14.2.3 Transmission Line

Power plant has 443 MW output and 230 kV transformers, and the transmission line for this generating power will be planned for 230 kV steel towers with one circuit using twin conductors 795 MCM ACSR up to Ban Houaykong.

The proposed line route was based on the topographical maps and reconnaissance by car on the existing roads and helicopter at site. The line route from power station passes through the mountainous terrain covered with tropical jungle along the Se Kong River. After arriving flat area in high hills, the line runs to west along the road and passes the narrow area between mountains to reach Ban Nonglom. And the route of line runs along the road through flat area and reaches Ban Houaykong substation site. This line route length is approximately 80 km.

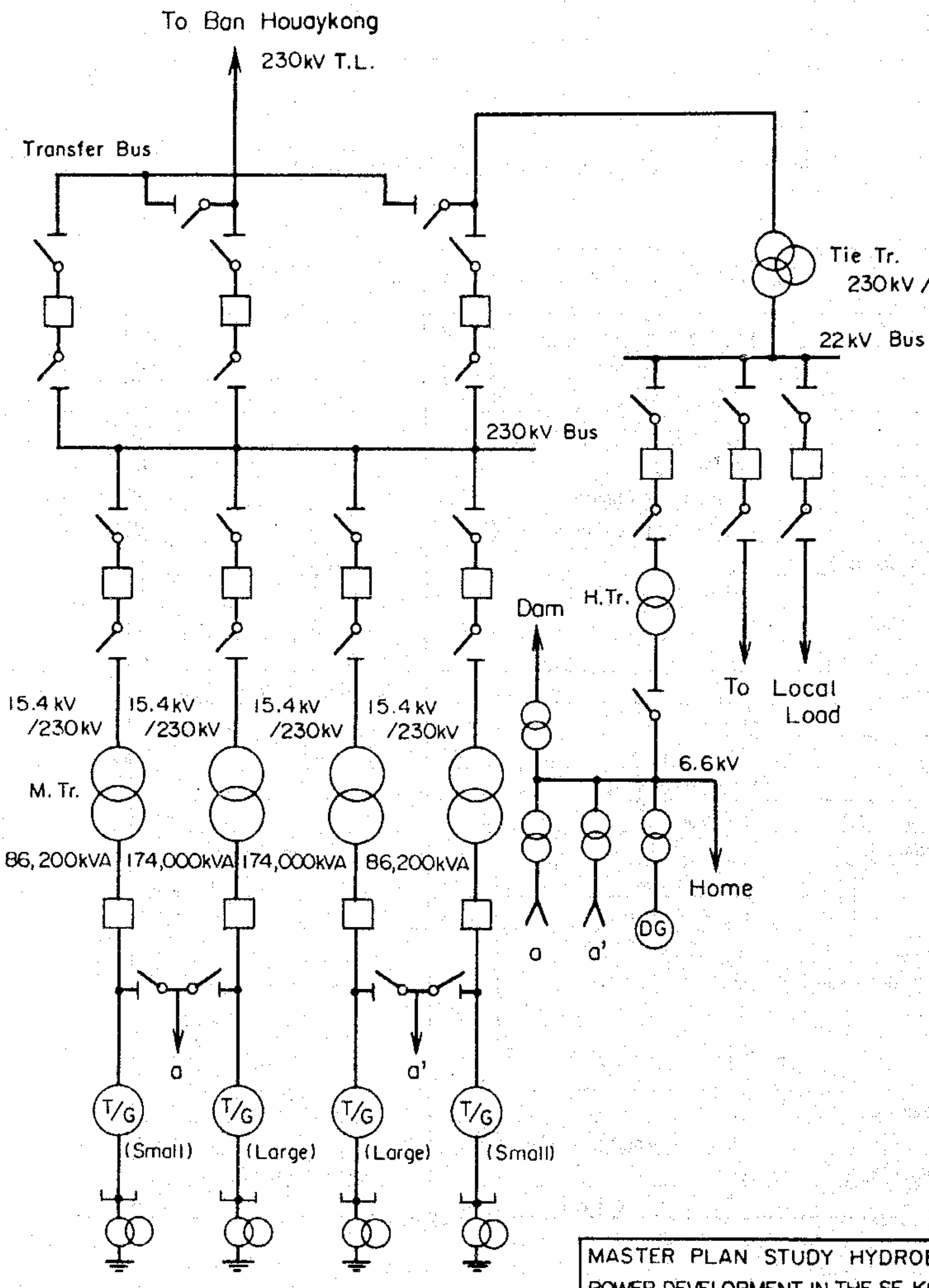
As stated in 12.2.2(3), following case studies were carried out.

For the Case-1 allocation transmission lines, after the transmitted power from power plant by a 140 km long 230 kV one circuit transmission line is connected to the Ban Houaykong substation, the power is step up to 500 kV, and the 500 kV transmission line of two circuits to the Thai border is about 100 km long.

For the Case-2 independent transmission line, the 230 kV transmission line with two circuits using bundle four conductors 795 MCM ACSR up to the Thai border is required. This line route length is about 150 km.

Table 14.2-1 Project Outline of Se Kong No.4

Item		Unit	Description
Reservoir			
	Catchment Area	km^2	5,400
	Annual Inflow Volume	$10^6 m^3$	6,443
	Average Inflow	m^3/s	204
	High Water Level	m	290.00
	Low Water Level	m	275.40
	Gross Storage Capacity	$10^6 m^3$	7,776
	Effective Storage Capacity	$10^6 m^3$	1,692
Diversion Tunnel	Type		Circular Tunnel
	Internal Diameter	m	12.5
	Length	m	No.1 : 850
			No.2 : 745
Dam	Type		Concrete Face Rockfill Dam
	Height		164
	Crest Length	m	910
	Width of Dm Crest	m	8
	Dam Volume	$10^3 m^3$	14,400
Spillway	Type		Chute Type
	Width x Length	m	136 x 645
	Discharge Capacity	m^3/s	16,400
Intake	Inlet Capacity	m^3/s	369
Headrace Tunnel	Type		Circular Pressure Tunnel
	Diameter	m	6.2
	Length	m	No.1 : 315
			No.2 : 365
Penstock	Type		Exposed Type
	Diameter x Length x Number	m	5.4 x 440 x 2
Powerhouse	Type		Semi-underground Type
	Width x Length x Height	m	20 x 43 x 83



Small
Turbine : 71,500 kW
Generator: 86,200 kVA

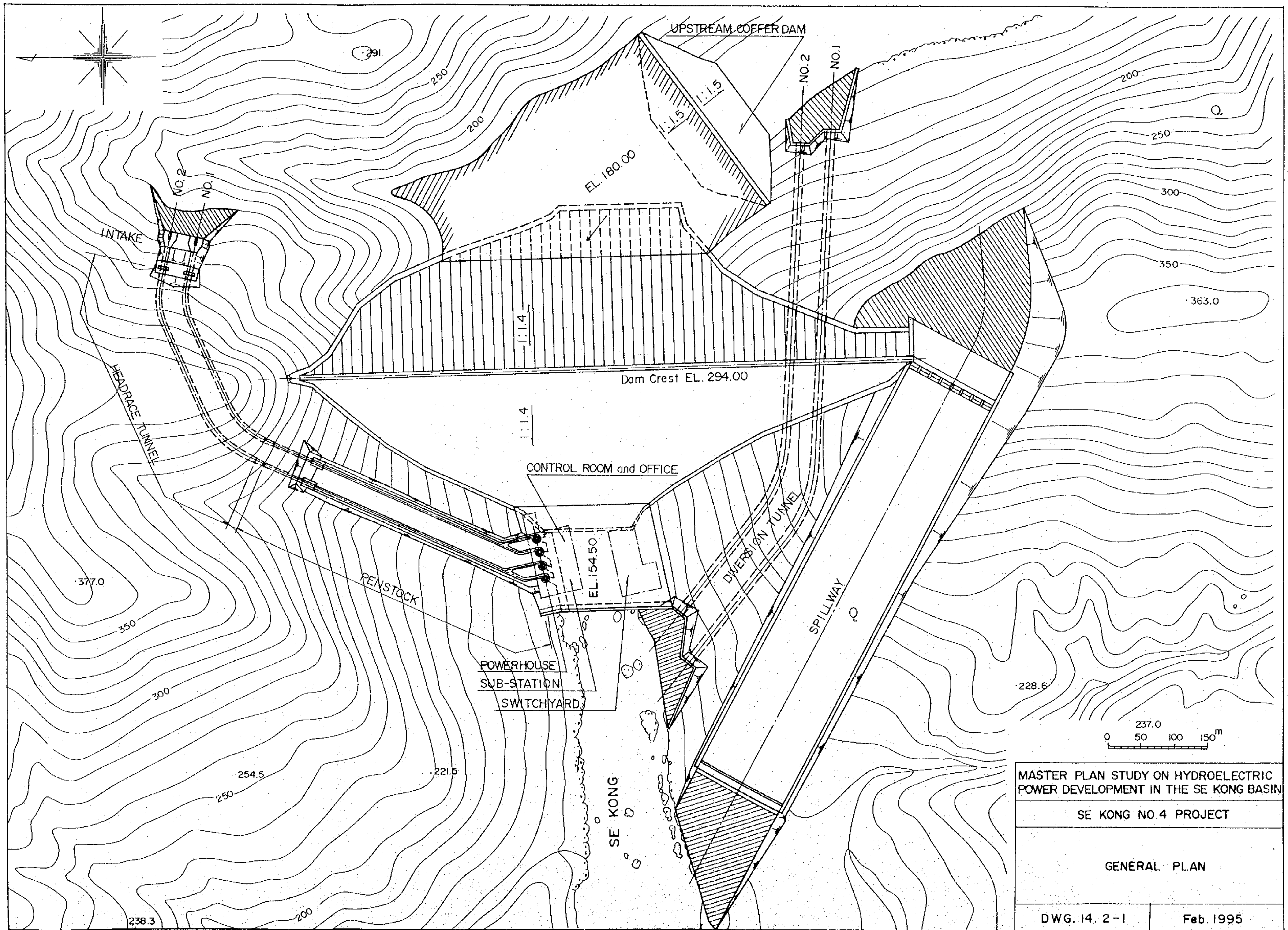
Large
Turbine : 150,000 kW
Generator : 174,000 kVA

