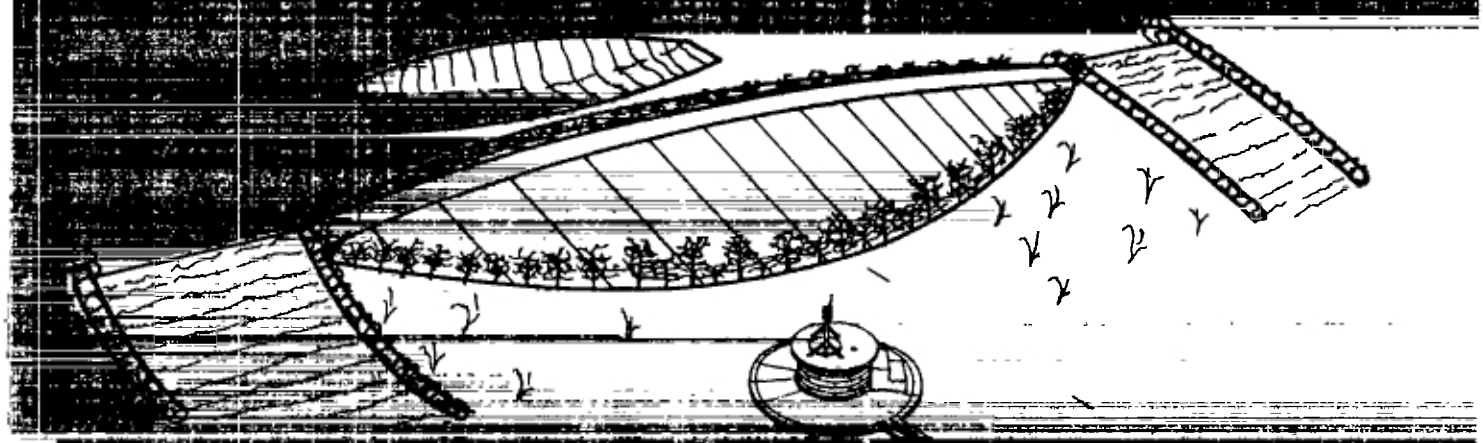
HARVESTING RAINWATER IN SEMI-ARID AFRICA

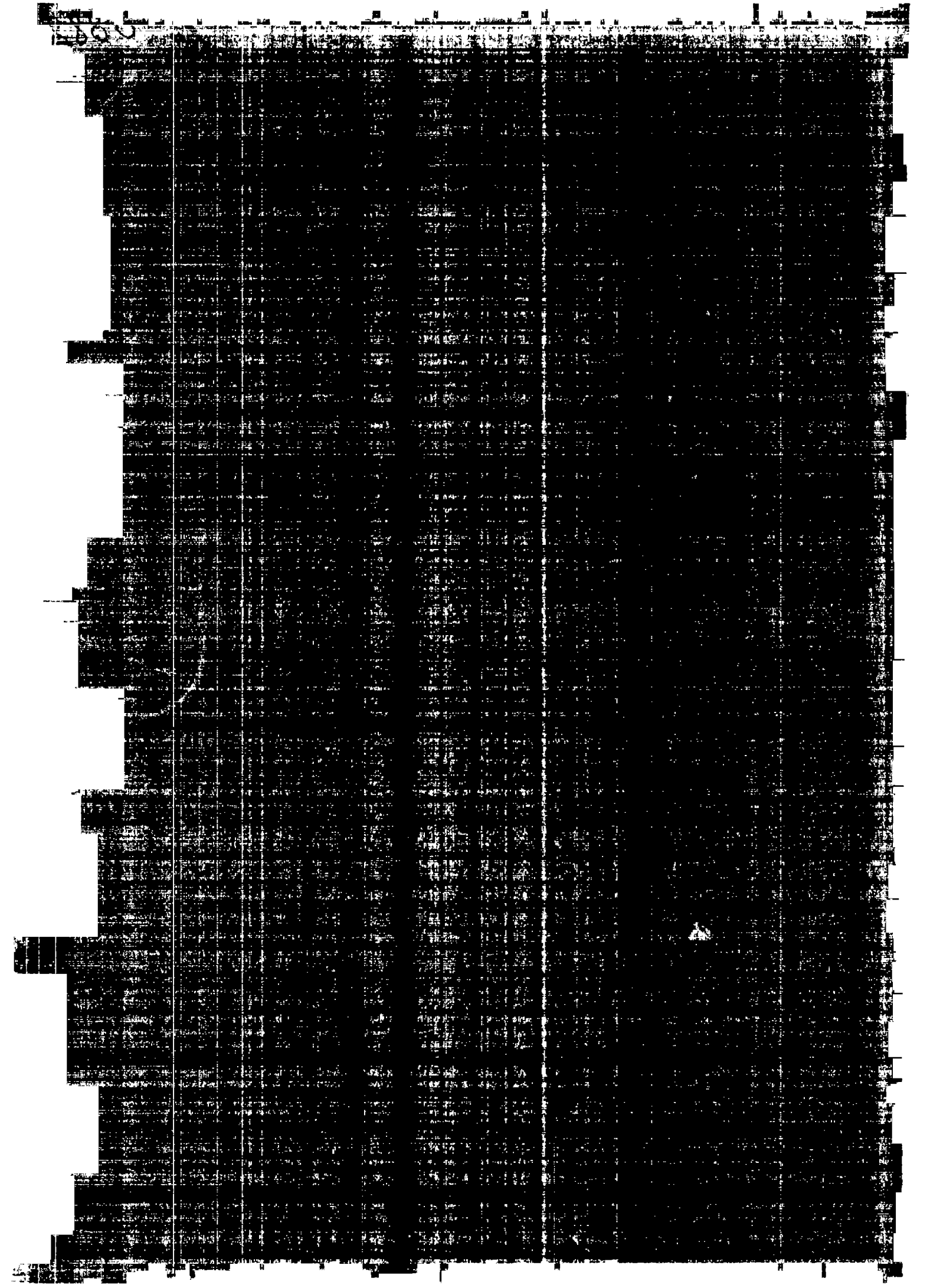
Manual No. 2

Small Earth Dam built by Animal Traction.



Erik Nissen-Petersen

Nairobi, 1990



Harvesting Rainwater in Semi-arid Africa" consists of 6 Manuals:

Manual No. 1. Water Tanks with Guttering and Hand-pump.

Manual No. 2. Small Earth Dam built by Animal Traction.

Manual No. 3. Rock Catchment Dam with self-closing Watertap.

Manual No. 4. Shallow Wells with Bucketlift.

Manual No. 5. Sub-surface and Sand-storage Dams.

Manual No. 6. Spring Protections.

Each Manual deals with siting criteria, standard designs, bills of quantities and construction in a simple text and drawings.

The Manuals are based on practical experience gained by building some 700 water structures for rainwater harvesting in semi-arid Kenya over the last 14 years.

ASAL Rainwater Harvesting
P. O. Box 14333
NAIROBI
Kenya

ACKNOWLEDGMENT

The authors of these manuals are grateful to DANIDA for grants which has made possible the compiling and publishing of their experience with rainwater harvesting for self-help groups in semi-arid areas of Africa.

Much gratitude is also due to the Ministry of Agriculture in Kenya, which together with DANIDA afforded the opportunity of developing low-technology and labour-intensive methods of harvesting rainwater and thereby enabling people and livestock in a semi-arid region of the country to have access to a steady water supply.

Thanks are also due to the local inhabitants with and for whom these techniques were developed and implemented. Their understandable skepticism in starting up these demanding activities gave the process a sound and realistic foundation on which to build.

