No. 22

THE REPUBLIC OF THE PHILIPPINES

FINAL REPORT OF FEASIBILITY STUDY ON KALAYAAN PUMPED STORAGE PLANT DEVELOPMENT PROJECT (STAGE II)

SUMMARY

NOVEMBER, 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

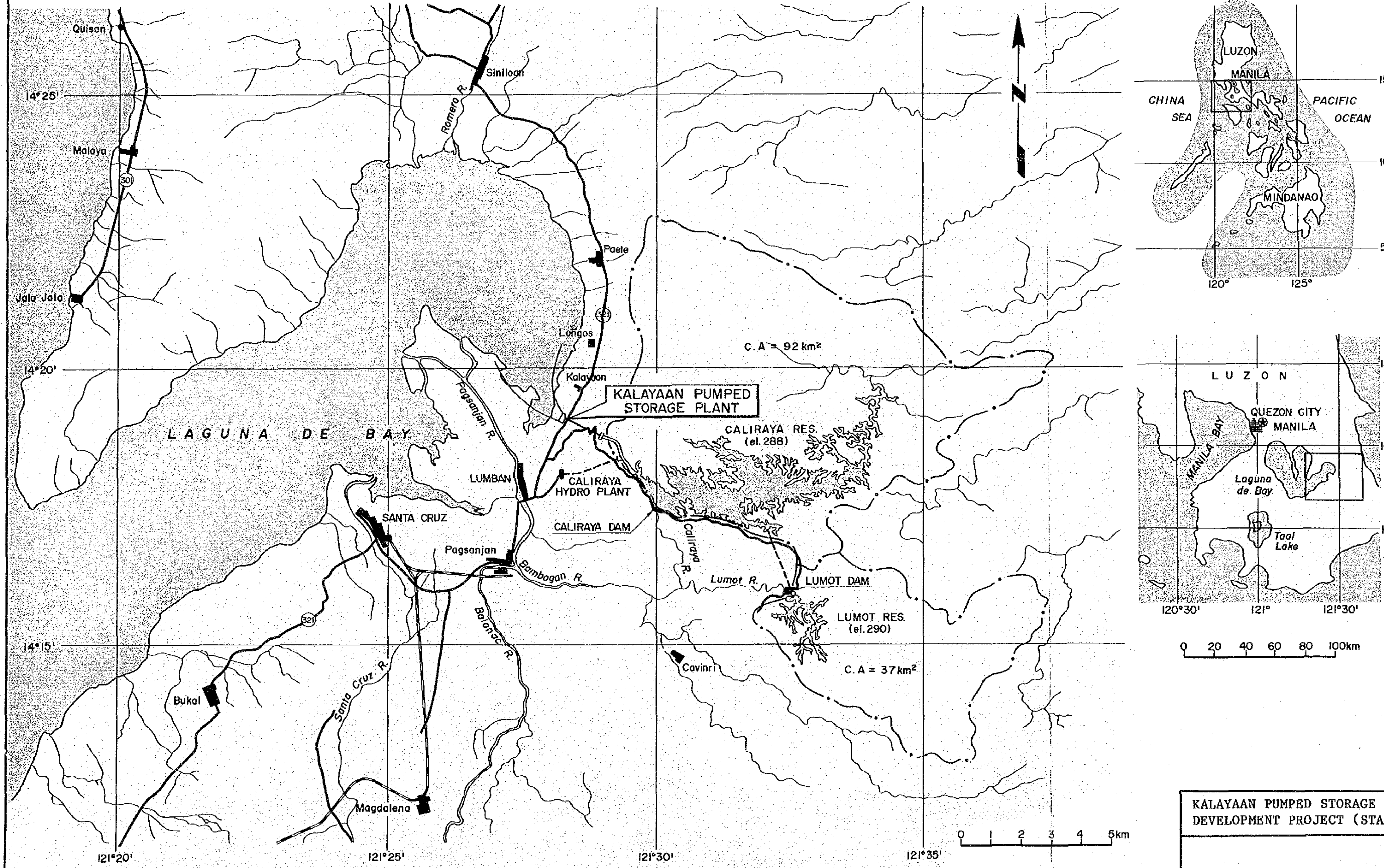
THE REPUBLIC OF THE PHILIPPINES

FINAL REPORT
OF
FEASIBILITY STUDY
ON
KALAYAAN PUMPED STORAGE PLANT DEVELOPMENT PROJECT (STAGE II)

SUMMARY

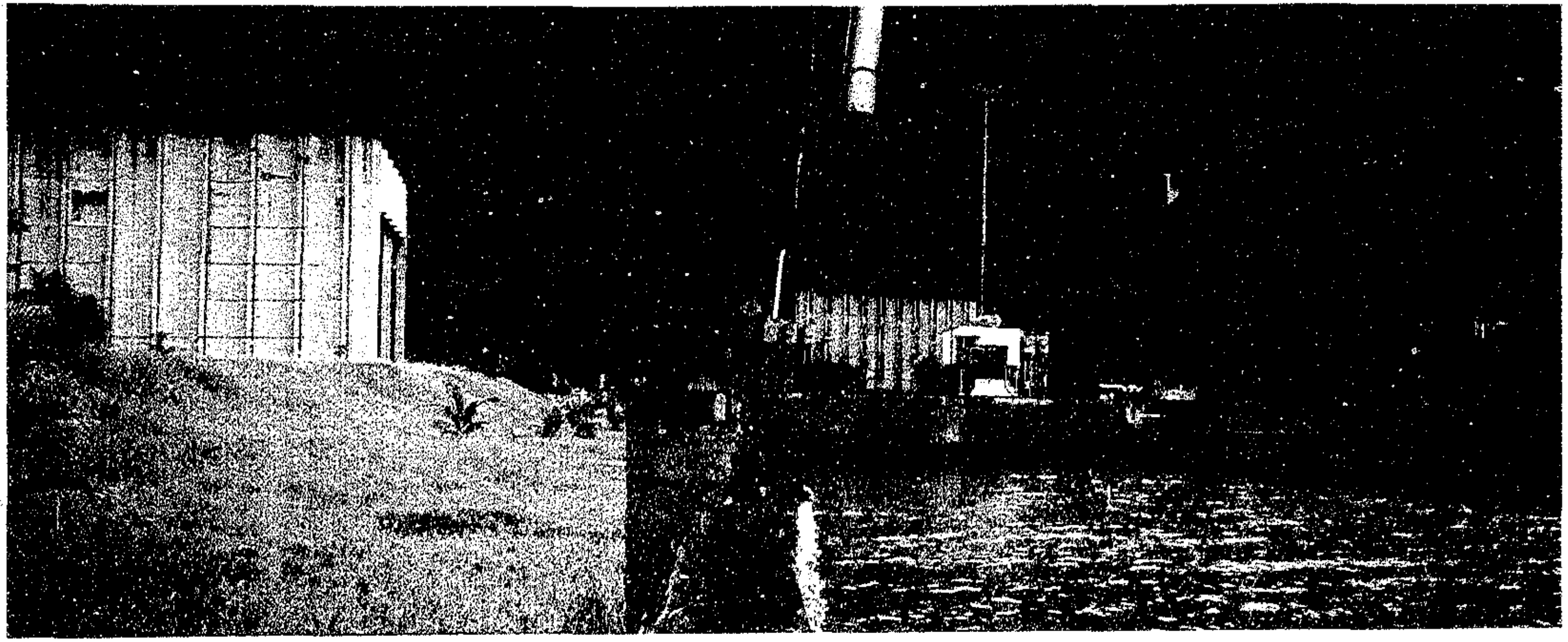
NOVEMBER, 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

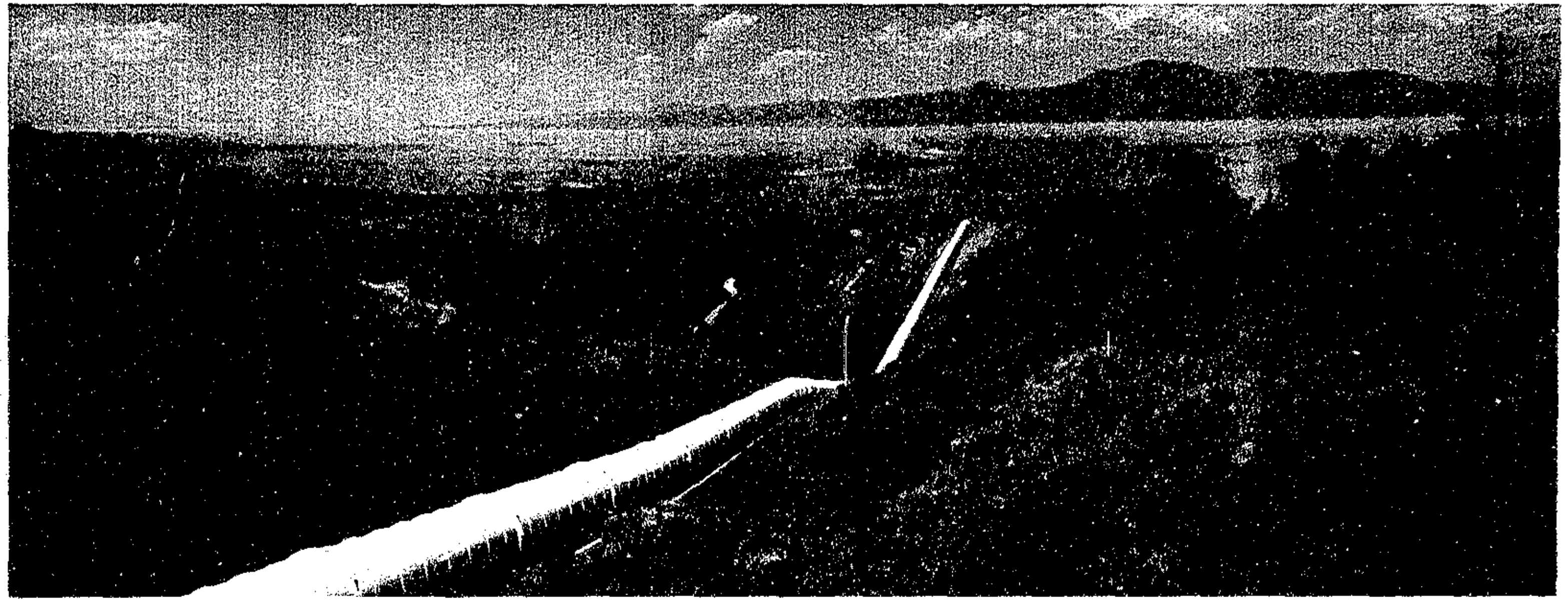


KALAYAAN PUMPED STORAGE PLANT DEVELOPMENT PROJECT (STAGE II)

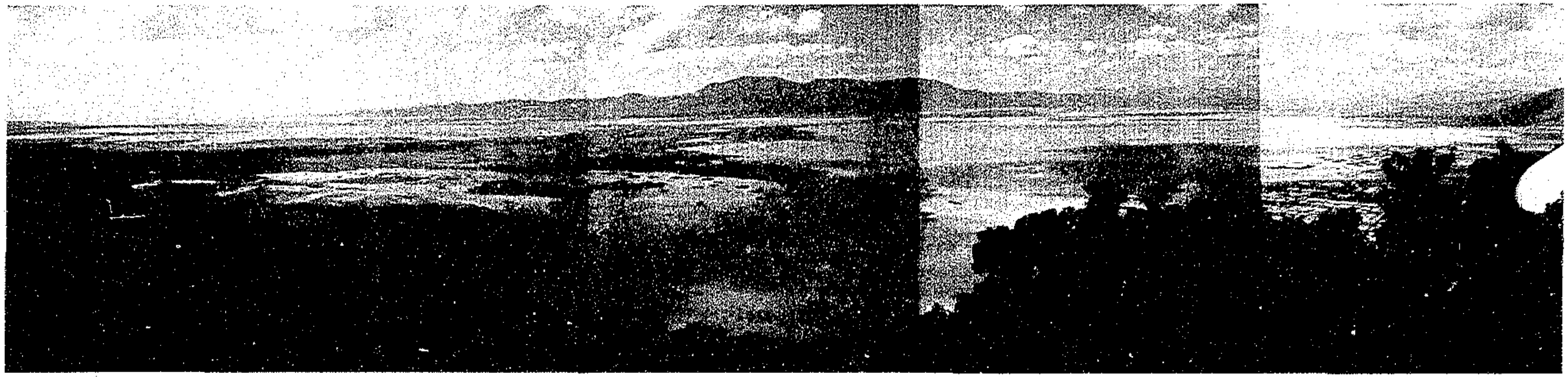
REGIONAL MAP & ROADS



Kalayaan Pumped Storage Power Plant and Tailrace



Existing Penstock for Stage I Project



Grown Floating Aquatic Plants in the Tailrace

CONTENTS

UNITS

m	-	meter, unit of length
km	-	kilometer (1,000 m)
m^2	-	square meter
m^3	-	cubic meter
m^3/s	-	cubic meter per second
V	-	volt, unit of voltage
kV	-	1,000 volts
W	-	watt, unit of active power
kW	-	1,000 W
MW	-	megawatt (1,000 kW)
VA	-	volt-ampere
MVA	-	megavolt-ampere (1,000 kVA)
Wh	-	watt-hour, unit of energy
kWh	-	1,000 Wh
MWh	-	megawatt-hour (1,000 kWh)
GWh	-	million kWh
rpm	-	revolutions per minute
Hz	-	hertz, unit of frequency
hr, (hrs)	-	hour
m-kW	-	unit of specific speed
g	-	gram, unit of weight
kg	-	1,000 g
t	-	ton (1,000 kg)
MT	-	metric ton
l	-	liter
BTU	-	British Thermal Unit
LB	-	pound
cal	-	calorie, thermal unit
Kcal	-	kilocalorie (1,000 cal)

CURRENCY

P	-	Philippine Peso
US$	-	U.S. Dollar
US$M	-	million dollars

Foreign Exchange Rate

P22.50 = $1.00
P 1.00 = $0.0444

ABBREVIATIONS

Stage I Project - Existing Kalayaan Pumped Storage Power Plant

Stage II Project - Extension of Kalayaan Pumped Storage Power Plant

NAPOCOR	-	National Power Corporation
JICA	-	Japan International Cooperation Agency
KPSPP	-	Kalayaan Pumped Storage Power Plant
AC	-	Alternating Current
AV	-	Average
AVR	-	Automatic Voltage Regulator
A.E.G.	-	Annual Energy Generation
BOD	-	Biochemical Oxygen Demand
B/C	-	Benefit Cost Ratio
CB	-	Circuit Breaker
CIF	-	Cost, Insurance and Freight
CL	-	Caliraya Lake
Comm	-	Commissioning
C&F	-	Cost and Freight
Dep Enr	-	Dependable Energy
Dia	-	Diameter
DO	-	Dissolved Oxygen
EDCOP	-	Engineering & Development Corporation
EIA	-	Environmental Impact Assessment
EIRR	-	Economic Internal Rate of Return
EL	-	Elevation
ELC	-	Electroconsult
EPA	-	Environmental Protection Agency
Ex Rate	-	Exchange Rate
FC	-	Foreign Currency
FWS	-	Free Water System
GDP	-	Gross Domestic Product
Gen	-	Generation
GOV	-	Speed Governor for Water Turbine
HWL	-	High Water Level
Hyd	-	Hydro
IDC	-	Interest During Construction
Ins Cap	-	Installed Capacity
LC	-	Local Currency
LEI	-	Lake Evaluation Index
Lf	-	Load Factor
LL	-	Laguna Lake
LLDA	-	Laguna Lake Development Authority
LOLP	-	Loss Of Load Probability
LWL	-	Low Water Level
Max	-	Maximum
MELARCO	-	
Min	-	Minimum
NEDA	-	National Economic Development Authority
NE-SW	-	Northeast-Southwest
ph	-	Phase

PLC	-	Programmable Logic Controller
Pow	-	Power
puMW	-	per unit MW
r	-	Discount Rate
SFS	-	Subsurface Flow System
St.s	-	Station Service
Thr	-	Thermal power
Tot	-	Total
TSI	-	Trophic State Index
VAT	-	Value Added Tax

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

(1) Introduction

The Kalayaan Pumped Storage Stage II Project has been studied in terms of its necessity, engineering problems, environmental impacts and its economic feasibility, and the conclusion as described below have been obtained.

(a) In meeting the rapid economic growth of the Republic of the Philippines, in particular Metro Manila, a large number of electric power supply facilities are needed in future. As these power sources are required urgently, and must be provided economically, the focus of power development will be placed on coal-fired thermal power plants in near future.

(b) The Stage II Project of Kalayaan Pumped Storage Power Plant should be implemented as soon as practicable in order to economically operate the thermal power plants referred to above, to have the supply capability respond quickly to load variation by means of hydroelectric power plants, and to assure stable and high quality supply of electric power.

(c) This Project is favorably situated for electricity supply as it is located only 60 km to the southeast of Metro Manila, which is the largest load center of the Republic. In addition, as certain civil structures, such as dam, intake, and penstock route have been provided in construction works of Stage I, they can be utilized for the Stage II Project. With these provisions, the construction period can be reduced and the construction cost of the Stage II Project will be low.

(2) Size and Timing of Development

(a) Size of the Project

The size of the Stage II Project shall be 300 MW, with two 150 MW units.

(b) Timing of Development

The following development schedule is proposed based on the projection of power supply and demand balance.

First Unit (Unit No. 3): January 1997
Second Unit (Unit No. 4): July 1997

(c) Transmission System

It is not necessary to prepare a new transmission line for the Stage II Project, because the existing transmission line of 230 kV can be utilized for the Project.

(3) Basic Design Parameters of the Project

The basic design parameters of the Stage II Project are presented in Table-1.

Table-1 Specifications of the Stage II Project

1. Upper Reservoir		Caliraya Reservoir	Lumot Reservoir
Catchment area	km^2	92	37
High Water Level	m	EL. 288.00	EL. 290.00
Low Water Level	m	EL. 286.00	EL. 286.00
Effective storage capacity	10^6 m^3	22.09	22.00
Total storage capacity	10^6 m^3	79.01	43.8

2. Dam (Existing)

Type		Upstream side concrete-protected earth-fill	Upstream side concrete-protected earth-fill
Crest elevation	m	EL. 292.00	EL. 294.00

3. Spillway (Existing)

Normal-use spillway type		Vertical shaft with gate	Overflow vertical shaft
Dia. x length	m	4.2 x 320	4.0 x 214
Emergency spillway type		Overflow	
Overflow crest EL	m	EL. 291.30	
Overflow crest length	m	160	

4. Lower Reservoir (Natural lake)

		Laguna de Bay
HWL	m	EL 3.24
Av. water level	m	EL. 0.60
LWL	m	EL.-0.36
Total storage	10^6 m^3	4,000

5. Upper Canal (Existing)

Water surface width	m	100.00
Bed width	m	45.00
Bed elevation	m	EL. 281.50

6. Penstock

Surface portion Dia. x length x lines	m	6.00-5.00 x 1,200 x 1
Tunnel portion Dia. x length x lines	m	3.30 x 100 x 2

7. Power Generation Scheme

		Generating	Pump-up
Gross head (Normal water level)	m	286.40	286.40
Normal effective head	m	282.00	-
Max. effective head (Max. total pump head)	m	287.20	291.40
Min. effective head (Min. total pump head)	m	278.40	283.80
Max. power discharge (Max. total pump head)	m^3/s	62.0 x 2	49.9 x 2
Max. output/input	MW	152 x 2	159 x 2
Pump-Turbine			
Type		Reversible vertical type Francis pump-turbine	
Number	Unit	2	2
Rated output	MW	154	
Input (Min. total pump head)	MW		155
Rated speed	rpm	360	360
Motor-Generator			
Type		3-ph, AC, synchronous generator-motor	
Number	Unit	2	2
Output	(MVA, MW)	167	155
Frequency	Hz	60	60
Pump-up starting system		Pony motor start and back to back start	
Main transformer			
Type		Outdoor, 3-ph forced oil, air-cooled	
Number	Unit	2	2
Capacity	MVA	170	170

Frequency	Hz	60	60
Voltage	kV	230/13.8	
Outdoor Switchyard			
Bus bar system		1 - 1/2 CB system, transmission line outgoing 6 cct	

(4) Construction Cost

The total construction cost of the Project, including interest during construction, is estimated at US$ 170.97 millions. The major items of the construction cost are presented in Table-2.

This construction cost is estimated based on the prices of January 1990. The annual interest rate is assumed to be 6.33% for foreign currency and 20.0% for domestic currency.

The construction cost items in the table are indicated in U.S. dollars, and the exchange rate is assumed to be 1 US$ = 22.5 pesos.

Table-2 Estimated Construction Cost

(Unit: US$M)

	Foreign Currency	Domestic Currency	Total	Note
Preparation Works	0.48	1.57	2.05	
Civil Works	9.26	17.17	26.44	
Hydraulic Equipment	16.75	14.45	31.20	including dredger
Electromechanical Equipment	60.40	5.80	66.20	
Administration Cost	4.00	3.55	7.55	6% of total
Physical Contingency	5.23	3.34	8.57	
Net Construction Cost	96.12	45.89	142.01	
Interest during Construction	11.23	17.73	28.96	Foreign; 6.33% Domestic;20.0%
Construction Cost	107.35	63.62	170.97	
Cost for Rehabilitation Works	4.82	5.60	10.42	Caliraya Dam
Total Construction Cost	112.17	69.22	181.39	

(5) Economic Evaluation

In terms of the Benefit (B) to Cost (C) ratio, the economics of the Stage II Project is favorable being higher than 1.0 as shown below. Therefore, this Project is sufficiently feasible in terms of economics.

