Rehabilitation of the Busongo Reservoir near Sirigu, Bolgatanga, Ghana

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Rapport 99

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REHABILITATION OF THE BUSONGO RESERVOIR NEAR SIRIGU, BOLGATANGA, GHANA

1. Introduction

This report has been drawn up to summarize the recommendations based on two studies carried out by students of Wageningen University to improve the performance of the Busongo Reservoir.

The referred studies are:

- Dry season water, a study into the performance of the Busongo dam near the village of Sirigu, Upper East Region, Ghana, by Liselot Smilde, March 1999.
- Spillway Busongo dam by Bart Jaeken, January 2001.

With the results of both studies all aspects to improve the operation of the reservoir have been highlighted, and all ingredients to carry out the engineering works have been made available.

The aim of this report is to inform all the authorities concerned into this project about its present state and the recommendations supported by Wageningen University to improve the use of water collected in the reservoir.

The authorities concerned are

in Ghana:

- Diocesan Development Office, Bolgatanga, Mr. Rex Asanga
- Busongo Dam Project Committee, Sirigu, Mr. Peter Anoah
- Ministry of Food and Agriculture, Bolgatanga, Mr. Jamboree Edward Andanye

in the Netherlands:

- Foundation "Ghana Fund P.M.", Brunssum, father Frans Meddens
- Netherlands Management Cooperation Programme (NMCP/PUM), The Hague, Mr. Cees IJsendoorn
- Wageningen University, Sub department Water Resources, Wageningen, Mr. Wubbo Boiten

This report has been composed of the following chapters:

2. The Busongo Reservoir
3. The authorities concerned
4. "Dry season water", study Liselot Smilde
5. "Busongo dam, spillway design", study Bart Jaeken
6. Additional remarks
7. Final recommendations

The author of this final report is Mr. Wubbo Boiten, guest lecturer with Wageningen University, and senior adviser water resources with NMCP. The author wishes to acknowledge both students, Liselot Smilde and Bart Jaeken, for their research, and his colleague Ir. G. de Jager for his contribution: the structural design of the spillway.

2. The Busongo Reservoir

The reservoir is located near the village of Sirigu in the Upper East Region of Ghana, not far from the city of Bolgatanga. The catchment area is about 27 hectares and slightly sloping (average slope 1%) at an elevation MSL + 650 m.

Figure 1 shows the catchment area between the Sirigu communities Busongo and Wugingo.

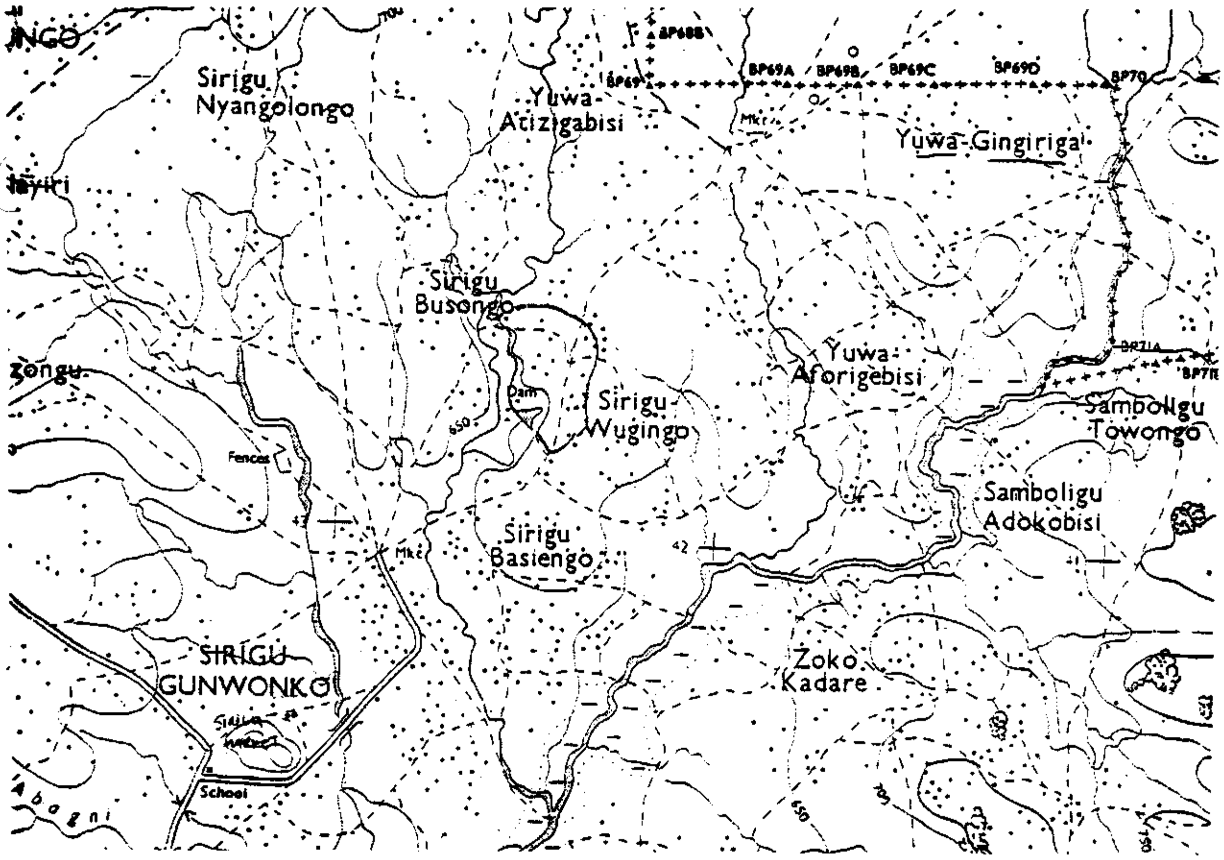


Figure 1 The Sirigu area (fragment from Ghana sheet 1001 A1. Survey of Ghana, 1966).

The present dam has been constructed by the Ghanaian Government in the 1960's. During the rainy season, mid April through mid October, the reservoir is filled by mainly overland flow. The average precipitation is 970 mm/year and the potential evaporation is about 1600 mm/year. The size of the reservoir is around 1.5 hectares when it is completely filled. The volume of the reservoir has a maximum of about 20.000 m^3.

During the long dry season the available water is used for domestic use, cattle drinking and building of houses.

Over the years the capacity of the reservoir is decreasing, both by silting up and by erosion of the dambody. In August 1996 there was a dam breach after heavy rains.

The dam was repaired in the next years.

At present the dam has a topwidth of 3 metres, an upstream slope 1:1,2 and a downstream slope 1:1. The dam has been made from clayey sand.

Figure 2 shows the reservoir. The overland inflow is from the north-eastern direction. The outflow is at the southern end of the dam through a natural earthen spillway, which has a

bottomwidth b=5 m, side slopes 1:20 and a depth d=0,45 m. In case the dam is spilling, excess water is flowing through the spillway in western direction forming a deep gully which is a threat for the stability of the dam.
Photo page I gives an impression of the dam as reported by Mark Boiten in April 2000 (at the end of the dry season).

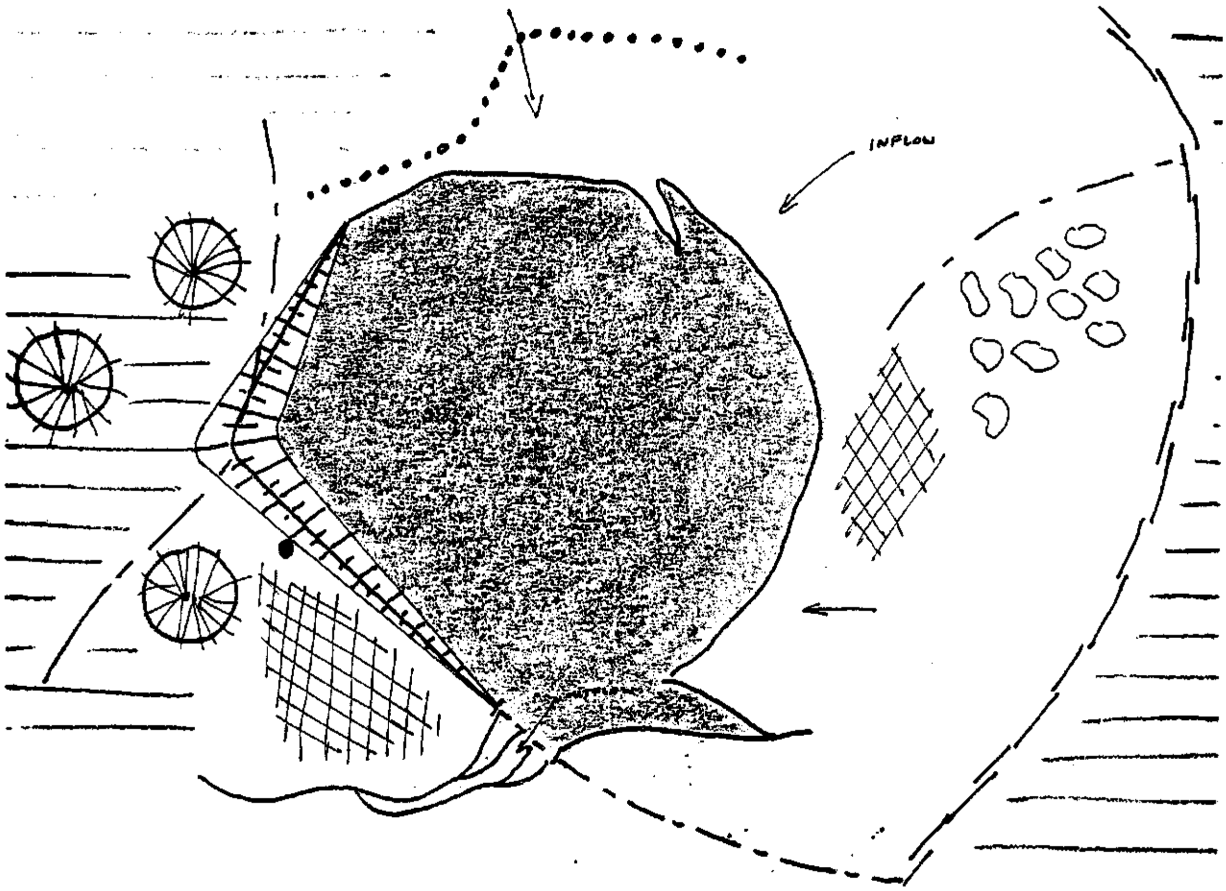


Figure 2 The Busongo reservoir and dam (after Smilde, 1999).

Waterharvesting with small reservoirs is very important to the local people as it forms part of the scarce water resources during the dry season.

Table 1 gives the averages (1978-1997) of monthly precipitation, maximum and minimum temperatures from the Navrongo weather station.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rain	0.0	0.0	16.9	49.5	112.5	137.5	168.5	273.2	161.2	44.6	2.6	1.7
t_{max}	35.2	37.7	39.5	38.7	36.0	33.0	31.3	30.7	31.8	34.2	36.8	35.9
t_{min}	20.1	22.7	25.7	26.5	25.3	23.9	22.9	22.6	22.7	22.6	20.6	19.2

Table 1 Climatological data (source: Ministry of Food and Agriculture, Bolgatanga).