Personal thanks are very much due to the following people:

Preben Enhard of Mutomo Soil and Water Conservation Project for his considerable support.

Jan Nissen-Petersen for assistance in the preparation of the drawings.

Kim Nissen-Petersen for the many proof-readings and useful comments.

Mr. Moki, Mr. Nguno and Mr. Dominic for their excellent work on developing the construction of small earth dams by animal traction in Southern Kitui, Kenya.

Erik Nissen-Petersen and Michael Lee

C O N T E N T S

SURVEYORS MANUAL ON

SMALL EARTH DAMS BUILT BY ANIMAL TRACTION

1. Introduction

The small earth dams discussed in this manual can store from 500 cubic metres to 10,000 cubic metres of water in banks of earth not more than 5 metres high and 60 metres long.

The dams are built by manual labour and animal traction .using ox-scoops.

The main purpose of a small earth dam is to have water closer to homesteads during rainy seasons and a few months thereafter in order to transfer labour from fetching water to activities in the fields.

Experience has shown that once a group of people have built a small earth dam, they keep on extending it until it can hold water for nearly all days in the year. In many places people also build a second and third earth dam to cater for more water near the homes of all members of the self-help group.

A small earth dam is usually built by a self-help group of people consisting of about 25 families living in dry and rather flat land with unreliable rainfalls.

The members of a group work on the dam from 1 to 3 days a week during the 6 dry months of the year. On Saturdays when schools are closed, 2 children from each family work on the dam. Besides providing labour for the dam construction, the children also learn that the dam is part of their life. That is important for the future maintenance and possible expansion of the dam.

Usually it will take about three dry seasons (3 years) to build and complete a small earth dam which can hold water for about 10 months of the year.

As with all sizes and types of earth dams, the stored water become polluted and is therefore only suitable for livestock and irrigation. The polluted water can of course be treated for domestic purposes, but that is not economically viable for people who live on very small cash incomes.

Instead some people use the polluted water as it is, claiming that the water is cleaner than the water they used before the dam was built.

Most people, however, prefer to have cleaner water by pulling it up from a shallow well sunk either in the side of the reservoir or just downstream of the dam wall. The polluted water is thus treated by seeping through the underground into the shallow well.

Small earth dams have some advantages over large earth dams because:

(a) They require very little capital investment.

(b) They do not require mechanized earth moving machinery.

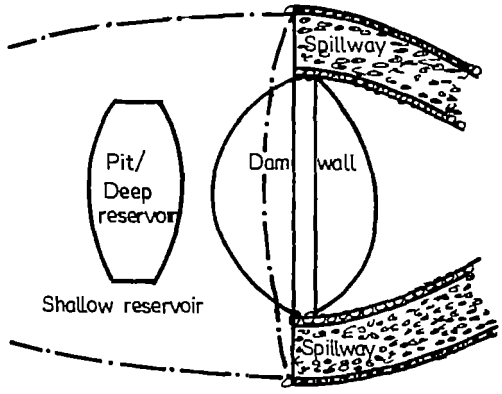
(c) They can be designed and supervised by local technicians.

(d) They can be build and maintained by the users themselves.

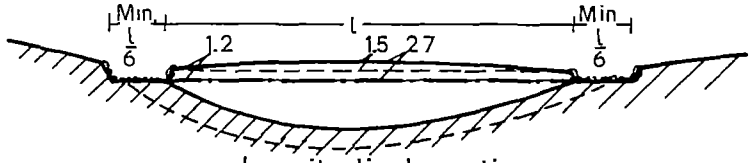
(e) They do not create erosion due to only small herds of livestock being watered by the dam.

(f) A small earth dam can harvest rainwater from small showers, while a large dam requires big showers for filling up.

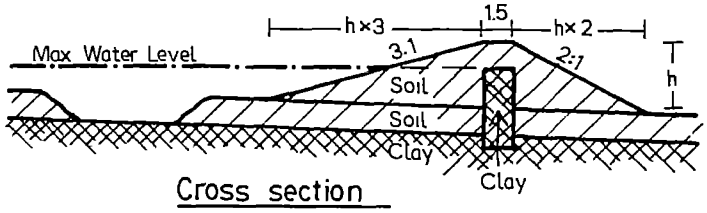
2. Standard Design



Lay-out plan



Longitudinal section



Cross section

3. Siting Considerations.

Construction of small earth dams by manual labour and animal traction is only possible where a determined and well-organized self-help group has a real need for having water situated nearer their homesteads.

Therefore a certain degree of mobilization has to be carried out in the procedure of siting and designing.

3.1. Phase 1. Information Campaign.

The first step in promoting construction of small earth dams is to make groups realize their needs and advantages of having water nearer their homes.

This message is brought about in a sort of information campaign at public meetings with officials from the ministries concerned. During or after such meetings people will organize themselves into groups with selected committees consisting of a chairman/lady, a secretary and a treasurer and their deputies.

Such committees will register their group with name and location, and file a request for technical assistance to the dam building with the relevant authorities.

3.2. Phase 2. Selection Criteria for Sites.

When such a request has been approved, an experienced surveyor will visit the group at their location for the purpose of assisting the group in the difficult task of locating the most viable site for their small earth dam.

A surveyor will tell the people that they have to select 3 viable sites according to below mentioned criteria, and that thereafter he will come back and select the most viable site of the 3 sites they have proposed.

The people will select 3 proposed sites according to following criteria which their secretary will write down:

(1) The most suitable sites are found at:

(a) A seasonal watercourse not wider than 3 metres and not deeper than 1 metre.

(b) Around the lower side of a natural waterhole.

(c) Around an excavation made by road builders.

(d) Around the downslope of a small depression on gradually sloping land.

(e) At the footslopes of a hillside where run-off accumulates.

(f) At the foot of rock outcrops where run-off passes during rains.

For all the types of sites mentioned, it is very important that rainwater run-off flows over the site several times during a rainy season, otherwise the dam reservoir might not be filled with water.

(2) The sites must not contain the following features:

(a) Black cotton soil.

(b) Light sandy soil.

(c) Lime situated near the soil surface.

(d) Ant hills or termite mounds.

(e) Stone boulders or exposed rock surfaces.

(3) The sites should preferably contain a natural depression for the purpose of providing free storage such as:

(a) A natural water hole.

(b) A depression in the landscape.

(c) A widening of a seasonal watercourse.

3.3. PHASE 3. Soil Type for Dam Sites.

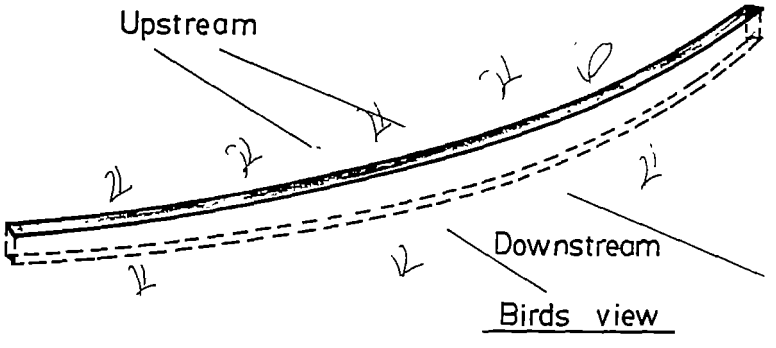
When a self-help group has selected 3 sites with regards to the above mentioned criteria, a surveyor will carry out the final selection using the following approach:

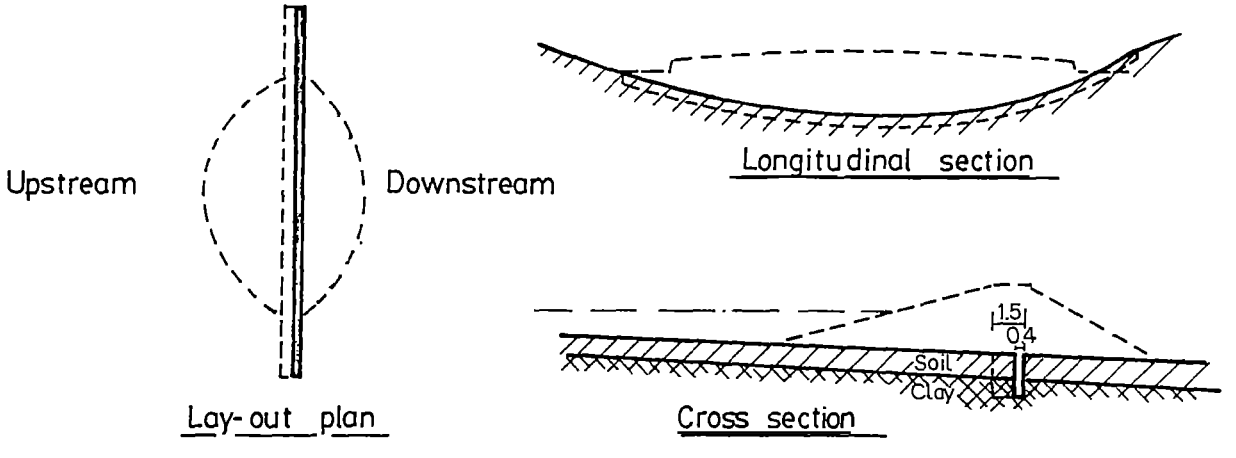
(a) Decide which of the 3 sites will provide maximum volume for minimum effort of labour.

(b) Investigate whether the site chosen by him has an impermeable (watertight) layer situated in the underground of the chosen dam site.

The best way of finding out about this is to dig a trench along the length of the planned dam wall. This trench will, at a later stage, be utilized for building a watertight vertical foundation under the dam wall which will prevent seepage underneath the dam wall. The depth of this trench has to be deeper than the floor of the reservoir after its excavation.

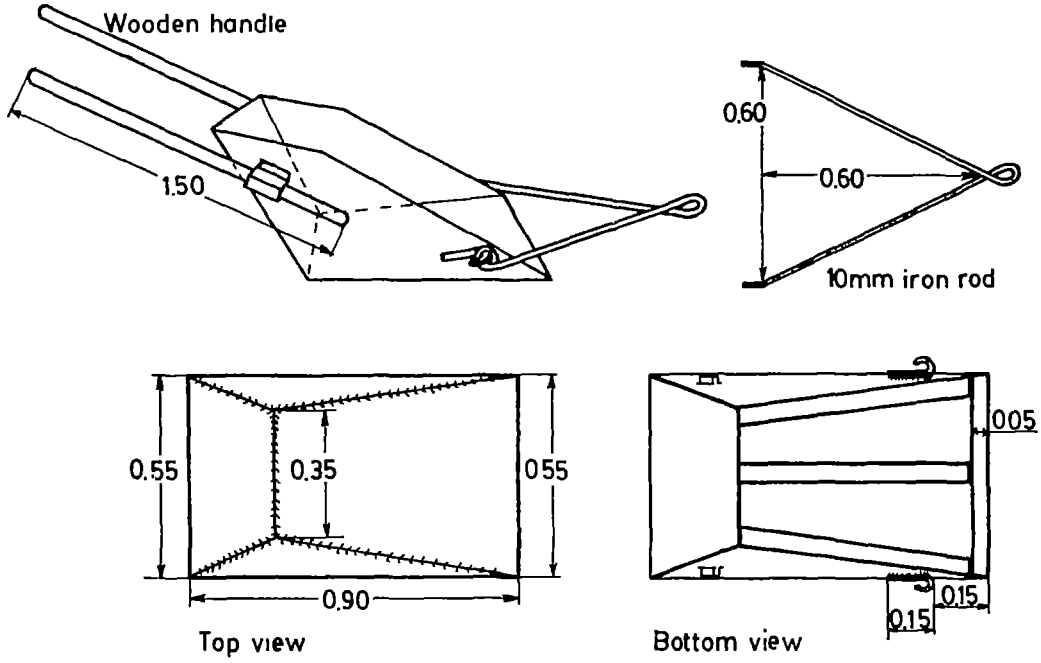
(c) The surveyor will explain the purpose of digging the trench and stake out the outline of the trench which should be about 40 cm. wide and as deep as possible.





(d) The surveyor will hand-over the following equipment to the group for excavating the trench and building the earth dam:

5 pick-axes	1 ox-scoop
5 shovels	2 harnesses for oxen or donkeys
5 spring jembes (hoes)	1 plough
10 karais (iron pans)	5 wheelbarrows



ox-scoop

(e) Instruct the people to place the excavated soil downstream of the trench.

(f) Tell the leaders to call for him to inspect the trench when the instructed excavation is completed.

(g) When the excavation is completed and approved by the surveyor, he will hand-over the technical assistance to a contractor who will be introduced to the self-help group by the surveyor.

Together they will peg out the outline of the dam site and the two spillways, and instruct the people to excavate the ditch to a width of 1.5 metres.

C O N T E N T S

CONTRACTORS MANUAL ON SMALL EARTH DAMS

1. Impermeable Foundation

The supervision of the site has now been handed over from the surveyor to the contractor. The outline of the dam wall and the two spillways have been staked out with wooden pegs and all parties concerned have agreed on it.

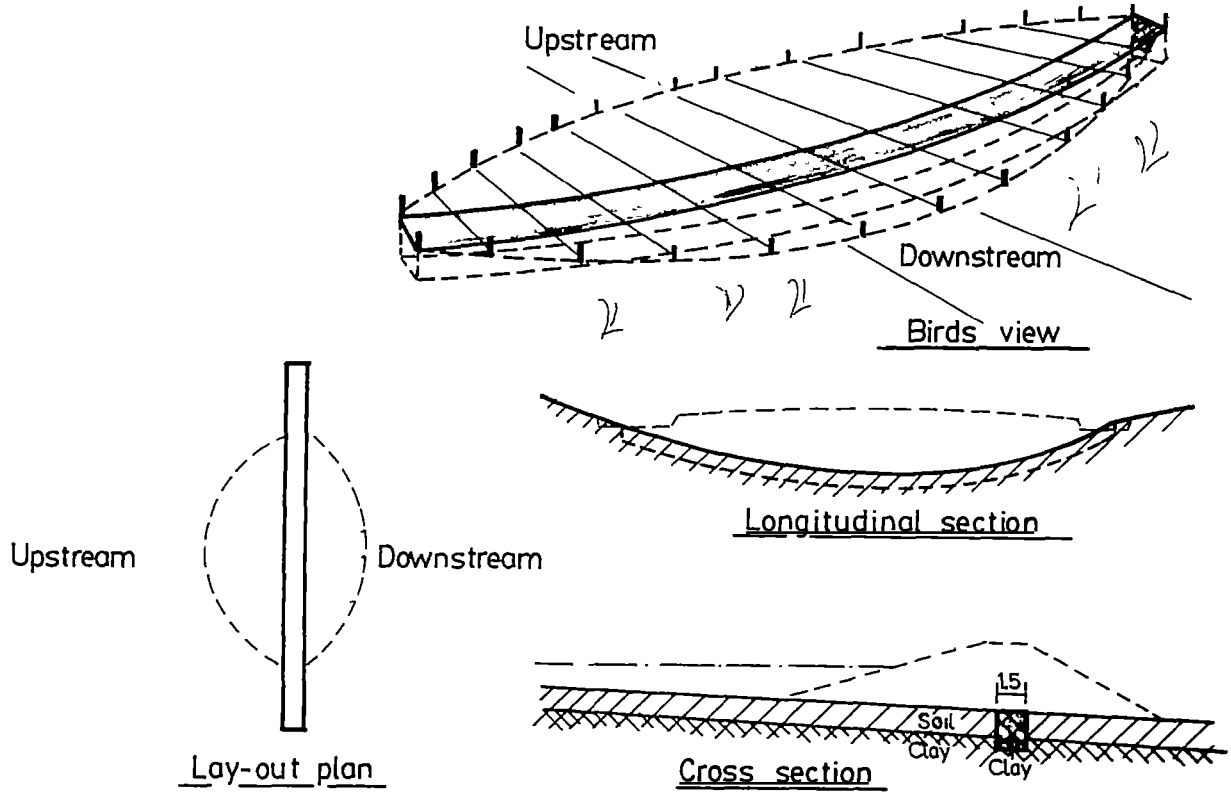
When the trench is dug to a width of 1.5 metres, it is to be filled up with compacted clayish soil to form a water-tight foundation of the dam wall. This is done as follows:

(a) Shovel into the trench a 15 cm. layer of clayish soil and compact it well with water and stamping by feet. If water is not available for this purpose, the soil can be compacted by stamping it with short lengths of tree trunks.
Alternatively, livestock can be driven forth and back over the soil in the trench for compacting.

(b) The whole trench is to be filled up this way of 15 cm. thick layers of compacted clayish soil until its top surface is even with the surrounding soil surface.

(c) Meanwhile other members of the group will clear the site for the dam wall and the two spillways for vegetation and place the debris downstream of the pegged out dam wall.

It is very important that roots of trees and bushes from the site are removed completely from the soil to avoid regrowth of roots within the dam wall.



2. Building the Lower Part of the Dam Wall.

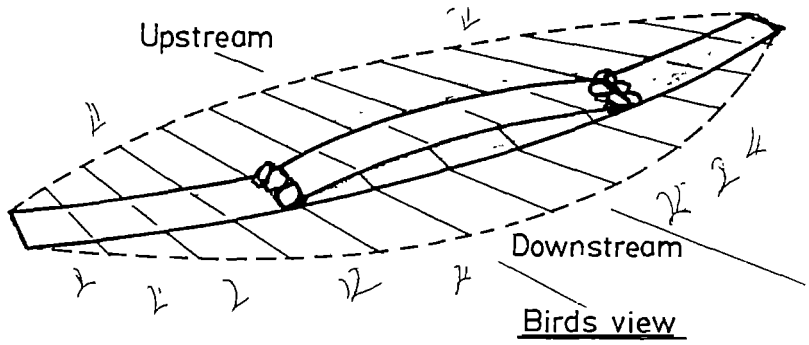
The soil for building the dam wall is taken first from the site of the reservoir for the purpose of making the reservoir as deep as possible in order to limit evaporation, and thereafter from the excavation of the spillways.

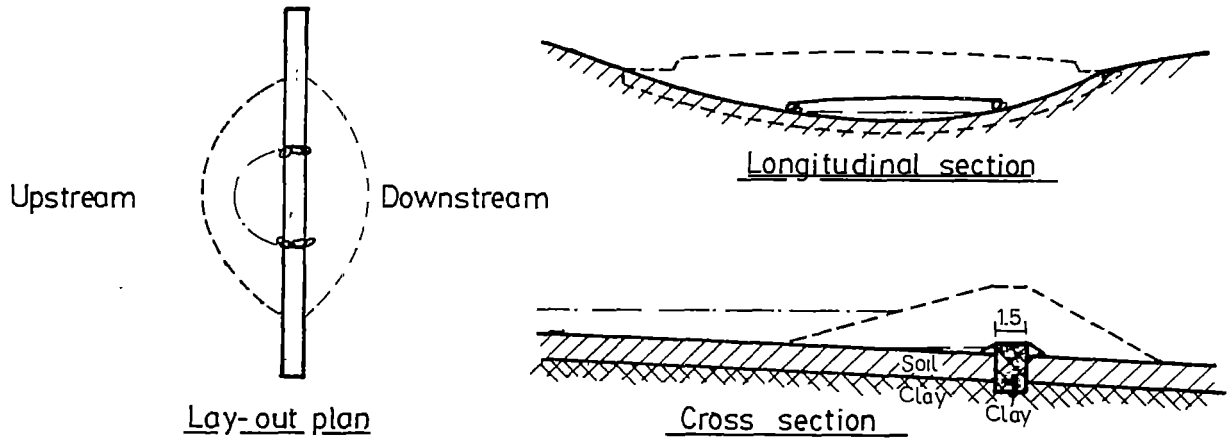
The depth of the reservoir must not, however, be lower than the depth of the impermeable foundation of the dam wall, because that could allow seepage from the reservoir to escape under the dam wall.

While transporting soil to the dam wall, it is important to bear in mind that the most clayish soil should be placed along the middle of the dam wall as an extension of the clayish foundation in the filled-up trench.

The most sandy soil, which is the poorest for building a dam wall, should be placed on the downstream part of the dam wall.

Soils being a mixture of clay and soil should be placed on the upstream side of the dam wall where it will limit infiltration of water into the wall.





The procedure for building a dam wall by draught animals is found to be most viable in the following way:

(a) Remove all vegetation and tree stumps from the site of the reservoir. Thereafter plough the site with the aim of loosening the top layer of the soil. A chisel plough is the best implement, but an ordinary plough can be used as well.

(b) Transport soil from the ploughed area to the site of the dam wall with the ox-scoop and wheelbarrows. The ox-scoop is driven in circular patterns over the dam wall and the excavation pit of the reservoir. Every hour or so the direction is turned opposite, that is clockwise and anti-clockwise, in order to get the deposited soil compacted evenly by the drought animals and people.

Loading and off-loading of the ox-scoop is done by manouvering the handles of the ox-scoop either upward or downward while driving around over the respective places of loading and off-loading.

(c) Off-loading should take place along the centre line of the lowest part of the dam wall and thereafter be extended upward and outward, so that the dam wall is always highest at its middle section.

This is important to keep in mind during the whole construction period, because if the dam wall is not highest at the middle at all times, then a single unexpected rainshower can produce sufficient run-off to wash-out the middle section of the dam wall instead of passing harmless around the ends of the dam wall.

In fact, by making the middle section of the dam wall about 1.5 metres higher than its ends at all times of the construction period and by placing a few large stones at the ends of the wall, it will function as a completed dam which can withstand heavy thunderstorms and store run-off water for quite some time.

(d) The off-loaded soil should placed in layers being about 15 cm. thick in order to get it compacted well by either livestock driven over the soil deposits or by compaction by short tree trunks operated by a person or two.

(e) The pit in the reservoir area from where the soil is removed will have to be ploughed now and then in different directions for loosening the soil to be transported to the dam wall.

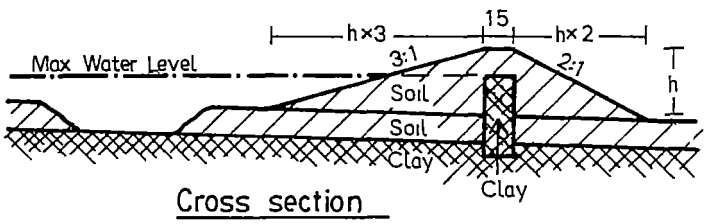
3. Slopes of Dam Wall.

