CHAPTER 2 SELECTION OF WATER RESOURCES DEVELOPMENT POINTS

2.1 Methodology and Procedures

Water resources development points (dam sites and intakes) for the Study were examined and selected through 2 steps of screening procedures. Methodology and procedure adopted for the selection are as follows.

(1) Identification of water resources development points through map study.
(2) Ranking of water resources development points in screening evaluation. (First Selection)
(3) Investigation in the survey of dam sites.
(4) Selection of water resources development points in evaluation from the investigation. (Second Selection)

2.2 Identification of Water Resources Development Points

The surface water development location of damsites and intakes were studied based on the topographical maps. First, about 270 locations were identified from topological maps with a scale of 1:250,000. Next, each locations were scrutinised on the maps with a scale of 1:50,000 or 1:100,000 and 136 locations were finally selected.

Location, coordinates, priority and reference maps of 136 water resources development points are compiled in Appendix N.1. (Tables and Location map (scale 1:1,500,000))

2.3 First Selection of Water Resources Development Points

The 136 locations were classified based upon development priorities as listed below.

1) Priority AA	: 23 locations	[Note]	21 dam sites and 2 intakes
2) Priority A	: 26 locations		
3) Priority B	: 47 locations		
4) Priority C	: 40 locations		
Total	136 locations		

The following factors were employed for determining the priority of each development location.

1) Topographical characteristics
Generally speaking, dam sites should be at the narrowest section of a valley. Dams with smaller ratio of B/H (B: width of a valley, H: depth of a valley) are constructed with less cost.

2) Catchment area of dam
Discharge amount depends on the catchment area at the dam sites. The wider the catchment area of the dam, higher discharge available. Dam sites selected in perennial river are preferable.

3) Distance to beneficiary areas from the development location
Water conveyance facilities such as pipe lines, channels, pumping stations etc. are required to transport developed water from dam sites to beneficial areas such as urban and rural townships, factories, farm lands etc. Shorter distances of water conveyance are more economical.

4) Accessibility of the site.
If the dam sites are located far from existing roads or at deep valley or at remote areas, it is difficult and expensive to approach the sites for investigation and construction of dams.

Finally 31 water resources development points are identified through the investigation study. They included 23 dam sites and intakes with priority AA, and 8 dam sites with priority A. The locations of 31 water resources development points are shown in Figure 2-1 and these coordinates and reference maps are shown in Table 2-1.

Note.1 The points of No.1~No.5-1, No.6~No.9-1, No.10-1, No.11~No.14-1, No.15 ~21 (Total 21 points) are dam sites with priority AA. The points of No. 22 and No.23 (Total 2 points) are intakes with priority AA.

Note.2 The points of No.5-2, No.9-2, No.10-2 (Total 3 points) are dam sites with priority A. These are selected for alternative sites of near another site.

Note.3 The points of No.24 and No.25 (Total 2 points) are dam sites with priority A. These are selected for the study of hydroelectric power plants reinforcement. Musonda Falls Power Station is No.24 and Chishimba Falls Power Station is No.25.

2.4 Investigation in the Survey of Dam Sites

Main items in the survey consist of ① Topography at the dam sites, ② Geology at the dam sites and foundation condition, ③ Possibility of dam construction, ④ Type of dam, and so on. The result of survey and geological assessment of the dam sites is described in "SUPPORTING REPORT [N], DAM GEOLOGY".

Table 2-1 Proposed Dams and Coordinates

Dam No.	Name of River	Coordinates		Reference Maps		Aerial Photographs
		X(1000m)	Y(1000m)	1:250,000	1:50,000	
1	Lufubu	729	8813	SC-35-12	1029C1	
2	West Lunga	221	8701	SC-35-13	1124C1	
3	Lukupa	278	8879	SC-39-9	1030B2	
4	Kapemba	521	8760	SD-36-15	1133A1	ZA 82/9 Chama R7-199/201
5-1	Solwezi	434	8655	SD-35-2	1226A2	ZA 91/11G Solwezi R1-5/6
5-2	Kifubwa	440	8655	SD-35-2	1226A2	
6	Kafue	626	8606	SD-35-3	1228C1	ZA 93/5 Mufulira R4-51/52
7	Mutundu	636	8598	SD-35-3	1228C2	ZA 93/5 Mufulira R6-81/83
8	Lubi	188	8495	SD-35-5	1324C1	
9-1	Lufupa (Downstream)	375	8510	SD-35-5	1325B4	
9-2	Lufupa (Upstream)	375	8519	SD-35-5	1325B4	
10-1	Baluba	47	8560	SD-35-5	1325B4	ZA 84/2 Luanshya R34-1944/1946
10-2	Kafubu	661	8538	SD-35-7	1328A2	
11	Lunsemfwa	746	8490	SD-35-8	1329C2	ZA 93/8 Mukushi R9-1019/1021
12	Mwomboshi	659	8361	SD-35-11	1428C4	ZA 88/8 Central Prov. R12-13/14
13	Kopyonga	556	8362	SD-35-15	1527B1	
14-1	Muchito (Upstream)	633	8263	SD-35-16	1528C1	ZA 19/1 Southern Prov. R53-53/54
14-2	Muchito (Downstream)	634	8254	SD-35-16	1528C1	ZA 19/1 Southern Prov. R51-58/60
15	Kanakantapa	672	8321	SD-35-16	1528B1	ZA 19/1 Southern Prov. 64A-14/15
16	Chongwe	682	8306	SD-35-16	1528B3	ZA 19/1 Southern Prov. 61A-8/9
17	Mwapula	712	8320	SD-35-16	1528B2	ZA 19/1 Southern Prov. R53-29/30
18	Lundazi	505	8665	SD-36-3	1233A1	
19	Lukusashi	202	8514	SD-36-5	1330A2	ZA 8/18 Serenje R10-305/306
20	Lutembwe	432	8501	SD-36-6	1332C2	
21	Katete	399	8449	SD-36-10	1432A1	ZA 2/73 Block C R125-485/486
22	Zambezi Mongu	728	8312	SD-34-16	1523A3	
23	Zambezi Livingstone	377	8022	SE-35-6	1725D4	
24	Luongo	698	8815	SC-35-12	1028D2	
25	Lwombe	171	8883	SC-36-9	1030B2	
26	Bwengwa	513	8178	SE-35-3	1627A3	ZA 80/3 Kafue/Liv.R17-1712/1713
27	Kalomo	439	8103	SE-35-6	1726A2	ZA 91/1 Southern Prov.R21-37/39

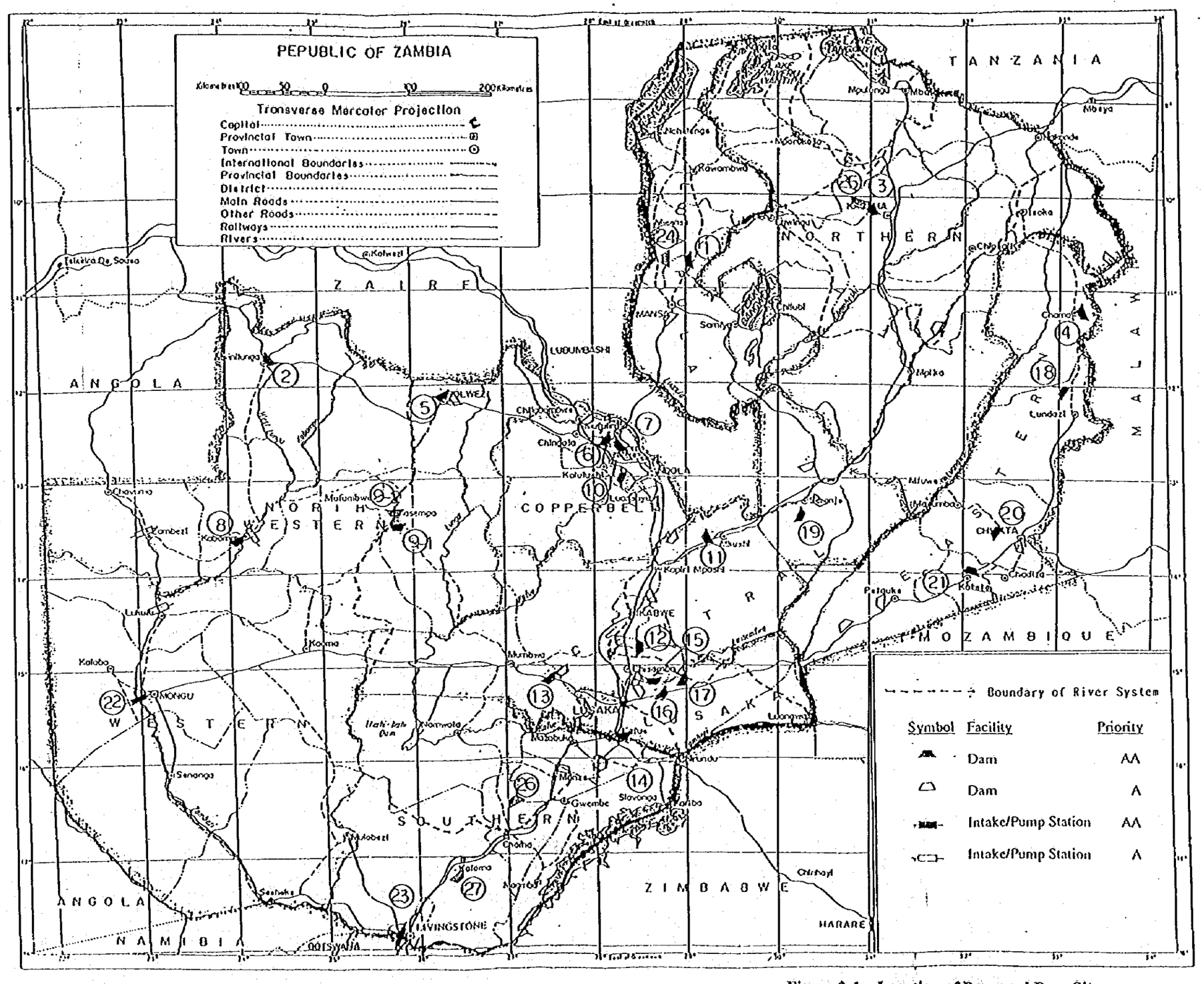


Figure 2-1 Location of Proposed Dam Sites

2.5 Second Selection of Water Resources Development Points

The proposed dam sites for the study of preliminary layout design were selected by eliminating of difficult dam sites in construction, into consideration of the result of survey findings. Finally 29 dam sites were selected. The following factors were employed for deterring the selection.

1) Geological difficulty
In case that foundation condition of a dam site is bad (for example, high permeability or low strength), construction cost increase extremely for foundation treatment cost. If the foundation condition is bad apparently, the other dam sites should be found.

2) Quantity of compensation object
In case that much compensation is necessary for the submerging facility by reservoir backwater, the compensation cost increase extremely and the time for mutual agreement extends long over. If compensation objects are many, the other dam sites should be found. The abandoned dam sites in this stage are No.8 Lubi Dam by reason of bad foundation (fine sand foundation), No.10-1 Baluba Dam by reason of much compensation cost, No.14-1 Muchito (Upstream) Dam as same, No.14-2 Muchito (Downstream) Dam as same. The selected proposed dam sites for the study of preliminary layout design are 27 sites without that 4 dam sites. The characteristics of each dam sites including abandoned dam sites are described at chapter 3.

CHAPTER 3 PRELIMINARY LAYOUT DESIGN OF PROPOSED DAMS

3.1 Methodology and Procedure

Methodology and Procedure adopted for preliminary layout design of proposed dams are as follows.

1) Preparation of basic planning data for selected water resources development points, i.e., catchment area, reservoir surface area-storage curve, dam embankment volume and so on.
2) Evaluation of maximum dam height according to investigation in the field survey and 1/50,000 topological map.
3) Preliminary design of proposed dams.
   Plain plan of a dam was studied on 1/10,000 topological map enlarged from 1/50,000 topological map. Longitudinal cross section plan studied on topological survey result on each sites.

3.2 Criteria for Dam Design

The criteria for the dam design was adopted as follows.

(1) Dam Crest Elevation (DCE)

DCE = Proposed FSL + Freeboard

where, DCE : Dam Crest Elevation
FSL : Full Supply Level
Freeboard : tentatively set out as follows (including the spillway overflow depth at a dam design flood)
Freeboard = 4.0m
A : The freeboard for the bellow at flood.
At least 1.0m is necessary.
B : The spillway overflow depth at a dam design flood.

(2) Effective Storage Capacity

Gross Storage Capacity minus Dead Storage Capacity

(3) Dead Storage Capacity

Dead Storage Capacity is determined by the sediment yield amount during a reservoir life.

Dead Storage Capacity
= (the annual sediment yield amount (m^3/year)) × (the reservoir life (years))

Annual sediment yield is based on the results of sediment study from existing dams. But necessary data of this study at existing dams was not able to be obtained in Zambia. Therefore the sediment yield is assumed from the design dead storage capacity of the existing dams in Zambia. The dead storage capacity of the existing dams were shown in Table 3-1.

The annual sediment yield is 70 m^3/km^2/year from the dead storage capacity at the Itezhi-Tezhi dam. Reservoir life is assumed to be 100 years.

Table 3-1 Dead Capacity of the Major Existing Dams in Zambia

The Name of Dam	Catchment Area (km^2)	Gross Storage Capacity (Mm^3)	Dead Storage Capacity (Mm^3)	Annual Sediment Yield * (m^3/km^2/year)	Remarks
Mulungushi	2,450	9.5	0.9	3.7	Kabwe Water Supply
Itezhi-Tezhi	105,620	5,700	700	66.0	
Kafue Gorge	152,810	840	140	9.2	
Kariba	663,880	180,600	64,800	976.0	
Mulungushi	4,500	275	unknown	-	ZCCM
Mita Hills	4,300	680	unknown	-	ZCCM

* Annual sediment yield is assumed as which the reservoir life is 100 years.

(4) Dam Type

Rockfill type dam with centre core is assumed for all schemes. The rockfill dam with an impervious core of natural materials is perhaps the most used type. This dam type could often be adopted to a dam site with weak foundation. In case that concrete dam would be constructed on such weak foundation, much amount of cement becomes necessary. The cement cost is high in Zambia. Also the transportation cost to remote construction sites is high. And skilled building tradesmen are not easily attracted to remote construction sites. The typical cross section of rockfill dam is shown in Figure 3-1.

(5) Dam Embankment Volume

Dam embankment volume is calculated by the following formula which is based principally on the damsite valley profile date from topological survey.

$$\text{Embankment Volume} = 1/2 \cdot B \times H \times (L1+L2) + 1/6 \times (m+n) \times H^2 \times (L1+2L2)$$

where, B = dam crest width (10m)
m = upstream slope of dam embankment (3.0)
n = downstream of dam embankment (2.5)
H = dam height (m)
L1 = dam length at crest (m)
L2 = dam length at bottom (m)

Note 1: Foundation excavation is assumed to be 3m below the ground line.
Note 2: Dam embankment slopes of upstream and downstream, are assumed to be 1:3.0 and 1:2.5.

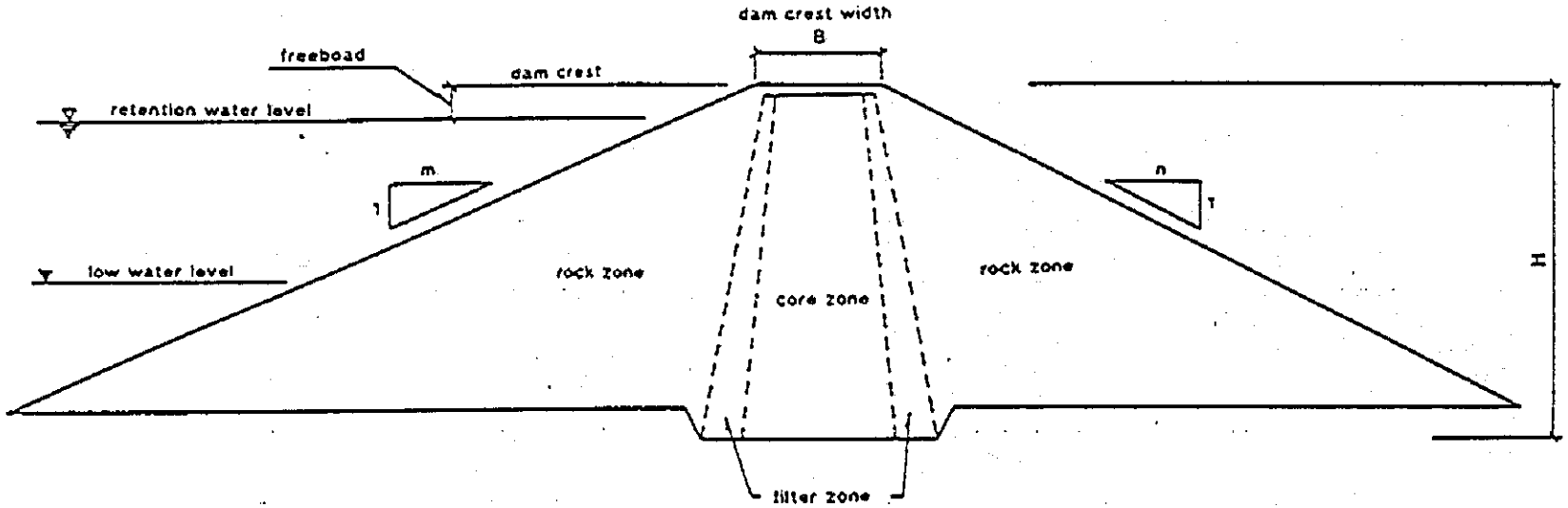


Figure 3-1 Typical Cross Section of Dam Embankment

Dam embankment volume (V):

A dam embankment volume is estimated by the empirical formula below:

$$V = 1/2 * B * H * (L1 + L2) + 1/6 * (m + n) * H^2 * (LI + 2 * L2)$$

where,

B : dam crest width (10 m)
m : upstream slope of dam embankment (3.0)
n : downstream slope of dam embankment (2.5)
H : dam height (m)
L1 : dam length at crest (m)
L2 : dam length at bottom (m)

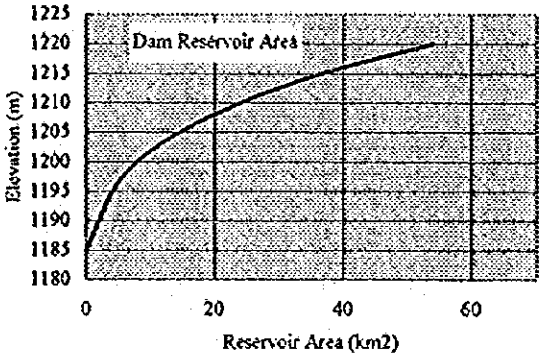
Freeboard (fb):

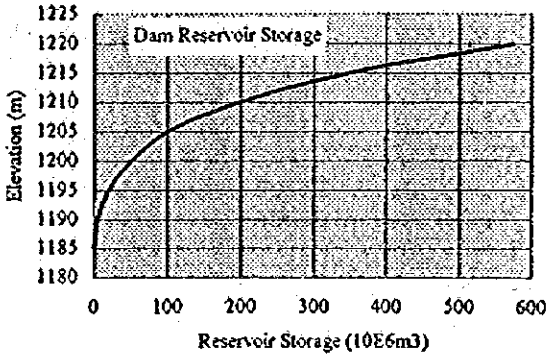
freeboard = 5 m

3.3 Preparation of Basic Planning Data

The reservoir capacity and surface area by elevation of the proposed dam sites are shown in Figure 3-2.

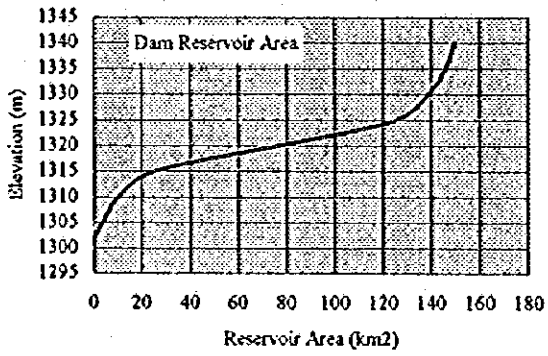
No.1 Lufubu Dam

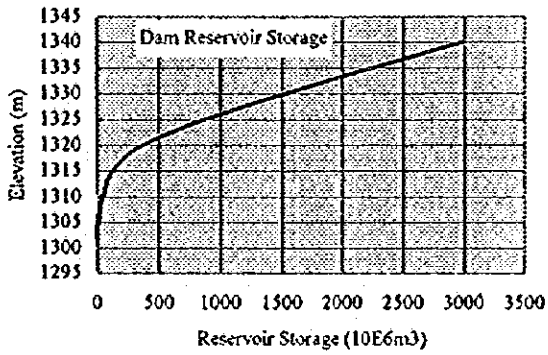




Elevation (m)	Reservoir Area (km2)	Selection Volume (10E6m3)	Reservoir Storage (10E6m3)
1185	0.0	0.0	0.0
1190	2.0	5.0	5.0
1195	4.1	15.3	20.3
1200	7.9	30.0	50.3
1205	14.6	50.3	100.6
1210	24.0	96.5	197.1
1215	36.5	151.3	348.4
1220	54.0	226.3	574.7

No.2 West Lunga Dam

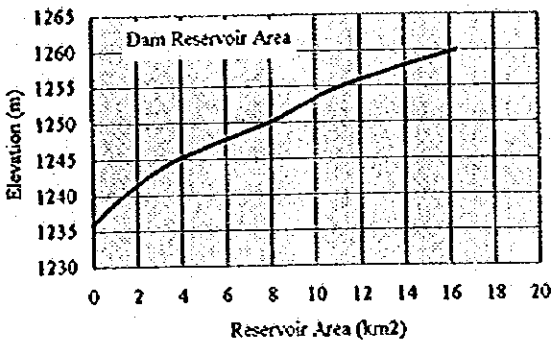


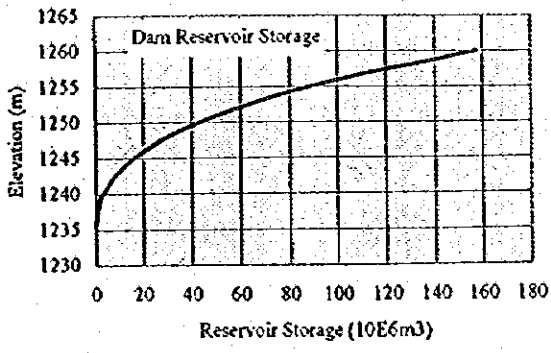


Elevation (m)	Reservoir Area (km2)	Selection Volume (10E6m3)	Reservoir Storage (10E6m3)
1302	0.0	0.0	0.0
1305	3.5	5.3	5.3
1310	10.0	33.8	39.1
1315	25.0	87.5	126.6
1320	76.3	234.5	361.1
1325	125.0	503.3	864.4
1330	139.0	660.0	1,524.4
1335	146.0	712.5	2,236.9
1340	149.8	739.5	2,976.4

Figure 3-2(1) Reservoir Water Level - Reservoir Storage Curve

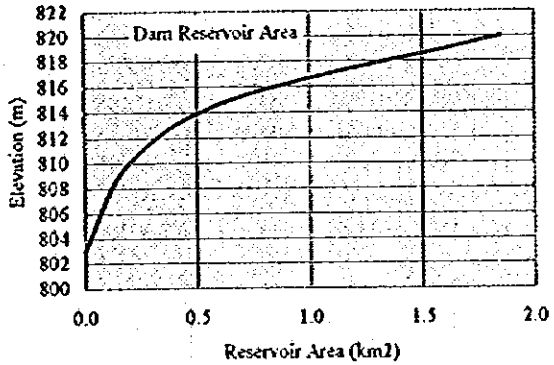
No.3 Lukupa Dam

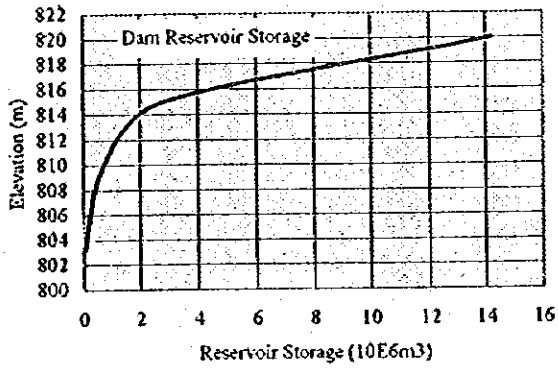




Elevation (m)	Reservoir Area (km2)	Selection Volume (10E6m3)	Reservoir Storage (10E6m3)
1236	0.0	0.0	0.0
1240	1.4	2.8	2.8
1245	3.8	13.0	15.8
1250	7.9	27.3	43.1
1255	11.2	45.8	88.1
1260	16.3	68.8	157.6

No.4 Kapemba Dam

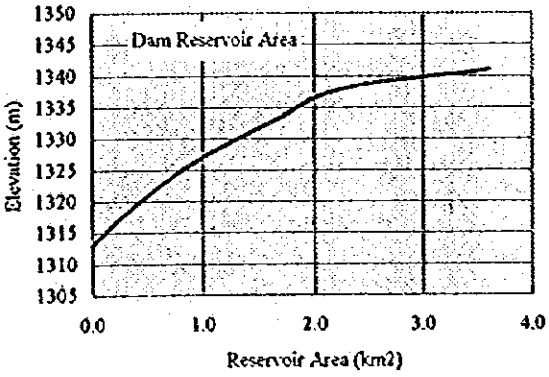


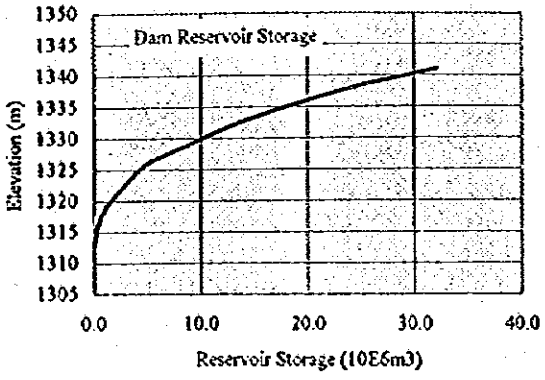


Elevation (m)	Reservoir Area (km2)	Selection Volume (10E6m3)	Reservoir Storage (10E6m3)
803	0.0	0.0	0.0
810	0.2	0.7	0.7
815	0.65	2.1	2.8
820	1.85	11.4	14.2

Figure 3-2(2) Reservoir Water Level - Reservoir Storage Curve

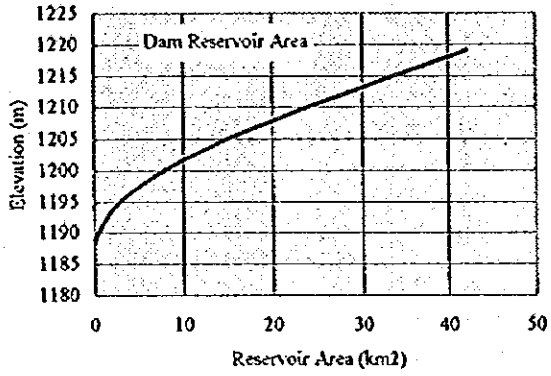
No.5 Solwezi Dam

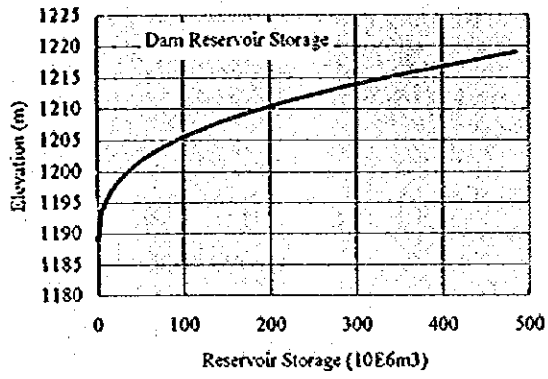




Elevation (m)	Reservoir Area (km2)	Selection Volume (10E6m3)	Reservoir Storage (10E6m3)
1313	0.0	0.0	0.0
1318	0.3	0.8	0.8
1323	0.65	2.3	3.1
1326	0.9	1.9	5.0
1328	1.1	2.5	7.6
1333	1.65	6.9	14.4
1338	2.25	9.8	24.2
1341	3.6	7.9	32.1

No.6 Kafue Dam

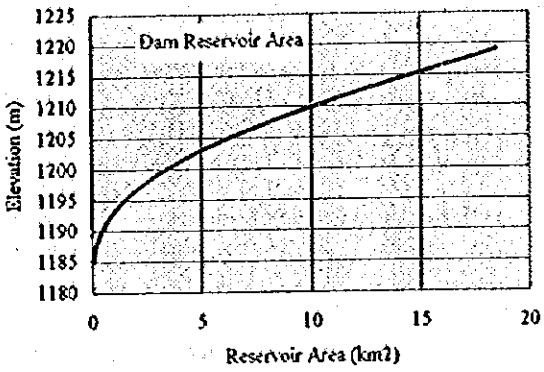


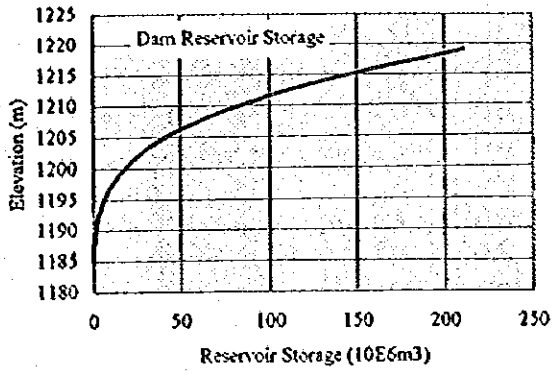


Elevation (m)	Reservoir Area (km2)	Selection Volume (10E6m3)	Reservoir Storage (10E6m3)
1189	0.0	0.0	0.0
1194	2.2	5.5	5.5
1199	6.60	22.0	27.5
1204	13.40	50.0	77.5
1209	22.1	88.8	166.3
1214	31.6	134.2	300.5
1219	42.0	184.0	484.5

Figure 3-2(3) Reservoir Water Level - Reservoir Storage Curve

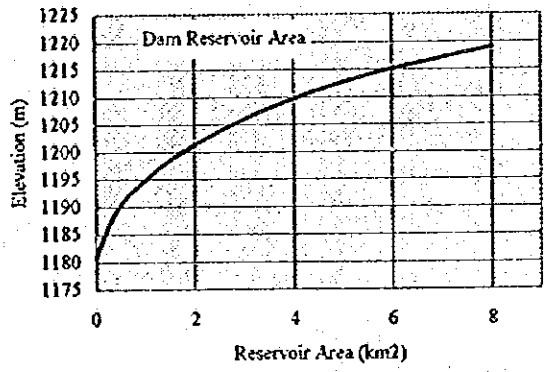
No.7 Mutundu

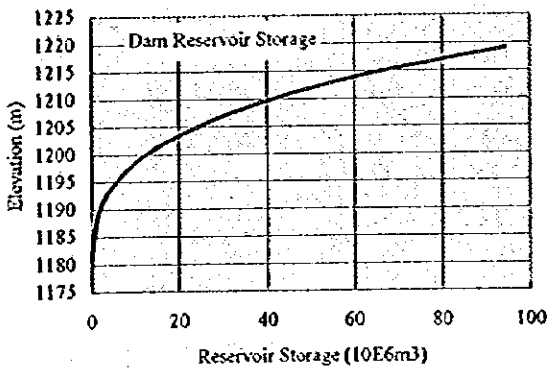




Elevation (m)	Reservoir Area (km2)	Selection Volume (10E6m3)	Reservoir Storage (10E6m3)
1185	0.00	0.00	0.00
1189	0.30	0.60	0.60
1194	1.20	3.80	4.40
1199	2.90	10.20	14.60
1204	5.60	21.20	35.58
1209	9.30	37.30	73.10
1214	13.70	57.50	130.60
1219	18.50	80.50	211.10

No.9-1 Lufupa Dam (Down streem)

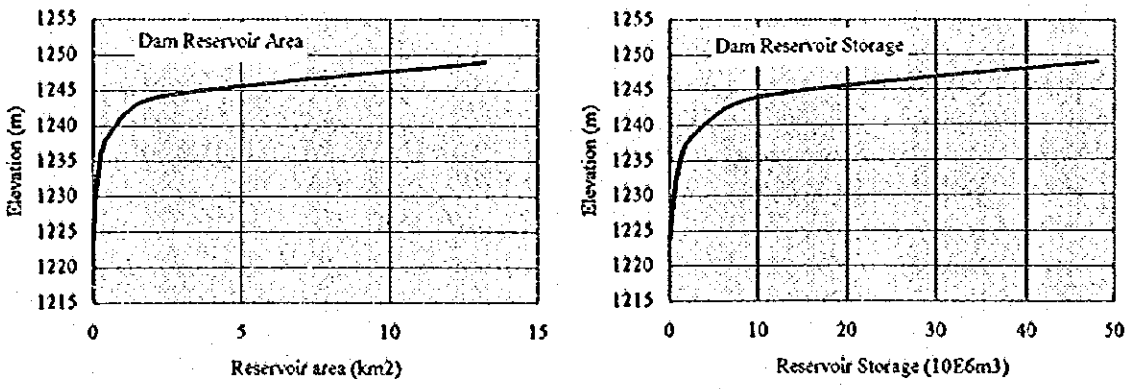




Elevation (m)	Reservoir Area (km2)	Selection Volume (10E6m3)	Reservoir Storage (10E6m3)
1181	0.00	0.00	0.00
1189	0.40	1.60	1.60
1194	0.90	3.20	4.80
1199	1.60	63.30	11.10
1204	2.55	10.40	21.50
1209	3.80	15.80	37.30
1214	5.50	23.30	60.60
1219	8.00	33.70	94.30

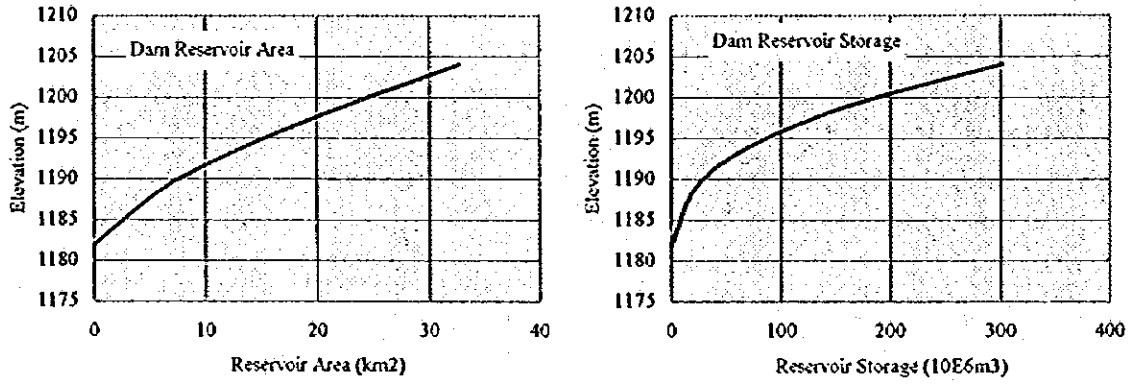
Figure 3-2(4) Reservoir Water Level - Reservoir Storage Curve

No.9-2 Lufupa Dam (Up streem)



Elevation (m)	Reservoir Area (km2)	Selection Volume (10E6m3)	Reservoir Storage (10E6m3)
1224	0.00	0.00	0.00
1234	0.20	1.00	1.00
1239	0.60	2.00	3.00
1244	2.10	6.80	9.80
1249	13.20	38.30	48.00

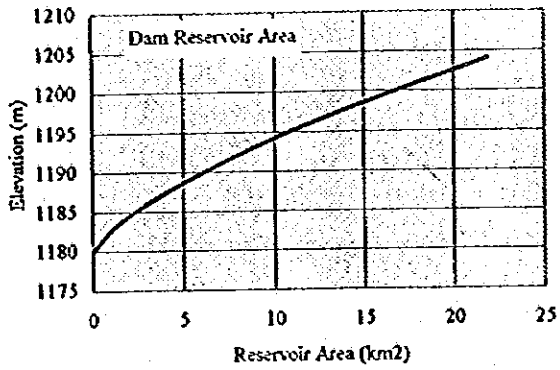
No.10 Kafubu Dam

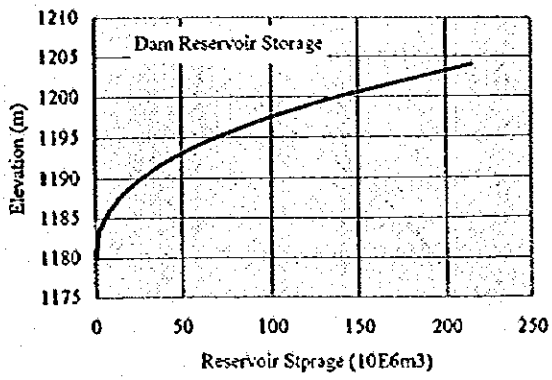


Elevation (m)	Reservoir Area (km2)	Selection Volume (10E6m3)	Reservoir Storage (10E6m3)
1182	0.00	0.00	0.00
1189	6.40	22.40	22.40
1194	13.60	50.00	72.40
1199	22.60	90.50	162.90
1204	32.70	138.30	301.10

Figure 3-2(5) Reservoir Water Level - Reservoir Storage Curve

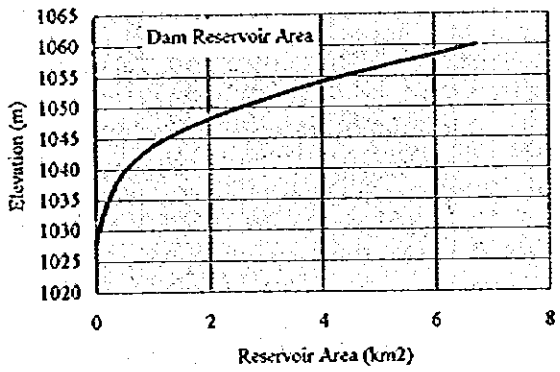
No.11 Lunsemfa Dam

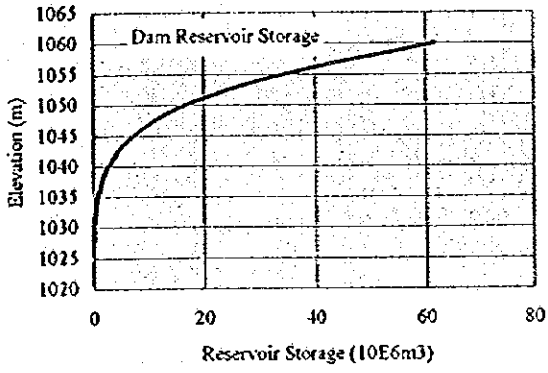




Elevation (m)	Reservoir Area (km2)	Selection Volume (10E6m3)	Reservoir Storage (10E6m3)
1180	0.00	0.00	0.00
1184	1.70	3.20	3.20
1189	5.30	17.50	20.70
1194	9.80	37.80	58.50
1199	15.50	63.20	121.70
1204	21.90	93.50	215.20

No.12 Mwonboshi Dam

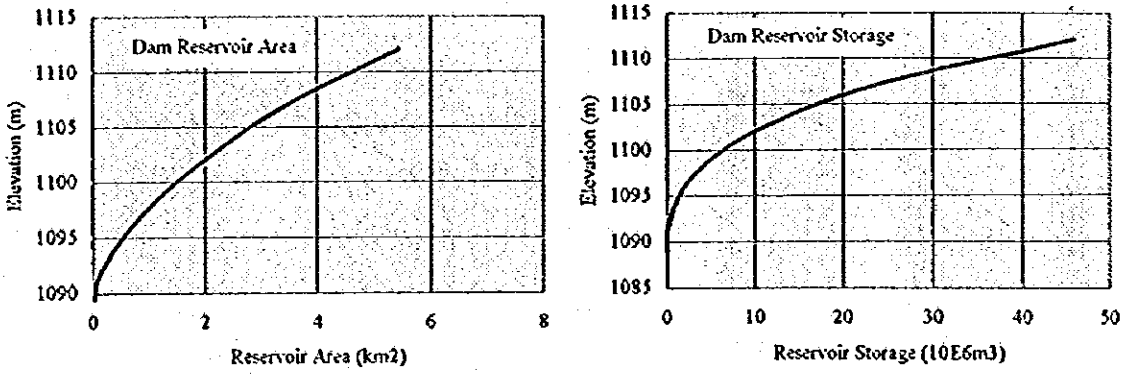




Elevation (m)	Reservoir Area (km2)	Selection Volume (10E6m3)	Reservoir Storage (10E6m3)
1028	0.00	0.00	0.00
1030	0.05	0.05	0.05
1035	0.23	0.70	0.75
1040	0.55	1.95	2.70
1045	1.25	4.50	7.20
1050	2.55	9.50	16.70
1055	4.35	17.25	33.95
1060	6.73	27.70	61.65

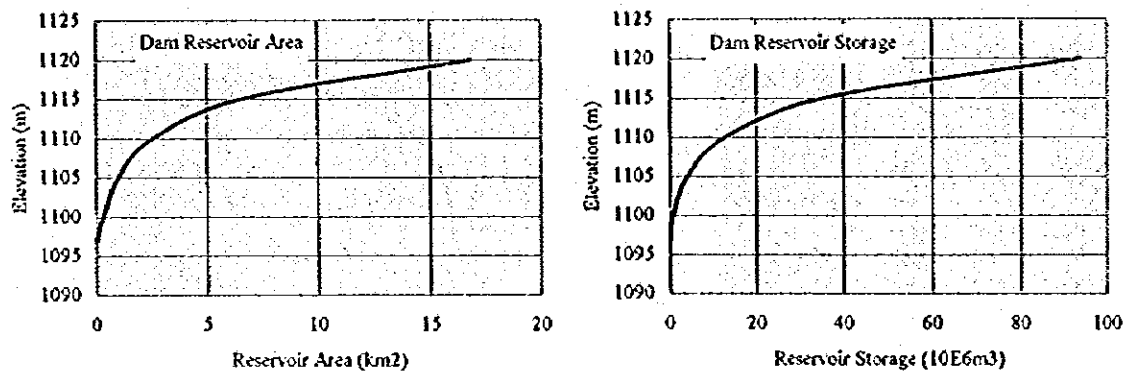
Figure 3-2(6) Reservoir Water Level - Reservoir Storage Curve

No.13 Kopyonga Dam



Elevation (m)	Reservoir Area (km2)	Selection Volume (10E6m3)	Reservoir Storage (10E6m3)
1089	0.00	0.00	0.00
1092	0.15	0.23	0.23
1097	0.87	2.55	2.78
1102	2.00	7.18	9.95
1107	3.45	13.63	23.58
1112	5.43	22.20	45.78

