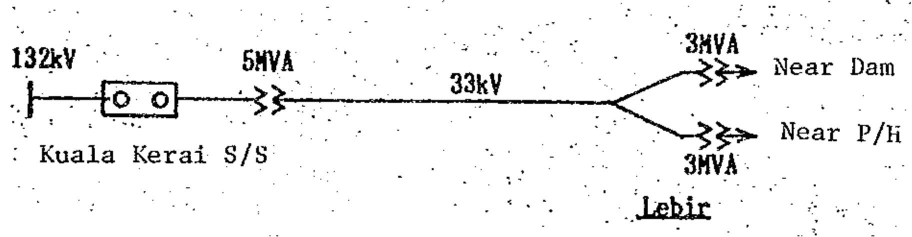
9.7. Construction Plant and Equipment

For construction of the Project, the following plant and equipment will be necessary

- Aggregate Production Plant	Downstream right bank at the Main Dam Site
- Concrete Batching Plant	"
- Construction Equipment Workshop	Between Quarry site and Main Dam Site
- Reinforcing Bar Fabrication Shop	Main Dam Right Bank
- Steel Pipe/Gate Fabrication Shop	Downstream Left Bank at the Powerhouse Site
- Material Stockyards	
- Explosives Magazine	
- Camp Facilities	

Construction power supply facilities are considered to be built by the Project Owner for use by Contractors.

The temporary power supply plan is outlined as follows:



T/L : 33 kV 60 km

S/S : Kuala Kerai S/S Outgoing 5 MVA
In-site substation 2 places 2 MVA x a
6 Feeders

Table 9-2-1 Reservoir Level and Volume

Reservoir Level (m)	Reservoir Volume (10^6 m^3)
40.0	32.00
41.0	40.78
42.0	50.60
43.0	61.48
44.0	73.40
45.0	86.38
46.0	100.40
47.0	115.47
48.0	131.60
49.0	148.78
50.0	167.00
51.0	185.20
52.0	206.80
53.0	231.80
54.0	260.20
55.0	292.00
56.0	327.20
57.0	365.80
58.0	407.80
59.0	453.20
60.0	502.00
61.0	554.20
62.0	609.80
63.0	668.80
64.0	731.20
65.0	797.00
66.0	866.20
67.0	938.80
68.0	1014.80
69.0	1094.20
70.0	1177.00
71.0	1262.95
72.0	1356.80
73.0	1458.55
74.0	1568.20
75.0	1685.74
76.0	1811.20
77.0	1944.54
78.0	2085.79
79.0	2234.95
80.0	2392.01
81.0	2556.94
82.0	2729.79
83.0	2910.56
84.0	3099.19
85.0	3295.75
86.0	3500.19
87.0	3712.55
88.0	3932.79
89.0	4160.94
90.0	4397.00

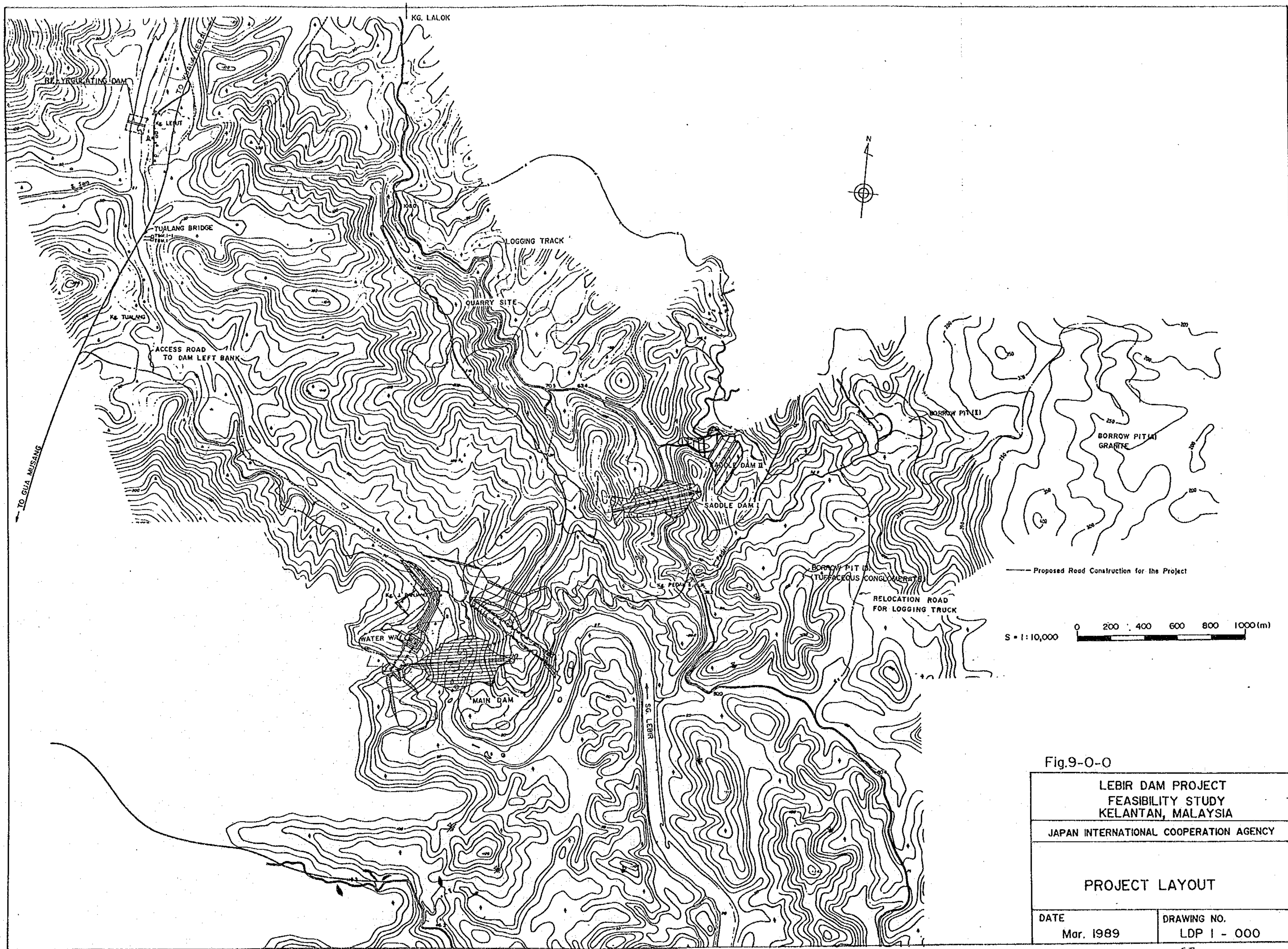


Fig.9-0-0

LEBIR DAM PROJECT
FEASIBILITY STUDY
KELANTAN, MALAYSIA

JAPAN INTERNATIONAL COOPERATION AGENCY

PROJECT LAYOUT

DATE	DRAWING NO.
Mar. 1989	LDP 1 - 000

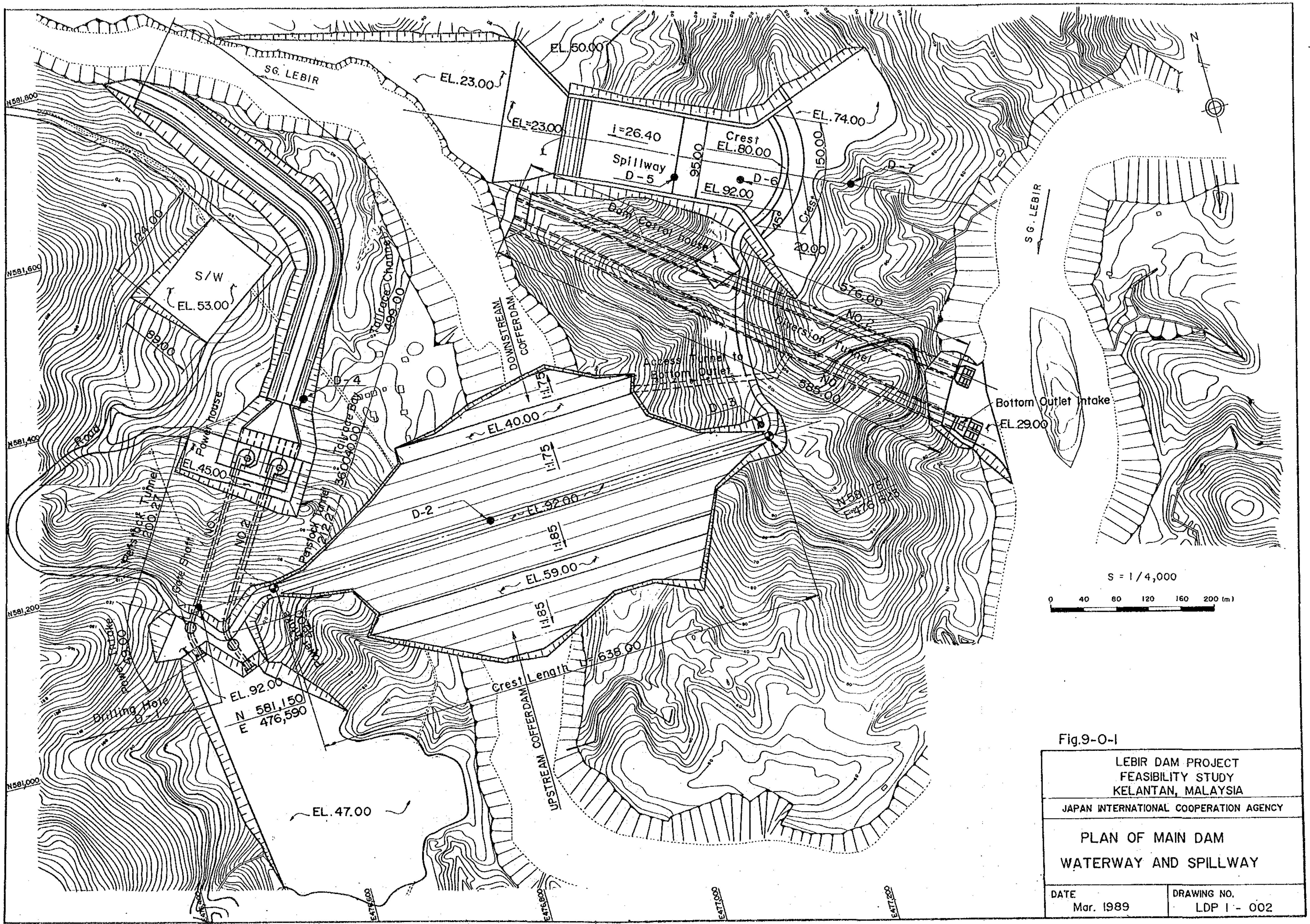


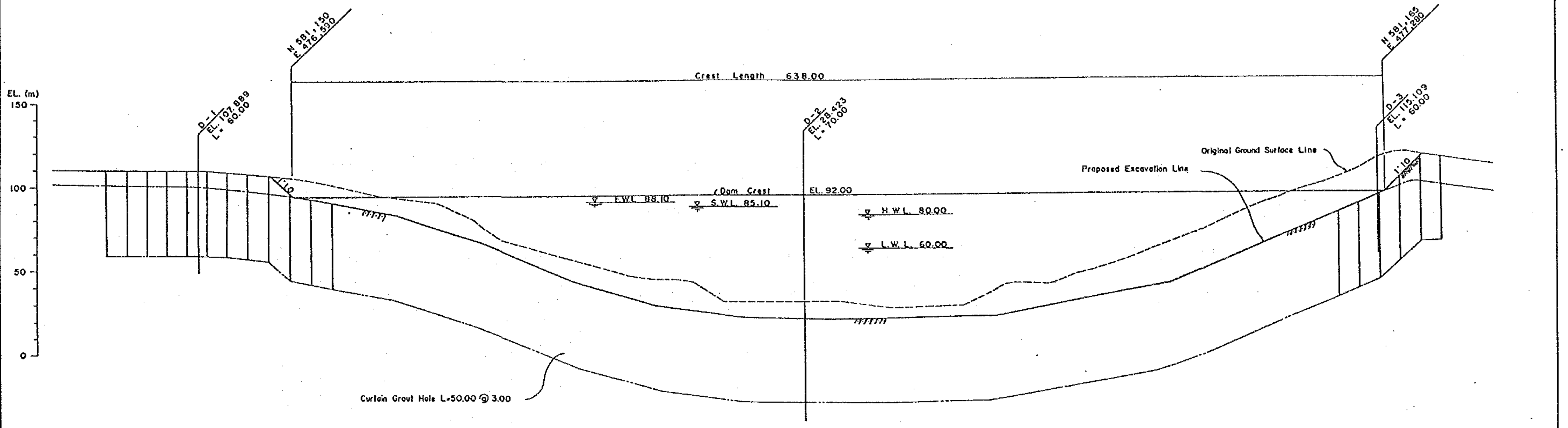
Fig.9-0-1

LEBIR DAM PROJECT
FEASIBILITY STUDY
KELANTAN, MALAYSIA

JAPAN INTERNATIONAL COOPERATION AGENCY

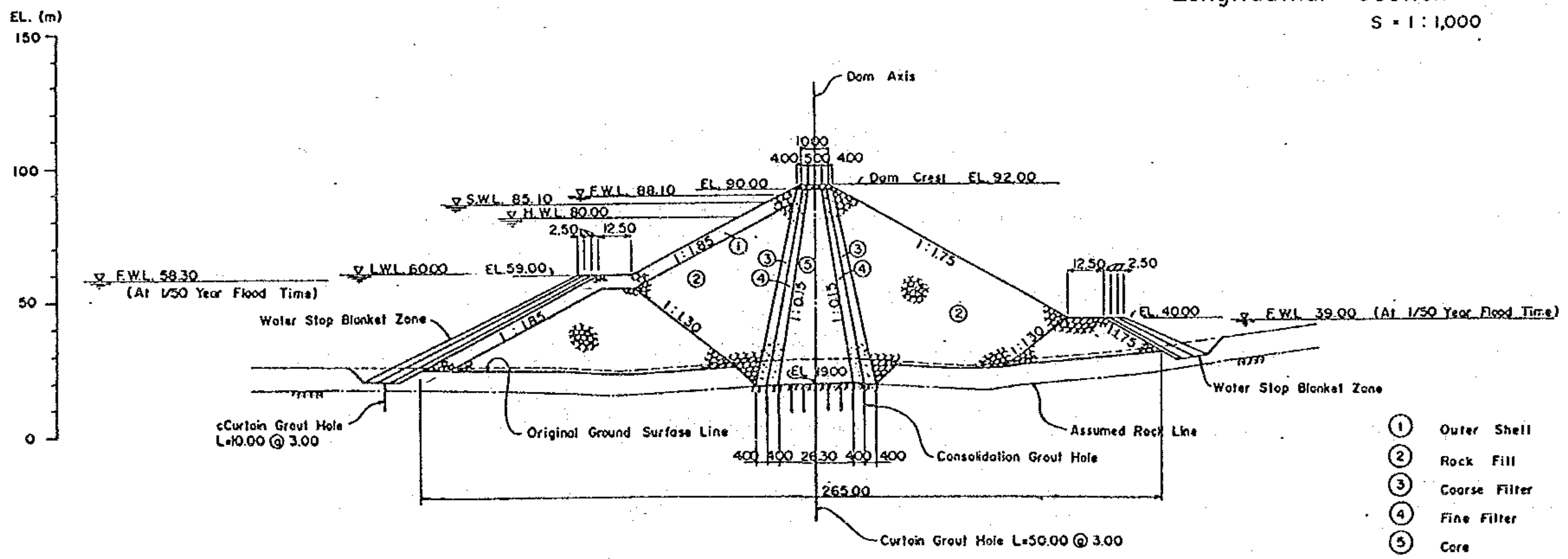
PLAN OF MAIN DAM
WATERWAY AND SPILLWAY

DATE	DRAWING NO.
Mar. 1989	LDP I - 002



Longitudinal Section
S = 1 : 1,000

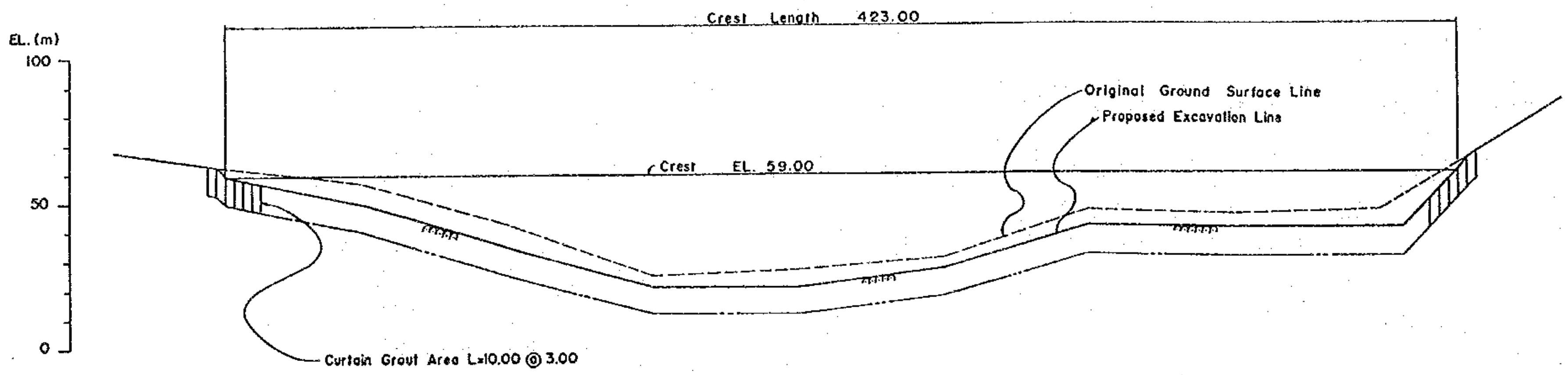
S = 1 : 1,000 0 20 40 60 80 100 (m)



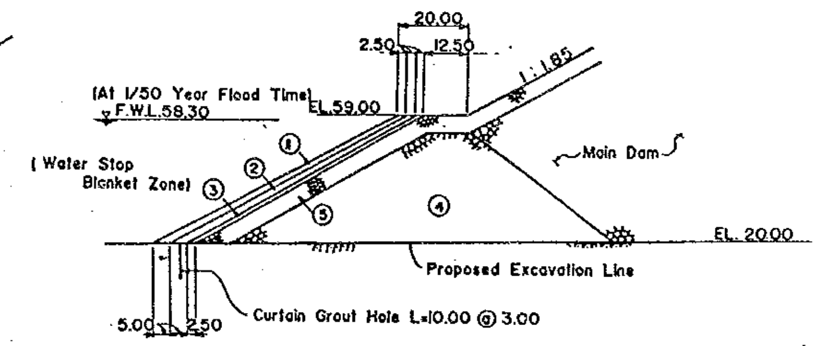
Typical Section
S = 1 : 1,000

Fig.9-0-2

LEBIR DAM PROJECT FEASIBILITY STUDY KELANTAN, MALAYSIA	
JAPAN INTERNATIONAL COOPERATION AGENCY	
MAIN DAM SECTIONS	
DATE Mar. 1989	DRAWING NO. LDP I - 002.



Longitudinal Section



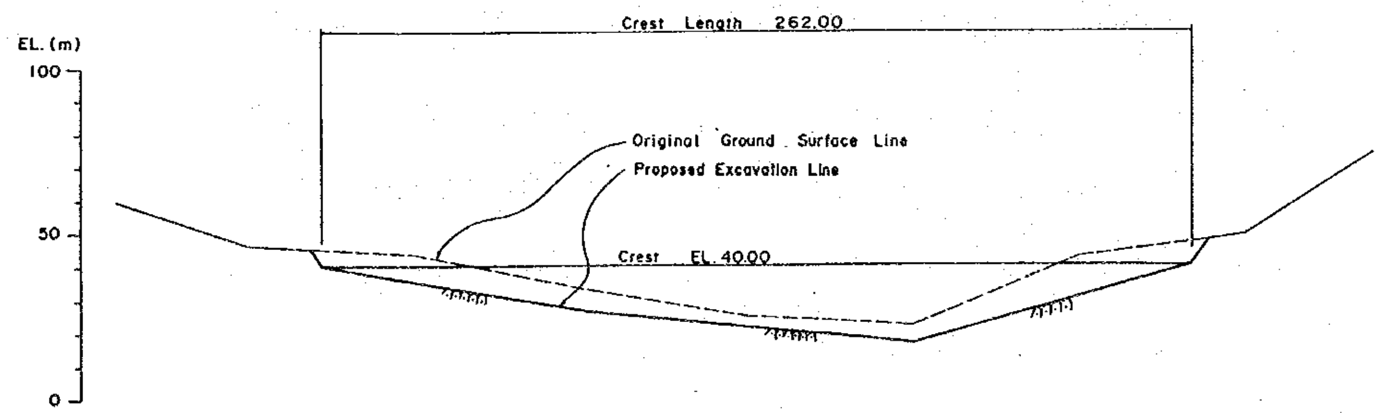
Typical Section

Up-stream Cofferdam

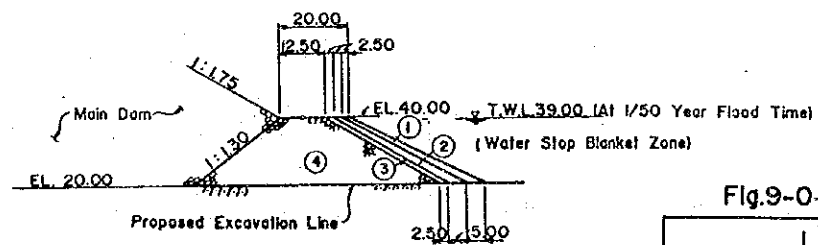
S = 1 : 1,000

① Random Fill
② Core
③ Fine Filter
④ Rock Fill
⑤ Outer Shell

S = 1 : 1,000 0 20 40 60 80 100 (m)



Longitudinal Section



Typical Section

Down-stream Cofferdam

S = 1 : 1,000

Fig.9-0-3

LEBIR DAM PROJECT FEASIBILITY STUDY KELANTAN, MALASIA	
JAPAN INTERNATIONAL COOPERATION AGENCY	
COFFER DAMS SECTIONS	
DATE Mar. 1989	DRAWING NO. LDP 1 - 003

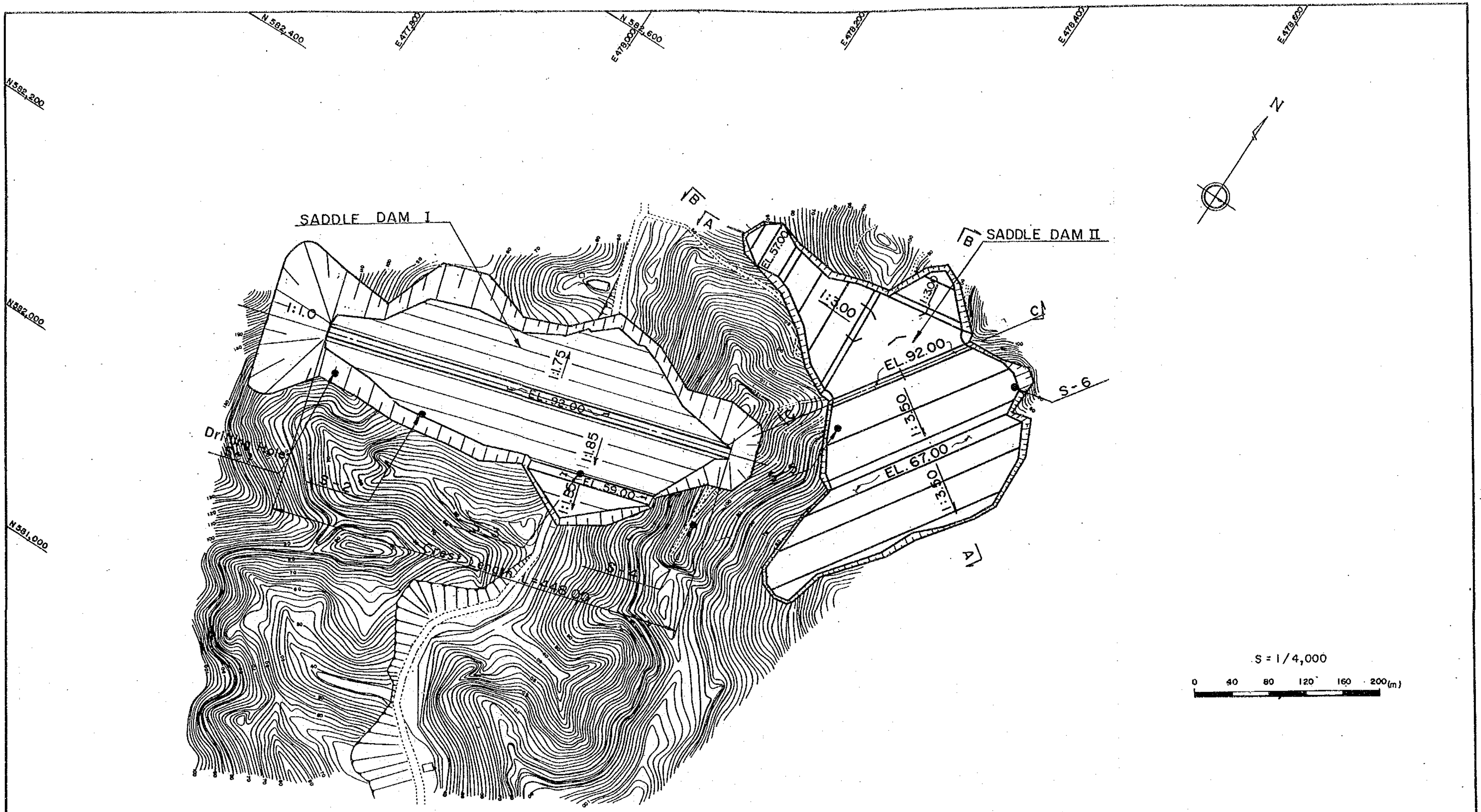


Fig.9-0-4

LEBIR DAM PROJECT FEASIBILITY STUDY KELANTAN, MALAYSIA	
JAPAN INTERNATIONAL COOPERATION AGENCY	
PLAN OF SADDLE DAM I AND II	
DATE Mar. 1989	DRAWING NO. LDP I - 004

