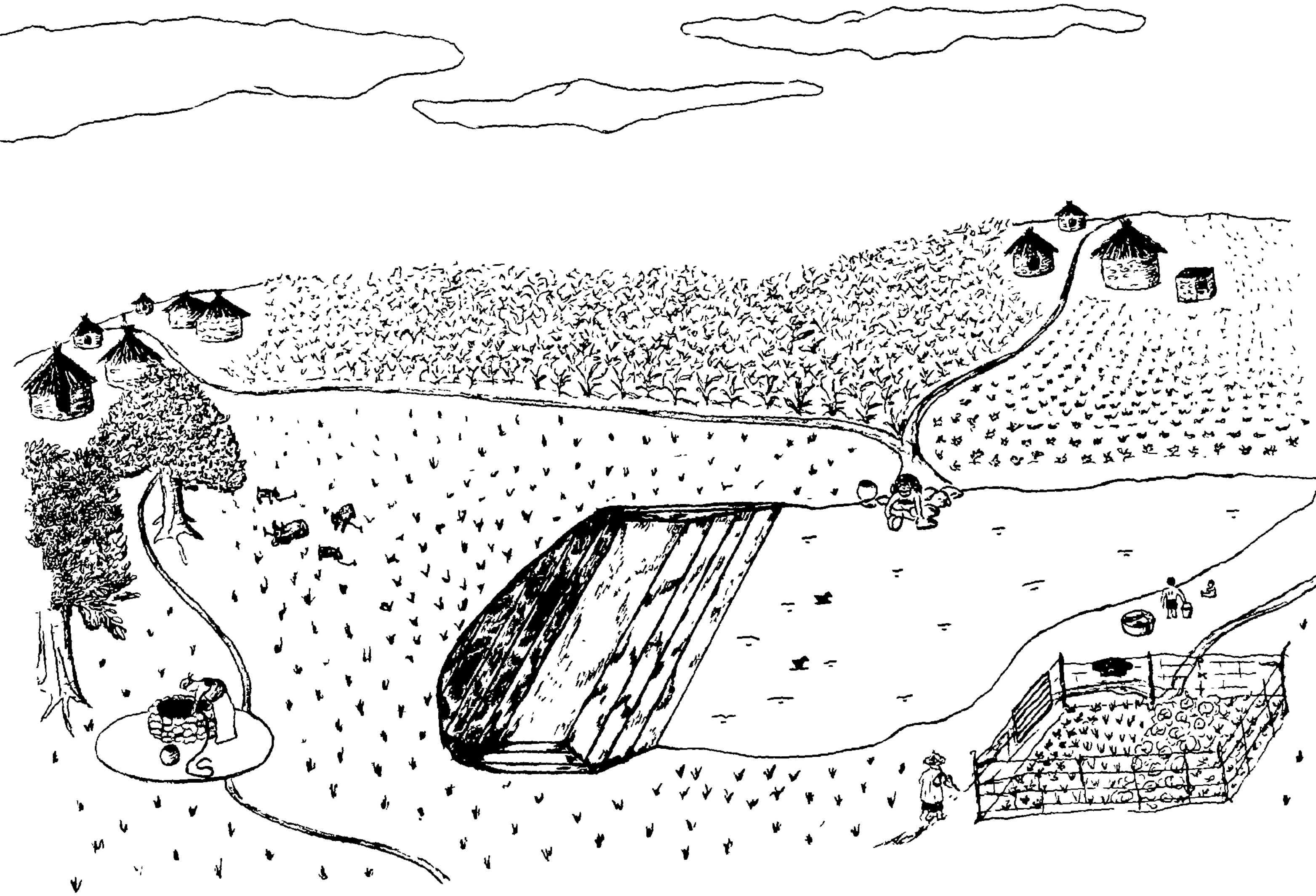
HAND-BUILT EARTHEN MICRO-DAMS

APPROPRIATE TECHNOLOGIES FOR VILLAGE SELF-DEVELOPMENT



ACKNOWLEDGMENTS

A special thanks to the following individuals and organizations for their input and help. This manual is simply a documentation of or an expansion on their work.

- Bali Sey (Richard) Youl

- The World Neighbors West Africa Team, especially:

  Peter and Alice Gubbels
  Koba-Koba Amukulu
  Tangawaki (Martin) Tchaagbam

- Mennonite Central Committee (MCC) volunteers who have worked with micro-dam related programs, especially:

  Johann Zimmermann
  Philip Martens
  Judy Unruh Goertzen
  Paul Brallier and Nancy Feagin
  Richard and Christine Coen
  Ann Reinert
  Steve and Sherri Saines
  Sam and Carol Bixler
  Alex and Anne Cambon
  Craig Andersen
  David Carrier

- Action Micro-Barrages (AMB; translated as "Project Micro-dams" in English) personnel, especially:

  Lieven De La Marche
  Ouoba (Bernard) Dihouada
  Lucien Tapsoba
  Harouna Ouedraogo
  Maureen Standaert

Also special thanks to:

  Joan Zahler
  Linford Martin and Chloe Grasse
  John and Tanya Horat
  Russ Toevs
  Griselda Shelly
  Jim Friesen

PREFACE

This manual is written for those interested in helping villages that have few financial resources to address recurring water shortage problems. Also this manual is written for those interested in helping villagers learn the process of improving and developing their lives by working together and using the resources they have to solve a common problem.

Many villages with dry season water shortage problems also have few financial resources available to solve those problems. However, the natural resources necessary to construct an earthen micro-dam are often readily available nearby. In most cases only two essential components are necessary for a successful village micro-dam project: 1) the villagers need to realize their potential for solving their own problem using their own resources of soil and manpower, and 2) they need to plan and organize the use of their resources to their best advantage.

In building a micro-dam, a village will need to learn the process of self-development. Ideally, after the dam is built, the village will continue to plan, organize, and work together to develop its resources and solve other common problems. This process of self-development will hopefully spread to neighboring villages as they witness its benefits.

Development cannot be brought to the people from the outside. An outsider can only nurture the people's potential for development. For example, an organization could suddenly arrive at a village uninvited and gain permission to build a dam nearby. The organization could build it with machines and leave. Since the villagers had no part in the dam they would feel no responsibility for it. It is doubtful that they would do the required maintenance. They would probably wait for the organization that owns the dam to come back and do the maintenance. Therefore, the useful life of the dam would be shorter than had it been a village project and therefore village owned. Some development might take place if villagers seized the initiative to use the water for gardening, fish raising, etc. But on the whole, instead of learning how to work to solve a problem together, the village will have simply learned dependency upon outside organizations to solve their problems for them. This type of situation can therefore be considered counter-development.

For village development to readily take place, the outsider should not play the part of the indispensable expert in charge. The outsider should be willing to pass on his knowledge and let the villagers lead the way. He should play the part of a catalyst, helping to motivate the village to act. As there is a need at times for outside expert advice, he can help the village make good decisions. But the village should always be recognized as the most important ingredient in a successful long-lasting village project and in long-term development. The "expert" should always remember that he will not be available to the village forever.

Tim Goertzen
MCC Burkina Faso 1988

MEASUREMENT ABBREVIATIONS

All measurements will be in metric terms and will be abbreviated as follows:

m = meters, example: 3m = 3 meters;
cm = centimeters, example: 6cm = 6 centimeters;
mm = millimeters, example: 9mm = 9 millimeters;
km^2 = square kilometers, example: $12km^2$ = 12 square kilometers;
m^3 = cubic meters, example: $15m^3$ = 15 cubic meters;
and etc.

MONETARY ABBREVIATION AND VALUES

When financial costs are spoken of in this manual they will be in terms of Francs CFA (Francs of the African Financial Community) and will be abbreviated as "cfa". For example, 500cfa means 500 Francs CFA.

The Franc CFA is tied directly to the French Franc so that 50cfa has always equaled 1 French Franc (1 FF = 50cfa). At the time of this writing the U.S. dollar equaled approximately 300cfa ($1 US = 300cfa, 1988).

REFERENCES

References to certain sections, figures, or appendixes in the manual that the reader can refer to for more information will be abbreviated and put in parentheses immediately following the text that the reference will help clarify. For example, "(sec.11D3)" will mean to see section 11D3 in the manual, "(fig.A30)" will refer the reader to figure A30, and "(app.E)" will refer the reader to appendix E.

Endnote numbers found in the manual will refer the reader to the numbered sources in the Bibliography section found at the end of the manual. For example, "...sand content.[15]" will refer the reader to the fifteenth entry in the Bibliography, which is a book by John Norton, as the source of the statements.

TERMINOLOGY USED IN THIS MANUAL

Become familiar with how the following terms are used in this manual.

Compacted earth - soil that has been compacted when it is damp (soil in a dry state resists compaction because the friction between the dry soil particles is great)(sec.13C).

Construction soil - the soil that is actually used in the construction of the dike (sec.13C).

Dam - the whole works: the dike, the reservoir, and the spillway (fig.A0).

Dike - only the constructed embankment (fig.A0).

Dike crest - the ridge, or the whole top, of the dike (fig.A0).

Freeboard - the part of the dike that is above water level of the reservoir when the reservoir is exactly full (fig.E10).

Impermeable soil - soil that does not allow water to pass through it (sec.10B).

Maximum flood - the largest probable flood that will occur <u>once in every 10 years</u> at a given site (sec.10D & app.D).

Natural spillway - a spillway (see below) which has nothing added to it; no concrete, no gabions (sec.22A), etc. It is made up of only the natural terrain that existed at the site before construction began (sec.10D).

Spillway - the part of the dam that allows the excess water that can not be contained by the dam to pass out of the reservoir (fig.A0).

Spillway discharge capacity - the maximum amount of excess water the spillway is capable of discharging out of the reservoir per second without causing excess erosion (sec.11D).

Spillway floor - the lowest area along the spillway ridge (see below) (fig.A0).

Spillway ridge - the crest of the spillway area, the uppermost line or area extending across the spillway from the end of the dike outwards, where once the excess water crosses this line it can be considered to be flowing out of the reservoir (fig.A0).

Valley - any low lying area that has the potential to be dammed. This term is preferable to ravine, gully, or channel because it suggests the more gentle, shallow terrain needed for hand-built earthen micro-dams (sec.10A).

Valley floor - the low area along a valley, the place where runoff water collects and forms streams or floods (sec.10A & fig.A0).

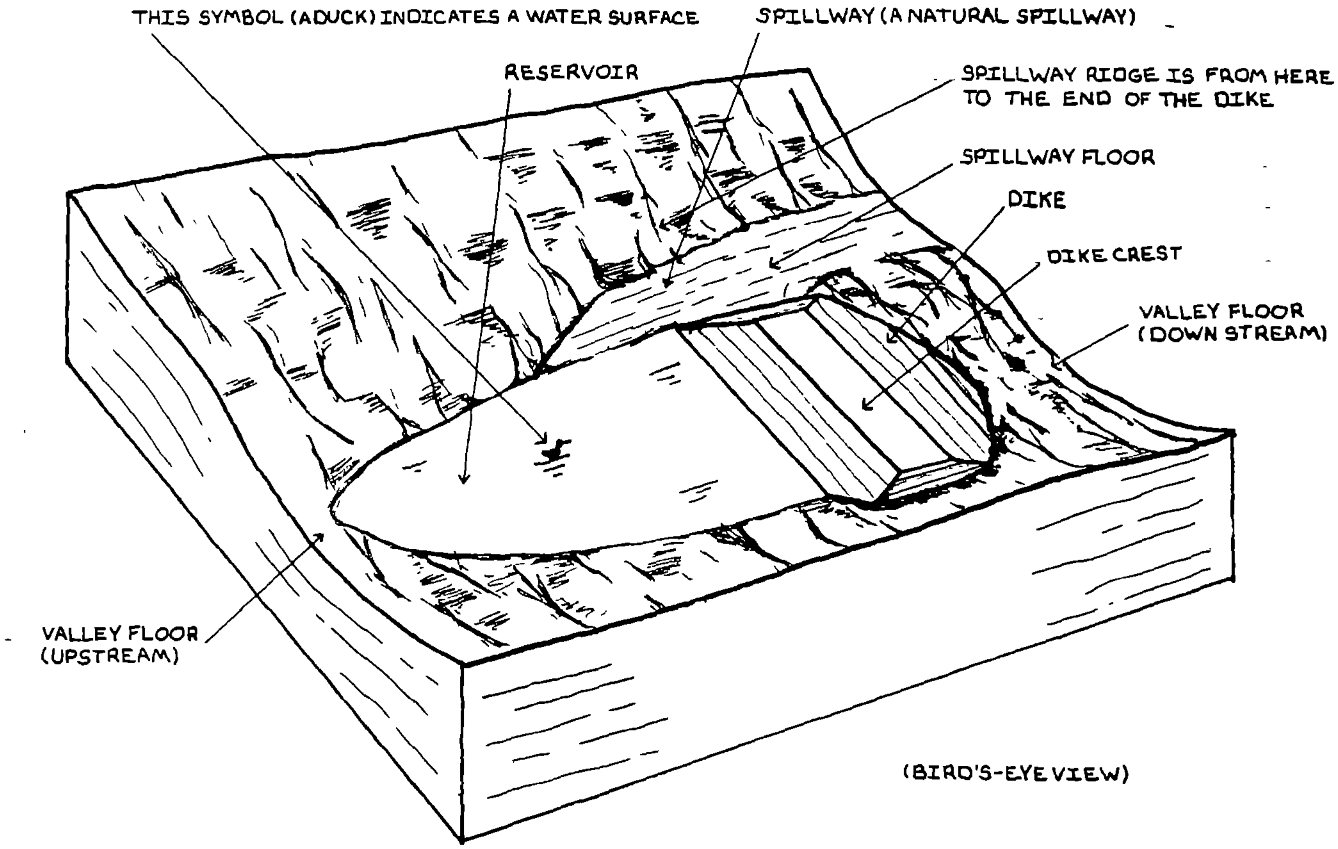
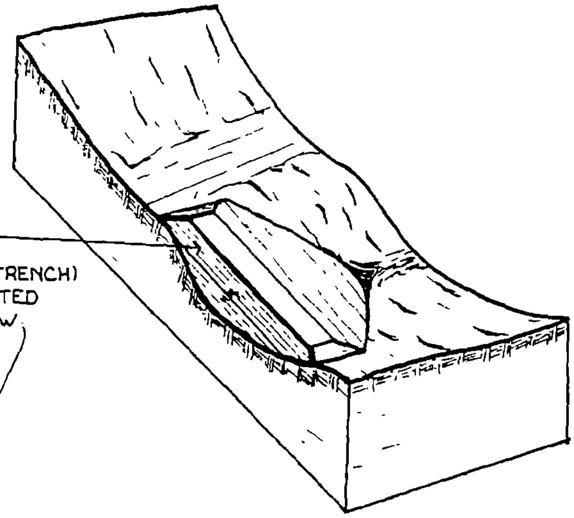
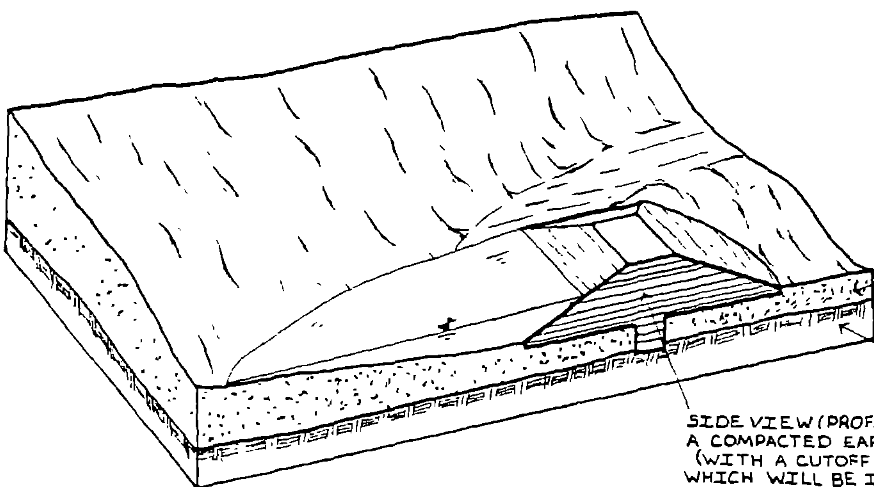


FIGURE A0: Components of a Micro-Dam

ILLUSTRATIONS AS USED IN THIS MANUAL





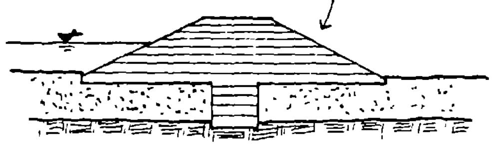


FIGURE B0: Illustrations in this Manual.

CONTENTS

SECTION PAGE

1. Introduction. 1-1
   A. The Context. 1-1
   B. The Objective. 1-1
   C. About This Manual. 1-1

2. Background of the MCC-Gaoua Dam Program. 2-1

PART I

THE BASIC TECHNOLOGY
[FOR COMPACTED EARTH MICRO-DAMS WITH NATURAL SPILLWAYS]

10. Choosing a Site. 10-1
    A. Narrow and Nearly Level Valley. 10-1
    B. Suitable Soils. 10-2
    C. Catchment Area and Runoff. 10-4
    D. Spillway. 10-6
    E. Seeking Expert Advice. 10-9

11. Surveying the Site. 11-1
    A. A Suggested Procedure. 11-1
    B. Using the Survey Information. 11-1

12. Planning the Dike. 12-1
    A. Height of the Dike Crest. 12-1
    B. Length of the Dike. 12-1
    C. Width of the Dike Crest. 12-1
    D. Slopes of the Dike Sides. 12-2
    E. Width of the Dike Base. 12-3
    F. Dimension of a Cutoff Trench. 12-4

13. Building the Dike. 13-1
    A. Laying Out and Staking the Dike. 13-1
    B. Excavating the Dike Foundation and a Cutoff Trench. 13-2
    C. Excavating and Preparing the Construction Soil. 13-2
    D. Placing and Packing the Construction Soil. 13-3
    E. Dealing with a Lack of Acceptable Soil. 13-4
    F. Dealing with a Lack of Water. 13-4
    G. Protecting the Dike Against Erosion. 13-5

14. Determining the Financial Costs. 14-1

PART II

VARIATIONS ON THE BASIC TECHNOLOGY

SECTION	PAGE
20. The MCC-Type Uncompacted Earth Micro-Dam with a Mud-Brick Wall.	20-1
A. Background.	20-1
B. Applications.	20-1
C. Advantages of Using a Mud-Brick Wall.	20-2
D. Construction of the Mud-Brick Wall.	20-2
E. Problems Encountered.	20-3
F. Safety Limits.	20-3
G. Financial Costs.	20-3
H. Future Directions.	20-4
I. For More Information.	20-4
21. The AMB-Type Micro-Dam with a Concrete Spillway Wall.	21-1
A. Background.	21-1
B. Description.	21-1
C. Advantages.	21-2
D. Financial Costs.	21-2
E. Problems Encountered.	21-3
F. Safety Limits.	21-3
G. Future Directions.	21-3
H. For More Information.	21-3
22. Compacted Earth Micro-Dam with Gabions.	22-1
A. Description.	22-1
B. Background.	22-1
C. Advantages.	22-1
D. Applications.	22-3
E. Safety Limits.	22-3
F. Financial Costs.	22-3
G. For More Information.	22-4

PART III

RECOMMENDED POST-MICRO-DAM CONSTRUCTION ACTIVITIES

30. Maintaining the Earthen Micro-Dam.	30-1
A. Maintenance of the Dike.	30-1
B. Maintenance of the Reservoir.	30-1
C. Maintenance of the Spillway.	30-2
D. Special Note About the Spillway.	30-3
31. Encouraging Prevention of Water-borne (Dam-related) Illnesses.	31-1
A. Illnesses that Result from Drinking Contaminated Water.	31-1
B. Illness that Results from Contacting Contaminated Water.	31-10
C. Preventing Malaria.	31-12

SECTION PAGE

32. Encouraging Other Dam-related Self-development Projects. 32-1
A. Wells Near the Dam. 32-1
B. Contour Barriers. 32-2
C. Other Projects. 32-4

33. Some Advantages of Micro-Dams Over Larger Dams. 33-1
A. Reservoir Maintenance Advantages. 33-1
B. Health Advantages. 33-1
C. Fish Harvesting Advantages. 33-1

PART IV

METHODOLOGY

40. Before the Micro-Dam Business. 40-1
A. Approaching the Village. 40-1
B. Gaining a Working Knowledge of the Village Milieu. 40-2

41. A Suggested Micro-Dam Meetings Format. 41-1
A. First Meeting: Determining the Need and Assuring Consensus. 41-1
B. Second Meeting: Determining If There Is an Adequate Site. 41-3
C. Third Meeting: Organizing the Village. 41-4
D. Fourth Meeting: Organizing the Work. 41-6

42. Training Aspects. 42-1
A. On the Job Training. 42-1
B. Training Sessions Away from the Village. 42-2
C. Sending a Trained Helper to the Village. 42-2
D. Future Directions. 42-3

43. Motivation Aspects. 43-1
A. Dealing with Halfway Point Discouragement. 43-1
B. Developing Good Working Relationships. 43-2
C. Evaluating "Food for Work". 43-2

44. Potential Limiting Factors. 44-1
A. Lack of Technical Help. 44-1
B. Lack of Suitable Sites. 44-1
C. Negative Village Dynamics. 44-2

45. Building on the Success. 45-1
A. Work on the Perceived Needs. 45-1
B. Work Through the Development Structure. 45-3
C. Discuss Maintenance Issues. 45-3
D. Discuss Preventative Health Issues. 45-4
E. Discuss the Other Dam-related Self-development Projects. 45-11

PART V

AN EXEMPLARY HISTORY OF A MICRO-DAM PROJECT IN THE VILLAGE OF KOLONDIOURA

PAGE: 50-1

APPENDIXES — PAGE

A. Doing Simple Soil Tests. 60-1

B. Using Topographical Maps to Estimate Catchment Area. 61-1

C. Using Water Tube Levels. 62-1

D. Estimating Flood Discharge Versus Spillway Capacity. 63-1
1. Estimation of the Maximum Discharge of a Flood Due to the Biggest Rainstorm in a Ten Year Period on a Small Catchment. 63-1
2. Another Method of Estimating Flood Discharge. 63-7
3. Estimating Spillway Discharge Capacity. 63-11

E. Estimating Dike Volume and the Number of Workdays Needed. 64-1
1. Estimating Total Dike (and Cutoff Trench) Volume. 64-1
2. Estimating the Number of Workdays Needed. 64-5
3. What Should Be Done If It Is Doubtful the Dike Will Be Completed in One Work Season. 64-7

F. Making Earth Compactors of Reinforced Concrete. 65-1

G. AMB Village Survey. 66-1

H. AMB Conditions for Collaboration. 67-1

I. MCC Letter of Agreement. 68-1

BIBLIOGRAPHY 70-1

1 INTRODUCTION

1A THE CONTEXT

Burkina Faso (formerly Upper Volta) is situated in central West Africa just south of the Sahara Desert and to the north of the coastal rain forests. The majority of its people are farmers who live in small villages and own the land they cultivate.

The land varies from semi-desert in the north to semi-humid tropical forest in the south. There is a cycle of a rainy season lasting 3-6 months and then a dry season lasting 6-9 months depending upon the location. During the dry season it becomes difficult for many villagers throughout the country to find enough water for themselves and for their animals. Very often these same villagers do not have the means to pursue some of the usual solutions to their water problem, such as wells, borehole pumps, machine built dams, etc. These villages need an alternative solution such as hand building an earthen micro-dam.

In Burkina Faso there are many organizations helping villagers build earthen micro-dams. The various technologies used have been adapted to suit a wide range of village conditions and resources. This manual is an attempt to share the knowledge of these simple technologies so that more villagers can learn how to help themselves solve water shortage problems.

1B THE OBJECTIVE

It is the hope of MCC and WORLD NEIGHBORS that this manual will be of help to others who wish to share in village development and the solution of water shortage problems. Any suggestions and critiques of this work are welcomed.

1C ABOUT THIS MANUAL

The first part of this manual presents the basic compacted earth micro-dam technology used by the MCC-Gaoua program.

Secondly, variations on the given technology will be presented as used by the MCC-Bourzanga/Korsimoro programs, the Action Micro-Barrage program, and the programs of some of the members of the French Association of Volunteers for Progress (AFVP).

The third part consists of recommended post-construction activities for the village that has successfully constructed a micro-dam. These activities are in response to: the maintenance that will be required; the health problems that might accompany the creation of a micro-dam; and the other micro-dam related projects that would be advantageous for the villagers and would encourage them to continue down the road to self-reliance.

In the fourth part of the manual a suggested process or methodology is presented for helping guide a village in developing itself, starting with a micro-dam. The factors determining whether a self-development project, such as a micro-dam, will be successfully completed are the degree to which there is a village consensus as to the problem and its solution as well as their willingness to work together. Therefore this part on methodology is perhaps the most important part of the manual, though in reality the technology and methodology of village built micro-dams go hand in hand.

Part five is an exemplary history of a micro-dam project in the village of Kolondioura, Burkina Faso. It is included as a real life example/review of points made in the manual.

There may be a French version of this manual available in the future.

2 BACKGROUND OF THE MCC-GAOUA PROGRAM

The micro-dam program in the region around Gaoua, in southwest Burkina Faso, was started by MCC in conjunction with the World Neighbors organization. It was started because the MCC personnel came to the realization that even their partially subsidized program of building basic wells with bricks was still too expensive for many villages in the area who were suffering due to lack of water in the dry season. Since MCC and World Neighbors are small organizations with limited resources, dedicated to working at the "grass roots" level of development, it was decided to try and encourage villagers to construct earthen micro-dams using their village's own resources, as MCC had been doing in the Leo and Korsimoro regions of Burkina Faso. At the same time it was decided to expand the health awareness program to accompany the micro-dam projects. This was done because it was realized that although micro-dams help solve a lack of water problem they do nothing to improve, and might even worsen, the health situation of a village.

Since 1983 eight hand-built earthen micro-dams have been built, two are in progress, and six were started and then abandoned. It was an uphill battle from the beginning to establish the program. First, it was difficult to convince the villagers that an earthen dike could hold back water when neither concrete nor machines were used to build it. Secondly, the villages of the ethnic group being worked with were made up of individualistic household groups who normally gave no great allegiance to any central authority figure or structure. Therefore, it was especially difficult for these villagers to reach consensus and mobilize themselves to work together on a solution to a problem for the whole dry season. With no traditional central structure to guide the micro-dam construction the work tended to be haphazard and inefficient.

MCC-Gaoua, learning from its early experiences, has found it a great help to try to have the village organize itself to work efficiently and steadily at the beginning of the construction when the morale is high and the villagers are enthusiastic. Too often if the work drags along with little work done each workday, the villagers become easily discouraged and many abandon the project. In the past 3 years none of the micro-dam projects that have been started have been abandoned.

Now that the Gaoua program has adapted an appropriate approach or methodology (sec.41) that suits their ethnic group, and now that there are 8 micro-dams in the area for neighboring villages to evaluate, the compacted earth micro-dam technology seems poised for a more rapid expansion in the region.

PART I

THE BASIC TECHNOLOGY
[FOR COMPACTED EARTH MICRO-DAMS WITH NATURAL SPILLWAYS]

10 CHOOSING A SITE

Choosing a good site is the most important technical consideration for a successful micro-dam. It is in the selection of a site that a village can most benefit from the aid of a person who understands the inter relationship of the factors determining a good site for a micro-dam.

Even if a village is highly motivated, their level of motivation might not be enough to finish a dam if a good site cannot be found near the village. The site must be one that the village will wholeheartedly accept and that will yield adequate results for the amount of work done. There will often be a trade-off between the best technical site and the site that is best for sociological reasons. Often a less than ideal site can still be workable.

In this section the five main factors to look for when choosing a site for a micro-dam will be examined in detail. The five main factors are:

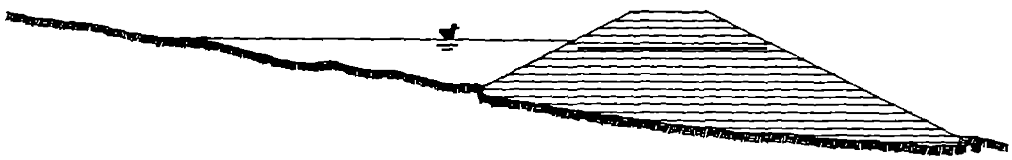
- a narrow valley
  (so the length of the dike can be shorter),
- a nearly level valley floor
  (so the dike can be low, simple, and yet secure),
- good soil
  (at the base of the dike and the spillway and for the construction of the dike),
- an adequate catchment area size
  (but not too large), and
- an adequately sized natural spillway.

10A NARROW AND NEARLY LEVEL VALLEY

In choosing a site for hand-built earthen dams it is best to find a place that is both narrow across the valley and nearly level along the valley floor.

The width is important because the narrower the site the shorter the dike length will be and the less work it will take to build it.

The levelness is important because the flatter the slope of the valley floor the slower the water will drain into the reservoir, the slower the water level in the reservoir will rise, and the greater the volume of water stored in the reservoir will be for a given depth (fig.A10). Therefore a dam built on a nearly level valley floor will not be as deep and therefore will not need to be as high, massive, or complicated as a dam built on a steeply sloped floor. In general the depth of the reservoir water within 5m to 10m of the dike should be limited to one meter or less.



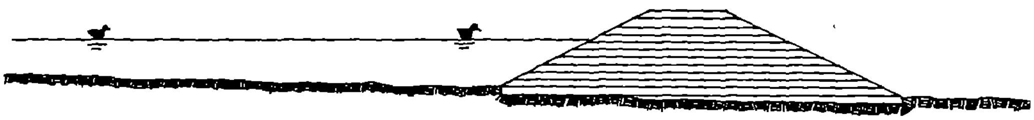


FIGURE A10: Acceptable and unacceptable valley floor slope.

The smaller the percentage of slope along a valley floor the more level the valley floor is (a slope of 0 percent indicates a perfectly level valley floor). As a rule, the slope along the valley floor should be less than two percent (sec.11B).

Finding a site that is both narrow and nearly level usually rules out building a dam across a narrow deep gully, which is usually the first place people think of for a micro-dam. In general a micro-dam built in a narrow gully will either not have enough water storage volume or will need to be too high, too massive, and too complicated to be covered by the scope of this manual. Also a deeply eroded gully signals that either the soil there is eroded quite easily[14] or the quantity and/or the force of the water draining through the gully is very high. Both of these situations should be avoided.

10B SUITABLE SOILS

The soil of a potential site should be carefully examined to determine if it is suitable at the base of the dike, the reservoir, and the spillway, as well as for the construction of the dike (app.A). The soil should contain some clay and silt. These fine-grained soil particles make the soil more impermeable. Soil in a dam that contains a fair amount of clay and silt will not allow much water to seep through the dam and drain away.

There needs to be some clay in the soil used to construct the dike so that the soil will stick together, giving it strength and erosion resistance. But if there is too much clay in the soil there may be a problem of big cracks developing in the dike as it dries.

When starting to evaluate a dam site, take note of surface of the soil. Cracks in dry soil indicates a high clay content. But dry soil that is grainy and loose indicates a high sand content.[15] Avoid rocky, stony, and lateritic soils because an earthen dam built upon such soils will have a tendency to have too much seepage.[23] Also watch out for soils that are mostly sand and gravel (permeable soils) that would underlay the dike because such soils will allow water to easily pass under the dike.

If there is sandy/gravelly soil at the site it still might be possible to construct a dam at that location provided there is a layer of more impermeable soil not too far below this permeable soil. A cutoff trench can be dug down just into the impermeable layer along where the dike will be built. This trench can then be packed with impermeable soil, in effect cutting off or sealing off the permeable sandy layer (fig.B10). To find out if this is a possibility some holes or test pits must be dug at the proposed location of the dike to verify the different types of soil layers and their depth. If the bottom of the permeable layer is deeper than 1 to 1.5 meters, the work required to dig the trench to that depth along the whole length of the dike might be too much for a village.