3. The authorities concerned

In the context of the Busongo Reservoir Project, the following authorities are involved:

- The Diocesan Development Office, in Bolgatanga.
  This office is since a long period of years strongly involved in the development of the Busongo Community through their Agricultural co-ordinator Mr. Rex Asanga. They are up to now the official counterpart organization which is applying for technical and financial assistance on behalf of the Busongo Community.
- The "Busongo Dam Project Committee", in Sirigu.
  This committee has been set up in 2000 by the local people of the Busongo community. The secretary is Mr. Peter Anoah. One of their objectives is to mobilise resources and work to develop and improve the wellbeing and standard of living of the people of Sirugu. There is a close co-operation and consultation with the Diocesan Development Office.
- The Ministry of Food and Agriculture, in Bolgatanga.
  This authority has among others a wide experience in the design, construction and maintenance of reservoirs and dams. During the mission in October 2000 there was a fruitful consultation with their Rural Infrastructure specialist and Project Manager, Mr. Jamboree Edward Andanye.
- "Ghana Fund PM", in Brunssum.
  This organization is the Dutch counterpart of the Diocesan Development Office in Bolgatanga since the 1960's. Their adviser is Father Frans Meddens who was living in the Sirigu area as a missionworker for many years. They support several activities in the Upper East Region of Ghana, such as a clinic school, installation of pumps, ecological agriculture, administration school, and the Busongo Reservoir.
- Wageningen University
  Since 1997 the Agricultural University has been involved in the Busongo Reservoir Project by request of the Ghana Fund. In 1998 Lieselot Smilde carried out a student's research, supervised by Mr. Wim Spaan and colleagues, and titled: "Dry Season Water, a study into the performance of the Busongo Dam". In 2000 Bart Jaeken continued the research, supervised by Mr. Wubbo Boiten and colleagues, resulting in the report "Busongo dam spillway design".
- The Netherlands Management Cooperation Programme (NMCP/PUM).
  This organization assigns senior advisers requested to institutions in developing countries.
  In the Busongo Dam Project, the Diocesan Development Office is the applicant for technical assistance by Mr. Wubbo Boiten, who is also one of NMCP's advisers. Mr. Cees IJsendoorn is NMCP's coordinator for projects in Ghana.
  Annex I gives information about NMCP.

4. "Dry season water", study Liselot Smilde

After the dam breach in August 1996 and the repairworks in the dry season of 1998 there was a need for more research. The main question was, how to improve the performance of the Busongo Reservoir in Sirigu. This very practical question came from the Sirigu communities and reached – through the Diocesan Development Office in Bolgatanga and the Foundation Ghana Fund P.M. in Brussum – Wageningen University, Department of Erosion and Soil and Water Conservation. Liselot Smilde carried out the research, as a result of five weeks fieldwork in Ghana, and wrote her report "Dry Season Water" in March 1999.

Liselot Smilde focussed her study on two aspects:
- stability of the dambody
- increase of the capacity of the reservoir

Reviewing the "Dry Season Water" report in this short note, attention will be paid to a number of interesting research topics and the recommendations.

Research topics

Among many others the following items can be mentioned:
- rainfall is measured in Navrongo weather station, which is about 30 km from Sirigu. Only daily rainfall data are available. As a consequence a clear insight into rainfall intensity and duration in the Sirigu area is missing.
- there is no information about the permeability of the bottom layers of the reservoir. Therefore the losses of deep percolation can only be estimated roughly.
- the dam is a homogeneous earthen dam made from clayey sand. The dimensions of the dam (average width and slopes) are given in figure 3.

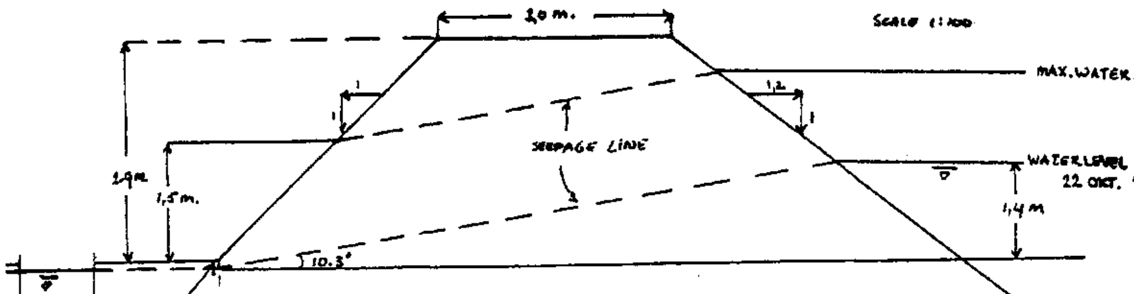


Figure 3 Cross section Busongo dam, next to the well, measured in November 1998

- clayey sands are pervious. Water from the reservoir will seep trough the dambody. Figure 3 shows the seepage line for the water level 22 October 1998 and the calculated seepage line for the maximum water level in the reservoir. Underneath the seepage line the dambody is saturated with water. Therefore, the seepage line should not end above the downstream toe of the dam. Neglecting this condition will add to the risk of dambreach. The best way to reduce this risk is to make the downstream slope flatter.

- the outflow of the reservoir – when it is at maximum water level – is a by nature created spillway, at the southern end of the dam. It is a local depression in the dam through which excess water is spilled, following a small gully, which flows into a nearby wadi. Neither the spillway nor the gully are protected against erosion.
- the peak discharge for the spillway has been estimated for a return period of T = 50 years at Q = 4.6 m^3/s (according to the Cook's method, which is one of the various methods to estimate peak discharges).

  A clear design for a protected spillway and downstream channel is missing in this study, mainly caused by lack of expertise in the field of civil engineering.
- A lot of attention has been paid in this study to erosion control measures how to reduce sediments – washed out from the upstream area – entering the reservoir. Vetiver grass strips, equally spaced at 20 metres are proposed along the contour lines.

Recommendations

S1 Broadening of the base of the dam to keep the seepage line underneath the downstream dam toe. The U.S. Department of the Interior recommends an upstream slope of 1:2.5 and a downstream slope 1:2 for small homogeneous earth fill dams, constructed from clayey sand and with adequate downstream drainage.

S2 Protection of the current spillway using gabions and stone mattresses. An expert should look into the possibilities how to guide the excess water from the reservoir towards the nearby wadi.

S3 Protection of the dam slopes. The upstream slope to be protected with stones. The downstream slope to be covered with vetiver grass and crotalaria (see figure 4) together with natural vegetation.

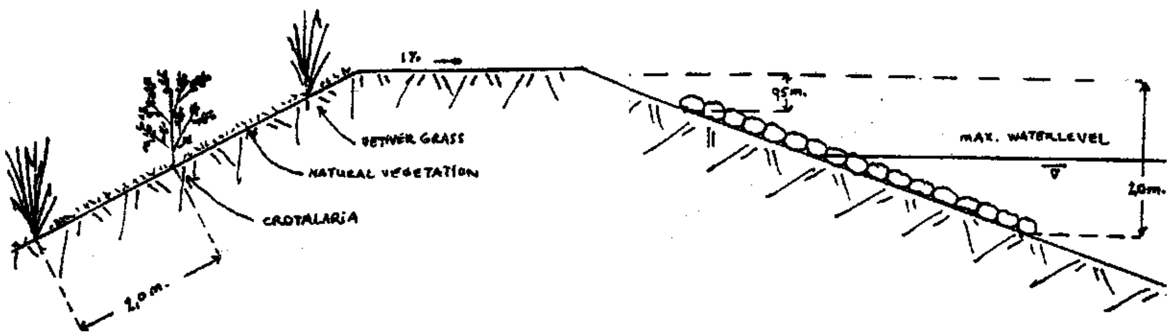


Figure 4 Protection of dam slopes

S4 The capacity of the reservoir will be increased by digging out part of the reservoir (keep a distance of 10 metres from the upstream toe of the dam with regard to dam stability). The excavated soil can be used for broadening the dam.

S5 Erosion control measures in the catchment area will reduce sediment inflow towards the reservoir. Both, strips of vetiver grass and crotalaria hedges are effective measures (a side effect is an increased retain of surface water in the catchment). Figure 5 gives an impression.

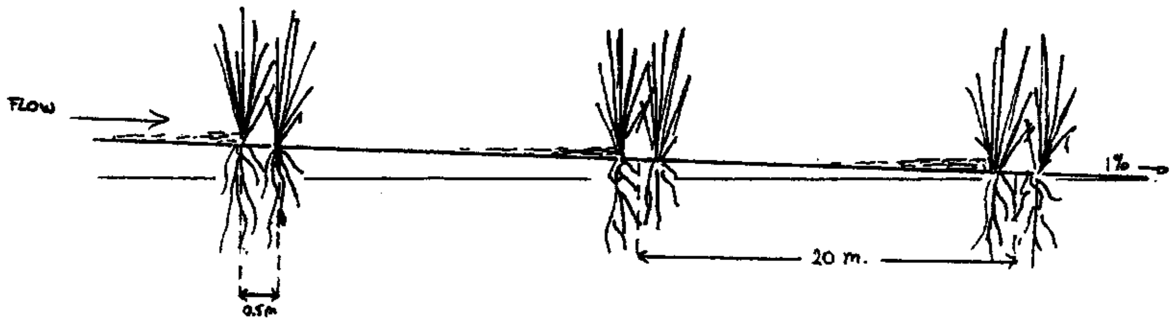


Figure 5 Vetiver grass strips for slope protection in the catchment

These five recommendations come back in chapter 6, Additional remarks, and chapter 7, Final recommendations.

5. "Spillway Busongo Dam", study Bart Jaeken

At the beginning of the year 2000, the Wageningen University, Sub-department Water Resources contacted the Foundation Ghana Fund P.M. about a possible continuation of the research on the Busongo Reservoir, now especially regarding the design of a spillway and downstream channel.

In June 2000 the author of this short note wrote a proposal for students research at the request of the Foundation Ghana Fund P.M. in consultation with the Diocesan Development Office in Bolgatanga.

Annex II gives the proposal for students research.

Bart Jaeken was available to carry out the research, supported by Mr. W. Boiten, senior project leader Hydrometry and senior adviser water resources with the NMCP.

Bart Jaeken focussed his study on three aspects:

- looking for possible indigenous technologies to spill excess water from small water reservoirs in Ghana or elsewhere in African countries.
- surveying the Busongo dam, part of the catchment upstream of the reservoir, and part of the area between the dam and the wadi.
- hydraulic design of a protected spillway and downstream channel towards the wadi.

Reviewing Bart Jaeken's report in this short note, attention will be paid to a number of interesting research topics and the recommendations.