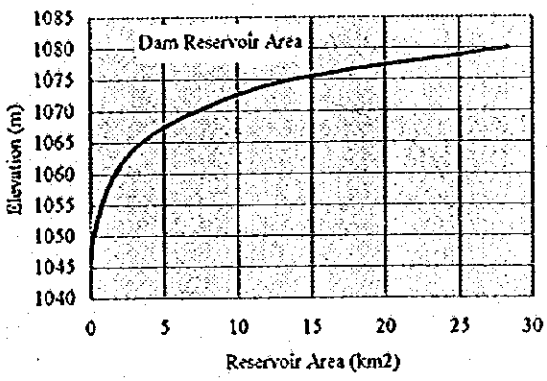
No.15 Kanakantapa Dam

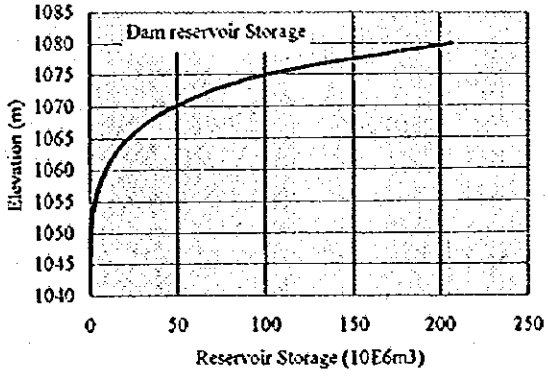


Elevation (m)	Reservoir Area (km2)	Selection Volume (10E6m3)	Reservoir Storage (10E6m3)
1097	0.00	0.00	0.00
1100	0.30	0.75	0.75
1105	1.00	3.25	4.00
1110	2.50	8.75	12.75
1115	6.50	22.50	35.25
1120	16.80	58.25	93.50

Figure 3-2(7) Reservoir Water Level - Reservoir Storage Curve

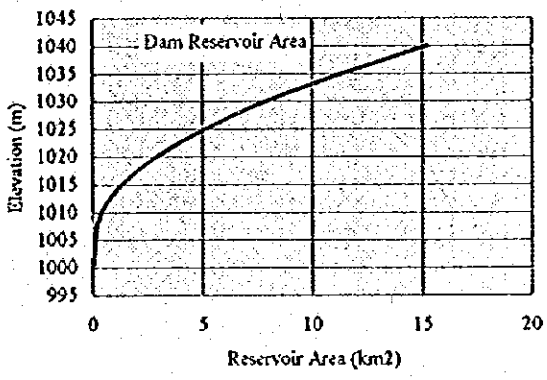
No.16 Chongwe Dam

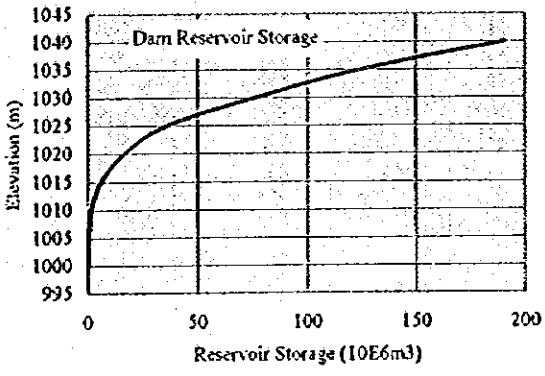




Elevation (m)	Reservoir Area (km2)	Selection Volume (10E6m3)	Reservoir Storage (10E6m3)
1046.5	0.00	0.00	0.00
1050	0.20	0.35	0.35
1055	0.80	2.50	2.85
1060	1.70	6.25	9.10
1065	3.50	13.00	22.10
1070	7.20	26.75	48.85
1075	13.80	52.50	101.35
1080	28.40	105.50	206.85

No.17 Mwapula Dam

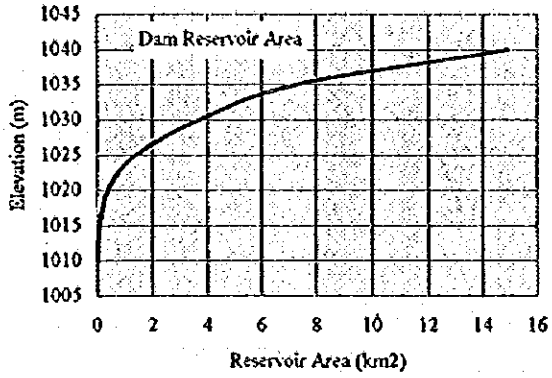


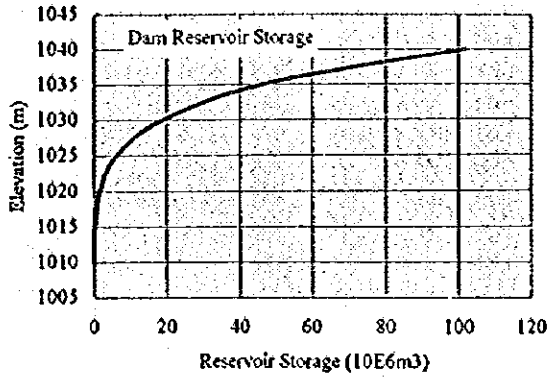


Elevation (m)	Reservoir Area (km2)	Selection Volume (10E6m3)	Reservoir Storage (10E6m3)
1000	0.00	0.00	0.00
1005	0.10	0.25	0.25
1010	0.40	1.25	1.50
1015	1.30	4.25	5.75
1020	2.90	10.50	16.25
1025	5.10	20.00	36.25
1030	7.90	39.75	76.00
1035	11.30	48.00	124.00
1040	15.2	66.25	190.25

Figure 3-2(8) Reservoir Water Level - Reservoir Storage Curve

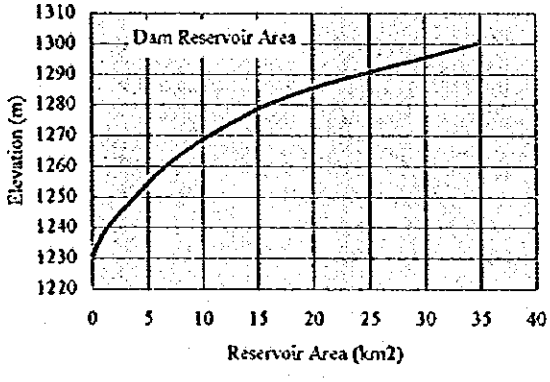
No.18 Lundazi Dam

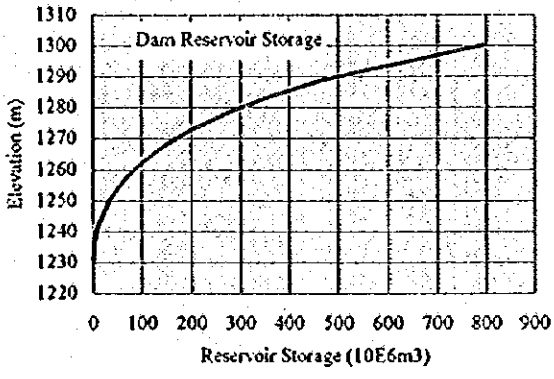




Elevation (m)	Reservoir Area (km2)	Selection Volume (10E6m3)	Reservoir Storage (10E6m3)
1010	0.00	0.00	0.00
1015	0.10	0.25	0.25
1020	0.40	1.25	1.50
1025	1.40	4.50	6.00
1030	3.70	12.75	18.75
1035	7.30	27.50	46.25
1040	14.90	55.50	101.75

No.19 Lukusashi Dam

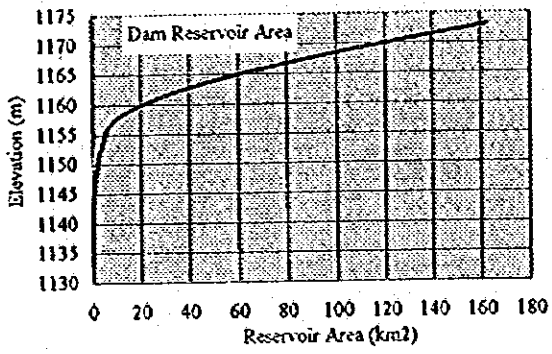


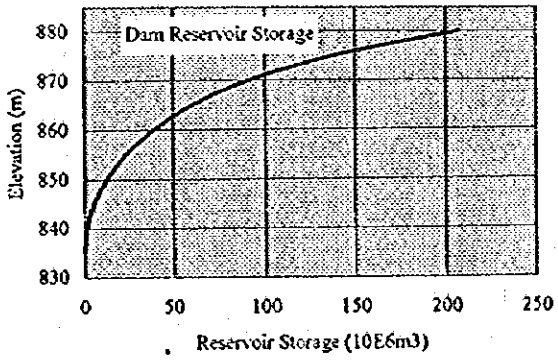


Elevation (m)	Reservoir Area (km2)	Selection Volume (10E6m3)	Reservoir Storage (10E6m3)
1231	0.00	0.00	0.00
1240	1.40	6.30	6.30
1250	3.80	26.00	32.30
1255	5.10	22.25	54.55
1260	6.60	29.25	83.80
1265	8.40	37.50	121.30
1270	10.60	47.50	168.80
1275	13.10	59.25	228.05
1280	15.9	72.50	300.55
1285	19.6	88.75	389.30
1290	24.1	109.25	498.55
1300	34.6	293.50	792.05

Figure 3-2(9) Reservoir Water Level - Reservoir Storage Curve

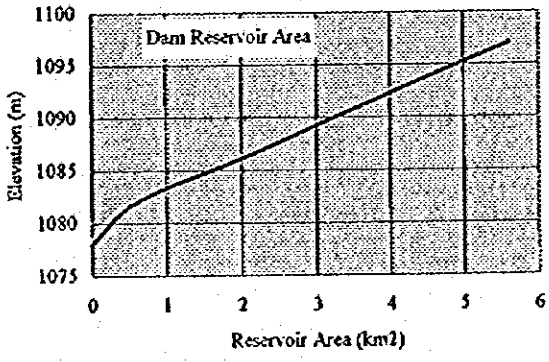
No.20 Lutembwe Dam

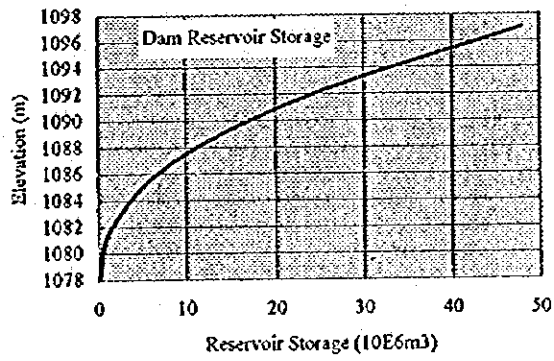




Elevation (m)	Reservoir Area (km2)	Selection Volume (10E6m3)	Reservoir Storage (10E6m3)
835.5	0.00	0.00	0.00
840	0.50	1.125	1.13
845	1.10	4.00	5.13
850	1.80	7.25	12.38
855	2.60	11.00	23.38
860	3.60	15.50	38.88
865	5.00	21.50	60.38
870	7.50	31.25	91.63
875	11.10	46.50	138.13
880	16.60	69.25	207.38

No.21 Katete

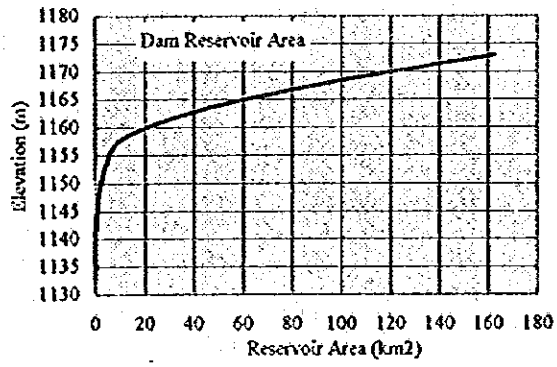


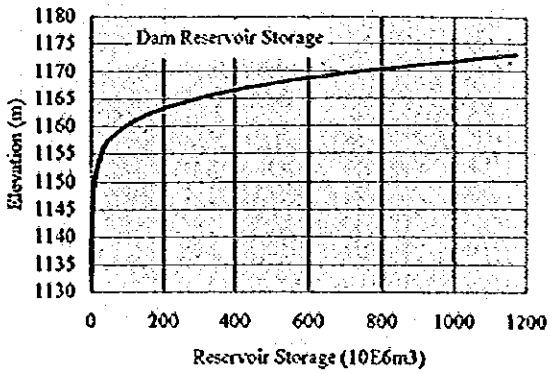


Elevation (m)	Reservoir Area (km2)	Selection Volume (10E6m3)	Reservoir Storage (10E6m3)
1078	0.00	0.00	0.00
1082	0.60	1.50	1.50
1087	2.30	7.25	8.75
1092	3.90	15.50	24.25
1097	5.60	23.75	48.00

Figure 3-2(10) Reservoir Water Level - Reservoir Storage Curve

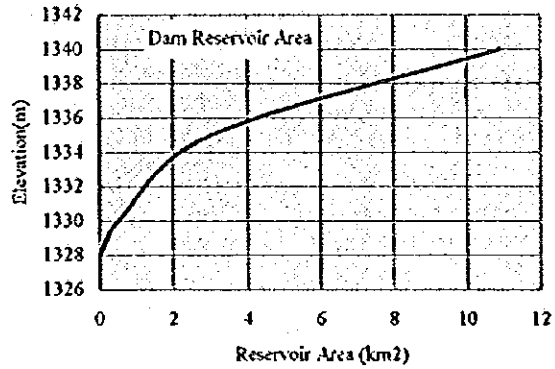
No.24 Luongo Dam

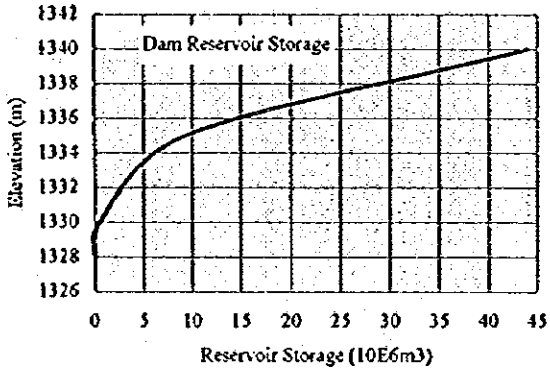




Elevation (m)	Reservoir Area (km2)	Selection Volume (10E6m3)	Reservoir Storage (10E6m3)
1133	0.00	0.00	0.00
1138	0.10	0.25	0.25
1143	0.20	0.75	1.00
1148	1.50	4.25	5.25
1153	4.00	13.75	19.00
1158	11.10	37.75	56.75
1163	42.00	132.75	189.50
1168	94.00	340.00	529.50
1173	162.6	641.50	1,171.00

No.25 Lwombe Dam

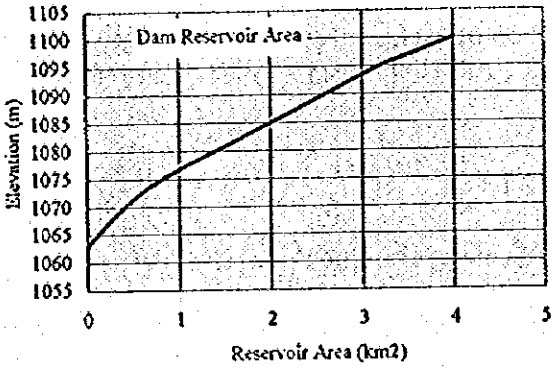


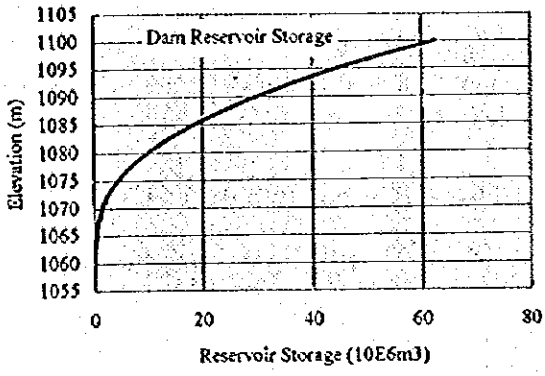


Elevation (m)	Reservoir Area (km2)	Selection Volume (10E6m3)	Reservoir Storage (10E6m3)
1328	0.00	0.00	0.00
1330	0.50	0.500	0.50
1335	3.00	8.75	9.25
1340	10.90	34.75	44.00

Figure 3-2(11) Reservoir Water Level - Reservoir Storage Curve

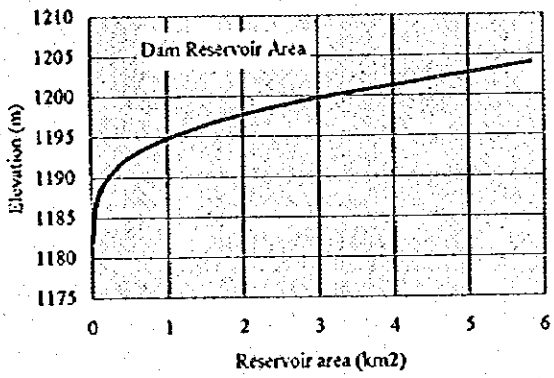
No.26 Bwengwa Dam

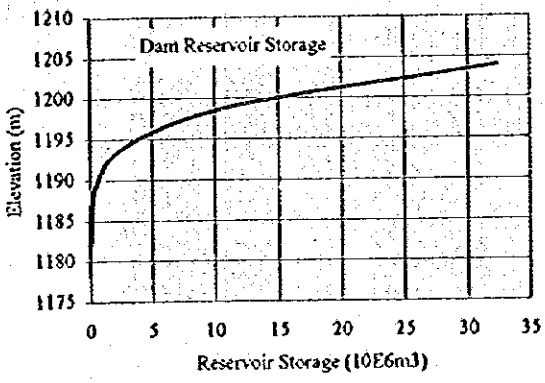




Elevation (m)	Reservoir Area (km2)	Selection Volume (10E6m3)	Reservoir Storage (10E6m3)
1063	0.00	0.00	0.00
1070	0.40	1.40	1.40
1075	0.80	3.00	4.40
1080	1.40	5.50	9.90
1085	2.00	8.50	18.40
1090	2.60	11.50	29.90
1095	3.20	14.50	44.40
1100	4.00	18.00	62.40

No.27 Kalomo Dam





Elevation (m)	Reservoir Area (km2)	Selection Volume (10E6m3)	Reservoir Storage (10E6m3)
1182	0.00	0.00	0.000
1189	0.15	0.375	0.375
1194	0.80	2.375	2.750
1199	2.60	8.500	11.250
1204	5.83	21.075	32.325

Figure 3-2(12) Reservoir Water Level - Reservoir Storage Curve

3.4 Preliminary Layout Design of Proposed Dam

The plane, profile dam axis and typical cross section of each dam are shown in Drawing 1～26. The principal features of the proposed dams as possible maximum scale are shown in Table 3-2

Brief descriptions of proposed dam sites are given below.

Table 3-2 Possible Maximum Scale of Dam at Each Site

Dam No.	Name of Dam	Catchment Area (km^2)	Dam			Dam Reservoir		
			Height (m)	Length (m)	Volume (10^3m^3)	Area (km^2)	Total Storage (Mm^3)	Effective Storage (Mm^3)
1	Lufubu	1,292	33	420	618	26.5	227	218
2	West Lunga	4,651	41	535	1,263	146.0	2,236	2,203
3	Lukupa	1,256	27	1,200	1,079	11.2	88	79
4	Kapemba	403	30	370	451	1.9	14	11
5-1	Solwezi	354	30	830	989	2.0	20	17
5-2	Kifubwa	-	-	-	-	-	-	-
6	Kafue	7,549	33	1,750	1,804	31.6	300	247
7	Mutundu	493	36	1,700	3,092	13.7	131	127
8	Lubi	-	-	-	-	-	-	-
9-1	Lufupa (Downstream)	1,038	31	400	472	2.6	21	13
9-2	Lufupa (Upstream)	904	28	900	1,325	2.1	10	3
10-1	Baluba	-	-	-	-	-	-	-
10-2	Kafubu	1,047	31	1,150	1,287	32.7	301	293
11	Lunsemfwa	1,473	27	700	650	15.5	122	111
12	Mwomboshi	1,985	35	700	1,030	4.4	34	20
13	Kopyonga	288	30	1,000	750	5.4	46	44
14-1	Muchito (Upstream)	40	25	450	695	5.3	35	34
14-2	Muchito (Downstream)	-	-	-	-	-	-	-
15	Knanakantapa	256	27	470	436	8.6	49	47
16	Chongwe	1,917	37	1,280	1,978	13.8	101	87
17	Mwapula	398	28	250	246	2.9	16	13
18	Lundazi	1,580	38	290	552	14.9	102	90
19	Lukusashi	961	56	300	1,308	15.9	301	293
20	Lutembwe	1,517	48	750	2,210	11.1	138	127
21	Katete	73	25	650	517	5.6	48	47
24	Luongo	6,493	43	1,200	2,508	94.0	529	483
25	Lwombe	2,580	20	1,150	620	10.9	44	26
26	Bengwa	1,677	40	1,300	2,417	3.2	44	32
27	Kalomo	1,925	27	950	910	4.5	20	7

(1) Lufubu Dam (Dam site No.1 : Luapula Province)

The dam site is located on the Lufubu River, at 1,180 m a.s.l., some 51 km NNE of Mansa town. The catchment area of this site is around 1,292 km^2. The average yield at the dam site is proposed to be 1,288,000 cmd (14.91 cms). The shape of valley is narrow. Dam site rock consists of quartzite of Muva Supergroup and rhylitic lava Basement Complex. The rock is hard and stable. The dam is about 33 m in height, about 50 m in river basin width, about 420 m in dam crest width, and embankment volume is 618,000 cm. The gross storage capacity may be about 227 mcm. There are a lot of facilities of Chipili village at just

upstream of the dam site. Twenty over houses, secondary school and its dormitory, main road to Kawambwa and its bridge, so on will be submerged by reservoir backwater.

(2) West Lunga Dam (Dam site No.2 : Northwest Province)

The dam site is located on the West Lunga River, at 1,300 m a.s.l., some 2.0 km NE of Mwinilunga town. The catchment area of this site is around 4,651 km^2. The average yield at the dam site is proposed to be 5,936,000 cmd (68.71 cms). The shape of valley is narrow. Dam site rock consists of psammitic schist and phyllite of Kundelunga Group of Kantanga Supergroup. The rock is hard and stable. The dam is about 41 m in height, about 100 m in river basin width, about 535 m in dam crest width, and embankment volume is 1,263,000 cm. The gross storage capacity may be about 2,236 mcm. Submerging facility by reservoir backwater seem to be little. But it's not sure because of reservoir area is very wide.

(3) Lukupa Dam (Dam site No.3 : Northern Province)

The dam site is located on the Lukupa River, at 1,240 m a.s.l., some 25 km NNW of Kasama town. The catchment area of this site is around 1,256 km^2. The average yield at the dam site is proposed to be 1,207,000 cmd (13.97 cms). The shape of valley is wide. Dam site rock consists of granitic gneiss o f Basement Complex. Sound rock is expected to be deep more than 5-10m. The dam is about 27 m in height, about 200 m in river basin width, about 1,200 m in dam crest width, and embankment volume is 1,079,000 cm. The gross storage capacity may be about 88 mcm. There are a District road from Kasama to Mporokoso and its bridge at 500m up stream of dam site. These facilities will be submerged by reservoir backwater.

(4) Kapemba Dam (Dam site No.4 : Eastern Province)

The dam site is located on the Kapemba River, at 1,200 m a.s.l., some 3.7 km west of Chama town. The catchment area of this site is around 403 km^2. The average yield at the dam site is proposed to be 63,000 cmd (0.73 cms). The shape of valley is narrow. The slop of river basin is very steep. Dam site rock consists of gneiss of Muva Supergroup and rhylitic lava Basement Complex. The rock is hard and stable. The dam is about 30 m in height, about 50 m in river basin width, about 370 m in dam crest width, and embankment volume is 451,000 cm. The gross storage capacity may be about 14 mcm. More over high dam may be able to construct in this site from topographical characteristics, but it can not because of reservoir water flow over from anther valley at left side of this site which has low bottom level than this site dam crest level. Submerging facility by reservoir backwater seem to be nothing. Many sediment yield seems to be expected. Many sand deposit is observed at down stream riverbed.

(5) Solwezi Dam (Dam site No.5-1 : Northwest Province)

The dam site is located on the Solwezi River at 1,300 m a.s.l., 2.5 km NW of Solwezi town. The catchment area of this site is around 354 km^2. The average yield at the dam site is proposed to be 294,600 cmd (3.41 cms). The shape of valley is narrow at the river basin, but rather wide at near the dam crest. Dam site rock consists of biotite-quartzite of Kundelunga group. The rock is hard and stable. The dam is about 30 m in height, about 30 m in river basin width, about 830 m in dam crest width, and embankment volume is 989,000

cm. The gross storage capacity may be about 20 mcm. Submerging facility by reservoir backwater seem to be nothing.

(6) Kifubwa Dam (Dam site No.5-2 : Northwest Province)

The dam site is located on the Kifubwa River at 1,300 m a.s.l., 4.5 km ESN of Solwezi town. The catchment area of this site is smaller than Solwezi Dam, and valley is wide. Solwezi Dam site is better than this site. So Solwezi Dam is selected, the plan for this site is eliminated.

(7) Kafue Dam (Dam site No.6 : Copperbelt Province)

The dam site is located on the Kafue River, at 1,190 m a.s.l., some 12 km SW of Mufulira town. The catchment area of this site is around 7,549 km^2. The average yield at the dam site is proposed to be 3,935,000 cmd (45.54 cms). The shape of valley is very wide. Dam site rock consists of quartzite and mica schist of Muva Supergroup. Out crops is rare. Sound rock is expected to be rather deep. The foundation condition is expected to be not so good and extensive treatment will be required. The dam is about 33 m in height, about 100 m in river basin width, about 1,750 m in dam crest width, and embankment volume is 1,804,000 cm. The gross storage capacity may be about 300 mcm. Submerging facility by reservoir backwater seem to be little.

(8) Mutundu Dam (Dam site No.7 : Copperbelt Province)

The dam site is located on the Mutundu River, at 1,190 m a.s.l., some 14 km south of Mufulira town. The catchment area of this site is around 493 km^2. The average yield at the dam site is proposed to be 332,000 cmd (3.85 cms). The shape of valley is very wide. Dam site rock consists of muscovite schist of Muva Supergroup. Out crops are scattered. Sound rock is expected to be rather deep. The foundation condition is expected to be fairly bad and extensive treatment will be required. The dam is about 36 m in height, about 200 m in river basin width, about 1,700 m in dam crest width, and embankment volume is 3,092,000 cm. The gross storage capacity may be about 131 mcm. Submerging facility by reservoir backwater seem to be nothing.

(9) Lubi Dam (Dam site No.8 : Northwest Province)

The dam site is located on the Lubi River, some 9.5 km WSW of Kabompo town. Base of dam site consists of fine sand of Kalahari group. Foundation condition is very bad because of unconsolidation fine sand. Dam construction is very difficult because of foundation condition. The plan for this site is eliminated.

(10) Lufupa downstream Dam (Dam site No.9-1 : Northwest Province)

The dam site is located on the Lufupa River, at 1,180 m a.s.l., some 3.0 km SSE of Kasempa town. The catchment area of this site is around 1,038 km^2. The average yield at the dam site is proposed to be 435,000 cmd (5.04 cms). The shape of valley is rather wide. Dam site rock consists of psammitic schist and phyllite of Kundelungu of Katanga Supergroup. Out crops are scattered. Sound rock is expected to be slightly deep. The dam is about 31 m in height, about 50 m in river basin width, about 400 m in dam crest width, and embankment volume is 472,000 cm. The gross storage capacity may be about 21 mcm.

District road and its bridge and generation power station and some houses in the reservoir are will be submerged with maximum dam height.

(11) Lufupa Upstream Dam (Dam site No.9-2 : Northwest Province)

The dam site is located on the Lufupa River, at 1,190 m a.s.l., some 6.5 km north of Kasempa town. The catchment area of this site is around 904 km^2. The average yield at the dam site is proposed to be 379,000 cmd (4.39 cms). The shape of valley is wide. Dam site rock consists of psammtic schist and phyllite of Kunedelunga group of Katanga Supergroup. Many rock out crops are scattered. The dam is about 28 m in height, about 50 m in river basin width, about 900 m in dam crest width, and embankment volume is 1,325,000 cm. The gross storage capacity may be about 10 mcm. Submerging facility by reservoir backwater seem to be nothing.

(12) Baluba Dam (Dam site No.10-1 : Copperbelt Province)

The dam site is located on the Baluba River, some 3.8 km NE of Luansya town. Dam construction is difficult, because there is a Main by ZCCM at near dam site. The plan for this site is eliminated.

(13) Kafubu Dam (Dam site No.10 -2 : Copperbelt Province)

The dam site is located on the Kafubu River, at 1,180 m a.s.l., some 13 km SE of Luanshya town. The catchment area of this site is around 1,047 km^2. The average yield at the dam site is proposed to be 834,000 cmd (9.66 cms). The shape of valley is wide. Dam site rock consists of granitic gneiss of. Sound rock is expected to be rather deep. The foundation condition is expected to be fairly bad and extensive treatment will be required for weathering zone. The dam is about 31 m in height, about 100 m in river basin width, about 1,150 m in dam crest width, and embankment volume is 1,287,000 cm. The gross storage capacity may be about 301 mcm. There are electric power line and trunk rout road from Lusaka to Kitwe and its bridge at reservoir area. These facilities will be submerged by reservoir backwater.

(14) Lunsemfwa Dam (Dam site No.11 : Central Province)

The dam site is located on the Lunsemfa River, at 1,180 m a.s.l., some 13 km WSW of Mukushi town. The catchment area of this site is around 1,473 km^2. The average yield at the dam site is proposed to be 1,003,000 cmd (11.61 cms). The shape of valley is rather wide. Dam site rock consists of muscova schist and phyllite of Basement Complex. Sound rock is expected to be deep. The dam is about 27 m in height, about 50 m in river basin width, about 700 m in dam crest width, and embankment volume is 650,000 cm. The gross storage capacity may be about 111 mcm. Submerging facility by reservoir backwater seem to be nothing.

(15) Mwonboshi Dam (Dam site No.12 : Central Province)

The dam site is located on the Mwonboshi River, at 1,030 m a.s.l., some 20 Km NNE of Chisama village. The catchment area of this site is around 1,985 km^2. The average yield at the dam site is proposed to be 706,800 cmd (8.18 cms). The shape of valley is narrow at the river basin, but rather wide at near the dam crest. Dam site rock consists of gneiss of

Basement Complex. The rock is hard and stable. The dam is about 35 m in height, about 20 m in river basin width, about 700 m in dam crest width, and embankment volume is 1,030,000 cm. The gross storage capacity may be about 34 mcm. Submerging facility by reservoir backwater seem to be nothing.

(16) Kopyonga Dam (Dam site No.13 : Central Province)

The dam site is located on the Kopyonga River, at 1,090 m a.s.l., some 78 km WNW of Lusaka City. The catchment area of this site is around 288 km^2. The average yield at the dam sites is proposed to be 101,000 cmd (1.17 cms). The shape of valley is rather wide. Dam site rock consists of quartzite of Basement Complex. The rock is hard and stable. The dam is about 30 m in height, about 50 m in river basin width, about 1,000 m in dam crest width, and embankment volume is 750,000 cm. The gross storage capacity may be about 46 mcm. Submerging facility by reservoir backwater seem to be nothing. More over high dam may be able to construct in this site from topographical characteristics, but it can not because of reservoir water flow over from anther valley at left side of this site which has low bottom level than this site dam crest level.

(17) Muchito upstream Dam (Dam site No.14-1 : Lusaka Province)

The dam site is located on the Katete River, at 1,110 m a.s.l., some 9.0 km east of Kafue town. The catchment area of this site is around 40 km^2. The average yield at the dam site is proposed to be 12,960 cmd (0.15 cms). The shape of valley is rather wide. Dam site rock consists of quartzite and phyllite of Broken Hill group of Katanga Supergroup. Out crops are scattered. Sound rock is expected to be fairly shallow. The dam is about 25 m in height, about 200 m in river basin width, about 450 m in dam crest width, and embankment volume is 695,000 cm. The gross storage capacity may be about 35 mcm. Trunk routs road from Lusaka to Kafue and Railways and many houses and farms, so on will be submerged by reservoir backwater. Dam construction at this site is very difficult by these facilities compensation.

(18) Muchito downstream Dam (Dam site No.14-2 : Lusaka Province)

The dam site is located on the Muchito River, at 1,100 m a.s.l., some 8.0 km WSW of Kafue town. Dam construction is very difficult, because there is a water supply pipeline to Lusaka by Lusaka Water Supply Company along the valley. The plan for this site is eliminated.

(19) Kanakantapa Dam (Dam site No.15 : Lusaka Province)

The dam site is located on the Kanakantapa River, at 1,080 m a.s.l., some 20 km north of Lusaka City. The catchment area of this site is around 256 km^2. The average yield at the dam site is proposed to be 40,000 cmd (0.47 cms). The shape of valley is rather wide. Dam site rock consists of quartzite of Basement Complex. Many rock out crops are scattered. and a lot of cracks are developed at the left side outcrops. The dam is about 27 m in height, about 100 m in river basin width, about 470 m in dam crest width, and embankment volume is 436,000 cm. The gross storage capacity may be about 49 mcm. Submerging facility by reservoir backwater seem to be nothing.

(20) Chongwe Dam (Dam site No.16 : Lusaka Province)

The dam site is located on the Chongwe River just upstream of the bridge on the Great East Road, at 1,050 m a.s.l., some 44 km ENE of Lusaka City. The catchment area of this site is around 1,917 km^2. The average yield at the dam site is proposed to be 530,500 cmd (6.14 cms). The shape of valley is narrow at the river basin, but very wide at near the dam crest. Dam site rock consists of mainly gneiss, partly mica schist and meta diabase duke of Basement Complex. The rock is hard and stable. The dam is about 37 m in height, about 20 m in river basin width, about 1,280 m in dam crest width, and embankment volume is 1,978,000 cm. The gross storage capacity may be about 101 mcm. There is the small intake dam and pumping station for water supply to Chongwe town at 200m upstream of dam sites. These facilities will be submerged by reservoir backwater.

(21) Mwapula Dam (Dam site No.17 : Lusaka Province)

The dam site is located on the Mwapula River, at 1,000 m a.s.l., some 20 km north of Lusaka City. The catchment area of this site is around 398 km^2. The average yield at the dam sites is proposed to be 63,000 cmd (0.73 cms). The shape of valley is narrow. Dam site rock consists of quartzite of Basement Complex. The rock is hard and stable. The dam is about 28 m in height, about 20 m in river basin width, about 250 m in dam crest width, and embankment volume is 246,000 cm. The gross storage capacity may be about 16 mcm. The gross storage volume is small because of shortage of reservoir valley wide. Submerging facility by reservoir backwater seem to be nothing. More over high dam may be able to construct in this site from topographical characteristics, but it can not because of reservoir water flow over from anther valley at left side of this site which has low bottom level than this site dam crest level.

(22) Lundazi Dam (Dam site No.18 : Eastern Province)

The dam sites is located on the Lundazi River, at 1,200 m a.s.l., some 20 km north of Lundazi City. The catchment area of this site is around 1,580 km^2. The average yield at the dam sites is proposed to be 420,000 cmd (4.87 cms). The shape of valley is narrow. Dam site rock consists of granitic gneiss of Basement Complex. The rock is hard and stable. The dam is about 38 m in height, about 50 m in river basin width, about 290 m in dam crest width, and embankment volume is 552,000 cm. The gross storage capacity may be about 102 mcm. Submerging main facility by reservoir backwater seem to be nothing.

(21) Lukusashi Dam (Dam site No.19 : Central Province)

The dam site is located on the Lukusashi River, at 1,230 m a.s.l., some 20 km south of Serenje town. The catchment area of this site is around 961 km^2. The average yield at the dam sites is proposed to be 688,600 cmd (7.97 cms). The shape of valley is narrow at the high ridges of "Busendaka Hills". Dam site rock consists of quartzite of Basement Complex. The rock is hard and stable. The dam is about 56 m in height, about 50 m in river basin width, about 300 m in dam crest width, and embankment volume is 1,308,000 cm. The gross storage capacity may be about 301 mcm. Submerging facility by reservoir backwater seem to be nothing. More over high dam may be able to construct in this site from topographical characteristics, but it can not because of reservoir water flow over from anther valley at left side of this site which has low bottom level than this site dam crest level.

(22) Lutembwe Dam (Dam site No.20 : Eastern Province)

The dam site is located on the Lutembwe River, at 840 m a.s.l., some 30 km WNW of Chipata town. The catchment area of this site is around 1,517 km^2. The average yield at the dam site is proposed to be 538,000 cmd (6.23 cms). The shape of valley is rather wide. Dam site rock consists of quartzite of Basement Complex. The rock is hard and stable. The dam is about 48 m in height, about 50 m in river basin width, about 750 m in dam crest width, and embankment volume is 2,210,000 cm. The gross storage capacity may be about 138 mcm. Submerging facility by reservoir backwater seem to be nothing. There are 2 dams for water supply at upstream near Chipata town.

(23) Katete Dam (Dam site No.21 : Eastern Province)

The dam site is located on the Katete River, at 1090 m a.s.l., some 7.0 km NNW of Katete town. The catchment area of this site is around 73 km^2. The average yield at the dam site is proposed to be 29,000 cmd (0.34 cms). The shape of valley is rather wide. Dam site rock consists of gneiss and quartzite of Basement Complex. Out crops are scattered. Sound rock is expected to be deep. The dam is about 25 m in height, about 50 m in river basin width, about 650 m in dam crest width, and embankment volume is 517,000 cm. The gross storage capacity may be about 48 mcm. There is the Great East road on the dam site. Travelling of road is necessary.

(24) Luongo Dam (Dam site No.24 : Luapula Province)

The dam site is located on the Luongo River at upstream of Musonda Fall Power Station, at 1,130 m a.s.l., some 51 km NNW of Mansa town. The catchment area of this site is around 6,493 km^2. The average yield at the dam site is proposed to be 6,298,000 cmd (72.89 cms). The shape of valley is narrow at the river basin, but very wide at near the dam crest. Dam site rock consists of quartzite of Muva Supergroup. Outcrops are scattered. Sound rock is expected to be shallow. The dam is about 43 m in height, about 50 m in river basin width, about 1,200 m in dam crest width, and embankment volume is 2,508,000 cm. The gross storage capacity may be about 529 mcm. There are regulation dam for Musonda Fall water power station at just upstream of the site in the new dam reservoir area. The dam is combine d dam style from concrete dam and embankment dam. The dam is old and many cracks occurred in the concert dam and occurred some leakage. Urgent repair is necessary. This dam and many houses for fisherman will be submerged by reservoir backwater.

(25) Lwombe Dam (Dam site No.25 : Northern Province)

The dam site is located on the Lwombe River at upstream of Lwombe water power station, at 1330 m a.s.l., some 31 km NW of Kasama town. The catchment area of this site is around 2,580 km^2. The average yield at the dam site is proposed to be 2,539,000 cmd (29.39 cms). The shape of valley is very wide and both side slope is very gentle. Outcrops are rare. Sound rock is expected to be rather deep. The dam is about 20 m in height, about 100 m in river basin width, about 1,150 m in dam crest width, and embankment volume is 620,000 cm. The gross storage capacity may be about 44 mcm. Submerging facility by reservoir backwater seem to be nothing.

(26) Bwengwa Dam (Dam site No.26 : Southern Province)

The dam site is located on the Bwengwa River, at 1,070 m a.s.l., some 25 km WNW of Pemba town. The catchment area of this site is around 1,677 km^2. The yield at the dam sites is proposed to be 890,000 cmd (10.31 cms). The shape of valley is wide. Dam site rock consists of gneiss of Basement Complex. Out crops are scattered. The dam is about 40 m in height, about 80 m in river basin width, about 1,300 m in dam crest width, and embankment volume is 2,417,000 cm. The gross storage capacity may be about 44 mcm. There are some dams for irrigation at upstream. There are a district road and its bridge from Pemba to Namwala at just upstream of dam site. These facilities will be submerged by reservoir backwater.

(27) Kalomo Dam (Dam site No.27 : Southern Province)

The dam site is located on the Kalomo River, at 1,180 m a.s.l., some 15 km SSN of Kalomo town. The catchment area of this site is around 1,925 km^2. The average yield at the dam site is proposed to be 498,000 cmd (5.77 cms). The shape of valley is wide. Dam site rock consists of gneiss of Basement Complex. Out crops are scattered. The dam is about 27 m in height, about 50 m in river basin width, about 950 m in dam crest width, and embankment volume is 910,000 cm. The gross storage capacity may be about 20 mcm. Submerging facility by reservoir backwater seem to be little.

CHAPTER 4 WATER RESOURCES DEVELOPMENT BY PROPOSED DAMS

4.1 Proposed Dams and Reference Hydrometric Stations

In order to estimate the water potential to be developed by proposed dams, it is necessary to study discharges at the dam sites. However discharges at the proposed dam sites can only rarely be obtained. Therefore, reference hydrometric stations near the dam sites were selected and the daily discharges at the proposed dam sites were calculated according to the ratio of a catchment area at the dam site to that at a reference hydrometric station. The proposed dam sites and their reference hydrometric stations are listed in Table 4-1 and their locations are shown in Figure 4-1.