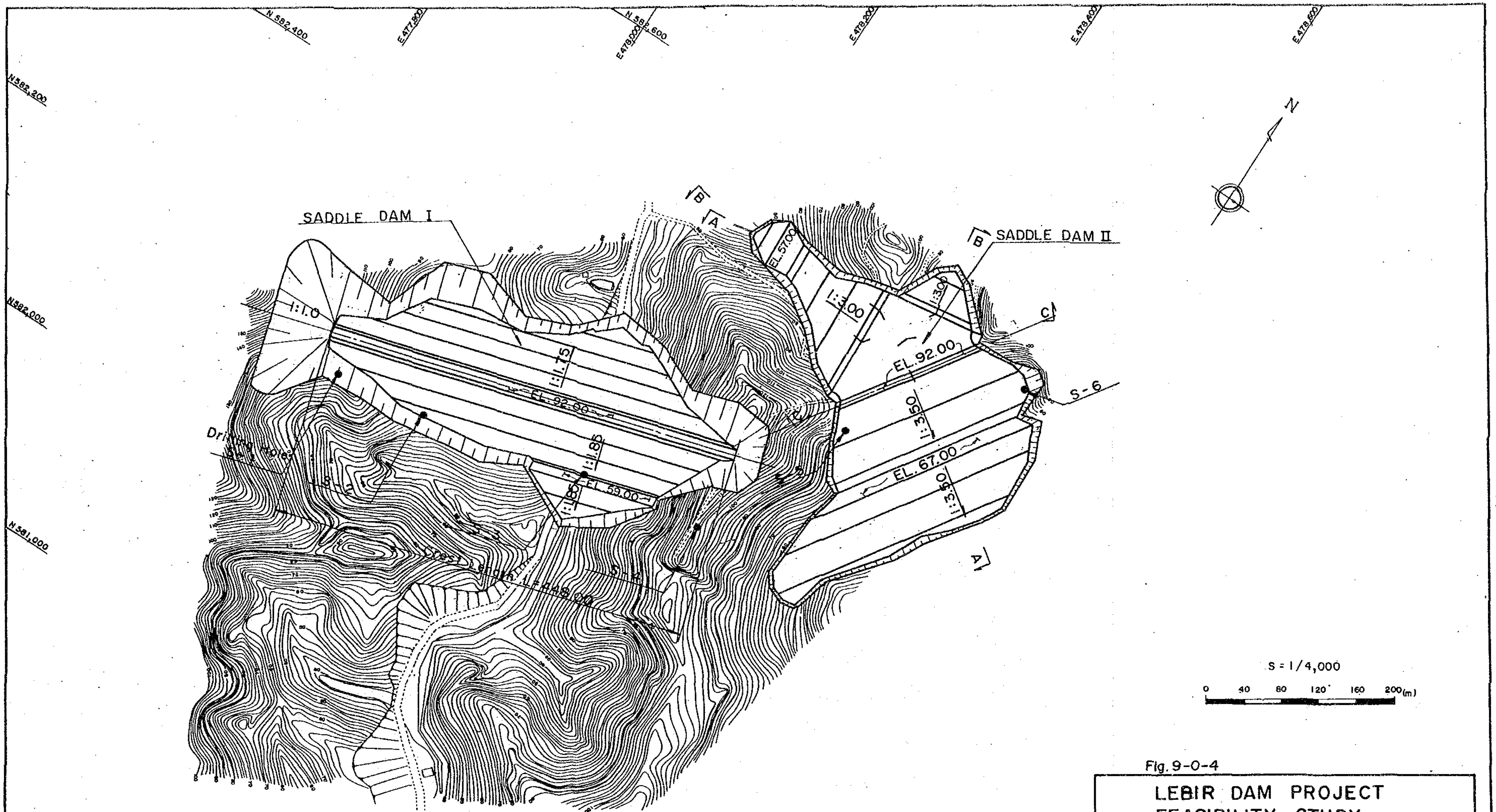


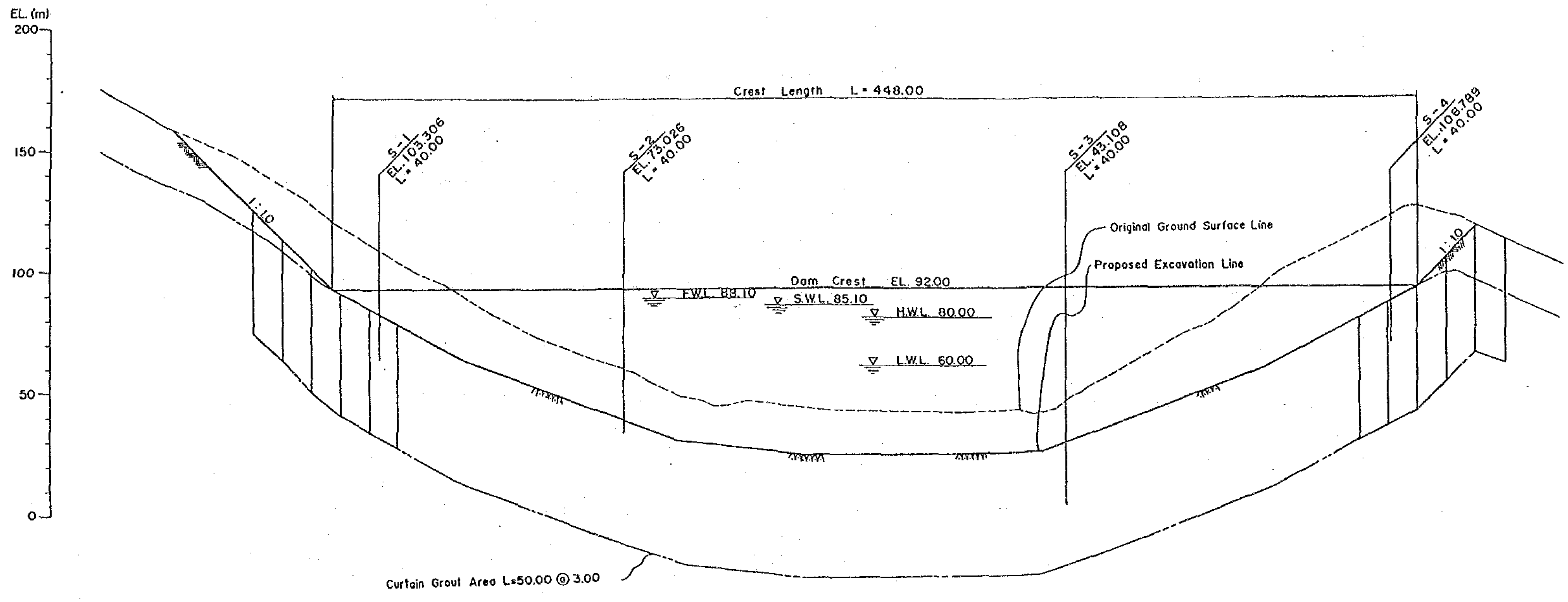
Fig. 9-0-4

LEBIR DAM PROJECT
FEASIBILITY STUDY
KELANTAN, MALAYSIA

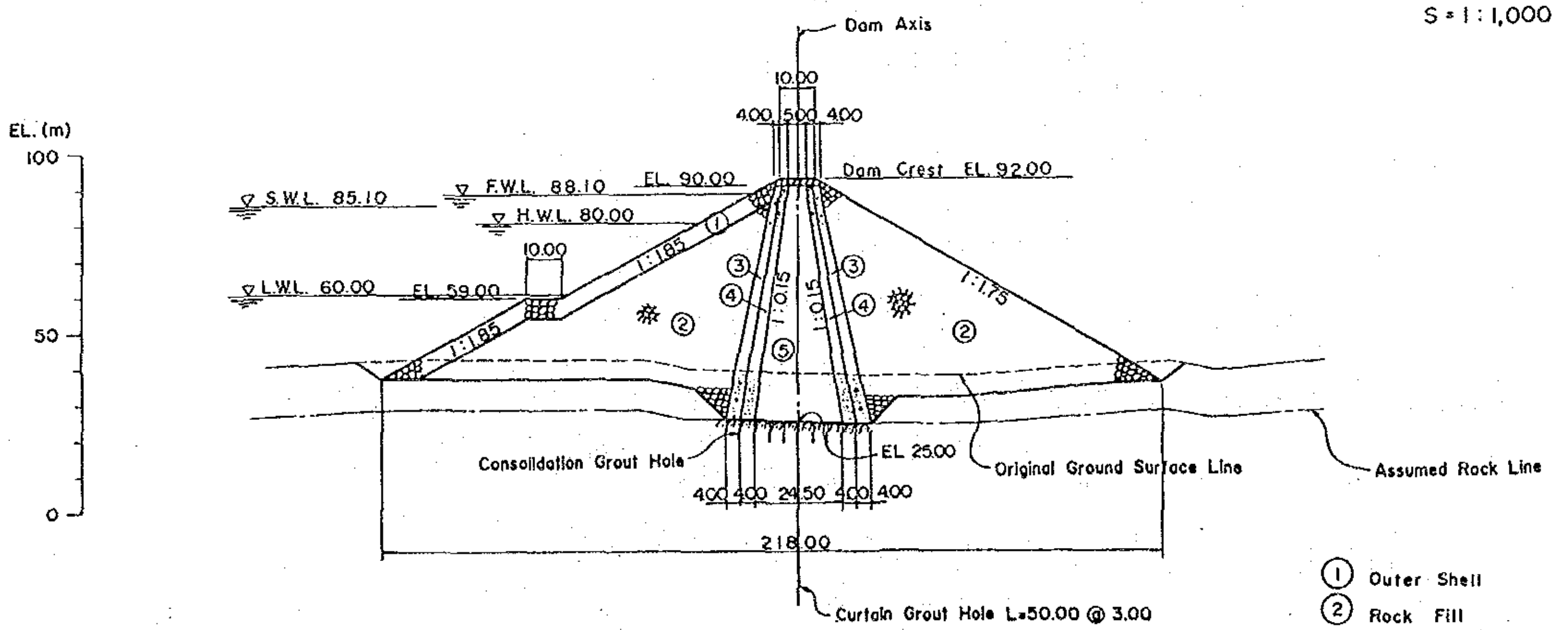
JAPAN INTERNATIONAL COOPERATION AGENCY

PLAN OF
SADDLE DAM I & II

DATE	DRAWING NO.
,1989	LDP - -



Longitudinal Section
S = 1 : 1,000



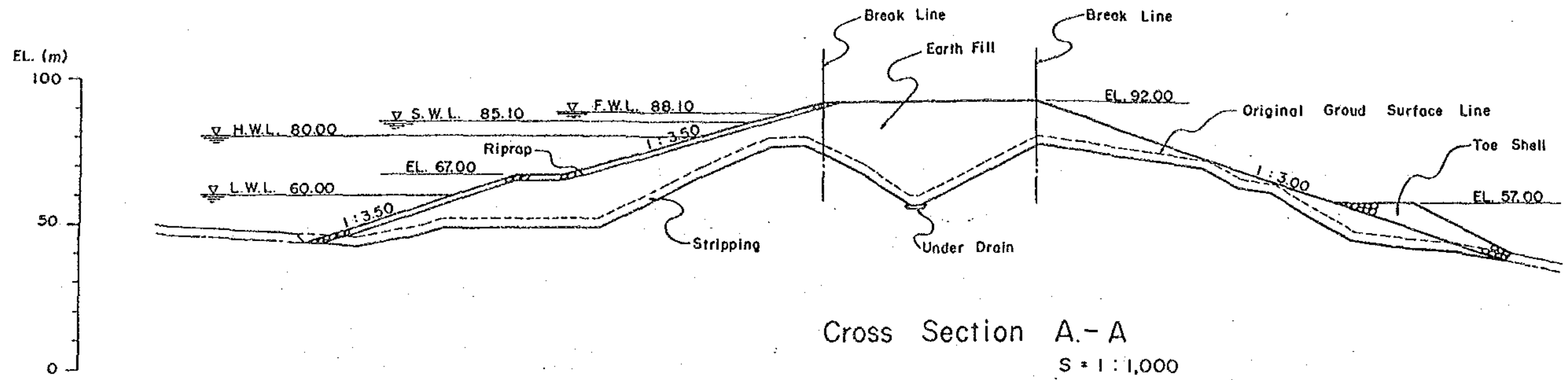
Typical Section
S = 1 : 1,000

(1) Outer Shell
(2) Rock Fill
(3) Coarse Filter
(4) Fine Filter
(5) Core

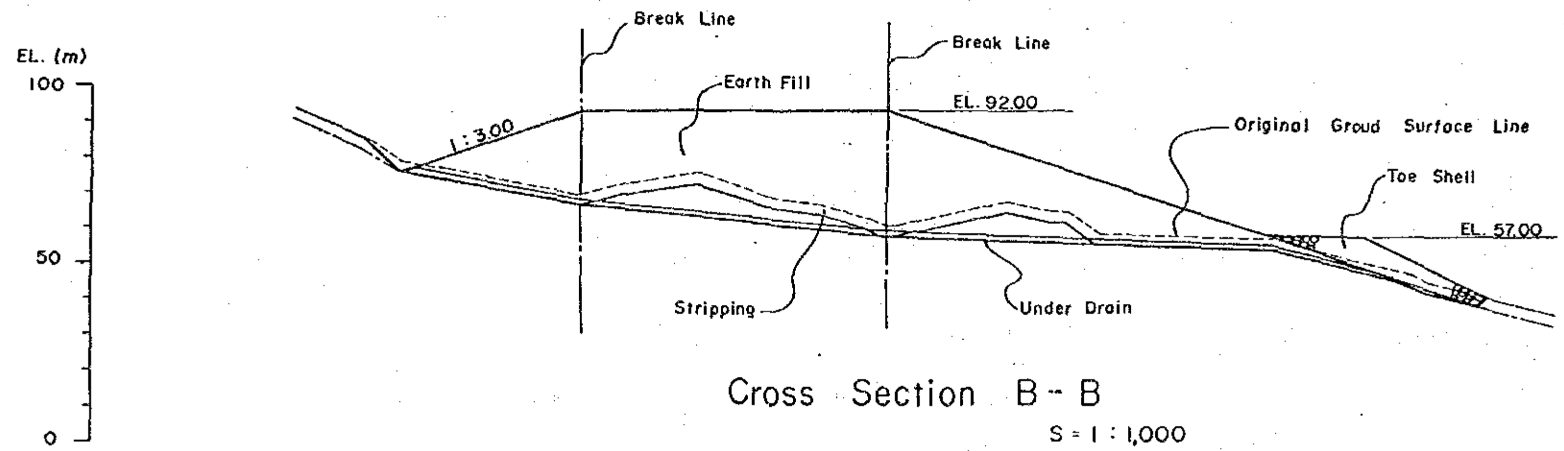
S = 1 : 1,000 0 20 40 60 80 100 (m)

Fig.9-0-5

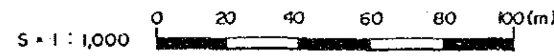
LEBIR DAM PROJECT FEASIBILITY STUDY KELANTAN, MALAYSIA	
JAPAN INTERNATIONAL COOPERATION AGENCY	
SADDLE DAM I SECTIONS	
DATE Mar. 1989	DRAWING NO. LDP I - 005

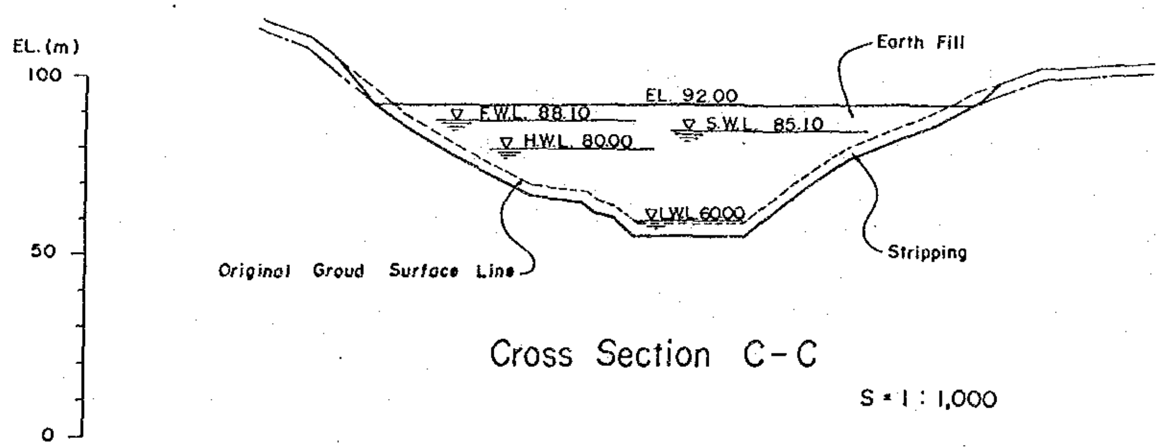


Cross Section A.- A
S = 1 : 1,000



Cross Section B - B
S = 1 : 1,000





Cross Section C - C
S = 1 : 1,000

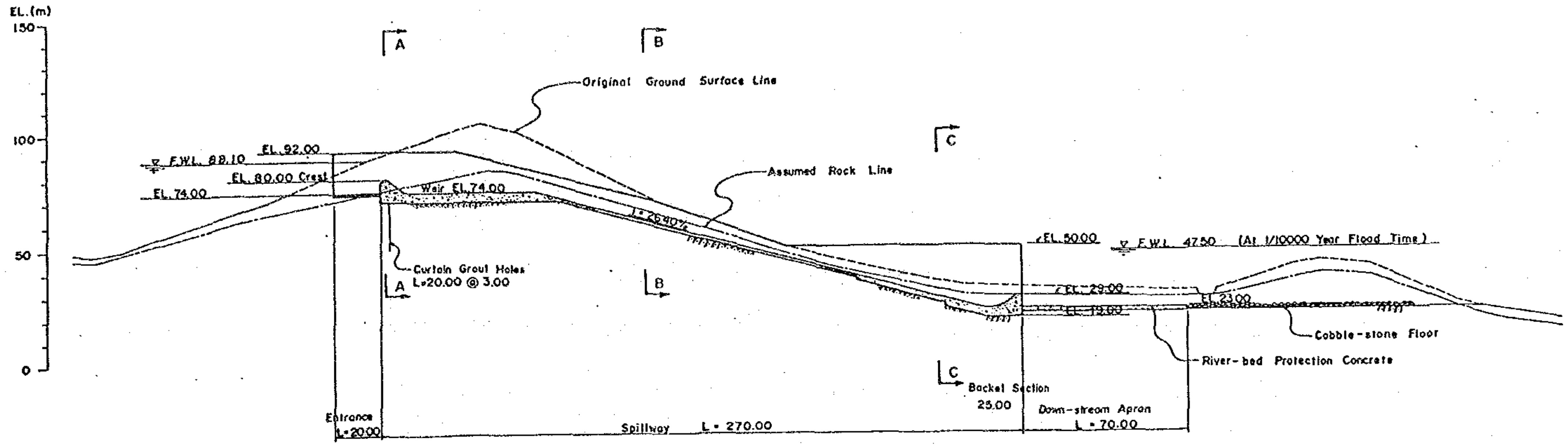
Fig.9-0-6

LEBIR DAM PROJECT
FEASIBILITY STUDY
KERANTAN, MALAYSIA

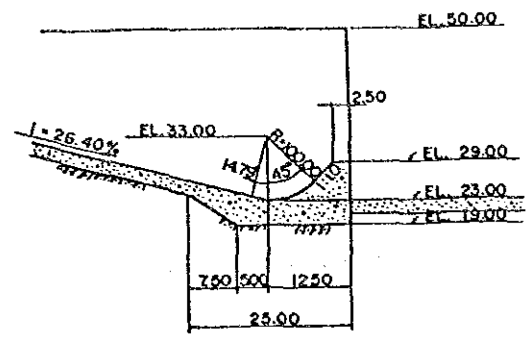
JAPAN INTERNATIONAL COOPERATION AGENCY

SADDLE DAM II
CROSS SECTIONS

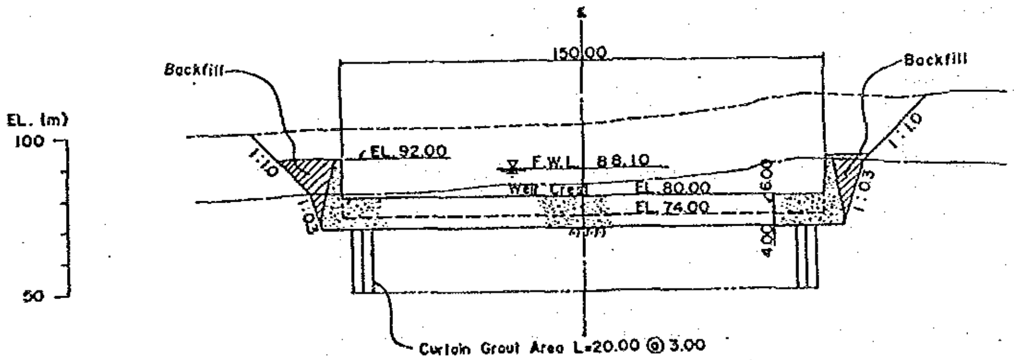
DATE	DRAWING NO.
Mar. 1989	LDP 1 - 006



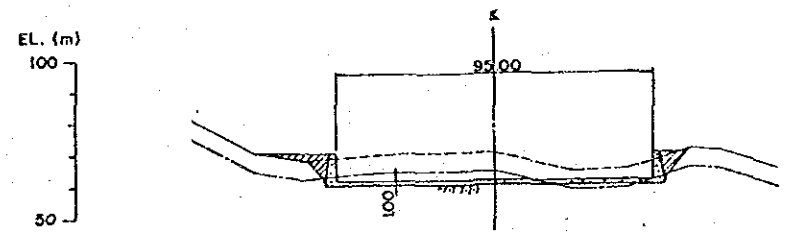
Profile
S = 1 : 1,000



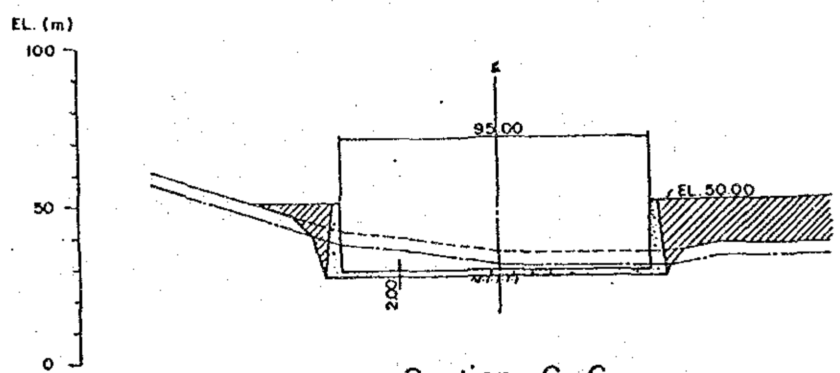
Detail of Backet
S = 1 : 500



Section A - A
(Development Profile)
S = 1 : 1,000



Section B - B
S = 1 : 1,000



Section C - C
S = 1 : 1,000

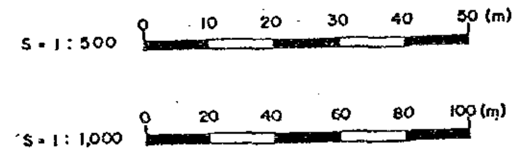


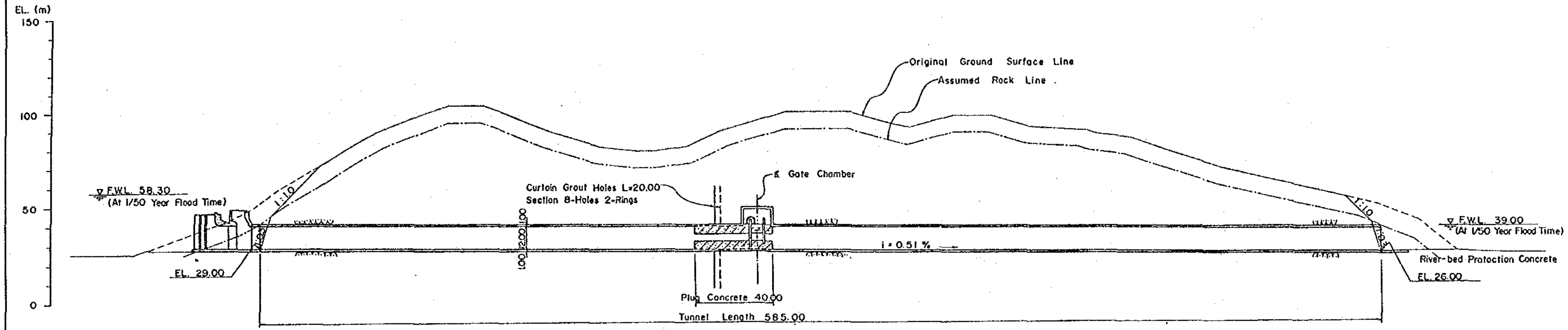
Fig.9-0-7

LEBIR DAM PROJECT
FEASIBILITY STUDY
KELANTAN, MALAYSIA

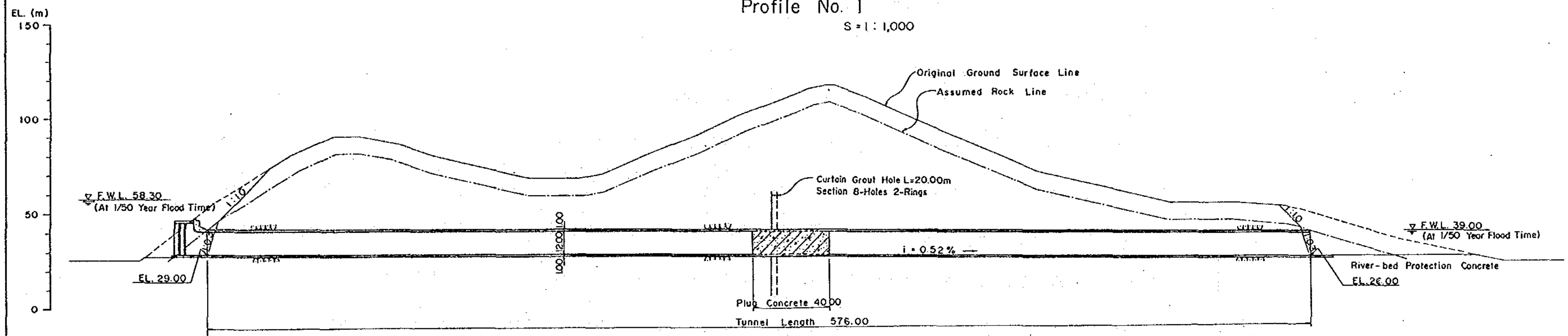
JAPAN INTERNATIONAL COOPERATION AGENCY

SPILLWAY
PROFILE AND CROSS SECTIONS

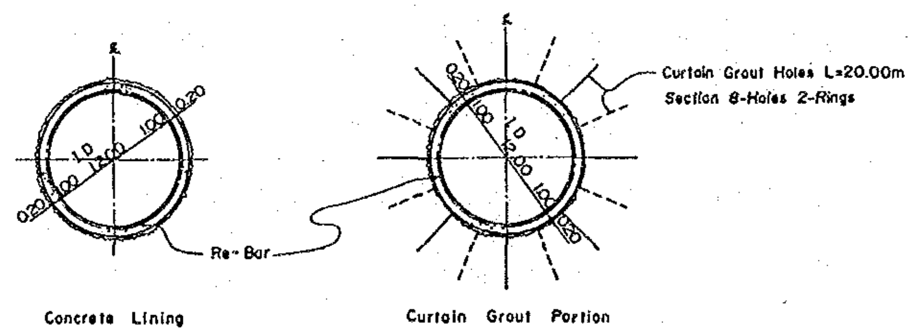
DATE	DRAWING NO.
Mar. 1989	LDP 1 - 007



Profile No. 1
S = 1 : 1,000



Profile No. 2
S = 1 : 1,000



Typical Section
S = 1 : 300

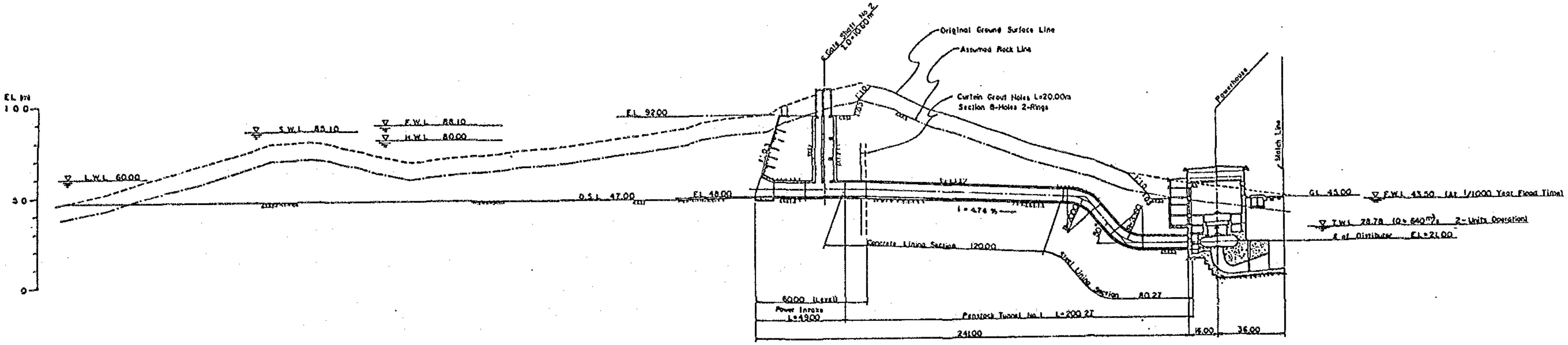
S = 1 : 300 — 0 5 10 15 20 25 30 (m)

S = 1 : 1,000 — 0 20 40 60 80 100 (m)

Fig.9-0-8

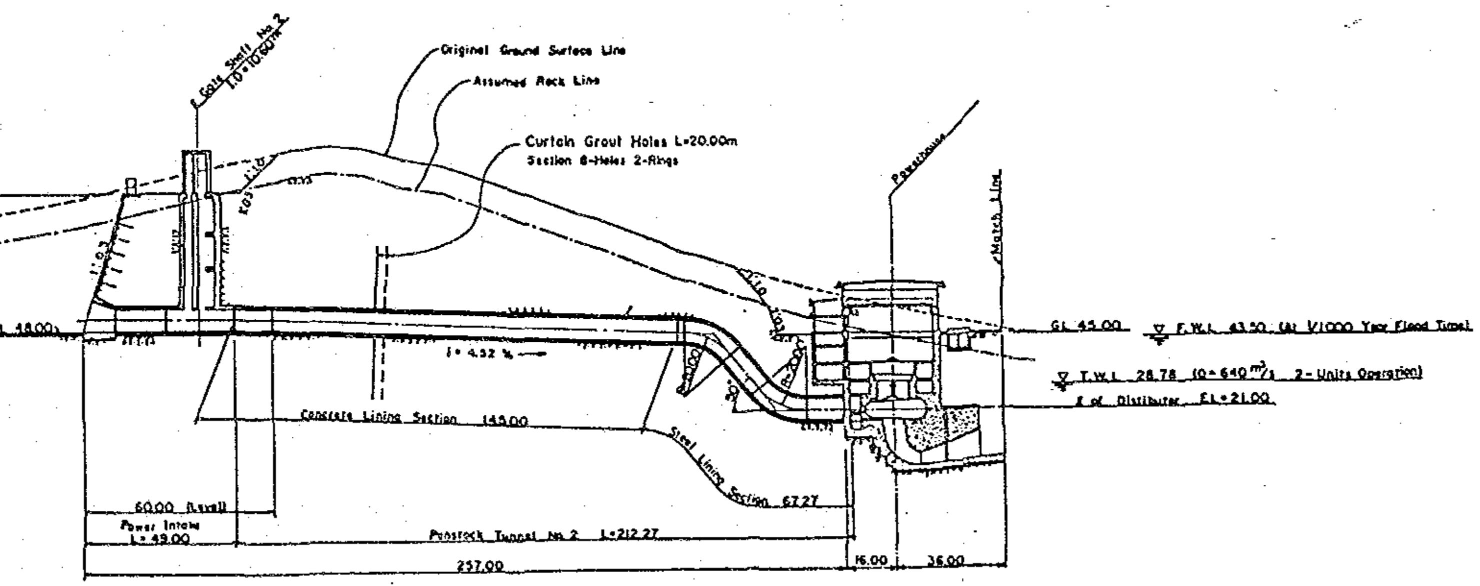
LEBIR DAM PROJECT FEASIBILITY STUDY KELANTAN, MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY
DIVERSION TUNNEL PROFILES AND TYPICAL SECTIONS

DATE	DRAWING NO.
Mar. 1989	LDP I - 008



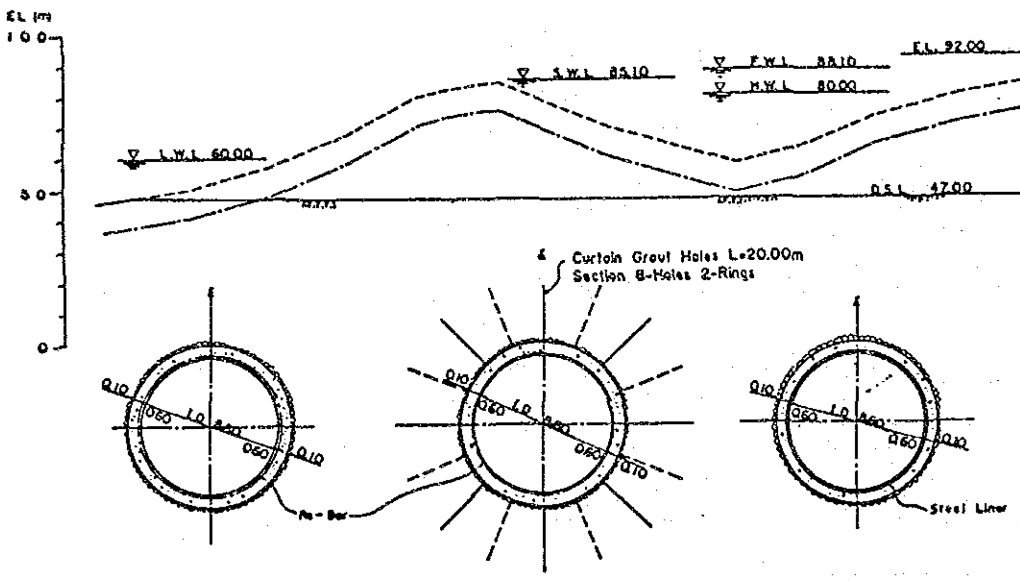
Profile No 1

S= 1:1000



Profile No 2

S=1:1000



Typical Sections

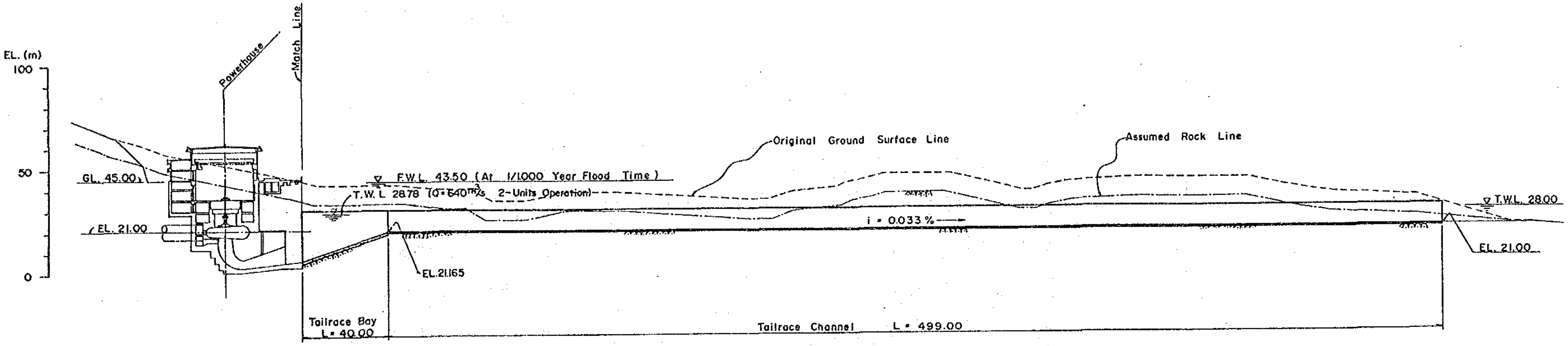
S=1:200

S=1:200 0 5 10 15 20 m

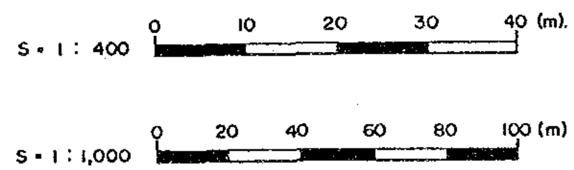
S=1:1,000 0 20 40 60 80 100 m

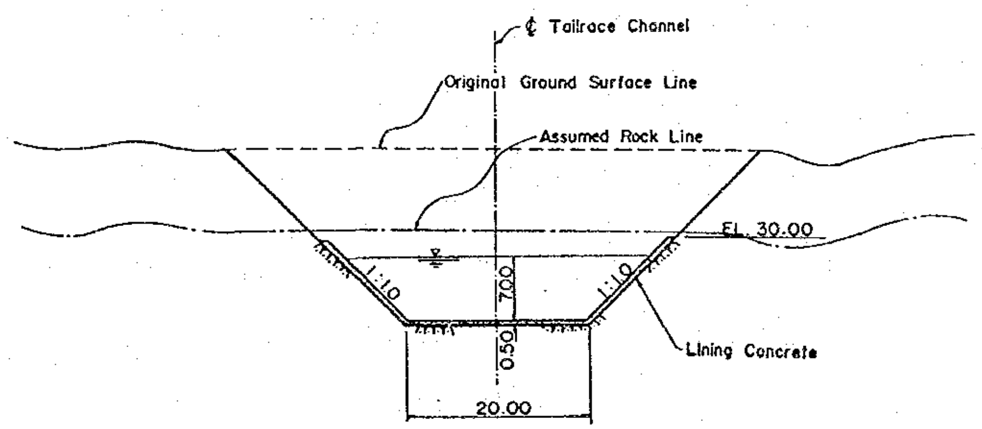
Fig.9-0-9

LEBIR DAM PROJECT FEASIBILITY STUDY KELANTAN, MALAYSIA	
JAPAN INTERNATIONAL COOPERATION AGENCY	
POWER WATERWAY (1) PROFILES AND TYPICAL SECTIONS	
DATE Mar. 1989	DRAWING NO. LDP I - 009



Profile
S = 1 : 1,000



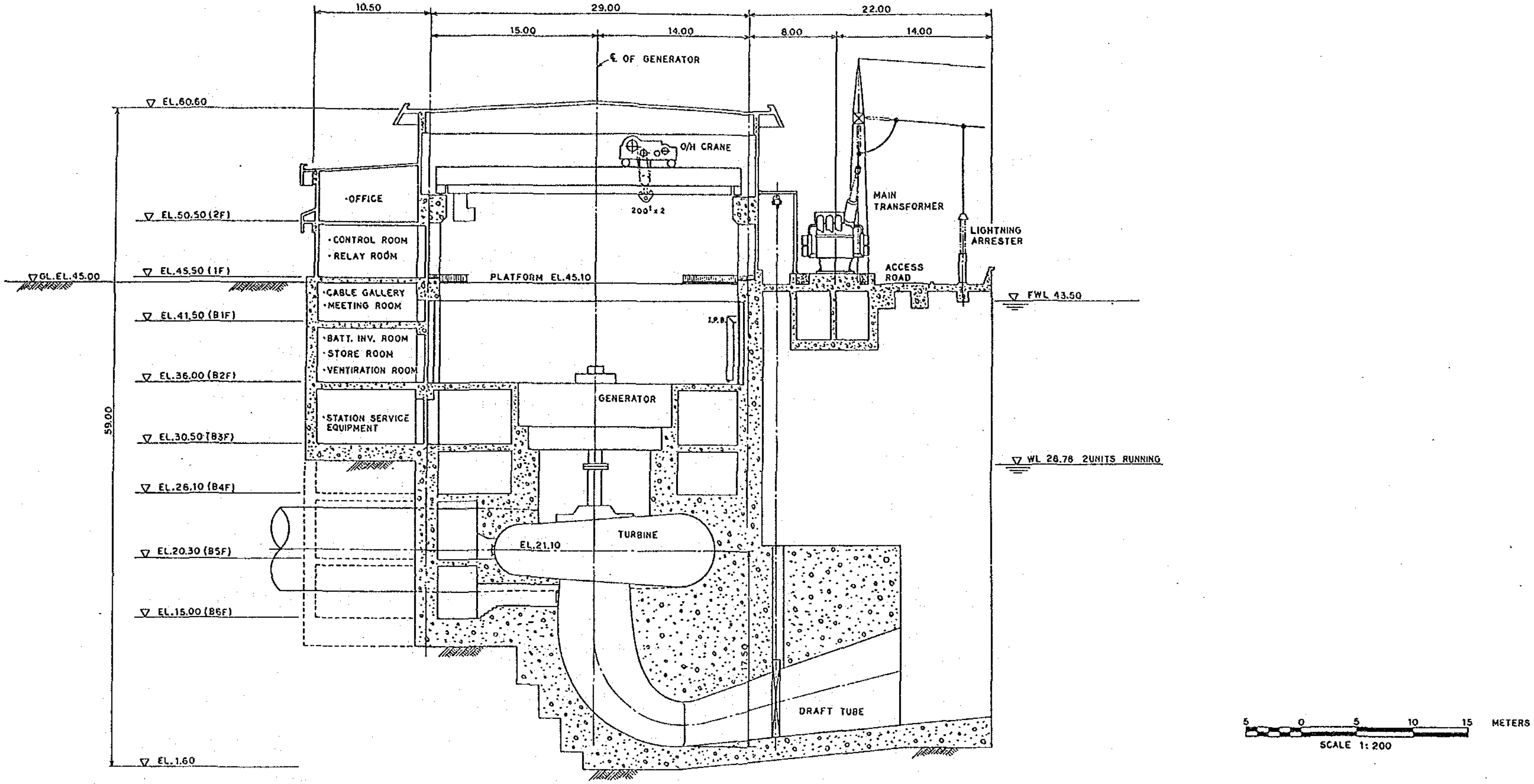


Typical Section
S = 1 : 400

Fig.9-0-10

LEBIR DAM PROJECT FEASIBILITY STUDY KELANTAN, MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY
POWER WATERWAY (II) TAILRACE CHANNEL PROFILE AND TYPICAL SECTION

