8.5 Finalization of Selected Development Plan (Feasibility Design Stage)

8.5.1 Selected Development Plan in Investigation Stage

In the investigation stage, Site No. 2 and No. 5 were selected for the Nam Ngao project and the Mae Lama Luang project, respectively. Then, optimization studies about NHWL, effective storage capacity and the maximum power discharge were carried out on the selected dam site of the Nam Ngao project and the Mae Lama Luang project.

In that stage, the optimum development scales were determined for the Nam Ngao individual development, the Mae Lama Luang individual development and the Nam Ngao and Mae Lama Luang integrated development, respectively.

The results obtained in the investigation stage are shown below.

Item	Individual Development	
	Nam Ngao	Mae Lama Luang
Total Storage Capacity (MCM)	902	486
Effective Storage Capacity (MCM)	320	240
Normal High Water Level (m)	270	165
Available Drawdown (m)	15.5	18.8
Normal Intake Water Level (m)	264.8	158.7
Tail Water Level (m)	162.8	66.3
Normal Effective Head (m)	96.9	87.8
95% Firm Discharge (m^3/s)	24.4	32.2
Maximum Power Discharge (m^3/s)	162.6	214.3
Installed Capacity (MW)	138.1	164.5

Item	Integrated Development	
	Nam Ngao	Mae Lama Luang
Total Storage Capacity (MCM)	902	486
Effective Storage Capacity (MCM)	320	210
Normal High Water Level (m)	270	165
Available Drawdown (m)	15.5	15.4
Normal Intake Water Level (m)	264.8	159.9
Tail Water Level (m)	162.8	67.0
Normal Effective Head (m)	96.9	88.3
95% Firm Discharge (m^3/s)	24.4	48.3
Maximum Power Discharge (m^3/s)	162.6	322.1
Installed Capacity (MW)	138.1	247.7

8.5.2 Finalization of the Projects

The objective of this paragraph is to finalize the development scales of the Nam Ngao individual project, the Mae Lama Luang individual project and the Nam Ngao and Mae Lama Luang integrated project, respectively.

The selected development scales in the investigation stage are the results of relatively rough studies, therefore more detail studies using up-to-date data are carried out to finalize the projects' feature in this stage.

The finalized development plans are modified from the selected development plans in the investigation stage, and following items are modified.

(1) Project Features

In the investigation stage (section 8.3.2 and 8.4), the optimum effective storage capacity of the Mae Lama Luang project is determined 240 MCM and 210 MCM for individual and integrated development respectively. The NHWL is determined to be EL. 165 m for the both developments. While, as mentioned in section 8.3.2, the reservoir water level is controlled to be lower than EL. 163 m during flood season, the storage capacity of 240 MCM and 210 MCM are to be secured for the water level of 163 m. Therefore, the storage capacity of about 40 MCM corresponding to the water level between 163 m and 165 m is added to the effective storage capacities determined in the investigation stage. As a result, 277 MCM and 252 MCM are adopted for the effective storage capacity for individual and integrated development respectively.

In the investigation stage, the normal intake water level was fixed at the elevation such that the level is below one-third of the available drawdown from NHWL. In this stage, it is fixed at the mean water level obtained from the result of the mass curve operation for the 28 years period from 1959 to 1986.

The 95% firm discharge changes in value with modification of the effective storage capacity.

The project features determined in this stage are shown below.

Item	Individual Development	
	Nam Ngao	Mae Lama Luang
Total Storage Capacity (MCM)	925	486
Effective Storage Capacity (MCM)	329	277
Normal High Water Level (m)	270	165
Available Drawdown (m)	15	22
Normal Intake Water Level (m)	264	156
Tail Water Level (m)	162.9	66.3
Normal Effective Head (m)	96.1	84.7
95% Firm Discharge (m^3/s)	24.7	33.9
Maximum Power Discharge (m^3/s)	170	220
Installed Capacity (MW)	140	160

Item	Integrated Development	
	Nam Ngao	Mae Lama Luang
Total Storage Capacity (MCM)	925	486
Effective Storage Capacity (MCM)	329	252
Normal High Water Level (m)	270	165
Available Drawdown (m)	15	19
Normal Intake Water Level (m)	264	157
Tail Water Level (m)	162.9	67
Normal Effective Head (m)	96.1	85
95% Firm Discharge (m^3/s)	24.7	49.7
Maximum Power Discharge (m^3/s)	170	330
Installed Capacity (MW)	140	240

(2) Reservoir Operation

In the investigation stage, the mass curve method was adopted for reservoir operation. This method is based on the assumption that future runoff is completely foreseeable. However it is impossible to predict future runoff precisely, therefore the rule curve method, which is more practical, was adopted in this stage.

The reservoir operation rules are determined for each development plan considering items below.

° The reservoir is to be operated in such a way that the inflow is stored in rainy season and supplied in dry season.

° The reservoir is to be operated in such a way that the spill is as small as possible and energy production is as large as possible.

Each reservoir operation rule curve was constructed by following procedures.

° Storage volumes of every month are calculated for the 28 years period from 1959 to 1986, under the assumption that reservoir water level is at NHWL in the beginning of every dry season and power station is operated with the 95% firm discharge. Curves of the water level for every year are drawn.

° A lower envelop curve is drawn. The curve is adopted as the reservoir operation rule curve.

° In case that the storage volume (or water level) of reservoir at a certain month is less than that of rule curve, the power station is operated using the 95% firm discharge.

° In case that the storage volume (or water level) of reservoir at a certain month is more than that of rule curve, the power station is operated using the discharge greater than the 95% firm discharge. In this study, the average runoff for the 28 years is adopted for this discharge.

° The daily discharge obtained is raised up to the maximum discharge that the turbine can use at the water level of the month (hereafter; the available maximum turbine discharge).

° However, in case that the peak duration hours become less than 3.6 hours, the available maximum turbine discharge is reduced to keep the minimum peak duration hours of 3.6 hours.

In this project site, the evaporation loss is negligibly small compared with "without the dam" and "with the dam". Therefore it can be neglected in the calculation of the reservoir operation. The detail of the evaporation loss is mentioned in 5.4.3.

The rule curves determined in this paragraph are shown in Fig. 8-16.

In accordance with the rule curves, the reservoirs are operated and their figures of the operation are shown in Fig. 8-17, 8-18 and 8-19.

(3) Calculation of Power and Energy Production

Calculation of power and energy production is carried out in every month for the 28 years period from 1959 to 1986. The flow diagram for the calculation of energy production is shown in Fig. 8-20.

The firm capacity is defined in this report as the output corresponding to the reservoir water level of 90% exceedance probability and the available maximum turbine discharge at this water level.

However, in case that the available maximum turbine discharge is greater than the peak discharge calculated from the 95% firm discharge (95% firm discharge x 24.0/3.6), this peak discharge is adopted for the calculation of the firm capacity.

In the investigation stage, the power and energy at generating end were used for the economic comparison of alternatives. Hereafter, those at the entrance of Chiang Mai 3 substation are used for the economic evaluation of projects.

(4) Construction Cost

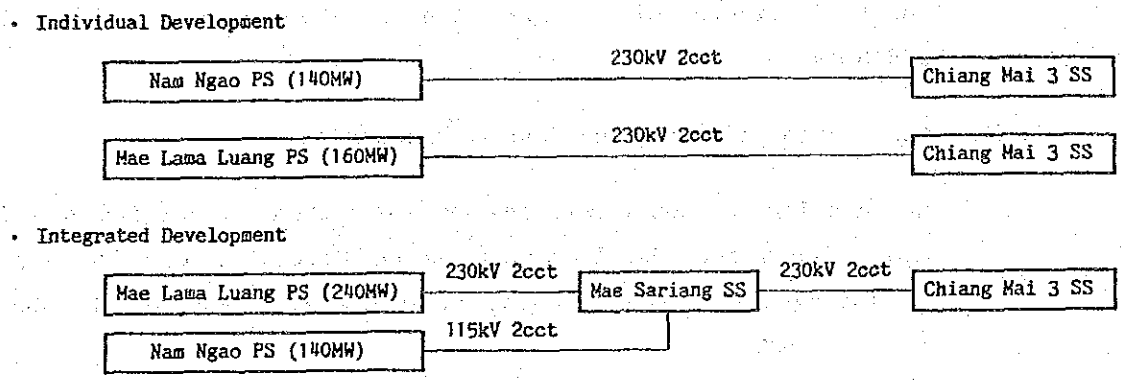
In the investigation stage, the construction cost was estimated using the same unit costs as the Master Plan. Hereafter, the cost estimations are carried out based on price level as of January 1989.

In this chapter, price escalation to the commencement of operation is not included in the construction cost.

The detail of the construction cost is mentioned in Chapter 11.

(5) Transmission Line

In the investigation stage, the transmission line cost was not considered. However in this stage, the transmission line cost (including substation) shown below are considered.



(Note) PS : Power station
SS : Substation

The detail of the transmission line is mentioned in Chapter 9.

(6) Finalized Development Plans

The development scales shown in Table 8-11 and 8-12 were determined for the finalized development plan of the Nam Ngao individual development, the Mae Lama Luang individual development and the Nam Ngao and Mae Lama Luang integrated development, respectively.

Table 8-11 Finalized Development Plan (Individual Development)

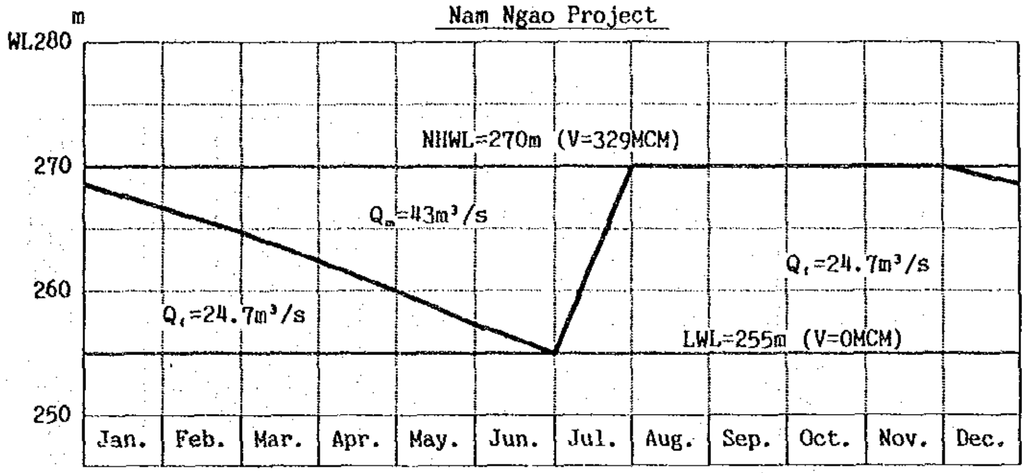
Item	Individual Development	
	Nam Ngao	Mae Lama Luang
Total Storage Capacity (MCM)	925	486
Effective Storage Capacity (MCM)	329	277
Normal High Water Level (m)	270	165
Available Drawdown (m)	15	22
Normal Intake Water Level (m)	264	156
Tail Water Level (m)	162.9	66.3
Normal Effective Head (m)	96.1	84.7
95% Firm Discharge (m^3/s)	24.7	33.9
Maximum Power Discharge (m^3/s)	170	220
Installed Capacity (MW)	140	160
Firm Capacity (MW)*	122.6	123.4
Annual Energy Production (GWh)*	306.8	540.9
Annual Capacity Factor (%)**	26.1	40.3
Construction Cost (M฿)***	4,332	4,374

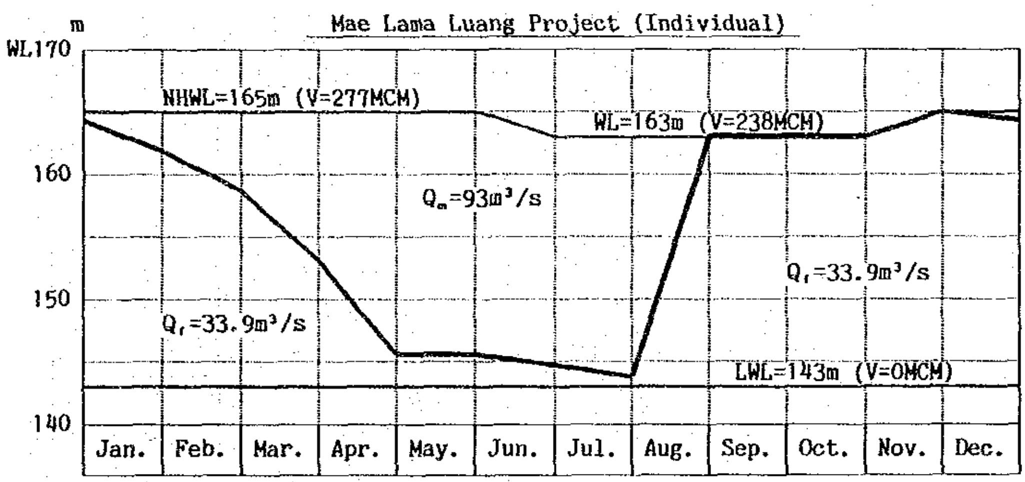
* At the entrance of Chiang Mai 3 Substation.
** At the generating end.
*** Including Transmission Line and Communication System Without IDC and Import Duty.

Table 8-12 Finalized Development Plan (Integrated Development)

Item	Integrated Development	
	Nam Ngao	Mae Lama Luang
Total Storage Capacity (MCM)	925	486
Effective Storage Capacity (MCM)	329	252
Normal High Water Level (m)	270	165
Available Drawdown (m)	15	19
Normal Intake Water Level (m)	264	157
Tail Water Level (m)	162.9	67
Normal Effective Head (m)	96.1	85
95% Firm Discharge (m^3/s)	24.7	49.7
Maximum Power Discharge (m^3/s)	170	330
Installed Capacity (MW)	140	240
	380	
Firm Capacity (MW)*	122.4	207.6
	330.0	
Annual Energy Production (GWh)*	300.7	583.4
	884.1	
Annual Capacity Factor (%)**	25.9	29.4
	28.1	
Construction Cost (M฿)***	4,028	5,103
	9,131	

* At the entrance of Chiang Mai 3 Substation.
** At the generating end.
*** Including Transmission Line and Communication System. Without IDC and Import Duty.





