参考資料7．クドゥダム計画のデザインレポート

KUDU DAM
(SITE NO. CUN 1/9)

DESIGN REPORT

FEBRUARY 1993

DESIGNS DIVISION
DEPARTMENT OF WATER DEVELOPMENT
MINISTRY OF LANDS AGRICULTURE AND
WATER DEVELOPMENT
ZIMBABWE

KUDU DAM

DESIGN REPORT

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KUDU DAM

DESIGN REPORT

1. INTRODUCTION

For most of its history, Zimbabwe has been self sufficient in food production, being able to produce enough for consumption with surplus for export. The Agricultural Industry is one of the major foreign currency earners in the country.

Hence the importance of Agriculture to Zimbabwe cannot be overemphasized.

However, the low mean annual rainfall in most of the country, coupled with the erratic pattern of the rainfall from year to year does not auger well for a balanced continuity in production and hence development of the industry.

It is with this in mind that the Government has stated a policy to promote irrigated agriculture throughout the country, particularly in communal and resettlement areas.

Kudu dam is sited and sized to gain complete control of the water resources of the Munyati river on a large catchment area, in a convenient situation to achieve Government stated policy.

The dam will to a very large extent develop the potentially productive communal areas of Sanyati, Copper Queen, Chenjeri and Lower Gokwe, all situated downstream of the dam. In addition it will also serve resettlement schemes in the vicinity of the dam and some of the highly productive commercial farms in the Kadoma district.

The areas to be served represent the major cotton producing zone of Zimbabwe, but the crop is currently grown under dry land conditions and is prone to droughts. Irrigation from the waters of Kudu dam would enhance yields and provide security against years of crop failure, as well as enabling the production of other food and cash crops like maize and groundnuts, which have also proved to flourish in the area.

Although Agritex is still carrying out investigations in irrigable land in some of the areas, to date about 25 000ha of irrigable land is anticipated downstream of the dam.

The current drought (1991/92 season) has starkly highlighted the importance and necessity of such schemes as the Kudu dam project.

2. LOCATION AND ACCESS

Kudu dam site (CUN 1/9) is located on the Munyati river, about 1.5 kilometres upstream of the Ngondoma river confluence. Its position is at Grid Reference QK 561775 on 1:50 000 Map number 1829 A4. (See Locality Sketches 15832-H and 14752-SK).

Access to site is via the Kadoma-Sanyati road. The tarred road leads northwestwards from Kadoma for 19 kilometres to Patchway Mine. At Patchway mine the route turns westwards along the Sanyati road for about 25 kilometres to Boterekwa turnoff. It then turns southwestwards into a gravel road for about 10 kilometres to Nyamatani School and Clinic. The gravel road continues for another 17 kilometres from here to the vicinity of the dam site.

3. GEOLOGY OF SITE

The geological report was produced by T.J. Broderick of Jeremy Prince and Associates in 1991. Details of the report can be found in the Water Development Designs library at Makombe buildings. The main features are summarised below.

3.1 General

The Munyati River has eroded downwards through an original cover of Karoo sediments into the underlying Lomagundi and Deweras rocks and onto a basement of granites and greenstones. Backward erosion of its tributaties has resulted in the face of the Mafungabusi Escarpment to the west and in a lesser slope break east of the river. Reflecting more recent periods of deposition and erosion, up to 60 metres of alluvium is present along the Munyati which is preserved in two terraces at about 15 and 35 metres above the present river level.

3.2 Regional Geology

The Basement rocks in the vicinity of Kudu dam site are assigned to the Maliyami Formation of the Bulawayan Group and are generally pale greenish-grey to slightly bluish-grey, fine to medium-grained, in part porphyritic, massive or locally foliated, pyroxene-bearing andesitic lava. These rocks outcrop a little over 1.5km upstream of the proposed centre line above the Karonika river confluence with the Munyati. Here their general trend is south-eastwards and they are interbanded with finely bedded tuff horizons and intrusive microdiorites. Some of the later rocks outcrop across the extreme right bank of the saddle dam below Ngondoma trigonometrical beacon. A further inlier has been mapped across Lodestar Ranch, north-west of the Ngondoma ridge. Some of the soils over these ancient volcanics have been identified as borrow areas.

Granites are intrusive into the basement lavas 6km south-west of the dam site along the Chevecheve valley below the Mafungabusi Escarpment. They do not affect the dam site.

Massive, often epidotized basaltic lavas of the Deweras Group lie across the distinctly cleaved lavas of the Basement Complex and in the vicinity of Kudu Dam they occupy a north-east trending zone crossing from Zhombe Communal Land onto Kudu River and Lodestar ranches. Basal ophitic basaltic greenstones represent the lowest Deweras unit near the dam and these were mapped near the Karonika confluence as an alternating sequence of lava flows and agglomerates. Overlying the basal unit to the north-west is the main lava unit which creates much of the bedrock across the main dam, spillway and saddle dam areas.

These lavas have been exposed to a fossil lateritic weathering process which has resulted in the development of purplish-brown horizons and in jasperlitic veining, particularly of fractured and brecciated lava. The phenomenon is well represented across the dam site, especially on the left bank of the main wall. In the field the Deweras lavas give rise to light chocolate-red soil upon which are seen small and large rounded boulders.

Faulting and fracturing across the dam environs appears to occur commonly on east-north-east, northerly, north-north-westerly, north-westerly and easterly trends. The main linesments identified as cutting across the centre line of the dam are north to north-north-west and, subordinately east and north-east. North-east trends cut the spillway and saddle dam area whilst a fairly large north-westerly fault crosses the saddle dam to the right of centre.

Karoo sediments have long since been eroded from the dam area. Some 20 metres depth of sandy alluvium is preserved in an upper terrace on the left bank of the dam and this has been degraded to 10 metres across the right bank. At least a 10 metre thick remnant of this alluvium fills the return channel to the munyati where it has been partly eroded. Colluvial soils develop closer to the proposed spillway. Narrow, low alluvial terraces occur on either bank adjacent to the Munyati and sand banks with basal boulder beds occur intermittently along the channel bed. The sand tends to be reddish in colour, is fine-grained and contains a fairly high percentage of clay minerals. Boulder scree occurs on and at the foot of steep slopes, especially on the left bank of the dam.

4. INVESTIGATIONS

4.1 Geotechnical Investigations

4.1.1 Materials Investigations

A materials report was completed in June 1992, and below is a summary of the quantities.

	Required (m^3)	Proved (m^3)
Impervious core	2 500 000	6 567 900
Rolled fill	5 000 000	2 485 400
Sand : Filters	85 000	42 400
(Crusher Run)	60 000	
Rockfill : Rip-Rap	360 000	not locally available
Total	8 005 000	

Core material was classified using plasticity products ranging from 501 - 1 200 and above, and fill material from 100 - 500.

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Sufficient core material was proved for the construction of the dam but more investigation on fill material is required further away from the dam when construction begins.

The cross-section of the dam has accordingly been designed to utilise the large volume of impervious material in close proximity of the site.

Drawing No. 15BBB-H shows a layout of the Borrow Arreas.

The investigation also shows that a source for all stone requirements will have to be established further away from the dam site.

Although there are sand deposits at the site, more river sand will have to be sourced from further upstream or downstream.

4.1.2 Seismic Investigations

A refraction seismic survey across the left and right bank of the main dam, the proposed spillway and the saddle dam was planned in September, 1989 and was completed in February, 1990 by Ministry of Energy and Water Resources and Development. This survey involved a line of 265 metres length on the left bank with one 92 metre cross line over the alluvial terrace. The right bank seismic was shot over 349 metres along the centre line with three 92 metre cross lines, one on the lower terrace, one on the upper terrace along the power line track and the third across the upper alluvium close to the break in slope. Test pits were dug in alluvium at the cross points of these seismic lines and at the base of the right bank slope where red clayey soil contains lava cobbles and overlies decomposed lava.

On the saddle dam the seismic traverse along the centre line totalled 926 metres. Three 92 metres cross lines were placed close to borehole SD1 near the left bank, in the centre where the centre line curves northwards and across the low saddle near borehole SD4. A test pit at the centre line curve exposed hard decomposed Deweras lava. One in the saddle showed green, epidotized decomposed. SD4 showed dark-green, spotted decomposed lava beneath red-brown soil and colluvial rubble.

The spillway region was investigated with two seismic lines set almost at right angles, being 162 metres long along the left bank abutment of the saddle dam and 276 metres across to the the right bank abutment of the planned spillway. There were two cross lines of 92 metres each and three test pits in the saddle showed the presence of deep, soft decomposed Deweras lava.

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4.1.3 Core Drilling

Tender No. E.W.R.D. 29/90 for site investigations on Kudu Dam was gazetted in August 1990. This called for the drilling of vertical and inclined exploratory boreholes. Eight boreholes were drilled along the left bank centre line and six along the line of the left bank outlet tunnel. A further eight boreholes where drilled to delineate the right bank centre line. Six boreholes were sited along the saddle dam centre line and eight boreholes were designed to test alternate locations for the founding of the spillway following the adverse indications of the seismic survey. A ninth hole (SP2B) was inclined across a possible fault line crossing the alternative spillway alignment. In all a total of 1 197 metres of diamond drilling was completed in May, 1991 by the contractor, C. Stenlunde and Company (Pvt) Ltd.

The core was geologically logged by T.J. Broderick of Jeremy Prince and detailed records of the drilled boreholes including colour photographs of the core are in the library at the Director of Water Development's offices in Makombe buildings. The 200 core boxes containing the recovered core are stored in a wired stockade at the dam site.

The initial report of the diamond drilling painted an adverse picture of the geology of the original intended position of the spillway.

Hence in November 1991, C. Stenslunde and Company (Pvt) Ltd. was recalled to site to drill boreholes at an alterantive position of the spillway. The alternative position was more to the left of the original position, nearer the main Embankment.

From the diamond drilling results, the alternative position was found to be slightly more favourable and is the position finally selected for the spillway.

The change in position necessitated changing the originally planned arch design of the spillway to a straight ogee spillway.