(a) As the dam wall is build higher it is also made wider by off-loading and compacting soil on its two sides, still bearing in mind that clayish soil is off-loaded along the upstream side of the dam wall.

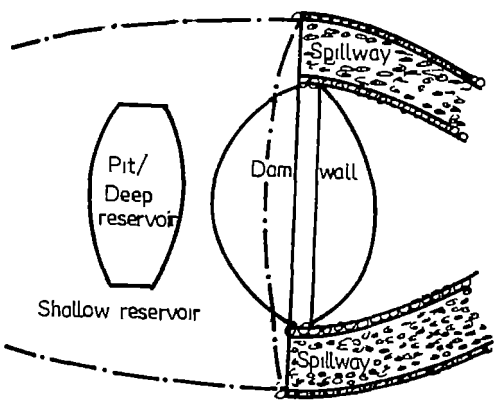
(b) The slope of the upstream side of the dam wall should be about 3:1, which is 3 metre horizontal width for every 1 metre height.

(c) The slope of the downstream side of the wall should be about 2:1, which is 2 metre horizontal with for every 1 metre height.

The above relations between width and height are of a some importance, but since a trained contractor can determine the correct relationships by eye, more sophisticated measurements are not needed for the time being.



Cross section



Lay-out plan

4. Designing the Two Spillways

To avoid a wash-out of a dam wall by heavy rains, it is most important that the spillways can discharge surplus run-off safely when the reservoir is filled up. Experience with small earth dams have shown that:

(a) There should always be two spillways built, that is one spill-way at each end of a dam wall.

(b) The freeboard, which is the vertical distance between the height of the spillways and the height of the ends of the dam wall, should at all times and also during the construction period, be at least 1.2 metres or preferably 1.5 metres.

(c) The total length of the two spillways should correspond to approximately 1/3 of the length of the dam wall, that is 1/3 for each spillway.

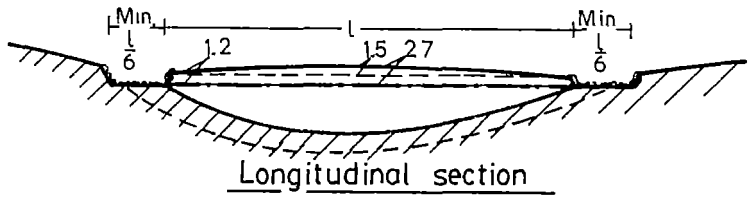
(d) This means that where a dam wall is not build to its final height before a rainy season, the spillways cannot be build to their final heights, because their height must be at least 1.2 metres below the ends of the dam wall.

As explained earlier, the height of the middle of the dam wall must be at least 1.5 metres higher than the ends of the wall.

Therefore the height between the spillways and the middle of the dam wall will be about 1.5 metres + 1.2 metres = 2.7 metres.

(e) The height of the spillways can be extended upwards by building a stone masonry wall across the spillway or if funds do not allow that, some big boulders packed in soil can be placed across the spillways and inter planted with creeping grass.

Longitudinal section



Longitudinal section

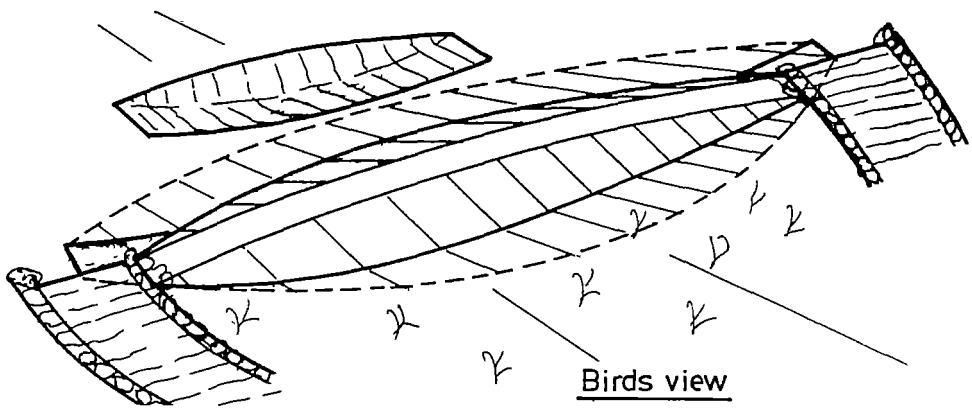
5. The Crest.

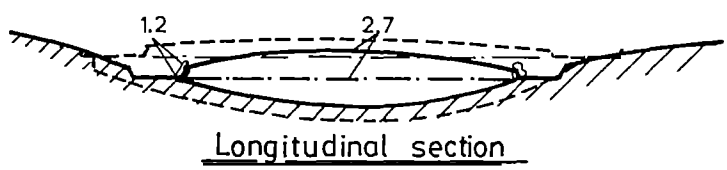
As mentioned above, the upper outline of a dam wall, called the crest, must always at least 1.5 metres higher than the ends of a dam wall, the reasons for this appearance of the being that:

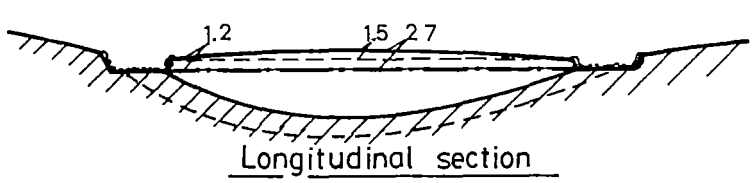
(a) In case the spillways is not be able to discharge an extra heavy flooding from a thunderstorm, a wash-out of a section of the dam wall can occur. Since it is much easier to repair a wash-out section at the low walls at the ends than at the high middle section, the middle section must be the highest place in the dam wall.

(b) Also since more soil is placed at the middle section than at the lower ends, the middle part will sink more than the ends when the reservoir will be filled with water and saturate the soil in the dam wall.

If the crest of the middle of the dam sinks to less than 1.0 metres above the ends of the dam wall, it must be raised to its former height, otherwise the middle section is in danger of being washed out in heavy rains.







6. Determining the Height of a Dam Wall.

The final height of a dam wall is determined by:

(a) The owners and builders demand for water.

(b) The catchments ability to supply sufficient run-off to fill the dam reservoir.

A dam wall can be build in stages during dry seasons, but before the onset of a rainy season the dam wall and spillways should be completed at those heights they have reached, otherwise heavy rains might damage or sweep away totally the whole structure.

A dam wall build in stages should therefore be completed before a rainy season as follows:

(a) The width of the crest should be 1.5 metres wide along its whole length. Its surface should curve upwards to avoid pools of water collecting on the crest, because that can create parts of the dam wall to slide down with disastrous results.

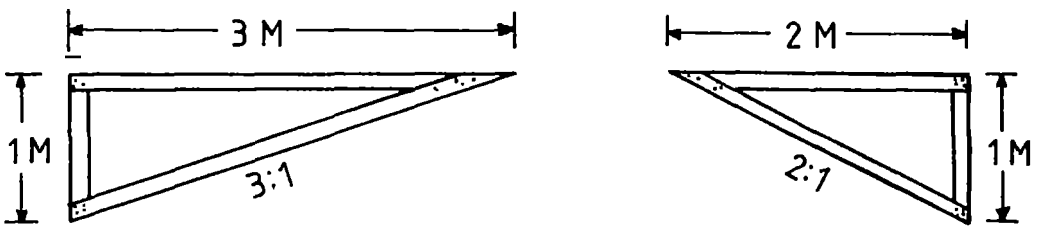
(b) As explained earlier, the crest must be at least 1.5 metres higher at the middle than at the ends of the dam wall to prevent storm water from spilling over at the middle of the dam wall which will result in a wash-out difficult to repair.