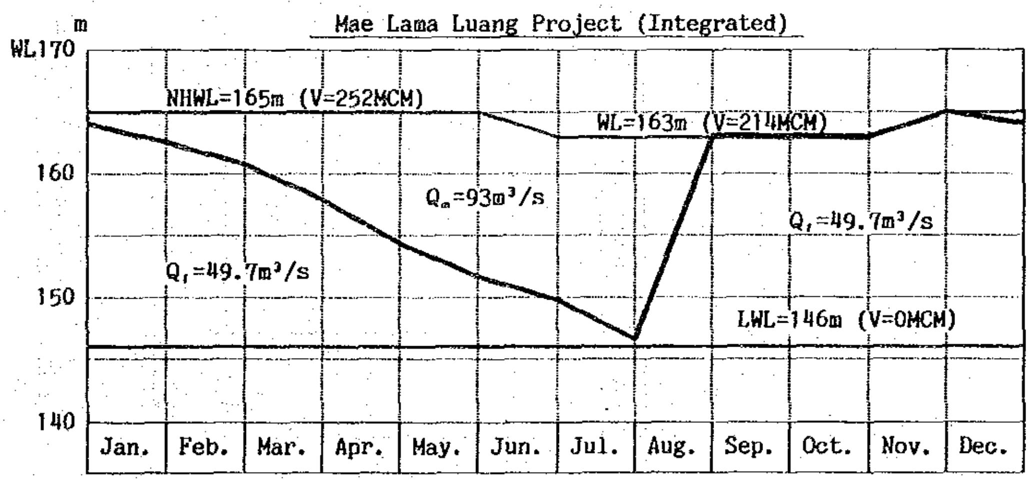


Fig. 8-16 Reservoir Operation Rule Curves

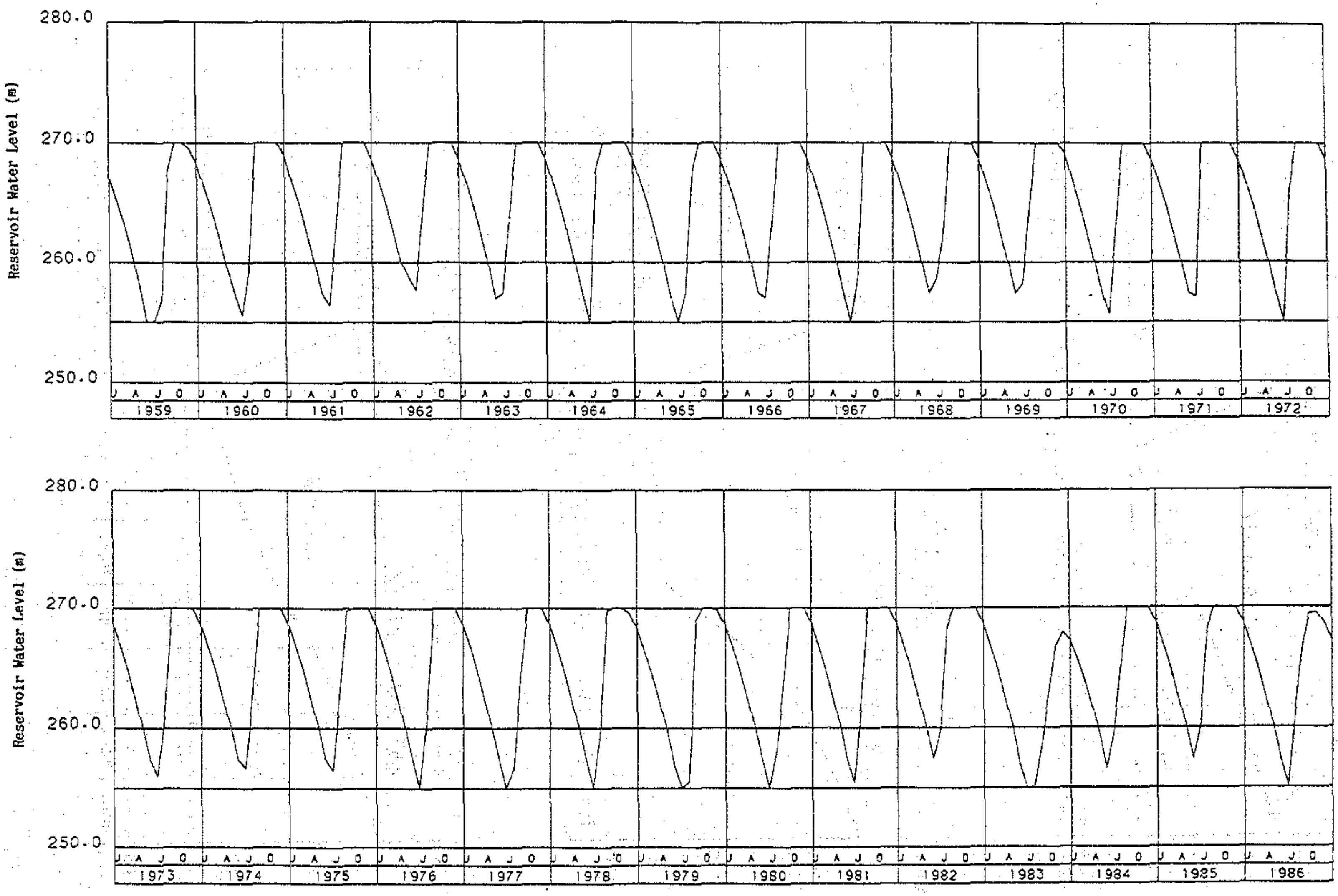


Fig. 8-17 Reservoir Operation of Nam Ngao Project

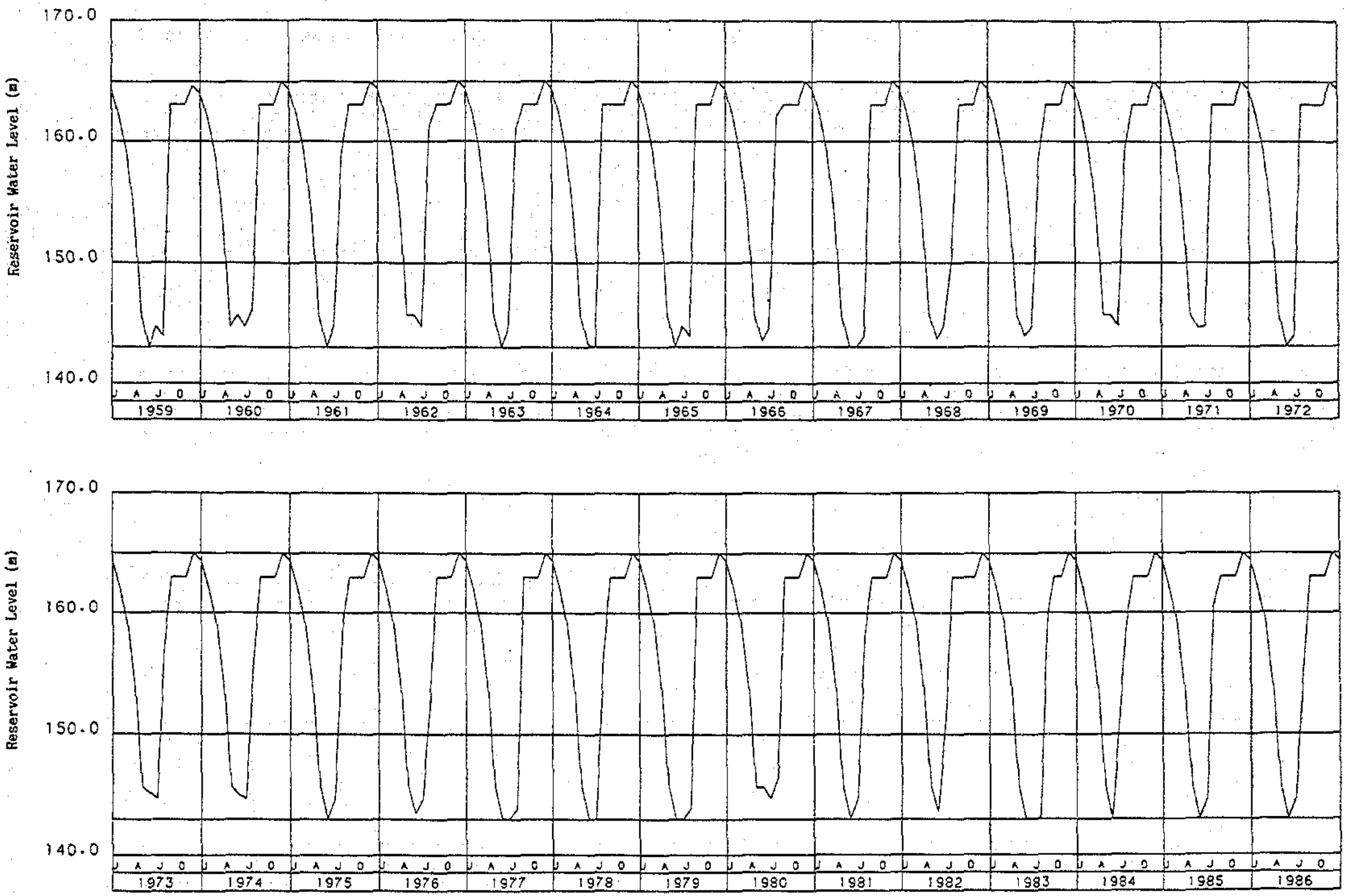


Fig. 8-18 Reservoir Operation of Mae Lama Luang Project (Individual Development)

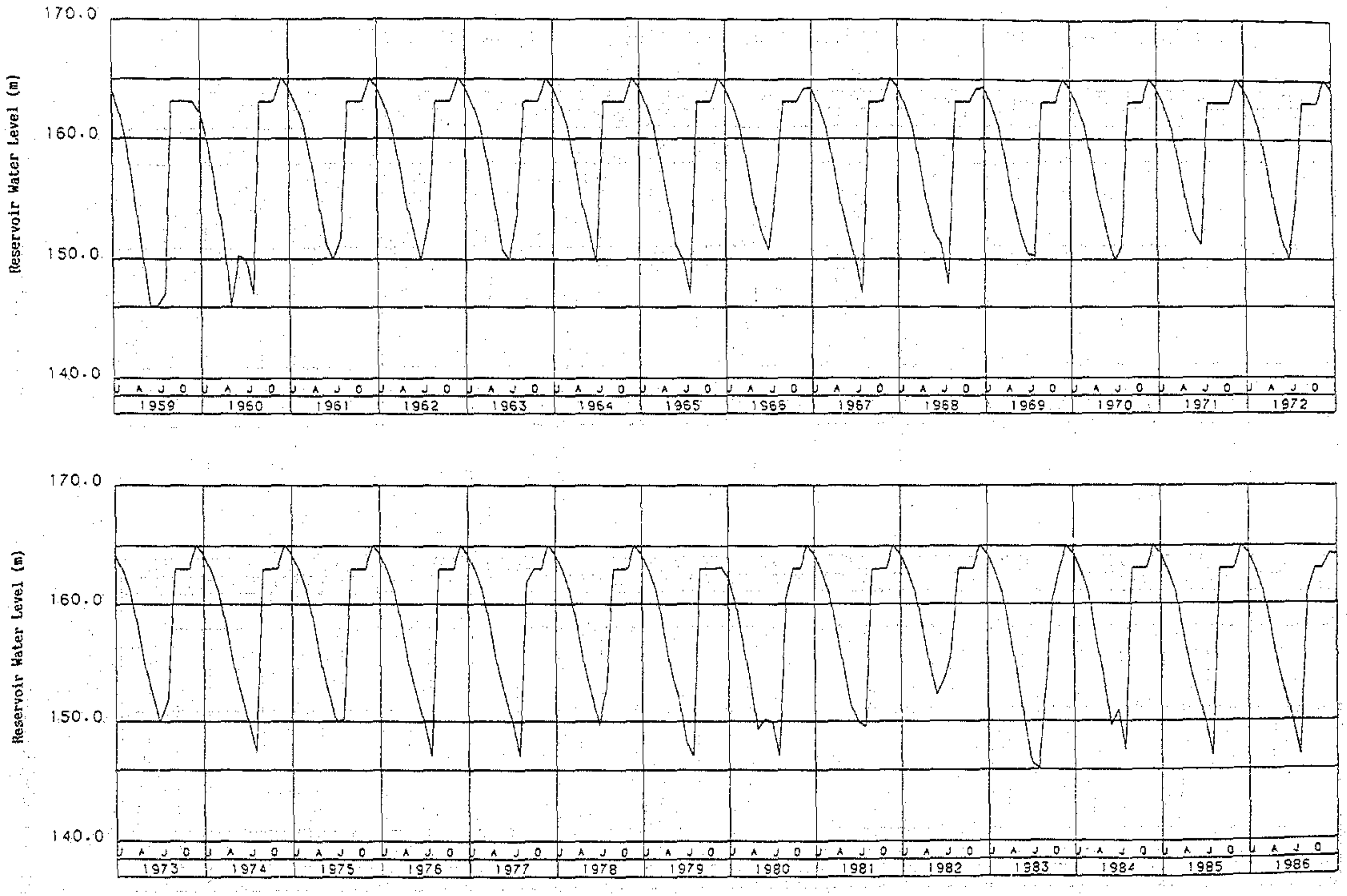


Fig. 8-19 Reservoir Operation of Mae Lama Luang Project (Integrated Development)

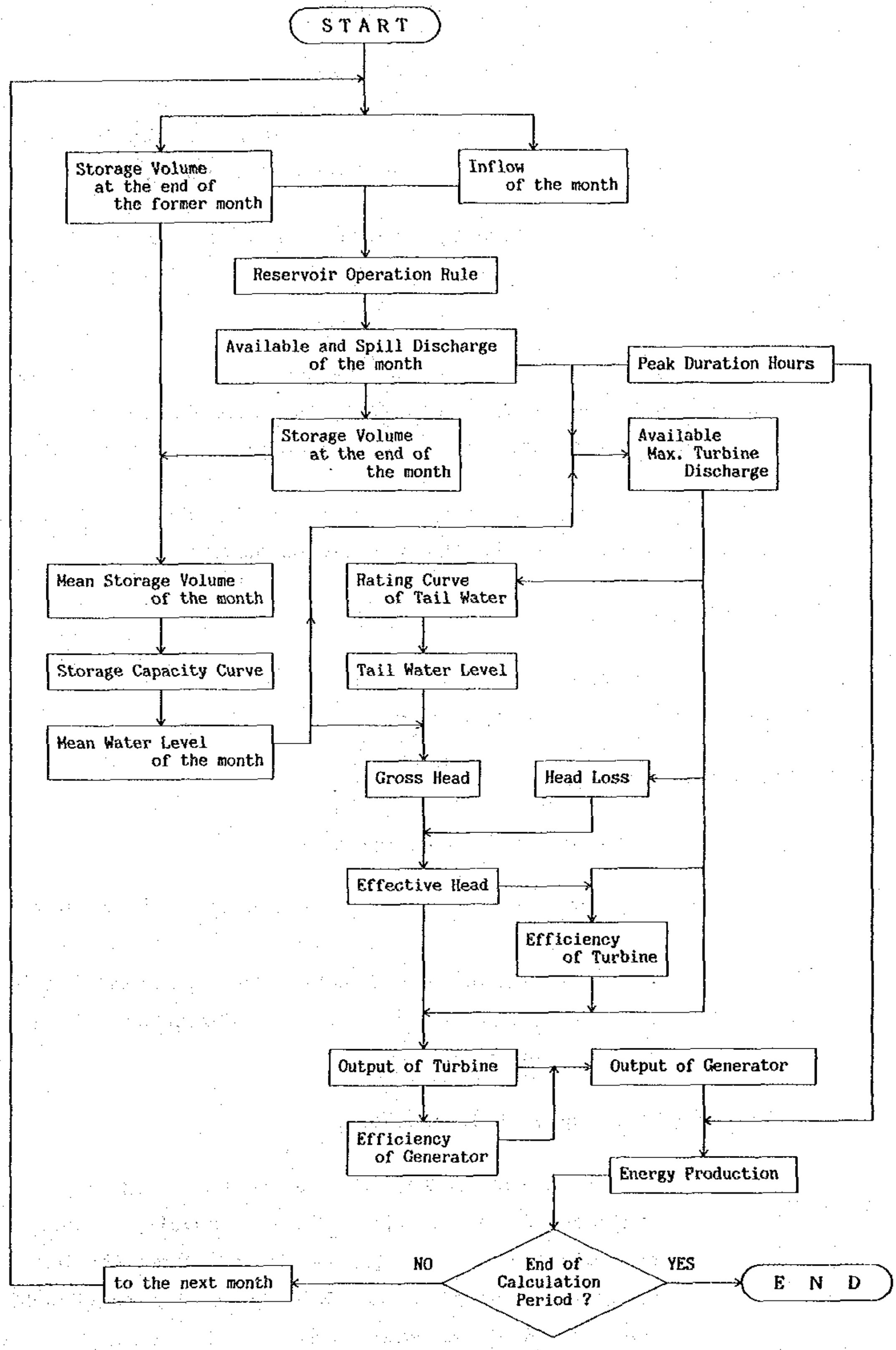


Fig. 8-20 Flow Diagram for the Calculation of Energy Production

8.6 Study on Sequence of Projects' Implementation

8.6.1 Alternatives of Projects' Implementation

The objective of this paragraph is to determine the sequence of implementation of the projects finalized in Section 8.5.

In the investigation stage, alternatives were evaluated by the technique of the Benefit-Cost ratio (B/C) and annual surplus benefit (B-C).

In this paragraph, alternatives of sequence of projects' implementation are evaluated by the Equalizing Discount Rate (EDR) and Net Present Value of B-C (NPV) using the discounted cash flow method.

The alternatives to be studied are shown in Fig. 8-21, and specific points of each alternative are described below.

° Individual Development

Case-A : Nam Ngao Project
Case-B : Mae Lama Luang Project

° Integrated Development

Case-C : Simultaneous Implementation

Both projects of the Mae Lama Luang and the Nam Ngao are implemented at the same time. The transmission lines from these power station to Chiang Mai 3 substation (CH-3-SS) and Mae Sariang substation (MS-SS) are constructed at the same time.

Case-D : Two Stages' Implementation

At the first stage, the Mae Lama Luang project is implemented with its full capacity, and the transmission line of 230 kV (2-cct) from the Mae Lama Luang power station (Mae Lama Luang PS) to CH-3-SS is constructed at the same time.

At the second stage, the Nam Ngao project is implemented with its full capacity after an interval of five years, and MS-SS and the transmission line of 115 kV (2-cct) from the Nam Ngao power station (Nam Ngao PS) to MS-SS are constructed at the same time.

Case-E : Two Stages' Implementation

At the first stage, the Mae Lama Luang project is implemented with the capacity of 160 MW (2-units), however the civil structures are constructed for the full capacity of 240 MW (3-units). And the transmission line of 230 kV (2-cct) from Mae Lama Luang PS to CH-3-SS is constructed at the same time.

At the second stage, the Nam Ngao project with its full capacity and the other unit (80 MW, 1-unit) of the Mae Lama Luang project are implemented after an interval of five years, and MS-SS and the transmission line from Nam Ngao PS to MS-SS are constructed at the same time.

Case-F : Two Stages' Implementation

At the first stage, the Nam Ngao project is implemented with its full capacity, and the transmission line of 230 kV (2-cct) from Nam Ngao PS to CH-3-SS is constructed at the same time.

At the second stage, the Mae Lama Luang project is implemented with its full capacity after an interval of five years, and MS-SS and the transmission line of 230 kV (2-cct) from Mae Lama Luang PS to MS-SS are constructed at the same time.

The result of study is shown in Table 8-13 and the outline is shown in the table below. The detail of the construction costs used for this study are shown in Appendix. Further, the construction costs do not include environmental mitigation cost, however, the tendency of the result does not change because the mitigation cost is negligibly small compared with the total cost.

Item	Case-A	Case-B	Case-C
Individual Development and Simultaneous Implementation of Integrated Development	Nam Ngao Individual (140 MW)	Mae Lama Luang Individual (160 MW)	Mae Lama Luang (240 MW) Nam Ngao (140 MW)
B - C (M฿)	-465	749	950
EDR (%)	9.96	14.95	14.02

Item		Case-D	Case-E	Case-F
Two Stages' Implementation of Integrated Development	1st stage	Mae Lama Luang (240 MW)	Mae Lama Luang (160 MW)	Nam Ngao (140 MW)
	2nd stage	Nam Ngao (140 MW)	Mae Lama Luang (80 MW) Nam Ngao (140 MW)	Mae Lama Luang (240 MW)
B - C (M฿)		755	726	340
EDR (%)		13.91	13.93	12.86

Note : Discount Rate 12%

8.6.2 Adopted Development Plan and Implementation

From the viewpoint that undeveloped hydro power resources is getting less in Thailand and should be utilized most effectively, the alternative with the largest B-C value should be adopted. Therefore, it can be said that simultaneous implementation of the integrated development (Case C) is much superior to the individual development and two stages' implementation of integrated development.

Further, in case one of the projects is to be implemented first due to certain situation, the Mae Lama Luang project should be implemented first. Becuase the Mae Lama Luang project is much more independent than the Nam Ngao project from economical viewpoint. In other words, the Mae Lama Luang project can afford to bear the transmission line cost.

The feature of adopted development plan is shown in Table 8-12, and the monthly power and energy for the plan are shown in Table 8-14 and 8-15.

Table 8-13 (1) Study on Sequence of Projects' Implementation

Item	Unit	Case-A	Case-B	Case-C	
		Nam Ngao	Mae Lama Luang	Mae Lama Luang	Nam Ngao
Total Storage Capacity	MCM	925	486	486	925
Effective Storage Capacity	MCM	329	277	252	329
Normal High Water Level	m	270	165	165	270
Available Drawdown	m	15	22	19	15
Normal Intake Water Level	m	264	156	157	264
Tail Water Level	m	162.9	66.3	67.0	162.9
Normal Effective Head	m	96.1	84.7	85.0	96.1
95% Firm Discharge	cms	24.7	33.9	49.7	24.7
Maximum Power Discharge	cms	170	220	330	170
Installed Capacity	MW	140	160	240	140
Firm Capacity*	MW	122.6	123.4	207.6	122.4
Annual Energy Production*	GWh	306.8	540.9	583.4	300.7
Annual Capacity Factor**	%	26.1	40.3	29.4	25.9
Economic Cost***	MB	4,332	4,374	5,103	4,028
B-C	MB	-465	749	950	
EDR	%	9.96	14.95	14.02	

Item	Unit	Case-D		
		1st Stage	2nd Stage	
		Mae Lama Luang	Mae Lama Luang	Nam Ngao
Total Storage Capacity	MCM	486	—	925
Effective Storage Capacity	MCM	252	—	329
Normal High Water Level	m	165	—	270
Available Drawdown	m	19	—	15
Normal Intake Water Level	m	157	—	264
Tail Water Level	m	67.0	—	162.9
Normal Effective Head	m	85.0	—	96.1
95% Firm Discharge	cms	33.9	—	24.7
Maximum Power Discharge	cms	330	—	170
Installed Capacity	MW	240	240	140
Firm Capacity*	MW	133.6	207.6	122.4
Annual Energy Production*	GWh	580.8	583.4	300.7
Annual Capacity Factor**	%	29.2	29.4	25.9
Economic Cost***	MB	5,103	—	4,028
B-C	MB	755		
EDR	%	13.91		

* At the entrance of Chiang Mai 3 Substation.
** At the generating end.
*** Without IDC and Import Duty.

Table 8-13 (2) Study on Sequence of Projects' Implementation

Item	Unit	Case-E		
		1st Stage Mae Lama Luang	2nd Stage Mae Lama Luang	2nd Stage Nam Ngao
Total Storage Capacity	MCM	486	—	925
Effective Storage Capacity	MCM	252	—	329
Normal High Water Level	m	165	—	270
Available Drawdown	m	19	—	15
Normal Intake Water Level	m	157	—	264
Tail Water Level	m	67.0	—	162.9
Normal Effective Head	m	85.0	—	96.1
95% Firm Discharge	cms	33.9	49.7	24.7
Maximum Power Discharge	cms	220	330	170
Installed Capacity	MW	160	240	140
Firm Capacity*	MW	127.8	207.6	122.4
Annual Energy Production*	GWh	543.7	583.4	300.7
Annual Capacity Factor**	%	40.5	29.4	25.9
Economic Cost***	MB	4,511	728	4,028
B-C	MB		726	
EDR	%		13.91	

Item	Unit	Case-F		
		1st Stage Nam Ngao	2nd Stage Nam Ngao	2nd Stage Mae Lama Luang
Total Storage Capacity	MCM	925	—	486
Effective Storage Capacity	MCM	329	—	252
Normal High Water Level	m	270	—	165
Available Drawdown	m	15	—	19
Normal Intake Water Level	m	264	—	157
Tail Water Level	m	162.9	—	67.0
Normal Effective Head	m	96.1	—	85.0
95% Firm Discharge	cms	24.7	—	49.7
Maximum Power Discharge	cms	170	—	330
Installed Capacity	MW	140	140	240
Firm Capacity*	MW	122.6	122.4	207.6
Annual Energy Production*	GWh	306.8	300.7	583.4
Annual Capacity Factor**	%	26.1	25.9	29.4
Economic Cost***	MB	4,332	—	4,793
B-C	MB		340	
EDR	%		12.86	

* At the entrance of Chiang Mai 3 Substation.
** At the generating end.
*** Without IDC and Import Duty.

