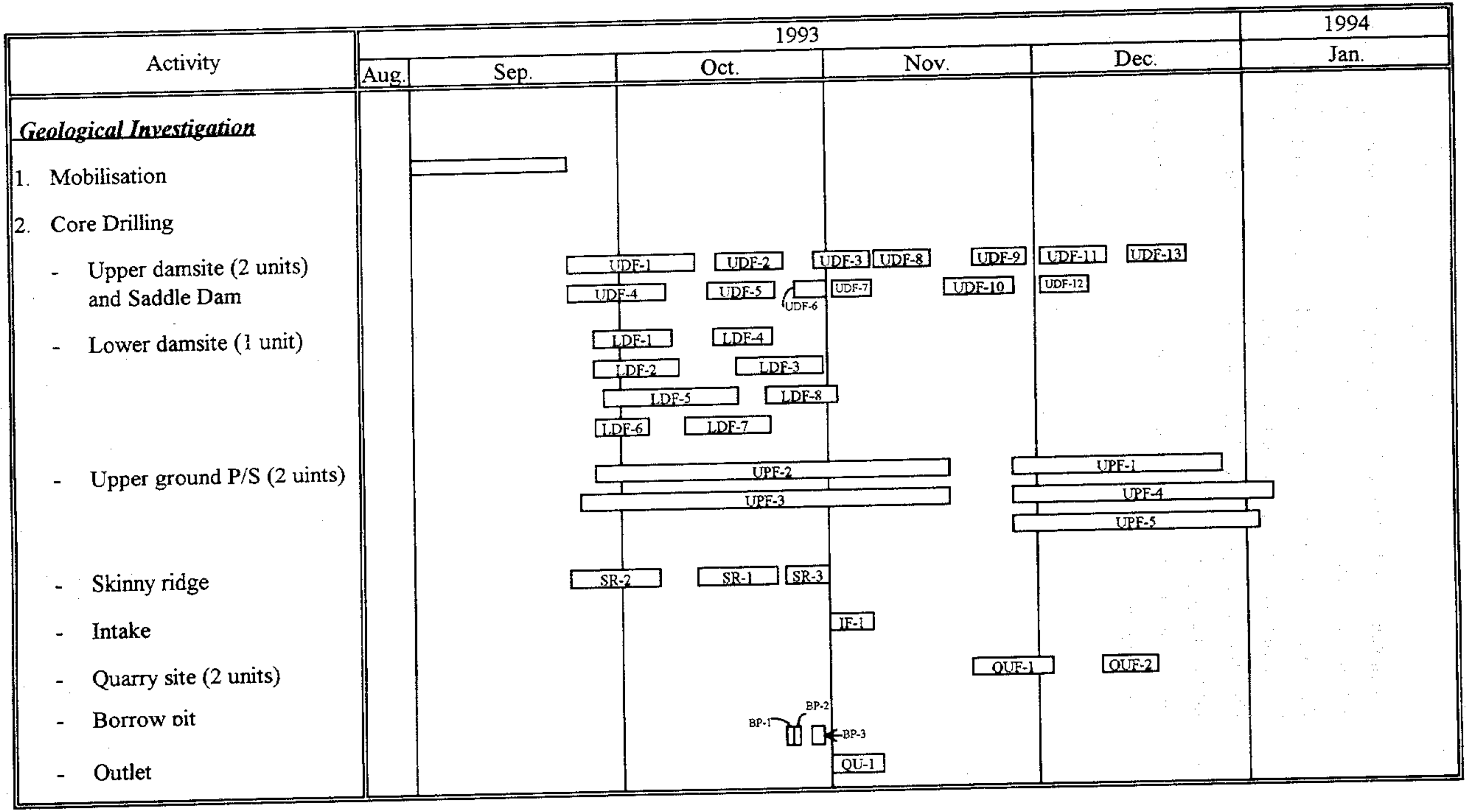
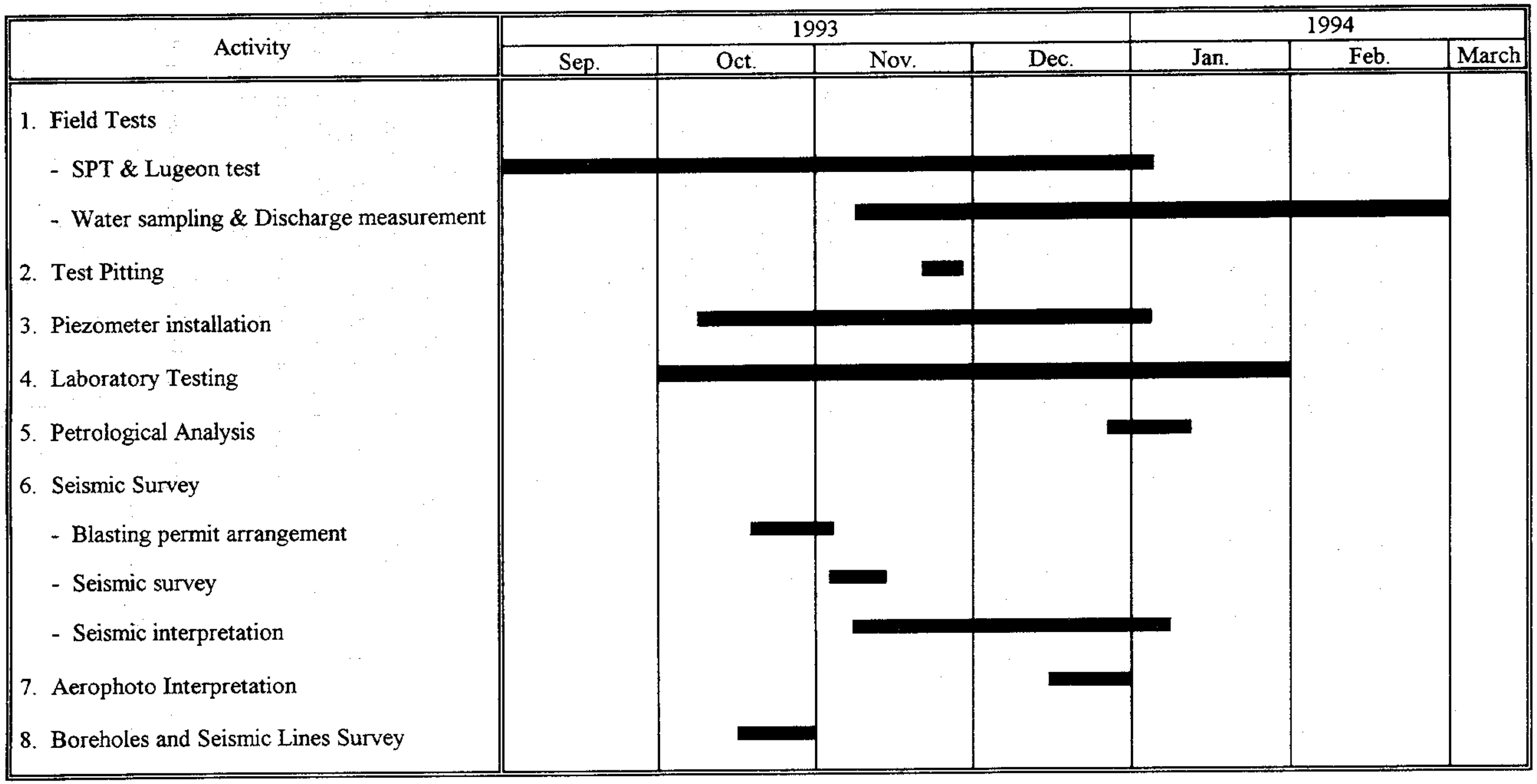