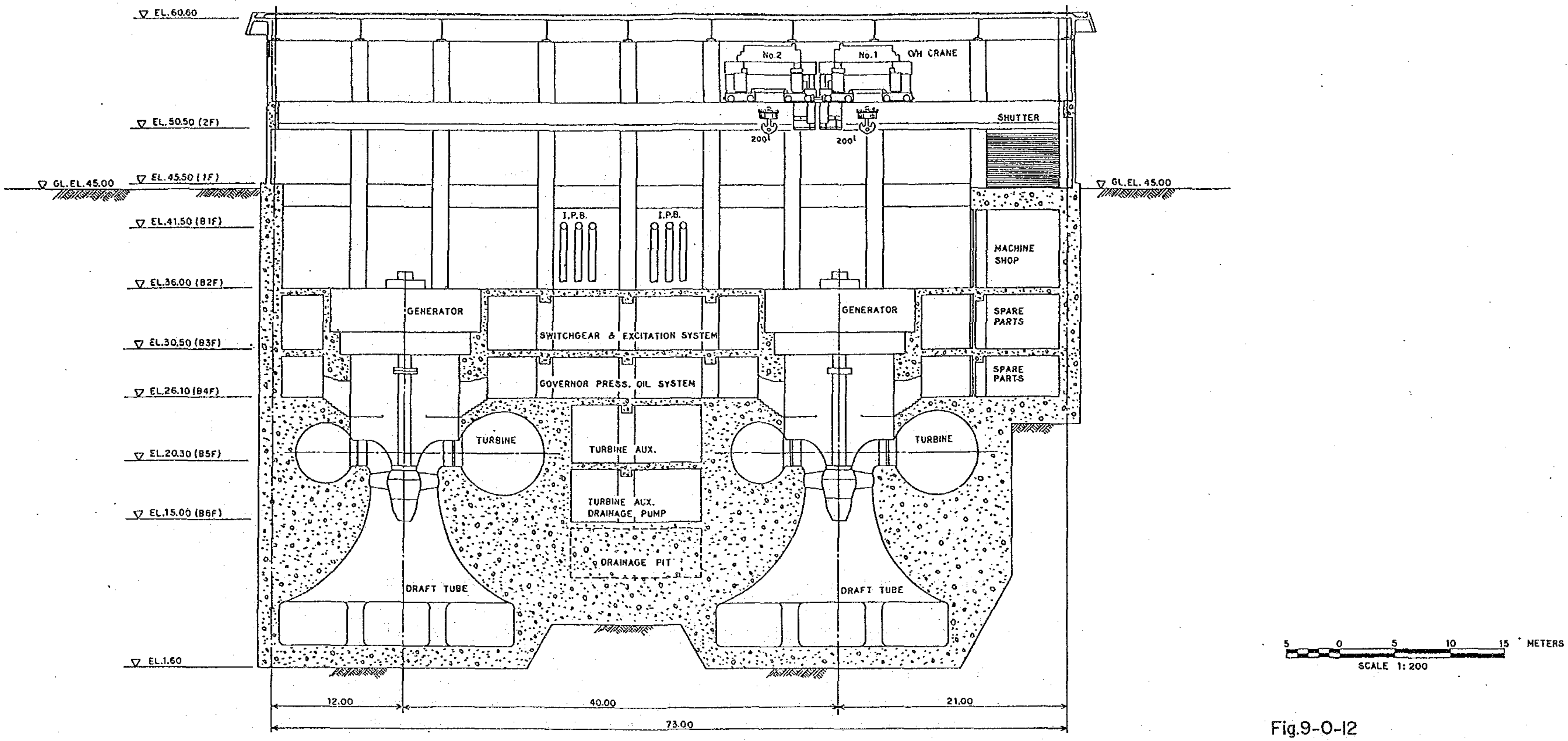
DATE	DRAWING NO.
Mar. 1989	LDP I - 010



CROSS SECTION

Fig.9-0-11

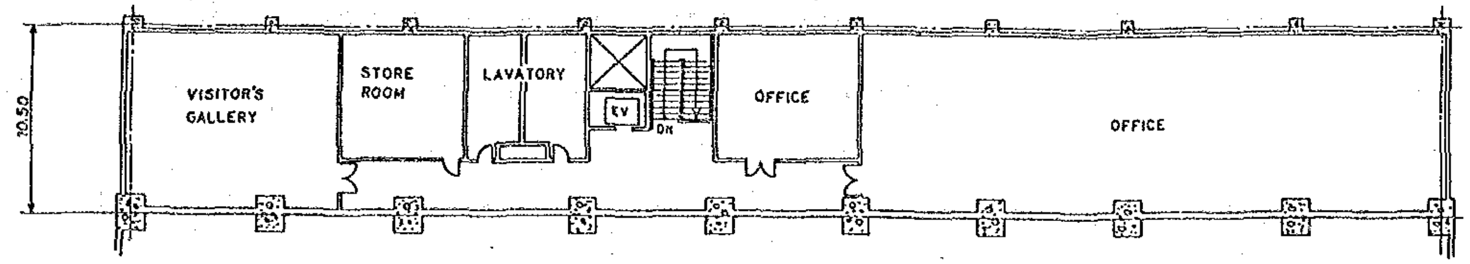
LEBIR DAM PROJECT FEASIBILITY STUDY KELANTAN, MALAYSIA	
JAPAN INTERNATIONAL COOPERATION AGENCY	
POWERHOUSE CROSS SECTION	
DATE Mar. 1989	DRAWING NO. LDP I - 011



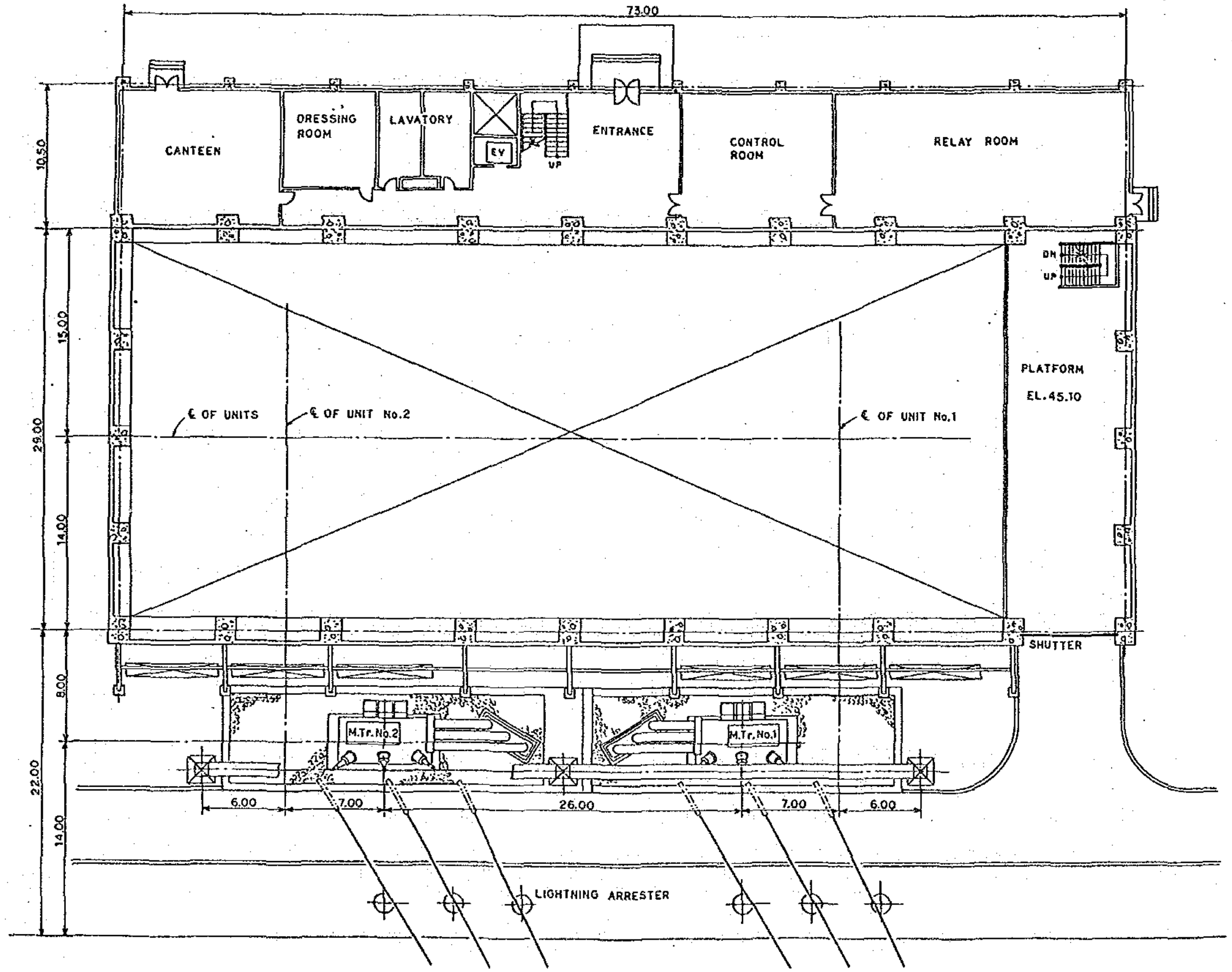
LONGITUDINAL SECTION

Fig.9-0-12

LEBIR DAM PROJECT FEASIBILITY STUDY KELANTAN, MALAYSIA	
JAPAN INTERNATIONAL COOPERATION AGENCY	
POWERHOUSE LONGITUDINAL SECTION	
DATE Mar. 1989	DRAWING NO. LDP 1 - 012



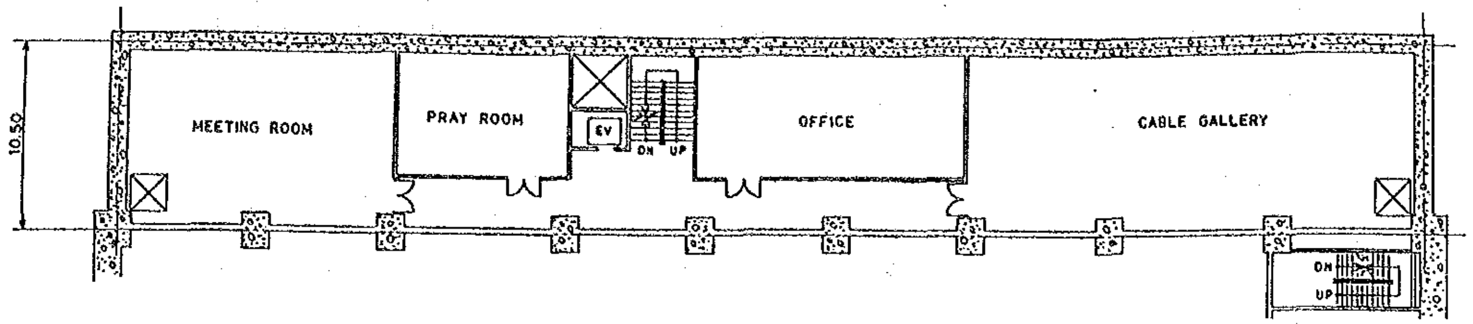
FLOOR (2F) EL.50.50



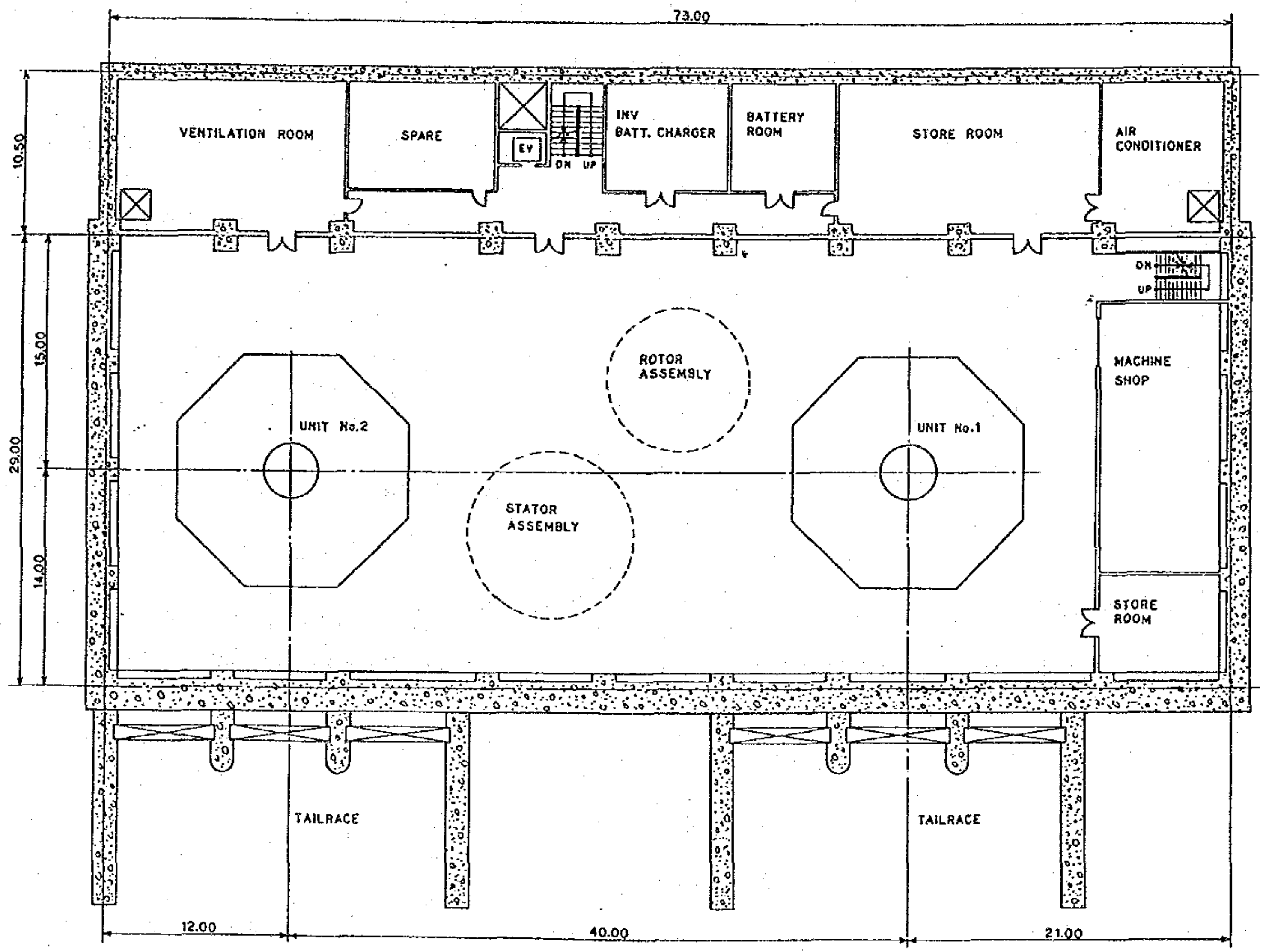
FLOOR (1F) EL.45.50 & M.Tr. YARD

Fig.9-0-13

LEBIR DAM PROJECT FEASIBILITY STUDY KELANTAN, MALAYSIA	
JAPAN INTERNATIONAL COOPERATION AGENCY	
POWERHOUSE PLAN FLOOR 1F, 2F AND M.Tr. YARD	
DATE Mar. 1989	DRAWING NO. LDP I - 013



FLOOR (B1F) EL.41.50



FLOOR (B2F) EL.36.00

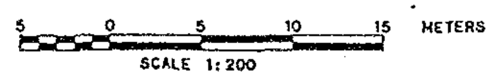


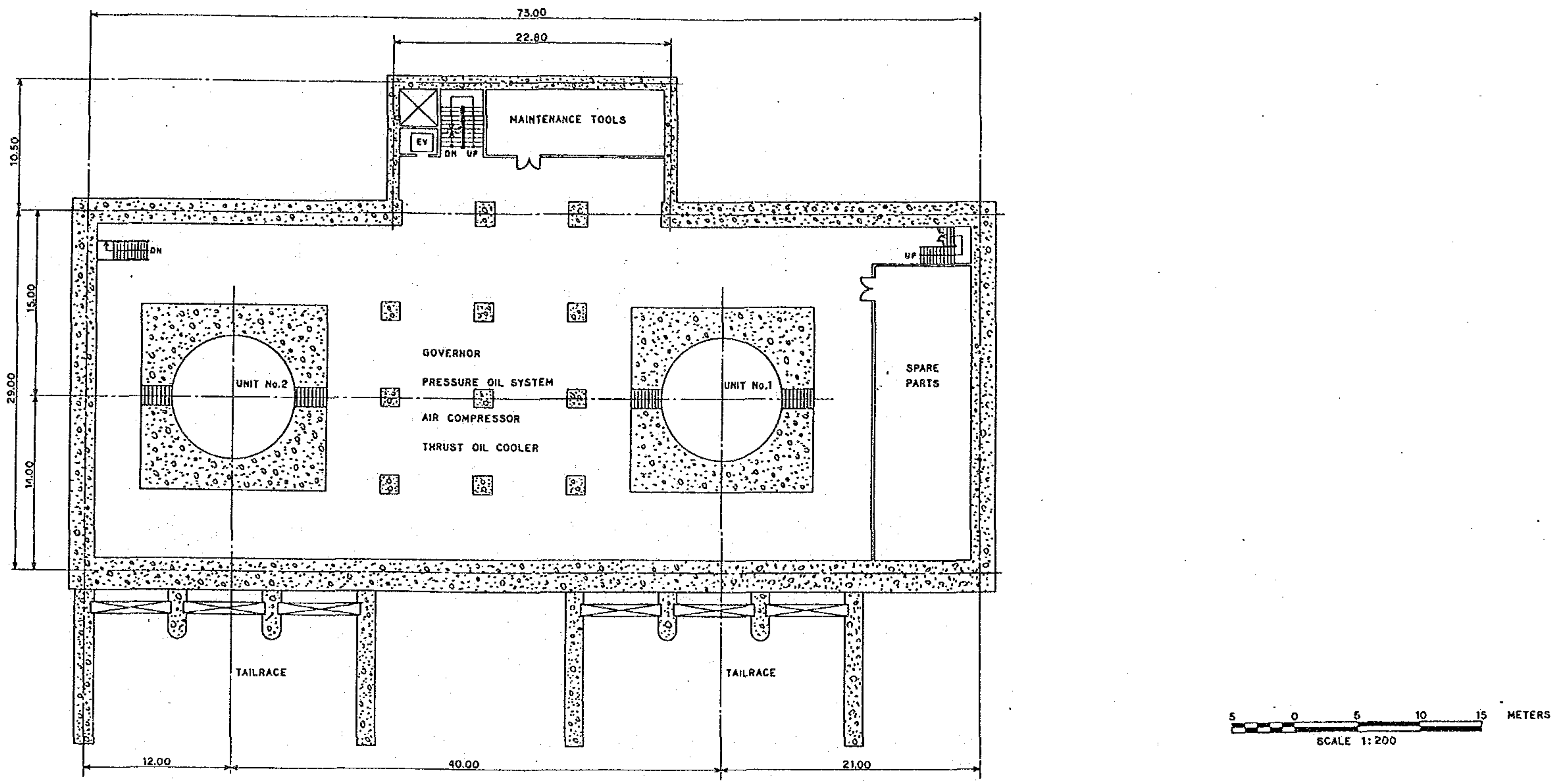
Fig.9-0-14

LEBIR DAM PROJECT
FEASIBILITY STUDY
KELANTAN, MALAYSIA

JAPAN INTERNATIONAL COOPERATION AGENCY

POWERHOUSE
PLAN
FLOOR B1F AND B2F

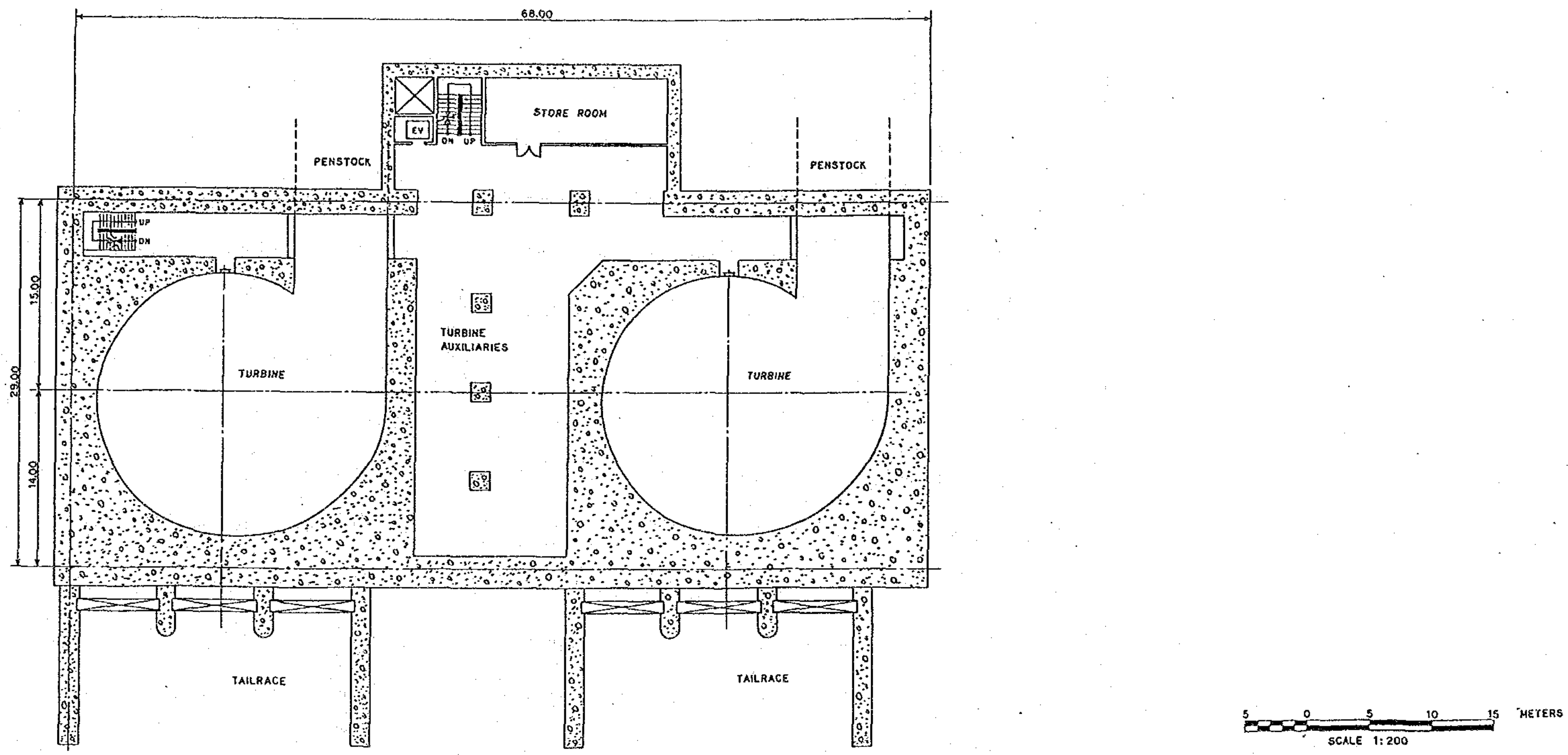
DATE	DRAWING NO.
Mar. 1989	LDP I - 014



FLOOR (B4F) EL.26.10

Fig.9-0-15

LEBIR DAM PROJECT FEASIBILITY STUDY KELANTAN, MALAYSIA	
JAPAN INTERNATIONAL COOPERATION AGENCY	
POWERHOUSE PLAN FLOOR B4F	
DATE Mar. 1989	DRAWING NO. LDP I - 015



FLOOR (B5F) EL.20.30

Fig.9-0-16

LEBIR DAM PROJECT FEASIBILITY STUDY KELANTAN, MALAYSIA	
JAPAN INTERNATIONAL COOPERATION AGENCY	
POWERHOUSE PLAN FLOOR B5F	
DATE Mar. 1989	DRAWING NO. LDP I - 016

Fig.9-2-1(1) Stability Analysis of Main Dam

Load Condition

Water Level (m)	Normal Case	Seismic Case
Reservoir empty	Case 1	Case 7
WL = 88.1	Case 2	-
WL = 85.1	Case 3	Case 8
WL = 80.0	Case 4	Case 9
WL = 70.0	Case 5	Case 10
WL = 60.0	Case 6	Case 11

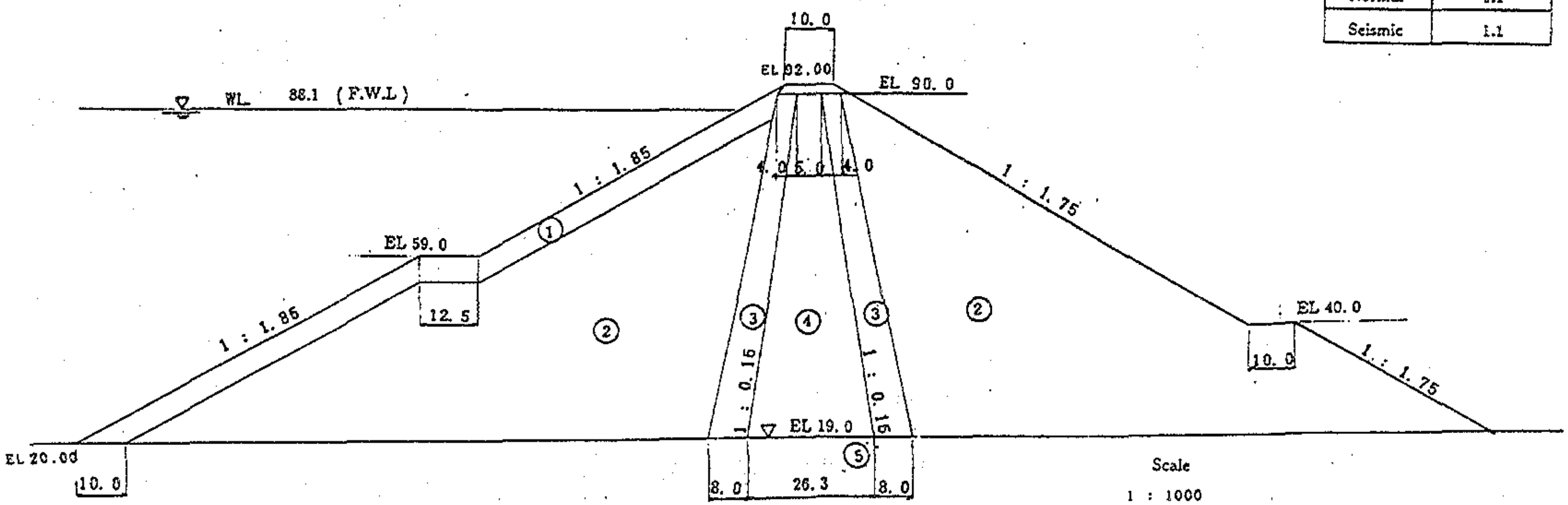
Note : horizontal accelaration k = 0.05 in case 7 and case 8,
k = 0.1 in other cases

Physical Properties of Embankment Material

	Material	γ (t/m^3)	γ' (t/m^3)	C (t/m^3)	ϕ (°)
Outer shell	①	1.85	2.10	0.00	43.00
Rock fill	②	1.85	2.10	0.00	41.00
Filters	③	1.85	2.10	0.00	35.00
Core	④	1.85	1.90	0.00	30.00
Foundation rock	⑤	2.50	2.50	20.00	50.00

Required Safety Factor

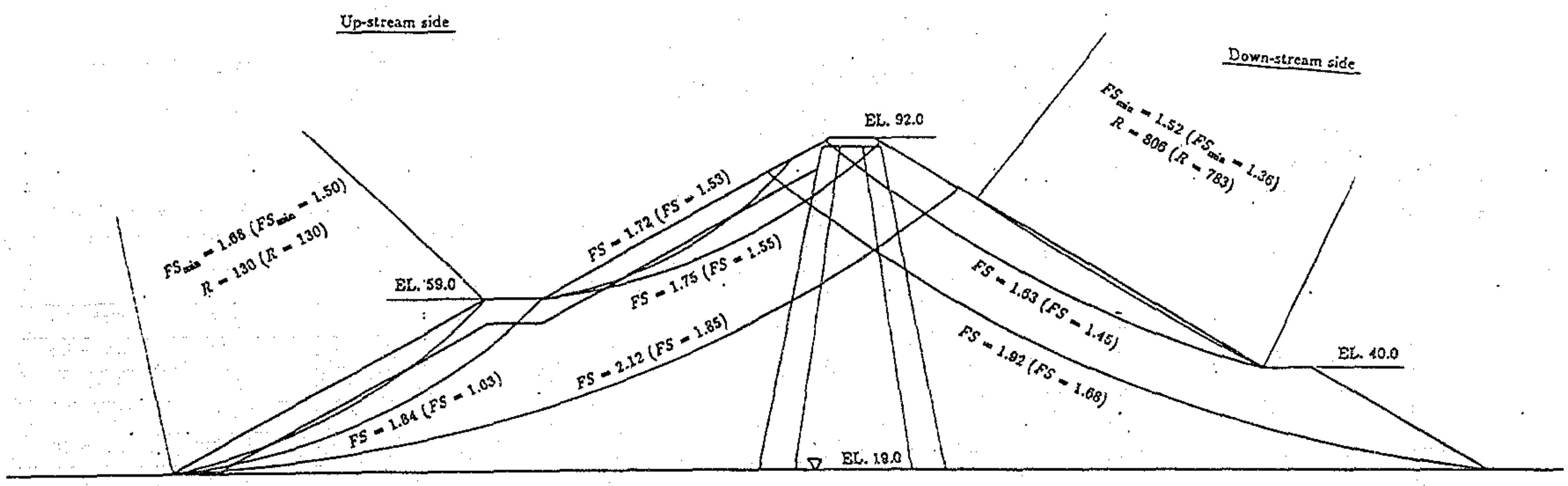
Condition	F.S.
Normal	1.1
Seismic	1.1



Scale
1 : 1000
0 10.0 20.0 m

Fig. 9-2-1(2) Stability Analysis of Main Dam (Result-1)

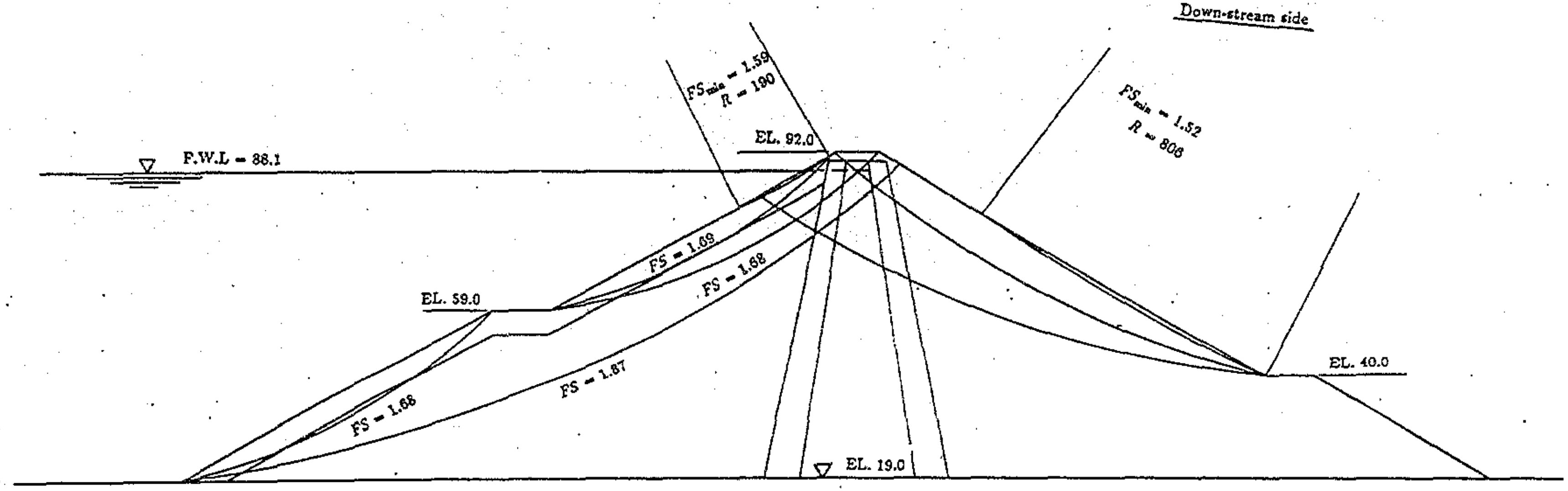
Load condition Case 1 and Case 7 reservoir empty



Note : -figures in bracket show the seismic case
-R presents a radius of a slip circle in meter

Fig. 9-2-1(3) Stability Analysis of Main Dam (Result-2)

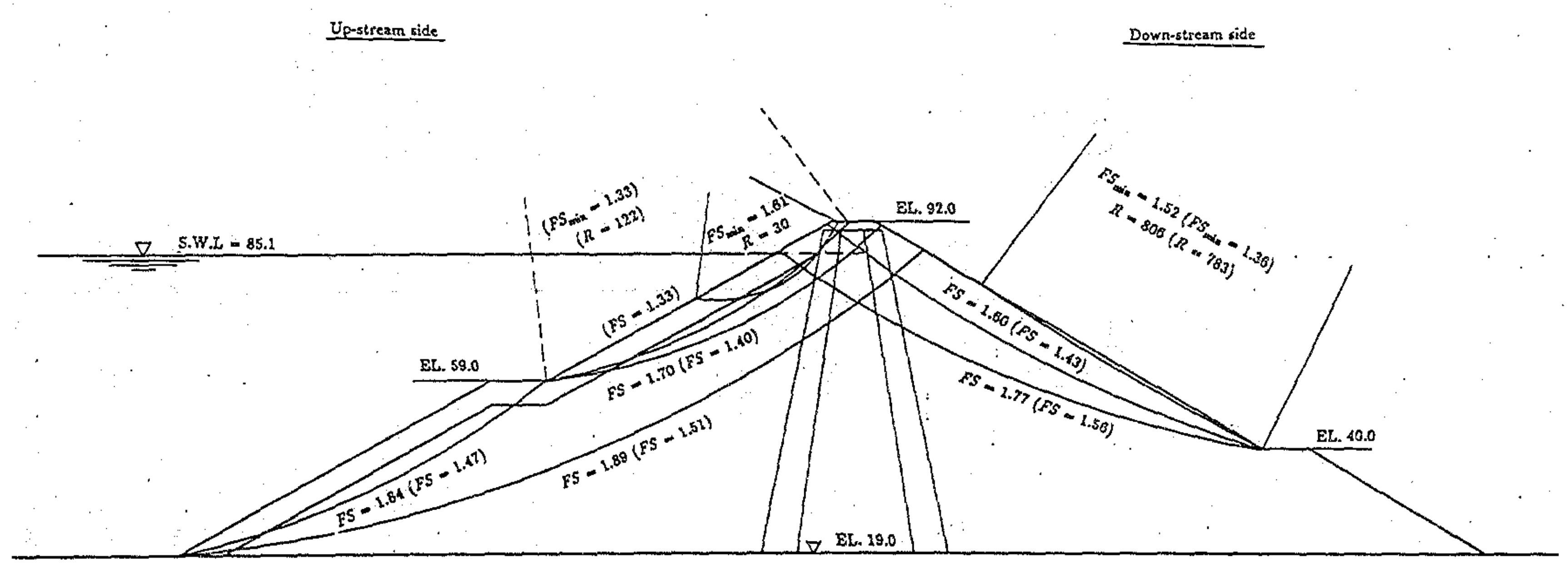
Load condition Case 2 F.W.L = 88.1 m



Note : -figures in bracket show the seismic case
-R presents a radius of a slip circle in meter

Fig. 9-2-1(4) Stability Analysis of Main Dam (Result-3)