Table 8-14 (1) Monthly List of Power (Nam Ngao Project : Integrated Development)

(Unit : MW)

	< JAN >	< FEB >	< MAR >	< APR >	< MAY >	< JUN >	< JUL >	< AUG >	< SEP >	< OCT >	< NOV >	< DEC >
1959	129.5	129.5	129.5	129.5	113.6	113.5	115.5	129.5	129.5	129.5	129.5	129.5
1960	129.5	129.5	129.5	129.5	120.5	116.5	118.5	129.5	129.5	129.5	129.5	129.5
1961	129.5	129.5	129.5	126.0	120.9	117.4	129.5	129.5	129.5	129.5	129.5	129.5
1962	129.5	129.5	129.5	126.0	122.2	119.9	129.5	129.5	129.5	129.5	129.5	129.5
1963	129.5	129.5	129.5	126.0	126.6	117.9	129.5	129.5	129.5	129.5	129.5	129.5
1964	129.5	129.5	129.5	126.0	120.9	116.0	129.5	129.5	129.5	129.5	129.5	129.5
1965	129.5	129.5	129.5	126.0	126.7	115.7	116.0	129.5	129.5	129.5	129.5	129.5
1966	129.5	129.5	129.5	126.0	120.9	117.9	129.5	129.5	129.5	129.5	129.5	129.5
1967	129.5	129.5	129.5	126.0	120.9	122.0	117.3	129.5	129.5	129.5	129.5	129.5
1968	129.5	129.5	129.5	126.0	120.9	119.5	129.5	129.5	129.5	129.5	129.5	129.5
1969	129.5	129.5	129.5	126.0	120.9	119.2	129.5	129.5	129.5	129.5	129.5	129.5
1970	129.5	129.5	129.5	126.0	120.9	116.6	129.5	129.5	129.5	129.5	129.5	129.5
1971	129.5	129.5	129.5	126.0	120.9	118.0	129.5	129.5	129.5	129.5	129.5	129.5
1972	129.5	129.5	129.5	126.0	126.9	116.0	129.5	129.5	129.5	129.5	129.5	129.5
1973	129.5	129.5	129.5	126.0	120.9	116.9	127.0	129.5	129.5	129.5	129.5	129.5
1974	129.5	129.5	129.5	126.0	120.9	117.6	129.5	129.5	129.5	129.5	129.5	129.5
1975	129.5	129.5	129.5	126.0	120.9	117.4	129.5	129.5	129.5	129.5	129.5	129.5
1976	129.5	129.5	129.5	126.0	120.9	116.1	126.0	129.5	129.5	129.5	129.5	129.5
1977	129.5	129.5	129.5	126.0	120.9	116.0	115.3	129.5	129.5	129.5	129.5	129.5
1978	129.5	129.5	129.5	126.0	120.9	116.0	118.8	129.5	129.5	129.5	129.5	129.5
1979	129.5	129.5	129.5	129.5	126.4	92.3	114.2	129.5	129.5	129.5	129.5	129.5
1980	129.5	129.5	129.5	126.2	121.0	116.0	116.8	129.5	129.5	129.5	129.5	129.5
1981	129.5	129.5	129.5	126.0	126.8	116.3	129.5	129.5	129.5	129.5	129.5	129.5
1982	129.5	129.5	129.5	126.0	120.9	120.8	129.5	129.5	129.5	129.5	129.5	129.5
1983	129.5	129.5	129.5	126.0	126.5	119.5	59.4	117.2	129.5	129.5	129.5	129.5
1984	129.5	129.5	129.5	129.5	125.9	119.7	129.5	129.5	129.5	129.5	129.5	129.5
1985	129.5	129.5	129.5	126.0	120.9	121.2	129.5	129.5	129.5	129.5	129.5	129.5
1986	129.5	129.5	129.5	126.0	120.9	116.1	126.5	129.5	129.5	129.5	129.5	129.5
T O T A L	3626.0	3626.0	3626.0	3542.5	3418.7	3268.1	3443.3	3613.7	3626.0	3626.0	3626.0	3626.0
A V E	129.5	129.5	129.5	126.5	122.1	116.7	123.0	129.1	129.5	129.5	129.5	129.5
M A X	129.5	129.5	129.5	129.5	126.9	122.0	129.5	129.5	129.5	129.5	129.5	129.5
M I N	129.5	129.5	129.5	126.0	113.6	92.3	59.4	117.2	129.5	129.5	129.5	129.5

Table 8-14 (2) Monthly List of Power (Mae Lama Luang Project : Integrated Development)

(Unit : MW)

	< JAN >	< FEB >	< MAR >	< APR >	< MAY >	< JUN >	< JUL >	< AUG >	< SEP >	< OCT >	< NOV >	< DEC >
1959	222.0	222.0	222.0	210.4	175.3	178.3	186.0	222.0	222.0	222.0	222.0	222.0
1960	222.0	222.0	213.7	203.8	192.6	199.3	193.5	222.0	222.0	222.0	222.0	222.0
1961	222.0	222.0	222.0	222.0	210.8	201.0	201.9	222.0	222.0	222.0	222.0	222.0
1962	222.0	222.0	222.0	222.0	212.4	203.2	205.2	222.0	222.0	222.0	222.0	222.0
1963	222.0	222.0	222.0	222.0	210.2	200.3	206.4	222.0	222.0	222.0	222.0	222.0
1964	222.0	222.0	222.0	222.0	212.4	202.9	222.0	222.0	222.0	222.0	222.0	222.0
1965	222.0	222.0	222.0	222.0	210.9	201.2	193.5	222.0	222.0	222.0	222.0	222.0
1966	222.0	222.0	222.0	222.0	212.4	204.6	212.6	222.0	222.0	222.0	222.0	222.0
1967	222.0	222.0	222.0	222.0	212.4	203.2	193.5	222.0	222.0	222.0	222.0	222.0
1968	222.0	222.0	222.0	222.0	212.4	205.6	197.7	222.0	222.0	222.0	222.0	222.0
1969	222.0	222.0	222.0	222.0	212.4	204.2	200.2	222.0	222.0	222.0	222.0	222.0
1970	222.0	222.0	222.0	222.0	212.4	203.2	200.7	222.0	222.0	222.0	222.0	222.0
1971	222.0	222.0	222.0	222.0	212.4	205.4	222.0	222.0	222.0	222.0	222.0	222.0
1972	222.0	222.0	222.0	222.0	211.6	202.2	209.9	222.0	222.0	222.0	222.0	222.0
1973	222.0	222.0	222.0	222.0	212.4	203.2	202.2	222.0	222.0	222.0	222.0	222.0
1974	222.0	222.0	222.0	222.0	212.4	203.2	194.1	222.0	222.0	222.0	222.0	222.0
1975	222.0	222.0	222.0	222.0	212.4	203.2	199.2	222.0	222.0	222.0	222.0	222.0
1976	222.0	222.0	222.0	222.0	212.4	203.2	193.5	222.0	222.0	222.0	222.0	222.0
1977	222.0	222.0	222.0	222.0	212.4	203.2	193.5	219.0	222.0	222.0	222.0	222.0
1978	222.0	222.0	222.0	222.0	212.4	202.8	204.2	222.0	222.0	222.0	222.0	222.0
1979	222.0	222.0	222.0	220.7	211.1	200.1	190.2	222.0	222.0	222.0	222.0	222.0
1980	222.0	222.0	217.7	205.0	198.0	199.1	193.5	215.9	222.0	222.0	222.0	222.0
1981	222.0	222.0	222.0	222.0	211.1	201.5	198.0	222.0	222.0	222.0	222.0	222.0
1982	222.0	222.0	222.0	222.0	212.4	210.2	216.7	222.0	222.0	222.0	222.0	222.0
1983	222.0	222.0	222.0	221.3	208.1	192.7	123.9	198.2	222.0	222.0	222.0	222.0
1984	222.0	222.0	222.0	219.0	206.3	199.9	196.3	222.0	222.0	222.0	222.0	222.0
1985	222.0	222.0	222.0	221.4	211.7	203.2	193.5	222.0	222.0	222.0	222.0	222.0
1986	222.0	222.0	222.0	222.0	212.4	203.2	193.5	216.7	222.0	222.0	222.0	222.0
T O T A L	6216.0	6216.0	6203.4	6163.5	5856.2	5643.5	5537.8	6177.8	6216.0	6216.0	6216.0	6216.0
A V E	222.0	222.0	221.6	220.1	209.2	201.6	197.8	220.6	222.0	222.0	222.0	222.0
M A X	222.0	222.0	222.0	222.0	212.4	210.2	222.0	222.0	222.0	222.0	222.0	222.0
M I N	222.0	222.0	213.7	203.8	175.3	178.3	123.9	198.2	222.0	222.0	222.0	222.0

Table 8-15 (1) Monthly List of Energy (Nam Ngao Project : Integrated Development)

(Unit : MWh)

	< JAN >	< FEB >	< MAR >	< APR >	< MAY >	< JUN >	< JUL >	< AUG >	< SEP >	< OCT >	< NOV >	< DEC >	<TOTAL>
1959	14765.	13336.	14765.	14288.	12957.	12520.	13291.	14765.	60171.	27747.	14789.	15141.	228534.
1960	14945.	13812.	14765.	14288.	21713.	22527.	13531.	38670.	72624.	77115.	31972.	26274.	362236.
1961	25487.	17879.	17073.	16311.	13836.	22647.	14765.	30921.	95256.	43532.	19537.	25234.	342476.
1962	21689.	16548.	17150.	16301.	24054.	22971.	14765.	32534.	63177.	94497.	23309.	23403.	370397.
1963	20488.	16137.	16997.	15830.	14437.	22711.	14765.	19551.	59340.	72196.	36704.	23982.	333136.
1964	21999.	16650.	16774.	16036.	16119.	14482.	14765.	42043.	81631.	67824.	19521.	22343.	350185.
1965	19780.	15794.	16804.	15933.	14446.	21560.	13336.	14765.	34526.	46921.	36132.	21842.	271837.
1966	20547.	15879.	16471.	15541.	15479.	22718.	14765.	68581.	63923.	21019.	14816.	16983.	306721.
1967	17178.	15233.	16168.	15192.	14083.	13461.	13434.	27376.	83582.	51410.	19789.	22341.	309249.
1968	19931.	16209.	16621.	15354.	15947.	22919.	14765.	26756.	48644.	32984.	14820.	18331.	263277.
1969	18318.	15294.	15251.	15215.	17051.	22876.	14765.	98431.	95256.	58628.	32654.	26296.	430035.
1970	25967.	20778.	18600.	18333.	20468.	22547.	14765.	29987.	75035.	40004.	20666.	21770.	328918.
1971	19701.	16051.	16438.	15125.	15753.	22725.	35054.	98431.	80149.	41524.	21690.	20494.	403135.
1972	19134.	16023.	16485.	16498.	14468.	16788.	14765.	75717.	62801.	40962.	26723.	26178.	346542.
1973	21919.	16920.	17773.	16049.	17398.	22587.	14478.	16507.	72887.	53026.	26362.	24357.	320264.
1974	19490.	15870.	15682.	15786.	17129.	22678.	14765.	32457.	49483.	35417.	20780.	18395.	277931.
1975	20102.	16262.	17460.	15795.	15774.	22649.	14765.	14951.	60687.	46634.	21515.	19414.	286007.
1976	19489.	16415.	16193.	15072.	16523.	22468.	14369.	22108.	54254.	44828.	23404.	19850.	284974.
1977	25868.	17128.	16735.	16105.	14263.	15117.	13274.	14765.	46584.	28029.	18182.	17844.	243893.
1978	17471.	15492.	15753.	14905.	15187.	13383.	13547.	14765.	45771.	33315.	14789.	14997.	229376.
1979	14786.	13336.	14765.	14288.	14406.	10181.	13192.	14765.	29341.	32967.	14812.	15176.	202017.
1980	15245.	14046.	15091.	14812.	17842.	18932.	13392.	14765.	54714.	58947.	25384.	22745.	285915.
1981	19773.	14860.	15294.	14993.	14459.	22501.	14765.	39935.	43968.	34575.	22210.	21221.	278554.
1982	18878.	15309.	15557.	15203.	16710.	23095.	14765.	98421.	81756.	49778.	21102.	19225.	389799.
1983	17787.	14422.	14832.	14208.	14428.	13183.	6777.	13425.	14288.	14765.	14392.	14765.	167273.
1984	14765.	13812.	14765.	14288.	14352.	22950.	14765.	54053.	54148.	32559.	15695.	17100.	283252.
1985	17142.	14925.	15605.	15218.	14443.	23141.	14765.	68982.	64124.	35024.	22244.	21856.	327469.
1986	20186.	16768.	16980.	16008.	14424.	22478.	14423.	14765.	14709.	15353.	14673.	14875.	195642.
T O T A L	542829.	441190.	452846.	432976.	448146.	558794.	413568.	1053189.	1662820.	1231576.	608665.	572433.	8419033.
A V E	19387.	15757.	16173.	15463.	16005.	19957.	14770.	37614.	59386.	43985.	21738.	20444.	300680.
M A X	25967.	20778.	18600.	18333.	24054.	23141.	35054.	98431.	95256.	94497.	36704.	26296.	430035.
M I N	14765.	13336.	14765.	14208.	12957.	10181.	6777.	13425.	14288.	14765.	14392.	14765.	167273.

Table 8-15 (2) Monthly List of Energy (Mae Lama Luang Project : Integrated Development)

(Unit : MWh)

	< JAN >	< FEB >	< MAR >	< APR >	< MAY >	< JUN >	< JUL >	< AUG >	< SEP >	< OCT >	< NOV >	< DEC >	<TOTAL>
1959	27962.	24578.	25898.	23836.	19984.	19675.	23958.	30561.	129876.	55865.	27067.	27808.	437067.
1960	27236.	24411.	24897.	22483.	23186.	31467.	37544.	89288.	138526.	145073.	54296.	51056.	669462.
1961	43944.	32670.	30150.	26809.	24667.	37152.	44819.	59816.	163296.	85587.	33080.	46516.	628505.
1962	39419.	30723.	30385.	27090.	45467.	39598.	45310.	59703.	120929.	168739.	38957.	42994.	689314.
1963	37180.	29681.	29876.	26480.	24616.	40877.	45494.	44182.	120778.	140130.	65417.	46624.	651335.
1964	40714.	31692.	30376.	27094.	28106.	23253.	51156.	96993.	163296.	131039.	35995.	43178.	702891.
1965	37599.	30457.	30775.	27413.	24667.	33362.	34448.	35317.	84187.	101161.	67273.	42849.	549507.
1966	38239.	30170.	29876.	26604.	28557.	43770.	46428.	155500.	131515.	47376.	27251.	29335.	634622.
1967	30907.	27417.	28137.	25550.	25503.	23778.	37496.	54312.	163296.	94951.	30932.	39262.	581540.
1968	34688.	28639.	28811.	26334.	28776.	43910.	44170.	46883.	93215.	72170.	27251.	29745.	504593.
1969	32111.	27364.	26957.	25774.	29209.	43703.	44564.	168739.	163296.	103463.	54167.	50006.	769354.
1970	44861.	35886.	32677.	31299.	40331.	42987.	44627.	65823.	148318.	84399.	35451.	43453.	650113.
1971	36320.	29761.	29750.	26139.	30203.	43884.	85534.	168739.	151448.	82210.	34785.	38797.	757570.
1972	34825.	29415.	29267.	28467.	24732.	27659.	46024.	130721.	109907.	74300.	45930.	46170.	627415.
1973	38909.	30298.	30828.	26835.	31148.	39529.	44866.	70188.	163296.	104620.	41843.	43219.	665578.
1974	36089.	29551.	28140.	26904.	30881.	41168.	43626.	47784.	98374.	66895.	38867.	34875.	523153.
1975	38206.	29817.	30476.	26402.	27681.	41459.	44401.	43806.	154286.	106213.	40495.	40173.	623414.
1976	36530.	30610.	28982.	25742.	28580.	35915.	40889.	35214.	106227.	89769.	39039.	39442.	536937.
1977	46238.	30393.	29242.	27901.	25316.	25799.	33880.	25309.	129551.	67717.	33630.	36946.	511923.
1978	34976.	29427.	28485.	25649.	26538.	23244.	45158.	59047.	119304.	82690.	28211.	30830.	533558.
1979	30156.	25922.	26729.	24626.	24689.	23039.	28774.	33597.	62364.	64142.	27086.	27845.	398970.
1980	27333.	24672.	25207.	23414.	23633.	32142.	40526.	25070.	139787.	108978.	39613.	41825.	552198.
1981	34786.	26778.	26801.	25068.	24689.	36023.	44217.	69761.	85250.	63582.	34880.	38111.	509945.
1982	33093.	27155.	26962.	26063.	28713.	44576.	47031.	168739.	154854.	101634.	34851.	36281.	729953.
1983	32507.	26636.	26766.	24667.	24451.	22446.	14130.	23652.	24702.	36831.	27419.	30681.	314889.
1984	28178.	25808.	26630.	24496.	24304.	43075.	43966.	66870.	116173.	79970.	28043.	32593.	540105.
1985	29951.	25881.	26753.	24673.	25579.	39443.	43193.	63192.	140845.	116736.	59436.	53046.	648727.
1986	39018.	31487.	30430.	28800.	26780.	33650.	41987.	25130.	40649.	37728.	27276.	28382.	391317.
T O T A L	991976.	807296.	800263.	732609.	770985.	976581.	1188211.	1963928.	3417534.	2513960.	1078541.	1092039.	16333940.
A V E	35428.	28832.	28581.	26165.	27535.	34878.	42436.	70140.	122055.	89784.	38519.	39001.	583355.
M A X	46238.	35886.	32677.	31299.	45467.	44576.	85534.	168739.	163296.	168739.	67273.	53046.	769354.
M I N	27236.	24411.	24897.	22483.	19984.	19675.	14130.	23652.	24702.	36831.	27067.	27808.	314889.

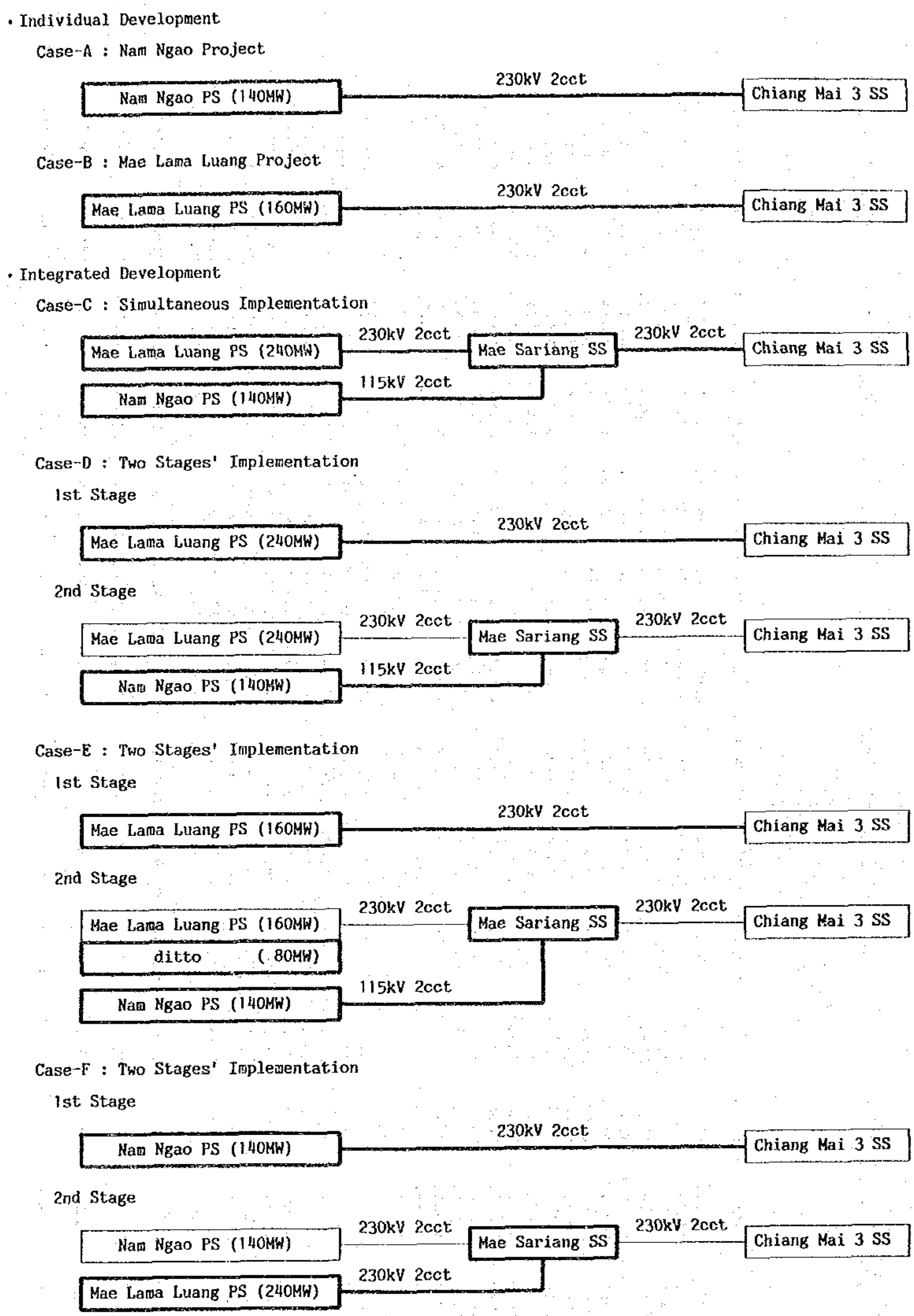


Fig. 8-21 Alternatives of Projects' Implementation

CHAPTER 9

TRANSMISSION LINE, POWER SYSTEM ANALYSIS AND TELECOMMUNICATION FACILITIES

CHAPTER 9 TRANSMISSION LINE, POWER SYSTEM ANALYSIS AND TELECOMMUNICATION FACILITIES

CONTENTS

List of Figures

CHAPTER 9 TRANSMISSION LINE, POWER SYSTEM ANALYSIS AND TELECOMMUNICATION FACILITIES

9.1 Transmission Scheme

The standard voltage of the transmission line system of EGAT is 500, 230, 115 and 69 kV, and the frequency is 50 Hz.