Table 4-1 Proposed Dam Sites and Reference Hydrometric Stations

	Proposed Dam Sites				Reference Hydrometric Station				C.A.
Province	No.	Name of River	C.A.	Met.	Station	Station Name	C.A.	Met.	Ratio
Lusaka	14	Muchito	40	Mt.Makulu	5-030	Exchange Farm	107	Lusaka	0.374
	15	Kanakantapa	256	Lusaka	5-024	Ngwerere	1,002	Lusaka	0.255
	16	Chongwe	1,917	Lusaka	5-025	Chongwe	1,922	Lusaka	0.997
	17	Mwapula	398	Lusaka	5-024	Ngwerere	1,002	Lusaka	0.397
Copperbe	6	Kafue	7,549	Kafironda	4-090	Kafironda	7,589	Kafironda	0.995
	7	Mutundu	493	Kafironda	4-120	Mwambashi	869	Kafironda	0.567
	10	Kafubu	1,047	Ndola	4-245	Masaiti Road Bridge	1,375	Ndola	0.761
Central	11	Lunsemfwa	1,473	Ndola	4-245	Masaiti Road Bridge	1,375	Ndola	1.071
	12	Mwomboshi	1,985	Kabwe	5-815	Mulungushi	1,448	Kabwe	1.371
	13	Kopyonga	288	Mumbwa	5-815	Mulungushi	1,448	Kabwe	0.199
	19	Lukusashi	961	Serenge	5-670	Masase	995	Serenge	0.966
North-Western	2	West Lunga	4,651	Mwinilung	1-430	Mwinilunga	4,656	Mwinilung	0.999
	5	Solwezi	354	Solwezi	4-120	Mwambashi	869	Kafironda	0.407
	9-1	Lower Lufupa	1,038	Kasempa	4-620	Kasempa P. House	1,010	Kasempa	1.028
	9-2	Upper Lufupa	904	Kasempa	4-620	Kasempa P. House	1,010	Kasempa	0.895
Western	22	Zambezi(Mongu)							
Southern	23	Zambezi(Livingstone)							
	26	Bwengwa	1,677	Choma	4-850	Mutama Rapids	1,677	Choma	1.000
	27	Kalomo	1,925	Choma	3-130	Kalomo Dam Site	2,190	Choma	0.879
Luapula	1	Lufubu	1,292	Mansa	6-765	Chipili	1,220	Mansa	1.059
	24	Luongo	6,493	Mansa	6-750	MwendaKashiba RB	4,170	Kawambw	1.557
Northern	3	Lukupa	1,256	Kasama	6-330	Chishimba Falls	2,580	Kasama	0.487
	25	Lwombe	2,580	Kasama	6-330	Chishimba Falls	2,580	Kasama	1.000
Eastern	4	Kapemba	403	Lundazi	5-024	Ngwerere	1,002	Lusaka	0.402
	18	Lundazi	1,580	Lundazi	5-025	Chongwe	1,922	Lusaka	0.822
	20	Lutembwe	1,517	Chipata	5-025	Chongwe	1,922	Lusaka	0.789
	21	Katete	73	Chipata	5-030	Exchange Farm	107	Lusaka	0.682

Note
* The station catchment area bolded was revised based on the figure measured by using satellite imagery map.
* C.A. means Catchment Area.

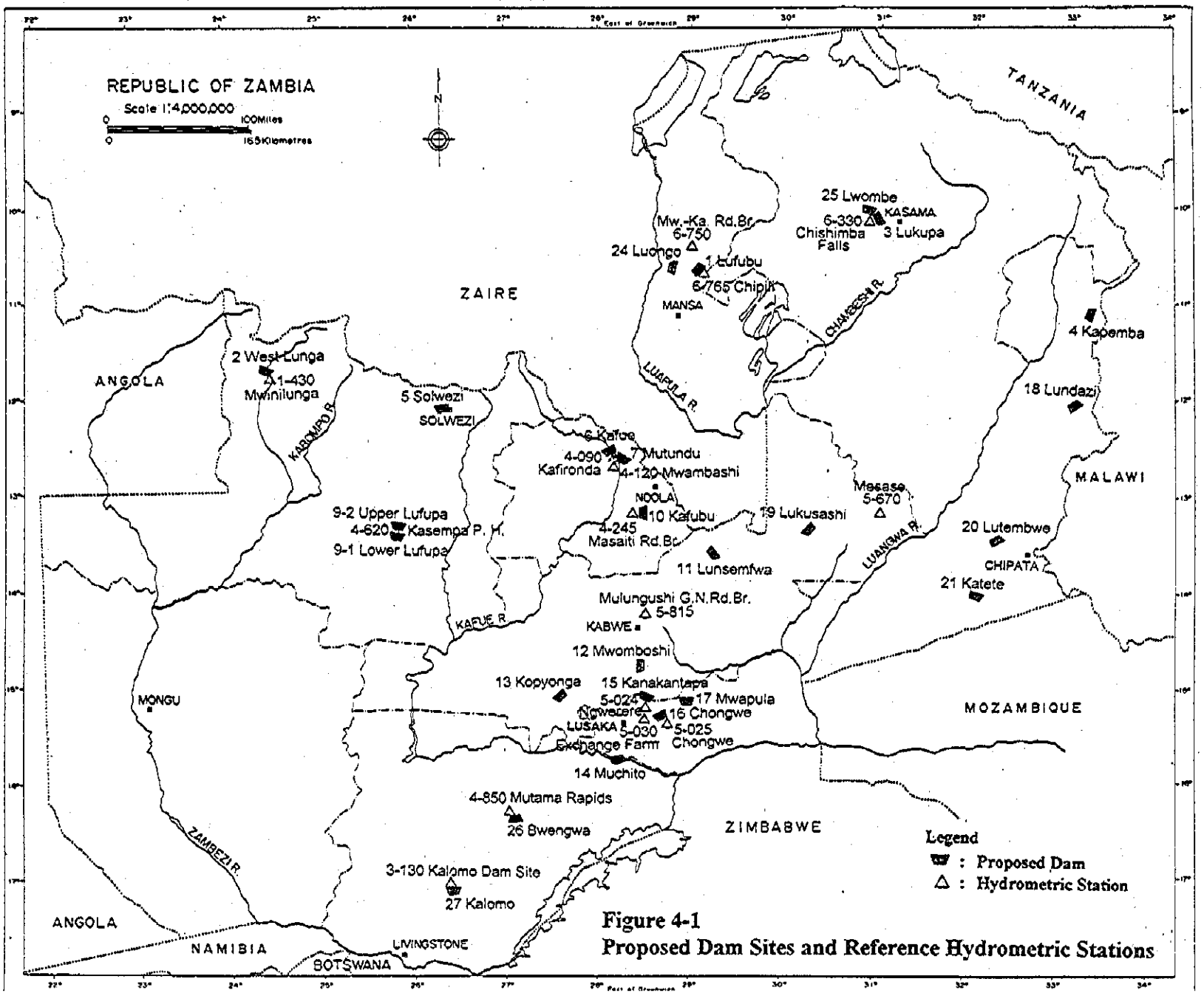


Figure 4-1
Proposed Dam Sites and Reference Hydrometric Stations

4.2 River Flow Characteristics at Proposed Dam Sites

Daily water level and flow measurement data at the closest hydrometric stations were collected and analysed to obtain the daily discharge at each station. The daily discharges at the proposed dam sites were then estimated according to the ratio of both basin mean rainfalls and catchment areas. The basin mean rainfall of each dam and hydrometric station are estimated as :

1) Dam or station basin mean rainfall by voluntary and meteorological stations, *Rv*, is calculated as the rainfall for the period 1980/81-1989/90 (10 years).
2) Dam or station basin mean rainfall by meteorological stations, *Rm*, is calculated. There are usually more than 30 years records available in the meteorological stations.
3) A linear regression equation between Rm and Rv is found by the least-squares fit.

$$Rv = a \times Rm + b$$

where: Rv : Basin mean rainfall at voluntary station
Rm : Basin mean rainfall at meteorological station
a, b : constants

4) The long-term dam/station basin rainfall is calculated by using Rm and the regression equation.

The daily discharge at the proposed dam site is calculated by using following equation :

$$Qd = Qs \times (Ad / As) \times (Rd / Rs)$$

where: Qd : Discharge at possible dam site
Qs : Discharge at the hydrometric station
Ad : Catchment area of possible dam site
As : Catchment area of the hydrometric station
Rd : Basin mean rainfall of possible dam site
Rs : Basin mean rainfall of the hydrometric station

Flow summaries at the proposed dam sites are described in Table 4-2 and the flow regimes are shown in Figure 4-3. The catchment areas and the runoff percentages at proposed dam sites in each province shown in Figure 4-2.

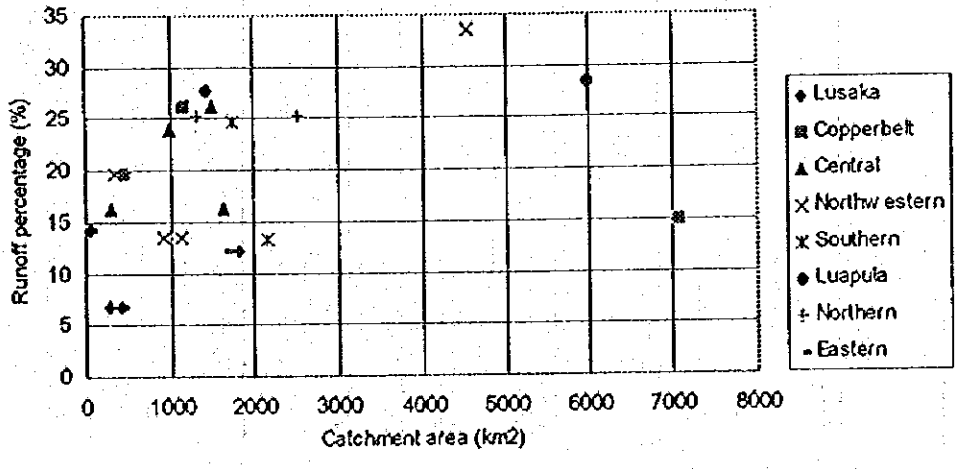
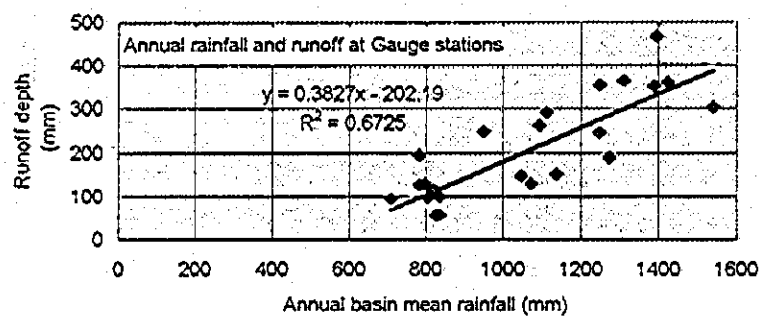
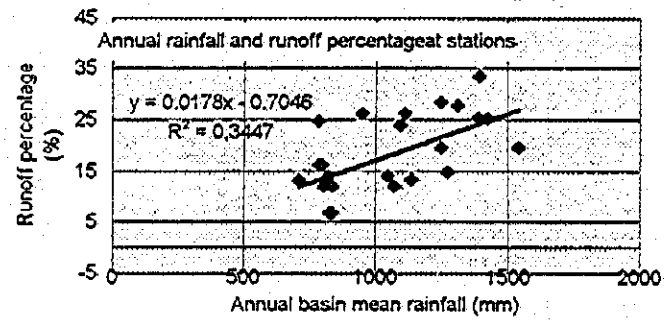


Figure 4-2 Catchment Area and Runoff Percentage at Proposed Dam Sites

Table 4-2 Flow Summary at Proposed Dam Sites

Province	Development Point No.	Name of River	C.A. (km2)	Annual Runoff Summary: Rainfall (mm)	Runoff (mm)	Runoff Percentage (%)	Annual Flow Summary: Max. (m3/s)	Q(95) (m3/s)	Q(185) (m3/s)	Q(275) (m3/s)	Q(355) (m3/s)	Min. (m3/s)	Average (m3/s)	Total m3/s*year)	Specific Discharge Summary (m3/s/1000km2): Max. 0.0	Q(95) 26.0	Q(185) 50.7	Q(275) 75.3	Q(355) 97.3	Min. 100.0	Average
Lusaka	14	Muchito	40	820.1	116.4	14.2	4.41	0.12	0.04	0.02	0.00	0.00	0.15	54	110.35	2.90	1.06	0.44	0.00	0.00	3.69
	15	Kanakantapa	256	835.1	56.9	6.8	5.28	0.41	0.19	0.12	0.06	0.03	0.47	169	20.63	1.60	0.74	0.47	0.23	0.12	1.84
	16	Chongwe	1917	835.1	101.1	12.1	76.79	6.62	2.23	1.10	0.21	0.14	6.14	2242	40.06	3.45	1.16	0.57	0.11	0.07	3.20
	17	Mwapula	398	835.1	57.0	6.8	8.22	0.64	0.29	0.18	0.09	0.05	0.73	262	20.65	1.61	0.73	0.45	0.23	0.13	1.83
Copperbelt	6	Kafue	7549	1273.7	190.4	14.9	185.82	75.70	22.71	4.96	0.74	0.57	45.54	16636	24.62	10.03	3.01	0.66	0.10	0.08	6.03
	7	Mutundu	493	1249.4	245.8	19.7	19.86	5.55	2.01	1.14	0.56	0.51	3.85	1403	40.28	11.26	4.08	2.31	1.14	1.03	7.81
	10	Kafubu	1047	1110.6	290.7	26.2	36.45	13.91	5.34	3.12	1.78	1.63	9.66	3523	34.81	13.29	5.10	2.98	1.70	1.56	9.23
Central	11	Lunsemfwa	1473	948.9	248.4	26.2	43.81	16.72	6.42	3.75	2.14	1.96	11.61	4234	29.74	11.35	4.36	2.55	1.45	1.33	7.88
	12	Mwomboshi	1985	796.4	129.7	16.3	64.41	9.96	3.71	1.99	0.99	0.89	8.18	2980	32.45	5.02	1.87	1.00	0.50	0.45	4.12
	13	Kopyonga	288	784.8	127.9	16.3	9.21	1.43	0.53	0.28	0.14	0.13	1.17	426	31.99	4.95	1.84	0.99	0.49	0.44	4.06
	19	Lukusashi	961	1094.2	261.7	23.9	42.60	10.16	5.16	3.48	2.21	1.84	7.97	2911	44.33	10.57	5.37	3.62	2.30	1.91	8.29
Northwest	2	West Lunga	4651	1394.9	466.2	33.4	237.22	82.96	51.74	39.30	31.81	30.42	68.71	25095	51.00	17.84	11.13	8.45	6.84	6.54	14.77
	5	Solwezi	354	1540.6	302.9	19.7	17.57	4.91	1.78	1.01	0.49	0.45	3.41	1241	49.63	13.88	5.02	2.85	1.40	1.27	9.63
	9-1	Lower Lufupa	1038	1136.9	152.7	13.4	50.72	5.81	2.35	1.44	0.50	0.42	5.04	1835	48.86	5.60	2.26	1.39	0.48	0.40	4.86
	9-2	Upper Lufupa	904	1136.9	152.7	13.4	44.16	5.06	2.04	1.26	0.44	0.37	4.39	1598	48.85	5.60	2.26	1.39	0.49	0.41	4.86
Western	22	Zambezi(Mongu)																			
Southern	23	Zambezi(Livingstone)																			
	26	Bwengwa	1677	782.9	193.8	24.7	283.20	6.17	0.67	0.04	0.00	0.00	10.31	3761	168.87	3.68	0.40	0.02	0.00	0.00	6.15
	27	Kalomo	1925	709.7	94.8	13.4	156.74	3.79	0.55	0.05	0.00	0.00	5.77	2111	81.42	1.97	0.29	0.03	0.00	0.00	3.00
Luapula	1	Lufubu	1292	1311.4	364.0	27.8	92.97	22.31	6.88	2.68	0.29	0.16	14.91	5443	71.96	17.27	5.33	2.07	0.22	0.12	11.54
	24	Luongo	6493	1248.5	354.3	28.4	198.99	114.63	50.71	25.20	11.87	10.68	72.89	26627	30.65	17.66	7.81	3.88	1.83	1.65	11.23
Northern	3	Lukupa	1256	1389.0	351.2	25.3	39.33	19.92	11.35	7.65	4.15	3.90	13.97	5106	31.32	15.86	9.04	6.09	3.30	3.10	11.12
	25	Lwombe	2580	1423.7	359.7	25.3	82.75	41.90	23.88	16.08	8.73	8.20	29.39	10742	32.07	16.24	9.25	6.23	3.38	3.18	11.39
Eastern	4	Kapemba	403	826.4	56.4	6.8	8.24	0.64	0.29	0.19	0.09	0.05	0.73	263	20.44	1.58	0.72	0.46	0.22	0.13	1.81
	18	Lundazi	1580	804.0	97.4	12.1	60.97	5.25	1.77	0.87	0.17	0.11	4.87	1780	38.59	3.32	1.12	0.55	0.11	0.07	3.08
	20	Lutembwe	1517	1071.5	129.7	12.1	77.97	6.72	2.26	1.11	0.21	0.14	6.23	2277	51.40	4.43	1.49	0.73	0.14	0.09	4.11
	21	Katete	73	1046.7	148.5	14.2	10.27	0.27	0.10	0.04	0.00	0.00	0.34	125	140.68	3.70	1.37	0.55	0.00	0.00	4.66





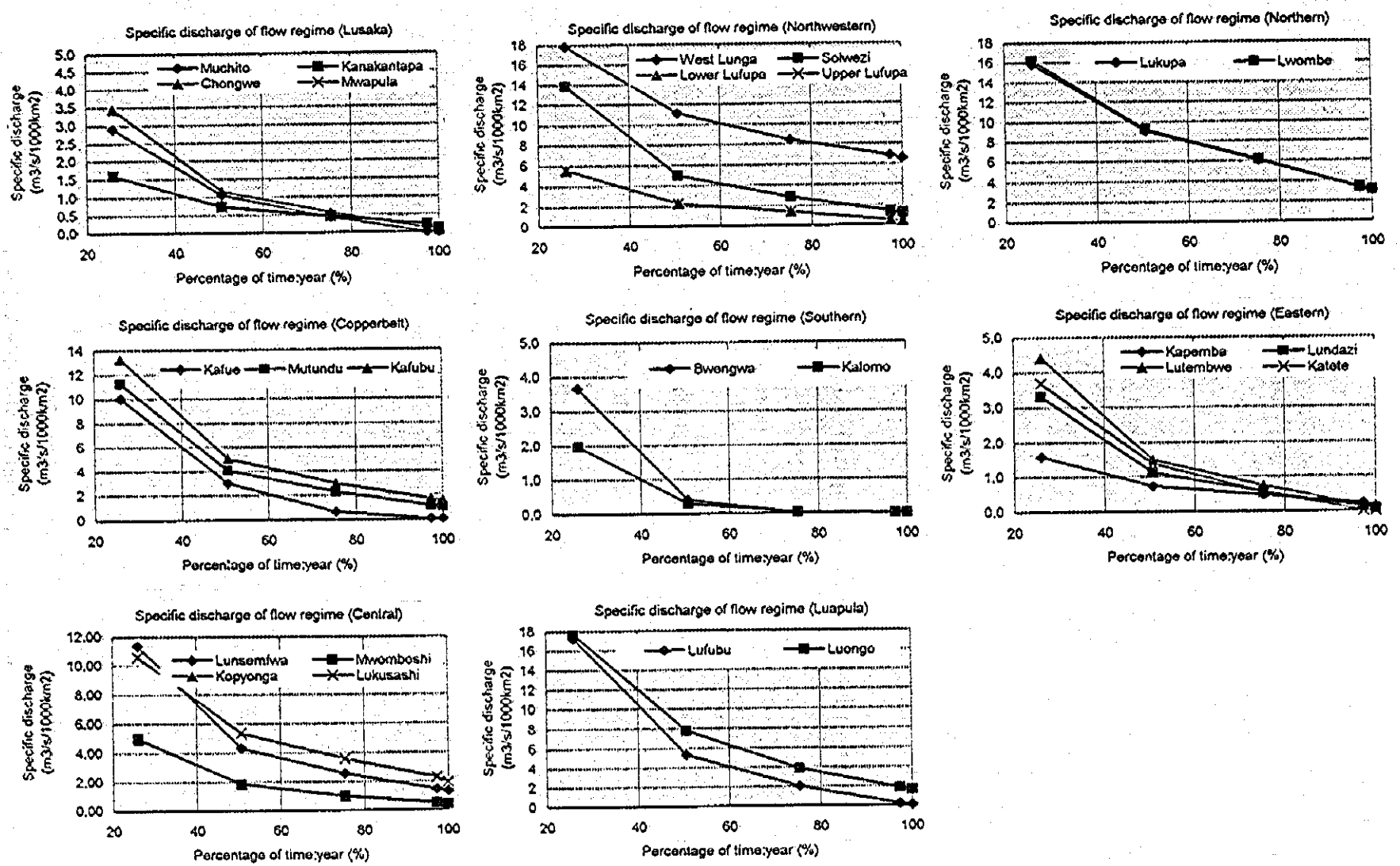


Figure 4-3 Flow Regime at Proposed Dam Sites

4.3 Intake Rate Potential at Proposed Dam Sites

The intake rate potential at the proposed dam sites was estimated by following the same method as mentioned in Supporting Report [C]. The intake rate potential for a 10-year return period is shown in Table 4-3. Although many proposed dam sites have no intake rate potential because of their small catchment areas, some sites have intake rate potential in the northern area where has much rain. However even in the northern area, intake rate potential is less than 0.6 m^3/s (50,000 m^3/day) at proposed dam sites under 2,000 km^2 of catchment area.

Table 4-3 Intake Rate Potential at Proposed Dam Site (10-year Return Period)

Province	Proposed Dam Site		Catchment Area	Intake Rate Potential	
Copperbelt	No. 7	Mutundu	493 km^2	0.06 m^3/s	4,900 m^3/day
	No.10	Kafubu	1,047 km^2	0.23 m^3/s	19,700 m^3/day
Central	No.11	Lunsemfwa	1,473 km^2	0.32 m^3/s	27,700 m^3/day
Northwestern	No. 2	West Lunga	4,651 km^2	4.70 m^3/s	405,600 m^3/day
Luapula	No.24	Luongo	6,493 km^2	1.56 m^3/s	134,500 m^3/day
Northern	No. 3	Lukupa	1,256 km^2	0.54 m^3/s	46,300 m^3/day
	No.25	Lwombe	2,580 km^2	1.10 m^3/s	95,000 m^3/day

Note : The intake rate potential of 10-year return period in the other dams is zero.

4.4 Water Potential Developed by Proposed Dams

Based on the monthly mean discharge and flow regime from Table 4-2, the potential discharge developed by the proposed dams were studied by using the following method. Figure 4-4 refers:

1) Select 10 years of available discharge, including drought years.
2) Adjust this 10 years of discharge according to the ratio (R30/R10), where R10 is the average annual basin rainfall of selected 10 years and R30 is the average annual basin rainfall of last 30 years.
3) Based on monthly mean discharge of selected average 10 years series, plot the cumulative volume converted from monthly discharge on the Y-axis and the corresponding month on the X-axis for 10 or more years.
4) The slope of the straight line BC represents an average flow rate over the period from B to C. For example, at a dam in Figure 4-4, to sustain a flow rate of 5.46 m^3/s as a steady abstraction from the reservoir (summing it is full at B), a storage of 457 Mm^3 would be required at the point of maximum deficit, X.

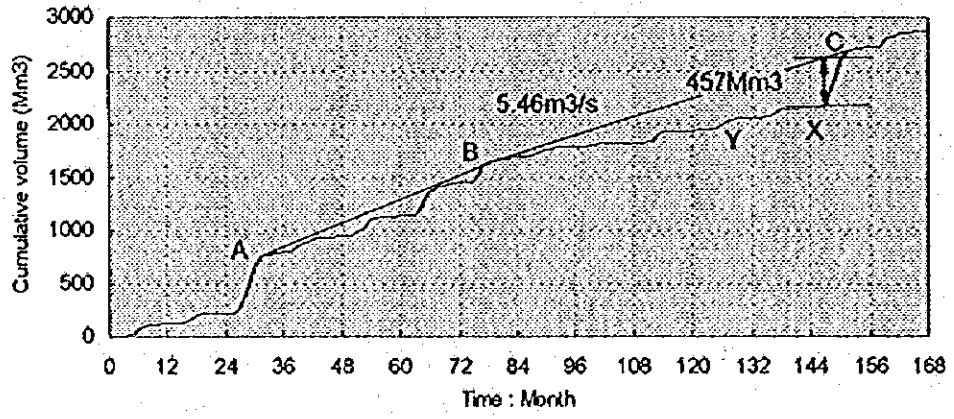


Figure 4-4 Cumulative Monthly Volumes

Applying the above method to the proposed dam sites, the relationship between regulated discharge and required reservoir storage was analysed and is shown in Figure 4-6. Using this relationship, the regulated discharges corresponding to the maximum reservoir were estimated. In the Study, average drought discharge was employed as compensation discharge. In addition, the evaporation loss from reservoir surface was estimated using the following equation :

$$Eloss = 0.7 \times Ep \times Ar \times 0.5 \div t$$

where, *Eloss* : Evaporation loss from reservoir (m/s)
Ep : Pan-evaporation
Ar : Maximum reservoir area (km^2)
t : Unit conversion coefficient (=365*86400)
0.7 : Pan-Coefficient (Class A evaporation pan)
the ratio of evaporation from reservoir and that from class A pan
0.5 : Actual reservoir area is assumed as half of maximum

Thus the discharge developed by a dam with a maximum scale is calculated using the following equation :

$$Qdev = Qreg - Eloss - Qd$$

where, *Qdev* : Discharge developed by dam
Qreg : Regulated discharge
Qd : Average drought discharge

The water potential developed by the proposed dams was estimated as the discharge to be able to be utilised even at the time of drought with 10 years return period. The study results are shown in Figure 4-5 and Table 4-4.

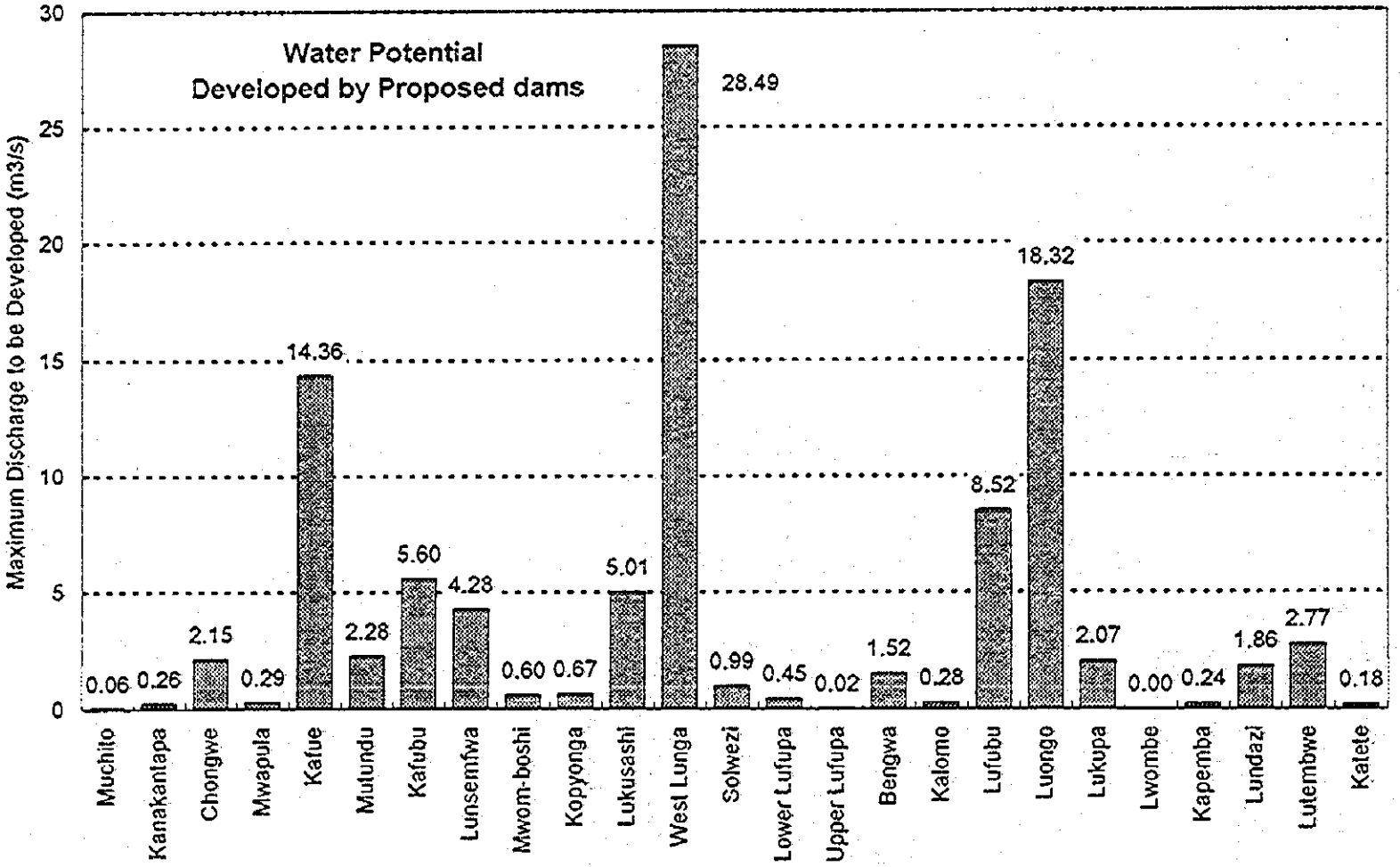


Figure 4-5 Water Resources Potential Developed by Proposed Maximum Dams

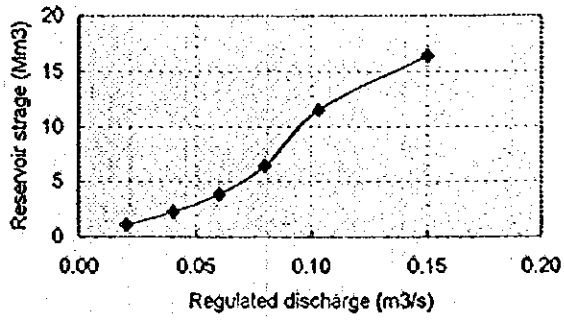
Table 4-4 Water Resources Potential Developed by Proposed Maximum Dams

Province	Development Point No.	Name of River	C.A. (km2)	Maximum Dam Scale: Dam hight (m)	Reservoir Area (km2)	Eff. Res. Storage (Mm3)	Discharge Developed on Maximum Dam Scale: Regulated discharge (m3/s)	Critical period (years)	Evaporation Loss (m3/s)	Compensation Discharge (m3/s)	Water Potential developed by Dam: Discharge (m3/s)	Discharge (m3/day)	Specif. Discharge (m3/s/1000km2)	Annual Flow Summary: Max. (m3/s)	Q(95) (m3/s)	Q(185) (m3/s)	Q(275) (m3/s)	Q(355) (m3/s)	Min. (m3/s)	Average (m3/s)
Lusaka	14	Muchito	40	25	5.3	34.0	-	-	-	-	-	-	-	4.41	0.12	0.04	0.02	0.00	0.00	0.15
	(Max. regulated discharge)			20	4.0	16.4	0.15	10	0.09	0.00	0.06	4,821	1.39							
	15	Kanukantapa	256	27	8.6	47.0	-	-	-	-	-	-	-	5.28	0.41	0.19	0.12	0.06	0.03	0.47
	(Max. regulated discharge)			24	5.8	29.6	0.47	10	0.15	0.06	0.26	22,460	1.02							
	16	Chongwe	1917	37	13.8	87.0	2.72	4	0.36	0.21	2.15	185,875	1.12	76.79	6.62	2.23	1.10	0.21	0.14	6.14
	17	Mwapula	398	28	2.9	13.0	0.46	3	0.08	0.09	0.29	25,486	0.74	8.22	0.64	0.29	0.18	0.09	0.05	0.73
Copperbelt	6	Kafue	7549	33	31.6	247.0	15.76	1	0.66	0.74	14.36	1,240,503	1.90	185.82	75.70	22.71	4.96	0.74	0.57	45.54
	7	Mutundu	493	36	13.7	127.0	3.13	6	0.29	0.56	2.28	197,193	4.63	19.86	5.55	2.01	1.14	0.56	0.51	3.85
	10	Kafubu	1047	31	32.7	293.0	8.05	5	0.67	1.78	5.60	484,095	5.35	36.45	13.91	5.34	3.12	1.78	1.63	9.66
Central	11	Lunsemfwa	1473	27	15.5	111.0	6.74	2	0.32	2.14	4.28	370,122	2.91	43.81	16.72	6.42	3.75	2.14	1.96	11.61
	12	Mwombushi	1985	35	4.4	20.0	1.70	1	0.11	0.99	0.60	52,239	0.30	64.41	9.96	3.71	1.99	0.99	0.89	8.18
	13	Kopyonga	288	30	5.4	44.0	0.94	2	0.13	0.14	0.67	57,848	2.32	9.21	1.43	0.53	0.28	0.14	0.13	1.17
	19	Lukusashi	961	56	15.9	293.0	7.54	7	0.32	2.21	5.01	432,519	5.21	42.60	10.16	5.16	3.48	2.21	1.84	7.97
Northwest	2	West Lunga	4651	41	146.0	2203.0	63.00	10	2.70	31.81	28.49	2,461,259	6.12	237.22	82.96	51.74	39.30	31.81	30.42	68.71
	5	Solwezi	354	30	2.0	17.0	1.53	1	0.05	0.49	0.99	85,480	2.79	17.57	4.91	1.78	1.01	0.49	0.45	3.41
	9-1	Lower Lufupa	1038	31	2.6	13.0	1.00	1	0.05	0.50	0.45	38,595	0.43	50.72	5.81	2.35	1.44	0.50	0.42	5.04
	9-2	Upper Lufupa	904	28	2.1	3.0	0.50	1	0.04	0.44	0.02	1,465	0.02	44.16	5.06	2.04	1.26	0.44	0.37	4.39
Western	22	Zambezi(Mongu)																		
Southern	23	Zambezi(Livingstone)																		
	26	Bengwa	1677	40	3.2	32.0	1.76	1	0.07	0.17	1.52	131,540	0.91	283.20	6.17	0.67	0.04	0.00	0.00	10.31
	27	Kalomo	1925	27	4.5	7.0	0.56	1	0.09	0.19	0.28	23,761	0.14	156.74	3.79	0.55	0.05	0.00	0.00	5.77
Luapula	1	Lufubu	1292	33	26.5	218.0	9.47	3	0.66	0.29	8.52	736,308	6.60	92.97	22.31	6.88	2.68	0.29	0.16	14.91
	24	Luongo	6493	43	94.0	483.0	32.53	2	2.33	11.87	18.32	1,583,143	2.82	198.99	114.63	50.71	25.20	11.87	10.68	72.89
Northern	3	Lukupa	1256	27	11.2	79.0	6.47	1	0.25	4.15	2.07	179,012	1.65	39.33	19.92	11.35	7.65	4.15	3.90	13.97
	25	Lwombe	2580	15	10.9	19.0	3.69	1	0.24	8.73	0.00	0	0.00	82.75	41.90	23.88	16.08	8.73	8.20	29.39
Eastern	4	Kapemba	403	30	1.9	11.0	0.39	3	0.06	0.09	0.24	20,967	0.60	8.24	0.64	0.29	0.19	0.09	0.05	0.73
	18	Lundazi	1580	38	14.9	90.0	2.47	4	0.44	0.17	1.86	160,300	1.17	60.97	5.25	1.77	0.87	0.17	0.11	4.87
	20	Lutembwe	1517	48	11.1	127.0	3.31	5	0.33	0.21	2.77	239,219	1.83	77.97	6.72	2.26	1.11	0.21	0.14	6.23
	21	Katete	73	25	5.6	47.0	-	-	-	-	-	-	-	10.27	0.27	0.10	0.04	0.00	0.00	0.34
	(Max. regulated discharge)			24	4.9	38.4	0.34	10	0.15	0.01	0.18	15,877	2.52							

Note.
(1) Drought discharge [Q(355)] or the value calculated as 0.1 m3/s/1000km2, was employed as compensation flow
(2) Compensation discharge : Compensation discharge downstream of dam
(3) Maximum regulated discharge should be less than annual average discharge.
(4) Evapolation loss is calculated using the following equation.

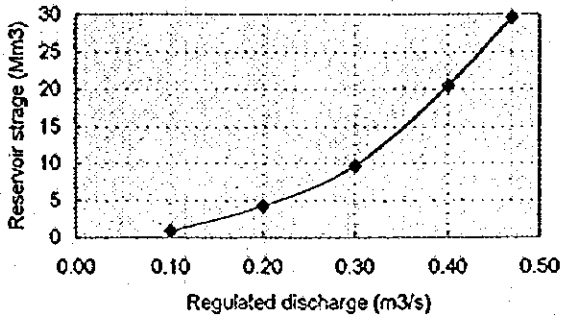
E.loss = 0.7*Ep*Ar*0.5/86.4/365

(5) Eff.Res. Storage : Effective Reservoir Storage



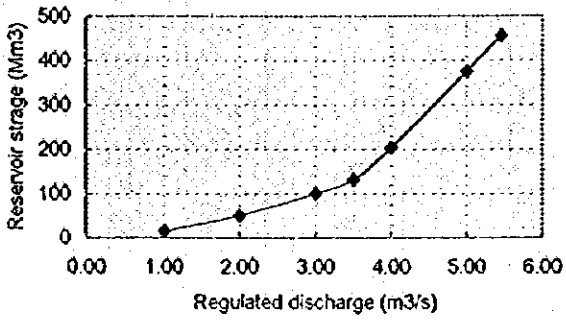
Muchito dam site (No.14)

Regulated Discharge (m3/s)	Reservoir strage (Mm3)
0.02	1.08
0.04	2.24
0.06	3.81
0.08	6.44
0.10	11.5
0.15	16.4



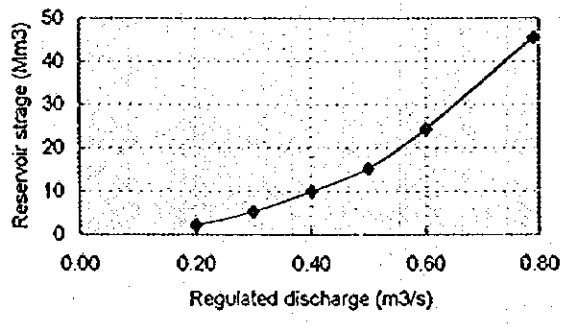
Kanakantapa dam site (No.15)

Regulated Discharge (m3/s)	Reservoir strage (Mm3)
0.10	0.91
0.20	4.23
0.30	9.66
0.40	20.5
0.47	29.6



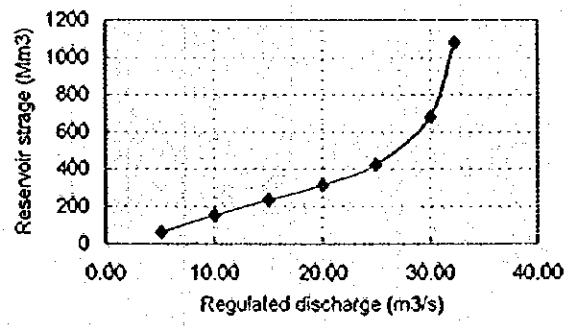
Chongwe dam site (No.16)

Regulated Discharge (m3/s)	Reservoir strage (Mm3)
1.00	15.0
2.00	51.0
3.00	101.0
3.50	132.0
4.00	204.0
5.00	375.0
5.46	457.0



Mwapula dam site (No.17)

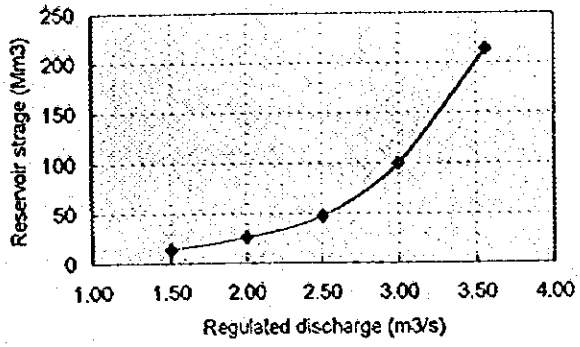
Regulated Discharge (m3/s)	Reservoir strage (Mm3)
0.20	2.09
0.30	5.32
0.40	10.0
0.50	15.2
0.60	24.4
0.79	45.6



Kafue dam site (No.6)

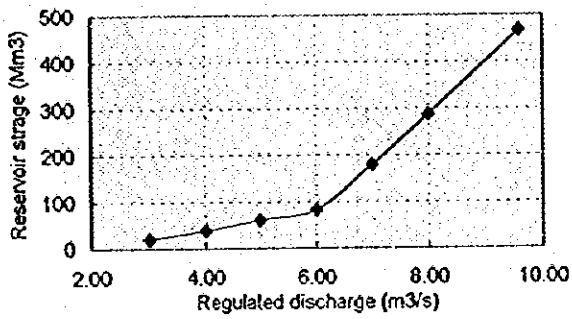
Regulated Discharge (m3/s)	Reservoir strage (Mm3)
5.00	64.0
10.00	152
15.00	235
20.00	314
25.00	424
30.00	682
32.30	1080

Figure 4-6(1) Relationship between Regulated Discharge and Reservoir Storage



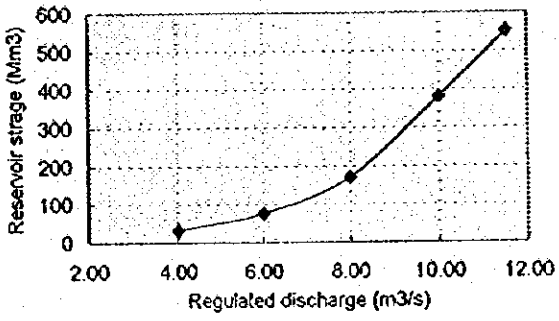
Mutundu dam site (No.7)

Regulated Discharge (m3/s)	Reservoir strage (Mm3)
1.50	13.9
2.00	26.0
2.50	47.6
3.00	100
3.56	214



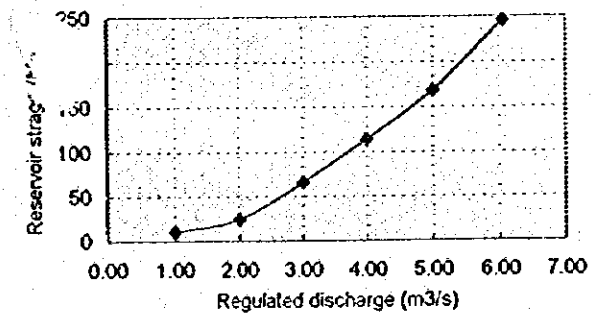
Kafubu dam site (No.10)

Regulated Discharge (m3/s)	Reservoir strage (Mm3)
3.00	20.0
4.00	38.3
5.00	61.7
6.00	83.0
7.00	180
8.00	287
9.58	467