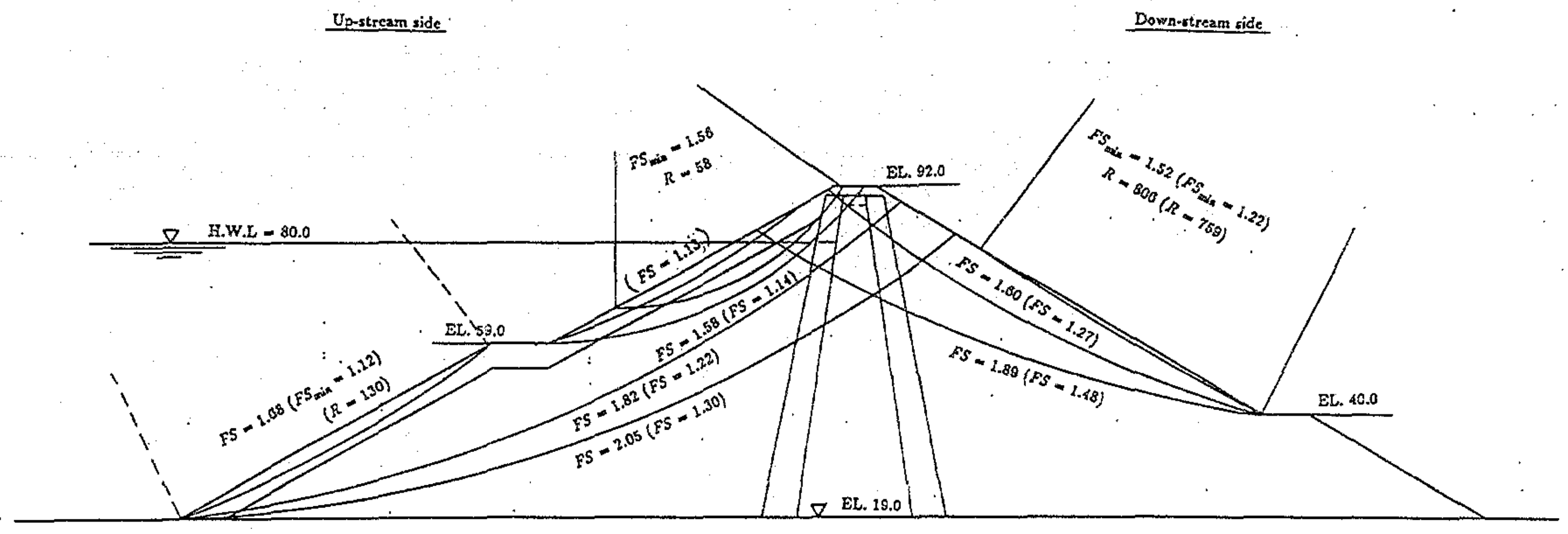
Load condition Case 3 and Case 8 S.W.L = 85.1 m



Note : -figures in bracket show the seismic case
-R presents a radius of a slip circle in meter

Fig. 9-2-1(5) Stability Analysis of Main Dam (Result-4)

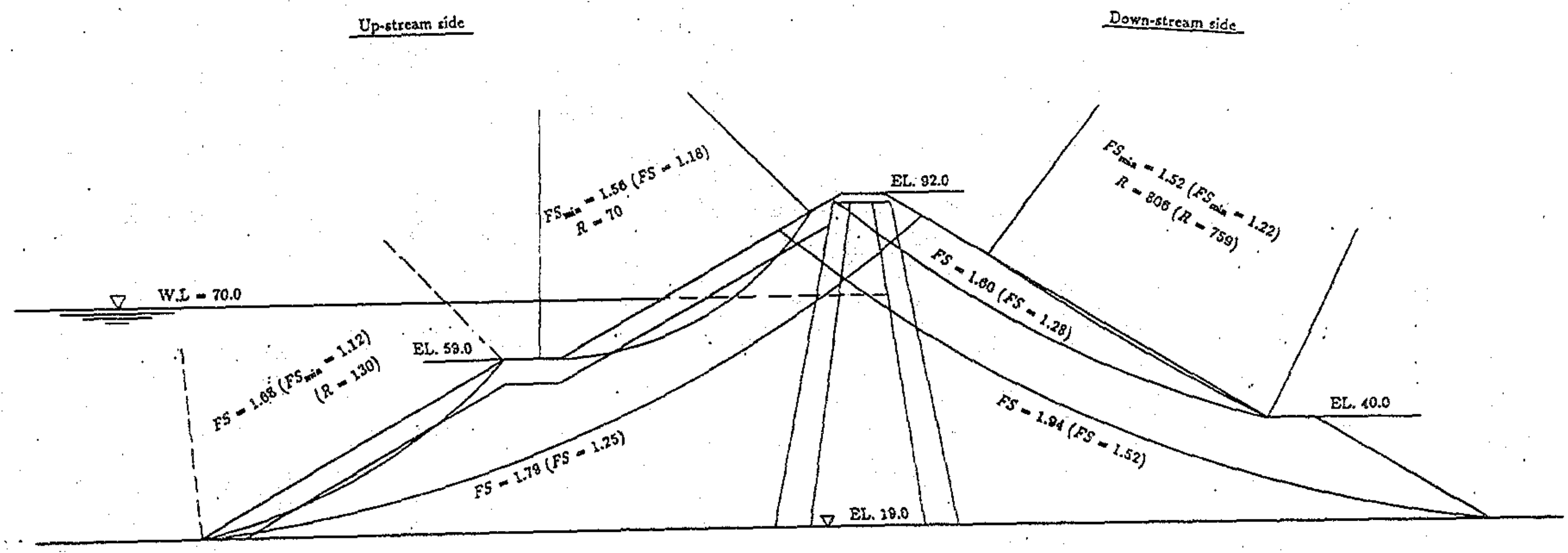
Load condition Case 4 and Case 9 H.W.L = 80.0 m



Note : -figures in bracket show the seismic case
-R presents a radius of a slip circle in meter

Fig. 9-2-1(6) Stability Analysis of Main Dam (Result-5)

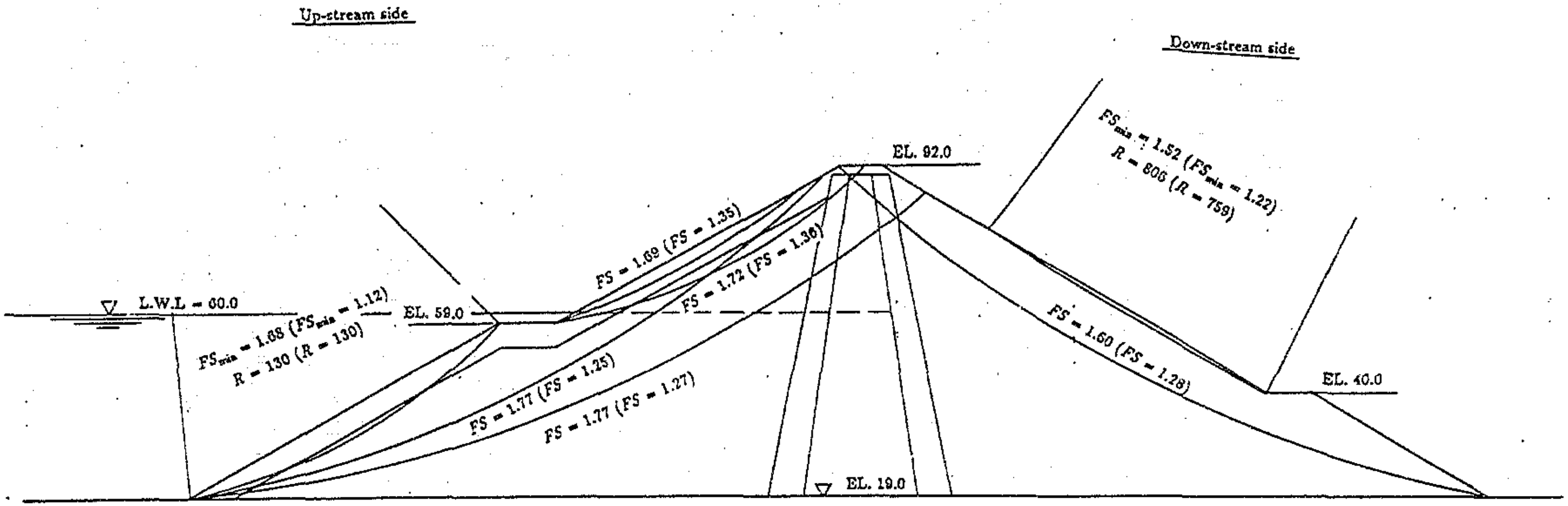
Load condition Case 5 and Case 10   W.L = 70.0 m



Note : -figures in bracket show the seismic case
-R presents a radius of a slip circle in meter

Fig. 9-2-1(7) Stability Analysis of Main Dam (Result-6)

Load condition Case 6 and Case 11   L.W.L = 60.0 m



Note : -figures in bracket show the seismic case
-R presents a radius of a slip circle in meter

Fig. 9-2-2(1) Stability Analysis of Saddle Dam (I)

Load Condition

Water Level (m)	Normal Case	Seismic Case
Reservoir empty	Case 1	Case 7
WL = 88.1	Case 2	-
WL = 85.1	Case 3	Case 8
WL = 80.0	Case 4	Case 9
WL = 70.0	Case 5	Case 10
WL = 60.0	Case 6	Case 11

Note : horizontal acceleration k = 0.05 in case 7 and case 8,
k = 0.1 in other cases

Physical Properties of Embankment Material

	Material	γ (t/m³)	γ' (t/m³)	C (t/m³)	φ (°)
Outer shell	①	1.85	2.10	0.00	43.00
Rock fill	②	1.85	2.10	0.00	41.00
Filters	③	1.85	2.10	0.00	35.00
Core	④	1.85	1.90	0.00	30.00
Foundation rock	⑤	2.50	2.50	20.00	50.00

Required Safety Factor

Condition	F.S.
Normal	1.1
Seismic	1.1

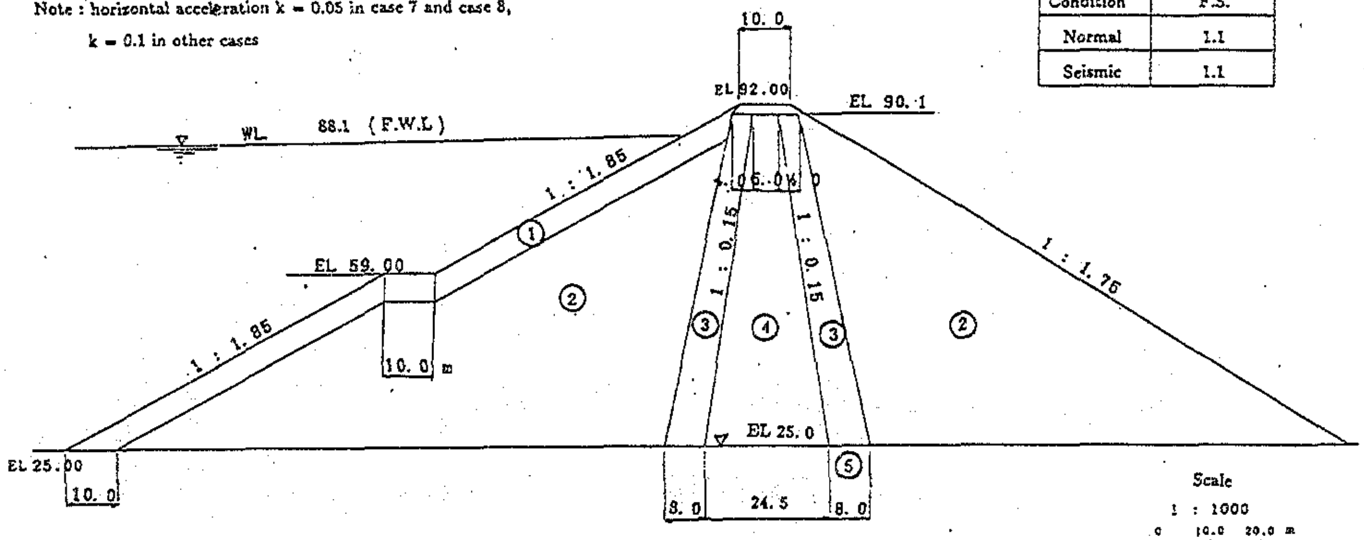
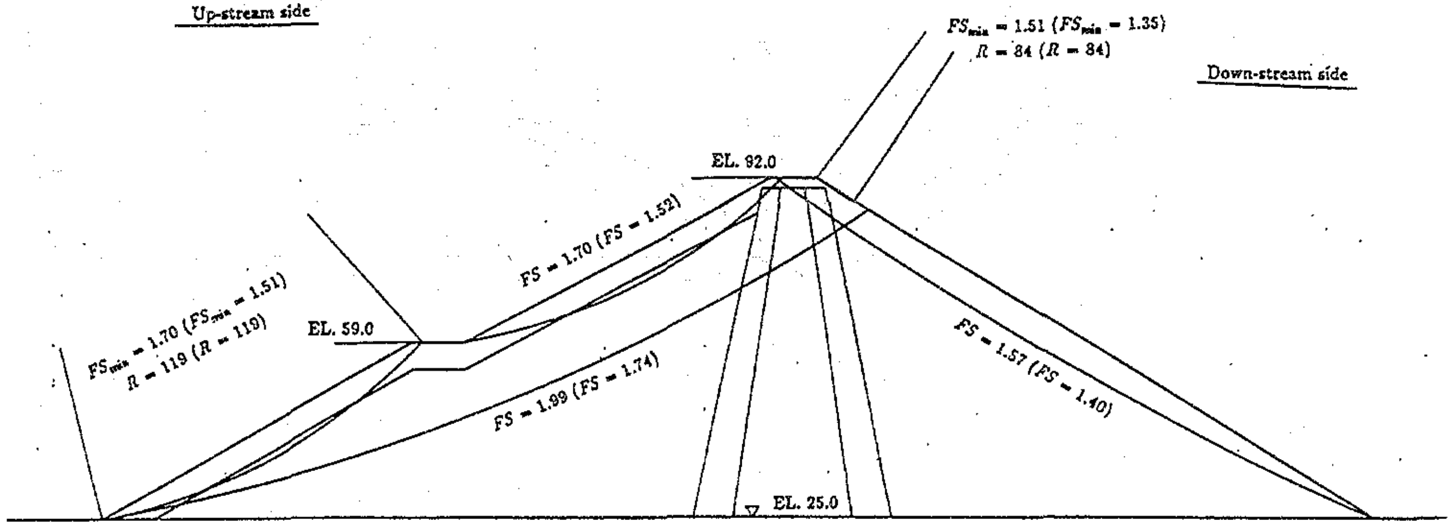


Fig. 9-2-2(2) Stability Analysis of Saddle Dam (-I) (Result-1)

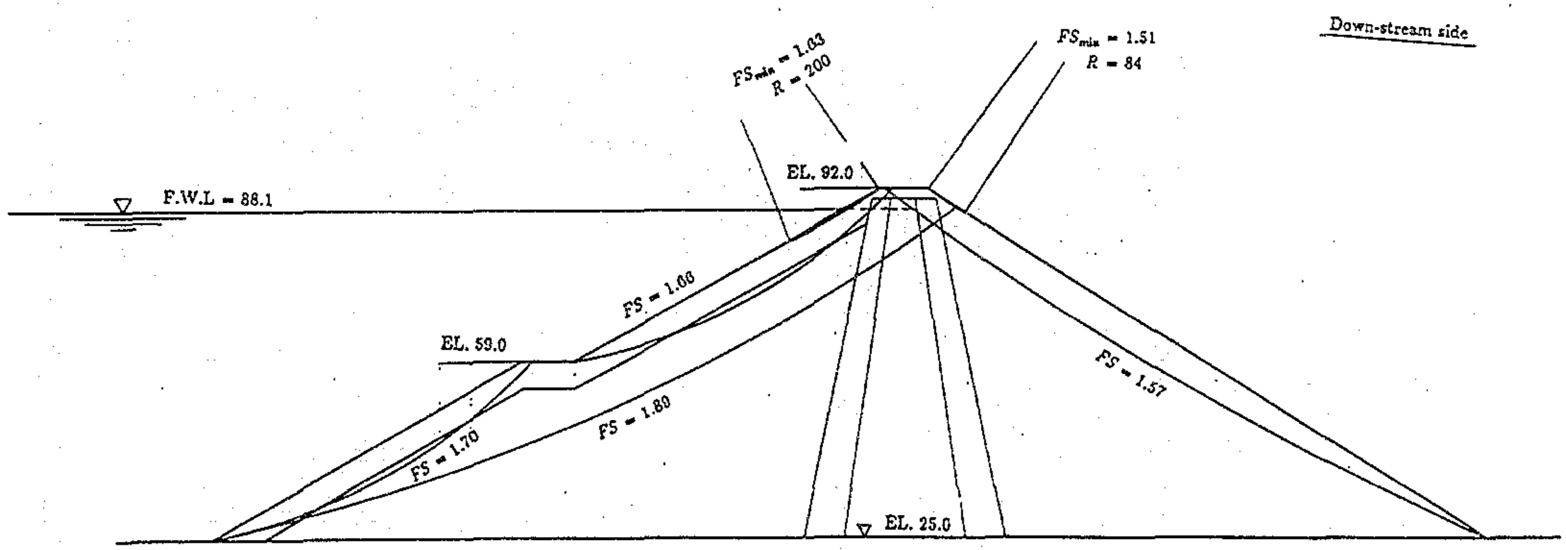
Load condition Case 1 and Case 7 reservoir empty



Note : -figures in bracket show the seismic case
-R presents a radius of a slip circle in meter

Fig. 9-2-2(3) Stability Analysis of Saddle Dam (II) (Result-2)

Load condition Case 2 F.W.L = 88.1 m

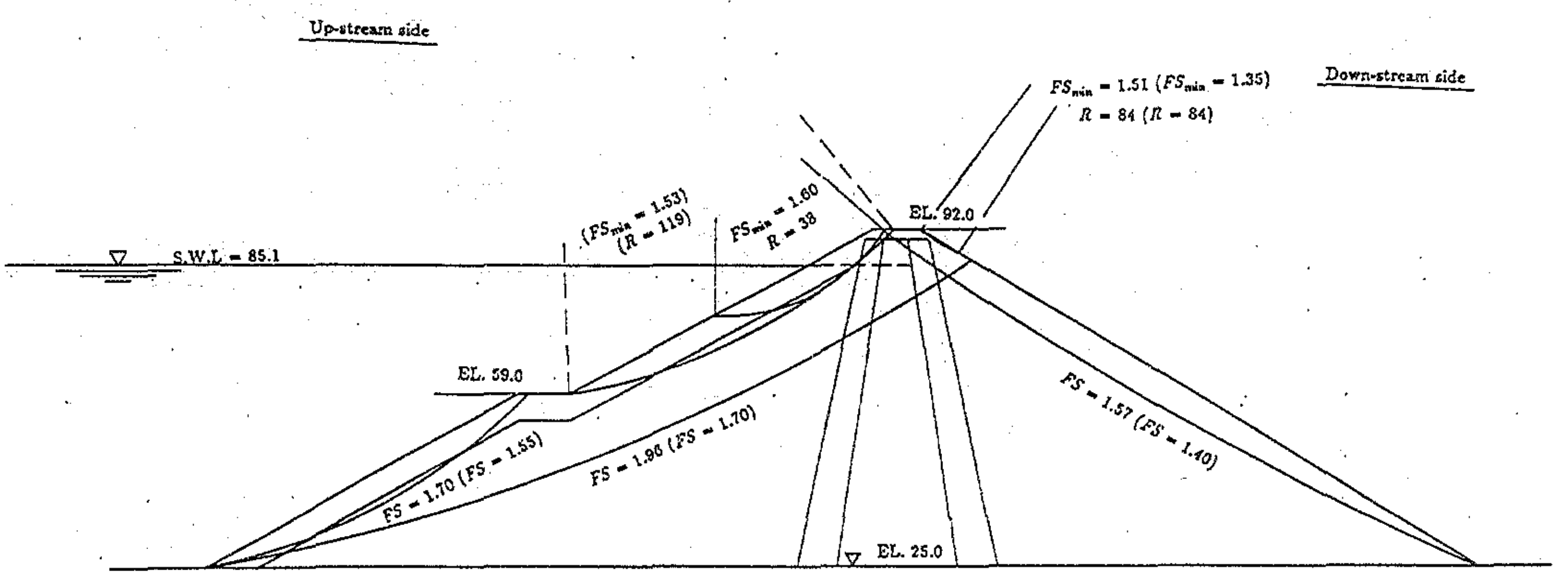


Note : -figures in bracket show the seismic case

-R presents a radius of a slip circle in meter

Fig.9-2-2(4) Stability Analysis of Saddle Dam (I) (Result-3)

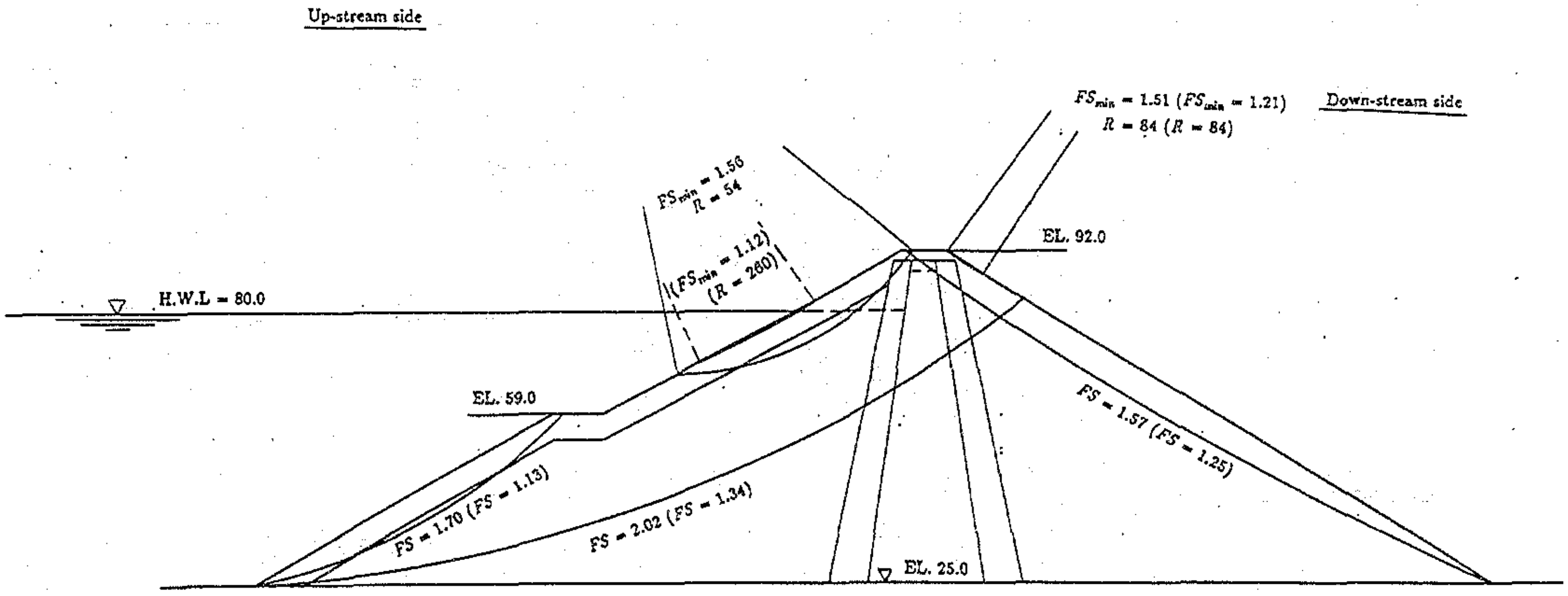
Load condition Case 3 and Case 8 S.W.L = 85.1 m



Note : -figures in bracket show the seismic case
-R presents a radius of a slip circle in meter

Fig. 9-2-2(5) Stability Analysis of Saddle Dam (I) (Result-4)

Load condition Case 4 and Case 9 H.W.L = 80.0 m

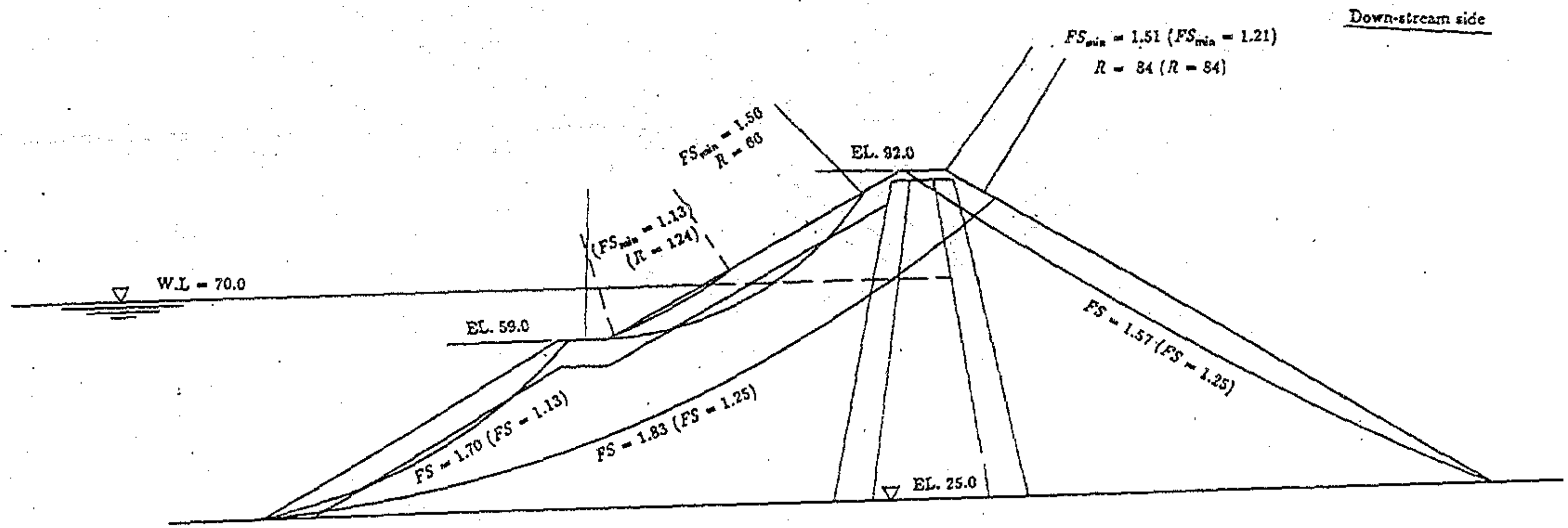


Note : -figures in bracket show the seismic case

-R presents a radius of a slip circle in meter

Fig. 9-2-2(6) Stability Analysis of Saddle Dam (I)(Result-5)

Load condition Case 5 and Case 10   W.L = 70.0 m

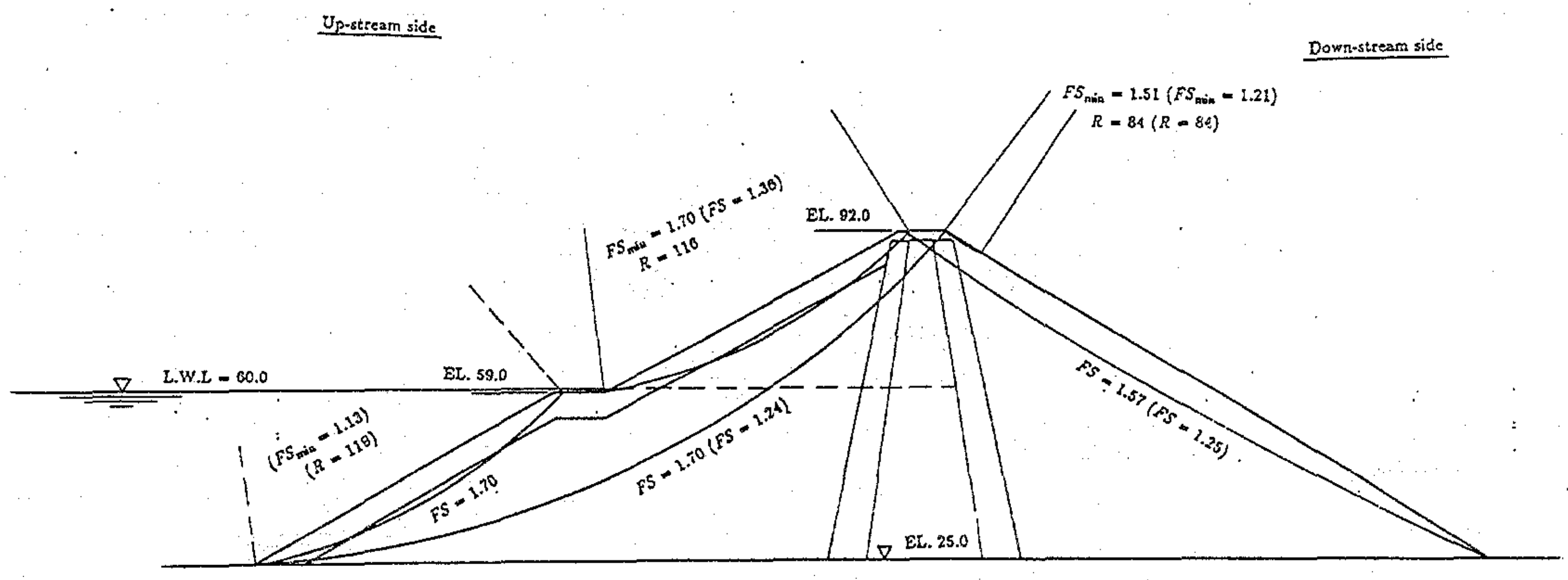


Note : -figures in bracket show the seismic case

-R presents a radius of a slip circle in meter

Fig. 9-2-2(7) Stability Analysis of Saddle Dam (I) (Result-6)

Load condition Case 6 and Case 11 − L.W.L = 60.0 m



Note : -figures in bracket show the seismic case
-R presents a radius of a slip circle in meter

Fig.9-2-3(1) Result of Stability Analysis of Saddle Dam (II) — (1)

Load condition Case 1 and Case 7 reservoir empty

Note : -figures in bracket show the sesmic case
-R presents a radius of a slip circle in meter

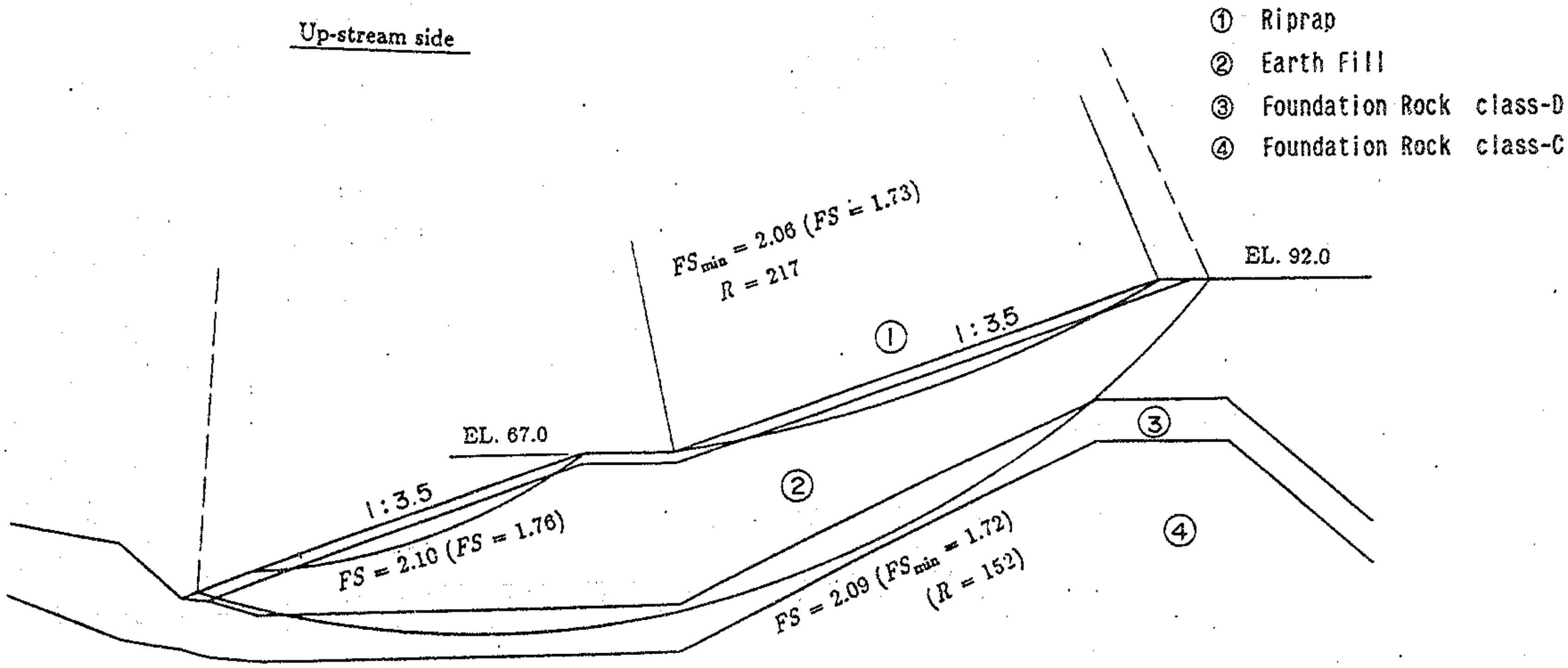


Fig.9-2-3(2) Result of Stability Analysis of Saddle Dam (Ⅱ) — (2)

Load condition Case 2 F.W.L = 88.1 m

Note : -figures in bracket show the seismic case
-R presents a radius of a slip circle in meter

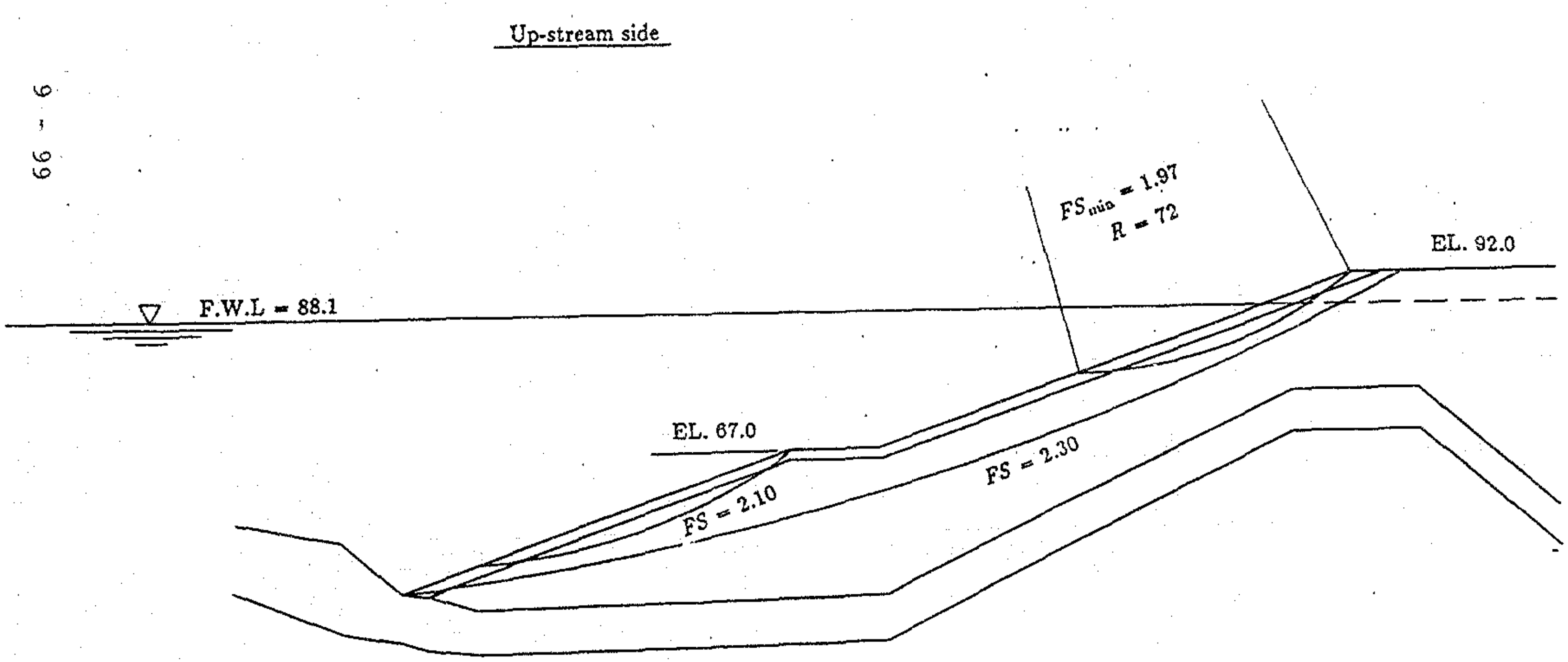


Fig. 9-2-3(3) Result of Stability Analysis of Saddle Dam (II) — (3)