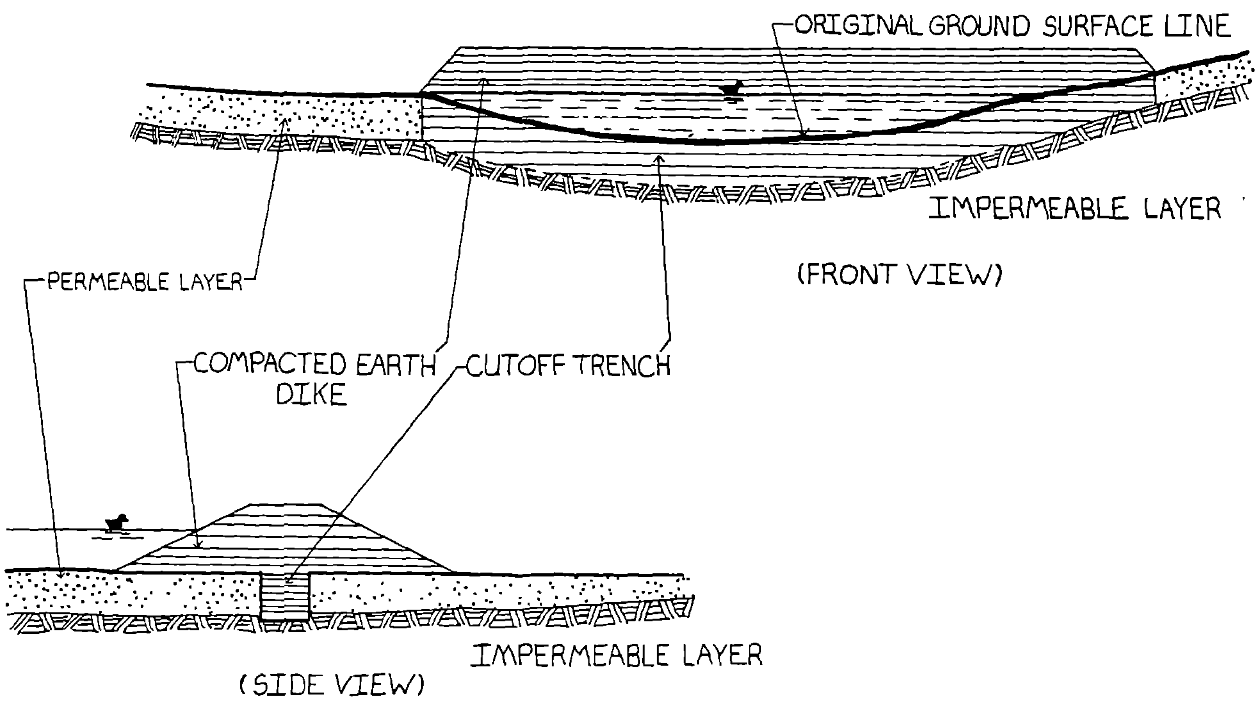


FIGURE B10: Cutoff trench.

Ideally, the soil used to build the dike (construction soil) should be excavated from what will be the reservoir area because this excavation will serve to deepen the reservoir and increase the volume of water retained. But be sure not to excavate down into a more permeable layer of soil that might be under the reservoir area and that would serve to drain the water away. A thick undisturbed layer of impermeable soil should be left to cover a more permeable soil layer to seal it off.[14] It is, therefore, also necessary to dig at least one test pit in the proposed reservoir to see if and how much good construction soil is there and if there is any permeable layer to watch out for.

If only a thin layer of acceptable construction soil can be found near the proposed site, a micro-dam might still be built at this location by using this acceptable soil only for the core (mid-section) and the cutoff trench of the dike (fig.C10).[22]

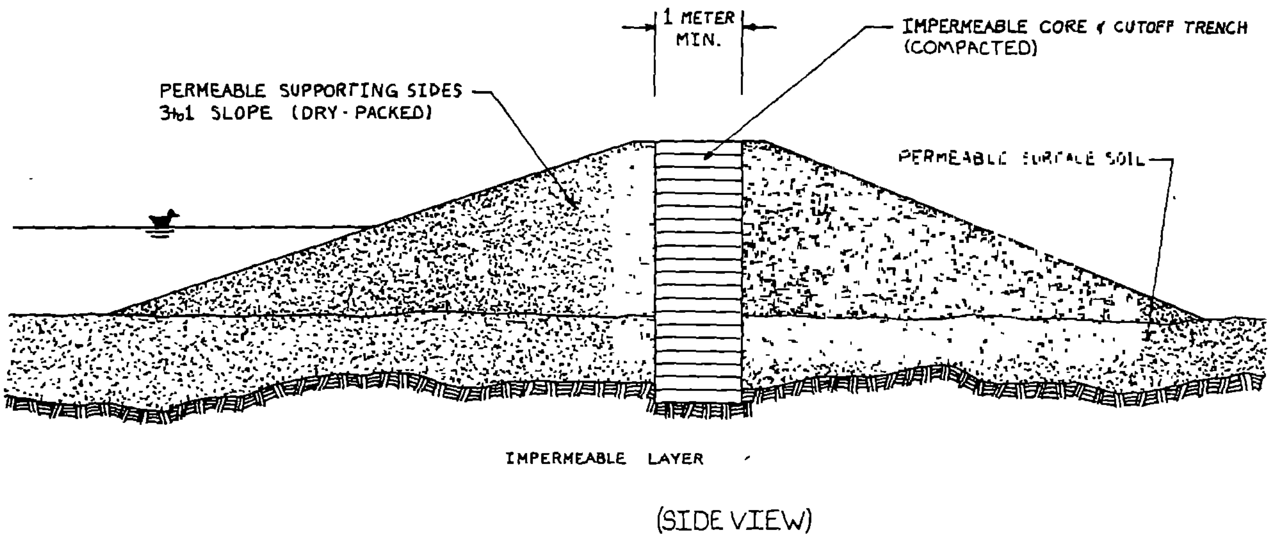


FIGURE C10: Effective use of only a small amount of impermeable soil.

Often the best place to look for a site is where water already rests for a long time after a rain, such as a pond. This is because these places indicate that the underlying soil is impermeable and that the location is level or basin-like. Also, it is likely that the villagers already use water from this type of site and they will likely be easier to motivate to improve the water-retaining capacity of the site.

10C CATCHMENT AREA AND RUNOFF

It is important to know something about the catchment area (also called the drainage basin) of a potential dam site, and its relationship to runoff.

10C1 WHAT IS THE CATCHMENT AREA?

The catchment area for the site of a dam is all of the land surface that is directly uphill from the site. All of the water that drains into the dam comes from the rain that falls on this land surface. In other words, the catchment area of a dam site is the land area that "catches" the rainfall and drains the excess rain water into the dam (fig.B61).

10C2 WHAT IS RUNOFF?

Runoff is excess rain water that does not soak into the ground or evaporate but instead drains away downhill. The runoff from a heavy rainstorm will accumulate along the valleys of a catchment and will create streams or floods.

10C3 WHAT DETERMINES THE AMOUNT OF RUNOFF?

The amount of runoff depends upon the following catchment area factors:[17]

- The absorption capacity (permeability) of the surface of the catchment. (A surface of sandy soil will absorb more rain water and have less runoff than a surface of clayey soil, all other things being equal).

- The size of the catchment area. (The larger the area the more potential runoff).

- The steepness of the slopes of the catchment. (The steeper the slopes are the less rain will soak in and the more runoff there will be).

- The amount and type of vegetation on the surface of the catchment. (The heavier the vegetation on the surface the more it will slow down the runoff water as it is draining off and thus allow more water to soak into the ground).

- The amount and intensity of rainfall on the catchment. (Heavier rainfall will yield more runoff. An intense rainfall, one where the rain falls over a shorter period of time, will yield more runoff than if the same amount of rain falls over a longer period).

The dimensions of the dike and spillway are dependent upon how much runoff is likely to come into the dam at one time. The more water that drains into the dam, the bigger the dike and the spillway must be.

In general, the size of a catchment area should be a maximum of thirty square kilometers and a minimum of four square kilometers.[23] The maximum limit ensures that the dike and the spillway are of a manageable size. Whereas the minimum limit ensures that the reservoir will fill up several times during a normal year and makes it more likely that it will also fill up at least once during a dry year.

The other four factors influencing runoff may require different limits. For example, if the catchment is flat, sandy, and does not experience heavy rainfall, the limits could be higher. Conversely, if the catchment surface is rock or clay, devoid of vegetation, steep-sided, and experiences heavy rainfall, the catchment area limits should be reduced.

To estimate the size of the catchment area for a site a topographical map of the area can be used (app.B). Also, special aerial photos can be used. If these are not available, the size can be estimated by following on foot or in a vehicle the main valleys in the catchment from the proposed dam site up to the perimeter, or upper limits, of the catchment area.

10D SPILLWAY

The spillway allows excess rain water that cannot be contained by the dam to pass out of the reservoir without causing serious erosion. If a natural spillway can be found for the dam, the cost of making concrete or other costly spillway constructions can be avoided.

If a dam is to rely on a natural spillway, finding an adequate location for the spillway is critical. Its form, size, and location will determine if this type of micro-dam can be built at the site. The other four already mentioned factors in determining a good site can indicate that a general area along a certain valley is a good place for a micro-dam. But the spillway location determines:

- the exact location of the dam,
- the height of the dike, and
- the amount of water it can retain.

10D1 DETERMINING THE LOCATION

Finding a natural spillway means locating a point along the shallow valley to be dammed where the land bordering at least one side of a potential reservoir area is fairly level. Choose a point where this nearly level strip of land bordering this potential reservoir site is as wide as possible to allow for as wide a spillway area as possible (fig.D10). The dike would be built across the valley at this point.

Figure D10 shows several possible dam sites and natural spillway configurations. The acceptable dam sites have a much greater area for the water to spill out than the unacceptable dam sites because their spillways are wider.

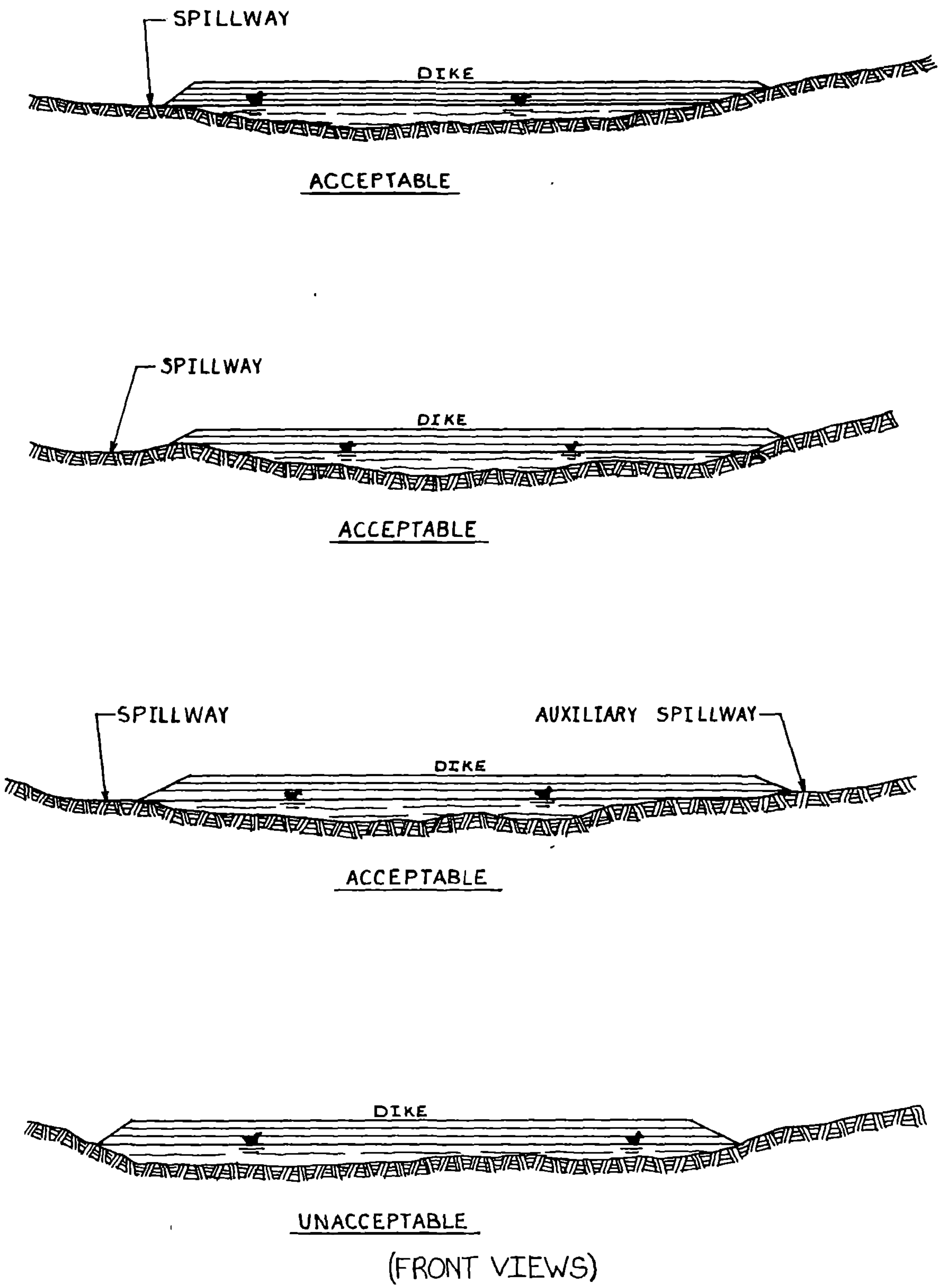


FIGURE D10: Acceptable and unacceptable spillway configurations.

The wider and more level the spillway is, the more likely it is that water flooding into the dam from a very intense rainstorm will not overload the spillway discharge capacity. Thus, the dam will be less likely to be overtopped and eroded away by the flood.

A wide and level spillway allows excess water to pass more slowly out of the reservoir than it would out of a narrow spillway since the water can spread and flow out at a lower depth. The slower this water moves, the less it will erode the dam. The level of flood water flowing out of the spillway should be less than 50cm above the spillway floor.[23] This is because above 50cm the water will cause too much erosion. This 50cm level is the absolute maximum flood level. It would be better if the water always flowed out at a level lower than 50cm.

10D2 DETERMINING THE HEIGHT OF THE DIKE

The crest of the dike should always be 50cm above the maximum flood level for the dam.[23] This added 50cm height is to provide a safety factor to be sure the dike is not overtopped due to any wave action during flooding, to settling or unevenness along the crest of the dike, to an unusually heavy rainstorm, and to errors in estimating runoff.

Therefore it is the spillway discharge capacity that determines how high a dike will need to be. This is because it determines the maximum flood level or how high the reservoir water level will rise for a given flood that might occur at the site. The wider and more level the spillway is the greater its capacity and the lower the maximum flood level will be.

Since it has already been stated that the maximum allowable flood level should be 50cm above the spillway floor and that the dike crest should be 50cm higher than the maximum flood level to provide a safety factor, the height of a dike crest above the spillway floor (the "freeboard" height) can be limited to one meter (fig.E10).
(50cm max. flood level + 50cm safety factor = 1m freeboard).

This 1m freeboard is good for the case where the site selected has all the desirable qualities of the aforementioned factors of site selection along with a large level spillway area. If there is any question whether it is safe to build at the site or if the site is so desirable that the maximum flood level might never reach close to 50cm, appendix D can be used to help determine if the site is acceptable or if the height of dike can be reduced to lessen the work load.

10D3 DETERMINING THE AMOUNT OF WATER RETAINED

The level of the floor of the spillway will also determine the level of the water retained in the reservoir because once the water level drops to that of the spillway floor, no more water will pass out of the reservoir (fig.E10). This level determines the depth of the water in the reservoir and, therefore, the amount of water retained by the reservoir.

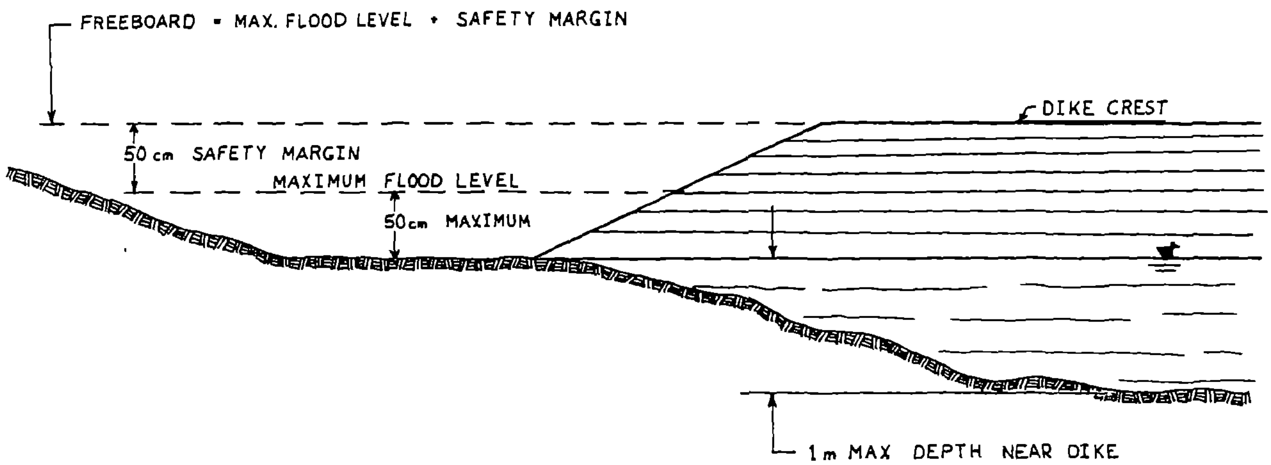


FIGURE E10: Illustration of micro-dam limits and definitions.

The level of the water retained should be limited to one meter or less above the base of the dike.[23] This is not to say that the reservoir cannot be dug down deeper than one meter some distance away from the dike, but the depth of the water resting directly against the dike should be no more than a meter. If the level of water retained is more than a meter above the base of the dike, the design and construction of the dike becomes more complicated, (requiring seepage drains, zoned embankments, etc.[20]) and is beyond the scope of this manual.

10E SEEKING EXPERT ADVICE

When choosing a site for an earthen micro-dam feel free to consult with experts in the field. But be sure to make it clear to them that the micro-dam will be built by hand by villagers who don't have money for machines. Also try to make them understand that the village is being encouraged to build an earthen micro-dam in this manner to not only help solve a water shortage problem but to also teach the villagers that they can better their conditions by their own initiative, using what they have, and working together. Explain the dangers of promoting the dependency of the villagers on outsiders.

If the expert doesn't understand or agree with the above he might be skeptical of the advisablility and/or the value of this method of dam construction. This might be especially true for an expert who usually designs large dams which are built with machines that could build one of these micro-dams in a day or two.

Feel free to contact or visit MCC (01 B.P. 1307) or World Neighbors (B.P. 1315) in Ouagadougou, Burkina Faso for advice from one of their people working in the field.

11 SURVEYING THE SITE

When a possible dam site has been located, it is usually necessary to survey the site to be sure the site is acceptable and to determine the dimensions of the dike. The site can be surveyed using simple surveying equipment such as a water tube level (app.C).

11A A SUGGESTED PROCEDURE

A site can be surveyed in the following manner:

- Examine the proposed spillway ridge to determine and mark where the spillway floor is (often this area is next to where the dike will start). This area will be the starting point for the survey.

- Establish a reference level one meter above the spillway floor (app.C).

- Using a water tube level or other survey equipment, measure the height of the reference level above the ground surface all along where the spillway ridge and dike crest will be.

  Measure these heights of the reference level at equal intervals and record these measurements systematically so this information can be accurately used later. The intervals between measurements are usually every five or ten meters. The shorter the intervals, the more accurate the results will be, but the more time the surveying will take. The measurements should be continued across the valley until the reference level is found to be less than 50cm above the surface of the ground on each side of the valley (fig.A11).

- In order to get some idea of the slope of the floor of the valley, go to the area where the dike will be located and measure and record the height of the reference level above the floor of the valley in this area. Then measure and record the height of the reference level above the valley floor 20 to 30 meters upstream from the potential site.

See Figure A11 for an example of how survey data can be recorded and graphed.

11B USING THE SURVEY INFORMATION

The survey information can then be used to calculate:

- the maximum depth of water beside the dike,
- the slope of the valley floor, and
- the spillway discharge capacity.

It can then be determined if the results are within acceptable limits.

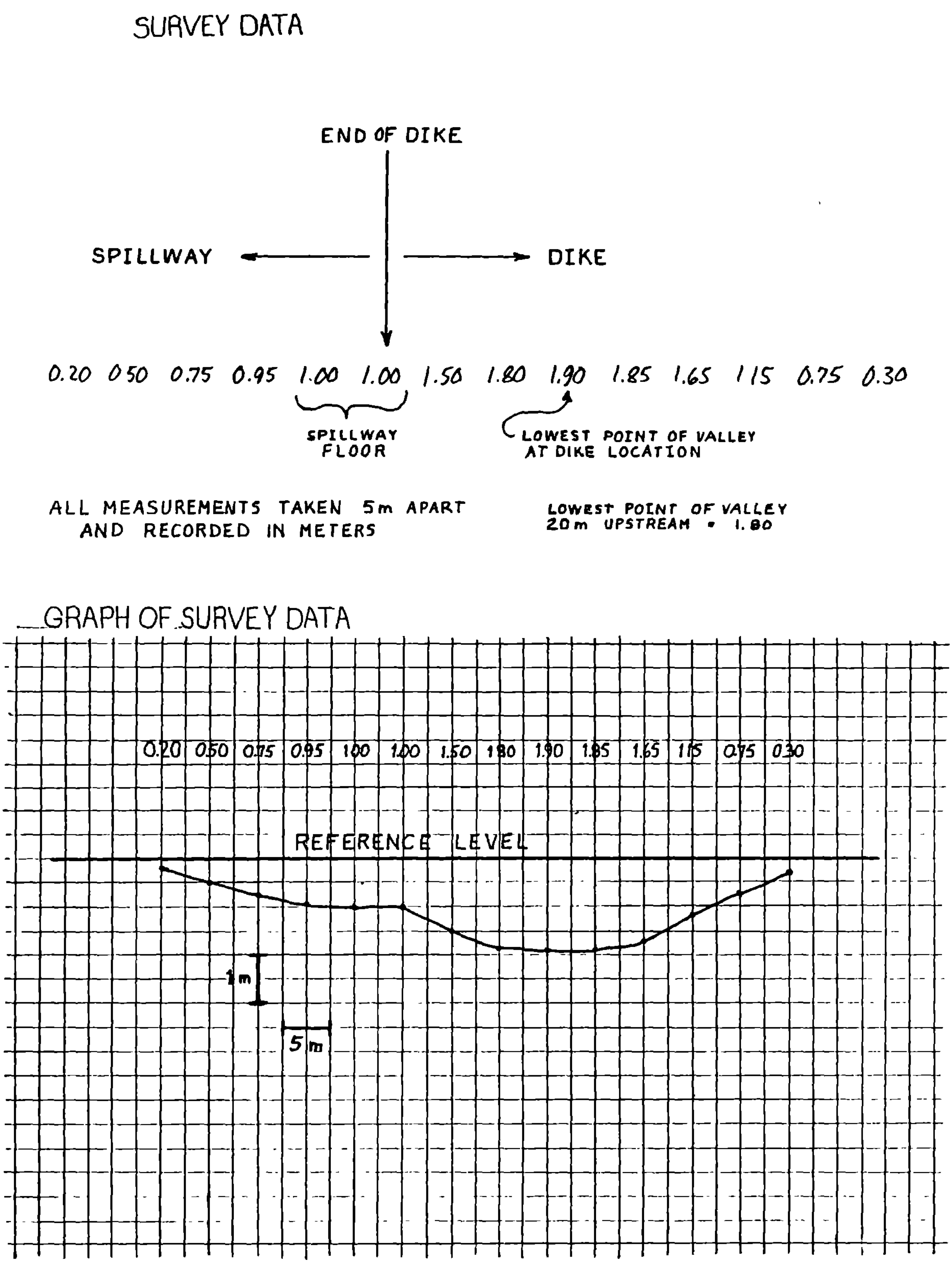


FIGURE A11: Example of survey data.

11B1 CALCULATING MAXIMUM DEPTH BESIDE THE DIKE

To calculate the maximum depth of water beside the dike (D^{max}) subtract the spillway floor measurement (S^{f}) from the measurement of the valley floor where the dike will be ($V^{f:dike}$).

Formula: $D^{max} = V^{f:dike}\ (m) - S^{f}\ (m)$

Example: (fig.A11) The valley floor measurement at the dike location is 1.90m. The spillway floor measures 1.00m from the reference level. Thus the maximum depth of water besides the dike is 0.90m ($D^{max} = 1.90 - 1.00 = 0.90$), which is less than one meter and therefore would be acceptable.

11B2 CALCULATING SLOPE OF VALLEY FLOOR

To calculate the slope of the valley floor, subtract the measure of the valley floor upstream ($V^{f:up}$) from the valley floor measurement at the dike ($V^{f:dike}$) location. Then divide by the distance between these two measures (d), and multiply by 100 to get the percentage of slope (V^{s}).

Formula: $V^{s} = \frac{V^{f:dike} - V^{f:up}}{d} \times 100$

Example: (fig.A11) The valley floor measurements are 1.80m for the up-stream and 1.90m at the dike location. The distance in between is 20m. Thus the valley floor has a slope of 0.5 percent at that location (see below) which is less than 2% and would be acceptable.

$$V^{s} = \frac{1.90 - 1.80}{20} \times 100 = 0.5\%$$

12 PLANNING THE DIKE

12A HEIGHT OF THE DIKE CREST

The height of the dike crest will usually be one meter above the spillway floor. But if the spillway discharge capacity is much greater than the estimated maximum flood discharge, the height of the dike can be lowered (app.D).

The dike can be lowered to 50cm above a level in the spillway that will provide just enough discharge capacity for the estimated maximum flood. For example, if it is found that a certain spillway has the capacity to discharge the maximum estimated flood at a level of only 25cm above the spillway floor the dike crest only needs to be 50cm above that level or only 75cm above the spillway floor (50cm safety factor + 25cm estimated max. flood discharge level = 75cm). This means less work for the villagers.

12B LENGTH OF THE DIKE

The length of the dike, and therefore the labor involved, can be reduced by having an auxiliary spillway on the other end of the dike (fig.A12).[23] In any case, the dike can be stopped on the other end at the point where the ground is at the estimated maximum flood discharge level (usually 50cm above spillway floor) unless the side slope of the valley on that side is too steep. If the valley side slope is too steep the dike should be continued until the dike crest meets this steeper slope (fig.A12).

Also, along with shortening the length of the dike, an auxiliary spillway will increase the total spillway discharge capacity.

12C WIDTH OF THE DIKE CREST

It must now be decided how wide to make the crest of the dike. Usually the crest should be at least one meter wide. It can be wider to allow carts to pass over or to make the dike more massive if the soil or other conditions are not ideal.

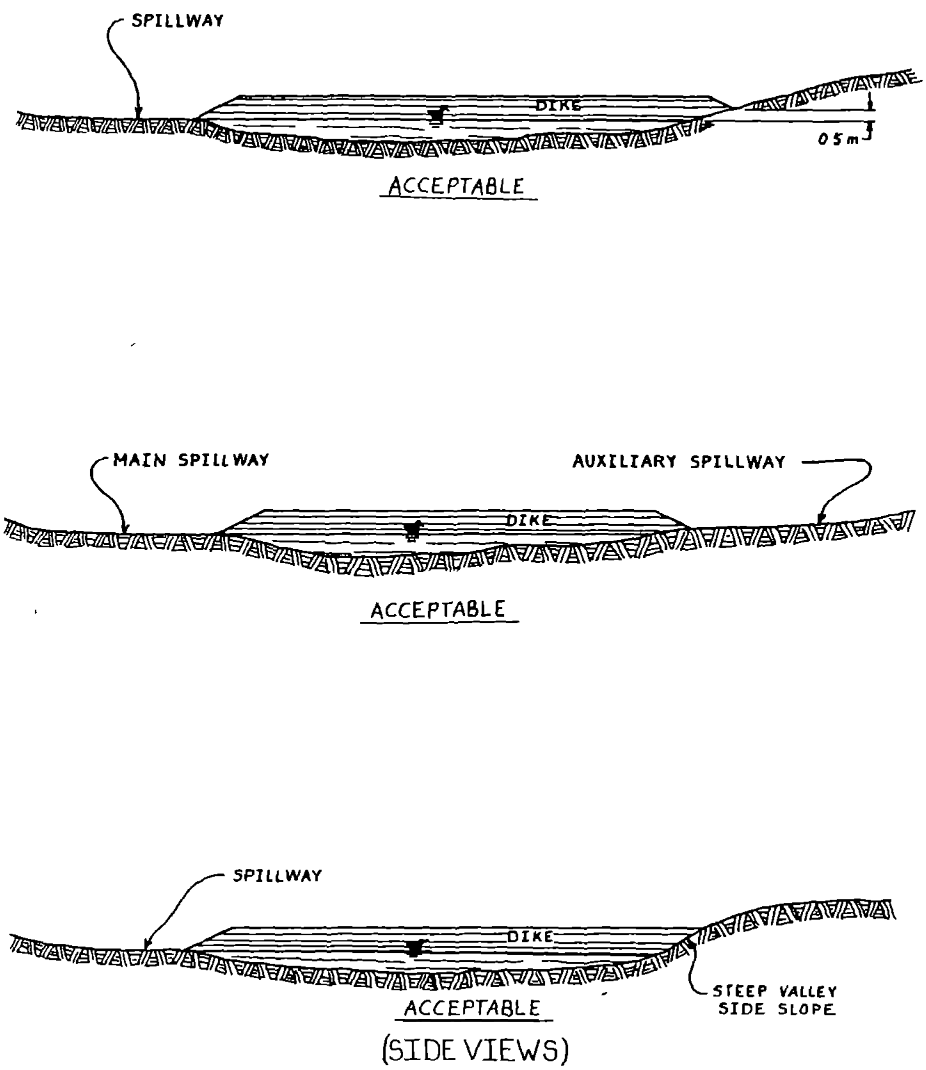


FIGURE A12: Dike length options.

12D **SLOPE OF THE DIKE SIDES**

Steeper slopes erode more easily and do not support the dike as well as flatter slopes. A side slope of 2 to 1 is usually sufficient for earthen micro-dams. This means that the horizontal distance or the base of the slope will be two times the height of the slope (fig.B12). For example, if at a particular point the dike is 1.45m high the base of the dike would have to extend out 2.90m (1.45m x 2 = 2.90m) from the edge of the dike crest in order to have a 2 to 1 slope on that side of the dike at that point (fig.B64).

If soil that is lacking in clay is used to construct the dike, even flatter slopes, such as 3 to 1, are advised.

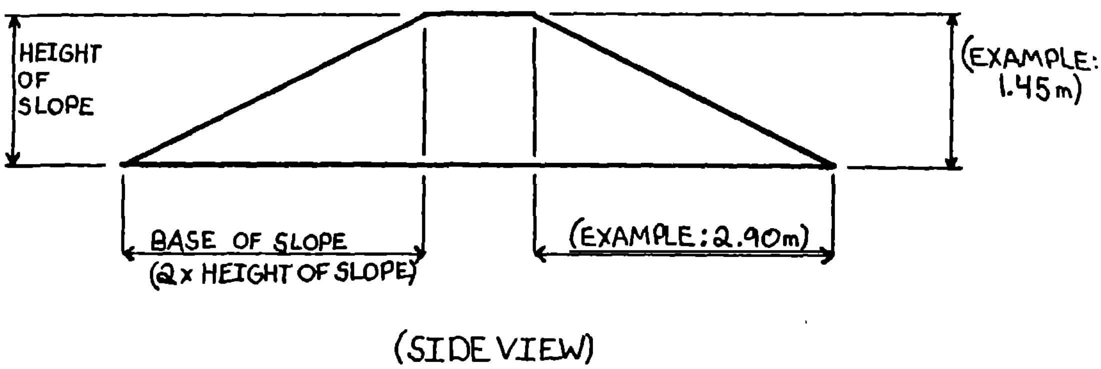


FIGURE B12: Dike side slope
of 2 to 1.

12E WIDTH OF THE DIKE BASE

The width of the base of a dike (D^{bw}) at a given point is dependent upon the height of the dike (D^{ht}) at that point, the length of the base of the slope on each side at that point, and the width of the crest (C^{w}) (fig.C12). For example, if the dike sides are to have slopes of 2 to 1 the lengths of the bases of the slopes will be two times the height of the dike ($2 \times D^{ht}$) (fig.C12). Thus for a dike with 2 to 1 slopes, the base width would be two times the length of the bases of the slopes plus the crest width ($2(2 \times D^{ht}) + C^{w}$), or four times the height of the dike at any point plus the crest width ($(4 \times D^{ht}) + C^{w}$) (fig.C12).

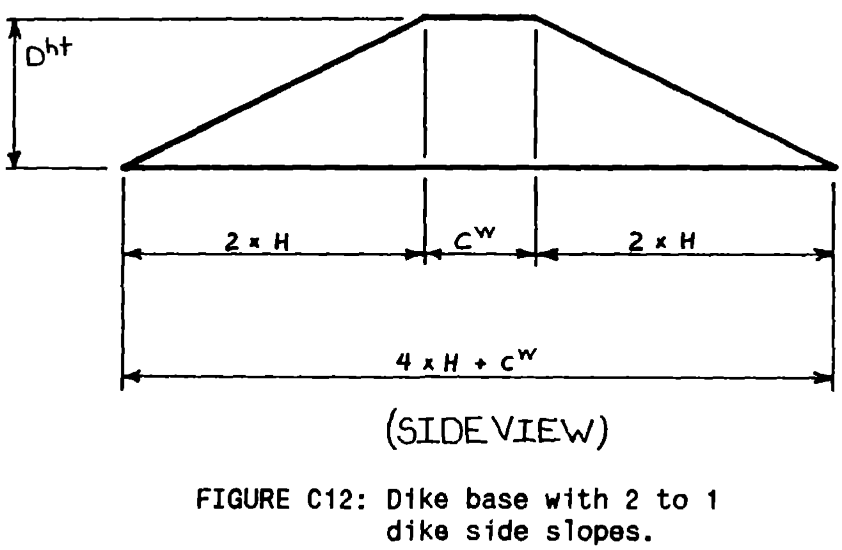


FIGURE C12: Dike base with 2 to 1
dike side slopes.