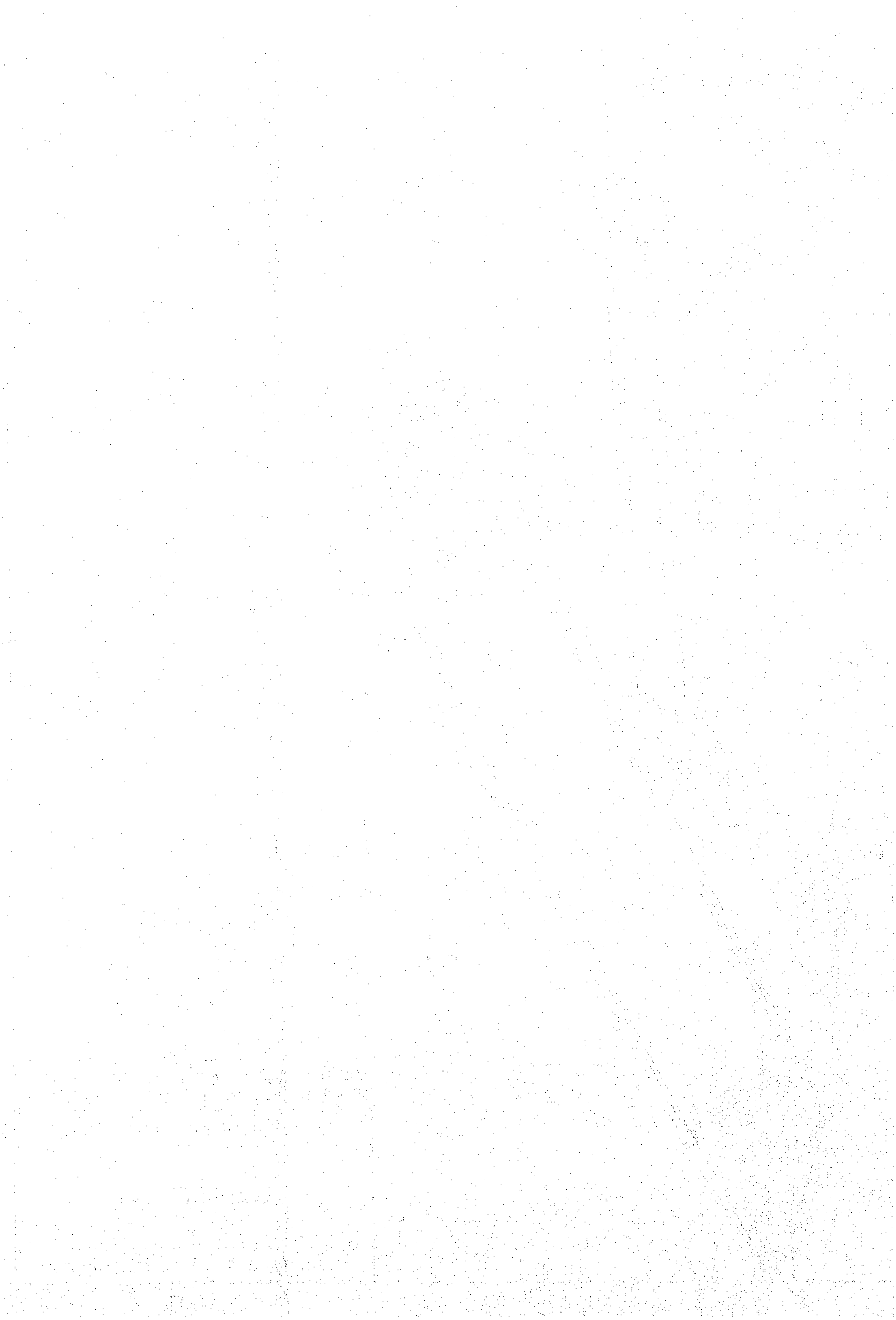
MASTER PLAN STUDY HYDROELECTRIC POWER DEVELOPMENT IN THE SE KONG BASIN

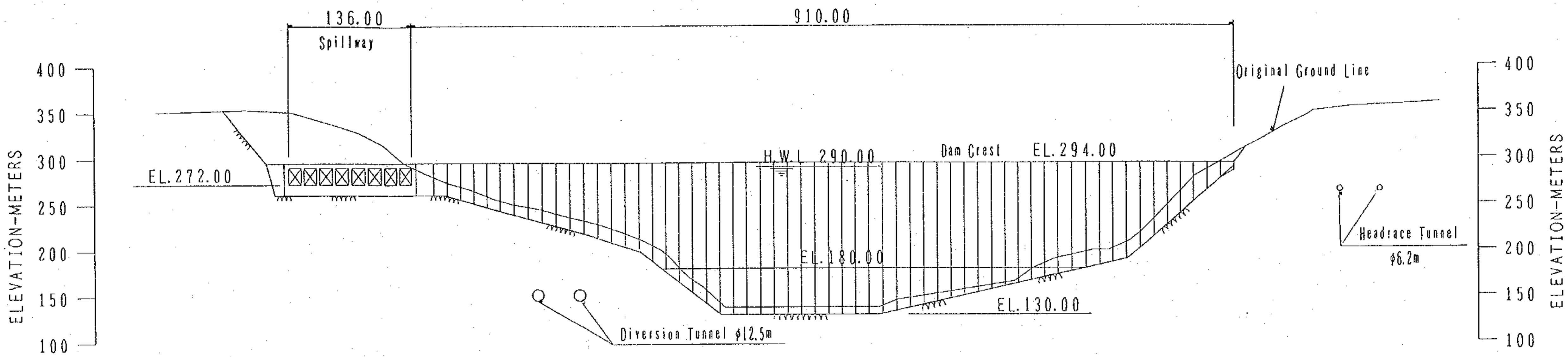
Se Kong No. 4

Single Line Diagram

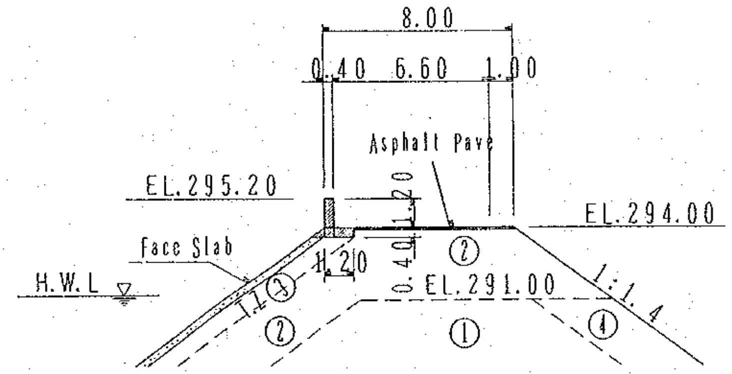
Fig. 14.2-1 | Feb. 1995


UPSTREAM COFFER DAM
NO.2
NO.1
291.
250
200
1:1.5
1:1.5
EL.180.00
NO.2
NO.1
INTAKE
300
350
363.0
1:1.4
Dam Crest EL. 294.00
1:1.4
HEADRACE TUNNEL
CONTROL ROOM and OFFICE
EL.154.50
DIVERSION TUNNEL
SPILLWAY
Q
Q
377.0
350
PENSTOCK
POWERHOUSE
SUB-STATION
SWITCHYARD
300
228.6
237.0
0 50 100 150 m
254.5
250
221.5
SE KONG
238.3
200
MASTER PLAN STUDY ON HYDROELECTRIC POWER DEVELOPMENT IN THE SE KONG BASIN
SE KONG NO.4 PROJECT
GENERAL PLAN
DWG. 14. 2-1
Feb. 1995

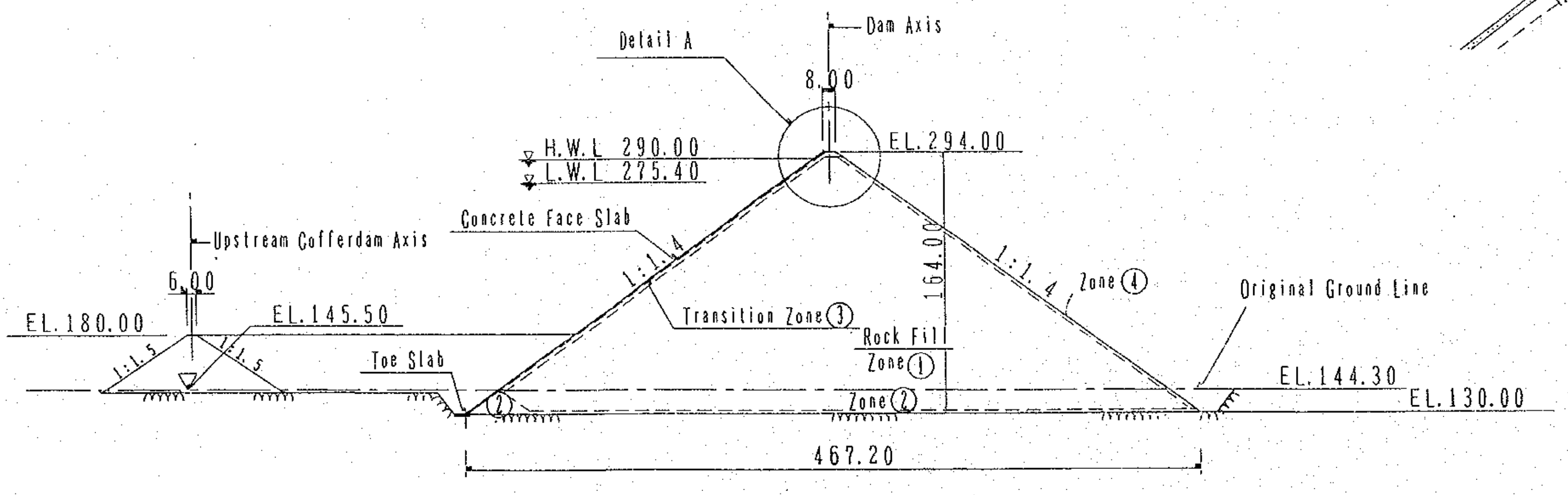




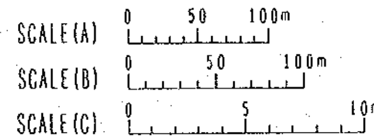
ELEVATION ALONG DAM AXIS
SCALE (A)



Detail A
SCALE (C)



SECTION OF CONCRETE FACED ROCKFILL DAM
SCALE (B)



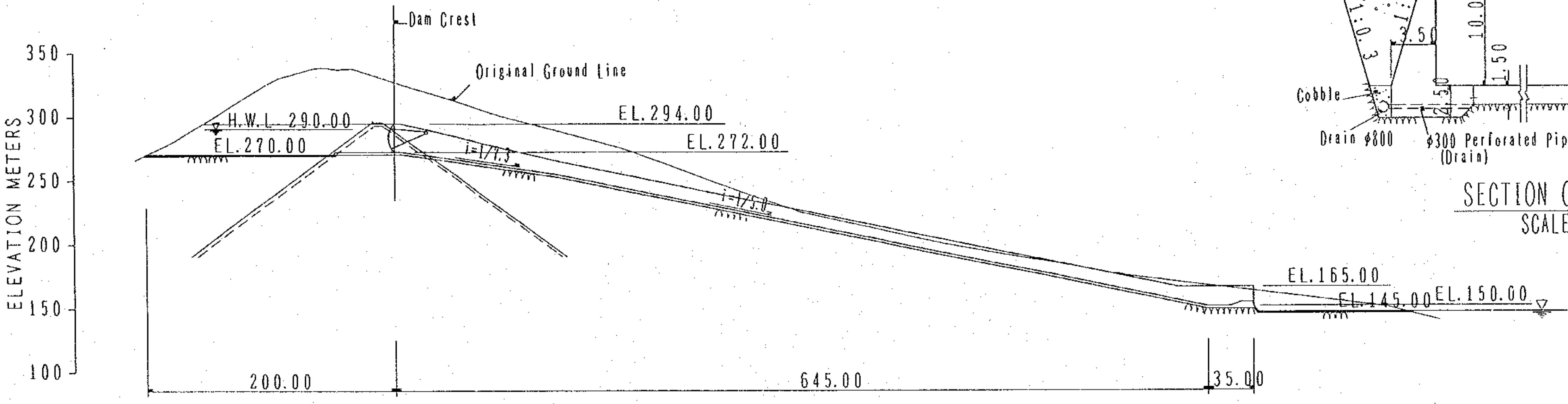
MASTER PLAN STUDY ON HYDROELECTRIC POWER DEVELOPMENT IN THE SE KONG BASIN

SE KONG NO.4 PROJECT

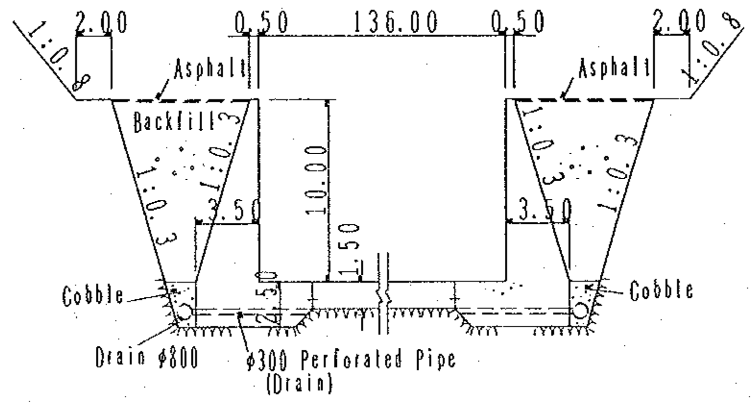
DAM

ELEVATION AND SECTIONS

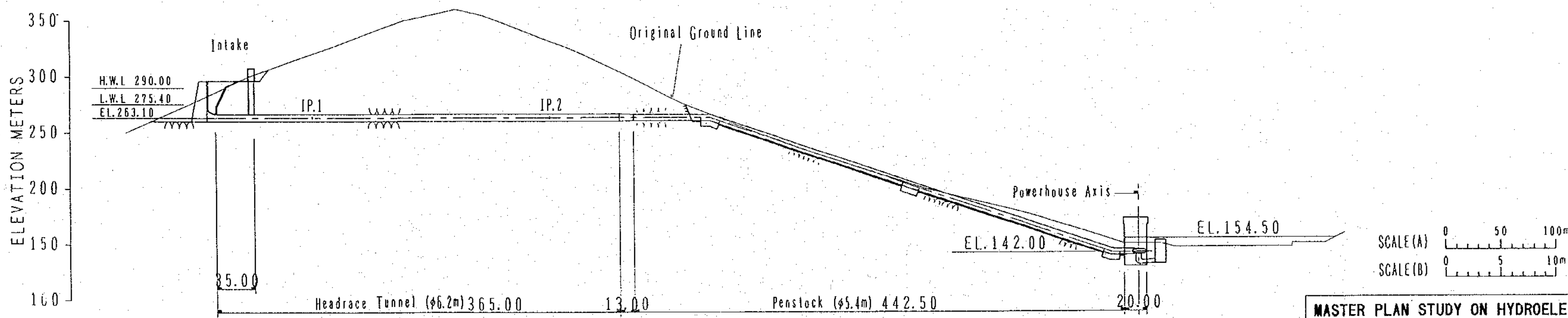
DWG. 14.2-2 | Feb. 1995



PROFILE OF SPILLWAY
SCALE (A)



SECTION OF SPILLWAY
SCALE (B)



PROFILE OF WATERWAY NO.2
SCALE (A)