Load condition Case 3 and Case 8   S.W.L = 85.1 m

Note : -figures in bracket show the seismic case

-R presents a radius of a slip circle in meter

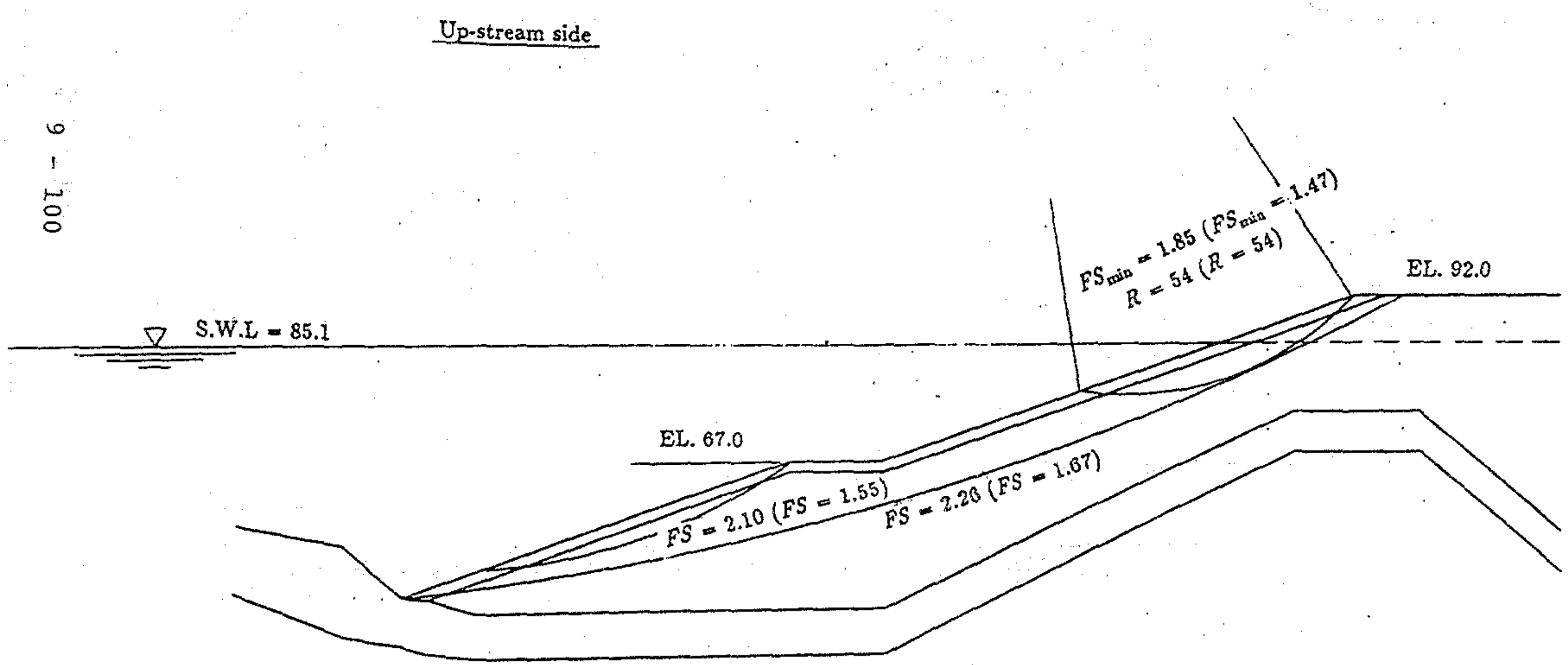


Fig.9-2-3(4) Result of Stability Analysis of Saddle Dam (II) — (4)

Load condition Case 4 and Case 9 H.W.L = 80.0 m

Note : -figures in bracket show the seismic case

-R presents a radius of a slip circle in meter

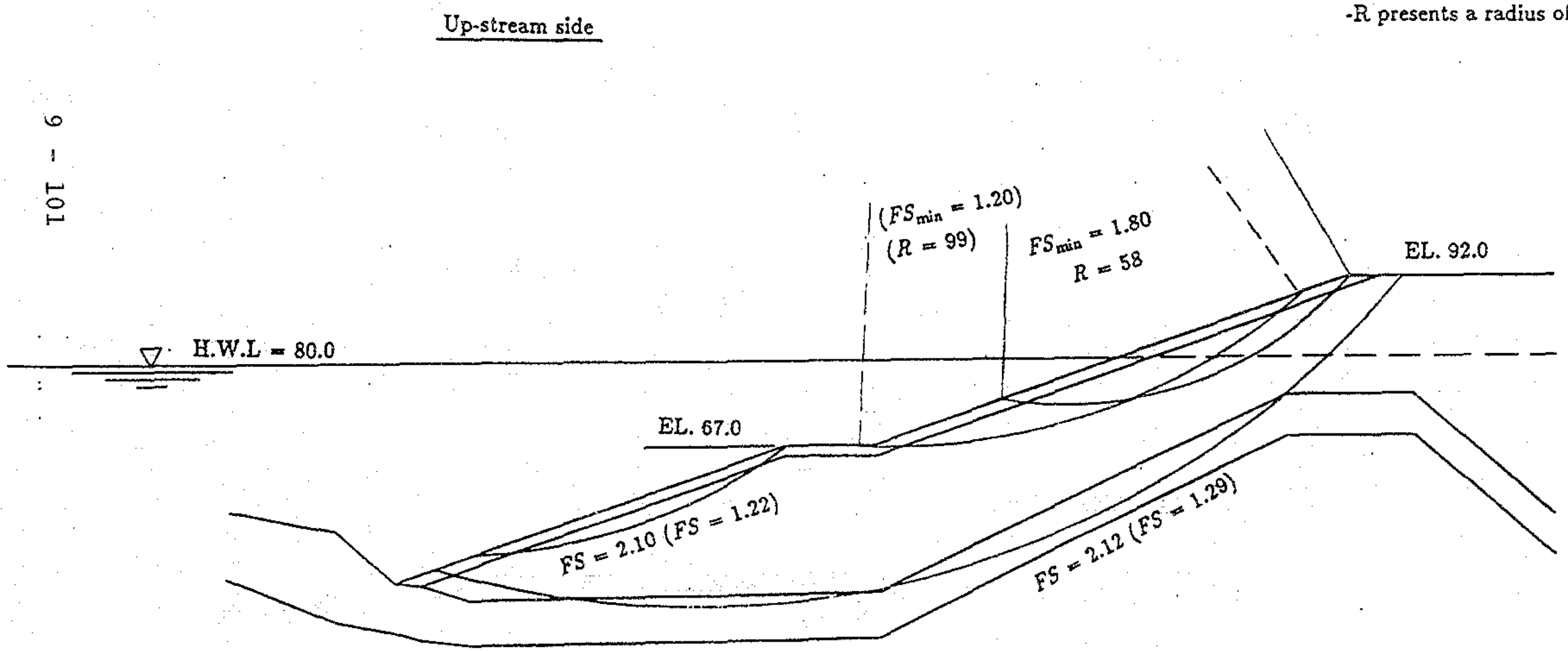


Fig. 9-2-3(5) Result of Stability Analysis of Saddle Dam (II) — (5)

Load condition Case 5 and Case 10 W.L = 70.0 m

Up-stream side

Note : -figures in bracket show the seismic case
-R presents a radius of a slip circle in meter

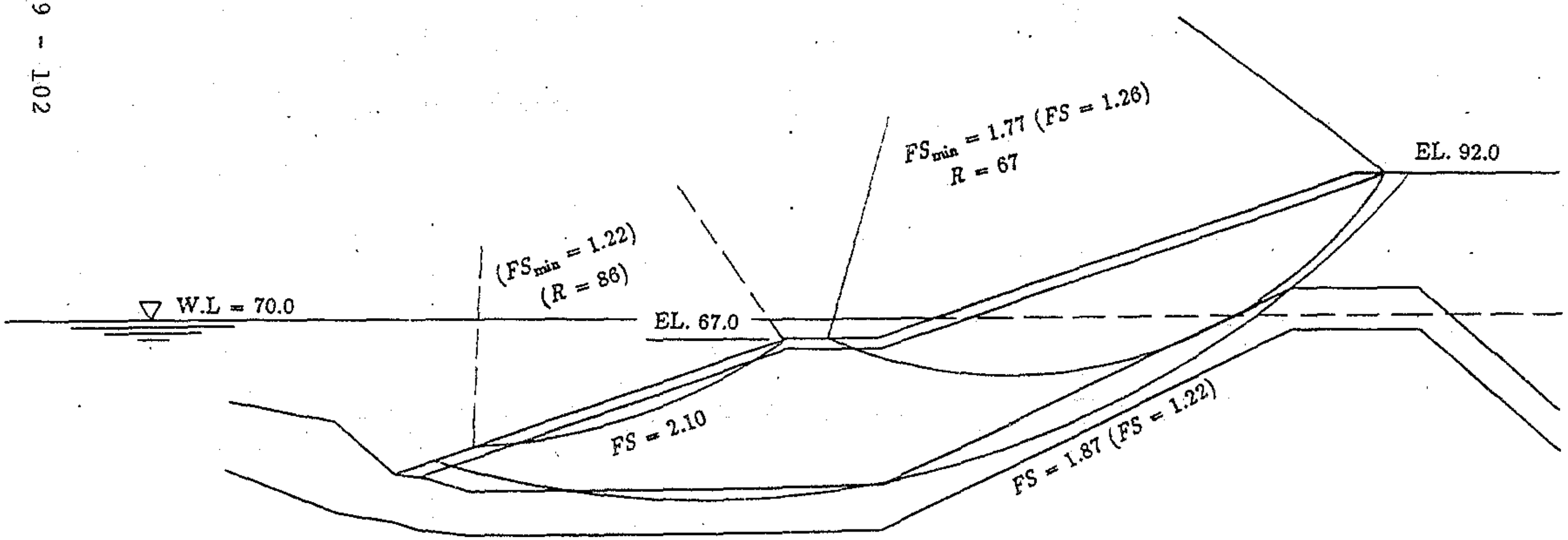


Fig.9-2-3(6) Result of Stability Analysis of Saddle Dam (II) — (6)

Load condition Case 6 and Case 11 L.W.L = 60.0 m

Note : -figures in bracket show the seismic case
-R presents a radius of a slip circle in meter

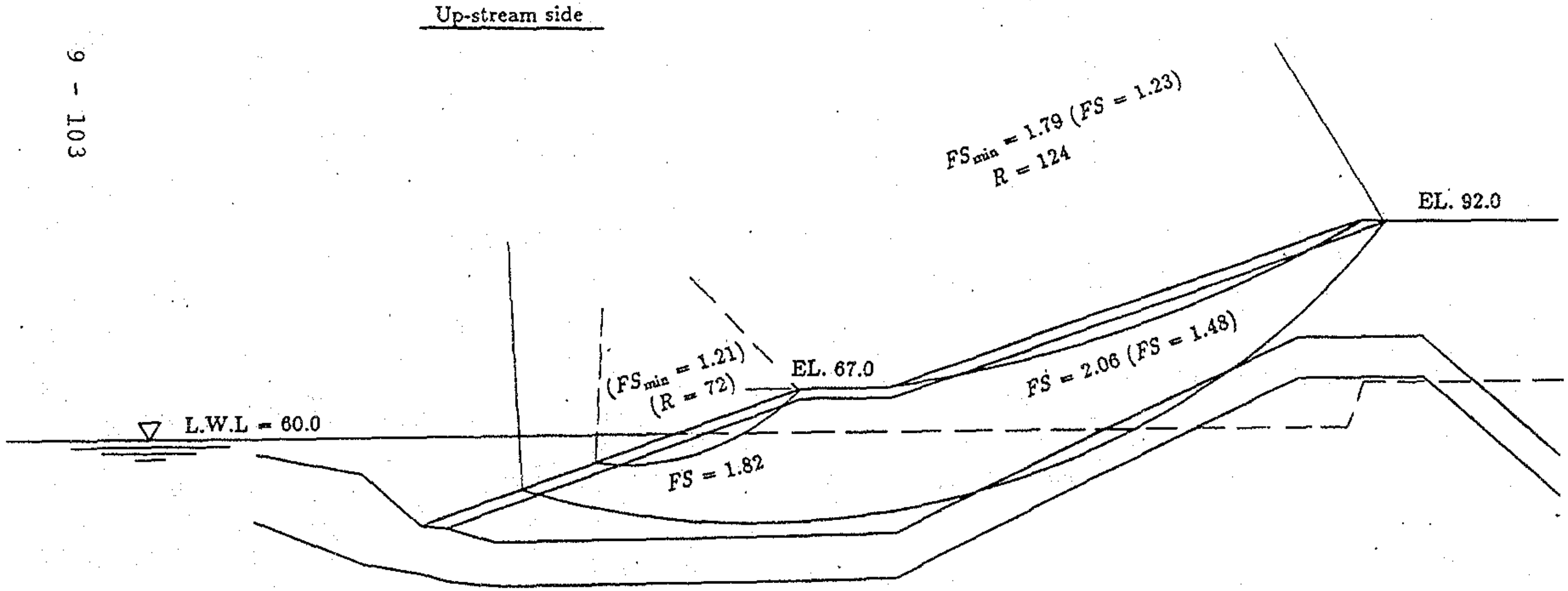


Fig.9-2-3(7) Result of Stability Analysis of Saddle Dam (II) — (7)

Load condition Case 1 and Case 7 reservoir empty

Down-stream side

Note : -figures in bracket show the seismic case
-R presents a radius of a slip circle in meter

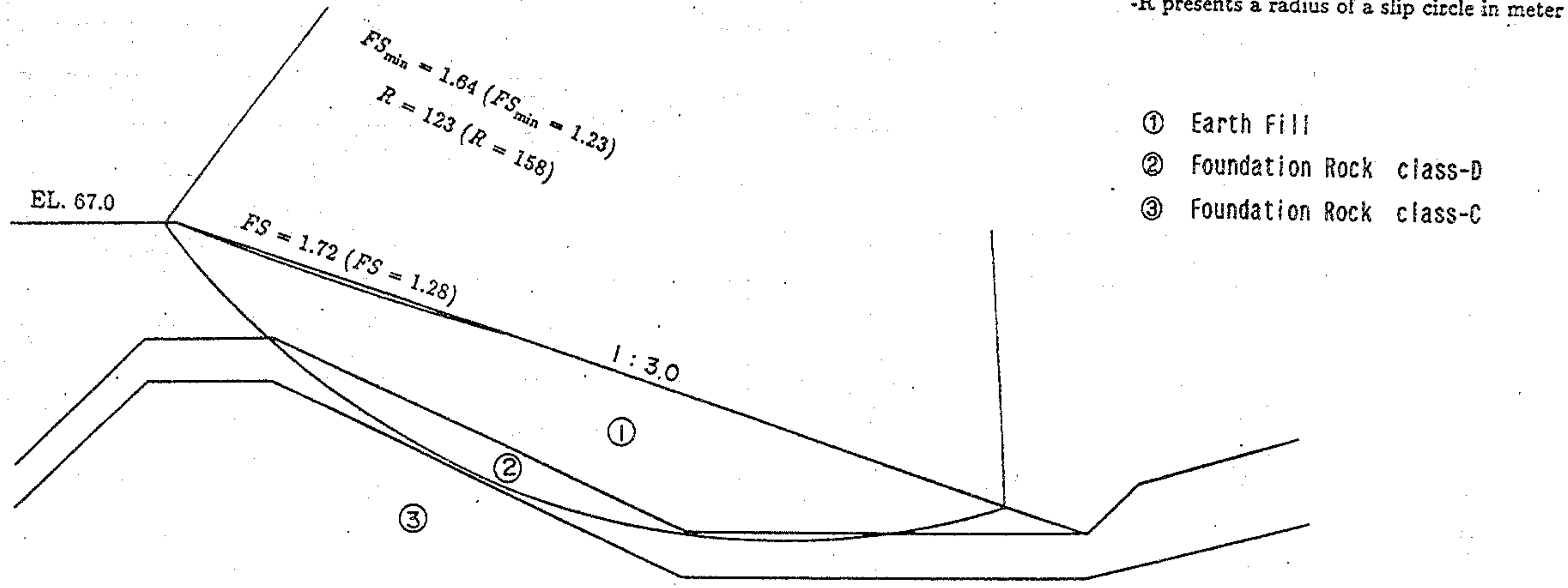


Fig. 9-2-4 Hydrographs of Floods of Various Return Period

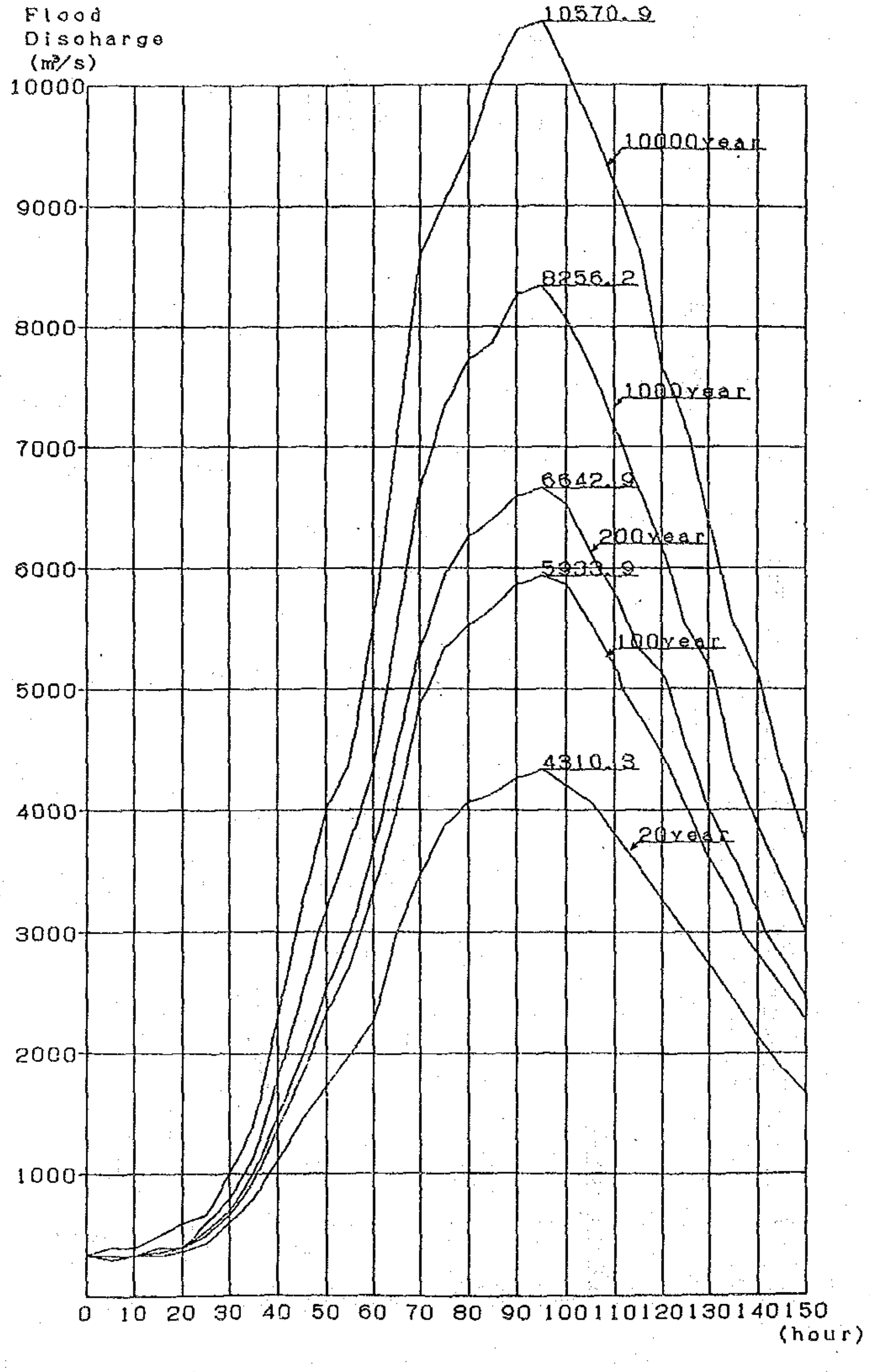


Fig.9-2-5 LEBIR DAM (JERAM PANJANG SITE) RESERVOIR VOLUME AND AREA V.S. RESERVOIR LEVEL

H (EL.m)	A (km²)	V ($10^9 m^3$)	H (EL.m)	A (km²)	V ($10^9 m^3$)
90	247	4.397	50	21	0.167
80	154	2.392	40	6	0.032
70	89	1.177	30	0.6	0.002
60	46	0.502			

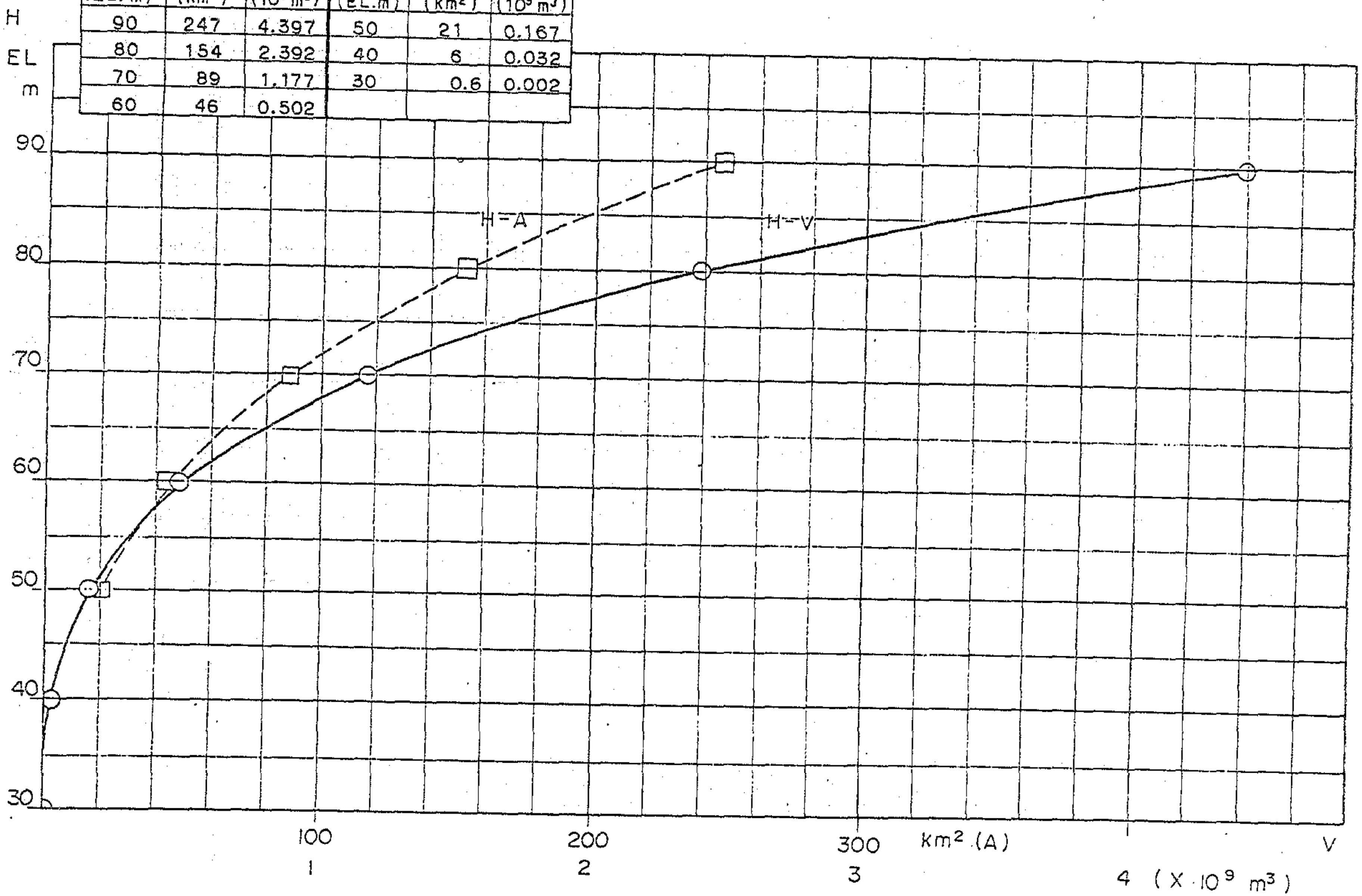


Fig.9-2-6 Relationship between Reservoir Level and Spillway Discharge with Non-gated Free Overflow Shute Type (orest length 150m)