The surface geological features were mapped across the dam site and are described in a detailed report by T.J. Broderick in the light of diamond drilling and the seismic investigation. The detailed report can be seen in the library at the Director of Water Development's offices.

Interpretations of the geology of the site may alter as new exposures are excavated during construction and design aspects may be required to take changed circumstances into account.

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5. HYDROLOGICAL DATA

RIVER	:	MUNYATI
MAJOR TRIBUTARIES	:	NYAMATANI, MAZOE, UMSWESWE, ZHOMBE, SESOMBI, SEBAKWE
CATCHMENT AREA	:	17520 km^2
MEAN ANNUAL RAINFALL	:	700mm
MEAN ANNUAL RUNOFF (mm)	:	56,7mm
COEFFICIENT OF VARIATION	:	110%
MEAN ANNUAL RUNOFF (m^3)	:	993 X $10^6 m^3$

5.1 FLOODS:

MAXIMUM PROBABLE	:	16 336m^3/S
1 : 2000 YEAR	:	12 122m^3/S
TIME TO PEAK INFLOW	:	33.33 hrs
STORM INTENSITY	:	4.75mm
VOLUME OF INFLOW HYDROGRAPH (1:2000)	:	1907.55 X $10^6 m^3$

5.2 DESIGN:

FULL SUPPLY CAPACITY	:	1551.4 X $10^6 m^3$
YIELD AT 10% RISK	:	380 X $10^6 m^3$/annum
CAPACITY/M.A.R. RATIO	:	1.60
10% YIELD/M.A.R.RATIO	:	0.38
CAPACITY/YIELD CURVE	:	DRG No. 14755-BK

6. DESIGN

6.1 SUMMARY OF DESIGN

RIVER BED LEVEL	:	882.50m
CREST LEVEL	:	955.20m
FULL SUPPLY LEVEL	:	947.00m
HIGH FLOOD LEVEL	:	953.12m
MAXIMUM HEIGHT OF DAM	:	72.70m
MAXIMUM DEPTH OF WATER	:	64.50m

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MINIMUM DRAW DOWN LEVEL :	905.00m
TOTAL STORAGE :	1551.4 X 10^6m^3
DEAD STORAGE :	60.0 X 10^6m^3
SEDIMENTATION ALLOWANCE AT (6.5% M.A.R) :	64.55 X 10^6m^3
LIVE STORAGE :	1 426.85 X 10^6m^3
10% YIELD :	380 X 10^6m^3/annum
CREST WIDTH :	8.00m
CREST LENGTH :	860m
MAXIMUM BASE WIDTH :	380 metres
SADDLE DAM (MAX HEIGHT) :	30 metres
SADDLE DAM (MAX LENGTH) :	875 metres
TOTAL VOLUME OF ALL MATERIALS	8005 X 10^3m^3
SPILLWAY CAPACITY (1:2000)	10 040m^3/S
OUTLET CAPACITY AT LEVEL (10% FULL CAPACITY)	31.49m^3/S
SURFACE AREA AT F.S.L.	7 800 ha

6.2 FOUNDATION AND CUT-OFF

6.2.1 Main Dam

The foundation below the core will be excavated to hard fresh and competent dewaras solid rock. Thus the whole length of the main dam will have a positive cut-off. This is considered to be essential in view of the large size of the dam.

Single line grouting will be carried out below this cut-off according to the normal practice of the Department of Water Development. Grouting is necessary to reduce seepage and is cost effective in view of the scarcity of water resources in Zimbabwe.

Where faces of the cut-off trench prove to be porous, fissured or any other form of incompetency, they shall be gunited.

The cut-off is to be excavated at 1:1 slopes in soft material and 1:05 in hard material (See drawing No. 15821-H).

In all conditions the fill will be founded on firm material. A lot of excavation is therefore required on the upper terraces of the river banks where in particular 20 metres depth of sandy alluvium has been observed on the left bank. The right bank terraces have sandy deposits of up to 10 metres depth.

Drawing No. 15834-H shows details of the foundation of the main dam.

6.2.2 Saddle Dam

Due to the considerable depth to competent solid rock and the relatively moderate height of the embankment it will not be economical to excavate a positive cut-off in this section. Hence core material will be founded on an intermediate cut-off along the whole length of the saddle dam.

Because of the intermediate nature of the foundations, a grout cap will be provided across the whole width of the cut-off, and an extensive grouting programme will be carried out to improve the impermeability of the intermediate zone.

For the same reason, that the core trench is founded in medium velocity material, both faces of the core trench will be gunited along the whole length of the embankment.

Just as on the main dam the slopes of the cut-off will be 1:1 in soft material and 1:05 in the weathered or intermediate material.

In the general area of the embankment a stripping of shallow depth to remove topsoil and vegetation should be sufficient enough to expose a firm foundation for the fill material.

Drawing No. 15822-H shows details of the foundations of the Saddle dam.

6.3 EMBANKMENT

Three types of embankments were considered for comparison of costs and other considerations;

(i) a Rockfill embankment with concrete facing (CFRD).

(ii) a Roller Compacted Concrete dam (RCC).

and (iii) an earthfill embankment.

a) CFRD. The materials investigation report shows that there is no rock material in the vicinity of the dam site. In fact the comparatively smaller quantity of rock required for rip-rap of an earth embankment will have to be imported to the site. Hence this alternative was discarded due to lack of rockfill material on the vicinity, and the high cost of transport from further afield.

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b) RCC. The whole embankment needs to sit on solid rock. Thus excavations for foundations will be extensive and costly.

Furthermore the quantity of concrete required is too enormous for the present trend of high cost of concrete in this country. Hence this alternative was discarded because of the anticipated cost.

c) An Earthfill embankment was selected because it was found to be the cheapest and easiest solution.

Although inadequate quantities of rolled fill material were found near the site, more than adequate impervious core material was proved in the proximity of the site.

Fill material can be sourced a bit further away from the site.

The dam has been designed as a zoned earthfill embankment with a central impervious core.

Due to the proven large quantities of core material and the scarcity of fill material the impervious core will have slopes of 1:1 rather than the conventional 1:0.5. At its crest the core will be 6 metres wide. Thus the impervious core will be wide.

The upstream slopes will be 1:2.6 to level 925 and 1:2.4 to crest and will be protected by rip-rap on a filter layer of crusher run.

The downstream face will have 4 berms at levels 904, 918, 931 and 944. The berms will be 4 metres wide and will have concrete lined drains. The downstream face will be protected by grassing.

A chimney drain and downstream drainage blanket have been incorporated to intercept seepage through the core and foundation and to improve the stability of the downstream fill. A downstream rockfill toe has been provided to assist in solving problems of drainage, uplift pressure and tailwater erosion.

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The major characteristics of the main dam are as follow:-

Maximum Height	72.7
Maximum Depth of Water	64.5
Crest Length	860m
Crest Width	8m
Crest Width (Impervious Core)	6m
River bed level	882.5
F.S.L	947.0
H.F.L (1:2000)	953.10
Dry Free Board (1:2000)	2.10
Crest Level	955.20
Main Dam Quantities	6.2 million
Saddle Dam	1.3 million
Embankment Volume	8 005 000m^3

Drawing No. 15821-H shows the details of the Embankment Cross Sections.

Saddle Dam

The saddle dam will be of similar cross-section to the main dam embankment.

Drawing No. 15822-H shows details of the embankment cross sections of the saddle dam.

6.4 SPILLWAY

Apart from the exposed rock in the river bed, there is no exposed competent rock on the embankment centreline or adjoining flanks on which to found a spillway. Hence extensive diamond drilling had to be carried out in the exercise of trying to find competent rock at a reasonable econimical depth.

The spillway is situated on the northern flank of the right bank embankment, between the main embankment and the saddle dam. It is designed to take advantage of a convenient saddle and natural return channel to the Munyati river.

Following worrying seismic results across the ideal spillway alignment, extensive diamond drilling was carried out in the area. The diamond drilling confirmed the seismic results that there was a pontential of up to 30 metres depth of highly weathered rock and extensive very soft decomposed lava within the ideal alignment area.

Thus the spillway alignment was then moved nearer the main embankment on the bouldery hill on the right bank in which the embankment is anchored. Diamond drilling in this area proved that competent solid rock was at a shallower depth than at the original area.

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However extensive excavation of eubble deposits will have to be carried out through the bouldry hill in order to create an approach channel to the spillway proper.

Drawing No. 15820-H shows the position and alignment of the spillway.

The foundation conditions and the required discharge favoured an OGEE TYPE spillway with an apron. On the left flank it will anchor into natural rock. On the right flank it will join a concrete thrust block which will also serve as a retaining wall for the saddle dam embankment.

The spillway has been designed for a 2000 YEAR flood plus dry freeboard allowance.

The basic parameters of the spillway are as follows:-

CREST LENGTH	300m
HEIGHT OF CILL	2.0m
MAXIMUM WIDTH OF CILL	5.2m
LENGTH OF CONCRETE APRON	30m
2000-YEAR INFLOW	12 122m^3/s
2000-YEAR TIME TO PEAK INFLOW	33.33 Hrs
2000-YEAR OUTFLOW FLOOD	10 040m^3/s
TIME TO PEAK OUTFLOW (2000 YEAR)	45.32 Hrs
2000 YEAR FLOOD RISE	6.12m
2000 YEAR HIGH FLOOD LEVEL	953.10

Other parameters are:-

10 000 YEAR FLOOD	16 336m^3/s
10 000 YEAR TIME TO PEAK	28.37 Hrs
10 000 YEAR OUTFLOW FLOOD	13 110m^3/s
10 000 YEAR TIME TO PEAK (OUTFLOW)	38.58Hrs
10 000 YEAR FLOOD RISE	7.2m
10 000 YEAR HIGH FLOOD LEVEL	954.2m

A slope of 1:200 was adopted for the return channel. Here again a bit of excavation is required through the bouldery hill for the channel that will direct the water to the natural water course that returns back to the Munyati river.