(c) The slopes of the sides of the dam wall should be 2:1 on the downstream side and 3:1 on the upstream side facing the reservoir.

The easiest way of measuring such slopes is to nail together 3 pieces of timber of 4" x 1" as shown below.

By placing a spirit-level horizontally on the upper edge of the timber the correct slope can be seen.

In case the slopes are too steep, they should be brought up to the correct slope by laying a blanket of top-soil on the slopes.



7. Building a Spillways in Stages.

Since it is of vital importance that the height of the two spillways must be at least 1.2 metres below the ends of the dam wall, the spillways are raised accordingly to the present height of the dam wall.

Never attempt to raise the spillways before the dam wall, because that could allow unexpected stormwater to wash away most of the structure overnight.

A spillway can be raised by placing stones on the floor and sides sloping downstream from that point of the spillway being 1.2 metres below the ends of the dam wall, that is where the discharge of surplus water will take place.

The crests of the two spillways should be horizontal and of the same height.

To prevent the stones being washed away by overflowing water, top soil can be packed around the stones and creeping grass planted in the soil.

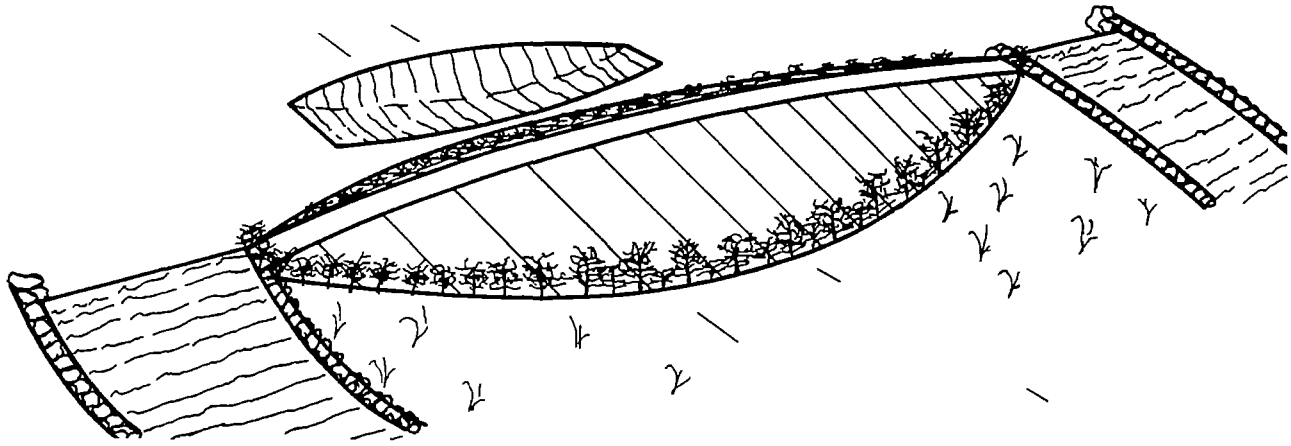
8. Protection of Dam Wall.

(a) A new dam wall has to protected against splash erosion from raindrops which can erode seriously the sides of a dam.

Creeping grass found locally and planted on the dam wall at the first onset of rains is very suitable for preventing erosion by rain and wind.

(b) To prevent long-term erosion which will wear down the dam wall by people and animals walking up and down on it, a dam wall has to be fenced off permanently.

It has been found that thorny bushes planted along the edges of a dam wall are more effective than barbed wire on posts. To protect newly planted thorny bushes from being destroyed by animals, the plants should be covered with cut-off thorny branches until the plants have reached a certain height.



9. Protection of the Spillways.

(a) The two spillways must be protected from erosion caused by surplus water flowing over their floors and along their sides during days with a full reservoir being recharged.

As mentioned earlier, the floor and sides of the spillways should be covered with stones packed in soil and interplanted with creeping grass.

10. Protection of the Dam Reservoir

Inflow of run-off water originating from cultivated fields and eroded soil surfaces brings dust, debris and a small portion of top soil with it. Unless checked this material will settle on the bottom of the reservoir as siltation.

(a) A small amount of siltation, say a 5 cm. layer, is desirable because that will act as a seal limiting seepage through the floor of the reservoir.

(b) However, if siltation is not kept at that minimum level it will gradually silt up the reservoir resulting in reduced or even no storage for water.

(c) Siltation and seepage through the floor of a dam reservoir is greatest in areas with sandy soils .

Fortunately, these two disadvantages can be combined to one advantage by utilizing the fine-grained siltation deposits as a sealing agent mixed with cattle dung and compacted into the sandy floor of a reservoir.

The mixing and compacting work is carried out by letting livestock graze the dam reservoir during dry seasons.

(d) Inflow of sediments can be reduced by building silt-traps of large stones packed with soil and interplanted with grass across the inflow channel supplying run-off water to the dam reservoir.

For reinforcement of such structures in larger channels long-rooted trees can be planted next to the lower side of the stone/soil/grass bunds.

11. Extraction of Water from an Earth Dam.

Some people prefer to take their water for domestic use directly from the dam reservoir, while at the same time some people are bathing and washing clothes in the very same reservoir.

To make matters even worse, domestic and wild animals are sharing the water by being allowed to enter into the reservoir for drinking and emptying their stomachs into the reservoir.

By using relatively simple measures such a situation can be improved greatly, if the owners and users of such a dam would see their benefits of having cleaner water at the same time protecting their dam from degradation.

(a) Domestic water should be drawn from a shallow well situated either in the reservoir or just downstream of the dam wall. The passage of water through the underground will clean it to an acceptable standard.

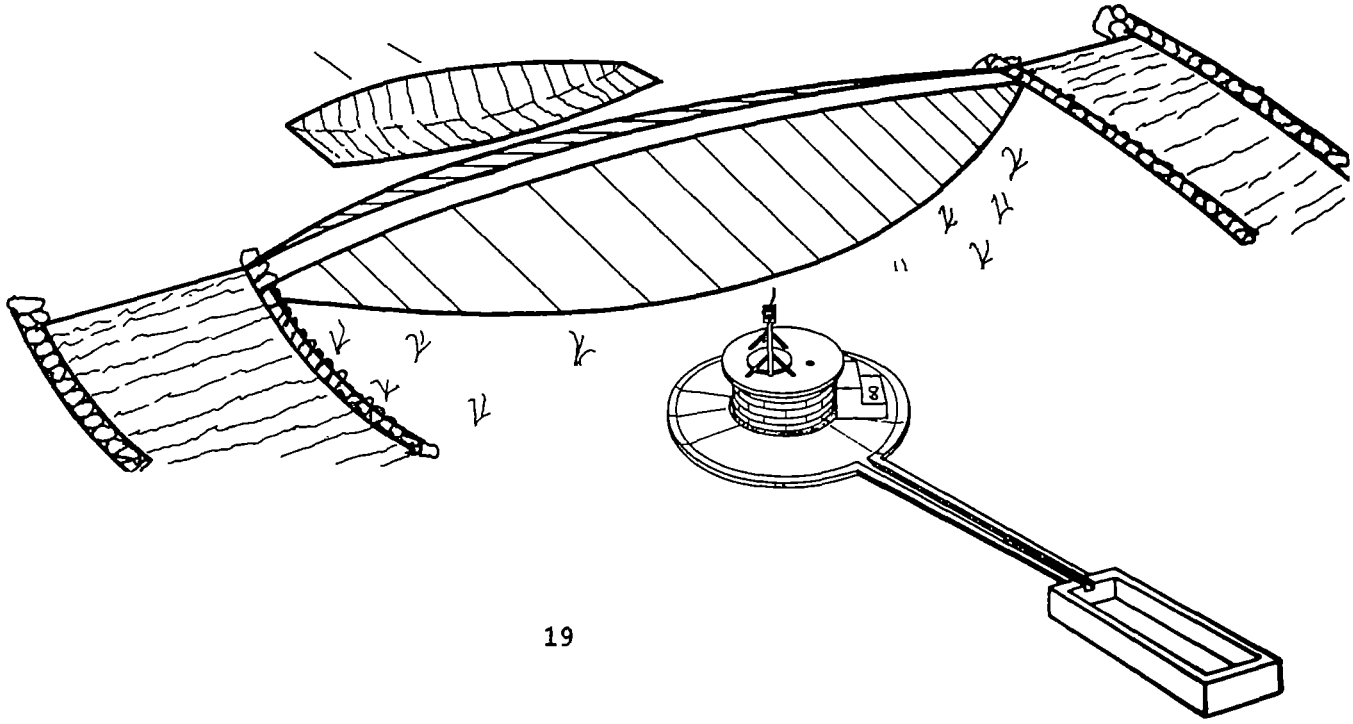
A few metres downstream of the shallow well, a washing slab and a bathing place for men and women could be built and fenced in.