12F DIMENSIONS OF A CUTOFF TRENCH

The test pits at the dike location will determine if a cutoff trench is needed and how deep it will have to be (sec.10B). The cutoff trench will need to be only 60cm to 1 meter wide to be an adequate seepage barrier if it is repacked with good impermeable soil. The cutoff trench only needs to be dug just where the soil that will be underneath the dike is unacceptably permeable, but usually when the trench is needed it is dug along the entire center line of the proposed dike (fig.B10).

If, even after digging the test pits, there is an uncertainty as to whether or not a cutoff trench is needed the dike can be built without it. Then after the dam has filled with water and it is seen that there is too much seepage under the dike, a cutoff trench can still be dug and packed under the upstream edge of the dike during the next dry season (fig.D12).[3]

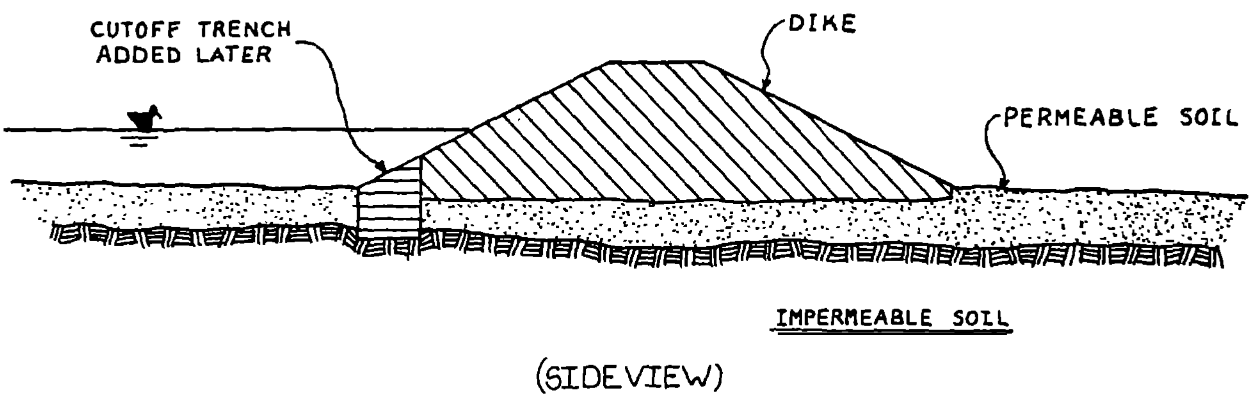


FIGURE D12: Cutoff trench that is added afterwards.

13 BUILDING THE DIKE

13A LAYING OUT AND STAKING THE DIKE

First, determine where the centerline of the crest of the dike will be. At each end of the dike pound in two sturdy semipermanent stakes. The distance between two stakes at each end should equal width of the crest (fig.A13), with the centerline of the crest midway between them. The tops of these four stakes should be at the planned level of the dike crest (fig.B13).

The perimeter of the base of the dike can now be marked with small stakes to show how large an area the base of the dike will be (fig.A13). If the dike is not too long and the valley is not too irregular, it is usually sufficient to calculate, measure, and mark the width of the base of the dike (sec.12E) at each end and at the lowest point in the valley. Then it can usually be estimated where to put in more perimeter stakes 5 to 10 meters apart. White wood ash sprinkled out of a tin can or lines dug into the ground with hoes may also be used along with stakes to temporarily define lines.

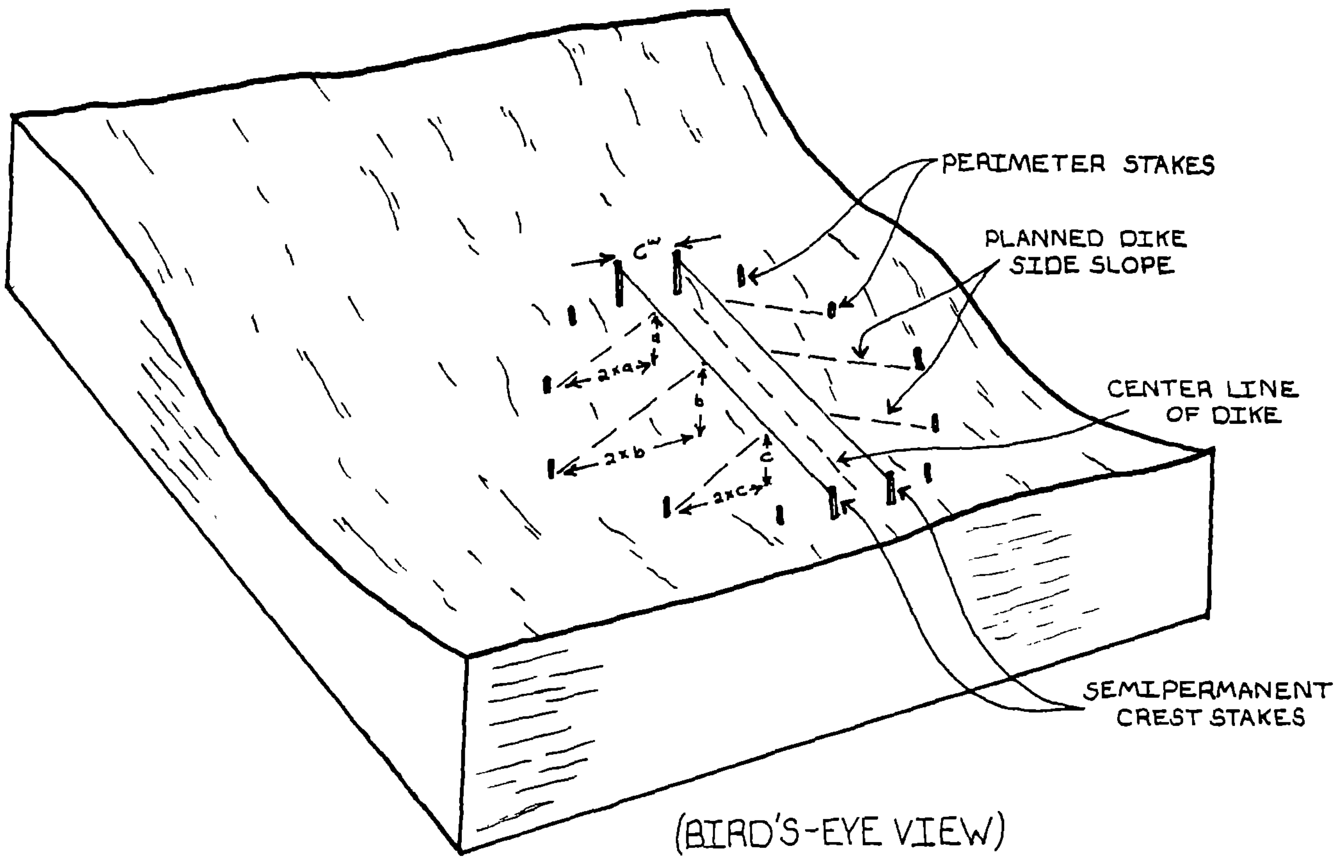


FIGURE A13: Laying out and staking of dike.

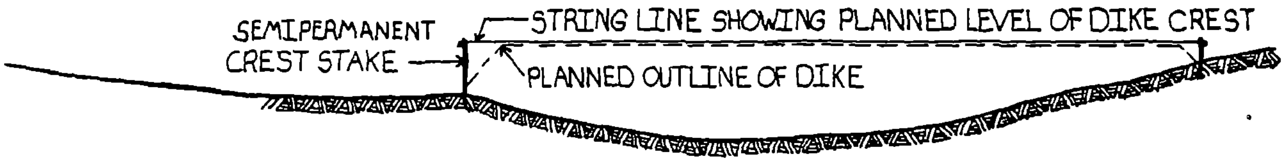


FIGURE B13: Staking the dike ends.

13B EXCAVATING THE DIKE FOUNDATION AND A CUTOFF TRENCH

The whole base of the dike (the area outlined by perimeter stakes) should be excavated to a depth of 15 to 20cm. This is to remove all of the vegetation and loose dirt and expose a bare firm layer of soil which will provide a good foundation for the dike. If any trees or bushes are found within or near the foundation area, care should be taken to remove the roots down to a depth of at least one meter below the surface.[3] The resulting hole should be well repacked.

If a cutoff trench is needed (sec.10B), stakes can be placed to mark each corner of the trench (sec.12F). Strings can be stretched from the stakes and the outline of the trench can then be marked. The trench should be dug down through any permeable layer into a more impermeable layer of soil.

Any soil excavated from the base or trench should be deposited well outside the downstream edge of the foundation. This soil can be placed on the backslope (downstream slope) of the dike after the dike is finished to help support and protect it.

13C EXCAVATING AND PREPARING THE CONSTRUCTION SOIL

The dike should be built with soil that contains some clay (sec.10B). Ideally this soil would be excavated from the reservoir area which will serve to increase the amount of water stored by the dam. Soil should not be dug closer than 5 to 10 meters to the foundation of the dike, as this would weaken the foundation and make it easier for water to seep out of the dam.[3]

For a compacted earth dam, the construction soil needs to be dampened so that it packs together well. Packing can be done by hand using heavy poles or sticks fitted with flat-ended weights of metal or concrete (app.F). The soil is damp enough when it is easily packed together. It is too damp when water can be seen leaving the soil upon impact or when the soil mushes instead of packing.

Sometimes if the work is started soon after the rainy season ends, the soil that is dug to construct the dike may be damp enough to be placed directly on the dike and tamped. If the soil is too dry it must be dampened by adding water to it.

Some village work crews mix the soil and water with hoes, much like they would mix concrete, before placing it on the dike. Other villages have saved lots of labor by simply adding water to the soil needed for the next day's construction and letting it soak in overnight. Usually in the morning the soil is uniformly damp and ready to be tamped with minimal mixing.

Still other villagers evenly sprinkle a certain amount of water over a dry layer of construction soil after it is placed on the dike. Then another dry layer of soil 10cm to 15cm thick is spread over the wetted layer. The layers are then packed by tamping and water is again evenly sprinkled over the top (dry) layer and the process is repeated as many times as necessary (sec.13D).[3]

13D PLACING AND PACKING THE CONSTRUCTION SOIL

The layers of construction soil should be spread on at a thickness of 10cm to 15cm (fig.C13). Each layer should be packed by tamping it before the next layer is spread on (unless the sprinkle method is used as described in the above section).

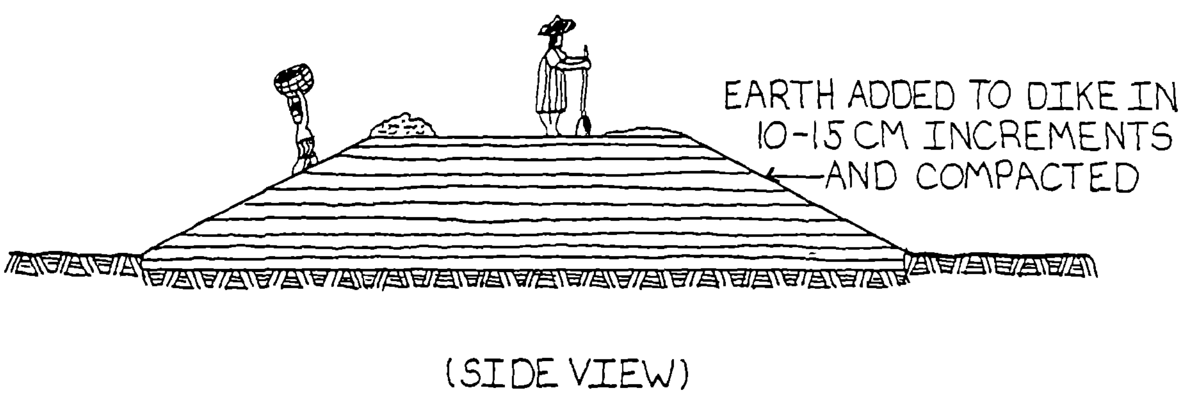


FIGURE C13: Tamping layers of construction soil.

If the surface of the bottom of the cutoff trench, the foundation, or the top of the previous layer becomes dry, the surface should be dampened before the next layer is spread on top. This is so the new layer will adhere well to the soil it is packed upon.

The sides of the dike can be sloped up from the edge of the dike foundation to where the edge of the dike crest will be. This slope can usually be estimated as the dike goes up, although string lines can be rigged to show the correct slope to attain (fig.A43).

When the dike is nearly finished, stakes can be pounded in along the centerline of the crest or along the two lines that define the width of the crest of the dike. The tops of these stakes should be made to indicate to the villagers the correct crest level to attain for the dike.

13E DEALING WITH A LACK OF ACCEPTABLE SOIL

A situation may be encountered where a good site is found but it lacks sufficient acceptable construction soil to construct the whole dike. One solution to this problem is to compact only the core of the dike and the cutoff trench with damp construction soil (fig.C10). The supporting sides of the dike can be built with dry soil and/or less acceptable construction soil. The supporting sides should probably be at a slope of 3 to 1.

The compacted core of the dike should be at least one meter wide. If there is a cutoff trench it should be packed first. Then the damp construction soil should be spread on at a width of one meter or more down the center length of the dike and tamped. Then an equally thick layer of dry and/or less suitable construction soil should be spread on both sides and tamped. Be sure to break up any clods in the soil. Then another layer of damp core soil is put down and the process is repeated. Thus the whole dike goes up at the same time, layer by layer.

13F DEALING WITH A LACK OF WATER

Often a village is motivated to build a micro-dam by hand because they lack water. Therefore it is often the case that there is not enough water available nearby to be able to construct a totally compacted dike. If there is a sufficient supply of acceptable construction soil available and the site is in a very flat area and is perfect in every other way (sec.10) the dike can be totally dry-packed. The same method is followed as for building a compacted dike but eliminating the addition of water. It may also be advisable to decrease the thickness of each added layer to ensure better compaction. Before totally dry-packing a dike be sure that the costruction soil has a good clay content (app.A), as this technique is not advised with marginally acceptable soil.

If some water is available, another option is to compact only the core of the dike with damp construction soil as explained in section 13E above.

13G PROTECTING THE DIKE AGAINST EROSION

If there are lots of rocks (from 10 to 30cm in diameter) and gravel nearby, use them to cover the sides of the dike. A layer of rocks fitted tightly together, with gravel then filled in between them works well.[23] A layer of gravel should also be put over the crest of the dike. The rocks and gravel will help protect the dike from erosion and will probably reduce the amount of maintenance work that will need to be done year after year. At the very least the dike end(s) next to a spillway should be protected with a covering of rocks and gravel.

Another way to help protect the surfaces of the dike and spillway from erosion is to plant grasses on them which have shallow root systems.[2]

14 DETERMINING THE FINANCIAL COSTS

The financial cost to the program for each micro-dam will depend upon the policies of the program since there is nothing essential for their constuction that cannot, potentially, be the responsibility of the villagers. For example, the AMB organization does not give or lend anything to the villages that they help except technical advice and some money to pay part of the cement cost for a concrete spillway (sec. 21). If a natural spillway, as described in this part of the manual, is used even that cost could be eliminated.

MCC has depended upon natural spillways but has usually hired a trained helper to help guide the construction and they have subsidized or lent certain tools to the village for the construction.

The current policies which affect the financial costs of the MCC-Gaoua program are as follows:*

- For Hired Helpers: We have trained these helpers using a combination of training sessions and on-the-job training (sec.42C). They are hired on a part-time basis and are sent to a village during the dry season to help them build their dike. Their salary is based on the volume of earth placed on the dike (app.E) while they are helping and the number of days they are in the village available to work. We pay them around 200cfa per cubic meter of earth (depending upon their experience and effectiveness) and 300cfa per day. We use this combination of fixed and piecework salary because we want to motivate the helpers to be efficient organizers, but we also realized that they have no real control over how and when the village works.

- For Pickaxes (Mattlocks): We buy them at 3000cfa each and sell them to the village for 2000cfa. Thus there is a cost of 1000cfa to MCC for each pick that is bought. We require that the village have 1 pick available for every 3 men that will be working each day. For example, if 16 men are to work each day and there are already 2 picks in the village that will be used, MCC-Gaoua will require the village to buy 3 more picks somewhere so they will have a total of 5 picks available.

- For Hand Tamping Tools: We buy them locally made out of metal for 3000cfa each and lend them to the village. These metal tamping tools are nearly indestructible and easily repaired, therefore they can be used repeatedly season after season. We usually lend one tamping tool for every 3 men that will work each day.

*For more information on policies of other programs see Part III of this manual.

- For Wheelbarrows: We buy metal wheelbarrows for 20,000cfa, reinforce them by welding rebar (iron reinforcement bars) around the rims, and lend them to the village (nonreinforced wheelbarrows will normally only last one work season, whereas reinforced ones will often last 2 to 3 seasons). We lend one or two wheelbarrows when there are not enough people available to transport earth in locally-made containers on their heads (which was usually done by women). We made this our policy because the traditional practice of transporting earth on the head can easily be continued in the future if the village wants to do another micro-dam.

- For Watercarts: We buy them locally made for 50,000cfa and lend one to a village if their water source is far away from the site or there are not enough people available to carry water for the construction. Usually these water carts (a 55 gal. barrel in a metal framework with wheels) would last 2 work seasons before the tires and other parts need to be replaced.

PART II

VARIATIONS ON THE BASIC TECHNOLOGY

20 THE MCC-TYPE UNCOMPACTED EARTH MICRO-DAM WITH A MUD-BRICK WALL

20A BACKGROUND

MCC started building micro-dams in the Korsimoro/Bourzanga region in central Burkina Faso in 1982 at the request of a pastor in Korsimoro. The first MCCer in the region started off the program in the area by hiring and training technicians to lead the work. Most of the dikes were built to improve existing water holes and the first two used concrete spillways.

The next MCCers in the area concentrated on improving the local church's interest and ownership of the program so that the church would look after the program when the MCCers were absent. They have been working on tailoring the program down to a minimum of cost and supervision so that the local people could continue the program in the future even without MCC input. The MCCers have also worked on developing a micro-dam technology that is appropriate for this poor and dry sahelian region.

To date MCC has helped complete 16 micro-dams in the region but only 10 are of the type described in this section. Organization of the individual village projects has not been a concern of the MCCers involved as the Mossi people who make up the majority in this region are quite gifted in organizing themselves.

20B APPLICATIONS

The type of micro-dam that MCC has been helping villages construct uses a level mud brick wall to define the crest of the dike (fig.A20) and to provide some stability. Dry, loose earth is then filled in on both sides of the wall to form a dike with side slopes of 1.5, or 2, to 1. Large clumps of dry earth are broken up with heavy sticks to help reduce voids in the fill earth. A cutoff trench has generally not been used, as the sites chosen for the dikes have provided adequate impermeability. Trenches have been added later in front of the dikes when necessary.

This type of dam is especially used where there is not enough water available nearby during the work season (dry season) to do compacting with water. These dams have been successfully used in very flat areas where the dikes can be long and low. They have often been used to improve preexisting, and heavily used, ponds and water holes by increasing their water storage capacity and/or their catchment area.

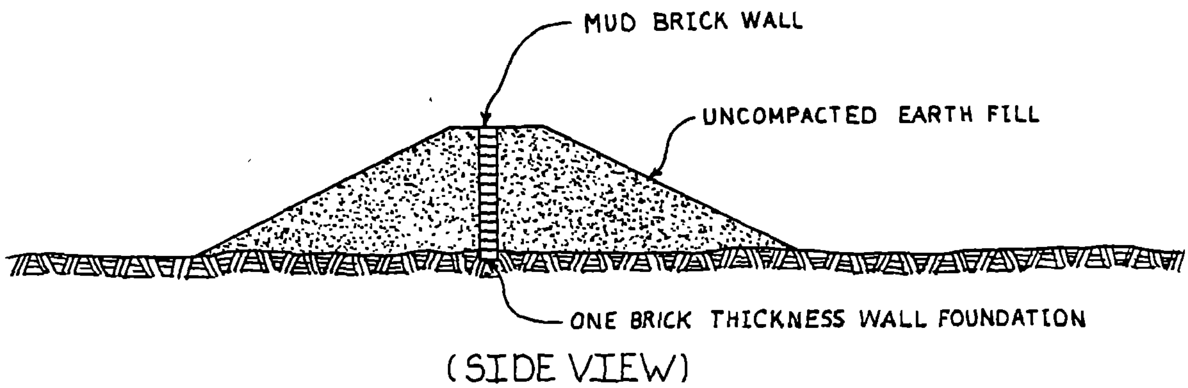


FIGURE A20: Dike with a mud-brick wall.

20C ADVANTAGES OF USING A MUD-BRICK WALL

The reasons for the mud-brick wall are threefold:[12]

1) it provides a ready level reference for the villagers placing the dry fill on the dike, thereby ensuring that there will be no low spots along the dike;

2) it gives some support to the earth in the dike to prevent sliding or slip-type dike failures; and

3) the brick wall shows where the uncompacted and porous fill earth has settled and needs maintenance.

20D CONSTRUCTION OF THE MUD-BRICK WALL [13]

The brick wall is built by digging a level foundation as wide as the wall and 10cm in depth. The foundation is stepped up the side slopes of the valley. A leveling tool such as a water hose level is used to ensure that the top of the wall is level. In practice, the wall construction and the earth fill are done in alternate stages, so the fill and the wall go up together. MCC has usually sent a trained helper to the village to help construct the wall, but it should be possible to teach a village mason how to do it.

Because the loose fill earth is so porous, a high degree of seepage through the dike can be expected, especially during the first year or two while the dike is settling. However, if the dike is built with and on good impermeable soil it can be expected that the seepage will reduce during the following years.

A method of building a second wall parallel to and behind (downstream) the original wall the following year has been used to stabilize the dike and reduce seepage (fig.B20). Earth is filled in between the two walls and against the back side of the new wall. The advantage of this method is that a dike can be built over a period of several years and will hold water after the first year.

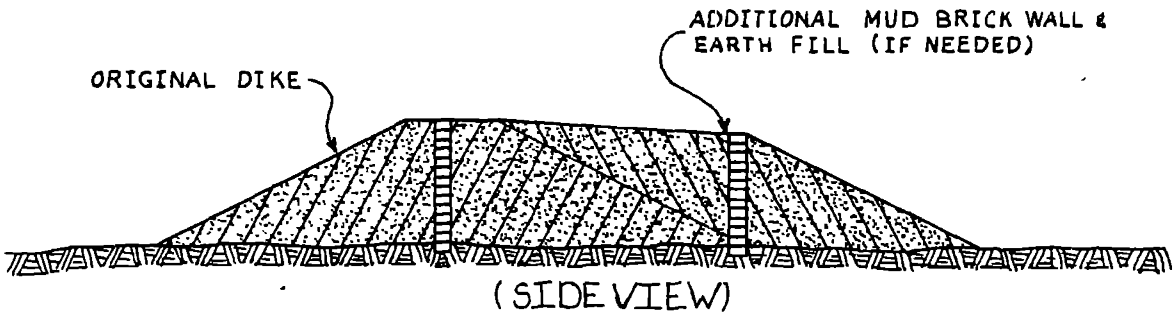


FIGURE B20: Dike with two mud-brick walls.

20E PROBLEMS ENCOUNTERED

One problem that has been noted at a few locations for this type of micro-dam is that the villagers think that the brick wall is the dike rather than just the core. The result is that some villagers do not take the loose earth fill work seriously. The importance of the supporting side slopes of these type of dikes needs to be emphasized.

20F SAFETY LIMITS

The safety limits for this type of dike are the same as for the compacted earth micro-dams described earlier: a maximum catchment area of 30 square kilometers; a maximum of one meter of water resting against the dike; and a maximum flood level at 50cm above the spillway floor.

20G FINANCIAL COSTS

The current policies affecting the financial costs of the MCC-Korsimoro (MCC-K) are the following:

- For Hired Helpers: The helpers that are sent to help villages are given on the job training using an apprenticeship system. They are paid 10,000cfa per month plus 100cfa per meter of dike length plus 5cfa per brick used in construction. MCC-K went to a monthly salary because their previous system based on the days of work and distance traveled to work site was severely abused.

- For Hand Tools: Most villages to be helped receive 3 to 5 pickaxes and 3 to 5 shovels from MCC-K at no cost. A small deposit had been required for the tools until it was found that the money collection process often prevented villages from getting an early start on the work. The villagers are allowed to keep these tools for future maintenance work or other community projects.

- For Wheelbarrows: If it is requested, a reinforced wheelbarrow is lent to the village for the dike construction period.

20H FUTURE DIRECTIONS

In 1989 MCC-Korsimoro will try a new policy whereby MCC pays no wages to the helpers. Instead the villages benefiting from the work of the helper will be encouraged to pay or otherwise reimburse him. Probably only those trained helpers who are really committed to working for the good of the village will continue to work. At the same time, the program will invite each interested village to choose two persons to be trained in the construction methods. This is to be done so that the people needing the micro-dam will know the technology and can do the work without an outsider needing to do it for them. Hopefully, these changes will result in a more stable self-sustainable program that the local church will be able to oversee in the future.

20I FOR MORE INFORMATION

For more information on this type of micro-dam and how it is built write to:

Mennonite Central Committee
01 B.P. 1307
Ouagadougou 01
BURKINA FASO
West Africa

Two pamphlets are available (in English or French):

1) Earthen Dike Construction Methods, Korsimoro and Bourzanga Programs 1982-1986

2) Foundations and Mud Brick Laying for Earthen Dam Construction

Both were written by Philip Martens in 1986.

21 THE AMB-TYPE MICRO-DAM WITH A CONCRETE SPILLWAY WALL

21A BACKGROUND [4]

Action Micro-Barrages (AMB; translated as "Project Micro-dams" in English) grew out of a non-profit development organization that was created in Belgium in 1976. The organization that became AMB has been helping villages near the center of Burkina Faso hand-build micro-dams since 1979. The first micro-dam that they were requested to help build in the region provoked lots of interest in and demands for this type of dam from villagers in the area.

In response to all of the demands for more micro-dams, the organization began specializing more and more on this work. Finally in 1982 the organization started concentrating mainly on micro-dams. They then moved their headquarters to Koudougou and changed their name to "Action Micro-Barrages Koudougou."

Their general objectives are to give technical support to villagers who want to hand-build micro-dams and encourage them to do other dam related development activities after they have built it. They also have the objective of gradually putting the program completely into national hands by replacing the expatriate program staff with nationals trained by the program. This process has already started. In 1984 two of the four staff members were replaced with nationals.

AMB now has nine years of experience helping villages do micro-dams. During these nine years they have helped complete 17 dams, of which only two have badly deteriorated. Also, there are 11 or more dams currently under construction and 20 dams that were started but then abandoned (sec.44C).

21B DESCRIPTION

The AMB-type micro-dam is built much the same as the MCC-type compacted earth micro-dam. The dike is constructed entirely with earth that is compacted by hand.

However the spillway includes a long, low, concrete wall, 20cm to 40cm wide and around 50cm high, embedded in the ground with rocks placed along its backside to protect against erosion (fig.A21). The level top of this wall defines the spillway ridge.

Also, AMB always requires a cutoff trench measuring at least 60cm wide and 1.5 meters deep (deeper if the permeable layer is deeper).

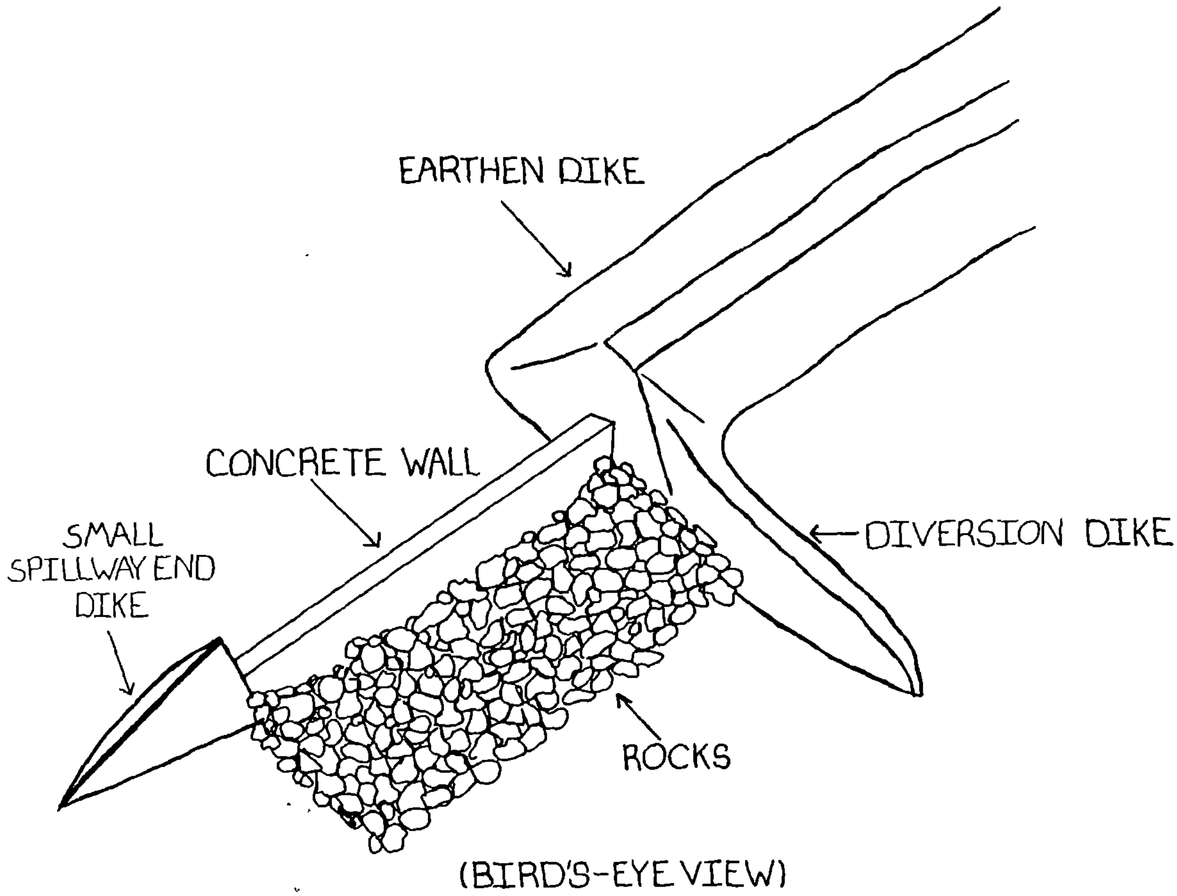


FIGURE A21: AMB-type spillway.

21C ADVANTAGES

The concrete spillway wall is a good idea for villages that can afford one, especially where the soil in the spillway is highly prone to erosion. The level concrete wall and the rocks behind it help protect the spillway from eroding by spreading out and dissipating the force of the water flowing out of the reservoir.

(Note: A spillway with a concrete wall still needs to be maintained each year. Any erosion on either side of the wall needs to be filled in. Any cracks or chips in the wall need to be patched).

21D FINANCIAL COSTS

The current policy of AMB is to ask each village to pay 75,000cfa for the cement for the wall.[4] Usually this is about half of the cost, and AMB pays the rest of the costs related specifically to the spillway wall.

21E PROBLEMS ENCOUNTERED

Even though the village pays around half of the spillway cost, its importance must still be explained. After paying their 75,000cfa, the village of Ndongale extended their dike over the concrete spillway and buried it in order to hold back more water. The dike was overtopped and broken because of this (the village has since repaired the breach).

21F SAFETY LIMITS

The limits for AMB-type dams are: 30 to 50km^2 maximum catchment area; a maximum of 1.5m and a minimum of 0.7m depth of water beside the dike at the deepest point; and a maximum flood level of 50cm above the spillway floor (top of wall).

21G FUTURE DIRECTIONS [4]

First, AMB would like to establish a board of directors to take charge of the direction, financing, and personnel of the program.

Secondly, AMB is hoping to find, with the collaboration of the Burkina Faso National Office of Employment, a national who will become the chief of the program staff and be in charge of the program after a year of training.

21H FOR MORE INFORMATION

For more information (in French) contact:

AMB
B.P. 26
Koudougou
BURKINA FASO
West Africa Tel. 44-03-34

Also see Appendix G (the village survey AMB uses), and Appendix H (the contract that AMB makes with the villages).