6.5 <u>OUTLET WORKS</u>

The Outlet works are located on the left bank of the Munyati river. The works consists of:-

i) An upstream Free Standing Tower.

ii) A circular concrete lined free flowing tunnel conduit running through the left bank hill.

iii) A multiple discharge structure comprising a radial gate at a lower level and weir at an upper level.

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The criteria for the Outlet design is that the outlets should be able to pass a flow of twice the potential 10% yield of the catchment in a year at the head available with the reservoir level at 10% of its full supply capacity. Separate standby capacity of at least 50% should also be provided.

6.5.1 <u>The Free Standing Tower</u>

The principal feature of the Outlet design is that all the pipework and valves controlling the flow are located in the upstream tower. This is largely dry, the level of water being controlled by the discharge weir at the downstream end of the embankment. The water flows at low pressure through the conduit to the discharge chamber.

There are three completely independent sets of 1 500mm diameter pipework and valves, two of which can pass the required flow, the third being on standby for periods when mechanical maintenance is required on one of the other sets. The butterfly valves are immediately adjacent to the inlets and the flow regulation is provided by the "bottom discharge valves" at the base of the tower.

An access bridge leads from the Mboro Cliffs into the Tower. The bridge has to be more substantial than usual as all the valves and 1 500mm diameter pipework have to be tranported across it.

The main advantages of this system are that the pipework can be very short, and the normal gate shaft, inlet tower and valve house are combined into the inlet tower. The problem of designing a gate shaft in the embankment strong enough to resist the huge passive pressures which would develop due to downstream deformation has been avoided.

6.5.2 <u>The Tunnel Conduit</u>

Diamond drilling along the hill on the left flank of the main embankment proved that at the required invert of the outlet conduit the rock is competent enough to excavate a tunnel through the hill.

The only section of the tunnel that will need careful watch during construction is the Intake point where the tunnel starts off in weathered and decomposed material.

The circular tunnel is 2.5 metres in diameter and is lined with a 400mm thick reinforced concrete lining. It is about 650 metres long from the Intake to the discharge structure and runs along the whole length at a slope of 1:200.

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For a dam of this large magnitude it was a great advantage to find foundation conditions that permit a tunnel outlet works. Besides being more economical, it has more advantages over the other types of outlet works. A tunnel is not in direct contact with the dam embankment and, therefore, provides a much safer and more durable layout than can be achieved with a cut-and-cover conduit. Little foundation settlement, differential movement, and structural displacement is experienced with a tunnel that has been bored through competent abutment material and seepage along the outer surfaces of the tunnel lining or leakage into the material surrounding the tunnel is less serious. Furthermore, it is less likely that failure of some portion of a tunnel would cause failure of the dam than the failure of a cut-and-cover conduit that passes under or through the dam.

At the Intake Tower end the tunnel invert level is 898.00 and at the discharge end it is about 895.00.

The conduit section of the outlet shall also serve as a diversion channel during construction.

6.5.3 <u>The Discharge Structure</u>

Investigations into the irrigation potential of the area below the dam revealed that a discharge level of 910.000 would enable the dam to irrigate land up to 90km below the dam by gravity flow. With the invert level of the conduit at 895.00 at the discharge, it became necessary to have a multiple discharge structure.

The lower discharge at invert of 895.00 will serve the normal purpose of diversion and maintaining river flow downstream of the dam. The higher discharge level at 910.000 will feed the irrigation canals.

For efficient working of this discharge system, it was found convinient to put radial gates at the lower level outlet and a discharge weir at the upper level outlet.

Drawing No. 15833-H shows details of the outlet works.

7. <u>MISCELLANEOUS</u>

The area to be flooded by the dam is about 7 800ha at HFL. On the right bank the flooded area is mostly commercial farming land, characterised by ranching. Some of these Ranches have however been recently turned into Resettlement Areas which largely concentrate on crop farming.

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On the left bank, the whole flooded area is part of Zhombe Communal lands and consists mainly of grazing land with some arable. Land acquisition and servitudes of storage will be obtained over the reservoir area, with a smaller portion of land acquired around the dam embankment and for permanent staff housing.

From recent practice, it is believed the Department of National Parks might also acquire a small portion of land around the reservoir for recreational and conservational purposes.

Natural Resources Board approval of the project has been obtained and Water Rights have been applied for.

8. COMPENSATION

8.1 Relocation

Some people in the Zhombe Communal Lands will have to be moved. One school in this area, Samabwa School will also be inundated. Allowance for the estimated costs of compensation for fixed assets and relocation of displaced persons has been made in the Project Cost Estimate.

8.2 Road Realignment

The only known road that will be affected is the Kadoma to Empress Mine highway, which might have to be realigned by 4Km. An alternative to realignment might be the raising of the bridge across the Munyati river as the highway is at the upper reaches of the reservoir. A smaller bridge across a stream near the Munyati would also require to be raised.

8.3 Power Lines

Power Lines will be affected at the upper reaches of the dam, one across the Munyati river and another across the Umsweswe arm of the reservoir. A power line bringing electricity to a homestead will be folooded at the dam site will also be affected.

9. CONSTRUCTION PROGRAMME

The dam is the largest embankment dam designed in Zimbabwe to date, the largest constructed being Osborne dam at 5 255 x 10^3m^3. There should be no problems in the rate of placing of core material as it is in the vicinity of the site. However, because the site location is hilly, access problems could be encountered in the placing of fill material. Thus the rate of placing fill material could be affected by lack of availability in the vicinity and access to site. It is therefore anticipated that the construction will be completed in FOUR years.

The starting date for construction will be highly dependent on receipt of a full Project Report on the use of the water (location of land, crops to be grown) and on the availability of finance. Consideration also has to be given to other priority water development projects. It is not considered probable that construction would start before June 1995 at the earliest.

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The proposed construction programme is as follows:-

JANUARY, 1995	CALL FOR TENDERS
APRIL, 1995	AWARD TENDER
JUNE, 1995	COMMENCEMENT OF CONSTRUCTION WORKS
MAY, 1999	COMPLETION OF WORKS

A detailed construction programme has not yet been drawn up and will depend on the time of award of contract.

Any delay in the approval and financing of the project will result in the postponement of the proposed programme. With the present trend of escalation of prices, such a postponement will result in an astronomical increase in the overall cost of the dam construction.

10. QUANTITIES AND COST ESTIMATE

The following Cost Estimate was determined as at November 1992.

10.1 KUDU DAM - DESIGN COST ESTIMATE

ITEM NO.	DESCRIPTION	QUANTITY	UNIT	RATE	AMOUNT
1	EXCAVATION				
	1.1 STRIPPING AND CLEARING				
	a) Main Dam Foundations	25	Ha	3500	8 500
	b) Saddle Dam Foundations	15	Ha	3500	52 500
	c) Spillway Area	10	Ha	3500	35 000
	1.2 SOFT EXCAVATION				
	a) Main Dam (Cut-Off)	144 500	m^3	6.00	867 000
	b) Saddle Dam (Cut-Off)	125 200	m^3	6.00	751 200
	c) Under Fill	300 000	m^3	4.50	1 350 000
	d) Spillway	453 600	m^3	4.50	2 041 200
	1.3 HARD EXCAVATION				
	a) Main Dam (Cut-Off)	83 900	m^3	47.50	3 985 250
	b) Saddle Dam (Cut-Off)	33 800	m^3	47.50	1 605 500
	c) Spillway	368 000	m^3	42.50	15 640 000
	d) Outlet Tunnel	10 000	m^3	250.00	2 500 000
2	EMBANKMENT				
	2.1 Core Material	2 500 000	m^3	9.00	22 500 000
	2.2 Fill Material	5 000 000	m^3	10.00	50 000 000
	2.3 Sand	85 000	m^3	10.00	850 000
	2.4 Crusher Run	60 000	m^3	50.00	3 000 000
	2.5 Rockfill : Rip-Rap	360 000	m^3	50.00	18 000 000
3	GROUTING				
	STAGE - 6m : All Costs	1 750	No.	750.00	1 312 500
	BILLED ITEMS SUB TOTAL				124 498 650

ITEM NO.	DESCRIPTION	QUANTITY	UNIT	RATE	AMOUNT
	SUB TOTAL BROUGHT FORWARD				124 498 650
4	CONCRETE				
	4.1 Grout Cap	2 650	m^2	300.00	795 000
	4.2 Spillway	16 170	m^3	350.00	5 659 500
	4.3 Outlet Works	7 580	m^3	500.00	3 790 000
	4.4 Reinforcement	80	Tons	1500.0	120 000
	4.5 Bridge Beams & Planks (Prestressed)		Sum	250000	250 000
5	STEELWORK				
	5.1 OutletPipes 3x1500Dia x 17m	51	m	500.00	25 500
	5.2 Butterfly Valves 1500 Dia	6	No.	20000	120 000
	5.3 Bottom Discharge Valves 1 500 Dia	3	No.	30000	90 000
	5.4 Ancillary Pipework and Steelwork		Sum	100000	100 000
	SUB TOTAL				135 448 650
6	MISCELLANEOUS		%	5%	6 772 432
7	PRELIMINARY AND GENERAL		%	20%	28 444 216
8	EXTRA P & G-FOREIGN CONTRACTORS		%	30%	51 199 590
9	CONTINGENCIES		%	15%	33 279 733
10	ESCALATION DURING CONSTRUCTION		%	30%	76 543 387
	CONTRACT PRICE				331 688 009
		SAY			331 688 010
	DEPARTMENTAL				
11	ACCESS & REROUTED ROADS	4	Km	25000	100 000
12	TEMPORARY HOUSING		Sum		1 200 000
13	PERMANENT BUILDINGS - WATER BAILIFF ETC.		Sum	500000	500 000
14	LAND COMPENSATION	3 000	Ha	250	750 000
15	SAMABWA SCHOOL		Sum		500 000
16	REPLACE FLOODED BRIDGES	1	No.	400000	400 000
17	GAUGING WEIRS	3	No.	50000	150 000
18	DEPARTMENTAL EXPENSES	4	Yrs	500000	2 000 000
19	CONTINGENCIES ON 11 TO 17		%	15%	660 000
	SUB TOTAL				5 060 000
	THEREFORE TOTAL PROJECT COST AT	NOV.1992		=	343 008 010
		SAY			343 000 000

NOTES:-

1. An extra 30% Preliminary and General Cost has been added in anticipation of the Contract being awarded to a foreign Contractor.