The discount rate was assumed to be 15%.

Benefit (B) = US$111.06 million
Cost (C) = US$100.70 million
B - C = US$10.36 million
B/C = 1.10
Equalized Discount Rate = 21.15%

(6) Environmental Assessment

The major environmental impact created by the Stage II Project will be the transfer of contaminated water in the lower reservoir of Laguna de Bay to the upper reservoir of Caliraya. This effect has already occurred by operation of the Stage I Project. Considering that no serious environmental issue has occurred by operation of the existing power plant, it is expected that the effect of expanding the power plant would be minor.

Recommendations

(1) Construction Schedule

Considering the construction schedule of the Stage II Project, it is expected that commissioning of the No. 3 Unit will take 39 months, and that of the No. 4 Unit 45 months. Therefore, the construction schedule presented below must be kept in proceeding with the construction in order to meet the increasing power demand.

1990-11 -- 1991-3:	Provision and Award of Definite Design
1991- 4 -- 1992-9:	Definite Design
1992-10 -- 1993-3:	Financing Formalities
1993- 4 -- 1993-9:	Bidding and Award of Contract for Construction
1993-10 :	Start of Construction
1997-1 & 7 :	Commissioning

(2) Mitigation Measures for Environmental Impact

Although the implementation of the Stage II Project will not create an environmental problem caused by the Project itself, the contamination of Laguna de Bay, which is the lower reservoir of the Project, will progress inevitably due to household and industrial waste water drained from the surrounding area. It is a matter of natural course that, as the contamination of the lower reservoir is intensified, the upper reservoir of Caliraya Lake will also be contaminated. Although it is impossible to stop the contamination of the lower reservoir, it should be possible to retard this process.

In order to retard this contamination, it is recommended, as a matter of general environmental protection, to take the following actions:

(a) Providing a coffer dam to separate a part of Laguna de Bay.

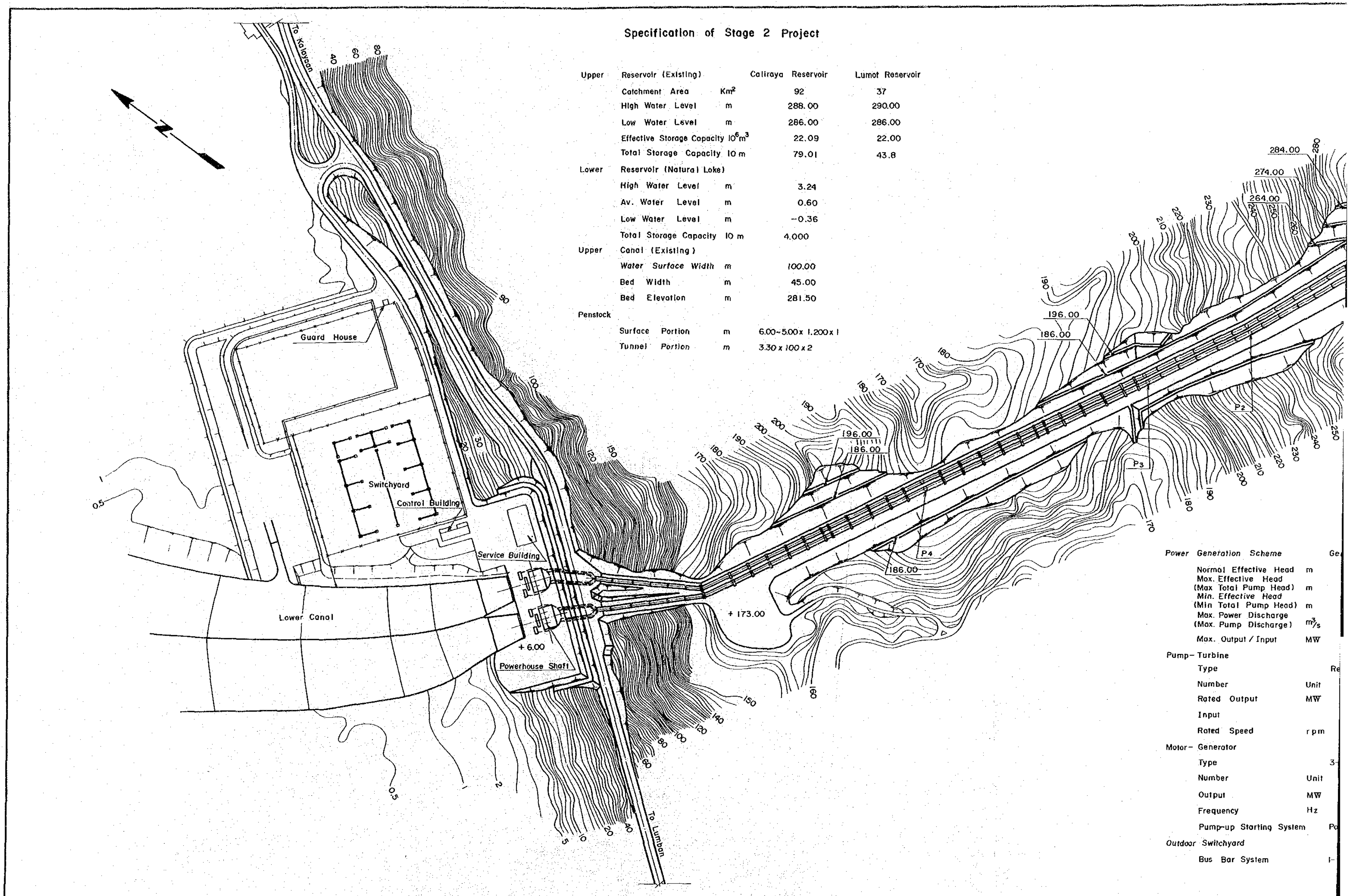
(b) Providing a "Wetland" in the lower reservoir to reduce contamination.

The cost of these provisions is approximately estimated at US$ 6 Million. It should be added that in implementing these retarding measures, a study of possible environmental problems by construction of the coffer dam, and a review of this construction cost will be necessary.

As previously mentioned, it is considered that the environmental impact concerning Laguna de Bay should be separated from the Kalayaan Stage II Project and be taken up as a national project.

The reason is that if the elimination of contamination of Laguna de Bay were to be considered in this Project, it would require a cost far greater than the Kalayaan Stage II Project itself, and as a consequence, the original objective of the Pumped Storage Power Generation Project itself will not be justifiable.

Incidentally, if the marginal cost that could be borne by the Project were to be tentatively examined, it would be as given below. That is, it would be the break-even point of the Project for B/C = 1.0, and the amount would be about US$ 20 Millions.



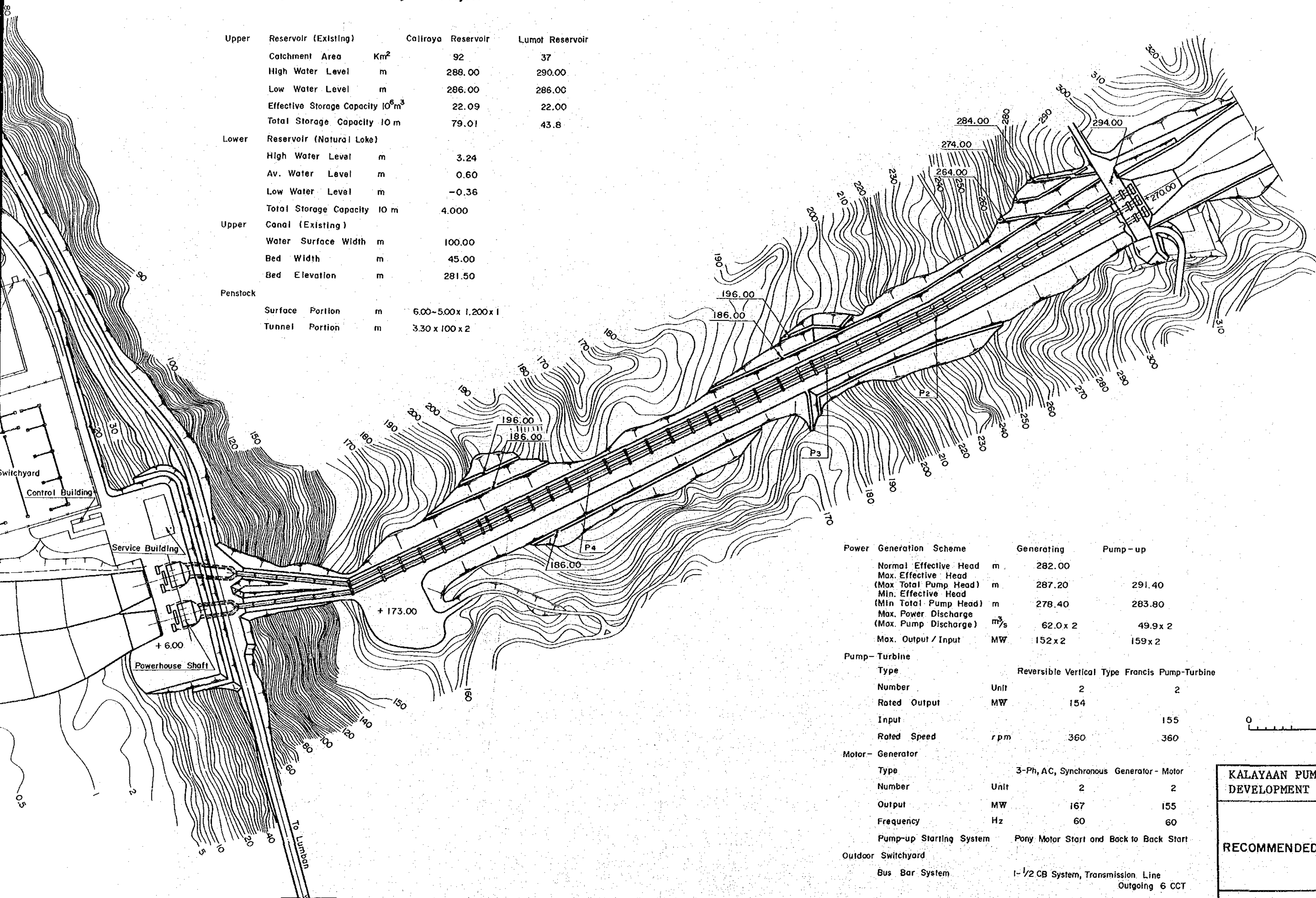
Specification of Stage 2 Project

			Caliraya Reservoir	Lumot Reservoir
Upper	Reservoir (Existing)		Caliraya Reservoir	Lumot Reservoir
	Catchment Area	Km^2	92	37
	High Water Level	m	288.00	290.00
	Low Water Level	m	286.00	286.00
	Effective Storage Capacity	10^6m^3	22.09	22.00
	Total Storage Capacity	10 m	79.01	43.8
Lower	Reservoir (Natural Lake)			
	High Water Level	m	3.24	
	Av. Water Level	m	0.60	
	Low Water Level	m	−0.36	
	Total Storage Capacity	10 m	4,000	
Upper	Canal (Existing)			
	Water Surface Width	m	100.00	
	Bed Width	m	45.00	
	Bed Elevation	m	281.50	
Penstock				
	Surface Portion	m	6.00~5.00 x 1,200 x 1	
	Tunnel Portion	m	3.30 x 100 x 2	

Power Generation Scheme			Ge
	Normal Effective Head	m	
	Max. Effective Head (Max Total Pump Head)	m	
	Min. Effective Head (Min Total Pump Head)	m	
	Max. Power Discharge (Max. Pump Discharge)	m^3/s	
	Max. Output / Input	MW	
Pump- Turbine			
	Type		Re
	Number	Unit	
	Rated Output	MW	
	Input		
	Rated Speed	rpm	
Motor- Generator			
	Type		3-
	Number	Unit	
	Output	MW	
	Frequency	Hz	
	Pump-up Starting System		Po
Outdoor Switchyard			
	Bus Bar System		I-

Specification of Stage 2 Project

			Caliroya Reservoir	Lumot Reservoir
Upper	Reservoir (Existing)			
	Catchment Area	Km^2	92	37
	High Water Level	m	288.00	290.00
	Low Water Level	m	286.00	286.00
	Effective Storage Capacity	$10^6 m^3$	22.09	22.00
	Total Storage Capacity	10 m	79.01	43.8
Lower	Reservoir (Natural Lake)			
	High Water Level	m	3.24	
	Av. Water Level	m	0.60	
	Low Water Level	m	−0.36	
	Total Storage Capacity	10 m	4.000	
Upper	Canal (Existing)			
	Water Surface Width	m	100.00	
	Bed Width	m	45.00	
	Bed Elevation	m	281.50	
Penstock				
	Surface Portion	m	6.00~5.00x 1,200x 1	
	Tunnel Portion	m	3.30 x 100 x 2	



			Generating	Pump-up
Power Generation Scheme				
	Normal Effective Head	m	282.00	
	Max. Effective Head (Max Total Pump Head)	m	287.20	291.40
	Min. Effective Head (Min Total Pump Head)	m	278.40	283.80
	Max. Power Discharge (Max. Pump Discharge)	m^3/s	62.0 x 2	49.9 x 2
	Max. Output / Input	MW	152 x 2	159 x 2
Pump-Turbine				
	Type		Reversible Vertical Type Francis Pump-Turbine	
	Number	Unit	2	2
	Rated Output	MW	154	
	Input			155
	Rated Speed	rpm	360	360
Motor-Generator				
	Type		3-Ph, AC, Synchronous Generator-Motor	
	Number	Unit	2	2
	Output	MW	167	155
	Frequency	Hz	60	60
	Pump-up Starting System		Pony Motor Start and Back to Back Start	
Outdoor Switchyard				
	Bus Bar System		1-1/2 CB System, Transmission Line Outgoing 6 CCT	

KALAYAAN PUMPED STORAGE PLANT DEVELOPMENT PROJECT (STAGE II)

RECOMMENDED GENERAL LAYOUT

Chapter 1 Object of the Study

1.1 Background and Role of the Project

NAPOCOR (National Power Corporation) projects that the power demand of the Luzon Grid, which accounts for 87% of the total power demand of the Republic of the Philippines, will grow to approximately 7,000 MW from the current maximum demand of 2,938 MW (as of June 1989) going ahead with electric power development projects to meet this growth of electric demand. As the reserve margin in the power system of Luzon is expected to fall to 4% from 1994 to 1996, NAPOCOR intends to overcome this supply crisis by installing 600 MW of new gas turbine plants, thereby providing a reserve margin rate of around 17%. However, considering the fact that the fuel cost of gas turbine is high, and the service life is generally short, these gas turbine plants can not be regarded as a permanent measure of dealing with the power supply shortage, and NAPOCOR is compelled to work out more permanent measures as soon as possible. As one of such permanent measures, NAPOCOR had been studying a plan of expanding the existing Kalayaan Pumped Storage Power Plant (called Stage I Project hereafter) by installing an additional plant (called Stage II Project hereafter) adjacent to the existing one, and through the Government of the Republic of the Philippines, requested the Government of Japan to conduct a feasibility study for this Stage II Project.

1.2 Objective of the Study

Upon the abovementioned request of the Philippine Government, the Japanese Government caused its agency, the Japan International Cooperation Agency (JICA), to dispatch a Preliminary Study Team to the Philippines in September, 1989, and the Team held discussions with NAPOCOR, the Philippine agency in charge of this matter. JICA then organized the Study Mission for Feasibility Study of the Stage II Project, and the Mission conducted the necessary study.

The objective of the study was to conduct on-site surveys and studies in Japan, to formulate the technically, economically and financially optimal development plan, and to produce a feasibility report on the

Kalayaan Pumped Storage Power Plant Stage II Project, as well as to transfer technologies to its Philippine counterpart through the process of the study.

1.3 Scope of the Study

(1) Preliminary Investigation Stage

(a) Collection and review of all existing data, reports and other relevant information on this Project.

(b) Site reconnaissance.

(c) Power survey

(d) Review of existing development schemes

(e) Formulation of alternative development schemes and their comparative studies to select the optimum development scheme

(2) Detailed Investigation Stage

(a) Topographic surveys (by NAPOCOR)

(b) Geological investigation and material tests (by NAPOCOR)

(c) Hydrological survey

(3) Feasibility-grade Design Stage

(a) Optimization studies of Project size

(b) Review and study of the optimum power generation program including relevant transmission line

(c) Establishment of dam operation program

(d) Environmental assessment

(e) Compensation survey

(f) Feasibility-grade design of structure components

(g) Construction program

(h) Cost estimation

(i) Economic and financial analyses

Chapter 2 General Description of the Republic of the Philippines

2.1 Current Status of National Economy

The national economic activity of the Philippines declined through 1984 and 1985, with her GNP exhibiting negative growth rates of -7.1% and -4.1% respectively. However, as the interest rate became stabilized, domestic demands such as consumption expenditure and investment in the private sector grew in 1986, 1987 and 1988, with GNP recovering rapidly with growth rates of 1.9, 5.9 and 6.7%, respectively.

However, the actual situation can not be considered too optimistically due to the accumulating external debts and shortage of foreign currency reserves which are needed for economic growth.

Current Status of Philippine Economy

(%)

	1985	1986	1987	1988
Real GNP Growth Rate	-4.1	1.9	5.9	6.7
Consumer Price Inflation Rate	23.1	0.8	3.8	8.8
Balance of Current Account/GNP	-0.3	3.3	-1.6	-1.1
Export/GNP	25.4	24.7	26.8	29.4
Foreign Reserves including Gold*	10.9	26.1	23.1	-
External Debt Outstanding/GNP	81.9	95.0	86.5	-

* Unit: US$ x 10^8

The Medium-Term Economic Plan (1989 to 1992) of the Philippine Government has been formulated in consultation with IMF under such economic situation. In this new Medium-Term Economic Plan, it is attempted to maintain a relatively high annual growth rate of 6.5% by means of a policy combining aggressive governmental finance, promotion of privatization, and intensified taxation.

Outline of Medium-Term Economic Plan of Government (1989 - 1992)

(1) Economic Development Target: Elimination of poverty, creation of employment, realization of social equity.

(2) Basic Task: Attaining continued economic growth.

(3) Main Targets in Socio-Economic Development

i) To attain an average GNP growth rate of 6.5%.

ii) To increase the ratio of investment to GNP from 18% in 1988 to 24.5% in 1992.

iii) In particular, to increase the ratio of government investment to GNP from 3% in 1988 to over 5.5% in 1991 - 1992.

iv) This will create a shortage of funds of 3 billion US$ during the period from 1989 to 1992. To deal with this, new loans will be secured from foreign commercial banks and the Paris Club (Public Debtors' Council) will be requested to reschedule loans again.

v) The tax revenue of the government is to be secured by the new taxation system introduced in 1988 which features a value-added tax, and at the same time streamlines government structures. This will reduce the current governmental expenditures of 13.9% in 1988 to 12% by 1992.

Major Targets in Medium-Term Economic Plan of Philippines
(1989 -- 1992)

(in %)

	1987	1988	1989	1990	1991	1992
GNP Growth Rate	5.9	6.7	6.5	6.5	6.5	6.5
Consumer Price Inflation Rate	3.8	3.8	8.0	6-7	5-6	5-6
Public Investment/GNP	3.6	3.4	4.2	4.7	5.6	5.8
Debt Service Ratio *	35.4	33.7	33.8	32.2	31.0	29.4

* Debt Service Ratio (TDS/NGS): Total debt service relative to export of goods and services.

2.2 Past Trend of Power Demand

Economic conditions in the Philippines have recovered rapidly since 1987, and the GDP growth rate of 1988 marked a 6.7% growth over the previous year.

Generally speaking, there is a strong correlation between GDP and electricity demand. The electricity consumption of 1988 was 22,944 GWh reflecting the growth of GDP, and this was a 9.3% growth over the previous year. This growing trend of demand will continue, even if the growth rate may be reduced a little.

Past Trend of Energy Demand

(in 10^6 kWh)

	1983	1984	1985	1986	1987	1988	1989
Philippines	18,682 (7.3)	18,666 (0)	18,757 (0.5)	19,263 (2.7)	20,995 (9.0)	22,944 (9.3)	24,076 (4.9)
Luzon Grid	15,294 (6.2)	14,655 (-4.2)	14,449 (-1.4)	14,756 (2.1)	16,030 (8.6)	17,439 (8.8)	18,215 (4.4)
Visayas Grid	1,057 (36)	1,177 (11.4)	1,343 (14.1)	1,467 (9.2)	1,693 (15.4)	1,876 (10.8)	1,998 (6.5)
Mindanao Grid	2,331 (4.2)	2,835 (21.6)	2,965 (4.6)	3,040 (2.5)	3,272 (7.6)	3,629 (10.9)	3,863 (6.4)

Figures in parentheses are growth rates over previous years (%).

Past Trend of Maximum Power Demand

(in MW)

	1983	1984	1985	1986	1987	1988	1989
Luzon	2,478 (4.8)	2,374 (-4.2)	2,311 (-2.7)	2,435 (5.4)	2,582 (6.4)	2,780 (7.3)	2,938 (5.7)
Visayas	229 (41.9)	242 (5.7)	256 (5.8)	284 (10.9)	307 (8.1)	333 (8.5)	350 (6.3)
Mindanao	410 (5.9)	433 (5.6)	470 (8.5)	484 (3.0)	533 (10.1)	571 (7.1)	617 (8.1)

Figures in parentheses are growth rates over previous years (%).