Table 3-2 in Chapter 3 shows the installed capacity of the substations and the overall length of the transmission lines. Fig. 3-1 in Chapter 3 shows the power system diagram of EGAT.

The area of Mae Lama Luang and Nam Ngao power stations is situated at about 200 km away from the demand area of northern region centering at Chiang Mai.

9.1.1 Transmission Line

(1) Basic Conditions

On the basis of the following conditions, a transmission line scheme is formulated.

- Energy generated at the Nam Ngao power station (140 MW) and the Mae Lama Luang power station (240 MW) is consumed in Region 4 centering at Chiang Mai.

- The transmission lines should be planned from the overall points of view such as construction cost, maintainability, transmission loss, etc., subject to the availability of transmitting the power without trouble even when one circuit happens to be stopped due to a fault.

- The transmission lines from the Mae Lama Luang and Nam Ngao power stations are connected to a nearest substation. The distance between the Mae Lama Luang power station and Chiang Mai 3 substation is about 200 km. Since the power transmission with a high reliability is required, study on optimal transmission voltage, corona voltage, size of cables, number of circuits, etc. is performed. Two circuits of 1,272 MCM or 795 MCM are adopted for 230 kV transmission line, and two-circuits of 795 MCM or 477 MCM are adopted for 115 kV line, taking into account the EGAT standard.

9.1.2 Study on Transmission Line Routes

(1) Access Road

The route of the transmission line from the Mae Lama Luang and Nam Ngao power stations to Region 4 is the route connecting to a substation in the vicinity of Chiang Mai.

For constructing the transmission lines, whether or not there are existing roads available for transporting the equipment and materials, and working yards available for extending the transmission lines, greatly influences the construction cost.

The Mae Lama Luang power station is situated in the mountaneous area and at an undeveloped area. The transmission line between the power station and the Mae Sariang substation has to cross over a mountain of 1,500 m class above the sea level. Then the access condition is not favorable.

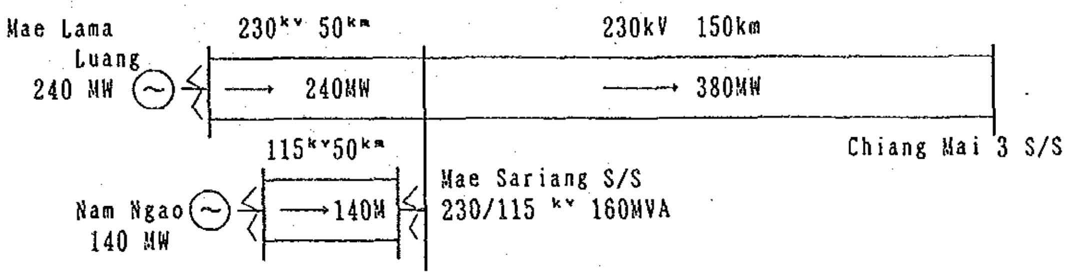
The route of about 150 km from the Mae Sariang substation up to the Chiang Mai 3 substation runs in parallel with the well maintained national route No. 108 which is paved road.

A part of the route from the Mae Sariang substation to the Nam Ngao power station runs in parallel with the maintained national route No. 1085 which is a laterite road.

The road between the Mae Lama Luang power station and the Mae Sariang substation, and the road between the Nam Ngao power station and the route No. 1085 are to be constructed.

(2) Transmission Line Route

- As a result of the study and the survey on site, the transmission line route from the power plants to Chiang Mai is as follows:



- The power generated at the Mae Lama Luang and Nam Ngao power stations is transmitted to the Chiang Mai 3 substation via the Mae Sariang substation, shown in Fig. 9-1.

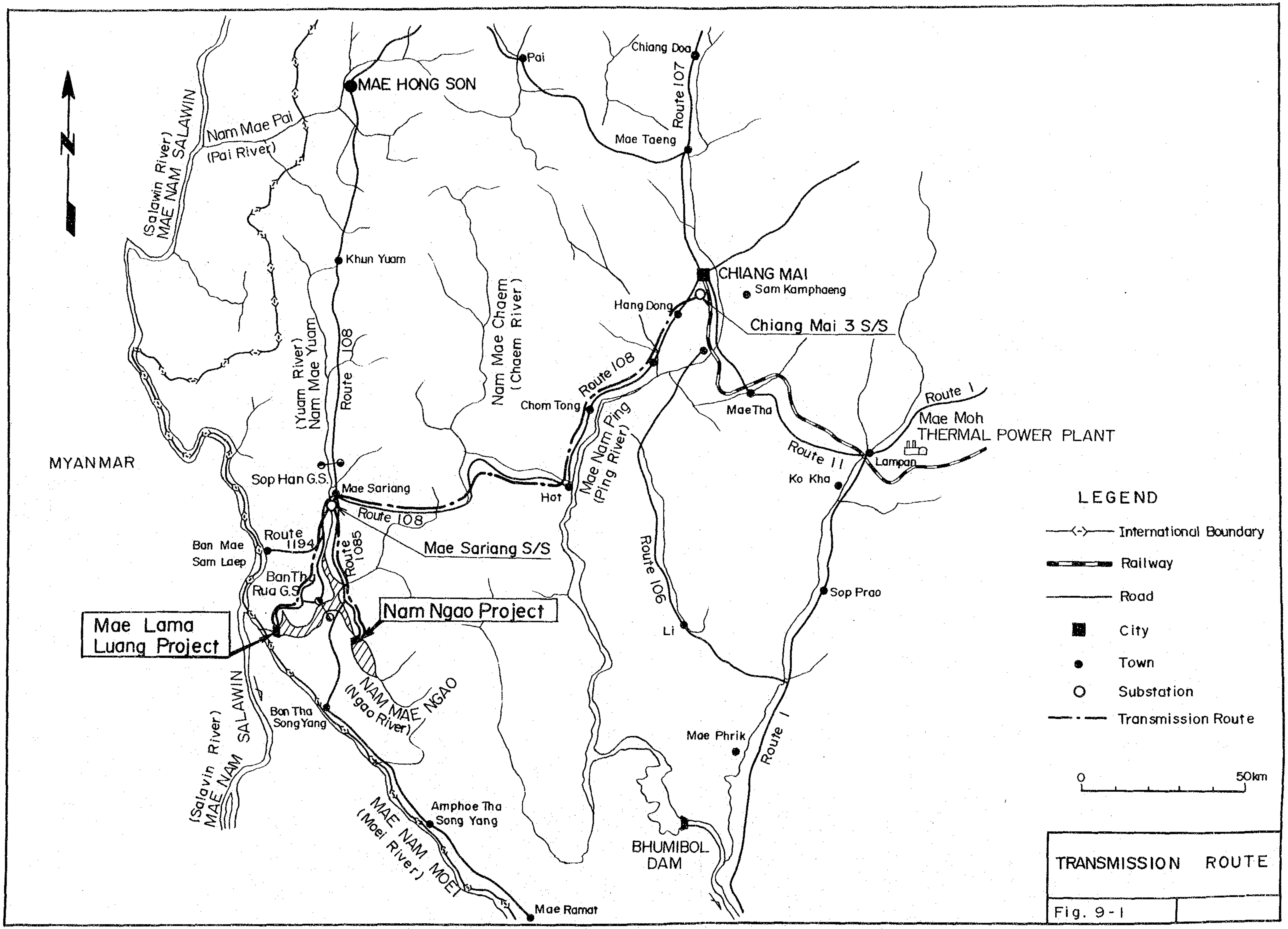
- The transmission line of 230 kV, 2-circuits ACSR 1,272 MCM is constructed for the distance of 50 km between the Mae Lama Luang power station and the Mae Sariang substation.

- The transmission line of 230 kV, 2-circuits ACSR 1,272 MCM is constructed for the distance of 150 km between the Mae Sariang substation and the Chiang Mai 3 substation.

- The transmission line of 115 kV, 2-circuits ACSR 795 MCM is constructed for the distance of 50 km between the Nam Ngao power station and the Mae Sariang substation.

- In case the implementation of the Nam Ngao power station delays but the Mae Lama Luang power plant is implemented only, the Mae Sariang substation is not necessary. In this case, 2-circuits transmission line of ACSR 1,272 MCM, 230 kV is constructed for the distance of 200 km from the Mae Lama Luang power plant to the Chiang Mai 3 substation.

- Furthermore, the Mae Sariang area which is isolated from the EGAT power net work can be connected with the system by the transmission line and the Mae Sariang substation.



TRANSMISSION ROUTE

Fig. 9-1

9.2 Power System Analysis

9.2.1 Basic Conditions for Calculation

We have performed the technical study on system analysis of the transmission pattern selected in connection with the following conditions.

(1) Items to be Calculated

Calculation of power flow
Calculation of system stabilization
Calculation of short circuit current

(2) Calculation Year and Peak Load Associated

Calculation year: 1997
Peak load : Approximately 12,000 MW

(3) The Scale of Nam Yuam River Basin Integrated Hydro Electric Development Project

Nam Ngao power station : 140 MW
Mae Lama Luang power station : 240 MW

(4) Calculation of Transient Stability

The swing of generator is verified in connection with the system disturbance of 3ØG-Fault which is affected so severe against to the Mae Lama Luang power station and the Nam Ngao power station. A clearing time of fault is set on 0.1 second.

(5) Calculation of Short Circuit Current

The generator capacity of whole system is an approximately 14,000 MVA commensurate with a peak load values. A reactance value of the generator is adopted as a transient reactance Xd'.

(6) Calculation of the Others

An electric power system construction, system constant and the condition of the power demand and supply are used the data submitted by EGAT.

The supplying power of 2.0 MW from the Mae Sariang substation to Mae Sariang service area is assumed.

9.2.2 Analysis

(1) Calculation of Power Flow

The power flow without Project is shown in Fig. 9-2 and the power flow with Project is shown in Fig. 9-3.

In case the Project is not inplemented the electric power of the Chaing Mai area is supplied from the Mae Moh 3 power station. Therefore, the following 115 kV transmission lines connected on both points become overload.

Mae Moh-3 (P.S) - Mae Moh-2 (P.S)	:	277 MW/2 cct
Mae Moh-2 (P.S) - Lampang-2 (S.S)	:	210 MW/2 cct
Mae Moh-2 (P.S) - Lampang-1 (S.S)	:	135 MW/cct
Lampang-1 (S.S) - Lampun-1 (S.S)	:	131 MW/cct

An allowable transmission capacity of the 115 kV line (795 MCM) is approximately 150 MW/cct (90°C), and it can be said that these lines are nearly closed to the limit, especially in the double circuit zones even when one circuit happens to be stopped due to fault, the allowable capacity is excessed. Furthermore, in the Chiang Mai area, serious system voltage drop occurs due to the overload on the 115 kV lines. Countermeasures to introduce the 230 kV transmission line rather than to strengthen 115 kV transmission lines are needed in order to cope with the overload and to improve the system voltage.

In case this Project is implemented, the electric power in the Chiang Mai area is supplied from an opposite direction. Therefore, the aforementioned overload zone can be improved. In this case, the supply power for the 115 kV system through the Chiang Mai 3 substation is approximately 270 MV in which 210 MV is sent to the Lamphun 1 substation through the single circuit of 115 kV line. The line is affected by overload.

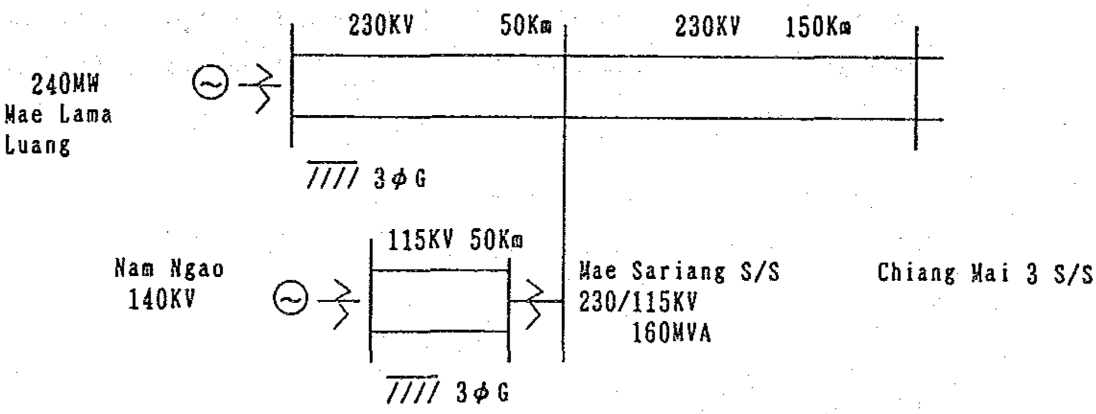
Then, it is needed that the expansion of 115 kV single line between the Lamphun 2 substation and the Chiang Mai 3 substation in connection with the Project inauguration period.

(2) Calculation of Transient Stability

The calculation of transient stability is performed in connection with the power flow indicated in the Fig. 9-3. The swing curves of the generator are shown below as the result of transient stabilization:

Fig. 9-4 Generator Swing Curve
(Mae Lama Luang - Mae Sariang, 230 kV, 3ØG-Fault)
Fig. 9-5 Generator Swing Curve
(Mae Sariang - Chiang Mai-3, 230 kV, 3ØG-Fault)
Fig. 9-6 Generator Swing Curve
(Nam Ngao - Mae Sariang, 115 kV, 3ØG-Fault)

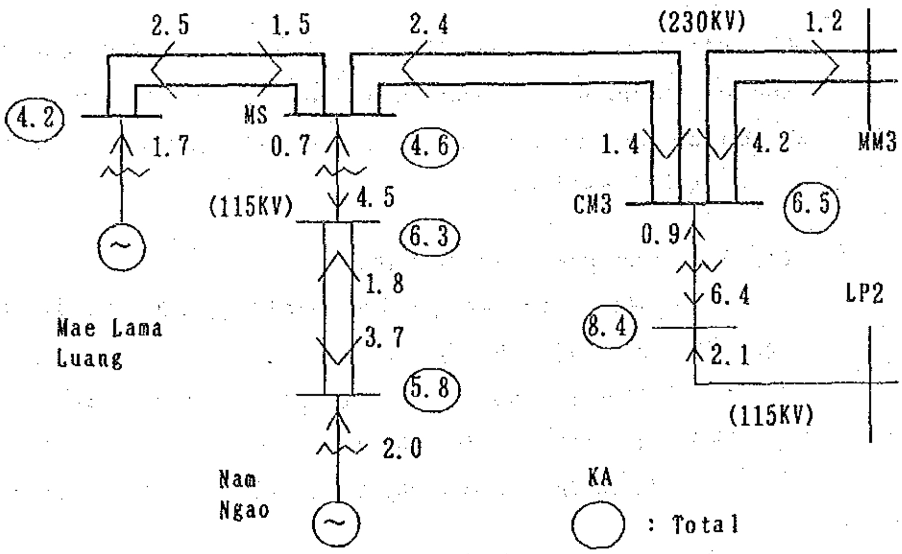
The swing curves and the fault transmission line simulated are shown below:



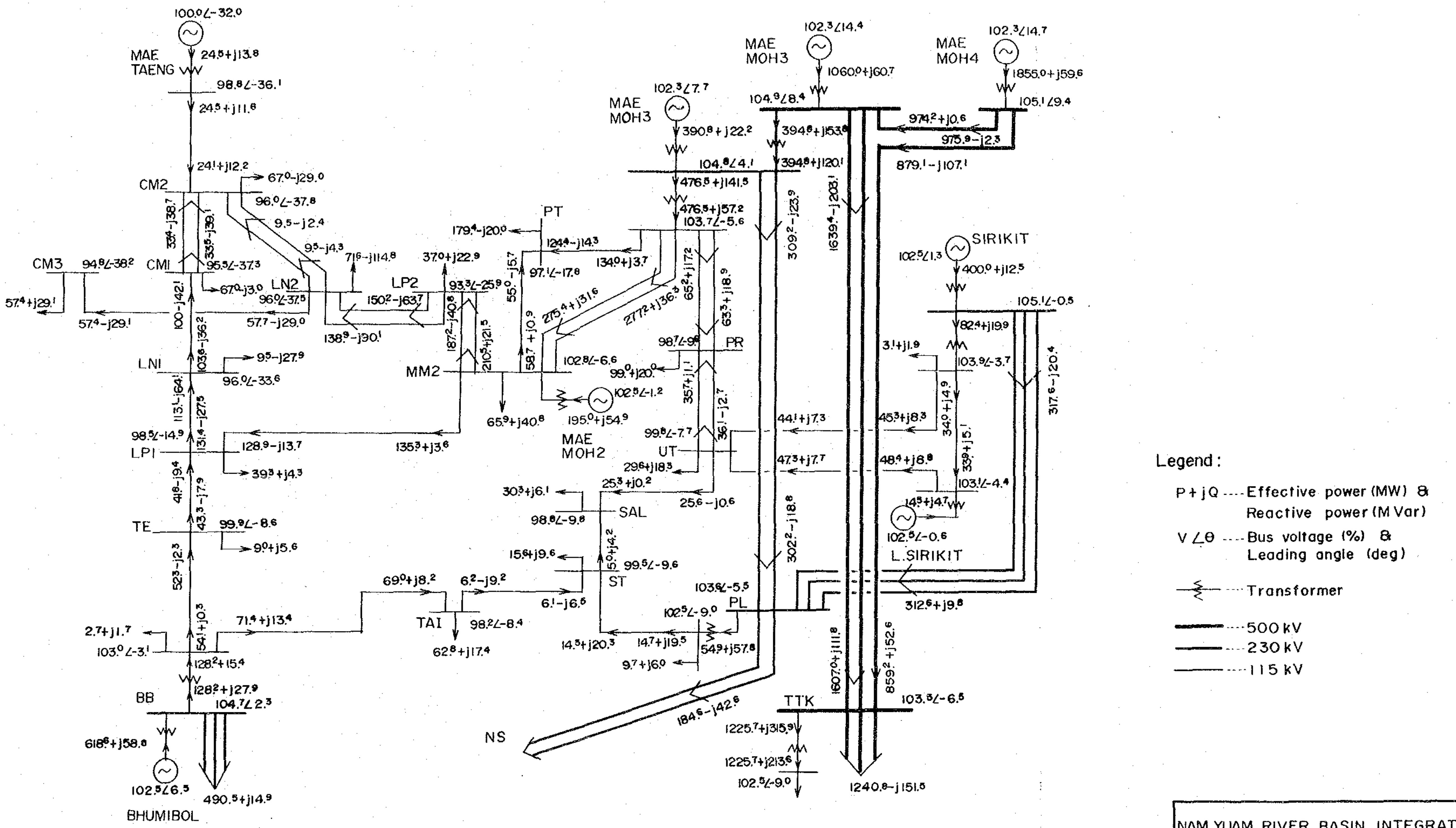
From the calculation result, each transmission line has enough stabilization for the 3ØG-Fault. Therefore, it is possible to send the power generated without any restriction of power output. It can be concluded that the system has no problem.