Research topics

Among many others the following items can be mentioned:

- local techniques to spill excess water from the reservoir have not been found in the upper East Region of Ghana. All existing dams had concrete made spillways.
- the results of the topographical survey are given in the following figures:
  Figure 6 The reservoir when it is completely filled (storage $V_{FS} = 14500\ m^3$)
  Figure 7 The catchment area, 27 hectares with an average slope of 1%
  Figure 8 The irrigable area, downstream of the reservoir and the wadi
  The point of reference for all measured levels and contourlines is a black painted cross on the corner of the doorstep of the school, which is at 101.19 metres, with regard to an imaginary datum plane
- the top level of the dam is very irregular (see figure 6). The differences in height are more than 0.80 m between the highest and the lowest point. Moreover the slopes of the embankment are rather irregular.
- the denudation speed (erosion) in the catchment is estimated at 2 mm/year, resulting in a sediment inflow into the reservoir $V_s = 270000 \times 0.002 = 540\ m^3$ soil/year.
  The design life time of the reservoir is 14500/540 = 26.8 years (roughly L = 30 years)
- the estimation of the peak discharge for the spillway has been based on the following assumptions:
  - maximum 24 hr rainfall P = 223 mm for a return period T = 500 years (6% risk of encountering an event for a life time L = 30 years)

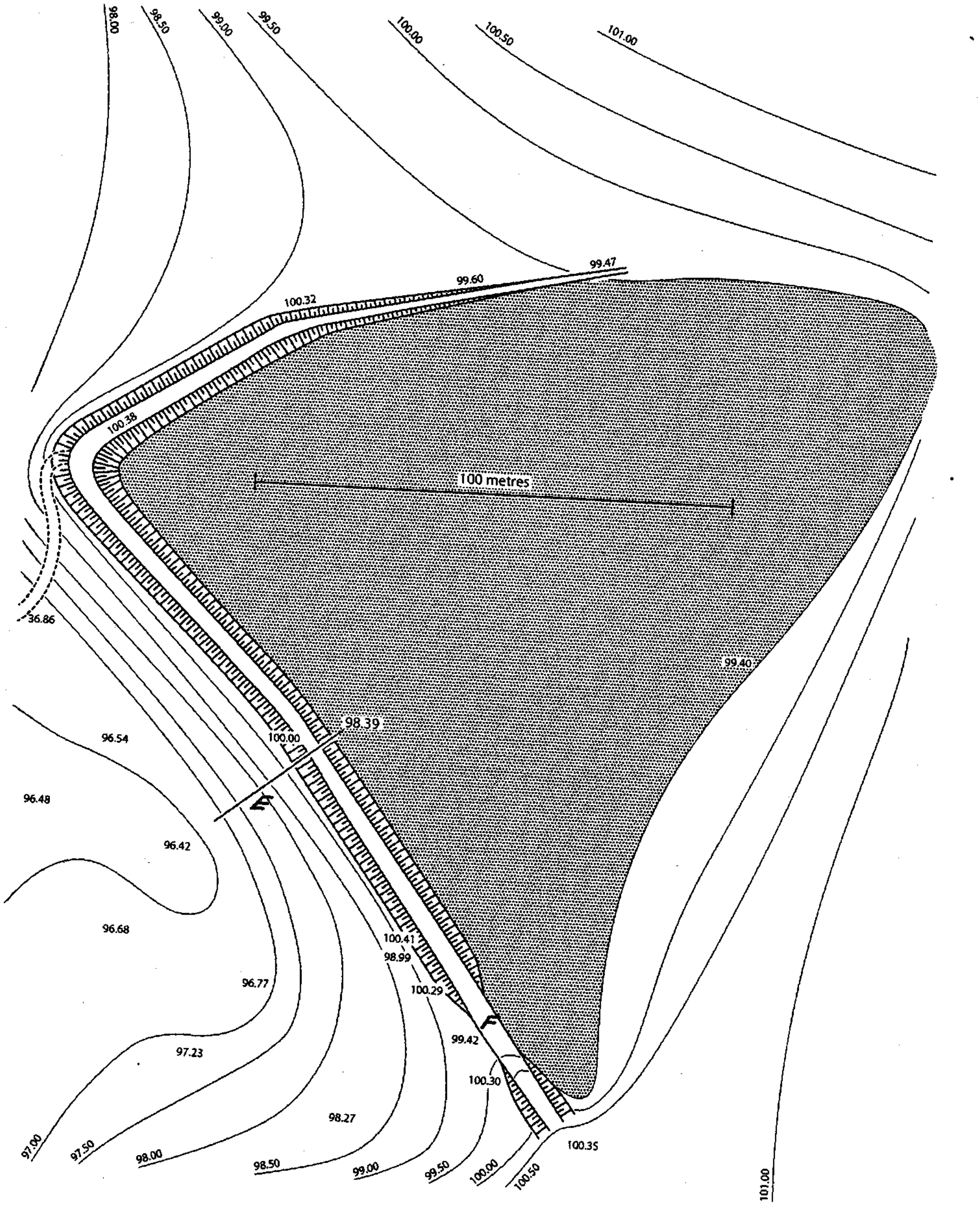


Figure 6 The reservoir, surveyed in November 2000

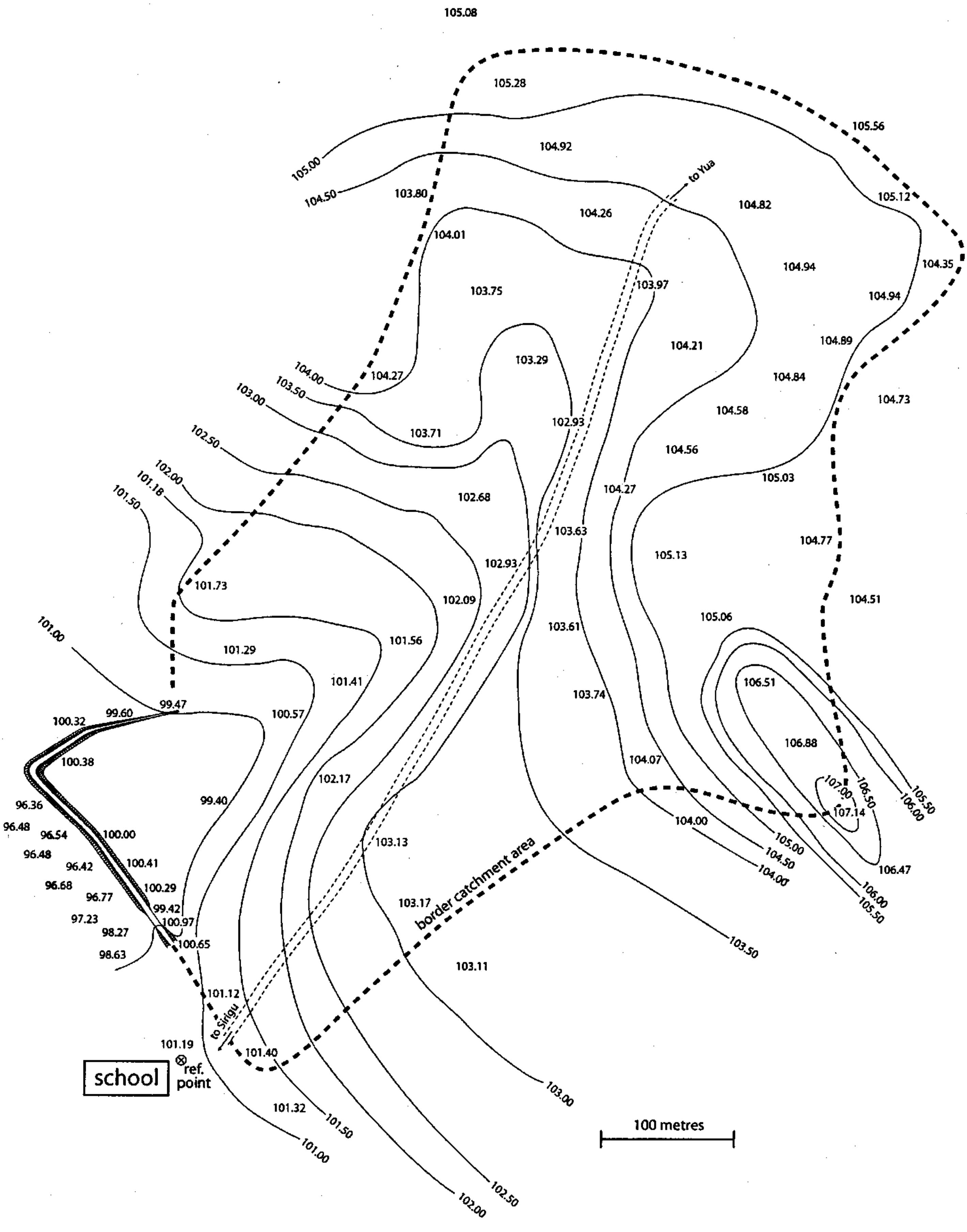


Figure 7 The catchment area, surveyed in November 2000

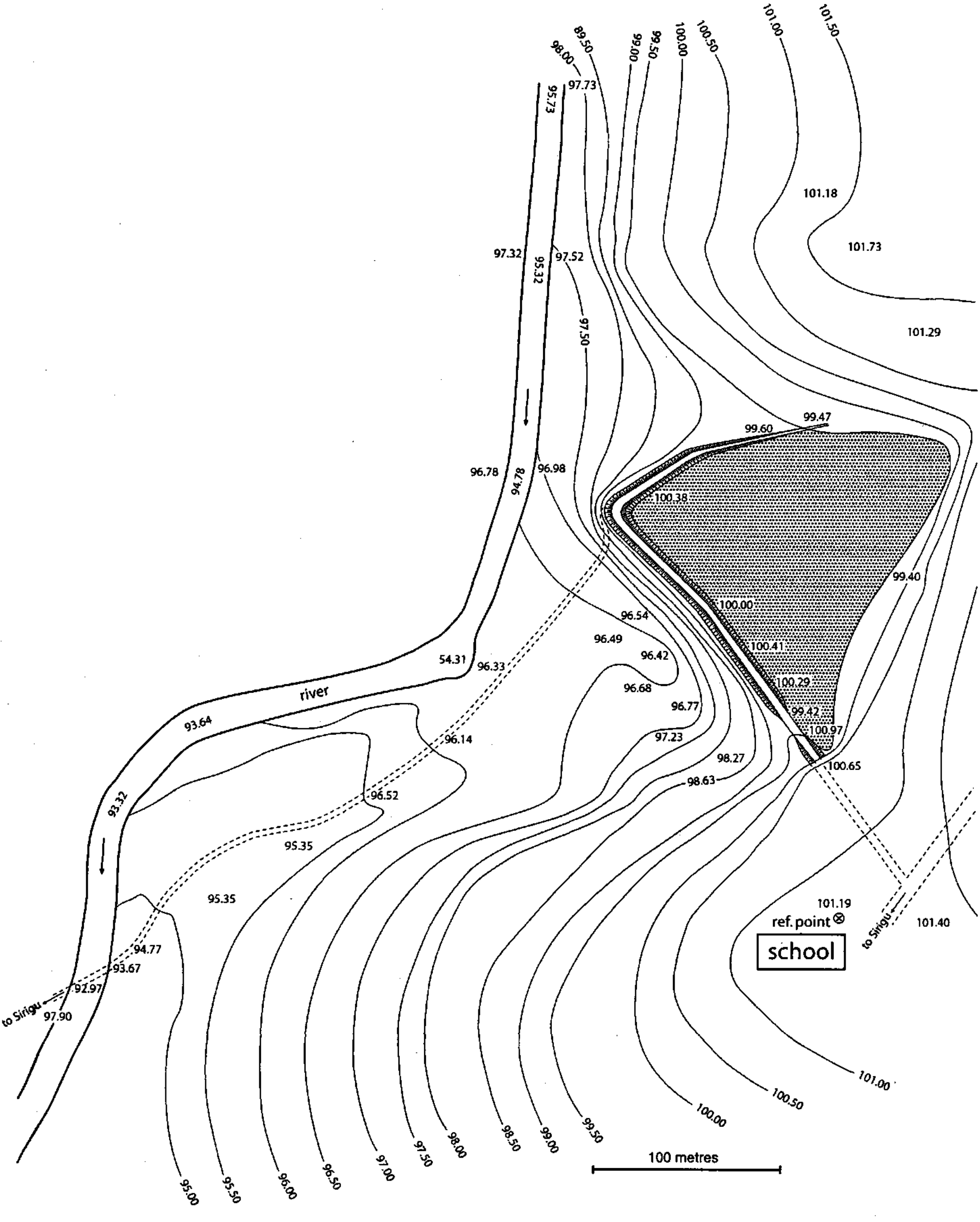


Figure 8 The irrigable area, surveyed in November 2000

- the run off factor (percentage of rainfall that reaches the reservoir) is estimated at f = 0.5, which gives a water inflow $V_w = 270000 * 0.223 * 0.5 = 30105\ m^3$.
- the inflow duration is taken at t = 6 hours. The maximum inflow intensity $Q_{max} = 30105\ m^3 / 0.5 * 6 = 10035\ m^3/h = 2.8\ m^3/s$ (according to the unit hydrograph method, which is one of the various methods to estimate peak discharges)
  The spillway and its downstream channel are designed for this peak discharge $Q_{max} = 2.8\ m^3/s$.