Chapter 3 Current Structure of Electric Utility

3.1 Electric Utility of the Philippines

The electric utility of the Philippines is operated by both public and private sector organizations. In the public sector, the National Power Corporation (NAPOCOR) surveys and develops all electric power resources, including such indigenous resources as geothermal and hydroelectric, and supplies electric power, which is generated by hydroelectric and thermal power plants developed by NAPOCOR, through its nation-wide transmission networks to electric cooperatives, Manila Electric Company, etc. In the private sector, Manila Electric Company (MERALCO) supplies power to Metro Manila. The power supply in remote areas where NAPOCOR has no transmission system is carried out by electric cooperatives.

(1) NAPOCOR

NAPOCOR was established in 1936 under full governmental subsidization with the objective of operating an electric utility using hydroelectric power and other natural resources. This was based on Commonwealth Act No. 120 of 1935. In 1972, the scope of business of NAPOCOR was expanded according to the NPC Charter and Presidential Decree 40, and today, NAPOCOR is engaged in surveys and development of all power resources, construction and operation of transmission networks, and supply of power to electric cooperatives all over the country, Manila Electric Company, and other corporations.

The total capacity of the generating facilities owned by NAPOCOR as of the end of 1988 was 5,782 MW, with the number of employees 11,294 persons.

(2) Manila Electric Company (MERALCO)

Manila Electric Company was founded in 1919 by merging three companies, Manila Electric Railroad & Lighting Co., Manila Suburban Railway Co., and La Electricista. Later, a bus transport division was separated, and the part of the company related to the electric utility was gradually expanded as the power demand increased.

Therefore, MERALCO is engaged in the distribution of power, purchased wholesale from NAPOCOR, to Manila City and its surrounding area, which covers 8,813 km^2 (approximately 3% of the national land area). According to the record for 1986, NAPOCOR supplied 10,260 GWh of electricity to MERALCO, and this corresponded to 58% of the total wholesale power of NAPOCOR which was 17,645 GWh.

(3) National Electrification Administration and Electric Cooperatives

In the Philippines, rural electrification has been one of the important government policies, and the National Electrification Administration (NEA) was established in 1969 for promotion of rural electrification. NEA arranges financing, prepares bidding documents and purchases equipment/materials for rural electrification, and the distribution facilities thereby completed are sold to electric cooperatives.

The electric cooperatives distribute power, which is supplied by NAPOCOR, to consumers in their territories.

3.2 Power Supply Facilities

The outline (installed capacity, commissioning date) of each power plant in the Luzon Grid is shown in Table S3.1.

Approximately one half of capacity of oil-fired thermal power plants, which account for 45% of the total installed capacity of the Luzon Grid, is almost 20 years old, and these facilities may not be operated at full power due to aging. It is being planned to rehabilitate these aged thermal power plants during the period from 1990 to 1992, starting with the Sucat No. 1 Unit.

3.3 Power Demand and Supply

The total installed capacity of the Luzon Grid as of 1989 was 4,322 MW. The peak demand (at generation end) was 2,938 MW, and there was ostensibly sufficient supply capability.

In reality, however, 41 blackouts and 97 GWh of power supply shortage occurred in the entire Philippines in 1989. It can be surmised that the major reasons for this situation were frequent natural hazards such as typhoons, and the low reliability of aged thermal power plants. It is expected that the power supply shortage in 1990 will be severer because of reduced hydroelectric output due to less rain of in the year.

With the objective of improving self-sufficiency in energy of the Luzon Grid, it is being planned to develop hydroelectric power in the northern area of Luzon Island, and utilize the hydroelectric and geothermal power developed in the southern areas by means of a Luzon-Visayas-Mindanao interconnection.

Table S3-1 Existing Power Plants in Luzon Grid (as of Dec. 1989)

(a) Pondage Hydro

Plant Name	Unit No.	Unit Capacity (MW)	Firm Out put (MW)	Comm. Year	Year of Retirement
1. Caliraya	1	8.00	15	10/45	1992
	2	8.00		11/45	1992
	3	8.00		10/47	1997
	4	8.00		2/57	2000
2. Ambuklao	1	25.00	36	12/56	2006
	2	25.00		12/56	2006
	3	25.00		9/57	2007
3. Binga	1	25.00	79	1/60	2010
	2	25.00		1/60	2010
	3	25.00		3/60	2010
	4	25.00		3/60	2010
4. Angat (main)	1	50.00		10/67	2017
	2	50.00		10/67	2017
	3	50.00		8/68	2018
	4	50.00	total 142	8/68	2018
5. Angat (aux.)	1	6.00		7/67	2017
	2	6.00		7/67	2017
	3	6.00		10/78	2028
	4	10.00		5/86	2036
6. Pantabangan	1	50.00	26	4/77	2027
	2	50.00		5/77	2027
7. Magat	1	90.00	180	8/83	2033
	2	90.00		9/83	2033
	3	90.00		11/83	2032
	4	90.00		8/84	2034
Sub-total		895	478	———	

(b) Pumped Hydro

Plant Name	Unit No.	Unit Capacity (MW)	Firm Out put (MW)	Comm. Year	Year of Retirement
1. Kalayaan	1	150.00	300	5/82	2032
	2	150.00		8/82	2032
Sub-total		300	300	———	

(c) Run-of-River Hydro

Plant Name	Unit No.	Unit Capacity (MW)	Firm Out put (MW)	Comm. Year	Year of Retirement
1. Botocan	1	8.00	0	1946	1998
	2	8.00		1948	1998
	3	0.96		1945	1995
2. Buhi-Barit	1	1.80	0	9/57	2007
3. Cawayan	1	0.40	0	10/59	2009
4. Masiway	1	12.00	0	12/80	2030
Sub-total		31.2	0		―――

(d) Oil Thermal

Plant Name	Unit No.	Unit Capacity	Minimum Out put	Comm. Year	Year of Retirement
1. Manila	1	100.00	30.0	9/65	1995
	2	100.00	30.0	10/65	1995
2. Sucat 1&2	1	150.00	50.0	10/68	1998
(Garoner)	2	200.00	120.0	1/70	2000
Sucat 3&4	3	200.00	120.0	7/71	2001
(Snyder)	4	300.00	120.0	9/72	2002
3. Bataan	1	75.00	50.0	9/72	2002
	2	150.00	80.0	2/77	2007
4. Malaya	1	300.00	120.0	9/75	2005
	2	350.00	150.0	3/79	2009
Sub-total		1,952	870.0		―――

(e) Gas turbine

Plant Name	Unit No.	Unit Cap.	Dependable Out put	Comm. Year	Year of Retirement
1. Malaya	1	30.0	30.0	9/89	2004
	2	30.0	30.0	9/89	2004
	3	30.0	30.0	9/89	2004
2. Bataan	1	30.0	30.0	9/89	2004
		30.0	30.0	9/89	2004
	1	30.0	30.0	9/89	2004
	·	30.0	30.0	9/89	2004
Sub-total		210	210.0		―――

(f) Geothemal

Plant Name	Unit No.	Unit Capacity (MW)	Minimum Out put (MW)	Comm. Year	Year of Retirement
1. Tiwi	1	55.00	30.0	1/79	2009
	2	55.00	30.0	5 79	2009
	3	55.00	30.0	1 80	2010
	4	55.00	30.0	4/80	2010
	5	55.00	30.0	12/81	2011
	6	55.00	30.0	3 82	2012
2. Mak-Ban	1	55.00	30.0	4/79	2009
	2	55.00	30.0	7 79	2009
	3	55.00	30.0	4/80	2010
	4	55.00	30.0	6/80	2010
3. Mak-Ban	5	55.00	30.0	7/84	2014
	6	55.00	30.0	9/84	2014
Sub-total		660	360		———

(g) Coal fired Thermal

Plant Name	Unit No.	Unit Capacity (MW)	Minimum Out put (MW)	Comm. Year	Year of Retirement
1. Calacal	1	300.0	230.0	9/84	2014
Sub-total		300	230		———
GRAND TOTAL (MW)		4,321			

Chapter 4 Load Projections

4.1 Load Forecast

(1) Load Forecast by Macroscopic Method

The expression of the local GDP (x) and energy sales (y) of Luzon Island from 1985 to 1989, when the economy was comparatively stable according to Fig S4-1, obtained by a primary regression technique is as follows:

$$y = 0.36624x - 7579.7$$

where, y: Energy sales of Luzon Grid (GWh)
x: Local GDP of Luzon Region (million pesos at 1972 level)

Load forecasts for the period of 1990 to 2005 were made using this expression for the two cases below.

(a) Mid Case (GDP growth rate: 6.4%)
(b) Steady Case (GDP growth rate: 5.5%)

Tables S4-1 and S4-2 give the respective forecast results.

(2) Load Forecast Result to be Adopted

According to the Medium-term Economic Outlook of NEDA the dominant view is that growth at 6 percent will be difficult to achieve for some time to come. Further, taking the actual performance of 1989 which was slightly poorer than originally forecast into consideration, it was decided to adopt the results of the Steady Case (GDP annual rate: 5.5%) which is more realistic.

4.2 Electric Power Development Program

An Electric Power Development Plan for the period from 1990 to 2000 has been formulated based on the Power Development Plan of NAPOCOR, as presented in Table S4-3.

In this plan, the power development program after 1996 has been modified in such a manner that the demand of each year can be met even if aged thermal power plants are retired and gas turbine plant output is reduced.

4.3 Demand and Supply Balance

As shown in Table S4-4 and Figs. S4-2 and S4-3, there will be a condition of both peak and energy supply capability being short for the time being, and this is seen in the present situation of frequent supply shortages.

The kW peak balance will be recovered once in 1993 with commissioning of the Coal 3 Power Plant, but true recovery including energy balance will not be achieved until after 1997.

Particularly, in the latter half of the 1990s, the peak supply capability will decline with aging of gas turbines commissioned in the period from 1989 to 1992, but on the other hand, it will be a period when pumping-up power sources will be created through development of large-scale coal-fired thermal plants. Accordingly, it is judged that the latter half of the 1990s will be a favorable time for the Stage II Project.

Table S4-1 Demand Forecast in Luzon Grid (Mid-case GDP: 6.4%)

Year	GDP Mil P at 1972	Demand (GWh)		Loss+St.s Load (%)	Peak Pow. in (MW)	Annual Lf (%)	Demand Rate (%)
		Sales Lev	Gen. Lev.				
1989	67,391	16,788	18,215	8.5	2,938.0	70.8	-
1990	71,704	18,681	20,269	8.5	3,305.5	70.0	11.3
1991	76,293	20,362	22,093	8.5	3,602.8	70.0	9.0
1992	81,176	22,150	24,033	8.5	3,919.3	70.0	8.8
1993	86,371	24,053	26,097	8.5	4,255.9	70.0	8.6
1994	91,899	26,077	28,294	8.5	4,614.1	70.0	8.4
1995	97,780	28,231	30,631	8.5	4,995.3	70.0	8.3
1996	104,038	30,523	33,118	8.5	5,400.8	70.0	8.1
1997	110,697	32,962	35,764	8.5	5,832.3	70.0	8.0
1998	117,781	35,557	38,579	8.5	6,291.4	70.0	7.9
1999	125,319	38,317	41,574	8.5	6,779.9	70.0	7.8
2000	133,340	41,255	44,761	8.5	7,299.6	70.0	7.7
2001	141,874	44,380	48,152	8.5	7,852.6	70.0	7.6
2002	150,953	47,705	51,760	8.5	8,441.0	70.0	7.5
2003	160,614	51,244	55,599	8.5	9,067.1	70.0	7.4
2004	170,894	55,008	59,684	8.5	9,733.2	70.0	7.3
2005	181,831	59,014	64,030	8.5	10,442.0	70.0	7.3

Table S4-2 Demand Forecast in Luzon Grid (Steady case GDP: 5.5%)

Year	GDP Mil P at 1972	Demand (GWh)		Loss+St.s Load (%)	Peak Pow. in (MW)	Annual Lf (%)	Demand Rate (%)
		Sales Lev	Gen. Lev.				
1989	67,391	16,788	18,215	8.5	2,938.0	70.8	-
1990	71,098	18,460	20,029	8.5	3,266.3	70.0	10.0
1991	75,008	19,892	21,583	8.5	3,519.7	70.0	7.8
1992	79,133	21,402	23,221	8.5	3,786.9	70.0	7.6
1993	83,486	22,997	24,952	8.5	4,069.1	70.0	7.5
1994	88,077	24,678	26,776	8.5	4,366.5	70.0	7.3
1995	92,922	26,452	28,700	8.5	4,680.4	70.0	7.2
1996	98,032	28,324	30,732	8.5	5,011.7	70.0	7.1
1997	103,424	30,299	32,874	8.5	5,361.1	70.0	7.0
1998	109,112	32,382	35,134	8.5	5,729.7	70.0	6.9
1999	115,114	34,580	37,519	8.5	6,118.6	70.0	6.8
2000	121,445	36,899	40,035	8.5	6,528.9	70.0	6.7
2001	128,124	39,345	42,689	8.5	6,961.7	70.0	6.6
2002	135,171	41,926	45,490	8.5	7,418.4	70.0	6.6
2003	142,606	44,649	48,444	8.5	7,900.2	70.0	6.5
2004	150,449	47,521	51,560	8.5	8,408.4	70.0	6.4
2005	158,724	50,552	54,849	8.5	8,944.7	70.0	6.4

Table S4-3 Power Development Program by the Mission

YEAR	New Power Plants (MW)	Retirement(MW)	Installed Cap.
1,989	————	————	Total:4,322MW
1,990	Hopwell GT 4×50 Power Barge GT 4×30	none	4,642
1,991	Sucat Land Barge GT 1×30 New GT 6×50	none	4,972
1,992	Power Barge GT 1×27.5 Bac-Man Geo 2×55 Combined Cycle 1×200	Carilaya #1,2 -16	5,293.5
1,993	Power Barge GT 1×27.5 Bulusan Geo 3×20 Coal Ⅲ 1×300 Maibarara Geo 1×10 Bac-Man Geo Ⅱ 2×20 Calaca Ⅱ 1×300	none	6,031
1,994	Balog-Balog Hyd. 2×11 Pinatubo Geo 3×20	none	6,113
1,995	Cagua Geo 2×20 Tongonan Geo-A 8×55 Del Gallego Geo 6×20	Botocan #3 -1 Manila#1,2 -200	6,512
1,996	Tongonan Geo-B 8×55 Coal A-1 * 1×300	none	7,252
1,997	Coal A-2 * 1×300 Kalayaan Ⅱ 2×150	Carilaya #3 -8	7,844
1,998	Coal B-1 1×300 Casecnan 268	Botocan#1,2 -16 Sucat #1 -150	8,246
1,999	Coal B-2 1×300 Combined Cycle 1×300	none	8,846
2,000	Combined Cycle 1×600	Carilaya #4 -8 Sucat #2 -200	9,238

* Coal A : Masinloc

Table S4-4 Demand and Supply Balance in MW and GWh

YEAR	1989	1990	1991	1992	1993	1994
Demand(Gwh) Gen.Lev	18,215	20,029	21,582	23,221	24,952	26,776
Peak pow.(MW)	2,938	3,266	3,520	3,787	4,069	4,367
Pondage Hyd.(MW)	895	895	895	879	879	901
Run-of-river	32	32	32	32	32	32
Pumped Hyd.(MW)	300	300	300	300	300	300
Hyd.Tot.Ins.Cap(MW)	1,227	1,227	1,227	1,211	1,211	1,233
Hyd.Tot.Firm Cap.	778	778	778	770	770	777
Hyd.Dep.Enr(GWh/yr)	2,410	2,410	2,410	2,375	2,375	2,423
Gas Turbine(MW)	210	530	860	888	915	810
Oil Thermal(MW)	1,925	1,925	1,925	1,925	1,925	1,925
Geo.Thermal	660	660	660	770	880	940
Coal	300	300	300	300	900	900
Combined cyc.	0	0	0	200	200	200
Thr.Tot.Ins.Cap(MW)	3,095	3,415	3,745	4,083	4,820	4,775
Thr.Tot.Firm Cap.	2,067	2,387	2,717	3,039	3,741	3,693
Thr.Dep.Enr(GWh/yr)	14,923	15,203	15,492	17,553	22,242	22,544
Tot.Ins.Cap(MW)	4,322	4,642	4,972	5,294	6,031	6,008
Ins.Cap.Margin(%)	47	42	41	40	48	38
Tot.Firm Cap(MW)	2,845	3,165	3,495	3,809	4,511	4,470
Firm Cap.Margin(%)	-3	-3	-1	1	11	2
Tot.Dep.Enr(GWh/yr)	17,333	17,613	17,902	19,928	24,617	24,967
Dep.Enr.Margin(%)	-5	-12	-17	-14	-1	-7

YEAR	1995	1996	1997	1998	1999	2,000
Demand(Gwh) Gen.Lev	28,700	30,732	32,874	35,134	37,519	40,035
Peak pow.(MW)	4,680	5,012	5,361	5,730	6,119	6,529
Pondage Hyd.(MW)	901	901	893	1,161	1,161	1,153
Run-of-river	31	31	31	15	15	15
Pumped Hyd.(MW)	300	300	600	600	600	600
Hyd.Tot.Ins.Cap(MW)	1,232	1,232	1,524	1,776	1,776	1,768
Hyd.Tot.Firm Cap.	777	777	1,073	1,167	1,167	1,163
Hyd.Dep.Enr(GWh/yr)	2,422	2,422	2,798	3,357	3,357	3,340
Gas Turbine(MW)	650	485	471	457	352	192
Oil Thermal(MW)	1,725	1,725	1,725	1,575	1,575	1,375
Geo.Thermal	1,540	1,980	1,980	1,980	1,980	1,980
Coal	900	1,200	1,500	1,800	2,100	2,100
Combined cyc.	200	200	200	200	500	1,100
Thr.Tot.Ins.Cap(MW)	5,015	5,590	5,876	6,012	6,507	6,747
Thr.Tot.Firm Cap.	3,983	4,521	4,792	4,973	5,438	5,728
Thr.Dep.Enr(GWh/yr)	25,470	30,187	32,146	33,447	37,297	40,223
Tot.Ins.Cap(MW)	6,247	6,822	7,400	7,788	8,283	8,515
Ins.Cap.Margin(%)	33	36	38	36	35	30
Tot.Firm Cap(MW)	4,760	5,298	5,865	6,140	6,605	6,891
Firm Cap.Margin(%)	2	6	9	7	8	6
Tot.Dep.Enr(GWh/yr)	27,891	32,609	34,944	36,805	40,655	43,563
Dep.Enr.Margin(%)	-3	6	6	5	8	9