22 COMPACTED EARTH MICRO-DAM WITH GABIONS

22A DESCRIPTION

Gabions are rectangular wire cages filled with rocks that are quite stable against the force of water flowing through, around, or over them. They are a less costly alternative to concrete when there are many medium- to large-sized rocks in the area of the dam site. But unlike concrete, gabions are very permeable. A dam that uses gabions must use them in conjunction with impermeable soil to produce an impermeable dike. Usually compacted earth is used for the upstream half of the dike while gabions and rocks are used for the downstream half (fig.A22).

22B BACKGROUND [5]

Micro-dams using gabions have been built in many parts of Burkina Faso, especially by the organizations in the French Association of Volunteers for Progress (AFVP) such as the French Volunteers and a Canadian organization that gives technical assistance (CECI).

The first gabion supported dam was built in Burkina Faso in 1974. Since that time AFVP has worked toward redesigning these dikes to reduce the number of gabions needed and thereby reducing the financial cost to the bare minimum necessary. In 1986 they came up with the currently used designs (fig.A22) based on the estimated maximum flood level above the dike crest.

22C ADVANTAGES

There are some major advantages for an earthen micro-dam where gabions and large rocks are used to construct the downstream half of the dike. The excess water that the reservoir cannot hold can simply spill over the crest of the dike since the rocks and gabions will prevent it from eroding the dike. Therefore, the whole crest of the dike is a long level spillway and there is no need for freeboard construction. This means the need to find an adequate side spillway location is eliminated, thus a gabion supported micro-dam can be located at many sites unsuitable for MCC or AMB type dams.

Gabion-supported dams can also have higher levels of water resting against the dike and therefore the dikes can be taller and the dams can retain more water than MCC or AMB type dams. This is due to various design advantages that gabion-supported dikes have, such as seepage drains and zoned embankments.[5]

(The drain filters indicated in Figure A22 are simply layers of sand positioned so that they block any tiny soil particles from being easily washed through the large gaps in the rocks by any water that seeps through the dike).

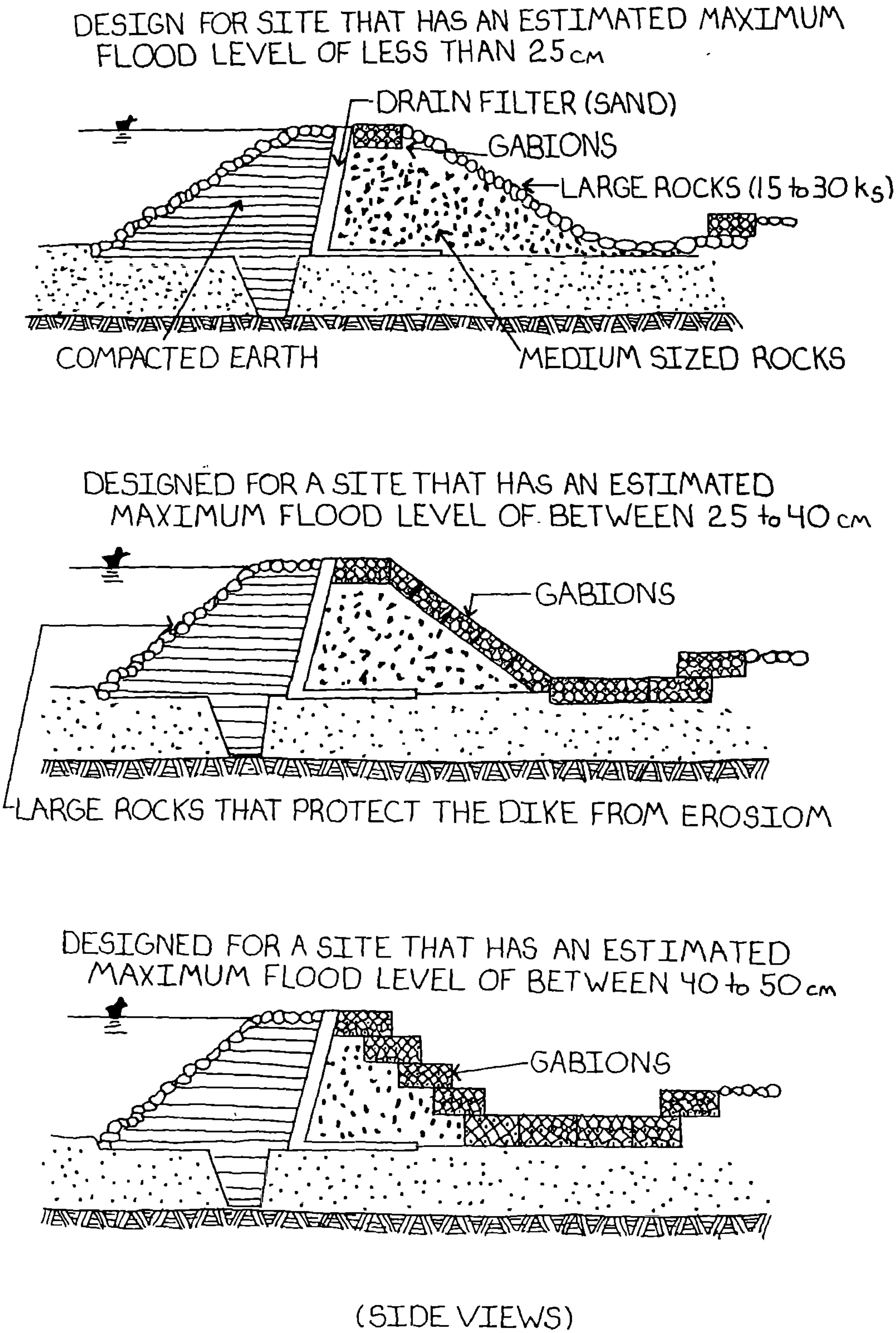


FIGURE A22: Gabion-supported earthen dikes.

22D APPLICATIONS

Dike construction using gabions is especially suitable where: 1) there are plenty of rocks available; 2) there is enough acceptable construction soil available; 3) a suitable side spillway cannot be found; 4) there is some money available to buy the wire needed to construct the cages.

22E SAFETY LIMITS

The limits for gabion-supported dams are: a maximum of 4m of water resting against the dike; and a maximum flood level at 50cm above the crest of the dike (this takes into account the size of the catchment area, therefore there is no predefined catchment area limit *).

22F FINANCIAL COSTS

The cost of a wire cage (1m x 2m x 50cm) can range from 3000 to 8000cfa depending on the cost of the galvanized wire (2.5mm diameter or larger) and the cost of fabrication. Sometimes the fabrication is done by hand by the villagers, though usually a skilled, trained technician employed by the sponsoring organization fabricates the wire cage.

Also, most organizations that help construct gabion-supported dikes have found it necessary to hire a truck to aid the villagers to collect all of the rocks and sand necessary. But it should be possible for certain villages that have oxen or donkey carts to collect the rocks and sand themselves for a very small gabion-supported micro-dam.

To help give somewhat of an idea of the costs of constructing a gabion-supported dike a quick example based loosely on some actual cases will be shown on the next page.

* The same could perhaps be said for MCC and AMB type dams if a good study can be made.

Assumptions:

- The dike is 60m long, 2m high, has side slopes of two to one, and is designed for a maximum flood level of less than 25cm (which requires the least number of gabions (fig.A22a)).

- A truck is hired for 40,000cfa per day including fuel and driver. The truck can haul $4m^3$ of rocks per trip. The rocks are loaded by hand by the villagers within 4km of the dam site and 10 truckloads can be loaded in a day.

- The gabions cost 5,000cfa each.

Estimations:

- Volume of rocks ($Rock^v$) needed for the dike equals approximately $240m^3$. ($Rock^v = 0.5 \times 2 \times 4 \times 60 = 240m^3$).

- Since a truckload (trkld) is $4m^3$, 60 truckloads of rocks will be needed to haul in the $240m^3$ needed for the dike. ($240m^3$ / $4m^3$ per trkld = 60 trklds).

- Since 10 truckloads can be loaded each day, 6 days will be needed to load enough rocks. (60 trklds / 10 trklds per day = 6 days).

- Since the truck costs 40,000cfa each day the total cost for the trucking is 240,000cfa. (6 days x 40,000cfa per day = 240,000cfa).

- Since the dike is 60m long and the most simple design is used (with gabions used only on the crest of the dike), 60 gabions are needed. At 5,000cfa each the gabions will cost a total of 300,000cfa. (60 gabions x 5,000cfa each = 300,000cfa)

- The total cost for the trucking and the gabions is 540,000cfa. (240,000cfa + 300,000cfa = 540,000cfa)

Note: usually 5 ox-cart loads equal $1m^3$, therefore 1200 ox-cart loads would be needed for the $240m^3$ of rocks needed in the example above.

22G FOR MORE INFORMATION

For more information (in French) contact:

AFVP,
B.P. 974
Ouagadougou
BURKINA FASO
West Africa

PART III

RECOMMENDED POST-CONSTRUCTION ACTIVITIES

30 MAINTAINING THE EARTHEN MICRO-DAM

The better the site and the better the micro-dam is built, the less maintenance and repairs will need to be done. With earthen micro-dams some maintenance will always be necessary. If a village wants their dam to last a long time they will need to be willing to do the necessary maintenance and repairs at least once a year.

30A MAINTENANCE OF THE DIKE

- Repair any erosion caused by rain, runoff, passage of animals, etc. by repacking and filling it in.

- Pull out any bushes or trees that start growing on or near the dike. The long roots of the trees and bushes will eventually provide a path along which water can seep out of the dike and possibly erode a hole through it, referred to as a piping failure. It is best to pull out the trees and bushes when they are tiny so that the whole root system can be removed without digging too far into the dike and weakening it.[2]

- Try to keep animals away from the dike. Try to stop larger animals, such as sheep and cattle, from climbing onto the dike. Try to exterminate burrowing animals, such as crocodiles and rats before they do much damage to the dike.[23]

- If there is too much seepage, a cutoff trench can be built under the upstream edge of the dike when the dam is dry (fig.D12).[2]

- If there is so much rapid seepage that a hole is being eroded away through the dike by the seepage (piping), the hole must be quickly filled in with a layer of sand, then gravel, and then a covering of rocks. This will not stop the seepage but it will prevent more soil particles from being washed or eroded out thus preventing a piping failure and a ruined dike.[18]

30B MAINTENANCE OF THE RESERVOIR

- Keep the reservoir clear of bushes and trees to reduce the habitat for mosquitoes, and to reduce the amount of dead leaves and branches that fill in the reservoir and might possibly block up the spillway.[23]

- Periodically dig out the sediments that collect in the reservoir. If sand is a particular problem, a low rock dike, or contour barrier (sec.32A), can be built across the valley floor at the entrance of the reservoir. This will cause the sand to settle on the upstream side of the rock dike instead of being carried into the reservoir.

30C MAINTENANCE OF THE SPILLWAY

- Repair and fortify any parts of the spillway that have been eroded.

- Pull out any bushes or trees that start growing in the spillway area.

- Remove any debris that collects in the spillway so that water will be able to pass out smoothly.

- If the water leaving via the spillway runs against the back side of the dike and begins to erode it, a small diversion dike should be built to divert the water away from the main dike (fig.A21).

- If a ravine begins to cut towards the spillway, an attempt can be made to stop it by building a series of rock dikes across the ravine to slow down the water. The crests of these rock dikes should be a bit higher than the ground surface at the edges of the ravine, but they should be lower than the ground surface in the centers (fig.A30). This will force the water to flow over the center part of the rock dikes instead of eroding the earth around them.

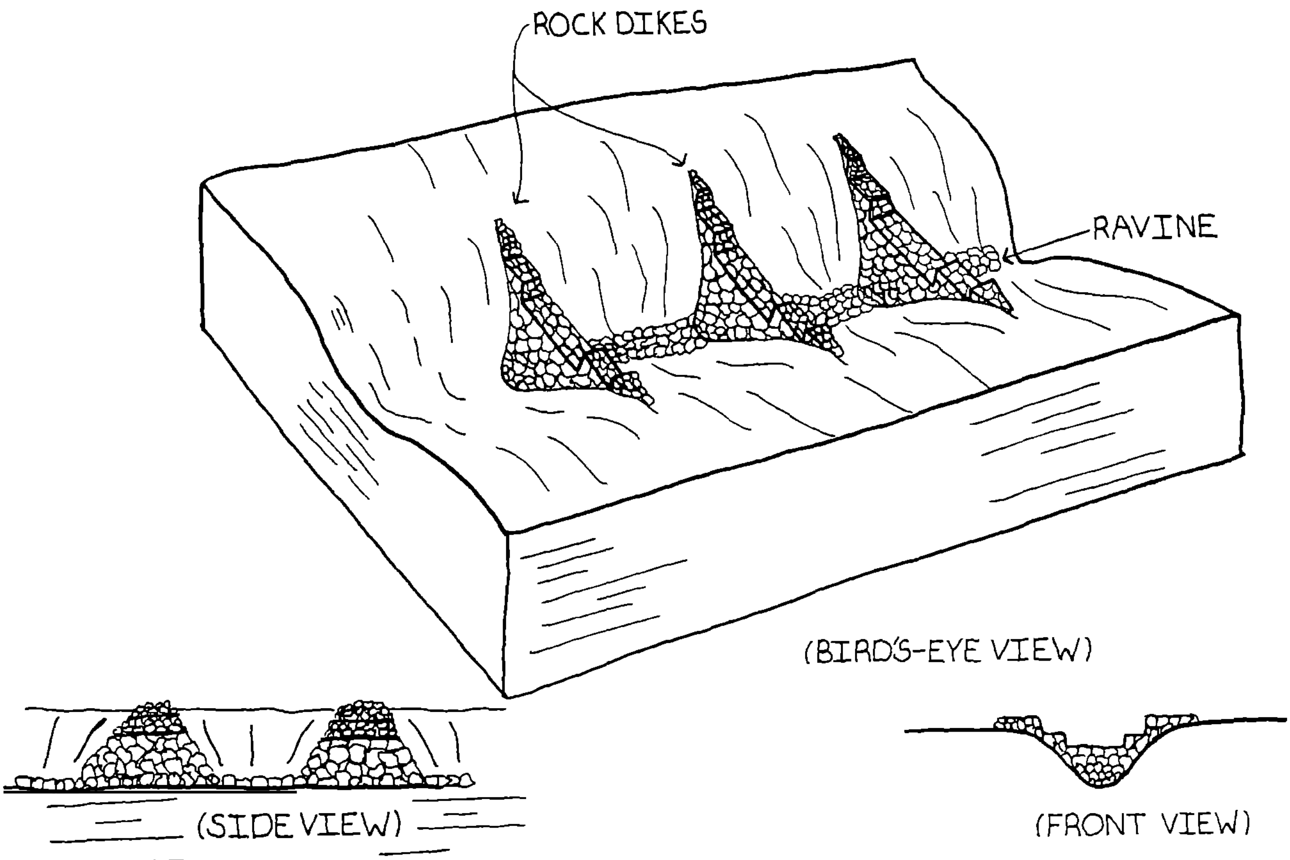


FIGURE A30: Ravine-stopping rock dikes.

30D SPECIAL NOTE ABOUT THE SPILLWAY

Perhaps one of the most difficult ideas to get some villagers to understand about a dam is the importance of allowing water to flow out of the spillway unhindered. Very often villagers have attempted to seal off the spillway when they have seen water running out of it in order to keep more water in the dam. In one instance, this has caused a dike to be overtopped by water and broken. A special effort must be made to ensure that the villagers understand the workings and importance of the spillway.

Perhaps a small working model of an earthen micro-dam can be built with no spillways or with spillways that are too small and water can be poured into it until it fills up and finally overtops and ruins the model dike (be sure the model dike is built with soil that is easily erodable by the small amount of water that will flow over it). This illustrates what happens when a flood comes into a micro-dam without spillways or with spillways that are not adequate for the site.

Another illustration that can be used to demonstrate the importance of the spillway is to have someone hold a mouthful of water in their mouth. Explain that the mouth is like the dike, it has to remain closed to hold back water, and the nose is like the spillway, it allows the dam to breathe. The nose should be held shut to demonstrate what will happen to the dike (mouth) when the spillway is closed off. The person holding in the water will eventually have to spit out the water in order to breathe thus "breaking the dike" and letting all of the water run away.

31 ENCOURAGING PREVENTION OF WATER-BORNE (DAM-RELATED) ILLNESSES

The purpose of this section is to help stress the fact that in helping a village to solve one problem, the lack of water, we have helped create a whole new group of problems that need to be addressed. This new group includes the illnesses that can arise from the water we ingest, the water we come into contact with, and the water we live near.

Being informed is the first step towards being prepared to help others learn. That is why there are included in this section brief explanations of water-borne illnesses, their causes, various preventive steps that can be taken to lower the chances of contracting them, and an examination of the practicality of the various preventive steps at the village level.

Treatments are obviously missing here as it is not the intent of this manual to be a complete medical document. Visiting with area health services personnel about appropriate health treatments that are recommended for your country is one suggestion as treatments of illnesses often vary depending on the variety of the sickness. For example, the treatmnet for malaria will depend on whether or not the chloroquine resistant strain of malaria is found in the local area. (Development information and efforts should always coincide with, not counteract, those of the local government administration). In addition to health personnel, the book Where There Is No Doctor written by David Werner, is another recommended resource that has useful information concerning all aspects, including prevention and treatment, of numerous common illnesses.

31A ILLNESSES THAT RESULT FROM DRINKING CONTAMINATED WATER [2]

31A1 BRIEF DESCRIPTIONS OF THESE ILLNESSES

DIARRHEAL DISEASES [21]

Diarrhea is the frequent and repeated passage of loose or watery stools. A person with diarrhea loses much water in his stools. Therefore, small children who have a smaller volume of water in their bodies are in great danger of becoming dehydrated quickly if they have diarrhea. Death may result from dehydration alone. Diarrhea is a symptom of numerous illnesses which are described below.

Amoebas

Amoebas are small microscopic animals that attack the intestines. The affected person has frequent bowel movements often containing mucus and blood. Intestinal cramping may be experienced. Generally there is no fever. Amoebas seldom cause dehydration and rarely death.

Bacterial Dysentery (Shigella)

This illness most often begins suddenly with fever, abdominal pain, and diarrhea containing blood. The number of stools a person has increases rapidly per day, therefore increasing the chances of dehydration. The failure to treat the dehydration especially in children can be fatal. This illness is caused by a bacteria that attacks the large intestine.

Cholera

Cholera is an acute infection involving the intestinal system. Severe cholera starts suddenly with watery diarrhea and sometimes vomiting. The stools resemble water in which rice has been cooked. Due to the rapid loss of fluids, the affected person may experience muscle cramps, intense thirst, weakness, and eventually dehydration. Cholera is caused by a bacteria and can cause death if the dehydration is not treated quickly.

Round Worm

The sick person is tired and has stomach pains or aches. He may have diarrhea but can sometimes be constipated. When a person has been sick with this illness a long time, white round worms, 15cm to 25cm long can be seen in his stools. These worms can even be coughed or vomited out of the body. This worm causes a general weakness in the affected person as the worm must eat to live and takes nourishment from the sick person's body. Round worms rarely cause death.

Typhoid Fever

This illness begins like a cold or flu with headache, sore throat, and general bodily discomfort. During the first week, fever is present which usually rises slowly until it reaches 40 degrees C. Pulse is slow considering the presence of fever. Sometimes there is vomiting, diarrhea, or constipation. During the second week, a high fever is present, a few pink spots may begin to appear on the body. Other symptoms are trembling, delirium, weakness, and dehydration. By the third week, if there are no complications, the symptoms slowly go away. However, if left untreated, typhoid fever can be fatal. It is caused by a bacteria that attacks the small intestines.

GUINEA WORM [6]

The appearance of the guinea worm itself is one of the first signs that indicates that one has contracted this illness. The affected person scratches the spot where the worm will eventually appear. This spot is swollen and very tender. A blister full of liquid forms and when it breaks, the head of the worm appears. The worm most often comes out on a person's legs but can also be found on any other part of the body. The worm appears 6 months to one year after it has been ingested into the body as a larva. This illness causes the affected person much pain as the area where the worm exits becomes sore and can become easily infected.

HEPATITIS

Initially, the person who has just contracted hepatitis is very tired and is not often hungry especially for fatty foods. After one to two weeks his urine is very dark like coca-cola and his stools become more clear and white (translucent) than usual. His body, especially his eyes, tongue, fingernails, and the palms of his hands turn yellow in color. These signs do not always present themselves clearly. Hepatitis is caused by a virus which attacks the liver. Untreated hepatitis causes severe liver damage and sometimes death.

POLIO

Polio starts like many other illnesses. In the beginning the sick person has a bit of fever. He aches all over and it hurts when he articulates his limbs. Sometimes vomiting and diarrhea accompany polio. After two to three days many affected persons can no longer move their legs and/or arms. Others become aware of loss of muscle function several weeks after the onset. Polio comes from a virus that attacks the nerves. Polio is a serious illness and one can die from it but it can also be treated. If treated quickly the body can regain most of its normal strength and movement but most often the affected person will not be able to move normally as before.

31A2 THE ROLE OF WATER IN THE TRANSMISSION OF THESE ILLNESSES

In all of the aforementioned illnesses, water is the means by which the microbes and worm larvae are transported to the body.

In the case of the diarrheal diseases, hepatitis, and polio, an affected person who defecates near or in a water source may contaminate it as the diarrhea producing microbes and worm larvae are contained in these stools and can live in water. Rain water runoff can further transport and spread these illnesses to outlying water sources.

However, guinea worm is not passed on through the stools of a sick person but rather by putting the sore where the female worm is exiting in contact with water. She will release her eggs into the water and they will develop into larvae, thereby contaminating it.

Therefore, when water is contaminated by these microbes or larvae, using it becomes hazardous. Either drinking it, or using dishes, fruits or vegetables washed in it, as well as preparing meals with it is running the risk of contracting one of the above illnesses.

31A3 PREVENTIVE MEASURES

USE POTABLE WATER FOR DRINKING AND FOOD PREPARATION

The most obvious preventive measure that one can take to reduce the risks of contracting an illness is to drink potable water and use it in the preparation of food and the washing of serving dishes. However, in a village where a dam is the only source of water, the untreated water is not safe for human consumption and solutions must be found.

Build a Well

One possible solution at the community level is to dig and case a well behind an existing dam. The existence of the dam causes the surrounding water table to rise therefore providing the conditions conducive for the construction of a shallow, cheaper well which will provide potable water year round (sec.32A).

FIGURE A31: Women at a well.

PROTECT WATER SOURCES FROM CONTAMINATION

Even if there is a potable water source available in the village, all precautions must be taken to keep this and other water sources, such as a dam, as free from contamination as possible. There are several measures that can be taken to reduce the chances of contaminating the water source one uses for drinking. These include:

- Use a latrine. Stools contain many dangerous microbes. Enclose stools by using a well-built latrine.

- Isolate wash water from the drinking water source. Isolate water used for washing dishes, clothes, and bathing away from water sources so that it will not transport microbes and larvae to the source and contaminate it. A drain pit filled with rocks used mainly as a recipient for bath water can be used also for dirty laundry and dish water (fig.B31).

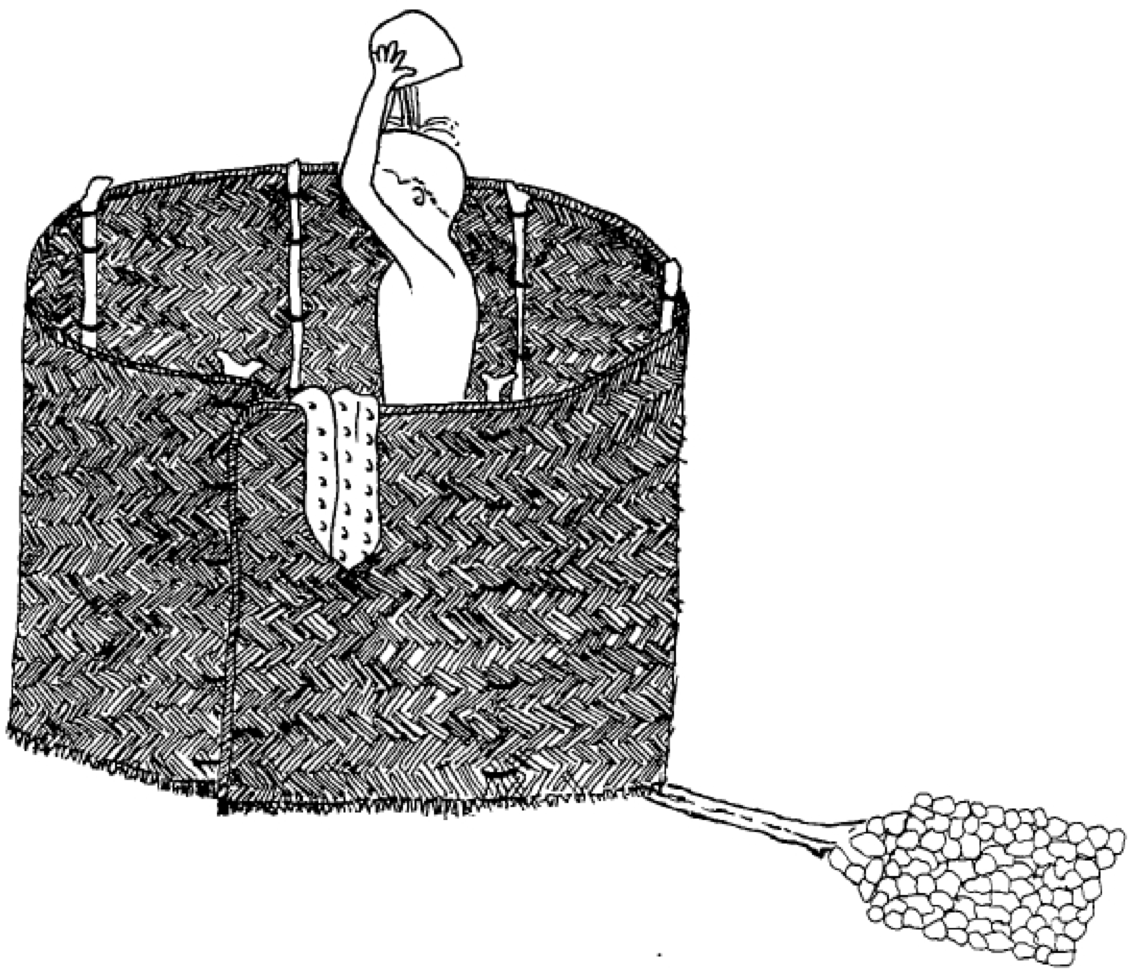


FIGURE B31: A shower with a rock filled drain pit.

- Wash hands with soap before handling drinking water, food, or serving dishes.

- Isolate guinea worms from the water source. Do not let anyone with a guinea worm wound place it in contact with water in or near a water source. Build platforms of rocks or poles so that people with guinea worms can fetch water without putting their wound into the water (fig.C31).

FIGURE C31: Guinea worm carriers avoiding contact with water.

TREAT CONTAMINATED WATER

If using dam-water or water from another unsafe source for drinking or food preparation is unavoidable some sort of treatment is necessary to make the water potable to avoid becoming sick from it. The following treatments can render the contaminated water potable if done properly.

<u>Boil the Water</u>

The surest way to make contaminated water potable is to boil it for 20 minutes. This is to ensure that all the illness causing microbes, especially those most resistant to treatment, are killed.

<u>Add Water Treatment Chemicals to the Water</u> [8]

Water treatment chemicals, such as chlorine compounds (commercially sold chlorine solutions, Halazone tablets) or iodine compounds (2% tincture of iodine, Globaline tablets, saturated iodine solution from iodine crystals) can be added to water to make it potable.

Simple chlorination is an unpredictable treatment for water. To know the correct amount of a chlorine compound to add requires continual testing of the water to be treated because the amount to add depends upon the pH and the amount of amino and ammonia ions present in the water. Also the shelf life of the chlorine compounds may be limited and they may rapidly lose their effectiveness when exposed to air.

In constrast, using iodine compounds to treat water can be a simple safe process. The amount of an iodine compound to add per liter of water is as follows:

2% tincture of iodine - 8 drops

Globaline tablets* - 1 tablet

saturated iodine solution - 10 cc (10cm^3)

(A saturated iodine solution is water that is saturated with iodine by being in contact with 4 to 8 grams of elemental iodine crystals (I_2) in a small bottle for a few minutes. The crystals themselves are to remain in the bottle and are not to be ingested.)

Let the water set an hour after treatment to allow the iodine enough time to act.

Filter the Water

Filtering out all illness-causing organisms can be done using a store-bought ceramic filter. Care must be taken to maintain the ceramic filter so that it continues to be effective.

Two other methods of filtering contaminated water that are readily available to villagers are filtering through a cloth and filtering through a sand/gravel/charcoal filter. These methods, which are explained below, do not filter out all the harmful organisms and therefore are not guaranteed to make contaminated water completely safe for human consumption but they are probably better than no treatment at all.

Filtering water through a piece of synthetic cloth with a small, tight weave is effective in removing the carrier of the guinea worm larva and eliminating this illness. However, this method allows all other harmful microbes to stay in the water.

Filtering water through a sand/gravel/charcoal filter is also effective in removing most larger organisms but smaller or very persistent organisms can still pass through.

* Has limited shelf life and will rapidly lose effectiveness when exposed to air.

VACCINATION AGAINST WATER-BORNE ILLNESSES

Vaccinating children as young as 2-3 months of age against polio is an easy, concrete step that can be taken to protect against this illness in the future. Check with local health officials for the complete vaccination schedule.

FIGURE D31: Vaccinations

31A4 PRACTICALITY OF THE PREVENTIVE MEASURES

Following are some suggested questions to consider with the villagers when discussing possible preventive actions against ingesting contaminated water. These questions relate primarily to the physical limiting factors that could prevent a village from successfully carrying through on a plan of action aimed at one of the health problems above. The degree of willingness of the villagers to practice one or all of the above preventive measures is usually the biggest limiting factor to overcome (sec.45D).

WELLS?

Is there money to finance a well? Are the villagers willing to dig the well? Is there an acceptable site to put it? Is there a well worker available who can construct it?

LATRINES?

Are the villagers willing to dig holes for the latrines? What tools are available for digging? Will people use it once it is constructed? Is it socially acceptable to be seen going to a latrine, etc.?

HAND WASHING?

Is there money available to buy the soap needed? What resources are available for making homemade soap? Is it traditional to make soap?

BOILING WATER?

Is there a sufficient wood or other fuel supply available to boil water? Is there money available to buy the fuel required if need be? Are the women willing to make time to boil water? Are the men willing to allow the women more time to do this task?

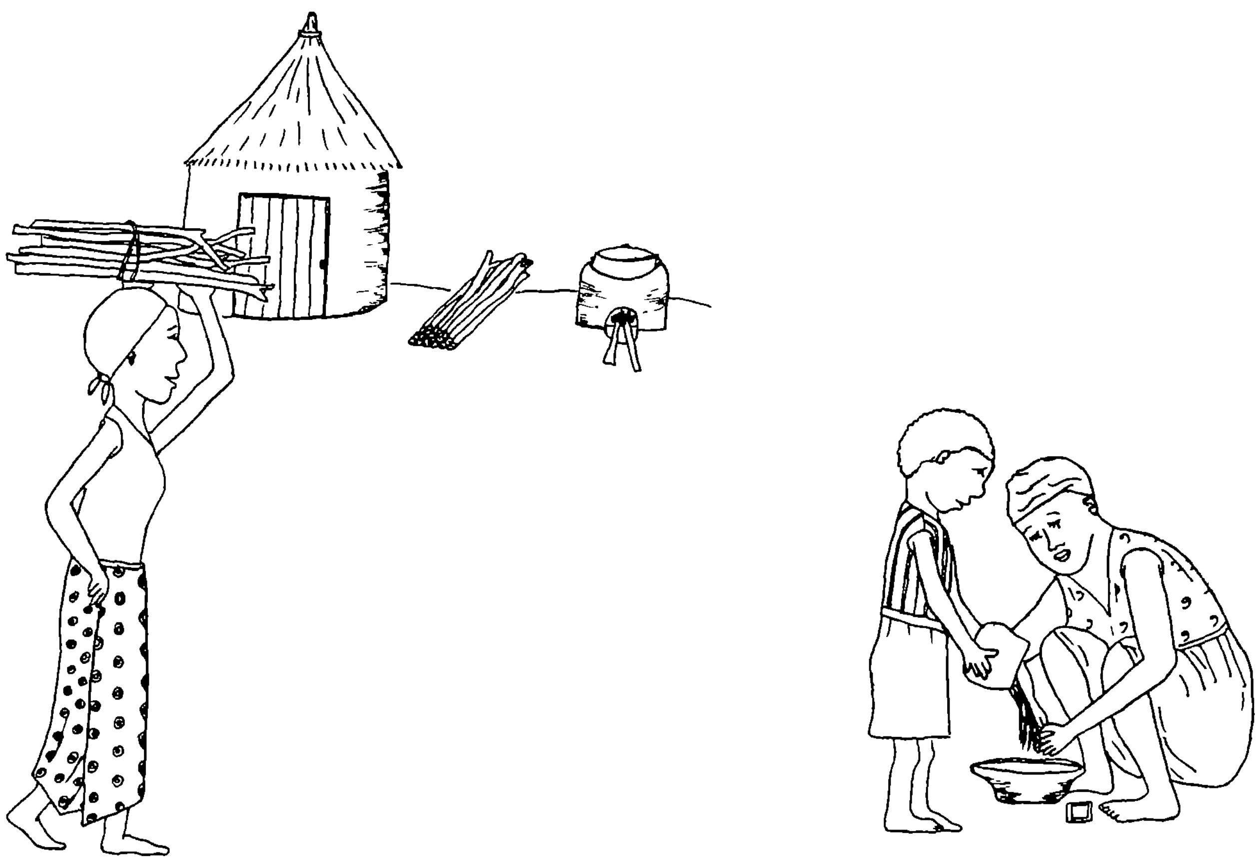


FIGURE E31: Transporting firewood and using soap.