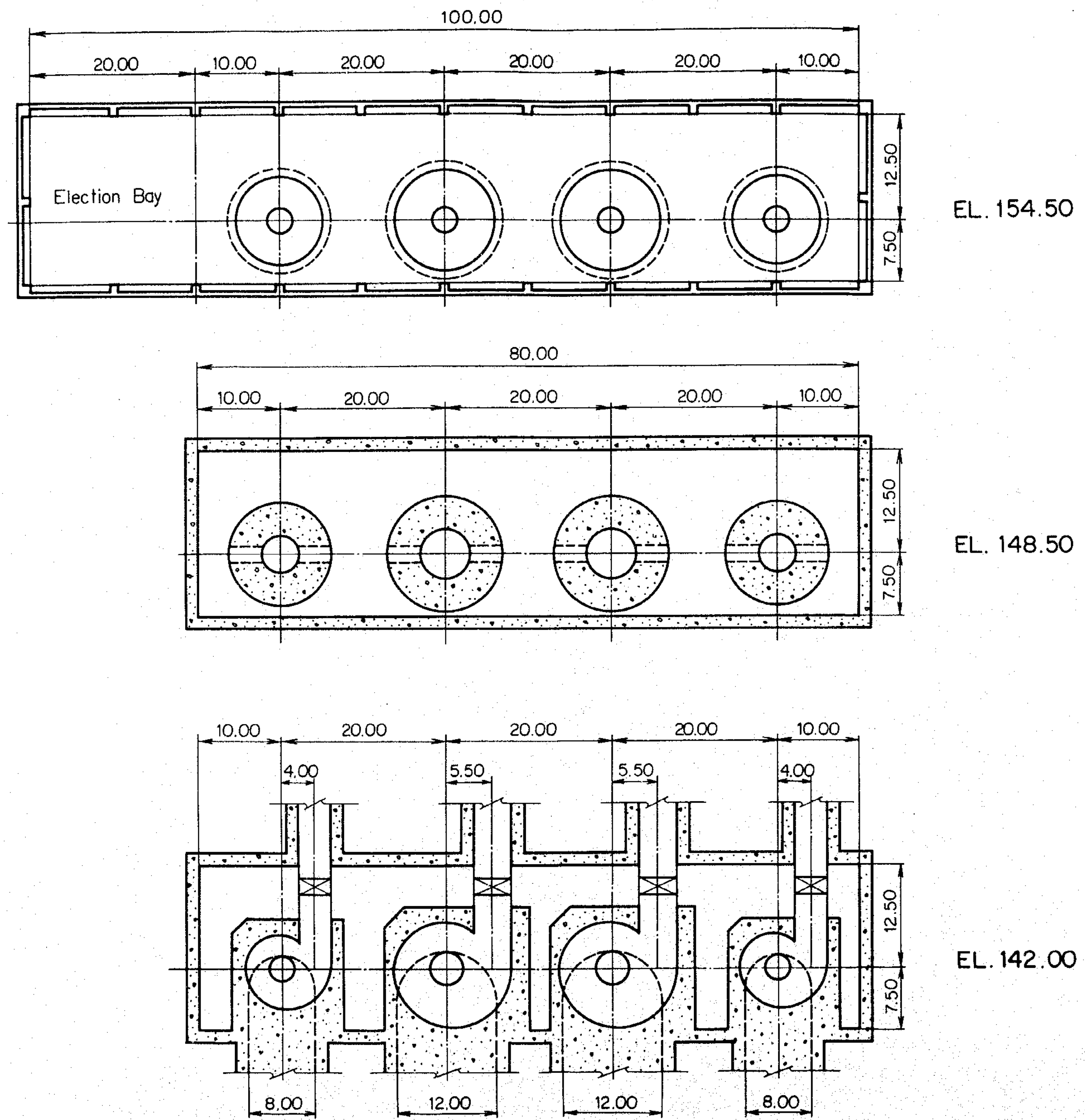
MASTER PLAN STUDY ON HYDROELECTRIC POWER DEVELOPMENT IN THE SE KONG BASIN

SE KONG NO.4 PROJECT

SPILLWAY AND WATERWAY

PROFILE

DWG. 14.2-3	Feb. 1995



MASTER PLAN STUDY ON HYDROELECTRIC POWER DEVELOPMENT IN THE SE KONG BASIN

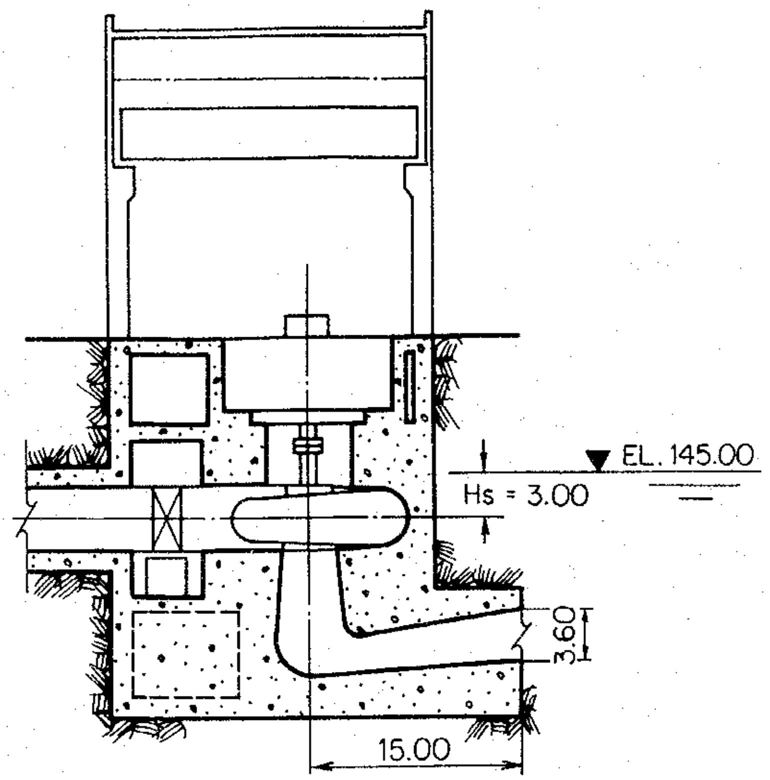
SE KONG No. 4

POWERHOUSE PLAN

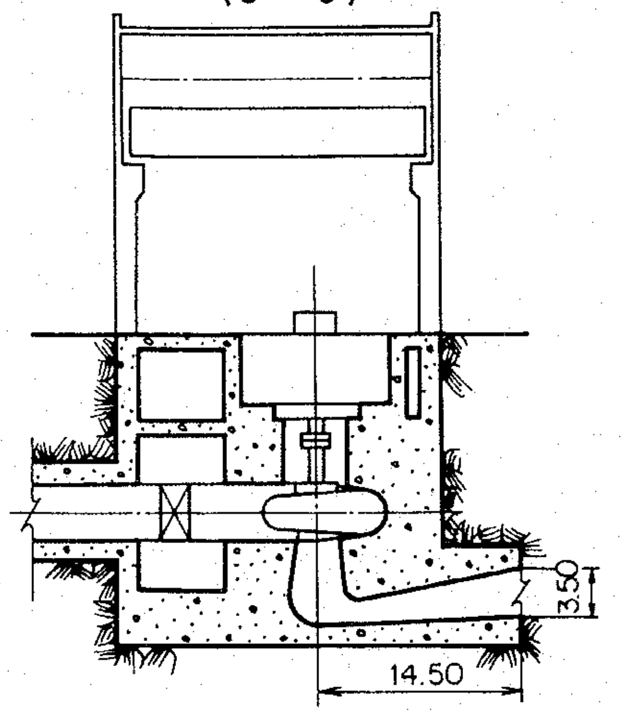
DWG. 14.2 - 4	Feb. 1995

TRANSVERSE SECTION

(B - B)

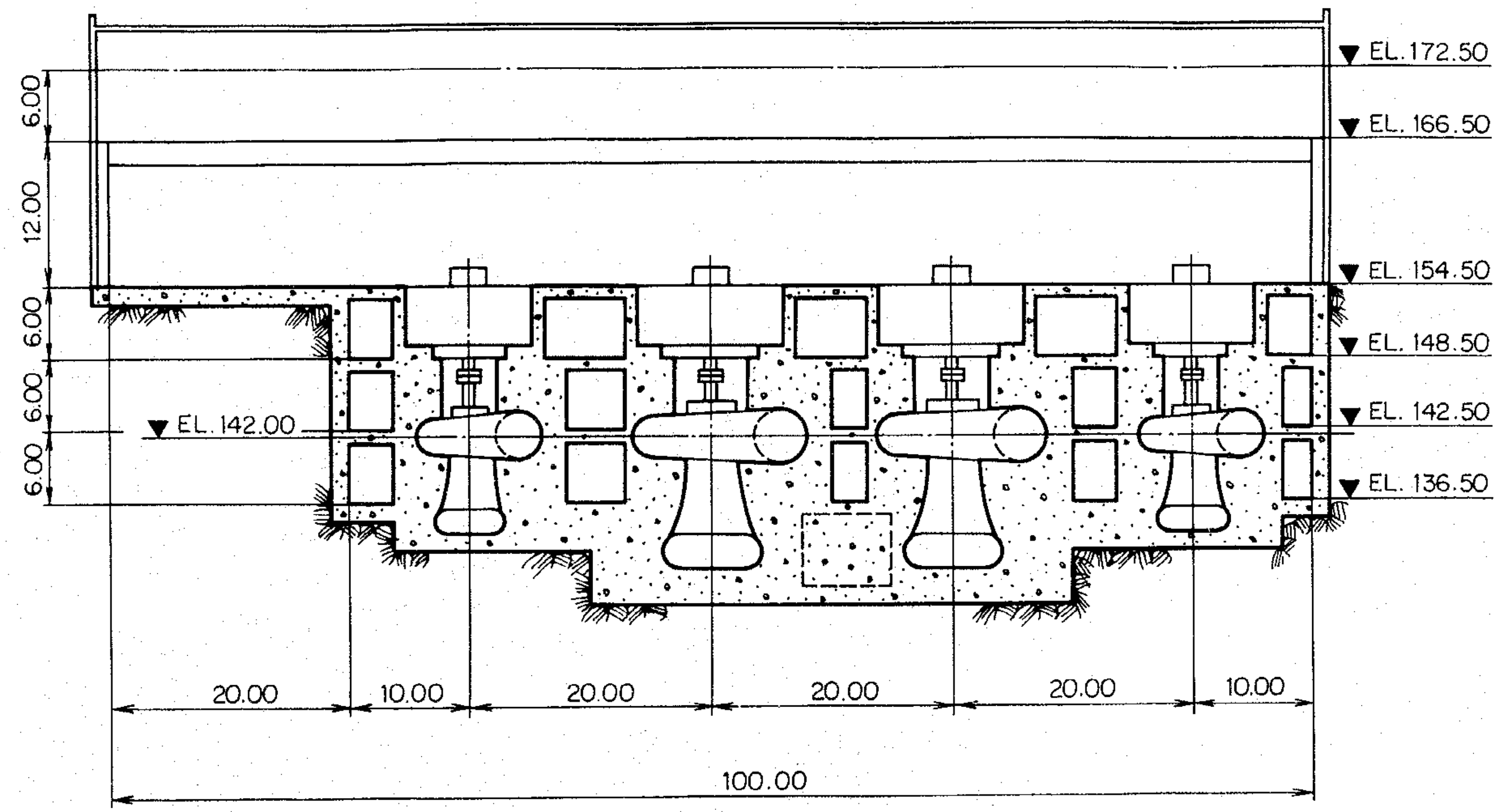


(C - C)

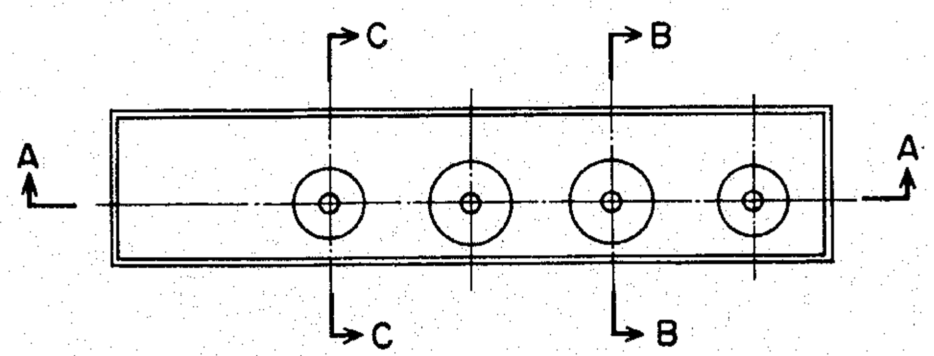


LONGITUDINAL SECTION

(A - A)



KEY PLAN



MASTER PLAN STUDY ON HYDROELECTRIC POWER DEVELOPMENT IN THE SE KONG BASIN

SE KONG No. 4

POWERHOUSE TRANSVERSE AND LONGITUDINAL SECTIONS

DWG. 14.2 - 5 | Feb. 1995

14.3 Xe Kaman No.1 Project

14.3.1 Civil Structures

(1) General

Xe Kaman No.1 Project is located about 50 km upstream from the junction between Se Kong river and Xe Kaman river, and the location is cited in the first mountainous area changing from the plain area where Attapu city is central to the mountain area.

The project is to generate electric power by construction of a 143 m high dam at the above mentioned location and by taking the water at an intake located at left bank and by building a powerhouse 500 m downstream from the dam site and by connecting these two locations by waterway.

The project description of Xe Kaman No.1 Project is shown in **Table 14.3-1**.

Preliminary design of main structures are described hereinafter.

(2) Dam

Around the dam site , there exist continuously rapids and waterfall and therefore it is said that a river bed gradient is rather steep. Slopes of both banks are steep and the gradient is 40 to 45 degrees and a width of the river at the dam site is about 60 m and it is rather narrow. So the site is preferable for dam construction. However, at upstream from the dam site, the river flow become "S" shape and in the right bank at downstream side there is a wide valley. By these conditions, there exists restriction for selection of dam site in relation to selection of dam type. On the other hand, as stated in Chapter 10,"Geology", there is no specific problem on geological features within the results of geological investigation carried out in this study.

From the examination in Chapter 13, "Selection of Optimum Development Plan", a high water level was decided EL. 260 m. This water level was a basis for selection of dam axis. Examining a topographic maps of scale 1/10,000, it was understood that a dam crest length at EL.260 is about 440 m. From this point, as a type of dam, both concrete gravity type and fill type dam were selected as alternatives.

In addition to the restriction from the topographic conditions mentioned above, a scale of spillway was also examined in relation to dam type, considering a figure of design flood (PMF : 14,321 m^3/sec). As a result, a concrete type dam was selected at this moment. However, even though a concrete type dam was selected, a total dam volume will be over 1,600,000 m^3. In such condition, even if a dam type is concrete type, it should be considered a heavy rain in a wet season and an influence of such rain to the construction program and also saving of the construction cost. Then , finally a RCC (roller compacted concrete) dam, which have been recently concerned in the world, was selected. RCC dam has some advantages that a construction period is shortened by its construction method and influence by rain is small and as a result, cost is saved.

An axis of dam selected is shown in **DWG. 14.3-1**. From the topographic map, the elevation of dam foundation is chosen at EL. 120 m and then the dam height is 143 m. This includes 3 m freeboard. The dam crest length is 440 m. A typical section of the dam consists of 1 : 0.12, at upstream surface slope and 1 : 0.7, at downstream surface slope. Although a data of earthquake was not collected in this time, it is supposed that there is not so many and strong earthquakes in the project area, referring to the reports of the existing projects and etc. and therefore, in this stage, consideration to the earthquake is taken as a minimum extent and a typical section of the dam was decided.
A dam shape was examined based on the same method for a concrete gravity dam and also the data on Roller Compacted Concrete Dam in the world were referred to the design in the project.

(3) Diversion Tunnel

A flood discharge is a basic figure for design of diversion tunnel. A flood discharge was decided by a hydrological analysis as follows;

Return Period (Year)	Flood Discharge (m^3/sec)
5	3,212
10	3,917
20	4,615
50	5,550
100	6,276
200	7,023

In case of decision of figures to be applied from these figures, it is necessary to take a type of dam into consideration.

In this project, the dam type was selected a concrete dam and therefore examination was carried out considering the type of dam. What return period is adopted, it depends on the project philosophy. In that time, timing of construction, construction method, influence to a construction cost and etc. shall be considered as affected factors for the examination.

In case of a concrete dam, in general a risk for construction period and overtopping from top of dam are considered more allowable range than a fill type dam and therefore, shorter period is selected.
In case of Xe Kaman No.1 project, it is characteristic that a reservoir capacity is very large compared with a scale of dam construction/construction period, and it is predicted that period of filling the reservoir is rather long. Therefore, if filling of reservoir would commenced after dam completion, a wet test for electrical and mechanical equipment at power station will not be carried out until a water level at reservoir reaches at a low water level at minimum and therefore, a commercial operation will be delayed and recovery of construction cost will be also delayed. This situation is not preferable for the project. In general in such case, an idea of earlier impounding prior to completion of dam is considered.
In the Xe Kaman No.1 Project, this idea of earlier impounding was chosen. By this idea, an effective period of usage of diversion tunnel become very short compared with total construction period. Then, it is understood that to design the diversion tunnel with a conventional consideration is not economically useful. As a result, a return period of flood is taken as same as a dam construction period and return period is 5 years. By this judgment, a design flood for the diversion tunnel is 3,212 m^3/sec from the table above.
In this regard, it is required that the idea mentioned above should be re-studied in further Feasibility Study stage together with review of flood discharge.

A tunnel diameter required for the flood discharge above is 13.5 m and number is one line. In this calculation, a height of coffer dam is arranged as 45 m and the crest elevation is EL.165 m.
An arrangement of the diversion tunnel is shown in **DWG. 14.3-1**.