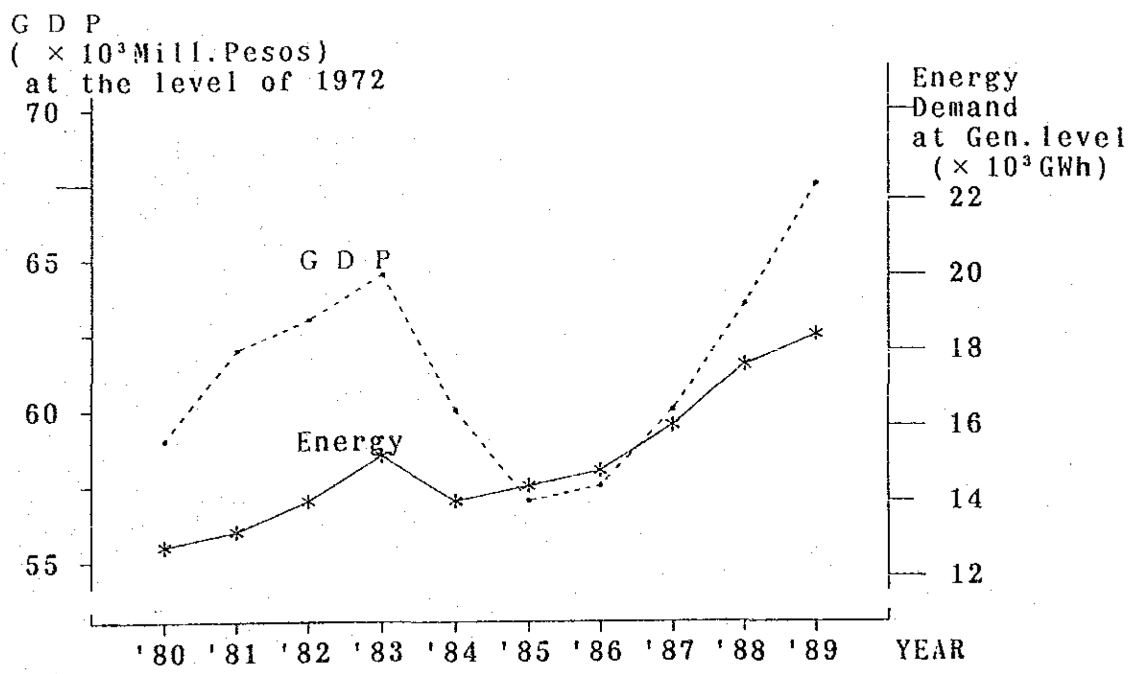


Fig. S4-1 Correlation between GDP and Electric Energy

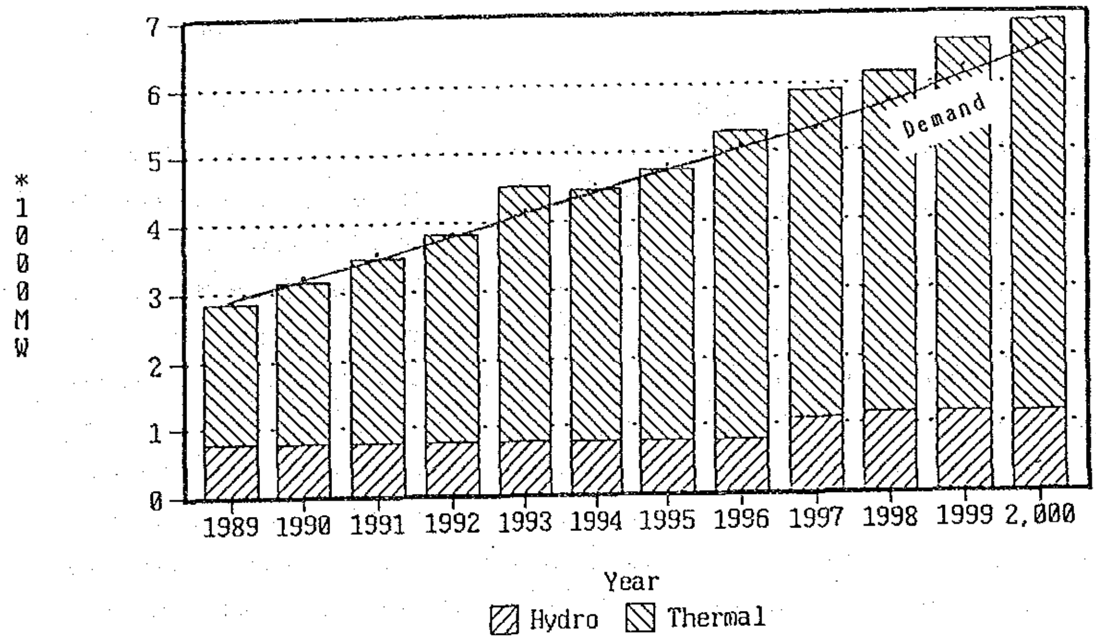


Fig. S4-2 Firm Power Balance in Luzon Grid

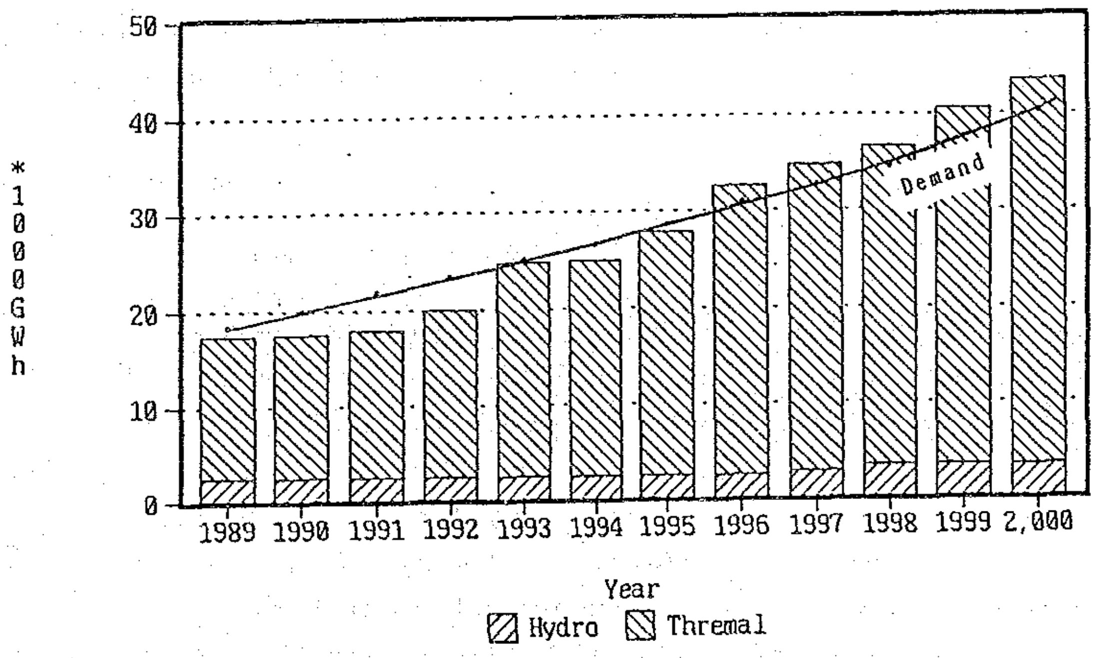


Fig. S4-3 Firm Energy Balance in Luzon Grid

Chapter 5 Hydrology

5.1 General Meteorology

The climate is oceanic and strongly influenced by the monsoons developed in the Indian Ocean and the north Pacific Ocean, with little temperature variation throughout the year except in mountainous areas. Rainfall is generally heavy and humidity is high.
The southwest monsoon due to Indian Ocean trade winds causes mostly southwest winds to begin blowing from around June, which become strongest in August and continue into September and October bringing rain all over the western coasts of the Philippines.
The northeast monsoon is a cold air current system developed due to high atmospheric pressures in the north Pacific Ocean causing mostly northeast winds to blow from around October, becoming strongest around January, and continuing to around April, and at times bringing heavy rains all over the eastern coasts of the Philippines.

5.2 Caliraya and Lumot Reservoirs

The Caliraya and Lumot reservoirs are provided by earthfill dams on the upstream stratches of the Caliraya and Lumot rivers which are tributaries of the Pagsanjan River, and the two reservoirs are connected by a tunnel with diameter of 2.0 m and length of 1,850 m.

5.2.1 Meteorology

(1) Geographical Conditions

Caliraya Reservoir is located approximately 60 km east-southeast of Manila, in the central area of Luzon Island. Geographically, the vicinity of the central region of Luzon is sandwiched by Manila Bay on the west side and by Lamon Bay on the east side, and the greater part of the central region is taken up by Laguna de Bay. Caliraya Reservoir is located at the west half of the approximately 30 km between the northeast part of Laguna de Bay and Lamon Bay. The area of Central Luzon has Mt. Banahao towering to an elevation of more than 2,000 m approximately 25 km south of Caliraya Reservoir, but mostly, the land on the Lamon Bay side is a tableland of elevation 400 to 500 m, while the land on the Manila Bay side has low-elevation topography.

(2) Precipitation

The meteorology of the vicinity of Caliraya tends to be affected by the two monsoons because of its geography and there is precipitation of more than 200 mm monthly from June to December, and the annual precipitation is around 3,000 mm. The maximum daily rainfall of the year occurs mostly in November or December, and in 1964, as much as 457.2 mm was recorded.

(3) Temperature

The temperature is about the same as at Manila, the minimum being from 20°C to 24°C, and the maximum being from 24°C to 33°C. It is the hottest in May, although generally, it is about 4°C cooler than Manila.

(4) Evaporation

Evaporation is about 1,200 mm annually.

5.2.2 Hydrology

(1) Inflow

Gauging stations for inflows had not been provided in the past. Therefore, inflow had been calculated by using the water level of Caliraya Reservoir, the energy productions of Caliraya and Kalayaan Power Plants, and pump-up energy of Kalayaan Power Plant.

Caliraya Reservoir is connected with Lumot Reservoir by a tunnel 2.0 m in diameter so that the inflow to Lumot Reservoir is regulated naturally and flows into Caliraya Reservoir to be included as part of the inflow to Caliraya Reservoir.

The past average annual inflow was 200 x 10^6 m^3. Table S5-1 gives the actual inflow at Caliraya Reservoir.

The peak flood discharge at Caliraya Reservoir has been analyzed in "Feasibility Report of Caliraya Dam Rehabilitation Project" by JICA in Sept. 1986, as shown below.

Return Period (yr)	Peak Flood Discharge (m^3/s)
1,000	2,632
200	2,173
100	1,968
50	1,770
10	1,300

(2) Runoff Regulation by Reservoir

The inflow to Lumot Reservoir is naturally regulated annually by the discharge through the connecting waterway, and runs into Carilaya Reservoir.

Water above the high water level is discharged by a morning glory type spillway 4 m in diameter.

The inflow of Caliraya Reservoir consists of stream inflow, pumped water by the Stage I Plant (Max.: 90.8 m^3/s), and discharge from Lumot Reservoir. The outflow consists of generation discharge of Caliraya Power Plant (maximum: 14.74 m^3/s), Kalayaan generation discharge (Stage I, maximum: 124.0 m^3/s), and outflow to Lumot Reservoir. The reservoirs are operated for these outflows and inflows to be optimum in using the effective storage capacity of 22.1 x 10^6 m^3 (See Fig. S5-1) for power generating operation on a weekly basis.

Water rising above EL.289.2m is discharged by a spillway tunnel 4.2 m in diameter with a cylinder gate and an emergency spillway.

(3) Water Level of Caliraya Reservoir

Recently, since there has come up the matter of rehabilitation of Caliraya Dam, the maximum water levels in operation have been made EL. 289.15 m in the dry season and EL. 288.0 m in the wet season to cope with water level rises during floods.

5.3 Laguna de Bay

5.3.1 Geographical Conditions

Laguna de Bay is located to the southeast of Manila and takes up the greater part of Central Luzon sandwiched by Manila Bay and Lamon Bay. It extends approximately 45 km east-west and 40 km north-south, and the area is approximately 900 km^2 with two peninsulas sticking out more than 20 km into the lake from the north. Laguna de Bay empties into Manila Bay by means of the Pasig River which starts out from the northwest part of the lake, goes northwest for approximately 20 km, and passes finally through Metro Manila.

5.3.2 Water Level of Laguna de Bay

The water level of Laguna de Bay fluctuates in a range between EL. -0.2 m and EL. 2.0 m in proportion to rainfall. Broadly divided seasonally, March to June make up the period of lowest water with water levels between EL. -0.2 m and EL. 0.4 m, January to February, and July to August are intermediate periods with water levels from EL. 0.2 m to EL. 0.9 m, while September to December correspond to a period of high water at EL. 0.8 m to EL. 2.0 m. On August 3, 1972, a water level of EL. 3.53 m was recorded.

5.3.3 Sediment Carried by Pagsanjan River

According to "*Feasibility Study Report of Kalayaan Pumped Storage Plant*" in May 1973 by ELC, the sediment discharged into Laguna de Bay by the Pagsanjan River has been at a rate of extension of 10 m a year from 1919 to 1969.

The largest source of the sediment transported is considered to be silt scoured from river terraces at the midstream and downstream stretches of the river due to rising water levels during floods.

Table S5-1 Actual Inflow at Caliraya Reservoir

YEAR	JAN	FEB	MAR	APR	MAY	JUN	Sub-total	JUL	AUG	SEP	OCT	NOV	DEC	Sub-total	TOTAL
1960	16.88	12.70	7.60	3.14	13.11	18.80	70.23	9.58	14.98	10.84	24.87	10.55	9.14	79.96	150.19
1961	8.01	5.39	4.34	2.64	9.19	9.00	38.57	8.77	6.35	13.24	12.21	28.32	9.79	78.68	117.25
1962	5.27	6.66	5.61	4.51	4.44	6.81	33.30	10.82	7.62	21.96	7.45	16.13	15.06	79.04	112.34
1963	5.39	6.61	3.61	3.95	3.21	5.84	28.61	6.58	15.03	12.35	9.96	8.81	12.70	65.43	94.04
1964	9.31	8.57	9.32	7.56	6.18	16.11	57.05	14.34	8.87	12.66	23.65	29.59	23.94	113.05	170.10
1965	9.99	5.96	7.44	5.69	6.57	2.45	38.10	9.55	7.51	9.59	8.74	19.39	25.26	80.04	118.14
1966	8.50	3.94	4.14	3.31	8.13	6.27	34.29	10.29	5.70	7.21	9.33	9.64	14.81	56.98	91.27
1967	13.08	2.55	4.64	5.58	3.55	4.32	33.72	4.82	12.15	8.56	10.44	22.23	8.93	67.13	100.85
1968	7.52	3.72	3.65	1.60	3.02	4.36	23.87	5.10	7.19	7.51	14.79	5.61	4.70	44.90	68.77
1969	6.73	0.46	0.97	0.83	0.51	1.09	10.59	8.52	4.64	8.01	4.01	8.55	21.07	54.80	65.39
1970	13.29	3.38	1.79	4.62	1.21	4.31	28.60	9.61	3.64	10.76	24.91	33.67	20.08	102.67	131.27
1971	8.54	19.25	16.96	10.95	18.17	37.91	111.78	49.32	16.69	15.41	72.79	49.85	69.53	273.59	385.37
1972	9.89	16.05	5.08	10.37	10.11	18.18	69.68	55.37	25.75	26.09	21.12	56.53	60.58	245.44	315.12
1973	15.56	8.28	5.18	9.67	4.58	5.75	49.02	11.82	8.31	27.15	44.69	76.59	84.49	253.05	302.07
1974	13.13	9.63	10.56	4.19	13.45	13.25	64.21	6.31	32.24	14.86	64.71	52.42	57.38	227.92	292.13
1975	26.22	10.69	14.28	38.37	13.63	11.86	115.05	2.04	15.87	24.64	26.08	33.15	86.78	188.56	303.61
1976	16.59	7.38	2.11	30.23	31.77	46.46	106.54	3.56	25.45	5.35	34.26	42.93	48.69	160.24	266.78
1977	19.94	13.08	5.95	2.45	26.64	9.94	78.00	12.21	16.46	19.74	16.14	40.82	46.01	151.38	229.38
1978	15.77	6.32	3.76	7.85	5.26	4.76	44.72	4.21	15.45	26.49	100.84	16.84	13.69	177.52	222.24
1979	4.21	0.29	0.28	5.96	15.81	22.02	48.57	7.53	20.37	15.79	24.91	35.03	16.46	120.09	168.66
1980	9.57	10.71	25.48	12.58	13.62	46.85	118.81	28.29	15.57	26.84	54.58	58.21	29.31	212.80	331.61
1981	18.12	8.16	12.78	11.93	15.28	15.62	92.09	29.34	18.71	32.01	37.90	65.89	45.00	228.85	310.94
1982	16.27	10.66	5.45	9.74	6.43	6.79	55.34	18.85	9.56	35.10	12.43	33.53	27.58	137.05	192.39
1983	28.57	10.14	8.15	6.01	4.54	2.76	60.17	29.16	16.02	20.38	58.62	19.19	21.60	164.97	225.14
1984	19.33	8.86	14.64	5.02	7.59	6.78	62.22	5.95	13.95	16.54	63.84	21.36	16.28	137.92	200.44
1985	6.15	8.02	5.52	3.98	8.67	26.95	39.29	30.01	6.86	27.86	75.21	39.42	30.05	209.41	268.70
1986	23.62	9.19	9.19	9.33	4.07	6.59	61.99	41.33	38.50	18.34	79.64	53.62	44.27	275.70	337.69
1987	18.70	7.68	6.62	4.50	2.03	5.55	45.08	4.01	14.08	9.79	16.58	54.00	62.19	160.65	205.73
1988	42.94	15.11	6.32	26.81	9.93	19.14	120.25	16.45	10.93	8.46	81.37	67.12	15.48	199.81	320.06
1989	17.38	21.03	18.93	9.49	29.90	32.10	128.83	26.73	13.99	16.67	26.92	17.71	21.52	123.53	252.36
TOTAL	434.47	260.47	230.35	262.86	301.60	388.82	1878.57	480.47	428.44	510.20	1062.99	1026.70	962.37	4471.16	6349.73
AVERAGE	14.48	8.68	7.68	8.76	10.05	12.96	62.62	16.02	14.28	17.01	35.43	34.22	32.08	149.04	211.66 (6.71 m^3/s)
MAXIMUM	42.94	21.03	25.48	38.37	31.77	46.85	128.83	55.37	38.50	35.10	100.84	76.59	86.78	275.70	385.37
MINIMUM	4.21	0.29	0.28	0.83	0.51	1.09	10.59	2.04	3.64	5.35	4.01	5.61	4.70	44.90	65.39

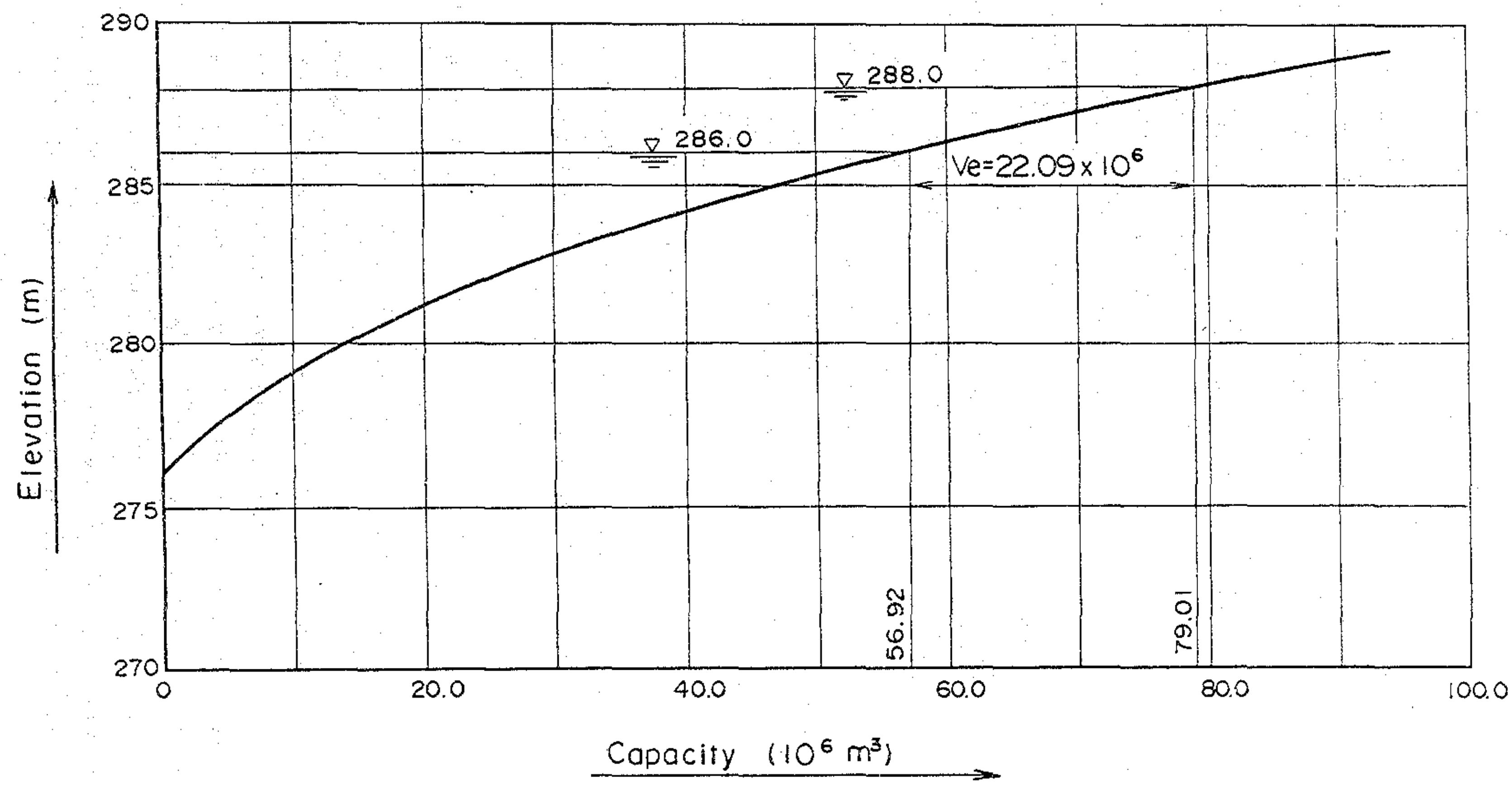


Fig. S5-1 Caliraya Reservoir Capacity

Chapter 6 Geology

6.1 Topography and Geology around Project Site

The topography of the area around the Project site, located to the eastern end of Laguna de Bay, is featured by lava plateaus, 200 to 400 m in altitude, which form steep cliffs at the shore of Laguna de Bay.

The tops of the lava plateaus are flat lands having relatively large numbers of small undulations. The western sides of there plateaus are steep slopes, from 200 to 300 m in relative hight and having 50° to 60° gradients, which face Laguna de Bay. The delta formed by the Pagsanjan River, stretching to the northwest, spreads to the south of the power plant site.

The geology of the area around the Project site is featured by a wide cover of volcanic products which were ejected from the Neogene Pliocene Epoch to the Quarternary Period.

These volcanic products consist of pyroclastic rocks of basalt-andesite lava, tuff, agglomerate, etc., which are widely distributed from the northern side to the eastern side of Laguna de Bay.

6.2 Geology around Each Structure Site

The materials collected during the investigation and the results of site survey indicate the following geological features. (Refer to Fig. S6-1.)

(1) Upper Canal

The upper canal already exists, having been constructed in the Stage I.

The ground surface consists of tuff and basalt, and tuff is widely distributed overlying basalt.