(3) Calculation of Short Circuit Current

The short circuit current values of each power stations and substations on this Project are shown below:



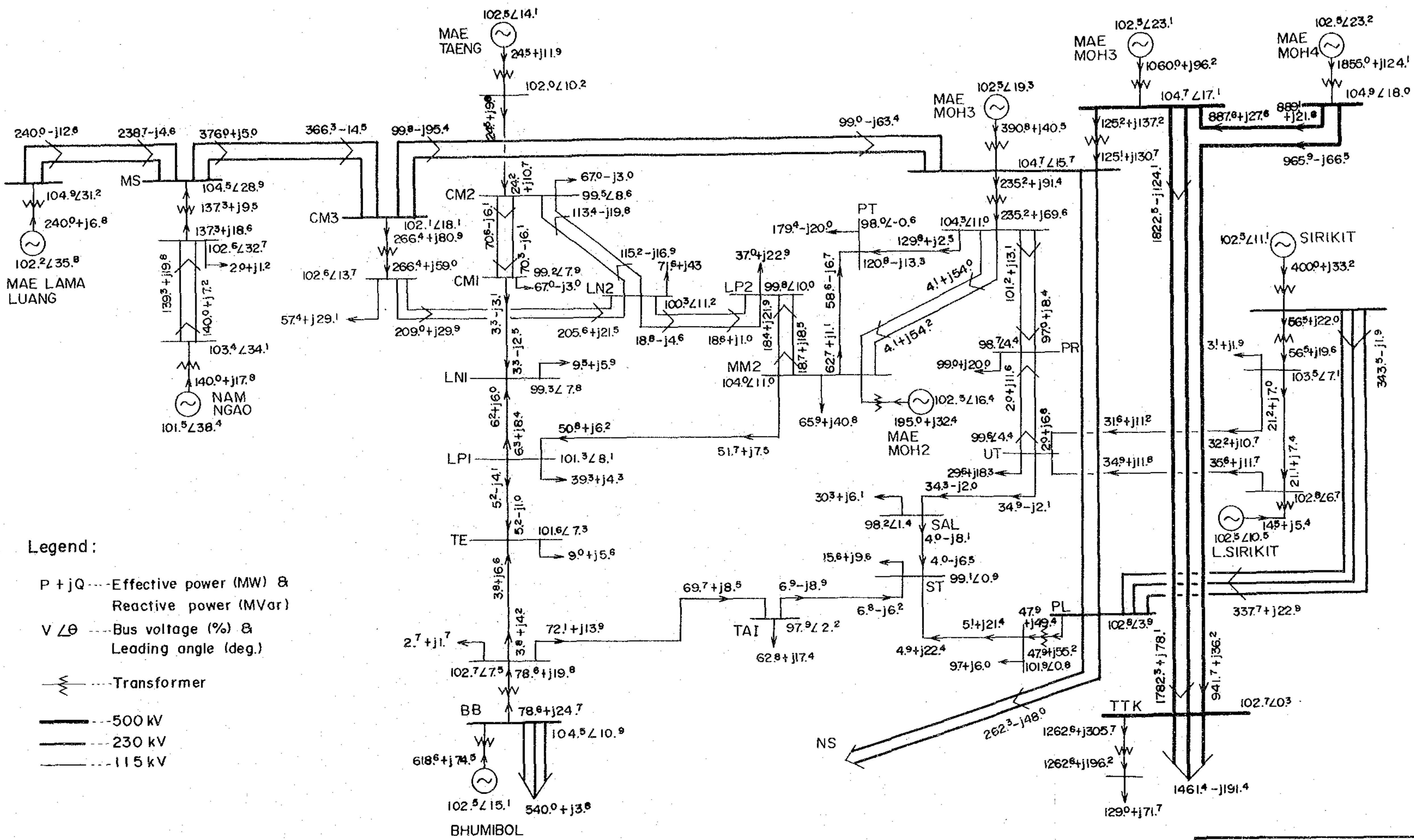
The short circuit current of the 230 kV buses at the Mae Lama Luang power station is derived 4.2 kA (equivalent to 1,670 MVA) and 115 kV buses at the Nam Ngao power station is derived 5.8 kA (equivalent to 1,160 MVA).



NAM YUAM RIVER BASIN INTEGRATED HYDROELECTRIC DEVELOPMENT PROJECT

POWER FLOW DIAGRAM

Fig. 9-2

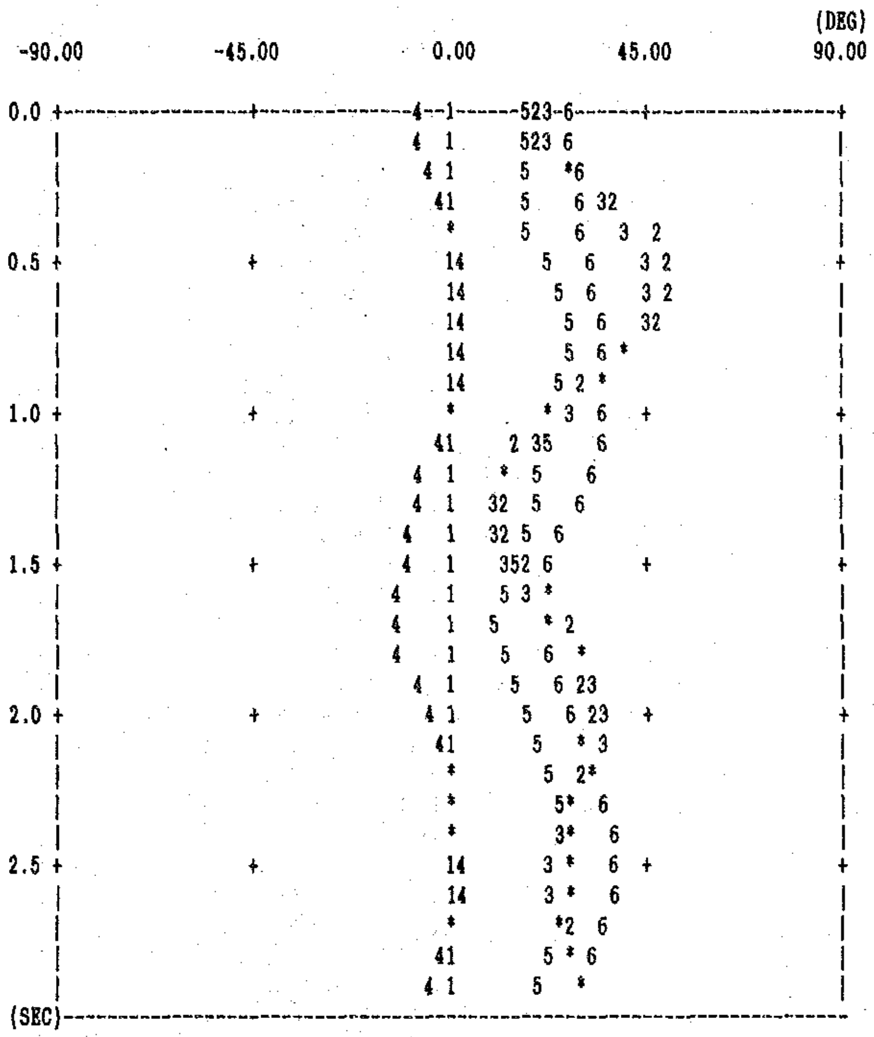


NAM YUAM RIVER BASIN INTEGRATED HYDROELECTRIC DEVELOPMENT PROJECT

POWER FLOW DIAGRAM

Fig. 9 – 3

BASE GENERATOR=BKK Network

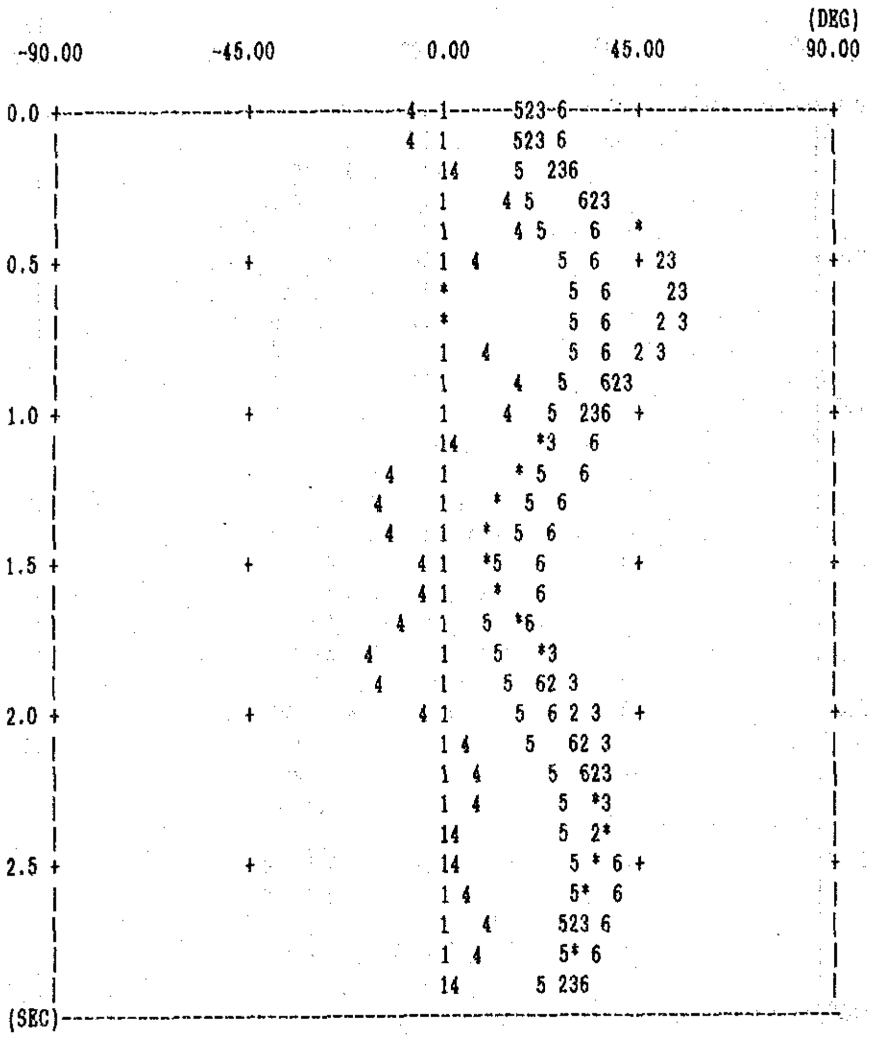


SYMBOL Gen.

1=BKK Network
2=M.L.Luang
3=Nam Ngao
4=Mae Taeng
5=Mae Moh-3(230kV)
6=Mae Moh-3(500kV)

Fig.9-4 GENERATOR SWING CURVE
(M.L.Luang -- M.Sariang 230kV line,3ØG-Fault)

BASE GENERATOR=BKK Network

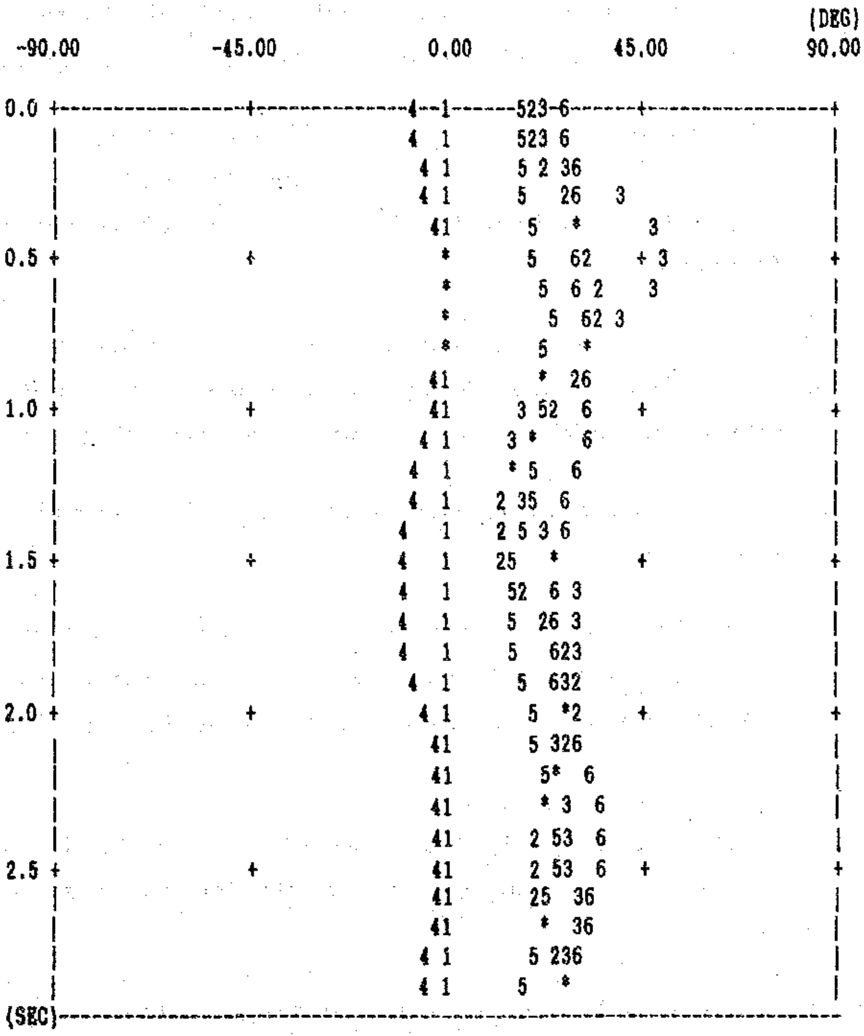


SYMBOL Gen.

1=BKK Network 2=M.L.Luang 3=Nam Ngao
4=Mae Taeng 5=mae Moh-3(230kV) 6=Mae Moh-3(500kV)

Fig.9-5 GENERATOR SWING CURVE
(M.Sariang -- C.Mai 230kV line,3ØG-Fault)

BASE GENERATOR=BKK Network



SYMBOL Gen.

1=BKK Network	2=M.L.Luang	3=Nam Ngao
4=Mae Taeng	5=Mae Moh-3(230kV)	6=Mae Moh-3(500kV)

Fig.9-6 GENERATOR SWING CURVE
(N.Ngao -- M.Sariang 115kV line,3ØG-Fault)

9.3 Telecommunication Facilities

The study on the telecommunication system was made taking into consideration the existing EGAT's telecommunication facilities.

(1) A 2 GHz microwave channel is established between the Mae Lama Luang/Nam Ngao power stations and the Chiang Mai 3 substation. Three repeater stations in the due course of telecommunication are installed.

(2) The telecommunication channels from the Mae Lama Luang/Nam Ngao power stations to the Chiang Mai 3 substation via Mae Sariang substation are composed of the power line carrier system.

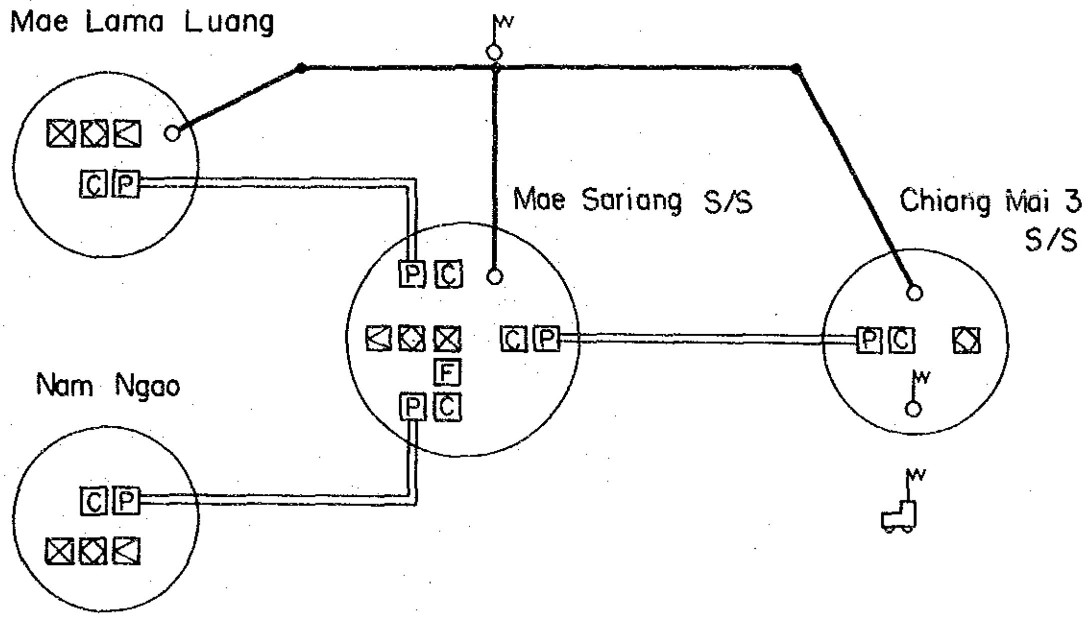
(3) The protective relays of each transmission line are of power line carrier system.

(4) The fault locater of the transmission lines is of pulse radar type, and is installed in the Mae Sariang substation to carry out the survillance of each directional transmission line for any fault.

(5) A telephone exchanger is installed in each of the Mae Lama Luang power station, the Nam Ngao power station and the Mae Sariang substation.

(6) A paging system is installed at the same stations as above.

(7) A mobile radio system is considered for maintaining the transmission lines. The base station for this purpose is established in each microwave repeater station and the Chiang Mai 3 substation.



LEGEND

- 2 GHz Microwave Radio Link
- 2 GHz Microwave Radio Link Repeator Station
- Power Line Carrier System
- Power Line Carrier Teleprotection Signalling Equipment
- Private Automatic Telephone Exchange
- Data Transmission Equipment
- Paging System
- Line Fault Locator
- VHF Communication System. Bass Station
- VHF Communication System. Mobile Station

Fig 9-7 TELECOMMUNICATION SYSTEM

CHAPTER 10

PRELIMINARY DESIGN

CHAPTER 10 PRELIMINARY DESIGN

CONTENTS

List of Drawings

CHAPTER 10 PRELIMINARY DESIGN

10.1 Nam Ngao Project

10.1.1 Dam and Appurtenant Structures

As shown in DWG. 10-1 and 10-2, a rockfill dam with concrete facing was selected as the dam type for the Nam Ngao Project, with the topographical and geological conditions taken into consideration.

The location of the spillway was studied, and it was determined to locate it on the left bank, considering the layout of the powerhouse.

The design flood of the dam is set at 2,100 m^3/sec based on PMF, and the design flood for diversion facilities is set at 940 m^3/sec with a 100-year return period.

The detail of the study is described below.

(1) Comparison of Dam Types

The most appropriate type of a 120-meter or so high dam at the Nam Ngao site is judged from topographical and geological conditions and material availability to be a rockfill dam. Two types of rockfill dam were studied: a rockfill dam with center clay core (Clay Core Type) and a rockfill dam with concrete facing (Concrete Facing Type).

A comparison study was made of a Clay Core Type and a Concrete Facing Type to select the dam type for the Nam Ngao dam. The drawings of the both types are shown in DWG. 10-1, 10-2, 10-3 and 10-4.

The dam volume, excavation volume and estimated construction cost of each type of dam are shown in the below.

Comparison of Dam Types

Item	Unit	Clay Core Type	Concrete Facing Type
Dam Volume*	10^3 m^3	8,330	5,980
Excavation Volume	10^3 m^3	1,200	510
Construction Cost	M฿	1,287	1,039

* Including upstream coffer dam

From an economic point of view, a Concrete Facing Type was selected in this feasibility study as the dam type for the Nam Ngao site having the characteristic of a wide river bed (See DWG 10-1 and 10-2).

However, it is suggested that the final decision on the dam type should be done at the definite design stage, taking into account the other factors such as maintenance, ability of local contractors, etc.

(2) Diversion Facilities

The design flood for diversion facilities at the Nam Ngao site is set at 940 m^3/sec with a 100-year return period.

A diversion method using tunnels was adopted taking into account the shape of the river and the layout of the structures. Two diversion tunnels are installed on the left bank which permits shorter tunnels than on the right bank.

The fill type dam is selected for the upstream cofferdam, and its location has been determined to be a point approximately 260 m upstream of the main dam.

The upstream cofferdam is separated from the main dam because of Concrete Facing Type dam and construction workability.

The crest elevation of the upstream cofferdam is determined by taking into account the embankment volume during the dry season of six months and the capacity of the diversion tunnel.

On this basis, it was determined to install two diversion tunnel of 7 m in inner diameter, 702 m (No. 1) and 658 m (No. 2) in length, and the upstream coffer dam has a crest elevation of 108 m.

The diversion tunnel has concrete lining for the entrance and exit, and shotcrete lining for the other parts.