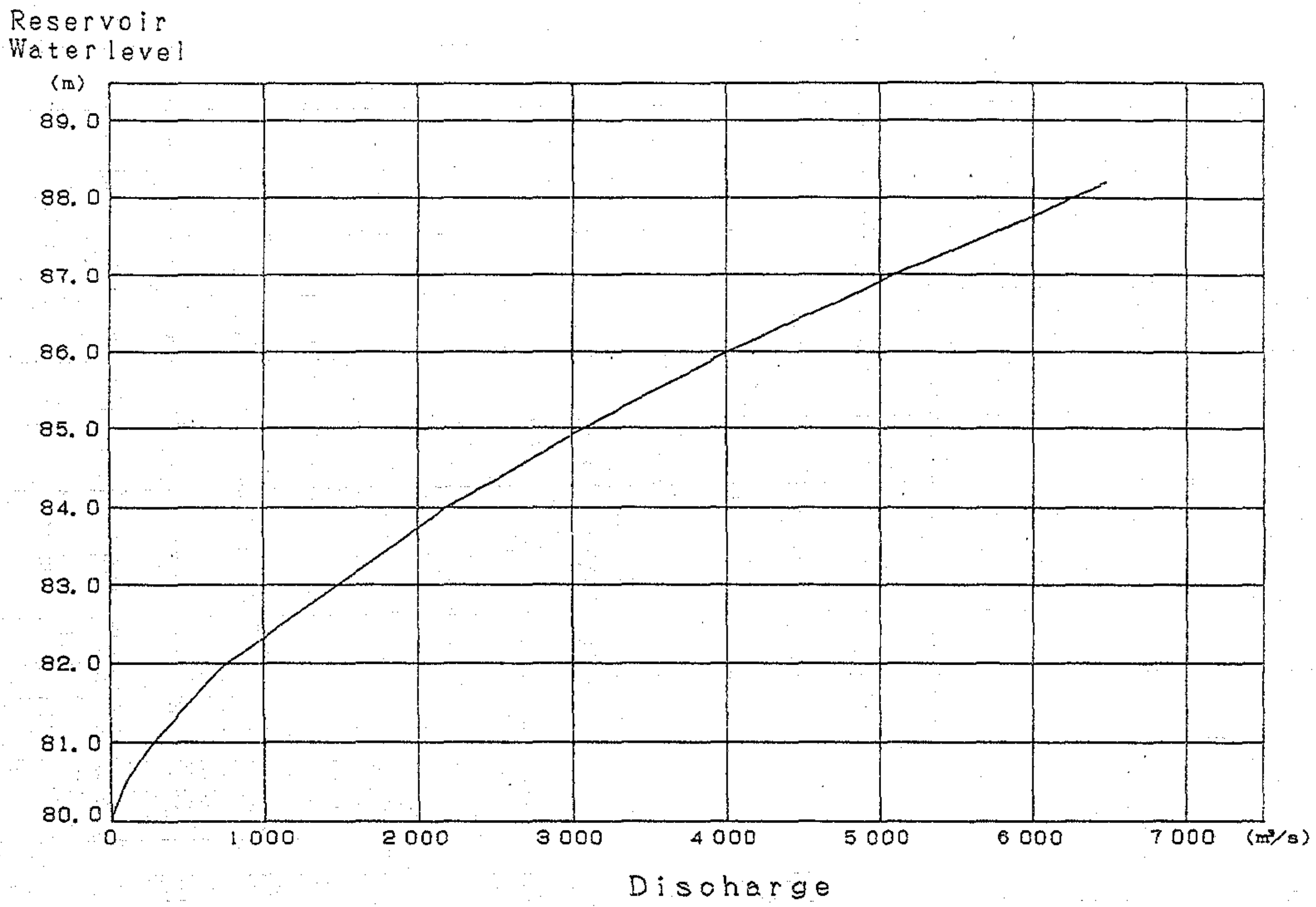


Fig.9-2-7(I) Flood Routine thru Spillway
—10,000Year Flood—

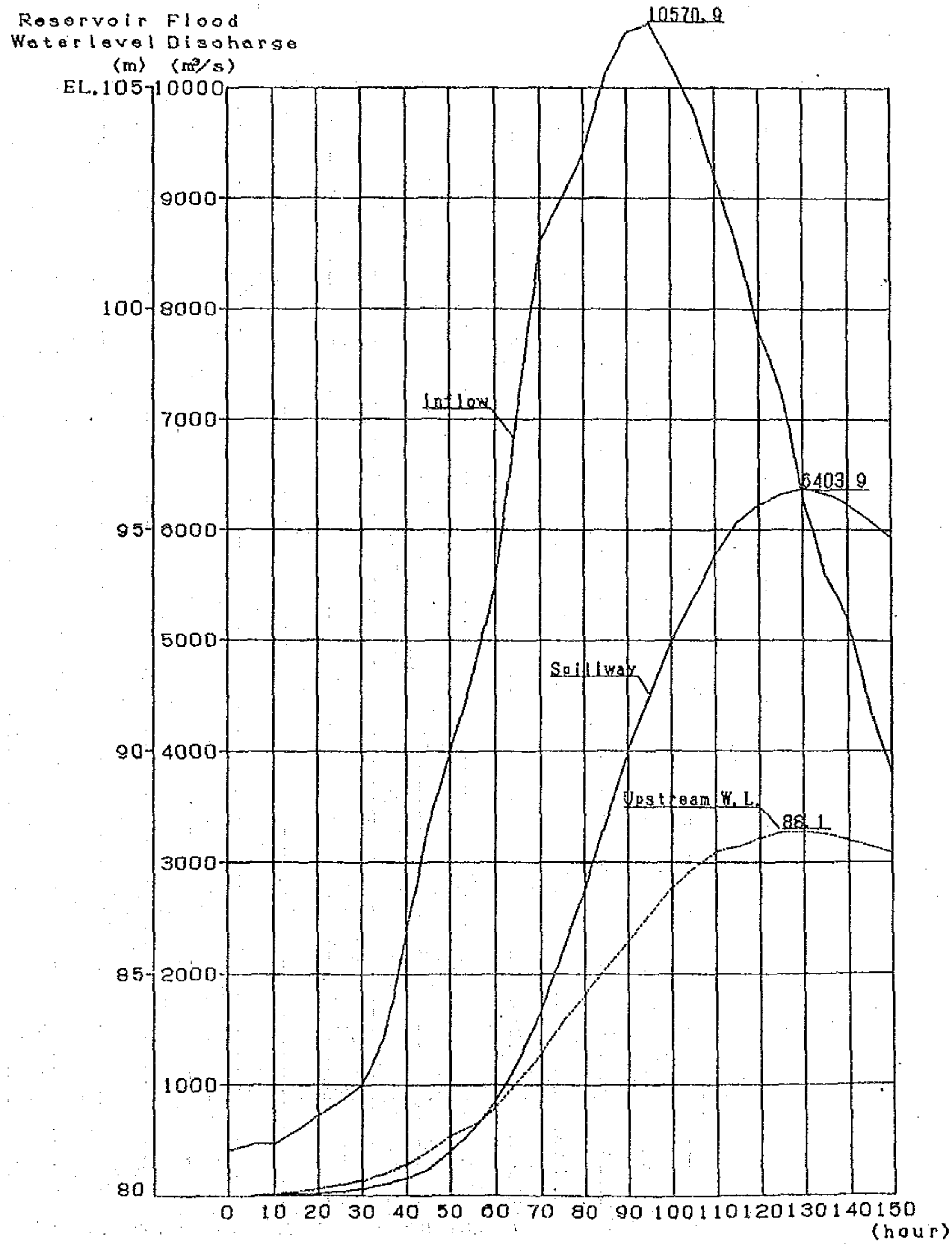


Fig.9-2-7 (2) Flood Routine thru Spillway
—1,000Year Flood—

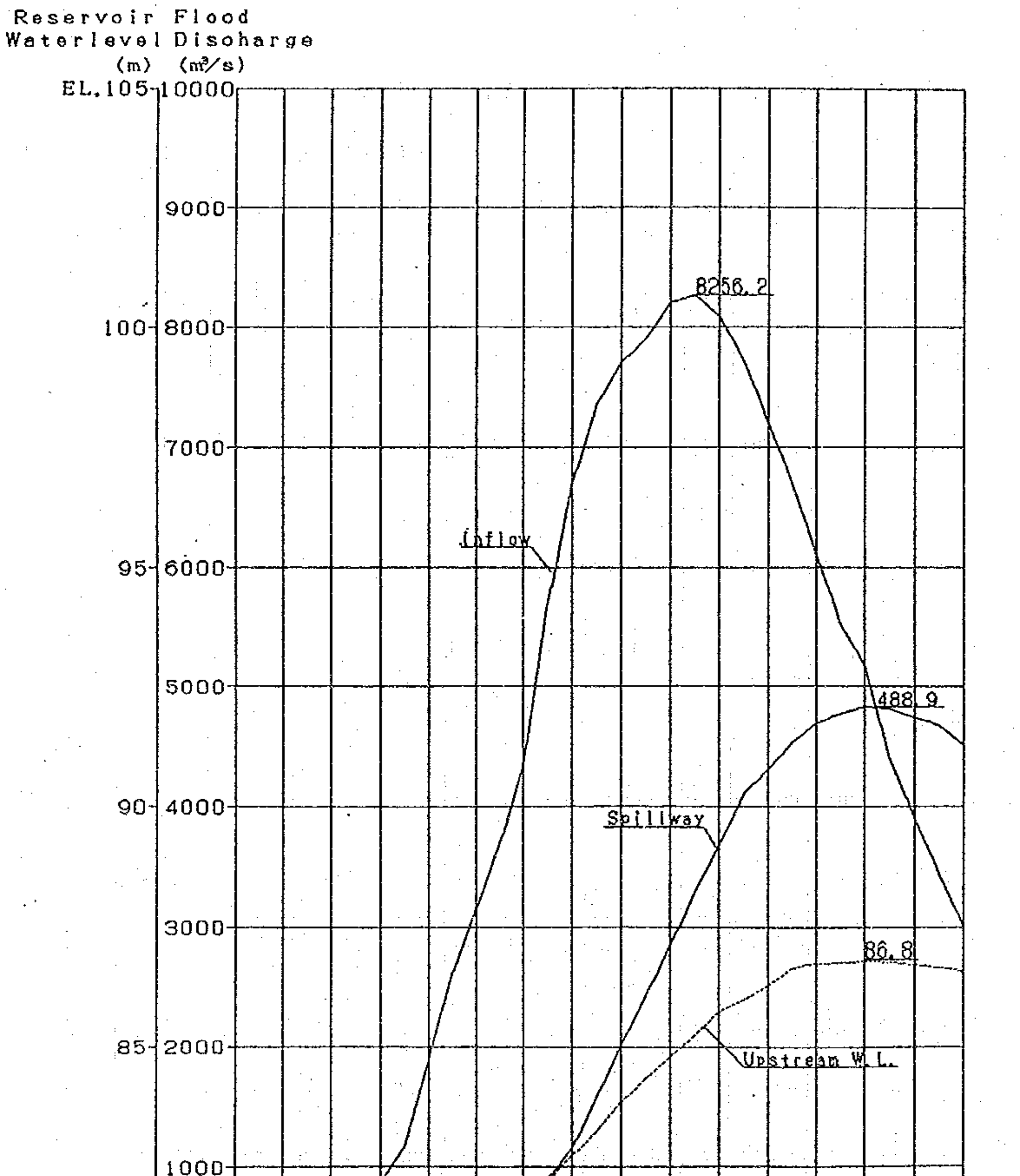


Fig.9-2-7(3) Flood Routine thru Spillway
—200 Year Flood—

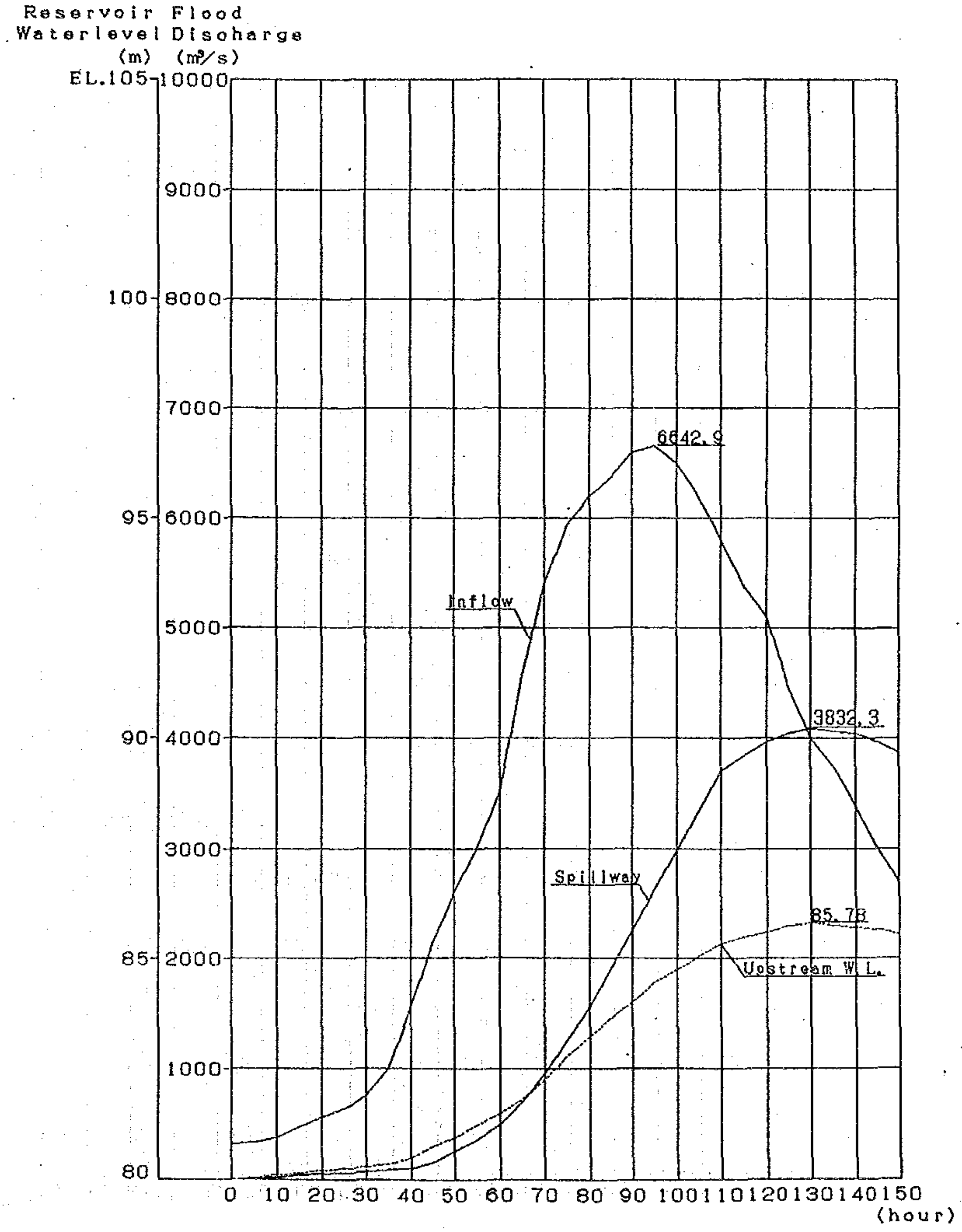


Fig.9-2-7(4) Flood Routine thru Spillway
—100Year Flood—

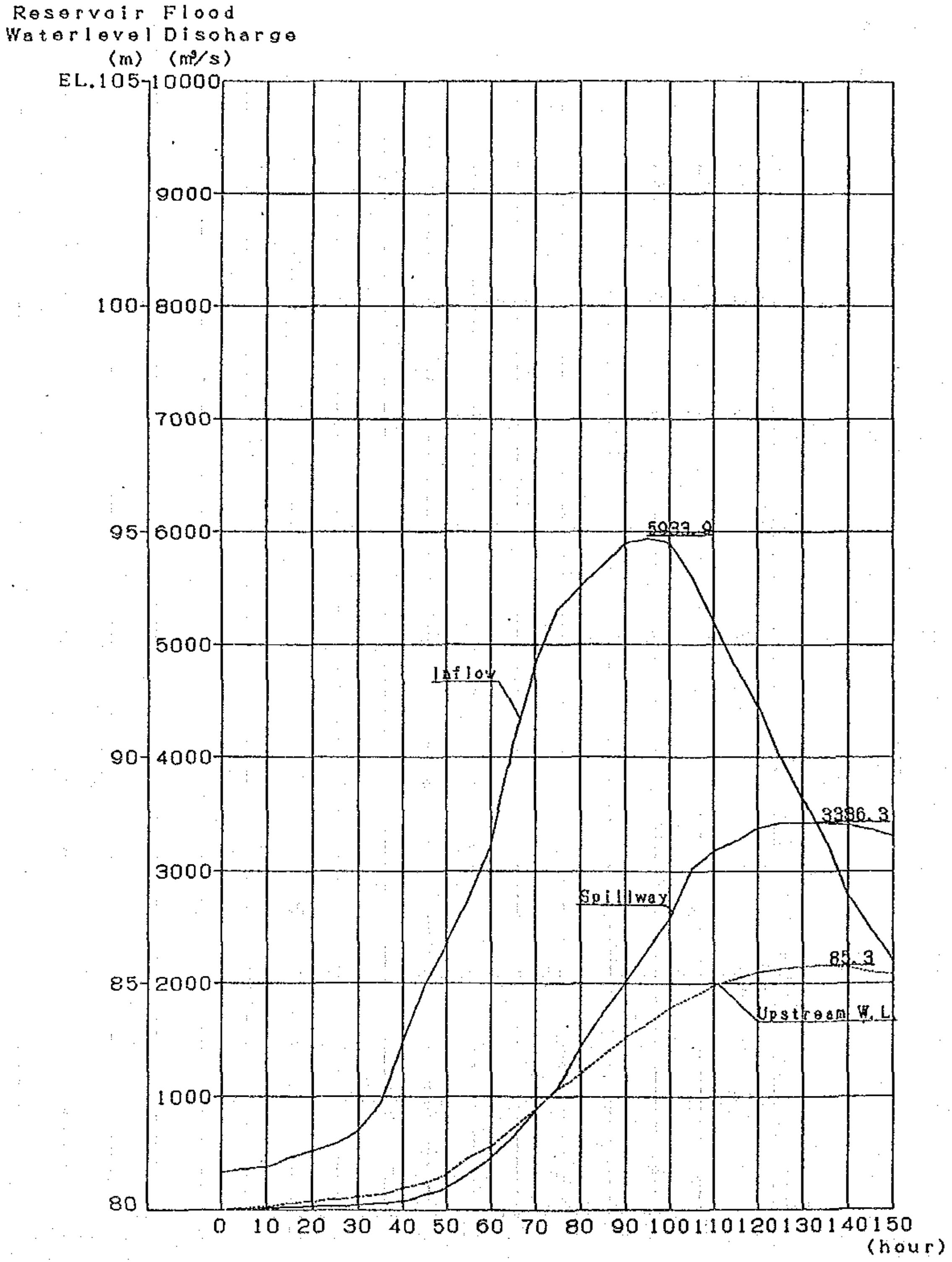


Fig.9-2-7(5) Flood Routine thru Spillway
—20Year Flood—

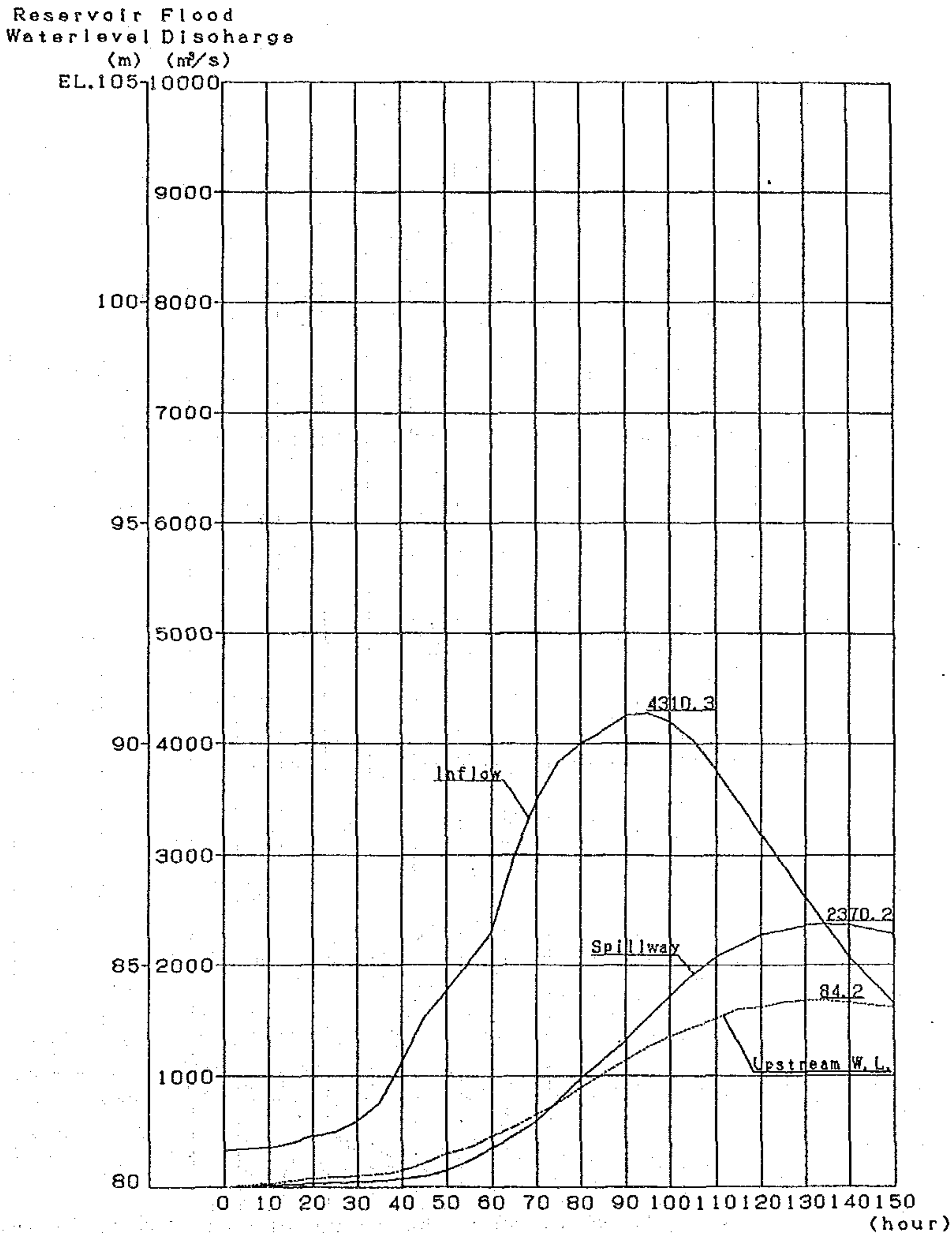


Fig.9-2-7(6) Flood Routine thru Spillway
—5 Year Flood—

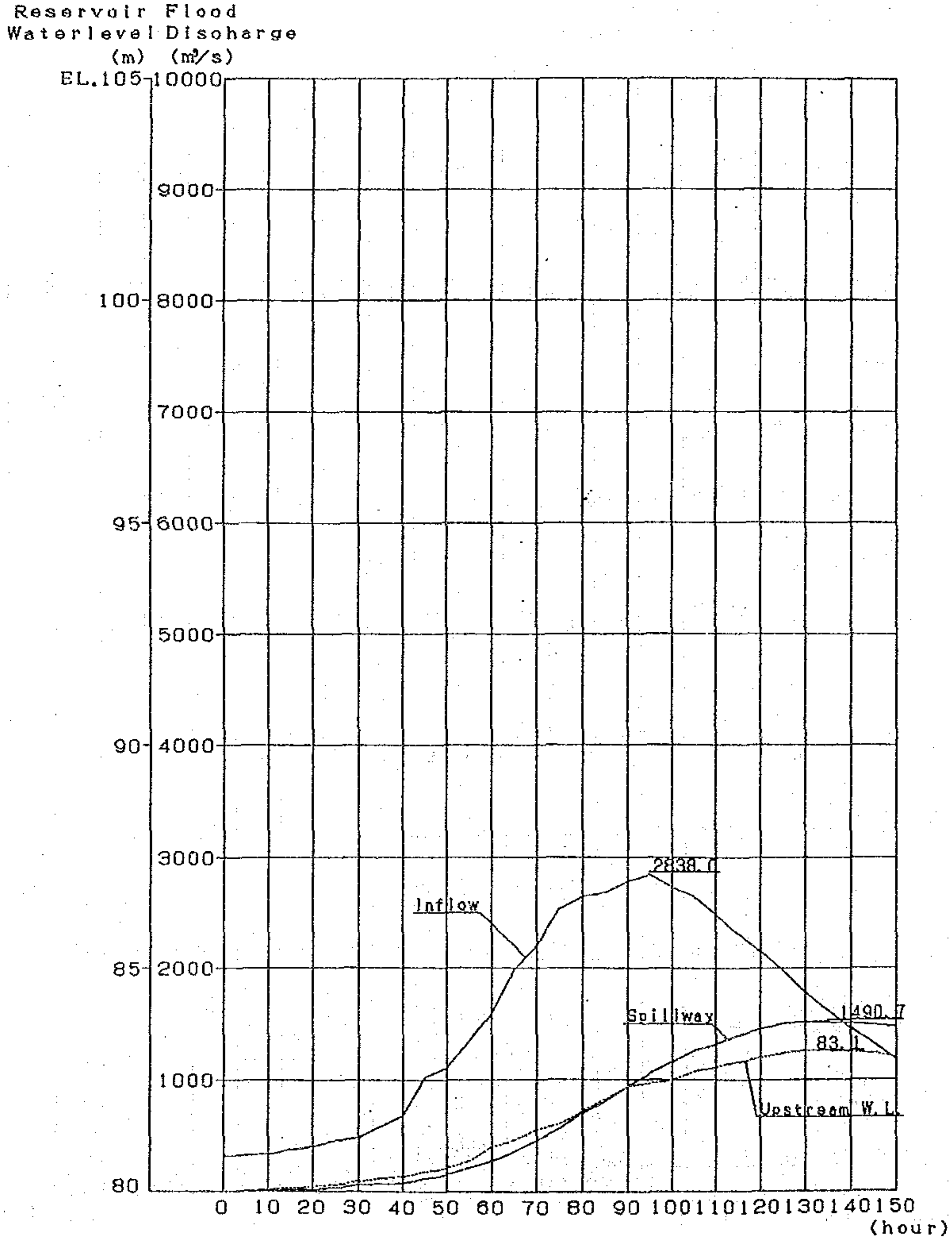


Fig.9-2-7(7) Flood Routine thru Spillway
—2 Year Flood—

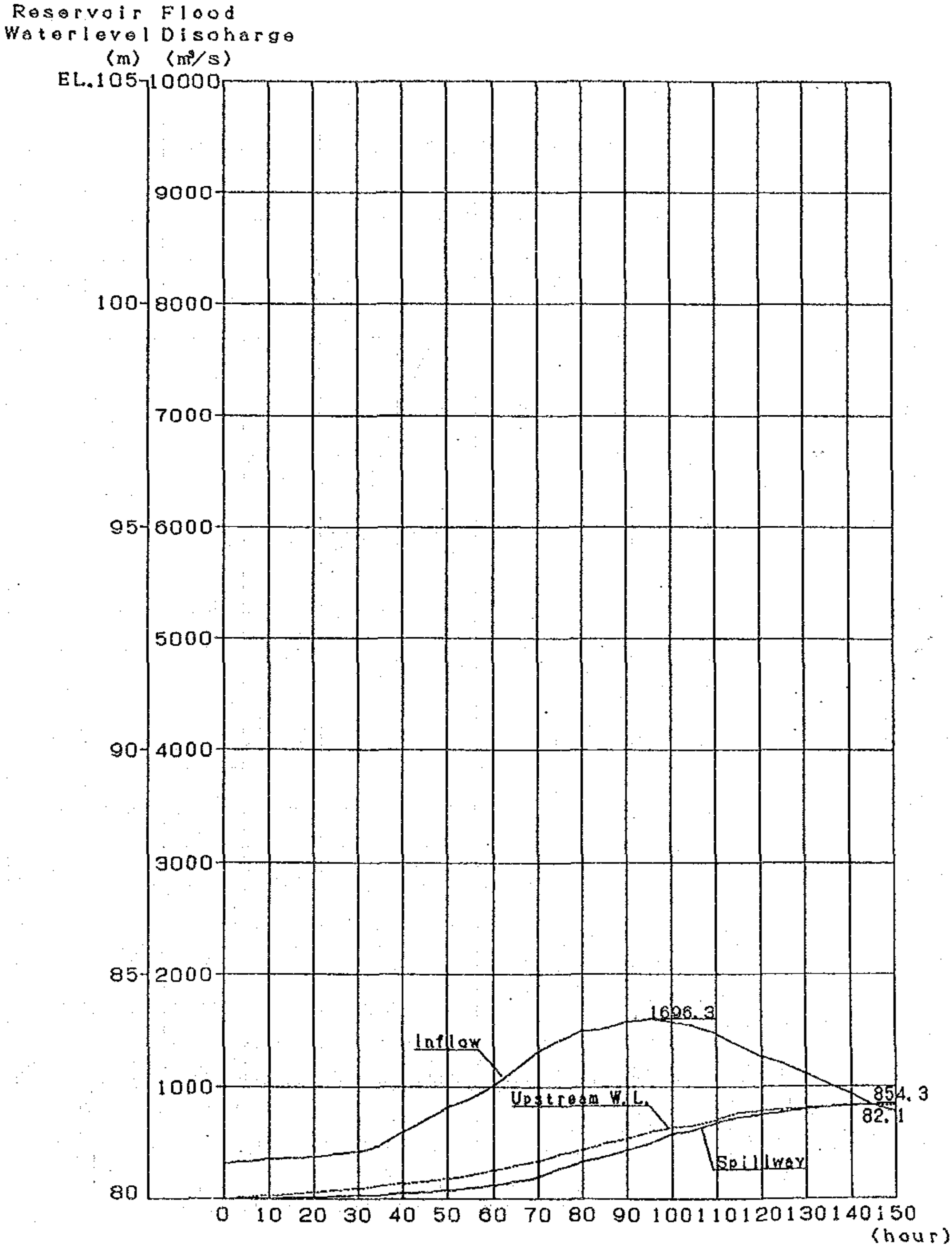


Fig.9-2-8 Relationship between Reservoir Level and Spillway Discharge with 2-Line Tunnel Spillway

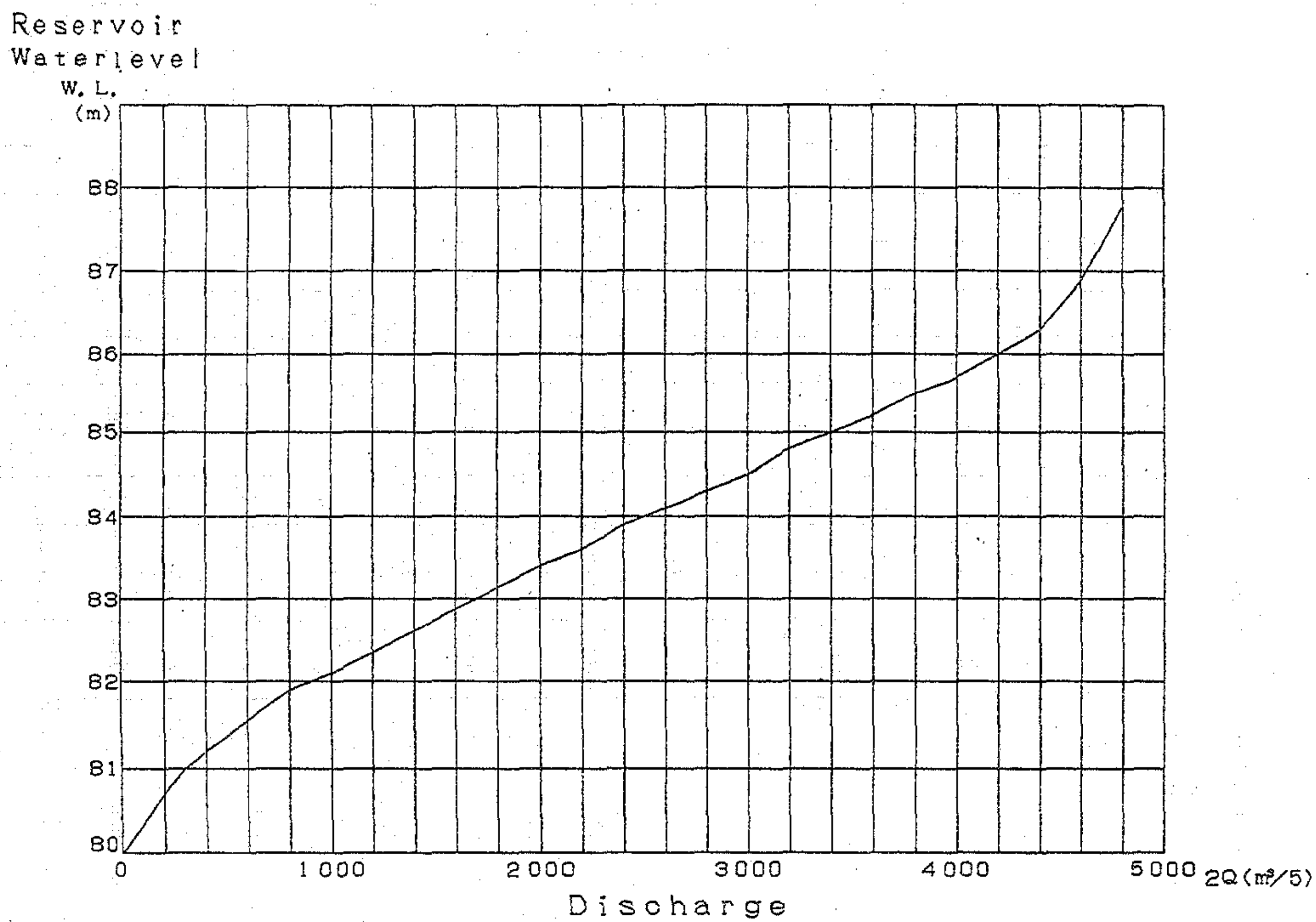
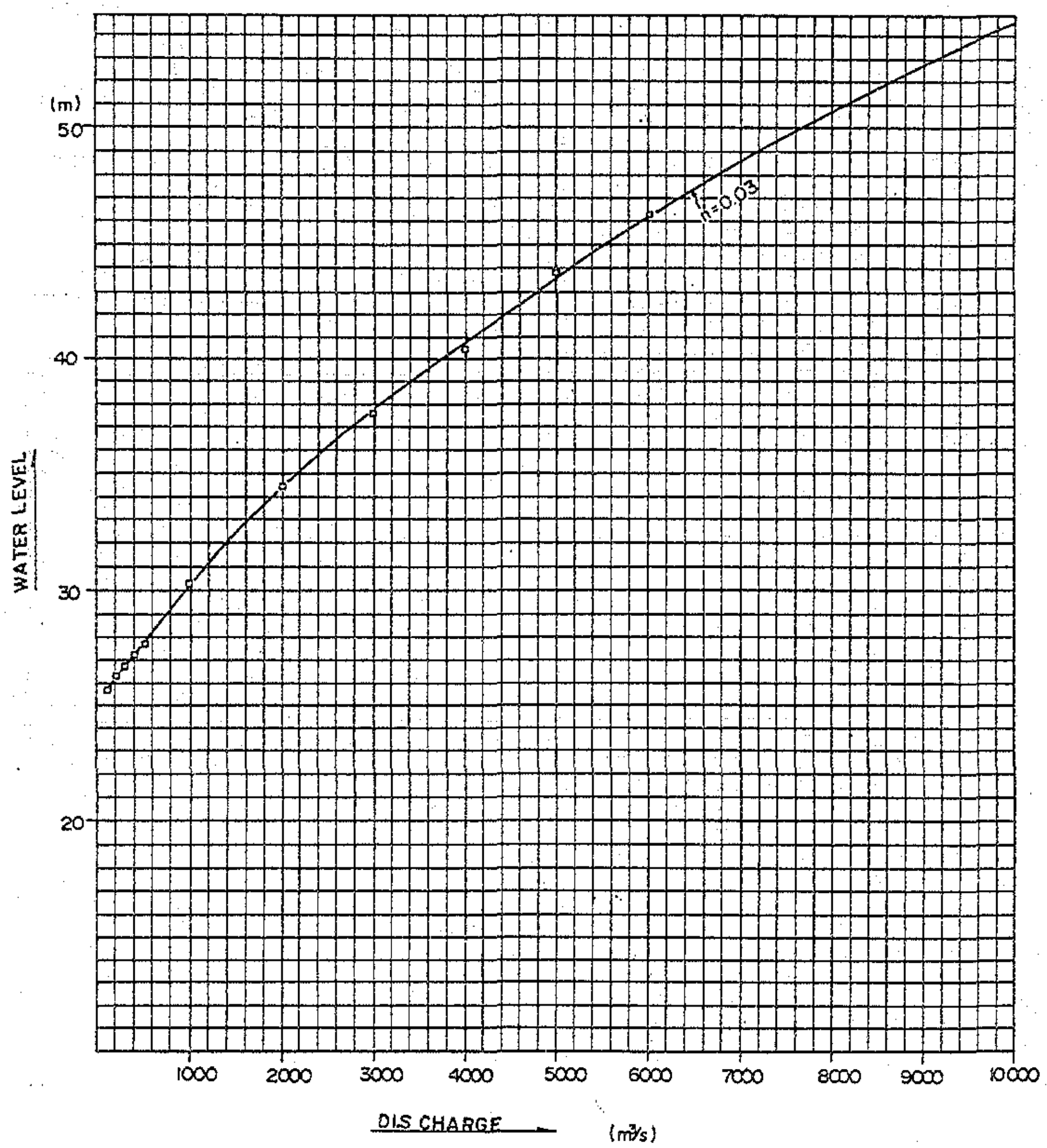


Fig.9-2-9 WATER LEVEL AT DAM DOWNSTREAM (TAILRACE OUTLET) V.S. RIVER DISCHARGE



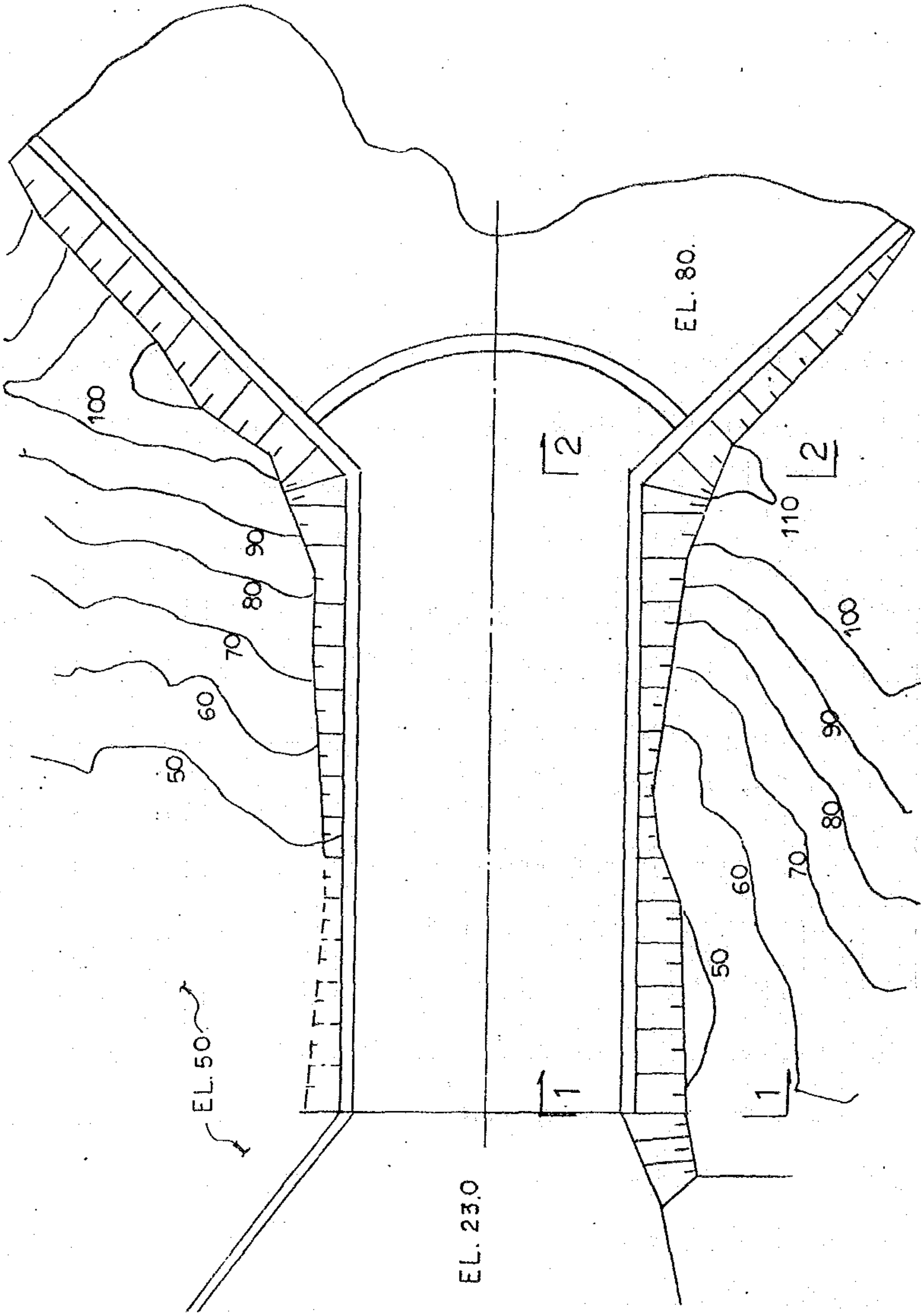
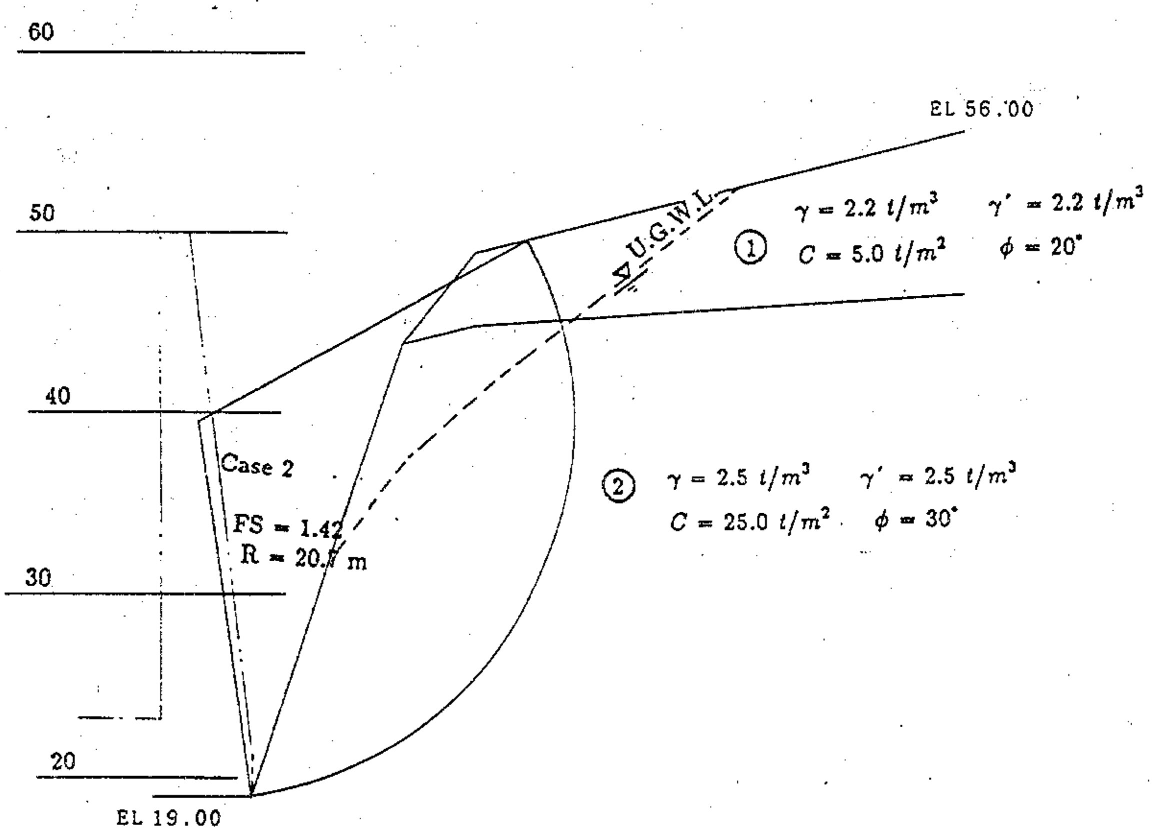