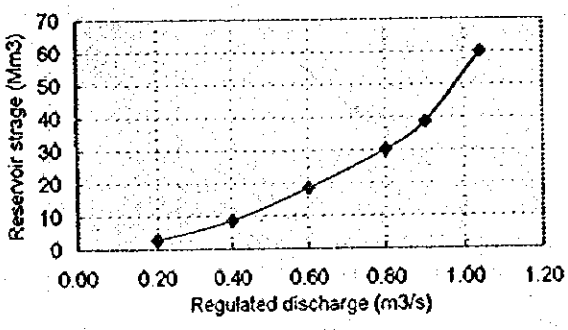
Lunsemfwa dam site (No.11)

Regulated Discharge (m3/s)	Reservoir strage (Mm3)
4.00	32.0
6.00	76.0
8.00	171
10.00	381
11.51	552



Mwomboshi dam site (No.12)

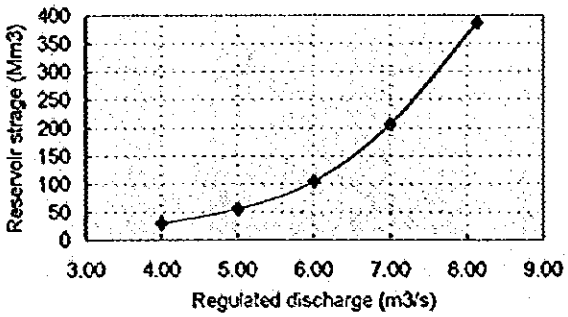
Regulated Discharge (m3/s)	Reservoir strage (Mm3)
1.00	10.6
2.00	24.0
3.00	65.7
4.00	114
5.00	168
6.05	246



Kopyonga dam site (No.13)

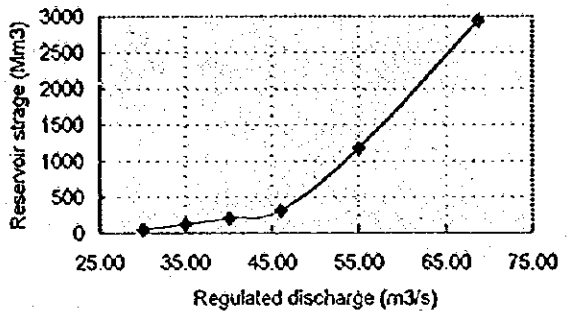
Regulated Discharge (m3/s)	Reservoir strage (Mm3)
0.20	2.8
0.40	8.6
0.60	18.4
0.80	30.1
0.90	38.6
1.04	60.0

Figure 4-6(2) Relationship between Regulated Discharge and Reservoir Storage



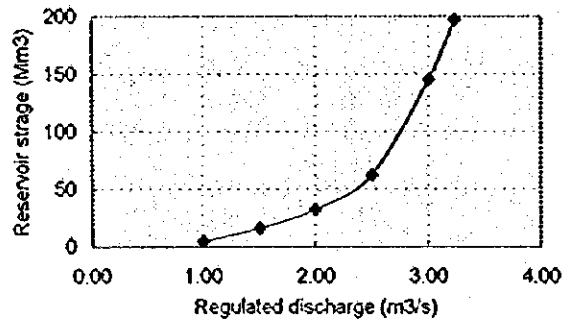
Lukusashi dam site (No.19)

Regulated Discharge (m3/s)	Reservoir strage (Mm3)
4.00	30.1
5.00	55.9
6.00	104
7.00	206
8.13	387



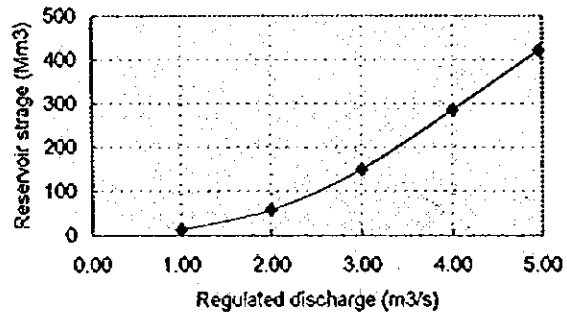
West Lunga dam site (No.2)

Regulated Discharge (m3/s)	Reservoir strage (Mm3)
30.00	48.0
35.00	118
40.00	208
46.00	311
55.00	1175
68.71	2937



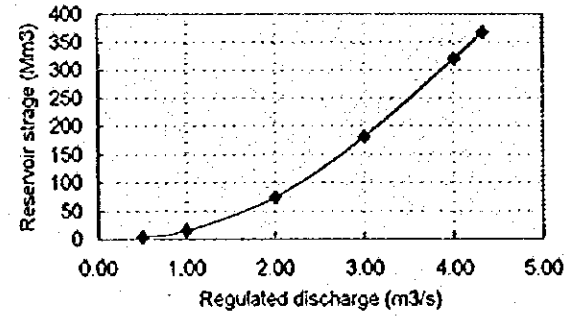
Solwezi dam site (No.5)

Regulated Discharge (m3/s)	Reservoir strage (Mm3)
1.00	5.1
1.50	16.0
2.00	32.4
2.50	62.5
3.00	145.0
3.23	197.0



Lower Lufupa dam site (No.9-1)

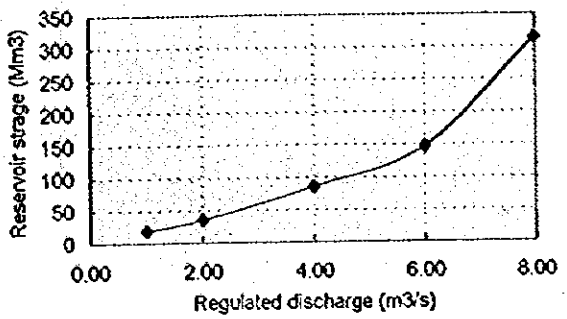
Regulated Discharge (m3/s)	Reservoir strage (Mm3)
1.00	12.9
2.00	57.1
3.00	150
4.00	286
4.96	421



Upper Lufupa dam site (No.9-2)

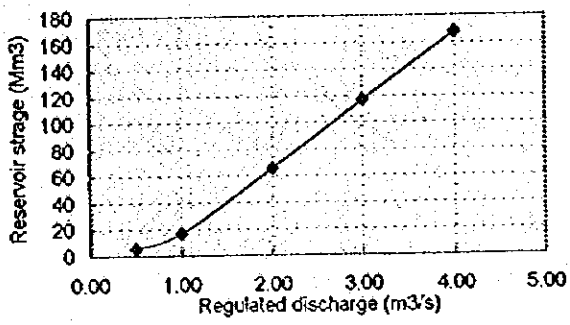
Regulated Discharge (m3/s)	Reservoir strage (Mm3)
0.50	2.9
1.00	15.7
2.00	73.3
3.00	181
4.00	320
4.32	367

Figure 4-6(3) Relationship between Regulated Discharge and Reservoir Storage



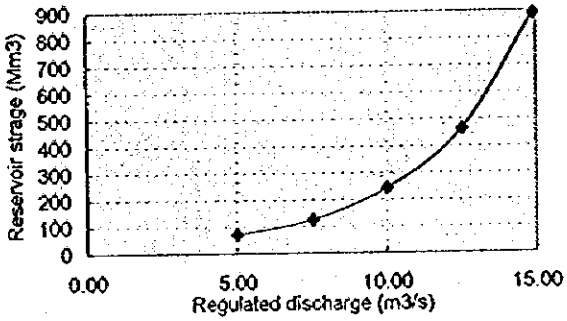
Bengwa dam site (No.26)

Regulated Discharge (m3/s)	Reservoir strage (Mm3)
1.00	19.0
2.00	36.0
4.00	86.0
6.00	147.0
7.98	313.0



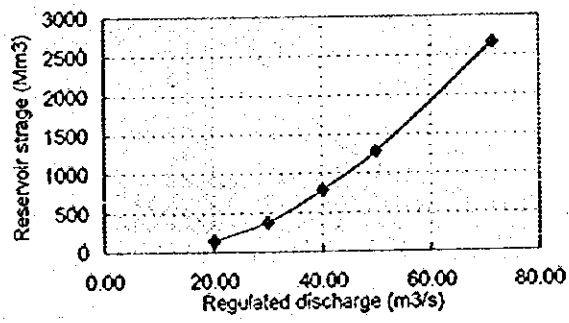
Kalomo dam site (No.27)

Regulated Discharge (m3/s)	Reservoir strage (Mm3)
0.50	5.7
1.00	17.1
2.00	66.0
3.00	117
4.00	168



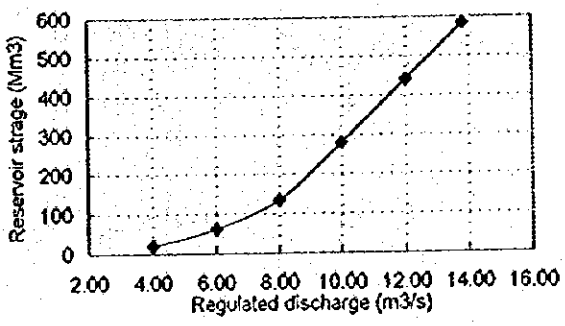
Lufubu dam site (No.1)

Regulated Discharge (m3/s)	Reservoir strage (Mm3)
5.00	71.1
7.50	125
10.00	243
12.50	465
14.90	890



Luongo dam site (No.24)

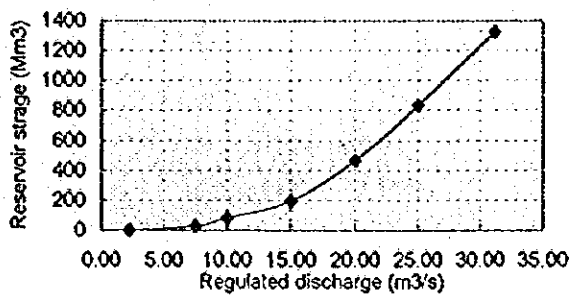
Regulated Discharge (m3/s)	Reservoir strage (Mm3)
20.00	146
30.00	378
40.00	793
50.00	1280
71.50	2659



Lukupa dam site (No.3)

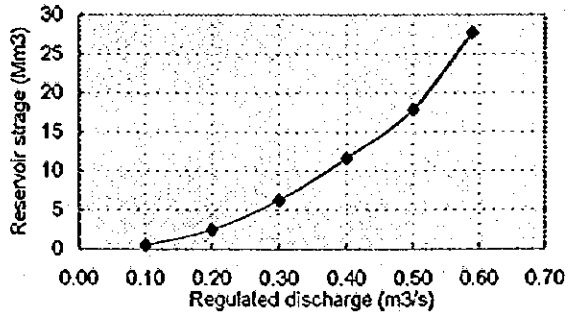
Regulated Discharge (m3/s)	Reservoir strage (Mm3)
4.00	19.3
6.00	61.8
8.00	135.0
10.00	280.0
12.00	440.0
13.81	585.0

Figure 4-6(4) Relationship between Regulated Discharge and Reservoir Storage



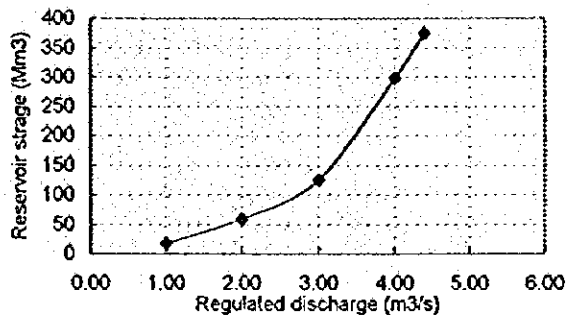
Lwombe dam site (No.25)

Regulated Discharge (m3/s)	Reservoir strage (Mm3)
2.20	0.0
7.50	27.3
10.00	81.8
15.00	195
20.00	464
25.00	836
31.17	1327



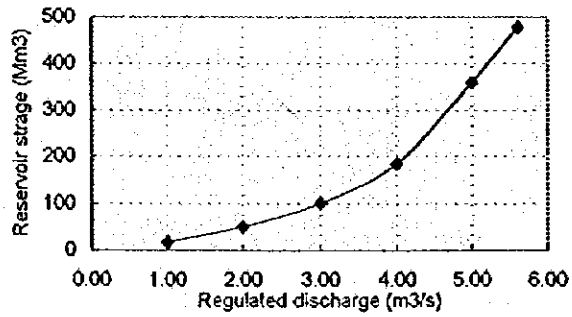
Kapemba dam site (No.4)

Regulated Discharge (m3/s)	Reservoir strage (Mm3)
0.10	0.5
0.20	2.5
0.30	6.3
0.40	11.6
0.50	17.8
0.59	27.7



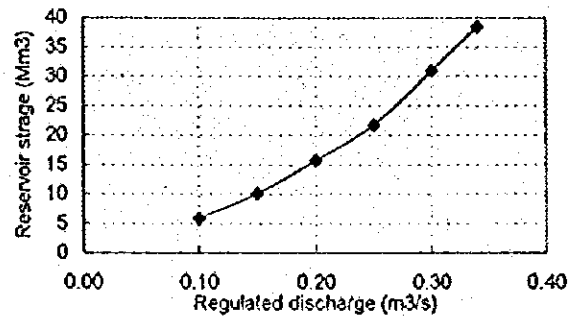
Lundazi dam site (No.18)

Regulated Discharge (m3/s)	Reservoir strage (Mm3)
1.00	17.8
2.00	59.3
3.00	125
4.00	298
4.39	375



Lutembwe dam site (No.20)

Regulated Discharge (m3/s)	Reservoir strage (Mm3)
1.00	16.7
2.00	50.8
3.00	101
4.00	185
5.00	360
5.61	477



Katete dam site (No.21)

Regulated Discharge (m3/s)	Reservoir strage (Mm3)
0.10	5.8
0.15	10.0
0.20	15.7
0.25	21.7
0.30	30.9
0.34	38.4

Figure 4-6(5) Relationship between Regulated Discharge and Reservoir Storage

CHAPTER 5 FACILITY PLANNING FOR PROSPECTIVE DAM DEVELOPMENT SCHEME

5.1 Dam Development Plan

From the Study of water demand and supply, 3 multi purpose dams were proposed. These 3 multi purpose dam schemes are as follows.

(1) Chongwe Dam

Purpose	:	water supply and irrigation
Supply area	:	Lusaka city and its round area
Total developed water	:	173,000 m^3/day= 2.002 m^3/s
Water supply	:	100,000 m^3/day= 1.157 m^3/s (Lusaka)
		3,000 m^3/day = 0.035 m^3/s (Chongwe)
Irrigation	:	7,000 m^3/day = 0.810 m^3/s
Storage effective volume	:	91.243 Mm^3
Normal water level	:	1074.0 m
Low water level	:	1061.4 m
Dam height	:	35.0 m
Dam type	:	Rock fill
Dam volume	:	1,315,000 m^3

(2) Kafubu Dam

Purpose	:	water supply and irrigation
Supply area	:	Ndola and Luansya and its around area
Total developed water	:	430,000 m^3/day = 4.977 m^3/s
Water supply	:	60,000 m^3/day = 0.694 m^3/s (Ndola)
		5,000 m^3/day = 0.058 m^3/s (Luansya)
Irrigation	:	365,000 m^3/day = 4.225 m^3/s
Storage effective volume	:	216,514 Mm^3
Normal water level	:	1201.0 m
Low water level	:	1184.3 m
Dam height	:	27.0 m
Dam tie	:	Rock fill
Dam volume	:	795,000 m^3

(3) Mutundu Dam

Purpose	:	water supply and irrigation
Supply area	:	Kitwe , Kalulushi , Mufulila and its around area
Total developed water	:	170,000 m^3/day = 1.968 m^3/s
Water supply	:	20,000 m^3/day = 0.231 m^3/s (Kitwe)
		10,000 m^3/day = 0.116 m^3/s (Kalulushi)
		5,000 m^3/day = 0.058 m^3/s (Mufulila)
Irrigation	:	135,000 m^3/day = 1.563 m^3/s
Storage effective volume	:	74.684 Mm^3
Normal water level	:	1209.0 m
Low water level	:	1192.8 m

Dam height	:	30.0 m
Dam tie	:	Rock fill
Dam volume	:	981,000 m^3

5.2 Preliminary Layout Design of Selected Dam Schemes

Preliminary layout designs of 3 multi-purpose dams are shown in Drawing 27 - 29.

CHAPTER 6 COST ESTIMATE

Construction cost of each prospective dam were estimated as a model dam. Finally unit cost by embankment volume was estimated as 37.5 US$/m^3.

Cost estimation of Chongwe dam as a model dam is shown in Table 6-1.

Table 6-1 Cost Estimation of Chongwe Dam

Description	Unit	Quantity	Unit cost US$	Amount (US$)
Felling	ha	40	1,000	40,000
Diversion work	set	1	2,500,000	2,500,000
Cut of soil	m^3	340,000	5	1,700,000
Cut of rock	m^3	130,000	25	3,250,000
Foundation treatment	set	1	3,000,000	3,000,000
Embankment Core	m^3	210,000	8	1,680,000
Embankment filter	m^3	160,000	12	1,920,000
Embankment rock	m^3	945,000	10	9,450,000
Spillway concrete	m^3	21,000	600	12,600,000
Grouting	m	22,000	280	6,160,000
Intake	set	1	3,000,000	3,000,000
Road	set	1	1,000,000	1,000,000
Control facility	set	1	3,000,000	3,000,000
Total				49,300,000
Cost by embankment volume = 49,300,000 US$/1,315,000 m^3 = 37.5 US$/m^3				

CHAPTER 7 RECOMMENDATION

This study dealt with the dam development plans to clarify the following aspects.

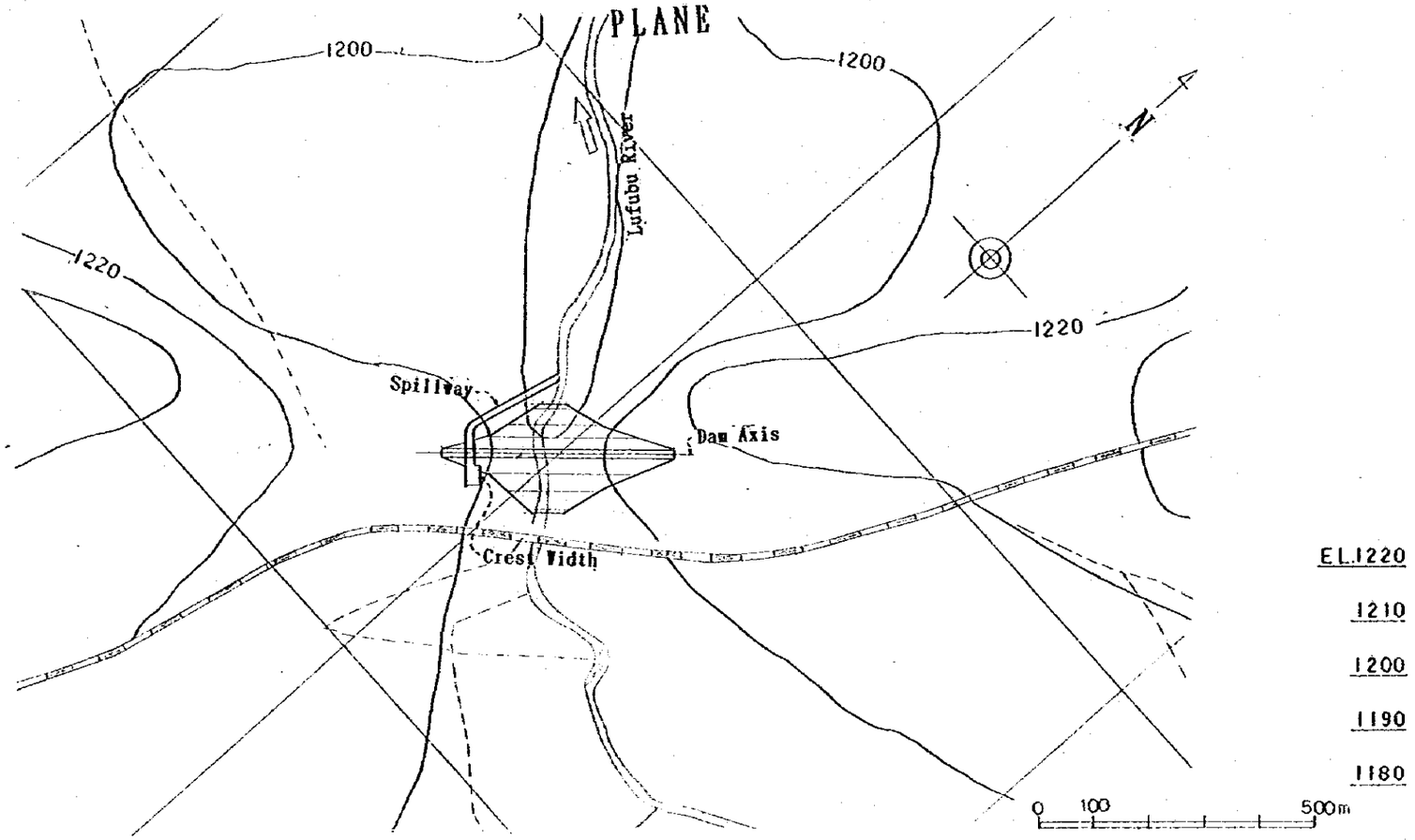
- Identification of potential dam sites in the country through studies on the maps of 1:50,000 scale.
- Possible maximum scale of proposed dams and these preliminary layout through field survey and studies on the maps of 1:50,000 scale.

For further study of dam development, the followings are recommended.

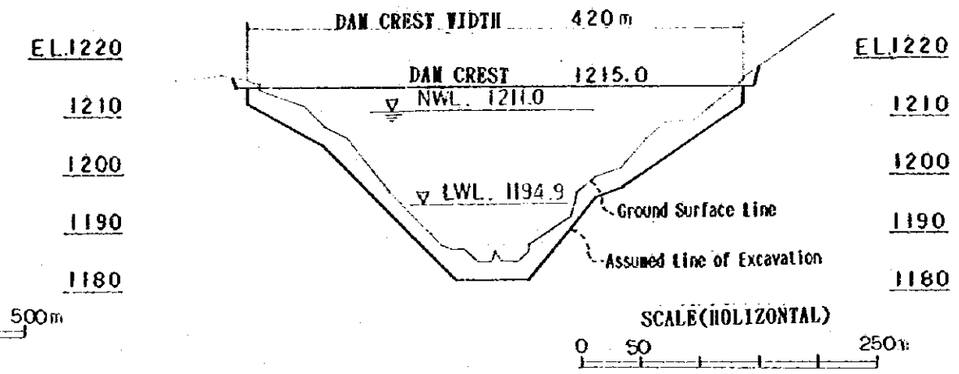
- Detailed survey on dam sites
  For the planning and design of dam construction with high priority, detailed topological and geological survey with high priority are necessary. In the Study, topological data is based mainly on the maps of 1:50,000 scale, and longitudinal cross section is based on topological survey of the dam axis. Geological survey is based only on field investigation from ground surface. Especially in case of finding rare outcrops or soil covered dam sites, sound rock base is not clear. Also reservoir volume is not enough correct, because the maps of 1:50,000 scale have only 10 m or 15 m interval of contour line against the 15 m to 40 m dam height.

- Detailed investigation of compensation objects in reservoir area
  The compensation objects in the reservoir area are not clear from the maps of 1:50,000 scale. Especially quantity of houses and field area are not clear by maps. Detailed investigation is necessary.

DRAWINGS



LONGITUDINAL SECTION OF DAM AXIS



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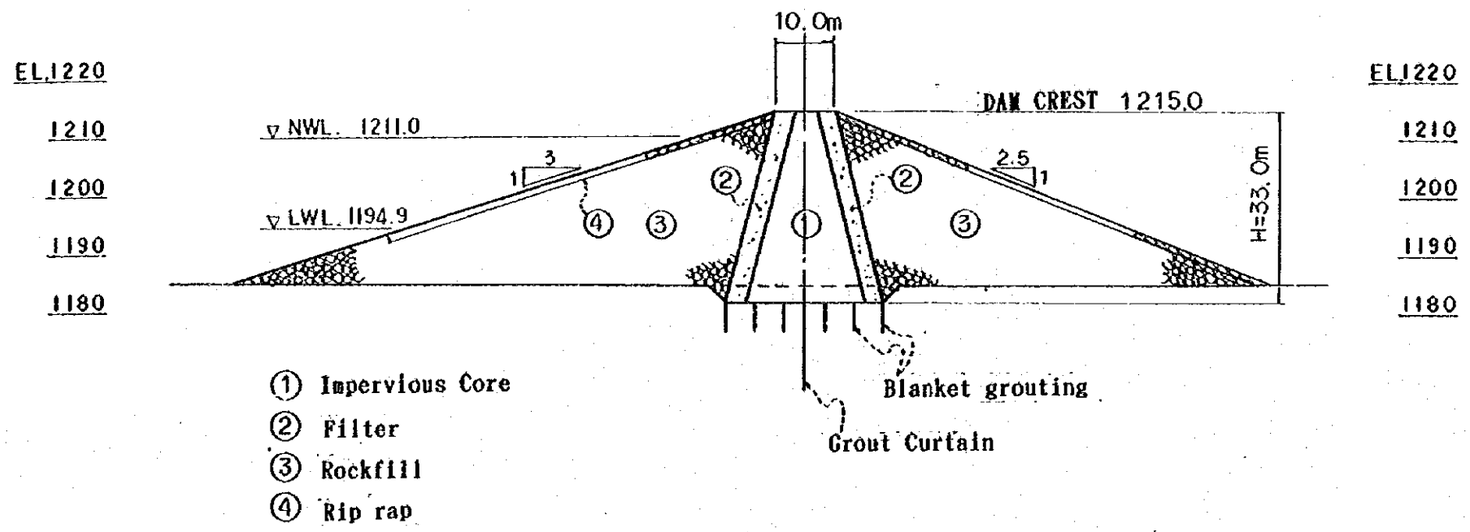
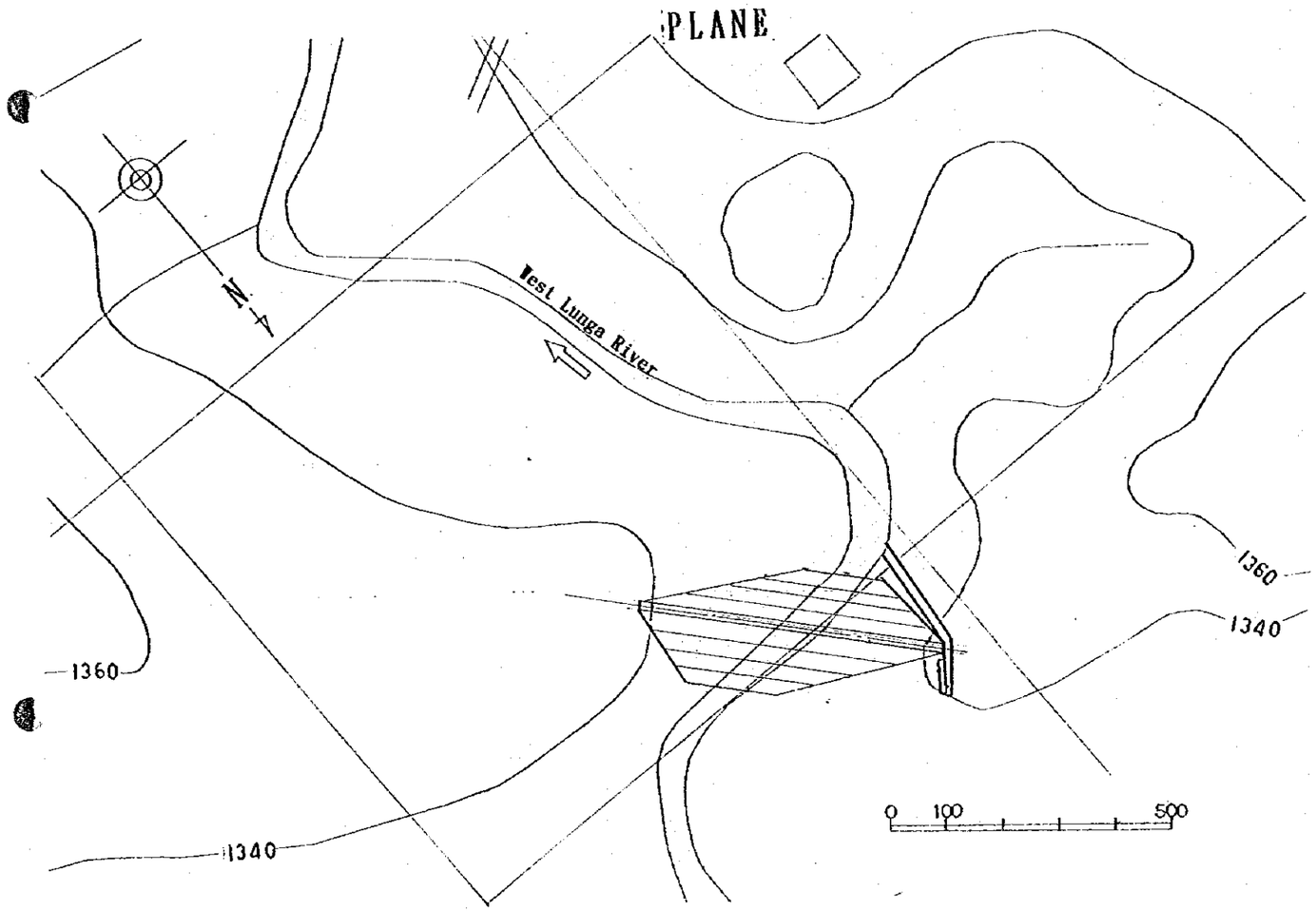


Drawing 1

LUFUBU DAM (NO. 1)



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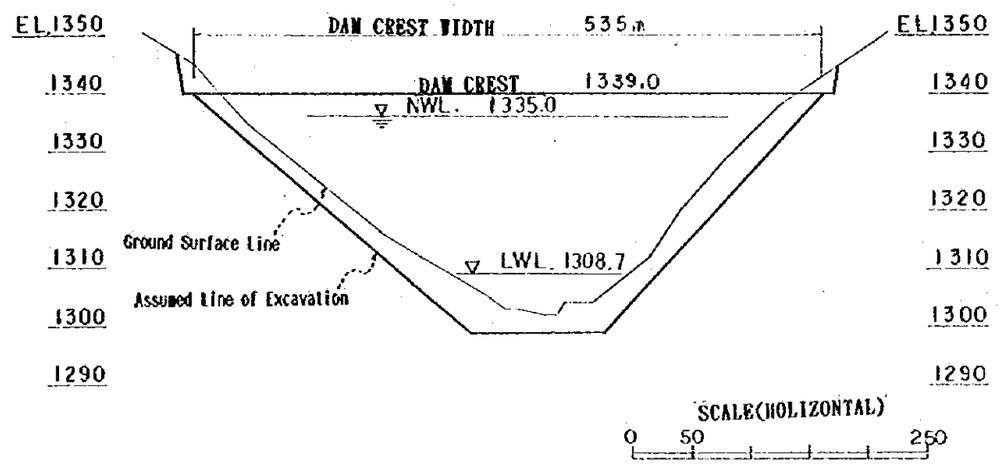

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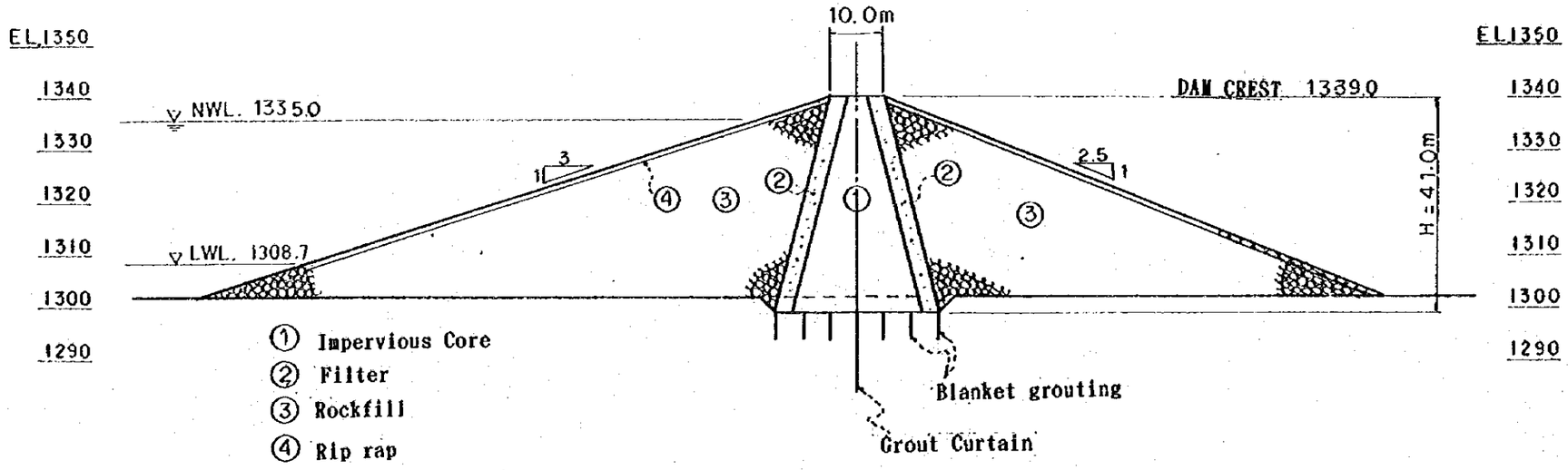
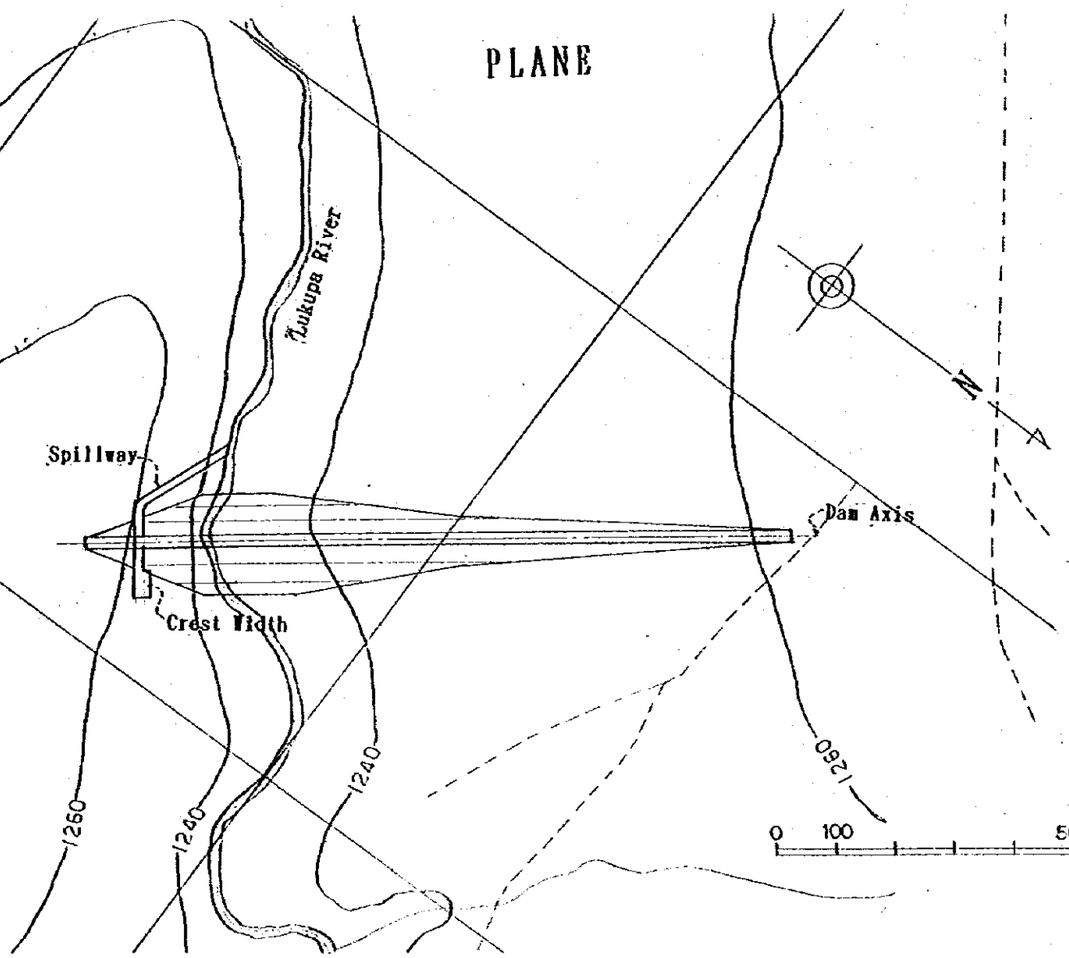


Drawing 2

WEST LUNGA DAM (NO. 2)

PLANE



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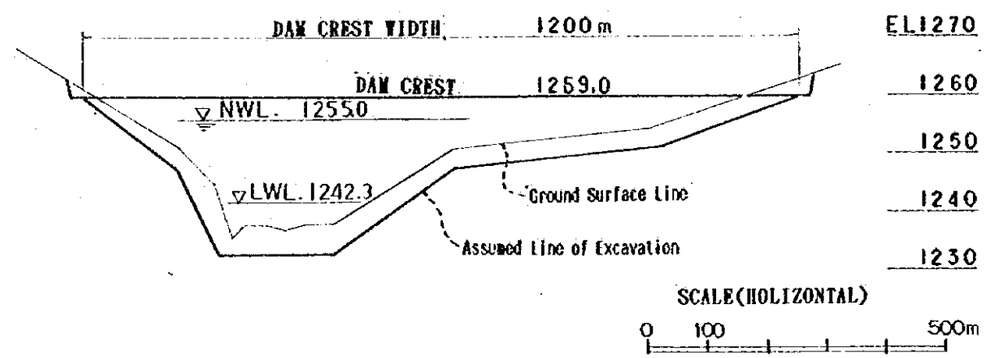

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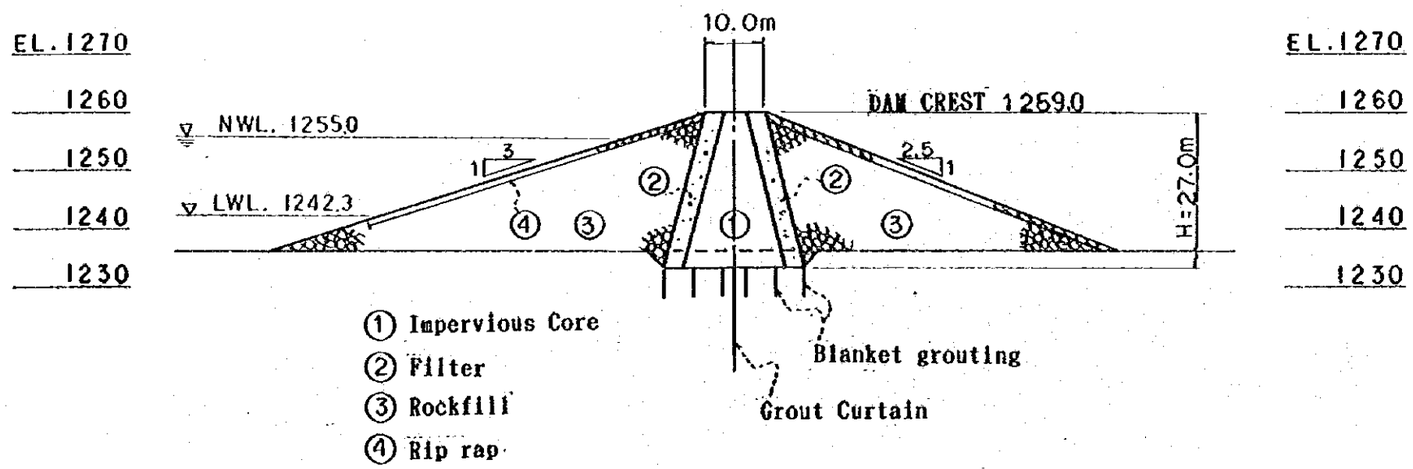
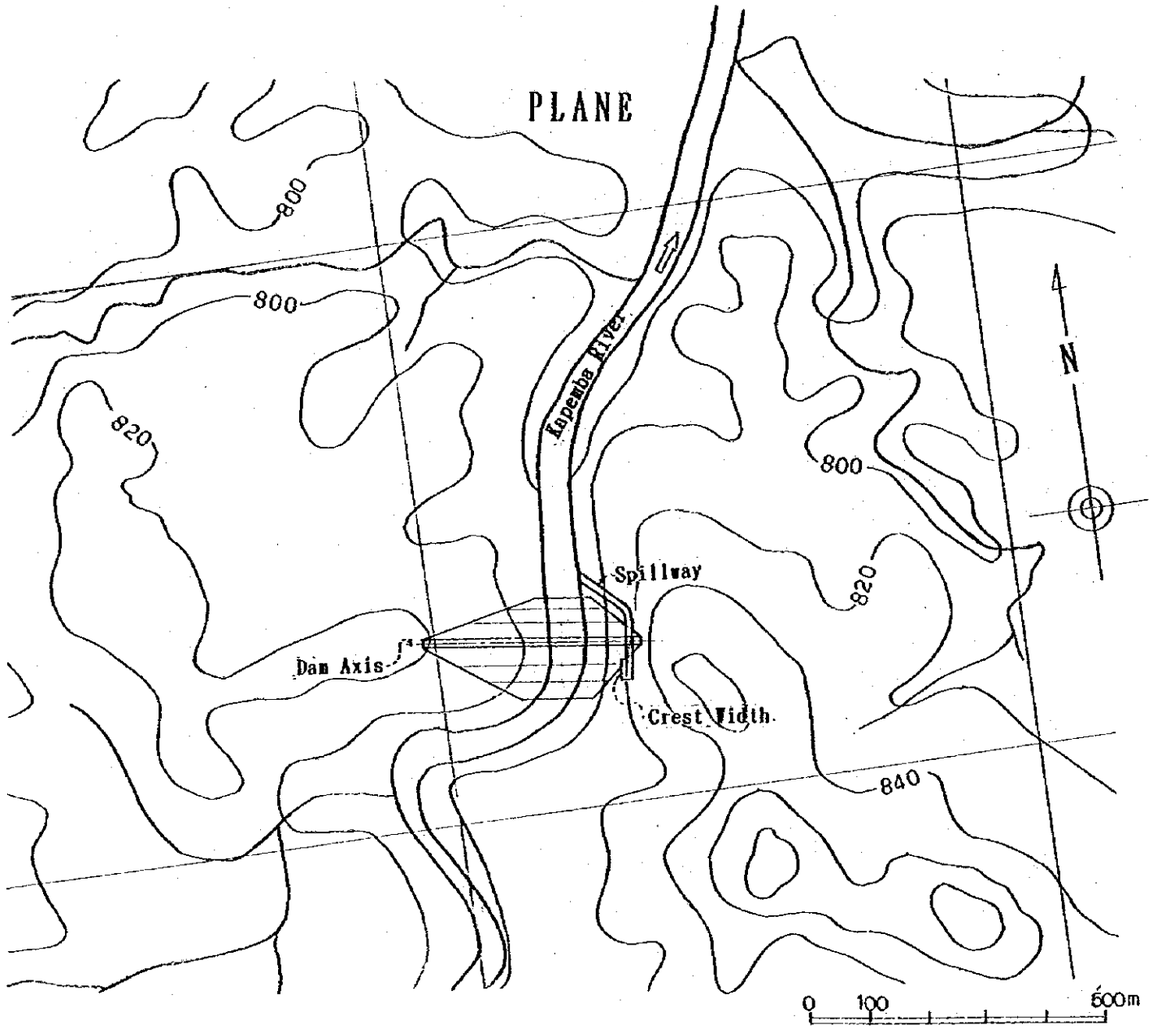