(4) Spillway

Xe Kaman dam is a concrete dam and therefore an overflow type spillway in which flood discharge overflows from top of dam was selected as a general type. A plan and cross section are shown in **DWG. 14.3-1** and **14.3-2**.

a) Design Flood

A value of the design flood required for the designing of spillway is estimated from the analysis of hydrology and the value is 14,321 m^3/sec as PMF. In general, peak discharge from hydrograph will be estimated and calculate the capacity of the spillway, however, in this stage we had not any data on flood discharge as hydrological data. And in this pre-feasibility study, without such data on actual flood discharge, it is not suitable to estimate a peak discharge under some assumption without enough reliable data, a design under such data is not also meaningful. Therefore, in this stage it is reasonable to consider that all of PMF will be discharged from the spillway.

b) Type of Spillway

Considering the high water level and low water level for usage of water, the type of the spillway was considered to discharge the PMF at the high water level. As a result of calculation of discharge capacity from these conditions, the scale of the spillway is 122 m width and water depth of overflow is 16.5 m. For treatment of this flood, 7 units of the spillway gates are required and the size is 14.0 m width and 16.5 m height.

(5) Intake

a) Type of Intake

The intake level of the dam is 260.0 m at HWL. and 253.2 m at LWL. and this means that water depth for usage is only 6.8 m. This is not big compared with the height of dam, 143 m. And concerning the sedimentation in the Xe Kaman reservoir, from the examination in Chapter 9, sub item 9.5 "Reservoir Sedimentation", it is not given any affect to selection of intake structure and location. And also considering the route of waterway at the downstream and a location of powerhouse, an examination of total layout using the topographic maps, was executed and as a location of the intake, a slope at a small valley located just upstream of the dam at the left bank was selected. This layout is shown in **DWG. 14.3-1**.

b) Capacity of Intake

The maximum discharge to be used in the Xe Kaman No.1 project is 228 m^3/sec and it is required for intake that one inlet has a capacity to take a discharge of 114 m^3/sec.

(6) Waterway

A route of the waterway selected to connect between intake and powerhouse by two lines of tunnel through the mountainous area and two penstock lines along the slope at the downstream side. The route alignment is shown in **DWG. 14.3-1**. The waterway consists of Headrace tunnel and penstock.

a) Headrace Tunnel

From the intake inlet level, a Headrace tunnel will be introduced and the number of tunnel is two lines. The tunnel diameter of both tunnels is 4.8 m and the length are 322 m and 315 m, respectively.

b) Penstock

After the tunnel outlet, the waterway become penstock, but considering the loosen rock due to construction work around the surface at outlet of the tunnel, a steel pipe is to be extended about 30 m into the mountain side for reinforcement of the tunnel. The type of penstock is ring girder type and supported by anchor blocks and saddles. Total length of penstock is 317 m each. An inner diameter of steel pipe is 4.2 m.

(7) Powerhouse and Switchyard

A type of powerhouse was selected a semi-underground type of which the generator floor is at EL.135.5 m. A scale of the powerhouse is 18 m width, 82 m length and 36 m height based on the design of the electrical and mechanical equipment.
Switchyard was sited in conjunction with the powerhouse site. The layout is shown in **DWG. 14.3-1** and also a building arrangement is shown in **DWG. 14.3-4**.

(8) Tailrace

As a design of tailrace structure, it is understood that a tailrace channel will be designed outside from the draft gate location. The size of this tailrace channel is 100 m width, and 15 m length and discharged water directly will be discharged to the river.

(9) Access Road

Xe Kaman No.1 project locates 50 km upstream from Attapu city which is a capital of Attapu Province and there is a local road of 10 km between Attapu and B. Fandeng. But from B.Fandeng to the site there is no access for mobile. Also to the project site, there is old Houchimin road but it was damaged by the war and no maintenance. And therefore, it is difficult to use for construction works without repair and improvement. Then for construction of main works, from the results of site reconnaissance study, it will be necessary to construct new road and/or improvement of the existing road.

1)	Improvement of the existing road	:	23 km
2)	New construction	:	22 km
3)	New Bridge Construction	:	At Se Kong River, and other several small bridges.

Besides, Road specification is 7 m width, two lanes for both driving direction, and pavement by gravel

14.3.2 Generators and Components

(1) Selection of Number and Capacity of Unit

The output of the Xe Kaman No. 1 Power Plant is planned to be 256MW. There are several combinations in the number and capacityof units required to satisfy this output. But the fewer number of units is, the lower the construction cost becomes. 2 or 3 units will be optimum for economical performance.

However, it is necessary to ensure a 20 m^3/sec river retaining flow for 24 hours for the Xe Kaman No. 1 Power Plant. There are two methods to discharge this river retaining flow to the downstream through the turbine/generator; install a dedicated turbine/generator, or determine the number and capacity of units so that the turbine/generator can operate at a min. 20 m^3/sec flow.

Regarding a plan to install the dedicated turbine/generator for river retaining flow, the retaining flow is relatively large at 20 m^3/sec and its output will be approx. 20MW. This plan was not accepted this time since its designs for a back-up system against incidents, the plant layout, penstock, and headrace would be complicated.

Therefore, despite the merit of its smaller scale, a combination of 4 units has been determined. As the maximum water discharge of the turbine is 57 m^3/sec, the Francis turbine is available for this effective head. It is operational with approx. 30% - 40% flow of the maximum flow. The river retaining flow is equivalent to 35% flow. It should be operate with no cavitation or vibration problems.

In the next Feasibility Study Stage, it is necessary that the optimum selection of number and capacity of unit be re-checked by considering the measures for river retaining flow, turbine/generator operation conditions, transport conditions, and the cost of not only the electrical components, but also the construction cost for civil strucrure.

The output of each turbine/generator was calculated as below;

$$\text{Turbine/generator output} = 9.8 \times He \times Q_{max} \times \eta_T \times \eta_G$$
$$= 9.8 \times 129.9\ \text{m} \times 57.0\ \text{m}^3/\text{sec} \times 0.908 \times 0.975$$
$$\fallingdotseq 64{,}000\ \text{kW}$$

(2) Type and Ratings of Major Equipment

The vertical shaft Francis turbine is appropriate considering the maximum discharge and the effective head. The vertical 3-phase AC synchronous generator is appropriate for direct connection to the turbine.

The rated power factor of the generator is 0.85 to contribute to voltage control in the system in response to the long distance transmission from the load end. The transmission lines from Xe Kaman No.1 to Roi Et Substation in load side via Ban Houaykong Substation are long distance and one direction transmission. Since above condition of the system is very difficult caused by the Ferranch Effect in night time and voltage drop in heavy load time. The selection of power factor would be re-studied in the next Feasibility study taking into these transmission consideration.

Considering the transport condition (max. 30 tons), 3 outdoor oil filled single phase transformers were selected for each unit as the major transformers in response to the increase from the generator voltage to the system transmission/distribution voltage of 230kV.

The combination of single bus and transfer bus, as in Nam Ngum, was selected for the swityard. The switching equipment is a conventional type. It is also possible to use a Gas Insulated Switchgear (GIS) when considering reduction of the switchyard area and simple maintenance. It is necessary that this matter be studied in the next Feasibility Study or in the Detailed Design stage. The switchyard is equipped with a terminal equipment with a 22kV transmission line to supply electricity to the local load and an interconnected transformer to step down from 230kV to 22kV.

Since this will be an important power plant, a diesel power generator will be installed as an emergency facility to back-up the power source in the plant. The single-line diagram is shown in **Fig. 14.3-1**.

The ratings of major equipment are described below;

Water Turbine

Type	Vertical shaft, Francis
Number of units	4
Normal effective head	129.9 m
Maximum discharge	57.0 m^3/sec
Turbine output	64,000 kW
Revolving speed	250 rpm

Generator

Type	Three phase, alternating current, synchronous
Number of units	4
Output	75,000 kVA
Power factor	0.85 lag
Voltage	13.2 kV
Frequency	50 Hz
Revolving speed	250 rpm

Main Transformer

Type	Outdoor, oil filled, single phase
Number of units	4 set (12 units)
Capacity	75,000 kVA
Voltage primary :	13.2 kV
secondary :	230 kV

Outdoor Switchyard

Bus system	Single bus + transfer bus
Bus	Aluminum line

Number of transmission lines connected	230 kV × 1 cct
	22 kV × 2 cct

14.3.3 Transmission Line

Power plant has 256 MW output and 230 kV transformers, and the transmission line for this generating power will be planned for 230 kV steel towers with one circuit using single conductor 1,272 MCM ACSR up to Ban Houaykong.

The proposed line route was based on the topographical maps and reconnaissance by car on the existing roads and, helicopter at site. The line route from power station climbs over the mountains and passes through the flat area covered with tropical jungle along the Xe Kaman River. The route proceeds to the road from Ban Phon along the Houoy Toy Yun River and then, the line route will be selected in parallel with the Se Kong No. 4 transmission line and extended to Ban Houaykong substation site. This line route length is approximately 140 km.

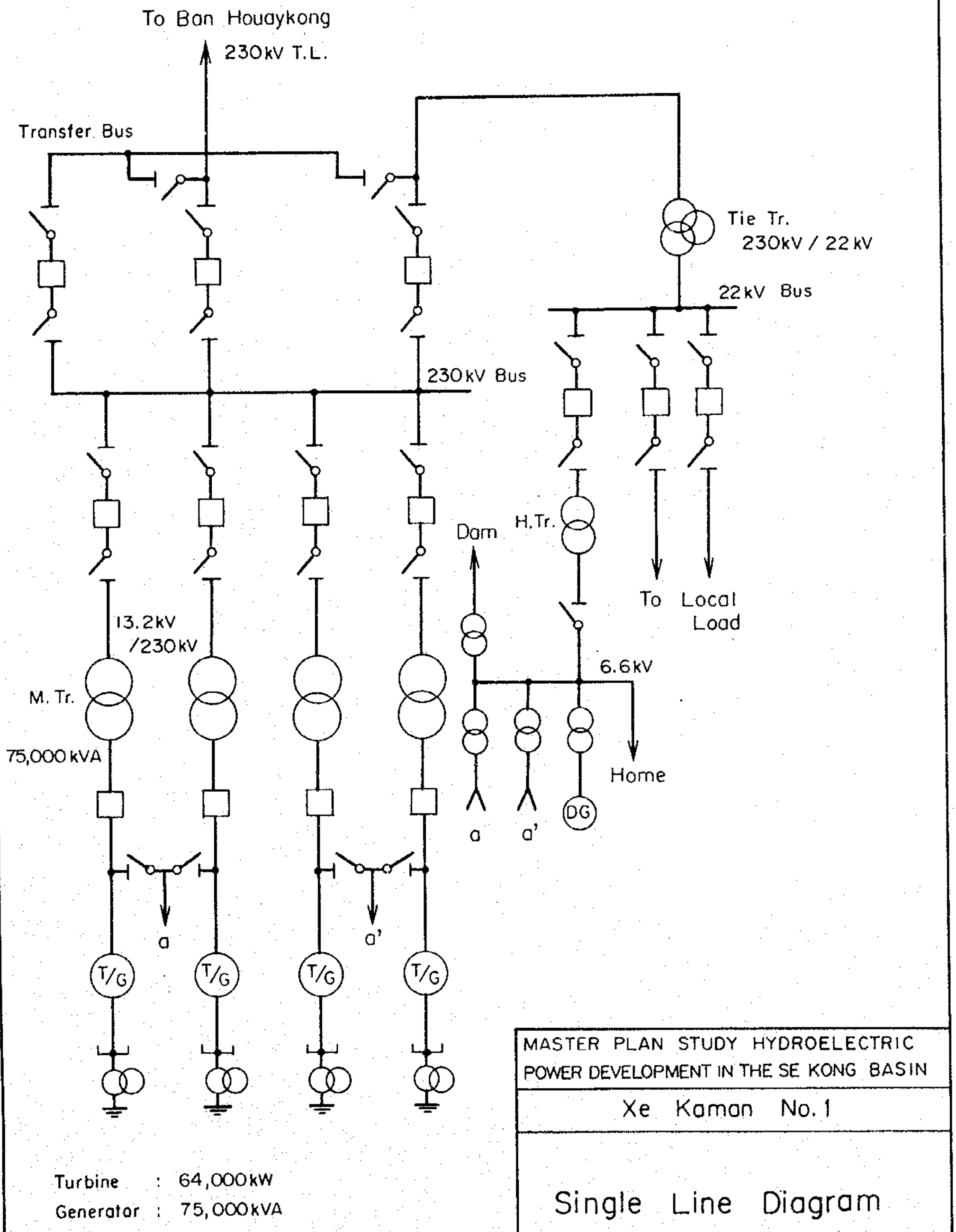
As stated in 12.2.2(3), following case studies were carried out.

For the Case-1 allocation transmission lines, after the transmitted power from power plant by a 140 km long 230 kV one circuit transmission line is connected to the Ban Houaykong substation, the power is step up to 500 kV, and the 500 kV transmission line of two circuits to the Thai border is about 100 km long.