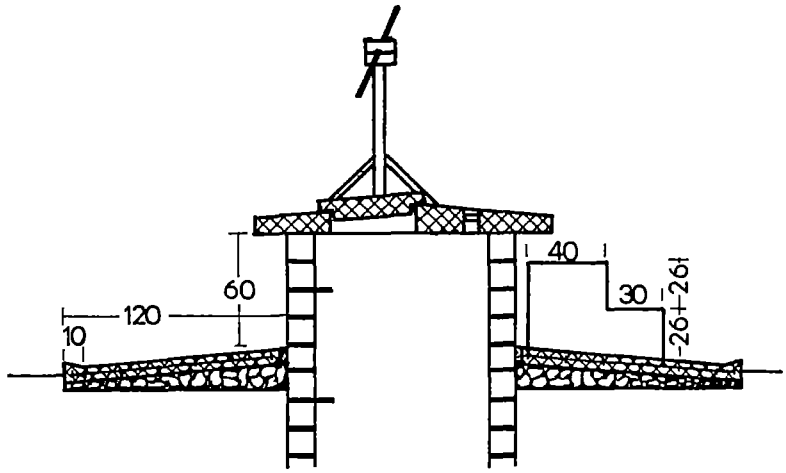
Toilet facilities and a cattle trough should be installed further away downstream of the shallow well in order to avoid pollution of the water for the shallow well.

(b) Water from livestock should be drawn from the shallow well to a drinking trough situated at least 50 to 100 metres downstream of the dam wall. Water can be delivered by gravity from the shallow well to the trough via concrete channel.

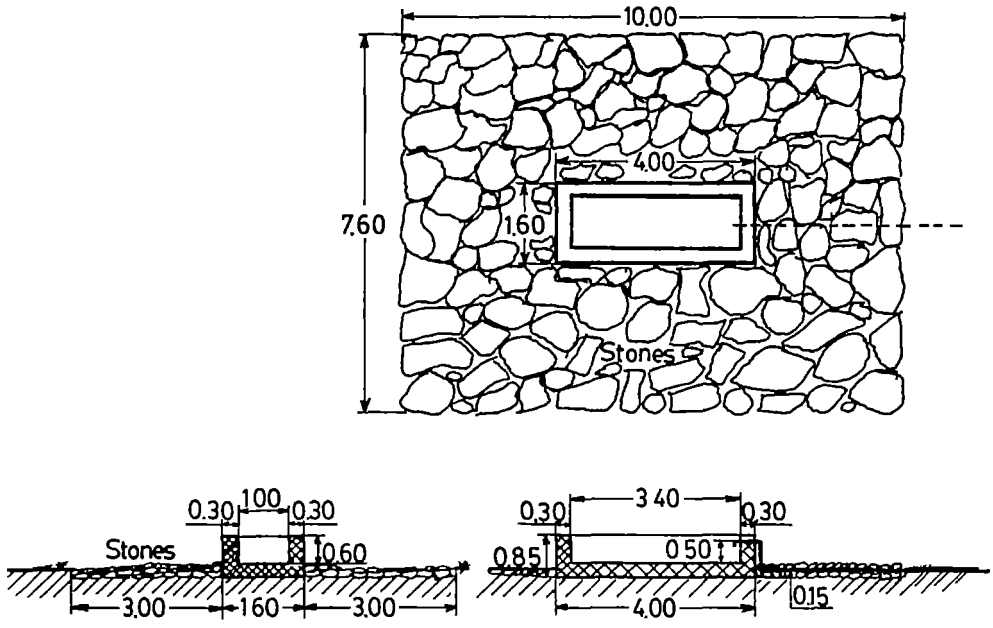
(c) Water for gardening and a tree nursery can be drawn from either the recommended shallow well or livestock trough.

(d) Wild and domestic animals can be kept out of the dam reservoir by a live fence of thorny vegetation planted around the site.





Shallow Well.



Livestock Trough

12. Improving Inflow to Dam Reservoir.

It may happen that a surveyor can misjudge the ability of a catchment area to provide rainwater run-off for filling up a dam reservoir. It can also happen that a rainy season is so poor that it cannot fill a dam reservoir.

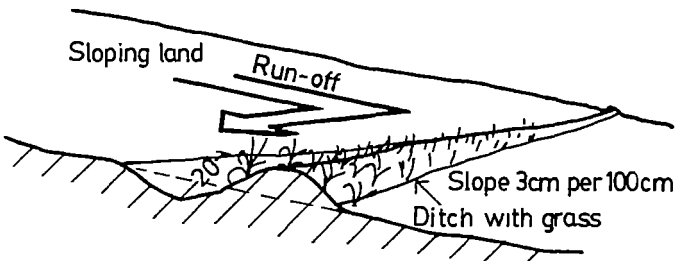
In such cases the inflow to a dam reservoir can be made bigger by enlarging the catchment area for the purpose of collecting more run-off.

The means of enlarging a catchment area consist of building gutters stretching outwards from the reservoir and surrounding a catchment area which drains run-off away from the reservoir. Such gutters slope slightly upwards from a reservoir in order to drain the collected run-off water towards the reservoir by means of gravity.

The materials for the gutters depend on the type of catchment area and the availability of local materials on the site.

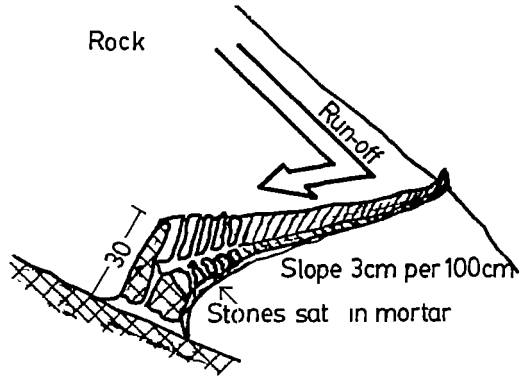
(a) On gently sloping land of soil e.g. farmland, the gutters can consist of a ditch with the excavated soil placed as a bund just downhill of the ditch. The bund should be planted with creeping grass to prevent it from being demolished by livestock.