Recommendations

T1 The dam body shall be reshaped, roughly corresponding with the present ground plan and taking into account the following:
- the top level is 100.60 m (actually the average height is about 100.25 m)
- the top width is b = 3.00 m
- both ends of the dam are extended as far as they reach the 100.60 m contourline.

T2 A concrete spillway has been planned at location E (not at the same location F as before) for two reasons:
- the spillway can be made as a straight structure (contourlines are parallel to the dam)
- an undisturbed compacted sand body for the foundation of the concrete spillway

The locations E and F have been indicated in figure 6

T3 The main dimensions of the spillway are as follows:
- spillway crest at a level 99.90 m and with a width B = 6.00 m
- basin floor at a level 96.90 m and with a width b = 4.00 m and a length l = 6.30 m. At the end of the floor there is a sill at a level 97.15 m.

The basin floor and the endsill are situated lower than the surrounding ground level.

T4 Downstream of the end sill there is a short spillway channel, necessary to bridge the difference in level between the end sill and the surrounding ground level. The channel is expanding from b = 4 m at the endsill to B = 14 m at the end, in order to reduce the flow velocities. The length is l = 14.50 m. Theoretically its bottom is sloping 1 $^{o}/_{oo}$. The channel bed has a carpet of stones d ≥ 0.03 m.

T5 Downstream of the spillway channel water flows in the direction of the wadi. However, countourbunds of stone can be constructed to use the spilled water for the cultivation of rice.

A complete construction drawing of the spillway and the spillway channel is given in chapter 7 of this short note.

The structural design (reinforced concrete) is given in Annex III.

These five recommendations come back in chapter 6, Additional remarks, and chapter 7, Final recommendations.

6. Additional remarks

Both studies – 'Dry season water' and 'Busongo dam spillway design'– have provided valuable materials for the rehabilitation of the present Busongo Reservoir. In fact they are complementary; the first study worked at the stability of the dam (seepage line) and erosion control measures, while the latter research aimed at a topographical survey and the design of a spillway.

Some remarks:

1. *Hydrological information* . There is a lack of reliable information on a number of data: rainfall intensity, permeability of the reservoir bed (percolation), permeability of the dambody (seepage) and the runoff factor. It is therefore difficult to set up a reliable water balance of the reservoir and to plan the rehabilitation of the existing reservoir (dam stability and spillway design).
   The recommendations of both studies have therefore been based on a number of assumptions.
2. The recommendations S_1, S_3 .... S_7 from the 'Dry season water' study and the recommendations T_1 ... T_5 from the 'Busongo dam spillway design' will be followed, except for some small adjustments, which will be summarized in chapter 7.
3. The spillway has been designed to spill excess water from the reservoir. This may occur only if both following conditions have been fulfilled:
   - the reservoir is at full supply level (99.90 m)
   - after one or various heavy rain showers

   The design discharge Q = 2.8 m^3/s is a correct base for further design.
4. It is common knowledge that an increasing discharge goes together with an increasing water level. Table II gives this relation for the water levels in the reservoir and in the spillway channel as a function of the discharge over the spillway.

Discharge on the spillway Q (m^3/s)	Head over the spillway h_1 (m)	Water level in the reservoir WL1 (m)	Water depth in spillway channel d (m)	Water level in spillway channel WL2 (m)
0.30	0.10	100.00	0.11	97.01
0.86	0.20	100.10	0.20	97.10
1.60	0.30	100.20	0.29	97.19
2.48	0.40	100.30	0.37	97.27
3.49	0.50	100.40	0.45	97.35

Table II Water levels in the reservoir and the spillway channel as a function of the discharge Q

7. Final recommendations

Figure 9 gives the layout of the spillway and the spillway channel.
Figure 10 shows the rehabilitated reservoir with extended dam ends and the location of the concrete spillway

The following recommendations have been compiled from the two students research projects, with some adjustments.

U1 *Reshaping the dambody* (T_1 and S_1)

- top level (crest of the dam) shall be brought at 100.60 m (tolerance ± 0.05 m)
  The point of reference is a black painted cross on the corner of the doorstep of the school, which has a level of 101.19 m.
- width of the crest b = 3.00 m
- both ends to be extended as far as the 100.60 m contour lines (see figure 10).
  The extension on the north end is AB = 80 m and on the south end CD = 10 m.
- broadening the base of the dam is recommended to keep the seepage line underneath the downstream toe of the dam. From a practical viewpoint broadening should be done only at the downstream slope as far as 1:2.5
- the present spillway shall be kept as it is until the construction of the spillway has been completed (thus maintaining the spilling capacity during the rainy season in 2001).

U2 *Protection of the damslopes* (S3)

The upstream slope to be protected with stones and the downstream slope to be covered with vetiver grass and crotalaria together with natural vegetation (see figure 4).

U3 *Reservoir capacity* (S4)

The capacity of the reservoir shall be maintained or increased by digging out the reservoir, starting at the inflow side (east), but keeping a distance of 10 metres from the toe of the dam (dam stability and control over the seepage).

U4 *Erosion control measures* (S5)

Erosion, caused by overland flow in the catchment area, can be reduced by strips of vetiver grass and crotalaria hedges (see figure 5)

U5 *Location of the concrete spillway* (T2)

The spillway has been planned at location E (see figure 10) for two reasons:
Parallel contour lines are favourable for a straight spillway, and an undisturbed compacted sand body is necessary for the foundation of the concrete spillway.

U6 *Dimensions of the spillway* (T3)

Figure 9 gives all dimensions of the spillway and the downstream spillway channel. The main dimensions are as follows:

- the spillway crest is at a level 99.90 m and has a width B = 6.00 m.
  The head over the crest is h_1 = 0.43 m for the design discharge Q = 2.8 m^3/s
- the basin floor is at a level 96.90 m and has a bottom width b = 4.00 m and a length l = 6.30 m. The endsill has a level 97.15 m.

U7 *Spillway channel* (T4)

Downstream of the endsill there is a short spillway channel, bridging the difference in level between the end sill and the surrounding ground level. The channel is expanding from b = 4.00 m at the endsill to b = 14.00 m at the end, and has a length l = 14.50 m. The channel bed is horizontal and has a carpet of stones d ≥ 0.03 m.

The expected water depth in the spillway channel is d = 0.40 m for the design discharge Q = 2.8 m^3/s.

U8 *Contour bunds* (T5)

Downstream of the spillway channel contour bunds of stone can be constructed to use the spilled water for rice cultivation.

U9 *Structural design of the concrete spillway*

Annex III gives all the calculations on which the structural design has been based:
- stability of the structure
- estimation of max. bending moments and shear forces
- concrete design

This design has been done by Ir. G. de Jager

U10 *The total costs*, including reshaping the dam and the construction of the spillway and the spillway channel have been estimated at DFL. 25.000,-. It is recommended to check this.

U11 *Hydrological equipment*

It is recommended to install a raingauge in the catchment area and a staff gauge in the reservoir. Daily readings of both gauges give a good insight in the runoff factor of the catchment area, which is of great value for future designs.

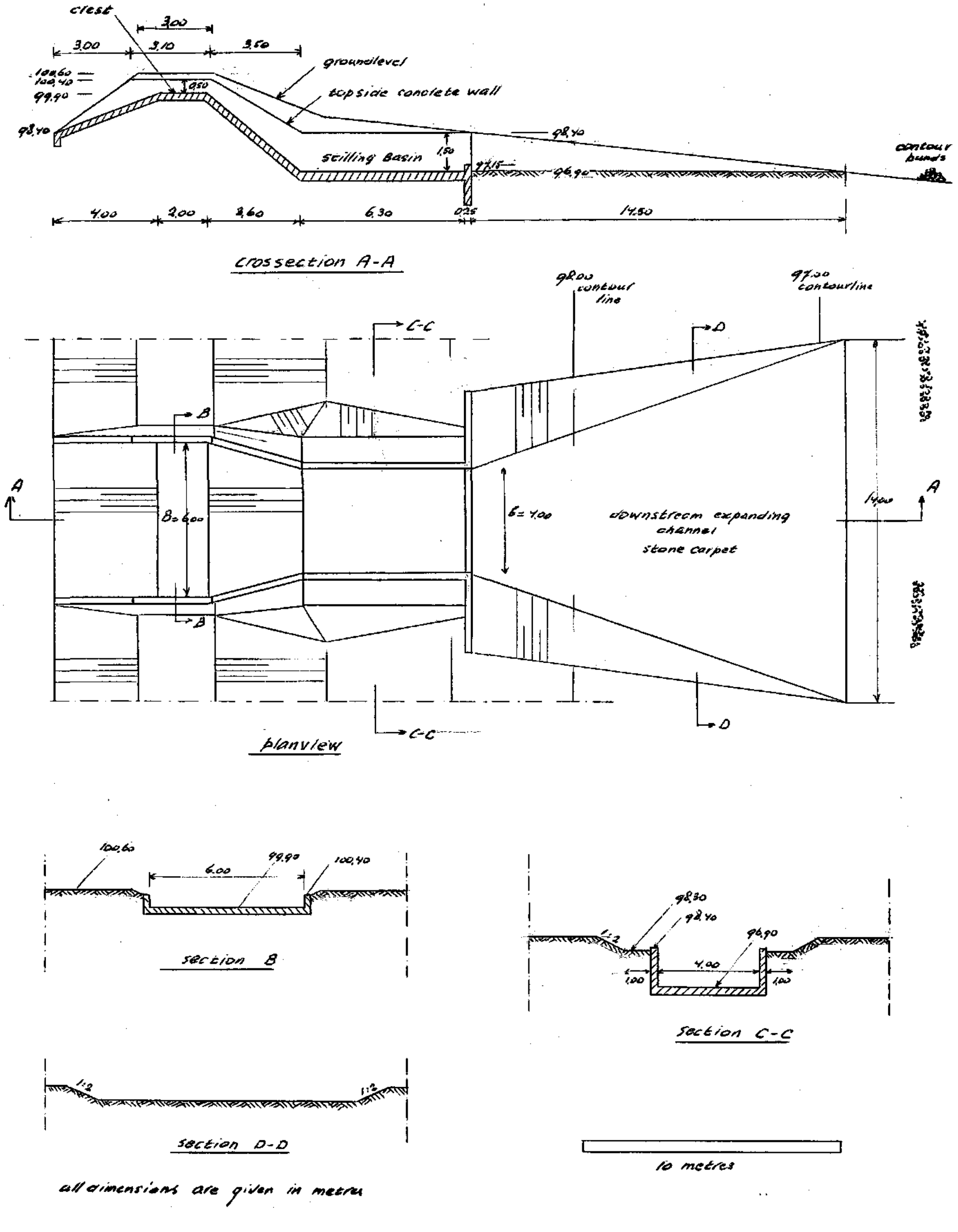


Figure 9 Layout spillway and spillway channel.