2. An escalation of 30% has been allowed for to cover the duration of the contract. This is considered reasonable for the current economic trend in Zimbabwe. The total estimate of Z$343 million is as at November 1992 and is equivalent to US $63.5 million. For construction starting in June 1995, the project cost is estimated at US$76.2 million. Any further delay in the commencement of works will result in the cost increasing by about 10% per year, when given in US$ currency.

10.2 UNIT COST OF WATER

Costing has been determined using a 40 year redemption period with $9^3/4$% interest rate:

TOTAL CONSTRUCTION COST	=	$ 343 000 000
INTEREST AND REDEMPTION AT $9^3/4$% OVER 40 YEARS	=	$ 33 443 000
ANNUAL OPERATION AND MAINTENANCE	=	$ 300 000
TOTAL ANNUAL COST	=	$ 33 743 000
ANNUAL DAM YIELD	=	380 X $10^6 m^3$
THEREFORE COST OF WATER	=	Z$ 88.80/1 000m^3

This represents an increase of about 193% since the feasibility report was written in 1987. The increases can be attributed to

(i) the rapid change in the Zimbabwe economy which has resulted in a very high inflation rate and

(ii) Changes in design after the result of the geological investigations.

11. CONCLUSION

(i) The area below and around Kudu dam has great agricultural potential. The major plantation crops in this area being cotton, maize and groundnuts. These crops are not only major crops for domestic consumption, but are also some of the chief export cash crops of Zimbabwe.

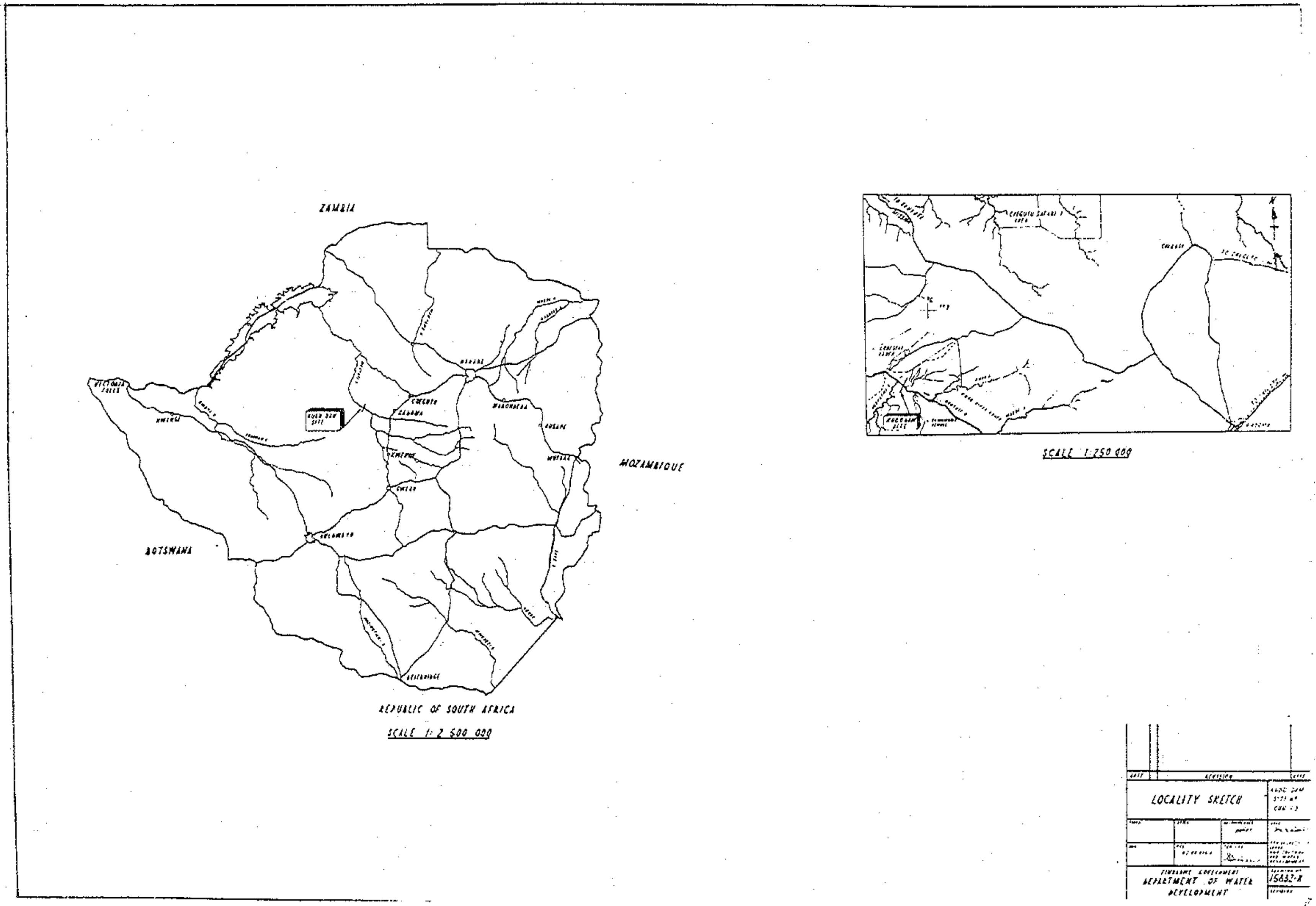
18/...

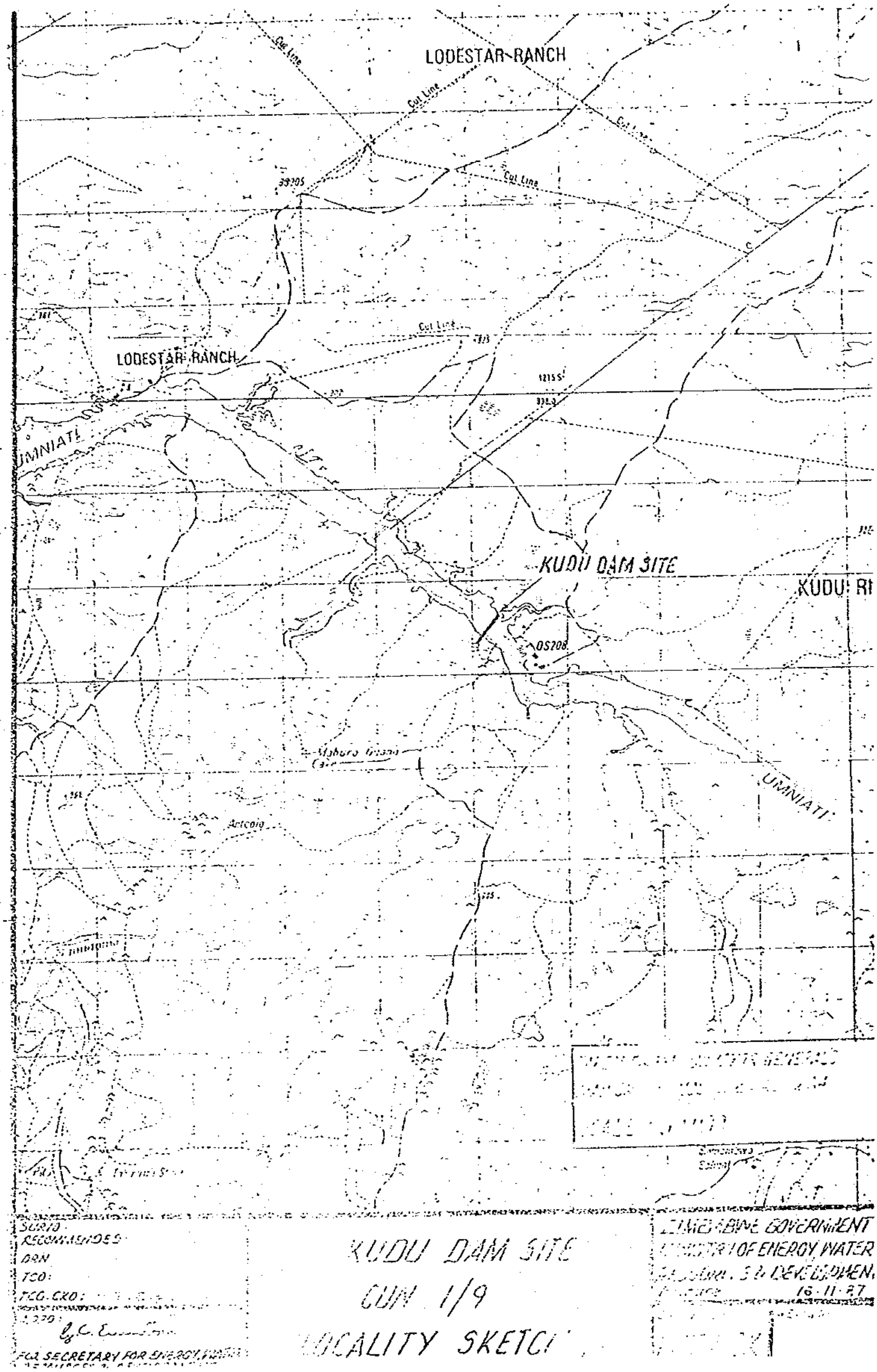
(ii) Zimbabwe has a great potential of water resources of which only a small percentage has been tapped to date. When built, Kudu dam will be the largest earth dam in Zimbabwe and will have the second greatest storage capacity of all internal dams, after the proposed Nukorsi Dam.