Drawing 3

LUKUPA DAM (NO. 3)

PLANE



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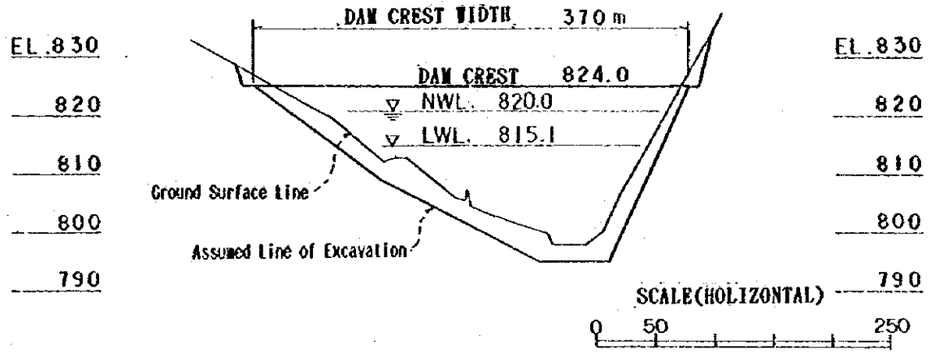

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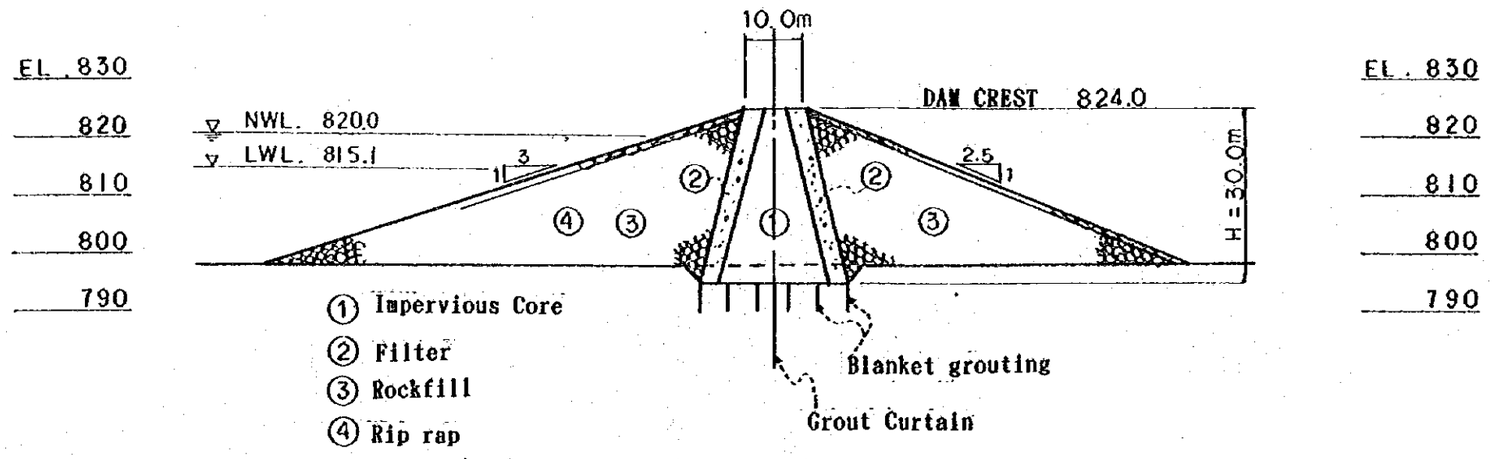
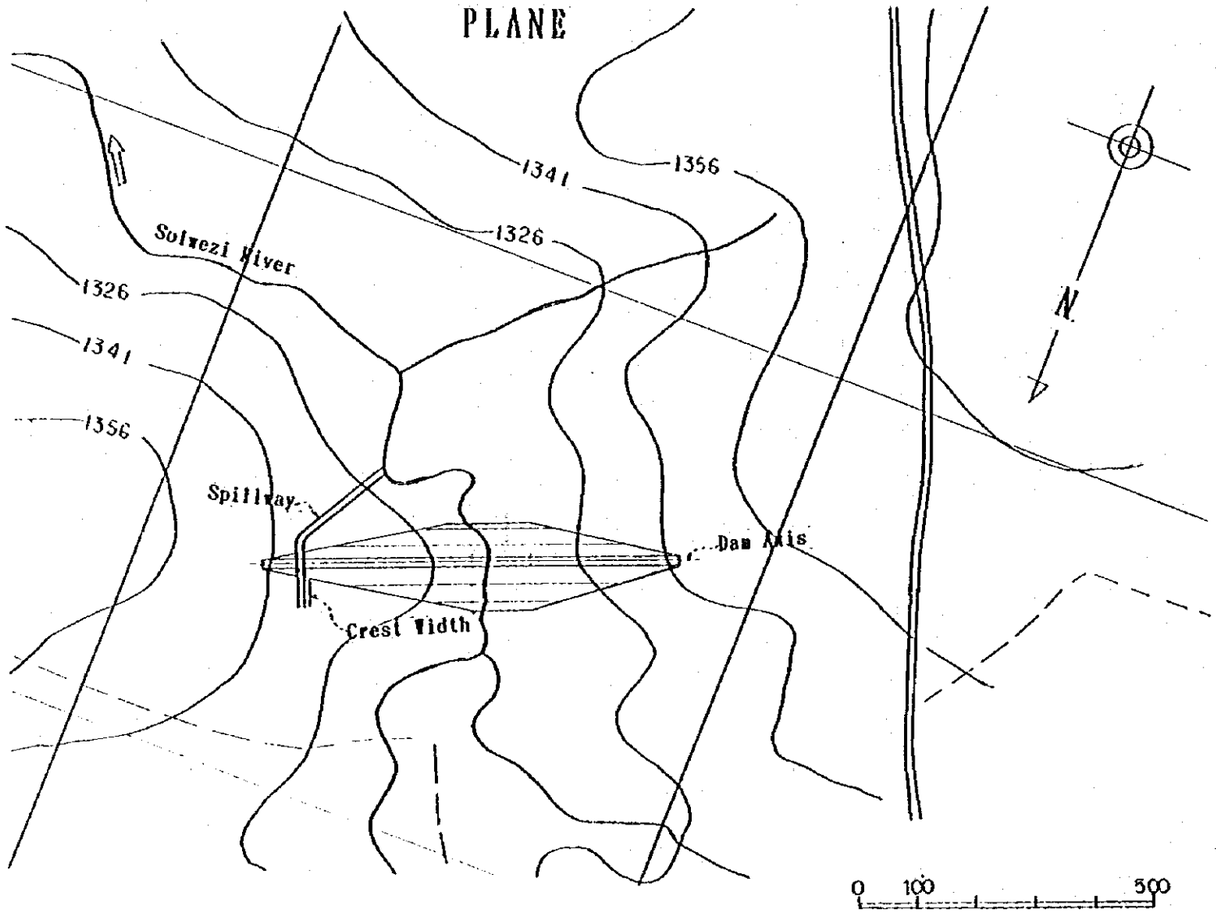


Drawing 4

KAPEMBA DAM (NO. 4)

PLANE



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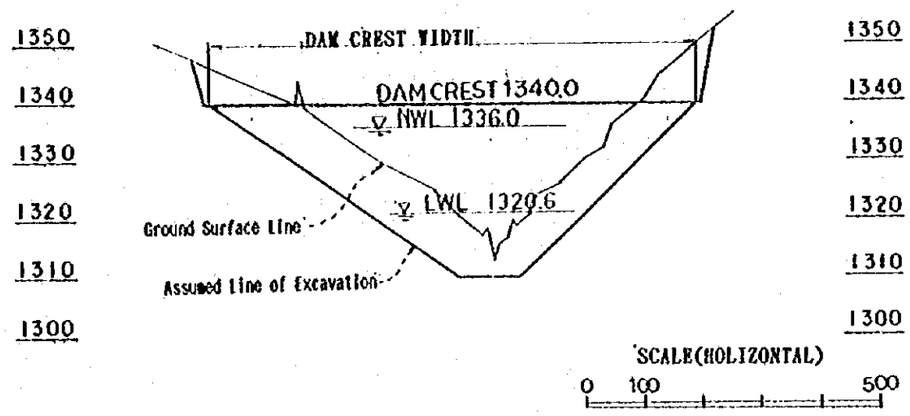

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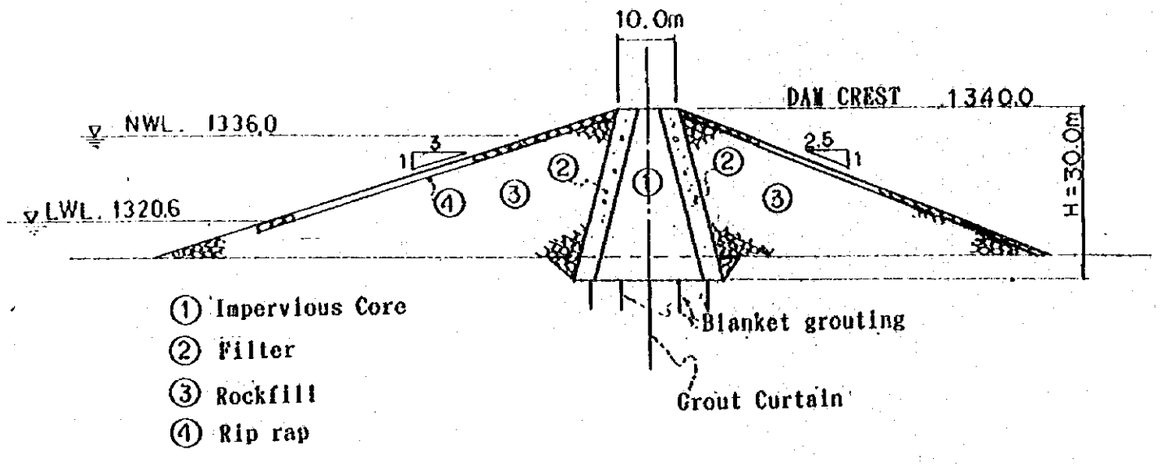
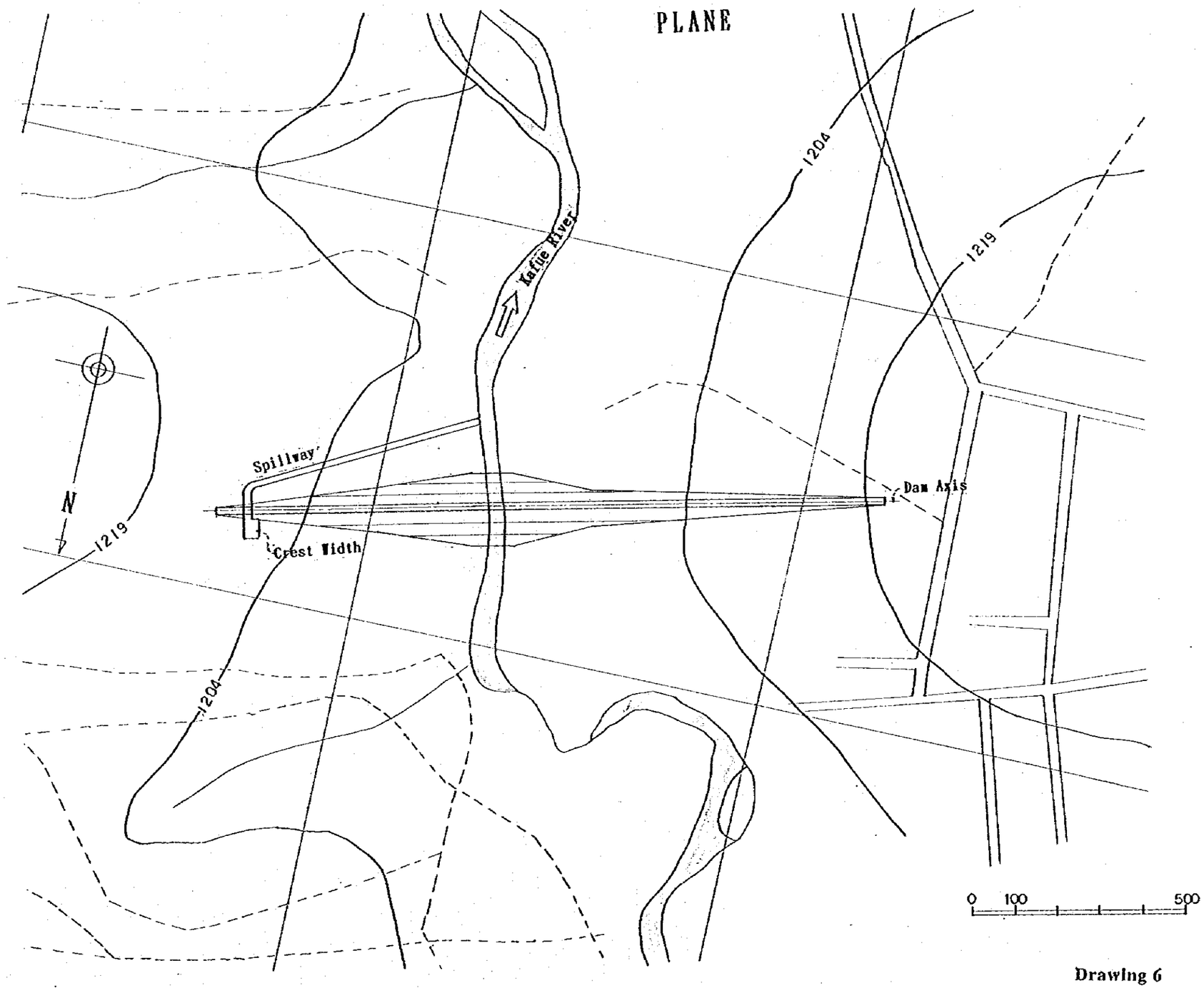


Drawing 5

SOLWEZI DAM (NO. 5)



Drawing 6

KAFUE DAM (NO. 6)

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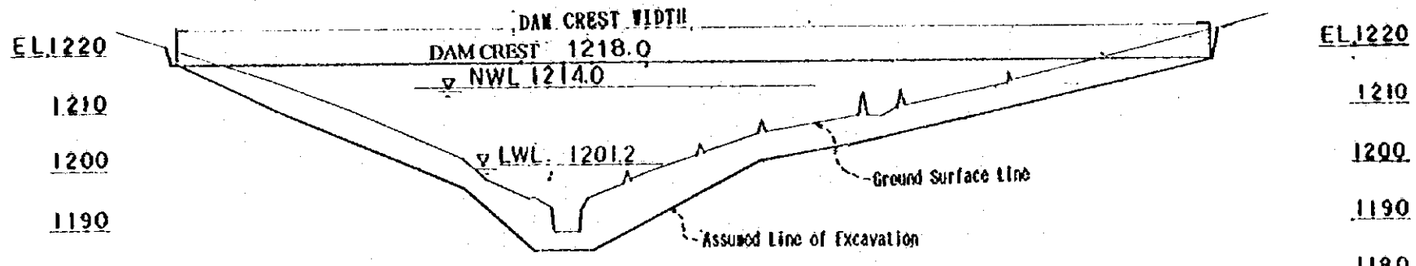

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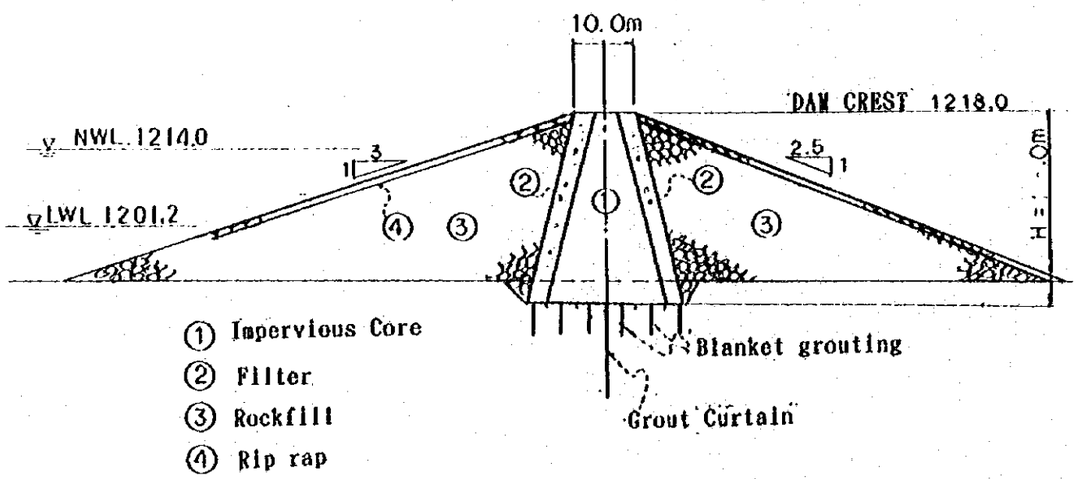
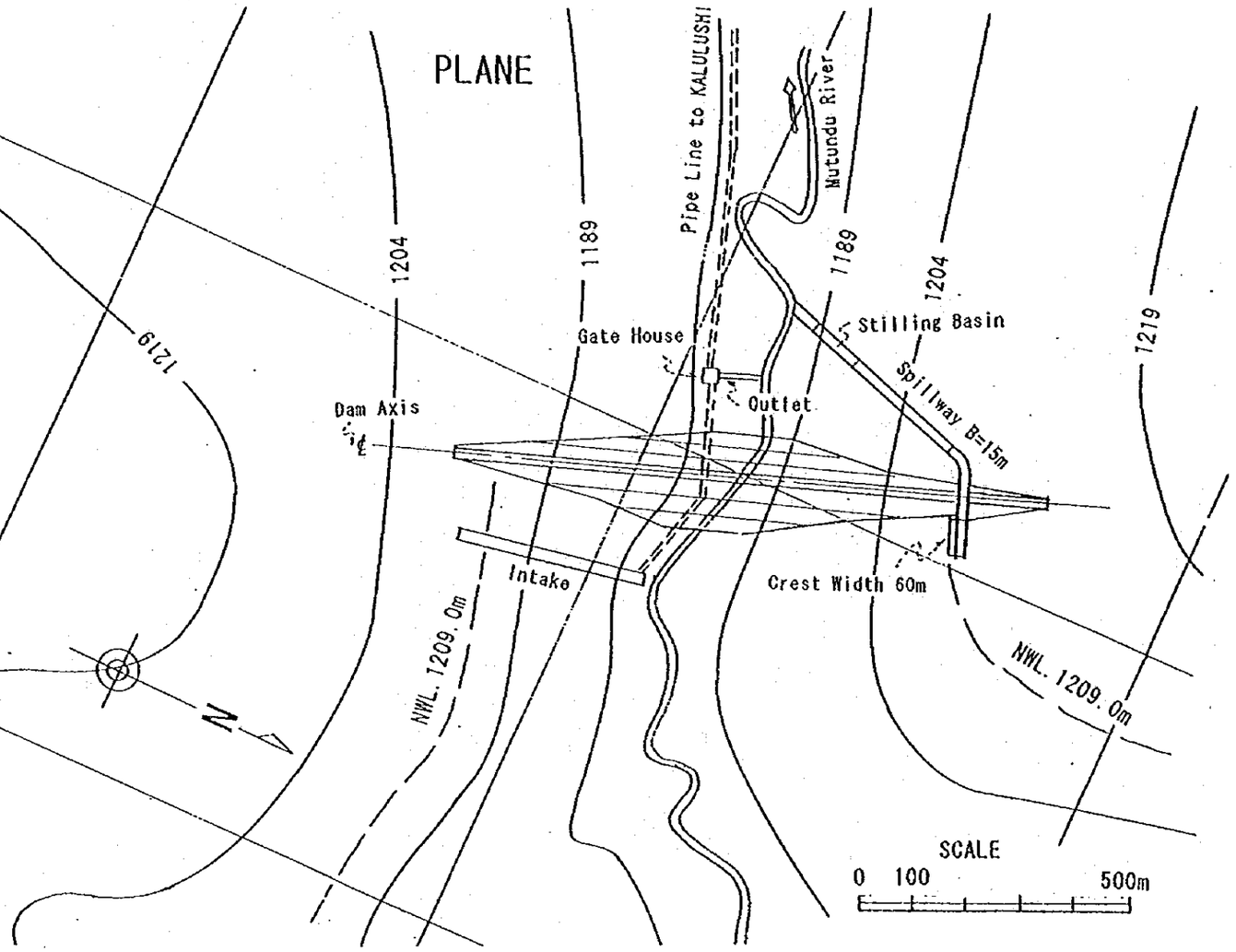


Drawing 7

KAFUE DAM (NO. 6)

PLANE



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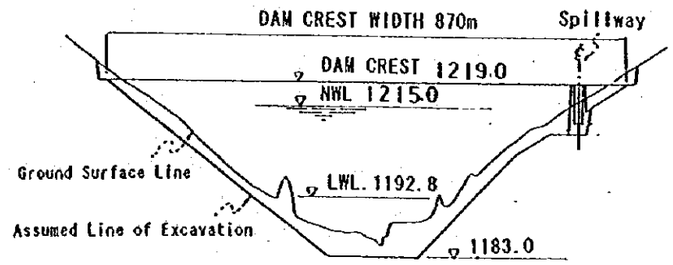

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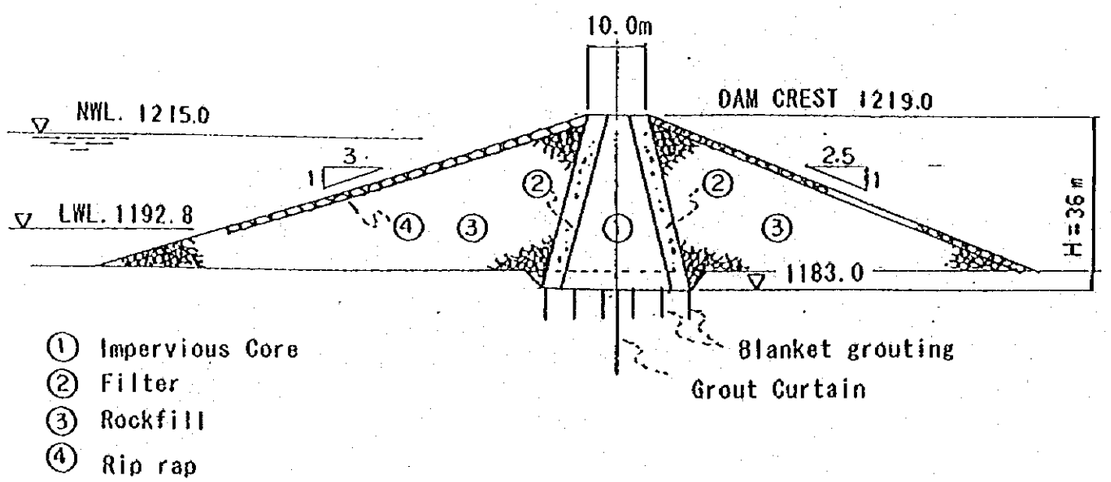
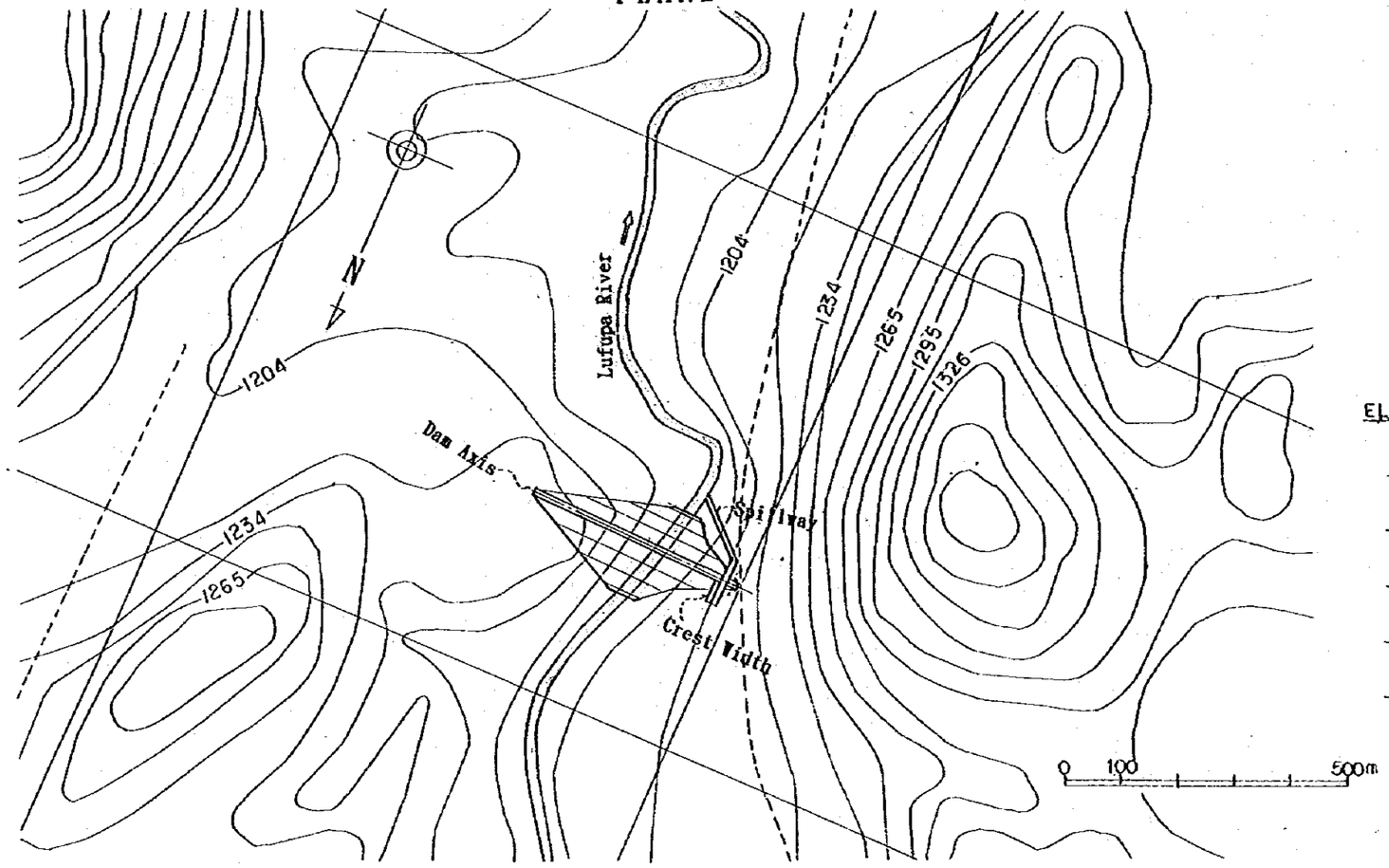


Drawing 8

MUTUNDU DAM (NO. 7)

PLANE



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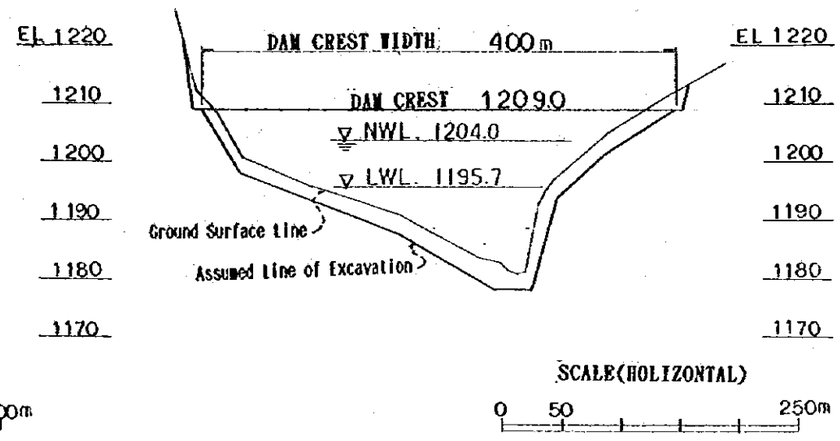

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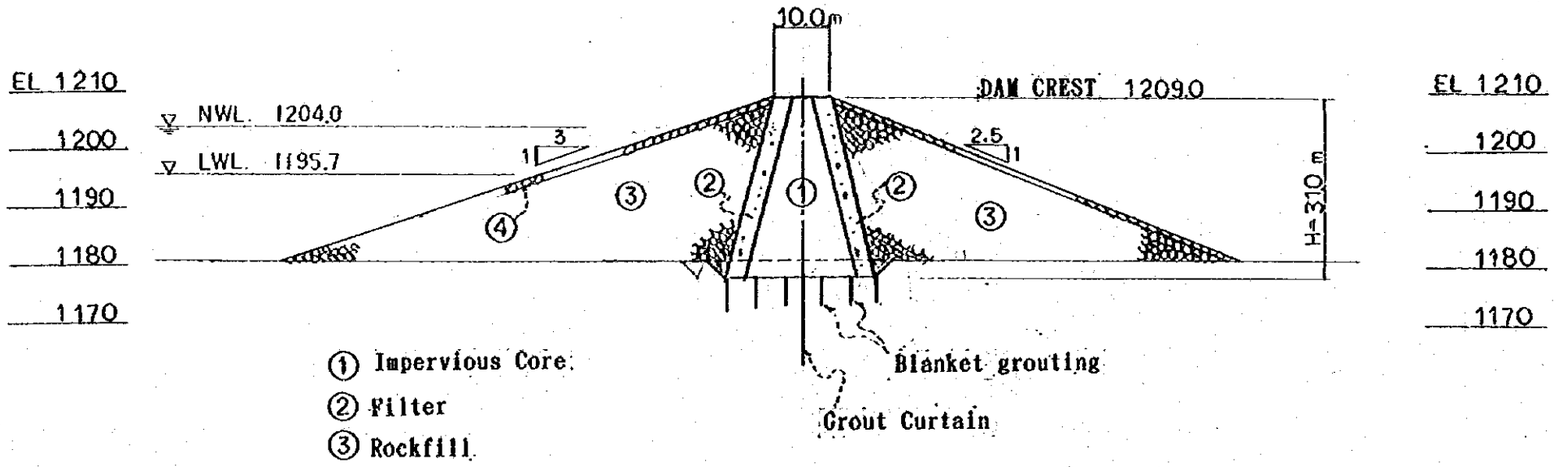
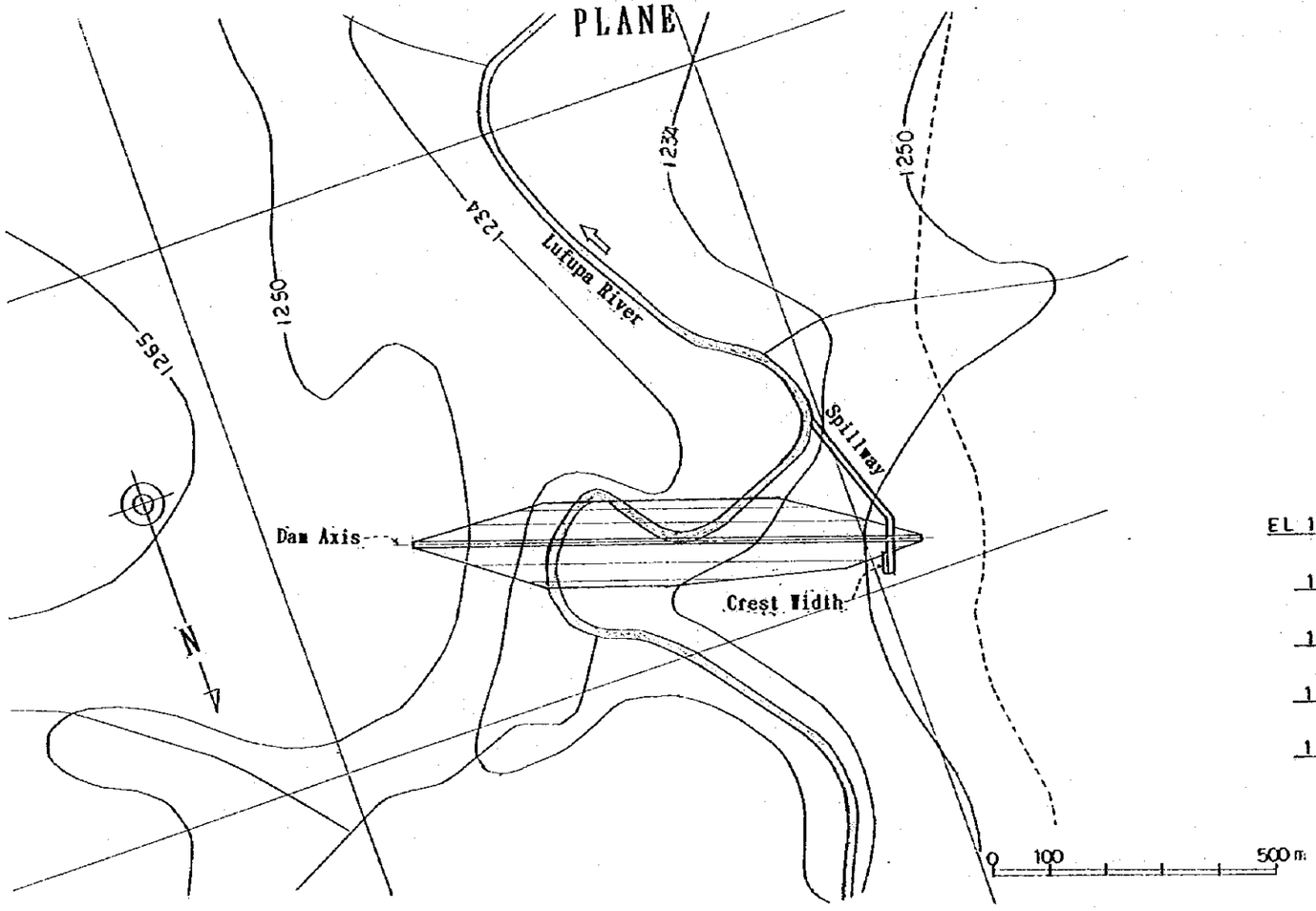


① Impervious Core
② Filter
③ Rockfill
④ Rip rap

Drawing 9

LUFUPA DAM (NO. 9-1)

PLANE



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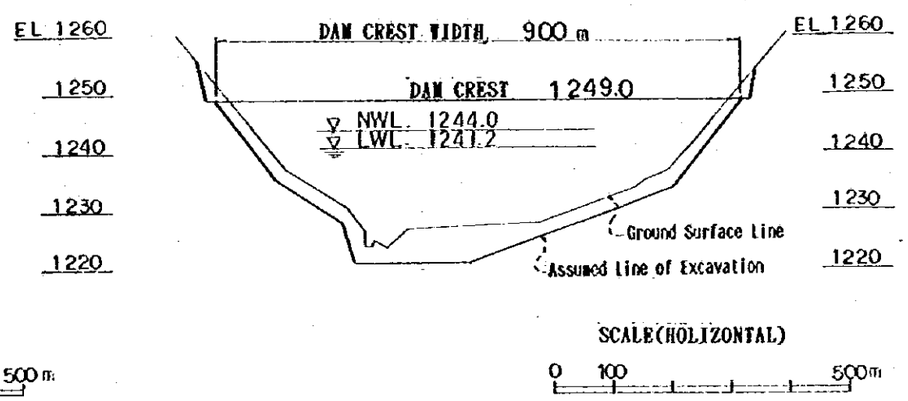

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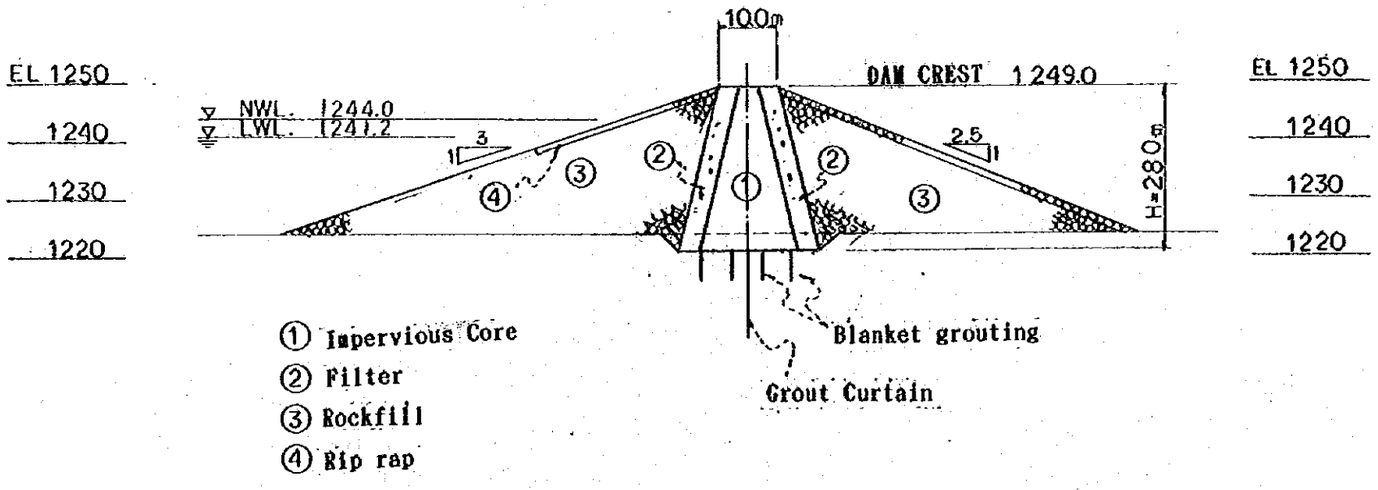
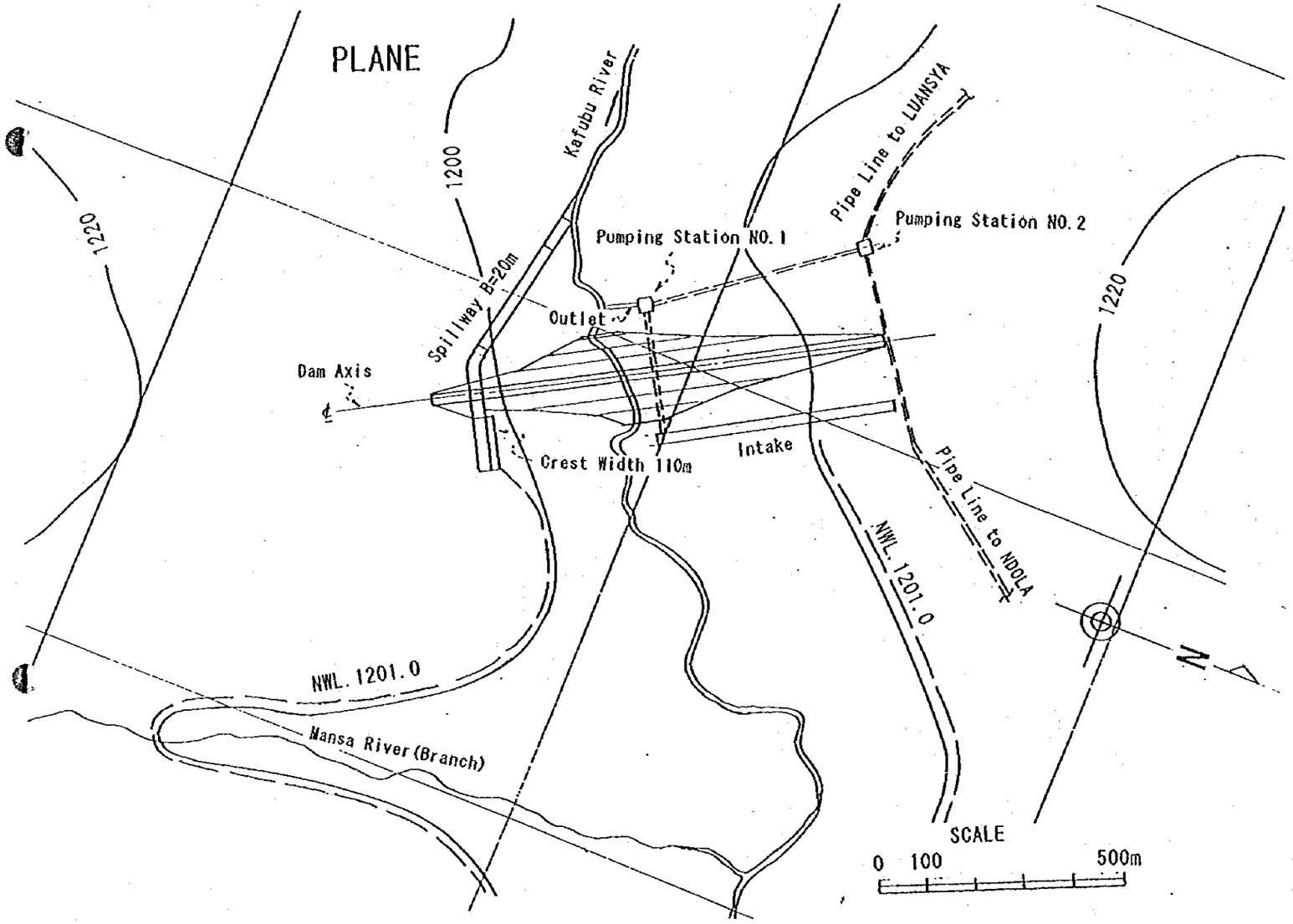


Drawing 10

LUFUPA DAM (NO. 9-2)