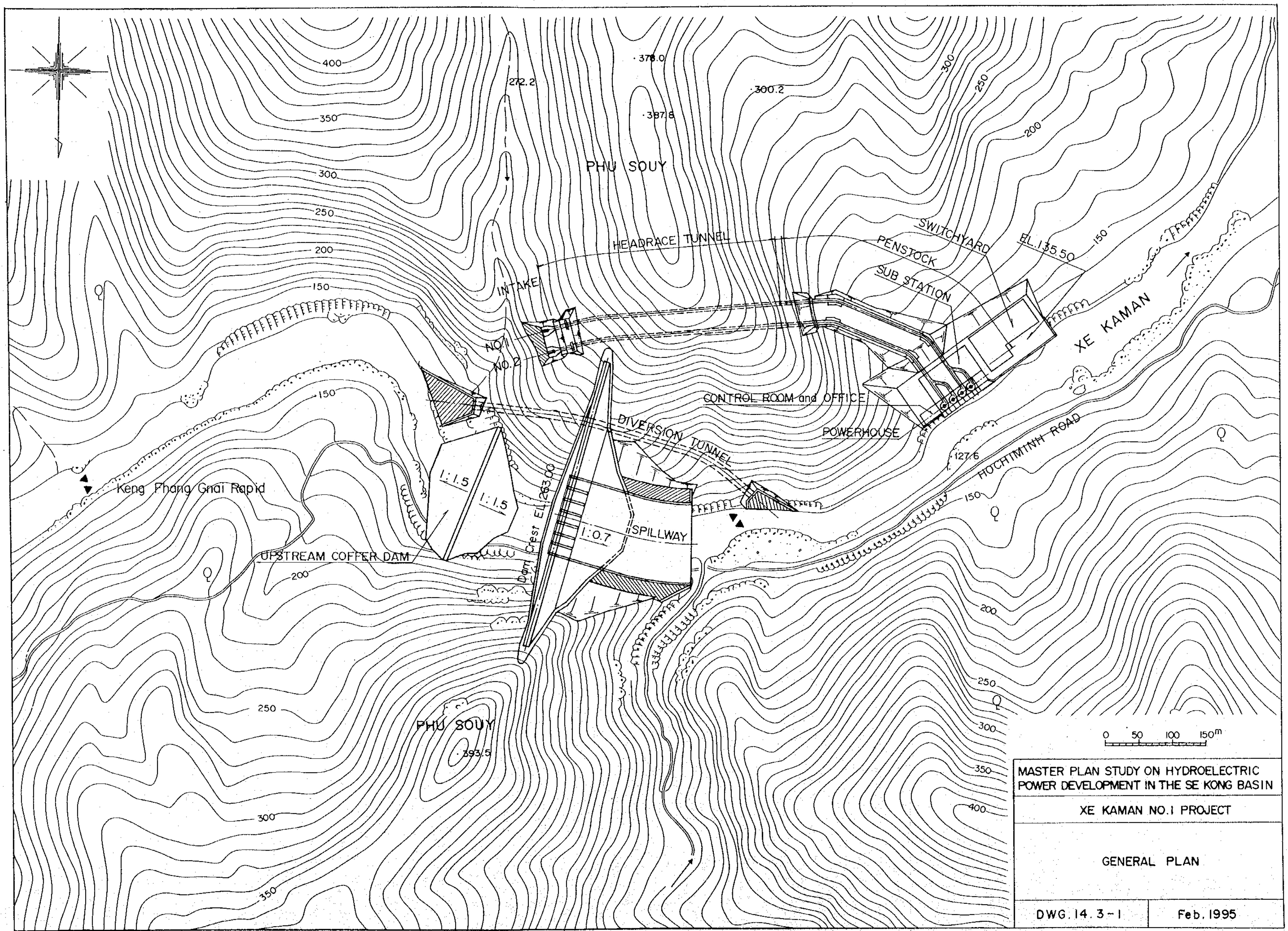
For the Case-2 independent transmission line, the 230 kV transmission line with two circuits using twin conductors 795 MCM ACSR up to the Thai border is required. This line route length is about 210 km.

Table 14.3-1 Project Outline of Xe Kaman No.1

I t e m		Unit	Description
Reservoir			
	Catchment Area	km^2	3,800
	Annual Inflow Volume	$10^6 m^3$	4,177
	Average Inflow	m^3/s	132
	High Water Level	m	260.00
	Low Water Level	m	253.20
	Gross Storage Capacity	$10^6 m^3$	16,208
	Effective Storage Capacity	$10^6 m^3$	1,274
Diversion Tunnel	Type		Circular Tunnel
	Internal Diameter	m	13.5
	Length	m	435
Dam	Type		Roller Compacted Condrete Dam
	Height	m	143
	Crest Length	m	440
	Width of Dm Crest	m	10
	Dam Volume	$10^3 m^3$	1,670
Spillway	Type		Overflow Spillway
	Width x Height : Length	m	122 x 203
	Discharge Capacity	m^3/s	14,321
Intake	Capacity	m^3/s	228
Headrace Tunnel	Type		Circular Pressure Tunnel
	Diameter	m	4.8
	Length	m	No.1 : 322
			No.2 : 315
Penstock	Type		Exposed Type
	Diameter x Length x Number	m	4.2 x 317 x 2
Powerhouse	Type		Semi-underground Type
	Width x Length x Height	m	18 x 36 x 64



MASTER PLAN STUDY HYDROELECTRIC POWER DEVELOPMENT IN THE SE KONG BASIN
Xe Kaman No. 1
Single Line Diagram
Fig. 14.3 – 1   Feb. 1995


PHU SOUY
378.0
300.2
387.8
272.2
HEADRACE TUNNEL
SWITCHYARD
PENSTOCK
SUB STATION
EL.135.50
INTAKE
NO.1
NO.2
XE KAMAN
CONTROL ROOM and OFFICE
DIVERSION TUNNEL
POWERHOUSE
HOCHIMINH ROAD
127.6
Keng Phang Gnai Rapid
1:1.5
1:1.5
Dam Crest EL.263.00
1:0.7
SPILLWAY
UPSTREAM COFFER DAM
PHU SOUY
393.5
0 50 100 150m
MASTER PLAN STUDY ON HYDROELECTRIC POWER DEVELOPMENT IN THE SE KONG BASIN
XE KAMAN NO.1 PROJECT
GENERAL PLAN
DWG.14.3-1
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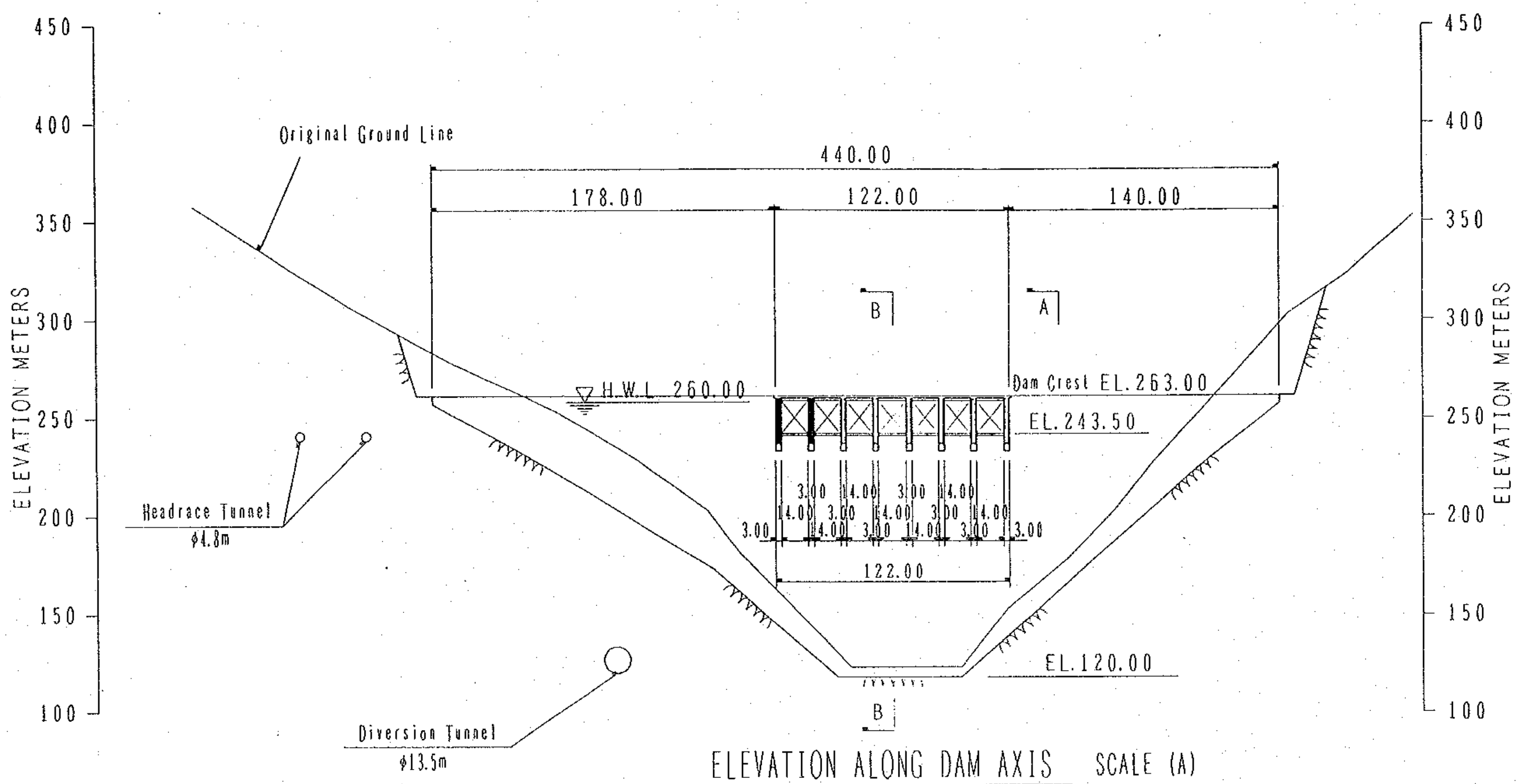
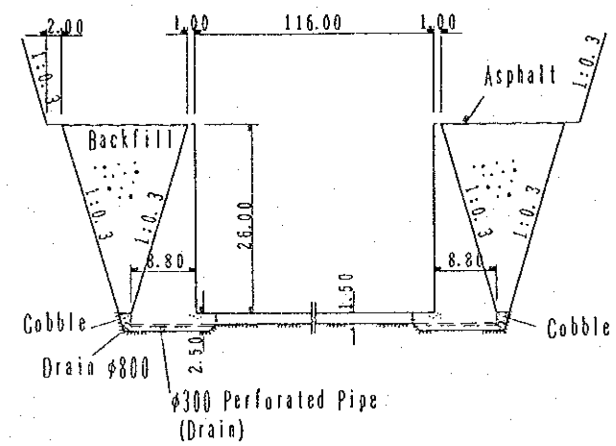
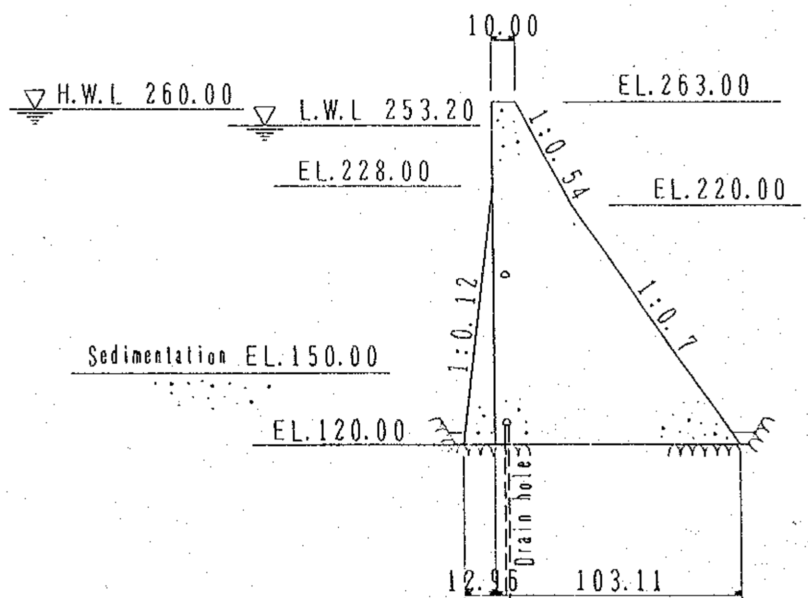


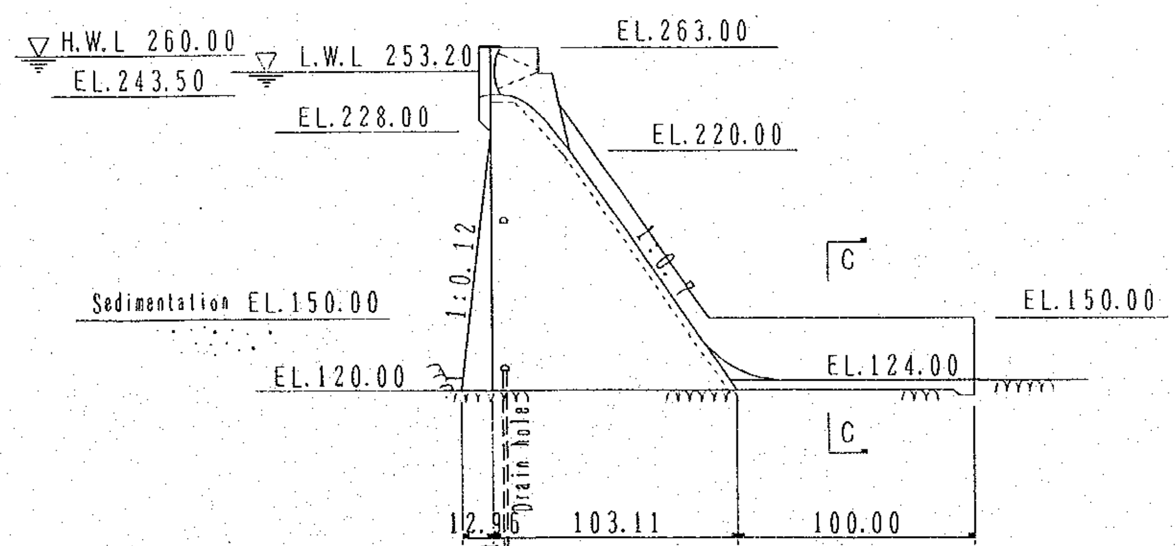
ELEVATION ALONG DAM AXIS SCALE (A)
(Upstream View)



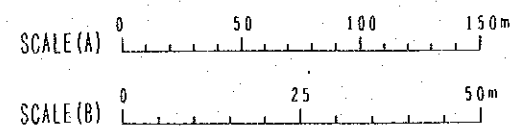
SECTION C-C
SCALE(B)



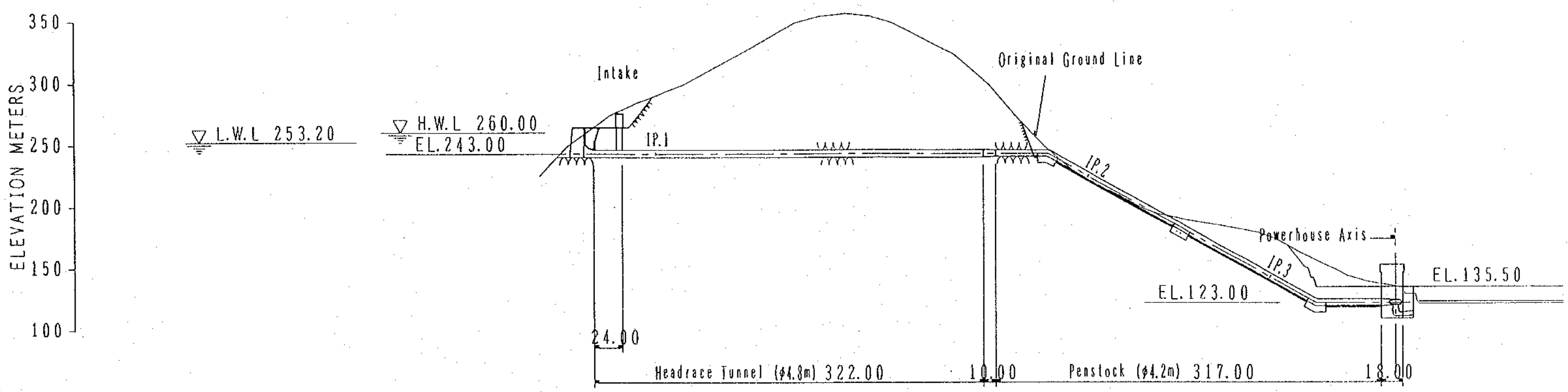
SECTION A-A SCALE(A)
(Non-Overflow Section)