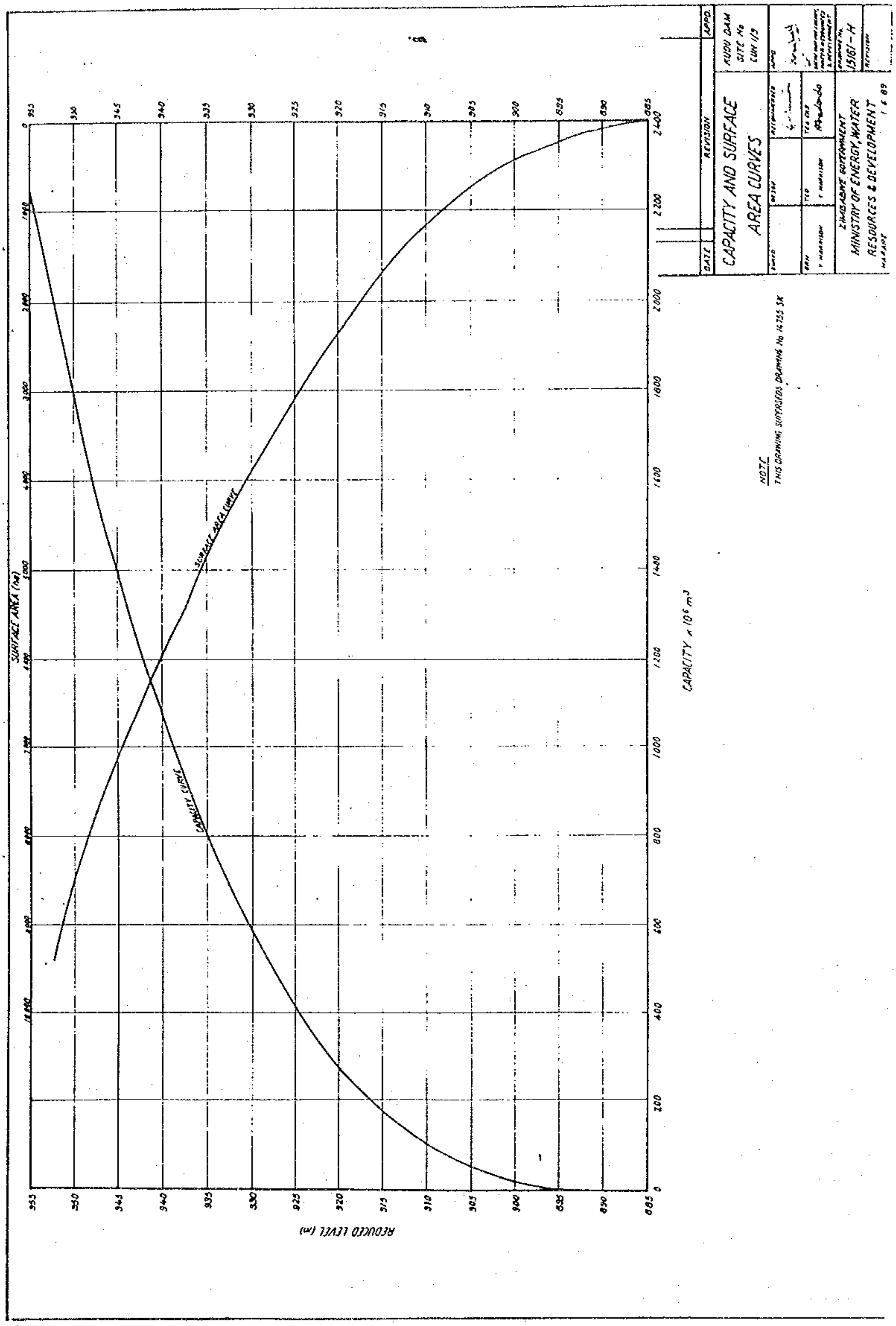
The construction of a dam of this magnitude will therefore go a long way in the quest of trying to tap the full potential of the water resources of the country, and enable greatly improved levels of agricultural production in the areas downstream.

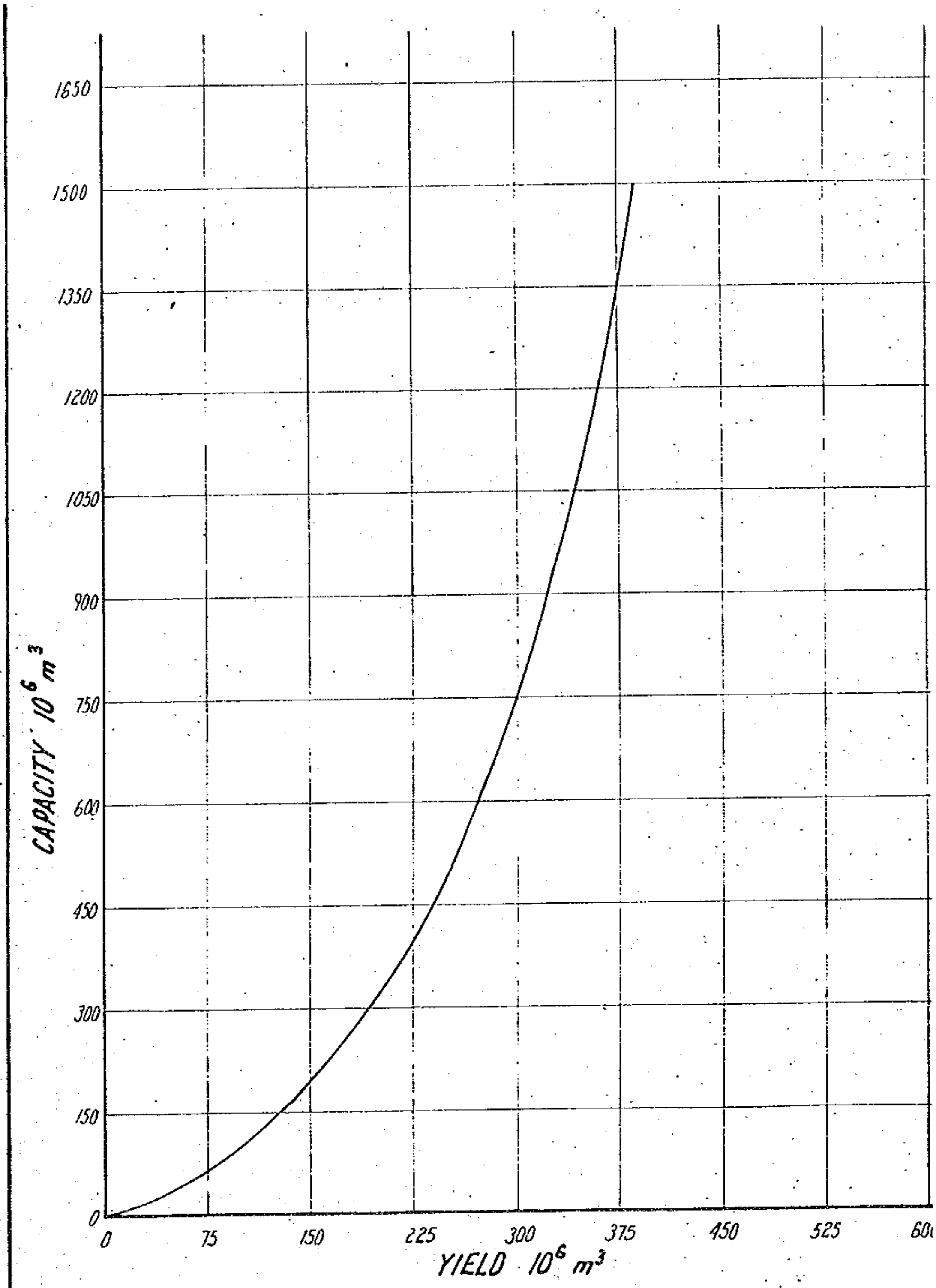
DESIGNS DIVISION - DEPARTMENT OF WATER DEVELOPMENT

/lk


ZAMBIA
MOZAMBIQUE
BOTSWANA
REPUBLIC OF SOUTH AFRICA
SCALE 1: 2 500 000
SCALE 1:250 000
LOCALITY SKETCH
DEPARTMENT OF WATER
DEVELOPMENT


LODESTAR RANCH
Cut Line
LODESTAR RANCH
UMNIATI
KUDU DAM SITE
KUDU RI
UMNIATI
ZIMBABWE GOVERNMENT
16.11.87
KUDU DAM SITE
CUN 1/9
LOCALITY SKETCH
FOR SECRETARY FOR ENERGY, WATER