PLANE



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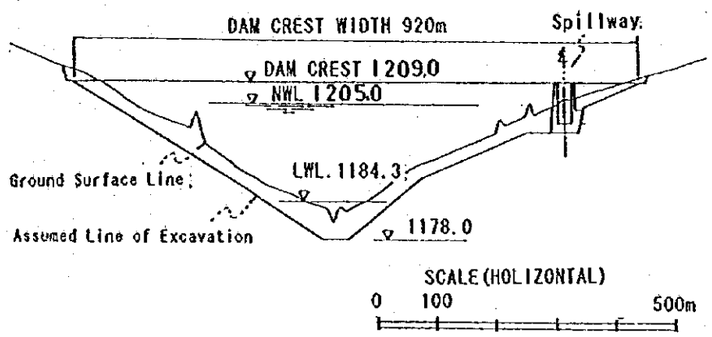

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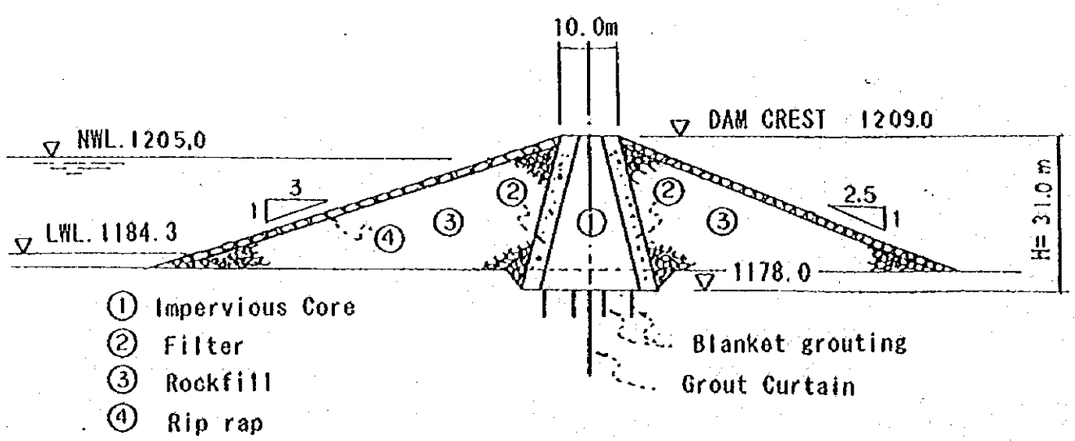
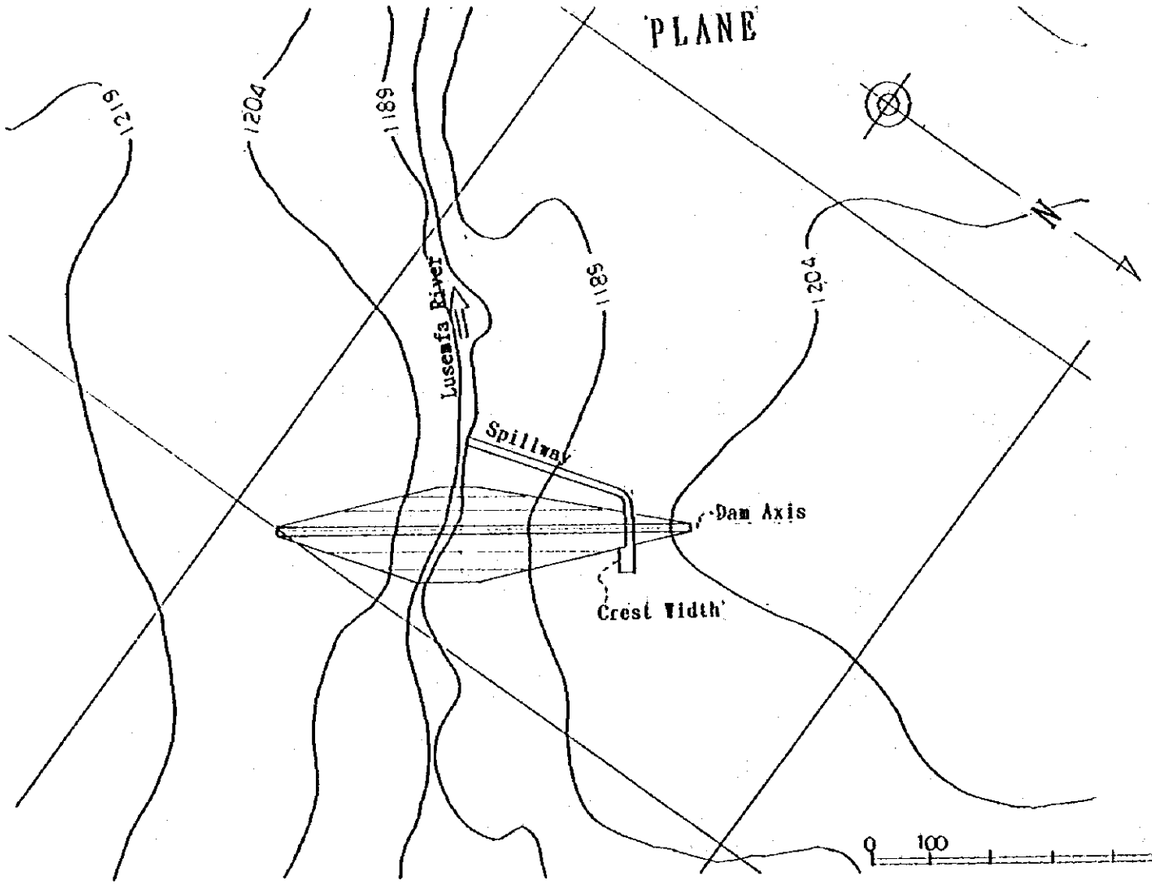


Drawing 11

KAFUBU DAM (NO. 10)

PLANE



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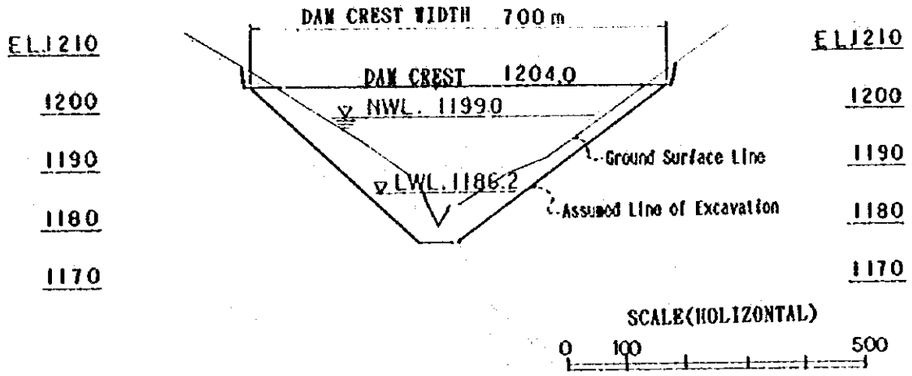

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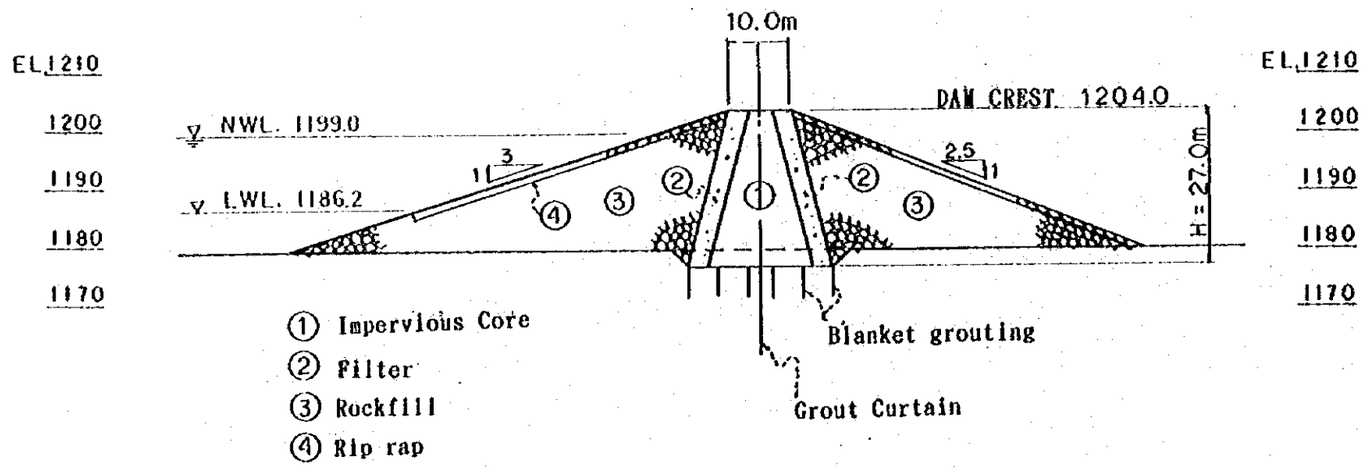
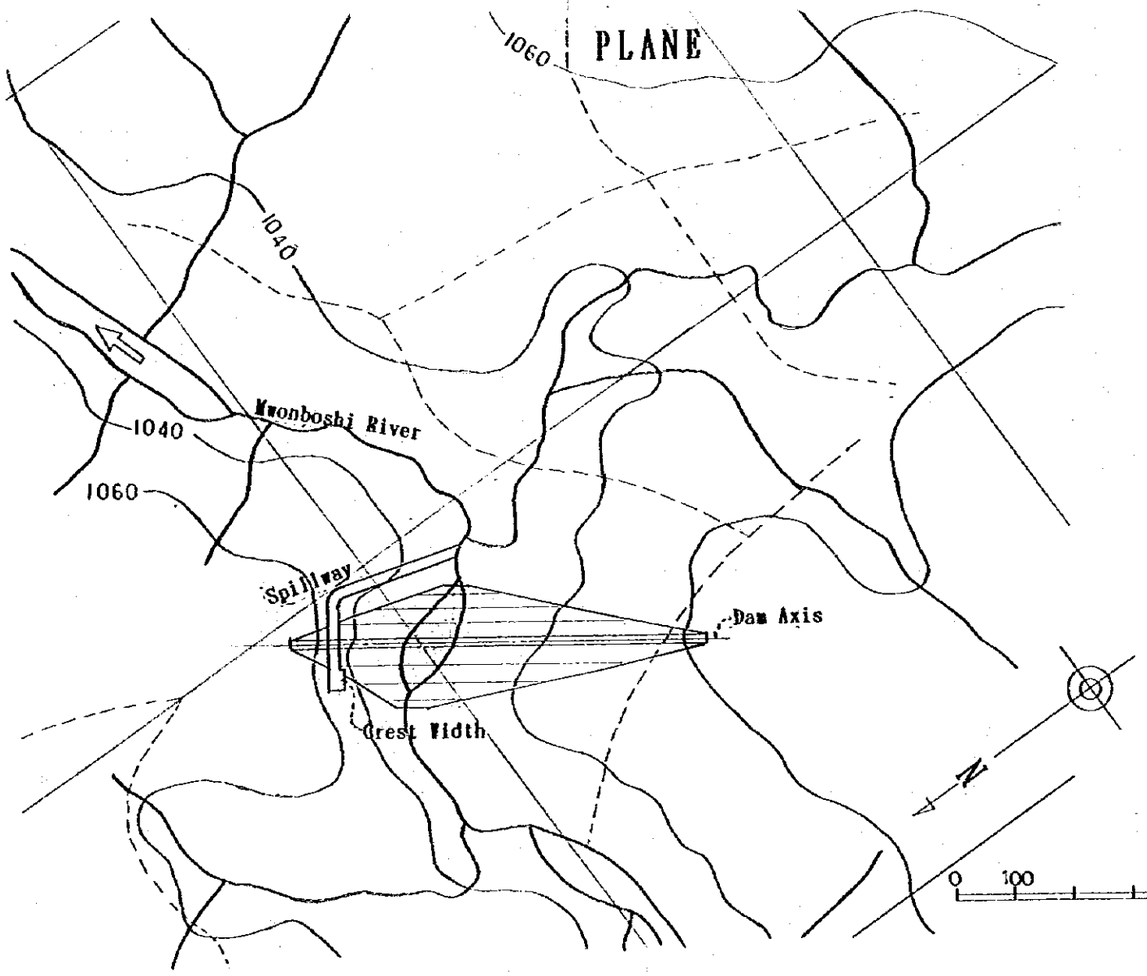


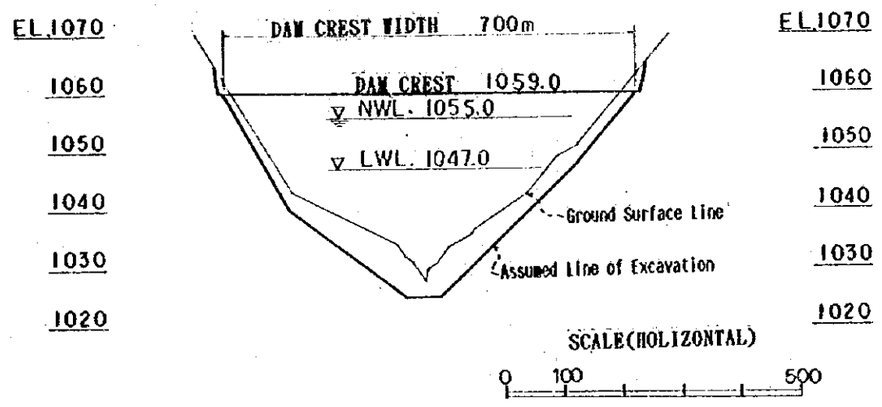
Drawing 12

LUSEMFA DAM (NO. 11)

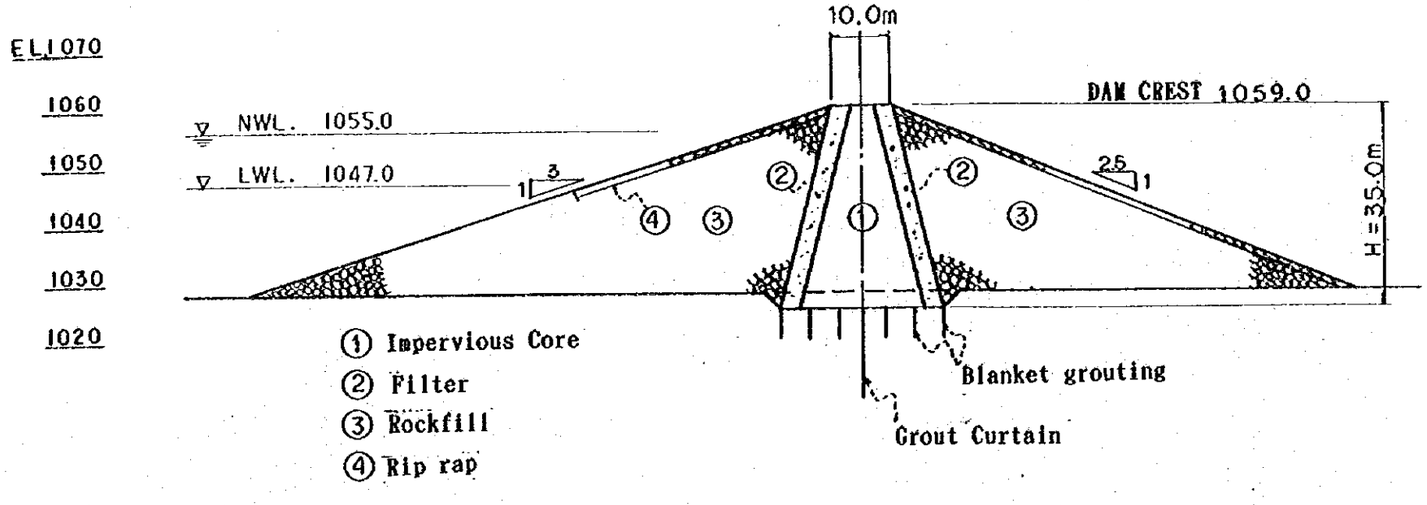
PLANE



LONGITUDINAL SECTION OF DAM AXIS



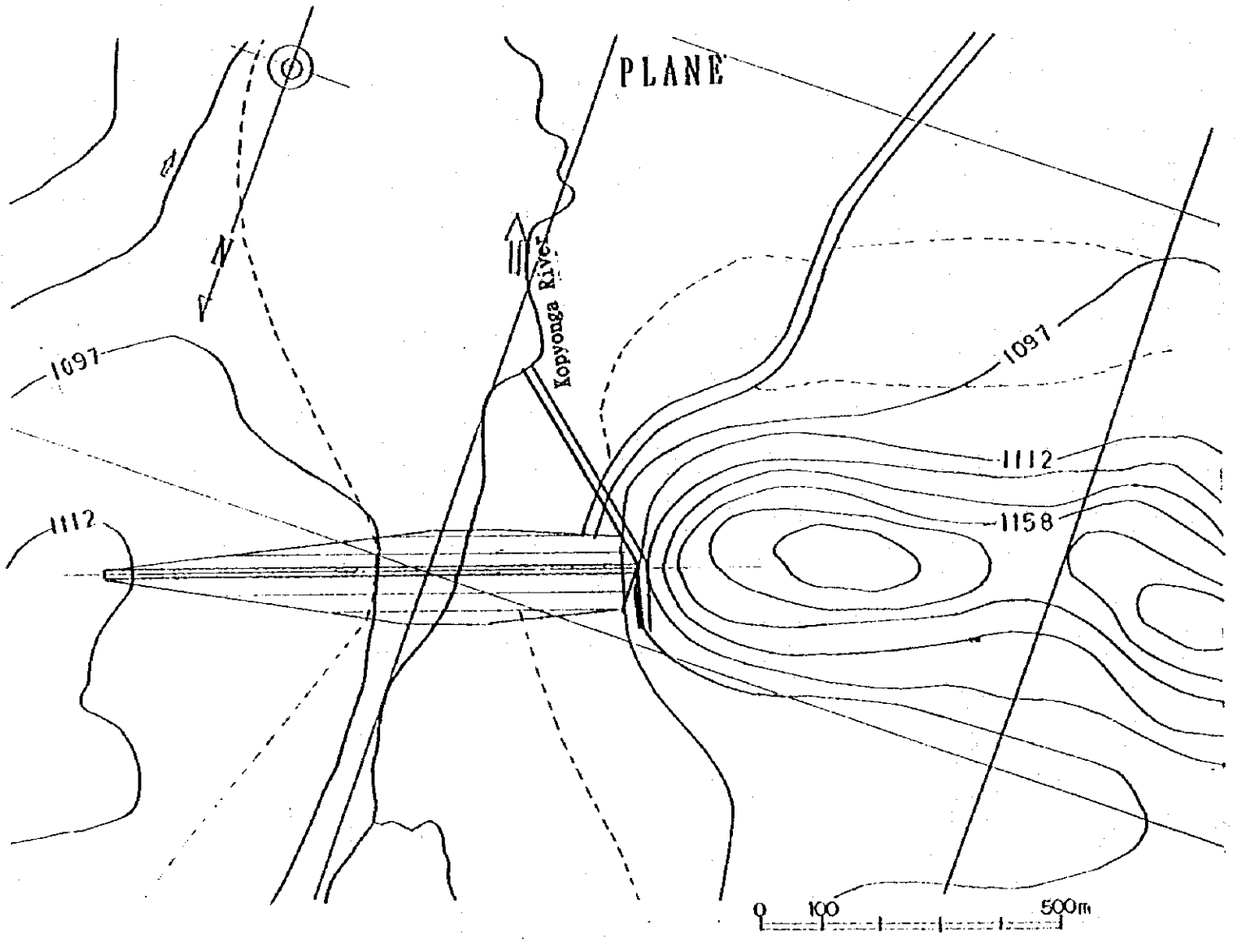
TYPICAL CROSS SECTION



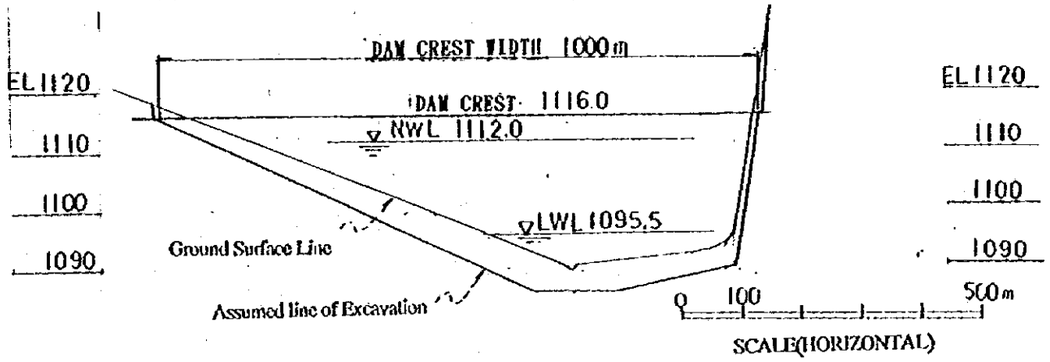
Drawing 13

MWONBOSHI DAM (NO. 12)

PLANE



LONGITUDINAL SECTION OF DAM AXIS



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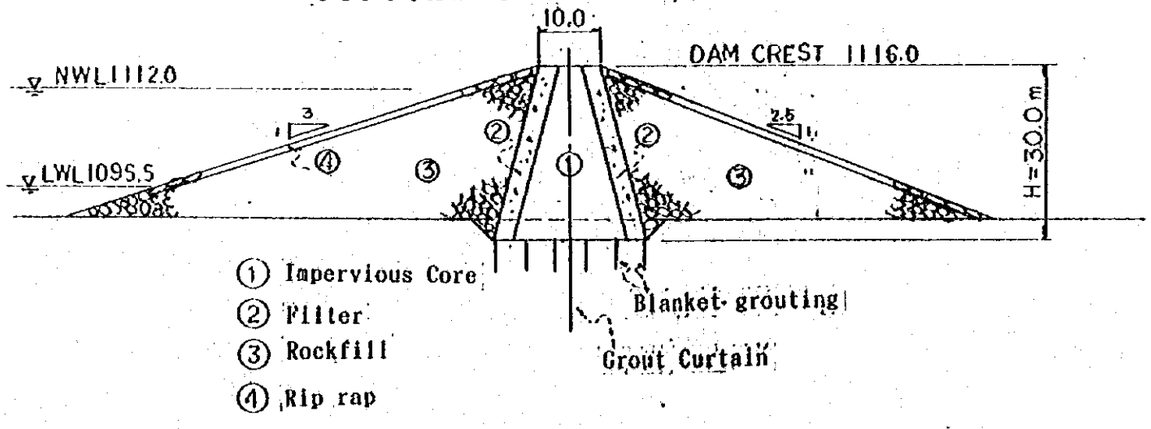
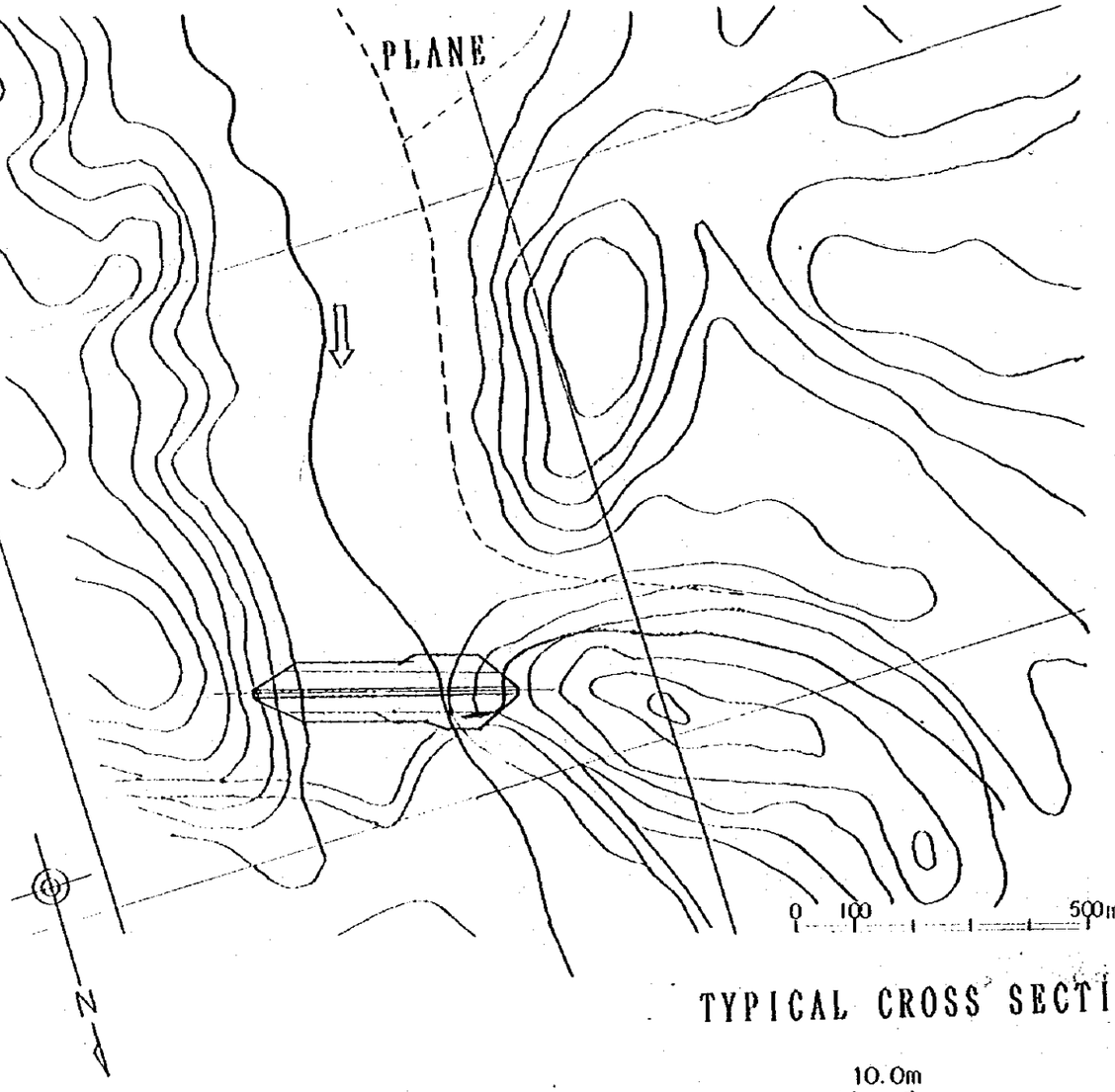
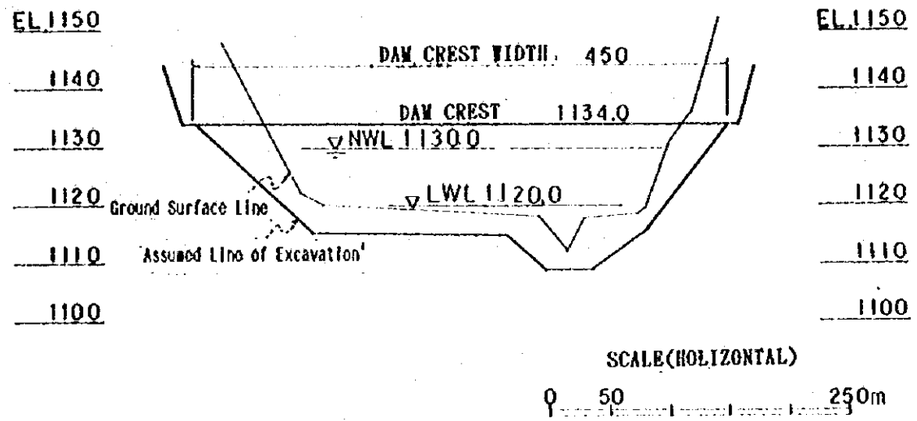


Drawing 14

KOPYONGA DAM (NO. 13)



LONGITUDINAL SECTION OF DAM AXIS



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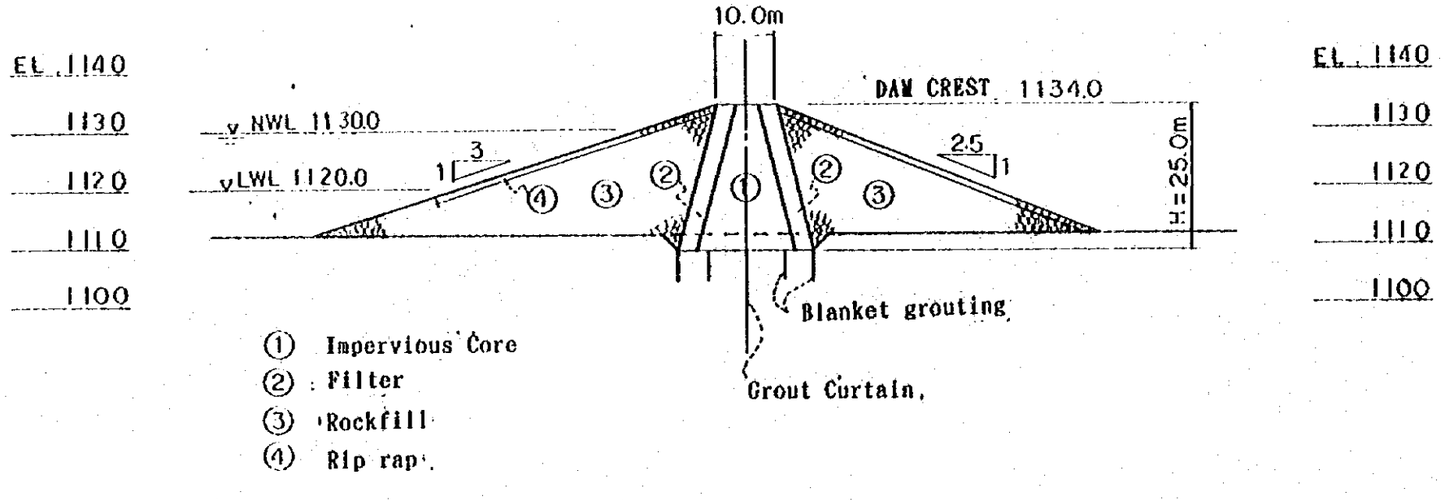
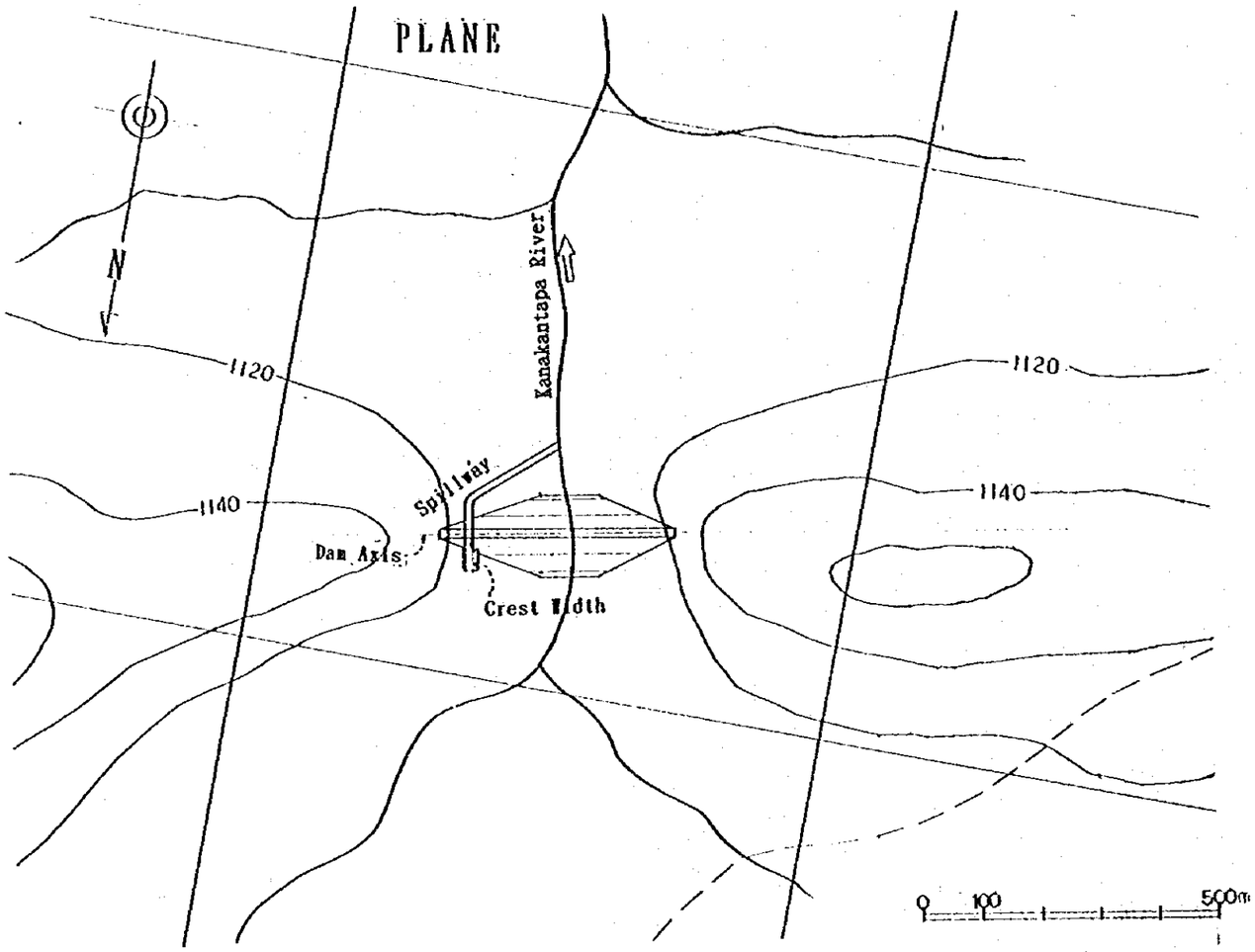


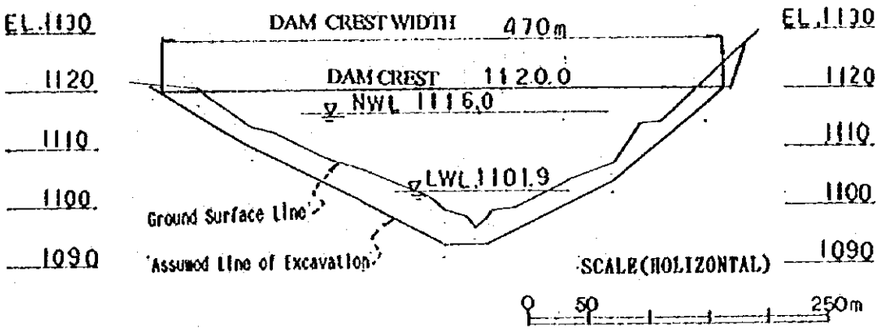
Drawing 15

MUCHITO DAM (NO. 14)

PLANE



LONGITUDINAL SECTION OF DAM AXIS



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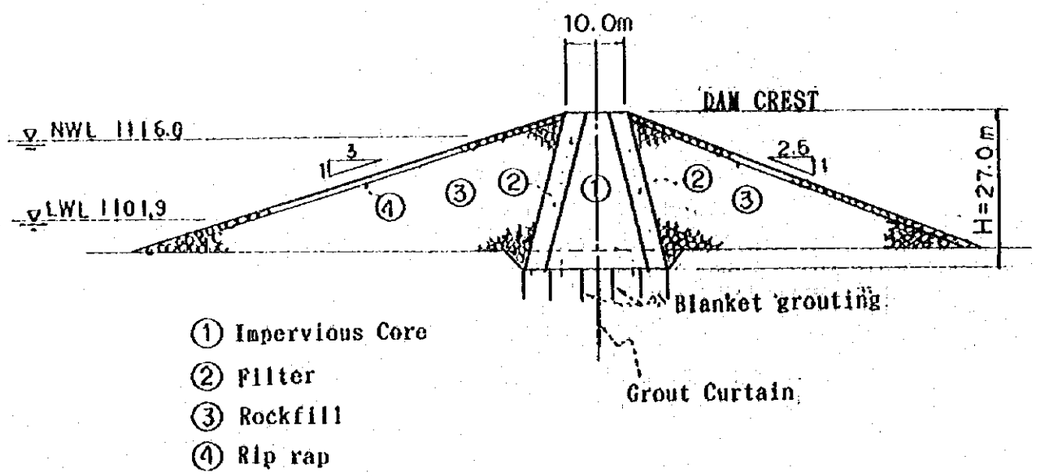
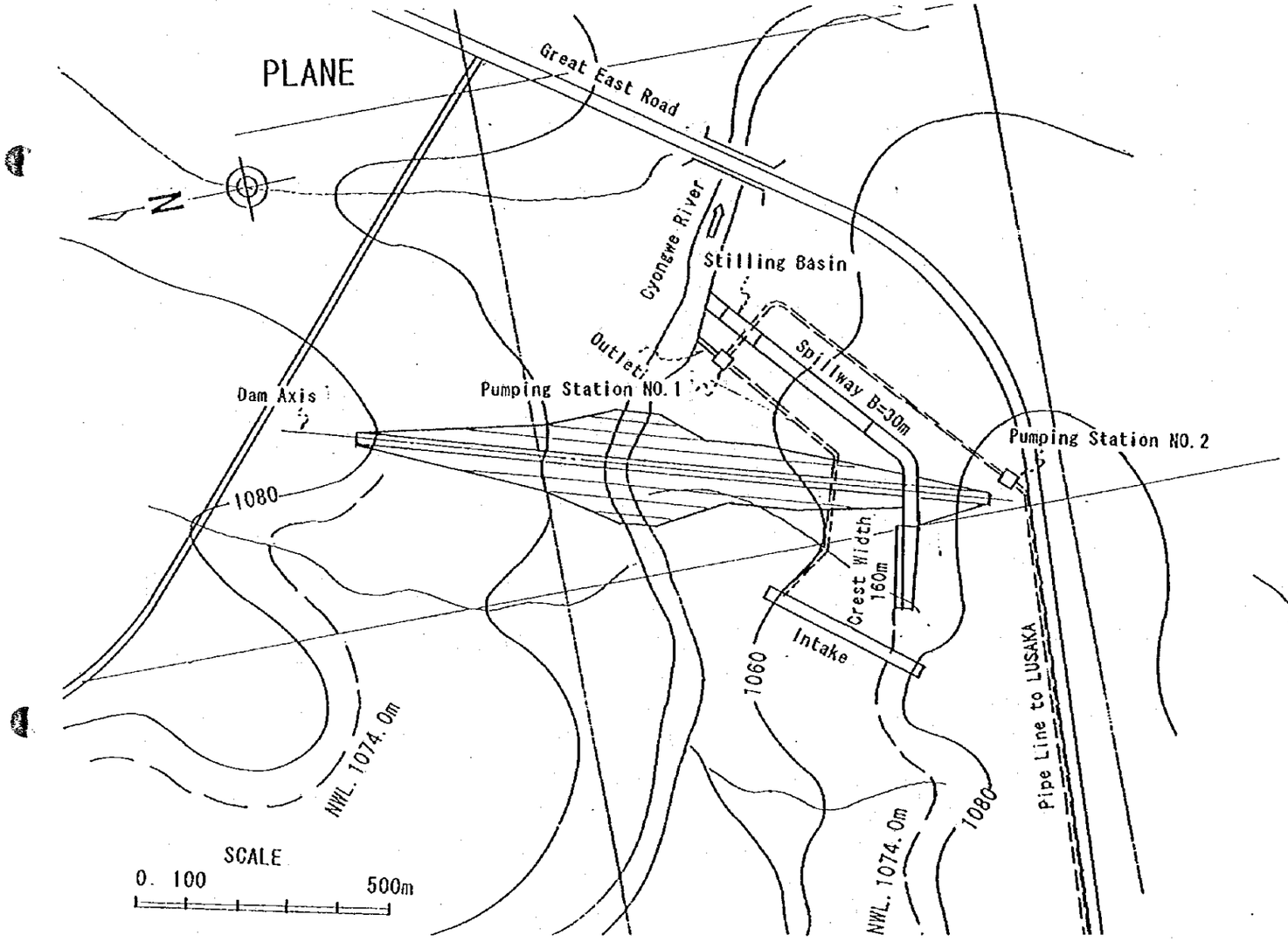


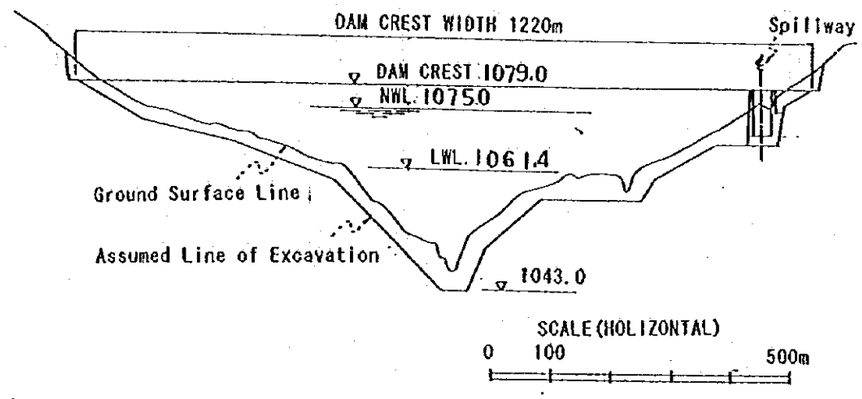
Drawing 16

KANAKANTAPA DAM (NO. 15)