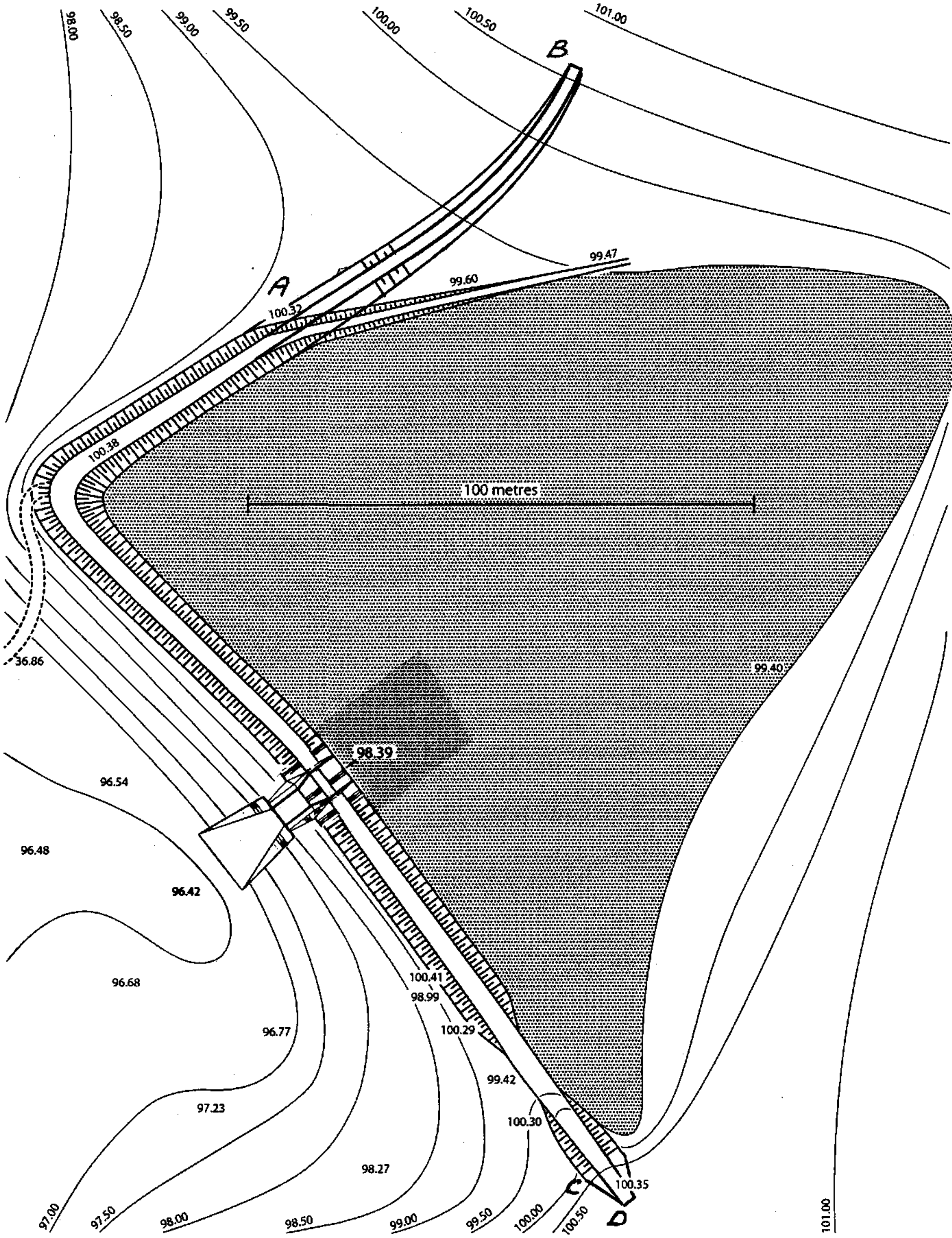


Figure 10 Extended dam alignment and location new spillway

Annex I Information about NMCP (taken from the Annual Review 1999)

Mission statement

The Netherlands Management Cooperation Programme (NMCP) assigns senior advisers when requested to businesses and institutions in developing countries and in Central and Eastern Europe.

NMCP's advisers are volunteers. They are asked to go on missions on the basis of their many years of experience and superior knowledge in a wide variety of fields. They are independent and receive no financial reward for their services. NMCP pays for travelling expenses and the other costs of missions. Applicants requesting assistance pay for local travel and accommodation costs.

NMCP only works for companies and institutions which are not in a position to recruit and finance the assistance their require themselves. In its choice of countries, NMCP adheres to the policy of the Netherlands government and of the European Commission both of which largely pay for the costs of missions by means of annual grants.

NMCP is a partnership between employers and the government, notably the Ministries of Foreign Affairs and of Economic Affairs and the VNO-NCW confederation of Netherlands industry and employers. NMCP was founded in 1978 by the employers' organisations and has been operating as an independent organisation since 1997 while still retaining close ties with VNO-NCW.

NMCP seeks to contribute to the development of market economies in the target group countries through the direct transfer of knowledge and experience. The programme also aims at expanding employment and promoting clean production processes in those countries.

Where possible NMCP supports the integration of industry in the world economy and in this context promotes trade, investment and partnerships between business and industry in the Netherlands and in the target group countries.

NMCP has programmes for trainees in the Netherlands intended for people from companies and institutions which have been advised by NMCP. A special programme in the Netherlands allows those in the target group countries to get in touch with business partners and acquire support in finding investment resources.

Activities in the world

Introduction

The year under review saw 1356 missions (1567 projects) being implemented: 260 (267) in Africa, 334 (372) in Asia and the Middle East, 207 (241) in Latin America, 555 (687) in Central Asia and Central and Eastern Europe. Of this total 750 missions were financed by the Directorate General of International Cooperation at the Ministry of Development Cooperation and 454 missions in Central and Eastern Europe were financed by the Ministry of Economic Affairs. Twenty-two missions were implemented with the support of the Ministry of Housing, Spatial Planning and the Environment. Their aim was to achieve a cleaner environment through sustainable development and production. Other missions were implemented with the financial support of other donors and agencies of the Ministries of Economic Affairs and Foreign Affairs (see other activities). Moreover 90 training programmes and 21 Business Link projects were organised including ten business trips of entrepreneurs from Central and Eastern Europe. Sometimes these activities produced initial agreements and more frequently actual business.
NMCP was active in 89 countries in 1999.

Trainee programmes

Ninety training courses were arranged in the Netherlands in 1999 bringing 146 trainees to the Netherlands. Companies which have been assisted by NMCP may have a member of their staff attend a practical training course in the Netherlands. The condition is that the NMCP adviser regards this as a worthwhile follow-up to the mission. The main aim of the period of practical training is to help eliminate bottlenecks that have been spotted in the company's business operations. The courses vary from one to six weeks. Trainees gain practical experience during this period in a number of companies in the Netherlands, which cooperate in the practical training programme for no financial reward. NMCP has concluded an agreement on formal training with a number of industry organisations in the Netherlands.

Annex II Proposal for students research (January 2000)

Waterharvesting in the Upper East Region of Ghana

The sub-department Water Resources of Wageningen University, is looking for a student who is willing to complete his/her study with a three months research project.
Objective: recommendations to improve the management of the Busongo Reservoir (2 ha) near Bolgatanga.

Project description. Small water reservoirs have been constructed by the local rural people in the Upper Region of Ghana for a long time: surface run-off from precipitation is collected in reservoirs during the wet season from May through October. In the dry season (November through April) water is used mainly to water cattle. The Busongo Reservoir is not always functioning properly, mainly for three reasons: inflow of sediments reduces the reservoir capacity, the dam surrounding the reservoir is unstable and therefore breaks occasionally, a spillway is lacking which increases the risk of dam failure during maximum supply levels.
In 1998/1999 Mrs. Lieselot Smilde (from Wageningen University) carried out a student's research "Dry Season" which focussed on the operation of the Busongo Reservoir. In this study much attention was paid to sediment inflow and dam instability. However the absence of a spillway was not clearly part of the scope of her research.
The problem definition for the present project is:

a) To investigate whether there are indigenous technologies to spill excess water from small water reservoirs in Ghana or elsewhere in countries where water harvesting is practised (literature search and inquiry in Ghana).
b) The hydraulic design of a spillway, according to the civil engineering guidelines.
c) To investigate what is the most appropriate spillway design for the Upper East Region of Ghana (from a cultural point of view, technical feasibility and financial feasibility).

The intention is to use the Busongo Reservoir as a good example for many other small reservoirs in the region.
The research has been requested by the Foundation "Ghana Fund P.M." in Brunssum, (The Netherlands) in consultation with the Diocese of the Roman Catholic Church in Bolgatanga (Ghana). The research in Ghana is supervised by the agricultural coordinator of the Diocese in Bolgatanga.

Desired background: Hydrology, Hydraulics and some affinity with the Civil Engineering.

Period: October through December 2000, subdivided as follows:

a) two weeks preparation in The Netherlands
b) five weeks in Ghana, collecting information and surveying the Busongo dam. The research lecturer from Wageningen University will provide support during the first week
c) six weeks reporting in The Netherlands. The report will include reservoir management recommendations
   The report shall be available in the English language in January 2001.

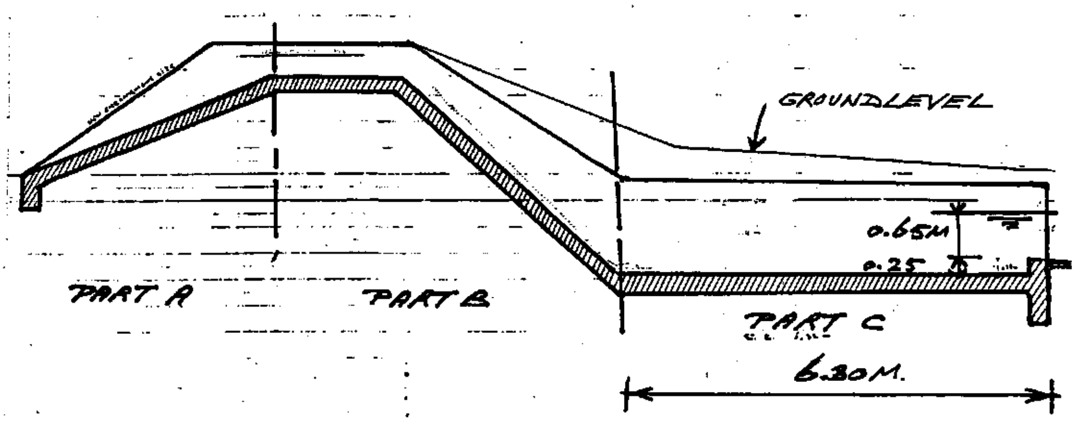
Research lecturer: Ing. Wubbo Boiten, senior project leader Hydrometry at the Wageningen University, phone: +31.317.482891, fax: +31.317.484885 and e-mail: wubbo.boiten@users.whh.wau.nl

Annex III Spillway – structural design

1. STABILITY OF STRUCTURE

THE SPILLWAY WILL BE CONSTRUCTED IN THREE FASES A, B AND C. EACH PART IS CONSIDERED TO BE A MONOLITH.

THE REINFORCEMENT IN ALL PARTS WILL BE IDENTICAL.
THE MOST CRITICAL PART FOR THE DESING WILL BE PART C.
THE THICKNESS OF THE FLOOR WILL BE DETERMINED BY THE UPLIFT PRESSURE, WHILE THE THICKNESS OF THE WALL IS DETERMINED BY THE BENDING MOMENTS.