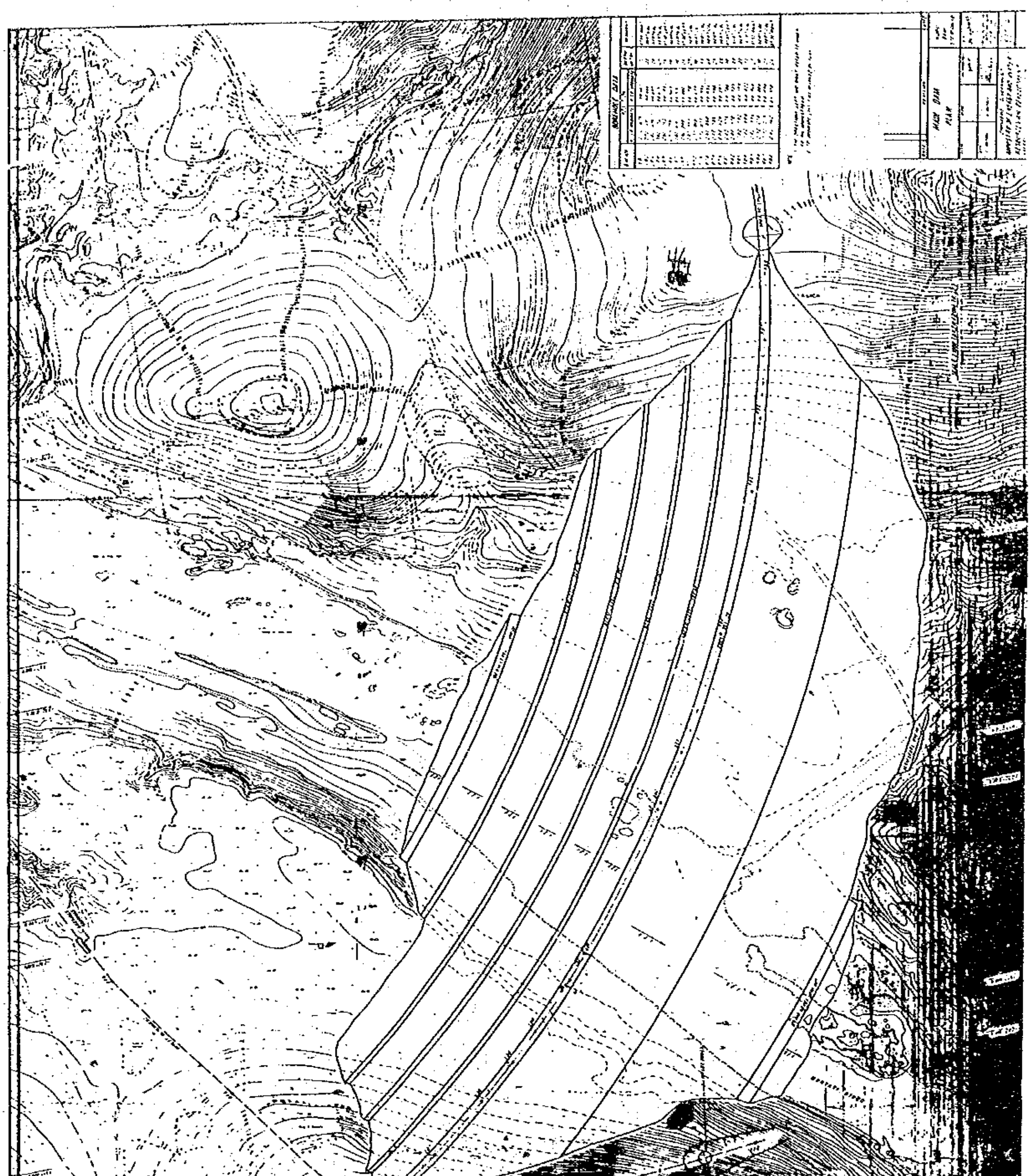

CAPACITY AND SURFACE AREA CURVES
KUDU DAM
SITE No
CUN 1/3
ZIMBABWE GOVERNMENT
MINISTRY OF ENERGY, WATER
RESOURCES & DEVELOPMENT
15161-H
DATE
REVISION
APPD.
NOTE
THIS DRAWING SUPERSEDES DRAWING No 14755 SK
SURFACE AREA (ha)
SURFACE AREA CURVE
CAPACITY CURVE
CAPACITY x 10⁶ m³
REDUCED LEVEL (m)

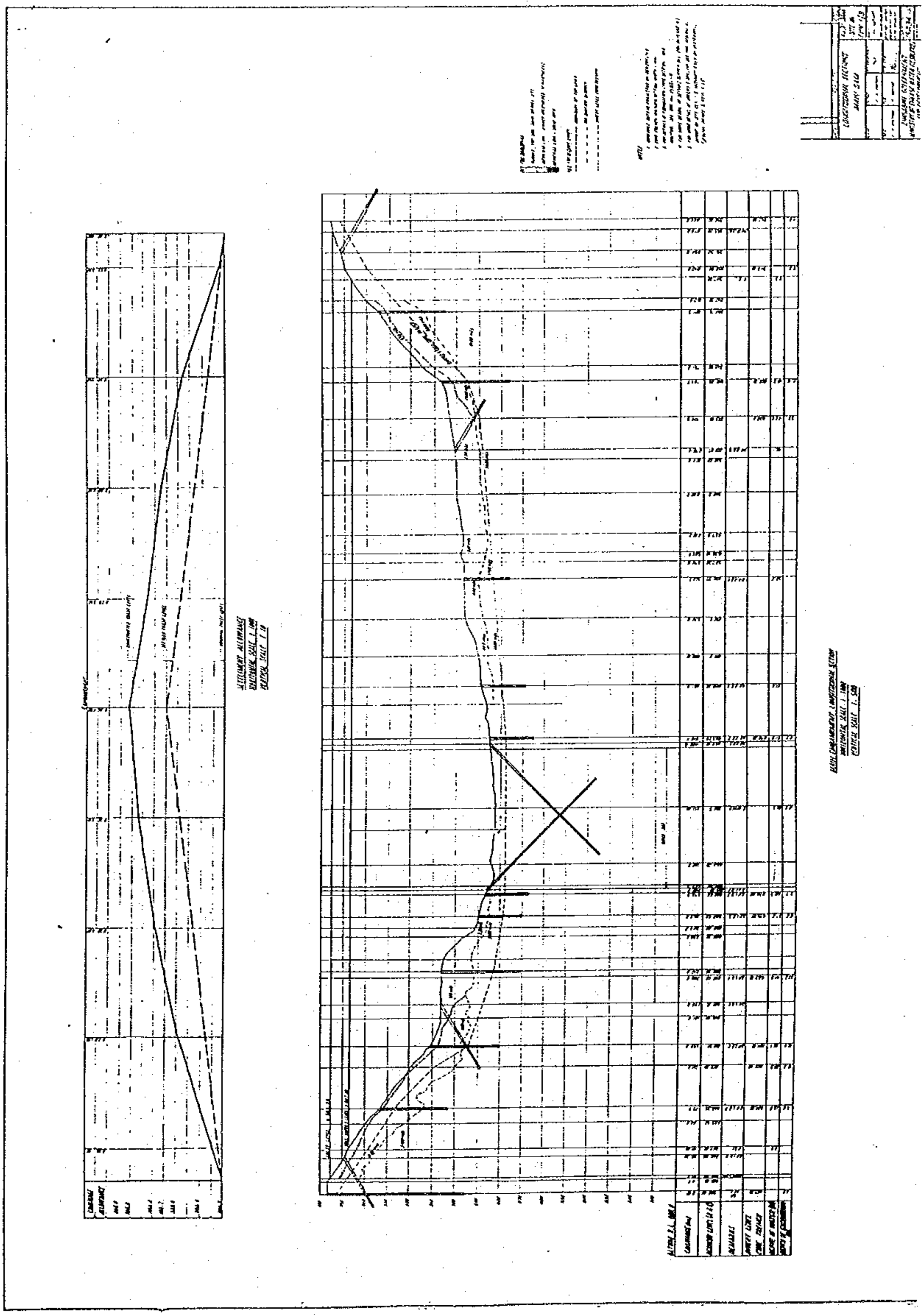


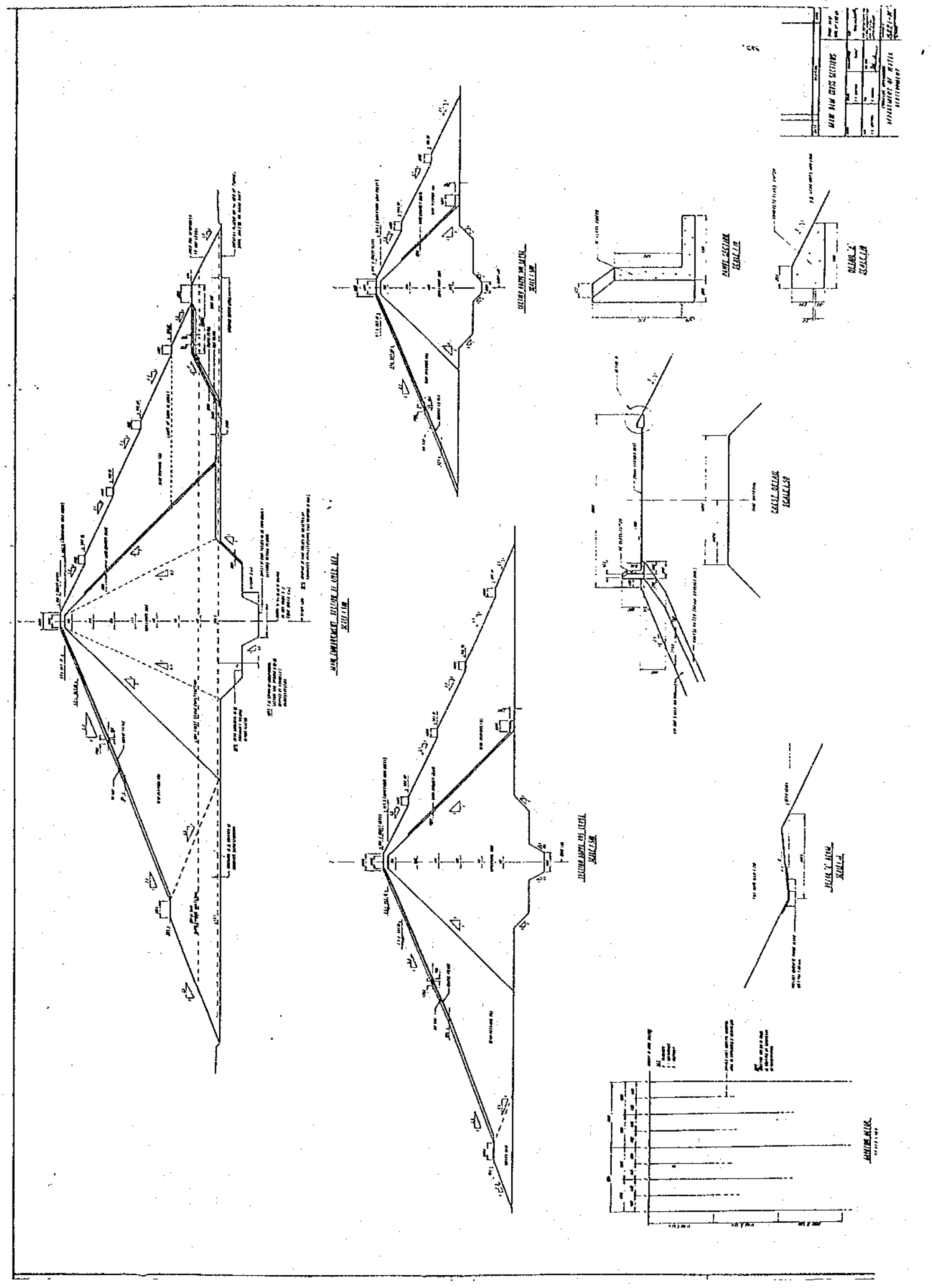
DESGD:
RECOMMENDED:
DRN: P. MUTASA
TCD: M. DICKSON
TCG. CKD: M.T.
APPD:
FOR SECRETARY FOR ENERGY AND