Fig.9-2-10 Spillway Plan

Fig.9-2-11(1) Stability Analysis of Excavation Slope of Spillway 1−1



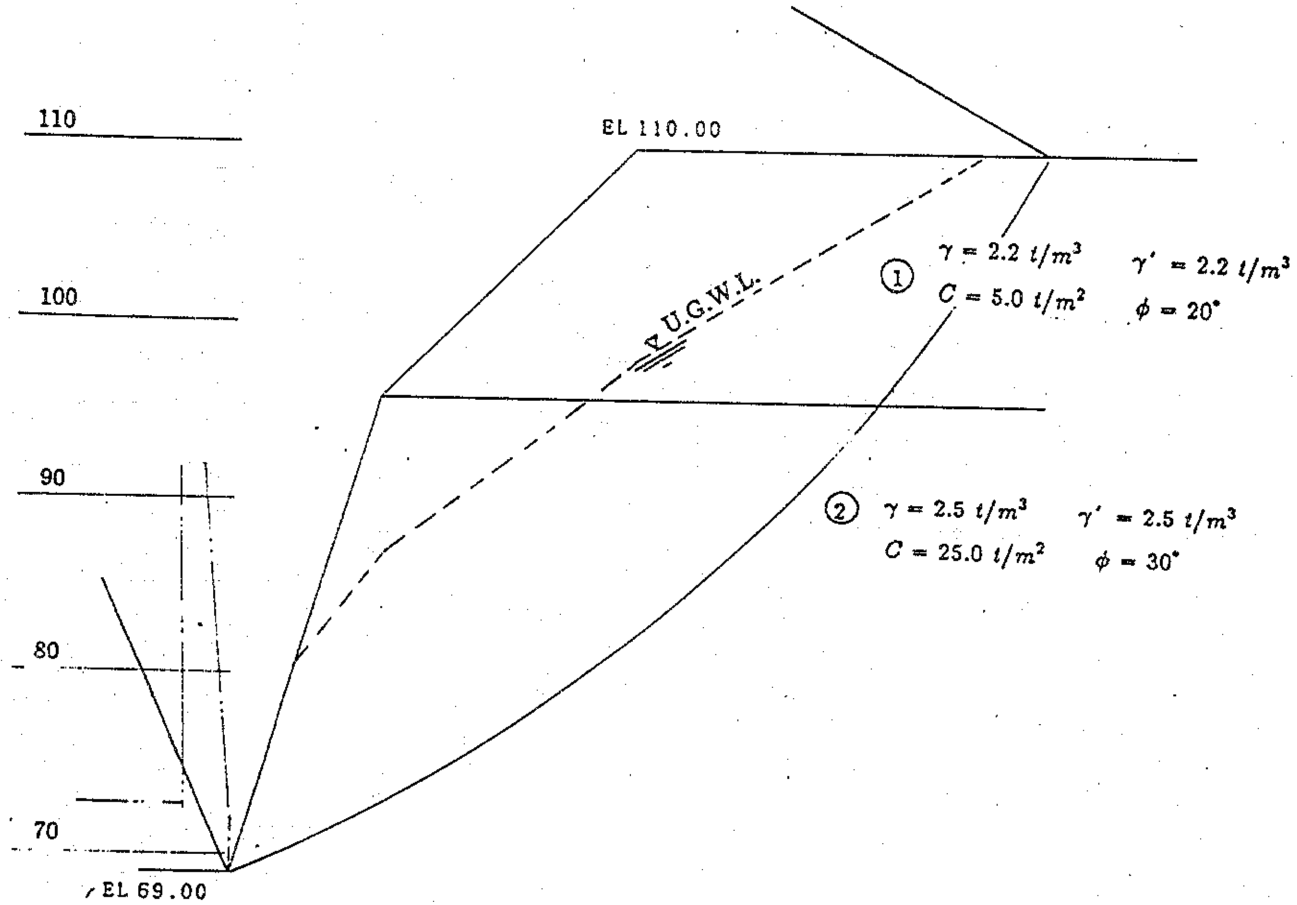
Load Condition and Result of Calculation

	Load Condition	FS_{min}
Case 1	Normal	1.54
Case 2	Seismic $K_H = 0.1$	1.42

Note : ① D class rock
② C class rock

Scale
1 : 400
0 4.0 8.0 m

Fig.9-2-11(2) Stability Analysis of Excavation Slope of Spillway 2 – 2



Load Condition and Result of Calculation

	Load Condition	FS_{min}
Case 1	Normal	1.38
Case 2	Seismic $K_H = 0.1$	1.21

Note : ① D class rock
② C class rock

Scale

1 : 400

0 4.0 8.0 m

Fig.9-2-12 Ralationship between Upstream Water Level and Diversion Tunnel Capacity at Various Return Period of Flood

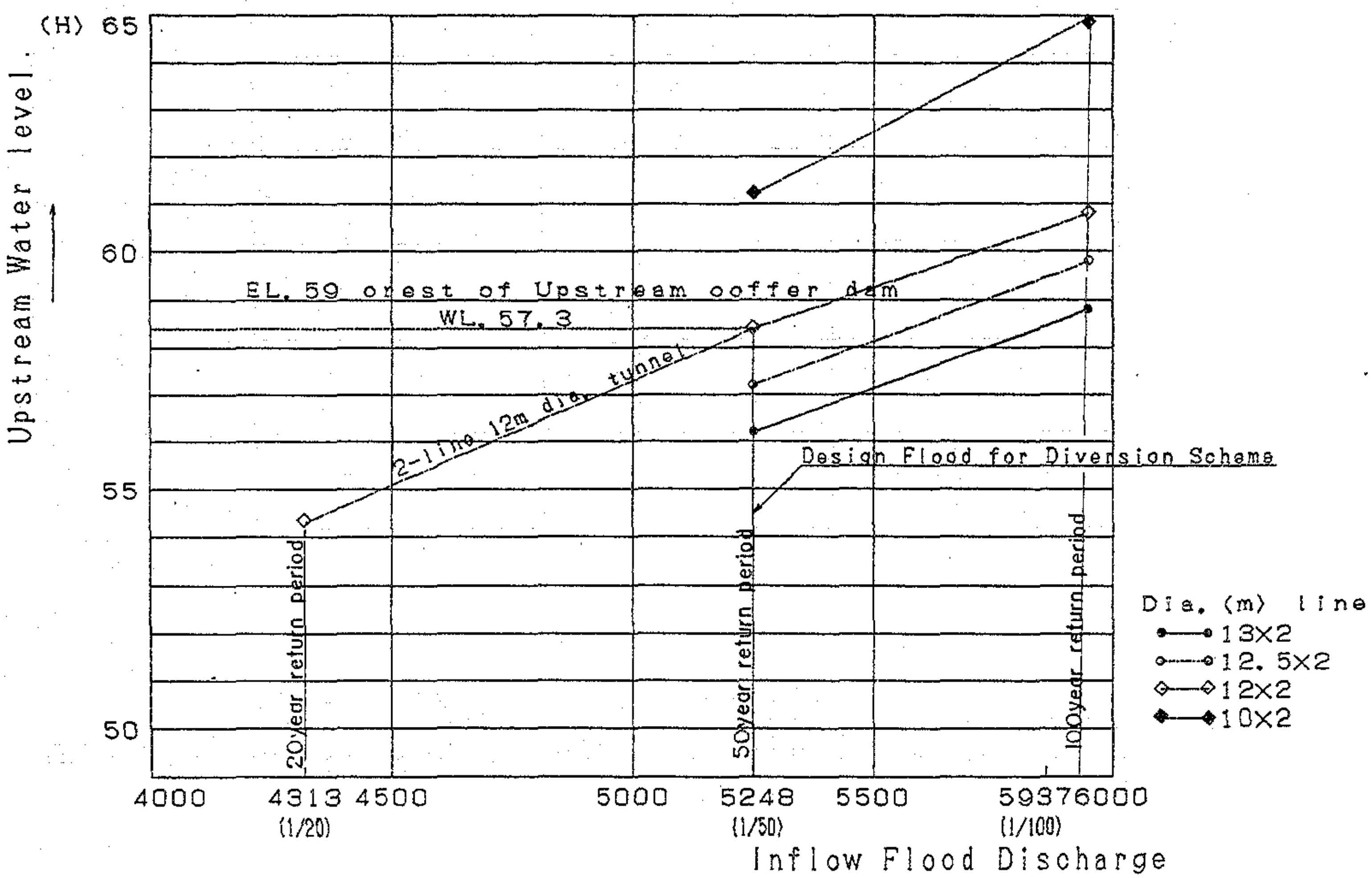


Fig.9-2-13 Relationship between Upstream Water Level and Tunnels Discharge Capacity with 2-Line Tunnel of 12m in diameter

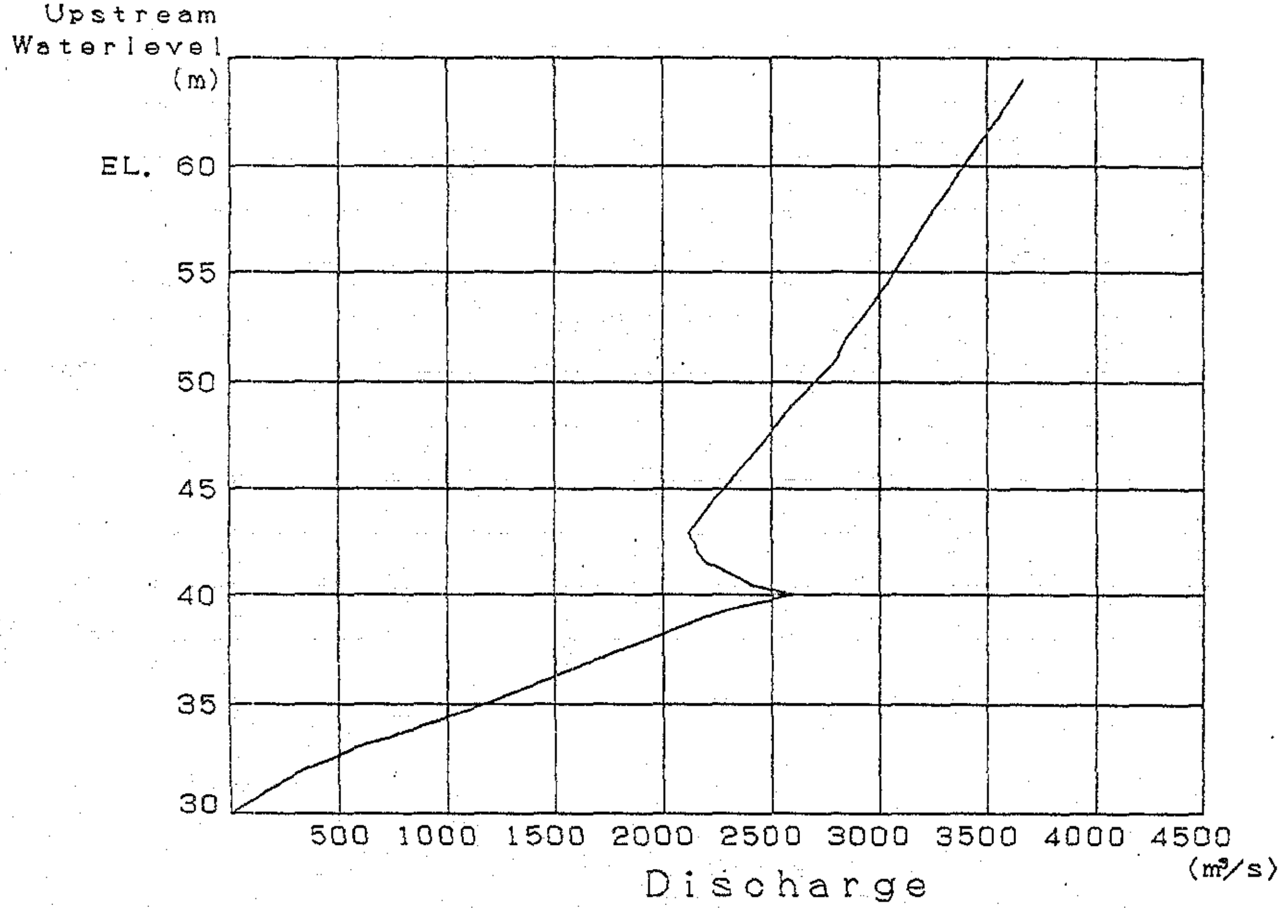


Fig.9-2-14(1) Flood Routine during Construction thru Diversion Tunnels
——100 Year Flood——

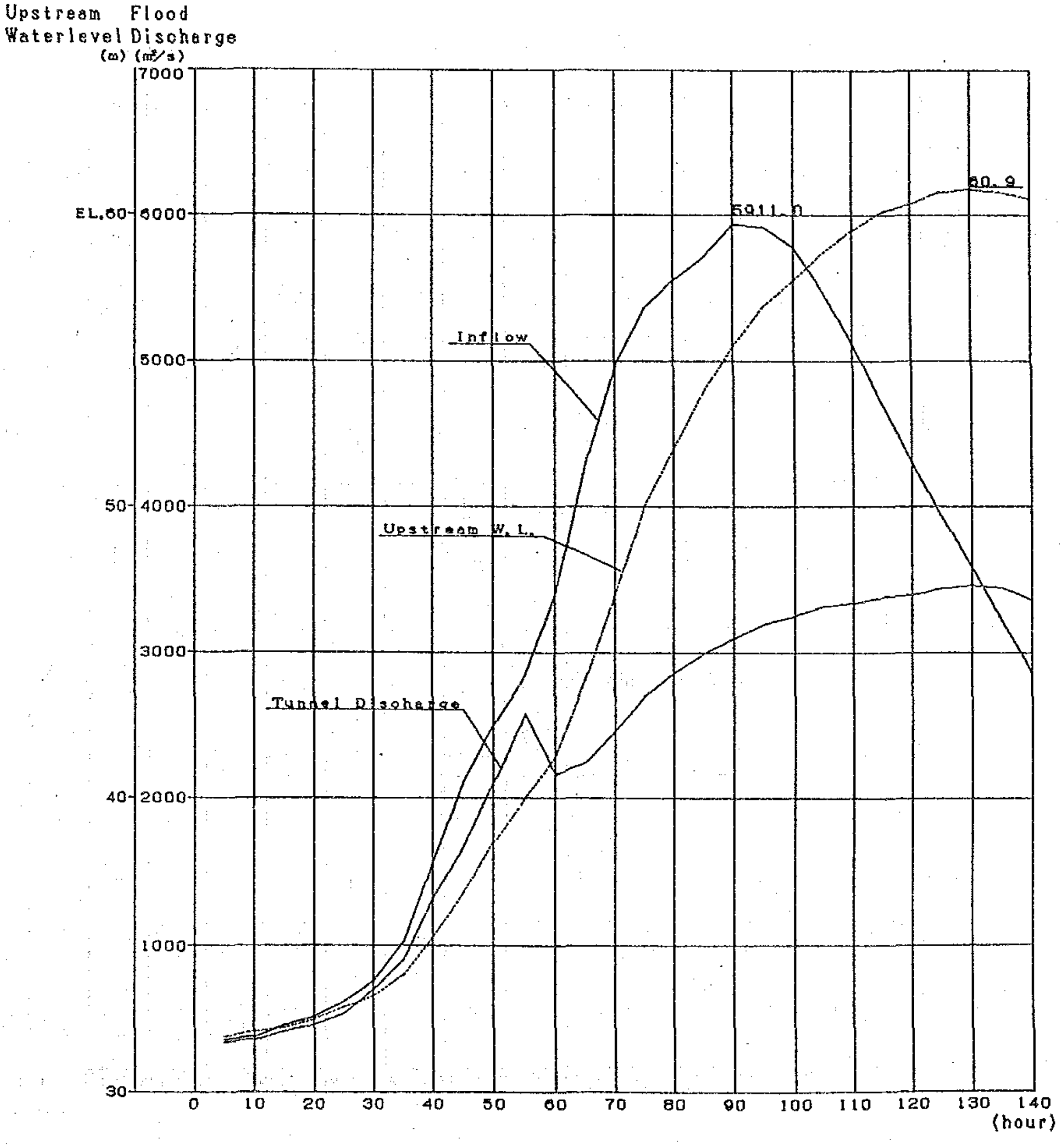


Fig.9-2-14(2) Flood Routine during Construction thru Diversion Tunnels
—— 50 Year Flood ——

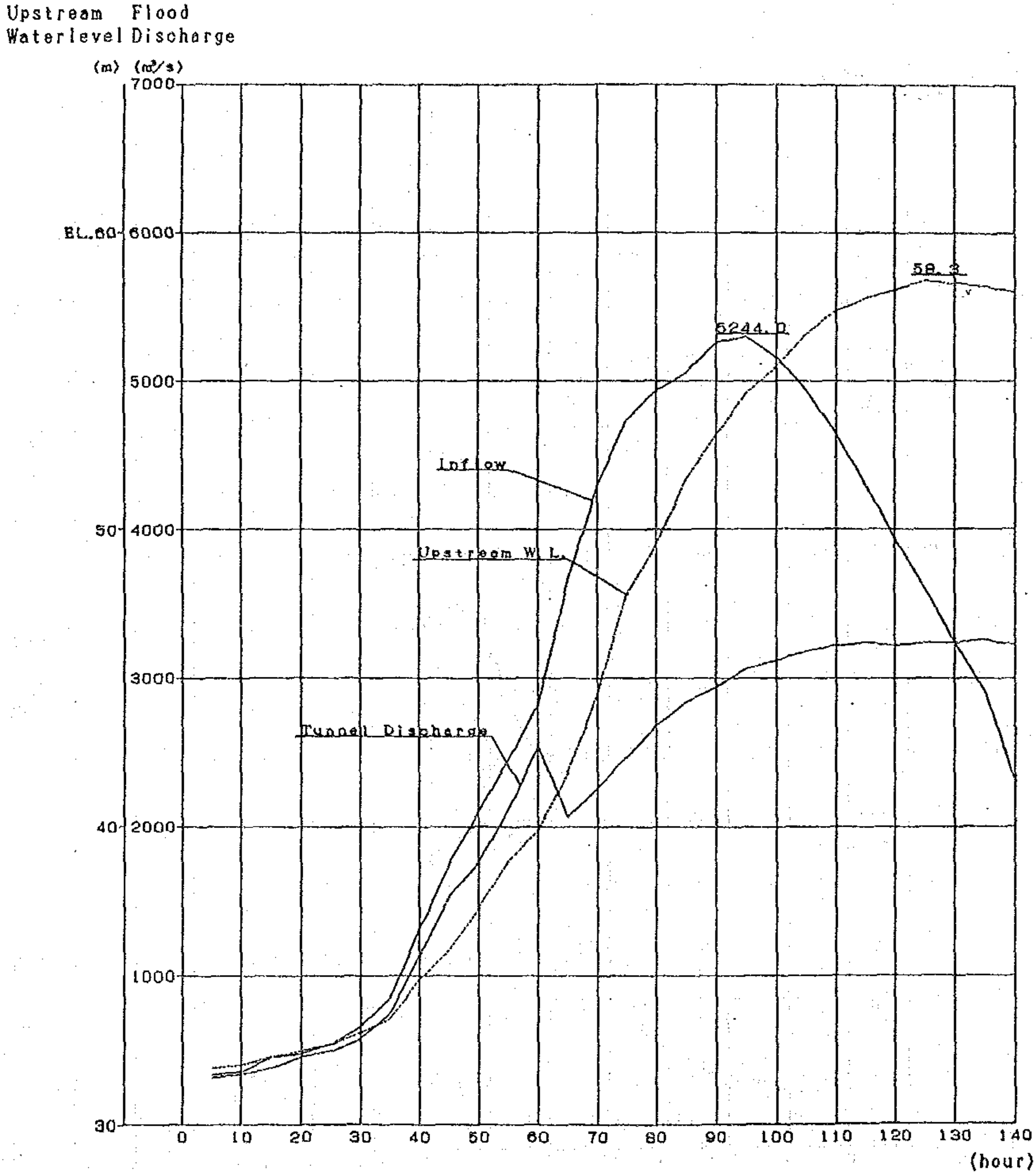
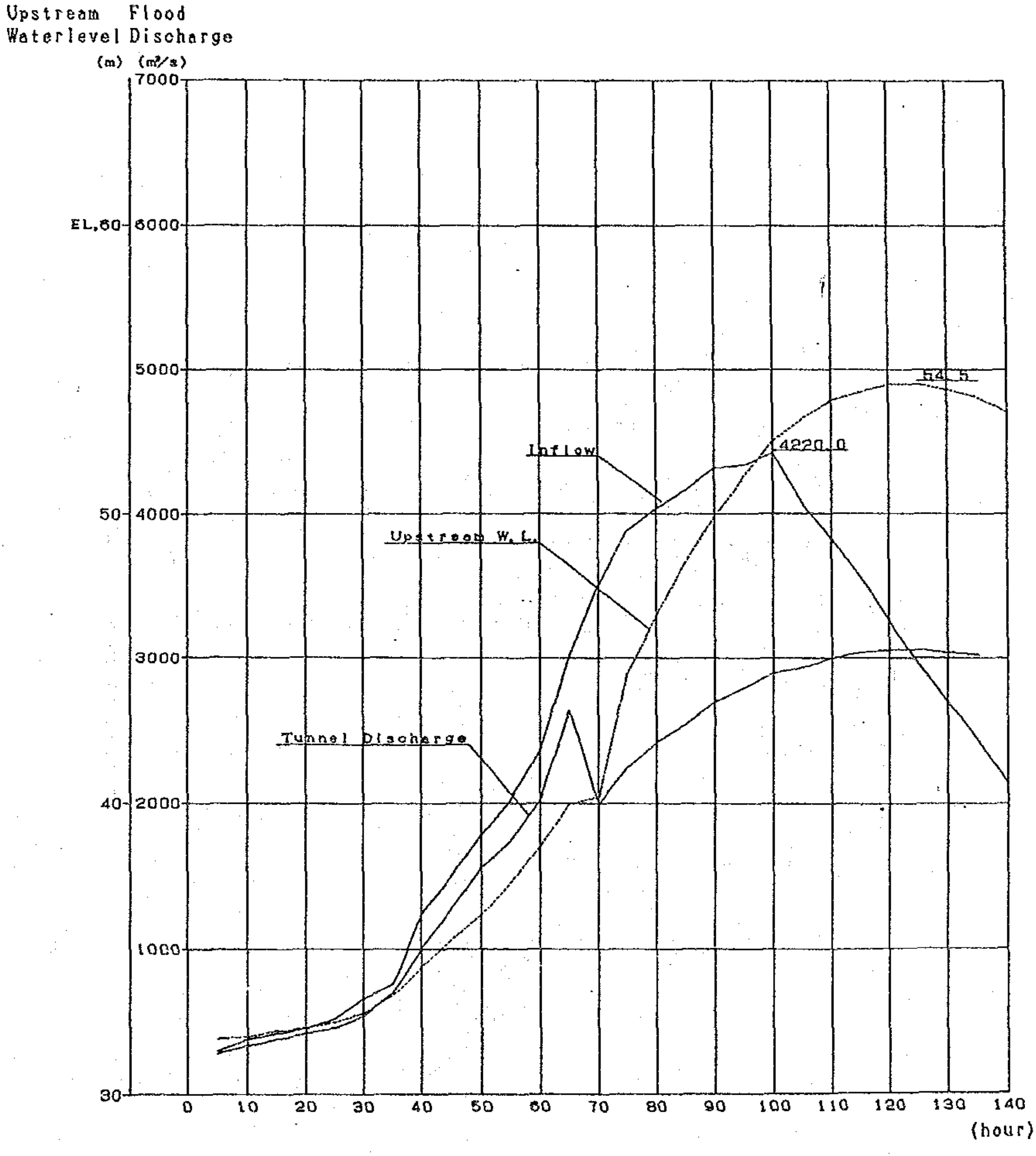


Fig.9-2-14(3) Flood Routine during Construction thru Diversion Tunnels
—— 20 Year Flood ——



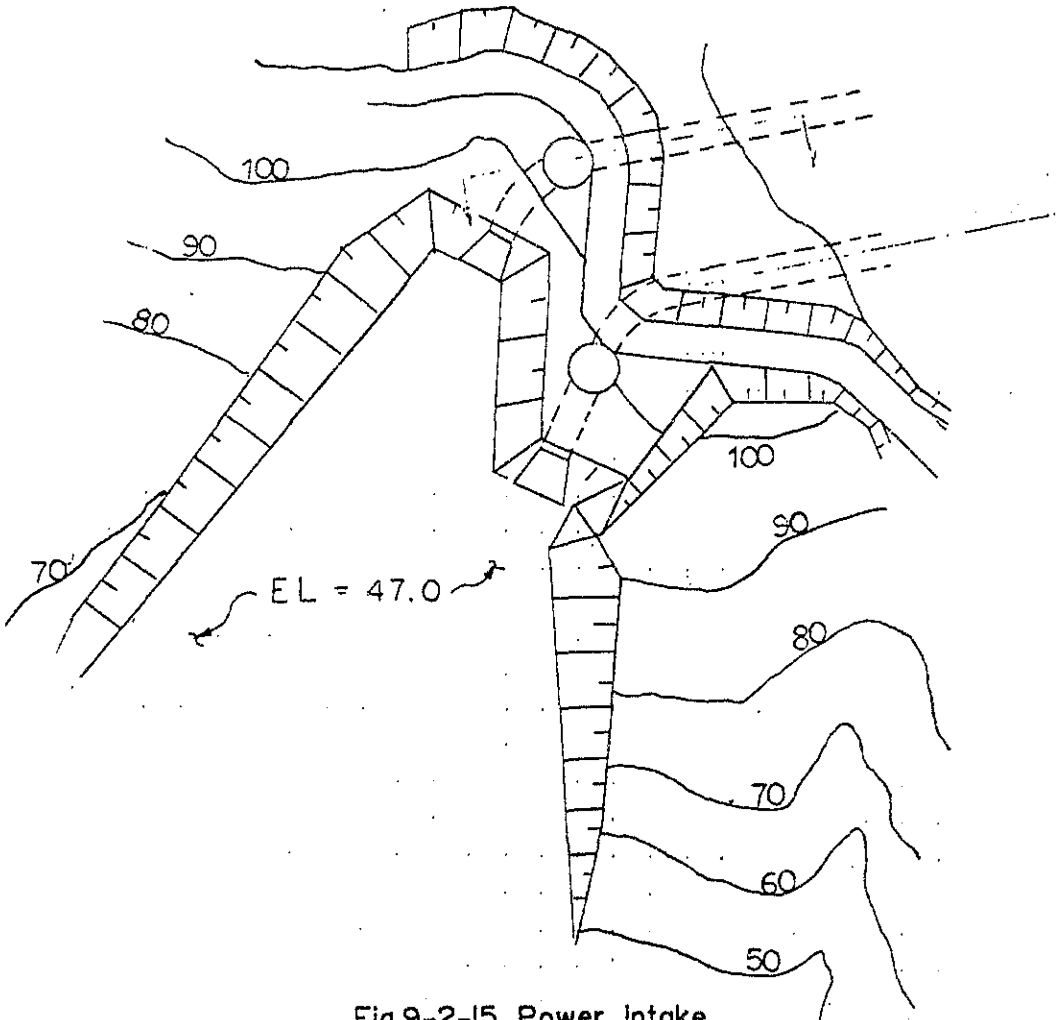
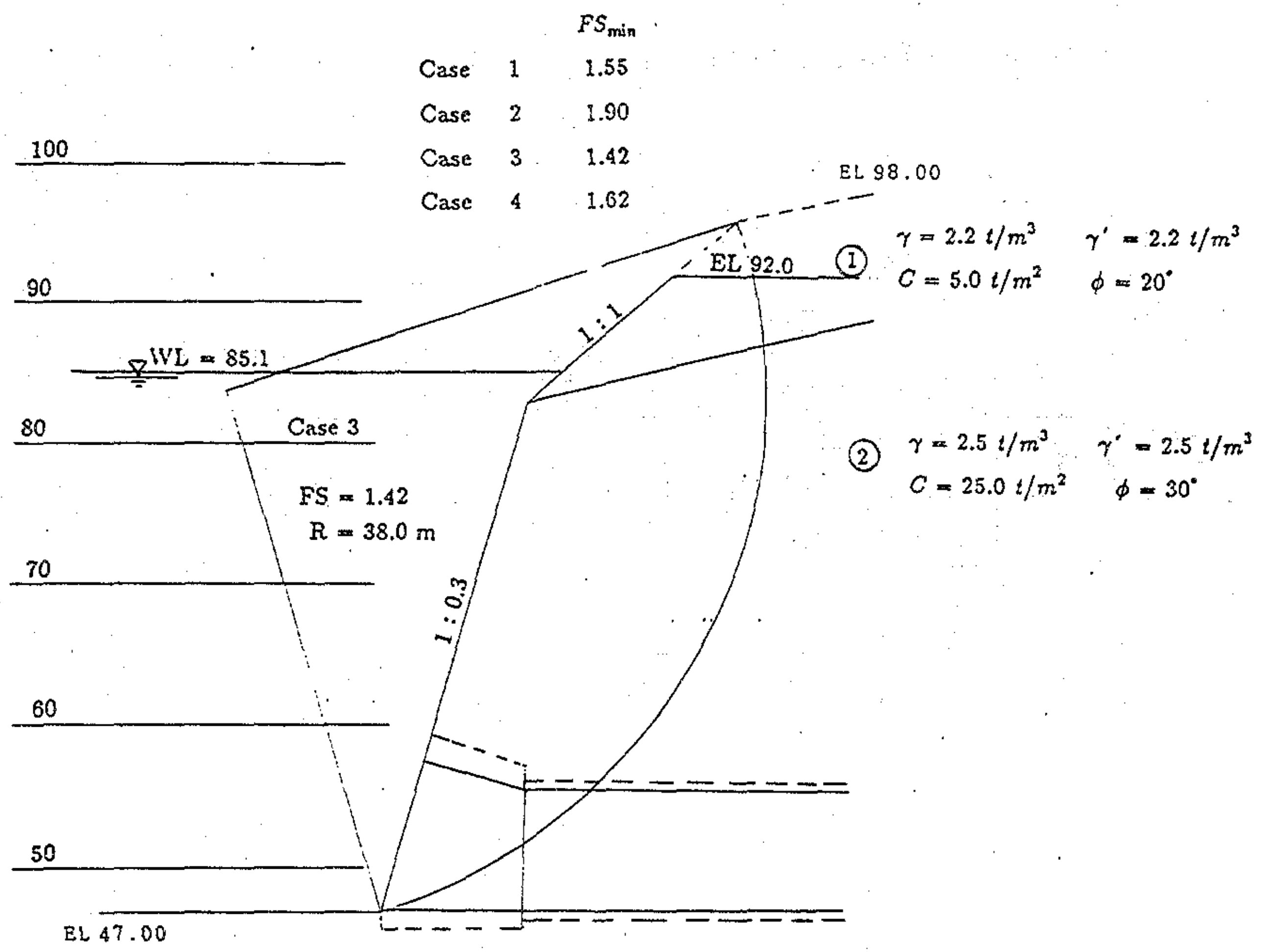