Figure 5-3 Actual Progress of Other Geological Investigations



5.2.2. Regional Geology

In order to know the overall geological setting of the project area, the existing geological map issued by Geological Survey of Indonesia is referred (Drawing 5-4).
According to this geological map, the project site stratigraphically lies in volcanic and sedimentary rocks of the Tertiary. Those rocks are divided into three formations termed "Pb", "Citarum Mts", and "Radjamandala Omc or Oml", respectively.

The "Pb" formation has been classified as Pleiocene age and the "Mts" as Miocene age, and the former overlies the latter unconformably.
The Omc or Oml belongs to Oeigocene age.
It is characterized that the "Pb" consists predominantly of tuffaceous breccia, lava, sandstone and conglomerate and has been depicted in the foregoing map to distribute widely in the north of the Project area.
Further, the "Pb" is classified as medium to hard rocks and generally has massive character.

Meanwhile, the "Mts" is composed chiefly of sandstone and siltstone, and distributed spreadly in the south of the Project.
The "Mts" is classified as medium soft to medium hard rocks and characterized by well stratified beds.
In general the "Mts" beds are striking NE to ENE and dipping 30 to 60°S but the dip is sporadically variable because those beds were suffered from certain orogeny and folded.

The Omc or Oml consists of marl, claystone, sandstone or limestone and is limited by distributed in the upstream of the lower reservoir.

Three (3) faults have been assumed near the Project area, and out of them two (2) faults appear to affect the Project construction. One is running along the Cisokan River near the proposed lower dam site trending from north-north-west to south-south-east and the other is also running along the Cisokan River in the lower reservoir trending from east-north-east to west-south-west and discontinued by the former fault where the Cisokan River takes its great west-south-westward bend.