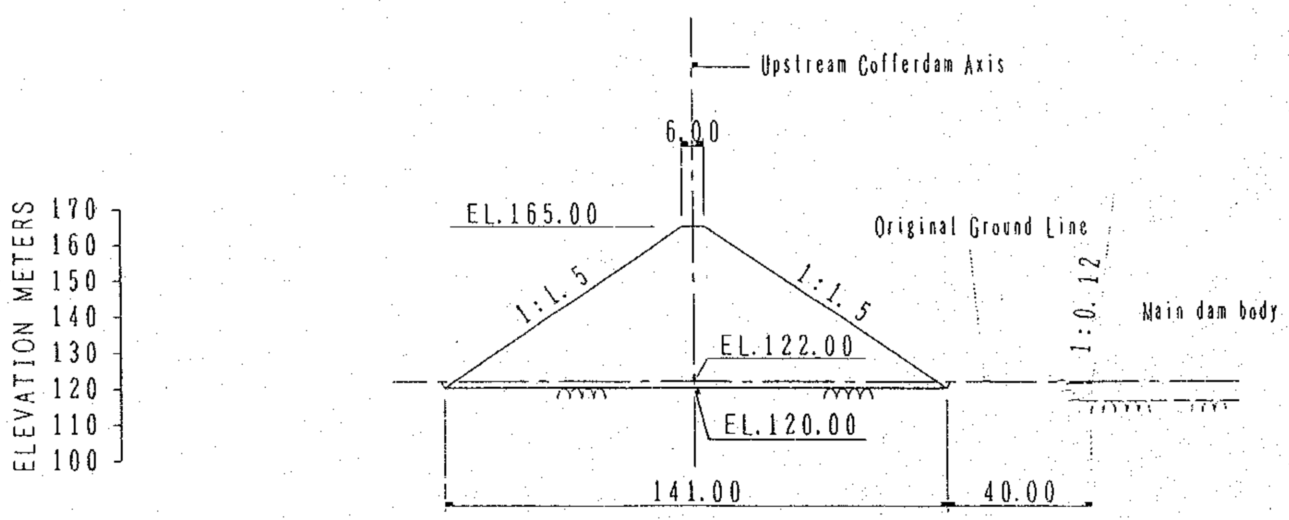
SECTION B-B SCALE(A)
(Overflow Section)



MASTER PLAN STUDY ON HYDROELECTRIC POWER DEVELOPMENT IN THE SE KONG BASIN	
XE KAMAN NO. 1 PROJECT	
DAM	
ELEVATION AND SECTIONS	
DWG. 14.3-2	Feb. 1995



PROFILE OF WATERWAY NO.1
SCALE (A)



SECTION OF UPSTREAM COFFERDAM
SCALE(B)

SCALE(A) 0 50 100m
SCALE(B) 0 25 50m

MASTER PLAN STUDY ON HYDROELECTRIC POWER DEVELOPMENT IN THE SE KONG BASIN

XE KAMAN NO.1 PROJECT

COFFER DAM AND WATERWAY

PROFILE AND SECTION

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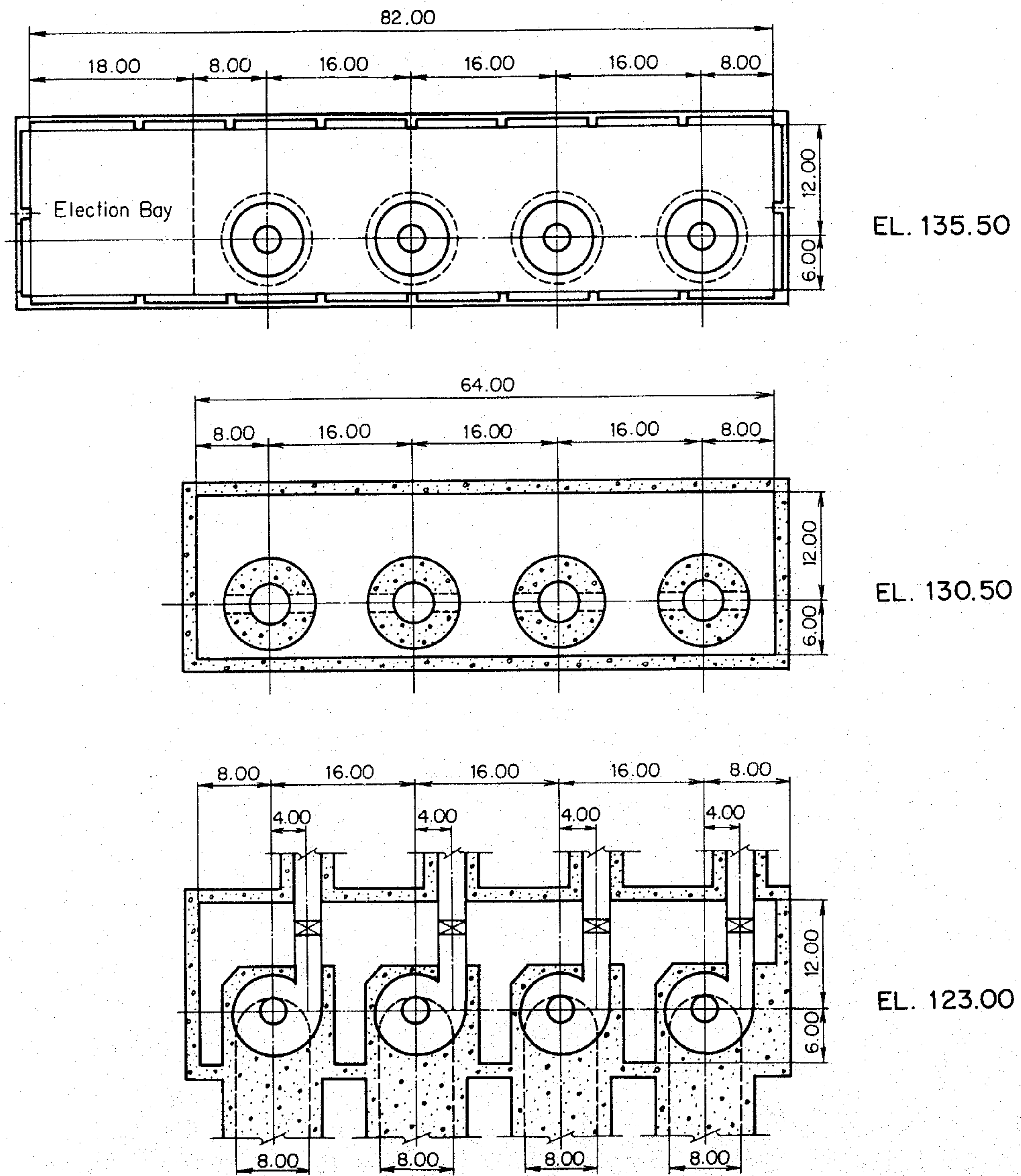


MASTER PLAN STUDY ON HYDROELECTRIC POWER DEVELOPMENT IN THE SE KONG BASIN

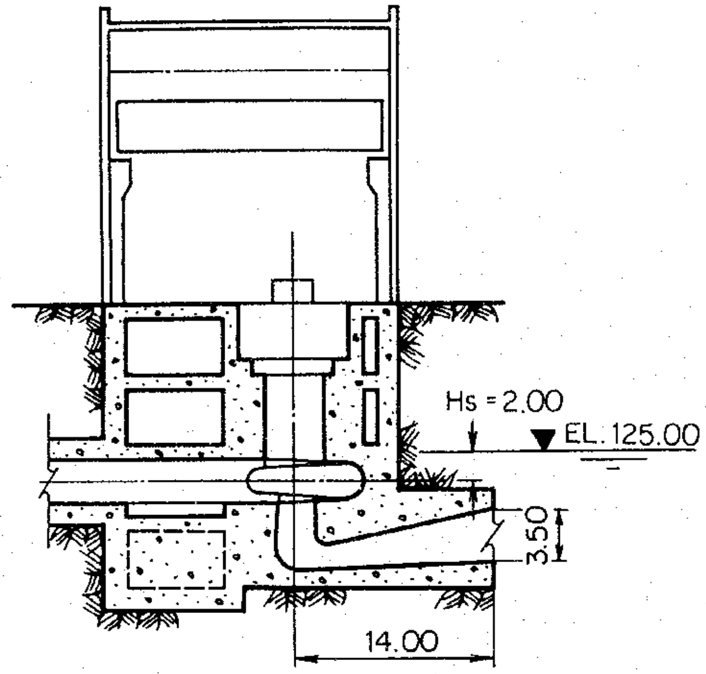
XE KAMAN No.1

POWERHOUSE PLAN

DWG. 14.3-4 | Feb. 1995

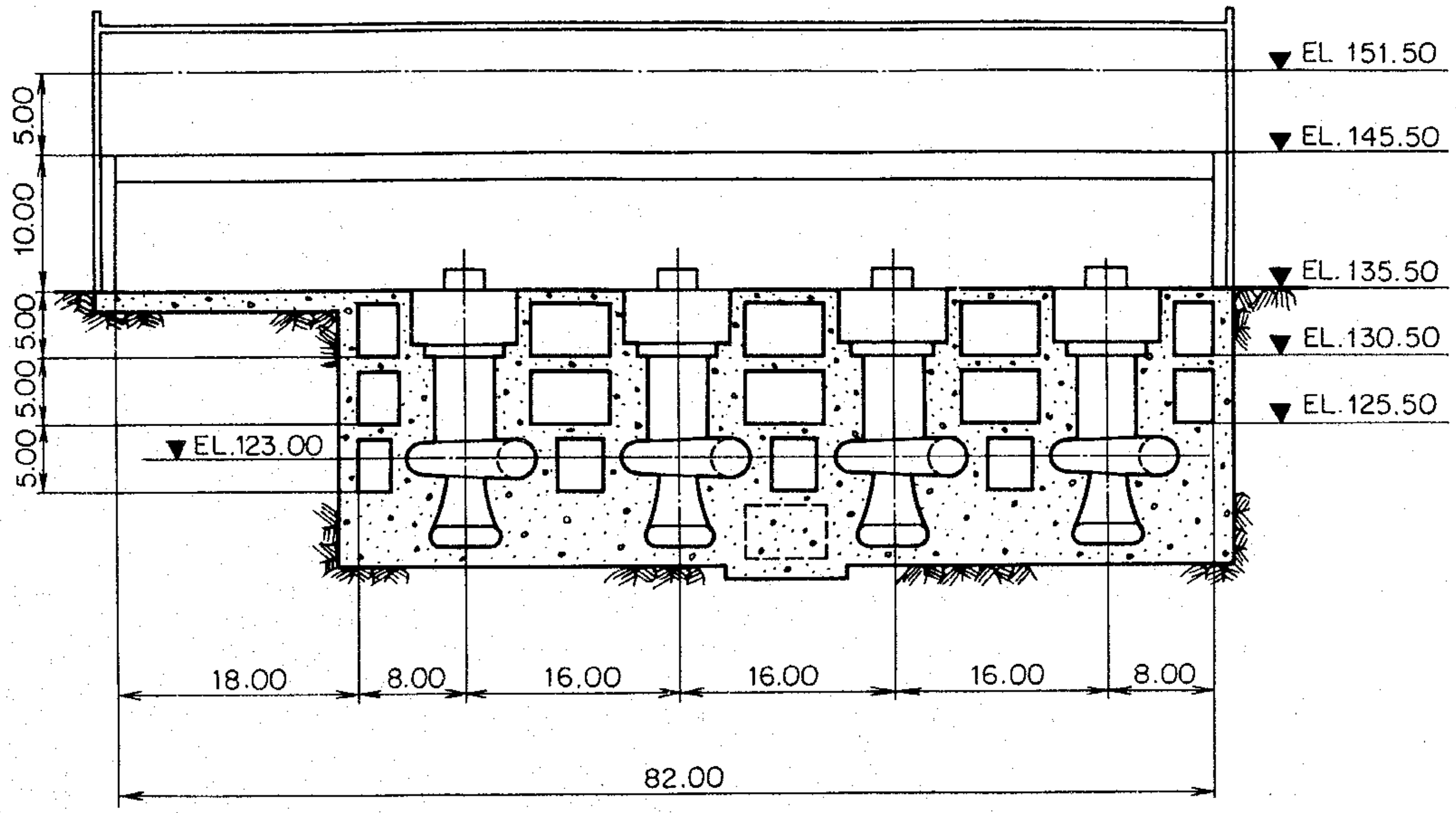
TRANSVERSE SECTION

(B - B)

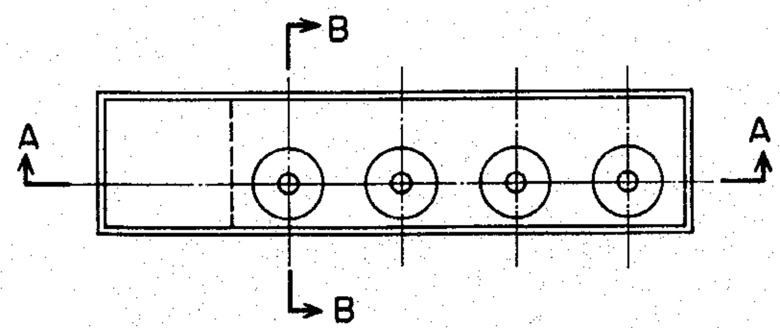


LONGITUDINAL SECTION

(A – A)



KEY PLAN



MASTER PLAN STUDY ON HYDROELECTRIC POWER DEVELOPMENT IN THE SE KONG BASIN

XE KAMAN No. 1

POWERHOUSE TRANSVERSE AND LONGITUDINAL SECTIONS

DWG. 14.3 – 5 | Feb. 1995

14.4 Xe Namnoy Project

14.4.1 Civil Structures

(1) Xe Namnoy Midstream Project

(1-1) General

Xe Namnoy Midstream Project locates 1.5 km upstream from B. Latsasin village, 45 km east from Pakson city that is a largest city on the Bolovan Plateau, and 30 km upstream from the junction of Xe Namnoy river and Se Kong main river.