A landslide is observed on the right bank at about 500 m to the upstream of the intake. The landslide seems to have affected an area of 250 to 300 m along the stream, 50 to 60 m in height. The affected area contains several slides of horseshoe shape, and there is no sign that they are moving now. If movement is found in future, some countermeasures will be required, including the removal of sliding deposits.

(2) Intake

The intake was constructed together with the upper channel during construction works of the Stage I. There is a transition boundary near the intake from agglomerate to basalt, and the foundation of the intake is weathered basalt.
No abnormal condition is found at the intake and its surrounding area, and it is deemed that there is no geological problem in terms of civil engineering.

(3) Penstock Route

The route of the penstock of the Stage II has been planned 10 m to the west of the existing penstock of the Stage I, and the area of the penstock route was mostly excavated during construction works of the Stage I.
In the upper inclined section, basalt of the same nature as that around the intake is distributed.
In the central section, agglomerates are widely distributed with thickness of approximately 40 m over the basalt base rock.
In the lower section, basalts are exposed all over the cliff along the road at elevation of 50 m.
Recording underparts of basalts there are developed cracks in some zones, but medium hard and lumpy agglomerates are generally distributed.
It can be concluded that there will be no particular problem concerning bearing force and stability in the foundation of the penstock route, its surrounding areas and the slope which has been already constructed.

(4) Power Plant

Agglomerates are exposed all over the steep slope of the mountain side. The agglomerates have various lithofacies, such as soft components containing much matrices of tuff materials, generally hard components containing many basalt gravels, as well as parts containing thin layers or lenses of tuff and basalt.

According to the boring survey materials of the Stage I, there is a fault with large base rock displacement in the NE-SW direction at about 30 m to the west of the power plant site, and a strong water gush was encountered at the power plant site.

In this survey, boring was performed on 2 holes at the power plant site.
According to this survey, the fault exists at the boundary between talus deposits distributed widely on the side of the tailrace and agglomerates. It was confirmed that the foundation rock is medium hard, and consists of generally lumpy agglomerates. Concerning the permeability of foundation rock, there were many zones where high permeabilities of 20 Lugeon or more were observed.

Based on the above survey result, it can be regarded that the foundation rock at the power plant site involves no particular problem concerning bearing force and slope stability during excavation. However, as high permeability is observed, and pressurized ground water exists, the measures of stopping water must be studied carefully.

(5) Tailrace

According to the boring survey record of the Stage I, the foundation of the tailrace is agglomerate for a distance of approximately 50 m from the power plant. On the west side of the fault located there, it probably consists of talus deposits made up of basalt boulders and cobbles, and deposits from Laguna de Bay consisting of clay, silt, and sand.
There appears to be no problem as a structural foundation, but thorough study will have to be made to stop water from Laguna de Bay during the construction work.

The results of boring are given in Fig. S6-2.

6.3 Blasting Test

6.3.1 Objective and Schedule of Blasting Test

The location of the Stage II Project is near the existing power plant, and in excavation of the power plant shaft for Stage II, there is a possibility that adverse effects will be exerted on the existing power plant.

Many studies have been conducted in the past concerning actual conditions and control methods with regard to blasting vibrations, and various suggestions have been made about the effects of blasting and limitation on structures built on base rock or unconsolidated ground.

Therefore, blasting tests must be conducted at the site in question to develop an experimental equation that is most suitable for the ground condition of the site, and the blasting control measures should be established based on specific conditions of the site.

Accordingly, blasting tests using conventional dynamite and static cracker (Calmmite), were conducted for 19 days from August 26 to September 13, 1990 (See Table 1-4 in Chapter 1), in order to identify the basic vibration characteristics of the foundation near the existing power plant, and so that the blasting method, the type of explosive, size of charge and the excavation method in the real construction work could be studied.

6.3.2 Test Site

The blasting tests were conducted on the foundation rock of the proposed site of the Stage II Project, as illustrated in Fig. S6-3.

6.3.3 Blasting Pattern

Prior to the main tests, preliminary tests, Cases-A and B, were conducted at a location farthest away from the existing power plant inside the site of the Stage II, in order to confirm the effect of blasting on the existing plant. Then, the main tests, Cases-E, F, I and J were conducted at the center of the Stage II site.

(1) Preliminary Blasting Test

The preliminary blasting tests, Cases-A and B were conducted at a point farthest from the existing plant using conventional dynamite to confirm the extent of the effect on the existing plant and to measure the vibration velocity (V) and K-value (K).

(2) Main Blasting Test

The blasting patterns, charges, etc. for the main test were studied based on the results of preliminary tests, and the effect on the existing power plant was re-examined. The main tests were conducted at the planned power plant site and near the existing plant using conventional dynamite and Calmmite.

6.3.4 Measurement Items and Method

Measuring points for vibration velocity were selected to be nearest to the blast center and, moreover, where prone to effects of vibration as shown in Fig. S6-4, and the three sites of the existing power plant which were chosen at the powerhouse side wall (2 measuring points), concrete foundation around generators (2 measuring points), and inside the generator control room (1 measuring point).

The measurement items consisted of measurement of acceleration (gal), with vibration velocity (kine) obtained performing analytic transformation of data to make comparisons with past measurement results.

6.3.5 Measurement Results

The data were analyzed by FFT analyzer to identify maximum acceleration amplitude and predominant vibration period for each blasting test, these were transformed into vibration velocities, and correlations with explosive charges were obtained.

The results are given in Fig. S6-5, and Fig. S6-6.

According to the measurement results, in all tests performed using conventional dynamite, vibration velocities were all less than 1 kine as shown in Fig. S6-5, and no effect at all was seen on the existing power plant.

In Cases I and J when the static cracker (Calmmite) was used, no noise, vibration, or flying of rock occurred as expansive force created by hydration reaction is taken advantage of.

Tests of Cases-C and D employing low detonation-velocity explosive (CCR) had been planned, but since it was found during drilling that the foundation rock was highly permeable and there would be a fairly great amount of springing of water, effects could not be expected even if tests were to be performed and, since it was already known that the vibration value would be about 1/5 to 1/10 of that of dynamite, testing was dropped.

6.3.6 Analysis and Evaluation of Measuring Results

In general, there is the relationship of the following equation between the vibration velocity generated by blasting and the amount of explosive used.

$$V = K \times W^m \times D^n$$

where:
- V: vibration velocity (kine = cm/s)
- W: amount of explosive (kg)
- D: distance (m)
- K: Coefficient determined by rock quality, explosive type, and blasting method

It was decided to use the above equation for analysis of the velocity measurement results obtained in these tests.

The basic equation concerning blasting vibrations in this case was the following:

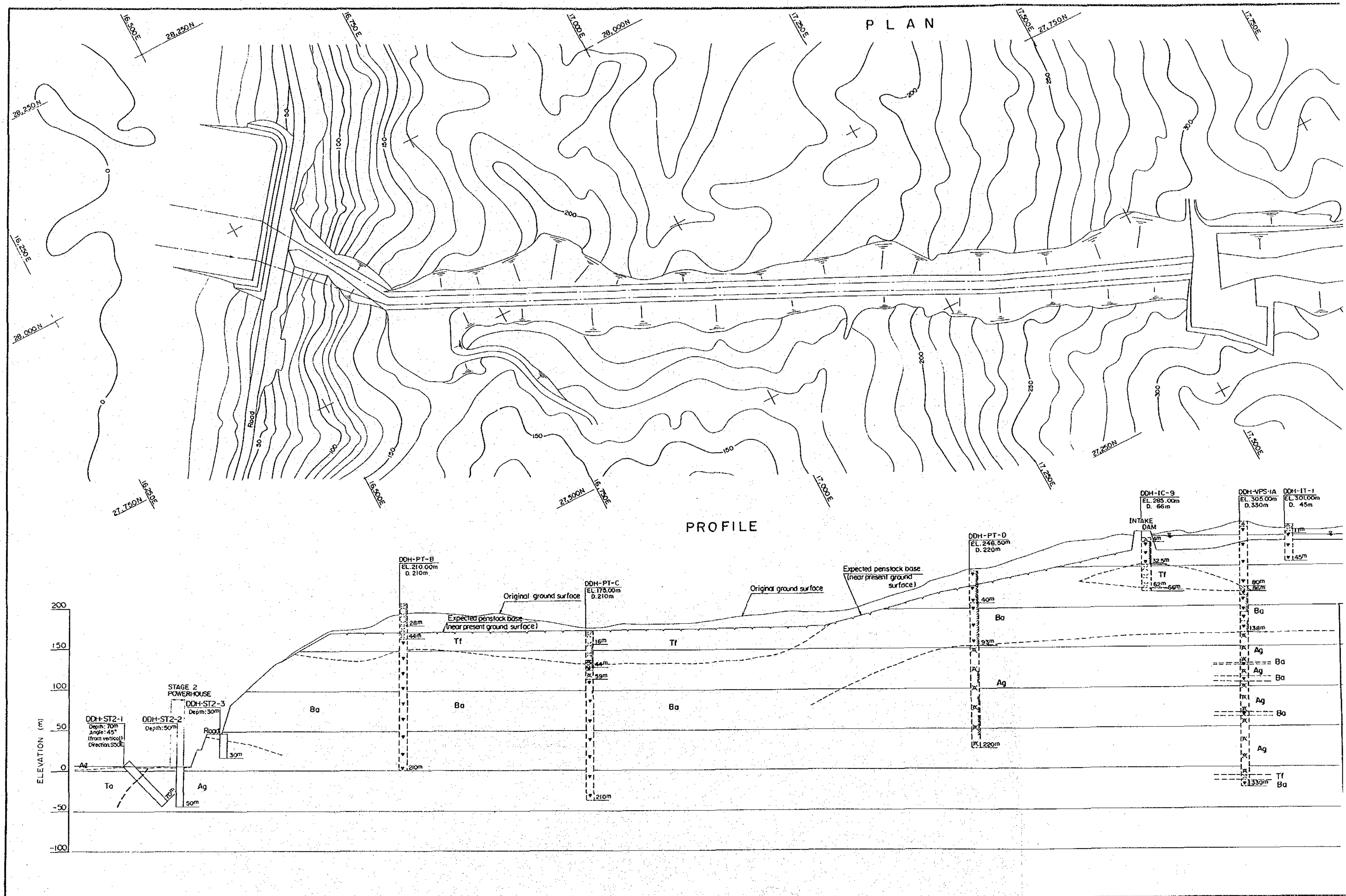
$$V = K \times W^{2/3} \times D^{-2}$$

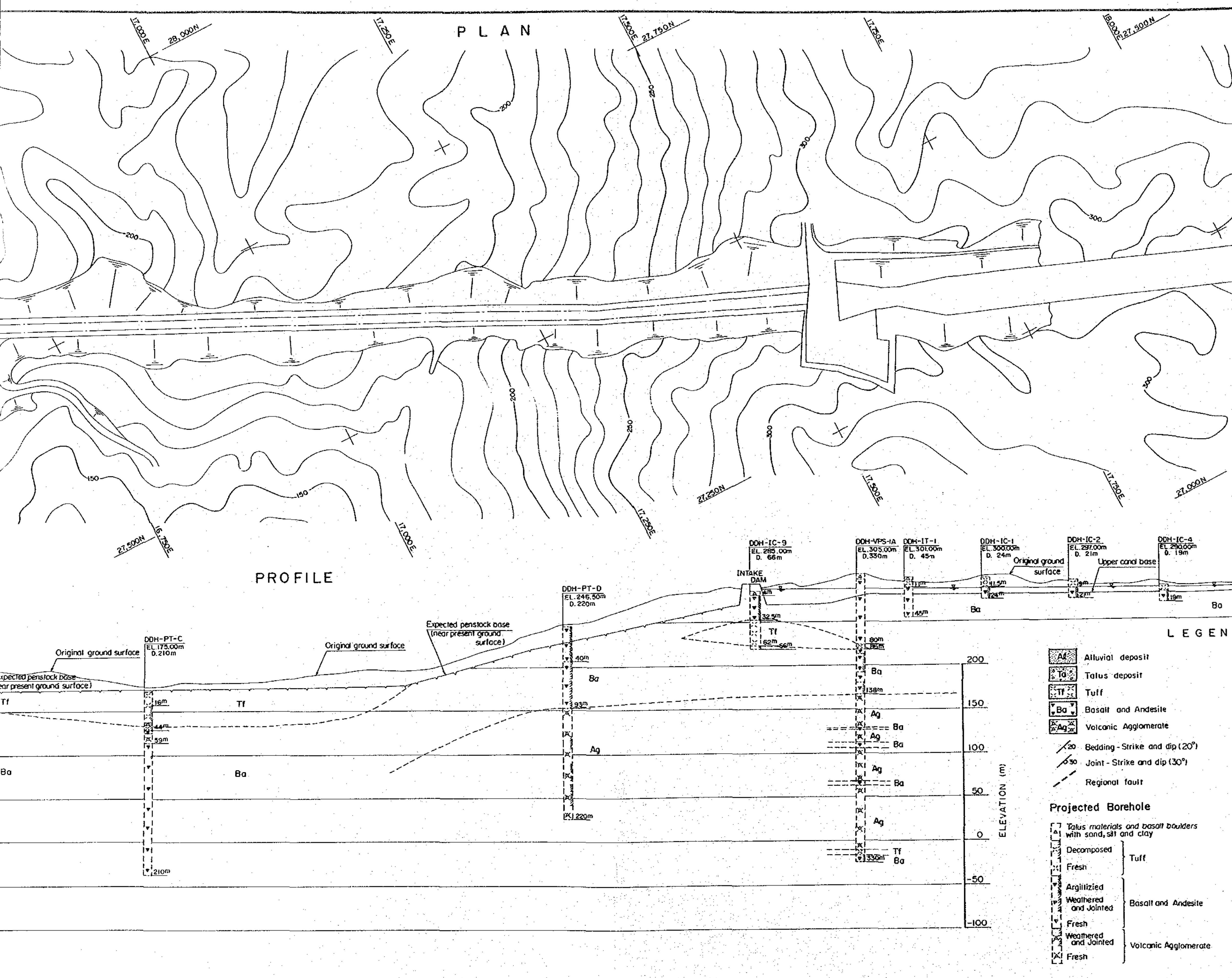
Applying the value of Case-F in which the maximum vibration velocity was recorded in actual measurements to this equation to obtain the value of the constant K, K = 974 was obtained, and rounding out to be on the conservative side, it came out as given below, although, incidentally, the simple average K-value for all data was 355.

Conventional dynamite K = 1000

Considering the results of these blasting tests, it is desirable for excavation to be done with controlled blasting at least holding vibration velocity to 2 kine in excavation for the main structure of the stage II Project in order that there will not be any adverse effects on the existing plant. In such case, it will be necessary for explosive charges and blasting vibrations to be controlled, monitoring blasting vibrations every time blasting is done. As reference, the relationships of explosive charges and distances with vibration velocities calculated employing the basic equation are shown in Fig. S6-7.

The low detonation-velocity explosive (CCR), and the static breaker (Calmmite) cannot be expected to have very much breaking effect at ground of high permeability as at this site, but it is conceivable for these low detonation-velocity explosives and static breakers to be used for supplemental rock excavation in the area close to the existing plant.


PLAN
PROFILE
16,500E
28,250N
16,750E
17,000E
28,000N
17,250E
17,500E
27,750N
17,750E
16,250E
28,000N
27,750N
16,500E
27,500N
16,750E
17,000E
17,250E
27,250N
17,500E
Road
DDH-PT-B
EL. 210.00m
D. 210m
DDH-PT-C
EL. 175.00m
D. 210m
DDH-PT-D
EL. 246.50m
D. 220m
DDH-IC-9
EL. 285.00m
D. 66m
INTAKE DAM
DDH-VPS-1A
EL. 305.00m
D. 330m
DDH-IT-1
EL. 301.00m
D. 45m
Original ground surface
Expected penstock base (near present ground surface)
STAGE 2 POWERHOUSE
DDH-ST2-1
Depth: 70m
Angle: 45°
(from vertical)
Direction: S50E
DDH-ST2-2
Depth: 50m
DDH-ST2-3
Depth: 30m
ELEVATION (m)
200
150
100
50
0
-50
-100
Tf
Ba
Ag
Ta
Al



KALAYAAN PUMPED STORAGE PLANT DEVELOPMENT PROJECT (STAGE II)