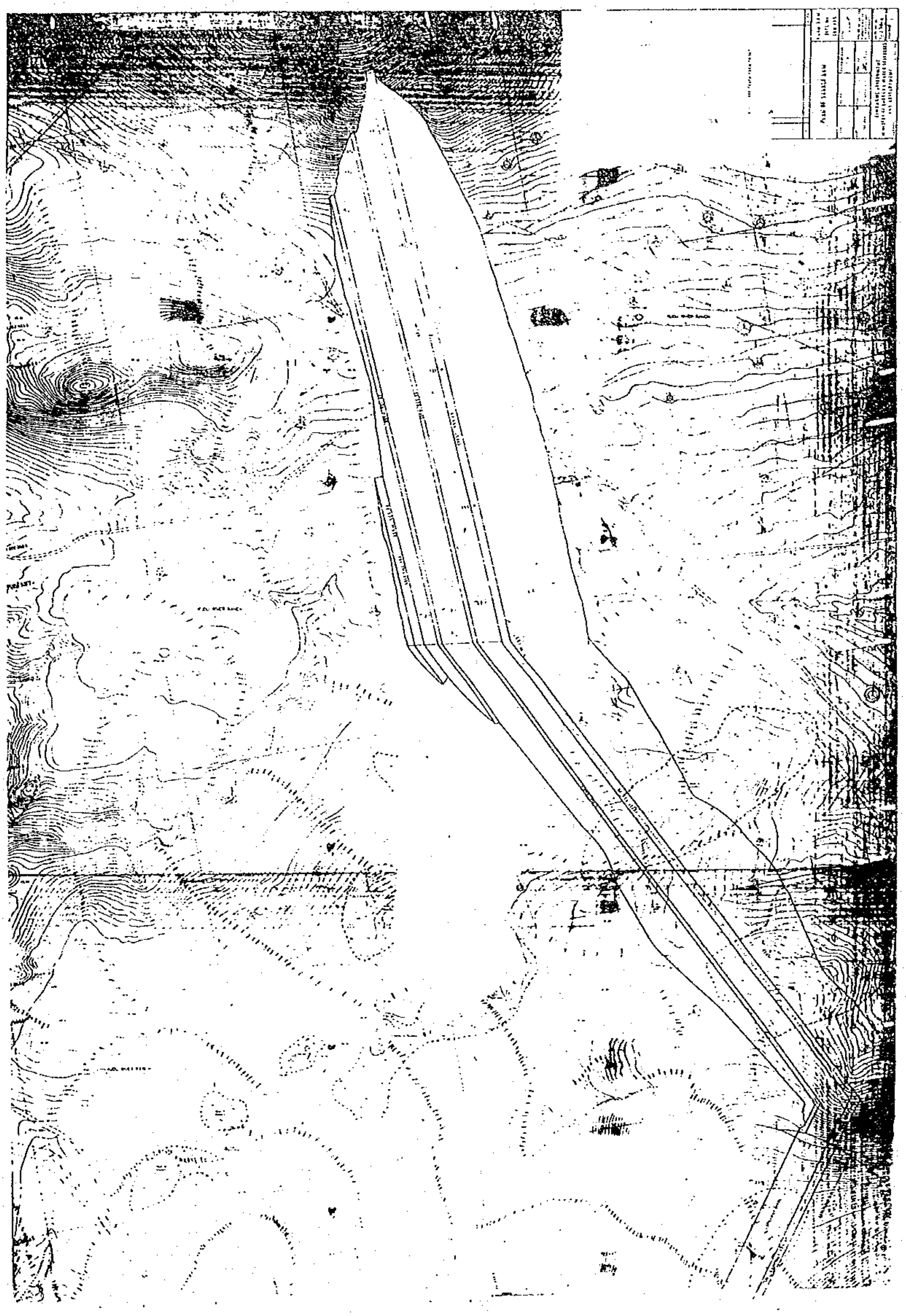
KUDU DAM CUN I/9
YIELD CURVE

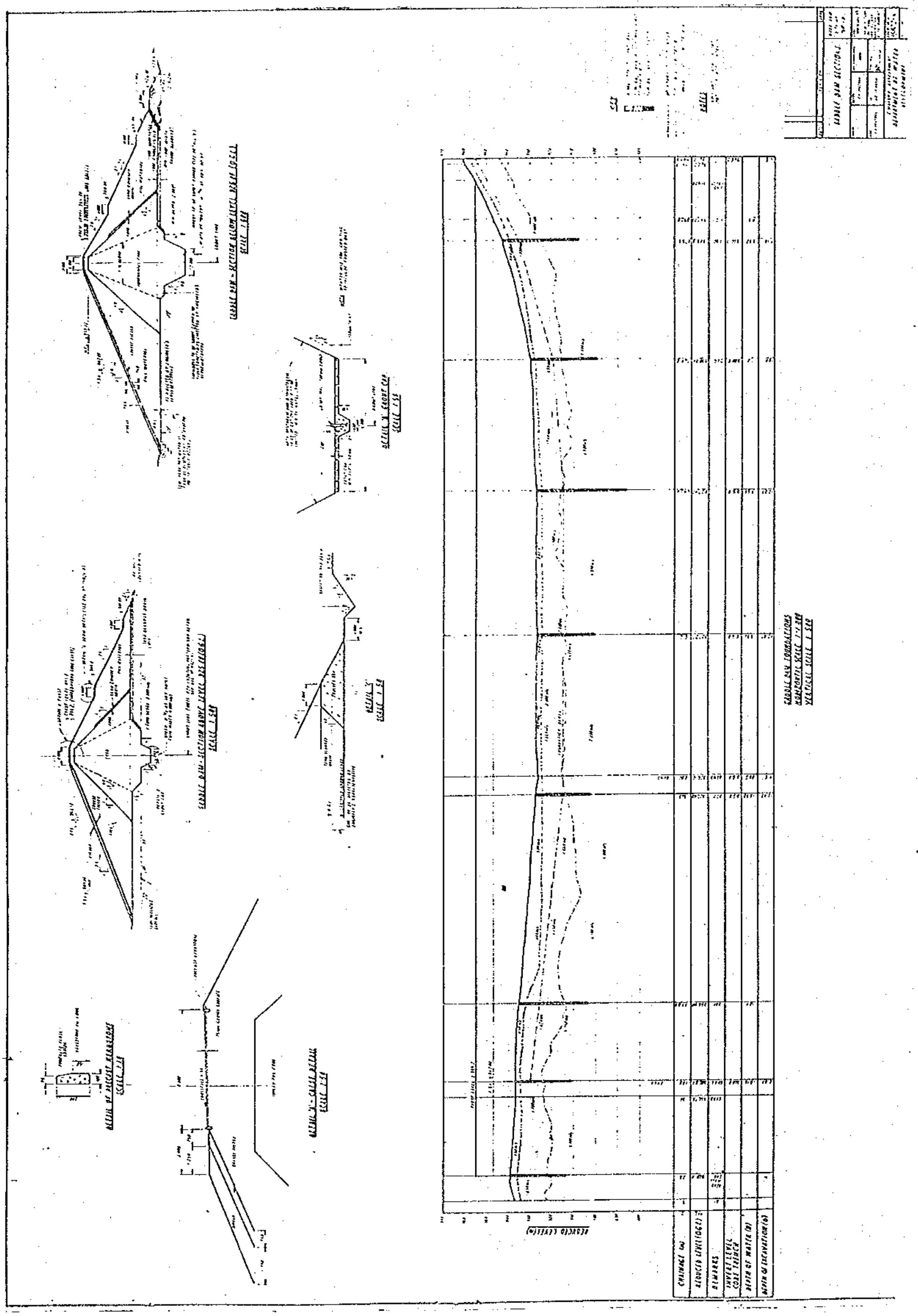
ZIMBABWE GOVERNMEN
MINISTRY OF ENERGY & WATE
RESOURCES & DEVELOPMENT
HARARE 16 NOV. 198
DRAWING No
REVISION