Fig.9-2-15 Power Intake



Load Condition

Water level (m)	Normal	Seismic
WL = 47.0	Case 1	Case 3
WL = 85.1	Case 2	Case 4

$K_H = 0.1$

Note : ① D class rock
② C class rock

Scale
1 : 500
0 5.0 10.0 m

Fig.9-2-16 Stability Analysis of Excavation Slope of Power Intake

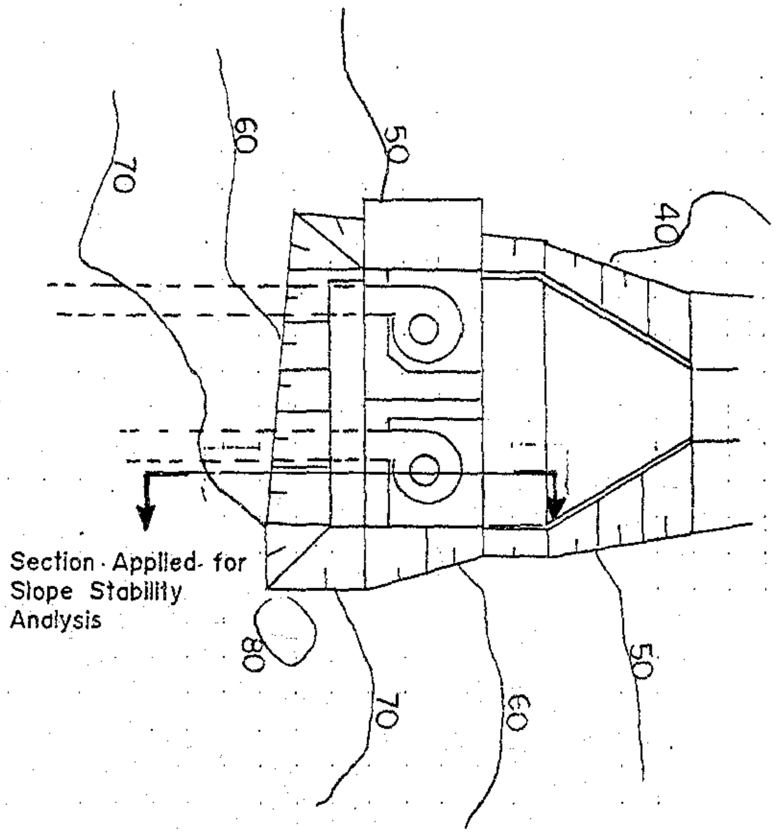
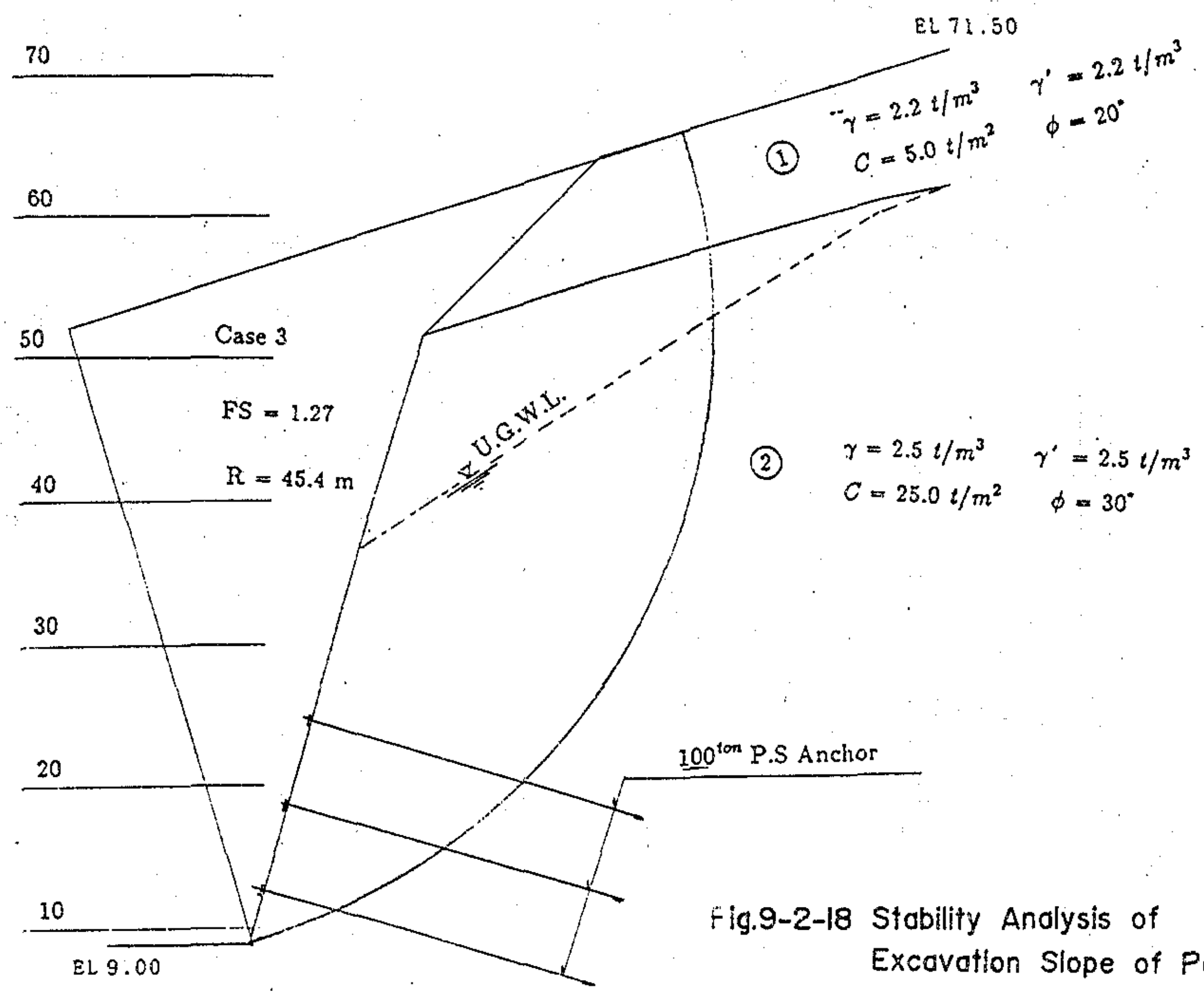


Fig.9-2-17 Powerhouse Plan



	Load Condition	FS_{min}
Case 1	No Water	1.37
Case 2	With Water Without P.S Anchor	1.02
Case 3	With Water With P.S Anchor	1.27

Note : ① D class rock
② C class rock

Scale
1 : 500
0 5.0 10.0 m

Fig.9-2-18 Stability Analysis of Excavation Slope of Powerhouse

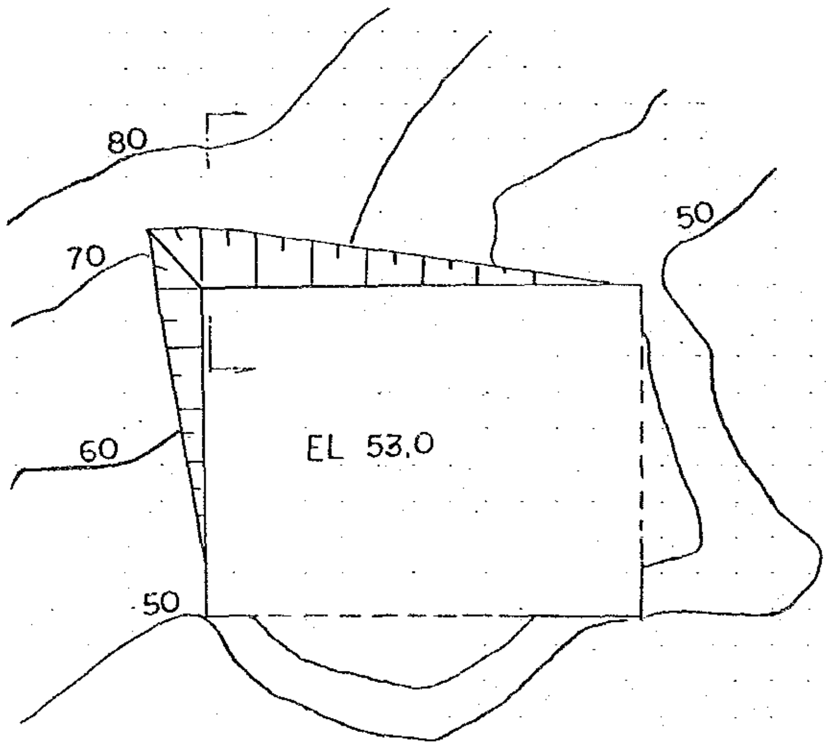
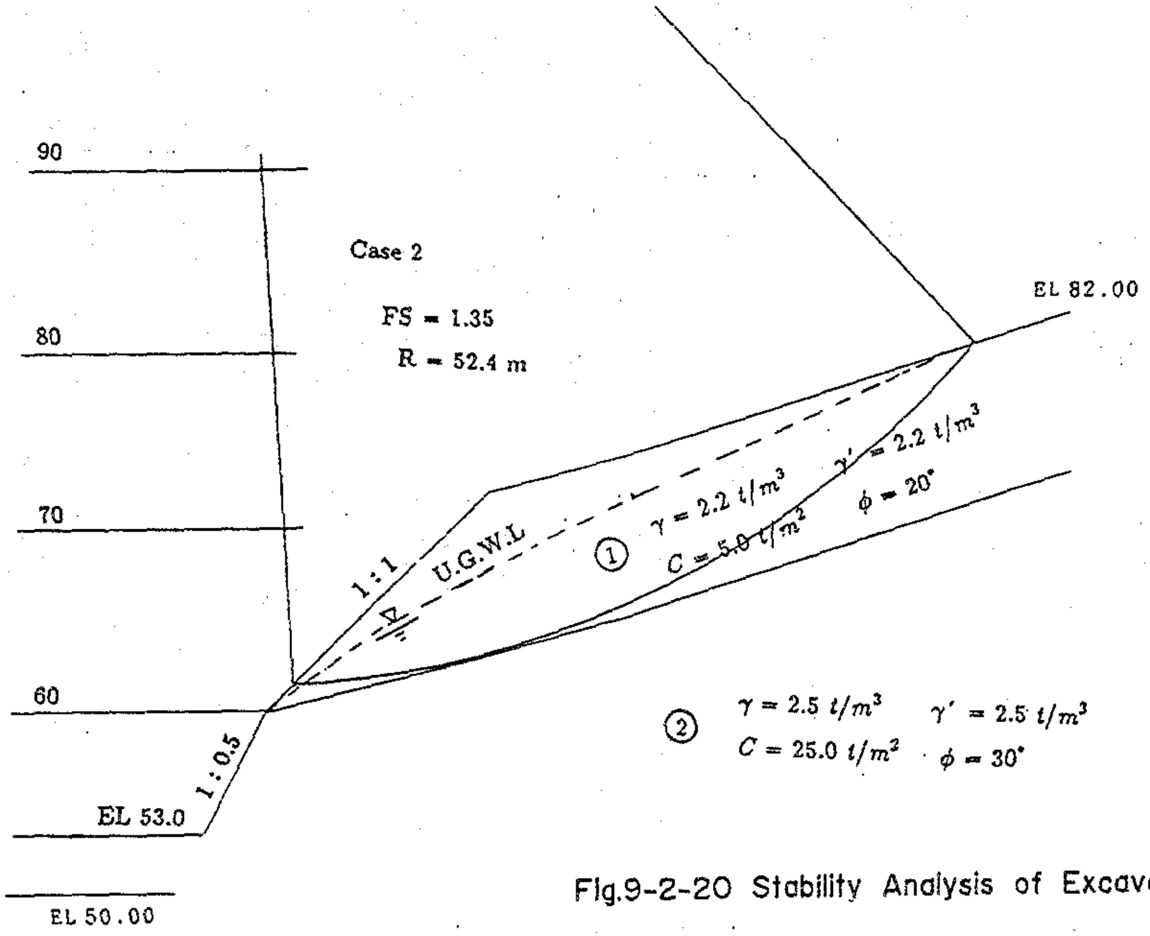


Fig.9-2-19 Switchyard Plan



Load Condition and Result of Calculation

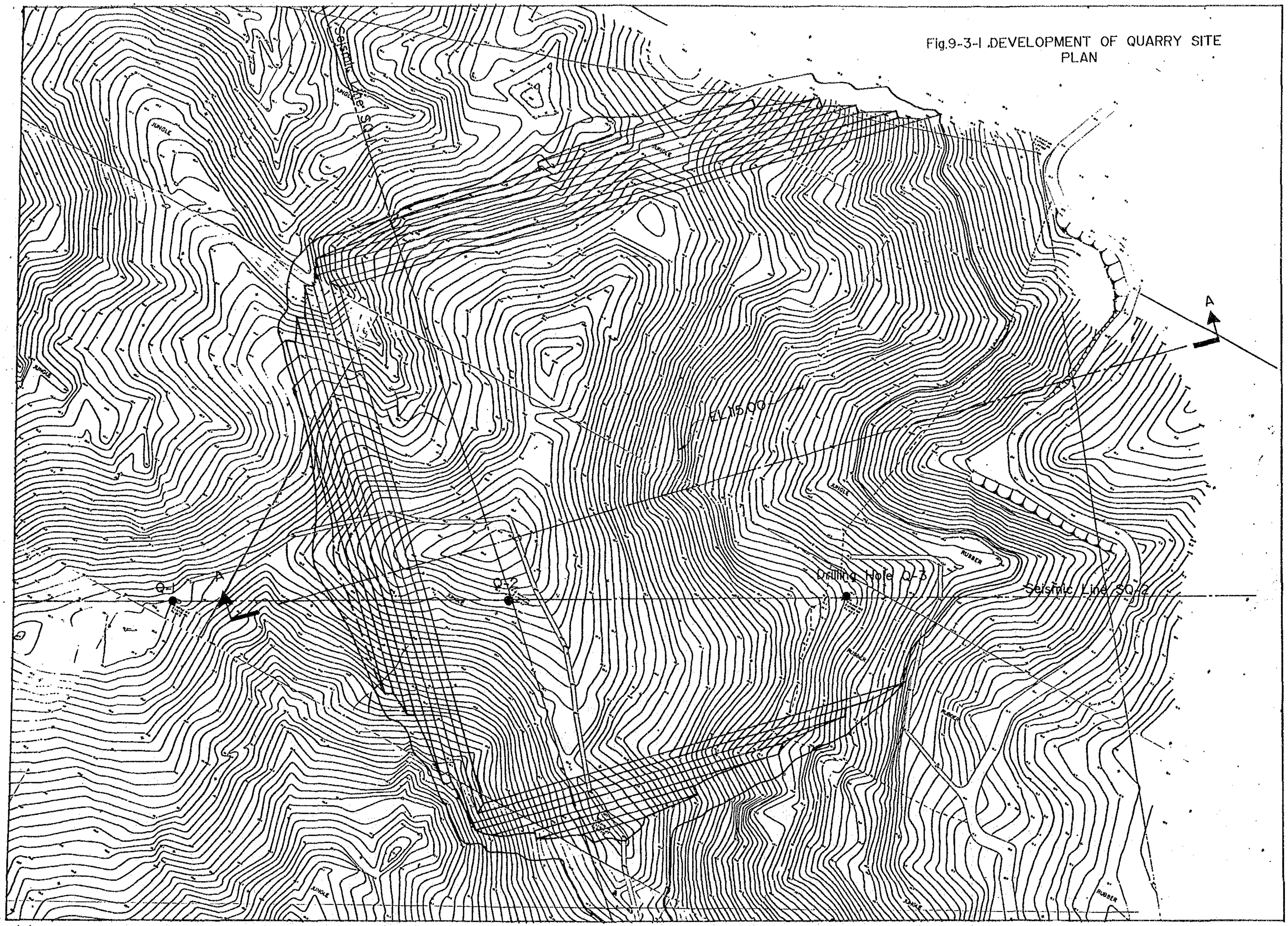
	Load Condition	FS_{min}
Case 1	Normal	1.67
Case 2	Seismic $K_H = 0.1$	1.35

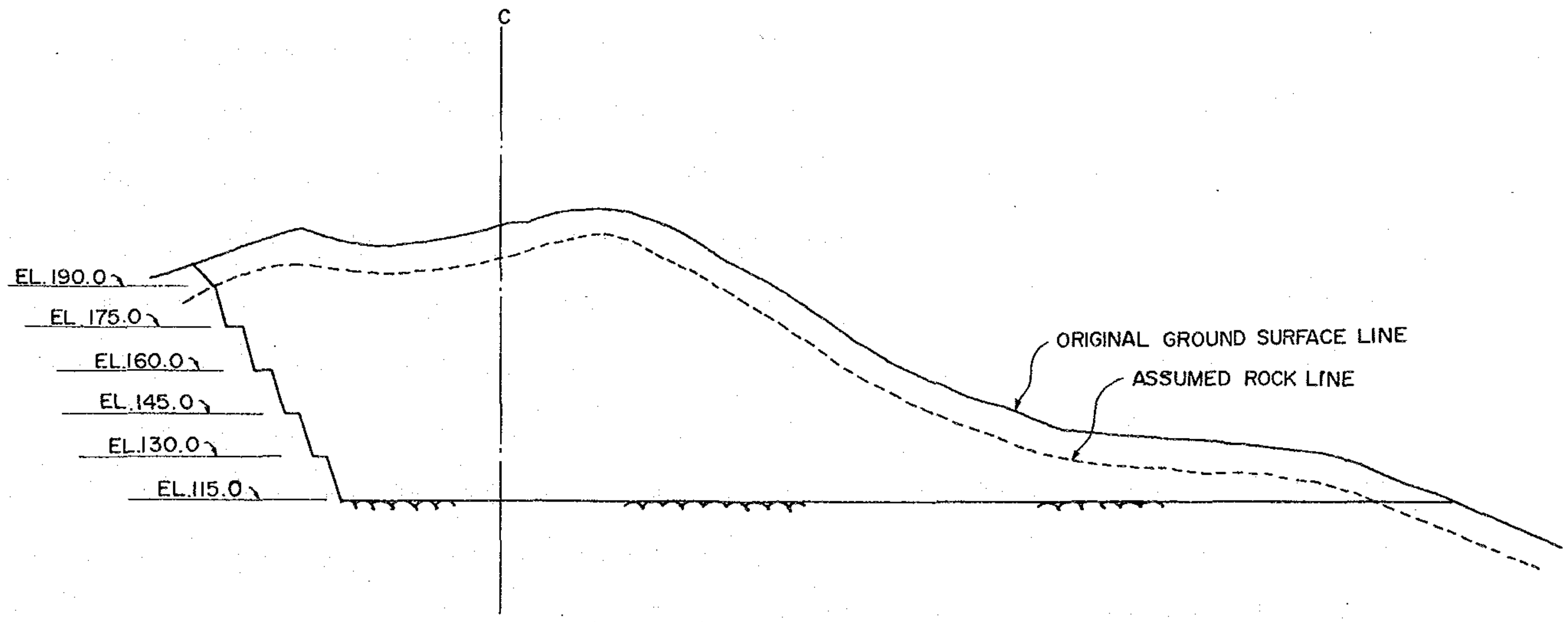
Note : ① D class rock
② C class rock

Scale
1 : 400
0 4.0 8.0 m

Fig.9-2-20 Stability Analysis of Excavation Slope of Switchyard

Fig.9-3-1 DEVELOPMENT OF QUARRY SITE
PLAN





SECTION A-A

Fig.9-3-2 DEVELOPMENT OF QUARRY SITE TYPICAL SECTION

10. Electrical Equipment

10. Electrical Equipment

10.1. Power Plant

(1) Numerical basis for planning

Basic numerical data for design of the powerhouse electrical equipment are as follows:

(a) Reservoir water levels

High water level	:	EL 80.0 m
Water level corresponding to the rated head	:	EL 78.0 m
Low water level	:	EL 60.0 m

A result of study on the reservoir operation shows that during the past 35 years between 1950 and 1984, the number of years in which an annual mean reservoir water level exceeded EL 75 m amounts to 25 and the same exceeded EL 78 m amounts to 18. From these facts, it is anticipated that the reservoir will be operated at rather higher levels. Therefore, the water level which corresponds to the rated net head for designing the turbines will be EL 78.0 m.

(b) Tailrace water level

EL 28.78 m	with two units operating full
EL 27.87 m	with one unit operating full

(c) Loss of head in waterway

1.55 m at $Q = 320\ m^3/s$

(d) Rated net head

47.67 m

(e) Maximum discharge

$640 \ m^3/s$

(2) Output of power plant

The output of Lebir hydropower plant which is topographically determined by the selected locations of the reservoir and the power station, is estimated to be 267,600 kW with a rated net head of 47.67 m, a maximum available discharge of 640 m^3/s, a turbine efficiency of 91.5 % and a generator efficiency of 97.8 %.

The plant output is obtained by multiplying the theoretical output by the turbine and generator efficiencies η_T and η_G, as formulated below:

$$\text{Plant output} \quad P = 9.8 \ Q \cdot H \cdot \eta_T \cdot \eta_G$$
$$= 9.8 \times 640 \times 47.67 \times 0.915 \times 0.978$$
$$= 267{,}600 \ (kW)$$

(3) Number of units

The number of generating units will be two, with consideration for reliability of supply, cost of initial installation, cost of operation and technical manufacturing limits of machines.

The initial capital cost per kilowatt for a hydropower plant of a given capacity generally increases with the number of units installed.

A multiplication of the generation units, however, enables the plant to meet a wider variation of power demand and operate efficiently by optimizing the number of units to be put into service.

10.2. Hydraulic Turbine

(1) Output of turbine

The output of a turbine is given by the following formula.

$$P_T = 9.8\ Q \cdot H\eta_T$$

where,
- P_T : output of turbine (kW)
- Q : maximum discharge per unit (m^3/s)
- H : design head (m)
- η_T : efficiency of turbine

Applying the following numerical values,

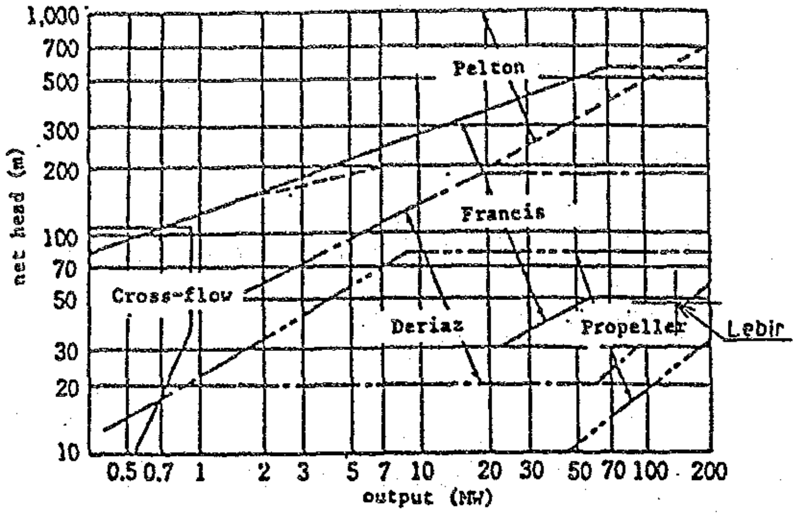
Max. discharge (Q)	: 320	(m^3/s)
Design head (H)	: 47.67	(m)
Efficiency of turbine (η_T)	: 91.5	(%)

the turbine output is obtained as below:

$$P_T = 9.8\ Q \cdot H \cdot \eta_T$$
$$= 9.8 \times 320 \times 47.67 \times 0.915$$
$$= 136.786\ kW$$
$$= 136,800\ (kW)$$

(2) Type of turbine

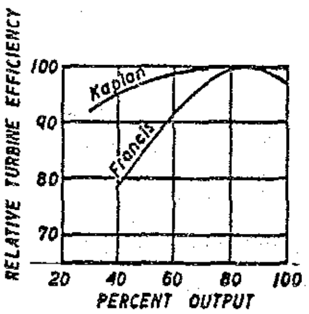
The turbines will be of the vertical shaft type. Whereas both of the types propeller and Francis are applicable to this Lebir case, the adjustable-blade propeller turbine (Kaplan turbine) will be here adopted because of the following reasons. A turbine type selection diagram is shown below.

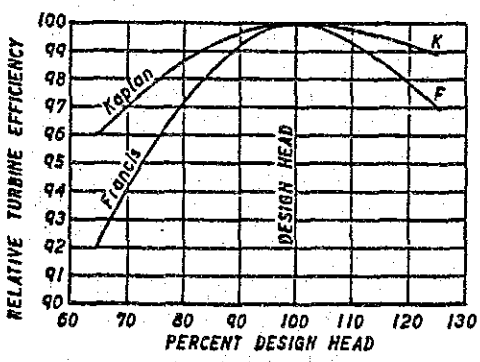


turbine type selection diagram

The Kaplan turbine is more suited than the Francis one for this kind of a low-head installation. The Kaplan turbine has the advantage over the Francis where the head and also load widely vary, because the Kaplan turbine gives good efficiency performances even under such varied conditions, as shown below.

Because of the low-head conditions of this project, an inlet valve will be dispensed with to cut down on the capital cost.





(3) Rated speed of turbine

In general, the higher the rated speed, the lower will be the cost for the turbine and generator, since the physical size of the machines will be smaller.

In practice, however, certain definite limits are imposed on the speed by considerations of cavitation damage to turbine runners.

The rated speed will be determined taking into account the following selection criterion.

$$Ns \leqq \frac{20,000}{H + 20} + 50$$

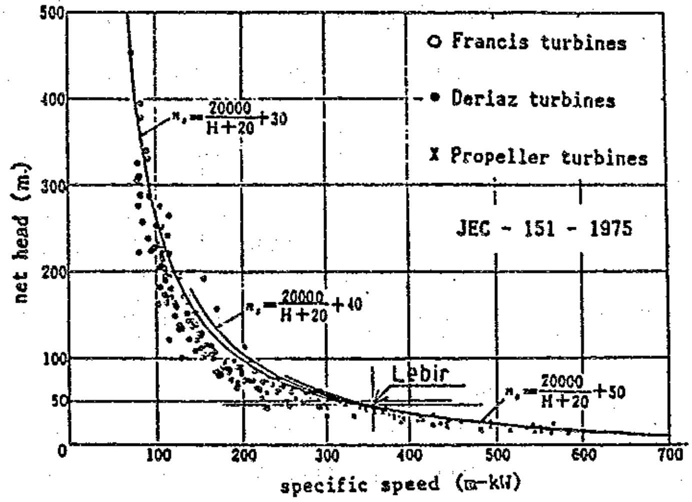
[m-kW] (recommended in the Standard of the Japanese Electro-technical Committee JEC - 151, 1975)

where,

Ns : specific speed (m-kW)

H : rated net head (m)

This criterion is graphically described below.



Meanwhile the rated speed N and specific speed Ns are inter-related as follows:

$$Ns = N \cdot P^{\frac{1}{2}} / H^{\frac{5}{4}} \qquad \text{(m-kW)}$$

where, N : rated speed of turbine (rpm)

P : output of turbine (kW)

The rated speed of a turbine is required to satisfy the following equation according to the number of generator poles:

$$N = \frac{120 \times f}{Po}$$

where, f : frequency (Hz)

Po : number of generator poles

In the case of the Lebir project the specific speed is determined as follows:

$$\frac{20,000}{H + 20} + 50 = \frac{20,000}{47.67 + 20} + 50 = 346 \text{ (m-kW)}$$

Picking out trials near this 346 m - kW, the following choices of the pairs are obtained:

Number of poles (Po)	52	50	48
Speed (N)	115	120	125
Specific speed (Ns)	339	354	369

From these and considering the latest developments in designing turbines, the specific speed Ns will be 369 (m-kW) and the rated speed N 125 (rpm).

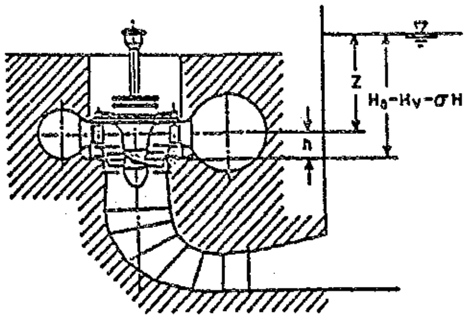
(4) Setting level of turbine

In the case of reaction turbines, the setting of the turbine in relation to the tailrace water level and the permissible draft head are most important considerations in connection with cavitation of the runner.

The setting level is decided according to the project conditions and the recommended cavitation coefficient as formulated below:

$$Z = Ha - Hv - \sigma \cdot H + h$$

where,



Z : required draft head (m)

Ha : atmospheric pressure (mAq)

Hv : vapour pressure of the water (mAq)

H : max. net head (m)

σ : cavitation coefficient

H : vertical level difference between the runner vane center and the distributor center (m)

Thus, the distributor center is set Z (m) below the tailrace water level produced when a single unit is operated at a full gate opening.

Applying numerical values, the setting level is decided as follows:

Ha = 10.3 mAq

Hv = 0.35 mAq

H = 49.67 m

σ = 0.39

h = 2.6 m

$Z = Ha - Hv - \sigma \cdot H + h$

$= 10.31 - 0.35 - 0.39 \times 49.67 + 2.6$

$= -6.81$ (m)

In this case the cavitation coefficient will be chosen to be 0.39 taking into account the following empirical criteria.

. Bureau of Reclamation (USA) 1976

$$= Ns^{1.64} / 39,600 = 0.409$$

. Water Power & Dam Construction, Dec. 1977 (F. de Siervo and F.de Leva)

$$= 6.40 \times 10^{-5} \times Ns^{1.46} = 0.358$$

. Water Power & Dam Construction, May 1988 (A. Lugaresi and Massa)

$$= 1.6 \times 10^{-4} \times Nq^{1.625} = 0.398$$

where, $Nq = N \cdot Q^{0.5} / H^{0.75} = 123$

In view of the tailrace water level with one unit in operation being EL 27.87 m, the level of the turbine center is determined to be EL 21.1 m.

10.3. Generator

(1) Type of generator

The generator will be coupled directly to the hydraulic turbine and be of the three-phase, synchronous and enclosed type with a vertical shaft and damper windings.

As for bearing arrangements, economically advantageous umbrella construction will be adopted because of the low speed of the machines.

(2) Capacity of generator

The capacity of the generators is obtained by the following formula on the assumption of the generator efficiency and rated power factor.

where, $P_G = P_T \cdot \eta_G / pf$

P_G : capacity of generator (kVA)
P_T : max. output of turbine (kW)
η_G : efficiency of generator (%)
pf : rated power factor of generator (%)

The rated power factor of the generator will be 90 %, which is commonly applied to generators connected to 275 kV transmission line system.

Applying numerical values, the capacity of the generators is determined assuming the generator efficiency is 97.8 %, as below:

$$
\begin{aligned}
P_G &= P \cdot \eta_G/pf \\
&= 136,800 \times 0.978/0.9 \\
&= 148,656 \\
&\doteqdot 149,000 \text{ (kVA)}
\end{aligned}
$$

10.4. Overhead Travelling Crane

The overhead travelling crane will be installed in the powerhouse for the purpose of handling equipment during erection of the machines and also maintenance after completion of the whole installation works.

The heaviest load to be lifted by the crane is the generator rotor, which is estimated to weigh approximately 400 tons. Two sets of 200-ton rated cranes will be installed.

Though duplication of cranes will cause some increase in the cost of cranes themselves, the total cost will decrease owing to lower cost of the powerhouse building; and duplicate cranes are more convenient when available at a construction stage and also in maintenance thereafter.

The crane will be equipped with an auxiliary hook and also an auxiliary hoist to handle small loads quickly.

10.5. Main Transformer

The main transformers will be of a three-phase, forced-oil forced-air-cooled type. The main transformers will be connected to the generators on a unit basis in view of ensuring security of power supply in the event of breakdown in either unit of the generating circuits by having another unit available.

The rated capacity of the main transformers will be 149,000 (kVA), the same as that of the generators. The generator-circuits voltage will be stepped up to the transmission line voltage of 275 kV through this transformer.

10.6. Switchyard

The 275 kV outdoor switchyard will be located approximately 100 m north of the powerhouse, at the place that gives topographical facilities for land formation, as shown in Fig. 10-1.

The main bus connection scheme will be a double-bus. The number of feeders will be four, two of which are for outgoing transmission lines and another two for the main transformer circuits.

Such 275 kV outdoor equipment will be installed therein, as circuit breakers, disconnecting switches, current transformers, voltage transformers, lightning arresters and the like.

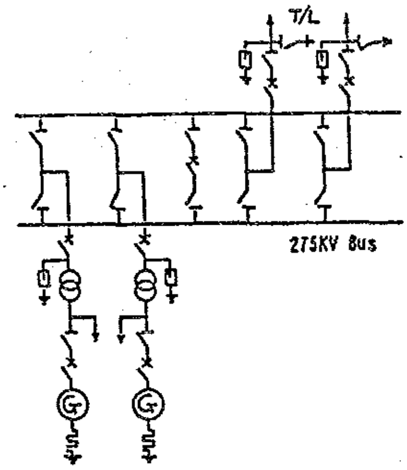
Concerning bus arrangements applicable to this switchyard, there are two possible schemes to be chosen from; one is a single-bus, the other a double-bus. The double-bus schemes have been adopted to ensure the power system reliability arising when the Lebir switchyard is connected to the existing 275 kV trunk line.

The area of the Lebir switchyard will be approximately 11,000 m^2 measuring about 124 m by 89 m. The switchyard plan is shown on Fig. 10-2.

10.7. Main Circuit Arrangements

As shown below the generator terminals will be connected through to the main transformer terminals via a circuit breaker, disconnecting switch and current transformer, and the neutral point of the generator windings will be grounded through a current transformer and a grounding resistor.

The station service supply circuits will be branched off from the main generator circuits. The main circuits between the generator and transformer and the branched circuits for the station service supply will be made by isolated-phase buses. The single line diagramme for Lebir power station is shown on Fig. 10-3.

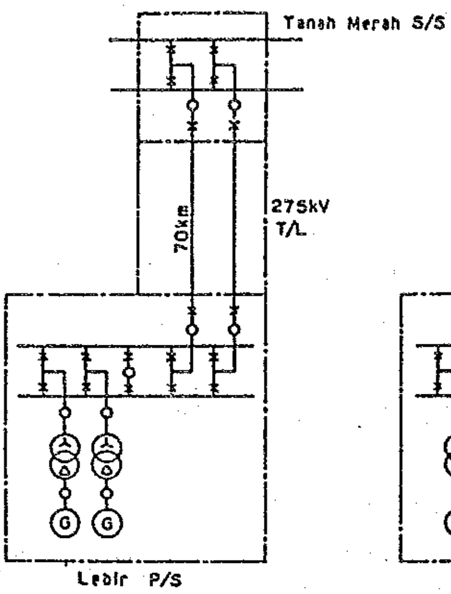


Main circuits connection for Lebir P/S

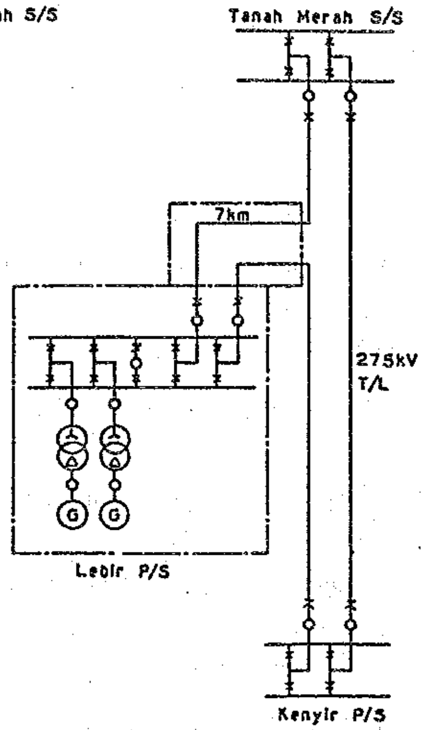
10.8. Transmission Line

As shown on Fig. 4, electric power generated by the Lebir power station will be transmitted to an intermediate point, which is located about 7 km from Lebir switchyard, of the existing 275 kV transmission line between Tanah Merah S/S and Kenyir P/S. The following two choices have been studied as methods to transmit the power, which are schematically shown below.

Plan - A



Plan - B



Plan A : To extend a 275 kV double-circuit line from the Lebir switchyard to Tanah Merah S/S which is estimated to be about 70 km long, and install additional two-feeder facilities at Tanah Merah S/S.

Construction cost:

Extension of Tanah Merah S/S ...... M$ 3,360,000
Transmission line .... M$41,200,000
Total .... M$44,560,000

Plan B : To make a π (pi)-shaped double-circuit line connection to the existing 275 kV trunk line between Tanah Merah S/S and Kenyir P/S at an intermediate point nearest to the Lebir switchyard.

Construction cost:

Transmission line only .... M$ 4,120,000

As a result of the comparison, Plan B has been chosen because of the lowest cost and no substantial problem to be envisaged in the power system operation. The topographical transmission line route is shown on Fig. 10-5.

The transmission line facilities are outlined as follows:

Voltage	:	275 kV
Number of circuits	:	2
Standard span length	:	300 m
Route length	:	approx. 7 km
Tower	:	Steel tower
Conductor	:	Batang (ACSR 323 mm^2) x 2
Ground wire	:	Skunk (ACSR 63 mm^2)

The typical tower assembly for the transmission line is shown on Fig. 10-6.

10.9. Cost for Electrical Facilities

Costs for the electro-mechanical works at the power station and for the transmission line are estimated as follows:

in M$

	Total	F/C	L/C
Turbines	45,400,000	39,190,000	6,210,000
Generators	75,315,000	69,321,000	5,994,000
Transformers/ switchgear	16,960,000	15,773,000	1,187,000
Transmission line	4,120,000	3,180,000	940,000
Subtotal	141,795,000	127,464,000	14,331,000
Contingencies	7,090,000	6,373,200	716,800
Total	148,885,000	133,837,200	15,047,800