WATER TREATMENT CHEMICALS?

Are they available in the immediate area? Do the villagers have the means to pay for them? Will they drink water that has a bit of a chemical taste? How can the villagers be sure they are using the right dosage of chemicals for the degree of contamination of the water?

FILTERING?

Are ceramics filters available? Can the villagers afford them? How many filters are needed to supply enough potable water? How long will the filter last before it needs to be replaced? Will the villagers be willing to maintain the filter?

VACCINATION?

How near to the village do vaccinations take place? How is the village informed of the time and place for vaccinations? Do the villagers believe in vaccination? Are they willing to take the time to vaccinate their children?

31B ILLNESS THAT RESULTS FROM CONTACTING CONTAMINATED WATER [2]

The major illness that results from contacting contaminated water is Bilharzia (also known as schistosomiasis or snail fever).

31B1 BRIEF DESCRIPTION OF BILHARZIA AND ITS CAUSE [21]

When someone detects blood in his urine or stools, he may have bilharzia. Sometimes the infected person feels that he needs to urinate or defecate but cannot or can only extrude a small amount. To know if one really has this disease, examinations of the urine and stools are necessary. If this disease is not treated, it can cause complications in the kidneys, genital organs, liver, and spleen. This can result in these organs ceasing to function and eventually death.

Bilharzia is caused by small worms called blood flukes that can get into and live in the bloodstream and in the lower part of the stomach. These worms reproduce in the body and their eggs are transported out of the body when the affected person urinates or defecates. When these eggs come into contact with water they develop into larva.

31B2 THE ROLE OF WATER IN THE TRANSMISSION OF BILHARZIA

Water provides the environment in which the larvae develop. For their development, the larvae must enter and live inside of a certain water snail. Without this carrier the larvae will die. After some time, young worms leave the snail and are ready to enter a human body. When someone bathes or works in water or in mud that contains these worms, his skin becomes soft and the worms can easily penetrate into his body.

31B3 PREVENTIVE MEASURES

PREVENT CONTAMINATION FROM SPREADING

Prevent bilharzia from spreading by using latrines, thereby containing any infected urine. Never urinate or defecate near or in a water source.

PREVENT THE WORMS FROM ENTERING THE BODY

Avoid bathing while standing in contaminated water and forbid children from swimming in it. Wear rubber boots when working in water or mud (for example, when working in rice paddies) to prevent the worms from entering the body.

PREVENT LARVAE FROM DEVELOPING

Prevent larvae from developing by raising fish that eat the snail that is necessary for the larvae's development.

31B4 PRACTICALITY OF THE PREVENTIVE MEASURES

Here are some suggested questions to discuss with the villagers so they can determine themselves the practicality of the solutions available for bilharzia.

LATRINES?

Are the villagers willing to dig and then use the latrine once it is constructed?

BOOTS?

Are boots available? Are they affordable? Would villagers wear them? Are they durable?

KILLING THE SNAIL?

Is the micro-dam conducive to raising fish or does it go dry too fast? Are the snail-eating fish available locally? How can they be transported to the new micro-dam?

31C PREVENTING MALARIA

31C1 BRIEF DESCRIPTION OF MALARIA AND ITS CAUSE

Malaria is an infection of the blood that causes chills and high fevers. It is spread by female anopheles mosquitoes that bite only during the night. These mosquitoes suck up blood containing malaria parasites when they bite an infected person and they inject them into the next person they bite and infect him. After some time, the parasites increase in number and begin destroying the blood cells of the infected person.

Malaria often starts with chills and a headache. The person becomes very tired and achey all over. High fevers then develop. Children with malaria may have convulsions. Malaria can be fatal if left untreated.

31C2 THE ROLE OF WATER IN THE TRANSMISSION OF MALARIA

The anopheles mosquito which spreads malaria needs large areas of standing water in which to lay its eggs. After 10 days, these eggs become mosquitoes and continue the reproduction cycle.

31C3 PREVENTIVE MEASURES

PREVENT THE BLOOD PARASITES FROM DEVELOPING

To protect oneself against contracting malaria, take recommended doses of antimalaria medication.

PREVENT THE MOSQUITOES FROM BITING

To reduce the chances of being bitten, prevent mosquitoes from entering the house where one sleeps. Screens are an effective solution for this. Certain plants, leaves, or commercially made mosquito coils can be burned; or sprays can be used to chase mosquitoes from sleeping quarters. Sleeping under a mosquito net is a sure way of protection against being bitten while sleeping.

PREVENT THE LARVAE FROM DEVELOPING

There are certain kinds of fish that can be introduced into a dam or swamp that eat the larvae of mosquitoes. These type of fish include most members of the carp family.

31C4 PRACTICALITY OF THE PREVENTIVE MEASURES

Consider the following questions when examining the practicality of the preventive measures.

ANTIMALARIA MEDICATION?

Is the medication locally available? Is it affordable? Is it safe over the long term for the villagers? Is the local strain of malaria resistant to the medication or will the strain readily become resistant to it if most villagers use it? Should the medication be used just as a cure instead of a protection?

MOSQUITO DETERRENCE?

Are traditional homes conducive to screening? Is screening affordable? Is it available? Are there products which repel mosquitoes that available in the local area? Are they affordable? Are they safe for long-term use? Are mosquito nets available? Are they affordable for the whole family?

KILLING THE LARVAE?

Are the larva-eating fish available in the area? How can they be transported to where they can help the most?

32 ENCOURAGING OTHER DAM RELATED SELF-DEVELOPMENT PROJECTS

32A WELLS NEAR THE DAM

The village should be encouraged (through awareness raising on preventive health (sec.45C)) to construct a permanent well near the reservoir so that the villagers will have an inexpensive source of potable water year round.

Because the micro-dam will cause the water table to rise in its immediate area (fig.A32), a well dug near the reservoir, especially just downstream from the dike, will not have to be as deep as other wells dug farther from the dam or another source of surface water to provide water year round. Thus it will usually be cheaper to case with masonry. For example, in the Gaoua region of Burkina Faso, the wells usually need to be 10 to 15 meters deep to provide water year round, while the wells dug just downstream from micro-dams have needed to be only 6 meters deep to provide year round water, even though the dams are dry for several months each year.

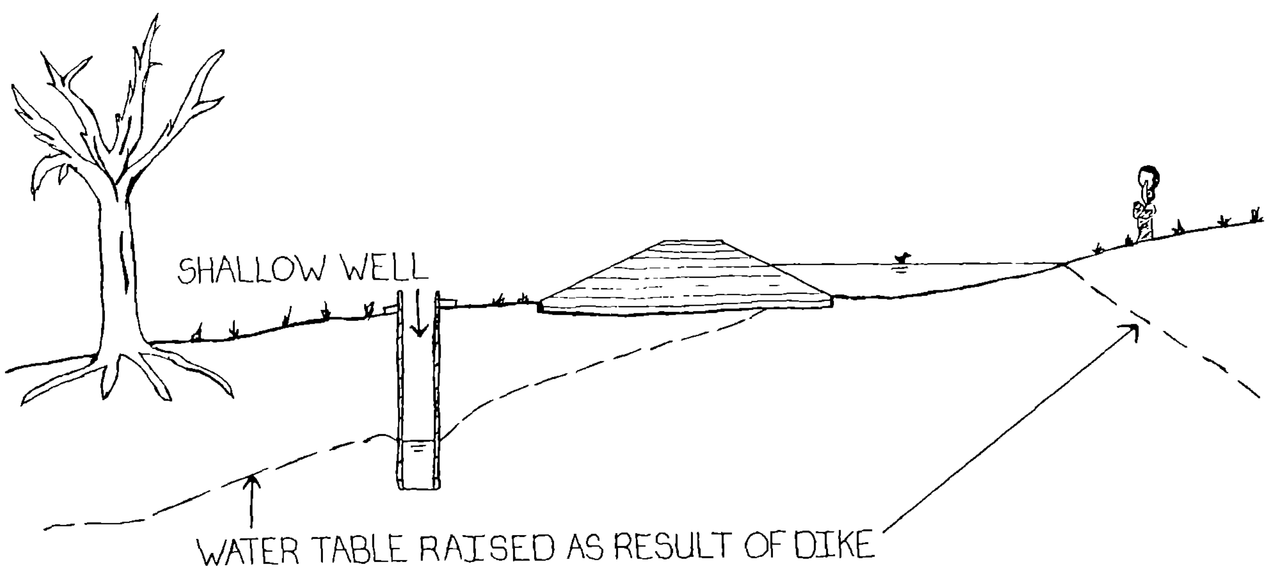


FIGURE A32: The rise in the water table caused by a dam.

The subsoil has a filtering effect on water seeping into a well from below. Thus a well can be a continuous source of clean, healthy water, if it is kept free from contamination from above. On the other hand, as discussed in section 31, if villagers drink dam water or contaminated well water, this may cause an increase in illness in the village. A well can be kept free from contamination by:

- casing at least the top three meters of the well and adding a well head with an apron to protect against the easy infiltration of surface water into the well
- keeping the area around the well clean and free from animals, animal waste, and dirty wash water
- keeping debris from falling into the well.

A masonry well should be dug at least five meters away from the dike (if it is dug downstream from the dike), and any uncased well should be at least ten meters downstream to avoid piping-type erosion problems (sec.30A).

For more information on how to build wells with masonry brick, the manual entitled Masonry Well Construction by Johann Zimmerman (French or English) is available from:

Mennonite Central Committee
21 S. 12th St.
Akron, PA 17501
U.S.A.

32B CONTOUR BARRIERS

The village should also be encouraged to construct contour barriers on their farm land, especially on the farm land inside the perimeter of the catchment area for their dam. As the name implies, contour barriers are small barriers constructed along the contours of the land (lines on the land that are at the same elevation). The purpose of the contour barriers is threefold:[7]

1) to slow down the speed of runoff water as it flows across a field and thus prevent erosion;
2) to allow time for water to soak into soils that have a hard surface crust; and
3) to allow sediments and nutrients that are carried along with the runoff water to settle out onto the field.

Thus, contour barriers on the land inside the catchment area for their dam will benefit the villagers in two ways: they will improve the land for farming and will greatly slow down the rate at which the dam will be filled in with sediments and have to be cleaned out.

There are many ways to construct contour barriers depending upon what is available on the land (fig.B32).[2] Simple surveying tools such as a water tube level (app.C) can be used to mark out the contours.

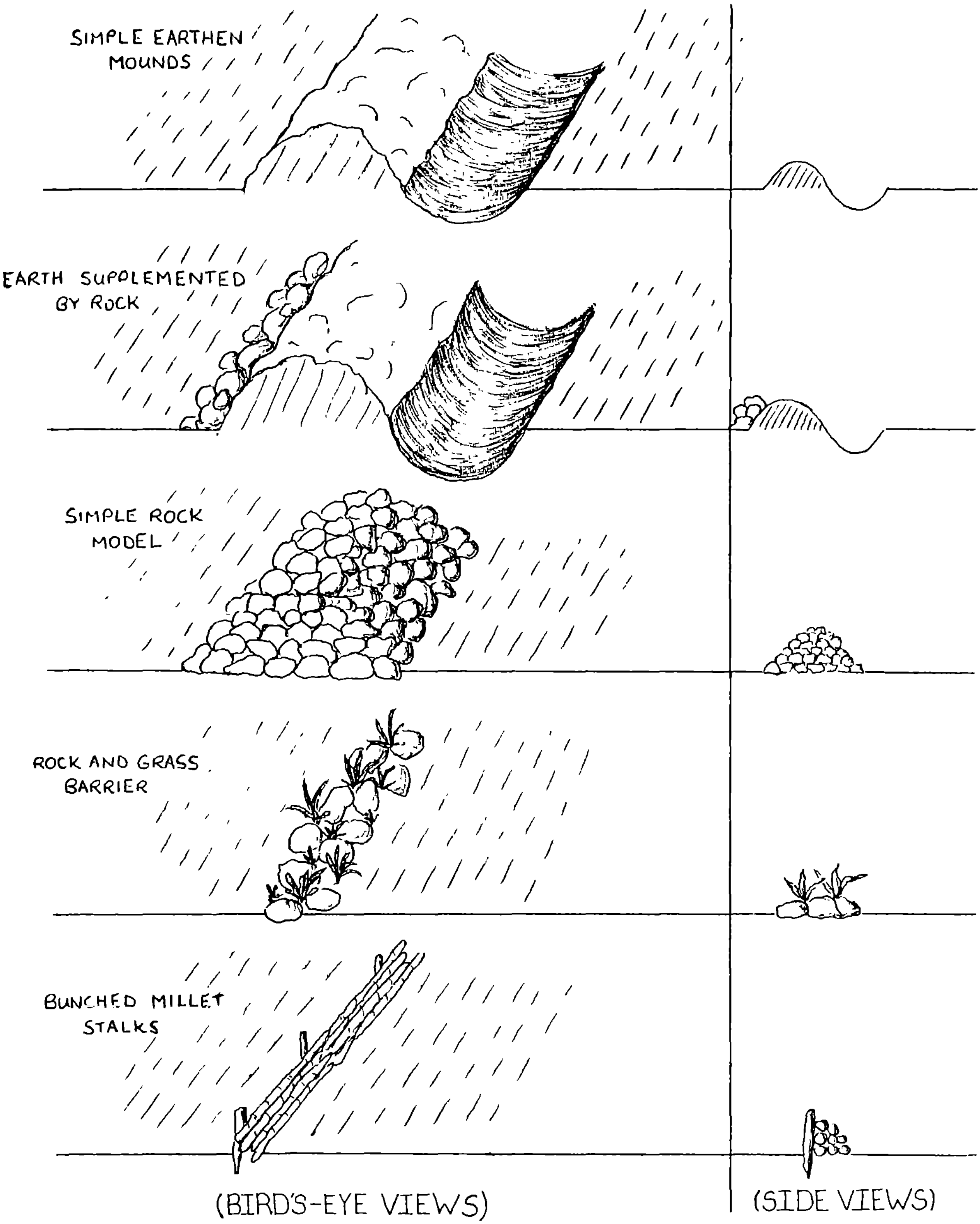


FIGURE B32: Some types of contour barriers.

For more information on contour barriers and how to build them contact:

OXFAM
B.P. 489
Ouagadougou
BURKINA FASO
West Africa

32C OTHER PROJECTS

Water from the dam or from nearby wells can be used for irrigation of gardens, tree nurseries, rice fields, and other agricultural projects. In addition, rice can be planted in the shallow areas of the reservoir itself.

Fish can be harvested out of the dam when it has nearly dried up.

Mud bricks can be made near the reservoir. There might be an additional advantage to making bricks if the soil used to make bricks is dug from inside the nearly dry reservoir, serving to deepen the reservoir or clean out sediments. However, the excavations for soil for the bricks must be at least 10 meters away from the dike and must not be dug so deep as to penetrate into a more permeable layer of soil that might be underlying the dam.

33 SOME ADVANTAGES OF MICRO-DAMS OVER LARGER DAMS

Now that some recommended post-micro-dam construction activities have been examined some advantages that a micro-dam can have over a larger dam can be pointed out.

33A RESERVOIR MAINTENANCE ADVANTAGES

Since the micro-dam does dry out from time to time it is easy to clean out the sediments or deepen the reservoir at those dry times instead of allowing the sediments to eventually fill up the reservoir. Often this is impossible in larger dams that always have lots of water in them.

Also, if the sediments are such that they can be used in making mud-bricks the villagers can benefit several ways if they make mud-bricks when the micro-dam is about dry: they gain bricks, they clean out the sediments, and they deepen the reservoir (sec.32C).

33B HEALTH ADVANTAGES

If the micro-dam dries up every so often, certain diseases that may thrive along with the dam water, such as guinea worm, malaria, bilharzia, etc., can be eliminated or reduced (sec.31).

33C FISH HARVESTING ADVANTAGES

It becomes much easier to harvest the fish in the reservoir when it is nearly dry. Often the sale of these fish has become an important source of community income for villages who have built micro-dams. This money has been used to finance community development activities.

It has also been our experience that there are, somehow, always more fish the next year no matter if the dam went dry or how heavily they were harvested the year before.

PART IV

METHODOLOGY

40 BEFORE THE MICRO-DAM BUSINESS

40A APPROACHING THE VILLAGE

This manual is written from the point of view that outsiders cannot bring development to villagers, but can only nurture their potential for development. Keeping this in mind an outsider must be very careful in how he approaches a village about doing a micro-dam or any other self-development project.

40A1 UNINVITED APPROACH

Especially in the case where an outsider goes, uninvited, to talk with a village about development, he must be sure not to tell the villagers what their problems are (in effect criticizing them). He must try not to impose his ideas as solutions to their problems. Instead, the village should be led to decide together what their biggest problems are and to discover what options there are to solve these problems by working together (sec.45A). If lack of water is agreed upon as being a big problem for the village, a micro-dam could then be appropriately suggested.

40A2 INVITED APPROACH

In many cases villages become familiar with a dam program through governmental officials, other villages, church contacts, program personnel, etc. Then, once a village contacts the program personnel specifically to come and discuss ways of alleviating their water shortage problem, they have already chosen their priority problem and they are taking steps to research their options.

Still, outsiders should not impose a solution nor should any other one individual impose a solution on the village. In general, a village that decides upon a solution as a group will work towards that solution as a group.

40A3 IMPORTANCE OF VILLAGE CONSENSUS

Numerous examples can be cited, such as that of the village of Takolo in southern Burkina Faso, where the representative of the government in the village decided for the village that they would build a micro-dam by hand. The work started but nothing came of it.

It is the people who build the dam. If they have not agreed that the water problem is the priority problem, or they don't agree upon the solution they are pursuing, no sizable work will be completed. They might start work but they will surely quit within a few weeks when they see how much hard work is involved. Starting a village project only to quit later ends up being a waste of time for everyone involved and a detriment to the development process by proving to the village that they could not work together to achieve solutions to their problems.

40B GAINING A WORKING KNOWLEDGE OF THE VILLAGE MILIEU

When a village asks for outside assistance to help them build a micro-dam, it is essential that the outsider becomes acquainted with the village. It is necessary to know something of the social structure, the resources, the motivation level, the history, and the activities of the village. It is necessary to identify potential problems that may arise during and after the construction (such as health problems, conflicts with other villages, etc.).

To gain a working knowledge of the village milieu, one can use formal surveys (app.G), discussions with government officials, pastors and others who know and work with the people. Also, village meetings and direct discussions with individual villagers are advised.

When using surveys, try not to suggest a response when questioning. It is our experience that very often a villager will want to answer a question the way he thinks the questioner wants it answered or the way the villager feels would best assure the project's approval. In this sense, an indirect and/or nonformal information gathering process often yields more accurate results.

Learning about the village milieu is an on-going and important process. The more an outsider knows about a village the easier it is for him to work effectively with them.

41 A SUGGESTED MICRO-DAM MEETINGS FORMAT

The village meeting is the main tool for communicating ideas, and for helping to motivate and organize the village. Because these meetings are important, one should be sure to take time and not allow them to be rushed. Good village meetings can save much time and frustration later on. Experience has shown that good village meetings, wherein most of the village participates (both men and women), the work has gone smoothly. However, when only a few powerful men make the decisions for the rest, problems are common.

The following is a suggested format for village meetings after the village has sought outside assistance in constructing a micro-dam. Although it is intended to be used as a flexible tool by a development worker and not as a rigid step-by-step process, at least two to four meetings (depending upon the degree of village organization and consensus) prior to the work have shown significant results. The principles outlined below can be applied to working with any type of village self-development project (sec.45A).

41A FIRST MEETING: DETERMINING THE NEED AND ASSURING CONSENSUS

- **Ask to be introduced to any of the chiefs, government officials, health services representatives, and any other important people in the village to whom you have not already been introduced.**

- **Explain, clearly, who you are and what organization you work for.**

  You should state simply and not in great detail why you are there. Often at this stage, it is adequate to simply state that your organization is interested in helping villages who want to find solutions to their water problems using their own natural and/or local resources by starting with a micro-dam.

- **Ask, if you do not already know, how many people, families, and/or houses there are in the village and what kinds of organizations and projects are in place.**

  Try to determine if the whole village is represented. If it appears that a group is not represented (for instance women), you should probably explain to the villagers the need for the group to be represented at the next meeting. Ask if there are any functioning cooperatives and/or other successfully completed village projects, and find out who the leaders of the projects were. Also ask if there are any other community projects in process or planned to take place in the following year.

- **Ask why the village wants a dam.**

  The reasons they give could influence the size, location and type of dam needed. For instance, if they want a dam primarily for water for gardening, a site should be found close to good garden land.

- **Explain as clearly as possible the conditions involved in building a micro-dam with the help of your organization.**

  Usually this is the time that you need to explain a little of your organization's philosophy of intervention, the way the dams are built, the responsibilities of the village, and the responsibilities of your organization.

  For MCC-type compacted earth micro-dams with natural spillways, MCC-Gaoua uses and recommends the following approach. Explain that you try to help villages that don't have money for cement, machines, transport costs, etc. Say that you try to help villages who are ready to work with what they have: their earth and their manpower. Explain that the dams are built by hand.

- **Deal with skepticism.**

  Frequently at this point villagers may express skepticism that a dam can be built without machines or that a dam built completely with earth can hold back water ("They don't do it that way in the Ivory Coast."). Counter this skepticism by using stories and examples from other villages which have done these micro-dams (see PART V). If possible, arrange a field trip to take influential villagers to see a completed micro-dam.

- **Outline clearly the responsibilities of the program and of the village.**

  Explain any requirement that the village sign a document before collaboration is approved, such as a letter of agreement outlining the above responsibilities (app.I). This letter of agreement is primarily used to ensure that important points of responsibility are understood and agreed upon and is not intended to be a legally binding document. (See appendix H for the conditions for working with AMB).

- **Ask them to recount for you what they have understood you to say to ensure everything is clear. Clarify if necessary.**

  This is the best way for you to know if you have made yourself understood to the villagers. Try not to insult their intelligence by implying that they might not be able to understand. Instead they should know that you are not sure you communicated clearly enough. Different villagers can be called upon to explain what they heard you say on different important points.

- **Insist that everyone in the village have another meeting to decide among themselves if they are still interested in doing a micro-dam with your help.**

  If they so decide, they need to call you to come back for another meeting. However, before this meeting, they will need to establish together three possible dam sites for you to choose from.

Ask the village to call you back so that you provide an easy way out for the village if they are not interested in constructing a dam under the conditions which you have explained. Even though some villagers might want to make an immediate decision and say that the community is ready to agree to the conditions that day, it is important that the village takes time to reflect on and discuss the conditions before they decide.

If it turns out that they are really not interested in your type of help, they will not make the effort to call you back for another meeting, which will save a lot of time and perhaps frustration for you and the village. However, there is a danger here that the village *might not* contact you again for a non-valid reason because they misunderstood the conditions. This is why it is so important to be sure you know that the conditions are understood correctly by the villagers before you leave this first meeting. Also you should arrange how the village can best contact you if they want to.

- **Delay looking for a micro-dam site.**

  It is *not advisable* to look for a site for a micro-dam before you know that the village is motivated enough to complete a dam. You should say that if a suitable site cannot be found it will not be possible for you to help them to do a micro-dam. This needs to be stated clearly to avoid raising expectations to a high level before a site is found. On the other hand, there may be a perfect site nearby, but if the village is not motivated enough to complete a dam there the site means nothing.

41B SECOND MEETING: DETERMINING IF THERE IS AN ADEQUATE SITE

- **Ask them why they called you back for this meeting.**

  Usually, they will say that they are in agreement to do a dam.

- **Review the conditions involved to be sure there are no questions.**

- **Ask who the dam and the water in it will be for.**

  It is the best that this be clarified and worked out now so that it will not be a big problem later. (If there is a potential for conflict over water rights with surrounding villages, ask the village to deal with those issues ahead of time . For instance, they might ask the surrounding villages to help construct the dam if they want to use the water.)

- **Ask to visit the sites they have selected.**

  Looking at these sites you will get some idea of whether it is possible to build a micro-dam near the village and of the priorities the village has for the utilization of the dam.

- **Seek alternatives to unacceptable sites.**

  If a site they show you is not acceptable (sec.10) first point out the good points about the site and then explain what might cause the site to be unacceptable. Try to dwell on the positive not the negative aspects of their selections.

  If none of the sites the villagers show are acceptable, make a through investigation around the village to find a good site. Usually it does not work well to ask the village to find 3 more sites as this causes the project to lose its momentum.

- **Survey a potentially acceptable site.**

  If a site is found that seems to be acceptable to both you and the village, survey the site at this time (sec.11) and calculate the approximate dimensions of the dike (app.E). Be sure the site is acceptable. Tell the village more about the dam, such as how long it might take to build (app.E). If the site is still judged to be acceptable to both you and the village, arrange to have a third meeting with the village.

- **Explore other options with the village if an acceptable site cannot be found.**

  If a good site cannot be found, go back to the village and discuss other options that might be available to help with their problem. Perhaps your organization or other organizations have alternative ideas they can offer to help with the water problem. It is advisable to do some research on this beforehand.

41C <u>THIRD MEETING: ORGANIZING THE VILLAGE</u>

- **Determine the structure of the village organization that will lead the work.**

  Be careful with this issue as it is often best, for village self-development, to tie into already existing village structures and let the village organize itself. This is especially true where the village is well organized and has a history of working well together on communal activities.

  If this is the case, ask what their organizational structure will be for the work. Get acquainted with the leaders for the project and move on to the fourth meeting agenda.

- **Develop a structure if it is needed.**

  If the village does not have a history of working well together, and/or there is not a strong village organizational structure in place to direct work on the dam, your most important job, as a development worker, is to help the community learn how to organize and work together.

When working with a village that needs help organizing, the following procedure is advised. Tell a story about the head of the family who received a visit from a stranger who does not intend to stay long. Ask the village,

> " Who will guide and take care of the problems in the family? The stranger or the head of the family? "

The answer is obviously the head of the family.

Explain that the village is like the family in the story. The development worker is the stranger who has come but won't stay long. Ask whether it would be a good idea to have a group from the village form a committee to act as the head of the family, to lead them in developing their village and handling problems that might arise while they work together.

- **Encourage good leadership.**

If the community agrees to form a committee, encourage them to choose good leaders. Ask them what they consider to be the qualities of good leaders to be selected for the committee. A good discussion on leadership should ensue.

- **Put it in the hands of the village.**

At the end of the meeting, help the community summarize what they have discussed and decided concerning the importance of forming a committee to lead the village development and the qualities that the committee members should have. Explain that the program does not know people in the village and so the responsibility of choosing committee members is theirs.

Ask them how much time they require to form a committee. Based on their response, schedule a fourth meeting with the village to talk with the newly formed committee and the community about organizing the work to build the dam.

- **Build strong connections to the village leaders.**

Make an effort to get to know those that will be the leaders of the project; where they live, what they do, etc. Build a friendship or at least a good working relationship with them, since they are the people with whom the program will be working closely.

41D FOURTH MEETING: ORGANIZING THE WORK

- **Meet together with the leaders of the project and the village as a whole to resolve any unfinished issues and to discuss organizing the work.**

  Work on any questions not completely answered and then sign contracts, letters of agreement, or anything else required by your organization.

  If it has not already been worked out in the above contracts, letters of agreement, etc., ask the village leaders to plan with the village how they will organize the work. They should decide how many days per week and how many hours per workday they will work and when they will start. They should also discuss how many people will work each workday and what should be done in case of absenteeism.

- **Make one or two suggestions which will help them work better as groups.**

  One suggestion is to divide the work force of the village into two or three equal groups with at least several families in each group. These groups can work on the same or on alternate work days. Have these groups work on their own separate sections of the dike. These sections should be equal in the amount of work required to finish them. This fosters some healthy and friendly competition because no group will want to fall behind in the work to another group.

  There is, though, a risk of too much competition. Competing groups may sacrifice quality work for speed. This risk can be reduced by reminding them that if the dike breaks at a particular section it will be easy to see which group was at fault and will need to repair the breach. It is better to divide into two or three larger groups rather than several small groups, such as family units, because there is a greater chance that the smaller groups will be unequal in strength, motivation, and/or talent.

- **Clarify how to work with a helper if one is sent.**

  If a helper is sent to the village, you should discuss with the leaders his role and how they plan to lodge him and provide him with regular and adequate meals. It is usually best if the helper is responsible to the leaders and the leaders are responsible for the helper.

42 TRAINING ASPECTS

There is usually a need to train construction foremen who can be on site each workday. The job they should be trained to do is to see that the construction is done correctly (sec.13), to organize the work force to work efficiently (sec.41D), and to be a morale booster and encourager of the work force (sec.43).

There are three basic approaches that have been used to provide trained construction foremen for the work. These are:

1) on-the-job training of village foremen;

2) training sessions for village foremen away from their village; and

3) sending trained helpers to the village.

A brief description of these approaches and their relative advantages and disadvantages follows.

42A ON-THE-JOB TRAINING

On-the-job training of village foremen requires that the program personnel make frequent visits to the construction site, especially at the start, to train the foremen on the construction steps and advise on work organization. As the work progresses the program personnel will be able to decide if they can visit the site less frequently. Some villages are able to work well independently and some are not.

It is best to let the village leadership structure decide how many foremen are needed and who they should be. But it is advisable for the program to hold a discussion with the leaders and the village on the qualities of a good foreman before they are chosen.

The advantages of training village foremen is that the knowledge and leadership skills gained by a foreman through the training and the experience of successfully completing a micro-dam will be available to the village in the future to do maintenance work or other community self-development activities (see Part III). These foremen could be a resource the program can use to help nearby villages who want to construct micro-dams after seeing the one these foremen constructed. There is also an advantage in that this type of training is flexible and can be adapted exactly to the needs of the village.

The disadvantages are that the program personnel will have to commit lots of time to working with the village. This is fine, even desirable, when the program is just starting. But as the program expands the personnel might find it hard to keep up with the demands. Frequent visits will be required because the foremen that are trained on-the-job will not have the experience to make major technical decisions. Another obvious disadvantage is that the foremen selected might not be good at the job.

42B TRAINING SESSIONS AWAY FROM THE VILLAGE

AMB has made especially good use of training sessions which take place just before the start of the work season. They invite all interested villages to select an influential village leader and two young people to attend their training sessions on improving rainwater management and basic earthen micro-dam construction.[4]

The advantages of using training sessions to teach interested villagers are that, like the on-the-job training mentioned above, the knowledge and leadership skills remain in the village to be a resource for the villagers in the area. There is an added advantage of being able to train people from many different villages at the same time. This makes it possible to manage an expanding program and to easily spread and share helpful ideas.

The training sessions approach has a disadvantage in that they are a little less flexible than the on-the-job training, both in the scheduling of the training and in adapting to the specific needs of the village. Scheduling conflicts and transportation problems could cause attendance to be lower than ideal. Again the people selected by the villages might not be good at the job and frequent site visits will still be required.

42C SENDING A TRAINED HELPER TO THE VILLAGE

MCC has trained part-time helpers who are available during the dry (work) season, to go to a village and help them build their dike. These helpers have been trained using a combination of training sessions and on-the-job experience. MCC has paid them a salary based mainly upon the amount of work done. Part of the helpers job is to pass on his knowledge, training, and experience to the village leaders.

An advantage of sending a trained helper to the village is that the presence of an outsider who represents the program usually causes the village to be more diligent in working and in setting and staying with a work schedule. If the salary for the helper is based on the quality and quantity of work done, he is usually motivated to work hard himself, to see that the construction is done correctly, to organize the work force to work efficiently and steadily, and to encourage the villagers and keep their morale high.

Another advantage is that if the helper is trained and experienced he will usually understand the best way to encourage, motivate, and organize the village and he will be able to oversee the construction and handle the minor problems that arise. Therefore the construction will go faster and less visits will be required of the program personnel. Also the helper's experience in successfully building other dikes will be a natural inspiration and encouragement to the village he is helping.

The trained helper can be an excellent on-the-job trainer for the villagers since he can be with them over a longer period of time. Also, if someone who willingly helps others and who will remain in the region (for instance a farmer) is recruited to be a trained helper, he could continue to be a resource for the region even after the program has left.