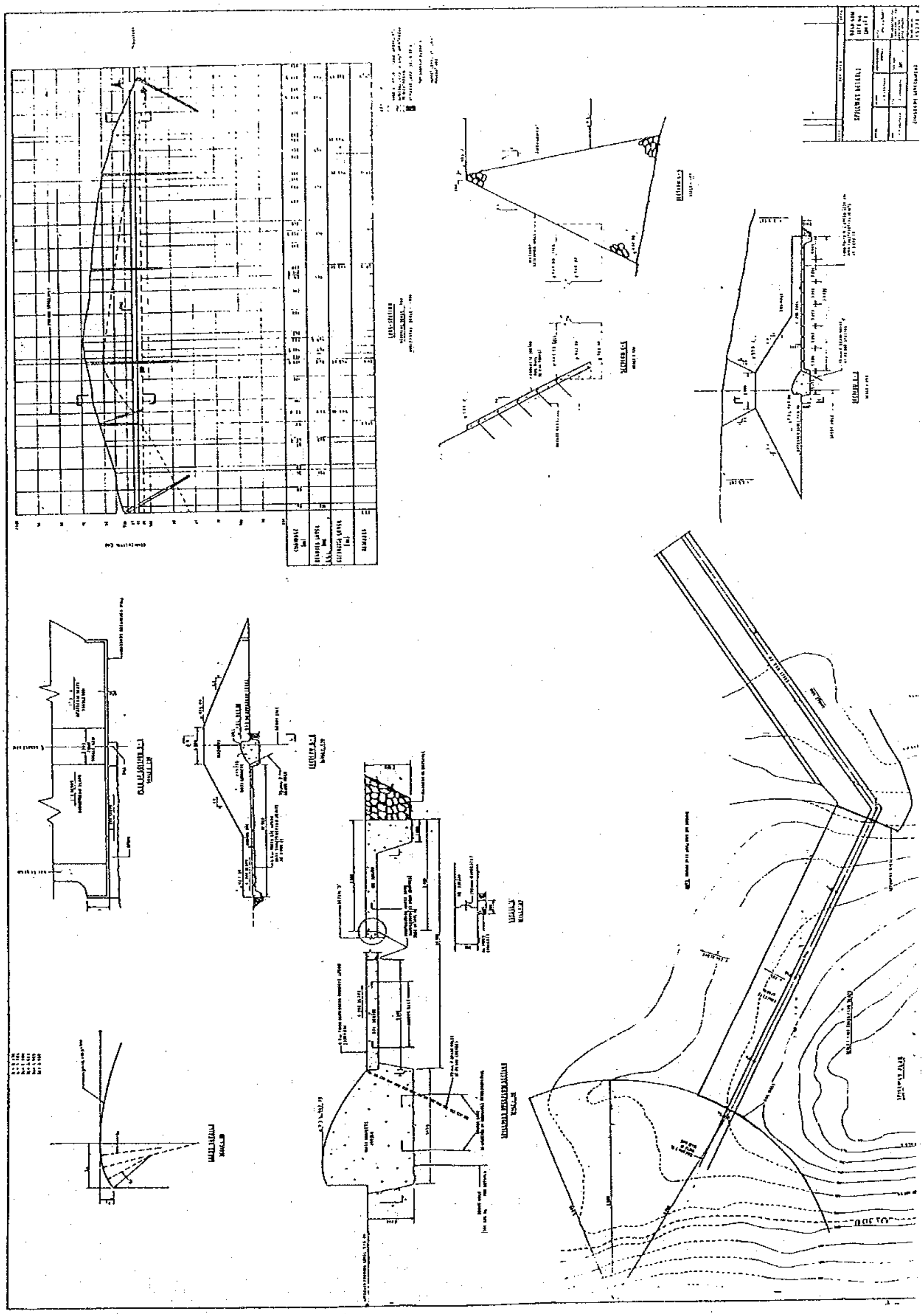


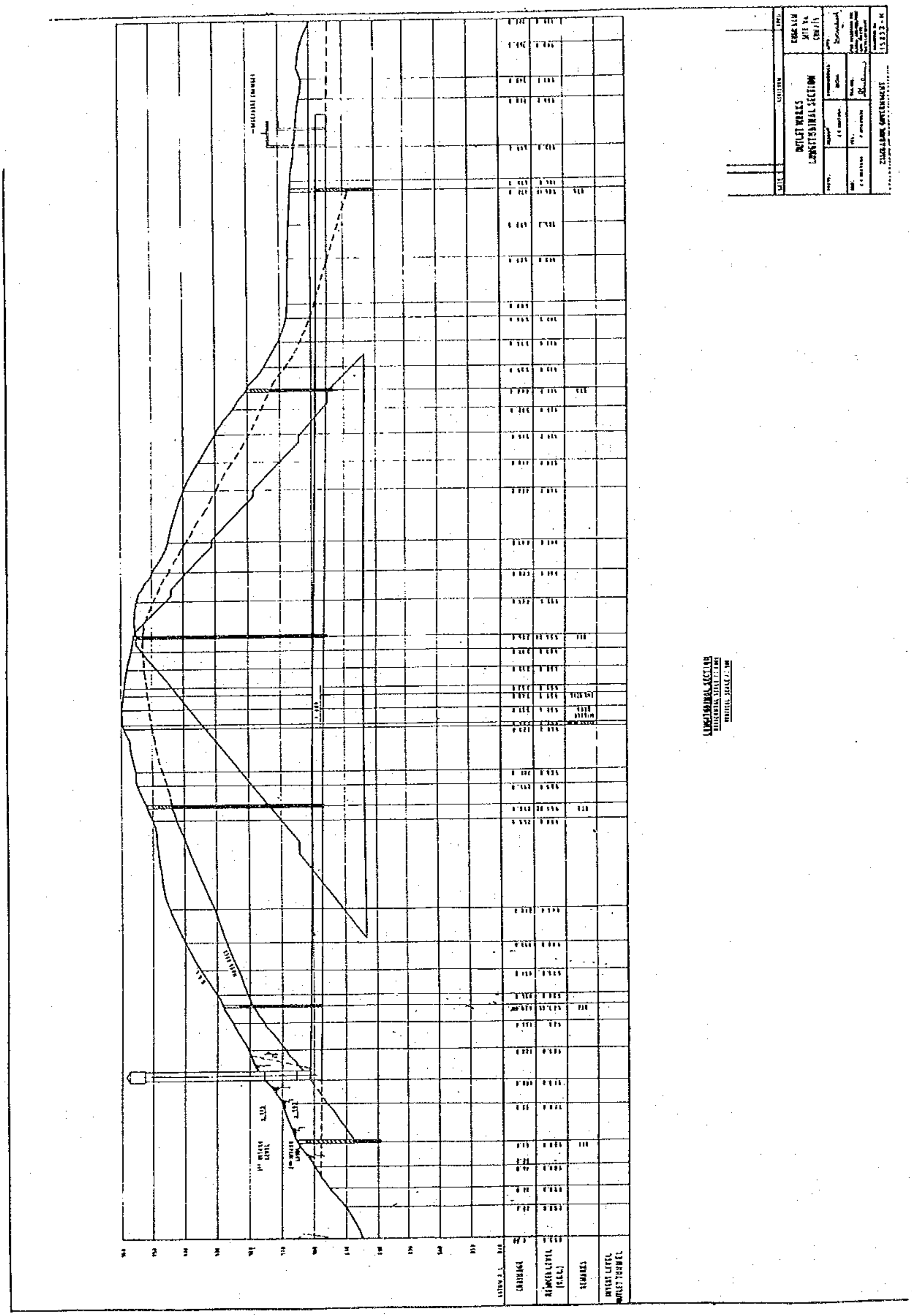


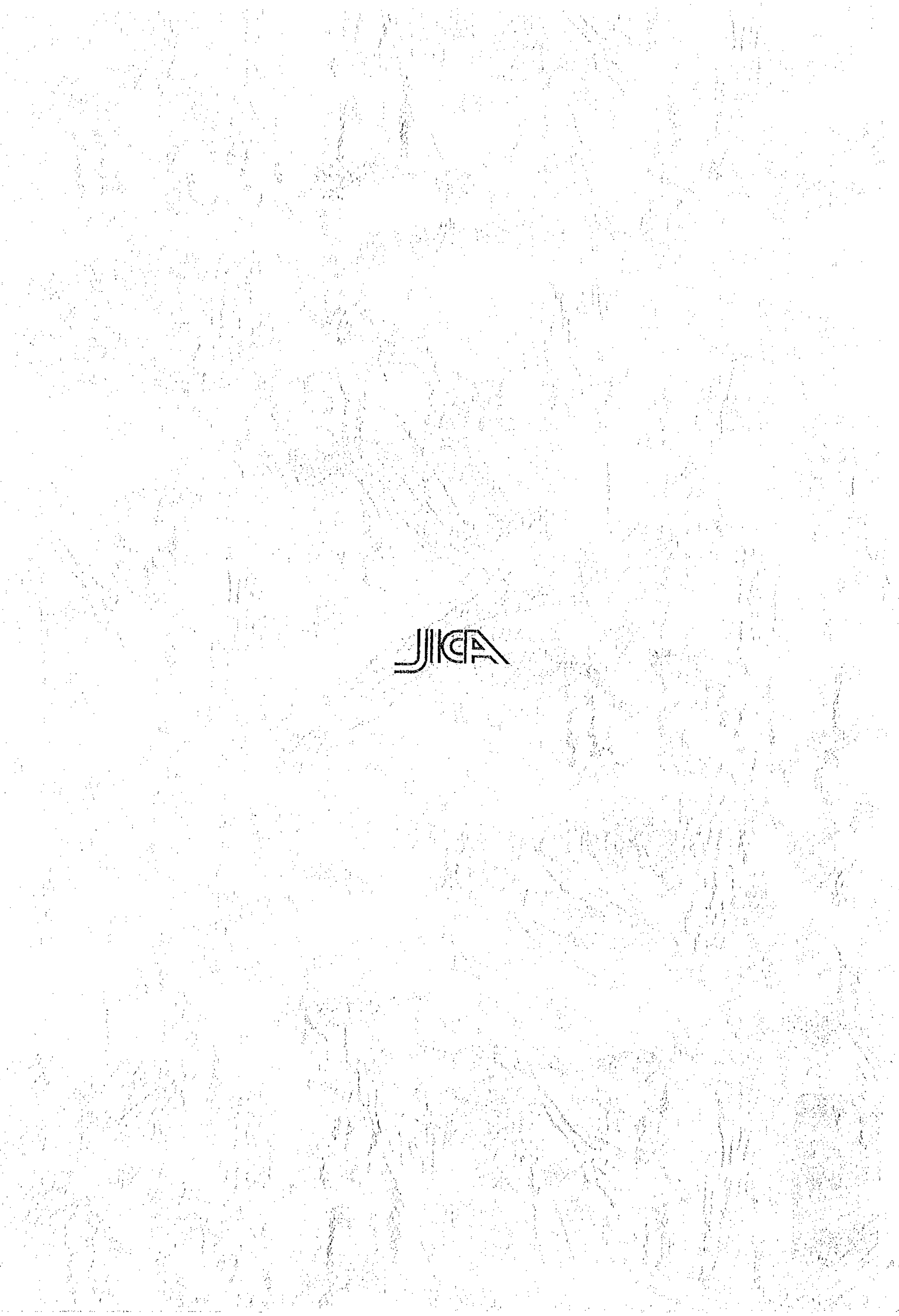











JICA