In accordance with the result of examination in Chapter 13, "Selection of Most probable development scheme", the project was considered as a dam-waterway type for power generation. Hydropower generation will be gained by this water transport about 10 km downstream and about 450 m head.
Design description of the Xe Namnoy Midstream is shown in **Table 14.4-1**.

(1-2) Dam

At the dam site, around EL.750 m the topographic feature become high flat mountain and below this elevation, a steep slope appear in the both banks. The elevation of riverbed is EL. 710 m and river width is about 80 m and the both banks composes "U" shape valley. This difference of 40 m high is to be used for dam construction and produce a reservoir to expect a power generation. Just at starting point for the preliminary design, there are two sites for dam construction; one is downstream site and the other is upstream site. These sites were selected at the time of commencement of site investigation for the preliminary design works.
According to the results of the site investigation and the environmental assessment in the Study, finally the upstream site was selected as the dam site. The main reason for the selection are as follows;

1) Topography : In case of the downstream site, a width of the valley is wider than at the upstream site and it means that a crest length become long. Further an elevation of the left abutment is low, so that the crest length might be longer in case that the geological condition is worse. As a result, the excavation volume may increase.

2) Geology : Around the both sites, the basalt with a high permeability is spread widely in the riverbed. The basalt layer flowed from the downstream to the upstream and therefore, its width become narrow toward the upstream and become shallow going on the upstream side. Even though at the upstream site there are still possibility that a problem of permeable basalt layer will remain in relation to the measures for the basalt layer, but the upstream site has an advantage that such possibility is to be decreased at the upstream site.

3) Submerging : In case of the downstream site, most of Ban Latsasin village will be submerged due to a completion of the project. Therefore, by the submerging, as there are wide flat area in the submerge area, there are so much losses of the rice fields. On the other hand, at the upstream site, there are few flat area and so the upstream site has an advantage. Besides, in the view point of land preparation for the construction, the upstream site has an advantages that the lands which are spread at Ban Latsasin village will be used. This means that the construction cost may be decreased.

a) Type of Dam

In the Chapter 13 "Selection of the most probable development", a high water level was selected at EL. 765 m. For this selection, a location of the dam axis and dam type was examined. The location which was selected at the master plan study stage was plotted on the topographic map, scale 1 : 10,000, which was produced in the study and examined several candidate of the dam structure. Finally the dam axis was moved 200 m upstream from the axis proposed in the master plan study, judging the conditions of the direction of river flow and the relation with the location of abutment.

Further with respect of the type of the dam, both concrete gravity dam and fill type dam were examined comparatively from the points of height of dam, crest length, and the shape of the valley. However, here also a scale of the design flood was discussed for selection of dam type. By the scale of the spillway, affect to construction cost, and affect to construction period was considered, and finally a fill type dam was selected. The layout of dam is shown in **DWG. 14.4-2**.

In future, at a feasibility study stage, the above items shall be examined including the examination of flood and the further geological investigation will be executed and in addition, further comparative design in detail should be executed.

b) **Grout (measures for permeable rock at left bank)**

From the results of site investigation (Drilling works and water pressure test) which were carried out at the Xe Namnoy Midstream dam site during the study, it was recognized at the left bank of the Midstream site that a layer of basalt which has comparatively high permeability is widely spread . This was described in detail in Chapter 10 "Geology ", but at this stage, a number of the curtain grout will be carried out along the dam axis at left bank in a range of deeper than the thickness of basalt layer thickness which is estimated from the results of the drilling works, in addition to a normal grouting which will be carried out for the purpose of dam foundation treatment. However, regarding the permeability of this rock shall be investigated in details together with study on range of spreading of the rock layer in the future F/S stage.

(1-3) **Diversion Tunnel**

For design of diversion tunnel, it is necessary to decide a value of the flood discharge. A flood discharge was decided by a hydrological analysis as follows;

Return Period (Year)	Flood Discharge (m^3/sec)
5	594
10	758
20	927
50	1,162
100	1,351
200	1,551

As a fill type dam was selected in the Xe Namnoy Midstream project, a return period was selected 20 years and flood discharge, 950 m^3/sec was applied for design of diversion tunnel.

To decide a tunnel diameter of diversion, a water level at a cofferdam is affected to discharge capacity of the tunnel. Then herewith, it was assumed that a flood discharge is treated with a water level, 735 m. From this assumption, a tunnel diameter was selected to be 9.6 m and number of tunnel was also selected to be one. An alignment of the diversion tunnel is shown in **DWG. 14.4-2**.

(1-4) Spillway

In accordance with the selection of fill type dam at this project, a type and location of the spillway was examined with an understanding that a spillway structure is located separately from the dam structure. As shown in **DWG. 14.4-2**, the spillway structure was located between a small hill about 300 m apart from the dam center and a high mountain locating further about 400 m left side from the small hill at the left bank. Also from the results of geological investigation, an existence of a wide distribution of basalt layer which has a high permeability was confirmed at the left bank and therefore, it is supposed that a lot of grouting work will be required. From this point, it should be also considered to avoid a possible complication of the relevant works at the dam area as much as possible and to shorten the construction period. Therefore, from this consideration, the selected site of the spillway is acceptable. The arrangement of the spillway is shown in **DWG. 14.4-2**.

a) Design Flood

As same as the other dams, a design flood was estimated by PMF equivalent which was gained from the hydrological analysis and the figure is 6,000 m^3/sec.
Also at this moment, as any record of flood in the Project area are not available, the examination of the spillway capacity by a flood analysis of a hydrograph method was not executed, but the examination of the spillway capacity to discharge all of the design flood at the high water level was studied. Under this condition, it is required that further study on the spillway capacity and design in an economical view point will be carried out at a feasibility study stage to be executed in the near future.

(1-5) Intake

Layout of waterway was studied from the relation between discharge of intake and number of generator and one line was selected.

a) Type of Intake

Taking a dam-waterway type of power generation into account, it is more economical to select a shorter length of the waterway as much as possible. In this point, from the topographic maps, scale 1:10,000, the location where an alignment of the waterway become shorter in the reservoir was chosen. The location of the intake structure is shown in **DWG. 14.4-1**.

Considering that a water intake level is between HWL. 765 m and LWL. 747.7 m, to avoid air sanction into the tunnel in case of low water level, an inlet level at the bottom was set at EL. 738.25 m.

b) Capacity of Intake

The maximum discharge to be used in the Xe Namnoy Midstream project is 60 m^3/sec. This is for 2 units of generator and from the layout of the waterway, one inlet will discharge all of this discharge to the downstream side. A typical section of the intake structure is shown in **DWG. 14.4-4**.

(1-6) Waterway

An alignment of the waterway is shown in **DWG. 14.4-1** and a longitudinal section is shown in **DWG. 14.4-4**, respectively, and the layout of each component is described in the following sections.

a) Headrace Tunnel

The headrace tunnel was the structural component to affect the total design of the project and therefore, a careful consideration was given to the decision of the tunnel alignment. Based on the topographic maps which has been supplied in the Study, of which a scale is 1 : 10,000 , the route was selected considering a total balance of the location between the powerhouse, the penstock route, and the surge tank.
As the tunnel length is 9,000 m and it is so long, it is also required to take location and number of adit(s) into consideration, together with construction method and construction schedule.

From the low water level at the reservoir, an elevation of inlet of the intake is decided and a tunnel sectional area and gradient of the tunnel will be decided to flow the required discharge to the downstream side. Also, a type and scale of surge tank by considering effect of surging of 454 m of high head will affect the tunnel structure.

Besides, from the topographic condition, along the route selected finally for design there is a deep valley around middle of total tunnel alignment and therefore, examination of covering required for the headrace tunnel is necessary. Through these examination, an alignment of the tunnel, longitudinal gradient and tunnel diameter was decided. As a result, a tunnel diameter is 4.5 m and total length is 9,030 m.

b) Surge Tank

Design of surge tank is to absorb the pressure due to water hammer at time of urgent shutdown of turbine and at re-starting of power generation and to decrease the influence to rising water level in the reservoir due to fluctuation of load at the surge tank. In this case, there is a relation with closing time of turbine and therefore, at this stage it can not be decided as a specific figure and also this time it is a preliminary design. Then, the examination was carried out by a simplified formula. As a result, a dimension of the surge tank was decided as 16 m diameter and 107 m height and it is considered that a surge tank will be placed under the ground, and at this moment a type of the surge tank was considered as a simple surge tank.

c) Penstock

A route of penstock in the Xe Namnoy Midstream Project was selected as a combined type, that one is a tunnel type at the upper portion and the other is exposed type at the lower portion, taking the topographic features at site into account.
Examination about internal diameter of pipe was carried out using a simplified formula, considering static pressure and water hammer in a waterway alignment and decided.
The result shows that internal diameter required is 4.0 m at upper portion and after bifurcation it is 3.5 m.

(1-7) Powerhouse and Switchyard

The layout is basically conformed with a data examined in the Chapter 13, "Selection of Probable Development Scheme' and taking the arrangement of the electrical and mechanical equipment into consideration. A type of the powerhouse was decided as semi-underground type below EL.278 m which is a level of generator. The layout is shown in **DWG. 14.4-1**. A building size is 18 m width, 82 m length and 35 m height as shown in **DWG. 14.4-6**.
The switchyard is located next to the powerhouse.

(1-8) Tailrace

As the powerhouse building is located a part from the river bank, about 50 m long tailrace outlet structure will be required from the portion of the draft gate structure.

(1-9) Discharge to Downstream for Life of Inhabitant

In the area of about 20 km distance between the downstream of dam site and the powerhouse site of the Xe Namnoy Midstream Project, it is probable that a number of inhabitant use river water for their lives. Due to completion of the dam, no discharge except at time of flooding will be supplied to the downstream and a trouble on water supply to them will be arisen. To solve the problem, a discharge facility to the downstream was examined in this study.
Although it is described in the Chapter 12, a discharge of 1.0 m^3/sec to the downstream was considered. For this purpose, a discharge pipe will be installed through the dam structure. It is a steel pipe of 500 mm diameter as a discharge facility and a valve will be installed at the downstream side of the dam.

(1-10) Access Road for Construction

Access to the Xe Namnoy Project is possible with the following route. From Pakse, that is a center of Bolovem Plateau, through National Road, reach to B. Houaykong and from B. Houaykong by 16 km of local road to B. Latsasin. However, for the project realization, the following conditions on these roads are considered.

1) The road from Pakse to B. Houaykong has a enough width, but its road subbase course and road surface condition is not in a good condition, and especially in wet season it is almost not possible for access. However, during the site investigation of the study, a part of this road was under improvement works. Therefore, it is assumed that in future such improvement works will be carried out continuously. And the road will be completely grade up before commencement of the project. Therefore, this improvement work was not included in the project.

2) Further, the 16 km road between B. Houaykong to B. Latsasin is not possible to use for the project, because the road specifications, such surface, subbase course condition, width, road slope and bridge are not sufficient for use during the main

construction work and therefore, improvement works in a great extent will be required. The improvement work is included in the main construction works.

3) Besides, there is no road which a vehicle can pass from B. Latsasin toward the project site. Therefore, for the access to the surge tank site through the dam site and along the waterway route, it is inevitable to construct new access road. The total length of the new access road is about 26 km.

4) On the other hand, for the construction of the powerhouse and penstock structures, it is required to make an access from the downstream. For this purpose, about 15 km of new road will be constructed from the junction with National road No.16 to the powerhouse site along the Xe Namnoy River. The cost will be included in the project.

Road specifications are considered as a 7 m wide road and 2 lanes for the traffics and gravel surface.

(1-11) Xe Pian River Diversion

Considering more effective development of the Xe Namnoy River, river diversion from the Xe Pian River which flows next to Xe Namnoy River in the upstream area to Xe Namnoy River is planned to expect increasing of power generation due to increase of reservoir volume in total year.

From the results of examination in Chapter 13, "Selection of Probable Development Scheme", a discharge available to divert from Xe Pian river to Xe Namnoy River is 20 m^3/sec as a most reliable figure. Then, a proposed route and preliminary design of structures for the river diversion is described herewith. Project outline of the river diversion is shown in **Table 14.3-3**.

a) Selection of Xe Pian River Diversion

A route of the river diversion from Xe Pian river to Xe Namnoy river is shown in **DWG. 14.4-5**. Total length of the river diversion is about 9 km and it composes mainly 5 portions as listed below;

(1) Intake Weir at Xe Pian River

(2) Open Channel between Xe Pian River and H. Lieng River

(3) Riverbed Improvement of H. Lieng River

(4) Intake Weir at H. Lieng River

(5) Water Channel between H. Lieng River and Xe Namnoy River

General concept of the design for each component is described as follows;

b) Intake Weir at Xe Pian River

Intake water level at Xe Pian intake weir shall be 775 m in order that it makes possible to divert water to Xe Namnoy River. A location of the proposed intake weir is as shown in **DWG. 14.4-5** and as a purpose of the weir is to reserve water, a weir structure is a overflow type at top of the weir, which is a structure to discharge surplus water without any disturbance.

A height of the weir is 17 m, assuming that the foundation of the weir is EL.758 m from the topographic map. A crest length is 120 m and weir type is a concrete gravity type.

c) Diversion Channel between Xe Pian River and H. Lieng River

It was selected that a suitable river diversion system from a proposed point as an intake at Xe Pian River to H. Lieng River located in the east is a open channel type, judging from the topographic condition.

A structure of open channel is a box culvert type as shown in **DWG. 14.4-5** and 5 m width, 3 m height and 530 m length.

d) Riverbed Improvement of H. Lieng River

The water diverted from Xe Pian River to H. Lieng River will be flowed to the downstream using H. Lieng River itself and further diverted to Xe Namnoy River constructing an artificial waterway. However, from the topographic maps, it seems that in this section the riverbed of the H. Lieng River is rather high to flow the diverted water to the downstream with the present scale and therefore, this section, about 3,100 m long, shall be required riverbed improvement work. The riverbed improvement work consists riverbed excavation with about 1 m depth.

e) **Intake Weir at H. Lieng River**

The water level of the water diverted to H. Lieng River is 771 m. In this case another intake weir at H. Lieng River shall be required to be constructed to make it possible to divert the water further to Xe Namnoy River. The water level at the proposed site of the weir is assumed as WL.770 m. The location of the proposed weir construction is as shown in **DWG. 14.4-5** and about 800 m downstream from the point for diversion channel to the Xe Namnoy River.