One of the main disadvantages is that the trained helper will normally need to be paid a salary of some kind to work a full work season for the program. Also, as an outsider he might not understand the village politics, language, etc. which could lead to problems. Another disadvantage is that sometimes the helper might be reluctant to pass on his knowledge to the villagers because he feels that to do so would make himself less needed.

42D FUTURE DIRECTIONS

MCC-Gaoua is hoping to leave a functioning micro-dam program that is basically self-sustaining, having only one or two salaried personnel who will help site micro-dams, help motivate and organize villagers, troubleshoot, and encourage post-construction activities (see Part III). To work towards this goal MCC-Gaoua is planning to reduce its use of paid trained helpers that are sent to the village, restricting their use to helping in new regions that are farther from Gaoua. Instead the program is hoping to make use of volunteer helpers from villages who have already successfully built their own micro-dam to help neighboring villages who want to build one. Perhaps the villagers will be encouraged to give the volunteer some compensation, such as grains, chickens, etc., for his time. Hopefully with a system like this the technology can continue to spread almost on its own.

Also MCC-Gaoua is planning on making use of training sessions. These sessions will be held in a village before the start of the work season. Construction foremen chosen by neighboring villages will be invited. The sessions will involve actually constructing a miniature micro-dam to teach the correct construction techniques, tips on organization and motivation, and the need for freeboard and adequate spillways.

43 MOTIVATION ASPECTS

43A DEALING WITH HALFWAY POINT DISCOURAGEMENT

Sometimes after a few weeks of work, a village might become discouraged and find it difficult to continue because the work does not seem to be going very fast. In this case it often helps to show, using string lines and/or long poles, how much work is left (fig.A43). This is because by the time the dike has reached about one third of its planned height the work is usually already more than half done.

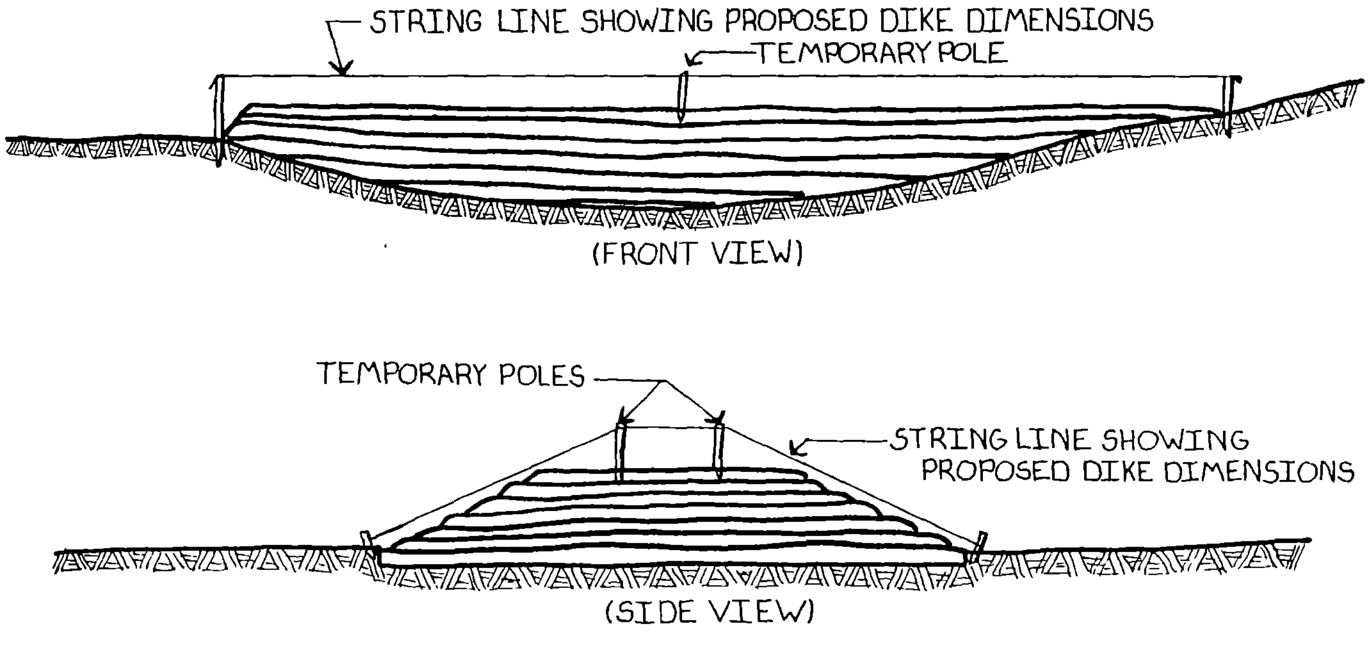


FIGURE A43: Using string lines to show progress.

43B DEVELOPING GOOD RELATIONSHIPS

It helps to work and spend time with the village, to make friends with the villagers, and talk positively about their ability to finish the dike. It never helps to criticize them or complain about their work.

43C EVALUATING "FOOD-FOR-WORK"

Many organizations use "Food-for-Work" to encourage community development projects. Food-for-work is food that villagers receive either after each day they work or after they finish a project.

From a development worker's point of view, the danger in giving out food-for-work is that, although it can be used to help motivate villagers to build a dam or do another project, they may be reluctant to work on other self-development projects later without again receiving food for their efforts. Food-for-work can change the village's goal or reason for the work from trying to develop their local resources and solve their water shortage problem to that of gaining food. This attitude change often diminishes the effect of the project on longer-term village self-development.

Our experience is that if a village that is not motivated enough to do a micro-dam without receiving food-for-work, it may not have the motivation to work hard and do quality work, even with it.

Perhaps food-for-work should only be given where there is a serious food shortage and the villagers do not have adequate financial resources to deal with the shortage. But even in this case, it might be better to give the food out as aid and not tie it to work that is done on the project, so that the reason for doing the project will not get confused.

44 POTENTIAL LIMITING FACTORS

There have are some factors that hinder the construction of micro-dams and the wider application of the technology. Some of the main limiting factors will be examined below.

44A LACK OF TECHNICAL HELP

Villagers are not totally ignorant of the factors influencing site selection (sec.10). They usually know that clayey soil is the best for constructing a dike and that a place where the valley is narrow is a good place for a dike. Most will know not to try and put a dike at a site where the runoff has been too great for a earthen micro-dam (because the catchment area is too big, too steep, too impermeable, etc.).

This is because they have seen the volume and speed of the floods going through the site and realize that hand-building anything out of earth at the site would be a risky proposition.

Successful dikes have been built by villagers without the aid of outsiders and the outsider's technology. But there have been lots of micro-dams independently built by villagers that have failed. They have usually failed because the villagers did not understand the need for an adequate spillway and the need for freeboard (sec.10D).

Most villagers interested in hand-building an earthen micro-dam can benefit from the help of a person who understands the factors involved in site selection (sec.10) and dike building (sec. 12 and 13) and how these factors relate to each other. Even villages that have a successful, independently built micro-dam usually jump at the chance of having a technician come and help them improve their dam (usually by leveling up the dike crest and fortifying certain parts of the dike).

Many villages will not start the big job of building a dike at a certain site unless they are assured, by someone they have confidence in, that the site is good and the dike they are planning to build will hold. This manual is an attempt to address this limiting factor by spreading the knowledge of hand-built earthen micro-dam technology so villages that have the potential and the need to build micro-dams can be encouraged to do so.

44B LACK OF SUITABLE SITES

The lack of suitable sites near a village interested in building a micro-dam can also be another limiting factor. At times it might be hard to find clayey soil near an otherwise suitable site.

Do not take risks when the program is just starting in an area, both for the sake of the hard work the villagers will put into building the dike and for the future of the program. Leave any uncertain site until the program has gained acceptance and experience in the area, then reevaluate the site.

44C NEGATIVE VILLAGE DYNAMICS

Certain village dynamics might also become factors in stopping or overly prolonging the construction of a micro-dam. The village dynamics that have stopped or slowed the work in the experiences of both the MCC and AMB programs in Burkina include:[1]

- social conflicts and village divisions

- the departure of most able-bodied young men in the village to cities or other countries in search of work

- other projects being done in the same village at the same time that compete for the same work force (such as village-built schools and grain banks)

- the appearance of organizations using earth moving machines to build dams nearby (this usually causes the village to stop and wait to see if the machines will come and help them)

The above village dynamics are examples of why it is important to do a good job of village and regional reconnaissance (sec.40B) so that many of these problems can be foreseen and some adjustments made.

45. BUILDING UPON THE SUCCESS

When a village has successfully built a micro-dam by hand, they have learned to organize themselves to work together to develop their resources. The knowledge and confidence they have gained can now enable them to pursue other village activities to continue to develop their resources (including their new micro-dam (sec.32)) and solve other community problems. The development worker should try to encourage the village to build on their initial success in solving a water problem by organizing themselves to solve another problem. The most effective method of motivating villagers to continue to work at their development is to help them prioritize their perceived needs, choose one of these needs to solve, and organize themselves to solve it.

45A WORK ON THE PERCEIVED NEEDS (AWARENESS-RAISING)

If the villagers do not perceive a particular issue to be a problem, they will not voluntarily work towards a solution to the problem. This is why the development worker must begin with the perceived needs of the villagers. If the villagers did not perceive a lack of water to be a problem, they probably would not have even started on building a micro-dam by hand. The same will be true for other problems.

In some of the following sections the program is encouraged to discuss doing maintenance, health, and other dam related self-development projects with the village development structure (committee). These discussions are intended to be an awareness-raising exercise. If the villagers do not perceive these issues to be relevant to their needs, the work on these issues will have to be left until the time comes when the village feels a need for them.

The following are some general awareness-raising techniques that a development worker can use to help a village discuss, prioritize, choose, find solutions for, and organize to solve other community needs.

<u>General Awareness-raising Procedure</u> [9]

1. Gain a knowledge of the villager's milieu.

   - By now, after working with the village for several weeks, there should be a fair understanding of the village milieu (sec.40B).

2. Help the villagers express their problems.

   - Often it is good to hold separate meetings with each of the different social groups that make up the village (such as men, women, young people, etc.) so that each will be encouraged to express themselves. In this way a truly representative list of problems can be drawn up.

   - Prepare questions to help facilitate expression of problems.

3. Have the villagers choose the problem to be tackled first.

   - Break this problem down to its clearest simplest form.

4. Analyze the problem.

   - First get information about the problem from the villagers and from outside sources, such as technicians or specialists on the problem.

   - Then have village meetings in groups or as a whole village to find out the knowledge of the village. Prepare questions to draw out the knowledge such as: how does this problem manifest itself? whom does this problem particularly concern? what are the causes of this problem? what are the consequences? how has the problem changed over the years?, etc..

5. Research the solutions for the problem together with the villagers.

   - Research and document solutions the villagers can pursue in books, booklets, and magazines on the subject and in visiting with others who have worked on the problem. Look at the different causes of the problem, the advantages and disadvantages of each proposed solution, and the inputs necessary for each solution.

   - Have another village meeting to gather more ideas and points of view about possible solutions. Prepare questions that allow the villagers to tell of solutions they have thought of or they have seen. Help by giving complete information or by presenting an analysis (such as the advantages or disadvantages of a certain idea). Avoid presenting a solution. The solution should come from the villagers.

   - Visit (together with some of the villagers, if possible) a village where a solution to the problem is being tried.

   - Do some practical demonstrations together.

6. Let the village choose a solution and help them organize their actions.

   - Ask questions which will help the village determine precisely: who will do what, with what, where, when, and how. Give information on how to do tasks that are new to the village.

   - Encourage the village to do the tasks on their own. Do not promote dependence on outsiders (such as yourself).

7. Evaluate the actions together with the villagers.

   - Determine concrete, measurable, and significant points which can be used to gauge progress towards the fixed objective of solving the problem.

   - Hold village meeting to discuss and evaluate progress.

45B WORK THROUGH THE DEVELOPMENT STRUCTURE

If the ultimate goal of the development program is to help the villagers learn self-development, it is perhaps more appropriate for the development worker to work directly only with the development committee (structure) of the village. This would enable him to reinforce the organizational and motivational skills already learned by the committee during the dam construction. Once these skills are fine tuned and strengthened through training and/or experience the committee will be better able to meet the future development needs of their village without the further need of an outsider as an organizer or motivator.

In the past, in village meetings concerning the construction of the micro-dam it was the development worker that served as the facilitator. His role was to ask questions to draw out responses, to review important points, to help establish group consensus, and help the village organize itself.

Now the development worker can work with the development committee so they can play the role of the facilitator, and an outsider will not have to be present at the village meetings. This has the advantage of allowing the development worker to start "stepping back"; allowing the village to take more responsibility and reducing the village's dependence upon him. This also has another advantage in that meetings with smaller groups are easier to call together and are more efficient,therefore the development worker's time will be used effectively.

45C DISCUSS MAINTENANCE ISSUES

It will often be difficult to discuss maintenance procedures with the villagers just after they have completed their dam. This is because the villagers are usually tired and happy to finally be finished and they will not be eager to hear about having to do more work in the future. Therefore it is best to mention, when the opportunity presents itself, from the very beginning and throughout the construction period that regular maintenance will be required to have a long-lasting micro-dam. In this way the idea will already be planted in the villagers minds and will not seem like an added burden after they have worked hard to complete their dam.

The development worker should discuss with the village development structure the maintenance that will be required (sec.30), what time of year would be the best for the village to do the regular maintenance, and how they will organize the village to do it.

Often the best motivator of the villagers to do maintenance is for them to see some erosion damage or seepage. If they are aware that they must do maintenance before the damage is serious, this system of doing maintenance "as needed" is workable though not ideal.

45D DISCUSS PREVENTIVE HEALTH ISSUES

As mentioned earlier (sec.31), health and water are closely linked together. Therefore, if the program is already aware of potential health problems associated with the improper use and handling of dam water, it has a certain responsibility to take the first step towards helping villagers become aware of these problems. Failure to take this first step would make the program indirectly responsible for the health problems that might afflict the village as a result of the water in the micro-dam that the program just helped build.

In order to give a village the opportunity to respond to potential water-related health problems, the development worker will more than likely need to be the initiator in raising the villager's awareness about these problems.

Helping villagers consider health issues and reach new levels of understanding is not something to be forced or done quickly, such as in one village meeting. Considering the educational nature of preventive health work, we should acknowledge and respect the time required in order for people to absorb, understand, and eventually accept new ideas. To be effective, in the context of a village who wants to build a dam, preventive health awareness raising should be a process of gradual discovery. It should start during the initial village contact and continue throughout the construction of the dam and thereafter, with the active participation of the villagers concerned.

The following two sections are aimed at helping a community development worker already involved in mobilizing villagers to construct dams, to become better prepared when entering the field of health.

In order to get an idea of what to expect when beginning work in the preventive health field, the following section presents a comparison of the differences between preventive health work and water resource (micro-dam) work. Then a suggested format is presented for village meetings during which water-related health problems are discussed in villages which are building or have built an earthen micro-dam.

45D1 WHAT TO EXPECT PREVENTIVE HEALTH WORK VERSUS WATER RESOURCE WORK

PREVENTIVE HEALTH WORK IS MORE TIME INTENSIVE

One of the most apparent differences between water resource work and preventive health work is the amount of time needed to identify the problem, analyze it, decide on a solution, and follow through on a plan of action. This process is much slower when working on health issues than when working with water resource problems. Let us examine why.

Requires a Longer Educational Process

Much education is needed in preventive health work to help people identify and understand the health problems they experience in their village. In some instances, education is needed first to help people see that a problem exists in their village. Often what is seen by an outsider as a health problem is seen by a villager not as a problem but as a part of life to be accepted, not changed. Before solutions to health problems can be talked about, villagers must be helped through education to see that they do have some control over their health.

Requires a Change of Habits or Beliefs

This educational process can be very delicate. Health problems are very closely tied to people's habits and beliefs. For example, in traditional African religion there are many reasons why a person becomes sick, very few of which are explained medically. In any culture habits and beliefs are slow to change. Therefore, much time and care must be taken to introduce additional ideas about health into an already existing belief system.

Requires a Longer Prioritizing Process

Prioritizing perceived problems is another time consuming yet very necessary element of preventive health work. Not every household in a village has interest in the same health problem. However, if effective community action is going to be taken towards improving health, one priority health problem must be agreed and acted upon by the community as a whole.

WATER RESOURCE WORK IS LESS TIME INTENSIVE

In comparison, water resource work is not as time intensive as health work for a number of reasons (this is not to say that it is a fast and easy process).

Firstly, if a real water problem exists in a village, that of lack of water, there is usually no questioning by the village population about its existence. Generally, little discussion is needed on this point.

Secondly, beliefs about water problems and their solutions do not seem to play as large a role in the development process as beliefs about health problems and their solutions. For example, accepting the technology that is needed to build a dam seems less difficult than accepting the idea that filtering water with a cloth will reduce the incidence of guinea worm.

Thirdly, general village agreement about the priority problem, lack of water, is most often detected during the first village contact. Prioritizing is usually not needed.

PREVENTIVE HEALTH WORK DOES NOT USUALLY PROVIDE IMMEDIATE AND VISIBLE RESULTS

Another difference between preventive health work and water resource work is the rate at which results are observed. Since changes in health beliefs and health habits begin taking place at the individual level and at different rates, progress in preventive health work is not so quickly observed. One by one, family by family, people slowly begin to implement change in their lives. It may be years later after the initial village contact that observable change in habits is noticed. For example, in his book "Christians in Development" Peter Bachelor tells of a pastor who had recently built a pit latrine in his family courtyard. When asked where he had learned about latrines, he said that it was during his schooling at Bible school twenty-five years earlier!

WATER RESOURCE WORK USUALLY PROVIDES MORE IMMEDIATE AND VISIBLE RESULTS

On the other hand, due to the constructional nature of water resource work, results are more immediately observed. Layer by layer the dam gets higher and people can <u>observe</u> the immediate results of their actions.

PREVENTIVE HEALTH WORK IS WORTH THE TIME REQUIRED

In conclusion, preventive health work demands our attention, our time, and above all else our patience and understanding. We need the patience to allow people time to work through their thoughts, to allow them time to decide, and to allow them time to act. We need understanding. An understanding that the seeds we sow will produce in their own time to benefit those we come to serve, not necessarily in time for us to see and enjoy.

45D2 SUGGESTED HEALTH MEETINGS FORMAT

The following is a suggested format for village meetings to discuss prevention of water-related health problems in villages which are building or have built an earthen micro-dam. As mentioned above (sec.45B) it is probably more appropriate to have these meetings just with the village development structure (committee) and let them be in charge of the big village meetings. It is assumed that: 1) the development worker already has a good understanding of the village milieu and 2) health issues have been mentioned and brought up with the villagers at every opportunity during the micro-dam construction process.

FIRST MEETING: EXPLANATIONS AND AWARENESS RAISING

- **Explain why you are there.**

  Say that the program has helped them have more water in their village and today you would like to discuss with them the effect this water may have on their lives, particularly their health.

- **Raise their awareness about water-related health problems using a visual example.**

  Place two bowls of water in front of the group. One bowl containing water that is obviously dirty and the other containing water obviously clean. Ask a member of the group to come and drink water from one of the bowls. Hopefully, he will choose to drink from the bowl with the clean water (one can never predict what will happen so be prepared for the opposite response.) Ask the other members if they would have done the same thing. Following is a suggested series of questions that can follow such an example in order to bring out the ideas and beliefs of the committee members about clean and dirty water. These questions also help clarify the relationship between water and health.

  1. Why did you drink this water and not that water?
  2. Why did you not want to drink the dirty water? What happens if you drink this water instead of the clean water?
  3. What is in dirty water that makes us sick?
  4. What sicknesses are caused by drinking dirty water?
  5. Which of these problems is the biggest problem for your village? Which problem has the most impact?
  6. Who does it affect? Ask for specific examples.
  7. What happens to people afflicted with this sickness?
  8. What causes it?
  9. How do you treat it?
  10. How can it be prevented?

  At this point the committee often starts asking the development worker questions about causes, treatment, and prevention. Try to continue with the first meeting agenda without giving them the answers. This is just an awareness-raising exercise to get the villagers thinking.

- **Explain that you came to briefly discuss some of the water-related health problems they experience in their village because if they are interested in doing something about them, you are willing to help them.**

- **Explain what the program's emphasis is and what it can do for them.**

  This is where it is very important to stress the fact (if it applies to your program) that the program's emphasis is on prevention of illness and that distribution of medicine is not a part of the program nor is money to buy medicine. The program is available to help those who want to find solutions to their health problems so that expensive treatments will not always be necessary in the future.

  If it is not made clear from the beginning that the program deals primarily with the prevention and not the treatment of illnesses, there is the possibility that the committee may feel deceived or tricked later on.

  The Gaoua health program experienced one such situation in the village of Sidoumoukar. The people attending the second meeting to discuss health issues were under the assumption, as we discovered much later, that we were coming to bring them medicine for treating guinea worm. As we were asking questions about the illness and it's causes, many of the group were growing impatient. Finally, someone spoke up and asked if we could not just tell them about the medicine needed and how to get it. We explained again that our program deals in prevention and that there are no medicines for guinea worm anyway. Many of the group left the meeting angry without even saying goodbye.

- **Ask someone from the group to summarize what they just heard you explain so that it is clear to you whether you explained your program clearly and whether the villagers correctly understood what you wanted to say.**

  Feedback is very important to the development worker and often it is not so easily attained. Questioning specific villagers about what they heard can facilitate the feedback process if the group is not talkative. Make clarifications if necessary.

- **Insist that the villagers take time to discuss amongst themselves what they heard during the meeting.**

  If they decide that they are interested, they can call you back. Refuse to take a decision from them the same day. It is always best to let them consider first and if they are really motivated to work on health problems, they will contact you. Arrange a way for the committee to easily contact you.

SECOND MEETING: MORE AWARENESS RAISING AND INFORMATION GIVING

- **Ask the village committee why they called you back.**

  This may seem trivial but assumptions can lead to future misunderstandings and many frustrations.

- **Review what the program is willing to offer and what it cannot offer just in case there were any misconceptions during the first meeting.**

  Often people attend the second meeting that were not present for the first so repeating the conditions of the program helps to inform these people before going on any further. Ask for questions.

- **Provoke discussion amongst the committee members using questions about the water-related health problem they themselves identified as a major problem for their village.**

  Participation in itself by the committee members is as important at this stage as the information they exchange. In order for the group to feel ownership for the development movement taking place, they must be allowed to discuss the health problem within the context of their own village.

  Get as many details as possible about how the villagers view this problem, how one contracts it, and the root causes. Find out what the committee's thoughts are about this sickness so that you will know how to approach them when it is time to talk about solutions.
  Following are some questions for discussion.

  1. What is the history of this health problem in your village? Has it always been here?
  2. What did your grandparents say about where it comes from? What do you say are the causes?
  3. What do others who are not present say about its causes? In the next village?
  4. How did your grandparents treat it? How do you treat it?
  5. How does one know that he has this sickness? What are the signs?
  6. How is the sickness contracted? By doing what?

- **Give simple additional information about what causes the illness if there are gaps in the explanations given by the committee members.**

  Use a story or pictures. Understanding the cause is the first step towards finding a solution. Be careful not to be judgmental or deny the villagers beliefs about the cause. This is not the time to challenge beliefs but rather a time to listen. Present your information as another way of looking at the problem. Ask for questions. Again, it is never a waste of time to ask someone to summarize when new information has just been given.

- **Ask the committee what they want to do about this problem.**

  They have just discussed, in detail, the illness and its impact on their village. Since the village development committee is responsible for development activities in their village, what do they want to do? Maybe they will decide that they just do not want to tackle the problem at the moment or they may decide to look for solutions to improve the situation.

  Depending on the length and intensity of the meeting, the development worker may want to stop here. If the committee decides that they want to work on solutions to the problem, another meeting date can be set. However, if the committee decides they do not want to pursue things further, the development worker should leave the door open so that if the committee ever decides to take action, they will feel free to contact him. If that is the case, the development worker should respect the committee's decision and not directly push health work, realizing all the while that a seed has been sown for the future.

- **Ask the committee members to research possible solutions once they have made the decision to do something about the health problem they indicated as a real problem.**

  This may include asking neighboring villagers, schoolteachers, nurses, etc. about what they know. At the same time, the development worker should research possible solutions at his level.

THIRD MEETING: EXPLORING SOLUTIONS AND INFORMATION GIVING

- **Ask the committee for their ideas about possible solutions to the problem.**

  Following are some suggested questions.

  1. What do they do to prevent this illness from attacking their families? Does it work? Why or why not?
  2. What solutions do others use? Are they effective?

  Exhaust all of their ideas before moving to the next step being careful not to criticize.

- **Present ideas about possible solutions, reinforcing appropriate ideas that were brought out by the villagers themselves.**

  Tell a story of what another village did to illustrate a solution. Even if you have read in a book about how another village dealt with a particular health problem successfully, use it in your discussion. Illustrate further by using simple pictures. Be careful not to present too much information at one time. Also explain things as simply as possible.

- **Ask the committee again, after hearing about all the possible solutions, what it is they want to do?**

  Help the committee to evaluate the different possibilities ,leading them to a decision about one solution to the problem that they want to put into action. Once the committee has decided on a solution, an approach for putting their thoughts into action must be discussed. It must be decided by the village committee precisely what is going to be done, who is going to do what, how, with what, when, and where.

45E <u>DISCUSS THE OTHER DAM-RELATED SELF-DEVELOPMENT PROJECTS</u>

It will be good to review some of the possible dam-related self-development projects that the village can do and their advantages for the village (sec.32) with the village development committee to see if they think the village would have an interest in pursuing one of the projects. If so, more specific information about the project can be shared with the committee and they can plan how they will present the idea at a village meeting.

PART V

AN EXEMPLARY HISTORY OF A MICRO-DAM PROJECT IN THE VILLAGE OF KOLONDIOURA

Volunteers working with MCC in the Gaoua area, whose program is also supported by World Neighbors, first visited with leaders of Kolondioura in 1983. There was considerable skepticism among villagers in the area as to whether earthen dikes could hold back water without using concrete or machines. In spite of this, the people of Kolondioura decided to give it a try. A dynamic village leader, named Yao, was instrumental in gaining the support of the people for the project.

An MCC volunteer and the village agreed upon a certain dam site and work was started in December, 1983. After a month, when the work started lagging, it was agreed to divide up the work into family units, each with its own section of the dike. This was intended to foster competition and help motivate the villagers to work.

The dam was finished in April, 1984, just before the rainy season started. The dike was broken by the first big rain because one family had not built their section of the dike properly. (Later it was found out that this family usually worked when the others were gone so they wouldn't have to pack as well. This made their work easier and faster and allowed them to save face by keeping up with the work of other families whose motivation level was higher). Instead of being discouraged and quitting, Yao, on his own, organized the villagers, who were willing to keep at it, to quickly repair the dike before the next big rain came. They repacked the breach correctly and when the next rains came the dike held and has held ever since.

Although the dam did not break again, it had too much seepage resulting from the bad packing methods. The village decided to try and stop the seepage using methods suggested by the MCCers. When the dam became dry during the dry season, they dug a trench along the front of the dike, and repacked it and the front of the dike with clayey soil. This considerably reduced the seepage problem.

In 1986 the village could afford to have an MCC-type masonry well built behind their dam, since it only had to be six meters deep instead of the usual 10 to 15 meters depth of most wells in the area. This well is currently the village's only nearby source of healthy clean water. It yields water year round even though the dam goes dry for several months each year.

Swimming in the reservoir was banned due to some health awareness-raising done by the MCC health team in the area.

The village also took advantage of the well and even of the seepage through the dike, to begin a tree nursery planted behind the dike, near the well. The trees were supplied by the Burkina government. Tree seedlings from the nursery were planted around the reservoir, but were, unfortunately, all destroyed by a bush fire.

The villagers are also starting to work on building rock dikes across the spillway to help stop a ravine which is eroding towards the spillway ridge.

This case study is just one example of what a village can do when their potential for self-development is tapped.

APPENDIX A

DOING SIMPLE SOIL TESTS

There are some simple field tests that can be done to determine if a certain soil is suitable for use in constructing a dike.

Stroke a moist lump of the soil with the flat of a knife blade or fingernail. If the stroked surface becomes shiny, the presence of clay is indicated.

A moistened sample of clayey soil should feel sticky.

Form a sample of moist but firm soil into a roll the size of a thumb but two or three times longer. Pinch this roll between the thumb and forefinger to form a ribbon of soil of a uniform thickness of 3 to 6 millimeters that hangs from the hand (fig.A60). If the formed ribbon gets to be from 4 to 30 cm long before breaking off, the soil contains a suitable amount of clay. If no ribbon is formed at all, there is not enough clay present in the soil. If the ribbon gets to be longer than 30 cm there might be too much clay [15] (This type of soil could still possibly be used if it is mixed with soils containing more sand and gravel).

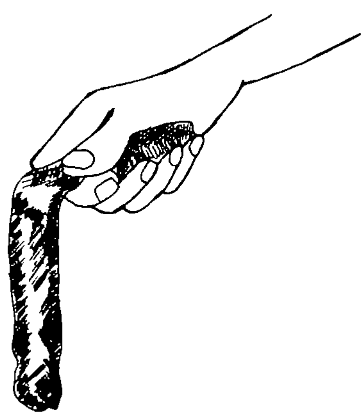


FIGURE A60: Pinching and forming a ribbon of soil.

Put a bit of this soil between the teeth. If no grit is detected, the soil is pure clay.

Take a small dry piece of the fine-grained part of the soil and/or moisten a lump of it and shape it into a small ball about 2cm in diameter and let the ball dry completely in the sun. Try to break and crush the dry soil with the fingers. It should be difficult or impossible to break and crush. If it crushes and powders easily there is not enough clay in the soil.[15]

To see if one soil type is more or less impermeable than another the "bottle test" can be used. Cut the bottom off of a large bottle, invert it, and fill it one third full with soil to be tested and pack the soil. The bottle is then filled with water. The soil that keeps the water from seeping through for the longest time is the most impermeable. If no water seeps through the soil in 24 hours the soil has a good water-holding quality.[14]

APPENDIX B

USING TOPOGRAPHICAL MAPS TO ESTIMATE CATCHMENT AREA

A topographical map will indicate, with blue dashed lines, where runoff water collects in the valleys to form streams. If the dam site can be found on a topographical map, an estimate of the size of the catchment area can be made using the map.

As stated (sec.10C), the catchment area for a site is that area on which rain falls and is funneled to the dam site. To estimate the size of a small catchment, using a topographical map, assume that the perimeter of the catchment area is a line made up of points equidistant from the streams that feed directly into the site and the streams that are adjacent to them (fig.A61).

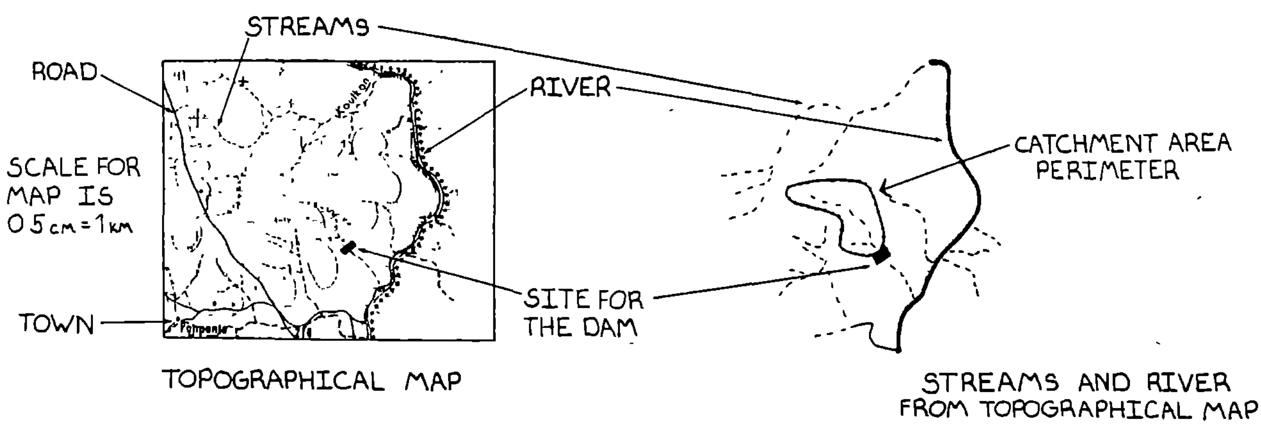


FIGURE A61: Estimating catchment area perimeter from a topographical map.

In other words, assume that a line halfway between adjacent streams defines the ridge between the two streams, thus it defines the perimeter of the catchment for the streams. Any rain that falls on one side of the ridge line will runoff to the stream on that side, while any rain that falls on the other side will runoff to the other stream (fig.B61).