(3) Dam

The dam projected to be built at the Nam Ngao site is a rockfill dam with concrete facing, and its dimensions are as follows:

Dam height	:	123 m
Crest length	:	655 m
Total embankment volume	:	5,380 x 10^3 m^3
(excluding coffer dam)		

Regarding the geological conditions of the dam site, the foundation is composed mainly of sandstone, alternate layers of sandstone and shale, and partly of limestone.

The dam axis is determined by taking account of the results of the geological and topographical survey.

The sound bed rock for the prince concrete is at around 5 m deep from the surface on the river bed, around 10 m at the right bank and 20 m at the left bank. Dental works are necessary for the sheared zone in the faults.

The dam has a upstream and downstream slope of 1:1.4, determined on the basis of a design seismic coefficient of 0.10 and examples of actual design value of the materials in Thailand.

For the foundation treatment, a grout curtain method should be adopted taking into account the geological conditions.

From the results of the past survey, it is found that the abutment on the left bank side of the dam site and the ridge adjoining it are composed of weathered sandstone and shale

30-40 m thick, and the ground water level is approximately 20 m lower than the normal high water level of EL. 270 m. Furthermore, limestone is developed along the stream gully called Mae Lui running into the upstream of the dam site on the right bank. Therefore, in view of the water permeability and ground water level, the foundation treatment is necessary to prevent leakage from the reservoir. DWG. 10-7 shows the grout lines for the foundation treatment of both abutments.

(4) Spillway

As shown in DWG. 10-5 the spillway is located on the left bank taking into account the geology and topography at the site.

The spillway capacity is designed so as to be capable of discharging a peak of 2,100 m^3/sec of PMF at a normal high water level of 270 m. The detailed spillway feature are a crest elevation of 256.5 m, a total crest length of 31 m including a pier 4 m wide. Further, the spillway is designed to be equipped with two radial gates 13.5 m in width.

The ski jump type is adopted for the dissipater of this spillway, and the direction of the center of the spillway and the location of the end sill is selected so as not to affect the other structures. Further, there is another alternative for the spillway layout, utilizing the gully on the right bank. After preliminary comparison, the adopted layout is superior to the alternative.

(5) Bottom Outlet

The bottom outlet shown in DWG. 10-2 is designed such that one of the two diversion tunnels can be utilized to discharge water downstream and draw down the reservoir water level in an emergency. The upstream part from the valve chamber in the tunnel is a structure having a concrete lining, and the downstream part is a structure having shotcrete (invert: concrete lining).

The elevation of the bottom outlet is set at 220 m, and water is discharged to the valve chamber installed in the tunnel through a vertical shaft (inner diameter: 4 m). A high-pressure slide gate of 1.5 m in diameter and a jet flow gate of 1.5 m in diameter are installed in the valve chamber.

10.1.2 Waterway and Powerhouse

As shown in DWG. 10-1 and 10-6, taking the topographical condition into account, the waterway and the powerhouse are located on the right bank.

(1) Waterway

The waterway is designed for the maximum power discharge of 170 m^3/sec.

The intake is located immediately upstream of the dam. The elevation of 232.5 m of the sill is in such position that there are no harmful effect from taking water even at the LWL of 255.0 m, considering sedimentation.

The headrace consists of one tunnel of 204 m long and 7.4 m in inner diameter. The route is determined taking into account the depth of the tunnel from ground surface.

A penstock, 525 m long and 7.4 m - 3.9 m in diameter, consists of both embedded and exposed types, and these are connected with the powerhouse approximately 230 m downstream of the dam axis. The penstock is bifurcated and connected to two turbines in the powerhouse. The penstock's route is selected taking into account the topographical and geological conditions.

(2) Powerhouse and Switchyard

The powerhouse is of the outdoor type and its location is selected so as to provide a smooth flow of power discharge from the drafts. The turbine center and draft dimensions are determined to ensure sufficient protection of the turbine and draft against cavitation. Also, the dimensions of the powerhouse are determined taking into account the dimensions of the turbine, generator and auxiliary equipment and the size of the rooms.

The switchyard is designed to be installed at a site having an elevation of 177 m which is to be located on the yard between the dam foot and the powerhouse. This elevation is determined taking account the highest water level of 175 m on the downstream side for the PMF.

10.1.3 Electromechanical Equipment

The layout of the electromechanical equipment is shown in DWG. 10-1 and 10-6.

(1) Selection of the Number of Main Units

Generally, the number of the main units should be determined to minimize the number of units, and to maximize the capacity of the each unit, considering the economics of scale regarding construction cost.

In addition, the selection of the number of the units requires a total technical examination, including power system condition, transportation limits, equipment production limits and facility operation as well as profitability described above.

The planned dimension of the Nam Ngao project include effective head of 96.1 m, maximum power discharge of 170 m^3/sec, and its development scale is to be 140 MW. Under these conditions, the number of the main units should be selected from the two plans; either a one unit plan or a two unit plan.

The one unit plan (140 MW x 1) is economical, but the main disadvantage is that operational flexibility is lost, and the large sized main unit makes construction difficult. For example, a one unit system requires a lot of huge components such as about a 50 ton runner, about a 550 ton rotor and about 200 ton stator causing problems with division under transportation conditions.

To the contrary, the two unit plan (70 MW x 2) is slightly more expensive compared with the one unit plan (The cost of the two unit plan is 1.16 times that of the one unit plan), but it is the best for the development scale because it has a large operational flexibility, and is better regarding workability.

From the above reasons, the number of units was decided as two units.

(2) Selection of Main Unit

As described in the previous item, the number of units for the Nam Ngao project is two, and the planned dimension include an effective head of 96.1 m, and maximum turbine discharge of a single unit of 85 m^3/sec. Under these conditions, the vertical Francis turbine is the most suitable, so this is to be employed. Followings are the feature of the main unit equipment.

Turbine

Type	Vertical Francis turbine
Number of units	2 units
Normal effective head	96.1 m
Maximum turbine discharge	85 m^3/s
Normal output	72 MW
Revolving speed	231 rpm

Generator

Type	Three phase AC synchronous generator
Number of units	2 units
Output	78 MVA
Power factor	0.9 (Lag.)
Voltage	13.8 kV
Frequency	50 Hz
Revolving speed	231 rpm

Main Transformer

Type	Outdoor three phase transformer
Number of units	2 units
Capacity	78 MVA
Voltage	13.8 kV : 115 kV

(3) Arrangement of Equipments in Powerhouse

The Nam Ngao powerhouse is planned as an outdoor type, and the distance between the two main units is 20 m.

A carrying-in crane is to be installed for carrying in equipment into underground, and an overhead crane is installed for assembling equipment in the main unit room.

Various accessories are installed underground as well as the turbines and generators. And in the buildings on the ground offices, a storage room and workshops are installed as well as these required for monitoring and control such as a control room, and a relay room.

(4) Main Circuit and Outdoor Switchyard

The main circuit of the Nam Ngao power station employs a unit system which has a higher reliability, considering that it is an important power source in the system of the northern region as well as the Mae Lama Luang power station.

The synchronous system employs a low voltage synchronous system for high maintainability, and to secure station service power supply.

Generators and main transformers are connected by an isolated phase bus, and the main transformer is connected to the switchyard through extension steel frames using an aerial cable.

The bus bar of the 115 kV switchyard consists of the ring bus system for maintainability and reliability. Further an aluminum bus bar is used, allowing the omission of outdoor steel frames.

A skeleton is shown in DWG. 10-8, and the equipment layout in the switchyard is shown in DWG. 10-9.

10.1.4 Transmission Lines and Mae Sariang Substation

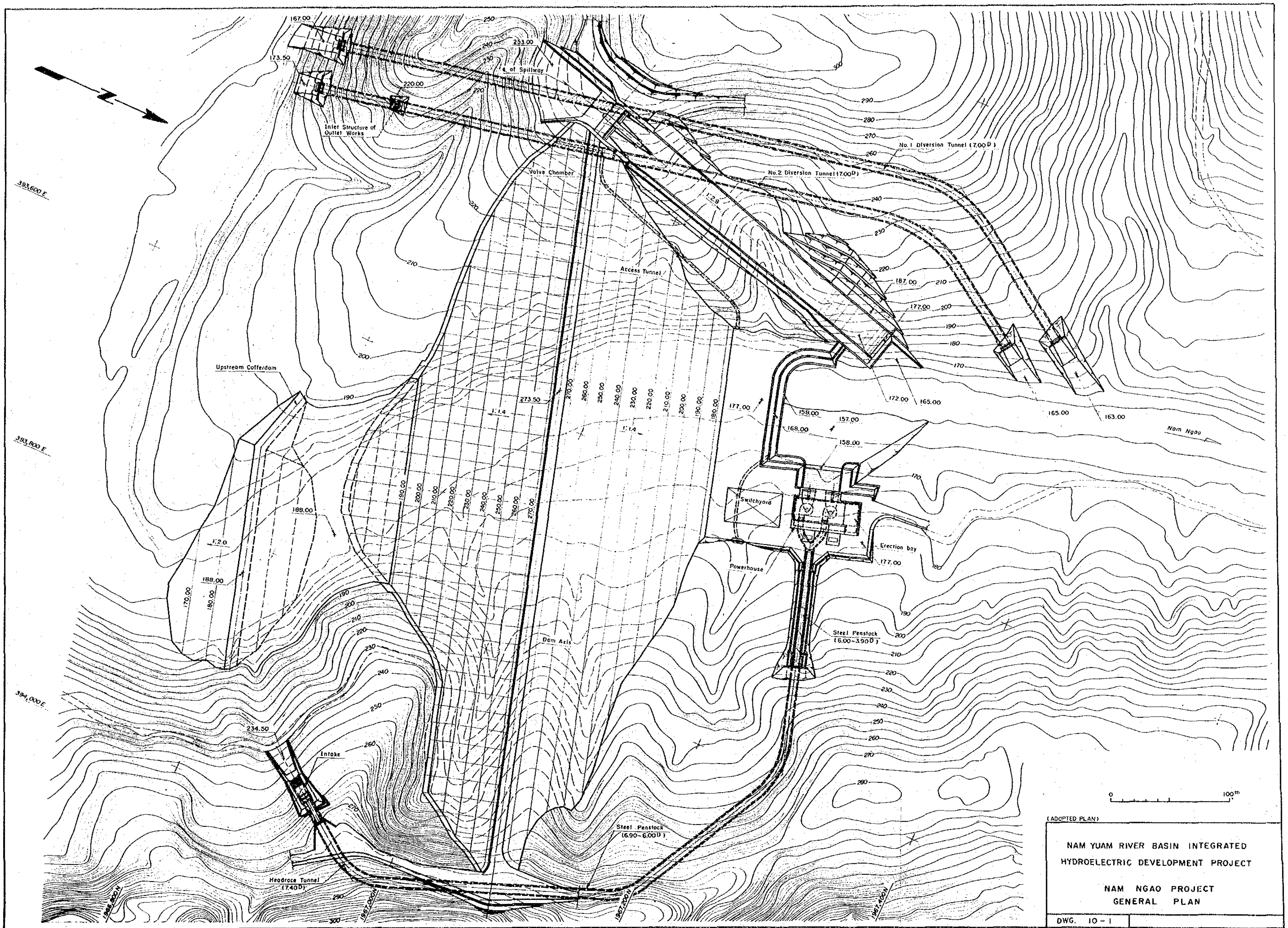
In order to connect the power generated by the Nam Ngao power station to the transmission lines between the Mae Lama Luang power station and the Chiang Mai 3 substation, 115 kV, 2-circuit ACSR 795 MCM transmission lines are constructed from the Nam Ngao power station up to Mae Sariang about 50 km north.

Also considering the EGAT's standards, the major dimensions of the steel towers for the 115 kV transmission line were designed and are shown in DWG. 10-10.

The 115 kV Nam Ngao transmission lines are interconnected to the Mae Lama Luang 230 kV transmission line via a 230/115 kV tie transformer in the Mae Sariang substation.

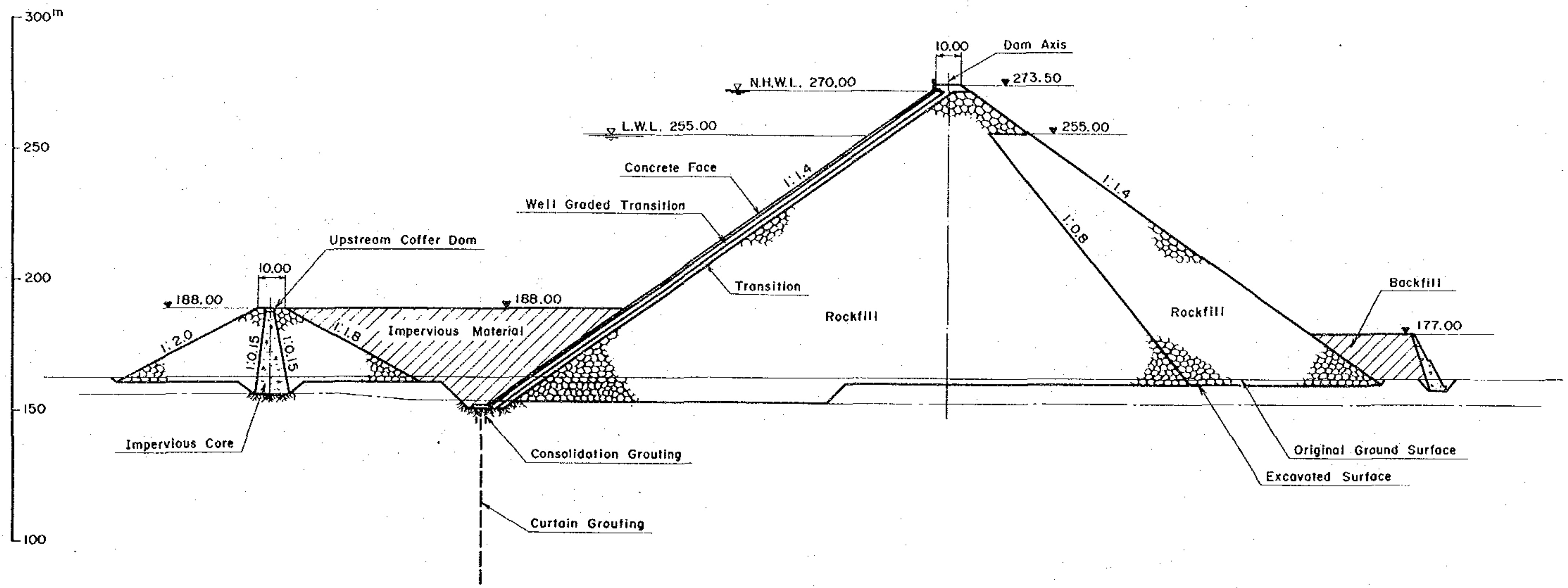
The single line diagram of the Mae Sariang substation is shown in DWG. 10-11. The general plan of the Mae Sariang substation is shown in DWG. 10-12.

Also considering the EGAT's standards, the Mae Sariang substation shall adopt $1\frac{1}{2}$ CB system aluminum pipe bus bars for 230 kV and the duplicated bus method, with 1-bus tie system, aluminum pipe bus bars for 115 kV.

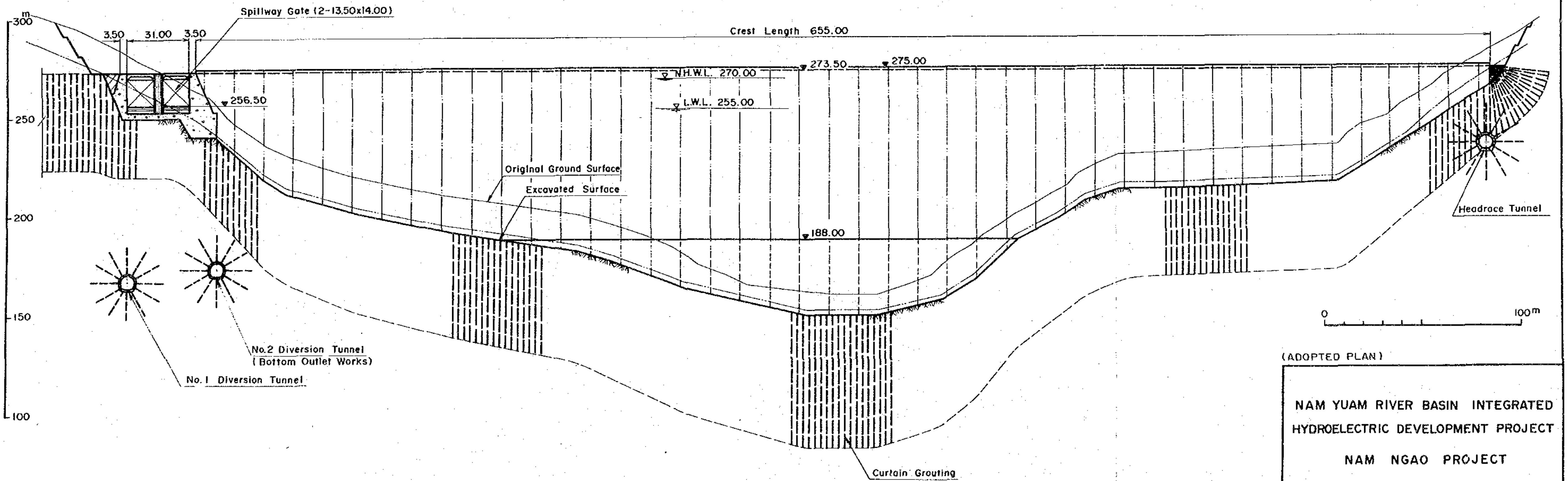


Inlet Structure of Outlet Works
Valve Chamber
No.1 Diversion Tunnel (7.00D)
No.2 Diversion Tunnel (7.00D)
Access Tunnel
Upstream Cofferdam
Switchyard
Powerhouse
Erection bay
Steel Penstock (6.00~3.90D)
Dam Axis
Intake
Steel Penstock (6.90~6.00D)
Headrace Tunnel (7.40D)
Nam Ngao
(ADOPTED PLAN)
NAM YUAM RIVER BASIN INTEGRATED
HYDROELECTRIC DEVELOPMENT PROJECT
NAM NGAO PROJECT
GENERAL PLAN
DWG. 10 - 1

TYPICAL SECTION OF DAM



PROFILE OF DAM



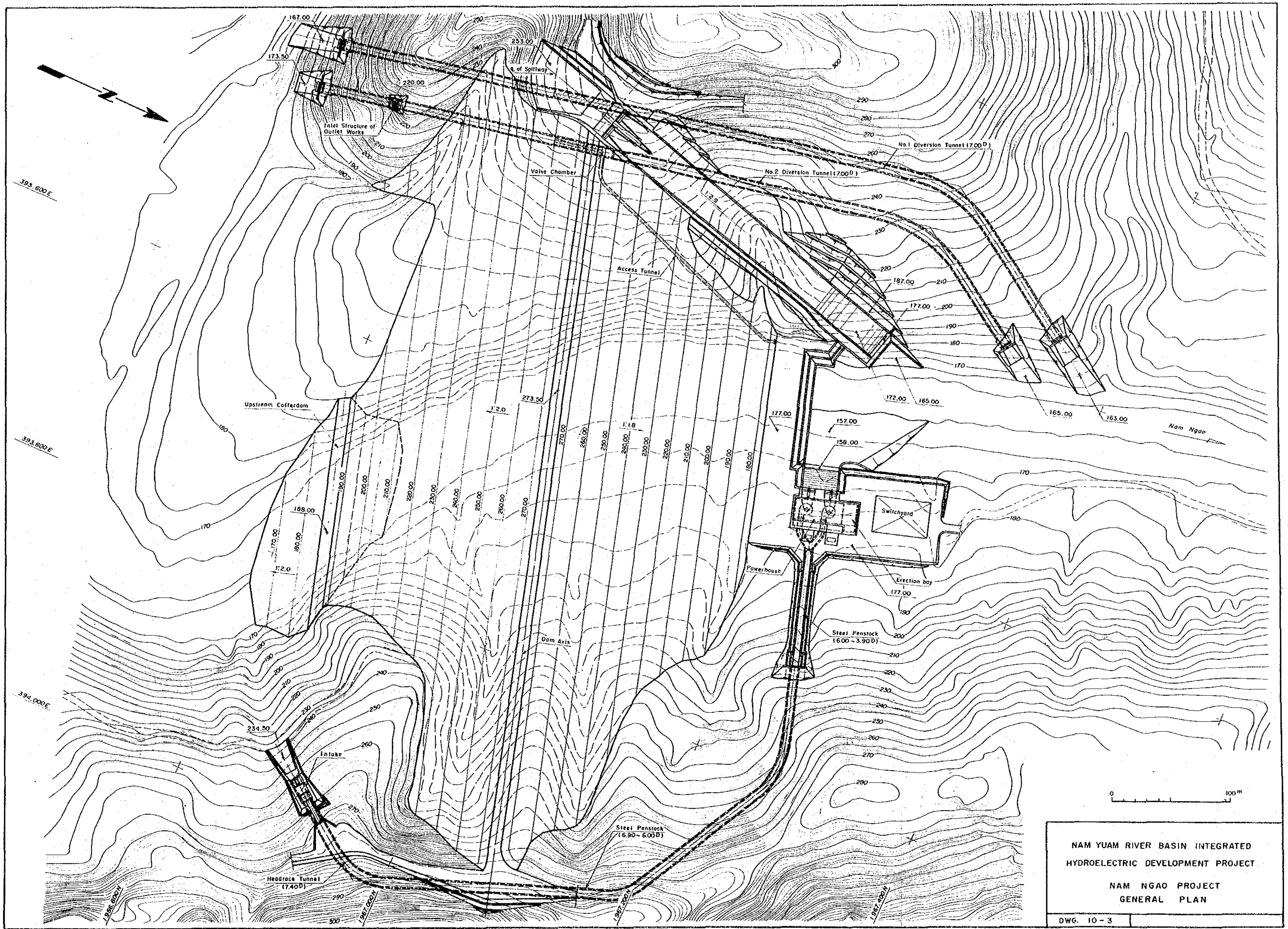
(ADOPTED PLAN)