GEOLOGY

PLAN AND PROFILE

Fig. S6-1

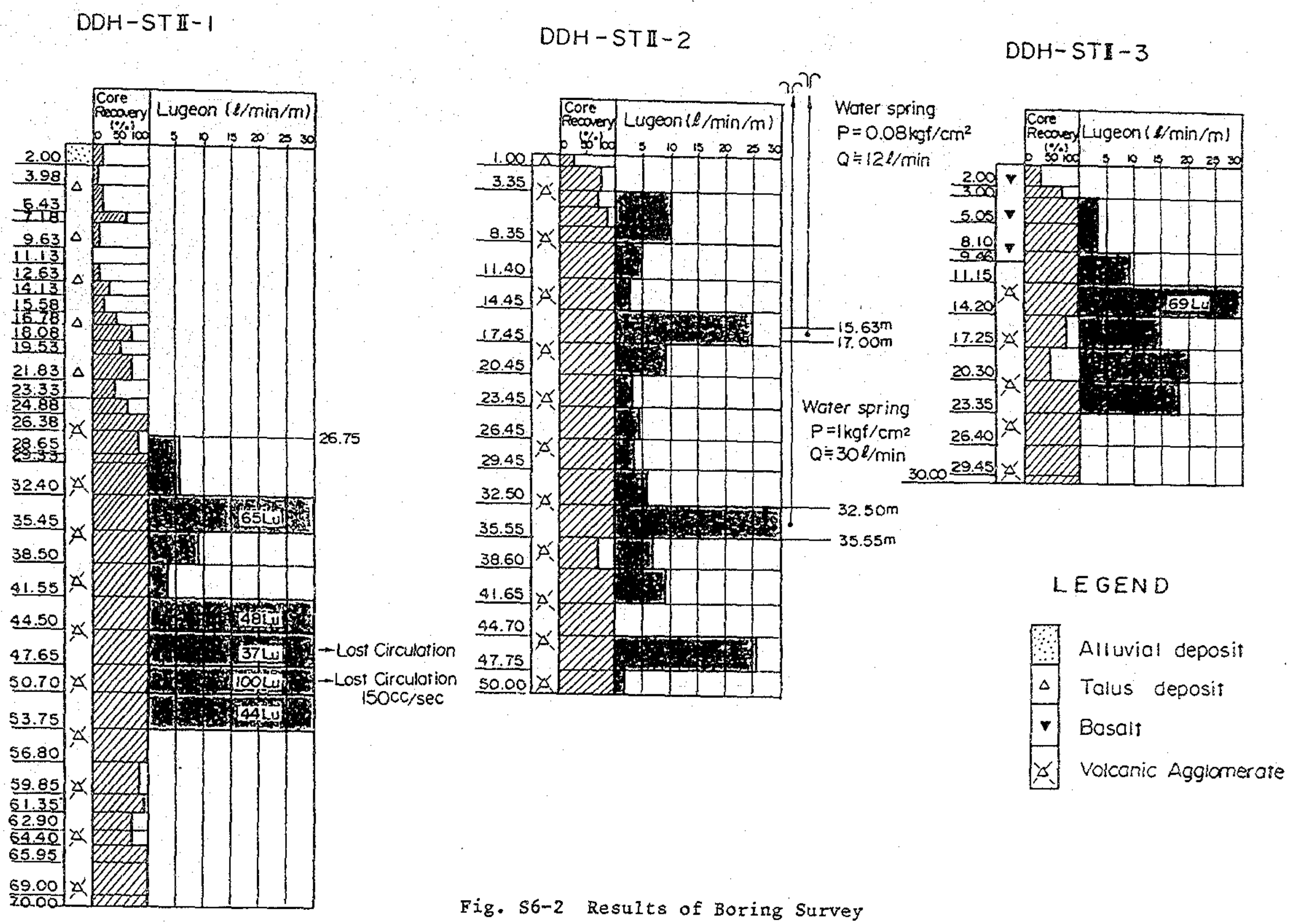
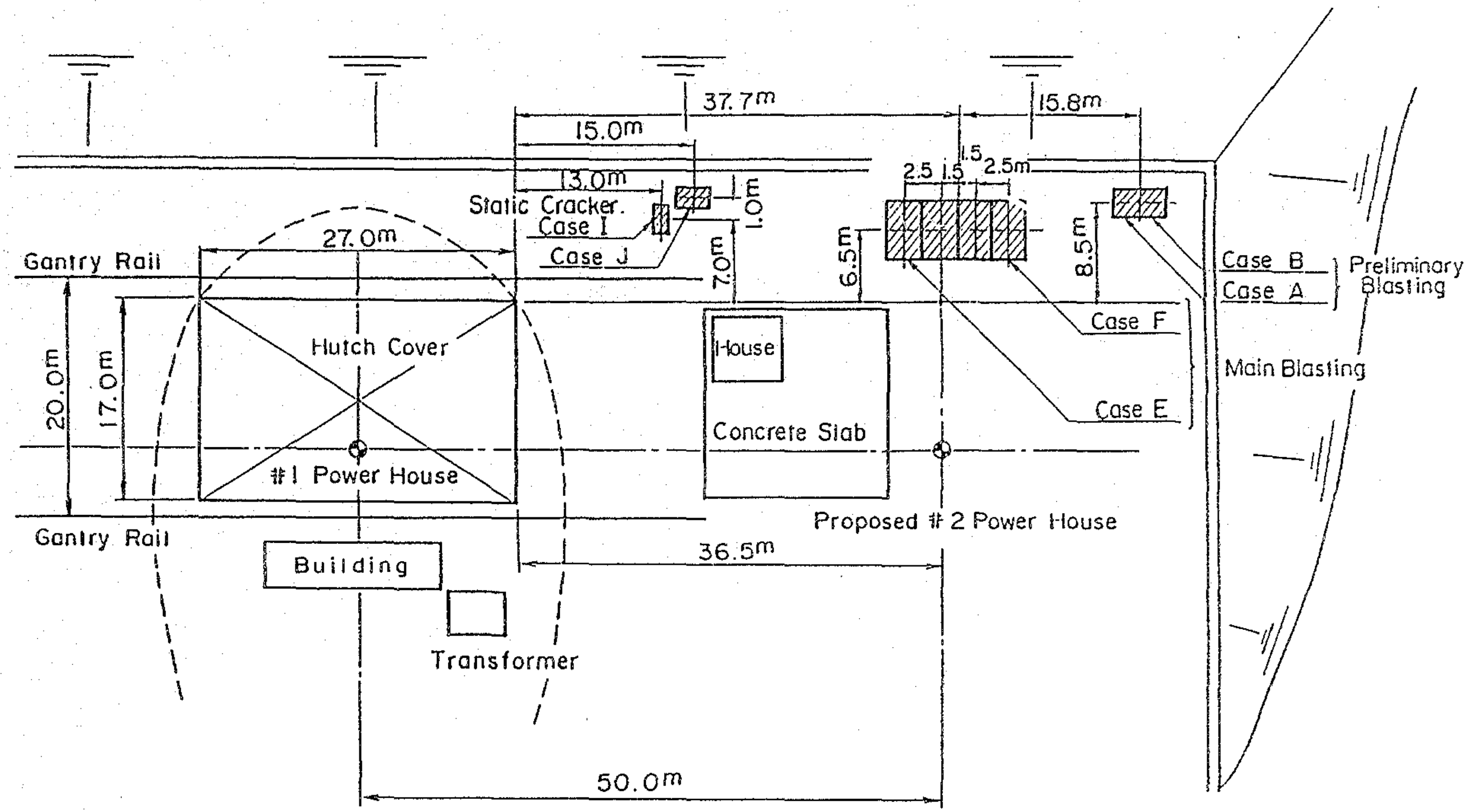
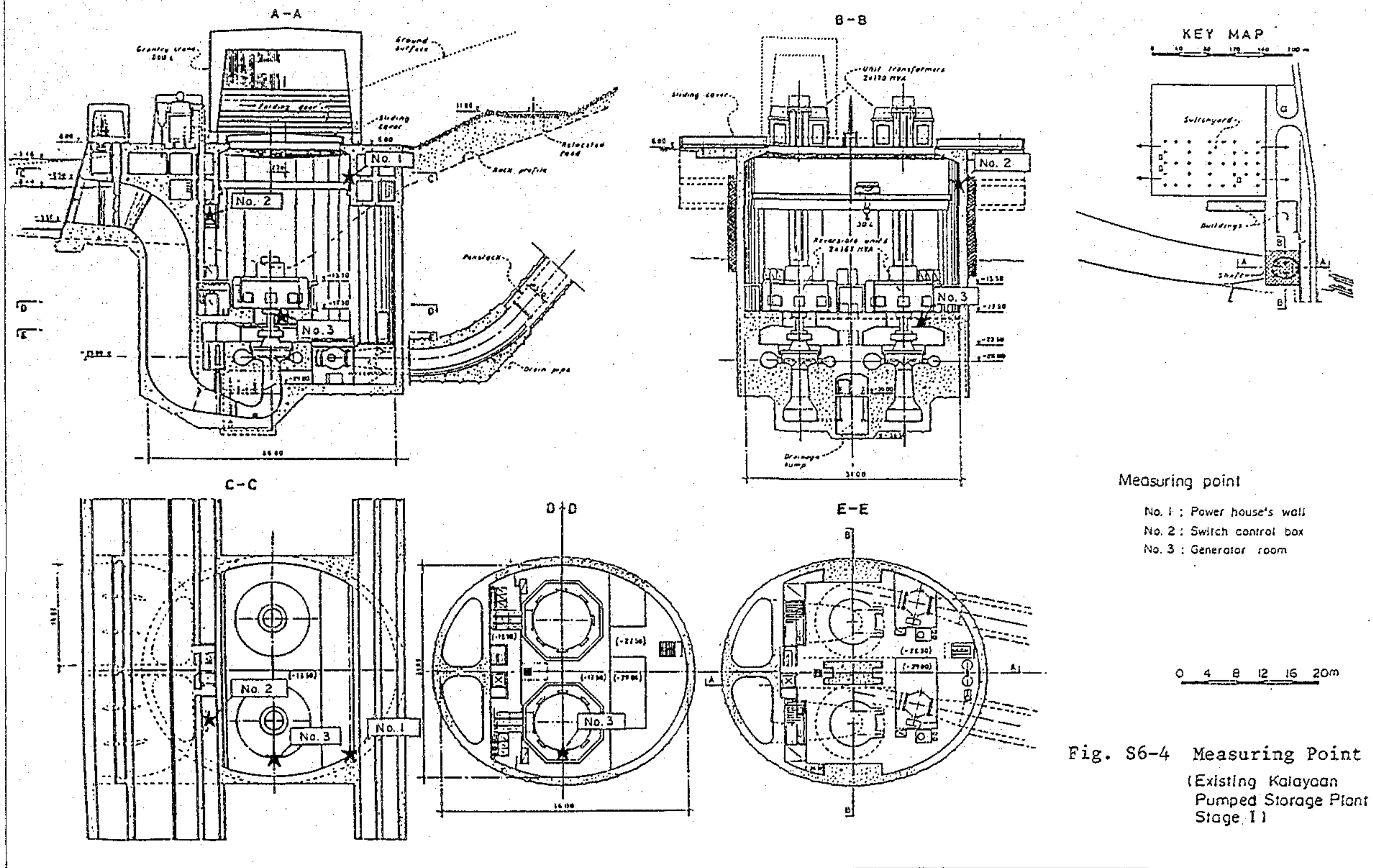


Fig. S6-2 Results of Boring Survey



PLAN (S=1/500)

Fig. S6-3 Blasting Test Area



Measuring point

No. 1 : Power house's wall
No. 2 : Switch control box
No. 3 : Generator room

0 4 8 12 16 20m

Fig. S6-4 Measuring Point
(Existing Kalayaan Pumped Storage Plant Stage I)

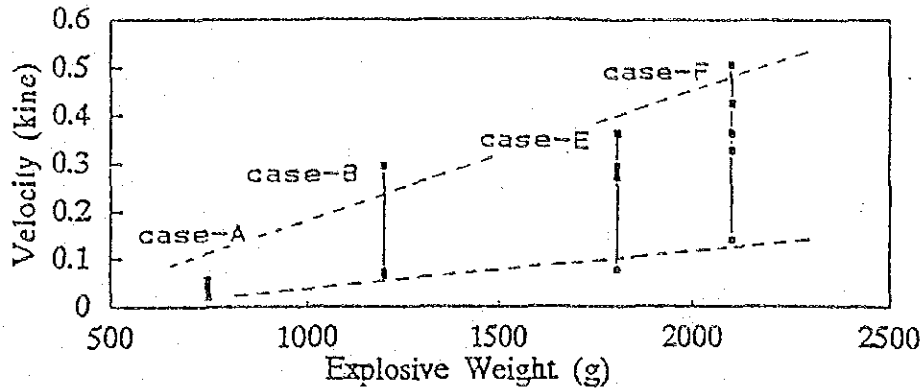


Fig. S6-5 KALAYAAN P.S.P.P. (II) Blasting Test
Explosive Weight - Velocity

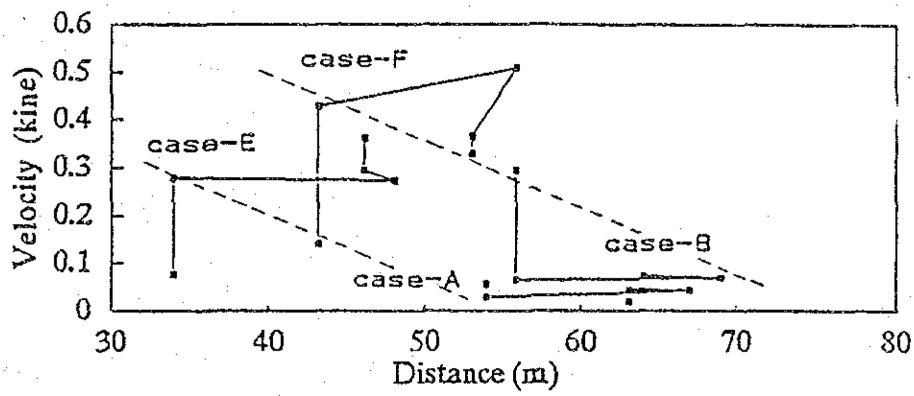


Fig. S6-6 KALAYAAN P.S.P.P. (II) Blasting Test
Distance - Velocity

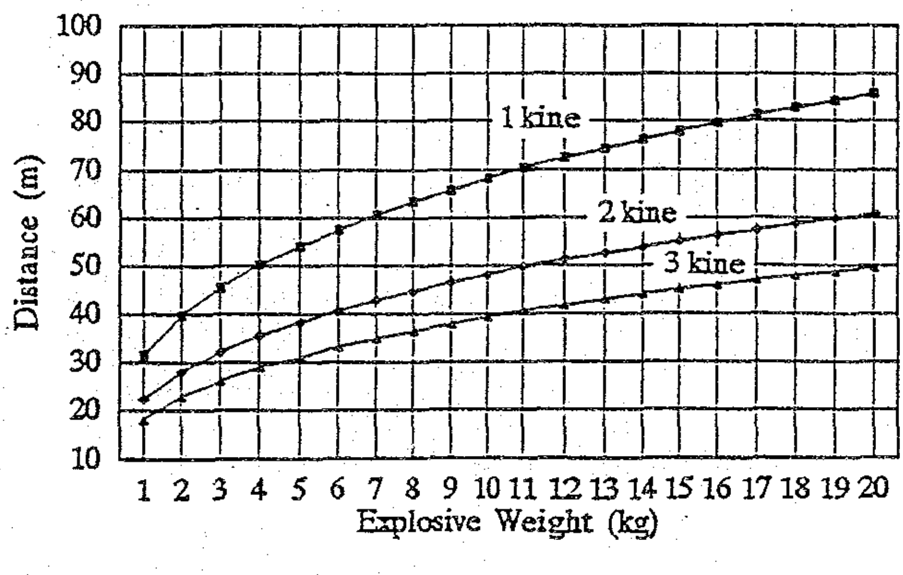


Fig. S6-7 KALAYAAN P.S.P.P. (II) Blasting Test
Explosive Weight - Distance - Velocity

Chapter 7 Earthquake

7.1 Outline of Characteristics of Seismicity in the Philippines

The Philippine Islands are located near the boundary between two great tectonic plates called the Philippine Sea Plate and the Eurasian Plate.

The high seismicity of the Philippines is owed to the interactions of these tectonic plates, relative displacements along the Philippine Trench, and the tectonic movements along other active faults.

The epicenters of 1,182 earthquakes occurring during the 93 years from 1897 to 1989 were within a radius of approximately 600 km from the project site.

It is seen from these epicenter distributions that where seismicity is high in the Philippines are eastern Mindanao, Samar, and Leyte situated at the eastern part of the islands, and this is due to the sinking under of the tectonic plate along the Philippine Trench. It may also be seen that other than the above, there are zones of comparatively high seismicities in the vicinities of northern Luzon, Lubang, and Mindoro.

7.2 Design Seismic Coefficient

(1) Evaluation of Maximum Acceleration at the Project Site

An evaluation of the maximum acceleration at the Project site was made by statistical techniques in order to select the design seismic coefficient. The earthquake data used in this case were those obtained from NAPOCOR at the time of the field survey and comprise data of 1,182 earthquakes from 1897 to 1989. In the evaluation of maximum acceleration, four kinds of models were employed, and the probable earthquake accelerations corresponding to various return periods were obtained from the maximum accelerations calculated from the individual models.

(2) Design Seismic Coefficient

The results of evaluation of maximum acceleration by a statistical technique is $_{n}$ = 80 gal for a return period of T = 1,000 years. Judged by this, it is considered that k_H = 0.10 g is reasonable as the horizontal design seismic coefficient of the Project site.

On the other hand, the horizontal design seismic coefficient used in design of Stage I Project was k_H = 0.15 g.

Judged comprehensively based on the above, the horizontal design seismic coefficient for the Stage II Project is to be k_H = 0.15 g.

Chapter 8 Development Plan

8.1 Size of Project

The Mission has studied the optimal project size of the pumped storage plant in near future from the point of view of the "best mix" of power supply sources. According to the result of demand forecast, the off-peak power demand in the Luzon Grid on weekdays is expected to be around 60% of the peak demand, and the daily load factor around 80%.
It was chosen to supply about one half of this peaking load of 20%, or 10%, with the pumped storage power plants which have high response and load-following characteristics.
As the peak power demand in the late 1990s (1996 to 2000) will be 5,800 MW on average, 10% of this amount, or about 600 MW should be supplied by pumped storage power plants.
As 300 MW of pumped storage plants are now in operation, it can be seen that an additional 300 MW will have to be developed.
In developing 300 MW, two 150-MW units will be installed, because the optimal unit size has been determined as 150 MW by the "Power System Analysis" which is described in Section 9.2 of Chapter 9.

8.2 Pumping Energy and Schedule of Development

The timing of development of the Stage II Project has been studied by estimating the pumping energy and reserve margin based on the demand projection and development program illustrated in Chapter 4.

As shown in Table S8-1 and Fig. S8-1, the pumping energy becomes available after 1997. As the kW supply margin is low at this time, the development of a new pumped storage plant has a significant meaning in power system operation because it can replace gas turbine plants as a peak supply source, and at the same time levels out the off-peak load.

The development schedule would be the following.

January 1997 : First unit (No. 3 unit), 150 MW, commissioned.

July 1997 : Second unit (No. 4 unit), 150 MW, commissioned.

8.3 Pumping Operation Pattern

The output for each kind of generating sources in the power system and the operation mode of the Kalayaan pump-turbines, on a peak day (a weekday) in July 1997, are illustrated in Fig. S8-2.
The operation cycle of the Kalayaan pumped storage plant for 1 week from a Monday in 1998 to the next Sunday is given in Fig. S8-3.

8.4 Weekly Reservoir Operation in May 1998

The reservoir operation pattern for a cycle of generation and pump-up has been studied for a week in May 1998 when the power demand is the highest in the year.
The study was conducted based on the following data:

Effective Capacity of Upper Reservoir	22.09×10^6 m^3
Pump-turbine Units	4 units from Stages I and II
Water Level at Start of Generation Mode	High water level, EL 288.0
Generator Output	4 x 150 MW
Discharge	4 x 62 m^3/s
Pumping Input	4 x 150 MW
Pump-up Quantity	4 x 49.9 m^3/s
Natural Inflow	0.32×10^6 m^3/day

The water level variation of the reservoir as shown in Table S8-1 was calculated from the operation cycle of generation and pump-up given in Fig. S8-3. The reservoir operation pattern was obtained as given in Fig. S8-4.
The following features could be pointed out from the results of the above analysis.

- The utilization factor of the reservoir during the week is 52%, and the maximum variation of water level is 0.91 m.

- The reason why the utilization factor remains at 52% is that the supply of base thermal power plants is not sufficient to provide a full pumping energy, as this is only the second year after commissioning.

- Forty-four percent of the pumping energy during a week is pumped on Saturday and Sunday, to reduce daytime pumping time from Monday through Friday.

Table S8-1 Power Development Program and Available Pumping Power

YEAR	New Power Plants	(MW)	Reiter/Power decay Site	(MW)	Installed capacity total	base p.p	Demand (MW)	Available pump pow.	Reserve Margin(%)
1989	Hydro	1227							
(existing)	Oil P.	1925							
	Geo P.	660							
	Coal P.	300							
	Gas. T	210							
	Total	4322	none	0	4322	960	2938	-850.8	47.1
1990	Hopwel GT	200							
	P. bargeGT	120							
	Sub tot.	320	none	0	4642	960	3266	-1047.6	42.1
1991	Sucat GT	30							
	New GT	300							
	Sub. tot.	330	none	0	4972	960	3520	-1200	41.3
1992	P.P Barge	27.5	Carilaya						
	BacMan Geo	110	#1, #2	-16					
	Comb cyc	200							
	Sub. tot.	337.5			5293.5	1270	3787	-1065.7	39.8
1993	P. P. Barge	27.5							
	BulsanGeo	60							
	Coal#3	300							
	MaibaraGeo	10							
	Bac-Man#2	40							
	Calaca#2	300							
	Sub. tot.	737.5	none	0	6031	1980	4069	-560.4	48.2
1994	Balo-Balo	22							
	PinatobGeo	60							
	Sub. tot.	82	GT	-105	6008	2040	4367	-682.2	37.6
1995	Cagua Geo	40	Botocan#3	-1					
	Tongo-GeoA	440	Manila#1, 2	-200					
	DelGallGeo	120	GT	-160					
	Sub. tot.	600		-361	6247	2640	4680	-300	33.5
1996	Tongo-GeoB	440							
	Coal A-1	300	GT	-165					
	SUb. tot.	740		-165	6822	3380	5012	203.8	36.1
1997	Coal A-2	300	Carilaya#3	-8					
	GT/PM	300	GT	-14					
	Sub. tot.	600		-22	7400	3680	5361	279.4	38.0
1998	Coal B-1	300	P. P. Barge	-14					
	Casecnan	268	Botocan1, 2	16					
			Sucat #1	-150					
	Sub. tot.	568		-180	7788	3980	5730	343	35.9
1999	Coal B-2	300							
	Comb. cyc	300	GT	-105					
	Sub. tot.	600		-105	8283	4580	6119	679.6	35.4
2000	Comb. cyc	600	GT	-160					
			Carilrya#4	-8					
			Sucat #2	-200					
	Sub. tot	600		-368	8515	5180	6529	1003.6	30.4

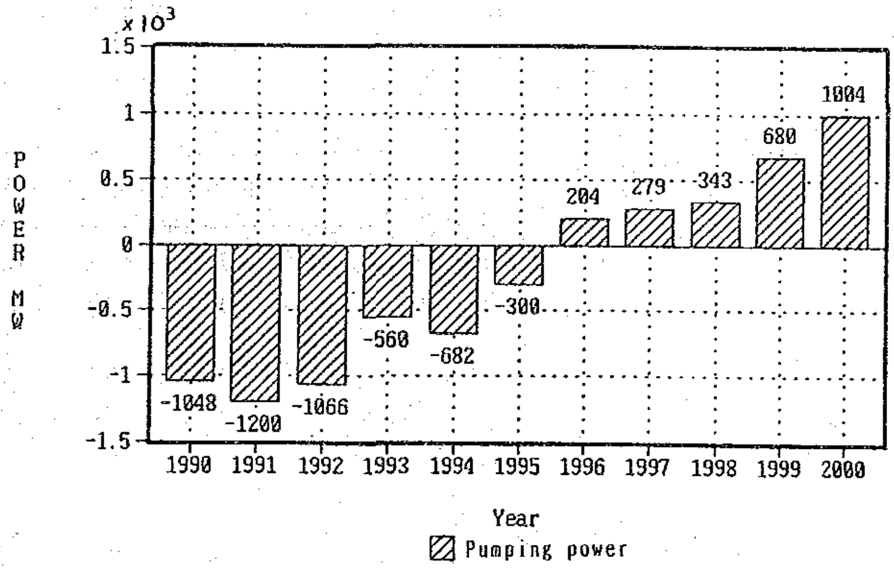


Fig. S8-1 Available Pomping Power from Base Power Plants

Table S8-2 Reservoir Operation of One Week (May, 1998)

Week	Pumping		Generating		Inflow	Reservoir			Operation time
	E	V	E	V	Zi	Ve	Vg	WL	
	Mwh	$10^6 m^3$	Mwh	$10^6 m^3$	$10^6 m^3$	$10^6 m^3$	$10^6 m^3$	m	hr
						17.92	74.84	287.65	
Mon	3,600	4.07	2,400	3.57	0.10	22.09	79.01	288.00	0 → 7.5Pum
					0.18	18.70	75.62	287.72	10 21 Gen
					0.04	18.74	75.66	287.72	24
Tue	1,800	2.03	2,800	4.17	0.10	20.87	77.80	287.90	0.5 → 7.5Pum
					0.20	16.90	73.83	287.56	10 22 Gen
					0.03	16.93	73.85	287.57	24
Wed	1,800	2.03	2,800	4.17	0.10	19.07	75.99	287.74	0.5 → 7.5Pum
					0.20	15.10	72.02	287.41	10 22 Gen
					0.03	15.12	72.05	287.41	24
Thu	1,800	2.03	2,800	4.17	0.10	17.26	74.18	287.59	0. → 7.5Pum
					0.20	13.29	70.21	287.25	10 22 Gen
					0.03	13.31	70.24	287.25	24
Fri	1,800	2.03	2,800	4.17	0.10	15.45	72.37	287.44	0.5 → 7.5Pum
					0.20	11.48	68.40	287.09	10 22 Gen
					0.03	11.51	68.43	287.09	24
Sat	2,800	3.16	0	0	0.11	14.78	71.70	287.38	0 → 8 Pum
					—	—	—	—	24
					0.22	14.99	71.92	287.40	
Sun	5,800	6.55	0	0	0.23	21.78	78.70	287.97	1 → 17 Pum
					—	—	—	—	24
					0.09	21.87	78.79	287.98	
Total	19,400	21.92	13,600	20.24	2.27				