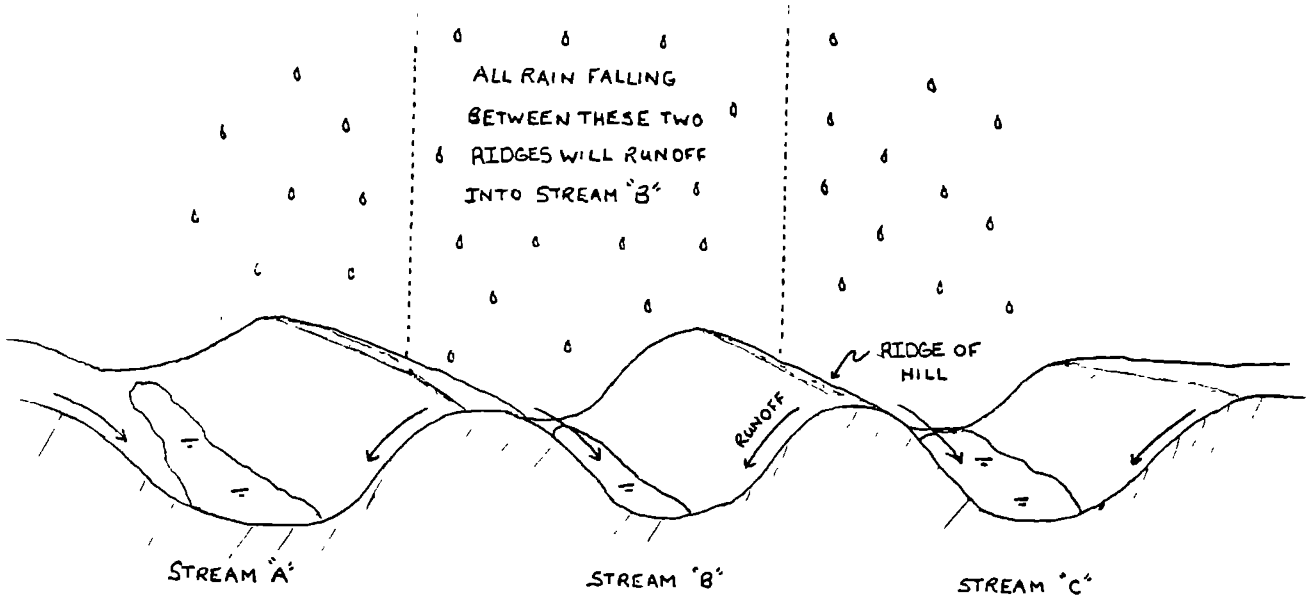


FIGURE B61: Runoff to adjacent streams.

An easy way to estimate the catchment area is to trace the perimeter of the catchment, using carbon paper, ontó graph paper that corresponds to the scale of the topographical map. Then count up the number of squares or partial squares that represent square kilometers that are within the trace of the perimeter of the catchment. This will yield the estimated area in square kilometers (fig.C61).

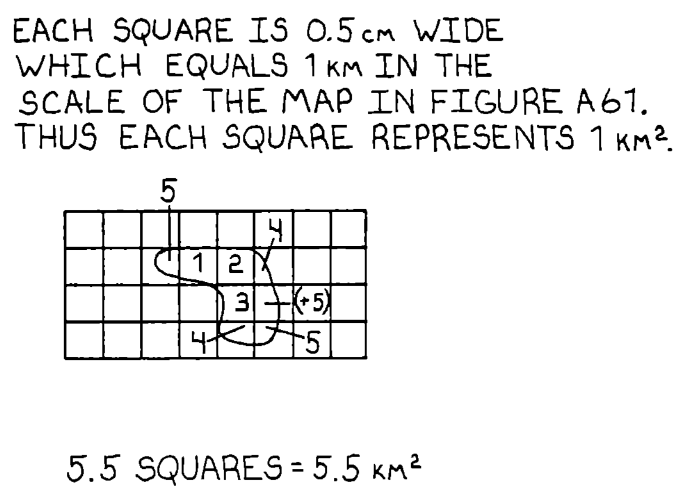


FIGURE C61: Estimating catchment area
using graph paper.

APPENDIX C

USING WATER TUBE LEVELS

A water tube level is an inexpensive yet accurate surveying tool used to find level. Any unenclosed surfaces of water in any sort of open container will be at the same level. The same is true for a length of tubing, the water levels at each end will always be at the same level (fig.A62).

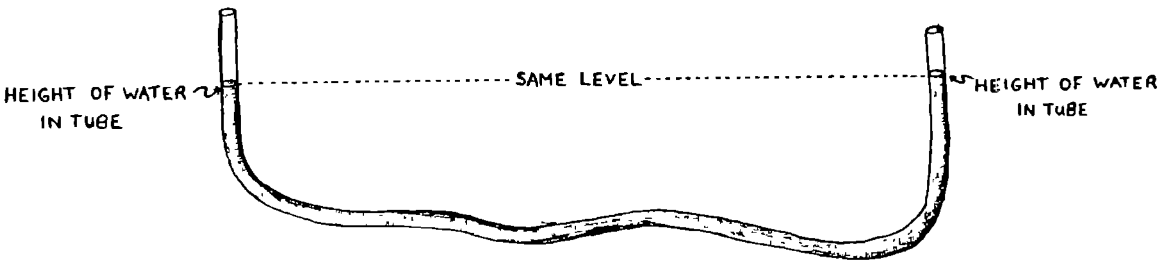


FIGURE A62: Level water surfaces in a water tube.

Flexible clear plastic tubing with an inside diameter of 3 to 10 mm and a length of at least 7 meters should be used for surveying.

Water can be siphoned into the tubing by placing one end into a container of water held at shoulder height and starting the siphon by sucking on the other end of the tubing which is held at a lower height. Remove any air bubbles.

One method of using water tube levels for surveying is as follows:

- Attach a 50 cm long measuring stick to each end of the tubing. These measuring sticks should be marked off in centimeters starting from the bottom ends. Whenever the water levels in the tubing are at the same centimeter mark the <u>bottom ends</u> of the measuring sticks are at the same level (fig.B62).

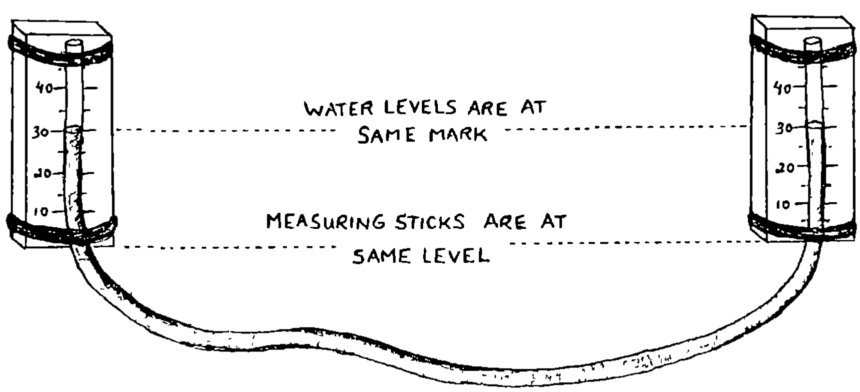


FIGURE B62: Leveling with measuring sticks.

- Find two straight support poles that are about 2 meters long to support the measuring sticks.

- One of the surveying team, person A, should place the bottom end of one of the measuring sticks at the height of the reference level to be measured and support it there by holding it to a support pole. Another person, person B, should take the other end of the tubing attached to its measuring stick a certain distance away (usually 5m to 10m). He should then raise or lower the stick until the water levels in the tubing are at the same centimeter marking on each stick (fig.C62).

  Now the bottom ends of the sticks are at the reference level and person B should support the measuring stick at this position with a support pole. The height of the reference level (the distance between the ground surface and the bottom of the measuring stick), at person B's location, can then be measured and recorded (fig.C62).

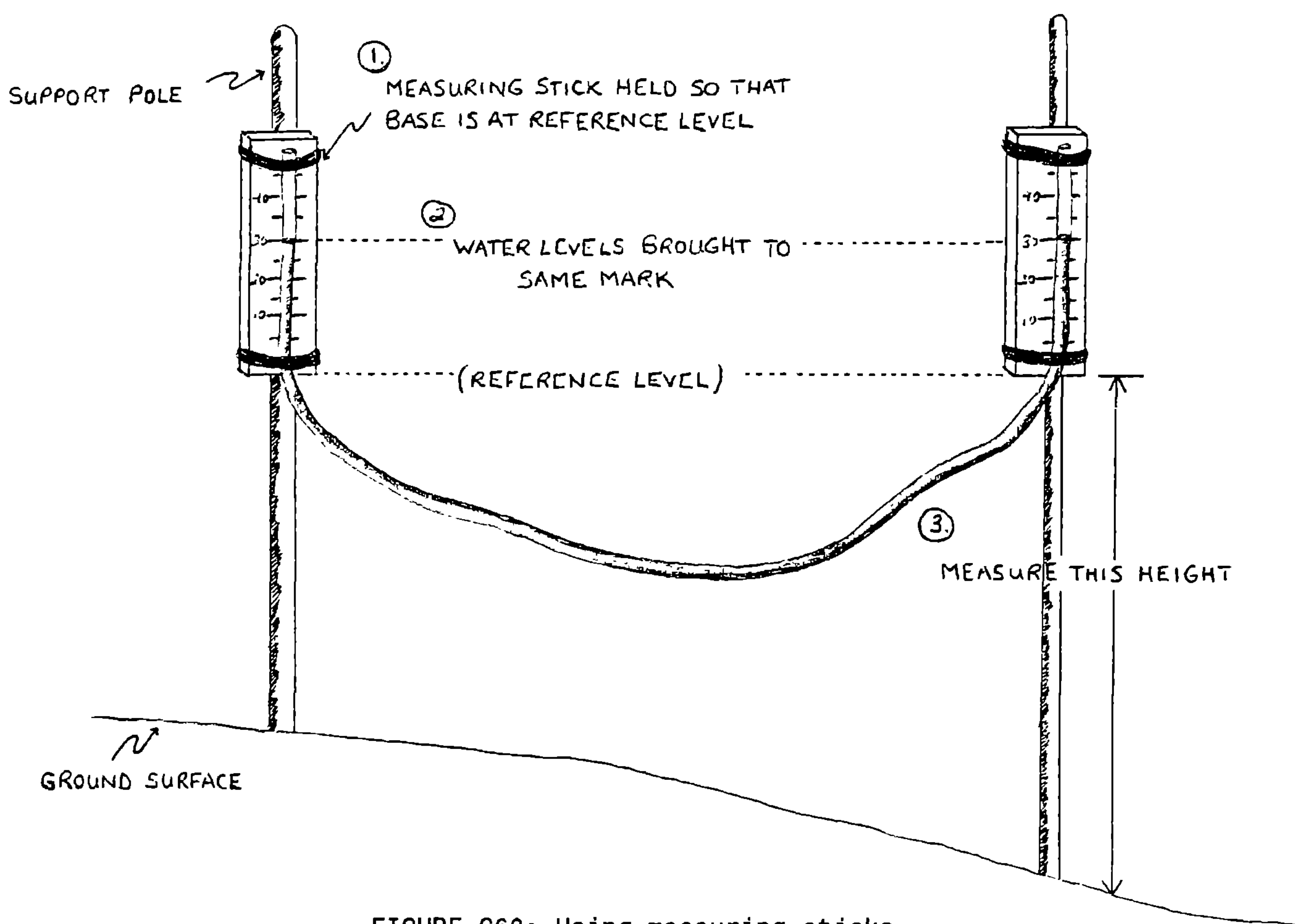


FIGURE C62: Using measuring sticks and support poles.

Hints: Three persons are usually needed to do surveying with water tube levels. Two persons are needed to work the water tube levels and another person to measure and record the heights. Also, the same centimeter mark which determines level in the beginning will continue to be the mark which determines level afterwards unless water spills out or the tube stretches or slips down the measuring stick a little.

- Person B should then remain stationary, with the measuring stick held at the reference level, while person A moves past B the certain distance and finds, measures, and records the height of the reference level at that point.

  Hint: When the measuring sticks are being moved it is a good idea to cover the ends of the tubing with a finger. This is so water will not accidentally spill out if one end is dropped too low. If too much water spills out of the tubing, the water levels will not show on both of the measuring sticks at the same time and more water will have to be added.

- Person A then remains stationary and the process is repeated as many times as is necessary.

  Hint: If the ground level drops so much that the reference level is above eye level and is hard to measure, the other person, who is staying stationary, can drop his measuring stick down exactly 50cm. Now when the new level is found and the measurement is made, 50cm is added to this measurement to give the height of the reference level.

APPENDIX D

ESTIMATING FLOOD DISCHARGE VERSUS SPILLWAY CAPACITY

This appendix is in three parts. Parts 1 and 2 cover two methods of estimating the amount of water that will flow through a certain site due to a certain type of flood (the flood discharge estimate). Part 3 covers a method of estimating how much water can flow through a certain spillway at the site (the spillway capacity estimate). By comparing the two types of estimates one can judge whether the spillway is adequate for the site.

The magnitude of a flood examined below will be labeled according to how often, on the average, a flood of this size will occur at a site. Normally, the bigger the flood is, the longer it will be before another flood of the same size will occur. If the magnitude of a flood is big enough that it can only be expected to occur at the site once every 10 years on the average, it is called a 10-year flood. If a certain size flood will usually occur at a certain site every 5 years it is called a 5-year flood. The largest flood that anyone can remember at a certain site is probably from a 50-year to a 100-year flood.

Keep in mind that if the micro-dam is designed to be able to handle a 10-year flood maximum, a larger than 10-year flood might wreck the dike. Perhaps within a few years a 20-year flood might hit the micro-dam and damage it. A dike can be built to handle any size of flood, but the larger the floods are that the dike is designed for, the larger the dike must be and the more work it will take. It is perhaps the most reasonable to design the micro-dam to withstand a maximum of a 10-year flood. This means the village can expect to make major repairs to the dike an average of every ten years, which is probably easier than building an even larger dike by hand that will last longer before needing major repairs.

PART 1: ESTIMATION OF THE MAXIMUM DISCHARGE OF A FLOOD DUE TO THE BIGGEST RAIN STORM IN A TEN-YEAR PERIOD ON A SMALL CATCHMENT

This method is condensed from a booklet entitled Estimation of Discharges of Ten Year Floods for Catchments With a Surface Area Less Than 200 sq. km. in West Africa, by J.Rodier & C. Auvray.[17] They obtained their findings by taking actual measurements in locations throughout non-Saharan West Africa. The booklet advises that although it is possible that their findings would be of use in other areas of the world with similar climates and conditions (and without typhoons or cyclones) it would be imprudent to use this material to draw conclusions in those areas without first testing its validity there.

To use their method of estimation, one must know the area of the catchment in square kilometers and the average yearly rainfall (in millimeters) for the region.

If one limits the catchment area to less than 25 or 30 km^2, which is strongly advised for hand-built earthen micro-dams, one finds that the estimation has fewer variables and is easier to calculate than for larger catchments.

TEN-YEAR RAIN AMOUNT

To begin one uses the graph below to find the predicted amount of rainfall in 24 hours from the biggest rain in a ten-year period (the ten-year rain) by using the average yearly rainfall (fig.A63).

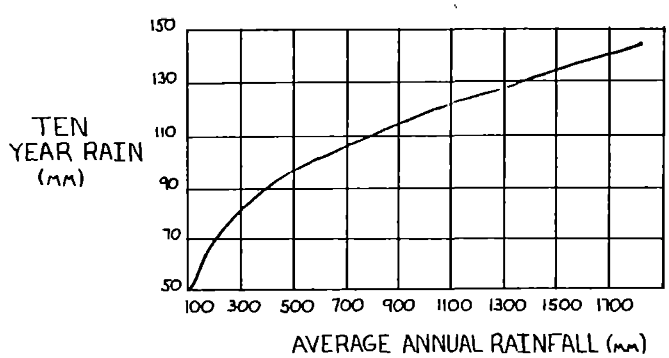


FIGURE A63: Ten-year rain amount.

Example: The average annual rainfall is 1100 millimeters per year. Therefore the ten-year rain amount from the graph (fig.A63) is 120 millimeters. (10-year rain amount = 120mm).

PERCENT OF RUNOFF

Then one needs to know how much of this ten-year rain will be absorbed into the catchment and how much will be runoff. The steeper the slopes are in the catchment and the less absorbent the surface of the catchment is the higher the percentage of the runoff will be. Also the type and amount of vegetation in the catchment and the degree of saturation of the catchment surface influences the amount of runoff.

One can divide non-Saharan West Africa into two different regions as far as vegetation, rainfall, and the expected amount of saturation of the catchment just before a ten-year-type storm would hit the region. There is the Sahelian and Sub-desert Regions with average yearly rainfalls of 150-800 mm. And there is the Tropical and Tropical Transition Regions with average yearly rainfalls of 800-1600 mm.

Notes on Use of Percent of Runoff Graph

To use the Percent of Runoff graphs (fig.B63-D63) one must decide if a catchment is in a sahelian/sub-desert region or in a tropical/tropical transition region. Then a curve on the graph is chosen according to the type of terrain found within the catchment. This curve together with the size of the catchment will show the probable percent of runoff.

If it is difficult to choose between certain categories, one should choose the category that yields a higher percentage of runoff. It is better to plan for more runoff than might be possible rather than less.

Listed below are the definitions of flat, flat to rolling, rolling, and hilly according to the percent of slope of the slopes within the catchment.

Flat - Slopes of less than 0.5%.

Flat to Rolling - Moderate slopes of between 0.5% and 1.0%.

Rolling - Rather steep slopes. Longitudinal slopes of between 1% and 2%, and cross slopes greater than 2%.

Hilly - Steep slopes. Longitudinal slopes of between 2% and 5%, and cross slopes of between 8% and 20%.

For catchments where most of the catchment surface has a very low overall water absorption capacity (impermeable surface). An example would be a surface of mostly clay and/or rock.

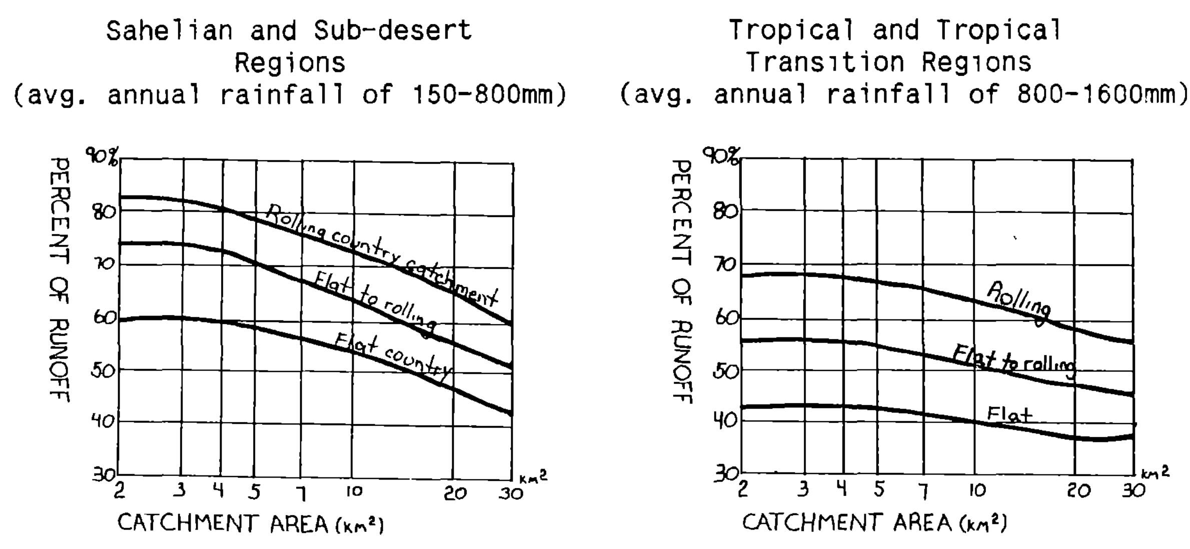
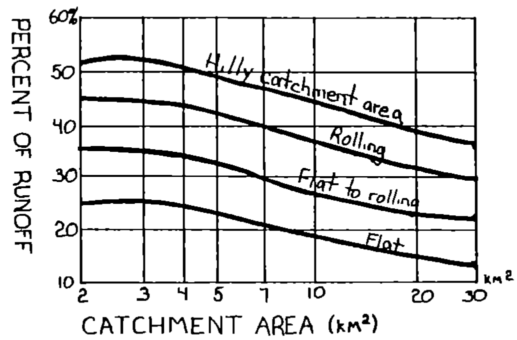


FIGURE B63: Percent of runoff graphs for impermeable catchments.

For catchments where much of the surface has a low overall absorption capacity with some areas of high absorption capacity. Or homogeneous catchments of low to fair absorption capacity (fairly impermeable).

Sahelian and Sub-desert Regions (avg. annual rainfall of 150-800mm)



Tropical and Tropical Transition Regions (avg. annual rainfall of 800-1600mm)

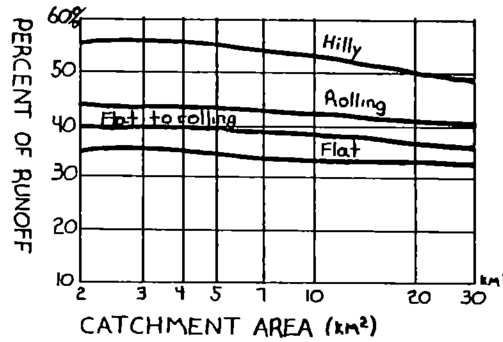
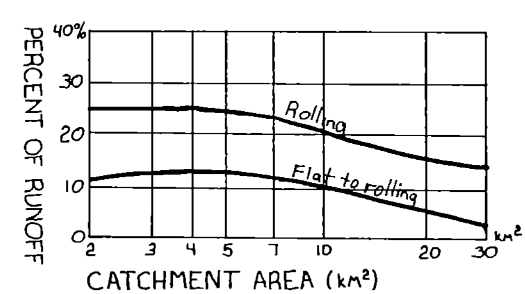


FIGURE C63: Percent of runoff graphs for fairly impermeable catchments.

For catchments where the overall absorption capacity of the surface is fairly high, such as areas of decomposed granite along with considerable sandy areas (fairly permeable).

Sahelian and Sub-desert Regions (avg. annual rainfall of 150-800mm)



Tropical and Tropical Transition Regions (avg. annual rainfall of 800-1600mm)

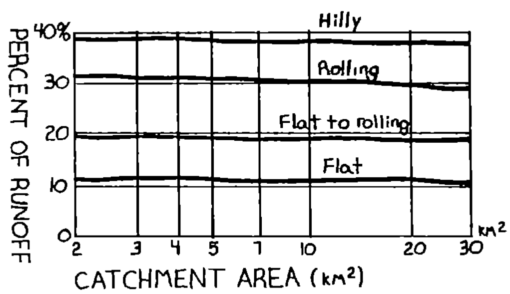


FIGURE D63: Percent of runoff graphs for fairly permeable catchments.

Example: The catchment is in a tropical transition region with a rolling terrain and its area is 10 square kilometers. The catchment surface is made up of mostly clayey soil with a very low absorption capacity. Thus the percent of runoff estimated from the graph (fig.B63) is 63 percent.

DEPTH AND VOLUME OF THE RUNOFF

The depth of the runoff (R^d)can be calculated by multiplying the ten-year rain amount (10-yr rain) by the percent of runoff ($R^\%$). The volume of runoff (R^v) can then be calculated by multiplying the depth of runoff by the surface area of the catchment (K) and by 1000 (to put the answer in terms of cubic meters).

Formulas: R^d (mm) = 10-yr rain (mm) x $R^\%$

R^v (m^3) = R^d (mm) x K (km^2) x 1000

Example: The ten-year rain amount is 120mm, the percent of runoff is 63%, and the catchment area is 10km^2. Therefore, the runoff depth is 75.6 millimeters (R^d = 120mm x 63% = 75.6mm), and the volume of runoff is 756,000 cubic meters (R^v = 75.6mm x 10km^2 x 1000 = 756,000m^3).

DURATION OF RUNOFF

One needs to estimate how long the runoff from a ten-year rain will last to know if all of the runoff will come through the spillway at almost the same time or if it will be more spread out. The graphs below (fig.E63) will be used in this estimation.

Sahelian and Sub-desert Regions (avg. annual rainfall of 150-800mm)

Tropical and Tropical Transition Regions (avg. annual rainfall of 800-1600mm)

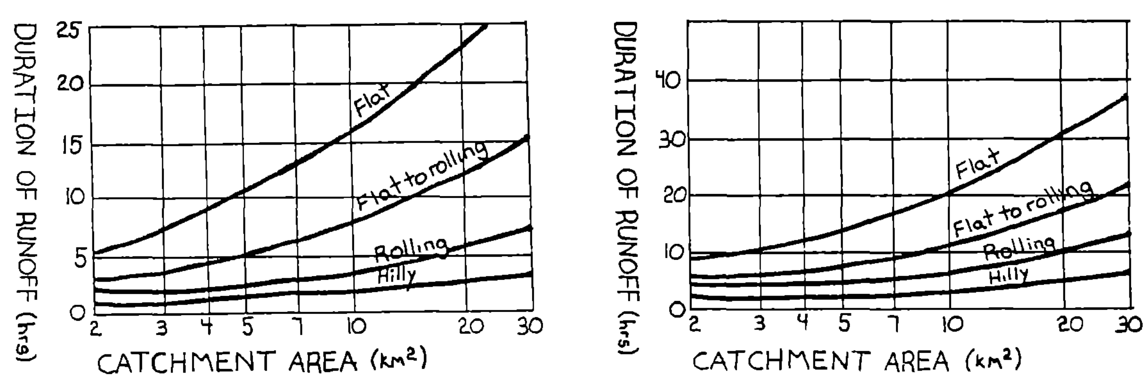


FIGURE E63: Duration of runoff graphs.

Example: The catchment is in a tropical transition region with a rolling terrain and its area is 10 square kilometers. According to the graph (fig.E63) the duration of the runoff can be estimated to be 7 hours. (R^{time} = 7 hrs).

AVERAGE DISCHARGE OF THE TEN-YEAR FLOOD

The average discharge of the ten-year flood ($Q^{10\ avg}$) can be estimated by dividing the volume of runoff (R^{v}) by the duration time of the runoff in hours (R^{time}) times 3600 (to put the answer in terms of cubic meters per second).

$$\text{Formula:}\quad \underset{(m^3/sec)}{Q^{10\ avg}} = \frac{R^{v}\ (m^3)}{R^{time}\ (hrs) \times 3600}$$

Example: The volume of runoff is 765,000 m^3 and the duration of the runoff is 7 hours. Thus, the average discharge of the ten-year flood is 30 cubic meters of water per second (765,000m^3 / (7 hrs x 3600) = 30m^3/sec).

This gives one the average discharge of the 10-year flood but those building earthen micro-dams are interested in making sure that the dikes and spillways are designed to handle the peak or maximum discharge of at least a 10-year flood.

MAXIMUM DISCHARGE OF THE TEN-YEAR FLOOD

To find the maximum discharge of the 10-year flood ($Q^{10\ max}$) one can simply multiply the average discharge of the 10-year flood ($Q^{10\ avg}$) by an appropriate factor (region factor) dependent on the type of region as shown below (fig.F63). (Note that it is assumed that the dam is already full before the maximum ten-year flood discharge comes into the reservoir).

Region	Region factor
Sahelian and sub-desert regions	3
Tropical and tropical transition regions	2.5
Forest regions	1.7

FIGURE F63: Regional maximum flood factors.

$$\text{Formula:}\quad \underset{(m^3/sec)}{Q^{10\ max}} = \underset{(m^3/sec)}{Q^{10\ avg}} \times \text{region factor}$$

Example: The average discharge of the ten-year flood is $30m^3/sec$, and since the region is a tropical transition region the appropriate factor is 2.5. Therefore the maximum discharge of the ten-year flood is 75 cubic meters per second ($30m^3/sec \times 2.5 = 75m^3/sec$).

Thus in this example one needs to design the spillway to easily handle a flood of $75m^3/sec$.

PART 2: ANOTHER METHOD OF ESTIMATING FLOOD DISCHARGE

Another method of estimating flood discharge is to study some actual high water marks left by a flood and use them to make an estimation of the discharge of that flood.[10]

This estimation is more complicated than the one preceding and the use of a slide rule or a calculator that can do exponential formulas will be required. Also one cannot be certain if the high water marks studied are from 5-year floods, 10-year floods, 50-year floods, etc. Even under the most favorable conditions this estimate can be expected to have an error of about 10 percent. But this estimation does provide a link with the physical reality at the site and can help one to make more informed decisions especially when used together with another type of estimation.

One way to be more certain as to how often the flood will come that created the high water marks being studied is to visit the site with different old people of the village at different times. If the old people's memories about the floods that created the high water marks are in agreement they will reveal how often one can expect this kind of flood. If the old people say that the high water marks being studied are from a less than a 10-year type flood, perhaps they can show you the exact high water marks from an approximately 10-year flood.

To do this estimate the cross-sectional area and the cross-valley perimeter length of the flooded part of the valley need to be determined using a high water mark. Also the slope of the surface of the flood water needs to be determined using high water marks, and a surface coefficient factor needs to be selected from a following table (fig.H63) according to an accurate description of the surface of the valley floor. As stated, under favorable conditions the results of this estimate will have a margin for error of about 10 percent. The major uncertainties are that the cross-section of the valley may have changed since the flood and that the description of the valley floor may not be accurate or may have changed.

DETERMINING FLOOD SURFACE SLOPE

Find two high water marks, near the site, one some distance upstream from the other. Using surveying equipment (app.C) measure how much lower the downstream mark is than the upstream mark. Divide this measure by the downstream distance (fig.G63) between the two marks. This will yield the flood surface slope (Q^s).

Formula: $$Q^s = \frac{\text{Change in elevation between high water marks (m)}}{\text{Downstream distance between the marks (m)}}$$

Example: High water mark B is 0.5m lower than high water mark A and the downstream distance between the two marks is 25m (fig.G63). Therefore the flood surface slope is 0.02 or 2 percent (Q^s = 0.5m/25m = 0.02 = 2%).

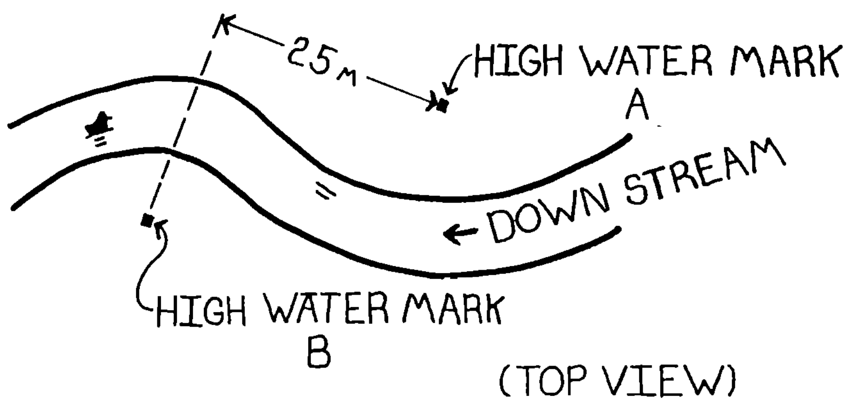


FIGURE G63: Downstream distance between two high water marks.

If only one high water mark can be found, it can be assumed that the flood surface slope will be the same as the slope along the floor of the valley. But since the flood surface slope is often greater than the valley slope, this could underestimate the flood surface slope.

SELECTING A SURFACE COEFFICIENT FACTOR

Choose a surface coefficient factor (n) from the table on the next page (fig.H63) according to which description most accurately describes the flooded part of the valley.

Example: The part of the valley that gets flooded is clean without obstacles along it. But it is winding and varies in its width. Thus a surface coefficient of 0.039 is selected (fig.H63).

Description of the flooded part of the valley	n
Straight, clean, no pools	0.029
Straight with weeds and stones	0.035
Winding, clean, pools and shallows	0.039
Winding with weeds and stones, pools and shallows	0.042
Winding with weeds and large stones, pools and shallows	0.052
Flat, wide, weedy, with deep pools	0.065
Very flat, wide, and weedy	0.112

FIGURE H63: Surface coefficient factors.

ESTIMATING THE CROSS-SECTIONAL AREA

To estimate the cross-sectional area of the flooded part of the valley, the average depth of the valley is determined by first surveying the valley (sec.11A). Establish the reference level at the height of the high water mark nearest to the proposed micro-dam site and measure and record the height of the reference level at equal intervals all the way across the valley. Using this survey information the cross-sectional area of the valley can be estimated by plotting the information to scale on graph paper or by calculating the average depth of this valley cross section (V^{Davg}) and multiplying it times the length of the reference level (l) to yield the cross-sectional area (A).

Formula: $A\ (m^2) = V^{Davg}\ (m) \times l\ (m)$

Example: The survey measurements (fig.I63) in meters, are 0.0, 0.1, 0.4, 0.5, 0.45, 0.25,and 0.0. The sum of these measures is 1.7m. Dividing 1.7m by the number of measurements yields an average depth of 0.24m. ($Q^{d\ avg}$ = 1.7m / 7 = 0.24m).