NAM YUAM RIVER BASIN INTEGRATED HYDROELECTRIC DEVELOPMENT PROJECT

NAM NGAO PROJECT

SECTION OF DAM

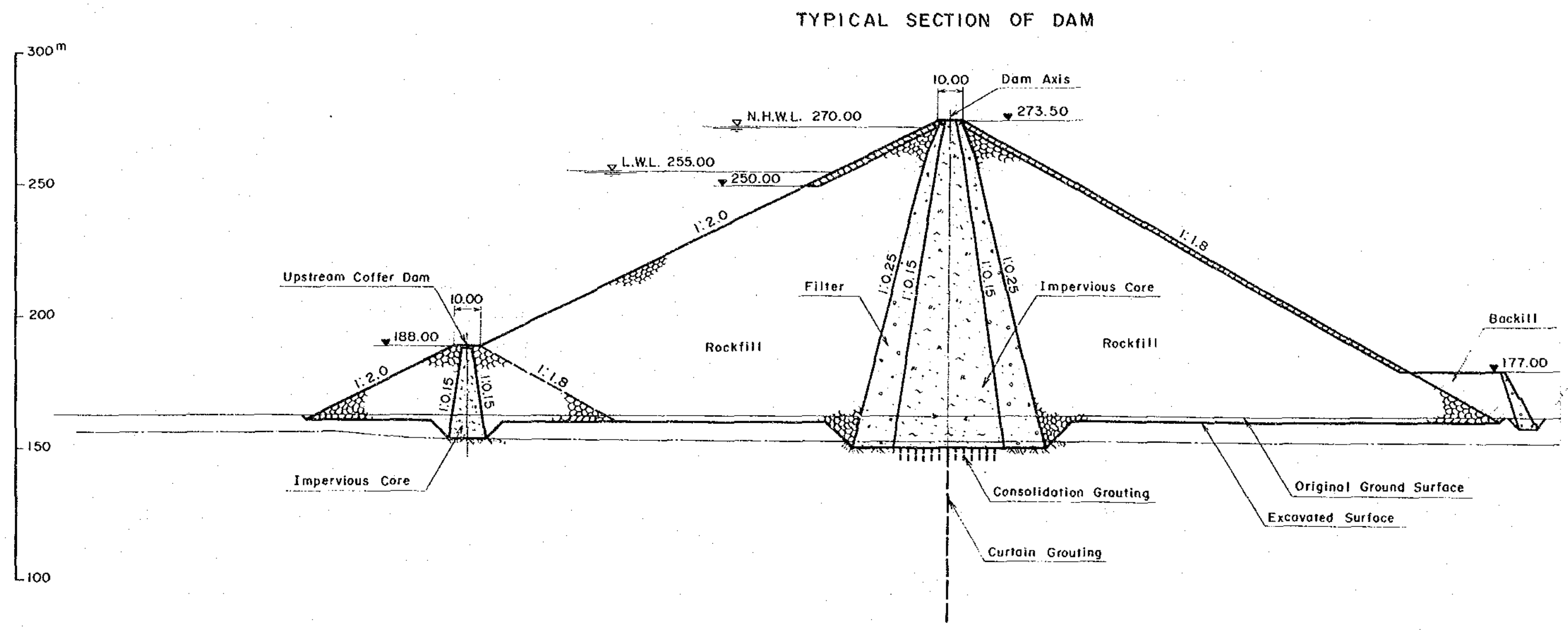
DWG. 10-2

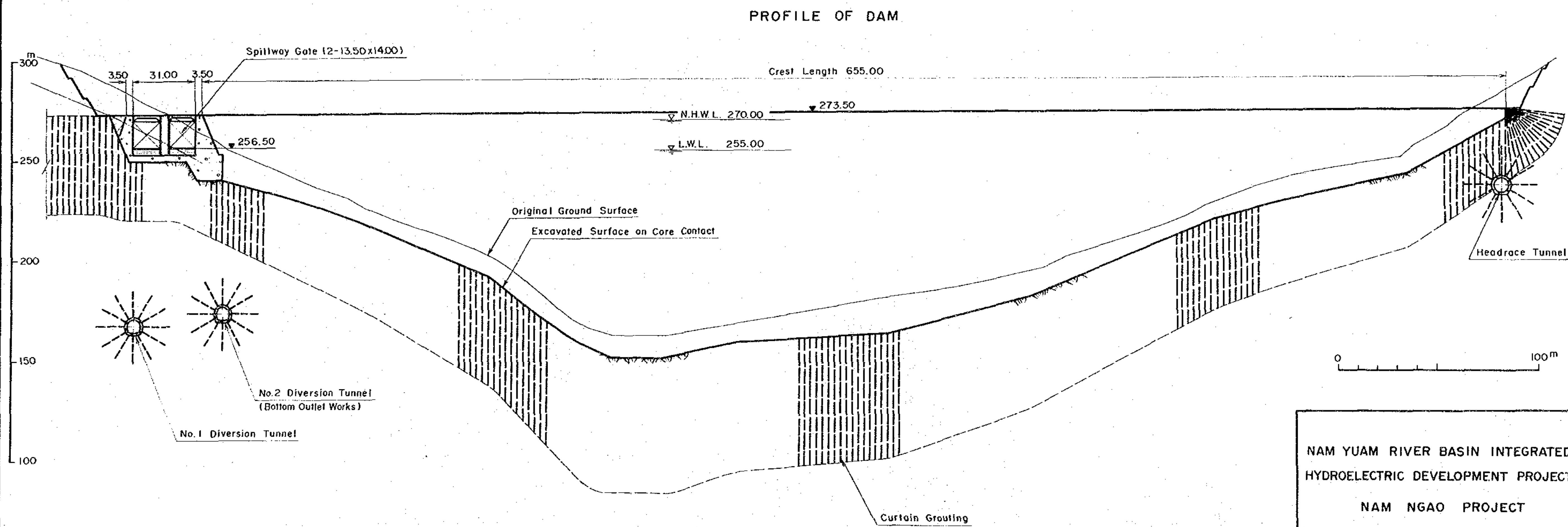


NAM YUAM RIVER BASIN INTEGRATED
HYDROELECTRIC DEVELOPMENT PROJECT

NAM NGAO PROJECT
GENERAL PLAN

DWG. 10 - 3





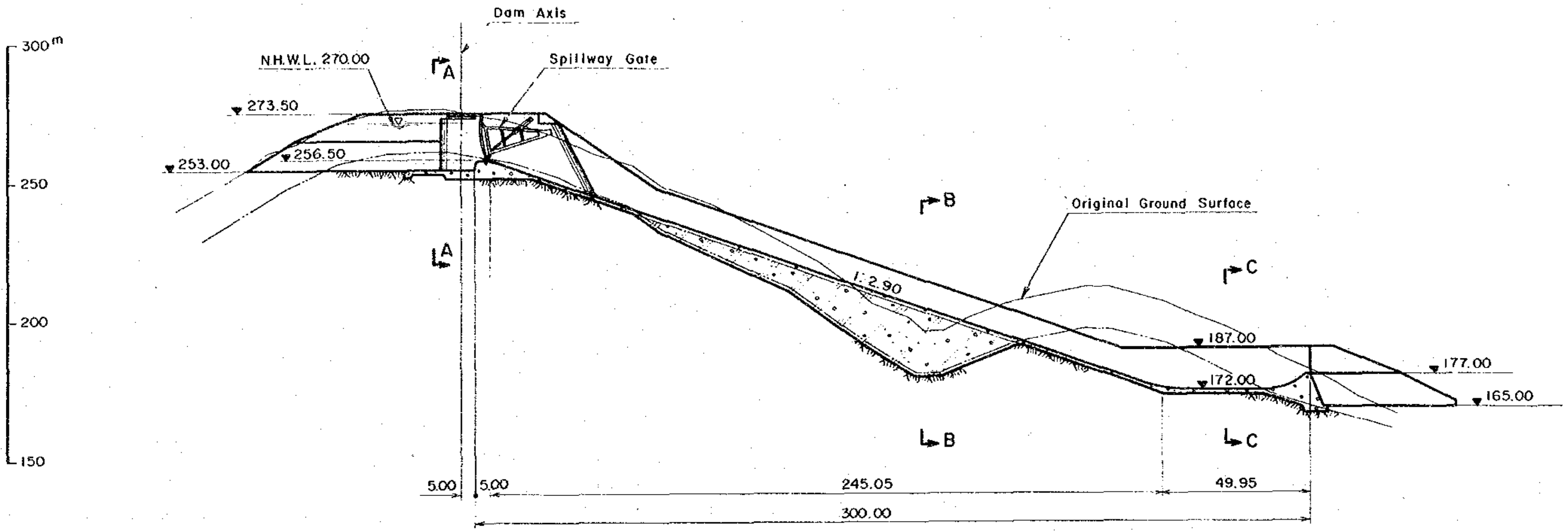
NAM YUAM RIVER BASIN INTEGRATED HYDROELECTRIC DEVELOPMENT PROJECT

NAM NGAO PROJECT

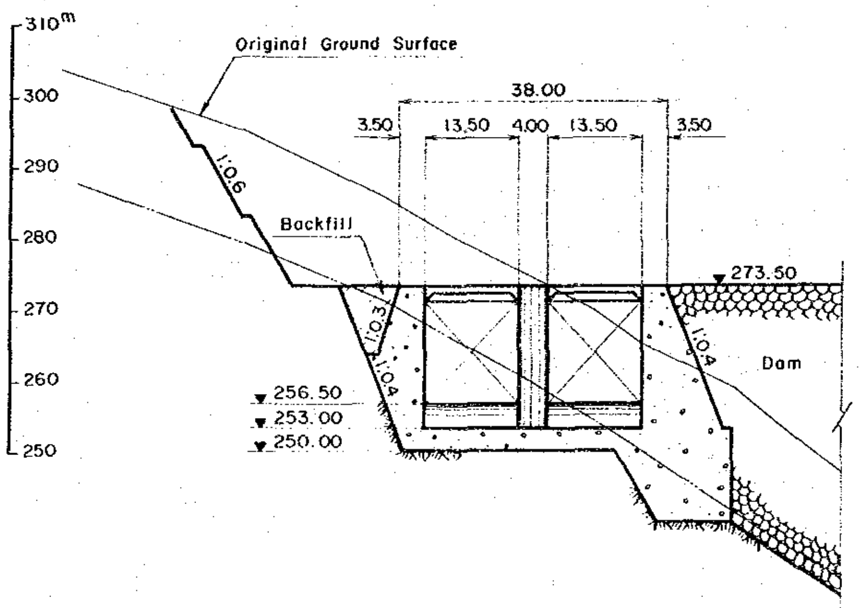
SECTION OF DAM

DWG. 10-4

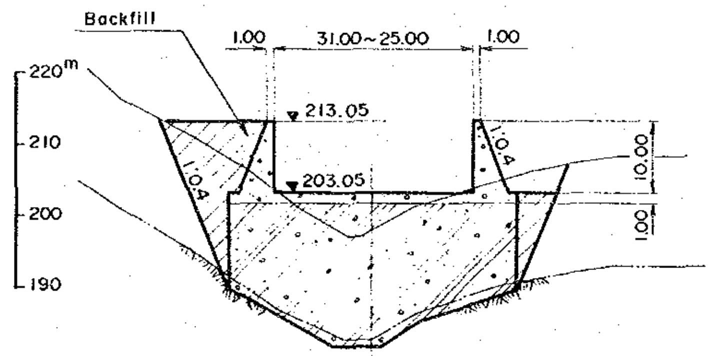
PROFILE



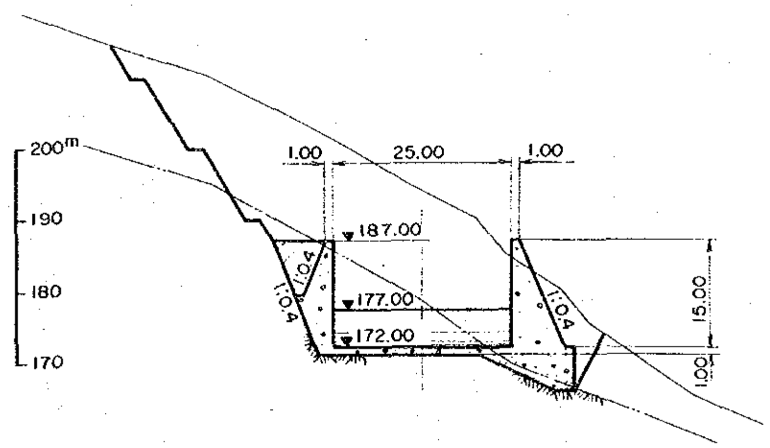
SECTION A – A

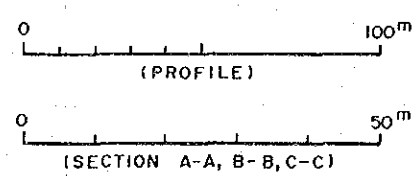


SECTION B – B



SECTION C – C





(ADOPTED PLAN)