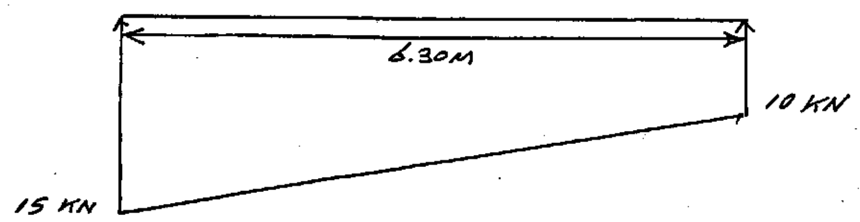


UPLIFT OF PART C

1) TAKE: THICKNESS WALL 0.25M.
FLOOR 0.30M.

2) UPLIFT PRESSURE: UPSTREAM END STILLING BASIN 1.50M
DOWNSTREAM END STILLING BASIN 1.00M.

3) IMMEDIATELY AFTER FLOOD STILLING BASIN EMPTY



TOTAL UPLIFT FORCE IS 6,30 * 4,5 * (15 + 10)/2 = 354 KN

UNIT WEIGHT CONCRETE 28 KN/M³

WEIGHT OF STILLING BASIN IS FOR

FLOOR = 6.30 * 4,50 * 0,30 * 28 = 238 KN.

WALLS = 2(1.60 * 6,30 * 0.25 * 28) = 141 KN.

379 KN.

UPLIFT 354 KN > 379 KN SAFE!

WE TAKE FOR PART C FLOOR THICKNESS 0.30 M.

WALL THICKNESS 0.25 M.

PAR B WALL THICKNESS 0.25 M

FLOOR THICKNESS 0.25 M.

PART A FLOOR AND WALL THICKNESS 0.25 M.

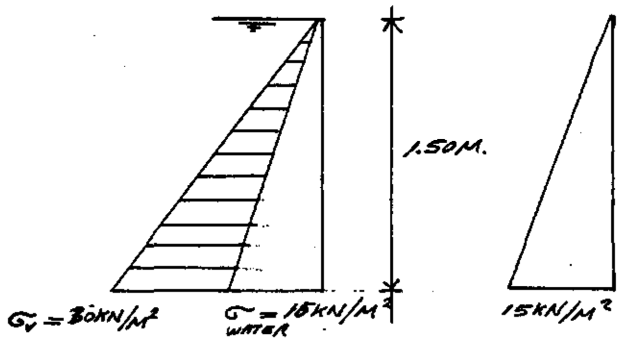
2. ESTIMATION OF MAX. BENDING MOMENTS AND SHEAR FORCES.

CASE A: HIGH GROUNDWATER LEVEL – STILLING BASIN EMPTY

SOIL CHARACTERISTICS COHESION $C = 2 KN/M^2$

ANGLE OF FRICTION $\varphi = 30°$

$\gamma = 20 KN/M^3$

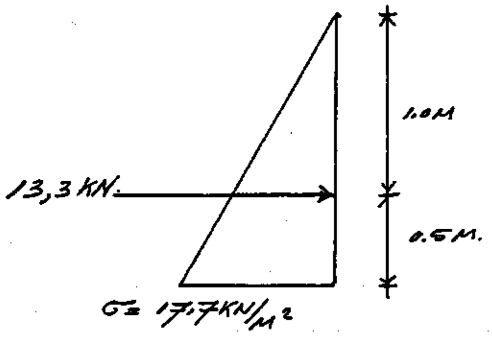


EFFECTIVE VERTICAL SOIL PRESSE = $\sigma_{SOIL} - \sigma_{WATER}$

$$\sigma_H = 15 * \tan^2(45 - \frac{30}{2}) - 2 * c \tan(45 - \frac{\varphi}{2})$$

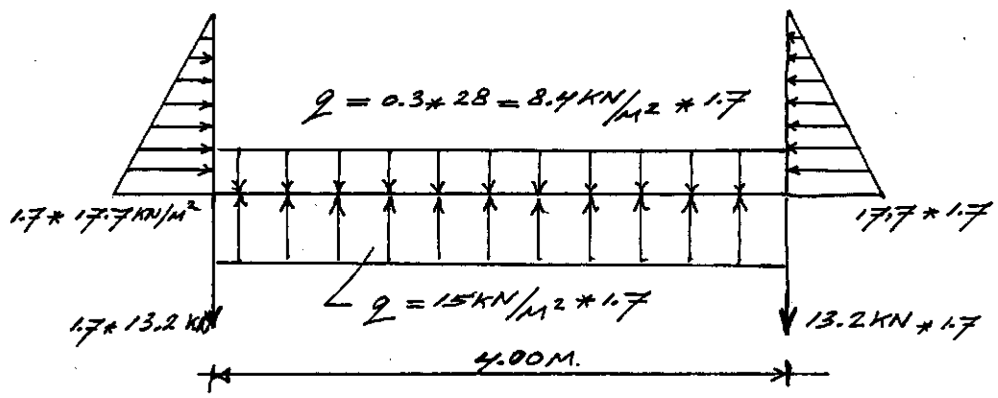
$$\sigma_H = 5 - 4 * 0,58 = 2,7 KN/M^2$$

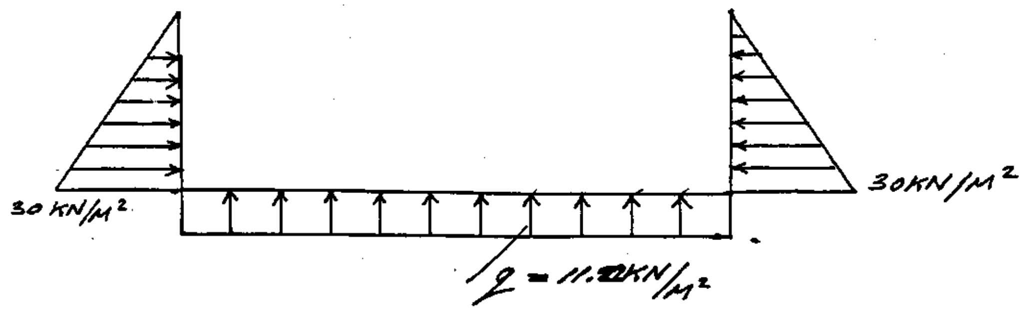
TOTAL PRESSURE AGAINST WALL

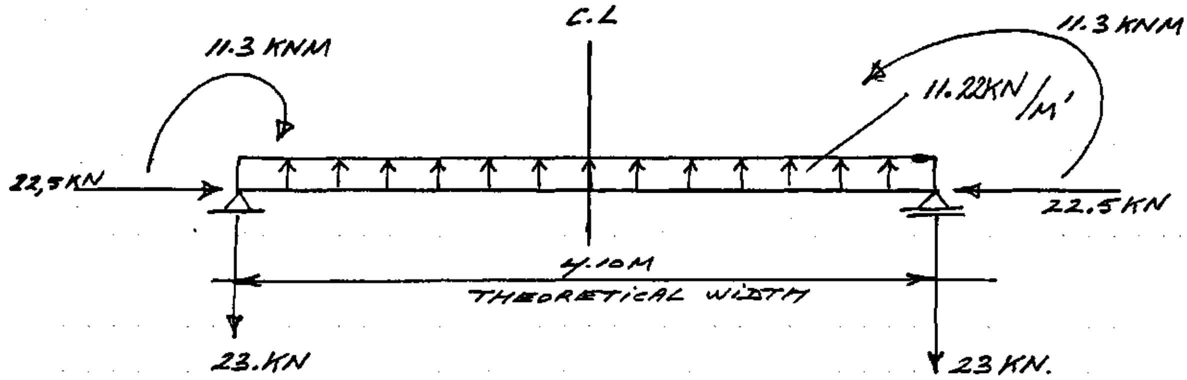


THE CONCRETE CALCULATION WILL BE BASED ON A STRIP OF 1.0 M. WIDTH AT THE UPSTREAM END OF THE STILLING BASIN.