PLANE



LONGITUDINAL CROSS SECTION



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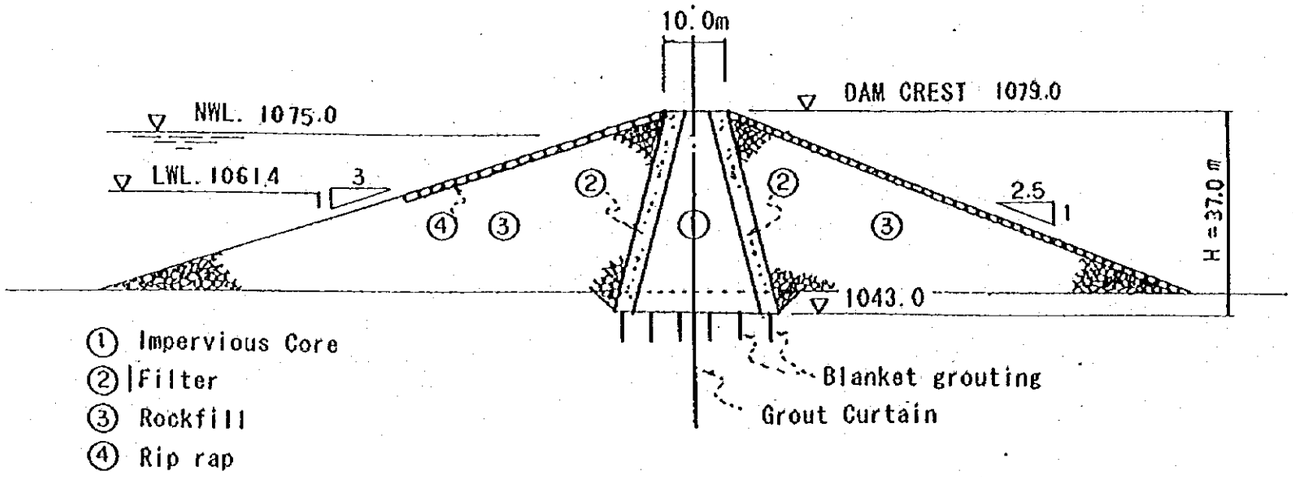
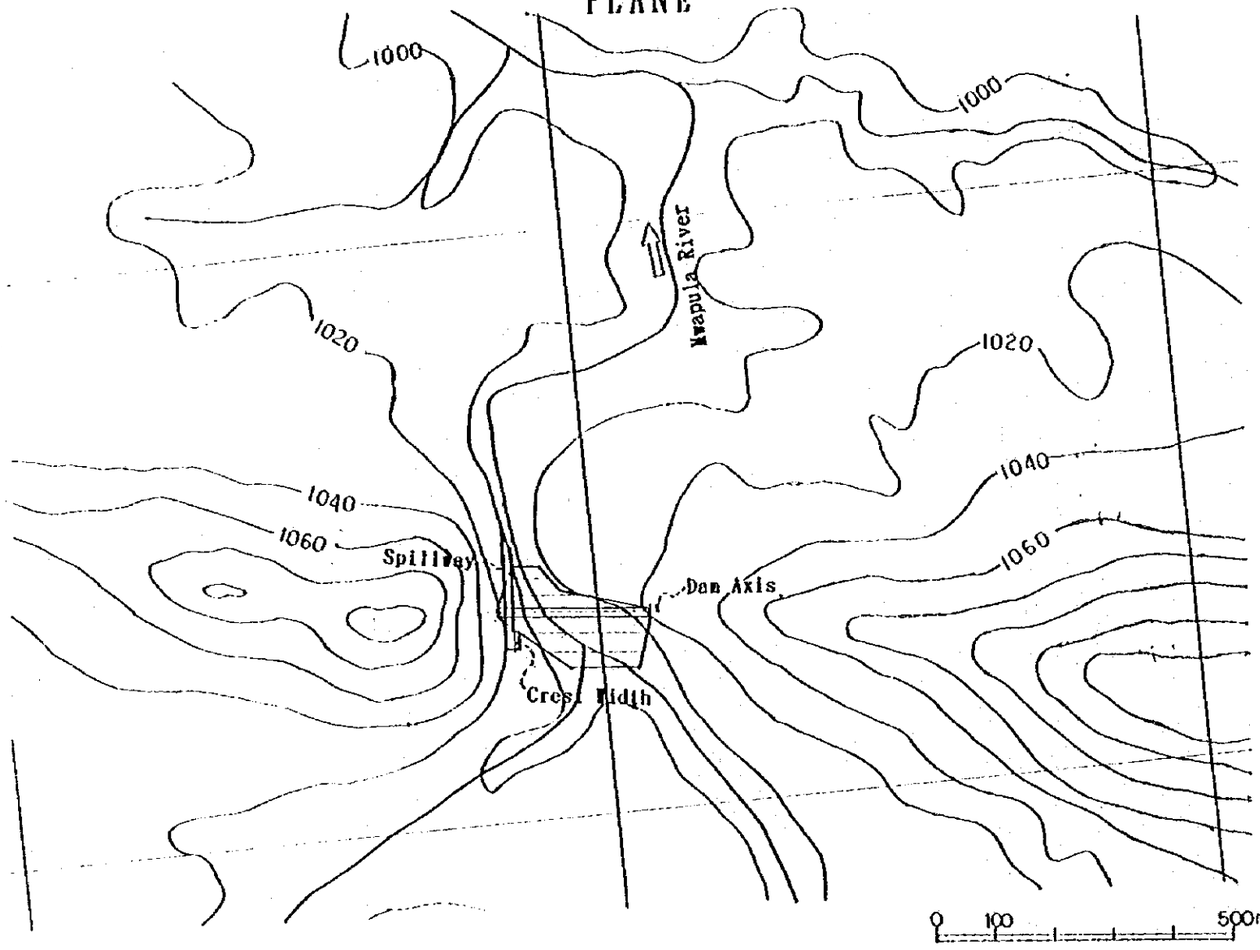


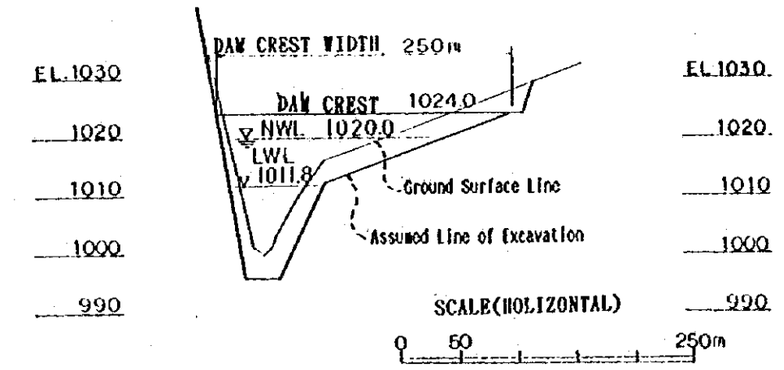
Drawing 17

CHONGWE DAM (NO. 16)

PLANE



LONGITUDINAL SECTION OF DAM AXIS



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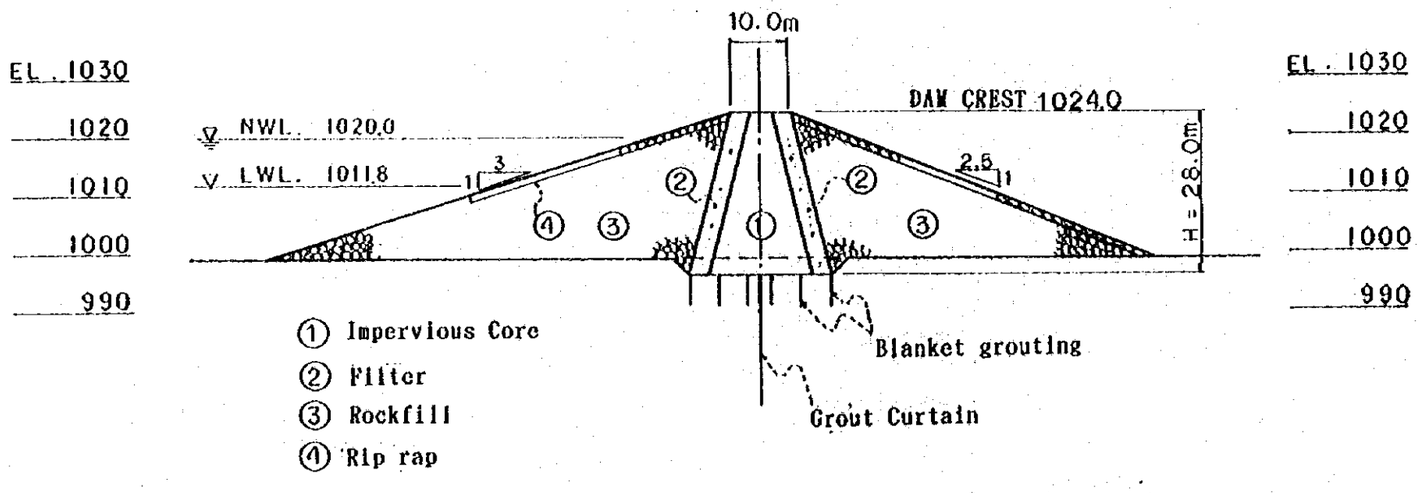
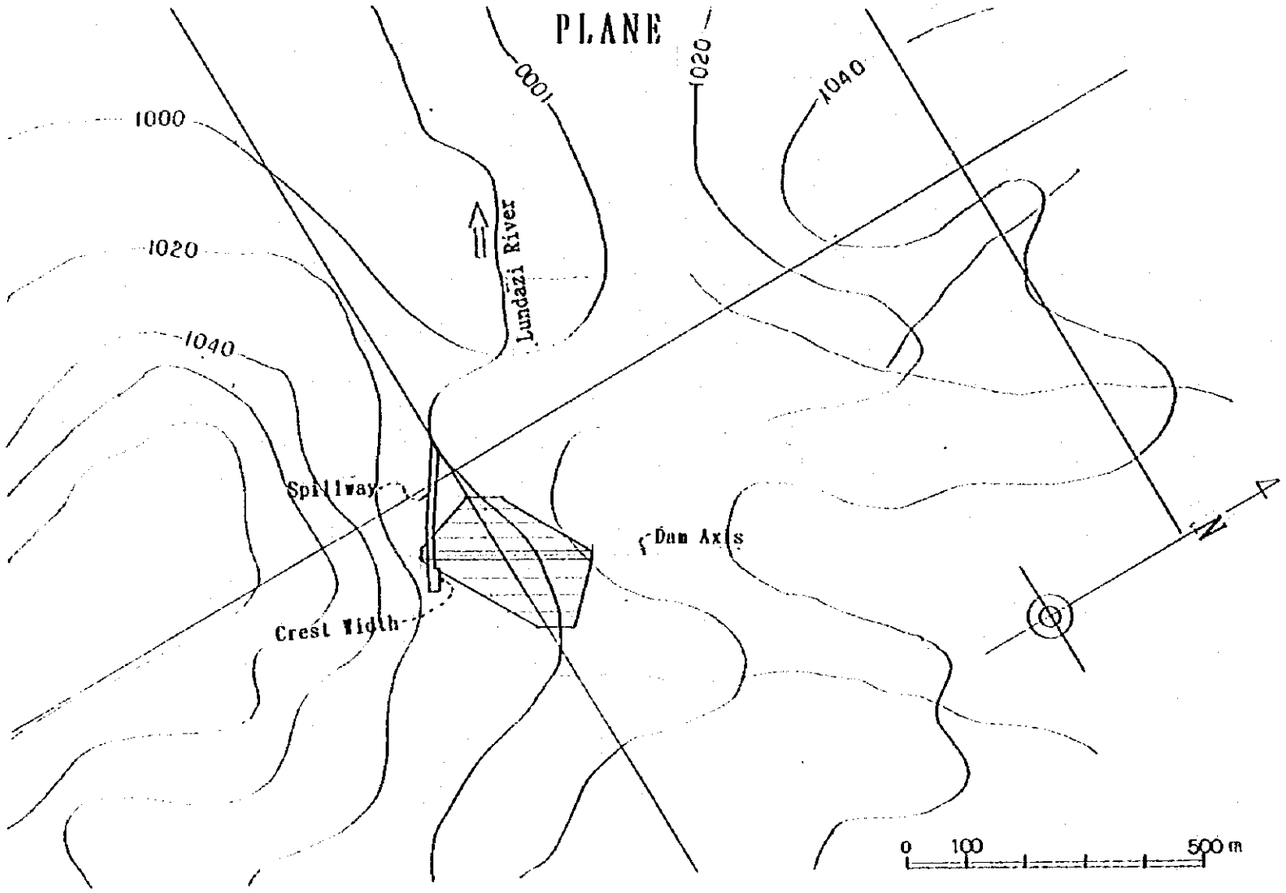


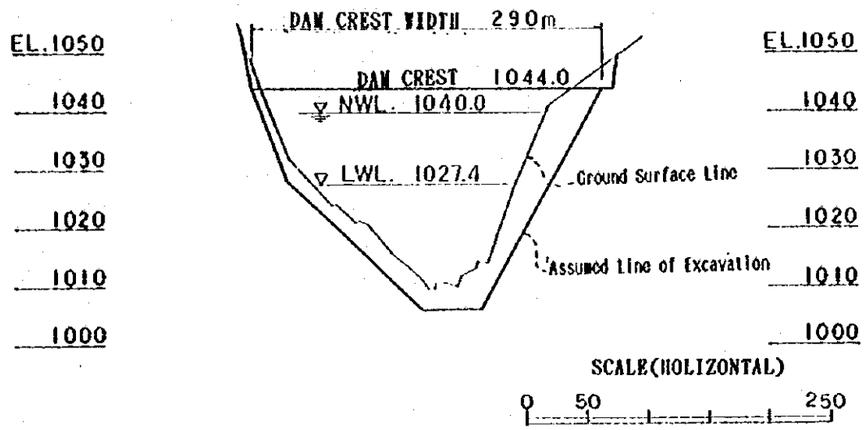
Drawing 18

MWAPULA DAM (NO. 17)

PLANE



LONGITUDINAL SECTION OF DAM AXIS



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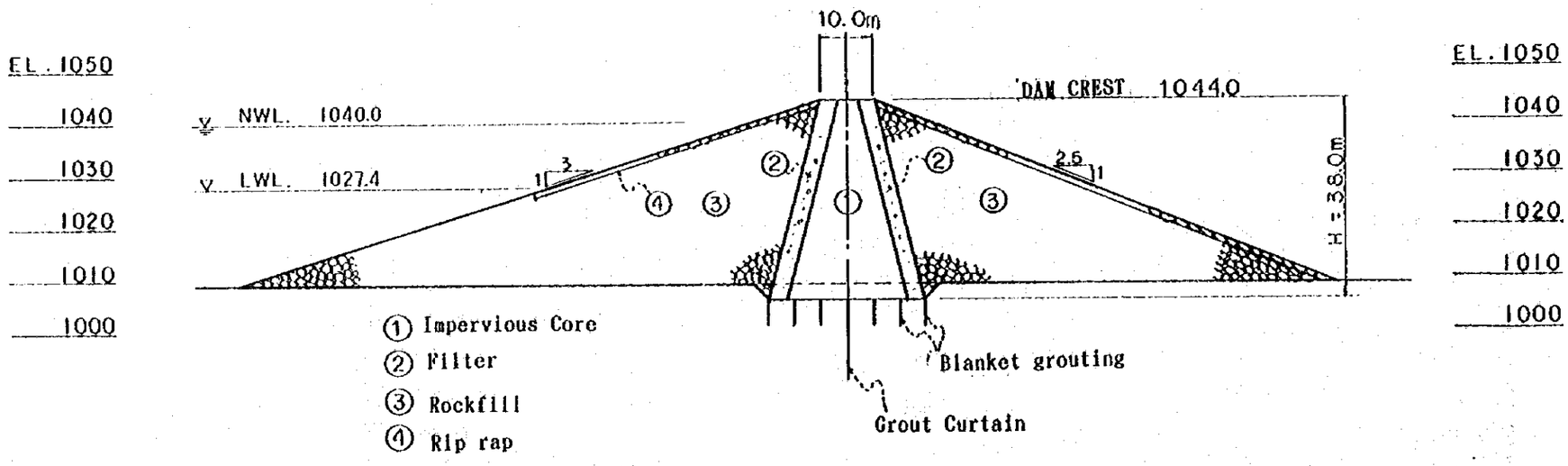
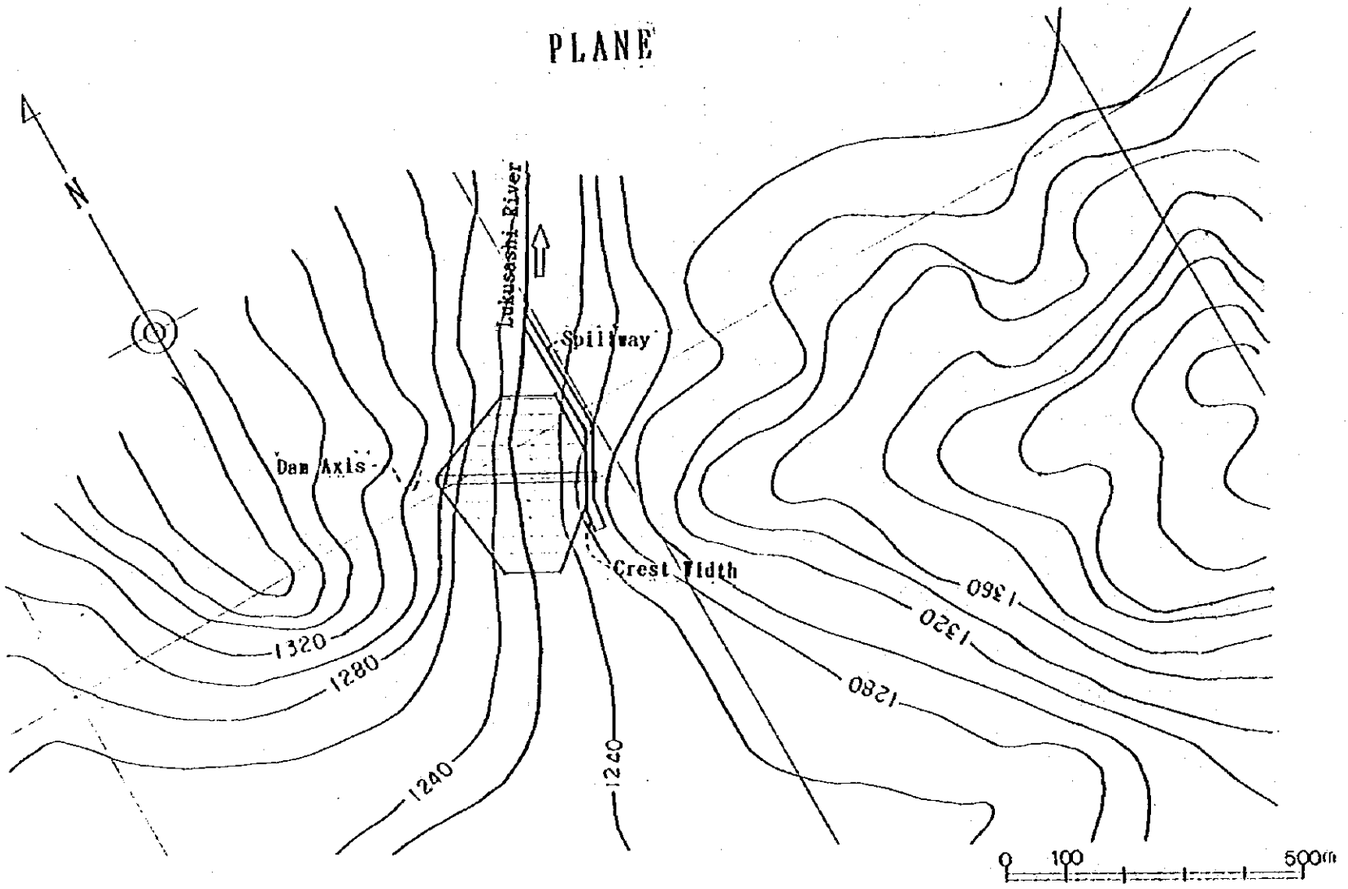


Drawing 19

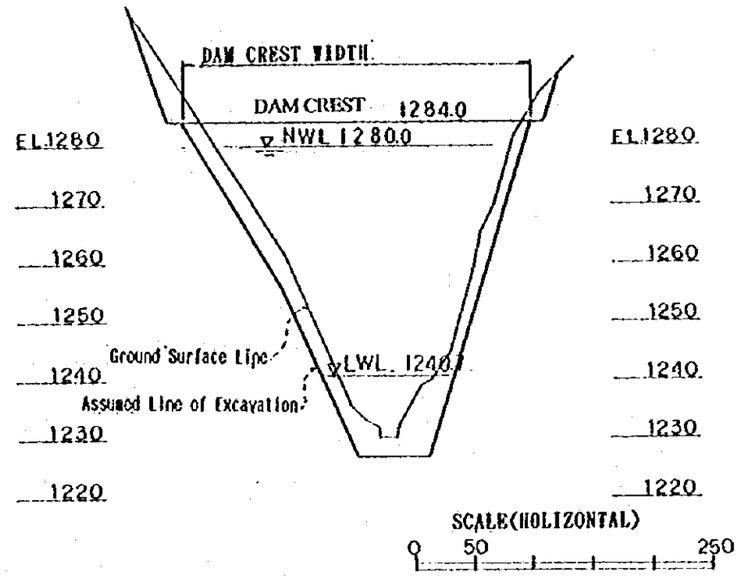
LUNDAZI DAM (NO. 18).

LUKUSASHI DAM (NO. 19)

PLANE



LONGITUDINAL SECTION OF DAM AXIS



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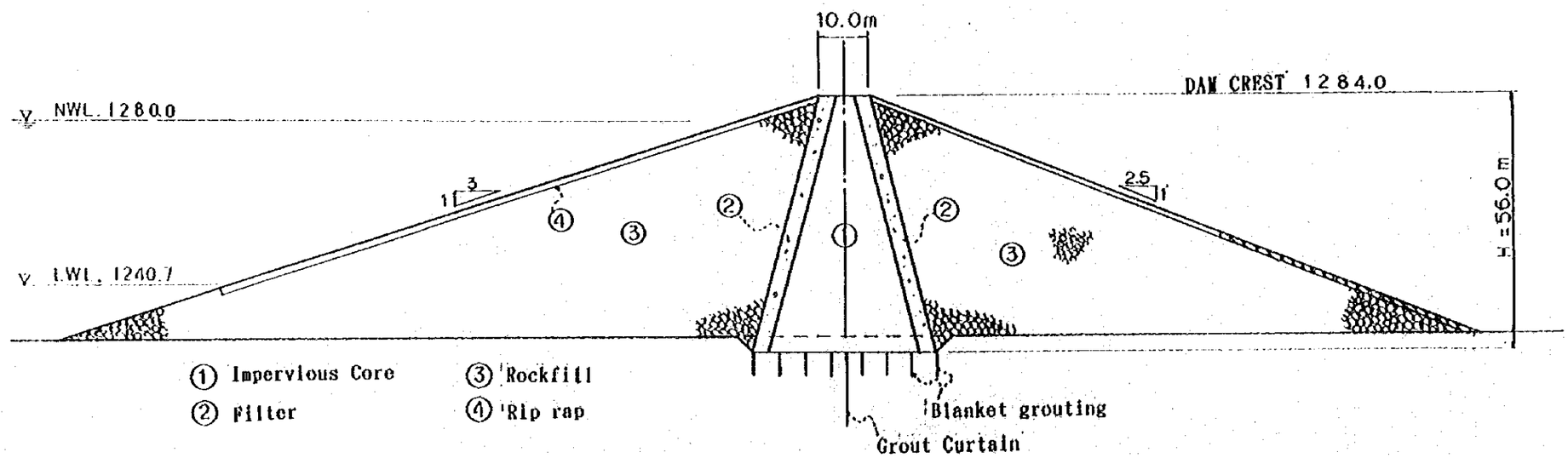
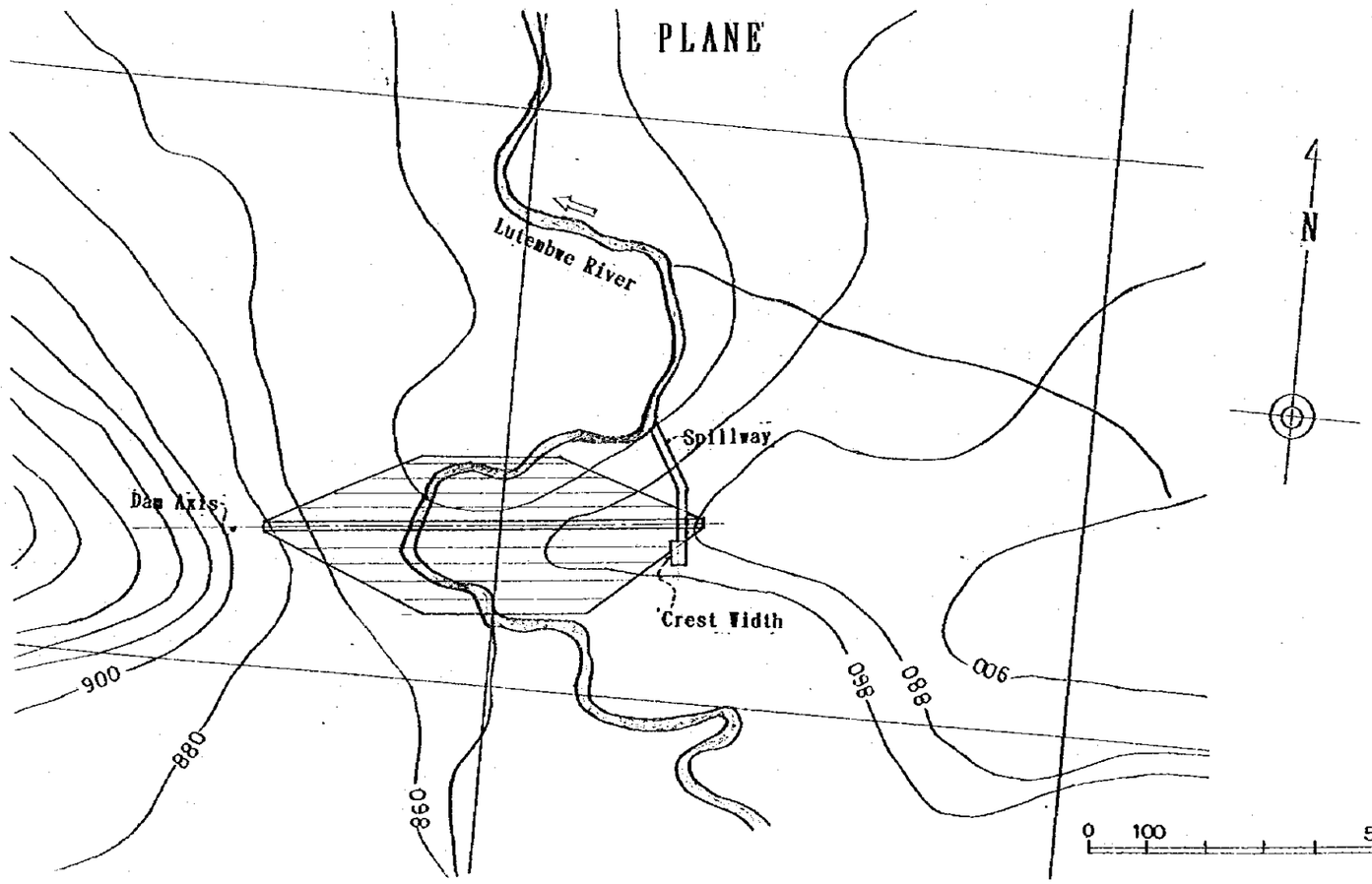
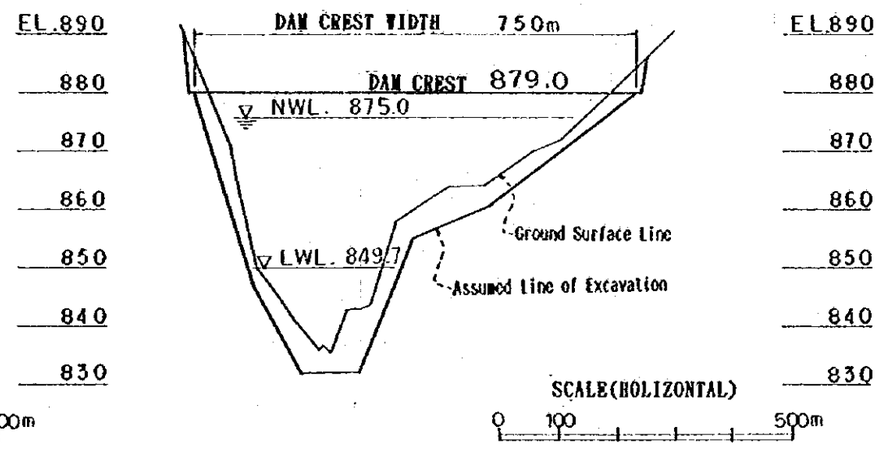


Drawing 20

PLANE



LONGITUDINAL SECTION OF DAM AXIS



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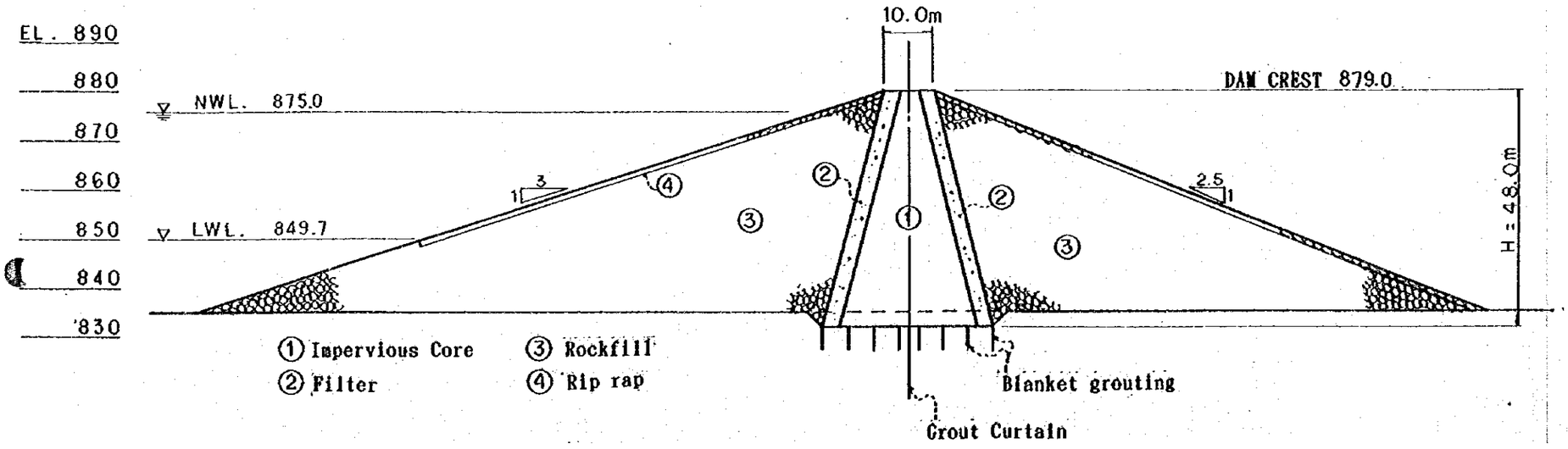
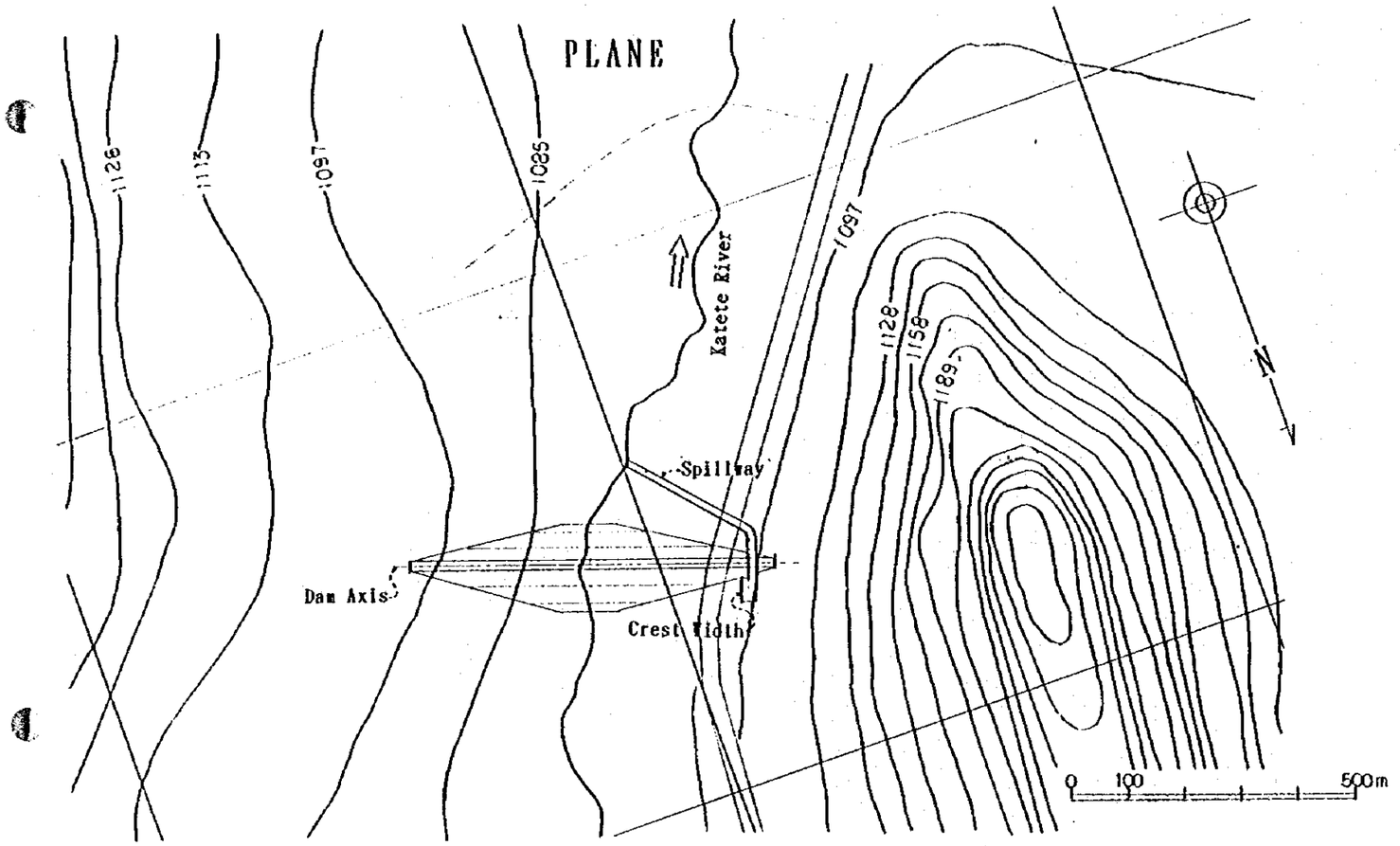


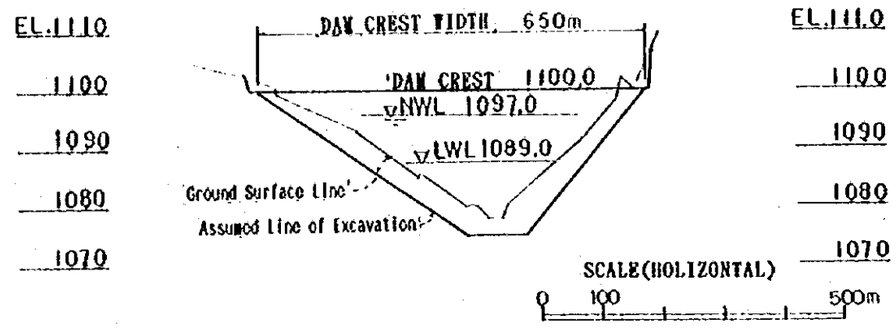
Drawing 21

LUTEMBWE DAM (NO. 20)

PLANE



LONGITUDINAL SECTION OF DAM AXIS



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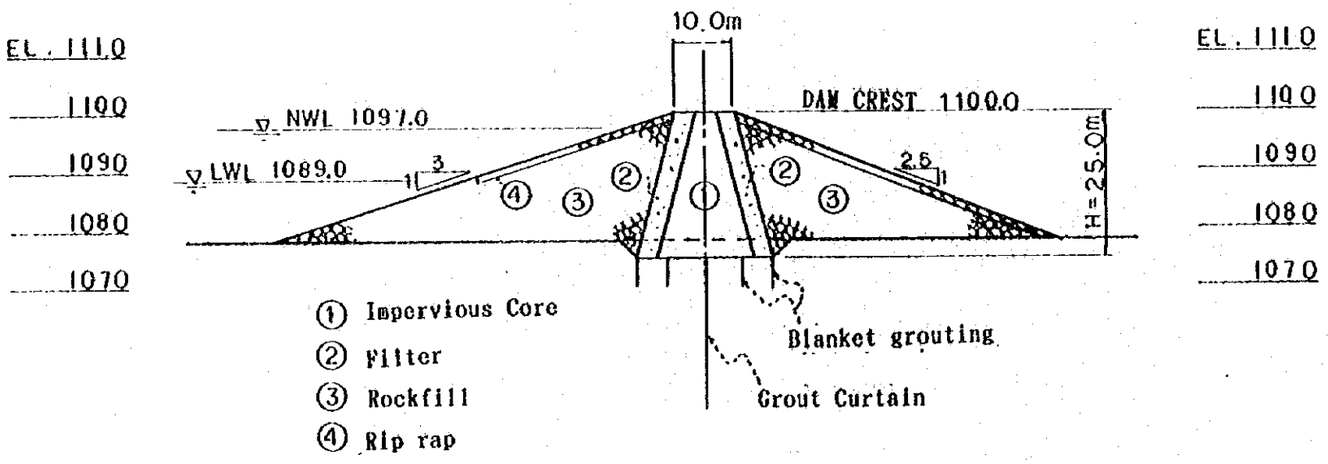
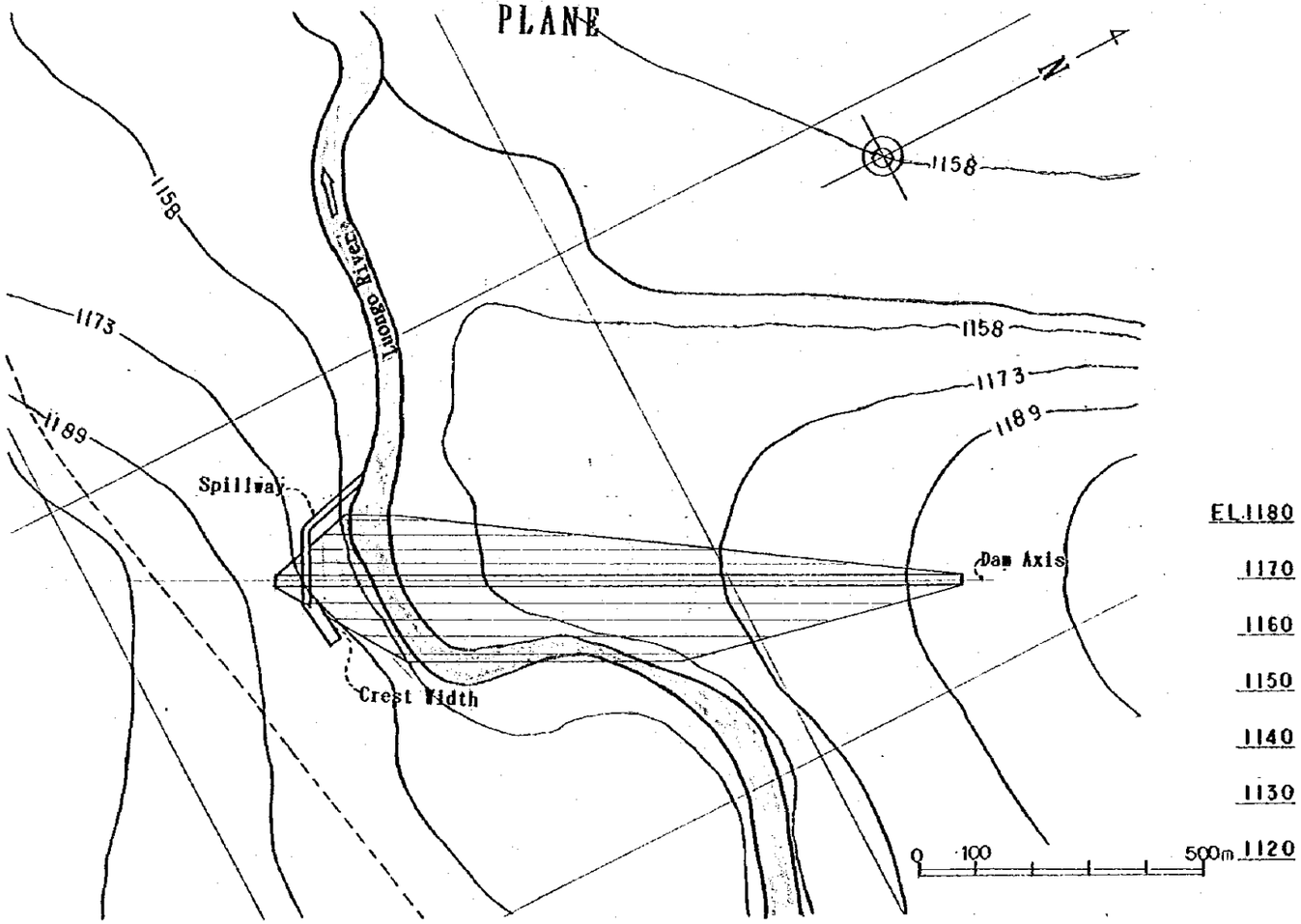


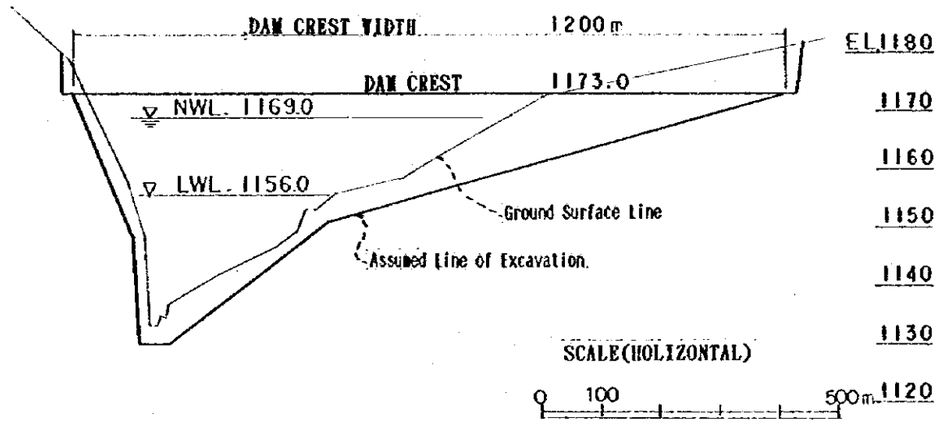
Drawing 22

KATETE DAM (NO. 21)