Almost similar types of guttering can be found in cut-off drains on lands with proper soil conservation, and from ditches along roads.



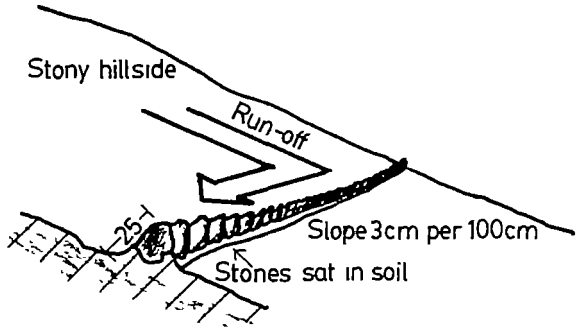
Collecting run-off from sloping land

(b) On stony hillsides, e.g. grazing land or forest, the gutters can consist of stones sat in soil. The uphill side of the guttering is covered with clayish soil for waterproofing. Non-palatable vegetation should be planted on the downhill side of the guttering to avoid livestock kicking the stones out of line



Collecting run-off from rocks

(c) In places with rock outcrops, gutters can be build of flat stones sat in cement mortar (see manual on rock catchment dams). The collected run-off water could be diverted to an earth dam by ditch similar to the one described above under (a).



Collecting run-off from hillside

13. Requirements of labour, materials and transport

1. Labour requirements

(a) A surveyor will visit a site 4 times if the first selected site has proved suitable, otherwise he will have to make more visits.

On the site visits he will carry out the following tasks:

1. Inform the self-help group concerned of the selection criteria for proposing 3 sites for the dam site.

   Investigate the proposed 3 sites then and select the most viable of them. Stake out the trench to be dug and distribute tools for excavation.

2. Investigate the soil profile in the trench and if viable, stake out the final dimensions of the trench and distribute ox-implements for earth moving. If the soil structure shows that the site cannot hold water, a new site has to be selected, pegged out and excavated.

3. Introduce the contractor to the group and hand-over the supervision of the construction work to him.

   Measure the site for production of drawings and bills of quantities.

4. Produce drawings and bills of quantities, and distribute them to the parties concerned.

Requirement of working days for a Surveyor:

4 field visits to a site = ...	4 days
Producing and distributing drawings	3 days
Total	7 days

(b) A Contractor should visit a dam construction group about twice a month for the purpose of:

- Teaching the group in moving earth by manual labour and animal draught, including training the animals.

- Instructing the group how to build their dam in accordance with the design given.

- Informing the relevant authorities of any changes in design or implementation procedures.

- Assisting the group in applying for additional activities such as construction of shallow well, trough, washing slab, tree nursery, fencing materials, etc.

Requirements of working days for a Contractor

Example: 2 visits x 6 months x 3 years = 36 days.
=======

(c) Skilled labour for building shallow well, trough, etc. can be estimated as follows:

- Cattle trough, standard design : 5 days per trough

- Shallow well with headworks : 4 days per metre depth

- Washing slab, : 4 days

(d) Unskilled labour provided free by self-help group may be estimated as follows for the purpose of having a value.

Example: 25 people x 3 days weekly x 6 months x 3 years = 1350 days.
=========

Enter the found requirements on the bills of quantities.

2. Material requirements.

(a) The earth for building an earth dam is not valued in terms of cost, because it has no sales value as such.

(b) The materials for building the installations at an earth dam can be estimated as:

	Bags of cement	Tonnes of sand	Tonnes of stones	Tonnes of water
			4	1
Shallow well 6 metre deep	24	6	3	4
Trough	6	3	9	1
Washing slab	4	2	3	1

Enter the found requirements on the bills of quantities.

3. Transport requirements

Transportation of materials is divided into two categories:

(a) Transport of local materials, such as soil, sand, stones and water, will be transported to the site by the self-help groups using oxen, donkey and hand carts, and are therefore difficult to estimate here.

(b) Transport of purchased materials, e.g. cement, etc. are estimated according to tonnage, distance and cost per km.

Example for category (a):

12 tonnes sand = 24 cart loads x Shs ..... = Shs .....

Example for category (b):

Transport of surveyor : 4 trips x ..... km x Shs ..... = Shs .....

Transport of contractor : 1 trip x ..... km x Shs ..... = Shs .....

Transport of cement : 5 tonnes x ..... km x Shs ..... = Shs .....

Enter the found requirements on the bills of quantities.

14. Bills of Quantities and Costing

Two bill of quantities are needed, because about half the items will be delivered by a donor/ministry and the other half will be delivered free of charge by the community concerned. Since the community is supposed to contribute about half the cost of the project, a value of their input has to be estimated.

Example:

Bills of Quantities for items to be delivered by donor/ministry

Skilled labour : 1 Surveyor for 7 day ..... x Shs ..... = Shs .....

1 Contractor for 36 days ..... x Shs ..... = Shs .....

1 Artisan for 10 days ..... x Shs ..... = Shs .....

Equipment: 5 pick-axes ..... x Shs ..... = Shs .....

5 shovels ..... x Shs ..... = Shs .....

5 spring jembes ..... x Shs ..... = Shs .....

10 karais ..... x Shs ..... = Shs .....

1 ox-scoop with harnesses ..... x Shs ..... = Shs .....

5 wheelbarrows ..... x Shs ..... = Shs .....

Materials: ..... bags of cement ..... x Shs ..... = Shs .....

Other items ..... x Shs ..... = Shs .....

Transport: ..... trips x ..... km ..... x Shs ..... = Shs .....

Total cost by donor/ministry Shs .....

Bills of Quantities for items to be delivered free by the group

Unskilled labour ..... days ..... x Shs ..... = Shs .....

Sand ..... tonnes x 2 = ... carts x 4 = ... wheelbarrows x Shs ..... = Shs .....

Stones ... tonnes x 2 = ... carts x 4 = ... wheelbarrows x Shs ..... = Shs .....

Water .... tonnes x 5 = ... drums ..... x Shs ..... = Shs .....

Total value of self-help Shs .....

Grand total cost and value of project Shs .....

15. Maintenance

To improve the strength and stability of the small earth dam, the following steps can be taken;

a. Plant and maintain a good live fencing of cactus or sisal plants around the water reservoir and downstream of the dam wall to prevent erosion of the dam wall and spillway by people and livestock. This fencing can be planted during a dry season. Protect young plants by covering them with thorny branches to keep off goats.

b. Dig contour lines or plant grass on the catchment area to prevent sheet erosion which will silt up the reservoir. Grass strips or stone lines are better than digging bench terraces because they slow down the water rather than stopping the run-off. Remember that all these changes to the catchment area will reduce the amount of water draining to the reservoir. Small earth dams are best built where the catchment area has been undisturbed by farming. The natural cover of shrubs and grasses will prevent serious soil loss. If the land is cleared, sediments will be washed in unless run-off farming is practiced which will conserve the soil but reduce the runoff.

c. Plant grass on both sides of the dam wall to prevent erosion.

d. Place lines of large stones in lines parallel to the spillway on the downstream side and plant grass between the stones to prevent erosion. Also place lines of stones from the reservoir downstream at right-angles to the spillway to prevent the water flowing sideways around the dam and causing erosion and undermining of the dam.

e. Check frequently for animal burrows in the dam banks. This will commonly occur because the less dense soil, moist conditions and closeness to water make the dam an ideal home. If burrows are found, the animals should be chased out with smoke, the burrows and the gap filled and compacted.