SAFETY FACTOR FOR LOADS IS 1,7

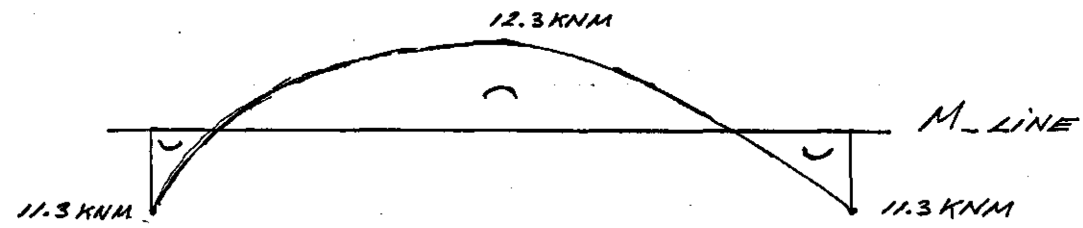


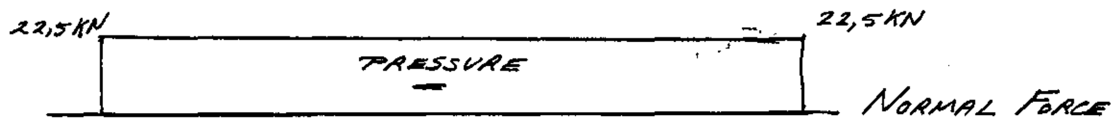


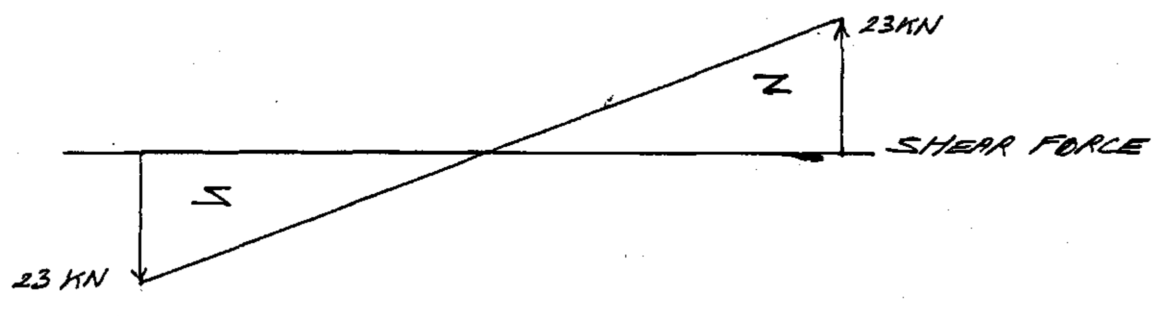


M MAX IN THE CENTER OF THE STILLING BASIN

$$M_{MAX} = +11.3 + 11.22 * (2.05)^2 * 0.5 - 23 * 2.05 = -12.3 KNM$$

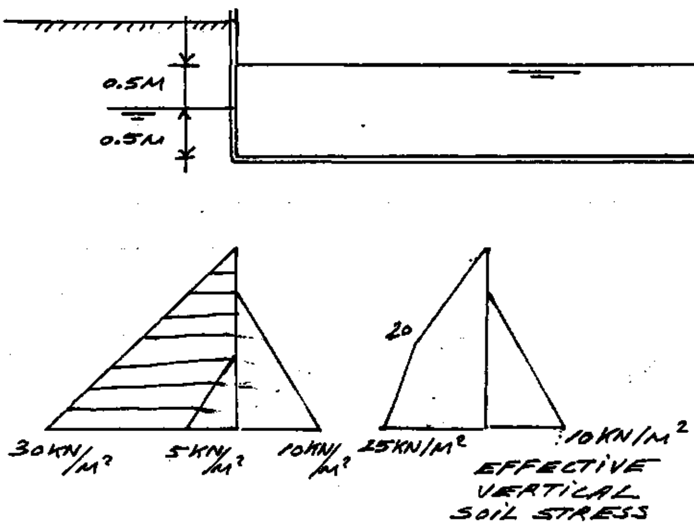






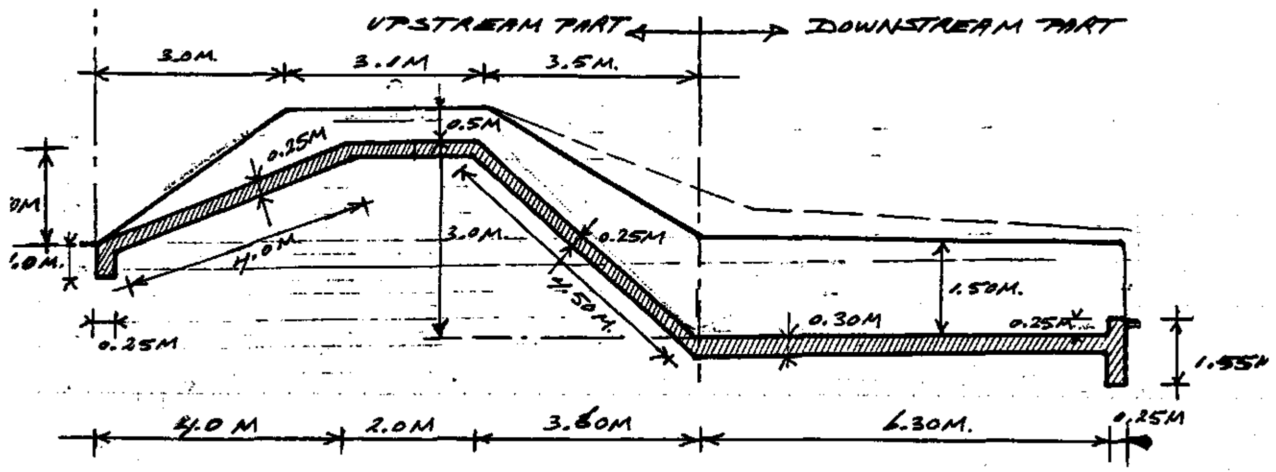
DIMENSIONS OF FLOOR AND WALLS BASED ON BENDING MOMENTS.

CASE B: LOW GROUNDWATERLEVEL, STILLING BASIN FULL OF WATER



BENDING MOMENTS OF CASE B WILL BE MUCH SMALLER THAN THOSE OF CASE A.

3. CONCRETE DESIGN

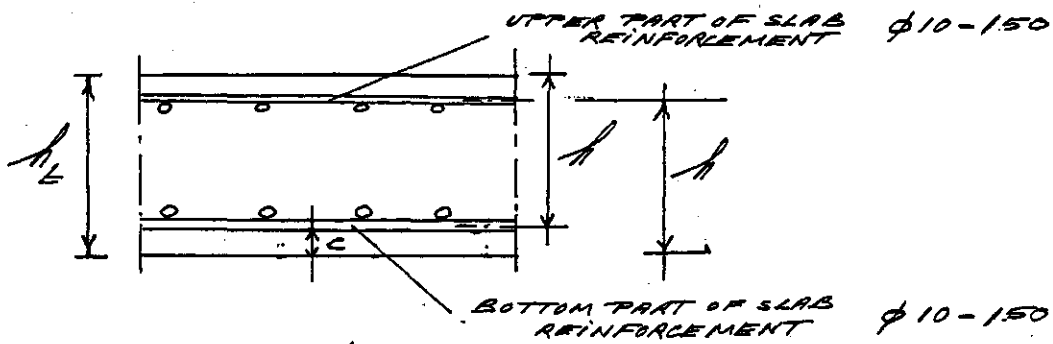


THE CONCRETE SPILLWAY IS DIVIDED IN TWO PARTS ; ONE WITH A FLOOR THICKNESS OF 0.30M AND ANOTHER WITH A FLOOR THICKNESS OF 0.25M. BOTH SIDEWALLS HAVE EVERYWHERE A THICKNESS OF 0.25M.
THE WALL THICKNESS OF THE UPSTREAM PART (A AND B) CAN BE REDUCED TO 0.20 M.

3.1. CONCRETE SPECIFICATIONS

- WE ASSUME IN OUR CALCULATIONS A CONCRETE QUALITY WITH A MECHANICAL STRENGTH OF 18 N/MM^2 ( ) AND CONCRETE STEEL WITH A MECHANICAL STRENGTH (ELASTIC LIMIT) OF 220 $N/MM^2 = f_A$
- CONCRETE COVER OF THE STEEL BARS OF 35 MM. (C)

3.2. CONCRETE CALCULATION OF FLOOR SLAB OF THE DOWNSTREAM PART OF SPILLWAY



$h = h_L - c - \frac{1}{2}\phi$ BAR

ASSUMPTION: $h_L = 300$ MM

$C = 35$ MM.

$\frac{1}{2}\cdot\phi = 6$ MM

WHEN $h_L/l = 300/4100 = 0.07 > 1/32$ THAN DEFLECTION UNIMPORTANT.

$h = 300 - 35 - 6 = 259$ MM.

$Z = 0.9\,h = 0.9 * 259 = 233$ MM.

REINFORCEMENT IN UPPER PART OF FLOOR SLAB DOWNSTREAM PART OF SPILLWAY

$M = 12.3$ KNM.

$$A_s = \frac{M}{f_A \cdot Z} = \frac{12.3 * 10^6}{220 * 233} = 240 \text{ MM}^2$$

TAKE $\phi 10 - 250 = 314$ MM^2 MAIN REINFORCEMENT

TRANSVERSE REINFORCEMENT $\phi 8 - 250 = 201$ MM^2

$$W_o = \frac{100 * 314}{1000 * 259} = 0.12\% < 0.20\%$$ SO NOT SUFFICIENT REINFORCEMENT

MAIN REINFORCEMENT MUST BE 518 MM²
TAKE $\phi 10 - 150 = 524\ MM^2$

CONTRÔLE OF TENSILE CRACKING

CRACK WIDTH MUST BE SMALLER THAN 0.3 MM.

$$W = 0.8 * \sigma_A * \Delta l * 10^{-5}$$

$$\Delta l = 1.25 \left(2 * C + 2.5 \frac{\phi}{\omega} \right)$$

$\omega = 0.2\%$
$\phi = 10\ MM$
$C = 35\ MM.$

$$\Delta l = 1.25 \left(70 + 2.5 * \frac{10}{0.2} \right) = 244\ MM.$$

$$\sigma_A = \frac{220}{1{,}7} * \frac{240}{524} = 59.2\ N/MM^2$$

$$W = 0.8 * 59.2 * 244 * 10^{-5} = 0.12\ MM < 0.3\ MM$$

O.K.!

REINFORCEMENT OF BOTTOM PART OF FLOOR SLAB

$M_{MAX} = 11.3$ KNM.

WE TAKE FOR MAIN REINFORCEMENT $\phi 10 - 250 = 314$ MM
TRANSVERSE REINFORCEMENT $\phi 8 - 250 = 201$ MM²

3.3. CONCRETE CALCULATION OF SIDE WALLS OF THE DOWNSTREAM PART OF THE SPILLWAY.

$M_{MAX} = 11.3$ KNM.

$h_t = 250$ MM
$c = 35$ MM
$\phi = 10$ MM

$h = 250 - 35 - 5 = 210$ MM.
$Z = 0.9 * h = 0.9 * 210 = 189$ MM.

$$A_s = \frac{11.3 * 10^6}{220 * 189} = 272 \text{ MM}^2$$

TAKE $\phi 10 - 250 = 314 \text{ MM}^2$

$$W = \frac{100 * 314}{1000 * 210} = 0.15\% < 0.20\%$$

$0,2\% \longrightarrow 0.2 * 10 * 210 = 410 \text{ MM}^2$

TAKE $\phi 10 - 175 = 449 \text{ MM}^2$ MAIN REINFORCEMENT

TRANSVERSE REINFORCEMENT $\phi 8 - 250 = 201 \text{ MM}^2$

CONTROL OF TENSILE CRACKING

$W < 0.3$ MM.

$$W = 0.8 * \frac{f}{A} * \Delta l * 10^{-5}$$

$$\Delta l = 1.25 \left(70 + 2.5 * \frac{10}{0.213} \right) = 234 \text{ MM.}$$

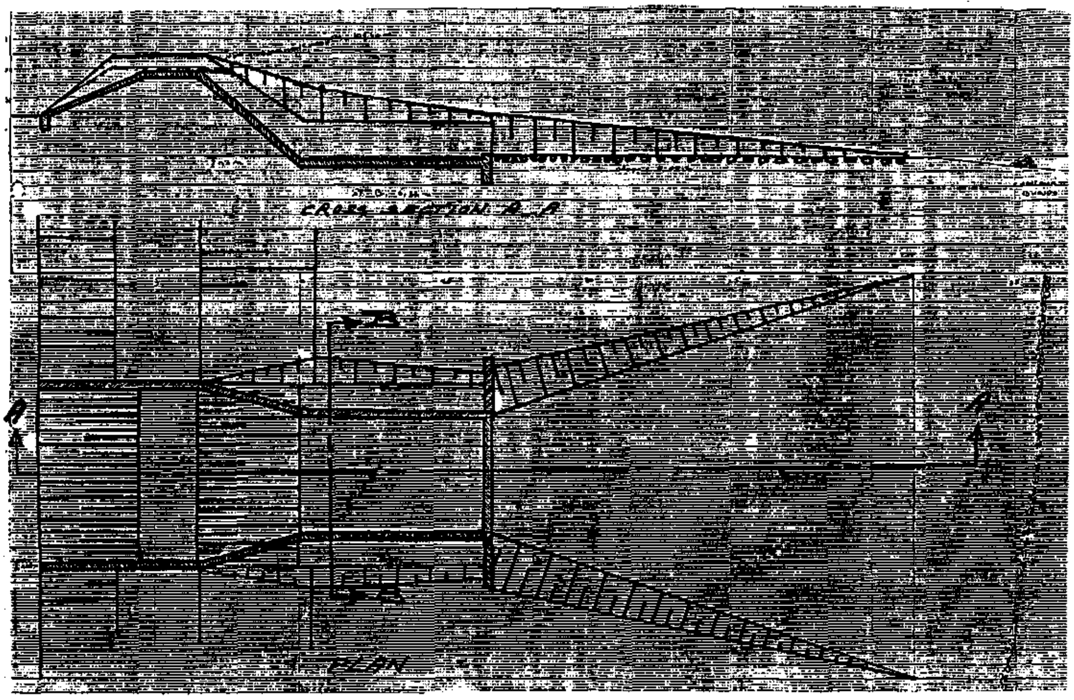
$$\frac{f}{A} = \frac{220}{1.7} * \frac{272}{449} = 78.4 \text{ N/MM}^2$$

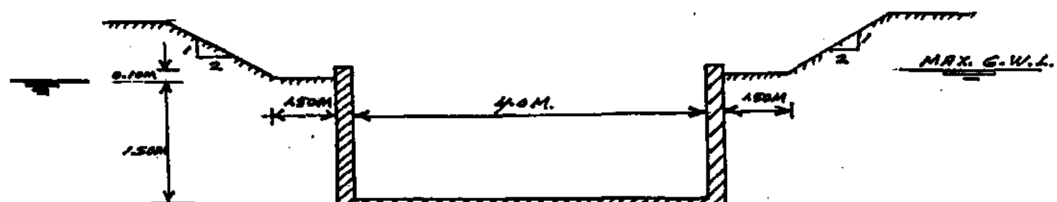
$$W = 0.8 * 78.4 * 234 * 10^{-5} = 0.15 \text{ MM} < 0.3 \text{ MM.}$$

O.K.!