The length of the reference level across the valley (fig.I63) is 30m. Multiplying this 30m length times the average depth of 0.24m yields a cross-sectional area of 7.2 square meters ($A = 30m \times 0.24m = 7.2m^2$).

ESTIMATING THE CROSS-VALLEY PERIMETER LENGTH

The cross-valley perimeter (P) can be estimated from a graph of the survey information plotted to scale or by actually measuring the ground surface of the valley from where the reference level measure is at zero on one side of the valley to where it is at zero on the other side. Measure by laying a measuring tape on the ground so that the measurement follows the ground surface (lay of the land).

Example: The surface is measured from point A to point B (fig.I63) by laying a measuring tape on the ground. The surface measurement is 32m, therefore the cross-valley perimeter length is 32m (P = 32m).

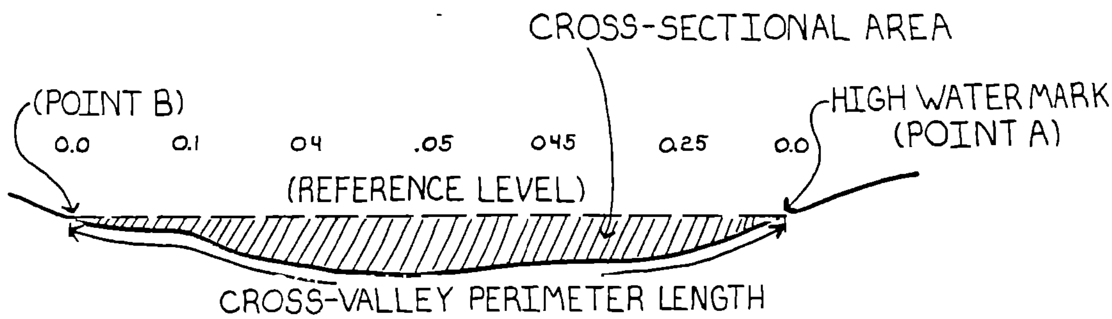


FIGURE I63: Cross-sectional area and cross-valley perimeter length.

ESTIMATE THE DISCHARGE OF THE FLOOD

Use the Chèzy-Manning formula below to estimate the discharge of the flood (Q^{mark}) that caused the high water marks being studied.

Formula: $$Q^{mark} = \frac{A\ (A/P)^{2/3}\ (Q^s)^{1/2}}{n}$$

Example: The cross-sectional area (A) was found to be 7.2 square meters. The cross-valley perimeter length (P) was found to be 32m long. The slope (Q^s) from one high water mark to the other was found to be 0.02. And the roughness coefficient (n) that most closely described the flooded surface of the valley was judged to be at 0.039. Therefore the estimated discharge of the flood that caused the high water marks is 9.6 cubic meters per second (see below).

$$Q^{mark} = \frac{7.2\ (7.2/32)^{2/3}\ 0.02^{1/2}}{0.039}$$

$$= \frac{7.2\ (0.37)\ 0.141}{0.039}$$

$$= 9.6\ m^3/sec.$$

PART 3: ESTIMATING SPILLWAY DISCHARGE CAPACITY

Now that the discharge from a given flood at the micro-dam site has been estimated, from Part 1 or 2 above, this discharge must be compared to the discharge capacity of the proposed spillway area to determine if the spillway size is adequate for the site.

To estimate the spillway discharge capacity the average depth and the effective length of the spillway need to be determined. Then these determined values can be used in a formula or on the graph below (fig.K63) to determine the spillway discharge capacity.

CALCULATING THE AVERAGE DEPTH

The average depth of the spillway (S^{Davg}) is calculated at a level 50cm above the spillway floor (maximum flood level) (sec.10D). This is done by <u>adding together</u> equally spaced apart measurements of the height of the maximum flood level ($Q^{lvl\ hts\ sum}$) above the spillway ridge and <u>dividing by</u> the number of measurements.

$$\text{Formula: } S^{Davg} = \frac{Q^{lvl\ hts\ sum}}{\text{Number of measurements}}$$

<u>Example</u>: The survey information (sec.11B, fig.A11) has the heights of the reference level above the spillway ridge. Since the reference level is one meter above the spillway floor and 50cm above a maximum flood level, 50cm needs to be subtracted from those measurements to yield the measurements of the heights of the maximum flood level. To help visualize this, the survey information concerning the spillway can be plotted to scale on graph paper (fig.J63). Subtracting 50cm from the reference level heights yields maximum flood level measurements of 0.0, 0.25, 0.45, 0.5, and 0.5 (fig.J63). Adding these measurements together yields 1.7 ($Q^{lvl\ hts\ sum}$ = 1.7m)and dividing this by 5 (the number of measurements) yields an average spillway depth of 0.34m (S^{Davg} = 1.7m / 5 = 0.34m).

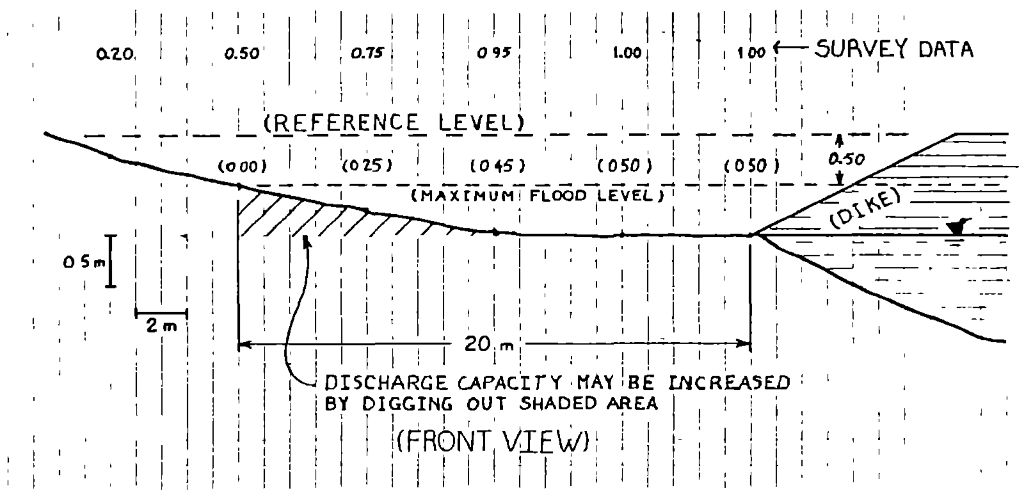


FIGURE J63: Spillway information graphed to scale.

DETERMINING THE EFFECTIVE SPILLWAY LENGTH

The effective spillway length (L) is determined by measuring the length of the maximum flood level along the spillway ridge, from where this level meets the dike across to where this level meets the ground surface on the other side of the spillway.

Example: From the survey information that has been plotted to scale it can be determined that the effective spillway length is 20m (fig.J63). (L = 20m).

ESTIMATING THE SPILLWAY DISCHARGE CAPACITY

The spillway discharge capacity (S^{cap}) can now be estimated by applying the average depth and the effective length of the spillway to the graph (fig.K63) or formula below.

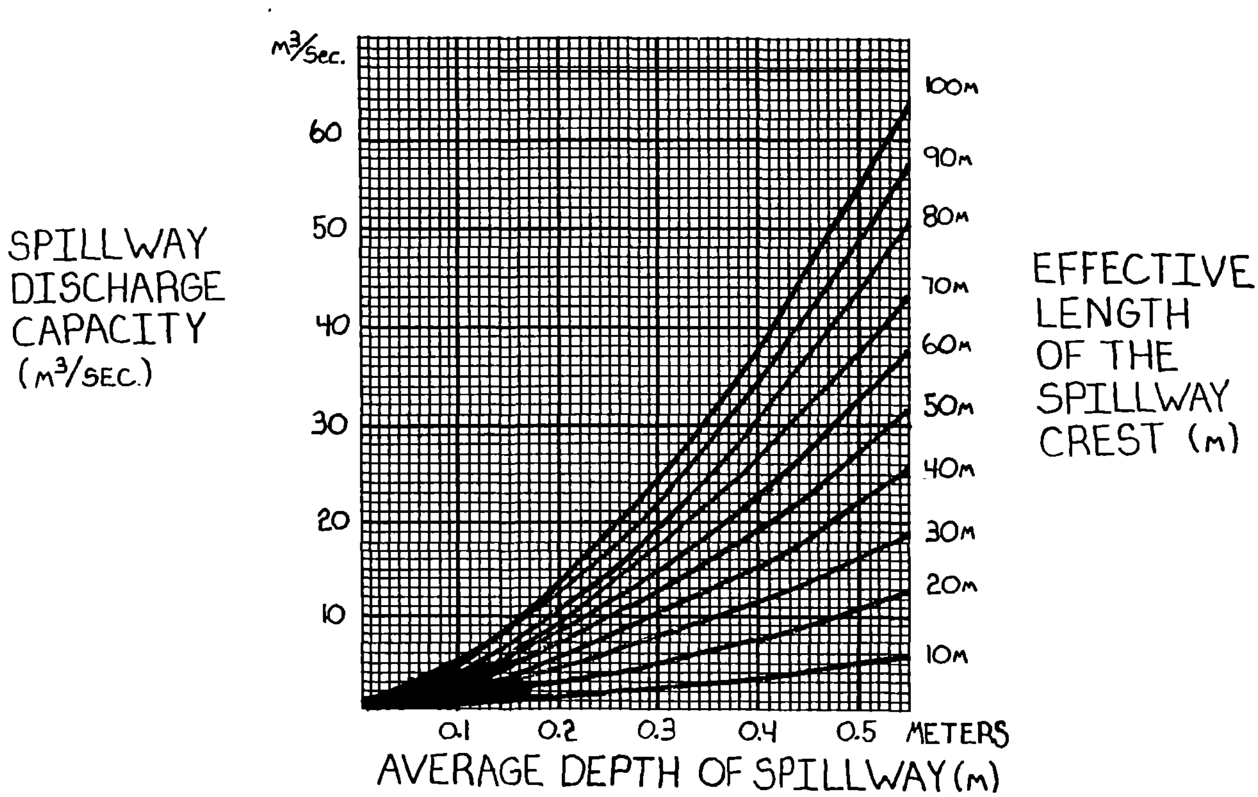


FIGURE K63: Spillway discharge capacity.

Formula (upon which the above graph is based):

$$S^{cap} = 0.35\ (2g)^{1/2}\ L\ (S^{Davg})^{3/2}$$
$$= 1.55\ L\ S^{Davg}\ (S^{Davg})^{1/2}$$

Example: The average depth of the spillway is 0.34 meters (S^{Davg} = 0.34m). The effective spillway length is 20 meters (L = 20m). Thus the Spillway discharge capacity is 6 cubic meters of water per second (fig.K63).
($S^{cap} = 1.55 \times 20 \times 0.34 (0.34)^{1/2} = 6m^3/sec$)

The spillway discharge capacity is compared to the estimated maximum flood discharge for the site from Part 1 or Part 2 of this Appendix. If the discharge capacity of the spillway is greater than the estimated maximum flood discharge, the spillway is acceptable.

Example: If the spillway, in Part 3 of this appendix, has a discharge capacity of $6m^3$/sec and the catchment, in Part 1, has an estimated a maximum flood discharge of $75m^3$/sec, this spillway is not adequate for this catchment and another site should be found.

If the spillway discharge capacity is slightly less than the estimated maximum flood discharge, it might be possible to dig out the higher part of the spillway crest down to a plane level with the spillway floor (fig.J63). This would increase the average depth of the spillway and thus its discharge capacity.

Example: The maximum estimated flood discharge for the catchment in Part 2 of this appendix is $9.6m^3$/sec. The spillway example in Part 3, with a discharge capacity of only $6m^3$, could be made acceptable for this catchment by digging out the spillway ridge to a plane level with the spillway floor and 50cm below the maximum flood level (fig.J63). This would make the average depth of the spillway 50cm, making the spillway's new discharge capacity $11m^3$/sec (fig.K63). The spillway would now be adequate for the site.

APPENDIX E

ESTIMATING DIKE VOLUME AND THE NUMBER OF WORKDAYS NEEDED

When the site has been surveyed (sec.11D) and the dike has been planned (sec.12), it is not too hard to estimate the volume of earth the dike will have if built as planned. This estimate will be examined in Part 1 of this appendix.

Then some idea of how long the dike will take to build can be calculated. This is done by estimating the volume of work the village can do, based on the volume of work the average villager in Burkina has done on earthen micro-dams and based on the number of villagers that will work on the dike, as will be shown in Part 2 of this appendix.

In Part 3 of this appendix some suggestions are made on how to go about building the dike if it is estimated that perhaps the villagers will not be able to finish the dike before the rains start.

PART 1: ESTIMATING TOTAL DIKE (AND CUTOFF TRENCH) VOLUME

To estimate dike volume the average cross-sectional area of the dike is multiplied by the proposed length of the dike. The average cross section of the dike is determined by the average height of the dike together with chosen slope of the sides of the dike and the chosen width of the dike crest.

CALCULATING THE AVERAGE DIKE HEIGHT

Using the survey information (sec.5B) the average dike height (D^{HTavg}) can be calculated by dividing the sum of the crest height measurements taken at equal intervals (C^{HTSsum}) by the number of measurements.

$$\text{Formula: } D^{HTavg}\ (m) = \frac{C^{HTSsum}\ (m)}{\text{number of measurements}}$$

Example: The dike crest is to be 1 meter above spillway floor. The crest heights are measured at 5m intervals along the proposed dike site (fig.B64). The measurements (in meters) are: 1.0, 1.5, 1.8, 1.9, 1.85, 1.65, 1.15, and 0.75. The sum of these eight measurements is 11.6 meters (C^{HTSsum} = 11.6m). Therefore the average Dike height will be 1.45 meters (D^{HTavg} = 11.6m / 8 = 1.45m).

CALCULATING THE DIKE'S AVERAGE CROSS-SECTIONAL AREA

The average cross-sectional area of a simple dike can be represented by the sum of the areas of two right triangles and a rectangle (fig.A64).

The height of these triangles and the rectangle is equal to the average dike height calculated above.

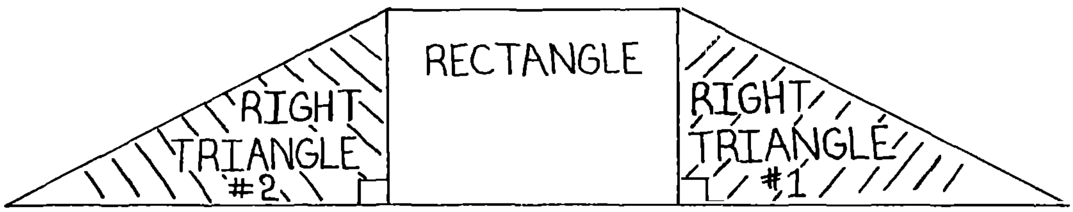


FIGURE A64: Cross-sectional area of a dike represented by two right triangles and a rectangle.

The length of the base of each triangle is determined by the chosen slope of the sides of the dike (sec.12D). The **area of each right triangle** (T^{area}) is calculated by multiplying the length of its base (T^{base}) by its height (D^{HTavg}) and dividing by 2.

Formula: $T^{area} = \dfrac{T^{base} \times D^{HTavg}}{2}$

Example: The average dike height will be 1.45m and the slope of the dike will be 2 to 1. Which means the base of the triangular section will be 2.90 meters long (fig.B64) (T^{base} = 1.45 x 2 = 2.90m) (sec.12D).

Therefore, the area of one triangular section is 2.10 square meters. (T^{area} = (1.45m x 2.90m) / 2 = 2.10m^2).

If the slopes of the 2 sides of the dike are to be the same the two triangular sectional areas on each side of the dike can be considered to be equal (fig.A64). Thus the **total area of the two triangular sections** ($T^{area\ total}$) is 2 times one triangular section's area.

Formula: $T^{area\ total} = T^{area} \times 2$

Example: The slope is to be 2 to 1 on both sides of the dike (fig.B64). Thus the two triangular areas are equal and the total area of these two triangular sections will be 4.20 square meters. ($T^{area\ total}$ = 2.10m^2 x 2 = 4.20m^2).

The width of the rectangular section is equal to the chosen width of the dike crest (C^W) (sec.12C) and its height is equal to the average dike height. The **area of the rectangle** (A^{rec}) is calculated by multiplying its height by its width.

Formula: A^{rec} (m^2) = C^{w} (m) x D^{HTavg} (m)

<u>Example</u>: The average height will be 1.45m and the width of the dike crest is to be 1.5m. Therefore the area of the rectangular section will be 2.2 square meters (A^{rec} = 1.45m x 1.5m = 2.2m^2).

The average cross-sectional area of the dike ($D^{Xarea\ avg}$) is determined by adding together the areas of the triangular sections ($T^{area\ total}$) and the rectangular section (A^{rec})(fig.A64).

Formula: $D^{Xarea\ avg} = T^{area\ total} + A^{rec}$

<u>Example</u>: The area of the two triangular sections will be 4.2m^2 and the area of the rectangular section will be 2.2m^2. Therefore the average cross-sectional area will be 6.4m^2 ($D^{Xarea\ avg}$ = 4.2m^2 + 2.2m^2 = 6.4m^2).

CALCULATING DIKE VOLUME

When the calculated value of the average cross-sectional area of the dike is known ($D^{Xarea\ avg}$), it can be multiplied by the length that the dike will be (D^{1}) to estimate the dike volume (D^{V}).

Formula: D^{V} (m^3) = $D^{Xarea\ avg}$ (m^2) x D^{1} (m)

<u>Example</u>: The average cross-sectional area of the dike will be 6.4m^2 and the length of the dike is to be 37.5m. Therefore the dike volume will be 240 cubic meters (D^{V} = 6.4m^2 X 3.75m = 240m^3).

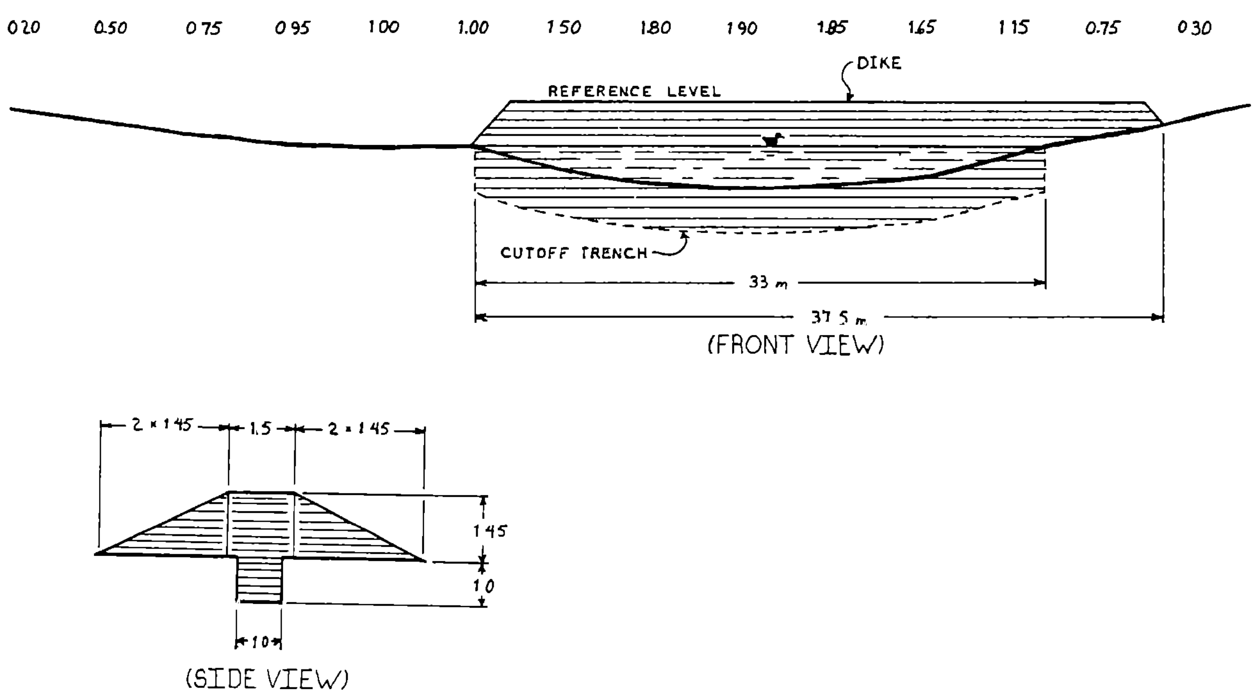


FIGURE B64: Dike example.

CALCULATING CUTOFF TRENCH VOLUME

If there is to be a cutoff trench (sec.12F), its volume must be estimated and then added to the estimated dike volume to estimate the total dike volume.

The cutoff trench will usually be nearly rectangular in shape so that its volume (CT^V) can be estimated by multiplying its length (CT^l), by its width (CT^w), by its depth (CT^d).

Formula: CT^V (m^3) = CT^l(m) x CT^w(m) x CT^d(m)

Example: A cutoff trench is needed and it is to be a meter wide and deep and 33m long. Therefore the estimated volume of the cutoff trench will be approximately 33 cubic meters (CT^V = 1m x 1m x 33m = 33m^3).

CALCULATING THE TOTAL ESTIMATED DIKE VOLUME

Adding the estimated dike volume to the estimated volume of the cutoff trench yields the total estimated dike volume (D^{Vtotal}).

Formula: D^{Vtotal} (m^3) = D^V (m^3) + CT^V (m^3)

Example: The dike volume will be approximately 240m^3 and the cutoff trench volume will be approximately 33m^3. Therefore the total estimated dike volume will be 273 cubic meters (D^{Vtotal} = 240m^3 + 33m^3 = 273m^3).

Note that if a cutoff trench is not needed (sec.10), the total estimated dike's volume (D^{Vtotal}) will be equal to the estimated dike volume (D^V).

PART 2: ESTIMATING THE NUMBER OF WORKDAYS NEEDED

When the total volume has been estimated and the villagers have decided how many persons will work for how many hours each workday, an estimate can be made to give an approximate idea of how many workdays will be needed to complete the dike. Then decisions can be made as to how to proceed with the construction of the dike depending on whether the dike can be finished during the time period the villagers are available to work on the dike (before the usual start of the next rainy season).

CALCULATE THE VOLUME OF EARTH THAT CAN BE ADDED TO THE DIKE EACH WORKDAY

A ratio of the average amount of earth, in cubic meters, that can be added to a dike per person per workday has been established by studying 16 completed hand-built earthen micro-dams in different regions of Burkina Faso. This average work ratio was found to be one fourth of a cubic meter per person per workday. In other words, it is estimated that each worker can add an average of $0.25m^3$ of earth to a dike each workday, and four workers should be able to add one cubic meter each workday.

This average work ratio ($0.25m^3$/person day) can be used to estimate the volume of earth that can be added to the dike each workday (E^V/day) by multiplying the work ratio by the number of persons available to work each day (persons/day).

Formula: $E^V/day\ (m^3) = 0.25m^3 \times persons/day$

Example: Village A has agreed that at least 20 persons will work each work day, therefore they should be able to add an average of 5 cubic meters of earth to the dike each workday ($E^V/day = 0.25m^3 \times 20 = 5m^3$).

CALCULATING THE NUMBER OF WORKDAYS

Dividing the total estimated dike volume (D^{Vtotal}), from Part 1 of this appendix, by the volume of earth that can be added each workday (E^V/day) yields the estimated number of workdays needed to complete the dike (Work days needed).*

Formula: $\text{Workdays needed} = \dfrac{D^{Vtotal}\ (m^3)}{E^V/day\ (m^3)}$

Example: It is estimated that village A's dike will have total volume of $273m^3$ and it was estimated, using the average work ratio, that the 20 villagers who will be working will add $5m^3$ to the dike each working day. Therefore, the dike should take 55 workdays to complete.
(Work days needed = $273m^3$ / $5m^3$ = 55 days).

* The average work ratio can also be used to estimate the number of persons needed per work day (Persons/day) to complete the dike in a given number of work days ($WD^{\#}$). Persons/day = $D^{Vtotal}\ (m^3)/(0.25m^3 \times WD^{\#})$.

BACKGROUND

The 0.25m^3/person day ratio was established by studying four dams from each of the four types of earthen micro-dams shown in this manual and averaging the actual ratios of these 16 dikes. The villagers building these 16 dikes worked an average of five hours each workday.

Since the 0.25m^3/person a day is an average, if the villagers building a dike work harder, longer and/or more efficiently than the average villager group studied in Burkina, the number of workdays needed will be less (and vice versa).

The type and method of hand-built earthen micro-dam construction was found not to be the determining factor in how long the dike took to build. Instead the villager's motivation and efficiency level determined if the dike was built faster or slower than the average.

Example: It is estimated, using the average work ratio, that village A will need 55 days to complete their dike. Village A has has agreed to work 5 days per week and there are 10 weeks left before the raining/planting season usually starts. Therefore there are 50 workdays available (5 days per week X 10 weeks = 50 days).

If village A villagers are known to be hard working and they decide to work at least five hours each workday, they should be able to finish their dike before the raining season starts.

But if they are not known to be exceptionally hard working and/or they decide to work less than five hours each workday, they might not finish the dike before the ten weeks are over.

PART 3: WHAT SHOULD BE DONE IF IT IS DOUBTFUL THE DIKE WILL BE COMPLETED IN ONE WORK SEASON

If it is estimated that perhaps the dike cannot be finished in one work season, two things might be done:

- Find and use a lower spillway location temporarily, or
- Leave a section of the dike open till the next work period to allow water to pass out without seriously eroding the dike.

TEMPORARY LOWER SPILLWAY LOCATION

If a temporary spillway with a lower spillway floor is used, the dike can be shorter in length and height, and thus its volume might be reduced enough that the village can finish the work in one period (fig.C64a). This has the added advantage that the dam will hold some water after one work period. Make the base width and the side slopes the same as the original final design to make it easy to continue the work on the dike the next work season (fig.C64b).

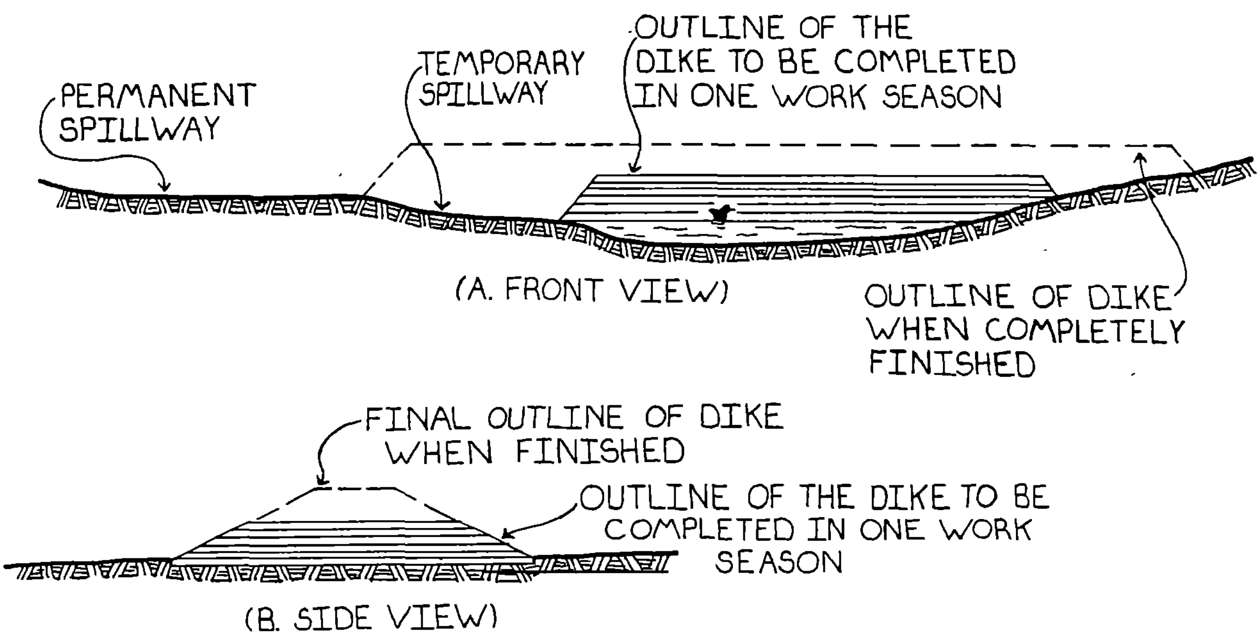


FIGURE C64: Temporary spillway location.

LEAVING A SECTION OPEN

If a suitable temporary spillway cannot be found, it would be good to leave a section of the dike open so that water can pass through without seriously eroding the dike (fig.D64). The dike can be built as planned on both sides of the opening and then when there is enough time the opening can be closed off and the dike completed.

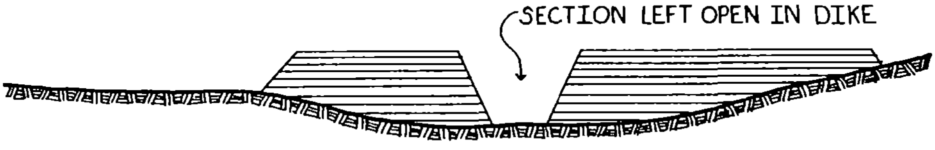


FIGURE D64: Section left open in Dike.

APPENDIX F

MAKING EARTH COMPACTORS OF REINFORCED CONCRETE [11]

INTRODUCTION

An earth compactor is essentially a heavy weight that can be fixed to a vertical handle, and which by being lifted and left to fall to the ground compacts the earth which it strikes. Compacting earth is a basic process for the construction of earthen micro-dams.

Commercially available compactors made of cast iron, imported from Europe or elsewhere, are very expensive in Burkina Faso, ranging from about 5,000cfa to 15,000cfa depending upon the size and place where they are being sold. Locally made metal compactors were also available in Burkina Faso for between 3,000cfa and 5,000cfa.

The following is a description of the current design of a reinforced concrete compactor and a step-by-step explanation of its construction.

COMPACTOR FRAME

Cut a 80mm long section from a steel pipe which has a diameter of approximately 50mm, using either a hacksaw or a rolling-type pipe cutter.

Cut two 400mm long sections of 8mm diameter rebar.

Bend each rebar to the triangular shape (fig.B65) using a vice. Make a rebar bending jig to help you if you need to construct many compactors (fig.A65).

Make the second bend where the rebar will fit onto the pipe using a vise, getting the angle right by eye (fig.B65).

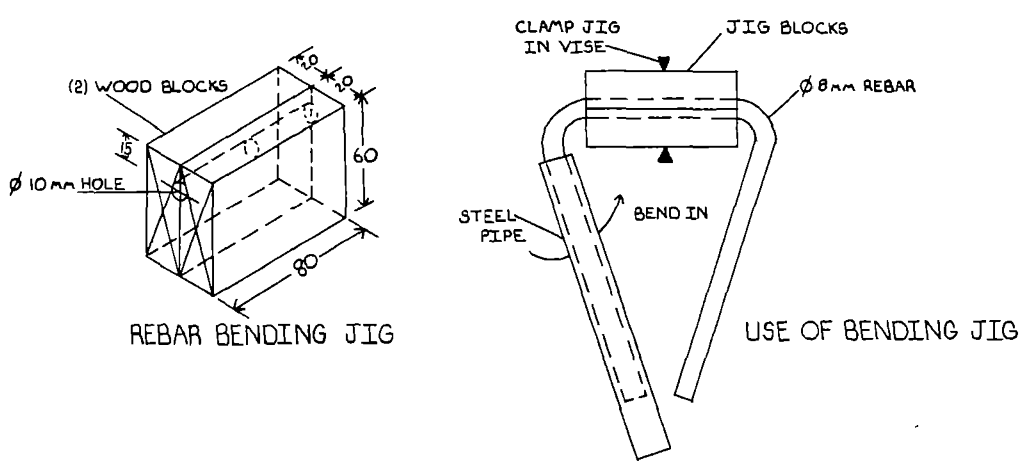


FIGURE A65: Rebar bending jig and its use.

[16] Perroud, Michel. Guide de Realisation d'une Etude d'une Barrage. Ouagadougou, Burkina Faso: AFVP, 1985.

[17] Rodier, J. and C. Auvray. Estimation of Discharges of Ten Year Floods for Catchments with a Surface Area of Less Than 200 Sq. Km. in West Africa. Paris: ICHS, 1965.

[18] Sherard, J.L., et al. Earth and Earth-Rock Dams. New York: 1963.

[19] M. Terrible P.B. Avoir Plus D'eau Est-ce Possible. Bobo-Dioulasso, Burkina Faso: CESAO, 1984.

[20] United States Department of the Interior - Bureau of Reclamation. Design of Small Dams. Washington,D.C.: 1974.

[21] Werner, David. Where There Is No Doctor. Palo Alto: Hesperian Foundation, 1977.

[22] Wood, A.D. and E.V. Richard. Design of Small Water Storage and Erosion Control Dams. Fort Collins, CO: Dept. Civil Engineering, Colorado State University, 1975.

[23] Zimmermann, Johann. La Construction de Retenue D'eau au Niveau du Village. Ouagadougou, Burkina Faso: MCC, 1982.