Note : P = 2× 300 MW, Qt = 2 × 124 m³/s
Pp = 2× 318 MW, Qp = 2 × 99.8 m³/s

Imflow qi = 324,194 m³/dy

Oil. P.		Rate	MIN	60%
BAT 1	:	75MW	50	45
BAT 2	:	150	80	90
SUC 1	:	150	50	90
SUC 2	:	200	120	120
SUC 3	:	200	120	120
SUC 4	:	300	120	180
MAL 1	:	300	120	180
Total	:	1 375	660	825

Peak demand : 5361 MW
off peak rate : 60%
Load factor : 82%

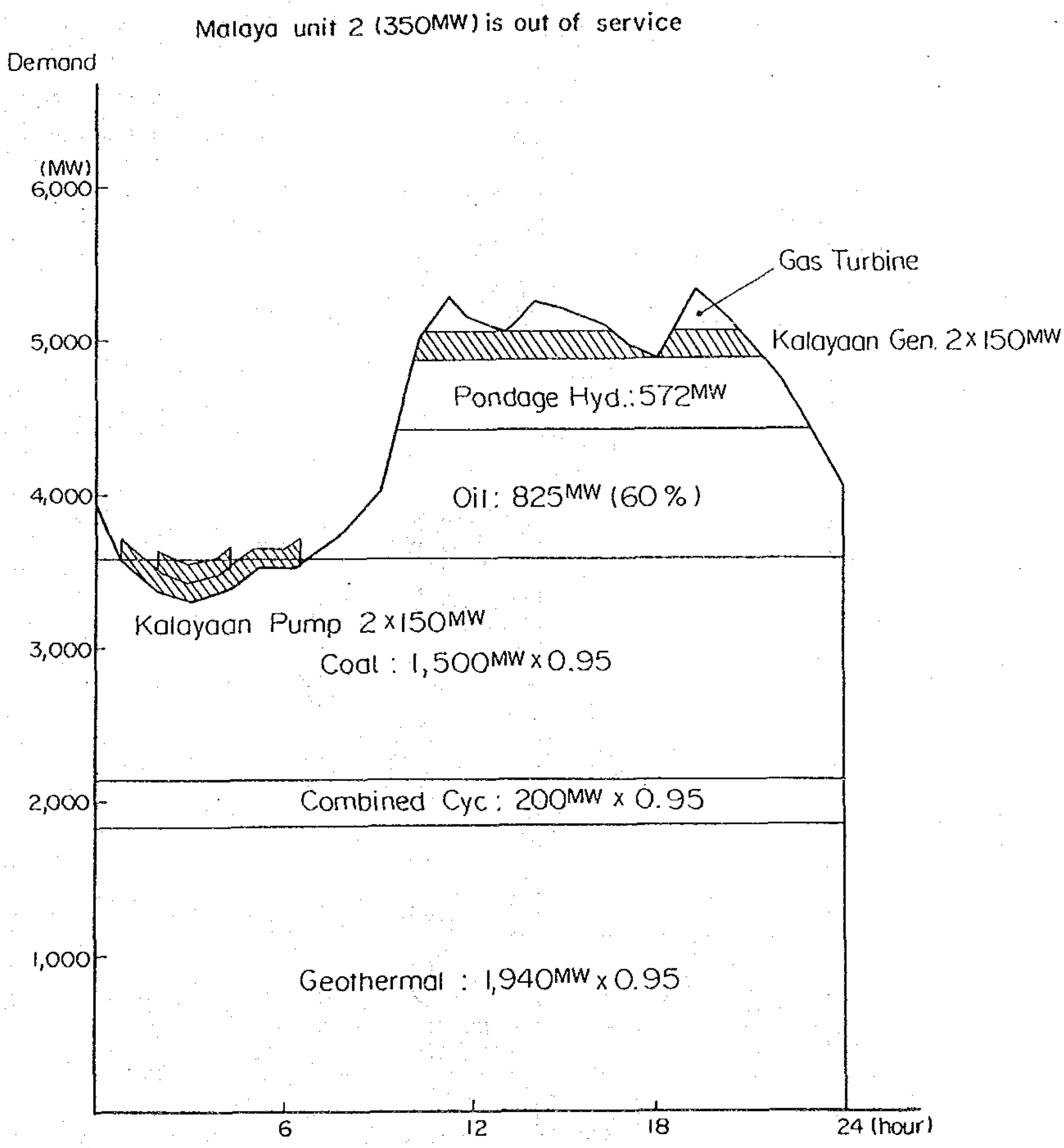


Fig. S8-2 Pumping and Generation Cycle of a Weekday in July 1997

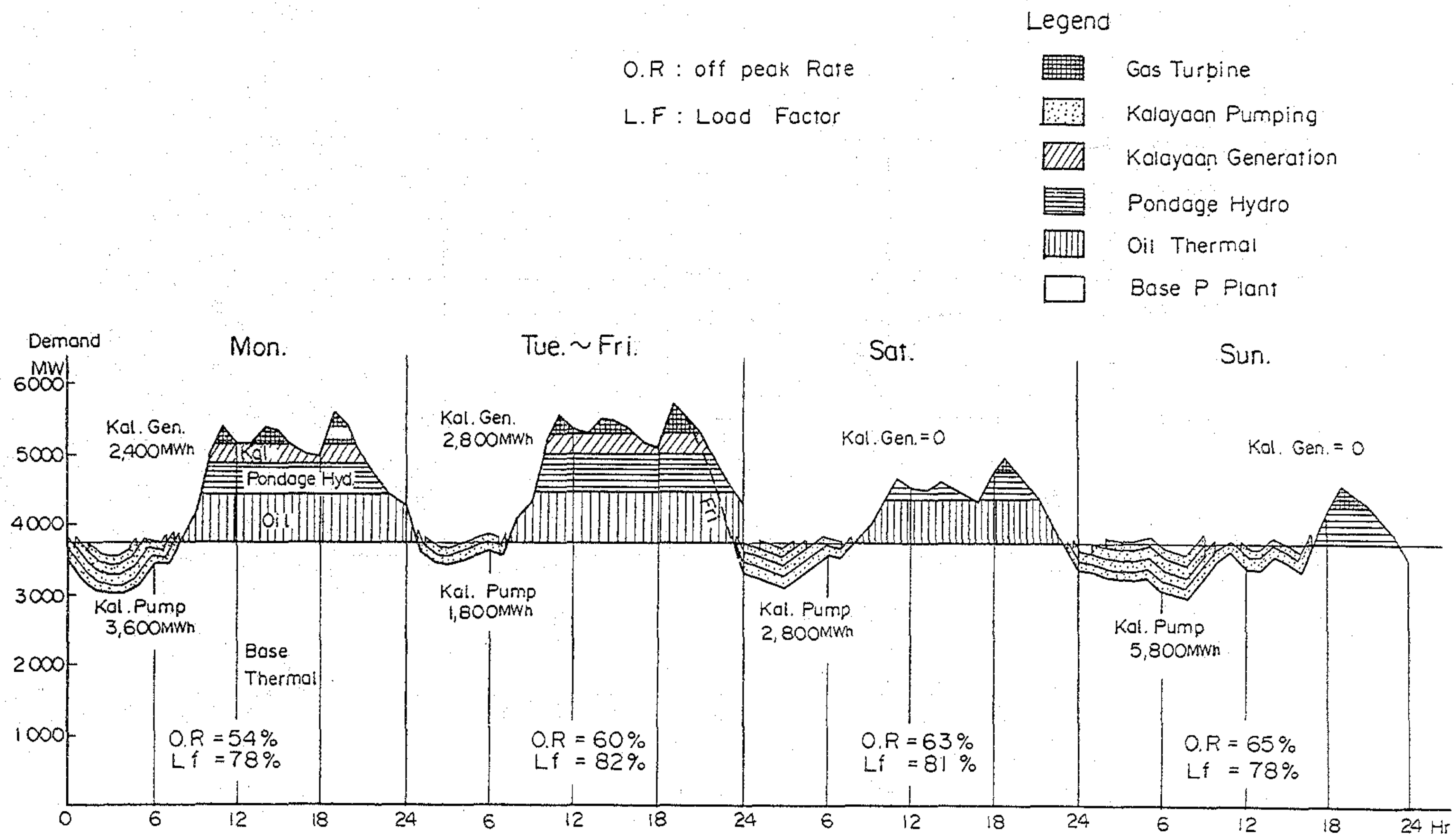


Fig. S8-3 Pumping and Generation Cycle of One Week in May 1998

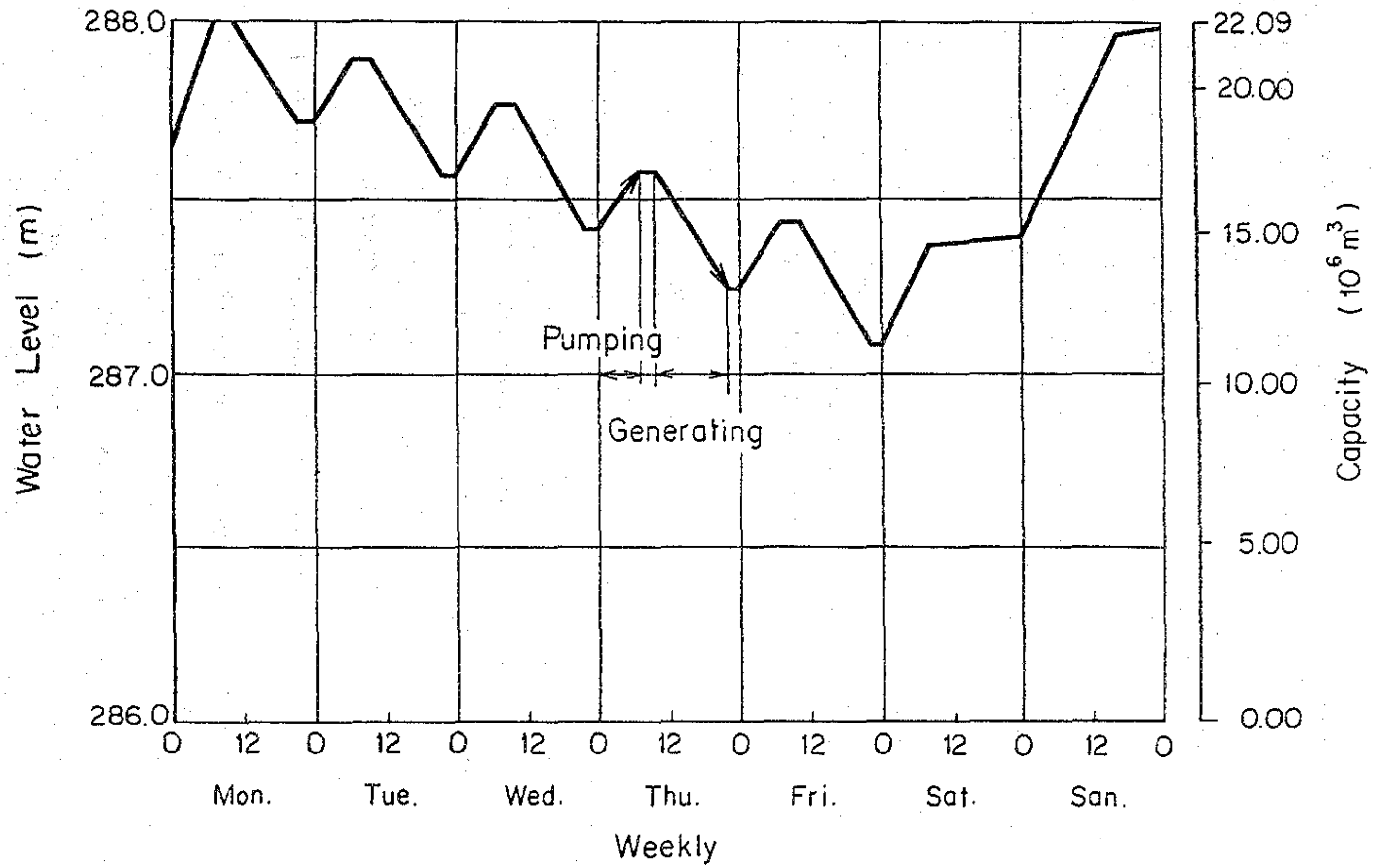


Fig. S8-7 Reservoir Operation of One Week (May, 1998)

Chapter 9 Transmission Line and Power System Analysis

9.1 Transmission Line

The transmission line (230kV, 795 MCMx1) running from Kalayaan to Malaya was replaced by a new line carrying two circuits of ACSR 795 MCMx4 several years ago. As this new transmission line has sufficient thermal capacity (1,200 MW per circuit), the transmission plan for the Stage II Project has been studied based on the concept of connecting this 230-kV line to the power plant switchyard.
The power system diagram of 500-kV lines on Luzon Island, at a time cross section of around year 2000, is presented in Fig. S9-1.

9.2 System Analysis

Calculation power flow, simplified frequency, and power system stability were made here for 1998, one year after the Stage II Project is completed.

(1) Power Flow Calculations

The results of power flow calculations are shown in Figs. S9-2 and S9-3. After the completion of the Stage II Project there will be no transmission line of related systems which would be overloaded, but in order to maintain voltage at the pumping-up operation during midnight hours, it will be desirable for the pump-up power factor to be made about 95 percent.

(2) Simplified Frequency Calculations

(a) Present Situation in Frequency Fluctuation

The frequency regulation target in the Luzon Grid is in the range of 60 ±0.3 Hz, but in reality, there are fluctuations of about ±0.3 Hz in the daytime, and about ±0.5 Hz in the nighttime when system capacity is small.

Incidentally, to estimate the system constant K of the system in its present state in the midnight, following calculation was carried out.

From the definition of system constant,

$$K = 0.6 \text{ Hz}/150 \text{ MW}/ \text{PG}$$

where,

PG: midnight system capacity in 1989

$\fallingdotseq$ 1,800 MW

Consequently,

$$K = 7.2 \text{ Hz/puMW}$$

(b) Appropriate Unit Capacity

When making the addition of the Stage II, it will be necessary to give consideration to the aspect of equipment with which starting and stopping can be done freely without prior frequency adjustments as at present. For this purpose, it is necessary for the range of frequency variation when starting and stopping pump-up in the nighttime in the future to be within 0.3 Hz.

Determining the unit capacity satisfying this condition, it is found to be approximately 150 MW with 1997 as the year scheduled for commissioning of 1 unit.

$$dF = 7.2 \text{ Hz/puMW} \times \text{PM}/ \text{PG} \leq 0.3 \text{ Hz}$$

Substituting

PG: 3,500 MW (midnight system capacity in 1997) in the equation above,

$PM \leq 145$ MW

is obtained.

(3) Stability

In terms of power system stability of generator/motor, the condition is severer while the plant is in the pumping mode in midnight, rather than during the daytime when the units are operated in the generating mode. For this reason, the stability at nighttime was analyzed.

As illustrated in Fig. S9-4, it was verified that the power system remains stable even when a three-phase short circuit occurs on the 230-kV transmission line at very close to the switchyard while all units of Kalayaan Stage I and Stage II are in full pumping operation.

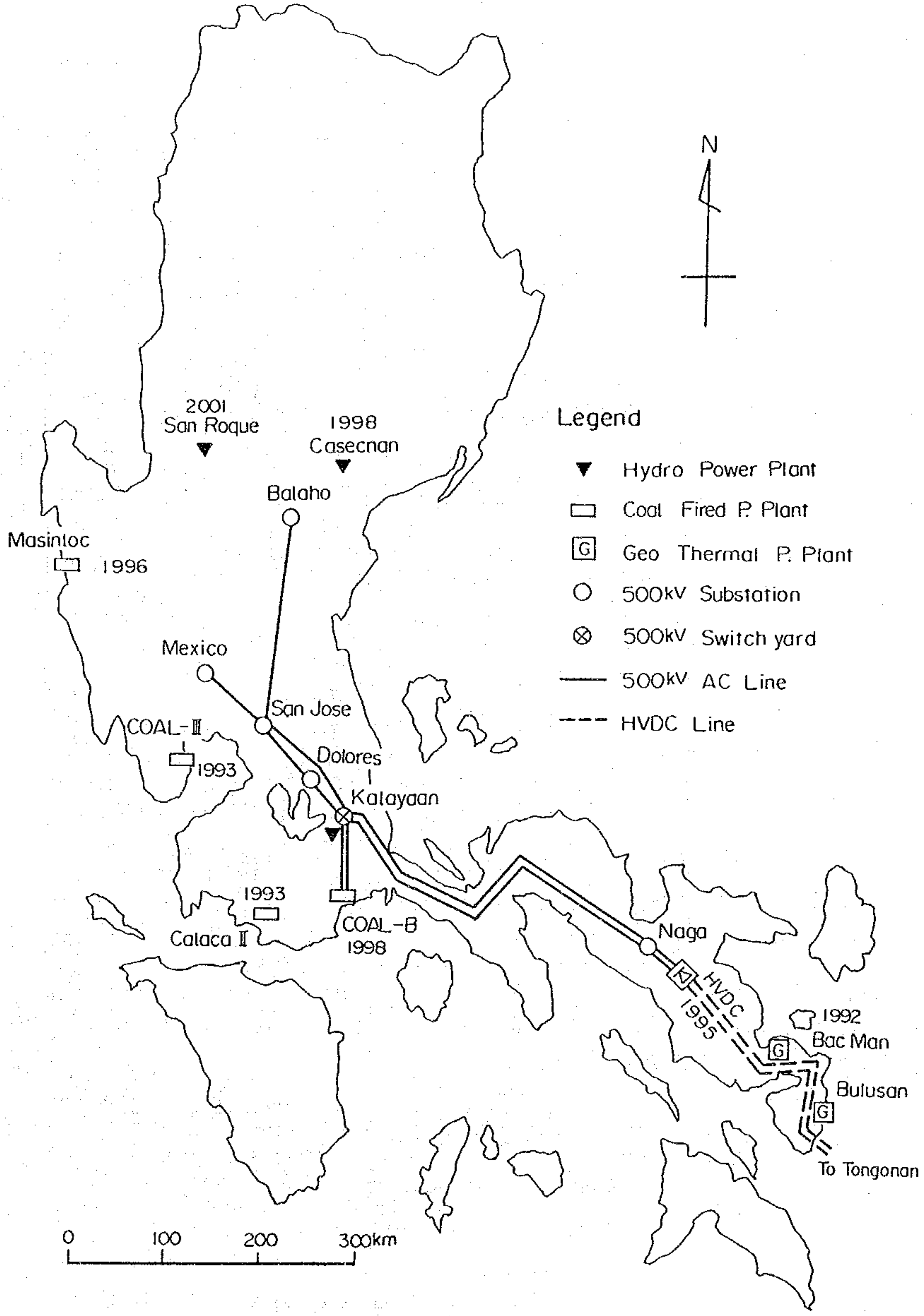


Fig. S9-1 Map of the Luzon Grid in the Late 1990s

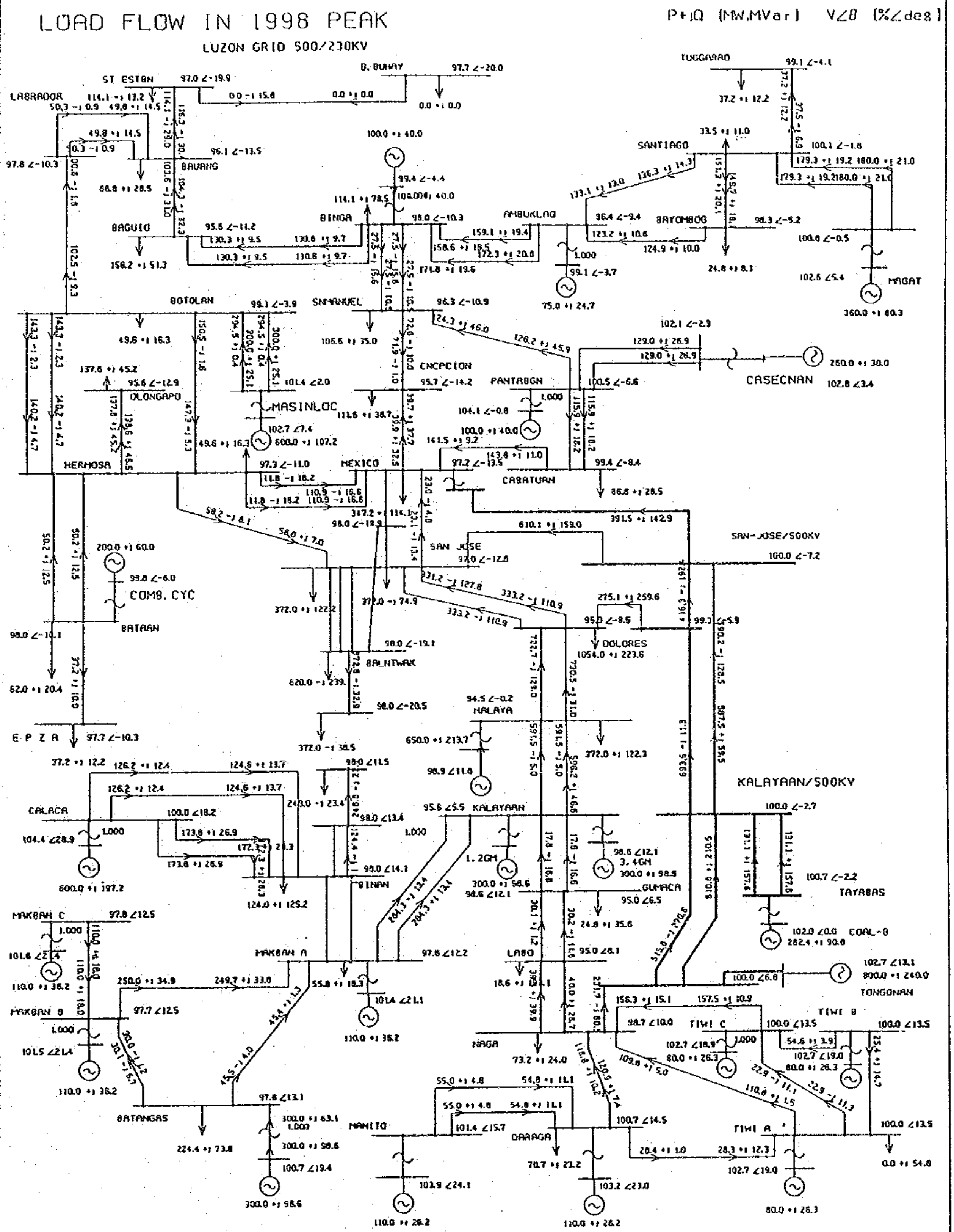


Fig. S9-2 Load Flow in 1998 (peak)