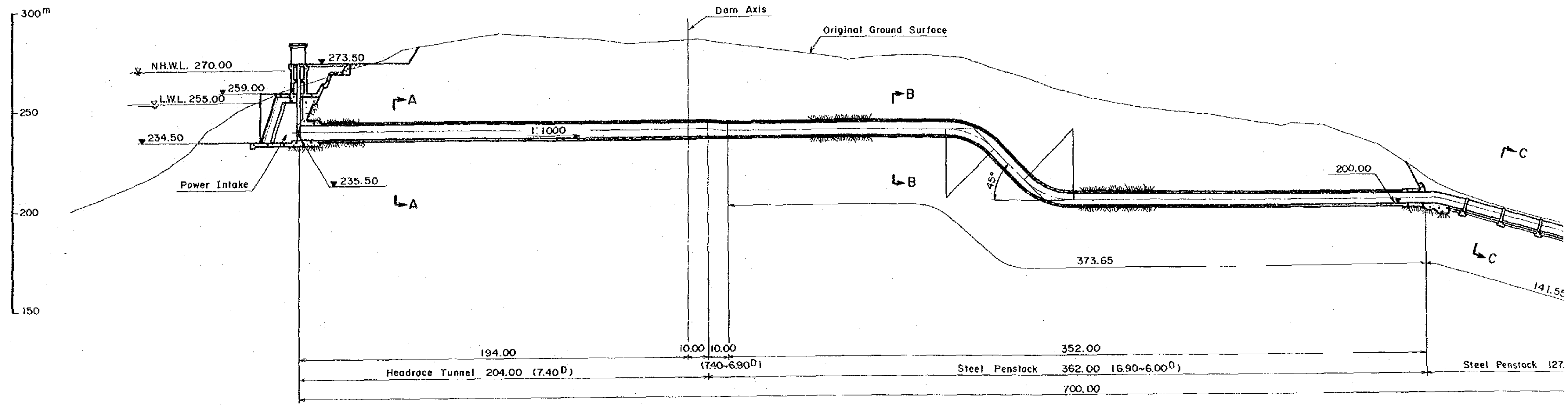
NAM YUAM RIVER BASIN INTEGRATED HYDROELECTRIC DEVELOPMENT PROJECT

NAM NGAO PROJECT

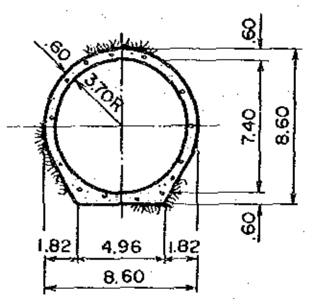
SPILLWAY

DWG. 10-5

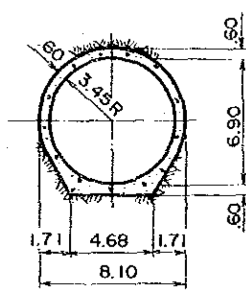
PROFILE OF WATERWAY



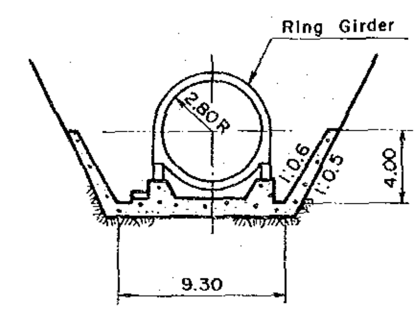
SECTION A – A



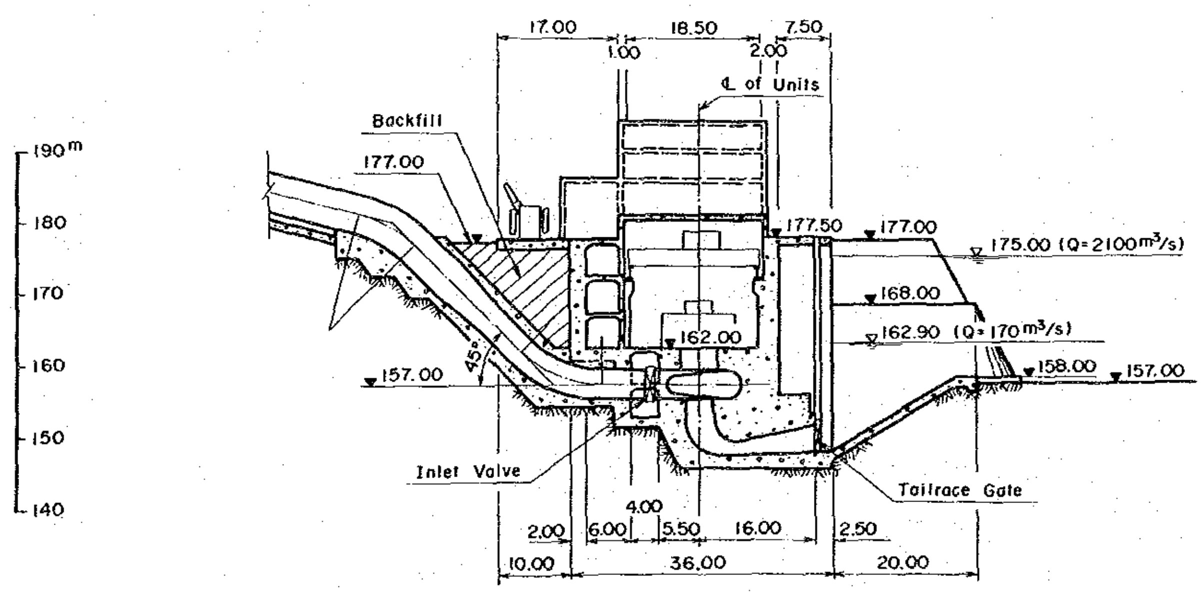
SECTION B – B



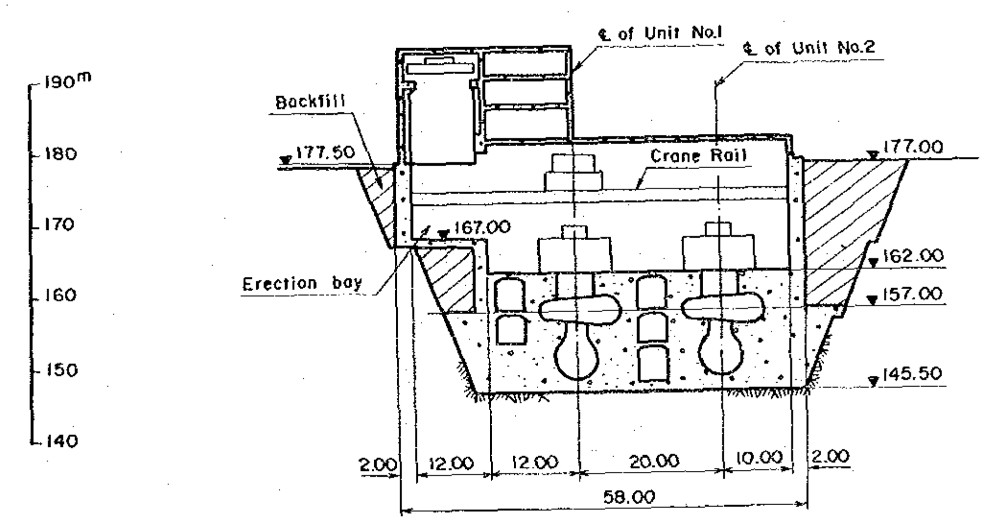
SECTION C – C

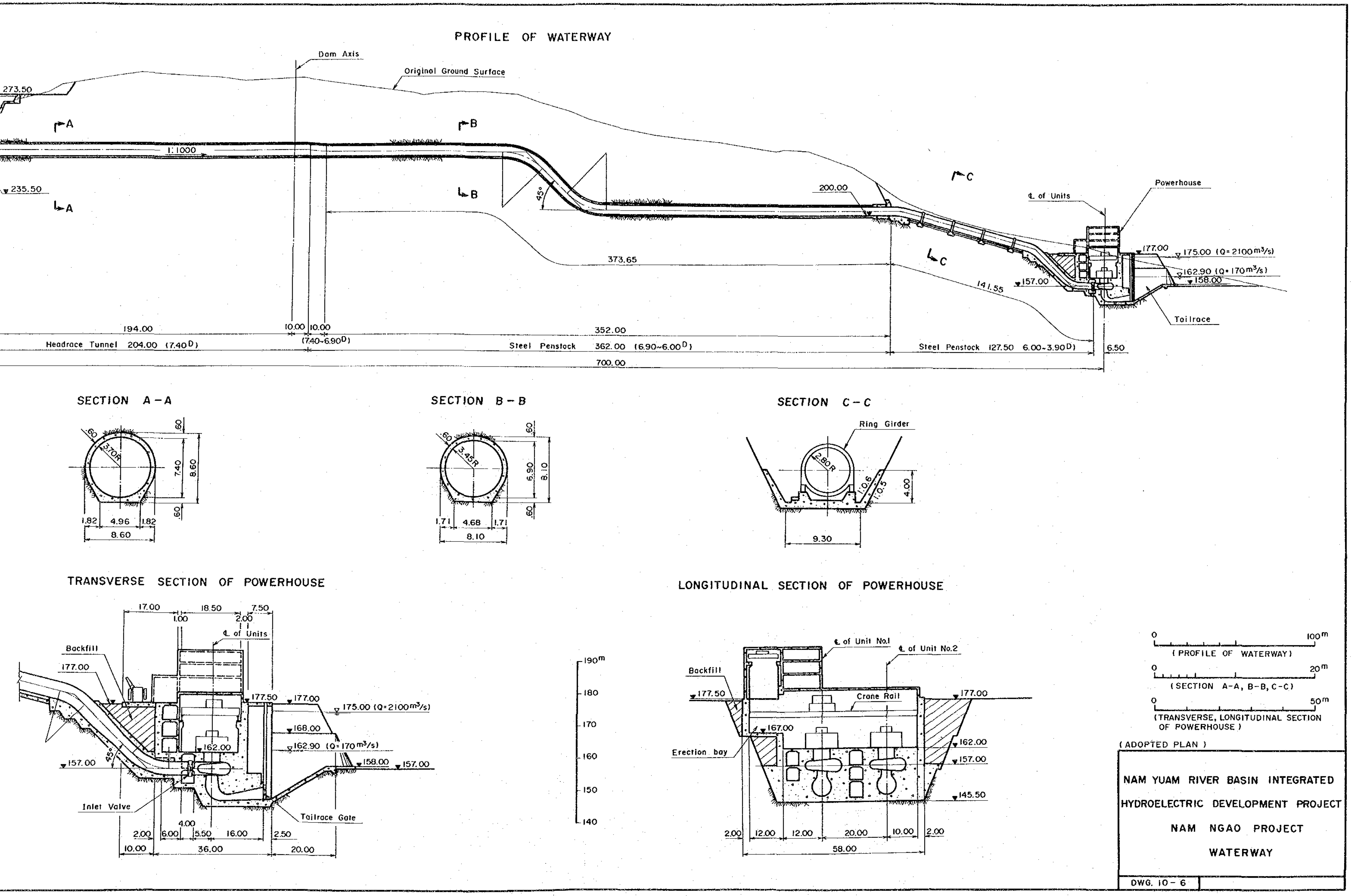


TRANSVERSE SECTION OF POWERHOUSE

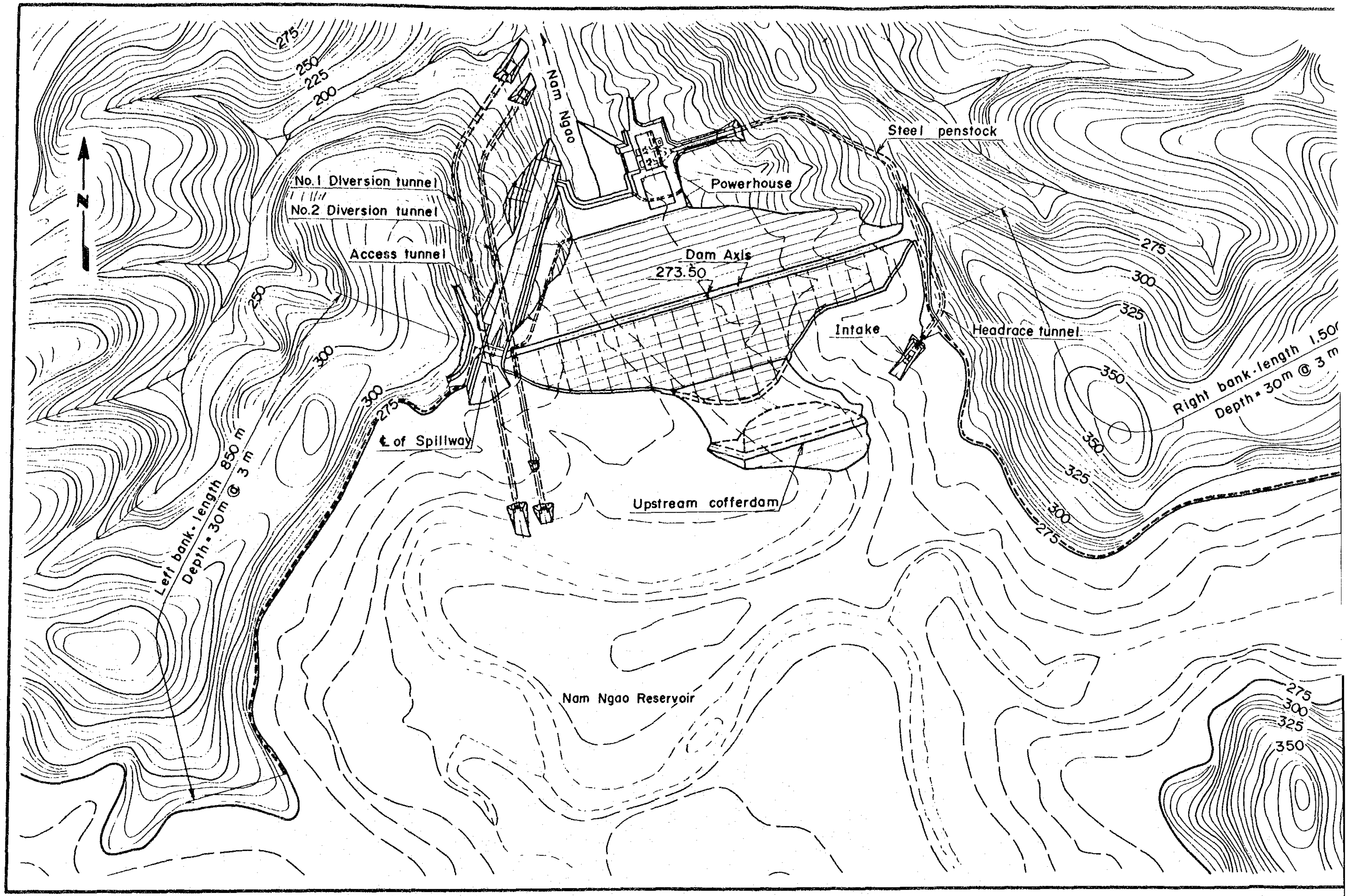


LONGITUDINAL SECTION OF POWERHOUSE

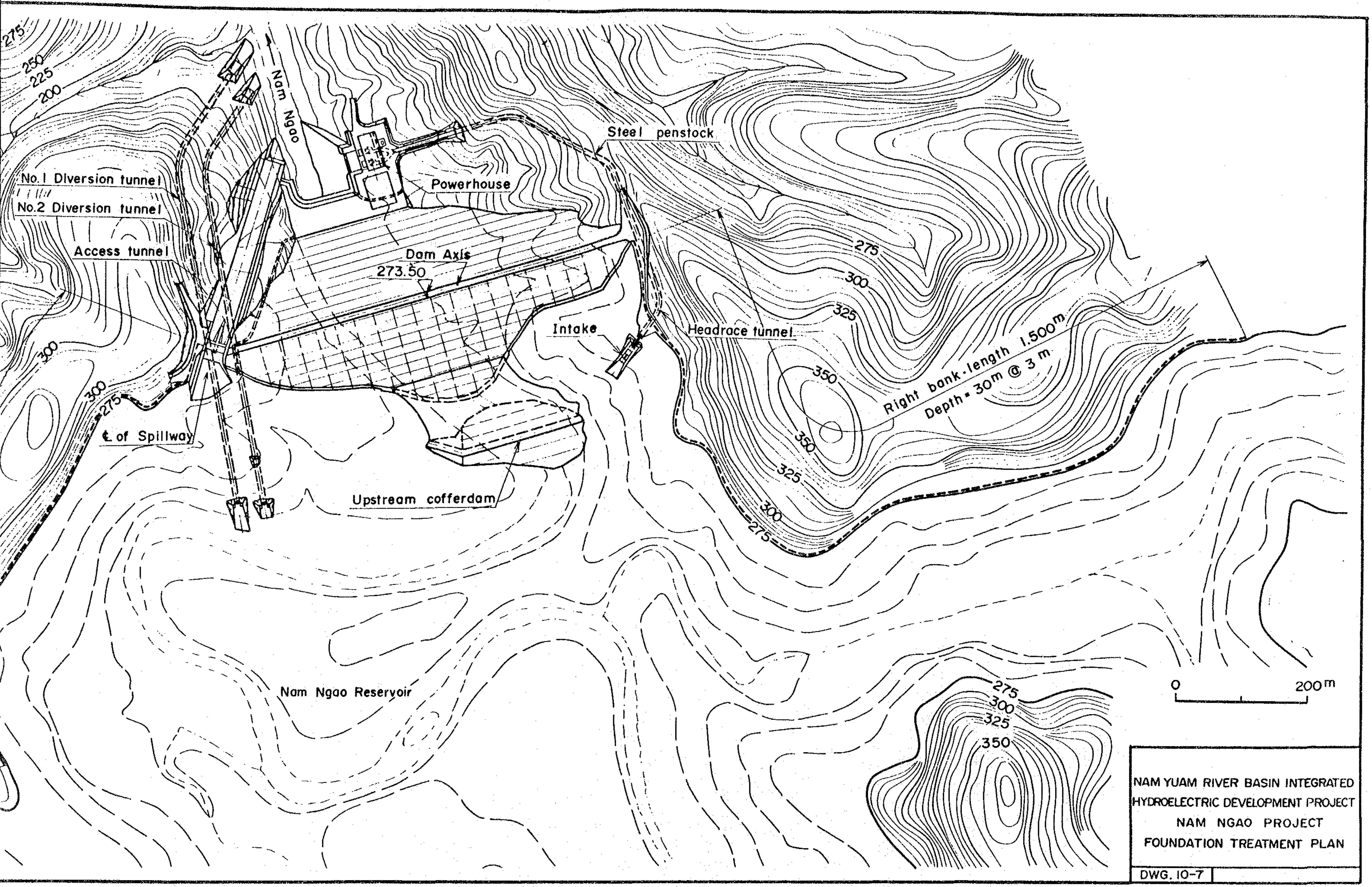




PROFILE OF WATERWAY
Dam Axis
Original Ground Surface
273.50
235.50
1:1000
200.00
Powerhouse
℄ of Units
177.00
175.00 (Q=2100m3/s)
162.90 (Q=170m3/s)
158.00
157.00
141.55
373.65
Tailrace
194.00
10.00
10.00
352.00
Headrace Tunnel 204.00 (7.40D)
(7.40~6.90D)
Steel Penstock 362.00 (6.90~6.00D)
Steel Penstock 127.50 6.00~3.90D
6.50
700.00
SECTION A-A
3.70R
7.40
8.60
1.82
4.96
8.60
SECTION B-B
3.45R
6.90
8.10
1.71
4.68
8.10
SECTION C-C
Ring Girder
2.80R
1:0.6
1:0.5
4.00
9.30
TRANSVERSE SECTION OF POWERHOUSE
17.00
18.50
7.50
1.00
2.00
℄ of Units
Backfill
177.00
177.50
175.00 (Q=2100m3/s)
168.00
162.00
162.90 (Q=170m3/s)
158.00
157.00
Inlet Valve
Tailrace Gate
4.00
2.00
6.00
5.50
16.00
2.50
10.00
36.00
20.00
190m
180
170
160
150
140
LONGITUDINAL SECTION OF POWERHOUSE
℄ of Unit No.1
℄ of Unit No.2
Backfill
177.50
Crane Rail
177.00
167.00
Erection bay
162.00
157.00
145.50
2.00
12.00
12.00
20.00
10.00
2.00
58.00
0
100m
(PROFILE OF WATERWAY)
0
20m
(SECTION A-A, B-B, C-C)
0
50m
(TRANSVERSE, LONGITUDINAL SECTION OF POWERHOUSE)
(ADOPTED PLAN)
NAM YUAM RIVER BASIN INTEGRATED
HYDROELECTRIC DEVELOPMENT PROJECT
NAM NGAO PROJECT
WATERWAY
DWG. 10-6



N
Nam Ngao
No.1 Diversion tunnel
No.2 Diversion tunnel
Access tunnel
Steel penstock
Powerhouse
Dam Axis
273.50
Intake
Headrace tunnel
Right bank-length 1.50
Depth = 30m @ 3 m
Left bank-length 850 m
Depth = 30m @ 3 m
℄ of Spillway
Upstream cofferdam
Nam Ngao Reservoir
275
250
225
200
300
325
350

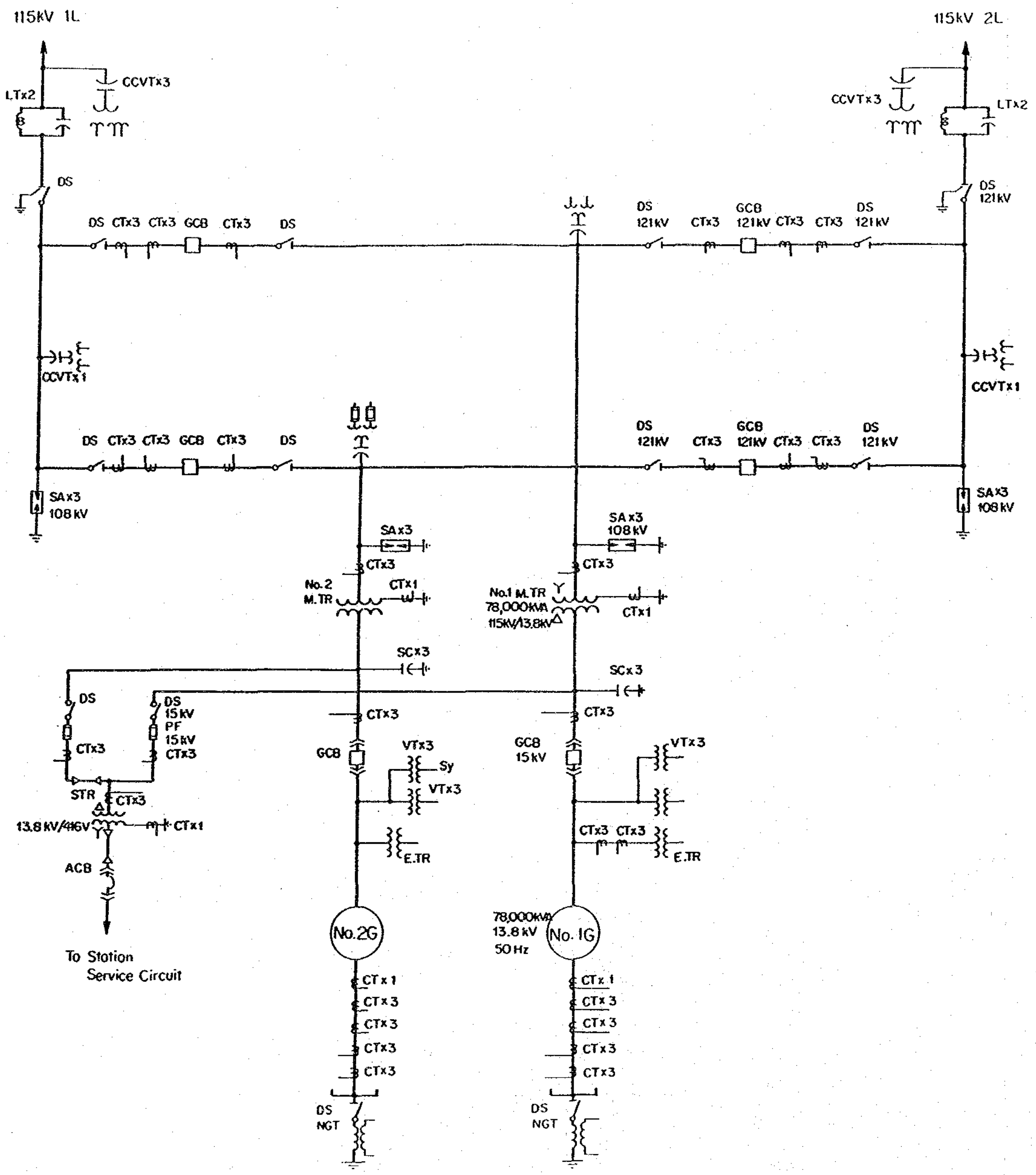


NAM YUAM RIVER BASIN INTEGRATED HYDROELECTRIC DEVELOPMENT PROJECT

NAM NGAO PROJECT

FOUNDATION TREATMENT PLAN

DWG. 10-7



LEGEND

GCB : Gas circuit breaker
VCB : Vacuum circuit breaker
ACB : Air circuit breaker
DS : Disconnecting switch
PF : Power fuse
CCVT : Coupling capacitor voltage transformer
VT : Voltage transformer
CT : Current transformer
M.TR. : Main transformer
S.TR. : Station service transformer
E.TR. : Excitation transformer
NGT : Neutral grounding transformer
PMG : Permanent magnet generator
SC : Static condenser
P.SW : Protection switch for loss of potential
41 : Field breaker
SA : Surge arrester
LT : Line trap

NAM YUAM RIVER BASIN INTEGRATED HYDROELECTRIC DEVELOPMENT PROJECT

NAM NGAO PROJECT

SINGLE LINE DIAGRAM

DWG. 10-8