The aerial photographic interpretation verifies that lineaments trending N 50 - 60°E and N 50 - 80°W, respectively.

In particular, the former is dominant in density and length. The most dominant lineament has been interpreted along the Cisokan to the Cilengkong rivers and suggest a definite fault. Other lineaments appear to be minor faults, fractures or joints.
The detail of the interpretation result is compiled in Drawing 5-5.

5.2.3. Reservoir

Geology of the reservoir area was studied in terms of potential instability such as landslides or leakage of filling water.
The investigation was conducted by means of the reconnaissance survey and interpretation of aerial photography. In addition, the skinny ridge of the upper reservoir was geotechnically verified by the core drilling and seismic prospecting.

5.2.3.1. Upper Reservoir

The upper reservoir entirely lies in Tertiary sedimentaries of alternating beds of sandstone, shale and breccia.
The breccia predominates over the alternating beds and are well exposed on the upstream river bed showing fresh faces, where they are well layered and generally striking N 60 - 80°E and dipping 50 - 60°S.
However, at approx. 600 m upstream from the proposed dam axis the alternating beds are strongly folded and their strike and dip significantly change (Drawing 5-6). The folding axis is trending N 60 -80°E almost parallel to the strike of beddings and this folding may have a considerable extent.
The breccia is cropping out on the river bed approx. 0.4 - 0.5 km upstream from the dam axis and indicates massive characteristic.

In general the bed rocks are limitedly exposed along the river and mostly mantled by top soil or strongly decomposed rocks, which suggests that overburden is thick.
Due to the unfavourable conditions of rock exposures in the upper reservoir no evidence or clue suggesting the prevalence of faults has been observed.

The aerial photograph interpretation suggests a representation of a couple of lineaments. It is understood that they are predominantly trending northeast by east and northwest by west. The former may represent stratification planes or folding and the latter dominant joints or minor faults.
It is assessed that neither strong lineaments have been interpreted nor considerable faults exist to affect on construction of the upper reservoir.

As pointed out in the foregoing Chapter 5.1.2.1, there are skinny ridges in the upper reservoir and one is in the upstream of the Cibima River where the intake will be located, and the other is in the upstream of the Cirumamis River.
Three (3) core drillings were executed to examine possible leakage through the former ridge. The drilling data reveals the following conditions.

a) In SRF-1 deeply weathered rocks are 13.35 m deep and high lugeon zone over 10 is up to 20.0 m.
The highest velocity layer having 2.5 km/sec lies at about 13.0 m deep from the surface.
In terms of weathering and permeability reliable rocks will be exposed at EL. 802.83 m (Ref. Drawings 5-7 and 5-8)

b) In SRF-2 deeply weathered rocks are 20.5 m deep.
From 22.0 m below low lugeon value less than 5.0 was obtained. Taking into account the seismic prospecting result reliable rocks will lie at EL. 846.64 m at this location.

c) In SRF-3 weathering is relatively thin and rocks below 5.0 m deep have low lugeon value and this favourable conditions continue up to the bottom of SRF-3.

It is summarized that reliable rocks will be exposed widely above H.W.L. El. 796 m as seen in the foregoing Figure.
Judging from the above conditions, it is not considered that leakage problem will take place at the skinny ridge.
In addition, throughout the surface mapping it has been reported that no considerable landslides occur in the upper reservoir except surface ones but taking into account that weathering of the bed rocks is rather deep at and above H.W.L., likelihood of slope instability is predicted particularly due to excavation work during construction or a draw-down of a filling water post construction or unquestionably heavy rainfall.
Detail investigation shall be necessary in the vicinity of the dam site at the subsequent investigation stage.

While, regarding the other ridge no subsurface information is available but the obtained topography suggests that H.W.L. should be restricted lower than EL. 800 m because weathering appears to be very deep and permeability to be very high, which result in a shortage of pass length at the ridge. Detail investigation will be also necessary in the following study.

5.2.3.2. Lower Reservoir

The lower reservoir is dominated by breccia with occasional alternating beds of marl and sandstone. Further, limestone is cropping out near a backwater of the lower reservoir.

Those bed rocks are generally mantled by top soil or river terrace.

In particular the terrace deposits are widely developed in the upstream from a confluence of the Cisokan and the Cilengkong rivers and cultivated mostly as paddy field.

Top soil and decomposed rocks are assumed in a range of 5.0 m to 10.0 m in the vicinity of the dam site but may increase in thickness towards the upstream.

Minor collapses have been observed on the left side slope of the Cilengkong River and certain area is prone to sliding.

As compared with the upper reservoir overall stability for the existing slope in the lower reservoir is superior.

No significant problem is geotechnically predicted in the lower reservoir.