SPILLWAY BUSONGO

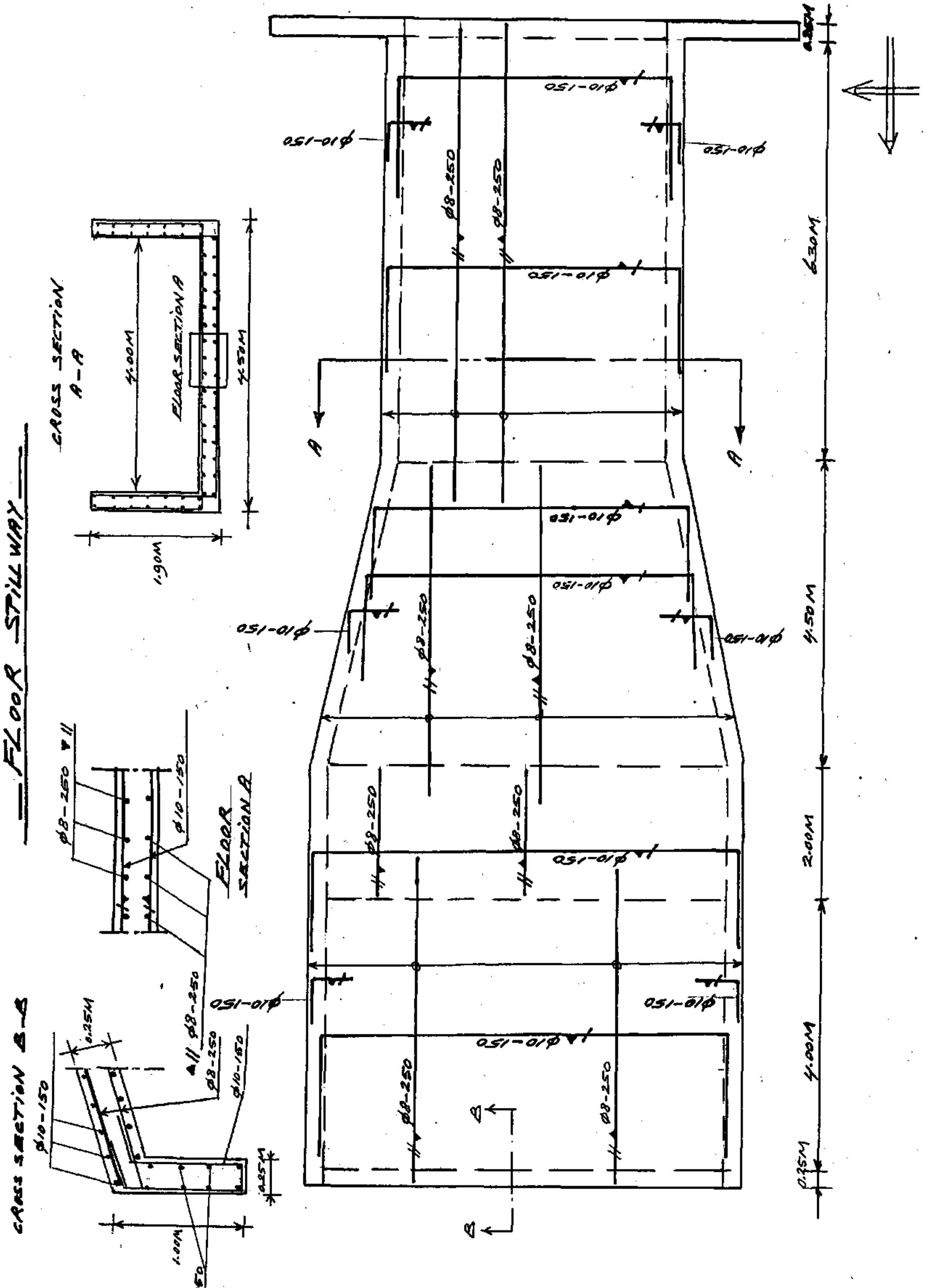
PLAN AND CROSS SECTIONS



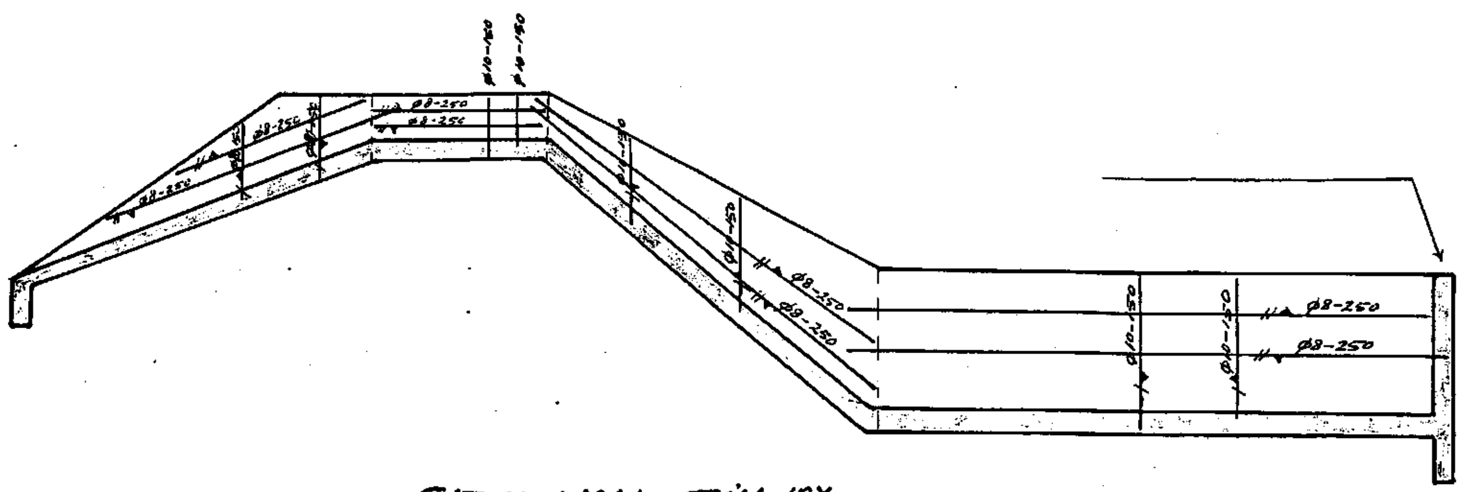


SECTION B-B

DRAWING 1


FLOOR SPILLWAY
CROSS SECTION A-A
FLOOR SECTION A
CROSS SECTION B-B
ϕ10-150
ϕ8-250
4.00M
4.50M
1.90M
6.30M
2.00M
0.25M
1.00M

DRAWING 2



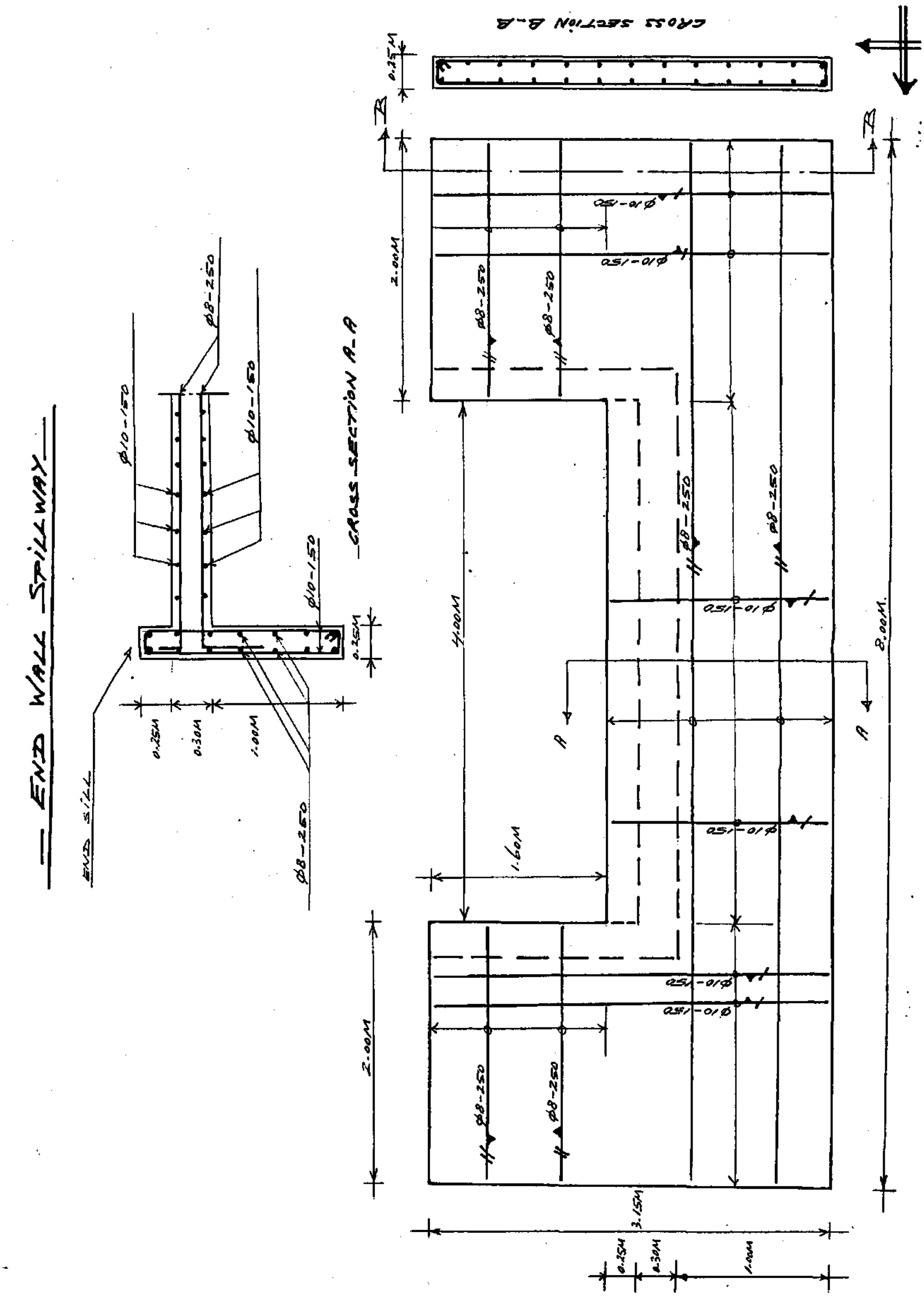
SIDE WALL SPILLWAY

REINFORCEMENT TOP OF THE SLAB, FIRST LAYER (OUTSIDE)
SECOND LAYER (INSIDE LAYER)

REINFORCEMENT AT THE BOTTOM OF THE SLAB
FIRST (OUTSIDE LAYER)
SECOND (INSIDE) LAYER

ø8 – 250 DIAMETER REINFORCEMENT 8MM., DISTANCE BETWEEN CENTRES OF THE BARS IN MM

DRAWING 3


END WALL SPILLWAY
END SILL
CROSS-SECTION A-A
CROSS SECTION B-B
ϕ10-150
ϕ8-250
0.25M
0.30M
1.00M
2.00M
4.00M
1.60M
3.15M
8.00M

DRAWING 4

Photo page I The dam of the Busongo reservoir

The dam in north-west direction (courtesy Mark Boiten)

Outflow by an earthen spillway at the
South end of the dam, April 2000