PLANE



LONGITUDINAL SECTION OF DAM AXIS



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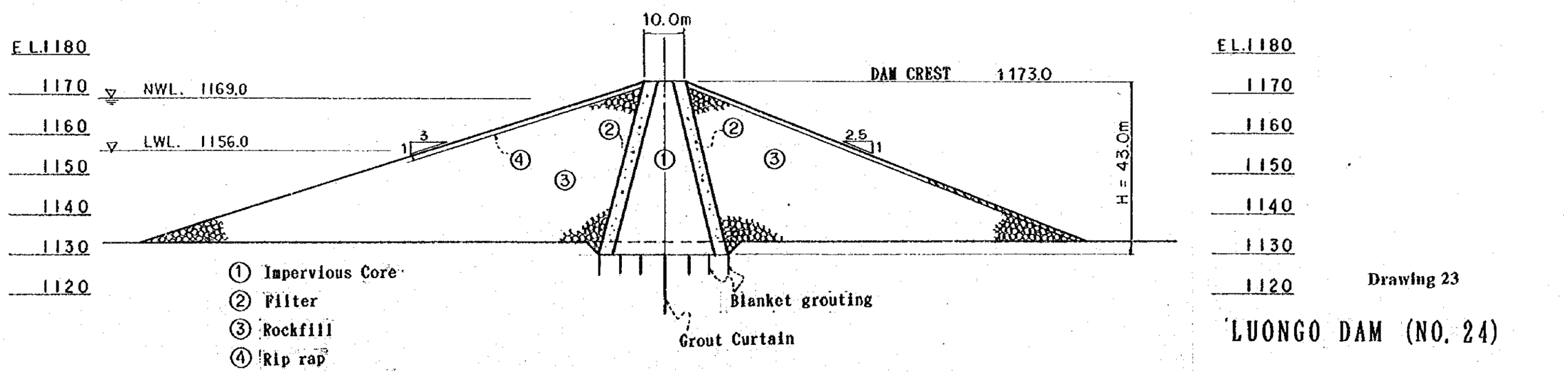
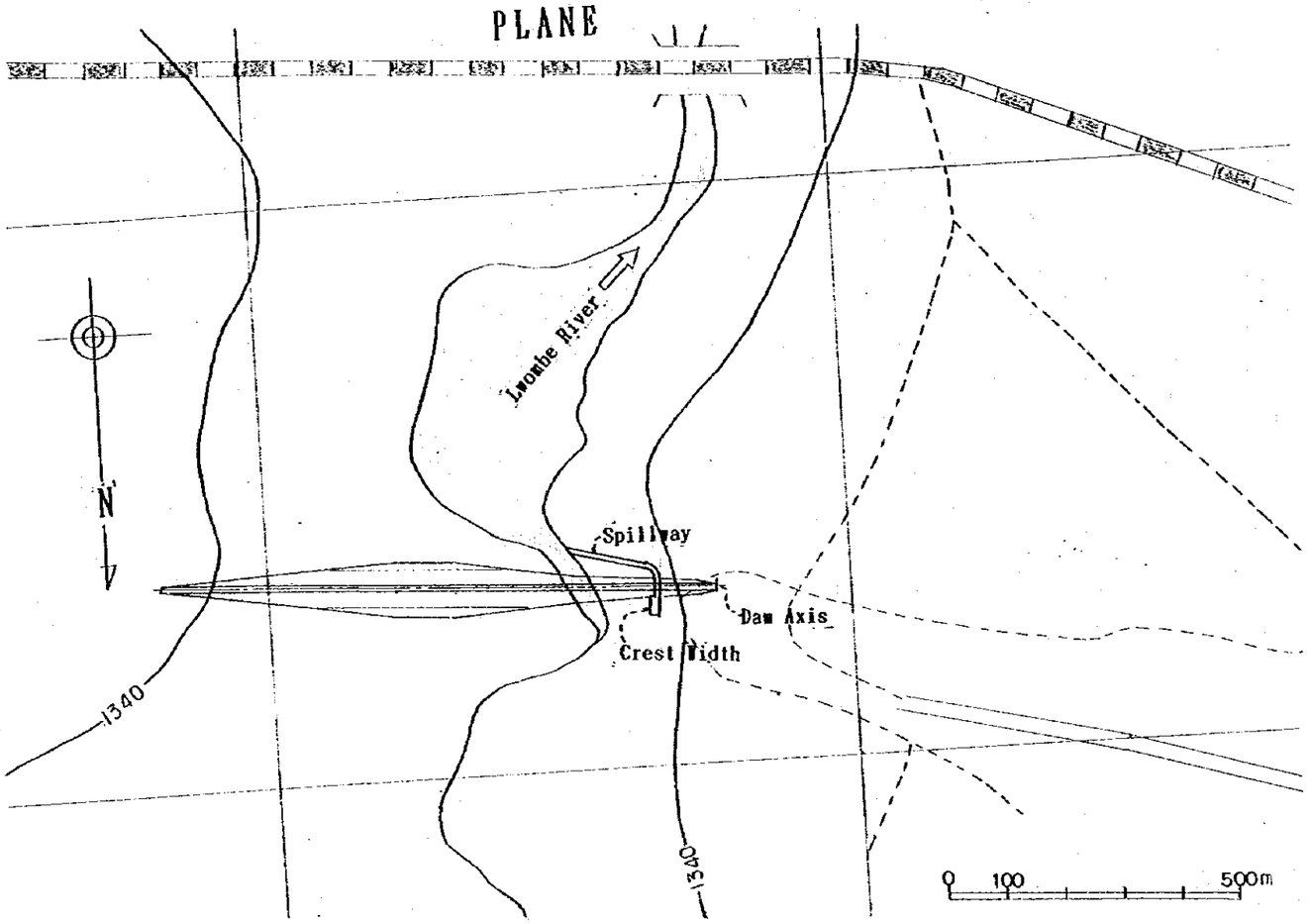


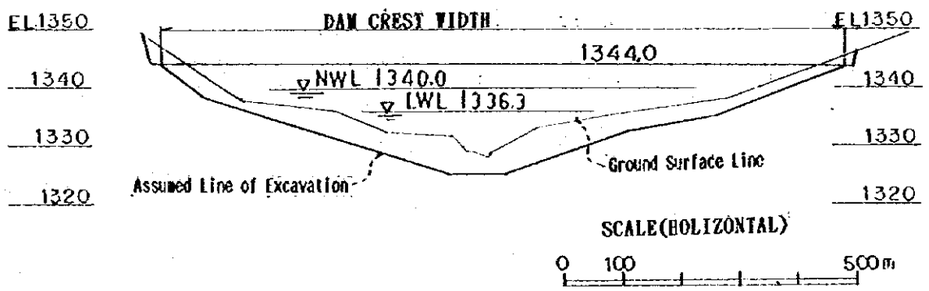
Drawing 23

LUONGO DAM (NO. 24)

PLANE



LONGITUDINAL SECTION OF DAM AXIS



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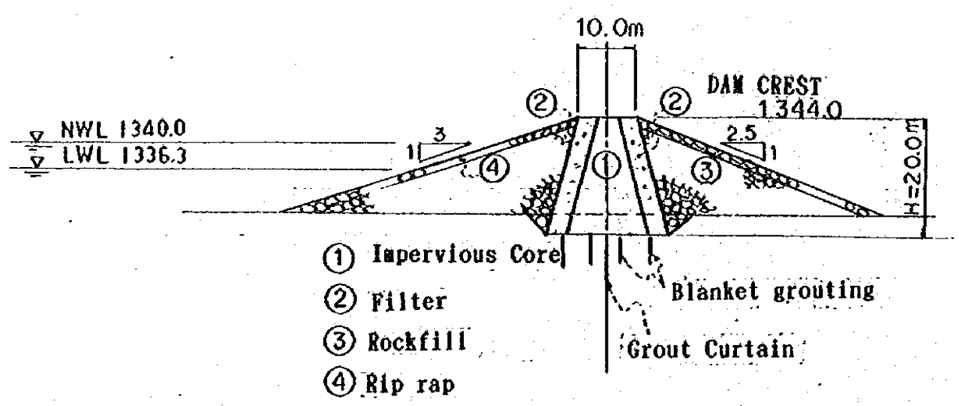
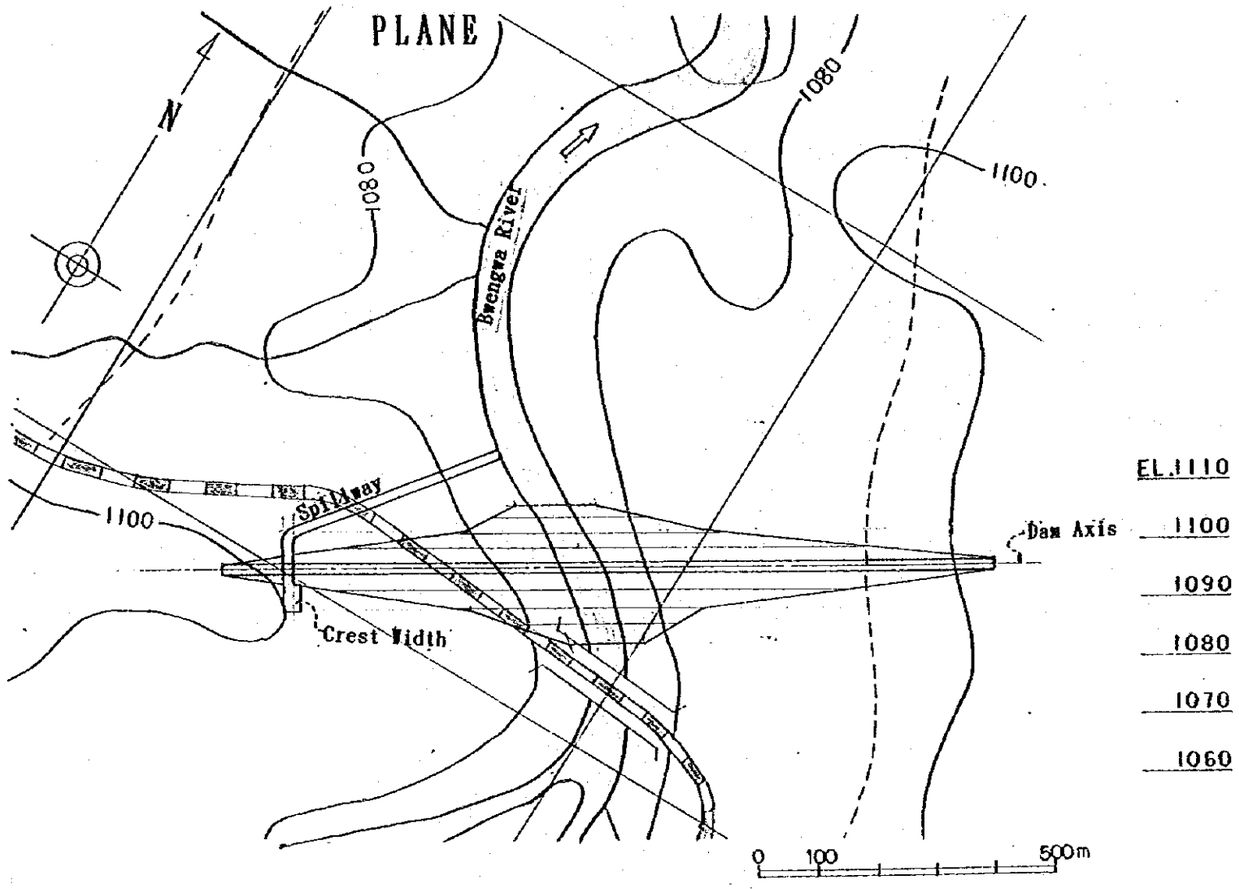


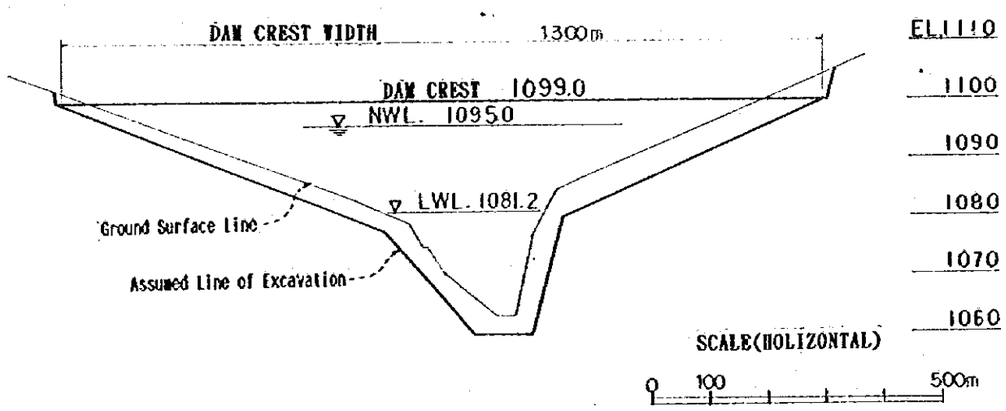
Drawing 24

LWOMBE DAM (NO. 25)

PLANE



LONGITUDINAL SECTION OF DAM AXIS



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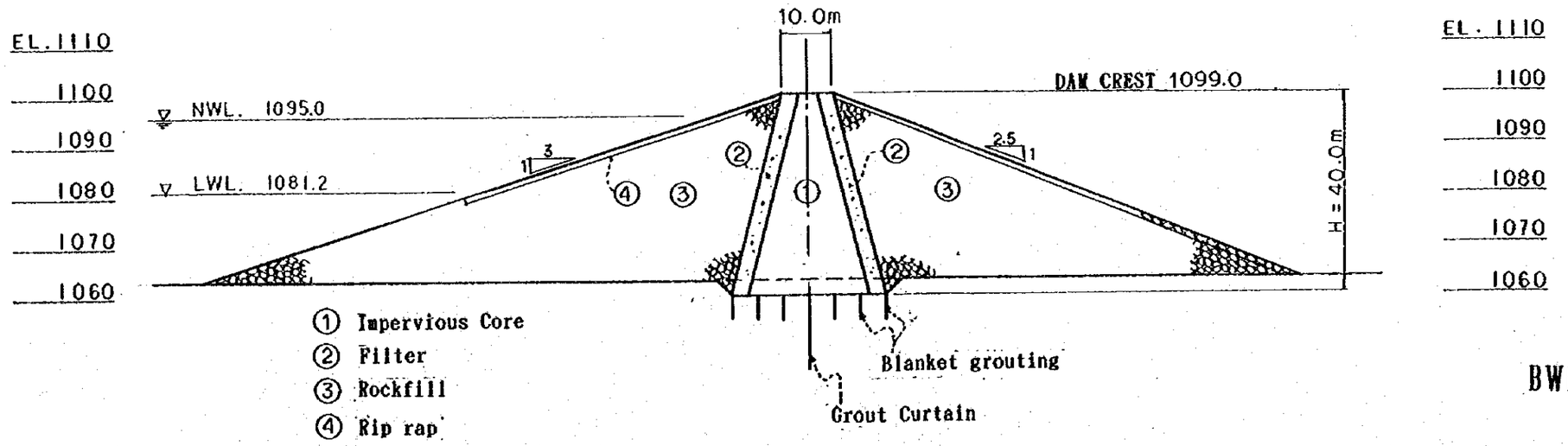
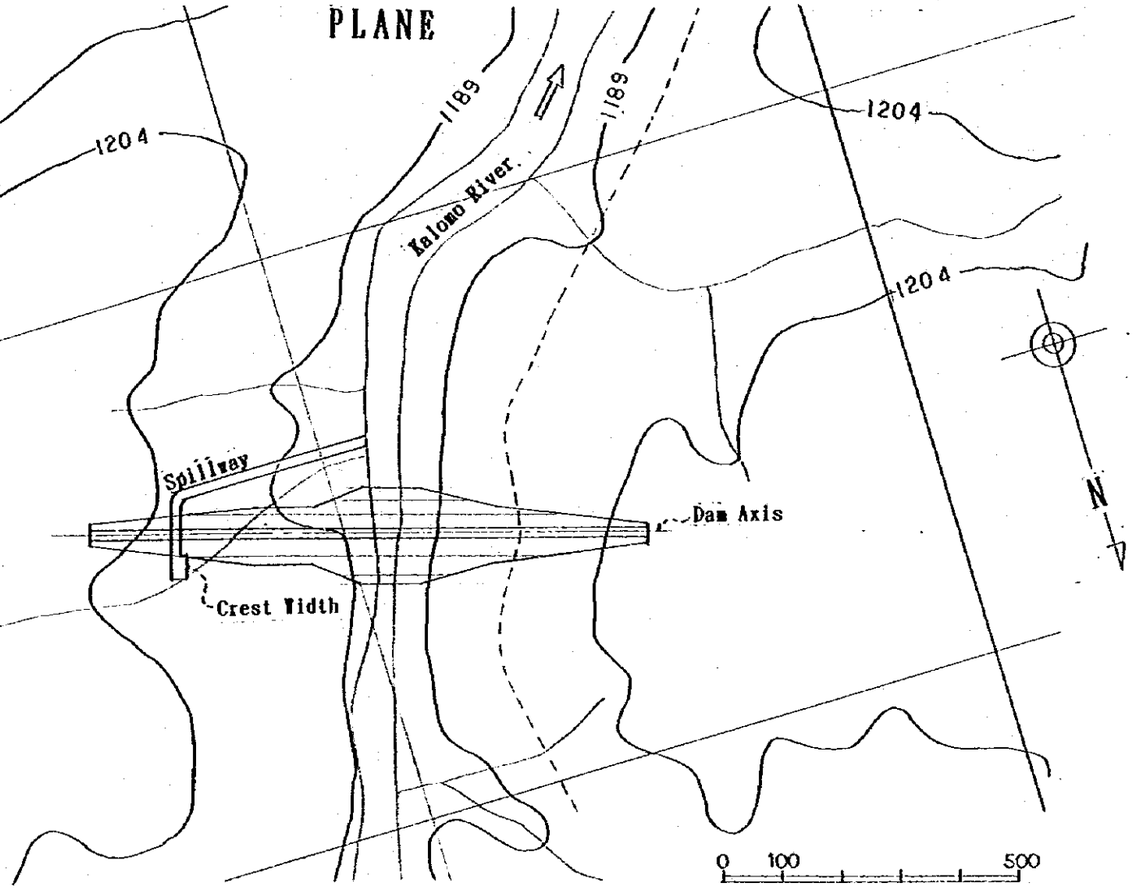


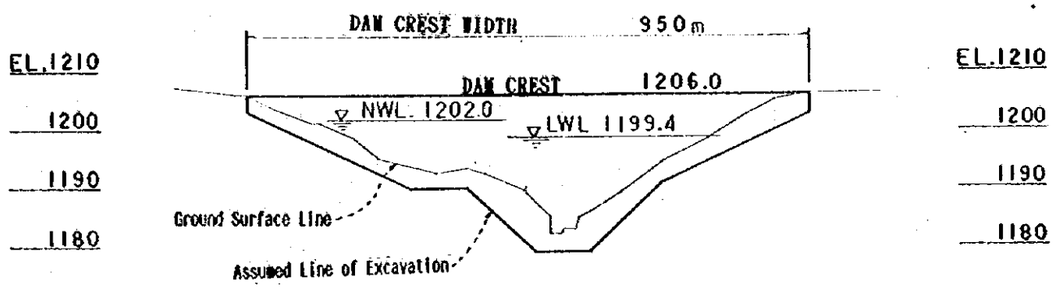
Drawing 25

BWENGWA DAM (NO. 26)

PLANE



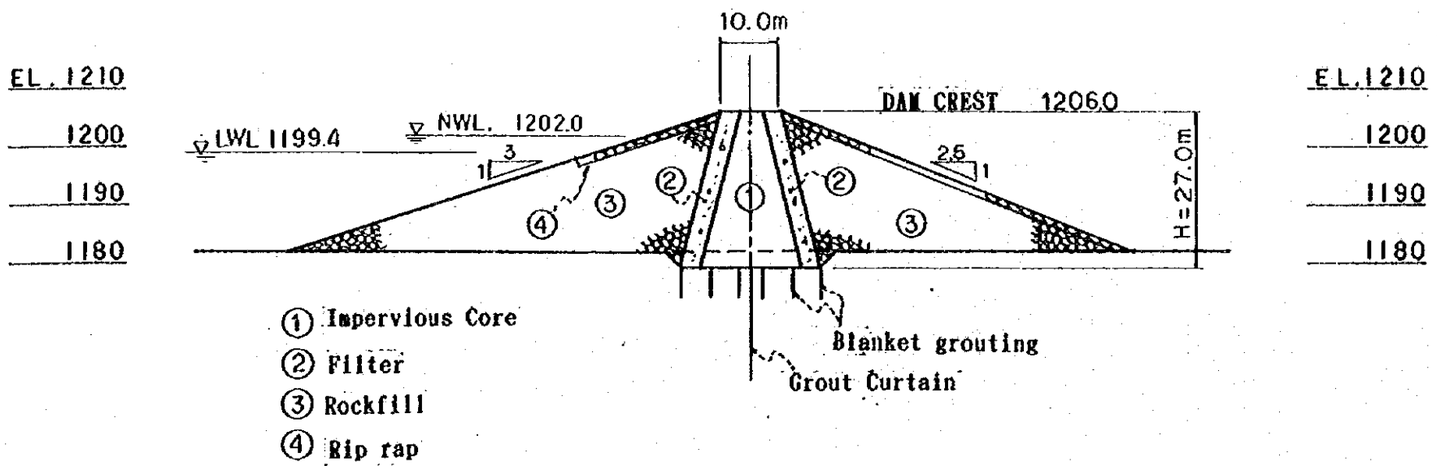
LONGITUDINAL SECTION OF DAM AXIS



SCALE(HOLIZONTAL)

0 100 500

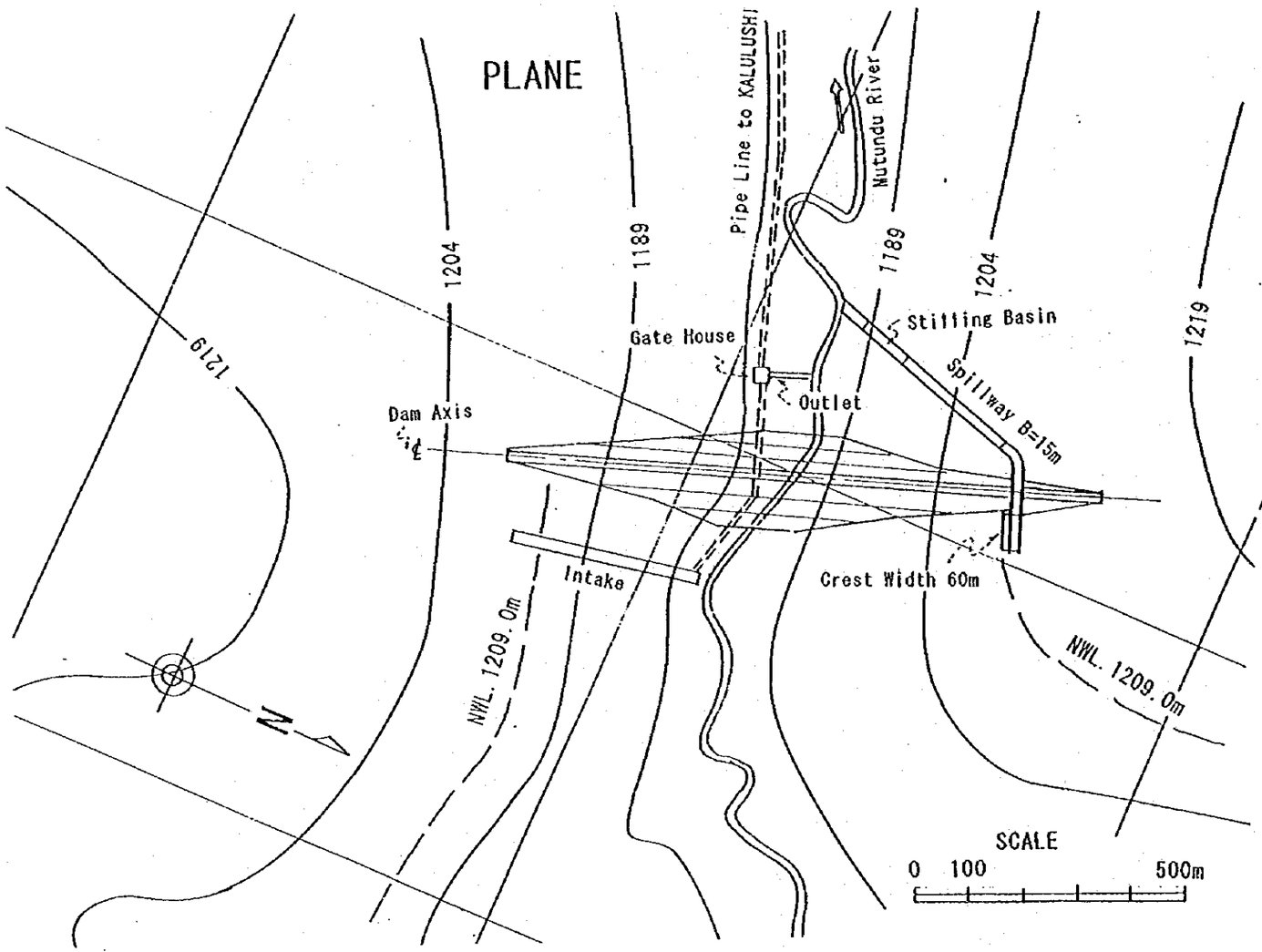
TYPICAL CROSS SECTION



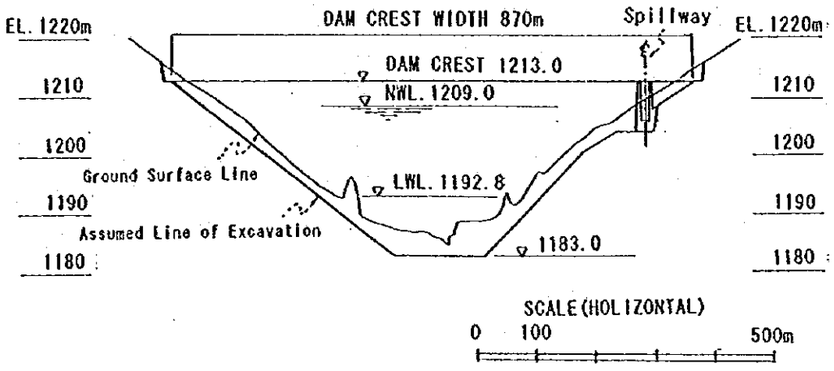
Drawing 26

KALOMO DAM (NO. 27)

PLANE



LONGITUDINAL SECTION OF DAM AXIS



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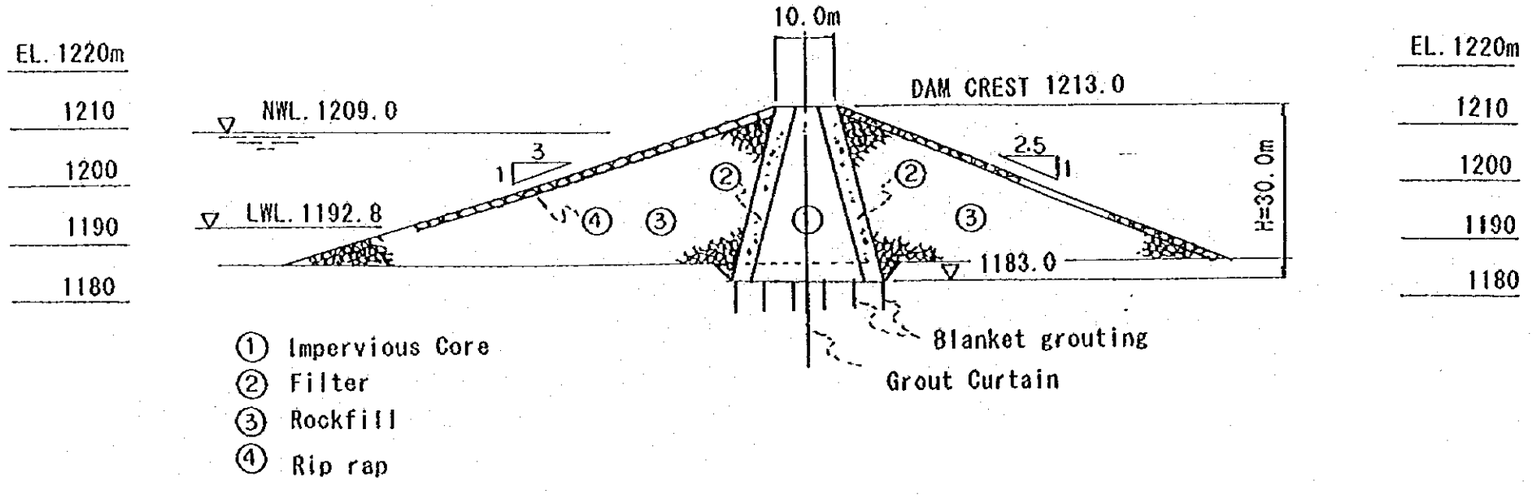
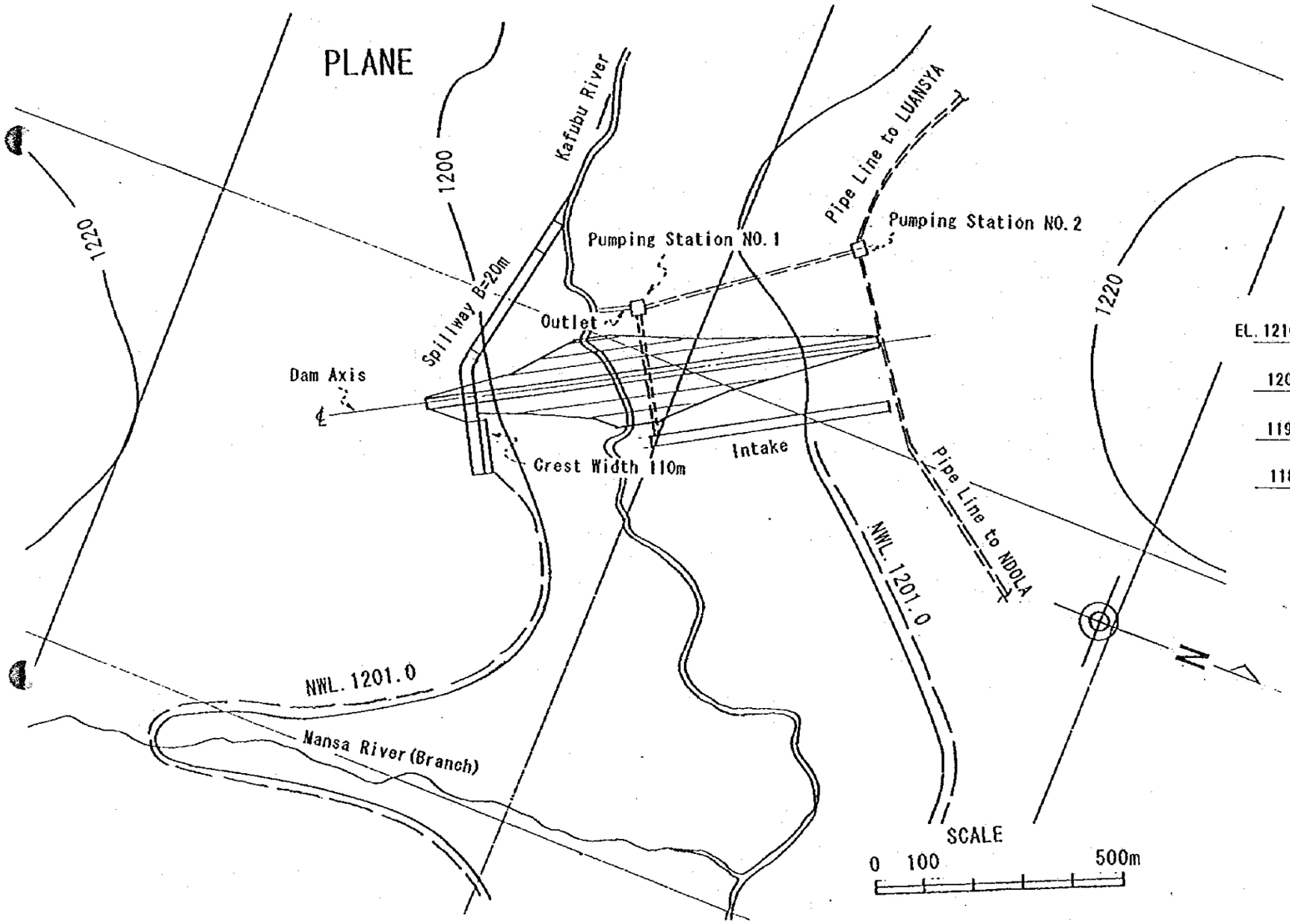


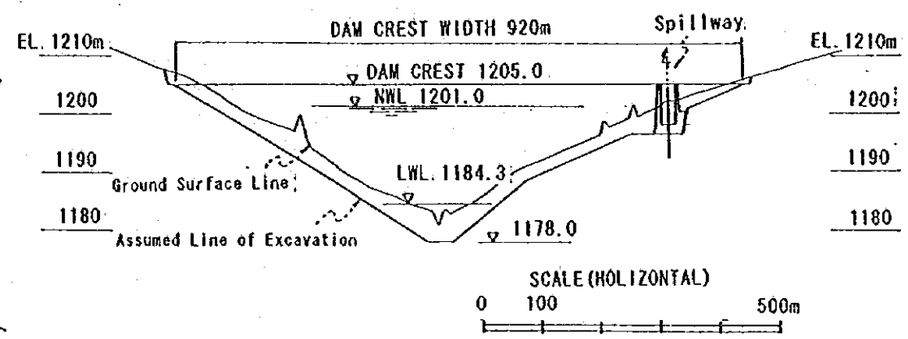
Drawing 27

MUTUNDU DAM (NO. 7)

PLANE



LONGITUDINAL SECTION OF DAM AXIS



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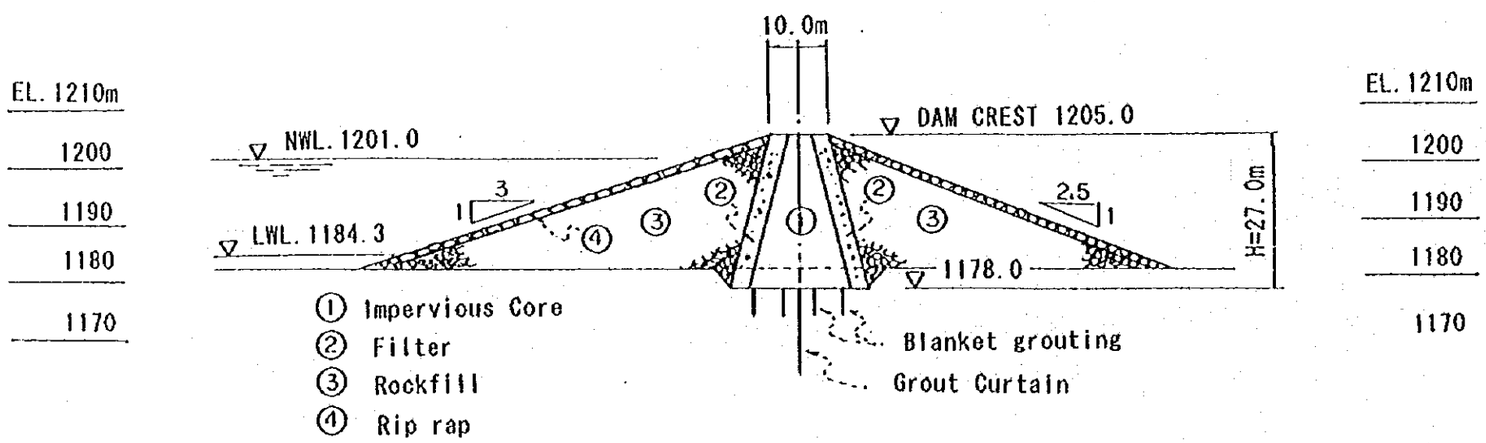
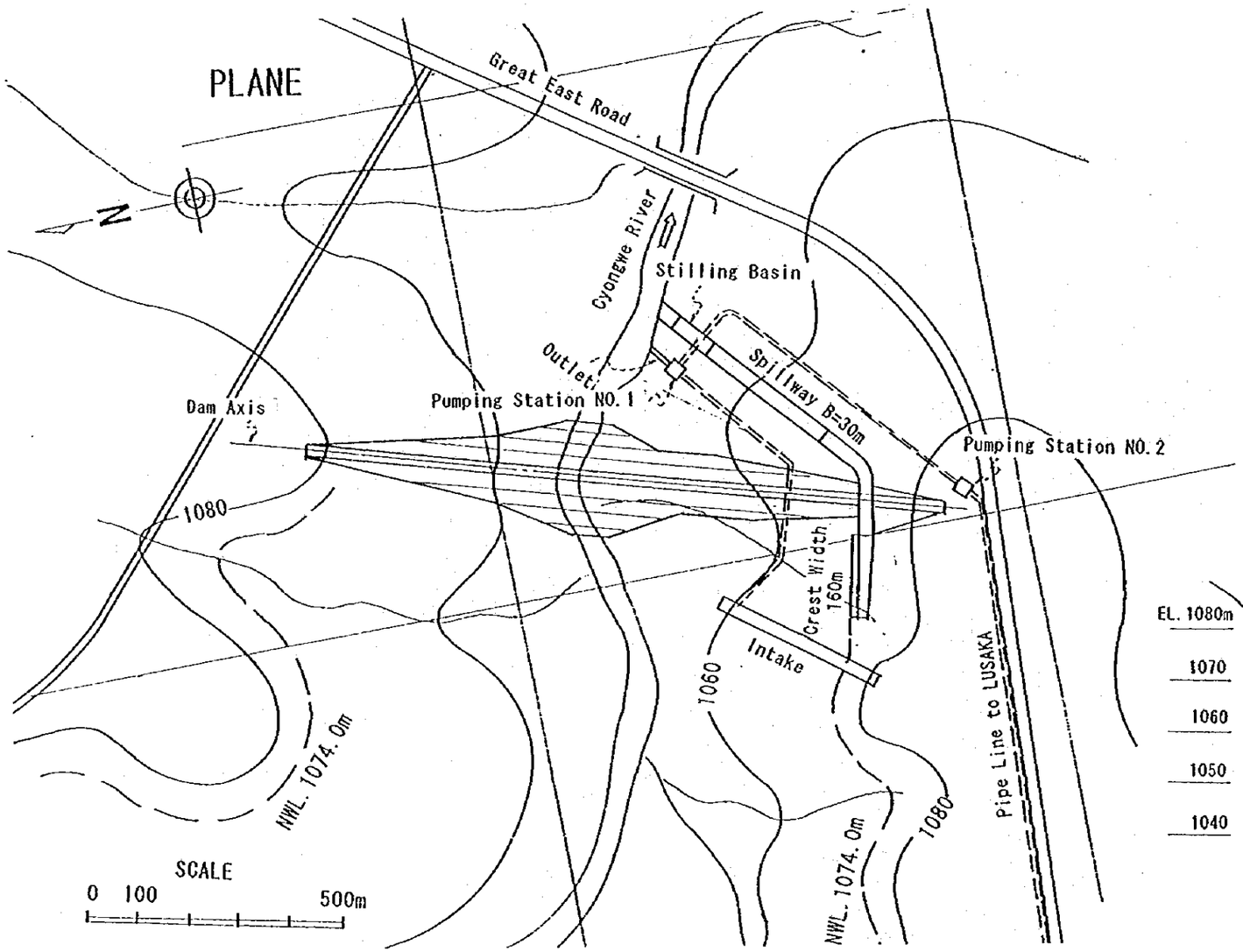


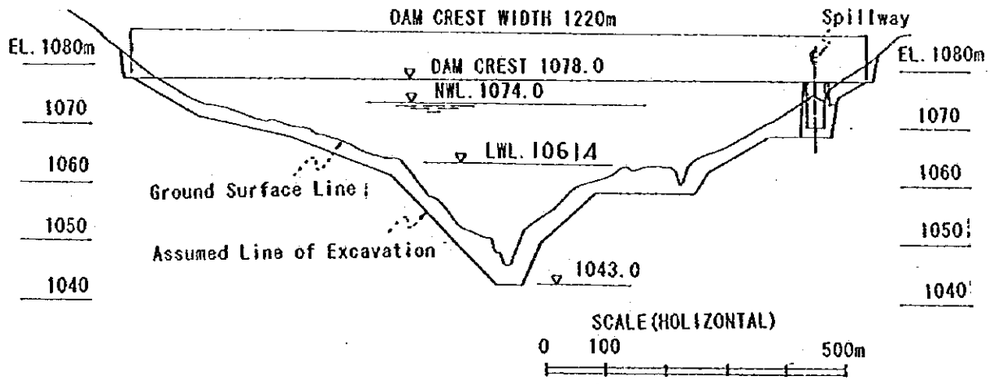
Drawing 28

KAFUBU DAM (NO. 10)

PLANE



LONGITUDINAL CROSS SECTION



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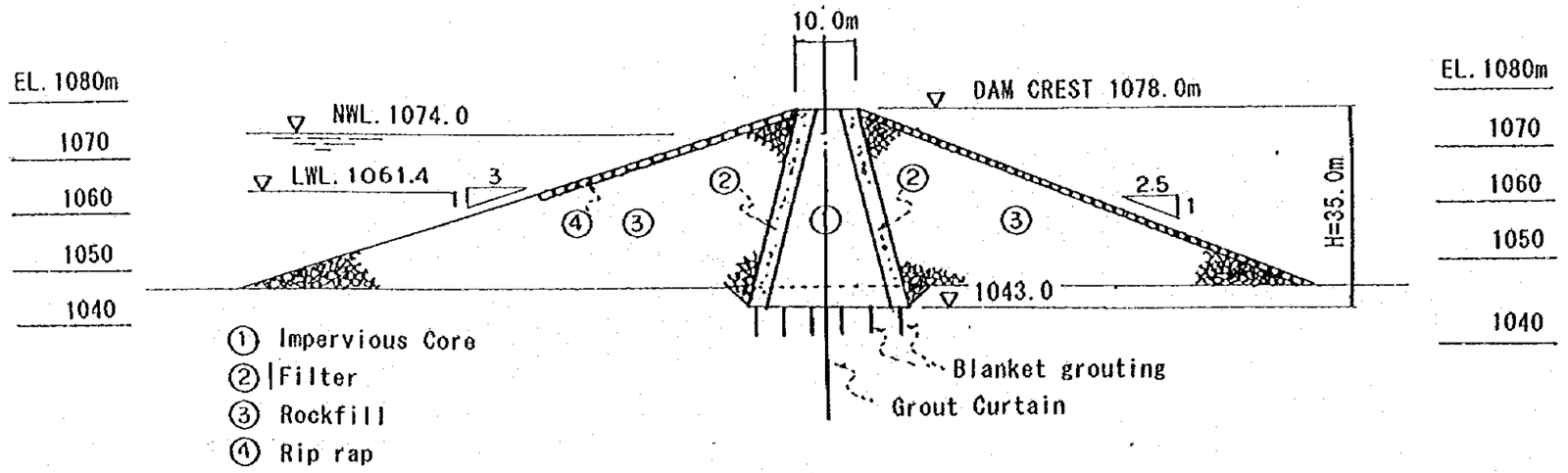

Drawing 29

CHONGWE DAM (NO. 16)