This weir is also for the purpose of water reserving and therefore, the type of weir is overflow type from the top of weir and concrete gravity type. The size is 10 m height and 500 m length at crest.

f) **River Diversion between H. Lieng River and Xe Namnoy River**

The river diversion channel is divided into two parts, that is;

(a) About 4,100 m length of Open channel from the junction of H.Lieng River to 1.0 km downstream of Nong Lom pond,

(b) Non-pressure tunnel from the point described above (a) to Xe Namnoy River crossing a mountain.

In relation to part (a), there is an alternative that partially a new open channel is constructed and in the remaining section, the existing pond (Nong Lom) is used as a waterway, but in this case, in a dry season the pond is dried up and from the topographic map, the elevation of riverbed is not clear and therefore, this time in all section a new construction of open channel was selected, because of uncertainty of usage of this pond to the project and the possibility of water right problem. Also, in the part (b) a breakthrough by a tunnel was applied because of existence of a mountain as a watershed of Xe Namnoy River.

A design profile of these structures are shown in **DWG. 14.4-5** and the open channel has a typical cross section of 5 m base width, 3 m height, and 4,100 m length, and a tunnel is non-pressure type and has a dimension of 4 m width and 4 m height and upper section is a half circle and lower section is a rectangle and the length of tunnel is 900 m.

g) **Access Road for Construction**

Even though the project area is spread in 10 km distance, there are partially local roads. And these roads can not be used for construction of the river diversion channel. Therefore, in connection to the access roads to be constructed for the Xe Namnoy Midstream project between B. Houaykong and B. Latsasin,, a branch road shall be constructed to the site and then it is possible to access to the site. In this stage total 6 km length of new road in three location s are considered. A profile of the road is 7 m width and two lanes for two directions and paved by gravel.

(2) Xe Namnoy Downstream Project

(2-1) General

The project is based on a concept that a remaining head of the Xe Namnoy river should be effectively used for power generation by construction the dam at the location downstream from the Xe Namnoy Midstream power station.

As stated in the Chapter 13, "Selection of Optimum Development Plan", the tailrace water level is 275 m after power generation at Midstream power station. and by construction of dam at just downstream, discharge water from the power station and inflow from the Xe Katam river will be stored and adjusted in a yearly basis. The water is connected to the power station through a waterway and the further head and generate power of additional 332 GWh to the Xe Namnoy Midstream project.

The major profile of the Xe Namnoy Downstream are shown in **Table 14.4-2**. Based on the profile, the results of examination of project layout are shown in **DWG. 14.4-7**. These layout is described in the following section.

(2-2) Dam

The selection of dam site was executed using the topographic maps produced newly in this study, because we have not visited the site during this study, but only by helicopter. The location of dam is at 4 km downstream from the junction of Xe Namnoy river and Xe Katam river, the tributary of Xe Namnoy, and 300 m downstream from the junction of Xe Namnoy and Houay Katak river, also a tributary of Xe Namnoy. From the topographic maps and examination of selection of most probable development, a concrete gravity dam was selected and the dimension is 33 m height and 350 m long crest.

(2-3) **Diversion Tunnel**

It is required to estimate a flood discharge in return period for design of diversion tunnel. A flood discharge was decided by a hydrological analysis.

In case of Xe Namnoy Downstream, a concrete gravity dam was selected, and therefore a flood discharge at 5 years of return period was applied as same as the case of Xe Kaman No.1 project, because it is allowable to meet a probable overflow from the top of concrete dam during the construction.

Indeed in the further F/S study stage, such figure of flood shall be reviewed by examination of data of flood and etc. which will be gained newly in the future
However, even though flood discharge at 5 years of return period was applied for the construction of dam which has 33 m height and 133,200 m^3 of concrete volume, the scale of the diversion tunnel is 11.0 m diameter. This seems that a percentage of construction cost of diversion tunnel compared with cost of dam construction is rather high.

Layout of the diversion tunnel is shown in **DWG. 14.4-8**.

(2-4) **Spillway**

In this project a figure of design flood discharge is 9,602 m^3/sec (PMF). To discharge the flood, it was decided that a spillway should be placed at the top of the dam structure, judging from the topographic condition and type of dam. The type and dimension of the spillway is 158 m width, 14 m high and for this spillway, ten units of gate (12.5 m wide, 14.0 m high) are required. The layout of the spillway is shown in **DWG. 14.4-9**.

(2-5) **Intake**

Discharge to be used for power generation in the Xe Namnoy Downstream Project is 96 m^3/sec. and as a type , it was selected that a intake structure is located at the right bank in order to send the water to powerhouse located about 4 km downstream using a waterway. The layout is shown in **DWG. 14.4-10**.

(2-6) **Headrace Tunnel**

Headrace tunnel was planed based on a rough calculation of total head loss in the waterway and the result shows that tunnel diameter is required 5.8 m and one lane is arranged . The plan is shown in **DWG. 14.4-7** and a longitudinal section is also shown in **DWG. 14.4-10**.

(2-7) Surge Tank

On the surge tank for the Xe Namnoy Downstream project, a surging was calculated by a simplified formula for quick shutdown and quick increasing conditions under the conditions that a tunnel length is 3,000 m and the effective head is 81 m. From these figures, a height of the surge tank required for the condition. A internal diameter of the surge tank was fixed 16.0 m. and all of the height is under the ground. At this moment, a type of the surge tank was considered as a simple surge tank.

(2-8) Penstock

In this project, a layout of the penstock was considered to be under the ground, from the arrangement of headrace tunnel, surge tank, and powerhouse. A diameter of the penstock was decided from a simplified formula and it is 5.6 m in the upper inclined portion and 5.4 m in the lower horizontal part. After bifurcation the diameter of the penstock became 3.5 m.

(2-9) Powerhouse and Switchyard

The location of powerhouse was selected at the place where is 4 km downstream from the dam site and 11 km upstream from the junction with Se Kong main river. This location is rather flat area along the riverbed at the right bank and considered in view of cost consideration. The type of powerhouse is the same as the other power house and it is a semi-underground type. And switchyard is considered to be located in conjunction to the powerhouse. The layout of the powerhouse is shown in **DWG. 14.4-11**.

(2-10) Tailrace

Type of tailrace is considered as a channel with guide wall at outside from a location of draft gate which is installed at the end of draft tube . The shape is to be 30 m width and 25 m length.

(2-11) Access Road for Construction

Access road for construction of Xe Namnoy Downstream project are included in the access road for Xe Namnoy Midstream project. Therefore, in this section it is not required to consider.

14.4.2 Generators and Components

(1) Xe Namnoy Midstream

(1-1) Selection of Number and Capacity of Unit

The output of the Xe Namnoy Midstream Power Plant is planned to be 238MW. There are several combinations in the number and capacity of unit to satisfy this output. but the fewer number of units is, the lower the construction cost becomes. A 1-unit plan is possible for the most economical factor since the river retaining flow operation is unnecessary. However, despite a lesser scale merit, a 2-unit plan would be optimum considering that the operation of the power generation is unclear at this stage, and the plant reliability due to main units failure and transportarion conditions. Also, the capacity of the major components at the other sites is approx. 100MW.

In the next Feasibility Study, it is necessary that the optimum number and capacity of units be re-checked by considering the turbine/generator operation conditions, transportation conditions, and the cost of not only the electrical components, but also the construction cost of civil structures.

The output of each turbine/generator was calculated as below;

$$\text{Turbine/generator output} = 9.8 \times He \times Q_{max} \times \eta_T \times \eta_G$$
$$= 9.8 \times 463.0\ \text{m} \times 30.0\ \text{m}^3/\text{sec} \times 0.889 \times 0.980$$
$$\fallingdotseq 119{,}000\ \text{kW}$$

(1-2) Type and Ratings of Major Equipment

When considering only the effective head, a Pelton turbine is appropriate. However, the maximum discharge is large at 60 m^3/sec, requiring a minimum of 3 Pelton turbine/generators. Also, as the max. efficiency of the Pelton turbine is approx. 80%, and thus lower than the Francis turbine, the vertical shaft Francis turbine was selected. The

Pelton turbine would be more beneficial, however, when frequent partial load operation is expected since the partial load efficiency of the Pelton turbine is better than that of the Francis turbine. It is, therefore, necessary to carefully study in the next Feasibility Study stage which turbine would be the most beneficial. The study should include the construction cost of civil structures.

The vertical 3-phase AC synchronous generator is the most appropriate for direct connection to the turbine. The rated power factor of this generator is 0.85 to contribute to voltage control in the system in response to the long distance transmission from the load end. The transmission lines from Xe Nomnoy Midstream to Roi Et Substation in load side via Ban Houaykong Substation are long distance and one direction transmission. Since above condition of the system is very difficult caused by the Ferranch Effect in night time and voltage drop in heavy load time. The selection of power factor would be re-studied in the next Feasibility study taking into these transmission consideration.

Considering a transport condition (max. 30 tons), 3 outdoor oil filled single phase transformers were selected for each unit as the major transformers in response to the increase from the generator voltage to the system transmission/distribution voltage of 230kV.

The combination of single bus and transfer bus, as in Nam Ngum, was selected for the switchyard. The switchyard equipment is a conventional type. It is also possible to use a Gas Insulated Switchgear (GIS) when considering reduction of the switchyard area and simple maintenance. It is necessary that this matter be studied in the next Feasibility Study or in the Detailed Design stage.

The switching station is equipped with two terminal equipment with 220kV transmission line to connected with the Xe Namnoy Downstream Power Plant and Ban Houaykong sub-station and 22kV transmission line to supply electricity to the local load and an interconnected transformer to step down from 230kV to 22kV.

Since this will be an important power plant, a diesel power generator will be installed as an emergency facility to back-up the power source in the plant. The single-line diagram is shown in **Fig. 14.4-1**.

The ratings of major equipment are described below;

Water Turbine

Type	Vertical shaft, Francis
Number of units	2
Normal effective head	463.0 m
Maximum discharge	30.0 m^3/sec
Turbine output	119,000 kW
Revolving speed	429 rpm

Generator

Type	Three phase, alternating current, synchronous
Number of units	2
Output	140,000 kVA
Power factor	0.85 lag
Voltage	15.4 kV
Frequency	50 Hz
Revolving speed	429 rpm

Main Transformer

Type	Outdoor, oil filled, single phase
Number of units	2 set (6 units)
Capacity	140,000 kVA
Voltage primary :	15.4 kV
secondary :	230 kV

Outdoor Switchyard

Bus system	Single bus + transfer bus
Bus	Aluminum line
Number of transmission lines connected	230 kV × 1 cct
	22 kV × 2 cct

(2) Xe-Namnoy Downstream

(2-1) Selection of Number and Capacity of Unit

The output of the Xe Namnoy Downstream Power Plant is planned to be 67MW. Since the turbine/ generator does not need to operate the river retaining flow, a single unit design is both possible and economical. However, considering that the operation of power generation is unclear in this stage, and plant reliability due to main unit accident, a 2-unit plan was accepted despite its lesser scale merit.

As the effective head is 81m, a Deriaz turbine with a broad operation range is also applicable. In the next Feasibility Study stage, it is necessary that the optimum number and capacity of units be re-checked by considering the type of turbine/ generator, operation conditions, transportation conditions, and the cost of not only the electrical components, but also the construction cost of the civil structures.

The output of each turbine/generator was calculated as below;

Turbine/generator output $= 9.8 \times He \times Q_{max} \times \eta_T \times \eta_G$

$= 9.8 \times 81.0\ m \times 48.0\ m^3/sec \times 0.908 \times 0.970$

$\fallingdotseq 33{,}500\ kW$

(2-2) Type and Ratings of Major Equipment

Although as previously described herein, while the Francis turbine/generator was adopted this time, the Deriaz turbine/generator is also applicable. With adjustable runner vanes, the Deriaz turbine is operational from approx. 25% of max. water flow. Compared with the Francis turbine, its partial load efficiency is also good. In many cases, it is installed in power plants where the head variation is large due to varied river flows or dam water levels.

The head variation at the Xe Namnoy Downstream Power plant is not large. The flow variation, however, may be large since it is a run-off-river power plant. It requires two Francis turbines to satisfy its operation range. Contrarily, one Deriaz turbine can satisfy the equivalent or better operation conditions. The cost of the Deriaz turbine is higher than that of the Francis turbine due to its complicated system with adjustable runner vanes. In the next Feasibility Study stage, it is necessary to carefully study which turbine would be more beneficial, including studying the construction cost of civil facilities.

The vertical 3-phase AC synchronous generator is appropriate for direct connection to the turbine. The rated power factor of this generator is 0.85 to contribute to voltage control in the system in response to the long distance transmission from the load end. The transmission lines from Xe Namnoy Downstream to Roi Et Substation in load side via Ban Houaykong Substation are long distance and one direction transmission. Since above condition of the system is very difficult caused by the Ferranch Effect in night time and voltage drop in heavy load time. The selection of power factor would be re-studied in the next Feasibility study taking into these transmission consideration.

Considering a transport condition (max. 30 tons), 3 outdoor oil filled single phase transformers were selected for each unit as the main transformers in response to the increase from the generator voltage to the system transmission/distribution voltage of 230kV.

The combination of single bus and transfer bus, as in Nam Ngum, was selected for the switchyard. The switchyard equipment is a conventional type. It is also possible to use a Gas Insulated Switchgear (GIS) when considering reduction of the switchyard area and simple maintenance. It is necessary that this matter be studied in the next Feasibility Study or in the Detailed Design stage. The switching station will not be equipped with a 22kV transmission line related facility since the electricity supply to the local load is presumed to be conducted by the component in the Xe Nanmoy Midstream Power Plant.

Since this will be an important power plant, a diesel power generator will be installed as an emergency facility to back-up the power source in the plant. The single-line diagram is shown in **Fig. 14.4-2**.

The ratings of major components are described below;

Water Turbine

Type	Vertical shaft, Francis
Number of units	2
Normal effective head	81.0 m
Maximum discharge	48.0 m^3/sec
Turbine output	33,500 kW
Revolving speed	250 rpm

Generator

Type	Three phase, alternating current, synchronous
Number of units	2
Output	39,500 kVA
Power factor	0.85 lag
Voltage	11.0 kV
Frequency	50 Hz
Revolving speed	250 rpm