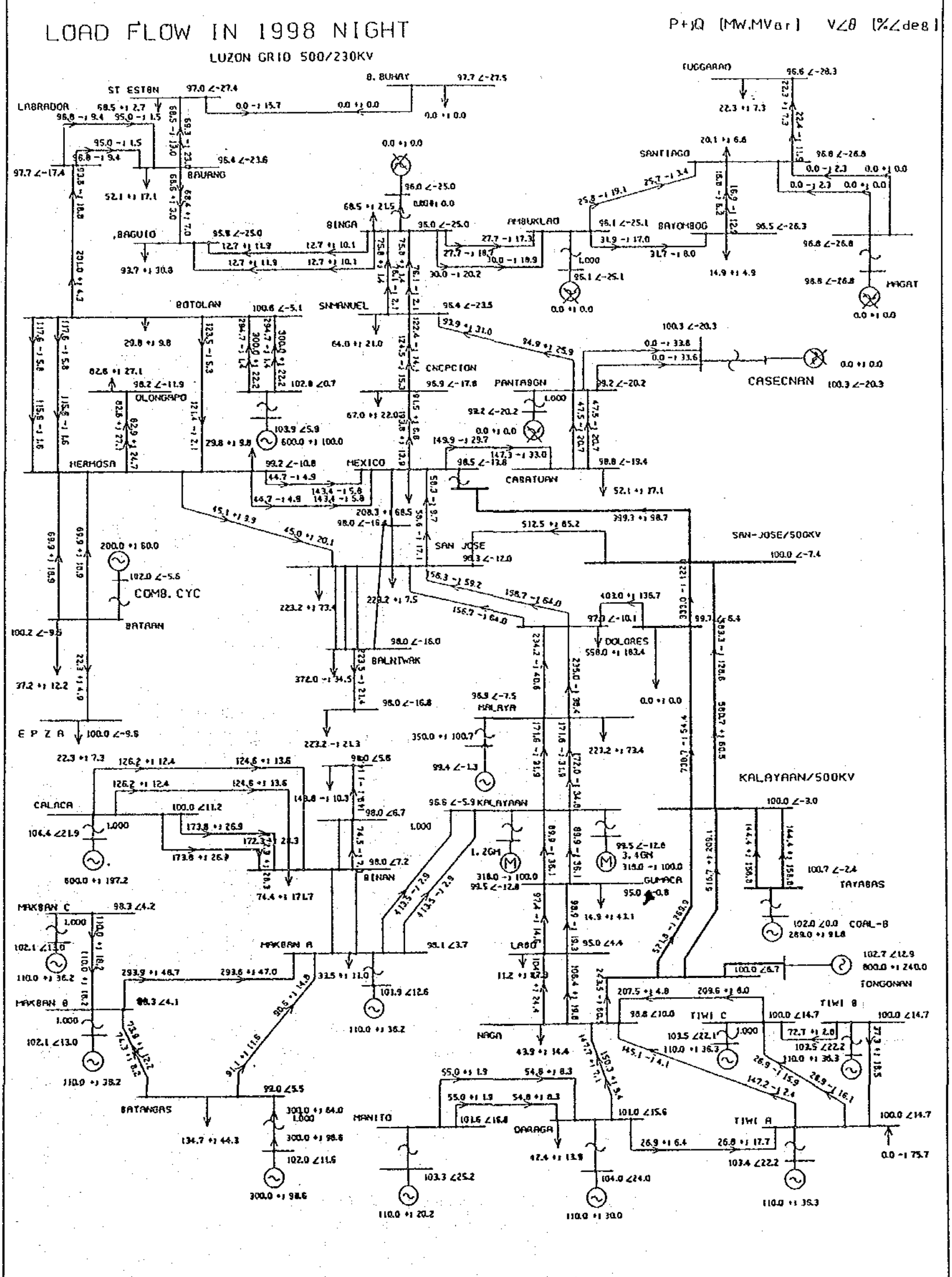


Fig. S9-3 Load Flow in 1998 (night)

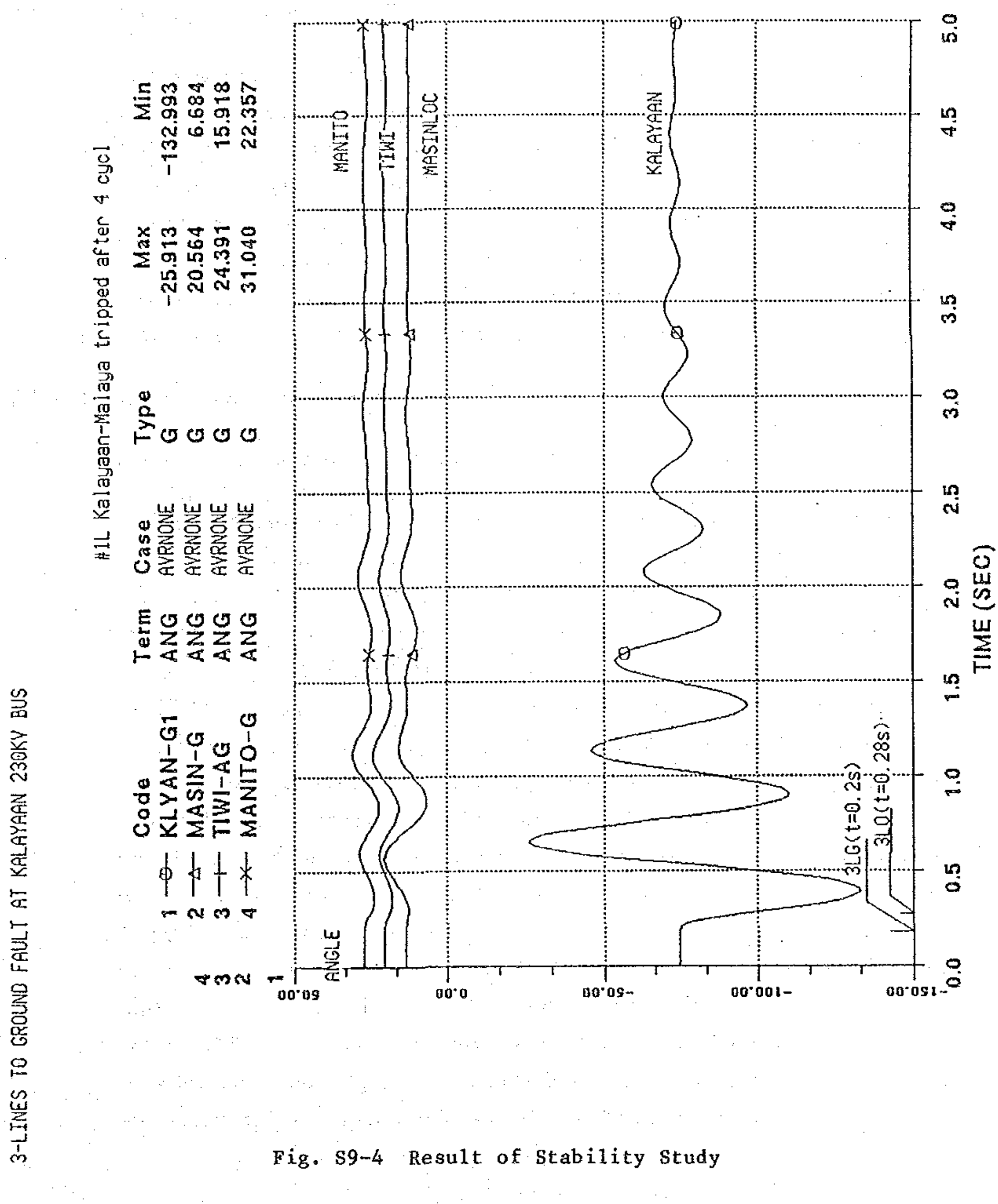


Fig. S9-4 Result of Stability Study

Chapter 10 Feasibility Design

10.1 Present Condition of Existing Facilities

10.1.1 Caliraya Reservoir

Caliraya Dam and its service spillway were built about 50 years ago and are showing their age.

Small scale erosion phenomena can be seen all along the lake shore, induced by the continuous filling and drawdown due to pumped storage plant operation. Erosion was also seen in some sections of the upstream concrete facing of the dam.

Rehabilitation work is presently under way in the spillway and is planned to start at the dam in the near future.

10.1.2 Upper Canal and Intake

The terminal end of upper canal is in good condition.

Traces sliding could be seen at the upper part of the excavated right-bank slope of the canal. Certain countermeasures had been applied against this sliding. Although there is no clear evidence that these slide areas are still moving, continuous monitoring may be necessary for a certain period.

Meanwhile, NAPOCOR carried out survey works for confirming the situation of sedimentation in Caliraya Reservoir including the upper canal in 1988. According to the results, there is considerable sedimentation at the upper canal bottom.

The intake structure was examined in detail including a diving inspection to the screens and gate slots already prepared for the Stage II Project.

No special problems were found during this diving inspection: it appears that only a good cleaning of the gate slots and of the floor will be necessary before installation of the racks and gates. In addition, some general maintenance on this structure will be necessary before implementation of the Stage II Project.

10.1.3 Penstock

The excavated trench is wide enough, along the subhorizontal part of the alignment, to accommodate the Stage II penstock to the left of the first one, as foreseen in the original design.
Additional provisions already taken, in anticipation of the extension of the plant, include the concrete lining of the more inclined part of the trench bottom in the Stage II extension zone, and construction of the terminal block of the subhorizontal section for the Stage II Project.

10.1.4 Powerhouse Shaft and Tailrace Canal

No problems were detected or reported concerning the civil structure of the powerhouse shaft of Stage I.
Provisions for plant expansion were limited in the powerhouse area to enlargement of the general platform at elevation 6.00 to include the zone where the second shaft will be located, and to construction of the Stage II tailrace canals.

10.1.5 Service and Control Buildings

The service building, where the auxiliary hydraulic unit is located and the main gantry crane is housed, was found to be in good condition. If the original general layout of the powerhouse is maintained, the building can be used for erection of new equipment without any problem. The control building is also in good maintenance condition.

10.1.6 Switchyard

In the switchyard, space has been provided for the additional bays required for the Stage II Project. The corresponding cable galleries have already been built.
Significant horizontal displacements and differential settlements have been reported in the galleries and in the pier built further downstream to unload the plant equipment during the construction of Stage I. As a consequence, some joints of the galleries, in the downstream part of the switchyard are displaced (horizontal displacements in the order of 5 cm, differential settlements of about 2

cm) and there is water leakage where the waterstops have been broken by the movement.

At present, it appears that the movement has already fully developed. Therefore, it will be possible to use the galleries already built for Stage II after the joints have been properly repaired.

10.2 Comparison Study of Alternative Layouts

10.2.1 Basic Conditions and Alternative Layouts

Comprehensive alternative layout studies were carried out during the initial feasibility studies of the Kalayaan Project (Kalayaan Pumped Storage Plant Technical Feasibility Report, May 1973 by ELC), analyzing in particular the following aspects:

- General location of the plant,
- Alignment and design capacity of the upper canal, in relation to the staged development of the scheme
- Position and structural characteristics of the intake
- Powerhouse type: shaft, at Laguna de Bay shore, or underground, at different distances from the intake
- Consequent alternative designs of the penstock

The layout selected according to the results of those studies was essentially maintained in the successive final and detailed construction drawings.

The following design criteria have been applied in the alternative layout studies for Stage II:

- The implementation of Stage II should not cause damage or significant interruption to the operation of Stage I.

- The layout of Stage II should not prevent a possible future further expansion of the plant.

- The total capacity of Stage II will be 300 MW (two-150 MW units) will be installed.

- Pending detailed studies of the electromechanical equipment including the penstock to be provided in the feasibility design stage, the same technical characteristics of the existing facilities have been considered.

- The operation levels of Caliraya Reservoir will remain unchanged after the implementation of the Stage II.

Three basic alternative layouts have been identified:

- Alternative A: Original layout for the Stage II

- Alternative B: Terminal part of the penstock embedded in a vertical shaft: shaft type powerhouse

- Alternative C: Underground Powerhouse

10.2.2 Alternative A

This alternative corresponds to the Stage II development of the plant, as foreseen in the original design, and is shown in Fig. S10-1.

Principal features include:

- Use of the existing intake, installing the required service gates,

- Essentially open air steel penstock, generally parallel to the existing one.

- Powerhouse shaft, 50 m apart and identical to the existing one, equipped with two 150-MW reversible units.

- Tailrace canal, as foreseen in the original design.

- Installation of the required additional equipment in the existing control building and switchyard.

10.2.3 Alternative B

This alternative, shown in Fig. S10-2, includes the following principal features:

- Use of the existing intake, installing the required service gates, as in Alternative A.
- Essentially open-air steel penstock, generally parallel to the existing one, with the following characteristics:
  - From anchor block 5, the two penstocks are installed in separate vertical shafts, 15 m apart.
  - Terminal horizontal stretch with the two penstocks are installed in parallel horizontal tunnels, 15 m apart.
- Powerhouse shaft and tailrace canal, as in Alternative A.
- Installation of required additional equipment in the existing control building and switchyard.

10.2.4 Alternative C

This alternative, shown in Fig. S10-3, includes the following principal features:

- Use of the existing intake, as in Alternatives A and B.
- Essentially open-air steel penstock, generally parallel to the existing one.
- Underground powerhouse, located some 250 m inside the rock mass, equipped with two 150-MW reversible units and provided with its own erection and service area. The main transformers to be installed in a separate adjacent cavern.
- The entrance of the access tunnel located adjacent to the existing Stage I service building.

- Separate cable gallery to the existing powerhouse shaft of Stage I and connecting with the cable galleries already provided for Stage II in the shaft structure.

- Tailrace pressure tunnel, 220 m long, 6.00 m in diameter.

- Tailrace canal, as in Alternatives A and B.

- Installation of required additional equipment in the existing control building and switchyard.

10.2.5 Economic Comparison

Preliminary quantity estimates of the main civil construction items have been formulated based on the attached drawings.

An economic comparison including the cost of civil works and the hydromechanical and electromechanical equipment costs of the three alternatives is shown below:

Unit: US$M

Alternative	A	B	C
Civil Works	28.5	30.5	40.0
Hydraulic Equipment	31.2	30.3	24.2
Electromechanical Equipment	66.2	66.2	69.0
Administration Cost	7.5	7.6	8.0
Physical Contingency	8.6	8.6	9.0
Total Cost	142.0	143.2	150.2

10.2.6 Results of Comparison Study for Alternative Layouts

Taking into account both the results of the economic comparison and the technical aspects discussed above, it is proposed that Alternative A be selected for the feasibility design of the Stage II Project.

This Alternative A has the basic advantages of allowing easier joint operation of the two stages, and keeping open the possibility of further expansion of the plant according to the original plans. In addition, the detailed design and the construction planning of the proposed solution can take full advantage of the experience already obtained during the construction of Stage I, avoiding the uncertainties typically related to large underground works.

10.3 Proposed Design of Civil Structures

After the selection of the general Project layout, further in depth studies and analyses were carried out to verify the hydraulic and structural adequacies of the design and to optimize the characteristics of the main structures.

10.3.1 Upper Canal

The hydraulic behavior of the canal with the increased discharges foreseen has been verified. (Completion Report, July 1983)

These results are considered acceptable. It will be advisable, especially with low reservoir water level, to start the turbine operation of four units simultaneously to avoid the risk for absorption of air into the penstocks.

10.3.2 Intake

The existing intake will be used for the Stage II Project. The implementation of Stage II will require:

- Installation of two service gates, each 2.80 m wide and 6.00 m high

- Installation of a steel-lined transition to be embedded in the existing structure and of the initial part of the surface penstock

10.3.3 Penstock

An economic analysis has been carried out. To determine the economical diameter of each section of the penstock, an economical comparison study was conducted applying the conventional method of minimizing the total present value of construction cost plus energy and power losses (in both pumping and generating modes) during the economic service life of the plant.

The results are the following:

Section	Economical Diameter (m)
Between intake and anchor block 2	4.8
Between anchor blocks 2 and 3	4.5
Between anchor blocks 3 and 5	4.3
Between anchor blocks 5 and 6	4.1
Between anchor blocks 6 and the road crossing	4.0
Underground stretch (two shafts)	2.9

It is necessary to check whether turbine stability is maintained during output variation for the economical diameter.
In order to keep within acceptable limits the frequency variations induced by a change in the power output, the time constant of the penstock, defined as

$$T_c = (L_1v_1 + L_2v_2 + L_3v_3 + \dots L_nv_n) / gH$$

where L_i and v_i are the length and maximum flow velocity of each penstock section,
g is the gravity acceleration, and
H is the minimum head,

shall be generally kept not higher than about 2.0.

In the present case, should the economical diameters be adopted, the penstock time constant will be about 3.75, far too high to have an acceptable behavior from a frequency regulation point of view, considering also the importance of the Stage II plant for the overall performance of the Luzon Grid.
Since the lengths of the different stretches are given by the topographical conditions, in order to reduce the penstock time constant to acceptable values, it is necessary to reduce the flow velocities, and therefore, to increase the diameters.
Therefore, the diameter of each section has been selected according

to the original design of the Stage I Project.
With these diameters, the penstock time constant would be reduced to 2.10, which can be considered acceptable.
Therefore, for feasibility design purposes, it is proposed to adopt for the penstock of Stage II the same diameters as used for the penstock of Stage I.

10.3.4 Temporary Detour of the Lumban - Kalayaan Road during Construction

A by-pass tunnel is proposed to maintain safe and continuous traffic conditions along the Lumban - Kalayaan road during construction.
The section of the detour tunnel will be 5.00 m wide by 5.00 m high, allowing one-lane traffic, with a walkway on one side. Lighting will be provided and signals installed at both ends to control the traffic. The tunnel bottom will be concrete paved. In principle, no lining is foreseen, except at the portals and where required by stability problems.

10.3.5 Powerhouse Shaft

The powerhouse will be located 50 m away from the existing one, as originally foreseen, and will be equipped with two 150 MW reversible units.
The excavation method will be essentially the same as that used for Stage I, with temporary concrete diaphragms to seal the pervious loose materials up to the rock surface, and grouting carried out in advance of the excavation to reduce seepage and to improve stability conditions.
One of the more important technical problems to be faced for the construction of the Stage II will be blasting control to be applied during excavation of the new powerhouse shaft in order to prevent damage to civil structures and to the equipment of the Stage I. The control measures are studied and described in Section 6.3 of Chapter 6.

In order to facilitate a possible further extension of the plant (Stage III), reducing future blasting control problems, it is proposed to include in the scope of works of Stage II the enlargement of the general platform at elevation 6 m to the left of the second shaft, corresponding to the zone for a third shaft. This additional excavation will also be very useful for installation of the construction equipment and related facilities.

10.3.6 Tailrace Canal

Since most of the canal had already been excavated during the construction of the Stage I and dredged again a few years later, the work will now be essentially limited to the area just in front of the new shaft, plus the dredging that will be necessary to reach the original bottom level at the full width.

In any case, it is considered that maintenance dredging during the initial period of operation of Stage II, as allowed by the new dredging equipment provided, will be sufficient to keep the problem under control.

10.3.7 Switchyard

Civil works in the switchyard area will include repair of leaking joints of the existing galleries and the construction of foundations for the new equipment.

10.3.8 Equipment Unloading and Transportation Facilities

As already mentioned, rehabilitation works will be required at the existing unloading facilities to allow their use during the construction of Stage II.

The gantry crane originally installed at the pier, which has remained out of operation and unprotected for quite a long period, will be inspected, repaired as necessary, and tested.